§13. Spectroscopic Measurements and Database Development for Highly Charged Rare Earth Elements

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The spectra of photoemissions due to the transitions between the sub-shell levels in N-sub-shell open atomic ions are of interest for the strong influence from the interactions between the electronic state configurations with different constituent orbitals. Modifications in unresolved transition array (UTA) spectral profile has been pointed out [1,2], and this effect is advantageous to the development of practical extreme ultraviolet (EUV) light sources. To obtain shorter wavelength light emissions, we suggest to investigate heavier elements. The wavelengths of the $4d$ - $4f$ transitions are reported to be, for example, 7.9 nm for Nd (Z=60), 7.0 nm for Eu (Z=63) , and 6.8 nm for Gd (Z=64) [3]. Recently, the 4d-4f transitions of Tb at 6.5 nm has been investigated theoretically by Sasaki et al [4].

In the present work, we inject the rare earth metal elements in LHD plasmas by means of laser brow off to the outer area of the plasmas and by means of the pellets injection to the core area of the plasmas. In the fiscal years of 2010 to 2011, we measured the emission spectra of Gd and Nd in detail. We have obtained the UTA spectra at 6.8 nm for Gd and at 8.0 nm for Nd. The details of the experimental results have been reported in J. Phys. B [5]. In the fiscal year of 2012, we measured the emission spectra of Tb and Dy in detail. We have obtained the UTA spectra at 6.5 nm for Tb and at 6.3 nm for Dy.

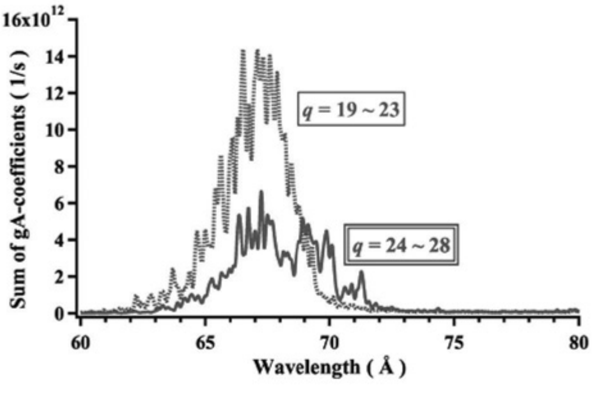

Fig. 1. Synthesized EUV photoemission spectra of Gd^{q+} ions. Broken line: the sum of gA-factors of Gd^{q+} with q = 19 to 23. Solid line: q = 24 to 28.

We compared the experimental results with elaborate calculations based on the MCDF method with Breit and QED corrections [6-9]. In Fig.1, we illustrate the synthesized EUV photoemission spectra of Gd^{q+} ions. Theoretical gA-factors were summed over through selected ranges of the charge state q. The corresponding experimental spectra are seen in figure 4 of our previous paper[4]. Further details will be appearing in the proceedings of ICAMDATA 6 [10].

In Fig. 2, we show the spectra for Tb ions in LHD plasmas. In Fig. 3, we show the spectra for Dy ions in LHD plasmas. They are newly observed in the 16'th cycle that was realized in fiscal year 2012. We are now in the course of analyzing these spectra with the use of a sophisticated set of atomic structure codes [6-9].

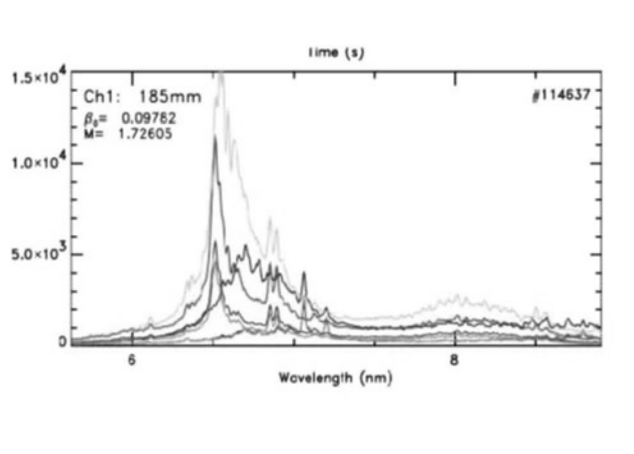

Fig. 2. EUV emission spectra of Tb in LHD plasmas for various electron temperatures.

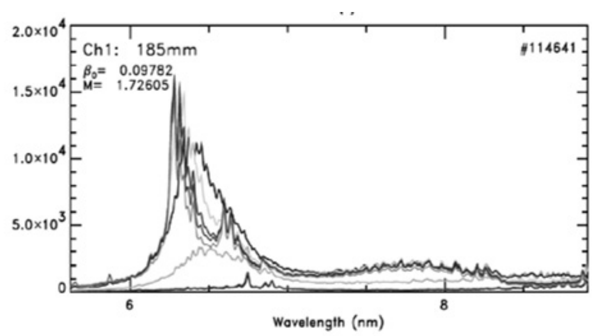

Fig. 3. EUV emission spectra of Dy in LHD plasmas for various electron temperatures

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