§23. Summary of Heliotron Non-neutral Plasma Experiments and Study on Image Charge Probe for Measuring Confinement Time

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Introduction During a past decade, physical properties of toroidal nonneutral plasmas have been extensively investigated on several medium size machines. Since the plasmas have strong self electric field, there appear many phenomena that can never been observed in toroidal neutral plasmas. One of those is the variation of space potential ϕ_s on each toroidal magnetic surface. The ϕ_s variation had been originally predicted by T. Pedersen and A. Boozer in 2002. Then, it was experimentally established by us in 2007 and subsequently the Columbia group. However, those were observed in machines with plane magnetic axes where the precise position of each winding magnetic field line has not easily been known except the plane magnetic axis. Thus, no direct data on the parallel electric field $E_{\|}$ along a magnetic field line has been taken yet.

Heliotron J has a helical magnetic axis. And the position of it has been precisely calculated. This strongly provides an opportunity for measuring $E_{\|}$ directly, because it is relatively easy to put a probe on the helical magnetic axis correctly. In prior to performing the experiment, we thus have tested if ϕ_s is certainly varied even on magnetic surfaces having the helical magnetic axis in Heliotron J.

First results and discussion The experimental setup along with the first data are shown in Figs. 1 and 2, respectively. As plotted in Fig. 2, on each magnetic surface, two different values of ϕ_s are measured, which is clearly recognized in the region of $\Psi > 0.5$. This means that ϕ_s is never constant on the magnetic surface; the ϕ_s variation happens even in Heliotron J. Because of page limitation, the detail cannot be described here. But, readers can know it from Ref. 1.

Preparation of image charge measurement In order to measure the confinement time of nonneutral plasmas in Heliotron J, we have been drawing and assembling the image charge probe that measures electrical positive charges induced on the surface of it due to ϕ_s of helical nonneutral plasmas. The first experiment will be conducted during this academic year.

1) D. Sugimoto, H. Himura *et al.*, Plasma and Fusion Research, (2010) vol. 5 pp. S2028.

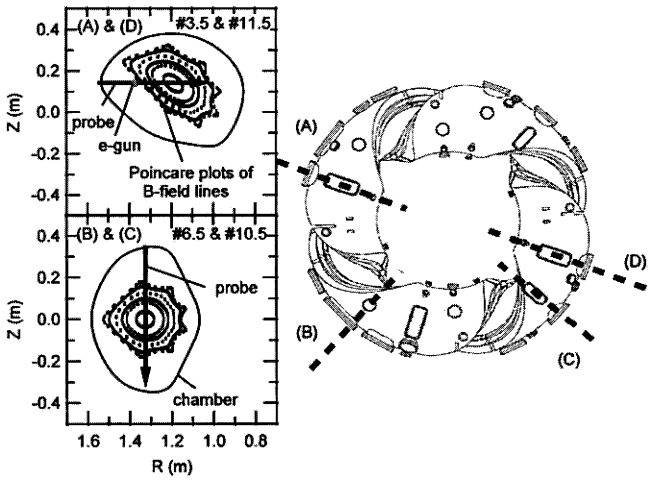

Fig. 1: A top view of Heliotron J. Electrons are launched from the cross-section (A). Then, they form a non-neutral plasma on helical magnetic surfaces of the machine. On the other hand, space potential ϕ_s along with the electron density n_e are measured on cross-sections of (B), (C), and (D).

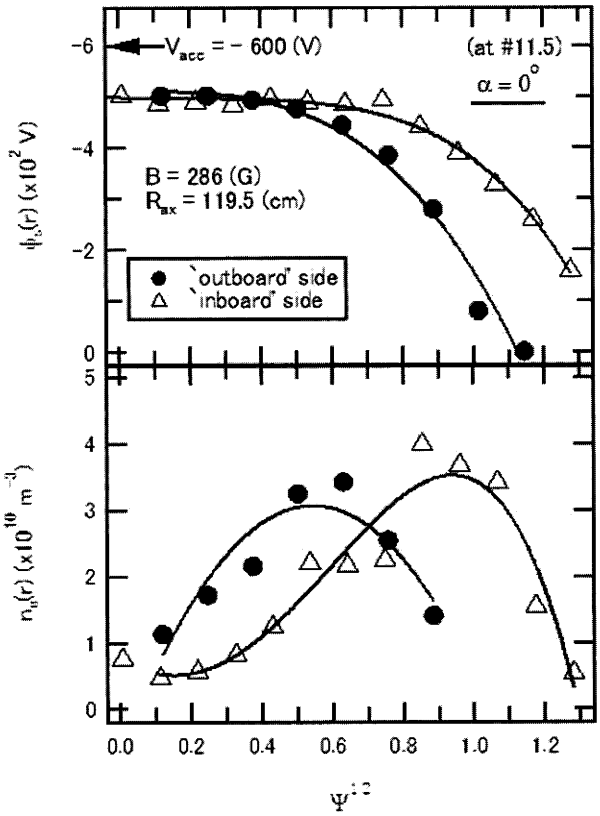

Fig. 2: Radial profiles of ϕ_s and n_e measured on the cross-section (D). Black circles and triangles are data at the outboard side and the inboard one, respectively. As recognized, both ϕ_s and n_e vary significantly on magnetic surfaces.