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Coherent Mode Providing Continuous Transport during ELM Mitigation with n=1 RMP in HL-2A H-mode plasma

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ABSTRACT

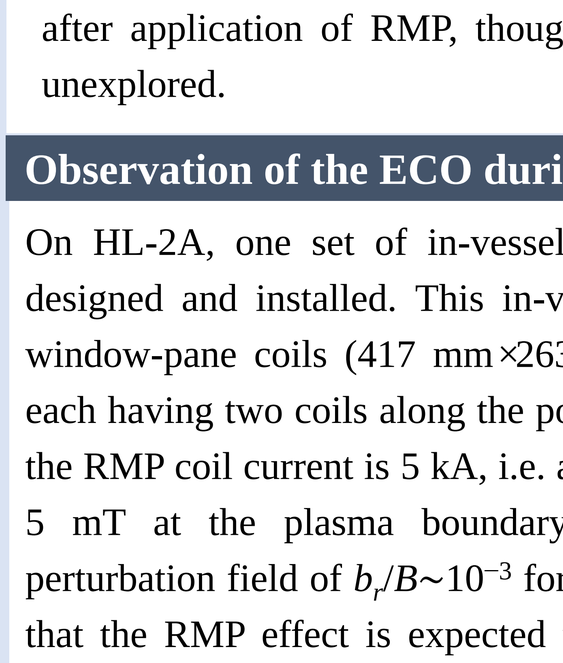
- An edge coherent oscillation (ECO) with a bursting feature was observed in the steep-gradient pedestal region of the H-mode plasmas in HL-2A tokamak, where the type-I edge-localized modes (ELMs) were mitigated by application of the n = 1 resonant magnetic perturbation (RMP).
- It was found that the ECO is located at the edge pedestal region, and is excited by three-wave interaction of turbulence enhanced by the RMP field through the change of electron density gradient in the pedestal region.
- The mode drives a significant outflow of particles as directly measured by probes, thus providing a channel for a nearly continuous extra particle transport across the pedestal during the ELM mitigation by RMP..

BACKGROUND

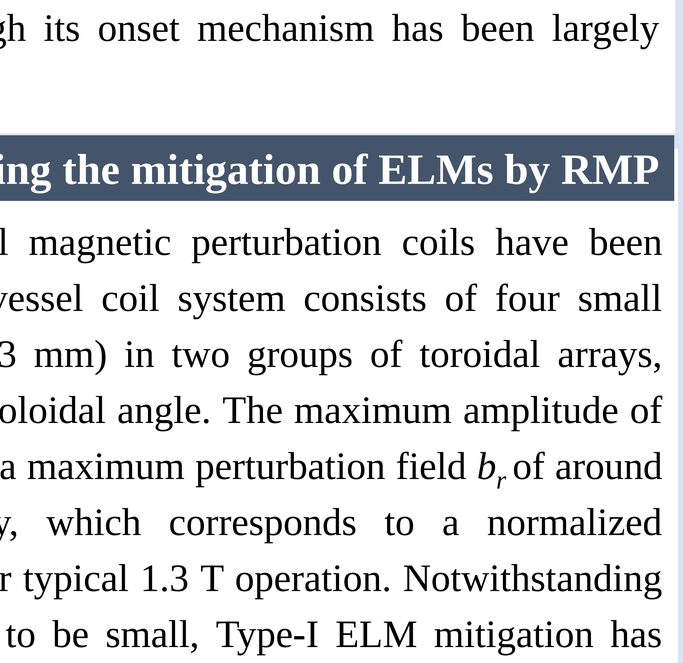
- Resonant magnetic perturbation (RMP) has been proposed as an attractive and effective way of controlling ELMs, and has been extensively investigated in both experiments and theory.
- In applying RMP, the interactions of magnetic perturbations, zonal flows, coherent or quasi-coherent mode, and microscopic turbulence take place.
- A common feature has been recently found that the nonlinear coupling between different frequency components of turbulence was substantially enhanced during the application of RMP
- Early studies provide indication that the coherent mode may play an important role in the transport dynamics of the resulting H-mode plasmas after application of RMP, though its onset mechanism has been largely unexplored.

Observation of the ECO during the mitigation of ELMs by RMP

On HL-2A, one set of in-vessel magnetic perturbation coils have been designed and installed. This in-vessel coil system consists of four small window-pane coils (417 mm ×263 mm) in two groups of toroidal arrays, each having two coils along the poloidal angle. The maximum amplitude of the RMP coil current is 5 kA, i.e. a maximum perturbation field b_r of around 5 mT at the plasma boundary, which corresponds to a normalized perturbation field of $b_r/B\sim10^{-3}$ for typical 1.3 T operation. Notwithstanding that the RMP effect is expected to be small, Type-I ELM mitigation has been successfully achieved in HL-2A experiments.



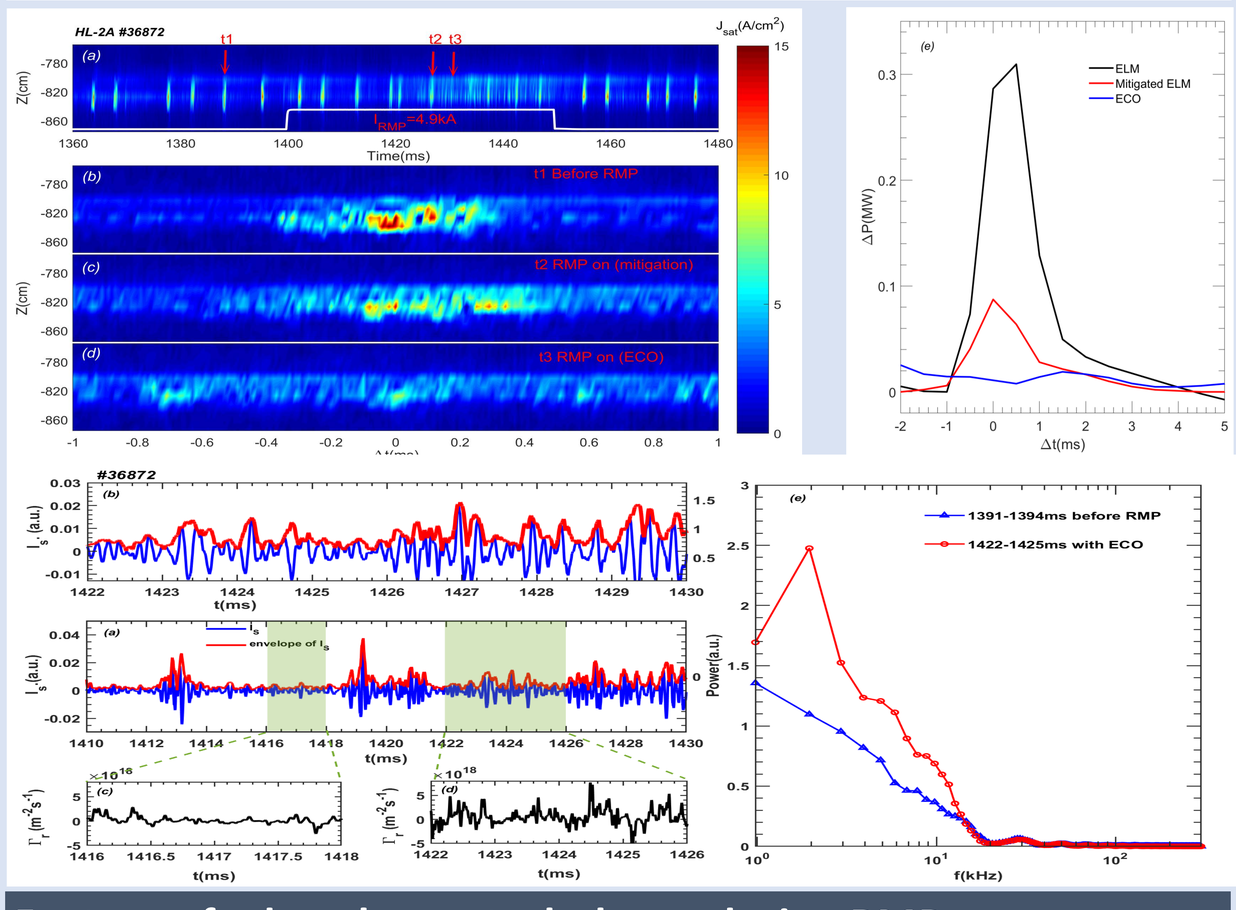
Type-I ELM mitigation discharge



ECO, Type- I and Grassy ELM

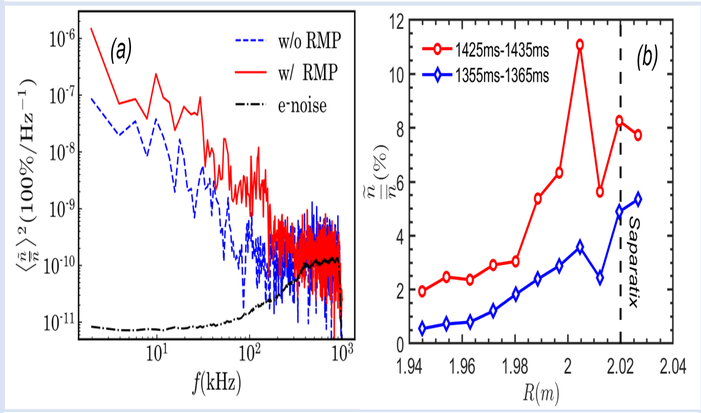
Influence of ECM on the edge heat and particle transport

- A key finding during these experiments are the small coherent oscillations at about 2 kHz, that appear either between the mitigated Type-I ELM events or ride on them.
- Clear evidence of particle exhaust by ECO has been obtained, via close examination of the measured particle flux in the plasma edge region.

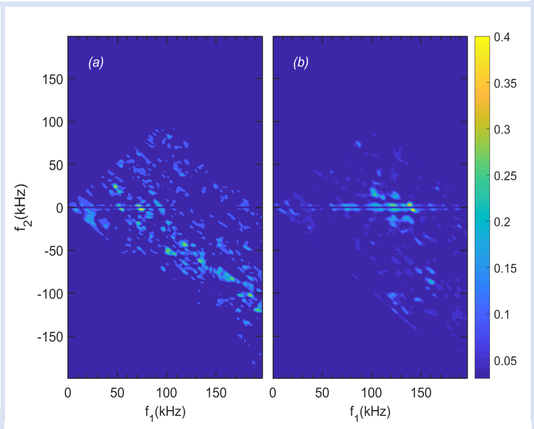


Feature of edge plasma turbulence during RMP

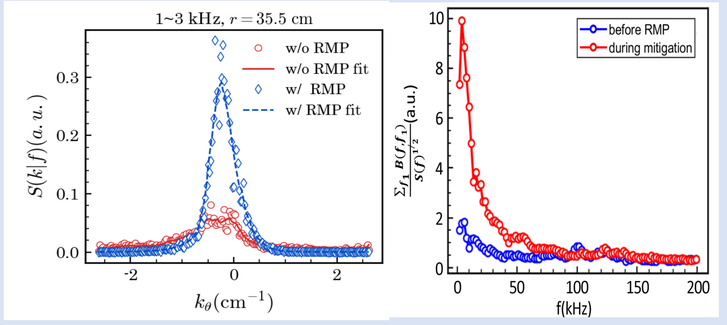
- Pronounced increase in the density fluctuation level during RMP.
- Clear evidence of particle exhaust by ECO has been obtained, via close examination of the measured particle flux in the plasma edge region.

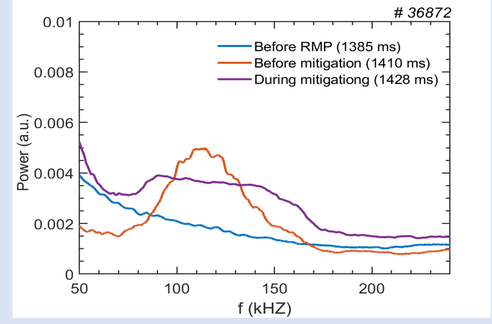


Feature of edge plasma turbulence during RMP



Nonlinear wave coupling among turbulence





CONCLUSION

- We discovered a new edge coherent oscillation in the steep-gradient pedestal region of H-mode plasmas, during mitigation of Type-I ELMs by the n = 1 resonant magnetic perturbation.
- These low-frequency edge oscillations, occurring at about 2 kHz, provide a channel for nearly continuous particle and energy exhaust across the pedestal region during ELM mitigation by RMP, as evidenced by direct probing inside the separatrix.
- It suggest that this mode is populated through three-wave coupling of turbulence, which is in turn enhanced by application of RMP.

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