

§9. Comparison of Neutral Hydrogen Spectra of the GAMMA10 and LHD Periphery Plasmas

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In magnetically confined plasmas, the behavior of hydrogen atoms in the peripheral region has a significant influence on the plasma confinement. Plasma emission spectroscopy is one of powerful tools for investigating their dynamics.

We recently developed a multi-wavelength-range fine-resolution spectrometer, with which the high resolution spectra of the Balmer- α , - β , - γ lines and the Fulcher- α band can be measured simultaneously from a single or multiple optical fibers input. It is found that the velocity distributions of excited atoms calculated from the Balmer- α , - β , and - γ line shapes observed for a LHD plasma show similar profiles to each other and the distribution depends on the electron temperature and density.¹⁾ In this work, we compare the velocity distribution observed for a GAMMA10 plasma to that observed for the LHD plasma.

For LHD, the spectra were measured for the neutral beam injection (NBI) discharge with a central magnetic field strength of 0.4 T. The temporal development of the central electron temperature and the line averaged electron density are shown in Fig. 1 (left).

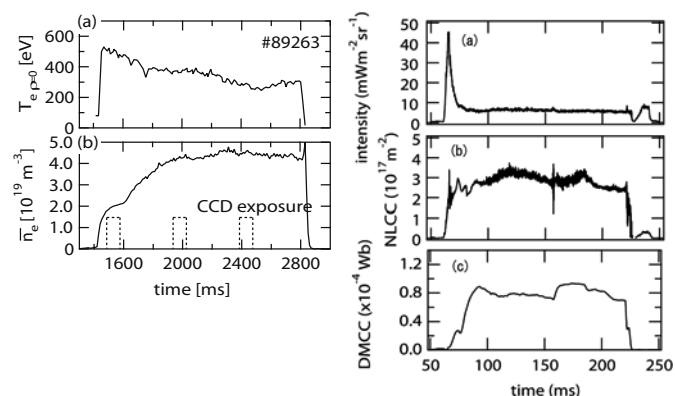


Fig. 1. (left): (a) The central electron temperature and (b) the line averaged electron density of the observed LHD plasma. (right): (a) The Balmer- α emission intensity, (b) the line averaged electron density and (c) the diamagnetism of the observed GAMMA10 plasma.

Figure 2 (left) shows the velocity distributions of the excited hydrogen atoms in the $n = 4$ state calculated from the observed Balmer- β spectra at $t = 1490 - 1580$, $1940 - 2030$, and $2390 - 2480$ ms, where n is the principal quantum number. It is clear that they are different from Maxwellian distribution. The average velocity is derived to be about 0.5×10^5 m/s and the corresponding translational kinetic energy of 13 eV is about 300 times larger than the rotational energy of hydrogen molecules of 0.03 – 0.04 eV estimated from the measured molecular emission intensities of Fulcher- α band. It is found that there is a significant amount of atoms having much higher velocity $|v| > 1 \times 10^5$ m/s. It is also found that

the time-dependence of the velocity distribution for $|v| < 1 \times 10^5$ m/s is very small, while that for $|v| > 1 \times 10^5$ m/s is prominent. The high velocity tail decreases as the discharge time passes, where the central electron temperature increases and the line averaged electron density decreases as shown in Fig. 1 (left). Since such high velocity excited atoms are not generated through molecular dissociation, they are thought to be generated by charge exchange collisions with high velocity protons, and whose velocity may depend on the core plasma parameters.

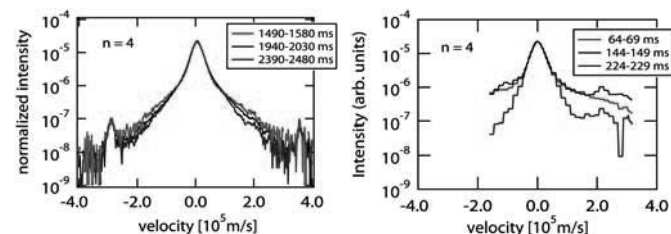


Fig. 2. Velocity distributions along the line of sight of the excited hydrogen atoms in the $n = 4$ state for the LHD plasma at $t = 1490 - 1580$, $1940 - 2030$, and $2390 - 2480$ ms (left) and those for the GAMMA10 plasma at $t = 64 - 69$, $144 - 149$ and $224 - 229$ ms (right).

Figure 1 (right) shows the temporal development of the Balmer- α emission intensity, line averaged electron density and diamagnetism of the observed GAMMA10 plasma. The corresponding electron density is about $2 \times 10^{18} \text{ m}^{-3}$ at the center, which is 1/10-1/20 of that of the LHD plasma. The Balmer- β spectrum is measured every 20 ms with an exposure time of 5 ms.

In order to obtain an enough S/N ratio, we sum the data obtained at the same timing of repeated 8 shots of the discharge (#213702 – 213709) and of 20 lines of sight. Fig. 2 (right) shows the velocity distributions of the $n = 4$ hydrogen atoms at $t = 64 - 69$, $144 - 149$ and $224 - 229$ ms calculated from the observed Balmer- β spectra.

Due to the ICCD detector and spectrometer used for the GAMMA10 observation, the measured wavelength range and resolution are smaller than those for the LHD. As the LHD plasma, however, the velocity distribution is different from Maxwellian and has the high velocity tail of $|v| > 1 \times 10^5$ m/s. From the beginning (60 ms) to the end (220 ms) of the discharge, the high velocity tail has a similar profile. The structure at $v = 2.1 \times 10^5$ m/s observed at $t = 144 - 149$ ms may be due to impurity emission. On the other hand, the high velocity tail is scarcely seen at $t = 224 - 229$ ms, where a recombination plasma after the end of discharge is observed. Since the high velocity hydrogen atoms are thought to be generated by charge exchange collisions with high velocity protons, the absence of the high energy tail at $t = 224 - 229$ ms is consistent with the change of the plasma parameters shown in Fig. 1 (right) at and after the end of the discharge.

1) Fujii, K. et al.: Nuc. Instrum. Methods Phys. Res. Sect. A, in press.