§27. Basic Investigation on Discrimination of Charged Particles in a Cusp Direct Energy Converter

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A direct energy conversion system designed for D-^{3}He fusion reactor based on a field reversed configuration consists of a CUSP direct energy converter (DEC) and a Traveling Wave (TW) DEC, where, respectively, electrons and thermal ions are deflected consecutively in the two stage cusp magnetic field and led to Venetian blind type electrodes to produce DC power, and fusion protons are velocity-modulated, bunched, and then decelerated by RF traveling waves to produce RF power. The concept of the TWDEC has been verified through numerical and experimental simulations.[1,2] It is therefore necessary to perform experimental survey on discrimination of charged particles in the cusp magnetic field.

We have constructed a CUSPDEC experimental device, which consists of low-energy plasma and ion sources, a guide field section, and a cusp magnetic field section.[3] The CUSPDEC experimental device has two magnetic coils, A and B, to form a slanted cusp field. By adjusting the current in the two coils, I_A and I_B, the field line curvature can be varied. Typical values are $I_A = 30$ A and $I_B = 40$ A. We inject a nitrogen plasma beam of density ~2×10^7 cm^{-3} and electron temperature ~7 eV into the slanted cusp field. Figure 1 shows the ion and electron fluxes along the axis as measured by a plane electrode, which is moved from $z = -15$ cm to 10 cm with $z = 0$ being the field null point. It is seen that the electron flux abruptly decreases after passing z = 0, while the ion flux is almost kept constant. The voltage-current characteristics of the electrodes at the line cusp and at the point cusp revealed that the flux to the point cusp is mostly of ions, whereas the flux to the line cusp is of electrons. We note that the sharp decrease in the electron flux at the field null shown in Fig.1 indicates that the electrons flow toward the line cusp along the field lines.

We define the transmission ratio of the particle as the ratio of the flux before entering the field null to that after passing through the null. The transmission ratio of electrons decreases to less than 0.05 and the ratio of ions increases toward the value of 1 as the curvature of the field lines of the cusp magnetic field is increased. The condition of the coil currents for minimum transmission ratio of electrons is: $I_B = 1.45\, I_A$.

Most of the electron flux flows into the line cusp as shown in Fig. 1. It is observed that some part of the ion flux that does not reach to the point cusp also flow into the line cusp. The fraction of ions to the line cusp is larger for the smaller curvature (smaller I_B). When the helium plasma is injected instead of the nitrogen plasma, the ion fraction to the line cusp increases for a fixed I_B.

The rate of separation of electrons and ions changes with the radius of the incoming plasma beam. This is mainly due to the difference in fraction of ions that go to the line cusp. Figure 2 shows the ion flux to the line cusp divided by the incident plasma density for two cases of the plasma radius, r_0, of 5 and 1.5 cm. As r_0 becomes larger, ions tend to flow into the line cusp, resulting in lower transmission ratio of ions to the point cusp. We note that r_0 must be restricted to a certain value to obtain a good separation.

In summary, the experiment shows that it is possible to discriminate the charged particles in the slanted cusp field. The separation of electrons from ions is improved when the curvature of the magnetic field is increased or the radius of the plasma is decreased.

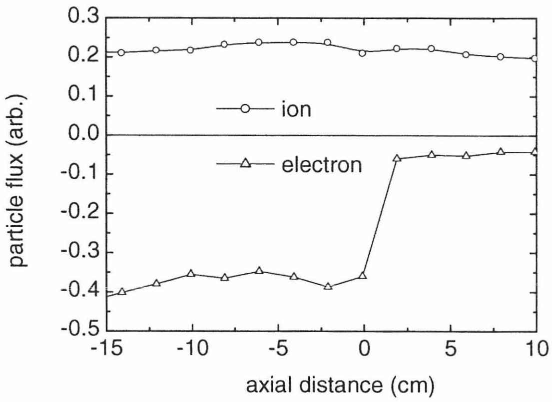

Fig. 1. Ion and electron flux along the axis.

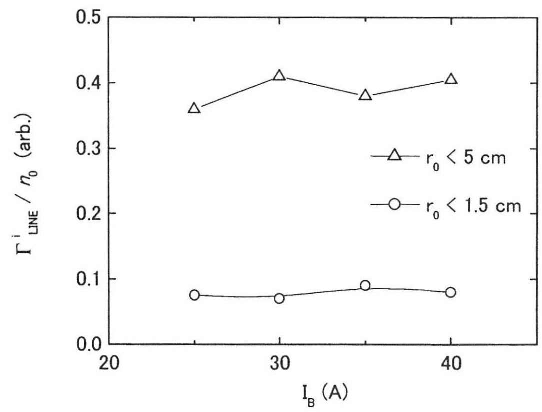

Fig. 2. Ion flux to the line cusp divided by the incident plasma density versus the plasma radius.

References

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