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

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Anti-$\boldsymbol{E} \times \boldsymbol{B}$ type vortexes have been found in a high density ECR plasma generated by the HYPER-I device at the National Institute for Fusion Science. The momentum exchange between neutral atoms and ions is considered to play an important role in the formation mechanism of this type of vortexes. The objective of the study is to get the 2-D map of neutral gas flow using the laser induced fluorescence (LIF) spectroscopy in the high density ECR plasma. However, the measurement of the neutral atoms is not so easy in such a condition, because the metastable atoms which are used for optical measurements will be quenched by electron collisions in high density plasma. As the beginning phase of the neutral gas flow measurements, Doppler laser absorption spectroscopy and LIF spectroscopy of argon metastable atoms are performed in a high power target plasma (2.45 GHz, 5 kW) and a low power reference plasma (2.45 GHz, 40W), respectively.

The schematic diagram of laser absorption spectroscopy and Doppler LIF spectroscopy is shown in Fig. 1. The wave length of the ECDL is tuned to 696.735 nm, which excites the $4s'[3/2]^o_2$ state of argon atom to the $4p'[1/2]_1$ state. The maximum laser power was 17 mW. A Fabry-Perot interferometer (FPI) is used to confirm single-mode oscillation of the ECDL. The free spectral range (FSR) of the FPI is 300MHz. The fringes of FPI are also used as a scale of frequency of the ECDL. A 1/2 wavelength plate was used in order to make the polarization direction of the laser light parallel to magnetic field. Doppler spectrum of argon atoms is observed by sweeping the wavelength around the resonant wavelength of the $4s'[3/2]^o_2$ - $4p'[1/2]_1$ transition. In the case of absorption spectroscopy, the laser light was attenuated to less than 100 μW using a neutral density (ND) filter so as to avoid saturation of laser absorption. Absorption spectra were detected by photo diodes and recorded by a computer. In the case of LIF spectroscopy, the excitation laser is chopped by an optical chopper at the frequency of 2.4 kHz. The deexitation to $4s'[1/2]^o_1$ state was observed as 826.679 nm fluorescence. A LIF detection box assembled from a focusing lens, slit, interference filter, photomultiplier tube (PMT), and shield box was mounted on a movable stage which was installed on the vacuum chamber. Signals from PMT were phase-detected by a lock-in amplifier and recorded by a data logger.

Absorption spectra were measured in the reference and target plasmas generated at 40 W and 5 kW microwave power, respectively. Figure 1 shows that the absorption rate of the target plasma was about 20% of the absorption rate of reference plasma. It means that the increase of the quenching rate of metastabe atom by electron collision is higher than the increase of the excitation rate of Ar atom in the target plasma. In addition to the decrease of the metastable density, the increase of the optical emission from plasma makes the S/N worse. Here, the optical emission from the target plasma was 8 times stronger than that of the reference plasma. From these results, we expect that the LIF signal which quality is comparable with that observed in reference plasma can be obtained in the target plasma by improving the S/N of the present detection system 40 times. Figure 3 shows a Doppler LIF spectrum observed in the reference plasma. It was sufficiently clear to discuss about the neutral gas flow. We are developing the detection system which can observe a LIF signal in sufficient accuracy also in the target plasma by increasing the chopping frequency from 2.4 kHz to 100 kHz.

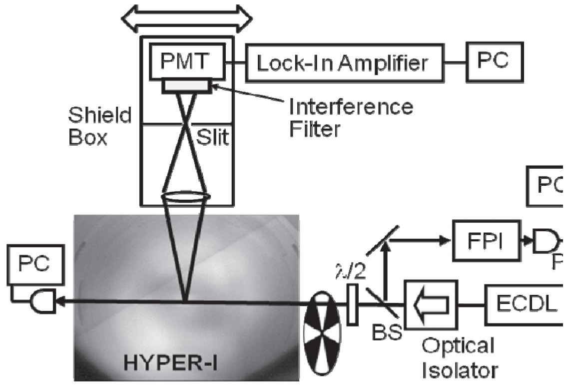

Fig. 1 Experimental setup for laser absorption and LIF spectroscopy.

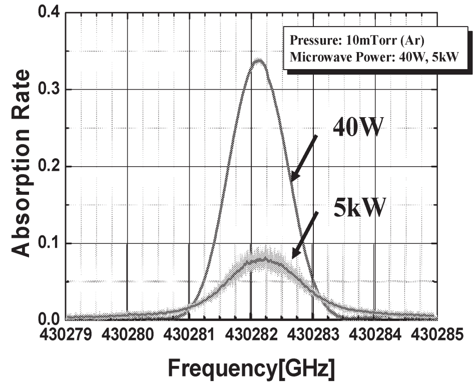

Fig. 2 Absorption spectra of Ar metastable atoms.

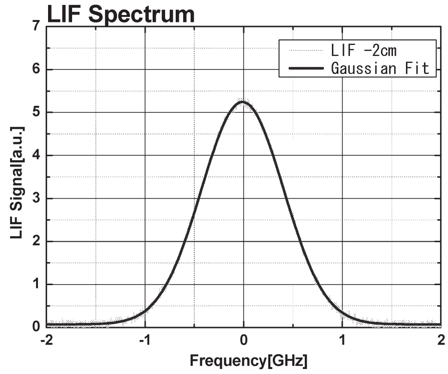

Fig. 3 LIF spectrum of Ar metastable atoms (40W discharge).