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

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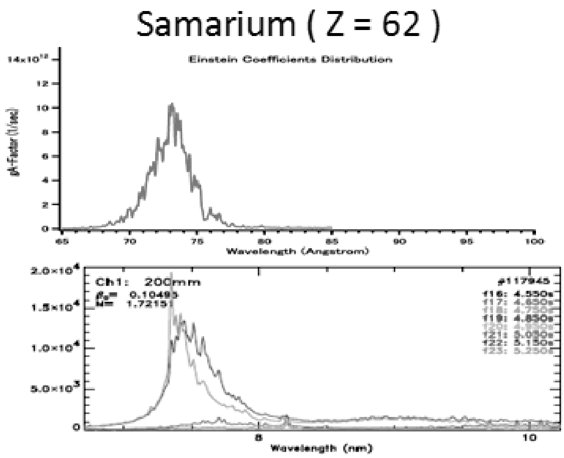
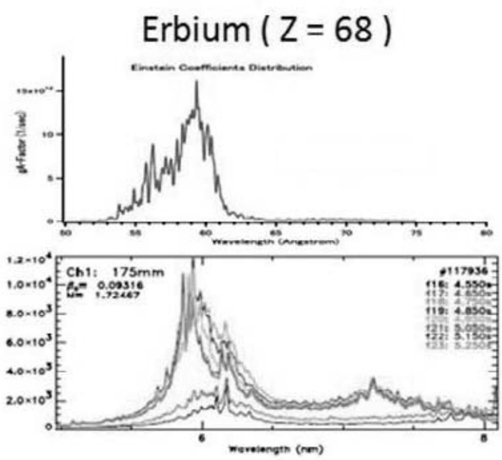
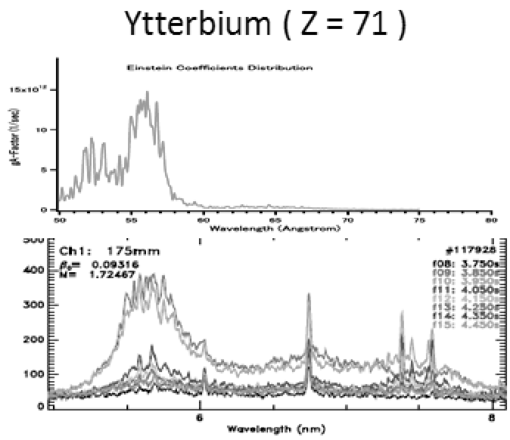
The spectra of photoemissions due to the transitions between the sub-shell levels in N-sub-shell open atomic ions are of interest for the strong influence from the interactions between the electronic state configurations with different constituent orbitals. Modifications in unresolved transition array (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 4*d* - 4*f* 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]. The 4d-4f transitions of Tb(Z=65) at 6.5 nm has been investigated theoretically by Sasaki et al [4].



(a)



(b)



(c)

Fig. 1. EUV emission spectra of Sm, Er, and Yb. in LHD plasmas for various electron temperatures, and the synthesized theoretical emission spectra for respective elements. The upper and lower entries in each figure give theoretical and experimental spectra, respectively.

In the fiscal year 2011, we measured the emission spectra of Gd(Z=64) and Nd(Z=60) in detail [5,6]. In the fiscal year 2012, we measured the emission spectra of Tb(Z=65) and Dy(Z=66) in detail. We have extended ourmeasurement for Yb(Z=70), Er(Z=68), and Sm(Z=62) in the 17'th cycle experiment in this fiscal year 2013. We have presently covered almost the whole range of atomic number in lanthanide atoms, say, for atoms with Z=60, 62, 63, 64, 65, 66, 68, and 71.

We compared the experimental results with elaborate calculations based on the MCDF method with Breit and QED corrections as given in Fig.1. Together with the previous results, we investigated the shift of the spectral peak with Z as shown in Fig.2.

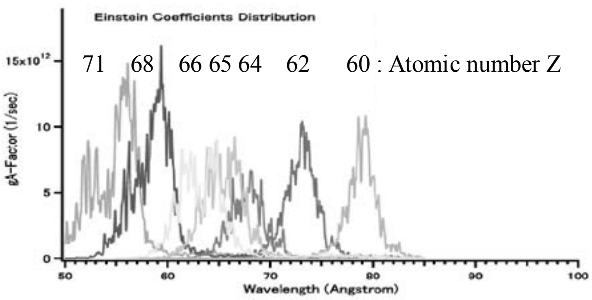


Fig.2. Spectral shift with the change of Z

1) G. O'Sullivan et al, Opt. Eng. **33**, 3978 (1994).
2) J. Bauche et al, J. Phys. **B20**, 1443 (1987).
3) O'Sullivan, et al J. Opt. Soc. America, **71**, 227(1981).
4) A. Sasaki et al, Appl. Phys. Lett. **97**, 231501 (2010).
5) C. Suzuki et al, J. Phys. **B45**, 135002 (2012).
6) F. Koike et al, *Proceedings of ICAMDATA 6* (2013)