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

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In tungsten (W, Z=74) highly charged ions, the spectral structures that are from the transitions between the *4d* and *4f* orbitals of the open-shell ionic systems are of interest in view of the development of the next generation fusion reactors as well as of academic view point. The spectral structures reflect the complex natures of the partially stripped open-shell ionic structures.

For other elements, the development of the next generation extreme-ultra-violet (EUV) light source has been focusing the use of this narrow band *4d - 4f* transitions of *4d* open-shell atomic ions with atomic numbers around 50 such as Sn or Xe. In this region of atomic numbers, we can obtain the 13.5 nm range of the emission wavelengths. To develop further shorter wavelength light source, we would be suggested to investigate the elements with further larger atomic numbers. The lanthanide elements can be the good candidates for investigation. 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)[1]. Recently, the *4d - 4f* transitions of Tb at 6.5 nm has been investigated theoretically by Sasaki et al[2].

In ions of atoms such as Sn or Xe, there is an overlap of energy ranges of 4d - 4f transitions and 4p - 4d transitions leading to the narrowing of the spectral range of optical emissions. In view of the development of shorter wavelength light sources, it is worthy to investigate if the similar effect will take place also in higher atomic number species such as lanthanides. Also from academic point of view, the investigation of the 4d - 4f transitions in lanthanides is quite interesting in relation to the so called 4d - 4f giant resonance phenomena.

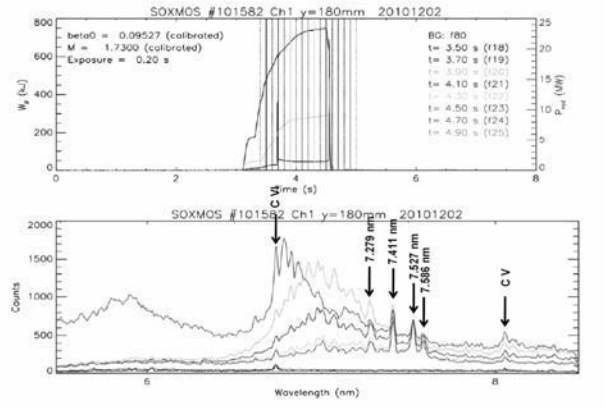

Fig.1. Gd (Z=64) EUV emission spectra from LHD plasmas. The Gd atoms are injected as a tracer into the LHD plasmas with 2~3 keV of the electron temperature. Four discrete lines are also observed around 7.5 nm, which are suspected to be of the higher charge state Gd ions.

At the machine time in the fiscal year of 2010, we have measued the EUV emission spectra at around 6.8 nm range from Gd (Z=64) atomic ions. In Fig.1, we show a typical result from the present experiment. As the tracer of the TESPEL, we have injected the Gd element into the LHD plasmas with 2~3 keV of the central electron temperature. The emission lines from Gd 4d open-shell ions has been observed. Four new spectral lines in the range from 7.729 nm to 7.586 nm have been observed for the first time. Those lines have been analyzed and compared to the presently carried out atomic structure calculations. Theoretical calculation has been performed using a group of computer codes GRASP92[3], RATIP[4], and GRASP2K[5] .

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3) F. A. Parpia, et al, Comput. Phys. Commun. **94** 249 (1996).
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