CO-SPONSORS OF **PLASMA-2022**

	Science and Engineering Research Board (SERB), Govt. of India
	Board of Research in Nuclear Sciences (BRNS), Govt. of India
	Council of Scientific and Industrial Research (CSIR), Govt. of India
	Department of Science & Technology, Govt. of Rajasthan
	North East Center for Technology Application and Reach, Govt. of India
	Sikkim University, Sikkim
	Institute for Plasma Research Bhat Gandhinagar, Gujarat
	Indian Institute of Technology, Jodhpur
	Industry Sponsor **Chempharm Industries India Pvt Ltd., Sonipat & Divya Plasma Solutions Pvt. Ltd., Noida**
	Industry Sponsor **Ftd Infocom Private Limited, Bangaluru**

37th National Symposium on Plasma Science and Technology (Plasma-2022)

॥ त्वं ज्ञानमयो विज्ञानमयोऽसि ॥

December 12-14, 2022

Organized by

Department of Physics
Indian Institute of Technology Jodhpur

In association with

Plasma Science Society of India (PSSI)

12-14 December, 2022
IIT Jodhpur

Contents

MESSAGE

I am happy to know that the 37th National Symposium on Plasma Science & Technology (PLASMA-2022) is being organized by the Department of Physics, IIT Jodhpur in association with the Plasma Science Society of India (PSSI) from 12th to 14th December, 2022. This meeting holds special importance as the first offline meeting after the Covid-19 pandemic.

The Institute for Plasma Research is pursuing research in Nuclear Science and Technology as well as Societal/Industrial applications of plasmas. Being an active partner in the ITER project, it is also involved in technology/sub-system development for ITER. Apart from the fusion programme, IPR is also involved in an ever-growing list of plasma applications in industry, agriculture, textile processing, waste disposal, aerospace technologies, medical/health systems, etc. A promising new area of particular importance for India is the application of plasmas for the eco-friendly and low-carbon production of hydrogen. I am happy to know that the theme of this edition of the Plasma symposium is "Plasma Technologies for Sustainable Development", which truly reflects how plasma will play an important role in our lives.

I hope that participation in this symposium will motivate young researchers from different branches of science and engineering to enter the challenging fields of plasma science & technology. Lastly, on behalf of IPR, I would like to thank PSSI and the organizers for their sincere efforts in organizing this symposium. I extend my best wishes to all the participants and hope that the symposium will achieve its desired objectives.

(Shashank Chaturvedi)
Director, Institute for Plasma Research

Indian Institute of Technology Jodhpur
NH 62, Nagaur Road, Karwar 342037, Jodhpur District
(0291) 280 1011; director@iitj.ac.in

Professor Santanu Chaudhury
FNAE, FNASc, FIAPR
Director

MESSAGE

I am happy to note that the 37th National Symposium on Plasma Science & Technology (PLASMA-2022) is being organized by the Department of Physics, IIT Jodhpur in association with the Plasma Science Society of India (PSSI) from 12th-14th December 2022. This is also the curtain raiser event on various scientific and technological events planned to be organized by IIT Jodhpur during the "Azadi Ka Amrit Mahotsav" initiative of the Govt. of India.

Plasma Science & Technology is one of the most important subjects in the current era and it is going to play a key role for sustainable development because most plasma technologies are environmentally benign. As one can see from the list of topics that have been covered in the symposium, the field of Plasma Science and Technology has rich potential, for academic research, as well as for industrial applications. These will have short term as well as long term impacts. In the latter category lies the holy grail of applied research, namely the achievement of Controlled Thermonuclear Fusion on Earth, as a source of energy for everyday use. It is to be recalled that Dr. Homi J. Bhabba, had highlighted this, as Chairman to the "Atoms for Peace Conference", about sixty years ago. This is a big challenge needing the cooperative effort of a world-wide team of scientists and engineers.

It is heartening to see that lately both the R&D community and the scale and sophistication of R&D efforts and actual delivery capability for plasma devices and systems in the country have got substantially strengthened. It is important to have a world class research, design and development and manufacturing base for plasma-based systems and devices within the country to serve the various industrial as well as strategic needs. I am glad PLASMA-2022 has attracted a very strong participation from researchers, academics, students, industry, users and government. I am sure all these stakeholders will be immensely benefited through the deliberations in the symposium and new directions of research and new opportunities for collaboration will also be identified.

I convey my best wishes to the organizing committee of PLASMA-2022 for organizing such a mega event in a very short notice.

(Prof. Santanu Chaudhury)
Director, IIT Jodhpur

The Plasma Science Society Of India

(Regn. No. F-828, Ahmedabad)

MASSAGE

I am pleased to announce that the 37th National Symposium on Plasma Science and Technology (PLASMA-2022) is being organised by IIT Jodhpur jointly with Plasma Science Society of India from 12th-14th December 2022. The major goal of PLASMA-2022 is to assess current research trends, present new findings, and discuss plans for further research work, particularly where it seems appropriate to set up new collaboration at different levels. We have an exciting program at this symposium that will allow members to encourage scientific fellowship and interchange of ideas among colleagues, Ph.D. scholars and experts at the national level. This symposium will be an excellent platform for young scientists and researcher to share their new findings through invited lectures, oral as well as poster presentations to jointly explore current and future research directions.

We hope that you will have a productive and fun-filled time at this symposium.

I convey my warmest greetings to all participants and wish the symposium a great success.

Prof. (Dr.) NPS Saini

President, PSSI

http://www.pssi.in

PHONE 91-79-2396 2000
FAX 91-79-2396 2255
E-MAIL pssi@ipr.res.in
WEB http://www.pssi.in

Institute For Plasma Research
Bhat, Near Indira Bridge
Gandhinagar 382 428
Gujarat (India)

From Conveners' Desk

The 37th National Symposium on Plasma Science & Technology (PLASMA-2022) is organized by the Department of Physics, IIT Jodhpur in association with the Plasma Science Society of India (PSSI) from 12th-14th December 2022. The aim is to motivate and provide adequate exposure to both young and senior researchers working in various areas of plasma science and technology. The symposium includes keynote addresses, invited talks by eminent scientists along with oral and poster presentations by the research scholars and other participants. The symposium will provide a forum for young researchers in the area of Plasma Science & Technology to interact with eminent plasma scientists from India and present their research work.

It is quite interesting to note that over the last few decades, the scenario of the plasma science and technology in general and controlled thermonuclear fusion in particular has undergone a sea change. Significant steps have been taken towards building nuclear fusion reactors for meeting the ever-growing clean energy requirements –maintaining harmony with the life sustaining natural processes. Besides gaining insight in to the basic plasma processes in laboratories, space and astrophysical plasmas, industrial applications of plasma have brought a veritable revolution in the advancement of the micro-electronics, new materials, environmental and energy technologies contributing to the improvement of quality of life. Scientists, technologists and engineers of our country are pursuing research and development on various aspects of plasma science and technology in the frontier areas. These includes Fusion research, Laboratory plasma research, Defence research, Space research, Material science, Food science, Health, Agriculture, etc.

The theme of the PLASMA-2022 is Plasma Technologies for Sustainable Development. We are in the era of the 21st Century and modern technologies have helped in ease of doing things. Despite our continued efforts, FEAR is all around. The growing population and meeting the resources for humankind in a sustainable manner is the key challenge. The scarcity of foods, increasing health risks, depletion of modern energy fuels, environmental damage due to high carbon emission, etc. are some of the concerns. It is a firm belief that cutting-edge plasma technologies can provide solutions for FEAR (i.e., Food/Health, Energy & Agriculture Retrievals). The scope of the symposium includes front-line research in basic plasma physics as well as significant advances in plasma technology.

Main topics covered in Plasma-2022 are:

- Basic Plasma
- Cross-disciplinary
- Exotic Plasma (Includes Dusty Plasma)
- Industrial Plasma Applications
- Laser Plasma
- Nuclear Fusion & Technology
- Plasma Diagnostics

- Plasma Processing
- Pulsed Power
- Space & Astrophysical Plasma
- Theory and Simulations in Plasma

We have received an overwhelming response for this symposium by having prospective National delegates including renowned scientists, technologists, young researchers and university/college faculties. We sincerely thank all the delegates coming from different parts of the country to make this event successful. The symposium comprises of 12 sessions in which there are 9 oral sessions and three poster sessions. Overall, there are around 490 presentations including 1 keynote address, 1 plenary talk, 16 invited talks, 27 oral talks, 5-Buti Young Scientist Award Presentations, 3 Distinguished Award Presentations of PSSI as well as 440 poster presentations. More than 400 research scholars and scientists are participating in this mega event. Various awards will be given for the best posters and oral presentations under various categories.

For organizing such an event, substantial financial support is needed to meet the various requirements. We have received support from several National funding agencies, Institutions, Universities and industries to make this event successful. We sincerely acknowledge all the funding agencies. Thanks are also due to the Patron, Chairman, Co-Chairmen, the members of the National Advisory Committee, National Organizing Committee, the members of the Local Organizing Committee for their continuous support, guidance and help. We also thank all other Sub-committee members including volunteers who have directly or indirectly contributed to make this national event successful.

Ram Prakash
Convenor, Plasma-2022
&
Monika Sinha
Co-convenor, Plasma-2022

About Jodhpur

Jodhpur, formerly known as Marwar, the capital of the Rajput rulers, has long history of various traditions which are followed till date. Located towards the western side of the capital city of Jaipur, this city is the second biggest city in the state of Rajasthan . Being a place of princely palaces, magnificent forts as well as age old temples, this city of Rajasthan is among the famous tourist destinations in the state as well as India. Positioned in the Thar Desert's stark landscape, Jodhpur experiences a bright and sunny weather all through the year. For this, the city is also known as "Sun City". One of the specialties of this metropolitan city is that almost all the houses based around the fort of Mehrangarh are painted in blue color, due to which the city is even known as the "Blue City".

Jodhpur city is one of the major cities of Rajasthan. It encompasses an area of 22,850 sq.km and houses a population of 21,53,483. It is well connected to the rest of Rajasthan by airways, road and rail links. This city basks in the golden history and heritage of the state and is located at the fringe of the great Thar desert. Some local festivals of Jodhpur city, which may interest visitors, are Nag Panchami, Marwar festivals, Nav Sati, Gangaur, Veerpuri fair, Holi, Diwali. These festivals are celebrated amidst great cheer and religious fervency. The entire city dons a colorful and gay look. The age old traditions and culture of Jodhpur City interest most tourists who undertake a visit to this city.

Jodhpur is also well known for its furniture industry, handicrafts, glass bangles, cutlery, carpets and marble goods. Jodhpur also boasts of a unique cuisine. The local eateries accord the tourists a delectable platter of local culinary delights. The traditional folk dance and music performances, which are held at night, are great attractions to the visitors.

Famous Food and Cuisine: Makhaniya Lassi, Pyaaj Ki Kachori, Mirchi Bada, Dal Bati Churma, Lasan Ki Chutney, Mirchi Ka Kutaa, Gatte Ki Sabzi, Ker Sangri Sabzi Raab, Lapsi, Jaggery, Aate Ka Halwa, Kachara Mircha Sabzi, Kadhi Pakoda, Baajre Ka Sogra, Makhanbada, Mawa Ki Kachori, Malpua, Ghevar, Motichur Ke Laddu, Besan barfi, Kabuli Pulaw, Thorr and Gulab Jamun, and Ras Malai etc.

Famous Monuments: Mehrangarh Fort, Umaid Bhawan Palace, Jaswant Thada, Ghanta Ghar and Flying Fox, Kaylana Lake and Garden, Balsamand Lake, Mandaleshwar Mahadev Temple (Mandalnath), Ratanada Ganesh Temple, Sardar Samand Lake and Palace, Masooria Hills, Veer Durgadas Smarak, Bhim Bhirak Cave etc.

Famous Markets: Sojati Gate, Station Road, Tripolia Bazaar, Mochi Bazaar, Nai Sarak, Clock Tower, Sarafa Bazaar, Lakhera Bazaar, Sardar Market etc.

Educational Institutions: All India Institute of Medical Sciences (AIIMS), Indian Institute of Technology Jodhpur (IITJ), National Law University (NLU), National Institute of Fashion Technology (NIFT), Dr. Sarvepalli Radhakrishnan Rajasthan Ayurved University, Jai Narain Vyas University (JNVU), Dr. S. N. Medical College, MBM Engineering College, Footwear Design and Development Institute (FDDI), Indian Institute of Handloom Technology, Sardar Patel University of Police Security and Criminal Justice, Agriculture University, Petroleum University etc.

About PSSI

Great advances have been made in plasma theory and applications throughout the world in the last couple of decades. In India too, significant contributions have been made for the past four decades or so. Plasma Science Society of India (PSSI), which was formed in 1978, is a promoting body of this subject in India. PSSI provides a forum of interaction amongst the scientists, engineers, faculties and students working in this exciting area of research. The Society has a wide network with more than 1000 members from research institutions, universities and industries. It is continuously growing with an objective of popularizing and creating awareness amongst the youngsters about the plasma science and technology and the immense research opportunities that this field now offers. To this end, PSSI organizes every year the Plasma Science and Technology Symposium at various national laboratories and university centres in India. In addition, various national Seminars/Workshops/Colloquium on focused themes are also being organized periodically. It has also started to organize national PSSI- Plasma Scholars Colloquium (PSSI-PSC) annually in various parts of the country.
Briefly the objectives of the society are as follows:

- To encourage the study of all aspects of plasma science & technology.
- To promote active interaction among all persons, bodies, educational and research institutions (private and/or state owned) and industries in the field of plasma science & technology.
- To issue such publications (e.g. newsletters, reports, bulletins, journals incorporating research and teaching ideas, e-newsletter, etc.) from time to time, as may be decided upon by the executive council of the society.
- To popularize the plasma science among the educational and research institutions and the general public of India by arranging lectures/conferences/workshops on various aspects of plasma science & technology.
- Striving to include plasma science courses in colleges and universities-curricula.
- Cooperating in the conducting of symposium, conferences, panel discussions, workshops, etc.
- Supporting research students in the form of research fellowships and travel support to attend plasma conferences in India.
- To encourage coordinated research programmes among Indian Plasma Scientists and exchange of research personnel between research institutions and Universities in India.

PSSI Awards

PSSI in conjunction with external sponsors, has instituted many awards for outstanding research works in the area of Plasma Science & Technology. Right now, the following awards are presented during the National Symposium every year in its annual meet.

- Buti Young Scientist Award
- Parvez Guzdar Award

- Z. H. Sholapurwala RF Award
- Jaidutt Saraswati Sodha PSSI Plasma Award
- PSSI Poster and Oral Awards
- Z. H. Sholapurwala Poster Award

About IIT Jodhpur

Indian Institute of Technology Jodhpur was established in 2008, to foster technology education and research in India. The Institute is committed to technological thought and action to benefit the economic development of India. Scholarship in teaching and learning; Scholarship in research and creative accomplishments; and relevance to Industry are three driving forces for us at IIT Jodhpur. IIT Jodhpur functions from its sprawling residential Permanent Campus of 852 acres on National Highway-62, north-northwest of Jodhpur towards Nagaur. This campus is meticulously planned and envisioned to stand as a symbol of academics – simple, but deep. The Institute is committed to multidisciplinary approach of technology development. Hence, it has established state-of-the-art laboratories for basic and applied research, and has organized its academic degree activities through Departments and its coordinated research through Centers for Technologies.

Vision of IITJ

" ***A future-driven institute for nurturing excellence of thought; generating, preserving, and imparting knowledge; and using transformational technologies/interventions with a multidisciplinary approach for responding to societal challenges and aspirations.*** "

Mission of IITJ

- *Foster humanitarian values, passion for learning, and creativity in faculty and students.*
- *Move towards high quality, futuristic educational, and research ecosystem.*
- *Develop socially responsible faculty, students, and future leaders, committed to creating a self-reliant India.*
- *Catalyze a professional internal culture along with enabling infrastructure and ancillary services.*
- *Forge Effective collaboration and partnership with industry for diverse purposes and activities.*

Mandate of IITJ

1. *Create a versatile institute that inculcates humanitarian values, passion for research and learning, ideation, resilience, innovation, and creativity in the faculty and students, for a better society and sustainable future.*
2. *Move towards a broad-based, future literate, high-quality education and research ecosystem, including through the use of Foresight and strengthening of the collaborative network of institutions, businesses, and other stakeholders.*
3. *Develop socially responsible faculty, students, and future leaders, committed to creating a self-reliant India, through futuristic and entrepreneurial technological*

interventions and policy advice for problems/aspirations of the people and different regions.

4. *Catalyse a highly professional internal culture, and put in place delivery-focused systems and processes along with efficient infrastructure and partnerships, to facilitate knowledge creation, preservation, and dissemination in diverse disciplines.*

5. *Forge a symbiotic relationship with industry, providing effective ecosystems and avenues for collaborative research/ projects/ consultancy, incubating start-ups, creating wealth and jobs, and grooming industry-ready students.*

The institute is well known for its future-driven approach and has a fast-growing reputation for the development/ application of translational technologies for meeting societal needs and aspirations. The ambiance facilitates creativity, diversity, and independence of thought, woven together by shared goals and collaborative culture. Minds of faculty and students alike are free to follow their interests and talent, within a flexible overall framework. Human Resource policies, performance appraisal systems, and a symbiotic relationship with the industry encourage high-quality research and knowledge creation, and new product/ IPR development.

The institute has excellent functional relationships and partnerships with the best of learning/ research institutions, corporate monoliths working on moonshots, grand challenges, and cutting-edge research on exponential technologies, leading thinkers, governmental organizations, and multi-lateral bodies world-wide. There is a constant multi-directional flow of ideas, along with exchange and joint research/ programs/ projects and efficient clearinghouse arrangements for knowledge, which is the life-blood of any educational institution. The 360-degree research ecosystem, covering a wide range including translational, blue-skies, and application-directed research, is impressive in terms of both the quality of the researchers and their output. The strong industry connection further strengthens the research and teaching systems, apart from creating other opportunities for the institute and the students.

The completely new paradigms of curriculum design/ content, with a broad-based multi-disciplinary approach, are tailored to meet future needs/ challenges. Pedagogy, with blended and immersive media-based teaching technologies, enables mindful learning for a large number of students on the campus and globally, adding fun in the process (including through narratives, stories, challenges, and digital games). An innovative system is in place to get a fair share of courses delivered digitally (in 3 D virtual classrooms) by some of the top teachers/ experts in the world, available through the institute's network. Many courses are also being conducted jointly by them and the institute's faculty members. New courses are being introduced periodically and the content of all courses is updated regularly, to keep pace with fast-developing technologies and expanding horizons of knowledge.

About Department of Physics, IITJ

The Department of Physics at IIT Jodhpur came into existence in February 2015. Based on the available expertise with the faculties of the department there are four cohesive and focussed research groups working in broad areas viz. (i) Condensed Matter and Plasma Physics, (ii) High Energy Physics and Astrophysics, (iii) Optics & Photonics, and (iv) Quantum Physics. The focussed groups are helping the department in multiplying its academic and research outputs in terms of quality as well as quantity. At present there are around 20 faculties and 68 PhD students pursuing research in different domains. During COVID-19 Pandemic, the faculties and students of the department developed three technologies which were successfully transferred to different industries/NGOs for mass production. Besides core teaching and research labs, four thematic labs in the areas of Cold Plasma Technologies, Energy, Photonics and Quantum Physics are being developed.

Symposium Schedule

12th December, 2022 (Monday)

08:15 AM	**Registration**
09:15-10:15 AM	**Inauguration** **Chief-guest:** Dr. R. Chidambaram, Former Chairman, Atomic Energy Commission & Principal Scientific Advisor to the Govt. of India **Guest-of-honour:** Prof. Bimla Buti, Former Sr. Professor, PRL, Ahmedabad & President Buti Foundation **Guest-of-honour:** Prof. Y. C. Saxena, Former Sr. Professor and Advisor ITER-India, IPR, Gandhinagar **Welcome Address:** Prof. Santanu Chaudhury, Director, IIT Jodhpur
10:15-10:45 AM	**Key Note Address:** Prof. Avinash Khare, Vice-Chancellor, SCU, Sikkim **Theme- Plasma Technologies for Sustainable Development**
10:45-11:00 AM	**High Tea**
Session 1 BP: Basic Plasma	(Session Chair: Prof. Amita Das, IIT Delhi)
11:00-11:25 AM	**Invited Talk-1 by Prof. Sudip Sengupta, IPR Gandhinagar** Radiation Reaction Effects on Charged Particle Dynamics in an Intense Electromagnetic Wave
11:25-11:50 PM	**Invited Talk-2 by Dr. Utpal Deka, MIT Bengaluru** Producing Smart Perovskite Manganites using Plasma Irradiation
11:50-01:00 PM	**4 Oral Presentations** **BP-O-1** Effect of External Grids on Ion Flow Dynamics in an Inertial Electrostatic Confinement Fusion Device Lucky Saikia, CPP-IPR, Guwahati **BP-O-2** Wave breaking Amplitude of Relativistically Intense Longitudinal Waves In Cold Magnetized Plasma Nidhi Rathee, IPR, Ghandhinahar **BP-O-3** Experimental Investigation of Double Layers Near a Fireball Boundary Pragjyoti Sut, IASST, Guwahati

BP-O-4
Influence Of Electron Temperature Inhomogeneity On Radial Density Profile In Cylindrical Discharges
Swati, IPR, Ghandhinahar

01:00-02:00 PM **Lunch Break**

Session 2 NF: Nuclear Fusion & Technology (Session Chair: To be announced)

02:00-02:35 PM **Plenary Talk -1 by Prof. Shishir Deshpande, IPR, Gandhinagar**
Harnessing Nuclear Fusion: India's ITER Participation and Fusion Roadmap

02:35-03:35 PM **5 Oral Presentations**

NF-O-1
Design, Development and Characterization of Flexible Plasma Focus Tube for Pulsed $\geq 10^6$ Neutrons Generation
Ram Niranjan, BARC, Mumbai

NF-O-2
Studies On The Retarded Recrystallization Of Tungsten In CIMPLE-PSI, Exposed Under Extreme Surface Temperature And He^+ Fluence
Mizanur Rahman, CPP-IPR, Guwahati

NF-O-3
Energy Confinement Studies of Hydrogen and Deuterium Ohmically heated Plasmas in ADITYA-U Tokamak
R L Tanna, IPR, Ghandhinahar

NF-O-4
Overview of Remote Handling and Robotics Technology Developments in IPR
Krishan Kumar Gotewal, IPR, Ghandhinahar

NF-O-5
Compact ECR Large Area Plasma Source as a Potential Negative Hydrogen Ion Source for Fusion Application
Shweta Sharma, IIT Delhi

Special Session 03:35:03:50 PM Student for ITER Project Cadarache France

Session 3 **Buti Young Scientist Award Presentations**

03.50-05.30 PM **5 Oral Presentations**

BYSA-1
Focusing of High Current Plasma Ion Beams Using Sheath Nonlinearity: Quantum Beams for Physics and Applications
Sushanta Barman, IIT Kanpur

BYSA-2
Synchronization of Dust Acoustic Waves in a Forced Korteweg-de Vries-Burgers model
Ajaz Mir, IIT Jammu

BYSA-3
Ar Plasma Nanostructured Superhydrophobic Surfaces for Self-cleaning
Vivek Pachchigar, IPR, Ghandhinahar

BYSA-4
Understanding the Physical Processes Prevailing in the Edge Plasma Region of ADITYA-U Tokamak using Spectroscopic Measurements
Nandini Yadava, Nirma University, Ahmedabad

BYSA-5
Hall Magnetohydrodynamical Evolution of the Solar Coronal Plasma
Kamlesh Bora, PRL, Ahmedabad

05.30-07.30 PM	**Session 4** **Poster Session (along with Tea/Coffee)** BP/NF/CD/TS (Session Chairs will be declared during the symposium)
07.30-08.00 PM	**Session 5** **Cross-Disciplinary** (Session Chair: Prof. M. Krishna Mohan, Birla Institute of Scientific Research (BISR), Jaipur) **Talk-1 by Dr. Pravin Kumar, Professor & Head Department of Dentistry, All India Institute of Medical Sciences (AIIMS) Jodhpur** Cold Plasma and its Potential uses in Medical and Dental Clinical Practices
8:00 PM Onwards	**Dinner**

13th December, 2022 (Tuesday)

Session 6 IP: **Industrial Plasma Applications**
(Session Chair: Prof. Subroto Mukherjee, Ex-Head, FCIPT-IPR Gandhinagar)

9:00-9:25 AM **Invited Talk -1 by Dr. Rohit Shukla, BARC, Vizag**
Electrical Pulsed Power in Applied Field

9:25-9:50 AM **Invited Talk -2 by Dr. Satyananda Kar, IIT Delhi**
Antimicrobial Efficacy of Cold Atmospheric Pressure Plasma Jet Against Clinically Isolated Multidrug-resistant Bacteria

9:50-10:50 AM **4 Oral Presentations**

IP-O-1
Cold Plasma Treatment for Surface Modification of Ceiba Pentandra Fiber
Ramyaranjan Das, NIT Rourkela

IP-O-2
Development of Asymmetric Cross Section Waveguide for Large Area Cold Plasma Generation for Radioactive Decontamination
Zahoor Dar, BARC, Mumbai

IP-O-3
DBD Plasma Based High-Efficiency Indoor Air Purifier
Ramavtar Jangra, IIT Jodhpur

IP-O-4
Synthesis of Mn_3O_4/Co_3O_4 Nanocomposite by Liquid Phase Microplasma Method for Supercapacitor Application
E R Kavitha, Bharathiar University, Coimbatore

10:50 -11:00 AM **Tea Break**

Session 7 SA: Space & Astrophysical Plasma
(Session Chair: Prof. Nareshpal Singh Saini, GNDU, Amritsar & President PSSI)

11:00-11:25 AM **Invited Talk -1 (Prof. Dibyendu Chakrabarty, PRL, Ahmedabad)**
Aditya-L1 Mission of India and Investigation of Solar Wind Plasma

11:25-11:50 AM **Invited Talk –2 (Dr. Piyali Chatterjee, IIA, Bangaluru)**
Unravelling the Nature of Solar Plasma Jets using Numerical Simulations and Laboratory Experiment

11:50-01:00 PM	**4 Oral Presentations**
	SA-O-1 Inertial Magnetohydrodynamic Formulation of Magnetosonic Waves due to Orbital Space Debris Siba Prasad Acharya, SINP, Kolkata
	SA-O-2 Kinetic Alfven Wave Interactions In 2.5D Kinetic Simulations Kirit Makwan, IIT Hyderabad
	SA-O-3 Role of Electron Beam and Higher Order Corrections on Ion Acoustic Shocks Sunidhi Singla, GNDU, Amritsar
	SA-O-4 Interaction of Dust Ion Acoustic Wave In Cometary Plasma Dr. Jit Sarkar, Jadavpur University, Kolkata
01:00-2:00 PM	**Lunch Break**
2:00-3:30 PM	**Talks by 2022 Awardees** (Session Chair: Dr. P. K. Atrey, IPR Gandhinagar) 1) Parvez Guzdar Award 2) Shodha-PSSI Award 3) Sholapurwala Award
3:30-5:30 PM	**Session 8** Poster Presentation **along with Tea/Coffee** (IP/SA/PP) (Session Chairs will be declared during the symposium)
	Special Session: Plasma Based Start-ups in India (Session Chair: Dr. Venkat N. Ramani, MD ADITYA HIGH VACUUM PVT. LTD., Kathwada, Gujarat)
5:30-5:50 PM	**Invited talk-1 Dr. Arun Sarma, DG, NECTAR, Delhi** Plasma Technology Based Start-up Ecosystem in India
5:50-6:10 PM	**Invited talk-2 Dr. Tarun P. Sharda, Director, Innovative Material Technologies Pvt. Ltd. Jaipur** Plasma Application: CVD Diamond from Laboratory to Production
6:15-7:00 PM	**PSSI GBM**
7:00-8:30 PM	**Cultural Program**
8:30 PM Onwards	**Director's Dinner**

14th December, 2022 (Wednesday)

Session 9 PD: **Plasma Diagnostics**
(Session Chair: To be announced)

9:00-9:25 AM **Invited Talk-1 Dr. Raju Daniel, IPR Gandhinagar**
Diagnostics: Tokamak Operator's Perspective

9:25-9:50 AM **Invited Talk-2 Dr. Reetesh Kumar Gangwar, IIT Tirupati**
Spectroscopic Diagnostic of Nonthermal Surface Dielectric Barrier Discharge and its feasibility for Environmental Applications

9:50-10:45 AM **3 Oral Presentations**

PD-O-1
Diagnostics of Laser Produced Cu Plasma through a Collisional Radiative Model Using Calculated Fully Relativistic Detailed Electron Excitation Cross-Sections
Ayushi Agarwal, IIT Roorke

PD-O-2
Overview of IN-DA Diagnostics for ITER
Gheesa Lal Vyas, ITER-India, IPR, Ghandhinagar

PD-O-3
Design and Installation of Fast Reciprocating Drive System for ADITYA-U Tokamak
Kaushlender Singh, IPR, Ghandhinahar

10:45-11:15 AM **Tea Break**

Session 10 PU/LP: **Pulsed and Laser Plasma**
(Session Chair: To be announced)

11:15-11:40 AM **Invited Talk-1 Dr. Amit D. Lad TIFR Mumbai**
Ultra-Intense Laser Produced Shock Waves

11:40-12:05 PM **Invited Talk-2 Dr J. A. Chakera, RRCAT Indore**
Laser Plasma Based Particle Accelerators and Some Recent Studies

12:05-1:05 PM **4 Oral Presentations**
PUPL-O-1
Point Projection Radiography of Slow Current Driven Exploding Wire Plasma using Microsecond X-pinch
S.C. Andola, A.C. Jaiswar, and K.D. Joshi
BARC, Mumbai
PULP-O-2

	A Collimated Electron Beam From The Laser-Driven Deuterium Cluster In Ambient Magnetic Field Kalyani Swain, IPR, Ghandhinahar
	PULP-O-3 Fabrication of Silicon Micro-Pillars Using Ultrashort Optical Vortex Beam In The Soft Ablation Regime Nancy Verma, RRI, Bungaluru
	PULP-O-4 Hydrodynamics of Laser-Induced Air Plasma Interaction with Plane and Structured Aluminum Surface DR. P S L Kameswari Durvasula, University of Hyderabad
1:05-2:00 PM	**Lunch Break**
Session 11 EP: Exotic/Dusty Plasma	(Session Chair: Prof. Bipul Kumar Saikia, Centre Director, CPP-IPR Guwahati)
2:00-02.25 PM	**Invited talk-1 Dr. Pintu Bandyopadhyay, IPR Gandhinagar** Experiments on Crystal Dynamics in Strongly Coupled Complex Plasmas
2:25-02:50 PM	**Invited talk-2 Prof. Nilakshi Das, Tezpur University, Tezpur** Self Diffusion of Complex Plasma in Magnetised Flowing Environment
2:50-3:35 PM	**3 Oral Presentations** **EP-O-1** Experimental Observation of Coulomb Screening and Coulomb Acoustic Wave in Nanodusty Plasmas Bidyut Chutia, IASST, Guwahati
	EP-O-2 Collective Excitations of Strongly Coupled Systems under the Quasi-localized Charge Approximation (QLCA) Framework Prince Kumar, IPR, Ghandhinahar
	EP-O-3 Effect of Negatively Biased Electrode on Two Ion Species Plasma Wall Transition and Dust Harging Shiva Bikram Thapa, Tribhuvan University, Nepal
3:35-5:15 PM	**Session 12 Poster Presentations** (PD/PU/LP/EP) (Session Chairs will be declared during the symposium)
5:15-5:45 PM	Concluding Session (**AWARDS CEREMONY)**
5:45 PM	**High Tea**

Key Note Address: Prof. Avinash Khare, Vice-Chancellor, SCU, Sikkim

Plasma Technologies for Sustainable Development

Avinash Khare

Sikkim Central University, Tadong, Sikkim, India

Abstract

According to Bruntland report 1987 “Sustainable Development” is the “Development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs". In simple terms it means the development without compromising earth’s natural resources and ecosystem. In recent times, the search for technologies which are consistent with the principles of sustainable development has intensified. In this search, the plasma based technologies have shown a great potential to provide a waste free, carbon footprint free, and clean technology consistent with sustainable development. The talk describes some of these technologies. The talk focuses mainly on Plasma Medicine. However, applications of plasma based technologies to textile industry, packaging industry, transport industry, furniture industry, plasma display panel etc. will also be briefly described.

Invited Talks		
Sr. No.	**Track**	**Title/Name/Affiliation**
1.	BP	**Radiation Reaction Effects on Charged Particle Dynamics in an Intense Electromagnetic Wave** *Prof. Sudip Sengupta, IPR, Ghandhinahar*
2.	BP	**Producing Smart Perovskite Manganites using Plasma Irradiation** *Dr. Utpal Deka, MIT, Begaluru*
3.	NF	**Harnessing Nuclear Fusion: India's ITER Participation and Fusion Roadmap** *Prof. Shishir Despande, IPR, Ghandhinahar*
4.	CD	**Cold Plasma and its Potential uses in Medical and Dental Clinical Practices** *Dr. Pravin Kumar, AIIMS, Jodhpur*
5.	IP	**Electrical Pulsed Power in applied field** *Dr. Rohit Shukla, BARC, Vizag*
6.	IP	**Antimicrobial Efficacy of Cold Atmospheric Pressure Plasma Jet Against Clinically Isolated Multidrug-resistant Bacteria** *Dr. Satyananda Kar, IIT Delhi*
7.	SA	**Aditya-L1 Mission of India and Investigation of Solar Wind Plasma** *Prof. Dibyendu Chakrabarty, PRL, Ahmedabad*
8.	SA	**Unravelling the Nature of Solar Plasma Jets using Numerical Simulations and Laboratory Experiment** *Dr. Piyali Chatterjee, IIA, Bengaluru*
9.	PD	**Diagnostics: Tokamak Operator's Perspective** *Dr. Raju Danial, IPR, Ghandhinahar*
10.	PD	**Spectroscopic Diagnostic of Nonthermal Surface Dielectric Barrier Discharge and its feasibility for Environmental Applications** *Dr. Reetesh Kumar Gangwar, IIT Tirupati*
11.	PU/LP	**Ultra-Intense Laser Produced Shock Waves**

		Dr. Amit D Lad, TIFR, Mumbai
12.	PU/LP	**Laser Plasma Based Particle Accelerators and Some Recent Studies** *Dr. J A Chakera, RRCAT, Indore*
13.	EP	**Experiments on Crystal Dynamics in Strongly Coupled Complex Plasmas** *Dr. Pintu Bandyopadhyay, IPR, Ghandhinahar*
14.	EP	**Self Diffusion of Complex Plasma in Magnetised Flowing Environment** *Prof. Nilakshi Das, Tezpur University*
15.	Plasma Based Start-ups in India	**Plasma Technology Based Start-up Ecosystem in India** *Dr. Arun Sarma, DG, NECTAR, Delhi*
16.	Plasma Based Start-ups in India	**Plasma Application: CVD Diamond from Laboratory to Production** *Dr. Tarun P. Sharda, Director, Innovative material Technologies Pvt. Ltd., Jaipur*

Radiation Reaction Effects on Charged Particle Dynamics in an Intense Electromagnetic Wave

Sudip Sengupta[a]

IPR, Ghandhinahar, Bhat, Gandhinagar 382428, India

Abstract

Advancement in laser technologies in the last few decades has resulted in the achievement of ultra-high intensities, of the order of $\sim 10^{23}$W/cm^2. Interaction of a charged particle with such intense electromagnetic waves, necessitates the inclusion of radiation reaction force in the charged particle equation of motion. In the present talk, effect of radiation reaction force on the dynamics of a charged particle interacting with an intense electromagnetic wave will be presented using the physically appealing Hartemann-Luhmann equation of motion[1]. It is found that the particle gains substantial amount of energy from the wave over a period of time. This "counter-intuitive" result is found to be independent of the polarization of the electromagnetic wave and also found to be independent of the choice of model equation of motion viz. Landau-Lifshitz and Ford-O'Connell equation of motion[2]. Studies, when further extended, for the case of a charged particle interacting with a focussed light wave, show that radiation reaction force can dominate over the ponderomotive force due to focussing and cause the particle to cross the focal region, thus further enhancing the forward energy gained by the particle from the intense light wave. From the perspective of energy gain, these studies clearly show that the parameter space for forward energy gain which is reduced by ponderomotive effects (earlier result by Kaw et. al.[3]), is compensated by radiation reaction effects[4]. These results are of crucial relevance to the present day direct laser acceleration schemes of charged particles.

[1] F. V. Hartemann and N. C. Luhmann, Phys. Rev. Lett. 74, 1107 (1995).
[2] Shivam Kumar Mishra and Sudip Sengupta, Eur. Phys. J. Spec. Top. 230, 4165 (2021).
[3] P. K, Kaw and R. M. Kulsrud, Phys. Fluids 16, 321 (1973).
[4] Shivam Kumar Mishra, Sarveshwar Sharma and Sudip Sengupta, Sci. Rep. 12, 19263 (2022).

[a]sudip@ipr.res.in

PRODUCING SMART PEROVSKITE MANGANITES USING PLASMA IRRADIATION

Utpal Deka

Manipal Institute of Technology Bengaluru, Manipal Academy of Higher Education, Manipal 576104

E-mail: deka.utpal@manipal.edu

Abstract

Perovskite manganites are of high demand because of its tunable physical properties suitable for various industrial applications. Perovskite manganites has the $RE_{1-x}AE_xMnO_3$ (RE = trivalent rare-earth ions, AE = divalent alkaline earth ions) structure, with x as the concentration of doping. By incorporating appropriate modifications in its structure its electrical, thermopower, magnetic, photo-physical, etc. properties its effectivity can be enhanced. Studies found that perovskite manganites exhibits colossal magnetoresistance (CMR), metal-insulator transition temperature (T_{MI}), and ferromagnetic to paramagnetic transition (FM-PM) at a certain temperature [1].

The variation of doping concentration is the widely used mechanism for manipulating the physical properties of manganites. However, it has its own limitations. It has been proven that ion beam and electron beam irradiation are other effective ways of altering the properties. In our studies, we have investigated the effect of oxygen plasma for smart modification of the manganites. It is found that oxygen plasma plays a novel mechanism for enhancing the properties, which is yet to be explored in depth. It is observed that the cell parameters of the maganite structure changes after plasma exposure. Oxygen plasma leads to a new methodology for tweaking the Mn^{3+} and Mn^{4+} ratios, which plays the vital role in varying the electrical resistivity when compared with the pristine samples. The decrease/increase in the resistivity may be credited to the stretching/decrease of the Mn-O-Mn bond angle after plasma exposure [2], which in turn affects the probability of charge carrier hopping between Mn^{3+} and Mn^{4+} states. The thermoelectric power also gets modified after certain temperature. Overall, it appears that plasma exposure acts as an alternate way of improving the physical properties of perovskite manganites.

References :

[1] Correlation between structural and transport properties of electron beam irradiated $PrMnO_3$ compounds, Christopher J. Benedict, et. al., Solid State Commun., **270**, p 30-372, (2018)
[2] Low pressure plasma induced surface modification of $La_{0.5}Sr_{0.5}MnO_3$ for enhancement of physical and electrical properties, Pronita Chettri, et. al., Applied Phys. A, **128,** p 821 (1-10), (2022)

Harnessing Nuclear Fusion: India's ITER Participation and Fusion Roadmap

S.P. Deshpande

IPR, Ghandhinahar, Bhat Gandhinagar, 382428, India

E-mail: spd@ipr.res.in

Abstract

Harnessing nuclear fusion for creating a futuristic, self-sufficient source of carbon-free energy with an equitable geographical accessibility is the aim of controlled thermonuclear fusion research. In a thermonuclear fusion reaction, where the deuterium-tritium plasma has been heated to almost 200 million K, a fusion reaction releases an α-particle of 3.5 MeV and a neutron of 14.1 MeV energy. Magnetically confined tokamak plasmas have become the basis for the fusion reactors due to their success in demonstrating D-T fusion. In such devices, the α-particle from fusion dumps its energy back to the plasma, keeping it hot enough for fusion whereas the neutron is captured in the blanket that surrounds the plasma, where it not only deposits its energy in the form of heat but also re-generates some tritium, to ensure self-sufficiency. But this idea will need practical demonstration on a large scale and will be tested on ITER. ITER is an international collaboration among seven parties (China, EU, India, Japan, S. Korea, Russia and the US). The shared construction is generating an experience for scientists/engineers around the globe and serving as a boost to industrial capability in various types of manufacturing and processes spanning multiple disciplines. To make fusion a commercial reality, one will have to go beyond ITER and build a demonstration of **net-**electrical power generation in a reliable manner so that the power-grid accepts it as a stable baseload source. Thus, a DEMO reactor is necessary for transition to full power plant. But DEMO is a large undertaking, with the current level scientific and technological maturity, we must take a staged approach where fusion is demonstrated on a smaller scale. Such stages require a device where alternative technologies (e.g., low temperature vs. high temperature superconductors) are tested in an integrated manner and a final selection is made. A pre-DEMO device, called Pilot Plant is also needed to simulate the DEMO conditions and validate solutions, especially the engineering-Q for gross electrical power generation, albeit on a small scale. So, a robust roadmap of fusion research is needed that is dotted with technology-development projects where components and systems gradually go from R&D phase to deployment-level; options are assessed, and difficulties are overcome. We also know that globally, new technologies are being developed for compact tokamak reactors, which also need to be explored. Thus, the fusion roadmap needs a flexible structure that continuously receives feedback from the latest results and has a set of clear intermediate targets. It will need involvement of academia and industries to achieve intermediate targets and steering the course based on the outcome. The elements of a fusion roadmap along with a summary of developments in nuclear fusion will be presented.

COLD PLASMA AND ITS POTENTIAL USES IN MEDICAL AND DENTAL CLINICAL PRACTICES

Dr. Pravin Kumar

Professor and Head, Department of Dentistry
All India Institute of Medical Sciences,
Jodhpur, Rajasthan, India - 342005.

E-mail: pravinkumar5@hotmail.com

Abstract

Low temperature plasmas that can be generated at atmospheric pressure and have temperatures below 40°C have opened up a new frontier in plasma usage in the last few decades: specially in biomedical applications. These plasma sources generate reactive species (radicals and non-radicals), charged particles, photons, and electric fields, all of which have **significant biological effects**. An understanding of biological cell mechanisms on macroscopic and microscopic scales have undoubtedly led to the development of novel plasma-based medical and dental applications. In the practice of medicine and surgery, Cold Atmospheric Plasma (CAP) treatment may be successfully applied in the fields of dermatology, blood coagulation mechanisms, electrosurgery, disinfection /sterilization of surgical instrument and consumables, and enhancement of hydrophilic property of biomaterials. It was reported that synergistic effect of plasma treatment on the antibacterial and therapeutic activities of natural extracts was potentiated in managing multidrug resistant bacterial infections. Plasma application is known to induce tumour cell death and decreases their adhesion, migration, and invasion, decreasing cancer cell diffusion and metastasis forming ability. In head and neck squamous cell carcinomas cold plasma is known to support lesion regression as well as pain reduction. However, determination of underlying mechanism of the tumour cell arrest and the relative immune response have not been elucidated. Cold Plasma has tested for the treatment of dental caries, periodontal disease, teeth whitening, tooth remineralization, and for increasing bonding efficacy of composite resin. Cold Atmospheric Plasma Jet is also known to be effective at destroying biofilms, disinfection of root canal systems and smear layer removal from dentinal surfaces. In the specialty of endodontics, the elimination of bacteria in infected root canals, especially with persistent periapical lesions, still remains an unresolved issue, as conventional chemical irrigants fail to achieve the eradication of bacteria in the region and for precisely these reasons, Cold Atmospheric Plasma can be seen not only as an alternative but also as an adjunct to investigate synergistic treatments. Similarly, its potential to achieve super-hydrophilic surface that may stabilize the blot clot and promote the early wound healing immediately after implant insertion leading to better osseointegration is an avenue for integration of physics into biomedical sciences.

Electrical Pulsed Power in applied field

Rohit Shukla[1,2], Archana Sharma[1,2]

[1]*Pulsed Power & Electromagnetics Division, BTDG*
Bhabha Atomic Research Centre, Visakhapatnam AP 530016
[2]*Homi Bhabha National Institute, Mumbai, India*

E-mail: rshukla@barc.gov.in

Abstract

The technology of electrical Pulsed Power is known for its ability to deliver intense powers upto Terawatts in certain load at higher voltage and higher currents for limited time durations like nanoseconds or microseconds. This intense pulse power experience in load material has shown to create a valuable outcome in terms of applied activity where the electronic nature of control of the event is desirable in terms of portability and safety of operation.

Some experimental activities of utilizing electrical pulsed power for generation of High magnetic field, its measurement and application in metal forming and welding using compression and expansion methods will be presented. Metal plasma production and utilizing its intense energy density in for production of metal nanopowder, shock pressure waves for some applications is also presented in this talk. Interaction of these shock waves with different media of applied activities like solids and liquids is also presented. Some of these works are also made available to industries through technology transfers. Compact pulsed power sources have also been known to deliver state of art radiation devices like that of neutrons and associated Hard X-rays. Some activity of pulsed radiation sources using pulsed power in plasma focus device is also presented.

Antimicrobial Efficacy of Cold Atmospheric Pressure Plasma Jet Against Clinically Isolated Multidrug-resistant Bacteria

Satyananda Kar[1], Sarthak Das[1] and Sarita Mohapatra[2]

[1]Department of Energy Science and Engineering, IIT Delhi, Hauz Khas, New Delhi –110016
[2]Department of Microbiology, AIIMS, New Delhi

E-mail: satyananda@dese.iitd.ac.in

Abstract

"Plasma" - an ionized gas discharge has sparked research interest in various industrial applications, including the health sector, waste treatment, air and water purification, and so on. At atmospheric pressure, plasma discharges ignited by various sources such as DC, AC, RF, and microwave can be classified into thermal ($T_e \approx T_i \approx T_g$) and non-thermal ($T_e >> T_i \approx T_g$) [1]. Thermal plasma is primarily used in high-temperature applications such as solid waste treatment via plasma pyrolysis. Non-thermal plasma, due to its low temperature and chemically selective nature, has found its usage in sterilization, disinfection, wound decontamination, dentistry, wastewater treatment, air purification, food decontamination, etc. [2] [3]. In Plasma Application Laboratory, IIT Delhi, we have developed cold atmospheric pressure plasma jet (CAPJ) systems being operated with various sources of RF [4], AC [5], and microwave. Our study emphasizes the characterization (electrical, optical, and species) of the CAPJ along with its effectiveness in applications such as wastewater treatment [5] and biomedical.

In collaboration with AIIMS, New Delhi, the antimicrobial efficacy of AC CAPJ is studied. These CAPJ systems with an average discharge power of ≈ 0.6 W and a plume temperature of ≈ 30 °C are proven to be suitable for biomedical applications. The preliminary investigation revealed that the CAPJ has high efficacy in inactivating clinically isolated multidrug-resistant (MDR) bacteria such as *E. coli, P. aeruginosa, S. aureus, K. pneumoniae, E. faecium, and A. baumannii.* Further, to achieve high productive efficacy, the developed CAPJ is currently being optimized with various operational parameters such as exposure time, exposure distance, gas flow rates, etc. The effectiveness of microbial inactivation by CAPJ increased as exposure time increased. There is also a reduction in bactericidal effect with increasing CAPJ exposure distance. The antimicrobial effect was enhanced with higher gas flow rates. The presence of RONS species (oxidative stress) and ions (electrostatic stress) might be responsible for microbial killing effect. Therefore, these experimental results illustrate the potential for using CAPJ in a wide range of antimicrobial applications, including sterilization, disinfection, decontamination, etc., in healthcare settings.

References:

[1] D. Braný, D. Dvorská, E. Halašová, and H. Škovierová, Int. J. Mol. Sci. **21**, (2020).
[2] S. Das, V.P. Gajula, S. Mohapatra, G. Singh, and S. Kar, Heal. Sci. Rev. **4**, 100037 (2022)
[3] M. Khan, P. Prasad, S. Kar, and J. Sahu, in Atmospheric Pressure Non-Thermal Plasma in Food Processing (2021), pp. 223–251.
[4] Mahreen, G.V. Prakash, S. Kar, D. Sahu, and A. Ganguli, Contrib. to Plasma Phys. 62, e202200007 (2022).
[5] D. Joshi, G.V. Prakash, S.Z. Ahammad, S. Kar, and T.R. Sreekrishnan, Plasma Sci. Technol. (2022), **24(10)**, 105501.

Aditya-L1 mission of India and investigation of solar wind plasma

Dibyendu Chakrabarty

Physical Research Laboratory, Navarangpura, Ahmedabad

The Aditya-L1 mission is India's first dedicated mission to observe the Sun round-the-clock. The satellite will be placed in a Halo orbit around the first Lagrangian point of the Sun-Earth system for the unhindered view of the Sun round-the-clock. There are seven experiments on-board this mission. Four of these experiments are for remote sensing of the Sun and three experiments are planned for the in-situ sampling of the solar wind plasma and magnetic field. While the remote sensing experiments are designed to understand the solar and coronal processes, the in-situ experiments are designed to understand the solar wind plasma processes. These in-situ experiments are Aditya Solar Wind Particle Experiment (ASPEX), Plasma Analyzer Package for Aditya (PAPA) and Magnetometer (MAG). These experiments are designed to measure solar wind ions and electrons, supra-thermal and solar energetic particles as well as magnetic field in multiple directions. Such direction-resolved measurements can throw light on a number of complex processes that include origin, acceleration, anisotropy of solar wind that are not comprehensively understood till date. The measurements from these experiments are of paramount importance for connecting the solar processes to the space weather conditions prevalent around our planet. Some of these aspects will be presented in this talk.

Ultra-Intense Laser Produced Shock Waves

Amit D. Lad[1], Kamalesh Jana[1], A. P. L. Robinson[2], J. Pasley[2,3], and G. Ravindra Kumar[1]

[1]*Tata Institute of Fundamental Research, 1 Homi Bhabha Road, Colaba, Mumbai 400 005, INDIA*
[2]*Central Laser Facility, Rutherford-Appleton Laboratory, Chilton, Didcot OX11 0QX, United Kingdom*
[3]*York Plasma Institute, University of York, Heslington, York YO10 5DQ, United Kingdom*

E-mail : amitlad@tifr.res.in

Abstract

Ultra-intense, femtosecond laser pulses are capable of producing hot, dense plasma and thereby generate intense shock waves. In the present study, a system is considered in which the laser contrast is high; yet, there is sufficient energy in the pre-pulse to form a limited pre-plasma. This turns out to have an interesting consequence as the cold target is now sitting sufficiently close to the probe critical surface. The cold target explodes under the influence of the intense pump pulse, driving a strong shock outward into the pre-plasma [1-4].

A detailed understanding of the critical surface motion of high intensity laser produced plasma is very crucial parameter for understanding the interaction [1]. Experimentally resolving the ultrafast dynamics of high intensity laser driven plasma at both the relevant length scales and timescales simultaneously is a challenging due to mainly the lack of diagnostic approach. Here, we present a novel technique based on pump-probe Doppler spectrometry to map spatially and temporally the ultrafast dynamics of hot-dense plasma generated by femtosecond, relativistic laser pulses [2]. Our technique offers hundreds of femtoseconds time resolution simultaneously with a few micron spatial resolution across the transverse length of the plasma. The experiment was carried out using TIFR 150 TW laser system with peak intensity of 10^{19} W/cm^2. The up-converted second harmonic probe (400 nm) allows us interrogate the dynamics in plasma which is over-dense with respect to pump laser. A normally incident time-delayed probe pulse reflected from its critical layer experiences a change in its wavelength due to the motion of the critical layer. Measuring the time dependent Doppler shifts at different locations across the probe beam we obtain 2D velocity maps of the probe-critical plasma layer at ultrafast timescales. The time and spatial resolution offered by the proposed technique could be improved using a short duration probe pulse and increasing number of detection channels respectively. Harmonics of the pump can be used to penetrate more deeper and capture the ultrafast motion of the solid density plasma [3,4]. Early time measurements using this technique provide valuable information about shock wave generation and propagation in dense medium [2].

References :
[1] P. K. Kaw, Rev. Mod. Plasma Phys. **1**, p 2, (2017).
[2] K. Jana, A. D. Lad, D. West, W. Trickey, C. Underwood, Y. M. Ved, A. P. L. Robinson, J. Pasley, and G. R. Kumar, Phys. Rev. Research **3**, p 033034, (2021).
[3] S. Mondal, A. D. Lad, S. N. Ahmed, V. Narayanan, J. Pasley, P. P. Rajeev, A. P. L. Robinson, and G. R. Kumar, Phys. Rev. Lett. **105**, p 105002, (2010).
[4] A. Adak, A. P. L. Robinson, P. K. Singh, G. Chatterjee, A. D. Lad, J. Pasley, and G. R. Kumar, Phys. Rev. Lett. **114**, p 115001, (2015).

Spectroscopic Diagnostic of Nonthermal Surface Dielectric Barrier Discharge and its feasibility for Environmental Applications

PSNSR Srikar[1], S. M. Allabakshi[2], S. M. Maliyekkal[2], **R. K. Gangwar[1,*]**

[1]*Department of Physics & CAMOST, IIT Tirupati, INDIA, 517619*
[2]*Department of Civil and Environmental Engineering, IIT Tirupati, INDIA, 517619*

*E-mail: reetesh@iittp.ac.in

Abstract

Nonthermal atmospheric pressure plasma-based advance oxidation process (AOP) is receiving significant attention in various environmental and biomedical applications. It is due to the fact that plasmas can provide a unique environment composed of neutral atoms, molecules, radicals, excited states, ions, and energetic electrons. Moreover, the in-situ production of these reactive chemical species (RCS) by plasma does not essentially require chemical agents. However, a crucial challenge is generating homogenous plasma for large-scale treatment in ambient conditions to make the technology viable for commercial-scale operation. Further, the plasma should produce adequate RCSs for efficient processing while maintaining the nonthermal nature. Therefore a reliable plasma diagnostic is highly required to optimize the production of RCSs and, thereby, the plasma-mediated processing. Plasma diagnostic also provides insight into the physics of plasma surface interaction.

In this regard, recently, we have performed a detailed study on the feasibility of surface dielectric barrier discharge (SDBD) for wastewater treatment applications. We have performed the plasma diagnostic of SDBD by coupling optical emission spectroscopy (OES) measurements with a suitable collision radiative (CR) model to extract information on crucial plasma parameters such as electron temperature and electron density. Further, the reactor efficiency is investigated by studying the degradation and mineralization of azo dye (Brilliant Red 5B) under various experimental conditions such as initial dye concentration, pH, and background salts (NaCl, Na_2SO_4, and Na_2CO_3). The reactive species (•OH and H_2O_2) quantification is also carried out.

Overall, our investigation shows that the SDBD reactor can be an energy-efficient and promising technology for wastewater treatment applications. Detailed information on our findings, including the SDBD setup, OES measurements, CR model, and reactive species variation under various operating conditions, will be presented in my talk during the conference.

References :

[1] S. M. Allabakshi, PSNSR Srikar, R. K. Gangwar, and S. M. Maliyekkal, “Feasibility of surface dielectric barrier discharge in wastewater treatment: Spectroscopic modeling, diagnostic, and dye mineralization,” Separation and Purification Technology, (2022), 296 (2022) 121344.

DIAGNOSTICS: TOKAMAK OPERATOR'S PERSPETIVE

Daniel Raju*

IPR, Ghandhinahar, Bhat, Gandhinagar-382 428, Gujarat, India

raju@ipr.res.in

Abstract

In a Tokamak device, plasma is confined in a strong toroidal magnetic field and its characteristics & dynamics are measured through various diagnostics [1]. Tokamak operators solely rely on these measured signals and take necessary decisions & actions so as to carry out their planned experiments. There are some basic measurements for monitoring the health of the machine (related to safety) along with characterizing the plasma (magnetics, spectroscopy, imaging, X-rays…) without which tokamak operators would always be helpless for operating the machine.

A good coordination among the diagnosticians and tokamak operators is very much required for conducting successful plasma experiments. Analysis of important diagnostics signals in between the two plasma shots or interesting features observed in the previous day's experiments; sometimes give quite crucial information to the tokamak operators for planning out the future experiments.

In this talk, some of the important measurement features would be highlighted that have impacted the tokamak operations. A few case studies would be presented to sensitize the necessity for real-time measurements & control of basic plasma parameters.

References:

[1] Tokamak Plasma Diagnostics, Equipe TFR, Nuclear Fusion, **18**, p 647-731, (1978)

** On behalf of ADITYA-U and SST-1 team*

Unravelling the nature of solar plasma jets using numerical simulations and laboratory experiment

Piyali Chatterjee

Affiliation: Indian Institute of Astrophysics, 2nd Block Koramangala, Bangalore-560034

E-mail: piyali.chatterjee@iiap.res.in

Abstract

Spicules are highly elongated plasma jets seen in the chromosphere of the Sun. These are believed to transport momentum to the solar wind and non-thermal energy to heat the solar corona. At any given time, it is estimated that about 3 million spicules are present on the Sun. We find an intriguing parallel between the simulated spicular forest in a solar-like atmosphere and the numerous jets of polymeric fluid in the laboratory when both are subjected to harmonic forcing at their bottom boundary. In our radiative MHD simulations with sub-surface convection, the solar surface oscillations are excited similarly to those harmonic vibrations. A forest of spicules are formed in our simulations with heights ranging between 6 and 25 megameters, bearing substantially closer resemblance to clusters of jets observed in the solar atmosphere. Taken together, the numerical simulations of the Sun and the laboratory fluid dynamics experiments provide insights into the mechanism underlying the ubiquity of jets. The insight provided by the polymeric fluid experiments when combined with the commonalities with the numerical solar MHD simulations is that four basic ingredients are sufficient to assemble a forest of spicules on the Sun by non-linear wave development.

References :

[1] Polymeric jets throw light on the origin and nature of the forest of solar spicules, Nature Physics, **18**, p 595-600, (2022), DOI: https://doi.org/10.1038/s41567-022-01522-1

Laser Plasma Based Particle Accelerators and Some Recent Studies

J. A. Chakera

Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore-13.

E-mail: chakera@rrcat.gov.in

Abstract

High energy particle accelerators have played a very important role in advancement of modern science. This has led to various new discoveries. In fact further advancement in science is nowadays dictated by the availability of high energy particle accelerators. Conventional particle accelerators are based on Radio Frequency (RF) accelerating electric field. In this the electric field gradient one can achieve is limited to ~ 80 MV/m as a result the length of the particle accelerators becomes very large ranges from few hundreds of meters to few tens of KM for electron beam energy ranging from GeV to few TeV's. Thus it imposes large challenges on technology development and involved huge cost. Limitation on the RF accelerating field comes mainly due to material breakdown occurring at such high field.

Alternatively, plasma based particle accelerators can sustained very high electrical field ~ 100 GV/m. As the field is produced in the plasma, which is already in a break down condition. Therefore it can sustain very high filed gradients. Thus the plasma based accelerators have very small size ranging from few cm to few meters. Therefore the plasma based accelerators are very attractive in terms of their small size and hence low cost. With the availability of ultrashort ultra high peak power Ti:sapphire lasers based on chirped pulse amplification (CPA) technique, realization of laser plasma based high energy particle accelerators are possible with ease.

Using laser plasma based plasma accelerator, electron beam energy in excess of 5 GeV has been demonstrated. Next, ion acceleration viz. proton energy > 50 MeV has been achieved. It may be noted here that the acceleration of electron [1] and proton/ions [2] takes place in laser plasma via two different mechanisms. Though the laser plasma based accelerators are compact and has a very good beam emittance but they have rather large energy spread, poor short to short beam energy stability, and beam pointing stability. Worldwide efforts are being made to address the above issues and achieve high beam quality.

Laser Plasma Division is involved in studies of electron and ion acceleration using 150 TW laser facility and also working in the direction to achieve high beam energy stability, pointing stability and narrow energy spread beam. The talk will summarize our recent studies in this direction. Further, application of electron beam in generation of high energy betatron x-ray source and application of the electron/proton beam in radiography will be presented.

References :

[1] Physics Today **62**, p44-49 (2009)
[2] Rep. Prog. Phys. **75,** p056401-056471 (2012)

Experiments on crystal dynamics in strongly coupled complex plasmas

Pintu Bandyopadhyay, Swarnima Singh, M. G. Hariprasad, Krishan Kumar, Ankit Dhaka, Asha Mudaliyar, Garima Arora, Abhijit Sen

IPR, Ghandhinahar, HBNI, Bhat, Gandhinagar, India

Email: pintu@ipr.res.in

Abstract

A dusty (or complex) plasma comprises of electrons, ions, neutrals, and micron sized charged dust particles. The great diversity in the space and time scales of these constituent components makes for a rich collective dynamics of this medium and has made dusty plasmas an active field of research in condensed matter physics for the last three decades. Dusty plasma crystals have traditionally been observed and studied in radio frequency discharge plasmas, and their formation in a DC glow discharge plasma remains always experimentally challenging. We present various experimental investigations in a stable dusty plasma Coulomb crystal produced in the cathode sheath of a DC glow discharge plasma [1]. These observations are made in the dusty plasma experimental (DPEx-II) device where crystals made of monodisperse melamine formaldehyde grains are produced in the background of an Argon plasma [2]. The crystalline nature of the structure is confirmed through a host of characteristic parameter estimations, which includes the radial pair correlation function, Voronoi diagram, Delaunay Triangulation, the structural order parameter, the dust temperature, and the Coulomb coupling parameter. The crystal formation is frequently found to be accompanied by the presence of one or more slightly heavier particles suspended a little below the monolayer. The interplay of one such test particle with the crystal is investigated for two distinct cases—(i) when the particle remains confined (trapped) in the space below the crystal and (ii) when it interacts for a short while with the crystal and then moves out of the vicinity. The trapped particle orbit induces permanent structural changes in the crystal in the form of micro-cracks, which can be enhanced by energizing the test particle with an incident laser [3]. In some specific discharge condition, the formation of square lattice is observed in this monodisperse complex plasma crystal, which coexists with the hexagonal structures [4]. This crystalline structure can be melted to a liquid state by changing the discharge parameters. The nature of the melting or formation process in our experiment is established as a first-order phase transition from the variations in the Coulomb coupling parameter, the dust temperature, the structural order parameter, and from the existence of a hysteresis behavior [5]. Our experimental results are distinctly different from existing theoretical predictions and indicate a mechanism that is akin to a fluctuation induced first-order phase transition in complex plasmas. In some set of the experiments, these liquid and crystalline states are found to coexist at a specific discharge condition [6].

References:

1. M. G. Hariprasad, P. Bandyopadhyay, Garima Arora, and A. Sen, "Experimental observation of a dusty plasma crystal in the cathode sheath of a DC glow discharge plasma", Phys. Plasmas 25, 123704 (2018).
2. Saravanan Arumugam, P Bandyopadhyay, Swarnima Singh, M G Hariprasad, Dinesh Rathod, Garima Arora and A Sen, "DPEx-II: a new dusty plasma device capable of producing large sized DC coulomb crystals", Plasma Sources Sci. Technol., 30, 085003 (2021).

3. M. G. Hariprasad, P. Bandyopadhyay, Garima Arora, and A. Sen, "Experimental investigation of test particle induced micro-structural changes in a finite two-dimensional complex plasma crystal", Phys. Plasmas 26, 103701 (2019).
4. Swarnima Singh, P. Bandyopadhyay, Krishan Kumar, and A. Sen, "Square lattice formation in a monodisperse complex plasma" Phys. Rev. Letts., 129, 115003 (2022).
5. M. G. Hariprasad, P. Bandyopadhyay, Garima Arora, and A. Sen, "Experimental observation of a first-order phase transition in a complex plasma monolayer crystal", Phys. Rev. E, 101, 043209 (2020).
6. M.G Hariprasad1, P. Bandyopadhyay, V. S. Nikolaev, D. A. Kolotinskii, S. Arumugam, G. Arora, S. Singh, A. Sen, and A. V. Timofeev, "Self-Sustained Non-Equilibrium Co-existence of Fluid and Solid States in a Strongly Coupled Complex Plasma System", Scientific Reports, 12, 13882 (2022).

Self Diffusion of Complex Plasma in Magnetised Flowing Environment

Nilakshi Das and Biswajit Dutta

Tezpur University, Napaam, Tezpur, Assam, 784028

E-mail : ndas@tezu.ernet.in

Abstract

Self diffusion is an important thermodynamic property of dusty plasma which is closely connected with its phase state and is governed by underlying interaction mechanism among charged microparticles. Interesting new physics emerge when charged dust particles are immersed in a magnetized plasma with flowing ions. In presence of magnetic field and ion streaming, the dynamics of plasma get modified which leads to superposition of usual Debye-Hückel potential operating among the dust particles with attractive wake potential, resulting in several novel features of structural and transport properties of dusty plasma. Here effect of wake potential on self-diffusion of dusty plasma is studied using Langevin dynamics simulation. It is shown that presence of ion flow induced wake may drive dusty plasma from sub-diffusive to super-diffusive regime in presence of magnetic field. Emphasis has been given on the fact that even magnetic field of moderate strength may influence transport property of dusty plasma due to the presence of wake potential.

References :

[1] Attractive forces between charged particulates in plasmas, Physics Letters A, **203(1)**, p 40-42, (1995)
[2] Wake potential in 2-d magnetized complex plasma, The European Physical Journal D, **71(5)** p 1-10, (2017)
[3] Transition from attractive to repulsive forces between dust molecules in a plasma sheath, Physical review letters, **83(16)**, p.3194, (1999)
[4] Ion-streaming induced order transition in three-dimensional dust clusters. Plasma Physics and Controlled Fusion, **54(4)**, p 045011, (2012)
[5] Self-diffusion in 2D dusty-plasma liquids: Numerical-simulation results, Physical review letters, **102(8)**, p.085002, (2009)

Plasma Technology Based Start-up Ecosystem in India

Arun Sarma

North East Centre for Technology Application & Reach, Department of Science & Technology, Govt. of India New Delhi-110016

E-mail: arun1970.sarma@gmail.com

Abstract

Plasma physics and Applications are getting more important in many fields and accordingly people are thinking initiate technology driven start-up not only globally but also in our country. According to Govt. report there are more than 40000 start-ups in our country and providing livelihood opportunities to around 4.7 lacs people [1]. From 2017 to 2020, there is an increase of almost 171% in the start-up ecosystem of the country with proper sustainability. Interestingly 30 states and union territories have a dedicated start-up policy and 44% of countries registered start-up is having one woman director and which is a very good sign. The start-up action plan in the country is comprised of 19 action items covering across three key areas of '*simplification and handholding*', '*funding support and incentives*', and '*industry-academia partnerships and incubation*'. Looking at the benefits provided Govt. of India for the development start-up ecosystem in country, it is high time for the plasma technology community to conceptualize few start-ups in the sector also. We have very limited numbers of start-up in this sector particularly in our country. This report will provide a prospective opportunity in plasma technology-based start-up ecosystem in our country.

References:

[1] Reports of Start-up India, Ministry of Commerce & Industry, Govt. of India

PLASMA APPLICATION: CVD DIAMOND FROM LABORATORY TO PRODUCTION

Dr. Tarun Sharda

Innovative Material Technologies Pvt. Ltd., Shri Gopal Nagar, Gopalpura bypass Road, Jaipur, Rajasthan

Email: tsharda@gmail.com

Abstract

Plasma, the fourth fundamental state of matter, when created artificially and controlled by some means, can become a great tool for material processing. One such example for producing an advanced engineering material by plasma is diamond. To make the highest quality of diamond, microwave plasma chemical vapour deposition (CVD) is used as the most preferred method. The last 3-5 decades have witnessed the complete development of making CVD diamond by microwave plasma from laboratory to mass level scale.
A combination of extreme properties of diamond such as high thermal conductivity, extreme hardness, wide range optical transparency and chemical inertness with electrical insulation makes it the most important material for new generation technologies in the 21st century. The growth or coating of diamond at sub atmospheric pressures by microwave plasma CVD is now a well-established method to produce diamond in various forms over large areas.
A complete range of mono, poly and nano-crystalline CVD diamond in various sizes and shapes are now available in a variety of grades, i.e., detector/electronic, optical, thermal, and mechanical for a wide range of applications as shown in the table below.

Field	**Application**	**CVD Diamond Grade** (Single/Poly)
Electronics	Radiation detection in high energy physics, medical dosimetry in radiotherapy, neutron detection for radiation level monitoring, etc.	Electronic
	Heat-spreaders, laser sub-mounts, X-ray targets	Thermal
	Secure quantum communication, quantum computing & magnetic/electric field sensing	Customized (high grade)
Optics	RF Windows (Klystron, Gyrotron) High Power Laser Windows & Components Lenses/ATR, X-ray Windows, Raman Lasers	Optical
Mechanical	Cutting tools, scalpels, knives, wear resistant components, insert for dresser tools	Optical, Thermal & Mechanical
Sensors	Gas sensors	Customized (high grade)
	Electrodes, electro-chemical detectors, bio-chemical sensors	Doped

The availability of CVD diamond has induced advancements into many technologies such as high-power CO_2 and solid-state lasers, high power microwave tubes, advanced materials for aviation, etc. In fact, for many applications that require extremely high-power densities or severe abrasive conditions, CVD diamond is the only solution.

In this presentation, we shall discuss some observations in the journey of taking microwave plasma CVD diamond from laboratory to production was made possible. We shall also present a live demonstration of thermal conductivity of diamond, which is highest amongst all the materials, i.e., 4-5 times more than copper.

Oral Presentations

Session 1

Basic Plasma (BP)			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	248	BP-O-1	**Effect of External Grids on Ion Flow Dynamics in an Inertial Electrostatic Confinement Fusion Device** *Lucky Saikia, CPP-IPR*
2.	252	BP-O-2	**Wave breaking Amplitude of Relativistically Intense Longitudinal Waves In Cold Magnetized Plasma** *Nidhi Rathee, IPR, Ghandhinahar*
3.	308	BP-O-3	**Experimental Investigation of Double Layers Near a Fireball Boundary** *Pragjyoti Sut, IASST, Guwahati*
4.	355	BP-O-4	**Influence Of Electron Temperature Inhomogeneity On Radial Density Profile In Cylindrical Discharges** *Swati, IPR, Ghandhinahar*

Effect of External Grids on Ion Flow Dynamics in an Inertial Electrostatic Confinement Fusion Device

L. Saikia[1], D. Bhattacharjee[1] and S. R. Mohanty[1, 2]

[1] *Centre of Plasma Physics-IPR, Ghandhinahar, Nazirakhat, Sonapur, Assam, 782402*
[2]*Homi Bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra, 400094*

E-mail: lucky.saikia@cppipr.res.in

Abstract

Exploring the ion flow dynamics in an inertial electrostatic confinement fusion (IECF) device is primarily motivated by the desire to create an explicit condition that makes large fusion products feasible from such a small device, allowing for a variety of applications [1-3]. In order to modify the existing IECF device, we introduced two additional grids in addition to the central grid. We then employed the Langmuir probe technique to investigate the plasma properties at various operating voltages. We optimized the device's grid potentials, discharge modes, and other aspects for better ion confinement and ion flow behaviour throughout the chamber. A comparison of plasma properties like ion density and potential in this new configuration at various spatial positions inside the device has been accomplished with the single gridded IECF system. Furthermore, particle-in-cell (PIC) simulation was used to validate the experimental findings for ion density determination. It is to be noted that the operating region of the triple-grid IECF device is moved towards the low pressure, which results in an increase in ion beam energy compared to the single-grid system. Application of positive voltage (30 V, 60 V, 90 V) to the external grid increased the breakdown voltage abnormally (i.e., by 16%, 32%, 61%, respectively) at the lowest 'Pd'. Therefore, by putting a sufficient positive potential on external grids, the triple-gridded configuration enables us to scale up the discharge voltage. However, the examination of I-V curves for hot cathode discharge demonstrates the differences in ion flow behaviour, plasma potential, and core ion density measurements when compared to a single-grid IEC system. It is evident from the impact on the external grid that positive potential has an advantage over negative potential. This paper discusses the experimental results in further depth.

References:

[1] K. Noborio, Y. Yamamoto, Y. Ueno, and S. Konishi, Fusion Eng. Des. 81, 1701 (2006).
[2] G. H. Miley and S. K. Murali, Inertial electrostatic confinement (IEC) fusion (Springer, 2014).
[3] N. Buzarbaruah, N. Dutta, D. Borgohain, S. R. Mohanty, and H. Bailung, Phys. Lett. A 381, 2391 (2017).

Wave breaking Amplitude of Relativistically Intense Longitudinal Waves In Cold Magnetized Plasma

Nidhi Rathee, Sudip Sengupta

IPR, Ghandhinahar, Bhat, Gandhinagar, 382428
Homi Bhabha National Institute, Traning School Complex, Mumbai, 400094

E-mail: nidhi.rathee@ipr.res.in

Abstract

Spatio-temporal evolution of relativistically intense upper-hybrid waves is studied analytically in a cold magnetized plasma using wave frame anstaz. Exact expressions for electron density, velocity and electric field have been derived analytically [1]. It is found that these exact expressions are valid only upto critical amplitude, known as the wave breaking amplitude [1,2,3,4,5,6,7]. This analytical expression for wave breaking amplitude has been verified using a 1-1/2 D code based on Dawson sheet model [2]. The results presented here are of crucial relevance to the surfatron scheme of particle acceleration [8,9].

References :

[1] M. Karmakar *et.al.* Physics of Plasmas **23**, 064503 (2016)
[2] J. M. Dawson, Phys. Rev. **113**, 383 (1959)
[3] C. Maity *et.al.* Phys. Rev. Lett. **110**, 215002 (2013)
[4] J.F. Drake *et.al.* Phys. Rev. Lett. **36**, 196 (1976)
[5] S. Sengupta *et.al.* Phys. Rev. E **79**, 026404 (2009)
[6] P.S. Verma *et.al.* Phys. Rev Lett. **108**, 125005 (2012)
[7] A. I. Akhiezer and R. V. Polovin, Sov. Phys. JETP., **3**, 696 (1956).
[8] T. Katsouleas and J. M. Dawson, Phys. Rev. Lett., **51**, 392–395, (1983).
[9]A. V. Artemyev, A. I. Neishtadt, A. A. Vasiliev, and L. M. Zelenyi, Phys. Rev. Lett., **115**,155001, (2015)

Experimental Investigation of Double Layers Near a Fireball Boundary

Paragjyoti Sut[1,3] and Prarthana Gogoi[1,3], N. C. Adhikary[1], H. Bailung[2,3]

Affiliation: [1]Physical Sciences Division, Institute of Advanced Study in Science & Technology (IASST), Paschim Boragaon, Guwahati 781035, Assam, India
[2]Department of Physics, Bodoland University, Kokrajhar 783370, Assam, India
[3]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India

E-mail: sutparagjyoti@gmail.com

Abstract

The concept of plasma double layer (DL) has been an exciting research topic, mainly in astrophysical phenomena, space propulsion, and electron and ion beam production [1]. Although numerous experiments have been done on the DL, the production of DL near a fireball boundary is exceptional. The fireball in a plasma refers to an additional discharge phenomenon that occurs in front of an immersed electrode which is biased far above the plasma potential [2], [3].

We have performed our experiment in the double plasma device where plasma is produced using filamentary discharge. A planar electrode (~ 1.5 cm in diameter) is immersed in the plasma and biased ~ (60-90) V, far above the plasma potential, to produce the fireball. The Langmuir probe is used to investigate the plasma parameters, whereas the emissive probe measures the plasma potential through the inflection point method. The axial potential profile measured from the bulk plasma towards the electrode indicates the existence of a DL at the boundary of the fireball and the background plasma. The characteristics of the DL under different discharge conditions will be presented.

References:

[1] C. Charles, "A review of recent laboratory double layer experiments," *Plasma Sources Sci. Technol.*, vol. 16, no. 4, *(2007)*, doi: 10.1088/0963-0252/16/4/R01.
[2] B. Scheiner, L. Beving, and S. D. Baalrud, "On the hysteresis in fireball formation and extinction," *Phys. Plasmas*, vol. 26, no. 1, *(2019)*, doi: 10.1063/1.5080945.
[3] S. D. Baalrud, B. Scheiner, B. T. Yee, M. M. Hopkins, and E. Barnat, "Interaction of biased electrodes and plasmas: Sheaths, double layers, and fireballs," *Plasma Sources Sci. Technol.*, vol. 29, no. 5, *(2020)*, doi: 10.1088/1361-6595/ab8177.

Influence Of Electron Temperature Inhomogeneity On Radial Density Profile In Cylindrical Discharges

Swati Swati[1,2], Pawandeep Singh[1,2], Satadal Das[1,2], Avnish K. Pandey[1,2], Shantanu K. Karkari[1,2]

[1]*IPR, Ghandhinahar, Bhat, Gandhinagar, Gujarat, 383428 India*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai-400094, India*

E-mail (speaker): swati.dahiya@ipr.res.in

Abstract

In low-pressure discharges, the electrons having isotropic temperature generally follows Boltzmann distribution in which the pressure gradient force acting on them balances the electrostatic force due to ambient electric field. However, the deviation from Boltzmann distribution can be observed in presence of magnetic field due to their finite Larmor radius around the field lines, causing cross field diffusion across the magnetic field [1]. The Boltzmann distribution of electrons can also be violated due to the presence of conducting/insulating plasma boundaries or even if there is a spatial non-uniformity in electron temperature [2][3].

In the present work, this deviation from Boltzmann distribution is observed experimentally in a 13.56 MHz cylindrical capacitive coupled radio-frequency device having uniform magnetic field along the cylindrical axis. The experimental results shows that the electron temperature becomes radially non-uniform on application of axial magnetic field, which further results in deviation from the Boltzmann distribution. An analytical model has been formulated using fluid approximations which accounts for this inhomogeneous electron temperature effect on the local plasma potential. When this effect is taken into account, the analytical model comes up with a profile of radial plasma density which is in line with the experiment. It is also found that the deviation from Boltzmann distribution increases from center towards edge due to increasing inhomogeneity in electron temperature.

References:

[1] N. Sternberg, V. Godyak, and D. Huffman, "Magnetic field effects on gas discharge plasmas," *Phys. Plasmas*, vol. 13, no. 6, 2006, doi: 10.1063/1.2214537.
[2] S. Das and S. K. Karkari, *Plasma Sources Sci. Technol.*, vol. 28, no. 7, 2019, doi:10.1088/1361-6595/ab1b00.
[3] Pawandeep Singh et al 2022 J. Phys. D: Appl. Phys. 55 235201

Session 2

Nuclear Fusion & Technology (NF)			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	19	NF-O-1	**Design, development and characterization of flexible plasma focus tube for pulsed ≥106 neutrons generation** *Ram Niranjan, BARC, Mumbai*
2.	75	NF-O-2	**Studies On The Retarded Recrystallization Of Tungsten In CIMPLE-PSI, Exposed Under Extreme Surface Temperature And He+ Fluence** *Mizanur Rahman, CPP-IPR, Guwahati*
3.	190	NF-O-3	**Energy Confinement Studies of Hydrogen and Deuterium Ohmically heated plasmas in ADITYA-U tokamak** *R L Tanna, IPR, Ghandhinahar*
4.	443	NF-O-4	**Overview Of Remote Handling and Robotics Technology Developments in IPR** *Krishan Kumar Gotewal, IPR, Ghandhinahar*
5.	446	NF-O-5	**Compact ECR Large Area Plasma Source as a Potential Negative Hydrogen Ion Source for Fusion Application** *Shweta Sharma, IIT Delhi*

DESIGN, DEVELOPMENT AND CHARACTERIZATION OF FLEXIBLE PLASMA FOCUS TUBE FOR PULSED ≥10^6 NEUTRONS GENERATION

Ram Niranjan[1,*], R. Srivastava[1], J. Joycee[1], K. D. Joshi[1,2]

[1]*Applied Physics Division, Bhabha Atomic Research Centre, Mumbai-400085, India*
[2]*Homi Bhabha National Institute, Mumbai-400094, India*

E-mail: niranjan@barc.gov.in

Abstract

Plasma focus device [1] is a laboratory fusion device based on z-pinch principle. High intensity, fast 2.45 MeV neutrons are generated for a few tens ns duration when deuterium is used as the filling gas in plasma focus device. Plasma focus devices in different geometries have been designed and developed suitable to its applications. A flexible plasma focus tube have been indigenously designed and developed for field applications. The size of the plasma focus tube [2] was around 5 cm diameter × 16 cm length with effective internal volume of around 130 cm^3. The plasma focus tube was coupled to a compact capacitor bank using 24 nos. of RG213 coaxial cables (each 10 m long) for its operation. These coaxial cables provide the flexibility to move plasma focus tube to any location in 10 m radius away from the capacitor bank which would be useful in reducing the EMI's interferences with signals in many applications. The capacitor bank (24 µF, 20 kV) was made of 04 nos. of energy storage capacitor (each, 6 µF, 20 kV, 20 cm × 20 cm × 30 cm). The plasma focus tube was operated at capacitor bank energy of 2.7 kJ (24 µF, 15 kV) and the maximum peak discharge current deliverable to the plasma focus tube was estimated to be 132 kA. The average neutron yield in the radial direction was observed to be maximum $(3.1\pm1.0)\times10^6$ neutrons/pulse with pulse duration of (20 ± 3) ns at 4 mbar D_2 gas filling pressure. Details about various components of this transportable neutron generator along with its neutron emission characteristics will be presented.

References:

[1] Formation of a high-density deuterium plasma focus, Phys. Fluids 8(2), p 366-377, (1965).

[2] The smallest plasma accelerator device as a radiation safe repetitive pulsed neutron source, Ind. J. Pure & Appl. Phys. 50, p785-788, (2012).

Studies On the Retarded Recrystallization Of Tungsten In CIMPLE-PSI, Exposed Under Extreme Surface Temperature And He^+ Fluence

Mizanur Rahman[1], S. Chetri[1], Bryan Teo[2], M. Thompson[2], M. Bilokur[2], S. Shekhar[3], C. Corr[2], G. De. Temmerman[4] and M. Kakati[1]

[1]*CIMPLE-PSI Laboratory, Centre of Plasma Physics-IPR, Sonapur 782 402, India*
[2]*Department of Materials Physics, Australian National University, Canberra ACT 2601, Australia*
[3]*Department of Materials Science & Engineering, IIT Kanpur, Kanpur 208 016, India*
[4]*MINES ParisTech, University PSL, Institute of Higher Studies for Innovation and Entrepreneurship (IHEIE), 75006 Paris, France*

E-mail: mizanur.rahman@cppipr.res.in

Abstract

In the ITER tokomak, the tungsten divertor will be exposed to extreme ion and heat-flux of low energy He particles, and the surface temperature may increase beyond 1573 ˚K in some areas. That will lead to recrystallization of tungsten and deterioration of its surface properties. CIMPLE-PSI is a linear tokamak divertor simulator device, which can reproduce ITER like intense ion ($\sim 10^{24}\ m^{-2}s^{-1}$) and heat-flux ($\sim 5\ MWm^{-2}$) [1] that may be used for controlled plasma fusion research relevant plasma surface interaction (PSI) studies. In this paper, we report results from experiments carried out at CIMPLE-PSI that investigates surface modifications of tungsten while irradiated by a very high helium ion-fluence and extreme target temperature, at $3\times10^{27}\ m^{-2}$ and 1866±5 ˚K respectively. Plasma exposure and high temperature annealing in this experiment are carried out simultaneously, in contrast to previous experiments where they were performed sequentially. Exposed samples are characterized by optical microscopy (OM), field emission scanning electron microscopy (FESEM) of the surfaces and focused ion beam (FIB) made cross-sections and electron backscattered diffraction (EBSD). A thin layer of W-fuzz is observed on the sample exposed at 1866 ˚K, as this approached the maximum limit for formation of the nano-tendril structures, while a 15 μm thick layer is seen on the W sample irradiated at 1699 ˚K. For both of these samples, the average grain size at the plasma exposed surface is about three times smaller than on the un-exposed side of the same samples, which confirms retarded recrystallization is effective even at the extreme target temperature and fluence. This is supported also by the EBSD measurements, which estimated the fraction of recrystallization as 34% (1866 ˚K) and 93.1% (1699 ˚K) respectively. It is seen that large pinholes densely populate the grain boundaries of the high temperature sample, with maximum size even beyond 500 nm. In the FESEM of the FIB made cross-sections, helium bubbles of mixed sizes are identified immediately below the surface, both inside the bulk as well as in the grain boundaries. FIB cross-section shows some deformed grains in the sub-surface region of the highest temperature sample.

Energy Confinement Studies of Hydrogen and Deuterium Ohmically heated plasmas in ADITYA-U tokamak

R.L. Tanna[1, 2], H. Raj[1], J. Ghosh[1,3], Chetna Chauhan[2], K.A. Jadeja[1,4] R. Kumar[1], Suman Aich[1], K.M.Patel[1], S. Patel[5], K. Singh[3], S. Dolui[3], A. Kumar[3], B. Hegde[3], A. Kumawat[3], M.N. Makwana[1], K.S.Shah[1], S. Gupta[1], S. Nair[1], N. Yadava[2], N. Ramaiya[1], M.B. Chowdhuri[1], R. Manchanda[1], U.C.Nagora[1,3], Kiran Patel[1,3], S. Purohit[1], A. Adhiya[1,2], M.K. Gupta[1], Varsha S[1,3], S.K. Jha[1], D. Kumawat[1], K. Tahiliani[1], P.K. Atrey[1], S.K. Pathak[1,3], Y.C. Saxena[1] and ADITYA-U team[1]

[1]IPR, Ghandhinahar, Bhat, Gandhinagar 382428, Gujarat, India
[2]Institute of Science, Nirma University, Ahmedabad 382 481, Gujarat, India
[3]Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094[4]Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360 005 [5]Pandit Deendayal Petroleum University, Raisan, Gandhinagar, 382 007, Gujarat, India

E-mail: rakesh@ipr.res.in

Abstract

Investigation of global energy confinement time is one of the key parameter for magnetically confinehot plasmas, as it benchmarks the tokamak operation as well as identify the parameters responsible for designing the next generation tokamaks [1]. ADITYA-U (R_0 = 75 cm, a = 25 cm) is an upgraded version of ADITYA tokamak is equipped with open divertor plates without any baffle [2]. Last couple of years, ADITYA-U operations have been focused on achieving the plasma parameters closeto the design parameters in ohmically heated circular plasmas, mostly with hydrogen as a fuel in graphite toroidal belt limiter configuration as well as performed preliminary shaped plasmas operation by energizing both upper and lower diverter coils. Furthermore, ADITYA-U has progressed towards production of fully deuterium plasmas, one of the major milestones for future developments in fusion research. The purpose of this experiments is to achieve confinement improvement through the isotope effect in comparison with the hydrogen discharges. The energy confinement time analysis for large number of discharges with varied plasma parameters in both H_2 and D_2 fuel of ADITYA-U has been carried out and compared. Experimentally estimated energy confinement time for both the fuels is compared with the confinement time estimated from neo- ALCATOR scaling [3] will be presented.

References:

[1] H. Urano, et al., 39th EPS Conference & 16th Int. Congress on Plasma Physics (P1.016)
[2] Tanna R. L. et al., *Nucl. Fusion.* **62**, 042017 (2022).
[3] Tanna R. L. et al., Nucl. Fusion. 57, 102008 (2017).

Overview Of Remote Handling and Robotics Technology Developments in IPR

Krishan Kumar Gotewal[1], Naveen Rastogi[1], Manoah Stephen[1], Ravi Ranjan Kumar[1], Jignesh Chauhan[1]

[1]*IPR, Ghandhinahar, Gandhinagar*

E-mail: kgotewal@ipr.res.in

Abstract

Remote handling (RH) in challenging environments such as nuclear machines is essential to enable operators to perform remote inspection and maintenance tasks safely and reliably from far away of the environment The objective of the activities catering to RH at IPR is to build versatile RH systems such as long reach articulated arm, hyper redundant inspection system, and dexterous master and slave manipulators etc. The systems are designed to perform inspection & maintenance activities using virtual reality (VR) based monitoring & control system in challenging environments such as narrow spaces, presence of ultra-high vacuum, high temperature, magnetic field, etc.

In tokamaks, the plasma facing components are subjected to high heat and particle flow, which damages them over time. An In-vessel Inspection System (IVIS) has been developed at IPR to conduct remote in-service inspection inside Toroidal Vacuum Vessel. The IVIS system is compatible to 1e-7 mbar vacuum and 100°C temperatures. The IVIS has a 6-DOF articulated arm (mounted on a linear guide) with a camera payload and maximum reach of 4 meters. During initial testing, position repeatability of ± 2 mm has been achieved. Precise controlling of IVIS like RH equipment inside tokamaks with limited number of cameras (to minimize radiation effects) requires the operators to have accurate perception of the dynamic working environment. To provide unlimited/uninterrupted information of the environment and customized training to the operators, a 3-sided fully immersive virtual environment facility integrated with a haptic force feedback arm has been established at IPR. The facility can provide complete 3D virtual views updated using real time feedback from various sensors placed in the RH equipment and the environment to the operators. This facility can also be used in development of 3D virtual walkthroughs of complex machines/plants, design reviews, virtual prototyping, system interface and integration studies, remote operation/realistic simulation of robot operations, etc.

The design of the various RH & VR systems developed at IPR such as IVIS, hyper-redundant inspection system, dual-arm manipulators, autonomous mobile robots, haptic arm, etc. are presented.

References:

[1] P. Dutta, N. Rastogi, and K. K. Gotewal, "Virtual reality applications in remote handling development for tokamaks in India," Fusion Eng. Des., vol. 118, pp. 73–80, 2017.
[2] R. Buckingham and A. Loving, "Remote-handling challenges in fusion research and beyond," Nat. Phys.,vol. 12, no. 5, pp. 391–393, May 2016.

Compact ECR Large Area Plasma Source as a Potential Negative Hydrogen Ion Source for Fusion Application

Shweta Sharma[a], D. Sahu[a], R. Narayanan[a], R. D. Tarey[a], S. Kar[a], A. Ganguli[a]
M. Bandyopadhyay[b], A. Chakraborty[b], M. J. Singh[b]

a Department of Energy Science and Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi110016, India
b IPR, Ghandhinahar, Bhat, Ahmedabad, Gujarat, 382428 India

E-mail: shwetasharma1102@gmail.com

Abstract

Ongoing research on hydrogen plasmas is quite extensive specifically for the application in production of H^- ion beams, which are utilized to produce high energy neutral beams (~ 1Mev/u) for fusion plasma heating [1]. An efficient large area H^- ion source requires highly dense and uniform plasma with low T_e (< 1 eV), since H^- have very low electron affinity of 0.75 eV. Present work describes the development of an ECR based novel source CEPS [2-3] as an efficient hydrogen negative ion production source vis-à-vis conventional RF scheme. The CEPS chamber has dimensions φ: 9.1 cm, l: 11.5 cm and is encapsulated by set of NdFeB ring magnets that provide necessary magnetic field for ECR. The CEPS is mounted centrally on the top dome ($z = 0$) of a large volume chamber ($\varphi \sim 100$ cm, $h \sim 100$ cm).

The plasmas are produced inside the CEPS at gas filling pressures ~ 1-5 mTorr with cw μ-wave power ~ 400W, and is allowed to flow into the expansion chamber along the diverging magnetic field produced by the magnets. High plasma density ($n_e \sim 2\times10^{11}$/cm^3) was observed near to the source mouth (z= 5-10 cm), which gradually is observed to decay to 7-8$\times10^{10}$/cm^3 at $z \approx 10$ cm and remains constant throughout the chamber. An interesting feature observed was the existence of a high temperature single population (T_e ~50 eV) very close to the source mouth (z = 0-5 cm) which then is observed to split into a two electron population (high density cold bulk population, T_e =1-2 eV and a low density warm electron population T_w ~ 50-60 eV) beyond z =10 cm. The existence of these distinct temperature zones along the axis of large volume expansion chamber is favorable for production of H^- ions in volume mode through the dissociative attachment reaction. Additionally, remarkable radial uniformity (~ 10% in both n_e and T_e) was found at z > 30 cm planes over 80 cm dia. Such low temperature and high uniformity span are in favor of large area surface production of H^-. The above-mentioned results indicate that the CEPS can be used both as volume or surface based H^- ion source for fusion scale requirements.

References:

[1] Negative hydrogen ion sources for fusion: From plasma generation to beam properties, Frontiers in Physics **9**: p 709651, (2021).
[2] Development and studies on a compact electron cyclotron resonance plasma source, Plasma Sources Sci. Technol. **25.2**, p 025026, (2016).

Session 3

Buti Young Scientist Presentation			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	413	BYSA-1	**Focusing of High Current Plasma Ion Beams Using Sheath Nonlinearity: Quantum Beams for Physics and Applications** *Sushanta Barman, IIT Kanpur*
2.	119	BYSA-2	**Synchronization of Dust Acoustic Waves in a forced Korteweg-de Vries-Burgers model** *Ajaz Mir, IIT Jammu*
3.	149	BYSA-3	**Ar Plasma nanostructured superhydrophobic surfaces for self-cleaning** *Vivek Pachchigar, IPR, Ghandhinahar*
4.	365	BYSA-4	**Understanding the Physical Processes Prevailing in the Edge Plasma Region of ADITYA-U Tokamak using Spectroscopic Measurements** *Nandini Yadava, Nirma University, Ahmedabad*
5.	158	BYSA-5	**Hall Magnetohydrodynamical Evolution of the Solar Coronal Plasma** *Kamlesh Bora, PRL, Ahmedabad*

Focusing of High Current Plasma Ion Beams Using Sheath Nonlinearity: Quantum Beams for Physics and Applications

Sushanta Barman and Sudeep Bhattacharjee

Department of Physics, Indian Institute of Technology, Kanpur

E-mail : sushanta@iitk.ac.in, sudeepb@iitk.ac.in

Abstract

Focused ion beams (FIB) are used in many emerging areas of science and technology. However, conventional liquid-metal (Ga) based FIBs suffer from metallic contamination issues and focus small amounts of current (~ pA), leading to significantly reduced surface processing rates. To overcome these limitations, a microwave plasma-based multi-element focused ion beam (MEFIB) system has been developed in our laboratory [1, 2]. The MEFIB delivers ion beams of various nobel gaseous elements, which can be non-toxic and provide rapid processing of materials. However, focusing of high current charged particle beams to nanometer sizes has always been a challenge because of the repulsive space charge forces, which motivates us to find novel methods to overcome this challenge.

In optics, the demagnification (*DM)* factor of a lens depends upon the geometry and material of the lens. However, for electrostatic lens systems employed in MEFIB, the *DM* factor is decided by the geometry and voltages applied to the electrodes, which are usually kept constant. Therefore, it is challenging to focus high current ion beams where the space charge forces dominate. To address this challenge, for the first time, we experimentally demonstrated a novel method to obtain tunable *DM* factor using the plasma sheath nonlinearity [3, 4]. It is found that for extraction aperture sizes smaller than the plasma Debye length (λ_d), the *DM* factor can be reduced nonlinearly. Results from experiments and a theoretical model show that plasma sheaths play a crucial role in generating nonlinear *DM, which can be controlled* by experimental parameters such as gas pressure and microwave power [4]. The nonlinear *DM* factor significantly enhances the performance of plasma-based FIBs in focusing high current ion beams in the nanometer and quantum regimes. In addition, the beams are further focused by micro-glass capillaries, which provides loss less guiding. Finally, as an application of the quantum ion beams, diffraction phenomena of low energetic (~ 8 eV) plasma ion beams by an electrically biased grating have been demonstrated [5].

References :

[1] J. V. Mathew, I. Dey, and S. Bhattacharjee, Appl. Phys. Lett., **91**, 041503 (2007).
[2] S. K. Maurya, S. Barman, S. Paul and S. Bhattacharjee, J. Phys. D: Appl. Phys., **52**, 055205 (2018).
[3] S. K. Maurya, S. Barman, N. Pan, and S. Bhattacharjee, Phys. Plasmas, **26**, 063103 (2019).
[4] S. Barman, S. K. Maurya, and S. Bhattacharjee, Plasma Res. Express, **4**, 025003 (2022).
[5] S. Barman and S. Bhattacharjee, J. Appl. Phys., **132**, 034401 (2022).

Synchronization of Dust Acoustic Waves in a forced Korteweg-de Vries-Burgers model

Ajaz Mir[1], Sanat Tiwari[1], Abhijit Sen[2], Chris Crabtree[3], Gurudas Ganguli[3], and John Goree[4]

[1]*Indian Institute of Technology Jammu, Jammu, Jammu & Kashmir, 181221, India*
[2]*IPR, Ghandhinahar, Gandhinagar, Gujarat, 382428, India*
[3]*Naval Research Laboratory, Washington, DC 20375, USA*
[4]*Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242, USA*

E-mail : ajaz.mir@iitjammu.ac.in

Abstract

We have developed a forced Korteweg-de Vries-Burgers (fKdV-B) equation based model for synchronization of waves in plasmas and other media. Synchronization is a ubiquitous nonlinear phenomenon where a weak nonlinear interaction between a driver and a system leads to an adjustment of their rhythms [1]. The van der Pol oscillator model has often been used as a reference for characterizing synchronization phenomena in plasmas [2, 3]. However, as a point oscillator model, its dynamics is restricted to nonlinear oscillations and cannot correctly represent nonlinear propagating waves. This is also evident from the fact that the van der Pol model is an ordinary differential equation in time and therefore has no spatial dynamics that characterize nonlinear propagating ion acoustic or dust acoustic waves. Also, for nonlinear ion acoustic or dust acoustic waves, dispersion plays an important role in defining their propagation characteristics. Hence, appropriate theoretical models are needed to describe the nonlinear synchronization of such dispersive waves.

The synchronization of dust acoustic waves has been demonstrated by the fKdV-B model under the weakly nonlinear dynamical regime retaining the medium's spatio-temporal nonlinearity, viscous damping and dispersion effects. Using a cnoidal square driver with both temporal and spatial periodicity, the fKdV-B model demonstrates harmonic (1:1) and super-harmonic (1:2) synchronization states. The existence domains of these states are delineated in the form of Arnold tongue in the parametric space of the forcing amplitude and forcing frequency showing significant agreement with the dusty plasma experiment [2]. The fKdV-B model provides the first unified fluid-based approach to study synchronization with fluid-like spatio-temporal convective nonlinearity.

References:

[1] A. Pikovsky, M. Rosenblum, and J. Kurths: Synchronization: A Universal Concept in Nonlinear Sciences (Cambridge University Press, Cambridge, 2001)
[2] W. D. Suranga Ruhunusiri, and J. Goree: Synchronization mechanism and Arnold tongues for dust density waves. Phys. Rev. E **85**, 046401 (2012)
[3] T. Deka, B. Chutia, Y. Bailung, S. K. Sharma, and H. Bailung: Suppression of a spontaneous dust density wave by modulation of ion streaming. Plasma Sci. Technol. **22**, 045002 (2020)

Ar Plasma nanostructured superhydrophobic surfaces for self-cleaning

Vivek Pachchigar[1,2], Mukesh Ranjan[1,2]

[1]*IPR, Ghandhinahar, Near Indira Bridge, Bhat, Gandhinagar-382428*
[2]*Homi Bhabha National Institute, 2nd floor, BARC Training School Complex, Anushaktinagar, Mumbai-400094*

E-mail: vivek.pachchigar@ipr.res.in

Abstract

The development of superhydrophobic surfaces using plasma processing techniques has been a great research interest for the last decade because of their unique functional wetting properties such as self-cleaning, anti-icing, anti-fogging, water harvesting, oil-water separation, etc. Specifically, polymer surfaces like polytetrafluoroethylene (PTFE) are the best candidate for superhydrophobic and self-cleaning applications due to their unique properties such as naturally hydrophobic, chemical inertness, and biocompatibility. Therefore, a quite good amount of research has been carried out to modify the wetting properties of PTFE using plasma processing. However, when PTFE is treated using a radiofrequency (RF) argon plasma, it is reported that PTFE undergoes a large defluorination, which results in hydrophilic surface properties. Therefore, we have carried out a systematic experimental investigation to understand the influence of RF power, plasma treatment time, impurities, and surface temperature on the wetting properties of PTFE surfaces. A single electrode-based system with a sacrificial PTFE disc between the specimen and the electrode was used to generate the plasma in order to reduce the impurities and electrode temperature effects. The RF power and the treatment time varied from 50 to 300 W, and 5 to 30 min, respectively. The peak-to-peak voltage corresponding to the applied RF power was varied from 0.8 to 2.0 kV. The surface morphology study of plasma-treated surfaces using atomic force microscopy (AFM) analysis revealed the formation of irregular nanoroughness at low RF power (i.e. 50 W) and regular isotropic nanostructures at comparatively higher RF power (150-300 W). The formation of isotropic nanostructures is mainly attributed to the high penetration depth of ions at higher RF power. Therefore, after 5 min treatment at 150 W, the surface became superhydrophobic (water contact angle, WCA=152°) due to the formation of nanostructures on the surface. However, 30 min of plasma treatment caused chemical changes and defluorination which resulted in a hydrophilic surface (WCA=14°) [1]. The surface temperature measurements revealed that the temperature of the surface during the plasma treatment reaches up to 160 °C after treating the surface at 300 W for 30 min, which has degraded the wetting properties after long plasma exposure. Also, a yellowish layer was formed on the surface due to crosslinking, redeposition of fluorocarbon species, and iron impurities as confirmed by XPS analysis. Due to this effect the F/C ratio after 30 min of treatment reduced from an initial 1.49 to 0.13. Finally, the superhydrophobic PTFE surfaces showed excellent self-cleaning performance. When the water droplet impacts the surface, it carries out dust particles from the surface and cleans the surface [2,3].

References :

[1] V. Pachchigar, U.K. Gaur, A. T. V., S. K. P., S. Hans, S.K. Srivastava, M. Ranjan, Plasma Process. Polym. n/a (**2022**) e2200037.

[2] V. Pachchigar, M. Ranjan, K.P. Sooraj, S. Augustine, D. Kumawat, K. Tahiliani, S. Mukherjee, Surf. Coatings Technol. 420 (**2021**) 127331.

[3] V. Pachchigar, M. Ranjan, S. Mukherjee, Sci. Rep. 9 (**2019**) 8675.

Understanding the Physical Processes Prevailing in the Edge Plasma Region of ADITYA-U Tokamak using Spectroscopic Measurements

Nandini Yadava[1*], J. Ghosh[2], M. B. Chowdhuri[2], Ankur Pandya[3], S. Patel[4], Ritu Dey[2], Sripathi Punchithaya K.[5], R. Manchanda[2], Nilam Nimavat[2], K. A. Jadeja[2], R. L. Tanna[1,2] and Aditya-U team[2]

[1] *Institute of Science, Nirma University, Ahmedabad 382481*
[2] *IPR, Ghandhinahar, Gandhinagar 382428*
[3] *Institute of Technology, Nirma University, Ahmedabad 382481*
[4]*Department of Physics, Pandit Deendayal Energy University, Raisan, Gandhinagar 382 007*
[5]*Department of Physics, Manipal Institute of Technology, MAHE, Manipal 576104, Karnataka*

E-mail: nandini7754@gmail.com

Abstract

The edge region of any tokamak plasma controls both the core plasma confinement as well as the particle and heat flux to the plasma facing components and vessel wall. The ADITYA-U tokamak edge plasma has been extensively explored using spectroscopy diagnostic to understand the prevailing physical phenomena in this region. The ion and neutral temperature, recycling influx from limiter and wall and impurity particle transport are deduced from spectroscopic measurements of emission intensities and spectral line profiles of fuel and impurity neutral and ions, emissions in ADITYA-U tokamak plasma. Along with this to develop the characterization technique for divertor plasma for future ADITYA-U experiments, molecular bands are identified and analyzed through molecular band modelling.

While deducing the ion and neutral temperatures, an anomaly arising due to Zeeman effect has been removed and real temperature are estimated. As the tokamak plasma is suspended in high-magnetic fields, Zeeman effects are important to be included in the line-shape profile analysis. By including the Zeeman effect in the line shape analysis of $H_\alpha(656.28\,nm)$ fuel neutral and C^{1+} $(657.8\,nm)$, O^{4+} $(650.02\,nm)$ impurity ions it has observed that there exists a poloidal asymmetry in neutral temperature, which is reported for very first time. The anomaly has been resolved through modelling of spectral line shape profile with by incorporating the Zeeman influenced components in simulation. The analysis also showed that there exists two components of neutral temperature (warm and hot) in ADITYA-U tokamak plasma, corresponding to different atomic and molecular processes. The corrected temperatures of $\mathrm{C}^{1+}$and O^{4+}ions and their radial profiles indicated that presence of magnetic islands significantly influence the impurity temperatures. *In the novel Li_2TiO_3 Inductive Pellet Injection (IPI) experiments, self-absorption phenomenon in Li_α spectral line emission has been identified and thoroughly analysed.*

For recycling and influx estimations emissions from stainless-stell wall and graphite limiter with and without Li coating are collected and analysed. Using this the temporal evolution of H_α, O^{1+} $(441.6\,nm)$ and $C^{2+}(464.7\,nm)$ emissions, the recycling from these surfaces is quantified. To further decipher the edge plasma physical processes, The Diffusion coefficient is estimated for C, O, Ne, Ar, and Fe with an in-house developed SITA code (Study of Impurity Transport in ADITYA-U tokamak). Using the code, it has been observed that with increasing

Z value the diffusion coefficient decreases. The observed mass dependency of diffusivity coefficient throws a new light towards understanding the impurity transport in tokamaks. Due to very low plasma temperatures near the wall, molecular processes become very important. The presence of different impurities in this region further complicates the molecular band identification. The overlapping of bands is studied in a RF produced plasma and correct impurity ion temperatures are estimated. A elaborated edge plasma diagnosis through spectroscopic technique and understanding of physics basis for the events occurring there will be presented in this paper.

References

[1] Yadava N, Ghosh J, Chowdhuri M B, *et al*. *Atoms* **7** **87** (2019)
[2] Yadava N, Ghosh J, Chowdhuri M B*, et al. Nucl. Fusion* **59** (2019)
[3] Yadava N, Ghosh J, Chowdhuri M B, *et al.* Investigation of Self-absorbed Lithium Spectral Line Emissions During Li_2TiO_3Injection in Aditya-U Tokamak, FEC-2021
[4] Yadava N, Chowdhuri M B, Ghosh J, *et al. Plasma Fusion Res.* **16** 2402055 (2021)
[5] Yadava N, Ghosh J, Chowdhuri M B*, et al.* Investigation of Charge Dependency in impurity transport in Aditya-U tokamak, APS-2021
[6] Yadava N, Chouhan S S, Sanyasi A, *et al. Plasma Fusion Res.***8** 2401095 (2022)
[7] Dey R, Yadava N, Chowdhuri M B *et al.* Quantification of molecular contribution in particle influx estimation using S/XB calculations of Hα emission in tokamaks (under review in Atoms)

Hall Magnetohydrodynamical evolution of the solar coronal plasma

Kamlesh Bora[1,2], Ramit Bhattacharyya[1], Avijeet Prasad[3,4,5], Bhuwan Joshi[1] and Qiang Hu[3,6]

[1]Udaipur Solar Observatory, Physical Research Laboratory, Dewali, Bari Road, Udaipur, 313001, India
[2]Discipline of Physics, Indian Institute of Technology, Gandhinagar 382355, India
[3]Center for Space Plasma & Aeronomic Research, The University of Alabama in Huntsville, Huntsville, AL 35899, USA
[4]Institute of Theoretical Astrophysics, University of Oslo, Postboks 1029, Blindern NO-0315 Oslo, Norway
[5]Rosseland Centre for Solar Physics, University of Oslo, Postboks 1029, Blindern NO-0315, Oslo, Norway
[6]Department of Space Science, The University of Alabama in Huntsville, Huntsville, AL 35899, USA

E-mail : kamleshb@prl.res.in

Abstract

Magnetic reconnection is a distinctive fundamental process which causes explosive energy release phenomena in various astrophysical plasmas through the rearrangement of magnetic field line connectivity. The outermost atmosphere of our nearest star Sun—solar corona, serves as a prototype astrophysical plasma. Large scale (~10^6 m) explosive events observed on the Sun, such as flares and coronal mass ejections (CMEs) are manifestations of magnetic reconnection. In particular, solar flares are fast and impulsive phenomena since a huge amount of energy (~10^{32} ergs) is released suddenly and rapidly within a very short time period (~few minutes). Therefore, the underlying reconnections must be fast and impulsive too. The reconnection length scale in the solar corona (based on observed impulsive rise time of hard X-ray emission during the solar flares) turns out to be a few tens of meters. At such a small scale, the standard magnetohydrodynamics (MHD) description is not valid. The order analysis of the induction equation at reconnection length scale indicates that the order of the Hall effect is much higher than the resistive diffusion. This leads to the Hall MHD description which can account for the fast and impulsive behavior as compared to the traditional theoretical models of reconnection within the standard MHD framework.

In the above backdrop, for the first time, the data-based Hall MHD and MHD models are employed to simulate a flaring solar active region as a test bed. This work is a combination of flare observations from SDO/AIA, magnetic field extrapolation using SDO/HMI vector magnetogram and the data-based simulations in the presence and absence of the Hall effect. Using the numerical analysis technique the magnetic structures such as flux rope, 3D null, quasi-separatrix-layers, and null line have been identified and the magnetic field line dynamics around these structures have been explored in the simulation results. A detailed comparative study between the observed flare brightening and the evolution of modeled 3D magnetic fields in two simulations, suggest the Hall MHD as a more convincing description to explain the observed transient phenomena

Session 6

Industrial Plasma Applications (IP)			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	257	IP-O-1	**Cold plasma treatment for surface modification of ceiba Pentandra Fiber** *Ramyaranjan Das, NIT Rourkela*
2.	438	IP-O-2	**Development of Asymmetric Cross Section Waveguide for Large Area Cold Plasma Generation for Radioactive Decontamination** Zahoor Dar, BARC, Mumbai
3.	440	IP-O-3	**DBD Plasma Based High-Efficiency Indoor Air Purifier** *Ramavtar Jangra, IIT Jodhpur*
4.	318	IP-O-4	**Synthesis of Mn3O4/Co3O4 nanocomposite by liquid phase microplasma method for supercapacitor application** *E R Kavitha, Bharathiar University, Coimbatore*

COLD PLASMA TREATMENT FOR SURFACE MODIFICATION OF CEIBA PENTANDRA FIBER

Ramyaranjan Das[1], Mukesh Ranjan[2], Dillip Kumar Bisoyi[1,*]

[1]Department of Physics and Astronomy, National Institute of Technology Rourkela, Rourkela, India -769008,
[2]Plasma surface Engineering Division (PSED), Institute of PlasmaResearch, Gandhinagar, India -382428

Corresponding author's Email address - dkbisoyi@nitrkl.ac.in[1,*]

Abstract

Due to the growing environmental awareness and environmental protection regulations, plant fiber and its reinforced composite products have gained enough attention from researchers and industries. Kapok fiber (Ceiba Pentandra Fiber) is a natural seed fiber decorated with wax and fatty acids on its surface. Wax and fatty acids on the surface of the fiber make it incompatible at the interface of the fiber and matrix of the composites[1][2]. So the structure of the fiber is modified and the surface of the fiber is activated by the cold plasma surface modification technique. The micro-nano binary surface structure of the fiber is conformed from contact angle measurement and is verified by SEM. Modification of the structure of the fiber is investigated using XRD, FTIR and SEM techniques. Ultimately cold plasma surface modification technique of the fiber may improve the interfacial adhesion between fiber and matrix

References :

[1] R. Das, C. Dash, P. Behera, and D. K. Bisoyi, "Influence Of Dewaxing on Mechanical properties of kapok fiber- reinforced polymer composite Influence Of Dewaxing on Mechanical properties of kapok fiber-reinforced polymer composite," 2022

[2] M. J. P. Macedo, G. S. Silva, M. C. Feitor, T. H. C. Costa, E. N. Ito, and J. D. D. Melo, "Composites from recycled polyethylene and plasma treated kapok fibers," *Cellulose*, vol. 27, no. 4, pp. 2115–2134, 2020

Development of Asymmetric Cross Section Waveguide for Large Area Cold Plasma Generation for Radioactive Decontamination

Zahoor Ahmed[1], Naresh Chand[2], Devendra Bhale[2], Rajib Kar[2], Namita Maiti[2]

[1]Astrophysical Sciences Division
[2] Laser & Plasma Technology Division
Bhabha Atomic Research Centre, Mumbai-400085, India

E-mail : zahoor@barc.gov.in, naresh@barc.gov.in, dbhale@barc.gov.in, rajibkar@barc.gov.in, nmaiti@barc.gov.in

Abstract

Various types of atmospheric pressure plasma sources have been reported especially dielectric barrier discharges, RF discharge, and pulsed DC discharge. Spatiotemporal intermittent discharges have rendered low and non-uniform plasma density in these sources. Microwave based atmospheric pressure plasma has high plasma density compared to RF, as power absorption efficiency is better. However, microwave has short wavelength of the order of few centimeters which generates standing waves resulting in spatially non uniform discrete plasma, which is also not suitable for large area. In microwave, low impedance slotted waveguide increases the surface currents without increasing power. It has symmetrical distribution of electromagnetic field and half of the total current does not aid in plasma generation. If the cross section of waveguide is reduced, the current density increases resulting in resistance losses in the waveguide.

In order to improve the plasma in microwave device, asymmetric cross section waveguide enhances the surface currents effectively and concentrate the current in the slot by improving the coupling between the power in the waveguide and the slot suppressing standing waves. In this technique of atmospheric pressure large area plasma generation, the ratio of two surface currents flowing in the waveguide wall has been changed by modifying the cross-sectional structure properly. Thus, the asymmetric waveguide structure is effective to localize the surface currents resulting in large current density compared to the conventional waveguide. Accordingly, the area of waveguide can be increased without increasing the power as magnetic field is strongly localized inside the gap. By modifying the waveguide, the possibility of high electric field is realized, resulting in large area plasma generation and subsequently plasma sustainment for required duration.

References:

[1] H. Suzuki, S. Nakano, H. Itoh, M. Sekine, M. Hori, and H. Toyoda, Appl. Phys. Express 8, 036001 (2015).
[2] H. Itoh, Y. Kubota, Y. Kashiwagi, K. Takeda, K. Ishikawa, H. Kondo, M. Sekine, H. Toyoda, and M. Hori, J. Phys.: Conf. Ser. 441, 012019 (2013).

DBD PLASMA BASED HIGH-EFFICIENCY INDOOR AIR PURIFIER

Ramavtar Jangra*, Kiran Ahlawat, Ambesh Dixit, Ram Prakash

Department of Physics, Indian Institute of Technology Jodhpur, N.H. 62, Nagaur Road, Karwar, Jodhpur, Rajasthan, 342037

*E-mail: jangra.1@iitj.ac.in

Abstract

With most of the world living in cities and growing villages, people spend most of their time, i.e., around 90% in indoors. It is essential to ensure a quality indoor environment since contrary to what we might think air pollution is much higher indoors than outdoors [1]. Indoor air pollution (IAP) is a complex issue involving a wide diversity and variability of contaminants that hazards human health. Therefore, there is a surge in demand to enhance indoor air quality.

We have designed and developed a novel Cold-plasma Detergent in Environment (CODE) Device based Indoor Air Purifier and its efficiency analysis has been carried out in terms of indoor air quality. This air purifier reduces the risks of infection from airborne pathogens in the indoor environment with multiple advantages for the quality indoor air. The concept is based on non-equilibrium cold plasma generation. The device used in the air purifier produces negative ions predominantly dominated by cold-plasma detergent ions as well as positive ions in the environment like mother nature. The concentrations are such that they can produce local fields similar to the bond energy of the chemical bonds of the harmful pathogens in the environment for faster deactivation. Also, the generated positive and negative ions can instantaneously bond on the surface of substances such as bacteria, fungi, viruses, and allergens, becoming cold-plasma detergent ions which break down the proteins on the surface of such pathogens.

The working performance of the developed source has been tested for the reduction of total microbial counts (TMCs), total fungal counts (TFCs), decomposition of volatile organic compounds (VOCs), removal of dust and pollens through a single device in an indoor environment of sizes more than 1,72,80,000 cm^3. Much higher efficiencies for the decomposition of TMCs and TFCs were achieved in just 90 minutes of source operation in an enclosed environment. The deactivation efficiency of *MS2 phage Virus* and *E. coli bacteria* has also been tested in the enclosed environment and more than 99.99% reductions has been achieved in just 30 minutes of continuous operation of the device at optimized parameters. The existence of negative ions for more than 25 seconds on average is the key advantage for better indoor air quality in our case. A comparative analysis with the existing air purifiers has been carried out which shows much higher efficiency through this air purifier and results of these efforts will be presented.

References:

[1] J. M. Samet, "Indoor Air Pollution: A Health Perspective," *Ann. Intern. Med.*, vol. 116, no. 2, p. 175, 1992, doi: 10.7326/0003-4819-116-2-175_4.

SYNTHESIS OF Mn_3O_4/Co_3O_4 NANOCOMPOSITE BY LIQUID PHASE MICROPLASMA METHOD FOR SUPERCAPACIOTR APPLICATION

E.R. Kavitha[1], S. Yugeswaran[2] and K. Suresh[1]*

[1]*Surface and Environmental Control Plasma Lab, Department of Physics, Bharathiar University, Coimbatore-641046, India*
[2]*Applied Thermal Plasma Laboratory, Department of Physics, Pondicherry University, Puducherry 605014, India,*

*Email: ksureshphy@buc.edu.in

Abstract

Highly efficient electrodes for supercapacitor application are necessary for future energy storage applications. Herein, Mn_3O_4/Co_3O_4 (MCO) nanocomposite was synthesized in liquid phase microplasma discharge method which is one of the efficient and reliable non-thermal plasma methods. MCO nanocomposite was synthesized via reduction of solution precursor KMnO4 and $Co(NO_3)_2.6H_2O$ by Air plasma. The radicals present in Air plasma are highly favourable for the formation of MCO nanocomposite. After 30 minutes treatment, the particles formed were collected and were subjected to various physicochemical characterizations. The multiphase and crystalline size was analyzed from XRD, and characteristic peaks in Raman spectrum confirmed the produced nanocomposites. Moreover, FE-SEM images show well-dispersed narrow size spherical nanoparticles with porous surface, emphasizing, that it can provide a large specific surface area for electrode-electrolyte interaction. The EDS spectrum denoted manganese, cobalt and oxygen; and purity of the synthesized nanocomposite was confirmed. The electrochemical performance of MCO nanocomposite as electrode material was investigated and it displayed pseudocapacitive behaviour in cyclic voltammetry study. High specific capacitance of $250Fg^{-1}$ at $0.5Ag^{-1}$ current density in alkali media was obtained through the galvanostatic charge –discharge study. Electrode material exhibited good cyclic stability upto 5000 cycles and the impedance analysis depicts the capacitive behaviour of electrode material. Hence, these remarkable results demonstrate that MCO nanocomposite have better capability to act as electrode material for supercapacitor application.

Session 7

Space & Astrophysical Plasma (SA)			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	8	SA-O-1	**Inertial Magnetohydrodynamic Formulation of Magnetosonic Waves due to Orbital Space Debris** *Siba Prasad Acharya, SINP, Kolkata*
2.	199	SA-O-2	**Kinetic Alfven Wave Interactions In 2.5D Kinetic Simulations** *Kirit Makwan, IIT Hyderabad*
3.	368	SA-O-3	**Role of Electron Beam and Higher Order Corrections on Ion Acoustic Shocks** *Sunidhi Singla, GNDU, Amritsar*
4.	378	SA-O-4	**Interaction of Dust Ion Acoustic Wave In Cometary Plasma** *Dr. Jit Sarkar, Jadavpur University, Kolkata*

INERTIAL MAGNETOHYDRODYNAMIC FORMULATION OF MAGNETOSONIC WAVES DUE TO ORBITAL SPACE DEBRIS

S. P. Acharya[1,*], A. Mukherjee[2], and M. S. Janaki[1]

[1]*Saha Institute of Nuclear Physics, Sector 1, Block AF, Bidhannagar, Kolkata-700064 (India)*
[2]*Indian Statistical Institute, Kolkata-700108 (India)*

*siba.acharya@saha.ac.in

Abstract

The excitations of nonlinear magnetosonic waves by orbiting charged space debris objects have been investigated in inertial magnetohydrodynamics (MHD) framework. The magnetosonic waves are found to be governed by a forced Kadomtsev-Petviashvili (KP) equation where the forcing function interprets effects of charged space debris objects functioning as current density sources. The dynamics of both slow and fast magnetosonic waves has been explored in detail. Different analytical lump wave solutions are derived and shown to be stable in entire parameter space of slow magnetosonic waves and a large region in parameter space of fast magnetosonic waves. These lump wave solutions can show accelerations and distortions as well under certain circumstances. In a similar manner, several solitary wave solutions are shown to be stable in the remaining small region of parameter space for fast magnetosonic waves some of which show accelerating as well as bending features. These exotic magnetosonic structures resulted from orbital motions of charged space debris objects can have potential implications in their indirect detection methods.

References :

[1] NASA's efforts to mitigate the risks posed by orbital debris, Report no. **IG-21-011**, NASA Office of Inspector General, Office of Audits, January 27, 2021.
[2] A. Sen, S. Tiwari, S. Mishra, and P. Kaw, Nonlinear wave excitations by orbiting charged space debris objects, Adv. Space Res. **56**, 429-435 (2015).
[3] A. S. Truitt, and C. M. Hartzell, Simulating plasma solitons from orbital debris using the forced Korteweg-de Vries equation, J. Spacecrafts Rockets **57**, 5 (2020).
[4] A. S. Truitt, and C. M. Hartzell, Simulating damped ion acoustic solitary waves from orbital debris, J. Spacecrafts Rockets **57**, 5 (2020).
[5] A. S. Truitt, and C. M. Hartzell, Three-dimensional Kadomtsev-Petviashvili damped forced ion acoustic solitary waves from orbital debris, J. Spacecrafts Rockets **58**, 3 (2021).
[6] S. P. Acharya, A. Mukherjee, and M. S. Janaki, Bending of pinned dust-ion acoustic solitary waves in presence of charged space debris, Phys. Rev. E **104**, 014214 (2021).
[7] S. P. Acharya, A. Mukherjee, and M. S. Janaki, Accelerated magnetosonic lump wave solutions by orbiting charged space debris, Nonlinear Dyn. **105**, 671-689 (2021).
[8] S. P. Acharya, A. Mukherjee, and M. S. Janaki, Charged space debris induced nonlinear magnetosonic waves using inertial magnetohydrodynamics, Adv. Space Res. **69**, 4045-4057 (2022).

Kinetic Alfven Wave Interactions In 2.5D Kinetic Simulations

Kirit Makwana, Johan Sharma, Srinikitha Bhagvati

Department of Physics, Indian Institute of Technology Hyderabad, Kandi, Sangareddy, Telangana 502284, India

E-mail : kdmakwana@phy.iith.ac.in

Abstract

Plasma turbulence is a ubiquitous phenomenon as a large part of the visible universe is in a plasma state that is constantly being disturbed and dynamic. It is often thought to consist of very many waves interacting nonlinearly and producing an energy transfer & spread (cascade) over decades of spatial and temporal scales. At the small kinetic scales where the particulate nature of the plasma becomes important, observations show the presence of an energy cascade, often thought to be mediated by kinetic-Alfven waves. The kinetic Alfven wave (KAW) eigenvector relations between the various physical fields (electric, magnetic, density, and velocity fields) are derived from a two-fluid model and are used to set up KAW modes in 2.5D particle-in-cell (PIC) simulations. The propagation of this wave is observed and its frequency is derived from its propagation speed. The frequency is also calculated by solving the dispersion relation derived from the two-fluid model, and from a hot-plasma kinetic dispersion relation solver. We find that the frequency obtained from simulations matches closely with the kinetic dispersion relation, even though a two-fluid eigenvector is used to setup the wave. Two and more KAW wavenumber modes are introduced and their nonlinear interactions are studied. Energy decay for the case with two or more waves is faster compared to the single wave mode case. Energy transfer is found to occur through three-wave interactions. Energy is transferred to higher field-perpendicular wavenumbers via local interactions, while there appears very little energy transfer to higher field-parallel wavenumbers. Bi-spectral analysis indicates that the three-wave interactions strongly favour same parallel-wavenumber interactions.

Role of Electron Beam and Higher Order Corrections on Ion Acoustic Shocks

Sunidhi Singla and N. S. Saini*

Department of Physics, Guru Nanak Dev University, Amritsar-143005, India.

E-mail: singla.sunidhi94@gmail.com

Abstract

The observations of inertial, drifting charged particles penetrating in various space and astrophysical plasma environments have led the researchers to investigate the influence of charged particle beams on nonlinear waves and structures formed in such environments. It has been indicated that the injection of drifting electrons in the upper layers of Earth's magnetosphere is caused by the solar wind. The observations of the Earth's magnetosphere region signify that the broadband electrostatic noise in this region is associated with the nonlinear electrostatic solitary/shock waves that might be related to the dynamics of electron beam instability. Non-Maxwellian distribution is used to model the superthermal charged particles. The contribution of higher-order nonlinearity and dissipation to nonlinear ion acoustic shock waves (IASWs) is investigated by using the reductive perturbation technique in dense electron beam-ion plasma. The motivation of this investigation is to study the ion acoustic shock waves in plasma comprising warm inertial ions, superthermal kappa-distributed hot electrons penetrated by an inertial electron beam. Using the reductive perturbation method, Burgers equation and higher order corrections in Burgers equation. The combined effects of an electron beam and variation in different physical parameters on the properties of IA shock structures have been analyzed. The findings of this investigation might be useful to understand the propagation of ion acoustic structures in different space and astrophysical plasma environments penetrated by an electron beam.

Interaction of Dust Ion Acoustic Wave In Cometary Plasma

Jit Sarkar[1], Chinmay Das[2], Swarniv Chandra[3]

[1]*Department of Physics, Jadavpur University, Kolkata-700032*
[2]*Department of Mathematics, Kabi Jagadram Roy Govt. General Degree College, India-722143*
[3]*Department of Physics, Government General Degree College at Kushmandi, India-733121*

E-mail: sarkarjit101@gmail.com

Abstract

In unmagnetized dusty plasma, the dispersion relation and propagation properties of small amplitude nonlinear dust ion acoustics waves (DIAW) were examined. The evolution equation for DIAW has been obtained in the form of the mKdV equation using the usual reductive perturbation method (RPT) and stretching parameters. The development of the solitary wavefront is then studied using homotopy-aided symbolic simulation (HASS). We compare the outcomes of Homotopy Perturbation Method and RPT. The effect of (Z_d) variation, streaming velocity variation, and ion to electron temperature ratio variation on the dispersion relation has been investigated. For K-dV, all of the aforementioned variables, as well as changes in Mach number, have been investigated. All of the above relationships and variants have been visually investigated for DIAW in order to investigate their wave characteristics (speed, width, amplitude etc.). We conducted a theoretical study of the wave-wave interaction in such plasma using FORK code. Next, we studied the dynamical properties of the DIAWs and analyze the stability criterion.

Session 9

Plasma Diagnostics (PD)			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	15	PD-O-1	**Diagnostics of Laser Produced Cu Plasma through a Collisional Radiative Model Using Calculated Fully Relativistic Detailed Electron Excitation Cross-Sections** *Ayushi Agarwal, IIT Roorke*
2.	162	PD-O-2	**Overview of IN-DA Diagnostics for ITER** *Gheesa Lal Vyas, ITER-India, IPR, Ghandhinagar*
3.	279	PD-O-3	**Design and installation of fast reciprocating drive system for ADITYA-U Tokamak** *Kaushlender Singh, IPR, Ghandhinahar*

Diagnostics of Laser Produced Cu Plasma through a Collisional Radiative Model Using Calculated Fully Relativistic Detailed Electron Excitation Cross-Sections

A Agrawal*, S S Baghel, L Sharma and R Srivastava

Indian Institute of Technology (IIT) Roorkee, Roorkee - 247667

*E-mail: ayushi.ph@sric.iitr.ac.in

Abstract

A fine structure resolved collisional-radiative (CR) model is developed for the laser-produced Cu plasma at atmospheric pressure. In such plasma, the electron impact excitation and de-excitation are the dominant processes [1] and need to be considered reliably in the model. We have calculated and incorporated the electron impact excitation cross-sections of a large number of the fine-structure levels of Cu. The required electron impact cross-sections for the transitions from the ground state $4s^1\ ^2S_{1/2}$ to the excited levels of the configurations $3d^94s^2$, $3d^{10}4p$, $3d^94s4p$, $3d^{10}5s$, $3d^{10}5p$, $3d^{10}4d$, $3d^{10}6s$, $3d^{10}6p$, $3d^{10}5d$, $3d^{10}4f$, $3d^{10}7s$, $3d^{10}7p$ are calculated using the fully relativistic distorted wave (RDW) theory [2]. In addition, cross-sections for the transitions from excited metastable states $3d^94s^2\ ^2D_{5/2}$ and $3d^94s^2\ ^2D_{3/2}$ to the levels of configuration $3d^{10}4p$, $3d^94s4p$, $3d^{10}5s$, $3d^{10}5p$, $3d^{10}4d$, $3d^{10}6s$, $3d^{10}6p$, $3d^{10}5d$, $3d^{10}4f$, $3d^{10}7s$, $3d^{10}7p$ levels are also calculated. These RDW calculated cross-sections are compared with the available experimental and theoretical results. Further, the model has been applied for the diagnostics of the laser-produced Cu plasma by coupling it with the spatially resolved optical emission spectroscopic (OES) measurements [3]. For the diagnostics, the intensities of three observed strong atomic emission lines of Cu viz., 510.5nm, 515.3nm and 521.8nm have been utilized in the absence and presence of magnetic field at different axial lengths (z= 0.5 - 6.5mm) from the Cu-target. Further, the intensities are corrected through self-absorption method and these are used to extract the plasma parameters i.e., electron temperature and electron density. The plasma parameters are then compared with the reported estimates from the Boltzmann plots [3]. The details of our RDW theory along with cross sections and CR model will be reported in the conference.

References:

[1] J B Boffard et al, J. Phys. D: Appl. Phys. **37**, R143, (2004)
[2] R Srivastava et al, Phys. Rev. A **74**, 012715 (2006)
[3] K S Singh and A K Sharma, Phys. Plasmas **23**, 122104, (2016)

Overview of IN-DA Diagnostics for ITER

Abha Maheshwari[1], Anil Bhardwaj[1], Anil Tyagi[1], Avik Bhattacharya[1], Bharathi Magesh[1], Bhargav Choksi[1], Bhoomi Gajjar[1], Deepak Mangde[1], Dilip Shukla[1], Gheesa Vyas[1], Hitesh Pandya[1], Kumar Rajneesh[1], Kunal Bhatt[1], Mahesh Patel[1], P V Subhash[1], Pratik Vagasiya[1], Ravinder Kumar[1], Ronak Shah[1], Sapna Mishra[1], Sarabjeet Singh[1], Saroj Jha[1], Shivakant Jha[1], Shriprakash Verma[1], Shrishail Padasalagi[1], Siddharth Kumar[1], Suman Danani[1], Suraj Pillai[1] & Vinay Kumar[1]

Cheng Zhifeng[2], Liu Yong[2], Marteen De Bock[2], Martin O' Mullane[3], Novimer Pablant[4], Philippe Bernascolle[2], Pak Sunil[2], Robin Barnsley[2], Kishonbabu K[2], Raphael Tieulent[2], Victor Udintsev[2], & Michael Walsh[2]

[1]ITER-India, IPR, Ghandhinagar, Ghandhinahar, Bhat, Gandhinagar -382428

[2]ITER Organization, St Paul-Lez-Durance, France-13115*

[3]Department of Physics, SUPA, University of Strathclyde, Glasgow, G4 ONG, United Kingdom of Great Britain and Northern Ireland

[4]Princeton Plasma Physics Laboratory, Princeton, NJ 08540 United States of America

Email: gheesa.vyas@iterindia.in

Abstract

To diagnose the ITER Plasma, ITER deployed suit of diagnostics (Magnetics, Neutron, Optical, Bolometric, laser based, Spectroscopic and NPA, Microwave) systems, spanning the entire electromagnetic spectrum. These diagnostics will provide measurements, necessary for machine protection, basic machine control, advance plasma control & evaluation, physics studies to optimize plasma performance and study advance plasma physics. All these diagnostics are developed to withstand and operate in harsh environment such as nuclear radiations and high heat flux. It is therefore, necessary to design and develop these diagnostics, adhering to stringent nuclear safety and strict quality protocols.

As an in-kind contribution to ITER, IN-DA (Indian Domestic Agency) is developing Electron cyclotron emission (ECE) based diagnostics to measure electron temperature and its fluctuations, a Charge eXchange Recombination Spectroscopy (CXRS) for probing ITER-pedestal region to measure ion temperature and plasma rotation a broad band X-Ray survey Crystal Spectrometers to measure plasma impurity content in real-time. A high-resolution imaging type X ray spectrometer for probing edge region to measure ion temperature.

In this presentation, an overview on the design development and present status of all these diagnostics will be discussed.

References:

[1] Chapter-7: Diagnostics, A.J.H. Donn et al, IOP PUBLISHING and INTERNATIONAL ATOMIC ENERGY AGENCY, Nucl. Fusion 47 (2007) S337–S384 (doi:10.1088/0029-5515/47/6/S07)

Design and installation of fast reciprocating drive system for ADITYA-U Tokamak

Kaushlender Singh[1,2], Bharat Hegde[1,2], Ashok K. Kumawat[1,2], M.S. Khan[1,2], Ankit Kumar[1,2], Suman Dolui[1,2], Laxmikanta Pradhan[1], Ankit Patel[1], K.A. Jadeja[1], K.M. Patel[1], Tanmay Macwan[1,2], Harshita Raj[1], Pramila Gautam[1], Rohit Kumar[1], Suman Aich[1], Imran Mansuri[1], Abhijeet Kumar[1], Kalpesh Galodiya[1], R.L. Tanna[1,3], Joydeep Ghosh[1,2] and ADITYA-U Team[1]

[1]*IPR, Ghandhinahar, Bhat, Gandhinagar, Gujarat 382428*
[2]*Homi Bhabha National Institute (HBNI), Mumbai 400 085*
[3]*Institute of Science, Nirma University, Ahmedabad 382 481, Gujarat, India*

E-mail (speaker): kaushlender.singh@ipr.res.in

Abstract

Data acquisition from the edge and SOL region of the tokamak plasma using electric and magnetic probes with high accuracy and low perturbation to the tokamak plasma is very important. If, probes are placed at limiter radius, the interaction of the surface of the probes and plasma causes impurities which can cause difficulty in attaining longer duration discharges. In addition to that it is observed that due to long discharge durations (≈ 300 ms in ADITYA-U) and runaway electrons, stationary probes (Langmuir and Magnetic) placed in the edge region of the tokamak are melting (Breaking). To resolve these issues reciprocating probes are being used in various tokamaks i.e. DIII-D [1], J-Text [2] and TCV [3].

Hence, A fast reciprocating drive system (FRDS) for probes is installed in ADITYA-U [4] for radial profile measurement of density (n_{edge}), temperature (T_{edge}), and current (I_p) with high spatial and temporal resolution. In this FRDS system, we have provision to change the probe tip depending on the experimental requirement, and currently, we are using Langmuir probes to measure radial profiles of n_{edge} and T_{edge}. To drive the probe set-up with the desired speed (≈ 1 cm in 26 ms) inside the plasma we are using a highly accurate and easy-to-control servo motor along with a controller, which can be controlled by the PXI system. Speed and distance to be traveled can be pre-programmed, which can also be varied on a shot-to-shot basis. The design and technical challenges in the installation of the FRDS system along with the data acquired in the plasma discharges and in the GDC (Glow Discharge Cleaning) of ADITYA-U will be presented in this paper.

References:

[1] Watkins J. G**.** *et al Review of Scientific Instruments* **68**, 373 (1997).
[2] Li Fuming, *et al Rev. Sci. Instruments*. 87, 11D436 (2016)
[3] Oliveira H. De. *et al Rev. Sci. Instruments*. **92**, 043547 (2021)
[4] Tanna R.L. *et al Nuclear Fusion* **62** 042017 (2022)

Session 10

Pulsed Laser Plasma (PU & LP)			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	113	PULP-O-1	**A Collimated Electron Beam From The Laser-Driven Deuterium Cluster In Ambient Magnetic Field** *Kalyani Swain, IPR, Ghandhinahar*
2.	385	PULP-O-2	**Fabrication of Silicon Micro-Pillars Using Ultrashort Optical Vortex Beam In The Soft Ablation Regime** *Nancy Verma, RRI, Bengaluru*
3.	387	PULP-O-3	**Hydrodynamics of Laser-Induced Air Plasma Interaction with Plane and Structured Aluminum Surface** *DR. P S L Kameswari Durvasula, University of Hyderabad*

A Collimated Electron Beam From The Laser-Driven Deuterium Cluster In Ambient Magnetic Field

[1,2]Kalyani Swain, [1,2]Mrityunjay Kundu

IPR, Ghandhinahar, Bhat, Gandhinagar – 382 428, India
Homi Bhaba National Institute, Anushaktinagar, Mumbai – 400094, India

E-mail : kalyani.swain@ipr.res.in

Abstract

Acceleration of charged particles (e.g., electrons) is a fundamental study in laser-plasma interaction due to wide applications for particle accelerators and table-top radiation sources (e.g, x-rays). Atomic clusters (a nanometric form of matter) can produce energetic electrons on effective coupling with an intense laser [1]. For lasers with intensity $I_0 > 10^{16}$ W/cm^2 and wavelength $\lambda > 600$ nm, light absorption is mostly collision-less. In this regime, most of the previous studies [1,2,3] (and many others) report that maximum energy absorption of a laser-driven cluster-electron **is limited near its ponderomotive energy** (Up). However, our recent work [4] on laser-driven deuterium cluster in an ambient magnetic field of 10-20 kT, shows that laser energy absorption occurs in two stages via anharmonic resonance (first stage) and electron cyclotron resonance (ECR) or relativistic ECR (second stage) resulting **an enhanced average absorbed energy per electron up to 30-70U_p**. In this work, we focus on the energy dispersion of these highly energetic electrons by analyzing their angular distribution and find that the ambient magnetic field not only enhances the electron energy but also collimates these accelerated electrons. The collimation angles of these electrons lie within 5^0 to 6^0. Additionally, we draw attention to how the angular distribution of these electrons is impacted by larger cluster size and increasing laser intensity. An intense collimated electron beam may have uses in fast ignition technique for inertial confinement fusion and ultra-short x-ray sources for medical applications.

References :

[1] T. Ditmire et al., Phys. Rev. Lett. **78**, 3121 (1997).

Fabrication of Silicon Micro-Pillars Using Ultrashort Optical Vortex Beam in The Soft Ablation Regime

Nancy Verma, Reji Philip

Ultrafast and Nonlinear Optics Lab, Light and Matter Physics Group, Raman Research Institute, Bangalore 560080, India

E-mail : reji@rri.res.in

Abstract

Surface structures have been produced on crystalline silicon (100) samples by employing ultrashort optical vortex (OV) beams (λ = 800 nm, 100 fs) carrying definite orbital angular momentum (OAM), in the soft ablation regime. An OV beam is a spatially structured beam having a donut-shaped intensity profile caused by the helical nature of its wave-front, advancing along the direction of propagation [1, 2]. The annular intensity profile and controllable polarization of the OV beam enables the generation of interesting hierarchical surface features.

For these experiments we used an OV beam having linear and circular states of polarization (SoP) in the transverse plane, generated by using a spiral phase plate (SPP) of topological charge (ℓ) = 4. Under loose focusing conditions (i.e., with a plano-convex lens of focal length 10 cm), the femtosecond OV beams were found to generate well-oriented annular regions containing sub-wavelength scale ripples and grooves, which are influenced by the SoP of the incident beam. In contrast, under tight focusing conditions (i.e., using an objective lens of N.A. = 0.30), the OV beam (with energy E = 1.0 mJ and N = 10) generates silicon micro-pillars on the surface.

Our experimental results suggest that in the case of the OV beam carrying higher OAM, local SoP does not affect the formation of micro-pillars. However, the chirality of the pillars is defined by the handedness of the OV beam, providing direct visualization of the helical beam. The uniqueness and versatility of fs-OV beams enables the design of unconventional surface features, as well as the characterization of complex ultrashort laser beams.

This talk will discuss details of the generation of the optical vortex beam and its application for fabricating micro-pillars on silicon surface.

References :

[1] Allen et.al., The orbital angular momentum of light, Progress in Optics, **39**, p. 291-372, 1999.
[2] Allen et.al., Orbital angular momentum of light and the transformation of Laguerre-Gaussian laser modes, Phys. Rev. A **45**, p. 8185, 1992.

Hydrodynamics of Laser-Induced Air Plasma Interaction with Plane and Structured Aluminum Surface

S. Sai Shiva[1], Elle Manikanta[1], D. P. S. L. Kameswari[1,2], G. S. Sasank[2], V. R. Ikkurthi[3], P. Prem Kiran[1,2*]

[1]*Advanced Centre of Research in High Energy Materials (ACRHEM), University of Hyderabad, Prof. C. R. Rao Road, Gachibowli, Hyderabad-500046, India.*

[2]*School of Physics, Prof. C. R. Rao Road, University of Hyderabad, Gachibowli, Hyderabad-500046, India.*

[3]*Computational Analysis Division, Bhabha Atomic Research Centre (BARC), Visakhapatnam, India.*

E-mail : prem@uohyd.ac.in

Abstract

The study of high temperature (~10^5 K) plasma-surface interactions is of great interest in applications like ICF, aerospace and defence technologies [1-4]. In this work, we study the hydrodynamics of laser-induced air plasma interaction with bulk aluminum (≥ 1 mm thick) slab having plane and structured surface, respectively. The simulations were performed using FLASH three dimensional radiation hydrodynamic (3D-RHD) code [5-6]. The air plasma was generated by focusing the second harmonics of Nd: YAG laser of wavelength 532 nm, pulse duration of 10 ns (FWHM) with the laser energy of 50 – 500 mJ per pulse focused to a spot-size of 250 µm. The plasma was generated parallel to the aluminum slab at a distance of 0.5 and 1 mm, respectively. The simulated spatio-temporal evolution of mass density, pressure, temperature etc. before and after the interaction with the plane and structured surfaces were compared, which show some of the interesting results in the reflected hydrodynamics from the target surface.

References :

[1] John Lindl, "*Development of the indirect-drive approach to internal confinement fusion and the target physics basis for ignition and gain",* Phys. Plas. **2**, p.3933 (1995). http://dx.doi.org/10.1063/1.871025.
[2] A. Benuzzi-Mounaix, M. Koenig et al., *"Laser-driven shock waves for the study of extreme matter states",* Plasma Phys. Control. Fusion, **48,** p. B347-B358, (2006)
[3] H. Jelassi and D. Benredjem, *"Plasma Science and Technology Basic Fundamentals and Modern Applications",* Chapter 3, IntechOpen, ISBN: 978-1-78985-240-0, DOI: 10.5772/intechopen.77157, p. 47-65, (2019).
[4] P. Bletzinger and B. N. Ganguly et al., "Plasmas in High Speed Aerodynamics," Journal of Physics D: Applied Physics, **38,** No. 4, p. R33-R57, (2005).
[5] Fryxell, B., et al., *FLASH: An Adaptive Mesh Hydrodynamics Code for Modeling Astrophysical Thermonuclear Flashes.* The Astrophys. J. Suppl. Series, **131** (1), p. 273-334, (2000).
[6] FLASH Code: http://flash.uchicago.edu/site/

Session 11

Exotic Plasma (Includes Dusty Plasma) (EP)			
Sr. No.	**Abstract ID**	**Oral ID**	**Title/Name/Affiliation**
1.	66	EP-O-1	**Experimental Observation of Coulomb Screening and Coulomb Acoustic Wave in Nanodusty Plasmas** *Bidyut Chutia, IASST*
2.	290	EP-O-2	**Collective excitations of strongly coupled systems under the Quasi-localized charge approximation (QLCA) framework** *Prince Kumar, IPR, Ghandhinahar*
3.	406	EP-O-3	**Effect of negatively biased electrode on two ion species plasma wall transition and dust charging** *Shiva Bikram Thapa, Tribhuvan University, Nepal*

Experimental Observation of Coulomb Screening and Coulomb Acoustic Wave in Nanodusty Plasmas

Bidyut Chutia[1*], K. Avinash[2], S. K. Sharma[1] and H. Bailung[1]

Affiliation: [1]Institute of Advanced Study in Science and Technology (IASST), Paschim Boragaon, Guwahati-781035, Assam, India
[2]Sikkim University, Tadong-737102, Gangtok, Sikkim, India
**Present address: Centre of Plasma Physics-IPR, Ghandhinahar (CPP-IPR), Nazirakhat, Sonapur-782402, Kamrup (M), Assam, India*

E-mail: bidyut.chutia.jist@gmail.com

Abstract

A nanodusty plasma is composed of electrons, ions and nanometer sized dust grains. A large volume nanodusty plasma medium is achieved in laboratory using reactive discharge of argon and acetylene gas mixture. Such type of plasmas can result in a highly dense dusty plasma where the ratio of dust density to ion density i.e., Havnes parameter becomes very large, $P \gg 1$. Due to high dust density, the nanodust particles float at a small potential resulting in a reduced average dust charge. In nanodusty plasmas, self-excited dust density waves dominate the cloud dynamics in most of the experimental scenarios. The measured wave properties are used to estimate spatially resolved plasma parameters and dust charge in such an exotic environment up to great accuracy. It has been shown theoretically by Avinash et al. [1],[2] that in high dust density regime, dust particles screen each other not by usual Debye screening but by a new screening mechanism called “Coulomb Screening”. This is shown to cause dust charge reduction. A characteristic scale length for “Coulomb screening” is obtained. It is shown that “Coulomb Screening” gives rise to a new acoustic mode called “Coulomb acoustic mode” in high density nanodusty plasma. In this particular work, the observations and results of an experiment [3] on the propagation of a self-excited dust density wave under strong Havnes effect will be presented based on these theoretical predictions. The experiment is performed in a vertically extended, highly dense nanodust cloud which is produced by using rf discharge of argon-acetylene gas mixture. The dust density wave appears spontaneously in the medium at a suitable set of discharge parameters. For the parameters of the experiment, the Coulomb screening dominates over the Debye screening. The dispersion relation is experimentally measured and compared with a theoretical dispersion which includes Debye as well as Coulomb screening. Based on this comparison the experimentally observed mode is identified as the “Coulomb Acoustic mode”. Average dust charge and other plasma parameters are also estimated.

References:

[1] A new acoustic-like mode in an unmagnetized dusty plasma, Phys. Plasmas **7**, 2763 (2000).
[2] Effect of charge reduction on shielding in dusty plasmas, Phys. Plasmas **10**, 2663 (2003).
[3] Spatiotemporal evolution of a self-excited dust density wave in a nanodusty plasma under strong Havnes effect, Phys. Plasmas **28**, 123702 (2021).

Collective excitations of strongly coupled systems under the Quasi-localized charge approximation (QLCA) framework

Prince Kumar and Devendra Sharma

IPR, Ghandhinahar, AC I of Homi Bhabha National Institute, Bhat, Gandhinagar-382428

E-mail(speaker): prince.kumar@ipr.res.in

Abstract

Strongly coupled systems are characterized by average potential energy per particle exceeding the average kinetic energy per particle. A wide variety of them, including, ions in cryogenic traps, molten salts, liquid metals, and electrons trapped on the free surface of liquid helium [1,2], are very efficiently represented by a dusty plasma. The Quasi-localized charged approximation (QLCA) theory is developed in the context of strongly coupled dusty plasma. The QLCA theory extends scope of the analysis to the cosmological scales where observations confirm the presence of magnetic fields strong enough to magnetize planetary dust [3]. Interestingly, a laboratory realization of such cosmological magnetization is possible by an externally driven rotation of the dusty plasma [4,5]. Our recent application of QLCA theory in a rotating frame allows treating strongly magnetized collective excitations in the disordered solid phase (amorphous solid) [3]. The resulting dispersion of the collective excitations accommodates the signatures of magnetoplasmons which closely correspond to the experimentally [4] measured dispersion at the higher rotational frequencies of the "effectively magnetized" strongly coupled rotating dust [3]. In order to validate these results numerically, a pseudo-spectral approach has been adopted which allows us further to extend the QLCA theory to its nonlinear limit [6]. The numerical dispersion, in a weak coupling limit of the QLCA theory, predict that strong coupling effects compete with strong magnetic field effects in the rotating dusty plasma. Nonlinear solutions of the QLCA theory are obtained numerically and analyzed in some detail [6].

References:

[1] Z Donkó, G J Kalman, P Hartmann J. Phys.: Condens. Matter 20, 413101 (2008)
[2] KI Golden, GJ Kalman - Physics of Plasmas, 2000
[3] Prince Kumar and Devendra Sharma, Physics of Plasmas 28, 083704 (2021)
[4] P. Hartmann, Z. Donkó, T. Ott, H. Kählert, and M. Bonitz, Phys. Rev. Lett. **111**, 155002 (2013).
[5] Prince Kumar, Devendra Sharma, Physics of Plasmas 2020, 27, 063703
[6] Prince Kumar and Devendra Sharma, "Quasilocalized charge approximation approach for the nonlinear structures in strongly coupled Yukawa systems" in Under Review (2022).

EFFECT OF NEGATIVELY BIASED ELECTRODE ON TWO ION SPECIES PLASMA WALL TRANSITION AND DUST CHARGING

Shiva Bikram Thapa[1], Suresh Basnet[1,2], and Raju Khanal[1]
[1]*Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[2]*Department of Physics, GoldenGate International College, Tribhuvan University, Battisputali, Kathmandu, Nepal*

E-mail: bikramthapashiva@gmail.com

Abstract

The overall dynamics, flow and the interaction of plasma with the electrode is dictated by the formation of the non-neutral positively charged region close to the biased electrode. Using the kinetic trajectory simulation method, we have studied the effect of electrode biasing voltage on the characteristics of two ion species magnetized plasma-wall transition region and the dust charging mechanism. The Debye sheath width increases from about 3.15 to 4.30 λ for the increase in biasing voltage from -20 to -50 V. The space charge density peak shifts towards the particle injection boundary as the biasing voltage is increased. The E×B drift velocity sharply increases near the electrode. The dust attains positive charge as we move from the injection boundary towards the electrode. In addition, the normalized dust charge close to the electrode gets increased from about -1.39 to 16.33 for the increase in biasing voltage from -20 to -50 V.

References:

[1] K. U. Riemann, J. Phys. D: Appl. Phys. **24**(4), 493 (1991).
[2] R. Chodura, Phys. Fluids **25**(9), 1628 (1982).
[3] M. Davoudabadi and F. Mashayek, Phys. Plasmas **12**(7), 089903 (2005).
[4] G. Foroutan, Phys. Plasmas **17**(12), 123711 (2010).

Year 2022 Awardees

Parvez Guzdar Award

On Probing the Solar Plasma Processes through UV/EUV Spectroscopy

Pradeep Kayshap
School of Advanced Science & Languages,
VIT Bhopal University, Kothri Kalan, Sehore, M.P.

Abstract

The Sun’s atmosphere consists of magnetized, hot, and ionized plasma, which exhibits a variety of physical processes (e.g, waves, shocks, instabilities, reconnection, etc.) at diverse spatio-temporal scales. These processes are crucial to understand the underlying physical conditions and energetics of such astrophysical plasma systems. In this talk, I will discuss some of the important results of solar plasma which are deduced using ultraviolet (UV) and extreme ultraviolet (EUV) spectroscopic observations. I describe the physical processes, in-situ plasma conditions, and dynamics of the localized solar atmosphere under the light of highresolution space-borne spectroscopic and imaging observations. The new scientific findings test the existing magnetohydrodynamic (MHD) processes and put a rigid constraint on the existing models. Such physical processes present in the solar atmosphere can act as a ready reference to understand the physics of plasmas at the laboratory scales also.

Jaidutt Saraswati Sodha PSSI Plasma Award

Low Temperature Plasma Applications for Societal Benefits

Ram Prakash
Department of Physics,
Indian Institute of Technology Jodhpur
NH-62, Nagaur Road, Karwar-342030, Jodhpur, Rajasthan
Email: ramprakash@iitj.ac.in

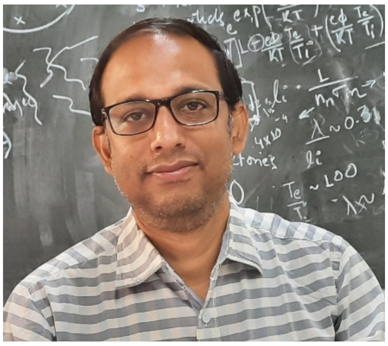
Abstract

The scarcity of foods, increasing health risks, depletion of modern energy fuels, environmental damage due to high carbon emission, etc. are some of the concerns in the recent time. Low temperature plasma technology has shown outstanding applications and worldwide efforts are underway. During the research tenure a significant contribution has been done in low-temperature plasma applications particularly for clean air, water purity, environmental safety, and for efficient energy systems. The unique aspects of work are related to innovations that have involved design, development, and translation of fundamental research into devices and systems that can be used in the field by common man and industries. The work done on novel Cold-plasma Detergent in Environment (CODE) device for better indoor air quality, Advanced Photocatalytic Oxidation Systems to fight COVID-19, Mercury-Free-Plasma UV-lamp for efficient water disinfection, VUV-spectrometer-detector system calibration source and radial multi-channel high-current Pseudospark Switch are some of them to cite. Such efforts made will be summarized in the presentation.

Jaidutt Saraswati Sodha PSSI Plasma Award

Experiments in complex plasmas

Pintu Bandyopadhyay
Institute for Plasma Research, Bhat, Gandhinagar, Gujarat



Abstract

A complex (or dusty) plasma comprises of micron or sub-micron sized dust grains along with plasma electrons, ions, and neutrals. These heavy dust particles acquire large negative charges and together with the electrons and the ions constitute an interesting charged medium that has very rich dynamics. Dust and dusty plasmas are ubiquitous in nature e.g., in planetary rings, comet tails, and interplanetary and interstellar clouds. The particles in dusty plasma exhibit a wide range of structural properties similar to solid, liquid, and gas depending upon the value of Coulomb coupling parameter, defined as the ratio of electrostatic energy to kinetic energy. During the last couple of decades, I have been involved in developing and leading a major experimental effort in investigating various research topics associated with Coulomb crystals, linear and nonlinear collective phenomena in stationary and flowing dusty plasmas and the dynamics of dust particles in high magnetic fields. To mention a few among many notable contributions – we have reported the first ever-experimental observation of solitons and precursor solitons in dusty plasmas, successfully made a structural transition in a 2D dust crystal, and explored pattern formation in magnetized dusty plasmas. In this award ceremony presentation, I will highlight some of these research findings obtained in the last twenty years.

Z. H. Sholapurwala Award

Analysis of Space Travelling Wave Tubes Based on Thermal Issues

Vishant Gahlaut
Department of Physical Sciences, Banasthali Vidyapith, Banasthali, Rajasthan – 304022

Abstract

Travelling Wave Tubes (TWTs) have their broad applications in satellite communication and defense due to wide bandwidth and unique power, gain and efficiency combinations. The increasing demand of TWTs for both high power and high frequency applications makes researcher to be more attentive towards thermal management. With the modern state-of-the-art innovative technologies and design concepts, high power, high frequency and high efficiency TWTs are designed but a gap remains for proper thermal management. Proper thermal management of helix TWT enhances the average power handling capabilities. With the reduction of structure dimensions, constituent elements sizes are reduced. Reduction in dimensions will enhance thermal issues and their management in the device. The method followed in this work is to consider the effect of different material properties for thermal dissipation. Heat dissipation is through conduction and radiation but dissipation through convection has been ignored due to very high vacuum inside the TWT. The concept related to the enhancement of heat dissipation capability is estimated by using the complete length of the helix slow-wave structure (SWS). The simulation result of the helix travelling wave will help to enhance the heat dissipation through helix SWS. The complete TWT is packaged to meet the environmental conditions, namely thermal shock, vibration, etc. For the thermal soaking, the packaged TWT is kept at -20 ^{o}C and +80 ^{o}C to study the structural integrity. TWT has to sustain both expansion and contraction at these two extreme temperatures. Effect of environmental conditions on thermal management of full integrated tube has been simulated and analyzed. Analysis is extended to extreme temperature conditions, namely, -20 ^{0}C and +80 ^{0}C. At these two extreme conditions, thermal management of assembly and that of packaged TWT is carried out.

Poster Presentations

Basic Plasma (BP)

Sr. No.	Abstract ID	Poster Number	Title/Name/Affiliation
1.	3	BP-1	**Dust–ion acoustic solitary waves in a collisionless magnetized five components plasma** Paltu Halder, Prof Anup Bandyopadhyay, Dr Sandip Dalui, Dr Sankirtan Sardar Jadavpur University, Kolkata
2.	4	BP-2	**Existence and Stability of Alternative Dust Ion Acoustic Solitary Waves in a Dusty Plasma Consisting of Nonthermal Electrons having Vortex-like Velocity Distribution** Dr. Sankirtan Sardar, Prof. Anup Bandyopadhyay, Prof. K.P. Das Guru Ghasidas Vishwavidyalaya, Bilaspur
3.	6	BP-3	**Effects of Radiative Heat-loss Function Neutral Collisions and Hall Current on Transverse Instability of Two-component Plasma with Finite Electron Inertia in HI Region** Dr. Sachin Kaothekar, Dr. Sachin Kaothekar, Dr Rajendra Chhajlani, Mr Sarvesh Mishra, Dr Sushil Phadke Prashanti Institute of Technology, Ujjain
4.	25	BP-4	**Characterization of Spiral Antenna-Based RF-plasma in Multi-Dipole Line Cusp Magnetic Field** Mumtaz Ali Ansari, Dr Amit D Patel, Dr Prabal K Chattopadhyay, Mr Raj Singh, Dr N. Ramasubramanian IPR, Ghandhinagar
5.	27	BP-5	**A technique to control electron temperature in filament discharge** Mrinal Kumar Mishra
6.	29	BP-6	**Nonlinear Excitations in Strongly Coupled Yukawa System under Quasi Localized Charge Approximation (QLCA) approach** Sandip Dalui, Devendra Sharma, Prince Kumar, IPR, Ghandhinagar
7.	36	BP-7	**Effect of floating ring on the atmospheric pressure plasma jet discharge mechanism and reactive species generation** Radhika T P, Dr Satyananda Kar IIT Delhi

8.	44	BP-8	**Directed motion in a 2D system of Yukawa particles on 1D Ratchet** Anshika Chugh, Prof. Rajaraman Ganesh IPR, Ghandhinagar
9.	56	BP-9	**Pulsed afterglow plasma for studies on electron magneto-hydrodynamic structures** Ambesh Kumari, Mr Kushagra Nigam, Mr Ravi G IPR, Ghandhinagar
10.	61	BP-10	**Dynamics of magnetized plasma sheath in the context of non-extensively distributed species** Rupali Paul, Kishor Deka, Rakesh Moulick, Dr Sayan Adhikari, Dr S.S Kausik, Prof. B.K Saikia CPP-IPR, Guwahati
11.	62	BP-11	**Investigating The Validity Of Boltzmann Relation For Electrons In A Magnetized Plasma Sheath** Gunjan Sharma, Rupali Paul, Mr Kishor, Rakesh Moulick, Dr Sayan Adhikari, Dr S. S. Kausik, Prof. B. K. Saikia CPP-IPR, Guwahati
12.	91	BP-12	**Generation of lump soliton structures in complex plasma media with superthermal electrons** Dr Uday Narayan Ghosh, K K M College, Jamui, Bihar
13.	94	BP-13	**Design, Simulation, development and testing of a High Power Microwve (HPM) DC break for SYMPLE** Dr Anitha V P, Ms Priyavandana J Rathod IPR, Ghandhinagar
14.	96	BP-14	**Development of Configuration Management Software for Laboratory Plasma Experiments** Ritesh Sugandhi, Ayan Adhikari, Ritesh Sugandhi, Amulya Kumar Sanyasi, Dr Lalit Mohan Awasthi, Ms Soumya V. IPR, Ghandhinagar
15.	122	BP-15	**Vector analysis of the electron phase-space vortices in electrostatic collision-less plasmas** Allen Lobo, Dr Vinod Kumar Sayal Sikkim Manipal University of Technology
16.	123	BP-16	**Kinetic simulation study of electron hole formation in highly magnetised, one dimensional, Q-machine plasma** Allen Lobo, Dr Vinod Kumar Sayal Sikkim Manipal Institutre of Technology

17.	124	BP-17	**Evolution of solitons in relativistic degenerate pair plasmas** Himanginee Gogoi, Siba Nath Gogoi, Dr Ridip Sarma Mandira Sarma D H S Kanoi College, Dibrugarh
18.	126	BP-18	**Role of argon metastable states inside argon-nitrogen RF plasma** Atri Mukhrjee, Dr Monojit Chakraborty, Mr Pabitra Saha CPP-IPR, Guwahati
19.	128	BP-19	**Formation of Axial Potential Structures in Oxygen RF plasma** Pabitra Kumar Saha, Dr Monojit Chakraborty, Mr Atri Mukherjee CPP-IPR, Guwahati
20.	130	BP-20	**Linear Plasma Device for Zonal Flow Study** Arita Tarafsar, Dr Subir Biswas, Mr Dibyajyoti Bora IASST, Guwahati
21.	132	BP-21	**Production Of Uniform Plasma With Filament Assisted DC Discharge In A Linear Plasma Device** Dibyajyoti Bora, Mr Aritra Tarafder, Dr Subir Biswas IASST, Guwahati
22.	134	BP-22	**Simulation study of electron hole-pair coalescence resulting in the formation of a single hole in collision-less plasmas** Mr Allen Lobo, Dr Vinod Kumar Sayal, Sikkim Manipal University of Technology
23.	142	BP-23	**Observation of electron temperature anisotropy in the double plasma device** Jocelyn Sangma, Dr Anuj Ram Baitha, Dr Monojit Chakraborty CPP-IPR, Guwahati
24.	153	BP-24	**Singular solitons interaction of quantum acoustic waves with degenerate electrons** Dr Barijder Kaur, Dr U N Ghosh GNA University, Punjab
25.	165	BP-25	**Simulations of Stimulated Raman Instability relevant to Fusion Plasma** Polly Biswas, Prof. DN Gupta University of Lucknow, Lucknow

26.	202	BP-26	**Study of 3D magnetohydrodynamic turbulence with different initial conditions** Pratik Patel, Sharad K Yadav SVNIT, Surat
27.	221	BP-27	**Finite Element Simulation of Plasma Production in a cusp field linear device** Amardas Ali, Amit D Patel, Raj Singh IPR, Ghandhinagar
28.	228	BP-28	**Lattice Ion Vibrations And Electron Waves Coupling Leading Spiky Solitons In Piezoelectric Semiconductor Quantum Plasma** Abhishek Yadav, Punit Kumar University of Lucknow, Lucknow
29.	234	BP-29	**Turbulence Mechanism in Quantum Plasma** Prabhat Singh, Punit Kumar University of Lucknow, Lucknow
30.	235	BP-30	**Jeans instability of quantum mgnetized resistive plasma** Sonali Patidar, Dr Ashok Ashok K. Patidar, Sonali Patidar Sonali Patidar, Hemlata Joshi, Dr Swati Swati Dubey Vikram University, Ujjain
31.	237	BP-31	**Radiation reaction in relativistic Quantum plasma** Priya Mishra, Dr Punit Kumar University of Lucknow, Lucknow
32.	240	BP-32	**Polarization of dust acoustic waves in quantum plasma** Aakanksha Singh, Dr Punit Kumar University of Lucknow, Lucknow
33.	241	BP-33	**The effect of magnetized quantum plasma on jeans instability** Ashok Kumar Patidar, Govt. P G College, Mandsaur
34.	253	BP-34	**COMSOL Simulation for the Experimental Study of a Capacitive Coupled Plasma (CCP) Source** Ramesh Kumar, Dr Bibhuti Bhusan Sahu IIT Delhi
35.	258	BP-35	**Plasma Sheath with two species of positive ions and surface produced negative ions** Sutapa Samanta, Dr Rakesh Moulick, Dr Bipul Saikia, Dr Pranjal Bhuyan CPP-IPR, Guwahati

36.	264	BP-36	**Nonlinear Effect on Plasma Waves Observed by Fluid Simulation Using LCPFCT Algorithm** Gaurav Kumar, Prof. Hitendra kumar Malik IIT Delhi
37.	266	BP-37	**Impact of Doubly-ionized Ions on Rayleigh-Taylor Instability in a Hall Thruster Plasma** Dhananjay Verma, Prof. Hitendra Kumar Malik IIT Delhi
38.	274	BP-38	**The effect of racetrack position on plasma characteristics in RF magnetron discharge** Hemen Kakati Nalbari College, Assam
39.	275	BP-39	**Analytical and Simulation studies of ion acoustic stationary formations at critical plasma density** Sharry Kapoor, Dr Chinmay Das, Dr Swarniv Chandra Govt. General Degree College, Kushmandi
40.	280	BP-40	**Shock wave in anisotropic quantized magneto pair ion plasma** Manoj Kumar Deka, Deepsikha Mahanta, Apul Narayan Dev Gauhati University,Guwahati
41.	281	BP-41	**EFFECT OF CONNECTION LENGTH ON PLASMA DYNAMICS IN A SIMPLE MAGNETIZED TORUS** Prince Alex, Ruggero Barni, Claudia Riccardi University of Milan-Bicocca, Italy & St Joseph College Devgiri
42.	292	BP-42	**Ion-acoustic double layers in negative ion plasmas with two temperature superthermal electrons** Kishan Kumar University of Rajasthan
43.	296	BP-43	**Magnetized Inhomogeneous Weakly Coupled Fusion Plasma: Dust-Driven Instabilities** Shachi Pachauri, Mr Shiva Shakti Singh, Dr Jyoti Malik, Dr Kamakhya Prakash Misra Manipal University Jaipur
44.	298	BP-44	**Lane Formation In 3D Pair-Ion Plasmas Driven By Non-Parallel External Forcing** Vishal K Prajapati, Dr Swati Baruah, Prof. Rajaraman Ganesh Assam Kaziranga University
45.	311	BP-45	**The influence of spin force on charge particles in Quantum Plasma**

			Shiva Shakti Singh, Mrs Shachi Pachauri, Dr Jyoti Malik, Dr Kamakhya Prakash Misra Manipal University Jaipur
46.	320	BP-46	**Electromagnetic Simulation of Microwave Coupling to Resonant Plasma Cavity with ECR Magnetic Field Configuration** Manish Pathak, Dr Sunil Kumar Jain RRCAT, Indore
47.	321	BP-47	**A Numerical Approach of Modified Burgers' Equation in Charged Dusty Plasmas** Harekrishna Deka, Dr Jnanjyoti Sarma Krishna Kanta Handikui State Open University
48.	325	BP-48	**Propagation of spin solitary wave driven by anisotropic ion beam in a quantum magneto plasma** Deepsikha Mahanta, Manoj Kumar Deka, Dr Apul Narayan Dev, Dr Jnanjyoti Sarma Guwahati University
49.	328	BP-49	**Comparative Study on Degradation of Methylene Blue using Gas Phase and Underwater Radio Frequency Atmospheric Pressure Plasma Jet** Aishik Basu Mallick, Ramesh Narayanan, Satyananda Kar IIT Delhi
50.	333	BP-50	**Particle simulations of tearing and surface preserving modes in electron current layers** Sushmita Mishra, Dr Gurudatt Gaur, Dr Bhavesh Patel IASST, Guwahati
51.	341	BP-51	**A Two-Fluid Approach To Study The Thrust Performance Of An ECR Thruster Experiment** Subhashish Bag, Vikrant Saxena IIT Delhi
52.	345	BP-52	**Effect Of Axial Magnetic Field On A Cylindrically Symmetric Electronegative Discharge** Avinesh Kumar Pandey, Prof. Shantanu Kumar Karkari, Mr Pawandeep Singh, Ms Swati Dahiya IPR, Ghandhinagar
53.	354	BP-53	**Turbulent Relaxation of Plasmas By Vanishing Nonlinear Transfer** Supratik Banerjee, Arijit Halder and Nandita Pan IIT Kanpur
54.	356	BP-54	**Understanding Transverse Diffused Plasma and Excited Turbulence In LVPD-U**

			Nandini Yadava, Amulya Kumar Sanyasi, Lalit Mohan Awasthi, Mainak Bandyopadhyay, Pankaj Kumar Srivastava, Ritesh Sugandhi IPR, Ghandhinagar
55.	357	BP-55	**Understanding Cross Field Density Depletion Phenomenon in LVPD-U Plasma** Ayan Adhikari, Amulya Kumar Sanyasi, Lalit Mohan Awasthi IPR, Ghandhinagar
56.	379	BP-56	**Cut Cell Technique To Model Curved Boundaries In Particle-In-Cell Code PASUPAT** Gaurav Singh, Prof. Debabrata Biswas, Mr Gaurav Singh, Dr Raghwendra Kumar BARC, Mumbai
57.	382	BP-57	**Laser-induced Photodetachment for the negative ions detection using Hairpin probe into the SPIN-ex Plasma device** Nageswara Rao Erupu, Ms Swati Dahiya, Dr Avnish Kumar Pandey, Mr Pawandeep Singh, Dr Shantanu Kumar Karkari, Ms Yashashri Patil IPR, Ghandhinagar
58.	384	BP-58	**Possible Applications of SMES from India's Perspective** Aashoo Sharma, Dr V. L. Tanna, Dr P. K. Atrey IPR, Ghandhinagar
59.	399	BP-59	**Role of Neutral Gas Flows in Double Layer Formation and Thrust Generation in an Expanding Magnetic Field Plasma** Vinod Saini, Rajaraman Ganesh IPR, HBNI, Gandhinagar
60.	403	BP-60	**Ion Beam Induced Nanopatterning Of Borosil Related To Plasma Thruster** Basanta Kumar Parida, Dr Mukesh Ranjan, Mr Sebin Augustine, Mr Sooraj K., Mrs Sukriti Hans, Mr Vivek Pachchigar IPR, Ghandhinagar
61.	407	BP-61	**Modulation in ion-acoustic wave with their stability in higher order nonlinearity** Rumi Chaharia Maharishi Vidya Mandir, Silpukhuri, Guwahati
62.	415	BP-62	**Creation and optimization of atmospheric pressure micro-plasma jets: physics and applications**

			Kalyani Barman, Sudeep Bhattacharjee IIT Kanpur
63.	417	BP-63	**Temperature Anisotropy Governed Current Density Profiles In A Compact Dipole Plasma Device Driven At Steady State** Ayesha Nanda, Prof. Sudeep Bhattacharjee IIT Kanpur
64.	420	BP-64	**Scheme for microwave mode excitations to have different effective angle of incidences in SYMPLE** Anitha V P, Priyavandana J Rathod IPR, Ghandhinagar
65.	425	BP-65	**Ion-acoustic soliton in magnetoplasma using nonlinear ZK equation with nonthermal electrons** Dr. J JKC R R Govt College Rajasthan
66.	429	BP-66	**Investigations of shocks and solitary structures in four components strongly coupled unmagnetized astrophysical dusty plasma** Jyotirmoy Goswami, S.S Kausik CPP-IPR, Guwahati
67.	439	BP-67	**Characteristics of active magnitized plasma sheath in the presence of non maxwellian source electron** Sudan Dhakal, Suresh Basnet, Raju Khanal Goldengate International College, Battisputalli, Kathmandhu, Nepal
68.	451	BP-68	**Parametric Instability in Forced Anharmonic Oscillator Model for Plasma Instability** Dr. Jayaprakash K, Saravanan A, Suraj Kumar Sinha Veltech University, Chennai
69.	468	BP-69	**Study of Plasma Wakefields Generation and Acceleration for Charged Particles using LCODE** Niketen Jakhar, Mr Chandan Thakur, Niketan Jakhar, Ms Jyotsna Sharma, Mr Manish Kumar Kashyap, Mr Sarvesh Kumar JNU, Delhi

Exotic Plasma (Includes Dusty Plasma) (EP)

Sr. No.	Abstract ID	Poster Number	Title/Name/Affiliation
1.	49	EP-1	**Streaming instabilities in magnetized quantum dusty plasmas** Sukhmander Singh Central University of Rajasthan
2.	80	EP-2	**Molecular Dynamics Simulation Of Three-Dimensional Yukawa Clusters Embedded In Plasma Environment** Hirakjyoti Sarma, Prof. Nilakshi Das Tezpur University, Tezpur
3.	88	EP-3	**Kelvin-Helmholtz instability in a compressible dust fluid flow** Krishan Kumar, Dr Pintu Bandyopadhyay, Swarnima Singh, Prof. Abhijit Sen IPR, Ghandhinagar
4.	89	EP-4	**Experimental Demonstration of Structural Phase Transition in 2-D Complex Plasma Crystals** Swarnima Singh, Krishan Kumar, Pintu Bandyopadhyay, Abhijit Sen IPR, Ghandhinagar
5.	137	EP-5	**Study of Nonlinear wave structures through damped modified Gardner Equations in Quantum Plasmas** Vanshika Khanna, Dr U N Ghosh, Dr Barjinder Kaur GNA University, Punjab
6.	148	EP-6	**Tunable rheological behaviour of magnetized complex plasma** Biswajit Dutta, Prof. Nilakshi Das Tezpur University, Tezpur
7.	161	EP-7	**Layer formation in stratified 3D Yukawa liquids** Suraj Kalita, Prof. Rajaraman Ganesh IPR, Ghandhinagar
8.	226	EP-8	**Effects Of Compressibility On The Rayleigh-Taylor Instability In Strongly Coupled Dusty Plasmas** Deepak Ahirwar, Dr Ram Prasad Prajapati JNU, Delhi
9.	268	EP-9	**Effect of Debye Hückel potential in the formation of Dust acoustic wave with dust charge variation** Prathana Borah Nanda Nath Sakya College, Assam

10.	269	EP-10	**Ion Streaming Instability in Dust Density Waves** Niranjan Gogoi, Prof. Nilakshi Das Tezpur University, Tezpur
11.	273	EP-11	**Formation Of Crystalline Structure In Ultracold Electron-Ion Plasma** Mamta Yadav, Ms Priya Deshwal, Dr Srimanta Maity, Prof. Amita Das IIT Delhi
12.	301	EP-12	**Effect of Ion Streaming in Shear Viscosity and Thermal Conductivity of Strongly Coupled Dusty Plasma in Presence of External Magnetic Field** Mahmuda Begum Lakhimpur Girls College, Lakhimpur
13.	306	EP-13	**Experimental study of the evolution of a non-planar solitary wave in a strongly coupled dusty plasma** Prarthana Gogoi, Dr Nirab Chandra Adhikary, Prof. Heremba Bailung, Mr Bidyut Chutia IASST, Guwahati
14.	314	EP-14	**Effect of negatively biased electrode on two ion species plasma sheath and levitation of dust particle** Suresh Basnet, Mr Shiva Bikram Thapa, Mr Anish Maskey, Prof. Raju Khanal Tribhuvan University, Nepal
15.	316	EP-15	**Self-Excited Vortex Formation in Three Dimensional Dusty Plasma** Sachin Sharma, Dr Sanat Tiwari, Dr G Veda Prakash, Dr Meenakshee Sharma, Prof. Yogesh Saxena IIT Jammu
16.	322	EP-16	**Hydrodynamic Stability of Convective Cells in 2D Complex Plasmas** Pawandeep Kaur, Mr Jagannath Mahapatra, Prof. Rajaraman Ganesh IPR, Ghandhinagar
17.	327	EP-17	**Active Complex Plasma: A new paradigm of research** Suomen De Karmakar, Rajaraman Ganesh, Soumen De Karmakar IPR, Ghandhinagar
18.	332	EP-18	**Dust charge fluctuation and ion acoustic wave propagation in dusty plasma with two groups of electrons**

			Raju Khanal, Mr Shiva Bikram Thapa Thapa, Dr Suresh Basnet Tribhuvan University, Nepal
19.	339	EP-19	**Study Of Plasma Sheath In The Presence Of Dust Particles In A Magnetic Mirror-like Field Configuration** K. Deka, G. Sharma, R. Paul, R. Moulick, S. Adhikari, S. S. Kausik, and B. K. Saikia CPP-IPR, Assam
20.	351	EP-20	**Characterizations of Spontaneous Fluctuations in Strongly Coupled Dusty Plasmas** Abhijit Sen, Ankit Dhaka, PV Subhash, Pintu Bandyopadhyay IPR, Ghandhinagar
21.	386	EP-21	**Interaction between approaching carrier waves in semiconductor Plasma** Swarniv Chandra, Chinmay Das Govt. General Degree College, Kushmandi
22.	418	EP-22	**Dynamics of dust particles in active magnetized plasma sheath with non thermal electrons** Madhusudan Dhungana, Num Prasad Acharya, Prof. Raju Khanal, Dr Suresh Basnet Tribhuvan University, Nepal
23.	430	EP-23	**Analytical studies of dust acoustic waves with kappa distributive ions and electrons in a viscous dusty plasma** Jyotirmoy Goswami, S.S Kausik CPP-IPR, Guwahati
24.	448	EP-24	**Wave Spectra in Yukawa system: The role of dusty plasma parameters on collective properties** Pratikshya Bezbaruah, Mr Hirak Sarma, Prof. Nilakshi Das Biswanath College, Assam
25.	454	EP-25	**Korteweg-de Vries model based nonlinear dispersion relations for dust acoustic wave** Farida Batool, Ajaz Mir , Sachin Sharma, Abhijit Sen and Sanat Tiwari IIT Jammu
26.	456	EP-26	**Dynamics of dust particles in active magnetized plasma sheath with non thermal electrons** Madhusudan Dhungana, Suresh Basnet, Prof. Raju Khanal Tribhuvan University, Nepal

Laser Plasma (LP)			
Sr. No.	**Abstract ID**	**Poster Number**	**Title/Name/Affiliation**
1.	14	LP-1	**Third Harmonic Generation by Nonlinear Interaction of Gaussian Laser Beam with an Array of Magnetized Anharmonic Carbon Nanotubes** Shivani Vij DAV Institute of Engineering & Technology, Jalandhar
2.	30	LP-2	**Sheet current generation in short pulse laser interaction with a linear array of gold nanorods** Nivedya Krishnan, Dr Ashok Kumar, Dr Gagan Kumar Amity University, Gurgaon
3.	54	LP-3	**Generation of the Strong Terahertz Field by Relativistic Cosh-Gaussian Laser Beam in Ripple Density Magnetized Plasma** Dr. Gunjan Purohit DAV Post Graduate College, Dehradun
4.	65	LP-4	**Establishing The Violation of Volkov Solutions in Strong Field Quantum Electrodynamics Regime of Intense Laser Magnetized Plasma Interaction** Prof. B S Sharma Bhawani Shankar, Garima Yadav Garima, Dr R.C.Dhabhai Ramesh Chand ,Gopal Saini Gopal, Prof B S Sharma Bhawani Shankar Lords University, Alwar
5.	87	LP-5	**Analytical study of terahertz generation by beat-wave mechanism of two Gaussian laser beams with corrugated noble-metal nanospheres in the presence of external magnetic field** Moses Simon, Prashant Kumar Chauhan, Jaypee Institute of Information Technology, Noida
6.	99	LP-6	**Increase in cluster size along the flow direction in supersonic expansion** Milaan Patel, Jinto Thomas, Hem Chandra, IPR, Ghandhinagar
7.	100	LP-7	**Laser-Driven Proton Acceleration From Nano-Structured Foils** Jubaraj Chaudhary, Ankita Bhagawati, Nilakshi Das Tezpur University
8.	116	LP-8	**Terahertz radiation generation by q-Gaussian Lasers in a plasma with density ripple** Dipender Singh, Harjit Singh Ghotra Harjit Singh Ghotra,

			LPU, Jalandhar
9.	154	LP-9	**Simulation Studies On Longitudinal Wakefield Generation Using Arbitrarily Polarized Two-Color Laser Pulses In Homogeneous Plasma** Dinkar Mishra, Bhupesh Kumar University of Lucknow, Lucknow
10.	157	LP-10	**Ion Acceleration by interaction of normally incident laser pulse with structured target in TNSA regime** Imran Khan, Vikrant Saxena IIT Delhi
11.	176	LP-11	**Enhancement of laser generated shocks in low density foam on Al- foil targets** Atul Kumar, Mrs S. Bhartiya, Mr A. Singh, Mrs S. Jain, Dr S. Barnwal, Mr A.K. Singh, Mr R.K. Patidar, Mr D.K. Kohli, Dr Y.B.S.R. Prasad, Mr N.S. Benerji, Mr M.K. Singh, Dr S.K. Dixit RRCAT, Indore
12.	181	LP-12	**Particle-In-Cell Observations Of Parametric Instabilities For Laser Interacting With Magnetized Plasma** Laxman Goswami, Amita Das IIT Delhi
13.	184	LP-13	**Investigation of signal enhancement in nanoparticle enhanced molecular LIBS of graphite** Sweta Pushpa, Prashant Kumar PRL, Ahmedabad
14.	197	LP-14	**THz Radiation Generation from Laser interaction with a Magnetized Plasma** Ashish, Krishna Gopal, Mr Ashish, Prof. DN Gupta, Dr Sukhmander Singh Central University of Rajasthan
15.	200	LP-15	**Emission of Terahertz Radiation by Oblique Incidence of Laser on Inhomogeneous Plasma** Anjana K P, Mrityunjay Kundu IPR, Ghandhinagar
16.	204	LP-16	**Dynamics of heterogeneous colliding laser-produced plasmas** Shilpa S, Pramod Gopinath International School of Photonics, CUSET, Kochi

17.	212	LP-17	**Numerical Studies on Controlled Trapping and Acceleration of Electron Bunch on a Gaussian Density Down Ramp** Deepraj Phadte, Mr Madhu babu Kommireddy , Dr Satya Ram Mishra RRCAT, Indore
18.	215	LP-18	**Anisotropic Emission from Laser Produced Plasma using Optical Emission Spectroscopy** Geethika B R, Dr Garima Arora, Hem Chandra Joshi, Jinto Thomas IPR, Ghandhinagar
19.	216	LP-19	**Time-frequency analysis of the attosecond pulse trains produced from high harmonics in argon filled cell** Mukund Kumar, Himanshu Singhal, Prof. Juzer Ali Chakera, Mr Ajmal Ansari RRCAT, Indore
20.	219	LP-20	**Time-Resolved Investigation of the Effect of External Electric Field on Laser-Produced Silver Plasma in Liquid Ambient** Kavil mehta, Swetapuspa Soumyashree , Dr Prashant Kumar , Dr Rajesh K. Kushawaha, Dr Prahlad K. Baruah Pandit Deendayal Energy University, Ahmedabad
21.	238	LP-21	**Picosecond Laser Ablative Mass Spectrometry of Polymer Target** Sasank G S, Prem Kiran P, Dr Ashok V.S., Sai Shiva S, Dr Manikanta Elle, Dr Nagaraju Guthikonda, Dr Sree Harsha S, University of Hyderabad, Hyderabad
22.	244	LP-22	**X-Ray Emission from Collective Betatron Oscillations of Electrons Excited by Chirped Laser Pulses in a Plasma Wiggler** Shikha Mishra, Sanyasi Rao Bobbili ,Dr Anand Moorti and Dr Juzer Ali Chakera RRCAT, Indore
23.	245	LP-23	**Study On Terahertz Radiation Generation by Interaction Of Lasers with Carbon Nanotubes** Dr Rakhee Malik Govt Degree College, Budaun
24.	247	LP-24	**Second Harmonic generation of elliptical laser beam in thermal quantum plasma** Kulkaran Singh, Keshav Walia DAV University, Jalandhar

25.	255	LP-25	**Interaction of Laser with gaas Structure for Terahertz Radiation Generation** Sandeep, **Sandeep[a,b*] and Hitendra K. Malik[a]** IIT Delhi & Deen Dayal Upadhayay College, New Dehli
26.	256	LP-26	**Effect of Topological Charge on Relativistic Self-Focusing of Optical Vortex Beam in an Under-dense Plasma** Subhajit Bhaskar, Hitendra K. Malik IIT Delhi
27.	259	LP-27	**Optimization of Electron Bunch Characteristics based on Plasma Channel Ramp in Laser Wakefield Acceleration** Mohit Kumar, Hitendra K. Malik, Dr Sandeep Kumar IIT Delhi
28.	276	LP-28	**Wakefield generation in magnetized homogeneous and inhomogeneous plasmas** Saumya Singh, Bhupesh Kumar University of Lucknow, Lucknow
29.	277	LP-29	**Terahertz generation by Hermite-Gaussian laser beam in magnetoplasma with an exponential density ramp** Proxy Kad, Vidisha Rana, Dr R Ambedkar NIT, Jalandhar
30.	282	LP-30	**Simulation Studies On The Effect Of Unchirped, Chirped And Two-Color Chirped Laser Pulses On Wakefield Generation** Shivani Agarwal, Bhupesh Kumar University Of Lucknow, Lucknow
31.	284	LP-31	**Study of High Harmonics Generation in RL Mode Configuration** Trishul Dhalia, Rohit Juneja , Mr Laxman Goswami, Prof. Amita Das, Dr Srimanta Maity IIT Delhi
32.	285	LP-32	**Chaotic Particle Trajectories For Laser Energy Absorption In Plasmas** Rohit Juneja, Trishul Dhalia ,Mr Laxman Goswami, Ms Priya Deshwal and Amita Das IIT Delhi
33.	293	LP-33	**Dynamics of Hermite-Gaussian laser beam in plasma and Terahertz generation** Vidisha Rana, Proxy Kad, Dr Arvinder Singh, B R Amedkar NIT Punjab

34.	294	LP-34	**Nonlinear Interactions in Magnetized Piezoelectric Semiconductor Quantum Plasma** Ratna Agrawal, Gopal Dangi , Dr Ratna Agrawal , Dr Ravi Vanshpal , Dr Swati Dubey Vikram University, Ujjain
35.	302	LP-35	**Development Of An Optical Delay Line For Probing The High Intensity Laser Foil Interaction Dynamics Using Optical Reflectometry** Riyaz Ahmed Khan, Anand Moorti , Juzer Ali Chakera , Mohammad Tayyab , Mr Riyaz Ahmed Khan , Dr Suman Bagchi RRCAT, Indore
36.	313	LP-36	**Influence of self-focused high-power beam on second harmonic generation in quantum plasma** Taranjot Singh, Keshav Walia DAV University, Jalandhar
37.	324	LP-37	**Plasma Wave Aided Heating of Nanocluster Plasma by Nonlinear Interaction of two Hermite-Gaussian Laser Beams** Arvind Kuma and Asheel Kumar University of Allahabad, Allahabad
38.	326	LP-38	**Excitation of Plasma Wave by Two Copropagating High Power Laser Beams in Nanocluster Plasma** Sujeet Kumar & Asheel Kumar University of Allahabad, Allahabad
39.	331	LP-39	**Plasma Electron Trapping in Laser Wakefield Acceleration** Ravina, D N Gupta Delhi University
40.	337	LP-40	**Effects of radiation-reaction on resonant phase locking in cyclotron auto-resonant particle acceleration scheme** Shivam Kumar Mishra, Sarveshwar Sharma, Sudip Sengupta IPR, Ghandhinagar
41.	346	LP-41	**Plasma shielding effect on hydrogen atom in intense laser field** Ashish Sharma, Alok Kumar Singh Jha, Mr Ashish Sharma, Prof. Man Mohan JNU, Delhi
42.	349	LP-42	**Determination of Heavy Metals in the Atmosphere by Laser Induced Breakdown Spectroscopy**

			Darshitsinh Parmar, Rajesh K. Kushawaha , Dr Rohit Srivastava , Prahlad K. Baruah Pandit Deendayan Energy University
43.	360	LP-43	**Generating Fast Protons From A Plasma Sphere Having Density Gradients With Short-Pulsed Laser Irradiation** Ankita Bhagawati, Nilakshi Das Tezpur University, Tezpur
44.	363	LP-44	**Effect of Fröhlich Coupling Constant on the Performance of Cost Effective Modulators** Ayushi Paliwal, Swati Dubey Vikram University, Ujjain
45.	367	LP-45	**Effect of Periodic Modulation of Target Surface on Ion Emission in Laser Induced Plasmas** Deepak Kumar Sahu, Anandam Anandam , Mr Aparajit, C. Dr Archit Bhardwaj Prof. M. Krishnamurthy TIFR, Mumbai
46.	401	LP-46	**Plasma Current Model for Second-Harmonic generation of a Laser in a Plasma** Tapti Bhardwaj, DAVKI NANDAN GUPTA , Prof. Anuj Vijay GLA University, Mathura
47.	414	LP-47	**Langmuir wave aided Resonant Laser Beat Wave thz generation in a Plasma channel** Arnika Sharma, Anuj Vijay , Dr Krishna Gopal GLA University, Mathura
48.	427	LP-48	**Spatial Dynamics Of Terahertz Generation Of Lower Order Bessel-Gaussian Laser Beam In Plasma.** Aman Bhatia, Manya Dawra , Dr Keshav Walia ,Prof. Arvinder Singh B R Ambedkar NIT, Jalandhar
49.	452	LP-49	**Radially Polarized Terahertz (THz) Radiation Generation: Scaling of THz** Mahendra, Anil K. Malik CCS University Meerut
50.	455	LP-50	**Efficient Harmonic Generation in a Tunnel-Ionizing Plasma** Mamta Singh University of Delhi

51.	459	LP-51	**Self-Focusing of a Bessel Gaussian Laser Beam in an Inhomogeneous Plasma** Nidhi Pathak, Sukhdeep Kaur, Dr T.S. Gill GNDU, Amritsar
52.	462	LP-52	**A Nomarski based interferometer for the investigation of Laser Produced plasmas generated by Femtosecond Laser pulses** Tomis Prajapati, V.Narayanan IIT Jodhpur

Plasma Diagnostics (PD)

Sr. No.	Abstract ID	Poster Number	Title/Name/Affiliation
1.	28	PD-1	**Design and Development of Homodyne FMCW Reflectometer for Estimation of Plasma Density in Multi-Dipole Line Cusp Configured Plasma Device** Rohit Mathur, Amit D Patel, J.J.U. Buch, Ramasubramanian Narayanan, Dr SK Pathak IPR, Ghandhinagar
2.	34	PD-2	**Optical Grayness factor and its effect on Electron Cyclotron Emission measurements during transient and steady state conditions**. Varsha Siju, SK Pathak IPR, Ghandhinagar
3.	58	PD-3	**Design, Simulation, Testing & Installation of Wave Collection and Transport System for Michelson Interferometer Diagnostic at SST-1 Tokamak** Abhishek Sinha, Sonam Shrama, Surya k Pathak IPR, Ghandhinagar
4.	60	PD-4	**First result of thomson scattering diagnostics on SST – 1** Neha Singh, Vishnu chaudhari, Mr Pabitra Kumar Mishra, Mr Kiran Patel, Dr Jinto Thomas, Dr Hem Chandra Joshi IPR, Ghandhinagar
5.	73	PD-5	**The Simulation Of Line Profile of C5+ Impurity Ions Emission Influenced By Zeeman Effect In ADITYA-U Tokamak** Abhishek B, J Ghosh , M. B. Chowdhuri , N Yadava , K. A. Jadeja ,R. L. Tanna , Aditya-U Team Manipal Institute of Technology, Manipal
6.	95	PD-6	**Postmortem Analysis Of Coatings On Viewport Of SST-1 Using LIBS And Micro-raman Technique** Pabitra Kumar Mishra, Hem Chandra Joshi ,Pabitra Kumar Mishra , Neha Singh , Jinto Thomas IPR, Ghandhinagar
7.	138	PD-7	**Study Of Instability In Low Pressure Plasma Generated By The Pulsed Washer Gun Inside A Curved Vacuum Chamber** Parthasarathi Das, Rita Paikaray, Mr Bipin Kumar Sethy, Mr Rajesh Kumar Barad, Dr Subrata Samantaray, Dr Gourishankar Sahoo, Amulya Kumar Sanyasi, Joydeep Ghosh

			Ravenshaw University, Cuttack
8.	143	PD-8	**Determination Of Electron Temperature of A Pulsed Washer Gun Plasma Using Triple Langmuir Probe** Vipin Kumar Sethy, Rita Paikaray, Parthasarathi Das, Subrata Samantaray, Gourishankar Sahoo, Amulya Kumar Sanyasi, Joydeep Ghosh Ravenshaw University, Cuttack
9.	152	PD-9	**Development of an algorithm for the Inversion of Line Integrated Emissivity Measurements from Tokamak Plasma** Vinit Pandya, Kumudni Tahiliani , Dr Santosh Pandya , Dr Surya Kumar Pathak, SVNIT, Surat
10.	164	PD-10	**Design and Testing of Thermo-electric Cooler Controller for Detection sub-system of Thomson Scattering Diagnostic** Vishnu Kumar Chaudhary, Jinto Thomas, Neha Singh, Vishnukumar Chaudhary, Pabitra Kumar Mishra IPR, Ghandhinagar
11.	180	PD-11	**Upgradation Of Diamagnetic Diagnostics On SST-1** Sameer Kumar, Sameer Kumar, Kumudni Tahiliani, Mr Praveen Lal Eduppa, Mr Suresh I, Mr Yuvakiran Devaraj Paravastu, SK Pathak, Raju Daniel IPR, Ghandhinagar
12.	195	PD-12	**Behavioral Modeling of High Temperature Plasma Diagnostic Plant I&C System** Nidhi Mehra, Mr Gheesa Vyas, Nidhi Mehra , Mr Sriprakash Verma, Mr Hitesh Pandya Devi Ahilya Vishwavidyalaya, Indore
13.	210	PD-13	**Tangential View Soft X-ray Imaging Diagnostics for Aditya-U Tokamak** Asha Adhiya, Manoj kumar Gupta , Suraj Gupta (IPR) Mr Abhishek Kumar, SK Pathak IPR, Ghandhinagar
14.	211	PD-14	**Energy calibration of silicon Drift detector based spectrometer for ADITYA-U plasma start-up studies** Yashika Taunk, Shishir Purohit Manoj kumar Gupta IPR, Ghandhinagar
15.	213	PD-15	**Analysis of VUV spectral lines for Investigating Impurity Behaviour in ADITYA and ADITYA-U Tokamak**

			Vishal Sharma, Malay Bikas Chowdhuri , Mr Sharvil Patel Nandini Yadava , Nilam Ramaiya ,Ranjana Manchanda ,Mr Manish Rathor , Rakesh Tanna , Kumarpalsinh A Jadeja ,Kaushal M Patel , Joydeep Ghosh IPR, Ghandhinagar
16.	217	PD-16	**Identification of edge in tokamak plasma using visible imaging in ADITYA-U** S. Aich, S. Patel, J. Ghosh, L.K. Pradhan, N. Yadava, N. Nimavat, P. Shrivastava, R.L. Tanna, M.B. Chowdhury, K. Singh, S. Dolui, A. Kumar, B. Hegde, A. Kumawat, K.A. Jadeja, K.M. Patel, H. Raj, A. Patel, R. Kumar and ADITYA-U team IPR, Ghandhinagar
17.	283	PD-17	**Edge Plasma Study using Fast Visible Imaging Diagnostic in Aditya-U Tokamak** Devilal Kumawat, Kumudni Tahiliani, Sameer Kumar, Suresh I, R.L Tanna, Kaushal M Patel, Kumarpalsinh Jadeja, Rohit Kumar, S.K Pathak, Joydeep Ghosh, and Aditya-U Team. IPR, Ghandhinagar
18.	287	PD-18	**Production, characterization and application of atmospheric rectangular dielectric barrier discharge in nepali paper** Narendra Chaudhary, Sharvil Patel , Joydeep Ghosh , Mr Laxmikanta Pradhan Nandini Yadava , Nilam Ramaiya ,Mr Rakesh Tanna ,Malay Bikas Chowdhuri ,Kaushlender Singh ,Suman Dolui , Ankit Kumar , Bharat Hegde ,Ashok Kumar Kumawat , Kumarpalsinh A Jadeja ,Kaushal M Patel ,Harshita Raj ,Ankit Patel ,Rohit Kumar Tribhuvan University, Nepal
19.	295	PD-19	**Preliminary Results of Magneto-Optic Current Sensor (MOCS) Diagnostic developed for Plasma Current Measurements in Aditya-U Tokamak** Santosh Pandya, Dr Santosh Pandya , Kumudni Tahiliani Suresh I , Mr Hrishikesh Kathale , Mr Shivam Dobariya , Praveenlal E.V. , Ms Jahanvi Lalwani , Sameer Kumar ,Dr Lavkesh Lachhvani , Suman Aich Rohit Kumar , SK Pathak ,Rakesh Tanna , Joydeep Ghosh IPR, Ghandhinagar
20.	307	PD-20	**Diagnostic of laser ablated silicon plasma using time dependent cr model with fully relativistic electron excitation cross-section of Si+2**

			Shubham Singh Baghel, Priti Priti , Mr Rajesh Srivastava IIT Roorke
21.	315	PD-21	**Saturation Current Ratio Method: Can It Be Really Useful for Negative Ion Diagnostic?** Pawandeep Singh, Swati Swati , Dr Avnish Pandey ,Prof. Shantanu Karkari IPR, Ghandhinagar
22.	338	PD-22	**RF compensated langmuir probe for the diagnostics of plasma parameters in magnetized capacitively coupled plasma discharge** Akanshu Khandelwal, Dhyey Raval , Dr Shantanu Karkari , Ms Yashshri Patil, Dr Nishant Sirse , Mr Ravi Ranjan IPS Academy
23.	359	PD-23	**High Impedance Langmuir Probe Diagnostics for Toroidal Non-Neutral Plasma Experiment: SMARTEX-C** Nikhil Mohurle, Lavkesh Lachhvani, Rajiv Goswami, Yogesh G. Yeole, Minsha Shah, Sambaran Pahari and Prabal K. Chattopadhyay IPR, Ghandhinagar, HBNI, Mumbai
24.	371	PD-24	**Simulation of Hard X-ray Spectrum for ADITYA limiter plasma using Geant4** K. Garg, S. Purohit, V. Ranga, M.K. Gupta, J. Ghosh IPR, Gandhinagar
25.	374	PD-25	**Calculation Of Electron Impact Excitation Cross Sections Of Sn I And Sn II Using RDW Method: Cross Sections Of Interest In Plasma Modeling Applications** Indhu Suresh, Srikar PSNSR ,Dr Priti Priti , Prof. Rajesh Srivastava , Dr Reetesh Kumar Gangwar IIT Tirupati
26.	389	PD-26	**Initial results of the Laser Heated Emissive Probes in the Aditya-U glow discharge plasma** Abha Kanik, Joydeep Ghosh, Arun Sarma, Kalpesh Galodiya, Laxmikanta Pradhan, Ankit Patel, Minsha Shah, Kaushlender Singh, Bharat Hegde, Tanmay Macwan, Sharvil Patel, R. L. Tanna, Kumarpal Jadeja, Ankit Kumar Ashok Kumar, Santosh Dubey, Suman Aich, Rohit Kumar, Kaushal Patel, and ADITYA-U Team UPES, Bidoli
27.	422	PD-27	**A study of empirical relation for observed Core ion temperature with other operational parameters of Aditya plasma discharges**

			Kumar Ajay, Santosh P Pandya, Dr Snehlata Aggarwal IPR, Ghandhinagar
28.	428	PD-28	**CODAC Based control system for Prototype Hot Source Operation for Local Calibration of ECE Diagnostic System** Shiva Jhar, Ravinder Kumar, Mrs Suman Danani, Mrs Hitesh Pandya ITER-India, IPR, Ghandhinagar
29.	431	PD-29	**Development of a photodiode-based detection system for the measurement of X-ray photon flux** Gaueav shukla, Dr Hitesh Pandya , Mrs Minsha Shah , Dr Sanjeev Varshney , Mrs Sapna Mishra ITER-India, IPR
30.	442	PD-30	**A Collisional Radiative Model for Tl II Plasma** Aloka Kumar Sahoo, Lalita Sharma IIT Roorke

Nuclear Fusion and Technology (NF)

Sr. No.	Abstract ID	Poster Number	Title/Name/Affiliation
1.	13	NF-1	**Numerical Investigation Of Thermal Mixing In T-Junction For Fusion Reactor Tokamak Application** Sandeep Rimza, Paritosh Choudhuri, Sayantan Mukhrjee, Brijesh Kumar Yadav IPR, Ghandhinahar
2.	21	NF-2	**Global Gyrokinetic Simulation Of Microturbulent Transport In W7-X Stellarator Including Kinetic Electron** Joydeep Das, Animesh Kuley, Jaya Kumar Alageshan, Sareshwar Sharma, IISc, Bengaluru
3.	26	NF-3	**Neural network assisted global gyrokinetic toroidal code using cylindrical coordinates** Jaya Kumar Alageshan, Animesh Kuley, Joydeep Das, Sareshwar Sharma IISc, Bengaluru
4.	33	NF-4	**Design and development of electrochemical based hydrogen isotope sensor and its testing setup** Deepak Yadav, Paritosh Chaudhuri, Rajendra Prasad, Bhattacharya, Pragnesh Dhorajiya, Amit Sircar, Aroh Srivastava IPR, Ghandhinahar
5.	37	NF-5	**Refurbishment of Current Limiting Resistor for the Charging System of Wave Shaper Capacitors** Shivam Kumar Gupta, Kunal S Shah, M N Makwana, Nagarji Thakor, V Balakrishnan, Supriya Nair, Rohit Kumar, R L Tanna, Joydeep Ghosh and ADITYA-U Team IPR, Ghandhinahar
6.	38	NF-6	**Final assembly of hydrogen isotopes extraction system at IPR and its present status** Rudreksh B. Patel, Pragnesh Dhorajiya, Sudhir Rai, P. A. Rayjada and Amit Sircar IPR, Ghandhinahar
7.	39	NF-7	**Role of Section Modulus in Conceptualizing and Designing the Support Structure for Linear Induction Motor** Ritesh Kumar Srivastava, Roopesh G., Manoj Kumar Gupta, Arvind Kumar, Narendra N. Kadamdhad, *Ankur Jaiswal*

			IPR, Ghandhinahar
8.	43	NF-8	**Testing of Toroidal Field Power Supply (TFPS) for Aditya-U Tokamak** M N Makwana, Kunal S Shah, Shivam Kumar Gupta, V Balakrishnan, Supriya Nair, Rohit Kumar, R L Tanna, Joydeep Ghosh and ADITYA-U Team IPR, Ghandhinahar
9.	55	NF-9	**Manufacturing Experience of Indigenously Developed Dished Head-Sub Assembly (DH-SA) for High Voltage Bushing (HVB) of Indian Test Facility (INTF)** Dheeraj Kumar Sharma, Jaydeep Joshi, Suraj Pillai, Kaushal Joshi, Deepak Parmar, Hardik Shishangiya, Sejal Shah, Akhil Jha, Mahendrajit Singh, Arun Kumar Chakraborty IPR, Ghandhinahar
10.	63	NF-10	**Upgradation of auxiliary power supplies for ITER deliverable RF source** Hrushikesh Dalicha, Gajendra Suthar, Kartik Mohan, Kumar Rajnish, Raghuraj Singh, Rajesh G Trivedi ITER-India, IPR, Ghandhinagar
11.	67	NF-11	**Instrumentation and interlock of 82.6 GHz Gurotron based ECRH system** Harshida Patel, Jatin Patel, Dharmesh Purohit, K G Parmar, Hardik Mistry, B K Shukla and ECRH Group IPR, Ghandhinahar
12.	68	NF-12	**Fabrication Aspects And Characterization Of Sandwich Configuration Flow Channel Inserts For Liquid Metal Applications Upto 600°C** Abhishek Saraswat, Rajendraprasad Bhattacharyay, Paritosh Chaudhuri, Sateesh Gedupudi IPR, Ghandhinahar
13.	71	NF-13	**Upgradation Of Instrumentation & Control System For Lead-Lithium MHD Experimental System** S. Verma, A. Deoghar, A. Patel, A. Saraswat, S. Gupta, T.S. Rao, R. Bhattacharyay IPR, Ghandhinahar
14.	77	NF-14	**Measurement Of The Modified Surface Hardness Of Tungsten As An Indicator To Understand The Recrystallization Kinetics And The Possibility Of Retardation Due To Helium Plasma Exposure** Sabir Chetri, Mizanur Rahman, Monoj Baruah and Mayur Kakati CPP-IPR, Guwahati

15.	78	NF-15	**Analysis of Neutron Yield From The PF400 Device By Varying Different Pressure** Bidhwan Belbase, Roshan Chalise Tribhuvan University, Nepal
16.	79	NF-16	**Comparative Study of Refractive Optics Based Endoscope and Wound Imaging Fiber Bundle** Suraj Kumar Gupta, Vishnu Chaudhari, Manoj Kumar IPR, Ghandhinahar
17.	81	NF-17	**Performance Test of a Prototype HTS Current Lead with mgb2 and NbTi: Cu Joints** N. Bairagi, V.L. Tanna, H. Nimavat, D. Sonara, R. Panchal, A. Garg, G. Mahesuria, R. Patel, D. Christian, P. Panchal, G. Purvar, U. Prasad, D. Raju IPR, Ghandhinahar
18.	82	NF-18	**Major upgradation plan of ICRH system on SST-1** Kishore Mishra, Sunil Kumar, D. Rathi, A. Varia, B. Kadia, K. M. Parmar, M. Parihar, H. M. Jadav, R. Joshi, A. K. Gayatri, R. Yadav and ICRH Team IPR, Ghandhinahar
19.	83	NF-19	**Arbitrary LH pulse and auto Feedback Control of LH Power to regulate the Plasma Current in SST-1** P.K. Sharma, C. G. Virani, Jasraj R Dhongde, Kirti Mahajan, Jignesh J Patel, Imran A Mansuri, K.K. Ambulkar, Jagabandhu Kumar, P.R. Parmar, S. Sharma, A.L. Thakur, C.S. Singh IPR, Ghandhinahar
20.	92	NF-20	**2D ion beam optics simulation using Axcel-INP and comparison with experimental results** M. R. Jana, P. Bharathi, V. Prahhad, U. K. Baruah and NBI Team IPR, Ghandhinahar
21.	93	NF-21	**3D Computational Fluid Dynamics Simulation of Heat Transfer for PINI Ion Source Back Plate** Tejendra Patel, M. R. Jana and U. K. Baruah IPR, Ghandhinahar
22.	97	NF-22	**12 kA / 16 VDC switch mode power supply Operation Experience during HTS Current Lead and MgB2-NbTi: Cu Joints test** D. Christian, N. Bairagi, P. Panchal, R. Panchal, G. Purvar, D. Sonara, H. Nimavat, A. Garg, R. Patel, G. Mahesuria, U. Prasad, V.L. Tanna IPR, Ghandhinahar

23.	98	NF-23	**Linear Induction Motor Design and Simulation Results of Electromagnetic stirrer for Sn-Li alloy** Prasada Rao P, Ananya Kundu, Arvind Kumar, Ankur Jaiswal, Vilas C. Chaudhari, Y.S.S. Srinivas, Rambabu Sidibomma, E.Rajendra Kumar IPR, Ghandhinahar
24.	101	NF-24	**Development of 3mw 12 inch mis-match transmission line test bed for ITER ICRF source** Ulhas Dethe, Rohit Anand, Sunil Dani, Akhil Jha, Paresh Vasava, Raghuraj Singh, Rajesh Trivedi ITER-India, IPR, Ghandhinagar
25.	103	NF-25	**Parameter Choices and Constraints for Indian DEMO** P.N. Maya and S.P. Deshpande IPR, Ghandhinahar
26.	104	NF-26	**CALIBRATION OF ASSEMBLED MASS FLOW METER USING labview** Priyadarsini Gaddam, Haresh Dave, A K Sahu, Omkar chandratra, Vishnu Patel, Hitesh Chudasma IPR, Ghandhinahar
27.	105	NF-27	**Preliminary Electromagnetic Analyses of Linear Induction Motor as Sn-Li Alloy Stirrer** Ananya Kundu, P Prasada Rao, Ankur Jaiswal, Arvind Kumar, Y.S.S. Srinivas, Vilas Chaudhari, Rambabu Sidibomma and E.Rajendra Kumar IPR, Ghandhinahar
28.	108	NF-28	**Conditioning installation testing and commissioning of pf converter transformer** Akhilesh Kumar Singh, Amit Ojha, Dinesh Kumar Sharma, Murtuza Vora, Supriya A Nair IPR, Ghandhinahar
29.	109	NF-29	**Booster System Performance Test After Electrical Refurbishment** Rakesh Patel, Gaurang Mahesuria, Rohit Panchal, G.L.N. Srikanth, Dikens Christian, Pankil Shah, Ketan Patel, Pradip Panchal, Hiren Nimavat and Vipul L Tanna IPR, Ghandhinahar
30.	111	NF-30	**Design and Development of labview based acquisition, control and measurement system for General Laboratory Plasma** Abhijeet Kumar, Hitesh Mandaliya, Rosh Roy, Rachana Rajpal, Dr. P. K. Chattopadhyay IPR, Ghandhinahar

31.	112	NF-31	**Migrate online impedance matching system for ICRH transmission line DAC** Ramesh Joshi, H M Jadav, Sunil Kumar and High Power ICRH systems Division IPR, Ghandhinahar
32.	114	NF-32	**Comparison of time series forecasting of future sequence of signals using deep learning models at Aditya/Aditya-U data** Ramesh Joshi, Joydeep Ghosh, Nilesh Kalani, R. L. Tanna and ADITYA/ADITYA-U Teams RK University, Rajkot & IPR, Ghandhinahar
33.	115	NF-33	**Instrument Reliability - Maintenance in SST-1 Cryogenic Warm Gas Management** Gaurang Mahesuria, Rohit Panchal, Pankil Shah, Ketan Patel, Rakesh Patel, Pradip Panchal, Hiren Nimavat and Vipul L Tanna IPR, Ghandhinahar
34.	117	NF-34	**Design, development and testing results of fault processing card for FRBPS** Murtuza Vora, Dinesh Kumar Sharma, Akhilesh Singh, Amit Ojha, Supriya A Nair IPR, Ghandhinahar
35.	120	NF-35	**Measurement of radial magnetic field in Aditya-U tokamak** A.Kundu, S.Aich, L.K.Pradhan, R.Kumar, Praveenlal E V, A.Kumar, J.Ghosh, R.L.Tanna, S.Dolui, K. Singh, A.Kumar,A.Kumawat, B.Hegde, K.A. Jadeja, K.M.Patel, A.Patel, H.Raj, S.Patel, K.Galodiya, N.Nimavat, A. Kanik, N.Yadava, K. Shah and the ADITYA-U team IPR, Ghandhinahar
36.	125	NF-36	**RF Characterization Of ECR System Components At 2.45 GHz** K. K. Ambulkar, P. R. Parmar, A. L. Thakur, P. K. Sharma IPR, Ghandhinahar
37.	127	NF-37	**Prototype vacuum control and monitoring system and its interface with epics** Arnab Dasgupta, Sunil S, Yohan Khristi, Hitesh Gulati, Amit Srivastava and S.Mukherjee IPR, Ghandhinahar
38.	129	NF-38	**Seismic Shake Table Test Qualification of Plant Control System Cubicles of ITER Cooling Water System** Aditya Singh*, Mahesh Jadhav, Nirav Patel, Jinendra Dangi,

			Hiren Patel, Mohit Kumar, Ajith Kumar ITER-India & IPR, Ghandhinagar
39.	135	NF-39	**Development of -5kv, 1A High Voltage DC Power Supply for Magnetron to develop ECR Plasma** Kirit Parmar, Bhavesh Kadia, Pravesh Dhani, Sunil Kumar, and High Power ICRH SystemsDivision IPR, Ghandhinahar
40.	136	NF-40	**Installation & Commissioning of Cooling Water System for SST1 ICRH at IPR** S. K. Sharma, M. Vasani, R Mishra IPR, Ghandhinahar
41.	139	NF-41	**Engineering upgrade of Cryogenics Instrumentation and control for NBI Beam Operation** Karishma Qureshi, Laxmikant Bansal, Vijay Vadher, C. B. Sumod, Dipal Thakkar, L. N. Gupta, Paresh Patel and U. K. Baruah IPR, Ghandhinahar
42.	140	NF-42	**Development of Supervisory Control and Data Acquisition application for Cryocooler based Helium Circulation System at 55K** Pradip Panchal, Hiren Nimavat, Upendra Prasad and Vipul Tanna IPR, Ghandhinahar
43.	141	NF-43	**Installation & Commissioning of MW level RF source for experiments on SST-1** Raghuraj Singh, Kishore Mishra, Kumar Rajnish, Manoj Parihar, Kartik Mohan, Dharmendra Rathi, Akhil Jha, Bhavesh Kadia, Manoj Patel, Kirit Parmar, Gajendra Suthar, Hiralal Jadav, Hrushikesh Dalicha, Rameshkumar Joshi, Dipal Soni, Rana Pratap Yadav, Sriprakash Verma, Rohit Anand, Atul Varia, Sunil Dani, Pareshkumar Vasava, Ulhas Dethe, Sunil Kumar, Rajesh Trivedi ITER- India & IPR, Ghandhinahar
44.	144	NF-44	**Design of water cooled Helholtz coils for hydrogen isotope permeation barrier coating experiment** Vilas Chaudhari, Arvind Kumar, P. A. Rayjada, Y.S.S. Srinivas IPR, Ghandhinahar
45.	145	NF-45	**Automation of Baking Control System for Aditya Upgrade Tokamak** Vismaysinh Raulji

			IPR, Ghandhinahar
46.	146	NF-46	**Design Development and Analysis of Drift Duct Liner (DDL) for Diagnostic Neutral Beam** Dhananjay Kumar Singh, M V Nagaraju, Jaydeep Joshi, Ashish Yadav, Mahendrajit Singh, A.K. Chakraborty IPR, Ghandhinahar
47.	150	NF-47	**Cleaning and contamination control methodology for large Ultra High vacuum (UHV) chamber** Rakesh Kumar, Sunil S, Vijay Bedakihale, Subroto Mukherjee IPR, Ghandhinahar
48.	151	NF-48	**Design of phase-I control system of large cryogenics plant and cryo-systems** V.B. Patel, A.L. Sharma, H.H. Chudasma, H. Masand, I. A. Mansuri, J.J. Patel, K.B. Patel, M.K. Bhandarkar, P. Gaddam, T.S. Rao, A.K.Sahu, H.J. Dave, O. Chandratre, P. Singh, K. Mahajan and LCPC Team. IPR, Ghandhinahar
49.	155	NF-49	**Design, assembly and testing results of IGBT inverter module for FRBPS** Dinesh Kumar Sharma, Murtuza M Vora, Amit Ojha, Akhilesh Kumar Singh, Supriya A Nair IPR, Ghandhinahar
50.	156	NF-50	**Development of an Experimental Facility to Measure Emissivity at Cryogenic Temperature** Avijit Dewasi, Samiran Shanti Mukherjee, Vishal Gupta, Rohan Dutta, Abhinav B. Desai, Jyoti Shankar Mishra, Paresh Panchal, Pratik A. Nayak, Ranjana Gangradey IPR, Ghandhinahar
51.	159	NF-51	**Engineering Design of Central Solenoid (CS) Coil for Small Scale Spherical Tokamak (SSST)** Arvind Kumar, Vilas C Chaudhari, S Ranjithkumar, Ananya Kundu, YSS Srinivas, E Rajendra Kumar IPR, Ghandhinahar
52.	160	NF-52	**Structural integrity assessment of Cryostat manufacturing model verifying the effect of introduction of slots on Top-lid radial ribs** Avik Bhattacharya, Gaurav Jogi, Rajnikant Prajapati, Mukesh Jindal, Amit Palaliya,Vipul More, Saroj Jha, Vaibhav Joshi & Anil Kumar Bhardwaj ITER-India & IPR, Ghandhinagar

53.	163	NF-53	**Arbitrary Pulse Generator using Xilinx FPGA for Tokamak Gas Fueling Control Circuit** Bharatkumar Arambhadiya, Hiteshkumar Mandlia, Vismaysinh Raulji, Mohammad Shoaib Khan, Kaushlender Singh, Rachana Rajpal, Kumarpalsinh Jadeja, Rohit Kumar, R.L Tanna, Joydeep Ghosh IPR, Ghandhinahar
54.	166	NF-54	**Qualitative Measurement of Radiation Symmetry during Disruptions in ADITYA-U Tokamak with a BPW-34 Photodiode and Development of a Metal Foil IR Bolometer** Ashok Kumar, Shwetang N. Pandya, Bharat Hegde, Ankit Kumar, Kaushlender Singh, Suman Dolui, Rohit Kumar, Harshita Raj, Suman Aich, Ananya Kundu, Laxmikant Pradhan Ankit Patel, Kalpesh Gadoliya, Ankit Patel, K.M. Patel, K.A. Jadeja, R.L. Tanna, Joydeep Ghosh and ADITYA-U Team IPR, Ghandhinahar
55.	167	NF-55	**In-house Development and Performance Testing of Pressure Relief Valves for application in High Vacuum System** P. Panchal, S. Mukherjee, R. Gangradey IPR, Ghandhinahar
56.	168	NF-56	**Indigenous development and testing of Post Insulators for TWIN Source experiments** Ravi Pandey, Deepak Parmar, Hardik Shishangiya, Vishnudev M.N, Mainak Bandyopadhyay, Jaydeep Joshi, Mahendrajit Singh & Arun K Chakraborty IPR, Ghandhinahar
57.	169	NF-357	**Effect of Baking on Reduction of Hydrogen in Austenitic Stainless steel for UHV Applications** Atul Prajapati, Rakesh Kumar, S Sunil, Subroto Mukherjee IPR, Ghandhinahar
58.	170	NF-58	**Experimental and numerical characterization of ceramic pebble beds under cyclic loading** Maulik Panchal, Chirag Sedani, Harsh Patel, Paritosh Chaudhuri IPR, Ghandhinahar
59.	171	NF-59	**Numerical Simulation of Transient Hot Wire Technique to Estimate Thermal Conductivity and Thermal Diffusivity of Li_2TiO_3 Pebble Bed** Harsh Patel, Maulik Panchal, Paritosh Chaudhuri

			IPR, Ghandhinahar
60.	172	NF-60	**Upgraded real-time feedback control system for horizontal plasma position stabilisation** Pramila Gautam, Vismaysinh Raulji, Rohit Kumar, Rachana Rajpal IPR, Ghandhinahar
61.	174	NF-61	**Conceptual design of an isolated control system for floating power supply of NBI for SST-1** Laxmi Kant Bansal, Paresh J Patel, Dipal Thakkar, Vijay V Vadher, Laxmi Narayan Gupta, C.B. Sumod, Karishma Qureshi, U K Barua IPR, Ghandhinahar
62.	175	NF-62	**Management of manufacturing design of vacuum vessel in-wall shielding blocks in collaboration with ITER** Mahesh Patel, Rahul Laad, Ulhas dethe, Shrishail Padasalgi, Xiang Bin ITER-India, IPR, Ghandhinagar
63.	177	NF-63	**Design & analysis of hydrogen gas pre-cooler for solid hydrogen pellet injections system of the Tokomak** P. Nayak, S. Mukherjee, P. Panchal, H. agravat, R. Gangradey, J. Mishra, V. Gupta IPR, Ghandhinahar
64.	178	NF-64	**Fault assessment on 3300 kva multi-secondary transformer of regulated high voltage power supply** L.N.Gupta, Paresh J. Patel, N.P.Singh, Dipal Thakkar, Sumod C.B, Bhavin Raval and U.K.Baruah IPR, Ghandhinahar
65.	179	NF-65	**FACTORY ACCEPTANCE TESTS CONDUCTED ON REPAIRED 3300 kva MULTI-SECONDARY TRANSFORMER OF REGULATED HIGH VOLTAGE POWER SUPPLY** Dipal Thakkar, L. N. Gupta, Paresh J. Patel, N. P. Singh, Sumod C. B., Bhavin Raval and U. K. Baruah IPR, Ghandhinahar
66.	183	NF-66	**Development of control cards for ITER deliverable SSPA** Manojkumar Patel, Hrushikesh Dalicha, Sriprakash Verma, Dipal Soni, Kumar Rajnish, Raghuraj Singh and R.G. Trivedi ITER- India, IPR
67.	185	NF-67	**Welding development during Manufacturing and Assembly of ITER Cryostat**

			Rajnikant Prajapati, Anil Bhardwaj, Vaibhav Joshi, Amit Palaliya, Mukesh Jindal, Mitul Patel, Avik Bhattacharya, Gaurav Jogi, Jimmy Dutt, Chirag Patel, Sivakumar ITER-India & IPR, Ghandhinagar
68.	186	NF-68	**Manufacturing design validation through mock-up for torus cryopump housing (TCPH)** Vaibhav Joshi, Rajnikant Prajapati, Anil Bhardwaj, Mukesh Jindal, Amit Palaliya[1] ITER-India & IPR, Ghandhinagar
69.	188	NF-69	**Performance of (regulated high voltage power supply) rhvps during two pulse operation of ecrh system** Sumod C. B., Dipal Thakkar, L. N. Gupta, Paresh J. Patel, U. K. Baruah & ECRH team IPR, Ghandhinahar
70.	189	NF-70	**Alternate Technology for Manufacturing of Actively Cooled Components for Neutral Beam** Ashish Yadav, Jaydeep Joshi, Amit Arora, Sooraj Patel, Mahendrajit Singh, Arun K Chakraborty ITER- India & IPR, Ghandhinagar
71.	191	NF-71	**Abrasive water jet cutting study for the manufacturing of in wall shielding blocks of ITER vacuum vessel** Rahul Kumar Laad ITER-India & IPR, Ghandhinagar
72.	192	NF-72	**Non-thermal electron studies for ADITYA/ ADITYA-U tokamak plasma via X-rays spectroscopy** S. Purohit, M. B. Chowdhuri[1], M. K. Gupta, J. Ghosh, K. A. Jadeja, S. K. Pathak, R.L. Tanna IPR, Ghandhinahar
73.	193	NF-73	**Compact Single Board Computer Based Data Acquisition System** Hiteshkumar Mandliaya, Vismaysinh Raulji, Abhijeet Kumar, Pramila Gautam, Bharat Arambhadiya, Rachana Rajpal IPR, Ghandhinahar
74.	194	NF-74	**Modification of a multi-pulse half-wafe rectfier to full wave rectifier with adapted control** Amit Ojha, Akhilesh Kumar Singh, Dinesh Kumar Sharma, Murtuza Vora, Supriya A Nair IPR, Ghandhinahar
75.	196	NF-75	**Development of pressurised oil filling system and preventive maintenance of oil removal system HRL plant**

			Pankil Shah, L.N.Srikanth G., Ketan Patel, Rohit Panchal, Rakesh Patel, Hiran Nimavat, Pradip Panchal, Gaurang Mehsuriya, Dasarath Sonara, Dikens Christian, Atul Garg, Gaurav Purwar, Rajiv Sharma and Vipul Tanna IPR, Ghandhinahar
76.	198	NF-76	**A Feasibility Study of Radio-Isotopes Breeding In a Compact Fusion Reactor** Shrichand Jakhar, Shailja Tiwari, Shashank Chaturvedi, Manika Sharma IPR, Ghandhinahar
77.	201	NF-77	**Experience in overhauling and alignment of helium screw compressor station** Ketan Patel, L.N.Srikanth G., Pankil Shah, Dikens Christian, Rohit Panchal, Rakesh Patel, Hiren Nimavat, Pradip Panchal, Gaurang Mehsuriya, Dasarath Sonara, Atul Garg, Gaurav Purwar, Rajiv Sharma and Vipul Tanna IPR, Ghandhinahar
78.	205	NF-78	**SOFTWARE DEVELOPMENT FOR DATA ACQUISITION OF $LaBr_3$(Ce) HARD X-RAY SPECTROMETER DIAGNOSTIC FOR SST-1** Imran Mansuri, Manisha Bhandarkar, Shishir Purohit, Asha Adhiya, Jignesh Patel, Vishnu Patel, Atish Sharma, Hitesh Chudasama, Harish Masand, Priyadarshini Gaddam, Srinivas Rao, Kirit patel, Manoj Kumar and Kirti Mahajan IPR, Ghandhinahar
79.	206	NF-79	**Development of milli ampere current sensor for the high voltage DC power supplies** Kumar Saurabh, Aritra Chakraborty, Amal S, Paul Christian and Ashok Mankani IPR, Ghandhinahar
80.	207	NF-80	**Development of an ice pellet injector for the multipurpose application in a high-temperature plasma** J. Mishra, P. M. Panchal, S. Mukherjee, V. Gupta, H. Agravat, M. Banaudha, P. Nayak, R. Gangradey IPR, Ghandhinahar
81.	208	NF-81	**Preliminary design of cooling water system for ITER-India laboratory** R. Ranjan, D. K. Gupta, R. Agarwal, L. Sharma, S. Jha, M. Chodavadiya, N. Parmar ITER-India & IPR, Ghandhinagar

82.	209	NF-82	**Automation of RF communication experiment using Python** Jignesh Patel, Manisha Bhandarkar, Imran Mansuri, Sarada Sree, Hitesh Chudasma, Vishnu Patel, Atish Sharma, Harish Masand, Kirit Patel, Priyadarshini Gaddam, Srinivas Rao, Rajesh Kumar and Kirti Mahajan IPR, Ghandhinahar
83.	214	NF-83	**Calorimetric Pulsed Power Measurement System for High Power Microwave Source** Hardik Mistry, Harshida Patel, Jatin Patel, Dharmesh Purohit, K G Parmar, B K Shukla IPR, Ghandhinahar
84.	222	NF-84	**Transient Lorentz Force Calculations on In-vessel Coils in SST-1 Operation** Amardas Alli IPR, Ghandhinahar
85.	223	NF-85	**Liquefaction rate measurement set-up and test results of indigenous helium liquefier plant of IPR** O. Chandratre, A K Sahu, P.Singh, H. Dave, V. B. Patel, H. Kavad, R. Bhatasana, N. Kumar and P. Brahmbhatt IPR, Ghandhinahar
86.	224	NF-86	**Simulation of Toroidal B-field for tight aspect ratio torus: SMARTEX-C** A. Amardas, Lavkesh Lachhvani, Nikhil Mohurle, Sambaran Pahari, Prabal K. Chattopadhyay IPR, Ghandhinahar
87.	231	NF-87	**Universal drift modes in a magnetized plasma - a study using gyrokinetic particle-in-cell methods** Sagar Choudhary, Jagannath Mahapatra, Amit K. Singh, Jugal Chowdhury, Rajaraman Ganesh, Laurent Villard IPR, Ghandhinahar
88.	236	NF-88	**Design and fabrication of a pneumatically operated bellow sealed valve for high temperature Pb-Li application** A Prajapati, S. Sahu, Deepak Sharma and R. Bhattacharyay IPR, Ghandhinahar
89.	249	NF-89	**Development of Serial Wireless module for the Remote operation of various Auxiliary systems in ITER-India Test Gyrotron Facility** Deepak Mandge, E Sharan, Rajiv Parmar, Vipal Rathod, Ronak Shah, Amit Yadav, Anjali Sharma, S.L. Rao and Kumar Rajnish

			ITER-India & IPR, Ghandhinagar
90.	250	NF-90	**Engineering design and assembly sequence of prototype center stack** S. Ranjithkumar, A.K. Verma, Prasada Rao P, Shiju Sam, Y.S.S. Srinivas, E.Rajendra Kumar IPR, Ghandhinahar
91.	251	NF-91	**Engineering Design of Toroidal Field Coil for Small Scale Spherical Tokamak (SSST)** S. Ranjithkumar, Vilas Chaudhuri, Chandan Danani, Arvind Kumar, Y.S.S. Srinivas, E.Rajendra Kumar IPR, Ghandhinahar
92.	260	NF-92	**Learning from the Non-destructive Examination of ITER Cryostat manufacturing** Mukesh Jindal, Amit Palaliya, Vaibhav Joshi, Mitul Patel, Vipul More, Saroj Jha, Avik Bhattacharya, Manish Pandey, Rajnikant Prajapati, Anil Kumar Bhardwaj, Girish Gupta, Sarath.S, Chirag Patel, S Sivakumar ITER-India & IPR, Ghandhinagar
93.	271	NF-93	**Overview of Electrical Power Network of the 1MW, 170ghz, 3600s ITER-India Gyrotron Test Facility** E. Sharan Dilip, Vipal Rathod, Ronak Shah, Shk Madeena Valli, Rajvi Parmar, Deepak Mandge, Amit Yadav, Anjali Sharma, N.P. Singh and S.L. Rao ITER-India & IPR, Ghandhinagar
94.	272	NF-94	**Integrated Testing of Cooling Manifold System for Megawatt Class Gyrotron Test Facility** Amit Yadav, Vipal Rathod, Deepak Mandge, Sharan E Dilip, Ronak Shah, Anjali Sharma, Rajvi Parmar & S. L. Rao ITER-India, IPR, Ghandhinagar
95.	278	NF-95	**Implementation of drift free integrators for Tokamaks** Praveena Kumari,Vismaysinh Raulji, Sameer Jha, Praveenlal E.V, Kumudni Tahiliani, Rachana Rajpal Daniel Raju, Joydeep Ghosh IPR, Ghandhinahar
96.	288	NF-96	**Fatigue analysis for ITER cryostat man way access duct system** Saroj Kumar Jha, Manish Kumar Pandey, Vipul More, Rajnikant Prajapati, Gaurav Jogi, Avik Bhattacharya, Girish Gupta, Anil Bhardwaj, Umesh Tilwani, Nirbhay Naik, Chirag Patel ITER-India, IPR, Ghandhinagar

97.	289	NF-97	**Transportation analysis of ITER cryostat top lid** Saroj Kumar Jha, Manish Kumar Pandey, Vipul More, Rajnikant Prajapati, Gaurav Jogi, Avik Bhattacharya, Girish Gupta, Anil Bhardwaj, Umesh Tilwani, Nirbhay Naik, Chirag Patel ITER-India & IPR, Ghandhinagar
98.	291	NF-98	**Arc Fault Detection and Repairing for the Insulation Breakdown of TF Coil No. 8 in ADITYA-U tokamak** Laxmikanta Pradhan, Ankit Patel, Suman Aich, Rohit Kumar, T. Macwan, K. Singh, S. Dolui, A. Kumar, A. Kanik, Kajal Shah, N. Yadava, S. Patel, B. Hegde, Ashok K. Kumawatr, K.A. Jadeja, K.M. Patel, K. Galodiya, Shwetang Pandya, R.L. Tanna and J. Ghosh IPR, Ghandhinahar
99.	310	NF-99	**Role of MHD activity in Sawtooth Induced Heat Pulse Propagation in ADITYA** S. Patel, J. Ghosh, M. B. Chowdhuri, K. B. K. Mayya, R. Manchanda, H. K. Pandya, R. L. Tanna, V. Kumar, S. Joisa, S. Purohit, D. Raju, S. Jha, P. K. Atrey, C. V. S. Rao, P. Vasu, D. Chenna Reddy, S. B. Bhatt, Y. C. Saxena and ADITYA Team Pandit Deendayal Energy University
100.	329	NF-100	**Design, development and commissioning of the tangential X-ray Crystal Spectrometer (XCS) on ADITYA-U Tokamak** K. Shah, J. Ghosh, M. B. Chowdhuri, A. Kumar, S. Tripathi, K. A. Jadeja, K. M. Patel, R. Manchanda, N. Ramaiya, R. L. Tanna, R. Kumar, S. Aich, H. Raj, K. Singh, S. Dolui, L. Pradhan, A. Patel, B. Hegde, A. Kumawat, K. B. K. Mayya Pandit Deendayal Energy University, Gujrat
101.	340	NF-101	**Development of GUI for automated analysis of voltage-swept Langmuir probe for Aditya-U tokamak** Bharat Hegde, Harshita Raj, Suman Dolui, Kaushlender Singh, Ashok K. Kumawat, Ankit Kumar, Pramila Gautam, Rohit Kumar, Suman Aich, Laxmikanta Pradhan, Ankit Patel, Kalpesh Galodiiya, Shwetang N. Pandya, K.M. Patel, K. A. Jadeja, R.L. Tanna, Joydeep Ghosh and ADITYA-U Team IPR, Ghandhinahar
102.	342	NF-102	**Wall Conditioning in Tokamak: Development and Implementation of Novel Wall Conditioning Techniques for ADITYA-U Tokamak** K.A.Jadeja, K.M.Patel, J.Ghosh, B.G.Arambhadiya, Kiran Patel, R.L.Tanna, A. B. Patel, K. D. Galodiya, Suman Aich, Rohit Kumar, Harshita Raj, Laxmikanta Pradhan, R.

			Manchanda, M.B. Chowdhuri, Nandini Yadava, Sharvil Patel, N.Ramaiya1, Kajal Shah, K.Singh, S. Dolui, Ankit Kumar, B. Hegde, A. Kumawat, Minsha Shah, Praveenlal E.V., V. Raulji, R. Rajpal, U. Nagora, P.K.Atrey, S.K. Pathak, Shishir Purohit, Manoj Kumar, Kumudni Assudani, Devilal Kumavat, K.S. Shah, M.N. Makwana, Shivam Gupta, Supriya Nair, S.B. Bhatt, P.K.Chattopadhyay, B.R. Kataria IPR, Ghandhinahar
103.	353	NF-103	**Measurement of Toroidal and Poloidal Rotation in ADITYA-U Tokamak** Ankit Kumar, K. Shah, N. Yadava, G. Shukla, Laxmikanta Pradhan, Nilam Ramaiya, Bharat Hegde, S. Patel, Kaushlender Singh, Suman Dolui, Ashok K. Kumawat, M.B. Chowdhuri, R. Manchanda, Ankit Patel, K. A. Jadeja, K. M. Patel, Harshita Raj, Rohit Kumar, Suman Aich, Kalpesh Galodiya, Shwetang N. Pandya, R.L. Tanna, Joydeep Ghosh and ADITYA-U Team IPR, Ghandhinahar & HBNI, Mumbai
104.	358	NF-104	**3D Plasma transport equilibrium study in the inboard limited Aditya-Upgrade Scrape-off layer** Arzoo Malwal, Bibhu Prasad Sahoo, Devendra Sharma IPR, Ghandhinahar
105.	361	NF-105	**Conditions & Testing of Distribution Transformers at IPR** Vaibhav Ranjan, Nagarji Thakor, Supriya A Nair IPR, Ghandhinahar
106.	362	NF-106	**Investigation of impulse voltage test of ohmic coil system in ADITYA-U tokamak** Rohit Kumar, R.L Tanna, Tanmay Macwan, S. Aich and J Ghosh IPR, Ghandhinahar
107.	364	NF-107	**Results and Lessons from Initial Shaped Plasma Experiments in ADITYA-U tokamak** Harshita Raj Ankit Kumar, SK Pathak, Asha Adhiya, Suman Aich, M. B. Chowdhuri, Suman Dolui, Manoj kumar Gupta, K. A. Jadeja, Bharat Hegde, Sameer Jha, Joydeep Ghosh, Shivam Kumar Gupta, Ashok K. Kumawat, Motibhai Makwana, R. Manchanda, Kaushal M Patel, Umesh Nagora, Shishir Purohit, R L Tanna, Rohit Kumar, Nilam Ramaiya, Supriya Nair, N Yadava, Kaushlendra Singh IPR, Ghandhinahar
108.	372	NF-108	**Design of ITER cryostat base section and lower cylinder alignment tools in tokamak pit and its demostration**

			Vipul More, Girish Gupta, Manish Kumar Pandey, Saroj Kumar Jha, Rajnikant Prajapati, Anil Kumar Bhardwaj, Umesh Tilwani, Dipen Shah, Chirag Patel ITER-India, IPR, Ghandhinagar, Ghandhinahar
109.	373	NF-109	**Dimensional Non-Conformity and Correction in ITER Cryostat Base Section Sectors** Amit Palaliya, Anil Kumar Bhardwaj, Rajnikant Prajapati, Vaibhav Joshi, Mitul Patel, Mukesh Jindal, Chirag Patel, S Sivakumar *ITER-India, IPR, Ghandhinagar, Ghandhinahar*
110.	375	NF-110	**Python based data-analysis utility for Non-Neutral Plasma experiment: SMARTEX-C** Manisha Bhandarkar, Imran Mansuri, Lavkesh Lachhvani, Nikhil Mohurle, Yogesh G. Yeloe, Manu Bajpai, Sambaran Pahari, Kirti Mahajan, Prabal K. Chattopadhyay IPR, Ghandhinahar
111.	377	NF-111	**Quality Control Perspectives during Mass Production of In-Wall Shielding Blocks with a Focus on Nuclear Requirement** S Dani, S padasalagi, R Laad, U Dethe, A Maheshwari, B Gajjar, M Patel, T Sharma, S Singh, J Raval, Prasad Ksvv, Deepu Francis ITER-India, IPR, Ghandhinagar, Ghandhinahar, Gandhinagar
112.	380	NF-112	**Effect of high and low frequency electrode biasing on anomalous transport in Aditya-U Tokamak.** Suman Dolui, Kaushlender Singh, Harshita Raj, Tanmay Macwan, Ankit Kumar, Bharat Hegde, Ashok Kumawat, Shivam Gupta, Rohit Kumar, Suman Aich, K. A. Jadeja, K. M. Patel, Laxmikant Pradhan, Ankit Patel, Kalpesh Gadoliya, Pramila Gautam, Praveenlal E V, R.L. Tanna, Joydeep Ghosh and ADITYA-U Team IPR, Ghandhinahar, Bhat, Gandhinagar Homi Bhabha National Institute (HBNI), Mumbai
113.	381	NF-113	**Conditional Assessment & Residual Life Enhancement of 2 Nos., 132kv / 11kv, 15 MVA rated Power Transformers installed at 132kv IPR Substation** Prakash Parmar, Chandra Kishor Gupta, Supriya Nair, Chirag Bhavsar IPR, Ghandhinahar
114.	383	NF-114	**Characterization of Deuterium Ion Beam for 14-mev neutron Generator** S. Vala, Ratnesh Kumar, M. Abhangi, H. Swami and Rajesh Kumar

			IPR, Ghandhinahar & HBNI, Mumbai
115	394	NF-115	**Vacuum Conditioning of Graphite Tiles of Aditya Upgrade Tokamak** ArunPrakash Arumugam, Kaushal Patel, D.C. Raval and Ziauddin Khan IPR, Ghandhinahar
116	398	NF-116	**An Overview of ADITYA-U Tokamak Results and Future Experiments** J. Ghosh, R.L. Tanna, K.A. Jadeja, K.M. Patel, Rohit Kumar, S. Aich, H. Raj, Shwetang Pandya, Deepti Sharma, K. Galodiya, Ankit Patel, L. Pradhan, M.B. Chowdhuri, R. Manchanda, N. Ramaiya, S. Purohit, U.C. Nagora, Kiran Patel, D. Kumawat, Santosh Pandya, J. S. Mishra, T. Macwan, K. Singh, S. Dolui, K. Shah, A. Kanik, N. Yadava, S. Patel, Ankit Kumar, A. Kumawat, B. Hegde, Dipexa Modi, R. Joshi, A. Kundu, G. Shukla, R. Dey, J. Mendonca, M.N. Makwana, Kunal Shah, S. Gupta, Supriya Nair, V. Balakrishnan, C.N. Gupta, Praveenlal Edappala, B. Arambhadiya, Minsha Shah, Pramila Gautam, V. Raulji, Praveena Shukla, Abhijeet Kumar, H. Mandliya, Mitesh Patel, R. Rajpal, M. Bhandarkar, Imran Mansuri, Kirti Mahajan, Varsha S, K. Tahiliani, Snehlata Gupta, Kumar Ajay, S.K. Jha, M.K. Gupta, M.V. Gopalkrishana, V. Menon, K. Mishra, Sunil Kumar, J. Patel, H. Mistry, H. Petal, U. Goswami, R. Singh, B.K. Shukla, Jagabandhu kumar, Pramod Sharma, P.K. Chattopadhyay, N. Bisai, P.K. Atrey, S.K. Pathak, M. Bandyopadhyay, R. Gangrade, B.R. Doshi, S. Pahari, D. Raju, V. Tanna, Y.C. Saxena, Abhijit Sen, R. Pal and S. Chaturvedi IPR, Ghandhinahar & HBNI, Mumbai
117	400	NF-117	**Development of experimental helium cooling facility at IPR** B. K. Yadav, A. Gandhi, A. Saraswat, S. Verma, P. Chaudhuri IPR, Ghandhinahar
118	402	NF-118	**Real Time Plasma Equilibrium study in ADITYA-U** Deepti Sharma, D. Raju, Sameer Kumar, Sharvil Patel, R. L. Tanna, J. Ghosh and ADITYA-U team IPR, Ghandhinahar
119	404	NF-119	**Up gradation of controller and load test for 1700 kva dg set no.1** Chirag Bhavsar, Chandra Kishore Gupta, G.K.Rajan, Supriya Nair, Prakash Parmar IPR, Ghandhinahar

120.	408	NF-120	**Understanding Cs dynamics for source conditioning in a Negative Ion Source** Manas Ranjan Bhuyan, Kaushal Pandya, Mahendrajit Singh, Mainak Bandyopadhyay, Kartik Patel, Himanshu Tyagi, Sejal Shah, Ratnakar K.Yadav, Hiren Mistri, Agrajit Gahlaut, Mahesh Vupugalla, Bhavesh Prajapati, Jignesh Bhagora and Arun.K.Chakraborty ITER-India & IPR, Ghandhinagar
121.	419	NF-121	**Far-infrared Interferometer for Plasma Density Profile Measurements in SST-1** Dusmanta Mohanta, Abhishek Sinha, Surya Kumar Pathak IPR, Ghandhinahar
122.	424	NF-122	**30-50 Ohms RF Coaxial 3-1/8" Demountable Ceramic High Vacuum Window** Dharmendra Rathi, Dr. Mumtaz Ansari, Raj Singh, Siju George, Sunil Kumar IPR, Ghandhinahar
123.	432	NF-123	**Experience in Developing LN2 Cooled Sorption Cryopump, Application and Technology Transfer** S. S. Mukherjee, V. Gupta, J. S. Mishra, R. Gangradey, P. Panchal, P. Nayak, H. Agravat IPR, Ghandhinahar
124.	444	NF-124	**Preparation and installation of PFC in divertor region at ADITYA-U tokamak** K.M. Patel, K.A Jadeja, Ankit Patel, H. Raj, L. Pradhan, R.L. Tanna, J. Ghosh, Deepti Sharma, Arun Prakash, S. Aich, R. Kumar, K. Singh, S. Dolui, Ankit Kumar, B. Hegde, Ashok Kumawat, Shwetang Pandya IPR, Ghandhinahar
125.	450	NF-125	**Multimode Analysis of 170 GHz Gyrotron Oscillator for Plasma Heating Applications** Ashutosh Sing Babasaheb Bhimrao Ambedkar Bihar University
126.	458	NF-126	**Effect of depth and field size on percentage depth dose in radiation therapy using nuclear source** Prajapati Dahal, Santosh Panth, Prakash Joshi, Satyanand Gupta, Dr. Suresh Basnet, Prof. Dr. Raju Khanal Tribhuvan University, Nepal
127.	461	NF-127	**A Fusion Pilot Plant: Analysis of Heat Extraction and Power Conversion System** Piyush Prajapati, S.P. Deshpande, P.N. Maya IPR, Ghandhinahar & HBNI, Mumbai

Plasma Processing (PP)			
Sr. No.	**Abstract ID**	**Poster Number**	**Title/Name/Affiliation**
1.	31	PP-1	**Plasma Interaction with Tumor Tissues associated with Drug Resistant Epilepsy (DRE) Pathologies** Akshay Vaid, Yogesh Aggarwal, Ramkrishna Rane, Anand Visani, Aparna Dixit, Ramesh Doddamani, Manjari Tripathi, P.Sarat Chandra, Alphonsa Joseph, Jyotirmoy Banerjee IPR, Ghandhinahar
2.	42	PP-2	**Studies on Microbial Inactivation Using Plasma Sterilization** Tejal Barkhade, Kushagra Nigam, G. Ravi, Seema Rawat and Sudhir Kumar Nema IPR, Ghandhinahar
3.	45	PP-3	**Inactivation Effect Of Argon Cold Atmospheric Pressure Plasma Jet On Clinically Isolated Multidrug-resistant E. Coli – An In-vitro Study** Sarthak Das, Sarita Mohapatra, and Satyananda Kar IIT Delhi
4.	47	PP-4	**Production, characterization and application of circular dielectric barrier discharge for bacterial inactivation** Oat Bahadur Dhakal, Lekha Nath Mishra, Roshan Chalise Tribhuvan University, Nepal
5.	53	PP-5	**An effectual strategy for development of novel carboxymethyl chitosan/ pva hydrogels in anticancer therapy through cold plasmas** Smruti Prava Das Ravenshaw University, Cuttack
6.	85	PP-6	**Production, characterization and application of plasma for coriander seed germination** Roshani Dahal, Nirmal K.C., Lekha Nath Mishra, Roshan Chalise, and Raju Khanal Tribhuvan University, Nepal
7.	106	PP-7	**Comparative study of DC and high power impulse magnetron sputtering for copper thin film deposition** R. Rane, P Maila, A. Joseph IPR, Ghandhinahar
8.	131	PP-8	**Degradation Of Harmful Dyes Using Plasma-Treated TiO2 Films Enhanced With CAP**

			Adarsh Thapa, Reetesh Borpatra Gohain, Sanu Sarkar, Sarathi Kundu, Subir Biswas IASST, Guwahati
9.	220	PP-9	**Effect of Plasma Treatment on Cauliflower Germination and Growth** Pooja Shrestha, Roshan Chalise, Raju Khanal Tribhuvan University, Nepal
10.	230	PP-10	**Rapid Crystal Growth and Controlled Tailoring of Defect Density in TiO2 Crystal Lattice using Plasma – Liquid Interaction** Parismita Kalita, Palash Jyoti Boruah, and Heremba Bailung *IASST, Guwahati & AcSIR, Ghaziabad*
11.	232	PP-11	**Shock free non-thermal atmospheric plasma jet at radio frequency** Abhijit Majumdar, Suranjana Banerjee, Sadhan handra Das,Subrato Mukherjee IIEST, Shibpur
12.	242	PP-12	**Dielectric Barrier Discharge (DBD) Plasma for Surface Modification of Polymers and Drug Delivery.** Gopika Suresh, M.H Vijay Dhanabal and G Shanmugavelayutham Bharathiar University, Coimbatore
13.	254	PP-13	**Single-step synthesis of magnetic ε-Fe3N nanoparticles by thermal plasma arc discharge technique for supercapacitor application** L. Kumaresan and G. Shanmugavelayutham Bharathiar University, Coimbatore
14.	261	PP-14	**Effects of Non-Extensivity, Negative Ions Mass and Ionization Rate on Plasma Material Interaction Carrying Electron Emission** Yetendra Prasad Jha, Mayank Kumar, Hitendra Kumar Malik IIT Delhi
15.	309	PP-15	**Synthesis and Electromagnetic characterisation of nano-ZnO** Arpita Priyadarsini Dikshit, Dibyaranjan Das, Kajal Parashar, S. K. S. Parashar Kalinga Institute of Technology, Bhuaneswar
16.	319	PP-16	**Electromagnetic Shielding of Bulk ZnO at Different Sintering Temperature in Ku-Band** Dibyaranjan Das, Arpita Priyadarsini Dikshit, Kajal Parashar, S.K.S. Parashar Kalinga Institute of Technology, Bhuaneswar

17.	323	PP-17	**Investigation Of Plasma-Surface Interaction In A Microplasma Device For Biomedical Applications** Rajsinh Rana, Sidharth and Shail Pandey SVNIT, Surat
18.	350	PP-18	**Spectroscopic investigation of plasma treatment of coal in RF generated plasmas** Dipexa Modi, Kundan Viliya, Nandini Yadava, Sachin S. Chohan, A. Sarkar, Amulya Sanyasi, Uttam Sharma, Jayashree Sharma, Malay B. Chowdhuri, Joydeep Ghosh, Balamurli Krishna Mayya, Uttam Bhui, Sudip Bhattacharyya, Krittibas Das, Jitendra Kumar Pandit Deendayal Energy University, Ghandhinagar
19.	369	PP-19	**Analysis of Antimicrobial Activity of Plasma Treated Chitosan Based Membranes** D. Sriram and M. H. Vijay Dhanabal, P. Premasudha, G. Shanmugavelayutham Bharathiar University, Coimbatore
20.	376	PP-20	**Cold plasma of N2-C2H2 with admixing of H2/Ar/Ar+H2 for plasma nitrocarburizing** Jeet Sah, Subroto Mukherjee, Pravin Dwivedi, Alphonsa Joseph IPR, Ghandhinagar
21.	416	PP-21	**Interaction of an atmospheric pressure plasma jet with substrates : copper, silicon, biological skin, quartz, and Teflon** Deepika Behmani and Sudeep Bhattacharjee IIT Kanpur
22.	421	PP-22	**NF3 Based Plasma Etching System For Etching Of Silicon Substrate** Vrushank Mehta, Rajesh Kumar, Y. Kumar[1], H. L. Swami[1], C. Jariwala IPR, Ghandhinahar
23.	423	PP-23	**Enhanced optical properties by argon plasma-induced surface texturing on the silicon surface** Y. Kumar, V. Mehta, C. Jariwala, H. L. Swami, S. Hans, M. Ranjan, R. Kumar IPR, Ghandhinahar
24.	445	PP-24	**Shelf-Life Study of Fresh-cut Fruits treated with Non-equilibrium Cold Plasma** Ritesh Mishra, Abhijit Mishra, Shikha Pandey, Sushma, Meenu Chhabra, Ram Prakash IIT Jodhpur

25.	465	PP-25	**Cold Plasma Seed Germination and Seedling Growth of Mung Bean Sprouts** Sushma, Abhijit Mishra, Ritesh Mishra, Shikha Pandey, Ram Prakash IIT Jodhpur
26.	467	PP-26	**Synthesis of Nanostructure Materials for Non-equilibrium Cold based Packed Bed Reactor and their Comparative Analysis** Jyoti Verma, Ramavtar Jangra, Kiran Ahlawat, Chandra Prakash, Ambesh Dixit, Ram Prakash IIT Jodhpur

Pulsed Power (PU)			
Sr. No.	**Abstract ID**	**Poster Number**	**Title/Name/Affiliation**
1.	16	PU-1	**Design of Two Channel Coaxial Current Transformer for Microsecond Rise Time High Current Applications** Sanjay Singh, A. K. Saxena, A. M. Rawool, S. C. Andola and K.D. Joshi BARC, Mumbai
2.	18	PU-2	**Studies of Dielectric Fiber Z-pinch on Moderate Energy Capacitor Bank** Jigyasa Batra, Ashutosh Jaiswar, Alok K. Saxena and K.D. Joshi BARC, Mumbai
3.	22	PU-3	**Finite-element simulations to study material response during electromagnetically-driven isentropic compression experiments using pulsed power systems** Ankur Chowdhury, Alok K. Saxena, Koushik Bhattacharya and K.D. Joshi BARC, Mumbai
4.	35	PU-4	**A double-barrel electric gun system for low amplitude shock studies** Koushik Bhattacharya, Alok Kumar Saxena, Mamta G. Sharma and K. D. Joshi BARC, Mumbai
5.	110	PU-5	**DESIGN, FABRICATION, TESTING, INSTALLATION AND COMMISSIONING OF EXHAUST SYSTEM FOR TRITITUM HANDLING AND RECOVERY SYSTEM OF ACCELERATOR BASED 14 mev NEUTRON GENERATOR** Sudhir Tripathi, Manoj K. Gupta, Mitul Abhangi, Sudhir Vala, H.L.Swami IPR, Gandhinagar
6.	118	PU-6	**Studies on spatial evolution of pulsed helium plasma** S. Singha, A. Ahmad, N.K. Neog, T.K. Borthakur CPP-IPR, Guwahati
7.	233	PU-7	**Design, simulations and experiments of optimized Faraday cup measurements of coaxial plasma source** Kanchi Sunil, Rohit Shukla, Archana Sharma HBNI-BARC Vizag, Mumbai
8.	243	PU-8	**Effect of SF6 concentration on switching performance of a triggered sparkgap switch in high pressure SF6 admix**

			Vinod Kumar Gandi, Rishi Verma, Manoj Kumar Warrier, Gurusharn Singh, J Balu Naik and Archana Sharma HBNI & BARC Mumbai
9.	405	PU-9	**Conceptual Design of Prototype Pulsed Alternator** Rambabu Sidibomma, Prasad Rao Pedada, Ankur Jaiswal, YSS Srinivas and E Rajendra kumar IPR, Ghandhinahar
10.	437	PU-10	**Discharge Analysis and Switching Characterization of High Power Pseudospark Switches for Fast Pulsed Power Applications** Akhilesh Mishra, Varun, Shikha Misra, Abhijit Ravindra Tillu, Bharat Lal Meena, Alok Mishra, Ram Prakash Lamba and Udit Narayan Pal CSIR-CEERI, Pilani

Space & Astrophysical Plasma (SA)			
Sr. No.	**Abstract ID**	**Poster Number**	**Title/Name/Affiliation**
1.	5	SA-1	**Solar plasma flows and associated geomagnetic activity during solar cycle 23 and maxima of solar cycle 24** Sham Singh Chandigarh Engineering College, Mohali
2.	7	SA-2	**Plasma Instability in Lunar Ionosphere** Mehul Chakraborty, Vipin K. Yadav and Rajneesh Kumar BHU, Varansi
3.	9	SA-3	**Linear study of kelvin helmholtz instability in two superposed incompresible magnetized fluids in porous medium with suspended particals** P.K.Sharma, Nusrat Khan and R.K.Chhajlani Barkatullah University, Bhopal
4.	10	SA-4	**Instabilities of magnetohydrodynamic waves in rotating cosmic magnetoplasmas** Jyoti Turi, A.P. Misra Visva-Bharti University, West Bengal
5.	11	SA-5	**Effects Of Heavier Ions (O+ & O-) On The Characteristics Of Ion Acoustic Double Layers In A Six Component Cometary Plasma** Manesh Michael, Shilpa S., Sijo Sebastian, Chandu Venugopal Bharta College, Kochi
6.	20	SA-6	**Study Of Ionospheric Plasma Parameter Using Observation And Model Over Indian Low Latitude Stations During 2004-2013** Mini Rajput, Sanjay Kumar, A. K. Singh, R.K. Choudhary, P.R. Shreedevi BHU, Varansi
7.	23	SA-7	**Dust Acoustic Rouge Waves in a Cometary Plasma Environment** Vineeth S and Noble P. Abraham Mar Thoma College, Tiruvalla
8.	24	SA-8	**Dissipation of MHD waves in the polytropic zone of the solar wind including non-ideal effects and FLR corrections** Ram Prasad Prajapati and R. K. Chhajlani JNU, New Delhi

9.	32	SA-9	**Nonlinear Wave Phenomena in Electron Beam Plasma** Manveet Kaur and N. S. Saini, Guru Nanak Dev University, Amritsar
10.	46	SA-10	**Laboratory Simulation to Study Magnetic Field Amplification and Turbulence Generation Relevant to Astrophysical Plasma Situations** Indraj Singh, R. Uma, and R. P. Sharma IIT Delhi
11.	50	SA-11	**Rayleigh- Taylor Instability In A Compressible Ultrarelativistic Degenerate Strongly Coupled Plasmas** Ravinder Bhambhu, Ram Prasad Prajapati JNU, New Delhi
12.	51	SA-1	**Cosmic Ray driven MHD waves in Magnetized Self-Gravitating Dusty Plasma** Pallab Boro, Ram Prasad Prajapati JNU, New Delhi
13.	52	SA-13	**Gravitational Instability In Astrophysical Degenerate Polytropic Quantum Plasmas Including Viscosity Tensor And FLR Corrections** Vinesh Kumar, Ram Prasad Prajapati JNU, New Delhi
14.	57	SA-14	**Study of D-Region Ionospheric Plasma Parameters Using Tweeks Analysis** Kshama Tiwari, S. B. Singh and A. K. Singh BHU, Varansi
15.	69	SA-15	**Plasma Relaxation using Data-Constrained Numerical Simulation of Solar Coronal Plasma** Satyam Agarwal, Ramit Bhattacharyya PRL, Udaipur
16.	74	SA-16	**Analysis of Growth rate and oscillations of axial-azimuthal waves in Hall thruster electron beam plasma** Saty Prakash Bharti, Sukhmander Singh Central University Rajasthan
17.	76	SA-17	**Periodic Variation of Plasma Parameters during Solar Cycles 22-24** Prithvi Raj Singh, Abhay Kumar Singh S S Khanna Girls Degree College
18.	84	SA-18	**Influence of rotation on MHD modes and instabilities in relativistic gravitational anisotropic plasma** Shweta Jain

			Govt. Madhav Science College, Ujjain
19.	90	SA-19	**Study of Rayleigh Taylor Instability in the Ionization Regions of Quantum Plasma** Rohit Kumar, Sukhmander Singh Central University of Rajasthan
20.	102	SA-20	**Whistler Wave Instabilities in a Complex Plasma** Amit Kumar and Jyotsna Sharma Amity University, Haryana
21.	225	SA-21	**Nonlinear propagation of kinetic Alfvén wave and turbulent spectrum in Solar corona reconnection region.** Garima Patel, R.Uma, R.P.Sharma IIT Delhi
22.	227	SA-22	**Exposition of Space Plasma Parameters Observed during Solar Cycles 21 – 24** A.K. Singh University of Lucknow, Lucknow
23.	229	SA-23	**Different Channels of Energy Transfer in Hall Magnetohydrodynamic Turbulence: A Phenomenological View** Arijit Halder & Supratik Banerjee IIT Kanpur
24.	239	SA-24	**Propagation Of Iasws In AGN Medium With The Effect Of Relativistic Charged Dust Particle** Ravi Kant Dwivedi and Punit Kumar University of Lucknow, Lucknow
25.	246	SA-25	**Seasonal Occurrence of Ionospheric Plasma Bubbles During Ascending Phase of 25th Solar Cycle Over Varanasi** Mukulika Mondal, Sanjay Kumar, A. K. Singh BHU, Varansi
26.	262	SA-26	**Weibel Instability Mediated Magnetic Field Evolution in Relativistic Counter-stream Plasma System** Rakesh Kumar, Hitendra Kumar Malik, Sandeep Kumar IIT Delhi
27.	263	SA-27	**Compressible Effects On Force-free 2d Magnetic Flux Tubes** Jagannath Mahapatra, Rajaraman Ganesh, and Abhijit Sen IPR, Ghandhinahar

28.	267	SA-28	**Plasma – Wave interaction of multiple particles in solar wind plasma and the Earth's magnetospheric plasma systems** Priyank Srivastava, A.K. Singh University of Lucknow, Lucknow
29.	270	SA-29	**Turbulence In Lower Hybrid Frequency Range In The Magnetopause As Observed by MMS Mission** Manoj Kumar Upadhyay, R. Uma and R.P. Sharma IIT Delhi
30.	297	SA-30	**Exploring the magnetic coupling of solar atmosphere using the amplitude and frequency modulation of 3-min waves above sunspot umbra** Ananya Rawat, Girjesh R Gupta PRL, Udaipur
31.	299	SA-31	**Observational properties of Solar Plasma Parameters associated with IMF and geo-effectiveness in Solar Cycle 24** Soumya Yadav, A.K. Singh University of Lucknow, Lucknow
32.	300	SA-32	**Spectroscopic and imaging observations of transient hot and cool loops in the solar atmosphere** Girjesh R Gupta, Sushree S Nayak PRL, Udaipur
33.	317	SA-33	**Analysis on the variation of ionospheric tec using nonlinear techniques** Aswini Thampi S L and Prince P.R. University College, Thiruvananthapuram, Kerala
34.	334	SA-34	**A correlative study of solar plasma associated with major geo-storms during 2008 -2022.** Pawan Kumar, Mahender Pal and Sham Singh IKGPTU Jalandhar
35.	335	SA-35	**Propagation Characteristics of Waves in Neutrino Magnetohydrodynamics** Subhash Kumar, Hrishabh Bhardwaj, Sukanta Deb University of Delhi
36.	344	SA-36	**High frequency solitons with higher order effects in multicomponent plasma** Rajneet Kaur and N. S. Saini GNDU Amritsar

37.	348	SA-37	**A study of Sun plasma associated with major storms during 2017-2021.** Mahender Pal, Pawan Kumar and Sham Singh IKGPTUU, Jalandhar
38.	366	SA-38	**Effect of Geomagnetic Storms on Ionosphere during Solar Cycle 24 over the low latitude** Vishnu Singh Rathore, Suhail Ahmad Siddiqui, A.K. Singh JS University
39.	370	SA-39	**Effect of flow shear on the onset of dynamo** Shishir Biswas, Rajaraman Ganesh IPR, Ghandhinahar
40.	388	SA-40	**Electrostatic ion acoustic solitary structures in a multicomponent dusty plasma** Geetika Slathia and N. S. Saini GNDU Amritsar
41.	390	SA-41	**Effect of kappa distribution function on firehose instability in electro-ion plasma of auroral acceleration region** N. Tandon, G.Ahirwar Vikram University, Ujjain
42.	391	SA-42	**Arbitrary Amplitude Solitary Wave - Coupling Of Langmuir Wave And Dust Acoustic Wave** Runmoni Gogoi Terna Engineering College, Mumbai
43.	392	SA-43	**Lunar Dusty Plasma Environment: Challenges for Upcoming Lunar Missions** Trinesh Sana, S. K. Mishra PRL, Ahmedabad
44.	426	SA-44	**Ion-acoustic double layers in magnetoplasma with presence of superthermal electrons and positrons** J. K. Chawla, M. Rawat and P. C. Singhadiya R R Govt College Alwar
45.	447	SA-45	**Oscillations Of The Magnetotail Plasma Sheet Parameters During A Solar Flare In The Maximum Activity Year** Vivekanandan R S , Dr. Bindhu S , Dr. Madhu G University College, Thiruvanthapuram
46.	460	SA-46	**Relevance of axion-like particles in the magnetic field of various astrophysical environments** Sarathykannan S, Bhanu Prakash Pant, Sunanda, and Reetanjali Moharana

			IIT Jodhpur
47.	466	SA-47	**Collisionless Shock Formation in Field-aligned Plasma Flow from Accretion Disk towards Poles in Neutron Stars** Anoop Singh, Mrityunjaya Kundu and Shishir P. Deshpande IPR, Ghandhinahar

Industrial Plasma Applications (IP)

Sr. No.	Abstract ID	Poster Number	Title/Name/Affiliation
1.	12	IP-1	**Numerical Simulation of Coal Devolatilization Process in Presence of High Power Plasma Arc in Plasma Fuel System** Sunil Bassi, S.K. Nema, A. Sanghariyat, C. Patil, P.V. Murugan, Shashank Chaturvedi IPR, Ghandhinahar
2.	48	IP-2	**Thermal Performance analysis Of Gate Valve Assembly With Cooling Provision for Safe Handling of Bio-Medical Waste Packets in Plasma Pyrolysis System** Atikkumar N. Mistry, Deepak Sharma, Paritosh Chaudhuri, S.K. Nema IPR, Ghandhinahar
3.	64	IP-3	**Design and Development of Plasma Activated Water setup and Optimization of Process Parameters and its Applications (Healthcare, Food Preservation, and Agriculture)** Vikas Rathore, Divyesh Patel, Shital Butani, Sudhir Kumar Nema IPR, Ghandhinahar
4.	70	IP-4	**Plasma Treatment on Palpali Dhaka** Angash Niroula, Roshan Chalise, Raju Khanal Tribhuvan University, Nepal
5.	107	IP-5	**Plasma Gasification Technology for Municipal Solid Waste treatment** Tejashwi rana, Satyananda kar IIT Delhi
6.	121	IP-6	**Development and characterization of Chitosan/zno Nanocomposites on plasma pretreated cotton fabrics for enhancement of their antimicrobial properties** V. Udaya, M.C. Ramkumar VIT Chennai
7.	147	IP-7	**Comparative Study of Dielectric Barrier Discharge Plasma With Different Configurations** Trivesh Kant, Kushagra Nigam, Abhijit Boruah, Chirayu Patil, B. Sahoo, G Ravi IPR, Ghandhinagar

8.	182	IP-8	**Surface Modification of Bharat Merino Wool (BMW) for improving its Shrink Resistance using atmospheric pressure non-thermal air plasma and bio-polymer coating** Nisha Chandwani, Vinod Kadam, Atik Mistry, Vishal Jain and S. K. Nema IPR, Ghandhinahar
9.	187	IP-9	**Surface Modification of High Density Polyethylene (HDPE) Geomembranes using atmospheric pressure nonthermal air plasma** Vishal Jain, Nisha Chandwani, Royal Christian, S. K. Nema IPR, Ghandhinahar
10.	218	IP-10	**Effect of Oxygen Plasma Treatment on Silk Fabrics for Enhancing Dyeing and Coating Properties** Bornali Sarma, K Vinisha Rani, Ramnaresh Kumar and D N Gupta University of Delhi
11.	265	IP-11	**Cold Atmospheric Plasma For The Deactivation Of Omicron Variant Of SARS-COV-2** Reema, Deepjyoti Basumatary, Kamatchi Sankaranarayanan IASST, Guwahati
12.	303	IP-12	**Cold Atmospheric Helium Plasma Jet Triggering Self-assembly of Amino Acids Enantiomers into Supramolecular Structures** Deepjyoti Basumatary, Kamatchi Sankaranarayanan IASST, Guwahati
13.	304	IP-13	**Discharge modes in a microwave plasma tube in the presence of dielectric bead** Anupama Ojha, Shubhankur Suvansh, Himanshu Pandey and Shail Pandey SVNIT Surat
14.	305	IP-14	**Microwave Miniaturized Multiband Absorber for Terahertz Application** Ritu Roumya Samal, Kajal Parashar, S.K.S. Parashar Kalinga Krishnan Institutre of Technology, Bhubneswar
15.	330	IP-15	**Morphological and Plasmonic Properties of Silver Nanostructures Fabricated using Hot and Dense Plasma** Bilasini D Naorem, Onkar Mangla and Savita Roy Miranda House, University of Delhi
16.	336	IP-16	**Atmospheric Plasma Spray Coated nife For Electrocatalytic Oxygen Evolution Reaction**

			N. Bharani L. Kumaresan and G. Shanmugavelayutham Bharathaiar University, Coimbatore
17.	343	IP-17	**Synergistic Effect of Nano CuO2 and Micro Discharge Plasma on Degradation of Congo red Dye** N. Thirumurugan, P. Amarnath, S. Yugeswaran, K. Suresh Bharathiar University, Coimbatore
18.	347	IP-18	**Application driven development of RF atmospheric pressure cold plasma jet: analysis of plasma by Optical emission spectroscopy** Vishakha Bende, Rajib Kar, Vandan Nagar, Vanita Sekar, Namita Maiti HBNI, Mumbai
19.	352	IP-19	**Plasma Activated Water For Inhibition Of SARS-COV-2 virus** Sidharth and Shail Pandey SVNIT, Surat
20.	393	IP-20	**Development of Glass-Metal joint for Plasma Antenna System** Vinod Kaila, Siju George, Rajan Babu, Vijay Patel, Dilip Raval, Prabal K. Chattopadhyay IPR, Ghandhinagar
21.	396	IP-21	**Production of Plasma Activated Water containing Hydrogen Peroxide and Ozone by Transient Spark Discharge and Electrospray** P.Pareek, M.Janda, S.Kooshki, P.Tóth *Comenius University Bratislava, Slovakia*
22.	434	IP-22	**Simulation and Experimental Analysis of Kr/Cl2 based 222 nm Far UV-C Excimer Source** Surbhi Bidawat, Navin Kumar Sharma, Ram Prakash Lamba, Mahendra Singh, Alok Mishra, Yaduvendra Choyal and Udit Narayan Pal CSIR-CEERI, Pilani
23.	435	IP-23	**Discharge Analysis and Characterization of Cold Atmospheric Pressure Plasma Jet Sources for Potential Biomedical Applications** Navin Kumar Sharma, Priti Pal, Vishali singh, Ravindra Kumar, Alok Misra, Mahendra Singh, Ram Prakash Lamba, Murali M Pandey, Yaduvendra Choyal and Udit Narayan Pal Devi Ahilya Vishwavidyalaya, Indore

24.	436	IP-24	**Analysis of Cold Atmospheric Pressure Plasma Source based Plasma Activated Water for Agriculture Application** Priti Pal, Vishali Singh, Navin K. Sharma, Mahendra Singh, Alok Mishra, Udit Narayan Pal, Shivendra Maurya and Ram Prakash Lamba CSIR-CEERI, Pilani
25.	441	IP-25	**DBD plasma based far UV-C excimer light source: A new paradigm for safe use of UV light** Kiran Ahlawat, Ramavtar Jangra, Vigyan Gadodia, Ram Prakash IIT Jodhpur
26.	449	IP-26	**Atmospheric Pressure Argon Plasma Jet for Wound Healing** Rajendra Shrestha, Tachal Niraula, Mukesh Pokharel, Puja Pandey, Sujata Bhattarai, Dr. Shreedevi Basukala, Jyoti Prakash Gurung, Deepak Prasad Subedi, Vishwa Prakash Shrivastava Nepal Banepa Polytechnic Institute
27.	464	IP-27	**Efficacy Analysis of a Cross Field Cold Atmospheric Pressure Plasma Jet for Smear Layer Removal in Intra-radicular Dentin** Abhijit Mishra, Ankita Kapoor, Pravin Kumar and Ram Prakash IIT Jodhpur

Post Deadline Contributions (PC)

Sr. No.	Abstract ID	Poster Number	Title/Name/Affiliation
1.	PC001	PC-1	**A 2.5D-Electrostatic PIC Simulation of Ion extraction Process from Laser-Induced Photoplasma** Priti Singh, G. Sridhar, Namita Maiti HBNI, Mumbai
2.	PC002	PC-2	**An In-Vitro Analysis To Evaluate The Disinfection Effectiveness Of Cold Atmospheric Pressure Plasma Jet In *Enterococcus Faecalis* Infected Root Canals** Pravin Kumar, Ram Prakash, Soundharrajan P, Abhijit Mishra AIIMS Jodhpur
3.	PC003	PC-3	**Measurement Of Electron Temperature And Density Of Argon Thermal Plasma Jet Using Optical Emission Spectrometer** Amarnath.P, Ekta yadav, Deepak.S, Sampad Saha, Soundharayaa.M, Jennifer.A, Joel Jeevan Tharakar, Nasih Mohammad, Yugeswaran.S Pondicherry University
4.	PC004	PC-4	**Measurement Of Electron Temperature (T_e) And Density (N_e) Using Langmuir Probe In Dc Glow Discharge Plasma** Smrutishree pratihary, Ekta Yadav, Deepak.S, Sampad Saha, Soundharayaa.M, Jennifer.A, Joel Jeevan Tharakar, Nasih Mohammad, Suraj kumar sinha Pondicherry University
5.	PC005	PC-5	**Study The Electron Behaviour At Plasma - Metal Junction** Smrutishree Pratihary, Sneha Latha Kommuguri, Suraj Kumar Sinha Pondicherry University
6.	PC006	PC-6	**Systematic analysis of whistler wave from fluid to kinetic limit with phase space dynamics** Anjan Paul, Devendra Sharma IPR, Ghandhinahar
7.	PC007	PC-7	**Effect of depth and field size on percentage depth dose in radiation therapy using nuclear source** Prajapati Dahal, Santosh Panth, Prakash Joshi, Satyanand Gupta, Dr. Suresh Basnet, Prof. Dr. Raju Khanal Tribhuvan University, Nepal

8.	PC008	PC-8	**Selective Generation of Energetic N_2 Extracted from Nitrogen Glow Discharge Plasma for Food Processing** M. Perumal, Ekta Yadav and Suraj Kumar Sinha Pondicherry University
9.	PC009	PC-9	**Selective Reactive Nitrogen Species Rich Plasma Activated Water for Agricultural Applications** Shikha Pandey, Ritesh Mishra, Ramavtar Jangra, Sushma, Kiran Ahlawat, and Ram Prakash IIT Jodhpur
10.	PC010	PC-10	**Excitation of electrostatics oscillations and their modification by nonlinear whistlers** Gayatri Barsagade, Devendra Sharma IPR, Ghandhinahar
11.	PC011	PC-11	**Study on Variation of Spark Gap Inductance With Medium, Pressure and Gap Between Electrodes** S.Mitra, Sandeep Singh, Senthil K, Ankur Patel, Ranjeet Kumar, Amitava Roy, R. I. Bakhtsingh and Archana Sharma BARC, Mumbai
12.	PC012	PC-12	**Design of Pulse Magnetic Field For Backward Wave Oscillators** V K Sharma, Romesh Chandra, A S Patel, Amitava Roy, Archana Sharma BARC, Mumbai
13.	PC013	PC-13	**Degradation of methylene blue dye as waste-water pollutant under transient corona discharge plasma treatment: A detailed study** Mangilal Choudhary, and Chintan Vyas Banasthali Vidiyapith, Tonk
14.	PC014	PC-14	**DESIGN OF 25% EFFICIENT X-BAND RBWO OPERATING AT LOW MAGNETIC FIELD** Chitaranjan Jadab, Romesh Chandra, Sandeep Kumar Singh, & Amitava Roy HBNI, Mumbai
15.	PC015	PC-15	**Simulation and Design of a 600 kV Tesla Transformer** Ankan Basak, Ankur Patel, Senthil Kalyanasundaram, Amitava Roy BARC, Mumbai
16.	PC016	PC-16	**A 9 MEV RF LINAC BASED PHOTO-NEUTRON**

			SOURCE FOR NEUTRON RADIOGRAPHY APPLICATION Rishi Verma, J. N. Rao, J. Balu Naik, D. B. Majumder, A. Dubey, R. Shukla, Shobhna Mishra, Basanta Das, Manraj Meena, Lakshman Rongali, Bijayalaxmi Sethi, Vivek Yadav, Dhruv Bhattacharjee, Shiv Chandan, R. Chauvan, Mayank Shukla, Tushar Roy, M. Srihari, D. H. Rathod, D. P. Chakravarthy, J. Subbaram, S. R. Ghodke, Archana Sharma BARC, Mumbai
17.	PC017	PC-17	**DEVELOPMENT AND MODELLING OF THREE PHASE HIGH CURRENT SOURCE CONVERTER FOR PLASMATRON APPLICATION** Pankaj Deb, Sunil Kanchi, V Appa Rao, Rohit Shukla, Archana Sharma BARC, Mumbai
18.	PC018	PC-18	**PIC simulation of the particle behavior in a compact IEC system** Somesh Vinayak Tewari, Surender Kumar Sharma, Archana Sharma BARC, Mumbai
19.	PC019	PC-19	**Particle-In-Cell Simulation of 1 MV Flash X-ray Diode** Rakhee Menon K, Ankur Patel, Senthil K, Ankan Basak and Amitava Roy BARC, Mumbai
20.	PC020	PC-20	**EXPERIMENTAL STUDY OF ELECTRON BEAM PARAMETERS OF 40 keV INJECTOR SECTION WITH 2856 MHz PRE-BUNCHER CAVITY** J. Mondal, L. Mishra, S. G. Sarkar, BARC, Mumbai
21.	PC021	PC-21	**Effect of initial pump intensity and plasma density on instabilities generated in the process of Stimulated Brillouin Scattering for production of High intensity and highly compressed Laser Pulses** Updesh Verma, Anil Malik, Beer Pal Singh M. K. R. Govt. Degree College, Ghaziabad, U.P.
22.	PC022	PC-22	**DEVELOPMENT OF MULTI-CHANNEL, SINGLE-SHOT, HIGH RESOLUTION DOPPLER SPECTROSCOPY FOR 2D VELOCITY MAPPING OF INTENSE LASER PRODUCED PLASMAS** Yash M. Ved, Amit D. Lad, Kamalesh Jana, and G. Ravindra Kumar TIFR, Mumbai

23.	PC023	PC-23	**Role of Ionic Lines in Investigating Low Pressure Argon Plasma using Optical Emission Spectroscopy** Vidhi Panchal and Shail Pandey SVNIT, Surat
24.	PC024	PC-24	**Acoustoelectric Amplification Characteristics in a High Mobility Semiconductor Plasma Medium: Quantum Effects** Drishti Chawda, Swati Dubey, S. Ghosh Vikram University, Ujjain

Patrons/National Advisory Committee/Committees

Patrons

Dr. R. Chidambaram, Chairman, Board of Governors, IIT Jodhpur

National Advisory Committee (NAC)

Dr. Shashank Chaturvedi, Director, IPR, Gandhinagar, **Chairman**
Prof. Santanu Chaudhury, Director, IIT Jodhpur, **Co-Chairman**
Dr. A. P. Dimri, Director, IIG Mumbai, Member
Prof. Abhijit Sen, IPR Gandhinagar, Member
Prof. Amita Das, IIT Delhi, Member
Dr. Amitava Roy, SERB-DST, Delhi, Member
Dr. Anand Moorti, RRCAT, Indore, Member
Dr. Anil Bhardwaj, Director, PRL Ahmedabad, Member
Dr. Archana Sharma, Director, BTDG BARC, Mumbai, Member
Dr. Arnab Roy Chowdhury, IISc, Bengaluru, Member
Dr. Arun Sarma, DG, NECTAR, Delhi, Member
Prof. Ashoka K. Das, OSHEC, Bhubaneshwar, Member
Prof. Avinash Khare, Vice-Chancellor, SCU, Sikkim, Member
Dr. G. Ravindra Kumar, TIFR, Mumbai, Member
Dr. H. Bailung, Bodoland University, Assam, Member
Prof. Indranil Manna, Vice-Chancellor, BIT Mesra Ranchi, Member
Dr. P.C. Panchariya, Director, CSIR-CEERI, Pilani, Member
Dr. P. K. Atrey, IPR, Gandhinagar, Member
Shri RV Hara Prasad, Director, DLJ-DRDO, Jodhpur, Member
Prof. Souvik Bhattacharyya, Vice-Chancellor, BITS Pilani
Prof. S. R. Vadera, Deputy Director, IIT Jodhpur
Dr. Ujjwal Baruah, ITER India, IPR, Gandhinagar, Member

Scientific Program Committee (SPC)

Prof. Nareshpal Singh Saini, GNDU, Amritsar, Chairman
Dr. Ram Prakash, IIT Jodhpur, Convener
Dr. Alphonsa Joseph, FCIPT-IPR Gandhinagar, Member
Dr. Amar Kakad, IIG Mumbai, Member
Dr. Bhuwan Joshi, PRL, Ahmedabad, Member
Dr. Devendra Sharma, IPR Gandhinagar, Member
Dr. Lalit Mohan Awasthi, IPR, Gandhinagar, Member
Dr. Mainak Bandyopadhyay, IPR, Gandhinagar, Member
Dr. Malay Bikas Chowdhuri, IPR, Gandhinagar, Member
Dr. Mrityunjay Kundu, Nirav Jamnapara, IPR, Member
Dr. Punit Kumar, LU, Lucknow, Member
Dr. Ram Prasad Prajapati, JNU, New Delhi, Member
Dr. Ramesh Narayanan, IIT, Delhi, Member

Mrs. Ranjana Manchanda, IPR, Gandhinagar, Member
Dr. Rishi Verma, BARC, Visakhapatnam, Member
Dr. S. R. Mohanty, CPP-IPR, Guwahati, Member
Dr. Shishir Deshpande, IPR, Member
Dr. Sudeep Bhattacharya, IIT, Kanpur, Member
Dr. Suraj K. Sinha, Pondicherry Univ., Puducherry, Member

Local Organizing Committee

Dr. V. Narayanan, IIT Jodhpur	Chairman
Dr. Ram Prakash, IIT Jodhpur	Convener
Dr. Monika Sinha, IIT Jodhpur	Co-Convener
Dr. Ambesh Dixit, IIT Jodhpur	Secretary (Scientific)
Dr. Satyajit Sahu, IIT Jodhpur	Secretary (Organizing)
Dr. Durgamadhab Mishra, IIT Jodhpur	Treasurer
Dr. Ajay Agarwal, IIT Jodhpur	Member
Dr. Ashutosh Kr. Alok, IIT Jodhpur	Member
Dr. Mahesh Kumar, IIT Jodhpur	Member
Dr. K. R. Ravi, IIT Jodhpur	Member
Dr. Anand K. Plappally, IIT Jodhpur	Member
Dr. Indranil Banerjee, IIT Jodhpur	Member
Dr. Meenu Chhabra, IIT Jodhpur	Member
Dr. Neha Jain, IIT Jodhpur	Member
Dr. Niraj Kumar, CSIR-CEERI, Pilani	Member
Dr. Praveen Kumar, AIIMS Jodhpur	Member
Dr. R. P. Lamba, CSIR-CEERI, Pilani	Member
Dr. Ritu Gupta, IIT Jodhpur	Member
Dr. S. K. Sharma JNVU, Jodhpur	Member
Dr. Shahab Ahmad, IIT Jodhpur	Member
Dr. Suman Kundu, IIT Jodhpur	Member
Dr. Udit Narayan Pal, CSIR-CEERI, Pilani	Member
Dr. Vibhor Tak, AIIMS Jodhpur	Member
Dr. Vivek Vijay, IIT Jodhpur	Member

Sub-Committees

1. Registration Committee

Dr. Monika Sinha, IIT Jodhpur, **Chairman**
Dr. Reetanjali Moharana, **Co-chairman**
Dr. Sunita, **Convenor**
Mr. Ramesh Chandra Vyas, Member
Mr. Narayan Dadhich, Member
Mr Vikram Singh Shekhawat, member
Ms. Shikha, Student Member
Ms. Madhusmita Swain, Student Member
Ms. Bharti Rani, Student Member
Mr. Biswajit, Student Member
Mr. Dibyajyoti, Student Member

2. Food Committee

Dr. Ajay Agarwal, **Chairman**
Mr. Raju Ram Parihar, **Co-chairman**
Mr. Shakti Ranjan Patra, **Convenor**
Dr. Ritu Gupta, Member
Mr. Kapil Tanwar, Member
Mr. Himmat Singh, Member
Mr. Gaurav Khichi, Member
Mr. Atanu Betal, Student Member
Mr. Sapta Sindhu Paul, Student Member
Ms. Sushma, Student Member
Ms. Minakshi, Student Member

3. Accommodation Committee

Dr. Vivek Vijay, **Chairman**
Mr. Amardeep Sharma, **Co-Chairman**
Dr. Vijay Kumar Singh, **Convenor**
Mr. Dheeraj Singh Khangarot, Member
Mr. Dhaniram, Member
Mr. Ramavtar Jangra, Student Member
Ms. Jyoti Verma, Student Member
Ms. Hema, Student Member
Mr. Ankit Yadav, Student Member
Mr. Chayan Das, Student Member
Mr. Debashish, Student Member
Mr. Chandra Prakash, Student Member

4. Transport Committee:

Dr. Satyajit Sahu, **Chairman**
Mr. Ashok Kumar Khanduri, **Co-chairman**

Dr. Santosh Mogurampelly, **Convenor**
Mr. Mohit Mathur, Member
Mr. Sunil Kumar, Member
Mr. Aman Prakash, Student Member
Ms. Sipra Mahopatra, Student Member
Mr. Abhijit Mishra, Student Member
Mr. Ritesh Mishra, Student Member
Mr. Piyush Chaudhary, Student Member
Mr. Anupam Chetia, Student Member
Mr. Abhishek Yadav, Student Member

5. Hall management and Excursion Committee

Dr. K. R. Ravi, **Chairman**
Dr. Mahesh Kumar, **Co-Chairman**
Dr. Suman Kundu, **Convenor**
Dr. Neha Jain, Member
Mr. Anil Kumar, member, Member
Dr. Lakshya Daukiya, Member
Mr. Vikar Janu, Member
Mr. Vigyan Gadodia, Student Member
Ms. Kiran Ahlawat, Student Member
Mr. Tomis, Student Member
Mr. Suleman Ansari, Student Member

6. Purchase and Account Committee

Dr. Ram Prakash, **Chairman**
Mr. Naresh Joshi, **Co-chairman**
Dr. Durgamadhab Mishra, IIT Jodhpur, **Convenor**
Mr. Ashish Kachhawaha, Member
Ms. T. Malati, Member
Mr. Sharad Shrivastava, Member
Mr. Suresh Chandra Phulera, Member
Mr. Srinivash Dwivedi, Member
Mr. Amit Sharma, Member
Mr. Ramavatar Jangra, Student Member
Ms. Kiran Ahlawat, Student Member

7. Printing and Media Committee

Dr. Ashutosh Kr. Alok, **Chairman**
Dr. Meenu Chhabra, **Co-chairman**
Dr. Anand K. Plappally, **Convenor**
Mr. Narendra Singh, Member
Mr. Vigyan Gadodia, Student Member
Mr. Abhijit Mishra, Student Member
Mr. Debashish, Student Member
Mr. Ravikant, Student Member

8. Exhibition Committee

Dr. Shahab Ahmed, **Chairman**
Dr. Indranil Banerjee, **Co-chairman**
Dr. Prabhat Jaiswal, **Convenor**
Ms. Priyanka, Student Member
Mr. Priyambada Sahoo, Student Member
Mr. Abhijit Kale, Student Member

9. Emergency services Committee

Dr. Ambesh Dixit, **Chairman**
Mr. Verander Singh, Security Officer, **Co-chairman**
Dr. B. M. Krishna, **Convenor**
Dr. Kiran Arya, Medical Officer, Member
Ms. Shikha, Student Member
Mr. Biswajit, Student Member

10. Lab Visit Committee

Dr. V. Narayanan, **Chairman**
Dr. Somnath Ghosh, **Co-Chairman**
Dr. Sankalp Pratap, **Convenor**
Dr. Shahab Ahmed, Member
Dr. Prabhat Jaiswal, Member
Ms. Madhusmita Swain, Student Member
Ms. Bharti Rani, Student Member

Advertisements

FTD Infocom Private limited.

A leader in product development and service solutions, we offer a wide range of domain specific services and solutions. The domains are Embedded, MEMS, CAD, CAE, PLM, and Plasma Physics Simulation.

Our Product development Software solutions are complemented by our training services and Product prototyping services and Manpower…

Our Technology Focus ...

DIVYA PLASMA SOLUTIONS PRIVATE LIMITED

Divya Plasma's Novel CODE indoor air purification technology is a superior solution because it proactively treats the air in the occupied space at the source of contamination in an environmentally sound manner with many added advantages

Contact:
IITJ-TISC

Divya plasma Solutions

Quality Indoor Air

NOVEL COD`E

- Produces Cold-plasma Detergent in Environment with optimum concentration
- Residency time of active ions more than 25 sec to effectively deactivate the long living pathogens
- Produces requisite active ions so as to balance negative and positive charges similar to mother nature and also to produce local fields in the air to rupture harmful pathogens in the aerosols
- Consumes less power (for optimized source avg. discharge power < 5 W)
- Deactivates bacteria, molds and viruses
- Captures dust and pollen
- Reduces VoCs
- Removes Odors

God created great outdoors

Can we create good indoors and relax?

Basic Plasma

VECTOR ANALYSIS OF THE ELECTRON PHASE-SPACE VORTICES IN ELECTROSTATIC COLLISION-LESS PLASMAS

Allen Lobo*, Vinod Kumar Sayal

Sikkim Manipal Institute of Technology, Majitar, East Sikkim – 737136

*Email: allen_20211084@smit.smu.edu.in

Abstract

The study of phase-space electron holes has been conducted using nonlinear approaches to the kinetic theory of collision-less plasmas. In the past, linear and nonlinear treatments to the Vlasov equation [1] have described the kinetic behaviors of collision-less plasmas [2], [3], [4], [5]. In the following work, we have produced a vector form of the phase-space density function in normalized phase-space coordinates. We observe that this phase-space vector field represents the vlasov equation and its evolution in the phase-space-time dimensions. We have performed the vector analysis of the same at the site of the electron-hole formation.

The vectorization of the particle distribution function and the vlasov equation introduces an interesting approach to study the growth of the phase-space vortices in collision-less plasmas. The temporal growth of the curl of the defined phase-space vector field at the site of the hole formation is observed and solved both numerically and analytically. Such an analysis, coupled with the poisson equation determines various structural properties associated with the nature of the distribution function at the site of the hole formation.

References:

[1] On vibration properties of electron gas, Zhurnal Eksp. i Teor. Fiz., vol. 8, no. 3, p. 291 (1938)

[2] On the vibrations of the electronic plasma, J. Physics–USSR, vol. 10, p. 25 (1946)

[3] On the theory of stationary waves in plasmas, Physica, vol. 21, no. 6–10, pp. 949–963 (1955)

[4] Exact nonlinear plasma oscillations, Phys. Rev., vol. 108, no. 3, p. 546 (1957)

[5] Theory of phase-space density holes, Phys. Fluids, vol. 25, no. 2, pp. 277–289 (1982)

Characterization of Spiral Antenna-Based RF-plasma in Multi-Dipole Line Cusp Magnetic Field

M. A. Ansari[1], A. D. Patel[2], Prabal K Chattopadhyay[2, 3], Raj Singh[1] and N. Ramasubramanian[2, 3]

[1]RF and Microwave Service Section (RFMS), [2]Fundamental Plasma Experiment Division (FPED),

Institute for Plasma Research, Gandhinagar-382428, India

[3]Homi Bhabha National Institute, Anushaktinagar-400094, Mumbai, India

mumtaz.ansari@ipr.res.in; amitphy9898@gmail.com; pkchatto@ipr.res.in; raj@ipr.res.in; mani@ipr.res.in

Abstract

A lot of efforts are going on to develop the RF plasma source which finds potential applications in semiconductor industries, plasma cleaning, ion beam etching etc. In the present work, the RF Plasma is produced using a high-power four-turn RF spiral antenna at 13.56 MHz in the power range of 0 to 1000 W and Argon gas–filled pressure between 2×10^{-3} mbar to 1×10^{-2} mbar. The block diagram for the complete experimental setup consists of an RF Source with a matching network, rigid coaxial transmission line section with the spiral antenna, RF shielding of antenna, vacuum chamber, triple Langmuir Probe (TLP), DC biasing for probes, Rogowski coil and CRO. The input impedance of the spiral antenna along with the vacuum chamber, glass window and RF shielding is measured using a VNA and is found to be ~0.37 + j80 Ω.

The antenna is matched to resonate at 13.56 MHz using an external L-type matching network with variable capacitors and fixed inductors under vacuum conditions with a base pressure of 5.5×10^{-3} mbar. The antenna resistance is then measured experimentally using the Rogowski coil under the matched condition and is found to be ~0.27 Ω which is in good agreement with the VNA readings. Finally, the characterization of Argon plasma is performed under the Multi-Dipole Line Cusp Magnetic Field (B_0) and it is observed that when RF power increases, the plasma density (n_e) moves to a maximum (3.2×10^{17} /m^3) value for large B_0 of 800 Gauss. In addition, the plasma resistance is also measured experimentally and is found to be ~0.55 Ω which shows the coupling efficiency of RF power with the plasma is ~68%.

References:

[1] J. S. Ogle, "Method and apparatus for producing magnetically-coupled planar plasma," U.S. Patent 4 948 458 A, Aug. 14, 1990.

J. Hopwood, "Review of inductively coupled plasmas for plasma processing," Plasma Sources Sci. Technol., vol. 1, no. 2, p. 109, 1992.

Nonlinear Excitations in Strongly Coupled Yukawa System under Quasi Localized Charge Approximation (QLCA) approach

Name(s) of the author: Sandip Dalui[1], Prince Kumar[1,2], Devendra Sharma[1,2]

[1] Institute for Plasma Research, HBNI, Bhat, Gandhinagar 382428, India, [2] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India

e-mail (speaker): sandip.dalui@ipr.res.in

Abstract

We have studied the nonlinear wave modulation of the strongly coupled Yukawa system by considering strongly coupled complex plasma in presence of ions and electrons under the Quasi-localized charge approximation (QLCA) [1] approach. When the plasma system is in a strongly coupled liquid state, then the QLCA approach is best fit to study the nonlinear excitations. Using the reductive perturbation method, a nonlinear Schrödinger equation [2] is derived to study the nonlinear wave modulation of the strongly coupled Yukawa system. A nonlinear dispersion relation is derived to see the existence of modulational instability for the strongly coupled Yukawa system. Analytically and numerically, we have investigated the modulational instability conditions and the maximum modulational growth rate of instability of the strongly coupled Yukawa system. For strongly coupled dusty plasma, we have seen that the wave frequency decreases with increasing values of the screening parameter (κ). For strongly coupled dusty plasma, we have seen that the existence of maximum growth rate of instability decreases with increasing κ. Also, we have seen that the region of existence of the maximum modulational growth rate of instability increases with increasing dust temperature.

References:

[1] Rosenberg M., Kalman G., Phys. Rev. E 1997, 56, 7166.

[2] Dalui S., Bandyopadhyay A., Das K. P., Phys. Plasmas 2017, 24, 042305

Dynamics Of Magnetized Plasma Sheath In The Context Of Non-extensively Distributed Species

R. Paul[1,*], K. Deka[1], G. Sharma[1], R. Moulick[1], S. Adhikari[2], S. S. Kausik[1, *], B. K. Saikia[1]

[1]*Centre of Plasma Physics-Institute for Plasma Research, Nazirakhat, Sonapur-782402, Kamrup, Assam, India*

[2]*Institute for Energy Technology, Instituttveien 8, 2007 Kjeller, Norway*

E-mail: rupali.paul@cppipr.res.in, kausikss@rediffmail.com

Abstract

A weakly magnetized sheath study for an electronegative plasma comprising of positive ions, electrons and negative ions is investigated numerically using the fluid approach. The electrons are considered to be non-Maxwellian in nature and described by Tsalli's distribution. The presence of non-extensive electrons has substantial effect on the plasma sheath characteristics. The present study also aims at understanding a suitable description of negative ions in a magnetized scenario. A non-Maxwellian description of negative ions appears to be more realistic in such cases. The present study finds application in the plasma processing and semiconductor industry as well as in space plasmas.

References :

[1] R. Paul, S. Adhikari, R. Moulick, S. S. Kausik, and B. K. Saikia, Phys. Plasmas **27** 063520, (2020)

[2] F. Taccogna, R. Schneider, K. Matyash, S. Longo, M. Capitelli and D. Tskhakaya, Journal of Nuclear Materials **363-365** 437-442,(2007)

[3] R. M. Crespo and J. Ballesteros and J.I. Fernandez Palop and M. A. Hernandez and J. M.Dıaz-Cabrera and M. V. Lucena-Polonio and A. Tejero-del-Caz Plasma Sources Sci. and Technology **21** 055026,(2012)

Investigating The Validity Of Boltzmann Relation For Electrons In A Magnetized Plasma Sheath

G. Sharma[1,*], R. Paul[1], K. Deka[1], R. Moulick[1], S. Adhikari[2], S. S. Kausik[1, *], B. K. Saikia[1]

[1]*Centre of Plasma Physics-Institute for Plasma Research, Nazirakhat, Sonapur-782402, Kamrup, Assam, India*

[2]*Institute for Energy Technology, Instituttveien 8, 2007 Kjeller, Norway*

*E-mail: gunjan.sharma@cppipr.res.in, kausikss@rediffmail.com

Abstract

The validity of Boltzmann relation for electrons in the vicinity of a wall with a nearly parallel magnetic field configuration has been investigated [1]. A comparison has been drawn between a fluid electron model and a Boltzmann electron model to analyze the deviation between the models. It is found that the Boltzmann electron assumption does not hold good in the presence of an almost parallel magnetic field near the wall. However, with an increasing angle of inclination, the Boltzmann model can nicely replicate the results obtained from the fluid description. As an alternative to Boltzmann model in such extreme cases, a generalized electron distribution popularly known as non-extensive distribution has been applied and an attempt has been made to predict some realistic values of the non-extensive parameter q.

References:

[1] Study of two-electron temperature plasma sheath using non-extensive electron distribution in presence of an external magnetic field, arXiv:2208.12445 [physics.plasm-ph], (2022).

Modulation in Ion-Acoustic Wave with their Stability in Higher Order Nonlinearity

Rumi Chaharia

Department of Mathematics, Maharishi Vidya Mandir, Silpukhuri, Guwahati, Assam

E-mail : rumi.chaharia@gmail.com

Abstract

To study strongly dispersive plasma waves and wave modulation, nonlinear Schrodinger Equation (NLSE) which is derived be a Modified Reductive Perturbation Technique (MRPT). Here, coefficient of the nonlinear and the dispersive terms in the derived equation of NLSE gives the stability and evolution of the modulated nonlinear plasma waves. Due to the effect of ion temperature and pressure term, result we obtained used to observe in our study. NLSE derivation in our work describes the nonlinearity of the modulated plasma waves which shows the higher order nonlinearity can be shown by another evolution equation and pressure term equation.

Keywords: NLSE, MRPT, nonlinearity, stability, instability, ion acoustic wave.

References:

[1] Demiray, H., J. Phys. Soc. Jpn., 71, 1921-1930(2002)

Design, Simulation, development and testing of a High Power Microwve (HPM) DC break for SYMPLE.

Priyavandna J. Rathod[1,2] and Anitha V. P.[1,2]

1. *Institute for Plasma Research, Bhat, Gandhinagar – 382428*
2. *Homi bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra - 400094*

E-mail: vandna@ipr.res.in

Abstract

SYMPLE (SYstem for Microwave PLasma Experiments)[1] is an experimental system developed at IPR for investigating interaction of High Power Microwave (HPM; 3 MW, 3 GHz) with an over-dense (Plasma frequency > Microwave frequency), unmagnetised plasma. The microwave power is so chosen to meet the condition: wave energy-density $\frac{1}{2}\varepsilon_o E_\mu^2$ ~ plasma particle pressure $n_e kT_e$ (E_μ is wave-field amplitude, n_e is plasma electron density, T_e is electron temperature). The plasma ($n_e \sim (1\text{-}10)\times10^{17}/m^3$) is washer-gun based, and is produced by discharge of about 10 MW power through a washer-gun, which gets ejected to a cylindrical chamber (30 cm diameter, 1 m long)[2]. The HPM – Plasma coupling is achieved by various components including circulator, variable attenuator, directional coupler, a TE – TM mode converter and appropriate transition structures to ensure desired mode excitation in the chamber.

Attaining electrical isolation between the HPM and coupling components and the plasma chamber, while ensuring electromagnetic continuity, is a critical requirement of the experimental system. A circular choke type coupling scheme is designed and simulated with the help of CST and is developed in-house. The design considerations include compatibility of the DC-break with WR-284 rectangular wave guide for single shot (5 μs flat top pulse) operation of 3.1 MW HPM at 3 GHz frequency. A quarter wavelength impedance transformer concept has been used to optimize the dimensions of DC break. S-parameter measurements on the DC-break developed demonstrate a return loss ~ 20 dB and transmittance loss ~ 0.02 dB for operating bandwidth of 15 MHz. Simulation results on field leakage analysis observing far field radiation show leakage field below well within the desired limit i.e $\leq$ 1 %, which is cross checked and verified by measurements using electric field probes. The high voltage isolation test of DC break is carried out up to 50 kV. This paper presents a brief account of design, development and experiments on the DC-break.

1. Developmental aspects of microwave plasma interaction experiments: Phase-1, Anitha V P, Priyavandana J Rathod, Raj Singh and D V Giri, IEEE Transactions on Plasma Science, 44, 2226-2231(2016)
2. A washer-gun plasma system for microwave plasma interaction experiments, Anitha V P, Priyavandana J Rathod, Jayesh Raval, Renu Bahl and Y C Saxena, Rev. Sci. Instrum. **90**, 013502 (2019)

Role of Neutral Gas Flows in Double Layer Formation and Thrust Generation in an Expanding Magnetic Field Plasma

Vinod Saini, Rajaraman Ganesh

Institute for Plasma Research, HBNI, Gandhinagar, Gujarat

E-mail: vinod.saini@ipr.res.in

Abstract

In an electrical plasma thruster, continuous erosion of electrode material due to heavy bombardment of charge particles compromises thruster mission longevity. To overcome this important setback, an expanding magnetic field plasma thrusters (or electrode-less thruster) are proposed. Recently, in a terrestrial laboratory experiment net thrust (~ 8mN) in a particular direction has achieved [1]. These experiments have also brought out the importance of neutral gas flow in the generation of thrust.

Using a in-house developed pseudo 1D3V PIC-MCC code EPPIC, in the absence of neutral flow dynamics , double layer formation and ion acceleration in a diverging magnetic field plasma has been reported [2] wherein around 2mN net thrust in a particular direction was realized numerically [3].

In the present work, the neutral gas flow has been included in EPPIC simulations and the results indicate that the impact of neutral flow can be substantial and controllable by neutral flow rate. A detailed numerical and physics study of neutral gas flow impact over net thrust generation will be presented.

References :

[1] K Takahashi et al, Sci. Rep 8, 14417 (2018).
[2] V. Saini & R. Ganesh, Physics of Plasmas 27, 093505 (2020).
[3] V. Saini & R. Ganesh, Journal of Plasma Physics , 88(2), 905880203, (2022).

SHOCK WAVE IN ANISOTROPIC QUANTIZED MAGNETO PAIR ION PLASMA

Manoj Kumar Deka[1], Deepsikha Mahanta[2], Apul Narayan Dev[3,]

[1]Department of Applied Sciences, Gauhati University,Guwahati,India, 781014
[2]Department of Mathematics, Gauhati University, Guwahati, India 781014
[3]Computer Science and Information Technology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, India 751030

E-mail: [1]manojd143@gmail.com
[2]mahanta2017@gmail.com
[3]apulnarayan@gmail.com

Abstract

The features of shock wave in a quantized magneto plasma under the influence of ionic pressure anisotropy of positive and negative ion collisional plasma is studied with the help of a Burgers' equation, derived using reductive perturbation technique. The governing Burgers' equation is analyzed numerically as the Burgers' equation can't be solved analytically using conventional methodologies due to the presence of collisional term. The initial numerical result shows the development of a monotonic shock in steady state situation whereas in time dependent situation, an initial monotonic shock transforms into an oscillatory shock pattern. Within physically admissible plasma parameters for such plasma environment, the shock potential is found to be rarefactive one. The present investigation may be useful to study the features of shock propagation in astrophysical plasma environment [1-2].

References:

[1] Effect of Pressure Anisotropy on Nonlinear Periodic Waves in a Magnetized Superthermal Electron-Positron-Ion Plasma, Braz.J. of Phys., **49**, p 379-390, (2019)
[2] Wave propagation with degenerate electron–positron in magnetically quantised ion beam plasma, Pramana J. of Phys., **95**, p 1-20 (2021)

EFFECT OF CONNECTION LENGTH ON PLASMA DYNAMICS IN A SIMPLE MAGNETIZED TORUS

Prince Alex*+, Ruggero Barni*, Claudia Riccardi*

*Department of Physics, University of Milan-Bicocca, Italy

Department of Physics, St.Joseph's College, Devagiri, Calicut, Kerala

princealexanderm@gmail.com

Abstract

A simply magnetized device (SMT) is a device in which plasma is confined purely by toroidal field. The cross-field drift of particles arising from the charge polarization is the major loss channel in the device, together, the lack of rotational transform prevents the system to be in MHD equilibrium. Whereas a quasi-stationary equilibrium can be realized by applying a vertical field together with the toroidal field or in other words, reducing the connection length $L_c = 2a\left(\frac{B_\varphi}{B_z}\right)$ from infinity to finite values. Different regimes of operation is identified when the applied vertical field was raised above 4 G and below 4G. Dynamics of plasma state under different connection length or applied vertical field is analyzed using time averaged measurements and conditional averaging techniques. Effect of vertical field on intermittent turbulent fluctuations or generally known as blobs are analyzed.

References

[1] Prince Alex et al, J. Phys. Commun. 6, 015010 (2022).

[2] R. Barni, S. Caldirola, L. Fattorini, and C. Riccardi, Physics of Plasmas 24, 032306 (2017).

Turbulence Mechanism In Quantum Plasma

Prabhat Singh and Punit Kumar

Department of physics, University of Lucknow, Lucknow-226007, India

E-mail : prabhatps0001@gmail.com

Abstract

Turbulence in plasma plays a significant role in experiments of basic and applied plasma science performed in laboratories around the world. Turbulence is a ubiquitous phenomenon that is responsible for many aspects of plasma dynamics, particularly, structure formation and transport of particles, momentum, and energy. Understanding plasma turbulence and specifically of quantum plasma is of tremendous importance in various areas of plasma physics, including fusion science, planetary science, and astrophysics.

In the present paper, we have studied small-scale turbulence observed in magnetic confinement fusion devices which determines their energy confinement time and thus influences their performance. Structure formation in turbulent quantum plasma is effectively instability in quantum plasma in transient forms. Transition of laminar flow of quantum plasma to fully turbulent quantum plasma is also important for complete understanding of stochastic and non linear dynamics. This transient phase has also been considered. Quantum electrodynamics is used to develop a model describing turbulence mechanism in quantum plasma. Formation and evolution of nonlinear turbulent structures and their transience is considered by kinetic equations. These kinetic equations are developed using QED where conditions of each point are considered by Eulerian approach.

Turbulent Relaxation of Plasmas By Vanishing Nonlinear Transfer

Supratik Banerjee, Arijit Halder and Nandita Pan

Department of Physics, Indian Institute of Technology Kanpur, 208016 India

E-mail : sbanerjee@iitk.ac.in

Abstract

The alignment between the magnetic field $\boldsymbol{b}$ and the current density $\boldsymbol{j}$ in the cosmic plasmas has been a topic of extensive research in the last seventy years. Such type of aligned states, commonly known as Beltrami-Taylor states can be achieved by minimizing the quickly varying quantities keeping the slowly varying inviscid invariants as approximately constants [1]. Similar conclusion can be drawn for the alignment between the velocity $\mathbf{u}$ and vorticity $\mathbf{w}$ in neutral fluids**.** However, it has been observed that the relaxed state of an MHD plasma is rather given by a force-balanced minimum energy state supporting a non-zero pressure gradient ∇P and the relaxed state is indeed given by $\boldsymbol{j} \times \boldsymbol{b} = \nabla P$. Similar type of relaxed states are also found for hydrodynamics where the final state is given by $\mathbf{u} \times \mathbf{w} = \nabla P$, with $\mathbf{u}$ and $\mathbf{w}$ being the velocity and the vorticity vectors respectively. Such relaxed states supporting the pressure gradients can also be obtained as a different class of solution of a richer multi-curl Beltrami states minimizing the dissipation rate of the quickly varying quantities [2].

The present work [3] proposes a simple and fundamental solution to the long-standing problem of dynamic relaxation of fluids and plasmas in terms of the principle of vanishing nonlinear transfer (PVNLT). According to our principle, the relaxed states are achieved when the total scale-to-scale nonlinear transfer vanishes. Rather than extremizing some quantity, these relaxed states are obtained to ensure a steady state in the inertial range in the absence of any energy input in the large scales. The proposed principle is universal for all kinds of flows consistent with a high Reynolds number turbulence regime. Unlike variational principle, PVNLT unambiguously predicts the relaxed states supporting a pressure gradient. The BT aligned states are hence obtained automatically in the limit of insignificant pressure gradient. Hence, our theory successfully explains the dynamic relaxation of both the neutral fluids and the plasmas and also naturally connects the relaxed states with and without the pressure gradient. However, unlike the variational approach, here, we do not require to compare the decay rates of those quantities in the presence of dissipation. Furthermore, our methodology is not affected by the direction of the cascades. Using the alternative form of exact relations in turbulence, one directly shows that the turbulent flux vanishes in the relaxed states.

References :

[1] J. B. Taylor, Phys. Rev. Lett. 33, 1139 (1974)
[2] B. Dasgupta *et al*., Phys. Rev. Lett. 81, 3144 (1998)
[3] S. Banerjee, A. Halder and N. Pan, https://arxiv.org/abs/2209.12735 (submitted to PRL)

Lattice Ion Vibrations And Electron Waves Coupling Leading Spiky Solitons In Piezoelectric Semiconductor Quantum Plasma

Abhishek Yadav and Punit Kumar

Department of physics, University of Lucknow, Lucknow-226007, India

E-mail : abhishekeffect8@gmail.com

Abstract

Due to drastic miniaturization of semiconductors in electronic devices, the length of doping profile is now of similar length as that of thermal de Broglie wavelength. Thus, the typical quantum effects such as the exchange correlation, the quantum fluctuation due to the density correlation, and the degenerate pressure will play a significant role in the electronic components to be constructed in future. In semiconductor quantum plasmas, the charge carriers obey the Fermi–Dirac distribution instead of Maxwell–Boltzmann distribution. Study of piezoelectric effects, nonlinearities and the plasma effects in semiconductors plays a significant role in countless technological and industrial applications such as in experimental and device fabrication work.

In the present paper, we have studied the coupling between the lattice ion vibrations and electron waves using quantum hydrodynamic model for piezoelectric semiconductor quantum plasma with the inclusion of various quantum effects. This study has been done in linear as well as nonlinear regime. Further, a set of coupled nonlinear equations developed and analyzed numerically by using the physical parameters of n-type piezoelectric semiconductor quantum plasma.

A Technique To Control Electron Temperature In Filament Discharge

Mrinal Kumar Mishra

Abstract

We are presenting a technique to control electron temperature in filament discharge plasma. In this proposed work, three multi-dipole magnetic cages will be needed. Plasma will be produced by hot filament discharge process at a pressure of around 10^{-4} mbar in two adjacent magnetic cages. At first, by applying a suitable potential difference between two cages, more electron-neutral collisions can be achieved in one of the magnetic cages. As a result, electron temperature will decrease with an increase in electron density. After that, this plasma will be allowed to diffuse through a magnetic filter field to the third magnetic cage. In the third magnetic cage, no direct plasma will be there. In this third cage, electron temperature is expected to decrease further.

FORMATION OF AXIAL POTENTIAL STRUCTURES IN OXYGEN RF PLASMA

P.K. Saha, M. Chakraborty, A. Mukherjee

Centre of Plasma Physics-Institute for Plasma Research,
Tepesia, Sonapur, Kamrup, Assam 782402, India.

E-mail: pabitra.saha@cppipr.res.in

Abstract

The experiment is conducted in a set up consisting of a 13.56 MHz plasma source, helicon antenna, matching network and a plasma source chamber made of glass followed by an expansion chamber [1]. Six electromagnets are present around the source chamber to produce an axial magnetic field. Axial plasma parameters have been measured from the source towards the expansion chamber in Oxygen gas in three different pressure of 7×10^{-4} mBar, 3×10^{-3} mBar and 5×10^{-3} mBar. A radio frequency (RF) compensated Langmuir probe is used to measure the plasma parameters. Multiple potential structures have been observed in low working pressure. In some axial positions, plasma potential drops suddenly which indicates presence of Double Layer (DL) [2, 3]. In gas filling pressure of 7×10^{-4} mBar, two potential drops of around 15 V and 6 V are observed. With the increase of working pressure, potential decreases almost exponentially. Potential drop of DL in expanding RF plasma is capable of accelerating electrons and ions without using any external magnetic field and electrodes [4, 5, 6] and hence has application in plasma based space thrusters.

References:

[1] N. Sharma, M. Chakraborty, N. K. Neog, M. Bandyopadhyay, Review of Scientific Instruments 89, 083508 (2018)
[2] C. Charles and R. W. Boswell, Applied Physics Letters 82, 1356 (2003)
[3] C. Charles, Plasma Sources Science and Technology 16, R1–R25 (2007)
[4] C Charles, Journal of Physics D: Applied Physics 42, 163001 (2009)
[5] K. Takahashi, T. Lafleur, C. Charles, P. Alexander, R. W. Boswell, M. Perren, R. Laine, S. Pottinger, V. Lappas, T. Harle, and D. Lamprou, Applied Physics Letters 98, 141503 (2011)
[6] Sabrina Pottinger, Vaios Lappas, Christine Charles and Rod Boswell, Journal of Physics D: Applied Physics 44, 235201 (2011)

Production Of Uniform Plasma with Filament Assisted DC Discharge in A Linear Plasma Device

Dibyajyoti Bora[1,2], Aritra Tarafder[1,2] and Subir Biswas[1,2]

[1]*Institute of Advanced Study in Science and Technology, Guwahati-781035, Assam, India*

[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201002, India*

E-mail: dibyajyotibora@iasst.res.in, subirb@iasst.gov.in

Abstract

Uniform and quiescent laboratory plasma is desired for the detailed study of different waves and instabilities in a controlled manner. Several laboratories around the world have developed a significant number of devices, mostly linear ones, for the purpose of conducting basic laboratory experiments [1-3]. Here, we present an in-house developed linear plasma device with a simple yet effective, easy-to-operate filament-assisted DC plasma source for producing uniform and quiescent ($\delta n/n < 1\%$) plasma over a large volume without the use of any external magnetic field. The source is flexible in terms of the filament arrangement configuration which is biased negatively with respect to a circular stainless steel grid that is placed in front of it. A 2-dimensional (2D) profile of different plasma parameters is obtained from Langmuir probe measurements made at various axial and radial points. Plasma density of the order $\sim 10^{15}$ m^{-3} is obtained at lower filling gas pressure of $\sim 10^{-4}$ mbar. The plasma uniformity and its quiescence are found to vary with the filling gas pressure. This paper primarily discusses the design of the plasma source and some basic characterization of the plasma produced for different operational conditions.

References :

[1] The maple device of Saha Institute of Nuclear Physics: Construction and its plasma aspects, Review of Scientific Instruments, **81(7),** 073507, (2010)

[2] Magnetized double-plasma device for wave studies, Rev. Sci. Instrum., **58(1)**, p 6–11, (1987)

[3] Inverse mirror plasma experimental device—a new magnetized linear plasma device with wide operating range, Review of Scientific Instruments, **86(6)**, 063501, (2015)

Simulations of Stimulated Raman Instability relevant to Fusion Plasmas

Polly Biswas and D. N. Gupta

Department of Physics and Astrophysics, University of Delhi, Delhi 110 007, India

E-mail: pollydu2008@gmail.com

Abstract

Stimulated Raman process of a laser in fusion plasmas with hot drifting electrons has been investigated via particle-in-cell simulations. The Langmuir wave and scattered electromagnetic sideband wave grow initially, and dump after attaining a maximum level that shows a periodic exchange of energy between the pump wave and the daughter waves. The presence of drifting energetic electrons in laser produced plasma influences the stimulated Raman scattering process. The plasma wave generated by Raman scattering may be influenced due to the presence of the energetic electrons, which enhances the growth rate of the instability. Our results show that the presence of energetic (hot) electrons in the plasma is shown to have an important effect on the evolution of the interacting waves. This phenomenon is modeled via two-dimensional particle-in-cell simulations of the propagation and interaction of the laser under Raman instability.

References:

[1] D.N. Gupta, P. Yadav, D.G. Jang, M.S. Hur, H. Suk, K. Avinash, Physics of Plasmas 22 (5), 052101 (2015).

[2] T. Matsuoka, C. McGuffey, P. G. Cummings, Y. Horovitz, F. Dollar, V. Chvykov, G. Kalintchenko, P. Rousseau, V. Yanovsky, S. S. Bulanov, A. G. R. Thomas, A. Maksimchuk, ans K. Krushelnick, Phys. Rev. Lett., **105**, 034801 (2010).

Production Of Uniform Plasma With Filament Assisted DC Discharge In A Linear Plasma Device

Dibyajyoti Bora[1,2], Aritra Tarafder[1,2] and Subir Biswas[1,2]

[1]*Institute of Advanced Study in Science and Technology, Guwahati-781035, Assam, India*

[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201002, India*

E-mail : dibyajyotibora@iasst.res.in, subirb@iasst.gov.in

Abstract

Uniform and quiescent laboratory plasma is desired for the detailed study of different waves and instabilities in a controlled manner. Several laboratories around the world have developed a significant number of devices, mostly linear ones, for the purpose of conducting basic laboratory experiments [1-3]. Here, we present an in-house developed linear plasma device with a simple yet effective, easy-to-operate filament-assisted DC plasma source for producing uniform and quiescent ($\delta n/n < 1\%$) plasma over a large volume without the use of any external magnetic field. The source is flexible in terms of the filament arrangement configuration which is biased negatively with respect to a circular stainless steel grid that is placed in front of it. A 2-dimensional (2D) profile of different plasma parameters is obtained from Langmuir probe measurements made at various axial and radial points. Plasma density of the order $\sim 10^{15}$ m^{-3} is obtained at lower filling gas pressure of $\sim 10^{-4}$ mbar. The plasma uniformity and its quiescence are found to vary with the filling gas pressure. This paper primarily discusses the design of the plasma source and some basic characterization of the plasma produced for different operational conditions.

References :

[1] The maple device of Saha Institute of Nuclear Physics: Construction and its plasma aspects, Review of Scientific Instruments, **81(7),** 073507, (2010)

[2] Magnetized double-plasma device for wave studies, Rev. Sci. Instrum., **58(1)**, p 6–11, (1987)

[3] Inverse mirror plasma experimental device—a new magnetized linear plasma device with wide operating range, Review of Scientific Instruments, **86(6)**, 063501, (2015)

STUDY OF 3D MAGNETOHYDRODYNAMIC TURBULENCE WITH DIFFERENT INITIAL CONDITIONS

Pratik Patel†, and Sharad K Yadav

Department of Physics, Sardar Vallabhbhai National Institute of Technology (SVNIT),

Surat 395007, Gujarat, India

† d21ph012@phy.svnit.ac.in

Abstract

The statistical features [1] of decaying, homogeneous and isotropic three-dimensional magnetohydrodynamic turbulence have been studied extensively [2]. All of these studies report the same scaling behavior varying as $k^{-5/3}$ for both kinetic and magnetic energy spectra in the inertial region. Further to explore the energy spectra depending upon initial conditions we performed many direct numerical simulations of MHD turbulence by varying Reynolds numbers. And we observe almost the similar behavior as reported in the literature. In this presentation we displayed our results on energy spectra and energy dissipation rates. Moreover, we have some preliminary results on energy spectra depending upon initial conditions in the presence of mean magnetic field [3].

References:

[1] Turbulence: The Legacy of A. N. Kolmogorov, Cambridge University Press, (1995)

[2] Systematics of the magnetic-Prandtl-number dependence of homogeneous, isotropic magnetohydrodynamic turbulence, New J. Phys., **13,** p 013-036, (2011)

[3] Statistical theory of magnetohydrodynamic turbulence: recent result, Phys. Rep., **401,** p 229-380, (2004)

Finite Element Simulation of Plasma Production in a cusp field linear device

A. Amardas*, Raj Singh, Amit D. Patel

Institute for Plasma Research, PO: Bhat, Gandhinagar-382428, India

*E-mail: amar@ipr.res.in

Abstract

Due to wide variety of applications like plasma etching [1], ion sources [2] etc., it is interesting to study cusp field confined plasmas. Numerically simulating such plasmas can give insight into the characteristics that are generally difficult to probe experimentally. In this poster, we will present the results of finite element simulations of filament produced discharge plasma and RF plasma. A spiral antenna at 13.5 MHz is used in the second method. A commercially available FEM software *Comsol Multiphysics* [3] is used to perform the simulations.

References :

[1] Plasma etching in a multipolar discharge, J. Appl. Phys. **57**, p 1638 (1985)

[2] Characteristics of a multidipole ion source, Rev. Sci. Instrum. **49**, p 321 (1978)

[2] *Comsol Multiphysics* http://www.comsol.com/

Radiation Reaction in Relativistic Quantum Plasma

Priya Mishra and Punit Kumar

Department of physics, University of Lucknow, Lucknow-226007, India

E-mail: priya41993m@gmail.com

Abstract

Plasma-based radiation sources play a leading role in pure science and in emerging technologies. Other important plasma-based radiation sources are light sources driven by laser-plasma interactions and glow discharges. It also covers the fundamental and applied aspects of laser–plasma accelerators, manipulating high-intensity laser pulses, and plasma mirrors. These processes have a significant role in advanced physical events such as laser fusion, X-ray lasers, charged particle acceleration, and optical harmonic generation. Successive generations of coherent radiation sources based on non-neutral plasmas (such as FELs) have been developed providing radiations with higher tunability. In laser plasma interactions, if the laser intensity is strong enough or the plasma is highly dense, quantum effects play a significant role. Recently, there has been a great deal of interest in investigating the properties of high density quantum plasmas. Due to the richness of phenomena encountered in quantum plasmas, theoretical physicists have experienced the multiple characters of the quantum plasma manifestations and have suggested the use of different theoretical models and approaches that have revealed interesting connections between theory and the experimental evidence.

In this paper, using quantum electro dynamical approach a set of relativistic kinetic equations considering spin +1/2 and -1/2 are derived. Quantum electro dynamical properties are explicit for energy ranges in this model which also includes effects accentuated by spin. Derivation of least action for this particular case defines constraints of the system. Feynman time slices technique has been used to consider the evolution of the dynamics. Each step gives linear evolution. Each of this when summed together even though they themselves are linear, give complete description of non linear phenomenon when interacting with lasers. It is seen that model agrees with earlier derived results for non relativistic limits by other models. The model is used to study interaction of lasers with strong but varying amplitude electric field. Effects like radiation reaction and Bremsstrahlung are included too. Model is applicable in all regimes of speed and laser strengths in quantum plasma.

Polarization of Dust Acoustic Waves in Quantum Plasma

Aakanksha Singh and Punit Kumar

Department of physics, University of Lucknow, Lucknow-226007, India

E-mail : aakankshasingh490@gmail.com

Abstract

The kappa distribution occurred almost permanently when dealing with particle distributions in plasmas encountered in space [1-4]. It was also inferred from cosmic ray spectra [5,6], extended into the relativistic domain, in the solar wind [7], near shocks [8], and in the heliosphere in general [9]. Various applications to statistical probabilities in correlated systems have been reviewed as well [10]. It thus seems to represent a general distribution function in physical systems which in theory have been identified as obeying some kind of internal correlations. It has been observed that quantum theory at low temperatures suppresses correlations of the Fokker□Planck kind, which cause the evolution of non-Gaussian tails on the distribution. Very recently, The quantum version of Olbert□s kappa distribution applicable to fermions has been obtained [11].

In the present paper, we investigate the effects of polarization forces on the characteristics of the linear and nonlinear dust acoustics waves in quantum plasma. The model equations incorporating the effects of polarization and quantum forces have been constructed and the linear dispersion of DAWs in this plasma system have been derived. The small but finite amplitude dust acoustic solitary structures in quantum plasma are investigated based on KdV equation by reductive perturbation method.

References

[1] G. Livadiotis, Kappa Distributions: Theory and Applications in Plasmas. Amsterdam, NL, Elsevier (2017).

[2] C. M. Espinoza et al, Geophys. Res. Lett. **45**, 6362 (2018).

[3] I. P. Kirpichev and E. E. Antonova, Astrophys. J **891**, 35 (2020).

[4] A. V. Eyelade et al, Astrophys. J. Supp. Ser **253**, 34 (2021).

[5] R. Schlickeiser, Cosmic Ray Astrophysics, Springer (2002).

[6] R. A. Treumann and W. Baumjohann, Astrophys. Space Sci. **363**, 37 (2018).

[7] G. Livadiotis, M. I. Desai and L. B. Wilson, Astrophys. J. **853**, 142 (2018).

[8] J. P. Eastwood et al, The Foreshock. Space Sci Rev **118**, 41 (2005).

[9] H. Fichtner et al, Astrophys. J. **901**, 76 (2020).

[10] K. Scherer et al, Ast. Soc **497**,1738 (2020).

[11] R. A. Treumann and W. Baumjohann, Frontiers in Phys. **9**, 672836 (2021).

Nonlinear Effect on Plasma Waves Observed by Fluid Simulation Using LCPFCT Algorithm

Gaurav Kumar[1], Hitendra K. Malik[2]

Plasma Waves and Particle Acceleration Laboratory, Department of Physics, Indian Institute of Technology Delhi, New Delhi, India

Email: (1) gauravkmr909@gmail.com, (2) hkmalik@physics.iitd.ac.in

Abstract

Several phenomena in plasmas rely on the excitation of plasma waves. The study of these waves is an important topic with regard to the laser-plasma interaction [1] and soliton generation [2]. However, several properties change, and the behaviour is altered when one considers a nonlinear regime [3, 4].

In the present work, using the LCPFCT Algorithm, the plasma waves in linear and nonlinear regimes have been studied considering 1-D fluid simulations. In the linear regime, the simulation results are similar to the theoretical results. However, when the perturbation field's amplitude increases, nonlinearity comes into the picture, and the plasma wave form is disturbed, and the dispersion curve does not obey the usual dispersion relation. Further increase in the field' amplitude leads to the wave breaking. The point of breaking depends on the magnitude of the field's amplitude. By comparing the measured and calculated density and field profiles, we can estimate the plasma properties. Our study puts light on the basic nonlinear mechanisms involved in a widely used configuration of induction plasma reactors [5] and soliton formation [3].

References:

[1] Malik, H.K. (2021). *Laser-Matter Interaction for Radiation and Energy* (Ist Ed.). CRC Press.
[2] Phys. Lett. A, 365, p 224-230, (2007).
[3] Chen, F. F. (1984). *Introduction to plasma physics and controlled fusion* (Vol. 1, pp. 19-51). New York: Plenum press.
[4] Boyd, T. J., Boyd, T. J. M., & Sanderson, J. J. (2003). *The Physics of Plasmas*. Cambridge University Press.
[5] Phys. Plasmas, 6, p 1804-1812, (1999).

Impact of Doubly-ionized Ions on Rayleigh-Taylor Instability in a Hall Thruster Plasma

Dhananjay Verma* and Hitendra K. Malik

Plasma Science and Technology Laboratory, Department of Physics, Indian Institute of Technology Delhi, New Delhi – 110016, India

*E-mail : dhananjayverma3510@gmail.com

Abstract

Hall thrusters are being used across the globe in governments and commercial satellites for orbital adjustment. These thrusters use a magnetic field to trap the electrons, which are used to ionize the fuel (gas), and these ionized gas atoms are accelerated using an axial electric field to produce the desired thrust [1]. These thrusters are one of the best space propulsion technologies available due to their high specific impulse and for not having any limitation on the maximum ion current, but anomalous electron transport across the magnetic field reduces the efficiency of the thrusters. Plasma instability plays a significant role in the transport of the electrons along the thruster channel [2]. The magnetic trapping of the electrons in the thruster channel leads to a density gradient which causes Rayleigh-Taylor instability. Since ions provide the restoring force to the electrons, the increased ion charge will definitely modify the properties of these unstable waves and electron transport and, thus, the thruster's efficiency.

In the current article, we use a three-fluid model with the continuity equation and equation of motion to investigate the effect of doubly-ionized ions on the growth rate of the instability propagating in the azimuthal direction. The behavior of the oscillation's frequency with the wave number and multi-ionized ions density are evaluated. The growth rate is found to change with the density of doubly-ionized ions and drift velocity of the electrons.

The plasma turbulence in the Hall thrusters' channel not only affects the efficiency in the form of electron's anomalous transport but also affects the local electric field in the thruster channel, which further affects the wall erosion rate and results in shorter life span of the thruster and the energy dissipated on the wall, resulting in a further decrease in the efficiency [3, 4]. With the help of the current study, the plasma parameters can be optimized for maximum efficiency and larger life span of the thruster.

References :

[1] J. Appl. Phys., **121**, 011101, (2017).

[2] Phys. Plasmas, **27**, 032301, (2020).

[3] Phys. Plasmas, **25**, 072110, (2018).

[4] Phys. Plasmas, **10**, p 3397-3409, (2003).

The effect of racetrack position on plasma characteristics in RF magnetron discharge

Dr. Hemen Kakati

Nalbari College, Nalbari, Assam, Pin-781335

E-mail : hemenkakati@gmail.com

Abstract

In magnetron plasma the racetrack position is very important as it controls the plasma characteristics around it [1]. A complete spatial variation of ion density and electron temperature is studied in the plasma with the help of cylindrical Langmuir probe. In the near-target region, the electron temperature and ion density shows maximum value corresponding to the racetrack position. The ion density is found to increase with the increase of pressure and power. The electron temperature is found to decrease with the increase of pressure whereas increases with the increase of power. Emissive probe is used to study the radial variation of sheath characteristics. It is seen that the plasma potential is different at different radial positions. From the sheath characteristics, the sheath thickness and the average sheath electric field is measured. Both the sheath thickness and average sheath electric field are found to have maximum value corresponding to the racetrack position which is an important criterion for effective sputtering to take place.

References

[1] Investigation of ExB rotation…., J. Phys. D: Appl. Phys. **40,** p 6865 – 6872, (2007).

EFFECT OF CONNECTION LENGTH ON PLASMA DYNAMICS IN A SIMPLE MAGNETIZED TORUS

Prince Alex*+, Ruggero Barni*, Claudia Riccardi*

Department of Physics, University of Milan-Bicocca, Italy

Department of Physics, St.Joseph's College, Devagiri, Calicut, Kerala

princealexanderm@gmail.com

Abstract

A simply magnetized device (SMT) is a device in which plasma is confined purely by toroidal field. The cross-field drift of particles arising from the charge polarization is the major loss channel in the device, together, the lack of rotational transform prevents the system to be in MHD equilibrium. Whereas a quasi-stationary equilibrium can be realized by applying a vertical field together with the toroidal field or in other words, reducing the connection length $L_c = 2a\left(\frac{B_\varphi}{B_z}\right)$ from infinity to finite values. Different regimes of operation is identified when the applied vertical field was raised above 4 G and below 4G. Dynamics of plasma state under different connection length or applied vertical field is analyzed using time averaged measurements and conditional averaging techniques. Effect of vertical field on intermittent turbulent fluctuations or generally known as blobs are analyzed.

References

[1] Prince Alex et al, J. Phys. Commun. 6, 015010 (2022).

[2] R. Barni, S. Caldirola, L. Fattorini, and C. Riccardi, Physics of Plasmas 24, 032306 (2017).

Electromagnetic Simulation of Microwave Coupling to Resonant Plasma Cavity with ECR Magnetic Field Configuration

*Manish Pathak[1,2], and S. K. Jain[1]

Proton Accelerator Group

[1]*Raja Ramanna Centre for Advanced Technology, Indore – 452 013, India*

[2]*Homi Bhabha National Institute, Anushakti Nagar, HBNI, Mumbai – 400 094, India*

*E-mail : mkpathak@rrcat.gov.in

Abstract

The sub-systems of high power pulsed proton linac are being developed at RRCAT, Indore. In this direction, the first step is to build a high current pulsed proton source as an injector. The electron cyclotron resonance (ECR) source is being widely used as proton current source in CW mode as well as pulsed mode [1]. An ECR ion source has been developed and 8 mA proton current up to 35 keV beam energy has been extracted. To understand the resonant microwave power absorption in the ECR surface by electrons and also to build a new high current ECR proton source, an electromagnetic simulation study of microwave coupling to resonant plasma cavity at 2450 MHz frequency with ECR magnetic field configuration has been carried out using COMSOL® multiphysics software [2,3]. In this exercise, first the static magnetic field using single solenoid coil was simulated and optimized to achieve the ECR resonant magnetic field. The simulated static magnetic field was applied to resonant plasma cavity to observe the behavior of microwave coupling. It was found that the microwave power was resonantly absorbed and created the plasma. The plasma density achieved is nearly two times higher than the critical density (7.46×10^{10} cm^{-3}). There are various methods to launch the microwave power to resonant plasma cavity like open ended waveguide, open ended waveguide with helical and slotted antenna, coaxial line, tapered waveguide, and ridged waveguide with varying ridged sections. Presently to validate the physics and to understand the microwave absorption under ECR resonant surface, the simulation was carried out with open ended waveguide.

References:

[1]H. M. Kewlani, S. H. Gharat, J. V. Mathew, S. V. L. S. Rao, P. Roychowdhary, and B. Dikshit, "Experimental study of pulsed ion beam generated by different pulsing topology in 2.45 GHz ECR proton source", Journal of Instrumentation, Volume 16, October 2021, P10018

[2] http://www.comsol.co.in, COMSOL Multiphysics Software

[3] www.lxcat.laplace.univtlse.fr/cross_sec_download.php

Laser-induced Photodetachment for the negative ions detection using Hairpin probe into the SPIN-eX Plasma device

E. Nageswara Rao, Pawandeep Singh, D. Swati, A. K. Panday, Y. Patil and Shantanu Karkari*

Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat

E-mail: skarkari@ipr.res.in

Abstract

Laser photodetachment is used to determine the negative ion density (n_-) in a 13.56 MHz rf discharge in oxygen plasma [1, 2]. The role of the laser pulse is to supply photon energy to knock the electrons from the negative ions, hence converting the negative ions into electron neutral pairs. The newly created electrons are then detected using electrostatic probe placed inside the beam path. Laser-induced photodetachment experiments were performed using pulsed Nd:YAG (EKSPLA NL300) laser light with pulse width of ~6 ns at 532 nm in SPIN-eX (Stimulated phenomena in negative ion experiments) device. Time resolved photodetachment data were recorded using a combination of pulsed laser and a resonance hairpin probe at different RF powers and gas pressures. In the results, the electron density (N_e) increased rapidly from 1 to 3 microseconds (μs) and fall to the background level in several microseconds. The absolute densities of negative ions (O_2^-, O^- and O_3^-) are measured in oxygen plasma. The electronegativity ($\alpha=n_-/n_e$) plotted was a function of the laser pulse energies when laser operated at 532 nm. We present the n_e, n_- and α values of plasma at different RF powers (10W, 20W, 40W, 60W and 80W) and gas pressures (0.33 Pa, 1 Pa, 3 Pa and 5 Pa) with laser flux [3].

References:

[1] J. Conway, N. Sirse, S. K. Karkari and M. M. Turner, *Plasma Sources Sci. and Technol.* **19,** 065002 (2010).
[2] M. Hasani, Z. Marvi and J. Beckers, *J. Phys. D: Appl. Phys.,* **54,** 495202 (2021).
[3] Pawandeep Sing, Swati and S. K. Karkari, *J. Phys. D: Appl. Phys.,* **55,** 235201 (2022).

Scheme for microwave mode excitations to have different effective angle of incidences in SYMPLE

Anitha V. P.[1,2] and Priyavandna J. Rathod[1,2]

1. *Institute for Plasma Research, Bhat, Gandhinagar – 382428*
2. *Homi bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra - 400094*

E-mail: anitha@ipr.res.in

Abstract

It is well known that low intensity (~ a few mW – a few W) electromagnetic (e.m.) waves incident upon an unmagnetized over-dense plasma (plasma freq. $f_p > f_{wave}$) undergo near perfect reflection at the wave plasma interface. However, when the intensity is high enough such that the wave pressure $\frac{1}{2}\varepsilon_o E^2_{wave} \sim n_e k T_e$ (E_{wave} is the wave electric field, n_e is the plasma electron density, T_e electron temperature), several interesting wave – plasma interactions lead to considerable absorption of wave energy in plasma. The underlying physics has implications in ionospheric modifications and in inertial fusion involving laser - plasma interactions.

There exist enormous theoretical and simulation works in this field though experimental studies are relatively limited due to limited availability of required resources. Experiments require power of the interacting wave to be ~ a few MW – a few GW to ensure large E_{wave} at the interaction layer. Further, E_{wave} should have a component parallel to the axial n_e gradient (∇n). The criteria to be met by the plasma include, i. high enough n_e, ii. scale length of ∇n, $L_n \sim \lambda_{wave}$ at interaction regime, iii. a uniform axial extent of n_e appropriate to study the propagation of fast electrons and iv. a uniform radial n_e extent to cover a few instability wavelengths. In case of laser – plasma experiments, the condition of E_{wave} parallel to ∇n has been met by using a P- polarized laser beam obliquely incident on plasma, enabling studies on wave absorption vs angle of incidence θ. These experiments however face diagnostic challenges due to the very small (~ a few μm) scale lengths and timescales (~ fs) of instabilities.

Experiments aiming at investigating e.m. wave interaction with plasma has been initiated in our laboratory using high power microwave (HPM) – plasma interactions, in SYMPLE[1,2] (SYstem for Microwave PLasma Experiments). The experiments form a frequency scaled-down investigation of laser-plasma studies whereby the diagnostic constrains is made less stringent, as the instability scale lengths (a few cms) and the time scales (a few ns) will be larger. In most of the existing literature on microwave-plasma interaction, the condition E_{wave} parallel to ∇n is achieved by relying on the wave divergence from finite size excitors, and choosing appropriate locations (off-axis) of the cylindrical plasma where the wave incidence is assumed oblique. In SYMPLE, the condition of parallel E_{wave} is attained by using a TE – TM mode converter and ensuring TM mode in the cylindrical plasma chamber. The location in the plasma where the relative permittivity ε_r satisfies cut-off condition depends on the eigen mode excited. Treating this ε_r as analogous to $(\sin\theta)^2$ of laser-plasma experiments, a unique scheme is proposed in SYMPLE wherein, by exciting different eigen modes of HPM, a situation analogous to varying angle of incidence in laser-plasma experiments can be brought in.

Experimental system of SYMPLE showing results on excitation of microwave with E_{wave} parallel to ∇n, as well as the proposed scheme supported by theoretical estimates demonstrating that excitation of different modes of microwave to plasma can be treated as analogous to varying angle of incidence in wave-plasma experiments involving oblique incidence, are presented here.

References

1. Developmental aspects of microwave plasma interaction experiments: Phase-1, Anitha V P, Priyavandana J Rathod, Raj Singh and D V Giri, IEEE Transactions on Plasma Science, 44, 2226-2231(2016)
2. A washer-gun plasma system for microwave plasma interaction experiments, Anitha V P, Priyavandana J Rathod, Jayesh Raval, Renu Bahl and Y C Saxena, Rev. Sci. Instrum. **90**, 013502 (2019)

CHARACTERISTICS OF ACTIVE MAGNETIZED PLASMA SHEATH IN THE PRESENCE OF NON MAXWELLIAN SOURCE ELECTRON

Sudan Dhakal[1], Suresh Basnet[1,2], and Raju Khanal[2]

[1]*Department of Physics, GoldenGate International College, Tribhuvan University, Battisputali, Kathmandu, Nepal*

[2]*Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal*

E-mail: sudandhakal49@gmail.com

Abstract

The characteristics of magnetized plasma sheath in the presence of two temperature groups of electrons: secondary hot and primary cold electrons have been investigated using fluid model. The secondary hot electrons are considered to be source electrons. The compiled set of fluid equations are solved for given initial condition using Runge-Kutta method. The obtained results show that the concentration of secondary hot source electron significantly affects the various plasma sheath parameters. The electric potential is monotonically increased towards the wall; however, it is found to be decreased for the increase in the hot source electrons. The particle densities decrease towards the wall, but the decreasing rate of electrons is faster than that of positive ions. For the increase in concentration of hot source electrons, the density of particles reaching at the wall increases. The peak value appears on the space charge density decreases with the increase in hot source electrons and also shifts towards the sheath edge. Due to sharp gradient of electric potential in the sheath region, the positive ions accelerate towards the wall and its magnitude decreases with the increase in concentration of secondary hot source electrons. Moreover, the comparative study of potential profile for two different source electrons shows that the profile is qualitatively similar, but quantitatively different.

References:

[1] W. D. Jones, A. Lee, S. M. Gleman and H. J. Doucet, Phys. Rev. Lett. 35, 1349 (1975).

[2] T. E. Sheridan and J. Goree, Phys. Plasmas 3, 2796 (1991).

Parametric Instability in Forced Anharmonic Oscillator Model for Plasma Instability.

Jayaprakash K[1] Saravanan A [2] Suraj Kumar Sinha[3]

[1]*Scool of Science and Humanities Department of Physics, Veltech University, Chennai-62.*

[2]*Dept of physics, Sikkim Manipal University, Majitar, East Sikkim, Sikkim-737136.*

[3]*Department of Physics, Pondicherry University, Puducherry -14.*

E-mail : jprakashplasmaphysics@gmail.com

Abstract

Parametric Instability in Forced Anharmonic Oscillator (FAHO) description of plasma is used to understand the Floating Potential Oscillation (FPO) in glow discharge plasma. The FPO is found to route to multiple transitions from periodic -to- chaotic nature. Numerically generated time series data of FPO, and its parametric instability has been analyzed, with help of Phase-space, FFT, and Largest Lyapunov Exponent. The aforementioned nonlinear characterization techniques are used to understand parametric instability that leads to chaotic phenomena, in low temperature plasma systems, and double layer evaluations. FAHO has been a key for understanding the complex nature of many astrophysical, biological systems.

References:

[1] Nonlinear dynamics of plasma oscillations modeled by an anharmonic oscillator Physics of plasmas 15 (2008).

[2] Doubly forced anharmonic oscillator model for floating potential fluctuations in DC glow discharge plasma, Phys. Lett. A, (2021).**410**, p 127521.

[3] Order–chaos–order–chaos transition and evolution of multiple anodic double layers in glow discharge plasma, Results in Physics 5 (2015) 235–240.

[4] Investigation of complexity dynamics of inverse and normal homoclinic bifurcation in a glow discharge plasma, Physics of Plasmas 21 (3) (2014) 032301.

Study of Plasma Wakefields Generation and Acceleration for Charged Particles using LCODE

Niketan Jakhar[a], Chandan Thakur[a], Sarvesh Kumar[b], Jyotsna Sharma[c], and Manish Kumar Kashyap[a]

[a] *School of Physical Sciences, Jawaharlal Nehru University, New Delhi 110067, India.*

[b] *Inter University Accelerator Center, Aruna Asaf Ali Marg, New Delhi 110067, India.*

[c] *Department of Applied Physics, Amity School of Applied Sciences, Amity University, Gurugram 122413, Haryana, India.*

E-mail : niketa27_sps@jnu.ac.in

Abstract

Plasma wakefield accelerators (PWFA) are the most promising and validated compact designs for charged particle acceleration to very high energy. But their optimization in terms of delivering fine energy spread and efficient acceleration for particle beams is yet to be achieved for usable outcome. Proton beam bunches close to the velocity of light while passing through the plasma, gets self-modulated and create wakefields inside plasma of the order of MV/m[1]. The electron beam is injected into such wakefields and gets accelerated to higher energies within short length of plasma column. We utilise LCODE[2-3] which is a quasistatic 2D3V code for simulating PWFA. The various processes are studied using this code. The simulations results are reported in the paper and compared with the existing literature on AWAKE facility at CERN[4].

References :

[1] K.V. Lotov, Phys. Rev. ST - Accel. Beams 13 (2010) 041301

[2] https://lcode3d.readthedocs.io/en/latest/

[3] www.inp.nsk.su/~lotov/lcode

[4] K. V. Lotov Physics of Plasmas **20**, 083119 (2013).

EFFECT OF A FLOATING RING ON THE ATMOSPHERIC PRESSURE PLASMA JET DISCHARGE MECHANISM AND REACTIVE SPECIES GENERATION

Radhika T. P.[1,a], Satyananda Kar[1,b]

[1]*Department of Energy Science and Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi – 110016*

Email: [a] radhikamanojtp1@gmail.com, [b] satyananda@dese.iitd.ac.in

Atmospheric pressure plasma jets (APPJ) offer the practical capability to provide plasma that is not spatially bound or confined by electrodes. And they attract special research interest mainly due to their capability to produce reactive Oxygen (·OH, ·O, ·H, ·HO2, O2) and Nitrogen (NO2, NO3, ·NO) species and are the best choice for treating liquids and heat-sensitive materials [1,2]. Considering the practical applicability of APPJs we need a better tool for externally tuning the plasma jet parameters according to our practical requirements. Extensive research has been done so far on multielectrode plasma jet systems and the results show that there are variations in the plasma parameters with multielectrode systems. We are using a conducting floating ring as a tool to tune the dynamics of the system by guiding the charged particles.

A Pyrex glass tube employing a pin-to-ring electrode configuration was used as the reactor and the plasma ignited using a 13.56MHz RF power supply connected to the plasma reactor through a matching network (Feed gas – Ar 3lpm). A concentric copper ring was placed between the ground electrode and nozzle at a fixed distance from the ground electrode. And noted the variation in the effective plasma jet length, and gas temperature for different applied power values in the presence of floating rings of different widths. Reactive Oxygen and Nitrogen Species (RONS) concentration and distribution were estimated from the Optical emission spectrum in 200-900nm obtained at different positions of the Plasma jet. The plasma jet has a cross-field electrode configuration and observed that the applied power needed for the plasma jet to cross the nozzle decreases in the presence of a floating ring. The threshold power needed for the jet to cross the nozzle dropped from 34 to 28W and the maximum jet length increased from 22 to 26mm with a floating ring of width 10mm. And this trend is in contrast to what was observed for a plasma jet with linear-field electrode configuration [3]. Temperature measurements show that the gas temperature increases and the RONS concentration have increased in the main discharge region in the presence of a floating ring. The above results show that the presence of a floating ring after the ground electrode can improve the short jet length of a plasma jet with a cross-field electrode configuration by guiding electrons in the axial direction. The improved jet length which offers increased air interaction and increased ionization rate suggests this system as a better candidate for treating liquids and biological targets that cannot withstand a vacuum environment.

References :

[1] Atmospheric pressure plasma jets: an overview of devices and new directions, *Plasma*

Sources Science and Technology 24.6 (2015): 064001.

[2] On atmospheric-pressure non-equilibrium plasma jets and plasma bullets, *Plasma Sources Science and Technology* 21.3 (2012): 034005.

[3] Effect of external electric and magnetic field on propagation of atmospheric pressure plasma jet, *Physics of Plasmas* 24.10 (2017): 103512.

Pulsed afterglow plasma for studies on electron magneto-hydrodynamic structures

Ambesh Kumari, Kushagra Nigam, G Ravi

Institute for Plasma Research, Gandhinagar, Gujarat, India – 382428
Homi Bhabha National Institute, Anushaktinagar, Mumbai, India – 400094

E-mail: ambesh.kumari@ipr.res.in

Abstract

The electron magneto-hydrodynamic (EMHD) regime of plasma is characterized by such spatial and temporal scales that electrons are fully magnetized and ions un-magnetized [1]. Excitation of electron vortices, which are exact nonlinear solutions of the EMHD equation, is possible only if extremely large amplitude perturbation of spatial dimension of the order or less than the natural scale length, the electron skin depth (c/ω_{pe}) is formed in the absence of any external magnetic field. The presence of such vortices has been predicted by several theoretical [2] and computational works; however, no experimental proof exists till date. How this large amplitude perturbation propagates in the plasma will depend on various physical processes such as formation of induced and space charge electric fields, Hall currents etc. In order to launch / excite such structures in the laboratory, moderately high density plasma of dimensions several times the natural scale length is required to be produced. This in turn results in a trade-off between plasma density and dimensions. Our calculations show that this density should be of in the range of 10^{10} – 10^{11} cm^{-3}. In our device (1.5 m length and 0.5 m diam), the plasma is produced using a multi-cusp multi-filamentary plasma source where the magnets are immersed in the cooling lines. The multi-cusp arrangement itself is novel and results in producing plasma in the range 10^{10} – 10^{11} cm^{-3} even in the absence of background magnetic field. The plasma is of low temperature (1 – 5 eV), pulsed and uniform (10 – 20 cm radial and 50 – 60 cm axial). The plasma density is $\approx 10^{11}$ cm^{-3} in the main glow and $3 - 5 \times 10^{10}$ cm^{-3} in the afterglow. It is unbounded from the viewpoint of the natural scale length. The afterglow plasma is found to be suitable for the EMHD experiments.

References:

[1] S. Kingsep, K. V. Chukbar, and V. V. Yankov, in Reviews of Plasma Physics, edited by M. A. Leontovich, Consultants Bureau, New York, **16**, pp. 243. (1990).
[2] M. B. Isichenko and A. M. Marnachev, Sov. Phys. JETP **66** (4), pp. 702 (1987)

KINETIC SIMULATION STUDY OF ELECTRON HOLE FORMATION IN HIGHLY MAGNETISED, ONE-DIMENSIONAL, Q-MACHINE PLASMA

Allen Lobo*, Vinod Kumar Sayal

Sikkim Manipal Institute of Technology, Majitar, East Sikkim – 737136

*Email: allen_20211084@smit.smu.edu.in

Abstract

The formation of stable, solitary phase-space electron holes in collision-less plasmas has been demonstrated experimentally and via simulation by many authors [1], [2], [3], [4], [5]. This phenomena is explained by the growth of a particle-trapping, bell-shaped potential [6] formed by introducing a localized external excitation in the plasma. In the following work, we have analyzed the formation of such phase-space vortices in a cylindrically confined plasma using a kinetic simulation resembling the experiment performed in a Q-machine [2]. We have employed reflecting boundary conditions and the splitting scheme [7] for numerically integrating the Vlasov-Poisson equations. We observe the growth and formation of solitary electron holes (SEH) by introducing an external electric field pulse to generate two-stream like conditions in a defined region of the plasma and have explored the range of the pulse amplitude and spatial width suitable for the formation of a single SEH.

References:

[1] One-, two-, and three-dimensional numerical simulation of two-beam plasmas, Phys. Rev. Lett., vol. 23, no. 19, p. 1087 (1969)

[2] Formation and coalescence of electron solitary holes, Phys. Rev. Lett., vol. 42, no. 8, p. 501, (1979)

[3] Computer simulation of the formation of langmuir solitons and holes in a cylindrical magnetized plasma column, Riso Report, no. 82 (1978)

[4] Electron phase space holes as localized BGK solutions, Phys. Scr., vol. 30, no. 1, pp. 73–77, (1984)

[5] Ultrafast electron holes in plasma phase space dynamics, Sci. Rep., vol. 11, pp. 1–9, (2021)

[6] Theory of electron holes , Phys. Scr., vol. 20, no. 3–4, p. 336 (1979)

[7] The integration of the vlasov equation in configuration space, J. Comput. Phys., vol. 22, no. 3, pp. 330–351 (1976)

EVOLUTION OF SOLITONS IN RELATIVISTIC DEGENERATE PAIR PLASMAS

[1]Himanginee Gogoi, [2]Ridip Sarma

[1]Department of Mathematics, D.H.S.Kanoi College, Dibrugarh-786001, Assam, India..

[2]Department of Mathematics, Assam Don Bosco University, Tapesia Campus, Sonapur-782402, India

E-mail: gogoihimanginee@gmail.com

Abstract

We have studied the nonlinear propagation of ion-acoustic waves (IAWs) in a collisionless magnetized plasma composed of strongly coupled pair of ions and relativistic degenerate inertia-less electrons and positrons. Starting from a generalized visco-elastic hydrodynamic model for both positive and negative ions and using the reductive perturbation technique, a (3+1)-dimensional Zakharov-Kuznetsov (ZK) equation is derived which governs the evolution of weakly nonlinear IAWs in a multi-component magneto-pair-plasma. A linear stability analysis of a soliton solution is performed [1-3], following which different stable and unstable regions are obtained for various ranges of values of the degeneracy parameter, the negative ion concentration, and the magnetic field strength. It is shown that the growth rate of instability is reduced by the effects of the degeneracy of electrons and positrons, and the obliqueness of propagating solitons in strongly coupled regimes. The results should be useful for understanding the existence and stability of ion-acoustic solitons in strongly coupled dense astrophysical objects.

References :

[1] M. A. Allen and G. Rowlands., J. Plasma Phys. **50** 413 (1993).
[2] M. A. Allen and G. Rowlands., J. Plasma Phys. **53** 63 (1995).
[3] S. Roy and A. P. Misra., J. Plasma Phys. **86**, 905860611 (2020).

Ion-acoustic double layers in negative ion plasmas with two temperature superthermal electrons

Kishan Kumar and M. K. Mishra

Department of Physics, University of Rajasthan, Jaipur - 302004, India

Email: (a) kishanjindal08@gmail.com (b) Mishramukesh105@yahoo.com

Abstract

Arbitrary-amplitude ion-acoustic double layers are investigated with two temperature superthermal electrons in an unmagnetized negative ion plasmas. In this study, we have considered the plasma contains two cold ion species with different masses, ion concentration and charge multiplicity, and two superthermal (non-Maxwellian) electrons. The energy integral equation has been derived by using the Sagdeev pseudopotential technique. We have investigated that both negative and positive potential double layers can exist in the selected domain of Mach number. The formation of double layers is analysed by phase portrait of the dynamic of the plasma system. The plasma system also supports the coexistence of compressive and rarefactive double layers for a selected set of plasma parameters. The present study is focused on ion-acoustic double layers in the D-and F-regime of Earth's ionosphere. Present investigations may be helpful to understand the nonlinear behavior of double layers in space and laboratory plasmas, where negative ions are present with superthermal electrons at two temperatures.

ROLE OF ARGON METASTABLE STATES INSIDE ARGON-NITROGEN RF PLASMA

A. Mukherjee, M. Chakraborty, P.K. Saha

Centre of Plasma Physics-Institute for Plasma Research, Tepesia, Sonapur, Kamrup, Assam 782402, India.

E-mail: atri.mukherjee@cppipr.res.in

Abstract

Nitrogen-argon plasma with varying concentration of argon from 10% to 80% has been investigated experimentally using Langmuir probe (LP) and optical emission spectroscopy (OES) in a radio frequency (RF) discharge of 13.56 MHz. It is observed that in the lower power regime (i.e. around 500 W) the dissociation fraction (DF) of nitrogen molecules as well as the relative fraction of argon metastable states shoot up after the argon percentage crosses 30% mark and stay there with minor fluctuations until argon reaches to 80%. However, at a relatively higher power of 1000 W or more the dissociation fraction rather falls with the increase in argon percentage. The fraction of argon metastable states, in the higher power domain, still closely follows the same trend that of the DF except for argon percentage below 20%.

OES Actinometry has been incorporated in this study to calculate the DF and the dominant emission lines originating from argon 2p-1s transitions have been utilized to obtain the metastable fractions [1,2].

The plasma density and temperature are measured using the LP and they show opposite behaviour with the variation of argon concentration. The plasma density goes up as argon concentration increases whereas the plasma temperature shows a steady decline for the same case. The results are explained in terms of direct electronic collisions and penning dissociation of nitrogen molecules due to argon metastable states. These results can be used to further improve the understanding of Ar-N_2 plasma along with the other pre-existing theoretical models and experimental data with possible applications in physical vapor deposition (PVD) [3] and nitride film deposition in semiconductors [4].

References :

[1] Ionization in inductively coupled argon plasmas studied by optical emission spectroscopy, J. Appl. Phys. **109**, 013306 (2011).
[2] Diagnosis of helicon plasma by local OES, Plasma Sources Sci. Technol. **29**,015018 (2020).
[3] Ionized physical vapor deposition of titanium nitride: A global plasma model, Journal of Applied Physics **91**, 4040 (2002).
[4] Nitrogen dissociation in a low pressure cylindrical ICP discharge studied by actinometry and mass spectrometry, J. Phys. D: Appl. Phys. **38** 4278 (2005).

Linear Plasma Device for Zonal Flow Study

Aritra Tarafder*, Dibyajyoti Bora, and Subir Biswas

Physical Sciences Division, Institute of Advanced Study in Science & Technology (IASST), Paschim Boragaon, Guwahati - 781035, Assam, India

E-mail: tarafderaritra@iasst.res.in, subirb@iasst.gov.in

Abstract

Zonal flows are azimuthally symmetric bands like shear flows, are ubiquitous phenomenon in nature and the laboratory; well-known examples are Jovian belts & atmospheric jet streams [1]. Zonal flows have been observed in magnetic confinement fusion devices like tokamak and stellarator. In those devices, zonal flow is azimuthally symmetric electric field perturbation primarily in the poloidal direction which is constant on the magnetic field surface but rapidly varies in the radial direction. Due to complex geometry and simultaneous arising of various types of wave & instability modes in toroidal plasma devices, studies of zonal flow in a controlled manner in those devices are challenging. A linear plasma device is more suitable for the experimental investigations of zonal flow in a controlled manner. Presently, we are working to build a linear plasma device in-house at IASST for such studies. Details description of the device will be presented.

References:

[1] PH Diamond et al., Zonal flows in plasma—a review, Plasma Phys. Control. Fusion 47, R35–R161 (2005)

SIMULATION STUDY OF ELECTRON HOLE-PAIR COALESCENCE RESULTING IN THE FORMATION OF A SINGLE HOLE IN COLLISION-LESS PLASMAS

Allen Lobo*, Vinod Kumar Sayal

Sikkim Manipal Institute of Technology, Majitar, East Sikkim – 737136

*Email: allen_20211084@smit.smu.edu.in

Abstract

The coalescing behavior of electron holes was observed as early as 1969[1] and since then, various numerical experiments and theoretical works have been conducted to produce and study this phenomenon[2],[3],[4],[5],[6],[7]. In the following work, we have investigated the formation of electron hole pair using various external excitation pulses. We have explored the parameters of the pulses such as its amplitude and width to produce coalescence of the electron hole pair into one stable electron hole. We have investigated the stability of this electron hole and its motion by introducing an asymmetric potential[8] pulse in the plasma. We explore the factors influencing the phase-space speed of these stable electron holes and their negative-mass like behavior[3] during their coalescence. We have employed vlasov simulation using the splitting scheme[9] and have used a cylindrically confined plasma with reflecting boundaries.

References:

[1] One-, two-, and three-dimensional numerical simulation of two-Beam plasmas, Phys. Rev. Lett., vol. 23, no. 19, pp. 1087–1090 (1969)

[2] Interaction between electron holes in a strongly magnetized plasma, Phys. Lett. A, vol. 80, no. 1, pp. 23–25 (1980)

[3] Theory of phase-space density holes, Phys. Fluids, vol. 25, no. 2, pp. 277–289 (1982)

[4] Growth of phase-space density holes, Phys. fluids, vol. 26, no. 9, pp. 2460–2481 (1983)

[5] Formation and coalescence of electron solitary holes, Phys. Rev. Lett., vol. 42, no. 8, p. 501 (1979)

[6] Electron holes, ion holes and double layers: Electrostatic phase space structures in theory and experiment, Phys. Rep., vol. 140, no. 3, pp. 161–191 (1986)

[7] Electron phase space holes as localized BGK solutions, Phys. Scr., vol. 30, no. 1, pp. 73–77 (1984)

[8] Observations of solitary structures in a magnetized, plasma loaded waveguide, Phys. Scr., vol. 20, no. 3–4, p. 328, (1979)

[9] The integration of the vlasov equation in configuration space, J. Comput. Phys., vol. 22, no. 3, pp. 330–351 (1976)

OBSERVATION OF ELECTRON TEMPERATURE ANISOTROPY IN THE DOUBLE PLASMA DEVICE

Jocelyn Sangma[1], A. R. Baitha[2], M. Chakraborty[1]

[1] Centre of Plasma Physics- Institute for Plasma Research (CPP-IPR), Nazirakhat, Sonapur, Assam-782402
[2] Department of Physics, School of Basic Sciences, Manipal University Jaipur, Dehmi Kalan, Jaipur, Rajasthan-303007

E-mail : jocelyn.sangma@cppipr.res.in

Abstract

The physical processes that regulate the plasma properties include plasma instabilities. Amongst various instabilities, there are also those that are driven by temperature anisotropy, which is the ratio of perpendicular ($T_{\perp}$) to the parallel temperature ($T_{//}$) with respect to the ambient magnetic field. The Chew-Goldberger-Low (CGL) relations [1, 2] predict that plasma should produce mirror instability for the case of perpendicular anisotropy ($T_{\perp}/T_{//} > 1$) and the oblique firehose instability for parallel anisotropy ($T_{\perp}/T_{//} < 1$). A lot of research has been carried out in both laboratory and space plasmas to understand the physics associated with plasma instabilities and temperature anisotropy. Yet the physical processes in such cases are many and even strange and not fully understood. Hence, the present motivation to investigate the temperature anisotropy in a negative ion source type configuration in a double plasma device, where charged particle transport across a transverse magnetic field (TMF), popularly known as the magnetic filter, [3].

In this regard, the study of electron temperature anisotropy has been carried out in the magnetic filter region. A planar Langmuir probe measured the electron temperature in the parallel and perpendicular direction to the magnetic filter field. The measurements taken by changing experimental parameters such as pressure, filament current and discharge voltage reveals the existence of temperature anisotropy in the magnetic filter region which could influence plasma stability and have effect on plasma diffusion. All these results will be presented at the conference.

References:

[1] G. F. Chew, M. L. Goldberger, and F. E. Low, Proc. R. Soc. A 236, 112 (1956).
[2] P. Hellinger, P.M. Travnciek, J. C. Kasper, and A. J. Lazarus, Geophys. Res. Lett. 33, L09101 (2006)
[3] B. K. Das, M. Chakraborty and M. Bandyopadhyay, Phys. Plasmas 19, 092104 (2012)

SINGULAR SOLITONS INTERACTION OF QUANTUM ACOUSTIC WAVES WITH DEGENERATE ELECTRONS

[1]Barjinder Kaur, [2]Uday Narayan Ghosh

[1]GNA University, Phagwara,144401,
[2]Munger University, Jamui, Bihar. 811307

[1]kaurbarjinder@gmail.com
[2]unghosh1@rediffmail.com

Abstract

Singular solitons are defined as the solitons bearing singularities created from a hydro dynamical model in its original form by utilizing reductive perturbation techniques (RPT). So far, only a few researches [1], [2] related to singular solitons have been reported. This research work deals with the study of interaction of obliquely propagating quantum acoustic multiple singular solitons in degenerate quantum magnetized plasma comprising of stationary heavy ions along with light ions and quantum electrons in framework of quantum hydrodynamic (QHD) model. Reductive perturbation technique has been adopted to derive the nonlinear evolution equations (NLEEs) viz. Korteweg-de Vries (KdV) and modified Korteweg-de Vries (mKdV) equations and singular soliton solutions are obtained. Further, the analytical multi singular soliton solutions of KdV and mKdV equations are derived by employing the efficiency and interactive approach of the Hirota's Bilinear method [3]. The impact of variation of time on the interaction features of multi singular solitons of both KdV and mKdV equations and their induced phase shifts has been analyzed. Our findings are briefly reviewed in terms of their implications in some space and laboratory plasma scenarios.

References:

[1] R. Roychoudhury, G. C. Das and J. Sharma, Phys. Plasmas. 6, 2725 (1999)
[2] G. C. Das, M. Talukdar, C. Uberoi and N. Sreeshylan, Indian J. Pure and Applied Physics, 37, 798 (1999)
[3] R. Hirota, J. Math. Phys., 14, 810 (1973).

Lattice Ion Vibrations And Electron Waves Coupling Leading Spiky Solitons In Piezoelectric Semiconductor Quantum Plasma

Abhishek Yadav and Punit Kumar

Department of physics, University of Lucknow, Lucknow-226007, India

E-mail : abhishekeffect8@gmail.com

Abstract

Due to drastic miniaturization of semiconductors in electronic devices, the length of doping profile is now of similar length as that of thermal de Broglie wavelength. Thus, the typical quantum effects such as the exchange correlation, the quantum fluctuation due to the density correlation, and the degenerate pressure will play a significant role in the electronic components to be constructed in future. In semiconductor quantum plasmas, the charge carriers obey the Fermi–Dirac distribution instead of Maxwell–Boltzmann distribution. Study of piezoelectric effects, nonlinearities and the plasma effects in semiconductors plays a significant role in countless technological and industrial applications such as in experimental and device fabrication work.

In the present paper, we have studied the coupling between the lattice ion vibrations and electron waves using quantum hydrodynamic model for piezoelectric semiconductor quantum plasma with the inclusion of various quantum effects. This study has been done in linear as well as nonlinear regime. Further, a set of coupled nonlinear equations developed and analyzed numerically by using the physical parameters of n-type piezoelectric semiconductor quantum plasma.

Turbulence Mechanism In Quantum Plasma

Prabhat Singh and Punit Kumar

Department of physics, University of Lucknow, Lucknow-226007, India

E-mail : prabhatps0001@gmail.com

Abstract

Turbulence in plasma plays a significant role in experiments of basic and applied plasma science performed in laboratories around the world. Turbulence is a ubiquitous phenomenon that is responsible for many aspects of plasma dynamics, particularly, structure formation and transport of particles, momentum, and energy. Understanding plasma turbulence and specifically of quantum plasma is of tremendous importance in various areas of plasma physics, including fusion science, planetary science, and astrophysics.

In the present paper, we have studied small-scale turbulence observed in magnetic confinement fusion devices which determines their energy confinement time and thus influences their performance. Structure formation in turbulent quantum plasma is effectively instability in quantum plasma in transient forms. Transition of laminar flow of quantum plasma to fully turbulent quantum plasma is also important for complete understanding of stochastic and non linear dynamics. This transient phase has also been considered. Quantum electrodynamics is used to develop a model describing turbulence mechanism in quantum plasma. Formation and evolution of nonlinear turbulent structures and their transience is considered by kinetic equations. These kinetic equations are developed using QED where conditions of each point are considered by Eulerian approach.

THE EFFECT OF MAGNETIZED QUANTUM PLASMA ON JEANS INSTABILITY

[1]Ashok K. Patidar, [2]Hemlata Joshi, [3]Sonali Patidar, and [4]Ram K. Pensia
[1]*Govt. P. G. College, Mandsaur (M.P.), 458001*
[2]*Govt. College Jeeran, Neemuch (M.P.), 458336*
[3]*School of Studies in Physics, Vikram University, Ujjain (M.P.), 456010*
[4] *Govt. Girl's College Neemach (M.P.), 458441*
[1]corresponding author:ashok.patidar341@gmail.com

Abstract

The influence of quantum plasma on Jeans instability is investigated in the presence of magnetic fields, the dispersion relation considering with parallel and perpendicular direction has shown the stabilizing effect on the growth rate of Jeans instability with moderate temperature high density regime. The graphical illustration is depicted to see the influence of magnetic field on Jeans criteria.

The inclusion of magnetic fields with quantum effect on the motion of a charged particle involves the essential properties of acceleration and the transport of highly ionized particles is important in connection with a well-known application of the confinement of magnetized plasma.

This framework has the potential in astronomical condition to shape the fusion research in shape science plasma such as neutron star, magnetars, white dwarfs which are formed from the collapse of low mass star, less than about 10 time the mass of the Sun.

COMSOL Simulation for the Experimental Study of a Capacitive Coupled Plasma (CCP) Source

Ramesh Kumar and Bibhuti Bhusan Sahu

Multifunctional Plasma Laboratory, Department of Energy Science and Engineering, Indian Institute of Technology, Delhi-110016, India

E-mail: bbsahu@dese.iitd.ac.in

Abstract

Capacitively coupled plasmas (CCPs) are widely used in different sectors like semiconductor processing, thin film etching and deposition, flat panel display, textile, healthcare, and environmental applications, due to their low cost and ability to adapt to large area applications. Particularly, CCPs have found applications as plasma-enhanced chemical vapor deposition (PECVD) due to their ability to produce high plasma density, generate plasma over a larger area, and hence, deposit thin films over a larger area substrate. The control of microstructure and other film properties of thin film is the prime requirement in such plasma-based deposition processes. It is well known that the structure of these films is closely associated with plasma parameters, radicals, and deposition energy in plasma processes. However, the precise control of plasma parameters is still limited and not straightforward due to requirement of various probe and optical diagnostics. Particularly, in CCPs there are various plasma parameters like electron density, electron temperature, and plasma potential, which strongly depend on operating conditions, electrode geometry, gas, and pressures One needs to perform a careful study to investigate the plasma parameters and the mechanism of electron heating in CCPs. In this regard, experimental studies using RF compensated Langmuir probe were earlier carried out to investigate the mechanism of plasma generation in CCPs operated at 13.56 MHZ RF powers. Also, a 1-D COMSOL simulation has been performed to understand the mechanism of electron heating and compare with the experimental data measured for a CCP source. Plasma parameters were characterized at different operating pressures, electrode geometry, and gas temperature. The data clearly shows a close correspondence between the simulation and experiments. The results have the basis for further design of plasma source and experiments.

References :

1. Comparison of plasma excitation, ionization, and energy influx in single and dual frequency capacitive discharges, Phys. Plasmas **23**, p 123504 (2016).
2. Understanding plasma sources, Curr. Sci. **83**, 279-290 (2002).
3. https://www.comsol.com/
4. Radiofrequency discharge benchmark model comparison, Plasma Sources Sci. Technol. 4, 56 (1995).

Plasma Sheath With Two Species Of Positive Ions And Surface Produced Negative Ions

Sutapa Samanta[1], Rakesh Moulick[1*], P. J. Bhuyan[1], and B. J. Saikia[1]

[1]*Centre of Plasma Physics, Institute for Plasma Research, Nazirakhat, Sonapur-782402, Kamrup(M), Assam, India*

E-mail: sutapa.samanta@cppipr.res.in

Abstract

The structure of the sheath has been studied in front of a cesium coated metallic plate using a simple theoretical model. Along with the electrons, the plasma is composed of two species of positive ions, surface produced and volume produced negative ions. The surface negative ions are produced via the coated metallic plate. With a single species of positive ion, the sheath edge potential is multivalued for a specific range of electronegativity (α_0) [1], [2]. Moreover, the positive ion current density tends to grow toward the metallic plate in the presence of surface produced negative ions, as does the sheath potential. However, the behavior is significantly impacted by the presence of an additional species of positive ion. It has been observed that the presence of the additional species of positive ion prevents any variation in the total positive ion current density with respect to the surface production yield (δ). The surface production yield (δ) is the parameter which increments the surface negative ion production based on the positive ion flux. Furthermore, the sheath edge potential is multi-valued only for a single specific range of electronegativity (α_0), for all values of the yield parameter (δ). This may have significant consequences which will be important to consider in the Neutral Beam Injection (NBI) systems.

References :

[1] S. Shah and M. Bandyopadhyay, "Effect of surface produced negative ions on near wall sheath," *Plasma Phys. Control. Fusion*, vol. **51**, no. 3, 2009, doi: 10.1088/0741-3335/51/3/035015.

[2] J. I. Fernández Palop, J. Ballesteros, V. Colomer, M. A. Hernández, and A. Dengra, "Sheath structure in a plane probe inmersed in an electronegative plasma," *J. Appl. Phys.*, vol. **77**, no. 7, pp. 2937–2944, Apr. 1995, doi: 10.1063/1.358709

Analytical and Simulation studies of ion acoustic stationary formations at critical plasma density

Sharry[1], Swarniv Chandra[2], Chinmay Das[3]

[1]Department of Physics, Guru Nanak Dev University, Amritsar, Punjab,143005
[2] Department of Physics, Government General Degree College, Kushmandi, India, 733121.
[3] Department of Mathematics, Kabi Jagadram Roy Govt. General Degree College, India-722143

E-mail : ksharry799@gmail.com

Abstract

In this work, both perturbative and non-perturbative technique have been employed to study the small to large amplitude stationary structure formations and their evolution of ion acoustic waves in a plasma containing degenerate electrons and non-degenerate ions. The expressions for double layers and solitons following the Sagdeev's pseudopotential approach have been derived. Such a stationary structure becomes interesting around the critical density. To study the nonlinear formations around the critical region, the modified Korteweg de–Vries (m-KdV) equation has been obtained and analysis of its parametric dependence has been done. Kink and Gardner solitons have been obtained and parametric dependence is studied. Additionally, the wave-wave interaction and the subsequent phase shifts have been studied with reference to various parameters. Additionally, simulation study for the evolution of these stationary structures is carried out and also the dynamical system study is provided to support our study. These findings will help in laser plasma interactions regarding the relaxation time and the energy context. Short pulse lasers and its applicability in various plasma applications may be predicted on these findings.

References :

[1] Degnan JJ. Optimization of passively q-switched lasers. IEEE journal of quantum electronics.
1995;31(11):1890|1901.
[2] Smith PW. Mode-locking of lasers. Proceedings of the IEEE. 1970;58(9):1342|1357.

SHOCK WAVE IN ANISOTROPIC QUANTIZED MAGNETO PAIR ION PLASMA

Manoj Kumar Deka[1], Deepsikha Mahanta[2], Apul Narayan Dev[3,]

[1]Department of Applied Sciences, Gauhati University,Guwahati,India, 781014
[2]Department of Mathematics, Gauhati University, Guwahati, India 781014
[3]Computer Science and Information Technology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, India 751030

E-mail: [1]manojd143@gmail.com
[2]mahanta2017@gmail.com
[3]apulnarayan@gmail.com

Abstract

The features of shock wave in a quantized magneto plasma under the influence of ionic pressure anisotropy of positive and negative ion collisional plasma is studied with the help of a Burgers' equation, derived using reductive perturbation technique. The governing Burgers' equation is analyzed numerically as the Burgers' equation can't be solved analytically using conventional methodologies due to the presence of collisional term. The initial numerical result shows the development of a monotonic shock in steady state situation whereas in time dependent situation, an initial monotonic shock transforms into an oscillatory shock pattern. Within physically admissible plasma parameters for such plasma environment, the shock potential is found to be rarefactive one. The present investigation may be useful to study the features of shock propagation in astrophysical plasma environment [1-2].

References:

[1] Effect of Pressure Anisotropy on Nonlinear Periodic Waves in a Magnetized Superthermal Electron-Positron-Ion Plasma, Braz.J. of Phys., **49**, p 379-390, (2019)
[2] Wave propagation with degenerate electron–positron in magnetically quantised ion beam plasma, Pramana J. of Phys., **95**, p 1-20 (2021)

The influence of spin force on charge particles in Quantum Plasma

Shiva Shakti Singh[1, 2], Shachi Pachauri[1], Jyoti[3], Kamakhya Prakash Misra[1,*]

[1]Department of Physics, School of Basic Sciences, Manipal University Jaipur, Dehmi Kalan, Jaipur, Rajasthan 303007, India

[2]Department of Physics, S. S. Jain Subodh P.G. (Autonomous) College, Jaipur-302004, India

[3]Department of Physics, Govt College for Women, Gurawara, Haryana-123035, India

**Email: kamakhyaprakash.misra@jaipur.manipal.edu*

Abstract

It is discussed where our understanding of some important linear collective process in degenerate electron [1] quantum plasma currently stands. When electron wave functions overlap, Heisenberg uncertainty principle and Pauli's exclusion principle apply. Tunnelling and the electron degeneracy pressure due to their nature as fermions, electrons are subjected to both a spin force and an electron spin current by the Bohr magneton. Additionally, the creation of quantum magneto hydrodynamics equations [2] are investigated, as well as the impact of an external magnetic field on the plasma wave spectrum. The findings have implications for plasma assisted nanotechnology as well as the dispersion relation for quantum plasma instability [3] (ex: nanophotonics, nanoplasmonics, metallic nanostructure, thin metal film, semiconductor quantum wells, quantum dots etc.)

Keyword: Spin force, Tunnelling, Magneto hydrodynamics, Quantum plasma.

References:

[1] P K Shukla and B. Eliasson,Rev. Mod. Phys.**83**, p 885-906 (2011).

[2]Shiva Shakti Singh, Jyoti and Kamakhya Prakash Misra , Plasma Res. Express **4** ,p 025006(2022).

[3] Gul, Nabi and Rashid Ahmad, Phys. Rev. E **106,** p 025206 (2022).

PROPAGATION OF SPIN SOLITARY WAVE DRIVEN BY ANISOTROPIC ION BEAM IN A QUANTUM MAGNETO PLASMA

Deepsikha Mahanta[1], Manoj Kumar Deka[2], Apul Narayan Dev[3], Jnanjyoti Sarma[4]

[1]Department of Mathematics, Gauhati University, Guwahati, India 781014
[2]Department of Applied Sciences, Gauhati University, Guwahati, India, 781014
[3]Computer Science and Information Technology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, India 751030
[4]Department of Mathematics, Radha Govinda Baruah, College, Guwahati 781025

E-mail : [1]manojd143@gmail.com
[2]mahanta2017@gmail.com
[3]apulnarayan@gmail.com
[4]sjnanjyoti@gmail.com

Abstract

The effect of pressure anisotropy and spin polarization density of electrons on the propagation of solitary waves in a spin polarized degenerate quantum magneto-plasma is studied under the influence of streaming energy of anisotropic ion beams. A Zakharov-Kuznetsov (Z-K) equation for the purpose is derived using the reductive perturbation technique and the effect of different plasma parameters on the solitary wave profile is studied from the steady state solution of Z-K equation. Under the suitable combination of physically admissible parameters, the existence conditions as well as nature of solitary wave propagation in such plasma systems are examined. Study of Mach number reveals a new class of Beam-Beam instability apart from the usual Ion-Ion instability along with different modes, namely Fast beam, Slow beam and Ion acoustic mode of ion beam plasma system. The range of beam velocities for appearance of both Ion-Ion and Beam-Beam instabilities has been examined for different parallel and perpendicular pressure anisotropy value of positive ion and ion beams as well as for different spin polarization ratio of up-spin and down-spin electron[1-2]. It has been observed that the amplitude of the solitary wave is not affected by perpendicular anisotropy while width of solitary waves generated by different ion beam modes is greatly affected perpendicular anisotropic value of positive ion and ion beam.

References :

[1] Supersonic Shock Wave with Landau Quantization in a Relativistic Degenerate Plasma, Chinese Phys. Lett**. 37** 016101(2020)

[2] Normal Modes in the Ion-Beam-Plasma System, Phys. Rev. Lett. 34, 77(1975)

Comparative Study on Degradation of Methylene Blue using Gas Phase and Underwater Radio Frequency Atmospheric Pressure Plasma Jet

Aishik Basu Mallick, Satyananda Kar, Ramesh Narayanan

Department of Energy Science and Engineering, Indian Institute of Technology Delhi, New Delhi-110016

E-mail: esz198524@iitd.ac.in

Abstract

Rapid growth of textile industries has led to an increase in the dye effluents in industrial waste water which can cause severe environmental and health issues. Atmospheric pressure plasma jet is an eco-friendly advanced oxidation process that generates highly reactive oxygen and nitrogen species (RONS) such as $\cdot OH$, O_3, H_2O_2 *etc* which aids in the mineralization of complex molecules into simpler compounds. It is observed that the delivery of an appropriate dose of gas phase $\cdot OH$ radical produced near to the plasma-to-water surface is responsible for breaking stable compounds such as dyes [1]. Operating conditions such as applied power, gas flow, and treatment time affects the production and dose to the targeted region. Decolouration of dye solution is an indication of a loss of chromophore nature of the dye which, in turn, indicates the dissociation of the dye compound.

This study compares the effectiveness of Radio Frequency (RF) atmospheric pressure plasma jet in the degradation of a typical aqueous dye such as methylene blue through two different treatment processes: (i) volume treatment mode (ii) surface treatment mode. In the first process, the plasma plume is produced after the jet is directly immersed into the solution (underwater) whereas in the other process the plasma plume is produced in the gas phase and which is touching the surface of the solution. These experiments were carried out at different applied power for fixed argon flow rate and for varying treatment time. Concentration of methylene blue solution is quantified in terms of absorption spectra analyzed in UV-VIS Spectroscopy at 665nm. The difference in pristine solution and after plasma treatment of dye samples provide the degradation rate achieved by plasma jet. Optical emission spectroscopy of RF atmospheric pressure plasma jet shows the signature of $\cdot OH$ radical present in the plasma plume responsible for dye degradation. It is found that the underwater jet sample degrades faster than that of the sample treated with the gas phase jet for specific power and treatment time. This can be attributed to the fact that faster $\cdot OH$ delivery can be achieved in an underwater jet condition as compared to that of gas phase jet.

References

[1] D. Joshi, G.V. Prakash, S.Z. Ahammad, S. Kar, and T.R. Sreekrishnan, Plasma Sci. Technol. **24**, 105501 (2022).

PARTICLE SIMULATIONS OF TEARING AND SURFACE PRESERVING MODES IN ELECTRON CURRENT LAYERS

[1]Sushmita Mishra, [2]Gurudatt Gaur, and [3]Bhavesh Patel

[1]Institute of Advanced Research, Koba, Gandhinagar, Gujarat – 382 426, India
[2]St. Xavier's (Autonomous) College, Navarangpura, Ahmedabad,Gujarat – 380 009, India
[3]Institute for Plasma Research, Bhat, Gandhinagar, Gujarat – 382 428, India

E-mail : mishra.sushmita0@gmail.com

Abstract

The deformation of magnetic field lines and later on, the reformation of the same has been frequently seen in various scenario of laboratory and astrophysical plasmas. Tearing instability is one of the major belief for the bending of these magnetic field topology in the plasma. There have been rigrous work done to study the instability through different plasma models viz., fluid, particle and hybrid model.

Earlier work [1] shows that the electron current layers are susceptible to tearing and surface preserving Electron Magnetohydrodynamics modes. In this work, we have performed the 2D particle-in-cell (PIC) simulations of the two modes to understand the particle effects, using OSIRIS code [2]. We have considered a tangent hyperbolic profile for equilibrium magnetic field which corresponds to a thin electron current layer. Ions have been chosen to be at rest. To include the second mode, the surface preserving mode, we add a uniform magnetic along the directi0on of equilibrium magnetic field. To understand the particle effects, we have compared the evolution at finite temperature with that at zero temperature (cold plasma limit). The early results show that in the presence of temperature, the growth of the two modes increases. More results are underway.

References :

[1] Gurudatt Gaur and Predhiman Kaw, Physics of Plasmas **23**, 032106 (2016).
[2] Fonseca, R. A., Silva, L. O., Tsung, F. S., Decyk, V. K., Lu, W., Ren, C., ... & Adam, J. C.,
International Conference on Computational Science (pp. 342-351), (2002).

A Two-Fluid Approach To Study The Thrust Performance Of An ECR Thruster Experiment

Subhasish Bag*, Vikrant Saxena

Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110016, India

E-mail : subhasishbag95@gmail.com

Abstract

The concept of magnetized plasma expansion is used for advanced research in the field of electric propulsion. Electrode-less Plasma Thruster (EPT) is the future technology in the domain of electric propulsion where a Magnetic Nozzle (MN) [1] helps to accelerate the plasma by its converging-diverging magnetic field. A magnetic nozzle basically accelerates the ions by converting the internal thermal energy of electrons into the directed kinetic energy of ions.

A Compact Electron Cyclotron Resonance (ECR) Plasma Source (CEPS) [2] has been developed by the Plasma Physics Laboratory (PPL) of IIT Delhi and used for thruster applications [3] where a Magnetic Nozzle (MN) is used. We are interested in modeling the expanding magnetized plasma coming out from the CEPS. We develop a Two-Fluid model for this system to study the thrust generation mechanism and performance improvement in order to understand the experimental observations.

References :

[1] Magnetic nozzles for space plasma thrusters. In J. Leon Shohet, editor, Encyclopedia of Plasma Technology, volume 2, pages 1329–1351. Taylor and Francis, 2016.

[2] Ganguli, A., et al. ``Development of compact electron cyclotron resonance plasma source." 2013 19th IEEE Pulsed Power Conference (PPC). IEEE, 2013.

[3] Ganguli, A., et al. ``Evaluation of compact ECR plasma source for thruster applications." Plasma Sources Science and Technology 28.3 (2019): 035014.

Turbulent Relaxation of Plasmas By Vanishing Nonlinear Transfer

Supratik Banerjee, Arijit Halder and Nandita Pan

Department of Physics, Indian Institute of Technology Kanpur, 208016 India

E-mail : sbanerjee@iitk.ac.in

Abstract

The alignment between the magnetic field ***b*** and the current density ***j*** in the cosmic plasmas has been a topic of extensive research in the last seventy years. Such type of aligned states, commonly known as Beltrami-Taylor states can be achieved by minimizing the quickly varying quantities keeping the slowly varying inviscid invariants as approximately constants [1]. Similar conclusion can be drawn for the alignment between the velocity **u** and vorticity **w** in neutral fluids**.** However, it has been observed that the relaxed state of an MHD plasma is rather given by a force-balanced minimum energy state supporting a non-zero pressure gradient ∇P and the relaxed state is indeed given by $\boldsymbol{j} \times \boldsymbol{b} = \nabla P$. Similar type of relaxed states are also found for hydrodynamics where the final state is given by $\mathbf{u} \times \mathbf{w} = \nabla P$, with **u** and **w** being the velocity and the vorticity vectors respectively. Such relaxed states supporting the pressure gradients can also be obtained as a different class of solution of a richer multi-curl Beltrami states minimizing the dissipation rate of the quickly varying quantities [2].

The present work [3] proposes a simple and fundamental solution to the long-standing problem of dynamic relaxation of fluids and plasmas in terms of the principle of vanishing nonlinear transfer (PVNLT). According to our principle, the relaxed states are achieved when the total scale-to-scale nonlinear transfer vanishes. Rather than extremizing some quantity, these relaxed states are obtained to ensure a steady state in the inertial range in the absence of any energy input in the large scales. The proposed principle is universal for all kinds of flows consistent with a high Reynolds number turbulence regime. Unlike variational principle, PVNLT unambiguously predicts the relaxed states supporting a pressure gradient. The BT aligned states are hence obtained automatically in the limit of insignificant pressure gradient. Hence, our theory successfully explains the dynamic relaxation of both the neutral fluids and the plasmas and also naturally connects the relaxed states with and without the pressure gradient. However, unlike the variational approach, here, we do not require to compare the decay rates of those quantities in the presence of dissipation. Furthermore, our methodology is not affected by the direction of the cascades. Using the alternative form of exact relations in turbulence, one directly shows that the turbulent flux vanishes in the relaxed states.

References :

[1] J. B. Taylor, Phys. Rev. Lett. 33, 1139 (1974)
[2] B. Dasgupta *et al*., Phys. Rev. Lett. 81, 3144 (1998)
[3] S. Banerjee, A. Halder and N. Pan, https://arxiv.org/abs/2209.12735 (submitted to PRL)

Understanding Transverse Diffused Plasma and Excited Turbulence In LVPD-U

Ayan Adhikari[1,2], A. K. Sanyasi[1], L. M. Awasthi[1,2], P. K. Srivastava[1], Mainak Bandyopadhyay[1,2] and R. Sugandhi[1,2]

[1] Institute for Plasma Research, Bhat, Gandhinagar, Gujarat
[2] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai

Email: ayan.adhikari@ipr.res.in

Abstract

A weekly magnetized, moderate density (~ 2- 6x10^{11}cm^{-3}), low temperature) (~ 2-5 eV), high beta (β~ 0.8) plasma is produced in LVPD-U by utilizing a modified source function consisting of a large area multi filamentary plasma source (LAMPS) [1] and electron energy filter (EEF). The EEF is a solenoidal shaped magnetic filter embedded at the axial centre of the device. The EEF divides LVPD-U plasma into three characteristically different regions of source, EEF and target plasmas. The EEF produces a strong, uniform transverse magnetic field of ≤120G [2] and induces cross-field transport. The EEF is subjected to two externally imposed conditions. The influenced plasma evolution and its correlation with excited turbulence is investigated. The imposed conditions are namely; 1) the variation of active region of EEF and 2) the variation of the ratio of transverse ( ) to ambient field ( ). The activation of physical structure of EEF forms large sheaths within the interacting plasma volume and imposes a barrier to the transport of energetic electrons from source to target region. Initial observations in LVPD-U confirms this phenomenon. The investigations also exhibit excitation of low frequency (~ few kHz) plasma turbulence with high degree of correlation between density- magnetic field and density-potential fluctuations in the target plasma region. The plasma thus shows its suitability for investigations on fundamental plasma waves and instability. Various characteristic features of evolved cross-field diffused plasma and excited turbulence under the two imposed conditions will be discussed.

References

[1] Rev. Sci. Instrum. (Accepted for publication, November 2022; RSI22-AR-00707).
[2] S. K. Singh et al., Rev. Sci. Instrum. **85**, 033507 (2014)

Understanding Cross Field Density Depletion Phenomenon in LVPD-U Plasma

Ayan Adhikari[1,2], A. K. Sanyasi[1], and L.M. Awasthi[1,2]

[1] Institute for Plasma Research, Bhat, Gandhinagar, Gujarat
[2] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai

E-mail: ayan.adhikari@ipr.res.in

Abstract

Time varying plasma density is observed in a cross field diffused pulsed ($50ms$) plasma of large volume plasma device –upgrade. The plasma cross field diffusion is controlled by varying the transverse magnetic field in electron energy filter (EEF). The EEF is a solenoid that produces a magnetic field perpendicular to the axial uniform magnetic field of LVPD-U within a thin axial (d) region limited to its width ($d \geq \rho_i \gg \rho_e$). Time variation of plasma density is observed to be prominent when EEF is charged to produce $\geq 100G$ with respect to the axial magnetic field of $B_z \sim 6.2G$, this resulted in sharp density decay temporally. Apart from the decay in density, diffused plasma also shows enhanced density and potential fluctuation levels. An attempt has been made to explain this time dependency of density using spatial-temporal plasma decay model discussed by F.F. Chen [2] for cross field diffusion using continuity equation and Flick's law. This allows modification of diffusion equation and the time dependent part is solved by using separation of variable method. We have tried to fit the time dependent expression with experimentally observed density decay. Initial observation shows good fit with non-linearity introduced by power factor to the time decay constant.

References:

[1] Rev. Sci. Instrum. (Accepted for publication, November 2022; RSI22-AR-00707).
[2] Introduction to Plasma Physics and Controlled Fusion, Francis F. Chen, Springer Cham, 3rd edition

Cut Cell Technique To Model Curved Boundaries In Particle-In-Cell Code PASUPAT

Gaurav Singh[1,2], Raghwendra Kumar[1,2] and Debabrata Biswas[1,2]

[1]Bhabha Atomic Research Centre, Mumbai, 400085
[2]Homi Bhabha National Institute, Mumbai, 400094

E-mail : gauravsin@barc.gov.in

Abstract

PASUPAT is a 3D fully relativistic electromagnetic Particle in Cell (PIC) code developed at Bhabha Atomic Research Centre, Mumbai, India. The field solver of PASUPAT is implemented using finite difference (FD) based methods such as Multigrid and finite difference time domain (FDTD). In the finite difference approximation, each computational cell is modeled as either perfectly conducting or perfectly vacuum depending on which of the two constitutes the majority of its volume fraction. Therefore, whenever a curved object such as sphere, cylinder or cone etc is encountered, its vacuum-conductor curved interface is naturally modeled as the closest staircase type of boundary. This kind of simplified boundary is easier to model but suffers due to inherent stair-casing error. As a result, the field solutions close to the boundary region may significantly differ from the actual values. Emission of charged particles from such staircase surfaces is also erroneous as the emission area and its normal direction are not accurately modeled. Further, when emitted current density is strongly dependent upon the surface field such as in field emission, it may lead unacceptable error in the emission current. To model the curved field emitters more accurately in the FD framework, we have implemented a cut-cell technique [1,2] in PASUPAT to deal with the boundary cells that are intersected by the curved surface. This technique is found to significantly improve the performance of the field-solver and particle emission near the curved boundary. We shall present the essence of the cut-cell technique including the basic idea, implementation and performance details in this symposium.

References:

[1] S. Dey and R. Mittra, "A locally conformal finite-difference time-domain (FDTD) algorithm for modeling three-dimensional perfectly conducting objects," in *IEEE Microwave and Guided Wave Letters*, vol. 7, no. 9, pp. 273-275, Sept. 1997.
[2] G. Singh, R. Kumar, and D. Biswas, “Enhanced space charge limited current for curved electron emitters”, Phys. Plasmas 27, 104501 (2020).

Role of Neutral Gas Flows in Double Layer Formation and Thrust Generation in an Expanding Magnetic Field Plasma

Name(s) of the author : Vinod Saini, Rajaraman Ganesh

Affiliation : Institute for Plasma Research, HBNI, Gandhinagar, Gujarat

E-mail : vinod.saini@ipr.res.in

Abstract

In an electrical plasma thruster, continuous erosion of electrode material due to heavy bombardment of charge particles compromises thruster mission longevity. To overcome this important setback, an expanding magnetic field plasma thrusters (or electrode-less thruster) are proposed. Recently, in a terrestrial laboratory experiment net thrust (~ 8mN) in a particular direction has achieved [1]. These experiments have also brought out the importance of neutral gas flow in the generation of thrust.

Using a in-house developed pseudo 1D3V PIC-MCC code EPPIC, in the absence of neutral flow dynamics , double layer formation and ion acceleration in a diverging magnetic field plasma has been reported [2] wherein around 2mN net thrust in a particular direction was realized numerically [3].

In the present work, the neutral gas flow has been included in EPPIC simulations and the results indicate that the impact of neutral flow can be substantial and controllable by neutral flow rate. A detailed numerical and physics study of neutral gas flow impact over net thrust generation will be presented.

References :

[1] K Takahashi et al, Sci. Rep 8, 14417 (2018).
[2] V. Saini & R. Ganesh, Physics of Plasmas 27, 093505 (2020).
[3] V. Saini & R. Ganesh, Journal of Plasma Physics , 88(2), 905880203, (2022).

Ion Beam Induced Nanopatterning Of Borosil Related To Plasma Thruster

Basanta Kumar Parida[1,*], Vivek Pachchigar[1,2], Sooraj K P[1], Sukriti Hans[1,2], Sebin Augustine[1,2], Mukesh Ranjan[1,2],

[1]*FCIPT, Institute for Plasma Research, Bhat, Gandhinagar 382428*
[2]*Homi Bhabha National Institute (HBNI, BARC Training School Complex, Anushaktinagar, Mumbai, Maharashtra 400094*

**Email:* basanta.parida@ipr.res.in

Abstract:

Surface morphology of solids can be tuned using ion beam at different parameters. Self-organized nanopatterns like nanoripples and nanodots can be formed using ion beam. $BNSiO_2$ (borosil) is used in stationary plasma thrusters as discharge chamber material due to its lower erosion rates. $BNSiO_2$ composite materials are of specific importance due to their good thermal stability, chemical inertness and low erosion behaviour [1-3]. In this study, we have developed a UHV compatible heating arrangement to externally heat the borosil specimens and observe the changes in their erosion rates with the help of in-situ quartz crystal microbalance sensor. We have presented the erosion rate and the morphology changes on the borosil surfaces at elevated temperatures (100^o-700^{o}C) using Xe ions. We observed a linear increase in the sputtering yield with temperature and it remains stable during long duration irradiation. The higher erosion rate at higher operating temperatures is proposed to be due to the thermal spike nature. The morphology changes show periodic nanoscale elevations and depressions (nanoripples) in the range of 70-190 nm. Local curvature dependent erosion plays significant role in such pattern evolution [4].

1. M. Ranjan et al., AIP Advances **6**, 095224 (2016)
2. Rubin et al., J. Phys. D: Appl. Phys. **42**, 205205 (2009)
3. Rubin et al., Rev. Sci. Instrum. **80**, 103506 (2009)
4. B. K. Parida et al., Nucl. Inst and Methods B **514**, 1 (2022)

Modulation in Ion-Acoustic Wave with their Stability in Higher Order Nonlinearity

Rumi Chaharia

Department of Mathematics, Maharishi Vidya Mandir, Silpukhuri, Guwahati, Assam

E-mail : rumi.chaharia@gmail.com

Abstract

To study strongly dispersive plasma waves and wave modulation, nonlinear Schrodinger Equation (NLSE) which is derived be a Modified Reductive Perturbation Technique (MRPT). Here, coefficient of the nonlinear and the dispersive terms in the derived equation of NLSE gives the stability and evolution of the modulated nonlinear plasma waves. Due to the effect of ion temperature and pressure term, result we obtained used to observe in our study. NLSE derivation in our work describes the nonlinearity of the modulated plasma waves which shows the higher order nonlinearity can be shown by another evolution equation and pressure term equation.

Keywords: NLSE, MRPT, nonlinearity, stability, instability, ion acoustic wave.

References:

[1] Demiray, H., J. Phys. Soc. Jpn., 71, 1921-1930(2002)

Temperature Anisotropy Governed Current Density Profiles In A Compact Dipole Plasma Device Driven At Steady State

Ayesha Nanda and Sudeep Bhattacharjee

Department of Physics, Indian Institute of Technology Kanpur, Kanpur, India, PIN - 208016

E-mail: ayesha@iitk.ac.in, sudeepb@iitk.ac.in

Abstract

Dipole field has emerged as a self-reliant alternative for plasma confinement and is essential for understanding of fundamental phenomena occurring in space. Therefore, it is crucial to investigate the physics of processes such as confinement, transport, particle energization before diving into its application for societal benefits. This necessitated the design of a steady state tabletop plasma device in which certain aspects such as global plasma sustenance [1], diffusion induced transport [2], optical emissions [3] and temperature anisotropy governed electrical conductivity [4], have been looked at. An overview of all the works carried out in the dipole device has been summarized in Ref. [5].

Temperature anisotropy being a free energy source have revealed possible explanations to heating and acceleration problems [6]. Apart from E×B drift, which is a characteristic of magnetized plasma, particles also undergo mirror, curvature and polarization drifts in dipole field resulting in net current flow along various directions. To understand the temperature anisotropy induced particle transport, current density profiles are obtained from Ohm's law by measuring the electrostatic and wave electric field and using the electrical conductivity tensor [4] determined earlier. It is observed that current along each direction is an amalgamation of Pedersen, Hall and longitudinal currents, unlike the ionospheric dynamics where Pedersen, Hall and field aligned currents are distinct [7]. We can also corroborate the current density results from power balance model which incorporates plasma heating by betatron, Fermi [8] and wave induced heating, and power loss mechanisms such as inelastic and elastic collision, isotropization and charge exchange loss [6]. Moreover, this study can concretize the investigation of self-energization mechanisms of particles such as betatron and Fermi heating [8] occurring in dipole field.

The detailed current profile in the dipole system along with some preliminary results of power balance modeling will be presented in the conference.

References:

[1] A. R. Baitha, A. Nanda, S. Hunjan and S. Bhattacharjee, Plasma Res. Exp., **1** 045005 (2019).
[2] A. R. Baitha, A. Nanda, S. Hunjan and S. Bhattacharjee, AIP Advances, **10** 045328 (2020).
[3] S. Bhattacharjee, A. R. Baitha, J. V. Mathew and S. Bhattacharjee, Phys. Scr., **96** 035605 (2021).
[4] A. Nanda and S. Bhattacharjee Phys. Plasmas, **29** 062105 (2022).
[5] S. Bhattacharjee, A. R. Baitha, A. Nanda, S. Hunjan and S. Bhattacharjee, Rev. Mod. Plasma Phys., **6** 16 (2022).

[6] Y. Kawazura *et al.*, Phys. Plasmas, **22** 112503 (2015).
[7] Michael C. Kelly, The Earth's Electric Field, 1st Edition, Elsevier (2014).
[8] Z. Zhong *et al.*, Geophys. Res. Lett., **47** 085141 (2019).

INVESTIGATIONS OF SHOCKS AND SOLITARY STRUCTURES IN FOUR COMPONENTS STRONGLY COUPLED UNMAGNETIZED ASTROPHYSICAL DUSTY PLASMA

J. Goswami and S.S. Kausik

Centre of Plasma Physics, Institute for Plasma Research,
Nazirakhat, Sonapur-782402, Kamrup (M), Assam, India

E-mail : jyotirmoy.goswami@cppipr.res.in, kausikss@rediffmail.com

Abstract

The nonlinear features like shock and solitary structures, derived from Korteweg–de Vries Burgers' and Korteweg–de Vries equations, of dust-acoustic waves (DAW) in a strongly coupled unmagnetized dusty plasma containing q-nonextensively distributed electrons, positrons and ions with negatively charged mobile dust are investigated by using reductive perturbation and stretching the variable methods. We have taken the strong coupling effect in the plasma along with the viscosity [1,2]. The effects of all plasma parameters especially the viscous coefficient in this DAWs mode have been discussed. The conditions of formation of solitary structures and two types of shock structures are discussed. In what conditions of astrophysical dusty plasma environment, our theoretical model and results have the implications are also discussed.

References:

[1] Dust-acoustic waves in strongly coupled dusty plasmas with nonextensive electrons and ions. Canadian Journal of Physics, **90**(7), p 675-681, (2022)

[2] Correlation function of the coupling parameter in dusty plasmas, AIP Conference Proceedings, **1925**(1), p 020027, (2018)

Existence and Stability of Alternative Dust Ion Acoustic Solitary Waves in a Dusty Plasma Consisting of Nonthermal Electrons having Vortex like Velocity Distribution

Sankirtan Sardar[1], Anup Bandyopadhyay[2], K.P Das[3]

Affiliation : [1]Department of Mathematics, Guru Ghasidas Vishwavidyalaya, Bilaspur, (C.G), 495009,
[2] Department of Mathematics, Jadavpur University, Kolkata 700032, India,
[3]Department of Applied Mathematics, University of Calcutta, 92 Acharya Prafulla Chandra Road,
Kolkata 700009, India

E-mail : sankirtansardar@gmail.com

Abstract

The recent work of Sardar et al. [1] on the existence and stability of the small amplitude dust ion acoustic solitary waves in a collisionless unmagnetized plasma consisting of warm adiabatic ions, static negatively charged dust grains, isothermal positrons, and nonthermal electrons due to Cairns et al. [2] has been extended by considering nonthermal electrons having a vortex-like velocity distribution due to Schamel [3,4] instead of taking nonthermal electrons. This distribution takes care of both free and trapped electrons. A Schamel's modified Kadomtsev Petviashvili (SKP) equation describes the nonlinear behaviour of dust ion acoustic waves in this plasma system. The nonlinear behaviour of the dust ion acoustic wave is described by the same Kadomtsev Petviashvili (KP) equation of Sardar et al. [1] when B = 0, where B is the coefficient of nonlinear term of the SKP equation. A combined SKP-KP equation more efficiently describes the nonlinear behaviour of dust ion acoustic waves when $B \to 0$. The solitary wave solution of the SKP equation and the alternative solitary wave solution of the combined SKP-KP equation having profile different from both sech^4 and sech^2 are stable at the lowest order of the wave number. It is found that this alternative solitary wave solution of the combined SKP-KP equation and its lowest order stability analysis are exactly the same as those of the solitary wave solution of the KP equation when $B \to 0$.

References :

[1] S. Sardar, A. Bandyopadhyay, and K. P. Das, Phys. Plasmas 23, 073703 (2016).
[2] R. A. Cairns, A. A. Mamum, R. Bingham, R. Boström, R. O. Dendy, C.M. C. Nairn, and P. K. Shukla, Geophys. Res. Lett. 22, 2709, (1995).
[3] H. Schamel, Plasma Phys. 13, 491 (1971).
[4] H. Schamel, Plasma Phys. 14, 905 (1972)

Effects of Radiative Heat-loss Function Neutral Collisions and Hall Current on Transverse Instability of Two-component Plasma with Finite Electron Inertia in HI Region

Sachin Kaothekar[1] and R. K. Chhajlani[2]

[1]Department of Physics, Medi-Caps University, Indore-453331, M.P., India.
[2]School of Studies in Physics, Vikram University, Ujjain-456010, M. P., India.

Email: sachin.kaothekar@medicaps.ac.in, sachinmgi007@gmail.com

Abstract. The effect of neutral friction, finite electron inertia, Hall current and radiative heat-loss function on the transverse thermal instability of viscous two-component plasma has been investigated incorporating the effects of finite electrical resistivity, permeability and thermal conductivity. A general dispersion relation is obtained using the normal mode analysis method with the help of relevant linearized perturbation equations of the problem and a tailored therml condition of instability is obtained. We find that the thermal condition of instability is tailored due the presence of radiative heat-loss function, thermal conductivity, finite electron inertia and neutral particle. The Hall current parameter has no consequence on the transverse mode of propagation. For the case of transverse mode of propagation, we find that the condition of thermal instability depends on the finite electron inertia, magnetic field strength, radiative heat-loss function, thermal conductivity, neutral particle and finite electrical resistivity, but independent of Hall current, permeability, and viscosity of two-components. From the curves we find that the temperature dependent heat-loss function, thermal conductivity, neutral collision frequency and viscosity of two-components show stabilizing effect, while finite electron inertia and finite electrical resistivity shows destabilizing effect. This study helps in understanding the process of star formation in HI regions.

Directed motion in a 2D system of Yukawa particles on 1D Ratchet

Anshika Chugh, Rajaraman Ganesh

Institute for Plasma Research, Bhat, Gandhinagar-382428, India
Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India

E-mail : anshikachugh93@gmail.com, anshika.chugh@ipr.res.in

Abstract

Gradients such as potential difference, temperature difference, or concentration gradients are responsible to drive macroscopic transport in non-equilibrium systems of large scales. However, at mesoscopic scales, fluctuations become important and therefore transport mechanism becomes complex [1]. One example of such a fluctuation-dominated system is molecular motors responsible for intercellular transport in our body. Inspired by the directed transport of these molecular motors in noisy environments, we aim to explore the ways to generate directed transport in fluctuation-dominated systems

In our study, we employ a special form of asymmetric potential called ratchet to study transport in an inertial 2D system of Yukawa particles driven by an unbiased drive [2]. We show the presence of directed motion despite zero-average external forces. The directed motion or average velocity is found to be a non-monotonic function of amplitude and frequency of external unbiased drive. It is the combination of inertial effects and hysteresis which drives directed motion in our system.

Two-dimensional Complex plasmas (also called Dusty Plasmas) is an interesting ‘‘test bed’’ for investigating Ratchet effects. Such studies are expected to help understand systems such as transport of ions through nanopores, colloidal monolayers driven across ordered surfaces, vortices and Josephson phase in superconductors.

References :

[1] Brownian motors: noisy transport far from equilibrium, Physics Reports, **361** (2002) 57 – 265
[2] Emergence of directed motion in a 2D system of Yukawa particles on 1D Ratchet, Physica A, 593 (2022) 126913

GENERATION OF LUMP SOLITON STRUCTURES IN COMPLEX PLASMA MEDIA WITH SUPERTHERMAL ELECTRONS

Uday Narayan Ghosh

Department of Mathematics, KKM College, A Constituent unit of Munger, Bihar-811307, India

E-mail: unghosh1@rediffmail.com

Abstract

Lump soliton structures in a magnetized dusty plasma with electrons featuring superthermal distribution have been investigated. Canonical Kadomstev-Petviashvili (KP) equations [1] have been derived from the fluid hydrodynamical model equations by employing the reductive perturbation technique (RPT). Using Hirota bilinear method[2], we have derived lump soliton solutions [3] by constructing appropriate bilinear form due to KP equations. Three sets of lump soliton solutions have been obtained. It has been shown that the lump solitons structures as well as in the one-dimensional form of lump soliton are varied with associated parameters of the plasma system. During the analysis of the features of the lump solitons, it is found that the superthermal parameter plays a crucial role in the lump solitons structures. The superthermal spectral index (κ) directly alters the amplitude of lump solitons. Destruction in oceanography, nonlinear optical fibers, plasmas, ferrite magnetic material, fluid dynamics and atmosphere, microwave oscillation, and financial systems can be controlled by amplifying signals with the help of lump solitons solutions.

References :

[1] B. B. Kadomtsev, V. I. Petviashvili, Soviet Phys. Doklady **15**, 539 (1970).
[2] R. Hirota, J. Math. Phys. **14**, 810 (1973).
[3] W. X. Ma, Phys. Lett. A **379**, 1975 (2015).

Development of Configuration Management Software for Laboratory Plasma Experiments

R. Sugandhi[1, 2,*], V. Soumya[3], Ayan Adhikari[1,2], A. K. Sanyasi[1], and L. M. Awasthi[1, 2]

[1]*Institute for Plasma Research, Gandhinagar, India 382428,*
[2]*Homi Bhabha National Institute, India 400085,*
[3]*Graduate School of Engineering and Technology, Ahmedabad, India 382424.*

E-mail: ritesh@ipr.res.in

Abstract

The experimental facilities around the world facilitate the investigation of plasma across evolving changes in physics objectives and engineering systems. The changes in physics objectives bring the change in operational configuration data, whereas the revision of a system brings changes at the micro and macro stages of configuration management. Many large-scale machines such as Tokamaks (e.g. ITER, EU-Demo), and Stellarator (e.g. W7-X) adopted a structured approach towards management and standardization of their heterogeneous configuration under a unified framework. Many commercial configuration management tools are available nowadays but they are costly and primarily suited best for large facilities. However, for small or medium-scale experiments, the development of a web-based configuration management system on open-source tools provides a cost-effective mechanism. This is relevant as it motivates the design and development of computerized software presented in the paper. As a proof of concept, the software is trained over configuration data of Large Volume Plasma Device- upgrade (LVPD-U) [1]. The developed software facilitates the abstraction of configuration schema at multiple levels in a platform independently as per prescribed guidelines mentioned in IEEE 828-2012 and ISO standards [2]. The novelties of the paper lie in web application design and development targeted for configuration management techniques over small-scale laboratory plasma devices, making use of latest and open-source web technologies. The paper discusses requirements, literature survey of existing tools and techniques, conceptual and technical architecture of the web-based editor software, obtained results, and lessons learned.

References:

[1] S. K. Mattoo, V. P. Anitha, L M Awasthi, et al., Rev. Sci. Instrum., **72**, 3864(2001).
[2] IEEE Standard for Configuration Management in Systems and Software Engineering, IEEE Std-828-2012, 1-71, 2012.

JEANS INSTABILITY OF QUANTUM MGNETIZED RESISTIVE PLASMA

[1]Ashok K. Patidar, [2]Sonali Patidar, [3]Hemlata Joshi and [4]Swati Dubey
[1]Govt. P. G. College, Mandsaur (M.P.)
[2 and 4]School of Studies in Physics, Vikram University, Ujjain (M.P.), 456010
[3]Govt. College Jeeran, Neemuch (M.P.)
[2]corresponding author:sonalipatidar14@gmail.com

Abstract

The Jeans instability of quantum plasmas in the presence of magnetic field and resistive effects is investigated using the hydrodynamic approach in connection with the well-known Chandrashekhar mass-limit of highly collapsed stellar configurations. A general dispersion relation is derived with the help of linearized perturbation equations using the normal mode analysis. The dispersion relation is then studied for both the longitudinal and transverse mode. It is also shown that for the longitudinal mode, the onset Jeans criterion remains unaffected by the magnetic field and resistivity and for transverse mode the growth rate of Jeans criteria gets affected due to the presence of magnetic field and resistivity. Further, the influence of magnetic field and resistivity on the growth rate of Jeans instability is depicted by the graphical illustration. It is shown that the magnetic field has stabilizing effect on the growth rate of Jeans instability criteria while resistivity evinces destabilizing effect.

Magnetized Inhomogeneous Weakly Coupled Fusion Plasma: Dust-Driven Instabilities

Shachi Pachauri[1], Shiva Shakti Singh[1, 2], Jyoti[3], Kamakhya Prakash Misra[1,*]

[1]*Department of Physics, School of Basic Sciences, Manipal University Jaipur, Dehmi Kalan, Jaipur, Rajasthan 303007, India*

[2]*Department of Physics, S. S. Jain Subodh P.G. (Autonomous) College, Jaipur-302004, India*

[3]*Department of Physics, Govt College for Women, Gurawara, Haryana-123035, India*

**Email: kamakhyaprakash.misra@jaipur.manipal.edu*

Abstract

This article discusses the important implications of negatively charged dust dynamics [1], together with Maxwellian electrons and positively charged ions, have on the growth profile of instabilities in uniformly magnetized inhomogeneous weakly coupled fusion dusty plasma. The aforementioned plasma model uses a numerical mode analysis method [2] in conjunction with linearization to derive the electrostatic perturbed potential from Poisson's equation while ignoring high order perturbation terms. Dispersion relations are successfully established using potential equations in terms of oscillation modes matching to the instability here caused by the dynamics of the dust. The effect of the charged dust density, dust charge, magnetic field, propagation angle, electrostatic potential, and the plasma oscillation wavelength to Debye wavelength ratio on the characteristics of this dust-driven instability is observed here. These findings can be used to comprehend the function of dust in fusion apparatus, such as long pulse fusion apparatus, which has been a major source of worry due to security concerns [3].

Keywords: Dust dynamics, Dust-driven instability, Maxwellian electrons, Fusion apparatus.

References:

[1] S Bal and M Bose, Pramana - J Phys **80**, p 643-664, (2013).
[2] Shachi Pachauri, Jyoti and Kamakhya Prakash Misra , Plasma Res. Express **4** ,p 025004(2022).
[3] J.P Sharpe, D.A Petti and H.-W Bartels, Fusion Eng. Des. **63**, p 153-163, (2002)

A NUMERICAL APPROACH OF MODIFIED BURGERS' EQUATION IN CHARGED DUSTY PLASMAS

Harekrishna Deka [1], Jnanjyoti Sarma [2]
[1]*Department of Mathematics, K.K. Handiqui State Open University, Guwahati-781022, India*
[2]*Department of Mathematics, R.G. Baruah College, Guwahati-781025, India*
[1]*harekrishnadeka11@gmail.com*, [2]*sjnanjyoti@gmail.com*

Abstract

In this paper, a well-known reductive perturbation method is employed to derive one dimensional nonlinear modified Burgers' equation in charged dusty plasmas. One-dimensional modified Burgers' equation (MBE) in charged dusty plasmas is investigated numerically by finite difference explicit method. The numerical results obtained by the finite difference explicit method for various values of the nonlinear and dissipative coefficient have been compared with the analytical solutions. The obtained numerical results are found to have good agreement with the analytical solutions. The error between the analytical and numerical solutions of the MBE is demonstrated by two error norms, namely L_2 and L_∞. The graphs of the error norms are plotted to make comparison between them. It has been observed that the waves profiles are become flatten and steeper when the dissipative coefficient decreases. It can be concluded that the finite difference explicit method is suitable and efficient method for solving the modified Burgers' equation.

Keywords: Plasma, Charged dusty plasmas, Reductive perturbation method, Modified Burgers' equation, Finite difference explicit method.

References

[1] P. K. Shukla, "A survey of dusty plasma physics," vol. 1791, no. 2001, 2013, doi: 10.1063/1.1343087.

[2] P. K. Shukla and A. A. Mamun, "Introduction to dusty plasmas," Inst. Phys., vol. 1, no., pp. 1–476, 2002.

[3] M. Horanyi and D. A. Mendis, "The Dynamics of Charged Dust in the Tail of Comet Giacobini-Zinner," vol. 91, pp. 355–361, 2013, doi: 10.1029/sp027p0313.

[4] I. E. Thrane, O. Havnes, W. Mortensen, L. I. Naesheim, and T. Tonnesen, "COLLECTOR !," vol. 101, pp. 839–847, 1996.

[5] J. M. Burgers, "A Mathematical Model Illustrating the Theory of Turbulence," Adv. Appl. Mech., vol. 1, no. C, pp. 171–199, 1948, doi: 10.1016/S0065-2156(08)70100-5.

[6] M. S. Zobaer, K. N. Mukta, L. Nahar, N. Roy, and A. A. Mamun, "Roles of dust grains on electrostatic IA shocks in highly nonlinear dense plasma with degenerate electrons," IEEE Trans. Plasma Sci., vol. 41, no. 5, pp. 1614–1619, 2013, doi: 10.1109/TPS.2013.2252927.

[7] A. N. Dev, M. K. Deka, J. Sarma, and N. C. Adhikary, "Shock Wave Solution in a Hot Adiabatic Dusty Plasma Having Negative and Positive Non-thermal Ions with Trapped Electrons," Artic. Journal-Korean Phys. Soc., vol. 67, no. 2, pp. 339–345, 2015, doi: 10.3938/jkps.67.339.
[8] H. Leblond, "The reductive perturbation method and some of its applications," J. Phys. B At. Mol. Opt. Phys., vol. 41, no. 4, 2008, doi: 10.1088/0953-4075/41/4/043001.
[9] A. G. Bratsos, "A fourth-order numerical scheme for solving the modified Burgers equation," Comput. Math. with Appl., vol. 60, no. 5, pp. 1393–1400, 2010, doi: 10.1016/j.camwa.2010.06.021.
[10] M. A. Ramadan and T. S. El-Danaf, "Numerical treatment for the modified burgers equation," Math. Comput. Simul., vol. 70, no. 2, pp. 90–98, 2005, doi: 10.1016/j.matcom.2005.04.002.
[11] M. A. Ramadan, T. S. El-Danaf, and F. E. I. A. Alaal, "A numerical solution of the Burgers' equation using septic B-splines," Chaos, Solitons and Fractals, vol. 26, no. 4, pp. 1249–1258, 2005, doi: 10.1016/j.chaos.2005.02.019.
[12] D. Irk, "Sextic B-spline collocation method for the modified Burgers' equation," Kybernetes, vol. 38, no. 9, pp. 1599–1620, 2009, doi: 10.1108/03684920910991568.
[13] V. S. Aswin and A. Awasthi, "Iterative differential quadrature algorithms for modified Burgers equation," Eng. Comput. (Swansea, Wales), vol. 35, no. 1, pp. 235–250, 2018, doi: 10.1108/EC-04-2017-0140.
[14] T. Roshan and K. S. Bhamra, "Numerical solutions of the modified Burgers' equation by Petrov-Galerkin method," Appl. Math. Comput., vol. 218, no. 7, pp. 3673–3679, 2011, doi: 10.1016/j.amc.2011.09.010.
[15] A. G. Bratsos, T. Papakostas, A. I. Delis, and D. G. Natsis, "an Implicit Numerical Scheme for," vol. 1, pp. 3–6.
[16] A. Griewank and T. S. El-Danaf, "Efficient accurate numerical treatment of the modified Burgers' equation," Appl. Anal., vol. 88, no. 1, pp. 75–87, 2009, doi: 10.1080/00036810802556787.
[17] Y. Duan, R. Liu, and Y. Jiang, "Lattice Boltzmann model for the modified Burgers' equation," Appl. Math. Comput., vol. 202, no. 2, pp. 489–497, 2008, doi: 10.1016/j.amc.2008.01.020.
[18] A. Bahan, S. Battal, G. Karakoç, and T. Geyikli, "B-spline Differential Quadrature Method for the Modified Burgers' Equation," Ç ankaya Univ. J. Sci. Eng., vol. 12, no. 1, pp. 1–13, 2015.
[19] R. S. Temsah, "Numerical solutions for convection-diffusion equation using El-Gendi method," Commun. Nonlinear Sci. Numer. Simul., vol. 14, no. 3, pp. 760–769, 2009, doi: 10.1016/j.cnsns.2007.11.004.
[20] Y. Ucar, N. M. Yagmurlu, and O. Tasbozan, "Numerical Solutions of the Modified Burgers' Equation by Finite Difference Methods," J. Appl. Math. Stat. Informatics, vol. 13, no. 1, pp. 19–30, 2017, doi: 10.1515/jamsi-2017-0002.

Lane Formation In 3D Pair-Ion Plasmas Driven By Non-Parallel External Forcing

*Vishal Kumar Prajapati[1], Swati Baruah[1], Rajaraman Ganesh[2]

[1]*Department of Physics, The Assam Kaziranga University, Jorhat-785006, Assam, India*
[2]*Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat, India*

E-mail : *vishalprjapati2335474@gmail.com

Abstract

Lane formation [1, 2] is an interesting non-equilibrium phase transition exhibited by system of particles when two species of particles are driven opposite to each other. It is a remarkable example of self-organization of particles where the particles of same species move collectively to form lanes.

In this study, non-equilibrium phase transition leading to lane formation is studied in 3D pair-ion plasmas (PIP) system. Extensive Langevin Dynamics (LD) simulations [2, 3] are performed to study the effect of external electric forces on the system. The system under study is subjected to a set of perpendicular external forces $\overrightarrow{F_A}$ and $\overrightarrow{F_B}$ such that one half of the particles (positively charged) are pulled by an external force $\overrightarrow{F_A}$ and the other half of the particles (negatively charged) are pushed by an external force $\overrightarrow{F_B}$. It is demonstrated that under such conditions the system undergoes a phase transition where the particles of same species move collectively to form lanes in a direction of the force difference vector given by $\overrightarrow{F_A} - \overrightarrow{F_B}$ which is characterized by angle of inclination (θ). A relation is also predicted to calculate this angle of inclination for any given field strength value. Several diagnostic techniques are implemented to detect the phase transition namely order parameter (ϕ) [1] and order parameter with gradient of θ (ϕ(θ)). We show the lane formation in presence of time varying non-parallel external forcing. In particular, the dynamics is studied for two different cases: firstly when $\overrightarrow{F_A}$ and $\overrightarrow{F_B}$ are oscillating with same frequencies and secondly, when $\overrightarrow{F_A}$ and $\overrightarrow{F_B}$ are oscillating with different frequencies. A spontaneous formation and breaking of lanes is observed for both the cases, however, the frequencies of this formation and breaking is different for both cases and is highly dependent on the applied frequency. It is shown that the orientation of the lanes formed is highly dependent on the ratio of the electric field strengths E_A/E_B. Further, in presence of forces with different frequencies a flipping of lanes is also observed in combination with the spontaneous formation and breaking of lanes. Depending on the ratio of the frequencies of the applied forces, two distinct patterns of oscillation of θ is also obtained for the latter case where the amplitude of oscillation is also dependent on the ratio of the applied frequencies.

References:

[1] U. Sarma, Swati Baruah and Rajaraman Ganesh. Phys. Plasmas **27**, 012106 (2020).
[2] Swati Baruah, U. Sarma and Rajaraman Ganesh, J. Plasma Phys. **87** (2), 905870202 (2021).
[3] Swati Baruah, Vishal K. Prajapati, Rajaraman Ganesh, J. Plasma Phys. **87** (6), 905870601 (2021)

Effect Of Axial Magnetic Field On A Cylindrically Symmetric Electronegative Discharge

Avnish Kumar Pandey[1], Pawandeep Singh[2], Swati Dahiya[3], Shantanu Kumar karkari[4]

Institute for Plasma Research, HBNI, Bhat, Gandhinagar, Gujarat, India 382428

E-mail: [1]avnish.pandey@ipr.res.in, pawandeep.singh@ipr.res.in, swati.dahiya@ipr.res.in, skarkari@ipr.res.in

Abstract

The Electronegative plasmas are the ones having a significant fraction of negative ions compared to electrons, whose charge to mass ratio is comparable to the background positive ions. These plasmas are often employed with externally applied magnetic field in semi-conductor industries to have a better control over the performance of dry etching of silicon based materials. In hydrogen based negative ion sources, in particular, the presence of magnetic field in the expansion region critically impacts the cross field extraction of hydrogen negative ion beam. Moreover, the diagnostic based on Langmuir probe also relies on the detailed interaction of negative ions accompanying magnetized electrons with the surrounding wall in presence of an axially symmetric external magnetic field.

In this study, the fluid model for a cylindrical quasi-neutral electronegative plasma in presence of an axial magnetic field is investigated. The model considers magnetized electrons but un-magnetized negative & positive ions and explore the behavior of plasma parameters for arbitrary magnitude of applied magnetic field, the gas pressure and arbitrary size of quasi-neutral plasma. The study is further carried out for parameter space appropriate for typical electronegative discharges wherein the dominant processes for negative ion production/loss are attachment-detachment (for example O_2) and attachment-recombination (for example CCl_4). The plausible explanations are given to explain the effects.

References :

[1] Natalia Sternberg, Valery Godyak and Daniel Hoffman, Phys. Plasmas **13**, 063511 (2006).

[2] R N Franklin and J Snell, J. Phys. D: Appl. Phys. **32,** 1031–1038 (1999)

Possible Applications of SMES from India's Perspective

A. N. Sharma, V. L. Tanna and P. K. Atrey
Institute for Plasma Research, Bhat, Gandhinagar – 382 428
E-mail: ansharma@ipr.res.in

Abstract

Superconducting Magnetic Energy Storage (SMES) is a technology that stores electricity from the grid within the magnetic field of a coil made of superconducting wires with near-zero loss of energy over a reasonably large period of time.

A typical SMES system has following main components: A LTS/HTS superconducting coil which stores the electricity, appropriate cryogenic cooling and protection system which keeps the coil at appropriate cryogenic temperature and a power conversion system which connects the coil to the source of electricity and to the load.

SMES systems can discharge almost all the energy stored in the system with a high-power output in a very short time, making them ideal for power quality applications. For example, the Electromagnetic launcher is an electric weapon that can launch a projectile at a very high velocity. Some electromagnetic launchers require high power pulse sources. Due to high power density and quick release of the stored energy, SMES is a potential energy storage device for an electromagnetic launcher. Renewable energy sources like storage type solar energy-based systems are recently getting a lot of attention. SMES can be an attractive solution for this energy storage system due to its long lifetime, high power sizing and high efficiency as compared to conventional batteries. Similar application can also be explored for batteries of electric vehicles. A SMES can balance fluctuating loads by releasing or absorbing electricity according to demand. They also can be used as a backup power supply for critical loads that may be sensitive to disturbances in power quality; for example, the plant systems that are operated on 24 x 7 basis and are prone to failures due to power fluctuations coming from power grids.

In this paper, the concepts and recent trends in the field of SMES will be reported. The possible applications of SMES from Indian R & D programs will also be presented in this paper.

Creation and Optimization of Atmospheric Pressure Micro-Plasma Jets: Physics and Applications

Kalyani Barman and Sudeep Bhattacharjee

Department of Physics, Indian Institute of Technology - Kanpur, Kanpur 208016, India

E-mail : kalyani@iitk.ac.in, sudeepb@iitk.ac.in

Abstract

Atmospheric pressure plasma jets (APPJs) have numerous applications in different fields, such as biomedical, surface modification, agriculture, and environmental applications. APPJs are created in atmospheric pressure and temperature without needing a highly maintained vacuum system. These kinds of plasmas are non-equilibrium plasmas having different gas (T_g~0.026 eV) and electron temperatures (T_e~0.5 eV) [1]. APPJs can be created with different types of electrode configurations. In our laboratory, there are two types of plasma jets having different kinds of electrode configurations. However, in both systems, the plasma is created through dielectric barrier discharge inside a capillary tube. The two systems are (i) low-frequency and high voltage system (LFHV) having two ring electrodes made of aluminum tape as high voltage and ground electrode and (ii) high-frequency, low voltage system (HFLV) having a tungsten pin as high voltage electrode and a copper ring as a ground electrode [1,2].

Both systems have been optimized with different parameters, such as applied voltage and gas flow rate, to obtain a comparative performance of the two systems. The reactive oxygen and nitrogen species (RONS) in plasma jets play a significant role in surface modification and biomedical applications. The dosage of RONS determines the effectiveness of plasma jets while applying it to any substrate. Hence, the generation and control of these RONS are essential. It has been reported in the literature that the density of RONS is affected by a magnetic field, and applying a magnetic field to the jet could be one of the ways to control the density of RONS [3]. In our study, we have applied a transverse magnetic field to the jet to observe the effect of a magnetic field on the optical emission intensity of RONS [4]. After optimizing the performance, we used the APPJs in the surface modification of screen-printed carbon electrodes (SPCEs). The APPJ treatment increases the electroactive surface area of the SPCE removing the binders and pollutants from the surface. The SPCEs were employed to detect dopamine in blood serum, and the detection capability of the treated SPCEs enhanced significantly in comparison to the untreated SPCEs.

References:

[1] K. Barman, D. Behmani, M. Mudgal, S. Bhattacharjee, R. Rane and S. K. Nema, Plasma Res. Express 2 (2020) 025007.
[2] D. Behmani, K. Barman and S. Bhattacharjee, AIP Advances 11, 085128 (2021).
[3] Y. Liu, H. Yan, H. Guo, Z. Fan, Y. Wang, and C. Ren, Phys. Plasmas 25, 023512 (2018).
[4] K. Barman, M. Mudgal, R. Rane, and S. Bhattacharjee Phys. Plasmas 28, 123503 (2021).

Ion-acoustic soliton in magnetoplasma using nonlinear ZK equation with nonthermal electrons

J. K. Chawla

R. R. Govt. College Alwar, Rajasthan, India-301001

ABSTRACT

Small amplitude 3D ion-acoustic waves are studied in magnetoplasma having nonthermal electrons using nonlinear ZK equation. Using basic equations for ion fluid, nonthermal electron and poisson's equation in small amplitude limit, nonlinear evolution ZK equation is derived and analyzed to determine the existence region of solitary pulses. It is found that ion acoustic solitary waves can exist in such a plasma and nonthermal electrons significantly affect the characteristics (amplitude and width) of these solitary waves.

Dusty Plasma

Streaming instabilities in magnetized quantum dusty plasmas

*Sukhmander Singh

[1]Department of Physics, Central University of Rajasthan, Ajmer, Kishangarh- 305817, India

*E-mail: sukhmandersingh@curaj.ac.in

Abstract

The study of dusty plasma has gained interest in the last few decades due to its observations and applications in the space and laboratory. Many authors studied the linear and nonlinear electrostatic wave in the presence and absence of the external magnetic field. The presence of charged dust grains modify the ion-acoustic waves, lower hybrid waves, ion-acoustic and introduces dust acoustic waves and dust ion acoustic waves. But due to the recent development in the technology basically in the nano science and the miniaturization of semiconductor devices, have made it possible to envisaged the practical application of quantum dusty plasma physics and where the quantum mechanical effect of the constituent particles a vital role [1-4]. The plasma physics which deals with the low temperature and high density, governed by the quantum mechanical effects [5]. In the present paper, we solve the dispersion relation for the dust and ions streaming instabilities under the effects of multi ions. The growth rate and the real frequency is determined for the further analysis of the characteristic of the motions.

References

[1] S. Ali, P. K. Shukla, Phys. Plasmas 13 (2006).
[2] M. Marklund, G. Brodin, phys. Rev. Let. 98, 025001 (2007).
[3] J. Cao, H. Ren, Z. Wu and P. K. Chu, Phys. Plasmas (2008).
[4] S. Ali, P.K. Shukla, Eur. Phys. J. D (2007)
[5] Ashish, Singh, S. J Astrophys Astron 43, 59 (2022).

Effects Of Compressibility On The Rayleigh-Taylor Instability In Strongly Coupled Dusty Plasmas

Deepak, Ram Prasad Prajapati

School of Physical Sciences, Jawaharlal Nehru University, New Delhi-110067 India

E-mail : deepak35_sps@jnu.ac.in , rpprajapati@mail.jnu.ac.in

Abstract

The Rayleigh-Taylor instability (RTI) arises at the interface between two fluids when the heavy fluid is supported by a lighter one under the influence of gravitational acceleration. In the strongly coupled complex plasma, the dust particles are strongly correlated while the electrons and ions remain in a weakly coupled state. The electrons and ions both are assumed to be isothermal inertialess and Boltzmann distributed fluid and the massive dust grains are described using GHD fluid equations. In this work, a generalized (GH) model is formulated for SCDP with the help of momentum transfer equations and continuity equations for electron and ion fluids. The general dispersion relation exhibiting RTI has been derived analytically for the considered SCDP and analyzed in both the incompressible and the compressible limits. The compressibility effects are considered through the equation of state for isothermal pressure to analyze the dynamics of compressible strongly correlated dust fluid.

It is found that the magnetic field and strong dust-dust correlation have a stabilizing influence on the growth rate of the R-T instability. A direct numerical solution is also performed to find the growth rate numerically and the results are compared with analytical results. The results are also relevant in experimental situations where dust is strongly coupled.

References :

[1] P.K. Shukla, Physics of Plasmas 19, 083704 (2012)
[2] K. Avinash and A. Sen, Physics of Plasmas 22, 083707 (2015)
[3] Bivash Dolai and R. P. Prajapati, Physics of Plasmas 25, 083708 (2018)

Ion Streaming Instability in Dust Density Waves

Niranjan Gogoi and Nilakshi Das

Department of Physics, Tezpur University, Assam, 784028

E-mail : ngogoi7@tezu.ernet.in

Abstract

The effect of magnetic field on excitation and propagation of dust density waves is studied in plasma. Such self excited dust density waves are driven by ion streaming. The analysis of the dispersion relation shows that such waves are excited with a frequency lower than the dust acoustic waves. The existence regime of the wave and instability conditions are studied. The study of dust density waves may be relevant for laboratory as well as astrophysical plasmas.

References :

[1] Some Thoughts About Dust Density Waves, AIP Conference Proceedings **1397**, 50, (2011)
[2] 25 Years of Dust Acoustic waves, Journal of Plasma Physics, **80**, 6, (2014)
[3] Excitation of low-frequency dust density waves in flowing complex plasmas, Physics of Plasmas **26**, 053702 (2019)
[4] Probing a dusty magnetized plasma with self-excited dust-density waves, Phys. Rev. E **97**, 033203, (2018)
[5] Spatiotemporal evolution of a self-excited dust density wave in a nanodusty plasma under strong Havnes effect, Physics of Plasmas **28**, 123702, (2021).

Effect of Ion Streaming in Shear Viscosity and Thermal Conductivity of Strongly Coupled Dusty Plasma in Presence of External Magnetic Field

Dr. Mahmuda Begum

Department of Physics, Lakhimpur Girls' College, North Lakhimpur, Assam-787031, India

Email: mbegumtu@gmail.com

Abstract

Two important transport properties of strongly coupled dusty plasma-Shear viscosity and Thermal conductivity have been investigated by using Langevin dynamics simulations in presence of external magnetic field. In laboratory dusty plasma, the flow of ions that arise due sheath electric field, interact with dust grains and this result in attractive wake potential. In presence of magnetic field, the motion of ions further gets affected and this changes the entire dynamics of dusty plasma system. It is of utmost interest to understand shear viscosity (η) and thermal conductivity (λ) that are inherently connected with the inter-particle interaction behave in presence of external magnetic field and attractive wake potential. In the present work these transport coefficients are calculated using Green-Kubo integral formulae and Langevin dynamics simulation. The results obtained from our simulation cover a wide range of Coulomb coupling parameter (Γ), screening parameter (κ), Mach number (M), neutral pressure (N_n) and magnetic field B.

References:

[1] Z. Donkó and and B. Nỳiri, Phys. Plasmas, **7**, 45 (2000)
[2] A. Shahzad and M. G. He, Contrib. Plasma Phys., **52**, 667 (2012)
[3] Z. Donkó, J. Goree, P. Hartmann and K. Kutasi, Phys. Rev. Lett., **96**, 145003 (2006)
[4] T. Saigo and S. Hamaguchi, Phys. Plasmas, **9**, 1210 (2002)
[5] Z. Donkó and P. Hartmann, Phys. Rev. E, **69**, 016405 (2004)

Study Of Plasma Sheath In The Presence Of Dust Particles In A Magnetic Mirror-like Field Configuration

K. Deka[1-3], G. Sharma[1], R. Paul[1], R. Moulick[1], S. Adhikari[2], S. S. Kausik[1], and B. K. Saikia[1]

[1]*Centre of Plasma Physics, Institute for Plasma Research, Sonapur 782402, Assam, India*

[2]*Institute for Energy Technology, Instituttveien 8 2007 Kjeller, Norway*

[3]*Pandit Deendayal Upadhyaya Adarsha Mahavidyalaya, Tulungia 783383, Bongaigaon, Assam, India.*

E-mail : kausikss@rediffmail.com

Abstract

The properties of a plasma sheath in the presence of dust grains and a magnetic mirror-like field configuration have been investigated in this study. All the plasma species viz. electrons, ions, and dust grains are described by fluid equations. The system of equations involved in the study is solved numerically using the Runge-Kutta fourth-order (RK4) method to explore the sheath properties. The results of the study suggest that in the presence of a magnetic mirror-like field configuration, the component of ion velocity perpendicular to the wall decreases near the wall, and consequently, the ion density increases. To the best of our knowledge, such observations has not been reported anywhere previously. This utterly different observation is due to the magnetic field configuration alone. Moreover, the ion-neutral collisions tend to reduce the effect of the magnetic field on the properties of the sheath. The study may be helpful to understand the interactions of plasma with the wall in different plasma-assisted industrial applications containing dust grains as contaminants. Besides, the study will play significant role in controlling the dynamics of positive ions and negatively charged dust grains in the sheath.

References :

[1] G-H Kim, N. Hershkowitz, D. A. Diebold, and M-H. Cho, Phys. Plasma. **2** 3222–3233 (1995)
[3] H-B. Valentini H-B, Phys. Plasma. 3 1459–1461 (1996)

DYNAMICS OF DUST PARTICLES IN ACTIVE MAGNETIZED PLASMA SHEATH WITH NON-THERMAL ELECTRONS

Madhusudan Dhungana[1], Num Prasad Acharya[2], Suresh Basnet[1,2], and Raju Khanal[2]
[1]*Department of Physics, GoldenGate International College, Tribhuvan University, Battisputali, Kathmandu, Nepal*
[2]*Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu 44613, Nepal*
Email: numacharya@gmail.com

ABSTRACT

We have investigated the effects of non-thermal electrons on the magnetized dusty plasma sheath in the presence of electron impact ionization source and sink terms using fluid model. The set of governing fluid equations have been solved for given initial conditions, whereas the dust charging equations have been solved using Newton-Raphson method to find the dust charge at every position in the sheath region. The magnitude of potential monotonically increases towards the wall and in terms of magnitude, the potential drop in the sheath region increases from 246 to 332 as the non-thermal electron distribution approaches to Boltzmann distribution. The particle densities decrease towards the wall; however, the decreasing rate of electrons is much faster than that of ions and dust particles. The peak value appears on the space charge density profile in between 6.0 to 13.0 electron Debye lengths from the sheath entrance and it decreases towards the wall after that peak value. The non-thermal electron distribution affects the flow of velocity of ions and dust particles in the sheath region. The dust is negatively charged close to the sheath entrance due to higher attachment rate of electrons and this decrease as the non-thermal electron distribution approaches to Boltzmann distribution. As the dust particles flow towards the wall, the attachment rate of ions increases and this dominates over the electrons attachment rate close to the wall.

References:

[1] T. Sheridan and J. Goree, Phys. Fluids B **3**, 2796 (1991).

[2] X. Zhao, B. Zhang and C. Wang, Phys. Plasmas **27** (11), 113705 (2020)

[3] R. A. Cairns, A. A. Mamun, R. Bingham, R. Bostrom, R. O. Dendy, C. M. C. Nairn and P. K. Shukla, Geophys. Res. Lett. **22**, 2709 (1995).

[4] P. Shukla and A. Mamun, Introduction to Dusty Plasma Physics (Institute of Physics Publishing Ltd, Bristol, (2002)

Molecular Dynamics Simulation Of Three-Dimensional Yukawa Clusters Embedded In Plasma Environment

Hirakjyoti Sarma and Nilakshi Das

Department of Physics, Tezpur University, Assam-784028

E-mail : herockx1995@gmail.com

Abstract

Yukawa cluster consisting of a finite number of charged dust particles interacting via Debye-Hückel potential and acted upon by a global harmonic oscillator potential is investigated. Due to the interplay of this repulsive Debye-Hückel potential and attractive harmonic oscillator potential the particles organize themselves into nested spherical shells [1][2]. In this work, screening parameter (κ), particle number (N) and neutral friction (ν) dependence of cluster configuration and static structure have been studied by using Langevin Dynamics simulation. Our results show that with increase in screening the cluster shrinks and the occupation numbers of different shells change. With increase in particle numbers the particles occupy shells of increasing radius. The effects of these parameters on the structure have been studied with the help of different diagnostic tools.

References:

[1] Shell structure of Yukawa balls. *Contributions to Plasma Physics*, *47*(4-5), 281-290, (2007).

[2] Structure of spherical Yukawa clusters: A model for dust particles in dusty plasmas in an isotropic environment. *Physical Review E*, *72*(3), 036406, (2005).

Kelvin-Helmholtz instability in a compressible dust fluid flow

Krishan Kumar[1], Pintu Bandyopadhyay[1], Swarnima Singh[1], Vikram S. Dharodi[2], Abhijit Sen[1]

[1)] *Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat*
[2)] *Physics Department, Auburn University, Auburn, Alabama, 36849, USA*

E-mail: krishan.kumar@ipr.res.in

Abstract

We report the first experimental observations of a single-mode Kelvin-Helmholtz instability in a compressible dust fluid flow. The experiments are performed in an inverted Π-shaped dusty plasma experimental (DPEx) device in a DC glow discharge Argon plasma environment [1]. A gas pulse valve (supersonic jet) is installed in the experimental chamber to initiate the directional motion to a particular dust layer. The shear generated at the interface of the moving and stationary layers leads to the genesis of the Kelvin-Helmholtz instability and a vortex is observed at the interface. The shear velocity increases even further when the stationary layer is made to flow in an opposite direction. The magnitude of vorticity becomes stronger whereas the vortex becomes smaller with the increase of the shear velocity. A molecular dynamics simulation is also performed to provide more theoretical support to the experimental findings.

References :

[1] S. Jaiswal, P. Bandyopadhyay, and A. Sen, Rev. Sci. Instrum. **86**, 113503 (2015).

Experimental Demonstration of Structural Phase Transition in 2-D Complex Plasma Crystals

Swarnima Singh, Krishan Kumar, P. Bandyopadhyay and A. Sen

Institute for Plasma Research, A CI of Homi Bhabha National Institute, Bhat, Gandhinagar-382428

E-mail: swarnima.singh@ipr.res.in

Abstract

Strongly coupled dust monolayer levitated in plasma traditionally acquires a hexagonal lattice structure. A structural phase transition in this 2D system has long been an experimental challenge in the field of complex plasma. In this work, we illustrate the first experimental observation of a square lattice in a 2-Dimensional mono-dispersive complex plasma crystal which transpires in our system due to a structural phase transition [1]. The principal impediment to this transition arises from the wake field created by the ions streaming past the dust particles. This triggers a melting instability or forms vertically aligned layers in the system before it can make any distinct structural changes [2]. Our experimental success has been achieved by reducing the strength of the ion wake fields through a special electrode configuration [3] as well as by judicious control of the background neutral pressure and the dust confining potential. Such a procedure leads to the buckling of the mono-layer creating a quasi-2D structure where the desired structural phase transition can be witnessed. Our experimental results are well corroborated by molecular dynamic simulations.

References :

[1] Swarnima Singh, P. Bandyopadhyay, Krishan Kumar, and A. Sen. Phys. Rev. Lett.,129:115003, (2022).
[2] A. V. Zampetaki, H. Huang, C.-R. Du, H. Löwen, A. V. Ivlev, Phys. Rev. E **102**, 043204 (2020).
[3] S. Arumugam, P. Bandyopadhyay, S. Singh, M. G. Hariprasad, D. Rathod, G. Arora, and A. Sen, Plasma Sources Sci. Technol. 30, 085003 (2021).

STUDY OF NONLINEAR WAVES STRUCTURES THROUGH DAMPED MODIFIED GARDNER EQUATIONS IN QUANTUM PLASMA

Vanshika Khanna[1], Uday Narayan Ghosh[2] and Barjinder Kaur[3]

[1,3] GNA University, Phagwara, Punjab, 144401
[2] Munger University, Jamui, Bihar, 811307

[1] vanshikakhaan1996@gmail.com
[2]unghosh1@rediffmail.com
[3]kaurbarjinder1@gmail.com

Abstract

Olivier et al. [1] have used an extended reductive perturbation technique and studied the small amplitude supersolitons. Recognition of the existence of supercritical plasma compositions [2] leads to its relationship with small amplitude supersolitons [3]. Inferencing the importance of collision properties of supersolitons, Olivier et al. [1] have obtained an equation with higher order nonlinearity and referred as modified Gardner equations. In this study, nonlinear damped modified Gardner equations is derived from the multi-fluid quantum hydrodynamic model of collisional, unmagnetized electron-ion-dust quantum plasma. An extended version of the reductive perturbation technique (RPT) is used to derive damped modified Gardner equations for compositional parameters near the critical composition. It is found that this electron-ion-dust quantum plasma provides the required critical composition. New approximate analytical solitary wave solution is obtained, which apparently illustrates novel nonlinear features embedded therein. The effect of collision between dust, ion and the quantum diffraction parameter on the solitary wave structures are studied through newly obtained approximate analytical solution. It is seen that dust ion collision and the quantum diffraction parameter distinguishingly modifies the structures of solitary wave solutions. The crucial role of collision parameter and the quantum diffraction parameter on the solitary wave structures have been studied extensively.

References :

[1] C. P. Olivier, F. Verheest and W. A. Hereman, Phys. Plasmas **25**, 032309 (2018).
[2] F. Verheest, C. P. Olivier and W. A. Hereman, J. Plasma Phys 82, 905820208 (2016)
[3] C. P. Olivier, F. Verheest and S. K. Maharaj, J. Plasma Phys. 83, 905830403 (2017)

TUNABLE RHEOLOGICAL BEHAVIOUR OF MAGNETIZED COMPLEX PLASMA

Biswajit Dutta, Nilakshi Das

Tezpur University, Tezpur, Assam, 784028
E-mail: biswa1995@tezu.ernet.in

Abstract

In complex plasma, the flow of the plasma ions from the bulk region to the plasma sheath give rise to an anisotropy in the interaction potential between two dust particles. In the presence of ion drift, an oscillatory and attractive wake potential develops among charged dust particles immersed in a plasma. The amplitude of this wake potential can be modulated by applying an external magnetic field.

In this work, we have explored the dependence of an external magnetic field on the rheological properties of complex plasma via anisotropic wake potential. With the help of Langevin dynamics simulation, the shear viscosity (η) of a 3D liquid dusty plasma has been estimated as a function of magnetic field (B) and normalized ion flow velocity (M) from the simulation data using Green–Kubo formalism. It has been shown that in the strongly correlated liquid state, complex plasma may exhibit sharp changes in viscosity with magnetic field and ion drift velocity. It is observed that the rheological property of such plasma depends on the dominant interaction operating among the particles and can be controlled by applying an external magnetic field. A novel regime of magnetic field is observed in which strongly correlated complex plasma liquid exhibits a sharp response to an external magnetic field. Due to this unique property, complex plasma may be used as a platform to study magneto-rheological characteristics of soft matter and there is a possibility of using dusty plasma as a magneto-rheological material in near future.

References :

[1] Ott, T., and M. Bonitz. "Diffusion in a strongly coupled magnetized plasma." *Physical review letters* 107, no. 13 (2011): 135003.
[2] Bezbaruah, Pratikshya, and Nilakshi Das. "Wake potential in 2-d magnetized complex plasma." *The European Physical Journal D* (2017).
[3] Dutta, Biswajit, Hirakjyoti Sarma, Pratikshya Bezbaruah, and Nilakshi Das. "Tunable rheological behaviour of magnetized complex plasma." *Physics Letters A* 438 (2022): 128110.

Layer formation in stratified 3D Yukawa liquids

Name(s) of the author : Suruj Kalita, Rajaraman Ganesh

Affiliation : Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428
Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India

E-mail : suruj.kalita@ipr.res.in

Abstract

When a 3D fluid is stably stratified in an external gravity, meaning when the density gradient is in the direction of gravity, the loss of isotropy can be expected to bring in interesting dynamics into play. For example, in a stratified plane Couette flow (PCF), the horizontal velocity component remain unaffected, leading to possible “layer formations”.

In this study, we investigate a PCF in a 3D Yukawa liquid [1] subjected to external gravity using 3D Molecular Dynamics simulation to address “layer formation”. We have perturbed the system linearly such that we remain in the linear regime and keep the Reynolds number as high as possible. We have considered two cases - In the first case, the velocity shear is taken along the vertical density gradient and in second case, the velocity shear is taken perpendicular to the density gradient present in the system. We consider two different range of interaction, corresponding to $\kappa = 1.0, 2.0$. We observe “layer formation” in all the cases. As the applied perturbation in velocity does not give rise to any vorticity. Therefore, the instability mechanism is mainly governed by "Phillips/Posmentier (PP)" [2] instability and preliminary results also implies the same. From, spatio-termporal analysis and growth dynamics in vertical velocity, it is found that the instability is higher for $\kappa = 1.0$. We further take the help of “arc-length continuation bifurcation” theory to know about the origin of the instability. A possible mechanism called “wave resonance mechanism” is suspected to play a key role in the “layer formation” problem in addition to the PP instability, which in under investigation. A more detailed analysis of the above mentioned results will be presented in the Conference.

References :

[1] S Kalita, R Ganesh, Physics of Fluids 33, 095118 (2021).
[2] S. A. Thorpe, Journal of Fluid Mechanics, Volume 793, 25 April 2016, pp. 380 - 413.

Effect of Debye Hückel potential in the formation of Dust acoustic wave with dust charge variation

Dr. Prathana Borah

Nanda Nath Saikia College, Titabar, Jorhat, Assam, India-785630

E-mail: pra.borah15@gmail.com

Abstract

A theoretical investigation on the effect of Debye Hückel potential on dust acoustic (DA) wave has been carried out in weakly nonlinear limit in strongly coupled regime with dust charge variation. Charging of dust grains in plasma environment and variation of dust charge is an important and unique feature of dusty plasma [1]. As an outcome of this feature a collisionless damping or dissipative effect emerges in the system leading to the formation of nonlinear coherent structures as the dissipation is balanced by nonlinearity. Moreover, the dust-dust strong electrostatic interaction [2] among the dust grains has an influential effect on the evolution of nonlinear structures in plasma. The coupling of these two fascinating events in dusty plasma alters the behavior of the DA [3] nonlinear wave structures. The present theoretical investigation provides a detailed insight of DA nonlinear wave structures in a strongly couple regime of dusty plasmas.

References :

[1] R. K. Verma, P. K. Shukla and V. Krishan, Phys. Rev. E 47, 3612, (1993).
[2] V. V. Yaroshenko, V. Nosenko, and G. E. Morfill, Phys. Plasma 17, 103709, (2010).
[3] P.K. Shukla, Phys. Plasma 8, 1791, (2001).

Formation Of Crystalline Structure In Ultracold Electron-Ion Plasma

Mamta Yadav, Priya Deshwal, Srimanta Maity, Amita Das

Department of physics, Indian Institute of technology Delhi (IITD), Hauz khas, New Delhi, 110016, India

E-mail: phz198493@iitd.ac.in

Abstract

Structure formation in electron-ion neutral ultracold plasma (UCP) [1] has been studied in 2-D and 3-D by molecular dynamics simulation using software LAMMPS [2]. Electrons and ions are interacting through long-range pair Coulomb potential and recombination between electrons and ions are avoided by repulsive short-range Lennard-Jones (LJ) potential. This provides for a minimum in the interaction potential between ions and electrons. The particles can, therefore, get trapped in such interaction potential and form classical bound states. Several distinct varieties of classical bound states comprises of two to ten particles forming the chain and ring like structures are observed and even these classical bound states are often not neutral but can have an unbalanced unit chrage. The behavior of ultracold plasma is also observed when an external perturbation (a point particle having charge hundred times the charge of ion) has been introduced inside the simulation box. The electrons try to shield the effect of potential of external perturbation by arranging themselves around the external perturbation. In response to the perturbation, the background species (electrons) of UCP are observed to form hexagonal crystalline structures and Coulomb-ball like structures around the externally inserted particle in 2D and 3D, respectively. The spatial properties of these crystalline structures have been analyzed using radial distribution function (RDF) and Voronoi diagram in 2D and 3D, respectively. Due to the formation of these crystalline structures, the modified potential profile around this external perturbation has been analyzed and compared to that of an ideal plasma.

References :

[1] T. Killian et al., Physical Review Letters, **83,** 4776 (1996)
[2] S. Plimpton, J. Comput. Phys. 117, 1–19 (1995).

Experimental study of the evolution of a non-planar solitary wave in a strongly coupled dusty plasma

Prarthana Gogoi[1, 2], Bidyut Chutia[3], N. C. Adhikary[1,] and H. Bailung[4]

[1.] *Physical Sciences Division, Institute of Advanced Study in Science & Technology (IASST), Paschim Boragaon, Guwahati 781035, Assam, India*
[2.] *Academy of Scientific and Innovative Research (AcSIR), Ghaziabad – 201002, India*
[3.] *Centre of Plasma Physics (CPP-IPR), Nazirakhat, 782402, Assam, India*
[4.] *Department of Physics, Bodoland University, Kokrajhar 783370, Assam, India*

E-mail: prarthanagogoi19@gmail.com

Abstract

The nonlinear propagation of a stable dust acoustic solitary wave in a non-planar geometry is investigated here [1][2]. The experiment is performed in a strongly coupled dusty plasma consisting of monodisperse micron-sized dust particles. The massive dust particles are levitated (by balancing gravitational and sheath electric field force) above an electrically grounded stainless-steel plate inside a vacuum glass chamber. The non-planar waves are excited by a cylindrical conducting pin placed at the centre of the dusty plasma medium. On applying a negative excitation pulse, the transient sheath surrounding the pin expands, forming a dust void [3]. From the void boundary, an outward moving density perturbation propagates which finally evolves into a nonlinear non-planar dust acoustic solitary wave. The propagating non-planar wavefronts are video recorded using a high-speed camera at a rate of 30-100 frames per second. The videos are converted into frames at constant time intervals for analysis. The wave's velocity, width, and amplitude are measured as a function of excitation parameters.

References :

[1] S. K. Sharma, A. Boruah, and H. Bailung, "Head-on collision of dust-acoustic solitons in a strongly coupled dusty plasma," *Phys. Rev. E - Stat. Nonlinear, Soft Matter Phys.*, vol. 89, no. 1, pp. 1–5, 2014, doi: 10.1103/PhysRevE.89.013110.

[2] P. Bandyopadhyay, G. Prasad, A. Sen, and P. K. Kaw, "Experimental study of nonlinear dust acoustic solitary waves in a dusty plasma," *Phys. Rev. Lett.*, vol. 101, no. 6, pp. 1–4, 2008, doi: 10.1103/PhysRevLett.101.065006.

[3] T. Chen and L. Schott, "Observation of diverging cylindrical solitons excited with a probe," *Phys. Lett. A*, vol. 58, no. 7, pp. 459–461, 1976, doi: 10.1016/0375-

Self-Excited Vortex Formation in Three Dimensional Dusty Plasma

Sachin Sharma[1], Meenakshee Sharma[2], G Veda Prakash[3], Yogesh Saxena[2], and Sanat Tiwari [1]

[1]*Indian Institute of Technology Jammu, Jammu & Kashmir, 181221, India*
[2]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, 382428, India*
[3]*Indian Institute of Technology Delhi, Hauz Khas, New Delhi, 110016, India*

E-mail : sachin.sharma@iitjammu.ac.in

Abstract

Dust vortex corresponds to the rotating motion of charged dust particles around an axial line(straight or curved). Self-excited dust vortices in an unmagnetized dusty plasma are due to the nonzero curl of the plasma forces on the dust particles that leads to the rotation of the dust particles.

We report self-excited large-scale dust vortices in a three-dimensional dusty plasma produced in a DC glow discharge with background argon plasma. The iondrag and electric forces acting on dust particles are responsible for dust rotation due to the non-conservative character of the ion drag force revealed by the finite curl of the forces. Theoretically, the vortex formation can be explained by a simple discharge model [1].

While the dust cloud is three-dimensional, the recorded frames contain a 2D plane perpendicular to the electrode assembly. The dust rotation dynamics are analyzed by using openPIV software for the vorticity profile. The power scaling shows double cascading, and the results agree with earlier experimental observations in the dusty plasma experiment [2].

References :

[1] T. Bockwoldt, O. Arp, K.O. Menzel, A. Piel: On the origin of dust vortices in complex plasmas under microgravity conditions. Phys. Plasmas **21**, 103703 (2014)
[2] M. Schwabe, S. Zhdanov, and C. Rath: Turbulence in an auto-oscillating complex plasma. IEEE Trans. Plasma Sci. **46**, 684 (2018)

Hydrodynamic Stability of Convective Cells in 2D Complex Plasmas

Pawandeep Kaur, Jagannath Mahapatra, Rajaraman Ganesh

Institute for Plasma Research, A CI of Homi Bhabha National Institute, Gandhinagar 382428, Gujarat, India

pawandeep.kaur@ipr.res.in

Abstract

Convection cells have been a subject of numerous studies for past few decades due to their relevance in wide variety of systems ranging from small scale systems such as tea kettle to large scale systems such as oceans, Sun, planetary atmosphere etc. Furthermore, one can also find convective cells in fusion devices such as tokamaks, ovens, solar devices etc. Recently, convection cells formed in a driven dissipative 2D Yukawa liquid have been addressed [1,2]. However, hydrodynamic studies [3] and molecular dynamics simulations of Yukawa liquid [4] have suggested that the stability of convection cells can be better understood under much simpler conditions, for example, if seen as an initial value problem.

In this work, we investigate the stability of an initial periodic array of convective cells formed in strongly coupled liquids using generalized hyrodynamic model [5], which is generally used to incorporate viscoelastic effects of the strongly coupled liquids, for example, liquid phase of the Complex plasma. Can the stability of convective cells be affected under infinitesimal perturbations in such viscoelastic liquids? What is the role of viscosity, coupling strength and aspect ratio of the system on the stability of convective cells? Several such questions will be answered and the details will be presented.

References :

[1] P. Kaur and R. Ganesh, Physics of Plasmas 28, 113703 (2021).
[2] P. Kaur and R. Ganesh, Physics of Plasmas 28, 063701 (2021).
[3] J. M. Finn, J. F. Drake and P. N. Guzdar, Physics of Fluids B: Plasma Physics 4, 2758 (1992).
[4] P. Kaur and R. Ganesh, Manuscript under preparation (2022)
[5] Akanksha Gupta, PhD Thesis, HBNI (2017).

Active Complex Plasma: A new paradigm of research

Soumen De Karmakar and Rajaraman Ganesh

Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat, India
Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India

E-mail : soumendekarmakar@gmail.com

Abstract

Complex Plasma consists of micron sized particles in a background plasma medium of low ionization. Background density of the neutrals and the charged elements are controlled easily in experiments, that in turn controls the strength and the range of inter-particle interaction between the microscopic particles. In the limit of large density of the microscopic particles or in the limit of large strength of interaction, the micron sized particles form solid-like structures.

When the micron sized particles are subjected to self-propulsion mechanism [1] by breaking their rotational symmetry, the system is regarded as Active Complex Plasma [2, 3]. In this presentation, we discuss various possible mechanisms by which Active Complex Plasmas can be realized in laboratories. One of the well known phenomena in a collection of self-propelled particles at substantially large density is motility induced phase separation (MIPS) [3, 4, 5], where the homogeneous system of repulsive particles spontaneously phase separated into high and low density regions, that are known to coexist. The open question of MIPS in active complex plasma, which is explored with particle based simulation, is presented.

References :

[1] C. Bechinger, R. Di Leonardo, H. Löwen, C. Reichhardt, G. Volpe, and G. Volpe, Active particles in complex and crowded environments, Rev. Mod. Phys. 88, 045006 (2016).
[2] S. De Karmakar and R. Ganesh, Phase transition and emergence of active temperature in an active brownian system in underdamped background, Phys. Rev. E 101, 032121 (2020).
[3] S. De Karmakar and R. Ganesh, Motility-induced phase separation of self-propelled soft inertial disks, Soft Matter 18, 7301 (2022).
[4] S. De Karmakar and R. Ganesh, Re-entrant phase separation of a sparse collection of non-reciprocally aligning self-propelled disks, Phys. Rev. E (accepted) (2022).
[5] S. De Karmakar, A. Chugh, R. Ganesh, Collective behavior of soft self-propelled disks with rotational inertia, Under communication in journal (2022).

DUST CHARGE FLUCTUATION AND ION ACOUSTIC WAVE PROPAGATION IN DUSTY PLASMA WITH TWO GROUPS OF ELECTRONS

Raju Khanal[1], Shiva Bikram Thapa[1] and Suresh Basnet[1,2]
[1]*Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[2]*Department of Physics, GoldenGate International College, Tribhuvan University, Battisputali, Kathmandu, Nepal*

E-mail: raju.khanal@cdp.tu.edu.np

Abstract

We have employed the self-consistent kinetic theory to study the linear dispersion relation of ion acoustic waves in four component plasma consisting of nonextensive hot electrons, Maxwellian cold electrons, positive ions, and dust particles. The dust charging process with the modified ion acoustic wave damping as well as its unstable mode has been graphically illustrated. It is found that the dust charging mechanism depends on the density of hot electrons, degree of nonextensive electron distribution, and temperature ratio of hot to cold electrons. It is shown that the damping and instability rates of ion acoustic wave due to dust charge fluctuations explicitly depends on the choice of electron distribution and magnitude of dusty plasma parameters. In addition, we have studied the ion acoustic Landau damping in the absence of dust particles. It is found that the weak damping region broadens, while the strong damping region shrinks and is shifted towards the short wavelength region for the increase in temperature ratio of hot to cold electrons.

References:

[1] C. Tsallisl, J. Stat. Phys. **52**, 479 (1988).
[2] N. d'Angelo, Planet. Space Sci. **38**, 1143 (1990).
[3] M. R. Jana, A. Sen, and P. K. Kaw, Phys. Rev. E **48**, 3930 (1993).
[4] P. K. Shukla and A. A. Mamun, *Introduction to dusty plasma physics* (Bristol: IoP) (2002).
[5] R. L. Merlino and S.-H. Kim, Appl. Phys. Lett. **89**, 091501 (2006).
[6] S. Basnet, A. Maskey, A. Deuja, and R. Khanal, Phys. Scr. **96**, 125632 (2021).

Characterizations of Spontaneous Fluctuations in Strongly Coupled Dusty Plasmas

Ankit Dhaka[1,2], PV Subhash[2,3], Pintu Bandyopadhyay [1,2], A. Sen [1,2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428, India*
[2]*Homi Bhabha National Institute, Anushaktinagar, Mumbai 400094, India*
[3]*ITER-India, Institute for Plasma Research, Gandhinagar, Gujarat 382428, India*

E-mail : ankit.dhaka@ipr.res.in

Abstract

The thermal motions of particles cause fluctuations in local density of a system which are responsible for transport processes at microscopic scales. We report an experimental study of microscopic fluctuations in density of a strongly coupled system using dusty plasmas which are a class of Yukawa systems. The experiments are carried out in capacitively coupled radio frequency Argon plasmas. The dusty plasmas are produced by introducing the mono-dispersive micron sized Melamine Formaldehyde particles in the background plasma. The space and time dynamics of dust particles are captured using high speed imaging systems and a full N-body distribution function is constructed by recording the velocities and positions. An autocorrelation of density is calculated in the inverse space to numerically obtain a density autocorrelation function (DAF) which is a marker of time dynamics of fluctuations. In order to characterize the experimentally obtained DAF, time evolution of density fluctuations of the dusty plasma system are analytically derived. The dynamics of dusty plasma are described in the framework of generalized hydrodynamic (GH) model that incorporates strong coupling and viscoelastic memory effects. A hydrodynamic matrix for dusty plasma systems is exactly derived in the GH framework and an analytical form of DAF is obtained in terms of transport parameters of the system. The experimentally obtained DAF is compared with the analytical and numerical results to estimate the important thermodynamic parameters of dusty plasmas. The potential extensions of present study has also been discussed along with applications of analytically obtained DAF to Molecular dynamics simulations to estimate thermodynamic parameters of a system.

References :

[1] André́ Melzer. Physics of Dusty Plasmas, volume 962 of Lecture Notes in Physics. Springer International Publishing, Cham, 2019

[2] Jean Pierre Hansen and I. R. McDonald. Theory of Simple Liquids: With Applications to Soft Matter: Fourth Edition. Elsevier, 2013.

[3] P. K. Kaw and A. Sen, "Low Frequency modes in strongy coupled dusty plasmas," *Physics of Plasma ,* pp. 3552-3559, 1998.

Interaction between approaching carrier waves in semiconductor Plasma

Swarniv Chandra[1] and Chinmay Das[2]

[1]Government General Degree College at Kushmandi, Dakshin Dinajpr, West Bengal 733121
[2]Kabi Jagadram Roy Govt. General Degree College, Mejia, Bankura, West Bengal 722143

E-mail : swarni147@gmail.com

Abstract

In this work we investigate some behavior and interaction of carrier waves in a semiconductor. The study has been carried by employing both analytical methods and simulation technique. In this paper, we have employed the quantum hydrodynamic model equations and the reductive perturbation methods along with Runge Kutta method of order four (RK4). Then we obtained a KdV family equation whose time evolution have been studied with our indigenously designed HASS technique. The interaction is studied by employing another indigenously designed INSAT-FORK code. The characteristics and interaction between the stationary structures have been studied for different parameters.

References :

1. Bifurcation Analysis of EAWs in Degenerate Astrophysical Plasma: Chaos and Multistability, S Chandra, S Kapoor, D Nandi, C Das, D Bhattacharjee, IEEE Transactions on Plasma Science 50 (6), 1495-1507 (2022)

EFFECT OF NEGATIVELY BIASED ELECTRODE ON TWO ION SPECIES PLASMA WALL TRANSITION AND DUST CHARGING

Shiva Bikram Thapa[1], Suresh Basnet[1,2], and Raju Khanal[1]
[1]*Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[2]*Department of Physics, GoldenGate International College, Tribhuvan University, Battisputali, Kathmandu, Nepal*

E-mail: bikramthapashiva@gmail.com

Abstract

The overall dynamics, flow and the interaction of plasma with the electrode is dictated by the formation of the non-neutral positively charged region close to the biased electrode. Using the kinetic trajectory simulation method, we have studied the effect of electrode biasing voltage on the characteristics of two ion species magnetized plasma-wall transition region and the dust charging mechanism. The Debye sheath width increases from about 3.15 to 4.30 λ for the increase in biasing voltage from -20 to -50 V. The space charge density peak shifts towards the particle injection boundary as the biasing voltage is increased. The E×B drift velocity sharply increases near the electrode. The dust attains positive charge as we move from the injection boundary towards the electrode. In addition, the normalized dust charge close to the electrode gets increased from about -1.39 to 16.33 for the increase in biasing voltage from -20 to -50 V.

References:

[1] K. U. Riemann, J. Phys. D: Appl. Phys. **24**(4), 493 (1991).

[2] R. Chodura, Phys. Fluids **25**(9), 1628 (1982).

[3] M. Davoudabadi and F. Mashayek, Phys. Plasmas **12**(7), 089903 (2005).

[4] G. Foroutan, Phys. Plasmas **17**(12), 123711 (2010).

ANALYTICAL STUDIES OF DUST ACOUSTIC WAVES WITH KAPPA DISTRIBUTIVE IONS AND ELECTRONS IN A VISCOUS DUSTY PLASMA

J. Goswami and S.S. Kausik

Centre of Plasma Physics, Institute for Plasma Research,
Nazirakhat, Sonapur-782402, Kamrup (M), Assam, India

*E-mail: jyotirmoy.goswami@cppipr.res.in, kausikss@rediffmail.com

<u>Abstract</u>

The most successful models to describe the dynamics of dust acoustic and similar kinds of mode is hydrodynamic model. We have constructed a model by considering a magnetized strongly coupled viscous plasma with kappa distributive ions and electrons. At first using reductive perturbation technique (RPT), we have derived the well-known KdV-Burger's (KdVB) equation. Then solving this equation, we have achieved the monotonic and oscillatory shock waves. Previous observations verified that kappa distributive ions and electrons are present in Saturn's magnetosphere [1,2]. The outcome of this particular research can interpret the nonlinear behavior of dust-acoustic waves in that region.

References:

[1] General characteristics of hot plasma and energetic particles in the Saturnian magnetosphere: Results from the Voyager spacecraft, J. Geophys. Res., **88** p. 8871-8892, (1983).
[2] Multi-instrument analysis of electron populations in Saturn's magnetosphere, J. Geophys. Res., **113**, p. A07208, (2008).

Wave Spectra in Yukawa system: The role of dusty plasma parameters on collective properties

Pratikshya Bezbaruah[1], Hirakjyoti Sarma[2] and Nilakshi Das[2]

[1]*Biswanath College, College Road, Biswanath Chariali, Assam, 784176*
[2]*Tezpur University, Napaam, Sonitpur, Assam, 784028*

E-mail: pratikshyabezbaruah1991@gmail.com

Abstract

Longitudinal and transverse waves due to dust oscillation are studied in Yukawa systems. Molecular Dynamics Simulation is performed to diagnose the collective properties. Space time auto correlation functions are estimated to characterize the collective motions of charged dust particles in plasma environment [1]. The present work may have direct relevance in the study of interaction potential. The nature of interaction between particles may substantially affect the dispersion of acoustic modes excited in the system. The result for longitudinal mode is compared with that of Hamaguchi's work for a given parameter range [2].

References:

[1] Two dimensional Yukawa liquids: Correlation and dynamics, Phys. Rev. Lett., **92**, p 065001-065005, (2004)
[2] Wave Dispersion Relation in Yukawa fluids, Phys.Rev.Lett., **84,** p 6026-6029, (2000)

KORTEWEG-DE VRIES MODEL BASED NONLINEAR DISPERSION RELATIONS FOR DUST ACOUSTIC WAVE

Farida Batool[1], Ajaz Mir [1], Sachin Sharma[1], Abhijit Sen [2] and Sanat Tiwari[1]

[1]*Indian Institute of Technology Jammu, Jammu, J&K, 181221, India*
[2]*Institute for Plasma Research, Gandhinagar, Gujarat, 382428, India*

E-mail: farida.batool@iitjammu.ac.in

Abstract

Dust acoustic waves (DAWs) are excited spontaneously due to ion-streaming instability in dusty plasma supported by the balance between dust inertia and the plasma pressure [1]. It shows sound wave nature in the long wavelength limits. Traditionally DAW dispersion is often studied in the linear regime. However, it is a fact that DAWs become nonlinear in experiments. Hence it is important to consider the role of nonlinearity in the DAW dispersion indicated by the generation of harmonics [2]. We have derived the nonlinear dispersion relation (NLDR) of DAW based on the solution of the Korteweg-de Vries (KdV) model [3]. The KdV model explains the wave phenomena in a weakly nonlinear regime in charged and neutral fluid with spatio-temporal nonlinearity. This theoretical model, though simplified and does not explicitly include various damping effects, does help us predict the shift of the wave's frequency with the increasing nonlinearity(κ). The NLDR of KdV-based systems will be helpful in determining the degree of nonlinearity of the medium. The parameters which give information about the wave amplitude and nonlinearity of the medium are determined by the Jacobi elliptic parameter.

Using the frequency and wavevector, we derived the dispersion relation that includes the nonlinearity parameter kappa (κ), which characterizes the nonlinearity of the medium [3]. In the long wavelength limit, we have found agreement between the KdV dispersion and the experimental DAW dispersion relation [1]. However, on increasing the nonlinearity parameter, we have observed a deviation from the linear dispersion, which leads to a shift in frequency. Thus our work indicates that in addition to various physical processes which effects the dispersion relation, we also have to include the nonlinearity effect in the dispersion relation of DAW.

References :

[1] Thompson, C., Barkan, A., D'Angelo, N., and Merlino, R. L.: Dust acoustic waves in a direct current glow discharge. Phys. Plasmas **4**, 2331 (1997)
[2] V. V. Yaroshenko, S. A. Khrapak, M. Y. Pustylnik, H. M. Thomas, O. F. Petrov, and V. E. Fortov, S. Jaiswal, A. M. Lipaev, A. D. Usachev: Excitation of low-frequency dust density waves in flowing complex plasmas. Phys. Plasmas 26, 053702 (2019)
[3] Mir, A. A., Tiwari, S. K., Goree, J., Sen, A., Crabtree, C., and Ganguli, G.: A forced Korteweg–de Vries model for nonlinear mixing of oscillations in a dusty plasma. Phys. Rev. E **102**, 023201 (2020)

DYNAMICS OF DUST PARTICLES IN ACTIVE MAGNETIZED PLASMA SHEATH WITH NON THERMAL ELECTRONS

Madhusudan Dhungana[1], Suresh Basnet[1,2], and Raju Khanal[2]

[1]*Department of Physics, GoldenGate International College, Tribhuvan University, Battisputali, Kathmandu, Nepal*
[2]*Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal*

E-mail: msudandhungana@gmail.com

Abstract

Using fluid model, we have investigated the effects of non-thermal electrons on the magnetized dusty plasma sheath in the presence of electron impact ionization source and sink terms. The magnitude of potential monotonically increases towards the wall and in terms of magnitude, the potential drop in the sheath region increases as the non-thermal electron distribution approaches to Boltzmann distribution. The particle densities decrease towards the wall; however, the decreasing rate of electrons is much faster than that of ions and dust particles. The peak value appears on the space charge density profile and it decreases towards the wall after that peak value. The non-thermal electron distribution affects the flow of velocity of ions and dust particles in the sheath region. As the non-thermal index decreases, the velocity of positive ions and dust particles at the wall increases. The dust is negatively charged close to the sheath entrance due to higher attachment rate of electrons and this decreases as the non-thermal electron distribution approaches to Boltzmann distribution. As the dust particles flow towards the wall, the attachment rate of ions increases and this dominates over the electrons attachment rate close to the wall. Thus, the dust particles become positively charged and the magnitude of dust charge is higher for Boltzmann distribution rather than non-thermal electron distribution.

References:

[1] O. El Ghani, I. Driouch and H. Chatei, *Phys. Plasmas* **27** (8), 083701 (2020).

[2] P. K. Shukla and A. A. Mamun, *Introduction to dusty plasma physics* (Bristol: IoP) (2002).

[3] T. E. Sheridan and J. Goree, *Phys. Plasmas* **3**, 2796 (1991).

DYNAMICS OF DUST PARTICLES IN ACTIVE MAGNETIZED PLASMA SHEATH WITH NON THERMAL ELECTRONS

Madhusudan Dhungana[1], Suresh Basnet[1,2], and Raju Khanal[2]
[1]*Department of Physics, GoldenGate International College, Tribhuvan University, Battisputali, Kathmandu, Nepal*
[2]*Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal*

E-mail: msudandhungana@gmail.com

Abstract

Using fluid model, we have investigated the effects of non-thermal electrons on the magnetized dusty plasma sheath in the presence of electron impact ionization source and sink terms. The magnitude of potential monotonically increases towards the wall and in terms of magnitude, the potential drop in the sheath region increases as the non-thermal electron distribution approaches to Boltzmann distribution. The particle densities decrease towards the wall; however, the decreasing rate of electrons is much faster than that of ions and dust particles. The peak value appears on the space charge density profile and it decreases towards the wall after that peak value. The non-thermal electron distribution affects the flow of velocity of ions and dust particles in the sheath region. As the non-thermal index decreases, the velocity of positive ions and dust particles at the wall increases. The dust is negatively charged close to the sheath entrance due to higher attachment rate of electrons and this decreases as the non-thermal electron distribution approaches to Boltzmann distribution. As the dust particles flow towards the wall, the attachment rate of ions increases and this dominates over the electrons attachment rate close to the wall. Thus, the dust particles become positively charged and the magnitude of dust charge is higher for Boltzmann distribution rather than non-thermal electron distribution.

References:

[1] O. El Ghani, I. Driouch and H. Chatei, *Phys. Plasmas* **27** (8), 083701 (2020).

[2] P. K. Shukla and A. A. Mamun, *Introduction to dusty plasma physics* (Bristol: IoP) (2002).

[3] T. E. Sheridan and J. Goree, *Phys. Plasmas* **3**, 2796 (1991).

KORTEWEG-DE VRIES MODEL BASED NONLINEAR DISPERSION RELATIONS FOR DUST ACOUSTIC WAVE

Farida Batool[1], Ajaz Mir [1], Sachin Sharma[1], Abhijit Sen [2] and Sanat Tiwari[1]

[1]*Indian Institute of Technology Jammu, Jammu, J&K, 181221, India*
[2]*Institute for Plasma Research, Gandhinagar, Gujarat, 382428, India*

E-mail : farida.batool@iitjammu.ac.in

Abstract

Dust acoustic waves (DAWs) are excited spontaneously due to ion-streaming instability in dusty plasma supported by the balance between dust inertia and the plasma pressure [1]. It shows sound wave nature in the long wavelength limits. Traditionally DAW dispersion is often studied in the linear regime. However, it is a fact that DAWs become nonlinear in experiments. Hence it is important to consider the role of nonlinearity in the DAW dispersion indicated by the generation of harmonics [2]. We have derived the nonlinear dispersion relation (NLDR) of DAW based on the solution of the Korteweg-de Vries (KdV) model [3]. The KdV model explains the wave phenomena in a weakly nonlinear regime in charged and neutral fluid with spatio-temporal nonlinearity. This theoretical model, though simplified and does not explicitly include various damping effects, does help us predict the shift of the wave's frequency with the increasing nonlinearity(κ). The NLDR of KdV-based systems will be helpful in determining the degree of nonlinearity of the medium. The parameters which give information about the wave amplitude and nonlinearity of the medium are determined by the Jacobi elliptic parameter.

Using the frequency and wavevector, we derived the dispersion relation that includes the nonlinearity parameter kappa (κ), which characterizes the nonlinearity of the medium [3]. In the long wavelength limit, we have found agreement between the KdV dispersion and the experimental DAW dispersion relation [1]. However, on increasing the nonlinearity parameter, we have observed a deviation from the linear dispersion, which leads to a shift in frequency. Thus our work indicates that in addition to various physical processes which effects the dispersion relation, we also have to include the nonlinearity effect in the dispersion relation of DAW.

References :

[1] Thompson, C., Barkan, A., D'Angelo, N., and Merlino, R. L.: Dust acoustic waves in a direct current glow discharge. Phys. Plasmas **4**, 2331 (1997)
[2] V. V. Yaroshenko, S. A. Khrapak, M. Y. Pustylnik, H. M. Thomas, O. F. Petrov, and V. E. Fortov, S. Jaiswal, A. M. Lipaev, A. D. Usachev: Excitation of low-frequency dust density waves in flowing complex plasmas. Phys. Plasmas 26, 053702 (2019)
[3] Mir, A. A., Tiwari, S. K., Goree, J., Sen, A., Crabtree, C., and Ganguli, G.: A forced Korteweg–de Vries model for nonlinear mixing of oscillations in a dusty plasma. Phys. Rev. E **102**, 023201 (2020)

Study Of Plasma Sheath In The Presence Of Dust Particles In A Magnetic Mirror-like Field Configuration

K. Deka[1-3], G. Sharma[1], R. Paul[1], R. Moulick[1], S. Adhikari[2], S. S. Kausik[1], and B. K. Saikia[1]

[1]*Centre of Plasma Physics, Institute for Plasma Research, Sonapur 782402, Assam, India*

[2]*Institute for Energy Technology, Instituttveien 8 2007 Kjeller, Norway*

[3]*Pandit Deendayal Upadhyaya Adarsha Mahavidyalaya, Tulungia 783383, Bongaigaon, Assam, India.*

E-mail : kausikss@rediffmail.com

Abstract

The properties of a plasma sheath in the presence of dust grains and a magnetic mirror-like field configuration have been investigated in this study. All the plasma species viz. electrons, ions, and dust grains are described by fluid equations. The system of equations involved in the study is solved numerically using the Runge-Kutta fourth-order (RK4) method to explore the sheath properties. The results of the study suggest that in the presence of a magnetic mirror-like field configuration, the component of ion velocity perpendicular to the wall decreases near the wall, and consequently, the ion density increases. To the best of our knowledge, such observations has not been reported anywhere previously. This utterly different observation is due to the magnetic field configuration alone. Moreover, the ion-neutral collisions tend to reduce the effect of the magnetic field on the properties of the sheath. The study may be helpful to understand the interactions of plasma with the wall in different plasma-assisted industrial applications containing dust grains as contaminants. Besides, the study will play significant role in controlling the dynamics of positive ions and negatively charged dust grains in the sheath.

References :

[1] G-H Kim, N. Hershkowitz, D. A. Diebold, and M-H. Cho, Phys. Plasma. **2** 3222–3233 (1995)

[3] H-B. Valentini H-B, Phys. Plasma. 3 1459–1461 (1996)

Streaming instabilities in magnetized quantum dusty plasmas

*Sukhmander Singh

[1]Department of Physics, Central University of Rajasthan, Ajmer, Kishangarh- 305817, India

*E-mail: sukhmandersingh@curaj.ac.in

Abstract

The study of dusty plasma has gained interest in the last few decades due to its observations and applications in the space and laboratory. Many authors studied the linear and nonlinear electrostatic wave in the presence and absence of the external magnetic field. The presence of charged dust grains modify the ion-acoustic waves, lower hybrid waves, ion-acoustic and introduces dust acoustic waves and dust ion acoustic waves. But due to the recent development in the technology basically in the nano science and the miniaturization of semiconductor devices, have made it possible to envisaged the practical application of quantum dusty plasma physics and where the quantum mechanical effect of the constituent particles a vital role [1-4]. The plasma physics which deals with the low temperature and high density, governed by the quantum mechanical effects [5]. In the present paper, we solve the dispersion relation for the dust and ions streaming instabilities under the effects of multi ions. The growth rate and the real frequency is determined for the further analysis of the characteristic of the motions.

References

[1] S. Ali, P. K. Shukla, Phys. Plasmas 13 (2006).
[2] M. Marklund, G. Brodin, phys. Rev. Let. 98, 025001 (2007).
[3] J. Cao, H. Ren, Z. Wu and P. K. Chu, Phys. Plasmas (2008).
[4] S. Ali, P.K. Shukla, Eur. Phys. J. D (2007)
[5] Ashish, Singh, S. J Astrophys Astron 43, 59 (2022).

Space & Astrophysical Plasma

LINEAR STUDY OF KELVIN HELMHOLTZ INSTABILITY IN TWO SUPERPOSED INCOMPRESIBLE MAGNETIZED FLUIDS IN POROUS MEDIUM WITH SUSPENDED PARTICALS

P.K.Sharma, Nusrat Khan and R.K.Chhajlani*

UIT, Barkatullah University Bhopal (M.P.) India,462026

* *Retired from, School of Studies in Physics, Vikram University Ujjain (M.P.) India*

E-mail : pks.buit@gmail.com, pk_sharma69123@rediffmail.com

Abstract

The study of linear theory of Kelvin Helmholtz instability of incompressible rotating magnetized fluids along with suspended particles in porous medium is carried out. A linear dispersion relation for this configuration has been obtained using generalized hydrodynamic equations. The effect of various parameters of the system according to the behavior of growth rate against the wave numbers are analyzed. It is observed graphically that the growth rate decreases on increasing the porosity of medium showing the stabilized nature of the system while the growth rate is increases on increasing the angular velocity and velocity of fluids marking the destabilizing nature of the system.

Laboratory Simulation to Study Magnetic Field Amplification and Turbulence Generation Relevant to Astrophysical Plasma Situations

Indraj Singh, R. Uma, and R. P. Sharma,

Department of Energy Science and Engineering, Indian Institute of Technology Delhi, India, 110016

E-mail : indraj436@gmail.com

Abstract

Turbulence is a pervasive phenomenon in the universe that affects the evolution of several astrophysical plasma and space situations like a supernova remnant (SNR), Cassiopeia A, the collision of galaxies, etc. Turbulence generation causes the energy transport from large scale to small scale, at which the energy is transformed to plasma heating or particle energization. Various experimental and theoretical investigations have been carried out at the scale of laboratory astrophysics to study magnetic turbulence. This study presents a nonlinear wave-based model to study the magnetic field amplification and turbulence generation by laboratory simulations.

References :

[1] Chatterjee G., Schoeffler K. M., Kumar Singh P., Adak A., Lad A. D., Sengupta S., Kaw P., Silva L. O., Das A. and Kumar G. R. "Magnetic turbulence in a table-top laser-plasma relevant to astrophysical scenarios", *Nat. Commun.* **8** 15970 (2017).

[2] J. Meinecke, H. W. Doyle, F. Miniati, A. R. Bell, R. Bingham, R. Crowston, R. P. Drake, M. Fatenejad, M. Koenig, Y. Kuramitsu, C. C. Kuranz, D. Q. Lamb, D. Lee, M. J. MacDonald, C. D. Murphy, H.-S. Park, A. Pelka, A. Ravasio, Y. Sakawa, A. A. Schekochihin, A. Scopatz, P. Tzeferacos, W. C. Wan, N. C. Woolsey, R. Yurchak, B. Reville, and G. Gregori, "Turbulent amplification of magnetic fields in laboratory laser produced shock waves," *Nat. Phys.* **10**, 520–524 (2014).

[3] J. Meinecke, P. Tzeferacos, A. Bella, R. Binghamc, R. Clarke, E. Churazove, R. Crowstong, H. Doylea, R. P. Drakeh, R. Heathcote, M. Koenigi, Y. Kuramitsu, C. Kuranz, D. Lee, M. MacDonald, C. Murphy, M. Notley, H. S. Park, A. Pelka, A. Ravasio, B. Reville, Y. Sakawa, W. Wan, N. Woolsey, R. Yurchak, F. Miniati, A. Schekochihin, D. Lamb, and G. Gregori, "Developed turbulence and nonlinear amplification of magnetic fields in laboratory and astrophysical plasmas," *Proc. Natl. Acad. Sci.* **112**, 8211-8215 (2015).

[4] P. Tzeferacos, A. Rigby, A. F. A. Bott, A. R. Bell, R. Bingham, A. Casner, F. Cattaneo, E. M. Churazov, J. Emig, F. Fiuza, C. B. Forest, J. Foster, C. Graziani, J. Katz, M. Koenig, C.-K. Li, J. Meinecke, R. Petrasso, H.-S. Park, B. A. Remington, J. S. Ross, D. Ryu, D. Ryutov, T. G. White, B. Reville, F. Miniati, A. A. Schekochihin, D. Q. Lamb, D. H. Froula, and G. Gregori, "Laboratory evidence of dynamo amplification of magnetic fields in a turbulent plasma," *Nat. Commun.* **9**, 591 (2018).

Rayleigh- Taylor Instability In A Compressible Ultrarelativistic Degenerate Strongly Coupled Plasmas

Ravinder Bhambhu, Ram Prasad Prajapati

School of Physical Sciences, Jawaharlal Nehru University, New Delhi, 110067

E-mail : ravind52_sps@jnu.ac.in, rpprajapati@mail.jnu.ac.in

Abstract

The hydrodynamic Rayleigh-Taylor instability (RTI) is a fluid macro-instability which arises at the interface of two fluids where the heavy fluid is supported by the lighter one under the influence of gravitational acceleration. In the presence of density gradient, a dense magnetized electron-ion plasma can be subjected to develop the RTI when it is supported against gravity. RTI has many applications in astrophysical plasmas viz. type Ia supernova, white dwarf, interior of heavy planets, high density matter, compact stars, dense plasma focus, and inertial confinement fusion (ICF).

The quantum effects in plasmas occur when the de- Broglie wavelength of the charge particle becomes comparable to the dimension of the system. The analysis of linear RTI in quantum plasma has been carried out by using Quantum magnetohydrodynamic model (QMHD) fluid model, which was proposed by Hass. [1] . Cao et al., Lu and Qui and B. Dolai and R. P. Prajapati [2, 3, 4] have investigated the quantum effects on RTI in incompressible and compressible plasmas by using the QMHD model. The effect of degeneracy arises in lighter plasma species (electron, positrons and holes) at very high density and relatively low temperature. The motion of electrons around its position exerts an outward pressure on the surrounding medium (electron degenerate pressure) which balances the strong inward gravitational force in dense astrophysical plasmas.

With this motivation, we have investigated the linear R-T instability in a compressible ultrarelativistic degenerate strongly coupled plasmas using the generalized hydrodynamic (GHD) fluid model. The electron fluid is assumed to be inertialess, degenerate, and weakly coupled while the ion fluid is treated as non- degenerate and strongly coupled. The dispersion properties of the R-T instability have been analyzed using the normal mode analysis. It is found that the compressibility effects play a decisive role in the suppression of the R-T modes in dense degenerate strongly coupled plasmas. The growth rate of RTI has been calculated and results have been discussed for dense degenerate astrophysical plasmas.

References :

[1] F. Haas, Phys. Plasma 12, 062117 (2005).
[2] J.cao, H. Ren, Z. Wu, and P. K. Chu, Phys. Plasmas 15, 012110 (2008).
[3] H. L. Lu and X. M. Qiu, Phys. Plasmas 18, 104508 (2011).
[4] B. Dolai and R. P. Prajapati, Phys. plasmas 24, 112101 (2017)

Lunar Dusty Plasma Environment: Challenges for Upcoming Lunar Missions

Trinesh Sana, S. K. Mishra

Physical Research Laboratory, Ahmedabad, 380009, India.

E-mail: sanatrinesh@gmail.com

Abstract

The Sun greatly influences the plasma environment around the Moon. Without any significant atmosphere and global magnetic field, the Moon's surface is directly exposed to the solar wind and/ or magnetospheric plasma and solar photons. Under direct exposure to dominant solar radiation, the sunlit lunar surface (and floating dust) generally acquires a positive charge and generates photoelectrons. The emitted photoelectrons and floating charged dust form a dusty photoelectron sheath in the vicinity of the lunar surface [1-2]. In contrast, plasma electrons typically predominate on the night side, and the surface acquires a negative charge and forms a classical plasma sheath. The signature of the dusty plasma over the Moon comes from the images of the lunar horizon glow captured by Surveyor's landers and the observations by Apollo 17 astronauts where the glow appears due to sunlight scattering by the charged dust particles floating near the lunar surface [3-4].

The signature of the water ice and hydrogen-based compounds around the poles set these locations as the prime focus for the forthcoming lunar exploration and future habitat programs. For that, we need technologies that enable us to explore the Moon's poles. It includes an ability to land on these uneven locations and requires the proper functioning of the instruments for a long time. Since plasma is key in generating the electrical environment, understanding the complex electric potential/ field structures and plasma dynamics is of technological interest to efficient instrument operation on lunar modules. For instance, in dark regions, a significant charge deposition over an operating instrument could lead to a break down like situation, which could be detrimental to the operational electronic setups/ devices – the dissipation of these charges is highly dependent on the local plasma environment [5]. Moreover, the variations in solar activity (radiation and plasma parameters), surface composition, and magnetic anomalies further complicate the picture.

This presentation introduces underlying physics and the current understanding of the lunar dusty plasma environment. We also discuss ideas for test experiments for future lunar exploration missions based on our present knowledge.

References :

[1] Sodha M. S. and Mishra S. K. Phys. Plasmas, **21**(9), 093704, (2014).
[2] Mishra S. K. and Bhardwaj A. APJ, **884**(1), 5, (2019).
[3] Rennilson J. J. and Criswell D. R. *Moon,* **10***(2), 121-142,* (1974).
[4] Zook H. A. and McCoy J. E. GRL, **18**(11), 2117-2120, (1991).
[5] Mishra S. K. and Sana T. MNRAS, **512**(4), 4730-4735, (2021).

Cosmic Ray driven MHD waves in Magnetized Self -Gravitating Dusty Plasma

Pallab Boro, Ram Prasad Prajapati

School of Physical Sciences, Jawaharlal Nehru University, New Delhi, 110067.

E-mail : pallab96_sps@jnu.ac.in, rpprajapati@mail.jnu.ac.in

Abstract

Cosmic rays (CRs) are highly energetic charged particles that are one of the major sources of interstellar gas ionization and transfer of energy and momentum in the ISM. The momentum transfer and pressure exerted by CRs on the ionized gas molecules in the plasmas may excite several kinds of wave modes and instabilities [1, 2]. Thus, the study of magnetohydrodynamic (MHD) waves considering the CR diffusion is an interesting research field. It is known that the existence of micron sized charged dust grains in the molecular dust clouds also affect the collective modes, waves and instabilities subjected to small perturbations in the system. Shukla and Rahman [3] observed the coupling between dust-Alfvén, dust-magnetosonic and dust-whistler waves. Although several researchers have put their effort into studying the role of energetic CRs particles on hydrodynamic waves and instabilities in classical electron-ion plasmas, the effects of CRs on the charged dust grains and associated MHD waves and instabilities are still insufficiently studied. This has motivated us to study the effects of CRs (mainly in terms of CR pressure and CR diffusion) on the low-frequency MHD waves and gravitational instability in dusty molecular clouds diffusion.

A three-component dusty plasma model is formulated accounting the magnetized electrons, ions and charged dust grains including the effects of CRs. The hydrodynamic fluid-fluid approach is considered to study the interactions between CR fluid and gravitating magnetized dusty plasmas. A dispersion relation of the MHD waves is derived using the normal mode analysis with the help of single fluid equations of dusty plasmas. It is found that CR pressure induced wave mode couples with the dust-acoustic and dust-Alfvén MHD mode in dusty plasmas. The Jeans instability remains unaffected by the CR effects when diffusion is present; but in the absence of diffusion coefficient, the Jeans instability criterion gets modified due to CR pressure.

References :

[1] Begelman M. C., Zweibel E. G., 1994, Astrophys. J., 431, 689, https://doi:10.1086/174519
[2] Bykov A. M *et al.,* 2013, Space Sci. Rev., 178, 201, https://doi:10.1007/s11214-013-9988-3
[3] Shukla P. K., Rahman H. U., 1996, Phys. Plasmas, 3, 430, https://doi.org/10.1063/1.871816

Arbitrary Amplitude Solitary Wave - Coupling Of Langmuir Wave And Dust Acoustic Wave

Runmoni Gogoi

Terna Engineering College, Nerul, Navi Mumbai 400706, India

E-mail: gogoirunmoni@ternaengg.ac.in

Abstract

Langmuir wave packets, ion acoustic waves are regularly seen during observations made on large amplitude solitary waves [1] in the auroral regions. We have studied different nonlinear behaviours in complex plasmas for different plasma models. In present theoretical work we have considered Langmuir wave coupling with dust acoustic wave in warm plasma by taking a fluid model for the situation along with the Boltzmann distribution of electrons and ions. Sagdeev's [2] pseudo potential method is used to derive an exact analytical expression to find a range of various parameters for the existence of solitary waves and other nonlinear structures. Computation of the derived energy integral shows the co-existence of both compressive and rarefactive solitary waves with equal amplitude for a given set of the parameters. It is also observed that the amplitude of both compressive and rarefactive solitary waves increases with the increase of the temperature, $\sigma = T_i/T_e$ (where T_i and T_e are ion and electron temperatures respectively). Changes in the behaviour of solitary waves and the bell-shaped solution are also investigated for other dusty plasma parameters.

References:

[1] R Gogoi and M khan; Physics of plasmas, **17**, 112311(1-7), (2010).
[2] Sagdeev R Z, Reviews of Plasma Physics (Consultants Bureau, New York), **4,** (1966).

Gravitational Instability In Astrophysical Degenerate Polytropic Quantum Plasmas Including Viscosity Tensor And FLR Corrections

Vinesh Kumar, Ram Prasad Prajapati
School of Physical Sciences, Jawaharlal Nehru University, New Delhi- 110067, India

E-Mail: vinesh41_sps@jnu.ac.in , rpprajapati@mail.jnu.ac.in

Abstract

In astrophysical and space plasmas, the collapse of self-gravitating objects leads to the fragmentation of the matter providing the classical Jeans instability. There is much evidence that the formation of stars, nebula and planetary disks occur through the gravitational collapse of an interstellar gas cloud [1]. In the dense quantum plasmas, the collapse of self-gravitating matter becomes very essential when the quantum corrections are present in the system. The quantum effects are taken into account in the magnetohydrodynamic (MHD) equations using the quantum MHD model. In the rarefied anisotropic plasmas, the Chew-Goldberger-Low (CGL) is the most appropriate fluid model to study the waves and instabilities and it can be extended for polytropic gas.

In this paper, we have investigated the gravitational instability in astrophysical degenerate quantum plasmas accounting for the effect of the finite ion Larmor radius and viscosity tensor. The mixed polytropic equations of state are used along with the CGL fluid equations of the gravitating, collisionless and anisotropic quantum plasmas. The modified dispersion relations have been derived using the normal mode analysis and QMHD fluid model for the considered system. The dispersion relations have been analyzed for various modes of propagations. The effects of viscosity tensor along with the polytropic exponents have been studied on the gravitational instability and collapse in the astrophysical plasmas.

References :

[1] R.P. Prajapati, Physics of Plasmas **21**, p 112101 (2014)
[2] F. Haas, Phys. Plasmas **12**, p 062117 (2005).

Solar plasma flows and associated geomagnetic activity during solar cycle 23 and maxima of solar cycle 24

Sham singh[1*]

[1]Department of Applied Sciences, Chandigarh Engineering College, Landran, Mohali, (Punjab) 140307 India

[*]**e-mail: shamrathore@yahoo.com**

Abstract

Geomagnetic storms can produce severe damage to us. It can cause billions of dollars of spoil to power grids, satellites, communications system, and may the cause of electrical blackout on an immense scale that may not be repaired for days. We present the findings of a study of the sequence of solar activity that eventually resulted in the 80 large geomagnetic storms (distinguished by minimum Dst -100nT to -200nT), 11 super geomagnetic storms (Dst -200nT to -300nT), and 6 super great geomagnetic storms (Dst -300 nT) that occurred between 1996 and 2012. Large storms were discovered to be mostly caused by solar flares (M- and X-class), while CIR was also a significant contributor to several of these storms. During the peak and waning phases of solar cycle 23, all extremely powerful storms were witnessed (2000-2004). It has been noted that CMEs and flares were always related with super and super tremendous storms (100%). M-class and X-class flares frequently accompany superstorms associated to CMEs.

Keywords: Solar flares, Interplanetary magnetic field, Coronal mass ejections and Geomagnetic storms.

Analysis of Growth rate and oscillations of axial-azimuthal waves in Hall thruster electron beam plasma

Saty Prakash Bharti[1,] Sukhmander Singh[1,*]

Department of Physics, Central University of Rajasthan, Ajmer, Kishangarh- 305817, India

*Corresponding author: satyapb26@gmail.com

Abstract

Hall thrusters are used in space electrical propulsion technologies because of its long specific impulsion and low-consumption propellant. Xenon gas is used as a propellant, which is ionized and then accelerated with electrostatic forces to create thrust [1, 2]. The stream of electrons is used from the virtual cathode to neutralize the outer surface of the HET to overcome the charging related problems. The electron beam can affect the oscillations of plasma and trigger instability called electron beam instability [3-5]. In this work, to derive the dispersion relation for the axial–azimuthal propagating waves and the instabilities using a magnetohydrodynamics model of plasma under the effects of an electron beam and various parameters. The real part of the root gives phase velocity of the wave and the imaginary part gives growth rate of the instability. The growth rate and the real frequency depend on various parameters like magnetic field, density of electron, ion and electron beam, the mass of the electron, ion and electron beam and initial velocity. The density and velocity of the electron beam affected the growth rate and real frequency of the wave. Therefore the electron beam plays an important role to control the growth rate and phase velocity of the wave. The effect of various parameters on the growth rate and phase velocity are investigated.

Keywords: Dispersion equations, electron collisions, growth rate, Hall thruster, low-frequency waves, resistive instability.

References :

[1] Choueiri E. Y., *Physics of Plasmas*, 8, 1411-26, (2001).
[2] Chesta E., Meezan N. B. & Cappelli M. A., *J. Appl. Phys.*, 89, 3099-107, (2001).
[3] Litvak A.A. & Raites Y. & Fisch N.J., *Physics of Plasmas*, 11, 1701-5, (2004).
[4] Singh S. & Malik H.K., *Physics of Plasmas*, **20,** 052115, (2013).
[5] Litvak A.A. & Fisch N.J., *Physics of Plasmas*, 8, 648-51, (2001).

Influence Of Rotation on MHD Modes And Instabilities In Relativistic Gravitational Anisotropic Plasma

Shweta Jain

Physics Department, Govt. Madhav Science College, Ujjain, M. P. - 456010, India

E-mail : jshweta09@gmail.com

Abstract

In the present paper, the magnetohydrodynamic modes and instabilities of electron ion plasma with self-gravitation of ion and relativistic effects of electron are studied. The propagation of linear MHD waves and instabilities in homogeneous nonrelativistic and ultrarelativistic plasmas are analysed considering rotation and different pressure along and across the wave propagation. In this formulation, the general dispersion relation is obtained using the normal mode analysis technique which can be reduced to nonrelativistic and/or isotropic limits. The obtained dispersion relation led to various magnetohydrodynamic waves which are further discussed for transverse and longitudinal modes of propagation. It is found that slow waves exhibit some variances due to the pressure anisotropy. They may also develop a mirror instability, as well as a new type of compressible fire-hose instability. The associated instabilities considering effects of rotation and self-gravitation are also presented analytically as well as numerically. The obtained results can be applicable to different astrophysical plasma situations.

Keywords: magnetohydrodynamic waves, rotation, relativistic effects, instabilities etc.

Study of Rayleigh Taylor Instability in the Ionization Regions of Quantum Plasma

Rohit Kumar, *Sukhmander Singh

[1]Department of Physics, Central University of Rajasthan, Ajmer, Kishangarh- 305817, India

*E-mail: sukhmandersingh@curaj.ac.in

Abstract

Rayleigh–Taylor instability are found in under extreme conditions of temperature and density, such as white dwarf stars, where the density is some ten order of magnitudes larger than that of ordinary solids. The quantum mechanical effects have wide applications in quantum plasma echoes, quantum plasma instabilities and microelectronics devices. In the present paper, the Rayleigh–Taylor instability is inspected in a non-uniform quantum magneto plasma under the effects of ionization rate and the thermal motions of species. Because there is continuous generation and recombination's of ion and electron in plasma by different processes. Therefore the effects of ionization rate is important parameter to control the growth rate and instability in plasma. It is depicted that the dispersion relation of the Rayleigh–Taylor instability becomes modified with the ionization rate of neutral atoms and thermal effects. The dispersion relation of various cases are solved analytically to the real frequency and growth rate of the instability. Obtained analytical expression shows that temperature, ionization rate and density gradient considerably modify the growth rate of Rayleigh–Taylor instability. To control the growth rate, the ionization rate and the thermal motion of plasma are playing the role of controlling parameters. So the effect of ionization rate on the growth rate of the instability will be investigated numerically in future. The present investigation may be useful in the studies of dense astrophysical magneto plasmas as well as in laser-produced plasmas.

References:

[1] G. Manfredi, M. Feix, physics Revised Edition 53 (1996).

[2] P.K. Shukla, L. Stenflo, Physics Letter A 355 (2006).

[3] F. Haas, Physics of Plasma (2005).

[4] G. Manfredi, F. Haas, M. Feix, Physics Revised Edition 62 (2000).

[5] S. Ali, Z. Ahmed, A. M. Mirza, I. Ahmad, Physics Letters, A 373 (2009).

Nonlinear propagation of kinetic Alfvén wave and turbulent spectrum in Solar corona reconnection region

Garima Patel, R.Uma, R.P.Sharma

Indian Institute of Technology, Haus Khas New Delhi,110016

esz208161@iitd.ac.in

Abstract

Kinetic Alfven wave (KAW) has a significant impact on magnetic reconnection and turbulence. We have studied the interaction of this KAW with different magnetic topologies found near the solar reconnection region. Inhomogeneity in the magnetic field resulting from nonlinearity and specific magnetic topology absorbs energy from KAW and produces a filamentous structure. We have developed a nonlinear dynamical equation considering the propagation in the neighbourhood of magnetic field. This equation is solved via the finite difference method for temporal evolution and pseudo spectral method for space integration. Numerical simulation shows that at a later time when the intensity is high, filaments break and the transfer of energy from low wavenumber to high wavenumber results in cascade energy comparable to the ion gyroradius for KAW. This cascading results into a steepening of the power spectrum. Structure. The results of the numerical simulation demonstrate that the field experiences a sluggish change in the absence of the nonlinearity, but a quick change in the presence of the nonlinearity. And when it moves closer to a state of quasi-steady equilibrium, it produces a truly chaotic structure, the signals of which are the progression of turbulent filamentation over time. The current sheet formed, because of these chaotic structures causes particle acceleration and coronal heating.

References :

[1] Stasiewicz, K., Bellan, P., Chaston, C. et al. Small Scale Alfvénic Structure in the Aurora. Space Science Reviews 92, 423–533 (2000). https://doi.org/10.1023/A:1005207202143
[2] K. Schindler et al., General magnetic reconnection, parallel electric fields, and helicity J. Geophys. Res. 93, 5547 (1988). https://doi.org/10.1029/JA093iA06p05547
[3] Priest, E. Heating the Solar Corona by Magnetic Reconnection. Astrophysics and Space Science 264, 77–100 (1998). https://doi.org/10.1023/A:1002440524834
[4] Prachi Sharma et al., Nonlinear interaction of kinetic Alfvén waves and ion acoustic waves in coronal loops. Physics of Plasmas 23, 052304 (2016); https://doi.org/10.1063/1.4949347

Different Channels Of Energy Transfer In Hall Magnetohydrodynamic Turbulence: A Phenomenological View

Arijit Halder* & Supratik Banerjee

Indian Institute of Technology Kanpur, Kalyanpur, Kanpur, 208016

*e-mail: harijit@iitk.ac.in

Abstract

Hall magnetohydrodynamics (HMHD) is a single-fluid plasma model which conceives a finite difference between the ion and the electron velocities. The Hall effect is introduced in the induction equation by adding the nonlinear term $-d_i\nabla \times (\boldsymbol{j} \times \boldsymbol{b})$, with $\boldsymbol{b}$ being the magnetic field (normalized to a velocity) and $\boldsymbol{j} = \nabla \times \boldsymbol{b}$. Thus, it becomes important for length scales smaller or comparable to d_i (ion-inertial length). Despite being a mono-fluid plasma model, HMHD is able to capture some the sub-ion scale plasma dynamics including the kinetic effects. Hence, it is regularly employed to study turbulent cascades in collisionless space-plasmas *e.g.,* the solar wind, the magnetospheric plasmas etc. In a turbulent medium, the ideal invariants of the flow are expected to cascade from one scale to the other with a constant flux rate. Such cascades can be shown to occur in the spectral space due to the interaction of wavevector triads $(\boldsymbol{k}, \boldsymbol{p}, \boldsymbol{q})$, satisfying $\boldsymbol{k} + \boldsymbol{p} + \boldsymbol{q} = \boldsymbol{0}$. Through rigorous calculations, one can show that the fluxes of such ideal invariants are conserved in each of the interacting triad. Furthermore, one can divide the total transfer rate of an ideal invariant to a particular mode in a triad as the sum of transfers from individual modes, known as mode-to-mode (M2M) transfer rates. Previously, such triadic conservations and M2M transfer rates have been obtained for hydrodynamic and magnetohydrodynamic turbulence [1].

In our work [2], we have analytically investigated aforementioned triadic conservation for the total energy and the corresponding M2M transfer rates in HMHD turbulence. In particular, the M2M transfers in HMHD have been categorized in two ways- (i) mode-specific, where the role of each field involved in the triadic interaction cannot be unambiguously determined and (ii) field-specific, where the role of each interacting field is fixed. Using field-specific transfers, it is found that there are two possible channels for transfer of magnetic energy, one is through $\boldsymbol{b}$-field and another through $\boldsymbol{j}$-field. Interestingly, the $\boldsymbol{b}$-to-$\boldsymbol{b}$ transfers are found to be bi-directional, whereas the $\boldsymbol{j}$-to-$\boldsymbol{b}$ transfers are only uni-directional. A clear picture is therefore found, providing us with better understanding of the role of Hall term in the sub-ion scales. Moreover, a thorough knowledge of different channels of energy transfer is extremely useful to understand the heating and dynamo mechanism in HMHD.

References:

[1] *Energy transfers in fluid flows: multiscale and spectral perspectives*. M. K Verma. CUP, 2019.
[2] Halder, A. & Banerjee, S. *Different channels of energy transfer in Hall magnetohydrodynamic turbulence,* to be submitted.

Propagation Of Iasws In AGN Medium With The Effect Of Relativistic Charged Dust Particle

Ravi Kant Dwivedi and Punit Kumar

Department of physics, University of Lucknow, Lucknow-226007, India

E-mail : ravikant.dubey96@gmail.com

Abstract

An active galactic nucleus (AGN) is a compact region at the centre of a galaxy that has a much higher than normal luminosity over at least some portion of the electromagnetic spectrum with characteristics indicating that the luminosity is not produced by stars. Such excess non-stellar emission has been observed in the radio, microwave, infrared, optical, ultra-violet, X-ray and gamma ray wavebands. A galaxy hosting an AGN is called an active galaxy. The non-stellar radiation from an AGN is theorized to result from the accretion of matter by a super massive black hole at the centre of its host galaxy.

In this paper, the propagation of ion acoustic solitary waves is investigated in high density degenerate quantum plasma of AGN with the effect of relativistic dust particle using quantum hydrodynamic model. Its dynamics has been studied through different equations of ion electron and dust, taking equation of dust gravity into account. Further, these equations have coupled to study the Jeans and Rayleigh Taylor instabilities.

Weibel Instability Mediated Magnetic Field Evolution in Relativistic Counter-stream Plasma System

Rakesh Kumar[(a)], Hitendra Kumar Malik[(b)], Sandeep Kumar[(c)]

[(a,b)] PWAPA Laboratory, Department of Physics, IIT Delhi, New Delhi-110016, India
[(c)] Department of Physics, Manav Rachna University, Faridabad-121004, India

[(a)] rakeshgangwar3401@gmail.com, [(b)] hkmalik@physics.iitd.ac.in,
[(c)] sandeepkumar@mru.edu.in

Abstract

Non-relativistic and relativistic counter-stream plasmas are common in astrophysical environments; for example in supernova remnants, gamma-ray bursts, and other astronomical sources. For their better understanding, kinetic plasma simulation becomes important at the microscopic scale.

In this work, we study the non-linear growth of magnetic field amplification mediated by Weibel instability [1] in an unmagnetized, counter-stream relativistic electron-positron (e^-/e^+) plasma having anisotropic density distributions [2]. We use two-dimensional EPOCH particle-in-cell (PIC) simulation. A closely relativistically drift velocities of 0.9c, 0.8c, and 0.7c order are considered for two counter-streaming e^-/e^+ plasma flows. Our simulations show that the magnetic field is generated and amplified by the Weibel instability which is developed due to finite temperature anisotropy. Further, the magnetic field is found to evolve exponentially in the linear domain and decays readily in the post saturation region to some extent and re-amplifies again due to inhomogeneous density distributions. The temperature anisotropy calculations show that the finite temperature anisotropy exists for inhomogeneous plasmas that results in the magnetic field amplification after the first saturation [3].

References:

[1] Weibel, E. S. (1959). Spontaneously growing transverse waves in a plasma due to an anisotropic velocity distribution. *Physical Review Letters*, *2*(3), 83.
[2] Medvedev, M. V., & Loeb, A. (1999). Generation of magnetic fields in the relativistic shock of gamma-ray burst sources. *The Astrophysical Journal*, *526*(2), 697.
[3] Kumar, S., Kim, Y., Kang, T., Hur, M., & Chung, M. (2020). Evolution of magnetic field in a weakly relativistic counterstreaming inhomogeneous e−/e plasmas. Laser and Particle Beams, 38(3), 181-187.

Plasma – Wave interaction of multiple particles in solar wind plasma and the Earth's magnetospheric plasma systems

Priyank Srivastava, A.K. Singh

University of Lucknow, Lucknow, 226007

E-mail: rajat.priyank12@gmail.com

Abstract

The Earth's magnetosphere and solar-wind systems are made up of numerous electron and ion populations, with interactions happening mostly through plasma waves [1]. Both the magnetosphere and the solar wind include numerous populations of ions and electrons that are co-located (i.e., exist on the same magnetic-field lines) and easily interact with one another [2]. The evolution of magnetized plasmas frequently results in anisotropies, which cause instabilities and wave-particle interactions: particle anisotropies in the magnetosphere arise from solar-wind-driven magnetospheric internal convection pushing particle populations into the strong magnetic field of the dipolar regions, and particle anisotropies in the solar wind arise from solar-wind expansion into weaker magnetic fields away from the Sun [3]. Wave-particle interactions work in two ways for any plasma-wave instability: pushing the waves and dispersing the waves. In this way, two distinct particle populations can interact with one another. We have examined 1) the Earth's magnetosphere, with ion and electron populations confined in closed flux tubes of the magnetic dipole, and 2) the solar wind, with ion and electron populations spreading away from the Sun in open magnetic flux tubes. Internal convection drives particle populations into stronger magnetic fields, resulting in particle anisotropies in the magnetosphere; expansion of the plasma away from the Sun leads in particle populations migrating into weaker magnetic fields, resulting in particle anisotropies in the solar wind. In both circumstances, the anisotropies of the various ion and electron populations cause kinetic instabilities, which result in the generation of various forms of plasma waves and wave-particle interactions.

References :

[1] Thorne, R. M. et al., Geophys. Monog. Ser., **222**, 117–125, (2017)
[2] Borovsky, J. E., Front. Astron. Space Sci., **08,** (2021)
[3] Gary, S. P. et. al., ApJ, **901**, 160, (2020)

Turbulence In Lower Hybrid Frequency Range In The Magnetopause As Observed by MMS Mission

Manoj Kumar Upadhyay [1(a)], R. Uma[1] and R.P. Sharma[1]

[1]*Department of Energy Science and Engineering, Indian Institute of Technology Delhi, New Delhi 110016, India.*

E-mail[1(a)]: esz198526@ces.iitd.ac.in

Abstract

The magnetosphere is a region around the earth that consists of the earth's magnetic field and gases in the plasma state. Magnetosphere can be divided into several regions, e.g. cusps, magnetotail, magnetopause. To investigate the magnetosphere, various space missions have been commissioned. The most recent mission is Magnetospheric Multiscale (MMS) mission. This mission was sent by NASA in 2015 and consisted of four satellites in a tetrahedral formation with various measuring instruments on board. MMS mission has observed turbulence, magnetic reconnection process, and waves in magnetopause lower hybrid frequency range[1].

Turbulence is the departure from the linear behavior of a system. The idea of turbulence can be used to explain various phenomena in space sciences, such as anomalous resistivity, radiation emitted during solar bursts, observations of lower hybrid cavities in the inner magnetosphere by the Cluster and Viking satellites[2].

Lower hybrid drift waves are waves that develop at frequencies between the ion and electron gyrofrequencies, with wavelengths between the electron and ion thermal gyro radii[3]. This work presents a model to understand the generation of Lower hybrid wave (LHW) turbulence in the reconnection region of magnetopause as observed by Magnetospheric Multiscale Mission (MMS 1) on the magnetopause crossing. With the help of two fluid dynamics, a non-linear two-dimensional (2D) model has been developed. In this model, the interaction between high-frequency LHW and low-frequency magnetosonic wave (MSW) have been taken into consideration. We have solved the dynamical equations for LHW and MSW, thus obtaining two coupled equations. These equations are normalised and solved with the help of the numerical simulation method. The simulation result shows the temporal evolution of the LHW waveform. The growth of waves culminates in turbulence and the formation of localised structures.

References :

[1] Graham DB, Khotyaintsev Yu v., Norgren C, et al. Universality of lower hybrid waves at Earth's magnetopause. Epub ahead of print 28 August 2019. DOI: 10.1029/2019JA027155.

[2] Vaivads A, André M, Buchert SC, et al. Cluster observations of lower hybrid turbulence within thin layers at the magnetopause. *Geophys Res Lett*; 31. Epub ahead of print 16 February 2004. DOI: 10.1029/2003GL018142.

[3] Davidson RC, Gladd NT, Wu CS, et al. Effects of finite plasma beta on the lower-hybrid-drift instability. *Physics of Fluids* 1977; 20: 301–310.

Observational properties of Solar Plasma Parameters associated with IMF and geo-effectiveness in Solar Cycle 24

Soumya Yadav, A.K. Singh

University of Lucknow, Lucknow – 226007

E-mail: somydv96@gmail.com

Abstract

The solar wind is a continuous stream of plasma-like protons and electrons that moves outward from the Sun [1]. The sun's magnetic field is incorporated in the plasma and is carried outward by the solar wind. Solar wind of varying speed and density is produced by various areas of the Sun. Coronal holes generate high-speed solar wind at speeds ranging from 500 to 800 km/s [2]. Because of the Sun's massive, persistent coronal holes at its north and south poles, high latitudes are brimming with rapid solar wind [3]. Geomagnetic storms are a result of these solar winds' interactions with the Earth's magnetic field. We studied 2017 geomagnetic data weighed by Dst < -50 nT observed throughout Solar Cycle 24 (2008-2019) and assessed it in relation to solar wind plasma properties (Vector B magnitude (nT), Bz (nT), SW Plasma Temperature (K), SW Plasma Speed (km/s), Flow pressure, Plasma beta). Although, there was no obvious association between Dst-index and the SW parameters, the research did show a significant relationship between magnetic field intensity. On the other side, lower SW plasma temperatures, proton densities, flow pressures, and plasma beta lead to larger Dst minima > -250nT. SW plasma speeds greater than 450 km/s have been observed to induce moderate to severe geomagnetic disturbances. The complete body of research shows that the solar wind plasma characteristics have an impact on the geomagnetic storm strength as measured by Dst, but it is not possible to use this information to precisely pinpoint this dependence.

Keywords: Solar wind, Geomagnetic Storms (Dst), Interplanetary magnetic field (IMF), SW
plasma, Solar cycle.

References:

[1] Verscharen, D. et. al. Living Rev Sol Phys **16**,p 5, (2019)
[2] Strong K., Viall N., Schmelz J., and Saba J., BAMS,**98**, p 2594-2597, (2017)
[3] Cranmer S.R., Living Rev. Solar Phys., **6**, p 13-14, (2009)

ANALYSIS ON THE VARIATION OF IONOSPHERIC TEC USING NONLINEAR TECHNIQUES

Aswini Thampi S L and Prince P.R.

Department of Physics, University College, Thiruvananthapuram, Kerala, India 695034

aswinithampislppd@gmail.com, princrprasad@gmail.com

Abstract

In the modern technological world, communication and navigation are very much dependent on the satellites. The satellite signals, before reaching to the Earth's surface, pass through the ionosphere and thereby get changed and lead to errors in communication and navigation. Ionosphere possess sufficient number of free electrons that can largely affect the propagation of radio waves. Hence, acting as a dispersive medium, the ionosphere has great influence on the satellite navigation and communication. This influence is directly proportional to the density of free electrons which could change the phase and strength of electromagnetic radio frequency waves. Signals of the global positioning satellites (GPS) are continuously received by suitable receivers on the ground and the changes in the ionospheric electron concentration could be indirectly inferred. Among all parameters that exist in the ionosphere, the TEC largely affects the electromagnetic waves propagating through the ionosphere. Hence, TEC studies have got a new impetus with the advent of GPS-based navigation and ground positioning.

The total electron content (TEC) measurements obtained from dual frequency GPS receivers are one of the most important methods of investigating the earth's ionosphere. Present study focuses on the investigation of ionospheric TEC variations on solstices and equinoxes during deep minimum (2008) and high solar activity periods using non-linear time series analysis for selected locations. We used GPS TEC data for studying the variation of ionospheric TEC.Also, in order to examine the nonlinearities in geomagnetic activity at auroral regions, 1-min AE index has been used for the period when ionospheric data were available. We observed seasonal variations in nonlinear parameters and the study will add to our current knowledge of ionospheric physics and aids in the evolution of better communication and navigation strategies. Also the results show that it can be further used to study the variations of the ionosphere which exhibit non -linear properties.

A correlative study of solar plasma associated with major geo-storms during 2008 -2022.

Pawan Kumar[1], Mahender Pal[1] and Sham Singh[2]

[1]Department of Physics, IKG Punjab Technical University, Jalandhar-144603
[2]Department of Applied Sciences, Chandigarh Engineering College, Landran, Mohali-140307
e:mail-pawanyy80@gmail.com

Abstract

In the current study, huge geomagnetic storms that occurred between 2008 and 2022, covering solar cycle 24 and the beginning of solar cycle 25, are identified. These storms are related to disturbance storm times (D_{st}) that decrease by more than -100 nT to -500 nT. Statistical analysis is done to determine the relationship between Dst strength and the peak value determined by solar wind plasma characteristics. We have utilized the DST index and wind speed hourly values to study the correlation between sunspot number, interplanetary magnetic field B_z and solar wind density with geomagnetic indices K_p, D_{st}, A_p, and AE during various geomagnetic storms. When magnetic storms are in their main phase, IMF B is extremely geoeffective; however, it becomes more significant during the storm peak, which is further aided by the southerly component of IMF (Bz) and proton density. Finally, a quantitative analysis of the relationship between the various events is performed using association rates and ranking correlations. The correlation between B_{avg} & D_{st}, Solar wind speed & K_p, SW Density & K_p, and wind speed & pressure and the correlation coefficient is observed in values 0.79, 0.67, 0.81, and 0.79 respectively.

Keywords: Solar plasma, Geomagnetic Storm, Interplanetary magnetic field (IMF), Disturbance storm time (Dst).

Propagation Characteristics of Waves in Neutrino Magnetohydrodynamics

Subhash Kumar[1], Hrishabh Bhardwaj[2], Sukanta Deb[3]

[1]*Acharya Narendra Dev College (University of Delhi), Govindpuri, Kalkaji, New Delhi 110019*

[2]*Rajkiya Mahila Mahavidyalaya (MJP Rohilkhand University, Bareilly), Budaun,* Uttar Pradesh.

[3]*Department of Physics, Cotton University, Pan Bazar, Guwahati- 781001*

Abstract

Neutrinos interact only weakly with ordinary matter. However, in certain astrophysical context, such as supernova explosion, the coupled interaction between neutrino and dense, highly ionized plasma contribute significantly to a system's evolution. Neutrino Magnetohydrodynamics (NMHD) has been recently formulated to model such systems. In this approach magnetohydrodynamics (MHD), which treats a plasma's electron and ions as fluid and considers the dynamics of the magnetic field they produce is extended to include weak interaction, which in particle physics describes the coupling between neutrinos and electron. Normal modes analysis is carried out to derive a dispersion relation of waves in such a system. Inclusion of neutrinos and their subsequent interactions with the MHD fluid can prevent flux freezing in such a system, which hitherto has been characteristic feature of all astrophysical plasmas. In the present paper, Friedrich's diagram of the NMHD waves, which are polar plots depicting the variation of phase speeds and group speeds of waves with the direction of propagation (with respect to the direction of the ambient field) are drawn. Using these diagrams, the propagation characteristics of NMHD waves are discerned vis-à-vis the MHD waves in astrophysical plasmas. Incidence of instabilities of NMHD are also pointed out.

HIGH FREQUENCY SOLITONS WITH HIGHER ORDER EFFECTS IN MULTICOMPONENT PLASMA

Rajneet Kaur* and N. S. Saini

Department of Physics, Guru Nanak Dev University, Amritsar-143005, India
*Email: rajneetkaur909@gmail.com

Abstract

The study of electron acoustic solitons (EASs) has gained great importance in the past many years because of their presence in various plasma systems such as astrophysical/ space plasmas and variety of applications. These kinds of solitons are formed due to presence of two distinct electron components at different temperatures in plasma. Depending upon the temperature difference, the cold electrons become inertial and hot electrons provide the necessary pressure to develop the restoring force for the EASs to exist likewise the ion acoustic solitons (IASs) in electron-ion plasma where the inertia is provided by the massive ions and the inertialess electrons provide the restoring force. Moreover, in the dynamics of EASs, the ions are assumed to form only a stationary background because of their larger dynamical time scale as compared to that of electrons [1]. In this investigation, the evolution of electron acoustic solitons and higher order electron acoustic solitons are formed in a non-Maxwellian plasma with the presence of an electron beam has been examined. The reductive perturbation method is employed to derive the nonlinear KdV-type inhomogeneous equations with contribution of higher-order effects of nonlinearity and dispersion. From the solutions of these nonlinear equations, the characteristics of EASs and higher order EASs are analysed under the influence of parameters of an electron beam and other plasma parameters [2]. The findings of present work may be useful to explore and understand the evolution of nonlinear structures in the space and laboratory plasmas especially in Earth's magnetospheres.

References :

[1] R.L. Mace, M.A. Hellberg, Higher-order electron modes in a two-electron temperature plasma, J. Plasma Phys., **43**, p 239–255, (1990).
[2] R. Kaur, N. S. Saini, Electron acoustic dressed solitons in an electron-beam plasma with
higher-order contributions, Chinese J. Phys. **77**, p 760–772, (2022).

A study of sun plasma associated with major storms during 2017-2021.

Mahender Pal[1], Pawan Kumar[1] and Sham Singh[2]

[1]Department of Physics, IKG Punjab Technical University, Jalandhar-144603
[2]Department of Applied Sciences, Chandigarh Engineering College, Landran, Mohali-140307
e:mail-mahenderkhormia@gmail.com

Abstract

In the present study, we study geomagnetic storms that occurred in last phase of solar cycle 24 and the rise phase of solar cycle 25, are identified. These storms are related to disturbance storm times (D_{st}) that decrease by more than -100 nT.There are three major storms that observed 8 September 2017, 26 august 2018 and 4 November 2021 are analyzed. Finally, a better analysis of the relationship between the various parameter is performed using correlations.

Keywords: Geomagnetic Storm, Interplanetary magnetic field (IMF), coronal mass ejection, Disturbance storm time (Dst).

Electrostatic ion acoustic solitary structures in a multicomponent dusty plasma

Geetika Slathia and N. S. Saini

Department of Physics, Guru Nanak Dev University, Amritsar-143005, India

E-mail: gslathia93@gmail.com

Abstract

It is witnessed by number of observations that dust is omnipresent in most of laboratory, space and astrophysical plasma environments. Dusty plasma is abundantly found in planetary rings, interplanetary space, cometary tails, different asteroid zones, solar nebulae, Earth's lower magnetosphere, etc [1,2]. A variety of waves are excited in the multicomponent plasmas. Various wave phenomena occur when the dusty plasma in Jupiter's atmosphere interact with the solar wind [3]. The streaming electrons and protons originating from the solar wind encounter with the electrons and protons of the dusty magnetosphere to achieve a steady state in the background of stationary charged dust grains. In this investigation, the evolution of dust acoustic solitary waves (DASWs) and dust acoustic higher order solitary waves have been studied in a dusty plasma comprising of positive dust grains, streaming solar wind protons and superthermally distributed electrons, isothermal ions and solar wind electrons. The Korteweg-de Vries (KdV) equation is derived by employing the reductive perturbation method. Also, further an inhomogeneous KdV-type equation accounting for the higher order contributions of nonlinearity and dispersion is also derived. With the insertion of higher order effects, a new type of soliton structures are obtained. The numerical analysis is performed in context with observation in Jupiter's atmosphere. The solitary profiles are significantly modified by the variation of concentration of dust. The influence of various plasma parameters viz., superthermality of ions, electrons, ion to electron temperature ratio, number density ratio etc. has been observed on characteristics of DA solitons, and DA higher order solitons respectively. The findings of this work maybe useful to understand the underlying physics of nonlinear phenomena for existence of nonlinear excitation in astrophysical environments like in Jupiter's rings.

References:

[1] Shukla, P.K., Mamun, A.A., Introduction to Dusty Plasma Physics*,* Institute of Physics, Bristol (2002)
[2] Horanyi, M., Mendis, D.A., Astrophys. J. 307, 800, (1986)
[3] Al-Yousef H., Alotaibi B. M., Tolba R. E., Moslem W. M. 2020. Results in Physics, d.o.i., 2020. 21. 103792.

EFFECT OF KAPPA DISTRIBUTION FUNCTION ON FIREHOSE INSTABILITY IN ELECTRO-ION PLASMA OF AURORAL ACCELERATION REGION

N. Tandon[1], G.Ahirwar[2],

School of Studies In Physics, Vikram University,University campus, Ujjain,456001

E-mail : tandon.neeti2019@gmail.com[1], ganpat.physics@gmail.com[2]

Abstract

Firehose instability has been studied by kinetic approach with Kappa distribution function [1] in auroral acceleration region of the earth's magnetosphere. The considered plasma is, hot, fully ionized, collisionless and assumed to be composite of electrons and ions, where both particle are behaving nonresonantly. The instability is assumed to propagate parallel to the ambient magnetic field. The dispersion formalism is based on the modified dispersion relation [2]. The dispersion relation ,growth rate in high beta plasma have been investigated. The effect of spectral index kappa, which defines super thermal population, have been studied on firehose instability. The range of beta parameter and temperature anisotropy for the electrons and ions that sets the condition for the existence of firehose instability, is analyzed at the different values of spectral index, kappa. The results are interpreted to the auroral acceleration plasma region of the earth's magnetosphere. The confirmation of the instability is presented here through observational evidence in the earth's magnetosphere [3,4] other astrophysical plasma regions and computer simulations [5]. The analytical findings may make possible to determine the spectral index kappa in other space plasma regions, also this analysis is applicable where the plasma system is composite of multi-component.

References :

[1] Vasyliunas, V. M. JGR **73**,p 2839-2884 (1968)
[2] Lazor M., Poedts. S. A&A **494** ,p 311-315 (2009)
[3] Pierrard et al., Solar Physics **269** ,p 421-438 (2011)
[4] Ahirwar G.,2012. IJSRP **2** ,(2012)
[5] Camporeale and Buragess JGR, **113**, A07107 (2008)

Relevance of axion-like particles in the magnetic field of various astrophysical environments

Authors: Sarathykannan S, Bhanu Prakash Pant, Sunanda, and Reetanjali Moharana

Affiliation : Indian Institute of Technology Jodhpur, Karwar, Jodhpur, Rajasthan – 342037.

E-mail : sarathy.1@iitj.ac.in, reetanjali@iitj.ac.in

Abstract

Axions are hypothetical particles proposed as an extension of physics beyond standard model [1,2]. In the presence of strong magnetic field, the photon state undergoes oscillation with the ALP state. The propagation medium is filled with cold plasma of homogenous magnetic field which provides a favorable condition to interact with the photon-ALP system [3]. This interaction modulates the gamma-ray spectra observed on the earth. In this study, we investigate the effect of magnetic field of various astrophysical environments on the photon-ALP oscillation, in particular the gamma-ray spectra of TXS 0506+056 blazar.

References:

[1] Peccei, Roberto D., and Helen R. Quinn. "Constraints imposed by CP conservation in the presence of pseudoparticles." *Physical Review D* 16.6 (1977): 1791.

[2] Peccei, Roberto D., and Helen R. Quinn. "CP conservation in the presence of pseudoparticles." *Physical Review Letters* 38.25 (1977): 1440.

[3] Galanti, Giorgio, and Marco Roncadelli. "Axion-like Particles Implications for High-Energy Astrophysics." *Universe* 8.5 (2022): 253.

Collisionless Shock Formation in Field-aligned Plasma Flow from Accretion Disk towards Poles in Neutron Stars

Anoop Singh, Mrityunjaya Kundu and Shishir P. Deshpande

Institute for Plasma Research Bhat, Gandhinagar, Gujarat, 382428

anoop.singh@ipr.res.in

Abstract

An increasing body of X-ray observations has revealed about 2000 neutron stars (NS) in and around the Milky-way galaxy. A subset of NS is known to have a companion in close orbit which leads to creation of an accretion disk. The NS have extreme magnetic fields and consequently an intriguing array of plasma phenomena particularly at the magnetopause where plasma and magnetic pressure are in quasi-static equilibrium. Neutron star traps the ionized matter in its gravitational field in the form of an accretion disk and eventually pulls it towards itself. Very strong magnetic field poses a barrier for plasma to simply cross over to the surface by perpendicular transport. In this work, we investigate the transport of the plasma from the accretion-disk, which occurs predominantly along the field lines. The dipole-nature of the field causes the plasma to undergo a severe compression as the motion is restricted along B.

A one-dimensional 'along B' model has been setup to understand the equilibrium of an axisymmetric system where rotational and magnetic axes are taken to be aligned. The uncertainty in the geometry of the accretion-disk at the magnetopause-boundary will be discussed.

References:

[1] Hao et al., A one-dimensional accretion column model for magnetized neutron stars, Chinese Astronomy and Astrophysics 23 (1999) 498-510.
[2] A. Bret, and A. Pe'er, On the Formation and Properties of Fluid Shocks and Collision less Shock Waves in Astrophysical Plasmas, Journal of Plasma Physics 84 (2018).
[3] Frank, King, Raine, 1991, Accretion power in astrophysics. Cambridge Univ. Press.
[4] P. Charles., LMXBs: An Overview, Evolution of compact binaries ASP Conference Series, Vol. 447 (2011), Astronomical Society of the Pacific.

Effects Of Heavier Ions (O+ & O-) On The Characteristics Of Ion Acoustic Double Layers In A Six Component Cometary Plasma

Manesh Michael[1*], Shilpa S.[2], Sijo Sebastian[3], Chandu Venugopal[4]

[1]*Department of Physics, Bharata Mata College, Kochi - 682 021, Kerala, India.*
[2]*International School of Photonics, Cochin University of Science and Technology, Kochi – 682 022, Kerala, India.*
[3]*Department of Physics, St. Aloysius College, Edathua, Alappuzha – 689 573, Kerala, India*
[4]*School of Pure & Applied Physics, Mahatma Gandhi University, Kottayam – 686 560, Kerala, India.*

E-mail : maneshmichael@gmail.com

Abstract

The effects of pair ions (O^+ & O^-) on the existence and propagation characteristics of ion-acoustic double layers in a six-component cometary plasma, consisting of two hot and one colder component of electrons, hot ions, and a pair of heavier ions are studied. One of the hotter and the colder component of electrons, together with the lighter hydrogen ions are modelled by kappa distributions. The second, hotter component of electrons is modelled by a q-nonextensive distribution. Both the Korteweg-deVries (KdV) and the modified Korteweg-deVries (mKdV) equations are derived for the system and its solutions are studied for parameters pertinent to comet Halley [1]. It is observed that the strength of the double layer profile and depth of Sagdeev potential well significantly depend on the heavier ion densities. The variations of both the quadratic and cubic nonlinearities with densities of the heavier ions are also studied. Our model and the results presented could be applied to different space, astrophysical and cometary environments [2, 3].

References:

[1] Unusual characteristics of electromagnetic waves excited by cometary newborn ions with large perpendicular energies, Astron. Astrophys., **187**, p 311- 319, (1987)
[2] The stability of the mesospheric plasma layer, Phys. Plasmas, **18**, p 122902, (2011)
[3] Characterizing cometary electrons with kappa distributions, J. Geophys. Res. Space Phys., **121**, p 7407-7422, (2016)

Study Of Ionospheric Plasma Parameter Using Observation And Model Over Indian Low Latitude Stations During 2004-2013

Mini Rajput, Sanjay Kumar, A. K. Singh, R.K. Choudhary, P.R. Shreedevi

Atmospheric Research Lab., Department of Physics, Institute of Science, Banaras Hindu University, Varanasi-221005

E-mail: mini.rajput.2015@gmail.com, sanjay.skitvns@gmail.com, abhay_s@rediffmail.com, rajkumar.choudhary@gmail.com, shreedevipr@gmail.com

Abstract

Ionosphere is part of upper atmosphere having existence of charged particles and neutral. Ionospheric perturbations are well known to affect radio wave communication and navigation system and hence knowledge of ionospheric variability quite significant to improve such radio-based system in different solar and geomagnetic conditions [1-2]. The presented work is an attempt to understand the variabilities of ionospheric Total Electron Content (TEC) over the Indian low latitude regions. In this paper ionospheric total electron content derived from Global Positioning System (GPS) at three Indian low latitude stations: Varanasi (25.3° N, 82.98° E), Hyderabad (17.38° N, 78.45° E) and Bangalore (12.97° N, 77.58° E) have been used to study diurnal, monthly, seasonal and annual variations during the period from 2004 to 2013. Diurnal variations of ionospheric TEC shows typical characteristics of low latitude station such as pre-dawn minimum then broad maximum in noon time followed by a decrease to a minimum during night time. TEC data from ground based GPS measurements has also been compared with those from the IRI-2016 model [3] during 2004-2013. Effect of solar cycle on variability of ionosphere using data from GPS-based observation and the IRI-2016 models has also been studied.

References:

[1] Galav, P., Dashora, N., Sharma, S., & Pandey, R., Journal of Atmospheric and Solar-Terrestrial Physics, **72**, p 1309–1317 (2010).
[2] Kumar, S., Priyadarshi, S., Krishna, G. G., & Singh, A. K. (2012). Astrophysics and Space Science, **339**, p 165–178 (2012).
[3] Bilitza, D., Altadill, D., Truhlik, V., Shubin, V., Galkin, I., Reinisch, B., & Huang, X., Space Weather, 15, 418– 429 (2017).

Dust Acoustic Rouge Waves in a Cometary Plasma Environment

Vineeth S[1, a] and Noble P. Abraham[1]

[1]*Department of Physics, Mar Thoma College Tiruvalla, Kerala – 689103*

[a] *E-mail: vineethsmaikkattu2@gmail.com*

Abstract

Dust is present in almost all astrophysical and laboratory plasma environments. They alter the plasma spectrum and give rise to various modes of electrostatic waves and vibrations. In this paper, we study the properties of Dust Acoustic Rouge Waves (DARW) in a cometary environment with positively and negatively charged dust components, hydrogen ions and electrons. The lighter components are assumed to follow non – Maxwellian Kappa distribution. The governing equation is found using reductive perturbation method, by deriving the Nonlinear Schrodinger Equation (NLSE). Modulational instability of the system is studied and hence the rogue wave solutions are found.

References:

[1] Ion-acoustic rouge waves in multi-ion plasmas, M. Hassan et al, *Commun. Theor. Phys.* **71** 1017 (2019)
[2] Solitary waves in a plasma with oppositely charged dust (heavier, pair-ions) and kappa modeled lighter ions and electrons, Sijo Sebastian *et al*, *Phys. Scr.* **90** 035601(2015)
[3] Electrostatic solitary structures in non-thermal plasmas, R.A. Cairns *et al*, *Geophys. Res. Lett.* **22** 2709 (1995)
[4] Modulational instability and localized excitations of dust-ion acoustic waves, I. Kourakis *et al*, Phys. Plasmas **10** 3459 (2003)

Dissipation Of MHD Waves In The Polytropic Zone Of The Solar Wind Including Non-ideal Effects And FLR Corrections

Ram Prasad Prajapati[1] and R. K. Chhajlani[2]

[1]*School of Physical Sciences, Jawaharlal Nehru University New Delhi-110067*
[2]*Retired Professor, School of Studies in Physics, Vikram University, Ujjain-456010*

E-mail: rpprajapati@mail.jnu.ac.in

Abstract

Recent observations by the Parker Solar Probe (PSP) have confirmed that the solar wind in the inner heliosphere exhibits thermal pressure anisotropy in the plasmas [1,2]. Thus, one cannot ignore its role in the dissipation of MHD waves in solar wind plasmas. In this paper, we have studied the dissipation of magnetohydromagnetic (MHD) waves and pressure-anisotropy-driven fluid instabilities in magnetized viscous plasmas, including finite Larmor radius (FLR) corrections and non-ideal MHD effects in the polytropic zone of the solar wind. The modified dispersion properties have been analysed in the MHD and Chew–Goldberger–Low (CGL) limits for typical conditions of the solar wind and corona. The theoretical results are found to be in good agreement with the observational data, which shows that the MHD and CGL waves are dissipated due to viscous and ohmic diffusion [3].

The FLR and Hall parameters show destabilizing and stabilizing influences, respectively, for the strong magnetic fields in the solar corona, and reversed effects in the case of weak magnetic fields in the solar wind. In the solar corona, the CGL wave dissipation achieves the required damping rate in the minimum time than the dissipation of the MHD waves. The damping time is mainly associated with the considered parameters and was found to be larger for the MHD wave dissipation than the CGL wave dissipation. The theoretical results successfully demonstrate the role of the considered parameters on the reverse and forward shock waves and instabilities as observed in the solar wind parameters versus heliolatitude graph using Ulysses observations for r = 5.41 au. The results are helpful to explore the possibilities of MHD waves and pressure-anisotropy-driven fluid instabilities in the polytropic zone of the solar wind that will probably be observed by the PSP mission [3].

References :

[1] Duan D., He J., Bowen T. A., Woodham L. D., Wang T., Chen C. H. K., Mallet A., Bale S. D., Astrophysical Journal, **915**, p L8 , (2021)
[2] Desta E. T., Prajapati R. P., Eritro T. H., European Phys. J. Plus, **137**, p 437, (2022)
[3] Prajapati, R. P., Desta, E. T., Fok, Mei-Ching, Eritro, T. H., Monthly Notices of the Royal
Astronomical Society, **515**, p 1444–1458 (2022)

Nonlinear Wave Phenomena in Electron Beam Plasma

Manveet Kaur and N. S. Saini,

Department of Physics, Guru Nanak Dev University, Amritsar, 143005

E-mail: manveetsandhu7@gmail.com

Abstract

The existence of nonlinear ion-acoustic (IA) solitary structures in different plasma environments has been confirmed theoretically as well as experimentally by a number of researchers. It is established that stationary nonlinear localized electrostatic (ES) waves may be excited when an electron beam is injected into a plasma. The presence of electron beams is also clearly indicated by space observations in the upper layer of the magnetosphere, where a coexistence of two different electron populations (say, warm energetic ones and cold, i.e., inertial electrons) is reported by various satellite missions (the S3-3, Viking, the FAST at the auroral region, GEOTAIL and POLAR). Focusing on nonlinear ES excitations, it is well known that the injection of an electron beam into a plasma strongly affects the conditions for the occurrence of solitary waves and may modify their properties. The nonlinear structures (solitons, breathers, shocks, double layers etc.) are significantly modified by the presence of electron beam in the given plasma system. Different experimental as well as theoretical investigations have confirmed the variation in the characteristics of nonlinear structures under the influence of energetic electron beam. Most of the investigations of KP equations have been studied in different plasma systems in the absence of beam. In the present investigation, the propagation properties of KP solitons have been studied in an electron-ion plasma embedded with electron beam and having hot electrons obeying non-Maxwellian distribution. The KP equation and nonlinear Schrodinger equation has been derived using reductive perturbation technique and their solutions is numerically studied. The solution of breather structures has also been derived. Further, Galilean transformation is used to transformation into planar dynamical systems. The dynamical system has been described in the form of phase portrait and small-amplitude Sagdeev's pseudopotential curve. The influence of various parameters, periodic waves in homoclinic and periodic orbits in phase portraits are studied numerically. The findings of this investigation may be of great importance to understand the nonlinear phenomena in the upper layer of the magnetosphere where two different electrons population exist.

References:

[1] N. S. Saini and I. Kourakis, Plasma Phys. Cont. Fusion, **52**, p 075009 (1-19) , (2010)
[2] N. S. Saini, N. Kaur, and T. S. Gill, Advances Space Res., **55**, p 2873-2882, (2015)
[3] N. S. Saini, Manveet Kaur, and Sunidhi Singla, J. Astrophys. Astr. **43** p 65 (1-8), (2022)

Plasma Relaxation using Data-Constrained Numerical Simulation of Solar Coronal Plasma

Satyam Agarwal[1], Ramit Bhattacharyya[1]

[1]*Udaipur Solar Observatory, Physical Research Laboratory, Udaipur 313 001, India*

satyam@prl.res.in, ramit@prl.res.in

Abstract

Solar coronal transients such as solar flares and jets are known to be driven by the process of magnetic reconnection. During such activities, the stored free magnetic energy is converted into heat and lost irrecoverably from the system. As a consequence of this, the magnetized plasma on Sun undergoes self-organization or relaxation, wherein the ideal invariants undergo selective decay. This allows the mathematical formulation of relaxation in terms of a variational principle. The earliest theory of relaxation was put forward by Taylor [1], wherein the total magnetic energy was taken as the minimizer and total helicity as an invariant. The corresponding relaxed state was shown by Woltjer [2] to be a linear force-free field. Importantly, the Taylor's theory was first adapted for the case of solar flares by Heyvaerts and Priest [3]. Subsequently, numerical experiments have been conducted to test the applicability of Taylor's theory in various contexts such as the nanoflare heating model [4] and topological dissipation problem [5]. Importantly, some of these studies have found the terminal state of relaxation to be nonlinear force-free, which does not agree with the Taylor's theory. Following this line of work, in this study we take an alternative approach to understand the relaxation process for a solar flare in the framework of extrapolation model and data-constrained magnetohydrodynamic simulation.

An active region, NOAA 12253 is chosen, which hosts an M1.3 class flare. The spatial and temporal evolution of the flare is analyzed primarily in 1600 and 304 angstrom channels of the SDO/AIA instrument to identify the possible reconnection sites. Using nonforce-free model, the extrapolated magnetic field lines are investigated, which reveals a hyperbolic flux tube (HFT) morphology at the flare location. We use the EULAG-MHD numerical model and extrapolated magnetic field as input to carry out the numerical simulation. In the simulated dynamics, we analyze the variation and distribution of parameters such as the magnetic and kinetic energy, current density, Lorentz force and twist in sub-volumes of varying extent to understand plasma relaxation and to draw our conclusions on the result, limitations, and future scope of this study.

The observational aspects of the flare, associated magnetic field line morphology and its relevance as a potential reconnection site will be presented. Also, the association of numerically simulated evolution with observations will be discussed. Further, in the context of plasma relaxation and Taylor's theory, some of the result of this study will be presented.

References:

[1] Taylor, J.B.: 1974, Relaxation of Toroidal Plasma and Generation of Reverse Magnetic Fields. Phys. Rev. Lett. 33, 1139
[2] Woltjer, L.: 1958, A Theorem on Force-Free Magnetic Fields. Proceedings of the National Academy of Science 44, 489
[3] Heyvaerts, J., Priest, E.R.: 1984, Coronal heating by reconnection in DC current systems – A theory based on Taylor's hypothesis. Astron. Astrophys. 137, 63
[4] Browning, P.K., Gerrard, C., Hood, A.W., Kevis, R., van der Linden, R.A.M.: 2008, Heating
the corona by nanoflares: simulations of energy release triggered by a kink instability. Astron. Astrophys. 485, 837
[5] Pontin, D.I., Wilmot-Smith, A.L., Hornig, G., Galsgaard, K.: 2011, Dynamics of braided coronal loops. II. Cascade to multiple small-scale reconnection events. Astron. Astrophys. 525,
A57

Periodic Variation of Plasma Parameters during Solar Cycles 22-24

Prithvi Raj Singh[1], Abhay Kumar Singh[2],

1. Department of Physics, S.S. Khanna Girl's Degree College, Prayagraj-211003

2. Department of Physics, Banaras Hindu University, Varanasi-221005, India

E-mail: prithvisingh77@gmail.com

Abstract

In this study, the relationship between the monthly variations of solar wind plasma velocity, interplanetary magnetic field (IMF), modulation parameter (ζ = V*B), and geomagnetic activity index (Ap) during solar cycles 22–24 (1986–2020) has been analysed. We have investigated the periodic variation of solar wind plasma velocity, interplanetary magnetic field (IMF), modulation parameters, and geomagnetic index 'Ap' during solar cycles 22-24 by using Fast Fourier Transform (FFT), RobPer periodogram, and Continuous Wavelet Transformation methods. We have found that the rotation rate at the base of the convection zone is ~1.30 years. The modulation parameter appears to be a better representative of the geomagnetic changes than the other two.

Exposition of Space Plasma Parameters Observed during Solar Cycles 21 - 24

A. K. Singh[#]

Department of Physics, University of Lucknow, Lucknow-226007, India
[#]Email: aksphys@gmail.com

Abstract

Solar activity has reduced during last few solar cycles. Thus the space plasma parameters have shown some fluctuating trends. Characteristic behavior of interplanetary magnetic field (IMF) and some space plasma component observed during the years 1976 – 2000 (solar cycles 21-24) are examined using probability distribution techniques. Ionospheric parameters like IMF vector and its component, solar wind proton density, plasma temperature, bulk velocity etc. are considered for investigation and their physical interpretations are presented. To that end, method of running histograms and Kolmogorov-Smirnov (K-S) test are applied on every parameter. Statistical analysis has clearly indicated that the probability density function which best interpret the solar wind (SW) and interplanetary magnetic fields (IMF) were the lognormal instead of normal (Gaussian) in nature. Solar wind plasma temperature, solar wind proton density, flow pressure of solar wind, scalar B and B_{xy} follow the lognormal distribution function while the z- component of IMF (B_z) follows the normal distribution. Fast-solar winds that were observed during the intense solar activities from solar cycle 21 to 24 were much hotter than the slow one. The intervals of cold solar wind with temperature T <15000 K were often sustained for substantial periods, up to several days. Those temperatures were associated mainly with the fast SW streams expanding from coronal holes at middle and high heliographic latitudes. The solar wind density has an anti-correlation with the solar wind velocity with a correlation coefficient value -0.26. This shows that during the range of 300 km/sec to 700 km/sec the plasma streams have lower density and vice-versa. We obtained a clear-cut correlation between fast solar wind and IMF with a value of Pearson's coefficient equal to 0.38.

Seasonal Occurrence of Ionospheric Plasma Bubbles During Ascending Phase of 25th Solar Cycle Over Varanasi

Mukulika Mondal, Sanjay Kumar, A. K. Singh

Atmospheric Research Lab., Department of Physics,
Banaras Hindu University, Varanasi - 221005, India.

Email: missmukulika@gmail.com, singhak@bhu.ac.in

Abstract

Ionospheric plasma bubbles are plasma density depletions and accompanying plumes of irregularities that give rise to severe radio signal disruptions [1]. These plasma bubbles are mostly observed in the pre-midnight period [2]. Radio signal suffers fluctuations in both phase and amplitude during their passage through these plasma bubbles. These fluctuations in phase and amplitude of the signal are known as phase and amplitude scintillations respectively [2]. The present study is carried out to observe the variation of occurrence of amplitude scintillations during ascending phase of solar cycle from November 2020 to October 2021 over equatorial anomaly region Varanasi (latitude 25.31° N, longitude 82.97° E). We have taken GNSS data from multifrequency GNSS receiver to study the occurrence of amplitude scintillation index S_4. To study the seasonal variation of S_4, three seasons of year are considered i.e., winter (November, December, January and February), Equinox (March, April, September and October) and summer (May, June, July and August). Diurnal and monthly variation of S_4 index is also analysed. Analysis found maximum scintillation occurrences during the equinox season. The scintillation activity is more prominent during night-time hours than daytime. To study the effect of geomagnetic activity on S_4, we have taken moderate class geomagnetic storm occurred on 14th March, 2022 ($DST_{minimum}$ = -85 nT). The geomagnetic storm modulates the scintillation occurrences.

References:

[1] Burke, W. J. et al., ***J. Geophys. Res***. 108(A5), 1221 (2003).
[2] Aarons J., ***Space Sci. Rev***. 63, 209 (1993).

Effect of Geomagnetic Storms on Ionosphere during Solar Cycle 24 over the low latitude

Vishnu Singh Rathore[1*],Suhail Ahmad Siddiqui[1], A.K. Singh[2]

1. J.S. University Shikohabad, 2. Banaras Hindu University

E-mail : vishnurathore1989@gmail.com

Abstract

In this paper, the ionospheric total electron content (TEC) derived from the GPS data recorded at the equatorial ionization anomaly (EIA) region; Varanasi Bangalore and Port Blair's is analyzed to study the geomagnetic storm signatures on low latitude ionosphere during the ascending page of current solar cycle 24. We considered all possible geomagnetic storms and their Dst indices, interplanetary magnetic field (IMF) and plasma conditions during the same period. Two GPS scintillation receivers GSV4004B and Trimble 5700 at the Varanasi low latitude, operating at L1 and L2 frequencies, experienced both phase and amplitude scintillation on several satellite-to-ground links during this period. Close examination of the GPS signals revealed the scintillation to be co-located with strong gradients in Total Electron Content (TEC) at the edge of the plasma stream. The data for storms is obtained from the OMNI database. The gradient-drift instability is a likely mechanism for the generation of the irregularities causing some of the scintillation at L band frequencies during this storm.

Penetration electric field, disturbance dynamo, neutral wind, neutral composition, etc., caused by geomagnetic storms have been reported. The results show variation of GPS derived total electron content (TEC) due to geomagnetic storm effect, local low latitude electrodynamics response to penetration of high latitude convection electric field and effect of modified fountain effect on GPS–TEC in low latitude region.

Ion-acoustic double layers in magnetoplasma with presence of superthermal electrons and positrons

J. K. Chawla, M. Rawat and P. C. Singhadiya*

Email: jitendra123chawla@yahoo.co.in, prakashsinghadiya82@gmail.com
Department of Physics, R. R. Govt. College Alwar, Rajasthan, India-301001

Department of Physics, Govt. College Jaipur, Rajasthan, India-302004*

Ion–acoustic double layers has been studied in magnetized plasma with presence of superthermal electrons and positrons. The modified Korteweg-de Vries (m-KdV) is derived using reductive perturbation method (RPM). The amplitude of compressive (rarefactive) DLs decreases (increases) with increase in ionic temperature ratio (σ_e) and obliqueness (θ), however increases with increase in positron concentration (δ),positron temperature ratio(σ_p) and spectral index (k) keeping other plasma parameters constant. Width of DLs increases with increase in parameters magnetization (ω_{pi}/Ω_i), however decreases with increase in θ, k, δ, σ_e and σ_p. Phase velocity of ion-acoustic waves (s) increases with increase k however decreases with increase in σ_e, σ_p and θ keeping other plasma parameters constant. We found that magnetization of plasma affect the width of DLs but not the amplitude.

Keywords: Double layer, RPM, m-KdV, Superthermal electron and positron

Oscillations Of The Magnetotail Plasma Sheet Parameters During A Solar Flare In The Maximum Activity Year

Vivekanandan R S , Dr. Bindhu S , Dr. Madhu G

Department of Physics, University College, Thiruvananthapuram, Kerala-695034

vivekanandanrs@gmail.com

Abstract

The conditions of the geomagnetotail plasma sheet is basically governed by the solar wind energy entering the magnetosphere and the magnitude and direction of the Interplanetary Magnetic Field. The energy carried by the solar wind is initially converted to electromagnetic energy and can be viewed as to be stored in the magnetic field, primarily in the magnetotail[1]. The energy of a storm/substorm could be supplied from delayed release of the energy stored in the magnetotail. Bursty Bulk Flows account for 70–100% of the total earthward transport of plasma, energy, and magnetic flux in the mid-tail plasma sheet[2]. During a storm, the configuration of the magnetotail becomes very complex. The neutral X line is occasionally formed close to Earth during magnetospheric storms, and the ring current can affect the plasma sheet dynamics. The solar activity was at a high level during 20-28 March 2012 and it was at a very high level during the last week of October and first week of November 2012. A number of solar flares of varying intensities occurred during this period. The present study concerned with the wavelet analysis of plasma sheet instabilities during the selected flare events of the maximum solar activity year and the results are discussed herewith.

During 20-28 March 2012, an X9/3B solar flare and an associated severe magnetic storm were observed. The first important solar event during the interval was an impulsive solar flare of a X9.4/3B class that took place in the active region. The Morlet wavelet transform was applied to identify the different periodicities present in the geomagnetotail plasma sheet parameters like plasma β –parameter, the ion density, ion temperature and the spectrum clearly showed the characteristics of the oscillations of the instabilities in the plasma sheet during the selected flare events. Long period oscillations of period 2-3 hours merge with oscillations of period 0.5- 1 hours on March 27, 2012 in plasma β -parameter and ion density. The Wavelet Transform analysis to the hourly values of electron density indicated the presence of long period oscillations of 5-12 hours. The oscillations of period less than 2 hours also can be identified from the analysis and this is due to the effect of magnetospheric substorms. The successive substorms during the storm enable favorable conditions for the plasma sheet for the smooth tail ward flows of plasma.

References :

[1] Kamide Y et al. J. Geophys. Res. 103, 705–17 (1998)
[2] Angelopoulos V J et al. J Geophys Res. 99, 257-280 (1994).

Plasma Instability in Lunar Ionosphere

Mehul Chakraborty[1], Vipin K. Yadav[2] and Rajneesh Kumar[1]

1 Department of Physics, Banaras Hindu University (BHU), Varanasi, Uttar Pradesh

2 Space Physics Laboratory (SPL), Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram, Kerala

Corresponding Author: vipin_ky@vssc.gov.in

Abstract

Plasma instabilities are the non-linear processes occurring in plasmas when excess energy gets accumulated in a plasma system which is unable to hold it. These instabilities are often observed in plasma systems residing in space such as the Sun, the planetary ionospheres, etc. Earth's natural satellite Moon has a very thin atmosphere and subsequently feeble plasma environment. However, this tenuous plasma environment is a place of several non-linear plasma phenomena. The solar wind, which strikes the lunar surface unhindered due to the absence of global lunar magnetic field, is capable of triggering plasma instability around the lunar exosphere.

The generation of Two-stream Instability (TSI) is studied analytically in the lunar plasma environment which comes into existence when the solar wind interacts unhindered with the tenuous lunar electron plasma in the surface bound exosphere. In this study, the conditions which allow the TSI to form and the subsequent instability growth with time is estimated. The Particle-In-Cell (PIC) simulations are also carried out to depict the plasma TSI evolution with time in phase space.

Instabilities of magnetohydrodynamic waves in rotating cosmic magnetoplasmas

Jyoti Turi, A.P. Misra

Department of Mathematics, Siksha Bhavana, Visva-Bharati (A Central University), Santiniketan-731 235, West Bengal, India

E-mail: jyotituri.maths@gmail.com, apmisra@visva-bharati.ac.in

Abstract

We study the propagation characteristics and instabilities of MHD waves in self-gravitating rotating magnetoplasmas with the effects of the magnetic field, the earth's rotation, the self-gravity, the diffusion-convection of cosmic rays, as well as the gas and cosmic-ray pressure. The instability conditions are shown to be modified by the Coriolis force and the cosmic-ray pressure. Due to the oblique orientation of the Coriolis force with respect to the magnetic field, a new wave mode, namely the Fast Jeans mode is found to coexist in the intermediate frequency regimes of the fast and slow Alfvén waves. The dispersion properties and the instabilities of different kinds of MHD waves reported here can play pivotal roles in the formation of various galactic structures at different length scales.

References:

[1] The dynamical state of the interstellar gas and field, The Astrophysical Journal **145**, 811 (1966).
[2] Effects of collisions and gyroviscosity on gravitational instability in a two-component plasma, Journal of Plasma Physics **8**, 393 (1972).
[3] Instability of low-frequency waves in a cold plasma mixed with hot electrons, Journal of plasma physics **33**, 437 (1985).
[4] The stability of a spherical nebula, Philosophical Transactions of the Royal Society of London. Series A, Containing Papers of a Mathematical or Physical Character **199**, 1 (1902).
[5] Self-gravitational instability of rotating anisotropic heat-conducting plasma, Physics of Plasmas **15**, 012107 (2008).
[6] Stability of Self-Gravitating Magnetized Hall Plasma with Electrical and Thermal Conductivity through Porous Medium, Contributions to Plasma Physics **33**, 227 (1993).
[7] Magnetohydrodynamic instabilities in a self-gravitating rotating cosmic plasma, J.Turi, A.P.Misra(submitted to Physica Scripta)

Study of D-Region Ionospheric Plasma Parameters Using Tweeks Analysis

Kshama Tiwari[1], S. B. Singh[2] and A. K. Singh[3]

Atmospheric Research Lab., Department of Physics, Banaras Hindu University, Varanasi - 221005, India.

Email: 1. kshmat1998@gmail.com
2. sbsingh_maharaja@yahoo.co.in
3. singhak@bhu.ac.in

Abstract

Tweek is a natural ELF/VLF wave emission which is caused by the lighting discharge and propagates in the Earth-Ionosphere waveguide over long distances by the process of multiple internal reflections [1]. The conductivity of the waveguide boundaries and total path travelled through the atmosphere provides appreciable dispersion of propagating VLF waves. The analysis of tweeks provided information about the D-region of the ionospheric plasma parameters like electron densities, reflection heights and travelling distances of the pulses [2].

We have analyzed the large no of Tweeks recorded by the installed instrument Automatic Whistler Detector (AWD) at our low latitude station Varanasi (geomag. lat = 14^0 55'N; L = 1.07) for the three seasons Summer, Equinox and Winter during the year 2018. The computed electron densities of the D-region of ionosphere vary between 23.2 - 66.8 el/cm, reflection heights of the lower ionosphere vary between 80 – 96 km and the propagation distances vary between 2658 - 3756 km. These computed ionospheric plasma parameters are found to be comparable to that of other measurements using radar and rockets.

References:

[1] Singh A.K. and Singh R.P. Earth Moon and Planets, **73**, p 277-292, (1996).
[2] Ohya et al., Earth Planets Space, **55**, p 627-635, (2003).

Whistler Wave Instabilities in a Complex Plasma

Amit Kumar[1*] *and Jyotsna Sharma*[1]

[1]*Department of Physics, Amity School of Applied Sciences, Amity University Haryana, Manesar, Gurugram-122051, India.*

Email id:[1*] *ak8689049@gmail.com.*

Abstract

In the present manuscript, the effect of fluctuations of dust grains on the parametric up conversion of lower hybrid wave into a whistler wave in a complex plasma is studied. In complex plasma which contains electrons, ions and dust grains an ambient magnetic field is applied, the large amplitude pump waves decays into two modes: a whistler wave mode and lower hybrid wave mode having low frequency. Further, a ponderomotive force by lower hybrid pump and whistler side band wave is exerted on the existing electrons, which drive the lower hybrid decay mode. Furthermore, the coupling of oscillatory velocity of low frequency lower hybrid wave with density perturbations produces a non-linear current, which drives the
whistler mode. The growth rate of lower hybrid waves scales linearly with the amplitude of the pump wave, it increases as the amplitude of lower hybrid pump wave increases. Moreover, the dust grain charges influence the instability appreciably. Our theoretically observed growth rate decreases with the size of dust grains. The growth rate varies inversely to the electron cyclotron frequency. i.e., it decreases as $_{ce}\omega$ increases. The results presented in the manuscript are efficiently able to elaborate the basics of the whistler wave excitation in space plasmas, processing in solid state plasmas, fusion plasmas, laboratory plasmas as well as industrial plasmas.

References

[1] R. A. Helliwell, Whistler and Related Ionospheric Phenomenon (Stanford University Press, Stanford (1965).
[2] J. W. Cipolla, K. I. & M. B. Silevitch, Phys. Fluids **20**, 282 (1977).
[3] R. L. Stenzel, J. Geophys. Res. **104,** 379 (1999).
[4] O. Moullard, A. Masson, H. Laakso, M. Parrot, P. Decreau, O. Santolik, and M. Andre,
GeoPhys. Res. Lett. **29**, 1975 (2002).
[5] G.-L. Haung, D.-Y. Wang, and Q.-W. Song, J. Geophys. Res. **109,** A02307 (2004).
[6] R. L. Stenzel, Phys. Fluids **19,** 857 (1976).
[7] J. F. Bamber, J. E. Maggs, and W. Gekelman, J. Geophys. Res. **100,** 23795 (1995).
[8] A. V. Kostrov, M. E. Gushchin, S. V. Korobkov, and A. V. Strikovskii, JETP Lett. **78,** 1026 (2003).
[9] L. James, L. Jassal, & V. K. Tripathi, J. Plasmas Phys. **54,** 119 (1995).
[10] R. C. Borcia, G. Matthieussent, E. L. Bel, F. Simonet & J. Solomon, Phys. Plasmas **7,** 359 (2000).

Compressible Effects On Force-free 2d Magnetic Flux Tubes

Jagannath Mahapatra, Rajaraman Ganesh, and Abhijit Sen

Institute for Plasma Research, A CI of Homi Bhabha National Institute, Gandhinagar-382428, Gujarat, India

E-mail: jagannath.mahapatra@ipr.res.in

Abstract

Magnetic reconnection (MR) is responsible for some of the most energetic/eruptive events observed in space and laboratory plasmas, for example solar flares, coronal mass ejections, magnetospheric aurora formation, saw-tooth crash in tokamaks, etc. during which the global magnetic energy is converted to kinetic energy, thermal energy and non-thermal particle acceleration [1]. The micro-scale current sheets (CSs) are the main site of MR and hence, it is a multi-scale phenomenon. Different plasma parameters around the CS controls the MR in many ways, for example, the plasma collisionality affects the CS dimension, the anti-parallel magnetic field profiles control the reconnection rate, shear flows controls the plasma inflow and out-flow etc.

In this work, we investigate the effect of compressibility on the reconnection dynamics of two interacting magnetic flux tubes or magnetic islands in the presence of shear flow, using a force-free Fadeev equilibrium [4]. A comparison of these results with a recently reported incompressible MIC problem [2.3] that uses a non-force-free equilibrium in the presence of a shear flow will be presented.

References :

[1] E. Priest and T. Forbes, The Astronomy and Astrophysics Review **10**, 313 (2002).
[2] J. Mahapatra, A. Bokshi, R. Ganesh, and A. Sen, Phys. Plasmas **28**, 072103 (2021).
[3] J. Mahapatra, R. Ganesh, and A. Sen, in comm. to Phys. Plasmas (2022), **arXiv:2207.14365**.
[4] G. Murtas, A. Hillier, and B. Snow, Phys. Plasmas **28**, 032901 (2021).

EXPLORING THE MAGNETIC COUPLING OF SOLAR ATMOSPHERE USING THE AMPLITUDE AND FREQUENCY MODULATION OF 3-MIN WAVES ABOVE SUNSPOT UMBRA

Ananya Rawat, Girjesh R Gupta

Udaipur Solar Observatory, Physical Research Laboratory, Dewali, Badi Road, Udaipur 313001

E-mail : ananyarawat@prl.res.in

Abstract

We are well aware of the fact that sunspots play host to various oscillations and wave phenomena like umbral flashes, umbral oscillation, running penumbral waves, and coronal waves. Slow magnetoacoustic waves display their longitudinal and compressive nature in the form of intensity perturbations while propagating along the magnetic field lines from the lower to the upper solar atmosphere. We studied these oscillations in detail along the clean fan-loop system rooted in active region AR12553 for 4hr duration on June 16, 2016 observed by IRIS and SDO. All the fan-loops rooted in sunspot umbra constantly show a 3-min period propagating slow waves. However, their origin in the lower atmosphere is still unclear. In this work, we are tracing their origin in the lower atmosphere by utilising their recently discovered characteristics of amplitude and frequency modulation with time while propagating. We found a range of periods in amplitude modulation, which led us to interpret that 3-min magnetoacoustic waves found in the solar corona owe their origin to the photospheric phenomenon. From frequency modulation of 3-min waves, we found that several other small time-scale modulations are added in the chromosphere while propagating. Obtained results provide clear evidence of magnetic coupling of the solar atmosphere from the propagation of 3-min period waves and expansion of magnetic loops in the upper solar atmosphere.

SPECTROSCOPIC AND IMAGING OBSERVATIONS OF TRANSIENT HOT AND COOL LOOPS IN THE SOLAR ATMOSPHERE

Girjesh R Gupta, Sushree S Nayak

Udaipur Solar Observatory, Physical Research Laboratory, Dewali, Badi Road, Udaipur 313001

E-mail : girjesh@prl.res.in

Abstract

Coronal loops are the basic building blocks of the solar atmosphere and are observed on various length scales. However, their formation mechanism is still unclear. In this paper, we present spectroscopic and imaging observations of small-scale transients and the subsequent formation of transient loops. For this purpose, we have utilized the multiwavelength observations recorded by the Atmospheric Imaging Assembly (AIA) and the Interface Region Imaging Spectrograph (IRIS) slit-jaw imager (SJI), along with spectroscopic measurements provided by IRIS. For the photospheric magnetic field data, we obtained line-of-sight magnetogram data provided by the Helioseismic and Magnetic Imager (HMI). Small-scale transients are simultaneously observed with several EUV and UV passbands of AIA and IRIS/SJI. The HMI magnetogram provides evidence of negative flux cancellations beneath these transients. Differential emission measure (DEM) analysis shows that one of the transients attains temperatures up to 8 MK, whereas another only reaches 0.4 MK. These transients further lead to small-scale loops with similar temperature distributions, thus termed hot and cool loops. During events, the IRIS slit was rastering the region and thus provided spectroscopic measurements at both transients and associated loops. This enabled us to perform in-depth investigations of the hot and cool loops. Energy estimates suggest that flux cancellation could easily power the hot transient while it is insufficient for the cool transient. Lifetime estimates and magnetic field extrapolation suggest the presence of small-scale and fine structures within these loops. The results provide crucial ingredients for the physics of loop formation and the thermodynamics involved.

Effect of flow shear on the onset of dynamo

Shishir Biswas, Rajaraman Ganesh

Institute for Plasma Research, Homi Bhabha National Institute, Bhat, Gandhinagar, Gujarat 382428, India

E-mail : shishirbeafriend@gmail.com, shishir.biswas@ipr.res.in

Abstract

Dynamos generate large scale magnetic fields by the motion of conducting fluids. This mechanism is believed to be the key mechanism behind the existence of high magnetic fields in various astrophysical bodies, for example, planets, galaxies, interstellar medium, accretion disks, also in the Sun. Various laboratory experiments, as well as numerical studies have been performed to understand these astro-physical scenarios in detail. Recently, the exact role of fluid helicity in the context of dynamo instability has been examined via direct numerical simulation **[1]**.

Shear flows often coexist in astrophysical conditions and the role of flow shear on the onset of dynamo is only beginning to be investigated **[2]**. For example, it has been identified that a superposition of large scale shear with small scale quasi-2D velocity fields produce Dynamo Waves **[2]**. In the present work, we demonstrate the flows which do not produce dynamos, tend to trigger a dynamo instability onset with increase in flow shear **[3]**. To test the generality of our finding, various quasi-2D flows and a variety of shear flow structures have been considered. We have performed the above said studies using an in-house developed, multi-node, multi-card GPU based 3D Magnetohydrodynamic solver (GMHD3D) **[4]**. Details of this study will be presented.

References:

[1] S. Biswas, R. Ganesh et al., Revisiting Induction Dynamo in 3-dimensional magnetohydrodynamic plasmas: Dynamo transition from non-Helical to Helical flows, **Manuscript under Review in MNRAS (2022)**.
[2] S. Tobias, F. Cattaneo, Shear-driven dynamo waves at high magnetic Reynolds number. Nature 497, 463–465 (2013). https://doi.org/10.1038/nature12177.
[3] S. Biswas, R. Ganesh et al. **Manuscript under preparation (2022).**
[4] S. Biswas, R. Ganesh et al. "GPU Technology Conference (GTC-2022)", https://www.nvidia.com/en-us/on-demand/session/gtcspring22-s41199/.

Industrial Plasma & Applications

Numerical Simulation of Coal Devolatilization Process in Presence of High Power Plasma Arc in Plasma Fuel System

Sunil Bassi[1,2], S.K. Nema[1,2], A. Sanghariyat[1], C. Patil[1], P.V. Murugan[1], Shashank Chaturvedi[1,2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar-382428*

[2]*Homi Bhabha National Institute, BARC Training School Complex, Anushaktinagar, Mumbai, 40094*

E-mail : sunil.bassi@ipr.res.in

Abstract

Plasma Fuel System (PFS) are used for oil free ignition of coal based thermal power plants as well as keeping the furnace from quenching when being operated at lower load. It has been established in many reports that high power arcs in the range of 10-30 kW can enhance the degree of coal devolatilization for quick and easy combustion of coals having higher ash content. PFS is a cylindrical chamber in which high power arc is maintained. Coal-air mixture is injected from one side of the system and other side is kept as an inlet to coal furnaces from which combustion flame exits the PFS chamber. As the coal-air passes through the arc region, pulverized coal particles are activated due to high temperature and presence of ionic species. The activated coal particles devolatilize and produce combustible mixture. High temperature combustion flame is generated as the volatiles move downstream in PFS chamber. This system generates a stable flame without the use of oil and thus advantageous economically as well as environmentally.

In this study, numerical simulations are performed for PFS system with a FORTRAN code which solves equation of mass, momentum and energy conservation using finite difference method. Both kinetic and equilibrium chemical reactions are solved for modelling the process of combustion. The time marching code solves these equations on a 2D mesh having azimuthal symmetry. Coal particles are tracked as Lagrangian system in otherwise Eulerian mesh. Provision for tracking multiple particles with a single parcel is used for computational cost reduction. Plasma arc is modelled as a constant power source in the cylindrical chamber. Coal particles of constant size of 60 micrometer mixed with air are injected from one end of 50 cm long cylinder. Other end is kept open by applying open boundary condition. Plasma arc is kept at a distance of 4 cm to the injection point. To model the process of coal devolatilization, single first order reaction (SFOR) model is employed as present in reported literature. Validation is performed by injecting 1 gram of coal particles in the chamber and measuring the volatile yield in the chamber. After sufficient validation, volatile yield for various inflow rates and different arc powers is calculated. Various parametric studies are to be performed to determine the optimum operating conditions for the operation of PFS, such as inflow rate, proportion of coal and air, arc power, arc location and chamber dimensions etc.

Plasma Gasification Technology for Municipal Solid Waste treatment

Tejashwi rana[1*], Satyananda kar[1]

[1] *Department of Energy Science and Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110016*

*Email Id: tejas.rana7797@gmail.com

Abstract

Municipal solid waste (MSW) is something we all produce in significant amounts, and nowadays, its management has become a major concern. It deserves special attention because of its negative externalities on the environment, health, and economy. Currently, a widely accepted technology used for MSW disposal is incineration. However, the demand for excess airflow limits the required temperature in incineration. Various technologies like pyrolysis, conventional gasification, and plasma pyrolysis/gasification are in practice to minimize the adverse effect on the environment. Plasma Gasification is an emerging and eco-friendly technology for waste management, converting waste to valuable products without affecting the environment. It may be considered one of the best technologies to manage solid waste since it has various advantages over conventional. A 42 kg/hr. capacity Plasma Gasification plant for MSW treatment is installed, and performance is studied. MSW is fed into the primary chamber (Plasma arc reactor) and processed at 850 ^{0}C. The hot gases generated in the reactor are sent to the secondary chamber for combustion to avoid the release of combustible gases into the environment. The hot gases from the secondary chamber are quenched in a wet scrubber to avoid the recombination reaction, thus reducing the generation of toxic gases like dioxin and furans. The gases are further cleaned through pollutant removal in a venturi scrubber. The composition and toxicity of bottom ash produced in the primary chamber are characterized by Energy dispersive X-Ray (EDX) and Inductively Coupled Plasma-Mass-Spectrometry (ICP-MS). The major components were oxygen (42.83%), calcium (33.24%), and silica (5.69%), and found to be non-toxic and carbonless. The exhaust gas sample collected and tested for pollutants concentration were well below the CPCB limits.

Development and characterization of Chitosan/ZnO Nanocomposites on plasma pretreated cotton fabrics for enhancement of their antimicrobial properties

V. Udaya [1], M.C. Ramkumar [1]

[1]*Division of physics, School of advanced Sciences, Vellore Institute of Technology Chennai, Chennai 600 127, Tamilnadu, India*

Abstract

In our study Chitosan/ZnO nanocomposites were developed on the surface of plasma pretreated cotton fabrics for enhancement of their antimicrobial properties. Initially, the cotton fabrics was pretreated using O_2 plasma at different exposure times (5, 10 and 15 mins). Subsequently chitosan and ZnO Nps was immobilized on the surface of plasma pretreated cotton fabrics. The effect of exposure time was studied with the objective to enhance the antimicrobial activity of the cotton fabrics. Plasma Enhanced Chemical Vapour Deposition (PECVD) reactor was used to activate the cotton fabrics. The amendment in surface properties of the cotton fabrics was examined by various characterization techniques. The change in hydrophilicity was analyzed using contact angle (CA) analysis. FTIR and XPS analysis was used to study the change in chemical structure of the surface modified cotton fabrics. SEM analysis was performed to study the change in surface morphology. The antimicrobial activity of surface modified fabrics was examined by subjecting against *E. Coli* and *S. aureus* . Substantial outcome have been achieved depending on the operating parameter, revealing that the non-thermal plasma is an excellent method to enhance the antimicrobial properties of textile fabrics by incorporating specific functionalities. This facilitates to increase in incorporation of chitosan and ZnO Nps on the surface of cotton fabrics. The prepared nanocomposite coating is intended to be employed in hospital-related applications as antimicrobial and self-cleaning clothing.

Keywords: Plasma activation, Cotton fabrics, Chitosan, ZnO NPs, antimicrobial activity.

Comparative Study of Dielectric Barrier Discharge Plasma With Different Configurations

Trivesh Kant, Kushagra Nigam, Abhijit Boruah, Chirayu Patil, B. Sahoo, G Ravi

Institute for Plasma Research, 382428 Gandhinagar

trivesh.kant@ipr.res.in

Abstract

Dielectric barrier discharge (DBD) is a form of atmospheric cold plasma which has evoked keen interest among researchers, both from fundamental as well as application point of view[1]. In recent years, many industrial systems have been developed that employ DBD, *viz.* textile, agriculture and health sectors. In our lab, we have developed novel DBD configurations for use in the after-treatment of exhaust gas from diesel engines and carried out comparative studies. While this technique has been used in several labs worldwide, the basic physical processes have still not been unraveled completely. The DBD configurations that have been developed in our lab maintain a discharge gap of 1 mm using axially symmetric geometry. The configurations are (i) knurling-staggered (ii) knurling-continuous (iii) non-knurling-staggered and (iv) non-knurling continuous. The influence of ambient air and flowing air with different flow rates on the discharge is also investigated. A high voltage power supply with output voltage in the range of 8-12kV having frequency of 15 kHz is applied to strike the discharges. On analyzing the I-V characteristics, it is found that peak-to-peak current is maximum in the knurling-staggered configuration. It is speculated that this may be because knurling provides the shortest path between spike and the other electrode for formation of streamers. Moreover, the staggered winding provides a fringing electric field and enhances the discharge mechanism. The air flow helps in extending the plasma over regions in between the fringing fields[2].

References :

[1] Dielectric barrier discharge—properties and applications, *Thin Solid Films* 390, p 237--242, (2001)
[2] Dielectric barrier discharge plasma actuators for flow control, *Annual review of fluid mech*. 42, p 505—529, (2010).

Surface Modification of Bharat Merino Wool (BMW) for improving its Shrink Resistance using atmospheric pressure non-thermal air plasma and bio-polymer coating

Nisha Chandwani[1], Vinod Kadam[2], Atik Mistry[1], Vishal Jain [1] and S.K.Nema[1]

[1] *Institute for Plasma Research, Bhat Village, Near Indira Bridge. Gandhinagar-382428*
[2] *Central Sheep and Wool Research Institute, Avikanagar-304501*

E-mail: nisha@ipr.res.in

Abstract

The shrinkage of woollen garments occurs due to wool fiber structure. The outer surface of woollen fiber consists of hydrophobic cuticle scales whereas the core is hydrophilic in nature. This leads to entanglement of fibers during laundering and hence results in shrinkage [1]. Plasma surface modification of wool is being globally explored as an eco-friendly alternative to impart shrink resistance properties to wool [2]. The present work investigates the effect of atmospheric pressure air plasma on surface characteristics of Bharat Merino wool (BMW), which is an indigenously developed wool breed by Central Sheep and Wool Research Institute (CSWRI). The Video Contact Angle (VCA) Goniometer, FE-SEM (Field Emission Scanning Electron Microscopy) and Fourier Transform Infrared (FTIR) spectroscopy are used to study physio-chemical changes induced by plasma. The relaxation and felting shrinkage, static and dynamic friction and tensile strength of the untreated and plasma treated BMW fabric has been analyzed as per the ASTM standard methods. The VCA goniometer results show the water contact angle of BMW fabric decreases from ~ 130° to 0° after plasma treatment. The SEM analysis reveals plasma treatment leads to blunting of sharp cuticle scales. The FTIR spectrum shows the formation of polar functional groups on plasma treated sample. The plasma exposure leads to reduction in relaxation shrinkage from ~ 7.2% to ~ 5.7% and felting shrinkage from ~24% to ~16%. The tensile strength of the fabric is unaffected by plasma treatment. Further experiments for plasma processing followed by bio-polymer coating are underway.

References :

[1] Comparative study on the felting propensity of animal fibers,Liu et.al Text.Res.J. 77, p 957-963 (2007)
[2] Plasma Technologies for textiles, R.Shishoo 1st edn . (Woodhead Publishing Limited, 2007)

Cold Atmospheric Plasma For The Deactivation Of Omicron Variant Of SARS-CoV-2

Reema, Deepjyoti Basumatary, Kamatchi Sankaranarayanan*

Institute of Advanced Study in Science and Technology, (An Autonomous Institute Under DST, Govt. of India), Vigyan Path, Paschim Boragaon, Garchuk, Guwahati, Assam 781035, India.

Email: shr.reema0301@gmail.com, kamatchi.sankaran@gmail.com

ABSTRACT

Cold atmospheric plasma (CAP) has gaining potential, and very effective to curb or deactivate the various microorganisms such as bacteria and virus. Lately, the major outbreak SARS-CoV-2 infection has affected humanity largely with added complexity of its ability to mutate to variants such as Omircron. We have earlier shown the effectiveness of CAP on SARS-CoV-2 spike protein and, in this study, we have evaluated the effectiveness of CAP to deactivate Omicron. We studied the ability of the binding of Angiotensin converting Enzyme Protein (ACE2) protein to the plasma treated spike S1-S2 protein and spike Receptor binding domain (RBD) using Cold atmospheric plasma direct treatment as well as Plasma activated water (PAW). Results have shown the binding efficiency of Omicron spike protein to ACE2 decrease with increase in treatment time with both direct treatment and PAW as evidenced using spectroscopic techniques. The reactive species (RONS) play a major role in the efficient deactivation of the binding of ACE2 to the Omicron spike protein. Correspondingly, the comparison between the efficiency between direct treatment and PAW has also been discussed.

References:

[1] Cold atmospheric pressure plasma for attenuation of SARS-CoV-2 spike protein binding to ACE2 protein and the RNA deactivation, RSC advances. 2022;12(15):9466-72.

DISCHARGE MODES IN A MICROWAVE PLASMA TUBE IN THE PRESENCE OF DIELECTRIC BEAD

Anupama Ojha, Shubhankur Suvansh, Himanshu Pandey and Shail Pandey

Department of Physics, Sardar Vallabhbhai National Institute of Technology Surat, Surat – 395007, India

E-mail: sp@phy.svnit.ac.in

Abstract

Non-thermal regime of microwave (MW) plasma has shown potential in tackling various environmental issues such as conversion of CO_2 and CH_4, ammonia production and abatement of volatile organics [1]. For CO_2 conversion, MW plasma exploits the vibrational excitation process of CO_2 levels, also called as ladder climbing process, in which only 5.5 eV energy is required to dissociate the C=O bond [2]. It is further observed that introduction of the dielectric beads in the quartz tube changes the electric field profile in the discharge system and hence may increase the efficiency of the plasma source to some extent [3]. An understanding of the discharge mode sustained by the surface MWs in the presence of dielectric beads is required to exploit the potential industrial applications of plasma, especially in CO_2 conversion where there is always a compromise between the energy efficiency and the conversion efficiency of CO_2 [4]. The present work is an attempt to address this quest in view of increasing the energy efficiency as well as CO_2 conversion efficiency using MW plasma.

A simulation of the discharge modes in a surface MW (2.45 GHz) sustained plasma is carried out with the help of COMSOL Multiphysics v5.6 [5]. A thorough investigation of the effect of dielectric bead density, dielectric constant and the gas flow rate on the argon discharge mode has been carried out and it is found that ferroelectric beads like $BaTiO_3$ creates discharge mode suitable for CO_2 conversion applications. At 1 torr of argon gas, the electron density increases from 1.1×10^{18} m^{-3} to as high as 8×10^{18} m^{-3} while electron temperature decreases from 1.78 eV to about 1.66 eV, with the inclusion of $BaTiO_3$ beads in the plasma tube – both of these conditions are favorable for efficient CO_2 conversion. The role of argon metastables in determining these discharge modes is also studied by investigating the rate reactions of electron-metastable and metastable-metastable reaction channels.

References :

[1] A. A. Zamri, M. Y. Ong, S. Nomanbhay, and P. L. Show, "Microwave plasma technology for sustainable energy production and the electromagnetic interaction within the plasma system: A review," *Environ. Res.*, vol. 197, p. 111204, Jun. 2021.
[2] S. Xu, H. Chen, C. Hardacre, and X. Fan, "Non-thermal plasma catalysis for CO $_2$ conversion and catalyst design for the process," *J. Phys. Appl. Phys.*, vol. 54, no. 23, p. 233001, Jun. 2021.
[3] E. C. Neyts, K. (Ken) Ostrikov, M. K. Sunkara, and A. Bogaerts, "Plasma Catalysis: Synergistic Effects at the Nanoscale," *Chem. Rev.*, vol. 115, no. 24, pp. 13408–13446, Dec. 2015.
[4] W. Wang, T. Butterworth, and A. Bogaerts, "Plasma propagation in a single bead DBD reactor at different dielectric constants: insights from fluid modelling," *J. Phys. Appl. Phys.*, vol. 54, no. 21, p. 214004, May 2021
[5] COMSOL Multiphysics® v. 5.6. www.comsol.com. COMSOL AB, Stockholm, Sweden.

Synergistic Effect of Nano CuO_2 and Micro Discharge Plasma on Degradation of Congo red Dye

N. Thirumurugan[1], P. Amarnath[2], S. Yugeswaran[2], K. Suresh*[1]

Affiliation: [1]Surface and Environmental Control Plasma Laboratory, Department of Physics,
Bharathiar University, Coimbatore-641046, India.
[2]Applied Thermal Plasma Laboratory, Department of Physics, Pondicherry University, Puducherry-605014, India.

E-mail: ksureshphy@buc.ac.in

Abstract

Degradation of organic pollutants in wastewater is highly essential to reduce its discharge into natural water resources. Carcinogenic dye, Congo red (CR) is degraded in the present study, using one of the advanced oxidation process of degradation- micro discharge plasma (MDP) combined with nano CuO_2. Here, CuO_2 nanoparticles were synthesized by thermal plasma method. The CR dye was degraded in 40 min of air plasma treatment with addition of nano CuO_2. The optical emission spectrum (OES) of MDP showed that air plasma generates OH● radicals that interact with aqueous medium containing CR dye, and effectively degrades it. The pH and electrical conductivity of treated solution further confirms reactive species formation. Dye concentration in solution was determined using UV-Vis spectroscopy; degradation percentage and energy yield was calculated to be respectively 99% and 69 mg/kWh. Intermediate products formed during degradation were detected by liquid chromatography and mass spectrometry (LC-MS) analysis and the probable degradation pathway was proposed. Total organic carbon (TOC) analysis showed that mineralization percentage of plasma treated solution with CuO_2 nanoparticle addition is twice high than mere plasma treated solution, and proves to be an efficient method for degradation of complex organic dyes.

Keywords: Micro discharge plasma, Air plasma, OH radicals, Dye degradation.

Development of Glass-Metal joint for Plasma Antenna System

Vinod Kaila[1*], Siju George[1], Rajan Babu[1], Vijay Patel[1], Dilip Raval[1], Prabal K. Chattopadhyay[1,2]

[1]Institute for Plasma Research, Bhat, Gandhinagar-382428, India

[2]Homi Bhabha National Insitute, Training School Complex, Anushaktinagar, Mumbai, 400094, India

E-mail*: vdkaila@ipr.res.in

Abstract

A novel method of joining glass with metal (stainless steel - SS304) using flexible metallic seals is developed at IPR and is discussed in this work. Metal to glass joints are generally used in the fabrication of a wide range of high and ultra-high vacuum components such as electrical isolators, glass view ports, gas discharge tubes, signal and power feed-through etc. These components have fixed glass-metal joints formed using solders or brazing followed by complex and precise engineering procedures to make a leak tight joint. The developed joint is used in the fabrication of microwave antenna which requires a few Torr of specific gas to be maintained for fairly long time i.e. several months/year. Different engineering parameters of the joint and final test results of the assembled joint are presented in this paper. The fabricated joint is leak tested for 1.0 x 10-9 mbar liter/second leak rate. The joint was kept under vacuum condition for three weeks without observing any significant deterioration of vacuum indicating long hold-time of vacuum.

Production Of Plasma Activated Water Containing Hydrogen Peroxide And Ozone By Transient Spark Discharge And Electrospray

P.Pareek, M.Janda, S.Kooshki, P.Tóth

Faculty of Mathematics, Physics and Informatics, Comenius University Bratislava, Slovakia

pareek1@uniba.sk

Abstract

Generation of plasma activated water (PAW) has become an important research topic in recent years due to many potential applications in medicine, agriculture, and food industries [1]. PAW may contain various reactive oxygen and nitrogen species (RONS), generated either by transfer of reactive species from plasma, or by secondary chemical reactions in water. Hydrogen peroxide (H_2O_2), ozone (O_3), nitrites (NO_2^-) and nitrates (NO_3^-) belong to the important long-lived species in PAW. Exact composition of PAW depends on many parameters, e.g., plasma source, inlet gas or plasma/water interface characteristics. In previous research in our group, it was found that the increase of gas/water interface by electrospray (ES) of water to microdroplets enable higher transport rate of RONS from gas to liquid phase in comparison to bulk water [2]. In this study, we employed TS with water ES in a one stage system (1SS) in dry oxygen (O_2) gas and TS operated in dry or humid O_2 followed by water ES in a two-stage system (2SS). The aim was to show the significance of direct plasma-liquid interaction in 1SS for the generation of high concentrations of reactive species in PAW. TS was operated in RC (R=4.6 MΩ, C=50 pF) driven circuit with DC power supply in closed reactor. A needle of 0.6 mm diameter was used as high voltage electrode, which was kept at a gap of 0.8 cm with the ground electrode. The needle electrode also served for deionized water inlet (flow rates 0.4-1 mL/min), pumped by syringe pump. Oxygen gas was supplied into the system at constant gas flow 1L/min. The concentrations of O_3 and H_2O_2 in water were detected using colorimetric methods. The concentration of hydrogen peroxide and ozone in PAW changed significantly with input energy density. Significantly higher concentration of O_3 and H_2O_2 were reached in 1SS, up to 7 mM and 2.9 μM, respectively. The gas phase concentrations of RONS were monitored using UV-Vis and FTIR absorption spectroscopy techniques. Gaseous O_3 concentration changed as function of input energy density with peak value around 300 ppm at 400 J/L, while no significant amount of H_2O_2 was detected in the gas phase. The time integrated optical emission spectroscopy (OES) revealed the presence of many lines of neutral atomic oxygen and atomic oxygen ion. In addition, Hα line at 656 nm appeared in emission spectra of TS generated in humid O_2 and in spectra of TS generated simultaneously with ES. The relative intensity of Hα line was almost twice as high in spectra of TS with ES compared to spectra of TS generated in humid O_2. The profile of Hα alpha line in all spectra was significantly broadened due to Stark broadening mechanism. The full width at half of the maximum was almost 2.2 nm. After subtracting the contribution of the instrumental broadening to line width, the electron density was found to be approximately 8×10^{17} cm^{-3}. Due to pulsed character of our discharge, the electron

density changes in time during the TS current pulse. Thus, time resolved OES measurements will be performed in the future to obtained more precise values of electron density.

References :

[1]Z Machala et al 2019 J. Phys. D: Appl. Phys. 52 034002
[2] EL Hassan et al Water **2021**, 13, 182. https://doi.org/10.3390/w13020182

Simulation and Experimental Analysis of Kr/Cl_2 based 222 nm Far UV-C Excimer Source

Surbhi Bidawat[1], Navin Kumar Sharma[2], Ram Prakash Lamba[1], Mahendra Singh[1], Alok Mishra[1], Yaduvendra Choyal[2] and Udit Narayan Pal[1]

[1]*CSIR- Central Electronics Engineering Research Institute, Pilani, Rajasthan-333031*
[2]*Devi Ahilya Vishwavidyalaya, Indore, Madhya Pradesh-452001*

Email : surbhibidawat0779@gmail.com, udit@ceeri.res.in

Abstract

Excimer lamps are efficient sources for the generation of non-coherent ultraviolet (UV) and vacuum ultraviolet (VUV) radiations emitted by rare gas dimers and rare gas halides [1, 2]. Dielectric barrier discharge (DBD) is a well-suited method to generate these excimer radiations [3, 4]. Traditionally, UV lamps with characteristic wavelength of 254 nm are used for the inactivation of viruses and bacteria, water purification, etc. However, these lamps are used only in unoccupied spaces as it may cause skin cancer to human beings [5]. The most promising solution is to use 222 nm radiation which is safe for the human being with better disinfection properties. An excimer lamp filled with the required composition of Kr/Cl_2 gases with volume discharge configuration can efficiently emit 222 nm radiation. In the present work, one dimensional model has been developed in the COMSOL Multiphysics Software for the analysis and discharge characterization of DBD based Kr/Cl_2 excimer lamp excited by short unipolar pulse for the effective generation of $KrCl^*$ excimer at different operating and geometrical conditions [6]. The model investigates the spatio-temporal behavior of the electrons, ions and the $KrCl^*$ excimer during the rising and falling phase of the applied voltage pulse. The absorbed electrical power, $KrCl^*$ excimer density and the radiative power density have also been evaluated at different gas pressures and compositions. The development and characterization of 222 nm excimer source have been carried out at different operating and geometrical parameters on the basis of simulation study for the effective generation of 222 nm radiation. The simulation and experimental discharge analysis would be very helpful for the design and development of Kr/Cl_2 based 222 nm Far UV-C Excimer Source.

References:

[1] V. F. Tarasenko, Pure Appl. Chem., **74**, 465–469, (2002).
[2] M. I. Lomaev, et al., Phys.-Usp.,**46**, 193, (2003).
[3] U. N. Pal, et al., Plasma Sci. and Tech.,**1**, 635, (2013).
[4] P. Gulati, R. Prakash, U. N. Pal, M. Kumar and V. Vyas, Appl. Phys. Lett., **105**, 013505, (2014).
[5] E. R. Blatchley III, et al., Critical Reviews in Environmental Sci. and Technol., (2022).
[6] COMSOL Multiphysics® v. 5.4 www.comsol.com. COMSOL AB, Stockholm, Sweden.

Discharge Analysis and Characterization of Cold Atmospheric Pressure Plasma Jet Sources for Potential Biomedical Applications

Navin Kumar Sharma[1], Priti Pal[2,3], Vishali singh[1], Ravindra Kumar[2], Alok Misra[2], Mahendra Singh[2], Ram Prakash Lamba[2,3], Murali M Pandey[4], Yaduvendra Choyal[1] and Udit Narayan Pal[2,3]

[1]Devi Ahilya Vishwavidyalaya, Indore, Madhya Pradesh-452001
[2]CSIR- Central Electronics Engineering Research Institute, Pilani, Rajasthan. -333031
[3]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, U.P. - 201002
[4]Birla Institute of Technology and Science, Pilani, Pilani Campus, Rajasthan– 333031

E-mail: navinshrma48@gmail.com, udit@ceeri.res.in

Abstract

Cold atmospheric pressure plasma (CAP) sources are widely utilized in the biomedical field due to its therapeutic nature [1]. The generation of the reactive oxygen and nitrogen species at biologically elevated temperature in the CAP sources have established the new field of research called "plasma medicine" [2,3]. In fact, cold atmospheric pressure plasma jet (C-APPJ) sources are gaining much consideration due to extraordinary capability of delivering the reactive oxygen and nitrogen species (RONS) in the narrow regions [4-5]. Actually, much more attentions are required for the design and development of C-APPJ sources for their potential applications in wound healing, cancer treatment etc. by optimizing the operating and geometrical parameters [1,6]. In the present work, characterization of different configurations of the C-APPJ sources have been carried out according to the basic requirement for wound healing and cancer treatment. The discharge formation and the propagation dynamics of the plasma have been investigated. The simulation analysis has also been performed to analyze the effect of gas flow dynamics in the formation of elongated and stable plasma plume. The plasma plume formed in different configurations of the C-APPJ are further characterized for the effective generation of RONS. These plasma plume generates the different reactive species which is diagnosed by using optical emission spectroscopy. The investigation has confirmed the formation of low temperature plasma plume and the generation of the metastable, hydroxyl (OH), Nitric oxide (NO), low plume current and required dose of UV radiation.

References:

[1] H Metelmann, et al., (Cham: Springer International Publishing), (2018).
[2] K. D. Weltmann and T. von Woedtke, Plasma Phys. Control. Fusion, **59**, 014031, (2017).
[3] S Reuter, et al., J. Phys. D: Appl. Phys., **51**, no. 23, 233001, (2018).
[4] Navin. K. Sharma, S. Misra, Varun, and U. N. Pal, Phy. of Plas., **27**, 113502, (2020).
[5] Navin K. Sharma et al., IEEE. Trans. Plas. Sci. **49**, 2799-2805, (2021).
[6] S.K. Dubey et al., Drug Discov. Today, **27**, 2425-2439, (2022)
[7] S.K. Dubey, S. Parab, A. Alexander, M. Agrawal, et al., Process Biochem, **112**, 112-123, (2022).

Analysis of Cold Atmospheric Pressure Plasma Source based Plasma Activated Water for Agriculture Application

Priti Pal[1,2], Vishali Singh[1], Navin K. Sharma[3], Mahendra Singh[1], Alok Mishra[1], Udit Narayan Pa[1,2] Shivendra Maurya[1] and Ram Prakash Lamba[1,2]

[1]CSIR- Central Electronics Engineering Research Institute, Pilani, Raj. -333031
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh-201002
[3]Devi Ahilya Vishwavidyalaya, Indore, Madhya Pradesh-452001

E-mail: pritipal1998@gmail.com, rplamba@ceeri.res.in

Abstract

Usually, when the water is passed through a non-thermal/ cold plasma source for a specific time is called plasma activated water (PAW). The PAW is full of various long- and short-lived reactive species of oxygen and nitrogen (RONS) which enhances its characteristic properties [1], [2]. The presence of reactive species makes the PAW suitable for applications in agriculture, food processing, surface sterilisation, decontamination, etc. [3][4]. In fact, the RONS are very much suitable for the plant growth enhancement, shelf-life extension, increase of the microbial inactivation property, etc. [5]. In the present work design, development, and characterization of cold atmospheric plasma (CAP) sources have been carried out to meet the needs of heat sensitive applications. The electrical and optical characterization of the developed CAP sources and the PAW have been carried out at different operating and geometrical conditions to analyse the presence of RONS such as nitrate (NO_3^-), nitrite (NO_2^-), ozone (O_3), hydrogen peroxide (H_2O_2). The developed sources are utilised to treat different water samples at various time intervals to produce the nutrient rich PAW for agriculture and food applications. An in-depth investigation of various PAW parameters such as conductivity, pH, turbidity, ORP, TDS, nitrite, nitrate, and hydrogen peroxide content have been analysed at different operating conditions. The properties of PAW are compared to those of untreated water. In comparison, the pH of the PAW exhibits practically constant behaviour, while the nitrate, nitrite, and hydrogen peroxide contents increase linearly with respect to the plasma treatment time. The investigation is very much useful for the design and development of cold plasma-based PAW system for food and agriculture applications.

References:

[1] K. F. Sergeichev, et al., *Front. Phys.*,**8**, 1–11, (2021)
[2] Talebizadeh, et al. *Renew. Sustain. Energy Rev.*, **40**, 886–901, (2014)
[3] C. Lin, C. Hsiao, H. Lin, J. S. Liou, and C. Hsieh, *Foods*, **9**,(2020)
[4] H. Cheng, Y. Li, K. Zheng, D. Liu, and X. Lu, *J. Phys. D. Appl. Phys.*, **54**, 184003, (2021)
[5] N. Punith, et al*, Adv. Mater. Lett.*,**10**, 700–704, (2019)

Atmospheric Pressure Argon Plasma Jet for Wound Healing

Rajendra Shrestha[1,4], Tachal Niraula[3], Mukesh Pokharel[3], Puja Pandey[3] , Sujata Bhattarai[3] , [5]Dr. Shreedevi Basukala [MBBS], Jyoti Prakash Gurung[2] , Deepak Prasad Subedi[2] , Vishwa Prakash Shrivastava[3]

[1] *Deparment of physics, Nepal Banepa Polytechnic Institute, Banepa, Kavre, Nepal*

[2] *Department of Natural Science, Kathmandu University, Dhulikhel, Nepal*

[3] *College of Biomedical Engineering and Applied Sciences, Hadigaun, Kathmandu, Nepal*

[4] *Deparment of physics, Patan Multiple Campus, Patandhoka, Lalitpur, Nepal*

[5]Nepal Korea *Friendship Municipality Hospital, Madhyapur Thimi, Nepal*

Email: rajendra.ts2002@gmail.com

Abstract

The Cold atmospheric pressure plasma jet has become an attractive tool for many biomedical applications, such as disinfection, treatment of skin diseases, cancer treatment, root canal treatment, and bone tissue modification, wound healing and other medical applications. This article presents an atmospheric pressure plasma jet (APPJ) generated in argon gas with an applied voltage of 3.5 kV and operating at a frequency of 27 kHz. The basic plasma parameters of the plasma jet, that is, electron temperature and electron density were estimated from the analysis of optical emission spectra and the current - voltage wave form of plasma jet discharge. The plume temperature was measured by using laser gun thermometer, which is in the range $(21\text{-}28)^0$ C and it is suitable for treating animal body. Diabetes was induced by the administration of Alloxan monohydrate to the rat's body. The plasma was then introduced into the wound area with different exposure time and doses. The application of APPJ treatment on the diabetic wounds of animal models prevented the wound on getting into the chronic stage. Similarly, histological analysis of tissue from the diabetic wound was done and proliferation of cells was observed. Multiple 2 minutes treatment was seen much effective. It was concluded that suitable dose of APPJ could inactivate bacteria around the wound to aid the healing process. This healing effect may be related to the possible death of bacteria in the wound due to the presence of reactive oxygen and nitrogen species (ROS and RNS) in plasma jet.

Key words: atmospheric pressure plasma jet (APPJ), diabetes chronic wound, wound healing.

Efficacy Analysis of a Cross Field Cold Atmospheric Pressure Plasma Jet for Smear Layer Removal in Intra-radicular Dentin

Abhijit Mishra[1], Ankita Kapoor[2], Pravin Kumar[2] and Ram Prakash[1]

[1]Department of Physics, Indian Institute of Technology (IIT) Jodhpur, Karwar, Rajasthan, 342030
[2]Department of Dentistry, All India Institute of Medical Sciences (AIIMS), Jodhpur, Rajasthan

E-mail: abhijit.1@iitj.ac.in

Abstract

The goal of successful and sustainable restorative dentistry and endodontic therapy is the removal of diseased tissue, the eradication of bacteria from canals and dentinal tubules, and the prevention of recontamination post-treatment. These can be accomplished through 3-dimensional obturation; meticulous cleaning, shaping, and disinfection of the root canal system [1]. The chemo-mechanical preparation of the root canal, based on the appropriate use of instruments and irrigating solutions, is one of the most crucial steps during treatment. Mechanical instrumentation invariably creates a smear layer (SL) on the root canal walls that occludes the dentinal tubules and prevent optimal penetration of medicaments, sealers, and root-filling materials into the lateral canals and dentinal tubules [2]. Also, an infected SL containing bacteria and necrotic tissue is the main reason for the multiplication of those bacteria. There has been the use of a variety of chelating agents to remove the SL, but none of them meets the ideal criteria.

The present study is aimed to evaluate comparatively the effectiveness of Cold Atmospheric Plasma Jet (CAP-Jet), MTAD and EDTA in removing the SL in root canal dentin surfaces using Scanning Electron Microscope (SEM) images. The developed cross-field configured CAP-Jet is a double dielectric barrier discharge (DBD) system which generates a plasma jet of length up to 35 mm through a dielectric material tube having dielectric constant 4.6 in which a copper wire mounted by similar tube acts as the central power electrode and a thin copper material as the outer ring electrode. The central electrode was connected through a pulsed high-voltage power source, and the outer electrode was grounded. Helium was used as the working gas at atmospheric pressure. The plasma discharge was optimized at different combinations of input parameters like its applied voltage, frequency, average power consumption and gas flow rate. Chemo-mechanical preparation has been done with 84 teeth samples using 5.25% Sodium Hypochlorite during instrumentation. For final irrigation, the samples are exposed to normal saline (control), CAP-Jet, EDTA and MTAD for 2 minutes. The samples are then prepared for SEM evaluation according to the tissue fixation protocol. The efficacy of CAP Jet is determined from the SEM images. The developed CAP-Jet has shown significant SL reduction compared to the control group and was found as effective as EDTA and MTAD, which could be a promising technique for root canal treatment.

References:

[1] Clinical implications of the smear layer in endodontics: A review, Oral Surg Oral Med Oral Pathol Oral Radiol Endodontology, 94(6), 658–66 (2002)
[2] Smear layer and debris removal from dentinal tubules using different irrigation protocols: scanning electron microscopic evaluation, an in vitro study. *Evid.-based endod* **2**, 5 (2017)

Thermal Performance analysis Of Gate Valve Assembly With Cooling Provision for Safe Handling of Bio-Medical Waste Packets in Plasma Pyrolysis System

Atikkumar N. Mistry[a], Deepak Sharma[a], Paritosh Chaudhuri,[a,b], S.K. Nema[a,b],

[a]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat – 382428, India*
[b]*Homi Bhabha National Institute, Anushaktinagar, Mumbai - 400 094*

E-mail: atik@ipr.res.in

<u>*Abstract*</u>

Safe disposal of hazardous waste stream is of importance nowadays, as conventional techniques emit toxic bi-products which is harmful to the nature and human being. Plasma pyrolysis is proven as environment friendly technology for disposing different kind waste streams in compliance with emission norms set by Central Pollution Control Board, India (CPCB) [1] [2]. Facilitation Centre for Industrial Plasma Technologies (FCIPT), Institute for Plasma Research (IPR), Gandhinagar is developing Common Biomedical Waste Treatment Facility (CBWTF) using plasma pyrolysis process having capacity to dispose ~200 kg per hour bio-medical waste using patented graphite plasma torch technique. This system dispose yellow color bio-medical waste packets and is comprises of waste feeding chamber, primary chamber, secondary chamber, gas cleaning and cooling system, conveyor system, etc. The waste feeding chamber which serves the purpose to transfer yellow color bio-medical waste packets from conveyor system to primary chamber is assembly of waste feed line, gate valve assembly with cooling provision, normal temperature gate valves and waste feed manifold. Before feeding waste packets into the primary chamber, the primary chamber is preheated to high temperature range of nearly 800-1000 ^{o}C where bio-medical waste disintegrates into gaseous products. The generated gaseous products are further treated to meet emission norms set by CPCB, India before releasing them to environment. The operation to transfer waste packets from conveyor system to waste feed line and further to primary chamber is controlled by programmable gate valves. The gate valve assembly with cooing provision has to fulfill dual functions. First is to isolate high temperature primary chamber from waste feeding line and second is to maintain the waste feeding line temperature below 60 ^{o}C for safe handling of waste packets.

In this report, thermal performance of gate valve assembly with cooling provision, a part of waste feeding chamber, is discussed. This gate valve assembly faces high temperature and heat flux from primary chamber. Conjugate heat transfer analyses of gate valve assembly with cooling provision in connection with primary chamber has been performed and temperature distribution on gate valve assembly and cooling provision for gate close condition and open condition is estimated using CFD analysis in ANSYS CFX. The report discusses various analysis performed to support water cooled gate valve assembly concept.

References:

[1] S. Nema, K Ganeshprasad, “Plasma Pyrolysis of medical waste,” Current science 83(3), August 2002
[2] S.K Nema et al ”Plasma Pyrolysis Technology and its Evolution at FCIPT, Institute for Plasma Research, India”, IPR/TR-364

Design and Development of Plasma Activated Water setup and Optimization of Process Parameters and its Applications (Healthcare, Food Preservation, and Agriculture)

Vikas Rathore[1,3], Divyesh Patel[3], Shital Butani[3], Sudhir Kumar Nema[1,2]

1. *Institute for Plasma Research (IPR), Gandhinagar, Gujarat, 382428, India*
2. *Homi Bhabha National Institute, Training School Complex, Mumbai 400094, India*
3. *Institute of Pharmacy, Nirma University, Ahmedabad, Gujarat, 382481, India*

E-mail : vikas.rathore@ipr.res.in

Abstract

The present work discusses a cost-effective design and development of a plasma device that is used for the production of plasma-activated water (PAW). The process parameters to produced PAW are optimized using the design of experiment methodology and MATLAB fmincon solver [1]. The plasma-water interaction generates various reactive species in water (PAW) and this activated water has shown enormous potential to be used in various applications [2]. The present work discusses the use of PAW as a disinfection solution to inactive pathogenic microbes. The results clearly indicate the long-term effectiveness of PAW and it has been observed that stored PAW is able to inactivate pathogenic microbes with significantly low treatment time (~10 s) [3]. This inactivation efficacy of PAW enhances the shelf life of fruits and vegetables when they are treated with PAW. The present study shows PAW treatment enhances shelf life of *citrus limon* L. (lemon). The results showed PAW treatment with lemon spoilage fungi can achieve 6+ $\log_{10}$ CFU ml^{-1} reduction with a treatment time of 10 minutes and retain this fungi inactivation efficacy for the long term [4]. Moreover, the lemons washed with PAW showed lower weight loss, lesser spoilage, better texture, better sensory (smell, appearance, taste), and color (L, a, b) evaluation compared to the control. Therefore, PAW-washed lemons have better overall acceptability compared to control. Finally, agriculture and aquaculture applications of PAW are explored. The PAW-treated seeds have higher germination and plant growth and better agronomy traits compared to control [5]. Also, as a rich source of nitrogen, it can be used as a nitrogen replacement for various agriculture and aquaculture applications as shown by the results of pea plants and freshwater green chlorella algae. In conclusion, PAW has the affinity to be used in numerous applications such as healthcare, food preservation, agriculture, aquaculture, etc.

References :

[1] Design and development of dielectric barrier discharge setup to form plasma-activated water and optimization of process parameters, Eur. Phys. J. D, **76**, p 1-14, (2022)
[2] Optimization of process parameters to generate plasma activated water and study of physicochemical properties of plasma activated solutions at optimum condition, J. Appl. Phys., **129**, p 084901, (2021)

[3] Investigation of physicochemical properties of plasma activated water and its bactericidal efficacy, Plasma Chem. Plasma Process., **41,** p 871-902, (2021)
[4] Inactivation of Candida albicans and lemon (Citrus limon) spoilage fungi using plasma activated water, Plasma Chem. Plasma Process., **41**, p 1397-1414, (2021)
[5] Treatment of pea seeds with plasma activated water to enhance germination, plant growth, and plant composition. Plasma Chem. Plasma Process., **42**, p 109-129, (2022)

Plasma Treatment on Palpali Dhaka

Angash Niroula[1], Roshan Chalise[2], Raju Khanal[2]

[1]*Patan Multiple Campus, Department of Physics, Tribhuvan University, Lalitpur Nepal.*
[2]*Central Department of Physics, Tribhuvan University, Kathmandu Nepal.*

E-mail: angashn@gmail.com/ Angash.755511@pmc.edu.np

Abstract

In this study, Palpali Dhaka textile samples were subjected to Dielectric Barrier Discharge plasma treatment to study their surface wettability and absorbency. The textile was treated in the discharge by making small samples and the effects of plasma treatment on treated samples were examined by water contact angle measurement. It was found that air plasma treatment was successful in incorporating hydrophilic functional groups on the textile surface due to which absorbency immediately after the treatment were highly improved. Effects of plasma treatment already started to appear after few second of treatment. Treatment time are varied several second for different input voltages. The contact angles are found to be reduced significantly in all the three samples after the treatment.

Surface Modification of High Density Polyethylene (HDPE) Geomembranes using atmospheric pressure nonthermal air plasma

Vishal Jain [1], Nisha Chandwani[1], Royal Christian[2], S.K.Nema[1]

[1] Institute for Plasma Research, Bhat Village, Near Indira Bridge. Gandhinagar-382428
2 Central Institute for Petrochemicals Technology, Ahmedabad- 382445

E-mail: vishal@ipr.res.in

Abstract

An atmospheric pressure nonthermal air plasma system for the inline surface modification of HDPE (High Density Polyethylene) film has been developed by APD (Atmospheric Pressure Plasma Division) ,IPR and commissioned at CIPET(Central Institute for Plastic and Engineering), Ahmedabad. This system comprises of 6 pairs of cylindrical electrodes and generates uniform glow discharge plasma in the air medium over a length of 1.5 meter and gap of 1mm between the electrodes. In this activity, a multi-layer Geo-membrane using plasma treated HDPE film was developed to increase adhesion. In this report, a detailed characterization results are presented of surface morphology, surface chemistry and wettability etc.

Geo-membranes are thin and low permeability polymeric sheets which are used to control liquid or gas migration in any man-made structure such as pond etc. Geo-membranes are generally made up of multiple layers of polymeric materials using adhesives. The adhesion strength among these layers and problem of delamination are the key issues which needed to be addressed using plasma treatment in this project activity. The plasma surface modification of HDPE film induces nano-scale surface roughness and polar functional groups on the surfaces. This plasma modification increases the surface energy and hence, improves the adhesion strength among these layers. The SEM image clearly demonstrates the changes in surface morphology of the film after the plasma treatment. The FTIR spectra reveals formation of the polar functional groups like C=O and COO^- that are responsible for improving the surface energy. The water contact angle of the HDPE film is also found to be reduced from ~ 90° to ~50°. The detailed study on the effect of these surface modifications on the adhesion strength of the Geo-membranes is being carried out by CIPET, Ahmedabad using the inline plasma treatment system developed by IPR.

Effect of Oxygen Plasma Treatment on Silk Fabrics for Enhancing Dyeing and Coating Properties

Bornali Sarma[1], K Vinisha Rani[2], Ramnaresh Kumar[1] and D N Gupta[1]

[1]Department of Physics & Astrophysics, University of Delhi, North Campus, University Road, New Delhi-110007
[2]Division of Physics, School of Advanced Sciences (SAS), VIT Chennai, Vandalur - Kelambakkam Road, Chennai-127, Tamil Nadu

.

E-mail : drbornalisarma@gmail.com
bornali_s2000@physics.du.ac.in

Abstract

In this work, two different silk fabrics such as raw silk (R silk) and degummed silk (D silk) are treated by low-pressure glow discharge plasma to improve hydrophilic properties for better dye ability and coatings process. Oxygen is used as a plasma forming gas. Oxygen plasma can produce etching and formation of polar functional groups on the surface of the fabrics. The plasma conditions like voltage and working pressure are maintained constant with different exposure times. The plasma exposed fabrics are characterized by XRD, SEM, AFM, XPS and adsorption test. SEM reveals that the changes in the surface of the fabrics are prominent for higher treatment time. AFM result confirms that the surface roughness is increased due to the plasma treatment. According to the results of XPS, the oxygen containing functional groups are increased after plasma treatment. Adsorption test indicates that plasma treated fabrics are more hydrophilic than untreated silk. Graphene oxide drop test is performed on fabric surface which shows the enhanced adhesion property of the coatings.

Cold Atmospheric Helium Plasma Jet Triggering Self-assembly of Amino Acids Enantiomers into Supramolecular Structures

Deepjyoti Basumatary, Kamatchi Sankaranarayanan*

Physical Sciences Division, Institute of Advanced Study in Science and Technology, (An Autonomous Institute Under DST, Govt. of India), Vigyan Path, Paschim Boragaon, Garchuk, Guwahati, Assam 781035, India.

E-mail: deepbstary@iasst.res.in, kamatchis@iasst.gov.in

Abstract

Amino acids are the building blocks for the synthesis of various peptides and proteins that regulate various key metabolic pathways. Aromatic amino acids are crucial hot spots for the acceleration of the several neurodegenerative diseases and amyloidosis due to overproduction of reactive oxygen species (ROS) and reactive nitrogen species (RNS) in the cells due to oxidative stress. To understand these molecular assemblies of amino acids fundamentally, *in vitro* assessments are much required. In this work, we have demonstrated the cold atmospheric plasma (CAP) aiding in the self-assembly process of aromatic amino acids: phenylalanine and tryptophan enantiomers into supramolecular structures with increase in plasma treatment time. The enantiomers of phenylalanine and tryptophan forms ordered supramolecular structures as substantiated by CLSM, SEM and TEM analysis. We have also analysed the modifications occurring in the amino acids after plasma treatment through fluorescence, FTIR spectroscopy and mass spectra studies. Furthermore, we have quantified the various ROS and RNS generated by the plasma source. These analysis and studies of self-assembly of phenylalanine and tryptophan due to ROS and RNS interactions will help us to explore new ways to mimic, create and design natural self-assembled functional biomaterials using CAP.

Microwave Miniaturized Multiband Absorber for Terahertz Application

Ritu Roumya Samal, Kajal Parashar, S.K.S. Parashar

Nanosensor Lab, School of Applied Sciences, Kalinga Institute of Industrial Technology, Deemed to be University, Bhubaneswar-751024, Odisha, India

sksparasharfpy@kiit.ac.in

Abstract

The absorbers are intended to operate at multiple bands in order to fulfill the miniaturization and compactness requirements of portable communication systems. Terahertz range absorbers are designed to perform at four resonating frequencies to accommodate high frequency applications. The simulated antenna is embedded with the substrate material of Gallium Arsenide (lossy) and it is grounded with the conducting material of gold with thickness of 0.2 µm. The substrate is fabricated with 7 slits of gold material of 0.2 µm thickness of different dimensions. The paper presents a design of an absorber with dimension of $100 \times 100 \times 6$ μm^3 resonating at the range of 0-5 THz. The absorber is analyzed to be resonating at -15.62 dB, -10.237 dB, -13.379 dB, and -19.824 dB at the frequency of 2.6822 THz, 2.8636 THz, 3.6171 THz, and 4.3972 THz respectively. The absorption is calculated to be around 100% for the same design of absorber. The parametric optimization is also done to optimize the best result of the simulated absorber to work in 0-5 THz range.

References:

[1] Design of an isolation improved MIMO antenna using metasurface based absorber for wireless applications. *Optik*, *259*, 168963, (2022).
[2] Design of metasurface absorber for low RCS and high isolation MIMO antenna for radio location & navigation. *AEU-International Journal of Electronics and Communications*, *133*, p.153680, (2021).

Morphological and Plasmonic Properties of Silver Nanostructures Fabricated using Hot and Dense Plasma

Bilasini D Naorem[1], Onkar Mangla[2] and Savita Roy[2]

[1] *Physics Department, Miranda House, University of Delhi, Delhi 110 007, India*
[2] *Physics Department, Daulat Ram College, University of Delhi, Delhi 110 007, India*

E-mail : Bilasini.devi@mirandahouse.ac.in

Abstract

The collective oscillation of conduction electrons of nanostructures of certain metals such as gold, silver etc. exhibit surface plasmon resonance (SPR) in the visible region. Silver nanostructures have high compatibility with living cells. Additionally, the spectral position of the resonance gets influenced by the size, shape, interparticle distance and dielectric properties of the nanostructures. These properties of the nanostructures offer an interesting area of research and has wide range of applications in biomarkers for Alzheimer's disease [1], diagnostics and therapy of cancer [2].

We present fabrication of silver nanostructures on glass using silver ions produced on top of the silver fitted anode by hot, dense and extremely non-equilibrium argon plasma such as found in dense plasma focus device. Focused plasma formed in one DPF shot was used to generate high fluence and energetic silver ions above the silver fitted central anode of the electrode arrangement. These ions subsequently lose their energies resulting in silver nanostructures on the substrates placed at 5.0 cm from the top of anode. SEM images show uniform nanostructures consisting of nanodots and nanocapsules. The absorption spectrum of silver nanostructures has SPR peak at 426 nm. X-ray diffraction shows the crystalline nature of the nanostructures.

References:

[1] A.J. Haes, W.P. Hall, L. Chang, W.L. Klein and R.P. Van Duyne, Nano Lett. **4** p 1029 (2004)
[2] P.K. Jain, I.H. El-Sayed and M.A. El-Sayed, Nano Today **2** p 18 (2007).

Atmospheric Plasma Spray Coated NiFe For Electrocatalytic Oxygen Evolution Reaction

N. Bharani L. Kumaresan and G. Shanmugavelayutham

Department of physics, Bharathiar University, Coimbatore-641046

E-mail : sgsvelu@buc.edu.in

Abstract

Water splitting as an advanced energy conversion technology driven by sustainable energy is attracting ever-increasing attention for clean hydrogen fuel generation from water. Two fundamental reaction, hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) are involved. Developing and designing high-performance and stable NiFe electrodes for efficient fuel production are the greatest challenges in electrochemical water splitting. In this work, NiFe deposited on stainless steel substrate by using atmospheric Plasma spray coating in different molar ratios of Ni/Fe. Prepared samples were characterized by X-Ray diffraction (XRD) to study the Crystal structure. Morphology and Elemental composition were analsed by Scanning electron microscope (SEM). Further coated samples tested with cyclic voltammetry using three electrode system and it exhibited better electrocatalytic activity for Oxygen evolution reaction (OER) reaction.

References :

[1] Dongze Li, Hui Liu and Ligang Feng Energy Fuels 2020, 34, 11, 13491–13522

[2] Yazid Messaoudi, Hamza Belhadj, Mohamed R. Khelladi and Amor Azizi RSC Adv., 2022, 12, 29143

[3] Sankaran Sivakumar, Subramaniam Yugeswaran, Kalimuthu Vijaya Sankar, Lakshmanan Kumaresan, Gurusamy Shanmugavelayutham, Yoed Tsur, Jianguo Zhu Journal of Power Sources, Volume - 473, 228526

APPLICATION DRIVEN DEVELOPMENT OF RF-ATMOSPHERIC PRESSURE COLD PLASMA JET: ANALYSIS OF PLASMA BY OPTICAL EMISSION SPECTROSCOPY

Vishakha Bende[1*], Rajib Kar[1, 2], Vandan Nagar[1, 3], Vanita Sekar[2], Namita Maiti[1, 2]

[1]*Homi Bhabha National Institute, Mumbai-400094,*
[2]*Laser & Plasma Technology Division, Bhabha Atomic Research Centre, Mumbai-400085*
[3]*Food Technology Division, Bhabha Atomic Research Centre, Mumbai 400085,*

[*]E-mail: vishakha@barc.gov.in

Abstract

Cold Atmospheric Pressure Plasma (CAPP) has rapidly evolved as a technology for several applications from material processing to medical industries owing to its low temperature and generation of chemical and bioactive radicals like reactive oxygen species (ROS) & reactive nitrogen species (RNS) [1]. In this study we have indigenously designed and developed a simple and user-friendly radio frequency (10 MHz) atmospheric pressure plasma jet (RF-APPJ) device. The device is built in coaxial geometry. A tesla coil has been used as a part of inner/powered electrode with a grounded Teflon outer covering. With this RF-APPJ, we investigated the use of RF-APPJ device in the inactivation of two type of bacteria gram positive (S. aureus) and gram negative bacteria (E. coli) and candida fungus. A parallel study was also conducted using the RF-APPJ device for plasma based chemical etching. For both the application argon (Ar) was used as plasma forming gas. In the first application, bacteria were cultivated in agar plate. After the treatment the plate were incubated for 24 hrs. The colony formed was counted and it was observed that RF-APPJ device proven to be beneficial plasma source for successfully decreasing no. of colonies and bacteria suffer damage due to reactive species generated in plasma. It has also been seen that as the treatment time reduced from 30 sec to 10, 5, and 2 sec almost eliminate the effect of plasma on bacteria. Role of various reactive species generated in plasma for inactivation process has been outlines by optical emission spectroscopy (OES). Subsequently, in the second application CF_4 was mixed into the Ar plasma to etch and plasma was characterized by OES. As soon as CF_4 was mixed into the Ar plasma, color of plasma turned greenish. Analysis of plasma emission indicated presence of C_2 swan band at 516.5 nm which is thought to be the reason for this color [2]. Emission of F_2 was measured by a detector and Fe atomic emission line was observed in OES due to erosion of stainless-steel electrode which occurs due to effect of F_2 in plasma.

References:

[1] Cold Plasma: Clean Technology to Destroy Pathogenic Micro-organisms, Transactions of the Indian National Academy of Engineering volume **5**, 327–33, (2020)
[2] Feasibility of using non-thermal microwave plasma for nuclear waste management: A detailed study backed by plasma spectroscopy, Environmental Technology & Innovation **12**, 219-229, 2018.

Plasma Activated Water For Inhibition Of SARS-COV-2 virus

Sidharth and Shail Pandey

Department of Physics, Sardar Vallabhbhai National Institute of Technology Surat, Surat – 395007, India

E-mail : sp@phy.svnit.ac.in

Abstract

Plasma is regarded as the fourth state of matter that contains energetic electrons, free radicals, reactive oxygen and nitrogen species (RONS) as well as UV radiation and photons. In particular, Plasma Activated Water (PAW) has found to be effective against bacteria, viruses and fungi, making it suitable for various biomedical applications [1] including sterlization. The biochemical activity of PAW is mainly determined by the RONS of plasma. These species react with the deionized water subsequently altering its pH value [2]. There are some articles that suggest that a suitable combination of pH and temperature of PAW are effective in inactivation of viruses having S protein like SARS-COV-2 [3, 4, 5]. During our review on the viral deactivation property of PAW, role of pH and temperature has been established and it is realized that a control over these parameters is desirable to extend its application in inactivation of such viruses.

The present work is an investigation of relative RONS concentration in a microplasma source with planar geometry [6]. The focus is on studying the concentration of RONS generated in the microplasma as a function of input parameters like DC bias, gas pressure and gas flow rate. The plasma will then be placed in contact with a water medium and transport of the plasma species in the water medium as a function of input voltage and water temperature will be discussed.

References:

[1] N. K. Kaushik, B. Ghimire, Y. Li, M. Adhikari, M. Veerana, N. Kaushik, N. Jha, B. Adhikari, S. Lee, K. Masur, T. Woedtke, K. Weltmann and E. Choi, Biol Chem. **400**, 39 (2018).
[2] P. Lukes, E. Dolezalova, I. Sisrova and M. Clupek, Plasma Sources Sci. Technol. **23**, 015019 (2014).
[3] N. Kaushik, P. Bhartiya, N. Kaushik, Y. Shin, L. N. Nguyen, J. S. Park, D. Kim, E. H. Choi, Bioactive Materials **19**, 569 (2023).
[4] O. D. Cortázar, Sci. Rep. **12**, 263 (2022).
[5] L. Guo, Z. Yao, L. Yang, H. Zhang, Y. Qi, L. Gou, W. Xi, D. Liu, L. Zhang, Y. Cheng, X. Wang, M. Rong, H. Chen, M. G. Kong, Chem. Eng. J. **421**, 127742 (2021).
[6] L. Guo, R. Xu, L. Gou, Z. Liu, Y. Zhao, D. Liu, L. Zhang, H. Chen, M. G. Kon, Appl. Environ. Microbiol. **84**, e00726 (2018).

DBD PLASMA BASED FAR UV-C EXCIMER LIGHT SOURCE: A NEW PARADIGM FOR SAFE USE OF UV LIGHT

Kiran Ahlawat*, Ramavtar Jangra, Vigyan Gadodia, Ram Prakash

Department of Physics, Indian Institute of Technology Jodhpur, N.H. 62, Nagaur Road, Karwar, Jodhpur, Rajasthan, 342037

*E-mail: ahlawat.1@iitj.ac.in

Abstract

Microbial infections spread by the air, such as influenza, tuberculosis, and Covid-19 are serious public health concerns. Inactivation of airborne pathogens is a direct approach to preventing airborne transmission, and the airborne antimicrobial potential of ultraviolet light (UV) has long been established. However, since conventional UV-C light sources are both carcinogenic and cataract genic, their widespread use in public seating is limited [1]. Some studies have previously demonstrated that there is a wavelength range, specifically between 207 and 222 nm, termed Far UV-C, that is as effective against germs as traditional germicidal lamps producing at 254 nm without the danger of skin harm [2]. This is due to the fact far-UV-C light cannot permeate even the outer (non-living) layers of human skin or eye due to its great absorbance in biological materials (i.e., because bacteria and viruses are micrometer or smaller in size, far-UVC can enter and inactivate them easily) [3].

To contribute to the solution of microbial infections, we have developed a high-efficiency Far UV-C source that emits the peak wavelength at 222 nm. The concept of Dielectric barrier discharge (DBD) has been utilized for producing plasma-based sources of Ultraviolet (UV) radiation which is an excimer light source. An optimized mixture of krypton with a very small fraction of chlorine has been used as the carrier gas. Co-axial quartz tubes with a gas gap of 1.5 mm between both tubes has been used to fill the gas mixture. Two electrodes are synergistically used to produce the cold plasma discharge in the source. The device optimization has been carried out for high-efficiency Far UV-C light source including gas pressure. A narrow band spectrum peaking at 222 nm has been reported through the optical emission spectroscopy studies. The absolute measurement of the UV radiation intensity has been performed by using a calibrated UV power meter at 222 nm. The found intensity in the developed sources is superior and has many added advantages. It is expected that these excimer sources will have many advantages over conventional UV light sources and will be safe for the environment and health. The results of these efforts will be presented.

References:

[1] D. Sliney, *Balancing the risk of eye irritation from UV-C with infection from bioaerosols*, *Photochem. Photobiol.* **89**, (2013) 770.

[2] J. Cadet, *Harmless Effects of Sterilizing 222-nm far-UV Radiation on Mouse Skin and Eye Tissues*, *Photochem. Photobiol.* **96**, (2020) 949.

[3] M. Buonanno, D. Welch, I. Shuryak and D. J. Brenner, *Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses*, *Sci. Rep.* **10**, (2020) 1.

Laser Plasma

Third Harmonic Generation by Nonlinear Interaction of Gaussian Laser Beam with an Array of Magnetized Anharmonic Carbon Nanotubes

Shivani Vij

Department of Applied Sciences,
DAV Institute of Engineering & Technology, Jalandhar-144008, India

*Email: svij25@yahoo.co.in

Abstract

Third harmonic generation in the nonlinear interaction of a modulated laser beam with an array of vertically aligned carbon nanotubes (CNTs) is studied. An electrostatic force of intense ultra-short laser pulse displaces the electrons of CNTs. Due to the nano-scaled dimensions of CNTs, this displacement is comparable to the radius of their electrons and hence the restoring force experienced by the electrons becomes nonlinear function of the displacement. As a result, the large resonance absorption of the laser by the electrons of CNTs occurs and plasmon resonance is broadened. The power conversion efficiency of harmonic generation increases significantly due to the anharmonicity of CNTs. The effect of an externally applied magnetic field is to significantly enhance the amplitude of the generated third harmonic.

Key Words: Third Harmonic Generation, CNTs, Anharmonicity

Sheet current generation in short pulse laser interaction with a linear array of gold nanorods

Names of the author: Nivedya Krishnan[1], Ashok Kumar[1], Gagan Kumar[2]

Affiliation: [1]Amity Institute Of Applied Sciences, Amity University, Noida-201301
[2]Indian Institute Of Technology Guwahati, Guwahati, Assam- 781039

E-mail: nivedyakrishnan97@gmail.com

Abstract

We investigate the guided particle acceleration scheme on a sheet of four gold nanorods placed parallel to each other, irradiated by high intensity laser pulse as a precursor to produce neutral atoms. It has been demonstrated that parallel gold nanorods with deuterium nanoparticles dispersed between can guide the acceleration [1-2] of nanoparticles. Using the ponderomotive force, high state ionization of gold atoms expels the free electrons [3]. The charged nanorod possess electric field that is axially outward and transversely oriented towards the axis of symmetry [4]. The nanoparticles are therefore restricted transversely and accelerated axially. By using this method, a deuterium beam with a few MeV of energy can be created. The beam can be neutralized, and a beam of neutral atoms can be generated.

References :

[1] J. W. Wang *et al.*, "Generation of quasi-monoenergetic carbon ions accelerated parallel to the plane of a sandwich target," *Physics of Plasmas*, vol. 21, no. 12, p. 123103, Dec. 2014, doi: 10.1063/1.4903327.

[2] S. N. Chen *et al.*, "Focusing Dynamics of High-Energy Density, Laser-Driven Ion Beams," *Phys. Rev. Lett.*, vol. 108, no. 5, p. 055001, Jan. 2012, doi: 10.1103/physrevlett.108.055001.

[3] M. Murakami and K. Mima, "Efficient generation of quasimonoenergetic ions by Coulomb explosions of optimized nanostructured clusters," *Physics of Plasmas*, vol. 16, no. 10, p. 103108, Oct. 2009, doi: 10.1063/1.3256183.

[4] M. Yadav, A. Kumar, and S. Mandal, "Guided acceleration of nanoparticles by laser irradiated parallel gold nanorods," *Plasma Research Express*, vol. 3, no. 4, p. 045005, Dec. 2021, doi: 10.1088/2516-1067/AC3FA3

INFLUENCE OF SELF-FOCUSED HIGH-POWER BEAM ON SECOND HARMONIC GENERATION IN QUANTUM PLASMA

Taranjot Singh and Keshav Walia

Department of Physics, DAV University Jalandhar, Punjab(India)-144012

Email: taranjotsingh64@gmail.com
keshavwalia86@gmail.com

In the present work, the influence of self-focused high power beam on second harmonic generation (SHG) in quantum plasma is investigated in detail. The relativistic and ponderomotive nonlinearities are taken together in present investigation. There is production of density gradients in plasma on account of combined action of relativistic and ponderomotive nonlinearities. When electric vector of laser beam is parallel to density gradients established in plasma, then electron plasma wave(EPW) at the frequency of input beam is produced. Further, the nonlinear coupling between input beam and EPW wave produces 2nd harmonics. The nonlinear differential equation for the beam width of input beam and expression for second harmonic yield(SHY) are derived by making use of WKB and paraxial theory approach. The effect of laser-plasma parameters, quantum contribution and combined action of relativistic and ponderomotive nonlinearities on focusing ability of input beam and SHY are investigated in detail.

Keywords: Second Harmonic Generation, Quantum Plasma, High power beam, Input beam, Density Gradients, Electron Plasma Wave

Interaction of Laser with GaAs Structure for Terahertz Radiation Generation

Sandeep[a,b*] **and Hitendra K. Malik**[a]

[a]Plasma Science and Technology Laboratory, Indian Institute of Technology Delhi, New Delhi – 110 016, India
[a]Department of Physics, Deen Dayal Upadhyaya College, University of Delhi, New Delhi - 110078, India

[*]**Corresponding author's email:** sandeepamrit@gmail.com; sandeep@ddu.du.ac.in

Abstract

Terahertz (THz) radiations known as submillimeter waves find applications in various fields such as communication, medical science, spectroscopy, material characterization and remote sensing in view of their low-energy photons. These radiations have been produced by various schemes viz. optical rectification, Cherenkov radiation, photoconductive emitters, laser-plasma interaction, semiconductor antennae, etc. [1, 2]. However, it has been difficult to simultaneously manage its intensity, focus, and frequency tuning.

In the current work, a method for producing THz radiation using a laser-induced transient current in an array of GaAs structures is proposed, which functions as phase array dipole antennae. The THz radiation is produced by the current flowing down the length of these devices. With a maximum output of 0.013 nW at a frequency of about 1 THz, it is simple to emit THz radiation pulses that climb quickly and descend slowly. The transient current density attained through electron-hole pair production determines the radiated power. The proposed GaAs periodic array allows us to have the THz profile in the frequency domain and realize the function of arrays and size of GaAs structure, making the produced radiation ideal for its THz Time Domain Spectroscopic applications. The greatest emitted THz power is attained in particular directions, which are discussed in detail.

References:

[1] Malik HK. Laser-Matter Interaction for Radiation and Energy. CRC Press; Ist Ed., 2021.
[2] Yardimci, N. T., Yang, S. H., Berry, C. W. & Jarrahi, M. High-power terahertz generation using large-area plasmonic photoconductive emitters. IEEE Trans. Terahertz Sci. Technol. **5**, 223–229 (2015).

DYNAMICS OF HETEROGENEOUS COLLIDING LASER-PRODUCED PLASMAS

Shilpa S.[1], and Pramod Gopinath[1,2]

[1]International School of Photonic and [2]Inter University Centre for Nanomaterials and Devices
Cochin University of Science and Technology, Kochi 682022, India.

E-mail : *pramod@cusat.ac.in*.

Abstract

The propagation dynamics of aluminium-copper colliding plasma plumes are studied by using time-gated fast imaging and optical emission spectroscopic techniques. The experiment is performed at 10^{-2} mbar of air ambient. Colliding laser produced plasmas are significant over the conventional laser-produced plasmas because of its additional possibilities of engineering the collision dynamics externally**.** Angular target geometry is employed for the efficient collision of two different laser produced plasmas. When two plasmas collide, it can either stagnate at the collision front or can interpenetrate each other. The dense layer of plasma stagnates at the interaction region called the stagnation layer. Multi species stagnation region is formed at the collision front of heterogeneous colliding laser produced plasma and its time-resolved expansion dynamics are analyzed. The emission intensities are different for the two materials. For a particular laser wavelength, the two metal targets have different thermal and optical properties and thereby different ablation rates. Al with less ablation threshold has more intense emission compare to that of Cu. Plasma parameters like electron density and electron temperature are also measured from the spectroscopic data.

References :

[1] P.K. Pandey, R.K. Thareja, J.T. Costello, Heterogeneous (Cu-Ti) colliding plasma dynamics, Phys. Plasmas. 23 (2016). https://doi.org/10.1063/1.4964728.

[2] S. Shilpa, P. Gopinath, Shock front interaction and dynamics of laterally colliding laser-produced plasmas, Vacuum. 198 (2022) 110872. https://doi.org/10.1016/j.vacuum.2022.110872.

Third Harmonic Generation by Nonlinear Interaction of Gaussian Laser Beam with an Array of Magnetized Anharmonic Carbon Nanotubes

Shivani Vij

Department of Applied Sciences,
DAV Institute of Engineering & Technology, Jalandhar-144008, India

*Email: svij25@yahoo.co.in

Abstract

Third harmonic generation in the nonlinear interaction of a modulated laser beam with an array of vertically aligned carbon nanotubes (CNTs) is studied. An electrostatic force of intense ultra-short laser pulse displaces the electrons of CNTs. Due to the nano-scaled dimensions of CNTs, this displacement is comparable to the radius of their electrons and hence the restoring force experienced by the electrons becomes nonlinear function of the displacement. As a result, the large resonance absorption of the laser by the electrons of CNTs occurs and plasmon resonance is broadened. The power conversion efficiency of harmonic generation increases significantly due to the anharmonicity of CNTs. The effect of an externally applied magnetic field is to significantly enhance the amplitude of the generated third harmonic.

Key Words: Third Harmonic Generation, CNTs, Anharmonicity

Generation of the Strong Terahertz Field by Relativistic Cosh-Gaussian Laser Beam in Ripple Density Magnetized Plasma

Gunjan Purohit
Laser Plasma Computational Laboratory, Department of Physics, DAV Post Graduate College, Dehradun, Uttarakhand-248001, India
E-mail: gunjan75@gmail.com

Abstract

This paper presents a scheme for the generation of terahertz (THz) field by self-focusing of a cosh-Gaussian laser beam in the magnetized and rippled density plasma, when relativistic nonlinearity is operative. Relativistic self-focusing occurs when an ultra-intense high power short pulse laser beam interacts with a plasma and the quivering motion of electrons modifies the refractive index of the plasma. The strong coupling between self-focused cosh-Gaussian laser beam and the pre-existing density ripple produces nonlinear current that generates the THz field under suitable phase matching conditions. Expressions for the beamwidth parameter of cosh-Gaussian laser beam and the electric vector of the THz field have been obtained using higher-order paraxial theory and solved numerically. The self-focusing of the cosh-Gaussian laser beam and its effect on the generated THz amplitude have been studied for specific laser and plasma parameters. Numerical study has been performed on various values of the decentered parameter, incident laser intensity, magnetic field, and relative density. The results have also been compared with the paraxial region as well as the Gaussian profile of laser beam. Numerical results suggest that the self-focusing of the cosh-Gaussian laser beam and the amplitude of THz field increase in the higher-order paraxial region compared to the paraxial region. It is also observed that the focusing of the cosh-Gaussian laser beam in the magnetized plasma and the amplitude of the THz field increases at higher values of the decentered parameter.

Key Words: Cosh-Gaussian laser beam, Magnetized plasma, Relativistic nonlinearity, Self-focusing, Terahertz radiation

Establishing The Violation of Volkov Solutions in Strong Field Quantum Electrodynamics Regime of Intense Laser Magnetized Plasma Interaction.

B.S. Sharma[1], **R.C. Dhabhai**[2], **Garima Yadav**[3], **and Gopal Saini**[4]

[1,3,4]Department of Physics, Lords University, Alwar-301020, India.

[2] Department of Physics, Govt. College Kota-324001, India.

E-mail: bssharma@lordsuni.edu.in

Abstract. In this paper, we have established new dynamics of relativistic electrons in terms of the solutions of the Dirac equation when an ultra-intense laser pulse of intensity $\geq 10^{23}$W cm^{-2} propagates through a dense plasma in the presence of a strong external azimuthal magnetic field $\approx$ 1MG. The interaction dynamics is analyzed near the strong-field quantum electrodynamics (SF-QED) regime. The most important prediction of our new solutions includes the effects of renormalized mass of the electron and a non-zero effective mass of the accelerated photon. We provide a general method for constructing exact solutions of Dirac equations that correctly explain the dynamics of electrons in the magnetized plasma medium instead of a vacuum. The modified new solutions of the Dirac equation for a single electron are obtained, which are pretty distinct as they have obtained a set of new solutions compared to the Volkov solutions in a vacuum. Our new solutions of Dirac equation can be used as a basis for a feasible explanation of quantum attributes of an accelerated relativistic electron in a strong electromagnetic field of very short ultra-intense laser pulses of intensity 10^{23}W cm^{-2}, an intensity much less than Schwinger field intensity. The new results could better understand the theory of quantum radiation reaction for the next-generation laser- plasma accelerator.

References:

[1] Ultra-high intensity 300TW laser at 0.1Hz repetition rate, *Opt. Exp.* **16**, 2109-2114 (2008).
[2] On Gauge invariance and vacuum polarization *Phys. Rev.* **82**, 664-679 (1951).
[3] Extremely high-intensity laser interaction with fundamental quantum systems *Rev. Mod. Phy,.* **84**, 1177-1228 (2012).
[4] Quantum limitations to the coherent emission of accelerated charges, *Phys. Rev. Lett.* **121**, 010402- 010402-6 (2018).
[5] Radiation reaction in electron-beam interactions with high-intensity lasers, *Rev. Mod.*

Plasma Phys. **4**, 1-37 (2020).
[6] On a class of solutions to Dirac's equation, *Z.Physik* **94**, 250-260 (1935).
[7] On the solution of the Dirac equation in the field of two beams of electromagnetic radiation
Z.Physzik **200**, 13-19 (1967).
[8] Radiation reaction as an energy enhancement mechanism for laser irradiated electrons in a strong plasma magnetic field, *Nature* **9**, 17181-17192 (2019).

Increase in cluster size along the flow direction in supersonic expansion.

Milaan Patel[1, 2], Jinto Thomas[1, 2], Hem Joshi[1, 2]

[1]*Institute for Plasma Research, Near Bhat, Gandhinagar 382428, India*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India*
E-mail: milaan.patel@ipr.res.in

Abstract

Cluster formation in the supersonic free expansion is a fundamental way to generate isolated molecules of particular species for laser fusion experiments, molecular spectroscopy and collision studies. Clusters are formed when free expanding jet undergoes isentropic cooling along the axis and temperature of the gas reaches below condensation the limit. The gas molecules get coagulated due to weak nuclear force and form clusters. Size of the cluster ranges from 10^2 to 10^5 molecules depending on the conditions of jet (mainly temperature and density). Due to small size of the cluster, accurate prediction of their size is relatively difficult and the reported size differs by at least an order of magnitude under the same experimental conditions. The well-known Hagena parameter [1] and its modified version [2] are simple empirical relations used to predict the cluster size for a particular nozzle operating at a known reservoir density and temperature. It has been reported that the size of cluster increases with the density of the gas jet according to power law $P_0^{2.5 - 4.0}$. Recently it has been observed that the cluster also grows along the axis up to few nozzle diameters [3]. This axial growth rate can be the reason behind the errors in different experiments as the axial distance for size measurements is typically chosen randomly based on convenience.

In this work we present precise measurements of cluster size along the jet axis. Measurements are carried out with Rayleigh scattering up to an axial distance of 30 nozzle diameters for argon and we observe that clusters continue to grow beyond few exit diameters. Rayleigh scattering is extremely suitable as it is a non-intrusive diagnostic technique and is accurate in determining size of the cluster provided initial calibration is accurate. The only limitation with it is that accuracy drops for density below 10^{22} molecules/cu.m due to poor signal to noise ratio. In our experiments we use pulsed nanosecond Nd-YAG laser with ICCD camera to image spatial distribution of the scattering signal. We improved our density detection limit to 10^{20} molecules/cu.m by reducing the background. This enabled us to calibrate the detectors using neutral argon gas for which the size is known. This significantly improves the accuracy in the measurement of the size of the cluster. Due to increased sensitivity we were able to measure the cluster size up to 30 mm for the nozzle of 1 mm even for room temperature jets with nozzle pressure of 1 bar. With this we observe axial growth of cluster size assuming constant liquid-mass fraction taken as 0.15 (theoretical value).

References :

[1] O. F. Hagena, W. Obert, Journal of Chemical Physics 56, 1793–1802 (1972).

[2] Y. Tao, et. al., Journal of Applied Physics 119, 16490104 (2016).
[3] Lee. et. al., Scientific Reports 10, 1297307 (2020).

Laser-Driven Proton Acceleration From Nano-Structured Foils

Jubaraj Choudhury, Ankita Bhagawati and Nilakshi Das

Tezpur University, Tezpur, Assam, 784028

E-mail: jubarajchoudhury@gmail.com

Abstract

Laser-driven acceleration of ions has become an active area of research because of its ability to provide us with desired quality of ion beams suitable for numerous practical applications [1]. In this work, an effort has been made to generate high energetic proton beam with low energy spread using PIC simulation. An advanced target geometry comprising of a planar plastic foil embedded with nanostructures on the laser irradiated side is used [2, 3]. Using suitable laser and target parameters, we intend to understand the effect of addition of nanostructures on the foil and hence try to control the quality of the accelerated protons [4]. A stronger electron heating is observed in the nanostructured target in comparison with plain foil targets which is an essential component of laser to proton energy conversion. The maximum proton energy is found to increase up to around 250% in nanostructured targets in comparison to flat foil targets.

References:

[1] Review of laser-driven ion sources and their applications, Reports on progress in physics **75**(5), p 056401, (2012).
[2] Modelling the interaction of an ultra-high intensity laser pulse with an ultra-thin nanostructured foil target, Plasma Physics and Controlled Fusion **62**(9), p 095014, (2020).
[3] Short pulse laser interaction with micro-structured targets: simulations of laser absorption and ion acceleration, New journal of physics **13**(5), p053028, (2011).
[4] Ultra-intense laser interaction with nanostructured near-critical plasmas, Scientific reports **8**(1), p 1-10, (2018).

Terahertz radiation generation by q-Gaussian Lasers in a plasma with density ripple

Dipender Singh, Harjit Singh Ghotra

Department of Physics, Lovely Professional University, G. T. Road, Phagwara- 144411, Punjab, India

E-mail: inder8@yahoo.in

Abstract

A theoretical model to produce THz generation by nonlinear mixing of two nonlinear q-Gaussian beams having frequency difference in ripple density plasma is proposed. Beating two lasers of same mode incident on plasma gives rise to nonlinear ponderomotive force induced electrons drift which couples with density ripple to produce nonlinear current. These current drives the resonant THz radiation at beat frequency. Density ripple provides proper phase matching and enhances the THz generation efficiency

Analytical formalism presented for terahertz (THz) generation by beating two lasers in a density hill plasma [1]. It appeared that the plasma density and oscillatory velocity combine resulting in a nonlinear current and driving a THz radiation at the beat frequency. Kumar and Tripathi explored that the THz amplitude increases with a ripple orientation angle on the influence of a density ripple at an angle in plasma for the THz generation via nonlinear mixing {2}.

Our investigation is around the generation of THz via nonlinear mixing of q-Gaussian laser beams in ripple density plasma.

References:

[1] Terahertz radiation generation by nonlinear mixing of two lasers in a plasma with density hill, Phys. Plasmas, **24**, p 033104, (2017).
[2] Resonant terahertz generation by optical mixing of two laser pulses in rippled density plasma, IEEE Journal of Quantum Electronics, **48**, p 8, (2012).

Simulation Studies On Longitudinal Wakefield Generation Using Arbitrarily Polarized Two-Color Laser Pulses In Homogeneous Plasma

Dinkar Mishra and Bhupesh Kumar

Department of Physics, University of Lucknow, Uttar Pradesh - 226007

E-mail: dinkarmishra.edu@gmail.com

Abstract

The interaction of high-intensity short laser pulses with preformed homogeneous plasma gives rise to the generation of strong longitudinal wakefields. The present study is based on 3-D PIC simulation using VSim to simulate the interaction of two-color laser pulses with homogeneous plasma. One of the laser pulses propagates along the x-axis and polarized along the y-direction whereas the second laser pulse propagates along the x-direction however it is polarized at an angle θ with respect to the polarization of the first laser pulse. The frequency difference between the two laser pulses is equal to the plasma frequency. It is observed that the amplitude and acceleration gradient of the generated longitudinal wakefields oscillating at plasma frequency varies with the polarization state of the two laser pulses. Simulation is conducted at various angles such as 0^0, 30^0, 45^0, 90^0 and 180^0 to study the effect of polarization angle on the generation of longitudinal wakefield and acceleration gradient. It is observed that amplitude is maximum for the opposite polarization state and minimum for the same polarization state. The significance of the simulation study is that two-color laser pulses generate a higher acceleration gradient than single-color laser pulse and its amplitude can be controlled by controlling the polarization state between the two pulses.

References:

[1] R. K. Mishra, A. Saroch and P. Jha, Physics of Plasmas **20**, 053102, (2013).
[2] T. Tajima and J. Dawson, Physical Review Letters **43**, 267, (1979).
[3] C. Geddes, C. Toth, J. van Tilborg, E. Esarey, C. Schroeder, D. Bruhwiler, C. Nieter, J.
Cary and W. Leemans, Nature **431**, (2004).
[4] N. Verma and P. Jha, Laser And Particle Beams **34**, (2016).
[5] G. Pert, Optics &Amp; Laser Technology **4**, (1972).
[6] P. Jha, A. Saroch and N. Kumar Verma, Physics Of Plasmas **20**, (2013).
[7] A. Saroch and P. Jha, Physics Of Plasmas **22**, (2015).

Ion Acceleration by interaction of normally incident laser pulse with structured target in TNSA regime

Imran Khan, Vikrant Saxena

Department of physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India-110016

imran.khan@physics.iitd.ac.in

Abstract

Ion acceleration using laser irradiation of solid hydrocarbon targets has been a topic of research interest in recent years. There have been reports on enhancement of ion cutoff energy by structuring the target front [1]. Using two-dimensional Particle-In-Cell (PIC) simulations, we study the interaction of an intense laser pulse with targets having semi-circular, triangular and rectangular cuts at the front side. The cut-off energy of accelerated ions depend upon the shape of cut. Compared to flat target, we observe an increase in proton cut-off energy up to a factor of four at the rear side, when the target front has a rectangular cut at front side. The improvement of TNSA performance for rectangular cut target[2,3], results from focused hot-electron beam generation. In all other cases, the hot electron motion in transverse direction is more than the longitudinal direction, which results in diverging sheath field and hence less cut-off energy of ion/proton.

References :

[1] I. Thiele, J. Ferri et al. J. Plasma Phys. **86,** p 905860101, (2020)
[2]A. Macchi, M. Borghesi, M. Passoni, Reviews of Modern Phys. **85**, p 751,(2013)
[3] H. Daido, M. Nishiuchi, A. S. Pirozhkov, Reports on progress in Phys. **75**, p 056401, (2012)

Enhancement of laser generated shocks in low density foam on Al- foil targets

A. Kumar[1], S. Bhartiya[2], A. Singh[3], S. Jain[3], S. Barnwal[1], A.K. Singh[2], R.K. Patidar[3], D.K. Kohli[2], Y.B.S.R. Prasad[1], N.S.Benerji[3], M. K.Singh[2], S.K. Dixit[1]

[1]Laser Technology Division, [2]Lasers & Functional Materials Division, [3]High Energy Laser & Optics Section, RRCAT, Indore 452013, M.P., India

**Email:* katul@rrcat.gov.in

Abstract:

The laser generated shock waves are used to generate high dynamic pressures of few tens of Mbar to Gbar in the laboratory. In the present work, a low density carbon (C) - foam of mass density ~ 300mg/cc was coated on thin Aluminum (Al)-foil targets (density~2700 mg/cc). The experiments were performed on these coated targets to study the laser produced shock propagation in foil targets using two frame shadowgraphy technique at laser intensities ~ 10^{13}-10^{14} W/cm^2. Laser intensities of this order were generated by focusing the output of Nd:Glass laser chain at HELOS, RRCAT (Laser energy ~5 J to 20 J) on to these coated foil targets. The generated shock wave travels from a low density to high density material, shock enhancement or multiplication occurs due to the mismatch in shock impedance (low density to high density) of the materials. From the results it is observed that C-foam coating on Al-foil increased the particle velocities by a factor ~50% with respect to bare Al-foils. Corresponding laser produced-shock pressure enhanced by a factor of two compared to uncoated Al-foil. The results are then compared with our earlier results using PMMA (density~1100mg/cc) coated Al-targets.

References:

1. W. J. Nellis*, et al. J. Appl. Phys*., **93**, 1, (2003).
2. M. D. Salas et al., *17th Shock Interaction Symposium, Rome, Italy, (*2006).
3. Betti R. *et al., Nat. Phys.* **12**, 435, (2016).
4. D. K. Spaulding, *Ph. D. Thesis, University of California, Berkeley,* (2010).
5. Y.B.S.R. Prasad, *et al., Pramana J. of Phys***. 87**, 1, (2016).
6. D. Batani *et al. Physical Rev. E, **63*****,** 046410, (2001).
7. S. Bhartiya, et al. *DAE-BRNS National Laser Symposium-NLS-30, Indore, (*2022).
8. A.S. Joshi *et al., EPJ Web of Conferences* **59**, 08001, (2013).
9. A. Kumar *et al. DAE-BRNS National Laser Symposium-NLS-24, Indore, (*2015).

Particle-In-Cell Observations Of Parametric Instabilities For Laser Interacting With Magnetized Plasma

Laxman Prasad Goswami, Amita Das

Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016

E-mail : phz198684@iitd.ac.in

Abstract

The recent technological advancements in laser technology in terms of laser intensity, high repetition rate, and the generation of the magnetic field of the order of 1.2kT [1] have led to growing interest in the studies on laser interaction with magnetized plasma [2-4]. It is now possible to perform laser experiments where the lighter electron species can show the magnetized response. These studies have unraveled many novel observations in terms of the generation of higher harmonics [5], laser energy absorption [6-8], complete transparency of electromagnetic radiation [8, 9], etc. In the recent studies using Particle-In-Cell (PIC) simulations (using OSIRIS [10]), we have observed the excitation of Brillouin scattering in magnetized cold plasma. This scattering process has application in enhanced laser energy absorption in fast ignition of fusion targets. We shall discuss the characterization details and suitable conditions for the excitation of parametric processes.

References :

[1] Nakamura et al, Review of Scientific Instruments, 89(9):095106, 2018.
[2] Mandal et al, Scientific Reports, 11(1), 2021
[3] Jha et al, Physics of Plasmas, 12(12):123104, 2005.
[4] A Das, Reviews of Modern Plasma Physics, 4(1):1 – 16, 2020.
[5] Maity et al, Journal of Plasma Physics, 87(5), 2021.
[6] Vashistha et al, New Journal of Physics, 22: 063023, 2020
[7] Vashistha et al, Nuclear Fusion, 61(2): 026016 , 2021
[8] Goswami et al, Plasma Physics and Controlled Fusion, 63(11):115003, 2021.
[9] Mandal et al, Scientific Reports, 11(1), 2021.
[10] Fonseca et al, Plasma Physics and Controlled Fusion, 50 (12):124034, 2008.

Investigation Of Signal Enhancement In Nanoparticle Enhanced Molecular LIBS Of Graphite

Swetapuspa Soumyashree, Prashant Kumar

Affiliation: Physical Research Laboratory, Ahmedabad, Gujarat – 380009

E-mail: swetapuspa@prl.res.in

Abstract

In this study, we have investigated the time evolution of molecular LIBS (MLIBS) and nanoparticle enhanced molecular LIBS (NEMLIBS) of graphite samples using 10 nm silver and gold nanoparticles. The plasma was generated using 1064 nm Nd: YAG laser of energy 60 mJ and pulse duration 7 ns and spectra were recorded in the perpendicular direction to that of plume propagation. A detailed study on the mechanism of signal enhancement in the spectral intervals of CN violet band ($B^2\Sigma^+ \rightarrow X^2\Sigma^+$) and C_2 swan band ($d^3\Pi_g \rightarrow a^3\Pi_u$)[1] was carried out. For acquisition delays of few μs to tens μs, we have observed typically 2-3 times enhancement in optical signal for the molecular bands of graphite using the Ag NPs and almost negligible enhancement using Au NPs. Signal enhancement in NEMLIBS on different samples like AlO and graphite were recently carried out by a few groups [2,3]. We have comprehensively studied the mechanism of signal enhancement in context of lifetime and plasma parameters for molecular bands of graphite samples. The relative enhancement observed in C2 and CN bands, which are produced through different routes/mechanisms, has been explained through our analysis. In summary, we have explored the NEMLIBS of graphite to understand the mechanisms of signal enhancement of molecular bands at different time delays.

References:

[1] Laser ablation molecular isotopic spectrometry of carbon isotopes, Spectrochim. Acta Part B., **113**, p 106-112, (2015)
[2] Nanoparticle Enhanced Laser Induced Breakdown Spectroscopy for Improving the Detection of Molecular Bands, Spectrochim. Acta Part B., **125**, p 11-17, (2016)
[3] The validity of nanoparticle enhanced molecular laser-induced breakdown spectroscopy, Journal of Analytical Atomic Spectrometry,**36**, p 1034-1040, (2021)

THz Radiation Generation from Laser interaction with a Magnetized Plasma

Ashish[1], Krishna Gopal[2], Sukhmander Singh[1] and Devki Nandan Gupta[3]

[1]*Department of Physics, Central University of Rajasthan, Ajmer, 305817, Rajasthan, India.*

[2]*Department of Physics and Electronics, Rajdhani College, University of Delhi, Delhi, 110015, India.*

[3]*Department of Physics and Astrophysics, University of Delhi, Delhi, 110007, India.*

E-mail: ashish151319@gmail.com

Abstract

An analytic formalism for generation of Terahertz (THz) field from the laser interaction with a magnetized plasma is developed. Theory of energy transfer between laser induced wakefield and THz field is elaborated through non-linear coupling in the presence of negative energy electron beam. An additional resonance to the THz field via this parametric interaction between the laser induced wakefield and electron beam is provided through the applied magnetic field. THz field strength is calculated and optimized as a function of velocity of electron beam, beam density, plasma density and applied magnetic field. THz field strength of this model strongly depends on the velocity of electron beam. This work demonstrates the generation of THz field from laser plasma interaction without the phase matching condition and paves the way to new model strategy for nonlinear optical devices.

Emission of Terahertz Radiation by Oblique Incidence of Laser on Inhomogeneous Plasma

[1,2]Anjana K P, [1,2]Mrityunjay Kundu

[1]Institute for Plasma Research, Bhat, Gandhinagar – 382428, India
[2]Homi Bhaba National Institute, Anushaktinagar, Mumbai – 400094, India

E-mail : anjana.kp@ipr.res.in

Abstract

Terahertz radiations occupy the non-ionizing region of electromagnetic spectrum with wavelength ranging from 1 mm – 10 micrometer (frequency 0.3 THz – 30 THz). They have applications in medical imaging, communications, spectroscopy, security-checking and many. Different sources based on non-linear crystals[1], electronic circuits have been devised for a narrow range of THz frequencies, whereas sources based on laser-plasma interactions (LPI) provide scope for tunable, powerful and broadband radiations. In LPI schemes, terahertz radiations are generated by numerous mechanisms, e.g., Cherenkov radiation, transition radiation, beat excitation, etc.. In this work, we focus on terahertz radiation produced by the oblique incidence of a short laser pulse (~fs) on an inhomogeneous underdense plasma. For a linear ramp-density profile of the target plasma, terahertz emission occurs through inverse linear mode conversion of electrostatic wakefield to electromagnetic radiation[2]. We perform 1D3V electromagnetic particle-in-cell (PIC) simulations with short laser pulse of intensity 8.78 PW/cm^2 falling on a linear ramp-density plasma of maximum plasma frequency 166.52 THz. Simulation results show that the linear region of the plasma acts as the source of terahertz radiation with peak emission frequency of 117.75 THz. When the maximum plasma frequency of target plasma is reduced to 51.81 THz, the peak frequency of the emitted radiation is observed around 70.065 THz. It has been found that the peak emission frequency of the output terahertz radiation can be controlled by changing the maximum value of plasma frequency.

References :

[1] Y .H .Jin and X .C .Zhang , J. Nonlinear Opt. Phys. Mater. 4, 2459-495(1995)
[2] Z.-M. Sheng et al, Commun. Comput. Phys. 4,1258-1278(2008)

DYNAMICS OF HETEROGENEOUS COLLIDING LASER-PRODUCED PLASMAS

Shilpa S.[1], and Pramod Gopinath[1,2]

[1]International School of Photonic and [2]Inter University Centre for Nanomaterials and Devices
Cochin University of Science and Technology, Kochi 682022, India.

E-mail : pramod@cusat.ac.in.

Abstract

The propagation dynamics of aluminium-copper colliding plasma plumes are studied by using time-gated fast imaging and optical emission spectroscopic techniques. The experiment is performed at 10^{-2} mbar of air ambient. Colliding laser produced plasmas are significant over the conventional laser-produced plasmas because of its additional possibilities of engineering the collision dynamics externally**.** Angular target geometry is employed for the efficient collision of two different laser produced plasmas. When two plasmas collide, it can either stagnate at the collision front or can interpenetrate each other. The dense layer of plasma stagnates at the interaction region called the stagnation layer. Multi species stagnation region is formed at the collision front of heterogeneous colliding laser produced plasma and its time-resolved expansion dynamics are analyzed. The emission intensities are different for the two materials. For a particular laser wavelength, the two metal targets have different thermal and optical properties and thereby different ablation rates. Al with less ablation threshold has more intense emission compare to that of Cu. Plasma parameters like electron density and electron temperature are also measured from the spectroscopic data.

References :

[1] P.K. Pandey, R.K. Thareja, J.T. Costello, Heterogeneous (Cu-Ti) colliding plasma dynamics, Phys. Plasmas. 23 (2016). https://doi.org/10.1063/1.4964728.

[2] S. Shilpa, P. Gopinath, Shock front interaction and dynamics of laterally colliding laser-produced plasmas, Vacuum. 198 (2022) 110872. https://doi.org/10.1016/j.vacuum.2022.110872.

Numerical Studies on Controlled Trapping and Acceleration of Electron Bunch on a Gaussian Density Down Ramp

D. Phadte, K. Madhubabu, A. Upadhyay, S. R. Mishra

Laser Physics Applications Division, Raja Ramanna Centre for Advanced Technology, Indore 452 013

E-mail : deepraj@rrcat.gov.in

Abstract

The Laser Wakefield Acceleration (LWFA) has interested many researchers around the world, due to high accelerating fields (~ 100's of GV/m). Such high gradients can result in compact accelerators which can replace the huge and costly RF accelerators. In conventional LWFA, the laser power is kept above the critical power required for self-focusing. Due to self-focusing the amplitude of the plasma wave is increased until the electron oscillatory velocity along wave propagation exceeds the phase velocity of the wave which leads to wave-breaking and electron trapping in the wave. This process called 'Self-Injection' leads to a poor quality beam with large energy spread and emittance since the injection is uncontrolled and depends on driver pulse evolution.

Another way to achieve trapping is to decrease the phase velocity of the wave itself with respect to the electron oscillatory velocity along laser propagation. This can be done by introducing a downward density variation of the plasma along the direction of laser propagation. This scheme called 'Density Gradient Method' as first proposed by Bulanov *et al*. who considered a gentle density transition and later by Suk *et al*. who used a sharper transition. The injection now only occurs over the part of the transition where the phase velocity of the wave becomes less than the electron oscillatory velocity. This leads to controlled injection with better beam parameters which may be suitable for applications such as Free Electron Laser or Compact Linear Colliders.

In this work we have studied the electron injection on the down ramp of a Gaussian density profile using 2D and 3D PIC simulations with the code VORPAL. The plasma comprises of plateau background density n_0=8.5e23 /m^3 of length 1 mm and a Gaussian density profile whose center lies at 0.35 mm. The FWHM and peak of the density profile were varied. The driver laser power (a_0=4) as slightly greater than critical power at this density. As a result the laser slightly focuses with the peak(a~4.6) occurring at about 0.8 mm and then defocusses. For these typical plasma and laser parameters the 3D simulations yielded a mono-energetic energy spectrum with peak energy of 26 MeV. The total charge was 725 pC and ΔE=13.6 MeV. The normalized emittance was 4 mm-mrad. The charge decreased by 87% and peak energy increased by 80% as the FWHM of density profile was varied from 50 to 230 μm. While the energy spread decreases by 35%. Increase in density peak height by 4 times showed the charge increase by 300% and energy decreased by 66%,

while the energy spread increases by 4 times

Anisotropic Emission From Laser Produced Plasma Using Optical Emission Spectroscopy

[1,2]Geethika B R, [1,2]Garima Arora, [1,2]Jinto Thomas, [1,2]Hem Chandra Joshi

[1]*Institute for Plasma Research, Gandhinagar -- 382428, India*
[2]*Homi Bhaba National Institute, Anushaktinagar, Mumbai – 400094, India*

E-mail : geethika.br@ipr.res.in

Abstract

Optical emission spectroscopy (OES) is one of the plasma diagnostics methods which are used for the characterization of laser produced plasma. As the laser plasma inherently has high plasma density and low temperature, assumption of Local Thermodynamic Equilibrium (LTE) holds, which facilitates the estimation of plasma parameters like density and temperature without any extensive modeling. However, certain care has to be taken while selecting the spectral lines to improve the accuracy of the estimation of the plasma parameters. The plasma density is estimated by Stark broadening and the temperature is calculated using Boltzmann plot method [1]. Anisotropic effects are observed in certain emission lines from neutrals as well as ionic species present in laser produced plasma plume due to the micro-electric field developed inside the plume [2]. In this work we demonstrate the method of selecting spectral lines for plasma parameter estimation as well as an experimental method to study the anisotropic emission from the plasma and its dynamics.

References :

[1] Devia, Diana and Rodriguez-Restrepo, L and Restrepo Parra, Elisabeth. Methods Employed in Optical Emission Spectroscopy Analysis: a Review. Ingeniería y Ciencia, 11:239-267. Jan 2015. https://doi.org/10.17230/ingciencia.11.21.12
[2] Jinto Thomas, Hem Chandra Joshi, Ajai Kumar and Reji Philip. Observation of ion acceleration in nanosecond laser generated plasma on a nickel thin film under rear ablation geometry. Phys. Rev. E, 102: 043205, Oct 2020. https://doi.org/10.1103/PhysRevE.102.043205

Time-frequency analysis of the attosecond pulse trains produced from high harmonics in argon filled cell

M. Kumar[1], H. Singhal[1,2], A. Ansari[1], and J. A. Chakera[1, 2]

[1]*Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore 452 013*

[2] *Homi Bhabha National Institute, Mumbai-85*

*E-mail: mukund@rrcat.gov.in

Abstract

The time-frequency analysis is an important tool to study the chirp structure of ultrashort attosecond pulses [1]. A time-frequency analysis using a short-time Fourier transform (STFT) was performed to understand the chirp structure of the attosecond pulse produced from higher harmonics in argon-filled gas cell. The Attosecond Pulse Train (APT) and a gate pulse is focused in a low-pressure argon gas sheath, which generates photoelectron replica of the high-harmonic pulse together with sideband photoelectron peaks. The gate pulse is an infra-red dressing laser pulse generated from a part of the femtosecond laser pulse. By varying the delay between the gate pulse and the APT, the sideband peak intensity oscillates, and this continues till the two pulses overlap. This is used to generate a spectrogram showing photoelectron count with delay. Using this spectrogram, the APT is reconstructed through a well-established FROG-CRAB technique using the principal component generalized projection algorithm (PCGPA) [2].

The time-frequency analysis of the reconstructed APT is performed using STFT for two different time windows, viz. large and small temporal gate windows of $5T_0$ and $0.35T_0$ (T_0: Laser cycle), to study high-harmonic chirp and the attosecond pulse-chirp respectively. A python code performed STFT and generates a spectrogram showing the frequency present at different times. The STFT analysis shows that the high harmonics from the 19th to 27th odd orders (with a peak at the 23rd order) are generated close to the peak of the laser pulse (T_0~0). The FWHM of the duration of the 23rd order is ~12 fs, much shorter than the duration of the laser pulse (~50 fs) used for HHG. The analysis also shows that the generated high-harmonics have a positive chirp, which may be due to the cumulative effect of the two components. The first is due to self-phase modulation (SPM) of laser pulse arising due to its propagation through the focusing lens, entrance glass window of HHG vacuum chamber, etc., and the second is due to a dominant contribution from short electron trajectory. The presence of a positive chirp shows that the reconstructed attosecond pulse width should be larger than the transform-limited value. For the 19th to 27th odd order, the transform-limited duration of attosecond pulse is ~240 as. The duration of the reconstructed attosecond pulse is determined to be ~ 320 as to 350 as.

To understand the instantaneous frequency structure of individual attosecond pulses in the pulse train, the STFT was performed at a small temporal gate window of ~ $0.35T_0$. The

atto-chirp (equivalent to group velocity dispersion) has been calculated from the second order phase ($\partial^2\phi(\omega)/\partial\omega^2$) and is estimated to be ~1.9×10^{-34} s^2. Due to the small chirp, a further higher bandwidth can be added constructively, and one can produce a shorter duration of the attosecond pulses.

References

1. L Cohen, Proc. IEEE, 77, 941 (1989)
2. K. T. Kim et al, New J. Phys., 12, 083019 (2010)

Time-Resolved Investigation of the Effect of External Electric Field on Laser-Produced Silver Plasma in Liquid Ambient

Kavil Mehta[1], Swetapuspa Soumyashree[2], Prashant Kumar[2], Rajesh K. Kushawaha[2], Prahlad K. Baruah[1]*

[1]*Department of Physics, Pandit Deendayal Energy University, Gandhinagar-382426, Gujarat, India*
[2]*Physical research Laboratory, Ahmedabad-380009, Gujarat, India*

*E-mail: Prahlad.Baruah@sot.pdpu.ac.in

Abstract

Pulsed laser ablation in liquid (PLAL) is steadily gaining popularity as a versatile method to synthesize a wide variety of nanoparticles (NPs). In this technique, a pulsed laser beam is focused on a solid target immersed in liquid, which gives rise to dynamic events such as plasma generation, cavitation bubble oscillations, etc. It becomes crucial to investigate these dynamical processes as the properties of the NPs so synthesized are dependent on it [1]. The properties of NPs can be tweaked by changing experimental parameters such as laser wavelength, pulse duration, laser energy, confining liquid, etc. The change in the properties of the NPs is ultimately attributed to the effect of the parameters on the dynamics. External parameters such as electric field have also been utilized to tune the NPs properties [2]. However, the effect of an electric field on the dynamics of PLAL is still unclear. There have been some articles reporting the changes in laser-produced plasma in atmospheric and vacuum conditions due to a high electric field but to the best of knowledge of the authors, not much work in this direction has been performed in liquid [3, 4]. Hence, in the present work, laser-produced silver (Ag) plasma in distilled water in the presence of an electric field is investigated by optical imaging. The experimental setup and optical imaging results in plasma evolution over various time delays with respect to laser pulse will be presented in the conference. A correlation of results obtained during the dynamical study with the change in properties of NPs will be established. This study will enable efficient control of the properties of NPs, such as size, shape, crystallinity, chemical composition, etc.

References:

[1] A comprehensive review and outlook on the experimental techniques to investigate the complex dynamics of pulsed laser ablation in liquid for nanoparticle synthesis, Review of Scientific Instruments **93(9)**, p 091501, (2022)

[2] Colloidal brass nanoparticles produced by pulsed laser ablation in deionized water and the effect of external electric field on particle size characteristics and ablation rate, Nano-Structures & Nano-Objects **24**, p 100580, (2020)

[3] Effect of applying static electric field on the physical parameters and dynamics of laser-induced plasma, Journal of Advanced Research **1(2)**, p 129-136, (2010)

[4] Enhancement of ultraviolet laser plasma emission produced in a strong static electric field, Optics communications, **67(2)**, p 124-128, (1988)

Picosecond Laser Ablative Mass Spectrometry of Polymer Target

G.S. Sasank[1], S. Sai Shiva[2], Elle Manikanta[2], Nagaraju Guthikonda[2], S. Sree Harsha[2], P. Prem Kiran[1, 2], V.S. Ashok[1, 2]

[1]*School of Physics, University of Hyderabad, Prof. C. R. Rao Road, Gachibowli, Hyderabad – 500046*
[2]*ACRHEM, University of Hyderabad, Prof. C. R. Rao Road, Gachibowli, Hyderabad – 500046*

E-mail: ashok_vs@uohyd.ac.in, prem@uohyd.ac.in

Abstract

The high intense laser pulse interaction with a solid material is known to generate ablative plasmas with temperatures of the order of few eV to tens of KeV. The expanding plasma due to momentum conversion launches a shockwave into the material with pressures of the order of MPa to GPa [1]. The initial conditions of the material P, T are known to play crucial role in the decomposition pathway of organic materials, which in turn are controlled by incident laser parameters [2]. Laser ablative mass spectrometry was used to study the molecular fragments produced due to picosecond laser ablation of polymer targets under vacuum conditions (~10^{-5} Torr). Mass spectrometer used is a residual gas analyzer (RGA300) with 3 or 8 eV ion energy, operating in first stability zone as confirmed by the numerical simulations [3]. Fundamental wavelength from Nd:YAG laser (1064nm) delivering 30ps pulses with 10Hz repetition rate and energy varied between 5-45mJ is used for the ablation of the targets. The laser interaction process is observed to be varying with the incident laser pulse energy resulting in enhanced plasma plume expansion along with the decomposition mechanism of target, which is measured in terms of partial pressures by RGA. The experimental setup was also used to study the plasma plume evolution. The evolution of different atomic masses from the polymer: Vinyl Chloride (62.5 amu), Methyl Chloro- (49.5 amu), Carbon dioxide (44 amu), Cyanomide (41 amu), Cyanomethylene (39 amu), Chloranium (37 amu), HCl (36.5 amu), Chlorine (35.5 amu), Nitrogen or Ethylene (28 amu), Acetylene or Cyanide (26 amu), Water (17, 18 amu) and Hydrogen (1 amu)) is studied with input laser energy. The atomic mass evolution is compared with that of the standard metal targets with increasing laser energy to study the role of laser shock pressure impulse (LSPI) on the laser ablation and subsequent mass emission.

References:

[1] S. Sai Shiva et al., *Physics of Plasmas* **23**, 053107 (2016).
[2] Richard Behrens,Jr. J.Phys.Chem.**94**, 6707-6718, (1990).
[3] G.S. Sasank, P. Prem Kiran, Ashoka Vudayagiri, APS March Meeting 2021, March 15 – 19, 2021.

X-Ray Emission from Collective Betatron Oscillations of Electrons Excited by Chirped Laser Pulses in a Plasma Wiggler

S. Mishra[2,*], B. S. Rao[1,2], A. Moorti[1,2], and J. A. Chakera[1,2]

[1] *HBNI, Training School Complex, Anushakti nagar, Mumbai 400 094*
[2]*Laser Plasma Division, RRCAT, Indore 452013*

*E-mail: shikham@rrcat.gov.in

Abstract

The interaction of a high-intensity and ultrashort laser pulse, with underdense plasma, produces large longitudinal accelerating electric fields, which accelerates trapped electrons up to GeV energies in a compact acceleration setup. These compact accelerators can also be used to generate bright collimated x-rays as a result of the wiggling of the energetic electrons. To date, the one of the most efficient mechanism for electron acceleration inside plasma is bubble or blow out regime. In this regime, a spherical shaped bubble is formed when the ponderomotive force of the laser pulse fully expels the background plasma electrons and leaves behind an ion cavity in its wake. In addition to the longitudinal force (accelerating field), the spherical shape of the ion cavity produces a transverse electric field that produces restoring force directed toward the laser pulse propagation axis. Therefore, electrons trapped and accelerated in the cavity also oscillate transversally (known as betatron oscillations). The oscillating electrons radiate pulsed collimated x-rays of femtosecond duration in the forward direction with few keV to tens of keV energy. The properties of these oscillating electrons inside the plasma bubble determine the characteristics of betatron x-rays, and one of the important variables affecting the critical energy and x-ray flux is the betatron oscillation amplitude (r).

In this report, we present an experimental study on the x-ray emission due to collective betatron oscillations of energetic-electrons in laser-plasma accelerator driven by a positively chirped 45fs, Ti: Sapphire laser-pulse interaction with 4mm long Nitrogen gas-jet at an intensity of ~2.8×10^{19} W/cm^2. We observed broad-spectrum electron beams up to 250 MeV that showed both collective and random betatron oscillations of electrons [1]. The x-ray emission for collective oscillations was found to be higher due to effective larger amplitude (r). In addition, collective oscillations started to emerge with a larger positive chirp, which resulted in efficient x-ray emission with a peak brightness of $\geq1\times10^{21}$ photons/s-mm^2-mrad^2 in 0.1% BW with a critical energy of 12±2 keV at plasma density ~3.4×10^{18}cm^{-3}. We have also demonstrated the application of the betatron x-ray in high-resolution phase-contrast imaging of an optical fiber.

References:

[1] S. Mishra, B. S. Rao, A. Moorti, and J. A. Chakera, Phys. Rev. Accel. Beams **25**, 090703 (2022)

Study On Terahertz Radiation Generation by Interaction Of Lasers with Carbon Nanotubes

Rakhee Malik [1,2] **and R. Uma** [2]

[1] *Department of Physics, Govt. Degree College, Nadhabhood, Budaun,243723 India*
[2] *Centre for Energy Studies, IIT Delhi, New Delhi, 110016, India*
malikrakheephys17@gmail.com

Abstract

Terahertz radiation (THz) generation has been a fascinating area of research now a days due to its diverse applications in imaging, explosive detection, characterization of electronic materials, chemical and biological sensing, non destructive testing, etc. Carbon nanotubes appear to be a favorable way to generate THz radiation by having surface plasmon resonance frequencies in Terahertz range via nonlinear coupling with lasers [1-3]. Carbon nanotubes provide the advantage of compactness with considerable efficiency.

In this paper, a feasible scheme of terahertz radiation generation by beating two laser beams in a carbon nanotube array mounted on a dielectric substrate is studied. A beat frequency Pondermotive force is experienced by free electrons of the carbon nanotubes due to the gain of large oscillatory velocity by electrons. Each nanotube acts as an osillating electron cylinder which acts as an oscillating dipole antenna which produces terahertz radiation. The terahertz radiation power is resonantly enhanced when the beat frequency of incident lasers equals $\omega_p / \sqrt{2}$, where ω_p is the electron plasma frequency [4].

[1] Q. Zhang et al., Nano Lett. 13, 5991 (2013).
[2] Ren, Q. Zhang, S. Nanot, I. Kawayama, M. Tonouchi, J. Kono, J. Infrared Millimeter Terahertz Waves **33**, 846 (2012).
[3] P. Avouris, M. Freitag, V. Perebeions, Nat. Photonics 2, 341 (2008).
[4] R. Malik and R. Uma, Phys. of Plasmas, 25, 013106 (2018).

Second Harmonic generation of elliptical laser beam in thermal quantum plasma

Kulkaran Singh and Keshav Walia

Affiliation: Department of Physics, DAV University Jalandhar, Punjab (India) -144012

E-mail : kssaggoo@gmail.com
keshavwalia86@gmail.com

Abstract

Second harmonic generation (SHG) of elliptical laser beam in thermal quantum plasma is explored in present investigation. Well known Paraxial theory and WKB approximations are used for deriving 2nd order differential equations representing the behavior of laser beam with normalized propagation distance and expression for efficiency of 2nd harmonics. Intensity gradients are produced inside plasma in a direction transverse to main beam on account of relativistic increase in mass of electrons. These intensity gradients excite electron plasma wave (EPW) at the pump wave frequency. Excited EPW interacts with pump beam to give 2nd harmonics. Numerical simulations are carried out for exploring the impact of various laser-plasma parameters and quantum contribution self-focusing of main beam and efficiency of 2nd harmonics. We have also made comparison of present work with classical relativistic plasma.

Keywords: Second Harmonic generation; Elliptical beam; Paraxial theory; Intensity Gradients; Electron Plasma Wave.

Interaction of Laser with GaAs Structure for Terahertz Radiation Generation

Sandeep[a,b*] and Hitendra K. Malik[a]

[a]Plasma Science and Technology Laboratory, Indian Institute of Technology Delhi, New Delhi – 110 016, India
[a]Department of Physics, Deen Dayal Upadhyaya College, University of Delhi, New Delhi - 110078, India

[*]**Corresponding author's email:** sandeepamrit@gmail.com; sandeep@ddu.du.ac.in

Abstract

Terahertz (THz) radiations known as submillimeter waves find applications in various fields such as communication, medical science, spectroscopy, material characterization and remote sensing in view of their low-energy photons. These radiations have been produced by various schemes viz. optical rectification, Cherenkov radiation, photoconductive emitters, laser-plasma interaction, semiconductor antennae, etc. [1, 2]. However, it has been difficult to simultaneously manage its intensity, focus, and frequency tuning.

In the current work, a method for producing THz radiation using a laser-induced transient current in an array of GaAs structures is proposed, which functions as phase array dipole antennae. The THz radiation is produced by the current flowing down the length of these devices. With a maximum output of 0.013 nW at a frequency of about 1 THz, it is simple to emit THz radiation pulses that climb quickly and descend slowly. The transient current density attained through electron-hole pair production determines the radiated power. The proposed GaAs periodic array allows us to have the THz profile in the frequency domain and realize the function of arrays and size of GaAs structure, making the produced radiation ideal for its THz Time Domain Spectroscopic applications. The greatest emitted THz power is attained in particular directions, which are discussed in detail.

References:

[1] Malik HK. Laser-Matter Interaction for Radiation and Energy. CRC Press; Ist Ed., 2021.
[2] Yardimci, N. T., Yang, S. H., Berry, C. W. & Jarrahi, M. High-power terahertz generation using large-area plasmonic photoconductive emitters. IEEE Trans. Terahertz Sci. Technol. **5**, 223–229 (2015).

Beam in an Under-dense Plasma

Subhajit Bhaskar[(a)], Hitendra K. Malik[(b)]

PWAPA Laboratory, Department of Physics, IIT Delhi, New Delhi-110016, India

[(a)]sbhaskar5995@gmail.com
[(b)]hkmalik@physics.iitd.ac.in

Abstract

Utilization of Chirped Pulse Amplification (CPA) technique has paved the way for the generation of ultrafast and ultra-intense laser beams and attracted many researchers in the theoretical and experimental study of these ultra-intense light beams in different areas like higher harmonic generation, laser wakefield acceleration (LWFA), ultrafast optical fiber communication, etc. [1, 2] Recently, the self-focusing phenomenon of the laser in plasma has proved its importance in producing ultra-intense and divergence-less beam.

In the present work, we have discussed the propagation and self-focusing of Laguerre-Gaussian (LG_{pl}) beam in an under-dense, cold, and collisionless plasma. LG beams (vortex beams with helical phase-fronts) carry orbital angular momentum (OAM) with topological charge $l = 0, \pm 1, \pm 2, \ldots$The effect of this topological charge on the self-focusing process is investigated in the presence of relativistic and ponderomotive nonlinearities [3, 4] in the medium. As a mathematical approach, we have adopted the WKB method under paraxial approximation and obtained a differential equation for the beam width parameter in the reduced form of the nonlinear wave equation. The effect of various parameters on the beam width is specifically studied for the discussion of self-focusing of the optical vortex beam.

References:

[1]. Malik, H. K. (2021). *Laser-Matter Interaction for Radiation and Energy*. CRC Press.

[2]. Malik, H. K., & Devi, L. (2020). Relativistic self focusing and frequency shift of super-Gaussian laser beam in plasma. *Results in Physics*, *17*, 103070.

[3]. Purohit, G., Sharma, R. K., & Kothiyal, P. (2022). Relativistic-ponderomotive effect on the self-focusing of a high-intensity cosh-Gaussian laser beam in plasma: higher-order paraxial regime. *Journal of Optics*, 1-9.

[4]. Dwivedi, M., Dhawan, R., Punia, S., & Malik, H. K. (2019, August). Relativistic self-focusing of Laguerre-Gaussian beam in an underdense plasma. In *AIP Conference Proceedings* (Vol. 2136, No. 1, p. 060006). AIP Publishing LLC.

Optimization of Electron Bunch Characteristics based on Plasma Channel Ramp in Laser Wakefield Acceleration

Mohit Kumar[(a)], Hitendra Kumar Malik[(b)], Sandeep Kumar[(c)]

[(a,b)]*PWAPA Laboratory, Department of Physics, IIT Delhi, New Delhi-110016, India*
[(c)]*Department of Physics, Manav Rachna University, Faridabad-121004, India*

[(a)]mohitkushwaha8793@gmail.com, [(b)]hkmalik@physics.iitd.ac.in,
[(c)]sandeepkumar@mru.edu.in

Abstract

Charged particle acceleration has received global attention due to its diverse applications in nuclear physics, fusion, radiation generation, materials probing, etc. [1]. Recently, laser wakefield acceleration (LWFA) [2] has acquired considerable attention with the potential of generating highly relativistic electron beams and x-ray radiation [3, 4]. The LWFA is a mechanism used for producing high-quality electron bunches.

In the present work, electron acceleration is studied using a linearly polarized Gaussian laser pulse in an under-dense plasma medium having an upward plasma density ramp with a density hill. The parameters for the laser and density ramp are optimized to maximize the electron-bunch energy gain, bunch charge and minimize the emittance. We study the effect of the width of the density hill on electron-bunch characteristics using Fourier-Bessel particle-in-cell (FBPIC) simulations and find that the energy gain of the electron bunch increases with the width of the density hill. Our simulation results show that the electron-bunch accelerated in the plasma bubble has the energy of 0.34 GeV in a 3.13 mm long plasma channel.

References:

[1] H.K. Malik, Laser-Matter Interaction for Radiation and Energy, CRC Press, Ist Ed. 2021.

[2] Faure, J., Glinec, Y., Pukhov, A., Kiselev, S., Gordienko, S., Lefebvre, E., ... & Malka, V. (2004). A laser-plasma accelerator producing monoenergetic electron beams. *Nature*, *431*(7008), 541-544.

[3] Rousse, A., Phuoc, K. T., Shah, R., Pukhov, A., Lefebvre, E., Malka, V., ... & Hulin, D. (2004). Production of a keV X-ray beam from synchrotron radiation in relativistic laser-plasma interaction. *Physical review letters*, *93*(13), 135005.

[4] Cipiccia, S., Islam, M. R., Ersfeld, B., Shanks, R. P., Brunetti, E., Vieux, G., ... & Jaroszynski, D. A. (2011). Gamma-rays from harmonically resonant betatron oscillations in a plasma wake. *Nature Physics*, *7*(11), 867-871.

Wakefield generation in magnetized homogeneous and inhomogeneous plasmas

Saumya Singh, Dinkar Mishra, and Bhupesh Kumar

University of Lucknow, Lucknow, Uttar Pradesh, 226007

E-mail : saumyasingh.phy@gmail.com

Abstract

The interaction of intense, short laser pulses with preformed cold plasma leads to the generation of wakefield of large amplitude, oscillating at plasma frequency. These generated wakefield are of great importance as they find many applications as particle accelerator, radiation generation, optical guiding, etc. Present work is based on the comparative study of wakefield generation by propagation of laser pulse in homogeneous and inhomogeneous plasmas in presence of an external magnetic field. Inhomogeneous plasma contains parabolically varying plasma density (plasma channel). Presence of plasma channel allows laser pulse to propagate to extended distance with lesser diffraction. The magnetic field is applied externally, along the propagation direction of the laser pulse. Particle-in cell (PIC) simulation has been done using V-Sim code for linearly polarized laser pulse propagating in preformed plasma. An enhancement in the transverse and longitudinal wakefield is observed in presence of magnetic field and plasma channel as compared to homogeneous plasma.

References :

[1] T. Tajima and J.M. Dawson, Phys. Rev. Lett. 43(4) 267 (1979)
[2] P. Jha, A. Saroch, and R. K. Mishra, Europhys. Lett. 94, 15001 (2011) [2]
[3] P.Jha, P.Kumar, A.K. Upadhyaya, G.Raj, Phy. Rev. ST Accel. Beam **8**, 071301 (2005)
[4] A. K. Upadhyay, V. Singh and P. Jha, Plasma Phys. Control. Fusion 51 10501 (2009)

Terahertz generation by Hermite-Gaussian laser beam in magnetoplasma with an exponential density ramp

Proxy Kad, Vidisha Rana, and Arvinder Singh

Dr. B.R. Ambedkar National Institute of Technology, Jalandhar-144027, Punjab, India

E-mail: proxykad59@gmail.com, vidisharana11@gmail.com, and arvinders@nitj.ac.in

Abstract

The present work studies the spatial variation of a Hermite-Gaussian (HG) laser beam propagating through the magnetoplasma having a relativistic-ponderomotive nonlinearity. In addition, the THz generation's dependency on laser dynamics has also been investigated. The plasma is considered to be inhomogeneous having an exponential density ramp. Two coupled second differential equations have been obtained using the methods of moments governing the dynamics of the laser beam. The laser beam propagating through plasma excites an electron plasma wave and that assists in generating THz radiation. It has been observed that different TEM modes, laser, and plasma parameters strongly affect the THz generation. It has also been observed that the applied magnetic field and density ramp have a significant effect on laser dynamics and generation of THz radiation.

Simulation Studies On The Effect Of Unchirped, Chirped And Two-Color Chirped Laser Pulses On Wakefield Generation

Shivani Aggarwal, Dinkar Mishra, and Bhupesh Kumar

Department of Physics, University of Lucknow, Uttar Pradesh - 226007

E-mail: shivani.aggarwal7343@gmail.com

Abstract

Today, the interaction of different configuration profiles of intense and short laser pulses with homogeneous and inhomogeneous plasmas is widely studied in the plasma physics community. In near future, laser-plasma interactions can play important role in development of sustainable technologies like power sources, particle accelerators, and radiation sources. Interaction of high intensity short laser pulses with plasma results in wakefield generation.

The wakefield can be greatly enhanced for both positively chirped laser pulses having a fast rise time and negatively chirped laser pulse having a slow rise time. Large amplitude longitudinal wakes produced by the beating of two-color short laser pulses can be utilized for particle acceleration. In the present study, 2-D simulations have been performed to study the interaction of sinusoidal unchirped, chirped and two-color chirped laser pulses with preformed homogeneous plasma under different laser pulse parameters.

References:

[1] H. Ghotra, Optik **260**, (2022).
[2] T. Tajima and J. Dawson, Physical Review Letters **43**, (1979).
[3] H. Tai, F. Li and Z. Wang, Journal of Modern Optics **63**, (2016).
[4] N. Verma and P. Jha, Laser and Particle Beams **34**, (2016).
[5] P. Jha, A. Saroch and N. Kumar Verma, Physics of Plasmas **20**, (2013).

Study Of High Harmonics Generation In RL Mode Configuration

Trishul Dhalia[1], Rohit Juneja[1], Laxman Goswami[1], Srimanta Maity[1] and Amita Das[1]

[1]*Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110016 , India*

E-mail : phz208850@iitd.ac.in

Abstract

High harmonics are known to be an essential source for generation of X-rays and high frequency coherent electromagnetic waves. Generation of high harmonics of circularly polarized EM waves through unmagnetized plasma is rather impossible to achieve [1]. Under a transverse external magnetic field (X and O mode) Generation of odd and even harmonics of linear polarized wave been observed in earlier studies [2,3]. But under a longitudinal external magnetic field ie. RL mode configuration when a linearly polarized EM wave encounters the vacuum plasma surface it has been observed that high harmonics of LCP and RCP waves are generated inside the magnetized plasma which travels with different group velocities.

Efficiency of these HHG have been found to be dependent of external magnetic field, density of plasma and Intensity of incoming EM wave. We have also provided an analytical theory of the HHG in RL-mode configuration.

References :

[1] Dromey, Brendan, et al. "High harmonic generation in the relativistic limit." Nature physics 2.7 (2006): 456-459.
[2] Maity, Srimanta, et al. "Harmonic generation in the interaction of laser with a magnetized overdense plasma." *Journal of Plasma Physics* 87.5 (2021).
[3] Lichters, R., Meyer-ter-Vehn, J., & Pukhov, A. (1996). Short-pulse laser harmonics from oscillating plasma surfaces driven at relativistic intensity. *Physics of Plasmas*, *3*(9), 3425-3437.

Chaotic Particle Trajectories For Laser Energy Absorption In Plasmas

Rohit Juneja*, Trishul Dhalia, Laxman Goswami, Priya Deshwal and Amita Das

Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110016, India

E-mail : Rohit.Juneja@physics.iitd.ac.in

Abstract

Laser energy absorption in plasma is important for many applications. The laser energy gets coupled with the lighter electron species through various collisional and collisionless [1-2] mechanisms. In the collisionless schemes the energy absorption relies on the excitation of electrostatic mode in the plasma. The wave breaking of these electrostatic modes then lead to the irreversible transfer of energy to plasma particles. This has been demonstrated both for unmagnetized and recently for magnetized cases (in both X and LR mode configurations). However, several non – resonant mechanisms of energy transfer for overdense plasma medium have also been demonstrated [2]. For such cases the lighter electron species is pulled out of the target surface either by the normal component of laser electric field (in the case of oblique **p** polarised laser) or through the J × B force (in the relativistic case) acting perpendicular to the plasma surface. It has so far been believed that the combination of the laser electric field and the sheath field generated by the electrons pulled out of the surface leads to the stochastization of electron trajectories leading to irreversible transfer of energy. In this work it has been demonstrated by carrying out particle-in-cell simulation using OSIRIS 4.0 framework that the electron trajectories indeed become chaotic. A detailed characterization and correlation with energy absorption has been established.

References :

[1] Kruer, William L. & Estabrook, Kent G. 1985 J×B heating by very intense laser light. Physics of Fluids 28, 430–432.
[2] Brunel 1987 Not-so-resonant, resonant absorption. Physical review letters 59 1, 52–55.

Dynamics of Hermite-Gaussian laser beam in plasma and Terahertz generation

Proxy Kad, Vidisha Rana, and Arvinder Singh

Dr. B.R. Ambedkar National Institute of Technology, Jalandhar-144027, Punjab, India

E-mail: proxykad59@gmail.com, vidisharana11@gmail.com, and arvinders@nitj.ac.in

Abstract

In the present work, the dynamical study of a Hermite-Gaussian (HG) laser beam propagating through plasma with relativistic nonlinearity has been carried out. Furthermore, the dependency of THz generation on the HG laser dynamics has also been investigated. Self-focusing of laser beam inside plasma is achieved due to the modification in electron's rest mass due to their motion at relativistic velocities. The coupled differential equations obtained using the method of moment determines the variation in spot size of laser beam and have been solved numerically. The laser beam propagating through plasma excites the plasma wave and the nonlinear coupling of HG beam and plasma wave generates THz radiation. It has been observed that THz generation strongly depends upon the variation of spot size, TEM modes, plasma density and intensity of laser beam. Furthermore, the self-trapping of HG laser beam has also been studied.

Nonlinear Interactions in Magnetized Piezoelectric Semiconductor Quantum Plasma

Ravi Vanshpal[1*], Ratna Agrawal[2], Gopal Dangi[1], Swati Dubey[2]

[1]*Shri Vaishnav Institute of Technology and science, Indore, 453551*
[2]*School of Studies in Physics, Vikram University, Ujjain,456010*

E-mail : ravivanshpal@gmail.com

Abstract

In the present paper Quantum Magnetized hydrodynamic (QMHD) model is extended for spin dynamics in the Quantum plasmas. Spin effect is analytically investigated in a magnetized n-type piezoelectric semiconductor. These effects not only influence the dispersive properties of waves and instabilities but also give rise to novel wave phenomena within the degenerate plasma regime [1–3]. We have considered that the origin of nonlinear interaction lies in the second order susceptibility arising from the nonlinear induced current density. Influence of spin effects in second order nonlinear interaction has been explored via determination of threshold electric field required for the onset of optical nonlinear processes and gain coefficient. Spin effects are found to affect the magnitude of gain coefficient appreciably.

References :

[1] G. Chabrier, F. Douchin, and A. Y. Potekhin, J. Phys: Condens. Matter **14**, p.9133 (2002).
[2] R. Maroof, A. Mushtaq and A. Qamar, Phys. Plasmas **23**, 013704 (2016).
[3] F. Haas, Phys. of Plasmas **12**, 062117 (2005).

Development Of An Optical Delay Line For Probing The High Intensity Laser Foil Interaction Dynamics Using Optical Reflectometry

R. A. Khan[1], S. Bagchi[1], M. Tayyab[1], A. Moorti[1,2] and J. A. Chakera[1,2]

[1]*Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore 452013*
[2]*Homi Bhabha National Institute, Anushakti Nagar, Mumbai – 400 094*

E-mail : tayyab@rrcat.gov.in

Abstract

The study of intense laser matter interaction is an important area of research with rich underlying physics and having lots of potential applications. Particularly, acceleration of energetic ions from the interaction of ultra-short, intense laser pulse with thin foil targets has generated considerable interest in recent times owing to its potential applications [1]. Ions are accelerated to MeV energies at target rear surface via the sheath field set up by the hot electrons produced during the interaction. The laser pulse contrast which is the ratio of pre-pulse to main laser pulse, plays a key role in controlling the interaction. The pre-pulse can modify the initial sharp interface between the target and vacuum by forming pre-plasma before the arrival of the main pulse. Further, the pre-heating and expansion of the target rear surface can drastically influence the laser interaction dynamics and hence the ion acceleration process [2]. Therefore, in such scenario it is quite important to study the spatio-temporal evolution of short pulse laser foil interaction. In the present work, we have developed a pump-probe fs laser beam line for spatio-temporal probing of laser plasma interaction dynamics. As an application of this beam line, the influence of laser pre-pulse on ion acceleration have been studied by capturing the real time snapshots of foil rear surface in ps time intervals using probe reflectometry. The captured images clearly reveal the rear surface pre-heating through the spatial variation in target reflectivity.
Experiment was performed using 25 fs, 150 TW laser system. The laser pulse was split into two; a pump (99%) and a probe (1%) pulse. The pump pulse was focused on 1.5 µm thick foil target using an f/3 off axis parabolic mirror to an intensity of 5×10^{19} W/cm^2. The probe beam was first converted to second harmonic and then directed towards rear surface. Reflected light in specular direction from target rear surface was collected onto 8-bit CCD camera at 6.4x magnification using f =20 cm lens. An optical delay line was constructed in the probe beam path for temporal scanning. The t = 0 point was established by monitoring the air plasma evolution. This was realized by focusing the pump pulse in air at low intensity and varying the relative timing of the probe beam until the initial plasma formation was just visible. The zero delay ("t = 0") point was established within ± 150 fs accuracy which is sufficient for probing the plasma dynamics on sub ps time scale. The arrival of the probe pulse can be varied from "- 400 ps" to "+ 267 ps" with respect to main pulse. Here, negative (positive) delays correspond to probe pulse arrival before (after) the main pulse. Images of the target rear surface was captured at different time delays. At "-1 ps" time delay i.e., just before the arrival of the main pulse a circular hollow of about 20 µm in diameter having ring structure was observed. The appearance of this feature before

the arrival of the main pulse clearly indicates the target perturbation / heating by the pre-pulse. The detail analysis of the result involving correlation of target rear surface heating with temporal contrast of the laser pulse will be presented.

References:

[1] Ion acceleration by superintense laser-plasma interaction, Rev. Mod. Phys., **85**, p 751-793, (2013)

INFLUENCE OF SELF-FOCUSED HIGH-POWER BEAM ON SECOND HARMONIC GENERATION IN QUANTUM PLASMA

Taranjot Singh and Keshav Walia

Department of Physics, DAV University Jalandhar, Punjab(India)-144012

Email: taranjotsingh64@gmail.com
keshavwalia86@gmail.com

In the present work, the influence of self-focused high power beam on second harmonic generation (SHG) in quantum plasma is investigated in detail. The relativistic and ponderomotive nonlinearities are taken together in present investigation. There is production of density gradients in plasma on account of combined action of relativistic and ponderomotive nonlinearities. When electric vector of laser beam is parallel to density gradients established in plasma, then electron plasma wave(EPW) at the frequency of input beam is produced. Further, the nonlinear coupling between input beam and EPW wave produces 2nd harmonics. The nonlinear differential equation for the beam width of input beam and expression for second harmonic yield(SHY) are derived by making use of WKB and paraxial theory approach. The effect of laser-plasma parameters, quantum contribution and combined action of relativistic and ponderomotive nonlinearities on focusing ability of input beam and SHY are investigated in detail.

Keywords: Second Harmonic Generation, Quantum Plasma, High power beam, Input beam, Density Gradients, Electron Plasma Wave

Plasma Wave Aided Heating of Nanocluster Plasma by Nonlinear Interaction of two Hermite-Gaussian Laser Beams

Arvind Kumar* and Asheel Kumar

Plasma Physics Research Group, Department of Physics, University of Allahabad, Prayagraj, India-211002

*E-mail: arvind@allduniv.ac.in, 1222arvind@gmail.com

Abstract

In this theoretical investigation, plasma wave aided heating scheme is analytically studied in nanocluster plasma by two high power Hermite -Gaussian laser beams. Nonlinear interaction of two laser beams causes the beat wave in plasma embedded with clusters. The oscillatory velocities of each laser beams produce the nonlinear ponderomotive force. This nonlinear force might have much potential to excite the plasma wave. Analytic expressions of anomalous heating rate and evolution of electron temperature is obtained. The heating rate is resonantly increased by surface plasmon oscillations. This extreme condition is achieved when the laser beat wave frequency comparatively near the frequency of surface charge oscillations of nanoclustered plasma. The graphical discussion of this theory promises that heating rate can be effectively enhanced by varying the beam decentred parameter, beam width, mode index, rippled clustered density and clustered radius.

References:

1. Phys. Scr. **73** 393–396, (2006)
2. Liu C S and Tripathi V K 2002 Fast and slow plasma waves excitation by counterpropagating lasers in a hot plasma. Phys. Plasmas **9** 3995, (2002)
3. Appl. Phys. B **111** 1–6, (2013)
4. J. Appl. Phys. **123** 153101, (2018)

Excitation of Plasma Wave by Two Copropagating High Power Laser Beams in Nanocluster Plasma

Sujeet Kumar* and Asheel Kumar

Plasma Physics Research Group, Department of Physics, University of Allahabad, Prayagraj, India-211002

*E-mail: stkr0512@gmail.com

Abstract

In this paper, we study the plasma wave excitation by beating of two super-Gaussian laser beams in nanocluster plasma. The interaction of electric field profile of laser beams cause the ionization of nanocluster and very quickly it converts into the plasma plume balls. The electric field profile of each laser beam impart the oscillatory velocity to the electron associated with nanoclustered plasma. The copropagating laser beams also cause the nonlinear ponderomotive force to these electrons at beat wave frequency $\omega = \omega_1 - \omega_2$ and wave number $k = k_1 - k_2$. This nonlinear ponderomotive force drive the self-consisted space charge wave and it might have much potential to excite the plasma wave in nanoclustered plasmas. An analytic formalism is derived for plasma wave potential in nanoclustered regime. The effective surface plasmons resonance at the surface of nanoclustered plasma cause the extreme and enhance excitation of plasma wave. The plasma wave excitation is tuned and controlled by varying the super-Gaussian index, clustered radius, density and laser beat wave frequency. This excited plasma wave might have possible application in harmonic generation, charged particle acceleration and heating.

References:

1. Phys. Scr. **73** 393–396, (2006)
2. Optik **178** 602-609, (2019)

Plasma Electron Trapping in Laser Wakefield Acceleration

Ravina Yadav and D. N. Gupta

Department of Physics and Astrophysics, University of Delhi, Delhi-110007, India

E-mail: ravina_yadav@outlook.com

Abstract

The number of particles in an electron beam from laser wakefield acceleration is determined at the moment of trapping of background electrons. The longitudinal and transverse wave-breaking initiates the electron trapping. After some time, the trapping stops because of the repulsive force by the trapped particles. From many simulations and experiments, it has been well known that trapping of the background electrons begins much below the longitudinal wave-breaking limit. This is related with transverse motion of the electrons. As an ultra-intense laser pulse propagates through a plasma, it pushes out the background plasma electrons and leaves behind a periodically-repeated bubble-like region. Inside the bubble, the electron density is very low, while the electron density at the rim of the bubble is very high. Highly energetic electrons make their trajectories along the rim of the bubble. Though many of such electrons turn around the rim and leave the bubble, some of those electrons are trapped in the transverse direction when their kinetic energies are lower than the depth of the potential well of the bubble. The idea suggested in this paper is that a magnetic field applied in the longitudinal direction is able to suppress the transverse drift of the electrons so that their trajectories are dragged more inward the bubble. Because of the sensitivity, even a very weak suppression of the transverse drift of the electron may be able to turn the outgoing path into the trapping path. The advantage of this technique is obtaining one more control of the beam charge in the laser-plasma accelerators, while keeping other parameters unmodified. Though the required magnetic field is strong, i.e. like a few tens or one hundred Tesla, magnetization of the plasma is still weak enough to put the wakefield uninfluenced.

References:

[1] W. P. Leemans, B. Nagler, A. J. Gonsalves, Cs. Toth, K. Nakamura, C. G. R. Geddes, E. Esarey,
C. B. Schroeder, and S. M. Hooker, Nature **2**, p. 696-699, (2006)

[2] J. Faure, C. Rechatin, A. Norlin, A. Lifschitz, Y. Glinec, and V. Malka, Nature, **444**, p. 737-739
(2006)

[3] A. Pukhov and J. Meyer-ter-Vehn, Appl. Phys. B **74**, p. 355-361 (2002)

[4] M. S. Hur, D. N. Gupta, and H. Suk, Phys. Lett. A **372**, p. 2684-2687 (2008)

Effects of radiation-reaction on resonant phase locking in cyclotron auto-resonant particle acceleration scheme

Shivam Kumar Mishra[1,2] Sudip Sengupta[1,2] and

Sarveshwar Sharma[1,2]

[1]Institute for Plasma Research, Bhat, Gandhinagar, Gujarat,India

382428

[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai,Maharashtra, India – 400094*

E-mail: mishrasshivam@gmail.com

Abstract

It is well known, that the cyclotron auto-resonance scheme, results in unbounded energy gain by the particle from the electromagnetic wave. Today the high intensity laser facilities have achieved laser intensities ~ 10^{23} W/cm^{2}. In such laser intensity the effect of the radiation-reaction force becomes comparable to the Lorentz force [1] and thus the study of charged particle dynamics under cyclotron auto-resonance requires inclusion of radiation-reaction effects.

It has been recently shown that the inclusion of radiation-reaction in the particle's equation of motion, leads to a net energy gain in the non-resonant case [2]. These results were obtained numerically for a monochromatic wave by solving the model equations of motion suggested by Landau-Lifshitz.In the present work, the above problem has been studied analytically and numerically by using the Modified-Hartemann-Luhmann equation of motion [1,3]. Our studies show that in the presence of radiation-reaction force, initially non-resonant particles (cyclotron frequency lesser than doppler shifted frequency of the wave) eventually get phase locked with the wave and the energy gain exhibits a peak which, then decreases through loss in transverse momentum. It is further found that farther the chosen initial conditions are from the resonant point greater is the energy maxima.

References :

[1] Mishra, Shivam Kumar, et. al., *Eur. Phys. J. Spec. Top.*, 230(23),4165-4174 (2021)
[2] Vikram Sagar, et. al., *Physics of Plasmas*, 22(12),123102(2015)
[3] F. V. Hartemann, et. al., *Phys. Rev. Lett.,* 74,1107–1110

(1995)

Determination of Heavy Metals in the Atmosphere by Laser Induced Breakdown Spectroscopy

Darshitsinh Parmar[1], Rajesh K. Kushawaha[2], Rohit Srivastava[1], Prahlad K. Baruah[1]*

[1]*Department of Physics, Pandit Deendayal Energy University, Gandhinagar, 382426, India*
[2]*Physical Research Laboratory, Ahmedabad – 380009, Gujarat, India*

*E-mail: prahlad.baruah@sot.pdpu.ac.in

Abstract

Urbanization and industrialization have resulted in the release of significant contaminants into the atmosphere, mainly in the form of heavy metals. Heavy metal emissions are caused by anthropogenic processes such as industrial, agricultural, mining, metallurgical, and vehicular activities, while natural sources of these emissions include sea-salt sprays, forest fires, volcanic eruptions, and wind-borne soil particles [1]. Many metallic components, particularly heavy metals such as As, Cd, Cr, Hg, and Pb, are ubiquitous, harmful, difficult to degrade, and their minor concentration can be dangerous to natural health. Hence, it is essential to monitor these contaminants in the main body of pollution. Traditional methods for detecting these metals are based on optical and mass spectrometry, such as X-ray fluorescence (XRF), inductively coupled plasma emission spectroscopy (ICP-AES), inductively coupled plasma mass spectrometry (ICP-MS) [2], atomic emission spectroscopy (AES), and atomic absorption spectrometry (AAS). These techniques are expensive, time-consuming, require sample pre-treatment and some of these may even cause secondary pollution. So, there is a need for an improved technique that provides the benefits of quick, in-situ, and easy sample preparation in order to enable the detection and monitoring of atmospheric contaminants. Laser Induced Breakdown Spectroscopy (LIBS) is a unique AES-based analytical approach that employs a pulsed laser to atomize material and form an instantaneous plasma, which gives the signature lines of elements for qualitative and quantitative measurements. It allows for quick analysis with very little sample preparation and is non-destructive, easy, and may be used for solids, liquids, gases, and aerosols. LIBS technology can be employed in atmospheric monitoring to analyse aerosols and impurity gases [3]. The present paper provides an insight onto the various experimental methodologies and highlights the advantages of LIBS over other conventional techniques for the detection of heavy metals in the atmosphere. The current status of work in the direction of atmospheric monitoring and comparison of LIBS with other techniques will be discussed in detail at the conference.

References:

[1] Ramesh P. Singh, Akshansha Chauhan, Chapter 1 - Sources of atmospheric pollution in India,
Asian Atmospheric Pollution, Elsevier, 2022, Pages 1-37, ISBN 9780128166932.

[2] Sah, D., Verma, P. K., Kandikonda, M. K., & Lakhani, A. (2019). Pollution characteristics, human health risk through multiple exposure pathways, and source apportionment of heavy metals in PM10 at Indo-Gangetic site. Urban Climate, 27, 149-162.
[3] Qu, Y., Zhang, Q., Yin, W., Hu, Y., & Liu, Y. (2019). Real-time in situ detection of the local air pollution with laser-induced breakdown spectroscopy. *Optics Express*, *27*(12), A790-A799.

Generating Fast Protons From A Plasma Sphere Having Density Gradients With Short-Pulsed Laser Irradiation

Ankita Bhagawati*, Nilakshi Das

Department of Physics, Tezpur University, Tezpur, Assam, India 784028

E-mail*: ankita8@tezu.ernet.in

Abstract

The generation of fast ions by impinging an intense laser pulse on a plasma target require further studies on the final energy enhancements and beam controllability. These short laser pulses are usually preceded by low-intense nanoseconds-long pre-pulses [1]. The purpose of the present study is to increase the laser energy absorption inside the plasma target by tailoring the plasma density distribution and the pre-pulse might be utilized to create the required smooth density gradient in the plasma. The target used here is a micrometre-sized hydrogen sphere having a slightly over-dense peak density at the centre of the sphere that drops radially outwards following a Gaussian density distribution. 3D PIC simulations are performed to study the plasma density effects on the proton dynamics. A number of acceleration processes were identified which are crucial in controlling the maximum energy and divergence of the proton bunches [2]. The resultant proton energies are found to have a strong dependence on the density gradient. A strongly collimated proton bunch having mean energy of 102 MeV is observed for the optimal case with laser intensity $\sim 10^{20}$ Wcm^{-2} and peak laser energy ~ 10 J [3].

References:

[1] Optimizing laser-driven proton acceleration from overdense targets, *Sci. Rep*. **6**, 29402, (2016).
[2] Laser-accelerated protons using density gradients in hydrogen plasma spheres, *J. Plasma Phys*. **87(4)** (2021).
[3] Effect of density gradients on the generation of a highly energetic and strongly collimated proton beam from a laser-irradiated Gaussian-shaped hydrogen microsphere, *Phys. Plasmas,* **29**, 053107 (2022).

Effect of Fröhlich Coupling Constant on the Performance of Cost Effective Modulators

AyushiPaliwal*, SwatiDubey

Vikram University, Ujjain, M.P.

*ayushipaliwal.paliwal@gmail.com

Abstract. Present study examines the effect of Fröhlich coupling constant on modulational threshold and gain characteristics of polar semicounductor plasma medium withan aim to design low cost modulators.In polar semiconductor materials, LO phonons produce a macroscopic electric field, which interacts with the electrons. This coupling of long range is known as Fröhlich interaction. The strength of this coupling is expressed by a dimensionless Fröhlich coupling constant. Value of this parameter is different for all materials which may be large or small.

Present study performs a comparative study of modulational characteristicsof different group polar semiconductorshaving different magnitudes of their Fröhlich coupling constant. We wish to find a suitable material for which higher modulational gaincould be realized at least threshold pump field with suitable values of external parameters.Analytical expressions for modulational threshold pump amplitude and growth rate of polaron mode are derived.Under the framework of hydrodynamic model and coupled mode theory a theoretical model is developed to determine threshold pump field required for the onset of modulational effects. Numerical estimations are carried out using the data of III-V GaAs and II-VI ZnS compound semiconductors.These prominent materials are assumed to be shined by a 10.6 μm CO_2 laser at 77 K so that nonlinearity could be induced in the medium. Present comparative study concludes that III-V GaAs, having smaller Fröhlich coupling constant, ismore suitable for a cost effective modulational interaction and for commercial optical communication devices as higher modulational gain is realized in this crystalat low input pump amplitude.We hope that results of the present study will contribute towardsbetter understanding and improved performance of modulator and help to design low cost modulators

Effect of Periodic Modulation of Target Surface on Ion Emission in Laser Induced Plasmas

Deepak Kumar Sahu[1], Anandam[1], C. Aparajit[1], Archit[2], M. Krishnamurthy[1,2]

1 Tata Institute of Fundamental Research (TIFR), Mumbai, 400005,
2 Tata Institute of Fundamental Research (TIFR), Hyderabad, 500046

deepak.sahu@tifr.res.in, mkrism@tifr.res.in

Abstract

Ion radiography by intense femtosecond laser induced ions have been used for very long time to estimate the source size of ions being emitted from the target surface [1]. This estimation gives information of lateral expansion of plasma in target rear [2] (non-irradiated side), electron refluxing through the target [3], estimation of TNSA field [4,5] etc.

All of the above measurements have been done in rear side of the target and very few have been done in target front (irradiated side). Here we present one such measurement which have been done by irradiating solid target (plain or grating) with very clean ultra-high contrast (better than 10^12), 400nm pulse having intensity of ~10^19 and making radiograph of ions on CR-39 detector. This 400nm beam was produced by passing 800nm beam through a frequency doubling crystal LBO and filtering 400nm only beam by using suitable optics.

The aim of the experiment was to understand the effect of periodic modulation of the target on the size of ion source which was estimated by ion radiographs by using different mesh sizes. We used Al coated BK7 glass as plain target and 3600lpi sinusoidal grating as periodically modulated target. We found that the source of ions in case of plain target is greater than that of grating target.

References :

[1] Borghesi, M., et al. "Multi-MeV proton source investigations in ultraintense laser-foil interactions." *Physical Review Letters* 92.5 (2004): 055003.
[2] Sentoku, Y., et al. "High energy proton acceleration in interaction of short laser pulse with dense plasma target." *Physics of plasmas* 10.5 (2003): 2009-2015.
[3] Buffechoux, S., et al. "Hot electrons transverse refluxing in ultraintense laser-solid interactions." *Physical review letters* 105.1 (2010): 015005.
[4] Schreiber, Jörg, et al. "Source-size measurements and charge distributions of ions accelerated from thin foils irradiated by high-intensity laser pulses." *Applied Physics B* 79.8 (2004): 1041-1045.
[5] McKenna, P., et al. "Lateral electron transport in high-intensity laser-irradiated foils diagnosed by ion emission." *Physical Review Letters* 98.14 (2007): 145001.

Plasma Current Model for Second-Harmonic generation of a Laser in a Plasma

Tapti Bhardwaj[1], Anuj Vijay[1], and Devki Nandan Gupta[2]
[1]Department of Physics, GLA University, Mathura-281406, U.P., India
[2]Department of Physics and Astrophysics, University of Delhi, Delhi, 110007, India

E-mail: tapti14@gmail.com

Abstract

Second-harmonic generation is a nonlinear optical effect in which photons interacting with a nonlinear medium can effectively generate new photons with frequency twice of the fundamental photons. The conversion efficiency basically depends on the medium nonlinearity. In this work, we emphasize a different model for second-harmonic generation of laser, which is based on plasma current generation in a tunnel ionizing gas. The fast electrons accelerated by the laser pulse generate a dynamic plasma current. Using computational fluid simulations, we then estimate the second-harmonic radiation field and the corresponding scaling laws of the process. Providing a simple method of optimization and controlling the second-harmonic field, our approach paves the way to new model strategy for nonlinear optical devices.

Langmuir wave aided Resonant Laser Beat Wave THz generation in a Plasma channel

Arnika Sharma[1], Krishna Gopal[2] and A. Vijay[1]
[1]Department of Physics, GLA University, Mathura-281406, India
[2]Department of Physics and Electronics, Rajdhani College(University of Delhi) Raja Garden New Delhi, Delhi -110015, India
Email: anujvijay@gmail.com

Abstract

Phase matched (THz) generation by non- linear mixing of two laser in a plasma channel is investigated. An electrostatic wave mediates in the non- linear process and provides phase matching. The TM mode lasers impart a beat frequency pondermotive force on electrons, giving then an oscillating velocity. The non- linear velocity beats with the density perturbation, associated with the electrostatic wave to produce a non-linear current, driving TM mode THz radiation. The non-local effects reduce the power conversion efficiency.

RADIALLY POLARIZED TERAHERTZ (THZ) RADIATION GENERATION: SCALING OF THz

Manendra[1] and Anil K Malik[1]

[1]*Department of Physics, Chaudhary Charan Singh University Meerut, UP-250004, India*

E-mail : manendrac@gmail.com

Abstract

We propose a theoretical model based on difference frequency generation in periodic density plasmas for bright, radially polarised terahertz (THz) generation. Our model incorporates the initial phase difference between two lasers. It has been found that the initial phase difference significantly affects THz field variation. Additionally, it is also observed that the periodic plasma density structure parameters (such as amplitude n_γ and wave vector γ) affect the THz field and efficiency. We also found that Peak THz fields$\sim$15 GV/m can be obtained for laser fields as $\sim 5 \times 10^{10}$ V/m close to the phase matching condition. We also found that the laser field profile parameters can be used to control the THz field distribution. The laser field profile and plasma parameters can be optimised to achieve the conversion efficiency of 0.01. High field and radially polarised THz can be obtained using our model to meet the demands of THz-matter interactions, nonlinear THz spectroscopy and imaging etc [1]. Radially polarised THz fields are also useful for penetrating deeply into the layers of the skin with less risk of collateral damage, resulting in improved treatment safety and efficacy [2].

References :

[1] X. C. Zhang, A. Shkurinov, and Y. Zhang, Nat. Photon. **11**, 16(2017).
[2] B. Varghese, S. Turco, V. Bonito, and R. Verhagen, Opt. Exp. **21**, 18304(2013).

Efficient Harmonic Generation in a Tunnel-Ionizing Plasma

Mamta Singh

Department of Physics, Shivaji College, University of Delhi, New Delhi-110027

E-mail: mamtasingh@shivaji.du.ac.in

Abstract

We report the generation of efficient second and third harmonics in laser-produced tunnel ionizing plasma. Tunneling happens when a sufficiently high-intensity laser pulse interacts with a neutral gas which subsequently generates free electron plasma density which is varying with time. We have numerically estimated the effect of electron-ion recombination on second and third-harmonic field generation during laser interactions with a neutral gas. The recombination is a dominant process of electron removal from an ionized gas for an appropriate laser pulse duration. Thus, the inclusion of electron-ion recombination is necessary for the exact estimation of second and third-harmonic fields in laser-plasma interaction. In the presence of electron-ion recombination, laser intensity increases due to laser periodic focusing. This is due to the reason that laser intensity distribution is nonuniform, so, the recombination is expected to be more on the axis of propagation and decreases radially away from the axis. So, the refractive index will get modified accordingly. Hence, the gas ionization due to the nonuniform intensity profile and the electron-ion recombination both factors lead to modifying the background electron density. The significant density modification contributes to the enhancement of second and third harmonic field amplitudes.

References :

[1] P. Kaw, Rev. Mod. Plasma Phys.**, 1,** p 1–42, (2017)
[2] M. D. Perry and G. Mourou, Science, **264,** p 917–24, (1994)
[3] M. Singh and D. N. Gupta, Laser Phys., **32,** p 085001 (8pp), (2022)

Self-Focusing of a Bessel Gaussian Laser Beam in an Inhomogeneous Plasma

Nidhi Pathak[1], Sukhdeep Kaur[1,a)] and T.S. Gill[1]

[1]Department of Physics, Guru Nanak Dev University, Amritsar, India, 143005
[a)] sukhdeep.iitd@gmail.com

This paper presents an investigation of self-focusing of a Bessel Gaussian laser beam in an inhomogeneous plasma by considering the ohmic nonlinearity into account. An envelope equation is derived for suitable laser plasma parameters by employing moment theory approach. The laser beam is meant to excite the density profile of plasma, which further leads to phenomena of self-focusing. The beam experiences self-focusing/ defocusing for specific important set of parameters including plasma density, laser beam intensity and transverse component. The repercussions are highly applicable in high harmonic generation, X-ray generation and inertial confinement fusion.

A Nomarski based interferometer for the investigation of Laser Produced plasmas generated by Femtosecond Laser pulses

Tomis Prajapati, Sonu Meena, and V. Narayanan

Affiliation: Indian Institute of Technology Jodhpur 342037, India

E-mail: tomis.1@iitj.ac.in, vnara@iitj.ac.in

Abstract

Laser produced plasmas (LPP) and plasma channels produced by pulsed laser have attracted considerable interest in this field in the recent past [1,2]. Plasma channeling finds its application in laser wakefield accelerators, high harmonic generation, and advanced laser fusion schemes [3]. The pulsed-laser breakdown of air has been investigated extensively for many years because of its potential applications in remote sensing and communication [4].

However, in the plasma channel the recombination between electrons and ions decreases radial electron density gradient which limits the channel life time, and hence make it unsuitable for the practical applications, which require channels not only long in terms of distance but also longer life-times. Thus, in plasma channel, for guiding a intense laser pulse, it is imperative that probe pulse be sent through the pre-formed plasma with controlled delay with respect to plasma creating pulse such that it enhances the radial electron density gradient and suppresses the recombination processes in the plasma. Thus, increase in life-time of plasma can be observed under suitable time delay between pre-formed plasma and a probe pulse for heating. The choice of the probe pulse for heating requires the complete characteristics of pre-formed plasmas and pre-formed plasmas are routinely characterized by interferometric methods. In this investigation, we report the plasma density via Nomarski Interferometer, while the plasma generation using femtosecond pulses. We record the interferogram at different pico-second time intervals.

It may be worth noticing that researchers have observed ten times enhancement in the life time of the plasma channel in air as compared to the single pulse case using femto-sec and sub nano-sec laser pulses [7,8].

References:

[1] C. G. R. Geddes, Cs. Toth, J. van Tilborg, E. Esarey, C. B. Schroeder, D. Bruhwiler, C. Nieter, J. Cary, and W. P. Leemans, Nature 431, 538 (2004).

[2] X. F. Li, A. L' Huillier, M. Ferray, L. A. Lompre, and G. Mainfray, Phys. Rev. A 39, 5751 (1989).

[3] J. Kasparian, M. Rodriguez, G. Me´jean, J. Yu, E. Salmon, H. Wille, R. Bourayou, S. Frey, Y. B. Andre´, A. Mysyrowicz, R. Sauerbrey, J. P. Wolf, and L. Wo¨ste, Science 301, 61 (2003).

[4] A. Pukhov and J. Meyerter-Vehn, Phys. Plasmas 5, 1880 (1998).

[5] C. G. Durfee III, J. Lynch, and H. M. Milchberg, Phys. Rev. E 51, 2368 (1995); Opt. Lett. 19, 1937 (1994).
[6] J. Ruiz-Camacho, F. N. Beg, and P. Lee, J. Phys. D: Appl. Phys. 40, 2026 (2007).
[7] V. Narayanan, V. Singh, P. K. Pandey, N. Shukla, and R. K. Thareja, J. Appl. Phys. 101, 073301 (2007).
[8] Air plasma waveguide using pico-sec and nano-sec laser pulses, Pramod K. Pandey, Shyam L. Gupta, V. Narayanan, and Raj K. Thareja, Phys. Plasmas 19, 023502 (2012)

Spatial Dynamics Of Terahertz Generation Of Lower Order Bessel-Gaussian Laser Beam In Plasma

Aman Bhatia[1], Manya Dawra[1], Keshav Walia[2], Arvinder Singh[1]

[1] *Dr. B R Ambedkar National Institute of Technology, Jalandhar Punjab 144027*

[2] *DAV University Jalandhar, Punjab 144012*

E-mail : amanb.ph.19@nitj.ac.in, manyadawía0@gmail.com, keshavwalia86@gmail.com, arvinders@nitj.ac.in

Abstract

The objective of the present study is to explore spatial dynamics of Terahertz generation of Lower Order Bessel-Gaussian Laser Beam in Plasma. Here, relativistic nonlinearity is considered in the present investigation. The relativistic nonlinearity causes an increase in the mass of electrons therebycausing variation in plasma's relativistic mass and hence leading to self-focusing of the beam. The strong intensity gradients get established in the plasma due to relativistic nonlinearity thereby exciting electron plasma wave (EPW). Excited EPW interacts with the main beam and hence produces Terahertz radiations in plasma. Well-known WKB approximation and method of moments are used for establishing non-linear differential equations for the laser beam's spot size and expression for THz yield. The results of the current investigation have led to the conclusion that the transverse wave parameter, normalized laser intensity, and plasma density have a major impact onthe laser beam's ability to produce THz.

- 346_PLASMA_SHIELDING_EFFECT_ON_HYDROGEN_ATOM_IN_INTENSE_LASER_FIELD
- 387_Hydrodynamics_of_Laser-Induced_Air_Plasma_Interaction_with_Plane_and_Structured_Aluminum_Surface

Pulsed Power

Point projection radiography of slow current driven exploding wire plasma using microsecond X-pinch

S.C. Andola, A.C. Jaiswar, and K.D. Joshi

Applied Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India, 400085

Email: scandola@barc.gov.in

Abstract

The electrically exploding wires (EEW's) found their application in various areas of high energy density physics including shock wave and EOS studies, nano-particle generation and laboratory astrophysics [1,2]. The study of dynamics of the EEW at the initiation and expansion stage is necessary for their application in shock and fusion studies. Due to ~µm source size and ns pulse width, x-pinches can be used to elucidate the plasma formation and the dynamics of EEW at the burst and post burst stages. In this work, we report on radiographic investigations carried out to understand the dynamics of Cu exploding wire plasma produced by a slow rising current. A compact slow current (max. 0.11kA/ns) driven X-pinch [3] made of metallic wires has been used for radiography of the exploding wire mounted in one of the return current conductor. Copper wires of 43µm and 60µm diameter exploded on a current of 10-21 kA/1µs have been radiographed at different instances. The core-corona structure is observed at post burst stages of these EEWs. In thin wires, the core is seen moving uniformly at higher current (21kA). The wire core is seen to expand non-uniformly along the length when the current is lower. The velocity of the core is observed to be >1.5km/s at 21 kA/1µs current. The 60 µm Cu wire in low current (~10kA/1µs) doesn't seem to explode uniformly along entire length but a few locations. The explosion sites form droplet like structures called unduloids. The study infers that the compact x-pinch system on <0.1kA/ns driver can be used for similar applications to understand the transient events formed in HED plasmas. The details of the system and obtained results on point projection radiography of EEW will be discussed in the presentation.

References

1. W. Mellor, et al., Experimental Techniques 44.2 (2020): 241-248.
2. Yu A. Kotov, Journal of nanoparticle research 5.5 (2003): 539-550.
3. S. C. Andola, et.al., Journal of Physics D: Applied Physics, 55 (2022), p.22520.

Studies of Dielectric Fiber Z-pinch on Moderate Energy Capacitor Bank

Jigyasa Batra, Ashutosh Jaiswal, Alok K. Saxena and K.D. Joshi

Bhabha Atomic Research Center, Trombay, Mumbai,400 085

E-mail: jigyasa@barc.gov.in

Abstract

Z-pinches of dielectric fibers have been subject of investigation in last few decades; pertaining to interest in thermonuclear and radiative plasma research; using deuterated polymer and carbon fibers for generation of pulsed neutrons and x-rays respectively. These experimental studies were carried out on high energy capacitor banks (5 kJ-200 kJ) with higher current rates in range of ~1 kA/ns-20 kA/ns [1]. Later, a few studies were carried out on moderate energy capacitor banks (~1 kJ) with carbon fibers for generation of pulsed X-rays [1]. Present study focuses on polymer based dielectric fiber pinch studies using moderate energy (~1.2 kJ) capacitor bank with current rate of around ~0.1 kA/ns aiming for implementing the same for producing high density plasma of deuterated polymer. In present work, behavior of electrical ablation of polymer fibers have been studied. Polyester or poly (ethylene terephthalate) polymer has been used in this experimental study. Effect of varying lengths (7-20 mm), diameter (7-285 micron), surrounding medium (in air at atmospheric pressure & vacuum at 1 x 10^{-4} mbar) and configuration (Single strand & in form of X) on electrical characteristics (voltage, current and rate of change of current) of plasma have been studied to understand the dynamics involved in implosion as well as in its ablation. Results indicate that surface discharge along the length of fiber is capable of ablating it in air but not in vacuum. Possible reason could be the interaction of adsorbed gases with impact ionization process in vacuum which causes to increase required voltages for surface flash over [2]. This might have resulted in weaker discharge channels just along the surface in vacuum. In air, where fiber ablation seems to happen, experimental results show that there is a threshold of length as well as diameter for creating sufficient surface current density to ablate the fiber. This threshold value for length is <10 mm and diameter is <280 micron for present capacitor bank parameters for which ablation of polyester fiber is observed in spite of configuration of fibers. Present study finds relevance in surface flash over studies in polyester dielectric fibers with pulsed voltages as well as in thermonuclear fusion studies if deuterated polymer fibers are used based upon behavior of present polymer fibers.

References:

[1] The Study of a Fibre Z–Pinch, Thesis, Daniel Klir, Czech Technical University in Prague, p 23-25, (2005).
[2] Synergic effect of adsorbed gas and charging on surface flashover, Shengtao Li et al., Scientific Report, Nature, 9:5464, (2019), https://doi.org/10.1038/s41598-019-41961-0.

Finite-element simulations to study material response during electromagnetically-driven isentropic compression experiments using pulsed power systems

Ankur Chowdhury, Alok K. Saxena, Koushik Bhattacharya and K.D. Joshi
Applied Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai-400085
E-mail: ankurc@barc.gov.in

Abstract

Electromagnetically-driven dynamic compression experiments using pulsed power systems has emerged as an efficient and useful technique for ramped compression of material samples to study their off-Hugoniot response[1]. High repeatability and pulse-tailorability are two important advantages that have led to the popularization of this technique in the last two decades.

An electromagnetically-driven isentropic compression experiment (ICE) consist of a strip-line (ICE) load of two parallel electrodes shorted at one end[2]. A fast-rising (order of several hundred nanoseconds), high magnitude (few Mega-amperes) current pulse, generated by a pulse power system, is passed through these electrodes. The resultant high magnetic pressures (JXB) generated by the current discharge drives a compression wave in the electrodes. A material sample of optimized dimensions is mounted on the rear surface of these electrodes to study their high-pressure behavior. Careful design of load geometry is essential to ensure isentropic loading of material samples and faithful conduction of ICE experiments[2], [3] respectively.

Accurate simulation of electromagnetic-loading of ICE loads is a complex phenomenon which involves a coupled solution of a number of physics interfaces viz. electric circuit analysis, Maxwell's equations, non-linear heat-diffusion equation, non-linear structural mechanics equation using various plasticity models etc., among others. This, coupled with the complex nature of the load geometry, requires the use of finite-element (FE) numerical technique for accurate simulation of ICE load subjected to a high current pulse.

In present work, COMSOL Multiphysics® 5.5 [4], a commercially available FE software, has been used to simulate electromagnetically-driven ICE experiments on an ICE load. A pulsed current of magnitude 1 MA and rise-time 900 ns is generated from solving an LC-discharge based pulse power circuit and fed to the load geometry. Temporal variation of various parameters; like magnetic field, current density, temperature, internal stress, displacement, velocity etc. as a function of time; have been obtained using these studies which have given a better understanding of the dynamics involved in ICE experiments. Various conductivity models as well as plasticity models have been employed in order to improve the accuracy of the simulations. Results of this simulation model show high conformity with the published simulation results [2].

References:

[1] R.D. McBride et al., "A Primer on Pulse Power and Linear Transformer Driver for High Energy Density Physics Experiments," IEEE Trans. Plasma Sci., Vol. 46, No. 11, November (2018).

[2] D.G. Tasker, C.H. Mielke, G. Rodriguez, and D.W. Rickel, “Isentropic Compression Studies at the Los Alamos National High Magnetic Field Laboratory”, Jun 2011, Los Alamos National Laboratory, WX-6, MS J566 Los Alamos, NM 87545, USA.
[3] Rothman, J P Davis, J Maw, C M Robinson, K Parker and J Palmer, “Measurement of the principal isentropes of lead and lead–antimony alloy to ~400 kbar by quasi-isentropic compression”, J. Phys. D: Appl. Phys. 38 (2005),733–740.
[4] COMSOL Multiphysics® 5.5.

EFFECT OF SF_6 CONCENTRATION ON SWITCHING PERFORMANCE OF A TRIGGERED SPARKGAP SWITCH IN HIGH PRESSURE SF_6 ADMIX

Vinod Kumar Gandi[1,2], Rishi Verma[1,2], Manoj Kumar Warrier[1,3], Gurusharn Singh[3], J Balu Naik[2] and Archana Sharma[1,2]

[1]*Homi Bhabha National Institute, Mumbai 400085, India*
[2]*Pulsed Power & Electromagnetic Division, Bhabha Atomic Research Centre, Visakhapatnam 531011*
[3]*Computational Analysis Division, Bhabha Atomic Research Centre, Visakhapatnam 531011*

E-mail: gvinod@barc.gov.in

Abstract

Plasma Closing Switches (PCS) are one of the key components used in high energy density pulsed power systems to generate high voltage and high-power impulse. As SF_6 is greenhouse gas, many researchers have endeavored to investigate the discharge and switching characteristics in binary mixtures of SF_6. This paper reports on the investigation of the switching characteristics of various volumetric concentrations of SF_6 in SF_6/N_2, SF_6/dry air and SF_6/Ar. The switching experiments have been carried out in indigenously developed co-axial sparkgap switch with corona discharge electrodes for a charging voltage of 0.8XSelf-Breakdown Voltage (V_{SBV}) by using a fast-raising trigger pulse (dV/dt = 4 kV/ns). From experimental work, breakdown delay times (t_d) and jitter were found to be strongly dependent on the % by vol of SF_6 for e.g. in SF_6/N_2 as % SF_6 varied 5-50% the t_d increased from 178±4.8 ns to 200 ±7.2 ns. The obtained breakdown delay times (t_d) was subjected to Weibull statiscal analysis to compare the reliability of switch. Furthermore, the electrode erosion and aging process of sparkgap under microsecond arc discharge in various SF_6 admix has been investigated. For a net charge transfer (Q~2 C), electrode erosion rate increased by ~300% as % by vol. of SF_6 increased from 5% to 50% in SF_6/N_2 admix.

References:

[1] Y.-J. Chen, J. J. Mankowski, J. C. Dickens, J. Walter, and M. Kristiansen, "Low-Jitter Triggered Spark Gap With High-Pressure Gas Mixtures," *IEEE Trans. Plasma Sci.*, vol. 36, no. 5, pp. 2546–2553, 2008, doi: 10.1109/TPS.2008.2004366.

[2] Y. Yao, I. V Timoshkin, S. J. MacGregor, M. P. Wilson, M. J. Given, and T. Wang, "Breakdown Characteristics of Plasma Closing Switch Filled With Air, N_2, CO_2, and Ar/O_2," *IEEE Trans. Plasma Sci.*, vol. 46, no. 10, pp. 3574–3583, 2018, doi: 10.1109/TPS.2018.2856306.

Design, Simulations and Experiments of Optimized Faraday Cup Measurements of Coaxial Plasma Source

Kanchi Sunil[1], Rohit Shukla[1,2], Archana Sharma[1,2]

[1]*Homi Bhabha National Institute Mumbai-400094,*
[2]*Pulsed Power & Electro-Magnetics Division, Bhabha Atomic Research Centre Facility, Atchutapuram, Visakhapatnam, Andhra Pradesh, India-531011,*

E-mail: sunilkanchi8125@gmail.com

Abstract

Many plasma experiments require suitable diagnostics for the measurement of plasma density, plasma velocity, and temperature [1]. Faraday cup is one of the most used devices for measuring the beam current of charged particles but optimizing for a specific set of experiments is a challenging task [2]. Faraday cup measurements were used in a wide range of applications including plasma focus devices, accelerators, ion sources, etc [1, 3-4]. In this paper, the Faraday cup is designed, simulated, and optimized for measuring the plasma density and characterization of the cable plasma guns used in plasma opening switch experiments. The plasma velocity is measured using the time of flight and two Faraday cup methods and a comparison is reported. The plasma temperature is estimated using the measured values of plasma density and velocity. During the experiments, the vacuum chamber is evacuated to ~10^{-4} torr.

References :

[1] W. Lochte-Holtgreven, “Plasma diagnostics”, North-Holland, 1968.

[2] A. Kashefian Naieni et al, Design and study of an enhanced Faraday cup detector, *Vacuum*, 83 pp. 1095–1099, 2009.

[3] Vahid Damideh *et al,* Fast Faraday cup for fast ion beam TOF measurements in deuterium filled plasma focus device and correlation with Lee model, *Physics of Plasmas*, 24, 063302, 2017.

[4] Bravin, E., *et al*. Optimization of a Short Faraday Cup for Low-Energy Ions using Numerical Simulations. No. CERN-BE-2014-015. 2014.

DESIGN [1], FABRICATION, TESTING, INSTALLATION AND COMMISSIONING OF EXHAUST SYSTEM FOR TRITITUM HANDLING AND RECOVERY SYSTEM OF ACCELERATOR BASED 14 MeV NEUTRON GENERATOR

Sudhir Tripathi[1], Manoj K. Gupta[1, 2], Mitul Abhangi[1], Sudhir Vala[1], H.L.Swami[1],

[1]Institute for Plasma Research,Bhat, Gandhinagar 380005,India

[2]Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India

E-mail: tripathi@ipr.res.in

Abstract

Tritium Handling and Recovery System (THRS) is a very important system attached with Accelerator based 14 MeV Neutron generator facility at IPR. THRS not only handles the radioactive Tritium gas but also recovers the Tritium gas so as to minimize the exhaust to environment at well below the permissible limits prescribed by the regulator.

The Exhaust system is very critical and attached with the outlet of THRS to release permitted Tritium gas to the environment in an organized manner. The salient design [1] features of the exhaust system described in this poster are very low maintenance of the exhaust fan, controlled flow and pressure of exhaust gas, ease of maintenance of pipe line and other components, drain line provision etc. Apart from the design features the poster will mainly be covering the major achievements and challenges of Fabrication, Testing, Installation and Commissioning of the Exhaust system at IPR.

References:

[1] Design of Exhaust system for Tritium Handling and Recovery system of Accelerator based 14 MeV Neutron generator- IPR-Technical Report –TR-685, Dt. 05-05-2022

STUDIES ON SPATIAL EVOLUTION OF PULSED HELIUM PLASMA

S. Singha, A. Ahmad, N.K. Neog, T.K. Borthakur

Centre of Plasma Physics, Institute for Plasma Research, Sonapur-782402, Kamrup (M), Assam, India

E-mail: sumit.singha@cppipr.res.in

Abstract

A helium pulsed plasma is produced in a pulsed plasma accelerator powered by 200 kJ pulsed power system. In general, it possesses high density, high velocity as well as high energy density. Due to this characteristics of the stream, it has drawn an interest for plasma surface interaction relevant to fusion research. Moreover, it is a potential source for probable plasma applications such as thruster application, basic studies of high-speed plasma, material plasma deposition, for generation of various radiation sources such as X-Ray and UV, plasma bubble formation, etc. In this study, a mapping of the plasma stream in terms of density and temperature in Helium medium is carried out by using electrostatic probe. Imaging of plasma stream is also performed by using high speed video camera to understand the spatial evolution of plasma. The preliminary results show that the plasma density is maximum at centre of the plasma plume and it decreases towards the periphery, while an opposite trend is observed in case of plasma temperature. Furthermore, some denser regions are also observed, which may be due to the generation of shock wave.

References :

[1] S. Kajita and W. Sakaguchi and N. Ohno and N. Yoshida and T. Saeki, Nuclear Fusion, 49, 095005(2009).
[2] A.I. Morozov, Fizika Plazmy 16,131-146 (1990).
[3] I. E. Garkusha and O. V. Byrka and V. V. Chebotarev and N. T. Derepovski and Gregor M ̈uller and Gustav Schumacher and N. S. Poltavtsev and V. I. Tereshin, Vacuum, 58, 195-201(2000)

Conceptual Design of Prototype Pulsed Alternator

Rambabu Sidibomma, Prasad Rao Pedada, Ankur Jaiswal, YSS Srinivas and E Rajendra kumar

Affiliation: Institute for Plasma Rsearch,Bhat, Gandhinagar,Gujarat-382428

E-mail: rambabu@ipr.res.in

Abstract

Compact prototype development of radial flux Pulsed Alternator is conceived in Phase-2. Flywheel driven Pulsed alternators are used for the short pulse high energy need applications. The main components of Pulsed Alternator are composite Flywheel with permanent magnets, AC Servomotor with Variable Frequency Drive, High speed Bearings, Shaft and stator with coils. Flywheel is basically a device to store kinetic energy. Kinetic Energy is stored in the flywheel over longer durations to the speed of 9000 RPM driven by low power Servomotor. Low vacuum housing is planned to reduce air frictional loss and same can be used as debris containment in case of failure. The coils have been simplified in the present design with low inductance to achieve very short pulse duration in milliSecond (mS). Flywheel's main characteristic compared to other systems is its capability to release high energy in very short periods of time with high repeatable cycle, for which flywheels have traditionally been used in shearing machines. Rotors are being made out of Stainless steel rim compounded by Carbon composite materials, resulting in a substantial increase in energy density storage capability due to higher speed of operation.
Conceptual design of Prototype development of 9000 rpm radial flux Pulsed Alternator system and design parameters would be presented in this poster.

References:

1. "Design and Analysis of a High-Speed Permanent Magnet Compensated Pulsed Alternator" by Shaopeng Wu, Member, IEEE, Songlin Wu, Shumei Cui, and Weiduo Zhao

Discharge Analysis and Switching Characterization of High Power Pseudospark Switches for Fast Pulsed Power Applications

Akhilesh Mishra[1,2], Varun[1,2], Shikha Misra[1], Abhijit Ravindra Tillu[3], Bharat Lal Meena[1], Alok Mishra[1], Ram Prakash Lamba[1,2] and Udit Narayan Pal[1,2]

[1]*CSIR- Central Electronics Engineering Research Institute, Pilani, Rajasthan-333031*
[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh-201002*
[3]*Accelerator and Pulse Power Division, Bhabha Atomic Research Centre (BARC), Mumbai-400085*

E-mail: akhileshmishra056@gmail.com/udit@ceeri.res.in

Abstract

The pseudospark switches (PSS) are special kind of cold cathode switches having higher power handling capabilities with higher hold-off voltages, higher current and fast switching characteristics, and are potentially used for better performance of fast pulsed power systems[1]–[3]. The PSS mainly consists of trigger unit, discharge gap, hollow cathode-anode, and apertures for commutation of the discharge. Efforts have been made to improve the switching characteristic of the high-power multi-aperture PSS by using a saturable inductor in series with anode. The saturable inductor resulted in the reduction of commutation losses by delaying the discharge current and also eased the discharge processes[4]. The temporal and spatial evolution of the discharge has been simulated to investigate the discharge phenomenon[5]. A ferroelectric trigger excited by pulse circuit has been used to initiate the discharge for fast switching. The pulse circuit has been simulated using MATLAB to generate required trigger pulse output of ~-8kv with rise time of ≤ 5ns[6]. The rise time of the designed pulse generator is too fast which could be very useful for the reduction in delay and jitter of the system during discharge operation. Such quantitative and qualitative investigations would be very much useful for the design and development of efficient PSS for fast pulsed power applications.

References:

[1] K. Frank et al., *IEEE Trans. Plasma Sci.*, **17**, 748–753, 1989.
[2] U. N. Pal et al., *IEEE Trans. Electron Devices*, **67**, 5600–5604, 2020.
[3] R. P. lamba et al., *Psst*, **27**, 035003, 2018.
[4] A. Mishra et al., *IEEE Trans. Electron Devices*, **69**, 5879–5885, 2022.
[5] Varun et al., *IEEE Trans. Electron Devices*, **67**, 1793–1796, 2020.
[6] J. Yan et al., *Rev. Sci. Instrum.*, **89**, 065102, 2018.

Design of Two Channel Coaxial Current Transformer for Microsecond Rise Time High Current Applications

Sanjay Singh, A. K. Saxena, A. M. Rawool, S. C. Andola and K.D. Joshi

Applied Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai-400085, India

Email: sanjay@barc.gov.in

Abstract

High voltage energy storage capacitor banks are commonly used as energy source in various pulse power applications where, high operational voltages are applied to generate high pulse currents. However, for certain applications driven by pulse magnetic fields such as electromagnetic projectile launchers [1], electromagnetic welding [2] and metal forming etc. high pulse current along with long rise time is required without much stringent requirement of high voltages. Long rise time of current pulse is normally achieved by using a pulse inductor in series to capacitor bank but at the cost of reduced peak current. High pulse current can be achieved by current step-up transformer [3].

In present work, a two-channel air cored co-axial pulse transformer have been designed and numerically optimized in COMSOL® Multiphysics software for shaping the current pulse without compromising the peak current and with desired output voltage. At present it is designed to have two output channels, but in principle it may have multiple output channels also which may be used separately or may be connected in parallel to enhance the total current depending on the application. Based on this design a transformer with two isolated output channels has been developed and tested with a 0.6 mF capacitor bank. It is found to generate a total output current of 121 kA at an input current of 65 kA of rise time 60 μs at 12.5 kV charging voltage.

More elaborations on design optimizations and experimental results shall be discussed in the presentation.

References

1. Y. Liu *et al.*, *IEEE Trans. Plasma Sci.*39, pp.304-309, (2011).
2. P. C. Saroj et al., *BARC Report: BARC/2012/I/021* (2012).
3. J. A. Pappas*et al.*, *IEEE 5th pulse power conference,PR-30*,Arlington, Virginia (1985)

A DOUBLE-BARREL ELECTRIC GUN SYSTEM FOR LOW AMPLITUDE SHOCK STUDIES

Koushik Bhattacharya, Alok Kumar Saxena, Mamta G. Sharma and K. D. Joshi

Applied physics Division, Bhabha Atomic Research Centre, Mumbai – 400085

E-mail: koushikb@barc.gov.in

Abstract

An electrically exploding foil accelerator, also known as electric gun [1], is a simple, economical, and compact device used to produce planar shock waves for studies related to equation of state [2] and hydrodynamics. It is desirable for any shock-generating system to probe a wide range of pressures for a comprehensive study of material behavior. However, in a conventional electric gun system, the inherent pressure generated by the electrical explosion of metallic foil restricts the minimum achievable flyer velocity, which limits the system's capability to achieve low impact pressures. Present work addresses this issue to increase the domain of applicability of the electric gun system towards low dynamic pressures. The conventional exploding foil geometry (where foil plasma directly accelerates the flyer) is modified to accommodate an additional expansion barrel between the exploding foil and flyer. The expansion barrel allows the plasma generated from the electrical explosion of foil to expand and spend its energy in the adiabatic expansion before accelerating the flyer, thus, reducing the pressure to drive the flyer and subsequently reducing the impact velocity. Experiments are performed on a 10.8 kJ capacitor bank with a current of 120 kA peak and rise time of 1 μs. An in-house developed Fabry-Perot velocimeter [3] is used to measure the flyer velocity profile for various expansion barrel configurations. From the velocity profiles obtained, velocities achieved at a distance of 1 mm from the initial flyer location are considered for comparison of different expansion barrel lengths. As the length of the expansion barrel increases, a distinct trend toward velocity reduction is observed. In contrast to the conventional single barrel system, where flyer velocity is measured to be 2.60 km/s; the use of double barrel resulted in a velocity of 1.68 km/s using an expansion barrel of length 4.96 mm. Nevertheless, the double barrel system is found to reduce the velocity by 35% compared to a single barrel system with a much smoother flyer travel. The details of experiments and analysis of results will be discussed at the conference.

References:

[1] H. H. Chau *et al.,* Rev. Sci. Instrum. **51**, 1676 (1980).
[2] G. J. Wang *et al.*, Rev. Sci. Instrum., **82**, 095105 (2011).
[3] A. K. Saxena *et al.,* BARC Report No. BARC/2007/E013 (2007).

Plasma Processing

Plasma Interaction with Tumor tissues associated with drug resistant epilepsy (DRE) Pathologies

[1]Akshay Vaid, [3]Yogesh Aggarwal, [1,2]Ramkrishna Rane, [1]Anand Visani, [4]Aparna Dixit, [3]Ramesh Doddamani, [3]Manjari Tripathi, [3]P.Sarat Chandra, [1,2]Alphonsa Joseph, [3]Jyotirmoy Banerjee

[1]Institute for Plasma Research, Bhat Gandhinagar, Gujarat-382428
[2]Homi Bhabha National Institute, Anushaktinagar, Mumbai, Maharastra-400094
[3]All India Institute of Medical Sciences, New Delhi-1100029
[4]University of Delhi, Delhi-110007

E-mail : akshay@ipr.res.in

Abstract

Epilepsy is the commonest neurological disorder (next only to headache) that affects a large population in India (approximately 12 million). Despite the availability of new antiepileptic drugs (AEDs), ~20%–30% of people with epilepsy will not be seizure free and are said to have drug resistant epilepsy (DRE). Dysembryoplastic neuroepithelial tumors (DNET) and Ganlioglioma (GG) are the two most common tumor associated DREs and are often described as a low-grade tumor. The most common course of treatment of DNET and GG is resective surgery. In order for the seizures to completely be stopped the tumor needs to be completely removed and incomplete resection leads to surgical failure. Therefore, new therapeutic applications are required for complete removal of tumors with minimal damage to the surrounding tissue. Previous studies show promising results of cold atmospheric plasma (CAP) treatment in various cancerous cell lines including gliomas.

In this work, we studied the effect of Atmospheric Pressure Plasma Jet (APPJ) on the tumor associated drug resistant epilepsy. APPJ is directed to be put on tumor tissues and the measurement of reactive oxygen species (ROS) and reactive nitrogen species (RNS) are done. Also the effect of plasma treatment time, voltage, tissue thickness, flow rate on the production of ROS is studied. The in-vitro effects of APPJ on resected brain tissues from DNET/GG patients are compared with the non-tumorous epileptic brain tissues (as controls) resected from epilepsy surgery patients with like focal cortical dysplasia (FCD).

Studies on Microbial Inactivation Using Plasma Sterilization

Tejal Barkhade[1], Kushagra Nigam[1], G. Ravi[1], Seema Rawat[2] and Sudhir Kumar Nema[1]

[1]Institute for Plasma Research, Gandhinagar- 382428, Gujarat, India
[2]Central University of Gujarat-382030, Gujarat, India

E-mail: tejal.barkhade@ipr.res.in

Abstract

Healthcare Associated Infections (HAIs) can be spread through any equipment used during medical and surgical treatment in hospitals. Therefore, sterilization or disinfection of this equipment must be achieved before any such treatment. While many conventional techniques are available to achieve the disinfection, they suffer from many disadvantages. In order to overcome these, novel techniques involving the use of plasma are emerging. Many earlier laboratory scale plasma experiments have clearly shown effective sterilization of the micro-organisms. The current work focuses on the use of plasma for the inactivation of the micro-organisms *Staphylococcus aureus* (*SA*), *Salmonella abony* (*SAb*) and *Pseudomonas aeruginosa (PA).* In this work, we investigate the underlying mechanisms and biochemical actions involved when micro-organisms are exposed to dc plasma at low pressure. As a first step, reduction in colony forming units (6-Log-CFU/ml) of the micro-organisms and 6-log reduction is established. Over-production of reactive oxygen species (e.g. H_2O_2 and $^{\cdot}OH$) on the bacterial membrane due to plasma exposure is observed using a Spectroflurometer [1]. Further, the denaturation of α-helix membrane protein is also observed using Circular Dichroism (CD) Spectrometer. In order to study the impact of plasma on genetic material of the micro-organism, UV-Visible Spectrophotometer is used. It is found that bacterial DNA concentration is decreased after plasma treatment. Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR) is then employed to study the alteration in functional groups present in bacteria due to plasma treatment [2]. The above findings pave way for better understanding of the processes and provide potential antimicrobial strategies to healthcare sectors led by plasma sterilization.

References:

[1] Antibacterial effects of low-temperature plasma generated by atmospheric-pressure plasma jet are mediated by reactive oxygen species. *Scientific reports*, 10(1), 1-11, (2020).

[2] Uncovering the inactivation kinetics of *Escherichia coli* in saline by atmospheric DBD plasma using ATR FT-IR. *Plasma Processes and Polymers*, *17*(9), 1900197, (2020)

Inactivation Effect Of Argon Cold Atmospheric Pressure Plasma Jet On Clinically Isolated Multidrug-resistant E. coli – An In-vitro Study

Sarthak Das[1*], Sarita Mohapatra[1,2], and Satyananda Kar[1,3]

[1]*School of Interdisciplinary Research, Indian Institute of Technology (IIT) Delhi, Hauz Khas, New Delhi – 110016, India*

[2]*Department of Microbiology, All India Institute of Medical Sciences (AIIMS), New Delhi – 110029, India*

[3]*Department of Energy Science and Engineering, Indian Institute of Technology (IIT) Delhi, Hauz Khas, New Delhi –110016, India*

[*]*Email id: sarthakdas.sd7@gmail.com*

Abstract

Emergence of antimicrobial-resistant (AMR) bacteria have become a major burden in healthcare facilities. Conventional antimicrobial methods have become ineffective, necessitating the development of novel approaches. In this aspect, antimicrobial studies involving cold atmospheric pressure plasma (CAP) have garnered attention. Many studies have reported the microbial killing efficacy of CAP on a wide range of bacteria. However, evaluating CAP's effectiveness against clinically isolated AMR would be more encouraging. Also, it would be insightful to identify reactive species such as reactive oxygen and nitrogen species (RONS) and ions (positive and negative) in CAP and determine their role in microbial inactivation. This study investigates the antimicrobial efficacy of a developed cold atmospheric pressure plasma jet (CAPJ) on clinically isolated multidrug-resistant *E. coli*. At an argon gas fed of 3 lpm, applied voltage 8.5 kV peak-to-peak and frequency 35 kHz, a CAP plume of length ~ 15 mm was ignited with an average discharge power of ~ 0.60 W. The bacteria were exposed to the argon CAPJ at an exposure distance of 10 mm for variable exposure time. An increase in CAP exposure time from 15 to 300 s resulted in an increase in bacterial inactivation area from 70.46 to 415.32 mm^2. The prolonged interaction of reactive species in CAP with the target on increasing exposure time might be attributed to increased inactivation efficacy. To illustrate the microbial inactivation mechanism, the presence of RONS and ions in CAP discharge was analyzed qualitatively (optical emission spectroscopy) and quantitatively (mass spectroscopy). It was observed that oxidative stress induced by RONS (O_2^-, OH^-, NO^+, OH^+, $N_2O_3^-$, $N_2O_2^-$, NO_3^-, HO_2^-, NO_2^-, etc.) and electrostatic stress by ions (Ar^+, O^+, O_2^+, O_2^-, OH^-, NO^+, OH^+, NO_3^-, HO_2^-, NO_2^-, etc.) might play a crucial role in microbial inactivation. Moreover, the CAP plume temperature was ~ 29.5 ℃, and the target temperature post 300 s CAP exposure was ~ 22.9 ℃. The above characteristics of the low plume and target temperature, low discharge power, and high antimicrobial activity of the developed CAPJ pave the path for in-vivo study with further parametric and risk assessment studies. Thus, these experimental outcomes signify the prospect of using developed CAPJ in assorted antimicrobial applications, such as sterilization, disinfection, decontamination, etc., in healthcare facilities.

Cold Plasma Seed Germination and Seedling Growth of Mung Bean Sprouts

Sushma*, Abhijit Mishra, Ritesh Mishra, Shikha Pandey, Ram Prakash

Department of Physics, Indian Institute of Technology Jodhpur, Karwar, 342030

*E-mail: sushma.1@iitj.ac.in

Abstract

The present work aimed to investigate the effect of Non-equilibrium Cold Plasma on seed germination and seedling growth of mung bean sprouts. Mung bean is a common Asian vegetable sold in public markets due to their accessibility, high nutritional content, and potential health benefits [1]. Mung bean sprouts have less calories and more health advantages than other vegetables. Numerous physical, chemical, and combination intervention strategies, including gamma irradiation, ultrasound, X-irradiation, electromagnetic field, and pesticides [2], have been used over the past ten years to promote the germination and decontamination of seeds. Despite of providing faster germination by all these advanced techniques each of them have some or other demerits. In recent years, cold plasma received a great deal of interest in agricultural applications [3] and, however, it has not been explored and tested on traditional Indian foods, vegetable and plants**.** The purpose of the present work is to investigate the influence of cold plasma on mung bean germination.

In this study a non-equilibrium cold plasma was produced using usual laboratory practices and applied voltage, frequency, and treatment time were taken as a process parameter to evaluate the effect on germination profile of mung bean sprouts. The seeds were exposed to cold plasma for 20, 40, 60, 120 and 180 s and different functional parameters were observed after plasma treatment such as germination rate, germination potential, electrical permeability, surface wettability, seed reserve utilization, vigor index and changes in microstructure. Compared to the control samples, cold plasma dramatically enhanced germination rate, shoot length, and electrical conductivity of treated seeds. The surface etching generated by the plasma species improved the water permeability of the seeds covering and appears to have lowered the contact angle, making the surface more hydrophilic. The reactive oxygen and nitrogen species (RONS) had their effects on seed germination and seedling growth during the germination process. The developed cold plasma process is an environment-friendly and low-cost method of stimulating seed germination, which has huge potential for scale-up on an industrial scale.

References:

[1] A. A. Gabriel *et al.*, "Microbiology of retail mung bean sprouts vended in public markets of National Capital Region , Philippines," vol. 18, pp. 1307–1313, 2007, doi: 10.1016/j.foodcont.2006.09.004.

[2] C. Lo *et al.*, "Plasma activated water and airborne ultrasound treatments for enhanced germination and growth of soybean," *Innov. Food Sci. Emerg. Technol.*, vol. 49, no. May, pp. 13–19, 2018, doi: 10.1016/j.ifset.2018.07.013.

[3] A. Phys, "Atmospheric cold plasma jet for plant disease treatment," vol. 043702, no. January, 2014, doi: 10.1063/1.4863204.

PRODUCTION, CHARACTERIZATION AND APPLICATION OF CIRCULAR DIELECTRIC BARRIER DISCHARGE FOR BACTERIAL INACTIVATION

Oat Bahadur Dhakal[1], Lekha Nath Mishra[1], Roshan Chalise[1]

[1]*Department of Physics, Patan Multiple Campus, Tribhuvan University, Patan Dhoka-44600, Nepal.*

E-mail : Oatbahadur32@gmail.com

Abstract

This work is an experimental investigation of the production of Dielectric Barrier Discharge (DBD) plasma and its application to the inactivation of bacteria. An AC power source with a 10 kV potential difference and a 30 kHz frequency is used to create the plasma. The plasma temperature was calculated using the intensity ratio and Boltzmann plot methods, and also was determined to be 5.585 eV and 5.83 eV, respectively. The electron density, which was calculated using the Boltzmann-Saha equation, was determined to be 1.167×10^{15} cm^{-3}.

For bacterial inactivation, the water is contaminated with staphylococcus aureus (Gram-positive) and Escherichia coli (Gram-negative) individually in the same environment. Measurements have been made of the treated water's conductivity, pH, and temperature both before and after the plasma treatment. During the experiment, the water's pH dropped from 6.2 at t = 0 min to 2.8 at t = 8 min, while the plasma-treated water's temperature increased from 12.2^o C at t = 0 min to 22^o C at t = 8 min. The conductivity of water has increased from 450 μs/cm to 1123 μs/cm. The decontamination of treated water using the colony counting technique has been studied. The DBD plasma reduces the CFU/ml of S. aureus from 208 to 10 and that of E. coli from 213 to 8 after 8 minutes of treatment. It is found that DBD plasma is a powerful and eco-friendly tool to decontaminate water without forming any byproducts

References:

[1] Kim et al., *Use of plasma gliding arc discharges on the inactivation of E. Coli in water,* Elsevier sci. **120**, p 423-428, (2013)
[2] Mehrnaz et al., *Water treatment by the AC gliding arc air plasma*, J. Theor. Appl. Phys. **11(3)**, p 171-180, (2017)

PRODUCTION, CHARACTERIZATION AND APPLICATION OF PLASMA FOR CORIANDER SEED GERMINATION

Roshani Dahal[1], Nirmal K.C., Lekha Nath Mishra[1], Roshan Chalise[1], and Raju Khanal[2]

[1]*Department of Physics, Patan Multiple Campus, Tribhuvan University, Patan Dhoka 44600, Nepal*

[2]*Central Department of Physics, Tribhuvan University, Kirtipur 44613, Nepal*

E-mail: dahal.roshni26@gmail.com

Abstract

Coriander is the one of most used kitchen items in Nepal which has high health benefits. It is used for its fragrance and taste it gives to the food. Coriander seeds are treated by plasma produced using gliding arc discharge and dielectric barrier discharge (DBD). Both gliding arc discharge air plasma and DBD plasma has found applications in diverse fields. Power source of 10 kV potential difference and 30 kHz frequency is used to produce the plasma. Plasma is characterized by optical emission spectroscopy and I-V characteristics. The average value of excitation temperature of electron for gliding and DBD plasmas are 7.98 eV and 5.11 eV respectively. The density of the electron in gliding is 9.60×10^{20} cm^{-3} and in DBD is 1.05×10^{16} cm^{-3}.

It is seen that the temperature of seed increases with the treatment time, and the weight of seeds decreases with the increase in treatment time. Further, wettability measurements indicate that the seeds become more hydrophilic after the plasma treatment. The germination rate is found to be highest for 8 minutes treated seeds in both discharges. However, the shoot length is found to be longer for 8 minutes treated seeds while root length is found to be longer for 10 minute treated seeds. Additionally, Germination rate is similar for all treatment times in the earlier days, but observations up to 29th day indicate that the germination rate is highest for 5 minutes treated seeds.

References:

[1] Lotfy et al., Effect of cold atmospheric Plasma Jet Treatment on the seed germination and enhancement growth of Watermelon, Open Journal of Applied Sciences, 7(12), 705 (2017)

[2] Guragain et al., Influence of plasma-activated water (PAW) on the germination of radish, fenugreek, and pea seeds, AIP Advances, 11(12), 125304 (2021)

COMPARATIVE STUDY OF DC AND HIGH POWER IMPULSE MAGNETRON SPUTTERING FOR COPPER THIN FILM DEPOSITION

R. Rane*, P Maila, A. Joseph

Institute for Plasma Research, Gandhinagar, Gujarat, India -382428

*E-mail: ramu@ipr.res.in

Abstract

A comparative study for plasma properties of DC magnetron sputtering and High Power Impulse Magnetron Sputtering (HIPIMS) is carried out. The deposition rate, structural and electrical properties of copper (Cu) thin film deposited by using both DC and HIPIMS are compared. The scanning electron microscopy, atomic force microscopy and X-ray diffraction are used to observe the structural properties of the films. The resistivity of the films was measured using four-point probe technique. The deposition rate for the HIPIMS is observed to be almost half of the DC magnetron sputtering at a similar power levels. The Cu films showed crystalline orientations of [111], [200] in the direction of the film growth. As peak power density was different in DC and HIPIMS, film properties were also greatly different. In case of DC sputtering, Cu films exhibit a porous columnar structure. However, HIPIMS Cu films showed slightly columnar and denser film. The Optical Emission spectroscopy (OES) measurement showed that, plasma produced by HIPIMS contains more Cu neutrals and ions indicating a higher metal ionization degree in HIPIMS compared to DC.

References:

[1] High power impulse magnetron sputtering discharge, J. Vac. Sci. Technol. A, **30(3)**, p 030801-030835, (2012)
[2] Plasma diagnostics for understanding the plasma–surface interaction in HiPIMS discharges: a review, J. Phys. D: Appl. Phys., **47**, p 224001-2240046, (2014)

Degradation Of Harmful Dyes Using Plasma-Treated TiO_2 Films Enhanced With CAP

Adarsh Thapa, Reetesh Borpatra Gohain, Sanu Sarkar, Sarathi Kundu, Subir Biswas

Institute of Advance Study in Science and Technology, Vigyan Path, Garchuk, Paschim Boragaon, Guwahati, Assam 781035

Email: adarshthapa80@iasst.res.in, subirb@iasst.gov.in

Abstract

Plasma-based technologies that offer maximum efficiency at minimal environmental costs are expected to promote sustainable societal and economic growth. With the ever-increasing demand for imparting color in various products used in the textile, leather, and paint industries, synthetic dyes are used constantly for these purposes; these dyes, when left untreated, are harmful to the environment. Titanium oxide thin films are widely used for degrading such toxic compounds. However, the efficiency of the degradation is not up to industrial standards. Hence, using TiO_2 thin films coupled with Cold Atmospheric Plasma (CAP) with increased reusability may have immense possibility to increase the dye degradation efficiency. Details results of this study will be presented.

References:

[1] Photocatalytic degradation of methyl orange as a model compound, Journal of Photochemistry and Photobiology A: Chemistry, 148 (2002) 161–168
[2] Mechanism and comparison of needle-type non-thermal direct and indirect atmospheric pressure plasma jets on the degradation of dyes. *Sci Rep* **6**, 34419 (2016)

Effect of Plasma Treatment on Cauliflower Germination and Growth

Pooja Shrestha[1], Roshan Chalise[2], Raju Khanal[2]

[1]Patan Multiple campus, Department of Physics, Tribhuvan University, Lalitpur Nepal.
[2]Central Department of Physics, Tribhuvan University, Kathmandu, Nepal.

E-mail: shresthapooja93@gmail.com

Abstract

While looking for a way to boost output for the productivity of Cauliflower without lowering its nutritional content, we came up with the concept of plasma treatment. We employed plasma activated water enhanced by gliding arc discharge in this experiment to monitor the germination and growth of the cauliflower plant. We chose 250 seeds in total, divided them into 5 groups, then activated the water using gliding arc discharge at different times for each group. In petridish, this experiment was carried out. The same procedure was conducted under the same circumstances using a 1:2:2 mixture of coco-peat, vermicompost, and garden soil. Then, we analyzed germination and growth on those five groups using plasma activated water. These two techniques involve treating plasma indirectly by introducing it into water. We examined how this affects seeds by altering the chemical properties of the water. The pH, TDS, ORS, and electrical conductivity of the plasma activated water was investigated. Chlorophyll content and presence of nitrate, nitrite and hydrogen peroxide was also studied. Result shows that compared with untreated and treated water used, the germination is observed quickly and to its maximum in 10 minutes of plasma activated water (10 PAW). pH decreases as activation time increases whereas ORS, EC, TDS, and temperature rise with activation time

Shock free non-thermal atmospheric plasma jet at radio frequency

Abhijit Majumdar,[1†] Suranjana Banerjee,[2] Sadhan handra Das,[3] Subrato Mukherjee[4]

[1]*Department of Physics, Indian Institute of Engineering Science and Technology, Shibpur, Howrah-711103, West Bengal, India.*
[2]*Dept. of Electronics, Dum Dum Motijheel College, South Dumdum-700074, WB, India*
[3]*UGC-DAE Consortium for Scientific Research, Indore-452017, MP, India.*
[4]*Institute for Plasma Research, Gandhinagar, Bhat, Gujarat, India*

†E-mail: majuabhijit@gmail.com (Abhijit Majumdar), Tel: +918240468551

Abstract

In this work, a shock-free non-thermal atmospheric plasma (or cold plasma) jet is generated and corresponding discharge characteristics were investigated from the voltage and current waveforms at 80 kHz. The plasma plume temperature is found to be 30 °C. The plasma plume become micro-discharge at lower gas flow rate (below 6 sL/min). The shock free property of plasma along with the accumulated average charge at the plasma plume tip is explored. The non-thermal plasma jet is applied and tested on human-skin irradiation on different areas (tongue, arms and cheeks). This study evident that the non-thermal argon plasma can be applied on human skin for disinfection and prevention of different diseases without any anesthesia [1, 2].

References:

[1] Avishek Roy, Arindam Banerjee, Sadhan Chandra Das, Akshay Vaid, Sumant Katiyal, Abhijit Majumdar, Applied Physics A, 128, 866 (2022)
[2] G. Fridman, Brooks, M. Galasubramanian, A. Fridman, A. Gutsol, V. Vasilets, H. Ayan, G. Friedman, Plasma Process. Polym. **4**, 370 (2007).

Dielectric Barrier Discharge (DBD) Plasma For Surface Modification Of Polymers And Drug Delivery

Gopika Suresh [1], M.H Vijay Dhanabal [1] and G Shanmugavelayutham [1]*

Plasma Physics Laboratory, Department of Physics, Bharathiar University, Coimbatore, 641046, Tamil Nadu, India

Email: sgsvelu@buc.edu.in

Abstract

Surface plasma treatment is the efficient method for the surface modification of polymers, fabrics, seeds etc. In this research work, the effects of argon plasma and helium plasma through Dielectric Barrier Discharge (DBD) for the Poly (ethylene-co-vinyl acetate) (EVA) polymer surface treatment and drug delivery is investigated. EVA, a hydrophobic biomedical polymer along with curcumin an anti-cancer drug is synthesized to a polymer film for surface modification and drug delivery. Surface morphology, hydrophilicity and the chemical state of the drug-loaded film were carried out by SEM, static contact angle measurements and FT-IR respectively. The surface roughness of the treated films was evaluated by Atomic Force Microscopy (AFM). According to the results, the hydrophilicity of the polymer films increases for both the argon and helium plasma was observed. The surface roughness increases after the helium plasma treatment compared to argon plasma. The experimental results showed that sustained drug release has been achieved by plasma treatments. The untreated EVA polymer showed a burst release whereas argon plasma treated polymer film showed a rapid decrease in the drug release profile followed by helium plasma treatment. The effect of plasma treatment on the drug release profile is observed in two working gases. This study could provide a new and alternative method for the controlled and sustainable drug release system for future medical applications.

References:

[1] K. Hagiwara et al., Effects of plasma treatments on the controlled drug release from poly (ethylene-co-vinyl acetate), Surface & coatings Technology, 216,318-323, (2013)

[2] H.Azimi et al., Effect of Dielectric Barrier Discharge (DBD) Plasma treatment on the Polypropylene film in presence of air and nitrogen at atmospheric pressure, Advances in Applied Nano Bío-Technologies , 2, 41-48, (2021)

Single-step synthesis of magnetic ε-Fe_3N nanoparticles by thermal plasma arc discharge technique for supercapacitor application

L. Kumaresan and G. Shanmugavelayutham*

Plasma Processing Laboratory, Department of Physics, Bharathiar University, Coimbatore-641046, Tamil Nadu, India

E-mail address:* sgsvelu@buc.edu.in *(G. Shanmugavelayutham)

Abstract

Transition metal nitrides (TMNs) have been employed as catalysts for electrochemical energy storage and conversion. Nonetheless, the preparation of such nanoparticles using hazardous precursors and chemical methods has a drawback in real-world applications. In the present study, the ferromagnetic iron nitride (ε-Fe_3N) nanoparticles (NPs) were synthesized using the direct current (DC) thermal plasma arc discharge (TPAD) method. The experiments were carried out using argon and ammonia (NH_3) gas atmospheres at different plasma powers such as 1.5, 3.0 and 4.5 kW. The synthesized ε-Fe_3N NPs have a spherical morphology with a crystalline nature. The saturation magnetization (Ms) and coercive force (Hc) values for single phase ε-Fe_3N NPs are 140 emu/g and 121.4 Oe respectively, which reveals a soft ferromagnetic nature. As ε-Fe_3N NPs shows superior storage properties with an outstanding specific capacitance of 556.1 F/g at 1 A/g with pseudocapacitive behavior. The ε-Fe_3N exhibited higher cycling stability with 73.6% capacitance retention after 5000 cycles at a current density of 5 A/g. Thermal plasma synthesized ε-Fe_3N NPs significantly improve electrochemical energy storage applications.

References

1. L. Kumaresan, G. Shanmugavelayutham, S. Surendran, U. Sim, Thermal plasma arc discharge method for high–yield production of hexagonal AlN nanoparticles : synthesis and characterization, J. Korean Ceram. Soc. 59, 338–349 (2022).

2. E. Haye, C. Soon Chang, G. Dudek, T. Hauet, J. Ghanbaja, Y. Busby, N. Job, L. Houssiau, J.J. Pireaux, Tuning the magnetism of plasma-synthesized iron nitride nanoparticles, ACS Appl. Nano Mater. 2 (2019) 2484–2493.

Effects of Non-Extensivity, Negative Ions Mass and Ionization Rate on Plasma Material Interaction Carrying Electron Emission

Yetendra Prasad Jha[(a)], Mayank Kumar[(b)], Hitendra Kumar Malik[(c)]

[(a, c)] *Plasma Science and Technology Laboratory, Department of Physics, IIT Delhi, New Delhi-110016, India*
[(b)] *Department of Mechanical Engineering, IIT Delhi, New Delhi-110016, India*

[(a)]yatit20@gmail.com, [(b)]Mayank.Kumar@mech.iitd.ac.in, [(c)]hkmalik@physics.iitd.ac.in

Abstract

In the laboratory plasmas, it is observed that the plasma interacts with the material wall and hence sheath (non-neutral region) formation takes place to balance the flow of charged species from the plasma to the wall. Emission of electrons from the wall occurs due to the bombardment of the wall by the electrons and ions present in the plasma or excessive heating of the wall by the applied external voltage or the plasma itself present in the container. The emitted electron's role is significant in changing the potential and thickness of the sheath [1, 2]. Researchers [3] described the emission in an electronegative plasma but neglected the temperature of the positive ions, the gradient of pressure, ionization, and collisions in their model. Boltzmann-Gibbs statistics used in their model is although gives the correct distribution for the charged particles in the thermodynamic equilibrium but the statistics fail for the system which is non-extensive and is distant from the thermodynamic equilibrium [4].

In the present work, we have developed a theoretical model in an electronegative plasma considering the temperature of positive ions, gradient in the pressure, source term, collisional parameter, q non-extensive distribution of the electrons, and emitted electrons from the wall. The negative ions are described with the fluid equation instead of Boltzmann distribution to see the contribution of the mass and temperature (of negative ions) in the sheath potential, space charge distribution, and in the thickness of the sheath. Our results are very much useful in the plasma processing e.g., etching, deposition plasmas and in extraction electrode of negative ions source where controlling of the potential is a difficult task.

References:

[1] Phys. Plasmas, 11, p 1220-1228, (2004)

[2] Phys. Plasmas 21, 063502, (2014)

[3] J. Plasma Phys., 60, p 81-93, (1998)

[4] J. Plasma Phys., 64, p 131-153, (2000)

SYNTHESIS AND ELECTROMAGNETIC CHARACTERISATION OF NANO- ZnO

Arpita Priyadarsini Dikshit, Dibyaranjan Das, Kajal Parashar, S. K. S. Parashar

Nanosensor Lab, Campus-3, School of Applied Sciences, Kalinga Institute of Industrial Technology (KIIT) Deemed to be University, Bhubaneswar-751024, Odisha, India.

sksparashar@yahoo.com

Abstract

This work describes the synthesis and electromagnetic characterization of nano ZnO ceramic powder which is sintered at 1300^{o}C for 2 hours to examine its potential as an EMI shielding material in Ku-band (12-18GHz) frequency range. X-ray diffraction (XRD) was employed for understanding the phase structure of nano ZnO ceramics. The average crystallite size of nano ZnO were obtained for sintering temperature of 1300^{o}C to be 9.8nm by using the Williamson-Hall (W-H) analysis. FESEM analysis was done to study the surface morphology and average grain size of nano ZnO ceramic pellets. The Raman spectrum was studied to understand the different modes of nano ZnO ceramics for sintering temperature of 1300^{o}C. Vector Network Analyser (VNA) was used to study the scattering parameters (S_{11}, S_{21}) in Ku-band region. Effective shielding due to absorbance was measured to be 30 dB in nano ZnO sintered at 1300^{o}C. The results indicate that nano ZnO ceramics sintered at 1300^{o}C have better shielding characteristics create a scope for application in electronic devices such as radar and satellite communication.

Investigation Of Plasma-Surface Interaction In A Microplasma Device For Biomedical Applications

Rajsinh Rana, Sidharth and Shail Pandey

Department of Physics, Sardar Vallabhbhai National Institute of Technology Surat, Surat – 395007, India

E-mail : sp@phy.svnit.ac.in

Abstract

Microplasma has been used in bio-medical applications [1] as it is non-equilibrium in nature ($T_g << T_e$) and hence can easily be applied for the treatment of heat sensitive surfaces. The electrons being more energetic enables selective reaction path to generate the required active radicals for the application. However, the process outcome is determined by the mutual interaction of the plasma with the surfaces which limits the applicability of these devices. For example, due to the mutual plasma-surface interaction, the mode of operation of plasma can also change from free-mode to the conductive-mode depending on the (i) conductivity of the surface, and (ii) distance of the surface from plasma [2, 3]. This makes it difficult to apply plasmas for treatment of the multiwell plates whose conductivity may not always be known [4]. There have been several works carried out to explore dynamics of the plasma-surface interaction but are limited to plasma volumes of macroscales [1, 2, 4]. The interaction of microplasmas with surfaces are limited and has been addressed in the present work.

The current work is a numerical investigation of the plasma properties obtained in a DC powered 2D microplasma source with planar geometry [5]. Keeping the positive electrode (l = 0.85 cm, b = 0.145 cm) same throughout the simulation, the dimension of the ground electrode is varied to observe its effect on the plasma parameters. Further, the surfaces of different conductivities are placed in contact with the plasma at different positions and their effect on the plasma parameters, like electron temperature, plasma potential and ion flux, is studied. The results are of significance to optimize the microplasma source for particular application as well as the distance of the surface to be kept within the plasma region.

References:

[1] K. Shimizu, H. Fukunaga, M. Blajan, Current Applied Physics **14**, S154 (2014).
[2] L. Miebach, E. Freund, R. Clemen, K. Weltmann, H. Metelmann, T. Woedtke, T. Gerling, K. Wende, S. Bekeschus, Free Radic. Biol. Med. **180**, 210 (2022).
[3] Torsten Gerling, Ronny Brandenburg, Christian Wilke, and Klaus-Dieter Weltmann, Eur. Phys. J. Appl. Phys. **78**, 10801 (2017)
[4] Andrei Vasile Nastuta and Torsten Gerling, Appl. Sci. **12**, 644 (2022).
[5] Li Guo, Ruobing Xu, Lu Gou, Zhichao Liu, Yiming Zhao, Dingxin Liu , LeiZhang, Hailan Chen, Michael G. Kon, Appl. Environ. Microbiol. **84**, e00726 (2018).

Spectroscopic investigation of plasma treatment of coal in RF generated plasmas

Dipexa Modi[1], Kundan Viliya[2], Nandini Yadava[3], Sachin S. Chohan[2], A. Sarkar[1], Amulya Sanyasi[4], Uttam Sharma[2], Jayashree Sharma[2], Malay B. Chowdhuri[4], Joydeep Ghosh[4, 5], Balamurli Krishna Mayya[1], Uttam Bhui[1], Sudip Bhattacharyya[6], Krittibas Das[6], Jitendra Kumar[6]

1) Pandit Deendayal Energy University, Raisan, Gandhinagar, 382 007, Gujarat, India
2) Shri Vaishnav Vidhyapeeth Vishwavidyalaya, Sanwer Road, Indore 453 111, India
3) Institute of Science, Nirma University, Ahmedabad 382 481, Gujarat, India
4) Institute for Plasma Research, Bhat, Gandhinagar 382 428, India
5) Homi Bhabha National Institute, Anushaktinagar, Mumbai, 400094, India
6) Natural Energy Resources, Geological Survey of India, Kolkata-700091, India

Plasma treatment of coal is one of the very unique techniques for understanding the complex macro-molecular network of coal also and for making hydrogen-rich coal. Coal mainly consists of polyaromatic clusters linked with side chains and functional groups on peripheral positions by covalent and non-covalent bonds. These bonds can be specifically broken by plasma species, when the coal is immersed in plasma eventually producing reactive molecules.

In order to understand the structure of different coal samples and the coal-hydrogenisation process, a specific coal sample is immersed in a RF plasma, produced in reactor chamber [1] with Hydrogen and Argon gases at 60 W of RF power. Coal contains mostly carbon with different types of other elements, such as hydrogen, oxygen, nitrogen etc. The coal sample is kept inside the plasma for 3 hours and the optical emission from the plasma is recorded using a miniature spectrometer (Ocean optics). The survey spectra are collected in the wavelength range of 300 - 1000 nm with exposure of 2, 3 & 5 sec at every 15 minutes during the 3-hour treatment duration. Firstly, the spectral lines presented in the above-mentioned survey spectra is identified. In the H_2 plasmas with coal the molecular bands are identified as (i) N_2 [$C^3\pi \rightarrow B^3\pi$] for $\Delta v = 0, -1, -2$ and -3, (ii) CN ($B^2\Sigma - X^2\Sigma$) for $\Delta v =$ -1, 0 & 1 along with atomic lines of hydrogen [2]. In Ar plasma, the Ar (I) atomic lines are identified along with molecular bands. Along with this the molecular OH bands present within 307-316 nm is also identified in both the plasmas. The intensity variations of identified lines during the course of 3-hour treatment showed that in the hydrogen plasma the intensity of H-Balmer line decreases while the intensity of N2 molecular lines increase as the time progresses. This indicate that the nitrogen is released from the coal while the hydrogen is absorbed by the coal. Along with this using Boltzmann plot method plasma, the gas temperature and its variations are also studied. For the above-mentioned analysis, a Python code has been developed in-house.

References:

[1] Sachin et al., Mater. Res. Express 5, 115020 (2018).
[2] Nandini et al., Plasma and Fusion Research, Vol.17, 2401095 (2022)

Analysis of Antimicrobial Activity of Plasma Treated Chitosan Based Membranes

D. Sriram[1] and M. H. Vijay Dhanabal[2], P. Premasudha[1*], G. Shanmugavelayutham[2]

[1]Nanobiotechnology Laboratory, Department of Nanoscience and Technology, Bharathiar University, Coimbatore – 641 046.
[2]Plasma Physics and Processing Laboratory, Department of Physics, Bharathiar University, Coimbatore – 641 046.

Email: ***premasudha@buc.edu.in***

Abstract

Polymers are very much useful in different sectors like Agriculture, Medicine, Sports and Industries. Most of the cloths that we wear daily are produced from the synthetic fibers and also Plastic bags, cups are made from some synthetic materials which is not eco-friendly and Bio-degradable. So, in recent years there is an increased interest in the production of more environmental-friendly, bio-degradable materials which will serve as the replacement for the synthetic materials. And there is also an interest in developing materials with antimicrobial surfaces. The non-thermal plasma treatment found to be a method for increasing the antimicrobial activity of materials [1]. Bio-polymers are proposed as one the replacement for the synthetic materials because of their similarities and also due to their bio-degradability and environmental-friendly nature. Chitosan is derived by the deacetylation of chitin and it is the second most abundant bio-polymer in nature. In this experiment, chitosan-based polymers are produced by the conventional solvent casting method. Further, the produced membranes are subject to plasma treatment to enhance the antimicrobial activity. The synthesized membranes are then subjected to FESEM, FTIR and Antimicrobial activity.

References:

1. Sri Devi, P., & Vijayalakshmi, K. A. (2019). Analysis of antibacterial activity and cytotoxicity of silver oxide doped hydroxyapatite exposed to DC glow discharge plasma. *Materials Today: Proceedings.* doi:10.1016/j.matpr.2019.09.204

Interaction Of An Atmospheric Pressure Plasma Jet With Substrates: Copper, Silicon, Biological Skin, Quartz, And Teflon

Deepika Behmani and Sudeep Bhattacharjee

Department of Physics, Indian Institute of Technology, Kanpur, Uttar Pradesh: 208016, India

E-mail: deepika@iitk.ac.in and sudeepb@iitk.ac.in

Abstract

In modern times, atmospheric pressure plasmas jets (APPJs) have gained noticeable attention due to their wide variety of applications and associated plasma phenomena. These are 'non-equilibrium' plasmas ascribed to different electron (~0.5-1 eV) and ion (~0.025 eV) temperatures. They are produced in ambient air, hence providing rich gaseous chemistry resulting in formation of reactive oxygen and nitrogen species (RONS) [1]. The low gas temperature and presence of RONS make them suitable for treatment of surface and biological matters [2]. The treated substrate influences both intrinsic, e.g., electron density (n_e), electron temperature (T_e), plasma potential, electric field and electron energy distribution function (EEDF), and acquired properties such as electric field fluctuations and instabilities of the plasma jet. The fluctuations may lead to modification of EEDF which can change the rate coefficients of chemical reactions involving RONS, hence may affect the applications. The typical evolution time scale of RONS (~500 μs - 1 ms) matches with the time scale of potential fluctuation (~100 μs - 1 ms) [3], therefore it is critical to understand the behaviour of potential and electric field fluctuations under the influence of the substrate.

A helium plasma jet having a ring-to-ring electrode configuration is used in this work, the details of the plasma jet set-up are provided in ref. [3,4]. The plasma jet is made to impinge on samples (copper, silicon, goat skin, quartz, and teflon) having a wide range of permittivity (ε_r) from 2 to ∞. The fluctuations in E_z and E_φ components of the electric field have been estimated by using a two-pin probe along the axial and poloidal direction of the jet. The plasma parameters and gas temperature has also been measured along the axial direction of the jet by optical emission spectroscopy (OES) methods. It has been observed that different phenomena take place in plasma plume for different substrates depending upon their permittivity. Mainly, a return stroke generates from the substrate's surface due to high n_e in case of high ε_r samples (i.e., copper and silicon) and a surface ionization wave develops along the sample's surface in case of low ε_r samples (i.e., goat skin, quartz, and teflon). The current work provides insight into the jet-substrate interaction which may influence the plasma processing, hence important from the application point of view.

References:

[1] L. Lin and M. Keidar, Appl. Phys. Rev. **8** 011306 (2021)
[2] M. Keidar, Plasma Sources Sci. Technol. **24** 033001 (2015)
[3] D. Behmani, K. Barman and S. Bhattacharjee 2021 AIP Adv. **11** 085128 (2021)
[4] K. Barman, D. Behmani, M. Mudgal., S. Bhattacharjee, R. Rane and S. K. Nema Plasma Res. Express **2** 02500 (2020)

NF_3 Based Plasma Etching System For Etching Of Silicon Substrate

Vrushank Mehta[1], Rajesh Kumar[1,2], Y. Kumar[1], H. L. Swami[1], C. Jariwala[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, India. 382428*
[2]*Homi Bhabha National Institute, Anushakti Nagar, Mumbai, Maharashtra, India 400094*

E-mail: rkumar@ipr.res.in

Abstract

Plasma etching process is used for modification of surfaces at microscopic level, removal of oxide layers and etching of semiconductors. A typical 13.56 MHz radio-frequency (RF) glow discharge plasma drives highly mobile electrons to collide with neutral gas atoms and molecules, resulting in ionization and dissociation of a reactant gas. A Facility of NF_3 RF glow plasma discharge is developed at Institute for plasma Research. In this plasma etching system, the substrate is placed in a vacuum chamber on the cathode of the plasma generator and gases are introduced to produce the reaction. NF_3 gas in plasma generates many Fluorine atoms (free radicals), which are highly reactive and spontaneously react with substrate (Si or SiO_2) to produce volatile product (SiF_4) which will be pumped away by the vacuum pump. NF_3 is selected as reactive gas because bond dissociation energy of various dissociative reactions in NF_3 is much lower than other fluorinated gases like CF_4, SF_6 etc. The basic operating parameter of this facility are pressure (5 to 80 Pa) and RF power from 50-150 Watt. Plasma etching can also be used in the decontamination of the depleted Uranium Oxides from the Stainless steel surfaces.

References:

[1] Vincent M. Donnelly and Avinoam Kornblit, Plasma etching: Yesterday, today, and tomorrow, J. Vac. Sci. Technol. A 31, 050825 (2013)

[2] J. Perrin et al., Mass Spectrometric Study of NF_3 Plasma Etching of Silicon, Plasma Chemistry and Plasma Processing, Vol. 10, No. 4, 1990

[3] J. M. Veilleux, et, al, Etching of UO_2 in NF_3 RF Plasma Glow Discharge, Journal of Nuclear Material, vol. 277, p. 315 (2000)

[4] Vrushank Mehta et, al, Experimental Facility Development of NF3 Based Plasma Etching System, presented at National Conference on Recent Developments and Evolving Trends in Plasma Science and Technology

Enhanced optical properties by argon plasma-induced surface texturing on the silicon surface

Y. Kumar[1], V. Mehta[1*], C. Jariwala[1], H. L. Swami[1], S. Hans[1], M. Ranjan[1, 2], R. Kumar[1, 2*]

[1]Institute for Plasma Research Bhat Gandhinagar Gujarat, 382428, India

[2]Homi Bhabha National Institute, Mumbai, 400 094, India

**Corresponding Author- Email: Rajesh.kumar@ipr.res.in, vrushankipr.res.in*

Abstract

Plasma etching/ texturing is a critical feature in the development of silicon-based electronic devices such as solar cells, integrated circuits (ICs), and photodiodes. In this study, to obtain the optimized surface texture for low optical reflection loss, the effect of argon plasma on the surface texturing of single crystalline silicon wafers has been investigated. The surface texturing and crystallinity of the pristine and plasma-treated c-Si samples were inspected by Atomic force microscopy, Field emission scanning electron microscopy, and Raman spectroscopy. FE-SEM and AFM results exhibited the engineering of surface texturing and roughness of c-Si samples correlated with the plasma treatment at different times. The surface roughness enhances for smaller plasma exposure time whereas it decreases for a longer time due to the attack on initially formed nanostructures. The spherical shape nanoparticle-like structure obtained upon plasma treatment of 15 min bestows the lowest reflectance and higher absorbance. Raman spectroscopy results confirm the enhancement of the Raman mode intensity of plasma-treated c-Si samples and strengthen the FE-SEM and AFM results.

Keywords: Plasma, silicon nanostructures, surface texturing, roughness, reflectance.

Shelf-Life Study of Fresh-cut Fruits treated with Non-equilibrium Cold Plasma

Ritesh Mishra[1*], Abhijit Mishra[2], Shikha Pandey[2], Sushma[2], Meenu Chhabra[1,3], Ram Prakash[1,2]

[1]Division of IDRP-Smart Healthcare, IIT Jodhpur, NH-62, Surpura Bypass, Karwar, Jodhpur, Rajasthan- 342037
[2]Department of Physics, IIT Jodhpur, NH-62, Surpura Bypass, Karwar, Jodhpur, Rajasthan- 342037
[3]Department of Bioscience and Bioengineering, IIT Jodhpur, NH-62, Surpura Bypass, Karwar, Jodhpur, Rajasthan- 342037
*E-mail: mishra.15@iitj.ac.in

Abstract

The desire for a healthy living has led to an upsurge in demand for fresh fruits during the past few decades. Fresh-cut fruits are edible products that have not undergone the extensive and customary traditional processing procedures. Fresh produces are vulnerable to microbial infection, which reduces shelf-life and presents a problem for the food sector and it is difficult to preserve their nutritional value and microbiological integrity of fresh cut fruits. Maintaining crucial food quality characteristics, raising the bar for food safety, and extending product shelf life are the fundamental challenges facing the field of food science. Consequently, to satiate the global need for fresh fruits and natural food products, non-thermal solutions for food processing have been developed, limiting typical thermal alterations like sensory changes, production of off tastes, and loss of nutritious components. [1][2]. The use of non-equilibrium cold plasma is a non-conventional approach to retain the quality and safety of fresh-cut fruits without changing their nutritional aspects.

In this study, fresh-cut apple and pineapple slices were treated with non-equilibrium cold plasma (NECP) and plasma activated water (PAW) at varying treatment time using a dielectric barrier discharge (DBD) concept and then shelf-life study has been carried out at 4°C for 5d, during which the physico-chemical parameters were evaluated. The results demonstrated that both NECP and PAW treatment significantly prevented the deterioration in physico-chemical properties, as shown by higher retentions of colour (L*, a*, and b*), hardness, soluble solids content (SSC), vitamin C content, and total carotenoids content in NECP and PAW-treated samples during storage. NECP and PAW treatment also maintained firmness of fresh cut apple and pineapple during storage. Such treatments also significantly slowed the increase in total microbial counts and hence helping to increase the safety of food in fresh cut apple and pineapple. The results of these efforts will be presented.

References:

[1] Pereira, R. N.; Vicente, A. A. Environmental impact of novel thermal and non-thermal technologies in food processing Food Res.Int. , 43 (7) 1936–1943 (2010)
[2] Surowsky, B.; Schlüter, O.; Knorr, D. Interactions of non-thermal atmospheric pressure plasma with solid and liquid food systems: A review Food Eng. Rev. 7, 82 (2015)

Synthesis of Nanostructure Materials for Non-equilibrium Cold based Packed Bed Reactor and their Comparative Analysis

Jyoti Verma*, Ramavtar Jangra, Kiran Ahlawat, Chandra Prakash, Ambesh Dixit, Ram Prakash

Department of Physics, Indian Institute of Technology Jodhpur, 342037

*E-mail: verma.29@iitj.ac.in

Abstract

Humans have gotten entangled in a web of air pollution due to fast technological advancements and the rising of automobiles, industries, etc. Worldwide efforts are under way to develop innovative devices and systems to mitigate the issue. For the said purpose some traditional methods have been used, such as absorption, adsorption, condensing[1-2], etc. However, these are not efficient and also consumes high-power. Non-equilibrium cold plasma (NECP) brought novelty to remove the toxicity of air by generating highly oxidizing reactive species. The concept of Dielectric Barrier Discharge (DBD) has been used to produce NECP in a cylindrical packed bed discharge system using dielectric and/or metal beads. In general, in packed bed reactors, different catalyst materials are used to remove toxic gases like VOCs, conversion of CO_2, etc. Such materials play a very important role due to the discharge characteristics, which are significantly influenced by packing different materials into the discharge gap. Packing material with high dielectric constant increases the electron's temperature and electric field strength near contact points of the catalyst resulting in an increase in the pollutant removal efficiency. The execution of the packed bed reactors depends on the type and the dielectric constant of the packing material and still sufficient studies are not available to choose a specified material.

In this work we have developed Al_2O_3, TiO_2, and $BaTiO_3$ as packing materials with different dielectric constants and material properties on aluminum beads for their usage in different packed bed reactor configurations. The study has been focused on the process development for the requisite coating on beads, their characterization, and the employment of these for non-equilibrium plasma productions. Different characterization techniques, such as XRD, SEM, and UV-Vis have been used to examine the phase purity and band gap of the materials. A comparative analysis has been carried out to highlighted applicability of a particular material for a particular application in a packed bed geometry. Efforts made in this direction will be presented.

References:

[1] B. Ozturk and D. Yilmaz, "Absorptive removal of volatile organic compounds

from flue gas streams," *Process Saf. Environ. Prot.*, vol. 84, no. 5 B, pp. 391–398, 2006, doi: 10.1205/psep05003.

[2] K. Nikolajsen, L. Kiwi-Minsker, and A. Renken, "Structured fixed-bed adsorber based on zeolite/sintered metal fibre for low concentration VOC removal," *Chem. Eng. Res. Des.*, vol. 84, no. 7 A, pp. 562–568, 2006, doi: 10.1205/cherd.05220.

AN EFFECTUAL STRATEGY FOR DEVELOPMENT OF NOVEL CARBOXYMETHYL CHITOSAN/ PVA HYDROGELS IN ANTICANCER THERAPY THROUGH COLD PLASMAS

Smruti Prava Das

Department of Chemistry, Ravenshaw University, Cuttack-753003, Odisha, India

E-mail: spdas@ravenshawuniversity.ac.in

Abstract

Increasing environmental awareness has introduced stringent regulations controlling pollution and as global population escalates; the need for better healthcare shall inevitably expected to enhance. The latest estimates of International Agency for Research on Cancer (IARC) predicts new cancer cases and cancer deaths at 18.1 million and 9.6 million respectively [1, 2]. This worrisome upsurge in cancer incidences and mortalities has fuelled the research in novel chemotherapeutic formulations. Of late, design of biomaterials comprising natural polysaccharides have gathered pace. Chitosan (CS), a natural cationic polymer and endowed with inimitable features like biodegradability and biocompatibility, is prominent in cancer therapy [3-4]. Current scenario, thus, calls for a versatile technology for the construction for smart biomaterials to cater to the needs. In this context; hydrogels comprising carboxymethyl chitosan and polyvinyl alcohol (CMCS/ PVA) were fabricated using a green cross linker, tetraethyl ortho silicate. To enhance their bio-efficacy; cold plasma assisted surface tailoring of the aforesaid hydrogels was performed as a function of four different gases viz Air, Ar, He and N_2. Apart from improving the surface wettability; plasma treatment endowed the hydrogels with an improved tensile strength. 5-Fluorouracil (5FU) release studies from the hydrogels validated their potential as oral colon-targeted delivery systems. Hemolytic experiments revealed no adverse effect on RBCs post-plasma treatment. Pristine hydrogels exhibited good cytocompatibility with MCF-7 cells. A strong cell growth inhibition was observed from 5FU-loaded hydrogels as validated by caspase-3 assay. Further assessment by the soil burial test revealed the hydrogels were biodegradable. Among all, the Ar-plasma treated hydrogel demonstrated superior hemocompatibility, chemosensitivity and biodegradability. Thus, cold plasma technology has invariably paved the path as an eco-friendly, economical and effectual strategy for development of novel CMCS/ PVA hydrogels in anticancer therapy.

Keywords Carboxymethyl chitosan · PVA · Cold plasma · Chemosensitivity · Hemocompatibility

Reference:

1. Bray F et al Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 68:394–424 (2018)

2. Cai Z, Liu Q Understanding the Global Cancer Statistics 2018: implications for cancer control. Sci China Life Sci. https:// doi.org/10.1007/s11427-019-9816-1(2019)

3. Ta HT, Dass CR, Dunstan DE Injectable chitosan hydrogels for localised cancer therapy. J Control Release 126:205–216(2008)

4. Rostami E Progresses in targeted drug delivery systems using chitosan nanoparticles in cancer therapy: a mini-review. J Drug Deliv Sci Technol 58:101813 (2020)

Rapid Crystal Growth and Controlled Tailoring of Defect Density in TiO_2 Crystal Lattice using Plasma – Liquid Interaction

Parisima Kalita[1, 2*], Palash Jyoti Boruah[1], and Heremba Bailung[1, 2]

[1]Plasma Application Laboratory, Physical Sciences Division, Institute of Advanced Study in Science and Technology (IASST), Paschim Boragaon, Guwahati – 781035, Assam, India
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad – 201002, India
[3]Department of Physics, Bodoland University, Kokrajhar – 783370, Assam, India

E-mail : 2015parismitakalita@gmail.com

Abstract

Plasma – Liquid Interaction (PLI) is a recently growing interdisciplinary research field in the interface between atmospheric pressure plasma and material science. The interface between two states of matter (plasma and liquid) is a highly complex zone, where a lot of physicochemical processes take place. These physicochemical processes give rise to the formation of a wide range of reactive species. The presence of a wide range of reactive species in the plasma zone results in an intrinsic high chemical reactivity compared to ordinary chemical reaction media that offers several advantages in material processing.

This work demonstrates the rapid phase transition of amorphous to phase pure anatase TiO_2 using titanium butoxide (TTB) as the raw material. 10 minutes of plasma treatment is sufficient for a highly crystalline phase of anatase TiO_2. The evolution of crystal growth in the plasma environment is studied extensively by varying the plasma treatment time. With the increase in plasma treatment time, the crystallinity of the material breaks due to the incorporation of oxygen vacancy and Ti-related defects. XPS and Mott-Schottky results reveal that the defect density in the TiO_2 crystal can be efficiently controlled by varying the plasma treatment time. We have also investigated the effect of nitrate/nitrite species in the crystal growth process. The cationic dye adsorption and photocatalytic activity of the plasma synthesized material are quite rapid, and the performance depends on the material's surface condition and the defect density in the crystal lattice.

References:

[1] P. Kalita, P. J. Boruah, R. R. Khanikar, and H. Bailung, J. Photochem. Photobiol. A: Chem., **434**, p 114251-114265, (2023)
[2] X. Kong, Y. Xu, Z. Cui, Z. Li, Y. Liang, Z. Gao, S. Zhu, and X. Yang, Appl. Catal. B Environ., **230**, p 11-17, (2018)

Electromagnetic Shielding of Bulk ZnO at Different Sintering Temperature in Ku-Band

Dibyaranjan Das, Arpita Priyadarsini Dikshit, Kajal Parashar, S.K.S. Parashar

Nanosensor Lab, Campus-3, Kalinga Institute of Industrial Technology, Deemed to be University, Bhubaneswar-751024, Odisha, India

sksparasharfpy@kiit.ac.in

Abstract

The need for effective shielding materials to protect electronic equipment from undesired electromagnetic waves is crucial. The interference due to EM waves has caused degradation to instrumental life leading to production of huge electronic waste. The present work describes, in detail the preparation and characterization of ZnO ceramic powder by conventional solid state method. The ZnO ceramic powder were sintered at 1200^{o}C, 1300^{o}C, 1400^{o}C for 2 hours. The synthesized material was examined for its potential application in EMI shielding. The Ku- frequency band (12-18GHz) was selected, which is very significant for industrial, radar and military application. X-ray diffraction was employed to confirm the phase formation and detect the impurities inside the sample. It confirms that there is no other impurity phase found and the average crystallite size was evaluated for 1200^{o}C, 1300^{o}C ,1400^{o}C sample by using Williamson Hall method. The surface morphology of the prepared sample was investigated by using FE-SEM. VNA was used to observe the electromagnetic interaction with ZnO having different sintering temperature to understand it's shielding and material properties.

Nuclear Fusion

Booster System Performance Test After Electrical Refurbishment

Rakesh Patel, Gaurang Mahesuria, Rohit Panchal, G.L.N. Srikanth, Dikens Christian, Pankil Shah, Ketan Patel, Pradip Panchal, Hiren Nimavat and Vipul L Tanna

Institute for Plasma Research, Bhat, Gandhinagar-382 428, India.

Email: rpatel@ipr.res.in

Abstract

The static heat loads on the 80 K thermal shields system of SST-1 will be removed using single phase liquid nitrogen cooling. The single phase liquid nitrogen is obtained using Liquid Nitrogen booster system. Booster system is in form of three storey building as pump cryostat at bottom, sub-cooler vessel cryostat at middle and pressurized vessel cryostat at upper. Boosting system utilized three centrifugal cold pumps at liquid nitrogen services among them two remain in operation and one remain in cold standby mode as redundant. 80K Booster's control system is powered through centralized UPS unit. Due to power surge from main power supply line, UPS power supply card got damaged. This surge also propagated to connected loads of UPS. Thus, several power supply components and associated wirings were affected. It is envisaged to test integrated performance of 80K booster system to obtain the performance benchmark as of today after heater drive replacement and to check VFD point of view booster pumps operation. After Replacement of 23kW heater drive and faulty SMPS power supply, no other problem found in the electrical wiring of Booster system. Automatic operation of booster system's process modes starting from idle, filling liquid, cool down 1st phase, cool down 2nd phase, steady state, self-test and warm up were tested successfully with their associated safety interlocks.

Design of water cooled Helholtz coils for hydrogen isotope permeation barrier coating experiment

Vilas Chaudhari, Arvind Kumar, P. A. Rayjada, Y.S.S. Srinivas

Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat, India

E-mail: vilas@ipr.res.in

Abstract

Hydrogen isotope permeation barrier coatings are of utmost importance in the next generation Nuclear Fusion Blanket and Fuel Cycle system components for effective containment of radioactive and hard earned (bred) tritium from safety as well as tritium accounting purpose. IPR has been developing the hydrogen isotope permeation barrier coatings using reactive planar magnetron sputter coating technique. Having the coating optimized and characterized extensively, it is planned to take the next leap by making the coating on internal surface of a pipe which is required in the fusion blanket and fuel cycle systems. Hence, a customized system has been designed to simulate magnetron like electro-magnetic environment on a cylindrical cathode surface to achieve the same. This design requires a magnetic field of about 300 Gauss parallel to the cylindrical surface of 300 mm length and 13 mm diameter.

Water cooled Helmholtz coils are designed using oxygen free copper conductor to produce this field. An optimized design of the coils is obtained by analyzing various coil parameters such as pancake configuration number of turns, size of the conductor, coil width and height. Further the design is optimized to keep the non-uniformity of the field to less than 1.8%. The field profiles were calculated analytically and verified by modelling in COMSOL multiphysics. Parameters of water cooling such as pressure drop, mass flow rate and temperature rise were calculated analytically. Double pancake configuration with forced cooling (water cooling) is considered to obtain the required parameters. Coil fabrication techniques were also studied considering ease of fabrication, cooling circuits and assembly of coils. The coils are under fabrication and their factory testing is expected soon.

This paper describes the details of the Helmholtz coil design.

References:

[1] Conceptual Design of Cylindrical Reactive Sputter Coating System, March 2021, Report number: IPR/TR-618/2021
[2] Process Optimization of Er2O3 Coating by Reactive Magnetron Sputtering for DEMO-Relevant Blanket Modules, Fusion Science and Technology, 65(2), (2014)

Engineering Design of Central Solenoid (CS) Coil for Small Scale Spherical Tokamak (SSST)

Arvind Kumar*, Vilas C Chaudhari, S Ranjithkumar, Ananya Kundu, YSS Srinivas, E Rajendra Kumar

Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382428

E-mail: arvindk@ipr.res.in

Abstract

A Small Scale Spherical Tokamak (SSST) is currently being designed and developed at Institute for Plasma Research, Gandhinagar to realize a low aspect ratio (R_0/a) and experimenting with such a compact tokamak machine. The objective of the machine is to achieve a Toroidal field (B_T) of 0.1 T, a plasma current (I_p) of 28.5 kA, major radius (R_0) of 28 cm, and aspect ratio (A) of 1.75. To attain the required Toroidal and other magnetic fields, the machine is equipped with one Central Solenoid (CS), 6 Transformer coils (TR), 6 Toroidal Field (TF), and 6 Poloidal Field (PF) coils. All these coils are resistive coils, having natural cooling, and therefore their thermo-mechanical behaviour is required to study.

High currents are pulsed in these coils for the SSST operation. Due to the short pulse length of the current and machine duty cycle, the thermo-mechanical behaviour of CS coil goes through the transient conditions. The pulse length of 50 milliseconds and sharp di/dt are key aspects for the coil design. A double layer CS coil has been designed considering the rectangular current waveforms and ensuing Joule heating and related stresses during the tokamak operation. Various design options evaluated and design constraints like, availability of limited space available at inboard side, etc. are also discussed in this poster.

Development of an ice pellet injector for the multipurpose application in a high-temperature plasma

J. Mishra, P. M. Panchal, S. Mukherjee, V. Gupta, H. Agravat,
M. Banaudha, P. Nayak, R. Gangradey

Institute for plasma research, Bhat, Gandhinagar, Gujarat-382421

E-mail: jsmishra@ipr.res.in

Abstract

Plasma fuelling using frozen solid pellets of hydrogen gas or its isotope is an established method. Currently, frozen pellets of hydrogen, argon, and neon have gained importance for plasma disruption mitigation studies in different tokamaks. A pellet injector has been developed at IPR for disruption mitigation and pellet-plasma interaction studies. This injector comprises sub-systems like a cryostat, a three-stage differential pumping system, and a gas feeding system. A GM cycle cryocooler has been used in the cryostat to achieve the desired temperature for freezing pellets of different gases. The cryostat design has been optimized to achieve a temperature of < 6 K at the pellet freezing zone. A screw-nut type joint employed in the cold block gives the flexibility to accommodate different size barrels without replacing the pellet freezing block (PFB). The freezing zone temperature can be varied from 5 K and 15 K by using the heater installed to the PFB. A gas feed system has been installed on the cryostat for the pellet freezing and propellant gas control. The gas feed system is capable of handling a propellant pressure of up to 100 bars. A three-stage differential pumping system has been installed in the injector to remove the propellant gas from the pellet transfer line.

Instead of the conventional fast valve, a new technique, called mechanical pellet launcher (MPL) has been developed and tested for pellet dislodging and acceleration. In the experiments, cylindrical hydrogen pellets of 4.2 mm $\boldsymbol{\varphi}$ × 6.2 mm ℓ has been successfully achieved. Using the MPL injection technique, a pellet speed of 80-140 m/s has been achieved. Further, this injector will be used for neon and argon pellet formation and injection. This paper will present the details of the injector design, test results, and the future experimental scope.

Comparative Study of Refractive Optics Based Endoscope and Wound Imaging Fiber Bundle

Suraj Kumar Gupta, Vishnu Chaudhari, Manoj Kumar,

Institute for Plasma Research, Bhat, Gandhinagar India.

E-mail: skgupta@ipr.res.in

Abstract

High speed visible imaging is novel field in the tokamak diagnostics. Being a direct measurement technique, it can provide information about plasma characteristics without any addition of other signals. This diagnostics is also challenging as camera does not work in high magnetic field. To resolve this problem, most wound imaging fiber bundle is used. The fiber bundle separates the objective lens and the sensor of the camera so that the camera can be placed outside the high magnetic field. The fiber bundle is has a disadvantage of honeycomb structure, which degrades the plasma image quality and requires post processing of the images to clean the image. To overcome this problem a refractive optics endoscope has been used. The system is designed and manufactured. In this report, study of images from endoscope and wound imaging fiber bundle is done. Image quality is much improved as compared to wound imaging fiber bundle. The endoscope can also be tested with tokamak plasma.

References:

[1]. A. Geraud et al, Fast Imaging system on Tore Supra Rev. Sci. Instrum., 80, 033504 (2009).

[2]. Minghui Xia et al, Fusion Engineering and Design Volume 146, (2019).

[3]. https://www.schott.com/en-ro/products/flexible-imaging-bundles-p1000343/downloads.

[4]. D. Iraji, A. Diallo, A. Fasoli, et al., Fast visible imaging of turbulent plasma in TORPEX Rev. Sci. Instrum., 79 (10) (2008), p. 10F508

Development of Serial Wireless module for the Remote operation of various Auxiliary systems in ITER-India Test Gyrotron Facility

Deepak Mandge, E Sharan Dilip, Rajvi Parmar, Vipal Rathod, Ronak Shah, Amit Yadav, Anjali Sharma, S.L Rao and Kumar Rajnish

ITER-India, Institute for Plasma Research
Bhat, Gandhinagar 382428

E-mail: deepak.mandge@iterindia.in

Abstract

The High Power RF Source (Gyrotron, 1MW, 170GHz) is installed at ITER-India Test Gyrotron Facility (IIGTF). The Gyrotron Source [1] requires various High Voltage Power Supplies, Auxiliary power supplies & services and a dedicated Local Control Unit (LCU) to operate it. The main functions of LCU are Sequence Control, Interlock & Protection and Real time Data acquisition. [2]

Many Auxiliary systems are remotely operated from LCU using various networking protocols such as RS232, RS485, Modbus & TCP/IP. In this context, The Serial Wireless module has been designed & developed successfully to operate remote auxiliary devices with inbuilt RS232 port over Wi-Fi network. This module is developed using Arduino ESP8266 NodeMCU[3] and MAX232 chip. Basically, this module converts serial RS232 data in Wi-Fi IEEE 802.11n format and vice versa using TCP communication. The Serial Wireless module is configured as a TCP server. The remote PC, configured as TCP client, connects to this Wi-Fi network and remote auxiliary device can be accessed using proprietary software or custom developed software. This module has many advantages such as completely Wireless [4], Portable, Independent of auxiliary device, Battery operated, Plug-n-play and easy to deploy type. The multiple such modules, connected to different auxiliary devices, can be connected in one Wi-Fi subnet and accessed from single PC for control & acquisition purpose.

This paper presents the design and deployment of this module in details. This module is currently installed in Pfeiffer Vacuum Gauge Controller (TPG 256A) along with custom developed Windows application. This application displays live pressure gauge values, save these values in database and can export to Excel sheet, can configure Threshold set points for digital alarm generation and send this pressure values to PLC for display in Graphical User Interface.

References:

[1] S.L. RAO et al., Fusion Science & Technology, 65, 129-144 (2014)
[2] V. RATHOD et al., Fusion Eng. Des., 112, 897-905 (2016).
[3] https://www.espressif.com/en/products/socs/esp8266
[4] Deepak Mandge et al., International Journal of Sensors, Wireless Communications and Control, Volume 9, Issue 3, 2019, Page: [345 - 356], DOI: 10.2174/2210327908666181107103604

DESIGN OF COOLING WATER SYSTEM FOR ITER-INDIA LABORATORY

R. Ranjan*, D. K. Gupta, R. Agarwal, L. Sharma, S. Jha, M. Chodavadiya, N. Parmar

ITER-India, Institute for plasma research, Ahmedabad-380005, Gujarat, India

*Email: rakesh.ranjan@iterindia.in

Abstract

In order to ensure the quality and performance of various components of experimental devices being provided to the ITER- France project by ITER-India , a Cooling Water testing facility is being procured by infrastructure, ITER-India for ITER-India laboratory (II-Lab). The various components are mainly related to Power Supply, ECRH, ICRH, IPR and DNB systems. In order to remove the heat generated during this testing, the Cooling Water System (CWS) with adequate capacity has been designed.

The key aspect of the CWS design for II-Lab lies in meeting the diverse requirements, with inlet temperatures 20°C and 38°C, from demineralized water to ultra-pure water with ionic conductivity as low as $\leq 0.1\mu S/cm$, the supply pressure upto 2.4 MPa and critical dissolved oxygen limit of $\leq$ 0.01 ppm. The primary heat transfer systems are designed based on grouping of consolidated requirements of various users (experimental devises) and the combined heat rejection system is designed to dissipate 15 MW heat to atmosphere.

As this CWS is primarily meant for testing of various components for ITER- France project, the optimization is to be done by considering duty cycle of the testing campaign, also by staggering the testing schedule of different components during final design. Being a centralized water cooling facility, requirements of cooling water for ongoing developmental projects of domestic fusion program in IPR also have been included in this design. Sufficient margin in the capacity is considered so that additional experimental devises of IPR may also be added in near future.

This paper describes the development of an optimized CWS design, which is capable of supplying cooling water with the required parameters to the components of ITER India Test Facility.

Keywords: ITER-India, Cooling water System, ITER

Experimental and Numerical Characterization of Ceramic Pebble Beds Under Cyclic Loading

Maulik Panchal[1,*], Chirag Sedani[1,2], Harsh Patel[1,2], Paritosh Chaudhuri[1,2]

[1]Institute for Plasma Research, Bhat, Gandhinagar, 382428, India.
[2]Homi Bhabha National Institute, Anushaktinagar, Mumbai, 400094, India.

[*]E-mail : maulikpanchal@ipr.res.in

Abstract

In the tritium breeding blankets, different candidates of lithium-based ceramics have been chosen to generate and release tritium. For the design and analysis of the tritium breeding blankets, it is important to study the influence of the compressive loads on the mechanical performance of lithium-based ceramics packed in the form of pebble beds. The pebble beds comprised almost spherical-shaped particles of lithium-based ceramics. The uniaxial compression test (UCT) is one of the available experiments to measure the representative parameters of the compressed pebble beds. In UCT, pebbles, contained in a cylindrical container, are compressed in the axial direction. The pebble bed axially deforms under the applied load while the lateral deformation is inhibited by the wall of the container. The stress-strain response of the bed is used to characterize the mechanical behaviors. In this work, the uniaxial compression test (UCT) experiments along with the discrete element methods (DEM) simulations have been performed on pebble beds of different types and sizes. The effect on the breeder blanket operational parameters like packing factor, pebble bed material type, pebble size, and compressive load has been studied under cyclic loading and unloading. DEM results have been compared with experiments and found to be in good qualitative agreement.

UP GRADATION OF CONTROLLER AND LOAD TEST FOR 1700KVA DG SET NO.1

Chirag Bhavsar, Chandra Kishore Gupta, G.K.Rajan, Supriya Nair, Prakash Parmar

Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382 428

E-mail: chirag@ipr.res.in

Abstract

Electrical Power Distribution System in IPR comprises of 132 kV Substation supplied by dedicated 2 GVA SCC line by the Grid Operator (UGVCL). The 132 kV substation hosts four 132 kV / 11.5 kV main step down transformers of 31.5 MVA, 37.5 MVA and 2 x 15 MVA and one 132kV/22 kV step down transformer of rating 31.5 MVA. The total installed capacity of around 130 MVA caters to both steady/continuous power demand (~6 MW) and pulse power demand (~50 MW) of the Institute. The power demanded by the systems is supplied at 11 kV, 22kV & 415 V voltage level

We have Emergency Power Distribution System: The Emergency Power distribution System caters electrical power demand from various systems viz. Cooling Water System, Cryogenic and other important safety and investment protection systems. It comprises of 2 x 1700 KVA Diesel Generators.

DG set No.1 have been commissioned in year of 2001 with EGCP-2 controller and it needs upgraded and retrofit with latest available controller i.e. .EASYGEN MAKE, MODEL: EASYGEN 3200XT.

This paper gives detailed information related the up gradation & retrofitting of controller and load test of 1700KVA DG set No.1.

References:

[1] Easygen_3200XT_Manual

Measurement of radial magnetic field in Aditya-U tokamak

A.Kundu[1,2], S.Aich[1], L.K.Pradhan[1], R.Kumar[1], Praveenlal E V[1], A.Kumar[1], J.Ghosh[1,2], R.L.Tanna[1,4], S.Dolui[1,2], K. Singh[1,2], A.Kumar[1,2],A.Kumawat[1,2], B.Hegde[1,2], K.A. Jadeja[1,5], K.M.Patel[1], A.Patel[1],H.Raj[1],S.Patel[3],K.Galodiya[1],N.Nimavat[1], A. Kanik[6], N.Yadava[4], K. Shah[3] and the ADITYA-U team[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar-382428*
[2]*Homi Bhaba National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094*
[3]*Department of Physics, Pandit Deendayal Energy University, Raisan, Gandhinagar 382007*
[4]*Institute of Science, Nirma University, Ahmedabad 382481*
[5]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360005*
[6]*University of Petroleum and Energy Studies, Dehradun, Uttarakhand 248007*

E-mail: ananya@ipr.res.in

Abstract

In a magnetically confined device like tokamak, the plasma is susceptible to many instabilities which tend to degrade the confinement. The plasma confinement in tokamak is significantly affected by the formation of magnetic island which enhance the radial transport of plasma. The uncontrolled growth of the magnetic island results in disruption of plasma. During the pre-cursor phase of the disruption, the magnitude of radial component of the magnetic field increases significantly [1]. Hence the prevention of the growth of radial magnetic field or nullifying the existing radial magnetic field by applying an external radial perturbation at the pre-cursor phase of the disruption may aid in mitigating the disruption.

In Aditya-U tokamak, it is planned to apply a radial magnetic perturbation to create a local magnetic ergodisation to study its effect on MHD activity, edge plasma transport and on disruption. Prior to the application of radial perturbation, the existing radial magnetic field of Aditya-U tokamak during vacuum shots and plasma shots are measured. To measure the radial magnetic field, a copper coil is designed, fabricated, tested and mounted in port #11 of Aditya-U tokamak during real time operation. A steady state simulation for the estimation of radial magnetic field for the existing coil assembly in Aditya-U tokamak has been carried out. In this work, the measurement details, data analyses and the results of the radial magnetic field measurement are discussed. The measured data are compared with the analytical and simulated value of the radial magnetic field for Aditya-U tokamak.

References :

[1] Wesson J 2004 Tokamaks (Oxford: Clarendon)

Instrument Reliability - Maintenance in SST-1 Cryogenic Warm Gas Management

Gaurang Mahesuria, Rohit Panchal, Pankil Shah, Ketan Patel, Rakesh Patel, Pradip Panchal, Hiren Nimavat and Vipul L Tanna

Institute for Plasma Research, Bhat, Gandhinagar-382 428, India.

Email: gaurang@ipr.res.in

Abstract

The SST-1 Cryogenic system has been widely spreader in terms of handling many auxiliary sub-systems, which include integrated flow distribution system (IFDCS), current feeder system (CFS), warm gas management system (WGM) and 80 K booster system [1]. These subsystems operate on a round-the-clock basis and it is mandatory to provide a safe and reliable solution in terms of a continuous operation of the system. The WGM consist of high and medium pressure Helium gas and Liquid Nitrogen storage tanks. The instrumentations involves transmitters for Pressure, Temperature, Level and control as well as ON/OFF valves which are accommodated in exposed region. Instruments play an essential role in the achievement of the expected results, but the instruments themselves can be sources of unreliability and fault within industrial plants. So preventive maintenance of these instruments plays major role in cryogenic system. This paper describes the preventive maintenance carried out for the safe and reliable operation of WGM.

References:

[1] V. L. Tanna et al., "SST-1 cryogenics requirements and the way forward," in Proc. 27th Int.At. Energy Agency Fusion Energy Conf., 2018, pp. 1–7.

Parameter Choices and Constraints for Indian DEMO

P.N. Maya and S.P. Deshpande

Institute for Plasma Research, Bhat, Gandhinagar, 382428, India

E-mail: pnmaya.n@gmail.com, spd@ipr.res.in

Abstract

One of the exciting questions for the development of a fusion DEMO roadmap is whether it is possible to design a compact tokamak reactor with a net electricity production. While there exists no unique roadmap to DEMO, the designs will continue to evolve based on the advances in fusion science and technology fronts. Therefore, multiple routes to DEMO will have to be explored before zeroing in to the final design choice [1]. In this work we present two potential design choices one based on the conventional aspect ratio tokamak and another one on the spherical tokamak-based design. Both the designs aim to produce a net electric power about 250 MW with a fusion gain of about 20. While the conventional choice is based on the low temperature superconducting magnets, the recent advances in the high-temperature superconductors and the novel ideas of extreme heat handling offers hitherto unexplored opportunities in the ST-based DEMO designs.

The parameter scans over several plasma physics and engineering parameters are carried out using SARAS code, a reactor design code developed in IPR [2, 3] and it was found that two potential design choices seem to be feasible. For a normal aspect ratio (A=3) design, a reactor with 1500 MW fusion power is explored with a major radius of 7.7 m. This is a modified parameter-space of an already suggested choice given in Ref [4]. The studies also show the requirement of a HTS based magnet with an engineering current density above 30 A/mm^2 for compact designs. The ST-DEMO is of 5.4 m major radius with an aspect ratio of 1.9. The choices for the machine size are explored based on the constraints arising from the magnet current density which is a crucial factor in the design of the centerpost, the shielding thickness at the inboard side, the capability for current drive, minimizing the transport power as well as the recirculating power and the maintenance scheme chosen. The details of the calculations along with the quantitative requirements for R&D targets will be discussed.

References:

[1] S.P. Deshpande, A Staged Approach to Indian DEMO, Submitted to review in IPR
[2] S.P. Deshpande and P.N. Maya, Parameter-Space for a ST-Reactor Roadmap, 2022 IPR/RR-1408/2022
[3] P N Maya S P Deshpande, 8th IAEA-DEMO Workshop, 30 Aug.- 02 Sept. 2022, Vienna
[4] Srinivasan R and Deshpande S 2008 Fusion Engineering and Design 83 889–892

12 kA / 16 VDC switch mode power supply Operation Experience during HTS Current Lead and MgB_2-NbTi: Cu Joints test

D. Christian[a,*] , N. Bairagi[a,b] , P. Panchal[a], R. Panchal[a], G. Purvar[a], D. Sonara[a], H. Nimavat[a], A. Garg[a], R. Patel[a], G. Mahesuria[a], U. Prasad[a], V.L. Tanna[a,b], D. Raju[a,b]

[a]*Institute for Plasma Research (IPR), Bhat, Gandhinagar-382 428 Gujarat, India*
[b]*Homi Bhaba National Institute, Training School Complex, Anushakti Nagar, Mumbai-400 094, Maharashtra, India*

E-mail: dikens@ipr.res.in

Abstract

Recently, prototype 3.3 kA high-temperature superconductor current leads (CL) pair is developed at IPR. The basic design of this CL is derived from an earlier version of 10 kA high temperature superconductors (HTS) CL from IPR, mainly the bottom joints section is replaced as HTS: Cu – Cu: MgB2 – Cu: NbTi. The bottom lap joints using composite magnesium diboride (MgB2) wires as an intermediate between HTS module and NbTi: Cu cable that act as a shunt between CL pair has been indigenously developed at IPR, For the testing of this newly developed joint (MgB2 – Cu: NbTi.) and HTS CL, dedicated 12 kA 16 VDC high current-low voltage programmable switch mode power supply (SMPS) is used. This power supply has special features such as modularity (8 modules), N+1 redundancy, very low ripple voltage (< 8 mVrms), precise current measurements with Direct Current - Current Transformer, CC/CV modes with auto-crossover and auto-sequence programming. The paper describes the salient features and state-of-art of power supply, prior experimental preparation, experience and results obtained from this converter during the testing of HTS CL and MgB2 and Cu: NbTi. Joint, especially for current control (CC) mode at various current levels are discussed.

References:

[1] Experience of 12 kA / 16 V SMPS during the HTS Current Leads Test, Journal of Physics: Conference Series 755 (2016) 10th Asia Plasma and Fusion Association Conference IOP Publishing

[2] Nitin Bairagi et al., IPR/RR-1434/2022 Performance Evaluation and Test Results of 3.3 kA rated HTS Current Leads at IPR

3D Computational Fluid Dynamics Simulation of Heat Transfer for PINI Ion Source Back Plate

Tejendra Patel, M. R. Jana and U. K. Baruah

Institute for Plasma Research
Bhat, Gandhinagar 382428, Gujarat, India

E-mail: tejendra.patel@ipr.res.in

Abstract

Neutral Beam Injection (NBI) is very efficient in heating and current drive of Tokamak fusion plasma. SST-1 has a Positive ion based NBI (PNBI) system capable of delivering 1.7 MW neutral hydrogen beam power at 55 keV. JET PINI (Positive Ion Neutral Injector) type ion source is used in PNBI systems. Back Plate (BP) is an important component of PINI ion source and consists of SS304L magnet positioning plate, SS304L magnet cover plate and OFE copper cooling plate respectively. During beam operation BP received 2.5 MW/m^2 heat load. To remove such heat load dense networks of water cooling channels are provided. BP is successfully fabricated in India and its performance test is also done at HHFTF center, IPR [1]. The present paper described three-dimensional Computational Fluid Dynamics (CFD) simulation of Back Plate using the numerical model with the help of ANSYS computer program. The 3D model is created in ANSYS workbench and meshed using advanced fluent meshing. The hybrid (hexahedral and tetrahedral) type of mesh has been used due to the non-uniform shape of the model. 60 LPM water at 34^0C is supplied to the inlet manifold of BP. The above mentioned heat load is intercepted on the surface of the OFE copper cooling plate. The realizable k-$\mathcal{E}$ turbulence model has used in simulation as the flow of water is turbulent. The Semi-Implicit Method for Pressure-velocity Linked Equation (SIMPLE) algorithm is used to solve the governing equation and boundary condition. The flow momentum and energy equations have been discretized by using second-order upwind methods. It has been observed that average water velocity in the cooling channel area is 9 m/s. The inlet pressure and outlet water temperature are found to be 8.4 bar and 46^{o}C respectively. The numerical result shows that the surface temperature of OFE copper cooling plate is ~ 176^{o}C and consistent with the experimental result.

Keywords: - Back Plate, Heat Transfer, Temperature, Computational Fluid Dynamics

Reference:-

[1] M.R. Jana, S.M. Belsare, K.S. Bhope, B. Choksi, N.S. Contractor, S.S. Khirwadkar, P.K. Mokaria, N.P. Patel, T.H. Patel, R. Swamy, S. Tripathi, Performance of High Heat Flux Test of Positive Ion Neutral Injector Ion Source Back Plate, in: 28th IAEA Fusion Energy Conf., 2020: p. 1.

Comparative Study of Refractive Optics Based Endoscope and Wound Imaging Fiber Bundle

Suraj Kumar Gupta, Vishnu Chaudhari, Manoj Kumar,

Institute for Plasma Research, Bhat, Gandhinagar India.

E-mail: skgupta@ipr.res.in

Abstract

High speed visible imaging is novel field in the tokamak diagnostics. Being a direct measurement technique, it can provide information about plasma characteristics without any addition of other signals. This diagnostics is also challenging as camera does not work in high magnetic field. To resolve this problem, most wound imaging fiber bundle is used. The fiber bundle separates the objective lens and the sensor of the camera so that the camera can be placed outside the high magnetic field. The fiber bundle is has a disadvantage of honeycomb structure, which degrades the plasma image quality and requires post processing of the images to clean the image. To overcome this problem a refractive optics endoscope has been used. The system is designed and manufactured. In this report, study of images from endoscope and wound imaging fiber bundle is done. Image quality is much improved as compared to wound imaging fiber bundle. The endoscope can also be tested with tokamak plasma.

References:

References:

[1]. A. Geraud et al, Fast Imaging system on Tore Supra Rev. Sci. Instrum., 80, 033504 (2009).

[2]. Minghui Xia et al, Fusion Engineering and Design Volume 146, (2019).

[3]. https://www.schott.com/en-ro/products/flexible-imaging-bundles-p1000343/downloads.

[4]. D. Iraji, A. Diallo, A. Fasoli, et al., Fast visible imaging of turbulent plasma in TORPEX Rev. Sci. Instrum., 79 (10) (2008), p. 10F508

Measurement Of The Modified Surface Hardness Of Tungsten As An Indicator To Understand The Recrystallization Kinetics And The Possibility Of Retardation Due To Helium Plasma Exposure

Sabir Chetri[1], Mizanur Rahman[1], Monoj Baruah[2] and Mayur Kakati[1]

[1]*CIMPLE-PSI Laboratory, Centre of Plasma Physics-IPR, Sonapur 782 402, India*
[2]*Dept. of Energy Engineering, Assam science and Technology University, Guwahati 781 013, India*

E-mail : sabir.chetri@cppipr.res.in

Abstract

In the ITER tokomak, the divertor region will be comprised of Tungsten (W) as the plasma facing material (PFM). During operation the plasma supplied thermal heat load may increase the surface temperature of W beyond 1573 ˚K leading to its recrystallization and reduction in the hardness of the material, thus degrading its mechanical properties. However, it was also observed that helium (He) plasma exposure of W could retard the process of recrystallization and grain growth, due to the drag force exerted by the He-bubbles/pinholes trapped on the W grain boundaries. CIMPLE-PSI is a linear tokamak divertor simulator device, which can reproduce ITER like intense ion ($\sim 10^{24}$ $m^{-2}s^{-1}$) and heat-flux (~ 5 MWm^{-2}) that may be used for controlled plasma fusion research relevant plasma surface interaction (PSI) studies[1]. In this paper, we report measurement of the change in surface hardness of W with increasing target temperature and changing recrystallization status, while exposed under He plasma in CIMPLE-PSI, under very high He^{+}-fluence (3×10^{27} m^{-2}) and extreme temperature up to 1866±5 ˚K. Some vacuum annealed samples are also used for comparison. Vickers micro hardness tester (Metatech, MVH Auto) was used for the measurements, with an indentation load and dwell time of 10gf to 500gf and 10s respectively. As expected, the surface micohardness reduced with increasing target temperature, which is in agreement with the previous observations. A large drop in microhardness is observed beyond the target temperature of 1407 ˚K for a vacuum annelaed W sample, which definitely marked the end of recovery stage and the onset of the recrystallization process. However, a plasma irradiated sample exposed almost at the same temperature shows higher microhardness, which must be because of the retardring effect caused by the diffused helium[2]. The surface microhardness for the sample exposed at the highest temeparture was measured as 391 HV, which may indicate completion of recrystallization. But large error bars associated with those samples, attributes to the co-existence of both deformed and recrystallized grains[2]. It may be concluded that surface hardness aptly reflects the progression of recrystallization and the retarding effect due to the plasma exposure. Further we would like to investigate the surface hardness as a function of applied load and the indentation depth which may also elucidate the recrystallization behavior of the He-plasma exposed W and possibility of retardation.

References:

[1] Design, development and recent experiments of the CIMPLE-PSI device, Nucl. Fusion, **59**, p 112008, (2019)
[2] Retarded recrystallization of helium-exposed tungsten, Nucl. Fusion **58,** p 106011, (2018)

CONDITIONING INSTALLATION TESTING AND COMMISSIONING OF PF CONVERTER TRANSFORMER

Akhilesh Kumar Singh, Amit Ojha, Dinesh Kumar Sharma, Murtuza Vora, Supriya A Nair

Institute for Plasma Research, Bhat, Gandhinagar,382428

akhilesh@ipr.res.in

Abstract

There are 13 coil power supplies for the SST-1 PF magnets. Each of these power supplies have associated converter transformers. Converter transformers are of core type and have different kVA rating and voltage ratio according to PF coil inductance and circuit resistance. Two transformers have been enclosed inside the tank and each having two secondary. The vector group of transformer is Ext.Delta+15 °/ Y_oY_6 & Ext.Delta-15 °/ Y_oY_6 to obtain 30 degree phase shift for 12 pulse converter. The duty cycle of transformer is 17 minutes ON and 43 Minutes OFF.

The converter transformers were manufactured in 2003-04 and a complete overhauling was required before going to final installation and commissioning to assert the healthiness of the transformers.

This paper describes initial physical observation, complete overhauling of converter transformers which covers lifting of core and coil assembly, cleaning of assembly and observation of paper insulation, core earthing, wooden block supports of core assembly, primary and secondary jumpers, replacements of all gaskets and oil seal, replacement of winding and oil temperature indicator, repairing and testing of buchholz relay, oil filtration and its testing, placing the transformer on foundation, painting, control wiring and its cold simulation and energization of transformers.

Keyword: Converter transformer, 12 pulse converter, PF magnets, kVA rating and vector group, Conditioning, Commissioning, Testing etc.

Migrate online impedance matching system for ICRH transmission line DAC

Ramesh Joshi, H M Jadav, Sunil Kumar and High Power ICRH systems Division

Institute for Plasma Research, Bhat, Gandhinagar 382428, India

E-mail : rjoshi@ipr.res.in

Abstract

The Ion Cyclotron Resonance Heating (ICRH) transmission line Data Acquisition and Control (DAC) system is a part of whole ICRH DAC system which was commissioned for RF transmission from RF source to antenna at tokamak end. To deliver constant full power, the matching system with dynamic response in between generator and antenna is very much essential for high power ICRF experiments. In the existing system, the analog data acquisition card (Pentland VGD4) has 96 channel simultaneous sampling which was used to implement real-time feedback control for online matching system. However because of card initiation and random data acquisition problem due to existing ADC card fault, this card must be replaced with redundant hardware inventory. Existing card is replaced by three acromag IP330 analog input cards as it contains 32 single ended ADC. IP330 analog cards have been included and integrated with existing system. Carrier board has been configured with three ADC cards and card driver is modified as per the requirement. Analog cards driver is added to the existing driver program. Additional classes have been developed to integrate the driver application with RTOS environment. User interface is modified on Linux host machine to monitor and acquire for additional signals. Online matching system is migrated in IP330 module and validated with dummy signals. In this paper, the design and development of online impedance matching system with analog input card is explained and results are discussed.

Comparison of time series forecasting of future sequence of signals using deep learning models at Aditya/Aditya-U data

Ramesh Joshi[12], Joydeep Ghosh[23], Nilesh Kalani[1], R. L. Tanna[24] and ADITYA/ADITYA-U Teams

[1]*RK University, Rajkot, India*
[2]*Institute for Plasma Research, Bhat, Gandhinagar 382428, India*
[3]*HBNI University, Mumbai, India*
[4]*Institute of Science, Nirma University, Ahmedabad 382481, Gujarat, India.*

E-mail : rjoshi@ipr.res.in

Abstract

Disruptions are events in which large fractions of the plasma thermal energy is lost due to the uncontrolled growth of some large-scale plasma instability. Major disruptions leads to the sudden termination of plasma current in a very short time-scale. The forces and heat loads released during disruptions, particularly for large machine like ITER leads to the damage of plasma facing components (PFC) and vacuum vessel wall. Therefore, in order to avoid this damaging effects, disruption prediction and later its mitigation are an essential part of tokamak research. Data driven methodology employing time series analysis using relevant plasma parameters for prediction of disruption event before sufficient alarming time is useful due to absence of first principle physics methods. ADITYA (R_0 = 75 cm, a = 25 cm), an ohmically heated circular limiter tokamak has been upgraded to a tokamak named the ADITYA Upgrade (ADITYA-U) with an open diverter configuration. Based on previous ADITYA shots analysis of almost ~ 8000 discharges and regression analysis of the time series analysis has been developed using various deep learning methods. We have implemented Autoregressive Integrated Moving Average (ARIMA) and RNN using LSTM. Deep learning models are compared with test data and validated with Root mean square error (RMSE) which may lead towards future development of time series data-driven model for accurate prediction of disruption event at Aditya-U tokamak.

Design Development and Analysis of Drift Duct Liner (DDL) for Diagnostic Neutral Beam

Dhananjay Kumar Singh, M V Nagaraju, Jaydeep Joshi, Ashish Yadav, Mahendrajit Singh, A.K. Chakraborty
ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, Gujarat- 382015

dhananjay.singh@iterindia.in

Abstract

The Drift Duct (DD), interfaces the exit flange of the absolute flange with NB duct in the diagnostic neutral beam (DNB) line of ITER. It is an assembly of two components, the Drift Duct Liner (DDL) and Drift Duct Bellow (DDB). The DDB provides primary vacuum confinement and accommodates the relative displacement between the Vacuum Vessel (VV) and the Neutral Beam Line under different loading condition [1]. The DDL is an actively water-cooled component with a primary function to accommodate the heat loads from the reionised beam deflected by the magnetic fields and incident upon its surfaces and from the direct interception of the beam due to its divergence.
Design calculations have been performed to finalize the size and configuration of the liner. Finite Element Analysis method using ANSYS [2] has been adopted to verify the design with respect to its different load combinations imposed by the dead weight, temperature, pressure, seismic, reaction forces from interfacing components and other accidental load scenarios [1]. Apart from the engineering design, manufacturing feasibility is also important from the fact that based on the RCCMR/ASME requirements, full penetration welding is incorporated into the design for all the vacuum boundary welds. For the active cooling, deep drilled channels are considered in the design.
This paper would give details of DDL design criteria, analytical assessment, final design & its validation and manufacturing feasibility as per RCCMR/ASME for structural and thermal compatibility.

References:

[1] Load_Specification_for_the_DNB_Drift_Duc_TMTAFF_v4_0
[2] Ansys reference manual: 2010

DESIGN, ASSEMBLY AND TESTING RESULTS OF IGBT INVERTER MODULE FOR FRBPS

Dinesh Kumar Sharma, Murtuza M Vora, Amit Ojha, Akhilesh Kumar Singh, Supriya A Nair

Institute for Plasma Research, Bhat, Gandhinagar,382428

dinesh@ipr.res.in

Abstract

FRBPS (Fast Response Bipolar power supply) is being developed in IPR for Aditya and SST-1 tokamak. The rating are of +/-5 kA (Aditya), +/-6 kA (SST-1) and 500 VDC. For development of FRBPS, a single module was designed and assembled with full functionalities. The power circuit was tested with step input provided from waveform generator. The load was selected as 150 micro henry air core inductor. PF4U 12 pulse rectifier was used as DC source for capacitor. IPR designed Analog controller was used as hysteresis band controller for gate pulse firing of IGBT. In house developed fault processing card was used for the protection of H bridge inverter circuit. A converter transformer with two secondary (star-delta) was purchased and installed for 12 pulse rectifier circuit.
This paper describes various power, protection and control component selection, its assembly and testing of full H bridge circuit for step response.

Key word: H Bridge, IGBT, DC link capacitor, bipolar and band controller

Development of an Experimental Facility to Measure Emissivity at Cryogenic Temperature

Avijit Dewasi*, Samiran Shanti Mukherjee, Vishal Gupta, Rohan Dutta, Abhinav B. Desai, Jyoti Shankar Mishra, Paresh Panchal, Pratik A. Nayak, Ranjana Gangradey

Affiliation : Institute for Plasma Research, Gandhinagar, Gujarat-382 428, India

E-mail : avijit.dewasi@ipr.res.in

Abstract

Emissivity of materials at cryogenic temperature plays a crucial role in designing cryogenic systems, fusion devices and space applications [1]. In general, the emissivity of a material decreases with the reduction of the surface temperature [2]. Cryogenic devices are operated below 123 K and the contribution of the radiation heat load is significant as compared to the conduction and convection heat load. Radiation heat load in a cryogenic system can be properly estimated only if the emissivity of the materials are known at the operated temperatures. Thus, the knowledge of emissivity of a material at cryogenic temperature helps in estimating the required cryogen supply, and improve system design and accuracy. However, scarce information is available in the literature about the emissivity of newly developed materials at cryogenic temperatures. Therefore, an experimental setup is developed for measuring emissivity of the materials around 80 K. A theoretical as well as experimental efforts have been made to understand the effectiveness of low and high emissive heat radiators for the system. In order to verify and validate this setup, emissivity of SS-304L is measured and compared with the data reported in the literature.

References :

[1] Barron R. F, Nellis G. F.,"Cryogenic Heat Transfer", 2nd edition, CRC press (2016).
[2] Musilova V., Hanzelka P., Kralik T., Srnka A., Cryogenics, **45**, p 529–36, (2005).

In-house Development and Performance Testing of Pressure Relief Valves for application in High Vacuum System

P. Panchal, S. Mukherjee, R. Gangradey

Institute for plasma research, Bhat, Gandhinagar, Gujarat-382421

E-mail: pmpanchal@ipr.res.in

Abstract

Cryo-sorption cryopumps are being developed by Institute for Plasma Research for the application in nuclear fusion and space research. A vacuum chamber of the cryopump as a sealed volume, has the potential to become pressurized, when regeneration of pumped gas occurs. The other sources being any occurrence of leakage from the liquid cryogen supply (LN_2 or LHe) and bath inside the vacuum chamber. Consideration of one of the methods to reduce this possible risk is to employ a Pressure Relief Valve (PRV) on it as a safety device. Therefore, in-house development and performance testing of PRVs have been carried out. The PRV body housing has an end connection of DN40 KF, which is compatible with the port on the vacuum chamber and a vacuum sealing plunger having a spring over it. The threaded shaft with disc head having an O-ring groove for high vacuum sealing, which are the parts of a plunger. The PRV can be adjusted for a pressure range from 20 mbar (g) to 200 mbar (g) or as per system safety interlock. A helical compression spring having ϕ1.6mm wire diameter and 40mm length is used to create spring force that release the pressure, exceeding their set over pressure from the vacuum chamber of the cryopump. There is ϕ14mm threaded shaft of the plunger that has been chosen for the PRV under different spring compression for the respective set pressure for a particular spring. The measured leak rate of the PRV is observed < 1E-09 mbar l/sec tested in vacuum mode by helium leak detector during each set of experiments. The details of high vacuum compatible Pressure Relief Valve (PRV) having single acting spring return plunger and cylinder system is discussed. Benchmark experiments have been performed to test the PRVs for repeatability of the pressure range and discussed the results.

References:

[1]. Design rules for vacuum chambers, *C. Hauviller,* CERN, and Geneva, Switzerland.

[2]. Selection and sizing of pressure relief valves, Randall W. Whitesides, P.E.

[3]. "Vacuum sealing Techniques", A.Roth, First edition, Pergamon Press.

[4]. "Vacuum sealing Technology", Kurt Sonderegger, CERN Accelerator School, Platja D'Aro, Spain May 16 – 24, 2006.

[5]. *Design of springs*, Module 7; IIT Kharagpur.

Effect of Baking on Reduction of Hydrogen in Austenitic Stainless steel for UHV Applications

Atul Prajapati[1], Rakesh Kumar[1], S Sunil[1], Subroto Mukherjee[1]

[1]*Institute for Plasma Research Bhat Gandhinagar-382428*
E-mail : atulprajapati@ipr.res.in

Abstract

Austenitic grade stainless steel (ASS) is a very common material used in construction of ultrahigh vacuum (UHV) and extremely high vacuum (XHV) chambers. The predominant residual gas at very low pressures, i.e. the UHV and XHV range, in vacuum systems made of ASS is Hydrogen. This Hydrogen enter the ASS during material manufacturing process. Presence of diffused Hydrogen in ASS plays significant role in outgassing performance from vacuum exposed surface in UHV regime. Tendency of atomic Hydrogen to recombine to form molecular hydrogen needs to be investigated to co-relate hydrogen outgassing rate.

We took up study to assess total and diffusible hydrogen present in the SS304 L coupons and co-related the outgassing performance of those samples in UHV regime. We selected SS304 L samples with different finish produced by different manufacturer for this study. These specimens were tested in raw condition and after air baking cycle (soaking at 450 ± 10° C for 36 Hrs.). Test were conducted at accredited labs.

Bruker made Instrument (IR 07) and (G8 GALILEO) is used for measurement of Diffusible and Total Hydrogen respectively. This instrument work on principal of measurement of change in thermal conductivity due to presence of hydrogen in carrier gas of Argon or Nitrogen. Diffusible and total Hydrogen contents in raw and air baked samples were measured and tabulated. Diffusible Hydrogen content was 0.4274 PPM and 0.0921 PPM in Baked and Unbaked samples respectively. This signify 4 times increases in diffusible hydrogen content after air baking. Study revealed hydrogen mobility in metal lattice increases significantly due to air baking, which leads to increase Hydrogen diffusion rate during baking cycle, which may be one of the reason for low outgassing rate resulting in enhanced vacuum performance of the material. Further thin oxide layer is formed on the surface which act as a barrier [1] for further Hydrogen outgassing from the surface, and hence improvement in the UHV performance.

References:

[1] Reduction in hydrogen outgassing from stainless steels by a medium-temperature heat treatment
C. D. Park, S. M. Chung, Xianghong Liu, and Yulin Li

Development of control cards for ITER deliverable SSPA

Manojkumar Patel, Hrushikesh Dalicha, Sriprakash Verma, Dipal Soni, Kumar Rajnish, Raghuraj Singh and R.G. Trivedi

ITER-India, Institute for Plasma Research, Block-A, Sangath Skyz, Bhat-Motera Road, Koteshwar, Ahmedabad – 380005, Gujarat

manoj.patel@iterindia.in

Abstract

The Ion Cyclotron Heating and Current Drive (ICH & CD) system for ITER application is being fabricated for the commissioning at ITER site to couple 20 MW Radio Frequency (RF) power into ITER plasma for heating and driving plasma current in the frequency range of 35-60MHz [1][2]. ITER-India is responsible to deliver 9 RF sources including one spare to meet 20MW power requirement. Each RF source will be capable to deliver 2.5MW output power at Voltage Standing Wave Ratio (VSWR) of 2.0 having bandwidth of ±1 MHz as per ITER requirement. Each RF source consists of two parallel amplifier chains of 1.5MW and a 3dB hybrid combiner to generate 2.5MW RF power. Each 1.5MW chain consists two tube based tuned amplifiers i.e. driver (100 kW), final (1.5 MW) stage amplifiers and a wideband Solid-State Power Amplifier (SSPA) having power handling capability of around 8 kW to drive the driver stage amplifier.

In the present design of SSPA, 16 RF amplifier modules are required to combine for achieving 8 kW of RF power. Each module is protected with control cards to prevent any failure in amplifier. Various control cards are developed for faults like over current, over VSWR, cooling failure, over temperature, SMPS failure, AC mains fault etc. for safe operation. Closed loop current transducer sensors are used for DC drain current to DC voltage conversion and interlock cards are integrated to generate fault signal in case of SSPA module current crosses the threshold value. RF power detectors are used for VSWR fault detection.

This paper describes the design and test results of different control cards.

References:

[1] Aparajita Mukherjee et al., Status of R&D activity for ITER ICRF power source system, Fusion Engineering and Design 96–97 (2015) 542–546

[2] Rajesh Trivedi et al., Outcome of R&D program for ITER ICRF Power Source System, Preprint, FEC-2018.

ABRASIVE WATER JET CUTTING STUDY FOR THE MANUFACTURING OF IN WALL SHIELDING BLOCKS OF ITER VACUUM VESSEL

R Laad[1],U Dethe[1], A Maheshwari[1],S Dani[1],M Patel[1], S Padasalagi[1], Murlidhar B[2], Prasad KSVV[2], D Francis [3]

[1] ITER-India, Institute For Plasma Research, Gandhinagar, Gujarat, India
[2] Avasarala Technologies Ltd Bangalore, Karnataka, India
[3] Larsen & Toubro Heavy Engineering, Surat, Gujarat, India

Email: rahul.laad@iterindia.in

Abstract:

The ITER Vacuum Vessel (VV) is constructed of double walls connected by ribs and flexible housings. The space between these walls is filled up with In Wall Shielding (IWS) blocks The IWS blocks are made of plates of borated and ferritic steel to enhance the shielding capabilities and optimise the electro-magnetic properties of the VV. Abrasive waterjet cutting (AWJ) is used as primary cutting process of In wall shielding plates.

In water jet cutting, the material is cut either by a high-pressure water jet alone or by the addition of an abrasive. An object cutting by water alone is known as waterjet cutting and the object cutting with addition of abrasive substance with water is known as abrasive waterjet cutting (AWJ) . AWJ is used as primary cutting process of In wall shielding plates. Abrasive AWJ cutting is one of the non- traditional manufacturing technologies. Abrasive water jet (AWJ) is a relatively new cutting technique among many of the non-conventional methods. AWJ cutting is extensively used in many industrial applications. There are many parameters, processes and type of abrasive which may affect quality of cutting surface when cut by AWJ. Important process parameters which mainly affect the quality of cutting are cutting speed, hydraulic pressure, stand-off distance, abrasive flow rate and types of abrasive. The parameters which define the quality and performance of AWJ are Material Removal Rate (MRR), Surface Roughness (SR), kerf width, tapering of kerf.

During manufacturing of In wall shielding plates the AWJ is used as cutting method to cut the specially developed materials SS304B4, SS304B7 , SS430 which are 40mm thick and SS316L(N)-IG plates for which thickness varies from 50 to 200mm.

The objective of this study is to investigate the AWJ process used for ITER IWS material for around 110KM cutting length and list out the parameters which affect the process, and material wastage during the process.

EXPERIENCE IN OVERHAULING AND ALIGNMENT OF HELIUM SCREW COMPRESSOR STATION

Ketan Patel, L.N.Srikanth G., Pankil Shah, Dikens Christian, Rohit Panchal, Rakesh Patel, Hiren Nimavat, Pradip Panchal, Gaurang Mehsuriya, Dasarath Sonara, Atul Garg, Gaurav Purwar, Rajiv Sharma and Vipul Tanna

Institute for Plasma Research, Village Bhat, Gandhinagar-382428

E-mail: ketan@ipr.res.in

Abstract

Institute for plasma research (IPR) has 1.3 kW at 4.5 K helium refrigeration and liquefaction plant (HRL) which is operation since last 20 years. The HRL plant is used to cool down TF and PF magnets to achieve superconducting state of SST-1 tokomak. The HRL plant consist of three helium screw compressor of Mycom make driven by 315 kW electrical motor. During the SST-1 campaign which lasts for ~30 to 35 days, at a time two compressors operates 24 x 7, to cater helium gas requirement of HRL plant i.e. 140 g/s at 14 bar (a) and the third one works as a redundant. To ensure the reliability of all three compressor, overhauling is necessary as per the OEM schedule. Post overhauling reinstallation of compressor on the skid and alignment with electrical motor is also very critical aspect. In this paper brief description of overhauling, installation and alignment of helium screw compressor has been explained.

References:

[1] Operation and Maintenance Manual Provided by OEM

[2] Sarkar B. et al., "1 kW Class Helium refrigerator/liquefier for SST-1”, Proc. 18th. International Cryogenics Engineering Conference- ICEC18

[3] Handbook on “A Practical Guide to Shaft Alignment” by Pruftechnik LTD.

SOFTWARE DEVELOPMENT FOR DATA ACQUISITION OF $LaBr_3$(Ce) HARD X-RAY SPECTROMETER DIAGNOSTIC FOR SST-1

Imran Mansuri, Manisha Bhandarkar, Shishir Purohit, Asha Adhiya, Jignesh Patel, Vishnu Patel, Atish Sharma, Hitesh Chudasama, Harish Masand, Priyadarshini Gaddam, Srinivas Rao, Kirit patel, Manoj Kumar and Kirti Mahajan

Insttitute for Plasma Research, Bhat, Gandhinagar 382428

Email: imran@ipr.res.in

Abstract

$LaBr_3$(Ce) scintillator based pulse height diagnostics system is used for the measurement of Hard X-Ray photon energy during tokamak plasma discharge. The Hard X-rays generated during tokamak plasma discharge due to interaction of runaway electrons with the first wall/vessel components in tokamak. Measurement of Hard X-Ray photon energy will tell maximum energy of runaway electron during plasma discharge.

For SST-1, Data acquisition software along with its Graphical user interface (GUI) has been developed using the Software Development Kit (SDK) to configure Osprey Multi Channel Analyzer (MCA) in Python. Salient features of the developed software are to communicate with SST-1 Machine control system for shot communication, to communicate with detector and setting up of detector parameters (like Bias voltage on and off control, gain settings, trigger settings, acquisition duration, acquisition mode etc.), data acquisition and post processing of acquired data using python along with its different modules e.g. matplotlib, numpy, scipy, panda etc.

DESIGN AND FABRICATION OF A PNEUMATICALLY OPERATED BELLOW SEALED VALVE FOR HIGH TEMPERATURE Pb-Li APPLICATION

A. Prajapati[1], S. Sahu[1], Deepak Sharma[1] and R. Bhattacharyay[1,2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, 382428, India*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai, 400094, India*

E-mail: ashokp@ipr.res.in

Abstract

Liquid metals are the most preferred coolants because of their high thermal capacity and high boiling point. Valve is an important component of a coolant circuit to control or cut off the coolant flow as per requirement. For ordinary fluid like water, oil, gases, steam, etc. at room temperature or relatively low temperature operational condition, different valves are available in the market. However, the essential criteria of a valve to be applicable for high temperature liquid metal loops, are high compatibility, coolant compatibility, remote operability, high reliability, etc. At present, there are only limited manufacturers who use to make such high temperature valves. However, these valves come with a high cost and for off the shelf valves, they don't possess any indicator for bellow leakage or failure, which poses high risk for valve operation. An in-house effort has been made to design a pneumatically operated bellow sealed ON/OFF valve for high temperature Pb-Li liquid metal. This valve is assembled with many components such as valve body, bonnet, stem, bellow, graphoil seal, pneumatic actuator, etc. The valve body is main component of the valve and it is designed in cylindrical shape so that stress distribution is uniform and also easy for mounting heating element without damaging of it. In the valve body, stem adaptor is seated very closely without leakage of the fluid from their seating area. A provision has also been made to indicate the bellow failure. All the valve components are designed using Maximum shear stress theory (MSST), Maximum distortion energy theory (MDET) and Maximum principal stress theory (MPST), and are discussed in details. Moreover, Finite Element Analysis (FEA) has been carried out for its critical component (Valve Body) using ANSYS Workbench 18.2. The numerical results are also verified against their theoretical values. The detailed design, analysis and fabrication of a pneumatically operated bellow sealed valve are discussed in this paper.

ENGINEERING DESIGN AND ASSEMBLY SEQUENCE OF PROTOTYPE CENTER STACK (PCS)

S. Ranjithkumar, A.K. Verma, Prasada Rao P, Shiju Sam, Y.S.S. Srinivas, E.Rajendra Kumar

Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat, India

E-mail: ranjith@ipr.res.in

Abstract

The center stack assembly is one of the most critical & challenging system (in magnetic and mechanical aspects) of Spherical Tokamak. A Prototype Center Stack (PCS) is to be designed, analysed, fabricated and assembled to study the challenges encountered in the development of the center stack. Being a part of a low aspect ratio tokamak, the PCS has to be confined to the least possible bore in the center due to which the resultant plasma shape is nearly spherical. The modular design and compactness are the key features of this machine.

The design and manufacturing of the center stack consisting of Toroidal Field (inner legs) and Ohmic coils have been a challenge considering the low availability of space in the bore region. Coils are designed so as to achieve a high packing factor occupying a maximum cross sectional area. The modular connection of the inner and outer legs of the TF coil was yet another challenge and required a careful study to decide on the sequence of current flow, considering the manufacturing aspects.

The 2D/3D engineering model of PCS has been prepared considering the acceptable precision limits, and tolerances are taken care during the assembly sequence. Engineering analyses of PCS such as Electromagnetic, Thermal-hydraulics and Structural has been carried out to verify the integrity of the system. The coil inter turns and layers are electrically insulated using polyester glass fiber tape (F-class). The insulation material and thickness are estimated as per the electric field stresses on critical areas of the coils. The support structure is also appropriately insulated as per requirement.

This poster mainly discusses the engineering design of PCS components and the issues faced during the process of designing of the machine, and managing the precision & tolerances considered during the insulation wrapping, machining of components, and the assembly sequence.

References:

1. “Conceptual Design and Analysis of Prototype Center Stack for Spherical Tokamak based Technologies Development” A.K. Verma, S. Ranjithkumar, Prasada Rao P., Shiju Sam, Y.S.S. Srinivas, E.Rajendra Kumar, J. Plasma and Fusion Res. **Volume 17,** 2405074 (2022).

2. Engineering Design Report of Prototype Center Stack, publication no. IPR/TR-678/2022, May 2022.

Implementation of drift free integrators for Tokamaks

Praveena Kumari,Vismaysinh Raulji, Sameer Jha, Praveenlal E.V, Kumudni Tahiliani, Rachana Rajpal Daniel Raju, Joydeep Ghosh

Affiliation : Institute For Plasma Reasearch,Gandhinagar,382428

E-mail : praveena@ipr.res.in

Abstract

In Tokamak operation, the magnetic diagnostic provides input to determine parameters for plasma control, plasma physics and machine protection. Magnetic sensors based on pickup coils and flux loops measure the time derivative of magnetic fluxes, and therefore, such signals have to be integrated in order to obtain flux signals. An analogue integrator is one of the method to achieve such measurements.

The op-amp based integrator is an ideal integrator. Because of inherent characteristics of an op-amp like input offset voltage and bias a drift voltage in output signal is produced. Thus design of a continuous drift-free real time integration system is really a challenge.

The basic blocks of integrator are double symmetrical analogue integrator, a differential amplifier at the output stage and an analogue compensation on each integrator. The analogue compensation uses sample and hold circuit to record and feedback the error offset at the input.The drift voltage recorded after hundreds of lab experiment is 2.8mV for 1000sec. A prototype of long pulse integrator for 1000second pulse operation has been implemented, tested and validated in SST-1 Tokamak. The experimental results were compared with numerical integration in time and frequency domain to evaluate the performance of the implemented integrator. The integrators examined in this study are unconditionally stable for a long period. With this accuracy and preciseness, plasma control action for shape and position can be achieved. The same integrators are also tested during the Aditya coil calibration.

The poster will present the implementation of hardware integrator and its comparison with numerical model of rogowsky signal.

Development of GUI for automated analysis of voltage-swept Langmuir probe for Aditya-U tokamak

Bharat Hegde[1,2] , Harshita Raj[1], Suman Dolui[1,2], Kaushlender Singh[1,2], Ashok K. Kumawat[1,2], Ankit Kumar[1,2], Pramila Gautam[1], Rohit Kumar[1], Suman Aich[1,2], Laxmikanta Pradhan[1], Ankit Patel[1], Kalpesh Galodiiya[1], Shwetang N. Pandya[1], K.M. Patel[1], K. A. Jadeja[1], R.L. Tanna[1,3], Joydeep Ghosh[1,2] and ADITYA-U Team[1]

[1]Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428
[2] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094
[3]Institute of Science, Nirma University, Ahmedabad 382 481

E-mail : bharat.hegde@ipr.res.in

Abstract

In tokamaks, Langmuir probes are commonly biased with periodic voltage ramp signal [1]. The voltage signal applied to the probe and current drawn by the probe are acquired in a DAQ system. This data can be used later to determine electron temperature by performing various types analysis on IV curve obtained in each period of the ramp. However, the interpretation of results obtained is a challenging task [2]. This is because the results are dependent on the method of analysis and model of fitting. Also, other challenges like electromagnetic coupling of noise, sheath expansion factor of the probe and angle that the probe makes with the magnetic field play an important role in selecting the best model for fitting the curve [3]. In ADITYA-U tokamak, lack of an automated code makes the analysis time consuming and cannot be done on shot-to-shot basis.

In this poster, we present the preliminary development of a MATLAB based GUI to automate the process of analysis for voltage-swept Langmuir probes in ADITYA-U tokamak. We also present various techniques and fitting models used and its effect on the results.

References :

[1] Rajpal, Rachana. *Proceedings of the national symposium for commemorating 30-years of ADITYA Tokamak: book of abstracts*. 2020.
[2] Février, O., et al. *Review of Scientific Instruments* 89.5 (2018): 053502.
[3] Bagatin, M., et al. *Review of scientific instruments* 68.1 (1997): 365-368.

Measurement of Toroidal and Poloidal Rotation in ADITYA-U Tokamak

Ankit Kumar[1,2], K. Shah[,3], N. Yadava[4], G. Shukla[1], Laxmikanta Pradhan[1,], Nilam Ramaiya[1], Bharat Hegde[1,2], S. Patel[3], Kaushlender Singh[1,2], Suman Dolui[1,2], Ashok K. Kumawat[1,2], M.B. Chowdhuri[1], R. Manchanda[1], Ankit Patel[1], K. A. Jadeja[1], K. M. Patel[1], Harshita Raj[1], Rohit Kumar[1], Suman Aich[1], Kalpesh Galodiya[1], Shwetang N. Pandya[1], R.L. Tanna[1,4], Joydeep Ghosh[1,2] and ADITYA-U Team[1]

[1]Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428
[2]Homi Bhabha National Institute (HBNI), Mumbai 400 085
[3]Pandit Deendayal Petroleum University, Raisan, Gandhinagar 382007, Gujarat, India
[4]Institute of Science, Nirma University, Ahmedabad 382481, Gujarat, India

E-mail (speaker) : ankit.kumar@ipr.res.in

Abstract

In tokamaks, plasma rotation is considered as a crucial phenomenon in context of improving the confinement time [1,2]. Plasma rotation inside a tokamak is either generated intrinsically [3,4] or can be enhanced externally by applying some external source such as Neutral Beam Injection (NBI) [5]. Observations in many tokamak suggests that the magnitude, direction as well as the radial shear present in both toroidal & poloidal rotation is correlated in suppressing the plasma turbulence, magneto-hydrodynamics instabilities & stabilizing the edge localized mode (ELM) resulting in the enhancement of confinement time [1,2,6,7]. In ADITYA-U tokamak, we have designed an experimental setup which utilizes doppler shift spectroscopy to measure both toroidal and poloidal rotation velocity in the ohmically heated plasma. Various emission lines can be monitored using this diagnostic which consists of a 1m multi-channel visible spectrometer (operated in Czerny-Turner configuration). Along with radial profile measurements of plasma rotation, this diagnostics can also be utilized for measuring the ion temperature profile of different ion species present in the plasma [2]. The measured rotation and ion temperature profiles of various ionized states of Carbon ions present in the circular plasma will be presented in this paper.

References:

1. Burrell K H et al 2009 Nucl. Fusion 49 085024
2. Gaurav Shukla et al 2019 Nucl. Fusion 59 106049
3. Ida K 1998 Plasma Phys. Control. Fusion 40 1429
4. deGrassie J S et al 2007 Phys. Plasmas 14 056115
5. S. Suckewer, H. P. Eubank, R. J. Goldston, J. McEnerney, Nucl. Fusion 21, 1301 1981.
6. Rice J.E. et al 2008 Plasma Phys. Control. Fusion 50 124042
7. M.F.M. De Bock et al 2008 Nucl. Fusion 48 015007

Conditioning & Testing of Distribution Transformers at IPR

Vaibhav Ranjan[1*], Nagarji Thakor[1], Supriya A Nair[1]

[1] *Institute for Plasma Research, Gandhinagar, Gujarat*

E-mail*-vranjan@ipr.res.in

Distribution Transformer is an equipment which converts electrical power from one voltage level to another voltage level without change in the system frequency. Essential components in a Distribution Transformer are a magnetic core with laminated iron with two winding, primary and secondary windings respectively. HV, LV and Neutral Bushings, Conservator Tank, Buchholz Relay, Radiators, Drain valves, Winding Temperature Indicators, Oil Temperature Indicators, Breathers are also some of the components of the Distribution Transformers. Distribution Transformer rated 11000V/433V, 1000 kVA is an equipment which is commonly used in the distribution network to provide the electrical power to the laboratories in IPR, Bhat, Gandhinagar.

Conditioning and Testing consists of proper visual inspection of oil leakages, insulating oil condition, moisture, insulation strength of the windings and condition of the components of Transformers. Steps taken towards overhauling of transformers, oil leakages are detected, HV, LV and Neutral Bushings are visually inspected for any cracks/leaks. Oil leakages were arrested by using **RC-70 C TR-9 Grade** Rubberized cork sheet gaskets. Breakdown Voltage of the Transformer Insulating Oil before overhauling was ~8 kV(rms) Voltage, which is detrimental to Transformer and Distribution system as per IS 335(1993). Oil cleaning was carried out by the degassing and dehumidification method as per in Oil filtration machine. Insulating Oil breakdown voltage came out to be ~80 kV (rms) during testing. Buchhloz Relay, neutral bushing was replaced with the new ones. After replacement of gaskets, buchhloz relay, bushing, oil leakages stopped, the tests were performed on the Transformers post overhauling, which will be discussed in the paper.

Distribution Transformer have been successfully overhauled, tested and operating continuously without any power failure. Apart from these, our experience during the commissioning and testing phase during conditioning and testing will also be presented.

References:

[1] IS 335:1993 (Reaffirmed 2005) New Insulating Oil Specifications (Fourth Revision) by Bureau of Indian Standards.

[2] IS 10028-1985 Code of Practice for selection, installation and maintenance of Transformers, part III-maintenance by Bureau of Indian Standards, updated in 2001.

Investigation of impulse voltage test of ohmic coil system in ADITYA-U tokamak

Rohit Kumar[1,*], R.L Tanna[1, 2], Tanmay Macwan[3], S. Aich[1, 4] and J Ghosh[1, 4]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat, India.*
[2]*Institute of Science, Nirma University, Ahmedabad 382 481, Gujarat, India.*
[3]*University of California, Los Angeles, USA.*
[4]*HBNI, Training School complex, Anushakti Nagar, Mumbai 400094, India.*

E-mail: rohit.kumar@ipr.res.in

Abstract

High voltage transients can severely damage the insulation of the electrical system, depending upon the magnitude and its location. A steep-fronted surges impinging on the insulation may result in puncture of the coil insulation. This also involves degradation of the insulation by partial discharges. There are several mechanisms that has been identified which could cause a similar failure. Impulse voltage test realizes the operational condition of high magnitude, low duration voltage spike during the instant switching or fault operation on the insulation of any electrical system. Successful impulse voltage test confirms the system integrity towards the safe operation of high voltage operation. Changing weather condition results in the degradation of the insulation of the electrical system and results in the failure of impulse voltage test even at the voltage value lower than the designed value. Impulse voltage test on the magnetic coil of ADITYA-U tokamak was performed under different operating conditions to investigate the probable cause and severity of the insulation failure.

Effect of high and low frequency electrode biasing in anomaloustransportin ADITYA-U Tokamak

Suman Dolui[1,2], Kaushlender Singh[1,2], Harshita Raj[1,2], Tanmay Macwan[1,2], Ankit Kumar[1,2], Bharat Hegde[1,2], Ashok Kumawat[1,2], Shivam Gupta[1], Rohit Kumar[1], Suman Aich[1,2], K. A. Jadeja[1], K. M. Patel[1], Laxmikant Pradhan[1], Ankit Patel[1], Kalpesh Gadoliya[1], Pramila Gautam[1], Praveenlal E V[1], R.L. Tanna[1], Joydeep Ghosh[1,2] and ADITYA-U Team[1]

1Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382428
2Homi Bhabha National Institute (HBNI), Mumbai 400 085

E-mail: suman.dolui@ipr.res.in

Abstract

Applying a high bias voltage, around or larger than plasma potential and drawing a large current (~100-300Amp) fromthe flux surfaces by anelectrodegenerates an inhomogeneous electric field in the edge region of tokamak. Sheared radial electric field is responsible for the sheared $E{\times}B$ poloidal flow. Numerous studies have shown essential roles of an edge-localized poloidal $E{\times}B$ flow structure on confinement improvement [1-2]. However, definitive conclusion regarding what aspect of the $E{\times}B$ flow suppresses the turbulent transport is still under debate [3]. In Aditya-U Tokamak a dedicated electrode bias experiment has been carried out to understand the above phenomenon in ohmically heated Tokamak plasma.An alternative positive and negative pulses are biased by means of inhousedevelopment of anIGBT based capacitor bank power supply.The experiment has been carried out in a wide range of biasing frequency from 20 Hz to 15 kHz and maximum voltage applied to the electrode is 400 V.Preliminary result shows low frequency or the long pulsed positive bias has more significant effect on transport in comparison to the high frequency biasing. In Aditya-U tokamak, a long distance coherence mode is confirmed to be zonal flows during biasing improved confinement mode [4]. The results presented here are crucial to understand the role of sheared radial electric field along with the ZFs on the suppression of turbulence and hence on modification of transport.

References:

[1]Itoh, S.-I. & Itoh, K. Model of L to H-mode transition in tokamak.*Phys. Rev. Lett.*60, 2276–2279 (1988).
[2]Ida, K.*et al*. Edge electric-field profiles of H-mode plasmas in the JFT-2M tokamak.*Phys. Rev. Lett.*65, 1364–1367 (1990).
[3] Kamiya, K. *et al*. Experimental validation of non-uniformity effect of the radial electric field on the edge transport barrier formation in JT-60U H-mode plasmas. *Sci. Rep.* 6, 30585 (2016).
[4] Observations of zonal flows in electrode biasing experiments on the Joint Texas experimental tokamak Phys. Plasmas 23, 042305 (2016)

UP GRADATION OF CONTROLLER AND LOAD TEST FOR 1700KVA DG SET NO.1

Chirag Bhavsar, Chandra Kishore Gupta, G.K.Rajan, Supriya Nair, Prakash Parmar

Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382 428

E-mail: chirag@ipr.res.in

Abstract

Electrical Power Distribution System in IPR comprises of 132 kV Substation supplied by dedicated 2 GVA SCC line by the Grid Operator (UGVCL). The 132 kV substation hosts four 132 kV / 11.5 kV main step down transformers of 31.5 MVA, 37.5 MVA and 2 x 15 MVA and one 132kV/22 kV step down transformer of rating 31.5 MVA. The total installed capacity of around 130 MVA caters to both steady/continuous power demand (~6 MW) and pulse power demand (~50 MW) of the Institute. The power demanded by the systems is supplied at 11 kV, 22kV & 415 V voltage level.

We have Emergency Power Distribution System: The Emergency Power distribution System caters electrical power demand from various systems viz. Cooling Water System, Cryogenic and other important safety and investment protection systems. It comprises of 2 x 1700 KVA Diesel Generators.

DG set No.1 have been commissioned in year of 2001 with EGCP-2 controller and it needs upgraded and retrofit with latest available controller i.e. EASYGEN MAKE, MODEL: EASYGEN 3200XT.

This paper gives detailed information related the up gradation & retrofitting of controller and load test of 1700KVA DG set No.1.

References:

[1] Easygen_3200XT_Manual

Understanding Cs dynamics for source conditioning in a Negative Ion Source.

Manas Ranjan Bhuyan*[1], Kaushal Pandya[2] ,Mahendrajit Singh[1], Mainak Bandyopadhyay[1,3], Kartik Patel[2] , Himanshu Tyagi[1], Sejal Shah[1,3] , Ratnakar K.Yadav[1], Hiren Mistri[2], Agrajit Gahlaut[2], Mahesh Vupugalla[2], Bhavesh Prajapati[2], Jignesh Bhagora[1] and Arun.K.Chakraborty[1]

[1]ITER-India, Institute for Plasma Research, Bhat, 382428, Gandhinagar, India.
[2]Institute for Plasma Research, Bhat, 382428, Gandhinagar, India.
[3]Homi Bhabha National Institute (HBNI), BARC, Anushaktinagar, 400094, Mumbai, Maharashtra, India.

*E-mail : manas.bhuyan@iterindia.in

Abstract

ROBIN [1, 2] experiments are being performed in surface mode by Caesium (Cs) vapour injection into the source to reduce the work function of the plasma grid to get enhanced negative ion production [3] with control over co-extracted electrons [4,5]. Cs flux is controlled by Cs reservoir as well as delivery tube temperature, which is kept usually 50 C above the Cs reservoir temperature. Temperature of all the parts of Cs delivery system is monitored. Control of Cs flux inside source enables better conditioning of source. The Cs delivery tube is 250 mm long, with 8mm OD and 6mm ID, which is 40mm inside back plate. The Cs conditions in the source are seen to have a huge impact on the performance of the source related to extracted H^- densities and the electron to ion ratios, both of which are of significant importance towards achieving a stable parameter regime for RF based negative ion sources. Cs injection and its effects on various parameters have been extensively studied in a recent experimental campaign on ROBIN and shall be presented and discussed.

References:

[1] M. J. Singh, et.al., AIP Conf. Proc. 1390, 604, (2012).IEEE Editorial Style Manual, IEEE Periodicals, Piscataway, NJ, USA, Oct. 2014, pp. 34-52.

[2] Gourab Bansal, et.al., Fusion Eng. & Design, 88, 778– 782 (2013)

[3] Yu. I. Belchenko and V. I. Davydenko Rev. Sci. Instrum., 77, 03B702, (2006).

[4] E. Speth, et.al, Nucl. Fusion 46, S220 (2006).

[5] L. Schiesko, at.al, Plasma Phys. Controlled Fusion 53, 085029 (2011).

Far-infrared Interferometer for Plasma Density Profile Measurements in SST-1

Dusmanta Mohanta, Abhishek Sinha, Surya Kumar Pathak

Institute for Plasma Research, Gandhinagar-382428

E-mail : dusmanta@ipr.res.in

Abstract

A Far-infrared (FIR) interferometer measures spatial and temporal behaviour of the plasma density profile radially as well as tangentially on the SST-1 tokamak. The system comprises of an optically pumped twin FIR Laser. Beams emerging from the twin FIR laser cavities are coupled to separate waveguides. Each laser output beam splits further into vertical and tangential viewing beams. Quartz crystal beam splitter is used to split each of these beams from twin source FIR laser. After traversing through plasma, the probing beam introduces a phase shift due to plasma line density. The phase modulated signal is then compared with the reference signal to determine plasma density profile along various chords.

Preparation and installation of PFC in divertor region at ADITYA-U tokamak

K.M. Patel[1], K.A Jadeja[1,2], Ankit Patel[1], H. Raj[1], L. Pradhan[1], R.L. Tanna[1,3], J. Ghosh[1,4], Deepti Sharma[1], Arun Prakash[1], S. Aich[1], R. Kumar[1], K. Singh[1,4], S. Dolui[1,4], Ankit Kumar[1,4], B. Hegde[1,4], Ashok Kumawat[1,4], Shwetang Pandya[1]

[1]Institute for Plasma Research, Near Indira Bridge, Bhat Village, Gandhinagar-382428
[2]Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360 005
[3]Institute of Science, Nirma University, Ahmedabad 382 481
[4]Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094

E-mail: kaushal@ipr.res.in

Abstract

The Plasma Facing Components (PFC) in a tokamak, not only restrict high temperature plasma from hitting the vacuum vessel wall but also provide the protection to the in-vessel components and vacuum vessel wall from the higher energetic electrons. Different set of limiter configurations is being used to solve the purpose. ADITYA tokamak has been upgraded to study the circular and shaped plasmas. It will be equipped with different set of limiters and divertors, such as (1) Inner limiter, (2) Outer limiter, (3) Safety limiter, (4) Upper and lower divertor plates. The positions of the limiter and divertor have been determined based on the numerical simulation of the plasma equilibrium profile. Special nuclear grade graphite is used as plasma facing material for all limiter and divertor plate. Graphite tiles were fabricated and vacuum conditioned using various procedure i.e. ultrasonic cleaning, baking in vacuum furnace@1000 C for 24 hrs at 1.0E-5 torr etc. Shaped graphite tiles will be fixed on specially designed support structures made out of SS-304L inside the torus shaped vacuum vessel. There are ~ 200 graphite tiles and ~240 graphite caps were installed before the commencement of phase-1 plasma operation.

ADITYA-U tokamak has successfully achieved the plasma current (I_P) ~ 200 kA, duration ~ 400 msec [1] in circular plasma formation and preliminary experiments for shaping the plasma by charging the upper and lower diverter coils has been initiated. During the shaped plasma experiment, elongated plasma will be restricted by toroidally continuous divertor plates located at upper and lower halves of the vessel. First set of top and bottom divertor plate have been installed inside the vessel. To understand the pattern of plasma interaction during these experiments, a flush mount probe is installed in each layer. In near future, ~160 graphite tiles & caps will be installed in this divertor region. A technical aspect related to initial preparation, simulation of installation sequences and challenge faced during in-situ installation of divertor plate inside ADITYA-U vessel will be discuss in detail in this paper.

References :

[1] Tanna R. L. et al., *Nucl. Fusion.* **62**, 042017 (2022).

Global Gyrokinetic Simulation Of Microturbulent Transport In W7-X Stellarator Including Kinetic Electron

Joydeep Das[a], Jaya Kumar Alageshan[a], Sarveshwar Sharma[b] and Animesh Kuley[a]

[a] Department of Physics, Indian Institute of Science Bengaluru 560012, India
[b] Institute for Plasma Research, Bhat, Gandhinagar 382428, India

E-mail : joydeepdas@iisc.ac.in

Abstract

Global gyrokinetic simulations are performed for electrostatic ion temperature gradient instability [1], specifically for the Wendelstein 7-X stellarator, to study the turbulence behavior in both linear and nonlinear regimes for adiabatic electron response in the presence and absence of zonal flow. We have also explored the kinetic electron effects to study turbulent transport, mode structure, and other properties. Finally, global gyrokinetic simulations are done for a different profile to speculate the observations made by synthetic Phase contrast image measurements [2] on W7-X to investigate dominant instabilities in W7-X for standard discharges and the radial and poloidal localization of turbulent density fluctuations.

References:

[1] H. Y. Wang, I. Holod, Z. Lin, J. Bao, J. Y. Fu, P. F. Liu, J. H. Nicolau, D. Spong, *and* Y. Xiao, "Global gyrokinetic particle simulations of microturbulence in W7-X and LHD stellarators", Physics of Plasmas 27, 082305 (2020) https://doi.org/10.1063/5.0014198
[2] "Phase contrast imaging measurements and numerical simulations of turbulent density fluctuations in gas-fuelled ECRH discharges in Wendelstein 7-X ", Bähner J-P et al (The W7-X Team) 2021 J. Plasma Phys. 87 905870314 DOI: https://doi.org/10.1017/S0022377821000635

DESIGN AND DEVELOPMENT OF ELECTROCHEMICAL BASED HYDROGEN ISOTOPE SENSOR AND ITS TESTING SETUP

Deepak Yadav[a], Aroh Srivastava[a], Amit Sircar[a], Pragnesh Dhorajiya[a], Rajendra Prasad Bhattacharya[a,b], and Paritosh Chaudhuri[a,b]

[a]*Institute for Plasma Research, Bhat, Gandhinagar -382428*
[b]*Homi Bhabha National Institute, Mumbai -400094*

E-mail: deepakyadav@ipr.res.in

Abstract

An online, fast, accurate and reliable measurement of hydrogen isotope concentration in liquid lead lithium (Pb-Li) is one of the most important tasks for Tritium Extraction System (TES) of Fusion Breeder Blanket system having liquid Pb-Li as tritium breeder. Though permeation based hydrogen isotope sensors have been reported for this, they get corroded in the presence of liquid Pb-Li. This corrosion reduces the permeation flux significantly with time. So, they may need to be replaced very often, which is a limitation. Solid state proton conducting ceramics have attracted a significant importance in applications related to hydrogen measurement, transport, fuel cell etc. In order to address the issues in hydrogen concentration measurement associated with permeation based sensor as well to establish an alternate measurement technique, solid state proton conducting electrolyte based hydrogen isotope sensors, which have high chemical and physical durability in liquid Pb-Li at elevated temperatures are being proposed for measuring hydrogen isotope concentration in liquid Pb-Li.

This work describes in detail the design and fabrication of Electrochemical based hydrogen isotope sensor using in house synthesized $SrCe_{0.85}Y_{0.15}O_{3-\delta}$ (SCY) ceramic. Disc shaped pellet of SCY is used as a solid electrolyte, which separates reference and working electrodes. The testing setup to test the sensor is fabricated too. This work also describes the challenges involved in the fabrication of sensor assembly and its testing setup such as preparing platinum electrodes on both sides of the ceramic pellet, attaching platinum wires to electrodes and taking them out of the assembly for potentiometric measurement. The other challenges include various connections/joints i.e. Ceramic to Ceramic, Ceramic to SS, etc. A detailed plan to test the sensor is also presented in the work.

Role of Section Modulus in Conceptualizing and Designing the Support Structure for Linear Induction Motor

Ritesh Kumar Srivastava[1], Roopesh G. [1], Manoj Kumar Gupta [1,2], Arvind Kumar [1], Narendra N. Kadamdhad [1], *Ankur Jaiswal*[1]

[1] *Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382428*
[2] *Homi Bhabha National Institute, Anushaktinagar, Mumbai-400094*

E-mail: riteshs@ipr.res.in

Abstract

Linear Induction Motor (LIM) are being used in several applications, LIM is used in the research applications that need very high thrust in a controlled manner. To hold such LIM, there is always a requirement of suitable support structure. The role of support structure is to provide the fixed constrained in either directions for the smooth operation. IPR is also employing the LIM in one of the research application that generate approximately 36 KN of static load. In this poster, the support structure is conceptualized and designed to withstand 54 KN of design load.

For the optimize design of support structure, hollow structural sections are being used. Towards conceptualization the support structure, two cases with rectangular and square hollow sections, have been studied and presented in the poster. The design is performed to limit the deformation of support structure within 1 mm in either direction and also within the maximum allowable stress limit.

Instrumentation and Interlock of 82.6GHz Gyroton Based ECRH System

Harshida Patel[1] ,Jatin Patel, Dharmesh Purohit, K G Parmar, Hardik Mistry, B K shukla and ECRH Group

Institute for Plasma research
Near Indira bridge, Bhat Gadhinagar-382480
[1]Email-harshita@ipr.res.in

Abstract

An 82.6GHz Gyrotron is being upgraded with according the requirement of SST-1 tokomak experiments.82.6GHz Gyrotron system would be used for various plasma experiment in SST-1 tokomak like pre ionization, heating. To analyze system and operation parameter, it is essential to monitor and acquire different system parameters along with an interlocking systems to operate system in fail safe manner. ECRH system is developed PXI based data acquisition and control system to execute the task of data acquisition from sub-system like different auxiliaries power supplies, cooling system, high power measurements and safety interlocks for Gyrotron safe guard. Signal conditioning instrumentation is medium between the control system and auxiliaries system. Fiber based design concept is used for all signals instrumentation for ECRH system. Different types of Analog and digital conditioning cards and interlocks are developed with optical fiber based isolation. There are 60-70 no's of signals monitors and control from different auxiliaries system.

Paper will discuss the design idea and layout of front end and interlocks signal electronics card and its performance and standalone results.

Performance Test of a Prototype HTS Current Lead with MgB_2 and NbTi: Cu Joints

N. Bairagi[a,b,*], V.L. Tanna[a,b], H. Nimavat[a], D. Sonara[a], R. Panchal[a], A. Garg[a], G. Mahesuria[a], R. Patel[a], D. Christian[a], P. Panchal[a], G. Purvar[a], U. Prasad[a], D. Raju[a,b]

[a]*Institute for Plasma Research (IPR), Bhat, Gandhinagar-382 428 Gujarat, India*
[b]*Homi Bhaba National Institute, Training School Complex, Anushakti Nagar, Mumbai-400 094, Maharashtra, India*

E-mail: nbairagi@ipr.res.in

Abstract

For a large scale superconducting steady state fusion device like Tokamak and Stellarator, almost 25% of the total power is consumed by current leads (CL) only. By adopting high temperature superconductors (HTS) CL technology, one can save significant cold capacity of cryo plant. A conduction cooled binary HTS CL connects room temperature power supply by means of an optimized heat exchanger, HTS module and joints with superconducting magnet at 5 K. Such a prototype CL pair is developed at IPR with the help of Indian industries. The basic design of this CL is derived from an earlier version of 10 kA HTS CL reported from IPR [1], mainly the bottom joints section is replaced as HTS: Cu – Cu: MgB_2 – Cu: NbTi. For testing purpose, we have developed bottom lap joints using composite magnesium diboride (MgB_2) wires as an intermediate between HTS module and NbTi: Cu cable that act as a shunt between CL pair [2]. It is characterized in a dedicated cryostat using necessary diagnostics and data is acquired by a dedicated Programmable Logic Controller (PLC). A Graphical User Interface (GUI) is used for real time data monitoring, controlling different parameters of CL with data logging facility for post experiment analysis. Finally assembled HTS CL are validated up to 1.2 kA transport current. Such a hybrid concept is adopted as a next step to developing MgB_2 superconducting current feeder which could be operated near 20 K and save cryogenic cost in future fusion machines [3]. This work demonstrates the feasibility of using MgB_2 as an intermediate between HTS and NbTi magnets with a possibility to cool using helium at ~ 5 K – 25 K.

References:

[1] A. Amardas, Development of 10 kA high Tc current leads, Asian Conf. Appl. Supercond. Cryo. 2011, Indian Jour. of Cryo. 38 (2012) 19-22.
[2] N. Bairagi et al., Copper electroplating technique for development of HTS current leads bottom joints using MgB_2 wires, Physica C, 601 (2022) 1354108.
[3] N. Bairagi et al., Preliminary design and analysis of 20 K helium cooled MgB_2 based superconducting current feeder system for Tokamak application, IEEE Trans. Appl. Supercond. 32 (6) (2022) 4802305.

PRELIMINARY DESIGN OF COOLING WATER SYSTEM FOR ITER-INDIA LABORATORY

R. Ranjan*, D. K. Gupta, R. Agarwal, L. Sharma, S. Jha, M. Chodavadiya, N. Parmar
ITER-India, Institute for plasma research, Ahmedabad-380005, Gujarat, India

*Email: rakesh.ranjan@iterindia.in

Abstract

In order to ensure the quality and performance of various components of experimental devices being provided to the ITER- France project by ITER-India , a Cooling Water testing facility is being procured by infrastructure, ITER-India for ITER-India laboratory (II-Lab). The various components are mainly related to Power Supply, ECRH, ICRH, IPR and DNB systems. In order to remove the heat generated during this testing, the Cooling Water System (CWS) with adequate capacity has been designed.

The key aspect of the CWS design for II-Lab lies in meeting the diverse requirements, with inlet temperatures 20°C and 38°C, from demineralized water to ultra-pure water with ionic conductivity as low as $\leq 0.1\mu S/cm$, the supply pressure upto 2.4 MPa and critical dissolved oxygen limit of $\leq$ 0.01 ppm. The primary heat transfer systems are designed based on grouping of consolidated requirements of various users (experimental devises) and the combined heat rejection system is designed to dissipate 15 MW heat to atmosphere.

As this CWS is primarily meant for testing of various components for ITER- France project, the optimization is to be done by considering duty cycle of the testing campaign, also by staggering the testing schedule of different components during final design. Being a centralized water cooling facility, requirements of cooling water for ongoing developmental projects of domestic fusion program in IPR also have been included in this design. Sufficient margin in the capacity is considered so that additional experimental devises of IPR may also be added in near future.

This paper describes the development of an optimized CWS design, which is capable of supplying cooling water with the required parameters to the components of ITER India Test Facility.

Keywords: ITER-India, Cooling water System, ITER

DEVELOPMENT OF PRESSURISED OIL FILLING SYSTEM AND PREVENTIVE MAINTENANCE OF OIL REMOVAL SYSTEM HRL PLANT

Pankil Shah, L.N.Srikanth G., Ketan Patel, Rohit Panchal, Rakesh Patel, Hiran Nimavat, Pradip Panchal, Gaurang Mehsuriya, Dasarath Sonara, Dikens Christian, Atul Garg, Gaurav Purwar, Rajiv Sharma and Vipul Tanna

Institute for Plasma Research, Village Bhat, Gandhinagar-382428

E-mail: Pankil@ipr.res.in

Abstract

Institute for plasma research (IPR) has 1.3 kW at 4.5 K helium refrigeration and liquefaction plant (HRL) which is in operation since the year 2001 to operate the SST-1 Magnets at superconducting stage. The HRL plant consists of various sub-systems i.e. helium screw compressors, oil removal system, purifier, cold box, flow distribution system, etc. To run the HRL plant Helium gas is required with a mass flow rate of 140 g/s at 14 bar. To cater this, 03 Oil flooded Helium screw compressor is used. The Breox B-35 oil is being used in compressors which act as a coolant as well as a sealant. After compression of Helium gas, this oil must be removed as the HRL plant needs pure helium in the range of <10 ppm. To remove this oil, an oil removal system is used which consists of Primary Oil Separator, coalescer filters, and Charcoal adsorber. The charcoal adsorber, consisting of activated carbon in granules form is used to remove moisture and oil aerosol from compressed helium gas. The activated carbon can be re-used once its adsorbing capacity is exhausted by the process called regeneration. Also at a regular time intervals, the Breox Oil has to be replaced with the new one. To replace the Breox oil in the Helium screw compressor station, a pressurized oil filling system has been developed with the help of pure Helium Gas.

In this paper preventive maintenance of the Oil removal system and Development of Pressurised Oil filling system have been explained in detail.

References:

[1] Sarkar B. et al., "1 kW Class Helium refrigerator/liquefier for SST-1", Proc. 18th. International Cryogenics Engineering Conference- ICEC18

[2] Maintenance Manual Provided by OEM

Compact Single Board Computer Based Data Acquisition System

Hiteshkumar Mandliaya[1], Vismaysinh Raulji[1], Abhijeet Kumar, Pramila Gautam, Bharat Arambhadiya, Rachana Rajpal[1]

[1]*Institute for Plasma Research, Nr.Indira Bridge, Bhat, Gandhinagar-382428*

mhitesh@ipr.res.in

Abstract

A compact 32 channel data acquisition system has been designed and developed for electromagnetics diagnostics signal acquisition for Aditya Tokamak. The indigenously designed system has sampling rate of 250KSPS for all channels with simultaneous sampling capability. All channels can be acquired for 500mS at 100KSPS rate. This systems are being used for Aditya and SST-1 Tokamak experiments.
A customized circuit has been developed using Xilinx Spartan 6 FPGA (Field Programmable Gate Array) and Single Board Computer having PC-104 bus. Four ADCs, each having eight channels and 32 Instrumentation Amplifiers are used to design the front end of the electronics circuit.

This work is an upgradation of our previously developed SBC-64 DAQ system. The new version has additional features like ADC scanning Mode, RAM Test Mode, and low power INA. This resulted in overall low power consumption for the board with various switching regulators followed by post linear regulators. No additional external power supply needs for this upgraded version, all the required power rails are generated from computer's SMPS.

This paper will describe the electronics circuit hardware architecture, PC-104 bus interface and ADC, RAM interface to the FPGA. The complex VHDL coding will be elaborated to describe various feature and controls of the circuit. The LabVIEW based GUI application interacts with the hardware and to acquired and store the captured results on the computer hard disk and Aditya Server. This version has Linux LabVIEW interfaced to the SBC, a custom Linux kernel object libraries are written and integrated into LabVIEW Linux to access the PC-104 bus from LabVIEW.

References :

[1] Embedded multi-channel data acquisition system on FPGA for Aditya Tokamak, April 2016Fusion Engineering and Design 112, DOI:10.1016/j.fusengdes.2016.03.068

Arbitrary LH pulse and auto Feedback Control of LH Power to regulate the Plasma Current in SST-1

P.K. Sharma[1,2] C.G. Virani[1], Jasraj R Dhongde[1], Kirti Mahajan[1], Jignesh J Patel[1], Imran A Mansuri[1], K.K. Ambulkar[1], Jagabandhu Kumar[1], P.R. Parmar[1], S. Sharma[1], A.L. Thakur[1], C.S. Singh[1]

[1]*Institute for Plasma Research, Bhat Gandhinagar-382428, Gujarat, India*
[2]*HBNI, Training School Complex, Anushakti Nagar, Mumbai-400085, Maharashtra, India*

E-mail: jagabandhu.kumar@ipr.res.in

Abstract

During the non-inductive current drive phase, the plasma current is mainly driven by LHCD [1] power whose coupling depends on various plasma parameters as well as edge plasma conditions [2]. To maintain the plasma current constant, a feedback system is desired to increase/decrease the LH power online based on the error signal generated by comparing the measured plasma current with the set plasma current value. The feedback process tries to minimize the error signal and thus maintains the plasma current constant at the predefined set value. The automatic LHCD power control algorithm is implemented on the PCS (plasma control system). Although the final architecture is based on the transfer of data through a reflective memory module but initial testing was done employing an analog fiber-optic link. The loop time of the control algorithm is one millisecond. The automatic LHCD power control algorithm is an event-based trigger i.e. either at a predefined time or based on the plasma current threshold set value. The above scheme is successfully tested during the 27th SST1 campaign in a standalone mode where the control was established without plasma.

The above feature could only be demonstrated once the launching of LH power in an arbitrary temporal profile was successfully incorporated into the LHCD control system. Several temporal profiles (like CW, steep/slow rise, and ramp cases) were tested and demonstrated on a dummy load before proceeding to actual plasma experiments.

Another essential control that is incorporated in the control system is to generate an end pulse from the timing control system which inhibits the LH power and prevents the deleterious effect of rf power launched in the machine in absence of plasma.

References:

[1] Current drive experiments in SST-1 tokamak with lower hybrid waves, Nucl. Fusion 62 (2022) 056020 (11pp).
[2] Advances in LHCD System for SST-1 tokamak, Fusion Sc. and Tech. vol. 65 Jan. 2014.

Linear Induction Motor Design and Simulation Results of Electromagnetic stirrer for Sn-Li alloy

Prasada Rao P, Ananya Kundu, Arvind Kumar, Ankur Jaiswal, Vilas C. Chaudhari, Y.S.S. Srinivas, Rambabu Sidibomma, E.Rajendra Kumar

Institute for Plasma Research, Bhat, Gandhinagar 382428

E-mail: prasad.rao@ipr.res.in

Abstract

Plasma facing components (PFC) are subjected to high heat loads in tokamaks and helps in long pulse operation. Liquid metals are also a potential candidate to use as a PFC [1]. In that Tin-lithium (Sn-Li) alloys are seen to have several properties that make it attractive to be used as liquid PFC. To form the Sn-Li alloy, a rigorous stirring and proper mixing of these two metals is required at high operating temperatures [2].

The stirrer is a non-contact type electromagnetic machine which interacts with the liquid metal inside a tank. The Lorentz forces produced in the liquid metal using a Linear Induction Motor (LIM) makes the liquid to rigorously move to produce a homogeneous mixture of the Sn-Li.

This paper describes, the preliminary design of LIM and COMSOL model of the stirrer. The simulation results and estimated velocities produced in liquid metal with respect to current in LIM are discussed.

References:

[1] Liquid surfaces for fusion plasma facing components—A critical review. Part I: Physics and PSI, R.E. Nygren & F.L. Tabarés : Nuclear Materials and Energy 9 (2016) 6–21

[2] Liu, Cheng-Tsung & Lin, Sheng-Yang & Lee, Weng-Jay & Chen, Jen-Hsin, Electromagnetic Stirring Systems. IEEE Industry Applications Magazine - IEEE IND APPL MAG. **17**, p 38-43,(2011)

Measurement of radial magnetic field in Aditya-U tokamak

A.Kundu[1,2], S.Aich[1], L.K.Pradhan[1], R.Kumar[1], Praveenlal E V[1], A.Kumar[1], J.Ghosh[1,2], R.L.Tanna[1,4], S.Dolui[1,2], K. Singh[1,2], A.Kumar[1,2],A.Kumawat[1,2], B.Hegde[1,2], K.A. Jadeja[1,5], K.M.Patel[1], A.Patel[1],H.Raj[1],S.Patel[3],K.Galodiya[1],N.Nimavat[1], A. Kanik[6], N.Yadava[4], K. Shah[3] and the ADITYA-U team[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar-382428*
[2]*Homi Bhaba National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094*
[3]*Department of Physics, Pandit Deendayal Energy University, Raisan, Gandhinagar 382007*
[4]*Institute of Science, Nirma University, Ahmedabad 382481*
[5]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360005*
[6]*University of Petroleum and Energy Studies, Dehradun, Uttarakhand 248007*

E-mail: ananya@ipr.res.in

Abstract

In a magnetically confined device like tokamak, the plasma is susceptible to many instabilities which tend to degrade the confinement. The plasma confinement in tokamak is significantly affected by the formation of magnetic island which enhance the radial transport of plasma. The uncontrolled growth of the magnetic island results in disruption of plasma. During the pre-cursor phase of the disruption, the magnitude of radial component of the magnetic field increases significantly [1]. Hence the prevention of the growth of radial magnetic field or nullifying the existing radial magnetic field by applying an external radial perturbation at the pre-cursor phase of the disruption may aid in mitigating the disruption.

In Aditya-U tokamak, it is planned to apply a radial magnetic perturbation to create a local magnetic ergodisation to study its effect on MHD activity, edge plasma transport and on disruption. Prior to the application of radial perturbation, the existing radial magnetic field of Aditya-U tokamak during vacuum shots and plasma shots are measured. To measure the radial magnetic field, a copper coil is designed, fabricated, tested and mounted in port #11 of Aditya-U tokamak during real time operation. A steady state simulation for the estimation of radial magnetic field for the existing coil assembly in Aditya-U tokamak has been carried out. In this work, the measurement details, data analyses and the results of the radial magnetic field measurement are discussed. The measured data are compared with the analytical and simulated value of the radial magnetic field for Aditya-U tokamak.

References:

[1] Wesson J 2004 Tokamaks (Oxford: Clarendon.

Engineering upgrade of Cryogenics Instrumentation and control for NBI Beam Operation

Karishma Qureshi*, Laxmikant Bansal, Vijay Vadher, C. B. Sumod, Dipal Thakkar, L. N. Gupta, Paresh Patel and U. K. Baruah

Institute for Plasma Research, Bhat, Gandhinagar, Gujarat

E-mail: karishma@ipr.res.in

Abstract

Cryopump is an essential part of the Neutral Beam extraction system for maintaining the required vacuum in NB chamber for high gas throughput. NB injector for SSt-1 requires 50-100 torr l/s in the neutralizer section for achieving the re-ionization losses within acceptable limits.

6 Cryopumps in SST-1 NBI receive the liquid helium from a Cryogenics System which is distributed over a large geographical area at IPR. Liquid Nitrogen distribution system for the Cryopump shielding is recently upgraded and also distributed widely.

For a smooth and reliable operation, the whole system is functionally broken down into few sub-systems. Plant equipment of the sub-systems are connected to a PLC for integrated and remote operation. The sub-system uses handshaking signals with another cryogenics sub-system for efficient control and interlock requirements. Upgraded liquid nitrogen distribution system is equipped with required instrumentation to achieve fully automatic operation. The PLC is interfaced with a supervisory control system for user interface and data exchange between PLC and instruments.

This paper will present the new architecture of the PLC system and its validation through the recent results.

Numerical Simulation of Transient Hot Wire Technique to Estimate Thermal Conductivity and Thermal Diffusivity of Li_2TiO_3 Pebble Bed

Harsh Patel[1, 2,*], Maulik Panchal[1], Paritosh Chaudhuri[1, 2]

[1]Institute for Plasma Research, Bhat, Gandhinagar, 382428, India
[2]Homi Bhabha National Institute, Anushaktinagar, Mumbai, 400094, India

[*]E-mail: harsh.patel@ipr.res.in

Abstract

Lithium ceramics as pebble beds are chosen for the tritium breeding materials in blanket of fusion reactor. The packing structure of the pebble bed influences its thermo-mechanical behavior. In this study thermal conductivity and thermal diffusivity of the pebble bed is estimated by simulating the transient hot wire technique in ANSYS. The pebble bed models for the study is generated using Discrete Element Model (DEM). The pebbles are generated at the top side of pebble bed container and are subjected to free fall under the influence of gravity resulting in a pebble randomly packed bed. The simulation has been carried out for two configurations naming mono and binary sized beds in helium and air environment. Results of the simulations are compared with the literature results and are in good agreement. The packing fraction in case of binary sized pebble bed is higher than mono sized bed resulting in higher value of thermal conductivity and thermal diffusivity.

MANAGEMENT OF MANUFACTURING DESIGN OF VACUUM VESSEL IN-WALL SHIELDING BLOCKS IN COLLABORATION WITH ITER

Mahesh Patel[1], Rahul Laad[1], Ulhas dethe[1], Shrishail Padasalgi[1], Xiang Bin[2]

[1] *ITER-India, IPR, Bhat, Gandhinagar-382428, Gujarat, India*
[2] *ITER Organization, Route de Vinon sur Verdon, 13115 Saint Paul Lez Durance, France*

mahesh.patel@iterindia.in

Abstract

The ITER vacuum vessel (VV) acts as a first safety containment barrier, a torus-shaped and double wall structure. The space between the double walls of the VV is filled with the In-wall shielding (IWS) blocks. The primary purpose of the IWS Blocks is to provide neutron shielding during ITER plasma operation and to reduce the ripple of the Toroidal magnetic field. Based on ITER VV structure and related requirements, about 8800 IWS blocks are designed with different sizes, shapes and materials distributed over nine vessel sectors and nine field joints. The Plates of IWS blocks are made of borated and Ferritic steel and fastened with the help of brackets and fasteners. Brackets are made from SS316L(N)-IG material and fasteners are made from XM-19 and Inconel 625 material.

The detailed design has been developed by ITER Organization (IO) in consultation with the ITER participant parties. Manufacturing drawings are prepared by the IWS supplier with the help of ITER-India. Manufacturing design evolves over the time based on the shop floor manufacturing feasibility and other designs constrain during the execution of the contract. The changes are implemented in drawings to meet the design and manufacturing requirements.

This paper emphasizes the change management of the manufacturing design of the IWS blocks along with support Ribs during the manufacturing phase in collaboration with the ITER organization and its partners. The Manufacturing design of IWS components are prepared using CAD software and managed using PLM software. All the design and manufacturing changes during the manufacturing phase are managed using the design life cycle management tool.

PERFORMANCE OF (REGULATED HIGH VOLTAGE POWER SUPPLY) RHVPS DURING TWO PULSE OPERATION OF ECRH SYSTEM

Sumod C.B, Dipal Thakkar, L.N.Gupta, Paresh J. Patel, U.K.Baruah & ECRH team

Institute for Plasma Research, Bhat Village, Gandhinagar 382 428

E-mail : sumod@ipr.res.in

Abstract

Regulated high voltage power supply (RHVPS) is the important power source for heating and RF sub systems used in Tokamak. A large number of switched power modules (SPM) connected in series, receives power from two multi secondary transformers are switched with pulse step modulation technology, and its output is fed to the load. RHVPS is regularly used for experiments involving NBI, ECRH, LHCD and ICRH systems for heating applications in SST-1 and Aditya-U. Most of the applications involve feeding high power to the load from RHVPS for a fixed duration.

This poster describes the performance of RHVPS where its output is switched on for a fixed duration, during which the anode voltage of Gyratron is fed with two or multiple small successive pulses resulting in varied current output of RHVPS.

References:

[1] P.J.Patel, et.al, "A Regulated Power Supply for Accelerator Driven System", International Topical Meeting on Nuclear Research Applications and Utilization of Accelerators, 2009, Organized by the International Atomic Energy Agency, In cooperation with the American Nuclear Society

[2] "Power Supply System for 1000 S Neutral Beam Injector", Presented at Symposium on Fusion Engineering, U.K. Baruah, P.J. Patel, et al., (1997)

Transient Lorentz Force Calculations on In-vessel Coils in SST-1 Operation

A. Amardas

Institute for Plasma Research, PO: Bhat, Gandhinagar-382428, India

E-mail: amar@ipr.res.in

Abstract

It is proposed to have two pairs of coils (PF6 and VF) closer to plasma inside the vacuum vessel of SST-1 tokamak at IPR for better control and thereby to increase the plasma duration. These multi turn coils carry fast changing currents in kilo ampere range and face time varying magnetic fields of other coils in the machine. In addition to that, eddy currents generated in the vacuum vessel and cryostat also contribute to rapidly varying forces on these coils. To calculate these transient forces on all the four coils, 2d and 3d finite element models are developed using a commercially available FEM software *Comsol Multiphysics* [1]. These results which guide the design of support structure will be presented in this poster.

References:

[1] *Comsol Multiphysics* http://www.comsol.com/

Wall Conditioning in Tokamak: Development and Implementation of Novel Wall Conditioning Techniques for ADITYA-U Tokamak

K.A.Jadeja[1,2,a)], K.M.Patel[1], J.Ghosh[1,3], B.G.Arambhadiya[1], Kiran Patel[1,3], R.L.Tanna[1,5], A. B. Patel[1], K. D. Galodiya[1], Suman Aich[1], Rohit Kumar[1], Harshita Raj[1],Laxmikanta Pradhan[1], R. Manchanda[1], M.B. Chowdhuri[1], Nandini Yadava[5], Sharvil Patel[6], N.Ramaiya[1], Kajal Shah[6], K.Singh[1,3], S. Dolui[1,3], Ankit Kumar[1,3], B. Hegde[1,3], A. Kumawat[1,3], Minsha Shah[1], Praveenlal E.V.[1], V. Raulji[1], R. Rajpal[1], U. Nagora[1,3], P.K.Atrey[1], S.K. Pathak[1,3], Shishir Purohit[1], Manoj Kumar[1], Kumudni Assudani[1], Devilal Kumavat[1], K.S. Shah[1], M.N. Makwana[1], Shivam Gupta[1], Supriya Nair[1],S.B. Bhatt[1], P.K.Chattopadhyay[1,3], B.R. Kataria[4]

[1]Institute for Plasma Research, Bhat, Gandhinagar
[2]Department of Physics, Saurashtra University, Rajkot
[3]HBNI, Training School complex, Anushakti Nagar, Mumbai
[4]Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot
[5]Institute of Science, Nirma University, Ahmedabad
[6]Pandit Deendayal Energy University, Gandhinagar

[a)]E-mail: kumarpal@ipr.res.in

Abstract

In Tokamak/Stellarator, wall conditioning is the primary requirement to prepare the machines for plasma operation. Wall conditioning maintains a low level of impurities and controls the plasma density. Optimum wall conditioning plays an important role in achieving record plasma performance. Traditional wall conditioning techniques such as Glow discharge wall conditioning (GDC) and Vessel Baking (VB) are performed in almost all fusion devices. These wall conditioning techniques reduce the impurities in bulk in form of H_2O, CO, CO_2, CH_4, and Hydro Carbon series. The Vessel Baking is started just after the vessel pump-down for long hours to a few days according to machine size. The GDC with H_2 fueling is performed during/after VB cycles. During the tokamak plasma operation, the vessel wall and plasma-facing components (PFCs) are contaminated with volatile impurities. Therefore the routine operation of GDC is required before/after the plasma discharges to prepare the wall for the next plasma operation cycle. Due to the H_2-fueled GDC and plasma discharges, H_2 retention is increased in the vessel wall creating higher H_2 recycling from the wall during plasma discharges. It makes the plasma density control difficult using external fueling. Helium-fueled GDC is used for a short period to control H_2 recycling. Additionally, the coating on PFCs and vessel wall using low atomic mass materials like lithium, and boron enhances the tokamak plasma performance in terms of high temperature and better confinement.

In ADITYA upgrade tokamak (ADITYA-U), the above-mentioned wall cleaning techniques are operated routinely according to plasma operation requirements. Additionally, few novel wall conditioning techniques have been developed to exceed the limitation of traditional wall conditioning. To control H_2 retention on the PFCs and vessel wall, Pulsed fueled GDC (P-GDC) has been developed using H_2 and He gases [1]. In the experimental comparison of P-GDC with normal GDC, the H_2O, CO, and CO_2 reduction efficiency were observed higher in P-GDC as 100, 50, and 65 %, respectively. Argon-H_2 mixture fueled GDC was successfully developed and implemented in ADITYA before upgradation. It was more effective in unbaked ADITYA vessel for removing H_2O in bulk as 5 times more compared to normal H_2-fueled GDC [2]. The Ar-H_2 GDC is also implemented successfully in ADITYA-U. The Ar-H_2 GDC is used for higher reduction of carbon and oxygen-contained impurities from PFCs and vessel wall. Resulting changes are observed in spectroscopic line radiation of C and O during plasma operation. To control of high-z and oxygen impurities, novel techniques of lithiumization have been developed for ADITYA-U [3]. Two methods of lithium coating are developed to introduce lithium into the vessel by Li-rod sputtering and Li-evaporation under H_2 glow plasma. The better performance of ADITYA-U is directly related to PFCs and vessel wall conditions, which are improved

more proficiently using the operation of newly developed techniques of wall conditioning. The details of the developed novel techniques of wall conditioning are presented with experimental results.

References:

[1] K.A. Jadeja, et al. "Novel approach of pulsed-glow discharge wall conditioning in the ADITYA ." Nucl. Fusion 59 (2019) 086005
[2] K.A. Jadeja, et al. "Experimental Study for Comparison of H2 and Ar–H2 Gas Mixture Glow Discharge Wall Conditioning in ADITYA Tokamak", IEEE Transactions on Plasma Science, Vol. 44, No. 4, 722, April 2016
[3] K.A. Jadeja, et al "Lithium wall conditioning techniques in ADITYA-U tokamak for impurity and fuel control" Nucl. Fusion 62 (2022) 016003.

Characterization of Deuterium Ion Beam for 14-MeV neutron Generator

*S. Vala[ab], Ratnesh Kumar[a], M. Abhangi[ab], H. Swami[a] and Rajesh Kumar[ab]

a. Institute for Plasma Research, Bhat, Gandhinagar, Gujarat -382428
b. Homi Bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra- 400094

E.mail: sudhir@ipr.res.in

Institute for Plasma Research has developed the accelerator-based 14-MeV neutron generator. The neutron is going to be generated from the nuclear reaction 3H(D, n)4He by bombarding deuterium ions on a solid tritium target. The stability, quality, and repeatability of the deuterium ion beam are the key parameters for the stable operation of the neutron generator. Two number beam diagnostic systems have been installed in the neutron generator to measure the deuterium ion beam parameters. It consists of the X-Y slits, beam profile monitor, and faraday cup to measure the ion beam emittance, beam diameter and beam current, respectively. The Slit-Wire combination-based BPM method has been used for the emittance measurement. The deuterium ion beam characterization experiment has been performed, and the beam's current is in a range of 5 to 20 mA as a function of the extraction voltage produced. All beam parameters have been measured at different currents. This paper presents the results of deuterium ion beam current, beam profile, and beam emittance.

Vacuum Conditioning of Graphite Tiles of Aditya Upgrade Tokamak

ArunPrakash Arumugam*, Kaushal Patel, D.C. Raval and Ziauddin Khan

Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat Department of Physics,

*E-mail: arun@ipr.res.in

Abstract

Graphite is widely used as armour material for plasma facing components in Tokamaks. High thermal shock resistance and low atomic number of carbon are the most important properties of graphite for its application as an armour material in many Tokamaks. Aditya Upgrade Tokamak has a major radius of 0.75m and minor radius of 0.25m. Plasma Facing Components (PFC) is one of the major sub-systems of Aditya Tokamak Upgrade. Aditya Upgrade Tokamak has both the limiter and divertor configurations. Aditya-U tokamak has different set of limiters and divertors, such as (1) Safety limiter, (2) Toroidal Inner limiter, (3) Toroidal outer limiter, (4) Upper and lower divertor plates. Initially graphite will be used as plasma facing material (PFM) in all the limiter and divertor plates. The dimensions of the limiter and divertor tiles are decided based on their installation inside the vacuum vessel as well as on the total plasma heat load falling on them. Shaped graphite tiles are fixed on specially designed support structures made out of SS-304L inside the torus shaped vacuum vessel. About 200 graphite tiles and 240 graphite caps are installed before the commencement of phase-1 plasma operation. PFCs are designed and fabricated to be Ultra High Vacuum (UHV) compatible and high temperature compatible for plasma operation. IG-430 grade graphite is chosen as first wall armour material in Aditya Upgrade Tokamak. Graphite, because of its porous nature absorbs water vapour and other gasses from atmosphere. Generally graphite tiles are given a high temperature bake-out treatment prior to installation inside the tokamak to reduce the in-situ wall conditioning time. All the graphite tiles were given a high temperature bake-out at 1000 ^{o}C to remove the entrapped gasses, under high vacuum ($<1.0\times10^{-5}$ mbar) in a vacuum furnace before installation inside the Aditya Upgrade Tokamak vacuum vessel. Residual Gas Analyser (RGA) was used to measure the outgassing at various temperatures during the entire vacuum baking process. RGA analysis shows that water vapour seems to be the dominant impurity. The remaining outgassing species are N_2, CO and H_2. In this paper, we will discuss about the vacuum conditioning procedure and residual gas analysis of Aditya-U Tokamak graphite tiles in high temperature vacuum baking process.

References

[1] Chenna Reddy D, et al., SST-1 First Wall: Design for UHV Compatibility, IVS Bulletin, Vol.5, No.4, 19-29, (2002)

[2] Kaushal Patel et al., Limiter and Divertor System – Conceptual and Mechanical Design for Aditya Tokamak Upgrade, IVSNS 2015.

DEVELOPMENT OF EXPERIMENTAL HELIUM COOLING FACILITY AT IPR

B. K. Yadav*[1], A. Gandhi[1], A. Saraswat[1], S. Verma[1], P. Chaudhuri[1, 2]

[1]Institute for Plasma Research, Bhat, Gandhinagar, India
[2]Homi Bhabha National Institute, Mumbai, India

*Email: byadav@ipr.res.in, brijesh9903@yahoo.com

Abstract

The Experimental Helium Cooling (EHCL) system is a close loop high-pressure (8.0 MPa), high-temperature (300- 450 ^{0}C) helium gas system. The objective of this facility is to contribute to the development of helium-cooled nuclear fusion components such as tritium breeding blanket and divertor by providing experimental data on the mock-up testing of these components. Tritium breeding blanket and divertor have intricate cooling circuits designed for heat extraction by high-pressure helium gas, and therefore, several mock-ups need to be tested before concluding the design and fabrication of these components. Furthermore, as the EHCL system is constructed using several specialized components such as helium circulators, printed circuit type heat exchangers, heaters, helium compressors, special instruments, and valves, etc., studying the performance of all these components, validation of the control logic and operation of integrated plant under different operating conditions are essential for the development of a high-pressure, high-temperature helium cooling system for Test Blanket Module (TBM) of ITER and for future high-pressure helium cooling plants. This paper describes the EHCL facility that has been commissioned at IPR. It briefly presents the features of the EHCL system, discusses its key design aspects, and highlights the assembly and commissioning activities including acceptance testing parameters. The paper also talks about the major components of the system, operation & control scheme of the loop and highlights the key features of the data acquisition & control system of the facility.

Key words: EHCL, TBM, ITER

References:

1. B. K. Yadav, K. T. Sandeep, A. Gandhi, A. Saraswat, D. Sharma, P. Chaudhuri, Design updates for helium cooling system of Indian LLCB blanket, Fusion Engineering and Design, Volume 167 (2021) 112342.

2. B.K. Yadav, A. Gandhi, et al., Helium Cooling Systems for Indian LLCB TBM, Fusion Engineering and Design, 124 (2017) 710–718.

3. B. K. Yadav, A. Gandhi, A. K. Verma, T. S. Rao, A. Saraswat, E. R. Kumar, M. Sarkar, K. N. Vyas, Conceptual design of Experimental Helium Cooling Loop for Indian TBM R&D experiments, World Academy of Science, Engineering and Technology, International Journal of Physical and Mathematical Sciences, Volume 8(2), February 2014

Real Time Plasma Equilibrium study in ADITYA-U

Deepti. Sharma[1], D. Raju, Sameer Kumar, Sharvil Patel, R. L. Tanna, J. Ghosh and ADITYA-U team

Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat, India

E-mail: deepti@ipr.res.in

Abstract

To undertand the plasma dynamics one has to study the real time plasma equilibrium dynamics. External magnetic measurements with flux loops and magnetic pick-up coils in tokamaks have provided vital information on the shape of the plasma column and also global current profile parameters, such as the poloidal beta (βp) and the internal inductance (ℓi). Such a real time study needs to be fast and sufficiently accurate such that it can be used routinely as a complementary input with other experimentally measured parameters for any sort of physics analysis of the plasma discharges.

In ADITYA-U there are 16 magnetic pick-up coils aligned to measure the poloidal magnetic field (B_θ) during a plasma discharge. Vacuum shots with OT and BV and no fill gas are used to calibrate these coils. Measurement from these coils and flux loops are used to reconstruct the equilibrium consistently with the peak density and temperature measurements. Finally, the
reconstructed equilibria are validated and fix the gain factor to study the plasma movement inside the vessel for some experimental shots.

Here we present a method which can be used to proficiently reconstruct the current profile parameters, the plasma shapes, and a current density profile satisfying the MHD equilibrium
constraint, reasonably conserving the external magnetic measurements. A Grad-Shafranov (GS) equation solver, named as IPREQ [1], has been developed in IPR to search for the best-fit current density profile. GS equation is a nonlinear elliptical differential equation describing axisymmetric toroidal equilibria. Ohmic transformer current (OT), vertical field coil current (BV) along with the plasma pressure (p) and current (Ip) profiles are used as inputs to the IPREQ code to reconstruct the equilibrium and the poloidal flux, plasma shape, βp and the safety factor (q) are inferred.

References:

[1]. Tokamak equilibrium code-IPREQ, R. Srinivasan and S. P. Deshpande IPR/RR-393/2007
(August, 2007)

Multimode Analysis of 170GHz Gyrotron Oscillator for Plasma Heating Applications

Ashutosh Singh

Department of Physics, M. P. Sinha Science College
Babasaheb Bhimrao Ambedkar Bihar University
Muzaffarpur, Bihar- 842001, India.

asingh.rs.ece@iitbhu.ac.in

Abstract

Gyrotron oscillators are sources of generating coherent EM radiation ranging from kilowatts to megawatt of output power in the microwave and millimeter wavelength [1]. Gyrotrons are used in various fields such as high resolution radars, atmospheric and planetary science, advanced communication systems, materials science, and medical imaging etc. However, megawatt class of gyrotrons are widely used in electron cyclotron current drive (ECCD), electron cyclotron resonance plasma heating (ECRH), stability control and diagnostics of magnetically confined plasmas [1-3]. Fusion energy comes up as a potential and clean energy source in future. Fusion reactions require plasma at very high temperatures. To achieve high temperature, MW class of gyrotrons are used [4].

The RF behavior of a 170 GHz tapered cylindrical cavity gyrotron operating in a higher order mode, using nonlinear time-dependent multimode analysis is presented. The coupling coefficient as well as start oscillation current is estimated for selecting the electron beam parameters. Magnetic field is kept uniform along the interaction structure. The bunching mechanism in electron beam and hence energy transfer phenomena are clearly demonstrated. The output powers in the designed mode along with all probable competing modes have been calculated using analysis. The output power is nearly 1.2MW with ~30% efficiency in the design mode while it is significantly lower in the competing modes.

References :

[1] M. Thumm, "State-of-the-art of high power gyro-devices and free electron maseres, update 2011," Karlsruhe Institute of Technology, Karlsruhe, Germany, Sci. Rep. 7606 (2012).

[2] K. Sakamoto, "Gyrotrons and mm wave technology for ITER," in *Proc. 32nd Int. Conf. Infr. Millimeter Waves*, Cardiff, U.K., pp. 4–7, (2007).

[3] M. V. Kartikeyan, E. Borie, and M. Thumm, *Gyrotrons—High Power Microwave and Millimeter Wave Technology*. Berlin, Germany: Springer- Verlag, 2004.

[4] P. C. Kalaria, M. V. Kartikeyan, and M. K. Thumm, "Design of 170 GHz, 1.5-MW Conventional Cavity Gyrotron for Plasma Heating," *IEEE Trans. Plasma Science*, vol. 42, no. 6, pp. 1522- 1528, June 2014.

A Fusion Pilot Plant: Analysis of Heat Extraction and Power Conversion System

Piyush Prajapati[1,2], S.P. Deshpande[1,2], P.N. Maya[1]

Institute for Plasma Research, Bhat Gandhinagar, 382428, India
Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India
E-mail : piyush.prajapati@ipr.res.in

Abstract

In some of the DEMO roadmaps [1], a pre-DEMO/Pilot plant design with a target of not just extracting heat but demonstrating electrical power generation has been considered. The Pilot plant (PP) designs aim at a low fusion power (~200 MW – 300 MW) compared to DEMO (>1 GW) so that the gaps between ITER and DEMO can be addressed. These gaps are: a breeding blanket that should cover almost all of the inner vessel, tritium and heat extraction on a large scale, demonstrations of a closed fuel cycle, power conversion systems and sustained electrical power generation. The attractiveness of a PP lies in proving that entire the plant works as desired, albeit on a small scale. In the ideal scenario, then, the DEMO should only require an 'engineering scaling' of the technologies perfected at the pilot plant level.

Although there are some PP studies at present, a integrated study involving the blanket design and the power conversion is missing, e.g., FDF (Fusion development Facilities) goal is to engineer the full blanket with the primary goal of only producing net tritium [2], SPARC [3] with fusion power 140 MW aims to achieve fusion gain Q > 2 and demonstration of the REBCO HTS magnets, in particular, an approach of high-field path to fusion. The FNSF [4] focuses on fusion nuclear science and advanced blanket design to maintain high relevance for power generation. We address the gap in integrated system design by conceptualizing a complete power extraction cycle while introducing a novel helium-cooled solid-breeder blanket design and pulse-length optimization with intermediate heat-exchanger-cum-storage. The reactor is based on a near conventional aspect ratio (A = 2.7) tokamak with R=3 m and fusion power of 200 MW and Q ~ 4.

The major component of heat extraction systems is the breeding blankets, although some power will be extracted from the divertor. The blanket has Li_2TiO_3 as breeder material, Be as neutron multiplier and reduced activation ferritic-martensitic (RAFM) steel as structural material. The breeder-units, cooling plates (CP) and multiplier-units in a given blanket module are stacked in vertical manner to allow full exploitation of hot-zone forming in the frontal region. The blanket has an overall dimension of 1.25 m (poloidal), 0.720 m (Toroidal) and 0.60 m (Radial) at the outer midplane with 14 modules in one sector which are shaped to fit the plasma surface. A unique 'backside assembly and maintenance' scheme has been proposed to overcome the doubly-curved compact blanket-torus which

results in trapezoidal modules. This allows a minimum streaming of the neutrons. Since this requires a space between blanket torus and the vessel for the withdrawal of the module, one gets some additional t-breeding opportunity by utilizing the large vacuum vessel surface as a result.

The thermo-hydraulics calculations were done assuming a generic nuclear load profile. The analysis of power conversion systems with intermediate energy storage systems (ESS) using both Rankine and Brayton cycles [5] has been carried out. The power conversion system is designed in such a way that the helium from the blanket heats molten salt in the ESS which can be connected to heat exchanger to use either Rankine or Brayton cycle. The thermal efficiencies are found to be ~36 % for Rankine and ~ 42 % for Brayton cycle which amounts to an engineering gain (Q_{eng}) of about 0.4-0.5. Adaptation of a steam-generator concept used in fission reactors has also been explored [6]. The analysis brings out the constraints on the minimum pulse length duration of the plasma from the requirement of the thermodynamic efficiency of the power conversion systems.

References:

[1] Srinivasan R and Deshpande S 2008 Fusion Engineering and Design **83** 889–892 ISSN 0920-
3796, Deshpande S and Kaw P 2013 SADHANA **38** 839, Srinivasan R 2016 Fusion Engineering and Design **112** 240–243 ISSN 0920-3796, P N Maya S P D 8th IAEA DEMO Workshop, 30 Aug.- 02 Sept. 2022, Vienna, Deshpande S P and Maya P N 2022 IPR/RR-1408/2022

[2] Stambaugh et al., Fusion science and Technology, September 3, 2010.

[3] Creely et al., J. Plasma Phys. (2020).

[4] Kessel et al., Volume 135, Part B, October 2018, Pages 236-270

[5] P. Prajapati and S. Deshpande Fusion Eng. Des., vol. 176, no. September 2021, p. 113024, 2022,

[6] P. Prajapati, et al., Fusion Eng. Des., vol. 161, no. September 2019, p. 112069, 2020.

30-50 Ohms RF Coaxial 3-1/8" Demountable Ceramic High Vacuum Window

Dharmendra Rathi[1], Dr. Mumtaz Ansari[1], Raj Singh[1], Siju George[1], Sunil Kumar[1]

[1]Institue for Plasma Research, Bhat, Gandhinagar-382428, Gujarat, India

E-mail: drathi@ipr.res.in

Abstract

A proposed high-power radio frequency (RF) antenna is made to resonate at 13.56 MHz with an external matching network to assist glow discharge cleaning (GDC) of a Steady-State Superconducting Tokamak (SST-1) under very low pressure.

A vacuum window is fabricated to isolate the SST-1 Vacuum Vessel (VV) and coaxial transmission line placed in the air. It is made of non-magnetic SS 304L and Alumina (Al2O3) ceramic between inner and outer straight conductors as a vacuum barrier placed between inn inner and outer straight conductor and mounted on the 50-ohm side flange of the 50-ohm to 30-ohm transition section. The ceramic window is tested for He leak test < 1e-10 mbar.l/s and high vacuum tested < 2e-7 mbar (base pressure of SST-1 VV).

The available port to mount the antenna inside the SST-1 is 63 CF while the available 50-ohm
transmission line is of an inner diameter of 76.9 mm with a flange outer diameter of ~110 mm. The distance from the port to the plasma limiter wall where the antenna is placed is around ~840 mm. Thus an 830 mm long 30-ohm section with an outer conductor inner diameter of ~56 mm and flange outer diameter of ~90 mm is designed and simulated. The 50 ohms to 30 ohms transition is modelled separately by keeping the outer diameter of the inner conductor the same about ~33.4 mm and optimised using CST-MWS. The simulated optimised reflection coefficient is found to be ~ -14 dB at the required frequency of 13.56 MHz. Low power VNA test of vacuum window without 30-50 Ohms transition shows a return loss and insertion loss less than 29 dB and 0.05 dB respectively in the frequency range of 10–40 MHz.

The design detail, tests conducted and the results obtained for the vacuum window will be reported in the work.

Numerical Investigation Of Thermal Mixing In T-Junction For Fusion Reactor Tokamak Application

Sandeep Rimza, Paritosh Chaudhuri, Brijesh Kumar Yadav. Sayantan Mukherjee

Institute for Plasma Research (IPR)
Bhat, Gandhinagar, 382428, Gujarat, India

E-mail: sandeep.rimza@ipr.res.in

Abstract

The development of an efficient Fusion Blanket Module (FBM) concept for a future fusion power plant is challenging because extraction of high heat flux from core plasma. To test various blanket design concepts, the Institute for Plasma Research (IPR) is building an Experimental Helium Cooling Loop (EHCL) [1]. Helium is employed as a coolant due to its better safety characteristics. The helium flow field is complicated due to the thermal mixing of hot and cold streams in the T-junction, which is a crucial component of the ECHL. Temperature variations that occur during the thermal mixing process might lead to pipe structural failure due to thermal fatigue [2].

The main objective of present research is to investigate the impact of the injection angle of the cold fluid branch pipe on the turbulent thermal-hydraulic performance in the main flow of T-junction. The impact of important flow parameters and geometrical modification on the thermal mixing degree are analyzed as a function of momentum ratio (M_r). Furthermore, steady state Fluid-Structure Interaction (FSI) analysis is performed to determine the stress induced in the T-junction. The flow performance and thermo-mechanical coupled analysis of the Experimental Helium Cooling Loop T-junction are carried out using the Computational Fluid Dynamics (CFD) simulation tool ANSYS. Pressure-velocity coupling is resolved in the computations using the semi-implicit pressure-linked equation (SIMPLE) algorithm. The second-order upwind approach is used to combine convection and diffusion transfer.

The 3-dimensional CFD simulation of the flow field is performed and validated against experimental data. Then, the stresses that occur from the impact of the fluid force fields on the T-junction pipe walls are predicted using a structural analysis model. The findings demonstrate that the injection angle has a significant impact on the thermal mixing performance and reduces the temperature gradient in the main pipe flow. For smaller Mr (0.045), the backflow from the upside of the T-junction mixing is more generous, and it becomes less significant as Mr increases (>0.56).

Keywords: Thermal mixing degree, Fusion blanket, Thermal stresses, Fluid simulation

References :

[1] B.K. Yadav, K.T. Sandeep, A. Gandhi, A. Saraswat, D. Sharma, P. Chaudhuri, Design updates for helium cooling system of Indian LLCB blanket, Fusi. Engg. and Desi., **167**, 2021, 112342.

[2] S. Taheri, Some advances on understanding of high cycle thermal fatigue crazing. Jour. of
Pres. Vessel Tech., **129** (2007) 400–410.

Neural network assisted global gyrokinetic toroidal code using cylindrical coordinates

Jaya Kumar Alageshan#, Joydeep Das#, Sarveshwar Sharma*, Animesh Kuley#

#Department of Physics, Indian Institute of Science, Bangalore 560012, India
**Institute for Plasma Research, Bhat, Gandhinagar-382428, India*

E-mail : jayaka@iisc.ac.in

Abstract

In the last three decades, several gyrokinetic simulation codes were developed, such as GTC[1], GYRO[2], ORB5[3], GENE[4], etc., to understand the microturbulence in the linear and nonlinear regime of tokamak core. These codes use flux coordinates, which encounter the mathematical singularity of the metric on the magnetic separatrix surface. To avoid such constraints, we have developed a new simulation code called global toroidal code using the X point (GTC-X)[5] using cylindrical coordinates, similar to XGC-1[6] and TRIMEG[7]. This coordinate system allows GTC- X, XGC-1, and TRIMEG to calculate the particle dynamics in arbitrarily shaped flux surfaces, including separatrix and X point in the tokamak. GTC-X has fully kinetic (FK) and guiding center (GC) particle dynamics, but XGC-1 and TRIMEG only have guiding center particle dynamics. GTC- X uses field-aligned gather-scatter operation based on a neural network prediction scheme to achieve field-aligned mesh efficiency. We train a multi-layered neural network with field line geometry estimates obtained by numerical integration to predict and locate the particles within the simulation grid. The main focus for developing GTC-X is to couple the core and SOL regions to understand the electromagnetic turbulence using the guiding center and fully kinetic particle dynamics.

References :

[1] Gyrokinetic particle simulation of microturbulence for general magnetic geometry and experimental profiles, Phys. Plasmas 22, 022516 (2015).
[2] Coupled ion temperature gradient and trapped electron mode to electron temperature gradient mode gyrokinetic simulations Phys. Plasmas, 14, 056116 (2007).
[3] A global collisionless PIC code in magnetic coordinates, Comput. Phys. Commun. 177, 409 (2007).
[4] Full-f version of GENE for turbulence in open-field-line systems, Phys. Plasmas 25, (2018).
[5] Kinetic particle simulations in a global toroidal geometry, Phys. Plasmas 26, 082507 (2019).
[6] Compressed ion temperature gradient turbulence in diverted tokamak edge, Phys. Plasmas 16, 056108 (2009).
[7] Development and testing of an unstructured mesh method for whole plasma gyrokinetic simulations in realistic tokamak geometry, Phys. Plasmas 26, 122503 (2019).

Refurbishment of Current Limiting Resistor for the Charging System of Wave Shaper Capacitors

Shivam Kumar Gupta, Kunal S Shah, M N Makwana, Nagarji Thakor, V Balakrishnan, Supriya Nair, Rohit Kumar, R L Tanna, Joydeep Ghosh and ADITYA-U Team

Institute for Plasma Research, Bhat near Indira Bridge, Gandhinagar, Gujarat (India) 382428

E-mail: shivam.gupta@ipr.res.in

Abstract

Wave Shaper (WS) unit is exclusively accountable for profiling and building up the loop voltage. Ignitrons, mechanical switches, mega joule grid type resistors, and commutating L-C are all components of the wave shaper unit. Here, two mechanical switches—one a VCB (Vacuum Circuit Breaker) and the other an FMS are being used (Fast Make Switch) [1].

VCB is in the on position during the Ohmic coil charging phase and normally carries 14–15 kA of current. Opening the VCB will allow the resistor bank to connect in series with a charged Ohmic coil, which is necessary to create the loop voltage. Opening the VCB now, with such a strong current flowing through it, is extremely dangerous. Commutating circuit is use to create an artificial zero current in the VCB in order to reduce risk.

The Capacitor, Ignitron, and Inductor are the three components of the Commutating Circuit, which creates an artificial zero current. The capacitor must be charged to a specific voltage level (max. 25kV) in order for the VCB to be commutated. The value of the coil charging current determines this voltage level. According to the needs of the experiment, the coil's charging current is changed, which changes the charging voltage level. To achieve the varied charging voltage levels, a very innovative design for the capacitor charging mechanism has been developed. A woven resistor has been utilised to restrict the initial surge charging current in the capacitor. It began to deteriorate as a result of ageing and approximate 60000 operations. Recently, the damaged woven resistors were replaced by the wire-wound resistor bank. It is in use right now and functioning properly.
In this Poster, the capacitor charging mechanism and the substituted current limiting resistor are presented. Some outcomes of the revised charging scheme will also be covered

References :

[1] Plasma current and position feedback control in ADITYA tokamak, V.Balakrishanan, C.N.Gupta, R.K.Sinha, Fusion Engineering and Design 66-68(2003) 809-813

Manufacturing Experience of Indigenously Developed Dished Head-Sub Assembly (DH-SA) for High Voltage Bushing (HVB) of Indian Test Facility (INTF)

Dheeraj Kumar Sharma[1], Jaydeep Joshi[2], Suraj Pillai[2], Kaushal Joshi[2], Deepak Parmar[2], Hardik Shishangiya[2], Sejal Shah[2], Akhil Jha[2], Mahendrajit Singh[2], Arun Kumar Chakraborty[2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat- 382428*
[2]*ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, Gujarat- 380005*

dheeraj@ipr.res.in

Abstract

INTF HVB [1] is a 100 kV feedthrough which allows electrical, RF, water, Cs, gas and diagnostic penetrations with Multi Pin Feedthroughs (MPF) transiting from air to high vacuum while maintaining electrical and vacuum isolation. INTF HVB consists of two sub-assemblies: i. DH-SA and ii. PR-SA. PR-SA consists of diameter 800 mm, 550 mm long Porcelain Insulator (PI) [3] with metallic end flanges, at both ends. While one of the end flange interfaces with the DH-SA the other connects to the vacuum vessel flange. DH-SA is a 669 mm diameter circular metal plate with 25 penetrations of various kinds including fragile ceramic feedthroughs.

The design of DH-SA along with the various feedthroughs and HV shields was optimized through detailed computer simulations by taking care the distances and isolations which provided the desired functionality with electrical stresses were limited to ~5 kV/mm. Simulations with CST helped in the design of the RF vacuum barrier. An Indian industry was identified to realize this first of a kind component. Several prototyping activities were performed to ensure the manufacturability and functionality of DH-SA

DH-SA has been realized with all the required acceptance tests of the assembly as per specifications. In the present work, manufacturing experience of DH-SA is presented with the main focus on the key challenging areas e.g. indigenous development of RF feedlines and vacuum feedthroughs, bus bar feedthroughs, joining of multipin feedthroughs for power, thermocouple and HV ceramic feedthroughs with DH plate and the qualifications.

References:

[1] Shah, S., *et al.* "100-kV feedthrough for the Indian Test Facility (INTF) — Design and Analysis". *Journal of the Korean Physical Society* **65,** 1294–1298, (2014).
[2] Sejal Shah, *et al.* "Indigenous Development of Large Dimension Insulator for HV Bushing of INTF", Transactions of the Indian Ceramic Society, 79:1, 30-34, (2020).

UPGRADATION OF AUXILIARY POWER SUPPLIES FOR ITER DELIVERABLE RF SOURCE

Hrushikesh Dalicha*, Gajendra Suthar, Kartik Mohan, Kumar Rajnish, Raghuraj Singh, Rajesh G Trivedi

ITER-India, Institute for Plasma Research, Gandhinagar, India 382428

E-mail : Hrushikesh.dalicha@iterindia.in

Abstract

ITER-India has developed a dedicated test facility for the testing of 1.5 MW RF chain. The RF chain consists 3-stages cascaded amplifiers; pre-driver, driver and final stage amplifiers based on solid state and vacuum tubes (Diacrode / Tetrode) technology respectively. The test facility includes high power RF Dummy load, transmission line components including mis-match transmission line system comprising of stub and phase shifter, AC power distribution network, Local Control Unit (LCU), Auxiliary power supplies for Control Grid, Screen Grid and Filament power supply for driver & final stage amplifiers and High Voltage power supply etc. The same facility shall be used in future for testing of RF sources at 3MW level related to ITER procurement. Auxiliary power supply provides DC biasing for Screen Grid, Control Grid and filament of vacuum tube-based amplifiers. Based on R&D experience, upgradation & optimization of auxiliary power supplies carried out considering performance, protection, and size constraint. The upgradation activities involve panel selection, installation, internal wiring, cooling provision and external protection circuits, which are designed and tested to meet the protection requirements. In this paper, the challenges faced during upgradation of auxiliary power supplies and appropriate solutions will be discussed.

References:

[1] Diacrode TH628 datasheet
[2] Tetrode TH781 datasheet
[2] Aparajita Mukherjee et al., Status of R&D activity for ITER ICRF power source system, Fusion Engineering and Design 96–97 (2015) 542–546
[3] Rajesh Trivedi et al., Outcome of R&D program for ITER ICRF Power Source System, Preprint, FEC-2018.

Fabrication Aspects And Characterization Of Sandwich Configuration Flow Channel Inserts For Liquid Metal Applications Upto 600°C

Abhishek Saraswat[a,*], Rajendraprasad Bhattacharyay[a,b], Paritosh Chaudhuri[a,b], Sateesh Gedupudi[c]

[a] *Institute for Plasma Research, Gandhinagar 382428, India*
[b] *Homi Bhabha National Institute, Trombay, Mumbai 400094, India*
[c] *Heat Transfer and Thermal Power Laboratory, Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai 600036, India*

E-mail: asaraswat@ipr.res.in

Abstract

Liquid metals exhibit several attractive characteristics justifying their utilization as coolants and breeders in nuclear fusion power plants. When such high temperature liquids circulate in presence of a transverse magnetic field, the inherently high electrical conductivity leads to the generation of a large magneto-hydrodynamic (MHD) pressure drop imposing significant demands on the pumping power and thereby challenging the designs of ancillary coolant systems. To address these concerns, Flow Channel Inserts (FCI) are being considered to electrically decouple the liquid metal from electrically conducting thick pipe/duct walls. In this study, three different configurations (circular, square and 90° bend) of sandwich FCI are fabricated. An elaborate characterization of electrical insulation performance is conducted, using high voltage tests, over an operating temperature range of 100°C-600°C, followed by welding trials and pneumatic pressure tests upto 10 kg/cm^2 (g) on the prototype FCIs towards validation of electrical and mechanical integrity. The paper presents fabrication aspects along with quantitative estimations of insulation filling density, electrical insulation performance and, for the first time, detailed systematic study of insulation degradation as a consequence of combined effects of TIG welding, exposure to pressure and machining operations on these FCIs. The paper also provides critical details derived from the metallurgical examinations as well as visual inspections from destructive tests executed on the prototypes.

2D ION BEAM OPTICS SIMULATION USING AXCEL-INP AND COMPARISON WITH EXPERIMENTAL RESULTS

M. R. Jana, P. Bharathi, V. Prahhad, U. K. Baruah and NBI Team

Institute for Plasma Research
Bhat, Gandhinagar – 382428

E-mail : mukti@ipr.res.in

Abstract

SST-1 has a provision of injection of a neutral hydrogen beam to raise plasma temperature to 1 keV [1]. To fulfill this requirement, a positive ion based Neutral Beam Injection System (PNBI) is designed and fabricated. At present this system is under operation and 14A at 20 - 32 keV beam extracted from JET PINI (Positive Ion Neutral Injector) type ion source which consists of 3 grid (e.g. Acceleration, Deceleration and Earth Grid) Accel-Decel extractor system. Each grid has multiple shaped apertures and water cooled by a dense network of embedded cooling channels. Most important beam parameter is divergence. To deliver the optimum neutral beam power into the tokamak plasma, ion source must operate in Perveance matched condition which means the beam divergence is minimum at a given beam energy. This will reduce the beam loss at different beam line components. This paper describes the work done on ion beam optics simulation of 3 grid ion extractor systems using 2D AXCEL-INP for the above mentioned beam energy range. The output results are ion trajectory plot, emittance plot and divergence of extracted positive hydrogen beam at 20 – 32 keV. At lower beam energy the divergence is 2.5^{o} whereas at higher beam energy it is about 6.7^{o}. These results are compared with experimental results.

Reference:

[1] M. R. Jana, S. K. Mattoo, A. K. Chakraborty, U. K. Baruah, G. B. Patel and P. K. Jayakumar. Fusion Engineering and Design, **83**, p 729-735, (2008).

CALIBRATION OF ASSEMBLED MASSFLOW METER USING LabVIEW

Priyadarsini Gaddam, Haresh Dave, A K Sahu, Omkar chandratra, Vishnu Patel, Hitesh Chudasma,

Institute For Plasma Research, Near Indira Bridge, Bhat, Gandhinagar,Gujarat,382428

E-mail : pgaddam@ipr.res.in

Abstract

LCPC (Large Cryogenic Plant and Cryosystem) is involved in the development of helium refrigerator-cum-liquefier plant and its components including various instruments. Plant has a requirement of mass flow rate measurements for different cryogenic and room temperature conditions of helium at different locations. To fulfill this requirement many mass flow meters are needed which is a costly solution. To avoid the usage of such costlier mass flow meters we have two different DAQ cards and HMI assembled systems, which works on two different platforms to measure mass flow rate. This assembly measures PT (Pressure Transmitter), DPT (Differential Pressure Transmitter) and Temperature data from the sensors and programmed to show Density and Mass Flow rate values.

We have developed applications to calibrate each mass flow meter assembly with the standard and existing Coriolis Mass flow meter using LabVIEW and Modbus RTU protocol. This application acquires the PT , DPT, Temperature (pt100), Density and Mass flow rates also displays and stores the sensor & calibrated data.

This poster presents the application of that calibration of the assembled Mass Flow meter and other details.

References:

[1] Modbus RTU made simple with detailed descriptions and examples (ipc2u.com)
[2] http://www.ni.com/ National instruments LabVIEW

RF Characterization Of ECR System Components At 2.45 GHz

K. K. Ambulkar, P. R. Parmar, A. L. Thakur, P. K. Sharma

Institute for Plasma Research, Bhat, Gandhinagar 382428, India

E-mail: kiran@ipr.res.in

Abstract

Electron Cyclotron Resonance (ECR) system [1] produces pre-ionized plasma and also used to drive plasma current non-inductively, which would increase the pulse length of plasma current up to few seconds. The 6 kW CW magnetron based system at 2.45 GHz is developed to produce the ECR plasma.

The ECR system consist of the WR340 waveguide components like waveguide, E-Bend, H-Bend, Dual Directional Coupler, Stub-tuner, DC break and Vacuum window. It is required to have low insertion loss for the waveguide components so that the rf power loss in the transmission line is minimum and the maximum power would be available at the antenna. Also the higher return loss or lower Voltage Standing Wave Ratio (VSWR) is desirable to have minimum signal reflection from the components. These parameters are tested at low power rf using the Vector Network Analyzer (VNA). The components are integrated in the 2.45 GHz, 6 kW CW magnetron setup and also subjected to the high power rf test to evaluate its performance.

This paper presents and discusses the test results of rf characterization of WR340 waveguide components both at low and high power.

References:

[1] P. K. Sharma et al., “ECR System At 2.45 GHz For Small Scale Spherical Tokamak,” in 34th National Symposium on Plasma Science & Technology (PLASMA 2019) (Poster NF-240).

PROTOTYPE VACUUM CONTROL AND MONITORING SYSTEM AND ITS INTERFACE WITH EPICS

Arnab Dasgupta[1,*], Sunil S[1], Yohan Khristi[1], Hitesh Gulati[1], Amit Srivastava[1, 2] and S.Mukherjee[1, 2]

[1]Institute for Plasma Research, Bhat, Gandhinagar-382428, India
[2]Homi Bhabha National Institute, Anushaktinagar, Mumbai-400094, India

*arnabdasg@ipr.res.in

Abstract

Supervisory Control and Monitoring is an important aspect in implementation/automation of any system. This helps in operation of the system, by reading, analyzing and providing data/parameters for the experiment. Here, an outgassing measurement system, consisting of various vacuum equipment is interfaced to operate at <1e-09 mbar vacuum to measure outgassing rate of critical vacuum components. An EtherCAT based Programmable Logic Controller (PLC) Hardware for performing its operation from a single operator console having a Graphical User Interface (GUI) has been described. The work done explains in detail the equipment/sensors interfaces, temperature control required for baking, program flow, GUI development and its integration needed for the automation. Experimental Physics and Industrial Control System (EPICS) is widely used in large scientific experiments across the globe for supervisory control [1]. Using available device driver support the PLC system is integrated to EPICS. Using the EPICS application interface and its client caQtDm, a GUI is developed for its operation from operator console. The system has been successfully integrated and is under operation for monitoring of different vacuum gauges, PID based temperature control for baking of vacuum chamber at 150°C, operation of electro-pneumatic gate valves and suitable interlocks implemented as required for the operation.

Keywords: Control, PLC, EPICS, GUI, Vacuum, outgassing, PID

References:

[1] https://epics.anl.gov/

Seismic Shake Table Test Qualification of Plant Control System Cubicles of ITER Cooling Water System

Aditya Singh*, Mahesh Jadhav, Nirav Patel, Jinendra Dangi, Hiren Patel, Mohit Kumar, Ajith Kumar

ITER-India, Institute for Plasma Research, Bhat Gandhinagar-382428 India

E-mail : aditya.singh@iterindia.in

Abstract

A key in-kind contribution of ITER-India to ITER project is the 'Design and Supply of Component Cooling Water System (CCWS), Chilled Water System (CHWS) and Heat Rejection System (HRS)'. Being Functional Specification nature of the package, the responsibility of design to ensure the structural and functional integrity of piping and equipment, complying to the requirements established as per loads and their combinations lies with ITER-India. Although the basic design is governed by primary and secondary loads, the occasional load such as seismic load is also equally critical because of high risk phenomenon even with rare probability of occurrence.

In order to meet the mandatory seismic requirements, most of the seismic qualifications were done using analysis method (linear elastic on CAESAR/STAAD Pro/Ansys); however, the equipment with the configurations 'too complex to model' were tested experimentally on shake table. Because of complex configuration, it was decided to qualify Plant Control Cubicles (PCS) using tri axial servo hydraulic shake table, complying to IEEE 344 and ITER guidelines with response spectra enveloping approximately 10% more than required response spectra for entire frequency range. The resonance test was performed with sinusoidal sweep test with sweep rate of one octave per minute having peak acceleration of 0.2g to determine the natural frequencies of cubicles. Five rounds of Operating Basis Earthquake in all three directions were applied simultaneously with frequency range of 01 to 44 Hz for the duration of 30 sec. The structural integrity and functionality were assessed after seismic test and the results were found as acceptable.

This poster summarises the procedure and physical shake table testing performed on the PCS cubicles.

References :

[1] Technical Specification for the Experimental Seismic Qualification of Active Electrical and
Mechanical Components (AGL2QP v2.1)
[2] IEEE-344

Installation & Commissioning of Cooling Water System for SST1 ICRH at IPR

S. K. Sharma, M. Vasani, R Mishra

Institute for Plasma Research, Bhat, Gandhinagar, Gujarat (India), Pin-382 428

E-mail: sks@ipr.res.in

Abstract

Institute for Plasma Research is having experimental SST1 (Steady State Tokamak-1) machine for research and development activities of Fusion Technology. The high power pulsed experiments will be done in this SST1 machine with Ion Cyclotron Resonance Heating (ICRH) system. Accordingly, the cooling water system has been designed to transfer the heat dissipated by the ICRH subsystems to the atmosphere. The cooling water system shall provide the DM water to various components at required temperature, flow, pressure and quality. The ICRH subsystems, which require cooling water, consist of 02 Anodes and 02 Dummy Loads. The cooling water system is designed to remove heat load of ~ 3MW. Depending upon the experimental requirement, the supply water temperature of 35°C, pumping heads 5- 8 barg, flow rate 2250 liters/min., conductivity ≤ 1μS/cm is to be supplied to the experimental system. Booster pumps (1W+1S) are installed to boost water inlet pressure from 5 barg to 8 barg for Anodes. Since the requirement of water quality for this system is pure water therefore one mixed bed unit is installed in re-circulation loop to maintain the conductivity of DM water. State of the art instruments are installed with signal re-transmission facility to monitor parameters like flow, temperature, pressure and conductivity for healthy operations of ICRH experiments. Cooling water shall be provided to the SST1 ICRH experimental system via this Water Distribution System from the existing Water Cooling Plant.

Structural integrity assessment of Cryostat manufacturing model verifying the effect of introduction of slots on Top-lid radial ribs.

Name(s) of the author : Avik Bhattacharya[1], Gaurav Jogi[1], Rajnikant Prajapati[1], Mukesh Jindal[1], Amit Palaliya[1],Vipul More[1], Saroj Jha[1], Vaibhav Joshi[1] & Anil Kumar Bhardwaj[1],

Affiliation : 1. ITER-India, Institute for Plasma Research, Bhat Motera, Road,Koteshwar,Ahmedabad-380005

E-mail : avik.bhattacharya@iterindia.in

Abstract

The ITER Cryostat is a large cylindrical vessel with diameter of ~ 29 m and height of ~29 m. It surrounds the ITER vacuum vessel (tokamak). The main function of the Cryostat is to provide a vacuum environment for the operation of the superconducting magnets. The material for Cryostat is dual mark SS 304/304L and the total mass of Cryostat is 3850 tons. The Cryostat is divided into four main sections- The base section, the lower cylinder, the upper cylinder & the top lid. Each of the sections are further divided into small sectors for the ease of manufacturing and transportation. The sectors are transported to ITER site in France for further assembly in workshop and pit.

The Cryostat model was developed in sub-sections similar to how the manufacturing was done in factory. The sections were individually imported in Ansys design modeler and combined to form the complete Cryostat model. Ansys mechanical was used to perform the FEA. An analysis was run to check the effect of introduction of rectangular slots (for welding & NDT access) on the Top-lid radial ribs resulting in stress concentration at slot corner due to applied load. ASME Sec VIII Div. 2 [2] was used of validation. The results show the effect of the change between the previous design & the modified design.

Qualitative Measurement of Radiation Symmetry during Disruptions in ADITYA-U Tokamak with a BPW-34 Photodiode and Development of a Metal Foil IR Bolometer

Ashok Kumar[1,2], Shwetang N. Pandya[1], Bharat Hegde[1,2], Ankit Kumar[1,2], Kaushlender Singh[1,2], Suman Dolui[1,2], Rohit Kumar[1], Harshita Raj[1], Suman Aich[1,2], Ananya Kundu[1,2], Laxmikant Pradhan[1], Ankit Patel[1], Kalpesh Gadoliya[1], Ankit Patel[1], K.M. Patel[1], K.A. Jadeja[1,3], R.L. Tanna[1,4], Joydeep Ghosh[1,2] and ADITYA-U Team[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382 428*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094*
[3]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360 005*
[4]*Institute of Science, Nirma University, Ahmedabad 382 481*

E-mail: ashok.kumawat@ipr.res.in

Abstract

Plasma disruption is a fierce event in tokamak plasma which is harmful for the Plasma Facing Components (PFC) as the plasma stored energy dump in a very short time-scale during disruption. A large amount of radiation is produced during plasma disruptions. In ITER like reactor, if this radiation is localized, it can melt the in-situ vessel components[1]. Therefore, plasma radiation symmetry study during disruption is an essential part of tokamak research to prevent the detrimental effects on PFCs and vacuum vessel wall. Plasma MHD activity and localized impurity injection could be the major causes of toroidal radiation asymmetry in tokamaks[2].

A qualitative measurement of toroidal radiation 90°, 180° and 270° quadrant of the tokamak plasma is measured during disruption in various shots by using photodiodes placed behind a pin hole at radial viewports on 3 different locations separated by 90°. These photodiodes have detection wavelength from 400 nm to 1100 nm. Radiation measurement observation indicates a high symmetricity in radiation in these three-quadrant regions during plasma disruptions.

A pin hole metal foil bolometer with an IR photo detector is being developed for quantitative and precise measurement of toroidal radiation asymmetry during disruption in ADITYA-U. This paper presents the design consideration for a single channel metal foil IR bolometer.

References:

1. N.S. Klimov, J. Linke, R.A. Pitts, A.M. Zhitlukhin, D.V. Kovalenko, V.L. Podkovyrov, V.A. Barsuk, C. Thomser, G. Pintsuk, B.N. Bazylev, R.N. Giniyatulin, V.P. Budaev, L.N. Khimchenko. Journal of Nuclear Materials 438 (2013) S241–S245.
2. N. Commaux, L. R. Baylor, T. C. Jernigan, et al. Phys. Plasmas **21**, 102510 (2014)

Indigenous development and testing of Post Insulators for TWIN Source experiments

Ravi Pandey[1,] Deepak Parmar[2], Hardik Shishangiya[2], Vishnudev M.N[2], Mainak Bandyopadhyay[2,], Jaydeep Joshi[2], Mahendrajit Singh[2] & Arun K Chakraborty[2]

[1]Institute for Plasma Research, Bhat, Gandhinagar, Gujarat- 382015
[2]ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, Gujarat- 382015

rpandey@ipr.res.in

Abstract

Post Insulators (PI) would be used to provide mechanical mounting and voltage isolation in between the grids for the next phase of Twin source experiments, where negative ion beams are to be extracted at voltage of 9-11 kV and would be further accelerated to a voltage of more than 35kV. Post Insulators are consist of ceramic (alumina) based cylinders and metallic flanges (especially designed to minimize the electrostatic filed stresses). TWIN source grids are designed on 1/4th scale of ITER DNB source. The benchmark design for TWIN Source post insulators has been taken similar to IN-TF (DNB) post insulators where design parameters had been validated with finite element based electro-mechanical analysis and their experimental validation [2].

Central part of post insulators are made of high purity (>99%) alumina, unglazed having 0% open porosity. Ceramic are manufactured by hot Iso Static process followed by green machining and furnace sintering. Final machining and grinding has achieved a tolerance of 50microns and surface roughness better than R_a 0.8. Alumina made cylinders are fitted with metallic flange which acts as electrostatic shield made of stainless steel. Post insulators are tested for voltage withstanding test in Air and Vacuum mode up to 90kV.

The paper would contain the details on manufacturing and testing procedures of these post insulators (ceramic cylinder with metallic flanges).

References:

[1] Design and analysis of TWIN source extraction system grids with indigenous manufacturing feasibility assessment, Ravi Pandey , Mainak Bandyopadhyay , M.J. Singh , Jaydeep Joshi , Arun K. Chakraborty, Fusion Engineering and Design (IF 1.905) Pub Date: 2020-06-01 , DOI:10.1016/j.fusengdes.2020.111552.

[2] Electro-Mechanical Design and Experimental Validation of Post Insulators for Beam Source for ITER Diagnostic Neutral Beam, V.N.Muvvala1, J.Joshi1, S.Shah1, D.Parmar1, C.Rotti1, M.Bandyopadhyay1, A.Chakraborty1, 26th IAEA Fusion Energy Conference - IAEA CN-234

MANUFACTURING DESIGN VALIDATION THROUGH MOCK-UP FOR TORUS CRYOPUMP HOUSING (TCPH)

Vaibhav Joshi[1], Rajnikant Prajapati[1], Anil Bhardwaj[1] , Mukesh Jindal[1], Amit Palaliya[1]
[1]*ITER-India, Institute for Plasma Research, Bhat-Matera Road, Ahmedabad, 380005*
vaibhav.joshi@iterindia.in

M. Khan[2], M. Girish[2], A. Manohar[2], Y. Rangrao[2]
[2]*Vacuum Techniques Pvt. Ltd, Peenya Industrial Estate, Bangluru. 560058*

Abstract

The ITER Torus Cryo-Pump Housing (TCPH) is a penetration located on the Cryostat cylinder with main functions to accommodate and support the Torus Cryo-Pump (TCP), connect it to the Vacuum Vessel and provide tritium confinement. The ITER Torus Cryo-Pump Housing (TCPH), thus forms a primary vacuum boundary, which is to be manufactured from SS304/304L material. TCPH consist of inner cylinder to support cryopump and tritium confinement whereas the outer rectangular box structure provides Re-generation volume for TCP. They are interconnected through vertical ribs for providing stiffness and transferring load of cryopump to the Cryostat.

As manufacturing design completed it is essential to validate it through the mock-up that represents the entire TCPH structure. The critical aspects of validation includes but not limited to are : 1) Selection of Mock-up 2)Validation for suitable Welding and NDE for production that ensures weld configuration with 100% volumetric inspectability 3) Assembly sequence to ensure required access suitable for manufacturing 4) Achievement of critical functional tolerances (For the flange & cylinder with consideration of interfacing components i.e cryopump flange and also ensure the critical dowel positioning that ensures correct installation etc. 5) Evaluation of manufacturing risks such as lamellar tearing risk for highly restrained 'T' joint , finalizing cleaning method and stage that allows access in assembly and final Assembly Helium Leak testing.

The present paper describes the complete experience of manufacturing mock-up that addressed most of the anticipated challenges along with possible remedial measures for manufacturing. Result of this validation have been successfully implemented with the proposed remedial actions for component manufacturing successfully while production assembly is in progress. Hence the present validation said to be satisfactory as it has ensured the full compliance with respect welding and NDE as per ASME Sec-VIII Div.2 along with supplementary requirement of ITER Vacuum handbook.

References:

[1] ASME Sec-VIII, Div.2
[2] ITER Vacuum Handbook

A Feasibility Study of Radio-Isotopes Breeding In a Compact Fusion Reactor

Shrichand Jakhar, Shailja Tiwari, Shashank Chaturvedi, Manika Sharma

Institute for Plasma Research, Bhat near Indira Bridge, Gandhinagar, Gujarat-380005

E-mail: scjakhar@ipr.res.in

Abstract

Radionuclides play an important role in medical and industrial applications such as radiotherapy, medical diagnosis, radio-tracing, radiography, food preservation etc. Their demand is increasing rapidly and supply is limited due to a limited number of production facilities, which are mostly cyclotrons or fission reactors. The generation of these isotopes using 14 MeV D-T fusion neutrons offers one major advantage – they can induce several threshold reactions which are not possible with fission neutrons. The main threshold reaction is (n, 2n) which has a high cross-section and also produces two low energy neutrons which can be further used for breeding. A study has been performed for a typical fusion reactor operating at 15 MW DT fusion power levels. Results of this study will be presented for the most extensively used radio-isotopes such as ^{99m}Tc, ^{131}I & ^{153}Sm with realistic irradiation scenario and sensitivity studies with respect to neutron moderator & multiplier materials, enrichment levels of the targets and concentration of the target isotopes in the irradiation material. The challenges involved in this method shall also be discussed.

DEVELOPMENT OF MILLI AMPERE CURRENT SENSOR FOR THE HIGH VOLTAGE DC POWER SUPPLIES.

Kumar Saurabh, Aritra Chakraborty, Amal S, Paul Christian and Ashok Mankani
Institute for Plasma Research, Gandhinagar-382428

saurabh@ipr.res.in

Abstract:

The Output DC Current of the High Voltage DC Power Supplies is an important parameter for the Control and Protection of HV system. This paper presents development of current sensor for the measurement of 100 mA output current of the 500kV DCPS. The current sensor is based on the commercial shunts. Shunts resistors are commonly used for the measurement of High Currents, for measuring the mA level current series combination of shunts are used. For the feedback and display purpose output signal is conditioned by separated signal conditioning circuits having outputs of 0- 10V and 4-20 mA signal level.

Static and Dynamic properties of the current sensors were characterized. The sensor has an accuracy of ± 1%, high linearity and excellent reproducibility and repeatability characteristics.
The current sensor is small in size, simple construction, low cost and good performance parameters makes it suitable for the monitoring and measuring od DC Currents of HVDC Power supplies.

References:
1. www.lem.com
2. www.ti.com
3. www.spellmanhv.com

Universal Drift Modes In A Magnetized Plasma - A Study Using Gyrokinetic Particle-In-Cell Methods

Sagar Choudhary[1,2], Jagannath Mahapatra[1,2], Amit K. Singh[1,2], Jugal Chowdhury[1], Rajaraman Ganesh[1,2], Laurent Villard[3]

[1]Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat, India
[2]Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India
[3]Swiss Plasma Center, EPFL, 1015 Lausanne, Switzerland

E-mail : sagar.choudhary@ipr.res.in

Abstract

Transport in a magnetised plasma is often driven by cross-field drift instabilities [1]. These instabilities are small in scale length (compared to particle gyro-radius) and low in frequency (compared to particle gyro-frequency). These instabilities draw free energy from inhomogeneities in the density and temperature of the plasma. One of the most virulent instabilities, in this regard, is driven by density gradients. These instabilities are present even in the absence of temperature gradients. They are called "universal" [2,3,4] as most laboratory conditions almost, always have some amount of spatial density variation.

In this study, we first investigate the stability of the universal drift mode (UDM) using a quasi-1D particle-in-cell (PIC), magnetised electrostatic code. In tandem, UDM is addressed as an eigenvalue problem using a local and a global gyrokinetic 2D code GLOGYSTO [5].

Once the parameter space is explored for UDM instability, a fully global, electrostatic, nonlinear, gyrokinetic PIC simulation is performed using ORB5 [6] code for a magnetised toroidal plasma to address transport due to UDM. Results from the nonlinear simulations are compared in the linear regime with the eigenvalue solutions, followed by further investigation of nonlinear properties.

Integrated Testing of Cooling Manifold System for Megawatt Class Gyrotron Test Facility

Amit Yadav#, Vipal Rathod, Deepak Mandge, Sharan E Dilip, Ronak Shah, Anjali Sharma, Rajvi Parmar & S. L. Rao

ITER-India, Institute for Plasma Research, Bhat, Gandhinagar-382 428, Gujarat, India

E-mail: #amit.yadav@iterindia.in

Abstract

ITER-India, the Indian domestic agency for ITER, has the responsibility to supply 2 high-power Gyrotron RF Sources (1MW, 170GHz, 3600sec) for the Electron Cyclotron Heating & Current Drive (ECH&CD) system on ITER [1]. The performance of integrated systems within these high power Gyrotron systems is one of its toughest aspects. Gyrotron Test Facility is being built by ITER-India (IIGTF) to assist the integrated system testing of megawatt class Gyrotron RF sources. Due to the high power and long pulse of these Gyrotron RF sources, there will be large thermal heat loads across several Gyrotron system components that need to be removed through active cooling. This test facility's water cooling distribution system is built to deliver and maintain the necessary flow rates, temperatures, pressures, and water quality in accordance with the specifications of the Gyrotron RF sources as well as for various Gyrotron manufacturers.

Recently, the work of integrating the cooling manifold system with the Gyrotron RF source assembly was completed. Data from flow metres (FM), pressure indicator cum transmitters (PIT), and resistance temperature detectors (RTD) were acquired during the site acceptance testing (SAT) activity to evaluate conformity with the specifications of individual components as advised by the supplier. Following initial test runs, non-compliant cooling channels have been found, and corrective measures have been implemented. These measures involve changing the setting for flow control valves, introducing extra pressure reducing valves and replacing conventional turbine type flow-meters with vortex type flow-meters. Gyrotron assemblies are cooled using 2100 LPM of water at an inlet pressure of 5 Bar through 25 cooling circuits in order to remove 2 to 2.5 MW of thermal load from the system, taking into account some percentage of surplus flow in the cooling channels. This paper presents system overview, requirements, and cooling manifold system recent updates.

References:

[1] S.L.Rao et al., "Electron Cyclotron Power Source System for ITER", Fusion Science & Technology, 65, p 129-144, (2014).

FATIGUE ANALYSIS FOR ITER CRYOSTAT MAN WAY ACCESS DUCT SYSTEM

Saroj Kumar Jha[1], Manish Kumar Pandey[1], Vipul More[1], Rajnikant Prajapati[1], Gaurav Jogi[1], Avik Bhattacharya[1], Girish Gupta[1], Anil Bhardwaj[1], Umesh Tilwani[2], Nirbhay Naik[2], Chirag Patel[2]

1. ITER-India, IPR, Ahmedabad, Gujarat-380005, India
2. Larsen & Toubro Limited, Hazira, Gujarat - 394 510, India

E-mail: saroj.jha@iterindia.in

Abstract

Cryostat is a large stainless steel vacuum vessel providing vacuum environment to ITER Machine components. The cryostat is ~29 meters in diameter and ~29 meters in height having thickness varies from 25 mm to 180 mm. Cryostat also has the interfaces with the many other ITER Machine components. To accommodate these interfaces there are many penetrations presents in the cryostat wall. One of them is Base Section Man way access penetration.

Initially base section Man way access penetration duct was planned to be welded with full penetration welding without backing strip. Due to space constrained, purging from backside was not possible. Hence weld design is modified to full penetration weld with backing strip. This design has been assessed for fatigue strength in accordance with ASME section VIII div-2 [1]. To assess the fatigue strength design by analysis approach has been adapted.

Fatigue failure mode have been assessed for individual and combination of loads by FE analysis. 20° sector of Base section has been modelled in ANSYS tool that has been used in FE analysis. Cumulative fatigue damage has been calculated in line with calculation rule mentioned in ASME section VIII div-2 [1] and found acceptable. Hence, the design of WEP for welding of duct with backing strip has been successfully changed and new design has been implemented in manufacturing.

References:

[1] ASME, "Rules for the Construction of Pressure Vessels," ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Alternative Rules, (2010).

TRANSPORTATION ANALYSIS OF ITER CRYOSTAT TOP LID

Name(s) of the author: Saroj Kumar Jha[1], Manish Kumar Pandey[1], Vipul More[1], Rajnikant Prajapati[1], Gaurav Jogi[1], Avik Bhattacharya[1], Girish Gupta[1], Anil Bhardwaj[1], Umesh Tilwani[2], Nirbhay Naik[2], Chirag Patel[2]

Affiliation: 1. ITER-India, IPR, Ahmedabad, Gujarat-380005, India
2. Larsen & Toubro Limited, Hazira, Gujarat - 394 510, India

E-mail : saroj.jha@iterindia.in

Abstract

ITER Cryostat is a large Vacuum vessel (~29m diameter, ~30 m height and ~3850-ton weight), which is made up of Austenitic stainless steel material. As per the assembly requirement it is fabricated in 4 major sections named as Base section, Lower Cylinder, Upper Cylinder, Top Lid. Major sections are Fabricated at ITER Site workshop and then transported to PIT for Final Assembly. Transportation of Major section to PIT is done by set of multi axle Self-propelled modular trailer (SPMT). Present work deal with the transportation analysis of ITER Cryostat Top Lid weighing approx. 650 Ton. Objective of Transportation analysis of Cryostat Top Lid Section is to assess the Structural Integrity of Top Lid Transportation Frame during Transportation by SPMTs. Top Lid is to be transported on Transportation Frame (31m X 31m) from Site workshop to Assembly area by SPMT.

To simulate the transportation scenario, SPMTs are configured in 3 hydraulic zones based on the concept of 3-point support system with rigid beam network. Each axle in the same hydraulic zone has the same axle load. Finite element analysis has been performed with help of ANSYS software to check the structural integrity of the Top Lid Transportation Frame. Load Calculation for design has been done and validated in compliance with Euro Code [1].

References:

[1] Eurocode EN1993-1-1

Arc Fault Detection and Repairing for the Insulation Breakdown of TF Coil No. 8 in ADITYA-U tokamak

Laxmikanta Pradhan[1], Ankit Patel[1], Suman Aich[1], Rohit Kumar[1], T. Macwan[1,2], K. Singh[1,2], S. Dolui[1,2], A. Kumar[1,2], A. Kanik[3], Kajal Shah[4], N. Yadava[5], S. Patel[4], B. Hegde[1,2], Ashok K. Kumawatr[1,2], K.A. Jadeja[1,6], K.M. Patel[1], K. Galodiya[1], Shwetang Pandya[1], R.L. Tanna[1,5] and J. Ghosh[1,2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382 428*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094*
[3]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360 005*
[4]*Department of Physics, Pandit Deendayal Energy University, Raisan, Gandhinagar*
[5]*Institute of Science, Nirma University, Ahmedabad 382 481*
[6]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot*

E-mail: Laxmikanta.pradhan@ipr.res.in

Abstract

The ADITYA-U tokamak (R_0 = 75 cm, a = 25 cm) is being regularly operated with toroidal magnetic field ranges from 1 T to maximum up to 1.5 T [1]. The high current (typically 33-47.5 kA) in pulsed mode through Toroidal Field (TF) coils in ADITYA-U tokamak causes severe stress, both mechanically and electrically in the coil insulating material. This sometimes leads to insulation breakdown in the TF coils (total 20 in number) resulting in a fault current through the structure of the machine. Because of the complicated surrounding structure and inaccessibility of most parts of the coils, it is very difficult and time consuming to find the exact fault location by mere visual inspection. During October-2021, arc-fault detected in TF coil No. 8 during plasma discharges operation of ADITYA-U observed through CCTV Dome camera. Existence of ground fault current and deflection in TF current pulse monitoring through current transformer at power supply end also noticed. Lot of carbon deposited nearby surrounded area of top I-beam of TF coil No.8 and at the exact location of the arc, a ~5 mm deep hole occurred in top I-beam No. 8 due to electrical breakdown. Two new methods are being developed employing simple electrical circuits to find the TF coil in which breakdown has taken place. These two methods, one employing AC current and the other employing DC current and the repairing work carried out after finding the fault location in TF coil No.8 will be discussed in detail in this paper.

References:

[1] Tanna R. L. et al., *Nucl. Fusion.* **62**, 042017 (2022).

Role of MHD activity in Sawtooth Induced Heat Pulse Propagation in ADITYA

S. Patel[1], J. Ghosh[2,3], M. B. Chowdhuri[2] , K. B. K. Mayya[1] , R. Manchanda[2] , H. K. Pandya[2] , R. L. Tanna[2] , V. Kumar[2] , S. Joisa[2] , S. Purohit[2] , D. Raju[2] , S. Jha[2] , P. K. Atrey[2] , C. V. S. Rao[2] , P. Vasu[2] , D. Chenna Reddy[2] , S. B. Bhatt[2] , Y. C. Saxena[2] and ADITYA Team2

[1]Pandit Deendayal Energy University, Raisan, Gandhinagar, 382 007, India
[2] Institute for Plasma Research, Bhat, Gandhinagar, 382 428, India
[3]Homi Bhabha National Institute (HBNI), Anushaktinagar, Mumbai 400 094, India

Email: sharvil.pphd19@sot.pdpu.ac.in

Abstract

To optimize and quantify the operating scenario of fusion devices for achieving well confined burning plasma, better understanding of the electron heat transport is required. Over the years, it has been established that steady-state electron heat transport is primarily driven by turbulent modes like trapped electron mode (TEM), electron temperature gradient (ETG) and ion temperature gradient (ITG) [1]. Besides steady-state heat transport, there is class of transient heat transport events like cold pulse propagation and sawtooth crash induced heat pulse propagation, which still require further research. It is observed that, the sawtooth crash induced electron heat pulse propagates with large electron heat diffusivity as compared to power balance estimate. This phenomena of fast propagation of sawtooth induced electron heat pulse has been studied for over two decades in various fusion devices [2-5], but a satisfactory explanation of this disparity is still not available. In ADITYA tokamak, we report, observed discrepancy between enhanced electron heat diffusivity $\chi e\ hp$ due sawtooth crash and power balance diffusivity $\chi e\ pb$ is reduced by considering electron heat transport in stochastic magnetic field. The sawtooth crash function as a source of heat perturbation and deposits heat beyond the inversion radius, which transports to the edge region of the plasma. This is reflected as inverted sawtooth modulation in the edge channels of electron cyclotron emission (ECE) and $H\alpha$ spectral line emission. The time-lag analysis on ECE signals reveal the propagation time from plasma core to edge of ~ 150 μs and the transport is diffusive in nature. From this analysis, the estimated transient electron heat diffusivity $\chi e\ hp$ is found to be ~ 50 – 60 m2 /s, which is around ten times that of power balance heat diffusivity $\chi e\ pb$. It is observed that, the presence of MHD activity significantly influences the electron heat transport from plasma core to edge region [6]. We find, formation of stochastic magnetic field region due to overlapping of m/n = 2/1 and 3/1 MHD islands helps the fast heat-pulse propagation during sawtooth crash in ADITYA tokamak.

References:

[1] Electron heat transport in ASDEX Upgrade: experiment and modelling, Nucl. Fusion, 43, p 1396, (2003)

[2] Experimental measurement of electron heat diffusivity in a tokamak, Phys. Rev. Lett., 38, p 491, (1976)
[3] Heat pulse propagation studies in TFTR, Nucl. Fusion, 26, p 849, (1986)
[4] Ballistic contribution to heat-pulse propagation in the TFTR Tokamak, Phys. Rev. Lett., 65, p2869, (1990)
[5] Heat pulse propagation studies on DIII-D and the Tokamak Fusion Test Reactor, Phys. Plasmas, 7, p 5051, (2000)
[6] Bifurcation physics of magnetic islands and stochasticity explored by heat pulse propagation studies in toroidal plasmas, Nucl. Fusion, 56, p 092001, (2016)

Design, development and commissioning of the tangential X-ray Crystal Spectrometer (XCS) on ADITYA-U Tokamak

K. Shah[1*], J. Ghosh[2,3], M. B. Chowdhuri[2], A. Kumar[3], S. Tripathi[2], K. A. Jadeja[2,4], K. M. Patel[2], R. Manchanda[2], N. Ramaiya[2], R. L. Tanna[2,5], R. Kumar[2], S. Aich[2], H. Raj[2], K. Singh[3], S. Dolui[3], L. Pradhan[2], A. Patel[2], B. Hegde[3], A. Kumawat[3], K. B. K. Mayya[1].

[1]*Department of Physics, Pandit Deendayal Energy University, Raisan, Gandhinagar 382 00*
[2]*Institute for Plasma Research, Bhat, Gandhinagar 382 428*
[3]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094*
[4]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360 005*
[5]*Institute of Science, Nirma University, Ahmedabad 382 481*

E-mail: kajal.sphd16@sot.pdpu.ac.in

Abstract

The X-ray crystal spectrometer is envisaged to be one of the crucial diagnostics for future generation tokamaks for impurity species identification, concentration and influx study, plasma rotation, ion temperature measurements etc. In that context, a new tangential X-ray Crystal Spectrometer (XCS) had been envisaged during commissioning of the ADITYA-U tokamak [1] to provide experimental measurements of plasma rotation, ion temperature, electron temperature and to study impurity transport. The XCS system has been designed [2], developed and commissioned on ADITYA-U tokamak. The spectrometer comprises of a cylindrically bent Silicon (111) crystal and a CCD detector to provide measurement of the resonance and satellite line emissions from He-like argon, Ar^{16+} in the wavelength region of 3.94 – 4.0 Å from the core of the plasma. The spectrometer views the plasma tangentially at an angle of 26° with respect to the toroidal direction in the magnetic axis. Based on the ADITYA-U plasma parameters and its geometrical constraints, plasma to crystal and crystal to detector distances have been kept at 1.47 m and 0.57 m respectively, to detect sufficient signal. The engineering design of the spectrometer has been optimized after addressing various issues due to port geometry and machine accessibility, adjacent diagnostics etc. The diagnostic is now commissioned on ADITYA-U to obtain the desired argon line emission from the plasma by injecting a small amount of argon puff during the plasma current flat-top region. The Ar^{16+} spectral data obtained through XCS will be used for the measurement of toroidal rotation velocity, ion and electron temperatures. In this paper, complete design of the ADITYA-U XCS system from conceptual design to fabrication of the components, testing and installation of the diagnostic together with the preliminary test results will be presented.

References:

[1] Tanna R. L. et al., *Nucl. Fusion.* **62**, 042017 (2022).
[2] Shah K. et al., *Rev. Sci. Instrum*. **89**, 10F115 (2018).

DESIGN OF ITER CRYOSTAT BASE SECTION AND LOWER CYLINDER ALIGNMENT TOOLS IN TOKAMAK PIT AND ITS DEMOSTRATION

Vipul More[1], Girish Gupta[1], Manish Kumar Pandey[1], Saroj Kumar Jha[1], Rajnikant Prajapati[1], Anil Kumar Bhardwaj, Umesh Tilwani[2], Dipen Shah[2], Chirag Patel[2]

[1] ITER-India, Institute for Plasma Research, Bhat, Gandhinagar-382428
[2] L&T Heavy Engineering Hazira, Surat Gujarat-394270

E-mail: vipulm@iterindia.in

Abstract

ITER cryostat is the largest stainless steel high-vacuum chamber, provides the high vacuum for the ITER vacuum vessel and the superconducting magnets. The ITER cryostat is nearly ~29 meters wide and ~29 in height, manufactured from stainless steel. Total weight of cryostat is ~ 3,850 tonnes. Cryostat consists of four main cryostat sections base section, lower cylinder, upper cylinder and top lid. Cryostat is manufactured and assembled in three stages at Indian factory, Workshop at Cadarache ITER France and in Tokamak Pit ITER France) The Base Section and Lower Cylinder of the ITER Cryostat weighs ~1,250 tonnes and ~375 tonnes respectively. Base section is the single largest load of ITER and aligned inside the Tokamak Pit. This involves fine adjustment of Base Section with respect to the Pit center within 2mm using Alignment tools. During the lowering of Base section with Crane in the Tokamak Pit, base section need to be align radially as well as toroidally. Similarly lower cylinder need to be installed on base section and align radially as well as toroidally with base section within the tolerances. Alignment has been achieved with combination of Jack movements. Design of Base Section and Lower Cylinder alignment tools are finalized based on the loads and tolerances. After finalization of alignment tool design, it is required to demonstrate the functionality of alignment tools before installation in Tokamak pit. A concept was developed for which scaled down load/dummy component is designed to demonstrate the functioning of hydraulic jacks. Concept was successfully demonstrated and implemented on scaled down assembly in Factory at India. Base Section and Lower Cylinder are successfully installed in Tokamak Pit with the application of these Alignment tools.

Dimensional Non-Conformity and Correction in ITER Cryostat Base Section Sectors

Amit Palaliya[1], Anil Kumar Bhardwaj[1], Rajnikant Prajapati[1], Vaibhav Joshi[1], Mitul Patel[1], Mukesh Jindal[1], Chirag Patel[2], S Sivakumar[2]

ITER-India[1], Institute for Plasma Research, Gandhinagar, 380005, Larsen & Toubro Ltd[2], Hazira HED Surat 394510

E-mail: amit.palaliya@iter-india.in

Abstract

Cryostat is a large stainless-steel vessel providing vacuum environment to ITER Machine components. The cryostat is ~29 meters in diameter and height having thickness varies from 40 mm to 180 mm.as required. Base section is the biggest section of cryostat and having most thickness variation and design configuration changes. ITER Cryostat is manufactured as per ASME Section VIII Div.2 [1], which tolerance need to be followed throughout manufacturing.

Base Section has been made of 12 sectors and all welded together to form whole Base section of 1205 ton. The offset dimension of three site weld joints are observed beyond acceptable limit during trial assembly at factory. Major non-conformity report issued according established procedure [2] and specific repair procedure has been prepared [3]. In order to maintain the flatness of large size components during their butt welding, Pre-cambering of adjoining components parts have been used to allow distortion forces works upwards movement of the free edge. This inherent welding phenomenon used to correct the offset and after performing rectification all site joints corrected to acceptable tolerance level. All Base section site weld joints successfully completed without any dimension anomaly.

References :

[1] ASME Section VIII Division 2, Rules for construction of the pressure vessels (2010 edition), Para 6.1.6
[2] L&T/NCR/10_NCR_on_ BS_T2_ Horizontal_ plates_ offset_ for_ site_ weld_ joint (IDM id: SFQV3Q).
[3] Repair Procedure for Base Section Tier-2 Sector 7 & 8 (ITER-CR-LTTS-164)
[4] NU_22137A_20_BS_101 - CR_BS_GENERAL-ASSEMBLY (IDM id: EHX6KW)

Experience in Developing LN2 Cooled Sorption Cryopump, Application and Technology Transfer

S. S. Mukherjee, V. Gupta, J. S. Mishra, R. Gangradey, P. Panchal, P. Nayak, H. Agravat

Institute for Plasma Research, Near Indira Bridge, Bhat, Gandhinagar 382428

E-mail : samiran@ipr.res.in

Abstract

Cryocoolers and liquid helium cooled sorption cryopumps are widely used for the generation of high and ultra-high vacuum in large size experimental systems. Application areas of the sorption cryopumps using only liquid nitrogen is not explored much. Aiming to that, various types of liquid nitrogen cooled cryopumps are designed, developed based on the need of the application. The pumping performance tests of the cryopump were carried out as per the AVS recommended method. The concept of the cryopumps are modular for the ease of assembly, integration and manufacturing suitability. In the recent years, 250 mm, 400mm and 500mm opening cryopumps were developed for the application in High Heat Flux Test Facility at IPR [1], Cryovac chambers in SAC, ISRO and SST-1 tokamak [2] and they are mounted in vertically downward, upward and horizontal configuration. As an example, the 400 mm opening cryopump system offers pumping speed of ~ 4000 l/s for nitrogen gas and >15000 l/s for water vapor using liquid nitrogen only. Details of the design methodology, manufacturing process, assembly and integration and associated challenges will be presented.

References:

[1] S.S. Mukherjee et al., "Design and development of LN2 cooled cryopump for application in high heat flux test facility", Fusion Engineering and Design, 184 (2022), 113315.

[2] V. Gupta et al. "Design and Analysis of liquid nitrogen cooled sorption cryopump for SST-1 Tokamak, Fusion Engineering and Design 159 (2020) 111757.

Upgradation Of Instrumentation & Control System For Lead-Lithium MHD Experimental System

S. Verma, A. Deoghar, A. Patel, A. Saraswat, S. Gupta, T.S. Rao, R. Bhattacharyay

Institute for Plasma Research, Bhat, Gandhinagar-382428, India

E-mail: sverma@ipr.res.in

Abstract

A liquid Lead Lithium (Pb-Li) Magneto Hydro Dynamic (MHD) experimental system has been developed at IPR to carry out MHD and heat transfer experiments associated with molten Pb-Li flow in presence of transverse magnetic field [1]. Experiments are being planned and conducted to study (i) MHD effects of strong magnetic fields (upto 1.4T) on the flow and heat transfer characteristics of molten Pb-Li in various test sections resembling geometrical elements present in Lead Lithium Ceramic Breeder (LLCB) Blanket; and (ii) Extraction of heat from molten Pb-Li using Thermic Fluid (TF). The experimental system consists of a Pb-Li loop, a thermic fluid loop, and a water cooling loop having process fluids of molten Pb-Li, Therminol-55 and DM water respectively.

An instrumentation and control system based on Eurotherm T2550 PAC was developed earlier for control and data acquisition of LLMHD experimental system [2]. However, many significant upgrades were incorporated in the system later on; based on process optimization, design and safety review, and operational experience. The existing instrumentation and control system was, therefore, modified and upgraded to incorporate process optimization, equipment protection interlocks, safety interlocks, and improved HMI (Human Machine Interface) for safe and convenient remote operation. The upgraded Instrumentation & Control System has been successfully utilized during different phases of experimental campaigns of LLMHD Experimental system. This paper presents design and features of Instrumentation & Control System like P&ID, sensors, controllers, PID loops, interlocks and HMI.

References :

[1] Engineering Design and Development of Lead Lithium Loop for Thermo-fluid MHD studies, Fusion Engineering and Design 138 (2019) 1-5

[2] Design & Development of Instrumentation & Control System for Lead-Lithium MHD Experimental Loop, IPR/TR-551/2019

ANALYSIS OF THE NEUTRON YIELD FROM THE PF400 DEVICE BY VARYING DIFFERENT PRESSURE

Bidhwan Belbase[1], Roshan Chalise[2]

[1]Patan Multiple Campus, Tribhuvan university, Patandhoka, Lalitpur, Nepal, 44707, [2]Central Department of physics, Tribhuvan University, Kathmandu Nepal

Email: bidhwan.755511@pmc.edu.np / bidhwankhimananda@gmail.com

Abstract

The average total neutron yield is measured using the lee code simulation of PF400 plasma focus device with deuterium gas at various combinations of filling gas pressures. The dynamical nature of the plasma focus is obtained merely from the analysis of the voltage and current electrical signals without considering any geometry for the plasma sheath. It is calculated that large neutron yields are obtained when plasma inductance, mechanical energy and plasma voltage at pinching time have larger values. The average total neutron yield is measured, using plasma focus device, at various combinations of filling gas pressures of deuterium to optimize the neutron yield from the PF400 plasma focus device. A remarkable result from this device is obtained for the neutron yield. The neutron yield, $0.000132336 \times 10^{10}$ is achieved at 4.6Torr pressure with deuterium filling gas. The nature of plasma temperature and tube voltage declines as pressure rises.

MAJOR UPGRADATION PLAN OF ICRH SYSTEM ON SST-1

Kishore Mishra[1], Sunil Kumar, D. Rathi, A. Varia, B. Kadia, K. M. Parmar, M. Parihar, H. M. Jadav, R. Joshi, A. K. Gayatri, R. Yadav and ICRH Team

[1]*Institue for Plasma Research, Bhat, Gandhinagar-382428, Gujarat, India*

E-mail: kmishra@ipr.res.in

Abstract

Ion Cyclotron Resonance Heating (ICRH) system [1] on SST1 tokamak designed for conducting experiments with 20-45.6 MHz, 1.5MW source. There is more than 150 meters of coaxial copper transmission lines with provision of actively cooled inner conductor, coarse matching and fast matching (automatic Matching Network (MN), abbreviated as AMN) systems, water cooled Vacuum Transmission Line (VTL) system and water cooled two strap antenna system. The system was designed a couple of decades earlier with consideration of steady-state operation for 1000s, which invited a more careful and optimistic approach to accommodate all the unforeseen challenges. Nevertheless, during the recent series of testing and experiments on SST1 machine, need of several subtle experimental upgrades were necessitated. An issue based approach is adopted to address the challenges and move towards their effective mitigation. Several up-gradations have been taken up recently, namely; (1) A variable RF source (CEC-USA made, earlier installed at Iter-India) is being commissioned by a joint team[#] near SST1 machine. This shall be used to conduct resonance based experiments for the entire range of operating magnetic fields. (2) Replacement of copper transmission lines with made in India light-weight aluminum coaxial lines and bringing much needed accessibility to carry out investigation and maintenance of them. (3) Optimization of MN by two pronged strategy i.e. reducing vulnerable high RF voltage line length and reducing the peak (Voltage Standing Wave Ratio) VSWR present in line during plasma. (4) The optimization of MN warranted a reduction and simplification of the VTL, hence a new VTL named Direct Injection Antenna Feeder (DIAF) without requirement of separate vacuum system and a reduction of 66% in size is being developed. (5) A new Center Fed Antenna (CFA) [2] for plasma heating and plasma production is also being developed. It is important to mention that these up-gradations are being carried out on one of the chain out of the existing two units to keep a flexibility in conducting experiments [3]. A detailed account of need of individual up-gradation, approach being taken towards each of them, and desirable outcomes shall be presented in detail.

[#] *A team comprising of members of HPICRH division IPR and ICRH group of Iter-India.*

3D Computational Fluid Dynamics Simulation of Heat Transfer for PINI Ion Source Back Plate

Tejendra Patel, M. R. Jana and U. K. Baruah

Institute for Plasma Research
Bhat, Gandhinagar 382428, Gujarat, India

E-mail: tejendra.patel@ipr.res.in

Abstract

Neutral Beam Injection (NBI) is very efficient in heating and current drive of Tokamak fusion plasma. SST-1 has a Positive ion based NBI (PNBI) system capable of delivering 1.7 MW neutral hydrogen beam power at 55 keV. JET PINI (Positive Ion Neutral Injector) type ion source is used in PNBI systems. Back Plate (BP) is an important component of PINI ion source and consists of SS304L magnet positioning plate, SS304L magnet cover plate and OFE copper cooling plate respectively. During beam operation BP received 2.5 MW/m^2 heat load. To remove such heat load dense networks of water cooling channels are provided. BP is successfully fabricated in India and its performance test is also done at HHFTF center, IPR [1]. The present paper described three-dimensional Computational Fluid Dynamics (CFD) simulation of Back Plate using the numerical model with the help of ANSYS computer program. The 3D model is created in ANSYS workbench and meshed using advanced fluent meshing. The hybrid (hexahedral and tetrahedral) type of mesh has been used due to the non-uniform shape of the model. 60 LPM water at 34^0C is supplied to the inlet manifold of BP. The above mentioned heat load is intercepted on the surface of the OFE copper cooling plate. The realizable k-$\mathcal{E}$ turbulence model has used in simulation as the flow of water is turbulent. The Semi-Implicit Method for Pressure-velocity Linked Equation (SIMPLE) algorithm is used to solve the governing equation and boundary condition. The flow momentum and energy equations have been discretized by using second-order upwind methods. It has been observed that average water velocity in the cooling channel area is 9 m/s. The inlet pressure and outlet water temperature are found to be 8.4 bar and 46°C respectively. The numerical result shows that the surface temperature of OFE copper cooling plate is ~ 176°C and consistent with the experimental result.

Keywords: - Back Plate, Heat Transfer, Temperature, Computational Fluid Dynamics

Reference:-

[1] M.R. Jana, S.M. Belsare, K.S. Bhope, B. Choksi, N.S. Contractor, S.S. Khirwadkar, P.K. Mokaria, N.P. Patel, T.H. Patel, R. Swamy, S. Tripathi, Performance of High Heat Flux Test of Positive Ion Neutral Injector Ion Source Back Plate, in: 28th IAEA Fusion Energy Conf., 2020: p. 1.

Conditional Assessment & Residual Life Enhancement of 2 Nos., 132kV / 11kV, 15 MVA rated Power Transformers installed at 132kV IPR Substation

Prakash Parmar, Chandra Kishor Gupta, Supriya Nair, Chirag Bhavsar

Institute for Plasma Research, Near Indira Bridge, Bhat, Gandhinagar

E-mail: pkparmar@ipr.res.in

Abstract

IPR has 132 KV, 3ph, 50Hz line coming from 220 kV substation at Ranasan through the single circuit overhead line. Maximum contract demand of IPR is 6 MVA. The Substation at IPR covers various equipment such as Power Transformers, Circuit Breakers, Isolators, Earth Switches, Lightning Arresters, Current Transformer, Potential Transformer, Control and Relay panel and Grounding System rated for 145 kV. There are five Power Transformers of different rating installed in substation which convert 132 KV voltage into 11 kV and 22 kV voltage. This is feed to corresponding 11 kV Bus (S1-S6) and 22 kV (S11-S14). The distribution system at IPR involves various voltage levels. All high power electrical loads are supplied from a 132 kV switchyard through 5 power transformer feeders with associated 11 kV and 22 kV systems. Further distribution in LT (415 V) supplies to various low power loads.

After the installation and commissioning in the year 2000, the TR#3 and TR#4 power transformers of rating 132kV/11kV, 15 MVA are in continuous service to cater to the continuous loads SST#1 auxiliary systems as well as that of IPR campus.

This paper presents the Residual Life Enhancement procedures, testing and up gradation done on both the power transformers. Transformer maintenance at regular intervals is very important which includes conditional assessment of the transformer. Conditional assessment tests on transformer gives the up gradation or modifications required for the Residual Life Enhancement of a large capacity power transformer. The Conditional Assessment tests and Residual Life Enhancement procedure is very complex which will be explained in easy steps in this paper.

References :

[1] Power Transformers Principles and Applications – John J. Winders, Jr
[2] NFPA70B – 2006, Recommended Practice for Electrical Equipment Maintenance.
[3] IEEE 902-1998 – Guide for Maintenance, Operation and Safety of Industrial and commercial Power System

Engineering Design of Toroidal Field (TF) Coil for Small Scale Spherical Tokamak (SSST)

S. Ranjithkumar*, Vilas Chaudhuri, Chandan Danani, Arvind Kumar, Y.S.S. Srinivas, E.Rajendra Kumar

Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat, India

E-mail: ranjith@ipr.res.in

Abstract

IPR is developing a Small Scale Spherical Tokamak (SSST) to realize a low aspect ratio ($R0/a < 2$) device for plasma experiments. The most challenging part of a Spherical Tokamak is to develop a compact center stack assembly consists of two coils – the Toroidal Field (TF) coil, which is required to achieve the required toroidal field of 0.1T at the plasma major radius (R0) at 0.28m, and the Central Solenoid (CS) coil required for producing a plasma discharge using inductively induced voltage. Apart from the TF and CS coils, the ST has Poloidal Field coils for attaining plasma equilibrium and correction coils to establish magnetic null along the plasma region.

Various configuration of the TF coil has been studied during the design phase considering the material of the coil, current density in the coils, profile of the coil, number of turns and number of coils. The design of the TF coil also takes into account the limiting of the spatial ripple to <1% at the plasma edge. The coil fabrication techniques was also considered during the study, and the TF coil is to be assembled in two parts – the inner leg and the outer leg. The assembly sequence of the machine also drives the configuration of the coil, as the vacuum vessel and most of the coils in ST have to be accommodated with the two coil legs.

Engineering analyses has also been carried out, namely electromagnetic, thermal and structural analysis, in order to validate the integrity of the TF coils. The insulation material and thickness for inter turns and outer layer are estimated as per the voltage drop in the coils. The appropriate support structure is also designed for the TF coils considering the forces acting during operation.

This poster mainly discusses the design and analysis aspects of the TF coil considering the input power transient waveform. It also discusses the convergence to the final design configuration from the earlier design variants and also the design and fabrication challenges encountered in the process.

Calorimetric Pulsed Power Measurement System for High Power Microwave Source

Hardik Mistry, Harshida Patel, Jatin Patel, Dharmesh Purohit, K G Parmar, B K Shukla

Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat, India

E-mail: hardik.mistry@ipr.res.in

Abstract

ECRH is one of the main heating systems of the tokomak. A Gyrotron is used to generate a high power microwave beam. The microwave power generated in Gyrotron travels through different transmission line components like waveguides, mitre bends, polariser etc. and it is launched into the plasma through ECRH launcher. The power measurement of microwave beam is important for carrying out controlled plasma experiments. The pulsed RF power can be measured by calorimetric principle. For calorimetric measurement, the microwave power is launched into a dummy load which has circulating water flow. The power is absorbed by the water and the temperature of the water rises. The total energy of the pulse can be estimated by measuring the time integrated temperature difference of the inlet and the outlet.

A calorimetric measurement system has been developed to measure the pulse RF power. Since the pulse length of the power is short (~200-500 ms), only a small amount of thermal energy is transferred to flowing water. This results in a minute temperature rise at the outlet. CFD analysis was carried out to predict the temperature rise of the water for different power levels and pulse lengths. Three different sensors were selected for the measurement of the water temperatures and their performance was measured for different known energy values at different flow rates. The poster describes the calorimetric pulsed power measurement principle, the construction of the measurement system and experimental results.

MODIFICATION OF A MULTI-PULSE HALF-WAFE RECTFIER TO FULL WAVE RECTIFIER WITH ADAPTED CONTROL

Amit Ojha, Akhilesh Kumar Singh, Dinesh Kumar Sharma, Murtuza Vora, Supriya A Nair

Institute for Plasma Research, Bhat, Gandhinagar,382428

aojha@ipr.res.in

Abstract

FRBPS (Fast Response Bipolar power supply) is being developed in IPR. FRBPS is converter-inverter type system with rating of +/-5kA, 500VDC and 1 MA/s ramp rate. To keep the cost of development low the converter section of FRBPS is being assembled from un-utilized components and spares of Poloidal Field Power Supply (PFPS) systems. PFPSs are multi-phase, low-voltage, high current systems with half-wave rectifier topology requiring 04 controller and auxiliaries for 12 pulse scheme.
This work describes the modification and customization of PFPS for application in FRBPS, which includes changes in rectifier topology, their associated controls, feedback circuits and converter transformer. The modified converter has V_{do} of 580VDC. Results of open circuit test and resistive load test with both current and voltage feedback control is presented.

Key word: Power supply, multi-phase rectifiers, SCR, converter transformer.

References:

[1] Large Current Rectifiers: State of the Art and Future Trends. Industrial Electronics, IEEE Transactions on. 52. 738 - 746. 10.1109/TIE.2005.843949.
[2] Power Electronics, P.C. Sen, Tata McGraw-Hill, 1988
[3] Rectifiers, Roberto Visintini, CERN document.

DESIGN OF PHASE-I CONTROL SYSTEM OF LARGE CRYOGENICS PLANT AND CRYO-SYSTEMS

V.B. Patel[a], A.L. Sharma[a], H.H. Chudasma[a], H. Masand[a], I.A Mansuri[a], J.J. Patel[a], K.B. Patel[a], M.K. Bhandarkar[a], P. Gaddam[a], T.S. Rao[a], A.K.Sahu[a], H.J. Dave[a], O. Chandratre[a], P. Singh[a], K. Mahajan[a] and LCPC Team.

Affiliation: [a] Institute for plasma research, Bhat, Gandhinagar, 382428

E-mail:- vishnu@ipr.res.in

Abstract

IPR has accomplished successful commissioning of indigenously designed Cryogenics plant test facility with 200W cooling capacity at 4.5 K. The test facility will be used for development and analysis of different cryogenics process algorithm which involves cryogenics components, different types of plate-fin heat exchangers. Such cryogenic test facility needs measurement of large number of sensors (temperature, pressure, level etc…) for diagnostic and controls of valves to operate in the controlled environment.
During commissioning phase the in-house design and development of monitoring and control system of this facility is demonstrated successfully. The Main control system logic is implemented in PLC connected with pressure and temperature sensors which are required for control operation of liquefier while for other diagnostics measurements Modbus and HART devices are used. The Control system of Compressor station has been developed as first module of Large Cryogenics Plant system with closed loop control system after analysis of the compressor operation. Coldbox and Turbine control algorithms are developed with manual operation which will be automated in coming operations. The control system is designed considering modular approach for ease of scalability and cost optimization.
Open source EPICS[1] and CS-Studio[2] tools are selected for SCADA development. This paper will describe commission phase design and architecture of the control system.

References:

[1]. https://epics.anl.gov
[2]. https://controlsystemstudio.org

Design and Development of LabVIEW based acquisition, control and measurement system for General Laboratory Plasma.

Abhijeet Kumar, Hitesh Mandaliya, Rosh Roy, Rachana Rajpal, Dr. P. K. Chattopadhyay

Institute For Plasma Research, Near Indira Bridge, Bhat, Gandhinagar, Gujarat - 382428

akumar@ipr.res.in

Abstract

To study the different plasma parameters, the radially movable probe diagnostic is needed which can measure (i) Electron Temperature (ii) Density (iii) Electric field (iv) Flow velocity etc. in a DC plasma within 8 hours of filament break time with precision. To fulfill the requirement a LabVIEW based acquisition, control and measurement system is made which can move the actuator with precision by precisely moving the dc motor to the desired location and acquire the data by applying user defined sweep voltage. User can also clean the tip of the probe by applying dc voltage through this application. This poster presents the implementation of the application in LabVIEW using the existing PXI (PCI eXtensions for Instrumentation) system for generating the analog signal, interface and control of actuator and acquiring the data using PXI system.

References:

[1] Automated Plasma Probing System for Laboratory Experiments in High Vaccum Using Closed Loop Control IPR/TR-673/2022, April 2022

DEVELOPMENT OF 3MW 12 INCH MIS-MATCH TRANSMISSION LINE TEST BED FOR ITER ICRF SOURCE

Ulhas Dethe, Rohit Anand, Sunil Dani, Akhil Jha, Paresh Vasava, Raghuraj Singh, Rajesh Trivedi

ITER-India, IPR, Bhat, Gandhinagar-382428

ulhas.dethe@iterindia.in

Abstract

ITER requires 20MW Ion Cyclotron Radio Frequency (ICRF) power in the frequency range of 35 to 60 MHz for Heating & Current Drive (H&CD) applications. ITER India is responsible to deliver 9 RF sources including one spare to meet the 20MW power requirement. Each RF Source will be capable to deliver 2.5MW/2000s RF power at a voltage standing wave ratio (VSWR) of 2:0 having a bandwidth of +/- 1MHz as per ITER requirement with 25% duty cycle. ITER-India, IPR has completed R &D program [1,2] for 1.5MW RF chain along with critical components and interfaces. To test RF amplifier with match and mismatch conditions by fast switchover to required configuration without much involvement of human resources to disassemble and reassemble manually, MMTL system with SPDT switch is being indigenously upgraded and developed from 1.5MW to 3MW.

The upgraded 3MW MMTL system consists of 12-inch stub, phase shifter, gas barrier, directional coupler and switch. All the components related to MMTL system contains coaxial cylinders/conductors with proper sliding arrangement. Sliding co-axial cylinders and plungers will be moved by servo/ stepper electric motor & driver. During 3MW/CW operation, the coaxial cylinders will be heated up and so, the appropriate cooling arrangement is made to prevent overheating of cylinders. The co-axial cylinders will be cooled by compressed air at approximately 2 bar inlet pressure and cooling water at approximately 3 bar inlet pressure.

This poster shall present the detail design and analysis for all the components of MMTL system.

References:

[1] Aparajita Mukherjee et al., Status of R&D activity for ITER ICRF power source system, Fusion Engineering and Design 96–97 (2015) 542–546
[2] Rajesh Trivedi et al., Outcome of R&D program for ITER ICRF Power Source System, Preprint, FEC-2018.

Testing of Toroidal Field Power Supply (TFPS) for Aditya-U Tokamak

M N Makwana, Kunal S Shah, Shivam Kumar Gupta, V Balakrishnan, Supriya Nair, Rohit Kumar,
R L Tanna, Joydeep Ghosh and ADITYA-U Team

Institute for Plasma Research, Bhat near Indira Bridge, Gandhinagar, Gujarat (India) 382428

E-mail: makwanam@ipr.res.in

Abstract

In a tokamak, magnetic field coils confine plasma particles to allow the plasma to achieve the conditions necessary for fusion. One set of magnetic coils generates an intense "toroidal" field, directed the long way around the torus. A central solenoid (a magnet that carries electric current) creates a second magnetic field directed along the "poloidal" direction, the short way around the torus. The two field components result in a twisted magnetic field that confines the particles in the plasma. Toroidal Field (TF) for ADITYA-U tokamak is generated by the current in TF coils. Toroidal field power supply (TFPS) is used to set the current in TF coils. It comprises 20 coils in series and the effective coil parameters are 5mH and 4 mΩ. Rated Current in TF coils set the Toroidal field up to 1.5 Tesla.

TFPS is 12 pulse thyristor based converter power supply, Installed and commissioned by the AEG Germany in1986. Since last three decade it is operating and fulfilled the experimental requirement for the ADITYA-U tokamak. Current Rating of TFPS is 50kA and output DC voltage is 350 VDC. It is designed for 2s current ramp up , 1 s flattop and 2 s ramp down, total rated pulse length is 5 s [1]. TFPS fed from converter transformer having Primary 11 KV and Double secondary 2*315V Rated PEAK MVA 11.16 (2MVA continuous rating).This is having four 6 pulse thyristorised converter, out of which two are fed from Delta/Delta transformer and remaining two are fed from delta/star transformer. These are connected through the Inter Phase Transformer (IPT), to appropriate current balancing and harmonics reduction.

The Operating pulse length of TFPS is about 4 second, out of which first 2 second is for the current ramp-up, 1 second is for flat top for the defined current level and ~1 sec for ramp down. Pre-defined Current reference for TFPS is pre-defined as per experimental requirement. Independent testing of TFPS from 5kA to 45kA is presented in this paper.

References:

[1]Bhatt, S B & D.Bora, & C.N.Gupta, & Jain, K.K. et. Al. (1989). Aditya: The first Indian Tokamak. Indian Journal of Pure and Applied Physics. 27. 710.

FINAL ASSEMBLY OF HYDROGEN ISOTOPES EXTRACTION SYSTEM AT IPR AND ITS PRESENT STATUS

Rudreksh B. Patel, Pragnesh Dhorajiya, Sudhir Rai, P. A. Rayjada and Amit Sircar

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail : rbpatel@ipr.res.in

Abstract

Tritium extraction from Lead Lithium (Pb-Li) is one of the most important task for any Pb-Li breeder based Test Blanket Module (TBM) concept. Indian Lead Lithium Ceramic Breeder (LLCB) TBM has two types of tritium breeders, viz., solid Ceramic Breeder (CB) and liquid Pb-Li eutectic alloy. To extract hydrogen isotopes dissolved in liquid Pb-Li, various methods have been utilized. It has been reported[1] that packed bed column for extracting dissolved hydrogen isotopes from liquid Pb-Li is more efficient compared to others, viz., plate, spray and bubble columns. Therefore, packed bed column is designed [2] and developed for hydrogen isotopes extraction from Liquid Pb-Li.

We have developed Hydrogen Isotopes Extraction System (HIES) for extracting hydrogen isotopes (H_2 or D_2) from liquid Pb-Li. HIES is designed for *70 litre* capacity of Pb-Li. The sizing of process tanks is carried out accordingly. Present work consists of final assembly and pre-operational activities of these process tanks including H_2 sensor testing tank and extractor column. It also highlights fabrication challenges for extractor column, its internal packing supports and flow channels. The extractor is the main component of HIES system where dissolved hydrogen isotopes is extracted from liquid Pb-Li by purging helium gas. All these major components are installed on supporting frame structure and joined together with inter-connecting pipes and valves to build complete HIES. The loop is pressure tested for leak at component as well as integrated level keeping gas pressure of *5 bar*. HIES piping and components are further covered with heaters and insulated with suitable insulation material. Integration of various measurement diagnostics for pressure, flow, temperature and concentration are mounted and integrated properly. The loop is tested for its temperature performance at *300-400 C*. The vacuum assembly is checked with helium leak detector to ensure better performance. Present work further describes the operational plan which is in line with updated Process Flow Diagram (PFD) of HIES loop. In addition to this, permeation based hydrogen sensor is installed in HIES and planned to test in liquid Pb-Li phase. This sensor is successfully tested in gas phase[3].

References :

[1] Sadhana Mohan., et al., "Experimental design of tritium extraction loop from lead lithium eutectic", *Fus. Eng. Des.*, 85, p 803–808, (2010)

[2] Rudreksh B. Patel, et al., "Conceptual Design of an Experimental set-up for Hydrogen Isotopes Extraction from Liquid Lead Lithium", IPR/TR-393/2016.

[3] Rudreksh B. Patel, et al., "Performance Testing of Permeation based Hydrogen Isotope Sensor in Hydrogen Gas" IPR/RR-1301/2021

An Overview of ADITYA-U Tokamak Results and Future Experiments

J. Ghosh[1,2], R.L. Tanna[1,3], K.A. Jadeja[1,4], K.M. Patel[1], Rohit Kumar[1], S. Aich[1], H. Raj[1], Shwetang Pandya[1], Deepti Sharma[1], K. Galodiya[1], Ankit Patel[1], L. Pradhan[1], M.B. Chowdhuri[1], R. Manchanda[1], N. Ramaiya[1], S. Purohit[1], U.C. Nagora[1,2], Kiran Patel[1,2], D. Kumawat[1], Santosh Pandya[1], J. S. Mishra[1], T. Macwan[1,2], K. Singh[1,2], S. Dolui[1,2], K. Shah[5], A. Kanik[6], N. Yadava[3], S. Patel[5], Ankit Kumar[1,2], A. Kumawat[1,2], B. Hegde[1,2], Dipexa Modi[5], R. Joshi[7], A. Kundu[1,2], G. Shukla[1], R. Dey[1], J. Mendonca[1], M.N. Makwana[1], Kunal Shah[1], S. Gupta[1], Supriya Nair[1], V. Balakrishnan[1], C.N. Gupta[1], Praveenlal Edappala[1], B. Arambhadiya[1], Minsha Shah[1], Pramila Gautam[1], V. Raulji[1], Praveena Shukla[1], Abhijeet Kumar[1], H. Mandliya[1], Mitesh Patel[1], R. Rajpal[1], M. Bhandarkar[1], Imran Mansuri[1], Kirti Mahajan[1], Varsha S[1,2], K. Tahiliani[1], Snehlata Gupta[1], Kumar Ajay[1], S.K. Jha[1], M.K. Gupta[1], M.V. Gopalkrishana[1], V. Menon[1], K. Mishra[1], Sunil Kumar[1], J. Patel[1], H. Mistry[1], H. Petal[1], U. Goswami[1], R. Singh[1], B.K. Shukla[1], Jagabandhu kumar[1], Pramod Sharma[1], P.K. Chattopadhyay[1,2], N. Bisai[1,2], P.K. Atrey[1], S.K. Pathak[1,2], M. Bandyopadhyay[1,2], R. Gangrade[1], B.R. Doshi[1], S. Pahari[1], D. Raju[1,2], V. Tanna[1,2], Y.C. Saxena[1], Abhijit Sen[1], R. Pal[8] and S. Chaturvedi[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat, India*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094*
[3]*Institute of Science, Nirma University, Ahmedabad 382481, Gujarat, India.*
[4]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360 005*
[5]*Department of Physics, Pandit Deendayal Energy University, Raisan, Gandhinagar*
[6]*University of Petroleum and Energy Studies, Dehradun, Uttarakhand 248007*
[7]*RK University, Rajkot, India*
[8]*Saha Institute of Nuclear Physics, Kolkata, India*

E-mail: jghosh@ipr.res.in

Abstract

The ADITYA-U tokamak is a complete transformation of first indigenously built mid-sized tokamak ADITYA, operated during the period from September 1989 to February 2015 having circular plasmas with single poloidal ring limiter. Several experiments, related to controlled thermonuclear fusion research and highly relevant for large size tokamaks, including ITER, have been carried out on ADITYA [1]. Promising results from novel experiments such as disruption control and runaway mitigation have been obtained from ADITYA [2]. Later, it has been upgraded to ADITYA-U tokamak, configured to have shaped plasmas operations in an open divertor configuration without any baffle. The main scientific objectives of ADITYA-U are to carry out dedicated experiments relevant for large size fusion machines including ITER, such as the generation and control of runaway electrons, disruption prediction, and mitigation studies, along with plasma position control and confinement improvement studies with shaped plasma. The dis-assembly of ADITYA tokamak and re-assembly of ADITYA-U took almost a year, followed by its commissioning and later the First Plasmas in ADITYA-U was established in December-2016 with the inclusion of new graphite toroidal belt limiter as the primary plasma-facing components [3]. The Phase-I plasma operations in ADITYA-U (January-March -2017) were mainly aimed at assembly validation of the machine and operated maximum toroidal magnetic field up to 1 T. Consistent plasma discharges of plasma currents of ~80 kA–95

kA were achieved, with durations of 80–180 ms, a chord averaged electron density of ~2.5 × 10^{19} m^{-3} [4]. Later, ADITYA-U operations have been targeted towards the demonstration of plasma parameters close to the design parameters of circular plasmas in toroidal belt limiter configuration as well as the initiation of shaped plasma operations in both hydrogen and deuterium fuels [5]. Achieved circular plasma parameters in ADITYA-U having $I_P \sim 100–210$ kA, t ~ 300–400 ms, ne ~ 3–6 × 10^{19} m^{-3}, core Te ~ 300–500 eV with a maximum B_T of ~1.5 T as well as exciting results of preliminary shapping of plasmas by charging upper and lower diverter coils have been attempted. Along with the parameter enhancements in the upgraded machine, several experiments addressing the key challenges for large-size fusion-grade devices, including ITER, have been carried out in ADITYA-U. In one such novel experiment, solid particles are inductively injected into the plasma to establish a unique mechanism for disruption mitigation technologies in tokamaks. Planning towards future experiments in ADITYA-U includes enhancement of plasma duration using lower hybrid current drive, auxiliary heating using ECRH & ICRH will be presented.

References:

[1] Tanna R.L. et al., *Nucl. Fusion* **57,** 102008 (2017)
[2] Tanna R.L. et al., *Nucl. Fusion* **55**, 063010 (2015)
[3] J. Ghosh et al., Pre-print, FEC-2016 (FIP/P4-46)
[4] Tanna R. et al *Plasma Sci. Technol.* **20** 074002 (2018)
[5] Tanna R. L. et al., *Nucl. Fusion.* **62**, 042017 (2022)

Quality Control Perspectives during Mass Production of In-Wall Shielding Blocks with a Focus on Nuclear Requirement

S Dani[1], S padasalagi[1], R Laad[1], U Dethe[1], A Maheshwari[1], B Gajjar[1], M Patel[1], T Sharma[1], S Singh[1], J Raval[2], Prasad Ksvv[3], Deepu Francis[4]

[1] ITER-India, Institute For Plasma Research, Gandhinagar, Gujarat,India
[2] Institute For Plasma Research, Gandhinagar, Gujarat,India
[3] Avasarala Technologies Ltd Bangalore
[4] Larsen & Toubro Heavy Engineering, Surat

Abstract: ITER vacuum vessel is a torus-shaped, double wall structure. The space between the double walls of the VV is filled with in-wall shielding (IWS) and water. The main purpose of IWS is to provide neutron shielding together with blanket and VV shells during ITER plasma operation and to reduce ripple of toroidal magnetic field (TF). In-Wall Shielding components are non-pressure retaining, they are not permanently attached to pressure retaining parts of the ITER Vacuum Vessel. However, integrity of the In-Wall Shielding blocks and their connection to supporting ribs shall be provided during all operational time.

The IWS manufacturing involved Assembly and inspection of 8809 In-Wall Shielding (IWS) blocks, using about 58,000 borated steel plates of complex 3D profile. In total about 2,00,000 components (like Plates, brackets, fasteners, spacers, washer etc.) manufactured and inspected to assemble and form the Blocks. The precision measurement device like Coordinate Measurement Machine (CMM) used in controlled temperature to ensure compliance to critical tolerance requirements. The codes applicable code to in achieving the quality requirements are ASME, ASTM and RCC-MR. The weld joint quality assured by NDT inspection like UT and LPT after due approval of the procedures as per MIP. The components are manufactured and inspected in compliance with the approved procedures. The IWS being the nuclear components large amount documentation involved to ensure the traceability components during entire life cycle of ITER.

The objective of this paper is to summarize the Inspection of components and block assemblies at various stages of manufacturing for quality control during the manufacturing and traceability of components right from raw material stage to the finished products and even during operational phase of ITER machine.

Learning from the Non-destructive Examination of ITER Cryostat manufacturing

Mukesh Jindal[a], Amit Palaliya[a], Vaibhav Joshi[a], Mitul Patel[a], Vipul More[a], Saroj Jha[a], Avik Bhattacharya[a], Manish Pandey[a], Rajnikant Prajapati[a], Anil Kumar Bhardwaj[a], Girish Gupta[b], Sarath.S[c], Chirag Patel[c], S Sivakumar[c]

[a]*ITER-India, Institute For Plasma Research, Gandhinagar, Gujarat,India*
[b]*ITER Organization Cadarache France*
[c]*Larsen & Toubro Limited, Heavy Engineering, Hazira Manufacturing Complex, Gujarat, India*

Email: mukesh.jindal@iterindia.in

Abstract

The ITER Cryostat- the largest austenitic stainless steel vessel provides an ultra-cool environment for the ITER Vacuum Vessel and the Superconducting Magnets. It weighs ~ 3500 t and measures up to ~29 meters in diameter and ~29 meters in height. The material of Construction is dual marked SS 304/304L and thickness varies from 25 mm to 200 mm. The design, manufacturing, and inspection of the cryostat are as per ASME Section VIII Division 2 with the supplementary requirement of ITER. A large number of penetrations and transportation limitations at the site call for the segmentation which results in several subassemblies. This has resulted in a large number of welding joints at site workshop and these segments are further taken to pit for in-situ welding.

Ultrasonic testing has been implemented for weld joints of ITER site workshop and in tokamak pit in lieu of Radiographic Testing through UT validation. If RT was implemented for all the joint planned in Pit and in site workshop, the restriction of parallel working could have been caused a schedule delay of ~3 years.

Ultrasonic testing of higher thickness joints (190mm) with single side access for base section with special probes has been completed. Also UT of circular joint (120mm thick) has been completed for Base section horizontal plate through validation.

This paper covers the learnings from implementation of Ultrasonic Testing in lieu of Radiographic Testing and development of UT of circular and higher thickness with single side access joints during in manufacturing of cryostat.

Simulation of Toroidal B-field for tight aspect ratio torus: SMARTEX-C

A. Amardas[1*], Lavkesh Lachhvani[1], Nikhil Mohurle[1,2], Sambaran Pahari[3], Prabal K. Chattopadhyay[1,2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar-382428, India*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai, 400094, India*
[3]*Bhabha Atomic Research Centre, HBNI, Visakhapatnam-530012, India*

E-mail*: amar@ipr.res.in

Abstract

Finite element simulation of Toroidal Field (TF) coil made up of copper bus-bar using COMSOL Multiphysics® [1] for steady state operation at 1 kGauss has been carried out for SMARTEX-C [2]. It is a SMall Aspect-Ratio (ε ~ 1.59) Toroidal Electron plasma eXperiment in 'C' shaped geometry. A new TF magnet is air-cooled and has been designed to generate maximum B-field of 1 kGauss at minor axis. The TF coil consists of 24 turns uniformly placed at 150 toroidal angular separations. Design makes optimal use of the limited space in the inner-bore. The electromagnetic force on the toroidally wound conductors carrying a current for 1kGauss will be high and can generate significant stresses detrimental to the coil especially the joints. To estimate the forces and resultant stresses and deformation of the conceived design has been analyzed. The magnetic field and Lorentz forces have been computed. To ensure reliable operation, an engineering analysis of the magnet design is carried out. Results of magnetic, structural, and transient thermal analyses are presented in this poster.

References:

[1] COMSOL Multiphysics http://www.comsol.com

[2] S. Pahari, H. S. Ramachandran, and P. I. John, "Electron plasmas: Confinement and mode structure in a small aspect ratio toroidal experiment," Phys. Plasmas, **13**, 092111, 2006

Automation of RF communication experiment using Python

Jignesh Patel, Manisha Bhandarkar, Imran Mansuri, Sarada Sree, Hitesh Chudasma, Vishnu Patel, Atish Sharma, , Harish Masand, Kirit Patel, Priyadarshini Gaddam, Srinivas Rao, Rajesh Kumar and Kirti Mahajan

Institute for Plasma Research, Gandhinagar 382428

E-mail : jjp@ipr.res.in

Abstract

Python based control and data acquisition software is developed for RF communication experiment. RF communication (transmission and reception) is tried using antennas in very high frequency range [1]. The control and data acquisition software along with Graphical user interface (GUI) has been developed in python to control and monitor RF signal generator and RTL-SDR (Computer based radio scanner). RTL-SDR is part of SDR (Software Defined Radio) system in which the components that have been traditionally implemented through hardware are implemented through software [2]. RTL-SDR consists of a RF front-end followed by analog to digital converter which provided samples to SDR software. Salient features of the developed software are to communicate and set parameters of RF signal generator, control and data acquisition of acquired data from RTL-SDR using different python modules e.g. python based SDR, GNU Radio, PyQt, vxi11, etc [3][4].

References :

[1] RF communication with salt water standing column and water jet, Technical Report IPR/TR-677/2022
[2] RTL-SDR https://www.rtl-sdr.com
[3] Python-based software-defined radio https://arachnoid.com/PLSDR/
[4] GNU Radio https://www.gnuradio.org/

Preliminary Electromagnetic Analyses of Linear Induction Motor as Sn-Li Alloy Stirrer

Ananya Kundu, P Prasada Rao, Ankur Jaiswal, Arvind Kumar, Y.S.S. Srinivas, Vilas Chaudhari, Rambabu Sidibomma and E.Rajendra Kumar

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382428*

E-mail: ananya@ipr.res.in

Abstract

Linear Induction Motor based electromagnetic stirring system is vividly used in industries for effective and reliable stirring of the metallic liquid. In this non-contact stirring application, the electromagnetic coils in the linear induction motor produces the Lorentz force required for stirring of the metallic alloy to increase the homogeneity of the mixture [1]. At IPR, a Linear Induction Motor (LIM) based electromagnetic stirrer system is being designed to produce required force for the mixing of the Tin-Lithium (Sn-Li) liquid alloy. Based on the designed parameters of the linear Induction Motor, a three-dimensional model of a single sided Linear Induction Motor is developed and FEM analyses of the motor are carried out to estimate the electromagnetic force exerted on the liquid metal. The rotor of the motor which is liquid metal in this case, is equivalently substituted by a SS plate of 20 mm thickness spanning over the length of the motor to verify the performance of the LIM prior to its design finalization, fabrication and real time application.

In the present work, the designed parameters of the motor, input current waveform, air gap between the rotor plate and the coils are defined as boundary conditions for the analyses and the transient and the time averaged and volume integrated Lorentz force components exerted on the rotor plate are estimated for a fixed air gap. The magnetic flux density and the induced current density on the rotor plate are also determined as a function of time.

References :

[1] Liu, Cheng-Tsung & Lin, Sheng-Yang & Lee, Weng-Jay & Chen, Jen-Hsin, Electromagnetic Stirring Systems. IEEE Industry Applications Magazine - IEEE IND APPL MAG. **17**, p 38-43,(2011)

DESIGN, DEVELOPMENT AND TESTING RESULTS OF FAULT PROCESSING CARD FOR FRBPS

Murtuza Vora, Dinesh Kumar Sharma, Akhilesh Singh, Amit Ojha , Supriya A Nair

Institute for Plasma Research, Bhat, Gandhinagar,382428

murtuza@ipr.res.in

Abstract

FRBPS (Fast Response Bipolar power supply) is being developed in IPR. The rating of FRBPS is +/-5kA, 500VDC and 1 MA/s ramp rate. There are 10 water cooled IGBT based Inverter modules each of 500A rating connected in parallel. Each IGBT inverter module has overcurrent, fuse failure, thermostat for heat sink, water flow and emergency protection signals. Each fault signal is monitored and processed by fault processing card continuously. When fault occurs, a trip signal is issued to block gate pulses at controller.
The paper describes the acquisition process, design, logic, internal circuitry, limit set, testing results of fault processing card of FRBPS.

Key word: Power supply, Fault, Protection, IGBT.

Development of -5kV, 1A High Voltage DC Power Supply for Magnetron todevelop ECR Plasma

Kirit Parmar, Bhavesh Kadia, Pravesh Dhani, Sunil Kumar, and High Power ICRH SystemsDivision

Institute for Plasma Research Gandhinagar (Gujarat) - 382428, India

ABSTRACT

The -5kV, 1A High Voltage DC Power Supply has developed with features like operation mode changeability, voltage variability, automation, low ripple, good regulation, over-voltage, and current protection for 1kW, 2.45GHz Magnetron operation to produce Electron Cyclotron Resonance (ECR) Source to generate an external poloidal field in Basic Experiment in Toroidal Assembly (BETA). This power supply can be selectively operated in either CW or pulse mode.

The High voltage DC is produced in conventional type topology with the help of a three-phase power controller, step-up transformer, and bridge rectifier followed by a capacitor bank. The IGBT switch is used at output to achieve pulse mode operation of the power supply. The over-voltage and over-current protection enable this power supply to switch off and pulse block in case of a fault.

The HVDC Power Supply has been designed, developed, and warranted its specification on a dummy load for more than -4 kV, 1A with fault simulation conditions. This power supply is developed and is being used for actual load.

The poster presents the topology used, circuit details, selection of components, various protections, and test results.

Development of Supervisory Control and Data Acquisition application for Cryocooler based Helium Circulation System at 55K

Pradip Panchal, Hiren Nimavat, Upendra Prasad and Vipul Tanna
Institute for Plasma Research, Gandhinagar, INDIA
E-mail : pradip@ipr.res.in

Abstract

High Temperature Superconductor (HTS) based applications are becoming practical and popular nowadays due to tremendous progress in R&D of HTS material, wires and lower cryogenic operating costs. HTS require only liquid nitrogen or cold Helium gas to cool to superconducting temperatures. HTS current leads are used in ITER, KSTAR, JT-60SA tokamaks. Recent developments in HTS coil manufacturing enabled scientists to use HTS based magnets in Spherical Tokamak (ST). The Cryocooler based Helium Circulation system at 55K has been commissioned recently for R&D activities of HTS based applications at IPR. This system can be used for forced flow cooling of HTS magnets or conduction cooled HTS current leads of HTS based small scale tokamak. The net refrigeration capacity of Helium circulation system is 600W at 55K. This system is controlled locally by Human Machine Interface (HMI) panel as well as remotely by Supervisory Control and Data Acquisition (SCADA) system. The SCADA application is developed for remote monitoring and control of the complete system using Modbus communication with main Programmable Logic Controller (PLC). The paper presents the development, integration and operational experience of SCADA system with Cryocooler based Helium Circulation System at 55K.

References :

[1] Ziad Melhem, Steven Ball, et al., High Temperature Superconducting (HTS) Coils for a Compact Spherical Tokamak, IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 25, NO. 3, (2015)
[2] R. Heller, W.H. Fietz, A. Kienzler, High power high temperature superconductor current leads at KIT, Fusion Engineering and Design 125 pp. 294–298 (2017).

Installation & Commissioning of MW level RF source for experiments on SST-1

Raghuraj Singh, Kishore Mishra, Kumar Rajnish, Manoj Parihar, Kartik Mohan, Dharmendra Rathi, Akhil Jha, Bhavesh Kadia, Manoj Patel, Kirit Parmar, Gajendra Suthar, Hiralal Jadav, Hrushikesh Dalicha, Rameshkumar Joshi, Dipal Soni, Rana Pratap Yadav, Sriprakash Verma, Rohit Anand, Atul Varia, Sunil Dani, Pareshkumar Vasava, Ulhas Dethe, Sunil Kumar, Rajesh Trivedi

ITER-India & Institute for Plasma Research, Bhat, Gandhinagar-382428

raghuraj.singh@iterindia.in

Abstract

Ion Cyclotron Radio Frequency (ICRF) Sources are being used for heating & current drive in tokamak plasma as well as for wall conditioning efficiently. ITER-India carried out an R&D program to develop two numbers of 1.5MW RF source using tetrode & Diacrode technologies [1] [2]in the final stage amplifier in the frequency range of 36 to 60 MHz as a prototype developmentbefore series production as ITER in-kind contribution for plasma Heating & Current Drive application in various Tokamaks. It was planned to install & commission anyone of the 1.5MW RF Source in SST-1 hall for the domestic use on SST-1 tokamak after completion of R&D phase. Each 1.5MW RF source is capable to generate 1.5MW/CW with VSWR 2:1 for 3600s with 25% duty cycle and remotely operated through local control unit (LCU). All the safety and controls as well as monitoring are facilitated in LCU for the safe operation. At ITER-India lab tetrode-based RF source was tested on dummy load as per SST-1 requirement for ICRH experiment.
As planned, tetrode-based RF source is disassembled, shifted from the third floor of ITER-India lab and re-installed in SST-1 hall along with required auxiliary power supplies and interconnecting transmission line components. Commissioning of the RF source is under progress, Presently, water cooling as per requirement, auxiliary power supplies and filaments have been tested in standalone mode along with their respective limiting thresholds. All the control cables have been laid down and handshaking between LCU and various subsystems is being carried out, soon RF test will beconducted as a part of commissioning.This poster will describe the installation procedures and high-power test results of the RF source achieved during commissioning.

References:

[1] Aparajita Mukherjee et al., Status of R&D activity for ITER ICRF power source system, FusionEngineering and Design 96–97 (2015) 542–546
[2] Rajesh Trivedi et al., Outcome of R&D program for ITER ICRF Power Source System, Preprint,FEC-2018.

Automation of Baking Control System for Aditya Upgrade Tokamak

Vismaysinh Raulji, Bharatkumar Arambhadiya, Kaushal Patel, Kumarpalsinh Jadeja, Rachana Rajpal, Rohit Kumar, R.L Tanna, Joydeep Ghosh,

Institute for Plasma Research, Nr.Indira Bridge, Bhat, Gandhinagar-382428

vismay@ipr.res.in

Abstract

In tokamak, baking of vacuum vessel and first wall components is a prerequisite in order to obtain impurity free plasmas. Baking is performed to remove impurities viz. H_2, H_2O and Hydro-Carbon from the vessel and first wall components. The Aditya-U baking system consists of ~80 heaters and numerous RTDs (Resistance Temperature Detector) installed on different sectors of the vessel and pumping lines. These heaters are operated remotely depending on temperature measured by the RTDs as per requirement of baking system.

To fulfill these requirement Industrial commercial-off-the-shelf (COTS) devices PLC (Programmable Logic Control), Supervisory control and data acquisition (SCADA) based system is installed in Aditya-U. The control system comprises of three main phases: Temperature ramp-up from room temperature, continuous baking at specified temperature set-point (called vessel baking time) and ramp-down to room temperature. It requires the operator to set baking temperature and time, the intermediate temperature set points and interlock is calculated and implemented by the in-house developed application software. The heaters are controlled in close loop system. The entire baking system has been tested thoroughly for its automatic operations for long operation hours (~48 hr.) with repeated cycles of baking the vacuum vessel up to ~135 °C, integration, ruggedness, reliability, small form factor. The baking control system is fully automatic, easy to operate and user friendly. This poster will describe the salient features of the developed control system in detail.

References :

[1] https://conferences.iaea.org/event/151/contributions/6291/

Cleaning and contamination control methodology for large Ultra High vacuum (UHV) chamber

Rakesh Kumar [1,*], Sunil S[1], Vijay Bedakihale[1], Subroto Mukherjee[1, 2]
[1] *Institute for Plasma Research, Bhat, Gandhinagar-382428, India*
[2]*Homi Bhabha National Institute, Anushaktinagar, Mumbai, 400094, India*
[*]Email address: rakeshk@ipr.res.in

Abstract

Many scientific experiments require Ultra-High Vacuum (UHV) with low residual species content to carry out the experiment. To achieve UHV especially in a large volume chamber within estimated time and with an effective pumping speed, the cleaning and contamination control throughout the fabrication, assembly, handling, storing and transportation stages plays a vital role. Predefined cleaning & contamination control procedure is to be strictly implemented and followed during entire shop floor activities. Recently, two large size vacuum chambers of volume ~10m^3 and ~25m^3 have been fabricated, assembled and helium leak tested meeting the specified UHV requirement. Specific cleaning process using identified cleaning agent were used for cleaning in a dirt free confined area. After assembly in clean area the chambers were evacuated to less than 10^{-7} mbar. The pumpdown time is found to be consistent with the estimated values. Measured partial pressure using Residual Gas Analyser (RGA) along with the pumpdown curve highlight cleanliness of the chamber. The details of procedure followed in cleaning & contamination control, partial pressures data and other parameters obtained will be presented in the poster.

Key words: UHV, Cleaning, contamination, chamber, RGA

Arbitrary Pulse Generator using Xilinx FPGA for Tokamak Gas Fueling Control Circuit

Bharatkumar Arambhadiya[1], Hiteshkumar Mandlia[1], Vismaysinh Raulji[1], Mohammad Shoaib Khan[1,2], Kaushlender Singh[1,2], Rachana Rajpal[1], Kumarpalsinh Jadeja, Rohit Kumar[1], R.L Tanna[1], Joydeep Ghosh[1,2]

[1]*Institute for Plasma Research, Nr.Indira Bridge, Bhat, Gandhinagar-382428*

[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India*

bharat@ipr.res.in

Abstract

A gas fueling control is an essential requirement in the Tokamak and plasma operations. It controls plasma initiation and plasma parameters such as density, temperature, disruption runaway mitigation by injecting the fuel gas in controlled amount. The Tokamak gas fueling control system uses piezo valves for gas feeding the vacuum vessel. This requires a user configurable gas fueling control circuit.

A customized gas fueling control circuit has been developed using Xilinx Spartan 6 FPGA (Field Programmable Gate Array) and NI (National Instrument) LabVIEW. The Xilinx Spartan 6 FPGA incorporates a soft core MicroBlaze™ Micro Controller System (MCS). The developed application uses Xilinx MCS for serial communication between FPGA and LabVIEW Graphical User Interface. The programming code uses Xilinx Block RAM (Random Access Memory) IP (Intellectual property) to store pulse parameters. The developed VHDL code generates configured pulse delay, pulse width and pulse amplitude. The gas fueling control circuit consists of four channels arbitrary pulse generator. Each channel can be configured with different set of parameters. A single channel is able to deliver burst of 64 pulses and parameter of each individual pulse of the burst can be configured for pulse delay, pulse width and pulse amplitude. The poster provides detail of VHDL coding, graphical interfacing, testing and its simulation in Xilinx ISE Simulator (ISim).

References :

[1] Embedded multi-channel data acquisition system on FPGA for Aditya Tokamak, April 2016Fusion Engineering and Design 112, DOI:10.1016/j.fusengdes.2016.03.068

Upgraded real-time feedback control system for horizontal plasma position stabilisation

Pramila Gautam, Vismaysinh Raulji, Rohit Kumar, Rachana Rajpal
Institute for Plasma Research, Gandhinagar, Gujarat- 382428
pramila@ipr.res.in

Abstract

Plasma position stabilization techniques are used in tokamaks during plasma operation. In Aditya-U, horizontal plasma position stabilization is done through real-time feedback control for improving plasma current and plasma current flat-top [1]. A real-time feedback control for horizontal plasma-positioning in Aditya-U was designed using NI-PXI-7831R card, mounted in a PXI chassis. The PID controller implemented in FPGA provides control signal to the fast feedback Power supply (FFPS) installed in Aditya-U for plasma position control. The horizontal plasma position was successfully controlled and demonstrated in Aditya-U for different parameters of the PID [2]. An upgraded feedback control system is implemented using Compact-RIO(c-RIO), which is a real time embedded industrial controller from National Instrument. The upgraded system deployed in Aditya-U is compact, low-cost and flexible with inbuilt FPGA. There is also software upgradation with multiple windows of PID parameter controls on the millisecond scale all-through the plasma shot duration using graphical user Interface terminal. The system also has functionality enhancement in terms of file saving in the excel format with all the details of feedback parameters, shot-no, date etc. and retrieval of various parameters of a particular shot in the user terminal window.

The poster will present the details of upgraded c-RIO system with both hardware and the software architecture.

References:

**[1] Plasma current and position feedback control in ADITYA Tokamak
Fusion Engineering and Design**, September 2003
[2] Real-time feedback control system for ADITYA-U horizontal plasma position stabilization,
Fusion Engineering and Design, Volume 165, April 2021, 112218

Conceptual design of an isolated control system for floating power supply of NBI for SST-1

Laxmi Kant Bansal, Paresh J Patel, Dipal Thakkar, Vijay V Vadher, Laxmi Narayan Gupta, C.B. Sumod, Karishma Qureshi, U K Barua
Institute for Plasma Research, Bhat, Gandhinagar, Gujarat 382424

Email:- lkbansal@ipr.res.in

A Positive Ion extraction-based neutral beam injection system for Steady-state Superconducting Tokamak-1 (SST-1) is currently on the test stand. The Ion source is in operation for characterization purposes. Presently a VME-based control system is controlling the operations of the power supplies and acquiring power supply parameters. The VME-based system is installed inside the high voltage deck. As per the design, the high voltage deck is referenced to the beam extraction voltages up to 80kV.
Currently, VME-based systems are obsolete in the industry and therefore it is almost impossible to upgrade or replace the existing components. This VME-based system is planned to be upgraded by a PXI-based control system.
A conceptual design of the PXI-based control system is developed not only to replace the obsolete VME system but also to enhance the safety and operational features. The new design includes learning from past experience in order to make the system EMI/ EMC complied, fault-tolerant, easy diagnostics, and low maintenance of critical components.
It is proposed to install the PXI controller at ground potential instead of inside the HV Deck as earlier. This will provide better protection to critical components and allow maintenance without turning off the High voltage transformer. Control signals will be transferred to the HV deck via low-cost optical fiber cable. Electronics at the HV deck is minimized for better fault tolerance. In addition to this, additional signals are integrated with PXI to develop a central platform for all control and data acquisition requirements.
The paper presents the conceptual design, I&C architecture, and interfaces of PXI based system with other sub systems including power supplies under control.

Design & analysis of hydrogen gas pre-cooler for solid hydrogen pellet injections system of the Tokomak

P. Nayak. S. Mukherjee, P. Panchal, H. agravat, R. Gangradey, J. Mishra, V. Gupta

Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382428

E-mail: pratik@ipr.res.in

Abstract

Solid hydrogen pellet injection has become a leading technology for refuelling magnetically confined plasmas for controlled thermonuclear fusion reaction [1]. A continuous supply of pellets is necessary for plasma fuelling of long-pulse fusion research devices and future power reactors [2]. Development of an Extruder based Solid Hydrogen pellet injector is under progress at Institute for Plasma research, (IPR). Solid hydrogen extruder system solidifies the room temperature hydrogen gas using a heat exchangers mounted on cryo-coolers [3]. The heat load on such a system can be reduced by pre-cooling the hydrogen gas with liquid nitrogen. To implement the same, liquid nitrogen based hydrogen pre-cooler has been designed. The pre-cooler consists of a helical copper coil heat exchanger submerged into the liquid nitrogen bath which is surrounded by a vacuum chamber. This pre-cooler cools the room temperature (≈300K) hydrogen gas to ≈80K at a flow rate of 25 Litre/min, with an estimated reduction of heat load of ≈108 W. This paper discusses the design, analysis and heat load optimization for the system in detail.

References:

[1]S. L. Milora, W. A. Houlberg, L. L. Lengyel, and V. Mertens, “Pellet fueling,” Nucl. Fusion 35, 657 (1995)

[2] S. K. Combs, “Pellet injection technology,” Rev. Sci. Instrum. 64, 1679 (1993).

[3] M. J. Gouge, L. R. Baylor, S. K. Combs, P. W. Fisher, C. A. Foster, C. R. Foust , S. L. Milora “Production and Innovative Applications of Cryogenic Solid Pellets” Advances in Cryogenic Engineering pp 1763-1770 Paper Code: Paper Code SA Preferred mode of presentation POSTE

Scientific approach to writing technical papers, Appl.Phys.Lett., 45, p 2301-2305, (2009)

Fault Assessment on 3300 kVA Multi-secondary Transformer of Regulated High Voltage Power Supply

L.N.Gupta, Paresh J. Patel, N.P.Singh, Dipal Thakkar, Sumod C.B, Bhavin Raval and U.K.Baruah

Abstract

Multi-secondary transformers are used at the input stage of Modular and Regulated High Voltage Power Supplies (RHVPS). These power supplies are used in various applications for steady state and pulsed electric fields; typical examples are neutral beam injectors, Radio Frequency systems, ion accelerators & microwave devices. IPR developed many such RHVPS and many systems are using these RHVPS since 20 years. One of 3300 kVA multi-secondary transformers associated with LHCD RHVPS had a heavy fault during SST-1 campaign in September, 2019. This Fault resulted in broken out its top epoxy termination plate, accommodating LV winding terminals.

This paper will present a systematic study of fault assessment of transformer. This paper will also discuss all the data collected prior and after fault, primary test conducted on faulty transformer and observation after dismantling of core coil assembly (CCA) at factory site.

References

[1] N P Singh, U K Baruah, P J Patel, S K Mattoo & NBI Team, "Studies on the behavior of Multisecondary transformers used for regulated HV power supplies"

[2] U.K. Baruah, P.J. Patel, et al., "Power Supply System for 1000 S Neutral Beam Injector", Presented at Symposium on Fusion Engineering, 1997

[3] L.N. Gupta et al, "Test Procedures and Results of Multi-secondary Transformers utilized for Regulated High Voltage Power Supply (RHVPS)" in International conference on Transformers organized by held on June 5-7, 2013 in Gdansk, Poland

[4] Singh, N.P., Baruah, U.K., Patel, P.J., Gupta, L.N., Mattoo, S.K, J U Mamtora , "Development of multisecondary transformers for regulated HV power supplies,"IEEMA Journal, 74-75 August 2006.

FACTORY ACCEPTANCE TESTS CONDUCTED ON REPAIRED 3300 kVA MULTI-SECONDARY TRANSFORMER OF REGULATED HIGH VOLTAGE POWER SUPPLY

Dipal Thakkar, L.N.Gupta, Paresh J. Patel, N.P.Singh, , Sumod C.B, Bhavin Raval and U.K.Baruah

Institute for Plasma Research, Bhat village, Near Indira bridge, Gandhinagar 382 428

E-mail : dipal@ipr.res.in

Abstract

Multi-secondary transformers are used at the input stage of Modular and Regulated High Voltage Power Supplies (RHVPS). These power supplies are used in various applications for steady state and pulsed electric fields; typical examples are neutral beam injectors, Radio Frequency systems, ion accelerators & microwave devices. IPR developed many such RHVPS and many systems are using these RHVPS since 20 years. One of 3300 kVA multi-secondary transformers associated with LHCD RHVPS had a heavy fault during SST-1 campaign in September, 2019. This Fault resulted in broken out its top epoxy termination plate, accommodating LV winding terminals.

This poster will describe special type tests, their set up and results conducted at repaired transformer

References :

[1] "Power Supply System for 1000 S Neutral Beam Injector", Presented at Symposium on Fusion Engineering, U.K. Baruah, P.J. Patel, et al., (1997)
[2] "Test Procedures and Results of Multi-secondary Transformers utilized for Regulated High Voltage Power Supply (RHVPS)", L.N. Gupta et al, in International conference on Transformers organized held in Gdansk, Poland, June 5-7 (2013)
[3] "Development of multisecondary transformers for regulated HV power supplies" , Singh, N.P., Baruah, U.K., Patel, P.J., Gupta, L.N., Mattoo, S.K, J U Mamtora, IEEMA Journal,74-75, August (2006)

Welding development during Manufacturing and Assembly of ITER Cryostat

Rajnikant Prajapati[1], Anil Bhardwaj[1], Vaibhav Joshi[1], Amit Palaliya[1], Mukesh Jindal[1], Mitul Patel[1],Avik Bhattacharya[1], Gaurav Jogi[1], Jimmy Dutt[2], Chirag Patel[2], Sivakumar[2]

Affiliation : 1. ITER-India, Bhat Motera Road,Koteshwar,Ahmedabad-380005
2. Larsen & Toubro Heavy Engineering, Surat

Email : rajnikant.prajapati@iterindia.in

Abstract : ITER Cryostat is a large vessel (~29m dia. and ~30 m height), which is made up of Austenitic stainless steel material.It houses and supports critical components like the vacuum vessel & superconducting magnets and also envelops the entire basic systems of the ITER Tokamakmachine. The Cryostat also provides a vacuum environment for the proper functioning of thesuperconducting magnets. The thickness of vessel varies from 25 mm to 200mm. The weight of the complete Cryostat is more than 3500 tons and to meet the weight limitations for handling inside the Tokamak building, the Cryostat is divided into four main sections (Base Section, Lower Cylinder, Upper Cylinder and Top Lid) vertically and Base section and Lower cylinder were installed in ITER Tokamak Pit.The Design, manufacturing and inspection of the Cryostat has been carried out as per ASME Section VIII Division 2 and supplementary requirement of ITER Vacuum Handbook with a stringent tolerance requirement as proposed by ITER Organization.

Manufacturing of Cryostat involves critical requirement of dimensional control, higher thickness weld joints in all position, welding accessibility and stringent ITER vacuum requirements at factory and Tokamak Pit. These demand innovations in existing welding technique and application ofadvanced welding processes. One of the important key factors for the manufacturing of welded components is to design weld edge preparation which facilitates the welder/welding operator to produce sound welds.This paper covers development of new welding procedure during manufacturing, sub-assembly and installation of Cryostat main sections by using of the traditional welding processes i.e. SAW, FCAW etc. for different configuration of weld joints in order to achieve dimensional requirement. All developments were validated on prototype prior to implementation.

References:

[1] ASME, "Rules for the Construction of Pressure Vessels," ASME Boiler and Pressure VesselCode, Section VIII, Division 2, Alternative Rules, (2010).

[2] ITER Vacuum Handbook and its appendices

Alternate Technology for Manufacturing of Actively Cooled Components for Neutral Beam

[1,3]Ashish Yadav, [1,3]Jaydeep Joshi, [2]Amit Arora, [2]Sooraj Patel, [1,3]Mahendrajit Singh, [1]Arun K Chakraborty

ITER-India, Institute for Plasma Research Gandhinagar Gujarat India
Indian Institute of Technology Gandhinagar Gujarat India
Homi Bhabha National Institute (HBNI) Anushaktinahar, Mumbai, India

ashish.yadav@iterindia.in

Abstract

Actively cooled components in neutral beam system like accelerator grids, driver plate and faraday shield plate are inherent part of beam injectors and the manufacturing technologies to realize the various features of these components are followed through machining the cooling channels and closing the channels with electrodeposition [1]. An alternate method of manufacturing the cooling channels with friction stir processing has been explored.

In the present work, channels are fabricated in copper using friction stir channeling (FSC) [2]. With the experimental design, tool design was finalized, which includes shape/configuration, size (pin & shoulder dimensions). With this, channels (~2 x 3 mm) were produced successfully on the copper plate of size of 100 x 50 mm. Continuity and uniformity of the channel were confirmed using digital X-ray radiography. The cross-section of the channel was observed using optical microscopy. He-leak test of the channel was performed to confirm the leak tightness of the channels. After that, a series of channels (9 channels, ~100 mm length) have been fabricated in the 250 × 250 mm plate

The paper shall present the parameter optimization, process of channel formation, testing and examinations carried out on the samples. Implementation of this technique for the channel production would reduce the several steps in conventional sequence of channel production for the actively cooled components manufacturing, like copper electrodeposition, brazing and different joining methods. This would also ensure the absolute reliability of the system operation and its performance in service conditions.

References:

[1] J. Joshi et.al. "Technologies for the realization of large size RF sources for negative neutral beam systems for ITER. Challenges, experience and the path ahead" Nuclear Fusion - 2019

[2] S. Pandya et.al. "Channel formation during friction stir channeling process—A material flow study using X-Ray micro-computed tomography and optical microscopy". Journal of Manufacturing Processes 41 (2019), 48-55.

Non-thermal electron studies for ADITYA/ ADITYA-U tokamak plasma via X-rays spectroscopy

S. Purohit[1,2]*, M. B. Chowdhuri[1], M.K.Gupta[1], J. Ghosh[1,2], K. A. Jadeja[1], S. K. Pathak[1], R.L. Tanna[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat, India*
[2]*Homi Bhaba National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India*

E-mail: *pshishir@ipr.res.in

Abstract

The Tokamak plasma is assumed to be having a Maxwellian electron distribution, however, it is practically impossible to have a perfect Maxwellian electron distribution function due to numerous reasons. Non-uniform heating, higher applied electric field and larger error fields are some of the possible reasons for having a non-Maxwellian component of the electron distribution function. Electrons falling into the non-Maxwellian component are referred to as non-thermal electrons (NTE). These electrons are converted to runaway electrons (RE) when the electron reached a velocity/energy capable to escape the magnetic confinement. The investigation becomes very much important considering non-thermal electrons degrade the overall plasma properties and runaway electrons may damage the first wall. The ITER is expected to have 20MA RE current, which poses a substantial threat to the device itself. The NTE emits X-rays whensubjected to acceleration/ retardation and are realized via X-ray spectroscopic measurements of such emissions for any given tokamak plasma. Depending on the emission energy, the X-rays are classified as soft X-rays (SX) or hard X-rays (HX). The ADITYA/ ADITYA-U tokamak are having SX/HX spectroscopy systems that have been developed to investigate the non-thermal electron. Here, the SX emission in the energy range of 1 - 30 keV is monitored via a silicon drift detector (SDD) based system, whereas a $LaBr_3$ system is chosen for HX of 100 keV to 4 MeV range to study the runaway electron present inside the plasma. The energy calibration for the system has been performed and the relative calibration for the photons for different energies donefor quantitative analysis[1-3]. The X-ray spectrum acquired from these systems for the tokamak plasma is analyzed to determine the NTE/ runaway electron temperature. This gives a general overview of how strong the RE or NTE is present in the plasma and how much plasma is qualitatively losing its energy[1-3]. The spectral shape also assists in commenting on the overall thermal content in the plasma, which is necessary to be known for plasma properties. Theoccasional line radiation, from high Z elements, is also an important aspect of the x-ray measurements mostly from highly charged Fe, which gives an insight into plasma-wall interaction as the vacuum vessel made of SS304L[3,4]. The SSD system has been employed to understand the electron cyclotron resonance (ECR) assisted plasma breakdown of ADITYA[4]. Theabstract offers an overview of the X-ray systems and their capabilities and their contribution to understanding the NTE.

1. S. Purohit *et al. Rev. Sci. Instrum*. **93**, 093512 (2022)
2. S. Purohit *et al. JINST* **15** P08015 (2020)
3. S. Purohit *et al. Rev. Sci. Instrum*. **85**, 11E419 (2014)
4. S. Purohit *et al. Plas. and Fus. Res*. **12**, 2402002 (2017)

Liquefaction rate measurement set-up and test results of indigenous helium liquefier plant of IPR

O. Chandratre, A K Sahu, P.Singh, H. Dave, V. B. Patel, H. Kavad, R. Bhatasana, N. Kumar
and
P. Brahmbhatt
Institute for Plasma Research, Gandhinagar
E-mail: omkar.chandratre@ipr.res.in

Abstract

The indigenous IPR helium refrigerator/liquefier (HRL) plant being developed at Gandhinagar, Gujarat, for tokamak application**,** has been successfully operated in Mar-2022 down to 4.5 K in refrigeration mode. This plant has design target of 200 watt refrigeration at 4.5 K and it has 7 heat exchangers, 3 helium turbines and one helium compressor. It was originally designed for the refrigeration mode operation, but certain plan was kept to include, later, the LHe extraction provision and operation in liquefaction mode. Considering shortage of helium gas inventory, a closed-loop helium extraction, heating to 300 K and feeding back to compressor suction have been implemented. For that, certain piping layout, cryogenic valves and safety valves have been included inside the cold box of the indigenous plant. A bigger LHe chamber has been included inside the cold box. LHe transfer line has been developed to transfer liquid from the cold box to the liquid helium Dewar, which is also developed in-house. This Dewar includes temperature sensor, superconducting level meter and provision for continuous helium vapour flow to an atmospheric heat exchanger. At the outlet of this heat exchanger helium will be at about 300 K, which is fed to the compressor suction to be reused in the cold box. It has a helium flow meter, which can show the flow rate, same as the LHe transferred from the LHe chamber of the cold box. This will provide continuous measurement of liquid helium production rate of IPR indigenous plant. The details of these will be presented in this paper.

Overview of Electrical Power Network of the 1MW, 170GHz, 3600s ITER-India Gyrotron Test Facility

E. Sharan Dilip#, Vipal Rathod, Ronak Shah, Shk Madeena Valli, Rajvi Parmar, Deepak Mandge, Amit Yadav, Anjali Sharma, N.P. Singh and S.L. Rao

ITER-India, Institute for Plasma Research, Bhat, Gandhinagar-382 428, Gujarat, India

E-mail: #sharan.dilip@iterindia.in

Abstract

ITER-India, the Indian domestic agency for the ITER project, has the responsibility to supply a set of two high-power gyrotron sources (1 MW, 170 GHz, 3600 s) along with the auxiliary systems for Electron Cyclotron Heating & Current Drive applications. One of the challenging areas for such high-power Gyrotron systems is the system integration and the establishment of reliable integrated system performance. ITER-India plans to establish the integrated Gyrotron system performance that essentially meets the ITER requirements in a Gyrotron Test Facility that is specifically being developed at ITER-India. To facilitate the integrated system testing of megawatt class Gyrotron RF sources, ITER-India is developing a Gyrotron Test Facility (IIGTF). Because these Gyrotron RF sources will be operating at high power and long pulse, various critical and non-critical components will need to be powered in order for the RF sources rated at 1MW and 170 GHz to operate continuously and reliably.

This paper discusses the recent updates towards the consolidation of high voltage power interfaces of the electrical power network for the necessary auxiliaries of the various assemblies for the 1MW and 170 GHz Gyrotron at the L3 level, such as the Main High Voltage Power Supply (MHVPS), Ignitron Based Crowbar, Current Limiting Resistance Units (CLRs), High Voltage Measurement Pedestal, and Body Power Supply (BPS). and supplying dependable and uninterruptible power to critical systems such as the LCU system, control racks (PXIe & PLC), CIM Protection, and Arc Detectors. Additionally, auxiliary power supplies for electromagnets (Gun Coil, Collector-Coil-DC & Sweep) and super-conducting magnet, along with Ion-Pump Power Supplies, various mechanical and electrical utilities, etc., will also be discussed.

References:

[1] S.L. RAO et al., Fusion Science & Technology, 65, 129-144 (2014)
[2] V. RATHOD et al., Fusion Eng. Des., 112, 897-905 (2016)

Python based data-analysis utility for Non-Neutral Plasma experiment: SMARTEX-C

Manisha Bhandarkar[1], Imran Mansuri[1], Lavkesh Lachhvani[1], Nikhil Mohurle[1,3], Yogesh G. Yeloe[1],Manu Bajpai[1], Sambaran Pahari[2], Kirti Mahajan[1], Prabal K. Chattopadhyay[1,3]

[1]Institute for Plasma Research, HBNI, Gandhinagar-382428, India
[2]Bhabha Atomic Research Centre, HBNI, Visakhapatnam-530012, India
[3]Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094,India

E-mail: manisha@ipr.res.in

Abstract

Python based utility has been developed for data analysis of raw signals acquired from multiple pressure sensors, voltage pulses applied on various electrodes, signal conditioned data from various plasma diagnostics i.e. capacitive probes, diocotron launch, and charge-collector. It gathers basic information of Non-Neutral Plasma shot of SMARTEX-C device from log-file generated by LabView® code developed for PXI based data-acquisition system. It has the set parameters of FPGAbased trigger-control system, experimental configuration and data-acquisition system. The utility analyses and obtains DC parameters of plasma shot, frequency and amplitude versus time from capacitive probe diagnostics, total stored charge from charge collector diagnostics and finds the launch frequency when diocotron wave is launched in the plasma. This utility eliminates the usage ofthe costly professional software licenses for data analysis.

3D Plasma transport equilibrium study in the inboard limited Aditya-Upgrade Scrape-off layer

Arzoo Malwal[1,3], Bibhu Prasad Sahoo[2], Devendra Sharma[1,3]

[1]Institute for Plasma Research,Bhat, Gandhinagar, Gujarat 382428,
[2]Bhubaneshwar College of Engineering, Khajuria, Jankia, Khurda, Odisha
[3]Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India
E-mail : arzoo.malwal@ipr.res.com

Abstract

Tokamak plasmas have been observed to spontaneously rotate toroidally even in absence of an external momentum source. Understanding of origin and nature of intrinsic toroidal rotation is important for future fusion devices. The experimental and theoretical research mostly focuses on toroidal rotation inside the last closed flux surface. There is strong experimental evidence for the role of the SOL in determining core rotation profiles [1].
The 3D coupled plasma neutral Monte-Carlo simulation code EMC3-EIRENE [2] is being used to study plasma transport and rotation in the SOL. First 3D simulations of inboard limited Aditya-Upgrade SOL plasma are performed and reported in this work. The 3D plasma flow characteristics show a set of mutually counter-propagating sonic flows to the toroidally inboard targets in the near and far SOL regions of plasma. These flows are present with larger anomalous diffusivity and higher toroidal magnetic fields and lead to plasma rotation. Results suggest that the equilibrium E x B flow, the sheath physics and the presence of poloidal asymmetries in the pressure profile act as sources of parallel flow and turbulence provide the mechanism for the radial momentum transport [4]. The results from the first 3D simulation setup for the inboard limiter configuration will be discussed.

References:

[1] B. LaBombard *et al* 2004 *Nucl. Fusion* **44** 1047
[2] FENG, Y., SARDEI, F., KISSLINGER, J., 3D fluid modelling of the edge plasma by means of a Monte Carlo technique, J. Nucl. Mater. 266-269, (1999) 81
[3] SAHOO, B. P., SHARMA, D., JHA, R., FENG, Y., Flow structure and shear generation in the 3D SOL of a circular tokamak plasma in Aditya, Nucl. Fusion 55, (2015) 063042
[4] Phys. Plasmas 21, 062309 (2014); https://doi.org/10.1063/1.4883498

Plasma Diagnostics

Third Harmonic Generation by Nonlinear Interaction of Gaussian Laser Beam with an Array of Magnetized Anharmonic Carbon Nanotubes

Shivani Vij

Department of Applied Sciences,
DAV Institute of Engineering & Technology, Jalandhar-144008, India

*Email: svij25@yahoo.co.in

Abstract

Third harmonic generation in the nonlinear interaction of a modulated laser beam with an array of vertically aligned carbon nanotubes (CNTs) is studied. An electrostatic force of intense ultra-short laser pulse displaces the electrons of CNTs. Due to the nano-scaled dimensions of CNTs, this displacement is comparable to the radius of their electrons and hence the restoring force experienced by the electrons becomes nonlinear function of the displacement. As a result, the large resonance absorption of the laser by the electrons of CNTs occurs and plasmon resonance is broadened. The power conversion efficiency of harmonic generation increases significantly due to the anharmonicity of CNTs. The effect of an externally applied magnetic field is to significantly enhance the amplitude of the generated third harmonic.

Key Words: Third Harmonic Generation, CNTs, Anharmonicity

Initial results of the Laser Heated Emissive Probes in the Aditya-U glow discharge plasma

Abha Kanik[1], Joydeep Ghosh[2], Arun Sarma[1,3], Kalpesh Galodiya[2], Laxmikanta Pradhan[2], Ankit Patel[2], Minsha Shah[2], Kaushlender Singh[2,4], Bharat Hegde[2], Tanmay Macwan[2,4], Sharvil Patel[5], R. L. Tanna[2], Kumarpal Jadeja[2], Ankit Kumar[2,4], Ashok Kumar[2], Santosh Dubey[1], Suman Aich[2], Rohit Kumar[2], Kaushal Patel[2], and ADITYA-U Team[2]

[1]*UPES, University of Petroleum and Energy Studies, Bidoli, Uttrakhand-248007*
[2]*Institute for Plasma Research, Near Indira Bridge, Gandhinagar District, Gujarat-382428*
[3]*NECTAR, 2nd Floor Viswakarma Bhawan, Shaheed Jeet Marg, New Delhi 110016, India*
[4]*Homi Bhabha National Institute, Mumbai, Maharashtra-400094*
[5]*Pandit Deendayal Energy University, Knowledge corridor, Gandhinagar, Gujarat-382007*

E-mail: abhakanik@institute.com

Abstract

Laser Heated Emissive Probes [LHEP] are an excellent diagnostic tool in terms of robustness and accuracy to measure the plasma parameters. The inherit construction of the LHEP eliminates the very drawbacks of the conventional emissive probes, which, otherwise gives the direct measurement of the plasma potential. Although advantageous but LHEP's are not very popular in the high density high temperature plasmas like that of fusion grade machines. A novel experimental arrangement with the aim to directly measure plasma potential in the edge region of Aditya-U tokamak was designed, fabricated and installed for the very first time. Two circular Graphite probes of 6 mm diameter each, separated by ~15 mm and located at same radial but different poloidal and toroidal location are used as LHEP probe tips. The Graphite probe tip is heated with a CO_2 laser of 10.6 μm wavelength at variable output power. In this paper we report the successful operation of the system in both hot mode and cold mode in the glow discharge plasma of the Aditya-U. Probe is biased with respect to the plasma potential and V-I characteristics are recorded for different probe temperatures to ascertain the constant emission region of the probe. We present the studies for the estimation of the plasma parameters using the recorded measurements in the edge region of the tokamak.

A STUDY OF EMPIRICAL RELATION FOR OBSERVED CORE ION TEMPERATURE WITH OTHER OPERATIONAL PARAMETERS OF ADITYA PLASMA DISCHARGES

Kumar Ajay, Snehlata Aggarwal, Santosh P. Pandya and Aditya Team

Institute for Plasma Research, Bhat Village, Gandhinagar-382428(Gujarat)

E-mail: ajaykuma@ipr.res.in

Abstract

Neutral particle Analyzer based Charge exchange diagnostics (CX-NPA) has been routinely operated during plasma discharges in Aditya tokamak [1]. The diagnostics has measured the core ion temperature for more than 500 plasma discharges and the reported plasma core ion temperature was in the range of 100 eV to 300 eV (measured during plasma ohmic heating as well as with ICRH assisted heating) with a time resolution of 10 ms at flat-top regime of plasma current[2]. The accuracies of such experimentally measured core ion temperature has been mostly within 30%.

We have attempted to observe a trend of measured core ion temperature with the reported central electron temperature and plasma density of Aditya in these many observations during the operation of CX-NPA. In this paper we report an empirical relation of observed Core ion temperature of plasma with the central electron density and the average plasma ion density.

References:

[1] Experimental Results of Core Ion Temperature and Neutral Density Measurements on ADITYA Tokamak using Four Channels Neutral Particle Analyzer, Journal of Fusion Energy, volume **39**, p 111–121 (2020)

[2] Core-Ion Temperature Measurement using Passive Charge Exchange Neutral Particle Energy Analyzer for the ADITYA tokamak", Review of Scientific Instrument, **84(2)**, p023503, (2013)

Design, Simulation, Testing & Installation of Wave Collection and Transport System for Michelson Interferometer Diagnostic at SST-1 Tokamak

*Abhishek Sinha[1], Sonam Sharma[2] and S. K. Pathak[1]

[1]*Institute for Plasma Research, HBNI, Bhat, Gandhinagar*
[2]*L D Engineering College, Ahmedabad*

abhishek@ipr.res.in*

Abstract

A Wave Collection and Transport System (WCTS) to transport the electromagnetic waves from SST-1 tokamak to Michelson interferometer (MI) diagnostic has been designed and simulated using the CST Microwave Studio. Operating frequency range of the MI diagnostic is 70-500 GHz. To reduce propagation losses oversized waveguides (WR-284) were selected over the fundamental waveguides. Oversized waveguides also reduce group delay of propagating wave in waveguides. To further reduce propagation loss, waves were transported in TE-01 mode instead of TE-10 mode in the oversized WCTS. The primary components of oversized WCTS are waveguides and miter bends in E and H planes which carry microwave energy and Wire-grid Polarizer (WGP) to choose the polarization of EM waves from the plasma. To avoid mode conversation linear transitions from WR-284 to WR-90 were utilized The overall losses of the system reduce significantly on using oversized waveguides while introduction of higher order modes is a major drawback of using oversized waveguides. In the SST-1 tokamak, the Michelson Interferometer diagnostic system consists of X-mode channels operating in the frequency range of 70-500 GHz and probing the plasma from edge to the core. The main purpose of the system is to measure the electron temperature profile for SST-1 Tokamak. In SST-1, through port no 12 which is quartz window of 150cf flange is used for the MI diagnostics.

References

[1] A. E. Costly, Proceedings from the Course on Diagnostics for Fusion Reactor Conditions, Varenna, Italy, 1982, Vol. 1, p. 129.

[2] D. A. Boyd, Applied Atomic Collision Physics ~Academic, New York, 1984, Vol. 2, p. 227.

[3] D. H. Martin and E. Puplett, Infrared Phys. 10, 105 (1969).

FIRST RESULT OF THOMSON SCATTERING DIAGNOSTICS ON SST – 1

Neh Singh, Vishnu Chaudhari, Pabitra Kumar Mishra, Kiran Patel, Jinto Thomas and Hem Chandra Joshi

Institute for Plasma Research

neha.singh@ipr.res.in

Abstract

Vertical Thomson scattering (VTS) system is designed to measure electron density (n_e) and temperature (T_e) profiles along the vertical chord (R= 1070 mm) in SST – 1 tokamak. SST-1 VTS system was designed with six Q-switched Nd: YAG (yttrium aluminium garnet) lasers (wavelength 1064 nm), multipoint imaging system (magnification: 0.2; numerical aperture (NA): 0.2) for collecting scattered photons and a five channel interference filter polychromator for spectral dispersion and avalanche photo diodes (APDs) for detection[1,2].

The VTS system with 10 spatial points at 30 Hz repetition rate has been successfully commissioned in SST-1. The system is completely calibrated for the wavelength response using standard pulsed white light source. In addition to the spectral calibration, the system is in situ calibrated for electron density measurement using Raman scattering of N_2 gas. The completely calibrated VTS is operational in SST-1. Data from different calibrations were analysed. First results obtained from the TS system in SST-1 will be discussed in this presentation.

References:

[1] **Design of multipulse Thomson scattering diagnostic for SST-1 tokamak Ajai Kumar et al**
Review of Scientific Instruments **78**, 043507 (2007); https://doi.org/10.1063/1.2724775

[2] Design and development of five-channel interference filter polychromator for SST-1 Thomson scattering system, Jinto Thomas et. al., Fusion Engineering and Design Volume 87, Issue 2, February 2012, Pages 134-140

The Simulation Of Line Profile Of C^{5+} Impurity Ions Emission Influenced By Zeeman Effect In ADITYA-U Tokamak

Abhishek B[1], J. Ghosh[2], M. B. Chowdhuri[2], Sripathi Punchithaya K[1], N. Yadava[3], K. A. Jadeja[2], R. L. Tanna[2] and Aditya-U Team[2].

[1]*Manipal Institute of Technology, Manipal, Karnataka, 576104.*
[2]*Institute for Plasma Research, Bhat, Gandhinagar, 382428.*
[3]*Institute of Science, Nirma University, Ahmedabad, 382481.*

E-mail: abhishekbelmannu@gmail.com

Abstract

In a tokamak, the impurity ion plays an important role in plasma confinement and control. The ion temperature is one of the most critical parameters in a tokamak as it is directly related to fusion reactions in fusion-grade devices like ITER. Hence its accurate measurement is essential for the experimentation on the enhancement of plasma parameters in a tokamak. The temperature of the ion species can be obtained by applying the Doppler broadening effect to the tokamak plasma. However, to get an accurate estimate of ion temperature, the Zeeman Effect must be considered, as the tokamak has a large toroidal magnetic field. Nowadays, ion temperature is mainly measured by monitoring charge exchange lines in the visible range using a visible spectrometer and a X-ray line by crystal spectrometer. The ion temperature profile in the core region of small and medium-sized tokamaks can also be measured by C^{5+} passive charge-exchange line, as graphite is the primary plasma-facing component in the tokamak.

In ADITYA-U tokamak, the magnetic field is sufficiently high to produce a shift in energy levels due to the Zeeman Effect. Hence the spectral line shape profile acquired through spectroscopic arrangement is the combination of the effect of the Doppler broadening and broadening due to the Zeeman Effect and instrumental function of the spectrometers. This paper presents the simulation of the spectral line shape of C^{5+} emission line at 529 nm (transition n = 7-8). In this simulation, all the Zeeman components are estimated and subsequently incorporated into the MATLAB program along with Doppler and Instrumental broadenings. Further in the paper, the line shape profiles are analyzed for several changing field strengths. Finally, the initial estimation of the accurate ion temperature of C^{5+} ion is also presented.

Simulation of Hard X-ray Spectrum for ADITYA limiter plasma using Geant4

K. Garg[1*], S. Purohit[1,2*], V. Ranga[3], M.K. Gupta[1], J. Ghosh[1,2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat, India*
[2]*Homi Bhaba National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India*
[3]*Indian Institute of Technology Rurkee,Uttarakhand,-247667, India*

E-mail*: kajal.garg@ipr.res.in/ pshishir@ipr.res.in

Abstract

Hard X-ray (HX) is mostly emitted by runaway electrons (RE) from the plasma volume hence the ADITYA tokamak plasma is also a wide band X-ray source with a large volume confined within a metal vessel. The X-ray measurements from a wide band source have a substantial Compton scattering probability within the X-ray detector, especially at higher energies. To measure the HX spectrum a spectroscopic diagnostic based on a LaBr3 (1.5 inch x1.5 inch) detector has been installed in ADITYA tokamak1. The experimental geometry adopts a tangential viewing single channel LaBr3 detector, where the line of sight is along the circular limiter and field of view contains the circular limiter. Experimental quantification of Compton cross-section is almost impossible. It can be understood with the help of simulation only, so for the first time Geant4, which is used in both nuclear physics experiments and space-bound physics experiments, has been used to analyses the geometry of the ADITYA circular limiter plasma and X-ray spectrum using the LaBr3 HX detector. The abstract presents an attempt for the realization of the Compton contribution via photon-detector simulation considering Geant4 platform2. The simulation is designed to produce an integrated HX spectrum that takes into account all possible HX and detector interactions. The emphasis has been given majorly to photoelectric and Compton scattering process. The simulation was performed for the flux of 105 particles having 5 MeV energy, and the carbon limiter was used as the sole X-ray source. The Geant4 procedure is develop for the separate realization of Compton scattering spectra as well as the photoelectric3.

References:

1. S. Purohit *et al. JINST* **15** P08015 (2020).
2. S. Agostinelli et al., Nucl. Instrum. Meth. A 506 (2003) 250-303.
3. S. Chauvie et al. Proceedings of Computing In High Energy Physics, Beijing (2001).

Identification of edge in tokamak plasma using visible imaging in ADITYA-U

S. Aich[1*], S. Patel[3], J. Ghosh[1,2], L.K. Pradhan[1], N. Yadava[4], N. Nimavat[1], P. Shrivastava[1], R.L. Tanna[1,4], M.B. Chowdhury[1], K. Singh[1,2], S. Dolui[1,2], A. Kumar[1,2], B. Hegde[1,2], A. Kumawat[1,2], K.A. Jadeja[1,5], K.M. Patel[1], H. Raj[1], A. Patel[1], R. Kumar[1] and ADITYA-U team

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382 428*
[2]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400 094*
[3]*Department of Physics, Pandit Deendayal Energy University, Raisan, Gandhinagar 382 00*
[4]*Institute of Science, Nirma University, Ahmedabad 382 481*
[5]*Department of Nano Science and Advanced Materials, Saurashtra University, Rajkot 360 005*

E-mail: suman.aich@ipr.res.in

Abstract

The interaction of plasma with plasma facing components (PFC) and vacuum vessel wall in a tokamak plays a vital role in terms of successful plasma operation. So, the estimation of column boundary is impactful for diagnosing a tokamak plasma. The positional estimation of the plasma column, which is done by means of magnetic and optical measurements, gives an overall idea of plasma centroid, though the complete picture of plasma boundary still remains incomplete, until and unless the edges are estimated explicitly. A visible radiation due to the interaction of plasma with PFC provides an opportunity to identify the edge regions. ADITYA-U is being operated with circular plasmas and also has started operation with shaped plasma using diverter configuration. Thus, the estimation of plasma shape has a tremendous importance towards the successful plasma operations in near future. ADITYA-U has a visible fast imaging camera that records the plasma discharges in a grey scale. The total intensity, captured by each frame, is contributed by all possible radiations in the visible range that majorly includes the H-Alpha radiation. In addition to that, there must be a finite fraction, may be even in negligible amount, which is contributed by the excited Carbon atoms. The presence of C ions is very obvious because of the graphite based limiters and diverter tiles and the corresponding radiations are expected to come from a localised boundary region, denser at the vicinity of C-plate, due to less temperature at plasma surface than the core regime. The majority of the captured intensity is radiated by H-Alpha and this radiation expands the edge region starting from SOL to some extent of depth inside the plasma column, making the edge region a blur zone, instead of a sharp edge. To have a better identification of plasma edge, tracking CIII radiations (~ 4647 Angstrom) is a promising method [1]. In this work, a technique is developed by the use of a C-filter in front of the visible camera that makes the camera enable to capture the radiation due to CIII excitations and hence identify the plasma boundary directly.

References:

[1] Chunfeng Dong *et al*, *Physics Of Plasmas*, **18**, 082511 (2011)

Postmortem Analysis Of Coatings On Viewport Of SST-1 Using LIBS And Microraman Technique

Pabitra Kumar Mishra*, Neha Singh, Jinto Thomas, and Hem Chandra Joshi

Institute for Plasma Research, Bhat, Gandhinagar, Guajrat-382428, India

E-mail : *pkmishra@ipr.res.in

Abstract

Plasma wall interaction, during a tokamak discharge, plays an important role in the operation of fusion device and leads to erosion of plasma facing components. The re-deposition of the material released from the plasma facing components (PFC's) on the view port can deteriorate optical transmittance and hence spectral responsivity. Recently there has been increased interest in the post mortem analysis of PFC's and other components for identifying the deposited elements and understanding the nature of the coatings etc. [1, 2]

In the present work, we report laser induced breakdown spectroscopy (LIBS) and micro-Raman study performed on the view ports from SST-1. For LIBS, an Nd-YAG laser at 1064 nm is used for ablation and a high resolution fiber spectrometer is used to record the emission spectra. LIBS spectra of the coatings on view port are compared with that from the original PFC material. In addition to the emission from carbon, substantial amount of non-carbon emission lines are also observed which are identified as Fe lines. The morphology of view port coating is studied using micro Raman analysis using a modular confocal micro-Raman system from Horiba, with 532nm laser. The micro-Raman spectral analysis shows that the coating is due to amorphous carbon.

Optical Grayness factor and its effect on Electron Cyclotron Emission measurements during transient and steady state conditions.

Varsha Siju[1, 2], and SK Pathak[1, 2]

[1]Institute for Plasma Research, Gandhinagar-382428, Gujarat, India
[3]Homi Bhabha National Institute, Anushaktinagar-400094, Mumbai, India

varsha@ipr.res.in

Abstract

Determination of spatially resolved temperature information by measuring the Electron Cyclotron Emission (ECE) spectrum requires optically thick plasma that follows certain requirements for steady state plasma1-5. However, this transformation of emitted radiation into thermal temperature is not that straightforward for plasmas that have small optical depth.6,7 The optical grayness factor satisfies the corrections required for thermal measurements in that case.

Under transient conditions, this factor gets further modified including the effect of perturbations in Te and ne. Also, vessel wall reflectivity alters this factor. This report explores the effects of such steady state as well as transient conditions including the effects of reflectivity and perturbed Te and ne variations. Corrections on the optical grayness factor due to these perturbations and further their effect on measurement of Te through ECE is also explored.

References:

1. J.F.M.VanGelder, PhD. Thesis, Proefschirft University, Netherlands. (1996)
2. X.Han, et.al.,Rev.ofSci.instrum 85,(2014).
3. Varsha siju, et.al.,JINST, (2021).
4. Y. Liu et al JINST 17 C04019 (2022)
5. G.Taylor, et.al. EPJ Web of Conferences 147, 02003 (2017)
6. C.Janicki, Nucl.Fusion 33 (1993) 513.
7. M.Peters et.al., Nucl.Fusion 35 (1995) 873.

Sheet current generation in short pulse laser interaction with a linear array of gold nanorods

Nivedya Krishnan[1], Ashok Kumar[1], Gagan Kumar[2]

[1]*Amity Institute Of Applied Sciences, Amity University, Noida-201301*
[2]*Indian Institute Of Technology Guwahati, Guwahati, Assam- 781039*

E-mail: nivedyakrishnan97@gmail.com

Abstract

We investigate the guided particle acceleration scheme on a sheet of four gold nanorods placed parallel to each other, irradiated by high intensity laser pulse as a precursor to produce neutral atoms. It has been demonstrated that parallel gold nanorods with deuterium nanoparticles dispersed between can guide the acceleration [1-2] of nanoparticles. Using the ponderomotive force, high state ionization of gold atoms expels the free electrons [3]. The charged nanorod possess electric field that is axially outward and transversely oriented towards the axis of symmetry [4]. The nanoparticles are therefore restricted transversely and accelerated axially. By using this method, a deuterium beam with a few MeV of energy can be created. The beam can be neutralized, and a beam of neutral atoms can be generated.

References :

[1] J. W. Wang *et al.*, "Generation of quasi-monoenergetic carbon ions accelerated parallel to the plane of a sandwich target," *Physics of Plasmas*, vol. 21, no. 12, p. 123103, Dec. 2014, doi: 10.1063/1.4903327.

[2] S. N. Chen *et al.*, "Focusing Dynamics of High-Energy Density, Laser-Driven Ion Beams," *Phys. Rev. Lett.*, vol. 108, no. 5, p. 055001, Jan. 2012, doi: 10.1103/physrevlett.108.055001.

[3] M. Murakami and K. Mima, "Efficient generation of quasimonoenergetic ions by Coulomb explosions of optimized nanostructured clusters," *Physics of Plasmas*, vol. 16, no. 10, p. 103108, Oct. 2009, doi: 10.1063/1.3256183.

[4] M. Yadav, A. Kumar, and S. Mandal, "Guided acceleration of nanoparticles by laser irradiated parallel gold nanorods," *Plasma Research Express*, vol. 3, no. 4, p. 045005, Dec. 2021, doi: 10.1088/2516-1067/AC3FA3.

Study Of Instability in Low Pressure Plasma Generated By The Pulsed Washer Gun Inside A Curved Vacuum Chamber

[1]P Das, [1]R Paikaray, [1]B K Sethy, [2]R K Barad, [3]S Samantaray, [4]G Sahoo, [5]A K Sanyasi, [5]J Ghosh

[1]Department of Physics, Ravenshaw University, Cuttack, Odisha, 753003
[2]Indian Institute of Geomagnetism, New Panvel, Navi Mumbai, 410218
[3]Department of Physics, Christ College, Cuttack, Odisha, 753008
[4]Department of Physics & Astronomical Science, Central University of Himachal Pradesh, Shahpur Parishar-176206, HP
[5]Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, 382428

E-mail : psdas.c2@gmail.com

Abstract

In this work we have analysed the probe potential obtained by a single Langmuir probe from the pulsed washer gun plasma in a Compact Plasma System (CPS)[1]. The pulsed argon plasma is generated by applying a voltage pulse of 1.2 kV with pulse width ~ 140 µs from the Pulse Forming Network (PFN) across the washer gun at base pressure 0.2 mbar. The potential signals are recorded by a digital storage oscilloscope with biasing the Langmuir probe at voltages varying form +1.5 V to +20 V within an interval of 1.5 V. All the signals are taken by keeping the probe at a distance of 0.1 m from the gun mouth. The voltage profile is then subjected to FFT analysis for investigation of the instability present in the pulse washer gun plasma.

References :

[1] G Sahoo, et al., A compact plasma system (CPS) for experimental study, Applied Mechanics and Materials, **278-280**, p. 90-100, (2013)

Development of an algorithm for the Inversion of Line Integrated

Emissivity Measurements from Tokamak Plasma

Vinit Pandya[1], Kumudni Tahiliani[2], Santosh Pandya[2,] and Surya Kumar Pathak[2,3]
[1]*Sardar Vallabhbhai National Institute of Technology, Dept. Of Physics, Surat - 395007*
[2]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382428*
[3]*Homi Bhabha National Institute (HBNI), Anushaktinagar, Mumbai-400094*
E-mail:kumud@ipr.res.in

Abstract

Radiation emission distribution in plasma is obtained by the inversion of line-integrated emissivity using tomography algorithms. The ill-posed nature of the tomography combined with the limited number of lines of sight and viewing angles in magnetic fusion experiments (MFE) makes the inversion challenging. Methods that can incorporate a-priori information therefore are preferred. In the present work, Minimum Fisher Information (MFI) regularization [1] has been used to deduce the phantom radiation emissivity profiles from AXUV bolometer diagnostics [2]. Multiple detectors in a fan camera geometry that view the plasma from two different angles are employed to measure this local emissivity value. Steady state cooling rates of impurities namely carbon, oxygen and iron [3] were used for generating the radiation phantoms and synthetic bolometer signals were inverted to yield local emissivity values. The radiation emissivity is circularly symmetric in most cases but exhibits radial and poloidal asymmetries due to plasma instabilities and interaction of plasma with plasma facing components. Both these cases were incorporated in the code. The developed code successfully reconstructs the synthetic emissivity profiles with a marginal deviation.

References :
[1]X-ray tomography on the TCV tokamak, M.Anton, H. Weisen et al, Plasma Phys. Control. Fusion, 38, 1849 (1996)
[2] Radiation power measurement on the Aditya tokamak, Kumudni Tahiliani, Ratneshwar Jha et.al., Plasma Phys. Control. Fusion, 51(8),85004 (2009)
[3] Steady state radiative cooling rates for low density high-temperature plasmas, D.E.Post and R.V. Jensen, Nucl. Fusion 17 1187 (1977)

Design and Testing of Thermo-electric Cooler Controller for Detection sub-

system of Thomson Scattering Diagnostic

Vishnu Chaudhari[1], Neha Singh, Pabitra Mishra and Jinto Thomas[1]

[1] *Institute for Plasma Research, Bhat, Gandhinagar, Guajrat-382428, India*

vjat@ipr.res.in

Abstract

Thomson scattering (TS) diagnostic [1, 2] is used to measure plasma electron temperature and density of Tokamak. Most of the operational TS system uses avalanche photo-diode (APD) to detect the low-intensity Thomson scattered photons. The detection efficiency of the APD depends on reverse biasing voltage and the temperature of the APD. Variations in ambient temperature significantly affect the gain and detection efficiency. Hence, maintaining the junction temperature constant is an important aspect of Thomson scattering measurement. The APD used for SST-1 TS (S8890, Hamamatsu) has an in-built Thermo-electric cooler. A thermo-electric cooler controller (TECC) is procured to control the temperature of the APD. The TECC operates in fixed resistor temperature mode as well as programmable voltage mode. The ATMEGA32 micro-controller-based electronics (TECE) is designed and developed to control the APD temperature using TEC and TECC. A LabVIEW-based graphical user interface (GUI) is developed for easy operation of TECE during the plasma operation and calibration. Details about TECE and its performance are reported in this article.

References:

[1] Design and development of five channel interference filter polychromators for SST-1 Thomson scattering system.
Jinto Thomas and et al., Fusion Engineering and Design (2011))
[2] Design of multipulse Thomson scattering diagnostic for SST-1 tokamak Ajai Kumar et al Review of Scientific Instruments **78**, 043507 (2007); https://doi.org/10.1063/1.2724775

Development of an Alignment System for ITER-CXRS-Pedestal

Diagnostics

Abha Maheshwari, Gheesa L Vyas, Bharathi Magesh, Hitesh K Pandya

ITER-India, IPR, Bhat, Gandhinagar-382428

abha.maheshwari@iterindia.in

Abstract

IN-DA is developing a Charge eXanchage Recombination Spectroscopy diagnostics system (ITER-CXRS-P) for the measurement of ion temperature and plasma rotation in the pedestal region of ITER plasma. ITER-CXRS-P system is designed to view the Diagnostics Neutral Beam (DNB) - Plasma interaction zone in the pedestal region. The plasma emissions are collected by a light collection system (LCS), constituting a combination of optical components (Mirrors and lenses) and then transported to the ITER-CXRS-P spectrometer via optical fiber bundle assembly (FBA).

When the image captured by this LCS are demagnified and transmitted through FBA, the image plane might get distorted or misaligned due to the manufacturing, assembly and operational tolerances of DNB geometry, collection optics and other mechanical components. Hence, a motorized alignment system with four degrees of freedom is designed to compensate these deviations and to align the fiber bundle head (FBH) with the plasma image. For obtaining the design requirements of this system, a detailed assessment on the possible deviations in the image, considering the worst-case scenarios was carried out. Additionally, this design will be made in such a way that it will withstand ITER's harsh environment and will also be operated remotely.

In this work, the details of the required movements and compatibility with environment is presented.

Upgradation Of Diamagnetic Diagnostics On SST-1

Sameer Kumar, Kumudni Tahiliani, Praveen Lal Eduppa, Suresh I, Yuvakiran Devaraj Paravastu, Surya Kumar Pathak, Daniel Raju and SST-1 Team
Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, India,382421

E-mai:skjha@ipr.res.in

Abstract

Confined thermal energy of tokamak plasma is estimated from diamagnetic flux (δφ) measurements. For typical SST-1 plasma parameters, β_p = 0.5, I_P= 60 -100 kA and B_T = 1.5 T, the diamagnetic flux is estimated to be 0.075 - 0.2 mWb. This flux is measured by the diamagnetic loop that encircles the plasma column. The output of this loop is equal to the time rate of change of diamagnetic flux and must be higher than the electronics noise. The number of turns of diamagnetic loop has been increased in order to obtain a high signal to noise ratio. For a 100 ms rise time of δφ, output will be ≥5 mV. The loops will be equipped with a new electronics which will be capable of detecting signal of lower amplitude. A compensating loop is also installed around the plasma column to measure the vacuum toroidal flux. The compensating loop signal is used to remove the contribution of vacuum toroidal flux from the diamagnetic loop signal. Both diamagnetic and compensating loops are placed in the same enclosure. The paper reports the detailed design, fabrication and installation of the diamagnetic loop system.

References:

[1] Sameer Kumar, Ratneshwar Jha , Praveen Lal, Chandresh Hansaliya , M. V. Gopalkrishna, Sanjay Kulkarni and Kishore Mishra , Rev. Sci. Instrum. **81,** 123505 (2010)
[2]. S. K. Saha, R. Kumar, and A. K. Hui, Rev. Sci. Instrum. **72**, 4289 (2001).

Determination Of Electron Temperature Of A Pulsed Washer Gun Plasma

Using Triple Langmuir Probe

[1]B K Sethy, [1]R Paikaray, [1]P Das, [2]S Samantaray, [3]G Sahoo, [4]A K Sanyasi, [4]J Ghosh

[1]Department of Physics, Ravenshaw University, Cuttack, Odisha, 753003
[2]Department of Physics, Christ College, Cuttack, Odisha, 753008
[3]Department of Physics & Astronomical Science, Central University of Himachal Pradesh, Shahpur Parishar-176206, HP
[4]Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, 382428

E-mail : bipinkumarsethy@gmail.com

Abstract

In our system we are doing experiments related to understanding the mechanism of ejection of plasma blobs [1] from the main plasma structure. A voltage pulse of width ~140 μs with discharge potential of 1.2 kV form a Pulse Forming Network (PFN) is applied to washer gun to generate the pulsed argon plasma inside the curved vacuum chamber. In this work we have introduced a triple Langmuir probe for the determination of electron temperature of pulsed argon plasma. Triple probe of pure tungsten material with appropriate circuit is designed and fabricated in our laboratory which is the most advanced method for measurement of plasma parameters like temperature and density of plasma. It does not require any voltage, frequency sweeps, or switching [2]. The triple probe signal is recorded by a digital storage oscilloscope at the distance of 0.05 m from the gun mouth.

References :

[1] C Theiler, I Furno, P Ricci, A Fasoli, B Labit, S H Muller, G Plyushchev, Cross-field motion of plasma blobs in an open magnetic field line configuration, Phy. Rev. Lett.,**103**, p. 065001-4, (2009)
[2] Chen and T Sekiguchi, Instantaneous direct display system of plasma parameters by means of triple probe, J. Appl. Phy., **36**, p. 23363-2375, (1965)

Behavioral Modeling of High Temperature Plasma Diagnostic Plant I&C

System

Shivakant Jha[1], Gheesa Vyas[1], Nidhi Mehra[3], Sriprakash Verma[1], Hitesh Pandya[1,2]

[1]ITER-India, Institute for Plasma Research, Ahmedabad-38005
[2]Homi Bhabha National Institute (HBNI) Anushaktinagar, Mumbai – 400094 India
[3]Devi Ahilya Vishwavidyalaya (DAVV), Indore - 452001

E-mail: shivakant.jha@iterindia.in

Abstract

The high temperature plasma diagnostic like a Charge Exchange Recombination Spectroscopy diagnostic measures line emission (visible wavelength region) of several low-Z impurities in the tokamak plasma. These usually fully ionized isotopes receive an electron in an excited level due to a charge exchange reaction with neutral hydrogen atoms injected into the plasma by the diagnostic neutral beam. The measured line emission provides ion temperature (Doppler broadening), plasma rotation velocity (Doppler Shift), and impurity density (line emission intensity) for advance plasma control and physics studies of tokamak machine [1]. The line emission measurements require the light collection (mirrors, lenses), transmission (fiber bundles), detection (spectrometer) system, data acquisition and analysis along with their instrumentation & control (I&C) to meet the diagnostic measurement requirements.

Behavioral modeling approach is based on the explicit specifying – Requirements, Use cases, procedure, functions, variables and states for diagnostic system sub-components (like - spectrometer, calibration and fiber baking), analyzing, verifying complex diagnostic system that include hardware, software, personnel and information about functioning and directionality of evolution of whole diagnostic plant I&C system using Unified Modeling Language (UML).

This paper presents the rationale for a new behavior modeling framework for diagnostic system for system analyzing, designing, verifying and validation of complex system. Identify the most appropriate model parameterization for use case. It has great potential for the software-hardware co-design of the system for further realization of plant system. In this presentation the UML modelling for a diagnostic system shall be discussed.

References:

[1] Dan M. Thomas 'Physics of Plasmas 19', 056118 (2012); doi: 10.1063/1.3699235)

Tangential View Soft X-ray Imaging Diagnostics for Aditya-U Tokamak

A. Adhiya[1,*], M. K. Gupta[1], S. K. Gupta[1], A. Kumar[1], and S. K. Pathak[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382 428, Gujarat, India.*

[*]E-mail: adhiya@ipr.res.in

Abstract

A Soft X-ray (SXR) imaging diagnostics is being developed for capturing tangential views of Aditya-U tokamak plasma. The diagnostics comprises of a scintillator screen followed by a Micro-channel Plate (MCP) with phosphor screen and a high frame rate camera. The scintillator screen will convert the plasma-produced SXR into visible photons which, in turn, will be amplified by a dual stage MCP and corresponding visible images will be formed on a phosphor screen attached to MCP. The high speed video camera can record the images at time interval of ~0.2msec, for full camera resolution of 1 MP. The temporal resolution can be further improved up to few microseconds with a compromise on image resolution. The diagnostics will capture two-dimensional (2D) line-integrated tangential view images of SXR emitted from the core of the tokamak. The captured SXR images in conjunction with the images acquired by visible imaging diagnostics will be useful in plasma monitoring and also for plasma position measurement.

References:

[1] Development of 2D soft X-ray measurement system in the large helical device, Rev. Sci. Instrum., **85**, 11E410 (2014).
[2] Fast Tangentially Viewed Soft X-Ray Imaging System Based on Image Intensifier with Microchannel Plate Detector on QUEST, Plasma Fusion Res., **14,** 1402128 (2019).
[3] High-speed tangentially viewing soft x-ray camera to study magnetohydrodynamic fluctuations in toroidally confined plasmas (invited), Rev. Sci. Instrum., **74**, p 2136 (2003).

Analysis of VUV spectral lines for Investigating Impurity Behaviour in

ADITYA and ADITYA-U Tokamak

Vishal Sharma[1], M. B. Chowdhuri[1], Sharvil Patel[2], Nandini Yadava[3], Nilam Ramaiya[1], Ranjana Manchanda[1], Manish Rathor[1], Rakesh L. Tanna[1,3], Kumarpal A. Jadeja[1,5], Kaushal M. Patel[1], Joydeep Ghosh[1,4], ADITYA[1], and ADITYA-U[1] Team

[1]*Institute for Plasma Research, Gandhinagar 382428, India*
[2]*Pandit Deendayal Energy University, Gandhinagar 382007, India*
[3]*Nirma University, Ahmedabad 382481, India*
[4]*HBNI, Anushakti Nagar, Mumbai 400094, India*
[5]*Saurashtra University, Rajkot 360005, India*

vishalmandhu02@gmail.com

Abstract

In magnetically confined fusion plasma like tokamak and stellarator, contains the fraction of impurities in addition to the bulk main ion. The study of impurities ranging from low – to medium-Z in magnetically confined fusion devices is an active area of ongoing research. Due to plasma-wall interaction, influx of impurities like carbon, oxygen, and iron to the plasma occurs. With presence of these impurities in plasma, due to their higher emissivity and direct contribution to the effective ion charge, can significantly influence the overall plasma confinement. While deliberate injection of gaseous impurities like neon and argon are important regarding study of plasma-wall interaction and heat exhaust.

In ADITYA and ADITYA-U tokamak, the spectral line emission from impurity ions like carbon, oxygen, iron, neon, and argon are regularly monitored using a VUV survey spectrometer. The VUV spectrometer is installed at one of the midplane radial port. The VUV spectrometer has three sets of grating, 290 grooves/mm, 450 grooves/mm, and 2105 grooves/mm covering 10-180 nm, 10-110 nm and 10 – 33 nm respectively. To identify different impurity ions, present in plasma, spectral line identification of the VUV spectrum recorded from all the three grating is carried out. We find spectral emission at 14.92 nm for O^{3+}, 17.16 nm for O^{4+}, 19.10 nm for O^{4+}, 28.17 nm for Fe^{14+}, 33.31 nm for Fe^{15+}, 55.32 nm for O^{3+}, 62.99 nm for O^{4+}, 76.00 nm for O^{4+}, 78.912 nm for O^{3+}, 97.7 nm for C^{2+} and 103.2 nm for O^{5+} in ADITYA and ADITYA-U plasmas. Further, to study and characterize the impurity ion behaviour in different plasma scenarios, parametric variation of these impurity spectral emission with the plasma current, edge safety factor and plasma density is carried out.

Edge Plasma Study using Fast Visible Imaging Diagnostic in Aditya-U

Tokamak

Devilal Kumawat[1], Kumudni Tahiliani[1], Sameer Kumar[1], Suresh I[1], R.L Tanna[1,2], Kaushal M Patel[1], Kumarpalsinh Jadeja[1], Rohit Kumar[1], S.K Pathak[1,3], Joydeep Ghosh[1,3], and Aditya-U Team.

[1]Institute for Plasma Research (IPR), Bhat, Gandhinagar, 382428, India
[2]Institute of Science, Nirma University, Ahmedabad 382 481, Gujarat, India
[3]Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India

E-mail: Devilal.kumawat@ipr.res.in

Abstract

A Fast Visible Imaging Diagnostic (FVID) system [1], measuring the emission spectrum in the visible range (400 nm to 900 nm) from tokamak plasma, is installed on Aditya-U tokamak to monitor the two-dimensional dynamics of the poloidal cross-section of the plasma. The images recorded by a CMOS image sensor-based fast-framing camera at a resolution of 256 x 256 pixels at up to 26 k frames/s (fps) are used to study the periodic oscillations in the edge and core of the plasma. These oscillations observed in the intensity of the individual pixels are further investigated using image processing techniques to study the magnetohydrodynamic instabilities, and oscillating modes [2-3]. Also, observation and study of prominent and frequent large toroidal filaments during the plasma disruptions will be reported in the work.

References:

[1] Devilal Kumawat, Kumudni Tahiliani et.al, article accepted in Review of Scientific Instruments,
RSI22-CF-HTPD2022-01243 (2022)

[2] J. H Yu and M. A Van Zeeland, Review of Scientific Instruments, 79, 10F516 (2008)

[3] T. Jirman, M. Peterka et. al., Energy Procedia 127, 360–368 (2017).10.1016/j.egypro.2017.08.082

PRODUCTION, CHARACTERIZATION AND APPLICATION OF ATMOSPHERIC RECTANGULAR DIELECTRIC BARRIER DISCHARGE IN NEPALI PAPER

Narendra Chaudhary[1], Roshan Chalise[1]

[1]*Department of Physics, Patan Multiple Campus,Tribhuvan University, Patan Dhoka-44600, Nepal.*

E-mail: narentz50@gmail.com

Abstract

This is an experimental work that focuses on the production of atmospheric pressure Dielectric Barrier Discharge (DBD) plasma and its application for the treatment of Nepali paper. An AC power source with a 10 kV potential difference and a 30 kHz frequency is used to produce the plasma. A parallel plate DBD plasma reactor is used for the treatment of the sample under ambient environmental conditions. From the study, the electrical and optical characterization of plasma reveals that most of the plasma constituent is Nitrogen. The average value of excitation temperature of electron calculated using Ratio method and Boltzmann plot method is 5.497eV. The density of the electron is 8.194×10^{14} cm^{-3}.

Nepali paper is basically made from Lokta bark and has many interesting and important uses because of its durability, resistant to insects and moths and non-perishability. Plasma-based technology is an exciting alternative for the surface modification of paper to enhance its properties. The plasma treatment significantly reduces the contact angle of the paper. It's value reduces from 125 degree to about 97 degree on treating the sample for 4 minutes. Which leads the change of hydrophobic surface towards hydrophilic nature. The wicking rate for the treated sample is high compared to the controlled one. The study also shows that the plasma treatment reduces the weight of the sample significantly. The wettability of the sample increases with the treatment time.

References:

[1] Sustainability of Local Hand-made Paper (Nepali Kagat) Enterprises: A Case Study of Dolakha
District**,** JFL, **4**(1), p 1-6 (2004).

[2] The atmospheric pressure plasma jet: a review and comparison to other plasma sources**,** IEEE T
Plasma Sci, **26**(6), p 1685-1694 (1998).

Preliminary Results of Magneto-Optic Current Sensor (MOCS) Diagnostic developed for Plasma Current Measurements in Aditya-U Tokamak

Santosh P. Pandya[1], Kumudni Tahiliani[1], I. Suresh[1], Hrishikesh Kathale[2], Shivam Dobariya[1], Praveenlal E. V. [1], Jahanvi Lalwani[3], Sameer Kumar Jha[1], Lavkesh T. Lachhvani[1], Suman Aich[1], Rohit Kumar[1], Surya Kumar Pathak[1,4], Rakesh L. Tanna[1,5] and Joydeep Ghosh[1,4]

[1]Institute for Plasma Research, Bhat, Gandhinagar 382428, India.
[2]Fergusson College, Shivajinagar, Pune-411004, India.
[3]St. Xavier's College, Navrangpura, Ahmedabad 380009, India.
[4]Homi Bhabha National Institute (HBNI), Anushaktinagar, Mumbai-400094, India.
[5]Institute of Science, Nirma University, Ahmedabad 382481, India.

E-mail: psantosh@ipr.res.in

Abstract

Plasma current is the most fundamental parameter measured in plasma devices. Recently, a Magneto-Optic Current Sensor (MOCS) diagnostic was developed and deployed on Aditya-Upgrade tokamak for plasma current measurements. The MOCS is essentially an optical technique based on the principle of the Faraday rotation effect in the single-mode optical fiber (SMF) and could provide redundant diagnostic measurement along with the existing Rogowski coil measurement. This technique has several advantages over the conventional current measurement techniques and is hence deployed on several plasma devices as well as it is proposed and under development for ITER tokamak. In this paper, we report the preliminary results of plasma current measurements carried out for the Aditya-U tokamak using a simple but efficient MOCS diagnostic system that can measure the plasma current with a sensitivity of ≤0.5 kA and a temporal resolution of ≤1 ms. We also report its characterization in a laboratory environment and validation for toroidal field coil current measurements with an accuracy close to ±5% achieved by employing an onsite calibration technique. The plasma current signals obtained showed a reasonable agreement with the conventional Rogowski coil measurements. It has also been observed that the intrinsic birefringence property of the SMF, mechanical vibration and pressure-induced birefringence, and contribution from the toroidal and vertical fields induced during the plasma operations can affect the MOCS-signal. However, the post-analysis presented herein shows that an application of the background correction can aid in recovering the shape of the plasma current despite these effects

DIAGNOSTIC OF LASER ABLATED SILICON PLASMA USING TIME DEPENDENT CR MODEL WITH FULLY RELATIVISTIC ELECTRON EXCITATION CROSS-SECTION OF Si^{+2}

S. S. Baghel[1*], Priti[2], R. Srivastava[1]

[1] *Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667*
[2] *National institute for fusion science, 322-6 Oroshicho, Toki, Gifu, Japan 509-5202*

E-mail: sbaghel@ph.iitr.ac.in

Abstract

Laser ablated silicon plasma has significant application in pulse laser deposition, etching processes etc. [1,2]. In view of these, we have developed a time dependent collisional radiative (CR) model for the diagnostics of laser ablated Silicon plasma. In such plasmas, the electron and gas temperatures are low and electron impact excitation (EIE) and de-excitation processes are dominant. For a reliable CR model, the EIE cross-sections for a large number of transitions of Si^{+2} are required [3] which we have calculated for the first time using Relativistic Distorted Wave (RDW) approach[4]. The transitions considered are from ground state $3s^2$ (J = 0) to the fine structure levels of the 3s3p, $3p^2$, 3s3d, 3s4s, 3s4p, 3s5s, 3s4d , 3s4f, 3s5p, 3s5d and 3s5f configurations as well as among the upper levels. We also include radiative decay, ionization, and recombination processes in the CR model. We have validated our model with the optical emission spectroscopic (OES) measurement of Wang et al.[5] on laser induced silicon plasma. The obtained plasma parameters viz. electron temperature, electron density etc. are compared with the corresponding experimental values. The details of our EIE cross-section calculations, full description of the CR model along with the obtained results will be presented in the conference.

References :

[1] J Schwan J et al., Controlled growth of silicon particles via plasma pulsing and their application as battery material, J. Phys. D. Appl. Phys., **55** 094002 (2022)
[2] S Traversari et al., Combined effect of silicon and non-thermal plasma treatments on yield, mineral content, and nutraceutical proprieties of edible flowers of Begonia cucullata Plant, Physiol. Biochem., **166** 1014–21 (2021)
[3] J B Boffard et al., Application of Excitation Cross-Section Measurements to Optical Plasma Diagnostics, Adv. At. Mol. Opt., **67** 1-76 (2018)
[4] S S Baghel et al., Diagnostics of low-temperature neon plasma through a fine-structure resolved collisional – radiative model, Plasma Sources Sci. Technol., **28** 115010–29 (2019)
[5] K Wang et al., Diagnosis of electron temperature and density in the early stage of laser-produced Si plasma expansion, Phys. Plasmas, **27** 063513 (2020)
.

Saturation Current Ratio Method: Can It Be Really Useful for Negative Ion Diagnostic?

Pawandeep Singh et al.

Institute for Plasma Research, A CI of Homi Bhabha National Institute, Gandhinagar, Gujarat-382428, India

E-mail: singh.pawandeep67@gmail.com

Abstract

One of the simplest method for negative ion diagnostic is the saturation current ratio method. In this method, a Langmuir probe is used to measure the current-voltage characteristic wherein the ratio of electron saturation to the positive ion saturation current is referred to as the saturation current ratio (SCR). As the negative ions' mobility is relatively lower than electrons' mobility, they get stagnated in the bulk plasma owing to the confining field to electrons. Consequently, this significantly alters the positive ion flux at the sheath edge [1]. Therefore, SCR reduces with the increase in negative ion density. However, this reduction is also observed even for pure electro-positive argon plasma. This anomaly is perhaps attributed to the expanding ionic sheath with negative bias, ground sheath resistance, and inaccurate determination of plasma potential. The edge-to-center positive ion density also becomes an important factor while modelling the SCR method for a range of negative ion density. Therefore, this work aims to address the various limitations associated with the SCR method and investigate the whole range of applicability of this method. This study proposes a hairpin probe assisted SCR method for better perceiving the negative ion determination [2].

References:

[1] Singh Shantanu Kumar P and S and K 2022 Equilibrium properties of inhomogeneous partially-magnetized plasma containing negative ions *J. Phys. D. Appl. Phys.*

[2] Singh P and Karkari S K 2021 Addressing the anomalies in determining negative ion parameters using electrostatic probes *arXiv:2109.09419 (http://arxiv.org/abs/2109.09419)*

Saturation Current Ratio Method: Can It Be Really Useful for Negative Ion Diagnostic?

Pawandeep Singh, Swati Swati, Avnish k Pandey, Shantanu Karkari

Institute for Plasma Research, A CI of Homi Bhabha National Institute, Gandhinagar, Gujarat-382428, India

E-mail: singh.pawandeep67@gmail.com

Abstract

One of the simplest method for negative ion diagnostic is the saturation current ratio method. In this method, a Langmuir probe is used to measure the current-voltage characteristic wherein the ratio of electron saturation to the positive ion saturation current is referred to as the saturation current ratio (SCR). As the negative ions' mobility is relatively lower than electrons' mobility, they get stagnated in the bulk plasma owing to the confining field to electrons. Consequently, this significantly alters the positive ion flux at the sheath edge [1]. Therefore, SCR reduces with the increase in negative ion density. However, this reduction is also observed even for pure electro-positive argon plasma. This anomaly is perhaps attributed to the expanding ionic sheath with negative bias, ground sheath resistance, and inaccurate determination of plasma potential. The edge-to-center positive ion density also becomes an important factor while modelling the SCR method for a range of negative ion density. Therefore, this work aims to address the various limitations associated with the SCR method and investigate the whole range of applicability of this method. This study proposes a hairpin probe assisted SCR method for better perceiving the negative ion determination [2].

References:

[1] Singh Shantanu Kumar P and S and K 2022 Equilibrium properties of inhomogeneous partially-magnetized plasma containing negative ions *J. Phys. D. Appl. Phys.*
[2] Singh P and Karkari S K 2021 Addressing the anomalies in determining negative ion parameters using electrostatic probes *arXiv:2109.09419 (http://arxiv.org/abs/2109.09419)*

RF COMPENSATED LANGMUIR PROBE FOR THE DIAGNOSTICS OF PLASMA PARAMETERS IN MAGNETIZED CAPACITIVELY COUPLED PLASMA DISCHARGE

Akanshu Khandelwal[1], Dhyey Raval[2], Ravi Ranjan[2] Y. Patil[2] and Nishant Sirse[1], S. Karkari[2,3]

1. Institute of Science and Research, IPS Academy, Indore, Madhya Pradesh, India, 452012
2. Institute for Plasma Research, Gandhinagar, Gujarat, India, 382428
3. Homi Bhabha National Institute, Anushaktinagar, Mumbai 400094, India

E-mail (speaker): akanshu.res@gmail.com

Abstract

Langmuir probes (LP) are one of the simplest diagnostic techniques for measuring the vital plasma parameters such as Electron Energy Distribution Function (EEDF), density, temperature and plasma potential. This technique relies on the analysis of DC (I-V) characteristics of a biased object, mainly a cylindrical probe, in the plasma with respect to the plasma potential. However, the accuracy of the measured plasma parameters is often compromised in radio frequency (RF) discharges due to the oscillations in the plasma potential. Both, active and passive, RF compensation methods have been proposed for eliminating the RF fluctuations and restoring the DC behavior of the I-V characteristics. In this paper, we presented both un-compensated and RF compensated LP to measure the plasma parameters in the magnetized capacitively coupled plasma discharge excited at a frequency of 13.56 MHz. A direct measurement of the EEDF is performed using a second harmonic technique i.e., with the superimposition of low frequency sinusoidal signal on the DC biasing voltage and from the second harmonic of the sinusoidal signal EEDF is calculated. The plasma parameters of the plasma deduced from the EEDF are compared with that obtained by the analysis of I-V characteristics. A discrepancy between both the methods are presented and discussed.

Acknowledgement: This work is supported by The Science & Engineering Research Board (SERB) Core Research Grant No. **CRG/2021/003536.**

High Impedance Langmuir Probe Diagnostics for Toroidal Non-Neutral Plasma Experiment: SMARTEX-C

Nikhil Mohurle[1, 3], Lavkesh Lachhvani[1], Rajiv Goswami[1], Yogesh G. Yeole[1], Minsha Shah[1], Sambaran Pahari[2] and Prabal K. Chattopadhyay[1, 3]

[1]*Institute for Plasma Research, HBNI, Gandhinagar-382428, India*
[2]*Bhabha Atomic Research Centre, HBNI, Visakhapatnam-530012, India*
[3]*Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India*
E-mail: nikhil.mohurle@ipr.res.in

Abstract

Non neutral plasma is an exclusive class of plasma consisting only single charged species *i.e.* electrons, ions, positrons, *etc* and thus governed by strong electrostatic energy over thermal energy ($-e\phi >> T_e$) contrary to conventional plasmas [1]. SMARTEX-C [2] is a SMall Aspect Ratio Toroidal Electron plasma eXperimental in a 'C' shaped geometry dedicated to the study of toroidal electron plasma. Investigation of electron plasma dynamics [3] and transport [4] in the pure toroidal magnetic field is carried out. Wall probes, diocotron wave launch and charge collection diagnostics are used to characterize the plasma in SMARTEX-C. Low plasma density, inherent non-neutrality and strong toroidicity poses challenges of diagnosing plasma. In this work, we have made attempts to measure plasma potential using High Impedance Langmuir Probe (HILP) [5], [6] and its comparison with emissive probe measurements.

References:

[1] R. C. Davidson, *Physics of Non-neutral Plasmas, 1994*. Allied Publishers.
[2] S. Pahari, H. S. Ramachandran, and P. I. John, "Electron plasmas: Confinement and mode structure in a small aspect ratio toroidal experiment," *Physics of Plasmas*, **13**, 092111, 2006.
[3] L. Lachhvani, S. Pahari, S. Sengupta, Y. G. Yeole, M. Bajpai, and P. K. Chattopadhyay, "Investigation of diocotron modes in toroidally trapped electron plasmas using non-destructive method," *Physics of Plasmas*, **24**, 102132, 2017.
[4] L. Lachhvani, S. Pahari, R. Goswami, M. Bajpai, Y. Yeole, and P. K. Chattopadhyay, "Confinement time of electron plasma approaching magnetic pumping transport limit in small aspect ratio C-shaped torus," *Physics of Plasmas*, **23**, 062109, 2016.
[5] H. Himura, C. Nakashima, H. Saito, and Z. Yoshida, "Probing of flowing electron plasmas," *Physics of Plasmas*, **8**, 4651, 2001.
[6] H. Himura, M. Fukao, H. Wakabayashi, and Z. Yoshida, "Filament size of floating-emissive probe for low density plasmas with large space potential," *Review of Scientific Instruments*, **74**, 4658, 2003.

Calculation Of Electron Impact Excitation Cross Sections Of Sn I And Sn II Using RDW Method: Cross Sections Of Interest In Plasma Modeling Applications

Indhu Suresh[1], P S N S R Srikar[1], Priti[2], R Srivastava[3], R K Gangwar[1]

[1]Department of Physics & CAMOST, Indian Institute of Technology Tirupati, Yerpedu – 517619 India
[2]National Institute for Fusion Science, Gifu, 506-5292, Japan
[3]Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, India

E-mail : ph20d501@iittp.ac.in

Abstract

Laser produced Sn plasma (LIP) is the most promising choice for the production of next generation extreme ultraviolet (EUV) light source utilized in semiconductor lithography for the fabrication of microchips. Since LIPs are having non-equilibrium nature, suitable population kinetic models must be employed for their characterization. This necessitates the calculation of electron impact excitation cross sections (EIE) of Sn atoms and Sn^+ ions as these are required to develop plasma population-kinetic models. The current work calculates the electron impact excitation cross sections for the fine structure resolved transitions between the ground state and different higher lying states in both the Tin atom (Sn I) and Tin ion (Sn II). The present calculations are carried out using the multi-configurational Dirac-Fock (MCDF) wavefunctions and the relativistic distorted wave (RDW) approximation, because Tin is a heavier element and relativistic effects will be more prominent. Precise information on electron scattering on Tin is very important in fusion research as well, particularly regarding tracking the vessel wall erosion of the future tokamak fusion reactor like ITER. The calculated oscillator strengths and transition probabilities are compared with the NIST atomic database to validate the reliability of the obtained cross sections. The present cross sections are also compared with the available calculations. The exact findings will be given at the conference together with the methodology and discussion.

Keywords: Laser induced plasma, electron impact excitation cross section, Relativistic distorted wave approximation, multi-configurational Dirac-Fock wavefunctions.

References :

[1] Electron impact excitation cross section calculations of the fine structure transitions of Mo and their applications in the diagnostics of the laser induced Mo plasma, Plasma Sources Sci. Technol., 31, 095016, (2022)

Initial results of the Laser Heated Emissive Probes in the Aditya-U glow discharge plasma

Abha Kanik[1], Joydeep Ghosh[2], Arun Sarma[1,3], Kalpesh Galodiya[2], Laxmikanta Pradhan[2], Ankit Patel[2], Minsha Shah[2], Kaushlender Singh[2,4], Bharat Hegde[2], Tanmay Macwan[2,4], Sharvil Patel[5], R. L. Tanna[2], Kumarpal Jadeja[2], Ankit Kumar[2,4], Ashok Kumar[2], Santosh Dubey[1], Suman Aich[2], Rohit Kumar[2], Kaushal Patel[2], and ADITYA-U Team[2]

[1]*UPES, University of Petroleum and Energy Studies, Bidoli, Uttrakhand-248007*
[2]*Institute for Plasma Research, Near Indira Bridge, Gandhinagar District, Gujarat-382428*
[3]*NECTAR, 2nd Floor Viswakarma Bhawan, Shaheed Jeet Marg, New Delhi 110016, India*
[4]*Homi Bhabha National Institute, Mumbai, Maharashtra-400094*
[5]*Pandit Deendayal Energy University, Knowledge corridor, Gandhinagar, Gujarat-382007*

E-mail: abhakanik@institute.com

Abstract

Laser Heated Emissive Probes [LHEP] are an excellent diagnostic tool in terms of robustness and accuracy to measure the plasma parameters. The inherit construction of the LHEP eliminates the very drawbacks of the conventional emissive probes, which, otherwise gives the direct measurement of the plasma potential. Although advantageous but LHEP's are not very popular in the high density high temperature plasmas like that of fusion grade machines. A novel experimental arrangement with the aim to directly measure plasma potential in the edge region of Aditya-U tokamak was designed, fabricated and installed for the very first time. Two circular Graphite probes of 6 mm diameter each, separated by ~15 mm and located at same radial but different poloidal and toroidal location are used as LHEP probe tips. The Graphite probe tip is heated with a CO_2 laser of 10.6 µm wavelength at variable output power. In this paper we report the successful operation of the system in both hot mode and cold mode in the glow discharge plasma of the Aditya-U. Probe is biased with respect to the plasma potential and V-I characteristics are recorded for different probe temperatures to ascertain the constant emission region of the probe. We present the studies for the estimation of the plasma parameters using the recorded measurements in the edge region of the tokamak.

A STUDY OF EMPIRICAL RELATION FOR OBSERVED CORE ION TEMPERATURE WITH OTHER OPERATIONAL PARAMETERS OF ADITYA PLASMA DISCHARGES

Kumar Ajay, Snehlata Aggarwal, Santosh P. Pandya and Aditya Team

Institute for Plasma Research, Bhat Village, Gandhinagar-382428(Gujarat)

E-mail: ajaykuma@ipr.res.in

Abstract

Neutral particle Analyzer based Charge exchange diagnostics (CX-NPA) has been routinely operated during plasma discharges in Aditya tokamak [1]. The diagnostics has measured the core ion temperature for more than 500 plasma discharges and the reported plasma core ion temperature was in the range of 100 eV to 300 eV (measured during plasma ohmic heating as well as with ICRH assisted heating) with a time resolution of 10 ms at flat-top regime of plasma current[2]. The accuracies of such experimentally measured core ion temperature has been mostly within 30%.

We have attempted to observe a trend of measured core ion temperature with the reported central electron temperature and plasma density of Aditya in these many observations during the operation of CX-NPA. In this paper we report an empirical relation of observed Core ion temperature of plasma with the central electron density and the average plasma ion density.

References:

[1] Experimental Results of Core Ion Temperature and Neutral Density Measurements on ADITYA Tokamak using Four Channels Neutral Particle Analyzer, Journal of Fusion Energy, volume **39**, p 111–121 (2020)

[2] Core-Ion Temperature Measurement using Passive Charge Exchange Neutral Particle Energy Analyzer for the ADITYA tokamak", Review of Scientific Instrument, **84(2)**, p023503, (2013)

CODAC Based control system for Prototype Hot Source Operation for Local Calibration of ECE Diagnostic System

Shivakant Jha[1], Ravinder Kumar[1], Suman Danani[1], Hitesh Pandya[1,2]

[1]*ITER-India, Institute for Plasma Research, Ahmedabad-38005*
[2]*Homi Bhabha National Institute (HBNI) Anushaktinagar, Mumbai – 400094 India*

E-mail: shivakant.jha@iterindia.in

Abstract

To measure the temperature profile (Core & edge) with good temporal and spatial resolution and also to detect high frequency instabilities like NTM, Electron Cyclotron Emission (ECE) Diagnostic system is used in tokamak fusion machine. In addition to that it is also contribute to measure the power loss due to ECE and non-thermal distribution. The instruments like radiometer and Michelson interferometer will be used to measure the same [1]. For functionality testing of these instruments a local hot calibration source is required. This calibration source has an emitter (Silicon Carbide) which radiates the thermal emissions in desired frequency range like 70 to 1000 GHz at certain temperature. I&C have been developed for the measurement and control of temperature of the hot source to full fil the requirement.

The hot source made of SiC is used to test to functionality of the ECE instruments. Uniform distributed temperature sensors over the calibration source provide the profile of temperature on various points. Precise measurement of temperature and stepwise temperature control using PLC based control system has been implemented for the remote operation of the hot source from the field. This continuous monitoring of the temperature from the state of input devices and applied control functionality based on developed program for the desirable output functions. CODAC (Control, Data Access and Communication) has been used as supervisory control to continuous monitoring the temperature and control the black body temperature for desired set point, Data Archiving, Alarming, Monitoring & control GUIs have been developed on different tools of CODAC Core system.

This paper presents the developed CODAC core software based control system to operate prototype hot calibration source and also tested & validated the I&C interfaces.

Development of a photodiode-based detection system for the measurement of X-ray photon flux

G Shukla[1], S Mishra[1,3], M Shah[2], S Varshney[1,3], H.B. Pandya[1,3]

[1]*ITER-India, Institute for Plasma Research, Koteshwar, Ahmedabad 380005*
[2]*Institute for Plasma Research, Bhat, Gandhinagar 382428*
[3]*Homi Bhabha National Institute, Anushakti Nagar, Mumbai 400094*

E-mail: gaurav.shukla_pdf@iterindia.in

Abstract

The Silicon Photodiode-based detection system is widely used in various industrial and scientific applications to measure the photon flux in a wide wavelength range covering visible, UV, and X-rays. To measure X-ray photon flux, direct or diffracted, from an X-ray source, a photodiode-based detection system is developed at the ITER-India laboratory. For this purpose, a low-cost photodiode having a small photosensitive area (2.65 mm x 2.65 mm) is used. A preamplifier circuit, together with an integrator, is also developed in-house for the amplification and integration of small current signals in the range of nA to μA, which are produced by the photons in the depletion layer of the PIN photodiode. The system is tested to ascertain the dark current level. Tests are performed with a standard white light source (LED) to measure its responsivity.

Further, the experiment is conducted to study the sensitivity of the detection system as a function of wavelength. Based on the sensitivity of the photodiode, photon flux from several calibrated light sources is determined. Measurements with radioactive sources, Mini-X tube with Au target are currently ongoing.

In this presentation, we will report the development of a photodiode-based X-ray detection system, measurement of responsivity, and experimental results from different types of light sources.

A Collisional Radiative Model for Tl II Plasma

Aloka Kumar Sahoo and Lalita Sharma,

Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, India

E-mail : aloka_s@ph.iitr.ac.in

Abstract

The interaction of electron with singly ionized thallium ion (Tl II) is studied using the relativistic distorted wave (RDW) approach [1]. In this regard, we have implemented the multiconfiguration Dirac-Fock (MCDF) approach [2] with configuration interaction and QED corrections to obtain the energy levels, transition rates and radiative lifetimes. Our obtained energy levels and lifetimes are benchmarked against the previously available data in the literature. After establishing the accuracy of our calculated atomic bound wavefunctions, the RDW approach is implemented to obtain the electron impact excitation and ionization collision strengths. Here, we have considered all the possible excitations between our reported 130 energy levels and the ionizations to the ground state of the next ionization state i.e., Tl III. The radiative recombinations are calculated for the recombination from the ground state of Tl III to the bound states of Tl II. The excitations and ionizations are calculated from their respective thresholds to 3000 eV incident electron energy

We further extended this study to develop a collisional radiative (CR) model [3] of thallium plasma. The generalized collisional radiative (GCR) coefficients and photon emissivity coefficients (PECs) are obtained by solving the rate equations in a quasistatic regime. In this regard, the effective collision strengths are calculated from our obtained excitation, ionization and radiative recombination cross-sections in the temperature range of 0.25-400 eV considering the electron energy distribution to be Maxwellian. These effective cross-sections are used in the collisional radiative model to solve rate equations and GCR ionization coefficients (SCD) and GCR recombination coefficients (ACD) over the temperature range of 0.25-400 eV are calculated. The detailed results will be presented at the conference.

References :

[1] Sharma, L., et al. "Electron-impact excitation of singly charged metal ions." Physical Review A 83.6 (2011): 062701.
[2] Fischer, C. Froese, et al. "GRASP2018—A Fortran 95 version of the general relativistic atomic structure package." Computer Physics Communications 237 (2019): 184-187.
[3] Johnson, C. A., et al. "ColRadPy: A Python collisional radiative solver." Nuclear Materials and Energy 20 (2019): 100579.

Post Deadline Contributions

A 2.5D-Electrostatic PIC Simulation of Ion extraction Process from Laser-Induced Photoplasma

Priti Singh[1], G. Sridhar[1,2], Namita Maiti[1,2]

[1]*Department of Engineering Science, Homi Bhabha National Institute, Mumbai-400094, India*
[2] *Laser and Plasma Technology Division, Bhabha Atomic Research Centre, Mumbai-400085, India*

E-mail : priti.singh740@gmail.com
priti.singh@barc.gov.in

Abstract

A 2.5D-electrostatic particle-in-cell (PIC) code is specifically developed to simulate the ion extraction process from the laser-induced photoplasma. Photoplasma is a special class of plasma, which is produced by multistep photoionization of the ion of interest by using a beam of a pulsed laser. Such plasmas have a very short lifetime that is of the order of 10-100 µs. Therefore, it is simulated by using the PIC code. PIC is an efficient tool that can recreate the experimental data and some additional data, which would be very tough to record otherwise. The developed PIC code is designed in an object-oriented framework and written in a C++ programming language. It can determine the plasma dynamics up to the 2.5-dimensions, which means it can resolve plasma positions in two dimensions and velocities in three dimensions. Through this code, the ion extraction process has been investigated to improve the ion extraction efficiency using different electrode configurations, namely parallel plate, M-type, wire-type, and plate-grid-grid-plate (PGGP) electrode configurations. These geometrical electrode configurations create spatial variation in the electric potential profile, thus varying the electric stress on the plasma. The present work explains all the simulation aspects that include the assignment of macro-particles, deciding the computational mesh size, computational step size, allocation of different boundary conditions for Poisson's solver to simulate different electrodes, and assignment of different particle boundary conditions. Subsequently, explain various physical processes that are occurring in the ion extraction process with the listed electrodes that include expansion of photoplasma in an electrostatic field, formation of electron and ion sheaths, and spatiotemporal evolution of electric potential. The obtained results can be utilized to understand the impact of electrode geometry on the ion extraction process, which can be further utilized to design or optimize an efficient ion extraction system.

References

[1]. R.Nishio, K.Yamada, K.Suzuki, M.Wakabayashi, Ion transport from laser induced metal plasma to ion extraction electrodes, Journal of nuclear science and technology 32, 180–190 (1995).
[2]. P.Singh, A.Majumder, A.K.Pulhani, G.Sridhar, N.Maiti, Development of a 1-d electrostatic particle-in-cell code, IEEE Transactions on Plasma Science 49, 3257–3267 (2021).

"An In-Vitro Analysis To Evaluate The Disinfection Effectiveness Of Cold Atmospheric Pressure Plasma Jet In *Enterococcus Faecalis* Infected Root Canals"

Pravin Kumar[1], Ram Prakash[2], Soundharrajan P[1], Abhijit Mishra[2].

1. *Conservative Dentistry and Endodontics section, Department of Dentistry, All India Institute of Medical Sciences, Jodhpur, Rajasthan- 342001.*
2. *Department of Physics, Indian Institute of Technology, Jodhpur, Rajasthan- 342027.*

E-mail : psoundharrajan1995@gmail.com

Abstract

Enterococcus faecalis (*E. Faecalis*) is one of the common microorganisms detected in persistent and recurrent endodontic infections [1]. Irrigating solutions play an indispensable role in disinfecting the root canals, but none of them meets the ideal criteria [2]. Hence, finding an irrigant with all the desired properties and effective specifically against the bacteria *E. Faecalis* causing recurrent infections still remains an area of interest in endodontics. The present in-vitro study was aimed to evaluate the disinfection effectiveness of an indigenously developed new geometry Cold Atmospheric-pressure Plasma (CAP) jet and its comparison with Sodium hypochlorite (NaOCl) and QMiX in the root canals infected with *E. Faecalis*.

The developed new geometry CAP-Jet system is a single barrier dielectric discharge system to generate plasma plume through a 23-gauge needle. It consists of a syringe that is used as a base geometry for consistent gas flow, a needle that is hermetically sealed with Teflon so as to cover 80% of it with dielectric barrier, and a synergistically used helical copper electrode. The cold atmospheric plasma is produced in the needle capillary with a stable jet of length up to ~10 mm. The central electrode was connected through a pulsed high-voltage power source and the outer electrode was grounded. Helium was used as a working gas, at an optimum flow rate of 2.5 lit/min.

210 extracted human mandibular premolar teeth were randomly divided into 3 experimental groups (CAP-Jet, NaOCl, and QMix) and 1 control group (Normal saline). The test samples in each group were incubated in the BHI broth with *E. faecalis* (ATCC 29212) for one week. The samples in the experimental groups were further divided into 3 subgroups depending on the exposure time (2, 5, and 10 minutes) of the irrigation regimens. Samples in the control group were irrigated with normal saline for 2 minutes. After root canal disinfection with the irrigation regimens, sterile paper points were used to collect the residual bacteria from the root canals. The disinfection of the *E.Faecalis* was evaluated by Colony Forming Unit (CFU) counting method. The results obtained were encouraging and the newly developed CAP-Jet has shown significant CFU reduction when compared with control group, as in line with the other experimental groups.

References:

[1] Zhang C, Du J, Peng Z. J Endod. Aug;41(8):1207-13, (2015).

[2] Haapasalo M, Shen Y, Wang Z, Gao Y. Br Dent J, Mar;216(6):299-303, (2014).

Measurement Of Electron Temperature And Density Of Argon Thermal Plasma Jet Using Optical Emission Spectrometer

Amarnath.P, Ekta yadav, Deepak.S, Sampad Saha, Soundharayaa.M, Jennifer.A, Joel Jeevan Tharakar, Nasih Mohammad, Yugeswaran.S

Department Of Physics, Pondicherry University, Kalapet, Pondicherry-605014

E-mail: amarbscphy@gmail.com

Abstract

Understanding the thermal plasma jet parameters is essential for plasma processing applications. In this work, a direct current (DC) non-transferred arc thermal plasma jet emanating from the plasma torch was characterized by using an optical emission spectrometer. Herein, pure argon (25 slpm) was used as a plasma gas with varying discharge currents of 100, 150 & 200 A at atmospheric pressure conditions. The optical emission spectrum of the produced plasma jet was recorded at the exit of the torch nozzle to understand the emission characteristics of plasma and estimate temperature and density. The plasma temperature and density were calculated by using the intensity ratio method and stark broadening method, respectively. The temperature of plasma increased from 7100 to 8320 K with respect to the discharge current. Meantime, the density of plasma increased (2.1×10^{16} to 3.57×10^{16} cm^{-3}) with an increase in discharge current (100, 150 & 200 A). Results showed that electron temperature and density increased with an increase in discharge current.

References:

1) S. Yugeswaran, V. Selvarajan, Electron number density measurement on a DC argon plasma jet by stark broadening of Ar I spectral line, Vacuum 81 (2006) 347–352.
2) L.F. Spencer, A.D. Gallimore, CO2 dissociation in an atmospheric pressure plasma/catalyst system: a study of efficiency, Plasma Sources Sci. Technol. 22 (1) (2012).

Measurement Of Electron Temperature (T_e) And Density (N_e) Using Langmuir Probe In Dc Glow Discharge Plasma

Smrutishree pratihary, Ekta Yadav, Deepak.S, Sampad Saha, Soundharayaa.M, Jennifer.A, Joel Jeevan Tharakar, Nasih Mohammad, Suraj kumar sinha

Department Of Physics, Pondicherry University, Kalapet, Pondicherry-605014

E-mail: smrutishreepratihary@gmail.com

Abstract

Electrostatic probes are the most important diagnostic tools in plasma discharges providing a simple method for the measurement of plasma parameters. A Langmuir probe consists of a bare wire or metal disk which is inserted into plasma and electrically biased to collect current. In this work, we analyzed a simple planar probe I-V Characteristics to measure plasma temperature (T_e) and plasma density (N_e). The discharge is produced in a SS chamber at different pressure in air with a discharge voltage -500V applied between the cathode and grounded chamber. Tungsten (W) planar metal probe was exposed to plasma with the biased voltage (-30v to +30V) to measure current. The observation shows that the probe current will increase exponentially with the probe voltage and after a certain applied voltage the current gets saturated. Electron temperature and density can be calculated from the I-V Plot. This probe method enables one to perform time as well as space-resolved measurements of the plasma parameters. This study can simplify the understanding of plasma wall interaction and material surface modification.

References:

[1] Brockhaus, A., C. Borchardt, and J. Engemann. "Langmuir probe measurements in commercial plasma plants." Plasma Sources Science and Technology 3, no. 4 (1994): 539.
[2] Hopwood, J., C. R. Guarnieri, S. J. Whitehair, and J. J. Cuomo. "Langmuir probe measurements of a radio frequency induction plasma." Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films 11, no. 1 (1993): 152-156.

Study The Electron Behaviour At Plasma - Metal Junction

Smrutishree Pratihary[1] , Sneha Latha Kommuguri[2] , Suraj Kumar Sinha[4]

Department Of Physics, Pondicherry University, Kalapet, Pondicherry-605014

E-mail : smrutishreepratihary@gmail.com

Abstract

The concept of plasma-metal junction (PM Junction) is presented. Like metal-semiconductor junction, PM Junction is a new kind of hetero-junction where electrons and holes in the semiconductor are compared with electrons and ions in plasma. This PM Junction can be produced in laboratory plasmas. The electrons in plasma are free to roam through out the plasma with no physical boundary to limit their motion while the electrons in the metals are bound within the surface of the metal. The plasma metal junction is a special kind of interface between plasma where the electrons obeying classical statistics follows Maxwell-Boltzmann Distribution and the metal electrons distributed quantum mechanically follows Fermi-Dirac Distribution. The main motivation is to understand the electron behaviour at the boundary of the hetero-junction where both plasma and metal have different electron densities and different temperatures. The distribution of charge carriers, current-voltage characteristics and the potential profile at quantum-classical junction can be studied from the well established distribution function of charges on both sides of the interface. The concept of PM Junction may simplify the complex plasma-material interactions in laboratory plasmas including fusion plasmas which is now an emerging field for energy production.

References:

[1] Plasma-metal junction, Phys. Plasmas 27, 023512(2020)

[2] Towards an integrated modeling of the plasma-solid interface.Frontiers of Chemical Science and Engineering 13, no. 2 (2019): 201-237.

Systematic analysis of whistler wave from fluid to kinetic limit with phase space dynamics

Anjan Paul[1,2], Devendra Sharma[1,2]

[1]Institute for Plasma Research, Bhat-382428, Gandhinagar, Gujarat
[2]Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094,India

E-mail : anjan.paul@ipr.res.in, devendra@ipr.res.in

Abstract

High temperature plasmas both in space and laboratory requires kinetic theory and simulation. One of best tools to analyze the energetic particle distributions is particle simulation but involves statistical noise. The numerical limitation is the resolution issue in the lowest frequency range. This kind of limitation is suppressed by developing a grid based Vlasov-Maxwell solver [1] with mode by mode computation involves GPU parallelization. Sufficient resolution is achieved for a single time period with longer execution procedure in the excitation of electromagnetic mode in magnetised plasmas. The present analysis is for Isotropic electron velocity distribution function (EVDF). Here we have analyzed [2] the characteristic for this kind of EVDF both in cold as well as in hot plasma limits. One to one mapping of the linear dispersion relation and corresponding phase space evolution for whistler wave in fluid and kinetic limit will be presented.

References:

[1] Boris, Jay P., et al. *LCPFCT-A flux-corrected transport algorithm for solving generalized continuity equations*. Naval Research Lab Washington DC, 1993.
[2] Edin Husidic et.al. Physics of Plasmas, 27, 042110, (2020)

EFFECT OF DEPTH AND FIELD SIZE ON PERCENTAGE DEPTH DOSE IN RADIATION THERAPY USING NUCLEAR SOURCE

Prajapati Dahal, Santosh Panth, Prakash Joshi, Satyanand Gupta, Dr. Suresh Basnet, Prof. Dr. Raju Khanal

Central Department of Physics Tribhuvan University, Kathmandu, Nepal

E-mail: prazz.pd@gmail.com

Abstract

This study is focused on study of various parameters related with dosimetry and specifically on effect of depth and field size on Percentage Depth Depth Dose (PDD) in radiation therapy using Co-60 gamma beams keeping source to axis distance (SAD) 100cm. For this purpose, secondary data was collected from B.P. Koirala Memorial Cancer Hospital (BPKMCH), Bharatpur, Nepal and data study was done.

Result revealed that PDD increases with increase in surface area due to increase in scattered contribution to the point in central axis[1]. It is found that when depth increases up to 0.5cm the PDD increases upto 1 i.e., 100% and then value of PDD starts to decreases. It is due to attenuation of intensity of radiation as depth increases[2]. This study can be further extended in future to study the inter-relationship between all the diametric parameters if Co-60 is replaced by Cold Plasma.

References:

[1] S. A. Memon et al., *Analysis and verification of percent depth dose and tissue maximum ratio for co-60 gamma ray beam*, *Worl App Sci J*, ***33*****(1)**, 109-113, (2015).

[2] I. M Aral, D. Cali, M. Nisse & J. Spira, *Dosimetry of irregular fields in cobalt 60 therapy*, *Acta radiologica: therapy, physics, biology*, ***9*****(1)**, 24-32, (1970). https://doi.org/10.3109/02841867009129088

Selective Generation of Energetic N_2 Extracted from Nitrogen Glow Discharge Plasma for Food Processing

M. Perumal, Ekta Yadav and Suraj Kumar Sinha

Department of Physics, Pondicherry University, Pondicherry - 605 014, India

E-mail: sinha_suraj@rediffmail.com

Abstract

The dc glow discharge plasma-based methods are rapidly emerging and serve as an alternative means for shelf-life extension and decontamination in food processing technology. In this work, a theoretical model has been developed and reported for charge exchange (CX) collisions inside the collision ion sheath. In a dc glow discharge plasma, there is a generation of a significant number of energetic neutrals. The velocity distribution of energetic N_2 is controlled by operating parameters. We demonstrate by the experiments that treatment with energetic neutrals extracted from dc glow discharge plasma results in modification of Physico-chemical, rheological and thermal properties of the sample. The theoretical and experimental condition is compared with the neutral velocity distribution estimated by integrating the ion velocity distribution and the CX collision over the entire sheath thickness. Furthermore, energetic N_2 in a dc glow discharge carries ~ 90% of the total discharge power. Therefore, this processing technique, based on energetic neutrals, and exceptionally increased energy efficiency, overcome the major drawback of all plasma-based processing methods of low energy efficiency, and may be highly useful for food processing industry.

References:

[1] S. K. Sinha and S. Mukherjee, Surf. Coat. Technol. 196 (1-3), 267-270, (2005).
[2] S. K. Sinha, P. Bharathi, V. Prahlad and S. Mukherjee, Surf. Coat. Technol. 202 (2), 301-309 (2007)
[3] M. Perumal, A. Saravanan, K. V. Sunooj and S. K. Sinha, IEEE Trans. Plasma Sci. 50 (4), 1122-1127 (2022).
[4] C. Sudheesh, K. V. Sunooj, S. K. Sinha, P. J. George, M. Perumal, A. Saravanan, A. Kumar, V. A. Sajeevkumar, Food Chemistry, 294, 194-202(2019).

Selective Reactive Nitrogen Species Rich Plasma Activated Water for Agricultural Applications

Shikha Pandey*, Ritesh Mishra, Ramavtar Jangra, Sushma, Kiran Ahlawat, and Ram Prakash

Department of Physics, Indian Institute of Technology Jodhpur, Rajasthan-343037

*Shikha.1@iitj.ac.in

Abstract

In the Agro-food industry, chemical techniques are still regarded as a staple for enhancing seed quality and limiting crop losses. But the utilization of Chemical techniques in agriculture is environmentally hazardous. Therefore, the use of eco-friendly stimulants for the crop revolution is highly desirable. Atmospheric cold plasma to produce functionalized water commonly known as "Plasma Activated Water" (PAW) is coming up as a sustainable alternative to this problem. The nitrogen-containing compounds are essential nutrients for agricultural purposes. However, the known PAWs are not application specific because of the presence of a cocktail of reactive oxygen and nitrogen species (RONS), and it may have a negative impact on agricultural applications [1]. Nowadays Dielectric Barrier Discharge (DBD) is the most distinguished plasma source and is often called the workhorse for the generation of PAW but DBD is less flexible in terms of size and shape and not that efficient to manage a large volume of liquid and also, the plasma characteristics of DBD are greatly impacted by the initial conditions of the sample [2].

In this work, an effort has been made to mitigate the issues in a laboratory-scale DBD plasma device. An attempt has been made to develop a Surface-DBD-based plasma source for PAW generation. The plasma source consists of co-axial electrodes, a liquid-facing grounded electrode, and a dielectric sandwiched between the electrodes. The SDBD plasma is formed between the dielectric and mesh of the grounded electrode when the developed device is powered by a bipolar pulsed power supply. For the studies of PAW, the deionized water (DI water) placed in the Petri dishes was treated by this source in a closed chamber. The process parameters such as voltage, frequency, water volume, and activation time for the generation of PAW were optimized by measuring the physicochemical properties of PAW. We have successfully measured the presence of reactive oxygen and nitrogen species (RONS) in PAW. Generated PAW has a low pH value and is acidic in nature, with high conductivity, nitrite concentration, nitrate concentration, and zero concentration of hydrogen peroxide. These results revealed that our developed plasma source is generating PAW which is rich in RNS and could be utilized for several agricultural applications.

References:

[1] R. E. Haling, R. J. Simpson, R. A. Culvenor, H. Lambers, and A. E. Richardson, "Effect of soil acidity, soil strength and macropores on root growth and morphology of perennial grass species differing in acid-soil resistance," *Plant Cell Environ*, vol. 34, no. 3, pp. 444–456, Mar. 2011, doi: 10.1111/j.1365-3040.2010.02254.x.

[2] K. Shang *et al.*, "Synergetic degradation of Acid Orange 7 (AO7) dye by DBD plasma and persulfate," *Chemical Engineering Journal*, vol. 311, pp. 378–384, 2017, doi: 10.1016/j.cej.2016.11.103.

Excitation of electrostatics oscillations and their modification by nonlinear whistlers

Gayatri Barsagade[1,2], Devendra Sharma[1,2]

[1]Institute for plasma Research, Bhat Gandhinagar 383428, India

[2]Homi Bhabha National Institute, Training School Complex Anushaktinagar Mumbai 400094 India

E-mail: gayatri.barsagade@ipr.res.in

Abstract

Whistler wave propagating in oblique direction with respect of external magnetic field (B_0) has been observed in laboratory experiments [1]. To study this, we have performed the electromagnetic fluid simulation in 1D setup. When whistler wave propagates near the resonance cone angle, it undergoes nonlinear wave steepening in low density plasma regime [2]. The study of simulation of the properties of whistler waves in a high-density laboratory plasma regime allow to address the issue related to the oblique propagation. Our study shows, that the whistler wave propagating obliquely with respect to magnetic field direction have strong electrostatic characteristic in high density regime. We have further observed that the strong electrostatic character of obliquely propagating whistler wave is due to its co-excitation with the upper hybrid class of resonant oscillations [3]. Details of the effects of whistler wave on resonant oscillations has been presented in this conference.

References:

[1] A. K. Sanyasi, L. M. Awasthi, P. K. Srivastava, S. K. Mattoo, D. Sharma, R. Singh, R. Paikaray, and P. Kaw, Physics of Plasmas 24, 102118 (2017).

[2]P. H. Yoon, V. S. Pandey, and D.-H. Lee, Journal of Geophysical Research: Space Physics 119, 1851 (2014).

[3] G. Barsagade and D. Sharma, Physics of Plasmas, Volume #: 29 Issue #: 10 Issue: 2022-10-10.

Study on Variation of Spark Gap Inductance With Medium, Pressure and Gap Between Electrodes

S.Mitra[1,2,a)], Sandeep Singh[1,2], Senthil K[1], Ankur Patel[1], Ranjeet Kumar[1], Amitava Roy[1,2], R. I. Bakhtsingh[1] and Archana Sharma[1,2]

[1]*Bhabha Atomic Research Center, Trombay, Mumbai-400085*

[2]*Homi Bhabha National Institute Mumbai-94, India*

E-mail : sabyam@barc.gov.in

Abstract

This paper presents a study on variation of spark gap inductance with variation of pressure of nitrogen medium and gap between two electrodes. Experiments are conducted using 120 kV, 2 kA pulser by varying the gap between electrodes from 1 mm to 9 mm and pressure of nitrogen from normal atmospheric pressure to 5 kg/cm^2. Variation of inductance is calculated using measured voltage waveform across copper sulphate load and plotted for their trends. A numerical code is developed to find out inductance of arc channel. Medium pressure, temperature, gap between electrodes etc. are fed to the code as an initial input. Inductance values obtained from simulation are plotted along with the experimentally obtained inductance values for different conditions. Simulations indicate that inductance of sparkgap arc channel increase with increase in gap between electrodes also with increase in medium pressure monotonously. Experimental and simulated results are found to be in coherence with each other for their trends. All the simulated and experimental results obtained during this study are narrated in this paper.

Design of Pulse Magnetic Field For Backward Wave Oscillators

V K Sharma, Romesh Chandra, A S Patel, Amitava Roy, Archana Sharma

Bhabha Atomic Research centre, Mumbai 400085

E-mail : vishnu@barc.gov.in

Abstract

A Backward Wave Oscillator (BWO) is a vacuum tube which generates High Power Microwave (HPM) up to Terahertz range. An electron beam is generated giving a negative high voltage pulse to cathode and interacts with slow wave structure. It propagates a traveling wave backwards against the beam. Slow wave structure is relatively high potential and attracts the electron beam. To overcome it, and to keep electron beam in axial direction, an axial magnetic field is generated through electromagnets. Repetitive HPM generation requires constant magnetic field, which in turn requires larger size of coil, water circulation unit and high power supplies. On the contrary, energizing electromagnet discharging capacitor bank into it allows much higher current density and results into compact magnetic system. This paper highlights the design aspects of electromagnets and capacitor bank required to generate 0.7T pulse magnetic field for S Band BWO system. Analytical results have been validated comparing it with experimental results.

References:

[1] Romesh Chandra et al., "A uniform, pulsed magnetic field coil for Gigawatt operation of relativistic Backward Wave oscillator", IEEE transactions on Plasma Science, Vol 46, p 2834-2839 (2018)

Degradation of methylene blue dye as waste-water pollutant under transient corona discharge plasma treatment: A detailed study

Mangilal Choudhary[1,a] , and Chintan Vyas[2]

1. School of Physical Sciences, Banasthali Vidiyapith, Tonk-304022, Rajasthan, India
2. Institute of Advanced Research Gandhinagar -382424, Gujarat, India

E-mail [a] : jaiijichoudhary@gmail.com

Abstract

A large-scale manufacturing and applications of synthetic reactive dyes in textile, rubber, plastic, cosmetic and pharmaceutical industries have been a source of worry since it is a major source of water pollutions. A very low concentration of organic compounds in the discharged waste-water into natural streams (e.g. rivers, ponds etc.) has been a cause of many significant problems. . It has been a priority for environmental researchers to remove the organic dyes and other organic compounds (toxic) from waste water for safety and saving the environment. There are various techniques such as physical, biological and chemical to degrade the organic dyes or organic contaminants present in the textile industrial waste-water [1]. Biological treatment is a one of the promising techniques to degrade the dye molecules but the treatment processes are very slow and need experts to handle the reactors. The high toxic level of the wastewater also restricts the biological treatment for the dyes degradation [1]. Chemical methods are also widely used to degrade the dyes molecules but there is a requirement of chemicals and safety to use the chemicals [1]. In recent years, the low-temperature plasma technology which is considered as an advanced oxidation technique has been investigated for the degradation of organic dyes in water or waste water [2, 3]. The non-thermal air or nitrogen-oxygen contains various RONS and energetic charged particles. If non-thermal (corona discharge) air plasma interacts with the water (wastewater) then the plasma reactive species, O3, UV radiation and energetic electrons interact with molecules of water and dissolved impurities. Due to the plasma-water interaction, strong oxygen-based oxidisers, mainly hydroxyl radicals ($OH^{\cdot}$), ozone (O3), hydrogen peroxide (H_2O_2), and oxygen radical ($O^{\cdot}$) are expected to form in the water solution. These advanced active oxidisers significantly contribute in degradation of organic contaminants (reactive dyes) in the wastewater of textile industries. We have performed a detailed study of Methylene Blue (MB) dye degradation with transient (pulse) corona discharge plasma interactions. The observed results show the potential of plasma technology in degrading the organic dyes.

References:

[1]. Dyes and their removal technologies from wastewater: A critical review, *Intelligent Environmental Data Monitoring for Pollution Management, Academic Press*, 127-160 (2021)
[2]. Degradation of various textile dyes as wastewater pollutants under dielectric barrier discharge plasma treatment, *Chemical Engineering Journal* **229**, 9-19 (2013)
[3]. Breakdown of methylene blue and methyl orange by pulsed corona discharge, *Plasma Sources Sci. Technol.* **16** 226 (2007)

DESIGN OF 25% EFFICIENT X-BAND RBWO OPERATING AT LOW MAGNETIC FIELD

Chitaranjan Jadab[1, 2], Romesh Chandra*[1, 2], Sandeep Kumar Singh[1, 2], & Amitava Roy[1, 2]

[1]*Homi Bhabha National Institute, Anushaktinagar, Mumbai, India-400094*

[2]*Accelerator & Pulse Power Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India-400085*

*E-mail : romesh@barc.gov.in

Abstract

Relativistic Backward Wave Oscillators (RBWO) are used for high power microwave generation. X-band RBWO operating at low magnetic field presents a promising opportunity to generate high power microwave in high repetition rate mode. A RBWO device having non-uniform semicircular profiled slow wave structure is being proposed here for high power microwave generation in low magnetic field. The full 3D particle in cell simulations predict a microwave conversion efficiency in excess of 25% in X-band at 9.8 GHz frequency. This device is capable of operating at Gigawatt level of peak microwave power.

References :

[1]. Pozar, D. M. Microwave engineering. John wiley & sons, 2011.
[2]. Benford, J., J. A. Swegle, and E. Schamiloglu. High power microwaves. CRC press, 2007.
[3]. Bruder, J., J. Carlo, J. Gurney, and J. Gorman. "IEEE standard for letter designations for radar-frequency bands." *IEEE Aerospace & Electronic Systems Society* (2003): 1-3.
[4]. Vlasov, A. N., Anatoly G. S., J. C. Rodgers, Y. Carmel, T. M. Antonsen, T. M. Abuelfadl, D. Lingze et al. "Overmoded GW-class surface-wave microwave oscillator." *IEEE Transactions on Plasma Science* 28, no. 3 (2000): 550-560.
[5]. "X- band BWO directly driven by a Marx generator", Romesh Chandra, S. Mitra, S. Singh, V. Sharma, K. Senthil, J. Mondal, A. Patel, A. Roy, D. Biswas and A. Sharma, *Journal of Instrumentation,* **2020,** Vol.15,P09019.
[6]. "Harmonic Generation in X-band RBWO Operating at Low Magnetic Field", Romesh Chandra, Sandeep Singh, Amitava Roy, Debabrata Biswas, Archana Sharma, *49th IEEE International Conference on Plasma Science (ICOPS),* **2022**.

Simulation and Design of a 600 kV Tesla Transformer

Ankan Basak[1,2], Ankur Patel[1], Senthil Kalyanasundaram[1], Amitava Roy[1,2]

1. *Bhabha Atomic Research Centre, Mumbai – 400088*
2. *Homi Bhabha National Institute, Mumbai – 400094*

E-mail : ankanb@barc.gov.in

Abstract

Electronic vulnerability testing recently is drawing attention of Pulsed Power Engineers in designing compact high repetition Pulsed Power Systems. Conventional MARX generators are bulky and incapable of operating in high repetition rates. To circumvent this, shift of attention towards Tesla transformers is inevitable. Tesla transformer based pulsed power systems are much more robust, compact and capable of operating in high repetition rates. A compact Tesla transformer has been designed using analytical calculations and simulations. Unlike conventional Tesla transformers, this transformer employs a high-permeability core to enhance the coupling and facilitate the use of semiconductor switches to increase the pulse repetition rate. In order to achieve compactness, the core of the transformer has been designed in such a way to work as a pulse-forming line (PFL) also. A comprehensive study based on simulation is also presented to visualize the non-uniform current density of the primary coil. The designed transformer can deliver a 600-kV voltage pulse of duration (FWHM) 30 ns on a 60- Ω load for an input voltage of around 1 kV.

A 9 MEV RF LINAC BASED PHOTO-NEUTRON SOURCE FOR NEUTRON RADIOGRAPHY APPLICATION

Rishi Verma[1], J. N. Rao[1], J. Balu Naik[1], D. B. Majumder[1], A. Dubey[1], R. Shukla[1], Shobhna Mishra[1], Basanta Das[1], Manraj Meena[1], Lakshman Rongali[1], Bijayalaxmi Sethi[1], Vivek Yadav[2], Dhruv Bhattacharjee[2], Shiv Chandan[2], R. Chauvan[2], Mayank Shukla[3], Tushar Roy[3], M. Srihari[4], D. H. Rathod[4], D. P. Chakravarthy[4], J. Subbaram[4], S. R. Ghodke[2], Archana Sharma[1,2]

[1]Pulsed Power & Electromagnetics Division, Bhabha Atomic Research Centre, Vizag
[2]Accelerator & Pulsed Power Division, Bhabha Atomic Research Centre, Mumbai
[3]Technical Physics Division, Bhabha Atomic Research Centre, Mumbai
[4]Control & Automation Division, Electronics Corporation of India Limited, Hyderabad

E-mail: rishiv@barc.gov.in

Abstract

A photo-neutron target assembly has been successfully integrated in to 9 MeV RF Electron LINAC at ECIL, Hyderabad for its utilization as neutron source. The entire LINAC setup is inside radiation shielded room and it is remotely operated through a PC in control room. At full rating, the X-ray dose rate of ~22 Gy/min is produced at 1m distance from Tantalum target. The photo-neutron target assembly for neutron radiography has overall dimensions of 700mm (L) × 855mm (W) × 700mm (H) and collimation ratio (L/D) of 50. To obtain maximum thermal neutron fluence rate, two beryllium cylinders of 63mm diameter having lengths of 44mm and 84mm have been used along with 60mm HDPE moderator in between. To minimize the gamma content at image plane, collimator is placed perpendicularly in between two Beryllium targets and also the Beryllium targets are cylindrically covered with lead shielding. Collimator has 500mm length, 10mm aperture and 200mm image plane diameter. Thermal neutron flux measured at aperture and image plane were ~2.7×10^6 and ~7.4×10^3 neutrons/cm^2/second/kW e-beam, respectively. Time resolved signatures of gamma and neutron pulses (obtained using plastic and NaI scintillator detectors) confirmed that gamma emission is coincident with electron beam pulse for same duration i.e. ~5µs, whereas neutron emission is subsequently followed upon for the duration of ~35µs. For reducing gamma dose at the image plane, design and fabrication of modified ϒ-n target assembly (gamma dose <60 R/hr) has recently been completed at BARCF (Vizag) and its integration work is presently underway. This paper will cover details on design, installation and test results of our first photo-neutron target assembly along with highlights on operational intricacies of LINAC.

DEVELOPMENT AND MODELLING OF THREE PHASE HIGH CURRENT SOURCE CONVERTER FOR PLASMATRON APPLICATION

Pankaj Deb*[1], Sunil Kanchi[2], V Appa Rao[1], Rohit Shukla[1,2], Archana Sharma[1,2]

[1]Pulse Power & Electromagnetics Division, BARC, Atchutapuram Visakhapatnam, India – 531011

[2]Homi Bhabha National Institute, Anushaktinagar, Mumbai, India - 400094

*E-mail: pankajd@barc.gov.in

Abstract

Plasmatron Technology is an eco-friendly technology to treat municipal waste, nuclear waste, medicial waste, electronic waste, toxic waste and has a wide range applications. A 6- pulse AC- DC converter power supply has been developed to operate a DC Plasmatron. The power supply includes 650 kVA, delta/star transformer rated 11 kV/0.415 kV. The transformer secondary output is fed to 3-phase choke to limit the transient. The 3-phase choke is employed to a 3-phase thyristor rectifier connected with LC filter, value 2 mH, 20 mF. The DC voltage across the DC-link capacitor produces output of 540 V. The voltage and current control of DC converter power supply was implemented along with synchronised gate pulse to the thyristor rectifier for smooth and reliable operation. The power supply is experimentally tested with 60 kW resistive load delivering a current of 100 A. The pf and per phase input current of power line measured 0.9 pf, 82 A respectively. The simulation analysis shows that output load current ramped up in 50ms and stays at steady state. The experimental output is validated with circuit modelling results.

References:

[1] N. Mohan, T M Undeland, W P Robbins, "Power Electronics, Converters, Applications and Design", 3rd edition, John Wiley & Sons, New York,2003.
[2] C Patil, V Jain, B Patel, A Visani, V Chauhan, "Stabilization of 25kW Plasma Torch (Graphite based) using IGBT based power supply at FCIPT", FCIPT, IPR Gandhinagar.
[3] A K Jha, R D Kulkarni, J Diwan, "Design, simulation and development of DC swith mode power supply feeding Plasma torch based incinerator for radioactive waste management", 2021 6th international conference for convergence in Technology, doi 10.1109/ I2CT51068.2021.9417951, IEEE.

PIC simulation of the particle behavior in a compact IEC system

Somesh Vinayak Tewari[1], Surender Kumar Sharma[2,3], Archana Sharma[2,3]

[1] SRM University-AP, AP, India
[2] Pulsed Power & Electromagnetics Division, BARC, Visakhapatnam, AP India
[3] Homi Bhabha National Institute, Mumbai, India

E-mail : somesh.vinayak@gmail.com

Abstract

PIC simulation of a compact Inertial Electrostatic Confinement system is carried out which consists of spherical concentric inner cathode and outer anode grids of 30mm and 120mm diameters respectively. The grids are placed in a cylindrical chamber of 450mm length and 300mm diameter. A DC voltage of 28kV is applied between the cathode and anode grids with anode grounded. Proper insulation feedthrough is provided between cathode grid and outer chamber in order to prevent breakdown. The system is operated at a pressure of 0.01-0.02 mbar with deuterium as the background gas. PIC simulations of electron movement, ion generation and growth are carried out using XOOPIC code. Simulations presented support in getting an insight into the particle behavior in a compact IEC system for neutron generation.

References:

[1] Miley, George H., and S. Krupakar Murali. "Inertial Electrostatic Confinement (IEC) Fusion" Springer, NewYork (2014)
[2] S Yu Gus'kov and Yu K Kurilenkov, "Neutron yield and Lawson criterion for plasma with inertial electrostatic confinement", Journal of Physics: Conference Series 774 012132 (2016)

Particle-In-Cell Simulation of 1 MV Flash X-ray Diode

Rakhee Menon K, Ankur Patel, Senthil K, Ankan Basak and Amitava Roy

Accelerator & Pulse Power Division, BARC, Mumbai, 400085

E-mail: rakheemk@barc.gov.in

Abstract

Flash X-rays (FXR) are used in the radiography of high speed events and also has applications in industry. The generation of FXR is by the process of Bremsstrahlung from intense short duration electron beams in a vacuum chamber. The typical electron beam parameters are few hundreds of keV, and tens of kA with a beam pulse width of 20 – 50 ns. The pulse power for beam and FXR generation is a Marx generator that can provide upto 1 MV volts over a 100 Ω load for 30 ns full width half maxima (FWHM). The Marx generator and FXR diode design was carried out and the field stress analysis of the diode has been carried out by CST simulation. The FXR diode has cylindrical geometry with a proposed spot size of 2-4 mm. The quality of radiographs is defined by the figure of merit (FoM) of the source and the optimum Anode-Cathode (A-K) gap yields the best possible FoM. This paper describes the beam dynamics of the 1 MeV FXR diode for maximum FoM.

EXPERIMENTAL STUDY OF ELECTRON BEAM PARAMETERS OF 40 keV INJECTOR SECTION WITH 2856 MHz PRE-BUNCHER CAVITY

J. Mondal, L. Mishra, S. G. Sarkar,

Accelerator & Pulse Power Division, Bhabha Atomic Research Centre, Mumbai - 400094

E-mail : jmondal@barc.gov.in

Abstract

In order to enhance the beam capture and to reduce the energy spread in main 10 MeV RF linear accelerator (LINAC) at Electron Beam Centre (EBC), Kharghar, a re-entrant type single cell 2856 MHz pre-buncher (PB) RF cavity has been designed and tested. The injector section of 10 MeV LINAC comprises of 40 keV thermionic electron gun with dispenser cathode followed by PB and low energy beam transport (LEBT) line along with beam diagnostics.

In this work the RF and beam measurement results of the 40 keV injector section are presented. The measured RF parameters of pre-buncher cavity are f_0= 2854.4 MHz in air, Q_L=600, tuning range ±2.5MHz. Electron beam transmission efficiency of 99% is achieved with minimum relative bunch length obtained at 400W of input RF power.

References:

[1] R. C. Sethi, V. T. Nimje, M. Sengupta, et al."Design& Development of 10 MeV RF Electron Linac for Applied Research and Industrial Applications", APAC-98, Conf. Proc. C 9803233 (1998) 193.

[2] "Design, fabrication and relative bunch length measurement of S-band pre-buncher", J. Mondal, L. Mishra, Shreya Sarkar, H.K. Manjunatha, Shiv Chandan, R.I. Bakhtsingh, Archana Sharma, Nuclear Inst. and Methods in Physics Research, A 1012 (2021) 165629.

DEVELOPMENT OF MULTI-CHANNEL, SINGLE-SHOT, HIGH RESOLUTION DOPPLER SPECTROSCOPY FOR 2D VELOCITY MAPPING OF INTENSE LASER PRODUCED PLASMAS

Yash M. Ved,[1] Amit D. Lad,[1] Kamalesh Jana,[1] and G. Ravindra Kumar[1]

[1]*Tata Institute of Fundamental Research, 1 Homi Bhabha Road, Colaba, Mumbai 400 005, INDIA*

E.mail: yash.ved_002@tifr.res.in

Abstract

We have conceptualised, designed, assembled, and developed two-dimensional high resolution Doppler spectrometry to spatial and temporal map the velocity of hot dense laser produced plasma. The measurements are carried out with TIFR 150 TW, ultrashort, high-contrast laser system. Our instrument is capable of providing an optical resolution of 0.03 nm and hence extremly small Doppler shifts can be measured[1]. The pump-probe technique offer high temporal resolution to study plasma dynamics. The device is designed with 16 high-spectrual resolution spectrometers which can be triggered in single shot mode. These spectometers are coupled to individual fibers across the reflected probe from the plasma. The spectrum at several spatial location of the reflected probe beam can be measured with a single laser shot and hence the corresponding Doppler shift. This technique has very high temporal resolution of the order of probe pulse-width (tens of femtosecond). As a result, it is possible to capture ultrafast dynamics of plasma at very early times which is not easily accessible by most of the other diagnostics. Spatial resolution offered by our technique depends on the total number of points across the probe beam (16, presently) and it can be improved by increasing the number of spectrometers. The time dependent velocity map can be inferred from the Doppler shifts due to large sptial locations offered by a technique[1].

References:

[1] K. Jana, A. D. Lad, D. West, W. Trickey, C. Underwood, Y. M. Ved, A. P. L. Robinson, J. Pasley, and G. R. Kumar, Phys. Rev. Research **3**, 033034 (2021)

Role of Ionic Lines in Investigating Low Pressure Argon Plasma using Optical Emission Spectroscopy

Vidhi Panchal[1] and Shail Pandey[2]

Sardar Vallabhbhai National Institute of Technology, Ichhanath Circle, Athwagate, Surat, 395007

E-mail: i17ph021@phy.svnit.ac.in[1], sp@phy.svnit.ac.in[2]

Abstract

Optical Emission Spectroscopy (OES) is a non-intrusive method to investigate plasma parameters and to control plasma processing [1-2] for applications like medical and semiconductor devices manufacturing. The advantage of OES lies in the fact that it can be exploited to resolve spectral lines with improved temporal and spatial resolution [3-4]. The present study proposes inclusion of atomic as well as ionic lines for monitoring the overall dynamics of low pressure argon plasma and its interaction with microwaves. For this, electron temperature (T_e) following the line ratio method [5] and excitation temperature (T_{exc}) following the conventional Boltzmann plot [6] are investigated and while doing so, role of the ionic lines in diagnostics of T_{exc} has been addressed. The former assumes plasma to be in Corona model while later assumes it to be in Local Thermodynamic Equilibrium (LTE). Mostly, atomic lines are selected for generating the Boltzmann plot and ionic lines are often neglected. However, suitable ionic lines obtained in the present work when introduced in the Boltzmann plot have shown reduced error in T_{exc} values by almost an order of magnitude. The results are compared with T_e obtained using the line ratio method as well as with those obtained using the Langmuir probe [7] and it paves path to introduce the ionic lines as well in calculating T_{exc} (z) in order to reduce the error significantly.

References:

[1] Real time sensor for monitoring oxygen in radio-frequency plasma applications, Opt. Express, **15**, p 13913 (2007)
[2] Endpoint detection in plasma etching, J. Vac. Sci. Technol. A., **3**, p 631-636 (1985)
[3] Spatio-temporally resolved spectroscopic diagnostics of the barrier discharge in air at atmospheric pressure, J. Phys. D: Appl. Phys., **34**, p 3164 (2001)
[4] Space-resolved characterization of high frequency atmospheric-pressure plasma in nitrogen, applying optical emission spectroscopy and numerical simulation, J. Phys. D: Appl. Phys., **44**, p 485205 (2011)
[5] Spectroscopic measurements of the electron temperature in low pressure radiofrequency $Ar/H_2/C_2H_2$ and $Ar/H_2/CH_4$ plasmas used for the synthesis of nanocarbon structures, Plasma Sources Sci. Technol., **15**, p 42 (2006)
[6] Plasma Spectroscopy, Rep. Prog. Phys., **29**, p 35 (1966)
[7] Trapping of electrons in troughs of self generated electromagnetic standing waves in a bounded plasma column, Phys. Plasmas, **21**, p 012111 (2014)

Effect of initial pump intensity and plasma density on instabilities generated in the process of Stimulated Brillouin Scattering for production of High intensity and highly compressed Laser Pulses

Updesh Verma [1,2], Anil Malik [3] Beer Pal Singh [3]

[1] M.K.R Govt. Degree College, Ghaziabad, U.P., India.
[2] Princeton Plasma Physics Laboratory, Princeton University, Princeton, New Jersey, USA.
[3] Dept. of Physics, C.C.S. University Meerut, U.P. India

e-mail: updeshv@gmail.com

Abstract

A Theoretical model is developed to study the effect of density as well as initial pump intensity on the instabilities developed during the process of laser pulse amplification and compression by stimulated Brillouin scattering (SBS). Modulational instability, filamentation instability, wave breaking are the common instabilities which develops at the time of interaction of two counter propagating laser pulses in preformed plasma to generate more amplified and compressed laser pulses by three wave mechanism. The main pump pulse interacts with counter propagating seed pulse via stimulated Brillouin scattering. Exchange of energy takes places between the two lasers via stimulated Brillouin scattering process. The long pump gives energy to the short seed and seed amplified as well as compressed whereas the pump gets depleted after losing its energy.

SBS mechanism is preferred than Raman scattering mechanism as nearly all the energy is transferred from pump to seed, also pump and seed can be at the same frequency as interaction of the two laser takes places via ion acoustic wave, which have very low frequency. We observed that high density implies filamenation whereas very low density gives wave breaking and modulational instability. Also one should avoid taking short pulses for better energy transfer efficiency and also avoid too long pulses to control wave breaking. The theoretical results are compared with simulation results which are in good agreements.

References:

[1] V.M. Malkin, G. Shvets and N.J. Fisch, "Fast compression of laser beams to highly overcritical powers ", Phys.Rev. Lett. 82, 4448 (1999). V.M. Malkin, Yu. A. Tsidulko, and N.J. Fisch, "Stimulated Raman Scattering of Rapidly Amplified Short Laser Pulses", Phys. Rev. Lett. 85, 4068 (2000).
[2] Y. Ping et al., "Amplification of ultrashort laser pulses by a resonant Raman scheme in a gas-jet plasma " Phys.Rev. Lett. 92, 175007 (2004).
[3] A.A. Andreev et al., "Short light pulse amplification and compression by stimulated Brillouin scattering in plasmas in the strong coupling regime" Phys.Plasmas 13, 053110 (2006).
[4] Ren, J., Cheng, W., Li, S. & Suckewer, S. "A new method for generating ultraintense and ultrashort laser pulses" Nature Physics 3, 732-736 (2007).
[5] R.M.G.M. Trines et al., "Simulations of efficient Raman amplification into the multipetawatt regime" Nature Physics 7, 87 (2011).

Acoustoelectric Amplification Characteristics in a High Mobility Semiconductor Plasma Medium: Quantum Effects

Drishti Chawda, Swati Dubey, S. Ghosh

S.S. in Physics, Vikram University, Ujjain, M.P. 456010

drishti.chawda412@gmail.com, dubeyswati2001@gmail.com, drsanjayghosh.ssp@gmail.com

Abstract

Current instabilities are found to have a significant influence on the amplification of acoustic waves through the piezoelectric and/or deformation potential coupling of free carriers with lattice vibrations. Many essential features of current instabilities could be explored by the amplification of acoustic waves. Present paper investigates influence of drift velocity of electrons on the amplification characteristics of acoustic wave. A phenomenological model based on the effective electron temperature concept has been developed for a piezoelectric semiconductor medium. Taking into consideration the momentum and energy transfer from phonons to electrons during the propagation of acoustic wave in a semiconductor medium, an expression for the normalized attenuation coefficient has been derived. Present paper describes the rigorous results based on numerical calculation for an n-type compound semiconductor at liquid nitrogen temperature. It is hoped that this simple theoretical investigation will be useful in an improved understanding of the field of nonlinear acoustics in semiconductor quantum plasmas.

Influence of viscosity and relaxation phenomena on ion transport in simple and complex electrolytes

Suleman Jalilahmad Ansari and Santosh Mogurampelly

Department of Physics, Indian Institute of Technology, Jodhpur, Karwar, Rajasthan, 342037, India

Understanding the transport properties of soft matter systems and examining the underlying controlling parameters is challenging and requires extensive analysis of viscosity, diffusion, and the dictating relaxation timescales. It is often appropriate to theoretically calculate a suitable relaxation timescale instead of viscosity (due to statistical convergence issues) to explain diffusivities that are related to each other by $D = \frac{k_B T}{6\pi\eta r}$. The present work aims to identify a suitable set of relaxation timescales that explains either or both viscosity and diffusivity in simple and complex electrolytes, including water, aqueous salt solutions, ionic liquids, and biopolymer mixed electrolytes. Our simulations reveal that the viscosity and ion-pair relaxation timescales are highly correlated for simple electrolytes such as ionic liquids and saltwater electrolytes ($\eta \propto \tau^{\alpha}, \alpha \cong 1$) implying that the diffusion is explained either by viscosity or ion-pair relaxation timescales. However, we found that $\alpha \neq 1$ for complex electrolytes such as pectin-loaded BMIM-PF6 or EC electrolytes and the pectin-loaded aqueous solution of NaCl and fluorinated EC.

References

1. Wei et al., Sci. Adv. 2018;4: eaat8632.
2. Zhang et al., J. Phys. Chem. Lett. 2015, 6, 700−705