§30. Radiation Trapping of Atomic Hydrogen and Helium in LHD Edge Plasma

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The radiation trapping of hydrogen atom resonance lines has been found in the divertor regions where strong net volume recombination resulting in the high atom density is observed.[1,2] At the Alcator C-Mod, it is observed that up to 50% of the L_β emission is trapped, indicating that L_α is strongly trapped in some case.[2] The goal of the present investigation is to understand the effects of the radiation trapping on the particle and energy balance of the LHD divertor plasma using our collisional radiative model of hydrogen atoms and molecules.

We have developed a novel self-consistent computational code for solving the radiative transfer equation coupled with the collisional radiative rate equation,[3] whose computational steps are as follows: First, the spatial distribution of populations of excited levels is calculated neglecting the radiation trapping. The obtained spatial distribution is then used as the photo excitation source, and thus resulting in a new spatial distribution of populations of excited levels. This spatial distribution is again employed for the next solution as the photo excitation source. These steps are repeated until a convergence appears. We have applied the new code to an infinite 1cm thickness slab plasma which has uniform temperature $T_e = T_H = 1\text{eV}$, electron density $n_e = n_{H^+} = 10^{15}\text{cm}^{-3}$, the ground state density $n(1) = 10^{14}\text{cm}^{-3}$, and calculated the effective ionization and recombination rate coefficients, which are defined by

$$\frac{dn(1)}{dt} = -S_{CR} n(1) n_e + \alpha_{CR} n_{\mathrm{H}^+} n_e. \qquad (1)$$

We include the absorption of L_α and L_β lines. If these absorptions are neglected, the effective ionization and recombination rate coefficients are

$$S_{CR} = 2.5 \times 10^{-13}, \qquad \alpha_{CR} = 4.6 \times 10^{-12} \qquad \left[\frac{\text{cm}^3}{\text{s}}\right].$$

The absorption of L_α and L_β lines increases S_{CR} nearly two orders of magnitude,

$$S_{CR} = 1.9 \times 10^{-11} \qquad \left[\frac{\text{cm}^3}{\text{s}}\right].$$

α_{CR} does not change because the induced emission is negligible.

In order to verify our code before applying it to the LHD plasmas, we have developed a simple rf plasma source at Shinshu university, where a plasma column with a diameter of 5 cm is created with densities in the rage of $10^{10} - 10^{12}$ cm^{-3} and electron temperatures in the 2-6 eV range.

We measured intensities of atomic emission lines of Balmer $\alpha, \beta, \gamma, \delta$ and molecular band ($d^3\Pi_u$-$a^3\Sigma_g^+$ fulcher transition). As a first step, we analyzed the emission intensities assuming no radiation trapping. Figure 1 shows the population of excited atom determined from the intensities of the Balmer lines emitted from a plasma with $n_e = 2.5 \times 10^{11}\text{cm}^{-3}$, $T_e = 3.0\text{eV}$. Figure 1 also shows population coefficients $R_0(p)$, $R_1(p)$, and $R_{MAR}(p)$ which are defined by

$$n(p) = R_0(p) n_z n_e + R_1(p) n(1) n_e + \Sigma_v R_{MAR}(p, v) n_{H_2(v)} n_e, \qquad (2)$$

where p is the principal quantum number. The last term denotes the population originated from the molecular assisted recombination (MAR).

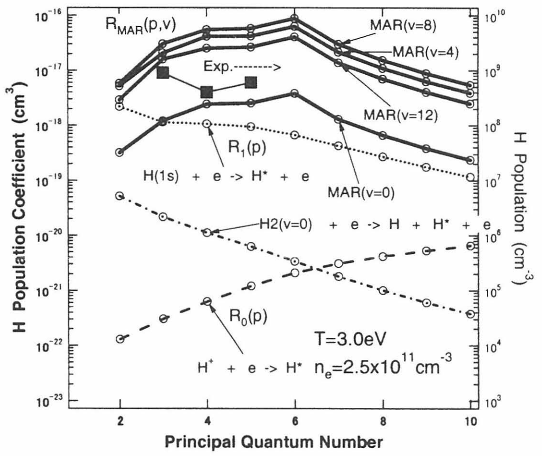

Fig.1. Populations of excited atoms determined from the Balmer line intensities (closed square). Population coefficients of eq.(2) are also shown (open circle).

The experimental populations were well fitted by eq.(2) with $n_H = 2.7 \times 10^{14}\text{cm}^{-3}$, $n_{H_2(v=0)} = 1.0 \times 10^{14}\text{cm}^{-3}$. The value of $n_{H_2(v=0)}$ was consistent with gas pressure of 0.015Torr within the experimental uncertainty. However, the atomic density indicates that the radiation trapping should not be neglected because the opacity at the line center of L_α is about 10^3. At present, our code needs the spatial distribution of the ground state atoms. We are planning to determine the distribution with the help of a neutral transport model.

Reference

1) B.Napiontek et al, Proceedings 24th EPS Conference Berchtesgaden (1997)1413

2) J.L.Terry et al, Phys. Plasmas 5, (1998)1759

3) T.Fujimoto, S.Miyachi, K.Sawada, Nuclea Fusion 28, (1988)1255