§2. Observation of Plasma Hole Transition Induced by Microwave Power Modulation

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Spontaneous formation of a stationary vortex structure with density depletion, or *plasma hole*, has been observed in a magnetized plasma. We have so far reported many characteristic properties of the plasma hole as follows. (i) The flow-velocity field is analogous to that of typhoon. (ii) The vorticity distribution is identified as Burgers vortex. (iii) Strong electric field that drives $E \times B$ rotation is attributed to anomalous quasi-neutrality breaking.

However the transitional behavior of plasma hole formation is not entirely revealed yet. In previous experiments, we have observed that the hole structure has been formed and sustained in a definite microwave power range. Thus we conducted a microwave power modulation experiment so as to investigate the detailed change in density and plasma potential. The experiment was carried out in the HYPER-I device at NIFS. A cylindrical plasma (30 cm in diameter and 200 cm in length) was produced by electron cyclotron heating. Helium gas was used at a pressure of 5.0×10^{-4} Torr. The frequency of the power modulation and the range of power variation are 0.1 Hz and 5.1 ± 3.3 kW, respectively. The temporal evolution of ion saturation current, which approximately corresponds to that of plasma density, was measured by a Langmuir probe, and that of plasma potential by an emissive probe.

Figure 1 shows the change in density and potential profile due to microwave power variation. When the microwave power is 1.8 kW, the density profile is almost flat and the potential forms a convex distribution with a gentle slope. By increasing the microwave power to a certain threshold value, which lies between 3.5 kW and 4.7 kW, an abrupt density drop in the central region takes place and the density depletion characterizing the plasma hole is established. Note that once the density hole is developed, the size of that remains unchanged. In other word, it is independent of the microwave power. In conjunction with the hole formation, the plasma potential starts building up around the central axis to establish a bell-shaped distribution. It is noteworthy that a steep gradient in potential, or strong electric field, is localized inside the hole, which gives rise to the vortex motion due to $E \times B$ drift. Moreover the potential attains its maximum value of +100 V, which is five times higher than the electron temperature.

The measurement of the evolution of flow-velocity field is planning to understand the dynamic behavior of vortex formation in detail. It should be emphasized that a definite inward-directed radial flow has been observed under the existence of hole structure in our preliminary experiments. In general, it is derived from the fluid equation that a viscous fluid with shear flow inevitably has radial flow. This fact implies that we should take a nonnegligible viscosity of the plasma into account to comprehend the property of the plasma hole integrally. In addition, a general relation between radial flow and viscosity has a possibility to provide a novel means for viscosity measurement.

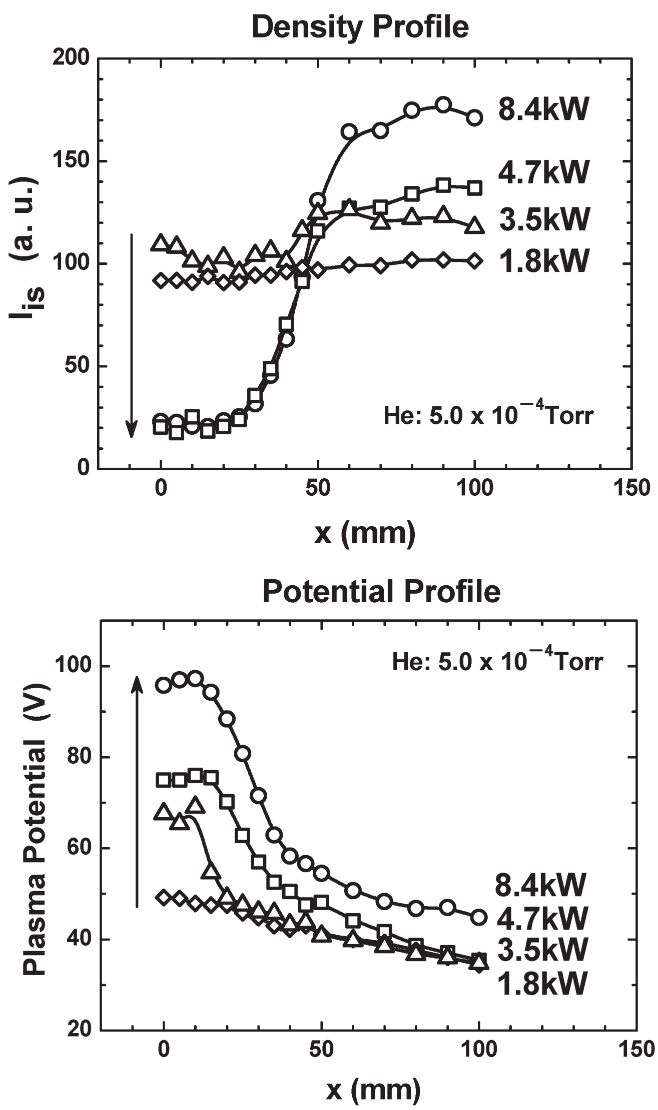

Figure 1 Change in density and potential profile due to microwave power variation.