§13. Characteristics of Charge Separation in a Slanted Cusp Field for Direct Energy Conversion

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A direct energy conversion system designed for D-^{3}He fusion reactor based on a field reversed configuration employs a Venetian blind type converter for thermal ions to produce DC power and a traveling wave type converter for fusion protons to produce RF power. It is therefore necessary to separate, discriminate, and guide three major particle components; electrons, thermal ions, and high-energy protons. For this purpose, proposed is a cusp magnetic field, in which the electrons are deflected and guided along the field line to the line cusp, the thermal ions are less deflected but flow into off-axis region, and the protons pass through the point cusp maintaining on-axis orbit.

Figure 1 shows the CUSPDEC experimental device, where the slanted cusp field is created by two magnetic coils A and B, with currents I_A and I_B, respectively. A plasma beam is injected into the point cusp of the coil A side. We measure the ion and electron fluxes with changing I_A and I_B. We define the separation rate of each particle species as $I_1/(I_1+I_2)$, where I_1 and I_2 are, respectively, the flux of each species obtained by probe 1 at the point cusp of the coil B side and that by probe 2 at the line cusp.

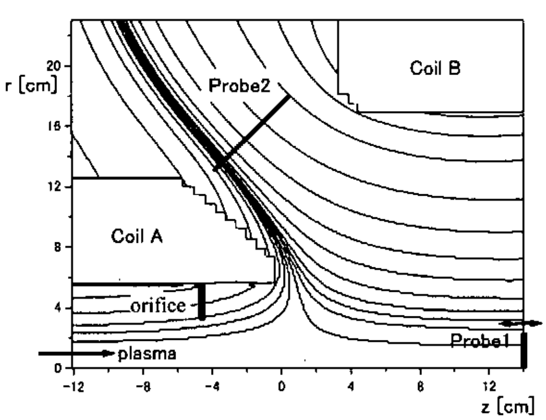

Fig. 1. CUSPDEC experimental device with typical magnetic field lines.

When the cusp field is formed, most of the electron flux flows into the line cusp and most of the ion flux into the point cusp, yielding the separation rate of electrons to a small value and that of ions close to 1. The values of separation rates are shown in Fig. 2 as a function of I_A with $I_A / I_B = 3 / 4$ and the ratio of the radius of the orifice to that of the plasma source $r / r_0 = 1$. We note that all electrons flow into the line cusp and do not appear at the point cusp exit for $I_A > 40$ A, Although the separation rate of ions gradually increase with I_A, its value is 0.6-0.7 or so indicating that not a small fraction of incident ions flows into the line cusp.

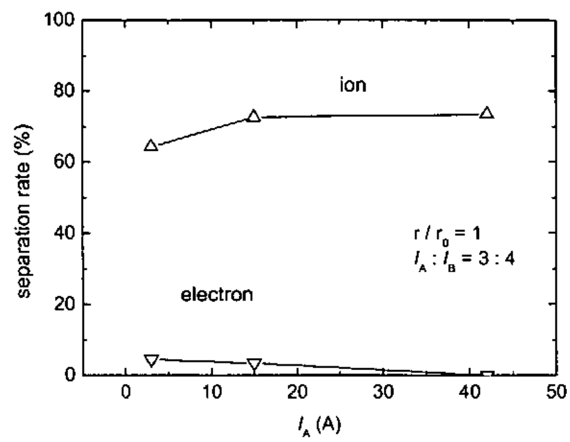

Fig. 2. Separation rate of ions and electrons as a function of the magnetic field strength.

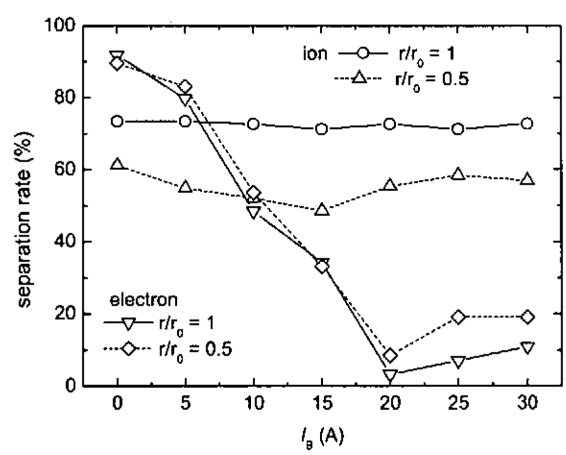

Fig. 3. Separation rate for ions and electrons versus I_B for two cases of the plasma radius.

We measured the separation rates of ion and electron fluxes with changing I_B for a fixed $I_A = 15$ A for the two cases of r / r_0 as shown in Fig. 3. For both cases of $r / r_0 = 1$ and 0.5, the separation rate of electrons decreases sharply with I_B showing the best separation at $I_B = 20$ A. The degree of separation of electrons with respect to ions increases with the curvature of the cusp field. This is consistent with the theoretical prediction by Tomita et al.[1] It is noted in Fig. 3 that the separation rate of ions improves from 0.6 to 0.75 when r / r_0 is decreased to 0.5. This indicates that the ions closer to the magnetic axis have a tendency to reach the point cusp exit.

Reference

1) Tomita, Y., Yasaka, Y., Takeno, H. et al., Proc. 5th Int'l Conf. on Open Magnetic Systems, 2004.