§4. Measurement of Rotational Flow Velocity Using Laser-Induced Fluorescence Spectroscopy

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Local measurement of flow velocity is required for researches on plasma interaction with boundaries, transport physics, and non-linear plasma structure. A variety of vortical flow structures, for example, has been observed in an electron cyclotron resonance plasma,[1] and is attracting much attention with respect to self- organization and transport. These vortices have eccentric feature; one has a supersonic rotation, the other has an anti-$\boldsymbol{E}\times\boldsymbol{B}$ rotation induced by neutral pressure gradient. Thus, a direct method of absolute velocity measurement, which complement to directional Langmuir probe (DLP) [2] methods, is needed. Doppler-shifted fluorescence induced by a tunable laser (LIF) has the advantages of both spatial resolution and absolute velocity measurement.[3]

The experiments were performed in the HYPER-I device at the National Institute for Fusion Science.[4] In the present experiment, laser wavelength is tuned to 611.5 nm, which excites an Ar II metastable state (3d $^2G_{9/2}$ - 4p $^2F_{7/2}$). We observe de-excited spontaneous emission of wavelength, 461.0 nm (4s $^2D_{5/2}$ - 4p $^2F_{7/2}$). By changing injecting beam path of the laser, we can measure the rotation (azimuthal) velocity of argon plasmas.

Azimuthal velocity profile in an $\boldsymbol{E}\times\boldsymbol{B}$ rotating plasma is shown in Fig. 1. The LIF Doppler spectrum was measured at five radial points, and the velocities were determined by shifts of the central wavelength of the line profile from that obtained at r = 0. The velocities quite well agree with the $\boldsymbol{E}\times\boldsymbol{B}$ drift velocities determined by potential measurement. It is worth noting that these methods are completely independent, and therefore the consistency of the two results, as seen in Fig. 1, is very satisfactory. In addition, ambiguity of the DLP method in determining absolute velocity is removed by using LIF spectroscopy as a calibration standard.

Azimuthal velocity profile of a plasma, where the plasma rotation is dominated by neutral pressure induced $\boldsymbol{F}\times\boldsymbol{B}$ drift, is shown in Fig. 2. The velocity determined by LIF spectroscopy and that determined by DLP show reversal of rotation around r = 40 mm, while $\boldsymbol{E}\times\boldsymbol{B}$ drift velocity monotonically increase with radius indicating the flow in the center of the plasma is in anti-$\boldsymbol{E}\times\boldsymbol{B}$ direction.[5]

These results show that LIF spectroscopy is a promising tool for local and absolute measurement of flow velocity. They also suggest that a combined system of DLP and LIF spectroscopy as a calibration standard resolves the ambiguity of absolute value in the DLP method and improves reliability even if the plasma flow is dominated by other than $\boldsymbol{E}\times\boldsymbol{B}$ drift as well as in the supersonic region.[6]

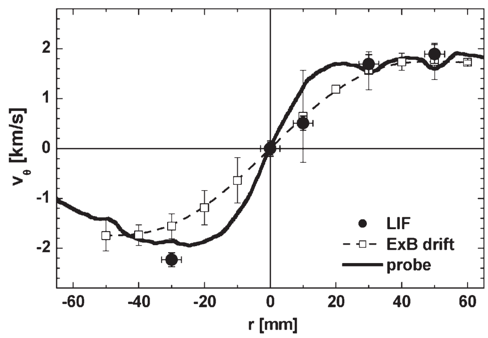

Fig. 1 Azimuthal velocity profile in an $\boldsymbol{E}\times\boldsymbol{B}$ rotating plasma. The filled circle indicates the velocity determined by LIF spectroscopy, the open square by $\boldsymbol{E}\times\boldsymbol{B}$ drift, and the solid line by DLP.

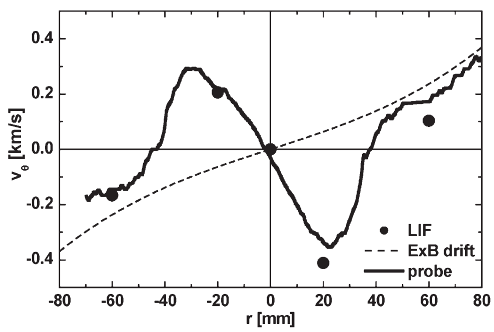

Fig. 2 Azimuthal velocity profile dominated by neutral pressure induced $\boldsymbol{F}\times\boldsymbol{B}$ drift. The direction of rotation measured by LIF spectroscopy is the same as that measured by DLP and is opposite to that of the $\boldsymbol{E}\times\boldsymbol{B}$ drift in the center of the plasma.

Reference

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