9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Observation of symmetry-breaking by RMP-induced edge kink-like modes in KSTAR and their effects on density pump-out

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In tokamak plasmas, the application of resonant magnetic perturbations (RMPs) is known to result in plasma density reduction, known as 'density pump-out'. In this work, we present that this decrease in density is accompanied by edge kink-like modes induced by RMPs in KSTAR. The dynamics of these modes were observed in both toroidal and poloidal direction using multiple diagnostic system, including charge exchange spectroscopy (CES), electron cyclotron emission imaging (ECEI), and in-vessel TV. It was captured that the phase of the edge kink-like modes aligns with the phase of the applied RMPs. Furthermore, a novel image processing technique applied to in-vessel TV revealed a nonuniform plasma surface displacement along the poloidal direction due to these modes. Specifically, the magnitude of displacement in the upper outboard region was measured to be approximately twice as large as that in the middle and lower outboard regions.

These observed nonuniform surface displacements along the poloidal direction were qualitatively and quantitatively compared with numerical calculations, MARS-F code [1]. Figure 1 shows that the numerically computed displacement is in good agreement with the observed displacement from CES and in-vessel TV, suggesting that the magnetic flux surface distortion is indeed triggered by the edge kink-like modes. In addition, the study finds that the symmetry-breaking effect of this displacement is approximately 50 times larger than that of the applied RMPs themselves.

While the symmetry-breaking effect by the applied RMPs themselves is generally negligible, the symmetry-breaking effect by the magnetohydrodynamics (MHD) modes can significantly enhance the neoclassical particle transport [2, 3]. Here, we calculate the enhanced neoclassical electron particle flux caused by the symmetry-breaking effect of the edge kink-like modes by applying experimentally estimated variation of the magnetic field strength [4].

A one-dimensional transport analysis was performed to verify how this enhanced transport alters the density profile. The analysis shows that when the enhanced neoclassical electron particle flux is incorporated into the transport equation, the calculated electron density profile gradually decreases. This reduction quantitatively accounts for a significant portion of the experimentally observed density pump-out.

This research was supported by the R&D Program of "High Performance Tokamak Plasma Research & Development (EN2501-16)" and "Korea-US Collaboration Research for High Performance Plasma on Tungsten Divertor (EN2503-01)" through the Korea Institute of Fusion Energy (KFE) funded by the Government funds, Republic of Korea.

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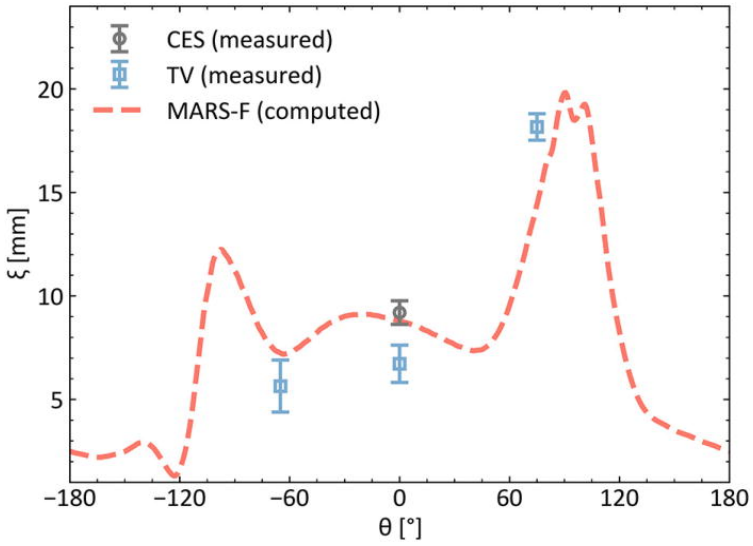

Figure 1. Poloidal distribution of the plasma surface displacement in KSTAR discharge #31097, comparing measurements from CES (gray circle) and in-vessel TV (blue squares) with numerical simulation (red dashed line).