ELM mitigation by externally induced ELMs -Physics and Prospects

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The ELM induced power load on the divertor occurring in the type-I ELMy H-mode reference scenario is one of the main areas of concern for ITER. Extrapolating the results of present day tokamaks indicating an acceptable lifetime for the divertor cannot be realised. ELM mitigation by externally induced ELMs aims on a modification of the ELM frequency f_{ELM} , causing a reduction of the ELM energy ΔW_{ELM} by enhancing f_{ELM} . Various methods, usually targeting the ELM drive terms edge pressure gradient p'_{edge} and current j_{edge} , have been tested. Some have shown to trigger prompt ELMs, establish f_{ELM} as a free parameter and mitigate ELMs according to the relation $f_{ELM} \times \Delta W_{ELM} = const$. The deleterious impact of ELM mitigation on the confinement is quite small, a relation for the plasma energy $W \sim f_{ELM}^{-0.2}$ was found. This is significantly less than $W \sim f_{ELM}^{-0.6}$ observed in the case of intrinsic ELMs. Meanwhile, ELM frequency control already became a part of the toolkit for plasma control and is incorporated e.g. into integrated plasma scenarios as candidate regimes for ITER.

We still do not understand properly how the different trigger techniques act, how the triggered ELM evolves temporally and spatially and why the correlation between local edge parameters like the collisionality ν^* and ΔW_{ELM} observed for intrinsic ELM can be broken. Detailled investigations aiming to resolve these puzzles are performed at ASDEX Upgrade. Local 3D perturbations were imposed by Deuterium (D) pellet injection, supersonic D gas jets, and Carbon and Aluminum micro pellet laser blow off. It is found that the gas jet, unlike the pellet, is insufficient to trigger prompt ELMs although the applied particle flux is of the same amount. On the other hand, investigations showed pellet masses reduced by more than a factor of ten - technically not feasible to date - would be still sufficient to release prompt ELMs. This shows that the perturbation required for ELM triggering has to fulfill local susceptibility criteria. Experiments conducted in order to uncover possible relations are reported as well as approaches to resolve the temporal and spatial evolution of a triggered ELMs with maximized resolution and compare it to its intrinsic counterparts. Furthermore, a fast framing camera system was set into operation for dedicated studies on the ELM trigger dynamics.

The pellet based ELM pacing approach will be discussed with respect to its potential extension towards higher ratios f_{ELM}/f_0 (f_0 : intrinsic ELM frequency). According experimental efforts at ASDEX Upgrade and JET will be described. Finally, a possible scheme for pellet ELM pacing at ITER will be presented.