§1. Static and Dynamical Spectroscopy on Neutral Hydrogen Transport in a Fusion Plasma

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Hydrogen atoms and molecules are dominantly ionized in the peripheral region of a magnetic fusion plasma. A certain part of the atoms penetrate deep inside the plasma as neutral through charge exchange collisions with hot protons. Recently, we found that the far wing part of the Balmer-α line profile is due to such high temperature atoms in the core region while the central part is due to low temperature atoms in the peripheral region of the plasma.[1)] The emission intensity from the core region can be over 10^5 times smaller than the peak intensity. We developed a spectrometer having the dynamic-range over 10^5 with the wavelength resolution of 0.031 nm to measure such Balmer-α emission spectra. [2)]

Last year, we expanded the wavelength bandwidth of the high dynamic-range spectrometer to observe Balmer-α emission from an LHD plasma having the ion temperature over 7 keV. It was found that intense continuum emission, which may be attributed to thermal radiation from the diverter surface, overlaps the Balmer-α emission.

In this year, we increased the number of optical fibers from 24 to 52 to observe the plasma from not only the 10O-port but also the 7.5L-port as shown in Fig. 1. From the 7.5L-port, lines of sight without the diverter plate can be available. We also introduced a new fiber bundle, an end of which is designed to compensate the grating smile of the spectrometer. Fig. 2 shows two dimensional images of the Balmer-α emission on the CMOS photoelectric surface of the spectrometer observed in the last and this years. The fiber number increase and grating smile compensation are clearly recognized. Fig. 3 shows an example of the Balmer-α emission spectra of a high ion temperature LHD plasma (#128518) observed with the 10O-port and 7.5L-port. The continuum emission spectra were separated in Fig. 3 and the Balmer-α emission spectra with the dynamic-range over 10^4 were measured for both the cases. The Balmer-α emission intensity was smaller for the 7.5L-port and the signal-to-noise ratio was not improved.

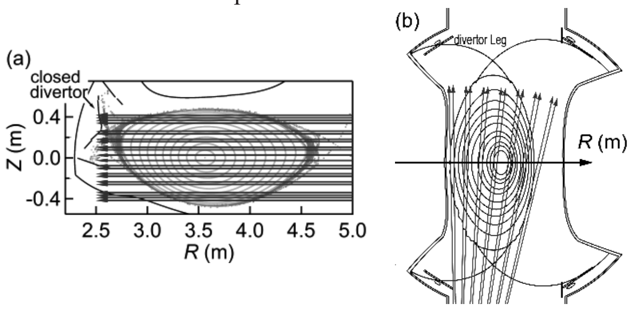

Fig.1. Lines of sight from (a) 10O-port and (b) 7.5L-port.

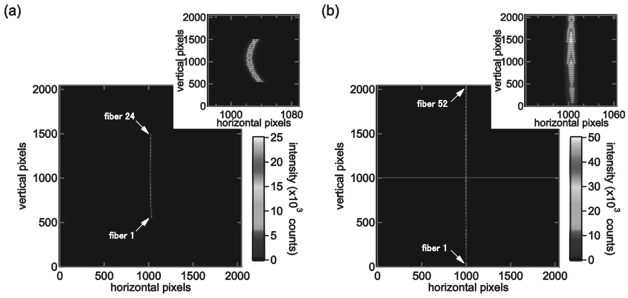

Fig.2. Balmer-α emission image on the CMOS photoelectric surface of the spectrometer. (a) last year, (b) this year.

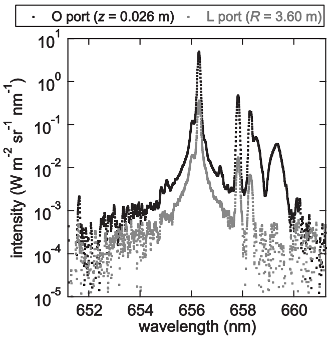

Fig.3. High dynamic-range Balmer-α emission spectra observed from the 10O-port (black dots) and 7.5L-port (grey dots). The measurement exposure time is 20 ms.

Regarding the dynamical spectroscopy, or time resolved spectroscopy in other word, of the Balmer-α emission, we have been developing a high dynamic-range spectrometer with adopting photomultiplier arrays. In this year, we introduced two two-dimensional photomultiplier arrays (Hamamatsu, H7546A-20, 8 × 8 channels) to observe Balmer-α emission with 16 lines of sight (8 channels × two photomultiplier arrays). The other 8 channels were used for the spectrum measurement. For this purpose, we modified focusing optics for the photomultiplier arrays, developed 128 channel transimpedance amplifier circuits and a measurement code, and then achieved Balmer-α spectra measurement with 200 kHz sampling rate, dynamic-range over 10^4 and 16 lines of sight for an LHD plasma.

A Monte-Carlo simulation code for the transport of hydrogen molecules and atoms in LHD including molecular desorption and atomic reflection at the plasma facing walls, molecular excitation and dissociation and atomic excitation, ionization and charge exchange in the plasma has been developed. With the simulation model, molecular and atomic spectra to be observed in LHD plasmas were calculated. In this year, we compared the calculated spectra with the experimental spectra in a whole visible wavelength range measured with our echelle spectrometer.

1) Fujii, K., Shikama, T., Goto, M., Morita, S, and Hasuo, M.: Phys. Plasmas **20** (2013) 012514.
2) Fujii, K., Atsumi, S., Watanabe, S., Shikama, T., Goto, M., Morita, S., and Hasuo, M.: Rev. Sci. Instrum. **85** (2014) 023502.