§2. Construction of a Deuterium Neutral Transport Code for Large Helical Device Boundary Plasmas

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We have developed collisional-radiative models of atomic and molecular hydrogen as well as a neutral transport code for hydrogen species. These codes are used to study the reaction and spatial flows of atoms and molecules in Large Helical Device (LHD) edge plasmas. The purpose of this study is to construct a code for deuterium plasmas to prepare the future deuterium discharge plan for the LHD.

The neutral transport code needs reaction rate coefficients for atoms and molecules. We are constructing a collisional-radiative model for the deuterium molecule to calculate the reaction rate coefficients that include the contribution of the excited states. The electron temperature and density of the plasma, which are the input data for the neutral transport code, are also expected to be determined by analyzing the emission intensity of molecular bands with the collisional-radiative model because the populations of the excited states are a function of the electron temperature and density.

To construct the collisional-radiative model, we have calculated the spontaneous transition probabilities for optically allowed transitions for upper states with the principal quantum number of the united atom $n \leq 4$ considering the electronic, vibrational, and rotational states. This year, as a simple version of the collisional-radiative model, we have constructed a corona model for the deuterium molecule. In the corona model, the population of each excited state is calculated from a balance between the electron impact excitation from the ground state and the spontaneous transition to lower states.

Figure 1 shows spectra measured in an RF deuterium discharge at Shinshu University. Many molecular bands are observed in addition to atomic Balmer lines. We identified the bands using energy level data in Ref.1. Identified bands are shown with arrows in Fig. 2. Corona models for analyzing the $d^3\Pi_u \rightarrow a^3\Sigma_g^+$, $J^1\Delta_g \rightarrow C^1\Pi_u$, and $I^1\Pi_g \rightarrow C^1\Pi_u$ bands were applied to the plasmas.

For the Fülcher band $d^3\Pi_u \rightarrow a^3\Sigma_g^+$, the electronic, vibrational, and rotational states are distinguished in the model. For the $J^1\Delta_g \rightarrow C^1\Pi_u$ and $I^1\Pi_g \rightarrow C^1\Pi_u$ bands, because the rotational state resolved electron impact excitation cross sections are not available, we distinguish only the electronic and vibrational states; the initial rotational state of the spontaneous transition is assumed to be the ground state. Using the electron temperature and density measured by the double electric probe, we calculate the population of the excited state and the emission intensity. For the Fülcher band, the measured and calculated spectra agree well as shown in Figs. 3(a) and 3(b). For the $J^1\Delta_g \rightarrow C^1\Pi_u$ and $I^1\Pi_g \rightarrow C^1\Pi_u$ bands, we summed experimentally obtained populations for the rotational state and compared with the result of the calculation. For these transitions, there is an apparent discrepancy at the present. We will continue to research the discrepancy and construct the collisional-radiative model.

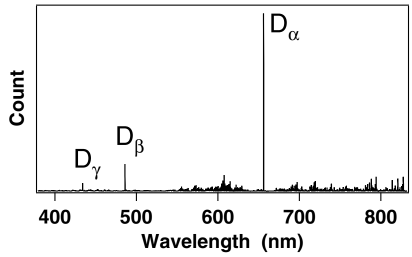

Fig. 1: Spectra observed in an RF deuterium plasma.

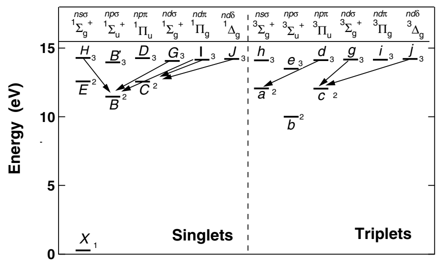

Fig. 2: Electronic states of the deuterium molecule. Identified bands in the RF deuterium plasma are shown with arrows.

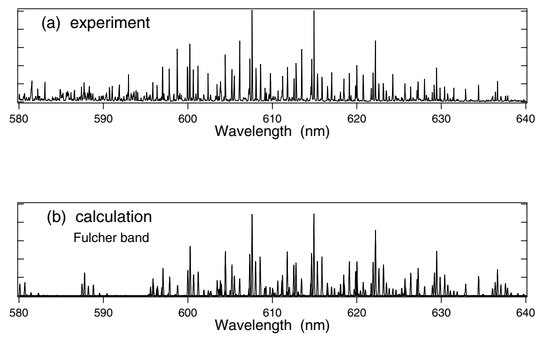

Fig. 3: Spectra in the wavelength range of 580-640 nm: (a) experiment, (b) calculation for Fülcher band.

1) Robert S. Freund and James A. Schiavone, The Electronic Spectrum and Energy Levels of the Deuterium Molecule, J. Phys. Chem. Ref. Data 14, (1985).