ABSTRACT

Plasma density and temperature profiles were measured for plasma electrons which were generated by a plasma source and ionization from a 1 kev electron beam. Electron plasma parameters were measured with a cylindrical Langmuir probe which was moved perpendicular to the axis of the beam and field.

Electron densities decreased exponentially from the beam center and the decay constant varied with magnetic field in accordance with the Bohm theory of cross field diffusion. This enhanced diffusion effect due to instabilities generated by the electron beam is orders of magnitude larger than that due to particle collisions.

INTRODUCTION

When a large magnetic field is applied to a group of electrons the electron motion along the field is not effected but the motion trasnsverse to the field is constrained to circular motion about the magnetic field lines. This constraint limits the transverse conductivity of a plasma. The electrons and ions both orbit about the field lines, but the ion radii are much larger because of their larger mass. The ions in a plasma then are not as easily magnetized as the electrons and their transverse conductivity is less effected by the magnetic field.

The usual way in which electrons diffuse across the field lines is through collisions. As the electrons orbit about the field they eventually collide with other particles and undergo a random walk type of trajectory. This is not a very efficient process because of the relatively large mean free paths for the electrons. A much more efficient way to enhance the transverse diffusion of electrons is to have them interact with plasma waves. Bohm[1] showed that plasma instabilities can have high frequency plasma oscillations associated with them which interact strongly with the plasma electrons. This interaction enhances the transverse electron diffusion by orders of magnitude over that due to collisions alone. Bohm also postulated that the form of the diffusion coeficient due to plasma oscillations (called the Bohm diffusion coeficient) should vary with magnetic field as 1/B. The collision dominated diffusion coefficient on the other hand varies as $1/B^2$, and so, in principle, the two diffusion mechanisms can be differentiated by varying the magnetic field.

The approach taken in this project was to inject an electron beam into a plasma parallel to a magnetic field. The electron beam tends to interact with the plasma and generate plasma oscillations which in turn enhance the transverse diffusion. According to Szuszczewicz[2], the plasma density should decrease exponentially from the beam center and the decay constant should vary as the inverse square root of the diffusion coefficient. By measuring the plasma density transverse to the beam for two different values of magnetic field, the field variation of the diffusion coefficient can be found. For Bohm diffusion the exponential decay constant varies directly as the square root of the field while for collision dominated diffusion it varies with the first power of field.

EXPERIMENTAL CONFIGURATION

A 3′ by 8′ vacuum chamber was configured with an electron gun on one end and a plasma source on the other. Both were aligned to produce beams centered on the axis of the chamber. The plasma source utilized argon gas and resulted in a chamber pressure of 0.2 millitorr. A hot filament in the source emited electrons which were accelerated and ionized the argon atoms. Equal numbers of electrons and ions were extracted through an exit grid so as to produce a plasma density in the chamber the order of 10^7 /cc. The electron gun was operated at 1 kev energy and 3-5 ma of current, well below the threshold for initiating any beam plasma discharge. A set of magnetic coils provided an axial magnetic field of 19 and 38 gauss. A cylindrical Langmuir probe was moved in one half inch intervals across the beam region. The function of the probe was to measure the plasma electron density and temperature. The electron density measurements were ploted on semilog graph paper and are shown in figure 1.

DISCUSSION

As seen from figure 1, the density profile can be used to identify the center region of the electron beam. The ionization produced by the electron beam falls off exponentially from the center region and far from the beam, the background plasma density falls off nearly linearly to the chamber walls. For both values of the magnetic field used the background plasma density from the plasma source was nearly equal. The electron density data shows that as the field increased to 38 gauss the electron current to the probe was decreased. The ion current to the probe was the same for both magnetic field values so this decrease in electron density is a real effect due to the magnetic field constraining electron collection. The data also illustrates the effect of a larger magnetic field in compressing the electron beam diameter. Although the raw probe data is not shown here, the probe characteristic curves indicated that electron current exhibited strong saturation effects far from the central beam region, while near the beam region they did not. The likely explaination for this behavior is that strong plasma oscillations in the central region result in Bohm diffusion and a large transverse conductivity to the probe. Outside this region the plasma oscillations are absent or of a low amplitude and the transverse conductivity to the probe is dominated by collisions and is much smaller and the electron current saturates.The slope of the density data in figure 1 increases by a factor of 1.5 as the magnetic field doubled. This implies that the slope varies as the square root of the field, the diffusion coefficient varies as the inverse of the field and Bohm diffusion dominates the transverse motion of the electrons.

REFERENCES

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2. Szuszczewicz, E.P., D.N.Walker, and J.C.Holmes "Plasma Diffusion in a Space Simulation Beam Plasma Discharge",Geophysics Research Letters, 6,201,1979

FIGURE CAPTION

FIGURE 1: Semilog plot of electron plasma density vs relative position of the Langmuir probe for two values of magnetic field.

FIGURE 1