§16. Ion Temperature Measurement of Carbon Impurities in the Ergodic Layer of LHD Using 3 m Normal Incidence VUV Spectrometer

Oishi, T., Morita, S., Dong, C.F., Wang, E.H., Huang, X.L., Zhang, H.M., Goto, M.

The effects of thick stochastic magnetic field layer located outside the core plasma of LHD called "ergodic layer" on the impurity transport have recently attracted attention. A space-resolved vacuum ultraviolet (VUV) spectroscopy using a 3 m normal incidence spectrometer (McPherson model 2253) is utilized to measure impurity emission profiles in the ergodic layer and divertor plasmas of LHD in wavelength range of 300 - 3200 Å.[1,2] The spectrometer is installed on a horizontal diagnostic port (#10-O). The vertical profile of VUV emissions as a wavelength-dispersed image is projected on a CCD detector by a slit for spatial resolution called "space-resolved slit" mounted between the entrance slit and the grating in the spectrometer. 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 to the ergodic layer. The observation range can be expanded to measure the full plasma profile with wider viewing angle by inserting a mirror unit which consists of a flat mirror and a cylindrical mirror installed between the spectrometer and the torus.

Figure 1 shows the observation range of VUV spectroscopy for the full profile measurement on the poloidal cross section with the magnetic axis of R_{ax} = 3.75 m. Full vertical intensity profile of CIV 1548.20 × 2 Å spectrum measured for a hydrogen discharge with electron density $n_e \sim 6.0 \times 10^{13}$ cm^{-3} is also shown together. We can find intensity peaks at both top and bottom edge of the intensity profile indicated by the solid allows in Fig. 1. at Z = 471 mm and -451 mm. They are exactly located along the top and bottom edge of the ergodic layer, which are called "edge O-points". It has been experimentally certificated that the CIV emission is located in the outermost region of ergodic layer because the ionization energy of 65 eV for C^{3+} ions is extremely low compared to the edge temperature of LHD plasmas. Therefore, long integral paths along those observation chords result in peaks around the LCFS in the intensity profile. On the other hand, the observation chords at the CIV intensity peaks indicated by the dotted allows at Z = 135 mm and -65 mm are located on the outboard divertor legs. It is a clear experimental demonstration for a three-dimensional simulation results calculated by EMC-EIRINE3 indicating that C^{3+} ion density increases around the divertor legs near the edge X-point in high density discharges.

Space-resolved measurement can provide vertical profile of ion temperature, T_i. Figure 2 shows T_i obtained from Dopplar broadening of CIV spectrum with R_{ax} = 3.60 m. T_i measured using observation chords locating top and bottom edge O-points and inboard X-point is plotted against edge electron density, $n_e(a_{99})$, which is defined as electron density at the effective minor radius enclosing 99 % of the electron stored energy. It is the first observation that suggests T_i measured in the edge O-point is higher than that measured in the edge X-point. It also indicates that difference of T_i between O-point and X-point is enhanced in the case with higher T_i and lower n_e. The variety of T_i along the poloidal location includes a result of heat and particle transport characteristics in the ergodic layer and difference of a line integral effect between observation locations. This should be clarified as a future subject on the transport study in edge plasmas.

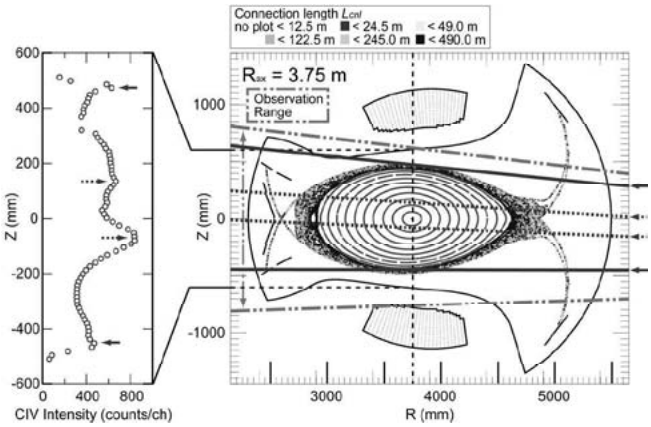

Fig. 1. The observation range of VUV spectroscopy shown on the poloidal cross section of LHD together with full vertical profile of line intensity of CIV 1548.20 × 2 Å spectrum.

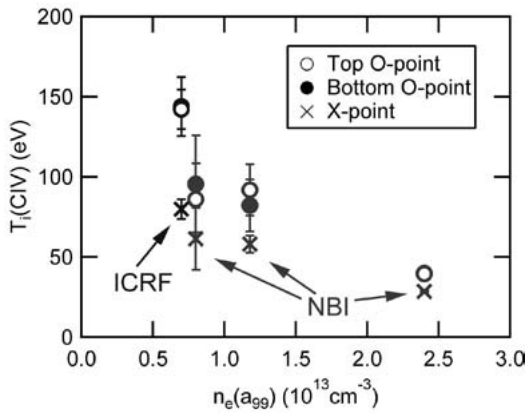

Fig. 2. Dependence of ion temperature T_i obtained from Dopplar broadening of CIV spectrum on edge electron density $n_e(a_{99})$.

1) Oishi, T. et. al.: Plasma and Fusion Research **8** (2013) 2402093.
2) Oishi, T. et. al.: Journal of the Korean Physical Society **64** (2014) 840.