§1. Construction of Deuterium Neutral Transport Code for LHD Boundary Plasmas

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In LHD project, a plan of deuterium discharge is discussed. We are developing collisional radiative models of atomic and molecular hydrogen, and a neutral transport code for the species. By using the codes, we have analyzed the intensities and profiles of spectra emitted from hydrogen atoms in the outer region of LHD plasmas and determined spatial flows of atoms and molecules, and reactions of hydrogen species. The purpose of this study is to construct numerical codes for the deuterium plasmas, and to understand the difference between hydrogen plasmas and deuterium plasmas. In this study, as a first step for the deuterium codes, we have constructed a corona model for the Fülcher band ($d^3\Pi_u \rightarrow a^3\Sigma_g^+$) of the deuterium molecule. Further, we have applied the code to RF deuterium plasmas in our laboratory in order to determine the vibrational and rotational temperatures in the electronic ground state of the deuterium molecule. The estimation of the temperatures is essential to evaluate the importance of the MAR (Molecular Assisted Recombination) in divertor plasmas because the effective rate coefficients of the processes strongly depend on the initial vibrational and rotational states of the molecular hydrogen[1),2)]. The processes of the MAR are as follows:

$$\begin{aligned} D_2 + D^+ &\rightarrow D_2^+ + D \\ D_2^+ + e &\rightarrow D + D \end{aligned}$$

and

$$\begin{aligned} D_2 + e &\rightarrow D^- + D \\ D^- + D^+ &\rightarrow D + D. \end{aligned}$$

In the corona model the population of each excited state is determined by balancing collisional excitation from the ground state with spontaneous radiative decay. In constructing the model for the deuterium molecule, as compared with the hydrogen molecule, the excitation cross sections and the Einstein A coefficients have not been investigated enough; we have calculated vibrational wave functions using reliable electronic potential data in order to produce the Einstein A coefficients and franck-condon factors.

The RF plasma device at Shinshu University is primarily designed to study atomic and molecular processes in plasmas. A 1 m long plasma column with a diameter of about 5 cm is created with densities in the $10^9 - 10^{12}$cm^3 range and electron temperatures in the $1 - 15$ eV range. We have applied the code to spectroscopic data of the Fülcher band of the RF plasmas. Figure 1 shows an example of the experimental results. Figure 2 shows the result of the calculation which reproduces the intensity of the fülcher band best by adjusting the vibrational and rotational temperatures. The determined vibrational temperature and rotational temperature were 3000 K and 350 K, respectively. Discrepancy of the experimental data and the calculation data is found in wavelength regions of around 600 nm and around 630 nm. At present we suppose the discrepancy is due to the negligence of the excitation from the metastable excited level ($c^3\Pi_u$). In order to estimate the contribution of the metastable level and to construct a model which can be used for higher electron density plasmas of LHD, we are investigating the molecular data to construct the collisional radiative model which includes the process.

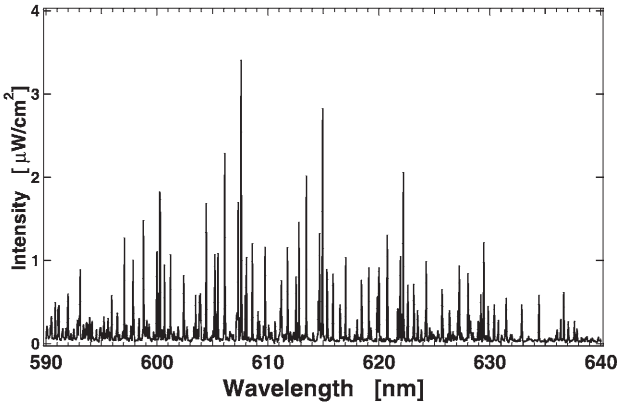

Fig. 1: The Fülcher band ($d^3\Pi_u \rightarrow a^3\Sigma_g^+$) spectra of the deuterium molecule measured in the RF plasma at Shinshu University.

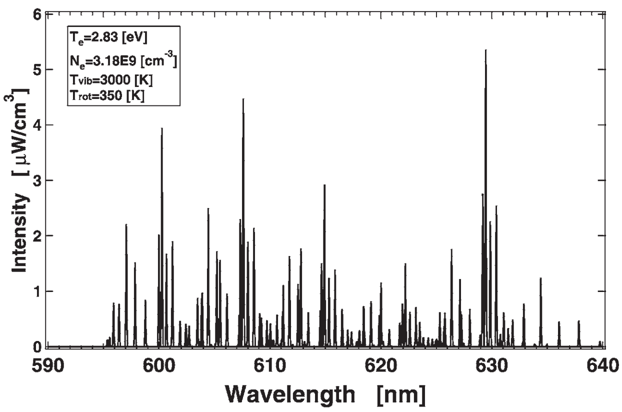

Fig. 2: Calculation by the corona model. The parameters of the vibrational and rotational temperatures are adjusted to reproduce the experimental data.

1) Sawada, K., J. Plasma Physics, **72**, (2006) 1025.
2) Horacek, J., Houfek, K., Cizek, M., Murakami, I., Kato, T., NIFS-DATA-73, (2003).