Experimental investigation of SOL and divertor plasma properties for vertical and horizontal outer target geometries during L-mode discharges in the KSTAR tokamak

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The properties of the scrape off layer (SOL) and divertor plasmas in the range of $n_e/n_G = 0.17 \sim 0.34$, where n_e and n_G are plasma and Greenwald densities, respectively, were experimentally investigated for vertical and horizontal target geometries under a lower single null (LSN) configuration during L-mode discharges in the KSTAR tokamak. The value of n_G was calculated by using n_G [10^{20} m^{-3}] = I_p[MA]/{π(a[m])^2} where I_p and a are plasma current and minor radius, respectively. Thus, n_G was ~8.0×10^{19} m^{-3} for the experimental conditions such as I_p = 0.6 MA and a = 0.5 m. The value of n_e was changed by adjusting an amount of D_2 gas fueling at a certain common flux region between the outboard mid-plane (OMP) and the divertor which correspond to upstream and downstream regions, respectively. Fig. 1 shows probe diagnostics and Dα channels used for comparing SOL properties for the two target geometries plasma shapes.

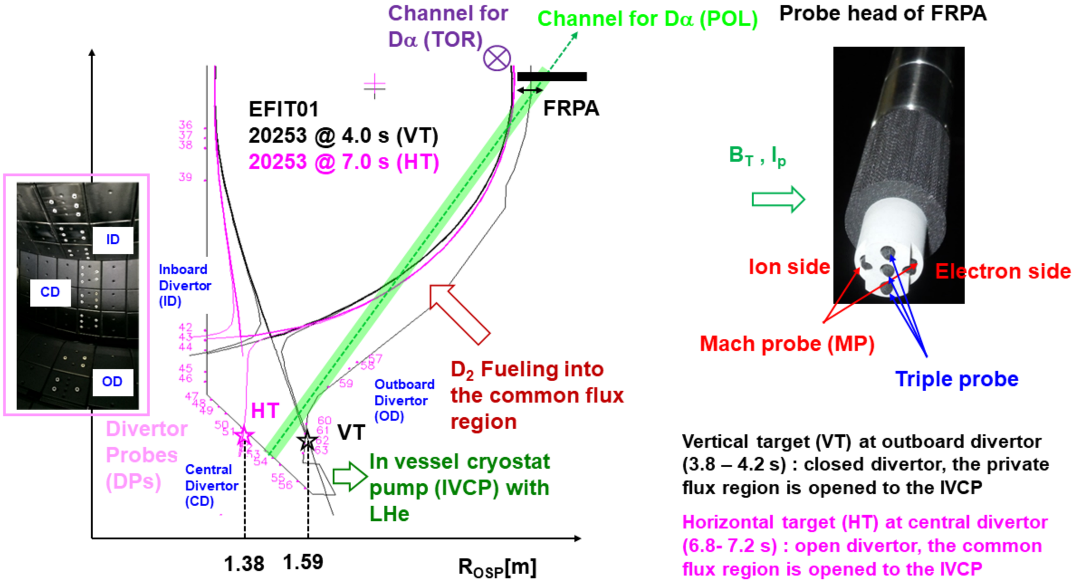


Fig. 1.Two plasma shapes with a vertical target (VT) and a horizontal target (HT) at the outboard and the central divertor regions during a discharge, respectively. Here, the toroidal and poloidal channels detecting Dα lines are used for the comparison between the two target geometries during a plasma discharge. In addition, fixed Langmuir probes for the ion saturation current measurements at the divertor region (as downstream region) and fast reciprocating probe assembly (FRPA) for the SOL profile measurements at the OMP (as upstream region)[1,2]. The private and common flux regions are opened to the IVCP for the VT and HT geometries, respectively.

Firstly, it is found that while the intensity of the Dα line emission $I_{D\alpha}$ in the lower divertor region (one channel in poloidal array) for the horizontal target (HT) is up to ~ 4 times higher than one for the vertical target (VT), the value of $I_{D\alpha}$ in the OMP region (one channel in toroidal array) for the HT is less than 1.5 times one for the VT as seen in Fig. 2(a). Here, there is no clear difference between two n_es in the two target geometries. Secondly, it is observed that the radial profile of the ion saturation current density J_{sat} obtained by using the FRPA at the OMP becomes clearly broader when n_e is higher than 2.31×10^{19} m^{-3} (= 0.28 n_G) in the HT as shown in Fig. 2(b). In addition, the Mach number, which represents the parallel flow velocity, in the near-SOL region also becomes clearly small (from ~0.65 to ~0.2 at R= 2.255 m) for higher n_e in the HT. Thus, the shoulder formation in the far-SOL region can be expected from broader profile of J_{sat} and lower Mach number at higher n_e in the HT geometry. However, the shoulder formation is not clearly seen in the VT, which is quite similar to the result from the JET tokamak [3].

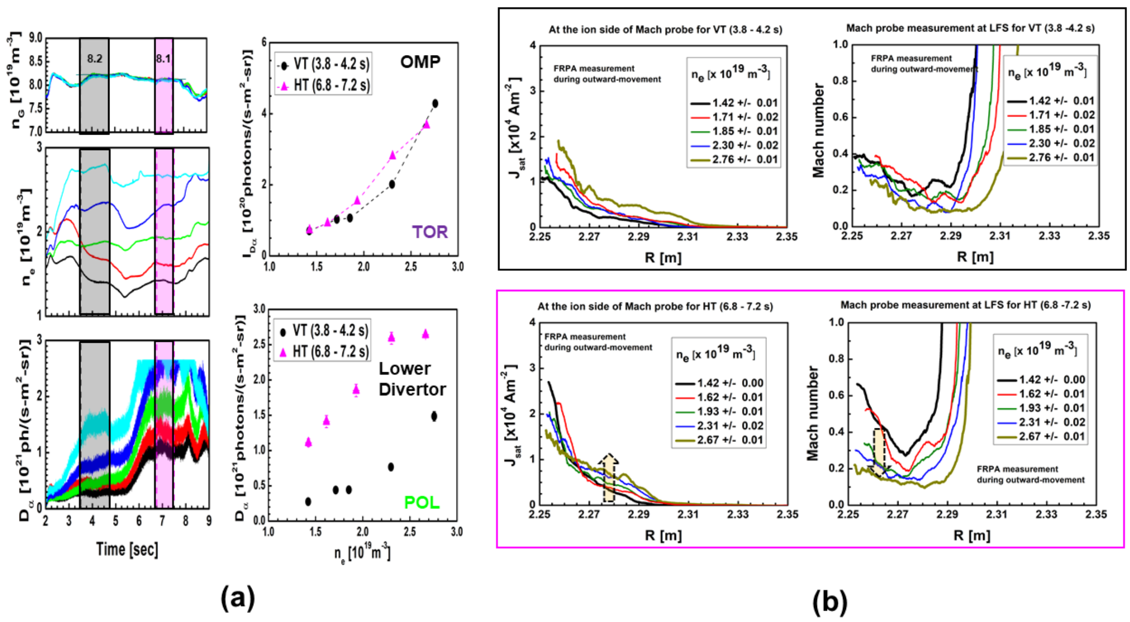
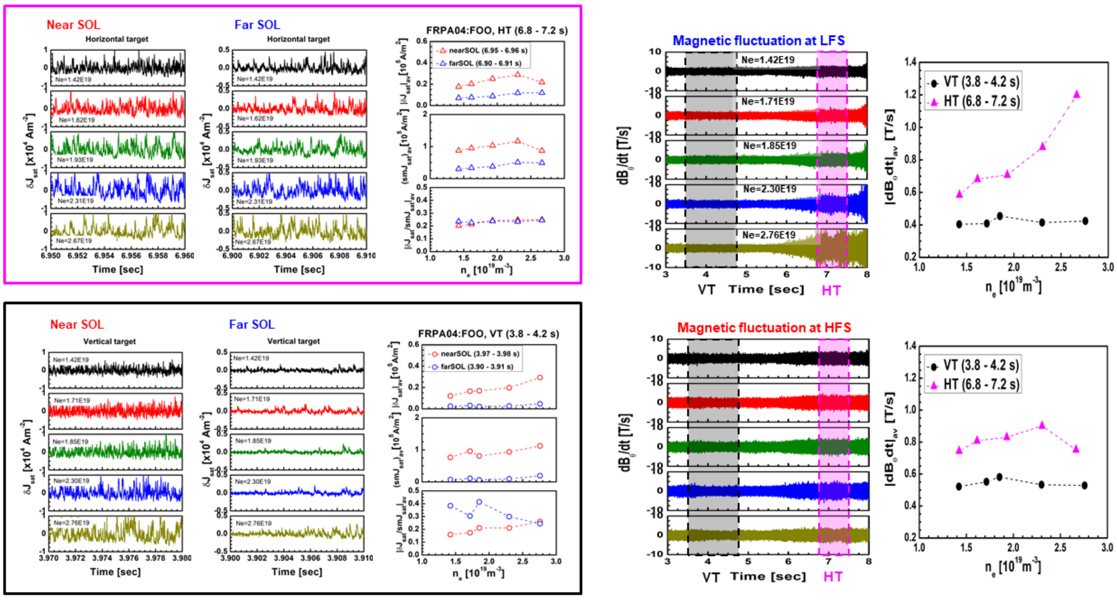


Fig. 2. (a) Time evolutions of n_G, n_e and the intensity of D_α line (one channel in poloidal array), and the intensities of two D_α lines in toroidal and poloidal arrays versus n_e under the VT and HT geometries for several n_es. (b) Radial profiles of J_{sat} and Mach number at the OMP for the two target geometries.

Thirdly, it is found that the magnitude of the electrostatic fluctuation δJ_{sat} in the far-SOL region increases from ~0.07×10^5 A/m^2 to ~0.12×10^5 A/m^2 for n_e/n_G= 0.17 ~ 0.34 in the HT even though ($\delta J_{sat}/J_{sat}$), as the relative value, is almost constant (~ 0.25) as shown in Fig. 3(a). For the VT case, the value of δJ_{sat} in the near-SOL region becomes larger for higher n_e such that ($\delta J_{sat}/J_{sat}$) increases from ~0.15 to ~0.26. The value of δJ_{sat} in the far-SOL region is quite smaller than one in near-SOL region for the VT case, comparing to the HT case. Fourthly, it is observed that the magnitude of the magnetic fluctuation dB_θ/dt near the OMP region corresponding to the low field side (LFS) also increases from ~0.6 T/s to ~1.2 T/s in the range of n_e/n_G in the HT as seen in Fig. 3(b). However, there is no clear changes in the magnitude of dB_θ/dt at the LFS (dB_θ/dt = ~0.4 T/s) due to the increase of ne in the VT case. In addition, the magnitude of dB_θ/dt near the inboard mid-plane region corresponding to the high field side (HFS) does not clearly depend upon the value of ne in the two target geometries even though the magnitude itself (dB_θ/dt = 0.75 - 0.9 T/s) in the HT usually is higher than one (dB_θ/dt = 0.5 - 0.6 T/s) in the VT.

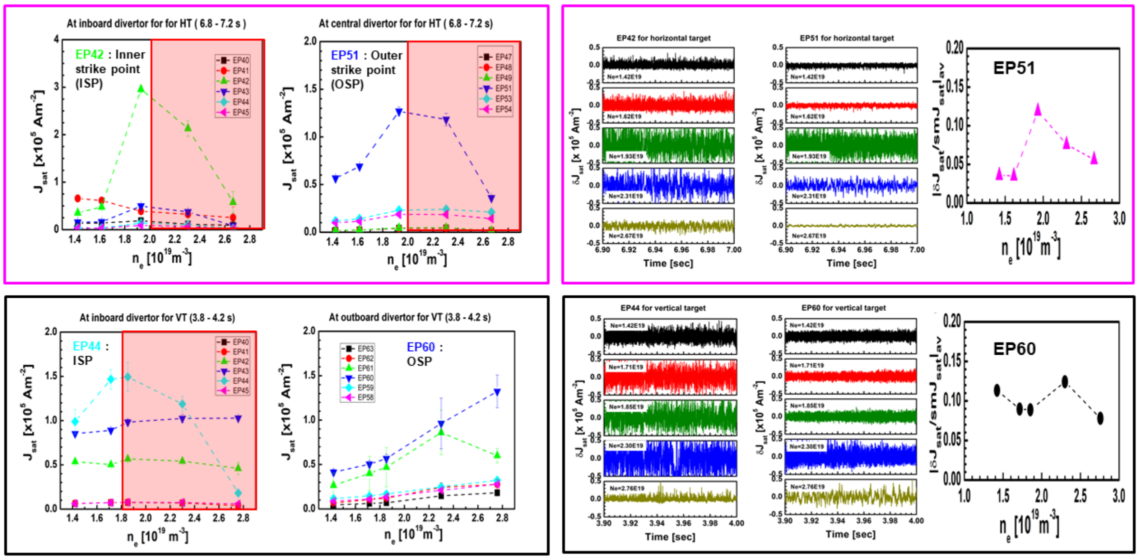


(a) (b)

Fig. 3. (a) Time evolutions of electrostatic fluctuations at the SOL region and three parameters versus n_e under the HT and VT geometries, and (b) Time evolutions of magnetic fluctuations at the low field side (LFS) and high field side (HFS) and magnetic fluctuations versus n_e under the two target geometries for several n_es. Here, the range of n_e/n_G is 0.17 ~ 0.34, and the three parameters are two averaged values such as $|\delta J_{sat}|_{av}$ and (J_{sat}), and relative value as $|\delta J_{sat}|_{av}/(J_{sat})_{av}$.

Fifthly, it is found that while the magnitudes of J_{sat} largely decrease at both inner strike point (ISP) and outer strike point (OSP) in the divertor region for $n_e/n_G > 0.25$ in the HT case, the value of J_{sat} drops at only the ISP for $n_e/n_G > 0.23$ in the VT as shown in Fig. 4(a). From the large decrease of J_{sat} above a certain level of n_e, it was thought that the particle flux was detached near the strike point. However, the detachment at the ISP occurred at lower n_e than the OSP was in opposite to the previous result [4]. The further study is needed in order to explain the conflicting results. Here, the maximum value of J_{sat} at the ISP is about 2 times higher than one at the OSP in the HT case, the maximum values of J_{sat} at both the ISP and the OSP are comparable each other in the VT case. Sixthly, it is observed that while the magnitude of δJ_{sat} near the OSP largely decreases for $n_e/n_G > 0.24$ in the HT such that $(\delta J_{sat}/J_{sat})$ decreases from

~0.12 to ~0.05, there is no drop in the value of δJ_{sat} in the range n_e in the VT as seen in Fig. 4(b). Even there is no dependence of ($\delta J_{sat}/J_{sat}$) upon n_e in the VT.



(a) **(b)**

Fig. 4 (a) The value of J_{sat} versus n_e at the inner and outer divertor regions under HT and VT geometries, and (b) time evolutions of δJ_{sat} at the ISP and the OSP together with the value of δJ_{sat} / J_{sat} at the OSP versus n_e under the two target geometries.

In this work, the preliminary results from the experimental investigations on the SOL property, which were needed for the study of the particle transport in the SOL region was reported. The shoulder formation in the far-SOL region was clearly observed in the HT geometry. While the magnitude of δJ_{sat} (upstream) was relatively large for higher n_e at far-SOL region in the HT, it was relatively large for higher n_e near-SOL region in the VT. The magnitude of dB_θ/dt at the LFS clearly increased for higher n_e in the HT. While the magnitude of J_{sat} (downstream) largely decreased at both the ISP and the OSP above a certain value of n_e in the HT, and it largely decreased only at the ISP above a certain value of n_e in the VT. The magnitude of δJ_{sat} near the OSP was clearly dropped above a certain value of n_e in the HT.

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