§23. Polarization Resolved Spectroscopy and Diagnostics on Hydrogen Atomic and Molecular Transport in the LHD Periphery Plasma

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Transport of neutral atoms and molecules in a periphery plasma is of great interest in controlling the performance of the magnetically confined plasma and the heat flux to the divertor plates. The emission location, intensity, temperature and velocity of neutral hydrogen atoms in the LHD periphery plasma have been studied by observation and analysis of their polarization resolved spectra. Here, we extend this method to molecular hydrogen.

Visible emission was collected into optical fibers with polarization-separation optics. The spectra were recorded with a high-resolution spectrometer (Jobin Yvon THR-1000: f = 1.00 m, 2400 grooves/mm), which was controlled from Kyoto University through the SNET. The wavelength and the intensity were calibrated with a Th-Ar hollow cathode lamp and a calibrated standard lamp, respectively.

Figure 1 shows polarization-separated spectra of molecular hydrogen (Fulcher-α band, $d^3\Pi_u$ - $a^3\Sigma_g^+$) observed in the lowest line of sight, which is adjacent to the helical coil. We obtained the spectra by averaging over several discharges with the same field configurations (R_{ax} = 4.00 m, B_{ax} = 2.475 T) resulting in the total exposure time of about 1 minute. The lines denoted with Q1, Q2, Q3 in figure 1 are due to the transitions between the upper and lower levels having the same vibration states (v = 2) but the different rotation states (J = 1, 2, 3). Their line intensity ratio indicates the rotation temperature of the upper level to be about 500 K, which is considered to correspond to the gas temperature of hydrogen.

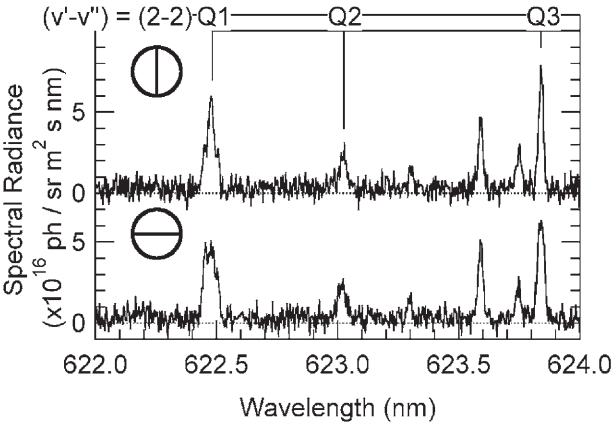

Fig. 1. Polarization-resolved spectra of molecular hydrogen Fulcher-α band.

The dots in figure 2 show the enlarged Q1 spectra. The line splitting depending on the polarization is seen. Assuming the observed line profiles to be due to the Zeeman effects on the molecular hydrogen and also the observed emission to be mainly radiated by molecular hydrogen at the ergodic layer (inner) and at the divertor leg (outer), we reproduced the observed spectra by fitting. These assumptions have been confirmed to be reasonable in the cases of atomic hydrogen and helium. The strength and direction of the magnetic field at the emission location determine the splitting and the polarization, respectively. The calculated spectra of the inner components (solid lines) and of the outer components (dotted lines) are indicated in figure 2. The calculated emission locations and intensities of the molecular hydrogen are shown in figure 3. The emission intensity at the divertor leg is about 4 times of that at the ergodic layer. This indicates the density of the molecular hydrogen is higher in the divertor leg than in the ergodic layer. The velocities along the sight lines evaluated from the Doppler shifts of the spectra are also shown with the arrows in figure 3. The flow of the molecular hydrogen directs to the outer region.

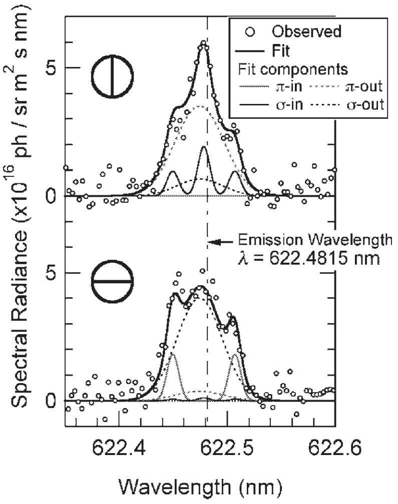

Fig. 2. Polarization-resolved spectra of the Fulcher-α (2-2) Q1 line.

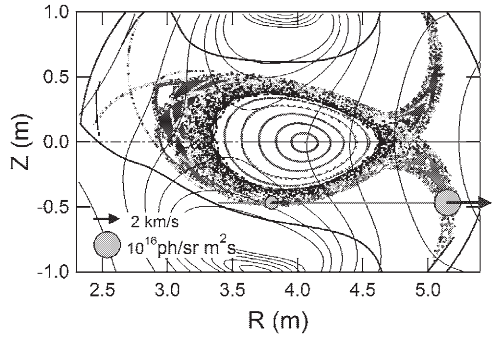

Fig. 3. The location and intensity of emission and velocity of molecular hydrogen calculated from the fitting.

We also attempted to improve the efficiency of the optics in order to record the hydrogen molecular spectra in a single discharge. Enough improvement of the efficiency, however, was not achieved despite we performed an adjustments of an astigmatism correction system.