§4. High Accuracy Spectroscopic Measurement of Emission Line Intensities of Tungsten in Pellet Ablation Plasmas

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In the LHD, tungsten-pellets have been injected into the plasma for the purpose of studying impurity transport as well as atomic structure of tungsten ions. Immediately after the injection, the pellet is ablated due to the heat flux from the plasma, and emission from tungsten ions in low charge states is observed. After the ablation, some of the tungsten ions are ionized into highly charge states and accumulated in the core plasma. Since the LHD can generate stable high temperature plasmas, it is suitable for the study of emission lines of such tungsten ions. For the purpose of performing wideband (400 - 700 nm) and high resolution (0.04 nm) measurements of these emission lines from the LHD plasmas, we have developed an échelle spectrometer[1].

In this year, we redesigned the spectrometer to have higher resolution and throughput. A schematic illustration of the new échelle spectrometer is shown in Fig. 1(a). Ends of 2 optical fibers are aligned along the entrance slit (SL1, 25 μm width). Light introduced through SL1 are collimated by a camera lens (L1, Nikon ED180mm F2.8D(IF), focal length: 180 mm; F number :2.8) and incident on an échelle grating (Richardson grating, ruling density: 52.67 grooves/mm; blaze angle: 63.5°; ruled area 46 × 92 mm^2). The light is dispersed by the grating in the z direction indicated in the figure. Light beams of the diffraction orders from 48 to 81 are incident on a cross disperser consisting of a custom-made prism (substrate: S-TIH1; apex angle: 30°; length of the hypotenuse: 58 mm; height: 60 mm) and a transmission grating (Richardson grating, ruling density: 100 grooves/mm; ruled area: 52×52 mm^2). The dispersed light beams are focused on a complementary metal-oxide semiconductor (CMOS) image sensor of the digital camera (Hamamatsu Photonics, Orca Flash-4.0, pixel size: 6.5×6.5 μm^2; 2048 × 2048 pixels). The resultant instrumental resolution was 0.02 nm.

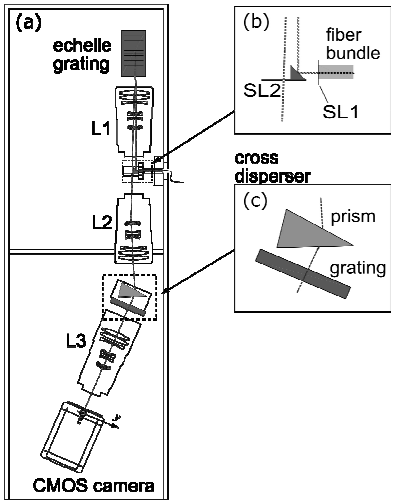

Fig. 1(a) A schematic illustration of the échelle spectrometer. Close-up views of (b) around the entrance slit and (c) around the cross disperser. The échelle grating disperses the light along the z direction, while the cross disperser separates the orders of the diffracted light along the y direction.

Using this spectrometer, we observed emissions from a hydrogen plasma generated in the LHD (#121550) with exposure time of 200 ms. A tungsten pellet consisting of a tungsten wire (0.15 mm diameter, 0.8 mm length) and a polyethylene tube (0.6 mm diameter, 0.8 mm length) was injected into the plasma.

The overall spectrum observed during the pellet ablation is shown in Fig. 2(a). Figure 2(b) shows the expanded spectrum in a wavelength range of 470 - 480 nm together with the spectrum observed last year by the previous spectrometer (gray curve). It is seen that the finer structures were detected by the new spectroscopic system. Emission lines of neutral, singly- and doubly-charged tungsten ions were identified from the NIST database. Some of them were indicated by vertical bars in Fig. 2(b). Several tens of unreported emission lines were also observed.

In the spectrum observed at 100 ms after the pellet ablation, some unreported emission lines appeared, which were not observed before and during the pellet ablation. Since significant broadenings were observed for these emission lines, which are consistent with the Doppler broadening of tungsten ions in the core plasma, we attributed them to those of highly charged tungsten ions.

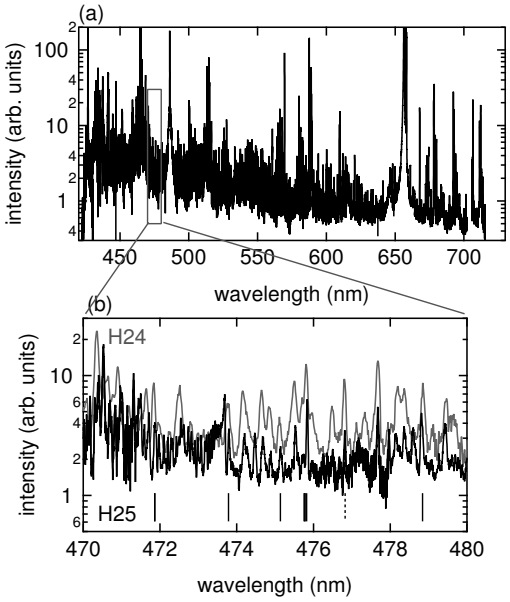

Fig. 2 Spectrum observed for the pellet ablation plasma. Vertical solid and dotted bars in (b) indicate the center wavelengths of WI and WII emission lines, respectively. The gray curve in (b) shows the observed spectrum by the previous spectrometer.

1) Hasuo, M., Fujii, K., Shikama, T., Morita, S., Goto, M. and Tanaka, H.: J. Phys. Conference Series **397** (2012) 012016