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Localizing resonant magnetic perturbation to optimize ELM controls in tokamak

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A new optimization proposes a unique path of a 3D field to safely access the ELM-suppressed High confinement (H-mode) from low confinement (L-mode) phases with improved plasma performance. Such an edge-localized resonant magnetic perturbation (ERMP) [1] is essential to minimize disruptive core components of low-n RMP while maintaining its efficiency in ELM suppression for the entire period of H-mode. The ERMP demonstrates safe access to ELM-controlled H-mode as predicted and exhibits robustness to abrupt changes in plasma responses from a discharge's initial L-mode phase. One static ERMP from multi-target optimization prevents disruptive n=1 core RMP penetration even in low-density L-mode plasmas and safely suppresses ELMs in H-mode. The core reduction in ERMP also expands the ELM suppression window, increasing the safety margin for feedback-based ELM control by 100%.

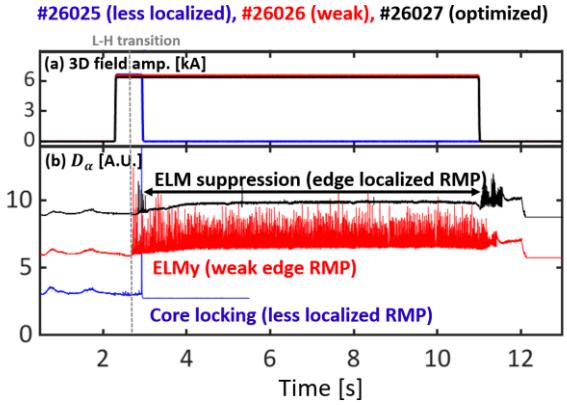

Figure 1. The time traces of main plasma parameters in KSTAR discharges. (a) The amplitude of root sum square IVCC coil current, (b) D_α emission indicating ELMs.

In addition, the ERMP reduces rotation damping and density degradation while maintaining ELM suppression. The confinement improvement from ERMP can be explained by a reduction in neoclassical transport and fast ion orbit losses, as demonstrated in GPEC [2] and NubDEC [3] simulations. Unlike ELM suppression in H-mode, the edge RMP penetration in L-mode delays the L-H transition with decreased non-linear interaction between zonal flow and turbulence. Additional optimization prevents the L-H transition delay and emphasizes the need to integrate different 3D physics through the entire discharge. The successful optimization also highlights the importance of the ELM control coil design, which the unique ERMP spectrum can improve. We will show progress towards disruption-free and ELM-free optimization based on intelligent coil design to avoid the unnecessary component of the 3D field.

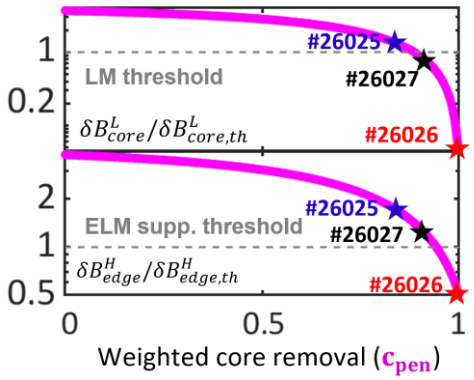

Figure 2. Weighted core removal (c_{opt}) dependence of (a) strength of core resonant fields in L-mode (δB^L_{core}) normalized by locked mode threshold, (b) edge resonant fields in H-mode (δB^H_{edge}) normalized by ELM suppression threshold.

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References

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