§7. Simultaneous Spectroscopic Measurements of Wide Wavelength Range for W Ions in LHD Plasmas

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Tungsten is plasma-facing material for the first wall in ASDEX Upgrade and divertor plates in JET and the ITER. Tungsten is sputtered and the spectral data are needed for spectroscopic diagnostics to examine impurity transfer and W concentration in fusion plasmas. Many experimental and theoretical studies have been carried out to identify W spectral lines and to understand characteristics of W spectra, such as unresolved transition arrays (UTAs) at wavelength region 4 – 7nm seen for plasmas with electron temperature around 1keV[1]. An impurity pellet or a TESPEL with tungsten is injected into LHD plasmas and we have measured various tungsten spectra from extreme ultraviolet (EUV) to visible region simultaneously to understand characteristics of the spectral feature.

In the 18th cycle experimental campaign, we tried to measure low charged W ions in LHD plasmas. There are several theoretical studied on W^{13+} ions to determine the atomic structure[2], since the ground state of Pm-like ions would change from $4f^{13}5s^2$ to $4f^{14}5s$ at a high Z element and strong 5s-5p transition was predicted by Curtis and Ellis[3] but not measured experimentally yet. The ground state of W^{13+} is now thought to be $4f^{13}5s^2$. Figure 1 shows calculated spectra of W XIV and W XV using a collisional-radiative model for which atomic data are calculated with the HULLAC atomic code[4].

Figure 2 shows spatial profiles of electron density and temperature for discharge #125869 with tungsten pellet injection at t=4.0 s. The electron temperature and density decrease at the central region due to radiation power loss of tungsten, and the central electron temperature became almost 0 at t=5.433 s. Figure 3 shows EUV spectra for the same discharge. The 5-nm UTA seen at t = 5.325 s nearly disappears at t = 5.425 s. This indicates W^{q+} ions with q>22 disappear. Figure 4 shows EUV spectra at 17-28 nm. It is difficult to identify the spectral structure of W XIV predicted by the calculation, however a peak at about 20.2nm seen in both spectra at t = 5.35s and 5.45s could be produced by low charged tungsten ions in low electron temperature region. We need further investigation on both measured EUV spectra and calculated ones in more detail for future study.

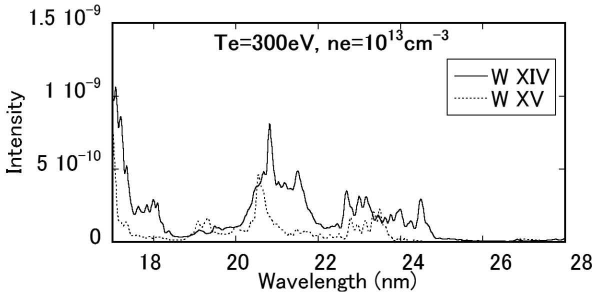

Fig.1 Calculated EUV spectra for W XIV and W XV using a collisional-radiative model with electron temperature 300eV and electron density $10^{13}cm^{-3}$ assumed.

1) Pütterich, T. et al., Plasma Phys. Control. Fusion **50**, 085016 (2008).

2) Safronova, U. I. et al., Phys. Rev. A **88**, 032512 (2013).

3) Curtis, L. J and Ellis, D. G., Phys. Rev. Lett. **45**, 2099 (1980)

4) Bar-Shalon, A. et al., J. Quant. Spect. Rad. Transf. **71**, 179 (2001).

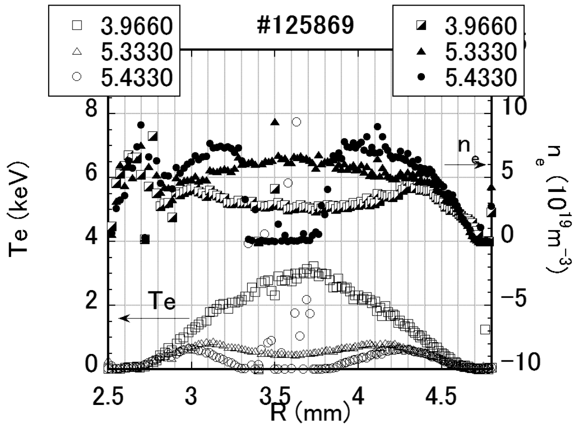

Fig. 2. Spatial profiles of electron density (upper) and temperature (lower) measured by a Thomson scattering for discharge #125869.

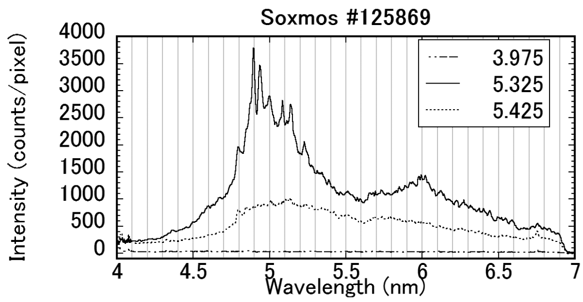

Fig.3 EUV spectra at wavelength region of 4 – 7 nm taken by SOXMOS for #125869. The 5-nm UTA is seen at t = 5.325s but not at t = 5.425s.

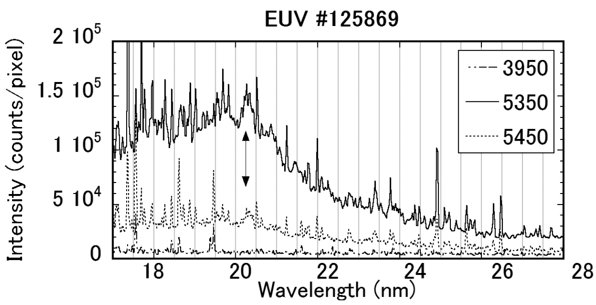

Fig. 4 EUV spectra at wavelength region of 17-28nm taken by an EUV spectrometer for #125869. A peak at around 20.2nm could be produced by low charged tungsten ions.