§13. High-speed Imaging Spectroscopy for Pellet Plasmoid Observation in LHD

Motojima, G., Sakamoto, R., Goto, M., Matsubara, A. (Chubu Univ.), Mishra, J.S. (Grad. Univ. Advanced Studies), Yamada, H., LHD Experiment Group

To investigate the physics of pellet plasmoid dynamics, internal distribution measurements in pellet plasmoid by high-speed imaging spectroscopy have been demonstrated successfully. In this spectroscopic system, a five-branch fiberscope is used. Each objective lens has a different narrow-band optical filter for the hydrogen Balmer lines and background continuum radiation. The electron density and temperature in a plasmoid can be obtained from the intensity ratio measured with these filters. The electron density distribution in the range of $10^{22} - 10^{24}$ m^{-3} and the temperature distribution in around 1 eV are observed, indicating that weakly-ionized plasmoid is spectroscopically measured. The electron density distribution of 0.1 m in size expands across the magnetic field line. The time dependence of electron density distribution is investigated. The different electron density distribution is confirmed at each time slice.

Solid hydrogen pellet injection is a primary technique for efficient core plasma fuelling in magnetic fusion devices. The pellet ablation and subsequent behavior of the dense plasmoid which is the pellet ablatant ionized by heat flux of the background plasma are key elements to determine the characteristics of pellet refuelling, and especially the behavior of the plasmoid has an important role as a density redistribution effect by grad B drift. To understand these behaviors, well diagnosed experiments which enable the quantification of internal distribution in the plasmoid are required. In LHD, the density distribution of the plasmoid was obtained by imaging measurements using a bifurcated fiberscope[1]. Here it was assumed that the temperature of the plasmoid is in the limited narrow range. However, it is essential for the deeper understanding of ionized state of the plasmoid to identify the electron temperature of the plasmoid. The objective of this study is to evaluate the two-dimensional electron density and temperature distribution in the plasmoid quantitatively by imaging measurements with high-speed spectroscopic diagnostics.

The spectra of hydrogen Balmer-lines and background continuum radiation are determined by the electron density and temperature of the plasmoid. In this study, it should be noted that the spectra are estimated from the fitting with the theoretical data. In the theoretical data, the intensity of the spectra is calculated on the assumption of local thermodynamic equilibrium. The broadening profile of the spectra is calculated using Ref. [2]. We concentrate on the Balmer-β line (wavelength: 486.1 nm) and continuum (wavelength: 576.8 nm) to evaluate the density and temperature of the plasmoid, because the influence of the self-absorption effect on the Balmer-β line profile is negligible. The filter parameters suitable for various presumed densities and temperatures in a plasmoid are selected on the basis of the spectra estimated from the theoretical data: (i) filter for Balmer-β line with full width at half maximum (FWHM) of 5 nm, (ii) filter for Balmer-β line with FWHM of 20 nm and (iii) filter for continuum radiation with FWHM of 50 nm.

The electron density and temperature distributions are obtained by comparing the intensities measured with the filters as seen above. We confirmed that the density distribution is in the range between 10^{22} and 10^{24} m^{-3} and the temperature distribution is about 1 eV, indicating that weakly-ionized plasmoid can be spectroscopically measured. These results are in agreement with the global spectroscopic measurement[3]. The time dependence of electron density distribution is investigated. As shown in Fig. 1, the different electron density distribution is confirmed at each time slice. Roughly speaking, the electron density is gradually decreased. The density distribution of 0.1 m in size expands to one direction at a certain angle. The angle gradually changes as the pellet penetration deepens, suggesting that the plasmoid location is estimated from these angles. Thereby, we identified the plasmoid location at each time slice and confirmed that the pellet moves at the constant speed of about 990 m/s. The relationship between electron density distribution and plasmoid location will be studied as a future work.

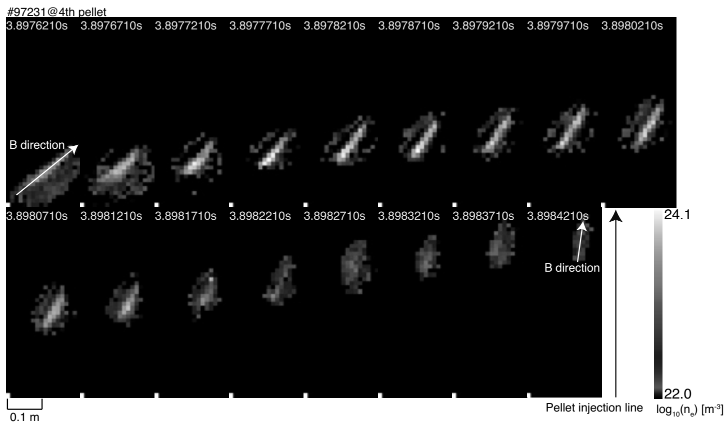

Fig. 1: Time dependence of electron density distribution.

1) G. Motojima *et al.*, Plasma. Fusion Res. **5**, S1033 (2010).

2) C. Stehle and R. Hutcheon, Astron. Astrophys. Suppl. Ser. **140**, 93 (1999).

3) M. Goto *et al.*, Plasma Phys. Control. Fusion **49**, 1163 (2007).