§30. Observation of Space Potential Variation on Magnetic Surfaces on CHS

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Magnetic surface is one of the most important and fundamental concepts in toroidal plasma confinement devices such as tokamaks and stellarators. In quasi-neutral fusion plasmas, physical parameters such as density and potential are thought to be constant on a magnetic surface.

However, in low density electron plasmas with finite temperature and irregular density, that is not the case. The parallel component of equillibrium force balance is written as

$$en_e \nabla_{||} \phi_s = \nabla_{||} p,$$

where $\nabla_{||}$ and ϕ_s stands for derivative along a magnetic field line of force and the space potential, respectively. Assuming that T_e is constant on the magnetic surfaces, this equation can be written as

$$en_e \nabla_{||} \phi_s = T_e \nabla_{||} n_e,$$

which leads to the Maxwell-Boltzmann distribution. As we can see in the equation above, if T_e is finite and there is steep gradient of n_e, the pressure gradient should be balanced with the parallel component of the electric force by the potential gradient. So ϕ_s can vary along the magnetic field lines of force, as well as on the magnetic surfaces.

In our experimental studies on electron plasmas, we have investigated the ϕ_s profile of the electron plasma on helical magnetic surface configuration. And we have observed that there are cases on which ϕ_s is not uniform on each magnetic surface. The experiments were performed in CHS. An electron gun (e-gun) is inserted horizontally in 2-O port of the CHS along the r axis. Electrons are launched out into the vacuum magnetic field B~0.09T from the e-gun with acceleration voltage V_{acc} up to 1kV and emission beam current I_b up to 100mA. The electron plasma is generated by continuous injection of electrons for 40ms. For diagnostics, a Langmuir emissive probe is inserted vertically on 6-U port along the z axis. The probe is terminated with 100MΩ impedence to measure the space potential ϕ_s of the electron plasma.

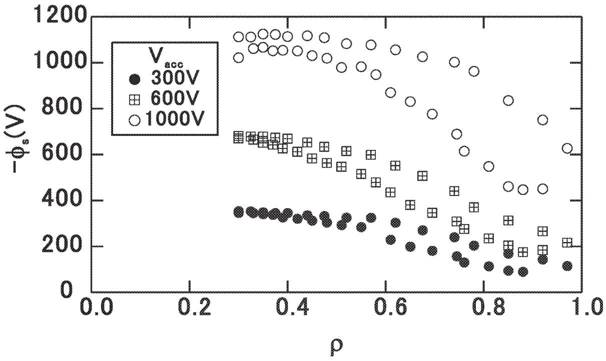

Fig. 1 Profiles of ϕ_s measured on the 6-U port of CHS. Two series of ϕ_s are recognized for each V_{acc}, insisting that ϕ_s is not constant on each magnetic surface. The e-gun is placed at ρ=0.9.

Figure 1 shows profiles of ϕ_s plotted against the normalized minor radius ρ. Three data sets are shown for V_{acc}=300V, 600V and 1kV. The position of the e-gun is 0.9 in this measurement.

Substantial differences of ϕ_s are clearly recognized on each magnetic surface, especially at the boundary region of the electron plasma. Two profiles of ϕ_s for each V_{acc} are measured in the z>0 and z<0 regions each other, and values at z>0 are negatively larger than z<0. The difference between the two series is alomost proportional to V_{acc}, which implies that the variation is closely related to the electron energy.

By a dimensional analysis of the force balance equation, one can find that the value of potential variation along a magnetic field line of force can be on the same order of T_e. On our experimental situation T_e is not known properly so far, but it is estimated to be some hundreds of eV, which seems to be approximately consistent with the observed potential variations. Further investigations quantitatively verifying the pontential variations will be shown later.