§1. Experiment on Charge Separation in a Small-Scale CUSPDEC Device

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It is necessary to separate, discriminate and guide electrons, thermal ions with hundreds of keV, and fusion protons with 14.7 MeV, which are created from D-^{3}He fusion reactor, in order to produce electric power by using a Venetian-blind direct energy converter (DEC) for the thermal ions and a traveling wave DEC for the protons. For this purpose, a use of cusp magnetic field is proposed. The electrons are deflected and guided along the field line to the line cusp, while the ions pass through the point cusp, because each Larmor radius is quite different.

We use a CUSPDEC experimental device, which consists of a low-energy plasma source, a guide field section, and a cusp magnetic field section. The device is capable of changing the curvature of the magnetic field from normal cusp to slanted cusp fields. We inject a plasma beam with ions accelerated up to a few hundreds of eV into the slanted cusp fields to simulate the separation of electrons and ions.

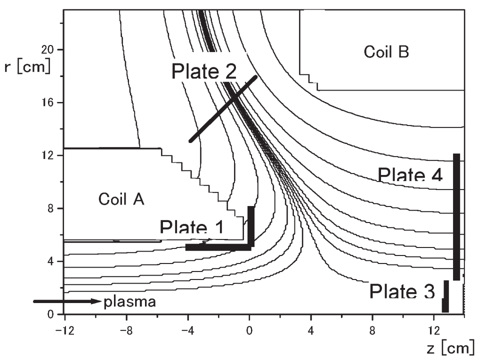

Fig. 1. CUSPDEC experimental device and typical field lines.

The CUSPDEC experimental device has two magnetic coils, A and B, as shown in Fig. 1 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. In Fig. 1, the field lines are plotted for I_A = 30 A and I_B = 20 A as an example. The magnetic field strength at z = –12 cm is ~350 G, with z = 0 being 0.8-cm right from the right edge of the coil A. A plasma beam of densities 1–10 x10^7 cm^{-3}, electron temperatures 5–15 eV, and a diameter of about 2.5 cm is injected from the left side into the slanted cusp field. The ions can be accelerated by the voltage applied at the exit of the plasma source up to 300 V in this experiment. If the density of the incident plasma is sufficiently low, electrons flow along the field line to the line cusp exit, whereas, ions can traverse wide regions and preferentially enter into the point cusp end. Plane electrodes shown in Fig. 1 are located at the entrance-line cusp (Plate 1), the line cusp exit (Plate 2), the inner point cusp (Plate 3), and the outer point cusp (Plate 4) to detect the particle flux..

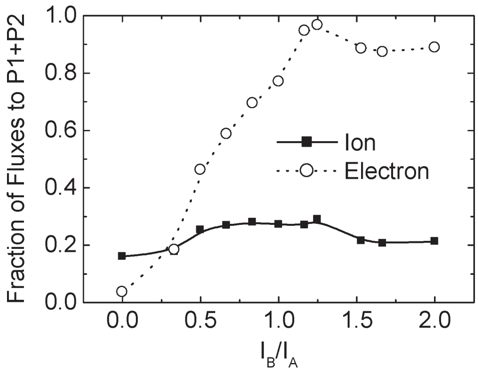

Fig. 2. Fraction of ion and electron flux as a function of I_B/I_A.

Saturation currents of ions and electrons at Plates 1~4 are measured in Ar plasma with changing I_B for a fixed I_A = 15 A. The fraction of flux to Plates 1 and 2 is the ratio of sum of currents at Plates 1 and 2 to sum of currents at Plates 1 to 4. It is shown in Fig. 2 that 95% of electrons are deflected by the magnetic field, while ~30% of ions flow into the line cusp region if an appropriate I_B/I_A is chosen,.

We measure the ratio of the saturation current into Plate3 in Ar and He plasma at z = 11.45 cm to that at -6.55 cm for several ion energies with I_B/I_A =1.33. The ratio, i.e., the transmission ratio is plotted as a function of the ion energy in Fig. 3. It is confirmed that electrons and ions can be separated by the slanted cusp field even for higher ion energies than in the previous experiments.[1] It is seen that He^+ with lower energy is influenced more sensitively by the magnetic field. Increased electrons arriving at the point cusp exit for higher ion energies may be due to the generation of secondary electrons.

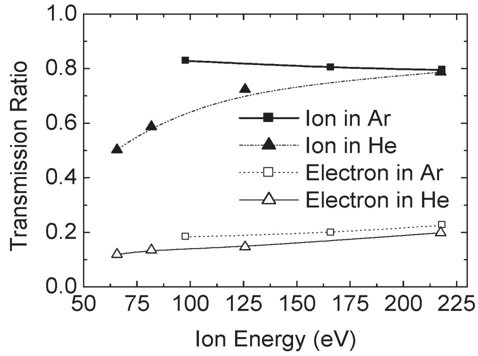

Fig. 3. Transmission ratio of ions and electrons in Ar and He plasmas as a function of the ion energy.

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