§3. Asymmetric Ion Velocity Distribution Functions in an Inhomogeneous Plasma

Yoshimura, S., Nagaoka, K., Morisaki, T.,
Okamoto, A. (Tohoku Univ.),
Aramaki, M. (Nagoya Univ.),
Ogiwara, K., Terasaka, K., Tanaka, M.Y. (Kyushu Univ.)

A velocity distribution function (VDF) is of great importance in plasma physics, since it can provide a wealth of information such as density, temperature and flow velocity of the particles of interest. Although determining the VDF from experiments has been a challenging task, it recently comes to be feasible for non-specialists to obtain VDFs of ions and neutrals by using laser-induced fluorescence (LIF) spectroscopy with a narrow bandwidth extended cavity diode laser (ECDL). Detailed measurement of VDFs opens up great possibilities to advance our understanding of plasma flow structure, because it enables us to develop a kinetic approach in place of a fluid model in which the information in the VDF is smeared out by integration. By the last fiscal year, we have developed a high resolution LIF spectroscopy system for measuring very slowly flowing neutrals.[1)] Replacing the ECDL in the system with the one whose frequency is suitable to excite metastable ions, we can obtain the VDFs of ions experimentally. In this report, a preliminary result of asymmetric ion velocity distribution functions (IVDFs) obtained in an inhomogeneous plasma with a steep ion density gradient, which is referred to as plasma hole[2)], is shown.

The experiments were performed in the HYPER-I device at the National Institute for Fusion Science. The plasma was produced by electron cyclotron resonance absorption of microwaves at 2.45 GHz under the conditions that the argon gas pressure and the microwave power were 8.3×10^{-5} Torr and 3 kW, respectively. The LIF scheme used in the present experiments is as follows: the atomic energy level terms used for laser-induced excitation ($3d^4F_{7/2}$ $-4p^4D^0{}_{5/2}$), and fluorescence ($4p^4D^0{}_{5/2}$ $-4s^4P_{3/2}$) correspond to (vacuum) wavelengths of 668.6 and 442.7 nm, respectively, for ions at rest in the laboratory frame.

Figure 1 shows a CCD image of the plasma hole together with two measurement positions indicated by open circles, A = (+5 cm, 0 cm) and B = (0 cm, +4 cm). The laser path was parallel to the x-axis in each measurement; therefore a radial IVDF in the position A and an azimuthal IVDF in the position B can be obtained. The LIF spectrum, or radial IVDF, taken at A is shown in Fig. 2. It is fitted very well with a Gaussian curve, and the ion temperature derived from the full width at half maximum (FWHM) is 1.1 eV. On the other hand, the LIF spectrum taken at B, or azimuthal IVDF, exhibits strong asymmetry as shown in Fig. 3. We consider the origin of this asymmetry may be attributable to the steep density gradient and electric field shear, which have the scale length comparable to a few ion Larmor radii, at the position B. Systematic analysis of LIF spectra is required for further understanding.

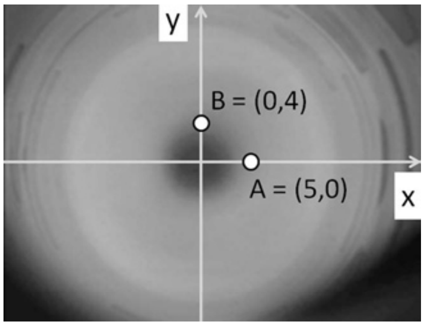

Fig. 1. A CCD image of the plasma hole. Density gradient presents between the dark region in the center and the ambient plasma, i.e. at the position B.

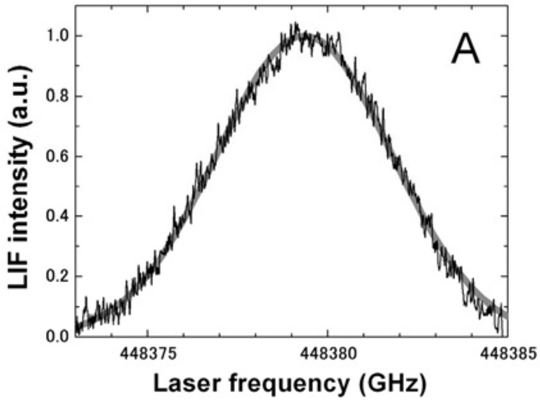

Fig. 2. The LIF spectrum (IVDF) taken at A.

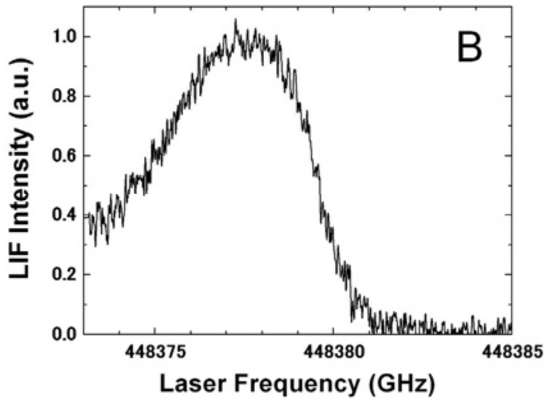

Fig. 3. The LIF spectrum (IVDF) taken at B. Strong asymmetry is evident in the IVDF.

1) M. Aramaki, K. Ogiwara, S. Etoh, S. Yoshimura, and M. Y. Tanaka, "High Resolution Laser Induced Fluorescence Doppler Velocimetry Utilizing Saturated Absorption Spectroscopy", Rev. Sci. Instrum. **80**, (2009) 053505-1 – 4.
2) M. Y. Tanaka, K. Nagaoka, A. Okamoto, S. Yoshimura, and M. Kono, "Plasma Hole", IEEE Trans. Plasma Sci. **33**, 454-455 (2005).