# §14. Construction of Collisional Radiative Model and Neutral Transport Code for Hydrogen and Deuterium Plasmas

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We are developing collisional radiative models of atomic hydrogen and molecular hydrogen. The codes are widely used to calculate population densities of excited states of atomic hydrogen and molecular hydrogen for understanding spectroscopic intensities of atomic or molecular hydrogen. The codes are also used to estimate effective reaction rate coefficients for various atomic and molecular processes, which are indispensable for neutral transport codes. For LHD plasmas, a neutral transport code for hydrogen species which includes the collisional radiative models has been constructed by the authors and this united code has been used to diagnose densities, spatial flows and chemical reactions of the hydrogen species in LHD plasmas.

In LHD project, experiments of deuterium plasmas are planned. The purpose of this study is to construct codes for deuterium plasmas. As a first step, we have constructed a corona model of the Fülcher band ($d^3\Pi_u \rightarrow a^3\Sigma_g^+$) of molecular deuterium. In the corona model, population of each excited state is determined assuming a balance of the excitation inflow from the ground state and the spontaneous emission outflow to lower levels. In the model, the vibrational and the rotational temperatures in the electronic ground state are adjustable input parameters to reproduce experimental data; we can determine both temperatures from observed spectroscopic intensity of the fülcher band. These temperatures are essential in evaluating the importance of the Molecular Assisted Recombination in the divertor plasmas because the rate coefficient strongly depends on the temperatures.

In constructing the corona model, the Einstein A coefficients and electron impact excitation cross sections of the deuterium molecule are necessary. However, they have not been studied well as compared with those of the hydrogen molecule. Thus we searched the most reliable electronic potential data for the ground and excited states and calculated vibrational wave functions of them by solving the Shrödinger equation by the Numerov method. The vibrational wave functions were used to calculate the franck-condon factors and the transition probabilities. Figure 1 shows the vibrational wave functions of the electronic ground state.

Figure 2 shows an example of the Fülcher band spectra of deuterium RF(13.56MHz) plasmas in our laboratory. The electron temperature and electron density were 3 eV and $3 \times 10^9 \mathrm{cm}^{-3}$, respectively. The gas pressure was 0.03 torr. Figure 3 shows a result of the corona model. The determined vibrational and rotational temperatures were 3000 K and 350 K, respectively. The experimental data was not reproduced well by the calculation in wavelength regions of around 600 nm and around 630 nm. At present we suppose it is due to the negligence of the excitation from the meta-stable state ($c^3\Pi_u$) of deuterium molecule.

In LHD plasmas, because of the high electron density, the excitation among the excited states can not be neglected. We are constructing a collisional radiative model which includes the processes.

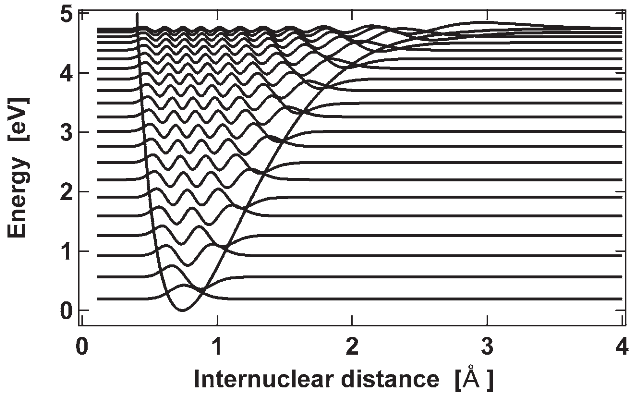


Fig. 1: Vibrational wave function of the ground electronic state of the deuterium molecule.

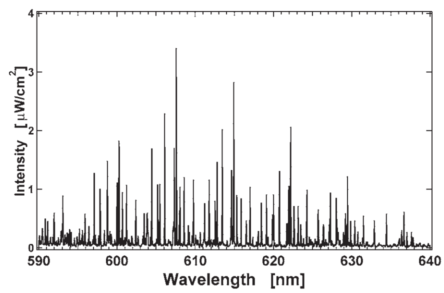


Fig. 2: Spectra of the Fülcher band of the deuterium molecule.

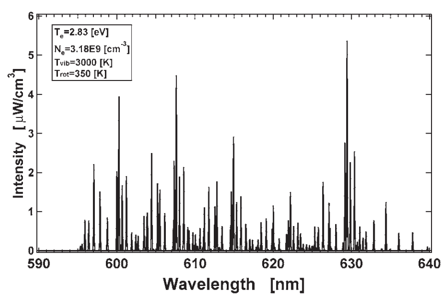


Fig. 3: Calculated intensity of the Fülcher band.