ELM Suppression in Low Edge Collisionality Discharges Using n=3 Magnetic Perturbations*

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A key issue for divertor design in next step devices is the large, pulsed heat load to divertor components which can be caused by isolated, giant edge localized modes (ELMs). As part of an international effort to develop controlled ELM regimes, we have recently discovered co-injected, ELM-free H-mode plasmas which exhibit constant density and constant radiated power levels. This ELM-free state is made using magnetic perturbations with toroidal mode number n=3 created by the DIII-D I-coil. Although the use of magnetic perturbations is common to this mode of operation and previously reported ELM control results [1-3], the present results were achieved at much lower density (pedestal collisionality $\nu_i^* \cong 0.02$ and $\nu_e^* \cong 0.2$) and are qualitatively more similar to the quiescent H-mode discharges achieved with counter neutral beam injection [4]. The divertor D_α traces, for example, are as featureless as those seen in QH-mode, unlike the D_α traces in previous, higher density results [1].

By utilizing n=3 magnetic perturbations in lower single-null divertor discharges, we have produced ELM-free plasmas with durations up to 2550 ms (~17 τ_E); the duration is limited by hardware constraints. These long durations were facilitated by lowering the pedestal density to 1.7×10^{19} m^{-3} and halting the plasma current ramp when q_{95} reached 3.6. The geometry of the I-coil produces a resonant perturbation at this q_{95} value. The n=3 perturbation is necessary for producing the ELM-free state; identical discharges without the magnetic perturbation

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continued ELMing. These shots exhibit clear H-mode edge pedestals and H-mode levels of confinement ($H_{ITER89P} \cong 2$).

Parameter scans indicate a power threshold of about 4 MW and an I-coil current threshold of about 2 kA ($\delta B_R/B_T = 1.4\times10^{-3}$). To date, we have successfully created the ELM suppressed state at powers up to 10 MW and I-coil currents up to 4 kA with no sign of upper power or current limits. The presence of the n=3 perturbation enhances the edge particle transport and the particle loss rate increases with I-coil current. There is a clear signature on the edge toroidal rotation which occurs when the ELMs are suppressed, suggesting a role for the edge flow shear in the ELM suppression.

In some shots, we turned off the I-coil current before the end of the discharge. The ELM suppressed state lasts for 100 to 150 ms after the I-coil current is gone. This behavior strongly suggests that the ELM suppression is not due to a direct interaction of the n=3 perturbation with the peeling-ballooning modes. Rather, the suppression appears to be due to changes in the edge parameters induced by the perturbation. As expected for a resonant effect, the ELM suppression is quite sensitive to the edge q_{95}; a small shape change which raised q_{95} to 3.8 brought back the ELMs.

These ELM suppression results, in low collisionality plasmas, combined with previous results in DIII-D plasmas using the ITER Scenario 2 shape at higher collisionality significantly strengthen the physics basis for ELM suppression using n=3 magnetic perturbations with a relatively simple coil set. Further experiments with enhanced I-coil current capabilities are planned for the present experimental campaign to further investigate the physics of ELM suppression.

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