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S.M.Ali	**KIIT**
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Som T	**IOP, BBSR**
Sahoo P.K	**NISER, BBSR**

PLASMA – 2013

Conference Schedule (03-06 December 2013)

	Time	Time	Min	Time	Time	Min	Time	Time	Min	Time	Time	Min	Time	
03-Dec-2013	8:00-9:00	9:00-10:15	75m	10:15-10:45	10:45-13:00	135m	13:00-14:00	14:00-16:30	150m	16:30-17:00	17:00-19:00	140	19:00-20:00	20:15
	Breakfast & Registration	Inaugural Function	Min	High Tea	Session - 1 (BP)	Min	Lunch	Session -2 (NF)	Min	Tea	Buti Award Presentations			
		Inauguration	30		Invited - BP-I-01	30		Invited - NF-I-01	30		Buti-01	20		
		Keynote address	45		Invited - BP-I-02	30		Invited - NF -I-02	30		Buti-02	20	Parvez Guzdar Award Presentation & Talk	Dinner
					Invited - BP-I-03	30		Invited - NF -I-03	30		Buti-03	20		
					Invited - BP-I-04	30		Invited - NF -I-04	30		Buti-04	20		
					Oral – BP-O-01	12		Oral - NF -O-01	12		Buti-05	20		
								Oral - NF -O-02	12					
					S1-Basic Plasma			S2-Nuclear Fusion						

04-Dec-2013	8:00-9:00	09:00-11:06	126m	11:06-11:30	11:30-13:00	13:00-14:00	14:00-15:45	15:45-16:15	16:15-18:30	2hr	18:30-19:30	19:30
	Breakfast	Session - 3 (IP+PLP)	Min	Tea	Poster Session - 1 Basic Plasma Exotic Plasma	Lunch	Poster Session - 2 Industrial Plasma Plasma Processing Computer Modeling Space Plasma	Tea	Session - 4 (SA +PP)	Min	PSSI -GBM	Dinner
		Invited –IP-I-01	30						Invited - SA-I-01	30		
		Invited -IP-I-02	30						Invited -SA-I-02	30		
		Invited -IP-I-03	30						Invited -PP-I-01	30		
		Oral - IP-O-01	12						Invited -PP-I-02	30		
		Oral - IP-O-02	12						Oral –PP-01	12		
		Oral - PP-O-03	12									
		S3-Industrial Plasma + Plasma processing			BP + EP		IP+PP+CM+SA		S4-Space Plasma & Pulsed Power			

05-Dec-2013	08:00-09:00	09:00-11:00	120m	11:00-11:15	11:15-12:45	12:45-13:45	13:45-16:00	135m	16:00-16-15	16:15-18:30	126m	18:30-20:00	20:00
	Breakfast	**Session - 5 (LP)**		Tea	**Poster Session - 3** **Nuclear Fusion** **Other Areas**	Lunch	**Session - 6 (EP+CM)**		Tea	**Session - 7 (PD)**		**Cultural Programme**	**Dinner**
		Invited – LP-I-01	30				Invited - EP-I-01	30		Invited - PD-I-01	30		
		Invited -LP-I-02	30				Invited -EP-I-02	30		Invited -PD-I-02	30		
		Invited -LP-I-03	30				Invited -CM-I-02	30		Invited -PD-I-03	30		
		Oral - LP-O-01	12				Invited -CM-I-02	30		Oral - PD-O-01	12		
		Oral - LP-O-02	12							Oral - PD-O-02	12		
							Oral-EP-O-01	12		Oral PD –O-03	12		
		S5-Laser Plasma			NF + OA		S6-Exotic Plasma + Computational Plasma			S7-Plasma Diagnostics			

06-Dec-2013	08:00-09:00	09:00-11:00	114	11:00-13:00	13:00-15:00	15:30-
	Breakfast	**Session - 8 (OA)**	PD + PU	**Poster Session - 4** **Plasma Diagnostics** **Pulsed Power** **Laser Plasma**	Visit to KISS and Lunch	**Concluding Session & Tea**
		Invited - OA-I-01	30			
		Invited -OA-I-02	30			
		Invited -OA-I-03	30			
		Oral - OA-O-01	12			
		Oral -OA-O-02	12			
		S8-Other Areas		PD + PU +LP		

03-Dec-13	KN-01	Keynote Address	Y. C. Saxena, IPR Gandhinagar		
03-Dec-13	**SESSION – 1 : BASIC PLASMA (BP)**			Email	Abs#
BP-I-01	Invited - 1	25+5	Rabindranath Pal, SINP, Kolkata	rabindranath.pal@saha.ac.in	
BP-I-02	Invited - 2	25+5	Mridul Bose, Jadavpur University, Kolkata	mridulbose@gmail.com	
BP-I-03	Invited - 3	25+5	Prabal Chattopadhyay, IPR, Gandhinagar	pkchatto@ipr.res.in	
BP-I-03	Invited - 4	25+5	N. Ramasubramanian, IPR Gandhinagar	mani@ipr.res.in	
BP-O-01	Oral – 1	10+2	Manas Kumar Paul, NIT Agartala	manashkr@gmail.com	15
03-Dec-13	**SESSION – 2 : NUCLEAR FUSION (NF)**				
NF-I-01	Invited - 5	25+5	S. Pradhan, IPR Gandhinagar	pradhan@ipr.res.in	
NF-I-02	Invited - 6	25+5	Joydeep Ghosh, IPR Gandhinagar	jghosh.ipr@gmail.com	
NF-I-03	Invited - 7	25+5	Shekar Iyengar, SINP, Kolkata	ansekar.iyengar@saha.ac.in	
NF-I-04	Invited - 8	25+5	Ananta Kumar Sahu, IPR Gandhinagar	aksahu@ipr.res.in	
NF-O-01	Oral – 2	10+2	R. K. Raut, BARC, Mumbai	rkrout@barc.gov.in	86
NF-O-01	Oral – 3	10+2	S. S. Udgata, I-Design, Pune	ssu@rsbglobal.com	399
04-Dec-13	**SESSION – 3 : INDUSTRIAL PLASMA & PLASMA PROCESSING (IP+PLP)**				
IP-I-01	Invited - 9	25+5	A. K. Das, BARC, Mumbai	akdas@barc.gov.in	
IP-I-02	Invited - 10	25+5	Alphonsa Joseph, FCIPT, IPR	alphonsa@ipr.res.in	
IP-I-03	Invited - 11	25+5	Sunil Kumar, CMSTC, Australia	sunilkumar@coatingsmantra.com.au	
IP-O-01	Oral - 4	10+2	Rajneesh Kumar, H S Gaur University, Sagar	rajneeshipr@gmail.com	36
IP-O-02	Oral - 5	10+2	Narendra Kumar Agarwal, MNIT Jaipur	jindal.phy@gmail.com	123

IP-O-03	Oral - 6	10+2	Tapan Barman, IASST, Guwahati	tpnbarman33@gmail.com	223
04-Dec-13	**SESSION – 4 : SPACE PLASMA & PULSED POWER (SA+PP)**				
PP-I-01	Invited - 12	25+5	Harishankar Ramachandran, IIT Madras	hsr@ee.iitm.ac.in	
SA-I-01	Invited - 13	25+5	Aravinakshan Pillai, VSSC, Trivandrum	l_aravindakshan@vssc.gov.in	
PP-I-02	Invited - 14	25+5	Rajesh Kumar, IPR Gandhinagar	rkumar@ipr.res.in	
SA-I-02	Invited - 15	25+5	Suktisama Ghosh, IIGM, Mumbai	sukti@iigs.iigm.res.in	
SA-O-01	Oral - 7	10+2	Sneha Gokani, KSK-GRL (IIGM), Allahabad	gokanisneha@gmail.com	165
05-Dec-13	**SESSION – 5 : LASER PLASMA (LP)**				
LP-I-01	Invited - 16	25+5	Alika Khare, IIT Guwahati	alika@iitg.ernet.in	
LP-I-02	Invited - 17	25+5	S. Bagchi, RRCAT, Indore	sbagchi@rrcat.gov.in	
LP-I-03	Invited - 18	2+5	Rajesh Kumar Singh, IPR, Gandhinagar	rajesh@ipr.res.in	
LP-O-01	Oral - 8	10+2	K. Nandakumar, MG University, Kottayam	drkalarikkal@gmail.com	390
LP-O-02	Oral - 9	10+2	Krishnagopal Goswami, Delhi University	kgopal874u@gmail.com	33
05-Dec-13	**SESSION – 6 : EXOTIC PLASMA (EP) + COMPUTER MODELING (CM)**				
CM-I-01	Invited - 19	25+5	Gursharn Singh, BARC, Vishakapatanam	gursharn76@gmail.com	
CM-I-02	Invited - 20	25+5	Sudip Sengupta, IPR, Gandhinagar	sudip@ipr.res.in	
EP-I-01	Invited - 21	25+5	Ganesh Rajaraman, IPR Gandhinagar	ganesh@ipr.res.in	
EP-I-02	Invited - 22	25+5	M. P. Srivastava, Delhi University	mps@physics.du.ac.in	
EP-O-01	Oral - 10	10+2	Jotirmoy Pramanik, Kharagpur College, Kolkata	jotir_moy@yahoo.com	26
05-Dec-13	**SESSION – 7 : PLASMA DIAGNOSTICS (PD)**				
PD-I-01	Invited - 23	25+5	Mainak Bandyopadhyay, ITER-India	mainakband@gmail.com	

PD-I-02	Invited - 24	25+5	Santosh Pandya, IPR Gandhinagar	psantosh@ipr.res.in	
PD-I-03	Invited - 25	25+5	J. A. Chakera, RRCAT, Indore	chakera@rrcat.gov.in	
PD-O-01	Oral - 11	10+2	Rajesh Srivastava, IIT Roorkee	rajsrfph@gmail.com	367
PP-O-02	Oral - 12	10+2	Rajib Kar, BARC, Mumbai	rajibkar.ph@gmail.com	146
PD-O-03	Oral - 13	10+2	Rahul Kumar, IIT Delhi	phz088370@physics.iitd.ac.in	40
06-Dec-13			**SESSION – 8 : OTHER AREAS (OA)**		
OA-I-01	Invited - 26	25+5	P. S. Mukherjee, IMMT, Bhubaneswar	psmukherjee52@gmail.com	
OA-I-02	Invited - 27	25+5	Pratap K. Sahoo, NISER, Bhubaneswar	pratap.sahoo@niser.ac.in	
OA-I-03	Invited - 28	25+5	Vijai Shankar Tripathi, I-Design, Pune	dr.vijai.s.tripathi@rsbglobal.com	
OA-O-01	Oral - 14	10+2	Srikumar Ghorui, BARC Mumbai	srikumarghorui@yahoo.com	284
OA-O-02	Oral - 15	10+2	Nitin Kumar, CEERI pilani	nitingkv@gmail.com	302

Inaugural Function
Keynote address

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03-12-2013 ***SESSION-1*** ***Time: 10:15-13:00***

[BASIC PLASMA]

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BP-I-01: **Selective Excitation Of Low Frequency Drift Waves In The SINP MaPLE Device**
Rabindranath Pal, Subir Biswas and Nikhil Chakrabarti ....

BP-I-02: **Experiments On Cogenerated Dusty Plasma**
Mridul Bose, Sanjib Sarkar, S. Mukherjee, J Pramanik..

BP-I-03: **Basic Plasma Experiments at IPR**
Prabal Chattopadhyay..

BP-I-04: **Quiescent Plasma Experiments: An Add-on**
N. Ramasubramanian...

BP-O-015: **Multiple Double Layer formation in High Pressure Glow Discharge**
Manash Kumar Paul, P.K.Sharma, A. Thakur and S. V. Kulkarni..............................

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03-12-2013 ***SESSION-2*** ***Time: 14:00-16:30***

[NUCLEAR FUSION]

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NF-I-01:**Steady State Superconducting Tokamak (SST-1)**
Subrata Pradhan & SST-1 Team

NF-I-02: **Recent Experiments And Upgradation Plans For Aditya Tokamak**
J. Ghosh and Aditya Team

NF-I-03: **Twenty Five Years Of The SINP Tokamak**
A.N.Sekar Iyengar & M.S.Janaki

NF-I-04: **The Giant Superconducting Magnet System of 10,000 Tons Mass for Fusion Experiment at Cadarache, France**
Ananta Kumar Sahu

NF-086: Evaluation Of Half Lives Through Thermal Neutron Activation Using Plasma Focus Neutron Source
R. K. Rout[1], B.S. Tomar[2], P.S. Ramanjaneyulu[2], D.B.Paranjape[2], Ram Niranjan[1], T.C. Kaushik[1] and Satish C. Gupta

NF-O-399:**Industry Support To Indian Tokamak Research**
S. S. Udgata

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03-12-2013 ***Buti Award Presentations*** ***Time: 17:00-19:00***

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BUTI-01: **Experimental Evidence of Multiple Current Free Double Layers in an Expanding Plasma Produced using Helicon Antenna**
Kshitish Barada, P.K. Chattopadhyay, J Ghosh, Devendra Sharma and Y.C. Saxena...

BUTI-02: **Time Dependent Physics Of Nano To Micro-pore Creation In Free Hanging Films By Multi Element Focused Ion Beams (MEFIB) From Intense Microwave**

Plasmas

Samit Paul, Jay Kumar Shah and Sudeep Bhattacharjee ....

BUTI-03: **Synthesis Of Carbon Encapsulated Magnetic (Fe/Fe_3C) Nanoparticles (CEMN) Optimized For Biomedical Applications**

N. Aomoa and M. Kakati...

BUTI-04: **Night Time D-Region Plasma Density Measurements From Lightning Generated Tweek Radio Atmospherics Recorded At Low Latitude India Station**

Ajeet K. Maurya, Rajesh Singh and B. Veenadhar ....

BUTI-05: **Observation and Theory of Electron Temperature Gradient Turbulence in Laboratory Plasma**

S. K. Singh, L. M. Awasthi, S. K. Mattoo, R. Singh, R. Jha, P. K. Kaw and LVPD Team..

Parvez Guzdar Award Presentation & Talk ***Time: 19:00-20:00***

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04-12-2013 ***SESSION-3*** ***Time: 09:00-11:06***

[INDUSTRIAL PLASMA & PLASMA PROCESSING]

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IP-I-01: **Plasma Nano-Synthesis, Generation of Complex Nano Structures Through Thermal and Non Thermal Plasmas**

A. K. Das ....

IP-I-02:**Development of Duplex Plasma Based Process For Improvement Of Surface Properties of Steel**

J. Alphonsa, P. Saikia,G. Jhala, R. Rane, S. B. Gupta, B.K. Saikia and S. Mukherjee ....

IP-I-03: **Plasma-Based Methods For Healthcare And Cleantech Applications**

Sunil Kumar ....

IP-O-036:**Microwave Plasma Torch for Waste to Energy Applications for Petrochemical Industry**

Rajneesh Kumar, B. O. Ogungbesan, S. Liu, M. Sassi ....

IP-O-123: **A Multi Step Argon & Nitrogen Plasma Surface Treatments Of PMMA For Improved Copper Adhesion**

Narendra Kumar Agrawal[1], Y. K. Vijay, K. C. Swami ....

PP-O-223: **Synthesis And Properties Of Pulse DC, RF Plasma Polymerized Aniline And Plasma Polymerized Aniline-Ag Composite Thin Films**

Tapan Barman, Arup R. Pal, Joyanti Chutia ....

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04-12-2013 ***POSTER SESSION-1*** ***Time:11:30-13:00***

[BASIC PLASMA+EXOTIC PLASMA]

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BP-007: **Nonlinear Dynamics Of Relativistically Intense Waves In Cylindrical And Spherical Geometry**

Arghya Mukherjee and Sudip Sengupta..

BP-379: **Temporal Evolution Of Nano To Micro-pores In Free Hanging Films By Multi Element Focused Ion Beams (MEFIB) From Intense Microwave Plasmas**
Samit Paul, Jay Kumar Shah, and Sudeep Bhattacharjee

BP-383: **Ion-Acoustic Solitary Waves In A Quantum Plasma With Ion-Streaming And Electron-Inertia**
H. Sahoo· K.K. Mondal and B. Ghosh

EP-043: **Theoretical Study Of Head-on Collision Of Dust Acoustic Solitary Waves In A Strongly Coupled Complex Plasma**
S. Jaiswal, P. Bandyopadhyay and A. Sen

EP-075: **Electrostatic Envelope Excitations In Multispecies Nonextensive Plasma**
Shalini and N. S. Saini

EP-079: **Dust Acoustic Solitary Waves In An Electron Depleted Dusty Plasma With Two Temperature Nonextensive Ions**
Ripin Kohli and N. S. Saini

EP-093: **Confinement In Toroidal Electron Plasma In SMARTEX-C**
Lavkesh Lachhvani, Manu Bajpai and Sambaran Pahari

EP-111: **Role Of Charged Dust Particles On Ion Acoustic Wave Propagation In Negative Ion Plasma**
N. C. Adhikary, M. K. Deka and H. Bailung

EP-114: **Small Amplitude Solitary Waves in Multi-ion Fluid Superthermal Plasma**
N. S. Saini, Ripin Kohli, Shalini and Nimardeep Kaur

EP-134: **KP Equation For High Frequency Solitary Waves in Dusty Plasma**
Nimardeep Kaur and N. S. Saini

EP-163: **Kelvin Helmholtz Instability in Complex Plasma**
Debabrata Banerjee, Sudip Garai, M. S. Janaki and Nikhil Chakrabarti

EP-199: **Large Amplitude Solitary Waves In A Five Component Dusty Plasma With Non Thermal Electrons And Ions**
Sijo Sebastian, Sreekala G., Noble P. Abraham and Chandu Venugopal

EP-234: **Electron-Drift Driven Nonlinear Ion-Acoustic Modulational Instability In A Dusty Plasma**
M. Khusroo, R. Goswami and Madhurjya P.Bora

EP-246: **Effect Of RF Fields On The Debye Sheath Around A Charged Protein**
Sumantra Chaudhuri, Harishankar Ramachandran

EP-253: **Velocity Shear Driven Instabilities In A Dusty Plasma**
Sudip Garai, Debabrata Banerjee, M. S. Janaki, and Nikhil Chakrabarti

EP-283: **Observation Of Dust Acoustic Waves In A Strongly Coupled Dusty Plasma**
Abhijit Boruah, Pallabi Pathak, S.K. Sharma, H. Bailung

EP-306: **Dust Acoustic Solitons In A Strongly Coupled Dusty Plasma**
S K Sharma, A Boruah and H Bailung

EP-308: **Solitary Waves Soliton Of Dusty Plasma With Higher Order Nonlinearity With Dust Charge Variation**

Ranjit Kumar Kalita[1] *and Jnanjyoti Sarma*

EP-309: **Excitation Of Lower Hybrid Waves By A Density Modulated Electron Beam In A Magnetized Dusty Plasma Cylinder**
Ved Prakash[1]*, Ruby Gupta*[2]*, Suresh C. Sharma*[3] *and Vijayshri*

EP-381: **Effect Of Dielectrics On Cogenerated Dusty Plasma**
Sanjib Sarkar[1]*, M.Bose*[1]*, S.Mukherjee*[2] *& J.Pramanik*

EP-396: **Nonlinear Fluctuation Dynamics Of A Planar Charge-Varying Collisional Inhomogeneous Dust Molecular Cloud**
B. Borah and P. K. Karmakar

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04-12-2013 ***POSTER SESSION-2*** ***Time: 14:00-15:45***

[IP+PP+CM+SA]

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IP-013: Surface Modification Of Polycarbonate (PC) By Using Atmospheric Pressure Plasma At 50 Hz
A.P. Sapkota and D.P.Subedi

IP-048: Analysis Of Microstructure, Wear And Corrosion Behaviour Of Plasma Sprayed Cr_2O_3, Al_2O_3 And TiO_2 Composite Coatings
S. Gowthamaraju, K.Praveen, S. Sivakumar and G..Shanmugavelayutham

IP-091: Generation And Characterization Of Metallic Nanoparticles By Electrical Explosion Of Metals
S Sahoo, A Jaiswar, A K Saxena, R. K. Rout, T C Kaushik and Satish C Gupta

IP-105: Surface Modification Of Textile Fabrics Using Radio Frequency Plasma Treatment
M.S. Nadkarni, A.N. Patil, V.H.Goswami, S.V. Maduskar, N.G. Durge, S. S. Pimpale

IP-151: Probing Argon-Hydrogen Magnetron Sputtering Discharge Plasma With Ion Acoustic Wave
P. Saikia, B. K. Saikia

IP-168: Data Acquisition Techniques For Randomly Occurring Arcs On A Dielectric Surface
Rashmi S. Joshi, Keena R. Kalaria, Suryakant B. Gupta

IP-175: Hydrophilization Of Polymers And Textiles By Atmospheric Pressure Argon Glow Discharge Plasma
R. B. Tyata[1,2]*, D. P. Subedi*[1]*, A. Huczko*[3] *and C. S. Wong*

IP-200: Development of Duplex Plasma Based Process For Improvement Of Surface Properties of Steel
J. Alphonsa, [2]*P. Saikia,* [1]*G. Jhala,* [1]*R. Rane,* [1]*S. B. Gupta,* [2] *B.K. Saikia and* [1]*S. Mukherjee*

IP-235: Effect Of Plasma Treatment On Cellulosic Textile
Kartick K. Samanta, Gayatri T. N., Sujata Saxena, A. Arputharaj, S. K. Chattopadhyay and S. Basak*

IP-237: Plasma Assisted Destruction Of Volatile Pollutants Using Dielectric Barrier Discharge Technique
S. Mohanty[1]*, S.P. Das*[1*]*, R. Paikaray*[2]*, G. Sahoo*[2]*, S. Samantaray*

IP-277: Non-Thermal Atmospheric pressure plasma Jet On Bio-Medical Application
Abhijit Majumdar, Vishal Jain, Chiruya Patil, Akshay Vaid, Subroto Mukherjee

IP-280: **Development And Characterization Of Iron Aluminide Coatings By Thermal Plasma Spray Technique Of Aluminum Powders On Mild Steel Followed By Subsequent Annealing And Evaluation Of Its Erosion Behavior**
R.Sahoo[1], S.Mantry[2] and B.B.Jha[*]

IP-281: Implementation Of Taguchi Design For Performance Evaluation Of Plasma Sprayed Nano-Structured YSZ Coatings
S.Mantry [1], B.B.Jha [2] and R.Sahoo

IP-286: Exploring The Problem Of Screening Length In Plasma Transport Properties
S. Ghorui and A.K. Das

IP-287:Thermodynamic Properties of CVL Lasing Medium
S. Ghorui, and A. K. Das

IP-288: Performance Study of Hafnium Cathodes under Different Current Ratings, Nozzle Diameters, and Plasma Environment
K.C. Meher, S. Ghorui, S.N. Sahasrabudhe and A.K. Das

IP-318: Plasma Spray Coating Of Yttrium Oxide On Graphite Substrates For Compatibility Studies In Molten Metals
Y.Chakravarthy, A.Pragatheeswaran[b], S.Bhandari, Vandana, P.V.A.Padmanabhan, A.K.Das

IP-329: Experimental And Simulation Studies For Optimisation Of Plasma Spraying Of Yttrium Oxide Powder
S.Bhandari[a], T.K.Thiyagrajan[a],Y. Chakravarthy[a], S.N.Sahasrabudhe[a],N. Tiwari[a], A.Pragatheeswaran[c],A.Khanna[b], P.V.A. Padmanabhan[a], A.K. Das

IP-332: In-Flight Particle Characteristic And Microstructure Of $SrZrO_3$
A Pragatheeswaran[a], Subhankar Bhandari, Y Chakravarthy, Vandana C, Nirupama Tiwari, S N Sahasrabudhe, T K Thiyagarajan, P V Ananthapadmanabhan, A K Das

IP-339: Experimental Results at High PRF Of Indigenously Developed 25kV/5kA Pseudospark Plasma Switch
B. L. Meena, U. N. Pal, Mahesh Kumar, Dharmendra Kumar, R. P. Lamba and Ram Prakash

IP-371:Measurement Of Ionization Efficiency Of Inductively Coupled Plasma Ion Source
Ranjini Menon and P. Y. Nabhiraj

IP-386: **Investigation Of The Role Of Shroud Gas In DC Non-Transferred Arc Plasma Torch**
Yugesh. V, Gavisidayyah Hiremath, G. Ravi, and K. Ramachandran

IP-394: Development Of An Efficient UV-B Mercury Free Plasma Based Light Radiating Source
Pooja Gulati[1], U N Pal[1], M. Kumar[1], Vimal Vyas[2] and Ram Prakash

PP-046: Surface Modification Of Polyvinyl Chloride (PVC) By Grafting TiO_2/PVP (Poly Vinyl Pyyrolidine) To Enhance Its Blood Compatibility And Anti-Bacterial Property Dc Glow Discharge Plasma.
A.Suganya[1], M.Kiruthika[1], E.M.Koushika[1], V.Udhayakumar[2], and G.Shanmugavelayutham

PP-047: Surface Modification And Anti-Bacterial Activity Of Polyester Fabrics By Using Non-Thermal Plasma Mode

Equilibrium Nitrogen Plasma
K.C. Meher, N. Tiwari, S. Ghorui and A.K. Das

CM-342: Modelling Of Heat Source Dynamics In Electron Beam Welding
Suresh Akella[1], B. Ramesh Kumar[2] and Y. Harinath

CM-343: Collisionless Microtearing Modes In Standard Tokamak Configurations
Aditya KS, R Ganesh, J. Chowdhury[#], S. Brunner[##], J. Vaclavick[##], L. Villard

CM-375: Simulation Of Multi-Cusp Magnetic Field For Efficient Confinement Of Hydrogen Plasma In H^-Ion Source
D.V. Ghodke,[1]ManishaAgnihotri,[1]Preet Jain,Dr. V.K Senecha & S.C. Joshi

CM-377: Analysis Of Thermal History And Residual Stress In Plasma Sprayed Coatings
M.Raja[1], Gavisiddayya Hiremath[1], K. Ramachandran[2], P.V.A. Padmanabhan[3], T.K. Thiyagarajan

CM-378:Temporal Evolution Of The Electron Energy Distribution During Birth Of A Wave Induced Plasma: Lapse And Relapse Of A Maxwellian
Sudeep Bhattacharjee, Samit Paul and Sayandip Ghosh

CM-388: PIC Modeling Of Laser Channeling Relevant To Fast Ignition
D. K. Singh[1], J. R. Davies[2], G. Sarri[3], F. Fiuza[4] and L. O. Silva

CM-393: PIC-FDTD Code Development For Beam-Wave Interaction In 'PASOTRON'
Nalini Pareek[1], Niladri Sarkar[2], Minhaz Ahmed[1],Udit Narayan Pal[1], Niraj Kumar[1] and Ram Prakash

SA-002: Sun: A Source of Plasma Waves
Vipin K. Yadav, Anil Bhardwaj and R. Satheesh Thampi

SP-004: Effect Of Self-Gravitation On Three-Component Strongly Coupled Dusty Quantum Fluid
R. P. Prajapati[1], P. K. Sharma[2] and R. K. Chhajlani

SP-025: Impacts Of Solar Plasma On Climate Change And Global Warming
S.C. Dubey

SP-052:The Study Of The Earth's Plasmasphere Using Whistlers Recorded At Indian Low Latitude Station, Varanasi (L= 1.07)
S. B. Singh and A. K. Singh

SP-082: Electromagnetic Ion-Cyclotron Waves In Saturn's Magnetospheric Plasma
Vishnu P. Ahirwar and G. Ahirwar

SP-103: Evidence Of Magnetic Reconnection During The Evolutionary Phases Of A Solar Prominence Eruption
Upendra Kushwaha and Bhuwan Joshi

SP-115: Numerical Simulation Of Current Sheet Formation Through Superposition Of Force-Free Magnetic Fields
Dinesh Kumar[1], R. Bhattacharyya[1], and P. K. Smolarkiewicz.

SP-117: Microflares : One Of The Possible Cause Of Coronal Heating
Meera Gupta[1], Rajmal Jain[2] & A. P. Mishra

SA-118: Alfvén Wave Turbulence Of Solar Wind: Role Of Landau Damping
Nitin Yadav, R. P. Sharma

SP-127: Study Of Duct-Lifetimes From Low Latitude Ground Observations Of Whistlers At Srinagar
K. K. Singh

SA-140: A Numerical Study Of Magnetohydrodynamics Relaxation Of Visco-Resistive Plasma
Sanjay Kumar and Ramit Bhattacharyya

SA-150: Farley Buneman Instability In The Dusty Topside Equatorial Electrojet
J. K. Atul and S. K. Singh

SA-164: Ionospheric And Magnetospheric Space Plasma Diagnostic Using ELF/VLF Waves In Low Latitude Region
Ajeet K. Maurya[1,], Rajesh Singh[1] and B. Veenadhar

SA-173: The Influence Of Rotation And Finite Larmor Radius Corrections On Jeans Instability Of Quantum Magnetoplasma
Shweta Jain[1], Prerana Sharma[1] and R. K. Chhajlani

SA-174: The Influence Of Spin Induced Magnetization On Jeans Instability Of Viscous Quantum Plasma With Resistive Effects
Prerana Sharma[1], Shweta Jain[1] and R. K. Chhajlani

SA-178: Perturbations In The Low Latitude D-Region Ionosphere Due To Solar Flares
K. Venkatesham, [1]Ajeet K. Maurya, [2]R. Selvakumaran, [2]B. Veenadhari, [1]Rajesh Singh

SA-187: Statistical Study Of Coronal Mass Ejections And Solar Flares
Apeksha Tonk, Uday P. Verma and A. K. Singh

SA-192: Excitation Of Anisotropic Kelvin Helmholtz Instability In Propagation Of Cosmic Rays In The Interstellar Medium
Subhash Kumar[1], Arijit Chowdhuri[1] and Harinder P. Singh

SA-197: Ion-Acoustic Waves In A Pair-Ion Plasma With A Third Species Of Ions : Application To Cometary Plasmas
Noble P. Abraham, Sreekala G., Sijo Sebastian, Savithri Devi E.
G. Renuka[1] and C. Venugopal

SA-198: Determination Of Ionospheric Electron Density And Reflecton Height Trough Very Low Frequency (VLF) Waves
U. P. Verma, Apeksha Tonk, R. Singh and A. K. Singh

SA-202: The Influence Of Negatively Charged Heavy Ions On Alfven Waves In A Cometary Environment
Sreekala G, Sijo Sebastian, Noble P. Abraham, Savithri Devi E.
Chandu Venugopal and G Renuka

SA-207: Statistical Study Of Coronal Mass Ejections And Solar Flares

Apeksha Tonk, U. P. Verma and A. K. Singh

SA-229: Highly Geo-effective Solar Transient Plasma Events and Associated Interplanetary Features
Subhash Chandra Kaushik

SA-241: Night Time D-Region Plasma Density Measurements From Lightning Generated Tweek Radio Atmospherics Recorded At Low Latitude India Stations
Ajeet K. Maurya[1], Rajesh Singh[1] and B. Veenadhar

SA-231: Characteristic of The Equatorial Plasma Bubbles Occurred Over Varanasi During 2009-2012 Using GPS Based Measurements
V. S. Rathore and A. K. Singh

SA-264: Fast MHD Waves In Coronal Loops With Flows And Heating
A Satya Narayanan and [2]V. S. Pandey

SA-270: Characteristic of The Equatorial Plasma Bubbles Occurred Over Varanasi During 2009-2012 Using GPS Based Measurements
V. S. Rathore and A. K. Singh.

SA-291:The Role of Diffusivity and Viscosity in Solar Plasma
Bhagvat K. Kumthekar[1] and Suresh Chandra

SA-296:Variability Of Propagation Factor During Low Solar Activity
S.K.Vijay, M. K. Richharia And Arun Gautam

SA-301:Disturbances in Solar Wind Plasma Parameters and Solar Features in Relation with Shock Related Geomagnetic Storms
P.L.Verma[1] and Preetam Singh Gour

SA-368:Non-thermal Effects On The Obliquely Propagating Electron-Acoustic Solitary Waves
S. Devanandhan[1], S. V. Singh[1,2], G. S. Lakhina[1] and R. Bharuthram

SA-387:Interaction Of Solar Plasma Near-Earth With Reference To Geomagnetic Storms During Maxima Of Solar Cycle 24
Sham Singh and A.P.Mishra

04-12-2013 ***SESSION-4*** ***Time: 16:15-18:30***

[SA+PP]

SA-I-01:Performance Evaluation of Thermal Protection Systems and High Temperature Materials in Arc Plasma High Enthalpy Facilities
L. Aravindakshan Pillai

SA-I-02:Fully Nonlinear Analysis Of Electrostatic Solitary Waves And Double Layers In The Presence of Magnetic Field
S. S. Ghosh

PP-I-01: Computational Electromagnetics Using GPUs
Harishankar Ramachandran

PP-I-02: HPM Development At IPR For Plasma Physics Applications

Rajesh Kumar, Saurabh kumar, Nasir Shah, Anitha V. P.
Renu Bahl and Anurag shyam.

SA-165 Arrival Azimuth Determination Of Multistation Recorded Low Latitude Whistlers In Indian Sector

Sneha Gokani and Rajesh Singh

05-12-2013 ***SESSION-5*** ***Time: 09:00-11:00***

[LP]

LP-I-01: Self-Modulated Proton-Driven Plasma Wakefield Accelerator: A New Approach to TeV Electron Acceleration

Ajit Upadhyay[1] and Alexander Pukhov[2]

LP-I-02: Generation Of Negative Ions From Solids Using Ultra-Short Laser Pulses

S. Bagchi, M. Tayyab, B. Ramakrishna, T. Mandal, J. A. Chakera,
P. A. Naik, and P. D. Gupta

LP-I-03: Laser-Blow-Off Of Thin Film: Spectral And Dynamical Behaviour In Different Experimental Conditions

Rajesh Kumar Singh

LP-390: Copper Laser Plasma Generation And Characterization

Tobin K Thomas,Subin P S, Smijesh N, Sabu Thomas,
Reji Philip[2], Nandakumar Kalarikkal

LP-033: Magnetic Field Enhanced Plasma Electron Trapping In Laser Wakefield Acceleration

K.Gopal and D. N. Gupta

05-12-2013 ***POSTER SESSION-3*** ***Time: 11:15-12:45***

[NF+OA]

NF-006: Main Vacuum Pumping System Of SST-1 Tokamak

Ziauddin Khan, Firozkhan Pathan, Siju George, Kalpesh Dhanani, Yuvakiran Paravastu, Pratibha Semwal and Subrata Pradhan

NF-008: Indigenous Development Of Compact Neutron Generator

Basanta Kumar Das[1], Anurag Shyam[1], Rashmita Das[1] and A. Durga Prasad Rao[1]*

NF-010: Development Of Epics Based Software Toolkit For Critical Heat Flux Computions For Divertor Mockups Testing At High Heat Flux Test Facility

S. K. Doddi[1], R. Sugandhi[2], R. Swamy[2] and S. Khirwadkar[2]

NF-011: Design And Development Of A 200KV, 15MA High Voltage Power Supply

Amal S, Urmil M Thaker, Kumar Saurabh and Ujjwal K Baruah

NF-014: Physics Aspects Of ICRF Wall-Conditioning Experiments In Textor

Manash K. Paul[1], A. Lyssoivan[3], R. Koch[3], G. Van Wassenhove[3], M.Vervier[3], G. Bertschinger[2], R.Laengner[2], B.Unterberg[2], G. Sergienko[2], V. Philipps[2], T. Wauters[4] and the TEXTOR Team

NF-023: Testing Of High Speed Profibus Link For VME V6PFB Profibus Card And Siemens DC Simoreg Master (6ra70)
Dinesh Kumar Sharma and SST-1 Power System Team

NF-027: Radiation Damage Study Of Graphite Exposed To Helium Ions
N. J. Dutta[1], N. Buzarbaruah, S. R. Mohanty, P. M. Raole, T. Dash, B. B. Nayak

NF-029: Application Of AACMM In Quality Control For Development Of Superconducting Magnet Components
Mahesh Ghate, Dhaval Bhavsar, Arun Panchal, Subrata Pradhan

NF-045: Development Of Experimental Helium Cooling Facility For Testing Of LLCB TBM First Wall Mock-Ups
Brijesh Kumar Yadav[a], Ankit Gandhi[a], Aditya Kumar Verma[a], T Srinivas Rao[a], E. Rajendra Kumar[a] , Mausam Sarkar[b] and K. N. Vyas

NF-056: MDSplus Integration With ICRH DAC Software
Ramesh Joshi, Manoj Parihar, H M Jadav, S V Kulkarni & ICRH Group

NF-057: Engineering Design Of Epics Based Prototype For ICRH DAC System
Ramesh Joshi[12], Manoj Singh[1], S V Kulkarni[1], Kiran Trivedi

NF-065: Codac Core Based Control System For 300KV Accelerator Based 14-MeV Neutron Generator
Vismaysinh Raulji, Praveenlal E V, Hitesh Mandaliya, Rachana Rajpal, Rajnikant Makwana and Sudhirsinh Vala

NF-080: DESIGN AND DEVELOPMENT OF A LINEAR NEUTRON SOURCE BASED ON INERTIAL ELECTROSTATIC CONFINEMENT FUSION SCHEME
N. Buzarbaruah[a], N. J. Dutta[a], M. K. Deka[a], S. R. Mohanty[a], M. Bandyopadhay[b], P. M. Raole,R. Verma and A. Shyam*

NF-083: Field Simulation Of Ohmic Ramp-down In Aditya – Need For Correction Coils For Improvement Of Magnetic Null
A. Amardas, R. L. Tanna, J. Ghosh, P. K. Chattopadhyay, C. N. Gupta, S. B. Bhattand the Aditya team

NF-085: Surface Damage From Exposure To Pulsed Fusion Grade Plasma Generated Using A Plasma Focus Device
Satish C. Gupta[1], Ram Niranjan[1], R. K. Rout[1], R. Srivastava[1], Y. Chakravarthy[2], N. N. Patel[3] and P. Alex[4]

NF-094: Joining Of Graphite To Heat Sink Material By Direct Vacuum Brazing Using Active Metal Filler Material
K.P Singh[1], S S Khirwadkar[1], Malti Verma[2], S Kanpara[1], M.S Khan[1], S Belsare[1], Nikunj Patel[1], Prakash Mokaria

NF-128: Cryogenic Operation Strategy For The SST-1 Device
V.L. Tanna, Cryogenic Team (SST-1) and S. Pradhan

NF-135: Design And Development Of High Flux Pulsed Neutron Source For Applications
Rishi Verma, R. Shukla, S. Sharma, B. K. Das, E. Mishra, K. Sagar, M. Meena and A. Shyam

NF-161: General Purpose Signal Acquisition System For Acquiring, Storing And Integrating Electrical Signals
Vijay Vadher, Paresh Patel, L. K. Bansal, Karishma Qureshi , Dipal Thakkar, Vishnu Patel, L. N. Gupta, C.B. Sumod and U. K. Baruah

NF-171: Timing Control Circuit For Real-Time Control Of Events In Aditya Tokamak

Praveenlal E V, Prakash Naicker, Rachana Rajpal, Pravesh Dhyani, Joydeep Ghosh, R. Tanna, P. K. Chattopadhyay and Aditya Team

NF-179: Control of Plasma Layer In a Fusion Reactor Correlated to Dc Motor Control Using PSO-ANFIS

Sakuntala Mahapatra, Raju Daniel and Deep Narayan Dey

NF-191: Variable Duty Cycle & Variable Amplitude Multi Pulse Generation Facilities Development In The PXIE System For Different Mode Of ICRH Operations

Manoj Singh[1], H.M. Jadav, Ramesh Joshi, Sunil kumar, YSS srinivas, B.R. Kadia, K. M. Parmar, Gayatri Ramesh, Atul varia,S.V. Kulkarni and ICRH-RF Group

NF-203: Acceptance Tests Of Cryogenic Components For SST-1

Rajiv Sharma, Hiren Nimawat, Nitin Bairagi, Pankil Shah, Ketan Patel, Srikanth, *D. Sonara, V. L. Tanna and S. Pradhan*

NF-206: Ramp Based Measurement Circuit For Langmuir Probe Diagnostic

Pramila, Jignesh Patel, Rachana Rajpal, R.Jha

NF-208: Design And Development Of IGBT Based Circuit For Switching Off The Plasma For Wave Experiments In Afterglow Plasma

Minsha Shah, Rachana Rajpal, Sayak Bose, P.K. Chattopadhyay

NF-215: Liquid Nitrogen Distribution Boxes For Cool Down Of 80K Thermal Shields Of SST-1

R. Panchal, GLN Srikanth, K. Patel, P. Shah, V.L. Tanna and S. Pradhan

NF-227: Base Pressure Is The Determining Factor For Blob Formation In Argon Plasma

G. Sahoo[1], R. Paikaray[1], S. Samantaray[2], P. Das[1], D. C. Patra[1], N. Sasini[1], J. Ghosh[3], A. Sanyasi

NF-228: Variation Of Intensity Of Atomic Lines In Atmospheric Gas Plasma Produced By Washer Plasma Gun

P. Das[1], R. Paikaray[1], S. Samantaray[2], G. Sahoo[1], D. C. Patra[1], N. Sasini[1], J. Ghosh[3], A. Sanyasi[3], M. B. Chowdhuri.

NF-239: Recent Run-Time Experience And Investigation Of Impurities In Turbines Circuit Of Helium Plant Of SST-1

P. Panchal, R. Panchal, R. Patel, G. Mahesuriya, J. Tank, D. Sonara, Srikanth LN, K. Patel, D. Christian, A. Garg, N. Bairagi, P. Shah, H. Nimavat, R. Sharma, V.L. Tanna and S. Pradhan

NF-245: Design Of An Experimental Setup For Determining Hydrogen Isotopes Solubility In Liquid Lead Lithium

Sudhir Rai, Amit Sircar and Sanjeev Kumar Sharma

NF-249: Studies Of Out-Gassing Rate Carried Out For Various Materials To Be Used In Cryoadsorption Cryopump

Samiran Mukherjee, Paresh Panchal, Agarwal Jyoti, Ranjana Gangradey, Ravi Prakash N.

NF-250: Degassing Measurement Studies Carried Out For Various Forms of Activated Carbon

Samiran Mukherjee, Sapana Guru, Pratik Nayak, Jyoti Agarwal, Ranjana Gangradey

NF-251: Indigenous Development of Single Barrel Hydrogen Pellet Injector System

Samiran Mukherjee, Paresh Panchal, Pratik Nayak, Pramit Dutta, Naveen Rastogi, Alaap Jagdale, Haresh Patel, Ranjana Gangradey, Ravi Prakash N.

NF-271: Design, Development And Characterization Of Interlock System For 42 GHz ECRH System On Aditya And SST-1 Tokamak
Rajan Babu.N, B K Shukla, Harshida R. Patel,Jatin Patel, Pragnesh B. Dhorajiya and ECRH Division

NF-272: Optimization Study Of ITER-VVPSS Tank
Gaurav Jogi, Girish Gupta, Vipul More, Avik Bhattacharya, Jagrut Bhavsar, Mukesh Jindal, Vaibhav Joshi, Mitul Patel, Rajnikant Prajapati, Amit Palaliya, Saroj Jha, Manish Pandey and Anil Bhardwaj

NF-273: Engineering Validations Of SST-1 Magnet system
A.N. Sharma, K. Doshi, U. Prasad, Y. Khristi, P. Varmora, M. Banaudha, B. Parghi and S. Pradhan

NF-274: Design Optimization Of The Transporter Frame For The Cryostat Lower Cylinder
Avik Bhattacharya, Girish Gupta, Jagrut Bhavsar, Mukesh Jindal, Gaurav Jogi, Vipul More, and Anil Bhardwaj

NF-276: Design Of An Extractor For Hydrogen Isotopes In Liquid Lead Lithium
Rudreksh B. Patel, Sudhir Rai and Amit Sircar

NF-282: Overview Of Instrumentation And Control Of ITER-Cryostat
Dileep Shukla, Mukesh Jindal, Girish Gupta, Anil Kumar Bhardwaj

NF-292: Commissioning Of -70KV Solid State Crowbar System
YSS Srinivas, N Rajan Babu, KM Parmar, Bhavesh Kadia, Chetan Virani, Pragnesh Dhorajiya, Jigalraj Vansia, Shefali Dalakoti, Doshi Ravikumar, Brahmbhatt Tushar, Patil Gajendra, Anil Vishwakarma and SV Kulkarni

NF-293 Simulation Of Scenarios Of LHCD Antenna For Pre-ionization In SST1 Machine
P. K. Sharma, K. K. Ambulkar, S. Dalakoti, C. G. Virani, P. R. Parmar, A. L. Thakur

NF-303: Scattering Matrix And Parasitic Mode Analyses For 170 GHZ, 1 MW Gyrotron Beam Tunnel
Nitin Kumar, Udaybir Singh, Mukesh Kr. Alaria and AK Sinha

NF-304: Control And Monitoring Of High Power Rf Dummy Load
Harsha Machchhar, R.G. Trivedi, and Aparajita Mukherjee

NF-305: Conceptual Design Of I-Q Demodulator Technique For ICH & CD Source
Dipal Soni, Kumar Rajnish, Manoj A Patel, Sriprakash Verma, RG Trivedi, Raghuraj Singh and Aparajita Mukherjee

NF-311: Cooldown Characteristics Of LN2 Transfer Lines And Chevron Shielding For NBI Cryo-Condensation Pumps
B.Pandya, A.K.Sahu, L.K.Bansal, B. Choksi, N.Contractor, S.L.Parmar, S.K.Sharma L.N.Gupta, P.Bharathi, V.B.Vadher, D.Thakkar, C.B.Sumod, K. Qureishi, V.Prahlad, P.J.Patel and U.K.Baruah

NF-314: Vacuum And Cryogenic Performance Study Of A Cryostat Used For Testing Different Cryopanels
Pratikkumar Nayak, Paresh Panchal, Samiran Mukharjee, Manoah Stephen M, Jyoti Agrawal, Ranjana Gangradey

NF-315: Design And Analysis Of Cryostat PHTS Circular Bellows
Manish Kumar Pandey, Girish Gupta, Avik Bhattacharya, Gaurav Jogi, Vipul More, *Saroj Kumar Jha and Anil Bhardwaj*

NF-320: Thermal Stress Analysis Of The Cryo-Adsorption Cryopump

NF-345: Joule Heating Analysis Of Cryo-Adsorption Cryopump Due To Induced Eddy Current For Various Magnetic Loading Conditions

Pramit Dutta, Ranjana Gangradey, RaviPrakash N, Hemant Patel, Krishna Kumari K

NF-346: Study Of Pellet Fuelling Requirements For Aditya And SST-1 Tokamak

J. Mishra, S. *Mukherjee, P. Nayak, P. Panchal, N. Rastogi, R. Gangradey, N Ravipragash*

NF-347: Development of Wireless Mobile Robot with Real time Obstacle Avoidance and Path Planning using FPGA

Naveen Rastogi[1], Ravi Prakash N[1]., Pramit Dutta[1], Pratik Bhimani, Pranav Manvar

NF-348: Development Of LabVIEW™ Based Application For Interfacing Of Cryo Pump With ROBIN DACS

Radhika Gupta[1], J. Soni[2], H. Tyagi[3], R.K.Yadav[3], H. Mistry[2], K. Pandya[2], G. Bansal[2] and A. Chakraborty

NF-349: Dynamic Navigation Simulation Of An Articulated Multi-Link Arm For In-Vessel Inspection Tasks In A Tokamak

Naveen Rastogi[1], Ravi Prakash[1], PramitDutta[1], Nirav Virpara

NF-350: Studies Of Adsorption Characteristic Of Various Activated Carbons Down To 4.5K

S. Kasthurirengan[1], Upendra Behra[2], Samiran Mukherjee[1], Ranjana Gangradey*

NF-351: PXI Based Data Acquisition and Control System for Single Barrel Pellet Injection System

Naveen Rastogi, Haresh Patel, Samiran Mukherjee, Alaap Jagdale, Ranjana Gangradey

NF-352: Development Of Two Series Ingnitron Based Crowbar Protection System For 42 GHz & 82.6 GHz Gyroton In SST-1

Pragnesh Dhorajiya, Shefali Dalakoti, Harshida Patel, Krunal ingle, Jatin patel, K. Sathyanarayana, Rajanbabu and B. K. Shukla

NF-354: Real Time Interfacing Of 3D CAD Simulation in Delmia with Articulated Robotic Arm

Naveen Rastogi[1], Ravi Prakash[1], PramitDutta[1], Nikunj Kachhadia[1], Archit Sureja[1], NiravVirpara

NF-356: Self-localization and Coordination Control of an articulated Manipulator using Photogrammetry & Stereo Vision Solution

Naveen Rastogi, Ravi Prakash, Pramit Dutta, Archit Sureja, Ankita Patel

NF-358: Commissioning, Interfacing, Testing And Operation Of -10KV, 400MA High Voltage Power Supply With ROBIN For Beam Extraction

K G Parmar, A. Gahlaut, V.Mahesh, R.K.Yadav[1], Deepak Parmar[1], J. Soni, G. Bansal, B Prajapati H Mistri, K. Pandya, M. Bandyopadhyay[*] and A. Chakraborty

NF-360: A Comparison Study Of Various Seismic Analysis Methods

S S Sandhu[1], Y Dileep

NF-361: Heater Design And Thermal Analysis Of Cathode Assembly For 170 GHZ, 1 MW Gyrotron

Udaybir Singh[1], Monika Sheoran[1,2], Nitin Kumar[1], Mukesh Kr. Alaria[1] and AK Sinha

NF-364: Disruption Characterization And Database Generation For Itpa Disruption Database From Aditya Tokamak Discharges

R.L. Tanna, V.K.Panchal, Pintu kumar, K.A. Jadeja, S.B. Bhatt, C.N. Gupta, U. Dhobi, P.K. Atrey, Y.S. Joisa, C.V.S. Rao, D.Raju. R. Jha, P.K. Chattopadhyay, J. Ghosh, A. Sen and ADITYA team

NF-365: THERMAL CHARACTERIZATION OF FBG SENSORS FOR NUCLEAR FUSION REACTOR RELEVANT APPLICATIONS
M. Sai Shankar[1], M. Manohar[1], R.L.N.Sai Prasad[1] & B Ramesh Kumar

NF-385: Upgradation Of Fibre Optic Based Analog Signal Link For ECRH System On SST-1
Harshida Patel, B. K. Shukla, Jatin Patel, N. Rajan Babu, Pragnesh Dhorajiya and Chetan Virani

OA-357: A Transient Finite Element Simulation For The Thermo-Mechanical Study Of Lip Seal Laser Weld Joints
Ashish Yadav[1], Chandramoulli Rotti[2,] Mukesh Jindal[1], Jaydeep Joshi[1], Arun Chakraborty[2]

OA-366: Study Of Thermo-Mechanical Behaviour Of Swirl Tube Element
M Venkata Nagaraju, Chandramouli Rotti and Arun Chakraborty

OA-369: Synthesis, Structural And Electrical Characterization Of Sr^{2+} Doped ZnO
Tanushree Das , Bikram keshari Das , Kajal Parashar, S.K.S.Parashar*

OA-376: NTCR Effect Of Nano BZT- x BCT Ceramic For Temperature Sensor Application
Nagamalleswara Rao Alluri, S.K.S Parashar , Kajal Parashar

OA-380: Design and Development Of Different Microwave Components For A High Frequency ECR Ion Source
Anuraag Misra, P. Y. Nabhiraj and Alok Chakrabarti

OA-397: Al Metal Matrix Composites Reinforced With Nanocrystalline Al-Ca Intermetallics
A.K Chaubey[1], B.B. Jha and K.G. Prashanth

OA-398: Innovative Thermal Plasma Processing For Treatment Of Mineral Wastes
K. Jayasankar and P. S. Mukherjee

OA-144: An Efficient Experimental Remedy To Protect Bell-metal From Losing Its Bright Golden Colour
Sankar Moni Borah

OA-217: Plasma Etching Of High Density Polystyrene Applicable For Fabrication Of Microfluidic Devices
Narendra Kumar Agrawal[1], Prashant Pimpliskar[2], Y. K. Vijay[3], K. C. Swami

OA-261: Propagation Of Microwave Plasma In The Range Of 700 Mhz - 5 GHz By Using 0.7-5 GeV Klysron Switching Data Packet With 3.3Gbps
A.B.R. Hazarika

OA-262: Use Of Microwave Plasma In The Range Of 700 MHz - 5 GHz By Using 0.7-5 GeV Klysron Switching Circuit In Automobiles
A.B.R. Hazarika

OA-263: Toroidal 12 Cavity Klystron : A Novel Approach
A.B.R. Hazarika

OA-340: Outgassing Testing Of Materials Of ITER Cryostat
Mukesh Jindal, Amit Palaliya, Ranjikant Prajapati, Vaibhav Joshi, Mitul Patel, Jagrut Bhavsar, Girish Gupta, Anil Bhardwaj

05-12-2013 SESSION-6 Time: 13:45-16:00
[EP+CM]

CM-I-01:3-D Particle-in-Cell simulations for a THz Range Vircator
Gursharn Singh and Shashank Chaturvedi

CM-I-02: Modeling Of Relativistic Longitudinal Plasma Waves
Sudip Sengupta

EP-I-01: Numerical Experiments In Pure Electron Plasmas Confined In Toroidal And Cylindrical Traps
Ganesh Rajaraman

EP-I-02: Nanofabrication By Plasma Route And Their Characterizations
M. P. Srivastava

EP-026: Self -Excited And Externally Driven Dust Acoustic Waves In Strongly Coupled Dusty Plasmas
Jyotirmoy Pramanik and Pankaj Patra

05-12-2013 SESSION-7 Time:16:15-18:30
[PD]

PD-I-01: Diagnostics in Indian Test Facility (INTF) for ITER-Diagnostic Neutral Beam
M. Bandyopadhyay and NNBD team

PD-I-02: Infrared Imaging Diagnostics For Plasma Confinement Devices
Santosh P. Pandya, Shwetang N. Pandya, Shamsuddin Shaikh, Zubin Shaikh, Kanchan Mahavar, Kumar Ajay, J. Govindarajan, ADITYA and SST-1 Team

PD-I-03: Recent Developments In Ultra-High Intensity Laser Plasma Diagnostics At RRCAT
J. A. Chakera, M. Tayyab, B. S. Rao, V. Arora, Y. B. S. R. Prasad, S. Bagchi, A. Moorti, T. Mandal, P. A. Naik, and P. D. Gupta

PD-367: Optical Diagnostic of Low Pressure Inductively Coupled Krypton Plasma using Emission Measurements and CR Model
R. Srivastava[1], Dipti[1], R. K. Gangwar[2] and L. Stafford[2]

PP-146: Effect Of Localized Surface Resonance On The Growth Of Carbon Nanowalls: Inference From Langmuir Probe Diagnostics
R. Kar[1], N.N. Patel[2], S. Mukherjee[1], A.K. Das[1] and D.S. Patil

PD-040: Characterization of DC Glow Discharge Plasma in Co-Axial Electrode Geometry
R. Kumar[1], R. Narayanan[2], R.D. Tarey[1], A. Ganguli

06-12-2013 SESSION-8 Time:09:00-11:00
[OA]

OA-I-01:Plasma Processing – A Green Revolutionary Technology Towards Future
P. S. Mukherjee and B. Bhoi

OA-I-02:Periodic Self Sub-Wavelength Periodic Nano-Patterned For Anti-Reflection Application

Pratap K. Sahoo

OA-I-03: Development Of Advanced Carbonaceous Micro Fiber Adsorbents And Novel Approach For Their Integration On Cryo Panels

Vijai Shankar Tripathi

OA-O-284: Engineering High Power Induction Plasma Unit at BARC for Mass Synthesis of Refractory Nano-Ceramics

S. Ghorui, S.N. Sahasrabudhe, G. Dhamale and A.K. Das

OA-302: Interaction Cavity Design For Tunable Gyrotron For DNP/NMR Spectroscopy

Nitin Kumar, Udaybir Singh and AK Sinha

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06-12-2013 *POSTER SESSION-4* *Time: 11:00-13:00*

[PD+PU+LP]

....

PD-003: Conceptual Design of an In-Vessel Inspection Robotic System for Tokamak Environment

Prabhat Kumar[#], Prateek Patel[§], Daniel Raju[#], Jatinkumar Dave[§], Vaibhav Ranjan[#] and Mehul Naik[§]

PD-030: Estimation Of Post Disruption Plasma Temperature For Fast Current Quench Aditya Plasma Shots

S. Purohit, M. B. Chowdhuri, Y.S. Joisa, J.V. Raval, J. Ghosh, R. Jha and Aditya team

PD-051: Plasma Diagnostics at Aditya Tokomak by Two Views Visible Light Tomography

Mayank Goswami [1], Prabhat Munshi [1, 2], Anupam Saxena[2], Manoj Kumar[3], and Ajai Kumar

PD-060: Studies of Impurity Behavior during Lithiumization Experiment In Aditya Tokamak

Niral Virani, M. B. Chowdhuri, R. Manchanda, Nilam Ramaiya, K. M. Jadej,Bhatt, R. L.Tanna, C. N. Gupta, J. Ghosh and Aditya Team

PD-061: A Pmt Array Based Diagnostics To Measure Spatial And Temporal Behavior Of H_α Emission From Aditya Tokamak

Nilam Ramaiya, Ajay Kumar, M. B. Chowdhuri, R. Manchanda, Niral Virani, Aniruddh Mali and J. Ghosh

PD-069: Laser Interferometery for Temporal Electron Density Measurement of Electrically Exploding Wire Plasmas

Jigyasa Batra, Ashutosh Jaiswar, Alok Saxena, T.C. Kaushik and S.C. Gupta

PD-090: Experimental Study Of Thermal Characteristic Of Different Thin Metal Foils For Infrared Imaging Video Bolometer And Comparison With FEM Simulations.

Kanchan Mahavar, Santosh P. Pandya, Hitesh Patel, Shamsuddin Shaikh, Zubin Shaikh Shwetang N. Pandya, Kumar Ajay and J. Govindrajan

PD-092: Improved Charge Collector Diagnostics For Electron Plasma In Smartex-C

Lavkesh Lachhvani, Karan Rathod, Manu Bajpai and Sambaran Pahari

PD-096: Ion Temperature Measurement On The Aditya Tokamak

Santosh P. Pandya, Kumar Ajay, Snehlata Gupta, Priyanka Mishra, Rajani D. Dhingra, J. Govindarajan and ADITYA-Team

PD-098: Infrared Thermographic Observation Of SST-1 Limiter During First Plasma Experiments

Santosh P. Pandya, Shamsuddin Shaikh, Zubin Shaikh, Kanchan Mahavar, Shwetang N. Pandya Kumar Ajay, J. Govindarajan and SST-1 Team

PD-102:Magnetic Measurements Of First Plasma Experiments Of Tokamak SST-1
Sameer Kumar, Daniel Raju, A. Amardas, Ratneshwar Jha and SST-1 team

PD-129: ND: YAG Laser Control For Thomson Scattering Diagnostic In SST-1
Kiran Patel, Jinto Thomas and Ajai Kumar

PD-152:Preliminary Design Considerations for Erosion/Deposition Monitor in ITER
Rajwinder Kaur[1], R. Huxford[2], G.Vayakis[2], J.Govindarajan[2], P.Andrew[2] and M. Walsh[2]

PD-155:Diagnostics of Microwave Based Atmospheric Pressure Plasma Jet
Rajib Kar, Naresh Chand, Arundhati Bute, A.K. Das, L. M. Gantayet and D. S. Patil

PD-158:Experimental And Monte-Carlo Absolute Efficiency Calibration Of HPGE γ-Ray Spectrometer For Application In Neutron Activation Analysis
S. Tiwari, S. Jakhar, M Abhangi, R Makwana, V. Chaudhari, C.V.S Rao, T.K.Basu

PD-159:Development of PXI based DAQ in LabVIEW® for SMARTEX – C
Yogesh Govind Yeole, Lavkesh Lachhvani, Sambran Pahari[1] and Manu Bajpai

PD-162: Estimation Of Effective Secondary Electron Emission Coefficient From The Power Balance Of Cathode Under Plasma Condition
Saravanan A, Prince Alex, Suraj Kumar Sinha.

PD-167:Measurement Of Electron Temperature And Electron Density In Atmospheric Pressure Dielectric Barrier Discharge By Optical Methods
R Shrestha[1, 2], R B Tyata[1, 3], A K Shrestha[1], D P Subedi

PD-177:Spectroscopic Diagnostics of the Washer Gun Plasma of SYMPLE
Piyali Adhikary, M. B. Chowdhuri, Priyavandna J. Rathod, B Ramesh Kumar and Anitha V.P.

PD-184:Operation and Control System Design for Large Volume Plasma Device
R. Sugandhi, P. K. Srivastava, Amit Patel, A. K. Sanyasi, S. K. Singh, L. M. Awasthi and S. K. Mattoo

PD-185:Magnetic Probe Diagnostics for SYMPLE
AnoopSuseel, Praveenlal E V, P.K. Srivastava, Priyavandna J. Rathod and Anitha V.P.

PD-186:Process Instrumentation Modeling for Vacuum System Automation of LVPD
P. K. Srivastava[2], R. Sugandhi[2], R. Jain[1], A. K. Sanyasi[2], S. K. Singh[2], Amit Patel[2], Kalpesh Raval[2],L. M. Awasthi[2] and S. K. Mattoo[2]

PD-188:Pulser Circuit for Plasma Potential and Beam Current Measurements in LVPD
Kalpesh Raval, P. K. Srivastava, A. K. Sanyasi, Amit Patel, S. K. Singh, L. M. Awasthi and S. K. Mattoo

PD-189:Design and Development of Electronics Circuit for TLP Diagnostics in LVPD
P. K. Srivastava, Kalpesh Raval, Amit Patel, S. K. Singh, A. K. Sanyasi, L. M. Awasthi and S. K. Mattoo

PD-193:Smart Trigger Clock System For Generic PXI DAQ System
Tushar Raval, Atish Sharma, Imran Mansuri Manika Sharma, S. Pradhan

PD-210: **Measurement of Electron Temperature Profile Using Absorption Foil Technique for ADITYA Tokamak Discharges**
Jayesh v. raval, Shishir purohit, Sudeshna maity[1], Shankar joisa and Aditya team

PD-211:Calibration And Performance Testing Of Pulse Counting Module And Channel Electron Multiplier Detector For Charge Exchange Diagnostic in SST-1
Snehlata Gupta, Santosh P. Pandya, Hitesh Patel, Kumar Ajay

PD-218:Influence Of Pressure And Voltage On The Plasma Parameters In A Low Pressure DC Glow Discharge Using Langmuir Double Probe Method
A. K. Shrestha, R. Shrestha, R. B. Tyata, D. P. Subedi

PD-222:Study of the Hα Line Broadening in Plasma Torch Used for Coating Application
Sarita Das, Debi Prasad Das, Sisir Mantry, Santosh Kumar Behera

PD-236:Study of neutral beam attenuation of 5MW hydrogen beam in SST-1 Tokomak
P.Bharathi, S.Ranjan, S.Thirumugam, S.K.Sharma, V.Prahlad, U.K.Barua and P.Vasu C.Giroud, E.Delabie and N.C.Hawkes

PD-240:Infrared Imaging Diagnostics For Plasma Confinement Devices
Santosh P. Pandya, Shwetang N. Pandya, Shamsuddin Shaikh, Zubin Shaikh, Kanchan Mahavar, Kumar Ajay, J. Govindarajan, ADITYA and SST-1 Team

PD-258:Engineering aspects of Microwave Diagnostics at ITER
K. M. Patel, V. S. Udintsev, G. Vayakis, O. Darcourt, T. Giacomin, D. Johnson, Ph. Maquet, H. B. Pandya, C. Penot, M. Portales, M. Proust, J. W. Oosterbeek, P. Sanchez, V. Vershkov, M. Walsh

PD-260:Measurement Of Stark Width In Laser Produced Copper Plasma In The Presence Of Magnetic Field
Kh. Shantakumar Singh and Ashwini K. Sharma

PD-294: 100 GHz Interferometer to Measure Chord Averaged Plasma Density at SST-1 Tokamak
P. K. Atrey, Umeshkumar C. Nagora and Abhishek Sinha

PD-295: Ku Band Reflectometer at SST-1 Tokamak
P. K. Atrey and Nirav Joshi

PD-312: Laser Induced Graphite Plasma In Liquid By Ccd Imaging
Indrajeet Kumar, P. K. Baruah, A. K. Sharma and Alika Khare

PD-337: Conceptual Design of Cavity Ring Down Spectroscopy (CRDS) in INTF
Dass Sudhir, M. Bandyopadhyay, H. Tyagi, A. Yadav, J. Joshi, R. Pandey, J. Soni, R. Yadav, C. Rotti, A. Chakraborty

PD-363: A Multi-Channel Photodiode Array System for Plasma Formation Location Studies in Aditya Tokamak
Aniruddh Mali, M.B.Chowdhari, R. Manchanda, N. Ramaiya, N. Chanchapara and J. Ghosh

PD-389: Modeling Of Plasma Emission Spectra Using Different Computer Codes
Sharvil Patel, J. Ghosh

PD-392: Experimental Study Of Thermal Characteristic Of Different Thin Metal Foils For Infrared Imaging Video Bolometer And Comparison With FEM Simulations
Kanchan Mahavar, Santosh P. Pandya, Hitesh Patel, Shamsuddin Shaikh, Zubin Shaikh Shwetang N. Pandya, Kumar Ajay Mishra and J. Govindrajan

PD-395: Development of a Penning Plasma Discharge Source with Different Anode Configurations for Simultaneous Emissions of Visible and VUV Lights
G. L. Vyas, R. Prakash, U. N. Pal, Nandini Singh, R. Manchanda and N. Halder

PU-005: Study Of Discharge Characteristic Of Exploding Wire
Rashmita Das, Basanta Kumar Das and Anurag Shyam

PU-070: Optimization and Characterization of Surface Discharge Switches
Jigyasa Batra, Ashutosh Jaiswar, T.C Kaushik and S.C Gupta

PU-071: Investigations On Electrically Exploded Conductors For Current Pulse Sharpening Applications
Soumya P. Nayak, M.D. Kale, T.C. Kaushik and Satish C. Gupta

PU-077: Effect Of Electron Emission Pattern On Vircator Performance
Gursharn Singh, Sijoy C.D. and Shashank Chaturvedi

PU-110: Effect Of Foil Parameters On Flyer Velocity In Electrically Exploding Foil Accelerators
A. K. Saxena, M. G. Sharma, T. C. Kaushik and Satish C. Gupta

PU-124: Compact Pulsed Power System For Pulsed Microwave Generation
Surender Kumar Sharma, P Deb, R Verma, R Shukla, P Banerjee, T Prabaharan & A Shyam

PU-126: Estimation Of Plasma Stream Parameters In A Pulsed Plasma Accelerator
S. Borthakur, P. Sah, N. K. Neog, T. K. Borthakur, R. Kumar, R. Verma, A.Shyam.

PU-130: Design And Development Of 200 KJ Energy Pulsed Power System To Drive Pulsed Plasma Devices
S. Borthakur, N. K. Neog, T. K. Borthakur, R. Kumar, R. Verma, A.Shyam

PU-131: Study On Neutron Emission From PF Device Using Two New Anode Shapes
N. Talukdar, N. K. Neog, S. Borthakur, T. K. Borthakur

PU-133: Design And Development Of Fast Pulser For Initiating Multichannel Breakdown In Railgap Switch
Rishi Verma, Ekansh Mishra, Rohit Shukla, Karuna Sagar, Manraj Meena and A. Shyam

PU-153: High Power Microwave Generation by a Reflex Triode Vircator
Biswajit Adhikary, R.Verma, R. Shukla, S.K.Sharma, P.Banerjee, R Das, P Deb, T. Prabaharan, BK Das and Anurag Shyam

PU-230: Setup Of MPP Capacitor Bank And Time Delay Circuit For The Electromagnet Of Compact Plasma System At Ravenshaw University
S. Samantaray, R. Paikaray, G. Sahoo, P. Das, D. C. Patra, N. Sasini, J. Ghosh, A. Sanyasi

PU-265: High Power Microwave Generation From Axially Extracted Virtual Cathode Oscillator Using Kali-1000 Pulse Power System
N. Satyanarayana, Shibaji Basu, Nitin Waghmare, Sachin Chavhan, Sunil Swamy, Samir Sahoo, Bijayalaxmi Sethi, Ramanand Raman, Rishi Verma, Rohit Shukla R.K. Rajawat, K.C. Mittal and A. Durga Prasada Rao

PU-300: Capacitive Pulsed Power Driver For Electromagnetic Launchers
Pankaj Deb and Anurag Shyam

PU-307: HPM Development At IPR For Plasma Physics Applications
Rajesh Kumar, Saurabh kumar, Nasir Shah, Anitha V. P. Renu Bahl and Anurag shyam.

PU-317: 3-D Particle-In-Cell Simulations For A THz Range Vircator
Gursharn Singh and Shashank Chaturvedi

PU-344: Intense Relativistic Electron Beam Generation Using Explosively Generated Tantalum Cathode Plasma
Romesh Chandra, Ankur Patel, R Menon, R Agarwal, K Senthil, Archana Sharma, K. C. Mittal

PU-396: Experimental Studies Of Radial Multi-Channel Pseudospark Switch

R. P. Lamba, B. L. Meena, U. N. Pal, D. K. Pal,
H. Rahaman and Ram Prakash

LP-024: Propagation Of Short Two-Color Laser Pulses In Homogeneous Plasma: Theory And Simulation Of Wakefield Generation
Akanksha Saroch and Pallavi Jha

LP-031: Laser Beat-Wave Acceleration In A Relativistic Collision-Dominated Plasma
Maninder Kaur and Devki Nandan Gupta

LP-032: Relativistic Second And Third Harmonic Generation Of A Laser In A Self-Sustained Magnetized Plasma Channel
Mamta Singh and Devki Nandan Gupta

LP-034: Effect Of Energetic Electrons On Temporal Evolution Of Stimulated Raman Scattering Of A Laser In Plasmas
Pinki Yadav and Devki Nandan Gupta

LP-035: Relativistic Second and Third Harmonic Generation Of A Laser In A Self-Sustained Magnetized Plasma Channel
Mamta Singh and Devki Nandan Gupta

LP-038: Relativistic Self-Focusing Of Intense Laser Beam In Cold Quantum Plasma Under Plasma Density Transition
Sonu Sen, Meenu Asthana Varshney and Dinesh Varshney

LP-073: Monoenergetic Electron Acceleration From 3TW – 45 Fsec Laser Puls
Ajit Upadhyay

LP-087: Modelling Of Effect Of Self-Generated Magnetic-Fields And Inhibited Thermal Flux On The Terminal Velocity Of Laser-Driven Thin Foils
C. D. Sijoy, V. Mishra, N. Sakthivel, and S. Chaturvedi, S. Chaurasia,
P. Leshma and S. M. Sharma

LP-106: Third Harmonic Generation Via Interaction Of Two-Colour Laser Beams With Plasma
Nirmal Kumar Verma and Pallavi Jha

LP-113: High Field Terahertz Pulse Generation Driven By Amplitude Modulated Laser Filaments
Subodh Kumar, Monika Singh and R. P. Sharma

LP-120: Self-Focusing Of Cosh-Gaussian Laser Beam In A Kerr Medium With Linear Absorption
R.Mahajan and T.S.Gill

LP-132: Oscillator Model For Nano-Tube Plasma Interacting With Intense Few Cycle Laser Pulses
U. Chakravarty, P.A Naik, J.A. Chakera, and P.D. Gupta

LP-136: Second Harmonic Generation By Propagation Of Laser Pulses In Overdense Plasma
Ekta Agrawal and Pallavi Jha

LP-138: Second Harmonic Generation Of Laser In A Plasma
Sukhdeep Kaur, Manpreet Kaur and Parveen Bala

LP-139: Study of Terahertz Radiation Generation by Beating of Two Spatial Triangular Lasers in Magnetized Plasma
Prateek Varshney, Kanika Verma, Vivek Sajal and Ravindra Kumar

LP-142: Comparative Study Of Dispersion Relation Of Surface Plasma Waves With And Without External Magnetic Field
Deepika, Prashant Chauhan, Anshu Varshney and Vivek Sajal
LP-143: Two Plasmon Decay Of Non-Resonant Beating Mode Of Counter Propagating Lasers In Plasma
Kanika Verma, Prateek Varshney, Vivek Sajal and Ravindra Kumar
LP-147: Modulation Instability In A Plasma Channel With Wiggler Magnetic Field
Nisha Singh Rathore
LP-148: Effect of Coulombic Expansion On The Second Harmonic Generation Via Intense Laser Interaction With Clustered Gas
Rohit Kumar Mishra
LP-169: Laser Wake-Field Acceleration In High-Z Gas Jets
B. S. Rao, A. Moorti, R. A. Khan, J. A. Chakera, P. A. Naik, and P. D. Gupta
LP-172: Dynamics Of Ion Acceleration By Solitary And Shock Waves Driven By Laer Plasma Interactions
Amritpal Singh Nindrayog, Andrea Macchi and Francesco Pegoraro
LP-180: Simultaneous Evolution Of Spot-Size And Pulse Length Of Short Laser Pulses In Electron-Positron-Ion Plasma
Hemlata and Pallavi Jha
LP-195: Experimental Investigation of Fast Electron Temperature by Direct and Indirect Measurements in High Intensity Laser-Matter Interaction
T. Mandal, R. Rathore, M. Tayyab, S. Bagchi, V. Arora, J. A. Chakera, P. A Naik, and P.D. Gupta
LP-201: Effect Of Laser Beam Filamentation On Coexisting Stimulated Raman And Brillouin Scattering At Relativistic Powers
Ashish Vyas, Ram Kishore Singh and R. P. Sharma
LP-204: The Electrodynamic Model Of X-Ray Emission By Laser Plasma Accelerator
Bimlendra Pratap Singh
LP-213: Self-Focusing Of Super-Gaussian Laser Beam In Magnetized Plasma Under Relativistic And Ponderomotive Regime
Ravinder Kaur, Tarsem Singh Gill and Ranju Mahajan
LP-220: Fluid Simulation Of Relativistic Electron Beam Driven Wake-Field Excitation In A Cold Plasma
Ratan Kumar Bera, Sudip Sengupta and Amita Das
LP-221: Relativistic Electron Beam Driven Wake-Field Excitation In A Cold Magnetized Plasma
Ratan Kumar Bera, Sudip Sengupta and Amita Das
LP-224: Enhancing The Collection Efficiency In Laser Induced Breakdown Spectroscopy For Multi-Elemental Analysis
M. Tamboli, Praveen Devangad, Unnikrishnan V. K., Santhosh C.
LP-225: Laser induced Breakdown Spectroscopy (LIBS) of Glass
Praveen. Devangad, M.M. Tamboli, V.K. Unnikrishnan, C. Santhosh
LP-233: Ion-Ion Two Stream Instability In Laser Produced Ba-Plasma
Narayan Behera, R. K. Singh, Manoj Gupta, D. Sharma and Ajai Kumar
LP-275: Effects Of Carrier Heating On Polaron Induced Parametric Interactions In Compound Semiconductor

Ratna Agrawal, Swati Dubey and S. Ghosh

LP-290: Guiding Of Relativistic Electron Beams Through Structured Plasma
Chandrasekhar Shukla, Bhavesh G. Patel, Amita Das and Kartik Patel

LP-334: Studies of Ions from Laser produced Carbon Plasma using Thomson Parabola Spectrometer
S. Chaurasia, Vinay Rastogi, R. K. Bhatia, V. Nataraju, S. M. Sharma

LP-362: Effect Of Linear Absorption On Relativistic Self Focusing Of Quadruple Gaussian Laser Beam In Magnetoplasma
Munish Aggarwal[1] and Shivani Vij

LP-370: Self-Focusing Of Cosh Gaussian Laser Beam In Magnetized Plasma With Upward Plasma Density Ramp
Munish Aggarwal, Harish Kumar and Richa Kashyap

Keynote Address
&
Invited Talks

Keynote Address

Fusion Science and Technology

Yogesh C. Saxena,

Institute for Plasma Research, Gandhinagar 382428 (Gujarat)

E-mail : saxena@ipr.res.in

Abstract

Fusion of light elements in the stars releases energy. Research into Controlled Nuclear Fusion, with aim of producing fusion power for the production of electricity, has been conducted for over 60 yars. This research has been accompanied by enormous scientific difficulties but has resulted in significant progress in understanding the Physics of Fusion Plasma and technological requirement of future fusion machines and DEMO reactors.

Fusion research is about to transit from Plasma Physics to Fusion Science and Technology involving science, engineering, technology and materials for fusion nuclear components that generate, control and utilize neutrons, energetic particles and tritium in a Fusion Nuclear Reactor.

Research in Physics of Plasmas has been strongly pursued during 1950-2010. The era starting from 2010 aims at Physics of Fusion, heating and sustaining fusion plasma with objective of attaining a Q~10. Mainly based on magnetic confinement principle using Tokamak devices this activity is likely to be continued till 2035. Machine like ITER based on Magnetic confinement) and National Ignition Facility, based n Inertial confinement are major devices pursuing this goal.

ITER is a major step forward in Fusion Research and aims to demonstrate Reactor Grade Plasma and Plasma Support systems (SC magnets, fueling, Heating, Current Drive ..). IFMIF will provide a facility for advanced material testing. The most challenging phase of Fusion Development, however, still lies ahead viz. the development of Fusion Science and Technology. A key goal of the Fusion plan in the world is the construction of Demonstration Power Plant (DEMO) which may enable the commercialization of Fusion Energy. It is anticipated that several such DEMOs will be built around the world.

In this talk present status of Fusion research will be summarized and future requirement of fusion science and technologies will be discussed.

BP-I-01

Selective Excitation Of Low Frequency Drift Waves In The SINP MaPLE Device

Rabindranath Pal, Subir Biswas and Nikhil Chakrabarti
Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700064
E-mail : rabindranath.pal@saha.ac.in

Abstract

Drift wave fluctuations in magnetized plasma arise because of a spatially inhomogeneous density (n_0) perpendicular to a steady magnetic field (B). It is generally believed that the low frequency drift have is the primary candidate behind anomalous particle transports across the confining magnetic field line in tokamaks and other fusion devices. The dynamics of drift modes has been extensively studied, and still remains one of the major topics of interest due to some unresolved issues. Its characteristics

and stability analysis have been studied in a series of experiments in various laboratories in different parameter regimes. In most of these experiments the wave is either spontaneously excited due to collisions of electrons with ions and neutrals or excited by driving an electron current parallel to the magnetic field or by ***E x B*** rotation. The mode is excited in the region of the strongest density gradient where a constant drift frequency ω_* $(= k_\theta v_d,\ v_d = T_e/eBL_n)$, can be assumed. Here k_θ $(=m/r)$ is the poloidal wave number, m is the poloidal mode number, v_d is the diamagnetic velocity, L_n is the density scale length and T_e is the electron temperature. However, in the central region of the plasma, the density gradient is generally low and varies slowly with radius and so is the drift frequency. Observation of such low frequency peaks for drift wave turbulence spectra in plasmas was reported before, but remains unattended

This talk will report the selective excitation of a low frequency drift mode in the MaPLE (Magnetized Plasma Linear Experimental) device [1]. In the region there exists a parallel flow of electrons causing the drift modes to have a strong growth rate over a band of frequencies. However, the frequency selection for excitation is done in the experiment by driving a strong modulation of electron density with a frequency that is resonant in this region. The parallel velocity component of the excited $m = 2$ mode couples nonlinearly with the externally created density fluctuation to produce a parallel current fluctuation with twice the frequency. This selectively drives a second drift mode resonant in a nearby location. In this experiment the $m = 4$ drift mode is stable and hence not excited. Interestingly, this mode starts appearing as the modulation parameters cross a threshold value to drive parametric mode-mode coupling in the plasma. The excited mode satisfies the frequency and wave number matching conditions. A parametric mode-mode coupling of drift waves was reported before [2] where the pump drift mode excites two lower frequency modes which are normally stable. In contrast, here it is demonstrated that the pump drift wave can parametrically excite the higher frequency drift mode with a substantial growth rate of the lower frequency.

References :

[1] R. Pal, S. Biswas, S. Basu, M. Chattopadhyay, D. Basu, and M. Chaudhury, Rev. Sci. Instrum. 81, 073507 (2010).
[2] A.Y. Wong, M.V. Goldman, F. Hai, and R. Rowberg, Phys. Rev. Lett. 21, 518 (1968).

BP-I-02

Experiments On Cogenerated Dusty Plasma

[1]Mridul Bose, [1]Sanjib Sarkar, [2]S. Mukherjee, [3]J Pramanik

[1]*Department of Physics, Jadavpur University, Kolkata 700032*
[2]*Institute for Plasma Research, Gandhinagar – 382 428*
[3]*Dept. of Physics, Kharagpur College, Kharagpur - 721305*

Abstract

We, at Jadavpur University, are doing experiments on unmagnetized dusty plasma with the help of a bipolar pulsed dc power supply. In our experiment, the dust particles have been generated through sputtering of graphite cathode and were stratified between two electrodes. We detected the Taylor-like instability at the interface of two dusty clouds with different densities. A very less dust density (void like) region inside the lesser dust density portion is also noted. Again, it has been observed that a self excited dust density wave propagates towards the higher density dust fluid inside the system as well as a stationary band structure of thin multiple layers of dust particles when we apply a higher voltage. The size of dust particles at different time shows a linear growth. A cauliflower structure of dust particles have been observed through ex-situ SEM analysis. Also, we have observed a periodic

appearance or disappearance of line dust density follow the growth of dust from laser extinction method.

Next, in presence of modified field induced by glass plate is experimented. Various dust density waves (DDW's), like vertical, oblique and stationary, were detected simultaneously for the first time. Evolution of spatiotemporal complexity like bifurcation, in propagating wavefronts is also observed. As dust concentration reaches extremely high value, the DDW collapses. Also, the oblique and nonpropagating mode vanishes when we increase the number of glass plates while dust particles were trapped above each glass plates showing only vertical DDWs.

We are also able to remove the signature of dust particles with the help of an external square wave pulse in a very specific condition. We have systematically shown that the effect of positive pulse of different voltages is different and the excitation of dust acoustic wave is more pronounced at higher voltage. We have also observed two counter-propagating dust acoustic waves, one is a slow wave (5.4cm/sec) while the other is fast (21.6cm/sec).

BP-I-03

Basic Plasma Experiments at IPR

P.K. Chattopadhyay

Institute for Plasma Research, Bhat, Gandhinagar, 382428

E-mail : pkchatto@ipr.res.in

Abstract

Institute for Plasma Research is committed to peruse experimental research in various areas in basic plasma. This presentation will outline of these experiments, both ongoing and planned. Couple of these experiments will be presented in detail.

Helicon plasma experiment in a diverging magnetic field configuration will be discussed. Results from the observations on unusual density peaking at low magnetic field, polarization reversal, downstream density peak far away from the antenna and single and multiple double layers will be presented. Later, dust rotation in an unmagnetized dusty plasma in a simple parallel plate glow discharge system will be presented. Results show that the self-organized dynamical flow pattern of the dust cloud forming a toroidal structure is a result from an interesting dynamical equilibrium of the constituent species of the plasma. Finally, a brief discussion will be made on a new and novel magnetized linear plasma device where nonlinear oscillation and related phenomena will be studied. Initial results from this device will be presented.

BP-I-04

Quiescent Plasma Experiments: An Add-on

N. Ramasubramanian

Institute for Plasma Research, Gandhiangar 382428

E-mail: mani@ipr.res.in

Abstract

In the classical literature of plasma physics, one cannot miss the references of Q-machines. It was such a powerful experimental device in which the very early basic plasma experiments were conducted and the results from those went into all plasma physics text-books. In those experiments, a highly ionized plasma produced by contact or resonance ionization of alkali atoms (mostly cesium)

on hot tungsten surfaces was confined in an axial magnetic field. This collision-less plasma was expected to be quiescent, because the temperature of both the species (ions and electrons) would be same as the temperature of the plate (~0.2 eV). But due to the inherent experimental set ups, many fluctuations were present, which were detected and were satisfactorily explained too. In this talk, the highlights of these Q-machine experiments conducted worldwide will be revisited and a possible add-on would be discussed.

NF-I-01

Steady State Superconducting Tokamak (SST-1)

Subrata Pradhan & SST-1 Team

Institute for Plasma Research, Bhat, Gandhinagar 382 428, Gujarat

E-mail : pradhan@ipr.res.in

Abstract

Steady State Superconducting Tokamak (SST-1) at Institute for Plasma Research (IPR) is a national initiative at developing an experimental facility to study plasmas in steady state in the run up to future thermo-nuclear fusion devices through magnetic confinement. SST-1 has a physics mandate to study steady state plasmas in circular and elongated configurations assisted with RF auxiliary systems and feedback controls. SST-1 has also several technological and engineering elements comprising of large current carrying high field large superconducting magnets, large cryogenic systems, large UHV vacuum systems, AC/DC power systems, particle and heat exhaust systems as well as auxiliary heating systems. SST-1 has recently got commissioned with the `First Plasma' being obtained in repeatable and reliable fashion in it on June 20, 2013 following a long and systematic engineering validation phase. This paper will elaborate the experiences with SST-1 leading to its successful commissioning, the present status of SST-1 and the future plans with SST-1. The paper will also highlight the potential contributions to the future devices as well as areas where pan-India initiatives may be undertaken towards the future devices.

NF-I-02

Recent Experiments And Upgradation Plans For Aditya Tokamak

J. Ghosh and Aditya Team

Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat

E-mail : jghosh.ipr@gmail.com

Abstract

Several experiments relevant to the operation of future big tokamaks including ITER and also contributing significantly to the tokamak based thermonuclear fusion research have been carried out in Aditya tokamak recently. Low loop voltage start-up of plasma current has been successfully obtained with ICR and ECR preionization. Reduced runaway generation is achieved by applying a local vertical magnetic field at one toroidal location. Plasma disruptions, a sudden loss of equilibrium and confinement, has been successfully mitigated through application of bias voltage on a Molybdenum (Mo) electrode placed inside the last closed flux surface (LCFS). Extensive studies on plasma flows, effect of gas puff on flows in the Scrape off layer (SOL) and impurity transport has been carried out. Effect of Helium glow discharge cleaning (GDC) on partial pressures and plasma parameters have also been studied for plasma performance improvement. To contribute more to the bigger tokamaks operated in the divertor configuration, the existing Aditya tokamak with limiter configuration, which is in operation for 24 years, is planned to be upgraded to a divertor machine. The main aim of the Aditya-U tokamak is to have a small/mid-size tokamak with divertor operation

and higher duty cycle, which will be test bed for new diagnostics, the students can be trained and those experiments can be tried out which are not desirable in big tokamaks, such as runaway mitigation and disruption control. Details of experimental results and upgradation plan will be discussed in the talk.

NF-I-03

Twenty Five Years Of The SINP Tokamak

A.N.Sekar Iyengar & M.S.Janaki
Plasma Physics Division, Saha Institute of Nuclear Physics, Kolkata 700064
E-mail : ansekar.iyengar@saha.ac.in

Abstract

The SINP tokamak has completed about 25 years of successful operation since its installation and produced many papers and Ph.Ds. Some of the interesting experiments that were carried out are those in low q configurations, Runaway investigations, Edge turbulence and impact of edge biasing on the confinement. We shall discuss some of the interesting results obtained from this tokamak during this period in this talk.

NF-I-04

The Giant Superconducting Magnet System of 10,000 Tons Mass for Fusion Experiment at Cadarache, France

A. K. Sahu
Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382428
E-mail : aksahu@ipr.res.in

Abstract

The International Thermonuclear Experimental Reactor (ITER) being built at Cadarache, France has many unique features and is one of the biggest scientific adventures in the history of science and technology. Seven partners (India, EU, US, China, Japan, Korea and Russia) have made an International Organization situated at Cadarache, France to provide direction and co-ordination for R&D and construction of this project. The R&D labs and manufacturing industries are spread in these seven partner countries. Components manufactured in these countries will be transported to Cadarache in France for assembly. Institute for Plasma Reasearch, Bhat, Gandhinagar, Gujarat is coordinating this project activities on behalf of India.

The magnet system, required for confinement and control of plasma leading to fusion reaction in ITER is one of the key systems of this project. There are 18 TF (Toroidal Field) Coils, 6 PF (Poloidal Field) coils, 6 CS (Central Solenoid) coils and 18 correction coils (CC), all of which are of superconducting type. All TF and CS coils have Nb3Sn superconductor and all PF and CC coils have NbTi superconductor. Each TF coil has height 15 m and width 9 m and 330 tons mass. The biggest PF coil has diameter 24 m and 300 tons mass. The total mass of these superconducting magnet systems is about 10000 tons. Use of Nb3Sn superconductor for manufacturing superconducting cables for successful use had not reached a matured stage earlier and this project gave a thrust for significant R&D activities worldwide and now due to this project, it is a matured and reliable technology. The jacketing and manufacturing of long cables need up to about 760 m long special infrastructure at Industry. The special building built for PF coil winding at ITER, Cadarache site is of size 250 mX45 m.

All these coils are made using cable-in-conduit conductors (CICC). These long CICCs have to carry current as high as 68 kA in case of TF coils. Due to this high current and large coil system, the inductive energy stored is about 51 GJ. Due to this, in case of quench, energy discharge and voltage developed across the conductors need special attention in design. 60 current leads, made using high Tc superconductor (BiSCCO 2223), for transition between room temperature power supply and magnet coils have been used.

All these coils will be cooled at 4.5 K using forced flow supercritical helium and special provision is also there to go down to about 3.8 K. The cold helium distribution and ensuring required flow rate in these

vast magnet systems is also a challenge. There will be 3 helium liquefier-cum-refrigerator plants with associated cryogenic distribution system to provide liquid helium and supercritical helium for cooling of this magnet system. Each of these 3 plants will have 25000 W equivalent cooling capacity at 4.5 K, the biggest ever built. There will be a no. of supercritical helium pumps to provide forced flow to the magnet coils and bus bars. The biggest one will provide about 3000 g/s supercritical helium, biggest ever built. Hundreds of cryogenic valves will be used and will be operated remotely through programmed automatic control system placed far away of this magnet system to avoid nuclear radiation hazard. Considering the vast system in size and energy, the safety system has 3 levels. In case of helium circuits, if there is any accidental pressure rise like quench, helium will be released out automatically through automatic control valves if pressure reaches to 16 bar as first level, if it is not sufficient helium will be released out when pressure reaches about 21 bar as second level and still if not sufficient, further 3rd level safety will open at 28 bar. All these interesting aspects with more details will be presented here.

Acknowledgement: Author is thankful to the Magnet Team at ITER for providing useful information of superconducting magnet system of ITER.

IP-I-01

Plasma Nano-Synthesis, Generation of Complex Nano Structures Through Thermal and Non Thermal Plasmas

A. K. Das
Laser and Plasma Technology Division, Bhabha Atomic Research Centre, Mumbai, 400085
E-mail : akdas@barc.gov.in

Abstract

Thermal and non thermal plasma are known to aid synthesis of complex nanostructured materials with novel functional properties that are otherwise difficult to prepare. Thermal plasmas (RF and DC) have been successfully used for bulk generation of nanostructures of high melting point binary oxides like alumina, yttria, neodymium oxide as well as complex ternary oxides like $NiFe_2O_4$ or $CoFe_2O_4$. The size, shape, purity and crystalline properties are controlled through evaporation rate, temperature gradient, electric field and chamber pressure. On the other hand, low pressure non thermal microwave electron cyclotron resonance plasmas have the capability of synthesizing one and two dimensional complex carbon nanostructures like tubes and walls consisting of graphene sheets. Depending on control of plasma parameters and operating conditions, a number of functional characteristics like electron emission, phase structure, magnetic and optical properties show considerable improvement over nanostructures developed through other means. The paper presents details of development of novel plasma systems for nano generation and results of experiment and simulation for generation of novel nanostructures and their functional characteristics. Case studies related to synthesis of binary and ternary oxides are presented. Interesting features like in-flight reaction, homogeneous nucleation in thermal plasmas and bias independent growth in non thermal systems are discussed.

IP-I-02

Development of Duplex Plasma Based Process For Improvement Of Surface Properties of Steel

[1]J. Alphonsa, [2]P. Saikia, [1]G. Jhala, [1]R. Rane, [1]S. B. Gupta, [2] B.K. Saikia and [1]S. Mukherjee
[1]*Facilitation Centre for Industrial Plasma Technologies, IPR, Gandhinagar, Gujarat*
[2]*Center of Plasma Physics, IPR, Guwahati, Assam*
E-mail: alphonsai@yahoo.com

Abstract

Though plasma nitriding (PN) process is a well known process for improving the surface hardness, it cannot be used alone for improving the life of the cutting tools because of its low surface hardness. The maximum hardness varies from 900-1200 HV0.1 for high alloy steel like H13 and D2 which are used for making cutting tools.

It has also been observed that on application of a thin film coating by plasma assisted physical vapour deposition process on cutting tools the tool performance get enhanced significantly. The maximum hardness varies from 1500-2300 HV0.1 for coatings like TIN, TiAlN etc. on steels like H13 and D2. However, application of PVD hard coatings to the substrate materials cannot guarantee the optimal tribological performance without pre treatment of the substrate materials due to plastic deformation of the substrate which results in eventual coating failure.

Hence, a combination of nitriding and PVD provides a product having properties superior to both. It was reported that plasma nitrided sub-layer improves the wear resistance of the tool by >1.5 times with PVD coatings [1]. It was also reported that the adhesion can be enhanced by the presence of a hard intermetallic layer between the coat and the substrate [2]. Hence it can be concluded that the usage of combination of coatings termed as duplex coatings results in superior corrosion and wear resistant surfaces.

In this paper an attempt is made to study the surface properties of AISI M2 after plasma nitriding and plasma assisted physical vapour deposition carried out at different nitrogen partial pressure and bias conditions. The surface properties of each of these processes were than compared with the duplex coated AISI M2 substrate. It was found that the presence of pre- nitrided layer enhanced the surface properties of the coated steel.

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IP-I-03

Plasma-Based Methods For Healthcare And Cleantech Applications

Sunil Kumar
CoatingsMantra Science and Technology Consulting,
11 Beresina Place, Greenwith, Adelaide, South Australia 5125
E-mail: sunilkumar@coatingsmantra.com.au

Abstract

Plasma-based methods offer great potential for developing technologies for realising the healthcare and cleantech revolutions currently underway. These technologies could impact a range of healthcare and cleantech sub-sectors (e.g., bone implants, drug delivery, molecular-level precision cleaning, renewable energy, water treatment, value-adding and outdoor applications, etc). Essentially, plasma-

based methods are employed either for depositing 2-dimensional nanomaterials (thin-film coatings, by definition) or for surface modification of materials for a range of everyday applications. The nature of healthcare and cleantech applications is such that the deposited thin-film coatings and the surface modification must be achieved economically and exhibit robust physico-chemical properties (purity, stability, adhesion, biocompatibility, etc).

This talk begins by citing a few examples where plasma-based methods have been the focus as an enabling tool for healthcare and cleantech technologies. Following this, a case study is presented where we have employed the technique of plasma-enhanced chemical vapour deposition (PECVD) for depositing compositionally and functionally graded silica thin-film coatings using a simple precursor (tetraethoxysilane) under rotary vacuum conditions. The coatings are very thin (~ 100 nm) and conformal, exhibit high purity and hydrophilicity and a graded interface with the substrate that results in high adhesive strength (> 27 MPa). These silica coatings have been demonstrated to be biocompatible and bioactive and suitable for designing bone implants with enhanced service life. The silica coatings can also be seen an ideal candidate for the renewable energy sector (anti-reflection coatings for solar cells, protective coatings for wind turbines and solar cells, hydrophilic coatings for fuel cell plates). Being a non-line-of-sight deposition technique, the PECVD method developed has also been demonstrated to be capable of coating a porous hydrophobic scaffold material in its entirety, that is, both the exterior and the interior surfaces (pores) of the scaffold were coated. Such 3-dimensional coating/surface modification of porous hydrophobic materials offers a range of applications, including enhanced gas storage capacity and catalysis and water purification. In another case study to be presented in this talk, it will be demonstrated that plasma cleaning is a simple, efficient and robust method for precision cleaning and molecular level removal of biomolecules from the surfaces of medical and dental relevance. The talk concludes by suggesting a plasma-based method (sputtering) capable of yielding surfaces with nanoscale chemical and morphological gradients for potential use in sustainable energy technologies.

PP-I-01

Computational Electromagnetics Using GPUs

Harishankar Ramachandran
EE Department, IIT Madras, Sardar Patel Road, Chennai 600036
E-mail : hsr@ee.iitm.ac.in

Abstract

This talk will briefly introduce the Finite Difference Time Domain[1] (FDTD) method and then move on to the issues involved in implementing it in a GPU system such as the Tesla. FDTD is a simple program to parallelize, since all operations are local. However, running it efficiently on a GPU[2] remains a challenge given the limited cache and texture memory of GPU systems.

In this talk I will discuss an implementation of FDTD-2D on a GPU machine with real time generation of the video file. Issues that will be discussed include how best to debug code, compressed storage techniques, cuda vs python-cuda, and what techniques work best on a GPU and what speed up can be expected. The results are unexpected in that the simplest optimization techniques turn out to be the most effective.

The work reported here was primarily carried out by two students, Satya Swaroop and M.R. Bharath.

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SA-I-01

Performance Evaluation of Thermal Protection Systems and High Temperature Materials in Arc Plasma High Enthalpy Facilities

L. Aravindakshan Pillai
Vikram Sarabhai Space Centre, ISRO, Trivandrum. 695022
E-mail : l_aravindakshan@vssc.gov.in

Abstract

Development and qualification of thermal protection systems for rocket motor and reentry vehicle requires extensive laboratory level testing to study material performance. Arc heated high enthalpy facilities have proved to be the most useful laboratory tool for thermal testing at high temperature and high heat flux and also for test durations as encountered in flight. Technology being classified construction of such facilities was initiated under advanced R&D program in VSSC which culminated in the development of four major arc plasma high enthalpy facilities which includes a 6 MW plasma wind tunnel for system level testing and qualification of reentry thermal protection. These facilities are being made use of for the performance evaluation of different type of thermal protection materials being developed for rocket motor and reentry vehicles.

Tests carried out in these facilities include material characterization tests, design validation tests and certification tests. Typical materials which are tested include ablative materials like Carbon-Carbon, Carbon phenolic, silica phenolic, graphite etc., high temperature metallic materials such as coated columbium and satellite, ceramic TPS materials such as silica tiles, Ceramic Matrix Composites, Zirconium diboride etc.

Parameters simulated in arc plasma tests for evaluating TPS material performance are heat flux, enthalpy, shear stress and test duration. Heat flux from 50 W/cm^2 to 1500 W/cm^2 and temperature up to 6000 K are simulated in atmospheric arc plasma generator facility. 1 MW High enthalpy facility and 6 MW Plasma Wind Tunnel facility are very unique facilities for reentry simulation testing. It plays a vital role for qualification of TPS materials under extreme thermal environments prevailing during reentry. Enthalpies up to 35 MJ/ Kg, temperatures up to 9000 K and also prevailing heat flux and ambient pressure and the hypersonic flow over the test model are simulated in these facilities

.

Data generated on material performance consists of surface and in-depth temperature history, heat of ablation, erosion rate, mass loss rate and material behaviour with surface chemical reactions. Specific tests to study the oxidation resistant coating effectiveness and impact analysis are also carried out. In the present paper details on the arc plasma high enthalpy facilities used for the thermal protection system evaluation, its capabilities, testing methodology and typical test results are explained.

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PP-I-02

HPM Development At IPR For Plasma Physics Applications

Rajesh Kumar, Saurabh kumar, Nasir Shah, Anitha V. P., Renu Bahl and Anurag shyam.
Institute for Plasma Research, Gandhinagar-382428, Gujarat
E-mail : rkumar.lboro@gmail.com

Abstract

Recent years, the studies of High power electromagnetic wave particularly microwave or laser propagation in plasma has attracted much attention because of its importance in many practical areas.

At IPR, an experimental system “SYMPLE” is recently conceived to investigate the physics of interaction of extremely intense e.m. waves ($eE_{em}/m\omega_{em} \sim c$) with an over dense ($\omega_p > \omega_{em}$) plasma. The study of such experiments remained constrained for a long time due to limited availability of High power required resources as well as limitation of diagnostic access but the advent of high power microwave (HPM) sources have opened a new arena of investigations.

VIRCATOR and Relativistic magnetron are two real contenders for the required HPM source both works on fast high voltage electrical discharge system. Virtual cathode is a nonlinear state, which develops when the electron beam injection current exceeds the space charge limiting current (defined by beam energy and wave guide geometry) and whose oscillations can generate high power microwaves. Whereas Relativistic magnetron works on the principle of gyration of electron in presence of high magnetic and electrical field produced by connected pulsed power.

A compact and repetitive generator based on Tesla transformer for application in plasma opening switch has been developed.. This system is designed to operate with up to 300 kV on water pulsed forming line to generate 40 kA (in short circuit condition), 50 ns pulse, which is further compressed in time with the help of plasma opening switch. Operation of this generator with VIRCATOR *(virtual cathode oscillator) as a load will be presented here.*

The overall efficiency of VIRCATOR is around 1%, which is far less than efficiency of Relativistic magnetron (around 30%).

Recently IPR has started work on Relativistic Magnetron (RM) for which design is completed and will be fabricated soon. This RM will produce power of the order of 1 GW and frequency in the range of 2-4 GHz.

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SA-I-02

Fully Nonlinear Analysis Of Electrostatic Solitary Waves And Double Layers In The Presence of Magnetic Field

S. S. Ghosh
Indian Institute of Geomagnetism, Plot 5, Sector 18, New Panvel (W), Navi Mumbai, 410218
E-mail : sukti@iigs.iigm.res.in

Abstract

In situ measurements of particles and fields of the Earth's auroral zone have revealed a reach variety of plasma phenomena on different spatial and temporal scales. One major aspects of them is the bursts of broadband electrostatic noise emissions (BEN) with frequencies from below the lower hybrid frequency (typically tens of Hertz) up to and higher than electron plasma and cyclotron frequencies (typically, a few kilohertz). Many detailed analysis of BEN have been performed using space-borne data from POLAR, FAST, GEOTAIL, and CLUSTER multi-spacecraft missions. Plasma wave measurements of GEOTAIL spacecraft revealed BEN emissions as a series of Electrostatic Solitary Waves (ESWs). While the low frequency part of the spectra is often interpreted as ion mode (ion acoustic) solitary waves [1], the time scale of the high frequency part indicates the involvement of electron dynamics [2].

Rapidly moving positive potential pulses have also been observed in the cusp, the magnetosheath, the bow shock or in the plasma sheet boundary layers. Theoretically they were often interpreted as BGK electron phase space holes. However, Berthomier et al. (2000) [3] have shown that a positive amplitude solitary wave may well exist for an electron acoustic mode. Besides the bipolar pulses, Clusters have also revealed monopolar and tripolar pulses at the auroral field lines [4]. The study of the generation and propagation of such microstructures is important for understanding the Sun-Earth coupling and the energy dissipation and particle transports across the magnetospheric boundary layers.

In the present work, we have delineated the parameter regime for the fully nonlinear solutions of ion (electron) acoustic solitary waves adopting Sagdeev pseudopontial techniques. The plasma is assumed to be magnetized and traversed by an ion (electron) beam respectively. A special emphasis has been given to the transition of the solitary waves to the respective double layers as the latter is known to play important roles in the particle acceleration. The analytical estimations have further been compared with satellite observations.

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LP-I-01

Self-Modulated Proton-Driven Plasma Wakefield Accelerator: A New Approach to TeV Electron Acceleration

Ajit Upadhyay[1] and Alexander Pukhov[2]

[1]*Laser Plasma Division, Raja Ramanna Center for Advanced Technology, Indore*
[2]*Institut für Theoretische Physik I, Heinrich Heine Universität Düsseldorf, 40225 Germany*
E-mail : ajitup@rrcat.gov.in

Abstract

Plasma sustains extremely high gradient fields through plasma waves, and can be used for acceleration of charged particles. The strong plasma waves can be excited either with lasers or with charged particle beams. Existing TeV proton beams (e.g. CERN) can be used as a driver to generate strong plasma wake fields. The energy gain of the witness beam cannot be much larger than the driver energy due to transformer ratio. Employing a TeV proton driver allows us in principle to accelerate an electron bunch to TeV energies in single stage thus alleviating the technical burden of multi-staging. It has recently been shown using detailed simulations [1,2] that high gradient plasma wake fields can be generated with an ultrashort bunch of protons. In that scenario, the proton bunch was shorter than the plasma wavelength (λ_p). Unfortunately, the existing TeV-class proton accelerators have bunch length ~ 10's centimetres. A plasma density of ~10^{14}cm-3 (λ_p ~3mm) is required for typical GeV/m accelerating field. Thus the existing proton bunches have 10-100 time more length than the required bunch-length and lead to poor wakefield inside the plasma.

A long proton bunch propagating in overdense plasma is also subject to self-modulation at the background plasma wavelength [3]. The effect of self-modulation opens a possibility to use existing proton bunches for large amplitude wake field excitation. An experimental program is currently under consideration at CERN. The Super Proton Synchrotron (SPS) bunch with 450 GeV protons is proposed as the driver for the initial stage of the experimental campaign. The wake field will be used for accelerating externally injected electrons. The injected particles must be trapped in the wake field. The trapping condition depends on the wake field amplitude and phase velocity. Because it is expected that the proton bunch will generate a weakly nonlinear plasma wave with the same phase velocity v_{ph} as the speed of the driver, it is natural to assume that the gamma factor of the injected electrons γ_{el} must be comparable to that of the proton driver γ_p for them to be trapped. However, simulations demonstrated that it is not the case because the spatiotemporal nature of the self-focusing instability of the proton bunch considerably reduces v_{ph} [4]. Simulations using a 3D quasi-static particle-in-cell code show that initially the γ_{ph} of plasma wake is an order lower than that of the driver and as the instability saturates, the γ_{ph} approaches beam γ. Also, the wake-phase can be controlled by plasma desnity gradience. It has been found that the injection of electrons should be done at the tail end of the driver as it supports much larger wakefield and maximum momentum of injected electrons as compared to head of the driver beam. The tail also traps electrons with lower energy.

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LP-I-02

Generation Of Negative Ions From Solids Using Ultra-Short Laser Pulses

S. Bagchi, M. Tayyab, B. Ramakrishna, T. Mandal, J. A. Chakera, P. A. Naik, and P. D. Gupta
Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore 452013
E-mail : sbagchi@rrcat.gov.in

Abstract

The interaction of ultra-short laser pulses with matter has been a very active area of research in recent times due to its potential applications towards understanding the inherent highly non-linear, non-perturbative physics as well as technological applications such as hadron therapy in medical field, compact table-top particle accelerators, fast ignition of the compressed thermonuclear fusion fuel etc. The laser-plasma based accelerators offer high brightness, low-emittance, short pulsed sources of photons and / or particles which can potentially lead to a plethora of innovative applications. Further, these sources offer integrability to conventional particle accelerators. In this direction, extensive work has been reported towards positive charge (proton, heavy ion) acceleration. Based on this, ion sources have been demonstrated. However, spallation neutron sources which have a proton storage ring need negative H ion source to start with. Conventional surface plasma sources and volume plasma sources employ controlled single or multi-step charge exchange processes to produce negative ions. However, they demand a cumbersome, high precision operation.

In this talk, we report the first time observation of energetic negative H ions for from ultra-short laser pulse interaction with solid targets of low atomic number. This laser plasma generated negative H ion source offers high brightness, and consistent production with reliable control over the flux and energy.

The negative H ion source is based on focussing 45 fs, 10 TW Ti: Sapphire laser pulses to an intensity of 3×10^{18} W-cm^{-2} on transparent solids, semiconductor, and on thin metallic foils. A 16 bit CCD camera in tandem with a Thomson Parabola Ion Spectrograph (TPIS) has been employed to record the ion emission on every single shot. The reflected beam energy and its spectrum were also monitored for each laser irradiation. The application of intentional laser pre-pulse was observed to drastically reduce the negative ion production. Preliminary results indicate that in the case of transparent solid targets and in silicon, the origin of the negative ions is in the expanding plasma inside the front surface of the targets. Whereas, in the case of thin foils, the protons from the front side seem to penetrate through the foil, undergo charge exchange and emerge as negative H ions from the rear side of the foil. The experimental results on negative H ion generation and our current understanding of the experimental results will be presented.

LP-I-03

Laser-Blow-Off Of Thin Film: Spectral And Dynamical Behaviour In Different Experimental Conditions

Rajesh Kumar Singh
Institute for Plasma Research, Gandhinagar 382 428
Email- rajesh@ipr.res.in

<u>Abstract</u>

In contrast to conventional laser ablation from a solid surface, in laser-blow-off (LBO), the laser beam interacts with a thin film supported on a thick transparent substrate and the ablated material propagates along the direction of the incident laser beam. Due to the difference in ablation mechanism and thermal history, dynamics and composition of LBO plume are different from that formed by bulk solid ablation. Due to highly directional, large particle density, low ionization fraction and geometrical simplicity, LBO plume has received great interest in various fundamental and applied researches which includes elemental analysis, pulse laser deposition, tokomak plasma diagnostics etc. The shape, size, composition and dynamics of the LBO plume play crucial role in above applications and therefore their understanding is essential for using these techniques in applied research.

In this talk, I shall present a brief review of the experimental technique to characterize the LBO plume in different experimental conditions. Details of various diagnostic techniques and their applicability in context of measurements of spatial and temporal evolution of plume species, velocity distribution and geometrical aspect of the expanding plasma plume will be discussed.

Several attempts have been made to characterize the expanding LBO plume by varying experimental factors like, ambient gas, laser fluence, laser profile and external magnetic field. External disturbance induced physical processes, e.g., acceleration/deceleration of ions & neutrals, attenuation/enhancement in optical emission, plume confinement and focussing, structural formation and formation of shock waves are briefly discussed. Quantitative analysis of the observed results in the frame of variable plasma parameters, photon absorption and excitation/ionisation mechanisms are also presented.

CM-I-01

3-D Particle-in-Cell simulations for a THz Range Vircator

Gursharn Singh and Shashank Chaturvedi
Bhabha Atomic Research Centre, Visakhapatnam-530012
E-mail : gursharn@barc.gov.in

<u>Abstract</u>

Pulsed, high-power electromagnetic radiation in the Terahertz (THz) range can have several applications, such as the direct excitation of vibrational modes of polar molecules. It is of interest to examine if concepts for high-power microwave sources like vircators, normally operating in the GHz frequency range, can be adapted to operate in the THz range. We had earlier reported on preliminary 2-D PIC simulations to examine this concept. It was found that a device having anode-cathode gaps in the range of 5-10 ❍m, operating at peak voltages in the range of 0.5-1 kV, with cathode radii ~25 ❍m, would yield a dominant frequency ~1-3 THz and power levels ~0.5-2.0 MW.

In the present work, we extend the study to three-dimensional, relativistic, electromagnetic, particle-

in-cell (PIC) simulations of an axially-extracted vircator using a locally-developed particle-in-cell code called MWS. Two important effects have been observed:

1. With the introduction of asymmetry in the device, the power output degrades very fast as compared to devices in the GHz range. For example, a tilt in the foil by 1 degree with respect to the anode-cathode axis results in reduction in power level by ~8 times. By comparison, in GHz range devices, the corresponding reduction would only be ~1.5 times.
2. In both GHz and THz range vircators, multiple radiation modes can be seen at the output window. In GHz-range devices studied in our work, for small levels of non-axisymmetry, the dominant mode remains symmetric. However, in the THz device studied here, the dominant mode is not symmetric about the axis of symmetry.

Details of the simulations, the limitations of the model and the major results will be presented in the paper.

CM-I-02

Modeling Of Relativistic Longitudinal Plasma Waves

Sudip Sengupta
Institute for Plasma Research, Gandhinagar – 382 428
E-mail : sudip@ipr.res.in

Abstract

Study of space-time evolution of relativistically intense large amplitude space charge waves in a cold homogeneous electron-ion plasma is a fascinating field in itself. A space charge wave is said to relativistically intense when the energy gained by an electron over a distance of one wavelength becomes of the order or more than its rest mass energy. Besides being of intrinsic academic interest, the ultimate fate of these gigantic waves is also of relevance to several areas of plasma physics / /astrophysics where such waves are routinely encountered [1].

In this talk, modeling of relativistic plasma waves in a cold homogeneous plasma, based on Dawson's sheet description of waves [2] will be presented. Excitation and evolution of relativistic plasma oscillations [3] and waves (longitudinal Akhiezer-Polovin waves [4]) will be treated both analytically and numerically, as an initial value problem using Dawson's sheet model. It will further be shown through extensive simulations, that except for very special initial conditions which excites the well known Akhiezer-Polovin mode, for all other initial conditions, the waves break at an amplitude well below the Akhiezer-Polovin limit, through a novel mechanism called phase mixing [5-7].

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EP-I-01

Numerical Experiments In Pure Electron Plasmas Confined In Toroidal And Cylindrical Traps

Meghraj Sengupta, Rajaraman Ganesh
Institute for Plasma Research, Gandhinagar 382 428
E-mail : ganesh@ipr.res.in

Abstract

Institute for Plasma Research, Gandhinagar (IPR) is a pioneer in performing controlled experiments in confining low density pure electron plasmas in tight aspect ratio toroidal magnetic fields. These traps routinely confine electron plasmas up to several 100s of rotation periods or Diocotron time scales. Similarly, experiments elsewhere continue to investigate the exciting physics of pure electron plasmas in low density limits, confined in large aspect ratio toroidal fields and in straight circular cylindrical traps. In this low density limit, several outstanding physics problems such as growth, saturation and damping of toroidal diocotron-like modes, role of aspect ratio in confining the plasma, effect of toroidal asymmetry etc are yet to be understood.

In the opposite limit of high density, where electron inertia becomes important, very little has been explored in pure electron plasmas either in uniform or toroidal traps [1]. In this limit, as analytical methods become less tenable, to understand the physics at high density, a new 2D particle-in-cell based code including electron inertia has been developed. After rigorous and exhaustive bench marking of the code in low density limit, several new and interesting findings in the uniform magnetic field have been obtained in the high density limit [2]. Many of these aspects and future direction will be discussed in this presentation.

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EP-I-03

Nanofabrication By Plasma Route And Their Characterizations

M. P. Srivastava
Department of Physics and Astrophysics, University of Delhi, Delhi-110 007
E-mail : pmps2010@gmail.com

Abstract

In this invited talk, we will highlight the plasma route for nanofabrication in which the ions can be controlled with the help of electric and magnetic fields. We have also indicated the classification of both pulsed and continuous plasma viz. low density, low temperature; moderate density, moderate temperature; high density and high temperature plasmas. In particular, the importance of high density, high temperature, and pulsed plasma is indicated for nanofabrication. The dynamics up to post focus phase for generation of energetic high fluence ions in dense plasma focus device having fusion conditions and its modifications for nanofabrication is described. The nanofabrication of some of the metal nanoparticles achieved recently, such as gold, silver, silver-gold bimetal and their surface plasmon resonance (SPR) studies are presented. The nanodots and nanorods have been obtained for gold nanoparticles in SEM and TEM studies and their SPR studies are also reported. Similar studies and their results are also presented for silver, silver-gold bimetal etc. The nanofabrication of electronic and optoelectronic materials such as gallium nitride, zinc oxide etc. has

also been established and presented through AFM studies. ZnO and GaN, show UV peak and red luminescence, respectively in PL spectra at room temperature which were obtained at liquid nitrogen temperatures by other methods. Their applications in optoelectronic devices are also indicated.

PD-I-01

Diagnostics in Indian Test Facility (INTF) for ITER-Diagnostic Neutral Beam

M. Bandyopadhyay and NNBD team*
ITER-India, Institute for Plasma Research, GIDC, Sector–25, Gandhinagar, 382025, Gujarat
E-mail: mainak@iter-india.org

Abstract

ITER Diagnostic Neutral Beam (DNB) will inject 5Hz modulated, 100 keV energetic neutral hydrogen atom beam of equivalent neutral beam current ~20 A, having duty cycle 3S ON/20S OFF into the ITER torus to measure He ash density using CXRS diagnostics during ITER's D–T phase. DNB is negative ion based neutral beam system and possesses many technological challenges in terms of producing high extracted and accelerated negative ion beam current (60A) with minimal divergence to ensure maximum neutral current transport over a path length of 20.7 m through different beamline components, maintaining their respective optimum functionalities. Modelling calculations have been carried out to optimise the design and dispersion of the beam line components. Besides validating these calculations, new concepts related to establishing the functionality of an 8 plasma driver based RF negative ion source, the beam line components specially residual ion dump (RID) and correspondingly the beam transport need to be tested to meet the DNB needs. This is envisaged in a test facility (INTF) to be set up in the ITER-India lab of IPR. Experimental set up of such a facility requires a judicious choice of various diagnostics to characterize the beam and functionality of individual beamline components. Appropriate diagnostics based on optical spectroscopy, electrical probe, thermal imaging, water calorimetry and thermocouples along with standard electrical voltage-current measurements will ensure safe operation of individual components and also the overall system. The conceptual designs of some of these diagnostics shall be presented.

* *Dass Sudhir, Jaydeep Joshi, C.Rotti, Himanshu Tyagi, Ravi Pandey, Gourab Bansal, Agrajit Gahlaut, Jignesh Soni, Kaushal Pandya, Dheeraj Sharma, Ratnakar Yadav, Suraj Pillai, Rambilas Prasad, Sejal Shah, Deepak Parmar, Hitesh Patel, Irfan Ahmed, G.Roopesh, Ashish Yadav, V.Nagraju, K.G.Parmar, Hiren Mistry, Bhavesh Prajapati, Mahesh.V, Dhananjay Singh and Arun Chakraborty.*

PD-I-02

Infrared Imaging Diagnostics For Plasma Confinement Devices

Santosh P. Pandya, Shwetang N. Pandya, Shamsuddin Shaikh, Zubin Shaikh, Kanchan Mahavar, Kumar Ajay, J. Govindarajan, ADITYA and SST-1 Team
Institute for Plasma Research, Gandhinagar – 382 428
E-mail: psantosh@ipr.res.in

Abstract

Recently Infrared Thermography emerged as an important tool in the field of high temperature plasma diagnostics and fusion research since it has the advantage of real time imaging of the surface temperature of an object, remotely. Infrared imaging has multiple applications. It can be used for surface temperature measurement of Plasma Facing Components (PFCs) for studying the plasma wall interaction and also for health and safety monitoring of PFCs. It is also used for in-vessel inspection during plasma discharges and heat load estimation on PFCs, whereby establishing power

balance between input and the exhaust power from the plasma. Another important application of Infrared imaging is for estimation of particle flux and radiation flux emitted from the confined plasma in broad wavelength range by using an Infrared Imaging Video Bolometer. Infrared imaging also finds an important application for studying the synchrotron radiation emitted by electrons accelerated by toroidal electric field. The radiation emitted by such electrons falls in IR range which can be detected by Infrared imaging & various parameters of runaway electrons can hence be derived. Infrared imaging diagnostics are less susceptible to the electro-magnetic and nuclear radiation induced noises, provided suitable shielding techniques are used. Considering all the merits of Infrared imaging diagnostics it can be concluded that it is an inevitable diagnostic for fusion research.

This talk reviews various infrared imaging diagnostics briefly with some recent results from the ADITYA and SST-1 tokamaks

PD-I-03

Recent Developments In Ultra-High Intensity Laser Plasma Diagnostics At RRCAT

J. A. Chakera, M. Tayyab, B. S. Rao, V. Arora, Y. B. S. R. Prasad, S. Bagchi, A. Moorti, T. Mandal, P. A. Naik, and P. D. Gupta

Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore, 452 013

E-mail : chakera@ rrcat.gov.in

Abstract

The commercial availability of laser systems with petawatt power has rejuvenated the research in the field of ultra-high intensity laser plasma interaction, especially in the field of particle acceleration. Electron acceleration by the *laser wake-field technique* has been demonstrated with electron beams of energy above GeV. Similarly, proton / ion acceleration has been demonstrated by the mechanism of *Target Normal Sheath Acceleration* in thin foil targets, with proton energy above 50 MeV. Both, the electron and ions acceleration mechanisms have shown particle energy scalability to higher energy with the ultra-short laser power. However, the particle beam stability in terms of beam energy, pointing stability, divergence, and narrow beam energy spread have been issues which limit the applicability of such sources for practical applications in research and technology development. Achievement of a better control on the beam parameters requires intense efforts to further understand the ultra-high intensity laser plasma interaction. This goal can be achieved with the support of ultra-high intensity laser plasma diagnostics. Such diagnostics demand very stringent requirements on parameters like very high spatial resolution (owing to very small source size), ultra-short temporal resolution of fs, and very high spectral range. Although the petawatt laser systems are commercially available, the ultra-high intensity laser plasma diagnostics are not available. These diagnostics have to be developed in-house due to their stringent requirements mentioned above.

At Laser Plasma Division, RRCAT, our group is also involved in development of these diagnostics to carry out ultra-high intensity plasma interaction studies viz. electron, proton / ion acceleration, and neutron generation. We have demonstrated well collimated, quasi-mono-energetic electron beam of 50 MeV by laser wakefiled acceleration technique, and proton beam up to 3 MeV in thin Al foil targets. Recently we have extended the electron acceleration technique to plasma plume produced by pre pulse laser solid target interaction, instead of the gas jet target. A well collimated, quasi-mono-energetic beam of 13 MeV has been demonstrated. We have also measured neutron flux of ~10^4 neutrons in single shot, produced in the interaction of ultra-high intensity laser pulses with solid CD_2 target by D-D fusion reaction.

In the present talk, I will be presenting details of various spatial and temporal plasma diagnostics developed for detection of x-rays and particles. These include : crystal, grating, and dispersionless spectrographs, Thomson parabola ion spectrograph, magnet based electron spectrograph, time of flight neutron detector, chirped laser pulse based time resolved optical diagnostics, x-ray bolometer, and optical and x-ray streak cameras.

OA-I-01

Plasma Processing – A Green Revolutionary Technology Towards Future

P. S. Mukherjee and B. Bhoi
Institute of Minerals and Materials Technology, Bhubaneswar
E-mail : psmukherjee52@gmail.com

Abstract

The application of thermal plasma in the field of materials processing is becoming an increasingly active and attractive field in the development of new technology. The promises of plasma technology and its application lies in its potential for innovations, value creation, sustainability and growth, its wide ranging opportunities for technological exploitation and its positive environmental influences. At present, plasma technology is developing into a cross-section technology whose full potential is far from being realised and whose importance is constantly growing. The enormous promise of plasma technology stems from its remarkable potential for environmentally friendly and energy saving processing, its high energy flux, its flexibility and broad areas of application and environment and its clear ecological advantage.

In this article, recent developments in IMMT, Bhubaneswar, on the recovery of pure grade metals by hydrogen plasma have been discussed.

Carbothermic reduction of oxide and sulphide minerals is one of the major routes of obtaining corresponding metals. This results an inevitable production of enormous green-house gases such as CO_2. Alternatively, hydrogen reduction assisted by thermal plasma offers kinetic advantages apart from being an environment friendly approach. Hydrogen plasma containing atomic and ionic hydrogen can reduce metallic oxides even at lower temperature than carbothermic reduction due to superior kinetic reaction as well as hydrogen-water cycle does not pose danger to the environment; thus will be key to the future environment problems regarding CO_2 emissions.

The application of hydrogen plasma for production of pure grade molybdenum from molybdenum oxide and sulphide lowers the multiple-stages practiced in industries and waste generations. Micro-wave assisted plasma as well as plasma torch have been utilised for reduction of MoO3 and MoS2. Process variables such as gas flow rate, energy and kinetics have been studied to optimize the process for production of pure grade molybdenum metal. The results confirmed a recovery of 95% metal with 98% grade molybdenum.

The steel production using hydrogen plasma which is one of the major breakthrough in the field of iron and steel making, has been successfully developed. Atomic hydrogen which is better reducing agent than carbon, has been utilised in thermal plasma. The emission of CO_2 has been avoided and a suitable reactor has been designed for hydrogen plasma operation. Further work is going on for a pilot plant study.

OA-I-02

Periodic Self Sub-Wavelength Periodic Nano-Patterned For Anti-Reflection Application

Pratap K. Sahoo

School of Physical Sciences, National Institute of Science Education and Research (NISER), Bhubaneswar-751005

E-mail : pratap.sahoo@niser.ac.in

Abstract

Light reflection from surfaces such as lenses, displays, or computer monitors, can significantly deteriorate the optical performance of a device by causing stray light or by degrading the transmission of optical components. Anti-reflective (AR) surfaces are therefore widely used. They mostly consist of vacuum-deposited coatings of dielectric material layers. An alternative method for reducing the reflectivity is to pattern the reflecting surface with a sub-wavelength grating [1]. This approach has the advantage of good suppression of the reflected light over a wide range of wavelengths and incident angles. In addition, the principle of AR gratings also works for UV light, where the choice of dielectric AR coating materials with low absorption becomes very limited. This is of major importance for intense, pulsed UV sources, as AR gratings can withstand substantially higher fluences. However, it is easy to fabricate the required structures by many different nanolithography techniques which is very challenging, especially over large and possibly curved surfaces.

The optical properties of such AR surfaces were simulated using Finite difference time domain (FDTD) technique by MATLAB code, as a function of wavelength in the range of 300-900 nm, showing a significant suppression of the reflected light [2]. Wavelength dependent real and complex refractive indexes were used in the simulation from the handbook of optics. Periodic nano-patterns with periods of 50 nm to 100 nm were assumed for simulation, which can be easily fabricated using Laser Interference Lithography (LIL). Theses nano-structures can be transferred into the quartz substrate by reactive ion etching or isotropic chemical etching. Moreover, we demonstrate how the optical performance can be tuned by varying the depth, width and period of the nano-structured pattern. The deeper 100 nm period structures exhibit excellent performance over the whole visible range, the shallower 50 nm period surface shows good performance in the UV range.

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OA-I-03

Development Of Advanced Carbonaceous Micro Fiber Adsorbents And Novel Approach For Their Integration On Cryo Panels

Vijai Shankar Tripathi

I-DESIGN Engineering Solutions Ltd., Wagholi, Pune 412 207

E-mail : dr.vijai.s.tripathi@rsbglobal.com

Abstract

In last decade or so, tremendous improvement in pumping speed and capability of cryopumps has been achieved by fixing a monolayer of coconut shell based microporous granular activated carbon (GAC) on its liquid Helium cooled panels. In fact after lot of experimentation, it was found that GAC gave the better performance compared to other microporous adsorbents such as zeolites, alumina and silicagel. However, Activated Carbons with extremely high surface area and microporosity in the desired range, in the fiber or fabric form have been developed using pitch, polyacrylonitrlle (PAN) or viscose rayon as precursor material in the recent past. These advanced carbonaceous adsorbents will be slowly but surely replacing conventional adsorbents in this niche application. Due to presence of large external surface area, to facilitate mass transfer, which is the determining step in the process of adsorption, fibrous adsorbents show higher rate of adsorption compared to GAC and also are easy to regenerate, at the same time.

Flocked carbon fibers have very large surface area and have a improved thermally conductive surface. ACF is a new type of efficient adsorption material developed in recent years. Its microscopic structure makes it occupy a large specific surface area (1000-3000m2/gm). Therefore its adsorption capacity is usually 2 to 10 times as the granular activated carbons, which makes it a bear obvious characters of broad spectrum adsorption, completely fast desorption and high reuse and regeneration capabilities.

As an outcome of a recently completed BRFST project three types of advanced adsorbents viz. activated carbon spheres, knitted activated carbon fabric and activated carbon non-woven fabric have been developed at I-DESIGN Engineering solutions Ltd. PUNE, which have a range of surface properties (surface area range 1000-2000 sqm/g). These materials have been characterized at 80 K using nitrogen as adsorbate, using different theoretical approaches and are now being evaluated at 4.2 K for Helium adsorbability at IISc, Banglore.

Basic Plasma (BP)

BP-007

Nonlinear Dynamics Of Relativistically Intense Waves In Cylindrical And Spherical Geometry

Arghya Mukherjee and Sudip Sengupta

Institute for Plasma Research, Bhat, Gandhinagar 382 428, India

E-mail : arghya@ipr.res.in , sudip@ipr.res.in

Abstract

Breaking of relativistically intense nonlinear space charge oscillations/waves is studied analytically and numerically in cylindrical and spherical geometries, using Dawson sheet model. It is found that oscillations/waves in these cases break via phase mixing at much lower amplitude compared to the slab geometry due to additional anharmonicity introduced by geometrical effects.

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BP-009

Experimental Studies On Different Properties of the DC Glow Discharge Plasma

Pankaj Patra, Jyotirmoy Pramanik

Dept. of Physics, Kharagpur College, Kharagpur - 721305, West Bengal

E-mail : pankajpatra1988@gmail.com

Abstract

A dc glow discharge Argon plasma has been produced in a SS make cylindrical chamber of 80 cm length and 26 cm in diameter. Different plasma properties like plasma temperature, plasma density, floating potential, and their variations with discharge voltage and neutral pressure have been studied using a single Langmuir probe. The dependence of plasma conductivity on launching signal frequency and plasma parameters have been studied using a SS make circular mesh, launcher and a SS make disk shaped receiver. In this poster, we also reported the variation of receiver voltage with different neutral pressure keeping discharge voltage constant and vice versa. The damping amplitude of the launching signal with the increase of the separation between the launcher and receiver is reported. The damping mechanism of the launching signal with different plasma parameters has also been explained

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BP-015

Multiple Double Layer formation in High Pressure Glow Discharge

Manash Kumar Paul[1], P.K.Sharma[2], A. Thakur[2] and S. V. Kulkarni[2]

[1]*Department of Physics, National Institute of Technology, Agartala, Tripura – 799 055*
[2]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat– 382 428*

E-mail: manashkr@gmail.com

Abstract

Formation of Double Layers (DL) in plasma has been intensely investigated [1] during past two decades with utmost scientific interest due to the innate rich physics [2], frequent natural occurrence and versatile applications in various plasma devices. Results obtained on generation and characterization of multiple double layers developed in front of a positively biased electrode during high pressure glow discharge in a toroidal vessel of tight aspect ratio[3], have been presented. The electron temperature, density and floating potential measured using electrical probe on poloidal plane, near and far from anode location, show signatures of double layer formation in our system. Although glow discharge (without magnetic field) is expected to be independent of device geometry, but boundary conditions imposed by the toroidal geometry produce conditions conducive for plasma to grow in size and eventually occupy the entire volume of the device. At higher anode bias voltage, the visibly glowing spots formed on the body of spatially extended anode gradually take the form of multiple quasi-spherical intense luminous plasma blobs attached to the tip of the positive electrode. Dependence and dynamics of multiple double layers on experimental parameters and toroidal magnetic field have been discussed in this paper.

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BP-017

Diagnostics Of Reverse Polarity Planar DC Magnetron

S. Chauhan, M. Ranjan, S. Mukherjee

Institute for plasma Research, Gandhinagar 382428

E-mail : samir@ipr.res.in

Abstract

Magnetron is being widely used in thin film deposition and other industrial manufacturing processes. Using special geometry of magnetic field on the cathode surface the ionization can be enhanced many fold [1], resulting in plasma density enhancement by few orders of magnitude [1]. Recently use of magnetron in reverse polarity as ion source has been reported [2][3]. The concept is also reported for better plasma polymerization process [4]. In present study plasma property of the discharge is being investigated in reverse polarity, the usual E × B region of electron trap is now disappeared. The characteristic ring of the normal magnetron now becomes donut shaped anode dark space, and plasma takes shape of an inverted funnel. A measurement of spatial variation of electron temperature and density has been done, in plume region across magnetron with the help of single and double Langmuir probe. The potential structure is mapped in transverse direction. Electron temperature was measured with respect to changing discharge voltage i.e. input power and background pressure. Density found to increases with both input power and pressure while temperature falls in the central region of the plume.

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BP-18

Sheath Formation in Electronegative Glow Discharges in the Presence of Two Species of Positive Ions

R. Moulick and K.S. Goswami

Center of Plasma Physics- Institute for Plasma Research, Nazirakhat, Sonapur, Guwahati 782402, Assam

E-Mail: rakesh.moulick@gmail.com

Abstract

Sheath formation is studied for electronegative plasma with two species of positive ions under the effect of collision. The usual processing plasma is electronegative in nature and ion-neutral collisions are inevitable therein. A sheath adjacent to the wall is a space charge region where electron flux to the wall is reduced to the corresponding ion flux. In processing reactors the substrate is given a slight negative bias and hence a positive space charge region is formed in its vicinity. Thus, understanding the dynamics of charged species in the sheath is of crucial importance from the point of view of processing reactors. However, attempts to study the sheath region only, has led scientists to other controversial topics like determining proper electric field at the beginning of the sheath and the prime objective of understanding the particle behavior deviates a little. Here, the attempt is to study the subject over whole plasma range i.e. instead of confining the topic only in the sheath region, it is studied from the bulk plasma region. Various processes inclusive are ionization, attachment and detachment in the bulk.

BP-19

Study of Electric Potential in a Magnetized Electronegative Plasma

A Phukan[1], P J Bhuyan[1, 2] and K S Goswami[1]

[1]Centre of Plasma Physics-Institute for Plasma Research, Nazirakhat, Sonapur - 782402
[2]Department of Physics, Tezpur University, Napaam, Tezpur – 781028

Email: ananya.phukan26@gmail.com

Abstract

The formation of sheath in a collisionless plasma with a finite-temperature negative ion particle source in a non-uniform open magnetic field is analytically investigated. Considering the effect of strong surface H^- production one dimensional electric potential profile is studied. It is observed that the potential profile depends on the strength the magnetic field, the production rate and the temperature of negative ions. As the production rate becomes large and the negative ion energy becomes small, the potential near the wall decreases. Also with different values of negative ion temperature the potential near the wall decreases.

BP-021

Effect On Electron Energy Probability Function In Presence Of Dust In Low Pressure Argon Additive Hydrogen Plasma

B Kakati[1], B K Saikia[1] and M Bandyopadhay[2]
[1]*Centre of Plasma Physics-IPR, Nazirakhat, Sonapur-782402, Kamrup, Assam*
[2]*Institute for Plasma Research, Bhat, Gandhinagar-382428*
E-mail : bharatkakati15@gmail.com

Abstract

Different researcher observed that the shape of EEDF or EEPF for molecular gases (like N_2, O_2) is completely different and much more complicated than atomic gases. Knowledge of the EEDF or EEPF is important for observing the different plasma parameters as well as for optimizing the plasma processes used for various applications [1, 2]. The shape of the EEDF significantly affects the effectiveness of ion beam sources, especially in tandem plasma sources used for the production of negative hydrogen ions [3]. Argon additive hydrogen plasma widely used in plasma processing as well as for efficient production of H^- ion. In the present work, the electron energy probability function (EEPF) due to the addition of Argon in hydrogen plasma is studied and its effect in presence of dust is examined. Hydrogen plasma is generated using hot cathode filament discharge technique. The EEPF measurements are performed axially at 4 cm away from the centre of the magnetic cage (at magnetic field free region) with the help of Hiden Analytical make (ESPION) single Langmuir probe system having 10 mm length and 0.15 mm diameter. The current carried by the dust grains is measured with the combination of Faraday cup and a sensitive electrometer. From the recent observation, a prominent change on the shape of EEPF due to the addition of Argon and dust in hydrogen plasma is observed.

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BP-022

Dust Charging In Low Pressure Filamentary Plasma In An Improved Multicusp Device

D. Kalita[1], B Kakati[1], B. K. Saikia[1] and M. Bandyopadhay[2]

Email : deijikalita2009@gmail.com

[1]Centre of Plasma Physics-IPR, Nazirakhat, Sonapur-782402, Kamrup, Assam
[2]Institute for Plasma Research, Bhat, Gandhinagar-382428

Abstract

Magnetic multipole confinement has been shown to be a very effective way for producing a dense uniform large volume quiescent plasma [l, 2]. To improve the plasma confinement, a magnetic cage is designed, made of samarium cobalt magnets of surface field strength 3.5 kG which are arranged in a full line cusped magnetic field configuration. The hydrogen plasma is produced in a dusty plasma device by striking a discharge between incandescent tungsten filaments and magnetic cage. A cylindrical Langmuir probe (Hiden Analytical Ltd. Make) having 10 mm length and 0.15 mm diameter is used to measure different plasma parameters like plasma density, electron temperature, EEDF etc. To evaluate the optimum working pressure in terms of plasma density, the plasma parameters are measured for different working pressures at constant discharge voltage. The effect of filament current on plasma parameters mainly on EEDF and dust charging are evaluated. The charge carried by the dust grains are calculated theoretically and are compared with the experimentally measured data. A combination of Faraday cup and sensitive electrometer is used to measure the dust current [3, 4]. Since plasma density and electron temperature plays an important role on dust charging in plasma environment, so the optimum operational discharge parameters are evaluated for dust charging.

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BP-28

Anomalous Collisional Absorption Of Intense Laser Pulses In Under-Dense Plasma

M. Kundu
Institute for Plasma Research, Gandhinagar – 382 428
E-mail : mkundu@ipr.res.in

Abstract

Collisional absorption is known to be one of the fundamental heating mechanisms in laser driven plasmas. The electron-ion collision frequency ν plays a crucial role in determining the level of laser absorption. In the conventional scenario, the expression of ν in the strong laser field assumes a constant value of the Coulomb logarithm which does not include the effect of the electron ponderomotive velocity. As a result the electron-ion collision frequency and the corresponding fractional absorption α of a laser pulse are found to remain constant (or decrease slowly) up to some value I_c of the increasing laser intensity I_0, after that ν, α both decrease rapidly as $I_0^{-3/2}$ for all temperatures and densities. In this work, below some temperature and density of the plasma, with a total velocity (thermal velocity plus the ponderomotive velocity) dependent Coulomb logarithm we show that both ν, α initially increase with increasing I_0 up to a maximum value close to I_c followed

by a conventional $I_0^{-3/2}$ decrease with the increasing I_0. Such a non-conventional, anomalous behavior of the fractional absorption with the increasing laser intensity up to a peak value was also observed in some experiments, but no explanation has been given so far. The modified Coulomb logarithm considered in this work may be useful to explain those experimental results. The anomalous behavior is found to occur only in the low temperature regime, otherwise both ν, α vary in the conventional way with the increasing I_0.

BP-037

Investigation Of Force Balance Dynamics In A Thermal Plasma Torch

Vidhi Goyal and G. Ravi
Institute for Plasma Research, Gandhinagar, Gujarat 382428
E-mail : vidhigoyal@ipr.res.in

Abstract

The thermal plasma torch is a device which works in the arc plasma regime. Plasma inside a non-transferred plasma torch undergoes many complex processes giving rise to fluctuations of the arc root as well as column. Forces such as gas-drag force, thrust force and electromagnetic forces decide the position of arc root attachment and govern the nature of fluctuations. In our experiments, return current and external magnetic field have been used as tools to explore this force balance mechanism. Experiments have been done with nitrogen as working gas at atmospheric pressure (1 atm) with 3 different return current configurations, while keeping the fluid element same in the presence of external magnetic fields up to 700 Gauss. It is observed that closer the return current closure path, lower is the voltage drop across the plasma column, indicating a change in the force balance dynamics. Similarly, higher external magnetic field results in spreading of plasma towards the anode walls instead of confinement, contrary of intuition. Detailed results and force balance analysis will be presented.

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BP-039

Plasma Sheath Boundary Identification

Vara Prasad.K[1], P. Mehta[2],Joydeep Ghosh[1],A. Sarma[2], D. Sharma[1], P. Chattopadhyay[1]
[1]*Institute for Plasma Research, Bhat, Gandhinagar, 382428*
[2]*Vellore Institute of Technology, Chennai, Tamilnadu*
E-mail : varam.ipr@gmail.com

Abstract

Ion flow velocities on the metal-plasma boundary region play an important role in Fusion experiments as well as in low temperature plasma experiments like etching in fabrication semiconductor devices. An experimental set-up is designed and fabricated to measure the ion flow velocities onto the plasma-sheath boundary formed around a metal plate inserted into a filament produced plasma using passive and active Doppler spectroscopy techniques. The sheath region

produced near the metal plate has been investigated using two types of emissive probes namely, conventional (tungsten wire) and Laser heated emissive probes for estimation of sheath dimensions by measuring the plasma potential profiles from the main plasma to the sheath region. Different emissive probe techniques are compared in the bulk plasma to estimate the plasma potential [1]. Comparison between conventional emissive probe and Laser heated emissive probe [2] has been carried out. Sheath spatial potential profile is measured with both the probesand sheath thickness of ~3 mm has been found in front of the metal plate. Modification of sheath thickness in plasma produced with electronegative gaseshas also been studied. An attempt is made to measure ion flow velocities using Passive Doppler Spectroscopy.

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BP-040

Characterization Of DC Glow Discharge Plasma In Co-Axial Electrode Geometry

R. Kumar[1], R. Narayanan[2], R.D. Tarey[1], A. Ganguli[2]

[1]*Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016*
[2]*Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016*

E-mail: rahul.cdhm@gmail.com

Abstract

In DC glow discharge plasmas, hysteresis effect in the V-I characteristics [1, 3], generation and dynamics of multiple double layers in front of a positively biased electrode [1] and formation of various anodic structures [1, 2] (a set of concentric luminous shells with different intensities) have been a subject of considerable interest in various system configurations [1-3]. Mostly these effects have been observed in the presence of an auxiliary (third) electrode. Further, nonlinear oscillations have been observed in either the discharge current or the floating potential of a Langmuir probe (LP). Recently, observations of floating potential oscillations have also been reported without the use of auxiliary electrodes in a coaxial electrode geometry [4, 5]. The plasma characterizations of such electrode geometry have not been studied in great detail.
Experiments were carried out in a similar coaxial electrode geometry [6] wherein the discharge characteristics showed hysteresis effect in the system. The DC discharge system is observed to have three stable states within the obtained range of discharge current with the system passing through a negative differential resistance (NDR) region as it transits from one state to another. Thus the V-I characteristic has two sharp jumps in the discharge voltage corresponding to the NDR regions. The first NDR is seen to trigger self excited oscillations in the floating potential of an LP as well as the discharge current that have identical waveform and phasing, whatever the discharge conditions are. After the onset of the second NDR; only the amplitudes of these oscillations are observed to increase by an order of magnitude.
This paper presents the characterization of DC glow discharge plasma in the above co-axial electrode configuration, near the NDR regions for different anode-cathode radii.

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BP-041

Arbitrary Amplitude Kinetic Alfvén Solitons In A Dusty Plasma With A *Q*-Non-extensive Electron Velocity Distribution

M. K. Ahmed and O. P. Sah
Department of Physics, Birjhora Mahavidyalaya, Bongaigaon 783380, Assam
E-mail: mnzur_27@rediffmail.com

Abstract

In most of the theoretical studies done so far on nonlinear structures of kinetic Alfvén waves in dusty plasmas, the particle distribution has been assumed to be Maxwellian. But for systems with long-range interactions, such as plasma (Coulombian long-range interaction), the traditional Maxwellian distributions might be inadequate for the description of the systems. Such a system can be described by q-nonextensive velocity distribution[1] which has been applied successfully in various cases[2,3]. Here, we consider nonextensive dusty plasma comprising of nonextensive electrons, cold ions and immobile negatively charged dust grains. In this model of dusty plasma, we have been investigating the existence of arbitrary amplitude solitary kinetic Alfvén waves and studying their properties theoretically and numerically by deriving Sagdeev's Pseudopotential.The results that we have obtained so far are encouraging because of the appearance of the parameter q in the Pseudopotential.The results in the case $q \rightarrow 1$ are consistent with those in the framework of the Maxwellian distribution.

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BP-042

Transient Evolution Of Electron Energy Distribution Function Of Solitary Electron Holes In Laboratory Plasmas

Mangilal Choudhary, S. Kar and S. Mukherjee
Institute for Plasma Research, Bhat, Gandhinagar – 382 428
E-mail : jaiijichoudhary@gmail.com

Abstract

Solitary electron hole is an electrostatic structure in collisionless plasma. Its existence is cause of distortion of the electron distribution in the resonant region. Theoretically, they were predicted by Schamel et.al first [*Phys. Scr*. **20,** 336 (1979) and *Phys.Plasmas***19,** 020501 (2012)]. These types of structures can be excited in the laboratory plasma by applying, the fast rising high voltage positive pulses of pulse widths $\tau_p < 3\tau_i$ and $\tau_p > 3\tau$, τ_p, τ_i are pulse width and ion response time respectively, to a metallic plate (act as an exciter) [Kar et. al., *Phys. Plasmas***17**, 102113 (2010)]. Propagation speed of these structures is of the order of the thermal speed of electron behavior of plasma after formation of solitary electron hole in plasma column can be extracted by knowing the behavior of electron energy distribution function (EEDF). We have measured the EEDF after formation of solitary electron hole in the plasma column for different pulse widths ($\tau_p < 3\tau_i$ and $\tau_p > 3\tau$). It was measured by help of planner probe. Since, first derivative of I – V characteristic of probe gives the EEDF. In our experimental studies, Measured EEDF having double hump like profile after 15 – 25 μs.This double hump like structure is an indication of existing the solitary electron hole in the plasma column. After long time, these structures go to vanish and plasma comes to its initial state. Furthermore, these structures are very sensitive to the collision of trapped electrons with neutral atoms. Therefore, in higher pressure case, only single hump profile is observed. It means that the solitary electron hole does not exist in the system.

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BP-044

Study Of Transition From Coherent To Turbulent Regime With Variation In Toroidal Magnetic Field

Umesh Kumar, T. S. Goud, R. Ganesh, Y. C. Saxena, D. Raju
Institute for Plasma Research, Bhat, Gandhinagar 382 428
Email: umeshks@ipr.res.in

Abstract

A mechanism has been observed in a simply magnetized toroidal current less devices which increases the confinement of plasma in the absence of any poloidal magnetic field and it also scales with increase in toroidal magnetic field strength [1, 2]. Radial profiles of various parameters has been measured which exhibit large fluctuations which possibly affect the radial profile themselves

[2]. On changing the toroidal magnetic field strength from 220 G to 440 G, coherent to turbulent transition, enhanced flows and confinement were observed in the past work [3]. In this work more controlled increment of toroidal magnetic field in units of 40 G was done, which confirms transition from Coherent to turbulent regime with increase in toroidal magnetic field strength. A improved and unambiguous transition has been observed with increase in toroidal magnetic field. A possible explanation is attempted.

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BP-055

Synchronization Between Two Plasma Sources With Unidirectional Coupling

Neeraj Chaubey,[1] S. Mukherjee,[1] A.N.Sekar Iyengar,[2] A.Sen,[1]
Institute for Plasma Research,[1]Gandhinagar-382428,
Saha Institute of Nuclear Physics,[2] Kolkata-700064
Email: cneeraj@ipr.res.in

Abstract

Synchronization is a universal phenomenon whose effects have been observed in all branches of sciences like pendulums, lasers, superconductors, fireflies, neurons etc. Understanding and realizing this phenomenon in laboratory has benefited us in making supercomputers, working with complex networks, finding cures of many diseases etc. A plasma is a highly complex and nonlinear system in which various types of oscillations can be observed. The study of synchronization in such a system poses interesting experimental and theoretical challenges. In this paper we report on the dependence of coupling strength in synchronization of two coupled laboratory plasma devices.

Two DC glow discharge plasma sources whose cathode and anode diameters are 70 mm and 10mm respectively and operating at a neutral pressure of 0.38 mbar have been deployed for synchronization experiments. In each of the chambers two Langmuir probes were placed, one for measuring floating potential fluctuations and other for coupling plasma fluctuations. The fluctuations from chamber I was amplified and fed to the cathode of chamber II. When the oscillations of both chambers were synchronized, we fixed the discharge voltage of both chambers and by varying the amplitude of the amplified signal; we investigated effect of coupling strength in synchronizing two unidirectional coupled plasma sources. It has been observed that a minimum value of strength of signal is needed for seeing synchronization effects.

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BP-058

Estimation Of Electric Fields On Plasma Pattern In An RF Produced Magnetized Plasma

P. Bandyopadhyay, D. Sharma, U. Konopka and G. Mrofill

Institute for Plasma Research, Bhat, Gandhinagar-382428
Max-Planck Institute for Extraterrestrial Physics, Garching, Germany-84748
Auburn University, 206 Allison Laboratory, AL 36849-5311, USA.

E-mail : pintu@ipr.res.in

Abstract

Electric filed inside the plasma patterns [1] formed in an rf produced magnetized plasma is measured experimentally. The homogeneous plasma breaks into spatio-temporal patterns when magnetic filed strength exceeds a threshold value for a given discharge parameter. The electrostatic potential of these patterns is seen to trap the micron size dust particles which are charged to large negative potential by the plasma particles. The experiment involves achieving an equilibrium between the radial component of the gravitational force and the electrostatic force produced by the patterns in order to evaluate the later. In order to verify our results we follow an alternate technique by introducing multiple particles and observe them rotate due to ion drag force. By calculating their average drift velocities we estimate the electric filed using the value of applied magnetic field. The details of the experiments will be presented in the conference.

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BP-059

Electron Trapping In Nonlinear Ion Acoustic Wave

Debraj Mandal and Devendra Sharma
Institute for Plasma Research, Bhat, Gandhinagar -382428
E-mail : debraj@ipr.res.in

Abstract

Evolution of kinetic particle distribution functions is studied computationally in a collision-less plasma with finite electron and ion temperatures. In addition to the trapped and reflected density of ions, a finite density of slow resonant electrons is observed to be trapped in the propagating solitary ion acoustic wave structures[1]. The trapped electrons show a large temporal modulation in their density, nearly with the electron plasma frequency which is distinct from their bounce frequency in the ion acoustic wave. The modulations indicate strong interaction of trapped electrons with a

growing high frequency plasma wave. The electron plasma wave is seen to grow parametrically and saturate by trapping a large density of fast resonant electrons, resulting in formation of electron plasma BGK modes. The procedure can be applied to analyze the impact of trapping of electrons by a slow wave on the process of particle acceleration by the fast waves.

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BP-062

Focusing/ Defocusing Of A Gaussian Electromagnetic Beam In A Multi-Ionized Plasma

Shikha Misra[a] and S. K. Mishra[b]

[a] *Centre of Energy Studies, Indian Institute of Technology Delhi* (IITD), *New Delhi* 110016
[b] *Institute for Plasma Research*, Gandhinagar *382 428*, *Gujarat*

E-mail : shikhamish@gmail.com

Abstract

In this paper the authors have developed a formulation for the dependence of electron and ion densities on the irradiance of an electromagnetic beam in a plasma with multiply charged ions, corresponding to collisional, ponderomotive and relativistic-ponderomotive nonlinearities and different electron/ ion temperatures; consequently the corresponding expressions for the electron density modification in the presence of an *electromagnetic* (*em*) field have been derived. Paraxial approach [1,2] in the vicinity of intensity maximum has been adopted to analyze the propagation characteristics of an *em* beam in such plasmas; on the basis of this analysis critical curves and self-focusing curves have been computed numerically and graphically illustrated. For a numerical appreciation of the analysis we have specifically carried out the computations for the simultaneous presence of singly and doubly charged ions in the plasma. As an important outcome it is seen that the nonlinear effects (and hence self-focusing) get suppressed in the presence of multiply ionized ions; the conditions for the three modes of *em*-beam propagation *viz*. oscillatory focusing/ defocusing and steady divergence have been discussed.

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BP-64

Theoretical Analysis Of Potential Distributions Across Plasma Sheath In Low Pressure Argon Discharge

S. S. Pimpale, S.V. Salvi, M. S. Nadkarni, S.V. Maduskar
Research Laboratory, Department of Physics, Patkar College, Munbai-400 062
Email: sushamapimpale04@gmail.com

Abstract

The electrons and ions in plasma have Maxwell-Boltzmann's distribution. These species arrange themselves according to the Poisson's equation and give self-consistent potential profile in the sheath. Applying the boundary conditions, the expression for sheath potential has been obtained for Siemen's ozonizer type vessel. It has also been found that on the basis of above calculations, the thickness of sheath, near a probe when floating, is of the same order of magnitude as the Debys's shielding distance.

BP-066

Electrostatic Solitary Waves In Magnetized Dusty Pair-Ion Plasmas

Amar P Misra

Department of Mathematics, Siksha Bhavana, Visva-Bharati University, Santiniketan-731 235

E-mail : apmisra@visva-bharati.ac.in

Abstract

A typical plasma consisting of electrons and positive ions essentially causes temporal as well as spatial variations of collective phenomena due to large-mass difference between these particles. This asymmetric diversity of collective plasma phenomena can, however, be nullified in pair-ion plasmas consisting of positive and negative ions with equal mass. In the latter, the space-time parity can be maintained because of the same mobility of the particles under electromagnetic forces. Such pair-ion plasmas have been generated and different kinds of electrostatic modes have been experimentally observed [1]. Furthermore, in many industries such as integrated-circuit fabrication, there requires a plasma source having no energetic electrons [2].On the other hand, *in situ* measurements of charged particles in the polar mesosphere revealed that there exist positively charged nanoparticles [3]. Such particles have been observed in a region of both positive and negative ions, and very few percentage of electrons. The positive charge of these dust particles is due to the dominant charging effects of lighter positive ions compared to the heavier negative ions, and the presence of a very small number of electrons. Furthermore, dust particles in pair-ion plasmas can become positively charged when the number density of negative ions greatly exceeds that of the electrons [4]. Thus, in laboratory and space environments, pair-ion plasmas with positively charged dusts and no high-energy electrons may not be infrequent.

In this paper, we present a systematic study on the existence and properties of various collective modes, namely ion-cyclotron and dust ion-acoustic waves in magnetized dusty pair-ion plasmas. We also study the evolution and characteristics of electrostatic solitary waves through the description of Korteweg de Vries (KdV)-like equations both analytically and numerically. We show that the existence of both compressive and rarefactive solitons strongly depend on the different masses, temperatures and number densities of ions. We also discuss the application of our results in space plasmas, e.g., a dusty meteor trail region in the upper atmosphere, in industrial electron-free pair-ion plasmas as well as for laboratory dusty pair-ion plasmas.

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BP-072

Detection Of Coherent Structures In The Chaotic Time Series Of A DC Glow Discharge Plasma Using Empirical Mode Decomposition

Pankaj Kumar Shaw, Debajyoti Saha, Sabuj Ghosh, Vramari Mitra, A. M. Wharton, M. S. Janaki and A. N. Sekar. Iyengar

Plasma Physics Division, Saha Institute of Nuclear Physics, 1/AF , Bidhan nagar Kolkata-700064

E-mail : pankaj.shaw@saha.ac.in

Abstract

In recent years the influence of coherent structures in determining the turbulent dynamics of plasmas has been of great interest and in particular their influence on transport processes of momentum and energy has been identified as a very relevant one. This suggests that for a better understanding of transport phenomena and turbulence, a clear understanding of the role played by coherent structures is important. In this paper, we have proposed a new method for the detection of coherent structures in the chaotic time series using empirical mode decomposition. This method is based on the decomposition of the signal into various time scale modes (Intrinsic mode functions). We have calculated the variance and correlation coefficients of the intrinsic mode functions to detect the coherent structures in the chaotic time series. We have first applied the empirical mode decomposition (EMD) technique on chaotic time series data obtained from the simulations of Ueda's oscillator, Lorenz's attractor and Rossler's attractor as a test to detect coherent structures in these chaotic time series and then applied this method on the experimental chaotic time series obtained from a hollow cathode glow discharge plasma to detect the presence of coherent structures in them. We feel that this method may have a slight advantage over others like wavelets and Fourier analysis.

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BP-081

Estimation Of Design Parameters For A Helicon Source

N. Sharma, M. Chakraborty, N.K. Neog, M. Bandyopadhyay[1]

Centre of Plasma Physics –Institute for Plasma Research, Tepesia, Kamrup 782402, Assam
[1]ITER-India, Institute for Plasma Research, Gandhinagar 382428, Gujarat

E-mail: narayansharma656@gmail.com

Abstract

Production of high-density plasma and low magnetic field (~100 Gauss) becomes extremely necessary in various technological fields such as electric propulsion [1] and plasma processing [2]. Helicon discharges produce higher density plasma at a comparatively lower given input power than any other RF or DC discharges. Helicon wave, a category of Whistler Wave, is right handed circularly polarized electromagnetic wave in free space [3]. Helicon discharge is an excitation of plasma by helicon waves induced through RF heating. By using the dispersion relation for left handed and right handed waves, parameters of the chamber such as tube radius, magnetic field, RF power, antenna length, etc. can be estimated. In this work, we present a detailed conceptual design to develop a helicon plasma source that includes chamber dimensions, pumping system parameters, electromagnet design parameters and discharge power requirements. The selection of a half wavelength, right handed helical antennae that will be used due to its ability to produce higher (10^{18}-10^{19} m^{-3}) plasma density and more total ionization than full wavelength antennae [4] is also discussed.

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BP-088

Spectroscopic Diagnostics Of UV Ionized Lithium Metal Vapor Plasma For Plasma Wakefield Accelerator Experiment

Mohandas K.K, Sangeeta Tripathi, Sonam Brahmbhatt and Ravi A. V. Kumar
Institute For Plasma Research, Gandhinagar 382428, Gujarat
E-mail : mohandas@ipr.res.in

Abstract

Diagnostic techniques employed for the characterization of a single photon ionized lithium vapor plasma for Plasma Wakefield Acceleration (PWFA) experiment are described here. The plasma source basically consists of a 400 mm x 40 mm uniform temperature lithium metal vapor column generated in a heat pipe oven system. The amount of optical energy absorbed and emitted by the lithium species provides valuable information on vapor and plasma densities. Spectroscopy

techniques based on this is fundamental to the study of PWFA Systems. Study of optical emission from the plasma in the visible region 570-670 nm in the temperature range 600-800^{o}C is the only possible non-invasive method that would provide in-situ data regarding vapour and plasma density during the PWFA experiment. The lithium vapour density for this temperature range was measured using white light absorption around the 670 nm region. This paper presents the results of the absorption as well as emission spectroscopy measurements on the 193 nm laser photoionised lithium in the wavelength range mentioned above. From these studies, we hope to obtain a usable calibration for the lithium vapour as well as lithium plasma density for *in-situ* measurements during PWFA experiments.

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BP-089

Auxiliary Filament's Influence On Plasma Parameters In The Target Region Of A Double Plasma Device

P. Hazarika, M. Chakraborty, B. K. Das, M. Bandyopadhyay[1]
Centre of Plasma Physics –Institute for Plasma Research, Tepesia, Kamrup 782402, Assam
[1]ITER-India, Institute for Plasma Research, Gandhinagar 382428, Gujarat
E-mail:hazarika.parismita@rediffmail.com

Abstract

In volume negative ion production technique, a transverse magnetic field (TMF) is used as a filter to reduce the electron temperature (T_e). Cold electrons (<1 eV) in the extraction region produce H^- ions through dissociative attachment with H_2 molecule [1]. But one of the main disadvantages of a volume negative ion source is that the magnetic filter field reduces the electron density (n_e) in the extraction region along with T_e [2]. The reduction in density of these cold electrons is undesirable as it limits the production of a large amount of negative ions in the extraction region. The present experiment has been carried out in a double plasma device (DPD) consisting of two identical multi-dipole cusped magnetic cages. The transverse magnetic field is set-up in between these magnetic cages. Plasma is produced in the source region by filament discharge method and diffuses into the target region through the TMF. A biased (20V - 40V) auxiliary electron source is also set up in the target region whose energy is kept lower than the ionization potential of neutral gas atoms to avoid electron impact ionization in this region [3]. In this work we have studied the influence of this auxiliary source on the plasma parameters in the target region.

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BP-095

Synthesis of Bamboo Charcoal/Tio_2 Nano Composite and Study Its Surface Property Using DC Glow Discharge Plasma

K.A.Vijayalakshmi, K.Vignesh and N.Karthikeyan

Sri Vasavi College, Erode-638316

E-mail : vignesh.kutti@gmail.com

Abstract

Bamboo Charcoal is an excellent material for its highest porous structure, removal of harmful gases, water treatment, improving blood circulation, blood purification, absorption, de-odorizing, air purification, composite materials of these carbon material used as EMI shielding, Far infrared ray and Anion Emission, and Ultraviolet Radiation Resistance etc., Bamboo charcoal powder /Tio_2 Nano composite (BC/Tio_2) was synthesized using organic synthesis method. This present study compares the surface properties of bamboo charcoal powder and BC/Tio_2 Nano composite. The bamboo charcoal (BC) and the Nano composite of BC/Tio_2 were treated using DC glow discharge plasma. The plasma treated BC and Nano composite of BC/TiO_2 were characterized by FTIR,XRD,SEM,EDX, and UV. Fourier transform infrared (FTIR) spectra (transmission) were employed to study the functional groups of the material .The crystalline nature was confirmed by X-ray powder diffraction (XRD) analysis. Morphological structure and an elements present in the sample were determined by using scanning electron microscopy (SEM) and energy dispersive spectrum (EDX).The transmittance of the sample were determined by UV-VIS.

BP-097

Experimental Measurement Of Electron Energy Distribution Function Of Solitary Electron Holes

S. Kar[1], M. Choudhary[2] and S. Mukherjee[2],

[1]*Indus University, Rancharda, Ahmedabad – 382115*

[2]*Institute for Plasma Research, Bhat, Gandhinagar – 382438*

E-mail : babuliphy@gmail.com

Abstract

Solitary electron holes are vortex like structures in the electron phase space. Its existence is cause of distortion of the electron distribution in the resonant region. Theoretically they were predicted by Schamel et.al first [1,2] as structures in collisionless plasmas. Propagating solitary electron holes can also be formed in a laboratory plasma when a fast rising high positive voltage pulse is applied to a metallic electrode (exciter) [3]. The fast pulse generates energetic electrons, and this changes the Electron Energy Distribution Function (EEDF). In the present work, EEDF is measured after formation of a solitary electron hole in uniform, unmagnetized, and collisionless plasma for pulse width $\tau_p < 3\tau_i$ and $\tau_p > 3\tau$, τ_p, τ_i are pulse width and ion response time respectively. In both type of pulse widths, double hump like profile of EEDF is observed, indicating that solitary electron hole exists in the system for time periods longer than the pulse duration. The presence of energetic electrons is also confirmed from the high energetic hump on the tail of the EEDF.

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BP-100

Undulator Radiation With An Electromagnet Undulator

Vijay Huse
School of physics, DAVV, Khandwa Road, Indore-452001
E-mail : vijayhuse@gmail.com

Abstract

In this paper we discuss the theory of undulator radiation with an electromagnet undulator. The electromagnet undulator (1-4) is important for designing short period free electron laser. We discuss the spectral properties of undulator radiation which arise when electron injected off the electromagnet undulator axis. The study highlights the distinctive features of electromagnet undulator radiation spectrum with respect to PPM based undulator and gives useful insights for understanding gain reduction in free electron laser.

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BP-101

Study On Zinc Oxide Nano Particles Coated Viscose Fabric Using DC Glow Discharge Plasma

K. A. Vijayalakshmi, N. Karthikeyan, [2]K.Vignesh
Department of Physics, Sri Vasavi College, Erode-638316
Email: karthck1947@gmail.com

Abstract

Plasma processing technology that aims to modified the chemical and physical properties of a surface. The nanotechnology creates the structure of excellent properties by controlling atoms, molecules and functional materials. The new properties of nanomaterial have revealed the scientific and research interest in textile industry and hence the research interest for the use of nanotechnology in textile has increase rapidly. The pure textile material viscose is taken and coated by nanomaterial. The material was cleaned in water and ethanol, and the fabric was tried at room temp for 4 Hrs. The Zinc oxide(ZnO) nano particles were prepared by sol-gel process, and the ZnO nano particles coated on a pure viscose material using tip coating method for 1 hr. The Plasma treatment levels of pressure 0.03mbar, voltage 400V and exposure time was 10 mins. ZnO nano particles coated viscose materials was analyzed different characterization study such as, XRD,FTIR, and SEM. Intensity variation was calculated in XRD(X-Ray diffraction) analysis, and the different functional groups were calculated in FTIR(Furies Transform Inferred spectrometry) for the wavelength range is 400-4000cm^{-1}, the morphology of the viscose fabric were analyzed using SEM(Scanning Electron Microscopy). Water absorption levels were calculated in Lab experimental process with different

time exposure in Air Plasma treatment. These results were showed that the fabric surface treated in plasma was modified when compare to the untreated fabric surface.

BP-104

The Investigation Of Solitary Waves In Non-Fermi Un-magnetized Quantum Plasma

B.C. Kalita, M. Choudhury
Gauhati University, Guwahati 781014
E-mail : choudhurymamani@gmail.com

Abstract

The relativistic, rarefactive but subsonic solitons are established in this plasma model with quantum effect both in ions and electrons. The demonstration of existence range of soliton amplitudes $0.5<N<1$ is the remarkable characteristic results in this relativistic quantum plasma, which is also a new result of this kind. Besides, electrons' quantum effect is found not to be effective on the growth of potential depths like that on amplitudes.

BP-107

Experimental Investigation Of Counter Propagating E×B Drifts In Magnetized Plasma Column Using Planar Directional Probe

S. K. Karkari, H. Kabariya, C.Soneji and D. Patel
Institute for Plasma Research, Gandhinagar 382428, Gujarat
E-mail : skarkari@ipr.res.in

Abstract

Radial confinement of cylindrical plasma column by imposing an axial magnetic field results in well known pressure-driven instabilities that falls under various categories of drift waves observed in laboratory plasmas [1-2]. These instabilities are primarily responsible for anomalous transport across the field lines. In this paper we present the characteristic property of counter propagating E×B drifts in a magnetized plasma column that is characterized by off-centered density peak. Using directional probes we observed the presence of counter propagating E × B azimuthally to the magnetic field. The drift is associated with low frequency oscillations in plasma density in the range of 90-110 Hz superimposed with high frequency oscillations of a few kHz. A theoretical model is presented that accounts for the radial electric field distribution in the magnetized plasma column. The model predicts that the radial potential gradient depends on the external magnetic field. A qualitative discussion is presented that accounts for the observed density fluctuations and discuss the salient features about the source.

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BP-108

Small Amplitude Ion-Acoustic Double Layers In Electron-Positron-Ion Plasmas With Finite Ion Temperature

S.K. Jain[a], J. K. Chawla[b] and M.K. Mishra[c]

[a] Government College, Dholpur-328001, Rajasthan
[b] Government College, Thanagazi-301022, Alwar, Rajasthan
[c]Department of Physics, University of Rajasthan, Jaipur-302004

E-mail : surendrajain0110@gmail.com

Abstract

The nonlinear small amplitude ion-acoustic double-layers in a collision less warm plasma consisting of isothermal positrons, warm ions and two-temperature distribution of electrons are investigated. Using standard hydrodynamic equations for the ions and the two species of electrons separately in thermal equilibrium following maxwellian distributions have been considered. Using reductive perturbation method we have derived modified Korteweg-de Vries (m-KdV) equation for the system. On numerical investigations the double layer solution of the system, we have found a new range of parameters for which system supports compressive double layers and rarefactive double layers depending on the concentration of cold electron (μ). Numerical analysis reveals that the system supports compressive double layer for lower values of cold electron concentration (μ), and rarefactive double layers for higher values of (μ). For these cases, the amplitude depends on positron concentration(α), finite ion temperature (σ) *and* the temperature ratio of the two electron species (β). The effect of various plasma parameters on the characteristics of the double layers have been investigated in detail. The results may be useful in space as well as in laboratory plasmas.

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BP-109

Effects Of Positron Density And Temperature On Modulational Instability In Electron-Positron-Ion Plasma With Two-Electron Temperature Distribution

S.K. Jain[a], M. K. Mishra, J. K. Chawla[b] and R. S. Tiwari[c]

[a] Government College, Dholpur-328001, Rajasthan
[b] Government College, Thanagazi-301022, Alwar, Rajasthan
[c] Regional College for Research and Technology Jaipur-302004, Rajasthan
Department of Physics, University of Rajasthan, Jaipur-302004
E-mail: surendrajain0110@gmail.com

Abstract

The modulational instability of ion-acoustic waves in a collisionless plasma with two-electron temperature distribution is studied. The Krylov-Bogoliubov-Mitropolosky (KBM) perturbation method is employed to derive the nonlinear Schrödinger equation. The dispersive and nonlinear

coefficients are obtained which depend on the temperature and concentration of the hot and cold electron species as well as the positron density and temperature. The modulationally stable and unstable regions are studied numerically for a wide range of wave number.

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BP-112

Comparative Study Of Nonlinearity In A Plasma And A Non- Plasma Device

S. Lahiri[1], D. Roy Chowdhury[2] and A.N.S. Iyengar[3]

[1]Dinabandhu Mahavidyalaya, Bongaon, North 24 pgs, WB, 743235
[2]Techno India, EM4/1, Sector V, Salt Lake, Kolkata- 700091
[3]Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Salt Lake, Kolkata-700064

E-mail : sudeshna_lh@yahoo.co.in

Abstract

The dissipative physical systems like plasmas are well known non linear media capable of sustaining a wide variety of waves and instabilities. The nonlinearity in plasma systems is well recognized, arising from the most fundamental processes, namely, the wave-wave and wave-particle interactions. A long standing fundamental issue in non-linear time series analysis is to determine whether a complex time series is regular, deterministically chaotic or random. The vast majority of these efforts are based on such characteristics as the Largest Lyapunov Exponent, Hurst exponent and correlation dimension calculation. In this paper we like to compare the dynamics lying behind a plasma [1] and a non plasma system [2]. As a plasma system we have chosen a glow discharge plasma and as a non plasma system we have chosen ‘BZ’ (Belousov-Zhabotinskii) reaction.
Fluctuations of the plasma floating potentials from cylindrical dc glow discharge argon plasma at an intermediate gas pressure of 0.22 mbar and at the range of discharge voltage (300-700 volt) have been investigated to probe the nature of the complex system dynamics. The system observable, i.e the electrostatic floating potential was measured using a Langmuir probe. The experiment was performed keeping the neutral pressure and electrode configuration constant, and discharge voltage (DV) was the control parameter. Over several regions of the discharge voltage, the floating potential fluctuation time series data exhibits periodic oscillations, and irregular fluctuations.
Study of chemical oscillations have focused primarily on the (BZ) reaction in which bromate ions are reduced in an acidic medium by an organic compound (usually malonic acid) with or without a catalyst (usually cerous and/or ferrous ions). We have varied the concentration of the solution and also the reaction temperature and collected data using an absorption spectrophotometer.
In the case of plasma, the discharge voltage has a discernible effect on the behaviour of this complicated system. As the discharge voltage increases, the system follows a quasiperiodic route to chaos. On the other hand in the non plasma system the nature of oscillation depends on the reaction temperature and also on the concentration of the solution. From the power spectrum plots and from the log frequency vs log power plots we have also seen a marked difference in the system dynamics lying behind the nonlinear oscillations. The value of Hurst exponent varies from 0.5 to 1.0 in plasma where it is around 1.0 in chemical oscillations.

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BP-116

Kinetic Alfven Waves Propagation In Plasmas With Non-Maxwellian Electrons And Their Relevance To Space Plasma

Nirupama Devi[1], Rumi Chaharia1 & Namita Sharma Bordoloi[2]

Department of Mathematics[1], Department of Physics[2], Cotton College, Guwahati, Assam

E-mail: nirupama_cotton@rediffmail.com

Abstract

The existence of Kinetic Alfve'n waves(KAW) in plasma dominated by kappa distributed electrons and warm adiabatic ions has been investigated. Arbitrary amplitude solitary waves known as Solitary Kinetic Alfve'n waves(SKAWs) are found to form. Parameter ranges plasma beta, propagation direction, kappa value for energy spectrum, mach number are seen to vary from lower to higher values in the transition of propagation from SKAWs to Double Layers(DLs) with net potential drop. Such phenomena change the energy level in space plasma regions. We have plotted the pseudopotential to describe the phenomenon.

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BP-119

Investigation Of Complexity Dynamics Through The Study Of Inverse Homoclinic Bifurcation In The Fluctuations Of Glow Discharge Plasma

Debajyoti Saha*, Pankaj Kumar Shaw , Sabuj Ghosh, Vramori Mitra , M. S. Janaki and A.N. Sekar. Iyengar

Plasma Physics Division, Saha Institute of Nuclear Physics, 1/AF ,Bidhannagar Kolkata-700064

E-mail : debajyoti.saha@saha.ac.in

Dissipative physical system like Plasma being a highly nonlinear medium is capable of sustaining a wide spectrum of waves and instabilities and the nonlinear coupling between the waves results in ample interesting phenomena like chaos, noise induced resonances, self-organized criticality, frequency entrainment, complex structures.Here we report the observation of inverse homoclinic bifurcation in the floating potential fluctuations and study the corresponding complexity dynamics in the glow dischargeplasma system.The system dynamics undergoes an appreciable transition with the increase in discharge voltage (DV) which is our control parameter. Initially we observe aninverse homoclinic bifurcation at the lower values of DV which results in higher frequencyoscillations at the intermediate values of DV and at last the fluctuations exhibit some sort of homoclinic bifurcation. We carried out several nonlinear techniques like Hurst exponent(H), largest lyapunov exponent(LLE) ,fast Fourier transform , correlation dimension. In this paper we explore a recently developed approach to calculate the quantitative measure of deterministic signal complexity by estimating Renyi number which is by definition an entropy, i.e., a classically used measure of disorder in physical systems .

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BP-121

Sheath Characteristics In A Very Low Temperature And Low Density Positive Ion - Negative Ion Plasma

M K Deka[a,], N. C. Adhikary[b] and H Bailung[b]

[a]*Centre of Plasma Physics-Institute for Plasma Research, Nazirakhat, Sonapur 782402*
[b]*Institute of Advanced Study in Science and Technology, Paschim Boragaon 781035*

E-mail : manojd143@gmail.com

Abstract

A low density and low temperature plasma is produced in target section of filamentary discharge device using a magnetic filter where plasma is produced only in the source section [1]. The electron temperature is 0.15 eV and ion temperature (~0.1 eV) is nearly equal to the electron temperature. The plasma density is 10^5 -10^6 cm^{-3}. Positive ion negative ion plasma is produced by injecting SF_6 gas into the plasma. SF_6 negative ions are produced by attachment of low energy electrons into SF_6 molecules. Presence of negative ions is detected with the help of plannar Langmuir probe from the reduction of electron saturation current. The lowest value of the ratio of electron to positive ion density has been measured to be 10^{-4}, when the positive ion and negative ion saturation current becomes nearly equal. An emissive probe is used to measure the sheath potential in front of a negatively biased metal plate. Inflection point techniques [2, 3] have been employed while floating point method is found to be ineffective in such plasma. The sheath potential is found to be more negative with increasing negative ion to positive ion density ratio *r*. However, after a certain critical value of *r* (~ 0.6), the sheath potential reaches a minimum and increases towards positive with increase of *r.* The sheath thickness found to increase initially with negative ion to positive ion density ratio, *r* which further decreases with increase of *r.* The observation indicates severe modification of Bohm criterion in positive ion negative ion plasma with heavier negative ion species, which may be helpful in design criterion consideration of negative ion source. The experimental

plasma parameters are very close to that encountered in nature (low earth orbit eg. D-layer of ionosphere) [4, 5].

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BP-122

Dust Acoustic Shock Waves With Maxwellian Electrons And Ions In Warm Dusty Plasma

Apul Narayan Dev[1] and Jnanjyoti Sarma[2]

[1]*Department of Science and Humanities, College of Science and Technology, RUB, Bhutan*
[2]*Department of Mathematics, R. G. Baruah College, Guwahati-781025, Assam*

E-mail : apul@cst.edu.bt

Abstract

The propagation of dust acoustic waves in unmagnetized warm dusty plasma system containing Maxwellian electrons and ions with positive and negative charge dust grains have emerged as an active topic of research in the nonlinear plasma physics area throughout the last decades due to its potential application in space and astrophysical plasma as well as in laboratory. Many researchers have studied the Korteweg-de-Vries-Burgers (KdV-Burgers) equation using a set of generalized hydrodynamic (GH) equations by reductive perturbation method [1] and thereby reported the properties of the solitons and shock waves for strongly coupled unmagnetized dusty plasmas [3, 4]. However, in this article the salient features of nonlinear propagation of solitary waves in warm dusty plasmas without viscosity effect for positive and negative dust charge fluctuation have been studied by deriving Korteweg-de Vries-Burgers (KdV-Burgers) equation. The analytical solution of KdV-Burgers equation is numerically analyzed and DA shock waves propagation is reported, which could be relevant in case of different space and astrophysical plasmas including Saturn's spokes, F-ring, etc. It is shown and theoretically discussed about the critical dust density n_{dc} in Saturn's F-ring and laboratory values for both positive and negative dust charge fluctuation. The effect caused by dispersive and dissipation are also discussed. It is found that the solution of KdV equation represent a rarefactive (compressive) solitary waves if $n_d < n_{dc}$ $\left(n_d > n_{dc}\right)$, where n_d is the dust density and the strength of dispersion term, the Burgers equation represent a negative (positive) shock waves when $n_d < n_{dc}$ $\left(n_d > n_{dc}\right)$ but with the combination of dispersion and dissipation term, the KdV-Burgers equation represent a positive (negative) shock waves when $n_d < n_{dc}$ $\left(n_d > n_{dc}\right)$. The effects of some important parameters for Saturn's F-ring such as $T_e = 10^4\, KV,\, T_i = 2\times10^3\, KV,\, z_d = 10$ and typical laboratory plasma [4], $T_e = 9\times10^3\, KV,\; T_i = 3\times10^2\, KV, z_d = 3\times10^3$ to the shock wave solution are illustrated from the wave evaluation for both dust positive and negative dust charge fluctuation.

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BP-137

Propagation Of Solitons Of Arbitary Amplitude Shear Kinetic Alfven Waves In Plasmas

Latika Kalita and Nirupama Devi

Cotton College, Department of Mathematics, Guwahati-1, Assam

Emails: latika84k@rediffmail.com

Abstract

A two fluid model has been employed to study the propagation of solitary kinetic Alfvén waves in presence of negatively charged dust particles. The set of basic equations governing the ions, electrons, and Maxwell's equation have been reduced to a single equation known as the Sagdeev Potential (SP) equation. An exact analytical expression for the SP or energy integral equation is obtained. Parametric ranges for the existence of arbitrary amplitude are studied in detail. The SP is evaluated numerically in cases when solitary waves exist analytically. Study has been made related to the transition of the waves from shear to kinetic Alfvén waves and corresponding characters in terms of Mach numbers.

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BP-145

Non Linear Phenomena Near The Anode Region Of The Glow Discharge

Prince Alex and Suraj Kumar Sinha

Affiliation: Pondicherry University, Pondicherry, 605014

E-mail: princealexanderm@gmail.com

Abstract

The nonlinear dynamic phenomenon near the anode region of the parallel plate electrode assembly had been studied in glow discharge plasma setup. Plasma strikes in a cylindrical chamber with an electrode separation of 14 cm by keeping a constant pressure of 0.3mbar with varying applied voltage. A very high intensity non linear structure called fire ball is observed near the anode at some particular discharge parameters. The ac components of the floating potential were recorded using a Langmuir probe at the anode zone. The time series oscillation of the floating potential indicates the strong nonlinearities associated with the transition from a stable anode sheath to unstable anode

fireball. The FFTs and phase space plot associated with the time series oscillations elucidate this transformation.

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BP-149

Experiments and theoretical Modeling of intermittency in glow discharge plasma.

S. Ghosh, P.K. Shaw, D. Saha, V.Mitra, A.M.Wharton, M.S. Janaki, A.N.Sekar Iyengar
Plasma Physics Division, Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata-700064
E-mail : sabuj.ghosh@saha.ac.in

Abstract

Intermittency was observed in a glow discharge plasma as the system went from relaxation oscillation having larger amplitude and lower dc level (type I) to another relaxation oscillation characterised by smaller amplitude and higher dc level (type II) as discharge voltage increased. Floating potential fluctuations were analysed by normal variance of inter-peak distance, power spectra, frequency bifurcation, phase space analysis, kurtosis and skewness.

The system was modelled by fluid equations for an un-magnetized plasma. Assuming as we increased the discharge voltage in the experiment the plasma noise level also increased. Solutions of the numerical model were analyzed with the same techniques used for experimental floating point potentials. Results of the numerical model is in very close agreement with the experimental results.

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BP-156

Design and Testing of Proto-type Magnet for Cesium Plasma Confined in a Multi-Line Cusp Magnetic Field

N.Ramasubramanian and P.K.Chattopadhyay
Institute for Plasma Research, Gandhinagar 382428
E-mail : mani@ipr.res.in

Abstract
This presentation will comprise the design and testing of prototype magnets for an experimental proposal to study contact-ionized cesium plasma in a multi-cusp magnetic field. It is expected that since in a cusp configuration, the field in the center is nearly zero, the drift wave oscillations observed before in the called as 'Q-machines or Quiescent machines' will be absent in the center and

it will be effective only in the edges. Even the edge dominant drift wave oscillations is expected to die in a few ion Larmor radius scale length. The magnets are designed such that a reasonable number of un-magnetized cesium ions will be present in the central region extending to a radial distance. This region is expected to be free of any drift wave oscillations and will be the center for further physics studies.

BP-157

Effect Of FLR Correction On Rayleigh -Taylor Instability Of Quantum And Stratified Plasma

P. K. Sharma, [1]Anita Tiwari, [1]Shraddha Argal and [2]R. K. Chhajlani

[1]*BUIT, Barkatullah University Bhopal 462026 (M.P.)*

[2]*School of Studies in Physics, Vikram University Ujjain (M.P.)*

E-mail : anitatiwari7987@gmail.com

Abstract

The Rayleigh Taylor instability of stratified incompressible fluids is studied in presence of FLR Correction and quantum effects in bounded medium. The Quantum magneto hydrodynamic equations of the problem are solved by using normal mode analysis method. A dispersion relation is carried out for the case where plasma is bounded by two rigid planes z = 0 and z = h. The dispersion relation is obtained in dimensionless form to discuss the growth rate of Rayleigh Taylor instability in presence of FLR Correction and quantum effects. The stabilizing or destabilizing behavior of quantum effect and FLR correction on the Rayleigh Taylor instability is analyzed.

BP-160

Higher Order Effects To The Ion-Acoustic Solitary Waves With Tsallis Distribution Of Electrons

Parveen Bala[1] and T. S Gill[2]

[1] *Department of Mathematics, Statistics & Physics, Punjab Agriculture University, Ludhiana- 141004*

[2]*Department of Physics, Guru Nanak Dev University, Amritsar-143005*

E-mail: pravi2506@gmail.com

Abstract

Using the standard reductive perturbation technique (RPT), ion-acoustic dressed solitons have been studied in a two component plasma system consisting of cold positive ions and the q-nonextensive distributed electrons. To the lowest order, well known Korteweg-de Vries (KdV) equation has been derived. RPT is further extended to include the contribution of higher order nonlinear and dispersion terms. Using renormalization method, a stationary solution resulting from higher order perturbation theory has been found. Results of numerical computation for such contribution are shown in the form of graphs in three different parameter regimes of nonextensive parameetr q. A comparison of dressed and KdV solitons has been presented pictorially. Further the effect of velocity and nonextensive parameter on the soliton dynamics has been studied and the results of the numerical computations are interpreted in the form of graphs for various parameter regimes.

BP-170

Non-linear Studies in Cold Cathode Argon Glow Discharge Plasma.

Anu Philip[1], Jacob George[1], Sajith Mathews T[1], P.J Kurian[1], P.K Chattopadyay[2].

[1]*Physics Research Centre, S.B College, Changanacherry, Kerala-686 101*
[2]*Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382428*

E-mail: pjkplasma@yahoo.ca

Abstract

The positive column of glow discharge plasma proves to be a suitable candidate to examine many non linear phenomena because it is non isothermal plasma far-off from equilibrium. The dynamics of various glow discharges is examined by calculating the Lyapunov exponent spectrum (LES) and correlation dimension (D_{corr}) from the experimental time series. The analysis refers to periodic, chaotic and quasi-periodic attractors. The results obtained are confirmed using Fourier power spectrum and autocorrelation function. The experiments are carried out in Argon gas. In the experiment the discharge current is measured at different supply voltage and pressure. Preliminary results indicate presence of chaos in the system.

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BP-176

Characteristic Study Of Plasma Waves By Varying The Applied RF Frequency And Electron Temperature In Single Frequency Capacitive Discharges

Sarveshwar Sharma[1], M. M. Turner[2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar 382428, Gujarat*
[2]*National Centre for Plasma Science & Technology, Dublin City University, Dublin, Ireland.*

E-mail : sarvesh@ipr.res.in

Abstract

In low-pressure capacitive discharges, stochastic heating is the dominant electron heating mechanism which occurs due to the momentum transfer from the oscillating electron sheath edge to electrons[1,2,3]. The existence of waves in electron density close to the sheath edge was firstly reported in literature [4,5] but a comprehensive analysis of their nature has not been discussed. The evidence of wave emission with a frequency near to electron plasma frequency adjacent the sheath territory in case of collisionless plasma in single frequency capacitive discharges was detailed investigated by S Sharma et al.[6]. Here the wave properties have been studied by varying the current density amplitude J_0 for a constant Radio-Frequency (RF), 27.12 MHz. The electron temperature was also constant (2.5 eV). The field reversal and ion reflection phenomena were reported.

In current research work, these waves are studied by varying the frequency of applied RF and keeping other parameters constant. The wave amplitude changes with the frequency of applied RF and the presence of strong field reversal region also observed. The wave properties are also studied by varying the electron temperature T_e for applied frequency 27.12 MHz by keeping all other controlling parameters constant. At low values of electron temperature i.e. ~ 2 eV the strong field reversal emerges. The wave amplitude is also varies by changing electron temperature.

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BP-181

Observation and Theory of Electron Temperature Gradient Turbulence in Laboratory Plasma

S. K. Singh, L. M. Awasthi, S. K. Mattoo, P. K. Srivastava, A. K. Sanyasi, Amit Patel, R. Sugandhi, R. Jha, R. Singh and P. K. Kaw
Institute for Plasma Research, Gandhinagar 382 428
E-mail: ssingh@ipr.res.in

Abstract

We present experimental demonstration and theoretical model of Electron Temperature Gradient (ETG) turbulence in the finite beta laboratory plasma of Large Volume Plasma Device (LVPD). Recent results reveal that ETG turbulence is more likely responsible for anomalous transport of the plasma. The small scale nature of ETG mode inhibits its direct measurement in fusion devices whereas the basic plasma devices provide conditions suitable to bring the scale length of the mode to measurable regime but faces problems because of the presence of ionizing hot and non-thermal electrons. The removal of unutilized primary ionizing and non-thermal electrons and control of radial gradient scale length in electron temperature are all achieved by placing a large Electron Energy Filter (EEF) in the middle of the LVPD dividing whole plasma in source, filter and target regions.

The electromagnetic ETG instability is investigated in the core plasma of the target region. We have established the turbulence by measuring the fluctuations (density, magnetic, temperature and potential), power-spectra, correlation, phase angle, propagation, wavenumber-frequency spectrum and beta scaling in suitable equilibrium plasma conditions for two EEF configurations. The observed turbulence is characterized by broadband spectra in the lower hybrid range of frequencies following the power law. Moreover, the experiment is also performed for nonlinear coherent structures on a cross-field plane of core plasma in the background of ETG turbulence. The density and potential structures are determined from the conditional averaging technique. The initial experimental results will brief on size, lifetime, time evolution characteristic and nature of the observed structures.

The linear and nonlinear theory of coupled Whistler-Electron Temperature Gradient (W-ETG) mode is developed using two-fluid model applicable for LVPD plasma. The role of parallel and perpendicular magnetic field perturbations, non-adiabatic ion response and electron collisions are considered in the derived dispersion relations. The compared experimental and numerical results consisting of fluctuations level, frequency, correlation properties, phase velocity, mode characteristic and beta scaling of all fluctuation amplitudes are found in good agreement in accordance with electromagnetic ETG turbulence. In addition to linear response, a theoretical model for secondary instabilities for long scale mode generation in the background of electromagnetic ETG turbulence is obtained using nonlinear fluid equations. The numerical results based on dispersion relation for zonal flows and streamers using standard wave kinetic formalism are also discussed.

BP-182

Study of Plasma Response to Electron Energy Filter in LVPD

A. K. Sanyasi, L. M. Awasthi, S. K. Mattoo, P. K. Srivastava, S. K. Singh, R. Singh and P. K. Kaw

Institute for Plasma Research,Gandhinagar- 382 428, Gujarat

E- mail: amulya@ipr.res.in

Abstract

An electron energy filter (EEF) [1] is embedded in the LVPD [2] plasma for carrying out studies on excitation of plasma turbulence by a gradient in electron temperature (ETG) [3]. It is shown that inhomogeneity in the magnetic field of the EEF switches on several physical phenomena resulting in plasma regions with different characteristics, including a plasma region free from energetic electrons named as target plasma, suitable for carrying out ETG turbulence. Specifically, we report here on the plasma turbulence excited in the EEF region because of localized gradients in plasma density, potential, electron temperature profiles. It is shown that profiles of electron temperature and potential are created due to energy dependence of the electron transport in the filter region. On the other hand, although structure of plasma density has origin in the particle transport but two distinct steps in the density profile emerge from the dominance of collisionality in the source-EEF region and from the Bohm diffusion in the EEF-target region. It is argued and experimental evidence is provided for the existence of drift like flute Rayleigh-Taylor instability in the EEF plasma [4]. The detailed results on it will be presented in the conference.

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BP-183

Turbulence Study in the Near EEF Target Plasma of LVPD

A. K. Sanyasi, L. M. Awasthi, S. K. Mattoo, S. K. Singh, P. K. Srivastava, R. Singh and P. K. Kaw
Institute for Plasma Research, Gandhinagar- 382 428, Gujarat
E- mail: amulya@ipr.res.in

Abstract

The installation of Electron Energy Filter (EEF) [1] in LVPD divides the plasma in it into three regions exhibiting different characteristics. The regions are defined as the source, EEF and target plasmas. The source region is a region bounded between the filaments and the EEF, the EEF region is limited to the volume within EEF boundaries and the target plasma is the region between the second surface of EEF to the end plate. The target region is further subdivided into two regions namely, far target and near EEF target region. The far target region ($z \geq 30cm$) is found suitable for carrying out study on ETG [2] turbulence as this region offers a sharp gradient in electron temperature but is not a subject of present study. The near target region ($z < 30cm$) which is being investigated, offers a plasma characterized by i) $\nabla n, \nabla \phi \neq 0$ but $\nabla T = 0$ (ii) $E \perp B_z$ and $E \parallel \nabla n$, (iii) weakly magnetized ions i.e. $\nu_{ci} \leq \nu_{in}$, (iv) magnetized electrons i.e. $\nu_{ce} >> \nu_{en}$. (v) the relative $E \times B_z$ drift velocity exceeds the ion sound speed, $v_{E\times B_z} > C_s$. The region offers density fluctuations ~ $10-12\%$. The propagation direction of the observed turbulence is in the ion diamagnetic drift direction. The joint wave number frequency spectra study, $S(k,\omega)$ is carried out to understand the intrinsic properties of turbulence [3]. Experimental results unfolding nature of instability will be presented in the conference.

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BP-190

Self -Diffusion In Strongly Coupled Dusty Plasma

Mahmuda Begum[a] and Nilakshi Das
Department of Physics, Tezpur University, Tezpur, Napaam 784028, Assam
Email: mahmuda@tezu.ernet.in

Abstract

Study of transport properties of strongly coupled dusty plasma is an important and emerging area of research due to its applicability in various dust crystal experiments in laboratory and in space plasmas. In this paper diffusion of dust particles in strongly coupled dusty plasma is investigated by using molecular dynamics simulations. Self- diffusion coefficients of complex plasmas are obtained for a wide range of plasma parameters using Green- Kubo expression which is based on integrated velocity autocorrelation function (VACF). It is assumed that dust particles interact with each other by Yukawa (i.e. screened Coulomb) potential. The study gives interesting results of dust particle

diffusion in plasma.

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BP-209

Large Amplitude Solitary Structures in a Quantum Plasma containing electrons at Two Different Temperatures

Swarniv Chandra, S. Banerjee and B. Ghosh
Department of Physics, Jadavpur University, Kolkata-700032
E-mail : swarniv147@gmail.com

Abstract

Using pseudopotential approach the properties of large amplitude solitary structures is investigated in a quantum plasma containing electrons at two different temperatures and stationary ions. It is found that both the compressive and rarefactive solitons are formed. The amplitude and width of such solitons depend significantly on plasma parameters like temperature, density of hot and cold electrons as well as quantum diffraction parameter.

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BP-242

Stability Of Bernstein-Greene-Kruskal (BGK) Modes In Q-Nonextensive Collisionless Plasmas

Anup K Mandal and Rajaraman Ganesh
Institute for Plasma Research, Gandhinagar-382428, Gujarat
E-mail : anupkumarmandal89@gmail.com

Abstract

In the past, long-time evolution of an initial perturbation in collisionless Maxwellian plasma has been simulated numerically. The controversy over the nonlinear fate of such electrostatic perturbation was resolved by Manfredi [1] using long-time simulations. The electric perturbation was found to continue indefinitely leading to BGK-like phase-space vortices. The question of formation of BGK modes in plasmas governed by q-nonextensive distributions (q=1 is a

Maxwellian) has been recently addressed [2] using a high resolution 1D Vlasov-Poisson solver based on Piecewise-Parabolic Method (PPM) advection scheme. It was found that BGK structures do form for certain range of q-values around q=1 and beyond this window, for generic parameters, formation of BGK structures was rendered difficult. In this work, the important question of stability BGK modes in collisionless plasmas governed by q-nonextensive distributions has been addressed . Considering a BGK mode as a steady state solution, a numerical stability analysis has been performed. A systematic parametric study will be presented.

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BP-248

Effect Of Porosity And FLR Corrections On Jeans Instability Of Self-Gravitating Radiative Thermally Conducting Viscous Plasma

Sachin Kaothekar[1] and R. K. Chhajlani[2]
[1]Department of Engineering Physics, Mahakal Institute of Technology, Ujjain 456664
[2]School of Studies in Physics, Vikram University, Ujjain 456010
E-mail: sac_kaothekar@rediff.com

Abstract

The effects of porosity, radiative heat-loss function, and finite ion Larmor radius (FLR) corrections on the selfgravitational instability of infinite homogeneous viscous plasma have been investigated incorporating the effects of thermal conductivity, finite electrical resistivity, and permeability. A general dispersion relation is derived using the normal mode analysis method with the help of relevant linearized perturbation equations of the problem. The wave propagation along and perpendicular to the direction of magnetic field has been discussed. The condition of stability of the medium is discussed by applying the Routh-Hurwitz criterion. We find that the presence of porosity, FLR corrections, radiative heat-loss function, and thermal conductivity modifies the fundamental Jeans criterion of gravitational instability. Analytical and numerical calculations are carried out to show the effect of various physical parameters on the growth rate of the self-gravitational instability. From the curves we find that temperature dependent heat-loss function, medium porosity, and FLR corrections have a stabilizing effect, while density dependent heat-loss function has a destabilizing effect on the growth rate of self-gravitational instability in the present medium.

BP-257

Wave-Breaking Of Nonlinear Electron Oscillations In Warm Magnetized Plasma

Sourav Pramanik, Chandan Maity and Nikhil Chakrabarti
Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata- 700064
E-mail : sourav.pramanik@saha.ac.in

Abstract

Wave-breaking [1] phenomena of nonlinear electron oscillations around a homogeneous background of massive ions have been studied in a warm magnetized plasma by using Lagrangian variables.An inhomogeneity in the background magnetic field is shown to induce phase-mixing and thus, breaking of the oscillations [2]. An effect of a finite electron temperature is found to delay the associated upper-hybrid wave-breaking process. The nonlinear analysis in Lagrangian variables also predicts wave-breaking may disappear above a critical value of the electron temperature.

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BP-259

Phase-Mixing of Electrostatic Modes in Arbitrary Mass Ratio Cold Magnetized Plasmas

Chandan Maity[1], Nikhil Chakrabarti[1], and Sudip Sengupta[2]
[1]*Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700 064*
[2]*Institute for Plasma Research, Bhat, Gandhinagar 382 428*
E-mail: chandan.maity@saha.ac.in

Abstract

Phase-mixing of electrostatic normal modes in cold arbitrary mass ratio magnetized plasmas has been analyzed within a fluid approach. Perturbative nonlinear results illustrate the nonlinear interaction between normal modes of magnetized plasmas and indicate phase-mixing and thus breaking of initially excited modes. Nonlinear results also provide an estimate for the phase-mixing time. Obtained results will be of relevance to astrophysical environments as well as laboratory experiments.

BP-266

Numerical Study Of Kinetic Energy Of Ion And Sheath Thickness In Magnetized Plasma Sheath

Bhesha Raj Adhikari, Roshan Chalise and Raju Khanal
Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal
E-mail: b.r.adhikari@hotmail.com

Abstract

In all plasma applications sheath is responsible for the flow of particles and energy towards the wall. The kinetic energy of ion and sheath thickness in magnetized plasma sheath region has been numerically investigated by using a kinetic trajectory simulation model keeping other parameter fixed, varying magnetic field and its obliqueness. It has been reveal that the kinetic energy of ions reaching the material wall can be controlled by the strength of applied magnetic field and orientation. Kinetic energy of ion increases as we move towards the wall where as the kinetic energy of electrons decreases as expected, which becomes prominent as the strength as well as obliqueness of the field increases. It is found that by increasing the magnetic field strength there is an increase in the ion energy and a decrease in the sheath thickness. Furthermore, the magnetic field has a direct effect on the ion flux toward the wall and sheath thickness.

BP-269

Self Consistent Kinetic Trajectory Simulation Model For Magnetized Plasma Sheath (1D3V)

Ghanashyam Thakur, Roshan Chalise and Raju Khanal
Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal
E-mail:thakurgs2010@yahoo.com

Abstract

A Kinetic Trajectory Simulation (KTS) model of a 1d3v(1D in space and 3D in velocity), time - independent, collisionless magnetized plasma is presented, which can be used for modeling various

situations of interest and yields results of high accuracy. Exact ion trajectories are followed, to calculate along them the ion distribution function, assuming an arbitrary injection ion distribution. The electrons, on the other hand, are assumed to have a half Maxwellian velocity distribution at injection so that their density can be calculated analytically. Starting from an initial guess, the potential profile is iterated towards the final time-independent self-consistent state. In the present work we develop a 1d3v (1D in space and 3D in velocity) kinetic trajectory simulation model of the magnetized plasma-wall transition layer, where the charged and neutral particle dynamics and interaction between them is included in a fully self-consistent way. The plasma-surface interactions are described via fixed emission coefficients for the secondary particles. We obtained different profiles of plasma and neutral particles and cross-checked classical boundary conditions, which are usually formulated inside the PWT.

BP-278

Selective Excitation of Low Frequency Drift Waves and Parametric Excitation of Higher Frequency Mode

Subir Biswas, Satyajit Chowdhury, Rabindranath Pal and Nikhil Chakrabarti
Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700064
E-mail : subir.biswas@saha.ac.in

Abstract

Drift wave in magnetized plasma arises due to the inhomogeneous density gradient perpendicular to the confining magnetic field [1]. It is generally believed that low frequency drift wave is one of the causes behind cross-field anomalous particle transport in Tokamaks and other fusion devices [1,2]. Though its characteristics have been extensively studied both experimentally and theoretically [1,3] still remains one of the major topics of interest due to some unresolved issues. In most of the experiments the wave is either spontaneously excited due to collisions of electrons with ions and neutrals or excited by driving an electron current parallel to the magnetic field or $\boldsymbol{E} \times \boldsymbol{B}$ rotation. The mode is generally observed in the region of strongest density gradient with constant drift frequency. However, in MaPLE device [4], a new method employed for the excitation of low drift wave in relatively low density gradient region [5]. A strong low frequency density modulation excited the drift wave in the resonant region of the low density gradient. In this region a parallel electron current is present in the MaPLE device which destabilizes the drift wave. Another drift wave with frequency twice of the modulation frequency is excited in the nearby region. Both the modes have azimuthal mode number m=2. Parametric coupling of these drift modes nonlinearly excited another higher frequency drift mode with mode number m=4. Experimental results will be presented.

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BP-279

Behavior of Parametrically Decayed Modes in the Wave Launching Experiment in Ion Cyclotron Range

Satyajit Chowdhury, Subir Biswas, Rabindranath Pal and Nikhil Chakrabarti
Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700064.
E-mail : satyajit.chowdhury@saha.ac.in

Abstract

In the MaPLE device of SINP a preliminary study with wave lunching was carried out in the ion cyclotron range of frequencies in a recent experiment [1]. The incident high amplitude pump waves were observed to decay parametrically [2] into two lower frequency modes, the higher one having frequency near ion Bernstein wave (IBW) mode. The experimentally observed dispersion curve of this mode, indeed, showed the nature of IBW, however, there was some discrepancy observed in it, namely, the corresponding wave numbers were about an order of magnitude lower than that of the standard IBW dispersion curve. In the present experiment we try to resolve this discrepancy by first, carefully determining the plasma parameters, and then measuring the wave numbers with suitably placed probes. Preliminary results obtained will be presented.

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BP-297

Effects of Nano-sized Ion Grains on Propagation of Shear Alfven Wave in Semiconductor Plasma

Giriraj Sharma[1] and R C Dad[2]
[1]*Shri Sitaram Jaju Govt. Girls' College, Neemuch 458441 (M.P.)*
[2]*Govt. Post Graduate College, Mandsaur 458001 (M.P.)*
E-mail : grsharma@gmail.com

Abstract

We have considered compensated semiconductor plasma embedded with nano-sized grains (NSGs) of implanted ions and analytically studied their effects on propagation of Shear Alfven wave (SAW) in the medium. We have employed multi-fluid theory and Maxwell's equations to derive linear dispersion relation for the SAW. In our analysis, we have extended theoretical studies of SAW in dusty plasma to semiconductor plasma embedded with NSGs. The semiconductor plasma duplicates the dusty plasma and the NSG behaves as stationary dust component for the wave phenomena.

In semiconductors, to enhance conductivity, ions are implanted which may agglomerate to form NSGs. The NSGs are also implanted in materials to give colour to the material. Like dust particles in dusty plasma [1-3], we assume that the NSGs acquire charge and produce imbalance of charge in the medium [1, 4, 5]. Semiconductor plasma with charged NSGs imitates the dusty plasma for the waves and instabilities related phenomena. For the present analysis, we have considered stationary negatively charged NSGs in compensated plasma of electrons and holes. It is found in our analysis that the imbalance of charge produced by the charging of NSGs in the semiconductor plasma not only modifies the two fundamental modes but also supports two new novel modes of SAW.

Semiconductor plasma embedded with NSGs is free from stringent confinement problems and the medium parameters can be varied over a wide range with ease. Moreover, the medium considered resembles the dusty plasma, therefore, the present model can serve as a proto-type model for theoretical study of waves and instabilities in dusty plasma. Dusty plasmas are ubiquitous and play

important role in variety of natural and man-made systems and semiconductor industries. A theoretical and experimental study of semiconductor plasma with embedded NSGs may be instrumental in finding favourable conditions for desired phenomena in dusty plasmas.

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BP-298

Long Range Correlations And Hurst Exponent In A Toroidal Magnetized Plasma

T. S. Goud[1], U. Kumar[1], R. Ganesh[1], Y.C. Saxena[1], D. Raju[1], and A.N.S. Iyengar[2]
[1] *Institute for Plasma Research, Bhat, Gandhinagar*
[2]*Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700064.*
Email : shekar@ipr.res.in

Abstract

Plasma produced in a Simple Magnetized Torus – BETA (Basic Experiments in Toroidal Assembly) is investigated for the existence of long-range correlations under varying operating conditions. In our recent work, the probability distributions of density and potential time series were found to deviate from Gaussian profiles, thus exhibit intermittent features similar to those found in the edge plasmas of fusion devices [1,2]. In the present experiments, plasma parameters are obtained with varying toroidal magnetic field topology; the resultant density and potential are analyzed for nonlinear properties. Significant change in the fluctuation trend is observed on varying the externally applied vertical magnetic field for a given toroidal magnetic field strength of 220 G. The Hurst exponent (H-parameter) is estimated for the density and potential time series and possible occurrence of long-range correlations and self-organized criticality is elucidated. Similar investigations revealed that within the edge plasma, the averaged H-parameter varies in a limited range in diversity of plasma confinement devices, whereas in the Scrape Off Layer (SOL) the averaged value of H-parameter varies in a broad range [3]. In the present work in BETA, variation in the values of H-parameter with varying magnetic field topology is explored and possible physics-implications are investigated.

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BP-310

Studies of Wave Phenomena in a Plasma Expanding in Diverging Magnetic Field

Abhijit Ghosh, M.S. Janaki, S.K. Saha, S. Chowdhury
Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata-70064
E-mail : abhijit.ghosh@saha.ac.in

Abstract

In our Double Plasma device, an Argon plasma is made to expand from a narrower quartz tube to a bigger stainless steel expansion chamber in a magnetic field that also diverges into the expansion chamber. The density profile shows central peaks which die down axially after some distance. But, simultaneously two secondary lobes start developing. i.e. the plasma density is highly inhomogeneous in such a configuration. This feature is generic in nature, i.e. exists with or without a double layer. On the other hand, if we look at the axial variation of plasma potential, we can see that the ions will be accelerated i.e. in such a configuration ion beams exist[1]. An ion beam acts as a source of free energy which can generate waves in plasma. Also since the ions are very weakly ionized compared to the electrons, the ions and the electrons become electrically detached when then enter the expansion chamber. As a result, an $\mathbf{E} \times \mathbf{B}$ force develops which act in the azimuthal direction[2]. This force can generate drift modes in the plasma. Keeping these factors in mind, we have measured floating potential fluctuations using a RF-compensated Langmuir probe. To detect the modes, initially we have done Fast Fourier Transform; and we have obtained frequencies mostly in the two regions: (a) 2-8 kHz. These frequencies fall near the ion cyclotron regime for Argon ions with the magnetic field varying from 300-50 G. And, (b) frequencies around 20kHz. Further measurements are required to detect these modes correctly.

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BP-336

Wall Charging of a Helicon Antenna Wrapped Dielectric tube filled with RF Produced Plasma

Kshitish Barada, P.K. Chattopadhyay, J Ghosh, Devendra Sharma and Y.C. Saxena

Institute for Plasma Research, Bhat, Gandhinagar, 382428

E-mail : kshitish@ipr.res.in

Abstract

Dielectric wall charging of a glass wall surrounded by a Helicon antenna of 18 cm length is measured in a linear Helicon plasma device with a diverging magnetic field. The ions because of their less mobility compared to the electrons do not respond to the high frequency electric field oscillating at 13.56 MHz. To maintain the floatingness of the glass wall, the electrons charge the wall to a negative DC potential also known as the DC self-bias so that the fluxes of the oppositely charged particles are equal. This wall potential is characterized for different neutral pressure, magnetic field and radio frequency (RF) power in a Helicon plasma device, where this wall charging is proposed to play a crucial role in the formation of potential structures known as current free double layers. Axial

variation of wall potential near the antenna is also measured. The results shows that the wall charging depends significantly on neutral pressure, gas mass, RF power and magnetic field.

BP-353

Study Of Linear And Nonlinear Evolution Of Buneman Instability

Roopendra Singh Rajawat, Sudip Sengupta and Predhiman K. Kaw

Institute for Plasma Research, Bhat, Ghandhinagar - 382428

E-mail : rupendra@ipr.res.in

Abstract

An one dimensional fluid simulation code has been developed using LCPFCT subroutine to simulate Buneman instability in the linear and nonlinear regime. The code has also been extended to include relativistic effects in the electron equation of motion. Growth of Buneman instability has been studied with different m_e/m_i ratio and the growth rate compared with analytical results [1-3].

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BP-355

Electron Acceleration By Ponderomotive Force In Magnetized Quantum Plasma

Punit Kumar and Abhisek Kumar Singh
Department of Physics, University of Lucknow, Lucknow-226007
E-mail : abhisheklu99@gmail.com

Abstract

Ultrashort, ultraintense laser pulses are of great interest in electron acceleration through laser-plasma interaction. Three schemes of particle acceleration have been proposed viz. LWFA [1-3], LBWFA [4] and the ponderomotive acceleration [5-8]. Motivated by its potential applications, The field of high density quantum plasma has gained attention over the last decade. In the present paper, the electron acceleration by ponderomotive force of a linearly polarized laser pulse in an axially magnetized quantum plasma have been studied. The basic mechanism involves acceleration of electron by the axial gradient in the ponderomotive potential of the laser. The quantum effects have been taken into account for a high density plasma using the recently developed quantum hydrodynamic model. The ponderomotive force of the laser is resonantly enhanced when Doppler upshifted laser frequency equals the cyclotron frequency.

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BP-372

Self-excitation And Energy Transfer Of Buneman Instability To Temporally Growing Plasma During A Short-pulse Microwave Discharge

Shail Pandey and Sudeep Bhattacharjee
Department of Physics, Indian Institute of Technology Kanpur, Kanpur-208016
E-mail : sshail@iitk.ac.in

Abstract

Waves and instabilities are inherent to plasma and can be used to reveal plasma properties. Of these, Buneman instability is known to be associated with plasma where charged particles have relative drift velocity greater than a certain critical value (electron thermal velocity) [1, 2]. While most of the experimental research discusses the waves in preformed steady-state plasma, there are very few studies on the excitation of waves in a pulsed discharge [3] – that too is limited to theoretical studies. In one of our earlier work [4], we had reported self-excitation of waves during plasma development in a short-pulse (~ 20 μs) microwave (2.45 GHz) discharge of low pressure argon (0.2 – 2.0 mTorr). The time scale of the growth of these waves is ~ 200 ns and it was observed that there are two dominating frequencies of 3.8 MHz and 13 MHz in the wave. Once excited, the waves transfer its energy to the temporally growing plasma within the pulse and thereafter get damped during the process within ~ 4 – 5 μs. This enhances the ionization and results in rapid growth of plasma.

Temporal evolution of the plasma can thus be classified in three phases [4]: (i) self-excited wave generation, (ii) plasma growth phase and finally, (iii) decay phase beyond the end of the pulse. The current study focuses on first two phases and the role of the self-excited wave in plasma growth. For this, space- and time-resolved measurements of electron energy probability function have been carried out using a gridded electron energy analyzer. The measurements indicate a drop in hot electron population accompanied by an increased cold electron population during transition from phase (i) to (ii). The origin of self-excitation of the waves lies in the difference in the ion and electron drift velocities [4]. The relative drift velocity is found to satisfy the criterion for excitation of Buneman type of instability. The growth rate and oscillation frequency values of this instability [1] are in agreement with the experimentally observed values.

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BP-373

Some Aspects of Ion-Acoustic Solitons In Inhomogeneous Plasma In Presence of Weak Ionization

[1]L. B. Gogoi and [2]P. N. Deka,
[1]Department of Mathematics, Duliajan College, Duliajan-786602, Assam
[2]Department of Mathematics, Dibrugarh University, Dibrugarh-786004, Assam
E-mail: glokbikash@gmail.com

Abstract

The nonlinear propagation of ion-acoustic solitons in weakly inhomogeneous plasma in presence of weak ionization is studied. For this study fluid model of plasma is considered and reductive perturbation method is employed for the basic set of fluid equations. In this formulation process a space time stretched co-ordinate is used. The system of equations has been reduced to a modified Korteweg - de – Vries (mKdV) equation and solved for obtaining the expressions of amplitudes and widths of the solitons. The soliton solutions are found to be affected by plasma inhomogeneities. The effective conditions for soliton propagation in weakly inhomogeneous plasma in presence of weak ionization have been analyzed.

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BP-374

Electron Energy Distribution In Non-equilibrium Transient Pulsed Microwave Plasmas Driven To Different Initial Conditions

Sudeep Bhattacharjee and Shail Pandey
Department of Physics, Indian Institute of Technology Kanpur, Kanpur-208016, India
E-mail : sudeepb@iitk.ac.in

Abstract

The electron energies and its distribution function are measured in non-equilibrium transient pulsed microwave plasmas in the interpulse regime [1, 2]. The plasmas are driven to different initial conditions by varying the electromagnetic wave pulse duration and peak power. Two cases are investigated: (i) short-pulse (~ 1 μs), high-power (~ 60 kW) waves and (ii) medium-pulse (~ 20 μs), and moderate power waves of ~ 3 kW. It is found that high-power short-duration pulses lead to a significantly different electron energy distribution function (EEDF) in the interpulse phase - a Maxwellian with a bump on the tail, although the average energy per pulse (~ 60 mJ) is maintained the same in the two modes of wave excitation. Electrons with energies > 250 eV are found to exist in the discharge in both the cases. By tailoring the EEDF of the transient plasma new applications in plasma processing and chemistry can be realized in the interpulse phase of the discharge [3, 4].

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BP-379

Temporal Evolution Of Nano To Micro-pores In Free Hanging Films By Multi Element Focused Ion Beams (MEFIB) From Intense Microwave Plasmas

Samit Paul, Jay Kumar Shah, and Sudeep Bhattacharjee
Department of Physics, Indian Institute of Technology, Kanpur 208016
E-mail : samit@iitk.ac.in

Abstract

Creation and application of nanopores has been of great interest in recent years particularly in biomedical, chemical and nanotechnology research areas. Conventional, liquid metal ion source (Ga ion) based focused ion beams (FIB) are used for fabricating nanopores, where Ga contamination is a major issue. To obviate this problem, a microwave plasma based multi-element focused ion beam (MEFIB) system [1,2] that can deliver focused ion beams of a variety of gaseous elements such as Ar, Kr, Ne, H_2 have been extracted and focused to 5 - 15 μm size using electrostatic Einzel Lens systems. When an ion beam of energy 1 - 20 keV impinges on a surface, its local physical properties are modified by mainly three processes: (a) sputtering, (b) local heating, and (c) atomic rearrangement in the substrate. Hence, it is difficult to predict milling time for different substrate thickness. There are almost no data available in the literature for milling time using gaseous ions on different metallic substrates as a function of beam energy and species. In this study we report multi element ion beam milling and a technique for controllably creating pores. The milling time (τ_d) is measured for different ionic mass, beam energies and film thickness. An empirical relation among the above experimental parameters is investigated.

It has been found that Ar ion beams of 4 keV energy takes ~ 100 seconds (τ_d) to just penetrate through an 11 μm thin aluminum substrate. The temporal measurement of the beam current (I) through the pore indicates that as the pore grows the current increases. This temporal current information is used as feedback to control the pore size and a pore of diameter ~ 3 μm has been successfully fabricated. It is observed that the milling time τ_d decreases with increase in beam energy non-linearly. Currently we are trying to reduce the pore size further by: (a) reducing the beam diameter and (b) using thinner photoresist and metallic film such that local heating can be minimized.

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BP-383

Ion-Acoustic Solitary Waves In A Quantum Plasma With Ion-Streaming And Electron-Inertia

H. Sahoo[1,] K.K. Mondal[2] and B. Ghosh[3]
[1]*Madan Mohanpur R.C.S. Vidyamandir, Kulpi, South 24-pgs-743374*
[2]*Sovarani Memorial College Jagatballavpur, Howrah-711408*
[3]*Departments of Physics, Jadavpur University Kolkata-700032*

Email: bsdvghosh@gmail.com

Abstract

Using reductive perturbation technique and quantum hydrodynamic model equations ion-acoustic solitary waves have been investigated in a quantum plasma including ion-streaming and electron-inertia. Endeavour has also been made to investigate effects of the ion-streaming and the electron-inertia on the linear instability of the ion-acoustic waves. From the linear dispersion relation which in this case is a eighth order algebraic equation in wave number (k) it is shown that a few of the possible modes of propagation are linearly unstable and the growth rate of this instability depends significantly on the ion-streaming velocity. To describe the nonlinear behavior of the wave we have derived a Korteweg-de Vries (KdV) equation including quantum diffraction effect, electron inertia and ion-streaming effect From a numerical study of the nonlinear and dispersion coefficients of the KdV equation it is shown that the amplitude and width of the solitary waves depend significantly on ion-streaming but weakly on electron inertia effect.

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Nuclear Fusion (NF)

NF-006

Main Vacuum Pumping System Of SST-1 Tokamak

Ziauddin Khan, Firozkhan Pathan, Siju George, Kalpesh Dhanani, Yuvakiran Paravastu, Pratibha Semwal and Subrata Pradhan

Institute for Plasma Research, Near Indira Bridge, Bhat, Gandingar – 382428

E-mail : ziauddin@ipr.res.in

Abstract

Steady-state Superconducting Tokamak (SST-1) was installed and it's commissioning for overall vacuum integrity, magnet systems functionality in terms of successful cool down to 4.5 K and charging up to 10 kA current was started from August 2012. Plasma operation of 100 kA current for more than 100 ms was also envisaged. It is comprised of vacuum vessel (VV) and cryostat (CST). Vacuum vessel, an ultra-high (UHV) vacuum chamber with net volume of 23 m3 was maintained below 1.0×10^{-7} mbar for plasma confinement. Cryostat, a high-vacuum (HV) chamber with empty volume 39 m3 housing superconducting magnet system, bubble thermal shields and hydraulics for these circuits was maintained below 1.0×10^{-5} mbar in order to provide suitable environment for these components. In order to achieve these ultimate vacuums, two numbers of turbo-molecular pumps (TMP) are installed in vacuum vessel while three numbers of turbo-molecular pumps are installed in cryostat. Initial pumping of both the chambers will be carried out by using suitable Roots pumps. PXI based real time controlled system is used for remote operation of the complete pumping operation. In order to achieve UHV inside the vacuum vessel, it was baked at 150 °C for longer duration. Aluminium wire-seals were used for all non-circular demountable ports and a leak tightness $< 1.0 \times 10^{-9}$ mbar l/s were achieved.

NF-008

Indigenous Development Of Compact Neutron Generator

Basanta Kumar Das[1*], Anurag Shyam[1], Rashmita Das[1] and A. Durga Prasad Rao[1]

[1]*Energetics and Electromagnetics Division, Bhabha Atomic Research Centre, Autonagar, Visakhapatnam-530012*

[2]*Department of Nuclear Physics, Andhra University, Visakhapatnam-530003*

E-mail: dasbabu31@gmail.com

Abstract

Compact neutron generators, due to their specific features are in demand for elemental analysis, detection of the illicit materials, characterization of materials related to fusion grade devices. Compact in size, controlled operation and radiation safety like features of neutron generator is suitable for research work with illicit materials. An accelerator based neutron generator can be operated in steady mode as well as in pulse mode. The main embodiment of this type of generator includes ion source, ion acceleration system and target. We are developing such type of neutron generator. This consists of one in-house developed penning ion source, a single electrode acceleration gap and one deuteriated titanium target or virgin titanium target. The neutron generator was operated at 80 KV acceleration potential, a deuterium pressure of 0.1 mtorr and ion source potential at 1 KV. The neutron generation was confirmed by the solid state nuclear track detector

CR-39. This generator is operated in pulse mode for a different frequencies and the neutron detection was carried out with plastic scintillator detector for fast neutrons. In this presentation, we will discuss various physics and technical issues related to the important components of this generator, operation of the generator, production and detection of neutrons.

NF-010

Development Of Epics Based Software Toolkit For Critical Heat Flux Computions For Divertor Mockups Testing At High Heat Flux Test Facility

S. K. Doddi[1], R. Sugandhi[2], R. Swamy[2] and S. Khirwadkar[2]

[1]*Jawaharlal Nehru Technological University, Hyderabad-500 085*
[2]*DFD Division, Institute for Plasma Research, Gandhinagar-382428*

Email: ritesh@ipr.res.in

Abstract

Critical Heat Flux (CHF) calculations are vital for the accurate measurement of thermal hydraulic response of High heat flux components like divertor mock ups. High heat flux test facility is under development at institute for plasma research for thermal testing of divertor mock-ups. It is desirable to know the operational set points required for efficient heat extraction of different type of mockups under the diverse high heat flux source operation. An integrated graphical software toolkit is developed to assist the calculation of Critical heat flux, Incident heat flux, absorbed heat flux, safety margin etc. and calculate the set points for pressure, temperature and flow condition for maximum heat extraction under given experimental conditions using optimization of CHF model. This toolkit abstracts the inter-parameter dependencies and empirical experimental relation and dynamically decide the suitable curve fitting within an acceptable error. The toolkit is developed using EPICS control system framework for a possible measurement extension and simulated I/O generation. SNS Control system studio toolkit is used for Graphical user interface development. The application layer of the toolkit is written using a python library development on scientific python libraries viz. numpy, scipy, matplotlib etc and tested using NOSE testing framework. This paper discusses the theoretical CHF model, Software architecture and test cases and results.

NF-011

Design And Development Of A 200KV, 15MA High Voltage Power Supply

Amal S, Urmil M Thaker, Kumar Saurabh and Ujjwal K Baruah

Institute for Plasma Research, Gandhinagar, Gujarat 382 428

Email: amal@ipr.res.in

Abstract

A compact, low power, portable 200kV High Voltage DC power supply has been designed and is in advanced stage of development at IPR, Gandhinagar. The design is based on symmetrical Cockcroft-Walton voltage generator with a high frequency front end converter. The high voltage is generated by a series fed seven stage voltage multiplier circuit driven by a 15 kHz quasi sine wave inverter. A 17 kV-0-17 kV, 15 kHz ferrite core transformer interfaces the voltage multiplier circuit with IGBT

based half-bridge inverter. The use of high frequency gives us advantages of less ripple, faster response and low stored energy in the system. Additionally the scheme allows the use of smaller capacitor and magnetic parts thus minimizing the weight of components and improving portability of the system. With a brief introduction on design aspects of voltage multiplier, this paper describes the design features and developmental aspects of various components for 200kV Power supply viz., high frequency inverter, high voltage high frequency transformer, high voltage feed through (HV Bushings) and voltage multiplier circuit in detail. This power supply will be used as a DC source for HV testing of electrical insulations in future.

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NF-014

Physics Aspects Of ICRF Wall-Conditioning Experiments In Textor

Manash K. Paul[1], A. Lyssoivan[3], R. Koch[3], G. Van Wassenhove[3], M.Vervier[3], G. Bertschinger[2], R.Laengner[2], B.Unterberg[2], G. Sergienko[2], V. Philipps[2], T. Wauters[4] and the TEXTOR Team

[1]National Institute of Technology Agartala, Jirania, Tripura, India 799 055
*[2]Institut für Energieforschung-Plasmaphysik FZ Jülich, Euratom Association, 52425 Jülich, Germany**
*[3]LPP-ERM/KMS, Association Euratom-Belgian State, 1000 Brussels, Belgium**
[4]CEA, IRFM, Association Euratom-CEA, 13108 St Paul lez Durance, France
**Partners in the Trilateral Euregio Cluster (TEC)*

Corresponding Author E-mail: manashkr@gmail.com

Abstract

Ion Cyclotron Wall Conditioning (ICWC) discharges [1], in pulsed-mode operation, have been carried out in the limiter tokamak TEXTOR to explore safe operational regimes for the experimental parameters for possible ICWC discharge cleaning in ITER at ITER half field. Antenna coupling properties obtained during the ICRF-Wall Conditioning experiments performed in helium-hydrogen mixture in TEXTOR [2] have been analyzed in relation to the ICWC-plasma characterization results obtained. Satisfactory antenna coupling in the Mode Conversion scenario [3] along with reproducible generation of ICRF plasmas for wall conditioning, have been achieved by coupling RF power from one or two ICRF antennas. The plasma breakdown results obtained in the TEXTOR tokamak have been compared with the predictions of a 0-D RF plasma production model [4]. The present paper on ICWC emphasizes on the beneficial effect of application of an additional (along with toroidal magnetic field) stationary vertical ($B_V \ll B_T$) or oscillating poloidal magnetic field ($B_P \ll B_T$) on antenna coupling and relevant plasma parameters.

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NF-023

Testing Of High Speed Profibus Link For VME V6PFB Profibus Card And Siemens DC Simoreg Master (6ra70)

Dinesh Kumar Sharma and SST-1 Power System Team

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail : dinesh@ipr.res.in

Abstract

High-speed profibus link is required for the master slave DP communication of VME V6PFB profibus card and slave CBP2 (communication board for profibus) module installed in 6RA70 gate pulse controller. For the reference and On/Off parameters and status monitoring, profibus link needs to be tested. V6PFB VME profibus card is used as master for the profibus link and CBP2 is used as slave device.

This paper describes the embedded programming and memory mapping of V6PFB VME profibus card, configuration of CBP2 module in 6RA70 DC simoreg master, master and one slave configuration in DP Configurator software and testing results DP mode (PP0 type) for master and one slave. This profibus link will be used for SST-1 PF power supply.

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[3] www.siemens.com

NF-027

Radiation Damage Study Of Graphite Exposed To Helium Ions

N. J. Dutta[1], N. Buzarbaruah[1], S. R. Mohanty[1*], P. M. Raole[2], T. Dash[3], B. B. Nayak[3]

[1]*Centre of Plasma Physics-Institute for Plasma Research, Sonapur, Kamrup-782402*
[2]*Institute for Plasma Research, Bhat, Gandhinagar-382428*
[3]*CSIR-Institute of Minerals and Materials Technology, Bhubaneswar-751013*
*Email: srmohanty@cppipr.res.in

Abstract

Graphite is used for various industrial applications such as moderators in atomic reactor, heat sinks for X-ray tube, refractory materials for furnaces etc. due to its good conductivity of heat and electricity, refractoriness and excellent thermo-mechanical property. It is still being considered as an

important material in the context of reactor engineering. The response of this material to the harsh condition of reactor is a subject of interest to the fusion community. Various accelerator facilities [1-3] have been employed to find out the possible radiation damages on graphite induced by ions. In this work, we have reported high energetic (a few keV to MeV) helium ion irradiation on graphite using a plasma focus ion accelerator. The helium ion radiated from this device is found to be pressure dependence and highest yield is obtained at 0.5 Torr as inferred from the voltage probe signal. Graphite specimens were irradiated to helium ions by keeping them at different angular positions (0^0, 20^0, 40^0 and 60^0) at a height of 7 cm from the electrode assembly and were exposed to different numbers of ion pulses (5, 10 and 20 shots). The irradiated and reference samples were characterized by employing various analytical instruments such as Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), X-Ray Diffraction (XRD), and X-Ray Photo-electron Spectroscopy (XPS). Optical micrographs of irradiated samples show mostly rounded microstructure with sparsely layered type structure at higher resolution. When viewed under TEM at very high resolution, the reference and irradiated samples illustrate layered type two dimensional sheaths and rounded structure with mean diameter ~10 nm, respectively. XRD spectrum of irradiated sample indicates appearance of some new peaks which may be resulted due to some mixed phases. The detailed results will be presented in the paper.

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NF-029

Application Of AACMM In Quality Control For Development Of Superconducting Magnet Components

Mahesh Ghate, Dhaval Bhavsar, Arun Panchal, Subrata Pradhan
Institute for Plasma Research, Bhat Village, Gandhinagar-382428, Gujarat
E-mail: mghate@ipr.res.in

Abstract

This paper discuss the application of Articulated Arm Coordinate Measuring Machine (AACMM) in quality control of various components related with superconducting magnets. Under this paper, the various case studies for inspection of components by AACMM have been presented. Implementation of contact probes and raster scanning technique for inspection has been elaborated. The factors affecting the accuracy of AACMM during inspection are mentioned. The surface based geometry generation and data comparison technique by CAD has been discussed. The effectiveness of AACMM based evaluation for quality control of magnet components is presented.

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NF-045

Development Of Experimental Helium Cooling Facility For Testing Of LLCB TBM First Wall Mock-Ups

Brijesh Kumar Yadav[a], Ankit Gandhi[a], Aditya Kumar Verma[a], T Srinivas Rao[a], E. Rajendra Kumar[a], Mausam Sarkar[b] and K. N. Vyas[b]

[a]*Institute for Plasma Research, Gandhianagr-382428*
[b] *Bhabha Atomic Research Center, Trombay, Mumbai- 400 085*

E-mail: byadav@ipr.res.in

Abstract

The experimental helium cooling facility is dedicated to the testing of **Lead Lithium Ceramic Breeder Test Blanket Module (LLCB TBM) First wall mock-ups.** This facility consists of high pressure and high temperature helium gas loop with its pressure and inventory control system and other auxiliary systems such as cooling water system, electrical system, instrumentation and control system, and Test Specimen Modules (TSMs). The main loop i.e. the Experimental Helium Cooling Loop (EHCL) of the facility is designed for a pressure and temperature of 8 MPa and 450 C respectively, and the main loop consists of electrical heater, recuperator, coolers, circulators, filter and associated piping, valves, and measurement systems.

The EHCL is similar but of lower capacity to the **First Wall Helium Cooling System (FWHCS)** of LLCB TBM to be tested in ITER. The EHCL is developed to demonstrate the thermal-hydraulic and thermal-mechanical capabilities of helium system components, TBM first wall mock ups and to get experience in operating the high pressure high temperature helium gas loop. The pressure and inventory control system maintain the desired operating pressure in the loop within $\pm$ 5 % (8$\pm$0.4 MPa) as well to store the inventory for the loop. The cooling water system provides the chilled water (~25 C) to the loop components such as cooler, compressor, and circulators etc. A number of test modules are planned to be tested in EHCL, these modules replicate the TBM FW channels. The EHCL is controlled and monitored remotely by centralised instrumentation and control system. The main requirements and characteristics of the experimental helium cooling facility are presented in this poster.

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NF-056

MDSplus Integration With ICRH DAC Software

Ramesh Joshi, Manoj Parihar, H M Jadav, S V Kulkarni & ICRH Group

Intitute for Plasma Research, Gandhinagar- 382428

Email: rjoshi@ipr.res.in

Abstract

(Modal data system) MDSplus is a data management system used in several Nuclear Fusion experiments to handle experimental and configuration data. Application Programming Interface (API) for local and remote data access are available with many languages, namely C, C++, Fortran, Java, Python, MATLAB and IDL, and a set of visualization and analysis tools are available for data browsing and display. In this way, it is possible to take advantage of the availability of the local and remote data access layers of MDSplus, widely used in the fusion community to handle large sets of data. The VME based Data Acquisition and Control (DAC) system is commissioned for remote operation of SST-1 Ion Cyclotron Resonance Heating (ICRH) system. MDSplus provide the hints to achieve continuous data acquisition during the experiments required to use acquired data in the active control of the experiment. We have successfully installed and integrated MDSplus with ICRH DAC systems for heating experiment requirement on SST1. There are around 128 analog input signals requires to acquire at the time of experiment. The requirement of ICRH system would be successfully achieved and tested with experiment. We have used C API adapter classes for integration with user interface program. This paper will explain such integration and test results.

NF-057

Engineering Design Of Epics Based Prototype For ICRH DAC System

Ramesh Joshi[12], Manoj Singh[1], S V Kulkarni[1], Kiran Trivedi[2]
[1] *Institute for Plasma Research, Bhat Village, Gandhinagar – 382428*
[2] *Shantilal Shah Engineering College, Bhavnagar – 364060*

[1]Email: rjoshi@ipr.res.in

Abstract

ICRH (Ion Cyclotron Resonance Heating) DAC (Data Acquisition Control system) has two different requirements for ICH heating experiment on SST1. RF Lab DAC controls and monitor RF power generator and RF Shield room DAC controls and monitor RF transmission to Antenna. The VME based ICRH DAC is commissioned for remote operation of heating experiment on SST-1 Tokamak. RF power generation DAC working as master DAC which communicates with SST1 central control system and another is slave DAC which triggers with Master DAC. Both the DAC systems are VME based and using VxWorks as hard real time OS on processor board and different analog and digital

IO boards for acquisition and control. Both VME must acquire the data at same time when trigger pulse is given by SST1 central control system. This synchronization of both DAC will be possible with EPICS (Experimental Physics and Industrial Control System) process variables, which broadcast and describe itself in Ethernet network. The existing system uses the TCP/IP Ethernet network for the same. The proposed prototype will be used for the purpose of real-time state parameters transmission and storage, dynamic graphical display, modification of the interactive system. This paper will describe the engineering design of EPICS based ICRH DAC software prototype toward complex data acquisition system.

NF-065

Codac Core Based Control System For 300KV Accelerator Based 14-MeV Neutron Generator

Vismaysinh Raulji, Praveenlal E V, Hitesh Mandaliya, Rachana Rajpal, Rajnikant Makwana and Sudhirsinh Vala

Institute for Plasma Research, Nr. Indira Bridge, Bhat, Gandhinagar-382428

E-mail : vismay@ipr.res.in

Abstract

CODAC based control system is developed for remote operation of Accelerator based 14-MeV Neutron Generator. The CODAC Core System is the Linux based Software package that is distributed by ITER Organization for the development of Plant System I&C software. It is based on the EPICS open source frame work with ITER specific extensions.

The control system of accelerator is divided in two sections. One is to control the components, which are kept on high voltage deck at 300kV floating potential, like Ion source, extraction system, focusing system and mass flow controller. Other section is at ground potential like Beam profile monitor, Faraday cup, Beam steerer, Gate valve and Turbo Molecular pump. The aim of control system is to control, monitor and data acquisition with operation of all safety interlock. To control the components on high voltage deck PLC system is used and kept at 300kV floating potential. TCP/IP fibre optic link (media converter) is used for communication between PLC and control room PC.

CODAC core system includes EPICS, CSS (Control System Studio), and Visual Database Configuration Tool, Eclipse etc. CSS is used for HMI, alarms and archives. SDD (Self Description Data) tool is used for configure plant system I&C. SDD Editor is an Eclipse based application to define the plant system, interface, I&C component, interfaced signals, configure variable. SCADA (Supervisory Control and Data Acquisition) system is developed in CSS. Data will be transferred between PLC and CSS through EPICS. SDD Editor generates .awl, .sdf for STEP7 software and is used for communication between CSS and PLC. The complete system with safety interlock is tested with Neutron Generator. This paper will describe the salient features of the developed control system in detail.

NF-078

DESIGN, FABRICATION, TESTING AND INTEGRATION OF 1.5 KV,1.5A SCREEN GRID POWER SUPPLY FOR 200 KW, 91.2 MHZ CWRF AMPLIFIER

Bhavesh R Kadia, YSS Srinivas, Kirit parmar, H. M. Jadav, S.V. Kulkarni & ICRH Group.
Institute For Plasma Research, Bhat, Gandhinagar-382428, Gujarat

E-mail: brkadia@ipr.res.in

Abstract

Tetrode based amplifiers are used, to generate high power at RF frequencies for plasma heating applications for tokamak plasmas. Stable operation of the amplifier demands low value of ripple, good regulation, reliable controls and protections for all high voltage and auxiliary power supplies. The Screen Grid Power Supply (SGPS) is used to feed the screen grid of tetrode in CWRF source which is connected between cathode and screen grid of tetrode tube. As the control grid of the tetrode is normally grounded, SGPS is supposed to be a floating supply with the negative end of the supply floating at ~500V with respect to ground in normal condition. In case of an arc fault it can be much higher depending on fault location and conditions.

The screen grid power supply for 200 kW RF amplifier is developed indigenously to satisfy above requirements. The selected SGPS topology is a conventional 12 pulse DC power supply with primary voltage control of step-up transformer that has two secondary windings. Primary voltage control is accomplished by using motorized autotransformer. The output of each secondary (star and delta) is rectified with diode-bridges. In order to get the desired DC output, the bridges are connected in series and filtered. These are optimized in order to minimize fluctuations in the RF output power. The fast switch-off capability of the HVDC power supply is incorporated using SCR based crowbar switch. It diverts the stored energy and protects the tube in case of fault. The protections like over voltage, over current and hard wired interlocks with system and DAC, are incorporated in the supply. The power supply can be operated in either local or remote mode. The power supply is integrated with the RF amplifier system and is currently in use with the 200 kW, 91.2 MHz CWRF Amplifier.

This report presents the required specifications, design criteria, fabrication details, results of testing of Screen grid DC power supply for 200 kW, 91.2 MHz CWRF amplifier.

NF-080

DESIGN AND DEVELOPMENT OF A LINEAR NEUTRON SOURCE BASED ON INERTIAL ELECTROSTATIC CONFINEMENT FUSION SCHEME

N. Buzarbaruah[a], N. J. Dutta[a], M. K. Deka[a], S. R. Mohanty[a*], M. Bandyopadhay[b], P. M. Raole[c], R. Verma[d] and A. Shyam[d]

[a] *Centre of Plasma Physics-Institute for Plasma Research, Nazirakhat, Sonapur, Assam-782402*
[b] *ITER-India, Institute for Plasma Research, Gandhinagar, Gujarat-382428*
[c] *Institute for Plasma Research, Bhat, Gandhinagar, Gujarat-382428*
[d] *Bhabha Atomic Research Centre, Visakhapatnam, Andhra Pradesh-530012*

*E-mail: srmohanty@cppipr.res.in

Abstract

Compact neutron sources are in demand for various applications such as cancer therapy, fusion material studies, non-invasive interrogation of illicit drugs and explosive materials. Inertial Electrostatic Confinement Fusion (IECF) device is relatively a simple and portable neutron source having the advantage of enhancing fusion grade plasma in a small scale regime. This device can effectively confine ions in converging electrostatic fields for fusion purposes in a cylindrical/spherical geometry. It has been reported that this simple device can produce neutron yield typically in the order of 10^8-10^{10} neutrons/sec from Deuterium-Deuterium (DD) reactions [1]. Here we present a detailed conceptual design to develop a linear neutron source based on the gridded

IECF scheme so as to obtain Neutron Production Rate (NPR) of the order of 10^6-10^8 n/s. The dimension of the chamber such as the height (30cm), diameter (50cm) and volume (76 liters) are chosen in order to develop 20 cm long neutron source. Two concentric grids namely an inner grid and an outer grid will be housed inside the vacuum chamber. The inner grid, cathode, will be powered from a -200 kV, 75 mA DC power supply by an electrical feedthru. On the other hand, the outer grid which will be at ground potential, acts as anode. Initially, the deuterium plasma will be created inside the chamber by making glow discharge. Then, the ions are accelerated towards the cathode due to the large electrostatic field in between anode and cathode and, subsequently, those ions fuses to produce neutrons [2]. Here we are aiming to achieve a plasma density of the order of 10^{19} –10^{20} m^{-3} which will enable us to generate NPR in the above mentioned range. A detailed theoretical estimation based on the cathode transparency, cathode current, ion cross section etc. to achieve the said range of NPR is carried out following the standard procedures [3]. A suitable shielding scheme for neutrons within the estimated neutron flux range is also proposed.

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NF-83

Field Simulation Of Ohmic Ramp-down In Aditya – Need For Correction Coils For Improvement Of Magnetic Null

A. Amardas, R. L. Tanna, J. Ghosh, P. K. Chattopadhyay, C. N. Gupta, S. B. Bhatt and the Aditya team

Institute For Plasma Research, Gandhinagar-382428

E-mail : amar@ipr.res.in

Abstract

The time evolution of magnetic null during the plasma breakdown and current start-up phase in Aditya tokamak is simulated using a finite element code Comsol Multiphysics[1]. Effect of vertical magnetic field on the dynamics of the null position has been studied in detail and is found to be not conducive for plasma break down and current ramp up in Aditya tokamak. It is shown in the simulation that the magnetic null moves inwards due to vertical field. With vertical field off the null is stable but remains outward. The limitation of generating zero vertical field at the breakdown time as well as limited control in its rise time can be overcome by driving current in additional correction coils with current value derived from the presented simulations. The plasma formation location has been observed experimentally using measurement of Hα radiation well matches with the simulation results in presence of vertical magnetic field. However, in absence of vertical magnetic field the experimental results defer from simulation results which is under investigation.

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NF-085

Surface Damage From Exposure To Pulsed Fusion Grade Plasma Generated Using A Plasma Focus Device

Satish C. Gupta[1], Ram Niranjan[1], R. K. Rout[1], R. Srivastava[1], Y. Chakravarthy[2], N. N. Patel[3] and P. Alex[4]

[1]Applied physics Division, [2]Laser and Plasma Technology Division, [3]High Pressure & Synchrotron Radiation Physics Division, [4]Materials Processing Division, Bhabha Atomic Research Centre, Mumbai-400 085

E-mail : satish@barc.gov.in

Abstract

An 11.5 kJ plasma focus (PF) device which produces intense pulsed plasma consisting of energetic ions, neutrons and electromagnetic radiations similar to fusion reactors was used here. Typical energy of ions emitted in a PF device varies from 10s of keV to MeV and energy of neutrons are of 2.45 MeV (with use of deuterium gas) or 14.1 MeV (with use of deuterium and tritium gases). The samples of copper, molybdenum, stainless steel and tungsten were irradiated. Most of these materials are likely to be used in future fusion reactor development. Each sample was exposed to 20 shots at a distance of 6 cm from the tip of anode of the PF device inside a plasma chamber. For irradiation, the device was connected to a 40μF capacitor bank and the plasma chamber was filled to 4 mb pressure of deuterium gas. The bank was charged to 24kV (11.5kJ) and discharged through the coaxial PF unit. At 6 cm from the anode tip, the ion fluence measured using a Faraday cup was $9x10^{17}$ ions/m^2 with an average energy of 105 keV and with pulse width of 700 ns, which was equivalent to power flux density of 22 GW/m^2. The neutron yield of the PF unit was measured with a calibrated silver activation detector. The neutron pulse width was obtained through a plastic scintillator detector coupled to a photomultiplier detector. The estimated 2.45 MeV neutron fluence at 6 cm was $(2.2\pm0.3)x10^{10}$ neutrons/m^2 (power flux density of $2.3x10^2$ kW/m^2) with pulse width of 46 ns. The virgin and irradiated samples were analyzed with scanning electron microscope (SEM), optical microscope (OM), grazing incidence X-ray diffraction (GIXRD) and Vicker's hardness gauge. The results obtained using OM, SEM shows formations of micro-cracks, blisters, pores and other defects on the sample surface. It is evident that the damages are mostly due to bombardment of energetic deuterons rather than neutrons. Irradiation process of the samples using PF device and characterizations of exposed sample surfaces shall be reported in this paper.

NF-086

Evaluation Of Half Lives Through Thermal Neutron Activation Using Plasma Focus Neutron Source

R. K. Rout[1], B.S. Tomar[2], P.S. Ramanjaneyulu[2], D.B.Paranjape[2], Ram Niranjan[1], T.C. Kaushik[1] and Satish C. Gupta[1]

[1]Applied physics Division, [2]Radioanalytical Chemistry Division, BARC, Mumbai-400 085

E-mail : rkrout@barc.gov.in

Abstract

One of the applications of the plasma focus (PF) device is presented here. The thermal neutron activation and analysis are used in this application. Fast neutrons (2.45 MeV energy) generated in an

11.5 kJ PF device were thermalised and were used for activation of the elements to produce radioisotopes. Characteristic gamma rays emitted during the decay process of the radioisotopes were monitored and were used successfully in estimation of half lives of the isotopes. The elements selected were dysprosium ($T_{1/2}$= 1.3 minutes), manganese ($T_{1/2}$=2.58 hours) and gold ($T_{1/2}$=2.69 days). A Mather-type 11.5 kJ plasma focus device emitting $(1.2\pm0.3)x10^9$ D-D fusion neutrons per pulse with a pulse width of 46±5 ns was used as the neutron source. The emitted neutrons were characterized by using a plastic scintillator detector for time resolved information and by a calibrated silver activation detector for yield evaluation. For neutron activation study one sample at a time was placed inside a well of thermalising material in axial direction of the PF device and was exposed to thermalised neutrons. The gamma rays emitted from the radionuclides ^{165}Dy, ^{56}Mn and ^{198}Au, produced in ^{164}Dy(n,γ), ^{55}Mn(n,γ), and ^{197}Au(n,γ) reactions respectively were immediately counted offline in a lead shielded well type 3 inch x 3 inch NaI(Tl) detector coupled to a calibrated 1024 multi channel analyzer. For dysprosium and manganese, exposure to a single plasma focus shot was enough to produce statistically good counts. But to produce measurable activation counts in gold sample, it was exposed to 8 discharges. The evaluated half lives from the measured decay process data were 1.43 minutes, 2.56 hours and 2.84 days for dysprosium ($T_{1/2}$= 1.3 minutes), manganese ($T_{1/2}$=2.58 hours) and gold ($T_{1/2}$=2.69 days) respectively. The estimated values are close to the literature data as mentioned in the brackets. The details of the experiment and the result shall be reported.

NF-094

Joining Of Graphite To Heat Sink Material By Direct Vacuum Brazing Using Active Metal Filler Material

K.P Singh[1], S S Khirwadkar[1], Malti Verma[2], S Kanpara[1], M.S Khan[1], S Belsare[1], Nikunj Patel[1], Prakash Mokaria[1]

[1]*Institute For Plasma Research, Bhat, Gandhinagar 382 428*
[2]*School of Physics and Materials Science, Thapar University, Patiala, Punjab*

E-mail : kpsingh@ipr.res.in

Abstract

One of most challenging part of the fusion research is developing the suitable Plasma Facing Components (PFCs). Carbon Fiber Composite (CFC) was chosen as one of the promising candidate for PFC in ITER tokamak.

To establish the dissimilar material joining such as Carbon material (Graphite or CFC) to heat sink material (CuCrZr) is an interesting area [1-2] . Due to having the large thermal mismatch between graphite material and CuCrZr material, the direct casting of Copper on Graphite surface is not possible. The reason is copper doesn't easy wet on the carbon surface. One can overcome this issue by selecting the possible the joining route such as surface modification of the Carbon using active metal casting technique (AMC) [3], Surface modification of CFC using Cr slurry by solid state reaction [4], Direct brazing using active metal brazing fillers [5] etc.

In the present study, with the help of titanium alloy filler materials, the joining of Graphite to CuCrZr materials is made possible by direct vacuum brazing route (active metal brazing). Different sizes of coupon based Graphite (C) samples were prepared by varying uniform loading during the brazing. The results of the experimental works will be presented in the paper.

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NF-128

Cryogenic Operation Strategy For The SST-1 Device

V.L. Tanna, Cryogenic Team (SST-1) and S. Pradhan

Institute for Plasma Research, Bhat, Gandhinagar 382 428

Abstract

The SST-1 has been operated since 2012 as part of its engineering commissioning and almost 5 experimental campaigns have been successfully completed. Before final assembling, cool-down and current excitation tests for the Toroidal field coils and PF 3 (Upper) coil were demonstrated successfully as part of validation under coils test program. These superconducting coils consist of a cable-in-conduit conductor, (CICC) is cooled by the forced-flow Two-phase flow as well as supercritical helium conditions [1]. During the recent campaigns, hydraulic characteristics of whole superconducting magnets along with the TF case cooling were studied as an integral system. Based on the experimental observations, efforts have been made to cryo stable conditions of the SST-1 superconducting magnets system in order to produce steady state TF magnetic field of 1.5 T at the plasma center. Optimization of Helium plant related processes have been worked out and implemented to realize the successful SST-1 device operation over a week [2]. In order to have long experimental campaign, an intermediate temperature cooling down philosophy has been adopted. The complete superconducting coils flow distribution among their cooling channels and pressure head requirements were studied from the measurements. In this paper, we will highlight the recent cool-down results, flow distribution and temperature uniformity aspects while cooling down the SST-1 magnets system.

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NF-135

Design And Development Of High Flux Pulsed Neutron Source For Applications

Rishi Verma, R. Shukla, S. Sharma, B. K. Das, E. Mishra, K. Sagar, M. Meena and A. Shyam
Energetics & Electromagnetics Division, BARC, Visakhapatnam 530012
Email: rishiv@barc.gov.in

Abstract

A dense plasma focus device based high flux pulsed neutron source has recently been made operational at Energetics & Electromagnetics Division, BARC Facility, Visakhapatnam. The 15kJ pulsed power system of this plasma focus device comprises of six modules (of ~2.5kJ each) and

cumulatively delivers peak current in the range of 200kA to 500kA (depending upon load and operating parameters) in a quarter time period of about 5μs. The major objective of preliminary phase of experiments was to investigate the neutron yield performance of this device at various deuterium filling gas pressures. At ~10kJ operation, the average neutron yield has been found to be in the order of 10^9 neutrons/pulse in 4πsr for the deuterium filling gas pressure range of 4 to 6mbar. The diagnostics used during these experiments were: ^{3}He detector for the neutron yield measurements, plastic scintillator-photomultiplier detector for gathering the time resolved information of hard X-ray and neutron emission, and Rogowski coil for *di/dt*, current measurements. The main application objective of this high neutron yield dense plasma focus device development is: (i) to explore the feasibility study towards development Pulsed Fast Neutron Analysis (PFNA) system for explosive and contraband material detection and (ii) to conduct novel fusion reactor material studies, by investigating their suitability as plasma facing component materials in large upcoming fusion facilities. Detailed characterization experiments of this device are presently underway and will be reported in the conference.

NF-161

General Purpose Signal Acquisition System For Acquiring, Storing And Integrating Electrical Signals

Vijay Vadher, Paresh Patel, L. K. Bansal, Karishma Qureshi , Dipal Thakkar, Vishnu Patel, L. N. Gupta, C.B. Sumod and U. K. Baruah

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail: vvadher@ipr.res.in

Abstract

Neutral Beam Injector is one of the heating systems for Tokomak plasma for SST-1. Various high power converters are engaged to power different NBI subcomponents at different platforms and at different potentials. To analyze power supply and electrical parameters, it is required to process data and integration of necessary multiple parameters in single graph with common time frame.

In this paper, a technique is discussed using dedicated application software (developed in house) and a particular hardware for data acquiring, storing and integration. This system integrates required signal parameters from different platforms (VME real time system, USB based DAQ, PLC) to a single window based platform. It is explained that how does a particular integration algorithm operates having different parameters like sampling rate, acquisition time and signal scaling with different hardware platforms. It replaces ordinary C/C++ based application to graphical data flow based application to minimize code complications and debugging time. Finally, it is shown that this software application is user friendly for acquiring, retrieving and viewing general electrical signals by applying dummy signals.

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NF-171

Timing Control Circuit For Real-Time Control Of Events In Aditya Tokamak

Praveenlal E V, Prakash Naicker, Rachana Rajpal, Pravesh Dhyani, Joydeep Ghosh, R. Tanna, P. K. Chattopadhyay and Aditya Team

Institute for Plasma Research, Gandhinagar-382428

E-mail : praveen@ipr.res.in

Abstract

Tokamak plasma is prone to many random events having potential for causing severe damages to the machine, such as disruptions, production and elimination of high-energy runaway electrons etc. These events can be mitigated by obtaining pre-cursor signal leading to these events and then taking proper measures just before their onset to avoid their happenings, like disruptions can be mitigated by massive gas injection or putting a bias voltage on an electrode placed inside the plasma, the runaways can be mitigated by gas injection and by applying specific magnetic fields. Hence for real time control of these events, the pre-cursors should be electronically recorded and the mitigation techniques should be initiated by sending triggers to their individual operational systems. To implement these methodologies of real-time controlling of events in Aditya Tokamak, a low cost multi-channel Micro-Controller based timing circuit is designed and developed in-house. This circuit first compares the precursor signals fed into it with the pre-set values and gives a trigger output whenever the signals overshoot the pre-set values. The circuit readies itself for operation along with start of the tokamak discharge and waits up to an initial pre-determined delay and then initiates a trigger at the time of overshooting of precursor signal. The circuit is fully integrated and assembled in compact enclosure with local LCD for threshold and initial trigger-delay monitoring and indicators for full stand-alone operation. The system has been successfully tested in the disruption control by biasing electrode experiments in Aditya tokamak. The MHD oscillations, precursor in this case, is monitored by this circuit and whenever the amplitude of these oscillations overshoot a particular pre-set value, a trigger is generated and delivered to a SCR switch which triggers the voltage on the electrode placed inside the plasma to avoid disruptions. The detailed design features and results will be described in this paper.

NF-179

Control of Plasma Layer In a Fusion Reactor Correlated to Dc Motor Control Using PSO-ANFIS

Sakuntala Mahapatra, Raju Daniel and Deep Narayan Dey

Dept. of Electronics and Telecommunication Engineering, Trident Academy of Technology, Bhubaneswar 751024, Odisha

Email: mahapatra.sakuntala@gmail.com

Abstract

Plasma position and shape control is very crucial for the overall performance of the fusion reactor such as tokamak. The quality of the discharge in the Saskatchewan TORus-Modified (STOR-M) tokamak is strongly related to the position of the plasma column within the discharge vessel. If the

plasma column approaches too near the wall, then either minor or complete disruption occurs. Consequently it is necessary to be able to control dynamically the position of the plasma column throughout the entire discharge. Now a day's most fusion reactor employs the traditional PID controller for the confinement of plasma layer. Fuzzy logic is used for the control of Plasma layer. In this paper we have used the hybrid of PSO-ANFIS technique to control the speed of a DC motor .We have used two input parameters like speed, torque and output is firing angle. In our work first order Sugeno fuzzy model is taken with three rules and the parameters of Gaussian membership function is controlled by the PSO technique. PSO-ANFIS speed controller obtains better dynamic behavior and superior performance of the DC motor speed control. Similar approach can be correlated to the control of plasma layer. For the plasma control two inputs can be taken as plasma position ΔH and the plasma current and the single output, the control decision u(t).

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NF-191

Variable Duty Cycle & Variable Amplitude Multi Pulse Generation Facilities Development In The PXIE System For Different Mode Of ICRH Operations

Manoj Singh[1], H.M. Jadav, Ramesh Joshi, Sunil kumar, YSS srinivas, B.R. Kadia, K. M. Parmar, Gayatri Ramesh, Atul varia,S.V. Kulkarni and ICRH-RF Group

Institute for Plasma Research, Bhat, Gandhinagar – 382428

E-mail: parihar@ipr.res.in

Abstract

ICRH-DAC (Data Acquisition and control) controls and monitors the delivery of RF power (1.5MW, 20-40 MHz) to dummy load /Aditya / SST-1 tokamak [1] for maximum 1000 seconds. As ICRH operation in the tokamak machine may involves for line-conditioning, heating, pre-ionization and current drive, controlling the RF-shot pulse is most important

The pulse generation is the most critical component in the application development as it has to be synchronized with the central control group as well with all local sub-systems. Controlling parameter of RF-pulse from the DAC is delay time, on time, off time, fall time, no of pulses, amplitude etc. for maximum 1000 seconds pulse durations. System operational performance monitoring and post acquisition shot analysis is referenced from this pulse only.

Recently ICRH group has procured the PXIe based DAC system with PXIe-1065 chassis, PXIe-8135 RTOS controller. On this system, required ICRH-shot pulse is designed, developed, tested for on line monitor, acquisition and control using multi-featured AIO PXIe-6363 module, Digital input output (DIO) PXI-6704 module cards. Pulse is integrated and interfaced with the RF-Signal generator, RF attenuator and LPA section.GUI and Labview-VI programming for monitoring and control has been successfully developed. Pulse is also acquired for the post shot analysis. Developed

application software provides pulse preview feature, so user can see the launching pulse on the screen to validate the pulse details before launching the actual pulse.

This paper will discuss functionality of in-house developed application software associated with pulse generation, integration with the system and testing results.

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NF-203

Acceptance Tests Of Cryogenic Components For SST-1

Rajiv Sharma, Hiren Nimawat, Nitin Bairagi, Pankil Shah, Ketan Patel, Srikanth, D. Sonara, V. L. Tanna and S. Pradhan

Institute for Plasma Research, Bhat, Gandhinagar 382 428

E-mail: rajivs@ipr.res.in

Abstract

The cryogenics system is one of the critical sub-systems in SST-1. The role of cryogenics systems is to facilitate the smooth cool-down, warm up and steady state operation as well as to take care about any abnormal events in safe mode during the operation. As a part of SST-1 machine shell, the cryogenics division is responsible for cold helium (at 4.5 K) and liquid nitrogen (at 77 K) hydraulics. This hydraulic network consists of headers, 80 K embossed shields [1], interconnecting loops, Ceramic feed through at the vacuum barrier, flexible hoses and electrical breaks for cold helium as well as liquid nitrogen circuits. Before installation of individual components in SST-1, the performance validation tests were mandatory as part of mandatory stringent protocols fulfillment [2]. The performance validation tests were conducted from individual components to integrated assembly level. In this paper, we report the essence of procedures followed and the performance test results.

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NF-206

Ramp Based Measurement Circuit For Langmuir Probe Diagnostic

Pramila, Jignesh Patel, Rachana Rajpal, R.Jha

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail : pramila@ipr.res.in

Abstract

A Langmuir probe technique based on the single-double probe method have been used to measure plasma parameters of low temperature(2 to 5eV) and low density(103 to 1011 /cc) plasma, yielding

measurement of ion-saturation current, ion-density and electron temperature. Biasing the probe with the fixed bias gives the density while the electron temperature is obtained by sweeping the probe potential relative to the plasma, thus allowing fast time resolution. The bias voltage is chosen to be few times the electron temperature so that the negative electrode draws the ion-saturation current, while the sweep frequency is taken a few times more than the discharge time.

A signal detection and conditioning electronics is designed for the single probe in dual cable method technique for magnetized linear plasma device(MLPD). For front-end current sensing requirement(100uA to few mA) ,high common mode difference amplifier is used for measurement in the presence of high dc as well as varying sweep bias voltage .The signal conditioning electronics is isolated from the data acquisition end using opto-isolation. The sweep generation circuit comprises of the resistor-programmable waveform generation integrated circuitry with frequency and amplitude adjustment. The high voltage amplification is done using power amplifier PA-85 for achiving the required sweep waveform. A detailed description of the design will be presented in this paper.

NF-208

Design And Development Of IGBT Based Circuit For Switching Off The Plasma For Wave Experiments In Afterglow Plasma

Minsha Shah, Rachana Rajpal, Sayak Bose, P.K. Chattopadhyay

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail : minsha@ipr.res.in

Abstract

A circuit for switching off the plasma has been designed and developed for carrying out wave experiments in afterglow plasma in Magnetized Linear Plasma Device (MLPD). The decaying plasma obtained after switching off the supply is termed as the afterglow plasma. This plasma is expected to be quiet and hence more conducive for wave experiments. The plasma source comprises of an array of joule-heated filaments biased with respect to the vessel wall by a 128V, 25Amp power supply. The switch is connected between the floating filament heating supply and the grounded biasing supply to break the circuit quickly whenever desired. The switch comprises of an IGBT with collector emitter terminals kept floating. The switching off circuit is also used to trigger the diagnostics of the system with a user selectable delay. The suitable snubber circuit has been used for protection. This allows voltage protection against anticipated back emf at turn off. The IGBT switch is operated using mechanical switch & debouncing circuit is implemented to avoid jitter. Also the IGBT switch is driven using a proper isolated gate driver. The entire scheme & results will be described in this paper.

NF-215

Liquid Nitrogen Distribution Boxes For Cool Down Of 80K Thermal Shields Of SST-1

R. Panchal, GLN Srikanth, K. Patel, P. Shah, V.L. Tanna and S. Pradhan

Institute for Plasma Research, Gandhinagar-382428

E-mail:rpanchal@ipr.res.in

Abstract

The 80 K thermal shields system of steady state superconducting Tokamak 1 (SST-1) consists of large number of complex shaped liquid nitrogen (LN2) cooled bubble shields. These shields can be cooled by two possible ways, using high pressure single phase (0.6 MPa) or low pressure (0.2 MPa) two-phase cooling using liquid nitrogen. In order to provide uniform temperature and even flow distribution among the different groups of 80 K thermal shields, it is essential to have automated remotely operated flow distribution system.

The Liquid Nitrogen (LN2) distribution boxes act as a bridge between LN2 system and 80K thermal shields system of SST 1 and it can be used for both the high and low pressure LN2 cooling system in the operating pressure range of 0.2 – 0.6 MPa. The LN2 boxes consist of complex hydraulics with flow control valves and specially designed piping network in it to provide uniform temperature and flow distribution within the thermal shields system of SST-1.

The distribution boxes also consist of instrumentation for temperature, pressure and flow measurements. This paper describes design, manufacturing and testing of LN2 distribution boxes with selection of instrumentations.

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NF-227

Base Pressure Is The Determining Factor For Blob Formation In Argon Plasma

G. Sahoo[1], R. Paikaray[1], S. Samantaray[2], P. Das[1], D. C. Patra[1], N. Sasini[1], J. Ghosh[3], A. Sanyasi[3]

[1]*Ravenshaw University, Cuttack-753003, Odisha*
[2]*Christ College, Cuttack- 753008, Odisha*
[3]*Institute for Plasma Research, Bhat, Gandhinagar-382010, Gujarat*

E mail: gourishankar.sahoo@gmail.com

Abstract

Recent experimental evidence suggests the importance of fast radial plasma transport in the scrape-off-layer (SOL) of tokamaks. The outward transport appears to be convective rather than diffusive, extends into the far SOL and can produce significant recycling from the main-chamber walls, partially bypassing the diverter. A plausible theoretical mechanism to explain this phenomenon is the radial transport of locally dense plasma created by turbulent processes. In our experiment a blob of plasma is produced using a gas injected washer plasma gun. It is observed that the life span of plasma column is dependent on the base pressure so also the blob formation. At very low and intermediate pressure ~10^{-4} mb – 4 mb blob/filaments are not formed from main plasma column, but as we make base pressure > 4 mb, blobs/filaments are formed from main plasma column. It was earlier expected that blob formation is a phenomena observed in magnetically confined fusion devices, due to the presence of plasma in magnetic field[1-5] but here the results obtained from probe as well as fast imaging diagnostics [6] reveals that even in the absence of magnetic field coherent plasma structures blobs/filaments are formed. Interestingly at low pressure 10^{-4} mb – 0.4

mb the plasma life time is nearly equal to the pulse width of the PFN, which energizes the plasma gun to produce plasma. But, in the presence of more neutrals (0.4 mb – 12 mb) the plasma is contained and plasma life time is 15-20 times more than that of pulse width. So, at higher pressure plasma self energizes itself, contained and triggers convective transport in form of blob/filament and moves towards the main wall with subsonic speed.

Acknowledgement:

We are grateful to Prof. R. Pal, SINP, Kolkota and Dr. A. Mishra, Retd. Reader, Ravenshaw College for their guidance and encouragement to carry out this work. This work is funded by Board of Research in Fusion Science and Technology (BRFST), India.

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NF-228

Variation Of Intensity Of Atomic Lines In Atmospheric Gas Plasma Produced By Washer Plasma Gun

P. Das[1], R. Paikaray[1], S. Samantaray[2], G. Sahoo[1], D. C. Patra[1], N. Sasini[1], J. Ghosh[3], A. Sanyasi[3], M. B. Chowdhuri[3]

[1]Ravenshaw University, Cuttack-753003, Odisha
[2]Christ College, Cuttack- 753008, Odisha
[3]Institute for Plasma Research, Bhat, Gandhinagar-382010, Gujarat

E mail: gourishankar.sahoo@gmail.com

Abstract

Role of neutrals is an exciting field of research in thermonuclear fusion device. In this paper we have studied the effect of neutrals on the ionization/excitation process of plasma blob produced by washer plasma gun. A gas injected plasma gun is used to produce the plasma blob. It is observed that intensity of different atomic lines changes with base pressure, injecting neutral atmospheric gas into the gun. The intensity of H_α decreases rapidly from 0.05 mb to 0.5 mb, slowly from 0.5 mb to 5 mb and remains almost constant from 0.5 to 12 mb. On the other hand the intensity of H_β line decreases slowly from 0.05 mb to 1 mb and from 1 mb to 12 mb it is almost constant. The intensity of OII, C1 line increases from 0.05 mb to 0.5 mb whereas it decreases from 0.5 mb to 12 mb. The electron temperature, as measured using ratio of intensity method assuming the plasma is in LTE, increases from 0.05 mb to 0.5 mb, decreases from 0.5 mb to 5 mb and when we further increase base pressure from 5 mb to 12 mb the temperature remains almost constant. It is observed that the electron temperature profile is very similar to that of the intensity profile of OII, C1 line. At higher base pressure all the parameters remain nearly constant.

NF-239

Recent Run-Time Experience And Investigation Of Impurities In Turbines Circuit Of Helium Plant Of SST-1

P. Panchal, R. Panchal, R. Patel, G. Mahesuriya, J. Tank, D. Sonara, Srikanth LN, K. Patel, D. Christian, A. Garg, N. Bairagi, P. Shah, H. Nimavat, R. Sharma, V.L. Tanna and S. Pradhan

Institute for Plasma Research, Bhat, Gandhinagar – 382 428

E-mail : pradip@ipr.res.in

Abstract

One of the key sub-systems of Steady State superconducting Tokamak (SST-1) is cryogenic 1.3 kW at 4.5 K Helium refrigerator / liquefier system. The helium plant consists of 3 nos. of screw compressors, oil removal system, purifier and cold-box with 3 turbo expanders (turbines) and helium cold circulator. During the recent SST-1 plasma campaigns, we observed high pressure drop of the order of 3 bar between the wheel outlet of turbine A and the wheel inlet of turbine – B. This was significant higher values of pressures drop across turbines, which reduced the speed of turbine A and B and in turn reduced the overall plant capacity. The helium circuits in the plant have 10-micron filter at the mouth of turbine – B. Initially, major suspects of such high blockage are assumed to be air-impurity, dust particles or collapse of filter. Several breaks in plant operation have been taken to warm up the turbines circuits up to 90 K to remove condensation of air-impurities at filter. Still this exercise did not solve blockage of filter in turbine circuits. A detailed investigation exercise with air / water regeneration and rinsing of cold box as well as purification of helium gas in buffer tanks are carried out to remove air impurities from cold-box. A trial run of cold box was executed in liquefier mode with turbines up to cryogenic temperatures and solved blockage in turbine circuits. The paper describes run-time experience of helium plant with helium impurity in turbine circuits, methods to remove impurity, demonstration of turbine performance and lessons learnt during this operation.

NF-245

Design Of An Experimental Setup For Determining Hydrogen Isotopes Solubility In Liquid Lead Lithium

Sudhir Rai, Amit Sircar and Sanjeev Kumar Sharma

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail : sudhirrai@ipr.res.in

Abstract

In Indian Liquid Lead Cooled Ceramic Breeder (LLCB) Test Blanket Module (TBM), eutectic alloy PbLi is used as breeder material in addition to its use as neutron multiplier and coolant. The low solubility of hydrogen isotopes in liquid PbLi creates a high partial pressure, which in turn results in an increased tritium permeation rate from the breeder into the He coolant and a considerable tritium inventory in the structural materials. Various experiments are conducted to find out hydrogen isotopes solubility in liquid PbLi. However, the solubility values obtained by different research groups vary between ~ 10^{-3} and 10^{-8} $mol.m^{-3}.Pa^{-1/2}$. Therefore, need for a reliable experiment to determine solubility of hydrogen isotopes in liquid PbLi is well established.

We have, in this work, designed an experimental setup for determining hydrogen solubility in liquid PbLi based on permeation process. The experiment would be done with hydrogen gas but can be used for deuterium and tritium too. The experiment would be done by keeping a constant pressure of hydrogen gas hydrogen gas (in the range of 10^2-10^4 *Pa*) at the upstream side of the PbLi with a *1 mm* thick pure iron membrane placed in between, in the temperature range *573 – 773 K* . The experiment would be first done without PbLi, which would give the values of solubility and diffusivity of pure iron membrane. After this, experiment would be performed with PbLi to obtain solubility and diffusivity of liquid PbLi.

This paper describes the design of the experiment and modelling of permeated flux of hydrogen using published data on solubility and diffusivity of hydrogen in PbLi. The model considers following fundamental processes of permeation of Hydrogen from upstream to downstream side, viz., (i) absorption and dissociation of H_2 molecules on the surface of the pure Fe membrane (ii) dissolution and diffusion of H atoms in the Fe to PbLi, (iv) diffusion of H in liquid PbLi and (v) recombination of H atoms into H_2 molecules and desorption from the surface of PbLi. The estimated permeation flux is used to determine different diagnostics like QMA, capacitance manometer etc., necessary for conducting the experiment.

NF-249

Studies Of Out-Gassing Rate Carried Out For Various Materials To Be Used In Cryoadsorption Cryopump

Samiran Mukherjee, Paresh Panchal, Agarwal Jyoti, Ranjana Gangradey, Ravi Prakash N.

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

E-mail : samiran@ipr.res.in

Abstract

Outgassing from materials is a principal impediment for creating and maintaining clean and ultrahigh-vacuum environments. Data about out-gassing rates of different materials is very important for designing any vacuum system operating in ultra- high vacuum regime. Gas load due to outgassing from different materials determines the size (capacity) of pumps and order of vacuum that can be achieved in the system. Data on outgassing rates of materials available in literature are for some specific materials at some specific temperature. Many times, it happens that outgassing rate for a material and the operating conditions required for a given experimental conditions are difficult to obtain from literature.

To get outgassing rate for various materials to be used in cryopump an Out Gassing Measurement System (OGMS) was set up. The OGMS facility has a known conductance of 2.46 L/s and base outgassing rate of ~ $3x10^{-12}$ mbar-ltr/s-cm^2. An ultimate vacuum of < 5 $x10^{-9}$ mbar was achieved in a sample chamber of volume ~7.5 liters. A dedicated control unit with temperature monitoring, gate valve operation, data logging like user interfaces has been developed. Controlled heating and safety locks for power failure is implemented. In addition the residual gas analyzers give the qualitative measurements of the gases evolving from materials. Development of cryoadsorption Cryopump involves selection of many materials like sorbents, black coatings, and adhesives and should have low outgassing rates under UHV conditions. During reactivation and regeneration the cryosurfaces carrying the adsorber is heated upto temperatures in the range of ~150 degC to activate the sorbent for the better cryoumping effect. Thermal outgassing studies of various samples including activated carbons, activated fibers, Al_2O_3,TiO_2 Coating, indigenous cryo-adhesives were carried out and are

discussed in the paper.

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NF-250

Degassing Measurement Studies Carried Out For Various Forms of Activated Carbon

Samiran Mukherjee, Sapana Guru, Pratik Nayak, Jyoti Agarwal, Ranjana Gangradey

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

E-mail : samiran@ipr.res.in

Abstract

Cryosorption cryopump, is a cryocondensation pump, with the adsorber surface having a layer of activated carbon cooled to cryogenic temperatures of the order of 20K and below. Activated carbon in its various forms with microporous structure is a promising sorbent for the concept of cryosorption cryopump applicable to fusion reactor, as the gases to be pumped are mainly hydrogen, its isotopes and helium. For effective pumping of helium the sorbent temperature should be below 5 K. Sorbent coated cryosurfaces are ideal and provide high pumping speed as well as are capable of handling of high throughput of gases to be pumped. Activated carbon with its large surface area has extraordinary adsorptive capabilities through physisorption, therefore shows high degassing when evacuated or heated for reactivation and regeneration.

To understand the amount of gases that desorbs from a sample of sorbent desorption characteristics are required to be studied. A DeGassing Measurement System (DGMS) was set up to carry out desorption studies. The DGMS facility works under vacuum environment with additional feature of heating to higher temperatures which improve adsorption capacity of the sorbent. DGMS provides accurate and sensitive measurements of weight change, with one microgram sensitivity, for a various samples (activated carbon granules of different mesh size, activated carbon spheres, activated carbon pellets & fabric i.e. non woven and flat knitted) exposed to controlled environmental conditions over an extended period of time. Degassing measurements were carried out with respect to weight measurement in vacuum followed by the baking the sample upto 150^0C and comparative studies done. This paper reports degassing measurement results obtained for various samples studied.

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NF-251

Indigenous Development of Single Barrel Hydrogen Pellet Injector System

Samiran Mukherjee, Paresh Panchal, Pratik Nayak, Pramit Dutta, Naveen Rastogi, Alaap Jagdale, Haresh Patel, Ranjana Gangradey, Ravi Prakash N.

Institute for Plasma Research, Gandhinagar,Gujarat-382428

E-mail: samiran@ipr.res.in

Abstract

High speed hydrogen pellet injection technique is and efficient fuelling method to replenish the fuel in a fusion machine. It deposits fuel at the core of plasmas and hence results in obtaining peaked density profiles. To cater the need an indigenous single barrel pipe gas gun type hydrogen pellet injector system has been developed at Institute for plasma Research, India. Single-barrel Pellet INjector System (SPINS) is a compact system using pneumatic method with high pressure propellant for injection of frozen hydrogen pellets as fuel into plasma confined by magnetic field in Tokamak. Hydrogen pellet is formed inside a barrel by "In Situ" technique. A GM based cryocooler with cooling capacity 1.5W at 4.2K has been used to freeze the hydrogen down to 7K inside a high vacuum environment. Pellets are dislodged and accelerated with high pressure helium gas injection through fast opening solenoid valve. The light barriers with photodiodes provide signals for pellet speed determination. The injector is able to form a ~3-4 mm in Dia.(Max.) and 4 mm in length cylindrical solid hydrogen pellet at 7–8 K temperature and the measured velocity of pellet has been measured up to 600 m/sec. This paper describes the pellet injector system SPINS and the experimental results.

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NF-271

Design, Development And Characterization Of Interlock System For 42 GHz ECRH System On Aditya And SST-1 Tokamak

Rajan Babu.N, B K Shukla, Harshida R. Patel,Jatin Patel, Pragnesh B. Dhorajiya and ECRH Division

Institute for Plasma Research, Gandhinagar, Gujarat – 382428

E-mail: rajan@ipr.res.in

Abstract

The 42GHz gyrotron is used in ECRH system for the tokamaks SST-1 and Aditya. The gyrotron delivers 500 kW of power at –50kV beam voltage and 20A beam current. The pulse duration is 500ms.The gyrotron has been tested on dummy load for its full parameters. The HV operation of the gyrotron involves with a dedicated interlocking system. When a fault occurs in gyrotron, the maximum allowable fault energy is an important parameter and the energy should not increase more than 10J.

The sensing of the faults is important for the reliable protection of the tube. The reliable sensing is through the arc detector that senses arc and operates the protection system. The arc detectors are installed at various locations in the system like Matching optical unit, Bends and in Windows.

Though the arc detectors are efficient sensor to detect the fault, they do not sense a fault inside the gyrotrons. So the interlocking systems are assisted with other fault sensing elements like beam over current sensor, Anode over current, beam current, dI/dt sensor. The sensors should be carefully selected and conditioned for the reliable operation. The conditioning system and the tripping levels should be selected in such a way that it should avoid nuisance tripping without jeopardizing the protection of the tube. The beam over current, anode current, and dI/dt sensors are characterized with suitable electronics and a simulation is carried to characterize the protection system in real time field situation. A suitable filter is designed and characterized with beam current interlock. The anode current and dI/dt are also characterized

The paper explains the characterization and implementation of the interlock systems for the safe and reliable operation of gyrotron.

NF-272

Optimization Study Of ITER-VVPSS Tank

Gaurav Jogi, Girish Gupta, Vipul More, Avik Bhattacharya, Jagrut Bhavsar, Mukesh Jindal, Vaibhav Joshi, Mitul Patel, Rajnikant Prajapati, Amit Palaliya, Saroj Jha, Manish Pandey and Anil Bhardwaj

ITER-India, Institute for Plasma Research, Gandhinagar, 382428

E-mail: gaurav.jogi@iter-india.org

Abstract

The ITER Vacuum Vessel Pressure Suppression System (VVPSS) is part of ITER machine, which is

used to protect the ITER Vacuum Vessel from an over-pressure situation in the Vaccum Vessel due to any incident/accident resulting in rise in pressure. During accident condition, there may be event of pressure rise in the vaccum vessel due to steam formation in event of breakage of pipes. The steam will rise through the relief line which connects VV & VVPSS Tank. VVPSS tank consists of a partially evacuated suppression tank that contains a sufficient amount of water at room temperature to condense the steam entering the tank. It also helps maintaining a sub atmospheric condition in a Loss of Vacuum event.

VVPSS Tank was available at conceptual stage of design. Design parameters for internal & external parameters were used & optimization of the tank was performed using design code ASME & stress analysis. CATIA was used to create a surface model of the VVPSS Tank & ANSYS Workbench was used in the stress analysis. Structural assessment of the VVPSS Tank was performed as per ASME Code 2010 Section VII Div. 2 Part 5 Design by Analysis. VVPSS Tank was assessed against failure due to Plastic Collapse, Local Failure, Ratcheting and Buckling. The optimization has been performed for various thickness of shell and it is optimized for 20mm thickness which meets all the design criteria.

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NF-273

Engineering Validations Of SST-1 Magnet system

A.N. Sharma, K. Doshi, U. Prasad, Y. Khristi, P. Varmora, M. Banaudha, B. Parghi and S. Pradhan

Institute for Plasma Research, Gandhinagar 382 428

Email : ansharma@ipr.res.in

Abstract

SST-1 magnet system is one of the most critical sub-system of SST-1 machine shell. Under the mandate of SST-1 mission, entire magnet system has been refurbished and successfully integrated and validated during different plasma operation campaigns. The major activities during refurbishment has been cold test of all TF magnets, repair and refurbishment of PF coils, fabrication and installation of a new resistive central solenoid, fabrication and installation of new radial control coil. The entire magnet system is equipped with state of the art and prequalified sensors and diagnostics to monitor the status and to protect the magnet system in off normal scenarios.

During the different plasma operation campaigns, the TF magnet system is successfully qualified up to 1.5 T operation, for more than 2000 s with two phase cooling. The magnet system was perfectly cryostable during these experimental campaigns. Various sensors and diagnostics have shown expected behavior during these experiments. This paper will elaborate the important refurbishment activities, important quality control aspects followed during the magnet integration. The performance of various sensors and diagnostics like temperature sensors, flow meters, strain gages, displacement

transducers, quench detection and data acquisition system during the initial engineering validations and different plasma experimental campaigns.

NF-274

Design Optimization Of The Transporter Frame For The Cryostat Lower Cylinder

Avik Bhattacharya, Girish Gupta, Jagrut Bhavsar, Mukesh Jindal, Gaurav Jogi, Vipul More, and Anil Bhardwaj

ITER-India, Institute for Plasma Research, A/29 GIDC Electronic Estate, Gandhinagar

E-mail : avik.bhattacharya@iter-india.org

Abstract

Cryostat is a part of the ITER machine. It is a large stainless steel structure surrounding the vacuum vessel & the superconducting magnets, providing a vacuum environment. Cryostat is a cylindrical vessel having a diameter of ~29 m and height of ~30m. The Cryostat being a very large component will be manufactured in four sections- The base section, lower cylinder, Upper cylinder & the Top lid. Each of the four sections will be manufactured in three stages. The first stage is the Factory fabrication stage in which each section will be manufactured in segments of size 9m x 9m x 18m (approx.). This stage will be carried out in India. From India the segments will be transported to ITER Cryostat Temporary workshop site at Cadarache in large containers. The second stage is the assembly of segments at Temporary workshop in which each section will be assembled separately, from its segments. The third stage is the Tokamak pit assembly. In this, all the four sections will be assembled to each other to form the complete Cryostat.

The assembly of the segments of the Cryostat four main sections will be carried out in the temporary workshop on fabrication frame. This whole assembly of the Cryostat section and its fabrication frame will be resting on the transporter frame. Once the assembly is complete the sections have to be taken to the cleaning area of the Tokamak pit with the help of transporter frame. The transporter frame will be further mounted on rollers for transportation.

The design, optimization and analysis of the transporter frame of the lower cylinder has been done to uniformly distribute the load of the Cryostat sections by proper placement of rollers, optimize the number of rollers and keep the reactions forces acting on each roller below 50 tons. The modelling has been done in CATIA V5 R19 and the Analysis has been carried out using ANSYS 13.0. The structure has been optimized within the allowable stress limits.

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NF-276

Design Of An Extractor For Hydrogen Isotopes In Liquid Lead Lithium

Rudreksh B. Patel, Sudhir Rai and Amit Sircar

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail : rbpatel@ipr.res.in

Abstract

Tritium Extraction is one of the most important tasks of Lead Lithium cooled Ceramic Breeder (LLCB) blanket fuel cycle. Indian LLCB blanket concept has two types of tritium breeder, viz., solid Ceramic Breeder (CB) and liquid PbLi eutectic alloy. Tritium extraction from liquid PbLi is more complicated than that from CB. To extract hydrogen isotopes dissolved in liquid PbLi, various methods have been utilized. It has been reported that packed bed column for extracting hydrogen isotopes from liquid PbLi is more efficient compared to others, viz. plate, spray and bubble columns. Therefore, packed bed column is considered for hydrogen isotopes extraction in our work.

We have designed a packed bed column made up of Sulzer structured packing. Liquid PbLi and He purge gas are flown in counter flow manner for stripping hydrogen isotopes from PbLi. The process calculations have been done to find out the height and diameter of packing for extractor. Design is based on the assumption of *90%* extraction efficiency. The effect of process parameters such as flow rates of gas and liquid has been obtained between temperature ranges *623 K* and *773 K*. Estimated results show that increase in the gas (He) flow rate decreases the required packing height. However, increase in liquid PbLi flow rate increases required packing height. Height of packing is found to be increasing with increase in operating temperature. These estimated process parameters are used to design the experimental setup for hydrogen isotope extractor for PbLi.

NF-282

Overview Of Instrumentation And Control Of ITER-Cryostat

Dileep Shukla, Mukesh Jindal, Girish Gupta, Anil Kumar Bhardwaj

ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, 382428

E-mail: dileep.shukla@iter-india.org

Abstract

The Cryostat is a cylindrical vacuum vessel of ~28 meter diameter and 30 meter height and 50 mm thickness. The Cryostat instrumentation is required to monitor variables such as temperature, strain, acceleration and displacement to insure mechanical structural integrity of cryostat. The instrumentation system design includes the design of transducers and their supports, selection of cables, design and selection of feedthroughs, as well as the development of adequate signal monitoring techniques.

Cryostat pedestal ring is Safety Important Component. As main components like Vacuum vessel and magnet system rests on the pedestal ring. There will be considerable temperature difference between inside and outside environment of pedestal ring. To avoid the ice formation, a heating system shall be used to control the temperature of the Cryostat pedestal ring.
Strain measurement will be used for monitoring structural integrity of cryostat during operational modes of ITER. Accelerometer will be used for off-normal effect on the cryostat. Cryostat shall be monitored for motion through the use of displacement Transducers.
The Cryostat instrumentation and Control System will contribute to Machine operation, investment

protection, Spill Localization, Maintenance.

NF-292

Commissioning Of -70KV Solid State Crowbar System

YSS Srinivas, N Rajan Babu, KM Parmar, Bhavesh Kadia, Chetan Virani, Pragnesh Dhorajiya, Jigalraj Vansia, Shefali Dalakoti, Doshi Ravikumar, Brahmbhatt Tushar, Patil Gajendra, Anil Vishwakarma and SV Kulkarni

Institute for Plasma Research, Gandhinagar-382428

E-mail : srinivas@ipr.res.in

Abstract

Our institute (IPR) is involved in the development of High Power RF and Microwave sources for various fusion related heating and current drive applications. All the high power RF and microwave tubes e.g. Klystron, Gyrotron, Tetrode etc need a high voltage DC power supply with necessary arc fault protection in addition to other protections.

To cater to the initial testing and commissioning requirements of various tubes, the development of 70kV, 22A Testing Power Supply (TPS) is initiated. The supply ratings are chosen to meet general tube requirements i.e. Klystron, Gyrotron and Tetrode used in RF group. All protections including crowbar protection are accommodated separately for each of the systems.

To enable continuous full power testing of 500kW Klystrons, a -70kV Solid State Crowbar is procured. This report presents power supply ratings, requirements of crowbar protection, specifications of Solid State Crowbar system, testing and commissioning details of solid state crowbar system with TPS.

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NF-293

Simulation Of Scenarios Of LHCD Antenna For Pre-ionization In SST1 Machine

P. K. Sharma, K. K. Ambulkar, S. Dalakoti, C. G. Virani, P. R. Parmar, A. L. Thakur

Institute for Plasma Research, Gandhinagar-382428, Gujarat

E-mail : pramod@ipr.res.in

Abstract

SST1 machine has a continuous vacuum vessel, which inhibits the penetration of Ohmic electric field in to the vessel thereby reducing the peak loop voltage in the machine required for Ohmic breakdown. Alternatively, electron cyclotron resonance (ECR) preionization technique [1] is used

for preionization, to assist plasma start-up with lower available loop voltages. In early eighties, lower hybrid current drive (LHCD) system, was also used in PLT machine, for preionization and start-up purpose [2]. The PLT LHCD system was based on 800MHz source and could have provided electric field across large distances because of longer wavelength, thereby assisting gas breakdown. In SST1 machine, the LHCD system is based on 3.7 GHz klystron sources [3] and may not produce favourable conditions for gas breakdown owing to its shorter wavelength.

In this paper, we have proposed a novel way to excite LHCD antenna so that electric field variation is created over large spatial distances, conducive for gas breakdown studies. In this scenario, all the elements of the grill antenna are not energized. Out of 32 elements of the grill antenna, only 16 elements are energized. In this special configuration, a periodic arrangement of four adjacent active elements is realized, leaving another set of four elements, adjacent to it, without any power. The CST microwave studio, commercially available software, is used to simulate the above scenario to study the behaviour of electric field produced in this configuration.

In this paper we present the modelling aspect of the antenna and the results obtained from the simulation analysis is discussed in details for proposing and planning of preionization experiments on SST1 machine.

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NF-303

Scattering Matrix And Parasitic Mode Analyses For 170 GHZ, 1 MW Gyrotron Beam Tunnel

Nitin Kumar, Udaybir Singh, Mukesh Kr. Alaria and AK Sinha

Gyrotron Laboratory, MWT Area
CSIR-Central Electronics Engineering Research Institute, Pilani- 333 031

E-mail : nitingkv@gmail.com

Abstract

170 GHz is decided Electron Cyclotron Resonance Heating (ECRH) frequency in ITER experiment. At present in microwave/millimeter wave devices family, only the gyrotron has capability to deliver 1 MW or more RF power in CW mode at 170 GHz frequency. Total 24 gyrotrons (1 MW RF power from each device) will be installed at ITER facility for the plasma heating [1,2]. Considering the importance of 170 GHz gyrotorn, an activity for design and development of this device is started at CEERI, Pilani with the financial help of CSIR. At present the electrical and thermal design of 170 GHz gyrotron is under progress. In the design of high frequency and high power gyrotrons, the instability in Helical Electron Beam (HEB) is a major issue, especially in the region between MIG and interaction cavity [3,4]. Due to the instability of HEB, some kinds of parasitic oscillations can emerge in the region between MIG and cavity (called beam tunnel). These kinds of unwanted parasitic oscillations are very harmful for the smooth functioning of the device and even can damage

MIG cathode. To suppress these kinds of modes and to avoid the backward propagation of RF from cavity to MIG, highly lossy ceramics are installed in the region of beam tunnel. These lossy ceramic rings are supported by copper rings. The design of copper rings and ceramic rings are carried out very carefully to avoid any kind of parasitic oscillations. The S matrix analysis is used to analyze the RF absorption by beam tunnel. The parasitic mode oscillations in beam tunnel are analyzed by calculating Q factor, symmetric modes, surface current at copper rings, etc.

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NF-304

Control And Monitoring Of High Power Rf Dummy Load

Harsha Machchhar, R.G. Trivedi, and Aparajita Mukherjee

ITER-India, Institute for Plasma Research, Bhat, Gandhinagar – 382428

E-mail: harsha@iter-india.org

Abstract

In Ion Cyclotron Resonance Heating and Current Drive (ICH & CD) system, high power (~MW level) dummy load is required to test the performance of RF amplifiers. Typically, resistive film type non-inductive dummy load, are used up to 300kW, due to the limitation on the power density of the film resistor. Therefore, for high power dummy load (MW level), soda water based dummy load are used, where the soda water plays a role in both RF power absorbing medium and the cooling water. In principle, there is no power density limit for such kind of dummy load, if it operates below the boiling point of soda water.

ITER-India, IPR, is developing high power 50 Ohm RF dummy load in MHz frequency range indigenously. Control and monitoring part is very important for the RF dummy load. All parameters, like pressure, water flow, inlet and outlet temperature of soda water and cooling parameters related to heat exchanger are monitored and stored. From these measurements, dissipated power in the dummy load is calculated.

This paper will describe software and hardware part of control and monitoring system for high power RF dummy load.

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NF-305

Conceptual Design Of I-Q Demodulator Technique For ICH & CD Source

Dipal Soni, Kumar Rajnish, Manoj A Patel, Sriprakash Verma, RG Trivedi, Raghuraj Singh and Aparajita Mukherjee

ITER-INDIA, Institute for Plasma Research, Bhat, Gandhinagar- 382 428

E-mail: dsoni@iter-india.org

Abstract

Ion Cyclotron Heating and Current Drive (ICH&CD) system is one of the important auxiliary heating and current drive system for ITER experiment [1]. ITER-India has to supply ICRF sources as in-kind contribution from India as an ITER partner. ITER requirement is to have 8+1 independent RF sources having 35-65MHz, with 2.5 MW output power at VSWR 2.0. RF parameters i.e. amplitude, phase and frequency of each RF source will be monitored and controlled with Data Acquisition module of Local Control Unit (LCU) [2,3].

Two chains of 3 stage cascaded power amplifier (pre-driver, driver and end stage), having power handling capacity of 1.5MW, is combined to get 2.5MW output power. At the output of each stage of amplifier and at the output of combiner, amplitude with 5% accuracy and phase with ±1° accuracy need to be measured. The measured value is used for monitoring the system performance as well as for feedback control loop. I-Q demodulator module is used to measure the amplitude and phase of RF signal. In this paper we shall discuss the test result of I-Q demodulator with synthesized signal in laboratory condition.

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NF-311

Cooldown Characteristics Of LN2 Transfer Lines And Chevron Shielding For NBI Cryo-Condensation Pumps

B.Pandya, A.K.Sahu, L.K.Bansal, B. Choksi, N.Contractor, S.L.Parmar, S.K.Sharma L.N.Gupta, P.Bharathi, V.B.Vadher, D.Thakkar, C.B.Sumod, K. Qureishi, V.Prahlad, P.J.Patel and U.K.Baruah

Institute for Plasma Research, Gandhinagar-382428

Email: bpandya@ipr.res.in

Abstract

Cryo-condensation pump is an important component of the Neutral Beam Injection system. They were developed for long duration pumping (~4000sec) having pumping speed of $2x10^5$l/sec of hydrogen for the SST-1 Neutral Beam Injection (NBI) system. Such pumps need to be cooled 4K to

maintain vacuum of ~10^{-5} Torr inside the vacuum chamber to handle the large gas load of 50-100 Torr·l/s. Recently two such cryopumps have been installed inside NBI vacuum vessel. Cryogenic lines for the supply and return of helium and nitrogen have been laid within vacuum vessel. The cryoplant is electrically isolated from the vessel potential by introducing a potential breaks made of FRP-G10 and metal (SS304L) junction to save the electronic appliance form the voltage lift. An operation was performed primarily to understand the cooldown characteristics of the LN_2 transfer line and chevron shielding for cryo-condensation pumps. It was performed in a controlled manner to establish desired flow rates for the simultaneous cooling of the two pumps and avoid thermal shocks. This paper describes the layout of cryogenic transfer lines and location of the cryo-condensation pumps, operational procedure and cool down of the cryogenic transfer lines and chevron shielding for the helium panel.

NF-314

Vacuum And Cryogenic Performance Study Of A Cryostat Used For Testing Different Cryopanels

Pratikkumar Nayak, Paresh Panchal, Samiran Mukharjee, Manoah Stephen M, Jyoti Agrawal, Ranjana Gangradey

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

Abstract

A fusion grade cryopump consist of a several components that include different type of panels coated with sorbents, adhesives and black coatings. A test-cryostat (TCS) is developed to carry out experimental studies for all cryopump components at cryogenic temperature. TCS is a cylindrical chamber (750 mm dia. and 1515 mm Length) having several test ports, and three Hydro-formed cryo panels, that are supported with non conducting support inside a chamber. All three Cryo panels are cooled down at liquid nitrogen (LN2) temperature and, it provides radiation shielding to the Liquid helium (LHe) cooled components which will be tested in TCS. The TCS was evacuated and tested for leaks with several methods, to get desired vacuum level of ~1.0E-5 mbar with turbo molecular pump (TMP).The pump down curve is compared with the results of Vacuum code. Radiation shields with a total mass of ~90 Kg are cool down with Liquid nitrogen. The minimum achieved temperature is 80 Kelvin and vacuum level in TCS is 6.38E-8 mbar. Temperature uniformity on the radiation shield is improved by changing a flow pattern. Thermal conduction through the radiation shield support is also reduced by reducing contact area. Leak test of TCS is repeated after each thermal cycle of the radiation shield. All modifications based on these studies have improved the TCS performance and thus it can be employed for testing of components.

NF-315

Design And Analysis Of Cryostat PHTS Circular Bellows

Manish Kumar Pandey, Girish Gupta, Avik Bhattacharya, Gaurav Jogi, Vipul More, Saroj Kumar Jha and Anil Bhardwaj

ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, 382428

Email: manish.pandey@iter-india.org

Abstract

ITER Cryostat envelops the entire basic systems of the ITER Tokamak machine and is a vacuum tight container. Cryostat has been designed to transfer all the loads like gravity, seismic etc. that derive from the Tokamak basic machine, and from the cryostat itself, to the floor of the Tokamak. PHTS circular bellows are used to accommodate the displacement of the systems due to various operating conditions.

Present work deals with the design and analysis of circular unreinforced bellows for cryostat Primary heat transfer system. The designing and analysis has been done for circular bellows for all load categories in which the primary heat transfer system is expected to work. The theoretical design has been done on the basis of EJMA standards. The result of EJMA calculation has been verified by using ANSYS WORKBENCH 13.0 (for linear and nonlinear structural analysis) software and for modeling CATIA V5 R21 has been used. Nonlinear structural analysis is performed on ANSYS software to get the true value of stress and to verify the fatigue life cycle of bellows, which is calculated as per the EJMA standards

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NF-320

Thermal Stress Analysis Of The Cryo-Adsorption Cryopump

ManoahStephen M[1], Ranjana Gangradey[1], Ravi Prakash[1], Nikunj Kachhadia[2]

[1]*Institute for Plasma Research, Gandhinagar, Gujarat-382428*
[2]*Altair Engineering India Pvt. Ltd., Bangalore, Karnataka- 560103*

Email: manoah@ipr.res.in

Abstract

The Cryo-Adsorption Cryopump (CAC) is a part of the vacuum system for tokamaks. The prime function of the CAC is to produce ultra - high vacuum in a fusion machine. The CAC design should withstand thermal cycling from 4K to room temperature and carrying high pressure cryogens (like liquid helium at 4 bar and helium gas at 80 K) with a stringent leak tightness of the components of the order $1x10^{-9}$ mbar lit/sec and increase the efficiency of the system as a whole. This paper summarizes the design by analysis methodology using finite element analysis method in ANSYS to optimize the CAC for thermal and structural loads. The analysis of the CAC is divided into two independent analyses – a static thermal analysis giving the stationary temperature distribution and then these temperature fields will be transferred on the corresponding structural models for the purposes of the thermal stress analysis. The purpose of this work is to check the structural integrity of the CAC by the thermal stress analysis results which will give the level of stresses in the CAC structures and the deformation effects.

NF-322

Application Of Multi Layer Insulation (MLI) On SST-1 Cryogenic Surfaces

N. Bairagi, H. Nimavat, R. Sharma, V. L. Tanna and S. Pradhan

Institute for Plasma Research, Bhat, Gandhinagar, 382428

E-mail: nbairagi@ipr.res.in

Abstract

Multilayer insulation (MLI) is widely used as cryogenic thermal insulation technique in high vacuum environments for minimization of radiation heat load to cryogenic systems. MLI is more popular on non current carrying cryogenic components whereas especially for current carrying parts, one needs to be cautious to ensure the electrical isolation of MLI with the sensors wires /leads at 4.2 K and 80 K. The cold surfaces (around 26 m^2 of surface area) of SST-1 cryogenic surfaces which include 3S-3R liquid helium transfer lines, 5S-5R liquid nitrogen supply-return transfer lines, current leads, liquid helium header and interconnecting cryogenic helium hydraulics etc. Some of these surfaces are complex shaped and have difficult accessibility, which necessitates extra precautions during installation process.

While applying MLI on current carrying cold surfaces like current leads (20 Nos.), parts of superconducting TF and PF bus-bar joints inside the joint box, electrical insulation between the layers and the cold surface have been ensured. During MLI wrapping, one has to be very careful on these critical parts so as to ensure thermal isolation between cold and warm layers. A detailed description of various heat transfer modes through MLI and effect of various parameters especially residual gas pressure, outgassing rate, optimum number of layers required on the cold surfaces is presented along with the details of standard cryogenic protocols followed for MLI. It has been experimentally demonstrated on SST-1 that we can get at least 1 K better temperature resolution on the temperature sensors while applying MLI. Additionally, it provides at least 40 - 50% reduction in radiation heat load compared to without MLI depending upon the shape and installation conditions.

NF-323

Neutronic Analysis Of X-Ray Survey Spectrometer For ITER Using Attila

P.V.Subhash[1], Russell Feder[2], Sajal Thomas[1], Sapna Misrha[1] and Deepak[3]

[1] *ITER-India, Institute for Plasma Research, Gandhinagar, Gujarat, 382428*
[2] *Princeton Plasma Physics Laboratory, Princeton, NJ 08543, USA*
[3] *Institute for Plasma Research, Gandhinagar, Gujarat, 382428*

E-mail: subhashpv@iter-india.org

Abstract

In order to ensure proper design and operation of ITER tokomak extensive neutronics analysis is warranted. Many of the ITER related calculations are carried out by Monte Carlo codes like MCNP. Along with MCNP, FEM 3D discrete ordinates codes like Attila are also being used for this purpose. at ITER-India, Indian domestic agency of ITER. An approximate neutronics analysis for XRCS system at (EPP#11) is carried out in order to understand the validity of such calculations for ITER related neutronics analysis. This is evoked due to the large memory and CPU requirements of Attila

for more accurate calculations. Further calculations with 46 energy groups are also performed for accurate flux calculations in the port interspace and around XRCS detector s and crystals. Both the accurate and approximate calculations are performed with a geometry that corresponds to ITER "b-lite model". The results show a clear agreement of the present calculations with other available results using both MCNP and Attila. The Attila calculations with 46 energy groups are subjected to many standard tests. The flux levels are in a good agreement with the results published. Further calculations like neutron wall loading are also performed for completeness. Finally we have compared Attila results with the results from our previous MCNP calculations in the EPP region.. Attila flux shows a general agreement with MCNP results up to a distance of 2m from first wall. The Attila fluxes are much higher than that of MCNP from the radial points after 2 m. The work is underway to understand these deviations.

NF-324

Design And Development Of Prototype Of FPGA Based 8 Channel Fiber Optics Serial Data Link For Digital Signals

Jignesh Soni[a], R. Patel[c], T. Vasoya[c], R.K. Yadav[b], H.Tyagi[b], H. Mistry[a], A. Gahlaut[a], K. G. Parmar[a], G. Bansal[a], K. Panday[a], M Bandyopadhyay[b] and A. Chakraborty[a]

[a]*Institute for Plasma Research, Bhat, Gandhinagar, 382 428*
[b]*ITER- India, Institute for Plasma Research, Gandhinagar, 382 025*
[c]*L.D.R.P. Institute Of Technology & Research, Gandhinagar, 382 015*

E-mail: jsoni@ipr.res.in

Abstract

For addressing the R& D activities in area of Negative Neutral Beam Injector, in IPR, Negative Neutral Beam development program has been started. As a part of the program, three test -bed viz [1] ROBIN – development under IPR-IPP (Germany) license agreement, [2] Twin Source (TS) and [3] Indian Test Facility (IN-TF) has been planned. Out of the three, the ROBIN- a signal RF driver based 100 KW, 1 MHz negative ion source test-bed is already commissioned and in operational stage. Subsequently, a development of Twin Source-two RF drivers based 180 kW; 1 MHz negative ion source experimental setup and IN-TF - eight RF drivers based Indian test facility is going on.

The Ion source and related sub-systems (viz. HV power supplies, Cs system, diagnostics systems etc) of all the three test-bed will be floated at high potential (more than 50KV DC) during the beam operation phase; therefore, for interfacing of analog and digital signals of the ion source and HV referenced sub-systems to the Data Acquisition and Control System (DACS), mainly two types of fiber optics (FO) links would be required, depending upon the signal type i.e analog and digital. For catering these requirements, two types of FO links have already been developed in-house, installed and tested in the ROBIN test-bed. These FO links have single channel or multi-channel parallel design because of which there is a large number of interfacing channels from sub-systems to DACS, and for each channel, separate fiber cable, transmitter (Tx) and receiver (Rx) circuits are required. These increase the complexity and cost. Further the analog signal FO link has limitation of accuracy i.e 0.5 % only. To overcome this limitation and to reduce the complexity and cost, new in-house development of FO links, based on digital communication technique and advanced FPGA technology has been started. As a part of the development, a prototype of FPGA based 8 channel FO serial data link for digital signals, has been design and successfully tested. Specialty of the link is that it can transmit 8 nos. TTL signals, having a bandwidth DC- 20 KHz, over 300 meter distance via single fiber cable.

The paper describes in detail about the design, implementation and test result of the FO link.

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NF-325

Design, Development And Integration Of Signal Conditioning Electronics For Probe Diagnostics In ROBIN

Himanshu Tyagi[1], J.Soni, R.K. Yadav[1], G. Bansal, K. Pandya, A. Gahlaut, H. Mistry, K.Vora, K.G. Parmar, B. Prajapati, V. Mahesh, M. Bandyopadhyay[1] and A. Chakraborty

Institute for Plasma Research, Bhat, Gandhinagar
[1]ITER-India, Institute for Plasma Research, Bhat, Gandhinagar

E-mail: himanshu.tyagi@iter-india.org

Abstract

ROBIN[1] is a single driver RF (1MHz, 100kW) based negative ion source experimental facility at IPR. Currently both the plasma and beam operations are carried out in ROBIN.

Electrostatic probe diagnostics form an important part of the ROBIN diagnostic system which are installed in the source and provide data related to source plasma to monitor its performance. Also the electronics must be able to source current of the range of 150 mAmp. Probes are biased by a ramp based electronics whose output varies from -80 to +40 volts at a frequency of 10Hz. This enables the probe to collect both the ions and electrons thereby providing information on plasma density and temperature.

The electronics for the diagnostics is located close to the ion source; as a result it needs to handle a large amount of RF noise in the range of ~150V/m. Also the electronics must perform floating measurements of current and voltage .The developed electronics must be able to provide data to central acquisition system[2] of ROBIN for online monitoring.

The plasma acts as a load to the amplifier output. When the plasma is generated in ion source depending on the voltage output direction a current flows in the circuit. Both the current and voltage are transmitted optically to central signal conditioning racks of ROBIN control system from a resistance based sensing unit based within the electronics system. The bandwidth of entire system is 1 KHz which is limited by the transmitter modules used in the circuit. These acts as a low pass filter thereby removing any unwanted noise pickups in the periphery. At the acquisition side NI pxi cards are used to sample the data at a sampling rate of 5 Ksps. The high sampling rate enables to view the accurate VI characteristics of the probe.

In this paper the setup of front end electronics used to bias the probes and provide data to the central acquisition system of ROBIN is described. Noise removing capacitors are placed at certain places to avoid noise transients. Also the protection techniques for the amplifier circuit used are described. The shielding and grounding schemes of the circuit are also described. The use of RF compensating

chokes in the electronics is also shown. Results obtained at Data acquisition side are also described.

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NF-326

CFD Analysis Of The Cryo-Adsorption Cryopump

Samiran Mukherjee[1*], Ranjana Gangradey[1], Ravi Prakash[1], Priyank Patel[2]

[1]*Institute for Plasma Research, Gandhinagar, Gujarat-382428*
[2]*Altair Engineering India Pvt. Ltd., Bangalore, Karnataka- 560103*

Email: samiran@ipr.res.in

Abstract

The Cryo-Adsorption Cryopump (CAC) is a part of the vacuum system for TOKAMAKs. The prime function of the CAC is to produce ultra - high vacuum in a fusion machine. The CAC should be able to take load of upcoming gases from TOKAMAK and should provide efficient pumping of hydrogen isotopes and helium. For this purpose there will be 20 numbers of 4K stainless steel hydro-formed panels which will be cooled using liquid helium at 4 K and 4 bar as inlet conditions. To protect these 4K panels from outer radiations coming from room temperature environment, there will be 80 K systems consisting 15 conical baffles, annular and cylindrical shields, which will be cooled using gaseous helium at 80K at 15 bar. All these components will be hydro-formed and needs to optimize flow path for better cooling efficiency. For designing a flow path for these panels, baffles and radiations shields, fluid dynamics of cooling fluid needs to be performed which can decide upon required mass flow rate of fluid and give an optimum flow patterns for uniform temperature distribution and desirable pressure drop. This paper summarizes the design by analysis methodology using finite element analysis method in ANSYS to optimize flow pattern of hydro-formed components of CAC for a given geometric configuration. Here Computational Fluid Dynamics (CFD) analysis is carried out for number of flow patterns for different components of CAC modeled as hydro-formed with bubbled shape as actual to decide upon optimum flow path for components based on uniform temperature distribution on larger surface area which is coming more than 90% for each of the components and taking into account the pressure drop which is limited to 200 mbar for liquid helium at 4K and 500 mbar for gaseous helium at 80K at given mass flow rates for 4K liquid helium and 80K gaseous helium.

NF-327

High Voltage Direct Current Water Load Bank

Rohit Agarwal, Aparajita Mukherjee, Gajendra Suthar, Kartik Mohan, P Ajesh, Raghuraj Singh, R.G. Trivedi
ITER-India, Institute for Plasma Research, Bhat, Gandhinagar – 382428
E-mail: rohit.agarwal@iter-india.org

Abstract

Ion Cyclotron Resonance Heating and Current Drive (ICH & CD) system uses High Voltage DC Power Supply to bias the RF amplifier tube. ITER-India, IPR, is developing indigenous high voltage

power supplies with different design philosophies like IGBT based, thyristor based, and resonance based. High power load bank is required to test these power supplies.

Typically, wire wound non-inductive resistors are used as a load, but they have limitations of power rating and effective resistance. To get required resistance and power rating, a large number of resistors have to be used in series & parallel combinations. This scheme has limitations of overheating of resistors within few minutes and high cost of wire wound resistors.

Therefore a water based load bank is designed and used, where the water plays the role of a non-inductive, kilo Ohm scale resistor and absorbs the power. DMDI water is used because of its very less conductivity. This system gives the flexibility of achieving any resistance from few hundred Ohms to few tens of kilo Ohms by changing the conductivity of DMDI water. System is designed and tested up to power level of 20-25 kW.

This paper will describe the design and the results for high voltage direct current water load bank.

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[2] http://en.wikipedia.org/wiki/Electrolysis_of_water

NF-328

Integration And Remote Operation Of 10kV,400mA High Voltage Power Supply With ROBIN DACS

R.K.Yadav[1], J. Soni, A. Gahlaut, V.Mahesh, K G Parmar , H.Tyagi[1],H.Mistry , B.Prajapati, G. Bansal, K. Pandya, M. Bandyopadhyay[1] and A. Chakraborty

[1]ITER-India, Institute for Plasma Research, Gandhinagar (Gujarat) 380 025
Institute for Plasma Research, Bhat, Gandhinagar 382 428

E-mail: rkyadav@iter-india.org

Abstract

The first RF based –ve ion source experiment test bed ROBIN [1] has been set up at Institute for Plasma Research (IPR), A 1 MHz RF generator launches 100 kW RF power into a single driver on the plasma source to produce a hydrogen plasma of density ~5 x 10^{12} cm^{-3}. Presently, the extraction phase has been initiated in ROBIN which is being operated without Cs using a 10 kV, 400 mA power supply and a negative ion beam of >9 mA/cm^2 has been extracted .

For integration and remote operation of 10kV, 400mA high voltage power supply with ROBIN the DACS requires signal conditioning hardware, integration scheme, breakdown (counter and controller) software & hardware, control GUI with the required interlocks, monitoring voltage and current signal through upgraded DAQ software & hardware, report generation module and video monitoring system.

In-house developed signal conditioning module (i.e Fiber Optic link) have been used for interconnection with PLC and PXI systems. This signal conditioning modules have been used for electrical isolation and noise immunity. The star based exist grounding scheme of Robin has been used for remote operation because this power supply is in RF environment. The control software for

breakdown (counter and controller) has been developed in step7 and Control GUI has been developed in WinCC SCADA .The breakdown(counter and control) is specific requirement of 10kV,400mA to switch off the power supply after reaching the nos. of arc pulse equal to set value. For online monitoring and acquisition of voltage and current signal DAQ software has been upgraded (i.e scaling, configuration, GUI and new report format) in ROBIN DACS [2]. The integration of 10 kV, 400mA power supply has completed with Robin DACS. The successful remote operation has performed with Robin.

The paper will describe details of integration scheme, up gradation of control and data acquisition software, development of control GUI and report format in Robin DACS for 10kV, 400mA high voltage power supply.

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NF-330

Stepper Motor Based Remote Tuning System For 100KW, 1MHz RF Matching Network Of ROBIN

Agrajit Gahlaut[1], Deepak Parmar[2], K G Parmar[1], Bhavesh Prajapati[1], Mahesh V[1], Gourab Bansal[1], Jignesh Soni[1] and Arun K Chakraborty[1]

[1]*Institute for Plasma Research, Bhat, Gandhinagar, 382 428*
[2]*ITER- India, Institute for Plasma Research, Gandhinagar, 382 025*
E-mail : agrajit@ipr.res.in

Abstract

The ROBIN [1] facility at IPR utilizes a 100 KW, 1 MHz RF Generator for generating plasma. The RF power is coupled to the ion source via a capacitor based RF matching network, made up of a combination of fixed & vacuum variable capacitors (VVC) and a 100kVA, 100kV isolated, ferrite based RF transformer. For achieving the optimized RF power matching, the value of VVC is varied in every shot and RF parameters are analysed for an appreciable increase in the value of cos Ø. Being installed in the HV area and enclosed in the RF shield (to minimized radiation), the manual tuning of matching network requires a complete shutdown of HV system and dismantling of RF shield. The accuracy of variation also could not be guaranteed during manual intervention. In order to effectively deal with these issues, a stepper motor based remote tuning system has been conceptually designed and successfully commissioned. The system implements a remote HMI with GUI, where the user can easily set and vary the remote VVCs right from the control room. Special HV couplers have been designed, tested and installed between the VVC and the stepper motor shaft as the secondary VVC of the matching network floats at the source potential (~ 50kV DC) [2]. Special care has been taken for grounding and shielding the stepper motors and its PLC based control system, in order to minimize the RF noise interferences.

The paper describes in detail about its conceptual design and implementation on the RF matching network.

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NF-331

Enhanced Oxygen And Carbon Removal From Vacuum Vessel Wall Of Aditya Tokamak Using Discharge Cleaning With Ar-H_2 Mixture

K.A. Jadeja, Deepak Sangwan, K.S. Acharya, S.B. Bhatt, T.P. Purabia, P.M. Chavda, R.L. Tanna, Pintu Kumar and J. Ghosh

Institute For Plasma Research, Near Indira Bridge, Bhat, Ghandhinagar-382428

E-mail: kumarpal@ipr.res.in

Abstract

Proper conditioning of vacuum vessel wall of any tokamak plays a very important role in its successful operation. Hydrogen glow discharge cleaning (GDC) is regularly carried out for wall conditioning of ADITYA tokamak vacuum vessel. Although GDC using Hydrogen (H_2) gas is effective in reduction of oxygen and carbon (low- Z) impurities from the metallic vessel wall, the retention of hydrogen in vessel wall as well as in in-vessel components increases significantly during long operation of hydrogen GDC. This results in higher hydrogen recycling during ADITYA plasma discharges. GDC with other inert gases like helium, argon, neon are useful to decrease the hydrogen retention, applied after H_2 GDC, but not effective to remove oxygen and carbon impurities from metallic vessel wall. On the other hand the GDC with argon-hydrogen gas mixture is helpful in reduction of oxygen and carbon impurities along with low hydrogen retention. The reason being the formation of ArH^+ hydride ions in Ar-H_2 GDC, which has quite long life and more energy compared to H_2^+ ions formed in H_2 GDC for breaking the bond of wall molecules [2]. A systematic comparative study of H_2 GDC and Ar-H_2 Mixture GDC has been carried out in ADITYA tokamak. The relative levels of oxygen and carbon impurities have been measured using residual gas analyzer in both GDC's. We have observed a substantial reduction in oxygen and carbon and a significant improvement in wall condition with Ar-H_2 GDC compared to the H_2 GDC. The detailed results along with variations in improvement with various proportions of Ar and H_2 mixing will be presented in this paper.

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NF-333

Crush Strength Of Lithium Titanate Pebbles For Breeder Blanket Application Of Fusion Reactor

S.K.Sinha, S.Yadav & P.M.Raole[1]

Department of Applied Physics, Birla Institute of Technology, Patna-800014

1Institute for Plasma Research, Gandhinagar-382428

E-mail : drsanjay1011@gmail.com

Abstract

Lithium titanae ceramics pebbles were prepared by sol. gel. technique. DTA/TG test of green powder were done to know the thermal reactions.XRD test of pure and calcium modified lithium titanate were carried out to know the phases of prepared ceramics. Crush strength test of pebbles were done.

Unmodified pebbles were shown a crush strength of 18 N while Ca (1 atomic %) modified pebbles were shown a crush strength of 36.67 N.

NF-335

Diagnostic Control And Operation Of Vacuum Interface Section In ICRH RF System On SST-1

H.M. Jadav, Manoj Singh, Ramesh Joshi, Gayatri Ashok, Atul Varia, S.V. Kulkarni and ICRH-RF Group

Institute for Plasma Research, Gandhinagar 382 428

Email: jadav@ipr.res.in

Abstract

This poster presents details of diagnostics of vacuum interface section of the control system which is VME based real time, Linux based operating system for Ion Cyclotron Resonance Heating System (ICRH).The ICRH system consists of 1.5MW RF generator operating at 22- 45.6MHz and91.2MHz. which will be used for second harmonic heating and pre-ionization experiments on SST-1 tokamak for1.5T & 3T magnetic field operation.The task of RF ICRH DAC is to control, monitor, interlocks and acquires the signals of interface diagnostic control and operation of ICRH RF on SST1 for 1000 second continuous pulse operation. Interface is a section of connecting atmosphere pressure vacuum transmission line to an antenna in side tokamak. The interface is under high vacuum and its status control and operation to be monitored from a distance because toroidal magnetic field is continuously on one can not go near the interface.

Various types signals coming from High power antenna RF interface with SST1 system signal are interfaced with the VME based microprocessor to monitor,control and has hardwired interlocks of critical signals like Arc detector,vacuum reading,gate valve to operate remote RF system in failsafe mode.Signal processing is achieved by developed electronics circuits for required level,attenuation,Isolation, latch, fiber optics links transmitter and receiver circuit,coverter RS485to232(two wire),protection through front end electronics circuits. Hence we present the design details and operation of interface and its diagnostics.

NF-338

Close Range Photogrammetry- A Tool For Shape Measurement And PFC Alignment

Gattu Ramesh Babu, Z. Khan, S. Pradhan

Institute for Plasma Research, Bhat, Gandhinagar 382428

E-mail : gattu@ipr.res.in

Abstract

Optical 3D coordinate measurements in close ranges viz., inside of a tokamak vacuum vessel, poses constraints on traditional methods viz., theodolites , rover arms etc., The ready availability of consumer-grade Digital Single Lens Reflective (DSLR) cameras has made photogrammetry an easier tool for many new applications including close-range coordinate measurements with an accuracy better than 100 μ. This poster discusses a simple approach which involves measurement with

Australis and coded targets with manual operations. Topics included are targeting, photography, feature measurements of Radial port and in-vessel surface of Prototype SST1.

NF-341

Conceptualization Of A Generic Remote Handling System For Tokamak Maintenance Applications

Ravi Prakash, Nikunj Kachhadia, , Priyank Patel, Milind Patel, Nirav Panchal, Naveen Rastogi

Institute for Plasma Research, Gandhinagar, Gujarat-382428

E-mail: prakash@ipr.res.in

Abstract

Remote handling will have an important role in the operation of the fusion machines. When operation begins, it will be impossible to make changes, conduct inspections, or repair any of the Tokamak components in the activated areas other than by remote handling. Very reliable and robust remote handling techniques will be necessary to manipulate and exchange components. With high temperatures and radiation levels and the huge work space, much of the inspection and maintenance tasks would be carried out by articulated manipulators The Tokamak remote handling (RH) maintenance system is a key component in Tokamak operation both for scheduled maintenance and for unexpected situations. It is a complex collection and integration of numerous systems, each one at its turn being the integration of diverse technologies into a coherent, space constrained, nuclearized design.

This paper presents a concept for a generic remote handling system which can cater to various repairing, installation and maintenance requirements of a tokamak device. The system is divided into several modules like Deployer, Multi-Purpose Manipulator, Task Module, Transfer and Service casks. Various RH end effectors and tools can be mounted on the manipulator to perform maintenance tasks such as cleaning of the In-Vessel components, heavy material handling, In-Vessel viewing and Inspection etc. The design and analysis methodology based on the kinematic parameters, Servo Joint mechanisms, and Gear based mechanisms is presented.

NF-345

Joule Heating Analysis Of Cryo-Adsorption Cryopump Due To Induced Eddy Current For Various Magnetic Loading Conditions

Pramit Dutta, Ranjana Gangradey, RaviPrakash N, Hemant Patel, Krishna Kumari K

Institute for Plasma Research, Gandhinagar 382428

E-mail : pramitd@ipr.res.in

Abstract

The Cryo-adsorption – cryopump, based on the principle of physical adsorption of gases on cryopanels cooled to 4K, is under development at Institute for Plasma Research (IPR). The major structural components of the cryopump assembly are the vacuum enclosure, cryo-panels, baffle-stack and the support structures. All components of the cryopump assemble are made of SS304L except

supports. The cryopump is located near the tokamak area and in the vicinity of the Toroidal and Poloidal Field Magnets. Thus, in the event of plasma disruptions like Vertical Disruption Event (VDE) and current quench or in the case of Poloidal Field Coil failure, the Cryopump assembly is subjected to changing magnetic field that gives rise to induced eddy currents on the cryopump components leading to the joule heating of the components and increased liquid helium usage for cooling.

A case study with ITER disruption scenarios is carried out to arrive at heat loads on cryopanels for various disruption cases. During the plasma current quench for ITER, the plasma is expected to maintain a constant position of 0.5m above the equatorial port while the current ramps down exponentially from 16.5MA to 0A in a time period of 16ms. Vertical displacement event of Type 2 & Type 3 for ITER are foreseen with an even worse condition with a linear current ramp down from 16.5MA to 0A in 36ms accompanied by a simultaneous shift in the plasma radial and vertical positions.

This article focuses on the investigation of the magnetic loading conditions on the cryopump with analysis of the induced eddy currents and thermal loads on the cryopanels. 2-D ANSYS models are created to study the effect of various plasma disruption conditions at the cryopump location. The resultant field variations are then applied in transient coupled field analyses on a 3-D ANSYS model of the cryopump with the vacuum enclosure and cryopanels to study the induced eddy currents. Further, thermal analyses are also performed to check the resultant heat loads on the cryopanels

NF-346

Study Of Pellet Fuelling Requirements For Aditya And SST-1 Tokamak

J. Mishra, *S.* Mukherjee, P. Nayak, P. Panchal, N. Rastogi, R. Gangradey, N Ravipragash

Institute for plasma research, Bhat, Gandhinagar, Gujarat-382428

E-mail: jsmishra@ipr.res.in

Abstract

In last few decades, pellet injection has become an important tool for fuelling high temperature plasma [1]. In this regard, pellet injection related scenarios in SST-1 and Aditya tokamak plasma is presented in this paper. Considering the density limit of plasma in various operational parameters, cylindrical pellet (equal aspect ratio) of different sizes is chosen for this purpose. With regard to the ablation rate of the pellet in plasma, for core penetration, the injection speed is decided to be <500 m/s. Single pellet injector system (SPINS) developed at IPR will be installed for this purpose [2]. The proposed injector is an *in-situ* light gas gun type injector, where a pellet is accelerated to higher speed by using high pressure propellant gas. At present, a cylindrical pellet size of 4 to 5 mm and speed ranging from 600 – 900 m/s has been achieved in test bench operation. In the early phase, pellet induced plasma disruption studies by injecting pellets from a radial outboard location have been planned.

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NF-347

Development of Wireless Mobile Robot with Real time Obstacle Avoidance and Path Planning using FPGA

Naveen Rastogi[1], Ravi Prakash N[1]., Pramit Dutta[1], Pratik Bhimani, Pranav Manvar

[1]*Institute for Plasma Research, Bhat Village, Gandhinagar, Gujarat-382428*

Email: naveen@ipr.res.in

Abstract

Motion planning is one of the important tasks in intelligent control of an autonomous mobile robot. It is often decomposed into path planning and trajectory planning. Path planning is to generate a collision free path in an environment with obstacles and optimize it with respect to some criterion. Trajectory planning is to schedule the movement of a mobile robot along the planned path. Mobile Robot navigation in real time environment requires prior knowledge about environment. While moving towards destination position it should detect the unknown obstacles which may be dynamic by sensing it continuously and avoid the collision with simultaneously steering the robot to the destination safely. The transport operations for tokamak applications require optimized trajectories. Taking advantage of hardware parallelism, FPGA give best performance when taking multiple sensors reading and simultaneously controlling the robot.

In this work, various techniques of path planning and trajectory optimization based on geometric constraints were studied and tested in the cluttered scenarios. The localization problem of mobile robots was also addressed, with a novel approach of using an optimized sensor network installed on the scenario with probabilistic algorithms to estimate, in real time, the coordinates of the mobile robot, or a set of mobile robot, operating in the scenario. The navigation is also considered with three modes of operation: automatic, semi-automatic and Joystick Control. 2.4 GHz Zigbee based wireless technology is used for wireless communication between the robot and the host. Destination position coordinates in 2d is given by user from remote host through Zigbee wireless module. The Mobile Robot processes the information in real time and considers the latest command received and will traverse to the destination position implementing the optimized path trajectory and simultaneously avoiding the obstacles in path. The algorithms were programmed and implemented using Lab-VIEW platform.

NF-348

Development Of LabVIEW™ Based Application For Interfacing Of Cryo Pump With ROBIN DACS

Radhika Gupta[1], J. Soni[2], H. Tyagi[3], R.K.Yadav[3], H. Mistry[2], K. Pandya[2], G. Bansal[2] and A. Chakraborty[2]

[1] *Jaipur Engineering College and Research Centre, Jaipur, 302022*
[2] *Institute for Plasma Research, Bhat, Gandhinagar-382428*
[3]*ITER-India, Institute for Plasma Research, Bhat, Gandhinagar-382428*

E-mail: radhika924@hotmail.com

Abstract

ROBIN[1] (Replica of BATMAN Source in India) is a negative ion experimental facility setup at Institute for Plasma Research. Currently both the plasma and beam operations are carried out in ROBIN.

ROBIN system consists of various sub-system like RF generators and a set of low and high voltage power supplies, hydraulic system, Cs oven system, gas feed system, vacuum chamber housing a calorimeter, cryosystem, etc. Automated successful operation of the system is done using a combination of PLC based control system (Siemens) and a PXI based data acquisition system (National Instruments) DACS.

ROBIN system is in operational and first phase i.e. Plasma production has been successfully completed, now the vacuum system has been upgraded for next phase of operation i.e. beam extraction for which Cryo-pump has been commissioned in the test bed. Presently the system is not integrated with the ROBIN DACS[2]. ROBIN control system is based on Siemens PLC technology which handles all the operations of ROBIN. To enable a convenient operation of the cryo pump it was required that it should be remotely operated. The cryo pump consists of a single RS-232 port for interfacing. Therefore it was decided that a Lab View based application be developed which can communicate with the controller of cryo pump. This application can then be executed from main control room for enabling remote operations. All the relevant commands for cryo pump operation are sent through this application and the status signals are also monitored from controller.

This paper describes the details off the work carried out and the result obtained by interfacing with the Cryo-pump controller.

References:

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NF-349

Dynamic Navigation Simulation Of An Articulated Multi-Link Arm For In-Vessel Inspection Tasks In A Tokamak

Naveen Rastogi[1], Ravi Prakash[1], PramitDutta[1], Nirav Virpara[1]

[1]*Institute for Plasma Research, Gandhinagar, Gujarat-382428*

E-mail: naveen@ipr.res.in

Abstract

This paper is part of the remote handling (RH) activities towards preparedness for the future fusion machines. The aim of the R&D program performed is to demonstrate the feasibility of the inspection tasks inside the Vacuum Vessel. Due to the toroidal geometry and huge dimensions of the Vacuum Vessel, there is an inevitable need of a precise and fast automated articulated inspection system that can perform the required inspection tasks without damaging the surface and to maintain the machine availability for the maximum time. When considering generic Tokamak relevant conditions, the set of major challenges for the Remote Equipment is to sustain the severe operating conditions: ultra high vacuum, temperature and tritium level. The limited number of machine access ports and the very constrained environment complicate the introduction of a robot into the machine. The Multi-

Link inspection arm is required to be deployed in the bounded environment inside the Tokamak Vessel.

This paper presents the development of software for implementation of autonomous navigation motion control algorithms based design simulations for the inspection Arm for routine inspection tasks, navigation to the targeted coordinates inside the Vessel, clash avoidance and to perform other auxiliary mechanical tasks. The software is also capable to store the joints and frame locations at every interval which can be used for the real time control application. The developed software has the flexibility to work with any number of links and joints.

NF-350

Studies Of Adsorption Characteristic Of Various Activated Carbons Down To 4.5K

S. Kasthurirengan[1*], Upendra Behra[2], Samiran Mukherjee[1], Ranjana Gangradey[1$]

[1]Institute for Plasma Research, Gandhinagar 382428
[2]Indian Institute of Science, Bangalore 560012

E-mail : fantasrini@gmail.com

Abstract

A Cryo-Adsorption Cryopump is the most suitable solution to pump helium, hydrogen and its isotopes in fusion devices. Activated carbon is used as the adsorbent in these pumps. Various activated carbons are being considered for the development of such pumps. To arrive at the right candidate, suitable for the application, adsorption characteristics of activated carbons down to 4.5K are needed. Hence an experimental setup has been designed and developed to measure adsorption characteristics of activated carbons down to 4.5K. The setup comprises of commercial micropore analyzer integrated with a GM cryocooler operating down to 4.5K. This work describes the detailed experimental studies of adsorption characteristics of various types of activated carbon samples such as granules, Globules, non woven cloth and flake knitted cloth in the temperature down to 4.5K with Helium gas as adsorbate. The results have been evaluated in terms of their surface area, pore sizes and their distributions. Further studies have been carried out to understand the effect of adhesive used for bonding the sorbents to small scale cryopanels. The relative performances of various sorbents are presented here.

NF-351

PXI Based Data Acquisition and Control System for Single Barrel Pellet Injection System

Naveen Rastogi, Haresh Patel, Samiran Mukherjee, Alaap Jagdale, Ranjana Gangradey

Institute for Plasma Research, Gandhinagar 382428

E-mail: naveen@ipr.res.in

Abstract

This paper describes the design and development of a stand-alone automated data acquisition and control (DAC) system for Single barrel Pellet Injector System (SPINS) developed at IPR. The system was able to generate pellets of length 4mm fired with a variable velocity of 300 – 800 m/s. The DAC system provides pellet formation, precise firing control, data collection and lased diagnostics of single-barrel injector.

The system graphical user interface (GUI) is based on LabVIEW –SCADA and allows the user to setup and control the pellet injector for fast pellet formation and highly repeatable results. The control system is capable of controlling a large number of valves and temperature of the cryo-cooler to form the pellet. The pellet firing from a fast acting propellant valve is controlled with microsecond precision. Application software running on PXI system is controlling and communicating with all the instruments (valves, gauges, vacuum pumps, gas analyzers temperature monitors, laser diodes and Flow meters etc.) interfaced with pellet injection system to execute the experiment. Conversion circuits have been developed to convert signal's operating voltage level to respective destination operating voltage level and vice versa accordingly. User can completely automate the pellet injection system and control them through software application to execute the system. Software application is developed to guide user for desired operation sequences to be followed for proper execution. At the end of test, user can analyze logged data in Microsoft Excel for post analysis. After each pellet shot the data collected from various monitors and diagnostics is displayed on the user's screen along with the pellet's calculated speed and graphs. The control system also has the capability of running different experiment templates with unique setup and output characteristics by simply changing the experiment variables. The overall description of the DAC system and examples of its use on the pellet injector system is presented.

NF-352

Development Of Two Series Ingnitron Based Crowbar Protection System For 42 GHz & 82.6 GHz Gyroton In SST-1

Pragnesh Dhorajiya, Shefali Dalakoti, Harshida Patel, Krunal ingle, Jatin patel,
K. Sathyanarayana, Rajanbabu and B. K. Shukla

Institute for Plasma Research, Gandhinagar 382428

E-mail : pragnesh@ipr.res.in

Abstract

Gyrotrons are used to generate the high power at microwave frequency that is used to heat the plasma inside a Tokamak. A conventional high voltage power supply is used for the testing of 82.6 GHz, 200 kW/CW & 42 GHz, 500 kW/500ms gyrotrons at our institute. Its maximum operating cathode parameters are -55 kV DC, 20 A. Like any other High RF power tubes gyrotrons need to be protected against arc faults within the tube. If the energy dumped in such arc fault is more than the critical crater energy of the tube, irreparable damage can occur inside the RF tube or microwave tube and rendering it useless. The specified maximum fault energy for the 42 GHz and 82.6 GHz gyrotrons is 10 joules.

When conventional HVDC power supplies feed high power RF tubes or microwave tubes, a reliable crowbar protection is required which is tested separately to limit the energy to the tube in case of any type of fault to assure the tube safety.

Two series ignitron (NL-37248) based crowbar system developed in-house is used to limit the arc

fault energy under the acceptance level by diverting the fault current from the load or Gyrotron. Fault current diversion and interruption are initiated by the sensing element and protection system. The required protection cards are designed and developed in-house and required performance is achieved. With this crowbar system the high voltage switch-off to the gyrotron is achieved within 5 µsec after occurrence of critical faults. The crowbar is tested for voltage hold-off up to 80 kV DC.

This paper presents the critical requirement of the time delay for the fault sensing and crowbar trigger generation and necessary protections that are incorporated with the ignitron switch crowbar like over voltage, pulsed over current and continuous over current. The crowbar system developed in-house, tested at rated value. The results obtained during the stand-alone tests and commissioning tests are also mentioned. Using this crowbar system the high voltage power supply voltage is removed from gyrotron in less than 5 µsec during certain critical faults.

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NF-354

Real Time Interfacing Of 3D CAD Simulation in Delmia with Articulated Robotic Arm

Naveen Rastogi[1], Ravi Prakash[1], PramitDutta[1], Nikunj Kachhadia[1], Archit Sureja[1], NiravVirpara[1]

[1]*Institute for Plasma Research, Gandhinagar 382428*

E-mail: naveen@ipr.res.in

Abstract

3D simulations have become an essential tool for cost effective preparation and training for Remote Handling operations. These kinematic and inverse kinematics simulations can help reduce the time required to prepare remote operation tasks, allow concurrent development of several tasks simultaneously, simplify and where possible ‘standardize’ the development of remote handling operation documentation. 3D detailed simulations can be used to evaluate new component and tool designs for ‘remote handling use’ and to prepare operational procedures. DELMIA Robotics Simulation software offers a scalable, flexible, easy-to-use solution for tooling definition, work-cell layout, robot programming, and work-cell simulation.

This paper describes the 3D Delmia simulation interfacing with real time hardware in field application using Inverse Kinematics. The interface was designed in labVIEW such that the Robot can directly communicate to the DELMIA Simulation. This can work with robots having any number of links and joints. The system provides an opportunity to verify the robot performance by changing online the controlling kinematic parameters and the trajectory of the desired motion.

NF-356

Self-localization and Coordination Control of an articulated Manipulator using Photogrammetry & Stereo Vision Solution

Naveen Rastogi, Ravi Prakash, Pramit Dutta, Archit Sureja, Ankita Patel

Institute for Plasma Research, Gandhinagar 382428

E-mail: naveen@ipr.res.in

Abstract

Since long, Manipulators have been using odometric techniques to estimate change in its position over time. This method is sensitive to errors due to the integration of velocity measurements over time to give position estimates. Rapid and accurate data collection, equipment calibration, and processing are required in most cases for odometry to be used effectively. Vision based techniques can be efficiently used to enhance the robot control system accuracy and precision. Self-localization in large environments is a vital task for accurately registered information visualization in outdoor Virtual reality (VR) applications.

This paper describes the implementation of vision based technique that provides the ability to place an arm's TCP and joint frame locations on a target designated in an image using optimized feedback from fixed stereo cameras. Here, two algorithms work simultaneously. First algorithm works by maintaining an error vector between the locations of the arm's end-effector as predicted by a kinematic model of the arm and detected and calculated by stereo cameras based vision system. It then uses this error vector to compensate for errors in the kinematic model and servo system to the target designated in the stereo camera pair. The second algorithm enables the robot to find its initial position and to verify its location during every movement. Photogrammetry techniques are used to accurately determine the pose of the robot end-effector in real-time for updating the robot model. The accuracy of 10 Microns is achieved using photogrammetric techniques. The global position of the robot is estimated using trilateration based techniques whenever distinct landmark features are extracted.

NF-358

Commissioning, Interfacing, Testing And Operation Of -10KV, 400MA High Voltage Power Supply With ROBIN For Beam Extraction

K G Parmar, A. Gahlaut, V.Mahesh, R.K.Yadav[1], Deepak Parmar[1], J. Soni, G. Bansal, B Prajapati H Mistri, K. Pandya, M. Bandyopadhyay[*] and A. Chakraborty

Institute for Plasma Research, Bhat, Gandhinagar 382 428
[1]ITER-India, Institute for Plasma Research, Gandhinagar 380 025

E-mail: kgparmar@ipr.res.in

Abstract

After successful plasma operation phase in ROBIN [1], it is necessary to go for negative ion extraction phase. The extraction phase is initiated using a -10 kV, 400 mA high voltage power supply (HVPS), using a very limited extraction area in the ion source. The said HVPS is having special

features compatible to the ion beam extraction requirements: low energy deposition during fault/ breakdown, can withstand repetitive breakdown occurred in the ion source grids, fast rate of rise time of few milli-seconds, cut off time of few micro-seconds, self tripping interlock for over voltage, overload and other internal fault.

This HVPS also has other features like low ripple and tight line-load regulation. Compatibility of remote setting and monitoring is also essential for this experiment, since ROBIN is placed inside a RF shielding cage and being operated remotely through Data Acquisition and Control System- (DACS) equipped with fiber optic based communication system. The installation and integration for local/ remote operation [2] of this HVPS has been successfully performed with ROBIN DACS. The integration scheme has been configured and implemented for safe operation of ROBIN taking into consideration the high voltage, door interlock, grounding and shielding. The extraction current measurement through a special current transducer circuit is also incorporated in this scheme, as a part of the electrical diagnostic in the experiment.

The paper will describe the experiences and results obtained during commissioning and testing of this -10 kV, 400 mA HVPS with ROBIN and also during experiment.

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NF-360

A Comparison Study Of Various Seismic Analysis Methods

S S Sandhu[1], Y Dileep[2]

[1]ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, 382428
[2]Electronics Corporation of India, Hyderabad

E-mail: sarbjeet@iter-india.org

Abstract

One of the main requirements of nuclear systems/components installation is its Seismic Qualification. With the emerging computational capability, new methods are constantly being developed and adapted. The current study compares various Seismic Analysis methods currently being used.

A simple FRP rack has been considered for the current study. Initial modeling details were completed with CATIA V5 software and ANSYS Workbench is used for simulation. Traditional Equivalent Static Method, Linear RSA and Non Linear time domain methods are compared in terms of results, computational resources and time required. Comparison is supported analytically where possible. Advantages and Disadvantages of these methods are presented in conclusion.

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NF-361

Heater Design And Thermal Analysis Of Cathode Assembly For 170 GHZ, 1 MW Gyrotron

Udaybir Singh[1], Monika Sheoran[1,2], Nitin Kumar[1], Mukesh Kr. Alaria[1] and AK Sinha[1]

[1]*Gyrotron Laboratory, MWT Area, CSIR-Central Electronics Engineering Research Institute, Pilani*
[2]*Department of Computer Science, Banasthali University, Banasthali, Rajasthan*

E-mail : uday.ceeri@gmail.com

Abstract

An activity of design and development of 170 GHz gyrotron is started at CEERI Pilani. 170 GHz is chosen ECRH frequency at ITER and total 24 MW of RF power generated from gyrotrons will be pumped into the ECRH system of ITER [1]. This paper presents the design of toroid shape heater for dispenser cathode and the thermal analysis of complete cathode assembly for 3.2 MW triode type MIG for 170 GHz gyrotron. Finite element method based simulation tool ANSYS Work Banch (v.14.0) is used in the simulations. In the heater design, various electrical and geometrical parameters such as filament radius, number of turns, wire thickness, heater voltage, etc are optimized. The temperature on heater is optimized around 1600 ^{o}C considering the cathode temperature around 1100 ^{o}C. Tungsten is used as the filament material due to its excellent thermal properties [3]. After the design of heater, thermal analysis is also performed for the complete cathode assembly. Various types of potting materials are also investigated.

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NF-364

Disruption Characterization And Database Generation For Itpa Disruption Database From Aditya Tokamak Discharges

R.L. Tanna, V.K.Panchal, Pintu kumar, K.A. Jadeja, S.B. Bhatt, C.N. Gupta, U. Dhobi, P.K. Atrey, Y.S. Joisa, C.V.S. Rao, D.Raju. R. Jha, P.K. Chattopadhyay, J. Ghosh, A. Sen and ADITYA team

Institute for Plasma Research, Gandhinagar – 382 428

E-mail: rakesh@ipr.res.in

Abstract

Disruptions are rapid events in which large fractions of the plasma thermal energy is lost due to the uncontrolled growth of some large-scale plasma instability. Aditya tokamak (R_0 = 75 cm, a = 25 cm), an ohmically heated circular limiter tokamak, is regularly being operated to carry out several experiments related to controlled thermonuclear fusion research. Different types of spontaneous and

deliberately-triggered disruptions are regularly observed in studied in Aditya Tokamak. In this work a thorough statistical analysis and characterization of different types of disruption observed in Aditya tokamak such as density limit disruption, MHD disruption etc. has been carried out. After identification and categorization of over 100 disruptive discharges of Aditya a database is generated as per ITPA suggested format and have been uploaded to ITPA disruption database working group. To identify the disrupted discharges from the large collection of ADITYA archive, the electronic database code has been upgraded by using logical channel numbers instead of physical channel numbers. An effort has been made to find out the causes of disruption in these shots. The following are observed as the main reasons for disruption in Aditya tokamak: MHD instabilities growing prior to the disruption and the density limit. Other than plasma properties sometime technical problems (hardware faults) are found to be the cause of disruption, for example sudden power supply failure, fuel gas failure, additional gas-puff, volt-sec failure etc. The Aditya disruptions are mostly found to be caused by MHD instabilities. The details of data analysis procedures, identification processes of different discharges, database generation etc. will be presented in this poster.

NF-365

THERMAL CHARACTERIZATION OF FBG SENSORS FOR NUCLEAR FUSION REACTOR RELEVANT APPLICATIONS

M. Sai Shankar[1], M. Manohar[1], R.L.N.Sai Prasad[1] & B Ramesh Kumar[2]

[1]*Department of Physics, National Institute of Technology, Warangal-506004*
[2]*Institute for Plasma Research, Bhat, Gandhinagar -382428*

Email: msainitw@gmail.com

Abstract

The FBG (Fiber Bragg Grating) sensors are having potential applications in Fusion reactor applications where huge electric and magnetic field environment is present. This is due to the sensor being immune to electric and magnetic fields. The utilization of optical sensors for the tokamak research has got special attention towards structural monitoring , strain sensing applications and temperature monitoring as per the advantages. The monitoring and preventive maintenance of such structures can be more effectively carried out with FBG sensors compared to conventional sensors like thermocouples, RTD etc. We present the theoretical and experimental investigations carried out on the thermal response of FBGs and LPGs for the measurement of temperatures upto 250 degrees centigrade. The results reveal good sensitivity and resolution in the measurement of temperatures. The present work reports the development and temperature characterization of the FBG sensors demand is highlighted for applications in the Fusion reactor machines.

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NF-385

Upgradation Of Fibre Optic Based Analog Signal Link For ECRH System On SST-1

Harshida Patel, B. K. Shukla, Jatin Patel, N. Rajan Babu, Pragnesh Dhorajiya and Chetan Virani

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail: harshita@ipr.res.in

Abstract

Electron Cyclotron Resonance Heating System (ECRH) is an important heating system for Steadystate Superconducting Tokamak (SST-1). The 42GHz/500kW and 82.6GHz/200kW ECRH systems are used in SST-1 to carry out experiments related to plasma heating. The ECRH system has its own data acquisition and control (DAC) system to execute the task of data acquisition from its high voltage sub-systems like cathode voltage power supply (CVPS), anode modulator power supply (AMPS) and filament etc. The field data is acquired at front end electronics circuit for signal conditioning, the conditioned data is used for monitoring and interlocks to control different parameters. The analysis of acquired data is carried out in off-line mode. In order to avoid any unwanted tripping of high voltage, fibre optic based data transmission is used. For the monitoring and control of analog signal, a Til300 based opto-coupler card and fiber based links are used to remote operation of individual power supply interfaced with DAC.

In the optical link, analog signal is converted into frequency and transmits through optical fiber to reduce the noise interference. Receiver side frequency again converted to analog signal. The active filter with gain and offsets adjustment is used to provide the linear data for clear operation. The existing transmitter and receiver cards are supply dependent and bigger in size, hence to remove the dependency of external power supply. The upgradation is carried out with SMD components for compactness. The Upgradation of analog fiber link is designed using DC-DC converter for stable functional operation of the system. The paper highlights the features of Analog link transmitter and receiver card for reliable operation of Gyrotron and discusses its results in detail.

NF-399

Industry Support To Indian Tokamak Research

S. S. Udgata

I-DESIGN Engineering Solutions Ltd., Wagholi, Pune 412207

E-mail : ssu@rsbglobal.com

Abstract

Under this topic we will speak on the (a) development of thermal shields for 80 K application (b) development and application of 5k thermal shield in tokomak (c) ELM coil cases development (d) 5K helium impeller design and development (e) bus-bar developments for SST-I (f) cryo-pump development initiatives (g) Cryo Panel characterizations at low temperatures (h) cryostat/vacuum vessel fabrications.

Industrial Plasma Applications (IP)

IP-013

Surface Modification Of Polycarbonate (PC) By Using Atmospheric Pressure Plasma At 50 Hz

A.P. Sapkota and D.P.Subedi

Patan Multiple Campus ,Tribhuvan University, Kathmandu, Nepal

E-mail : galaxyanp@gmail.com

Abstract

Atmospheric pressure DBD (Dielectric Barrier Discharge) system with single dielectric barrier was designed to generate micro-discharge plasma at low frequency(50 Hz) which is very practical for the material processing applications. DBD having circular electrodes with diameter 5.05cm and thickness 1.02cm of each has been used for the plasma generation. Plasma is produced at fixed inter-electrode gap and different types of plasma have been produced for the study of effectiveness of treatment on the surface of the Polycarbonate(PC). After the treatment of the sample in different treatment time: 20sec, 40sec, 1min, 2min, 5min, 8min and 10min , the hydrophobic properties of sample changed to the hydrophilic. To measure the wetting of the sample, contact angle was measured by using goniometer with water as a testing liquid. Effect on the sample due to treatment time, voltage applied and gas used were studied. To maximize the accuracy, contact angles was measured at 5 different places of the treated sample ,and their mean was taken for the processing of the data. More effect has been seen on the argon plasma , and in high voltage applied.

Aging effect at different aging time was also studied to see the evolution of the properties after time elapsed by measuring the contact angle till one month after the treatment. Plasma treatment effect was seen for the long time after the treatment[1]. This result can be helpful in understanding the dependence of voltage applied and gas used in DBD plasma production along with aging.

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IP-036

Microwave Plasma Torch for Waste to Energy Applications for Petrochemical Industry

Rajneesh Kumar[1,2], B. O. Ogungbesan[1], S. Liu[1], M. Sassi[1]

[1]*Dept. of Mechanical Engineering, Masdar Institute of Science and Technology, Masdar City, Abu Dhabi, U.A.E*

[2]*Department of Physics and Electronics, Dr. Hari Singh Gour University, Sagar, MP*

E-mail: rajneeshipr@gmail.com

Abstract

Atmospheric pressure microwave induced plasma (MIP) sources have been studied for decades due to their potential advantages such as electrode less operation, high-throughput atmospheric processing, efficient microwave to plasma coupling and availability of inexpensive sources. Recently developed microwave plasma sources seem to have a high potential for hydrogen

production via hydrocarbon reforming. Thermal decomposition of hydrocarbons /natural gas or methane into more valuable compounds, such as hydrogen, synthesis gas (H2 + CO), acetylene and other higher hydrocarbon or black carbon represents great chemical and technological challenges for both the chemical engineering and petrochemical industry. Especially hydrogen gains in importance as fuel in fuel cell applications, combustion engines or gas turbines with the goal achieve more efficient exploiting of energy sources and to reduce noxious emission. Due to more applicable than DC plasmas, microwave plasmas have been extensively studied by simulation [1] and experiments [2, 3] for waste (especially H_2S) to energy (H_2) applications. Therefore, this paper devotes attention to the study of methane dissociation for hydrogen production in a microwave plasma torch (MPT), which can be operated up to 2 kW power of 2.45 GHz frequency. Methane was dissociated into black carbon and hydrogen. Methane dissociation with the variation of operating parameters such as different gas combinations, axial flow rates, swirl flow rates and microwave powers was studied. Atomic emission spectroscopy suggests that the plasma is in the local thermal equilibrium (LTE). This study reveals that present MPT can be used to get energy (hydrogen) from different kind of wastes.

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IP-048

Analysis Of Microstructure, Wear And Corrosion Behaviour Of Plasma Sprayed Cr_2O_3, Al_2O_3 And TiO_2 Composite Coatings

S. Gowthamaraju, K.Praveen, S. Sivakumar and G..Shanmugavelayutham

Plasma Physics Laboratory, Dept. of Physics, Bharathiar University, Coimbatore- 641046

E-mail:velu1976@yahoo.co.in

Abstract

In the field of plasma physics, plasma spray coating technique has been successfully applied to a wide range of industrial applications such as aerospace industry, automobile and biomedical industry etc. Oxide ceramic coatings are suitable in high temperature environments in both wear and corrosion applications. The present investigation is to study the formation of plasma sprayed Cr_2O_3, TiO_2 and Al_2O_3 composites coatings and characterization. Composites of oxide powders were prepared by ball milling of 50wt%Cr_2O_3-50wt%TiO_2 and 30wt%Al_2O_3-70wt%TiO_2 powders were coated on stainless steel and aluminium substrate through DC non-transferred Atmospheric Plasma Spray (APS) torch under different operating conditions. Phase analyses were determined by X-ray Diffraction method, microstructure of the coatings were analysed by FE-SEM and coating thickness was observed by using Optical Microscopy. Further, wear and corrosion behaviour of the coated samples were analysed by pin-on-disk and Tafel-polarization curve respectively. From this observation, plasma operating parameters were optimized for better coatings in suitable applications.

Key words: Plasma spray coating, Cr_2O_3, TiO_2 and Al_2O_3, wear, corrosion.

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IP-091

Generation And Characterization Of Metallic Nanoparticles By Electrical Explosion Of Metals

S Sahoo, A Jaiswar, A K Saxena, R. K. Rout, T C Kaushik and Satish C Gupta

Applied Physics Division, Bhaba Atomic Research Center, Mumbai-400 085

E-mail: somanand@barc.gov.in

Abstract

Metal nanoparticle generation by electrical explosion of foils or wires (EEW) has been gaining popularity as a novel technique because of its potential for mass production. Availability of small particles (especially Al) has prompted researchers to examine the effect that particle size has on energetic materials. As particle size is decreased, the speed of burning rate increases and the ability for complete conversion to the oxide is increased [1].

The method involves a very high current pulse discharge through a metallic conductor which then explodes, forms ionized vapour plasma and finally condenses to yield nano sized powders. In our laboratory, such experiments have been carried out in ambient air and nitrogen atmosphere with an aim to control the rise time or burst time of explosion by changing the conductor dimensions and energy delivery from a capacitor bank. The powder from aluminum so generated has been characterized by XRD and TEM techniques. XRD patterns reveal characteristic peaks of Al. The nanoparticles generated in ambient air are found to be distributed with an average size of 45 nm and spherical in shape. But particles in nitrogen atmosphere tend to agglomerate and seen to be non-spherical in shape. This appears to be due to the limited expansion of plasma because of higher pressure in the surrounding [2]. We also investigate relationship between rate of energy deposition and burst time etc on composition of the powder so generated. The nanoparticles tend to be smaller in size with lower surrounding pressure and higher charging voltage [3].

Further studies looking at the role of rate of plasma expansion [4], cooling rate, overheat factor in determining average size of such particles are underway.

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IP-105

Surface Modification Of Textile Fabrics Using Radio Frequency Plasma Treatment

M.S. Nadkarni, A.N. Patil, V.H.Goswami, S.V. Maduskar, N.G. Durge, S. S. Pimpale

Department of Physics, Patkar College, Goregaon (w), Munbai-400062

E-mail : msnadkarni1958@rediffmail.com

Abstract

Cotton and PET (polyethyleneterephthalate) fabrics was treated in RF (Radio Frequency) plasma for different duration and optimized exposure power condition. Treatment was carried out using different gases such as N_2, Ar, O_2 etc.[1] The PET fabric shows different behavior with different gas plasmas. In case of Ar & N_2 surface modification is mainly due to etching effect. The physical properties of fabrics changes in surface morphology and composition were studied using atomic force microscopy (AFM) and Fourier Transformed Infra-Red (FTIR) spectroscopy[2]. It is observed that plasma treatment has contributed in enhancement of different parameters of cotton and PET fabrics.

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IP-123

A Multi Step Argon & Nitrogen Plasma Surface Treatments Of PMMA For Improved Copper Adhesion

Narendra Kumar Agrawal[1], Y. K. Vijay[2], K. C. Swami[1]

Department of Physics, Malaviya National Institute of Technology, Jaipur 302017, India[1].
Department of Physics, University of Rajasthan, Jaipur-302004, India[2].

E-mail : research.nka@gmail.com

Abstract

Argon and nitrogen plasma processes were used for one-dimensional multi step surface treatment of PMMA membranes. The PMMA membranes surface was exposed to Ar and N2 plasmas in five treatment cycles. Chemical and physical modifications on PMMA membranes caused by the multi-step plasma processing were characterized by using X-ray photoelectron spectroscopy (XPS), FTIR and atomic force microscope (AFM). Membranes are further coated with a thin layer of copper and adhesion of copper is examined. Membranes shows improve adhesion of copper on PMMA membranes after multi-step plasma treatment.

IP-151

Probing Argon-Hydrogen Magnetron Sputtering Discharge Plasma With Ion Acoustic Wave

P. Saikia, B. K. Saikia

Centre of Plasma Physics- Institute for Plasma Research, Nazirakhat, Sonapur-782402, Assam

E-mail : partha.008@gmail.com

Abstract

In this study, ion acoustic wave is used as a diagnostic tool of plasma parameters in magnetron discharge plasma. Plasma with positive ions is formed by adding hydrogen in pure argon discharge. Precise determination of relative concentration of positive ions is very important for the optimization of sputtering process. In magnetron sputtering, popular diagnostic device like Langmuir probe and optical emission spectroscopy are widely used for this cause. However, due to prolonged deposition duration the results obtained by such diagnostics may be erroneous. Also, ion acoustic phase velocity is a better diagnostic of the ratio of relative ion concentration than Langmuir probe. Thus, in such discharge, ion acoustic wave can serve as an effective diagnostic tool. The results obtained in this study show that addition of hydrogen leads to increase of ion acoustic phase velocity. The value of relative positive ion concentration is obtained by using ion acoustic phase velocity and is found to increase with hydrogen addition. The effect of hydrogen addition on the sputtering efficiency of DC magnetron discharge plasma is also investigated in present study.

IP-168

Data Acquisition Techniques For Randomly Occurring Arcs On A Dielectric Surface

Rashmi S. Joshi, Keena R. Kalaria, Suryakant B. Gupta

FCIPT, A-10, GIDC, Sector-25, Gandhinagar, Gujarat, 382024

E-mail : rashmij@ipr.res.in

Abstract

Conventionally an electrical arc is defined as a low impedance conducting channel formed between two objects. Arcs are characterized on the basis of their physical parameters, current density luminosity etc. In many cases the duration of arcs lies in the range of microseconds and therefore it appears as an impulse which may or may not be visible by naked eyes. Also for various experiments it is important to identify the arc locations because each arc causes detrimental effects which in turn can lead to serious threats for operating devices or systems. In this paper arc originating form a metal insulator junction placed on a dielectric surface under a charged environment is discussed. A technique for the identification of arcs initiating from a charged dielectric surface is developed. In order to simulate such experimental condition in the laboratory a specially designed circuit is used for the experiments. The basic inherent characteristics of different types of arcs are defined by their electrical and optical parameters. For electrical diagnostics sensitive voltage and current probes are connected to a high speed digitizer whereas for optical measurements a progressive scan CCD

camera capable of detecting minimum illumination of 2 lx are used. Camera is synchronized with the arc detecting mechanism to record online videos or save arc images after necessary image processing operations. Images captured during arc acknowledge their location and brightness.

A dedicated algorithm which performs parallel processing of different processes occurring during arc and automatically calculates the arc rate is developed which provides all the useful information for randomly occurring non-thermal arcs. On plotting the V-I characteristics after processing the available data, negative resistance is measured. Brightness and negative resistance categorizes the arc into a non-thermal type.

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IP-175

Hydrophilization Of Polymers And Textiles By Atmospheric Pressure Argon Glow Discharge Plasma

R. B. Tyata[1,2], D. P. Subedi[1], A. Huczko[3] and C. S. Wong[4]

[1]*Department of Natural Sciences, School of Science, Kathmandu University, Dhulikhel, Nepal*
[2]*Department of Electrical, Khwopa College of Engineering, Libali-2, Bhaktapur, Nepal*
[3]*UW Laboratory of Nanomaterial's Physics, Warsaw University, Warsaw, Poland*
[4]*Plasma Technology Research Centre, Physics Department, University of Malaya, Malaysia*

Email: rbtyata@yahoo.com

Abstract

The present work reports the results of surface modification of different polymers; Polypropylene (PP), Polyethylene terephthalate (PET) and Polytetrafluoroethylene (PTFE) and textiles; Dynema SB21, Dynema SB51 and Dynema SB71 in order to improve their hydrophilic properties. Using a high voltage (0-20 kV) power supply operating at 27 kHz, atmospheric pressure glow discharge (APGD) has been generated between the electrodes with gap spacing 2 mm and with a glass dielectric of 2 mm thickness while argon gas is fed at a controlled flow rate of 1 litre per min. The effect of treatment time on the wettability of the samples was investigated by contact angle measurement. Contact angles of water and glycerol were used to determine the surface free energy of the sample. The surface property was also characterized scanning electronic microscope (SEM) which showed that the smooth and glossy surface of polymers and textiles became rough and deep in color after treatment by the reason of etching action of the discharge. The argon glow discharge plasma has been tested to be effective in reducing the hydrophobicity of polymers film and textiles significantly.

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IP-200

Development of Duplex Plasma Based Process For Improvement Of Surface Properties of Steel

[1]J. Alphonsa, [2]P. Saikia, [1]G. Jhala, [1]R. Rane, [1]S. B. Gupta, [2] B.K. Saikia and [1]S. Mukherjee

[1]*Facilitation Centre for Industrial Plasma Technologies, IPR, Gandhinagar, Gujarat*
[2]*Center of Plasma Physics-IPR, Guwahati, Assam*

E-mail: alphonsai@yahoo.com

Abstract

Though plasma nitriding (PN) process is a well known process for improving the surface hardness, it cannot be used alone for improving the life of the cutting tools because of its low surface hardness. The maximum hardness varies from 900-1200 HV0.1 for high alloy steel like H13 and D2 which are used for making cutting tools.

It has also been observed that on application of a thin film coating by plasma assisted physical vapour deposition process on cutting tools the tool performance get enhanced significantly. The maximum hardness varies from 1500-2300 HV0.1 for coatings like TIN, TiAlN etc. on steels like H13 and D2. However, application of PVD hard coatings to the substrate materials cannot guarantee the optimal tribological performance without pre treatment of the substrate materials due to plastic deformation of the substrate which results in eventual coating failure.

Hence, a combination of nitriding and PVD provides a product having properties superior to both. It was reported that plasma nitrided sub-layer improves the wear resistance of the tool by >1.5 times with PVD coatings [1]. It was also reported that the adhesion can be enhanced by the presence of a hard intermetallic layer between the coat and the substrate [2]. Hence it can be concluded that the usage of combination of coatings termed as duplex coatings results in superior corrosion and wear resistant surfaces.

In this paper an attempt is made to study the surface properties of AISI M2 after plasma nitriding and plasma assisted physical vapour deposition carried out at different nitrogen partial pressure and bias conditions. The surface properties of each of these processes were than compared with the duplex coated AISI M2 substrate. It was found that the presence of pre- nitrided layer enhanced the surface properties of the coated steel.

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IP-235

Effect Of Plasma Treatment On Cellulosic Textile

Kartick K. Samanta*, Gayatri T. N., Sujata Saxena, A. Arputharaj, S. K. Chattopadhyay and S. Basak

Plasma Nanotech Lab, Chemical and Bio-chemical Processing Division
ICAR-Central Institute for Research on Cotton Technology
Adenwala Road, Matunga, Mumbai - 400019

E-mail : karticksamanta@gmail.com

Abstract

Wet chemical processing of textile causes significant water pollution. Approximately, 100 lits of water is used to process 1 kg of textile, which is finally discharged as an effluent contaminated with unutilized dyes, pigments, and other hazards chemicals. Due to the more environmental awareness, textile industries are now slowly moving towards the implementation of water-less (dry) or low water based processing technologies, such as digital printing, spray & foam finishing and plasma processing. Plasma, an ionized gas, can be used for nano-scale surface engineering of polymeric (textile) substrate without using water as a processing media. In this study, cellulosic cotton and jute textiles were plasma treated in an indigenously developed atmospheric pressure cold plasma reactor in presence of helium (He), He/O_2, He/N_2, and He/air gaseous. Plasma was generated at a discharge voltage of 5 kV and frequency of 18-23 kHz in between the two aluminium rectangular electrodes. Optical emission spectra (OES) showed the ionization of He and strong atomic lines at 705 nm, 655 nm, 587 nm, 666 nm & 725 nm. Similarly in He/air plasma, the atomic line of oxygen was observed at 776 nm. After the plasma treatment, cotton and jute became more hydrophilic. In the plasma treated cotton, water took only 420s for 8 cm wicking in the vertical direction compared to 482s in the untreated sample. Similar in jute, water absorbency time significantly decrease to 3s compared to 90s in the untreated sample. Water contact angle decreased from ~110° in the untreated samples to ~0° in the plasma treated jute samples. The ATR-FTIR spectra showed the appearance of two new peaks correspond to aldehyde and -CH stretching in addition with change in intensity of the other peaks in the plasma treated samples. In the plasma treated cotton sample, surface roughness was increased significantly and it was measured in terms of co-efficient of friction. The untreated sample showed the co-efficient of friction of 0.171 and it significantly increased to 0.336 (96% increase) in the helium (He) plasma treated sample. Similar results were observed when the samples were plasma treated in the presence of He/O_2, He/N_2, and He/air gaseous mixture. AFM micrograph also showed similar result. SEM-EDX spectra showed that in the plasma treated cotton textiles there was 2-4% more oxygen than the untreated sample due to possible formation of hydrophilic molecules. Similar result was also observed under secondary ion mass spectrometry (SIMS) analysis. After plasma treatment there was no significant change in tensile properties of the cotton sample.

IP-237

Plasma Assisted Destruction Of Volatile Pollutants Using Dielectric Barrier Discharge Technique

S. Mohanty[1], S.P. Das[1*], R. Paikaray[2], G. Sahoo[2], S. Samantaray[2]

[1]Department of Chemistry, [2]Department of Physics,
Ravenshaw University, Cuttack-753003, Odisha

E mail: dassmrutiprava@yahoo.in

Abstract

Volatile aromatic compounds like benzene, chlorobenzene, toulene, xylene are inflammable and having adverse effect on living organisms. Benzene is carcinogenic in nature; and volatile aromatic compounds have severe medical side effects & these VOC are the byproduct of several paint and chemical industries. So, in industries and laboratories we need effective and economic process to destroy these hazardous compounds. Plasma assisted destruction of volatile pollutants like benzene, chlorobenzene, toulene, xylene are studied using dielectric barrier discharge (DBD) technique. In this work we report the decomposition of volatile aromatic pollutants using DBD reactor [1] at the plasma research laboratory at Department of Chemistry, Ravenshaw University. We have observed that the breakdown starts at 3.0 kV, 2.7 kV, 3.0 kV, 3.8 kV for benzene, chlorobenzene, toulene, xylene respectively. The glow region starts at 14.5 kV, 11.5 kV, 14 kV, and 13 kV respectively in the presence of helium plasma. In this glow region large numbers of electrons have been produced by ionization/excitation of helium. Interestingly, the bond dissociation energy of C-H bond in benzene is ~ 390 kCal/mol [2], in toulene is ~ 77.5 kCal/mol, in xylene 77.5 kCal/mol [3] and the bond dissociation energy of C-Cl bond in chlorobenzene is ~ 399.19 kCal/mol [4]. So, it is expected that chlorobenzene should dissociate at slightly higher voltage than benzene and other compounds at appreciable lower voltages. But, it is observed that chlorobenzene dissociate at comparatively low voltage i.e.at 2.7 kV and glow discharge starts at ~ 11.5 kV. This may be because, since the electron affinity of Cl is appreciable, as soon as the chamber is filled with helium plasma, Cl gets ionized hence detached from chlorobenzene and becomes neutral recombining with free electron in the plasma. Again, for benzene maximum current is drawn i.e. 0.67 A and for chlorobenzene it is lower than benzene i.e. 0.41 A. This may be because the chlorine ions get detached from chlorobenzene which acts as scavenger of the free electrons. So, less current, destruction of pollutants like chlorobenzene is achieved by using DBD reactor. It is a useful technique to destroy volatile compounds like chlorobenzene etc. The I-V characteristic curve of the volatile aromatic compounds is very interesting features which is reported in this work.

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IP-277

Non-Thermal Atmospheric Pressure Plasma Jet On Bio-Medical Application

Abhijit Majumdar,† Vishal Jain, Chiruya Patil, Akshay Vaid, Subroto Mukherjee
FCIPT Division, Institute for Plasma Research A10-B, GIDC, Gandhinagar - 382044
E-mail : abhijit_majumdar2005@yahoo.com

Abstract

Atmospheric pressure plasma jets offer a unique environment in plasma medicine, allowing treatment of soft materials, including biomaterials such as living tissues [1-4]. We report the development of a simple atmospheric pressure plasma jet (APPJ) which offers the plasma plume temperature is about 50 ^{0}C to 70 ^{0}C. The mechanism underlying this non-thermal discharge, however, remains unsettled that it has been often taken as resulting from dielectric barrier discharge or vaguely referred as streamer like. In the present research work, the plasma jet of Ar is formed between two metallic electrodes at mid frequency range (50 to 150 kHz). The ignition voltage is about 1 kV, 100 mA but it is sustainable even at 700 V, 80 mA with the executed power is about 30 W across the plasma. The plasma plume length is about 7 mm which can vary with gas flow and applied voltage.

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IP-280

Development And Characterization Of Iron Aluminide Coatings By Thermal Plasma Spray Technique Of Aluminum Powders On Mild Steel Followed By Subsequent Annealing And Evaluation Of Its Erosion Behavior

R.Sahoo[1], S.Mantry[2] and B.B.Jha[*]

[1]Surface Engineering Department, [2]Design and Rural Technology Department
CSIR – Institute of Minerals and Materials Technology, Bhubaneswar – 751013

E-mail: bbjha@immt.res.in

Abstract

Iron aluminides are of interest for applications in power generation from fossil fuels due to their attractive properties such as high specific strength, high specific stiffness, good wear resistance, and excellent high temperature oxidation as well as corrosion resistance in aggressive environments (i.e. Sulfur containing atmosphere) and are considered as potential replacements for high temperature structural steels. The iron base composition ensures relative cheapness, while the high aluminum contents leads to significant density reduction over commercial steels. However, with FeAl compound, as in the case of other intermetallics, the industrial application of this alloy has been limited due to its relatively low room temperature ductility as a result of high hardness and brittleness. Although these problems can be alleviated to some degree by appropriate alloying element additions, it has proven difficult to formulate an alloy with both good creep resistance and low-temperature ductility. Significant effort has been devoted over the past few years to develop iron

aluminides as coatings to make use of their excellent oxidation and corrosion properties while accepting that processing to bulk shapes is difficult and the poor strength/ductility/creep characteristics are insufficient for fabrication into components. In the present work, plasma spraying of aluminum powders on mild steel and subsequent annealing has been carried out to deposit different type of iron aluminides on mild steel substrate in order to utilize its excellent wear and corrosion resistance at elevated temperature in the form of coating. While annealing of the mild steel substrate with plasma spray deposited Al layer at 700 ^{0}C and 800 ^{0}C yielded a Fe_2Al_5 layer on the surface, annealing at 900 ^{0}C generated FeAl as a dominant phase on the surface. Solid particle erosion tests have been carried out using a sand blast type test rig following a well planned experimental schedule based on Taguchi's orthogonal arrays. This study also evaluates the influence of independent control factors such as type of iron aluminides, impact velocity, impingement angle, and erodent size on solid particle erosion behavior of developed Iron aluminide coatings using statistical approach. With the help of signal to noise ratios and analysis of variance (ANOVA), effect of control factors on the solid particle erosion behavior of developed Iron aluminide coatings will be discussed.

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IP-281

Implementation Of Taguchi Design For Performance Evaluation Of Plasma Sprayed Nano-Structured YSZ Coatings

S.Mantry [1], B.B.Jha [2] and R.Sahoo[2]

[1]Design and Rural Technology Department, [2]Surface Engineering Department, CSIR – Institute of Minerals and Materials Technology, Bhubaneswar – 751013

E-mail: bbjha@immt.res.in

Abstract

Nanostructured YSZ coatings were developed using atmospheric using plasma spraying technique by optimizing process parameters. NiCrCoAlY bond coats were applied on Inconel 718 substrates by HVOF. To achieve retention of nanostructure, molten state of nano-agglomerates (Temperature & Velocity) has been monitored using particle diagnostics tool. The microstructure and mechanical properties of sprayed coatings were studied. FESEM results revealed that morphology of coating exhibits bimodal microstructure consisting of nano zones reinforced in the matrix of fully-molten particles. XRD pattern of coating shows tetragonal zirconia and average grain size of as-sprayed YSZ coatings is ~50-80 nm. This article also depicts the dependence of mechanical properties of nanostructured YSZ coatings on process parameters and effect of those process parameters on performance output has been studied using Taguchi's L_{16} orthogonal array design. Particle velocity, Torch to Base distance and Particle temperature are found to be most significant parameter affecting the bond strength. Maximum adhesion strength of 40.56 MPa has been found out by selecting optimum levels of selected factors. The improved mechanical behavior is mainly due to dense,

packed structure of coating and higher interfacial toughness due to cracks being interrupted by strong adherent nano-zones.

IP-286

Exploring The Problem Of Screening Length In Plasma Transport Properties

S. Ghorui and A.K. Das

Laser and Plasma Technology Division, Bhabha Atomic Research Center, Mumbai-400085

E-mail : srikumarghorui@yahoo.com

Abstract

The thermodynamic and transport properties of plasma are indispensable prerequisite for any investigation in plasma chemistry and plasma processing. Charge-charge interactions play the most dominant role in influencing these properties in the plasma state. Collisions happen under pure coulomb potential when the colliding particles are sufficiently close. However, a modified potential (screened Coulomb potential) is experienced by them due to screening by the surrounding charge cloud as their separation increases. Associated collision integrals for computation of transport properties under pure coulomb potential are known for their divergences due to long range nature of the coulomb interaction. A cut off for the range of interaction is necessary to keep the integrals finite. While initially different means like uncertainty principle, inter-ionic distance etc. were tried to put a cut off, later the Debye shielding length (λ_D) was found to be a better choice. A relatively more appropriate method was introduced by Liboff in which pure coulomb potential was used for ranges much smaller than λ_D and shielded coulomb potential was used for the ranges beyond that. We show that the choice of the different forms of λ_D, used by different workers in the field, have significant impact on the computed transport properties of the plasmas. While some do not include the effect of the ions in the shielding, some result in negative collision integrals when higher charge states are involved. Transport properties computed using one form, differ significantly from the same computed using the other forms. Whether only the electrons or both electrons and ions should be considered to participate in the shielding stayed as an unsolved problem over more than half a century. When wide variations are involved in two choices, one needs to be clear about which one to accept and which one to reject. Resolving this issue is extremely necessary for further progress in plasma CFD simulation, especially in the regimes of higher temperature and higher thermal non-equilibrium.

The present study derives a simple set of expressions for collision integrals under charged-charged interactions and demonstrates its potential to deliver thermodynamic and transport property values in close agreement with experimentally realized values for range of processing plasmas. Demonstrates that the definition of shielding length including both electrons (at T e) and ions (at T i) may result in negative integral values for active species present in the plasma and therefore not acceptable. It is pointed out that the fact that mismatch of theoretically computed property values with experimental data is consistently observed at higher temperatures when shielding is considered through electrons only. A new definition of screening length is introduced which includes the effect of both electrons and ions in the shielding but considers only one temperature T_e. Impacts of the use of different screening lengths including the proposed one on the computed properties under two-temperature consideration have been brought out with specific reference to nitrogen plasma.

IP-287

Thermodynamic Properties of CVL Lasing Medium

S. Ghorui, and A. K. Das

Laser and Plasma Technology Division, Bhabha Atomic Research Center, Mumbai-400085

E-mail: srikumarghorui@yahoo.com

Abstract

CVL lasers find wide application in the areas of medicine, microscopy, machining, material processing, molecular pumping, atmospheric probing, navigation and many others. Apart from usual green and yellow line emission, CVL systems are also capable of lasing in the UV near 250 nm from Copper ions. The first step to optimize performance of such systems is to acquire the knowledge of composition of the gaseous lasing media under different operating conditions. Optimising gain volume, gas pressure, tube impedance, copper vapour density, buffer gas density, input power and stabilized output power are some of the interlinked quantities, best understood through theoretical modelling. The present paper develops a theoretical model of the gaseous lasing media of CVL laser and determines its composition and thermodynamic properties as a function of temperature, pressure and thermal non-equilibrium.

A CVL lasing media primarily consists of copper vapour with neon as buffer gas. Tungsten is included in the system from the observation that tungsten anode pins of the CVL discharge tube get substantially eroded as the discharge continues. Impurities that may creep in from the ceramic enclosure are not considered. Species density and other thermodynamic properties are computed for a 13 species model of gaseous media. Accounted constituents are: Ne, Ne^{+}, Ne^{++}, Ne^{+++}, Cu, Cu^{+}, Cu^{++}, Cu^{+++}, W, W^{+}, W^{++}, W^{+++} and e^{-}. The species are generated through nine independent reactions formulated through Saha/Guldebarg-Waage equations. Another four equations, required for solution, are derived from total pressure, charge neutrality, assumed mass fraction of copper and assumed mass fraction of tungsten. A simultaneous solution of these 13 equations gives the number densities of all the 13 species. Associated rate equations are properly evaluated from respective partition functions. Necessary ionization energy and energy level-degeneracy data for estimating the partition functions are taken from latest NIST data tables. Once the composition is known, the associated thermodynamic are computed from standard thermodynamic relationships under different degrees of thermal non-equilibrium, pressures, temperatures and mass fraction of copper and tungsten. Results are presented for pressure ranging from 50 mbar to 3 bar, electron temperature ranging from 300K to 30000K and thermal non-equilibrium (T_e/T_h) ranging from 1 to 10. The results are compared with published data under local thermodynamic equilibrium (LTE) regime and an overall good agreement is observed.

IP-288

Performance Study of Hafnium Cathodes under Different Current Ratings, Nozzle Diameters, and Plasma Environment

K.C. Meher, S. Ghorui, S.N. Sahasrabudhe and A.K. Das

Laser and Plasma Technology Division, Bhabha Atomic Research Center, Mumbai-400085

E-mail : kcmphy@gmail.com

Abstract

Thermal plasma torches function as the key devices for numerous processing applications like plasma cutting, welding, melting, surface treatment, waste treatment, nano-synthesis etc. Plasma torches with hafnium electrodes find a special place in this because of its ability to operate with all types of gases including oxidizing, non-oxidizing, chemically inert as well as active environment including air. Operation with air not only reduces the processing cost but also offers an attractive option for application in plasma pyrolysis and incineration for direct reduction. However, its efficient utilization has always remained restricted due to its short cathode life owing to high erosion rate. Relatively low melting point of hafnium, flow driven droplet ejection and thermal evaporation are found to be the primary mechanisms of cathode erosion.

Most of the earlier works relating hafnium electrodes are concerned with plasma arc cutting torches that primarily involve oxygen as plasma gas. Almost no studies are reported on erosion of such electrodes for operation under air, argon, and nitrogen environment. Nevertheless, such studies are very much important to check viability of application of such electrodes in other areas of plasma processing. While it has been observed that major cathode erosion occurs during events like start up and shut down, change in the operating condition like gas flow and current are also found to affect the same. Advanced cathode engineering backed up by simulation allowed us to reduce the erosion rate for such cathodes drastically. The present study gives an account of experimental erosion studies of hafnium electrodes together with measured efficiency as a function of arc current, plasma generating gas, and nozzle diameter. Achieved extremely low erosion rate even in crude oxidizing environment like atmospheric air plasma, establishes these electrodes as promising candidates for high power application areas, so far unexplored.

IP-318

Plasma Spray Coating Of Yttrium Oxide On Graphite Substrates For Compatibility Studies In Molten Metals

Y.Chakravarthy, A.Pragatheeswaran[b], S.Bhandari, Vandana, P.V.A.Padmanabhan, A.K.Das

L&PTD, Bhabha Atomic Research Centre, Mumbai 400 085
[b]Dept. of Physics, Karunya University, Coimbatore 641 114

E-mail: chakri@barc.gov.in

Abstract

Yttrium Oxide has been effectively used against corrosion by molten Uranium because of its low solubility and good thermodynamic stability [1][2][3][4]. Results of Plasma Sprayed Yttrium Oxide coatings for protection of graphite parts towards molten Uranium are reported in this paper. The coating was done by using 40kW Atmospheric Plasma Spray Coating System (APS). The coatings deposited at a power level of 22 kW were observed to have good mechanical properties with less porosity.

Corrosion studies of Yttrium Oxide coated graphite with molten Uranium were carried out by Differential Thermo gravimetric Analysis (DTA) of Yttrium Oxide-coated Graphite-Uranium couple from room temperature to 1200^{O}C for 2 hours under vacuum (10^{-6}bar). The coatings were removed and cross sectioned samples were observed under SEM and EDX. The coating was intact after the experiment and there is no carbon dissolution found in Uranium. The EDX result shows that, there is no Uranium penetration in to the coating. The Uranium found is below the detection limit of EDX indicating that the coatings offer adequate protection to the substrate against Uranium corrosion.

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IP-329

Experimental And Simulation Studies For Optimisation Of Plasma Spraying Of Yttrium Oxide Powder

S.Bhandari[a], T.K.Thiyagrajan[a],Y. Chakravarthy[a], S.N.Sahasrabudhe[a],N. Tiwari[a], A.Pragatheeswaran[c],A.Khanna[b], P.V.A. Padmanabhan[a], A.K. Das[a]
[a]laser And Plasma Technology Division ,Bhabha Atomic Research Centre, Mumbai-400085
[b]Department Of Chemical Engineering,IIT Kanpur, UP-208016
[c]Center For Research In Material Sciences And Thermal Management. Karunya University, Coimbatore -641114
Email : subhb@barc.gov.in

Abstract

Yttium oxide coating by virtue of its excellent thermal property and chemical stability shows very strong resistance to high temperature and corrosive environment. Present paper presents extensive experimental and simulation work for optimised process parameters of yttria coating in Ar-N_2 plasma. Simulation studies on temperature field, velocity field and species transport between Ar-N_2 plasma and entrained air have been reported. Temperature and velocity profiles of yttria particle have been calculated assuming dilute loading condition. The velocity and temperature of yttria particles have been experimentally determined by using Spray watch imaging system. Calculated values of velocity and temperature of yttria particles are found to agree fairly well with the experimentally measured values.

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IP-332

In-Flight Particle Characteristic And Microstructure Of $SrZrO_3$

A Pragatheeswaran[a], Subhankar Bhandari, Y Chakravarthy, Vandana C, Nirupama Tiwari, S N Sahasrabudhe, T K Thiyagarajan, P V Ananthapadmanabhan, A K Das
[a]Department of Physics, Karunya University, Coimbatore – 641114
L&PTD, Bhabha Atomic Research Centre, Mumbai- 400085
Email : pvananth@barc.gov.in

Abstract

State-of-art atmospheric plasma spraying (APS) technique is generally used for ceramic coatings due to the high enthalpy and temperature available in the plasma jet. The injected spray grade powder particles are rapidly melted, accelerated and propelled at a particular velocity to the substrate [1,2].

Many parameters are involved in plasma spraying that determine the quality of the coatings. Diagnostics of these parameters are used to obtain reproducibility and consistency of the plasma spray coating. In-flight particle behavior is one of the most important parameters to achieve worthy microstructure of plasma sprayed deposit. By virtue of the low thermal conductivity, high melting point, high chemical and thermal stability, ceramic coatings have been of special attention in modern science and technology industries.

Strontium zirconate($SrZrO_3$)is a potential material for thermal barrier coating and has thermal properties similar to yttrium stabilized zirconate (YSZ) [3]. In this study, SparyWatch 2i system was used to study the in-flight behavior of $SrZrO_3$ particles in atmospheric thermal plasma jet for different torch input power levels of 16, 20, 22 and 24kW with various standoff distances of 60, 80 and 100mm. The resultant coating microstructures, deposition efficiency was also examined. Among the various process parameters, input plasma power is the most important one that affects coating microstructure and other properties. It was seen that the in-flight particle temperature increased with increase in power. Porosity of the coating reduced noticeably with increasing input power. Overall experimental results showed that less porosity and high deposition efficiency of the coatings were obtained for power at 24kW and standoff distance 80mm respectively. Details od the results will be presented in the paper.

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IP-339

Experimental Results at High PRF Of Indigenously Developed 25kV/5kA Pseudospark Plasma Switch

B. L. Meena, U. N. Pal, Mahesh Kumar, Dharmendra Kumar, R. P. Lamba and Ram Prakash

CSIR-Central Electronics Engineering Research Institute (CEERI), Pilani 333031, Rajasthan-

E-mail : blm2430@gmail.com

Abstract

The Pseudospark switch (PSS) is a low-pressure gas discharge based plasma switching device used as a bipolar closing switch in high-power pulsed systems. It finds wide applications for driving pulsed laser systems, crowbar systems, pulse modulators, accelerators, etc. [1]. At present these switches can hold very high voltages up to ~100kV, conduct peak current up to ~100 kA for pulse widths ranging from hundreds of nanoseconds to tens of microseconds [2].

The development of such plasma switches started in India at CSIR-CEERI in 1995. First a moderate hydrogen thyratron was developed to use it in copper vapor laser systems with rating 25 kV hold-off voltage, 1kA peak current, 1-5 nanoseconds Jitter, 5-10 kA/microsecond di/dt and up to 10 kHz Pulsed Repetition Rate (PRR). Later the development of 40 kV, 3 kA peak current, 1-5 nanosecond Jitter, 5kA/microsecond di/dt and up to 200 Hz PRR deuterium Thyratron was started to use this technology in pulsed modulator and Linac, which has been completed successfully. The work on

Pseudospark switch (PSS) dates back to late 1999. Recently CSIR-CEERI has developed a 25 kV/5 kA sealed-off pseudospark switch. This paper presents the switching performance at high pulse repetition frequency (PRF) of sealed off pseudospark switch (25kV/5kA). Switching behavior has been observed at different anode voltages and we achieved ~1.08 kA discharge current at 13.5kV applied voltage and at 50Hz PRF in hydrogen atmosphere (37 Pa) and the obtained testing results of the developed PSS meet the designed parameters. The results of these efforts will be presented.

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IP-371

Measurement Of Ionization Efficiency Of Inductively Coupled Plasma Ion Source

Ranjini Menon and P. Y. Nabhiraj

Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata-700064

E-mail : ranjini@vecc.gov.in

Abstract

An indigenously developed inductively coupled plasma ion source is in operation at VECC which is capable of generating high current beam of all gaseous elements [1]. The ion source is being used for different applications such as, development studies on plasma ion source based Focused ion beams, Ion beam sputter deposition for synthesis of single and multilayer thin films and development of high current ion source for accelerators. Several techniques were utilized to improve the performance of the ion source in terms of energy spread, current density, angular current density and emittance [2, 3, 4]. Here in this article, we report the measurement and analysis of the ionization efficiency (η) of the ion source. Ionization efficiency is the ratio of ion beam extracted from the ion source to the neutral particle flux fed into the ion source. The particle flux into the system is measured accurately using a calibrated gas dosing valve. The current extracted from the ion source is measured using a secondary electron suppressed Faraday cup. η for various gaseous beams was studied. Highest η of > 25 % is measured for the heavier gases like Kr and Xe owing to their lower ionisation potential and little inferior efficiency of about 15% for Ar. Improvement in η by 1.5 -2 times for all the gases was obtained by reducing the volume of the plasma by half. Reduction in plasma volume facilitates higher power density coupled to the plasma and thereby increasing the ionization. There is still a scope to improve the ionization efficiency by optimizing the extraction system.

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IP-386

Investigation Of The Role Of Shroud Gas In DC Non-Transferred Arc Plasma Torch

Yugesh. V[1,2], Gavisidayyah Hiremath[1], G. Ravi[2], and K. Ramachandran[1]

[1]*Karunya University, Coimbatore, Tamil Nadu 641114*
[2]*Institute for Plasma Research, Gandhinagar , Gujarat 382428*

E-mail: yugeshv@gmail.com

Abstract

Dc non-transferred arc plasma torches have received considerable attention due to their high heat flux applications. A low power (~10−15 kW) dc non transferred arc plasma torch with different stabilization mechanisms has been used in our experiments with nitrogen as working gas at atmospheric pressure. Two distinct gas feed systems are incorporated in the torch design, one the plasmagen gas which is fed axially and the other which is fed like a shroud that engulfs the axial gas coaxially. A comparison is made with and without the shroud gas while the plasmagen gas is always on. The results indicate that besides keeping some key components safe and cool and away from the hot gas or plasma, the shroud gas has a key role to play in the torch electro-thermal efficiency and also the operation itself. The torch was operated over a wide regime of gas flows (0 - 60 lpm) with or without keeping a feeble external magnetic field on. It is observed that in the presence of shroud gas the efficiency of the torch is increased. It is speculated that the thickness of the cold gas boundary layer may be restricting the heat to the anode. Preliminary numerical results also vindicate the experimental results. Detailed results and a physical picture of the processes will be presented.

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IP-394

Development Of An Efficient UV-B Mercury Free Plasma Based Light Radiating Source

Pooja Gulati[1], U N Pal[1], M. Kumar[1], Vimal Vyas[2] and Ram Prakash[1]

[1]*CSIR-Central Electronics Engineering Research Institute, Pilani, Rajasthan-333031*
[2]*Banasthali University Banasthali-304022, Rajasthan*

E-mail: pgulati1512@gmail.com

Abstract

The excimer formations in plasma have great potential and can lead to develop plasma based incoherent UV light sources [1]. In fact, applications of ultraviolet light, over the years, have become very important and find several applications in electronics, chemical reactions, multilayer techniques, medical treatments and many more. Several methods have been developed to generate excimers, such as, dielectric barrier discharges (DBDs), high-energy electron beams, x-rays interaction, through synchrotron radiation, microwave discharges, etc. [1-2]. Although several methods have been researched, the DBD methods have found huge potential for industrial applications because of their simplicity, high efficiency and low cost. Hence we have developed a single barrier DBD tube of quartz with multi-strip gold-tin coatings on the tube surface, which acts as anode for the formation of excimer between the anode strips and centrally placed helical electrode for efficient UV-B light radiation. The generation of excimer radiation from the mixtures of the rare-gas Xe together with chlorine and with Cl_2 and Air admixture have been investigated. For this the characteristics emission spectra, centered at 308 nm, have analyzed using UV-monochromator at different pressures and frequencies using a pulsed power source. The influence of the chlorine and air content in the mixture and the effect of total gas pressure have been critically examined. It is found that in the admixture of Xe and Cl_2, the addition of air increases the radiation of UV-B-308 nm even at lower pressure, which would be cost effective method for this specific wavelength emission in the DBD based technologies. This specific UV-B light radiation is highly applicable for

long-term treatment of many ill-skins and certain fungal growths under the toenail can also be treated using this specific wavelength and can be safer than traditional systemic drugs.

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Plasma Processing (PP)

PP-046

Surface Modification Of Polyvinyl Chloride (PVC) By Grafting TiO_2/PVP (Poly Vinyl Pyyrolidine) To Enhance Its Blood Compatibility And Anti-Bacterial Property Dc Glow Discharge Plasma

A.Suganya[1], M.Kiruthika[1], E.M.Koushika[1], V.Udhayakumar[2], and G.Shanmugavelayutham[1*]

[1]*Plasma Physics Laboratory, Department of Physics, Bharathiar University, Coimbatore-641046*
[2]*Department of Zoology, Bharathiar University, Coimbatore-641046*

E-mail: velu197@yahoo.co.in

Abstract

Polyvinyl chloride (PVC) film were treated by DC glow discharge plasma with TiO_2/PVP coating in order to improve blood compatibility of the surface of polyvinyl chloride (PVC), thus cross linking TiO_2/PVP and PVC film together. The surface properties of untreated and plasma treated PVC film with TiO_2/PVP grafted on it were investigated by water contact angle measurement, weight loss study and Fourier Transform Infrared Spectroscopy (FTIR). The surface topography of PVC films was observed by Atomic Force Microscope (AFM) which exhibits the significant change as a result of the plasma treatment and subsequent grafting process. In Blood compatibility, functional group of TiO_2/PVP grafted on the PVC were investigated using *in vitro* thrombus formation and the result were observed by Scanning Electron Microscope (SEM) and optical microscope. This present an investigation shows that the plasma modified PVC with TiO_2/PVP exhibits better blood compatibility and antibacterial properties against *E.coli* and *S.Aureus* than without modification of PVC.

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PP-047

Surface Modification And Anti-Bacterial Activity Of Polyester Fabrics By Using Non-Thermal Plasma Mode

M. Kiruthika[1], A. Suganya[1], E.M. Koushika[1], T.Priya[2] and G.Shanmugavelayutham[1]

[1]*Department of Physics, Plasma Physics Laboratory, Bharathiar University, Coimbatore-641046*
[2] *Department of Bio-Technology, Bharathiar University, Coimbatore-641046*

E-mail : velu1976@yahoo.co.in

Abstract

Plasma treatment has become very popular for improvement of antibacterial activity in various materials in recent times. In my study natural fibers are very susceptible to bacterial attacks.Various antibacterial finishes have been developed to control the bacterial growth.The aim of this paper is to enhance the antibacterial activity of Air and Argon plasma treated polyester fabrics.The treated polyester fabrics were tested for its antibacterial activity against bacterial strain like *Escherichia*

coli(E.coli).The result indicates that the treated polyester fabric shows a clear zone of inhibition in the agar diffusion test. The hydrophilicity of fabric was also remarkably improved after plasma treatment were determined bywicking rate and contact anglemeasurement.The function analyses of plasma treated samples were characterized by FTIR and the surface morphology of the sample were analyzed by SEM.Further the plasma operating parameters for better performance were analyzed and optimized.

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PP-067

Experimental Setup For Producing Tungsten Coated Graphite Tiles Using Plasma Enhanced Chemical Vapor Deposition Technique For Fusion Plasma Applications

Sachin Singh Chauhan[1], Uttam Sharma[1], A. K. Sanyasi[3], K K Choudhary[1], Jayshree Sharma[2], J. Ghosh[3]

[1] *Department of Physics, Shri Vaishnav Institute of Technology and Science, Baroli, Sanwer Road, Indore -453331*

[2] *Department of Physics, M.B. Khalsa College, Indore 452009*

[3] *Institute for Plasma Research, Bhat, Gandhinagar 382 428*

E-mail : druttamsharma1971@gmail.com

Abstract

Plasma wall interaction (PWI) in fusion grade machines puts stringent demands on the choice of materials in terms of high heat load handling capabilities and low sputtering yields. Choice of suitable material still remains a challenge and open topic of research for the PWI community. Carbon fibre composites (CFC), Beryllium (Be), and Tungsten (W) are now being considered as first runners for the first wall components of future fusion machines. Tungsten is considered to be one of the suitable materials for the job because of its superior properties than carbon like low physical sputtering yield and high sputter energy threshold, high melting point, fairly high re-crystallization temperature, low fuel retention capabilities, low chemical sputtering with hydrogen and its isotopes and most importantly the reparability with various plasma techniques both ex-situ and in-situ. Plasma assisted chemical vapour deposition is considered among various techniques as the most preferable technique for fabricating tungsten coated graphite tiles to be used as tokamak first wall and target components. These coated tiles are more favourable compared to pure tungsten due to their light weight and easier machining. A system has been designed, fabricated and installed at SVITS, Indore for producing tungsten coated graphite tiles using Plasma Enhanced Chemical Vapor Deposition (PE-CVD) technique for Fusion plasma applications. The system contains a vacuum chamber, a turbo-molecular pump, two electrodes, vacuum gauges, mass analyzer, mass flow controllers and a RF power supply for producing the plasma using hydrogen gas. The graphite tiles will be put on one of the electrodes and WF6 gas will be inserted in a controlled manner in the hydrogen plasma to achieve the tungsten-coating with WF6 dissociation. The system is integrated at SVITS, Indore and a vacuum of the order of $3*10^{-6}$ is achieved and glow discharge plasma has been created to test all the sub-systems. The system design with all sub-system specifications for creating plasma leading to manufacturing of coated tiles will be presented in details in this paper.

PP-146

Effect Of Localized Surface Resonance On The Growth Of Carbon Nanowalls: Inference From Langmuir Probe Diagnostics

R. Kar[1], N.N. Patel[2], S. Mukherjee[1], A.K. Das[1] and D.S. Patil[1]

[1]*Laser and Plasma Technology Division, Bhabha Atomic Research Centre, Mumbai- 400 085*
[2]*High Pressure and Synchrotron Radiation Physics Division, Bhabha Atomic Research Centre, Mumbai- 400 085*

E-mail : rajibkar@barc.gov.in

Abstract

Carbon nanowall (CNW) is a two-dimensional nanostructure consisting of graphene sheets which stand on the substrate like a wall. It is shown that CNWs can be used as a good catalyst support structure for fuel cell, as the negative electrode for lithium ion battery. Moreover, because of its high surface area and high aspect ratio, the field-emission capabilities of CNW are also comparable to CNT. We have recently grown CNWs by catalytic ECR-CVD process by using Ni as catalyst.

The novelty of the deposition process is that we have been able to grow CNWs by ECR-CVD without application of any external bias [1]. Generally an electrical substrate bias (-50 to -200 V) is used during growth of any carbon nanostructures in ECR plasma as it is thought to be essential for enhancement of ion bombardment energy to attract more positive species without causing sputtering effect. Since our investigations revealed that electrical bias is not necessary for the growth, it was necessary to find out the reason for it. During SEM observations of CNWs we have found some indications which revealed that localized surface plasmon resonance (LSPR) might be responsible for the growth. We then experimentally investigated the formation of Ni nanoparticles during pre-treatment with varying experimental parameters. Metal nanoparticles are associated with LSPR but normally believed that Ni nanoparticles cannot generate LSPR in normal conditions due to high value of imaginary part of dielectric constant. To understand if favourable conditions for LSPR in Ni do exist in plasma, we have done Langmuir probe diagnostics in ECR plasma to calculate EEDF and electron temperature of plasma. During analysis of the results we have found out that there is indeed a realistic possibility where LSPR is possible in Ni particles inside ECR plasma. We have formulated an electrostatic model for it. This paper will give a detailed discussion on the growth procedure of CNWs by ECR-CVD without application of any external bias and how growth mechanism of a particular nanostructure can be understood in terms of plasma diagnostics.

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PP-154

Synthesis Of Carbon Encapsulated Magnetic (Fe/Fe_3C) Nanoparticles (CEMN) Optimized For Biomedical Applications

N. Aomoa and M. Kakati

Thermal Plasma Processed Materials Laboratory,
Centre of Plasma Physics-Institute for Plasma Research, Sonapur – 782 402

E-mail: ngangomaomoa@yahoo.com

Abstract

This paper reports the synthesis of Carbon Encapsulated Magnetic (Fe/Fe_3C) Nanoparticles (CEMN), by thermal plasma expansion technique [1], with properties optimized for biomedical applications. Magnetic nanoparticles, when protected from oxidation by encapsulation, ideally with carbon, have vast application potential, with biomedical applications being an important one. CEMNs can be used for targeted drugs delivery, annihilation of the cancerous cells through hyperthermia and in Magnetic Resonance Imaging (MRI). For such applications, super-paramagnetic materials with particle size in the range of 50 – 300 nm is strictly demanded and desired [2, 3]. Materials with mesopores are also highly desirable for drug delivery.

CEMNs were synthesized from ferrocene ($FeC_{10}H_{10}$) in a DC plasma torch assisted thermal plasma reactor. Raw and purified samples were thoroughly characterized with HRTEM, SAED, XRD, VSM, XPS, Raman, BET, DLS, Mossbauer and TGA to study the morphology, elemental and phase composition, magnetic properties etc. Single crystal, spherical iron and carbide nanoparticles, well encapsulated by crystalline graphene sheets, were formed with core particles having average size less than 10 nm and a very narrow size distribution, one of the best by a thermal plasma process. The magnetic phases were identified to be α-Fe and Fe_3C with saturation magnetization in the range of 30-75 emu/g at room temperature with magnetic properties tending towards super-paramagnetism. But the CEMNs were agglomerated into clusters in the size range of 40 – 400 nm which also contained mesopores. These characteristics are ideal for biomedical applications. It is seen that by changing the chamber pressure, the core particles size can be controlled thereby extending control over the magnetic properties of the samples. Purification of the raw samples by acid treatment could effectively remove unwanted oxides from raw samples. OES studies were also conducted to better understand the plasma chemistry and CEMN formation process.

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PP-212

Treatment Of Waste Water By Electric Discharge

Sita Dugu[1] and Deepak Prasad Subedi[2]
[1]*Sanothimi Campus, Sanothimi, Bhaktapur, Nepal*
[2]*Department of natural Science, Kathmandu University, Dhulikhel, Nepal*
Email: sita.dugu@yahoo.com

Abstract

Electric discharge in air was produced between pointed steel electrodes and water electrode by applying a high voltage (up to 18 kV). This discharge was used for the treatment of waste water of three different sources: domestic, dairy and dye industry of Bhaktapur Industrial Sector, Bhaktapur, Nepal. The main objectives of the study were to study the electric and optical properties of the discharge and to investigate the effect of the discharge on the physicochemical and biological properties of treated water.

The first part of the work consists of the electrical and optical characteristics of the discharge. The electrical measurement was made by high frequency digital oscilloscope. The current waveform of the discharge showed that there are several spikes in each half cycle of the waveform. These spikes indicate the existence of micro-discharge in the system. The optical spectra were analysed in the range of 200-800 nm using an optical spectrometer. The spectra showed that the discharge was dominated by emission from different excited states of nitrogen in the air. The UV radiation plays a role in the formation of ozone required for the treatment of water.

In the second part of the work, estimation of the ozone concentration and analysis of the different parameters of untreated and treated waters were carried out. The treatment of water was much more convenient by this method due to the presence of different radiations and shock wave within the discharge. Different parameters (pH, conductivity, total solids, dissolved oxygen, chemical oxygen demand, metals, coliforms) were analysed before treatment and after treatment. Analysis of parameter showed that the DO was increased after treatment but COD, TS, Fecal coliform, heavy metals and conductivity were significantly reduced. There was no significant change in the value of pH and color.

PP-216

Surface Modification Of Si Wafer By Argon Ion Plasma For Solar Cell Application

Narendra Kumar Agrawal[1], Bhawna Bagra[2], Y. K. Vijay[3], K. C. Swami[1]
[1]*Department of Physics, Malaviya National Institute of Technology, Jaipur 302017*
[2]*Centre for converging Technologies, University of Rajasthan, Jaipur-302004*
[3]*Department of Physics, University of Rajasthan, Jaipur-302004*
E-mail : research.nka@gmail.com

Abstract

Recently silicon wafers are receiving grate interest for the synthesis of multilayer solar cell. Life and efficiency of these solar cells are also depends on adhesion of these multilayer on Si surface. Hence a systemic study has been carried out to characterize the effect of low temperature Ar ion plasma treatment for surface modification of silicon wafers. Surface of silicon wafers are modified by low temperature Ar ion plasma treatment and surface modifications are characterized by UV-Vis, SEM, and atomic force microscope (AFM). Conductivity of Si wafers before and after plasma treatment

were calculated by measuring I-V characteristic, which shows significant variation with plasma treatment time.

PP-223

Synthesis And Properties Of Pulse DC, RF Plasma Polymerized Aniline And Plasma Polymerized Aniline-Ag Composite Thin Films

Tapan Barman, Arup R. Pal, Joyanti Chutia
Physical Sciences Division, Institute of Advanced Study in Science and Technology, Paschim Boragaon, Guwahati–781035
E-mail : tpnbarman33@gmail.com

Abstract

Plasma polymerization of aniline is carried out by means of continuous RF and pulse DC glow discharge plasma in a common reactor at different applied powers. Plasma polymerized aniline (PPAni) – silver (Ag) composite thin films are prepared by simultaneous DC magnetron sputtering and continuous RF plasma polymerization of aniline. The optical emission spectra (OES) of the glow discharge are recorded during the film growth in order to study the role of fragmentation of the molecular structure on the structural, optical, morphological and optophysical properties of the deposited layers. Retention of the conjugated structure is found to be prominent at lower applied power to the plasma in both the continuous RF and pulse DC polymerization techniques [1]. Retention of conjugated structure and effect of Ag doping are investigated in the plasma polymerized aniline Ag composite thin films. The Polyaniline-Ag composite film is found to be decorated with Ag nano particle of size 5 to 30 nm. A decrease in conjugated structure and increase in chain length have been observed in both the continuous RF and pulse DC PPAni thin films with the increase in applied power to the plasma. Almost similar chemical structure and surface morphology are observed at the same applied power density in both cases. Optical band gap of pulse DC PPAni is found to remain fixed approximately at 3.6 eV, while in the continuous RF PPAni thin films a decrease in optical band gap from 3.61 to 2.62 eV is recorded due to the increase in chain length with increase in power [2]. The plasma polymerized aniline and PPAni-Ag composite thin films are found to emit photoluminescence due to band to band transition and defects.

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PP-247

Radio Frequency Thermal Plasma Synthesis of Nano Crystalline Yttium Oxide

G. D. Dhamale[a], S. Ghorui[b,*], S. N. Sahasrabudhe[b], V. L. Mathe[a,*], S.V. Bhoraskar[a] and A. K. Das[b]
[a]*Department of Physics, University Of Pune, Pune-411007*
[b]*Laser and Plasma Technology Division, Bhabha Atomic Research Center, Mumbai-400085*
E-mail : gdhamale@gmail.com

Abstract

Inductively coupled radio frequency plasma synthesis of nano-materials near atmospheric pressure is one of the clean and attractive routes for achieving high production rate. It has added advantage over conventional dc thermal plasma synthesis because of its larger volume, higher purity, and narrower size distribution through better precursor containment via central feeding. In recent days, nano-structured yttrium-based metal oxides received special attention because of their excellent thermo-

mechanical properties and thermodynamically stable crystal structure. They are widely used as host material for phosphors and constituents of ceramic laser media like YAG. In this study, we report RF thermal plasma synthesis of yttrium oxide (Y_2O_3) nano-particles and their characterization.

Synthesis of yttrium oxide is carried out in a 3 MHz, 30 kW inductively coupled atmospheric pressure RF thermal plasma reactor. Argon is used as plasma forming gas, sheath gas as well as carrier gas. The unit consists of an oscillator circuit, RF- torch followed by bottom chamber unit, heat exchanger unit, cyclone chamber, filter cartridge assembly, vacuum pump, and a process-cooling unit. During synthesis, coarse grain (micron size) powder is fed axially near the top edge of the plasma ball, which subsequently enters inside the plasma, gets melt, evaporated, atomized, and finally becomes a part of the plasma itself. A steep temperature gradient, existing in the tailing edge of the plasma forms the nano-particles through nucleation and quenching. The synthesized particles, deposited in different regions of the reactor, are collected, labeled, and characterized in terms of their phase, purity, size distribution, morphology, and elemental composition. Different characterization techniques used in the analysis are X-Ray Diffraction (XRD), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), Fourier Infra-Red Spectroscopy (FTIR) and BET specific surface area analysis.

Nano-particles, collected at the sidewall of the bottom chamber possesses mixed cubic and monoclinic phase. However, the particles deposited over the filters exhibit only monoclinic phase as revealed from XRD result. The particles collected from the inner wall of the torch and in the base portion of bottom chamber are found to be in cubic phase alone. It is observed from TEM that the nano-particles deposited over the sidewall of the bottom chamber and the filters possess very narrow size distribution around 20-25 nm. Existence of metal-oxygen peak was confirmed by Fourier Transform Infra-Red Spectroscopy. BET surface area analysis gives specific surface area around $40m^2/gm$. Morphology and elemental analysis was done by SEM and EDS respectively. Observed characteristics of the synthesized particles are found to be promising for high end optical and other technological applications.

PP-252

Carbo-thermal Reduction Process To Synthesize TiC From Ilmenite Using DC Extended Thermal Plasma Reactor

Sangita Mohapatra[a], S. K. Singh[a] and D. K. Mishra[b]

[a]Advanced Materials Technology Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar 751005, Odisha
[b]Department of Physics, Institute of Technical Education and Research, Siksha 'O' Anusandhan University, Bhubaneswar 751030, Odisha

E-mail: dilipiuac@gmail.com

Abstract

Thermal plasma processing is a suitable technique to synthesize various high temperature oxide and non-oxide materials within a short duration of time. Considering the advantage of the thermal plasma, titanium carbide (TiC) has been prepared from ilmenite using direct current (DC) extended arc plasma reactor in an argon atmosphere. A mixture of ilmenite and activated carbon was taken in the plasma reactor with a stoichiometry ratio of 1:4 for the carbothermal reduction of ilmenite to TiC. The X-ray diffraction pattern clearly shows that the formation of TiC from ilmenite starts after the plasma treatment of 10 minutes and the complete conversion of ilmenite to Fe-TiC composites occurs after 20 minutes of plasma treatment in an argon atmosphere. However, Fe is present in the final product. The pure form of TiC product is obtained only after the acid treatment. The XRD and

Raman analysis clearly predicts that the acid treated product contains only TiC matrix without having any impurity. The particle size measurement and scanning electron micrograph predicts the average size of the powder is of 10 µm. Hence, it opens a new avenue to synthesize pure TiC powders from ilmenite by the carbothermal reduction process using DC extended arc thermal plasma reactor

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PP-277

Non-Thermal Atmospheric Pressure Plasma Jet On Bio-Medical Application

Abhijit Majumdar, Vishal Jain, Chiruya Patil, Akshay Vaid and Subroto Mukherjee

FCIPT Division, Institute for Plasma Research A10-B, GIDC, Gandhinagar - 382044

E-mail : abhijit_majumdar2005@yahoo.com

Abstract

Atmospheric pressure plasma jets offer a unique environment in plasma medicine, allowing treatment of soft materials, including biomaterials such as living tissues [1-4]. We report the development of a simple atmospheric pressure plasma jet (APPJ) which offers the plasma plume temperature is about 50 ^{0}C to 70 ^{0}C. The mechanism underlying this non-thermal discharge, however, remains unsettled that it has been often taken as resulting from dielectric barrier discharge or vaguely referred as streamer like. In the present research work, the plasma jet of Ar is formed between two metallic electrodes at mid frequency range (50 to 150 kHz). The ignition voltage is about 1 kV, 100 mA but it is sustainable even at 700 V, 80 mA with the executed power is about 30 W across the plasma. The plasma plume length is about 7 mm which can vary with gas flow and applied voltage.

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PP-299

Titanium-Aluminum Co-deposition By Magnetron Sputtering

R. Rane, A. Sanghariyat, C. Jariwala, P. Rayjada, N. Chauhan and S. Mukherjee

FCIPT, Institute For Plasma Research, Gandhinagar 382044

E mail : ramu@ipr.res.in

Abstract

Titanium Aluminum (Ti-Al) alloy coatings are attractive materials for a wide range of applications depending on their deposition conditions and its corresponding obtained properties. In this study, Ti-Al films have been deposited by Physical Vapor Deposition (PVD) using two unbalanced planar magnetrons. Pure Titanium(Ti) and Aluminum (Al) sputtering targets were used for the co-deposition of coatings with varying compositions .It is found that power of the individual target can control the sputtering and hence composition in the film. The coatings were deposited on silicon substrates. The deposited films were analyzed by Energy Dispersive X-ray Analysis (EDAX), X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) in the as deposited and after high temperature annealing, to investigate changes in the structure and phase compositions. The result indicates that during co-sputtering the quasi-amorphous state has been formed and only titanium phases are observed in the coating. As the aluminum content increases crystallanity of the film decreases. After annealing at 800^0C it is found that width of the Titanium peak decreases indicating crystallite size change.

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PP-313

Thermal Plasma Spheroidization Of Aluminium Oxide And Characterization Of The Spheroidized Alumina Powder

V. Chaturvedi, P. V. Ananthapadmanabhan, Y.Chakravarthy, N.Tiwari, A.Pragatheeswaran, A. Nagaraj, A. K. Das

Laser and Plasma Technology Division, Bhabha Atomic Research Centre, Mumbai 400 085

E-mail : vandanachaturvedi15@gmail.com

Abstract

The work describes the spheroidization of Aluminium oxide powder by thermal plasma processing. Trajectories of the particles were seen using high speed camera. Temperature and velocity of the alumina particles exiting the plasma jet were determined online using 'spray watch' system. Characterization of the spheroidized powder was done by scanning electron microscopy and X-ray powder diffraction. Results obtained can be used to select the appropriate power level to melt a large fraction of the powder and optimize spray deposition.

Plasma Processing is a process that combines particle melting and quenching in a single operation. The process involves injection of powder particles (metallic, ceramic or cermet powders) into the plasma jet created by heating an inert gas in an electric arc confined within a water-cooled nozzle [1]. The temperature at the core of the plasma jet is 10,000-15,000 K[2]. Plasma processing was carried out using the 40kW in-house developed atmospheric plasma system. Input DC power to the plasma torch was varied from 08 kW to 20 kW by controlling the arc current. The particles injected into the plasma jet undergo rapid melting and at the same time are accelerated. By virtue of the high cooling rates, typically 10^5 to 10^6 K/sec, the resulting microstructures are fine-grained and homogeneous[2].

Results showed that as the input power to the plasma increased, the extent of particle melting increased as indicated by the larger number of spherical particles. Alumina powder processed at 20 kW showed practically complete melting of the feed powder particles. However, results of x-ray diffraction showed considerable amount of the α-phase indicating that the core of the particles remained un-melted.

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PP-316

Investigation Of Ferromagnetic Behavior In Nanocrystalline ZnO Synthesized By In-flight Thermal Plasma Technique

Jyoshnarani Mohapatra[a], Urmishree Routray, Dilip kumar Mishra[a], and S. K. Singh[b]

Department of Physics, Institute of Technical Education and Research, Siksha 'O' Anusandhan University, Bhubaneswar 751030, Odihsa
Advanced Materials Technology Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar-751005, Odisha

E-mail: jyoshnarani.mohapatra@gmail.com

Abstract

A novel thermal plasma in-flight technique has been adopted to synthesize nanocrystalline ZnO. The X-ray diffraction pattern clearly establishes the wurtzite structure of ZnO without having any impurity phase. The lattice parameter of ZnO nanoparticle is estimated to be a = 3.244 Å and c = 5.198 Å which is close agreement to the reported value. The average crystallite size determined from the X-ray diffraction analysis is of the order of 20 nm whereas transmission electron microscopy (TEM) studies on these samples show the average particle sizes to be around 32 nm for ZnO. The magnetization studies show the room temperature ferromagnetic behavior for pure ZnO nanoparticles having saturation magnetization of 2.7×10^{-2} emu/g with remnant magnetization of 3.8×10^{-3} emu/g and the coercivity of 114 Oe. The development of point defects in form of oxygen cluster is responsible for the room temperature ferromagnetic behavior in nanocrystalline ZnO and the freezing of spins at low temperature gives rise to a spin glass system.

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PP-359

Influence Of Argon Gas Addition On Growth And Properties Of SnO_2 Thin Film By Plasma Assisted Thermal Evaporation

C. Jariwala[1], S. Das[1,2], P. A. Rayjada[1], R. Rane[1], N. Chauhan[1] and P. M. Raole[1]

[1]*Institute for Plasma Research, A-10/B, GIDC, Sector-25, Gandhinagar-382016*
[2]*Department of Physics, Ravenshaw University, Cuttack-753003, Odisha*

E-mail : chetan@ipr.res.in

Abstract

SnO_2 thin films possess very interesting physical properties such as high electric conductivity and large optical transmission in the visible region. Owing to their conductivity and optical transparency, SnO_2 thin films are of great interest in optoelectronics industries as Transparent Conducting Oxide. Addition of Argon (Ar) gas in Oxygen (O_2) plasma significantly improves electrical properties of SnO_2 films deposited by plasma based deposition techniques due to Ar ion bombardment effect.

In present work, the effect of Ar gas addition (10-30 SCCM) on growth of SnO_2 thin films have been studied during deposition by plasma assisted thermal evaporation (PATE) in presence of O_2 RF plasma with lower substrate temperature of 150˚C. The electrical resistivity of the SnO_2 film is 6.52 Ω-cm without Ar gas addition, whereas 0.23 to 1.15 Ω-cm with Ar gas flow of 10-30 SCCM and minimum (0.23 Ω-cm) at 10 SCCM Ar gas flow. Here, oxygen atoms are preferentially sputtered out by Ar ion bombardment during deposition and create oxygen vacancies, results in enhancement of carrier concentration, and hence reduce films resistivities. Surface morphology obtained by Scanning Electron Microscopy revealed the surface smoothening for films grown with Ar gas with respect to films grown without Ar gas. Optical transmittance measurements of the SnO_2 films in the wavelength region of 300-1100nm show the transparency higher than 80% for all films. Whereas, XRD results indicated crystallization caused by Ar ion bombardment with preferred orientation of SnO (101) phase at 31.72 (2 theta value) in case of film grown with Ar gas. Ar gas addition during SnO_2 thin film deposition has improved the electrical and structural properties without degrading optical transparency confirm the importance of Ar ion bombardment effect during deposition.

PP-391

Plasma Modified Polyethylene Based Blends And Composites

Sari P. S[1], Nandakumar Kalarikkal[1,2] and Sabu Thomas[1,3]

[1]*International and Inter University Centre for Nanoscience and Nanotechnology,* [2]*School of Pure and Applied Physics,* [3]*School of Chemical Sciences, Mahatma Gandhi University, Kottayam-686 560, Kerala*

E-mail : sarips1@gmail.com

Abstract

Plasma treatment is an environment friendly process which alters the surface properties without changing the intrinsic bulk properties. The modification of polymer surfaces is of enormous importance in today's chemical industry. The surface properties of the polymer can be changed dramatically on plasma modification [1]. This can result in an increase in the number of scientific studies on the surface modification of polymers with the aim of developing new materials that combine desirable bulk (elasticity, strain, vitrous transition temperature etc.) and surface properties (acid-base behavior, hydrophilicity) [2]. Plasma treatment generates wide range of reactive species in the treated system (carbonyl, carboxyl, ether, peroxides etc.) as well as improves its surface microhardness and surface roughness [3]. Usually plasma modification of polyethylene (PE) is used to improve its printability, adhesion to metal, protein absorption. Here we have tried to use plasma modified PE for preparing natural rubber blends and composites.

Plasma modified blends and composites have been prepared by melt mixing and two roll mill mixing methods. The cure characteristic, morphology, mechanical properties and cross link density of these blends and composites have been systematically studied. From the studies done, it was found that plasma modified polyethylene showed poor polymer filler interactions, while two roll mill mixing was found to be more beneficial in improving the properties of the composites. The results from bound rubber content and the cross link density measurements were also comparable. A further study to improve the polymer filler interaction was done by introducing a compatibilizer and it was found that the presence of compatibilizer improved the polymer-filler interaction significantly.

The PE-NR composite prepared using two roll mill mixing and the PE-NR blend prepared by melt mixing method were characterized by measuring their mechanical properties, morphology, cure behaviour and by plotting the Kruas plot, to know the polymer-filler interaction. The studies were done based on modification and preparation method. Cure characteristics like cure time, scorch time and cure rate index of the NR-PE composites with unmodified and modified PE ,prepared using two roll mill was studied in detail. Although there is an improvement in the mechanical properties like tensile strength, tensile modulus and elongation at break for the modified PE composites, comparatively better properties were shown by unmodified PE composites. A study based on the preparation method showed that NR-PE composite prepared using two roll mill mixing showed better properties compared to NR-PE blends prepared using melt mixing method.

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Pulsed Power
(PU)

PU-005

Study Of Discharge Characteristic Of Exploding Wire

Rashmita Das, Basanta Kumar Das and Anurag Shyam

Energetics and Electromagnetics Division, BARC, Visakhapatnam-530012

E-mail : rashmita78@gmail.com

Abstract

Wire explosion is a simple method of generating plasma column in a dense gas, which can be used for further experimental work or for direct study of the properties of the dense plasma. In the discharge of exploding wire (EW), the conductor changes into dielectric. The vapor produced by an exploding wire is highly ionized and may be used as a plasma source. In our work a capacitor of 7.1 microfarad was charged to different voltages to study the behavior of exploding wire. Current flowing in the circuit is guided by LCR circuit and should match the burst condition. Inductance of circuit obtained from ringing curve is 700 nano hennery. In this process the wire heats up with joules heating. First it melts, vaporizes and converted to plasma . For lower voltages the voltage across the wire increases with the increase of vapor resistance. After reaching to burst condition it drops suddenly due to developed plasma channel making resistance to zero. So voltage and current shows the trend of increasing and reaching to peak and then decreases to zero. But in higher voltages there is a breakdown of remaining vapors due to voltage spike developed across the inductance of circuit. So Current waveform shows re-striking portion.

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PU-070

Optimization and Characterization of Surface Discharge Switches

Jigyasa Batra, Ashutosh Jaiswar, T.C Kaushik and S.C Gupta

Bhabha Atomic Research Centre, Trombay, Mumbai-400 085

E-mail: jigyasa@barc.gov.in

Abstract

Surface Discharge Switches (SDSs) are used to reduce inductance and erosion in applications of very high value of currents like kilo amperes to mega amperes. Experimental work has been carried out to develop and characterize the performance of a SDS. The SDS is characterized by varying different parameters like length of switch electrodes, discharge surface, trigger position and triggering voltage pulse. Inductance, resistance, closing time and jitter are experimentally found for SDSs of different dimensions. But life time is not so good because dielectrics used as surfaces have to be replaced after a particular number of shots for consistent performance. Shot life differs for different dielectrics. In our experiment, two knife edged brass electrodes of width 15mm and thickness 4mm were bolted on dielectric of thickness 2.4mm. Gap between two electrodes was 15mm. Different dielectric surfaces

of Kepton, Mylar, Perspex and Fiber glass have been used to see their effect. For triggering the SDS, trigger wire (insulated) is used and a pulse of 56 kV with rise time of 20 ns is provided from available blumlein. Trigger position is at the centre of insulator surface between two electrodes. Different lengths of electrodes have been used to see the effect of length on parameters like inductance and resistance of switch. Minimum inductance has been observed in self closing mode i.e around 9nH, 3nH, 7nH for electrodes of length 50mm, 100mm and 150mm respectively. Switch inductances in triggered mode have also been measured. Inductance first decreases with length of electrodes then reaches a minimum then increases again with increase of length of electrodes. There is an optimum length of switch electrodes for which inductance has minimum value. Resistance has been found in the range of around 130-160 mΩ in all length of electrodes. Jitter is around 50-70ns. Switch closing time has been observed about 150ns. It has been observed by noting the voltage drop across the switch with TEKTRONIX probe P6015A with response time of 4ns. Work is underway for designing and implementing the SDS in 500 kA application in our Lab.

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PU-071

Investigations On Electrically Exploded Conductors For Current Pulse Sharpening Applications

Soumya P. Nayak, M.D. Kale, T.C. Kaushik and Satish C. Gupta

Applied Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai-400 085

E-mail : spnayak@barc.gov.in

Abstract

Kilo-Ampere level high current pulses with rate of current rise of 10^{12} A/s and above are useful in variety of applications such as generation of high temperature plasma to serve as pulse fusion [1] or X-Ray source [2], hypervelocity projectiles [3-4] etc. Such pulses have been conventionally generated using capacitor based energy storage devices and a closing switch. However, such systems become relatively difficult to design and develop for generating current pulses having sub-microsecond level rise times in loads. As an alternate method, we have attempted to use using electrically exploding conductors (EEC) in conjunction with inductive storage system to generate fast current pulses. This system has been used to successfully sharpen microsecond rise time current pulses from relatively slow capacitors into nanosecond rise time pulses. The experiments and results obtained have been described here.

Initially energy is stored in energy storage capacitor which is switched into a series combination of inductor and EEC using a triggered spark gap. Load is connected in parallel with EEC, initially separated by a peaking gap. High current flowing in EEC leads to its Ohmic heating and causes the conductor to undergo rapid explosion. Consequently, its electrical resistance increases rapidly, interrupting the current flowing through it. This leads to generation of high voltage across the EEC and electrical breakdown of peaking gap. Inductor releases energy stored in it into load thereby generating fast rising current in it. In our experiments, aluminum foils have been used as EEC. Readily available low inductance load has been used. Keeping other circuit parameters like capacitance, inductance, thickness of aluminum foils, its length, peaking gap and load inductance constant, width of the foil have been varied and its effect on load current was observed. Current discharged by the capacitor having quarter cycle time of 3.7 μs was sharpened using these foils and a typical current of 40kA has been generated across the load with rise time of 440 ns with peak rate of current rise of the order of 10^{11}A/s. It has also been observed that upon increasing the width, peak current in the load reduces but with increased rate of current rise.

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PU-077

Effect Of Electron Emission Pattern On Vircator Performance

Gursharn Singh, Sijoy C.D. and Shashank Chaturvedi

Bhabha Atomic Research Centre, Visakhapatnam-530012

E-mail : gursharn@barc.gov.in

Abstract

Axially-extracted Virtual Cathode Oscillators (vircators) have traditionally been used as pulsed sources of high-power microwaves in the GHz frequency range. In our earlier work, we had self-consistently calculated the electron emission pattern assuming field emission from a perfectly smooth cathode (“standard case”). This implies two simplifications. Firstly, surface roughness on the cathode gives rise to emission from a few micro-points on the surface. Secondly, the high current densities at these points lead to explosive emission.

In the present work, we attempt to quantify the error introduced by the first simplification. This has been done using a locally-developed three-dimensional, relativistic, electromagnetic, particle-in-cell (PIC) code called MWS.

For this sensitivity study, we have used three models. The first is a single point (computational cell) with higher probability of electron emission. The second is a set of points lying on a ring. The third is a fixed number of points with random locations lying anywhere on the cathode. The study shows that, compared to the “standard” case, a ring-like pattern with higher probability generally shows an increase in output microwave power, while a random selection generally yields a decrease in radiated power. For example, in one of the “random” simulations, the power was reduced by 50%.

Details of the simulations, the limitations of the model and the major results will be presented in the paper.

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PU-110

Effect Of Foil Parameters On Flyer Velocity In Electrically Exploding Foil Accelerators

A. K. Saxena, M. G. Sharma, T. C. Kaushik and Satish C. Gupta

Applied Physics Division,Bhabha Atomic Research Centre, Trombay, Mumbai – 400 085

E-mail: a_saxena@barc.gov.in

Abstract

Electrical explosion of thin metallic foils are commonly used for generating confined high pressure plasmas to accelerate small diameter dielectric flyers to high velocities [1] and is a well known technique for shock research [2]. The rate of current rise and burst current density has strong influence on flyer velocity [3], so even capacitor banks with small energy can accelerate appropriate size flyers to high velocities if low inductance capacitor bank and optimized foil dimension are chosen. As the inductance of the capacitor bank cannot be reduced beyond a practical value, therefore optimization of exploding foil parameters becomes significant for a given system. The flyer is accelerated by both hydrodynamic and magnetic forces. When the contribution by magnetic forces are relatively small, an empirical model proposed by Tucker & Stanton [4], based on Gurney [5] formulation is found to provide a good match to the experimentally observed final velocities of the flyer. In present work we have theoretically as well as experimentally investigated the effect of foil parameters on flyer velocity. Empirical constants of electrical analogue of Gurney formulation are determined by experimentally measuring the flyer velocities at different burst current densities on 8kJ exploding foil accelerator system [6] using a Fabry-Perot velocimeter. A numerical code based on false position algorithm is written in FORTRAN to calculate burst current densities for different foil thicknesses or widths using equation of action integral for a given capacitor bank. Using these current densities in Gurney relation, flyer velocities are calculated for different foil dimensions. Which indicates that for a given foil width, flyer velocity saturates after a certain foil thickness and to achieve higher velocities it is preferable to use foils of relatively lesser width and higher thickness. Experimental measurements have been carried out to verify the outcome of numerical simulations. Flyer velocities have been measured for foils of different dimensions and faster rise in velocity have been observed for foils of relatively smaller width and higher thickness. Flyer velocity up to 6.1 km/sec has been recorded on Kapton flyers of diameter 6 mm and thickness 140 μm.

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PU-124

Compact Pulsed Power System For Pulsed Microwave Generation

Surender Kumar Sharma, P Deb, R Verma, R Shukla, P Banerjee, T Prabaharan & A Shyam

E&ED, Bhabha Atomic Research Center, Visakhapatnam- 530012

E-mail : surender80@gmail.com

Abstract

A compact 0.5 GW pulsed power system is designed and developed for pulsed high power microwave generation. The compact pulsed power system has a primary energy storage, which charges the intermediate energy storage system and then further discharges into the load. The primary energy storage system has a capacitor bank of 1.2 uF/ 25 kV. The intermediate storage has a tesla transformer and a helical pulse forming line (PFL). The tesla transformer is single turn primary made up of 1 mm copper sheet and 28 turn secondary made of stripped RG 213 cable with tapered construction which charges the helical pulse forming line to 200 kV. We have designed a helical PFL which has higher inductance as compared to coaxial PFL, which in turns increases, the pulse width and reduce the length of the PFL. The helical PFL inner conductor is made of SS-304 strip rolled on delrin cylinder and outer conductor is made of SS-304 cylinder. The length of the PFL is 800 mm. The PFL inner strip is 0.5 mm thick and 39.5 mm wide rolled on the 168 mm delrin cylinder. 13 turns are wounded on delrin cylinder and the inter turn gap is 20.5 mm. The outer cylinder is 2mm thick and has internal diameter of 232 mm. The volume between the inner strip and outer cylinder was filled with deionised water circulated through a pump and deionizer unit. The impedance of the helical PFL is 22 Ω. The compactness is achieved in terms of reduction in length of the PFL by a factor of 5.5 using helical water PFL as compared to coaxial water PFL of same length [1, 2]. Deionised water dielectric medium is used because of its high dielectric constant, high dielectric strength and efficient energy storage capability. The time dependent breakdown property and high relative permittivity of water makes it an ideal choice for low impedance coaxial system. The effect of reduction in the water temperate on the pulse width is also experimentally studied from 5 ^{0}C to 25 ^{0}C and it was found that the pulse width increases by 7% by reducing the temperature of water to 5 ^{0}C which makes the system further compact [3]. The short duration, high power pulse with fast rise time and good flattop is applied to vacuum field emission diode for high power microwave generation. In this paper we will discuss the design details, modeling and experimental results of compact pulsed power system for pulsed microwave generation.

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PU-126

Estimation Of Plasma Stream Parameters In A Pulsed Plasma Accelerator

S. Borthakur[1], P. Sah[1], N. K. Neog[1], T. K. Borthakur[1], R. Kumar[2], R. Verma[3], A.Shyam[3]

[1]*Centre of Plasma Physics- Institute for Plasma Research*
Nazirakhat, Sonapur-782402, Assam
[2] *Institute for Plasma Research, Bhat, Gandhinagar -382 428*
[3]Energetics & Electromagnetics Division, *Bhabha Atomic Research Centre, Visakhapatnam -530012*

E-mail : sbcppipr@gmail.com

Abstract

A pulsed-plasma accelerator is being developed at CPP-IPR. The system consists of a co-axial electrode assembly where plasma stream of density 10^{22} m^{-3} is created in the annular space at the close end of the assembly. A 15 kV discharged voltage from a capacitor bank is applied across the electrode assembly which breaks down the gas present in the system and creates the plasma. The plasma, once created, is accelerated towards the open end of the electrode system and moves to a target chamber at a supersonic velocity due to J×B force. The parameters of the accelerator such as plasma stream velocity, self generated magnetic field, magnetic pressure, etc are numerically simulated by using MATLAB programming. The simulated results shows generation of a self-generated magnetic field of peak value 0.26 T, when a tailored damped sinusoidal high current pulse (300 kA), having time period of 0.5 ms, is applied across the electrodes. The maximum velocity attained by the plasma stream is found to be of the order of 10^7 cm/s. The variation of the magnetic field and magnetic pressure in the system is also analyzed in the simulation work. This simulation will give out values that can be used in designing the pulsed plasma accelerator.

PU-130

Design And Development Of 200 KJ Energy Pulsed Power System To Drive Pulsed Plasma Devices

S. Borthakur[1], N. K. Neog[1], T. K. Borthakur[1], R. Kumar[2], R. Verma[3], A.Shyam[3]

[1]*Centre of Plasma Physics- Institute for Plasma Research*
Nazirakhat, Sonapur-782402, Assam
[2] *Institute for Plasma Research, Bhat, Gandhinagar -382 428*
[3]Energetics & Electromagnetics Division, *Bhabha Atomic Research Centre, Visakhapatnam -530012*

E-mail : sbcppipr@gmail.com

Abstract

A 200 kJ pulsed power system (PPS) is being developed at CPP-IPR. In general, the conventional high voltage pulse power system is basically for producing fast output pulses (time periods of few microseconds) according to their uses. In contrast to that, the newly designed pulsed power system at CPP-IPR will produce pulses of relatively longer duration (time periods of several tens of micro-seconds to several hundreds of microsecond). The necessary parameters for the system are derived from PSpice simulating software. The PPS consists of 10 capacitors of rating 178μF, 15 kV each. This PPS is charged to 15 kV using full charging technique. The PPS is designed for delivering a

peak current in the range of few hundred of kilo ampere to a load (resistive and Inductive) for a time period of 1.0 ms. In simulation, results for different inductive and resistive loads were verified and the most efficient values are used in the developing system. A 10 mΩ system resistance and a 10μH pulse shaping inductor would give out a damped sinusoidal current pulse of time duration 1 ms in the principal waveform and then it will start to damp off with a desired and set damping constant and voltage reversal value. The switch that connects the supply and the driving device should be able to bear high Coulomb transfer. This cannot be achieved using normal connecting-disconnecting switches rather electrical switches such as ignitrons, thyratron etc. of very high coulomb rating and capable of withstanding high voltages at its electrodes must be used. The detailed design procedure will be presented. This PPS can be able to drive various energetic pulsed Plasma Devices, Thrusters, etc.

PU-131

Study On Neutron Emission From PF Device Using Two New Anode Shapes

N. Talukdar, N. K. Neog, S. Borthakur, T. K. Borthakur

Centre of Plasma Physics- Institute for Plasma Research, Nazirakhat, Sonapur-782402, Assam

E-mail : nayan.cpp@rediffmail.com

Abstract

The neutron emission from a 2.2 kJ Mather-type plasma focus, is investigated in deuterium medium by using two different shaped anode tips namely oval and converging tip along with the conventional cylindrical anode tip. Correlation of the emitted neutrons with ions and X-ray emission is also attempted. Two numbers of PMTs are used simultaneously in axial and radial direction of the pinch plasma column to acquire the data of neutron emission in both the directions. A Faraday cup is used to measure the ion emission and a vacuum photodiode is used to measure the X-ray emission. Along with the PMTs, two bubble dosimeters are used to measure the total neutron count in axial and radial direction. It has been observed that there is a strong correlation between hard X-ray and neutron emission. It has been observed that the hard X-ray pulse corresponding to an intense neutron pulse is relatively a smaller pulse while the smaller neutron pulses corresponds to very intense hard X-ray pulses in most of the PF discharges. The inverse relation on the intensity of neutron pulse with that of hard X-ray pulse is new to the neutron emission phenomena from PF and is thought to be due to the current abruption in pinch formation. The detail results will be presented.

PU-133

Design And Development Of Fast Pulser For Initiating Multichannel Breakdown In Railgap Switch

Rishi Verma, Ekansh Mishra, Rohit Shukla, Karuna Sagar, Manraj Meena and A. Shyam
Energetics & Electromagnetics Division,
Bhabha Atomic Research Centre, Autonagar, Visakhapatnam 530012
Email: rishiv@barc.gov.in

Abstract

The design, construction and operational characteristics of a transmission line transformer (TLT) based trigger generator that is capable of initiating multichannel breakdown in a high voltage, low inductance railgap switch is reported. Railgap switches are high voltage gas discharge switches normally used in high-energy capacitor banks to enable large coulomb transfers in distributed mode.

The performance of railgap switch critically relies upon multichannel breakdown between the extended electrodes (rails) in order to ensure distributed current transfer along electrode length and to minimize the switch inductance. The initiation of several simultaneous arc channels along the switch length depends on the gap triggering technique and on the rate at which the electric field changes within the gap. In our case, the consequently imposed stringent requirement on the trigger pulse was that it must have a fast rate of rise >5kV/ns and high peak voltage, largely exceeding the main gap voltage (i.e. typically in the range of 10kV– 40kV).

The aforesaid criteria of the trigger pulse characteristic has been fulfilled by the innovatively designed cable based three-stage TLT. In each stage three identical lengths of cables have been used in parallel and they have been wounded in separate cassettes to enhance the isolation of the output of the transformer from the input. The input and output impedance of the transformer is ~5.5Ω and 50Ω respectively. The primary capacitance of ~8nF has been used to minimize the droop while the transmission lines are being charged. At -16kV of primary charging, the TLT produces ~80kV output pulse of 50ns duration (FWHM) with rise time of better than 10ns (10% – 90%). This corresponds to voltage gain efficiency of >80% and *dV/dt* of ~8kV/ns. The uniquely defined 50Ω output impedance of the TLT based trigger generator facilitates transport of trigger pulse to switch without any distortion in its temporal characteristics.

PU-153

High Power Microwave Generation by a Reflex Triode Vircator

Biswajit Adhikary, R.Verma, R. Shukla, S.K.Sharma, P.Banerjee, R Das, P Deb,T Prabaharan, BK Das and Anurag Shyam

Energetics and Electromagnetics Division, Bhabha Atomic Research Centre, Visakhapatnam,

E-mail: biswajitadhikary@yahoo.com

Abstract

A reflex triode type virtual cathode oscillator was studied experimentally. Reflex triode has higher efficiency and can run with longer pulse lengths [1]. The design of Reflex Triode with an impedance of 20ohm will be described. Reflex triode has been directly driven by a compact fast Marx generator [2]. Study of Reflex Triode has been done with different types of cathodes like velvet cloth, graphite electrodes and circular array of pins. The anode consists of a round wire mesh with ~70% transparency through which the electron beam passes, generating a dense cloud of negative charge known as a virtual cathode. High Power Microwave output was measured in single shot operation at 20 kV charging with the *A-K* gap set to 10 mm. The experiments were carried with typical electron beam parameters of 140kV, 7kA and 170ns rise time. The whole experimental setup and diagnostics for HPM measurement will be discussed.

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PU-230

Setup Of MPP Capacitor Bank And Time Delay Circuit For The Electromagnet Of Compact Plasma System At Ravenshaw University

S. Samantaray[1], R. Paikaray[2], G. Sahoo[2], P. Das[2], D. C. Patra[2], N. Sasini[2], J. Ghosh[3], A. Sanyasi[3]
[1]*Christ College, Cuttack- 753008, Odisha*
[2]*Ravenshaw University, Cuttack-753003, Odisha*
[3]*Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat*
E mail: samantaray.subrata@gmail.com

Abstract

To simulate the plasma blob motion in a tokamak edge/SOL like situation we need a plasma chamber with electromagnet. These studies will address burning issue of particle transport as blobs in tokamak edge as well as in SOL. In this paper we report the set up of an electromagnet using metalized poly propylene (MPP) capacitor bank for the Plasma Chamber at Ravenshaw University. The electromagnet is capable of producing a pulsed magnetic field inside the plasma chamber. The magnetic field strength at the centre of plasma chamber i.e. 0.1 m from the mouth of plasma source is ~ 0.0238 T for input current ~ 120 A. The pulse width is ~ 1.7 ms. The radial profiles of field strength at different discharging potential/input current obey ~ 1/R fall as expected. The theoretical and experimental values are comparable. It is observed from probe and imaging techniques that the plasma discharge takes a few ms to initiate after triggering. Therefore, we have fabricated and tested a variable time delay circuit so that the magnetic field is created simultaneously in the chamber with the discharge.

PU-265

High Power Microwave Generation From Axially Extracted Virtual Cathode Oscillator Using Kali-1000 Pulse Power System

N. Satyanarayana[1], Shibaji Basu[1], Nitin Waghmare[1], Sachin Chavhan[1], Sunil Swamy[1], Samir Sahoo[1], Bijayalaxmi Sethi[1], Ramanand Raman[1], Rishi Verma[3], Rohit Shukla[3] R.K. Rajawat[1], K.C. Mittal[2] and A. Durga Prasada Rao[4]

[1]*Accelerator & Pulse Power Division, Bhabha Atomic Research Centre, Vishakapatnam-530012*
[2]*Accelerator & Pulse Power Division, Bhabha Atomic Research Centre, Mumbai-400085*
[3]*Energetics & Electromagnetics Division, Bhabha Atomic Research Centre, Vishakapatnam-530012*
[4] *Department of Nuclear Physics, Andhra University, Vishakapatnam-530003*
E-mail: satya_3026@yahoo.com

Abstract
Experiments were carried out to generate intense relativistic electron beams and High Power Microwaves (HPM) with axial **Vir**tual **Ca**thode Oscilla**tor (Vircator)** geometry from Kali-1000 pulse power system. Kali-1000 pulse power system is a low impedance high voltage generator, consisting of Radial Tesla-transformer to step up the voltage from "30 kV to 350 kV in 5 μs to store the energy in a coaxial DM water line of 4 Ohm characteristic impedance. Line is pulse discharged by a self triggered pressurized SF_6 closing switch across a Relativistic Electron Beam (REB) diode load. Experiments were carried with a REB diode consisting of graphite cathode and SS anode mesh. The typical electron beam parameters were 300 kV, 15 kA, and 100 ns, with a current density of a

few hundreds of amperes per square centimeter. Particle-in-Cell (PIC) simulation has been performed for a set of Vircator experiments being driven by the Kali-1000 system. Experimentally measured Cathode current, dominant output frequency, radiation pattern, etc, have been compared with simulation results. We present a power optimization study of the HPM generated from the axially extracted vircator for various anode–cathode (AK) gaps. A double ridged waveguide horn antenna setup with diode detector and attenuators was used to measure the microwave power. The HPM frequency was measured with a B-dot probe along with a high band width oscilloscope. The major operating output frequencies have been measured to be 5.8 GHz & 6.2 GHz within a range of 4.8 – 6.7 GHz. The estimated beam to microwave power conversion efficiency is thereby found to be 1.1%. The dominant emission mode from the virtual cathode oscillator is shown to be the TE01 mode based on the emission pattern of microwave induced air breakdown in this experiment.

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PU-300

Capacitive Pulsed Power Driver For Electromagnetic Launchers

Pankaj Deb and Anurag Shyam

Energetics and Electromagnetics Division, Bhabha Atomic Research Centre, Visakhapatnam 530012

E-mail : pankajdeb24@gmail.com

Abstract

High energy density energy storage capacitors are used in capacitor banks having energy density 1-2 J/cc for their millisecond discharge time and are used in driving electromagnetic rail gun launchers. A 20 kJ, 1100 volt capacitor driven Pulse Forming Network (PFN) system has been designed and developed for electromagnetic rail gun application.

The capacitor driven PFN system can deliver 30 kA of pulsed peak current, 2 ms duration to the electromagnetic rails with a rail resistance of 9 mΩ. An electromagnetic rail gun of rail length 450mm with barrel dimension 10mm x 7mm has been built. The paper describes the electromagnetic rail gun system with pulse conditioning system and its experimental results.

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PU-307

HPM Development At IPR For Plasma Physics Applications

Rajesh Kumar, Saurabh kumar, Nasir Shah, Anitha V. P., Renu Bahl and Anurag shyam.

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

E-mail : rkumar.lboro@gmail.com

Abstract

Recent years, the studies of High power electromagnetic wave particularly microwave or laser propagation in plasma has attracted much attention because of its importance in many practical areas.

At IPR, an experimental system “SYMPLE” is recently conceived to investigate the physics of interaction of extremely intense e.m. waves ($eE_{em}/m\omega_{em} \sim c$) with an over dense ($\omega_p > \omega_{em}$) plasma. The study of such experiments remained constrained for a long time due to limited availability of High power required resources as well as limitation of diagnostic access but the advent of high power microwave (HPM) sources have opened a new arena of investigations.

VIRCATOR and Relativistic magnetron are two real contenders for the required HPM source both works on fast high voltage electrical discharge system. Virtual cathode is a nonlinear state, which develops when the electron beam injection current exceeds the space charge limiting current (defined by beam energy and wave guide geometry) and whose oscillations can generate high power microwaves. Whereas Relativistic magnetron works on the principle of gyration of electron in presence of high magnetic and electrical field produced by connected pulsed power.

A compact and repetitive generator based on Tesla transformer for application in plasma opening switch has been developed.. This system is designed to operate with up to 300 kV on water pulsed forming line to generate 40 kA (in short circuit condition), 50 ns pulse, which is further compressed in time with the help of plasma opening switch. Operation of this generator with VIRCATOR (virtual cathode oscillator) as a load will be presented here.

The overall efficiency of VIRCATOR is around 1%, which is far less than efficiency of Relativistic magnetron (around 30%).

Recently IPR has started work on Relativistic Magnetron (RM) for which design is completed and will be fabricated soon. This RM will produce power of the order of 1 GW and frequency in the range of 2-4 GHz.

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PU-317

3-D Particle-In-Cell Simulations For A THz Range Vircator

Gursharn Singh and Shashank Chaturvedi
Bhabha Atomic Research Centre, Visakhapatnam-530012
E-mail : gursharn@barc.gov.in

Abstract

Pulsed, high-power electromagnetic radiation in the Terahertz (THz) range can have several applications, such as the direct excitation of vibrational modes of polar molecules. It is of interest to examine if concepts for high-power microwave sources like vircators, normally operating in the GHz frequency range, can be adapted to operate in the THz range. We had earlier reported on preliminary 2-D PIC simulations to examine this concept. It was found that a device having anode-cathode gaps in the range of 5-10 mm, operating at peak voltages in the range of 0.5-1 kV, with cathode radii ~25 mm, would yield a dominant frequency ~1-3 THz and power levels ~0.5-2.0 MW.

In the present work, we extend the study to three-dimensional, relativistic, electromagnetic, particle-in-cell (PIC) simulations of an axially-extracted vircator using a locally-developed particle-in-cell code called MWS. Two important effects have been observed:

3. With the introduction of asymmetry in the device, the power output degrades very fast as compared to devices in the GHz range. For example, a tilt in the foil by 1 degree with respect to the anode-cathode axis results in reduction in power level by ~8 times. By comparison, in GHz range devices, the corresponding reduction would only be ~1.5 times.
4. In both GHz and THz range vircators, multiple radiation modes can be seen at the output window. In GHz-range devices studied in our work, for small levels of non-axisymmetry, the dominant mode remains symmetric. However, in the THz device studied here, the dominant mode is not symmetric about the axis of symmetry.

Details of the simulations, the limitations of the model and the major results will be presented in the paper.

PU-344

Intense Relativistic Electron Beam Generation Using Explosively Generated Tantalum Cathode Plasma

Romesh Chandra, Ankur Patel, R Menon, R Agarwal, K Senthil, Archana Sharma, K. C. Mittal
Bhabha Atomic Research centre, Trombay, Mumbai 400085
E-mail: romesh@barc.gov.in

Abstract

Relativistic electron beam generation experiments are performed on Linear Induction Accelerator-400 using Tantalum cathode and Stainless Steel Anode in single shot mode as well as at 10 Hz repetition rate. A bipolar flow of current as well as anode plasma generation is observed by comparing the results for diode perveance with the theoretical Child Langmuir law. A better electron beam current duration is observed while using Tantalum cathode due to its lower plasma expansion velocity. The diode voltage is 195 kV and diode current is 2.3 kA. The edge plasma generation effect for the cathode over the electron emission is also considered. The variation in diode emission properties at various operating voltages is also observed.

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PU-396

Experimental Studies Of Radial Multi-Channel Pseudospark Switch

R. P. Lamba[a,b], B. L. Meena[b], U. N. Pal[a,b], D. K. Pal[b], H. Rahaman[b] and Ram Prakash[a,b]
[a]*Academy of Scientific and Innovative Research (AcSIR), New Delhi*
[b] *CSIR-Central Electronics Engineering Research Institute, Pilani*
E-mail : rplamba19@gmail.com

Abstract

The Pseudospark discharge switches (PSS) are low pressure (typically 10 to 100 Pascal) plasma switches which are used for generation of pulse power. The high power PSS, specially with high current rating (≥20 kA), would be of great importance in many emerging areas, such as, pulsed-power switching, mine blasting, rock fractioning, pulse power modulator, laser, radar, etc.[1]. For high current application, the radial channel PSS are the most obvious choice due to homogeneous distribution of plasma discharge in all the radial channels [2]. At CSIR-CEERI, we have already developed a sealed-off 25kV/5kA co-axial PSS, but so far no effort has been made in India to develop high current radial channel PSS. Internationally some theoretical, empirical and simulation studies have been used as a tool to design and develop radial multichannel pseudospark switches for high current applications but still there is no unique method available to design and develop such PSS in the literature.

In this work we report the design and development of a radial multichannel pseudospark switch (RM-PSS), which has been made using laboratory accessories and simple machining skills. In this RM-PSS, the discharge spreads to several discharge channels radially and hence the radial multichannel PSS promises low erosion rate of electrodes and high current rise because of lower inductance. All the channels of the multichannel geometry are simultaneously ignited for homogenous distribution of the plasma discharge among all the channels. Simultaneous ignition of all the linear channels has occurred by placing a high dielectric constant ferroelectric disk inside the cathode cavity. The developed RM-PSS has also been characterized for self-breakdown voltage at varying pressure of argon and hydrogen gas and has been found to obey the Paschen curve. A series of experiments have been performed at different gas pressures to analyze the switching characteristics. The obtained pulse shape and parameters show that this device is suitable for pulse power applications.

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Laser Plasma
(LP)

LP-024

Propagation Of Short Two-Color Laser Pulses In Homogeneous Plasma: Theory And Simulation Of Wakefield Generation

Akanksha Saroch and Pallavi Jha
Department of Physics, University of Lucknow Lucknow 226007
E-mail : akshusaroch@gmail.com

Abstract

The interaction of intense, short two-color laser pulses with plasma can lead to a variety of wave-particle phenomena which includes generation of high order harmonics [1], attosecond laser pulses [2] and Terahertz radiation [3]. Yao *et al.* have theoretically demonstrated the generation of XUV super continuum by optimizing the angle between polarization planes of two color, linearly polarized laser pulses [4].

In the present analytical study, a perturbative expansion of various parameters in orders of $a_i (= eE_i / mc\omega_i$, where $i = 1,2$ represents the parameters of the first and second laser pulses) is used to determine the longitudinal wakefields, generated behind the two linearly polarized laser pulses, in the mildly relativistic regime. The frequency difference between the two laser pulses is taken to be equal to the plasma frequency. The relative angle between the directions of polarization of the two pulses, having sinusoidal longitudinal profile, is varied and the wakefield amplitudes are compared. An enhancement in the amplitudes of longitudinal wakefields, generated by two oppositely polarized laser pulses, compared to that generated with similar polarization directions, is reported. Further, two-dimensional Particle-in-cell simulations using VORPAL code are also conducted to validate the results reported in the analytical study.

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LP-031

Laser Beat-Wave Acceleration In A Relativistic Collision-Dominated Plasma

Maninder Kaur and Devki Nandan Gupta
Department of Physics and Astrophysics, University of Delhi, Delhi-110007
E-mail: maninder.panesar@gmail.com

Abstract

We study the energy exchange between a plasma wave and two co-propagating lasers in a relativistic collision-dominated plasma. Two lasers, having frequency difference equal to the plasma frequency, excite a plasma beat wave resonantly by the pondermotive force, which obeys the energy and

momentum conservation. The relativistic effect and the electron-ion collision both contribute in energy exchange between the interacting waves in the beat-wave acceleration mechanism. Our study shows that the initial phase difference between interacting waves generates a phase mismatch between lasers and plasma wave, which alters the rate of amplitude variations of the interacting waves and, hence, affects the energy exchange between the interacting waves.

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LP-032

Relativistic Second And Third Harmonic Generation Of A Laser In A Self-Sustained Magnetized Plasma Channel

Mamta Singh and Devki Nandan Gupta

Department of Physics and Astrophysics, University of Delhi, Delhi-110007

E-mail : mamtaphysics21@gmail.com

Abstract

Relativistic second and third harmonics of a laser in a magnetized plasma channel is studied. Due to relativistic self-focusing in plasma, a high-intensity pulse laser pushes the plasma electrons radially outward to create a plasma channel. The self-focusing of a high-intensity laser in the presence of a magnetic field is affected significantly. The relativistic mass effect and the magnetic field contribute to the nonlinear dielectric response of the plasma. The self-sustained plasma channel may seriously affect the efficiency of second and third harmonic generation of the interacting laser beam. The velocity and density perturbation associated with the self-focused laser beam can generate a nonlinear current at double and triple fold frequency of the fundamental laser. Our results show that the self-sustained plasma channel and the magnetic field both enhance the efficiency of the second and third harmonic generation of the laser beam.

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LP-033

Magnetic Field Enhanced Plasma Electron Trapping In Laser Wakefield Acceleration

K.Gopal and D. N. Gupta
Department of Physics and Astrophysics, University of Delhi, Delhi-110009
E-Mail: kgopal874u@gmail.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 wavebreaking initiates the electron trapping. After sometime, 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 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 plasma, it pushes out the background plasma electron 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 an applied magnetic field 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.

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LP-034

Effect Of Energetic Electrons On Temporal Evolution Of Stimulated Raman Scattering Of A Laser In Plasmas

Pinki Yadav and Devki Nandan Gupta
Department of Physics and Astrophysics, University of Delhi, Delhi -110 007
E-mail : pinkiyadav864u@gmail.com

Abstract

Stimulated Raman process of a laser in plasmas with energetic electrons has been investigated, where the temporal growth of interacting waves during the Raman scattering process is analyzed.

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 plasmas 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 reduces 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 temporal evolution of the interacting waves.

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LP-035

Relativistic Second and Third Harmonic Generation Of A Laser In A Self-Sustained Magnetized Plasma Channel

Mamta Singh and Devki Nandan Gupta
Department of Physics and Astrophysics, University of Delhi, Delhi-110007
E-mail : mamtaphysics21@gmail.com

Abstract

Relativistic second and third harmonics of a laser in a magnetized plasma channel is studied. Due to relativistic self-focusing in plasma, a high-intensity pulse laser pushes the plasma electrons radially outward to create a plasma channel. The self-focusing of a high-intensity laser in the presence of a magnetic field is affected significantly. The relativistic mass effect and the magnetic field contribute to the nonlinear dielectric response of the plasma. The self-sustained plasma channel may seriously affect the efficiency of second and third harmonic generation of the interacting laser beam. The velocity and density perturbation associated with the self-focused laser beam can generate a nonlinear current at double and triple fold frequency of the fundamental laser. Our results show that the self-sustained plasma channel and the magnetic field both enhance the efficiency of the second and third harmonic generation of the laser beam.

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LP-038

Relativistic Self-Focusing Of Intense Laser Beam In Cold Quantum Plasma Under Plasma Density Transition

Sonu Sen[1], Meenu Asthana Varshney[2] and Dinesh Varshney[3]
[1]*Department of Engineering Physics, Indore Institute of Science and Technology, Indore-453331*
[2]*Department of Physics, M. B. Khalsa College, Indore-452002*
[3]*School of Physics, Devi Ahilya University, Khandwa road Campus, Indore-452001*

E-mail: ssen.plasma@gmail.com

Abstract

This paper presents an investigation of relativistic self-focusing of laser beam in cold quantum plasma, under plasma density transition. The laser beam may acquire a minimum beamwidth due to relativistic self-focusing. Beyond the focus, the nonlinear refraction starts weakening, and the beamwidth of the laser beam increases, resulting in an oscillatory convergence and divergence behavior of the beam with the distance of propagation. To reduce divergence of the laser beam we introduce upward plasma density transition in cold quantum plasma. The beamwidth of the laser beam decreases as the beam penetrates into the plasma and significantly adds self-focusing in cold quantum plasma. This causes the laser beam to become more focused by reduction of diffraction effect, which is an important phenomenon in Inertial Confinement Fusion. It is found that quantum effect and upward density transition plays vital role in laser-plasma interaction and enhances self-focusing of laser beam in plasma as compared to that of normal relativistic case. Employing the expression for the dielectric function for density transitions in cold quantum plasma, a nonlinear second-order ordinary differential equation for beamwidth parameter is derived under WKB and paraxial approximation and solved numerically. Numerical computations and simulations are presented and discussed for typical parameters of laser plasma interaction.

LP-073

Monoenergetic Electron Acceleration From 3TW – 45 Fsec Laser Pulse

Ajit Upadhyay
Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore 452 013
E-mail: ajitup@rrcat.gov.in

Abstract

This article demonstrates quasi-monoenergetic acceleration of electrons to 32 MeV energy in a plasma of electron density $6x10^{19}cm^{-3}$ (λ_p=4.3μm) using a 3TW laser of 45 fsec long pulse length. The long pulse length of laser ($\tau_L >> \lambda_p$) puts it into the self-modulated laser wakefield acceleration (SM-LWFA) regime [1] where one expects a plateau in the spectrum of electron energy. However, our simulation results predict the formation of bubble structure leading to quasi-monoenergetic acceleration of electrons. Two dimensional and three dimensional simulations using the code VORPAL [2] and Virtual Laser Plasma Laboratory (VLPL) [3] show that the long laser pulse not only undergoes strong self-modulation but also develops multiple fragments in transverse as well as longitudinal plane leading to multiple cavity like structures in the initial phase of simulation. At a later stage, a stable cavity (bubble) develops due to a small stable axial fragment of laser pulse of transverse dimension ~ λ_p and spatial dimension < $\lambda_p/2$ being guided for ~40μm. The field inside the cavity is ~1TV/m, leading to quasi mono-energetic acceleration of electron bunch to 32±3 MeV.

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LP-087

Modelling Of Effect Of Self-Generated Magnetic-Fields And Inhibited Thermal Flux On The Terminal Velocity Of Laser-Driven Thin Foils

C. D. Sijoy[1], V. Mishra[1], N. Sakthivel[1], and S. Chaturvedi[1], S. Chaurasia[2], P. Leshma[2] and S. M. Sharma[2]

[1]*CAD, Bhabha Atomic Research Centre, Visakhapatnam*
[2]*HP&SRPD, Bhabha Atomic Research Centre, Mumbai*

E-mail : sijoy@barc.gov.in

Abstract

HP&SRPD has been performing experiments on laser-driven acceleration of thin metal foils, and CAD is performing numerical simulations to understand the dominant physical phenomena. We have numerically investigated the effect of inhibited electron thermal flux and self-generated magnetic fields on the terminal velocity of laser-accelerated thin foils. The laser intensities used in experiments lie in the range $5x10^{13}$ to $2.2x10^{14}$ W/cm^2. The targets used were Aluminum foils of thickness 2-10 μm. During the interaction of high power laser pulses with solids, electron heat conduction plays an important role in energy transport from the critical surface to the ablation front. Therefore, it affects the mass ablation rate, ablation pressure and laser absorption [1]. It also affects the efficiency of conversion of laser energy into kinetic energy in the case of thin foils accelerated by laser-driven ablation. Commonly-used models for electron thermal conductivity, such as Spitzer-Harm [2], assume that the electron collision mean free path is much smaller than typical temperature scale lengths. However, in high-power laser produced plasmas, this assumption fails because of the short scale lengths (steep temperature gradients), along with high temperatures that lead to larger collision mean free paths near the thermal front. Hence conventional models tend to overestimate thermal diffusion, making it necessary to use a “flux-inhibitor” [2,3]. Apart from these, self-generated magnetic fields may also reduce the heat flow [2,4]. These effects are studied using an indigenously-developed two-dimensional (2D) radiation hydrodynamics code. This paper reports on a comparison of experimental and computational results.

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LP-106

Third Harmonic Generation Via Interaction Of Two-Colour Laser Beams With Plasma

Nirmal Kumar Verma and Pallavi Jha
Department of Physics, University of Lucknow, Lucknow -226007
E-mail : nirmal87lu@gmail.com

Abstract

Generation of high harmonic radiation is an important subject of laser plasma interaction and attracts great attention due to wide range of applications. Interaction of linearly polarized laser pulses with homogeneous plasma leads to generation of odd harmonics of laser frequency [1]. However second harmonics have been reported when linearly polarized laser pulses propagate in plasma in presence of density gradients [2] and externally applied magnetic fields [3]. Recently Ganeev *et al*. have experimentally demonstrated an enhancement in efficiency of harmonics using two-colour laser beams in plasma plumes [4]. Efficiency enhancements for harmonics have been reported in Helium gas jet by propagation of two-colour laser beams [5].

In the present paper, an analytical study of generation of enhanced third harmonic by interaction of two-colour linearly polarized, laser beams in underdense plasma has been proposed. The frequency of second laser is considered to be twice that of the first laser. The Lorentz force, continuity and Poisson's equations are perturbatively expanded in orders of the normalized vector potential $a\ (= eA/mc^2)$ of the laser field amplitude, to derive the source term driving the wave equation, governing the amplitude of the third harmonic. Evaluation of amplitudes of third harmonic amplitude and comparison with the single beam case has been presented.

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LP-113

High Field Terahertz Pulse Generation Driven By Amplitude Modulated Laser Filaments

Subodh Kumar, Monika Singh and R. P. Sharma
Centre for Energy Studies, Indian Institute of Technology Delhi, New Delhi 110016
Email: monikaiitd09@gmail.com

Abstract

At present the development in strong terahertz (THz) pulses sources are being witnessed [1]. A scheme is proposed to generate high field terahertz (THz) pulses by using amplitude modulated laser pulse that undergo filamentation in a plasma couple nonlinearly in the presence of low density ripples to generate THz radiation at the modulated frequency. Here, the laser exert a ponderomotive force along the transverse direction which imparts an oscillatory velocity to electrons that couples with the density ripple to generate a stronger transient transverse current due to the temporal variation of their fields, driving THz radiation. Numerical simulations show that THz emission with high electric field strength can be obtained and the corresponding energy conversion efficiency is higher. The broad tunability range in amplitude, frequency spectra, efficiency and temporal shape is found in the THz source generation.

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LP-120

Self-Focusing Of Cosh-Gaussian Laser Beam In A Kerr Medium With Linear Absorption

R.Mahajan and T.S.Gill

Department of Physics, Lyallpur Khalsa College, Jalandhar-144001

Email: mahajan_ranju@yahoo.co.in

Abstract

This paper presents an investigation of self-focusing and self-phase modulation of cosh-Gaussian laser beam in a Kerr medium with linear absorption. Variational approach, rigorous and global in nature as well as quantitatively more accurate, is used in the present analysis. The field distribution in the medium is expressed in terms of beam width, decentered parameter and absorption coefficient. Numerical analysis shows that these parameters play vital role on propagation characteristics.

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LP-132

Oscillator Model For Nano-Tube Plasma Interacting With Intense Few Cycle Laser Pulses

U. Chakravarty, P.A Naik, J.A. Chakera, and P.D. Gupta

Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore 452 013

E-mail :uday@rrcat.gov.in

Abstract

Enhanced absorption of intense ultra-short laser pulses interacting with nano-particles / clusters has led to the generation of bright, ultra-short pulses of x-rays and charged particles. The observed enhanced absorption in clusters has been convincingly modeled by considering a damped driven harmonic oscillator formulation [1]. The important features of this model are as follows. When an intense laser pulse irradiates a nano-particle, free electrons are generated initially forming an electron cloud. This is followed by the displacement of the electrons in the laser field (the ions being massive are considered stationary). The separation of the charged clouds causes the setting of space charge fields which provides the restoring force and causes the oscillation of the electron cloud about the ion sphere. The resonance takes place when $\omega=\omega_p/\sqrt{3}$, where ω is the laser frequency and ω_p is the plasma frequency. For a cylindrical nano-particle, the resonance occurs when $\omega=\omega_p/\sqrt{2}$. The plasma frequency is very high initially due to the solid density plasma created in the foot of the intense laser pulse. Therefore, for resonance, the cluster has to expand sufficiently so that the resonance frequency is reduced to become equal to the laser frequency. This requires few hundreds of fs time so that the resonance condition is not met during the laser pulse. Therefore, for enhanced energy coupling, longer duration pulses are needed so that the resonance occurs during the laser pulse. This implies a compromise on the laser intensity.

To overcome the above limitations, we report in this paper an interesting alternative nano-structured target. It is shown that for hollow cylindrical nano-tubes like carbon nano-tubes, the resonance condition can be met even without hydrodynamic expansion. Interestingly, in the case of hollow nano-particles, the resonance can be tailored to occur at high density by choosing thin shells. To understand the role of hollow nanostructure, the interaction is modeled considering the oscillation of hollow electron cylinder about the hollow ion cylinder using a damped harmonic oscillator model. Physically, the difference between a hollow nano-particle and solid nano-particle lies in the fact that in solid the restoring force has to be lowered to meet the resonance condition; therefore nano-particle expansion is a necessary condition. For solid nano-particles, sub-ps pulses are required for achieving the resonance during the laser pulse. Even if the resonance condition is realized, the resonance electron density is two orders of magnitude lower than the solid density. Alternatively, hollow nano-particles have an inherent lowered restoring force and hence resonance condition can be met at high density without any hydrodynamic expansion. Therefore, even with few cycle laser pulses, resonance can be achieved.

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LP-136

Second Harmonic Generation By Propagation Of Laser Pulses In Overdense Plasma

Ekta Agrawal and Pallavi Jha
Department Of Physics,University Of Luucknow,Lucknow-226007
E-mail : ektaagrawal555@gmail.com

Abstract

Interaction of short, intense laser pulses with inhomogeneous plasma leads to generation of high order harmonics [1]. High order (even and odd) harmonics have been reported experimentally from solid surfaces by intense P-polarized femtosecond pulses at a large angle of incidence [2]. Resonance absorption is one of the collisionless process for the generation of high harmonics in obliquely incident P-polarized laser in overdense plasma. Baeva *et al*. have analytically studied generation of high order harmonics in relativistic laser interaction with overdense plasma [3]. Recently Ding *et al*. have used two dimensional particle-in-cell simulation to study the resonance absorption and high order harmonics at the reflected light spectrum in mildly relativistic regime in overdense plasma with linear density gradient [4].

In the present paper, an analytical study of second harmonic generation via resonance absorption due to interaction of obliquely P-polarized laser propagating with overdense plasma in the mildly relativistic regime has been proposed. The Lorentz force, continuity and Poisson's equations are perturbatively expanded to derive the source driving the amplitude of the second harmonic. Efficiency of second harmonic radiation is thus obtained.

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LP-138

Second Harmonic Generation Of Laser In A Plasma

Sukhdeep Kaur[1], Manpreet Kaur[1] and Parveen Bala[2]
[1]*Department of Physics, Guru Nanak Dev University, Amritsar-143005*
[2] *Department of Mathematics, Statistics & Physics, Punjab Agriculture University, Ludhiana- 141004*
E-mail: manpreet_preeti@ymail.com

Abstract

The generation of second harmonic by a laser incident obliquely on a plasma is studied. The laser imparts a nonlinear current to electrons, which generates the second harmonic. They are observed in reflected and transmitted component both. The normalized second harmonic amplitude varies with angle of incidence. More than one order of magnitude enhancement in second harmonic amplitude is observed for a particular set of parameters.

LP-139

Study of Terahertz Radiation Generation by Beating of Two Spatial Triangular Lasers in Magnetized Plasma

Prateek Varshney, Kanika Verma, Vivek Sajal and Ravindra Kumar

Department of Physics and Materials Science & Engineering, Jaypee Institute of Information Technology, A-10, Sec. 62, Noida- 201307

E-mail: varshneyprateek28@gmail.com

Abstract

A scheme of producing tunable terahertz radiation by beating of two spatial triangular lasers is proposed in a magnetized plasma. In this process, lasers exert a beat ponderomotive force on plasma electrons and impart them an oscillatory velocity with both transverse and longitudinal components in the presence of transverse static magnetic field. The oscillatory velocity couples with density ripples and produces a nonlinear current that resonantly excites the terahertz radiation.

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LP-142

Comparative Study Of Dispersion Relation Of Surface Plasma Waves With And Without External Magnetic Field

Deepika, Prashant Chauhan, Anshu Varshney and Vivek Sajal

Department of Physics and Material Science and Engineering,
Jaypee Institute of Information Technology, Sector-128,
Noida, U.P. 201307.

E-mail: deepika7nov@yahoo.co.in

Abstract

Surface plasmons are collective oscillation of free electrons localized at surface of structures made of metals. The electromagnetic fields associated with these surface plasmons are localized at the surface of metal surface. This surface plasma mode can be excited by a laser using Kretschmann technique in double metal surface configuration. Two parallel metal sheets separated by a vacuum region supports a surface plasma wave of maximum amplitude at the two interfaces and minimum in the middle. The dispersion relation of surface plasma waves is studied for this configuration with and without external magnetic field. The modification in the dispersion relation is studied by varying the strength and direction of applied magnetic field parallel and perpendicular to the surface plasma

wave. In the presence of external magnetic field (for both directions) the cut-off frequency is observed higher to that of without magnetic field. It also affects the divergence and power gain of electrons by surface plasma waves significantly.

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LP-143

Two Plasmon Decay Of Non-Resonant Beating Mode Of Counter Propagating Lasers In Plasma

Kanika Verma, Prateek Varshney, Vivek Sajal and Ravindra Kumar

Physics Department, Jaypee Institute of Information Technology, Noida, U.P.201307.

Email: kanikaverma307@gmail.com

Abstract

Generation of fast and slow lower hybrid waves by two plasmon decay of non-resonant beating mode of two counter propagating lasers is modeled in magnetized plasma. Two counter-propagating lasers having frequencies and wave-vector $(\omega_1, k_1) \& (\omega_2, k_2)$, respectively, generates a non resonant beat wave at frequency difference $\omega_0 \approx \omega_1 \sim \omega_2$ and wave number $\vec{k}_0 \approx \vec{k}_1 + \vec{k}_2$ which parametrically excites a pair of co-propagating fast and slow lower hybrid waves at $\omega_0 = 2\omega_h + \frac{3k_1^2 v_{th}^2}{\omega_h}\left(1 - \frac{\omega_h}{\omega_1}\right)$. The fast lower hybrid wave can be utilized for electron acceleration because its phase velocity is close to c. The growth rate of this process is greater than the growth rate of Raman back scattering process.

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LP-147

Modulation Instability In A Plasma Channel With Wiggler Magnetic Field

Nisha Singh Rathore
University of Lucknow, Lucknow 226001

Abstract

An analytic linear theory of the plasma dynamics in a external transverse magnetic wiggler field is presented. In this paper the modulational instability associated with propagation of intense laser pulses in plasma channel is analysed. The effect of the wiggler filed on plasma dynamics is studied and modified steady-state orbits and their stabilities have been analysed considering variation of electron energy and density. Wiggler magnetic field plays both a dynamic role in producing the

traverse harmonic current and a kinematical role in ensuring phase-matching due to this the obtained the growth rate of modulation instability from laser beam propagating in plasma immersed in combined axial and longitudinal wiggler magnetic fields. The, the growth rate is substantially larger than the standard slow wave free electron laser scheme utilizing a transverse wiggler field.

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LP-148

Effect of Coulombic Expansion On The Second Harmonic Generation Via Intense Laser Interaction With Clustered Gas

Rohit Kumar Mishra

Department of Physics, Plasma Electrodynamics Group
University of Lucknow, Lucknow-226007

E-mail : mrohitk@gmail.com

Abstract

The interaction of intense laser pulses with atomic clusters has attracted considerable interest in the course of past decade. Laser cluster interactions have a wide range of application, for example, as a source of energetic electrons or ions [1, 2], as a source of X-rays or Extreme Ultra Violet radiation that is applicable to the X-ray microscopy [3] or lithography [4]. The exploding cluster dynamics also gives rise to significant nonlinear effects such as self-focusing of laser beam [5, 6] and harmonic generation.

In this paper an analytical study of the generation of second harmonics via intense, short and linearly polarized laser interaction with clustered gas has been presented. The efficiency of second harmonics has been calculated using numerical methods and compared with that of second harmonics generated via laser interaction with homogeneous plasma. The clustered gas is assumed to be tenuous. Coulombic expansion of a single nanometer sized cluster irradiated with a short (~100fs) laser pulse is taken into account and instantaneous change in the cluster radius is averaged over ion time scale.

Acknowledgement:
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LP-169

Laser Wake-Field Acceleration In High-Z Gas Jets

B. S. Rao, A. Moorti, R. A. Khan, J. A. Chakera, P. A. Naik, and P. D. Gupta

Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore, 452013

E-mail : sunnyb@rrcat.gov.in

Abstract

Laser wake-field acceleration (LWFA) is currently recognized as the most promising advanced technology to realize compact high energy electron accelerators in the future, due to its ability to sustain ultra-high acceleration gradient ~100 GV/m and recent demonstration of high quality electron bunches with peak energy of few 10 MeV to 1 GeV from sub-mm to cm-scale acceleration lengths [1-4]. In a typical LWFA experiment, a low-Z gas like helium is used to produce supersonic gas jet target in which a femtosecond duration laser pulse with intensity > 10^{18} W/cm^2 is focussed to create wake-field and accelerate electrons. When the laser pulse propagates through the gas jet, it strips off all the electrons from the low-Z gas atoms and forms plasma at its pedestal intensity of about 10^{16} W/cm^2. Therefore, the intense portion of the laser pulse interacts with the plasma and results in electron acceleration. In the case of high-Z gas (e.g. nitrogen), however, the laser pulse continues to ionize the gas until the peak of the laser pulse which may facilitate ionization induced injection and LWFA, and may be exploited to produce stable and controllable electron acceleration by optimum choice of target gas.

In this paper, we present investigation of LWFA in nitrogen (N_2) and argon (Ar) gas jets using a chirped pulse amplification based table-top terawatt Ti:sapphire laser system delivering 3 TW, 45 fs duration laser pulses on target. The laser pulse is guided over ~ 450 μm and high-quality electron beams are produced from self-injected laser wake-field acceleration in N_2 plasma at density 3×10^{19} cm^{-3}. The electron beam has virtually background free quasi-monoenergetic distribution with peak energy ~ 25 MeV, charge ~ 30 pC, with divergence and pointing both ~10 mrad. In the case of Ar, the laser pulse is guided over a much longer length ~700 μm in plasma. However, the electron acceleration was observed to be highly unstable and a collimated electron beam with divergence ~ 40 mard, charge ~ 40 pC and energy mostly < 10 MeV was observed once in a while, at a plasma density >10^{20} cm^{-3}. The difference in the laser pulse propagation and the electron acceleration arise due to the large variation in the ionization dynamics in both gases, and possibly due to cluster formation in the case of Ar gas jet. The results will be presented in detail discussed in terms of the effect of ionization induced defocussing and ionization induced injection on laser guiding and electron acceleration.

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LP-172

Dynamics Of Ion Acceleration By Solitary And Shock Waves Driven By Laer Plasma Interactions

Amritpal Singh Nindrayog[1], Andrea Macchi[2] and Francesco Pegoraro[2]
[1]Lyallpur Khalsa College, Jalandhar-India 144001,
[2]Department of Physics, University of Pisa, Italy 56127
E-mail : amrit_physics@yahoo.co.in

Abstract

The excitation of non-linear electrostatic waves, such as shocks or solitons, by ultraintense laser interaction with over dense plasmas and related acceleration of ions by reflection from the moving wave front have been investigated numerically by 1D particle-in-cell simulations. Linearly polarized pulses with dimensionless amplitude \$a_0 ~ n_e /n_c\$ drive solitary waves or multi-peak structures depending on the pulse duration. Such nonlinear waves drive secondary ion acceleration in the plasma bulk, the acceleration dynamics being more complex than "specular" reflection of ions from the wave front. Possibly novel features observed in the dynamics of solitary waves include a strong collective oscillation of the electrostatic field and the pulsed nature of ion acceleration. In a cold ion background, wave loading effects prevent “true” shock wave formation and efficient mono-energetic acceleration. Acceleration of large fraction of ions lead to quenching and slowing down of the wave, resulting in broadening of the energy spectrum. The background ion distribution., i.e; ions with some initial energy spread, plays an important role in the ion acceleration dynamics[1]. For instance, appearance of “true” shock waves with steady ion reflection from the wave front is observed only for warm ions. Simulations performed at moderate intensity \$I = 10^{18} – 10^{19}\$ W/cm^2 using linearly polarized pulses suggest the existence of an “optimal” initial ion temperature at which a shock wave reflects monoenergetic ions, as a result from a trade-off between beam monoenergeticity and efficiency. Circularly polarized pulses in initially warm plasmas exhibit a distinct transition from the laser driven piston scenario with all ions being reflected to the collisionless shock/soliton scenario having partial ion reflection. Preliminary 2D simulations suggest that the onset of surface rippling affects the width of the ion spectrum.

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LP-180

Simultaneous Evolution Of Spot-Size And Pulse Length Of Short Laser Pulses In Electron-Positron-Ion Plasma

Hemlata and Pallavi Jha
Department of Physics, University Of Lucknow, Lucknow-226007
E-mail : hemlata.7.kashyap@gmail.com

Abstract

Understanding the evolution of high-intensity lasers as they propagate through under dense plasma is essential for the successful development of plasma based accelerators and radiation generation

schemes , as well as for inertial confinement fusion.

The process of electron-positron pair creation and annihilation occurs in relativistic plasma at high temperatures, when the temperatures of the plasma exceeds the rest mass energy of the electron [1]. Electron -positron pair production can also be possible by intense short laser pulses propagating in plasma [2]. Since the positrons have a sufficient lifetime, the plasma becomes an admixture of electrons, positrons and ions.

Studies related to the interaction of intense laser pulses with electron -positron-ion [3] plasma have been recently reported. The present study deals with analytical and numerical investigation of the evolution of spot-size and length of a laser pulse as it propagates in electron -positron-ion plasma.

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LP-195

Experimental Investigation of Fast Electron Temperature by Direct and Indirect Measurements in High Intensity Laser-Matter Interaction

T. Mandal, R. Rathore, M. Tayyab, S. Bagchi, V. Arora, J. A. Chakera, P. A Naik, and P.D. Gupta

Laser Plasma Division, Raja Ramanna Centre for Advanced Technology, Indore 452 013

E.mail: tirtham@rrcat.gov.in

Abstract

Understanding the generation of energetic fast electrons in laser-matter interaction at ultra-high intensity is a subject of considerable importance for the scientific investigations relevant to fast ignition scheme of inertial confinement fusion and several technological applications such as development of high energy proton sources for cancer therapy, ultra-fast x-ray sources for time resolved studies etc. The generation and transport of the fast electrons through the over dense plasma and bulk solid region depend on the laser irradiation parameters and the resistivity and the density of the medium through which they are traversing. Further, the self-generated magnetic fields and the electro-static potentials generated during the laser pulse strongly modify the transport of these fast electrons. In this paper, we report the experimental measurements of the fast electrons spectra from the rear side of foil targets using a home-made Thomson parabola electron spectrograph (TPES), and the x-ray emission when these fast electrons traverse through the foil targets. The shape and the intensity of the bremsstrahlung radiation has the distribution similar to the fast electrons. The fast electron temperature is derived by fitting the electron spectra and the x-ray spectra with Maxwellian distribution.

The experiment was carried out with a 10 TW Ti:sapphire laser system which delivers 45 fs duration pulses of energy up to 400 mJ, at a repetition rate of up to 10 Hz. A TPES has been employed in conjunction with a micro-channel plate detector to measure the electron emission spectrum in a single shot. A MATLAB routine was written to derive the number of electron and their energy for a

given electric and magnetic field. The electron temperature derived from the slope of the semi-log plot of the electron spectrum. At a laser intensity of 2.5×10^{18} W-cm^{-2}, a maximum electron energy of ~ 1.5 MeV was measured, and electron spectrum was fitted to a non-Maxwellian distribution with two temperatures: one at 120 keV and other at 344 keV. The electron spectrum was measured at different laser intensities to derive the scaling laws. A dispersion-less spectrograph was used to measure the x-ray radiation in the range of 1-40 keV and the fast electron temperature was derived by fitting the continuum bremsstrahlung radiation to an exponential distribution. An indigenously developed high energy x-ray bremsstrahlung spectrograph (HXBS) was used to measure the high energy bremsstrahlung x-ray radiation up to 100 keV energy. A fast electron temperature of 496 keV derived, which was nearly the same as that derived from the electron spectrum.
The details of the experimental investigations will be presented, and our present understanding of the various processes involved will be discussed.

LP-201

Effect Of Laser Beam Filamentation On Coexisting Stimulated Raman And Brillouin Scattering At Relativistic Powers

Ashish Vyas[1], Ram Kishore Singh[1] and R. P. Sharma[1]

[1]*Indian Institute of Technology, Delhi-110016*

Email: ashishvyas.optics@gmail.com

Abstract

We propose to study the stimulated Raman scattering and stimulated Brillouin scattering, when both of these processes are coexisting in unmagnetized plasma [1]. On account of the relativistic nonlinearity, the pump laser beam gets filamented [2] and both the scattering processes get affected. Simultaneous presence of the stimulated Raman scattering and stimulated Brillouin scattering (five wave interaction case) also affects the pump filamentation process due to pump depletion. To investigate this process, governing dynamical equations of the pump laser beam and backscattered beams have been setup. These set of equations have been solved numerically for the typical laser fusion parameters. Laser beam intensity and modified reflectivity (for both stimulated Raman scattering and stimulated Brillouin scattering) have been presented. Also the effect of coexistence of the stimulated Raman scattering and stimulated Brillouin scattering on the back reflectivities has been studied.

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LP-204

The Electrodynamic Model Of X-Ray Emission By Laser Plasma Accelerator

Bimlendra Pratap Singh
Amity University, Sec-125, Taj Express Highway Noida, 201313
E-mail: singh.bimlendra2@gmail.com

Abstract

Recent dramatic progress in laser technology has given rise to new projects (e.g., ELI, XFEL) which may bring intensities of the order of 1023-1024 Wcm^{-2}. [1] Most experiments are currently done at large laser facilities that can create bright X-ray sources; however the advent of the X-ray free electron laser (XFEL) provides a new bright source to use in these experiments. One challenge with X-ray scattering experiments is understand how to model the scattering for partially ionized plasmas in order to include the contributions of the bound electrons in the scattered intensity [2].
We demonstrate a method for probing the acceleration process. A second laser beam, propagating perpendicular to the main beam is focused in the gas jet few nanosecond before the main beam creates the accelerating plasma wave. This second beam is intense enough to ionize the gas and form a density depletion which will locally inhibit the acceleration. The position of the density depletion is scanned along the interaction length to probe the electron injection and acceleration, and the betatron X-ray emission. The electric field associated with the plasma wave has very large amplitude, of a few hundreds of gi-gavolt per meter. Electrons can therefore be accelerated to a few hundreds of MeV within just a few millimeters. Three phenomena play an important role in a laser plasma accelerator: the laser propagation; the electron injection; and the electron acceleration itself. [3] Further information about the plasma wave was obtained from interferometric and magnetic fields measurements. Techniques were also developed to determine whether electrons are trapped in the first plasma wave period. [4]

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LP-213

Self-Focusing Of Super-Gaussian Laser Beam In Magnetized Plasma Under Relativistic And Ponderomotive Regime

Ravinder Kaur, Tarsem Singh Gill and Ranju Mahajan
Department of Physics, Guru Nanak Dev University, Amritsar – 143005
Email: physics_ravinder@yahoo.co.in

Abstract

In this paper, we have investigated the propagation characteristics of super-Gaussian laser beam in magnetized plasma. Self-focusing of short pulselaser propagating along the direction of ambient magnetic field in plasma isstudied. The nonlinearity arises through the combined effect of

relativisticmass variation and ponderomotive force induced electron cavitation. An appropriate nonlinear Schrö dinger equation has been solved analytically using variational approach. Self-phase modulation is also studied under variety of parameters. Further, the effect of magnetic field on self-focusing of the beam have been explored.

LP-220

Fluid Simulation Of Relativistic Electron Beam Driven Wake-Field Excitation In A Cold Plasma

Ratan Kumar Bera, Sudip Sengupta and Amita Das
Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat
E-mail : rkbera@ipr.res.in

Abstract

Studies of charged-particle acceleration process using plasma based schemes remain one of the most important areas of research in laboratory, space and astrophysical plasmas[1]. In this work, excitation of nonlinear wake-fields by an ultrashort, ultra-relativistic electron beam in a cold plasma is studied analytically and numerically, using fluid simulation techniques. One dimensional analytical calculations of relativistically intense wake-fields, excited in a cold homogeneous plasma, in the limit of β_{ph} (ratio of wave phase velocity and speed of light) ~ 1, and beam density to plasma density ratio (α) less than 0.5, shows generation of large amplitude acceleration gradients[2]. Here we extend these calculations to the case of ($\alpha > 0.5$) and for arbitrary values of β_{ph} . These analytical calculations are verified against our fluid simulation results. Further to study self-trapping of electrons in the wake field we have also performed simulations with an inhomogeneous plasma density profile [3,4].

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LP-221

Relativistic Electron Beam Driven Wake-Field Excitation In A Cold Magnetized Plasma

Ratan Kumar Bera, Sudip Sengupta and Amita Das
Institute for Plasma Research, Bhat, Gandhinagar-382428, Gujarat
E-mail : rkbera@ipr.res.in

Abstract

Excitation of nonlinear wake-fields by an intense, short, ultra relativistic electron beam in a cold, magnetized plasma is studied analytically, in the electrostatic limit, following the method discussed in ref [1]. From the analytical solution of one dimensional fluid equations, together with Maxwell's equations, in the limit of β_{ph} (ratio of wave phase velocity and speed of light) ~ 1, it is found that under certain conditions of beam density to plasma density ratio, a large amplitude accelerating gradient is generated in the beam's wake. Further the structure of the excited Wake field is compared with Akhiezer-Polovin[2]like wave for a magnetized plasma.

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LP-224

Enhancing The Collection Efficiency In Laser Induced Breakdown Spectroscopy For Multi-Elemental Analysis

M. Tamboli[1], Praveen Devangad[1], Unnikrishnan V. K.[1], Santhosh C.[1]
[1] *Department of Atomic & Molecular Physics, Manipal University, Manipal-576104*
E-mail: maktumt@gmail.com

Abstract

Laser Induced Breakdown Spectroscopy (LIBS) or Laser Induced Plasma Spectroscopy (LIPS) is a well know and established technique for elemental analysis [1,3]. The evident for this statement is that the number of papers published is increasing every year at a remarkable rate. LIBS have an ability to detect neutral and ion spectral features of atomic and molecular species of all elements using a single laser shot. In a recent paper it's reported that by imaging larger region of the plasma can improve the signal collection efficiency [2]. The laser beam used to generate the plasma was produced by a Q-switched Nd: YAG laser. The laser has pulse duration of 6 ns, a repetition rate of 10 Hz, and a wavelength of 355 nm. The laser energy used for this experiment is 25mJ. The generated plasma is fed to an Echelle spectrograph coupled with a gated ICCD. The present work deals with the imaging of larger area of a laser produced plasma using biconvex lenses of apertures 2.5, 4 and 5 cm and of focal length 5 cm, which would fairly increase the collection efficiency. We have adapted different configuration of the lenses for the collection of plasma and studied the enhancement in the signal. Comparative study of LIBS spectra using all these lens schemes has been done and results shows the enhancement in the intensities of the spectral lines. The biconvex lens of diameter 5 cm shows a better enhancement.

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LP-225

Laser induced Breakdown Spectroscopy (LIBS) of Glass

Praveen. Devangad[1], M.M. Tamboli[1], V.K. Unnikrishnan[1], C. Santhosh[1]
[1]*Department of Atomic and Molecular Physics, MIT,* [1]*Manipal University, Manipal, 576104*
E-mail: praveen17dev@gmail.com

Abstract

Laser induced breakdown spectroscopy (LIBS) is an analytical technique which is based on atomic emission spectroscopy [1-2]. LIBS has many attracting features compare to other analytical techniques. This method is fast and no/minimal sample preparation helped to use this in process control in industries and many other fields. A high intensity laser beam is used to produce the plasma where a small quantity (few micro grams) of the sample is ablated. The emission from the plasma is

collected and analyzed spectroscopically to know elements present in the sample.

Here in our experiment we have used Q-switched Nd:YAG laser (355 nm, 6 ns, 10 Hz) to optimize the few experimental parameters of LIBS system. The irradiance of ~8×10^{10} W/cm^2 was used to ionize the very small quantity on the surface of the sheet glass. This glass was mounted on a translation stage so that the laser falls on fresh surface each time and which helps in obtaining LIBS spectra with minimum noise. A high resolution (0.05 nm) echelle spectrograph-ICCD system which covers a spectral range of 200-975 nm was used to record the spectra.

Recording of the LIBS spectra have to be delayed for few hundreds of nano seconds after the formation of plasma. This is to avoid the continuum which occurs from the Bremsstrahlung (free-free) and the recombination (free-bound) radiations [3]. Optimizing the gate width is also important to collect the enough emission from the plasma. Therefore we have recorded the spectra for various gate delays (100 ns- 2500 ns) and gate widths (300 ns- 6000 ns). Here the spectra recorded between 700 ns and 1000 ns were having less continuum. The intensity of the emission line was found maximum for 5000 ns gate width which decreased further for higher gate widths. The laser energy was altered (9.5 mJ, 17 mJ and 38 mJ) by using neutral density filters, and observed the enhancement in the emission intensity. The LIBS spectra recorded with 38 mJ was found better compare to other laser energies. We have also observed the enhancement in the emission line intensity with the increase in the number of laser pulses.

In this work, few important experimental parameters (gate delay, gate width, laser energy and number of laser pulses) were investigated to optimize the LIBS spectra of glass and determined the suitable range where spectra would be free from continuum.

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LP-233

Ion-Ion Two Stream Instability In Laser Produced Ba-Plasma

Narayan Behera[*], R. K. Singh, Manoj Gupta, D. Sharma and Ajai Kumar
Institute for Plasma Research, Gandhinagar-382 428, Gujarat
E-mail: nbehera@ipr.res.in

Abstract

The time resolved emission profiles of the Ba II line from Laser-produced barium plasma plume have been investigated using optical emission spectroscopic technique. The evolution features of the 455.4 nm line are studied in different ambient pressures. It has been observed that temporal profiles of Ba II line split into fast and slow components and their separation and intensities are varied with spatial position and ambient gas pressure. By considering the slow and fast component as two different fluids, we have tried to explain the above observations with the ion-ion two stream instability theory. Details of theoretical approach to apply the two stream instability in laser produced plasma and its outcome will be briefly discussed.

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LP-275

Effects Of Carrier Heating On Polaron Induced Parametric Interactions In Compound Semiconductor

Ratna Agrawal[a], Swati Dubey and S. Ghosh

School of Studies in Physics, Vikram University, Ujjain 456010

E-mail : ratnagarwal@gmail.com

Abstract

We developed a theoretical model for compound semiconductor to study the effects of carrier heating on parametrically interacting electron-longitudinal optical phonons in compound semiconductors. Expressions for threshold pump field required for the onset of polaron induced parametric interaction and dispersion characteristics are explicitly derived. The nonparabolicity and carrier heating effects are found to modify the threshold and dispersion characteristics in the presence of external electric and magnetic fields. It is found that threshold electric field decreases with increase in wave vector. Threshold and dispersion characteristics strongly affected by nonlinearity in effective electron mass and effective collision frequency at low magnetic field and moderate carrier concentrations. Typical dependence of threshold electric field on wave vector could be utilized to device optical switches.

LP-290

Guiding Of Relativistic Electron Beams Through Structured Plasma

Chandrasekhar Shukla, Bhavesh G. Patel, Amita Das and Kartik Patel[1]

Institute for Plasma Research, Bhat, Gandhinagar - 382428
[1]Bhabha Atomic Research Centre, Trombay, Mumbai - 400 085

Email : chandrasekhar.shukla@gmail.com

Abstract

The propagation of ultrafast electron beam (generated by laser-solid interaction) through dense plasma plays a crucial role in the process of ignition in Fast Ignition Inertial confinement Scheme of fusion. However, the propagation of energetic electron beam through a plasma is fraught with instabilities. The propagating electron beam produces return currents, and the combination of the forward and return current is in general unstable to Weibel instability (Weibel). The Weibel instability can have a totally electromagnetic and/or a mixed electromagnetic/electrostatic character. This causes the two currents to separate and creation of magnetic fields, the subsequent nonlinear development causes the fields to get turbulent and is believed to be responsible for the stopping of

the electron beam. Some recent experimental studies indicate that an inhomogeneous plasma can help the process of guiding the electron beam, thereby improving upon the beam propagation distance inside the plasma medium. Keeping this in view, a $2\frac{1}{2}$D particle-in-cell simulations have been carried out to study various aspects (viz. the linear and nonlinear development of the instability) on the propagation of electron beams through a structured plasma medium. The detailed study of the role of inhomogeneity scale length on propagation distance have been carried out. The studies suggest that inhomogeneity helps in guiding the beam to longer distance inside the plasma.

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LP-334

Studies of Ions from Laser produced Carbon Plasma using Thomson Parabola Spectrometer

S. Chaurasia[1], Vinay Rastogi[1], R. K. Bhatia[2], V. Nataraju[2], S. M. Sharma[1]
[1]*High Pressure & Synchrotron Radiation Physics Division*
[2]*Technical Physics Division*
Bhabha Atomic Research Centre, Mumbai – 400085
Email : shibu@barc.gov.in

Abstract

Hot plasma is produced when a solid target is irradiated with intense laser in vacuum. Properties of the generated plasmas depend strongly on the laser and the target parameters and on the target irradiation geometry. Physical characterization of such non-equilibrium plasma can be studied using different fast diagnostic techniques based on the detection of energetic charged particles and photons. In our lab, we measure both charged particle and photons. In this paper, we present the effect of laser intensity on the energy and flux of each charge states of carbon (i.e. C+1 to C+6) along with protons generated from impurities. Ion emission studies from carbon plasma irradiated with laser of intensity > 10^{14}W/cm^2 have been done using high resolution Thomson parabola spectrometer (TPS). It has been observed that the ion energy and flux of charge states C+4 and C+5 increases with the laser intensity. However, for the charge C+2 and C+3 the ion energy increases and ion flux decreases with laser intensity. The angular distribution of charge states and the corresponding ion flux have been measured. The energy spectrum for each charges corresponding to the target normal has also been measured. It is evident from the TPS images that, the ion energy and flux are highly directional towards the target normal. It is also seen that the angular spread of the higher charge states are less.

LP-362

Effect Of Linear Absorption On Relativistic Self Focusing Of Quadruple Gaussian Laser Beam In Magnetoplasma

Munish Aggarwal[1] and Shivani Vij[2]
[1]*Lyallpur Khalsa College, Jalandhar-145001*
[2]*Dav Institute of Engineering and Technology, Jalandhar-145004*
Email : sonuphy333@gmail.com

Abstract

The self-focusing of an intense Quadrouple Gaussian laser beam in magnetized plasma with linear absorption is studied. The nonlinearity in the dielectric constant arises on account of the relativistic variation of mass of electrons which modifies the plasma frequency and hence the refractive index profile. We have obtained the differential equation for beam width parameter by using parabolic

equation approach under the usual Wentzel–Kramers–Brillouin and paraxial approximations. We have optimized the parameters of intensity and wavelength for better self focusing. The presence of magnetic field enhances self focusing in the case of extraordinary mode than in the ordinary mode. From the numerical analysis it has been observed that linear absorption plays a vital role in determining the propagation characteristic of the laser beam.

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LP-370

Self-Focusing Of Cosh Gaussian Laser Beam In Magnetized Plasma With Upward Plasma Density Ramp

Munish Aggarwal, Harish Kumar and Richa Kashyap

Lyallpur Khalsa College, Jalandhar-145001

Email : sonuphy333@gmail.com

Abstract

Self-focusing of Cosh Gaussian laser beam in magnetized plasma with upward increasing plasma density ramp and linear absorption is studied. The slowly increasing plasma density ramp profile $n(\xi) = n_o \tan(\xi/d)$ is taken similar to Sadigi-Bonabi et al. (2009). Such density profile is quite useful in decreasing the beam width parameter which leads to strong self focusing. The nonlinearity in the dielectric constant arises on account of the ponderomotive force. We have obtained the nonlinear differential equation for beam width parameter by using parabolic equation approach under the usual Wentzel–Kramers–Brillouin and paraxial approximations. We have optimized the parameters of intensity and decentered parameter b for stronger self focusing. From the numerical analysis it has been observed that linear absorption plays a vital role in determining the propagation characteristic of the laser beam.

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LP-390

Copper Laser Plasma Generation And Characterization

Tobin K Thomas[1],Subin P S[1,3], Smijesh N[2], Sabu Thomas[3,4], Reji Philip[2], Nandakumar Kalarikkal[1,3*]

[1]School of Pure and Applied Physics, [3]International and Inter University Centre for Nanoscience and Nanotechnology, [4]School of Chemical Sciences
Mahatma Gandhi University, Kottayam-686 560, Kerala
[2]Light and Matter Physics Group
Raman Research Institute, Bangalore-560 080, Karnataka

Email : nkkalarikkal@mgu.ac.in

Abstract

Laser driven plasmas provide a key gateway to the study of high energy density Physics. Laser plasma interactions are a key component of high energy density physics [1]. These interactions are a fascinating and challenging test bed for non-linear physics. Nanosecond pulsed laser ablation of bulk metals, in atmospheric air and vacuum represents several processes which are very important to be well studied in the scope of industrial applications.

In this work, copper plasma was created using a Q-switched Nd:YAG laser at 1064 nm wavelength. The 200 ns pulse FWHM was used to ablate 1 cm thickness Cu target in two different methods of single pulse mode and scanning mode at 16, 18, 20 and 25 mJ pulse energy in air. Beam was focused on to the target by 80 mm *f*-theta lens to 100 μm spot diameter. In the case of scanning mode Cu targets was irradiated at each run in straight line by the laser beam moved by means of a scanner located at the laser head with 0.2 m/s speed. In this case where the applied repetition rate was 2 kHz, successive interactions were occurred without overlapping.

The emission spectrum of the plasma formed on the Cu target surface was recorded simultaneously by an AvaSpec-2048 Fiber Optic Spectrograph system. The emission spectra have been collected by a 5 mm diameter lens collimator located at a distance of 3 cm from the plasma plume and propagates through a thermally resistant optical fiber to the spectrometer. The data were acquired during each run by the Avantes software displaying the spectra with a resolution of 0.25 nm. Spectroscopic data are always located in a wide background of thermal radiation, which were eliminated in the output of the software.

The plasma temperature and plasma electron density were calculated using Boltzmann plot method and stark broadening mechanism [2]. The present investigations indicate that the plasma temperature and electron densities increase with increase in laser energies.

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Exotic Plasma
(EP)

EP-026

Self -Excited And Externally Driven Dust Acoustic Waves In Strongly Coupled Dusty Plasmas

Jyotirmoy Pramanik and Pankaj Patra
Department of Physics, Kharagpur College, Kharagpur – 721305
E-mail : jotir_moy@yahoo.com

Abstract

Dusty plasmas are low-temperature multispecies ionized gases including electrons, ions, and negatively (or positively) charged dust grains typically micrometer or sub micrometer size. Under typical laboratory condition, massive dust particles acquire a very high dynamic electric charge; bring about many significant changes in the overall collective behavior of the system including creation of new modes such as dust acoustic waves (DAW) and transverse shear waves (TSW). These spontaneous oscillations occur when the ambient neutral pressure is reduced below a threshold value. In this paper, we have reported the changes of different properties of DAW like wavelength, frequency and phase velocity with change in discharge parameters like pressure and discharge currents.

The linear dispersion properties of dust acoustic waves are experimentally studied by exciting them in a controlled manner with a variable frequency external source and have also been verified with existing theory [1-6].

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EP-043

Theoretical Study Of Head-on Collision Of Dust Acoustic Solitary Waves In A Strongly Coupled Complex Plasma

S. Jaiswal, P. Bandyopadhyay and A. Sen
Institute For Plasma Research, Gandhinagar 382428, Gujarat
E-mail : surabhi@ipr.res.in

Abstract

We investigate the head-on collision between two dust acoustic solitary waves (DASW) in the presence of strong coupling [1] between micron sized charged dust particles in a complex plasma. Using the extended Poincaré-Lighthill-Kuo perturbation technique [2] we derive a coupled set of nonlinear dynamical equations describing the evolution of the two DASWs. The nature and extent of post collision phase-shifts of these solitons is studied over a wide range of dusty plasma parameters. In particular the influence of the strong coupling parameter on the phase shift is delineated by appropriate comparisions with weak coupling model results.

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EP-075

Electrostatic Envelope Excitations In Multispecies Nonextensive Plasma

Shalini and N. S. Saini
Department of Physics, Guru Nanak Dev University, Amritsar-143005
E-mail: shal.phy29@gmail.com

Abstract

Many laboratory as well as geophysical plasmas has witnessed the propagation of ion acoustic waves with hot and relatively cold electrons [1]. Over last many years, it has been shown from observations that Maxwellian distribution is inadequate to model the systems with long range interactions (such as plasma and gravitational systems etc.). Lima et al. (2000) [2] confirmed experimentally the existence of a non-Maxwellian velocity distribution and stated that the q nonextensive (Tsallis formalism) [3] is very important for systems with long range interactions. The propagation of nonlinear waves in dispersive media is governed by a generic nonlinear phenomenon e.g. Modulational instability. Using the multi scale reductive perturbation method, the nonlinear Schrodinger equation (NLSE) which governs the amplitude modulation of ion acoustic waves in a plasma consisting of adiabatic electrons at different populations of thermal electrons at different temperatures obeying Tsallis distribution [4]. Nonextensivity of electron affects the critical wave number at which modulational instability sets in. Stationary profile localized ion acoustic excitations may exist in form of bright solitons (envelope pulses) or dark envelopes (voids). We have also observed the effects of concentration of hot/cold electrons and temperature ratio on the amplitude modulation of ion acoustic waves.

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EP-079

Dust Acoustic Solitary Waves In An Electron Depleted Dusty Plasma With Two Temperature Nonextensive Ions

Ripin Kohli and N. S. Saini
Department of Physics, Guru Nanak Dev University, Amritsar-143005
ripin.kohli@gmail.com

Abstract

Most of the space and astrophysical environments show the presence of dust particles. Presence of dust particulates may give rise to either new or modified waves in dusty plasma. Dust acoustic waves (DAWs) are one of the low frequency modes that occur in dusty plasmas, where the dust particle mass provides the inertia and pressures of inertialess electrons and ions provide the restoring force. In the present investigation, electron number density is assumed to be sufficiently depleted owing to the electron attachment during the dust charging process. The Sagdeev method is employed to derive the energy balance equation in terms of Sagdeev potential. From the expression of Sagdeev potential the range of the Mach number is determined to see the existence of solitary structures. The nonextensivity of ions significantly affects the characteristics of dust acoustic solitary waves .

EP-093

Confinement In Toroidal Electron Plasma In SMARTEX-C

Lavkesh Lachhvani, Manu Bajpai and Sambaran Pahari[1]
Institute for Plasma Research, Gandhinagar – 382428
[1]Bhabha Atomic Research Center, Vishakhapatanam – 530012
E-mail: lavkesh@ipr.res.in

Abstract

Electron plasmas with interesting toroidal signatures in SMARTEX-C, (SMall Aspect Ratio Toroidal Experiment-C trap) is being confined for 200 - 400 Diocotron oscillations(2 - 4 ms) in the purely toroidal pulsed magnetic field of 200 Gauss at pressures 1x 10^{-7} mbar[1]. Owing to its small aspect ratio, SMARTEX-C has uniqueness of investigating strong toroidal effects on pure electron plasmas. However, in spite of a confinement time exceeding 4 ms it was believed that any further improvement in the confinement required a steady state B field.

This paper reports that it is not the pulsed confining B field but primarily the instability driven losses that severely limits the lifetime. The control of onset of instability has been demonstrated by regulating the strength of the B field and neutral density. With instability driven charge losses controlled, an extended B field is seen to extend the lifetime of the plasma up to ~0.1 s. Same has been confirmed by measurement of total confined charge in trap using charge collection diagnostics.

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EP-111

Role Of Charged Dust Particles On Ion Acoustic Wave Propagation In Negative Ion Plasma

N. C. Adhikary, M. K. Deka and H. Bailung
Physical Science Division,Institute of Advanced Study in Science and Technology,
Paschim Boragaon, Guwahati - 781035, Assam
E-mail : nirab_iasst@yahoo.co.in

Abstract

The properties of nonlinear electrostatic wave propagation in dusty plasma have been widely studied in recent years, because the extremely massive charged dust particles play a vital role in understanding the electrostatic disturbances in space plasma environments as well as in laboratory plasma devices [1]. In the present work nonlinear propagation of dust ion-acoustic (DIA) solitary waves (SWs) in a negative ion rich dusty plasma is experimentally investigated. The effect of negative ion on the formation of rarefactive solitary wave in a dusty double plasma device [2] is observed and its characteristics are analyzed. The important observation in this work is that; for the present dusty plasma condition, the applied electric perturbation cannot form a train of rarefactive solitons while propagating, until a sufficient amount of negative ions is introduced into the dusty plasma. It is also observed that the viscosity in the dusty plasma plays a crucial role in the formation and dissipation of solitary waves. The velocity and width of the solitary waves are measured and compared with numerical results obtained from the Korteweg–de Vries (K-dV) Burgers equation.

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EP-114

Small Amplitude Solitary Waves in Multi-ion Fluid Superthermal Plasma

N. S. Saini, Ripin Kohli, Shalini and Nimardeep Kaur
Department of Physics, Guru Nanak Dev University, Amritsar- 143005
E-mail : nssaini@yahoo.com

Abstract

Dust particles are frequently found in various space environments as well as in laboratory devices and industrial processes in the form of complex plasma. The presence of these highly massive and negatively charged dust particles in plasma is responsible for the generation of dust acoustic and dust ion-acoustic modes. Dust ion acoustic waves have been observed theoretically as well as experimentally. In the present investigation we have studied the properties of dust ion acoustic solitary waves in multi-ions fluid plasma in the presence of superthermal electrons. Reductive perturbation method is employed to derive the KdV equation. From the solutions of KdV equation, it is observed that only negative potential solitary structures are observed. The amplitude and width of the solitary structures are significantly influenced by the combined effects of superthermality of electrons and concentration of negative as well as positive ions. We have also observed the effect of dust concentration on the characteristics of solitary waves.

EP-134

KP Equation For High Frequency Solitary Waves in Dusty Plasma

Nimardeep Kaur and N. S. Saini

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

E-mail : nimarsabharwal777@gmail.com

Abstract

A large number of investigations have been reported for the existence of nonlinear solitary structures in different plasma environments. The study of non-Maxwellian plasma is crucial to the understanding of space and astrophysical plasma dynamics. Since dust particles are omnipresent in space and astrophysical environments, so it is interesting to study the dynamics of dust acoustic solitary (DAS) waves in a dusty plasma. The characteristics of nonlinear dust acoustic solitary waves in a dusty plasma with non-Maxwellian electrons as well as ions are investigated. The Kadomstev-Petviashvili (KP) equation is derived using reductive perturbation method. The combined effects of

superthermality of electrons as well as ions has been analysed on the amplitude and width of DAS waves. It is observed that negative/positive potential solitary structures exist in the given plasma system. The findings of the present investigation may be very useful for understanding the solitary excitations in astrophysical environments.

EP-163

Kelvin Helmholtz Instability in Complex Plasma

Debabrata Banerjee, Sudip Garai, M. S. Janaki and Nikhil Chakrabarti
Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata-700064
E-mail : debabrata.banerjee@saha.ac.in

Abstract

Kelvin-Helmholtz (KH) instability of bounded and unbounded dust shear flow has been investigated in linear regime with numerical technique of matrix eigenvalue analysis. With proper invariant generalized hydrodynamic (GH) equation [1], both weakly coupled and strongly coupled limits are considered for the analysis. In strongly coupled fluid regime, long range correlation leads to elastic property along with inherent viscosity of fluid. In such visco-elastic media, the celebrated Orr-Sommerfeld equation can be generalized into the GHOS equation as [2].

In weakly coupled limit, stability of bounded dust flow has also been studied for non-Newtonian behaviour of dusty plasma. Strong velocity shear exists in the boundary layer and viscosity for its diffusive nature drives this shear energy to midstream flow to launch the instability. With numerical eigenvalue analysis, we have reported that shear thinning property enhances the instability but shear thickening property stabilizes it [3]. The maximum growth rate is observed in incompressible limit and the effect of compressibility is found to decrease the growth rate.

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EP-199

Large Amplitude Solitary Waves In A Five Component Dusty Plasma With Non Thermal Electrons And Ions

Sijo Sebastian, Sreekala G., Noble P. Abraham and Chandu Venugopal
School of Pure & Applied Physics, Mahatma Gandhi University, Priyadarshini Hills, Kottayam – 686 560, Kerala
E-mail : cvgmgphys@yahoo.co.in

Abstract

We investigate the existence of rarefactive and compressive solitary waves in a five component dusty plasma. Positively and negatively charged mobile dust, kappa function described hot ions and electrons and Boltzmann distributed electrons form the five components. Such a plasma approximates very well the plasma environment of many astrophysical objects, such as comets. The pseudo-potential approach is used to determine the existence of the soliton. It is shown that the ions have a significant effect on the amplitude of the solitary wave.

EP-234

Electron-Drift Driven Nonlinear Ion-Acoustic Modulational Instability In A Dusty Plasma

M. Khusroo, R. Goswami and Madhurjya P.Bora,
Department of Physics, Gauhati University, Guwahati, 781014
E-mail : madhurjyap.bora@gmail.com

Abstract

In this paper, we analyze the possible scenario for existence of ion-acoustic modulational instability in dusty plasma with equilibrium electron drift. These kinds of plasma are realizable in laboratory as well as in space environments. In particular, there are several situations including near-earth plasmas, where these environments are plausible. In this work, we go on to derive the non-linear Schrödinger equation for this plasmas and show that under appropriate conditions, it can give rise to freak (or rogue) waves, which can drive large-scale variation of the electric field in these plasmas, which should be easily detectable.

EP-246

Effect Of RF Fields On The Debye Sheath Around A Charged Protein

Sumantra Chaudhuri, Harishankar Ramachandran
Indian Institute of Technology, Electrical Engineering Department, Chennai- 600036
E-mail: sumantra61@gmail.com

Abstract

This work presents an analysis of the structure and evolution of the Debye sheath surrounding a charged protein **[1]** in the presence of an RF perturbation. Albumin, the main protein found in blood, is negatively charged and hence is shielded by a Debye sheath comprising of Hydrogen ions. When an RF field is present, this Debye sheath is shaken and its modes of relaxation are presented. Issues addressed include (a) the proper fluid equations appropriate for the problem, (b) nature of the eigen modes of vibration, (c) time scales of relaxation, (d) the long term evolution of the sheath after an impulse is applied, (e) the response of the sheath to a steady state RF perturbation (f) relationship between E-field strength and displacement of the sheath. The amplitude and scale of the response of the sheath are found to depend on frequency. Low frequency perturbations produce stronger fluctuations in the sheath profile and hence affect the charge shielding to a greater extent.

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EP-253

Velocity Shear Driven Instabilities In A Dusty Plasma

Sudip Garai, Debabrata Banerjee, M. S. Janaki, and Nikhil Chakrabarti
Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata - 700064
E-mail : sudip.garai@saha.ac.in

Abstract

Shear flow has been an important agent to drive the instabilities in a dusty plasma both in weakly and strongly coupled regime [1, 2]. We present the longitudinal dust acoustic wave instability in presence of velocity shear in a strongly coupled dusty plasma by using the generalized hydrodynamic (GH) model. In the hydrodynamic regime, the viscosity in the GH model plays the usual role of wave damping, whereas in the kinetic regime, viscosity shows energy storing property in the wave. In the kinetic regime, it is shown that velocity shear can destabilize this mode. Both non-modal and modal techniques are employed to demonstrate the growth rate of the instability.

Viscous heating occurs in plasma whenever there is a shear in the velocity profile. Recently, Feng *et al.* [3] report the observation of the temperature peaks due the strong viscous heating in the dusty plasma. Motivated by this we are trying to find the instabilities of acoustic like mode in presence of temperature gradient with a shear flow in a weakly coupled compressible dusty plasma. Local analysis, where the perturbation scale lengths are much smaller than the equilibrium scale lengths, predicts the instability of such mode. As the local prediction does not always present the true picture, we are pursuing the non local analysis (where the perturbation scale lengths are comparable the equilibrium scale lengths) taking all the in-homogeneities into account with numerical techniques and also with proper equilibrium profiles of the temperature and velocity shear.

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EP-283

Observation Of Dust Acoustic Waves In A Strongly Coupled Dusty Plasma

Abhijit Boruah, Pallabi Pathak, S.K. Sharma, H. Bailung
Physical Sciences Division, Institute of Advanced Study in Science and Technology, Guwahati-781035, Assam
E-mail: abhijitboruah@rocketmail.com

Abstract

Dusty plasma is a three-component plasma consisting of electrons, ions, and massive solid particles held in suspension. The solid particles usually charge negatively to a large value. One of the interesting features of dusty plasma is that under certain conditions the highly charged dust particles become strongly coupled leading to the formation of dust crystal [1, 2]. In this paper we are going to present experimental observation of Dust Acoustic Solitary Waves in strongly coupled dusty plasma. The experiment is performed in a cylindrical glass chamber of 100 cm in length and 15 cm diameter [3]. Floating dust particles (gold coated silica particles of diameter ~ 5μm) are being confined above a graphite plate. Dust particles are illuminated by using a green laser sheet. Dust Acoustic waves are excited by applying a low frequency(1-10Hz) sinusoidal signal to an exciter on the graphite plate. Dispersion relation is obtained from the observed waves at different frequencies of the appiled signal. Dust Acoustic Solitary Wave is excited by applying a short negative pulse to the exciter.

Propagation is recorded at a high frame rate by a video camera and analysed to obtain the solitary wave amplitude,width and velocity.The measured values are compared with the theoritical results obtained from the Korteweg-de Vries equation.

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EP-306

Dust Acoustic Solitons In A Strongly Coupled Dusty Plasma

S K Sharma, A Boruah and H Bailung
Institute of Advanced Study in Science and Technology, Guwahati, 781035
E-mail : sumita_sharma82@yahoo.com

Abstract

Soliton, a special nonlinear structure, has been actively investigated in various physical media including plasma. It is formed in a nonlinear dispersive media as a result of delicate balance between nonlinearity and dispersion. Solitons maintain their shape and velocity after a collision with other soliton. Dust acoustic waves (DAW) can also transform into solitons or shock in a dusty plasma [1-3] similar to the nonlinear evolution of ion acoustic waves in a normal plasma [4]. In this work, we studied the characteristics of dust acoustic solitons (DAS) as well as their collision property in a strongly coupled dusty plasma. The experiment is performed in a cylindrical glass chamber which is 100 cm in length and 15 cm in diameter. Argon discharge is produced by applying rf power 6-10 W at pressure ~ 0.1 - 2 Pa [5]. Gold coated silica particles (5 micron diameter) are dispersed into the plasma and levitated in the sheath just above a graphite plate kept inside the chamber. Microparticles are illuminated by using a green laser sheet and recorded by using a digital camera. Typical plasma parameters are ion density ~ 10^8 cm^{-3}, electron temperature ~ 5 eV, dust charge ~ 10^4 electronic charge. DAS (DAW) is excited by applying a short negative pulse, 5 - 20 V (a continuous sinusoidal signal) to an exciter above the graphite plate. The velocity, amplitude and width of the observed soliton is measured and compared with the theoretical values obtained from the soliton solution of the Korteweg-de Vries equation. A head on collision between two counterpropagating DASs have been observed. The two interacting solitons merge into a large peak (temporarily) at the time of interaction and then pass through each other. The solitons suffer a time delay in propagation after collision which is found to vary with the change in excitation voltage.

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EP-308

Solitary Waves Soliton Of Dusty Plasma With Higher Order Nonlinearity With Dust Charge Variation

Ranjit Kumar Kalita[1] and Jnanjyoti Sarma[2]

[1] Department of Mathematics, Morigaon College, Morigaon 782105, Assam
[2] Department of Mathematics, R.G. Baruah College, Guwahati 781025, Assam

Email: kalitaranjit@yahoo.com

Abstract

The effects of higher order nonlinearity on dust acoustic waves are studied with dust charge variation. Using the reductive perturbation techniques K-dV and mK-dV equations are derived. The stationary solutions of the coupled equations are obtained in the case of dust ions, retaining terms up to the third order Applying the analytical and numerical methods for the higher order nonlinear equation studied the effects of amplitude and width of soliton in dusty plasma. The effects of dust charge fluctuation are also discussed in terms of higher order nonlinearity. The model of charge fluctuation, taken here when the charge equilibrium occurs, i.e. of the form $I_e + I_i = 0$, I_e and I_i being the currents of electron and ion.

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EP-309

Excitation Of Lower Hybrid Waves By A Density Modulated Electron Beam In A Magnetized Dusty Plasma Cylinder

Ved Prakash[1], Ruby Gupta[2], Suresh C. Sharma[3] and Vijayshri[1]

[1]School of Sciences, IGNOU, Maidan Garhi, New Delhi- 110 068
[2] Dept. of Physics, Swami Shraddhanand College, Alipur, Delhi-110 036
[3] Dept. of Applied Physics, Delhi Technological University, Delhi-110 042

E-mail : vedprakashimd@gmail.com

Abstract

A premodulated electron beam propagating through a magnetized plasma cylinder drives electrostatic lower hybrid waves (LHWs) to instability via Cerenkov interaction. Numerical calculations of the growth rate and unstable mode frequencies have been carried out for the laboratory LHW and dusty plasma parameters. The growth rate of the unstable wave instability increases with the modulation index and attains a maximum value when the frequency and wave number of the modulation are comparable that of the unstable wave. Moreover, the growth rate

increases with beam density and scales as the one-third power of the beam density. The results of the theory are applied to explain some of the experimental [1,2] and theoretical observations [3,4]. The dependence of the growth rate on the beam velocity is also discussed.

A nonlocal theory of LHWs driven to instabily by a modulated electron beam propagating parallel to the external static magnetic field is developed. In Sec II, we carry out the instability analysis. The plasma and beam responses are obtained using fluid treatment. The growth rate is obtained using the first-order perturbation theory. Results and Discussions are given in Sec III.

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EP-381

Effect Of Dielectrics On Cogenerated Dusty Plasma

Sanjib Sarkar[1], M.Bose[1], S.Mukherjee[2] & J.Pramanik[3]

[1] Department of Physics; Jadavpur University; Kolkata 700032
[2] FCIPT, Institute for Plasma Research; Gandhinagar 382428
[3]Department of Physics; Kharagpur College 721305

Abstract

Spatiotemporal evolution of dust density waves (DDW's) in cogenerated dusty plasma, in presence of glass plates is observed. For the first time ever we have observed various DDW's, like vertical, oblique and stationary simultaneously. Evolution of spatiotemporal complexity like bifurcation, in propagating wavefronts is also observed. The DDW collapses when dust concentration reaches extremely high value. When we increase the number of glass plates the oblique and nonpropagating mode vanishes while dust particles were trapped above each glass plates showing only vertical DDW's.

EP-396

Nonlinear Fluctuation Dynamics Of A Planar Charge-Varying Collisional Inhomogeneous Dust Molecular Cloud

B. Borah and P. K. Karmakar
Department of Physics, Tezpur University, Napaam784028, Tezpur, Assam
E-mail: bhupen354@gmail.com

Abstract

We propose theoretical evolutionary model for investigating the nonlinear gravito-electrostatic eigenmode dynamics in a self-gravitating inhomogeneous [1] collisional dust molecular cloud (DMC) with dust-charge variation [1, 2] on the Jeans scale. The lowest-order inertial correction [3]

of the thermal species and the complex spatio-temporal dependence of the equilibrium are taken into account under planar geometry approximation. We apply a standard multiple scaling technique [2] methodologically to derive a new coupled pair of driven Korteweg-de Vries (*d*-KdV) [2] equations involving self-consistent linear sources on the fluctuations. A detailed numerical analysis portrays the excitation of electrostatic and self-gravitational eigenmodes spatio-temporarily evolving as oscillatory shocks and solitons-like structures. The relevance of the observed spectral patterns in diverse space and astrophysical situations is explored and compared with the stability analyses by others based on the Jeans homogenization assumption [1, 2]. This is conjectured that depending on various realistic plasma conditions and the degree of spatio-temporal inhomogeneity, a unique transition from soliton-to-shock and vice versa is observed for both the classes of eigenmodes. In addition, that such structures trigger the initial conditions for star formation [4] is confirmed by a detailed spatio-temporal shape analysis with multi-parameter variation. Tentative applicability of the results in realistic inhomogeneous space and astrophysical environments are summarily highlighted.

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Computer Modeling For Plasma (CM)

CM-012

Stability And Nonlinear Studies Of Shear Flow In Strongly Coupled Fluids

Akanksha Gupta and R.Ganesh

Institute for Plasma Research,bhat Gandhinagar Gujarat-382428

Email : akankshag@ipr.res.in

Abstract

Complex plasma are formed when large micron size dust particles are suspended in the usual electron-ion plasmas. In particular, the dusts tend to acquire large average charge (~10 4e) and the dust-dust interaction becomes strongly coupled. For example, the average potential energy to average kinetic energy ratio per dust can become grater than 1. These systems can be addressed by computer simulation [1] and also using phenomenological generalized hydrodynamic (G-H) Models [2]. Shear flow are ubiquitous in nature[3,4]. It is natural to ask how the nonlinearity introduced by strongly coupling in this visco-elastic medium manifests itself in a variety of shear flows. For example, the growth rate spectra for Kelvin-Helmholtz instability has been observed for double step profile using Molecular Dynamics simulation[1]. To make a comparison, here we consider double Tanh-profile with doubly periodic boundary condition. An eigen value problem is constructed using linearized G-H model and growth rate are obtained. In parallel, MPI based pseudo spectral fluid code is also developed. The growth rates obtained from the spectral code is compared with Eigen value results.

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CM-016

2-D XOOPIC Simulation On Sheath Formation In Magnetized Plasmas

S. Adhikari and K.S. Goswami

Centre of Plasma Physics-Institute for Plasma Research, Nazirakhat, Sonapur-782 402, Kamrup

E-mail: sayanadhikari207@gmail.com

Abstract

The study of sheath formation in a magnetized plasma has received considerable attention in recent years. There exists a very large number of works on analytical, experimental and numerical investigations of magnetized sheaths. However, there are only few studies on the effect of the magnetic field on the electron sheath formation. Using XOOPIC simulation code a detailed analysis of the formation of two dimensional sheath structure in a magnetized plasma containing fast electrons, slow electrons and ions. The influence of the magnetic field on the sheath formation is also analysed. We assume that at the sheath entrance the average velocities of the slow and fast electrons

are directed along the magnetic field. The effect of fast and slow electrons and the variation of angle between the magnetic field and the wall on the sheath structure is discussed.

CM-020

Influence of Filter Magnetic Field on the Co-Extracted Electron Current in a Negative Ion Extraction System

A Phukan[1] and P J Bhuyan[1,2]

[1]Centre of plasma Physics-Institute for Plasma Research, Nazirakhat, Sonapur -782402, Kamrup
[2]Department of Physics, Tezpur University, Napaam, Tezpur – 781028 Assam

E-mail *:* ananya.phukan26@gmail.com

Abstract

A 3D-3V electrostatic Particle-in-Cell (PIC) code has been developed to study the extraction region of negative ion sources. The code encompasses realistic 3-D geometry along with the applied electric and magnetic fields to model the region around a single hole of the plasma grid of a negative ion extraction system. The code has been benchmarked using a fleet of single – particle and plasma behavior tests. The code is then applied to a plasma system containing electrons and positive ions (with a mass ratio of 100). Dynamics of these species have been studied under various applied electric and magnetic fields. In the initial stage, a steady electron current is established through the extraction grid by applying a potential of ~ 10KV to the extraction grid. Next, filter magnetic fields of various strength, ranging from 1mT to 8 mT have been applied along a direction normal to the extraction grid, and variation of electron current through the plasma grid have been observed for these values of the filter magnetic field.

CM-050

Modelling Of Electromagnetic Fields During Plasma Startup In SST-1 Tokamak

A. K. Singh, I. Bandyopadhyay, D. Raju, R. Srinivasan and SST-1 Team

ITER-India, Institute for Plasma Research
A-29 GIDC Electronic Estate, Sector-25, Gandhinagar–382 016, Gujarat

E-mail: amit.singh@iter-india.org

Abstract

The time varying currents in the Ohmic transformer in SST-1 tokamak induce large eddy currents in the passive structures like the vacuum vessel and cryostat. Especially since the vacuum vessel and the cryostat are toroidally continuous without breaks in SST-1, this leads to a shielding effect on the flux penetrating the vacuum vessel. This reduces the magnitude of the loop voltage seen by the plasma as also delays its buildup. Also the induced currents alter the null location of magnetic field. Studying the effective loop voltage and magnetic null location during the plasma breakdown and startup is important, as corrective measures may be required in case of an insufficient loop voltage or an improper null. The dynamics of the evolution of the loop voltage and the magnetic null due to the toroidal eddy currents in SST-1 passive structure has been studied in the breakdown phase of SST-1. At the time of the plasma initiation, the Ohmic transformer current is discharged by short-circuiting

the central solenoid (CS) coil through a resistance. The flux stored in the CS coil is linked to the plasma region, as also the conductors surrounding the plasma region. The resulting eddy currents flowing in the passive conductors lead to Joule heating losses of the stored flux in the CS coil. The amount of this eddy current and the associated flux loss has to be accurately determined in order to estimate the external loop voltage seen by the plasma required for plasma breakdown and current ramp-up. We have studied the effect of the induced currents on the loop voltage and the magnetic null using a toroidal-filament model. As the vessel and cryostat are conductors with large poloidal cross-section, for the approximation to be valid and results to be accurate, they are broken up into a large number of co-axial toroidal current carrying filaments. The inductance matrix for this large set of toroidal current carrying conductors is calculated using the standard Green functions and the induced currents evaluated by solving a set first order ODEs for the circuit equations. Of course the induced flux of the Ohmic transformer will also generate local non-toroidal eddies around, for example, around the port structures; however they are expected to provide space localized higher order correction to the field due to toroidal components of the induced current and are neglected in this work. The loop voltages calculated on flux loop locations in SST-1 from these circuit simulations match very well with the experimentally measured loop voltage signals, which prove that this simple model indeed works very well. We also investigate the magnetic null evolution, which indicate a gradual inward shift of the null location during the plasma breakdown.

CM-063

3D Character Of Plasma Transport In The Aditya Limiter Scrape Off Layer : EMC3-EIRENE Simulations And Analysis

Bibhu Prasad Sahoo[1], Devendra Sharma[1], Ratneshwar Jha [1],Yuhe Feng[2]

[1] *Institute for Plasma Research, Bhat, Gandhinagar, Gujarat, 382428*
[2]*Max-Planck-instite fur Plasmaphysik, Germany*

Email : bibhuprasad@ipr.res.in

Abstract

Strong 3-dimensional character of plasma transport properties was identified in the first SOL plasma transport simulations for the tokamak Aditya using 3D edge plasma transport simulation code EMC3-Eirene [1]. The origin of many interesting 3D attributes of the SOL plasma flows was traced,and reported for the first time [2,3], to be in a region of relatively long connection lengths that exists in the device SOL as identified by these simulations. These predictions were recently corroborated also by the analysis of the experimental measurements of the SOL plasma flows on the device [4]. The analysis of rest of the EMC3-Eirene simulation results also indicates that the root of many interesting properties of edge plasma fluctuations may as well be in the standing 3D perturbations of the plasma parameters as observed in the simulations.

Capacity of these perturbation to generate the finite temporal correlations, as necessary to produce the typical flow velocity fluctuations and related quantities like Reynolds stress, will be discussed in the present work. The progress of the activity and recent developments in order to do advanced 3D EMC3-Eirene simulations of the Aditya SOL plasma using the upgraded plasma configurations will also be reported.

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CM-084

Three temperature, Two-dimensional Radiation Hydrodynamics Model for the Analysis of Self-generated Magnetic Fields in Laser Produced Plasmas

C.D. Sijoy, H. Hemani, V. Mishra, N. Sakthivel, G. Singh and S. Chaturvedi

Computational Analysis Division, Bhabha Atomic Research Centre, Visakhapatnam

E-mail : sijoy@barc.gov.in

Abstract

We have developed a three temperature (electron, ion and radiation temperatures), two-dimensional (2D) radiation hydrodynamic model for the analysis of self-generated magnetic fields [1] and its effect on electron thermal conduction [2,3] in laser produced plasmas. The hydrodynamics is solved in two-dimensions (planar and axisymmetric cylindrical) by using an unstructured Lagrangian mesh. It accounts for laser energy deposition, energy transport via thermal radiation, thermal conduction . A conservative material remap scheme [4] is included to handle large material deformation that is expected for the blow-off plasma. The self-generated magnetic fields are calculated by using instantaneous gradients of electron temperature and electron number density [1]. Laser energy deposition is determined either by directly solving Maxwell's equations for the cases with plasma scale lengths < laser wavelength (short laser pulses—femto second) or by using a ray-tracing scheme under the WKB approximation for plasma scale lengths > laser wavelength (for longer laser pulses—nano second). The electron-ion collision frequency, required for laser absorption calculations, electron thermal conduction and electron-ion energy relaxation, is calculated using a model valid in the warm dense matter regime, i.e., from normal density ❒$_0$ down to rarefied states. An improved version of the Quotidian EOS model [5,6], is used to close the hydrodynamics equations. The radiation transport scheme can handle both optically thick and thin media [7]. A Flux limited scheme is used for electron heat transport due to thermal conduction. A symmetric-semi-implicit (SSI) scheme is used for updating energy. This paper reports the details of the physics models, numerical scheme and its validation for a sample problem.

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CM-108

Small Amplitude Ion-Acoustic Double Layers In Electron-Positron-Ion Plasmas With Finite Ion Temperature

S.K. Jain[a], J. K. Chawla[b] and M.K. Mishra[c]

[a] *Government College, Dholpur-328001, Rajasthan*
[b] *Government College, Thanagazi-301022, Alwar, Rajasthan*
[c] *Department of Physics, University of Rajasthan, Jaipur-302004*

E-mail : surendrajain0110@gmail.com

Abstract

The nonlinear small amplitude ion-acoustic double-layers in a collision less warm plasma consisting of isothermal positrons, warm ions and two-temperature distribution of electrons are investigated. Using standard hydrodynamic equations for the ions and the two species of electrons separately in thermal equilibrium following maxwellian distributions have been considered. Using reductive perturbation method we have derived modified Korteweg-de Vries (m-KdV) equation for the system. On numerical investigations the double layer solution of the system, we have found a new range of parameters for which system supports compressive double layers and rarefactive double layers depending on the concentration of cold electron (μ). Numerical analysis reveals that the system supports compressive double layer for lower values of cold electron concentration (μ), and rarefactive double layers for higher values of (μ). For these cases, the amplitude depends on positron concentration(α), finite ion temperature (σ) *and* the temperature ratio of the two electron species (β). The effect of various plasma parameters on the characteristics of the double layers have been investigated in detail. The results may be useful in space as well as in laboratory plasmas.

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CM-125

Role Of The Ponderomotive Force For Sustaining Plasma In A Microwave-Induced Plasma System

Projesh Basu and Harishankar Ramachandran

Indian Institute of Technology, Electrical Department, Chennai- 600036

E-mail : projeshbasu@gmail.com

Abstract

This talk discusses the nature of the plasma equilibrium in a microwave generated plasma. The material that is converted to plasma consists of water droplets in which minerals have been dissolved. The water-mineral droplet mixture is heated by RF waves in a waveguide and results in a

plasma. The spectral emission lines obtained from the experiment are used to estimate the plasma temperature. It is found that plasma is not generated without the iris [1] and the water droplets need to be introduced in an iris region of the waveguide. To understand this, the plasma generation process was simulated in a coupled Matlab-Comsol simulation and different iris configurations were studied. We find that the iris geometry provides the necessary ponderomotive force (formed by strong gradient electric fields) through which the plasma is confined. In the absence of the iris, the RF wave is better matched to the plasma and we would expect plasma formation to occur. However, in the absence of ponderomotive forces, there is considerable loss of particles and energy and plasma formation does not take place. This shows that the ponderomotive force is critical to the behaviour of microwave generated plasmas.

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CM-141

Breaking Of Ion Acoustic Solitary Waves In Warm Plasma

Amar Kakad[1], Bharati Kakad[1] and Yoshiharu Omura[2]

[1]*Indian Institute of Geomagnetism, New Panvel (West), Navi Mumbai, 410218*
[2]*Research Institute for Sustainable Humanosphere, Kyoto University,Kyoto, 6110011, JAPAN.*

E-mail : amar@iigs.iigm.res.in

Abstract

We perform one-dimensional fluid simulation of ion acoustic (IA) solitary waves in warm plasma. Our simulation demonstrates that the breaking of IA solitary waves is depending on wavelength of initial density perturbations (IDP). The short wavelength IDP evolve into two oppositely propagating identical IA solitons, whereas the long wavelength IDP develop into two indistinguishable chains of multiple IA solitons through a wave breaking process [1]. The wave breaking amplitude and time of its initiation are found to be dependent on characteristics of the IDP and electron to ion temperature ratio. We found that the wave breaking occurs close to the time when electrostatic energy exceeds half of the kinetic energy of the electron fluid in the simulation.

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CM-226

Statistical Mechanics Of Pure Repulsive And Pure Attractive Yukawa Systems With A Soft Core - A Molecular Dynamics Study

Swati Baruah and R. Ganesh
Institute for Plasma Research, Bhat – 382 428, Gandhinagar, Gujarat
E-mail : swatibaruah@ipr.res.in

Abstract

The formation of dust crystal [1] is a well-known phenomenon in dusty plasma physics. The discovery of plasma crystals has encouraged the plasma physics community as well as the condensed

matter physicist to study phase transitions, melting processes, different equilibrium properties etc. Phase transition in multi-component mixtures is an interesting phenomena occuring in different systems, ranging from molecular fluids to colloidal suspension to Complex Plasmas [1, 2]. Despites its long research history, the phenomena of phase transition remains of fundamental importance. Hard/soft core Yukawa potentials with soft cores/tails, either repulsive or attractive, are used to model colloid-solvent and solvent-solvent interactions. Here, a comparative study has been made on the role of pure repulsive Yukawa and attractive soft Yukawa potential on phase transition. Extensive Molecular Dynamics simulations are performed on such plasma systems at different temperatures to analyze the phase stability. To understand the physics of such systems different equilibrium properties are studied by calculationg pair-correlation function function, self-diffusion coefficient, velocity autocorrelation function, shear viscosity correlation function and correlation function for thermal conductivity and the results will be presented.

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CM-242

Stability Of Bernstein-Greene-Kruskal (BGK) Modes In Q-Nonextensive Collisionless Plasmas

Anup K Mandal and Rajaraman Ganesh

Institute for Plasma Research, Gandhinagar-382428, Gujarat

anupkumarmandal89@gmail.com

Abstract

In the past, long-time evolution of an initial perturbation in collisionless Maxwellian plasma has been simulated numerically. The controversy over the nonlinear fate of such electrostatic perturbation was resolved by Manfredi [1] using long-time simulations. The electric perturbation was found to continue indefinitely leading to BGK-like phase-space vortices. The question of formation of BGK modes in plasmas governed by q-nonextensive distributions (q=1 is a Maxwellian) has been recently addressed [2] using a high resolution 1D Vlasov-Poisson solver based on Piecewise-Parabolic Method (PPM) advection scheme. It was found that BGK structures do form for certain range of q-values around q=1 and beyond this window, for generic parameters, formation of BGK structures was rendered difficult. In this work, the important question of stability BGK modes in collisionless plasmas governed by q-nonextensive distributions has been addressed . Considering a BGK mode as a steady state solution, a numerical stability analysis has been performed. A systematic parametric study will be presented.

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CM-243

Equilibrium And Dynamical Studies Of Strongly Coupled Yukawa Liquids - Molecular Dynamics Simulations

Harish Charan[1], Rajaraman Ganesh[1], Ashwin Joy[2]

[1]*Institute for Plasma Research, Gandhinagar-382428, Gujarat*
[2]*Room 720 Perlman Building Weizmann Institute of Science Rehovot - 76100, Israel*

Email : charan.harish@gmail.com

Abstract

When micron-sized particles are immersed in conventional low temperature plasmas, these grains acquire an average charge of about 10,000-30,000 electronic charges. Experimentally, it has been demonstrated that one could get gas-like, liquid-like or solid-like phases according to strengh of strong coupling factor determined by the ratio of potential energy to kinetic energy per particle. The phase of micro-sized Coulomb particles screened by background plasma dynamics can be modelled by Yukawa interactions. Using 2D MD simulation [1], the equilibrium and dynamical properties of a Yukawa liquid is investigated. Several new diagnostics, hitherto not incorporated in 2D [1] have been included and bench marked against known results. For example, Velocity auto-correlation function, Diffusion coefficient using Einstein method, 2D-angular radial distribution functions and space-time correlation functions have been incorported in an earlier reported MD code [1]. A comparision of running Diffusion coefficient obtained from both Einstein diffusion as well has time integral of velocity autocorrelation match well pointing out to the correctness of these calculations. Depending on the values of strong coupling parameter and screening parameter, diffusion coefficient shows regular or super-diffusion. Furthermore, the spectra of longitudinal and transverse current correlation function show that for smaller values of coupling factors there is no transverse peak in the dispersion relation. These and other interesting results obtained will be presented.

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CM-244

Particle-In-Cell Simulation Of Non-Neutral Plasma

Meghraj Sengupta and Rajaraman Ganesh
Institute for Plasma Research, Gandhinagar – 382428
email : msengupta87@gmail.com

Abstract

Electron plasma experiments can be broadly divided into two categories based on the geometry of the confinement **(1)** in cylindrical traps (Penning-Malmberg traps), **(2)** in toroidal traps. Also based on ratio of strength of the dispersing space charge field (i.e. density, n) of the single species plasma to that of the applied magnetic field, B used to confine it, the experiments can be categorized into being performed in **(a)** the low density limit (low n/B^2) in which the mass inertia and finite larmour radius of electrons can be neglected and the entire motion of the electron fluid can be described by an $\mathbf{E} \times \mathbf{B}$ approximated or guiding centre approximated motion, and **(b)** the high density limit (high

n/B^2) in which the above approximation can not be made, and the full equation of motion of the electron fluid including mass will have to be considered while describing the nonneutral plasma.

Institute for Plasma Research (IPR) is a pioneer in confining electrons in toroidal traps - especially using very tight aspect ratio methods. IPR's SMARTEX-C machine routinely confines electron plasmas in the low n/B2 limit. Several aspects of the experimental results are not yet understood.
For example, the oscillations in electron cloud turn into a instability and it is suspected that the presence of resonant ions drive this mode. Also, the IPR trap is 3 dimensional with a toroidal cut. The extent to which this toroidal cut affects the dynamics is not clear. Linear and nonlinear dynamics of this experiment is yet to be fully understood. Apart from these, the theory of linear and toroidal electron plasma devices are of fundamental interest, not all of which can be addressed analytically.[1]

A 2D PIC code written in FORTRAN-90 and parallelized with OPEN-MP, has been developed to simulate electron plasma experiments in both high and low density limit and in all standard geometries (i.e. boundary shapes and aspect ratios). After bench marking with known analytical results at both high density and low density limits for pure electron plasmas in a straight magnetic field, we demonstrate existence of new radial breathing oscillations for certain initial angular velocity profiles and an algebraically growing mode which saturates into a global rigid rotor for various values of Brillouin densities.

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CM-268

A Numerical Study Of Rotating Flows In Strongly Coupled Dusty Plasma

Vikram Singh Dharodi, Amita Das and Sanat Kumar Tiwari
Institute for Plasma Research, Gandhinagar 382428
E-mail : vikramsingh@ipr.res.in

Abstract

The formation and evolution of localized nonlinear structures in strongly coupled dusty plasma using the generalized hydrodynamic (GHD) fluid model has been investigated numerically. The GHD model treats the dusty plasma as a visco-elastic medium and introduces strong coupling effects in terms of relaxation parameter τ_m and the viscosity, η [1]. In our present two-dimensional simulation studies, we observe the emission of transverse shear (TS) waves from rotating vorticity patches. The phase velocity of the emitted waves show a good agreement with the work Kaw et. al. [1] in hydrodynamic regime as well as for kinematic regime. In addition the $1/\sqrt{r}$ fall due to the cylindrical nature of the emitted wave has also been demonstrated.

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CM-285

Accounting Multi-component Species Diffusion in CFD Simulation of Processing Plasma under Thermal Non-equilibrium

S. Ghorui and A.K. Das
Laser and Plasma Technology Division, Bhabha Atomic Research Center, Mumbai-400085
E-mail : srikumarghorui@yahoo.com

Abstract

Recent investigations in processing plasmas find that appreciable non-equilibrium exists in many of the so-called LTE plasma devices. While plenty of works have been done on CFD simulation under LTE consideration and even included in few commercial codes, the field of non-equilibrium simulation is still emerging. Two-temperature non-equilibrium simulation is the simplest approach in which all the electrons are assumed to follow a temperature T_e, and the rest of the particles are assumed to follow a different temperature T_h. In the associated Navier-Stokes equation, the energy equation splits into two: one for electrons and the other for heavy species. While exchange of energy occurs through collisional exchange, redistribution of energy through conductive transport includes electronic, heavy species, intrinsic and reactive components. It is obvious that electronic component needs to be associated with electron energy equation, and the heavy species and intrinsic components must be associated with heavy species equation. However, the reactive components, which occur only when certain reactions happen inside the plasma, include both heavy species and electrons. Varieties of approaches have been adopted in the past to account for this reaction driven multi-component diffusion dominated contribution in non-equilibrium simulation. Here, we present a simple formalism to handle this term that offers easy breakup of electronic and heavy species contribution of the reactive thermal conductivity and allows one to use a lookup table for respective conductivities in the same manner like LTE simulations.

The net change in enthalpy at a particular location in the r^{th} reaction affects the nearby regions through the heat flux vector generated via the number flux vector of the species evolved in the r^{th} reaction, commensurate with the existing partial pressure gradients. The particle flux vector on the other hand is controlled by associated general ambipolar diffusion coefficients and species temperature. We show that in a two-temperature plasma, accounting temperature dependence of partial pressure of each species, the total heat flux can be expressed as a sum of two distinct groups of terms: one depends on the gradient in electron temperature and the other depends on the gradient in heavy species temperature. Following the analogy of equilibrium simulation, we call the first group of terms as the reactive thermal conductivity of electrons and the second group of terms as the reactive thermal conductivity for heavy particles. For two-temperature CFD simulation, the formalism then allows easy splitting of the single energy equation of equilibrium simulation into two: one for electrons and the other for rest of the heavy species. Respective reactive thermal conductivities then take care of the diffusion driven energy transport associated with reactions.

CM-289

Study of Binary, Thermal and Ambipolar Diffusion Coefficients in Non-Equilibrium Nitrogen Plasma

K.C. Meher, N. Tiwari, S. Ghorui and A.K. Das
Laser and Plasma Technology Division, Bhabha Atomic Research Center, Mumbai-400085
E-mail : srikumarghorui@yahoo.com

Abstract

Multi-component species diffusion in processing plasmas plays important role in controlling gas phase reaction kinetics as well as transport of energy. Usually a number of simultaneous reactions at

different rates in different regions of the plasma generates the species present inside and affects the nearby regions through the diffusive flux of the particles so generated. Nitrogen as a plasma forming gas receives special attention as it can operate with usual tungsten based refractory electrodes and offer radical rich non-oxidizing high temperature environment for plasma chemistry and plasma processing. It finds wide application in plasma cutting, nitriding, synthesis of nitride nanotubes and nanoparticles, arc jet thrusters in satellite propulsion, protective shielding for plasma applications etc. Understanding of gas phase plasma kinetics requires accurate knowledge of the associated diffusion coefficients for each and every species present inside the plasma. Thermodynamic and transport properties of nitrogen have been subjected to a number of investigations in the past under LTE and non-LTE conditions. However, apart from the studies by Murphy under LTE conditions as a function of temperature, very limited information is available on the behaviour of different multi-component diffusion coefficients in non-LTE nitrogen plasma.

The present study focuses on investigation of the binary diffusion coefficients, general diffusion coefficients, general ambipolar diffusion coefficients, thermal ambipolar diffusion coefficients, thermal diffusion coefficient of electrons and thermal diffusion coefficients of heavy particles for a pure nitrogen plasma as a function of electron temperature and pressure under different degrees of thermal non-equilibrium within the framework of two temperature fluid model. We present the formalism considered, the method of calculation, considered interactions, used collision integrals, validation of the results using data available in literature and finally the results of the calculation of different diffusion coefficients.

CM-342

Modelling Of Heat Source Dynamics In Electron Beam Welding

Suresh Akella[1], B. Ramesh Kumar[2] and Y. Harinath[1]

[1] *Sreyas Institute of Engineering and Technology, Nagole, Hyderabad-500068*
[2] *Institute for Plasma Research, bhat,Gandhinagar-382428.*

Email: s4akella@gmail.com

Abstract

Electron beam welding is one of the important fabrication processes for fusion reactor components subsystems. This weld process offers superior advantages over other techniques by producing very low distortions, high aspect ratios, lower stresses and deep penetration with single pass. The complete understanding of the electron beam welding with heat flux and temperature profiles during the beam metal interaction is still not completely understood. In addition, the formation of the weld bead geometry in weld pool is completely governed by the plasma key hole kinetics and their control over the depth due to the combined gaseous (vapor) and liquidous molten material during high speed electron beam welding process. The weld defects caused by the process are completely dependent on the keyhole plasma shape and movement during the electron beam interaction within material. The present investigations are focused on understanding the keyhole effects on the weld bead formation with various heat input parameters like flux and power density. Corresponding analytical estimations based on point source and line source models have been attempted to estimate the temperature profile during the keyhole formation. The conductive and radiative regimes are considered for the estimation of temperature profile of the molten pool cavity over the penetration depths. The power density distribution over the depth of the materials for stainless steel is attempted and temperature and heat flux distributions are evaluated. The analytical results are presented for this work and potential applications with electron beam welding in the fusion reactor are highlighted.

CM-343

Collisionless Microtearing Modes In Standard Tokamak Configurations

Aditya KS, R Ganesh, J. Chowdhury[#], S. Brunner[##], J. Vaclavick[##], L. Villard[##]

Institute for Plasma Research, Bhat, Gandhinagar 382428
[#]Dept of Physics, University of Colorado, Boulder, CO, 80309, USA
[##]CRPP, EPFL, 1015 Lausanne, Switzerland

Email : adityaks@ipr.res.in

Abstract

Microtearing Modes (MTM) are electromagnetic microinstabilities occuring in magnetically confined fusion plasmas driven by parallel electron current and collisions in the presence of electron temperature gradient. MTMs were first predicted to occur in such plasmas in early 70s [1,2]. Collisional MTMs have recently gathered attention in Spherical Tokamak configurations and RFPs [3,4]. Very recently collisional MTMs have been reported in configuration relevant to standard tokamak, namely ASDEX-U [5]. Perhaps for the first time, we show the existence of MTMs in purely collisionless limit and in large aspect ratio tokamak configurations using fully gyrokinetic full radius linear calculations. The physics of both electron scale as well as minor radius scale are resolved in the studies. Results of the studies, such as the 2-D structure of the mode and the dependence of growth rates on plasma pressure, perpendicular (to $\mathbf{B_0}$) wavelength spectrum and the effect of Landau damping and magnetic drift resonance will be presented. A comparison with another electromagnetic mode, namely Kinetic Ballooning Mode, which is driven by ion temperature gradient will also be shown.

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CM-375

Simulation Of Multi-Cusp Magnetic Field For Efficient Confinement Of Hydrogen Plasma In H^-Ion Source

Dr. D.V. Ghodke,[1]ManishaAgnihotri,[1]Preet Jain,Dr. V.K Senecha & S.C. Joshi

Raja Ramanna Center for Advanced Technology, Indore, India-462013
[1]E & C Department, SVITS, Indore, India-453331

Email : dvghodke@rrcat.gov.in

Abstract

This paper presents the simulation of permanent magnet multi-cusp field for hydrogen plasma confinement in H^- ion source using Opera-3D. In order to increase plasma density and making it uniformalong the axis of plasma chamber reduces the scattering losses, a multi-cusp magnetic field is

used. For better plasma confinement, the dimensions of configurations have been optimized to increase the field free region at the center of the plasma chamber and to increase the magnetic field (B) at the plasma chamber wall.In the region of increased magnetic field, the plasma particles are reflected back into the central plasma region rather than being lost from the plasma, due to magnetic force exerted on it. A cusp magnetic field provides a way to control the shape and size of the plasma volume and slow down the loss rate of plasma particles.
Different types of multi-cusp permanent magnetic field configurationshave beenused for hydrogen plasma confinement in H^- ion source. The proposed configuration with iron cylinder not only reduces the stray magnetic field outside the plasma chamber but also provides thereturn pathso as to producethe Hal-bach type cusping field. Octa-pole configuration was simulated extensively using TOSCA module of Opera-3D software package. The permanent magnet used for octa-pole configuration is NdFeB of N32SH grade having dimensions of 66.25 x 10 x 14 mm^3. The outer radius of iron cylinder is 54mm, length 66.25mm& thickness is 5mm with 2mm gap between magnets & iron cylinder.The inner diameter of plasma chamber is 48mm. The magnetic flux density along plasma chamber wall is ~101mTand field free region is ~18mm, which is sufficient to confine the plasma particles.In order to check the confinement effect, particles of5 eVenergy were simulated to understand theirloss near the plasma chamber wall.

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CM-377

Analysis Of Thermal History And Residual Stress In Plasma Sprayed Coatings

M.Raja[1], Gavisiddayya Hiremath[1], K. Ramachandran[2], P.V.A. Padmanabhan[3], T.K. Thiyagarajan[3]

[1]*CRMS & TM, School of Mechanical Sciences, Karunya University, Coimbatore-641114*
[2]*Department of Physics, Bharathiyar University, Coimbatore-641046*
[3]*L & PT Division, Bhabha Atomic Research Centre, Mumbai-400085*

E-mail: rajam@karunya.edu

Abstract

Plasma spraying has been extensively used for producing different kinds of coatings to protect from wear, corrosion and high temperature etc. The temperature and stress distribution both in substrate and coating during spraying has significant effect on adhesive strength and coating properties [1, 2]. Also, residual stresses depend on the thermal history during deposition [3]. Therefore, it is important to understand the mechanisms of stress development, to predict and control the temperature and stresses.

1-D computational and analytical model was used to predict the thermal history and stress distribution of substrate and /or coating during plasma spraying respectively. The computational model includes plasma and particle heat flux to predict temperature distribution of alumina coating on cu substrate by considering semi-infinite body. The influence of spraying parameter such as coating thickness, stand-off distance and coating growth rate on temperature distribution are also taken into account and discussed.

Using the stress model proposed in this study, the stress distribution within the alumina coating and copper substrate was derived from the thermal history. Results are discussed and compared with previously published results.

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CM-378

Temporal Evolution Of The Electron Energy Distribution During Birth Of A Wave Induced Plasma: Lapse And Relapse Of A Maxwellian

Sudeep Bhattacharjee, Samit Paul and Sayandip Ghosh

Department of Physics, Indian Institute of Technology, Kanpur 208016

E-mail : sudeepb@iitk.ac.in

Abstract

Plasma ignition can be achieved by energizing initial seed electrons present in the volume such that the electrons can ionize neutral atoms to cause breakdown. Initially the electrons are in thermal equilibrium following Maxwell-Boltzmann energy distribution with the mean energy corresponding to room temperature. When the energy source is turned on, electrons gain energy and as soon as they cross excitation or ionization thresholds they take part in inelastic collisions. Each ionization process gives birth to a new electron through which the total number of electron increases. There are also processes like excitation, de-excitation, recombination, particle loss (diffusion) during the evolution process in the presence of external fields which eventually drives the system to deviate from equilibrium. The temporal evolution of electron energy distribution function (EEDF) from the seed electrons until a plasma is formed is not well studied. It is reported that the plasma initiation takes about 1-25 ns depending on the ignition criterion [1-2]. Performing experiments within such a small time scale is challenging. In this work we therefore present a Monte-Carlo simulation study to investigate the temporal evolution of EEDF during birth of a plasma.

The simulation considers initial seed electrons of density ~ 1×10^4 /cc in a spherical volume of radius 1.5 cm, that interact with microwaves (MW) of 2.45 GHz in the presence of magnetostatic fields [1]. The individual electrons are allowed to interact with the atoms by elastic or inelastic process depending on their energy and collision cross-sections. Accurate cross section data are taken from literature to ensure realistic collisions [3]. It is found that the electrons deviate from equilibrium

quickly and again they equilibrate after some time prior to breakdown. In this work we present a mathematical treatment of measuring deviation from equilibrium and a detailed study of equilibrium regain time (τ). It is observed that the density of neutral atoms play an important role to bring the system back to equilibrium. For lower pressures, ~ 0.05 Torr the system does not reach equilibrium in the pre-breakdown stage due to fewer numbers of collisions. The effect of MW intensity and external magnetostatic field on τ has also been studied. Increasing MW intensity expedites the equilibrium since the electron energy is higher and they move faster to undergo more collisions within the time. Similarly, when the magnetic field is close to electron cyclotron resonance (875.5 Gauss) τ is a minimum and τ increases away from resonance.

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CM-388

PIC Modeling Of Laser Channeling Relevant To Fast Ignition

D. K. Singh[1], J. R. Davies[2], G. Sarri[3], F. Fiuza[4] and L. O. Silva[4]

[1]*Department of Physics, P.K.R.M. College (Vinoba Bhave University), Dhanbad – 826 004*
[2]*Fusion Science Center, Laboratory for Laser Energetics and Mechanical Engineering, University of Rochester, New York 14623, USA*
[3]*School of Mathematics and Physics, The Queens University of Belfast, Belfast BT7 1NN, United Kingdom*
[4]*GoLP, Instituto de Plasmas e Fusão Nuclear – Laboratório Associado, Instituto Superior Técnico, 1049-001 Lisboa, Portugal*

E-mail: dkdltg@gmail.com

Abstract

The Fast Ignition [1] concept is a variant of Inertial Confinement Fusion in which DT fuel is first compressed to high density and then ignited by a relativistic electron beam generated by a fast (< 20 ps) ultra-intense laser pulse. However, to achieve Fast Ignition the high intensity ignition pulse needs to propagate into the compressed fuel core through about 4 mm of coronal plasma that contains underdense as well as overdense regions where it is subjectd to various instabilities that could significantly reduce its coupling efficiency to the core. One idea to avoid various instabilities and losses in the long coronal plasma is to use a low intensity laser to create a channel in the underdense plasma for the propagation of the ignition pulse. The channeling pulse could be a separate pulse or a pre-pulse of the ignition laser. Creation of mm scale channel was verified in the HiPER [2] channeling experiment at Vulcan [3].

In this presentation, PIC modeling of laser channelling for Fast Ignition in the corona of HiPER baseline target has been demonstrated. Simulations in two and three-dimensions has been performed using the PIC code OSIRIS [4]. Long (mm scale) and persistent channels in underdense plasma have been observed following the relativistic self-focusing of laser. 2D simulations with both s and p-polarizations (electric field vector perpendicular and parallel to the plane of propagation, respectively) and 3D simulations using linearly and circularly polarized laser were performed and these results revels the polarization dependent dynamics of intense laser pulse in underdense plasma.

These simulations for various plasma densities and different laser parameters suggest preliminary specifications of a channelling laser for Fast Ignition.

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CM-393

PIC-FDTD Code Development For Beam-Wave Interaction In 'PASOTRON'

Nalini Pareek[1], Niladri Sarkar[2], Minhaz Ahmed[1], Udit Narayan Pal[1], Niraj Kumar[1] and Ram Prakash[1]

[1]*Microwave Tubes Division, CSIR-CEERI, Pilani 333031*
[2]*Birla Institute of Technology and Sciences (BITS), Pilani 333031*

E-mail : nalinipareek@gmail.com

Abstract

Plasma-assisted high power microwave source 'PASOTRON' is being developed at a few places internationally to utilize plasma channel transport of the beam through Slow Wave Structure (SWS) to significantly reduce the size and weight in conventional linear high power microwave (HPM) sources by eliminating the need for the applied axial magnetic field [1-3]. Typically, the PASOTRON requires an electron gun, SWS and an output coupler/antenna. The use of the plasma cathode electron (PCE) gun for electron beam generation from electron gun eliminates the problem of back streaming ion bombardment from the beam generated plasma and improves the capability of the microwave sources. However, much attention has not been paid on the theoretical and simulation studies related to beam-wave interaction in presence of plasma. In fact, in PASOTRON device very strong non-linear interaction between electron beam and electromagnetic wave can occur, thus making their analytical design very cumbersome. Consequently, a particle simulation code is very much required to make HPM designs simpler.

We have made some efforts to study beam wave interaction in plasma filled SWS, which is a backward wave oscillator (BWO). The aim is to develop a PIC-FDTD [4] code using MATLAB for the simulation of beam-wave interaction in the PASOTRON. The updating equations for electromagnetic fields are formulated using FDTD, in cylindrical coordinates since the SWS geometry is axially symmetric. In order to examine the field configuration in 3D, a field solver is implemented using the BOR-FDTD (Body of revolution FDTD) [5]. The results are being compared with MAGIC [6] tool software to validate the analysis. The results of the analysis will be presented.

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Plasma Diagnostics (PD)

PD-003

Conceptual Design of an In-Vessel Inspection Robotic System for Tokamak Environment

Prabhat Kumar[#], Prateek Patel[§], Daniel Raju[#], Jatinkumar Dave[§], Vaibhav Ranjan[#] and Mehul Naik[§]

[#]*Institute for Plasma Research, Bhat, Gandhinagar, 382428*
[§]*Nirma Institute of Technology, Gota, Ahmedabad, 382481*

E-mail : prabhat@ipr.res.in

Abstract

An in-vessel inspection robotic system has been conceptualized for operation inside a tokamak vessel. The robotic system is envisaged to comprise of a robotic arm, end-effector, microcontroller and wireless communication system. The end-effector is envisaged to be a special purpose camera for in-situ inspection between plasma shots. The three-link robotic arm, designed for ITER-like environment, has 4 revolute joints- 3 providing manipulation in poloidal plane and the fourth one providing limited movement in adjacent toroidal planes. This paper provides the conceptual design of the system along with kinematic analysis of robotic arm. Solutions have been derived for forward and inverse kinematic models and the Jacobian matrix for the robotic arm linkage. In forward kinematic model, given a set of joint-link parameters, the position and orientation of end-effector are determined with respect to a reference frame. In inverse kinematic model, given the specified position and orientation of end-effector with respect to a reference frame, a set of joint variables are derived that would bring the end-effector into the required posture. Using Jacobian matrix, the relation between the end-effector velocity and the joint velocity of a manipulator is obtained i.e. given the individual joint velocity; the end-effector velocity is obtained. A CAD model has been generated using CATIA to simulate the kinematic model and carry out computational stress analysis.

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PD-030

Estimation Of Post Disruption Plasma Temperature For Fast Current Quench Aditya Plasma Shots

S. Purohit, M. B. Chowdhuri, Y.S. Joisa, J.V. Raval, J. Ghosh, R. Jha and Aditya team

Institute for Plasma Research, Bhat, Gandhinagar, 382 428

E-mail: pshishir@ipr.res.in

Abstract

Characteristics of tokamak current quenches are an important issue for the determination of electro-magnetic forces that act on the in-vessel components and vacuum vessel during major disruptions. It

is observed that thermal quench is followed by a sharp current decay. Fast current quench disruptive plasma shots were investigated for ADITYA tokamak. The current decay time was determined for the selected shots, which were in the range of 0.8msec to 2.5 msec. This current decay information was then applied to *L/R* model, frequently employed for the estimation of the current decay time in tokamak plasmas, considering plasma inductance and plasma resistivity. This methodology was adopted for the estimation of the post disruption plasma temperature using the experimentally observed current decay time for the fast current quench disruptive ADITYA plasma shots.

The study reveals that for the identified shots there is a constant increase in the current decay time with the post disruption plasma temperature. The investigations also explore the behavior post disruption plasma temperature and the current decay time as a function of the edge safety factor, Q. Post disruption plasma temperature and the current decay time exhibits a decrease with the increase in the value Q.

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PD-040

Characterization of DC Glow Discharge Plasma in Co-Axial Electrode Geometry

R. Kumar[1], R. Narayanan[2], R.D. Tarey[1], A. Ganguli[2]

[1]*Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016*
[2]*Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016*

E-mail: phz088370@physics.iitd.ac.in

Abstract

In DC glow discharge plasmas, hysteresis effect in the V-I characteristics [1, 3], generation and dynamics of multiple double layers in front of a positively biased electrode [1] and formation of various anodic structures [1, 2] (a set of concentric luminous shells with different intensities) have been a subject of considerable interest in various system configurations [1-3]. Mostly these effects have been observed in the presence of an auxiliary (third) electrode. Further, nonlinear oscillations have been observed in either the discharge current or the floating potential of a Langmuir probe (LP). Recently, observations of floating potential oscillations have also been reported without the use of auxiliary electrodes in a coaxial electrode geometry [4, 5]. The plasma characterizations of such electrode geometry have not been studied in great detail.
Experiments were carried out in a similar coaxial electrode geometry [6] wherein the discharge characteristics showed hysteresis effect in the system. The DC discharge system is observed to have three stable states within the obtained range of discharge current with the system passing through a

negative differential resistance (NDR) region as it transits from one state to another. Thus the V-I characteristic has two sharp jumps in the discharge voltage corresponding to the NDR regions. The first NDR is seen to trigger self excited oscillations in the floating potential of an LP as well as the discharge current that have identical waveform and phasing, whatever the discharge conditions are. After the onset of the second NDR; only the amplitudes of these oscillations are observed to increase by an order of magnitude.This paper presents the characterization of DC glow discharge plasma in the above co-axial electrode configuration, near the NDR regions for different anode-cathode radii.

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PD-051

Plasma Diagnostics at Aditya Tokomak by Two Views Visible Light Tomography

Mayank Goswami [1], Prabhat Munshi [1, 2], Anupam Saxena[2], Manoj Kumar[3], and Ajai Kumar[3]

[1]*Nuclear Engineering and Technology Programme*
[2] *Department of Mechanical Engineering*
Indian Institute of Technology, Kanpur
[3]*Institute for Plasma Research, Gandhinagar 382 428*

E-mail: mayan@iitk.ac.in

Abstract

Plasma imaging has always been a requirement for development of correlations between theoretical and engineering advancements in tokomak reactors. Technological constraints do not allow putting sufficient imaging instruments. This visible tomography exercise is a part of a project for establishing an auxiliary imaging method that would assist other surrounding imaging facilities at Institute of Plasma Research (IPR) India [1, 2]. Space constraints around Aditya Tokomak allow only two orthogonal ports. Data measurement is performed using two arrays of 64 detectors that are sensitive to optical spectrum. The two view arrangement is a worst case scenario (as far as number of projections is concerned) but it is not implausible [3]. An algorithm is developed for such limited-detector and limited-view tomography cases [4, 5]. Spatial filtered entropy maximization technique is hybridized with adaptive discretization grids to find the best possible solution. Reconstruction using synthetic projection data, similar to the real measurement geometry, shows that significant reduction in $r.m.s.$ error is obtained. Real time plasma images/profiles are reconstructed using multiple shots of thin hot plasma from Aditya Tokomak. These profiles help to understand the real

time plasma-wall interaction at different stages of plasma generation due to edge plasma turbulence. It also helps to control the generation of plasma.

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PD-060

Studies of Impurity Behavior during Lithiumization Experiment In Aditya Tokamak

Niral Virani, M. B. Chowdhuri, R. Manchanda, Nilam Ramaiya, K. M. Jadeja, S. B. Bhatt, R. L. Tanna, C. N. Gupta, J. Ghosh and Aditya Team

Institute for Plasma Research, Bhat, Gandhinagar 382 428

E-mail: niralpatel.87@gmail.com

Abstract

Coating of plasma facing components mainly the vacuum vessel wall in tokamaks using low Z material is well known for improving the plasma performance in terms of achieving higher temperatures and low impurities. Among various materials used for coating, lithium has become immensely useful to reduce wall recycling and to decrease the plasma impurity content. In Aditya tokamak Lithiumization, carried out by inserting two Lithium rods inside the glow discharge cleaning plasma, is regularly done to study its effect on plasma performance. Impurity behaviors in the plasma after Li coating have been studied using spectroscopic diagnostics containing optical fibers, interference filters, PMT based filter-scopes and a 0.5 m visible spectrometer through the observations of visible spectra from different species. The temporal behavior of emissions from the plasma shows a decrease in H_α emission after lithiumization indicating reduction in wall recycling. Reduction of O II spectral emission intensity at 441.5 nm and visible continuum at 536.0 nm indicates lower oxygen content in plasma and reduced effective charge, respectively. However, no change is observed in CIII signal monitored at 464.7 nm which might be related to its source i.e. carbon graphite Limiter, on which Lithium coating wiped out quickly due its more direct interaction with plasma compared to the vacuum vessel wall. From the behavior of spectral line of neutral lithium at 670.8 nm monitored by spectrometer, it has been found that the lithium coating, obtained by inserting lithium rods in glow discharge plasmas in Aditya tokamak for 12 hours, sustains up to 12 – 14 long (~ 100 ms) discharges and then gradually fades away. The Sputtering yield of Lithium has been estimated spectroscopically, which provides many useful information about the plasma wall interaction in Aditya tokamak.

PD-061

A Pmt Array Based Diagnostics To Measure Spatial And Temporal Behavior Of H_α Emission From Aditya Tokamak

Nilam Ramaiya, Ajay Kumar, M. B. Chowdhuri, R. Manchanda, Niral Virani, Aniruddh Mali and J. Ghosh

Institute for Plasma Research, Bhat, Gandhinagar 382 428

E-mail: nilam@ipr.res.in

Abstract

The detailed information on fast changing plasma behavior during the breakdown and start-up phase of a tokamak plasma is very essential for achieving good plasma current flat-top region. A Photo multiplier tube (PMT) array based spectroscopic diagnostics has been designed and developed to measure the spatial profile of H_α, H_β and C III radiation from Aditya tokamak plasma with very fast time response ~100 μs and also with a good spatial resolution ~ 3.5 cm at plasma mid plane. The system has been installed on Aditya tokamak to study the breakdown location by monitoring the H_α emission during the plasma formation stage. Two 8 channels linear multi anode PMT arrays with high gains, wide dynamic range and low noise are used as detector. The module comes with built-in high voltage power supply and built-in amplifier. Collimated light has been collected from the plasma along 16 line-of-sights passing through the entire plasma poloidal cross section from the top port of Aditya tokamak and transferred to the PMT array using 1 mm core diameter optical fibers. The H_α spectra is obtained using 8 miniature interference filters (IF) centered at 656.3 nm placed in front of the PMT array. For the 2nd PMT array, another arrangement for wavelength selection is developed using bigger 2.5" IF, where lights from multiple fibers can be passed through for wavelength selection simultaneously. The spatial and temporal profiles of H_α emissions have been studied during the formation phase of Aditya tokamak plasma by changing the vertical field and delay of its application with respect to loop voltage. It was found that the plasma initiates in the high field side of tokamak most of the times. The details on experimental set-up and the results of the experiments will be discussed in this presentation.

PD-069

Laser Interferometery for Temporal Electron Density Measurement of Electrically Exploding Wire Plasmas

Jigyasa Batra, Ashutosh Jaiswar, Alok Saxena, T.C. Kaushik and S.C. Gupta

Bhabha Atomic Research Centre, Trombay, Mumbai-400 085

E-mail: jigyasa@barc.gov.in

Abstract

Exploding wires are good pulsed sources of electromagnetic radiations which can emit the spectrum from infra red rays to hard x-rays depending on the experimental conditions. Single exploding wire and arrays are being used for this purpose. Electromagnetic radiations are produced when imploding plasma stagnates on axis and radial kinetic energy is converted into internal energy. Electron density

profile during explosion can help in optimization of experimental parameters for maximum radiation output. We have developed a Mach Zhender Laser interferometer for diagnosing the electron density profile of pulsed plasmas. Temporal electron density profile has been measured in streak camera of single exploding wires in air using 532 nm green laser. Diameters of wires used are 58 μm, 81 μm and 233 μm. Capacitor bank of 50 J has been used to explode the wires. A fortran program has been developed to read the streak interferograms. Electron density in present experiments is found to be of the order of 7×10^{24} m^{-3} in exploding wire of 58 μm at the time of burst which continuously decreases with time. Work on characterization of the performance of single exploding wire plasmas with varying parameters will be presented.

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PD-090

Experimental Study Of Thermal Characteristic Of Different Thin Metal Foils For Infrared Imaging Video Bolometer And Comparison With FEM Simulations

Kanchan Mahavar, Santosh P. Pandya, Hitesh Patel, Shamsuddin Shaikh, Zubin Shaikh
Shwetang N. Pandya, Kumar Ajay and J. Govindrajan

Institute for Plasma Research, Bhat Village, Near Indira Bridge, Gandhinagar – 382 428

E-mail: psantosh@ipr.res.in

Abstract

The IR imaging video bolometer provides 2-Dimensional (2-D) temporally resolved, total radiated power from plasma confinement devices. IRVB utilizes free standing metal foil having thickness of few microns. The foil acts as a radiation absorbing element. It absorbed the plasma radiation in a broad wavelength band from Soft X-rays to infrared band, depending upon thickness and the thermal and optical properties of the foil material. Radiated power from the plasma is incident on the foil through a pinhole. The power gets absorbed by the foil and raises the foil's temperature. An infrared camera monitors the foils temperature from outside the vacuum vessel. Power brightness profiles can be obtained by numerically solving the heat diffusion equation from 2-D temperature distribution obtained from the IR-camera. The sensitivity of the IRVB depends on the thermo-physical properties of the bolometer foil. In order to achieve a better sensitivity and high temporal resolution, suitable foil material needs to be identified and to be used for IRVBs deployed on SST-1 and ADITYA tokamaks.

Different foil materials namely Pt, *Al, Sn, Ta, Ti, Au, Ni and Mo* are experimentally investigated and a comparison with estimation from FEM simulations is attempted in this poster.It has been found that Pt foils are relatively more sensitive than other foils investigated in the experiments, though the simulation results shows relatively less sensitivity.

PD-092

Improved Charge Collector Diagnostics For Electron Plasma In Smartex-C

Lavkesh Lachhvani, Karan Rathod, Manu Bajpai and Sambaran Pahari[1]

Institute for Plasma Research, Gandhinagar – 382428
[1]Bhabha Atomic Research Center, Vishakhapatanam – 530012
E-mail: lavkesh@ipr.res.in

Abstract

Cylindrical electron-plasma-traps inject plasma into a uniform axial magnetic field region and hold it with the help of electrostatic potentials applied on the axial ends of the trap. Charge measurement at any instant is carried out by *unplugging* one end: the plasma then flows out along the axial magnetic field lines on to a charge collector located at the far end of the trap [1]. Several inject-hold-dump cycles (with an incremental delay in the dump, each time) allow one to recreate the spatio-temporal charge distribution of the plasma. In toroidal traps, similar charge measurement is challenging due to the lack of "end wall". The estimation of the total charge requires a "dump diagnostic" *a la* cylindrical traps and fortunately a C-shaped toroidal trap offers this opportunity as a charge collector can be placed at the end of the "C".

However, a new set of problems arises in a small aspect ratio trap as the toroidal length of the trap is short and the plasma is shifted inwards. These result in short transit time of the charges. As the end grid is rapidly gated from negative potential to ground in about ~ 50 ns, the electrons rapidly collect on the charge collector mostly during the rise time itself. This plasma current is therefore accompanied by a strong displacement current resulting from fast rise time (dV/dt) and the capacitive coupling (C) of the collector grid with the vessel. Inductive effects also become prominent due to fast time scale of the phenomena. Due to the tenuous nature of the plasma, the plasma current is several orders of magnitude smaller than the displacement current. Effective means of reducing the displacement current by introducing a separate electrode and effectively grounding and shielding it, has been worked out. A prototype arrangement similar to the diagnostics to be installed in SMARTEX-C is first modeled outside. After characterizing it, similar arrangements have been implemented in the trap. The paper presents the charge collection scheme worked out, its performance and results of the pertaining charge measurements on SMARTEX-C.

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PD-096

Ion Temperature Measurement On The Aditya Tokamak

Santosh P. Pandya, Kumar Ajay, Snehlata Gupta, Priyanka Mishra, Rajani D. Dhingra,
J. Govindarajan and ADITYA-Team

Institute for Plasma Research, Gandhinagar – 382 428

E-mail: ajaykuma@ipr.res.in

Abstract

An accepted means of determining the ion temperature of magnetically confined plasma is to measure the energy distribution of neutral particles escaping from it [1-3]. These neutrals are the product of charge-exchange (CX) collisions between energetic plasma ions and neutral atoms which have penetrated into the plasma. The energy distribution of the resulting CX-Neutrals (CXN) is closely related to that of the original plasma ions. A Neutral Particle Energy Analyzer (NPA) is developed for the ADITYA tokamak [4] to measure energy distribution of these CXN and to estimate time resolved ion-temperature. A collimated beam of neutrals through series of baffles is allowed to enter in a H_2 gas-filled stripping cell, where these CXN re-ionize. These ions are then analyzed in a 45° electro-static energy analyzer and detected by channel electron multipliers. The energy channels are calibrated using H^+ ion source. The NPA channels are tuned for the high energy spectrum E_{ch} >> *3 to 5* x $T_i(0)$ to make sure that the detected ions are those coming from plasma core mostly. The NPA can analyze the ions in energy range of *100eV* to *3 keV* with the energy resolution $\Delta E/E\sim$ 10% to 40% and a time resolution $\Delta t\sim 10\text{-}15ms$. In the present paper, ion temperature estimation technique is described and temporal evolution of the ADITYA core-ion temperature is reported for various plasma discharges. An increase in the CXN counts and hence the higher core-ion temperature has been observed during RF heating as compared to Ohmic heating of plasma. Peak value of the core-ion temperature for various plasma discharges in ADITYA is found to be in the range of *80eV* to *250eV*. Comparison of core ion temperature and cord integrated electron temperature for a few plasma discharges has been made and $T_i(0)$ has been found to be ~ *40%* of cord integrated electron temperature $<T_e>$.

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PD-098

Infrared Thermographic Observation Of SST-1 Limiter During First Plasma Experiments

Santosh P. Pandya, Shamsuddin Shaikh, Zubin Shaikh, Kanchan Mahavar, Shwetang N. Pandya
Kumar Ajay, J. Govindarajan and SST-1 Team
Institute for Plasma Research, Gandhinagar – 382 428
E-mail: psantosh@ipr.res.in

Abstract

Infrared Thermography (IRT) of Plasma Facing Components (PFCs) is one of the most essential tools to investigate the interactions of the plasma with PFCs as it has an advantage of real time

monitoring of the surface temperatures remotely with a wide field of view (FOV). First plasma experiments of Steady State Superconducting Tokamak-1 (SST-1) were commenced with limiter configuration, having graphite tiles. There is a possibility of damage to the limiter tiles of SST-1 due to intense localized heating load under various conditions and also the particles ejected from the tiles can affect plasma boundary condition. For this reason, infrared thermographic measurement has become important for monitoring surface temperature and estimating thermal loads on inboard and out board limiter tiles. Infrared imaging system provides information on excessive temperature of component and power deposition profile.

An IRT system is deployed on the SST-1 tokamak at radial port#*12* having an IR-Camera located out side the vacuum vessel and a CaF2 vacuum view port has been used for the IR signal transmission *(>95%)*. The IRT system can measure temperature in the range of *-10°C* to *1200°C* with temperature resolution of *0.025°C* and time resolution of 5ms to 10ms. The system has a wide FOV*~22°* (*horizontally*) x *17°* (*vertically*) which covers inboard limiter in direct view and outboard limiter in reflected view using stainless steel mirror reflectivity (*>90%)* mounted on the inboard side. The system provides spatial resolution of *~1* x *1* mm^2 on the inboard limiter tiles and *~6* x *6* mm^2 on the outboard limiter tiles. Presently this IRT system has a measurement role for health monitoring of the limiter tiles and related physics studies. In the present paper, thermographic observations of SST-1 first plasma is reported which includes temporal evolution of temperature profile of inboard & outboard limiter, estimation of heat flux impinging on the limiter and power drawn by limiter tiles. From the observed set of first plasma discharges, it is found that there is a significant temperature rise from the initial temperature of the inboard limiter tiles and no significant rise was observed in the outboard tiles. From these observations it seemed that the plasma was mostly leaning on the inner side. Localized heating of the limiter tiles was also observed and thermographic frame sequences shows some material being ejected out of the inboard limiter tiles. Typical mean temperature rise of inboard-limiter tiles is found *>5°C* while peak temperature rise *~70°C* corresponds to a very localized hot spot. Heat flux impinging on the limiter is estimated in the range of $0.1\ MW/m^2$ to $2\ MW/m^2$.

PD-102

Magnetic Measurements Of First Plasma Experiments Of Tokamak SST-1

Sameer Kumar, Daniel Raju, A. Amardas, Ratneshwar Jha and SST-1 team

Institute for Plasma Research, Bhat, Gandhinagar-382428 Gujarat

E-mail : skjha@ipr.res.in

Abstract

Magnetic measurements are carried out in Steady-state Superconducting tokamak SST-1 [1] during the first plasma experiments. Measurements are done by using flux loops, Rogowski coils and magnetic pickup probes. In-situ calibrations of flux loops and magnetic pickup probes are carried out by energizing the central Ohmic and Vertical field coils. To calibrate the Rogowski coils (to be used to measure plasma current), an in-vessel coil has been used. This coil is energized with different current amplitudes and temporal profiles and the Rogowski coil responses were measured.

Magnetic measurements are also compared with the simulations done with the finite element code, Comsol Multipysics [2]. Comparison of measurements with simulations would be presented in this work.

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PD-129

ND: YAG Laser Control For Thomson Scattering Diagnostic In SST-1

Kiran Patel, Jinto Thomas and Ajai Kumar

Abstract

The paper describes a design of a laser control electronics module to operate the Thomson Scattering diagnostic in synchronization with the distributed control system in SST-1 Tokamak. The module is based on microcontroller that makes the design relatively simple and cost effective. The control electronics module operates flash lamp in continuos mode. During the plasma duration, the module generates a finite number of the laser pulse with programmable delay interval. The module also sends the status signal to the other control sub-system of the Thomson scattering diagnostic. Due to use of controller, the module can be controlled by a PC computer and used in automated application.

PD-152

Preliminary Design Considerations for Erosion/Deposition Monitor in ITER

Rajwinder Kaur[1], R. Huxford[2], G.Vayakis[2], J.Govindarajan[2], P.Andrew[2] and M. Walsh[2]

[1]*Institute for Plasma Research, Bhat, Gandhinagar -382 428*
[2]*ITER Organization, Route de Vinon sur Verdon, 13115 Saint Paul-lez-Durance, France*

E-mail : nikky@ipr.res.in

Abstract

Erosion Monitor diagnostics were initially foreseen in ITER to investigate the reliability of plasma facing components (PFC). Significant amount of erosion was expected in carbon divertor. Hence real-time erosion measurements were considered crucial to find the optimum condition for divertor plasma operation and for basic control and machine protection. With the planned change in strategy to go for tungsten divertor in ITER, the conditions on erosion monitor have changed substantially. The estimated steady state erosion on the tungsten divertor is negligibly [1,2] small and is mainly expected near strike points and during transients. However, net re-deposition of Beryllium with Tritium co-deposition is expected to be substantial on PFCs. The deposition is expected to grow more on inner upper baffle (~10μm/1h pulse) than on divertor (~1μm/1h pulse). One can conclude that the change in surface topography of PFCs due to deposition growth, being directly related to Tritium inventory, is of extreme importance for safety considerations. It is, therefore, required to monitor it with a highly reliable system. Nevertheless, the net erosion/deposition rates are not high enough to call for real time measurements.

In this work, we have presented the preliminary design considerations for a speckle interferometer to monitor the surface topography (i.e., net erosion depth/deposition thickness) of inner and outer divertor and inner baffle in between the plasma shots. The basic issue in designing the interferometer is the selection of laser wavelength. Five main considerations go into the selection of laser wavelength. These are: (i) measurable signal level against background thermal radiations, (ii) depth/thickness measurement range, (iii) sensitivity, (iv) spatial resolution and (v) errors arising due to mechanical vibrations. High sensitivity and spatial resolution favor shorter wavelengths, whereas large measurement range and lesser sensitivity to mechanical vibrations favor longer wavelengths. For divertor viewing geometry, an additional constraint, favoring shorter wavelength, is imposed due

to the fact that laser beams enter and exit the divertor cassette through a small opening. This limits the diagnostics access drastically, restricting the beam sizes and thereby the laser wavelength. The laser wavelength has to be carefully selected to have trade off among all these competing effects. In order to increase the range of depth/thickness measurement, dual wavelength method[3,4] has been planned. The set up will take advantage of temporal phase shifting techniques to retrieve phase change due to surface modification from measured intensities.

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PD-155

Diagnostics of Microwave Based Atmospheric Pressure Plasma Jet

Rajib Kar, Naresh Chand, Arundhati Bute, A.K. Das, L. M. Gantayet and D. S. Patil
Laser and Plasma Technology Division, Bhabha Atomic Research Centre, Mumbai- 400 085
E-mail: dspatil@barc.gov.in

Abstract

Microwave based atmospheric pressure plasma jets (APPJ) are being widely used in various analytical chemistry applications and other industrial fields, such as surface treatment, sterilization, and decontamination. Applications with these devices depend primarily on the nature of its characteristics. In order to understand the characteristics of the plasma that is generated at atmospheric pressure, it is essential and important to study the basic parameters of the plasma such as electron number density (n_e), Electron temperature (T_e) and varitaion of these parameters with applied power. This paper focusses on the optical emission spectroscopic (OES) diagnostics of the plasma generated using microwave based APPJ. Plasma is genarted using argon gas and the electron/ excitation temperature of the plasma is calculated by OES after judging the validity of different models in relations to the operating regime. The dependence of the electron temperature on the microwave power is studied. Furthermore, variation of the electron density with microwave power has also been studied by OES by stark broadening of 696.5 nm line of Argon. This paper will discuss about the details of the diagnostics experiment and results.

PD-158

Experimental And Monte-Carlo Absolute Efficiency Calibration Of HPGE γ-Ray Spectrometer For Application In Neutron Activation Analysis

S. Tiwari, S. Jakhar, M Abhangi, R Makwana, V. Chaudhari, C.V.S Rao, T.K.Basu[1]
Institute for Plasma Research, Bhat, Near Indira Bridge, Gandhinagar-382428
[1]*Raja Ramanna Fellow of DAE*
E-mail: shailja@ipr.res.in

Abstract

High Purity Germanium (HPGe) detector is widely used to measure the γ-rays from neutron activated foils used for neutron spectra measurement due to its better energy resolution and photo-peak efficiency. To determine the neutron induced activity in foils, it is very important to carry out absolute calibration for photo-peak efficiency in a wide range of γ-ray energy.Neutron activated foils

are considered as extended γ-ray sources. The sources available for efficiency calibration are usually point sources. Therefore it is difficult to determine the photo-peak efficiency for extended sources using these point sources. A method has been developed to address this problem. This method is a combination of experimental measurement with point sources and development of an optimized model for Monte-carlo N-Particle Code (MCNP) with the help of these experimental measurements. This MCNP model then can be used to find the photo-peak efficiency for any kind of source at any energy.

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PD-159

Development of PXI based DAQ in LabVIEW® for SMARTEX – C

Yogesh Govind Yeole, Lavkesh Lachhvani, Sambran Pahari[1] and Manu Bajpai

Institute for Plasma Research, Gandhinagar – 382 428

[1]BARC, Vishakhapattanam – 5300012

E-mail: yogesh@ipr.res.in

Abstract

The PXI based Data Acquisition System (DAQ) reported here, has been dedicated to *SM*all *A*spect *R*atio *T*oroidal *EX*periment in C – shaped geometry (SMARTEX – C) which is a device to create and confine non-neutral plasma. The DAQ includes (a) data acquisition card NI PXI-5105 with 8 channels and simultaneous sampling rate of 60 MSPS (b) data acquisition card NI PXI-6133 with 8 analog input channels as well as 8 digital input/output channels and a sampling rate of 2.5 MSPS (c) MXI-4 communication card (d) PXI chassis (e) Optical fiber link and (f) a dedicated PC. The operating system is Windows-Vista® Business (Service Pack 1).

The code for NI PXI-5105 in LabVIEW® – 2012 has been developed. The code has been incorporated with features like safety against unauthorized execution of the code, online and offline analysis. The online analysis is used to acquire data from respective channels. The offline analysis is invoked for the analysis of data stored in storage devices. The data can be stored in three file formats *viz*: bin, txt and xls. The code provides choice for the selection of any number of channels out of 8, their respective attenuation factor and voltage range. The trigger source is also selectable; either from analog channel, digital channel or software. The code development for NI PXI-6133 as well as a comprehensive integration with the experimental hardware including an oscilloscope having analog bandwidth of 500 MHz at 5 GSPS, is under progress.

This paper discusses the details of the developed LabVIEW® code and data acquired in 4 different channels of NI PXI-5105.

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PD-162

Estimation Of Effective Secondary Electron Emission Coefficient From The Power Balance Of Cathode Under Plasma Condition

Saravanan A, Prince Alex, Suraj Kumar Sinha.
Pondicherry University, Puducherry-605 014
E-mail: sarvaanphysics@gmail.com

Abstract

In this paper, we propose a more reliable experiment which gives accurate estimation of effective secondary electron emission coefficient (ESEE) of cathode material under plasma condition. Here the material whose ESEE to be found is used as a cathode material in glow discharge plasma. This method is based on the power balance at the cathode. By suitable variation of the experimental conditions the different contributions to cathode heating can be separated and studied independently. From the measured temporal temperature profile, various modes of power input to the cathode and power across the plasma, we can find effective secondary electron emission coefficient of cathode material.

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PD-167

Measurement Of Electron Temperature And Electron Density In Atmospheric Pressure Dielectric Barrier Discharge By Optical Methods

R Shrestha[1, 2], R B Tyata[1, 3], A K Shrestha[1], D P Subedi[1]
[1]*Department of Natural Science, Kathmandu University, Dhulikhel, Nepal*
[2]*Department of physics, Basu College, Kalighat, Byasi, Bhaktapur, Nepal*
[3]*Department of Electrical, Khwopa College of Engineering, Libali-2, Bhaktapur, Nepal*

E-mail: rajendra_t2002@yahoo.com

Abstract

Atmospheric pressure dielectric barrier discharge (DBD) in argon gas was generated using a high voltage (0-20 kV) power supply operating at (10-30) kHz in parallel plate electrodes system and was studied by means of optical measurements. Homogeneous and steady discharge was observed between the electrodes with gap spacing 2 mm and with a dielectric barrier glass of thickness 1.5 mm. Argon gas was fed at a controlled flow rate of 2 liters per minute. The electron temperature (T_e) and electron density (n_e) of the plasma were determined by means of optical emission spectroscopy (OES). Different transitions of ArI (696.54nm, 751.03nm) ArII (314.13nm, 378.75nm) in the spectra

were studied which are observed. Relevant broadening mechanism such as Doppler and Stark were used to calculate electron temperature (T_e) and electron density (n_e). Also the line intensity ratio method was used to determine the electron temperature and electron density from the spectra. Results show that the electron density is of the order of 10^{16} cm^{-3} while the electron temperature is estimated to be ~ 1 eV.

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PD-177

Spectroscopic Diagnostics of the Washer Gun Plasma of SYMPLE

Piyali Adhikary, M. B. Chowdhuri, Priyavandna J. Rathod, B Ramesh Kumar and Anitha V.P.

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

E-mail : anitha@ipr.res.in

Abstract

A device, SYMPLE (SYstem for Microwave PLasma Experiments), is being developed at IPR to study the interaction of high power microwave with plasma. The plasma that enables the proposed investigation needs to satisfy certain criteria such as moderate ((1-10)x10^{18}/m^3), density ($n_{e)}$, uniform axial (~1 m) and radial (~ 10 cm) extends and a sharp gradient (~ scale length ~ λ_{HPM} =10 cm in the microwave-plasma interaction regime. These requirements have necessitated a choice of washer – gun (~ 10 MW) based pulse (100μs) plasma source. Langmuir Probe based measurements are routinely carried out to understand the n_e and T_e of the plasma and their dependence on various parameters. However, due to the experimental environment involving high voltage, electrostatic noise has been a major concern and at most care is adopted in grounding system to minimize the noise level and ensure reliability of the probe data acquired from these probes.

An additional, alternative and non-intrusive diagnostics based on optical emission spectroscopy is carried out in order to cross check the density and temperature estimated using Langmuir probe data. Here, information on the time and space averaged n_e and T_e is derived from the line intensity ratio technique using spectral emissions from the neutral and singly ionized Argon. Preliminary analysis of the data has been carried out using local thermodynamic equilibrium (LTE) model. The T_e obtained is lower (~0.6 – 2 eV), by about a factor of 5, compared to those derived using Langmuir probe results. This could partly be due to the limitations with respect to the applicability of the LTE model for this type of plasma. Further, the data is averaged over the whole plasma pulse duration and the spatial radial extent including the plasma gradients, giving rise to a lower chord averaged value of n_e and $T_{e.}$ In this presentation, details of spectroscopy diagnostics, applicability of LTE technique and a comparison of the results obtained with those based on Langmuir probe data will be discussed.

PD-184

Operation and Control System Design for Large Volume Plasma Device

R. Sugandhi, P. K. Srivastava, Amit Patel, A. K. Sanyasi, S. K. Singh, L. M. Awasthi and S. K. Mattoo

Institute for Plasma Research,Bhat, Gandhinagar- 382428

E-mail: ritesh@ipr.res.in

Abstract

The Large Volume Plasma Device (LVPD) is a plasma device dedicated for carrying out studies on the excitation of waves and unfolding various characteristics of plasma turbulence. The device has significantly contributed in the past towards 1) unfolding various characteristics of Whistler waves, 2) developing this as a suitable facility for carrying out controlled study on ETG turbulence, 3) carrying out non-linear structure studies, and 4) exciting conditions suitable for understanding energetic electron loss, similar to the condition of radiation belt regions of earth magnetosphere etc. The LVPD system consist of various subsystems which includes double walled vacuum vessel, vacuum pumps, magnet coils, power supplies and various diagnostics installed at different locations spread over the entire span of device. The task of operation and control system includes coordinating operation of various subsystems for carrying out an experimental investigation to the proper representation of data unfolding information about the plasma produced.

A task is undertaken for the design and development of a new operation and control system capable of facilitating experiments and data analysis on a single console. The task is systematically divided into four phases namely, (1) Requirement phase (2) Design phase (3) Development phase and (4) System integration and testing phase. The requirements and rationales are written using IEEE-1233(1998) system requirement guidelines. The design models are prepared using ISO/IEC 19501. Unified modeling languages and instrumentation modules are prepared using ISA 5.1 (1998) standards. The signal I/O list is prepared to cover acquisition, status and control signals. The acquisition signals are classified under fast signals ($\geq 200 MHz$), medium signals ($\geq 5 MHz$) and slow signals ($1-10 kHz$). The system architecture is broadly divided into (1) slow and fast controller based technical system for automating system readiness and diagnostics data measurements during operation pulse , (2) MDS+ based technical system for data archival and (3) data analysis and scientific data visualization subsystem.

This paper will discuss conceptual aspects of the design i.e., requirement and rationales, static and dynamic design models, signal and I/O integration, testing and development plans. The paper will also discuss software, hardware controllers, I/O boards, technologies under consideration and involved logic for selection.

PD-185

Magnetic Probe Diagnostics for SYMPLE

AnoopSuseel, Praveenlal E V, P.K. Srivastava, Priyavandna J. Rathod and Anitha V.P.
Institute for Plasma Research, Bhat, Gandhinagar – 382428, Gujarat
E-mail : anitha@ipr.res.in

Abstract

SYMPLE (SYstem for Microwave PLasma Experiments), is an experimental system, aimed at investigating interaction of pulsed (~30 ns) high power (~ 500 MW) microwave (HPM) of

frequency ~3 GHz, with plasma. The diagnostics requirements here include measurement of wave magnetic field ($\tilde{B}$) in air / vacuum as well as the plasma response by picking up magnetic fluctuations generated in the plasma. Considerable database exists for studies at relatively low frequencies (~ a few Mega Hertz), on the design of miniature (~ a few mm^2) magnetic probes using special winding and shielding to extract noise free information. For high frequency (a few Giga Hertz), HEMP (high altitude electromagnetic pulse) and HPE (high power electromagnetic) applications, probes of appropriate bandwidth are now commercially manufactured, for enabling vacuum measurements. However, not much work has been carried out towards development of plasma compatible, high frequency (a few Giga Hertz)$\tilde{B}$probes.

Design of high frequency (~a few GHz) $\tilde{B}$ probes is challenging due to limitations with respect to ensuring minimum, practically realizable probe inductance which decides the upper cutoff frequency and further imposes a tradeoff with the probe sensitivity. The size and geometry of the pick-up loop should ensured) desired bandwidth, ii) minimum perturbation to plasma, iii) sensitivity sufficient enough to detect weakest $\tilde{B}$ signals. A yet another stringent design requirement is with regard to excellent electrostatic shielding to the prevailing conductive and radiative pickups generated with fast high voltage switching. Further, proper signal transmission line and its matching are to be adopted to ensure optimum sensitivity and minimum reflections. The design, fabrication and performance test of miniature magnetic probes, compatible for plasma measurements at frequencies ~ 3 GHz is presented in this paper.

PD-186

Process Instrumentation Modeling for Vacuum System Automation of LVPD

P. K. Srivastava[2], R. Sugandhi[2], R. Jain[1], A. K. Sanyasi[2], S. K. Singh[2], Amit Patel[2], Kalpesh Raval[2], L. M. Awasthi[2] and S. K. Mattoo[2]

[1]Charusat University, Anand, India
[2]Institute for Plasma Research, Bhat, Gandhinagar – 382428

E-mail: pkumar@ipr.res.in

Abstract

In Large Volume Plasma Device (LVPD), high vacuum ($\sim 2\times10^{-6}\,Torr$) is produced by the cascaded operation of a combination of Root-Rotary-Diffstak vacuum pumps. The vacuum system presently works with hard wired electrical interlocks using manual mode of operation. We have explored the feasibility for the process automation of vacuum production system. In pursuit of this, we have designed and simulated a model and categorized the whole process of automation into three stages before its integration. The processes are (1) high level dynamic process model using ISO/IEC 19501 unified modeling language standard, (2) process instrumentation models preparation using ISA 5.1-1(1998) standard and (3) operational model execution to obtain pressure and pumps activation profiles. The process model is prepared using the instrumentation symbols and tagging schema defined in International Society of Automation (ISA) 5.1-1(1998) standard and prepared using EDRAW software. The simulation is developed on an open source Real Time Application Interface (RTAI), which is a real time extension of Linux Kernel offering real time simulation capabilities and wide range of hardware connectivity. The simulation model is prepared in SCICOS control system simulation toolkit. The realization of automation and control hold significant importance with regards to the enhancement in the operational capabilities.

PD-188

Pulser Circuit for Plasma Potential and Beam Current Measurements in LVPD

Kalpesh Raval, P. K. Srivastava, A. K. Sanyasi, Amit Patel, S. K. Singh, L. M. Awasthi and S. K. Mattoo

Institute for Plasma Research, Bhat, Gandhinagar - 382428

E-mail: pkumar@ipr.res.in

Abstract

A pulser circuit is developed to measure 1) the plasma potential and 2) excite an electron beam from an electron gun in LVPD plasma. The measurement of plasma potential is generally affected by the magnetic inhibition produced because of current passing through the emissive probe used for electron emission. In this method, the effect of magnetic inhibition due to self produced magnetic field which otherwise poison the plasma potential measurement because of restricted electron emission, is overcome. A heated tungsten wire of ($\phi \sim 0.1mm, L = 10mm$) is used as emissive probe and the measurements are carried out as soon as the current fed to the emissive probe is cutoff in the main glow plasma ($\Delta_{t,discharge} \sim 9.2ms, duty\,cycle \sim 0.01\%$). The newly designed pulser allows accurate measurement of plasma potential over an interrupted current period ofΔt ~ 200μs to 3ms with ~ 50%duty cycle. This pulser is also used in the measurement of electron beam emitted from an oxide coated electron gun installed in LVPD. The pulser is used to apply negative bias to the cathode of the gun with respect to the acceleration grid which is grounded. This enables us receive periodic electrons coming out through the grid at 0 potential but the periodicity enables their differential distinction in noisy background at anode. The periodic pulsing facility of pulser circuit enables clear detection of electron beam through digital averaging and helps in identifying the beam.

This current interrupter cum voltage pulser circuit is based upon the Insulated Gate Bipolar Transistor (IGBT) switch driven bi-stable multivibrator suitably gated for pulsed operation. The circuit operates through a digital trigger obtained from discharge supply and allows conduction / cutoff states through optically isolated digitally synchronized signals. The paper will present the construction details of the pulsar circuit and experimental results obtained in plasma will be presented in the conference.

PD-189

Design and Development of Electronics Circuit for TLP Diagnostics in LVPD

P. K. Srivastava, Kalpesh Raval, Amit Patel, S. K. Singh, A. K. Sanyasi, L. M. Awasthi and S. K. Mattoo

Institute for Plasma Research, Bhat, Gandhinagar- 382428

E-mail: pkumar@ipr.res.in

Abstract

Excitation of Electron Temperature Gradient Driven turbulence in laboratory plasma of LVPD has made electron temperature an extremely important parameter to be investigated upon. Presently diagnostics like fast swept Langmuir probe and two probe measurements are used for this purpose. Real time measurement of electron temperature carries great significance for ETG investigations. We

have therefore made an attempt to use Triple Langmuir Probe (TLP) for meeting this purpose. In TLP diagnostic, three Langmuir probes are kept very close to each other in such a way that they overcome the shadowing effect and also satisfy the sheath criteria required for its proper use.

The circuit is designed for the accurate measurements of electron temperature by choosing 1) extremely high input impedance with high voltage measurement OPAMP ICs (PA85A) that buffers the probe signals and 2) biasing a pair of probe through a floating DC power supply offering large ground impedance (~10MΩ) and very small capacitance (≤10pF) and leakage current (≤ 1μA) using ultra isolation transformer based supply. Front end of the circuit comprises of 3 numbers of PA85A connected to each probe, offering input impedance of $\geq 10M\Omega$ and subsequently sends signal to the data acquisition system via differential amplifiers. This ensures minimum corruption and loading to the probe in the presence of a floating DC power supply. Design details of electronics for this probe diagnostic will be presented in the paper.

PD-193

Smart Trigger Clock System For Generic PXI DAQ System

Tushar Raval, Atish Sharma, Imran Mansuri Manika Sharma, S. Pradhan

Institute for Plasma Research, Near Indira Bridge, Bhat, Gandhinagar-382 428

E-mail: tushar@ipr.res.in

Abstract

The architecture of Data Acquisition system (DAS) for the SST-1 TOKAMAK is essentially distributed and heterogeneous. The SST-1 data acquisition systems are synchronised with external clock and trigger provided by central Timing System. Clock and trigger play an important role for synchronization of DAQ with external event. There are transition states depending upon the scenario during SST1 Shots where at times DAQ subsystem receives STOP/ABORT event from Central control system (CCS) in a state when PXI based DAQ systems itself is busy in acquisition and is waiting for Trigger from Central timing system. This is a crucial time for PXI DAQ System, as it requires physical hardware trigger to come out of the situation and be ready for next shot. A customized hardware is developed for towards it. The developed hardware is integrated with the PXI DAQ software.

The present work describes the customized hardware developed in SST-1 DAQ LAB and its integration with the PXI DAQ systems. These implementations have made the PXI DAQ Systems fully automated and no manual intervention is required for any situation controlled by CCS.

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PD-210

Measurement of Electron Temperature Profile Using Absorption Foil Technique for ADITYA Tokamak Discharges

JAYESH V. RAVAL, SHISHIR PUROHIT, SUDESHNA MAITY[1], SHANKAR JOISA AND ADITYA TEAM

INSTITUTE FOR PLASMA RESEARCH, BHAT, GANDHINAGAR, GUJARAT 382428
[1]*JADAVPUR UNIVERSITY, KOLKATA 700098*

E-MAIL : RAVALJV@IPR.RES.IN

ABSTRACT

Soft X-Ray imaging array system installed in Aditya tokamak is useful for study the characteristics of sawtooth oscillation, major disruption, Magneto Hydro Dynamic (MHD) activity, and measurement of electron temperature. In most of the tokamaks [1-4] electron temperature has been calculated using the absorption foil method developed F.C. Jahoda et al [5]. Soft X-Ray imaging system consists of two array silicon surface barrier detectors (SBD) modified for the measurement of chord average electron temperature profile. In this paper, we are first time reporting, temporal and spatial measurement of chord averaged electron temperature (Te) for five different radial positions. In most of Aditya plasma discharges, radial profile of Te is very close to parabolic in nature. Details of experiment and plasma parameter will be discussed.

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PD-211

Calibration And Performance Testing Of Pulse Counting Module And Channel Electron Multiplier Detector For Charge Exchange Diagnostic in SST-1

Snehlata Gupta, Santosh P. Pandya, Hitesh Patel, Kumar Ajay

Institute for Plasma Research, , Gandhinagar – 382428

E-mail: ajaykuma@ipr.res.in

Abstract

Estimation of the core ion temperature in magnetically confined plasma using passive charge exchange diagnostic (CXD) is based on the energy analysis of the charge exchange neutrals escaping out of the plasma confinement [1]. The charge exchange (CX) neutrals are produced due to the charge exchange collisions between the neutrals which have penetrated into the plasma and the hot plasma ions inside the plasma. As the energy exchange is negligible in these collisions, the charge exchange neutrals have the same energy distribution as that of ions inside the plasma. The CXD uses a stripping gas-cell configuration for stripping the CX-neutrals into ions and these ions are further analyzed in a 45^o parallel plate electrostatic analyzer using ion detectors [2]. The electrostatic analyzer contains the detectors (the channel electron multipliers, CEM) and the Pulse Counting Module for counting these ions.

The pulse counting module of the CXD system to be deployed in SST-1, uses the MESAR System

[3]. MESAR is a modular electronic instrument from Dr. Sjuts GmbH to operate systems with multiple CEMs or photomultipliers (PMTs) and evaluate all output signals simultaneously by pulse counting. It has provisions for setting high voltage bias to CEMs, discriminator threshold, dead time and measurement time interval adjustment, pulse counting and recording the signal via a RS232 interfaced PC. This paper reports the performance testing and the calibration results of the pulse counting module and the CEM detectors for newly developed compact CXD system for SST-1 Tokamak.

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PD-218

Influence Of Pressure And Voltage On The Plasma Parameters In A Low Pressure DC Glow Discharge Using Langmuir Double Probe Method

A. K. Shrestha[1,2], R. Shrestha[1], R. B. Tyata[1], D. P. Subedi[1]

[1]*Kathmandu University, Dhulikhel, Nepal*
[2]*Damak Multiple campus, Jhapa, Nepal*

arundmk1010@yahoo.com

Abstract

This paper reports the measurement of electron density (n_e) and electron temperature (T_e) in a low pressure DC glow discharge in air using Langmuir double probe method by plotting current voltage characteristics. Plasma parameters measured at different pressure ranging from 0.07mbar to 0.75 mbar at constant voltage (980V) showed that electron temperature decreases with the increase in pressure. However, the variation of electron density with the pressure showed a maximum at a particular pressure and decreases on either side. Similarly the variation of (T_e) and (n_e) have been observed at different voltages, and were found that (T_e) slightly decreases but (n_e) increases as the voltage increases from 800V to 980V. Final result showed that electron temperature in the discharge lies in the range (2.31- 8.66) eV and the density in the order of (10^{15}- 10^{16})m^{-3}.

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PD-222

Study of the Hα Line Broadening in Plasma Torch Used for Coating Application

Sarita Das[1], Debi Prasad Das, Sisir Mantry, Santosh Kumar Behera

CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha, 751013
[1]Academy of Scientific and Innovative Research (AcSIR)

E-mail: sarita@immt.res.in

Abstract

Plasma torch is a device which is used to generate DC plasma jet and this plasma jet is mainly used for spray coating, cutting, and welding of metals etc. In this case, plasma torch is used for the spray coating application. The plasma is created by a constant current flow to the plasma torch device. Due to this current flow, an electric arc is created between the two electrodes, which are copper anode and tungsten tipped copper cathode. With the injection of gas flow (Argon gas and Hydrogen gas), the plasma is formed as a jet, extended to certain distance. The plasma is used as a heat source to carry the semi-molten spray particles at a higher velocity to stick to the substrate. In this study the plasma is diagnosed by optical emission spectroscopy (OES) method [1] in order to achieve consistency in coating. Special spectroscopic arrangements were made which includes the arrangement of 10 optical fibers in connection with a Czerny Turner spectrograph and ICCD camera from M/s. Princeton Instruments. The experiments were carried out at a constant argon flow rate (40 liters per minute (lpm)) and hydrogen flow rate was increased from 0.8 lpm to 2 lpm. The emission spectra of plasma were recorded for each hydrogen flow rate. H_α (656.279nm), major argon lines (811.5311, 810.3693, 801.4786, 800.6157 etc) were observed from the recorded spectra. It was observed that the H_α line shows a broadened line with split types for each hydrogen flow rate. This is due to high velocity of charge particle inside the plasma jet. The velocity is due to charge distribution as well as the velocity of gases (Argon and Hydrogen) coming out through the nozzle. Assuming the broadening to be due to Doppler effect, the gas temperature was estimated [2]. In order to find the broadening of the spectra, the H_α lines were fitted with multiple Gaussian functions and the full width at half maximum (FWHM) were obtained from each Gaussian curve obtained from the spectra. In addition to this, it is observed that H_α spectra for low hydrogen flow rate requires higher order Gaussian fitting, while the same for high hydrogen flow rate requires a relative low order Gaussian fitting. This shows that the velocity distribution of the excited hydrogen atom and hydrogen ion are more spread for lower hydrogen flow rate compared to the higher flow rate. These findings will be very helpful in the real-time monitoring of the consistency of the plasma used to obtain uniformity in spray coating application.

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PD-236

Study of neutral beam attenuation of 5MW hydrogen beam in SST-1 Tokomak

P.Bharathi[1] , S.Ranjan[1], S.Thirumugam[1], S.K.Sharma[1], V.Prahlad[1], U.K.Barua[1] and P.Vasu[1]
C.Giroud[2], E.Delabie[2] and N.C.Hawkes[2]

[1]*Institute for plasma research, BHAT, Gandhinagar 382428*
[2] *JET, EFDA, Culham Science centre, Abingdon, UK*

Abstract

The neutral beam injector (NBI) system at IPR is capable of injecting ~1 MW of neutral beam (H^o, 30-50 keV) power to the Tokamak (SST-1) plasma for performing heating and current drive experiments. Currently, preparations are underway for integrating the NBI injector with the SST-1 Tokamak. For understanding the power transmission into the tokomak and power delivered to the NB shine-through, knowledge on the neutral beam attenuation profile for different impurity composition and in various operating scenarios of SST-1 operation is necessary.
A comprehensive Charge Exchange Recombination and Beam emission analysis package is being developed under JET-IPR collaboration, for analysing the CX and Beam emissions from Tokamaks. A neutral beam attenuation package for SST-1 is being developed to suit the SST-1 NBI geometries and plasma, which is expected to have Carbon and Oxygen as the main impurity species. We will describe in our presentation the main features of the package and the computed neutral beam attenuation profiles, for various operation scenarios of SST1.

PD-240

Infrared Imaging Diagnostics For Plasma Confinement Devices

Santosh P. Pandya, Shwetang N. Pandya, Shamsuddin Shaikh, Zubin Shaikh, Kanchan Mahavar, Kumar Ajay, J. Govindarajan, ADITYA and SST-1 Team

Institute for Plasma Research, Bhat, Near Indira Bridge, Gandhinagar – 382 428

E-mail: psantosh@ipr.res.in

Abstract

Infrared imaging is an important plasma diagnostics since it has the advantage of real time monitoring of the surface temperature of an object, remotely. Infrared imaging has multiple applications in the field of plasma physics and fusion research. Infrared imaging is used for surface temperature measurement of Plasma Facing Components (PFCs) for studying the plasma wall interaction and also for health and safety monitoring of PFCs. It is also used for in-vessel inspection during plasma discharges and heat load estimation on PFCs, whereby establishing power balance between input and the exhaust power from the plasma. Another important application of Infrared imaging is for estimation of particle flux and radiation flux emitted from the confined plasma in broad wavelength range by using an Infrared Imaging Video Bolometer. Infrared imaging also finds an important application for studying the synchrotron radiation emitted by electrons accelerated by toroidal electric field. The radiation emitted by such electrons falls in IR range which can be detected by Infrared imaging & various parameters of runaway electrons can hence be derived. Infrared imaging diagnostics are less susceptible to the electro-magnetic and nuclear radiation induced noises, provided suitable shielding techniques are used. Considering all the merits of Infrared imaging diagnostics it can be concluded that it is an inevitable diagnostic for fusion research.

This talk reviews various infrared imaging diagnostics briefly with some recent results from the ADITYA and SST-1 tokamaks

PD-258

Engineering aspects of Microwave Diagnostics at ITER

K. M. Patel[1], V. S. Udintsev[1], G. Vayakis[1], O. Darcourt[1], T. Giacomin[1], D. Johnson[2], Ph. Maquet[1], H. B. Pandya[3], C. Penot[1], M. Portales[1], M. Proust[1], J. W. Oosterbeek[4], P. Sanchez[5], V. Vershkov[6], M. Walsh[1]

[1] *ITER Organization, Route de Vinon sur Verdon, 13115 Saint Paul-lez-Durance, France*
[2] *Princeton Plasma Physics Laboratory, Princeton University, Princeton, New Jersey, USA*
[3] *Institute for Plasma Research, Bhat, Gandhinagar -382 428*
[4] *Technical University of Eindhoven, 5600 MB Eindhoven, The Netherlands*
[5] *Fusion for Energy, ITER Department, Diagnostic group, 08019 Barcelona, Spain*
[6] *Fusion Center, Moscow, Russia*

E-mail : kaushal.patel@iter.org

Abstract

Microwave diagnostic has potential to provide localized measurement of the electron density (n_e) and temperature (T_e) with good spatial (a few cm) and temporal (< 1 ms) resolutions through all phases of ITER.

Development of these diagnostics is a major challenge because of severe environment, strict engineering requirements, safety issues and the need for high reliability in the measurements. Most of the diagnostic components that are placed in a high radiation environment are expected to operate in this environment for a period at least until the next planned maintenance session.

This paper will cover the conceptual design of microwave diagnostics and their interface with vacuum vessel and port plugs.

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PD-260

Measurement Of Stark Width In Laser Produced Copper Plasma In The Presence Of Magnetic Field

Kh. Shantakumar Singh and Ashwini K. Sharma
Department of Physics, Indian Institute of Technology, Guwahati, Assam -781039
E-mail: aksharma@iitg.ernet.in

Abstract

Copper is one of the most exploited metal in various fields of industry and technology elements [1]. The spectral line broadening parameters of Cu are very important not only for plasma research but also for spectroscopic analysis in various fields. We report the measurement of Stark width of Cu atomic line (λ = 521.8 nm) in absence and presence of magnetic field of 0.5 T. Since, magnetic confinement

increases sensitivity of transitions in laser induced plasma, therefore, Stark broadening parameter in presence of magnetic field is very important to determine plasma parameter like electron density. We used the Q-Switched Nd: YAG pulsed laser at $\lambda = 532$ nm with a laser fluence of 5 Jcm^{-2}. The spectral line broadening is mainly due to many phenomena such as natural broadening, self-absorption, Doppler broadening, instrumental broadening, Stark broadening, etc. For laser energy 40 mJ, the Doppler width of the Cu I, 521.8 nm ($3d^{10}4d^2D_{5/2}$ - $3d^{10}4p^2P_{3/2}$) at an electron temperature of 0.93 eV was 0.004 nm. The instrumental width was 0.09 nm. The experimentally measured electron Stark width in the absence of magnetic field, after instrumental correction, was 0.19 ± 0.02 nm which is very close to the numerical value of 0.209 nm [2] . The ratio of Stark effect due to mean electric microfield and Zeeman effect due to external magnetic field [3] was much larger than the one in our present work. So, the Zeeman effect in line broadening can be safely neglected. The width of the Cu I (521.8 nm) in the presence of the magnetic field was 0.24 ± 0.02 nm which is slightly greater than that without magnetic field. This is attributed to the fact that electron density is higher in the presence of magnetic field due to confinement of plasma. It increases linearly as $T^{1/6}$ in both cases with and without magnetic field. It has been shown that at lower temperature the Stark width of atomic line increases as $T^{1/6}$ and decreases after attaining a critical value [4]. Therefore, further investigation of line width at higher temperature is required to give more accurate width parameters.

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PD-294

100 GHz Interferometer to Measure Chord Averaged Plasma Density at SST-1 Tokamak

P. K. Atrey, Umeshkumar C. Nagora and Abhishek Sinha

Institute for Plasma Research, Bhat, Gandhinagar –382 428

E-mail: atrey@ipr.res.in

Abstract

A 100 GHz Microwave interferometer is designed, developed and used to measure the chord averaged plasma density in SST-1 tokamak. A Gunn Oscillator, which output (13 dBm) is used as microwave source, which is kept about 5 meters away from the center of vacuum vessel. The transmitting and receiving antenna is a 25 dB standard horn. Plano Convex Teflon lenses are used to focus the microwave beam. The horn is oriented such that the microwave beam is transmitted in O – mode through plasma, received by receiving horn and then mixed with the reference signal in a magic tee. A 20 m oversized waveguide in X – band is used in plasma path to reduce the losses in the paths. H-plane mitre bends (8 nos.) in X-band are used in plasma path, which are designed and developed indigenously. The total loss of plasma path is approximately 37 dB. A low noise amplifier of gain 20 dB is used in plasma path. In reference path, a phase shifter and an attenuator are used. The final output of the detector is 80 mV. The chord averaged density is measured in the range of 3 ×

10^{18} to 9×10^{18} m^{-3} with different power levels in initial ECR assisted discharges in SST-1 Tokamak. The details of the designs, the developments, an overview of the experimental setup and initial results will be reported in paper.

PD-295

Ku Band Reflectometer at SST-1 Tokamak

P. K. Atrey and Nirav Joshi
Institute for Plasma Research, Bhat, Gandhinagar –382 428
E-mail: atrey@ipr.res.in

Abstract

A broadband (12 to 18 GHz) reflectometer to measure the radial profile of the plasma density in SST-1 tokamak is designed and developed. The planned O – mode propagation allows determination of density profile for the range from 1.78×10^{18} to 4×10^{18} m^{-3}. A Varactor Controlled Oscillator, which output (11 dBm) can be swept from 12 – 18 GHz in 10 μsec. The transmitting and receiving antenna is a 20 dB standard horn. The horn is oriented such that the microwave beam is reflected by plasma O – mode cutoff layer, back to the horn where reflected signal is sampled by a circulator, and then mixed with the reference signal in a matched hybrid tee. A 10 m oversized waveguide and mitre bends (4 nos.) in X – band are used in plasma path to reduce the losses. The estimated loss in the system and expected output signal are 15 dB and 40 mV respectively. The spatial and temporal resolutions of the reflectometer are about 1 cm and 10 μsec, respectively. The details of the designs, the developments, an overview of the experimental setup and the detection technique will be reported in paper.

PD-312

Laser Induced Graphite Plasma In Liquid By Ccd Imaging

Indrajeet Kumar, P. K. Baruah, A. K. Sharma and Alika Khare
Laser and Photonics Lab, Department of Physics,
Indian Institute of Technology Guwahati, Guwahati-781039

E-mail: alika@iitg.ernet.in

Abstract

In this paper, the laser induced graphite plasma formation were studied in liquid regime by imaging technique. The plasma was produced by focusing the second harmonic of a Q-switched Nd: YAG laser at repetition rate 10 Hz on a graphite rod. Distilled water was used as confining medium. The images were captured by CCD at different delay w.r.t. laser pulse to study the dynamics of expansion and decay of the plasma in liquid. The captured images were analyzed by the obtaining contour, intensity profiles etc. Higher laser fluence shows the multiple breakdowns within the Rayleigh length. The detailed information of the above work shall be presented during the conference.

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PD-337

Conceptual Design of Cavity Ring Down Spectroscopy (CRDS) in INTF

Dass Sudhir[1], M. Bandyopadhyay[1], H. Tyagi[1], A. Yadav[1], J. Joshi[1],
R. Pandey[2], J. Soni[2], R. Yadav[1], C. Rotti[2], A. Chakraborty[1]

[1]*ITER-India, Institute for Plasma Research, GIDC,Sector–25,Gandhinagar, 382025, Gujarat*
[2]*Institute for Plasma Research, Bhat, Gandhinagar, 382428, Gujarat*

E-mail: dass.sudhir@iter-india.org

Abstract

Indian testing facility INTF will test the Diagnostic neutral Beam (DNB) performance with its full specifications. The most critical component of DNB is a large (0.6m × 1.6m) inductively coupled negative hydrogen ion source having eight RF plasma drivers. DNB performance is highly dependent of this ion source performance. For characterization and monitoring of the ion source for its safe and efficient operation, various diagnostics are planned to use. Cavity Ring Down Spectroscopy (CRDS) is one of them and will measure the absolute line-of-sight (LOS) integrated density of negative H (-) ions. Due to the large size and presence of complicated magnetic field structure inside the ion source, plasma therein is expected to be non-uniform and as a result that of negative ion density. Therefore, CRDS system layout will accommodate multiple LOSs inside the source. The system comprised of a Nd-YAG laser beam of wavelength 1064nm passing through the ion source plasma multiple times along a LOS axis utilizing the highly reflecting mirror cavity concept. The CRDS diagnostic principle is based on photo detachment process: negative ions are converted to hydrogen neutrals by electron stripping at the cost of energy from laser pulse and temporal profile of the laser pulse energy will give estimated line integrated value of negative ion density along a particular LOS. InGaAs based fast (rise time ~ 10ns) detector associated with a dedicated data acquisition system with high sampling rate (2GS/s) is an integral part of the diagnostic system. The conceptual design of the CRDS diagnostic system is presented with expected performance simulations.

PD-363

A Multi-Channel Photodiode Array System for Plasma Formation Location Studies in Aditya Tokamak

Aniruddh Mali[1], M.B.Chowdhari[2], R. Manchanda[2], N. Ramaiya[2], N. Chanchapara[2] and J. Ghosh[2]

[1]*ITER, India*
[2]*Institute for Plasma Research, Gandhinagar - 382428*
E-mail: aniruddhkmali@gmail.com

Abstract

Information about the plasma formation location and its characteristics play an important role in evolution of plasma current in tokamaks. The plasma formation location identification experiments are carried out in Aditya tokamak using an 8 channel photodiode detection system. The visible light from the plasma is collected with 8 lens-fiber combinations placed from vertical (top) port of Aditya

tokamak covering whole plasma poloidal cross-section (from a top port view) and transferred through to eight photodiodes. Each photodiode with individual electronic circuitry has been mounted in aluminum housing having optical input through SMA connector and BNC output for voltage measurements. The location of plasma formation coincides with the location of maximum light emission and is identified from the light intensity variation observed in the eight photodiodes. The results show that the plasma starts forming in the inboard (high-field) region of Aditya tokamak. The details of electronic circuitry, optical arrangement will be presented in the poster.

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PD-367

Optical Diagnostic of Low Pressure Inductively Coupled Krypton Plasma using Emission Measurements and CR Model

R. Srivastava[1], Dipti[1], R. K. Gangwar[2] and L. Stafford[2]

[1]*Department of Physics, Indian Institute of Technology Roorkee 247667*
[2]*Departement de Physique, Université de Montréal, Montréal (Québec) H3C 3J7, Canada*

E-mail : rajsrfph@iitr.ac.in

Abstract

Optical emission measurements along with suitable population kinetic model provide a very promising alternative for plasma diagnostics. Various plasma parameters such as electron temperature, electron density and species concentrations can be extracted using this technique. The accuracy of the extracted parameters highly depends on the selection of populating and depopulating processes as well as corresponding cross sections used in model. In low pressure and temperature plasmas the electron induced processes plays dominant role and should be considered in systematic manner [1, 2].

In this light we have reported various studies [2 and references there in] on the electron impact processes for inert gases using fully relativistic- distorted wave (RDW) theory for excitation from ground and excited levels to higher lying fine-structure levels. The reliability of our RDW cross-sections for modeling of plasma has been checked earlier in case of xenon fed thruster plasma [3] as well as for low pressure argon plasmas [2, 4].

In the present work, we have extended our study to low pressure inductively coupled (ICP) Kr plasma. Emission spectra have been recorded from 300-900 nm range at various pressures in the range 1-50 mTorr. A collisional radiative model has developed by incorporating 40 fine structure levels in addition to atomic as well as ion ground state. The various processes considered in the model are electron-impact excitation, ionization and their reverse processes through detailed balance principle. All the used cross sections for electron impact excitation processes have obtained by RDW approach. In addition, absorption and spontaneous emission of radiation has also considered in the model, which can also contribute. To extract the plasma parameters, we have fitted the $2p_i \rightarrow 1s_j$ line ratios with the corresponding measurements. These results are also compared with probe

measurements. The detailed results along with discussions will be presented during the conference.

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PD-389

Modeling Of Plasma Emission Spectra Using Different Computer Codes

Sharvil Patel[1], J. Ghosh[2]

[1] *Gujarat University, Ahmedabad-380009,*
[2] *Institute for Plasma Research, Gandhinagar - 382428*

E-mail : patel.sharvil8@gmail.com

Abstract

Radiation emitted by the plasma is routinely used for the diagnostics purpose to obtain basic plasma parameters. To obtain plasma parameters from measurements of spectral emissions, different models have to be used such as LTE, Corona, Collisional – Radiative model [1]. This is generally carried out using different computer codes. In this paper we have modeled various plasmas like, Aditya Tokamak plasma, Plasma-Gun plasma, Glow discharge plasma, Filament produced plasmas and some species of space plasma (Solar flare kernel etc.) using the FLYCHK [2] and OPEN-ADAS codes [3]. Line intensity ratio of $H_{alpha}\ to\ the\ H_{beta}$ is used to model the various plasma. Basic parameter electron temperature T_e , electron density n_e and information about the type of the plasma are determined, i.e. recombining or ionizing plasma. Detailed comparisons have been made between the computer codes to know about their validity and limitations.

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PD-392

Experimental Study Of Thermal Characteristic Of Different Thin Metal Foils For Infrared Imaging Video Bolometer And Comparison With FEM Simulations

Kanchan Mahavar, Santosh P. Pandya, Hitesh Patel, Shamsuddin Shaikh, Zubin Shaikh
Shwetang N. Pandya, Kumar Ajay Mishra and J. Govindrajan
Institute for Plasma Research, Gandhinagar – 382 428
E-mail: psantosh@ipr.res.in

Abstract

The IR imaging video bolometer is an imaging bolometer which provides total radiation power loss, 2-Dimensional (2-D) temporally resolved radiated power profile from the plasma devices. It utilizes

free standing large area metal foil having thickness of few microns as a broad band radiation absorbing element. It absorbed the plasma radiation in Soft X-rays to visible band depending upon foil thickness, reflectivity and physical properties. Radiated power from the plasma incident on the foil through a pinhole, increases the foil temperature. An Infrared Camera sitting outside the vacuum vessel images the foil temperature rise with time and by analyzing thermographs, 2-D temporally resolved power brightness profile can be obtain using heat diffusion equation. In order to achieve maximum sensitivity and high temporal resolution, best suitable foil material has to be identified and to be employed in the IRVB system deployed in the SST-1 and ADITYA tokamak.

The sensitivity of the IR imaging bolometer is depends on the physical and thermal properties of the radiation absorbing bolometer foil. These characteristics or properties of different foil materials and thickness of the foil provides information about the sensitivity of the IR imaging bolometer which is useful to choose the best foil material. In the present experiments, different foils are investigated namely Pt, *Al, Sn, Ta, Ti, Au, Ni and Mo.* These foils are classified under various categories like high energy photon stopping cutoff, lower energy photon reflection cutoff, thermal conductivity (k), thermal diffusivity (α). Theoretical study of the thermal sensitivity of these foils was carried using simulation. In experimental study, the foils were blackened on one side, on both sides by graphite spray in order to increase its emissivity ($\varepsilon \sim 0.9$). These foils were kept inside the vacuum vessel (pressure $\sim 10^{-3}$ mbar) and irradiated using laser source with known power level (P$\sim 10mW$, $\lambda \sim 658nm$, beam diameter$\sim 1\ mm$). Infrared camera located outside the vacuum vessel, measures the temporal evolution of the foil temperature through infrared transmission vacuum view port (*transmission>90%*). Steady state temperature rise (ΔT) of the foil is measured which provides estimation of product of the foil k and t_f. Chopping the laser beam time varying temperature rise and decay profiles were obtained. Analysis these profiles provide estimate of thermal time constant (τ) and finally α of the foil material is estimated. Comparison between experimental results and simulation is made. Experimentally, it has been found that Platinum foil (Pt) provide relatively good sensitivity as compare to other foils.

PD-395

Development of a Penning Plasma Discharge Source with Different Anode Configurations for Simultaneous Emissions of Visible and VUV Lights

G. L. Vyas[1,3], R. Prakash[1], U. N. Pal[1], Nandini Singh[4], R. Manchanda[2] and N. Halder[3]

[1]*Microwave Tubes Division, CSIR-CEERI, Pilani-333031.*
[2] *Institute for Plasma Research, Bhat, Gandhinagar-382428.*
[3] *Manipal University Jaipur, Jaipur*
[4] *Banasthali Vidyapith, Rajasthan - 304022*
E-mail : glvyas27@gmail.com

Abstract

A Penning discharge source has been developed with two different anode configurations, namely double anode ring configuration and rectangular configuration, as a simultaneous light emission source of visible and VUV lights. This source has been developed to calibrate a VUV-spectrometer detector system based on a laboratory plasma based system [1, 2], which is usually done by branching ratio method or by synchrotron radiation sources in Tokamak plasma research. This device is a continuous discharge source where discharge occurs between two cathodes and single anode configuration when high voltage DC electric field is applied between the cathodes and anode along with an axial magnetic field in the discharge region. The electrons in the discharge region follow the magnetic field lines and have back and forth oscillations. This also lead to have increased path length

of electrons for multiple collisions and excitations. Due to this fact the spectral lines in both visible and VUV regions are emanated from the same source. The emitted visible and VUV radiations are recorded simultaneously using Princeton spectrometer having a resolution (0.09nm) with wavelength range (300-1100nm) and McPherson 234/302 spectrometer having a resolution (0.06nm) with wavelength range (30-275nm). The radiated intensities of the visible helium spectral lines (He I 7281.3 Å , He I 7065.1 Å, He I 6678.1 Å, He I 5875.6 Å, He I 5047.7 Å and He I 4921.9 Å) and VUV helium spectral lines (He II 243.0 Å, He II 256.3Å, He II 303.7 Å, He I 507.7 Å, He I 512.0 Å, He I 522.2 Å, He I 537.7 Å, He I584.3 Å) have been analyzed at different working pressures (e.g., 1×10^{-4} and 7×10^{-3} mbar) as a function of the applied discharge voltage in the range of 0.5kV-2kV. The variation of the spectral intensities in the two configurations at different discharge voltages and working pressures have been studied to qualify the optimum discharge configuration. The results of these efforts will be presented.

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Space & Atmospheric Plasma (SA)

SA-002

Sun: A Source of Plasma Waves

Vipin K. Yadav, Anil Bhardwaj and R. Satheesh Thampi

Space Physics Laboratory, Vikram Sarabhai Space Centre
Thiruvananthapuram 695022

E-mail : vipin_ky@vssc.gov.in

Abstract

Plasma waves are omnipresent and thus are a unique feature of space plasmas. Electrostatic (ES) and electromagnetic (EM) plasma waves are observed in almost all the solar system objects, such as planets, their satellites, comets, interplanetary medium (IPM) [1, 2] and Sun. Plasma waves propagate energy across different space regions and transport particles in the absence of collisions in the form of anomalous resistivity, viscosity, etc, and accelerate them to attain high energies. These plasma waves are specific to different instabilities and their properties depend upon the background plasma prevailing at that location.

It is reported that different plasma waves gets generated in and near the Sun due to various plasma instabilities. There is a clear distinction between the plasma in photosphere and in corona, the plasma wave thus generated are also different. They transmit information about the local plasma properties from regions not accessible to *in-situ* measurements, such as solar corona.

ES electron plasma waves are generated in solar corona by bump-on-tail instability, whereas the EM ion cyclotron waves are predicted to emanate from the solar corona along with the coronal mass ejection due to the kinetic instability driven by the ion temperature anisotropy. The electron-heat-flux instability gives rise to electromagnetic whistler waves. The ion acoustic waves observed in the solar wind are closely correlated with the electron heat flux. Plasma waves are also generated by the thermal and non-thermal particle distributions of the plasma populations such as ES electron and proton cyclotron waves. The discontinuities in solar magnetic field give rise to the Alfven waves.

This paper presents an overview on the plasma waves in and around the Sun and suggests the best possible location and instruments to observe solar plasma waves.

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SP-004

Effect Of Self-Gravitation On Three-Component Strongly Coupled Dusty Quantum Fluid

R. P. Prajapati[1], P. K. Sharma[2] and R. K. Chhajlani[3]

[1]Department of Pure & Applied Physics, Guru Ghasidas Central University, Bilaspur (C.G)
[2]BUIT, Barkatullah University, Bhopal (M.P.)
[3]School of Studies in Physics, Vikram University Ujjain (M.P.)

E-mail : prajapati_iter@yahoo.co.in

Abstract

The study of strongly coupled dusty (complex) plasma is of current interest in the formation of plasma crystal and so many other theoretical and experimental situations [1,2]. In the astrophysical situations formations of the dense stars through gravitating quantum fluid is an exciting phenomena [3]. In our previous study we have discussed the self-gravitational instability of finitely conducting viscoelastic fluids [4]. In this problem we have investigated the effect of self-gravitation on the electron-ion Fermi degenerate, self-gravitating strongly coupled dusty quantum fluid. It is our assumption that the massive self-gravitating dust grains are strongly coupled and non-degenerate but the inertialess electrons and ions are weakly coupled and Fermi degenerate. The general dispersion relation is derived using the generalized hydrodynamic (GH) model with the help of relevant perturbations equations.

We find that the dispersion properties are affected due to the presence of viscoelastic effects and quantum statistical corrections. The onset criterion of Jeans instability and expression of critical Jeans wavenumber are also obtained. The numerical calculations have been performed and it is found that viscoelastic effects, dust plasma frequency and quantum statistical effects all have stabilizing influence on the growth rate of gravitational Jeans mode. The growth rates are also compared in kinetic and hydrodynamic limits and it is found that decay in the growth of unstable Jeans mode is larger under the kinetic limits than the hydrodynamic limits.

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SP-025

Impacts Of Solar Plasma On Climate Change And Global Warming

S.C. Dubey

Department of Physics, S.G.S. Govt. P.G. College, Sidhi (M.P.)

E-mail : subhas1236@rediffmail.com

Abstract

Of the many objects in the universe, only two are well known for our climate change and global warming, one is Earth itself and other the Sun. According to IPCC 2007, it has been observed that over the 20th century, the mean global surface temperature increased by 0.7°C. The Earth's climate system constantly adjusts so as to maintain a balance between the energy that reaches it from the Sun and the energy that goes from Earth back to space. An increase in the levels of Greenhouse Gases (GHGs) could lead to greater warming, and have an impact on the world's climate, known as climate change. The basic components that influence the Earth's climatic system can occur externally (from extraterrestrial systems) and internally (from ocean, atmosphere and land systems). The external change may involve a variation in the Sun's output. Internal variations in the Earth's climatic system may be caused by changes in the concentrations of atmospheric gases, mountain building, volcanic activity, and changes in surface or atmospheric albedo**.** There is an abrupt and drastic cooling in the climate can be possible in near future due to large scale melting of global ice by global warming, and prolonged sunspot minima. There is a close correlation between variations in the 11-year sunspot cycle and Earth's climate. Solar activity varies on shorter-time scales, including the 11-year sunspot cycle and longer-term as Milankovitch cycle. The potential role of solar luminosity in modulating recent climate has been debated for many decades. Before the satellite period solar luminosity had been scaled from proxy data that exists large uncertainty. Recently, variations measured from spacecraft since 1978 are too small to have contributed appreciably to accelerate global warming over the past 32 years. The long-term solar irradiance variations might contribute to global warming over decades or hundreds of years. Sun has shown a slight cooling trend since 1960, over the same period that global temperatures have been warm. According to TSI variation trends in recent decades, the Sun has contributed a slight cooling influence but our globe is warmed up continuously. It is indication for a dangerous period and high awareness about global warming is most essential. Adverse impact of climate change and global warming in our ecosystems and challenges in the 21st century along-with perspective role of solar source activities in recent climate change have been discussed.

SP-052

The Study Of The Earth's Plasmasphere Using Whistlers Recorded At Indian Low Latitude Station, Varanasi (L= 1.07)

S. B. Singh and A. K. Singh
Atmospheric Research Lab., Department of Physics, Banaras Hindu University, Varanasi – 221005
Email: abhay_s@rediffmail.com

Abstract

Whistlers have been used as cheap and effective tool for the studies of the Earth's plasmasphere since the last past decades [1]. The propagation characteristics of the low latitude whistlers are poorly understood [2, 3] compared to the high latitude and mid latitude due to lack of knowledge of

the whistlers source lightning location. The low latitude whistlers are characterized with very low dispersion.

In this paper, we have analyzed the large number of whistlers recorded during continuous recording of VLF waves by recently installed Automatic Whistler Detector (AWD) [4] at our low latitude station, Varanasi (L=1.07). We have computed Earth's Plasmaspheric parameters and also tried to correlate with lighting source location of the conjugate region in the opposite hemisphere.

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SP-082

Electromagnetic Ion-Cyclotron Waves In Saturn's Magnetospheric Plasma

Vishnu P. Ahirwar and G. Ahirwar

School of Studies in Physics, Vikram University, Ujjain (M.P.)-456010

E-Mail: ganpat.physics@gmail.com

Abstract

Electromagnetic ion-cyclotron (EMIC) waves have been studied by single particle approaches. The cold plasma dispersion relation, growth rate of the electromagnetic ion-cyclotron waves in a low β (ratio of plasma pressure to magnetic pressure), homogeneous plasma have been obtained. The wave is assumed to propagate parallel to the static magnetic field. The effect of general loss-cone distribution function for different Saturn's Radii on EMIC waves is to enhance the growth rate. The results are interpreted for the Saturn magnetosphere has been applied by Cassini parameters appropriate to the magneto-plasma.

SP-103

Evidence Of Magnetic Reconnection During The Evolutionary Phases Of A Solar Prominence Eruption

Upendra Kushwaha and Bhuwan Joshi

Udaipur Solar Observatory, Physical Research Laboratory, Udaipur 313 004

E-mail: upendra@prl.res.in

Abstract

In this paper, we present a multi-wavelength study to understand the triggering mechanism and energy release processes in an M1.8 solar eruptive flare that occurred on 2012 August 18 and which was associated with a symmetric prominence eruption. Excellent set of high temporal and spatial resolution measurements obtained from Solar Dynamics Observatory (SDO), Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and Nobeyama Radio Heliograph (NoRH) provide us with an opportunity to understand the crucial physical processes related to destabilization of prominence and triggering of associated flare along with the large-scale reorganization of coronal magnetic structures. The X-ray light curves of the flare clearly indicate a precursor phase during which prominence undergoes a slow dynamical evolution. Several plasmoid eruptions were observed from the coronal region above the apex of expanding prominence prior and during the precursor phase. The fast rise of the prominence is accompanied with the onset of HXR emission above 100 keV energies. We conclude that although the slow rise phase of the prominence was associated with the heating in the core region, eruption of the prominence was essentially triggered due to the break-out reconnection initiated at the overlying magnetic loops during the pre-impulsive phase of the flare.

SP-115

Numerical Simulation Of Current Sheet Formation Through Superposition Of Force-Free Magnetic Fields

Dinesh Kumar[1], R. Bhattacharyya[1], and P. K. Smolarkiewicz[2]

[1]Udaipur Solar Observatory, Physical Research Laboratory, Udaipur
[2]European Centre for Medium-Range Weather Forecasts, Reading RG2 9AX, UK

E-mail: dineshbhu@prl.res.in

Abstract

We present numerical demonstration of the formation of magnetic discontinuities (MDs), or current sheets (CSs), in a viscous incompressible magnetofluid characterized by infinite electrical conductivity. For the purpose suitably tailored Initial Value Problems (IVPs) are proposed. The dynamics of the MD formation is understood through the progressive pressing of magnetofluid by an unbalanced force. The initial magnetic field is a superposition of two linear force-free magnetic fields and is relevant to the observed eruptive events in solar corona through the process of magnetic flux emergence.

SP-117

Microflares : One Of The Possible Cause Of Coronal Heating

Meera Gupta[1], Rajmal Jain[2] & A. P. Mishra[3]

1 Department of Physics, Govt. Girls College, Durg (C.G.)
2 Physical Research Laboratory, Navrangpura, Ahmedabad
3 Department of Physics, A.P.S. University, Rewa (M.P.)

E-mail*: soumya_rishi@rediffmail.com*

Abstract

In the present paper we have studied the 27 microflares observed by Solar X-ray Spectrometer (SOXS) mission. We found that all 27 microflares show the Fe-line feature peaking around 6.7 keV, which is an indicator of the presence of coronal plasma temperature $\geq$ 9 MK. On the other hand, the spectra of microflares show hybrid model of thermal and non-thermal emission, which further supports them as possible sources of coronal heating. Our results based on the analysis show that the energy relapsed by the microflares is good enough for heating of the active corona. We discuss our

results in the light of the hybrid model of microflares production.

SA-118

Alfvén Wave Turbulence Of Solar Wind: Role Of Landau Damping

Nitin Yadav, R. P. Sharma

Indian Institute of Technology, Delhi

Email: nitinyadv@gmail.com

Abstract

We propose to study the nonlinear evolution of kinetic Alfvén wave (KAW), propagating in the solar wind where background linear fluctuations are also present in the medium. To investigate this nonlinear process, governing dynamical equation is derived. Then numerical simulation is performed to analyse this evolution process. The power spectrum of magnetic field fluctuations is also investigated. Power spectrum illustrated the transfer of energy from higher wavelength modes to lower wavelength modes. The dependence of turbulent spectrum on the coupling parameter g is also discussed. In the inertial range of power spectrum, scaling follows almost Kolmogorovian power law but after the spectral break power spectrum steepens. Our results are consistent with the solar wind observations. The steepening of power spectrum in the dispersive range can be explained as an effect of Landau damping. With variation in the wavenumber of background linear fluctuations, effective Landau damping also changes. As a result of change in effective Landau damping, scaling of power spectrum also changes. The relevance of present study with the recent Cluster spacecraft observations is also discussed [1].

To derive the governing dynamical equation of KAW, two-fluid model has been used. To study the nonlinear stage of the KAW evolution numerical simulation is performed using pseudo spectral method. The expression of effective Landau damping rate is derived taking into account the background linear fluctuations.

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SA-127

Study Of Duct-Lifetimes From Low Latitude Ground Observations Of Whistlers At Srinagar

K. K. Singh

Department of Physics, Banaras Hindu University, Varanasi

E-mail: krishna23singh@rediffmail.com

Abstract

Whistler data recorded during 4-h period at our low latitude ground station Srinagar (geomag. lat.

24^0 10' N; L=1.28) are used to determine lifetime of whistler ducts. On certain occasions, whistler occurrence rate at Srinagar are found to exhibit some periodicity. Power spectrum analysis of occurrence rate yield a dominant period of about one hour. It is suggested that this period is an indication of the duct-lifetimes at low L- values. Dispersion analysis of these whistlers have qualitatively confirmed the existence of separate ducts during the period of observation. Further the dispersion analysis shows that these whistlers have propagated in the magnetosphere along higher L-values (L= 2.10 – 4.12). Power spectrum analysis may not be applicable to the whistler data corresponding to high L- values because at high latitudes the occurrence rate of whistlers is very high and a large number of ducts might simultaneously contribute to the occurrence rate.

SA-140

A Numerical Study Of Magnetohydrodynamics Relaxation Of Visco-Resistive Plasma

Sanjay Kumar and Ramit Bhattacharyya

Udaipur Solar Observatory, Physical Research Laboratory, Udaipur 313 004

E-mail: sanjayk@prl.res.in

Abstract

The relaxation of magnetized plasma is a subject of fundamental importance in magnetohydrodyamics. The terminal states of such relaxation processes, called as relaxed states, are found to be quiescent and long lived. For examples, in laboratory plasma confinement schemes like Spheromak and RFP, magnetic field is believed to be in relax state. In solar corona, more than the expected life time of coronal loops qualify them as possible relaxed states. In most of the existing theories of relaxation, only the terminal states are predicted without any details of the inherent dynamics that leads to these terminal states at the first place. In our study, we propose to explore the dynamics of relaxation through numerical simulation of a visco-resistive plasma with the initial magnetic field to be in confirmation to general topology of the solar coronal magnetic field.

SA-150

Farley Buneman Instability In The Dusty Topside Equatorial Electrojet

J. K. Atul and S. K. Singh

Department of physics, College of Commerce, Magadh University, Patna-800020

E-mail : jkatulphysics@gmail.com

Abstract

The presence of small scale waves (3m) in the Topside (108-118km) Equatorial Electrojet (EEJ) can be attributed to the naturally occurring streaming plasma instability viz Farley Buneman Instability (FBI) [1]. Meteoric dust grains generated through thermal or non-thermal ablation processes further reconstitute the EEJ configuration [2]. In context with it, a mathematical model have been presented

primarily to seek the effect of negatively charged dust grains on FBI operating in the Topside EEJ. Electron and Ion susceptibilities have been estimated separately through their respective species fluid dynamics. Dust effects have been incorporated through equilibrium charge neutrality in accordance with EEJ parameters. Moreover, it turns out that instability criterion as well as phase velocity for the wave propagation gets influenced due to the presence of negatively charged dust in the Daytime Topside EEJ. Suitable comparison in light of earlier works [3] [4] on space dust plasma interaction has been made.

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SA-164

Ionospheric And Magnetospheric Space Plasma Diagnostic Using ELF/VLF Waves In Low Latitude Region

Ajeet K. Maurya[1,], Rajesh Singh[1] and B. Veenadhar[2],

[1]*KSK Geomagnetic Research Laboratory, IIG, Chamanganj, Allahabad*
[2]*Indian Institute of Geomagnetism (IIG), New Panvel, Navi Mumbai*

E-mail : akmaurya@iigm.iigs.res.in

Abstract

The return strokes of lightning discharges are powerful natural transmitters of the electromagnetic (EM) energy over a wide EM spectrum extending from few Hz to few tens of MHz with maximum spectral energy in the Extremely Low Frequency (ELF, 3-3000 Hz) and the Very Low Frequency (VLF, 3-30 kHz) bands. These EM waves at the ELF-VLF frequency propagate by multiple reflections in the atmospheric waveguide formed between the surface of the earth and the lower boundaries of ionosphere called Earth-Ionosphere Waveguide (EIWG) with very low attenuation rate (2-3 dB/1000 km) and hence are observed around the globe. On propagating large distances in the EIWG, EM waves undergo appreciable dispersions near the cutoff frequencies of different modes. Such dispersed waves are known as 'tweeks' as they sound like 'tweet' when heard with loudspeaker. The fact that tweeks are reflected from lower ionosphere makes them a useful probing tool to investigate the nighttime D-region ionosphere. Tweek covers most part of present study,

which includes study of tweek occurrence features during four part of local night and during three seasons. They have been utilized to estimate ionospheric reflection height and equivalent electron density at the reflection height, in order to understand nighttime D-region variability during selected quite days in three seasons. An equivalent electron density profile of night time D-region ionosphere is estimated using tweek up to 100 km altitudes, which shows comparable results with IRI-2001 and rocket data. Under certain conditions a small part of lightning energy leaks through the upper boundary of the waveguide and is guided through the magnetosphere by field aligned irregularities called ducts with no appreciable attenuation, before re-entering the EIWG to be received as whistlers. As whistler waves propagate toward the conjugate hemisphere, dispersion is introduced so that the received signal is no longer impulsive, but has a distinct frequency-time characteristic which is the reason for their whistling sound. The propagation characteristics of whistler waves at low latitudes have remained poorly understood, and hence the powerful diagnostic potential of whistlers for the low latitude ionosphere remains unrealized. The present study gives details about the first direct correlation between whistlers observed at a low latitude station Allahabad with their causative lightning discharges located near the conjugate region, in the Indian Ocean, in order to establish propagation theory for low latitude whistlers.

SA-165

Arrival Azimuth Determination Of Multistation Recorded Low Latitude Whistlers In Indian Sector

Sneha Gokani and Rajesh Singh

Dr. K. S. Krishnan Geomagnetic Research Laboratory, Indian Institute of Geomagnetism, Leelapur road, Near Chamanganj (Jhunsi), Allahabad-221505

Email-gokanisneha@gmail.com

Abstract

A whistler is a very low frequency (VLF) phenomenon that acquires its characteristics from dispersive propagation in the magnetosphere. Whistlers are derived from the intense VLF radiation produced in lightning strikes, which can travel great distances within the Earth-ionosphere waveguide (EIWG) before penetrating the ionosphere, and exciting a duct. Field-aligned ducts of enhanced plasma density guide the propagation from one hemisphere to the other. The location of the duct, relative to the strike that causes the whistler, is unknown. These waves are very common at mid and high latitudes and are well understood in terms of propagation path and are effectively used to probe the Earth's plasmasphere and magnetosphere. The low latitude ground observations of whistler waves are less frequent. There propagation characteristics are not well understood because their source lightning discharges region are not identified and hence they have not been utilized to probe the ionosphere and plasmasphere. We present here the multi-station recorded whistlers from Indian low latitude stations Allahabad (L=1.08), Varanasi (L=1.14) and Nainital (L=1.22) on the night of 19 March 2011. The correlation of observed whistlers is established with the lightning activity at respective conjugate regions on the basis of time, distance and arrival azimuth calculations. The results lead to the positive correlation of ~ 60 %. The dispersion values for Allahabad lied in the range 8.62-15.42 sec $^{1/2}$ and that of Varanasi lied in the range 8.22-15.09 sec $^{1/2}$. Also the arrival azimuth for the observed whistlers is found to be 173.9° for Allahabad and 174.8° which are close to the standard azimuth values, 179.98° and 177.26°, of the two locations respectively. The analysis of

energy values of WWLLN detected lightnings sets a threshold of 100-2000J to produce a whistler wave. With a close look to the results, we propose ducted mode of propagation for low latitude whistlers observed in Indian region.

SA-173

The Influence Of Rotation And Finite Larmor Radius Corrections On Jeans Instability Of Quantum Magnetoplasma

Shweta Jain[1], Prerana Sharma[1] and R. K. Chhajlani[2]

[1]Physics Department, Ujjain Engineering College, Ujjain, M. P.
[2]School of Studies in Physics, Vikram University Ujjain, M. P.

E-mail : jshweta09@gmail.com

Abstract

The quantum hydrodynamic model is employed to investigate the effects of spin induced magnetization on the Jeans instability of a magneto plasma by taking into account the effects of finite Larmor radius corrections and rotation. The linearized quantum magneto hydrodynamic (QMHD) equations are used for obtaining the general dispersion relation and the analysis is done by using normal node analysis theory. The analytical expressions of the growth rate of Jeans instability are obtained for both the longitudinal and transverse mode of propagations separately. In both the longitudinal and transverse propagations the condition of instability is achieved. In the longitudinal mode of propagation, the Jeans criterion of instability is modified due to quantum corrections but the Jeans criterion is found to be modified by the quantum corrections as well as magnetization in the transverse direction of propagation. The influence of different parameters on the system is discussed analytically. In this analysis the inclination of the direction of rotation to the direction of wave propagation is used.

SA-174

The Influence Of Spin Induced Magnetization On Jeans Instability Of Viscous Quantum Plasma With Resistive Effects

Prerana Sharma[1], Shweta Jain[1]and R. K. Chhajlani[2]

[1]Physics Department, Ujjain Engineering College, Ujjain, M. P.
[2]School of Studies in Physics, Vikram University Ujjain, M. P.

E-mail : preranaiitd@rediffmail.com

Abstract

The influence of spin induced magnetization and electrical resistivity is investigated on the Jeans instability of magneto quantum plasma incorporating the viscosity of the medium. The quantum magneto hydrodynamic (QMHD) model is used to formulate the system and the analysis is done by normal mode analysis theory. The general dispersion relation is derived to analyse the growth rate and condition of instability. The dispersion relation is reduced for both longitudinal and transverse

mode of propagations to discuss the influence of different parameters on it. In the longitudinal mode of propagation, a non-gravitating Alfven viscous mode is obtained which is modified by finite electrical resistivity, intrinsic magnetization and viscosity. The Jeans criterion of instability is found to be modified by the magnetization in the transverse direction of propagation. The results are relevant to dense astrophysical objects, e.g., adjacent area of pulsars, magnetars and the interior of white dwarfs, as well as low-temperature laboratory plasmas.

SA-178

Perturbations In The Low Latitude D-Region Ionosphere Due To Solar Flares

[1]K. Venkatesham, [1]Ajeet K. Maurya, [2]R. Selvakumaran, [2]B. Veenadhari, [1]Rajesh Singh

[1]Dr. KSK Geomagnetic Research Laboratory, Indian Institute of Geomagnetism, Allahabad
[2]Indian Institute of Geomagnetism, Navi Mumbai

email: kvenkateshphysics@gmail.com

Abstract

Observations and modeling of D-region ionospheric perturbations caused by solar flares events of solar cycle 24 from the interpretation of 19.8 kHz NWC Very Low Frequency (VLF, 3-30 kHz) narrowband transmitter signal propagating in earth-ionosphere wave guide and recorded at Indian stations Allahabad (Geographic lat. 25.75 °N; long. 81.85 °E) and Nainital (Geographic lat. 29.35 °N; long. 79.46 °E) is presented in this work. The D-region ionosphere electron densities characterized by two traditional parameters, ionospheric reflection height ($H^{/}$) in km and sharpness factor (β) in km^{-1} are estimated by modeling of the observed VLF signal perturbation using the Long Wave Propagation Capability (LWPC) program. VLF signal amplitude while propagating in Earth-ionosphere waveguide is affected as per the class of Solar flares. Ionospheric perturbations due to solar flares, measured at VLF in both phase and amplitude on long subionospheric paths are used to determine the accompanying D-region electron density enhancements as a function of the flare X-ray fluxes measured by the GOES satellites. The electron concentration profiles in the D-region of the ionosphere and the effects of X-ray flares in the profile structure under both quiet and disturbed conditions are considered in the present study.

SA-187

Statistical Study Of Coronal Mass Ejections And Solar Flares

Apeksha Tonk, Uday P. Verma and A. K. Singh

Department of Physics, University of Lucknow, Lucknow

E-mail: Apeksha.nam.25@gmail.com

Abstract

The Sun is the epicenter of space weather events. It affects the Earth and its environment in a variety of ways and on many different time scales. Coronal Mass Ejections and solar flares phenomena show the dynamic conditions of the Sun. Solar flares and coronal mass ejection are the result of the sudden release of magnetic stresses accumulated for some period of time in lower solar atmosphere. Solar

flares are the primary sources of both energy release in the corona and disturbed interplanetary flows. In the present paper, an attempt has been made to analyze the solar data during the year 2000-2003 statistically. Results reveal that solar flares are associated with coronal mass ejections. Particular relation between solar flares and coronal mass ejections are investigated. Our analysis support that the solar flare can not be derived by coronal mass ejection but they are closely related to each other.

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Space Weather: Physics, Effects and Predictability, A. K. Singh, D. Siingh and R. P. Singh, Surv. Geophys., **31**, 581-638, (2010)

SA-192

Excitation Of Anisotropic Kelvin Helmholtz Instability In Propagation Of Cosmic Rays In The Interstellar Medium

Subhash Kumar[1], Arijit Chowdhuri[1] and Harinder P. Singh[2]

[1]*Department of Physics, Acharya Narendra Dev College (University of Delhi),Kalkaji, New Delhi-19*
[2]*Department of Physics & Astrophysics, University of Delhi, Delhi – 110 007*

E-mail: subhashkumar2005@gmail.com

Abstract

The paper investigates linear stability characteristics of the plane interface separating two relativistic magnetized flows in relative motion. The two flows are assumed to evolve by the (special) relativistic anisotropic magnetohydrodynamics equations. This modeling is used to simulate the propagation of cosmic rays in the interstellar medium, wherein the hydrodynamic pressure of cosmic ray along and transverse to the ambient magnetic field are different and assume a tensorial form. By adopting the vortex-sheet approximation, the relativistic anisotropic magnetohydrodynamics equations are linearized around the equilibrium state and the corresponding dispersion relation is derived using the normal modes technique and discussed both analytically and numerically for parameters appropriate for the propagation of cosmic rays in the interstellar medium. The salient features of the configuration and regimes of instabilities are investigated by following the effects of various physical parameters, namely: the flow velocity, the relativistic and Alfv´enic Mach numbers, degree of pressure anisotropy and the inclination of the wave vector on the plane of the interface. The relevance of these results to the study of the stability of astrophysical situations having various kinds of velocity shear configurations is also briefly commented.

SA-197

Ion-Acoustic Waves In A Pair-Ion Plasma With A Third Species Of Ions : Application To Cometary Plasmas

Noble P. Abraham, Sreekala G., Sijo Sebastian, Savithri Devi E., G. Renuka[1] and C. Venugopal
School of Pure & Applied Physics, Mahatma Gandhi University, Priyadarshini Hills, Kottayam - 686 560, Kerala
[1]*Kerala State Council for Science, Technology & Environment, Sasthra Bhavan, Pattom, Thiruvananthapuram - 695 004, Kerala*

E-mail : cvgmgphys@yahoo.co.in

Abstract

A popular model of a cometary plasma is hydrogen (H^+) with positively charged oxygen (O^+) as a heavier ion component. However, the discovery of negatively charged oxygen (O^-) ions enables one to model, a cometary plasma as a pair-ion plasma (of O^+ and O^-) with hydrogen as a third constituent.

We have, therefore, studied the stability of the ion-acoustic wave in such a pair-ion plasma with hydrogen and electrons streaming with velocities V_{dH^+} and V_{de}, respectively, relative to the oxygen ions. All constituents have been described by Lorentzian distributions. We find the calculated frequency of the ion-acoustic wave with this model to be in good agreement with the observed frequencies. The ion-acoustic wave can also be driven unstable by the streaming velocity of the hydrogen ions. The growth rate increases with increasing hydrogen density n_{H^+}, and streaming velocities V_{dH^+} and V_{de}. It, however, decreases with increasing oxygen ion densities n_{O^+} and n_{O^-}.

SA-198

Determination Of Ionospheric Electron Density And Reflecton Height Trough Very Low Frequency (VLF) Waves

U. P. Verma, Apeksha Tonk, R. Singh and A. K. Singh

Department of Physics, University of Lucknow, Lucknow

E-mail: upverma001@gmail.com

Abstract

Very Low Frequency (VLF) waves are generated by lightning discharges during thunderstorms. Lightning discharges produce electromagnetic radiation over a wide frequency range from a few hertz to tens of megahertz. VLF waves can be used as a remote sensing tool to understand the different process in upper atmosphere. Sometimes these lightning generated signals/waves are known as radio atmospherics or sferics, travel large distances in the Earth-Ionosphere waveguide (EIWG) formed by the Earth and lower boundary of Ionosphere with a little attenuation (2-3dB/1000Km). D-region of ionosphere acts as a good electrical conductor at very low frequency. Lightning generated tweeks form a useful diagnostic tool to determine the nighttime D-region electron density at ionospheric reflection height. It is important to mention here that the altitude of D-region ionosphere is too low for satellites and too high for balloons to make any reasonable measurements. So, for the study of D-region ionosphere VLF signals are very important because of their propagation in EIWG.

D-region is very important in the study of radio communication, space weather and navigational systems. So, the determination of electron density profiles of the D-region ionosphere is of great interest to study the space weather. In this paper, we have investigated tweeks to determine the equivalent nighttime electron densities of D-region at reflection height. Tweeks recorded at Lucknow (Geomag. Lat. 17.6°N, Geomag. Long. 154.6°E) during the night of December 16, 2010 have been used in this analysis. The ionospheric reflection height of the tweeks analyzed observed at Lucknow was found to vary between ~53.3 and 68.5 km. Electron densities lie between 30.41 and 39.10 el/cm^3 at reflection height of ~53.3 - 68.5 km during the night of December 16, 2010.

SA-202

The Influence Of Negatively Charged Heavy Ions On Alfven Waves In A Cometary Environment

Sreekala G, Sijo Sebastian, Noble P. Abraham, Savithri Devi E., Chandu Venugopal and G Renuka[1]

School of Pure & Applied Physics, Mahatma Gandhi University, Priyadarshini Hills, Kottayam – 686 560, Kerala
[1]Kerala State Council for Science, Technology & Environment, Sasthra Bhavan, Pattom, Thiruvananthapuram - 695 001, Kerala

E-mail : cvgmgphys@yahoo.co.in

Abstract

Alfven waves are important in a wide variety of areas like astrophysical, space and laboratory plasmas. In cometary environments, waves in the hydromagnetic range of frequencies are excited predominantly by heavy ions. We, therefore, study the stability of Alfven waves in a plasma of hydrogen ions, positively and negatively charged oxygen ions and electrons. Each species has been modeled by drifting ring distributions in the direction parallel to the magnetic field; in the perpendicular direction the distribution is simulated with a loss cone type distribution obtained through the subtraction of two Maxwellian distributions with different temperatures. We find that for frequencies $\omega^* < \omega_{cH^+}$ (ω^* and ω_{cH^+} being respectively the Doppler shifted and hydrogen ion gyro-frequencies), the peak growth rate increases with increasing negatively charged oxygen ion densities. On the other hand, for frequencies $\omega^* < \omega_{cO^+}, \omega_{cO^-}$ (ω_{cO} being the oxygen ion gyro-frequencies) the region of wave growth increases with increasing negatively charged oxygen ion densities.

SA-207

Statistical Study Of Coronal Mass Ejections And Solar Flares

Apeksha Tonk, U. P. Verma and A. K. Singh

Department of Physics, University of Lucknow, Lucknow 2260 07

E-mail: Apeksha.nam.25@gmail.com

Abstract

The Sun is the epicenter of space weather events. It affects the Earth and its environment in a variety of ways and on many different time scales. Coronal Mass Ejections and solar flares phenomena show the dynamic conditions of the Sun. Solar flares and coronal mass ejection are the result of the sudden release of magnetic stresses accumulated for some period of time in lower solar atmosphere. Solar flares are the primary sources of both energy release in the corona and disturbed interplanetary flows. In the present paper, an attempt has been made to analyze the solar data during the year 2000-2003 statistically. Results reveal that solar flares are associated with coronal mass ejections. Particular relation between solar flares and coronal mass ejections are investigated. Our analysis support that the solar flare can not be derived by coronal mass ejection but they are closely related to each other.

References:

[1] Space Weather: Physics, Effects and Predictability, A. K. Singh, D. Siingh and R. P. Singh, Surv. Geophys, **31**, 581-638, (2010)

SA-229

Highly Geo-effective Solar Transient Plasma Events and Associated Interplanetary Features

Subhash Chandra Kaushik

Department of Physics, Government PG College, Datia, 475 661

E-mail : subash_kuushik@rediffmail.com

Abstract

The solar Cycle 23 has shown some peculiar features, i.e. slow and prolonged decline phase. It is when combined with the ascending phase of Cycle 24, it provides a long phase during which the overall magnetic activity was very low. During this interval the average sunspot number appeared on the solar disk was very low and signifies the weak polar magnetic fields, and solar wind streams mainly originating from coronal holes. The study investigated the relationship between magnetic structure of coronal holes and/or coronal mass ejection (CME) source region and their influence on Earth's geomagnetic field, i.e. storms and sub storms. The study is performed mainly considering very intense geomagnetic storms that occurred during Solar Cycle 23. The disturbance storm time index *Dst* is taken as an indicator of geomagnetic activity by setting a value of $Dst_{min} \leq -200$ nT as threshold. By examining halo CMEs that erupted between 2000 and 2008. We selected 07 events associated with M-class and X-class solar flares. Furthermore, as the geomagnetic field (B_{Geomag}) puts a lower cutoff rigidity (R_c) to the entry of cosmic particles in to the earth's atmosphere. It depends upon the nature of geomagnetic activity and also upon the reconnection of field with the plasma regions formed due to the solar ejections. Sometimes when this entry of charged particles exhibits very sudden sharp and short lived increases in cosmic ray intensities, registered by the neutron monitor, it is termed as Ground-level enhancement (GLEs). These enhancements are known to take place during the result of powerful solar eruption. In present investigation GLE event associated with solar flare and coronal mass ejection (CME) occurred during the study period also studied. The spacecraft data acquired by STEREO mission and those provided by SOHO, ACE and geomagnetic data from the geomagnetic stations like WDC-Kyoto are utilized in the study. It is found that the GLE's are well associated to X-class solar flares. The average speed of GLE associated CME was much faster than the average speed of non GLE associated CMEs.

SA-231

Characteristic of The Equatorial Plasma Bubbles Occurred Over Varanasi During 2009-2012 Using GPS Based Measurements

V. S. Rathore and A. K. Singh

Atmospheric Research Lab., Department of Physics, Banaras Hindu University, Varanasi-221005

E-mail: abhay_s@rediffmail.com

Abstract

Equatorial plasma bubbles (EPBs) are plasma density depletions and accompanying plumes of irregularities that give rise to severe radio signal disruptions. EPBs are most frequently observed in the pre-midnight sector, as shown by in-situ and ground based measurements, such as a range spread echo in ionogram, radio scintillation shown as rapid amplitude or phase fluctuations for the radio wave communication between space and ground, the pronounced density depletion in airglow, significant bite-outs in density from in-situ observations etc.

In the present study, we have considered the propagation of electromagnetic waves through the irregular ionosphere in the L-band frequency range using dual frequency (f1 = 1.575 GHz and f2 = 1.227 GHz) GPS receiver. To study the characteristic of plasma bubbles the GPS data recorded at our low latitude station, Varanasi have been analyzed to compute amplitude scintillation index (S4) during the years 2009-2012. The seasonal, monthly and longitudinal study has been done, along with their solar and geomagnetic activity. The autocorrelation functions, power spectral densities and signal de-correlation times are computed to study the temporal features of EPBs. The velocities the spectral indices and the characteristic lengths of the EPBs are estimated. The computed horizontal velocities vary between 10 m/sec to 40 m/sec. The spectral indices vary between -1 and -7 having maximum occurrence for -2 and the characteristic lengths vary between 100 m - 1000 m having maximum occurrence for 400m.

SA-241

Night Time D-Region Plasma Density Measurements From Lightning Generated Tweek Radio Atmospherics Recorded At Low Latitude India Stations

Ajeet K. Maurya[1], Rajesh Singh[1] and B. Veenadhar[2]

[1]*KSK Geomagnetic Research Laboratory, IIG, Chamanganj, Allahabad*
[2]*Indian Institute of Geomagnetism (IIG), New Panvel, Navi Mumbai*

E-mail : akmaurya@iigm.iigs.res.in

Abstract

Dispersive atmospherics (tweeks) observed simultaneously at two low latitude stations Allahabad (geomagnetic lat. 16.79^{o} N and long. 155.34^{o} E) and Nainital (geomagnetic lat. 20.48^{o} N and long. 153.7^{o}E) in the Indian region have been utilized to estimate the D-region electron density/plasma density at the ionospheric reflection heights under the local nighttime propagation conditions (21:00 – 02:00 hrs LT or 15:30UT – 20:30UT). Simultaneously recorded tweeks at both the stations on selected days during one month from summer (June), winter (January) and from equinox (March)

seasons during 2010 show that D-region plasma density varies 20-24el/cc over the path integrated ionospheric reflection heights of 89-95 km. The wait lower ionospheric parameters; ionospheric reference height (h') and sharpness factor (β), for both the stations during three seasons have been calculated. The values of h' and β are almost same (84.5-85.5 km, and 0.56-0.59 km^{-1}) during winter and equinox seasons. The values of h' and β during summer season are about 82.5 km and 0.60-0.61 km^{-1} at both stations. The plasma density by all three techniques is consistent in the altitude range of 88-92 km. Over all, equivalent plasma density profile obtained using tweek method shows lower values of plasma density by about 5-60- % than that obtained from the IRI-2007 model and higher by 20-50 % over the rocket data. Geographic locations of causative lightnings of tweeks determined in this paper are found to match well with locations and times of lightnings detected by World-Wide Lightning Location Network.

SA-264

Fast MHD Waves In Coronal Loops With Flows And Heating

[1]A Satya Narayanan and [2]V. S. Pandey

[1]Indian Institute of Astrophysics, Bangalore – 560034
[2]Department of Physics, National Institute of Technology, New Delhi

E-mail : satya@iiap.res.in

Abstract

The effect of steady-flows on the spatial profiles of velocities and heating rates of the fast MHD kink waves for surface and body modes is examined in the uniform structured coronal loops. We assume the equilibrium magnetic and plasma configuration of solar coronal loops as a straight slab geometry: z-axis of the slab is along the uniform background magnetic field. We allow step-size density stratification perpendicular to the direction of background magnetic field. In this study, we evaluate the extent to which these waves can be collisionally dissipated under the consideration of both field-aligned and oblique propagations. We evaluate their dissipation by viscosity and heat conduction in the solar coronal loops by invoking the presence of steady flow and compare the results with minimum required optically thin radiative cooling rate. Only body waves exist for the field-aligned propagation showing incompressible characteristics. However, surface waves are also present along with body waves for oblique propagation, however, existence of the obliquely propagating body waves are possible when it propagates very close to 90 degrees i.e., almost lateral to the background magnetic field, but theta = 90 degrees Unlike field-aligned body waves, thebehaviour of obliquely propagating body waves are compressible. We find that obliquely propagating surface and field-aligned propagating body waves are in-sufficient to heat the coronal loops. However, the high frequency obliquely propagating body waves dissipated by ion-compressive viscosity may provide sufficient heating to balance the coronal radiative losses provided the amplitudes of the waves are of the order of nonthermal broadening measurements or of the order of recently observed amplitude 37 ± 7 km/s by SOT/Hinode.

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SA-270

Characteristic of The Equatorial Plasma Bubbles Occurred Over Varanasi During 2009-2012 Using GPS Based Measurements

V. S. Rathore and A. K. Singh

Atmospheric Research Lab., Department of Physics, Banaras Hindu University, Varanasi-221005

E-mail: abhay_s@rediffmail.com

Abstract

Equatorial plasma bubbles (EPBs) are plasma density depletions and accompanying plumes of irregularities that give rise to severe radio signal disruptions. EPBs are most frequently observed in the pre-midnight sector, as shown by in-situ and ground based measurements, such as a range spread echo in ionogram, radio scintillation shown as rapid amplitude or phase fluctuations for the radio wave communication between space and ground, the pronounced density depletion in airglow, significant bite-outs in density from in-situ observations etc.

In the present study, we have considered the propagation of electromagnetic waves through the irregular ionosphere in the L-band frequency range using dual frequency (f1 = 1.575 GHz and f2 = 1.227 GHz) GPS receiver. To study the characteristic of plasma bubbles the GPS data recorded at our low latitude station, Varanasi have been analyzed to compute amplitude scintillation index (S4) during the years 2009-2012. The seasonal, monthly and longitudinal study has been done, along with their solar and geomagnetic activity. The autocorrelation functions, power spectral densities and signal de-correlation times are computed to study the temporal features of EPBs. The velocities the spectral indices and the characteristic lengths of the EPBs are estimated. The computed horizontal velocities vary between 10 m/sec to 40 m/sec. The spectral indices vary between -1 and -7 having maximum occurrence for -2 and the characteristic lengths vary between 100 m - 1000 m having maximum occurrence for 400m.

SA-291

The Role of Diffusivity and Viscosity in Solar Plasma

Bhagvat K. Kumthekar[1] and Suresh Chandra[2]

[1]*Department of Physics, Nutan Mahavidyalaya, sailu, Dist: Parbhani (MS)*
[2]*Department of Physics, Lovely Professional University, Phagawara, Punjab*

Abstract

For diffusive and viscous plasma, the dispersion relation is applied for the North Polar Coronal Hole, where we assumed the angular frequency w to be a real quantity and the wave number k as a complex quantity. For w we have chosen three values for τ. For each value of τ, we considered three situations: (i) where $\nu = 0$, (ii) where $\eta = 0$ and (iii) where both the diffusivity and viscosity are

present. For the cases (i) and (ii), we get two solutions, *+(kr + iki)* and *-(kr + iki)*. But for the case (iii), we get two pairs of solutions, *+(kr1 + iki1) & -(kr1 + iki1)* and *+(kr2 + iki2) & -(kr2 + iki2)*. These two pairs correspond to the fast-mode and slow-mode waves.

SA-296

Variability Of Propagation Factor During Low Solar Activity

S.K.Vijay, M. K. Richharia And Arun Gautam

Institute For Excellence In Higher Education, Bhopal (M.P.)
Govt. Model Science College, Jabalpur (M.P.)

E-Mail : mkrichharia@yahoo.com

Abstract

Propagation factor, M(3000)F2 were closely correlated with the height of F2-Peak and also proportional to the secant of the ray zenith angle which is defined as the highest frequency at which a radio wave can be received over distance of 3000 Km after reflection in the ionosphere. Variability of this ionosphere parameter is of scientific interest in view of causative mechanism and of great importance in assessing prediction which is of practical importance in communication system, navigational control etc. To study this we used hourly value of M(3000)F2 during low solar activity period, January, 2006 to December, 2010. Athens show that the variability is maximum during Post mid night and morning hours while at Sanvito it is maximum during post sunset hours.

SA-301

Disturbances in Solar Wind Plasma Parameters and Solar Features in Relation with Shock Related Geomagnetic Storms

P.L.Verma[1] and Preetam Singh Gour[2]

[1]Department of Physics Govt.Vivekanand P.G.College Maihar Satna (M.P)
[2]Govt. P.G. College, Satna (M.P)

E-mail : pl_verma2003@yahoo.com

Abstract

We have studied shock related geomagnetic storms (Dst ≤ - 90nT) observed during the period of 1997-2011 with halo and partial halo coronal mass ejections, X-ray solar flares and disturbances in solar wind plasma parameters. We have found that 88.09 % shock related geomagnetic storms are associated with halo and partial halo coronal mass ejections. The association rate of halo and partial halo coronal mass ejections are found 75% and 25% respectively. Positive correlation with correlation coefficient 0.26 has been found between magnitudes of shock related geomagnetic storms and speed of associated CMEs. Further we have observed that all the shock related geomagnetic storms are associated with X ray solar flares of different categories. The association rate of A-class, B-class, C-class and M-class X-ray solar flares are found 1.85%, 14.81%, 20.37%, 50%, and 12.96% respectively. From the study of shock related geomagnetic storms with disturbances in solar wind plasma parameters ,we have determined positive co-relation between magnitude of geomagnetic storms and peak values of associated jump in solar wind plasma parameters with co-relation coefficient, 0.75 between magnitude of geomagnetic storms and peak values of associated jump in interplanetary magnetic field, 0.21 between magnitude of geomagnetic storms and peak value of associated jump in solar wind plasma temperature, 0.42 between magnitude of geomagnetic storms and peak value of associated jump in solar wind plasma velocity, 0.52 between magnitude of geomagnetic storms and peak value of associated jump in solar wind plasma pressure.

SA-368

Non-thermal Effects On The Obliquely Propagating Electron-Acoustic Solitary Waves

S. Devanandhan[1], S. V. Singh[1,2], G. S. Lakhina[1] and R. Bharuthram[3]

[1]*Indian Institute of Geomagnetism, New Panvel (West), Navi Mumbai*
[2]*RISH, Kyoto University, Gokasho, Uji, Kyoto, Japan*
[3]*University of the Western Cape, Belville, South Africa*

E-mail : devanandhan@gmail.com

Abstract

Electron acoustic solitons are considered in a four component magnetized plasma consisting of cold electrons, beam electrons, hot electrons and ions. The hot electrons are modeled by non-thermal velocity distribution. The linear dispersion relation for electron acoustic solitons is derived. Using reductive perturbation technique a hybrid Korteweg-de-Vries-Zakharov-Kuznetsov (KdV-ZK) equation is obtained. The effects of non-thermal electrons on the behavior of electron acoustic solitary structures are discussed in detail. Furthermore, the parametric dependence of such electron acoustic solitons on obliquity, electron beam velocity and temperature are investigated.

SA-387

Interaction Of Solar Plasma Near-Earth With Reference To Geomagnetic Storms During Maxima Of Solar Cycle 24

Sham Singh and A.P.Mishra
Department of Physics, A.P.S.University, Rewa 486003 (M.P.)
E-mail: shamrathore@yahoo.com

Abstract

Plasmas are found all over the Solar System and outside in the solar corona and solar wind, in the magnetospheres of the Earth. The shock wave of the travelling mass of solar energetic particles causes geomagnetic storms that may disrupt the Earth's magnetosphere, compressing it on the day side and extending the nightside magnetic tail, when the magnetosphere reconnects on the nightside. The interaction between the solar wind and the Earth's magnetosphere can make the Earth's magnetic field oscillate. Oscillating magnetic fields can generate electric currents, which in the case of Earth's magnetic field can then flow in power grids. Space Weather and the dynamics in the magnetosphere can also effect the surface of the Earth and our atmosphere. During space weather events there is a higher than normal flux of charged particles impacting the upper atmosphere. In the present paper, we have analyzed four large geomagnetic storms occurred during maxima of solar cycle 24. The solar and interplanetary parameters and their relationship with geomagnetic parameters have also been investigated.

Other Areas (OA)

OA-144

An Efficient Experimental Remedy To Protect Bell-metal From Losing Its Bright Golden Colour

Sankar Moni Borah
Department of Physical Science, Gauhati University, Jalukbari, Guwahati – 781014, Assam
E-mail : sankarmoni@gauhati.ac.in

Abstract

Bell-metal, which is an alloy of copper and tin, has enormous industrial applications throughout the north eastern region of India. Nano-structured titanium nitride (TiN) thin films have been deposited by reactive plasma sputtering in cylindrical magnetron device in argon and nitrogen gas mixtures. This coating of TiN provides anti-corrosive hard protective layering over the bell-metal. The TiN film's radiant golden colour at proper deposition condition makes it a very suitable candidate to be used for decorative applications.

OA-217

Plasma Etching Of High Density Polystyrene Applicable For Fabrication Of Microfluidic Devices

Narendra Kumar Agrawal[1], Prashant Pimpliskar[2], Y. K. Vijay[3], K. C. Swami[1]
[1]*Department of Physics, Malaviya National Institute of Technology, Jaipur 302017*
[2]*Centre for converging technologies, University of Rajasthan, Jaipur-302004*
[3]*Department of Physics, University of Rajasthan, Jaipur-302004*
E-mail : research.nka@gmail.com

Abstract

The polystyrene (PS) membranes were irradiated by 16 W argon ions plasma for different exposure time of 10, 30 and 60 minute. Argon ions irradiation affects optical, structure and chemical properties of PS membrane. These induced effects were characterized and correlated by UV-Visible spectroscopy, Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM). In AFM results simultaneous formation of plasma-induced nano to micro order roughness is observed, which shows applicability of plasma treatment for fabrication of microchannels for microfluidic devices.

OA-261

Propagation Of Microwave Plasma In The Range Of 700 Mhz - 5 GHz By Using 0.7-5 GeV Klysron Switching Data Packet With 3.3Gbps

A.B.R. Hazarika
Dept. Of Mathematics, Diphu Govt. College, Diphu 782462 Assam
E-mail : drabrh_dgc5163@rediffmail.com

Abstract

A microwave plasma model is studied theoretically for the frequency spectrum of 700 MHz to 5 GHz by using a klystron of 0.7- 5GeV with 12 cores microprocessor to propagate the data packet switching at the speed of 3.3 Gbps. It comprises of the frequency spectrum of 2G(800,900,1600,1800)MHz , 3G (1900,2100)MHz ,4G(700MHz) upto UHF,EHF range ,here klystron acts as microwave propagator as well as the power generator.

OA-262

Use Of Microwave Plasma In The Range Of 700 MHz - 5 GHz By Using 0.7-5 GeV Klysron Switching Circuit In Automobiles

A.B.R. Hazarika

Dept. Of Mathematics, Diphu Govt. College, Diphu 782462 Assam

E-mail : drabrh_dgc5163@rediffmail.com

Abstract

A microwave plasma model is studied theoretically for the frequency spectrum of 700 MHz to 5 GHz by using a klystron of 0.7- 5GeV with 12 cores microprocessor switching circuit in automobiles. Klystron acts as the power generator for coil to charge the battery. It gives more thrust to the engine of the automobile providing more speed to the vehicle in short span of time.

OA-263

Toroidal 12 Cavity Klystron : A Novel Approach

A.B.R. Hazarika

Dept. Of Mathematics, Diphu Govt. College, Diphu 782462 Assam

E-mail : drabrh_dgc5163@rediffmail.com

Abstract

A toroidal 12 cavity klystron is designed to provide with high energy power with the high frequency microwave rf- plasma generated from it. The cavities are positioned in clock hour positions. The theoretical modeling and designing is done to study the novel approach.

OA-284

Engineering High Power Induction Plasma Unit at BARC for Mass Synthesis of Refractory Nano-Ceramics

S. Ghorui, S.N. Sahasrabudhe, G. Dhamale and A.K. Das

Laser and Plasma Technology Division, Bhabha Atomic Research Center, Mumbai-400085

E-mail : srikumarghorui@yahoo.com

Abstract

Atmospheric pressure RF thermal plasma sources are gaining increasing importance for production of high purity novel nano-materials in different high-end technological applications. Inherent electrode-less features of the discharge together with the large volume and high energy density of the produced plasma ensures contamination free process environment and mass production ability. We report the development of an indigenous induction plasma system for mass synthesis of nano-

powders of refractory ceramic materials. The system has been tested for continuous synthesis of Al_2O_3 nano-powder at a rate of more than 600 gm per hour and checked for its viability for bulk production of nano-particles of other refractory ceramics like Yttrium oxide and Neodymium Oxide.

The system consists of a high voltage dc power supply unit feeding an oscillator circuit, powder feeder unit, a gas supply system, RF plasma torch, primary deposition chamber, gas cooling chamber, cooling coils, cyclone separator, filter cartridge assembly, process cooling unit and a vacuum pump unit. The RF generation unit consists of a high voltage power supply unit, connected to a triode based L-C-R oscillator circuit. A hollow copper tube in the form of a coil, surrounding the plasma tube of an RF plasma torch, acts as the inductive component of the circuit. The oscillator includes a power triode amplifier in class-C mode. The generated plasma acts as a lossy medium, inductively coupled to the coil of the tank circuit. The oscillator elements are designed for a plate power of 100 kW. The tube filament is powered separately using a 16 V, 200 A AC supply. The resonant tank circuit consists of an inductance coil and high voltage, high frequency capacitors. Intense water-cooling is provided to the plates of the valves, the coil of the tank and other components through a high capacity microprocessor controlled chiller unit with inlet temperature controllable from 7 C to 30 C within a precision of 1 C. The values of the capacitors are chosen such that the system operates at a frequency of 3 MHz.

The synthesis chamber consists of the RF plasma torch on the top of a cylindrical SS chamber, connected to a horizontal extension chamber fitted with water-cooled coils for further cooling of the flowing gas and deposition of particles. The relatively cooler gas then passes through a cyclone separator for settling down of the remaining particles and finally goes out into the atmosphere after passing through a set of metallic filters. A Pneumatically controlled root pump connected with the system sets the chamber pressure at any desired level between 50 millibar and 1 bar. A powder feeder unit feeds the fluidized powder exactly in the middle of the plasma column formed inside the plasma tube, which undergoesr melting, evaporation and subsequent nucleation. The system makes continuous production at 30KW of plate power without interruption.

From collected evidences, the process of formation of the nano-particles is identified as the evaporation and subsequent homogeneous nucleation. Major features observed for alumina are complete conversion into highly spherical nano-sized particles, small particle sizes, very narrow size distribution, highly crystallite nature and mixed phases depending on the zone of collection. For alumina, the particles are found to exhibit a uni-modal distribution with peak near 15 nm.

OA-302

Interaction Cavity Design For Tunable Gyrotron For DNP/NMR Spectroscopy

Nitin Kumar, Udaybir Singh and AK Sinha

Gyrotron Laboratory, MWT Area
CSIR-Central Electronics Engineering Research Institute, Pilani- 333 031

E-mail : nitingkv@gmail.com

Abstract

Nuclear Magnetic Resonance (NMR) is a well known and established technique for the characterization of chemical and biological samples. The signal intensity of this technique is not sufficient high to characterize the complex and higher molecular weight molecules such as protein, carbohydrate etc. Dynamic Nuclear Polarization (DNP) is a technique to enhance the signal intensity of NMR experiments several folds [1,2]. In this technique, a source of sub-THz/THz wave with more than tens of watt RF power is required as per the proton frequency of NMR experiment. Gyrotron as a high power sub-THz/THz wave source can fulfill all the technical specifications (High power in

high frequency band, tunability, very high stability in power and frequency, etc) required in DNP/NMR experiments. Since last one decade, huge efforts are made by researchers to develop the sub-THz and THz gyrotrons specifically for NMR spectroscopy. The gyrotrons at different frequencies has been developed at MIT, USA, University of Fukui, IAP Russia for different proton frequency NMR systems and the present development status of DNP gyrotrons are given in Ref. [2, 3]. 132 GHz frequency is required to enhance the intensity of 200 MHz DNP/NMR experiment. Considering this frequency, the design work on 132 GHz gyrotron is started considering more than 20 W RF power with at least 2 GHz frequency tunability. In this article, the feasibility study and the design work for mode selection, cavity design, RF power growth and the frequency tunabilty are presented. In-house developed code and one commercial PIC code are used in the cavity design and mode selection. The simulation results confirm the generation of required RF power at 132 GHz frequency. The frequency tunabilty can be achieved by varying either the magnetic field profile or the cathode voltage. Here, the technique of magnetic field profile variation is accepted for the frequency tunabilty and also discussed in this article.

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OA-340

Outgassing Testing Of Materials Of ITER Cryostat

Mukesh Jindal, Amit Palaliya, Ranjikant Prajapati, Vaibhav Joshi, Mitul Patel, Jagrut Bhavsar, Girish Gupta, Anil Bhardwaj

ITER-India, Institute for Plasma Research, Bhat, Gandhinagar, 382428

Email: mjindal@iter-india.org

Abstract

For maintaining high vacuum environments, outgassing plays an important role. Outgassing is a surface phenomenon which directly proportionate to extent of cleanliness, surface roughness and temperature of material. For most solid materials, the method of manufacturing and preparation can reduce the level of outgassing significantly.

The Cryostat is a cylindrical vacuum vessel of ~28m diameter, ~30 m height and 50mm thickness and weights ~3200 Tons. The material of Cryostat is dual marked stainless steel 304/304L. Various manufacturing processes shall be involved in the fabrication of ITER Cryostat. Outgassing tests has been performed on represented coupons that was subject to the same manufacturing processes as used for the Cryostat and has been performed at room temperature.

There are various established methods for the measurement of out-gassing rate in Laboratories. In Cryostat, **Dynamic Flow Method** has been used. In this method coupon is pumped through a known conductance and the pressure difference across this conductance is measured.

For Cryostat, maximum steady state outgassing rate (for all impurities except water and hydrogen)

measured at 20° C shall be **< 10^{-7} Pa.$m^3s^{-1}m^{-2}$**. Study on measurement of out-gassing of Cryostat surface has been done and process has established

Reference:

[1] ITER Vacuum Handbook: Appendix 17
[2] Mandatory Appendix : CON-II-CR-APB1_06 – Vacuum Requirements, Surface Treatment And Baking

OA-357

A Transient Finite Element Simulation For The Thermo-Mechanical Study Of Lip Seal Laser Weld Joints

Ashish Yadav[1], Chandramoulli Rotti[2], Mukesh Jindal[1], Jaydeep Joshi[1], Arun Chakraborty[2]

[1]*ITER-India, Institute for Plasma Research, Gandhinagar, Gujarat, 382016*
[2]*Institute for Plasma Research, Gandhinagar, Gujarat, 382428*

E-mail: ashish.yadav@iter-india.org

Abstract

Laser welding has the capability of focusing the beam power to a very small spot diameter. Its characteristics such as high precision, low and concentrated heat input; resulting in a low distortion and the ability to weld sensitive component. To obtain good weld bead geometry the selection of input parameter is very important. In this study, finite element method (FEM) is adapted to predicting the weld bead geometry of welded structure, to analyze the temperature distribution and have displacement and stress contours in a lip seal joint weld produced by the laser welding process. Lip seal are widely used for high vacuum sealing purpose in pressure vessel and other mechanical components. Temperature-dependent thermal properties of AISI304L stainless steel, effect of latent heat of fusion, and the convective and radiative boundary condition are included in the model. The heat input to the model is assumed to be a 3D conical Gaussian heat source and the finite element code SYSWELD is used to obtain the numerical results.

This paper presents the thermal field, the bead shape and displacement & stress contours of edge joint made by laser welding of AISI304 stainless steel sheet of dimension (100 ×400) mm having thickness of 2 mm, using FE transient thermal analysis. The effect of laser beam power and focal length on weld bead geometry is investigated. Lip seal weld joint are made using Nd: YAG laser having a maximum power of 2.3kW with focal length of 100 mm to achieve the required penetration of 3 mm.

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OA-366

Study Of Thermo-Mechanical Behaviour Of Swirl Tube Element

M Venkata Nagaraju, Chandramouli Rotti and Arun Chakraborty

ITER-India, Gandhinagar- 382025, Gujarat

E-mail : mvnraju@iter-india.org

Abstract

Neutral Beam Systems in tokomaks constituent Beam Line Components (BLCs) like Neutralizer, RID and Calorimeter/Beam Dump. All of these BLCs, in general, employ elements which are actively cooled by pressurized water. They are designed to absorb power densities as high as 10 MW/m^2. Hypervapotron based Heat Transfer Elements (HTEs) and Swirl Tube Elements (STEs) are considered as candidate elements for Calorimeter and Beam Dump.

In this paper, we discuss thermo-mechanical analyses of STEs as options of Calorimeter/Beam Dump. STE is a tube with swirl or twisted tape inside, which is actively cooled by demineralised water. CuCrZr alloy material is selected for the construction of STE. The presence of twisted tape enhances the heat transfer between the wall and coolant operating at sub-cooled boiling region. Thermal hydraulic calculations are performed with absorbed power. Finite Element Analysis (FEA) is carried out on a STE facing maximum beam power of calorimeter. The thermal response has been validated with respect to acceptable maximum temperature and acceptable local wall heat flux. Then the thermal results are employed to structural analysis to arrive at stress distribution. The structural damage verification is carried out using a reference code; ITER Structural Design Criteria on In-vessel Components (SDC-IC). Both monotonic and cycling damages are considered.

OA-369

Synthesis, Structural And Electrical Characterization Of Sr^{2+} Doped ZnO

Tanushree Das* , Bikram keshari Das , Kajal Parashar, S.K.S.Parashar

School of Applied Sciences, Centre for Nanotechnology, KIIT University, Bhubaneswar-751024
E-mail : vdmscchem@yahoo.co.in

Abstract

Hexagonal Sr^{2+} doped ZnO polycrystalline ceramic powder having composition $Zn_{1-x}Sr_xO$ with x=0, 0.01,0.02,0.03 were synthesized by simple solid state reaction technique. Structural analysis of the synthesized powder was carried out by using X-ray diffraction technique suggesting single phase, hexagonal wurtzite structure with a space group of $P6_3mc$. Increased oxygen positional parameter (u) in Sr^{2+} doped ZnO indicates distortion in the crystal structure. The dielectric constant of undoped ZnO is higher than that of Sr^{2+} doped ZnO studied within temp. range 30^0c - 500^0c with frequency range of 1KHz to 1MHz. Electrical properties were studied by using complex impedance spectroscopy and follow the non-Debye relaxation process. It was observed that ac conductivity of Sr^{2+} doped ZnO (in the range of 10^{-3} to10^{-6}) is smaller than that of undoped ZnO(10^{-1} to 10^0).

OA-376

NTCR Effect Of Nano BZT- xBCT Ceramic For Temperature Sensor Application

Nagamalleswara Rao Alluri[1], S.K.S Parashar [1], Kajal Parashar[2]

[1, 2] School of Applied Sciences, KIIT University, Bhubaneswar-751024, Odisha

Email Id: nag.alluri@gmail.com

Abstract

The electrical and optical properties of $(BaZr_{0.2}Ti_{0.8}O_3) - x(Ba_{0.7}Ca_{0.3}TiO_3)$ with $x = 0.5$ were analyzed by the Impedance spectroscopy and PL, FT-IR measurements. The single phase polycrystalline system were prepared by High energy ball milling (HEBM) technique having curie temperature 106 ^{0}C and dielectric loss < 0.03 at 1 kHz. The electrical properties of nanoceramic system explained that the material has semiconducting nature and following the non-Debye's relaxation process. AC Conductivity measurements revel that ceramic has negative temperature effect (NTCR) and follows double power law. PL measurements reveal an intense and broad band at around the blue colour emission region (399 nm to 470 nm). The FT-IR analysis confirmed the presence of $BaCO_3$ is able to change the interaction forces between O-Ti-O and O-Zr-O bonds even after 10h ball milling.

OA-380

Design and Development Of Different Microwave Components For A High Frequency ECR Ion Source

Anuraag Misra, P. Y. Nabhiraj and Alok Chakrabarti

Variable Energy Cyclotron Centre, 1/AF, Bidhannagar, Salt Lake, Kolkata-700064

E-mail : anuraag@vecc.gov.in

Abstract

An ECRIS (Electron cyclotron resonance ion source) produces highly charged ions with the help of a high frequency electric field and a confining (minimum-B) magnetic field [1,2]. The electron gyration frequency for mono-charged to multi-charged ion sources ranges between 2-28 GHz, which lies in the microwave band of the electromagnetic spectrum. The microwave feeding system of the ECRIS primarily consists of microwave generator (typically a klystron or travelling wave tube), circulator, tuner, dual directional coupler, waveguide break and a microwave coupler to enhance the microwave efficiency of the ion source. The waveguide break and microwave coupler needs to be custom designed suiting to a particular configuration of the ion source.

At VECC, we have produced significant amount of (>100 μA) multi-charged ions of different gaseous and metallic species by a 14.5 GHz ECR-2 ion source. These ions are subsequently injected into a K-500 superconducting cyclotron for further acceleration [3]. We have also designed and installed a 14.5 GHz ECR-3 ion source, which is in advanced stage of testing. This source has a provision for double frequency heating (14.5 + 18 GHz), coaxial injection system and a very low

radiation loss waveguide break which would increase its performance significantly over the ECR-2 ion source.

In this paper we describe the design and implementation of a 0 dB coupler in the Ku band, which achieves <-20 dB coupling between 14.5 and 18 GHz frequencies. We also show a systematic design procedure of an optimized coaxial injection system for a high frequency ECRIS and its implementation. Finally a the design , simulation and test results of a 30 kV waveguide break are discussed along with its low radiation loss characteristics.

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OA-397

Al Metal Matrix Composites Reinforced With Nanocrystalline Al-Ca Intermetallics

A.K Chaubey[1], B.B. Jha[1] and K.G. Prashanth[2]

[1]*Institute of Minerals and Materials Technology (IMMT) Bhubaneswar-751013*
[2] *IFW Dresden, Institut für Komplexe Materialien, Postfach 270116, D-01171 Dresden, Germany*

Email- anil_chaubey@yahoo.com

Abstract

Al based metal matrix composites (MMCs) are becoming very popular for aerospace and automobile applications due to their lightweight, high strength to weight ratio, large stiffness and wear resistance[1]. In order to improve the properties of the composites, the development of reinforcements with enhanced specific properties is a necessary prerequisite. Among the high-strength, lightweight reinforcement, the Al-Ca intermetallics Al_3Ca_8 (triclinic) and $Al_{14}Ca_{13}$ (monoclinic) phases[2] deserve a special attention for the use as reinforcing agent due to their extremely low density (1.859 and 2.013 g/cm^3, respectively).

In order to produce Al MMCs reinforced with Al-Ca intermetallic particles, the Al powder was blended with 20, 40 and 60 vol. % of Al-Ca intermetallic powder. The Al-Ca intermetallic reinforcement was produced by pre-alloying of elemental Al-Ca powders followed my mechanical milling. The composite powders were consolidated by hot pressing at 673 K and 400 MPa. This gives rise to consolidated composites with a relative density of about 98 %. Two distinct approaches have been used for the dispersion of the reinforcing particles within the Al matrix: manual blending and ball milling. Manual blending leads to the agglomeration of the Al-Ca particles to form a cell network throughout the consolidated sample. On the other hand, the composites prepared by milling display a more homogeneous distribution of the reinforcing particles. This has a strong impact on the mechanical properties. The strength increases from 112 MPa for pure Al to 140 and 165 MPa for the blended composites with 20 and 40 vol. %, while the strength increases to 250 and 280 for the corresponding composites produced by milling. This behavior is linked to the reduced matrix

ligament size characterizing the milled composites.

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OA-398

Innovative Thermal Plasma Processing For Treatment Of Mineral Wastes

K. Jayasankar and P. S. Mukherjee

CSIR-Institute of Minerals & Materials Technology, Bhubaneswar- 751013

Email : jayasankar@immt.res.in

Abstract

Industrial waste generated by developing and developed countries pose a major threat to the environment. No serious efforts are made for its disposal. Storage in landfills has been used most often in the past, but as more and more of these wastes are being declared hazardous and landfill cost have risen significantly, a environmental friendly method has to be found for treatment of these wastes. The high cost of present disposal is a strong incentive for developing such a process with minimum environmental hazards. Further with the depletion of natural industrial mineral resources and the increasing emphasis on the protection of the environment from the expanding waste generation, it is critical that sustained effort is necessary to develop processes to recover some of the valuable resource from these waste as well as to make secondary products from these for the benefit of mankind. It is with the above theme in mind a systematic approach has been undertaken to find suitable treatment of the large amount of hazardous solid waste generated.

Thermal plasma processing is an eco-friendly clean technology for treatment of wastes. Thermal plasma technology is now an established alternative to be considered for improving existing metallurgical processes. The present work will be aimed to develop a ecofriendly process for utilization of mineral wastes to the value addition using thermal plasma technology. The following areas will be discussed during the presentation. a) Preparation of brown color pigments from mixed rare earth carbonates which is by product of monazite mineral using thermal plasma b) Preparation of TiC and TiC based composites from wastes and mineral from Ti mineral industries by in-flight thermal plasma.

Buti Young Scientist Award Presentations

BUTI-01

Experimental Evidence of Multiple Current Free Double Layers in an Expanding Plasma Produced using Helicon Antenna

Kshitish Barada, P.K. Chattopadhyay, J Ghosh, Devendra Sharma and Y.C. Saxena

Institute for Plasma Research, Bhat, Gandhinagar, 382428

E-mail : kshitish@ipr.res.in

Abstract

Experimental results on formation of multiple, current free double layers (CFDL) in an expanding Helicon plasma are presented. The potential in the insulated source chamber, in geometrically and magnetically expanding plasma, increases initially as the magnetic field gradient near the interface of source and expansion chamber increases, decreasing as the gradients are increased further. The potential starts increasing again, as the gradient is further increased and an axial null and radial cusp is formed inside the expansion chamber. The strength of CFDL is shown to increase with increase in the magnetic field gradient at the interface. A multiple CFDL is observed in source chamber, in presence of strong magnetic field gradient, an axial null and a strong radial cusp near the interface. Correlation of the source potential with the edge density in the source chamber is also observed. This observation may play significant role in the proposed, Helicon Plasma based thrusters for space applications.

Introduction:

A Double layer (DL) is a strongly non-linear Plasma entity which belongs to BGK class of solutions of Valsov-Poisson equations [1]. A DL is a localized structure of layers of unequal positive and negative space charge giving rise to a localized electric field much higher than the electric field outside double layer. In general, various groups of trapped electron/ion and passing electron/ion are postulated to maintain DL structure. The combination of these groups decides the net current across DL. A nonzero net current corresponds to current driven DL (CDDL) whereas zero net current corresponds to current free DL (CFDL).

Studies of DL have stemmed from the need to explain the acceleration of charged particles in cosmic plasmas [2] and from the point of view of understanding non-linear processes in Plasma. Observation of DL in Helicon plasma [3] has created renewed interest in understanding of the CFDL. Such plasma studies are further being pursued for development of thrusters for space propulsion [4].A large number of experiments on DL have been carried out in different devices such as, discharge tube, double and triple plasma devices, Q-machines and expanding plasma devices [5,6,7 and references there in].

Following prediction of CFDL by Perkins and Sun [8] experimental observations on CFDL have been reported in triple plasma devices [9, 10]. Subsequently, two new classes of CFDL were reported in expanding plasmas produced by helicon antenna [3, 11-12] and in electronegative plasma in the absence of magnetic field [13]. CFDL in a helicon plasma device is forced to be current free due to insulating source tube allowing no net current. Hairapetian and Stenzel [12] have explained the existence of CFDL based on two electron population. Three prominent models have however been proposed for expanding plasma in helicon devices[14-18].Since the observations by Charles and Boswell [3] a number of experiments [19-22] have been focussed on parametric study like effect of magnetic field, pressure, gas mass, geometry of experimental set up and antenna frequency.

We report an interesting feature of the double layer in an expanding helicon plasma device. The Magnetic field gradient, near the boundary of the source and expansion chamber, and configuration of the magnetic field have been varied so as to have an axial null and radial cusp in expansion Chamber and the effect on CFDL is studied. It is observed that strength and nature of double layer are strongly influenced by the magnetic field gradients at the boundary of source and expansion chamber (interface) as well as configuration of the magnetic field near the interface. We present first direct observation of multiple CFDL in this plasma, in presence of strong magnetic field gradient, an axial null and a strong radial cusp near the interface. In following the description of experimental system and observation on CFDL and their dependence on magnetic field gradients and field configuration are presented.

Experimental set up:

The experimental set up [fig. 1a] used here is a diverging magnetic field helicon discharge with an expanding geometry [23]. The cylindrical source chamber is made of borosilicate glass and has diameter of 10 cm and length 70 cm. One end of it is attached to a cylindrical expansion, chamber made of stainless steel with diameter 21 cm and length 50 cm. The other end of the source tube is connected to an insulating flange. A half helical m = +1 helicon antenna of length 18 cm is wrapped concentrically around the source tube. The axial centre of the antenna is taken as the axial origin (z=0) of the experimental set up. The interface is located at z ~ 36cm. RF power is fed from a 2.5 kW RF generator through an L-type capacitive matching network which is subsequently connected to the helicon antenna through a parallel shielded coaxial transmission line.

Five coils locate at z = -24.5 cm, -6.5cm , 12.5 cm, 28 cm, and 46 cm, are used to produce axial magnetic field in source and expansion chambers. While a single power supply is used to power Coils I-IV in series, an independent power supply feeds the current I_v to the Coil V. Thus by keeping current I_i-I_{iv} in coils I-IV fixed, the current I_v can be varied to achieve different gradients near the interface and the field configuration in expansion chamber. Plots of axial magnetic field and Magnetic field gradient for a fixed current of +95A in Coils I-IV and different values of I_v (from 0 A to -95A; negative sign implying a current direction opposite to that in Coils I-IV), are shown in fig 1b and fig 1c respectively.

The plasma is produce with Argon gas introduced in the expansion chamber using a gas dosing valve and pressure is maintained at ~ $2x10^{-4}$ mbar. RF power of 100 W is applied to the Helicon antenna with reflected power <2%.

Results and Discussion:

The plasma potentials, measured using an emissive prove, as a function of I_v at z= 20 cm (inside the source) at the axis and near the edge, are shown in fig2a. It is seen that the plasma potential, on the axis, increases initially as I_v is changed from 0 to I_v = -35 Amp. Further change of I_v results in decrease of this potential till $I_v \rightarrow$-50 amp. Finally, for larger negative values of $I_{v,}$ plasma potential starts increasing again and continues rising and saturates near I_v = -95. It may be noted that the magnetic field in the source region does not change significantly as I_v is changed from 0A to -95A. The gradient at the interface, however, changes from 4.7 Gauss/cm to 11 Gauss/cm.

To understand the reason for plasma potential increase in source chamber for increase in magnetic field gradient scale length near the throat, we measured floating potential near the source tube wall, and Plasma densities, at edge as well on the axis, in the source chamber at z=20cm (fig 2) as a function of I_v. Edge density is observed to increase, as I_v is made more negative, whereas, there is marginal change in central density. This means there is an extra source of ionization at the edge. Electrons are lost to the wall by two mechanisms. One is through ambipolar diffusion in presence of the radial electric and the other one is the motion along the magnetic field line which cut the dielectric wall. The increasing negative current I_v increases the divergence of magnetic field lines at the interface and more field lines reach the wall of the insulated source chamber. This will lead to trapping of the electrons reaching the dielectric wall, as proposed by Takahashi et al. [21].The electrons bounce back and forth between the field lines cutting the source tube wall on one side and the sheath on the insulated end plate of the source chamber on the other side. This back and forth motion of electrons, causes additional local ionization. The area of the shell of the terminated field lines not going to expansion chamber increases as I_v becomes more negative. As edge density increases/decreases wall charging should decreases/increases. This should lead to lower/higher floating potential near the wall. This is evident from the floating potential measurement near the source chamber wall (fig 2). As the edge density increases floating potential decreases. This leads to reduction in the radial loss of ion and hence electron. Now to maintain electron energy balance, the plasma potential in the source has to increase to facilitate more axial electron loss and thus compensate less electron loss in the radial direction. Initial increase, of on axis potential in source chamber, is similar to the observation reported earlier [3]. The decrease of this plasma potential between Iv = -35A and -50A is a new feature which may be due to very strong divergence of field lines near the interface. In addition to strong gradients and divergence, as discussed below, an axial null and a radial cusp gets formed for negative values of I_v. The positions of the null and cusp are within the expansion chamber for $I_v \gtrsim -50$A. The increase in the potential, for $I_v \gtrsim -50$A may be the effect of presence of the null and the cusp in expansion chamber. This aspect will be discussed later.

Further studies were made by scanning plasma potential axially for different I_v. Fig. 3 shows the axial plasma potential variation for 95A current in the first four coils and I_v = +35 A, 0A, -35A and -95A. For I_v = +35 A, the plasma potential φ is constant from z=15-20cm and falls smoothly, from ~ 100V to ~ 50V over a distance of ~ 8cm remaining constant at 50V beyond z=28cm and thus indicating the presence of a broad CFDL. Upstream plasma density and temperature are ~3×10^{16}cm^{-3} and ~5eV respectively. This corresponds to a Debye length (λ_D) of 0.07 mm and therefore, a CFDL with potential drop of $100kT_e/e$ and width ~$100\lambda_D$.

For I_v = 0A, the plasma potential structure evolves to a narrower DL structure. A constant potential of 150V up to z=20cm, is followed by a sharp fall to 100V, within ~4 cm and a further slower fall to ~50V at z= 34cm, beyond which the potential remains constant at 50V. Upstream density and temperature at the axis remains same. The potential in the region of z=20-34 cm, thus, exhibits a knee like structure, with total drop of 100V, the drop in within first 4 cm being ~50V.

As I_v is changed further to -35A, the potential in the region z=15-20cm rises to 156V and drops within ~4cm to 100V followed by a slower drop to 54 V from z=24 to z= 34, beyond which it becomes constant at ~54V. The knee like feature seen in case of I_v = 0A becomes more prominent in this case with an initial drop of ~54 V in ~4cm followed by further fall of ~46V over ~10 cm.

Finally, as I_v is changed to -95A, instead of the knee like structure seen in above two cases,a multiple DL structure is seen. The potential between z=15-20 cm now goes up to 300V and this is followed by a sharp fall (~1.8 cm) to180V at z ~ 22 cm. We designate this as 1st DL with drop of 120 volts within ~1.8 cm. The potential remains nearly constant at 180V till z~27 beyond which the potential drops to ~120V within ~7cm. This drop of potential by ~60V within ~7 cm is designated as 2nd DL. Beyond z=34 cm the potential remains nearly constant at 120V till z~40 cm and a slower drop in observed beyond ~40 cm. We thus observe a sharp DL (~120V; ~5 cm) followed by a shallower DL (~ 60V; ~ 7 cm) for this value of I_v.

We note that sharp drop of potential in first three cases as well as 1st DL in last case, are located well within the source chamber around z ~ 20 cm; the 2nd DL in last case and the knee like structure observed in cases of I_v = 0 and -35V, are all located closer to the interface, but still within the source chamber. In all cases, the potential between, z=15-20cm, rises sharply as I_v is changed from +35A through 0A to negative values (consistent with observations presented in Fig 2), while the potentials in the expansion chamber beyond z=35 cm, for all these cases, also increase but not as strongly as within the source chamber.

The observed increase in the strength of CFDL may be due to increasing field gradient at the interface and increasing divergence of filed lines, as discussed above. Besides increasing the Magnetic field gradient, the negative I_v also changes the configuration of the magnetic field in expansion chamber such that an axial null and radial cusp are formed in expansion region, the location of which depends upon the relative strength of I_v and current in Coils I-IV. We have generated magnetic field maps for different I_v values to identify the location of the null and strength of the cusp. We note that the increase in the axial potential in source region (z=20; fig 2) described earlier, for increasing negative $I_{v,}$ occurs till the null point is outside the expansion chamber

For negative values of I_v < 35 A, the null is outside the system till $I_{v\,\sim}$-35A.When the null and cusp are, however, inside the expansion chamber, the cusp geometry is results in the improved confinement in the axial direction. This improved confinement, and hence reduced axial loss, forces plasma potential to decrease in the source chamber. Higher the $I_{v,}$ better is the cups confinement till the null comes close the interface. The plasma potential in source region, thus, decreases continuously till I_v~ -50 Amp, when null is located at z ~40 cm. As the null approaches the source chamber more and more field lines cut the source tube wall resulting in increased particle loss along the field lines to the source chamber wall. This leads to more electrons to bouncing back and forth between the sheath and the last magnetic field lines intersecting source tube wall, leading to higher edge density as observed. Under this situation the plasma potential in the source chamber has to go up to increase the axial loss and maintain electron energy balance. Thus stronger DL is observed as the null moves closure to interface and in the process the cusp becomes stronger.

A 2nd DL is observed for I_v= -95A, near the interface where the B-field gradient is maximum. Magnetic field geometry plays an important role in helicon CFDL as observed in previous studies [24]. Multiple CDDL have been reported earlier in other devices. It is, however, for the first time that, a direct observation of multiple CFDL is being reported in an expanding Helicon plasma with an axial null and a radial cusp field near the interface. A plot of the magnetic field lines for I = -95A is shown in fig 4 along with the plot of axial potential to illustrate the role of the null position and cusp strength in the formation of strong DL.

We note that the diverging field with strong field gradient at the interface results in the formation of strong CFDL (50-100V corresponding to 10-20 kT_e/e; with widths ~100-50λ_D) in source region. Change of I_v from positive values through 0A to negative values increases the strength of CFDL and at I_v = -95A, a multiple CFDL is formed, with 2nd DL located in source chamber closure to the interface in region of strong field gradient. We further, note that for negative I_v values, an axial null and an asymmetric radial cusp is formed which move closure to the interface with the cusp becoming stronger for larger values of negative I_v. We speculate that the change of trapped and free particle populations in source and expansion chamber, due to the presence of the null and the cusp, is responsible for the observed features. Even though the exact role of null and cusp geometry near the interface is not clear, it is clear from the experimental observation that it is possible to have a control on the strength of the DL by changing I_v.

Summary:

In summary, it is shown that magnetic field gradient plays an important role to control the plasma potential in source as well as expansion chambers and, hence, the strength of CFDL in the source.An axial null and radial cusp field configuration near the geometric expansion is shown to aid in formation of stronger and multiple CFDLs. Present results should have an important bearing on the development of electrical thrusters based on Helicon plasma source with a cusp field in an expanding geometry.

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Figure caption:

Fig 1: (a) Schematic of experimental device, z=0 is antenna centre; (b) Axial component of dc magnetic field and (c) the field gradient for different coil current. Coils I-IV carry identical currents of value +95A and current in V coil, I_v, is varied.

Fig. 2 : Variation of plasma potential at the edge and on the axis of the device at Z=20 cm for different current in coil V (top); variation of edge and central current density in the source chamber with the current in coil V (bottom). Current in four other coils are +95A each.

Fig 3: Variation in axial potential, in source and expansion chamber, for different values of I_v with other coils carrying identical currents of value +95A. The vertical scale for the case of I_v = -95A is shown of left hand side while the scale for other curves is on right.

Fig 4: A plot of magnetic field (top) in the source and expansion chamber (boundaries shown by solid black lines) for I_v = -95A, currents in other four coils being +95A each and axial potential for this case along the axis. The strength of field is indicated in the colour code bar; the arrows indicate the field directions are indicated by the arrows (the size of arrows, however, does not represent the field strength). Plasma potential (down) axial profile is shown for reference.

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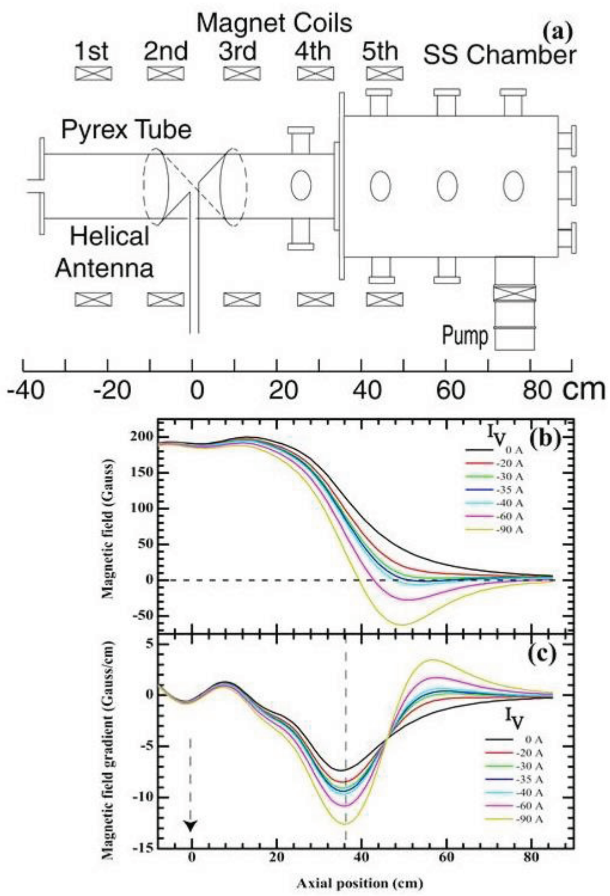
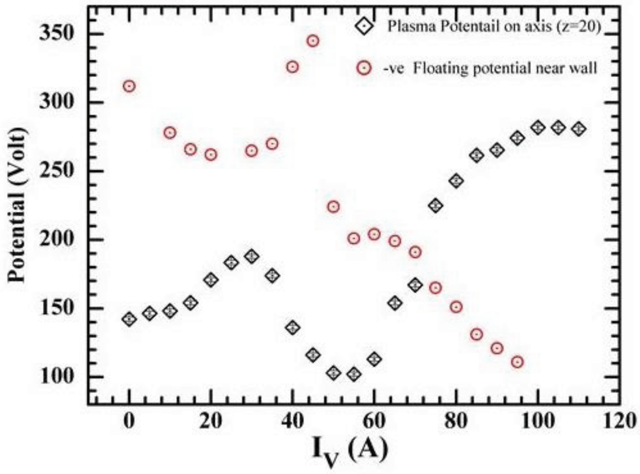


Fig 1


Plasma Potentail on axis (z=20)
-ve Floating potential near wall
Potential (Volt)
I_V (A)

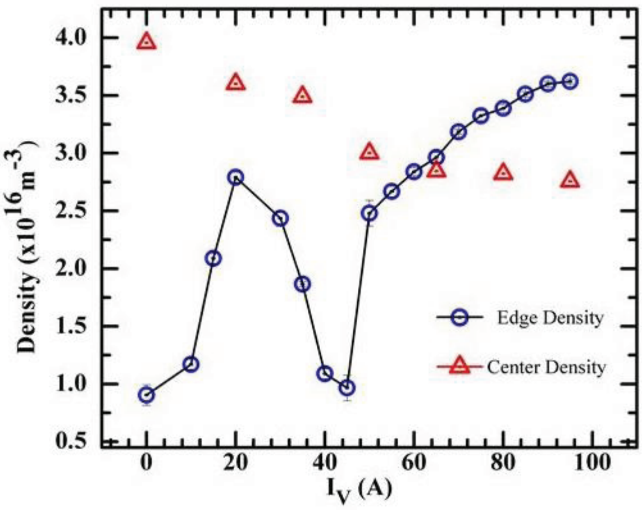

Density (x10^16 m^-3)
Edge Density
Center Density
I_V (A)

Fig 2

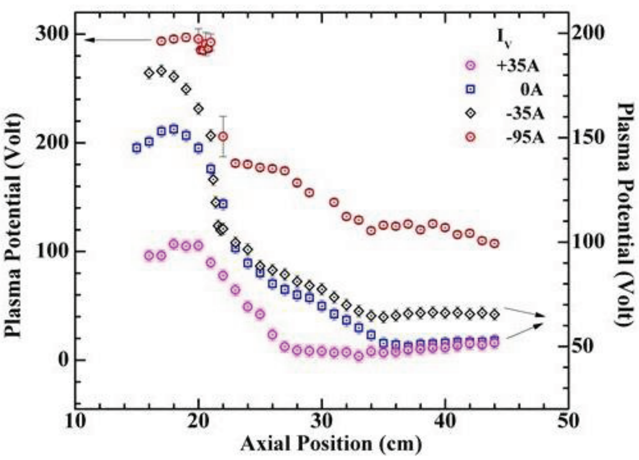

I_V
+35A
0A
-35A
-95A
Plasma Potential (Volt)
Plasma Potential (Volt)
Axial Position (cm)

Fig 3

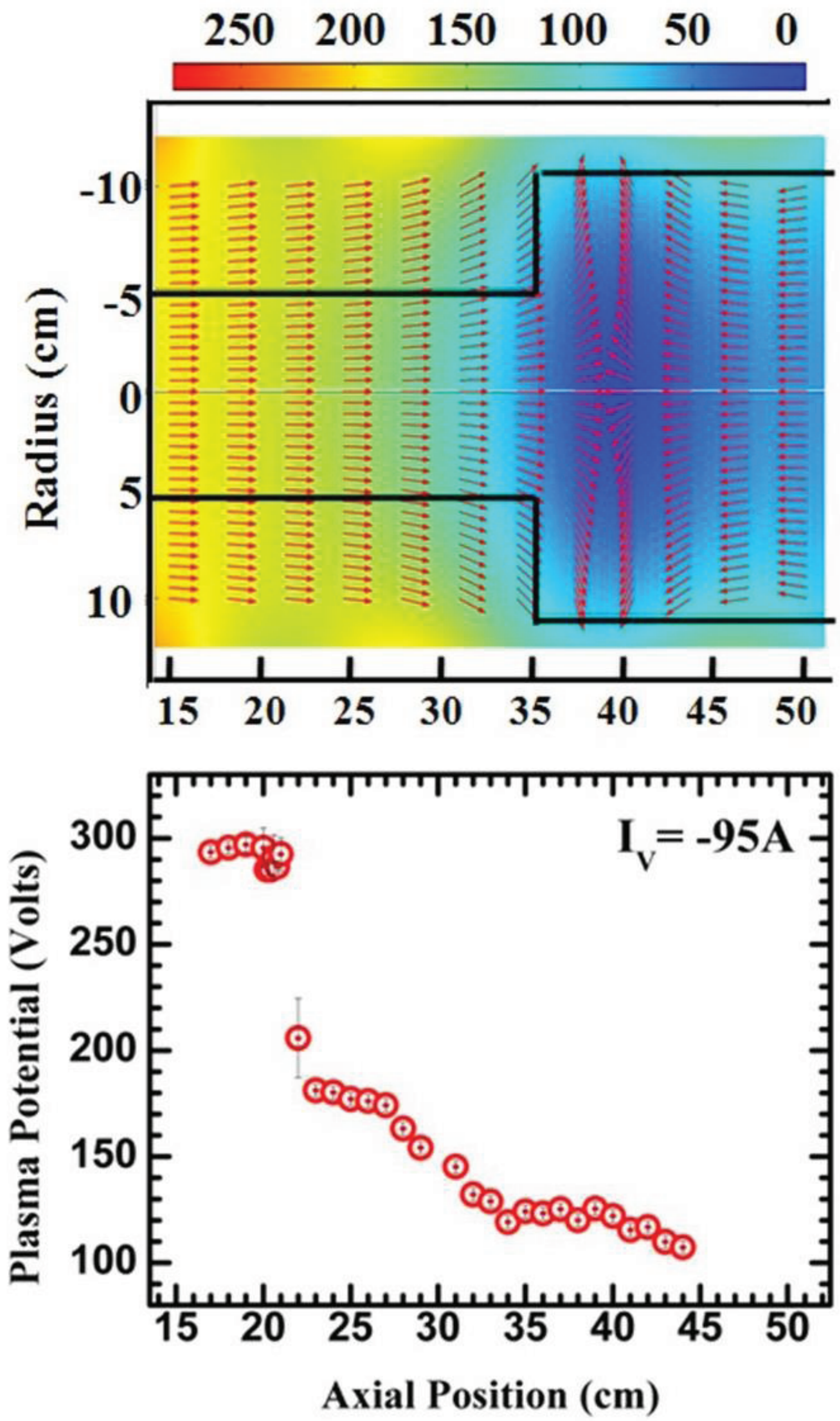

250 200 150 100 50 0
Radius (cm)
-10
-5
0
5
10
15 20 25 30 35 40 45 50
Plasma Potential (Volts)
300
250
200
150
100
I_V= -95A
15 20 25 30 35 40 45 50
Axial Position (cm)

Fig 4

BUTI-02

Time Dependent Physics Of Nano To Micro-pore Creation In Free Hanging Films By Multi Element Focused Ion Beams (MEFIB) From Intense Microwave Plasmas

Samit Paul, Jay Kumar Shah and Sudeep Bhattacharjee

Department of Physics, Indian Institute of Technology, Kanpur 208016

E-mail : samit@iitk.ac.in

Abstract

Focused ion beams (FIB) are an inevitable tool for research and application in nano-science and technology. An emerging area is development of plasma based focused ion beams of a variety of elements and using them for novel applications. A compact microwave plasma based multi-element focused ion beam (MEFIB) system has been developed in our lab. The reported experiments utilize the focused ion beams from the MEFIB plasma and apply them for creation of micron to submicron pores in metallic thin films. Experiments have been performed on controllably sculpting micron scale pore in metallic thin film of aluminium by varying the ion beam energy in the range 4 – 18 keV and for Ar and Kr ions.

I. INTRODUCTION

Focused ion beam (FIB) system plays an important role in the research field of nano-science and technology [1-4], sample preparation for transmission electron microscope (TEM) [4], secondary ion mass spectroscopy (SIMS) [5], integrated circuit repairing [6], and surface analysis. Conventional liquid metal ion source (LMIS) based FIB system provides only Gallium ions and the beam current (*Ic*) at the substrate is extremely small (pA). Moreover the availability of primarily Ga ions limits is applicability and functionality. Since, the beam current is small, large time is required to mill even a small volume. For example, the time required to mill 25×10^4 μm^3 volume using 10 nA Ga ions at 30 keV is more than 24 hours (sputtering yield ~2.7 $\mu m^3/s$) [7]. Moreover, Ga contamination is a major issue in many applications [8]. A microwave plasma based focused ion beam (MEFIB) system has therefore been developed in our laboratory that can deliver ions of various gaseous elements such as Neon (Ne), Argon (Ar), krypton (Kr), Hydrogen (H_2), etc. [9-15]. The plasma based MEFIB system is a useful equipment that has the flexibility of utilizing both for large scale rapid milling at high currents and for small scale precision milling at low currents.

The aim of this paper is to demonstrate the unique multielement sculpting capability of the ion beams extracted from the MEFIB plasma. The milling capability of noble gas ion beams is studied by sculpting small pores in a free hanging aluminium thin film of ~11 μm in thickness. When an ion beam of energy 1 - 20 keV impinges on a substrate, its local physical properties are modified by mainly three processes: (a) sputtering, (b) local heating, and (c) atomic rearrangement in the substrate. Hence, it is difficult to predict milling time for different substrate thickness. There are almost no data available in the literature for milling time using gaseous ions on different metallic substrates as a function of beam energy and species. Here we report the study of multi element ion beam milling and a technique of controllably creating pores utilizing the above study. The milling time (τ_d) is measured for different ionic mass and beam energies. We propose an empirical relation among the above experimental parameters.

II. EXPERIMENTAL SETUP

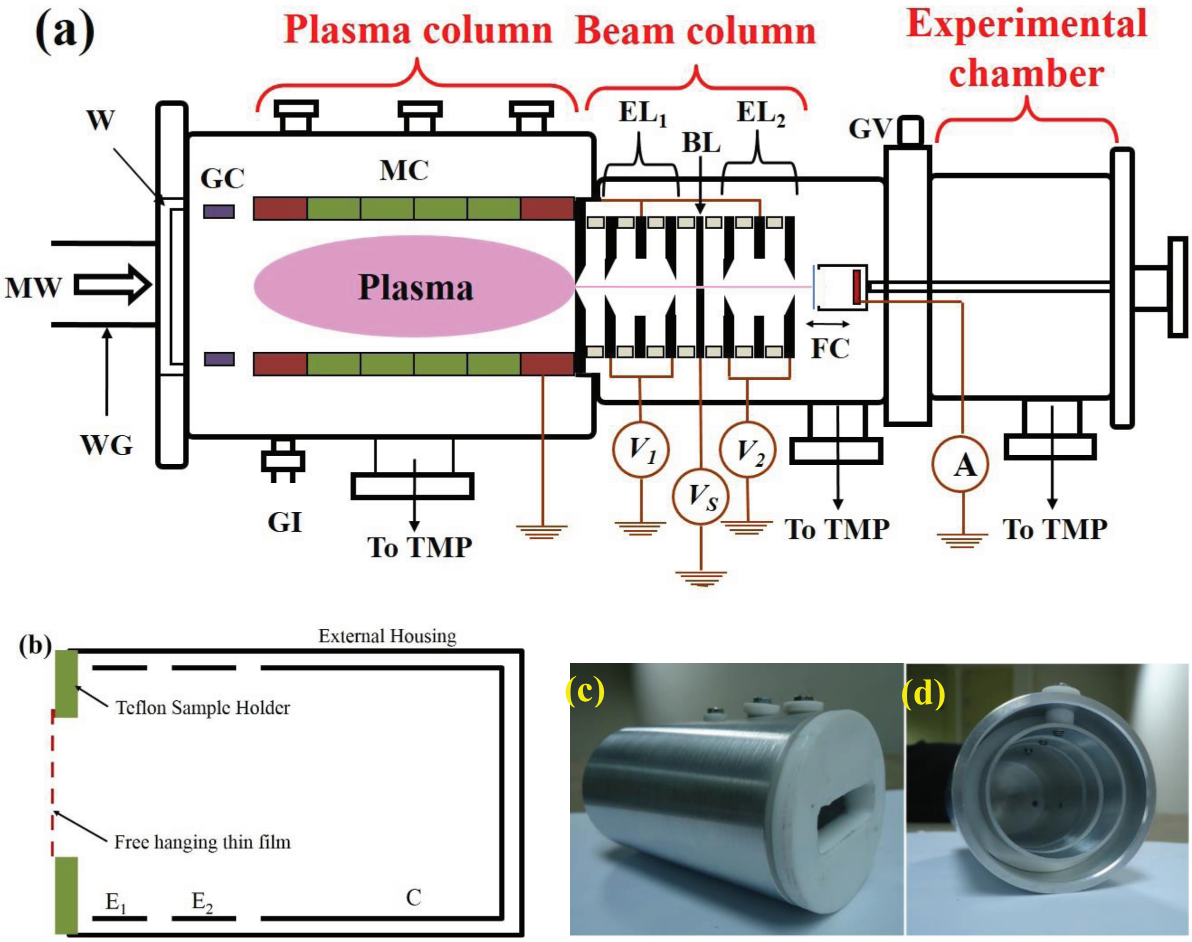


Figure 1(a): Experimental Setup; WG: Waveguide, MW: Microwave, W: Quartz window, GC: Guiding Cylinder, GI: Gas Inlet, MC: Magnetic Multicusp, EL_1: Einzel Lens 1, EL_2: Einzel Lens 2, BL: Beam limiter, GV: Gate Valve, FC: Faraday Cup, TMP: Turbo Molecular Pump, V_1, V_S, V_2: Potentials applied to El_1, BL and EL_2 respectively, A: Ammeter. **(b):** Schematic of the free hanging metallic thin film mounted on a Faraday Cup (FC). E_1, E_2: Secondary electron suppressor electrode, C: Collector **(c):** Digital images of the Faraday Cup side view without the free hanging film, **(d):** Top view

The experimental setup consists of three parts: (a) Plasma Column, (b) Beam column and (c) Experimental chamber as shown in shown in Fig. 1(a). The details of the experimental setup can be found in reference. 9. High density (10^{11}/cc) plasma is created by 2.45 GHz microwaves and confined by octupole magnetic multicusp inside the plasma column as reported in reference 10 and reproduced in Fig. 2(a). The beam column consists of a plasma electrode (PL) and two decel-accel einzel lens (EL_1 and EL_2) separated by a beam limiter (BL) as shown in Fig. 1(a). The EL_1 is biased to a negative potential V_1. The BL, having an aperture of 0.25 mm diameter is biased to a negative potential Vs to reduce the beam size and control the beam current (I). The EL_2 is biased to a higher negative potential V_2. The function of EL_1 is to extract ion beams from the plasma through PL and produce a parallel beam. Once the beam is passed through the BL, EL_2 focuses them. The optimum dimensions, separations between electrodes and applied potentials have been reported in an earlier work [9]. A sample holder mounted on the mouth of a Faraday Cup (FC) is kept next to EL_2 to get the beam impression on the free hanging metallic film and measure the total beam current (I) when the beam penetrates the sample. The Faraday Cup is attached to a XYZ stage (VG Scienta) which can move the FC in all three directions with a precision of 0.5 μm and rotate about Z axis. The schematic diagram and a digital picture of the Faraday Cup is shown in Fig 1(b), (c) and (d) respectively. The FC consist of cylindrical electrodes (E_1, E_2), a collector (C), external metallic housing and a Teflon sample holder. The electrodes E1, E2 and the collector C are placed coaxially separated by Teflon rings inside the metallic housing as shown in Fig. 1(b), (c) and (d). Suitable voltages are applied to E_1 and E_2 to supress secondary electrons emitted from the collector due to ion beam bombardment. The grounded aluminium housing prevents any external electrons to be collected at the collector C. A thick Teflon sample holder is attached at the mouth of FC to hold a biased thin film. The applied bias on the film determines the final energy of the ion beam. The dimensions of the electrodes are decided after SIMION [16] simulation. The FC collector is connected to a HAMEG multimeter (HM 8112-3).

III. RESULTS AND DISCUSSIONS

The variation of plasma ion density and magnetic confinement field with radial distance is shown in Fig. 2(a). For octupole multicusp, the ion density at the center is more than 10^{11}/cc and fall towards the wall. It can be noted that the for 2.45 GHz microwaves the cut-off density is 7.44 $\times 10^{10}$/cc. Hence, the plasma is overdense [10]. Moreover, the ion energy distribution measured by an ion energy analyser probe indicates that the energy spread is ~5 eV at the plasma meniscus which is comparable to that of a LMIS (Liquid Metal Ion Source) based FIB [15]. The result is reproduced in Fig. 2(b).

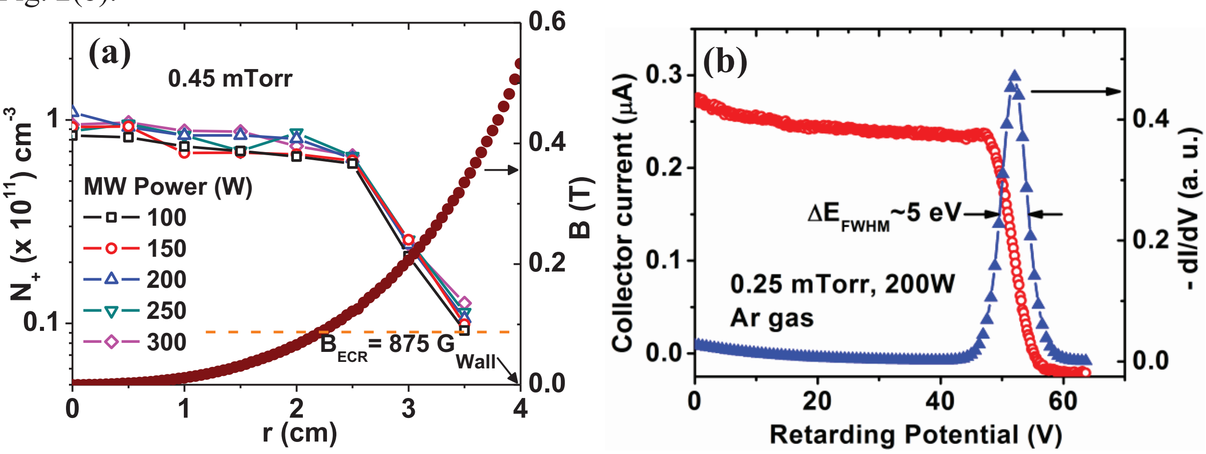


Figure 2 (a): Radial variations of plasma (ion) density N_+ and magnetic field B at 0.45 mTorr and different MW powers.(source: *Rev. Sci. Instrum.*, **79**, 063504 (2008))
(b): I-V characteristics for Argon plasma at 0.25 mTorr and 200 W power using ion energy analyser probe. The FWHM of the Gaussian distribution fit to – dI/dV vs. V plot (solid line) gives the ion energy spread. (source: *Indian J. Phys.*, **85,**1863(2011))

The biased sample is moved along Z direction parallel to the beam at an interval of 0.2 mm with the help of XYZ stage and at every location the sample is irradiated for 30 seconds to get beam impression. These beam impressions are then analysed under an optical microscope to determine the beam spot size. The variation of beam spot size with the distance of the film from the last electrode (z) is shown in Fig 3. It is observed that the beam diameter is minimum at $z \approx 10.5$ mm and increases on both sides as shown in Fig. 3. Therefore, the focal point is at 10.5 mm (cf. Fig. 3 Inset). We have also observed that the beam diameter is minimum at the focal point when the film is biased with equal voltage as applied to EL_2 (V_2). From henceforth all the experiments are carried out by keeping the film at the focal point.

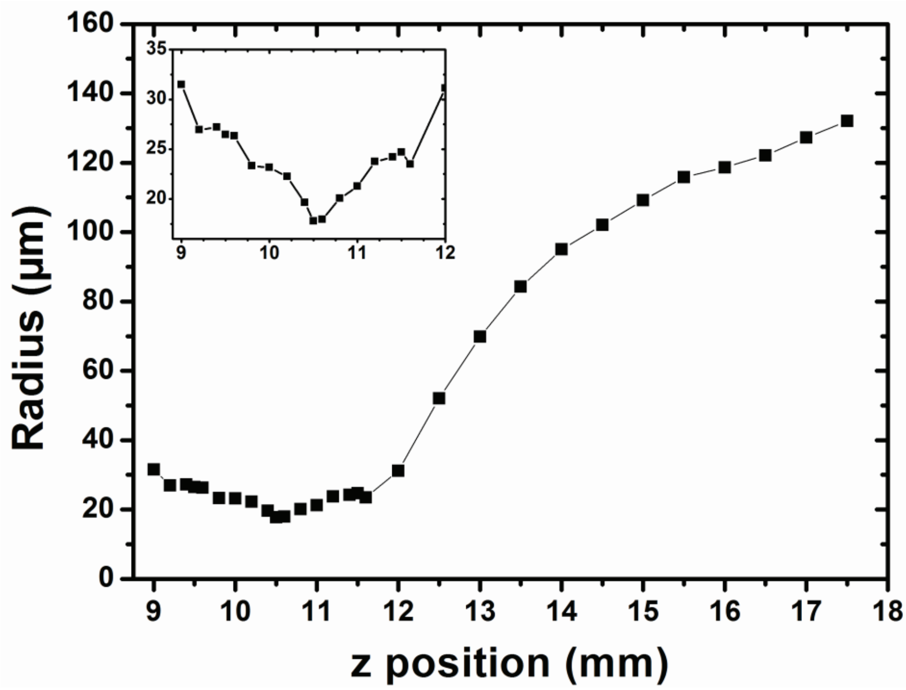


Figure 3: Variation of beam spot size with distance from the last electrode (*z*). **Inset:** Variation of beam spot size zoomed around the focal point.

To study the time dependent current profile during ion beam milling and time required to penetrate through a metallic film, the FC collector current is recorded in real time at an interval of 0.1 s by a digital multimeter. A Lab View program has been developed to communicate and acquire data from the multimeter through RS-232 protocol. Argon ion beams of different energies are allowed to fall on the biased film and simultaneously beam current is recorded. The irradiation process continued until the ion beam makes a clear aperture and recorded current reaches saturation. The time dependent ion current profiles are shown in Fig 4(a). It is observed that initially the ion current (I_C) is zero and after some time Ic increases slowly with time and eventually reaches a saturation. In the initial phase the ion beam sputters the film from top and does not penetrate it, giving rise to zero current. When the beam reaches the bottom of the film and few ions penetrate through the aperture created by milling process, the current starts increasing. The time (typically ~50-100 seconds for Argon beams of ~ 0.8 μA beam current) is defined as the threshold penetration time (τ_d). At this point most of the ions take part in sputtering the film and very few ions pass through the small aperture created by the same beam. After this, the beam sputters from the wall of the aperture and increases its size allowing more ions to pass through, giving rise to increase in current. When the ions can completely pass through the aperture the ion current saturates and the aperture size does not increase further.

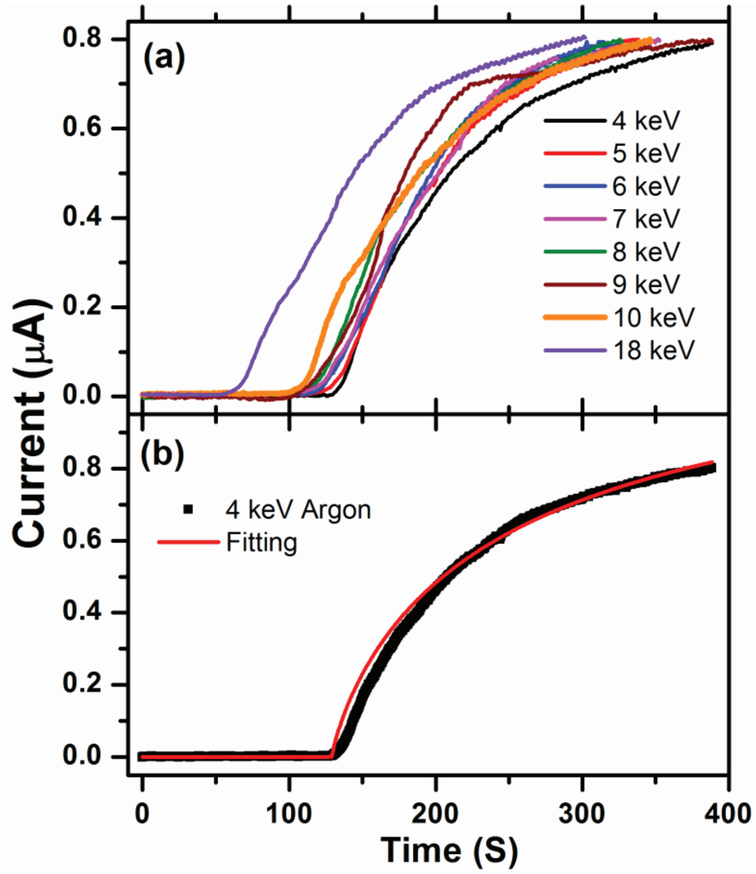


Figure. 4(a): Varition of collector current (I_C) with time for argon ion beams of different energies . **(b):** Fitting with Eq. 1 on current profile obtained for 4 keV argon ion beams.

The temporal measurement variation of the of beam current (I) through the pore may be represented by equation 1 which is a product of a step function at τ_d and a Hill function as follows,

$$I(t) = I_{\max} \frac{1}{e^{\tau_d - t/d} + 1} \frac{(t-\tau_d)^n}{\tau_g{}^n + (t-\tau_d)^n} \qquad (1)$$

where τ_d : penetration time, τ_g : time required to grow to 50% of the maximum current I_{max}, d and n are constants. For 4 keV Ar ion beam current profile, equation 1 is fitted as shown in Fig. 4(b) and the following fitting properties are obtained. I_{max}: 1.2 μA, τ_d = 129 s, τ_g=125 s, d=0.5, n=0.84.

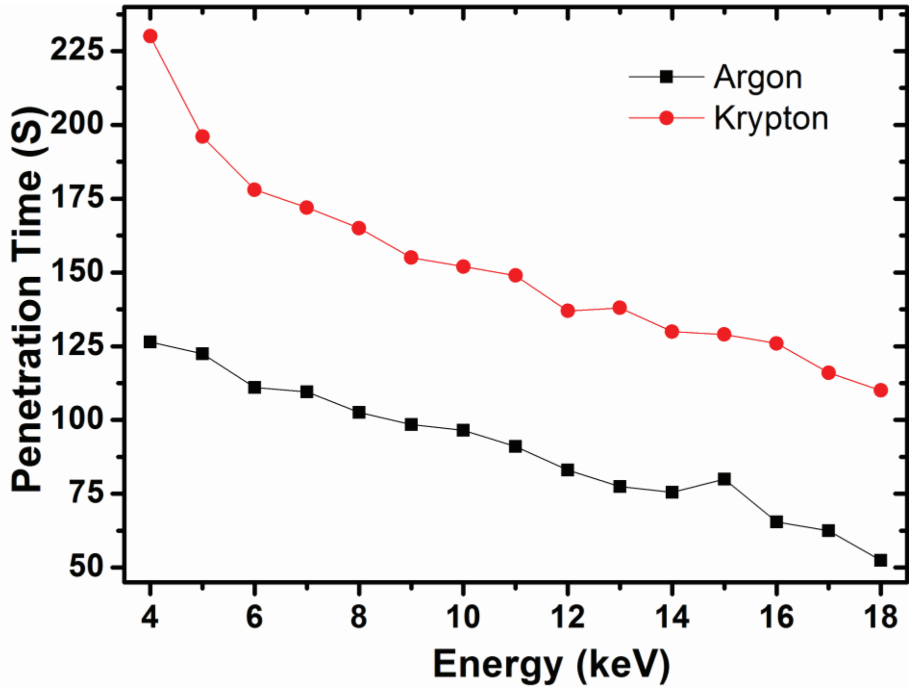


Figure 5: Variation of penetration time (τ_d) with the ion beam energy for Argon .

The above experiments are repeated for different beam energies (4 - 18 keV) by varying potential applied to the film. The natures of the current profiles for all the energies are similar as shown in Fig 4(a). The penetration time (τ_d) is also determined for all the energies by fitting with Eq. 1 and plotted in Fig. 5. It can be seen that τ_d decreases with increase in the beam energy. As the energy increases the sputtering increases giving rise to quick penetration of the ion beam.

Similar set of experiments have been performed using Kr beam and the results obtained are similar to that obtained for Ar ion beam. The variation of penetration time for Kr ion beam with the beam energy is shown in Fig. 4(b). It can be noted that Kr ion beam requires longer time than Ar. This would be related to the mass of the ionic species and the current associated with beam.

The above temporal current information is used as feedback to controllably create different size pores on the free hanging film. For instance, 18 keV argon ion beam penetrates 11 µm thin aluminium film after $\tau_d \approx 53$ seconds and at this time, a tiny aperture is just created. As ion beam irradiation is prolonged, the pore size increases allowing more ions to pass through the aperture resulting in increment of the collector current. Our aim is to stop beam irradiation at different instants of time after the penetration ($\tau_d + \Delta t$). For example by stopping the irradiation immediately after penetration, we may be able to generate a very tiny pore. The irradiation time is varied from 40 Seconds to 100 seconds at an interval of 5 seconds. At every interval, 5 independent irradiations are carried out and then the pores created by the beams are analysed under an optical microscope (Carl Zeiss AXIO Imager.A1m). Both sides (top and back) of all the pores are measured. It is found that the pore size measured on the top side is always greater than that of the back side giving conical shapes to the pores. Few microscope images are shown in Fig. 6 for 18 keV argon ion beam.

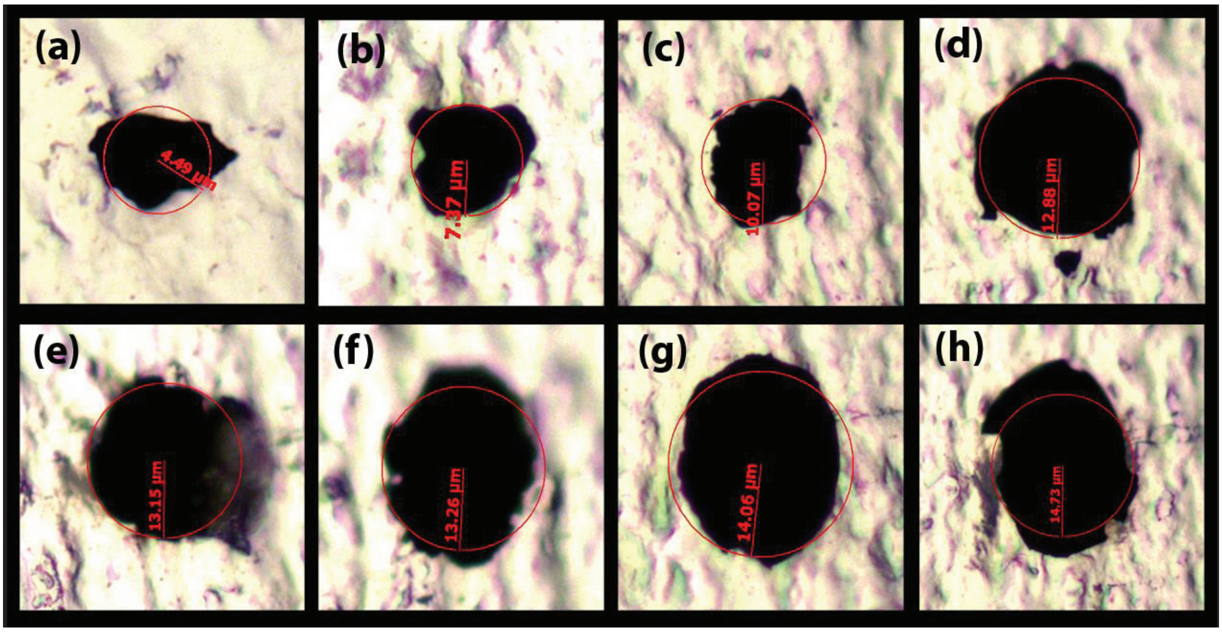


Figure 6: Microscopic imaged of the pores created by 18 keV argon ion beam at different irradiation times **(a):** 50s – 4.5 µm, **(b):** 50s – 7.4 µm, **(c):** 55s – 10.1 µm, **(d):** 60s – 12.9 µm, **(e):** 65s – 13.2 µm, **(f):** 70s – 13.3 µm, **(g):** 70s – 14.1 µm, **(h):** 75s – 14.7 µm,

The variation of the pore sizes with the irradiation time for 18 keV argon beam is shown in Fig. 7. It can be noted that the pore is not created below 50 seconds irradiation time and at 50 s irradiation through apertures are created only in three samples out of five. This confirms that the beam penetration time $\tau_d \sim 50$ s matches with Fig. 5.

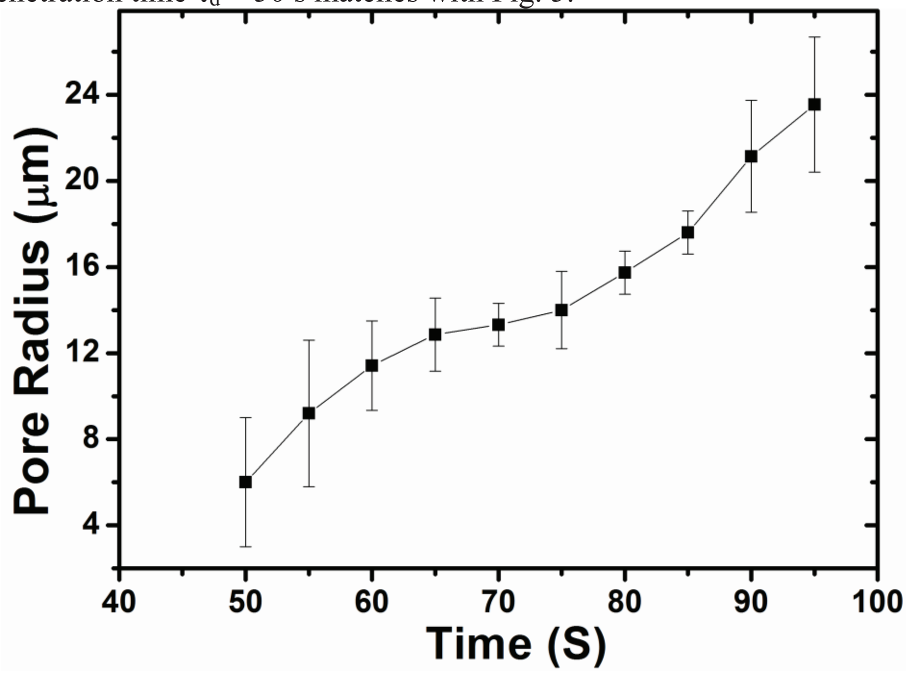


Figure 7: Varition of pore size with the irradiation time for 18 keV argon ion beam. Below 50s no through apertures are created.

IV. SUMMARY

In this report the milling capability of focused ion beams of Ar and Kr ions from a microwave plasma is demonstrated. The focal point for 18 keV Ar beam is obtained experimentally by measuring beam impression on a metallic thin film. A Faraday cup is designed and fabricated to measure the ion beam current. The time required to create an aperture (τ_d) on a thin (11μm) aluminium film is determined by measuring ion current obtained from a faraday cup kept just behind the film. An equation has been obtained which describes the temporal current profile recorded by the FC. The variation of τ_d with beam energy and for different species (Ar, Kr,) have been studied. The pores created by the ion beam are observed to have a conical shape with the irradiated side having a larger aperture size. The variation of the pore size with the beam irradiation time has been studied.

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BUTI-03

Synthesis Of Carbon Encapsulated Magnetic (Fe/Fe_3C) Nanoparticles (CEMN) Optimized For Biomedical Applications

N. Aomoa and M. Kakati

Thermal Plasma Processed Materials Laboratory,
Centre of Plasma Physic-Institute for Plasma Research,
Sonapur – 782 402, Assam

E-mail: ngangomaomoa@yahoo.com

Abstract

This paper reports the synthesis of Carbon Encapsulated Magnetic (Fe/Fe_3C) Nanoparticles (CEMN), by thermal plasma expansion technique, with properties optimized for biomedical applications. Magnetic nanoparticles, when protected from oxidation by encapsulation, ideally with carbon, have vast application potential, with biomedical applications being an important one. CEMNs can be used for targeted drugs delivery, annihilation of the cancerous cells through hyperthermia and in Magnetic Resonance Imaging (MRI). For such applications, super-paramagnetic materials with particle size in the range of 50 – 300 nm is strictly demanded and desired [2, 3]. Materials with mesopores are also highly desirable for drug delivery. CEMNs were synthesized from ferrocene ($FeC_{10}H_{10}$) in a DC plasma torch assisted thermal plasma reactor. Raw and purified samples were thoroughly characterized with HRTEM, SAED, XRD, VSM, XPS, Raman, BET, DLS, Mossbauer and TGA to study the morphology, elemental and phase composition, magnetic properties etc.

I. Introduction

Carbon Encapsulated Magnetic Nanoparticles (CEMN) are an important class of nanomaterials due to their interesting size dependent properties and vast application potential in wide array of technologies [1]. Encapsulation is important to protect the magnetic nanoparticles from oxidation which often diminishes the magnetic properties of metals and is ideally done with carbon, which is light and inert even in extreme chemical and physical environments. Among the various potential applications of CEMNs, its application in biomedicine is an important one where they find use in more than one way like targeted drugs delivery, annihilation of the cancerous cells through hyperthermia and in Magnetic Resonance Imaging (MRI) [2].

But for biomedical applications, particle size plays an important role where the diameter of the capillary walls puts a limit to the use of large particles while very small particles are easily removed through extravasation and renal clearance. Therefore, particles size in the range of 50 – 300 nm is strictly demanded and desired [3]. Another important issue for biomedical application is that the particles should be super-paramagnetic and not ferromagnetic, which may cause serious particle agglomeration inside the living tissues [4]. But this is possible at room temperature only when the particle size is smaller than the critical domain size which is around 15 nm for iron.

CEMNs have been synthesized by different methods such as chemical vapor deposition, combustion, laser irradiation, spray pyrolysis, thermal plasmas (transferred and non-transferred). The thermal plasma assisted processes has the advantage of bulk productivity and fine crystallinity of the product material and non-transferred thermal plasma torch mediated processes may be designed to be a continuous process but on the negative side, high temperature plasma processes usually produce particles with bigger average sizes and wide size distribution. Recent experiments on synthesis of

CEMNs have emphasized on achieving better control over the sizes of the core magnetic particles. We have developed a dc segmented plasma torch based experimental reactor configuration for synthesis of different high temperature nanomaterials, where gas phase reactants are injected just upstream of a water cooled converging nozzle through which a plasma jet accelerates and expands into a low pressure sample collection vacuum chamber kept at the bottom. In this technique, the vapor phase precursors laden on the plasma jet undergo a very rapid but uniform cooling as a result of this nozzle expansion, which leads to nucleation of superfine particles with a relatively narrow size distribution [5]. The present experiment aims at synthesizing carbon stabilized iron nanostructures by this plasma expansion technique and thus combine the conventional advantages of thermal plasmas with better size control as likely to be offered by this particular technique. The materials are synthesized over wide variation of reactor pressure conditions and characterized thoroughly for their magnetic and other properties.

II. Experimental details

A non-transferred segmented DC plasma torch, which produces a highly stable and homogeneous power jet, was used as the plasma source. The torch consisted of a thoriated tungsten cathode and a stack of copper ring segments separated by Teflon gaskets and a copper anode, all of which were intensely water-cooled. The anode of the torch is followed by the copper injection section (15 mm inner diameter, 25 mm long) and a 50 mm long converging nozzle (10 mm inner inlet diameter, 5 mm outlet). The vertical torch–injection section–nozzle combination exhausts into a stainless-steel sample collection cylindrical vacuum chamber kept at the bottom (300 mm diameter and 300 mm in height). Schematic drawings and photograph of the complete system may be found elsewhere [6].
Argon, used as the plasma gas, was injected at the rate of 20 liter per minute (lpm) near the cathode. Ferrocene ($FeC_{10}H_{10}$), used as the source material for both carbon and iron, was evaporated in a tubular furnace, kept at 230 ^{o}C and fed into the injection section carried by 2 lpm hydrogen gas. The plasma current was kept constant at 200 ampere (12.3 kW). Samples were collected from the water cooled chamber wall. In this communication, we present results primarily from variation of pressure in the sample collection chamber, for three different values of 600, 350 and 20 mbar. Parts of the samples were purified by aqua-regia.
Raw and purified samples were thoroughly characterized with high resolution transmission electron microscope (HRTEM), selected area electron diffraction (SAED), X-ray diffraction (XRD), vibrating sample magnetometer (VSM), X-ray photoelectron spectroscopy (XPS), Raman spectroscopy, Nitrogen adsorption (BET area and pore size), dynamic light scattering (DLS), Mossbauer spectroscopy and thermo-gravimetric analysis (TGA) to study the morphology, elemental and phase composition, magnetic properties etc.

III. Results and discussions

Transmission electron microscopy photographs (fig. 1) shows nanoparticles in the size range of 2-40 nm, dispersed in carbon matrix. Higher resolution confirms that the nanomaterials have hybrid structure; well crystalline iron nanoparticles almost spherical in shape are tightly encapsulated inside a nano-layered shell with typical graphitized carbon like structure. It may be pointed out that both raw and pure samples were actually much better homogeneous compared to other typical high temperature plasma processed encapsulated particles; devoid of any carbon nanotubes or micron sized impurities. Selected area electron diffraction (SAED) showed that the core particles are single crystal (fig. 1). Size distribution of the core nanoparticles under different pressure conditions were calculated from the corresponding HRTEM photographs. Size distribution histograms (Fig. 2) so constructed clearly demonstrate that both average sizes of the nanoparticles as well as the width of the distribution clearly increase with increase in pressure in the sample collection chamber. For different pressure of 20, 350 and 600 mbar in the chamber, the average particle size was increasing as 7.7, 8.5 and 10 nanometers. This is significant, as the average sizes are one of the smallest synthesized by a thermal plasma assisted technique.

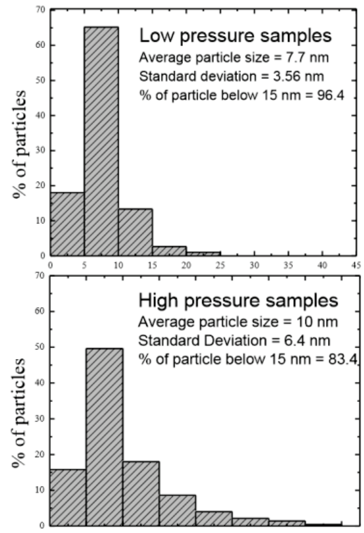


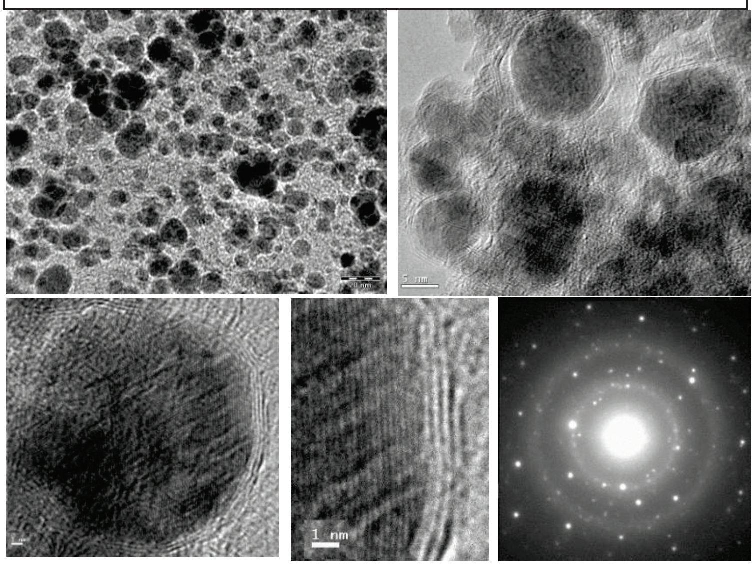
Figure 1: HRTEM images at different magnification and SAED pattern of CEMN samples.

Figure 2: Size distribution of Low and high pressure samples.

0 5 10 15 20

25 30 35 40

Particle size (nm)



XRD spectrum (Fig. 3.a) shows the presence of αFe {peaks at 44.7 (110) and 65 (200)}, Fe_3C {peak at 43.7 (102)} as well as γFe iron phases, {peaks at 43 (111) and 50 (200)}. Raw samples also showed the presence of iron oxides Fe_3O_4 {peaks at 35.4 (311) and 62.4 (440)}, which increased with decrease in chamber pressure and FeO {peaks at 36 (111), 41.8 (200) and 60.7 (220)} which was more pronounced in high pressure samples. But for the purified samples, the oxide peaks were totally absent showing that the acid treatment purification process was able to eliminate all the oxides from the sample. This result was also confirmed from XPS and Raman results. XPS spectrum (Fig. 3.b) showed the presence of elements Fe, C and O in the samples. The spectrum of the raw samples showed the presence of O-Fe bonds which were absent from that of the purified samples. Raman spectrum (Fig. 3.c) of the raw samples also showed the presence of oxides which were absent in the purified ones and showed better graphitization.

The magnetic properties of the samples were studied by vibrating sample magnetometer (VSM). The hysteresis shape (Fig. 4a) resembled that of ferromagnetic materials. The saturation magnetization of raw as well as purified samples increased with increase in chamber pressure with purified samples having higher values both at 300^oK and 0^oK (Table 1). Almost similar trend was seen for the remnant magnetization values and coercive field enhancing with pressure, upon purification and lowering of measurement temperature. It can be pointed out that the remnant magnetization and coercive field of our samples is one of the smallest by any thermal plasma assisted technique and these very small values indicate that the magnetic properties of our samples are tending towards super-paramagnetism, more so for the low pressure samples, which is favorable for biomedical applications. This is a consequence of the small sizes of the core particles of our samples where the magnetic property shifts from ferromagnetism to super-paramagnetism when the particle size reduces below the magnetic domain size.

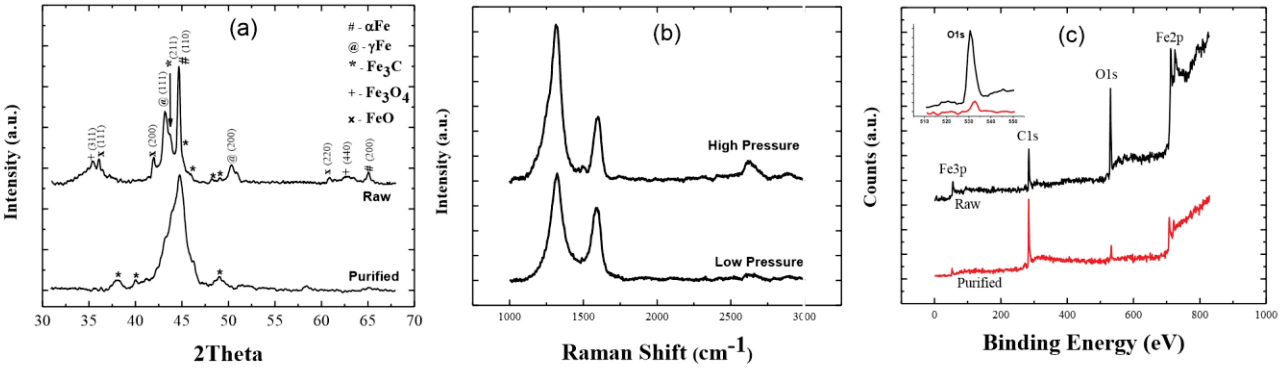


Figure 3: (a) XRD spectrum of raw and purified high pressure samples (b) Raman spectrum of low and high pressure purified samples (c) XPS spectrum of raw and purified high pressure samples.

Table 1: Magnetic properties of the raw and purified samples taken at 300 K and 0 K.

Sample	Chamber pressure	Ave. size (nm)	Saturation magnetization (M_s)		Remnant magnetization (M_r)		(M_r/M_s)		Coercive field (H_c) Gauss	
			300 K	0 K	300 K	0 K	300 K	0 K	300 K	0 K
C1W	20 mbar		33.74		2.066		6.1		58	
C2W	350 mbar		52.90		3.033		5.7		72	
C3W	600 mbar		51.59		4.940		9.5		101	
C1W (Purified)	20 mbar	7.7	51.83	58.4	2.562	12.6	4.9	21.5	54	305
C2W (Purified)	350 mbar	8.5	74.55	85.5	5.092	22.5	6.8	26.3	98	360
C3W (Purified)	600 mbar	10.0	76.28	96.9	5.719	23.9	7.5	24.7	123	370

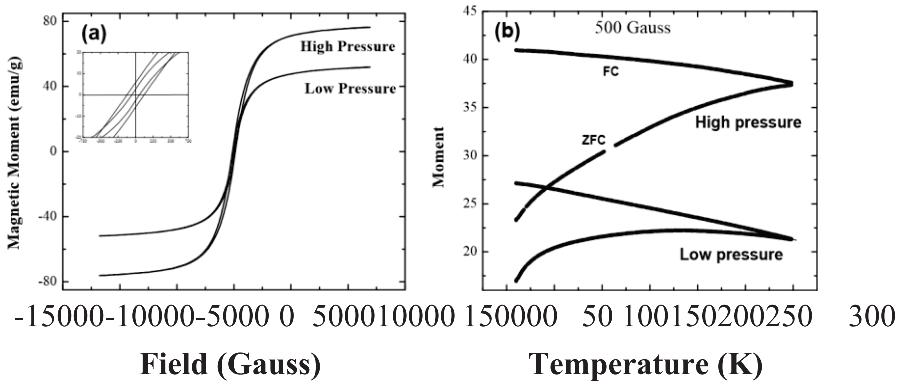


Figure 4: (a) VSM hysteresis loops of low and high pressure purified samples (b) Zero field cooled (ZFC) and field cooled (FC) magnetization curves of low and high pressure purified samples.

In order to check the paramagnetic behavior, the temperature dependence of the magnetization at constant applied magnetic field of 500 Oe was also studied and the zero field cooled (ZFC) and the field cooled (FC) curves were obtained (Fig. 4b). For high pressure samples, the ZFC and FC curves almost intersect around 300 K, showing that the blocking temperature, T_B, of these samples is just a little above 300 K. As for the low pressure samples, the ZFC curve gives a peak in magnetization around 180 K, which is the blocking temperature. Above the blocking temperature, the nanoparticles are superparamagnetic. This is a confirmation of the superparamagnetic properties of the low pressure sample at room temperature which is a consequence of the smaller particle sizes.
In order to evaluate the phase composition, the samples were analyzed with Mossbauer spectroscopy. The spectra were fitted with two magnetically split sextets (αFe and Fe_3C) and two paramagnets (a doublet from γFe(C) and a singlet from γFe). This allows the separation of magnetic and paramagnetic phases and their respective quantities. We see that as we increase the chamber pressure, the percentage of paramagnetic phase (γFe and γFe(C)) decreases from about 25% to 8%. This is in agreement with the VSM studies which show that magnetization increases with increase in chamber pressure. As for the magnetic phases, the percentage of αFe remains almost same around 10% but the carbide phase increases from 64% to 81%. So, we can conclude that the increase in magnetization of our samples with increase in chamber pressure is due to the decrease in paramagnetic phase and increase in carbide phase.

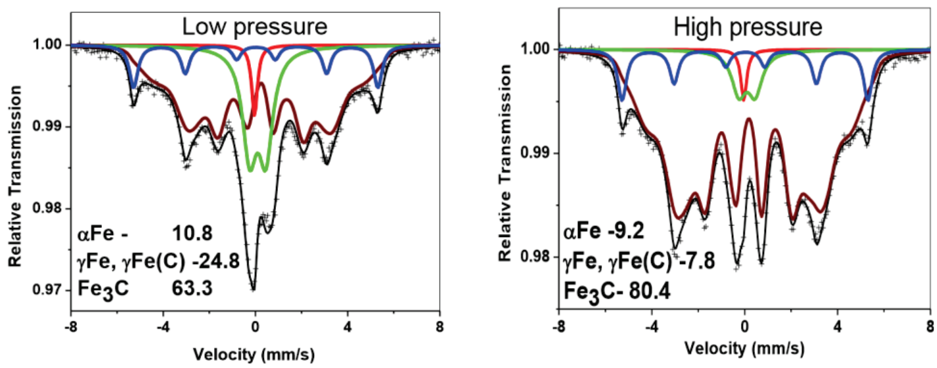


Figure 5: Mossbauer spectrum of the low and high pressure purified samples.

So far, we have discussed the sizes of the core magnetic particles which affect the magnetic properties of the samples. But the effective sizes and specific surface area of the CEMN samples, as a consequence of some core particles being in carbon matrix and agglomeration to some degree, are also very important for biomedical applications. So, Nitrogen adsorption isotherms for our samples were obtained from which the specific surface area was calculated using BET theory and the pore volume and average pore size was calculated using the BJH theory. Low pressure samples have specific surface area of 45 m^2/g and pore volume of 0.568 cm^3/g with average pore diameter 45 nm. High pressure samples have a little lower specific surface area of 40 m^2/g and pore volume of 0.338 cm^3/g with average pore size of 34 nm.

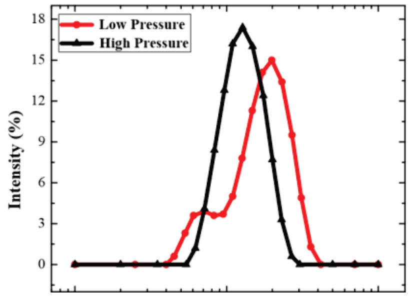


Figure 6: DLS spectrum showing the effective particle sizes of low and high pressure raw samples.

The presence of mesopores in both the samples is significant as mesopores can be utilized for storing drugs during drug delivery. The effective sizes of the samples were also measured by dynamic light scattering which shows the low pressure samples have effective sizes ranging from 40 – 400 nm while high pressure samples are in the range of 55 – 300 nm. These effective sizes are also ideal for biomedical applications

IV. Conclusions

Magnetic nanoparticles (Fe/Fe_3C) well encapsulated by graphitized carbon was synthesized by a supersonic plasma expansion technique, with properties optimized for biomedical properties. The sizes of the core magnetic particles as well as their phase composition could be controlled by varying the chamber pressure. Thus, we could control the magnetic properties of the samples since size and phase composition determines the magnetic properties. It was also found that the effective sizes of our samples were in the range of 40 – 400 nm and had average pore sizes 30 – 45 nm. Thus, we were able to synthesize CEMNs with very small core magnetic nanoparticles possessing superparamagnetic properties but having much larger effective sizes which also had mesopores making these samples ideal for biomedical applications.

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BUTI-04

Night Time D-Region Plasma Density Measurements From Lightning Generated Tweek Radio Atmospherics Recorded At Low Latitude India Station

Ajeet K. Maurya[1], Rajesh Singh[1] and B. Veenadhar[2],

[1]*KSK Geomagnetic Research Laboratory, IIG, Chamanganj, Allahabad, India,* [2]*Indian Institute of Geomagnetism (IIG), New Panvel, Navi Mumbai*

E-mail : ajeetphoton09@gmail.com

Abstract

Dispersive atmospherics (tweeks) observed simultaneously at low latitude station Allahabad (geomagnetic lat. 16.79^o N and long. 155.34^o E) in the Indian region have been utilized to estimate the D-region electron density/plasma density at the ionospheric reflection heights under the local nighttime propagation conditions (21:00 – 02:00 hrs LT or 15:30UT – 20:30UT). Tweeks recorded at Allahabad stations on selected days during one month from summer (June), winter (January) and from equinox (March) seasons during 2010 show that D-region plasma density varies 20-24el/cc over the path integrated ionospheric reflection heights of 89-95 km. The wait lower ionospheric parameters; ionospheric reference height (*h'*) and sharpness factor (β), for Allahabad station during three seasons have been calculated. The values of *h'* and β are almost same (84.5-85.5 km, and 0.56-0.59 km^{-1}) during winter and equinox seasons. The values of *h'* and β at Allahabad during summer season are ~ 82.5 km and 0.60-0.61 km^{-1}. The plasma density by all three techniques is consistent in the altitude range of 88-92 km. Over all, equivalent plasma density profile obtained using tweek method shows lower values of plasma density by about 5-60- % than that obtained from the IRI-2007 model and higher by 20-50 % over the rocket data.

1. Introduction

The D-region of ionosphere ranges from ~ 60-75 km in the day and ~ 75-95 km in the night [*Hargreaves,* 1992]. It is the lowest part of Earth's ionosphere where collisions between charged particles and neutrals dominate. It plays an important role in the propagation of Extremely Low Frequency (ELF: 30-3000Hz) and Very Low Frequency (VLF: 3-30 kHz) waves through the Earth-ionosphere wave-guide (EIWG) bounded below by the ground or the ocean and above by the D-region of the ionosphere.

The ELF-VLF signals radiated by lightning discharges (global lightning flash rate ~ 50-100 sec^{-1} km^{-2}) [*Rakov and Uman,* 2006] can be used to investigate the D-region ionosphere globally. The radio bursts from the lightnings are called atmospherics or 'sferics' in short which propagate in the EIWG with low attenuation rate (2-3 dB/1000 km) [*Yamashita,* 1978]. We have utilized the cutoff frequencies of different modes of dispersed sferics known as 'tweeks' to estimate the nighttime D-region electron density and Wait ionospheric parameters: *h'* and β . The *h'* represents virtual reflection height in km and β represents the gradient in the D-region electron density in km^{-1}.

In the present work we have utilized tweeks recorded at the Indian low latitude station, Allahabad, during one year period January to December 2010, on five international quiet days during one month from summer (June), winter (January) and equinox (March) seasons, to study seasonal and day-to-day variability of the nighttime D-region reflection height and the electron density at the reflection height. The values wait ionospheric parameters; ionospheric reference height *h'* and exponential sharpness factor β [*Wait and Spies,* 1964] from the cutoff frequencies of multimode tweeks is also obtained for three different seasons (summer, winter and equinox). The average values of h' and β have been used to obtain the electron density profile of the nighttime D-region up to 100 km altitude during three seasons.

2. Summary of the Formulas Utilized

The EIWG is taken with perfectly reflecting walls separated by a distance *h*. The electromagnetic field in the waveguide can be comprised of a sequence of independent field structures (modes) that propagate with different group velocities. Each mode is defined by its cutoff frequency (f_{cm}). The f_{cm} of m^{th} mode is given [*Budden,* 1961] as:

$$f_{cm} = \frac{mc}{2h} \quad (1)$$

Where *c* is velocity of light in free space and *h* is the tweek reflection height.

The electron density n_e at the *h* is estimated using the expression obtained by *Shvets and Hayakawa* [1998] given as $n_e = 1.39\times10^{-2} f_{cm}$ [cm^{-3}] (2)

The distribution of charged particles in the ionosphere depends in a complicated way on latitude, solar zenith angle, season, and solar activity etc. In the simplest approach, the exponential increase of the lower-ionospheric electron density n_e expressed in cm^{-3}, described by *Wait profile* valid up to about 100 km altitude [*Wait and Spies,* 1964] is obtained as

$$n_e(h) = 1.43\times10^{7}\exp(-0.15h')\exp[(\beta-0.15)(h-h')] \quad (3)$$

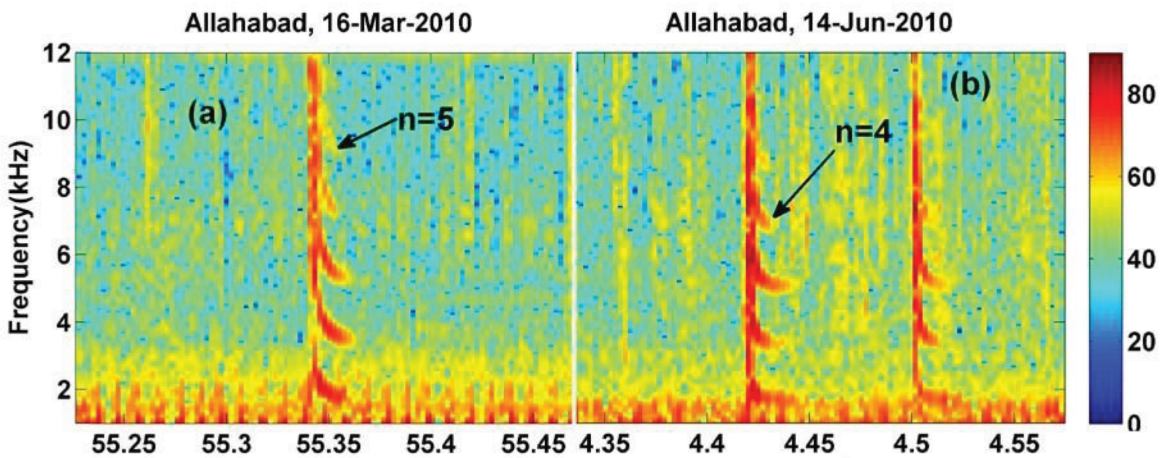

Fig 1: Spectrograms showing typical multimode tweeks observed at Allahabad.

3. Data and Analysis

The ELF-VLF data recording system at Allahabad, consists of Stanford University designed Atmospheric Weather Electromagnetic System for Observation, Modelling and Education (AWESOME) VLF receiver [*Singh et al*., 2010]. Data was recorded in the synoptic mode with 1 minute at every 15 minute interval. Tweek data is analysed using a Matlab code which produces dynamic spectrogram of selected durations showing atmospherics, tweeks as shown in Fig 1. The first order cutoff frequency f_c of tweeks in spectrograms was measured and used to calculate the ionospheric reflection height *h* and the D-region electron density n_e at the reflection height. We have utilized tweeks data recorded at Allahabad (geog. lat., 25.40º N; geog. long., 81.93º E; geomag. lat., 16.05◦ N) on five international quiet days during one month from summer (June), winter (January) and equinox (March) seasons under the pure nighttime propagation (21:00– 02:00 LT or 15:30 UT –

20:30 UT) condition.

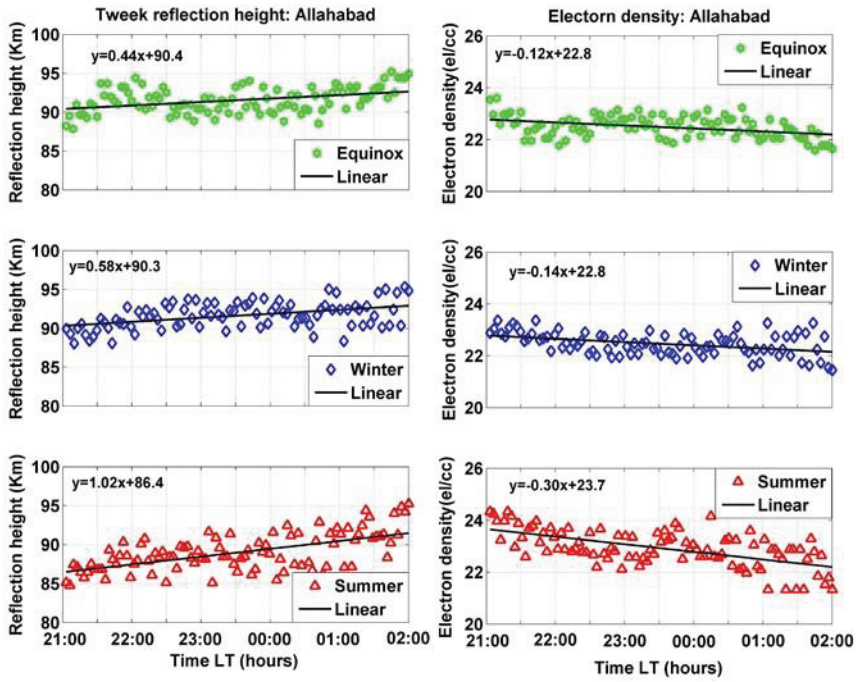

Fig 2: Variation in the reflection height and electron density estimated from first mode cutoff frequency of tweeks recorded at Allahabad in pure night time 21:00-02 LT (15:30 20:30 UT) conditions. The trend of variation is shown by the linear fit lines.

4. Results and Discussion

4. 1 Night Time D-Region Reflection Height and Electron Density

The D-region of ionosphere acts as a good electrical conductor at the ELF and VLF frequencies. Lightning generated ELF-VLF tweeks form a useful diagnostic tool to estimate the nighttime ionospheric reflection height *h* and the electron density n_e at *h*. The *h* and n_e at tweek *h* at Allahabad during three seasons (Summer, Winter, Equinox) determined from the cutoff frequency of first mode of tweeks and plotted in Fig 2 shows nearly constant increase in the *h* and constant decrease in n_e at tweek *h* with time for all three seasons as indicated by the linear fit lines. The *h* also shows the day-to-day variability which is up to 9 km with a maximum variation of about 1-2 km on any day in any one hour duration (not shown here) It is also noted that n_e is higher by 2 cm^{-3} during the summer as compared to that during winter and equinox seasons. Average value of n_e at Allahabad on selected days (15 day) varies 21–24.5 cm^{-3} at the *h* of 85-95 km and at Nainital 21.5-24 cm^{-3} at the *h* of 86-95 km. using the same method, *Ohya et al.* [2003] estimated n_e in the range from 20-28 cm^{-3} at the *h* of 80-85 km for a mid-latitude Japanese station.

The period of observation in present study falls under low solar activity period of solar cycle 23 with tweek propagation paths mainly over the low latitude and equatorial regions. Taking this into consideration we have tried to explain possible factors of the nighttime D-region variations shown in Fig 2. *Ohya et al.* [2011] reported that about 67% of nighttime lower ionospheric ionization is caused by Lyman-α and Lyman-β coming from the geocorona which ionizes NO and O_2 at 95 km altitude. Another important source of ionization during nighttime is Galactic Cosmic Rays (GCRs) which has nearly half of ionization rate of Lyman-$_\alpha$ at 85 km altitude [*Thomson et al.*, 2007]. The GCRs intensity varies with solar activity with maximum during solar minimum [*Heaps*, 1978]. The ionization by GCRs also depends on the geomagnetic latitude with minimum at the geomagnetic equator [*Heaps*, 1978]. Since period of study falls under solar minimum, GCRs are supposed to be the important ionizing source at the low and equatorial latitudes and hence an understating of GCRs variability during different seasons at the low and equatorial latitudes is essential to explain the D-region electron density variation.

The day-to-day variability can also be caused by heating of the D-region by lighting discharges. *Han and Cummer* [2010] suggested that either direct lightning coupling to the ionosphere or ducted lightning-induced electron precipitation can drive significant D-region variability on the time scales from minutes to hours. At our stations direct lightning coupling to the ionosphere producing short-term (10-100 s) significant electron density changes is most likely the source of day-to-day variability as lightning-induced electron precipitation is very unlikely to occur in the low-latitude region. The direct energy coupling between lightning discharges and lower ionosphere causing short-term changes in the electron density or conductivity at the VLF reflection heights have been reported by many researchers [e.g. *Rodger*, 2003 and references therein]. The heating of lower ionosphere by strong quasi-electrostatic field generated by strong lightnings causes the conductivity enhancements [e. g. *Pasko et al*., 1995] and the electromagnetic pulses from cloud-to-ground and/or successive in-cloud lightning discharges associated with cloud-to-ground discharges can produce appreciable electron density changes which could be the electron density enhancements/reductions at the VLF reflection height.

Table 1: The mode number, cut-off frequency, mean cut-off frequency, ionospheric reflection height *h*, and electron density n_e for tweeks shown in the spectrogram for modes *m* =1-5.

Station	Mode	Cutoff frequency	Mean Cutoff frequency	Reflection height	Electron density
	(*m*)	kHz	kHz	km	cm-3
Allahabad	(a)	1.6693	1.6693	89.9	23.20
		3.3212	1.6606	90.3	46.16
		4.9546	1.6515	90.8	68.87
		6.5839	1.6460	91.0	91.52
		8.1933	1.6387	91.5	113.89
	(b)	1.6159	1.6159	92.8	22.46
		3.1918	1.5959	94.0	44.37
		4.7843	1.5948	94.1	66.50
		6.3168	1.5792	95.0	87.80

The *h* and n_e at *h* calculated for all modes of tweeks shown in Fig 1 using equations (1) and (2) are given in Table 1 (method 2). From the Table 1, it can be noted that higher modes of any tweek are reflected comparatively from higher altitude (about 1-3 km for *m* =1-5) with fundamental mode (*m* =1) being reflected from lowest height. The results are consistent with the earlier findings of *Shvets and Hayakawa* [1998]. Theoretically, for a waveguide with perfectly conducing boundaries, the higher modes also should have been reflected from same altitude. Since the real EIWG is not perfectly conducing rather D-region forms a diffuse boundary of which conductivity/ionization increases exponentially with the altitude, the higher modes are reflected from slightly higher altitudes as compared to lower modes. The electron density estimated from cutoff frequencies of first five modes of tweek shown in Fig 1 varies from 23-112 cm^{-3} in the altitude range of about 1.7 km (89.9-91.5 km). The electron density for second mode is almost double to that obtained from first mode and so on for higher modes. The modes are reflected from the altitude where plasma frequency equals the cutoff frequency for that particular mode [*Shvets and Hayakawa,* 1998] which for higher modes happens where electron density (plasma frequency) and reflection height are higher. Since the electron density of the D-region increases exponentially, the reflection height for higher modes increases accordingly. *Shvets and Hayakawa* [1998] from the cutoff frequency of modes *m* =1-8 of tweeks observed during low solar activity months (January-April 1991) found an increase in the electron density from 28-224 cm^{-3} in the altitude range of about 2 km at an altitude of 88 km. Thus tweek method is useful in studying the variation in the electron density of the nighttime D-region ionosphere over a limited altitude range of about 1-2 km but requires clear multimode tweeks with at least three modes. The tweeks with higher modes (*m* >3) occur less frequently due to higher attenuation for the higher modes. To overcome with height limitation of method 2 and less occurrence of tweeks with higher modes ($m \geq 3$) tweeks, method 3, which gives h' and β, has been utilized to estimate electron density.

4.2. Equivalent electron density profile from h′ *and* β *parameters calculated from tweek and comparison with IRI-*

2007 and Rocket Measurements

The lower ionosphere up to 100 km altitude [*Wait and Spies,* 1964] can be characterized by the reference height h' in km and the exponential sharpness factor β in km^{-1}. We have used the method developed by *Kumar et al.* [2009] to estimate the values of h' and β from first three modes of tweeks observed during summer, winter and equinox seasons. For this purpose we have selected 2 tweeks (total 10 from five quiet days) at every 15 minute interval in the period of 21:00 - 02:00 LT on the five international quiet days of the months, January, March and June 2010. These months are taken as representative of winter, equinox and summer seasons. The method involves two steps; in first step the path integrated reflection height *h* and the electron density n_e are obtained using modes *m* =1, 2, 3 of tweeks (mostly using *m* = 1-2) by equation (1) and (2) for each selected tweek during three seasons. The values of n_e and *h* thus obtained have been used to calculate the values h' and β using equation (3) as described by *Kumar et al.* [2009]. We have estimated average values of nighttime h' and β, for summer, winter and equinox seasons. Seasonally, h' and β are same during winter and equinox but h' is lower and β is higher during summer. The values of h' and β estimated for each season are employed in equation (3) to calculate electron density profile in the altitude range of 80-100 km. Electron density calculated by tweek method has been compared with that obtained using IRI-2007 model and past Rocket measurements available in the Indian region.

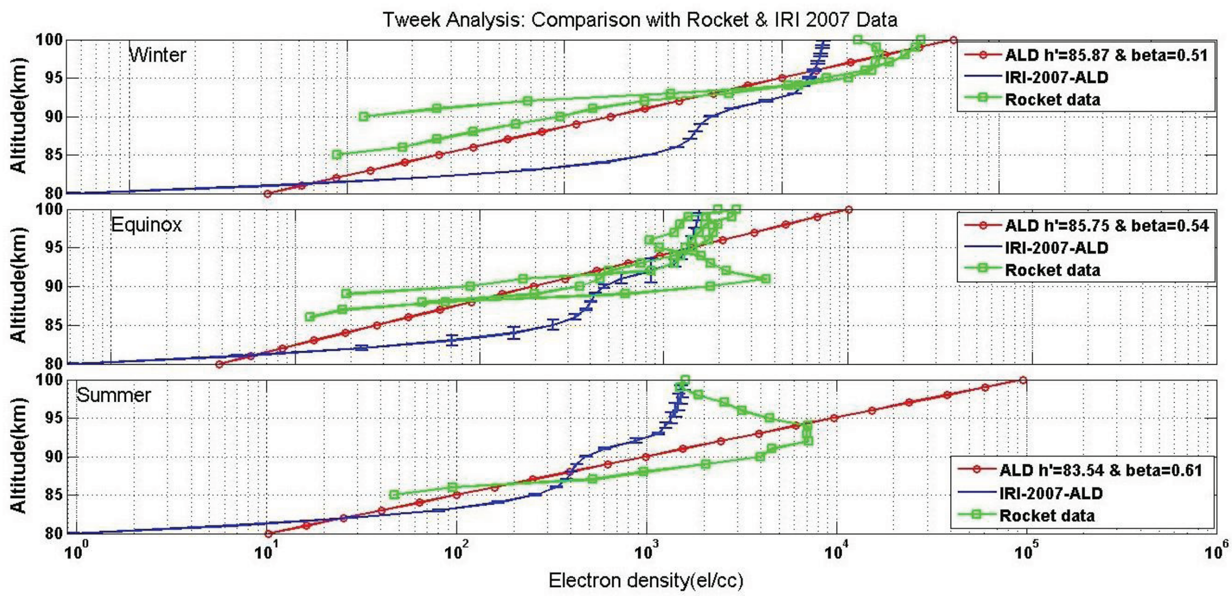

Fig 3: A comparison of electron density profiles of the D-region obtained using tweek method, IRI-2007 Model, and rocket data during winter, summer and equinox seasons. Error bars shown in IRI-2007 data are standard deviations

4.2.1 Comparison with IRI-2007 Model & Rocket data

We have obtained electron density for the location of Allahabad at 00:00 LT on five international quiet days during January, March and June of 2010. IRI-2007 model shows no significant seasonal variation in the electron density profile..

However, the values of h' and β obtained from tweek analysis are different for each seasons and hence the electron density profile for summer is different than those for winter and equinox. As shown in Fig 3 (panel a), during winter season electron density obtained from tweek method varies in the range of 4-6194 cm^{-3} in the altitude range of 80-100 km. Also the electron density thus obtained is quiet comparable to electron density obtained from IRI-2007 in the altitude range of 91-95 km with a very good match at 94 km altitude but it is significantly low at the lower altitudes (Fig 3). The electron density obtained from tweek method during summer season (Fig 3, panel b) varies in the range of 10-95476 cm^{-3} in the altitude range of 80-100 km and shows a good comparison with IRI-2007 in the altitude range of 82-89 km with very good match at 88 km. The electron density variation during the equinox (Fig 3, panel c) is very much similar to that during winter with a very good agreement in the altitude range of 89-93 km. In general, equivalent electron density profile of the nighttime lower ionosphere using tweek method shows lower values of electron density by about 5-60% than those obtained using IRI-2007 model at both the stations. *Kumar et al.* [2009] have shown that electron density using tweek method is lower by about 20-45 % than those obtained using IRI-2001 model at a low latitude station in the South Pacific Region. From the analysis of tweek atmospherics observed in Japan, *Ohya et al.* [2003] found tweek estimated electron density almost consistent with electron density profile obtained using IRI-95 model in the altitude range of 80-85 km. Tweek method shows seasonal variation in the nighttime Dregion electron density whereas IRI 2007 model does not show significant seasonal variation. The results are consistent with IRI-2007 model in certain ranges of altitudes during different seasons.

Rocket data provides a direct measurement of electron density of the lower ionosphere. Rocket experiment for the Dregion electron density measurement at a low latitude, Thumba, an Equatorial Rocket Launching Station (geographic lat., 8° 32′ N, magnetic dip., 0° 24′ S), in the Indian region, was carried out using Langmuir probe method on different types of rockets. The results of extensive series of measurements of lower ionospheric electron density at Thumba made under various solar and geographical conditions have been reported by *Subbaraya et al.*[1983]. During winter season, the electron density is higher by about 30-52% in the altitude range of 86-94 km and lower by about 2-20% in the altitude range of 96-98 km with a good match in the range of 94-96 km. Similarly electron density is lower by about 3-40% in the altitude range of 96-98 km with good match at 95 km as compared to rocket profile 2. During summer season, the electron density measured by rockets varies consistently with the electron density estimated by tweek method in the altitude range of 87-93 km with a difference of about 15-58%. For equinox season, electron density is available for three rocket profiles only which vary concurrently with electron density profile estimated by tweek method in the altitude range of 89-94 km, 92-94 km, 92-95 km but with lower/higher values by 32-68%, 2-55% and 6-65%, respectively. The difference in the electron density is due to the fact that some of the rocket experiments were conducted during high solar activity period. Overall the trend of variation of electron density calculated by tweek method is consistent with available rocket electron density profiles in the altitude range of 86-98 km with a difference in electron density of about 2-68% during different seasons. Seasonal variation in the electron density estimated by tweek method is consistent with the seasonal variation observed with the rocket experiments. The electron density estimated by all three techniques is consistent in the altitude range of 82-98 km indicating that tweek method is also useful for obtaining electron density profile of the nighttime D-region.

5. Summary and Conclusions

The main findings of the study can be concluded as

1. The path integrated reflection height *h* of nighttime D-region ionosphere calculated by using first order cutoff frequency of tweeks varies in the range 87-95 km at both the stations. The path integrated electron density n_e estimated using first order cutoff frequency of tweeks varies as 21-24.5 cm^{-3} at Allahabad and 21.5-24 cm^{-3} at Nainital.
2. The average values of h' and β for both the stations are almost same (86.1-85.6 km, and 0.51-0.54 km^{-1}) during winter and equinox seasons. The h' is lower by 2-3 km and β is higher by 0.07-0.09 km^{-1} during summer as compared to winter and equinox seasons.
3. The day-to-day variability in *h* is about 8-9 km with temporal variability of 1-2 km in any one hour duration. The n_e obtained using tweek method shows lower values than those obtained using IRI-2007 model and higher during winter and equinox and lower during summer when compared with Rocket data, however, the trend of n_e variation in the altitude range of 85-98 km is almost the same. This shows that tweek method is one of the useful methods for estimating the electron density profile of the nighttime D-region iono*s*phere.

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Observation and Theory of Electron Temperature Gradient Turbulence in Laboratory Plasma

S. K. Singh, L. M. Awasthi, S. K. Mattoo, R. Singh, R. Jha, P. K. Kaw and LVPD Team

Institute for Plasma Research, Bhat, Gandhinagar-382428

E-mail: ssingh@ipr.res.in

I. Introduction

It is well known that micro-turbulence plays a major role in determining the global confinement properties of fusion plasmas. Indeed, anomalously large transport of heat and matter across magnetic field in magnetically confined plasma is determined by the turbulence due to micro-instabilities and is considered as one of the major impediments in achieving the goal of a thermonuclear fusion reactor. The driving free energy source for these micro-instabilities lies in the gradients of mean plasma parameters. The physics of particle and energy transport of ions and electrons has been studied in detail [1]. Ion temperature gradient (ITG) turbulence, trapped electron mode (TEM) and drift resistive ballooning mode (DRBM) are identified as the primary cause of heat and particle transport. However, these drift instabilities of ion Larmor radius ($\rho_s = c_s / \Omega_i$) scale (such as ITG, TEM, DRBM) are suppressed due to rapid formation of $\vec{E} \times \vec{B}$ shear and zonal flows [2] in the high confinement mode (H-mode) pedestal and internal transport barrier but electron energy transport remains anomalous. The interest is then focused, again on electron transport. Interestingly, Electron Temperature Gradient (ETG) turbulence [3-8] is envisaged as a responsible candidate for electron thermal transport.

The ETG mode is a small scale reactive and negative compressible mode associated with magnetized plasma having a short wavelength ($k_\perp \rho_e \leq 1 << k_\perp \rho_i$) and low frequency ($\Omega_i < \omega << \Omega_e$), where $k_\perp$ is the perpendicular wave vector, ρ_e and ρ_i are the Larmor radii of electron and ion respectively, Ω_i, Ω_e and ω are ion, electron gyro frequencies and the mode frequency respectively. The linear calculations of the ETG mode reveal a threshold in $\eta_e = L_n / L_{T_e}$ where L_n and $L_{T e}$ are the electron density and temperature gradient scale lengths respectively. Recent investigations on turbulence in devices like National Spherical Torus Experiment [9], Tore Supra and CLM [10] have reported some interesting observations on electron gyro scale fluctuations and their role on plasma transport. However, detailed characterization of the turbulence in these devices for various plasma parameters like temperature, density, magnetic field and floating potential through measurement of properties like correlations and wave number and frequency spectra is still an unresolved issue. Making these measurements altogether in tokamaks is a very difficult task because of the small-scale nature of turbulence, complex geometry and restricted measurement capability. The basic plasma devices provide a simplified geometry, a good realization of turbulence and control of experimental parameters. In these devices producing moderate density plasma at lower magnetic fields, in order to bring the scale length of the ETG instability to conveniently measurable regime, by making use of probes is not a difficult task but plasma in these devices is plagued by the presence of ionising hot and non-thermal electrons due to radio frequency and filamentary discharges [11]. Each of these plasma production methods itself is a potential source of instability as it populates plasma with energetic electrons. Furthermore, the presence of energetic electrons makes the temperature measurement ambiguous. This makes it difficult to ascribe the origin of the turbulence unambiguously to ETG. Therefore, it becomes necessary to remove the primary energetic electrons from the plasma before carrying out ETG study. Although the magnetic configuration in Large Volume Plasma Device (LVPD) [12] is quite different than that of tokamaks but the fundamental physics of ETG turbulence should not change as in both cases, $\rho_e / L_{T_e} << 1$, $\Omega_i < \omega < \Omega_e$. A similarity in the nature of turbulence is also observed from the fact that mode approaches electrostatic nature with reducing plasma beta.

Based upon these observations, we have designed and installed a highly transparent ($\sim 82\%$) variable aspect ratio, rectangular solenoid, named as Electron Energy Filter (EEF) [13] suitable to fit across the cross- section of LVPD in such a way that it divides the whole plasma into three regions of source, filter and target plasmas. The performance of EEF makes three significant changes in the characteristics of the plasma in a self-consistent manner. Firstly, energetic electrons are constrained to remain in the source and EEF region. Secondly, the electron temperature is reduced in the target region because of the transport of cold electrons and thirdly, a significant gradient in the electron temperature and density profiles are introduced by adjusting current density along the length of solenoid. We have investigated an unambiguous controlled observations on ETG driven turbulence in finite beta ($\beta \sim 0.6$) in the core region of target plasma of LVPD in two extreme EEF configurations. The spectral features such as power spectra, correlation, threshold, S(k,w) beta scaling and relationship with plasma parameters are measured to characterize the ETG turbulence. In addition to the experimental observation, the theory of ETG mode in finite beta inhomogeneous plasma has been discussed using two-fluid model. Several signatures of the observed turbulence are found consistent with the theoretical predictions made for finite beta ETG modes.

II Experimental set-up and diagnostic

The experimental setup of LVPD consists of large double walled vacuum chamber (diameter = 2m and length = 3m) supplemented by a combination of rotary – root – diffstak pumps, capable of pumping the system to $1x10^{-6}$ mbar of base pressure. The plasma source is a multi-filamentary cathode with thirty-six numbers of filaments arranged in a rectangular periphery. The pulsed plasma (V_d~-70 V, $I_d \sim 200$ A, $\Delta t_{dis} \sim 9.2$ ms) of Argon gas at a fill pressure of $4x10^{-4}$ mbar is produced in LVPD using a discharge power supply. The radial confinement of the plasma is provided by magnetic field produced by a set of 10 coils garlanded on the device. The axial confinement to the plasma is provided by broken line cusp arrangements using samarium cobalt magnets accommodated on both ends of the device with effective surface field of ~ 4kG. The plasma is characterized by typical plasma parameters such as plasma density, $n_e \sim 3x10^{11}$ cm^{-3}, electron temperature, $T_e \sim 2$ eV and the applied ambient field, $B_z \sim 6.2$ G. In the diagnostic, we have developed a compensated Langmuir probe and established a technique for accurate measurement of electron temperature and its fluctuations [14]. The plasma density, floating potential are measured using Langmuir probe whereas plasma potential has been measured using emissive probe. B-dot probe has been used for the determination of magnetic fluctuations.

III. Experimental Results

In the experimental results, we have observed that energetic electrons are trapped in the mirror of solenoid field of EEF on the source side of LVPD. Hence they are not found in the target region. The decrease in electron temperature is enabled by the velocity dependence of the particle transport of electrons across the magnetic field. In figure 1, I-V characteristic of Langmuir probe shows that the target plasma is devoid of energetic primary ionising and non-thermal electrons. It may be noted that the peak value of floating potential, an indicator of energetic electrons is considerably reduced when EEF is introduced. The steady state value of floating potential also shows a significant reduction thus exhibiting a clear demonstration of scavenging of energetic electrons [Fig. 1(c)].

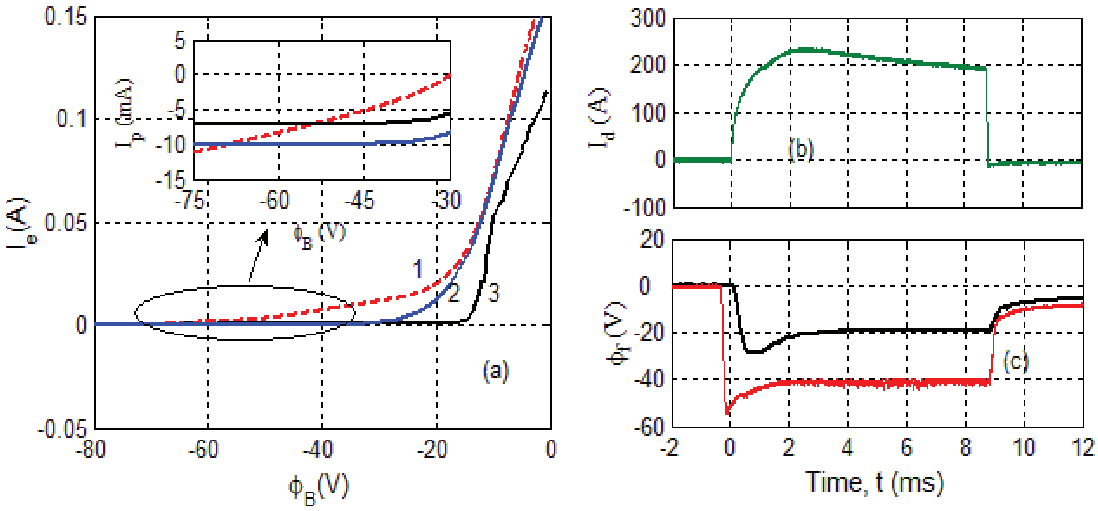

Figure 1: Shows in (a) the I-V characteristics obtained by fast swept Langmuir probe, after subtracting ion-saturation current and the curve is marked as 1 for plasma when EEF is not embedded physically whereas 2 and 3 for the source and target plasma when it is physically embedded and energized. The inset shows the zoomed view of ion saturation currents for the three cases. In figure (c), time profile of floating potential is shown for plasma without (continuous) and with EEF embedded and energized (dashed) during the plasma discharge period (figure b).

In the present study, we have restricted our measurements to two EEF configurations for studying mean plasma parameters and their ac components in the target plasma of LVPD. The core region of target plasma is characterized by flat density and gradient in electron temperature (Fn_eGT_e) and by hollow density and flat electron temperature (Hn_eFT_e) for EEF active and inactive cases respectively. We now discuss the equilibrium profiles of mean plasma parameters for Fn_eGT_e case. The region for $x < 50\ cm$ is defined as core plasma and the remaining region beyond it as edge plasma. The core region of target plasma is dominated solely by the gradient in electron temperature whereas the outer region is dominated by the pressure gradients [Fig. 2]. Moreover, the core region for Fn_eGT_e case, radial profiles of plasma density and plasma potential (ϕ_p) are typically flat but electron temperature gradient exhibits scale length, $L_{Te} \sim 50\,cm$.

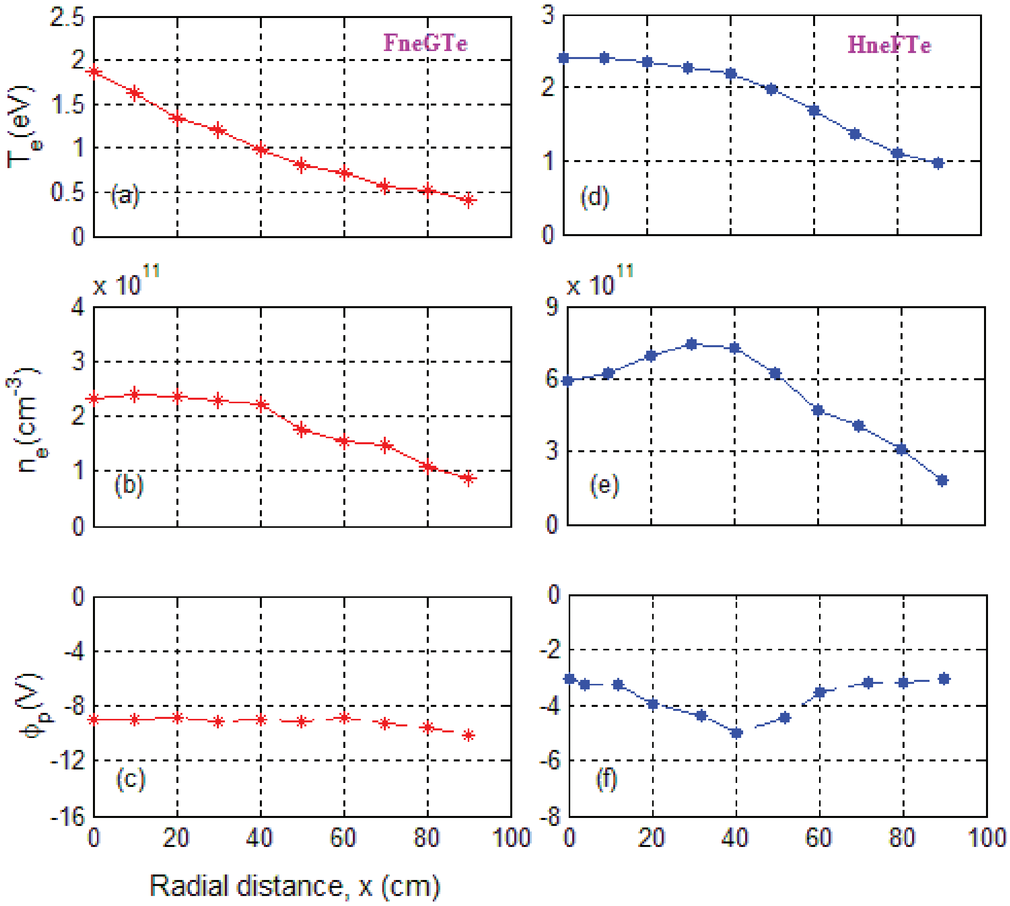

Figure 1: Radial profiles of mean plasma parameters are shown for, (a, d) electron temperature, T_e, (b, e) plasma density, n_e and (c, f) plasma potential, ϕ_p for two configurations of EEF active and inactive respectively. It is seen that the finite electron temperature gradient of scale length, $L_{Te} \sim 50\,cm$ exists only in the core region of LVPD plasma for filter active condition.

In the core region for the Hn_eFT_e case, filter exhibits a flat temperature and hollow density profiles whereas radial profile of ϕ_p represents significant gradient. Therefore, we have two equilibrium conditions, one is for the excitation of ETG mode and second is for the confirmation that indeed the observed mode is ETG.

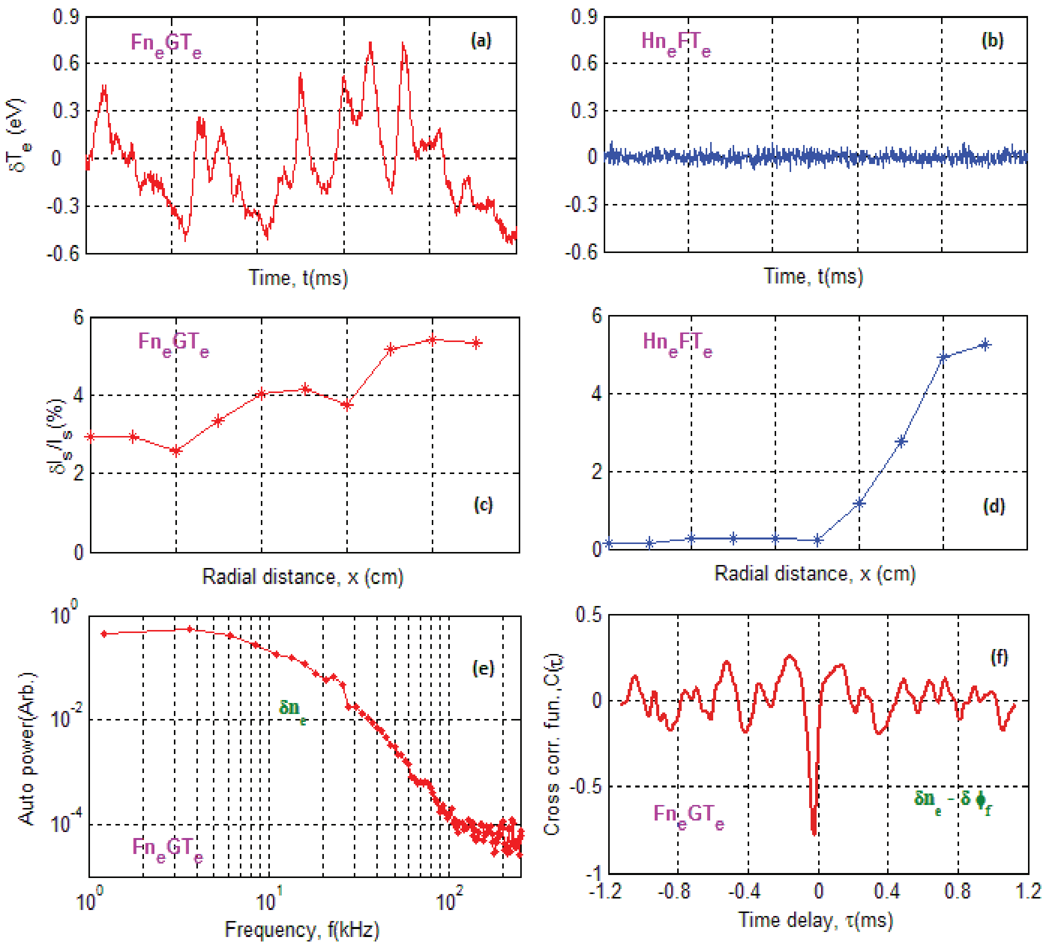

Figure 3: Time series for electron temperature fluctuations are shown for the EEF active (a) and inactive (b) cases. At the radial centre in target plasma, the fluctuation exists only in the case of FneGTe and suppresses to the level of noise for HneFTe case. In figure (c-d), the radial profiles shows a comparison of normalized fluctuations in ion saturation current ($\delta I_s / I_s$) for both cases. Auto-power spectrum of density fluctuation (δn_e) is shown in figure (e) for Fn_eGT_e and in (f), the cross-correlation function between density (δn_e) and potential ($\delta \phi_f$) fluctuation exhibits strong anti-correlation.

Figure 3(a-b) displays the time series profiles of temperature fluctuations for Fn_eGT_e and Hn_eFT_e plasmas in the core region. It may be noticed that electron temperature fluctuation is present in the Fn_eGT_e case and get suppressed for the Hn_eFT_e case. Similar observations have been observed for density, potential and magnetic fluctuations. The core plasma for filter active case supports turbulence of ETG nature while for Hn_eFT_e case, no such signatures are seen. The radial profiles of density fluctuation ($\delta n_e / n_e$) is shown in figure 3(c-d). It is observed that for FneGTe, the density fluctuation amplitude is higher as similar for density and magnetic fluctuations. The values obtained for $\delta T_e / T_e$, $\delta n_e / n_e$ and $\delta B_z / B_z$ are $\sim 13\%$, $\sim 4\%$ and $\sim 2\%$ respectively. These fluctuations reduce to noise level for Hn_eFT_e. Moreover, the presence of magnetic fluctuations reveal that observed turbulence is electromagnetic in nature. The important characteristic features like power spectra and cross-correlation function are necessary to identify the instability. The observed turbulence exhibits broad band spectra with significant power for the_frequency band between of $\leq 2-20\ kHz$ [Fig. 3(e)]. It follows a power law of $1/\nu^{1.8}$ for $\nu \leq 10-80\,kHz$ for density fluctuation. The observed frequency of the mode lies in the lower hybrid range of frequency ($\Omega_i < 2\pi\nu << \Omega_e$) and it indicates that the basic instability driving the turbulence is the only ETG driven mode. In addition, we measure correlation coefficients of density (δn_e) with potential ($\delta\phi_f$) fluctuations and the result is shown in figure 3(f). The cross-correlation function between two is found strongly anti-correlated.

The propagation velocity and wave number-frequency spectrum, $S(k,\omega)$ are determined for δn_e and δB_z fluctuations and are shown in figure 4. We have used data obtained from probes separated in the vertical direction with probe spacing between two consecutive probes as 1.5 cm for the density fluctuations and 2.2 cm for the magnetic fluctuations. The spectrum peaks at $\omega \approx 10\,krad/s$ and $k_\perp \approx 0.12\,cm^{-1}$ for the δn_e and at $\omega \approx 40\,krad/s$ and $k_\perp \approx 0.15\,cm^{-1}$ for the δB_z fluctuations. The spectrum also exhibits a spectral width in frequency, $\Delta\omega/\omega \approx 2.5$ and wave number, $\Delta k/k \approx 2$ for the density fluctuations. The magnetic field fluctuation exhibits spectral width as, $\Delta\omega/\omega \approx 2$ and $\Delta k/k \approx 3$ respectively. The plasma fluctuation exhibits long wavelength ~ 50 cm. The phase shift observed corresponds to the velocity, $V_{2,1} \approx 2.8\times10^5\,cm/s$ in the electron diamagnetic drift direction with same order of magnitude as for the electron diamagnetic drift velocity ($V_{de} \approx 5\times10^5\,cm/s$).

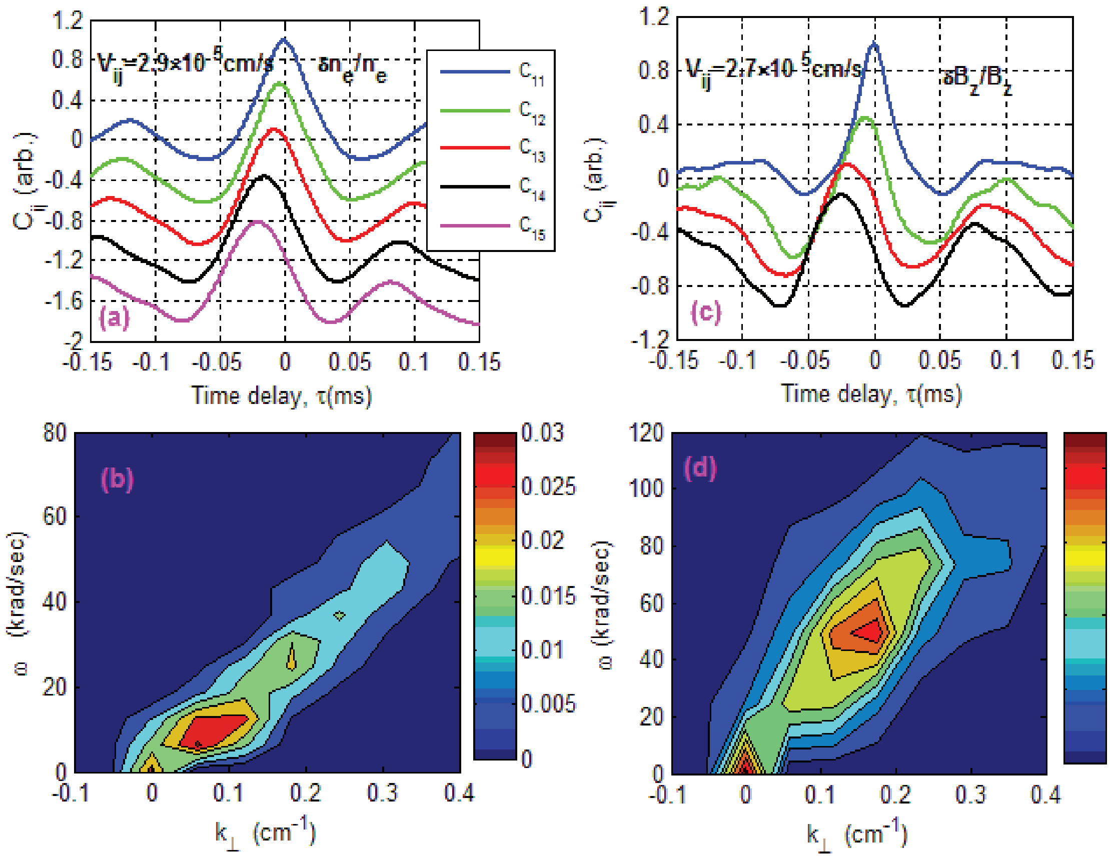

Figure 4: Cross-correlation function is shown for fluctuations in both density (a) and magnetic field (c). The contour plot of the joint wave number- frequency spectrum, S(k,w) for (b) density and (d) magnetic field fluctuations are shown.

IV. Discussion

We have experimentally demonstrated that in a plasma with Fn_eGT_e, the fluctuations in δT_e, δn_e and δB_z exhibits strong signatures of electron temperature gradient driven turbulence. We have also verified experimentally that the condition of $k_z / k_\perp << 1$ is satisfied. The estimated axial phase velocity for the density fluctuation is $V_{ph} \sim 6\times10^6 cm/s$.

We also estimate saturated levels for the observed turbulence by using the simple mixing length which comes only through nonlinear effects. To estimate the fluctuation levels at saturation, we note that for $k_\parallel / k_\perp << 1$, the perpendicular electron current $J_\perp = -en_e(v_{E\times B} + v_{*e})$ yields $\delta B_z / B = \tilde{B} \approx (\beta_e/2)(\tilde{\phi} - \tilde{n}_e - \tilde{T}_e)$ [7]. Hence the fluctuation amplitudes of $\tilde{n}$, $\tilde{B}$ and $\tilde{T}$ can be expressed in term of $\tilde{\phi}$ (using linear relations) as following.

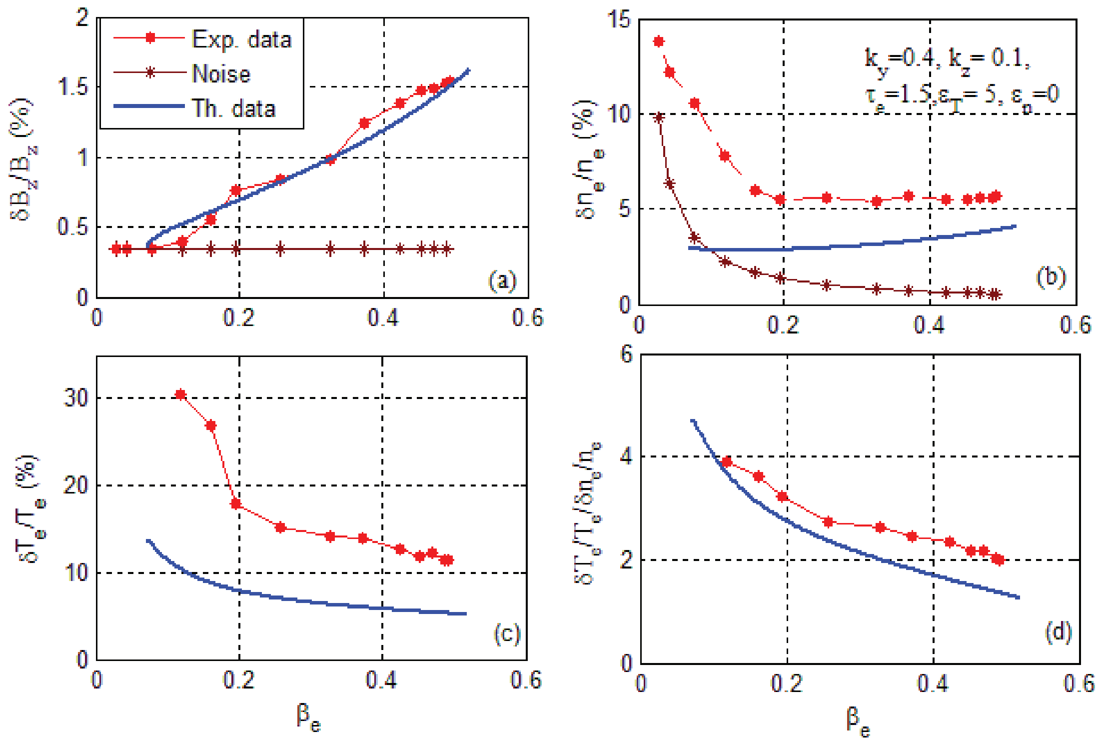

Figure 5: The profiles represent the comparison between theoretically estimated (continuous line) and experimental observed (filled circle) fluctuations with plasma beta. The beta scaling is compared for normalized fluctuations of (a) magnetic field (b) density (c) electron temperature and (d) ratio of electron temperature to density fluctuations.

$\langle\tilde{n}\rangle = -|\tau_e^*|\langle\tilde{\phi}\rangle$, $\langle\tilde{B}\rangle = \hat{\beta}\left|[(1+5\tau_e^*/3) - (\varepsilon_T - 2\varepsilon_n/3)(\hat{k}_y/\hat{\omega})]\right|\langle\tilde{\phi}\rangle$ and

$\langle\tilde{T}\rangle = \left|[(\varepsilon_T - 2\varepsilon_n/3)(\hat{k}_y/\hat{\omega}) - 2\tau_e^*/3]\right|\langle\tilde{\phi}\rangle$

In order to calculate fluctuation level of above parameters, we approximate saturated values of $\tilde{\phi}$ using the mixing length estimates $\langle\tilde{\phi}\rangle \approx 1/k_x L_T = \varepsilon_T \rho_e / \hat{k}_\perp R$ [4]. Figure 5 shows the comparison of experimentally observed and theoretically estimated $\delta B_Z / B_Z$, $\delta n_e / n_e$, $\delta T_e / T_e$ and ratio of normalized temperature to density fluctuations as function of plasma beta ($\beta_e = 2\mu_0 n_e T_e / B_z^2$). In the experiment, the ambient magnetic field remains constant and β_e is varied by only changing the plasma density via changing filament current. The results show that magnetic fluctuation increases with β_e whereas density fluctuation, temperature fluctuation decreases with β_e [Fig. 5(a-c)]. In the figure 5(d), the estimated ratio of $\delta T_e / T_e$ and $\delta n_e / n_e$ amplitudes decreases with β_e and found very close to the experimental observations. Moreover, the theoretical estimated value of phase angles between $\hat{n}-\hat{\phi}_f$, $\hat{n}-\hat{B}_z$ and $\hat{T}_e-\hat{\phi}_f$ for the observed frequency of the mode are 159^0, 108^0 and 134^0 whereas experimentally obtained phase angles are 152^0, 132^0 and 127^0 respectively. These theoretical findings are also in good agreement with experimental results. It is also seen that experimentally obtained normalized gradient, $\eta_{e,\exp}\sim 6$ is found to be greater than the theoretical critical gradient for this plasma, $\eta_{e,\,th}\sim 1.5$ which is threshold value for the excitation of ETG turbulence.

V. Conclusions

In summary, we have successfully produced plasma in LVPD devoid of free energy sources other than required for driving ETG mode which includes absence of energetic electrons and realized a variation in electron temperature gradient scale length from 50 to 600 cm by using different configuration of EEF. First unambiguous signature of ETG turbulence is reported in the core region of target plasma in the presence of radial gradient in electron temperature. Important signatures and the key characteristics of ETG mode have been measured to define the turbulence. The correlation coefficient between plasma density and floating potential is found anti-correlated. The comparison of experimental observation with theoretical results based on general mixing length arguments are found to be in reasonable agreement in terms of fluctuation magnitude, frequency, correlations, wavenumber, phase angle and beta scaling. The ETG instability is observed for the first time in a new operating paradigm of finite beta plasma in a laboratory device. These laboratory observations have significant implications for understanding electron transport in tokamak fusion plasmas.

LVPD Team: P. K. Srivastava, A. K. Sanyasi, Amit Patel and R. Sugandhi.

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A:

B:

H:

I:

J:

Koushika E.M.(PP-046)(PP-047)
Krunal ingle NF- 352
Kulkarni S.V. (BP-O-015)
Kulkarni SV NF-335,292,056,191
Kumar A.V. Ravi (BP-088)
Kumar Ajay PD- I-02
Kumar Dharmendra (IP-339)
Kumar Dinesh (SP-115)
Kumar E Rajendra NF-045
Kumar Mahesh (IP-339)(IP-394)
Kumar Niraj (IM-393)
Kumar Nitin NF-302,303,361
Kumar Pintu NF- 331,364
Kumar Punit (BP-355)
Kumar R (BP-040)
Kumar Rajesh PP-I -02
Kumar Rajnesh (IP-O-36)
Kumar Ramesh B (CM-342)
Kumar Sanjay (SA-140)
Kumar Saurabh PP-I -02 ,NF 011
Kumar Subhash (SA-192)
Kumar Sunil nf-197
Kumar Sunil (IP-I-03)
Kumar U(BP-298)
Kumar Umesh (BP-044)
Kumthekar Bhagawat K (SA-291)
Kundu M (BP-28)
Kurian P.J. (BP-170)
Kushwaha Upendra (SP-115)

L:
Lachhvani Lavkesh (PD-092)(PD-159)
Lamba R.P. (PU-396)
Leshma P. (LP-087)
Laengner R NF- NF-014
Lahiri S (BP-112)
Lakhina G.S. (SA-368)
Lamba R.P.(IP-399)
Lavkesh Lachhvani (EP-093)
Lui. S. (IP-O-086)
LVPD Team (Buti-05)
Lyssoivan V NF- 014

M:
Mukherjee P.S. (OA-I-01)
Munshi Prabhat (PD-051)
Manchanda R. (PD-060) (PD-061) (PD-363) (PD-395)
Mali Aniruddh (PD-061) (PD-363)
Mahavar Kanchan (PD-090) (PD-098) (PD-240)(PD-392)
Mishra Priyanka (PD-096)
Makwana R. (PD-158)
Mattoo S.K. (PD-184) (PD-186)(PD-188) (PD-189)
Mansuri Imran (PD-193)
Maity Sudeshna (PD-210)
Mantry Sisir (PD-222)
Maquet Ph. (PD-258)
Mittal K.C. (PU-344) (PU-265)
Menon R. (PU-344)
Meena B.L. (PU-396)
Mishra Ajay Kumar (PD-392)
Mishra V. (LP-087)
Mahajan R. (LP-120)
Mishra Ekansh (PU-133)
Meena Manraj (PU-133)
Mishra rohit Kumar (LP-148)
Moorti A. (LP-169)
Macchi Andrea (LP-172)
Mandal T. (LP-195)
Mahajan Ranju (LP-213)
M S Nadkarni (IP-105)
M Venkat Nagaraju NF-366
M. Bose (EP-381)
Machchhar Harsha NF-304
M.K. Deka (EP-111)
M.K. Mishra (CM-108)
M.Khusroo (EP-234)

M.S. Janaki (EP-253)
M.S.Janaki (EP-163)
M.Sassi (IP-036)
Madhurjya P. Bora (EP-234)
Madhuskar S.V. (BP-64)
Mahapatra Saskuntala NF-179
Mahesh V NF-325,328,330358
Mahesuriya G NF- 239
Mahohar M NF- 365
Maily Chandan (BP-257)(BP-259)
Majumdar Abhijit (PP-277)
Makwana Rajanikant NF-065
Mandal Anuk K. (BP-242)
Mandal Debraj (BP-059)
Mandal T LP-I-02
Mandal T PD-I-03
Mandaliya Hitesh NF-065
Manoah Stephen NF-320
Manoah Stephen M NF-314
Mantry S (IP-280)(IP-281)
Manu Bajpai (EP-093)
Mathe V.L. (PP-247)
Mathews Sanjith (BP-170)
Matto S.K. (Buti - 05) (BP-181)(BP-182)(BP-183)

Q:

R:

Shah P NF-215
Shah P NF-239
Shanmugavelayutham G (PP-046)(PP-047)
Sharma A N nf-273
Sharma Devendra (Buti-01)(BP-039)(BP-058)(BP-059)(BP-336)
Sharma Dinesh Kumar nf-023
Sharma Giriraj (BP-297)
Sharma Jayshree (PP-067)
Sharma Jnanjyoti (BP-122)
Sharma N. (BP-081)
Sharma P.K. (BP-157)(SA-004)
Sharma P.K. (BP-O-015)
Sharma PK NF-293
Sharma Prerana (SA-174)
S. Adhikari (CM-016)
Shantakumar Kh. (PD-260)
Shah Nasir (PU-307)
Shyam Anurag (PU-307)
Sinha Abhishek (PD-294)
Sharma A.K. (PD-312)
Singh Gursharan (PU-317)
Sharma Archana (PU-344)
Senthil K. (PU-344)
Soni J. (PD-337)
Srivastava R. (PD-367)
Stafford L. (PD-367)
Saroch Akansha (LP-024)
Shaikh Shamsuddin (PD-392)
Shaikh Zubin (PD-392)
Singh Mamta (LP-032)
(LP-035)
Singh Nandini (PD-395)
Sen Sonu (LP-038)
Shyam Anurag (PU-005)
Sakthird N. (LP-087)
Sharma S.M. (LP-087)
Sijoy C.D. (LP-087)
Singh Gursharn (PU-077)
Sijoy C.D. (PU-077)
Singh Monika (LP-113)
Sharma R.P. (LP-113)
Saxena A.K. (PU-110)
Sharma H.G. (PU-110)
Sharma Surendra Kumar (PU-124)
Shukla R. (PU-124)
Shyam A. (PU-124)
Sah P.(PU-126)
Shyam A. (PU-126)
(PU-130)
Sajal Vivek (LP-139)
(LP-143)
(LP-142)
Singh Ram Kishore (LP-201)
Sharma R.P. (LP-201)
Singh Gill Tarsem (LP-213)
Sagar Karuna (PU-133)
Shyam A. (PU-133)
Shukla R. (PU-153)
Sharma S.K. (PU-153)
Shyam Anurag (PU-153)
Samantaray S. (PU-230)
Sahoo G. (PU-230)
Sasini N. (PU-230)
Sanyasi A. (PU-230)
Singh Rathore Nisha (LP-147)
Singh Nindrayog Amritpal (LP-172)
Singh Bimlendra Pratap (LP-204)
Sengupta Sudip (LP-220)
(lp-221)
Santhosh C. (LP-224)
(LP-225)
Singh R.K . (LP-233)
Sharma D. (LP-233)
Shukla Chandresekhar (LP-290)
Sharma S.M. (LP-334)
Satyanarayan N. (PU-265)
Swamy Sunil (PU-265)
Sahoo Samir (PU-265)
Sethi Bijaylaxmi (PU-265)
Sukla Rohit (PU-265)
Shivani Vij (LP-362)Shyam Anurag (PU-300) Shaik Shamsuddin (PD-240)Sanchez P. (PD-258)

T:
Tripathi Vijai Shankar (0A-I-03)
Team Aditya (PD-030)
Tarey R.D. (PD-040)
Tanna R.L.(PD-060)
Team Aditya (PD-060)
(PD-096)
Team SST -1(PD-098)
(PD-102)
Thomas Tinto (PD-129)
Tiwari S. (PD-158)
Tyata R.V. (PD-167)
Team Aditya (PD-210)
Tyata R.V.(PD-218)
Thirumugam S. (PD-236)
Team Aditya (PD-240)
Team SST-1 (PD-240)
Tyagi H. (PD-337)
Talukdar N. (PU-131)
Tamboli M. (LP-224)
Tamboli M.M. (LP-225)
Tayyab M. (LP-195)
T.C. Kaushik (IP-091)
Tank J NF-239
Tanna R NF-171
Tanna RL NF-331,364,083
Tanna VL nf-332,128,203,215,239
Tarey R.D. (BP-040)
Tarey RD NF-PD-040
Tayyab M- PD-I-03.NF-LP-I-02
Team Aditya and SST-1 – PD-I-02
Textor M Team NF-014
Thakar D NF-311
Thaker Urmila M NF-011
THAKKAR Dipal NF-161
Thakur A (BP-O-015)
Thakur AL NF- 293