§5. 2-D Optical Emission Spectroscopy in the HYPER-I Device

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The formation of anti-$\boldsymbol{E}\times\boldsymbol{B}$ type vortexes have been found in the high density plasma experiment-I (HYPER-I) device at the National Institute for Fusion Science. Since the anti-$\boldsymbol{E}\times\boldsymbol{B}$ type vortexes are always accompanied by deep neutral depletion, the dynamic pressure of the neutral gas flow generated by the steep neutral density gradient is expected to play an important role in the formation of the vortexes. We have developed an accurate laser induced fluorescence (LIF) measurement system[1, 2]. The neutral flow has been observed using the LIF system. The observed 2-D neutral gas flow field was consistent with our model of the anti-$\boldsymbol{E}\times\boldsymbol{B}$ type vortexes generation.

This study aims at performing 2-D optical emission spectroscopy of the ECR plasma using an image intensified CCD (ICCD) camera. The spatial distributions of electron density and temperature will be obtained by analyzing the optical emission images using a collisional–radiative model (CRM). In highly ionized plasmas, electron pressure can be comparable to neutral gas pressure and sustain the neutral depletion. By combining the 2-D electron distribution measurements with 2-D flow field measurements, the deeper understanding of the mechanism of the anti-$\boldsymbol{E}\times\boldsymbol{B}$ type vortexes generation will be gained.

The dimensions of the HYPER-I vacuum vessel are 30 cm in diameter and 200 cm in axial length. Plasma is generated by ECR heating. The power of microwave was 5 kW at 2.45 GHz. The argon gas pressure was 1.2×10^{-2} Torr. We developed a 2-D OES measurement system using an ICCD camera (Princeton Instruments) equipped with a camera lens (Nikon AF Nikkor ED 80-200 mm). An interference filer is inserted between the camera lens and the ICCD camera for the measurement of an individual emission line. Since the optical access to the plasma is limited, optical emission is observed from the off-axis end viewport of the cylindrical vacuum vessel (Fig. 1).

This year, we performed a preliminary optical emission measurement using the imaging system with a 750-nm interference filter ($\Delta\lambda = 10\mathrm{nm}$). Figure 2 shows an image of 750-nm emission of the ECR Ar plasma. The bright region at the lower left is the center of the plasma. As seen from the image, interference fringes appeared around the circumference of the field of the view. It might arise from the incidence angle of light. To decrease the interference fringes, the inserting position of the interference filter should be optimized. Since the intensity of the optical emission was enough strong, the (old) ICCD camera might be replaced by a cooled CCD camera to improve the signal-noise ratio.

We plan to analyze the images taken at individual emission lines using a line intensity ratio method based on simplified CRM. Investigation of an analysis model suitable for the high-density plasma is also a subject of the next research.

[1] K. Ogiwara, M. Aramaki, S. Yoshimura Y. Itoh, Y. Kato and M. Y. Tanaka, Lamb-dip Laser Induced Fluorescence Method for Measuring Magnetic Field in a Plasma, Jpn. J. Appl. Phys. **50**, 036101-1-5, (2011).

[2] M. Aramaki, K. Ogiwara, S. Etoh, S. Yoshimura, and M. Y. Tanaka, Measurement of neutral flow velocity in an ECR plasma using tunable diode laser LIF spectroscopy combined with saturated absorption spectroscopy, Journal of Physics: Conference Series, **227**, 012008, (2010).

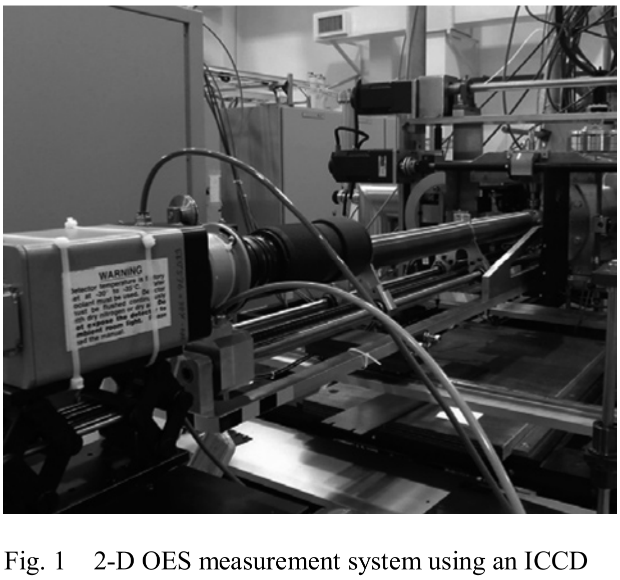

Fig. 1 2-D OES measurement system using an ICCD camera.

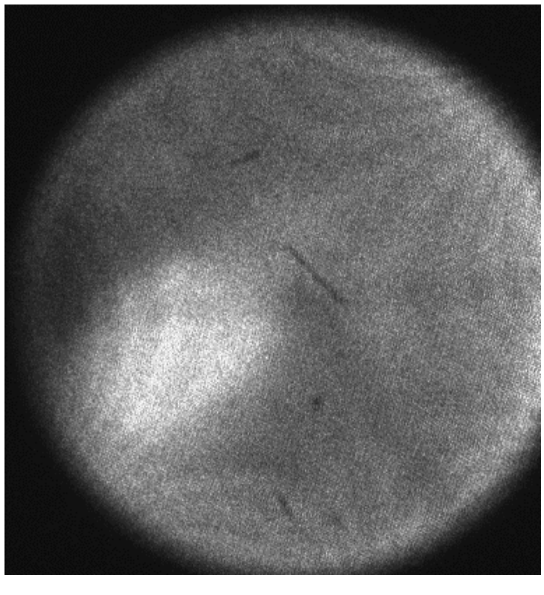

Fig. 2 Image of 750-nm emission taken by the ICCD camera with an interference filter.