§19. Studies on Non-constant Potential and Density on Magnetic Surfaces of Helical Nonneutral Plasmas

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For the first time, we have experimentally verified the variation of space potential ϕ_s and electron density n_e on magnetic surfaces of helical electron plasmas. The paper explaining the detail of the findings has been published in Phys. Plasmas[1] and other related topics have been reported in Ref. (2).

The data plotted in Fig. 1 (A) are $\phi_s(z)$ measured with the z-probe using the high-impedance emissive method. The horizontal axis is $\Psi^{1/2}$, where $\Psi^{1/2} = 0$ and 1 correspond to the R_{ax} and LCFS, respectively. In experiments presented here, R_{ax} is fixed at $r = 101.6$ cm. All data points plotted in Fig. 1 (A) are averaged values for three different series of experiments. At each shot, the value of ϕ_s is determined by time-averaging $\phi_s(t)$ for 0.2 – 0.5 ms just after the signal curve has risen completely, except at $\Psi^{1/2} = 0.9$ where data are time-averaged for ~ 2 ms, because taking longer time to rise up. Error bars denote the maximum and minimum values of $\phi_s(t)$ during the time-average.

Differences between two values of ϕ_s at $z > 0$ (henceforth ϕ_{s_u}) and ϕ_s at $z < 0$ (henceforth ϕ_{s_d}) on each magnetic surface (at same value of $\Psi^{1/2}$) are observed. This means that ϕ_s is not constant on magnetic surfaces. As is shown from the data, the difference in ϕ_s becomes larger in the outer region of magnetic surfaces. Actually, the difference reaches about 120 V at $\Psi^{1/2} \sim 0.9$, while at $\Psi^{1/2} \sim 0.3$ the difference almost disappears.

Meanwhile, at the 6-U cross-section, the helical magnetic surfaces have been slightly shifted downward with respect to the center of the elliptic chamber wall. The inferred contours of ϕ_s (equi-potential surfaces) from the measured $\phi_s(z)$ are shifted upward inside $\Psi^{1/2} \sim 0.8$, while downward outside $\Psi^{1/2} \sim 0.8$, with respect to the contours of constant ψ (magnetic surfaces).

In this research, the current-voltage (I_e-V_p) characteristics are also measured on each magnetic surface with the same emissive probes that are used to measure ϕ_s. From the I_e-V_p characteristic curve, we have determined the electron temperature T_e, as will be described. Then, assuming I_e ($\sim e n_e v_{th} S$) at $V_p = \phi_s$, the electron particle flux Γ_e is obtained as $\Gamma_e \sim I_e/eS$, as shown in Fig. 2 (B). Subsequently, the electron density n_e is calculated. Here, v_{th} is electron thermal speed and S is the probe area.

Figure 1 (C) shows $n_e(z)$ for $B = 0.9$ kG and $V_{acc} = -600$ V. Substantial nonuniformity on each magnetic surface is clearly observed. Fitting curves on $n_e(z)$ are calculated using polynomial functions and put for reader's convenience. Another significant point is that $n_e(z)$ has only one crossover point that appears at $\Psi^{1/2} \sim 0.4$. Also, n_{e_d} is always larger than n_{e_u} outside $\Psi^{1/2} \sim 0.4$. This result means that electrons tend to move towards the grounded chamber wall.

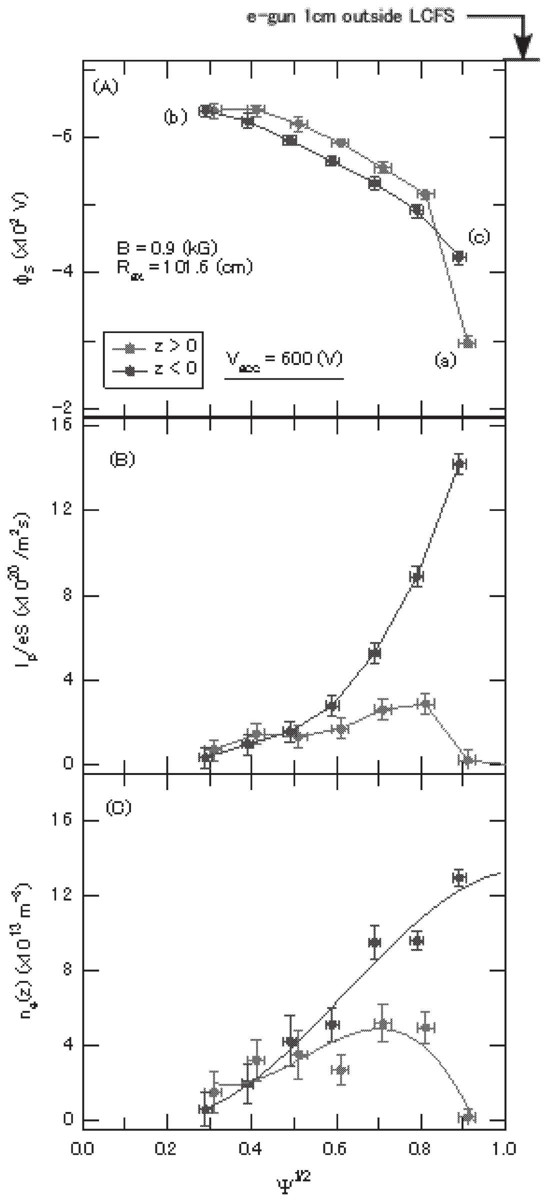

Fig. 1 Profiles of (A) space potential $\phi_s(z)$, (B) electron particle flux $\Gamma_e(z)$, and (C) electron density $n_e(z)$ measured at the 6-U cross-section for the case of $V_{acc} = -600$ V. The horizontal axis is the normalized minor radius. The position of the e-gun is at 1 cm outside the LCFS on a different poloidal cross-section.

1) H. Himura *et al*., Phys. Plasmas **14** (2007) 022507.
2) H. Himura *et al*., Non-Neutral Plasma Physics VI, Vol. **862** (2006) 51.