§11. Observation of Intermittent Break-away of Pellet Plasmoid in LHD

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In order to optimize the pellet fueling based on an understanding of the mechanism, experimental observation of the pellet ablation has been performed by employing fast imaging camera with stereoscopic viewing and two-dimensional bundled fiber optics in a mutually complementary manner on LHD.

Fig. 1(a) shows a parallelized stereo pair image of the pellet ablatant. Spindly bright part is a high density pellet ablatant which expand along the field line. Several low intensity blobs which are located parallel to the pellet ablatant is observed. Similar phenomenon has been reported from TEXT and ASDEX-U, and it can be explained by intermittently breakaway plasmoid from the pellet ablatant. This observation suggests that the pellet ablated particles are expelled from the pellet ablated position before depositing particles there and effective pellet deposition profile must be influenced. From the viewpoint of fueling efficiency, direction of the plasmoid movement is important. Assuming that the most bright point represent the plasmoid, three dimensional positions are estimated from the stereo observation. Stereo reconstructed plasmoid position in major radius is shown in Fig. 1(b). Broken line, black and open circles denote a predicted pellet ablation position assuming the constant pellet velocity, measured pellet ablatant and blob position. Correspondence of the black circle with the broken line suggests that the initial pellet injection velocity is maintained during the pellet lifetime and the pellet eventually penetrate to R= 4.3 m. On the other hand, the intermittently breakaway plasmoid, which is denoted by open circle, is observed up to 15 cm outer side of the pellet ablation position. This observation suggests that a portion of the pellet fueled particles are lost from the ablation position toward the major radius direction. This speculation is also supported by effective pellet deposition profile, which is estimated from density profile change just before and after pellet injection, namely, the pellet deposition peak is located around R= 4.5 m despite the pellet penetrate to R= 4.3 m.

In order to investigate dynamics of the intermittently breakaway plasmoid, which play a key role in fueling, the fast time resolution (> 1 MHz) observation with limited spatial resolution (10×10 pixels) has been performed by using a two-dimensional bundled fiber optics with fast PIN-photodiode. Fig. 2(a) shows alteration of H_α intensity at an array of channels along the pass of the intermittently breakaway plasmoid. Ch. 58 is located on the pellet trajectory and the other channels are observing only the breakaway plasmoid. The H_α intensity is consist of a lot of spikes and they are propagated. It is satisfactory to consider the spikes as the intermittently breakaway plasmoid and its breakaway frequency is estimated at around 100 kHz. A number of the spikes decrease as the distance and drop to half in the second channel. Fig. 2(b) shows the movement of a representative breakaway plasmoid. A drift speed of the breakaway plasmoid has attained up to 30 km/s in the beginning of drift and then slow down in the end of the drift. The lifetime of the breakaway plasmoid is around 10 μs.

These observations suggest that there is a non-diffusive transport of the pellet ablatant to the low magnetic field side simultaneously with the pellet ablation. A part of the ablated pellet mass is, therefore, promptly lost from a flux surface in which pellet is ablated. In order to understand the pellet fueling properties with sufficient accuracy, it is important to evaluate non-diffusive transport of the pellet ablatant in addition to the pellet ablation. The non-diffusive transport to the low magnetic field side is qualitatively consistent with the ∇B induced drift model in the tokamak system which is based on the assumption that the magnetic field is axially symmetrical and proportional to $1/R$. However, advanced modeling that takes into account three-dimensionality of the helical magnetic configuration is required in order to identify the ∇B induced drift effects in the LHD plasmas.

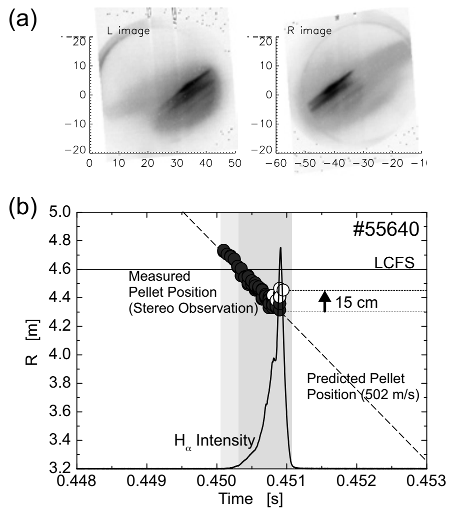

Fig. 1: (a) Stereo pair image of pellet plasmoid, and (b) reconstructed pellet position in major radius.

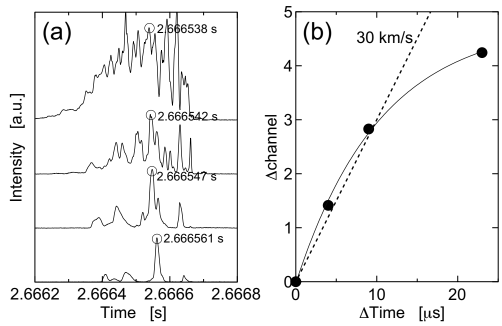

Fig. 2: (a) Temporal change of plasmoid emission, and (b) movement of break away plasmoid.