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原子構造計算プログラム FAC による多価タングステンイオンのスペクトル解析
Analysis of spectra from multiply ionized W ions by atomic structure code FAC

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Tungsten is one of the candidates for plasma facing components in future fusion devices such as ITER and DEMO. However, because of its high Z number, tungsten is not fully ionized in plasmas, and the intense line-radiation dissipates plasma energy, leading to a plasma collapse. Hence it is of significance to avoid accumulation of tungsten ions in the core plasma. For this purpose, it is required to establish a method to determine tungsten ion density in the plasma quantitatively. Spectroscopic measurement of tungsten spectra has been widely used and analysis with an atomic code has been extensively performed. In the present work, tungsten spectra measured in JT-60U and LHD have been analyzed with an atomic code, named FAC [1].

Figures 1 (a) and (b) show a vacuum ultra-violet spectra taken, respectively, from the peripheral plasma of JT-60U at T_e ~ 2 keV and from the core plasma of LHD at T_e ~ 3 keV. In order to identify tungsten lines, spectrum calculation with FAC was performed for W^{14+} - W^{71+}. In the calculation, for instance, for W^{27+} (Ag-like tungsten ion), the following electron configurations besides the ground state ($4d^{10}$ 4f) were considered:

$4d^9 + 4f^2$
$4d^{10}$ + 5s, 5p, 5d, 5f, 5g, 6s
$4d^9$ 4f + 5s, 5p

In calculation for W^{14+} - W^{24+}, only Δn=0 transitions between n=4 level were considered because calculation of Δn=1 transitions from n=5 to n=4 consumed huge computation time. Then, a collisional-radiative model, which included the processes of (de-) excitation between these levels and radiative transition from these levels, was used to calculate spectra of each W ion. As shown in Fig. 2, many spectral lines due to transitions between 4p - 4d and 4d - 4f, in particular from W^{27+} - W^{34+}, distributed between 4.5 nm and 5.5 nm. These spectra, weighted by a fractional abundance, were summed up and a synthesized spectrum was obtained.

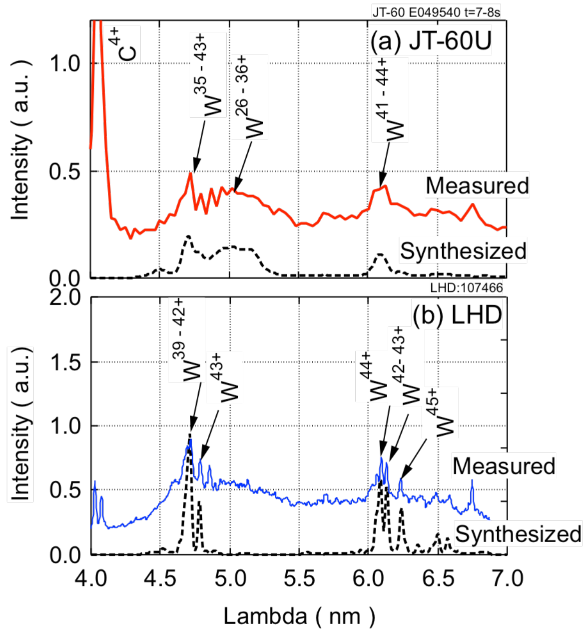

Fig. 1. Measured and synthesized spectrum (a) for JT-60U and (b) LHD.

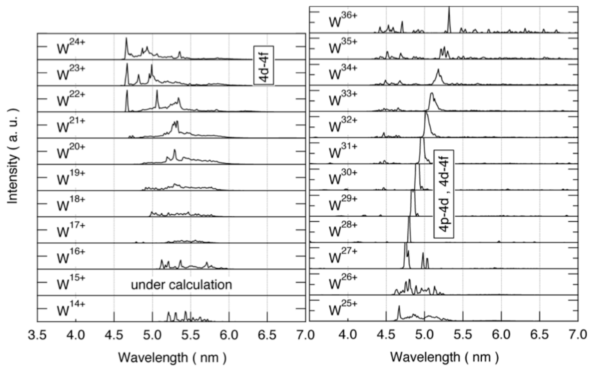

Fig. 2. Calculated spectrum with FAC code.

In Fig 1 (a), comparison of the measured and the synthesized spectrum for JT-60U [2] is shown. The measured spectrum is well reproduced by the synthesized spectrum, which includes contribution of an additional peak of the fractional abundance around W^{32+} besides a peak around W^{43+}. This additional peak of the fractional abundance contributes to the broad peak observed around 5.0 nm in Fig. 1 (a). In contrast, because the synthesized spectrum for LHD does not include contribution of the additional peak, discrepancy between the measured and the synthesized spectrum is significant around 5.0 nm as shown in Fig. 1(b), showing necessity for adding the additional peak for lower charge states of W ions. This necessity is commonly seen in JT-60U and LHD. The reason why the additional peak is needed is unknown and will be investigated.

[1] Gu, M. F. et al., Astrophys. J. **582** (2003) 1241.
[2] Nakano, T. et al,: Nucl. Fusion. **49** (2009) 115024.