§17. Polarization Resolved H_α Spectra from the LHD: Emission Location, Temperature and Inward Flux of Neutral Hydrogen

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In the fusion-relevant magnetic confinement devices the influx of hydrogen atoms from the periphery region to the main plasma plays an important role in realizing the *H*-mode and the edge thermal transport barrier. Its quantitative estimate is required to evaluate the particle fueling rate and to control recycling neutrals in the long pulse discharge operation. Information on helium atoms has been obtained from the He I lines emitted from the LHD[1]. The line profiles showed Zeeman (Paschen-Back) structures, and they were interpreted as a superposition of two Zeeman profiles corresponding to different magnetic field strengths and directions on the line of sight. The locations of the He I emission were identified on the magnetic field map to be just outside the ergodic layer as shown in Fig. 1. However a similar interpretation was found impractical for the H_α line owing to its lack of structure. In the following we report our polarization resolved observation on H_α.

The emission from the hydrogen discharge in LHD was observed from one of the spectroscopy ports. The line of sight was at the height 0.026 m, just above the equatorial plane; see Fig. 1. The cross section of the plasma was elongated in the major radius direction. The emission lines were resolved with the polarization separation optics (PSO) into two orthogonal polarized components. The PSO transmitted the extraordinary ray undeviated and reflected the ordinary ray at 104 degrees with respect to the input light ray. Optical fibers transmitted the light to a spectrometer. Spectra dispersed by the grating were recorded with a CCD. A fast mechanical shutter defined the exposure time. The time span was 478 ms and the repetition frequency was 2.00 Hz. The measurement was carried out for 40 s stationary phase of a hydrogen discharge heated by an NBI. The input power of the NBI was 600 kW. The gas-fueling rate was controlled so as to keep the line-averaged $n_e \sim 1\times10^{19}$ m^{-3} ,and the ion temperature was $T_i = 1.5$ keV.

The rotation angle of PSO around the line of sight, α, was defined as the angle of the polarization direction of the o-ray with respect to the horizontal plane. We fixed α at -45°. An example of the observed H_α line profiles is shown in Fig. 2; Figure 2(a) and (b) shows the e-ray and o-ray components, respectively. Upper panels are the spectra recorded during the NBI injection in the time span starting $t = 1.000$ s.

Least-squares fitting was performed on the observed e-ray and o-ray profiles simultaneously with four sets of Zeeman profiles, i.e. cold and warm components for the inner and outer regions, plus a broad Gaussian profile. Each set of Zeeman profiles had an independent intensity, a

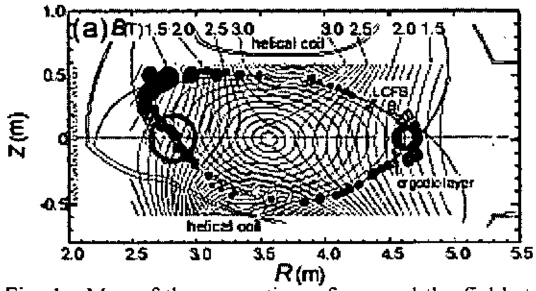

Fig. 1 Map of the magnetic surfaces and the field strength for the configuration of $R_{ax} = 3.6$ m and $B_{ax} = 2.75$ T. The R and Z axes indicate the major radial direction and the direction perpendicular to the equatorial plane, respectively. The long dashed line at Z=0.026 m indicates the line of sight of the present polarization separation observation. The open circles indicate the locations of the H_α line emission and their diameters indicates the intensity of the emission. The closed circles and triangles indicate the location of the He I λ728.1 and 667.8 nm emission lines reported in Ref. 1.

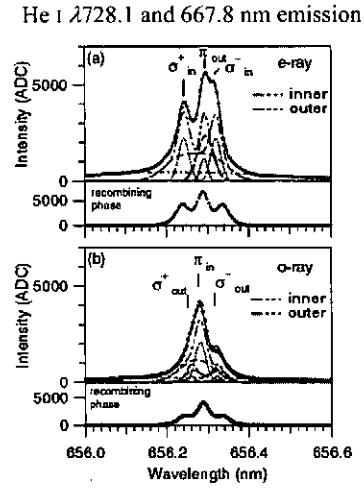

Fig. 2 The profiles of (a) the e-ray and (b) the o-ray components of the H_α line spectra. Filled and open circles show observed intensity. Upper panels are for the plasma. Lower panels are for the recombining phase after the NBI heating is turned off. Solid curves are the result of the least-squares fitting with four sets of Zeeman profiles plus a broad Gaussian profile.

Doppler width and shift. The relative transmittance between the e-ray and the o-ray was set to be constant. The result of a fitting is shown in Fig. 2 with the solid curves. The emission locations determined for the nine time spans (starting at $t = 1.0$, 3.5, 6.0, 8.5, 11.0, 13.5, 16.0, 18.5 and 21.0 s) are shown in Fig. 1. It is seen that the H_α is emitted just outside the main plasma like the case of neutral helium and the emission intensity of the inner point is twice that of the outer point.

At the inner point, hydrogen atoms have two temperatures, 0.2 and 3.2 eV, with inward velocities, 3.0×10^3 and 7.2×10^3 m/s, respectively. At the outer point, the hydrogen atoms have two temperatures, ≤ 0.1 and 0.68 eV, with inward velocities, -1.3×10^3 and -3.2×10^3m/s, respectively. The origin of the warm component on each emission location may be identified as due to dissociative excitation of molecular hydrogen. In this case the velocity distribution of the dissociated atoms can not be described by a simple Gaussian profile as assumed here. A quantitative discussion is in progress on the basis of a neutral particle transport code that includes molecular and molecular-ion dissociation processes.

Reference

1) Goto, M. and Morita, S., Phys. Rev. E **65**, (2002) 026401