§7. Measurements of Visible Forbidden Lines and Ion Distributions of Tungsten Highly Charged Ions at the LHD

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i) Introduction Visible forbidden lines of highly charged ions (HCIs) of heavy elements have potential usefulness for diagnostics of heavy impurity ions in fusion plasmas. Recently, a visible magnetic-dipole (M1) line of Cd-like W^{26+} has been observed at 389.4 nm by means of electron beam ion traps (EBITs)[1, 2] and Large Helical Device (LHD)[3]. The line has been identified as the ground-term fine-structure transition of $4f^2\ ^3H_5$ - $^3H_4$. In the present work, a vertical distribution of the M1 line intensity in a horizontally elongated poloidal cross section was investigated, and further measurements of visible lines of tungsten HCIs have been conducted at the LHD using a spectrometer of a smaller focal length and a smaller F-number.

ii) Vertical distribution of an M1 line intensity of W^{26+} Using an optical fiber array, photon emission was observed at 44 lines of sight divided along the vertical direction (Z) of the horizontally elongated poloidal cross section. Figure 1 shows the vertical distribution of the M1 line intensity measured for $t = 3800 - 3940$ ms in a LHD discharge (No. 108785). A tungsten pellet (TESPEL) was injected at $t = 3800$ ms. Central electron temperatures decreased from about 2 keV down to 850 eV during the measurement. The distribution is fitted to a Gaussian distribution in the figure. The fitting gives a peak located near the plasma center $Z = 0$. Using a radial profile of electron temperatures measured at $t = 3933$ ms by the Thomson scattering system of the LHD, a radial distribution of W^{26+} ions was calculated. A peak of the radial distribution is apart from the plasma center (major radius $R = 3.6$ m), which is inconsistent with the vertical profile of the M1 line intensity. This discrepancy may be ascribed to inaccuracy of ionization and recombination rate coefficients and/or ionization-equilibrium assumed in the present calculations. Further investigation will be addressed in future works.

iii) Tentative assignments of new visible lines of tungsten HCIs In Figure 2, line-integrated spectra along two lines of sight are compared. One is integrated along a line of sight at a small vertical position ($Z = 2.6$ cm), and the other is along that at a large vertical position ($Z = 49.5$ cm) of a horizontally elongated poloidal cross section. The former line of sight passes through about the plasma center, whereas the later grazes peripheral regions of the poloidal cross section. By comparing the two spectra, emission lines from the core plasma can be identified, which are indicated by arrows in the figure. Two of them are assigned to the previously identified M1 line of W^{26+} and a visible line of W^{24+} ions, respectively. The other lines are presumably also visible lines of tungsten HCIs.

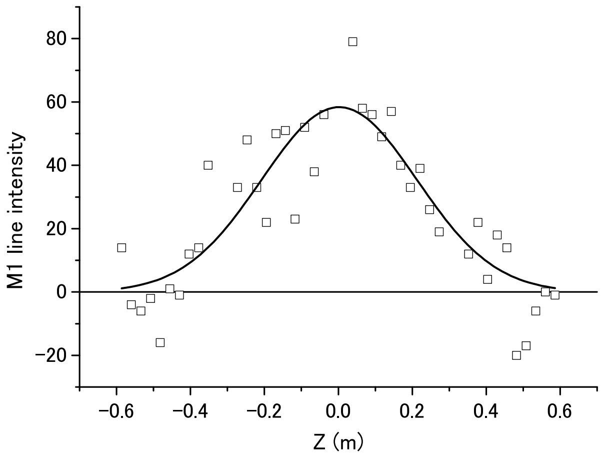

Fig. 1: Vertical distribution of a M1 line (389.4 nm) intensity of W^{26+}.

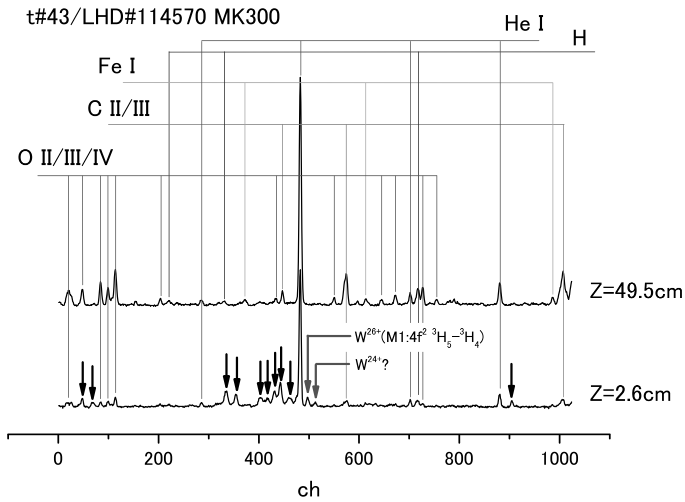

Fig. 2: Line-integrated spectra measured for $t = 4200 - 4238$ ms (No. 114570). A tungsten pellet was injected at $t = 4060$ ms. Central electron temperatures decreased from about 1 keV down to 250 eV during the measurement.

1) A. Komatsu *et al.*, Phys. Scr. (2011) T144 014012; Plasma Fusion Res. (2012) vol.7 1201158.

2) H. Watanabe *et al.*, Can. J. Phys. (2012) vol.90 497.

3) D. Kato *et al.* to be published in a topical issue of Phys. Scr. as proceedings of the 16th Int. Conf. on the Phys. of Highly Charged Ions (HCI2012), Heidelberg, Germany, 2-7 Sept. 2012.