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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

ON THE ROLE OF FAST NEUTRALS IN THE PROCESS OF BLOB FORMATION IN LOW TEMPERATURE PLASMAS

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ABSTRACT
The variation of electron temperature of argon plasma with base pressure is reported using emission spectroscopy signature. It is observed that the electron temperature of plasma is < 1 eV. It is reported that at higher base pressure ~ 1 mb or above a number of prominent argon lines are observed unlike that at lower base pressure. This indicates formation of more fast neutrals inside bulk plasma at high base pressure value. Fast imaging results (~9100 fps) shows blob formation from main plasma column at base pressure 1 mb and above. For these experimental findings it can be proposed that the asymmetry force due to fast neutrals inside bulk plasma and slow neutrals outside main plasma column is responsible for blob formation at higher base pressure.

Key words: Plasma gun, Convective transport, Scrape-off-layer, Fast neutral

INTRODUCTION
Gas injected washer plasma guns are very good source to produce moving plasma and have wide range of applications in plasma science and nuclear technology [1-3]. Measurement of plasma parameters in short lived pulsed plasma produced from gas injected washer plasma gun is very challenging [3]. Again, convective transport of plasma at edge and Scrape-off-layer (SOL) of plasma is an important issue in all the fusion machines needs to be addressed for future fusion machines [4-8]. Again it is observed in all the fusion devices that the edge and SOL region where plasma detachment region is observed is having higher base/background/ambient pressure and the electron temperature of plasma is very low [9-12] ~ 1 eV. The effect of base pressure upon plasma containment and transport is an interesting problem need to be addressed.

EXPERIMENTAL SET UP
The experimental set up for plasma experiments at Ravenshaw University i.e. Compact Plasma System (CPS) [3] consists of Plasma Chamber, Pulse forming network (PFN), Plasma Gun, [13] Gas fed system, Diagnostic tools and data acquisition system and data analysis software [14]. The plasma chamber is having major radius 40 cm and minor radius 10 cm. The pulse forming network (PFN) is capable of producing square wave pulse ~ 140 μs. By changing the stages of

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PFN the pulse width can be changed. The gas fed system is designed to maintain desired base/background/ ambient pressure in the plasma chamber. Langmuir probe, emission spectroscopy technique and fast imaging were carried out for plasma diagnostics. The schematic diagram of the set up is given in fig 1.

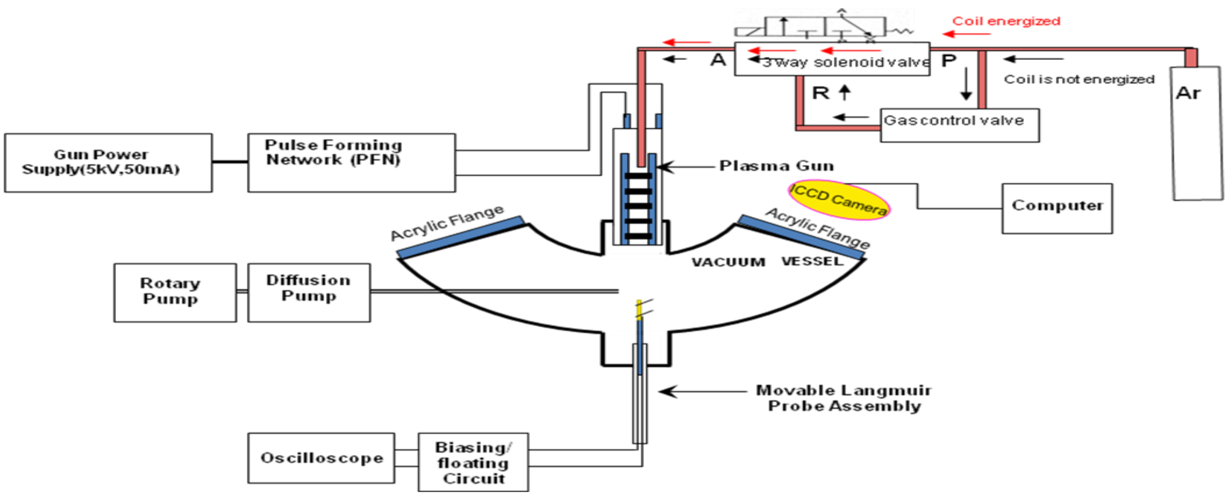

Fig 1: Experimental set up

RESULTS

The base/background/ambient pressure is increased inside the chamber by injecting argon gas into it through the gas fed network. Different diagnostic tools are used to measure plasma parameters. Electron temperature is measured from spectroscopic signature.

Spectroscopic measurements

A compact spectrometer is used to measure the electron temperature of plasma. Different excited/ionized states of plasma (produced from gun) were detected. It has high resolution and fast integration time with sensitivity of sixty photons per count at 600 nm. This spectrometer was controlled by spectra suit software that operates on windows operating systems. The spectroscopic signature of plasma at low base pressure (~0.1 mb) and comparatively high base pressure (0.3 mb) is given in fig 2.1 and 2.2 respectively.

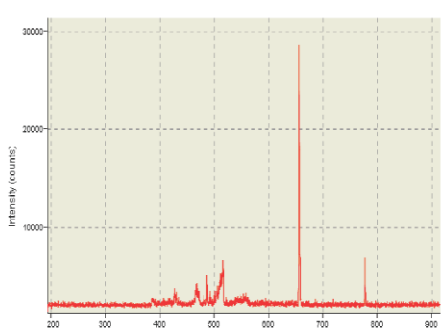

Fig 2. 1: Base pressure 0.1 mb (Argon plasma)

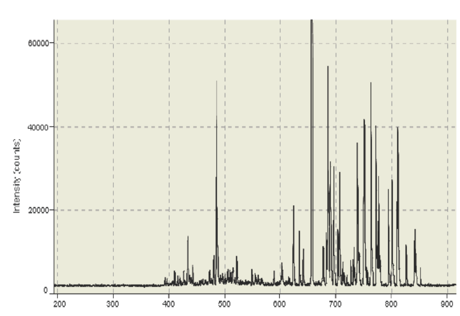

Fig 2. 2: Base pressure 3 mb (Argon plasma)

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It is observed that at lower base pressure no prominent line of argon is there in the signature where as at higher base pressure a number of argon lines are there. Assuming the plasma is in partially local thermodynamic equilibrium the electron temperature of plasma can be estimated using ratio of intensity of spectral lines. Here from the line spectra H_α and H_β due to impurity atoms injected into the plasma gun electron temperature is calculated.

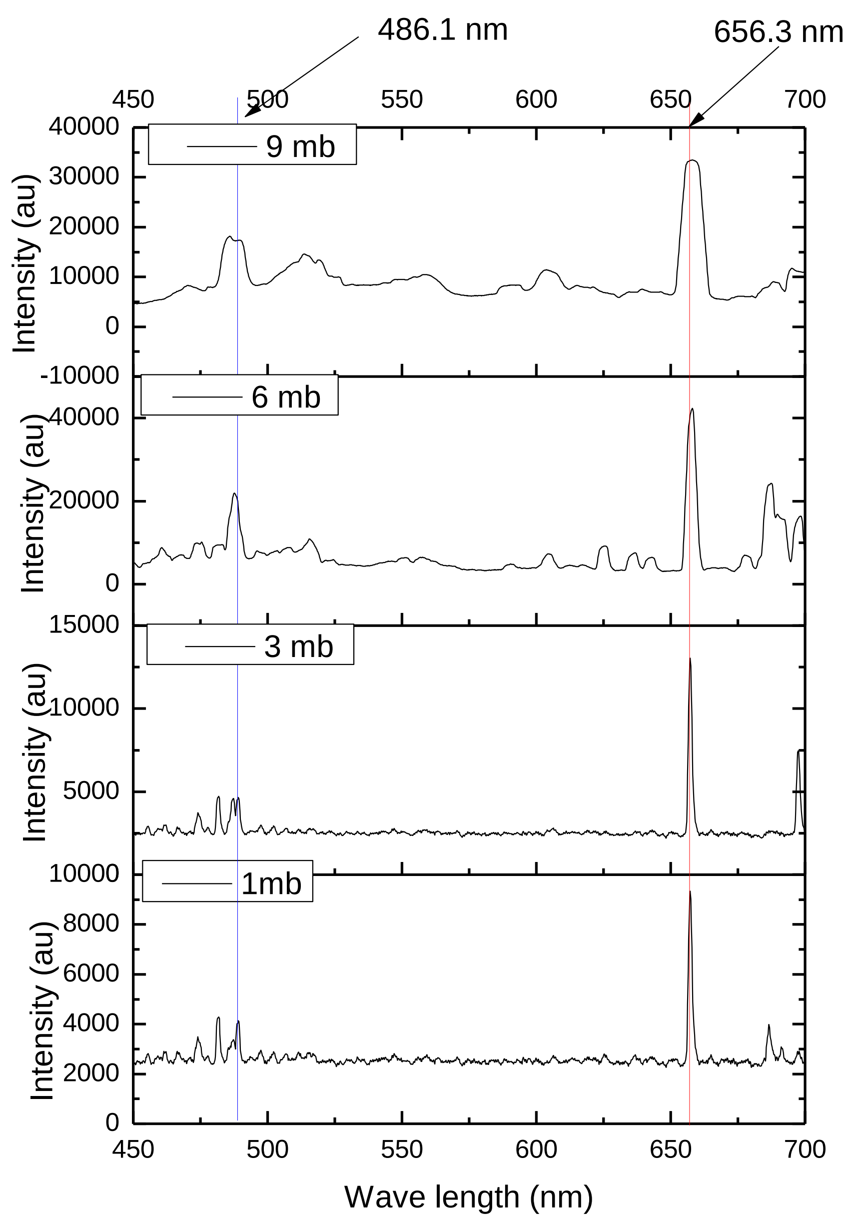

Fig 3: H_α and H_β lines at different base pressures

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The value of electron temperature estimated using ratio of intensity of spectral line method [15] for different base pressure value is expressed in fig 4.

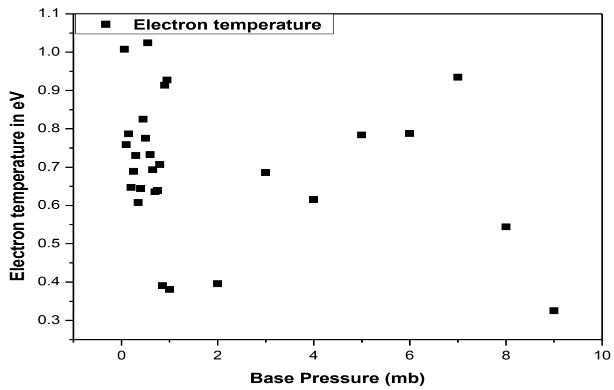

Fig 4: Electron temperature of plasma from H lines

Interestingly it is also observed that at low base pressure (~0.1 mb) no line spectra of argon is noticed where as at high base pressure a number of argon lines are present in spectroscopic signature as shown in fig 5.

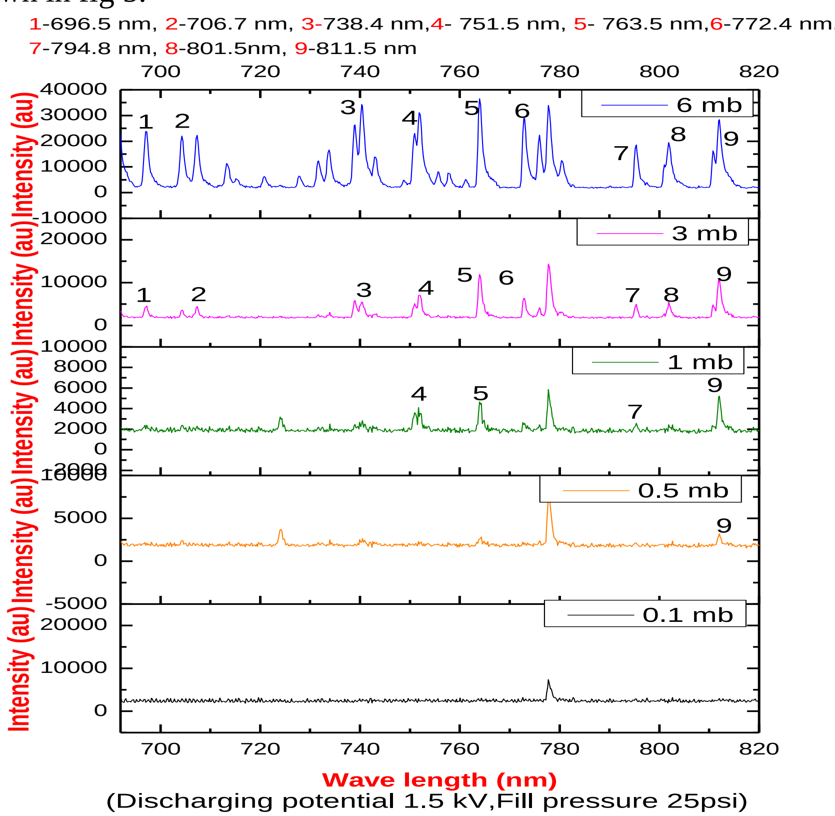

Fig 5: Signature of a number of argon lines at higher base pressure

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Argon excited states represent neutral argon atoms having more energy than that of normal neutral argon atom in ground state configuration. So, it may be concluded from spectroscopic signature that at higher base pressure a number of fast neutrals are present in bulk plasma.

Probe measurements

At the edge of plasma i.e. at a distance 8 cm or more from plasma gun coherent structures of plasma are observed. The coherent structure is not spherical rather an elliptical one as perceived by the signal received by the probe. The events are intermittent. But, usually such signal structures are received at the edge of plasma at higher base pressure. The probability distribution function (PDF) of density for this structure is a positive skewed non-Gaussian function as shown in fig 6. From fig 7, the velocity of blob measured using time of flight technique is ~ 213 m/s.

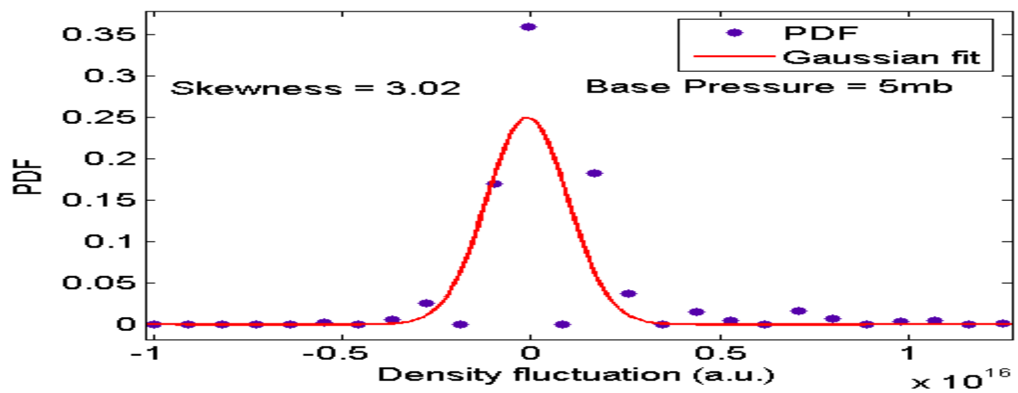

Fig 6: Signature of blobs at edge of plasma

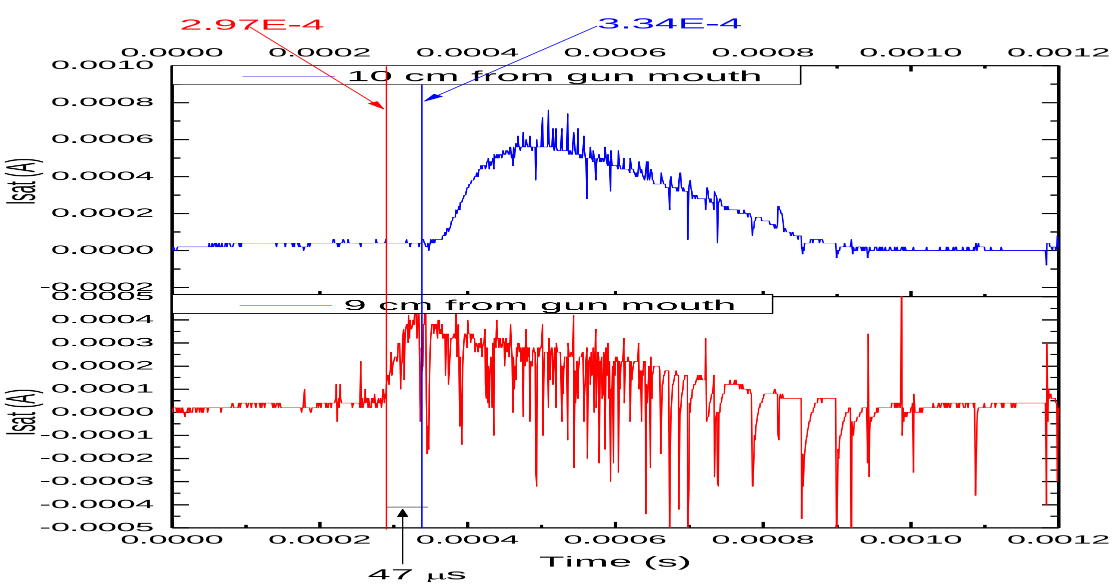

Fig 7: Ion saturation signal received by two Langmuir probes at a distance 9 cm (red) and 10 cm (blue) from the plasma gun

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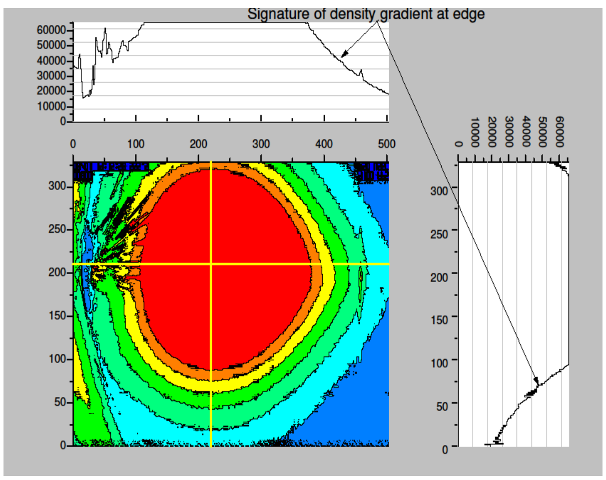
High Speed Imaging results

At 1 mb or above the confinement is appreciable and convective transport from main plasma in form of coherent structures, blobs is clearly observed in imaging experiments. Light ray coming out from the plasma may be due to bremsstrahlung radiation, line radiation and/or recombination radiation. In the present case each pixel in CCD camera received the light ray and converts it to electrical signal. The information about light of how much intensity was coming from which point in the plasma or surrounding was stored in the data acquisition system. The signal received by the camera was in form of movie. Then using camera software the frames are being extracted. Origin software was used to extract data from the frames. The exposure time of the camera is 50 μs and frame rate is 9100 frames per second (fps). The discharging potential of gun is 1.5 kV.



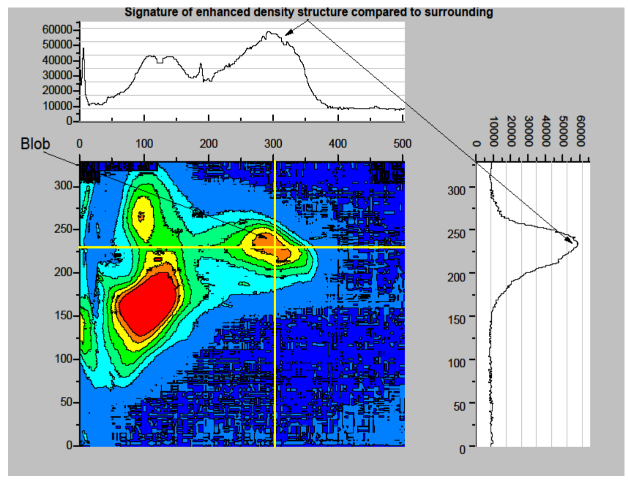


Fig 8: Image of plasma at base pressure 0.1 mb Fig 9: Signature of plasma blob at high base pressure 4mb (600μs)

Discussion and Summary

It was earlier predicted by S. I. Krasheninnikov *et al.* that asymmetry of neutral components going to and fro from the wall results in a net force [16]. Asymmetry in the force $\mathbf{F}_{Ni}$ imposed by these neutrals on plasma may be written as

$$\mathbf{F}_{Ni} = \mu_{Ni} n\{(N\mathbf{V})_{fast}.\ K_{fast} + \{(N\mathbf{V})_{slow}.\ K_{slow}\} \quad (1)$$

Where n is plasma density; μ_{Ni} reduced ion neutral mass, $(N\mathbf{V})_{fast}$, $(N\mathbf{V})_{slow}$ are the flux of fast and slow neutrals; K_{fast}, K_{slow} are the neutral-ion collision rate constants of fast or slow neutrals.

In special condition, when ionization of neutrals in shadow region is small and the wall is usually completely saturated with neutrals, There is zero net neutral flux, i.e.

$(N\mathbf{V})_{fast} = -(N\mathbf{V})_{slow}$ and equation may be written as

$$\mathbf{F}_{Ni} = \mu_{Ni} n\{(N\mathbf{V})_{fast}.\ (K_{fast} - K_{slow})\} \quad (2)$$

From the force term, an acceleration and hence, a velocity term arise which makes the bunch of fast neutrals to leave the bulk plasma and move towards the wall. When fast neutral lumps are thrown away from bulk plasma, ion-neutral friction creates instability in plasma and only if ions are carried out by neutral lumps from plasma surface, the perturbation 'wash out'. This is the reverse process predicted by earlier investigators to ensure stability in the system [16]. When ions in the vicinity of fast neutral lump, leave the bulk plasma, electrons in their very neighborhood, follow them to ensure quasi-neutrality both in bulk plasma and plasma blob. The pictorial representation was earlier proposed [14]. So, fast neutrals in bulk plasma are responsible for blob formation at the edge.

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