Effect of magnetic perturbations for ELM control on divertor heat loads and detachment in ASDEX Upgrade

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The reduction of transient heat loads induced by edge localised modes (ELM) in H-Mode is fundamental to the success of ITER/DEMO. The application of 3D magnetic perturbation (MP) fields is studied as a method for ELM control and full ELM suppression in ASDEX Upgrade. These 3D fields lead to toroidal asymmetries of the heat load pattern in the divertor that cause further challenges for future devices. ASDEX Upgrade is equipped with a versatile set of MP coils and high resolution edge and target diagnostics to characterise the impact of MPs on divertor heat loads and the access to detachment. The heat flux in L- and H-Mode can be studied in ASDEX Upgrade, thanks to the flexible power supply, with slowly rotating MP fields, allowing the complete toroidal characterisation of the heat flux pattern.

For a scan of various poloidal perturbation field spectra in low density discharges, a large toroidal variation is only observed in the so called resonant configuration which is foreseen for ITER for ELM control. When the profiles are toroidally averaged and the standard 1D Fit-Function for diffusive power spreading is applied, the same power fall-off length λ_q and divertor broadening S as in the non-perturbed reference case is found throughout the scan.

With increasing density, while still being in attached conditions, the toroidal variation of the heat flux pattern is reduced. This is accredited to an increase of S. The *toroidal peaking*, the toroidal maximum divided by the mean value, decreases from 1.9 to 1.2 when increasing line averaged edge density from 0.8 to $1.8 \cdot 10^{19}\,\mathrm{m}^{-3}$ in L-Mode. Here, S increases from 0.3 to 1.2 mm and λ_q from 3.6 to 6.0 mm leading to an increase of the integral width λ_{int} - and thereby also a reduction of normalised peak heat flux - by a factor of two.

By increasing the density even further, the *toroidal peaking* in the ITER relevant high recycling regime reaches about unity. On the other hand, no detriment effect on the access to detachment is observed. Hence, for ITER a problematic toroidal peaking of the inter-ELM heat flux is expected to be alleviated by operating with high scrape-off layer and/or divertor density and thereby a cold divertor. However, ELM filaments lock to the perturbation and may lead to enhanced sputtering at distinct toroidal locations if no variation of the perturbation is applied.