Topic number 9

Study of ECR plasma expansion in diverging magnetic field geometry

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While considerable work has been carried out in Helicon thrusters, potential of ECR based plasma thrusters have yet to be explored. The present work therefore, attempts to explore the possibility of using ECR based plasma sources for such applications. The experiments were carried out by allowing the plasma produced by a small ECR source to expand into a bigger expansion chamber. Two expansion chambers with different dimensions were used to study the geometrical effect on plasma parameters during the expansion. It was observed that the electron density in the expansion chamber decreased along the axis, but the density and electron temperature variation scale length differ for the two chambers. The results indicate that in the smaller chamber plasma expansion is isothermal, while in bigger chamber, it obeys a polytropic law. An attempt has been made to understand the results in light of 1-D, gyro-averaged fluid equations.

1. Introduction

In recent years magnetized expanding plasmas have been studied widely because of their large span of application ranging from thrusters for space exploration [1] to ion beam production [2]. In the present paper behaviour of expanding magnetized ECR plasma has been studied.

2. Experimental setup

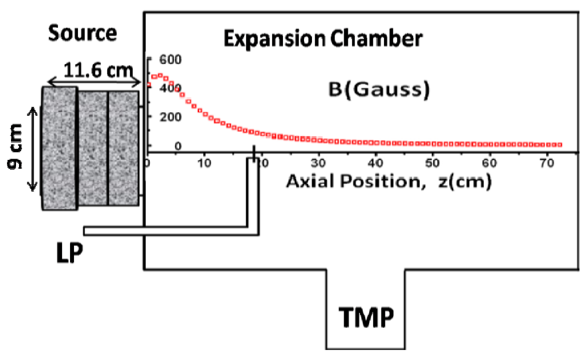

Figure 1 Experimental setup with B vs z plot

The experimental system shown in Figure1 uses a compact ECR plasma source (CEPS) [3] that consists of a small stainless steel source section (ID 9 cm × Length 11.6 cm), mounted coaxially onto a larger expansion chamber (stainless steel cylinder). Two expansion chambers of different sizes ((I) ID 15 cm × Length 37 cm; (II) ID 49 cm × Length 75 cm) were used. Ar plasma was produced using the ECR heating mechanism at 2.45 GHz microwave frequency. The CEPS uses ring magnets (concentric with the source chamber) to provide the magnetic field for the ECR as well as in the expansion region, which helps guide the plasma into the volume of larger expansion chamber. It is found that B falls exponentially in the expansion chamber with a scale length, $L_m = 9.2$ cm.

3. Results and discussion

Axial measurement of electron density n_e at 500W microwave power and Ar neutral pressure of 0.5 mTorr in the two expansion chambers were carried out and compared with magnetic field variation on axis. Moving away from the source n_e is seen to fall exponentially in both cases but with different scale lengths.

In setup I the density fall follows the magnetic field while in setup II the density decreases more slowly. Plots of $\log_{10}(T_e)$ vs $\log_{10}(n_e)$ show that the axial electron temperature variations are very different for the two set ups. From the thermodynamic relation for a polytropic process, $T_e/n_e^{\gamma-1}$ = constant, it is inferred that in setup I plasma expansion in the diverging magnetic field is isothermal ($\gamma_e \approx 1$) while in setup II it is no longer isothermal, but varies as given by the value, $\gamma_e \approx 1.22$.

Using gyro-averaged fluid equations that hold along a field line, it can be shown that the expansion along the field lines obeys the double-adiabatic equation of state and that the quantity $n_e^2/[B^2 T_e] \approx$constant. Experiments in setup I yield that n_e/B remain a constant along the field lines near the axis, implying isothermal expansion. However, in system II, n_e scales as B^s where $s<1$ and the expansion does not remain isothermal. Detailed analysis need to be done and will be presented in conference.

4. References

[1] C. Charles, *J. Phys. D. Appl. Phys.*,**42**, 16, (2009) 163001.

[2] W. Lu et.al, Rev. Sci. Instrum., **87**, (2016) 02A738.

[3] A. Ganguli et.al, *Plasma Sources Sci. Technol.*, **25**, 2 (2016) 25026.