§2. Measurements of 2-D Distributions of Neutral-gas Flow in HYPER-I

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The experiments were performed using the high density plasma experiment (HYPER-I) device at the National Institute for Fusion Science. Anti-$\boldsymbol{E}\times\boldsymbol{B}$ type vortexes have been found in the device. The momentum exchange between neutral atoms and ions is considered to play an important role in the formation mechanism of this type of vortexes. Thus, the measurement of the neutral gas flow is fundamentally important. Since the flow velocity of Ar I is expected to be of the order of $10^1 \sim 10^2$ m/s, the drift of Doppler spectrum corresponding to this velocity range is significantly smaller than the width of Doppler broadening at room temperature. Therefore, the high-accuracy calibration of the laser wavelength is needed to detect the small drift. Here, we calibrate the absolute wavelength using a Doppler free spectrum obtained by the saturated absorption (pump-probe) spectroscopy. A Fabry-Perot interferometer is used as frequency markers when the laser is operated in the frequency scanning mode. This study aims to get the 2-D distribution of neutral gas flow using the laser induced fluorescence (LIF) spectroscopy.

The size of a cylindrical vacuum vessel is 30 cm in diameter and 200 cm in axial length. Plasma is generated by electron cyclotron resonance (ECR) heating. The frequency of microwave was 2.45 GHz. Here, the input power and the argon gas pressure were fixed at 250 W and 1.0×10^{-2} Torr, respectively. Figure 1 shows the LIF scheme used in this study. Here, we used Racah (j-l coupling) designation. Ar I metastable atoms populated in $4s[3/2]^0_2$ state are excited to $4p'[1/2]_1$ state by an extended-cavity diode laser (ECDL) tuned at 696.73 nm. The output power of the ECDL was 16 mW. The direction of the polarization of the laser is aligned with the magnetic field. By sweeping the laser wavelength around the resonance center of π components of $4s[3/2]^0_2$ - $4p'[1/2]_1$ transition, we obtain the fluorescence of 826.68nm caused by decaying $4p'[1/2]_1$ atoms to $4s'[1/2]^0_1$. LIF was detected using a photomultiplier tube (PMT) installed on a horizontally movable stage placed on the top viewing port of the vacuum vessel. We adopt the Lamb dip of $4s[3/2]^0_2$ (M_J = 0) - $4p'[1/2]_1$ (M_J = 0) transition of Ar I metastable as a frequency standard. The excitation laser of LIF spectroscopy was used as a pump laser in the saturated absorption spectroscopy. The transmitted laser beam is reduced to 1% by a neutral density (ND) filter and reflected back by a mirror along the same path of incident beam. This backward beam is used as the probe beam of saturated absorption spectroscopy. The absorption signal of the probe beam was detected using a photo diode. To ensure the accuracy of the frequency calibration of the laser, the saturated absorption spectrum and the fringes of Fabry-Perot interferometer were simultaneously recorded with the Doppler LIF spectrum. Figure 2 (a) shows a Doppler LIF spectrum that was observed at the center of the vacuum vessel. Figure 2 (b) shows a saturated absorption spectrum that was composed of the Doppler-broadened absorption spectrum and the three Doppler-free Lamb dips. The Lamb dips are originated on the Zeeman splitting of the fine structures of $4s[3/2]^0_2$ and $4p'[1/2]_1$ states. The center dip is M_J = 0 to 0 transition. Figure 2 (c) shows fringes of Fabry-Perot interferometer. The frequency between each fringe was 299 MHz. By combining the two calibration methods, the laser frequency was accurately calibrated through the frequency scan. The deviation of observations estimated for 20 discharges was 2.6 MHz. The radial distribution of the flow of Ar I metastable was observed using the optical system in the low-density ECR plasma (Fig.3). We are trying to measure the radial flow in higher-density ECR plasma.

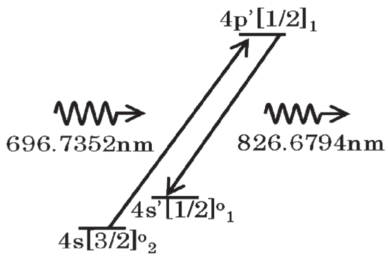

Fig. 1 LIF scheme

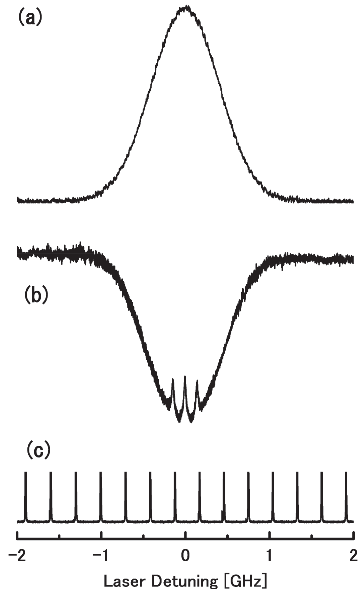

Fig.2 (a) LIF spectrum, (b) saturated absorption spectrum, (c) fringes of Fabry-Perot interferometer

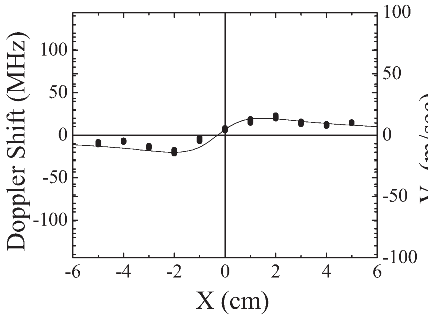

Fig.3 Radial flow of metastable Argon.