§59. Investigation of the H_2 Rotational Excitation Process in QUEST

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The penetration depth of hydrogen molecules into the plasma depends on the translational temperature of the molecules. The change in the depth can affect the spatial distributions of the atomic hydrogen density and reaction rate of recombination in particular under the detached divertor operation. The evaluation of the penetration depth is therefore essential for the modeling of the edge plasma behavior. For low temperature molecules, the deduction of the translational temperature based on a thermal equilibrium between the rotational and translational temperatures has been utilized instead of the estimation of the small Doppler broadening. Development of a reliable diagnostics for the rotational temperature is thus significant.

The rotational population distribution in the electronic ground state ($X^1\Sigma_g^+$) of hydrogen molecules is known to be approximately represented by two temperatures (cold and hot), and the cold component reflects the translational temperature[1]. However, since direct measurements of the rotational population distribution in the *X*-state require experimental elaboration, visible radiative transitions between the elecrtronic excited states have been utilized alternatively[2]. In this case, an excitation-emission model should be constructed to deduce the rotational temperature in the *X*-state because the rotational temperatures in the excited states are usually not in the thermal equilibrium with that in the *X*-state. In the present work, we have developed an excitation-emission model for the $d^3\Pi_u$ - $a^3\Sigma_g^+$ transition based on the coronal equilibrium, and applied it to the QUEST plasma.

H_2 Fulcher-α band emission ($d^3\Pi_u$ - $a^3\Sigma_g^+$, $v' = v'' = 0$), where v' and v'' are the vibrational quantum numbers of the upper and lower states respectively, from a tungsten limiter located in front of the QUEST center stack was observed using a radial viewing chord installed at MH16 port. The collected emission was transferred to a Czerny-Turner type spectrometer (Acton Research AM-510; focal length 1 m, grating 1800 grooves/mm) via bundled quartz optical fiber, and spectra were recorded by a CCD (Andor DU-440BU2; 2048 x 512 pixels, 13.5 square μm pixel). The instrumental function was about 0.04 nm at FWHM, and reciprocal linear dispersion was about 0.00575 nm/pixel.

Fig. 1 shows the measured Fulcher-α band *Q*-branch spectrum. The rotational excitation distribution in the *d*-state was evaluated from the emission intensities of the *Q*1, *Q*2, *Q*4, and *Q*5 transitions. We excluded the *Q*3 transition because of the contamination of another emission spectrum, a slight broadening of the spectrum can be seen at the wing of the spectrum. The evaluated population densities divided by the statistical weights are shown in Fig. 2. To deduce the rotational temperature in the *X*-state, we developed an excitation-emission model based on the coronal equilibrium[3], and the rotational temperature in the *X*-state was evaluated as 380 K. Dependence of the rotational temperature on the plasma parameters as well as on the surface temperature of the center stack will be investigated in the future.

1) T. Mosbach, H. –M. Katsch, H. F. Dobele, *Phys. Rev. Lett.* **85** (2000) 3420.
2) T. Shikama, S. Kado, K. Kurihara, and K. Kuwahara, *Phys. Plasmas* **16** (2009) 033504, and references therein.
3) T. Shikama, S. Kado, Y. Iida, and K. Suzuki, *Nucl. Instrum. Methods A* **623** (2010) 744.

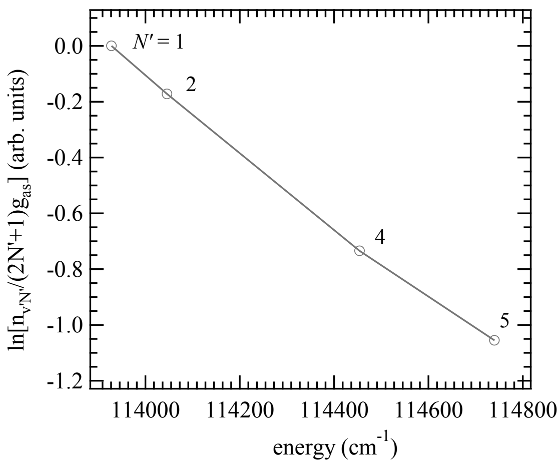

Fig. 2. Evaluated rotational population distribution in the $d^3\Pi_u$ state. In the figure, $n_{v'N'}$ is the population density, *N'* is the rotational quantum number, and g_{as} is the nuclear spin statistical weight.

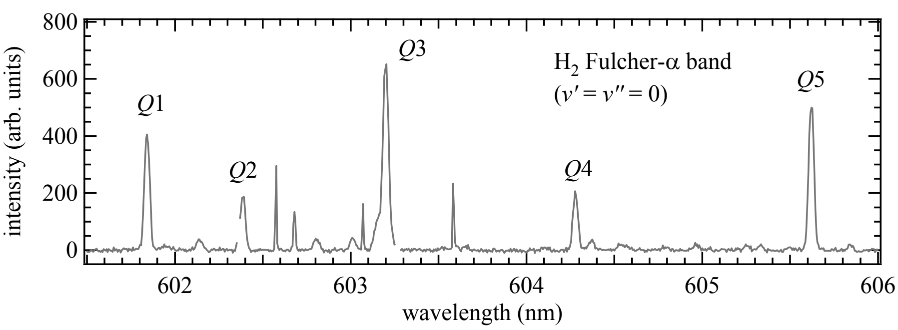

Fig. 1. Observed H_2 Fulcher-α band *Q*-branch spectra ($v' = v'' = 0$) from the QUEST center stack.