§5. Investigation on Applicability of a CUSPDEC to the GAMMA 10 Tandem Mirror

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A cusp-type direct energy converter (CUSPDEC) for thermal ions produced in a D-^{3}He fusion reactor[1] has been investigated using a small-scale experimental device with a low-energy plasma source. The cusp magnetic field is used to separate ions from electrons, and a dc-biased plane collector decelerates and collects ions as a one-stage direct energy converter. Experimental results have revealed that the slanted cusp field has better capability of the charge separation than the normal cusp field. It is also found that the efficiency of energy conversion depends on the shape of the energy distribution function of incoming ions. Based on these experimental findings as well as theoretical and numerical studies, we here investigate applicability of the experimental device as a test direct energy converter for the GAMMA10 tandem mirror.

The CUSPDEC device consists of a plasma source, a guide field section, a cusp magnetic field section, and electron and ion collectors. The cusp field is created by two magnetic coils, A and B as shown in Fig.1. 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. A plasma beam with ions accelerated up to 0.3 keV is injected into the cusp field. We measured the ion and electron fluxes with changing I_B for a fixed I_A = 30 A. We define the transmission ratio of the particles as the ratio of the flux at the point cusp to that at the entrance. 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

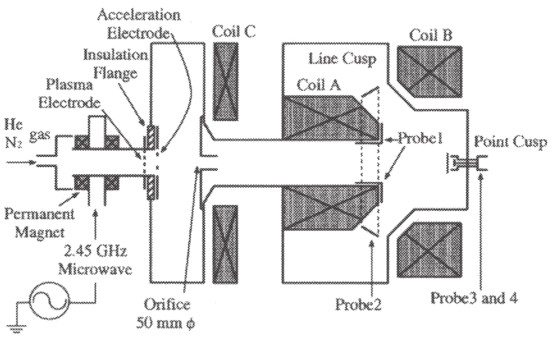

Fig. 1. Schematic diagram of CUSPDEC experimental device.

transmission ratio of electrons to about 0.1 and that of ion to 0.7~0.8.

The CUSPDEC device is assumed to be connected to an end flange of the GAMMA10 device, after removing the plasma source section, to accept end loss flux from the plasma. The axial length between an end plate of the GAMMA10 device and the entrance of the CUSPDEC is about 2.5 m. Among several operation modes in the GAMMA10 device, we choose the hot ion mode and the ECRH plug mode[2] as shot examples. The data from an end loss analyzer for these particular shots show that the electron temperature for the hot ion mode is ~0.1 keV and that for the ECRH plug mode is ~ 0.7 keV with 2.9-keV tail component. The parallel ion temperature is 0.3~0.5 keV.

When the end loss flux is introduced to the CUSPDEC device, it is expected that electrons are deflected toward the line cusp region along the field lines and ions pass through the null point flowing into the point cusp region. We here

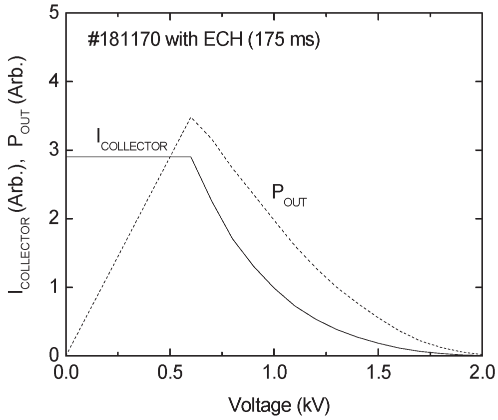

Fig. 2. Estimated current-voltage characteristics of the ion collector (solid line) and dc power output (dotted line) from the CUSPDEC..

assume that the transmission ratio of electrons is 0.

The solid curve in Fig. 2 is the current-voltage characteristics of the ion collector operating as the one-stage direct energy converter, which is located at the point cusp region of the CUSPDEC device. This curve is obtained from the measured ion energy distribution function for the ECRH plug mode in the GAMMA10 device. The dotted curve in Fig. 2 shows the output dc power P available for an external load. The conversion efficiency is defined as

$$\eta = \frac{P(V = V_{opt})}{I_0 \cdot E},$$

where V_{opt} is the voltage that gives a maximum P, I_0 is the collector current at low voltage, and E is the average energy of incoming ions. The value of η in this case is calculated to be 0.67. We will proceed to perform an experiment on the direct energy conversion in the GAMMA10 device.

References

1) Momota, H., Ishida, A., Kohzaki, Y., Miley, G., et al.: Fusion Technol., **21**, 2307 (1992).
2) Saito, T., Tatematsu, Y., Kiwamoto, Y., et al.: Trans. Fusion Technol., **35**, 233 (1999).