§65. Spectroscopic Diagnostics on LHD Periphery Plasmas with a Simultaneous Measurement of Several High Resolution Spectra of Hydrogen and Helium

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For the purpose of understanding and controlling of hydrogen and helium recycling in magnetically confined plasmas, we investigate emission locations, population densities and distributions, temperature and flow velocity of neutral hydrogen and helium in the periphery of LHD plasmas from simultaneous observation of their emission line profiles with the multi-wavelength range high-resolution spectrometer developed by ourselves [1-3]. For the purpose, elementally atomic and molecular processes such as charge exchange collisions and molecular dissociations are also examined, which are necessary for model analysis of hydrogen and helium transport from chamber walls to the core region.

Since the control board of the CCD detector, which is crucial for multi-wavelength range observation, was broken this year, we changed our plan for hydrogen experiment from multi-line observation to rapid measurement of Balmer-α line profile as follows.

Rapid measurement of a hydrogen Balmer-α line profile of an LHD plasma

From a simultaneous measurement of Balmer-α, -β and -γ line spectra, velocity distributions of the excited hydrogen atoms in the n = 3, 4, and 5 states in the LHD plasma were derived, and then found to have similar profiles to each other, which are far from a Maxwellian distribution and composed of $|v| < 0.5 \times 10^5$ m/s and $|v| > 0.5 \times 10^5$ m/s components [4)]. The $|v| > 0.5 \times 10^5$ m/s component can be attributed to high energy hydrogen atoms penetrated into the confined region from the peripheral region, which are generated through charge exchange collisions with high energy protons [4-5)].

We developed a time-resolved spectroscopic system for the Balmer-α line profile measurement. We observed emission from an LHD plasma with a horizontal line of sight with a height of 0.05 m. The field of view was roughly 150 mm height and 100 mm width. The emission was introduced by optical fibers into a high dispersion spectrometer (THR1000, Jobin Yvon, focal length: 1 m, grating: 2400 grooves/mm). The spectrum focused on the exit of the spectrometer was refocused on the photo cathodes of a multi-anode photo-multiplier-tube (PMT, R-5900U-20-L16, Hamamatsu) by an achromatic lens (diameter: 30 mm, focal length: 100 mm) with twice enlargement. The PMT equips 16 channels along the dispersion direction with a pitch of 1 mm. The output signal was digitized by a 16-channels AD converter (National Instruments, USB-6251). The sampling rate was 70 kHz and the cut-off frequency of all the channels was set to be 40 kHz. The linear wavelength dispersion at the photo cathodes of the PMT was 0.14 nm/ch and the wavelength bandwidth was 2.1 nm.

From experimental results, we found that the $|v| < 0.5 \times 10^5$ m/s component increases while the $|v| > 0.5 \times 10^5$ m/s component decreases by a pellet injection. We also found that both the components synchronize to an oscillation of pressure driven MHD instability and there is an ocillation phase shift between the two components. These phenomena suggest that this kind of measurement offers information about temporal changes of electron temperature and density, and plasma turbulance at the emission locations of the components.

Multi-line high-resolution measurement helium emission spectra of an LHD plasma and its improvement of the resolution

The polarization resolved spectra of helium 2^3P-3^3D (587.6 nm), 2^1P-3^1D (667.8 nm) and 2^3P-3^3S (706.5 nm) transition lines of an LHD plasma were simultaneously measured. From the analysis of the spectra, we deduced the emission locations and intensities of these lines. The deduced results were compared with a one-dimensional penetration model of helium atoms based on collisional-radiative calculation. It was found that the systematic dependence of the emission locations and intensities on the transition lines reflects the spatial distribution of the electron density and temperature in the periphery region, where neutral helium atoms penetrate from the edge.

We developed a higher-resolution spectrometer for simultaneous observation of helium 2^3P-4^3S (471.3 nm) and 2^3P-3^3D (587.6 nm) lines in order to obtain the Doppler profile precisely. Zeeman splittings of the emission lines were observed. However, the emission intensity of the 2^3P-4^3S line was very small and the signal to noise ratio was not enough to identify the emission locations.

1) K.Fujii, K.Mizushiri, T.Nishioka, T.Shikama, A.Iwamae, M.Goto, S.Morita, S.Kado, K.Sawada and M.Hasuo, *Rev. Sci. Instrum*, **81** (2010) 033106.
2) K.Fujii, T.Shikama, A.Iwamae, M.Goto, S.Morita and M.Hasuo, *J. of Plasma and Fusion Res.*, **5** (2010) S2079.
3) T.Shikama, K.Fujii, S.Kado, H.Zushi, M.Sakamoto, A.Iwamae, M.Goto, S.Morita and M.Hasuo, *Can. J. Phys.* **89** (2011) 495.
4) K.Fujii, K.Mizushiri, T.Nishioka, T.Shikama, A.Iwamae, M.Goto, S.Morita, and M.Hasuo, *Nucl. Instrum. Methods A*, **623** (2010) 690.
5) M.Goto, K.Sawada, K.Fujii, M.Hasuo and S.Morita, *Nucl. Fusion.,* **51** (2011) 023005.