§4. Measurement of Flow Velocity around a Cylindrical Obstacle

Okamoto, A. (Tohoku Univ.),
Tanaka, M.Y. (Kyushu Univ.), Yoshimura, S.

Understanding of flow velocity field near an obstacle is an interesting topic in the research field of plasma-surface interaction as well as basic plasma physics. Probe theories applicable to ion flow measurement especially in the supersonic flow can be improved by the help of the detailed flow field around the probe.[1)] In terms of basic plasma physics, a viscosity of plasma would be determined using a flow passing by an obstacle. That permits direct comparison with the viscosity of ordinary fluid. While some simulation results are reported,[2)] experimental approach should be intensively conducted. Then the measurement method that does not disturb the plasma flow itself and that enables us to obtain local flow velocity is required. We have developed such the measurement method using the laser induced fluorescence (LIF) technique.[3)] In this report, it is described that the measurement of flow velocity near a cylindrical obstacle using the LIF method.

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. In the present experiment, the discharge condition is so chosen that parallel flow dominates both radial and azimuthal flows in the observation volume located in the diverging magnetic field region.[5)] LIF Doppler spectroscopy was used for the ion flow velocity measurement.[3)] 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 ion flow velocity along the magnetic field was measured using the quasi-parallel LIF method,[6)] where 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. This method enables us to distinguish the LIF spectrum obtained from the incident beam from that of the reflected beam, and to determine the absolute ion flow velocity from half of the shift between those LIF spectra.

Experimental setup is shown in Fig. 1. A cylindrical obstacle (x-direction) is installed perpendicular to the magnetic field (z-direction) in the center of a downstream port. The cylindrical obstacle is made of an Al_2O_3 insulating tube, diameter and length of which are $a = 1$ cm and $l = 14$ cm, respectively. Assuming the ion temperature $T_\mathrm{i} \simeq 1$eV, Larmor radius satisfies $a < \rho_\mathrm{i} < l$. The laser is injected in the quasi-parallel direction to the magnetic field, while the fluorescence is collected along a line of sight from a port perpendicular to both the magnetic field and the cylindrical obstacle. Observation volume of the LIF is about 1 cm in x direction, 0.5 cm in y direction, and 3 cm in z direction, respectively. Moving the laser injection position in y direction and moving the line of sight in z direction, two dimensional spatial distribution of the parallel flow velocity $v_z(y, z)$ is obtained.

For the first experiment, flow velocity profile perpendicular to the ion flow without the cylinder was measured by moving the laser injection position in y direction. The parallel ion flow is almost constant around $v_z \simeq 4$km/s. Then the flow velocity profile was measured with the cylindrical obstacle. The ion flow velocity at a volume 1 cm apart from the cylinder surface was about 90% of that measured without the cylinder. However, it is comparable to the fitting error of LIF spectrum in the present experimental condition. More accurate measurement is on going.

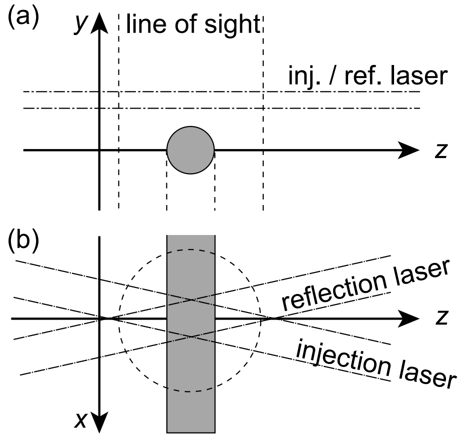

Fig. 1: Schematic of the experimental setup in (a) side view and (b) top view. Dot-dashed lines and broken lines represent footprints of the lasers and a fluorescence-collecting line of sight, respectively. Both external magnetic field and ion flow are along in z direction

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