§9. Study on Ion Separation by Control of Radial Electric Field in Magnetized Plasma

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In the future nuclear fusion studies, understandings of bifurcation and transport barrier and their formation mechanisms, which have been actively investigated in NIFS, are crucial for plasma confinement. Here, dynamic changes of ion trajectory, which can demonstrate the mass separation method, are studied[1)] by applying the steady or pulsed bias voltages to concentric circular rings: above the critical electric field applied, ions can escape from the main plasma. This study is related to the bifurcation study in magnetized plasma such as improvement of the plasma confinement based on the plasma rotation driven by so-called $\boldsymbol{E}\times\boldsymbol{B}$ drift, as well as the electric pulsation, bifurcation, and fine structures in CHS device.

Here, fundamental principle of mass separation is based on the ion trajectory in the presence of the crossed electric and magnetic fields in cylindrical geometry: below (above) the critical electric field, ions can be trapped in the plasma core (can escape from the plasma core). On the other hand, in the case of the parabolic potential profile, critical mass, above which ions are not trapped, is proportional to $a^2 B/V_0$, where a, B and V_0 are plasma radius, magnetic field and the central potential, respectively.

Experiments are carried out in the following conditions: With a pressure P (argon and xenon) of ~ 0.16 mTorr in the cylindrical chamber, 45 cm in diameter and 170 cm in axial length, plasma is produced by a RF wave of 7 MHz. Electric fields in the plasma is controlled using ten concentric circular rings as biased electrodes.[2-5)] Plasma parameters are measured by a Langmuir and the Mach probe, whose data are stored with a data logger. Typical plasma density and electron temperature were $2.5 \times 10^9 \sim 1.4 \times 10^{10}$ cm^{-3} cm^{-3}and 3 - 6 eV, respectively.

Figure 1 show the radial profiles of Mach number M, i.e., azimuthal rotation velocity normalized by the ion sound velocity, floating potential V_f and ion saturation current I_{is}, using Xe gas. With the increase in the bias voltage, M increases, and then decreases near the plasma edge, where V_f and I_{is} changes monotonically with this voltage near central region. Figure 2 shows that M saturates and decays in Xe discharges with the increase in the voltage difference in the plasma, whereas M does not have this feature in Ar ones. These results such as the rotation velocity as a function of external parameters is supported by simple simulation and theory.

In conclusion, we have investigated the detailed profiles of plasma parameters to demonstrate the different ion mass separation, relating to the transitions by voltage biasing. Obtained results are consistent with the expectations. These understandings will be expected to contribute to the plasma confinement and stability control.

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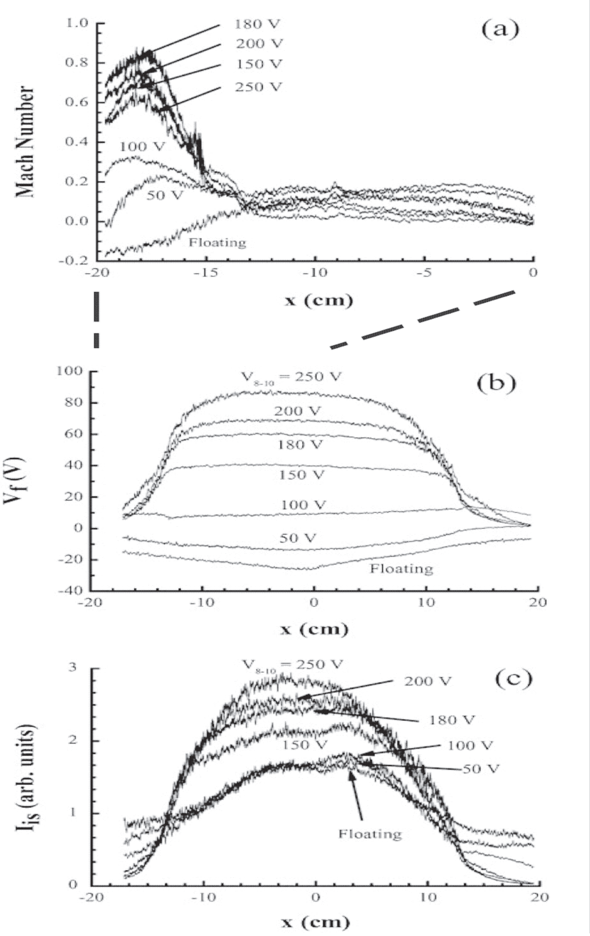

Fig. 1. Radial distributions of (a) Mach number, (b) floating potential, and (c) ion saturation current.

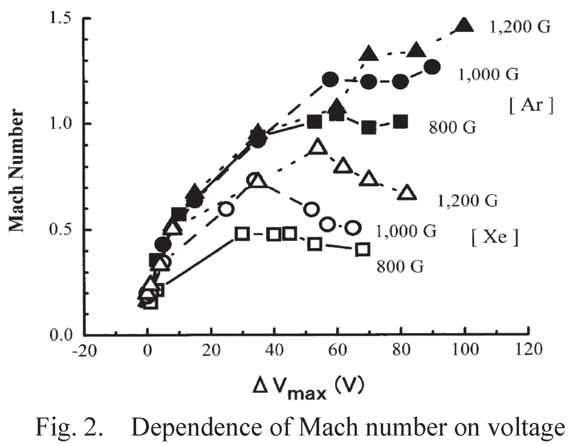

Fig. 2. Dependence of Mach number on voltage difference for various magnetic fields.