21PB-067

Hydrogen and Helium Spectroscopy of LHD Plasmas
LHDにおける水素原子・分子およびヘリウム原子の発光線解析

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We included our collisional-radiative models of atomic hydrogen and molecular hydrogen into our neutral particle transport 3D-code for LHD. Emission intensity of atomic hydrogen and molecular hydrogen and line profile of Balmer α are calculated. We investigated source and wall reflection condition of the neutral particles which reproduces spectroscopic data of the line intensity and profile.

1. Introduction

We are constructing a collisional-radiative model of molecular hydrogen in which the electronic, vibrational, and rotational states are considered to deal with molecular processes whose cross sections strongly depend on the initial vibrational and rotational states, e.g., the dissociative attachment. This model is included in our neutral transport code for LHD plasmas. In the calculation, giving adequate particle source condition and wall reflection condition is essential; The particle emitted from the divertor plate goes through a divertor plasma. However, the source condition and the divertor plasma condition, which are necessary for the simulation, are not well known. Particle reflection condition on the wall is also not well known. In this study, we investigate these conditions which reproduces spectroscopic data of the line intensity and profile of the atoms and molecules.

2. Experimental

Spectroscopic data (Shot Number 123334, Time 3 s,1-O port) of Fujii and Hasuo (Kyoto Univ.) is analyzed. Figure 1 shows poloidal cross section of the measurement. Figures 2 and 3 show emission spectra measured by an echelle spectrometer at z= -0.026 m. Figure 3 is an enlarged one of Fig.2, where the molecular emission lines are seen. Figure 4 shows line profiles of the atomic Balmer α measured by a high-resolution spectrometer.

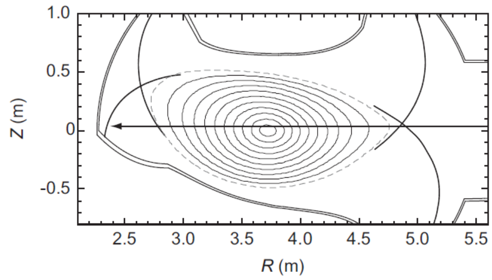

Fig.1. Poloidal cross section of the measurement. The direction of the line-of-sight is shown with the arrow.

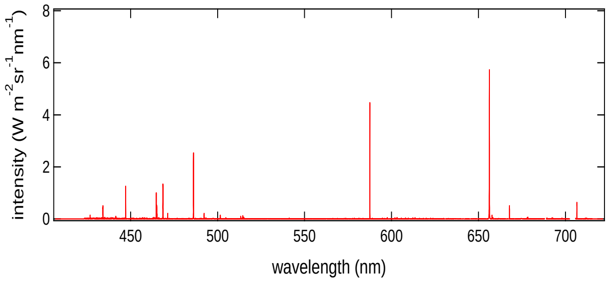

Fig.2. Emission spectra measured by an echelle spectrometer at z= -0.026 m.

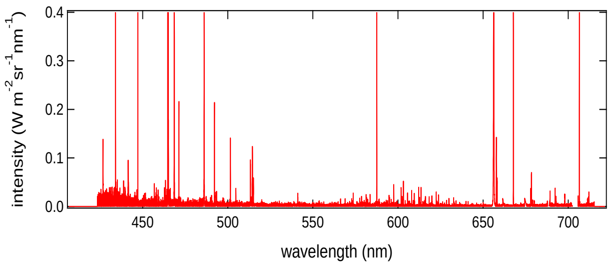

Fig.3. Figure 2 is enlarged.

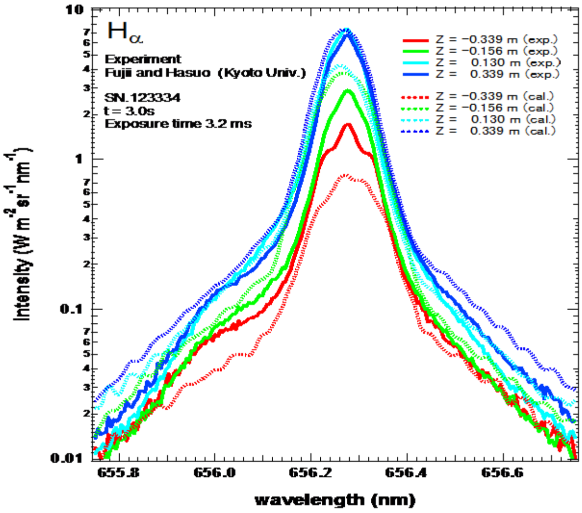

Fig.4. Line profiles of the atomic Balmer α measured by a high-resolution spectrometer. solid : experiment. dotted : calculation.

3. Model

In order to calculate the line-of-sight integrated spectra, we evaluated atomic and molecular hydrogen density distribution using the neutral transport code for LHD. Figure 5 shows atomic and molecular processes considered in the code.

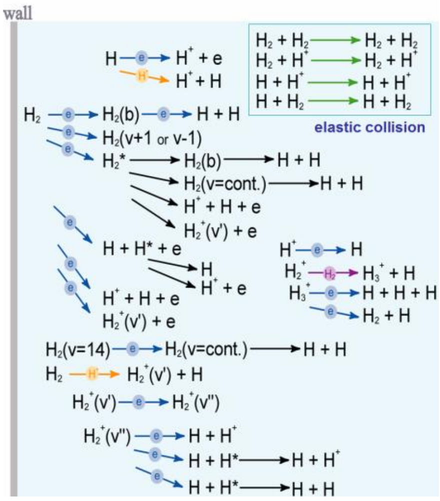

Fig.5 Atomic and molecular processes considered in the neutral transport code for LHD.

Absolute densities of hydrogen species are calculated from the observed absolute intensity of the atomic Balmer α emission line intensity.

We used electron temperature and density data provided by Thomson scattering. Divertor plasma is not set in the model; We give particle source along divertor plate. In the present model, particle emitted from the source should be interpreted as that emitted from the divertor plasma surface.

We calculate the emission spectra of molecular hydrogen using our collisional- radiative model in which the electronic, vibrational, and rotational states are resolved. Assuming Hund's (b) case, the levels are labeled by the principal quantum number n, and Λ, N, and J. The number of 4133 levels for $n < 7$ are included. This model was tested using an RF plasma device of our laboratory at Shinshu University. Measured absolute emission intensity of Fulcher band ($d^3\Pi_u$ to $a^3\Sigma_g^+$) intensity was well reproduced by the model.

In calculating the line profile of the atomic Balmer α, Doppler broadening and Zeeman splitting are considered.

4. Results and Discussion

Figure 4 shows an example of calculated line profiles of the atomic Balmer α. The ratio of atoms and molecules emitted from the source is set to be 1:0. In the present wall model, a molecule is reflected as a molecule, and an atom is reflected (emitted) as an atom (10%) or a molecule (90%). Measured profiles are roughly reproduced by the calculation. Figures 6 and 7 show calculated emission lines. In this case, the intensity of the molecular lines is larger than the experimental one. We are now testing the various source and wall reflection condition of neutral particles which reproduces the Balmer α line profile and intensity of molecular emission simultaneously.

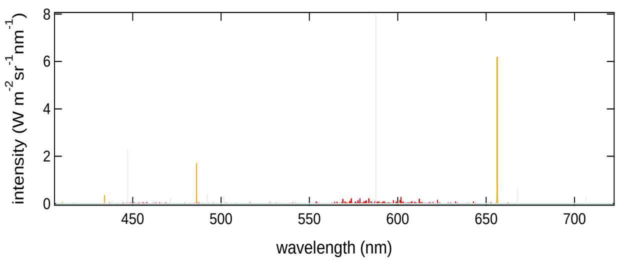

Fig.6. Calculated spectra.
orange: atom . red: molecule.
gray: helium atom (crude calculation).

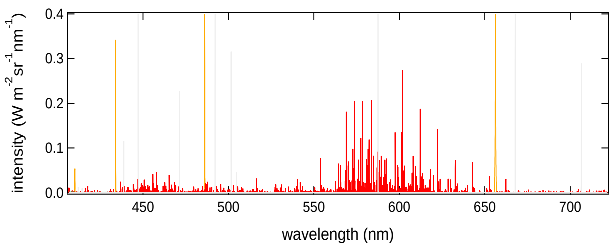

Fig.7. Figure 6 is enlarged.

References

[1] K. Fujii, T. Shikama, M. Goto, S. Morita, and M. Hasuo: Phys. Plasmas 20 (2013) 012514.