ELM Mitigation Techniques*

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Large Edge Localized Modes (ELMs) are a significant concern for fusion relevant plasmas in tokamaks. Predictions, based on the scaling of ELM energy impulses to divertor target plates in today's sub-gigajoule tokamaks, indicate that an average ELM in ITER will release energy impulses of order 20 MJ in less than a millisecond. Estimates of the ELM interaction area in ITER imply an ELM energy density of approximately 7-10 MJ/m^2. Tungsten divertor plates are expected to develop cracks and undergo surface melting at energy densities exceeding 0.5 MJ/m^2. Thus, it is imperative to reduce the energy density of the ELMs in ITER by at least a factor of 14 and possibly by as much as a factor of 20 depending on the details of the operating scenario and the energy distribution on the divertor target plates.

A very active worldwide program has recently emerged to address various techniques for mitigating and suppressing ELMs in ITER. Examples of several techniques being studied include triggering small ELMs with cryogenic deuterium pellets or with vertical kicks of the equilibrium magnetic field, and injecting supersonic molecular beams to mitigate ELMs. Other methods being investigated include operating in parameter regimes that are compatible with existence of edge coherent modes, which appear to suppress ELMs completely. Examples of this approach include the QH-mode and the EDA H-mode. Small ELM regimes have also been studied extensively in some tokamaks with the hope of scaling these to ITER relevant operating scenarios. Various types of divertor geometries and wall coating techniques are also being investigated. Finally, one of the most widespread and possibly the most promising approach being studied on a growing number of tokamaks and stellarators is the use of small 3D resonant magnetic perturbations (RMP) fields to control the properties of the H-mode pedestal plasma leading to either ELM mitigation or suppression.

A general review of these techniques will be given in this talk. In addition, a more detailed review of the current status of the resonant magnetic perturbation approach and its applicability to ITER operating conditions will be discussed.

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