§4. Measurement of Flow Velocity Profile in an Argon Plasma Hole Using Laser-Induced Fluorescence

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Local measurement of flow velocity is required for researches on plasma interaction with boundaries, transport physics, and non-linear plasma structures like vortex. One of the vortical structures, the "Plasma Hole," observed in an ECR plasma has eccentric feature; an $E \times B$ rotation caused by strong radial electric field produces supersonic ion flow in some cases.[1)] In order to clarify the formation mechanism of the plasma hole, precise information on ion flow velocity field is needed. For that purpose we have developed a laser induced fluorescence (LIF) Doppler spectroscopy system[2)]. Radial velocity profile of the plasma hole in an argon plasma[3)] is presented in this report.

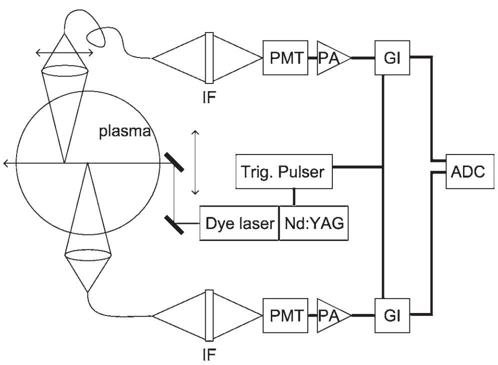

Fig. 1: Schematic of the LIF measurement system with two observation volume. IF stands for interference filter; PMT, photomultiplier tube; PA, pre-amplifier; GI, gated integrator.

The experiments were performed in the HYPER-I device at the National Institute for Fusion Science.[4)] Schematic of the LIF Doppler spectrometry is shown in Fig. 1. A tunable dye laser excited by a Nd:YAG laser was used. The laser wavelength is tuned to 611.5 nm, which excites a metastable argon ion ($3d\ ^2G_{9/2} - 4p\ ^2F_{7/2}$). The laser-induced fluorescence (461.0 nm, $4s\ ^2D_{5/2} - 4p\ ^2F_{7/2}$) from the argon ion is collected by two collecting optics and is detected by photomultiplier tubes through interference band-pass filters. Two gated integrator circuits enable us to measure two LIF spectra at different observation volume simultaneously. One of the collecting optics is used as a reference of the Doppler shift at a fixed position, while the other is moved to obtain radial profile of the Doppler shift.

Figure 2(a) shows the azimuthal flow velocity profile determined from the Doppler shifts of the LIF spectra. The azimuthal rotation is in clockwise direction, which corresponds to that of the $E \times B$ drift driven by an outward electric field. In the hole region ($|y| < 3$ cm), rigid-like rotation is clearly seen, which is the property of azimuthal flow of the plasma hole. Figure 2(b) shows the radial flow velocity profile of the argon plasma hole. In contrast to the azimuthal flow velocity, the absolute values of the velocities are considerably small. The direction of radial flow was outward in this case, which is different from the previous directional Langmuir probe measurements of the plasma hole in a helium plasma. This result implies the possibility of axial position and ion mass dependence of the flow pattern of plasma hole.

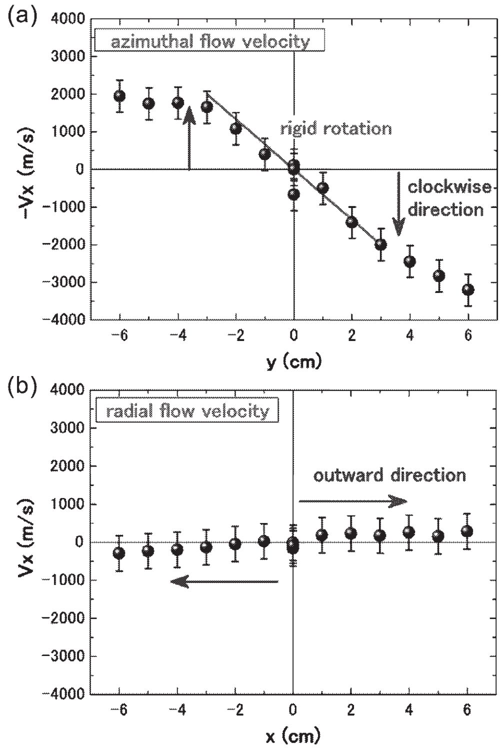

Fig. 2: Ion flow velocity profiles determined by the LIF Doppler Spectroscopy. (a) The azimuthal flow velocity profile reconstructed from axisymmetric condition. (b) The radial flow velocity profile.

1) Nagaoka, K. et al. : Phys. Rev. Lett. **89** (2002) 075001, Tanaka, M.Y. et al. : IEEE Trans. Plasma Sci., **33** (2005) 454.

2) Okamoto, A. et al.: J. Plasma Fusion Res., **80** (2004) 1003.

3) Yoshimura, S. et al. : J. Plasma Fusion Res. SERIES **6** (2004) 610, Yoshimura, S. et al. : J. Plasma Fusion Res. SERIES (2009) *in press.*

4) Tanaka, M. et al. : J. Phys. Soc. Jpn. **60** (1991) 1600.