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On the Effect of Magnetic Field upon Plasma Parameters

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Abstract: ***Plasma confinement is the most important issue in nuclear fusion research. Among all the confinement techniques magnetic confinement is most popular across the globe. We have successfully accomplished a plasma gun which is capable of producing moving plasma. This plasma gun is a compact and effective device. The density of plasma is of the order of 10^{16} m^{-3} for discharging potential 1kV and ambient pressure 0.2 mb. It is observed that in the presence of magnetic field 250 Gauss the plasma parameters are modified. The pulse width of pulse forming network (PFN) associated with gun is 140 µs.***

Keywords: plasma confinement, plasma gun, pulse forming network

1. Introduction

In a present era of rapid development there is an urgent demand for clean energy[1, 4]. Harnessing nuclear fusion technology will supply enormous energy to mankind, which is clean and environmental friendly. [5, 6]To achieve fusion, confinement/ containment of high density plasma material is very much essential. [7]Among various confinement schemes magnetic confinement of plasma is very popular across the globe. [8] Research on the effect of magnetic field upon plasma parameters has ample scope even today.[8]

2. Experimental

A compact plasma system (CPS) is set up to perform table top experiments on plasma physics and technology. [9] The plasma gun is designed, fabricated and tested and mounted on the CPS device as a source of moving plasma. The gas feed network injects desired gaseous substance into gun body to make it operational. The schematic diagram of plasma gun and allied circuit is shown in figure 1. An electromagnetic valve is used to inject gas into the gun from backside (cathode side). The gun is energized by a pulse forming network, which produces square wave pulse. [10] An electromagnet is set up to produce pulsed magnetic field in the CPS device. [11]It is modified to create a flat top magnetic field inside the plasma chamber. The LC network is replaced by a PFN network to achieve this. The potential field profiles in both type of EM are shown in figure 2 and 3 respectively.

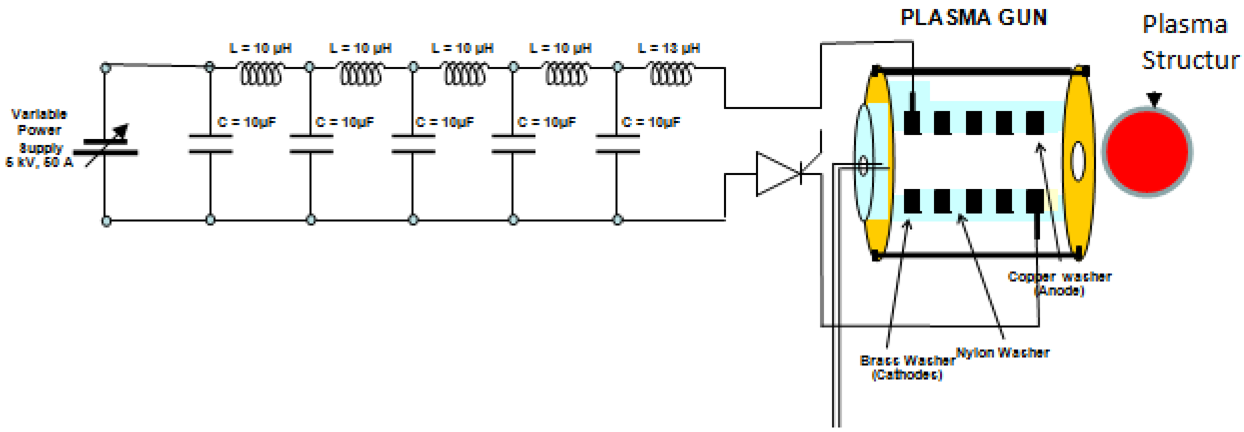

Figure 1: Schematic diagram of plasma gun and allied circuit

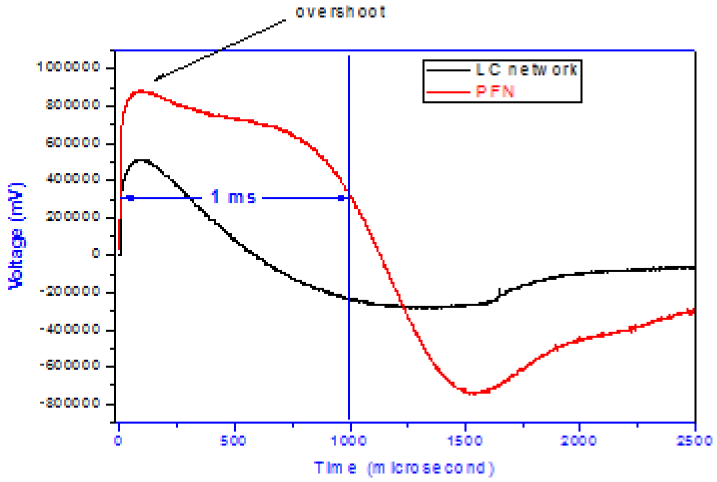

Figure 2: Potential profile showing flat top region

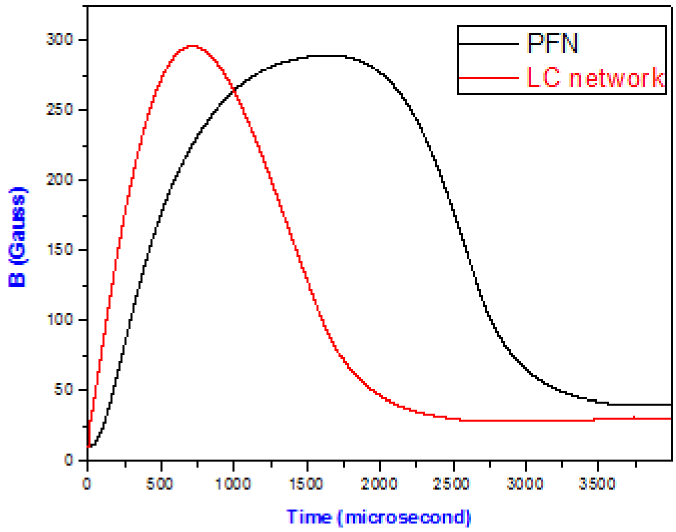

Figure 3: Field profile showing flat top region.

The pulse width of EM pulse is ~ 2 ms where as the plasma produced from plasma gun is contained for < 1 ms. Both circuits are synchronized using a delay circuit to study the effect of magnetic field upon plasma. The capacitance of capacitors and inductance of inductors used in the PFN circuit in each stage of EM is 200 µF and 200 µH respectively.

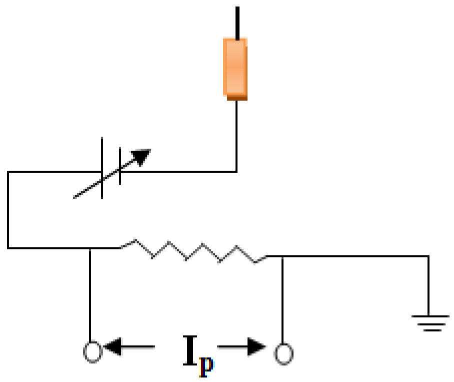

Figure 4: Langmuir probe biasing scheme.

Langmuir probe is a very good diagnostic tool to measure plasma parameters like density, temperature and floating potential, both in the absent and in the presence of magnetic field. [12-20]Plasma parameters are measured by using Langmuir probes and emission spectroscopy technique. The biasing scheme in Langmuir probe is shown in figure 4. The probe is aligned perpendicular to the field lines inside the chamber.

3. Results and Discussion

The Electron density is measured using Langmuir probe. If I_{sat} is the electron current flowing through the circuit when probe is maintained at plasma potential and lower than floating potential then,

$$I = I_{sat}\exp(-eV_p/kT) \quad (1)$$

Where T, V_p, k are the electron temperature, probe potential and Boltzmann Constant respectively.

$$V_p = V_a - V_s$$

$$I = I_{sat}\exp(-e(V_a - V_s)/kT)$$

So we have,

$$\log I = \log I_{sat} - (eV_a)/kT) + (eV_s/kT)$$

Electron temperature is estimated from the slope of I ~ V

Curve.

I_{sat} in terms of electron density is given by,
$I_{sat} = A_p\, e\, n_e\, u = A_p e\, n_e\, (kT/2m)^{1/2}$

Where A_p, e, n_e , u and m are the area of the probe, charge associated with an electron density, mean thermal velocity and mass of the electron respectively.

The electron density is

$$n_e = (I_{sat}/A_p)(2\pi m_e/e^3)^{1/2}\,(e/kT_e)^{1/2} \qquad (2)$$

Where, $A_p = \pi r^2 + 2\pi rl$ = Area of the probe, r and l are the radius and length of the probe.

The peak electron density of plasma from plasma gun is found to be of the order of $10^{16}m^{-3}$ at discharging potential 1 kV and ambient pressure 0.2 mb. In the presence magnetic field 250 Gauss the peak electron density of plasma from plasma gun is found to be of the order of $10^{16}m^{-3}$ at discharging potential 1 kV and ambient pressure 0.2 mb. The electron density profiles of plasma are shown in figures 5 and 6. The electron density of plasma structure at rear as well as front region is smaller than that at center. Electron density at front edge is ~ $10^{15}m^{-3}$ where as at central region it is ~ $10^{16}m^{-3}$. On the other hand in the presence of magnetic field (250 Gauss), the electron density of plasma is ~ $10^{16}m^{-3}$ through out. Again plasma confinement time is around one and half times more in the presence of magnetic field.

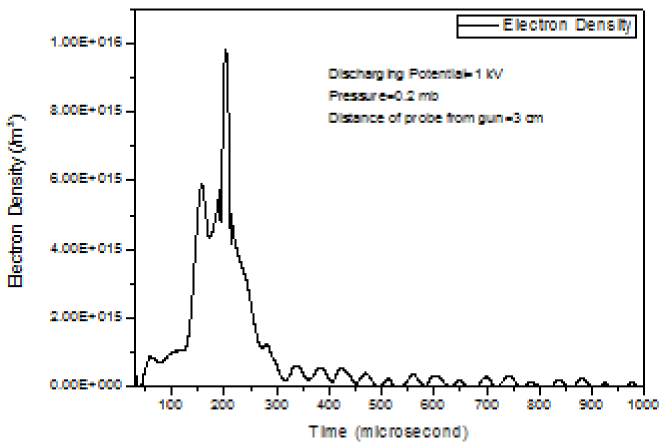

Figure 5: Density profile of plasma from plasma gun

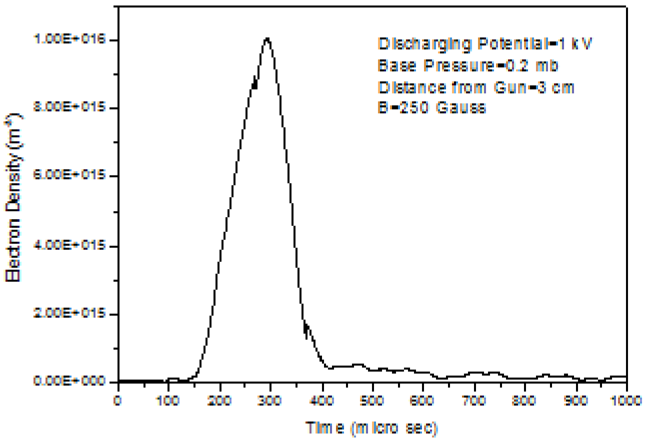

Figure 6: Density profile of plasma from plasma gun in the presence of magnetic field

The floating potential profile of plasma in the absence and in the presence of magnetic field is shown in figures 7 and 8 respectively.

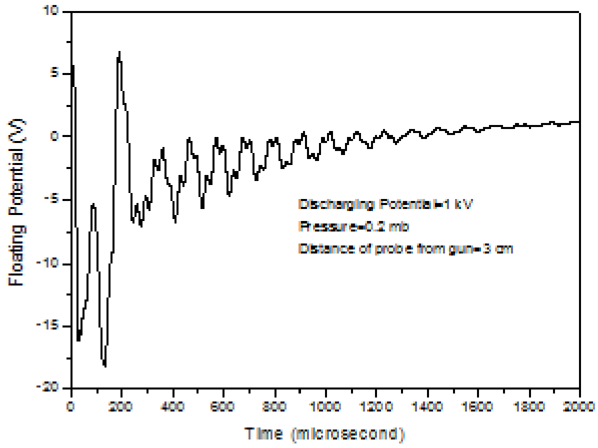

Figure 7: Floating potential profile of plasma from plasma gun

The floating potential of plasma is – 20.4 V in the absence of magnetic field, where as in the presence of magnetic field it becomes - 14 V. The presence of magnetic field makes the species in plasma more orderly, which is evident from figures 7 and 8. The signature of ions in plasma structure gives positive value in floating potential profile. In the absence of magnetic field the peak positive value in floating potential is ~ 7 V, where as in the presence of magnetic field, the peak positive value becomes ~ 14 V. The asymmetry in peak negative value and positive value in floating potential profile, in the absence of magnetic filed is not observed in the presence of magnetic field. The plasma structure is electron dominated in the absence of magnetic field, where as in the presence of magnetic field it is quasi-neutral.

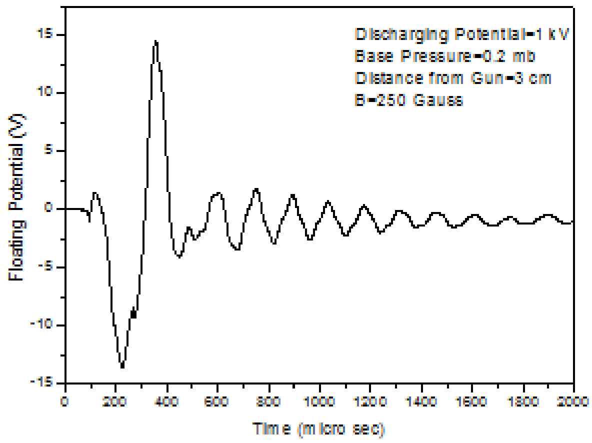

Figure 8: Floating potential profile of plasma from plasma gun in the presence of magnetic field.

4. Conclusion

Effect of magnetic field upon plasma structure fired from a plasma gun is reported here. It is observed that PFN serves as a better pulse generator as it gives a square wave pulse for EM. The asymmetry in peak negative value and positive value in floating potential profile, in the absence of magnetic filed is not observed in the presence of magnetic field. The plasma structure is electron dominated in the absence of magnetic field, where as in the presence of magnetic filed it is quasi-neutral. The peak density of plasma remains for around 25 μs in the absence of magnetic field, where as it remain at the peak value for more than 50 μs. In the presence of magnetic field plasma becomes more ordered.

5. Acknowledgement

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