§23. Construction of Neutral Transport Code for LHD

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Understanding reactions of the atomic and molecular hydrogen in LHD plasmas is essential to improve the performance of the main plasmas and to reduce the heat flux to the divtertor wall. In order to investigate the reactions, we have been developing collisional-radiative models and neutral transport code for the hydrogen species. Improvements of the models in this study are as follows:
(1) The collisional-radiative model of the molecule is an important part of the neutral transport code because it gives the effective reaction coefficients to the neutral transport code. We have already constructed a collisional-radiative model of molecular hydrogen in which the electronic and vibrational states are resolved [1, 2]. We are now developing a new model that includes electronic, vibrational, and rotational states. This model can provide more precise effective reaction rate coefficients of the molecule. Emission line intensities of hydrogen molecules in plasmas are also calculated as a function of the molecular density n_{H2}, the electron temperature T_{e} and electron density n_{e}, the vibrational temperature T_{v} and rotational temperature T_{rot} in the ground electronic state. From observed spectra, these parameters can be determined. In the new model, assuming Hund's (b) case, the levels are labeled by the principal quantum number n, and Λ, N, and J. The model includes the levels for $n \leq 6$. The number of 4133 levels is considered in the model. Level energies for $EF^1\Sigma_g^+$, $GK^1\Sigma_g^+$, $H^1\Sigma_g^+$, $B^1\Sigma_u^+$, $C^1\Pi_u$, $B'^1\Sigma_u^+$, $D^1\Pi_u$, $I^1\Pi_g$, $J^1\Delta_g$ are taken from Ref.3. Other level energies for $n \leq 4$ states are taken from Ref.4. Level energies for n =5 and 6 states are calculated from electronic potentials.
(2) In the trace of the particles in the neutral transport code, spatial cells, in which the electron temperature and density are given, are used. In our model, approximately 4 cm×4 cm×4 cm volume cell was used. However, in the surface region of the main plasma, actually, T_{e} changes about 100 eV in one cell. Because the effective rate coefficients depend strongly on T_{e}, we introduced sub-cells. In the code, when we give the range of T_{e} or n_{e} for which the sub-cells are applied, the original cells with this range are divided into given number of sub-cells automatically. We have applied the new code to a LHD plasma. Figure 1 shows atomic hydrogen Balmer α line profile calculated by the new code. In this case, the change of the emission intensity and line profile with and without the sub-cells is not significant.
(3) We have revised cross sections of elastic collision [5] and charge exchange [6] between neutral hydrogen and proton. Before the revision, the elastic collision is calculated based on the classical mechanics. However, in the quantum mechanics, these cross sections cannot be dealt with separately. In the revised model, the cross section based on the quantum mechanics [7] was included. The line shape in Fig. 1 is calculated with the revised cross section. The high energy tail of the line shape differs slightly from the experimental one. We are investigating the origin of this difference.

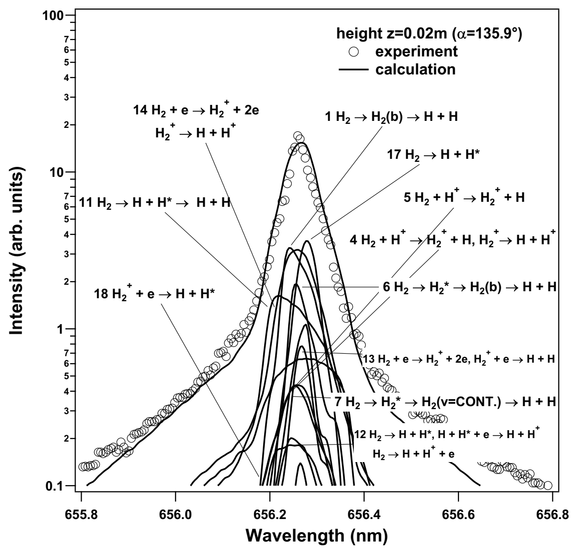

Fig. 1: Atomic hydrogen Balmer α line profile of a LHD plasma calculated by using the sub-cells. Cross section of $\mathrm{H} + \mathrm{H}^+ \to \mathrm{H}^+ + \mathrm{H}$ based on the quantum mechanics is used.

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