§24. Basic Investigation of Cusp and Traveling Wave Direct Energy Converters for D-^{3}He Fusion

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A direct energy conversion system designed for FRC-based D-^{3}He fusion reactor[1] consists of a CUSP direct energy converter (DEC) and a Traveling Wave (TW) DEC, where, respectively, electrons and thermal ions are separated from fusion protons and decelerated via Venetian blind type electrodes to produce DC power, and protons are velocity-modulated, bunched, and then decelerated by RF traveling waves to produce RF power. For the basic investigation of these DEC's, we use small experimental devices; a single cusp with low-energy plasma and ion sources simulating the CUSPDEC, and a TWDEC simulator consisting of an ion source and an array of modulator-decelerator electrodes driven by a 7-MHz RF.

i) Charge separation in the CUSPDEC

We have constructed a CUSPDEC experimental device, which consists of the plasma/ion source, the guide field section, and the cusp section. The single cusp device is capable of changing the curvature of the magnetic fields from normal cusp to slanted cusp. 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. The numerically calculated trajectories of electrons and ions show that the electrons with energy of 10 eV can be separated from ions in a cusp field of 0.1 kG at the entrance. We inject a plasma beam of density $\sim 2 \times 10^7$ cm^{-3} and electron temperature $\sim$ 7 eV into the slanted cusp field changing R_B, the ratio of the current in the back coil to that in the front coil. The observed current to the charge collector at the point cusp I_{point} is positive, while the collector current at the line cusp I_{line} is negative as shown in Fig. 1. This indicates that the electrons and ions can be separated as expected. The figure also shows that the degree of separation increases with R_B that is proportional to the curvature of the cusp field. This is consistent with the theoretical prediction that the region of ion motion in the Stoermer potential trough is wider for larger curvature.

By using a low energy ion source instead of the plasma source, we simulate the energy discrimination of ions. The value of I_{point} and the ratio of I_{point} to I_{line} increase steeply as the energy of incident ions is increased from 0.1 to 1 keV. This confirms basic principle of the discrimination of 14.7-MeV protons from the thermal ions.

ii) Beam deceleration in the TWDEC

Ion beam deceleration experiments are performed in the TWDEC simulator. The deceleration RF field is externally excited, and desirable RF field axial structure is examined by evaluating change of ion energy distribution. As the length of the decelerator (L_d) expands, the ion energy distribution function spreads from initial thermal energy range to wider energy range. When the ratio of the wavelength of the deceleration field (l_d) to the initial wavelength of the ion beam (l_x) is not close to unity (ex. $l_d/l_x = 0.75$), the deceleration becomes better as L_d expands simply (keeping l_d fixed) within $L_d < 2l_d$, but the extent of the deceleration is not so large. When the ratio (l_d/l_x) is close to unity, the extent of the deceleration is larger, but the simple expansion of L_d does not necessarily result in better deceleration. If L_d is varied axially with matching to the variation of the wavelength of the ion beam, it is observed that the ion energy distribution spreads in the lower energy region, and better deceleration is obtained. These experimental results are confirmed by 1-D particle orbit calculation.

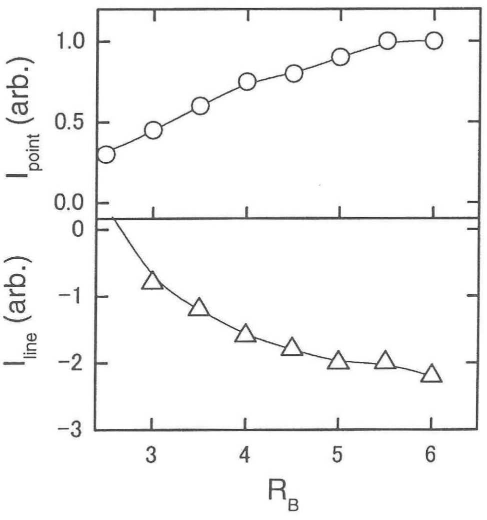

Fig. 1 Current to the point and line cusps versus R_B.

Reference

1) Momota, H. et al., Nucl. Fusion Supplement 1993 **3** , Int'l. Atomic Energy Agency, 1993, p. 319.