§14. Analysis of Toroidal Asymmetric Properties of Non-diffusive Transport and Magnetic Island Geometry in the LHD Detached Plasma

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Establishment of handling the huge divertor heat flux is the essential issue to design a realistic fusion reactor. One of the effective solutions is employing the "plasma detachment," which uses plasma-gas interactions. In LHD, an n/m = 1/1 resonant magnetic perturbation (RMP) field stabilizes the detached plasma condition with a highly-radiating zone near the island X-point inside the ergodic region[1]. In the previous experimental campaigns, propagation of ion saturation current (I_{sat}) spikes across the magnetic field was clearly observed and distribution of the mean value broadened on the detached divertor plates. These results suggest that the non-diffusive plasma transport would be enhanced in the RMP assisted detached plasma and it could contribute to reduce the peak heat load on the divertor plate[2]. Moreover, generation region of this transport would have a positional relationship to the magnetic island, because there was a toroidal asymmetry of the propagation characteristics.

In order to reveal the transport mechanism, we inserted a fast scanning Langmuir probe (FSP) in the RMP assisted detached discharge in LHD. Figure 1(a) shows the two-dimensional (2D) distribution of the magnetic-field connection length (L_c) under the RMP applied vacuum condition for R_{ax} = 3.9 m. This 2D plane is roughly perpendicular to the magnetic field. The probe head had three electrodes, which measured I_{sat} and floating potentials (V_{f1} and V_{f2}), as shown in Fig. 1(b). This FSP head has been also utilized for estimation of a typical internal electric field ($E_\perp$) perpendicular to the magnetic field inside blobs by assuming that electron temperatures of a passing blob on two electrodes were the same[3]. Sampling frequency was 1 MHz.

By inserting the FSP at z > ~0.89 m, highly positive spikes of I_{sat} were clearly observed at z ~ [0.89, 0.95] m, which involves the laminar region and edge surface layers. To investigate the internal electric field of the positive events, we applied the auto- and cross-conditional averaging techniques, which are often used in blobby-plasma-transport studies. Figure 2(a) shows the auto-conditional averaged I_{sat} at z = [0.9, 0.94] m. Before the analysis, low frequency (below 100 Hz) components were removed by using a high-pass filter. Threshold value was twice as much as the standard deviation and the number of detected spikes was 111. From Fig. 2(a), typical duration time of I_{sat} was ~10–20 ms. Figure 2(b) shows the cross-conditional averaged fluctuations of V_{f1}, V_{f2} and (V_{f1} − V_{f2}). It was found that there was $E_\perp$ inside the positive I_{sat} spikes and $E_\perp$ ~ (5.4 V) / (7 mm) ~ 771 V/m. This means that the **E**×**B** drift speed corresponds to (771 V/m) / (1.63 T) ~ 470 m/s and the size along the propagation direction was estimated as ~70 mm. The **E**×**B** drift vector points to the opposite side of the plasma center.

These results indicate that the cross-field transport observed in the RMP assisted detached discharge would be driven by **E**×**B** drift force. The size is quite large compared with typical size of blobs; it might be caused by the magnetic flux expansion in between the generation region of the blob-like structures and the FSP measurement position.

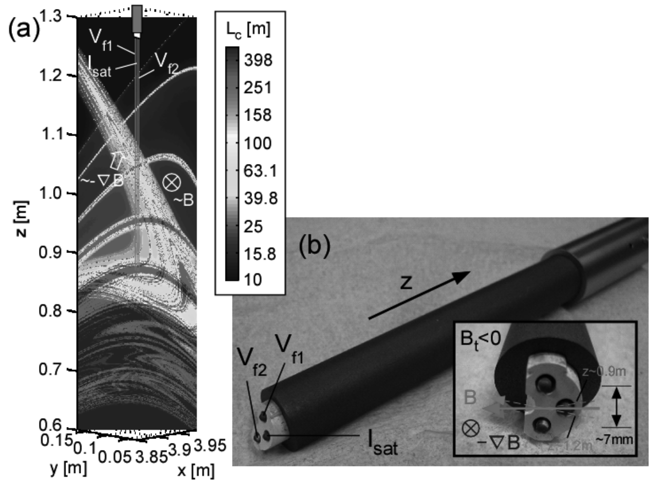

Fig. 1. (a) Insertion trajectories of probe electrodes and a cross-section of L_c. (b) Photographs of the probe head.

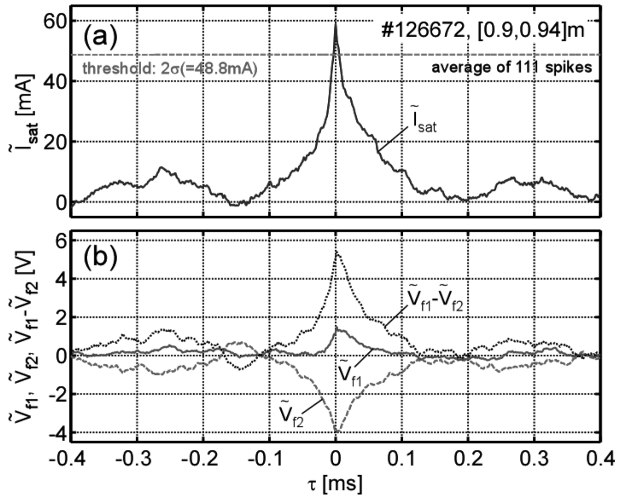

Fig. 2. (a) Auto-conditional averaged I_{sat} (solid line) and threshold line (dashed line). (b) Cross-conditional averaged V_{f1} (solid line), V_{f2} (dashed line) and (V_{f1} − V_{f2}) (dotted line).

1) Kobayashi, M. et al.: Nucl. Fusion **53** (2013) 093032.

2) Ohno, N. et al.: Proc. 25th Fusion Energy Conf. (Saint Petersburg, Russia 2014) CD-ROM file EX/P6-26.

3) Tanaka, H. et al.: J. Nucl. Mater. (in press).