§3. Measurement of Parallel Ion Flow Velocity in an Argon Plasma Using Laser-Induced Fluorescence

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Parallel flow along the magnetic field line has been studied extensively in various fields of plasma research. Local measurement of ion flow velocity is required for those researches. Directional Langmuir probes (DLPs)[1] or Mach probes that provide an easy-to-use way to measure ion flow velocity profiles have been widely used in preceding experiments. The ion Mach number shows nonnegligible difference depending on the model used for analysis especially in supersonic flow. On the other hand, laser induced fluorescence (LIF) method[2] has been regarded as a powerful tool for flow velocity measurement, since the absolute value can be directly obtained from the Doppler shift of the LIF spectrum. Measurement of parallel ion flow in an argon plasma[3] is presented in this report.

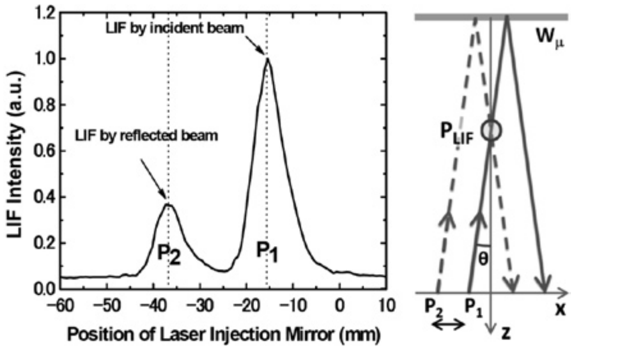

Fig. 1: The intensity of LIF signal as a function of the laser injection position. The incident angle θ is depicted in an exaggerated manner. W_μ is the microwave injection window ($z = 0$mm), $P_{\rm LIF}$ is the LIF measurement position ($z = 950$mm), P_1 and P_2 are the laser injection positions ($z = 2680$mm) of incident and reflected beams.

The experiments were performed in the HYPER-I device at the National Institute for Fusion Science.[4] An argon plasma was produced by the electron cyclotron resonance of a 2.45 GHz microwave injected from the high field side along the magnetic field. 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 and is detected by a photomultiplier tube through an interference band-pass filter.

The laser was injected from the end of low field-side. At the opposite side of laser injection, a laser beam dump or a mirror are usually equipped to absorb or to correctly reflect the incident laser. In the present experiment, the microwave injection window made of quartz was utilized to reflect the laser. The laser was injected with slightly tilted incident angle against the z-axis in order to avoid overlap of incident and reflected laser at the observation volume.

Figure 1 shows the dependence of LIF intensity on the laser injection position, where the laser wavelength was fixed at 611.492 nm and the collecting optics was fixed at a certain position. Separation of the LIF emission induced by the incident and reflected beams is successfully achieved, where the incident angle $\theta \sim 10^{-2}$ rad and can be considered as quasi-parallel to the z-axis. The spatial resolution of the LIF measurement is about 10 mm.

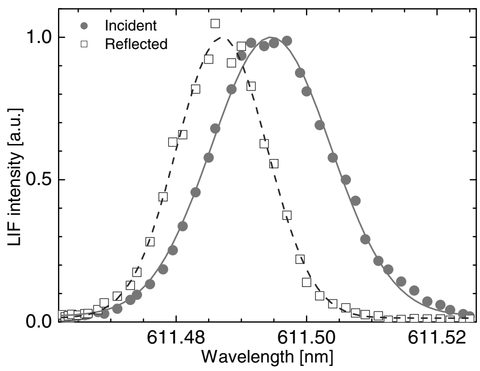

Fig. 2: LIF spectra obtained with incident laser (filled circle) and with reflected laser (open square). Intensities of both spectra are normalized to the peak intensity.

Typical LIF spectra are shown in Fig. 2. A red shifted spectrum and a blue shifted one are obtained using the incident laser and the reflected laser, respectively. The result clearly indicates that the ions are flowing toward the laser injection port. Besides the flow direction, absolute flow velocity is determined by the spectra. Separation of two peaks of the incident and reflected spectra, about 0.008 nm, results from the Doppler shift. Then the parallel flow velocity is $v_z \simeq 2$km/s in the observation volume.

Profile measurements using this measurement method are clarifying the existence of parallel flow velocity shear in radial direction and ion acceleration along the magnetic field line.[3]

1) Nagaoka, K. et al. : J. Phys. Soc. Jpn. **70** (2001) 131.

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

3) Yoshimura, S. et al. : Plasma Fusion Res. *in press.*

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