§23. Direct Observation of the Pellet Plasmoid Homogenization Process in LHD

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Pellet injection timing synchronized Thomson scattering measurements have been carried out to understand the elementary processes of the pellet fueling. Extremely asymmetric electron density profiles between the inboard-side and outboard-side are observed by the Thomson scattering measurement during pellet ablation. The density peaks in the asymmetric density profile consider to be due to plasmoids which across the laser of the Thomson scattering measurements.

Pellet fueling consist of the two processes, namely, solid hydrogen ablation and homogenization of the ablated materials. The pellet ablation process can be investigated by observing strongly emitted visible light from the ablated materials. At the same time, observation of the homogenization process is very restricted because the completely ionized ablated material, namely, plasmoid doesn't emit strong light. Thomson scattering measurement, which is installed at a section apart from the pellet injection position, is employed to observe the invisible plasmoid. Since the pellet plasmoid is homogenized within the time scale of several 10 μs, a laser of the Thomson scattering measurement is fired in synchronization with the pellet ablation position which is estimated by the multiple right-gate signal (Fig. 1 and Eq. (1)) in real-time using a delay pulser with FPGA; Field Programable Gate Array.

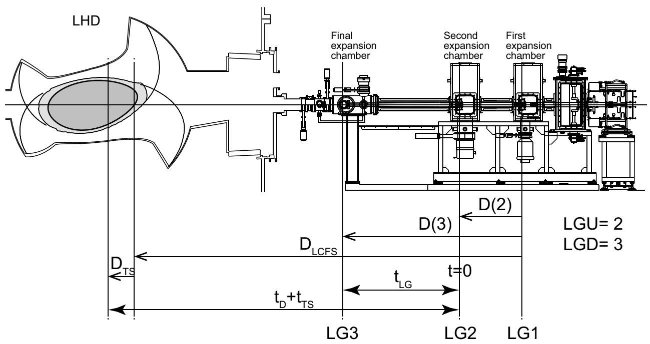

Fig. 1: Pellet injector and multiple light-gate system for realtime estimation of pellet position.

$$t_{\mathrm{D}} = \frac{D_{\mathrm{LCFS}} + D_{\mathrm{TS}} - D(LGU)}{D(LGD) - D(LGU)} t_{\mathrm{LG}} - t_{\mathrm{TS}} \qquad (1)$$

Pellet ablation light emission signal and laser firing timing of the Thomson scattering measurement are indicated in Fig. 2 (a), and electron temperature and electron density profiles are shown in (b) and (c), respectively. Strongly asymmetric density profiles with sharp peaks only at the outboard side are observed during ablation as shown by symbols (◯ and △), at the same time electron density profile become homogenized both inboard and outboard side. It is satisfactory to consider the asymmetric sharp peaks as an expanding pellet plasmoids. Since the density propagates with ion sound velocity while the temperature propagates with electron thermal velocity which is about 50 times faster than the ion sound velocity, the plasmoid density is not homogenized in a flux surface at the timing of the Thomson scattering measurements. The plasmoid density is compared with the time-dependent simulations by the pellet ablation/deposition code HPI2. The measured peak density agrees with the calculated plasmoid density. Since both the pellet injection trajectory and laser of the Thomson scattering measurement are located on the mid-plane with a section distance ($\sim 36°$) each other, the pellet plasmoid that is expected to extend along a field line from the pellet ablation position cannot cross the laser. This fact indicates that the pellet plasmoid does not simply extend along the field line. Possible explanation is that the cross-field plasmoid transport due to the ∇B induced drift is exist in the plasmoid homogenization process. To support this assumption, the cross-field dynamics of the plasmoid is investigating taking into account the three-dimensional effects.

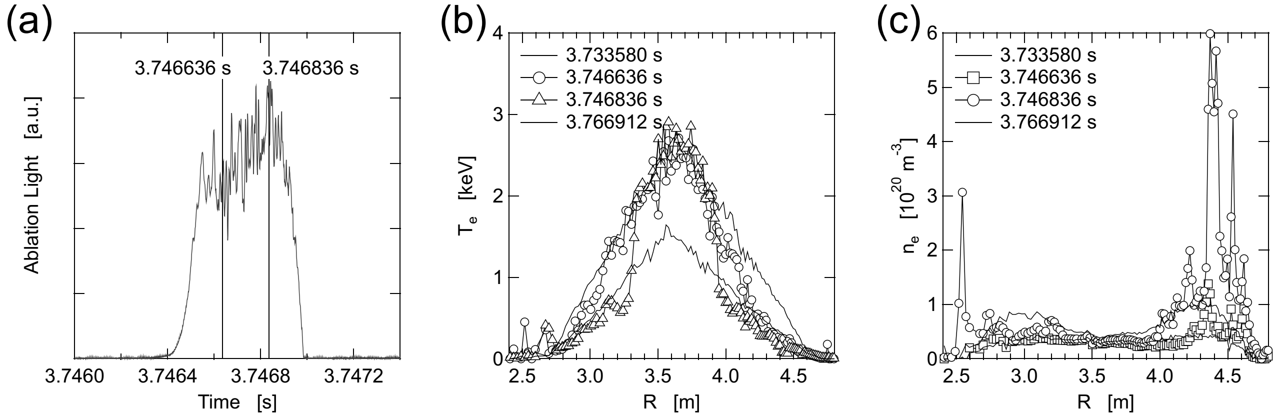

Fig. 2 (a) Ablation light signal and laser timing of Thomson scattering measurement , (b) electron temperature and (c) electron density profiles.