DEVELOPMENT OF A SEGMENTED PLASMA TORCH ASSISTED TAILORED HEAT SOURCE FOR PERFORMANCE EVALUATION OF PLASMA FACING COMPONENTS IN FUSION DEVICES

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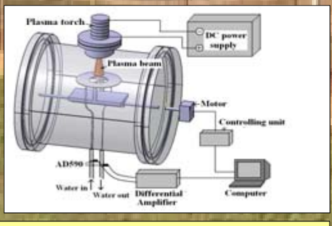
Introduction

- For the modern Tokamak Divertors, power and particle flux densities of 1-10 Mw^2/m^2 and 10^{24} $m^{-2}s^{-1}$respectively are foreseen, at $n_e \approx 10^{20-21}$ m^{-3} and T_e in the range of 1-5 *eV*. For all components to be exposed in such an environment, it is customary to ascertain that they can withstand such extreme conditions.
- In this first phase, we are developing a segmented plasma torch assisted heat source which can produce this level of heat flux. Once produced, materials and components will be tested under these conditions.
- This system was developed also with a long-term aim of establishing a complete Tokamak Divertor simulator, not only in terms of heat flux, but also for reproduction of the typical hydrogen ion density, ion flux and electron temperature.
- Electron beam sources are more suitable for producing this level of heat flux, but use of a segmented type plasma torch operating typically at high pressure offered with the additional advantage of producing very high density hydrogen plasma with intense ion flux.

Photograph of The Experimental Setup and the Laminar Plasma Jet Produced



Measurement of average plasma heat flux

- Simple calorimetric techniques were used to estimate heat deposited on a substrate kept in front of the plasma jet in the chamber, by measuring the rise in water temperature flowing through the component, either with AD590 or RTD sensors.

Results

Table 1: Average heat flux measured with a 50 mm diameter substrate

Plasma Argon (lpm)	Nitrogen (lpm)	Current (Ampere)	Input Power (kW)	Averaged Heat Flux (MW/m^2)
25	0	250	15.2	2.5
25	0	300	19.5	3.1
25	10	300	27.6	3.9

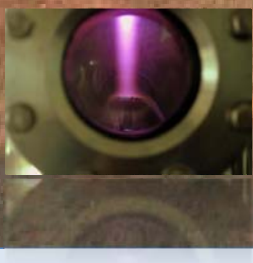
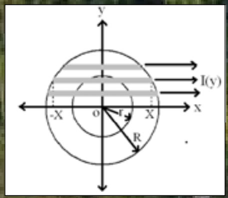


Table 2: Average heat flux measured with a 30 mm diameter substrate

Argon (lpm)	Current (ampere)	Input Power (kW)	Averaged Heat Flux (MW/m^2)
15	250	15.3	3.8
	300	19.7	4.6
20	200	12.0	3.3
	250	16.5	4.5
25	200	12.56	3.5
	250	17.4	4.4

Measurement of the Radial Profile of the Heat Flux on the Substrate by Abel Inversion:



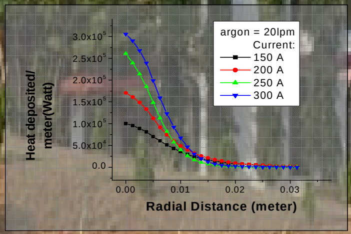
The measured heat density 'I(y)' is related to the local heat density 'F(r)' as, $I(y) = \int F(r)\, dx$

By inverse formula, we get,

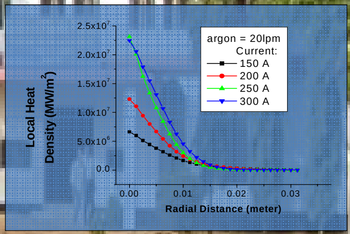
$$F(r) = -\frac{1}{\pi}\int_r^R \frac{I'(y)}{\sqrt{(y^2 - r^2)}}dy$$

This is Abel integral equation.

Results for Variable Plasma Current (Plasma Argon 20 lpm)

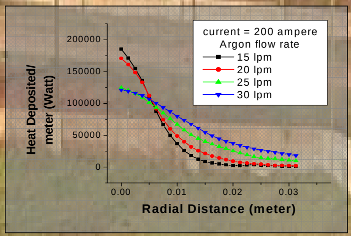


As Measured Heat density

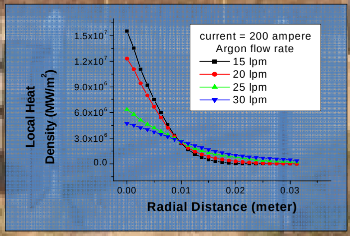


Abel Inverted Local Heat density

Results for Variable Plasma Argon Flow Rate (Plasma Current 200 lpm)



As Measured Heat density



Abel Inverted Local Heat density

Conclusions

- The plasma jet inside the vacuum chamber forms an laminar beam even without any magnetic field and extends up to the target.
- As expected, heat deposited increases with increasing plasma current (power).
- Heat deposited with plasma argon flow rate shows an optimum value around 20 lpm, consistent with our earlier torch efficiency measurement results.
- Abel Inversion reveals that a more collimated, laminar beam is produced as plasma gas flow rate decreases.
- Further substantial heat flux enhancement is possible only after upgrading the input power capacity. We are in the process of procuring a 80 kW power supply for the same.
- Initial results clearly indicates that this system can be easily upgraded to a complete Tokamak Divertor simulator, with the addition of an axial magnetic field of moderate strength and enhanced input power.

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