Progress and issues in physics understanding of dynamics, mitigation and control of ELMs

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High-confinement mode (H-mode) plasmas with edge localized mode (ELM), so called ELMy H-mode, has been considered as the standard operating scenario with Q=10 in ITER. Although ELMs play an important role on particle control to achieve stationary H-mode plasmas, an instantaneous heat load to divertor target plates has been considered as an important issue in ITER. Therefore, extensive studies of ELMs have been performed such as ELM dynamics and models/theories of ELMs for better prediction of ELM in ITER [1, 2], small ELM regimes [3] and various active control methods. In this paper, recent progress and remaining issues in physics understanding of ELMs are reviewed in terms of ELM dynamics, ELM mitigation with small ELMs, and active ELM control.

Improvements in temporal and spatial resolution of edge plasma diagnostics reveal various pictures of fast type I ELM dynamics during a collapse of the pedestal structure. One typical example is that filamentary structures have been observed on most devices. Because of the fact that ELM filaments also carry some amount of ELM energy loss, it is important to understand what physics determine the size of filament and how much density and temperature in a filament are. As for the normalized ELM energy loss to the stored energy at the pedestal ($\Delta W_{ELM}/W_{PED}$), an effect of toroidal field ripple and/or toroidal plasma rotation has been observed in JET and JT-60U.

There are many efforts to expand their operational regime and to identify required/sufficient plasma condition to obtain small ELMs, because the limited operational space in contrast to the type I ELM is remaining issue in small ELM regimes. For instance, an operational boundary at $\nu_e^*\sim 1$ has been found in some small ELM regimes [3], so that expansion of the operational space toward lower ν_e^* regime has been tried. In addition to this, dedicated study to understand the mechanism to suppress type I ELMs has also been progressed. However, effects of toroidal rotation/torque input to obtain grassy ELMs and QH-mode have not been fully understood.

In order to reduce the ELM heat load in ITER, active ELM controls using pellet pace making developed in AUG and edge ergodization demonstrated in DIII-D and JET have been considered so far. Although these methods successfully reduce the ELM heat load in some plasma conditions, more experimental results will be required for reliable predictions for ITER, because minimum pellet size for triggering ELMs determines the operational window from the view point of the pumping capability in ITER and required radial width of island overlap region is necessary for the design of ELM control coils in ITER.

[1] Leonard, A. W., *et al.*, Plasma Phys. Control. Fusion **48**, A149 (2006).
[2] Wilson, H. R., *et al.*, Plasma Phys. Control. Fusion **48**, A71 (2006).
[3] Oyama, N., *et al.*, Plasma Phys. Control. Fusion **48**, A171 (2006).