A STUDY OF SOME PLASMA - PHYSICAL ASPECTS OF RADIAL EXTRACTION TYPE RF ION SOURCE WITH AN INJECTED ELECTRON BEAM

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Abstract

In this study the diffusion losses across the axial magnetic field, inside an RF ion source with an injected electron beam, are investigated without and with electron beam injection, under different experimental conditions of magnetic field, extraction potential, filament power and discharge pressure. Also, the vibrations inside the RF plasma are photographed.

It is noticed that with electron injection there is a certain decrease of the crossed diffusion losses and that the electron beam acts to stabilize the plasma.

1. Introduction

The injection of electrons inisde the source in the region of plasma confinement[1], produces more intense plasma. The density gradient and the presence of plasma oscillations cause diffustion losses across the magnetic field. Among the oscillations that exist in a plasma column with axial magnetic field[2] are: The plasma electron oscillations, plasma ion oscillations, electron cyclotron oscillations, ion cyclotron oscillations, Alfven oscillations which are perpendicular to the magnetic field, pseudo-sonor reflex oscillations and hybrid oscillations. In RF plasma the use of axial magnetic field greater than a certain critical value B_c, causes electromagnetic instabilities of very severe oscillations, leading to an unstable plasma having abnormal behaviour where the classical laws cannot be applied[3]. It has been shown by Akhiezer and Fainberg[4], and by Bohm and Gross[5], that an electron beam passing trhough a plasma causes instability. If eneregy is fed into one of the above oscillations, it heats the plasma and causes a large flux of plasma particles in the form of diffusion losses[2].

In the present paper the diffusion losses across the magnetic field are measured under different experimental conditions. Also the plasma instabilities in the presence of electron injection are investigated.

2. Apparatus

The ion source[1] is featured by using an electron gun consisting of a filament heated electrically by 60 watts AC, and a 150 VDC accelerating anode, with an electromagnet surrounding the filament to confine the injected beam and the RF plasma. The diffusion losses and the plasma instabilities are investigated by using a tungsten electric probe 5 cm long and of 1 mm diameter immersed 2 mm inside the discharge vessel at a distance 3 cm from the anode, (Fig. 1). It is polarized with potential (+) 90 volt to measure the diffusion losses for the electrons and the ions. The instabilities are photographed using an oscilloscope with a camera. More details about the apparatus are given in previous papers[1,6].

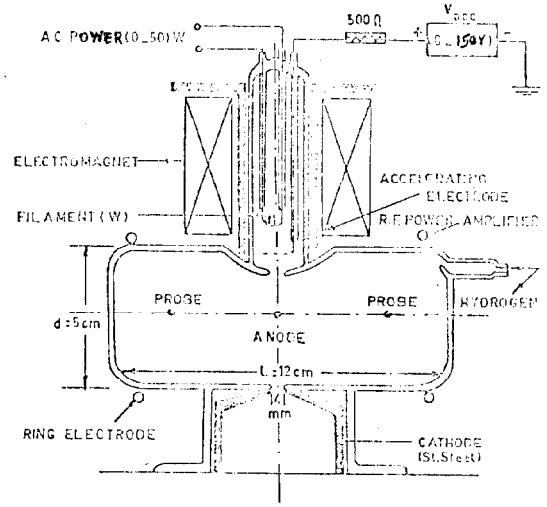

Fig. 1: The source

3. Results and Discussions

This study deals with the influence of the electron beam injection on the lateral diffusion losses and the possible changes in plasma instabilities. Fig. 2 (a,b) shows the influence of magnetic field on both the electron and ion losses before and after electron injection. The increase of diffusion losses with extraction potential is also indicated.

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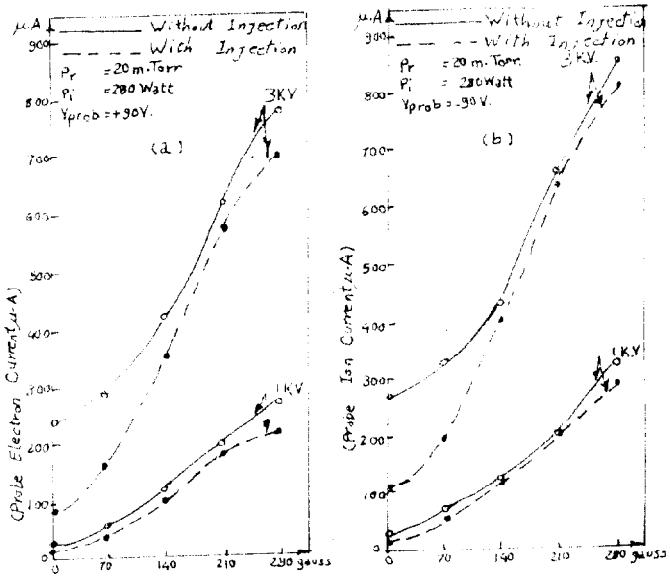

Fig. 2: Effect of magnetic field on the diffusion losses

From these figures it is clear that:

1. The ion losses are greater than electron losses since it can escape from the magnetic field due to its heavy mass under the influence of plasma oscillations.
2. The gradual increase of diffusion losses with the magnetic field confirms the disagreement between the classical laws and the experimental results and this is due to the presence of plasma instabilities.
3. The diffusion losses decrease after electron beam injection, possibly due to space charge neutralization[7] between the injected electrons and the positive ions. In this case the repulsive force between the charged particles decreases leading to smaller losses.
4. The increase of the extraction potential increases the diffusion losses[6], possibly due to the increase in frequency and amplitude of the plasma instabilities with the extraction potential.

By examining many pictures of plasma instabilities taken at different magnetic fields before and after electron injection, it is found that at zero magnetic field the frequency of the electrostatic instability increases after the injection process. Also, at maximum magnetic field (B_{max}) the frequency of the electromagnetic instability increases, while at $B < B_{max}$ the frequency decreases (after injection) from 4 kc/sec to 2 kc/sec at the resonance magnetic field(Fig.3).

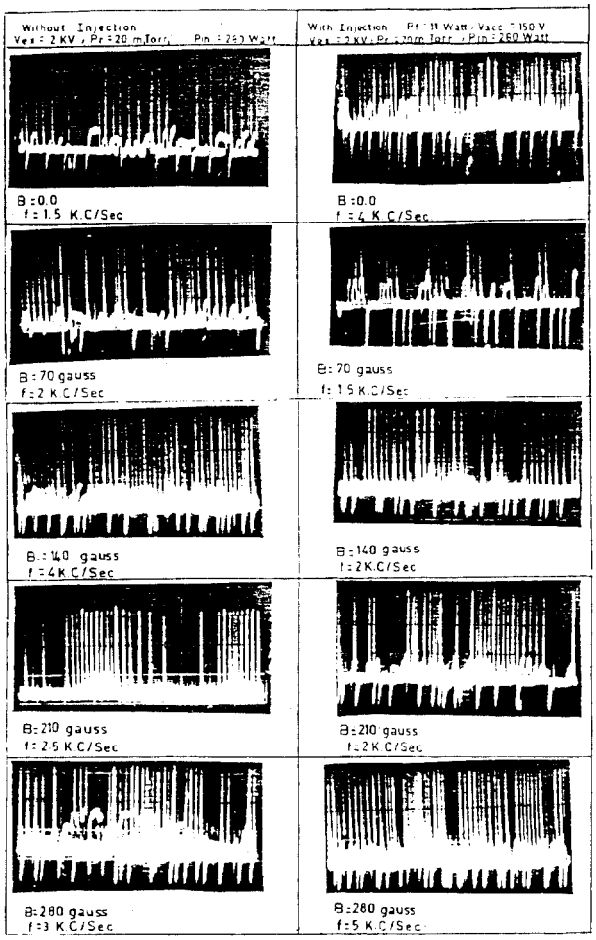

Fig. 3: Variation of oscillation with magnetic field (without & with) injection.

This means that electron injection tends to stabilize the plasma and this is reflected on the decrease in diffusion losses.

Fig. 4 shows the variation of diffusion losses with filament power at the resonance value of magnetic field (B_r = 140 gauss).

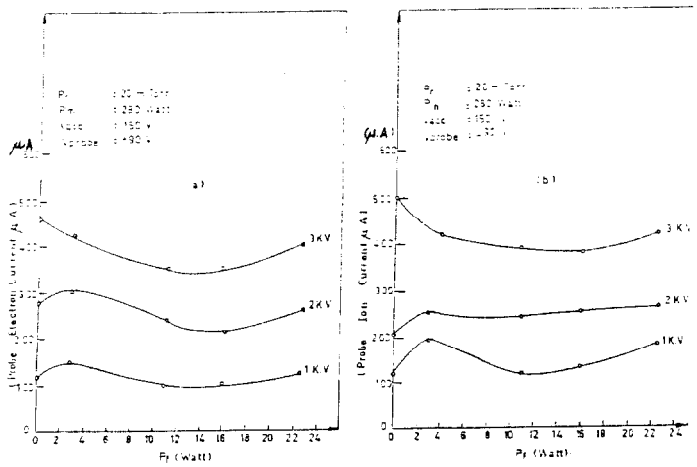

Fig. 4: Effect of filament power on the diffusion losses.

It is clear that the increase in filament power causes a slight decrease in the diffusion losses while at higher filament power an increase is noticed which may be due to plasma heating.

Fig. 5 shows the variation of diffusion losses with the discharge pressure.

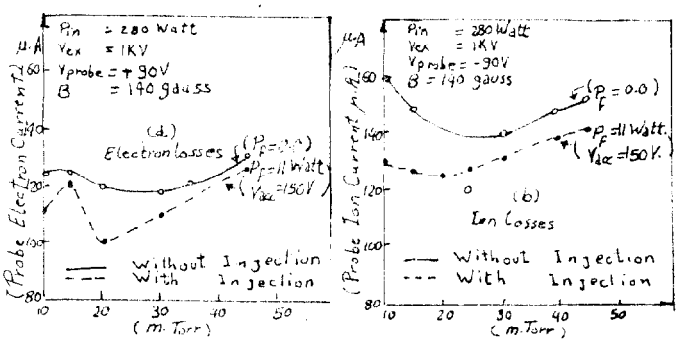

Fig.5:Effect of discharge pressure on the diffusion losses

The diffusion of ions is greater than that of electrons and the diffusion losses decrease with electron injection. At low pressure $\simeq$ 10 m.Torr the diffusion losses are greater due to the appearance of plasma instabilities at low pressures [6]. Also, at low pressures (10-20 m.Torr) the decrease of ion and electron losses due to electron injection is large compared with larger pressures (30-50 m.Torr).

Conclusion

The significance of electron beam injection in the low pressure RF plasma is due to its effect on increasing the extracted ion current[1]. In this study it is also found that electron injection decreases both the diffusion losses across the axial magnetic field and the frequency of the plasma instabilities. This decrease occurs at magnetic field $B \leqslant B_r$. For $B \geqslant B_r$ the rate of increase of diffusion losses and the instabilities are larger. Also, the frequency of electrostatic instability increases after electron injection. Accordingly, the electron injection process is a good method to decrease the effect of plasma instabilities on diffusion losses at low pressures.

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