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The distribution of the parallel electron-current at the boundary of plasma on J-TEXT

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The current structure at the plasma boundary is complex in a magnetic confinement device. Typically, currents are primarily contributed by electron flows, as the mass of electron is significantly smaller than that of ions. On the one hand, it has been shown that the electron-currents can convectively transport a significant fraction of the electron heat flux in the scrape-off-layer (SOL)[1], a contribution often neglected. On the other hand, SOL electron-currents have a significant impact on plasma stability, especially for the edge-localized-modes, (ELMs)[2]. Therefore, it is important to determine the SOL electron-current structure to better understand their roles in plasma transport and stability.

A novel probe, named directional electron probe (DEP), has been developed to measure the edge electron current on EAST[3] and W7-X[4]. The DEP consists of two opposing channels aligned with the local magnetic field. Each channel features a narrow radial aperture and sufficient thickness to block high-energy ions with large Larmor radii. A positively biased collector at the end repels low-energy ions, ensuring that the collected current is dominated by electrons. It is also equipped with a four-tip Langmuir probe to measure edge plasma parameters.

The J-TEXT device allows flexible control of plasma discharge configurations. Experiments were conducted in three representative configurations: two-dimensional (2D) limiter and high-field-side (HFS) divertor, and a three-dimensional (3D) island divertor. By adjusting the currents in the resonant magnetic perturbation (RMP) coils, the phase of the magnetic island can be controlled, enabling the probe measurements under different magnetic topologies. Therefore, experiments with DEP on J-TEXT provide a comparative analysis across different configurations.

Figure 1 presents the four discharge configurations (top) and the corresponding electron current distributions along the Z-direction (bottom). Preliminary analysis indicates that the magnetic topology has a significant impact on the electron current distribution.

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References

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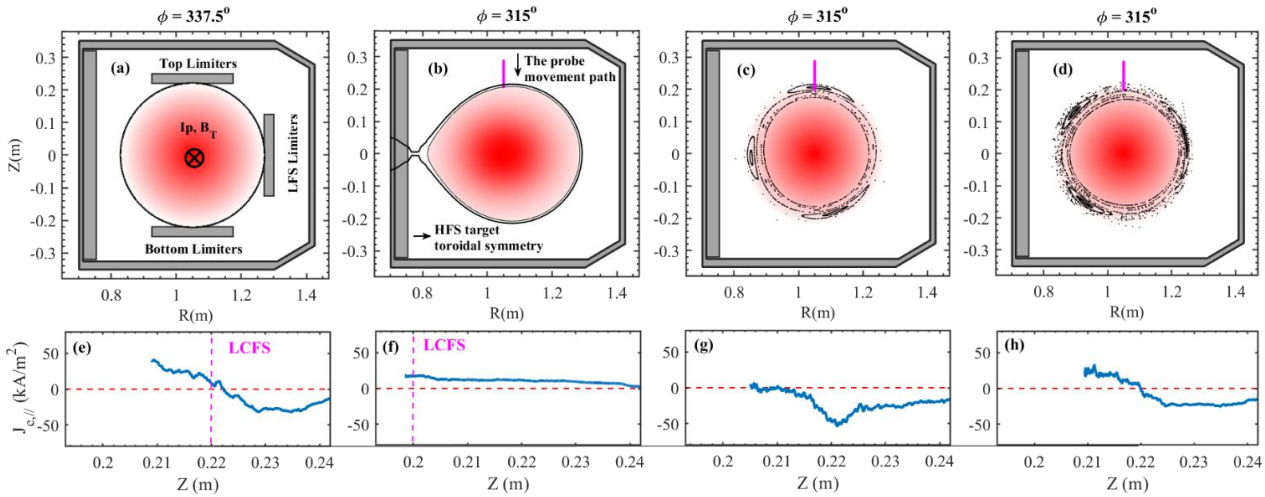

Figure 1. (a ~ d) discharge configurations: limiter configuration, HFS divertor configuration, island divertor configuration I, island divertor configuration II; (e ~ h) parallel electron current measured by DEP in these four configurations. The pink line is the movement path of DEP in $\phi = 315°$ cross section.