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# Effectiveness of high-frequency ELM pacing with D2 and non-fuel pellets in DIII-D

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DIII-D studies of high-frequency ELM pacing by pellet injection were extended to ITER scenarios at low beam torque, demonstrating ELM peak heat flux mitigation with D2 pellets, and also with Li spheres, proving the concept of ELM pacing with non fuel pellets, a technique that could potentially reduce the throughput to the pumping and fuel reprocessing systems in ITER.

Injection of D2 pellets at frequencies up to 90 Hz was performed in low-torque ITER baseline scenarios (q_95=3.1, beta_N=1.7, n_e=4x10ˆ19 mˆ-3,T_inj=0.1 N m). High frequency injection resulted in ELM pacing at frequencies as much as 8x the natural ELM frequency (10 Hz). The resulting inner divertor peak heat flux was reduced by more than a factor of 10. During the high frequency injection, confinement remained similar to the reference discharge (H98y2˜0.8) with reduced concentration of metal impurities (Fe, Ni, Mo).

Injection frequencies up to 200 Hz were obtained with new Impurity Granule Injector (IGI), capable of injecting spherical pellets of non-fuel materials (e.g. Li, C, B4C), with controllable speed (60 120 m/s) and selectable pellet size.

By using the IGI with Li spheres (0.3-1.0 mm) in ITER shaped plasmas at moderate torque of 3.0 N m, ELM pacing was demonstrated for the full discharge length, with constant H98y2≈ 1.0, effective density control and reduced high-Z impurities. In this scenario the ELM frequency was increased by 3-5x over the natural ELM frequency (12 Hz), but the maximum ELM frequency appears to be limited only by the injection frequency of the larger granules. The increase of paced ELM frequency resulted in a lower q_ELM, at the outer strike point, where q_ELM˜1/f_ELM. Measurements of q_ELM at the inner strike point found q_ELM often higher than expected at high frequency of ELM pacing. Li spheres of 0.7-1.0 mm diameter were also used to pace ELMs in the low torque ITER baseline scenario (beta_N=1.9, T_inj=0.75 N m), achieving 100% pacing efficiency at f_inj≤200 Hz. A broad distribution of triggered ELM size was observed, where 5% paced ELMs had q_ELM similar to natural ELMs.

The combined dataset provides unique support of ITER mitigation research, both in terms of operational demonstrations and understanding of the physics of ELM pacing and mitigation.

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