§12. Studies on Two-stage Deceleration Scheme in a Cusp-type Direct Energy Converter Simulator

Takeno, H., Yasaka, Y. (Kobe Univ.),
Tomita, Y.,
Ishikawa, M., Nakashima, Y., Katanuma, I. (Univ. Tsukuba)

Cusp-type Direct Energy Converter (CUSPDEC) was proposed as an efficient charged particle discriminator[1]. In the device, electrons are deflected along magnetic field lines although ions go straight, thus the charge separation is achieved without grid electrodes. After the charge separation, kinetic energies of the particles are directly converted into electricity using conventional electrostatic energy converters: those for electrons and ions are located at line cusp and point cusp, respectively. A demonstration of power generation in GAMMA 10 tandem mirror was reported by the authors[2].

In a practical CUSPDEC, particle density of incident flux increases. Then fields of space charges are not negligible which may affect to charge separation. At the front of the ion collector, ions are stagnated and high space potential is created. Low energy ions are reflected by this potential, and conversion efficiency is degraded. In order to improve conversion efficiency, two-stage deceleration scheme was proposed[3]. The scenario of this scheme on high density plasma is illustrated in Fig. 1. As in the figure, electrons, low energy ions, and high energy ions are collected by the electron collector at the line cusp, the lateral ion sub-collector near the entrance, and main ion collector at the point cusp, respectively. The guidance of electrons can be controlled by magnetic field. The main collector can be biased with high voltage corresponding to high energy ions.

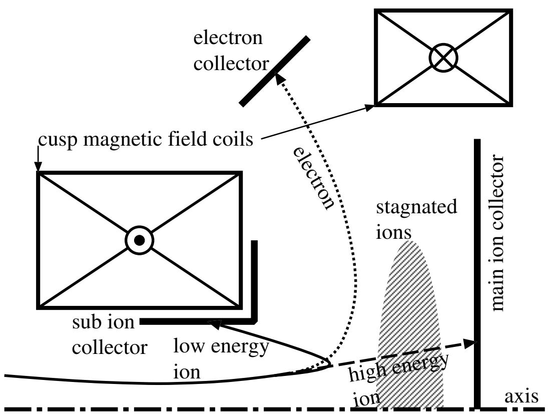

Fig. 1: Illustration of scenario of two-stage deceleration scheme on high density plasma.

In the scheme, orbits of ions are complex and determined by incident conditions and distribution of electric field. As the beginning of the optimization study of the scheme, the conversion efficiency using a modified shape of the ion collectors is calculated using orbit calculation[4]. For simplicity, space charges are not taken into account, and the reflection of low energy ions are considered by the potential of the main collector. The orbits of test particles, of which incident radial position and incident kinetic energy are varied, are traced and their arrival on the sub-collector are examined for pairs of V_{m} and V_{s}, which are the voltages of main- and sub-collectors, respectively.

By assuming energy distribution of incident ions, arrival probability of ions can be evaluated. On one hand, a simple improved efficiency, in which arrival probability is not taken into account, can also be obtained when ion energy distribution is determined. In this report, ion energy distribution is assumed to be that of end-loss flux of GAMMA 10 tandem mirror in the hot-ion mode operation.

The result of the calculation is summarized as functions of V_{m} and V_{s} in Fig. 2. In the figure, gray scale contour map shows an arrival probability, and solid contour curves indicate a simple improved efficiency. The real improved efficiency is obtained by multiplying those values. As an optimum value, $7 \sim 9\,\%$ is expected on $V_{\mathrm{m}} = 1 \sim 1.4\,\mathrm{kV}$ and $V_{\mathrm{s}} \sim 0.4\,\mathrm{kV}$.

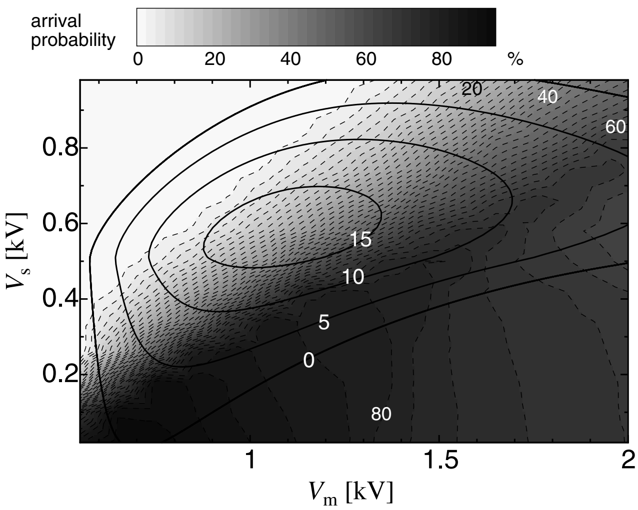

Fig. 2: Contour map of calculated deceleration efficiency. Solid curves shows a simple improved efficiency and gray scale contours indicate an arrival probability.

1) H. Momota, et al., *Proc. 7th Int. Conf. Emerging Nuclear Energy Systems*, Makuhari, 1993, p.16 (1994).

2) Y. Yasaka, et al., Trans. Fusion Sci. Technol., **51** (2007) 171.

3) Y. Yasaka, et al., Trans. Fusion Sci. Technol., **55** (2009) 1.

4) K. Goto, et al., J. Plasma Fusion Res. Series, **8** (2009) 1501.