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


A novel idea of this work is to use 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 cycle, an M1 line of W^{27+} has been clearly identified, and its intensity distribution on a poloidal cross section was measured. The measured intensity distribution was compared with calculated W^{27+} ion distribution.

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 solid pellet containing tungsten 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 40 lines of sight divided along the vertical direction (Z) of a horizontally elongated poloidal cross section.

Fig. 1 shows a UV line emission measured after a tungsten pellet injection. The line at 337.82 nm is identified as the magnetic-dipole (M1) transition, 4f^{2}F_{5/2} \rightarrow 2F_{7/2}, of W^{27+} ions. This M1 line has been discovered by using an electron beam ion trap at Fudan University 1); its wavelength was determined to be 337.84 nm. Vertical profile of the M1 line emission indicates a line intensity distribution localized inside the core plasma where electron temperatures are high enough to produce the W^{27+} ions. In the spectrum, another three lines are also identified as emission lines of W^{q+} ions, because its vertical profiles are similar to that of the M1 line at 337.82 nm.

Fig. 2 shows an intensity distribution of the M1 line along the effective small radius, which is transformed from the vertical profile. In the ionization equilibrium assumption, W^{27+} ion distributions are calculated using a measured T_e profile and available data for ionization/recombination rate coefficients. ADPAK data gives the ion distribution consistent with the M1 line intensity distribution.