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Plasma response of external magnetic perturbations at the edge: Comparisons between measurements and 3D MHD models

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At ASDEX Upgrade ELM mitigation using external magnetic perturbations has been achieved at high plasma densities (n_e/n_GW > 0.65, corresponding to nu>*1.2) and, more recently, at low pedestal collisionality (nu*<0.4) accompanied with density pump-out. To investigate the interaction between the plasma response and ELM mitigation, comprehensive experiments using various plasma configurations have been conducted.
These studies indicate that the optimum poloidal spectrum for ELM mitigation does not show a maximum of the magnetic field pitch-aligned component. Instead, it is aligned with the mode at the edge that is most strongly amplified by the plasma as calculated using magnetohydrodynamic (MHD) response codes. These experimental investigations in comparison with MARS-F are consistent with previous observations and underline the hypothesis that the plasma response around the X-point causes the ELM mitigation.

In order to measure the plasma response, we combined rigid rotating MP fields and measurements from toroidally localized high resolution diagnostics. Electron cyclotron emission (ECE) diagnostics, among others, have been used to determine the amplitude, the penetration and the poloidal mode structure of the flux surface displacements. To interpret the ECE measurements accurately, forward modeling of the radiation transport has been extended with ray tracing. The measurements are compared to synthetic data generated by combining the said forward model and a 3D ideal MHD equilibrium calculated by VMEC.

The measured penetration of the helical displacement is in good agreement with VMEC, whereas the measured amplitudes in the midplane are slightly larger. The measured amplitudes also exceed the vacuum field calculations, which indicates the presence of an amplified kink response at the edge. Although the calculated magnetic structure of this edge kink peaks at poloidal mode numbers larger than the resonant components |m|>|nq|, the displacement derived from ECE-imaging appears as mostly resonant. This is expected from ideal MHD in the proximity of rational surfaces. Both, VMEC and MARS-F calculations reproduce this experimental observation. Further rigid rotating field experiments using different poloidal spectra of the external MP suggests that the same least stable modes are excited by the MP- field.

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