27pB01

LHDにおける中性水素ダイナミクスの分光研究
Spectroscopic Diagnostics of the Hydrogen Dynamics in LHD

藤井 恵介[1], 四竈 泰一[1], 後藤 基志[2], 森田 繁[2], 蓮尾 昌裕[1]
Keisuke Fujii[1], Taiichi Shikama[1], Motoshi Goto[2], Shigeru Morita[2], Masahiro Hasuo[1]

[1]京都大学工学研究科
[2]核融合科学研究所
[1]Department of Engineering, Kyoto university
[2] National Institute for Fusion Science

1. Introduction

In the fusion devices of magnetic plasma confinement, neutral hydrogen molecules and atoms are mainly generated from desorption or recombination on the first walls. Some of them travel toward the plasma and are ionized by electron impacts. Since the outflux of charged particles from the confined region is blanced with the ionization flux of the hydrogen atoms and molecules a steady condition, the dynamics of the neutrals have great influence on the confinement performance. For establishing a high-performance plasma, it is important to understand and control their dynamics [1,2].

The dynamics have been frequently observed by emission measurements. In simple emission measurements, the line integrated intensity is observed and no spatial information along the line of sight (LOS) is usually obtained. However, Weaver et al. have proposed a method to determine the two emission locations of the Balmer-α line along LOS from comparisons of its Zeeman split and the spatial distribution of the magnetic field [3].

For the purpose of further improving this technique, we recently demonstrated a method to observe several emission spectra of hydrogen atoms and molecules simultaneously with developing a multi-wavelength high-resolution spectrometer [4,5]. During these researches it has been found that line profiles of the Balmer-series emissions have substantial wings, which reflect the existence of high velocity neutral atoms [6].

In this paper, we briefly review our recent progresses.

2. Experiment and Results

Figure 1(a) shows a poloidal cross section of LHD. We observe the hydrogen spectra with two LOSs with the perpendicular linear polarization components resolved. Details of the measurement system are explained in detail in ref. [4,5].

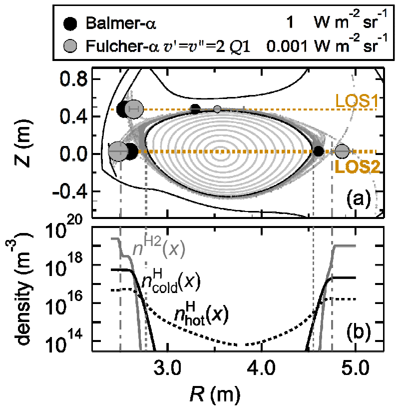

Fig.1 (a): A poloidal cross section of LHD and lines of sight (LOS1 and LOS2). Derived emission locations and intensities are shown by centers and areas of circles, respectively, by the spectral analysis. (b): Simulated density distributions of hydrogen molecules (gray curve), cold atoms (black solid curve) and hot atoms (black dotted curve) along LOS2.

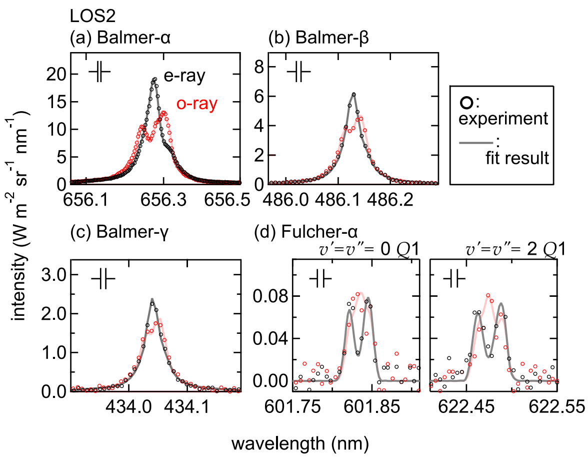

Fig.2 An example of the polarization resolved spectra of (a): the Balmer-α, (b): -β, (c): -γ lines of hydrogen atom and (d): the $Q1$ lines in the Fulcher-α band with the vibronic transitions of v' = v'' = 0 and 2. The instrumental widths are shown by intervals of the two vertical bars. The reconstructed profiles by the spectral analysis are shown by bold curves.

In figure 2, we show an example of the observed spectra of the hydrogen atomic emissions (a-c) and molecular ones (d). Split structures and their polarization dependences are clearly seen, which are due to the Zeeman effect. From the analysis of the line profiles, in which two localized emission locations and sum of three Maxwell distributions as the atom velocity distributions are assumed, the observed profiles are well reconstructed and the emission locations and the intensities along LOSs are derived as shown in figure 1(a). The analytical method is described in ref. [7]. It is found that the molecular emission locations are close to the divertors than the atomic ones. It suggests hydrogen transport; the desorbed molecules from the divertor plates are ionized and dissociated near the divertor legs, and the generated atoms are ionized close to the last closed flux surface (LCFS).

In figure 3, we show the Balmer-α spectral profiles observed for LOS1 and LOS2 with a logarithemic vertical axis. It is found that the spectrum observed for LOS2 has larger wings than that for LOS1. The wings are attributed to the emissions from the high velocity atoms. However, such wing profiles are not reconstructed with the conventional spectral analysis.

We develop a one-dimensional hydrogen transport model which concerns dissociation and ionization of molecules, and ionization and charge exchange collisions of atoms. The simulated density distribution of hydrogen atoms and molecules along LOS2 are shown in figure 1 (b). In the figure, the black solid curve shows the density of cold atoms which are generated via dissociation while the dotted one shows that of hot atoms generated via charge exchange collisions with protons. It can be seen that the hot atoms exist even in the core region of LHD.

We reconstruct a Balmer-α spectrum from the simulated spatial and velocity distribution taking the Doppler and Zeeman effects into account. The reconstructed spectrum is shown in figure 4 by a thick curve. The simulated spectrum also shows wings.

In the figure, we also plot the simulated spectral components which are emitted in the regions of $\rho < 0.4$, $0.4 < \rho < 0.8$, $0.8 < \rho < 1$, and, $1 < \rho$, where ρ is a normalized radius of LHD, which is a measure of the magnetic flux surfaces (Here, $\rho = 0$ and 1 indicate the magnetic axis and the LCFS, respectively). It can be seen that the emission from the core plasma is dominant in the line wings. It is consistent to the small wing intensity in the observed spectrum for LOS1.

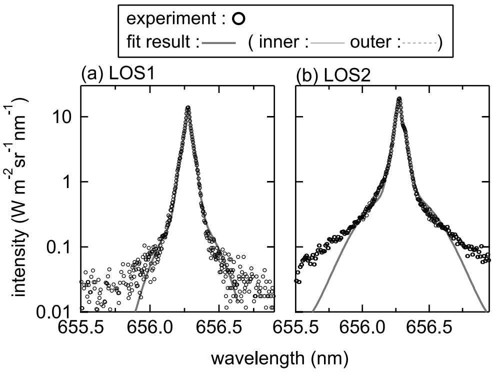

Fig.3 The e-ray components of the observed Balmer-α spectra for (a): LOS1 and (b):LOS2. The vertical axis is logarithmic. The reconstructed spectra by the conventional analysis are shown by bold curves.

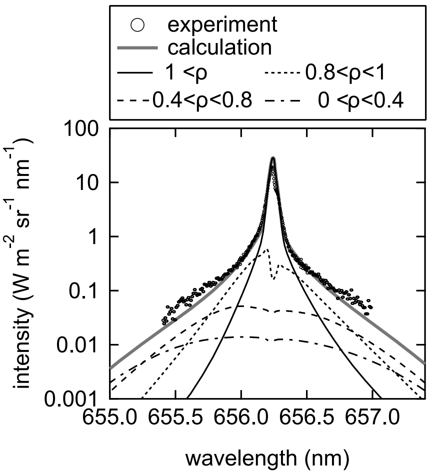

Fig.4 The e-ray components of the observed Balmer-α spectra for LOS2 (open circles) and the reconstructed profile by the one-dimensional transportation model (thick curve). The emission components emitted in the core regions and edge region are also shown by thin curves.

References

[1]. F. Wagner, G. Becker, K. Behringer, et al.: Phys. Rev. Lett. 49 (1982) 1408.

[2]. N. Ohyabu, K. Narihara, H. Funaba, et al.: Phys. Rev. Lett. 84 (2000) 103

[3]. J. L. Weaver, B. L. Welch, H. R. Griem, et al.: Rev. Sci. Instrum. 71, 1664 (2000)

[4]. K. Fujii, K. Mizushiri, T. Nishioka, et al.: Rev. Sci. Instrum. 81, 033106 (2010)

[5]. K. Fujii, T. Shikama, A. Iwamae, et al.: Plasma and Fusion Res. 5, S2079 (2010)

[6]. K. Fujii, K. Mizushiri, T. Nishioka, et al.: NIMA 623, 620 (2010)

[7]. A. Iwamae, M. Hayakawa, M. Atake, et al.: Phys. Plasmas 12, 042501 (2005)