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Observation of tungsten UTA spectra in the EUV wavelength range around 200 Å in the Large Helical Device

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Tungsten (W) is a candidate material for plasma-facing components in the divertor region of nuclear fusion reactors because of its excellent properties, such as high melting point and low sputtering yield. On the other hand, a large energy loss due to radiation and ionization will cause if the plasma is contaminated by tungsten ions with a large atomic number of 74. Therefore, it is essential to understand the behavior of tungsten ions and control impurity transport for achieving steady-state operation of nuclear fusion reactors.

Spectroscopy has been used for diagnostics of tungsten ions in the fusion plasma experiments. Tungsten ions in high temperature plasmas can take a wide range of charge states. So far, spectroscopic studies on tungsten ions have been intensively carried out on Large Helical Device (LHD) with tungsten pellet injection technique [1]. However, there is a lack of data on emission lines emitted from tungsten ions in low charge states of W^{10+} - W^{25+} [2]. In the presence of such low charge state ions, the resulting spectrum may be a pseudo-continuum that cannot be resolved further, called unresolved transition array (UTA). In this study, we attempted to understand the charge states of the ions included in UTA by conducting analyses from multiple angles.

Waveforms of (a) heating power of neutral beam injections (b) central electron temperature, T_{e0}, and electron density, n_{e0}, (c) plasma stored energy, W_p, and radiation power, P_{rad}, of tungsten injection experiment in LHD are shown in Fig. 1. A tungsten pellet was injected at 4.1s. Immediately after the tungsten pellet injection, there was a sharp increase in P_{rad} with a corresponding drop in W_p. After that, T_{e0} decreased from 1keV to 0.3keV by 5.3s, while n_{e0} increased from $2\times10^{19}m^{-3}$ to $4\times10^{19}m^{-3}$. Spectroscopic measurements were performed with multiple spectrometers, covering the wavelength range from EUV to visible light. Since the UTA spectra of tungsten were observed around 200 Å in the EUV region, which has not been identified so far, we focused on these UTA spectra in this study.

Figure 2 shows the EUV spectra around 200 Å including tungsten UTA measured at 4.95-5.30s. During 4.95-5.30s, T_{e0} decreased from 0.83 keV to 0.31 keV. An overall shift of the UTA toward longer wavelengths was observed following the decrease in T_{e0}. Therefore, it is considered that the UTA is composed of the ions in low charge states, such that the emission is enhanced at electron temperatures of a few hundred eV, and that the longer range of wavelengths contains components with lower charge states. The UTA spectral shape of the 5.20-5.25s and 5.25-5.30s is characterized by the superposition of several peaks (e.g., 200-204 Å, 204-209 Å) with finite wavelength width. Since each peak possibly corresponds to a different charge state, we attempted to extract the behavior of specific charge state from the quasi-continuous spectrum by dividing the UTA into smaller wavelength regions and investigating them separately.

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References
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[2] A. Kramida *et. al.*, http://physics.nist.gov/asd for NIST Atomic Spectra Database (ver. 5.10).

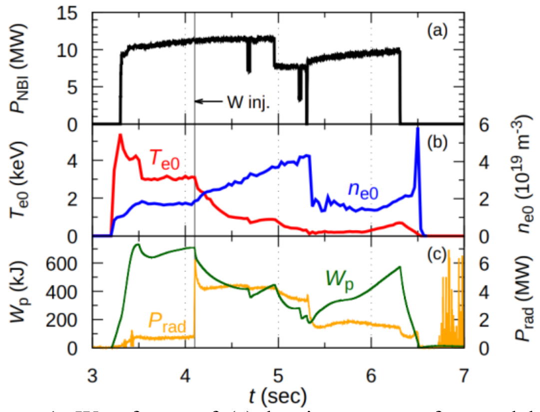

Figure 1. Waveforms of (a) heating power of neutral beam injections, (b) central electron temperature and electron density, (c) plasma stored energy and radiation power in a tungsten pellet injection experiment in LHD for the discharge #170347.

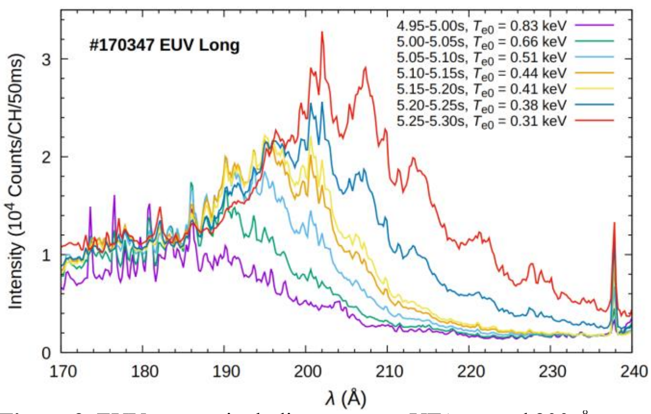

Figure 2. EUV spectra including tungsten UTA around 200 Å measured at 4.95-5.30s.