OBSERVATION OF EDGE MAGNETIC ISLANDS AND 3D TURBULENCE STRUCTURE DURING RMP ELM SUPPRESSION

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For the first time, a "phase flip" is observed in the ion temperature signal associated with a rotating n=1 edge localized RMP (ERMP) [1,2] on the KSTAR tokamak. This phase flip did not require subtraction of an edge kink response unlike an investigation carried out at higher-n RMP [3], which provides direct evidence of small magnetic islands forming near the pedestal top—a key region of the plasma edge—during ELM suppression, as shown in Fig. 1. These findings are crucial for uncovering the mechanisms behind RMP-induced ELM suppression and demonstrate the ability to directly investigate these island structures. The estimated island centre is located around the pedestal top region at $\psi_N \sim 0.9$. This implies that magnetic island could be located at $q_{90} \sim 4$, possibly with a wide pedestal structure.

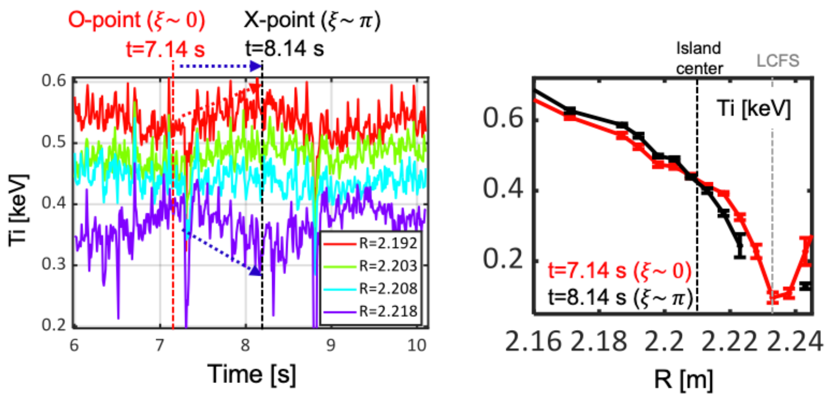

Figure 1. (Left) Time evolution of ion temperature during rotating n=1 ERMP with ELM suppression, (right) ion temperature profiles at O-point and X-point.

The experiments also found that the phase flip, an indicator of a magnetic island, is clear only during the ELM suppression phase but not during the ELM mitigation phase, where multiple discharges are investigated to clarify potential uncertainties. In addition, a sharp drop in pedestal temperature was observed during the transition from ELM mitigation to complete suppression, as shown in Fig. 2, supporting the idea that edge magnetic islands play an important role in ELM suppression. This change is localized at the edge as indicated by core temperature that decreases more slowly on a transport time scale. These results imply penetration of an edge magnetic island when transitioning to ELM suppression. We also gradually increased the RMP current after ELM suppression to observe the evolution of the ion temperature profile. At R < 2.22 m, the temperature gradually decreases with the slow RMP ramp, whereas at R > 2.22 m, the temperature either remains unchanged or increases. This behavior suggests a slow growth in the island size and a more distinct island structure at the O-point angle.

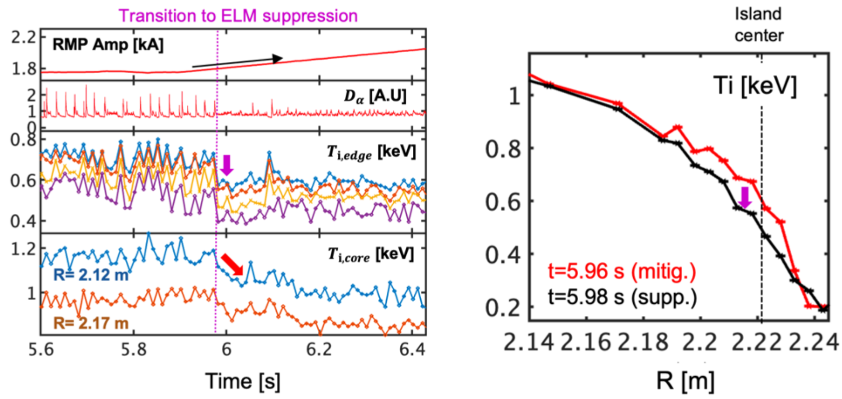

Figure 2. (Left) Time evolution of edge and core ion temperature during the transition from ELM mitigation to suppression with a gradual increase of RMP amplitude. (Right) Radial profile of ion temperature near the magnetic island centre, observed between mitigation (t=5.96 s) and suppression (t=5.98 s) phases.

The study also uncovered a unique turbulent structure associated with these small magnetic islands. Unlike the turbulence with larger core islands due to tearing modes, the turbulence near the edge islands showed distinct asymmetry relative to the X-point (Fig. 3). This was characterized by a non-zero phase shift, indicating unconventional turbulence properties influenced by the edge magnetic islands. These results emphasize how turbulence dynamics at the plasma edge differs fundamentally from that in the core. The asymmetric 3D structure at the pedestal is also evident in the non-linear interaction estimated with bicoherence of the density fluctuations. These interactions are more pronounced at the X-point and +45° from the X-point, while they are significantly weaker, comparable to the O-point, at −45° from the X-point.

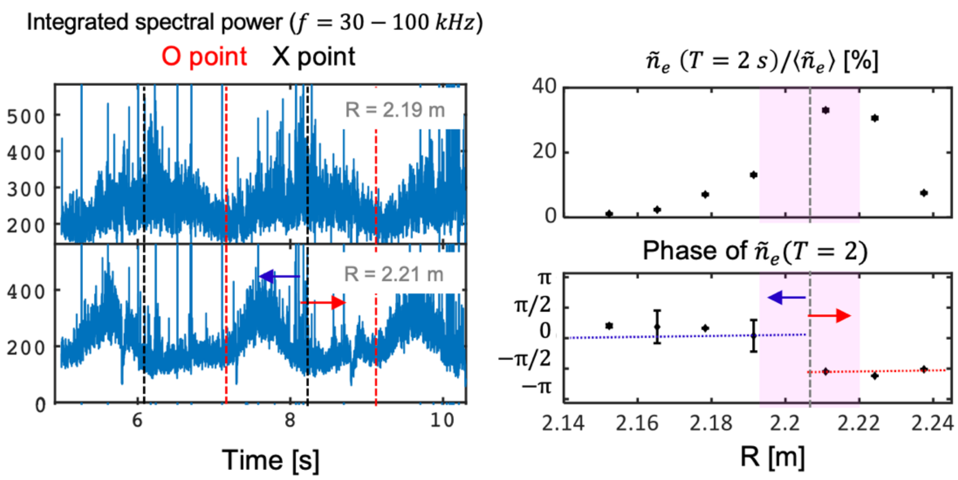

Figure 3. (Left) Time evolution of integrated spectral power (f=30−100 kHz) at R=2.19 m and R=2.21 m. (Right) Radial profile of normalized electron density fluctuation amplitude and its phase using the period (T = 2 s) of rotating RMP, showing a phase difference with respect to R=2.2 m

Ongoing theoretical and simulation studies aim to further analyze the 3D turbulence structure and bifurcation behavior observed during ELM suppression. These efforts will also focus on predicting how turbulence evolves under different pedestal conditions, contributing to the broader understanding of plasma stability and control in fusion devices.

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