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Buffering transient heat pulses with long-legged divertors in MAST Upgrade

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The detached divertor regime has been demonstrated to be effective in mitigating steady-state particle and heat loads to divertor plasma-facing components in current devices and is a key aspect of operating regimes in future high power devices including ITER [1]. Alternative divertor configurations, such as the Super-X [2] offer advantages to conventional divertors such as a wider operating space with detached divertors [3], reduced impact on the confined plasma and improved controllability of the detachment front [4]. However, data from detached conventional divertor configurations suggests their ability to buffer transient heat loads is limited, motivating the community to mitigate the source of these transients. The relatively large volume available for exhaust in alternative divertor configurations offers potentially greater capacity to buffer transient heat loads.

This contribution summarises recent experiments performed on MAST-U to study the buffering of transient heat loads arising from ELMs and sawteeth with long-legged divertor configurations within tightly baffled divertor chambers. New diagnostics have been developed to characterise the propagation and buffering of transients through the lower divertor of MAST-U in unprecedented detail, including a 500 kHz multi-channel ultra-fast spectroscopy system, divertor Langmuir probes, divertor Thomson scattering and fast visible and infra-red imaging.

The divertor ne and Te profiles prior to an ELM indicate deeply detached conditions, with Te < 1eV, ne < 1018 m-3 or both. Measurements taken as ELMs are propagating through this background plasma show an order of magnitude increase in ne and an increase in Te by factors of several up to 1ms after the ELM event. Analysis of ultra-fast spectroscopy data of the D2 Fulcher band emission across the lower divertor shows that the ratio of the Fulcher band emission from the Target and Upstream locations is well correlated with the transient heat flux arriving at the divertor plate. It also provides a valuable metric for characterising the degree to which transients are buffered by the neutral gas in the divertor chamber, where D2 Fulcher Target:Upstream emission ratios less than 1 are buffered or otherwise burn through the detachment front to the target. Measurements from a database of MAST-U pulses will be presented, containing deuterium and nitrogen gas seeding scans. Measurements performed in experiments with no impurity seeding agree well with a simplified 0D model describing the radiative dissipation of the transient heat flux via plasma-neutral interactions.

References

[1] R. A. Pitts et al., Nucl. Mater. Energy, 20 100696 (2019) [2] P. Valanju et al., Phys. Plasmas 16, 056110 (2009), [3] K. Verhaegh et al Nucl. Fusion 63 016014 (2023), [4] C. Cowley et al., Nucl. Fusion 62 086046 (2022)

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