

### §3. Spatial Structures of Ion Flow and Electric Fields in a Diverging Magnetic Field

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It is a well-known fact that the plasma is accelerated along the magnetic field line in an inhomogeneous magnetic field region. In particular, the electrostatic acceleration dominantly takes place, when the electron temperature is higher than the ion temperature. The plasma flow is characterized by the magnetic field configuration, when both ions and electrons are magnetized. The accelerated plasma in the magnetized region flows to a weaker magnetic field region, where the ions become unmagnetized and are detached from the magnetic field lines. Since the electrons remain magnetized in this magnetic field region (ion detachment region), a relative motion between the detached ions and the magnetized electrons is generated. However, the electrostatic potential profile in the ion detachment region has not been measured so far.

In a diverging magnetic field region of an electron cyclotron resonance (ECR) plasma, we have found an evidence of the ion stream line detachment by measuring the flow velocity using a directional Langmuir probe.<sup>1)</sup> In addition, the onset of an azimuthal plasma rotation and the suppression of acceleration parallel to the magnetic field line in the ion detachment region were also observed. These results indicate that the electrostatic potential structure formed in the ion detachment region is different from that in the magnetized region.

The experiments were performed in the high-density plasma experiment-I (HYPER-I) device. The HYPER-I device has a cylindrical vacuum chamber with a diameter of 0.3 m and an axial length of 2.0 m. An ECR argon plasma was produced with a 2.45 GHz microwave injected from an open end of the chamber.

The ion flow velocity measured with the directional Langmuir probes, which were calibrated with a laser induced fluorescence spectroscopy method. An axially movable Langmuir probe was also used to measure the floating potential. Note that the floating potential profile reflects the plasma potential profile, because the electron temperature is almost uniform in our plasma.

A contour map of the ion saturation current on the  $r-z$  plane is shown in the upper box of Fig. 1, where  $r$  and  $z$  stand for the radial and the axial positions, respectively. The density decreases along the axial direction; this reflects the motion of the magnetized electrons. The electrostatic potential profile on the  $r-z$  plane is also depicted in the lower box of Fig. 1. The potential is almost uniform along the axial direction for  $z > 1600$  mm. The axial potential profile is qualitatively different from that of the density profile. Figure 2 shows the axial profile of the electrostatic potential normalized to the electron temperature. The potential profiles are flat compared with both the electron

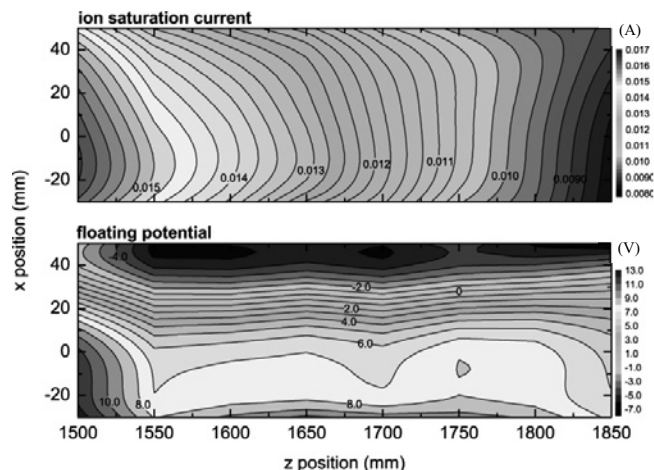


Fig. 1. The contour maps of (upper box) the ion saturation current and (lower box) the floating potential on the  $r-z$  plane in the ion detachment region.

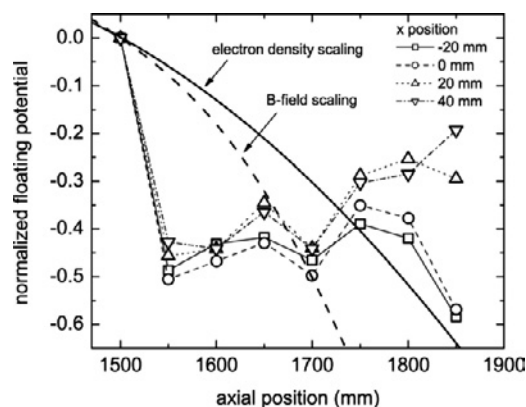


Fig. 2. The axial profiles of the normalized electrostatic potential in each  $x$  position are shown. The normalized electron density (solid line) and the magnetic field scaling (dashed line) are also shown.

density scaling and the magnetic field scaling, and the Boltzmann relation is not satisfied in the ion detachment region. In addition, the countergradient potential profile, which indicates the presence of a decelerating electric field for ions, is also found in outer plasma region.

We have measured the two-dimensional electrostatic potential profile in the ion detachment region. The electron density profile is characterized by the magnetic field scaling, but both scalings are slightly different from each other in the weaker field region.<sup>2)</sup> The electrostatic potential profile is clearly different from the scaling of the magnetic field, and the electrostatic acceleration efficiency in the weaker field region is suppressed compared with that in the magnetized region. The generation of radial electric field, which drives the azimuthal plasma rotation due to an ExB drift, is also found. These results are summarized as follows: the angular momentum generation due to the radial electric field becomes important to understand the plasma acceleration in the ion detachment region.

- 1) Terasaka, K. *et al.*: Phys. Plasmas **17**, 072106 (2010).
- 2) Terasaka, K. *et al.*: Proc. 39th EPS Conference/16th ICPP, P1.166 (2012).