§1. Exploration of Visible Emission Lines of Highly Charged Tungsten Ion Using the LHD Plasma

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Since highly charged tungsten ions in the plasma core cause the radiative cooling, establishment of the tungsten transport diagnostics have been demanded. Several diagnostic methods based on spectroscopy have been proposed; most of them utilize extreme ultraviolet emission lines due to dipole transitions of the highly charged tungsten ions. Since visible emission spectroscopy has advantages in the flexibility of the observation port arrangement and in the neutron protection of the measurement system, a method based on the visible spectroscopy has been also proposed. However, only a few emission lines of highly charged tungsten ion have been observed and identified in the visible range.

The objective of this research is to find such visible emission lines with our échelle spectrometer. We observe the high resolution spectrum in a whole visible range simultaneously for an LHD plasma, in which tungsten ions are accumulated. Determination of the ion charge state of the found emission line is also planned. For this purpose, we will examine the correlation between the temporal evolution of the emission intensity and those of the electron temperature and density.

In this year, we redesigned our échelle spectrometer to increase its wavelength resolution and light throughput. Fig.1 show schematic illustrations of the previous and redesigned spectrometers. In the previous version, the light passes camera lens (L1, Nikon ED180mm F2.8D(IF), focal length: 180 mm; F number :2.8) for four times. This layout has an advantage in removing the stray light inside the spectrometer but causes the small light throughput and the large optical aberration. In the redesigned spectrometer with the same optical components used in the previous version, since light passes the lens only for two times, the improvement in the light throughput and high wavelength resolution are expected.

We constructed a new spectrometer based on this optical design. We confirmed the improvement in the wavelength resolution in the wavelength range of $\lambda > 630$ nm. However, the light throughput decreased to 30 % of that of the previous version. Insufficient optical alignment in the newly constructed spectrometer was expected as the reason of the decrease. Detection of any visible emission line of highly charged tungsten ions was not achieved in this LHD experimental campaign.

In this year, we also made a detailed analysis of the spectrum observed for the tungsten-accumulated LHD plasma (#121545) taken with the previous spectrometer in the last experimental campaign. In the plasma, a tungsten pellet was injected and highly charged tungsten ions were accumulated in the core region. From the careful examination of the observed spectrum, we found 11 unknown emission lines as well as two already known emission lines of highly charged tungsten ions. These emission lines showed the following characteristics;

(1) They were observed only after the tungsten pellet was injected.
(2) They were observed only with the line of sight passing through the region where the electron temperature is larger than 1 keV.
(3) They show broadening, the widths of which are consistent with the Doppler widths of the tungsten ions with ~ 1 keV temperature.

These characteristics suggest that these unknown emission lines are due to the highly charged tungsten ions. The wavelengths of these emission lines are listed in table 1.

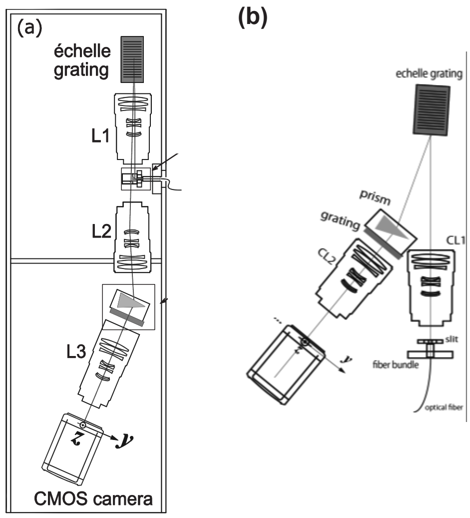

Fig.1 Schematic illustrations of (a) previous and (b) redesigned versions of the échelle spectrometer.

Table I. Wavelengths of the newly found emission lines of highly charged tungsten ions.

wavelength (nm)	wavelength (nm)
462.64	539.63
498.92	579.75
499.90	585.56
509.11	620.27
509.81	668.89
537.61	