§4. Study on Non-equilibrium Ionization of Highly Charged Tungsten Ions by Using Forbidden Lines

Kato, D., Sakaue, H.A., Murakami, I., Goto, M.,
Oishi, T., Morita, S., Tamura, N.,
Fujii, K. (Kyoto Univ.), Nakamura, N. (ILS/UEC),
Koike, F. (Sophia Univ.), Sasaki, A. (JAEA)

A novel idea of this work is to use near UV-visible forbidden lines to measure W^{q+} ions distributions in the Large Helical Device (LHD). Inherently narrow natural width of the forbidden lines is a suitable feature for identifying a specific charge state of ions in emission spectra. In the last LHD cycles, wavelengths of emission lines from tungsten highly-charged ions have been precisely measured for 320 − 356 nm and 382 − 402 nm by tungsten pellet injection. In the present work, the tungsten emission lines were assigned based on its line-integrated intensity profiles on a poloidal cross section. The ground-term magnetic-dipole (M1) lines of $W^{26+,27+}$ and an M1 line of a metastable excited state of W^{28+}, whose wavelengths have been determined by measurements using a compact electron-beam-ion-trap (CoBIT), were identified in the LHD spectra. The present results partially compliment wavelength data of tungsten highly-charged ions in the near UV-visible range.

Discharges for present measurements were started with electron cyclotron heating followed by hydrogen neutral beam injection (NBI) heating. In steady state, the maximum electron temperature is about 3 keV at the plasma center. Then, a polyethylene pellet containing tungsten wire (0.6 mm long and 0.15 mm diameter) was injected into background hydrogen plasmas. Time-resolved (sampling time of 38 ms at every 100 ms) measurements were performed using Czerny-Turner UV-visible spectrometers equipped with CCD detectors. Using an optical fiber array, photon emission was observed at 44 lines of sight divided along the vertical direction of a horizontally elongated poloidal cross section.

Fig. 1 shows examples of measured spectra for 330 − 340 nm (shot no. 121534). We could identify 11 lines of W^{q+} ($q = 20-28$) in 320−356 nm and 382−402 nm. Among them, three lines are identified as ground-term M1 lines of W^{26+}, *i. e.* $(4f^2)$ $^3F_4$ - $^3F_3$, $^3F_4$ - $^1G_4$, and $^3H_5$ - $^3H_4$. One line is that of W^{27+}, *i. e.* (4f) $^2F_{7/2}$ - $^2F_{5/2}$. Another is an M1 line in a metastable excited state of W^{28+}, *i. e.* $(4d^9 4f)$ $(5/2,5/2)_3$ - $(5/2,7/2)_4$. Spatial distributions of those M1 line intensities in the core plasmas were deduced by Abel inversion of line-integrated intensities on a cross-section of a helical plasma torus (see Fig. 2), which will be compared to the emisivities of the M1 lines calculated by using ionization and recombination rate coefficients and ion transport coefficients.

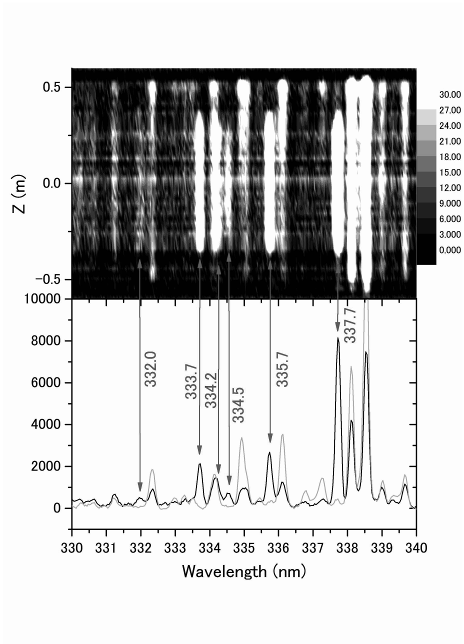

Fig. 1: Upper panel shows vertical distribution of line-integrated intensities. Solid indicates spectra measured after tungsten injection ($t = 4.1-4.138$ s), and light gray those before the tungsten injection. Red arrows indicate the emission lines assigned to tungsten. Numbers are the central wavelengths in nm.

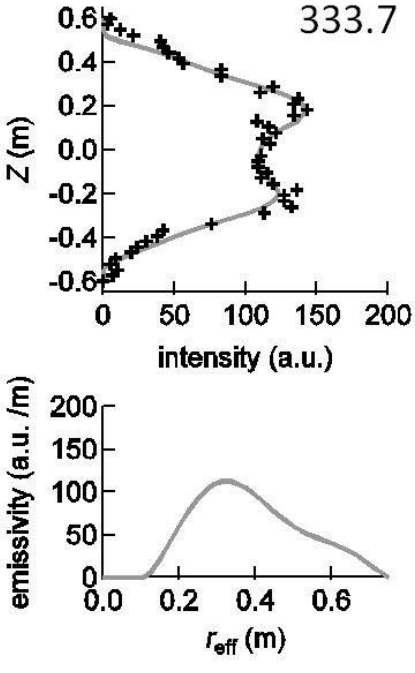

Fig. 2: Radial distributions for the M1 line of W^{26+} $(4f^2)$ $^3F_4$ - $^3F_3$ at 333.7 nm.