

§6. Charge Separation Characteristics of a Cusp-type Direct Energy Converter Simulator in a Wide Density Region

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A Cusp-type Direct Energy Converter can be expected to use in an advanced-fusion power generation plant to discriminate charged particles flowing from a fusion reactor¹⁾. The device discriminates particles based on the difference among Larmor radii, however, electric field created by space charges may reduce its separation capability for high density plasma. The separation characteristics in a wide density region were experimentally investigated using a small-scale simulator.

The small-scale simulator adopts variable slanted cusp field which is valuable to perform efficient two-stage deceleration²⁾. The gradient of the cusp field can be controlled by current ratio R_c between cusp magnetic coils. For efficient two-stage deceleration, high separation capability is required for a wide range of R_c .

The separation capability was evaluated by relative amount of deflected electrons, which was calculated by $Q_d(R_c) = 1 - I_{es}(R_c)/I_{es}(0)$ where $I_{es}(R_c)$ was electron saturation current of the point cusp electrode when the field gradient was settled with R_c . As the value $I_{es}(R_c)/I_{es}(0)$ means relative amount of electrons undeflected ($R_c = 0$ means straight field), Q_d represents relative amount of deflected electrons.

In Fig. 1, the experimental results are summarized as a function of electron density (n_e) with a parameter of R_c . According to Fig. 1, Q_d increases as R_c increases which means improvement of separation and this is the effect of slanted cusp field. About the dependence on n_e ,

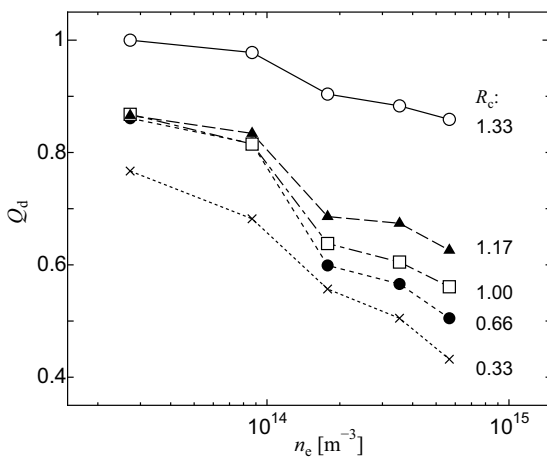


Fig. 1: Variation of the amount of deflected electrons.

however, Q_d decreases as n_e increases and this might be due to space potential of stagnant ions in front of the point cusp collector.

The variation of Q_d is explained by the modified Stömer potential which includes electrostatic potential $\phi(r, z)$:

$$F_{mS}(r, z) = \frac{q^2 A_0^2 r_0^2}{2m r^2} \left(1 - \frac{r A(r, z)}{r_0 A_0} \right)^2 + q\phi(r, z) \quad (1)$$

where m and q are mass and charge, respectively. A , r , and z are an azimuthal component of vector potential, radial position, and axial position, respectively, and a subscript 0 means the value at the incident position.

In Fig. 2, distribution of F_{mS} calculated for a typical experimental condition is shown. There is a low potential valley along the field line, and low energy electrons move along this curve. High energy electrons, however, can ride over the potential hill, and electrons with higher energy than the barrier potential of the stagnation point (F_{mSb} indicated by a dotted circle in Fig. 2) could pass through and reach point cusp region.

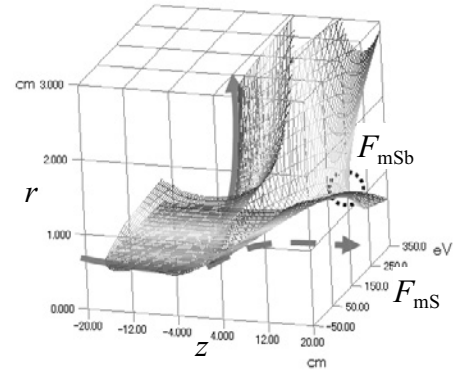


Fig. 2: Distribution of modified Stömer potential.

As for the dependence of Q_d on R_c in Fig. 1, it can be explained by the variation of F_{mSb} : it increases as R_c increases, thus the amount of electrons riding over F_{mSb} decreases which means increase of deflected electrons.

As for the dependence of Q_d on n_e in Fig. 1, the change of F_{mSb} by space potential might be concerning. The electrostatic potential $\phi(r, z)$ includes not only potential due to bias voltage of the electrode, but also space potential due to stagnant ions. Around the position of barrier potential, separated ions are decelerated by the field of the biased point cusp electrode. Thus, they are stagnant around the position, and their space potential may reduce the barrier potential.

Some supplementary means is necessary to achieve efficient charge separation for high density plasma.

- 1) H. Momota, et al.: *Proc. 7th Int. Conf. Emerging Nuclear Energy Systems*, Makuhari, 1993, p.16 (1994).
- 2) Takeo, H., et al.: *Ann. Rep. NIFS (2010-2011)*, p.490.