S15-3

Spectroscopic Diagnostics of Multiply Charged Ions in Fusion Plasmas
核融合プラズマにおける多価電離イオンの分光診断

Tetsutarou Oishi
大石鉄太郎

National Institute for Fusion Science, 322-6, Oroshi-cho, Toki, GIFU, 509-5292, Japan
核融合科学研究所 〒509-5292 岐阜県土岐市下石町322-6

Behavior of multiply charged ions in fusion plasmas represented by tungsten ions has attracted attention because tungsten is regarded as a leading candidate material for the plasma facing components in ITER and future fusion reactors. Spectra of emissions released from tungsten ions have been measured using visible, vacuum ultraviolet, and extreme ultraviolet spectroscopy in the Large Helical Device.

1. Introduction

Behavior of multiply charged ions in fusion plasmas represented by tungsten ions has attracted attention because tungsten is regarded as a leading candidate material for the plasma facing components in ITER and future fusion reactors. Considering tungsten impurity transport in ITER, the following three transport processes need to be evaluated: (1) release of neutral tungsten atoms from the divertor plates; (2) transport of tungsten ions at lower ionization stages in the edge plasmas; and (3) accumulation of tungsten ions at higher ionization stages in the core plasmas. Therefore, diagnostics for tungsten impurity ions in magnetically-confined high-temperature plasmas have been intensively conducted, such as visible spectroscopy for neutral tungsten atoms in the wavelength range around 4000 Å and extreme ultraviolet (EUV) spectroscopy for highly-ionized tungsten ions in the wavelength range around 15-70 Å [1]. Moreover, measurement of tungsten ions at lower ionization stages has just started using vacuum ultraviolet (VUV) spectroscopy in the wavelength range around 500-2200 Å because it is necessary for accurate evaluation of tungsten influx and comprehensive understanding of the tungsten impurity transport in high temperature plasmas [2]. In the present study, spectra of emissions released from tungsten ions are measured using various kinds of spectroscopic systems in the Large Helical Device (LHD).

2. Experimental Setup

Tungsten ions are distributed in the LHD plasma by injecting a polyethylene pellet containing a small piece of tungsten metal. LHD has the major/minor radii of 3.6/0.64 m in the standard configuration with maximum plasma volume of 30 m^3 and toroidal magnetic field of 3 T. The coil system consists of a set of two continuous superconducting helical coils with poloidal pitch number of 2 and toroidal pitch number of 10 and three pairs of superconducting poloidal coils. The tungsten impurity pellet consists of a small piece of tungsten wire covered by a polyethylene tube. The length and diameter of tungsten wire is 0.6 mm and 0.15 mm, respectively. The polyethylene tube has a dimension of 0.6 mm in length, 0.6 mm in outer diameter, and 0.3 mm in inner diameter [3]. The pellet is accelerated by pressurized He gas of 10-20 atm. The pellet injection orbit is located on the midplane of the plasma having a 12° angle from the normal to the toroidal magnetic axis [4].

3. Line Spectra Measurement

Figure 1 shows tungsten spectra measured in the time frame just after the tungsten pellet injection in hydrogen discharge in LHD. The plasma was initiated by the electron cyclotron heating, and three neutral hydrogen beams based on negative ion sources with total port-through power of 8 MW were injected. Central electron density and temperature just before the pellet injection was 2×10^{13} cm^{-3} and 3 keV, respectively. Figure 1(a) shows a spectrum measured using a 3 m noemal incidence VUV spectrometer [5]. A bright WVI 677.72 Å line which is isolated from other intrinsic impurity lines was clearly observed. Figure 1(b) shows a spectrum measured using a flat-field EUV spectrometer [6]. The spectrum consists of two pseudo-continuums in the wavelength ranges of 15-40 Å and 45-70 Å and line emissions from ionization stages between W^{24+} to W^{33+}.

The temporal evolution of the line emission was investigated, as shown in Fig. 2. As shown in Fig. 2(a), the electron temperature drops and the electron density increases rapidly when the pellet is injected. Figures 2(b) and (c) show the temporal evolutions of line emission intensities evaluated by the area of

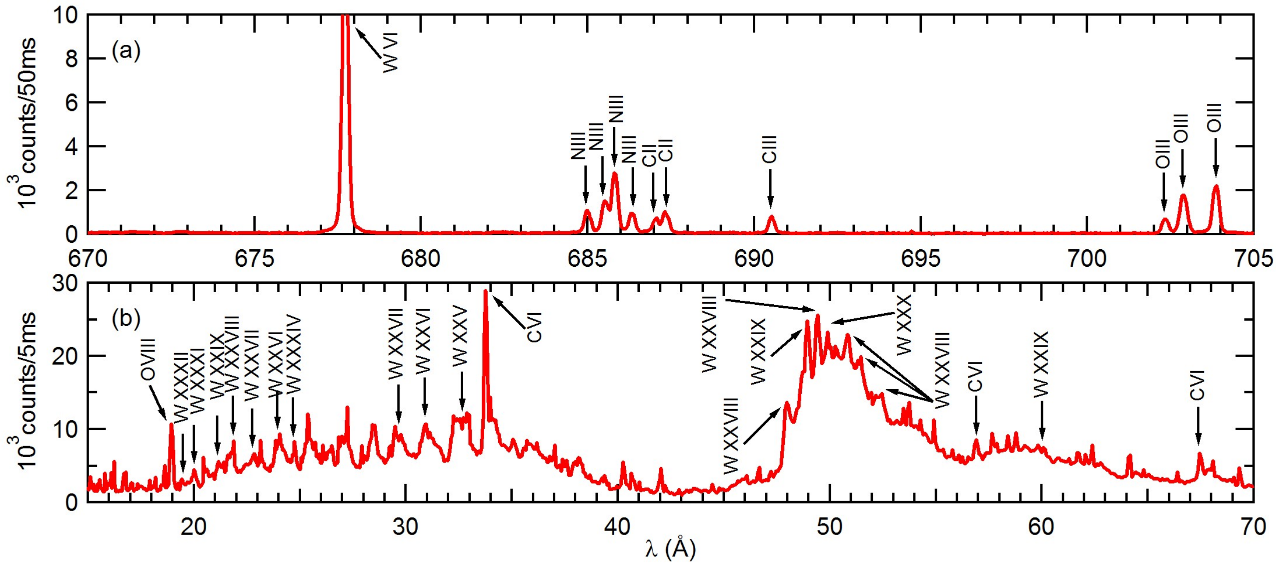

Fig.1. Tungsten spectrum measured by (a) a 3m VUV normal incidence spectrometer and (b) a flat-field EUV spectrometer in LHD.

the spectral peaks for WVI 677.72 Å, WXXV 32.3 Å, WXXVI 30.9 Å, and WXXVII 29.6 Å. The line intensity of WVI (ionization potential E_i = 64.8 eV) increased once at the timing of the pellet injection and turned to decrease down to 4.3s. On the other hand, WXXV, WXXVI, and WXXVII (E_i = 734.1 eV, 784.4 eV, and 833.4 eV, respectively) lines increased in the latter half of the discharge because the electron temperature recovered by a continuous neutral beam heating. Their sequential increasing behavior is reasonable when considering the relationship between the electron temperature and their ionization energies.

Acknowledgments

The author is grateful to Prof. S. Morita and Dr. M. Goto in NIFS, and Mr. X. L. Huang and Mr. H. M. Zhang in the Graduate University for Advanced Studies for their cooperation with spectroscopy diagnostics and fruitful discussion. The author thanks all the members of the LHD team for their cooperation with the LHD operation. This work is partially conducted under the LHD project financial support (NIFS13ULPP010). This work was also supported by Grant-in-Aid for Young Scientists (B) 26800282 and partially supported by the JSPS-NRF-NSFC A3 Foresight Program in the Field of Plasma Physics (NSFC: No.11261140328, NRF: No.2012K2A2A6000443).

References

[1] S. Morita *et al.*, AIP conference proceedings **1545**, 143 (2013), Proceedings of ICAMDATA-2012, Gaithersburg, 30 Sept.–4 Oct. 2012.
[2] T. Oishi *et al.*, Rev. Sci. Instrum. **85** (2014) 11E415.
[3] X. L. Huang *et al.*, Rev. Sci. Instrum. **85** (2014) 11E818.
[4] H. Nozato *et al.*, Rev. Sci. Instrum. **74** (2003) 2032.
[5] T. Oishi *et al.*, Appl. Opt. 53 (2014) 6900.
[6] M. B. Chowdhuri *et al.*, Appl. Opt. **47** (2008) 135.

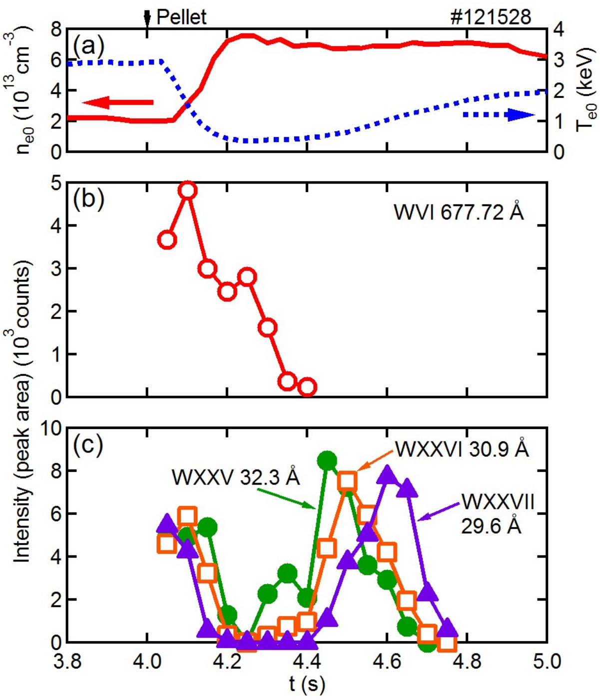

Fig.2. (a) Temporal evolutions of central electron density n_{e0} and temperature T_{e0} in a hydrogen discharge with tungsten pellet injection. Line intensities of (b) WVI 677.72 Å, (c) WXXV 32.3 Å, WXXVI 30.9 Å, and WXXVII 29.6 Å are shown together.