§82. High-speed and High-resolution Spectroscopy for Hydrogen Atom Emission Spectra of an LHD Plasma with a Linear-array Photo-detector

Hasuo, M., Fujii, K., Hoshika, N., Atsumi, S., Shikama, T. (Kyoto Univ. Eng.),
Goto, M., Morita, S.

In our simultaneous measurement of the line shapes of the hydrogen Balmer-α, -β and -γ lines with the intensity dynamic range of 10^4, we revealed that velocity distributions of the hydrogen atoms converted from these line shapes show similar profiles to each other and are much different from a Maxwell distribution; a large number of the high speed atoms having $|v| > 50$ km/s are detected.[1] Such high speed atoms are thought to be generated by charge exchange collisions with hot protons in high temperature regions of the plasma because momentum transfer (in other word, velocity exchange) takes place efficiently in a charge exchange collision. Therefore, it may become possible to monitor not only electron excitation behavior of hydrogen atoms but also proton dynamics in the plasma by the velocity-component resolved measurement of the Balmer-α line.

For the purpose of carrying out such measurements with high time resolution, we are developing a spectroscopic system which consists of a high-dispersion spectrometer (Jobin Yvon, THR1000, focal length: 1 m, 2400 grooves/mm holographic grating) and a linear array of photomultiplier tubes (Hamamatsu photonics, R5900U-20-L16, 16 anodes with 1 mm pitch). So far, we achieved the time resolution of 14 μs and the dynamic range of 10^3.[2,3] The disadvantages of the photomultiplier tube is its low quantum efficiency, which is less than 15 %, and relatively large cross-talk among the channels, which is over 3 % between two adjacent channels.

In this year, we tried to improve the system with adopting an avalanche photodiode array as the photo detector to increase the quantum efficiency and reduce the cross-talk. The quantum efficiency of an avalanche photodiode is typically about 80%, but its multiplication factor of photoelectrons is not large, i.e., up to 10^2, in comparison with that of the photomultiplier of over 10^4. Therefore, signal amplification is necessary to detect small optical signals.

We developed a pre-amplifier circuit to read output current from the photodiode array with a precision resistor of 50 MΩ. Although the gain of the pre-amplifier affects the cutoff frequency, we achieved a nearly equal cutoff frequency of 50 kHz to that of the photomultiplier system by adjusting the feedback capacitance of the amplifiers. However, we found that the dark current of the photodiodes at room temperature is a significant noise source and the resultant sensitivity of the newly developed system is two orders of magnitude smaller than that of the photomultiplier system. For the purpose of achieving the previous sensitivity, cooling the photodiode down to -20 ℃ is found to be necessary to reduce the dark current.

In this year, we also considered a method to increase the dynamic range of the photomultiplier system. Since the intensity of the Balmer-α line center is over 10^3 times as large as that of the line wing, the dynamic range over 10^4 is required for the precise measurement of the line profile. However, because of the cross-talk of the photomultiplier tubes, there has been a possibility for the measured wing intensity to be blended with the line center intensity with the magnitude of 20 % of the wing intensity in some experimental conditions.

For the purpose of decreasing effective cross-talk, we tried to reduce the intense light at the line center by putting dark films on the corresponding positions of the photomultiplier tube linear array. We doubly put the dark film, the transmittance of which is about 37 %, and confirmed that the line center intensity was reduced to 10 % of that without the dark films.

On the other hand, we carried out time-resolved measurements of Balmer-α spectral components with the photomultiplier system for a plasma under the outward-shifted configuration of the confinement magnetic field, in which ELM-like magnetic fluctuations were observed. We found that the line center intensity rapidly increases in synchronization with the magnetic fluctuation, while the wing intensity shows decrease, which is delayed a bit to the magnetic fluctuation as seen in Fig. 1.[1,4]

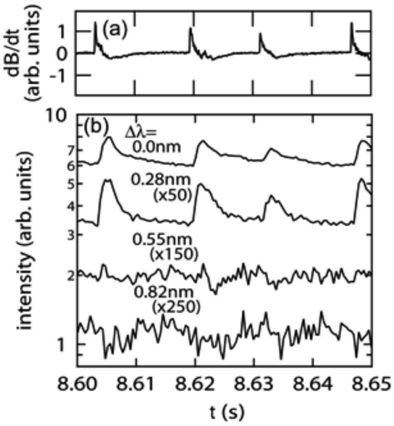

Fig.1. (a) ELM-like magnetic fluctuation and (b) the observed intensity change of Balmer-α line components form the line center (Δλ = 0.0 nm) to the wing (Δλ = 0.82 nm).

1) Hasuo, M. et al.: "Fusion of Advanced Plasma Spectroscopy and Confinement Research", Plasma Conference 2011, Nov. 22-25, 2011, Ishikawa.
2) Fujii, K., Shikama, T., Goto, M., Morita, S. and Hasuo, M.: "Spectrally-resolved Fluctuation Measurement of the Balmer-α Line Emission from an LHD Plasma", 1st Asia Pacific Transport Working Group (APTWG), Jun. 14-17, 2011, Toki, Japan.
3) Fujii, K., Shikama, T., Goto, M., Morita, S. and Hasuo, M.: "Fast and high-resolution spectroscopy of a Balmer-α line profile for an LHD plasma", European Physical Society 38th Conference on Plasma Physics (EPS2011), Jun. 27- Jul.1 2011, Strasbourg, France.
4) Fujii, K. et al.: "Observation of Plasma Fluctuation by a Fast Balmer-α Line Shape Measurement in LHD", Plasma Conference 2011, Nov. 22-25, 2011, Ishikawa.