§7. Study of an Edge Transport Barrier by Langmuir Probes in the Compact Helical System

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Measurements of detailed structure of ETB plasmas are crucial for better understanding of the L-H transition and ETB formation. A triple Langmuir Probe (LP) is well suited for this purpose, because it can measure electron temperature (T_e), density (n_e), space potential (V_s) and their fluctuations in the plasma edge having high time (1 μ s) and spatial resolutions. Moreover, measurements of the toroidal uniformity of the ETB structure are particularly important for an ETB plasma in three-dimensional configuration such as CHS. We attempted to measure the ETB structures by using two sets of LPs at two toroidal locations of CHS (the “6U port” and the “3U port”) as shown in Fig.1. The LP installed at each port section was moved vertically shot by shot from the normalized minor radius ($\rho = r / \langle a \rangle$) $\rho \sim 0.93$ to $\rho \sim 1.1$ for about 40 ETB shots with high reproducibility.

Figure 2 shows the radial profiles of T_e , n_e , floating potential (V_f), V_s and radial electric field (E_r) measured at the 6U port section (left) and at the 3U port section (right), for four time slices averaged over a 1 ms time window, where “0 ms” stands for the transition defined by the start time of the drop in the H_α emission. At the 6U port, the radial profile of T_e has a hollow structure at $0.95 < \rho < 0.98$ before the transition, and evolves to the profile with a modest gradient inside $\rho \sim 1.0$ after the transition. Just after the transition ($t = +4 \sim +5$ ms), the radial profile of n_e has a steep gradient inside $\rho \sim 0.96$, having a hollow structure at $0.95 < \rho < 0.98$. After that ($t = +8 \sim +9$ ms), the hollow region of n_e is filled from the inner side toward $\rho \sim 0.97$, and at $t = +16 \sim +17$ ms the hollow structure of n_e disappears and is filled up to $\rho \sim 1.0$. This peculiar edge structure may be linked to the presence of a magnetic island at the rotational transform $\iota / 2\pi = 1$, of which the position of the rational surface is calculated to be $\rho \sim 0.95$ - 0.96 . On the other hand, at the 3U port, n_e has a steep gradient inside $\rho \sim 1$ just after the transition. The radial profile of T_e is almost fixed across the transition. These observations suggest that the ETB will be formed inside $\rho \sim 1$. However, the initial growth of the ETB in n_e and T_e profiles at the 6U port section may be locally blocked by the presence of a non-rotating magnetic island, which is predicted to be in the region of $0.95 < \rho < 0.98$ from the shape of the n_e -profile and to be ~ 6 mm width. It is seen from time evolutions of n_e and T_e profiles that the island seems to shrink in the deep H-phase after ~ 15 ms from the transition.

It is generally thought that E_r and its shear (E_r') play an important role in the formation of an ETB. The E_r was evaluated from the radial derivative of fitted profiles of V_s . In the 6U port, E_r behaves peculiarly having a positive hump for about 10 ms after the transition in the region of

$0.96 < \rho < 0.99$. Before ($t = -4 \sim -3$ ms) and just after ($t = +4 \sim +5$ ms) the transition, the E_r shear in the region of $0.94 < \rho < 0.96$ changed largely from ~ -600 kV/m² to ~ 2700 kV/m² and that in the region of $0.98 < \rho < 1.0$ also changed from ~ 200 kV/m² to ~ -1800 kV/m². On the other hand, at the 3U port, the V_s and E_r profiles have a rather monotonic shape without any hollowness or hump. And the E_r shear changed from ~ -200 kV/m² to ~ 400 kV/m² in the region of $0.94 < \rho < 0.96$.

Fig.1 Arrangement of two LPs at two toroidally different sections in CHS (6U and 3U port sections).

Fig.2 Radial profiles of T_e , n_e , V_f , V_s and E_r at four time slices averaged for a 1 ms time window at the 6U port section (left) and at the 3U port section