§24. Experiments on Magnetic Surface Confinement of Nonneutral Plasmas on Heliotron J

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In this academic year of 2009, we resumed the experiment of toroidally confined nonneutral plasmas on Heliotron J. it is experimentally demonstrated that toroidal nonneutral plasmas can be formed on the HMS having a helical magnetic axis. The observed difference in space potential ϕ_s on each helical magnetic surface (HMS) becomes larger near the last closed flux surface (LCFS). This result is similar to those observed in past CHS experiments where helical nonneutral plasmas had plane magnetic axes. A paper explaining the digest of the obtained results and related calculations has been accepted for publication in a special issue of PFR[1]. In the following, we will explain the results briefly.

Data have been measured on the three different cross-sections of Heliotron J. Figure 1 shows a typical set of measured profiles of ϕ_s and n_e at one of cross-sections. All plotted data are time-averaged values between for 1 ms. Although no data are presented in this short report, substantial differences between the two values of ϕ_s measured in the upper and lower regions on each magnetic surface have been clearly observed, which is similar to those observed in the past CHS nonneutral experiments[2]. These results mean that ϕ_s is never constant on the HMS even with a helical magnetic axis. As also recognized, the difference in ϕ_s is larger in the upper region of HMS on the 6.5 poloidal cross-section. This means that equi-potential surfaces have shifted upwardly from the HMS there. With regard to the magnitude of the difference in ϕ_s, the absolute value reaches about 500 V at the LCFS, while at $\Psi^{1/2} \sim 0.3$ the difference in ϕ_s almost disappears.

In order to examine the measured data in Fig. 1 numerically, we calculate n_e using a two-dimensional model. Since $\phi_s(r)$ has been obtained, $n_e(r)$ can be approximately calculated from Poisson's equation: $\nabla^2\phi_s = -en_e/\epsilon_0$. It should be mentioned here that neither three-dimensional effects nor positive image charge induced on the inner surface of the vacuum chamber are taken into account. It is recognized that the calculated $n_e(r)$ has the same order as the measured one. This result means that within an experimental error both ϕ_s and n_e are consistent each other, which thus strongly suggests the existence of equilibrium of heical non-neutral plasmas having a helical magnetic axis. However, there are some disagreements between measurements and calculations. Firstly, the peak position of the calculated $n_e(r)$ locates at $z \sim -0.13$, while at $z \sim -0.1$ for the measured $n_e(r)$.

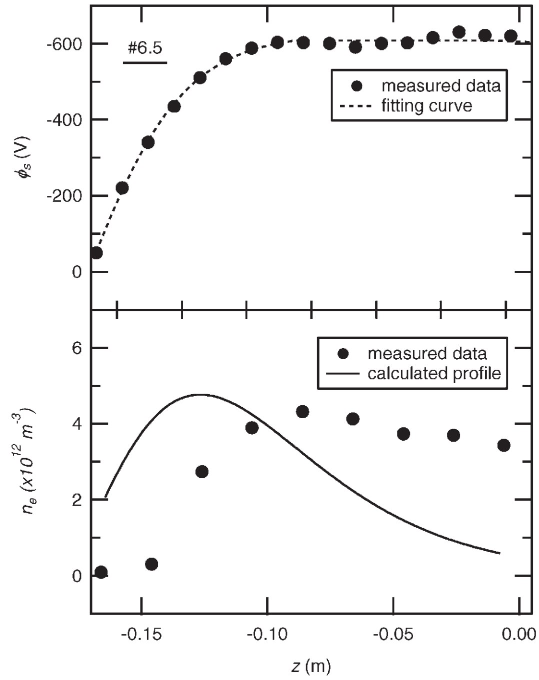

Fig. 1: Comparisons of calculated n_e (solid curves) with measured data (solid circles) on the 6.5 cross-section.

Secondly, apparent difference in the magnitude of $n_e(r)$ is observed near the helical magnetic axis at $z \sim 0$. Possible reasons are considered; first of all, values of n_e near the helical magnetic axis may be overestimated. This is because the measured I_p is actually very small there, which can easily bring about a considerable experimental error. Secondly, as mentioned in the above, we have solved Poisson's equation along only the radial direction (in fact, along the x axis only) just to avoid complicated calculations. If larger gradients of ϕ_s existed along both the y axis and the toroidal direction, such an overestimation of n_e would occur easily. In fact, in experiments, larger variations of both n_e and ϕ_s have been clearly observed along the x axis (that is, the direction of the minor radius r) near the LCFS, while those become much smaller near the helical magnetic axis. Furthermore, it should be pointed out again that Heliotron J has a helical magnetic axis so that the space variation of B along the toroidal direction would be hardly small. If ϕ_s also varied considerably along the toroidal direction at the plasma core, the calculated n_e would be larger. As a result, the discrepancy in Fig. 1 will be reduced. Further data along the helical magnetic axis needs to be measured in order to answer this question. Readers can find out the detail of this motion in Ref. 1).

1) D. Sugimoto, H. Himura, H. Okada, S Yamamoto, S. Kobayashi, T. Mizuuchi, S Masamune, and F. Sano, "Experimental Studies on Helical Non-neutral Plasmas with Helical Magnetic Axis", *accepted for publication in a special issue of PFR* (2010).

2) H. Himura *et al.*, Phys. Plasmas **14** 022507 (2007).