§2. 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.

Last year we developed a spectrometer having the dynamic-range over 10^5 and keeping the wavelength resolution of 0.031 nm and the time resolution of 100 ms, and applied it to the observation of the Balmer-α emission from an LHD plasma (#112883).[2] From the observed spectrum together with the spatial distributions of the electron density and temperature, and the ion temperature, we quantitatively estimated the spatial distribution of the hydrogen atom density in the core region.[2] For a plasma having the ion temperature over 7 keV, however, we found that separation of the Balmer-α far wing from a continuum spectrum is difficult because of the small observation bandwidth (about 5 nm) of the spectrometer.

In this year, we expanded the bandwidth to be 10 nm by changing the collimating lens of the spectrometer. Fig. 1 shows an example of the observed Balmer-α spectra for an LHD plasma (#119127). It can be seen that the continuum spectrum, which may be attributed to thermal radiation from the diverter surface, is well separated from the Balmer-α far wing. From the result, it is expected that emission from 10 keV atoms is detectable, whose Doppler shift is about 3 nm.

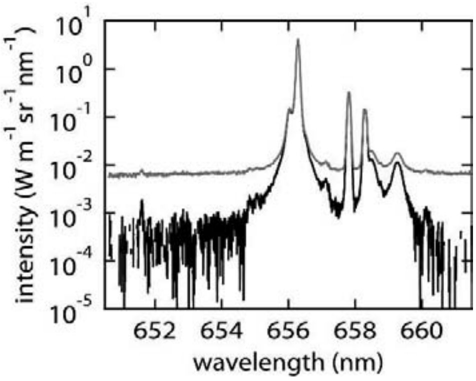

Fig.1. Observed Balmer-α spectrum with the high dynamic-range spectrometer developed and improved in this work after separation of the continuum spectrum. The grey curve shows the raw spectrum.

In this year, we also newly developed a high dynamic-range spectrometer having high time resolution. For the purpose of increasing the time resolution, we adopted a photomultiplier linear array (Hamamatsu Photonics, H7260S-20) with the high throughput optics[2] and a telescope lens (Takahashi Seisakusho, FC100-DC). We kept the high dynamic-range by setting a custom-ordered spatial filter in front of the photomultiplier linear array to selectively reduce the emission intensity around the Balmer-α line center. We achieved the dynamic-range of about 10^5, the observation bandwidth of 5.1 nm, the wavelength resolution of 0.16 nm, and the time resolution of 30 μs. We applied this spectrometer to the Balmer-α emission observation for an LHD plasma with hydrogen ice pellet injection (#122011). Fig. 2 shows the result. After the sudden increase in all the emission intensities at the pellet injection, the increase in the central part and decrease in the wing part of the Balmer-α spectrum were detected, which can be attributed qualitatively to the increase in the hydrogen atom number and decrease in the core ion temperature, respectively.

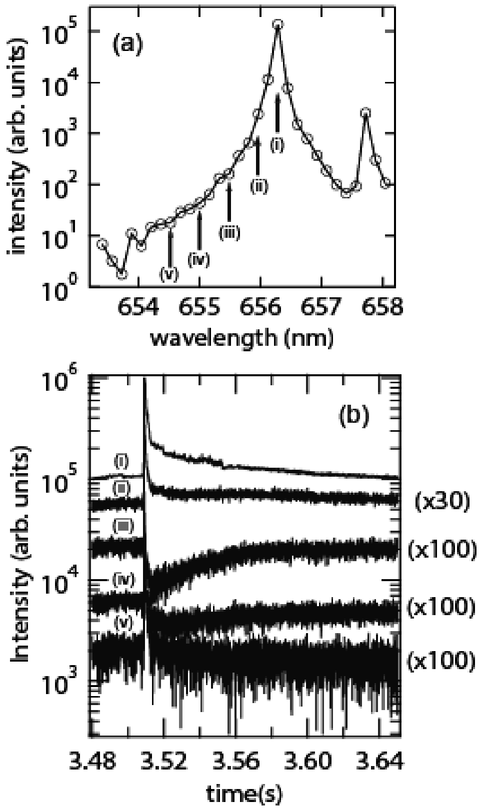

Fig.2. (a) Observed Balmer-α spectrum with the high dynamic-range and high time resolution spectrometer developed in this work. (b) Temporal change of the intensities of the Doppler shifted components, which is indicated by the arrows in (a), for the injection of a hydrogen ice pellet at 3.51 s.

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.