§15. Observation of Flow and Ion Temperature of Carbon Impurities in the Ergodic Layer of LHD

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The effects of thick stochastic magnetic field layer located outside the core plasma of Large Helical Device (LHD) called "ergodic layer" on the impurity transport have recently attracted attention. A precise measurement on the spatial profile of impurity line emissions in the ergodic layer is required to investigate the impurity transport in such stochastic magnetic field. The vacuum ultraviolet (VUV) lines from impurity ions are significantly emitted in the ergodic layer because the electron temperature around the last closed flux surface (LCFS) ranges from 10 to 500 eV. Therefore, space-resolved spectroscopy using a 3 m normal incidence VUV spectrometer was developed to measure the intensity profiles of the VUV emission in wavelength range of 300-3200 Å from impurities in the ergodic layer.[1)]

Figure 1 shows an observation range of the VUV spectroscopy and edge magnetic fields with magnetic axis R_{ax} = 3.9 m and the toroidal magnetic field B_t = 2.539 T. The VUV spectrometer was installed on a horizontal diagnostic port (#10-O). The optical axis was arranged perpendicular to the toroidal magnetic field in the bottom edge at holizontally-elongated plasma cross section to adjust the observation range, in which the vertical profile of VUV emissions was measured, to the ergodic layer.

Figure 2 (a) shows the vertical profiles of CIV line intensity with the wavelength of 1548.20 × 2 Å. It is known that the spatial profile of the CIV intensity has a steep peak in the ergodic layer. CIV emission is released only in the outermost region of the ergodic layer in LHD plasmas because the low ionization energy of 65eV for C^{3+} ions causes less fractional abundance in the core plasma. Therefore, the peak of the intensity profile outside LCFS shown in Fig. 2 (a) is a result of line integration in a long path along the sightline through the ergodic layer at the bottom edge of the holizontally-elongated elliptical plasma. Figure 2 (b) shows the profiles of ion temperature T_i derived from the Doppler broadening of CIV spectra. The T_i profile also indicates the edge T_i in the ergodic layer at corresponding vertical position.

Figure 3 shows relative flows along the observation chords located at vertical positions corresponding to Z = -454, -403, and -369 mm on the horizontal axis of Fig. 2 as a function of the averaged electron density. The relative flows were derived by the Doppler shift of the CIV spectra taking the spectra measured in the case of $n_e = 0.8 \times 10^{13}$ cm^{-3} as references of the flows. Negative values in the vertical axis indicate increment of flows directing toward the outer horizontal diagnostics port. As shown in Fig. 3, the relative flow increased with the electron density. A three-dimensional simulation code EMC3-EIRINE predicts that a friction force between bulk ions and impurity ions becomes dominant in the parallel impurity momentum balance in the ergodic layer when the electron density is increased[2)]. It results in impurity flows toward the divertor plates, which is the main mechanism of the impurity screening phenomena. Now we are comparing the results of experiment and calculation to validate the measurements of the impurity flows.

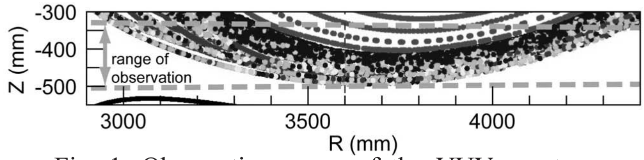

Fig. 1. Observation range of the VUV spectroscopy and edge magnetic fields.

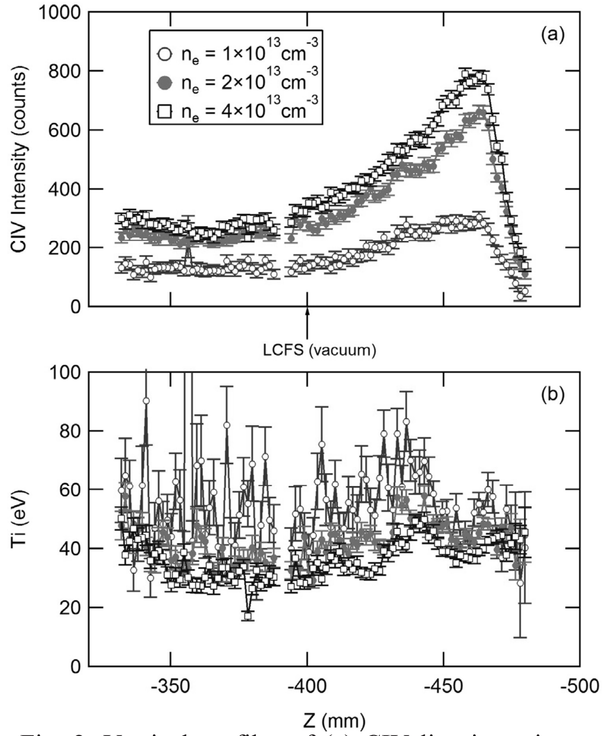

Fig. 2. Vertical profiles of (a) CIV line intensity and (b) ion temperature derived from the Doppler broadening of CIV spectra.

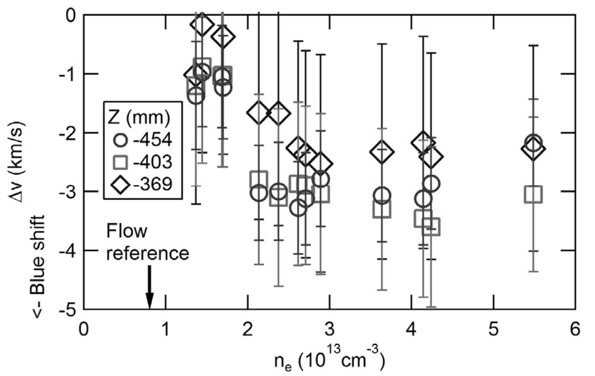

Fig. 3. Relative flow along the observation chords located at several vertical positions as a function of the averaged electron density.

1) Oishi, T. et al.: Applied Optics **53** (2014) 6900.
2) Kobayashi, M. et al.: Nuclear Fusion **53** (2013) 033011.