§66. A Study of Particle Transport Based on the Balmer-α Line Profile

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The Balmer-α line profile has been observed with high wavelength resolution for discharges aiming at getting higher plasma performance with respect to T_i, n_e, and β, which are the ion temperature, the electron density, and the ratio of the plasma pressure to the magnetic field pressure, respectively.

Figure 1 shows the line profiles obtained. In the all three cases the line profile is found not to be approximated with a single Gaussian function. Actually, a Gaussian function would be a parabola when the magnitude is shown in the logarithmic scale and that is not the case for the results in Fig. 1. Here, the line profile is regarded as a superposition of various Gaussian components having different widths and magnitudes. Since the Gaussian width is directly related to the atom temperature T, T is used instead of the line width hereafter.

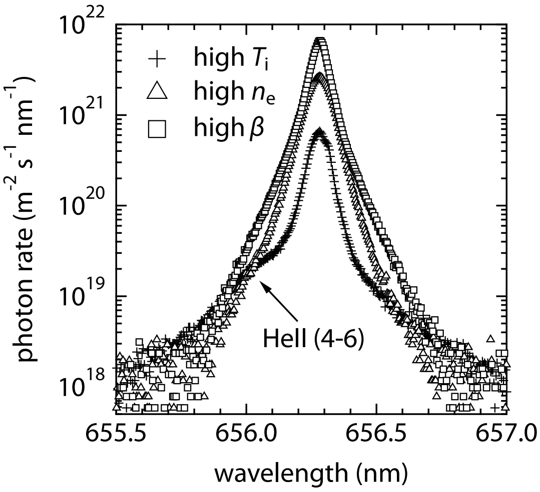

Fig. 1: Balmer-α line profiles measured for a high-T_i discharge (plus), for a high-n_e discharge (triangle), and for a high-β discharge (square).

Mathematically, the line profile $I(\lambda)$ can be expressed as an integral transform such as $I(\lambda) = \int_0^\infty g(T) f(\lambda, T) \mathrm{d}T$, where $f(\lambda, T)$ represents the Gaussian function of the temperature T and $g(T)$ is its fraction in the whole profile. It is readily shown that the equation above can be rewritten as the form of Laplace transform after replacement of several parameters.

The Balmer-α line shows a large variety of profiles as shown in Fig. 1 depending on the conditions of the discharge. The high-n_e discharge shows a peaked n_e profile and a flat T_e profile. The central T_e and n_e at the timing of the line profile observation are 0.3 keV and 4×10^{20} m^{-3}, respectively. The high-T_i and high-β discharges have a peaked T_e profile and a flat n_e profile. The central T_e and n_e for the high-T_i discharge are 3.5 keV and 9×10^{18} m^{-3}, respectively, and those for the high-β discharge are 0.4 keV and 2.5×10^{19} m^{-3}, respectively.

It is noted that the hump shown at around 656.0 nm for the high-T_i discharge is due to the HeII (n = 4–6) line. Since other profiles are also potentially influenced by the same line, the wavelength range longer than the line center is only used in the following analysis.

We have carried out numerical inversion of the Laplace transform [1] of the line profile and derived $g(T)$ [2]. The temperature dependence is then translated to the radial distribution, where the ion temperature profile which is approximated by the T_e profile is used, so that the radial profile of the photon emission rate $\epsilon(R)$ is evaluated from $g(T)$. The ionization rate $S(R)$ and the neutral influx $\Gamma(R)$ are finally derived with the help of collisional-radiative model calculation.

Figure 2 shows $\Gamma(R)$ obtained. The influx Γ at the outmost location is in the similar magnitude between in the high-β discharge and in the high-n_e discharge, while in the high-n_e discharge the decay is much faster and Γ in the core region is much smaller. Since the absolute n_e is lower in the high-β discharge, its higher Γ values leads to a smaller value of the particle confinement time.

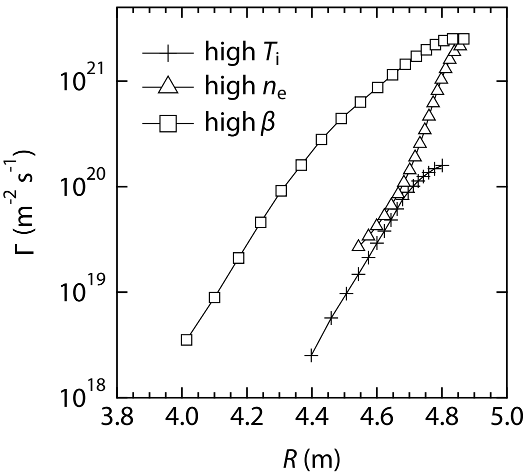

Fig. 2: Radial profile of inward atom flux derived from $g(T)$ for the discharges analyzed here.

The relative Γ profile is similar between in the high-T_i discharge and in the high-β discharge while the magnitude is approximately one order smaller in the former. However, n_e in the high-β discharge is larger only by a factor of three. This result also leads to a smaller particle confinement time in the high-β discharge.

These results are understandable because the central magnetic field strength in the high-β discharge is 0.41 T which is rather weaker than 2.539 T in the high-n_e discharge and than 2.75 T in the high-T_i discharge.

1) Bellman, R. E. et al.: Numerical Inversion of the Laplace Transform, Elsevier, New York (1966).

2) Goto, M. et al.: Nucl. Fusion **51**, 023005 (2011).