Dynamics of the edge transport during edge localized mode cycles

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Recent advances in the diagnostic capabilities at ASDEX Upgrade (AUG) allow us to measure the edge profiles on a sub-ms timescale and with a spatial resolution of less than 5 mm. This makes it ideal to study the profile recovery during fast transient events. Here, we present the dynamic behaviour of the energy, particle and momentum transport during edge localized mode cycles at the plasma edge of AUG by combining a comprehensive set of pedestal measurements with interpretive and predictive modelling.
The dynamics of the ion and electron kinetic profiles were measured in deuterium and helium plasmas with unprecedented time resolution down to 100 μs. At the ELM onset, the separatrix T_i increases, leading to a reduced gradient in the pedestal [1]. Shortly after the initial separatrix increase, the whole profile drops and then the pedestal starts to build up again. The pre-ELM profile is fully recovered 3-4 ms after the ELM crash. Comparing the ion to the electron temperature profile revealed that the ion temperature gradient reaches its pre-ELM value after the ELM crash on a faster timescale than the electron temperature gradient. The ion temperature and electron density gradient recover to their pre-ELM values on similar timescales, while the electron temperature gradient recovers only 7-8 ms after the ELM onset. The saturation of ∇T_i and ∇n_e is correlated with the onset of medium-frequency fluctuations ($f\sim50$ kHz) [2], while high-frequency fluctuations ($f\sim200$ kHz) appear when ∇T_e recovers [3], indicating a different clamping mechanism for the ion and electron energy and particle transport.
The edge toroidal rotation recovers on a similar timescale as ∇T_i. This was observed in both deuterium and helium plasmas, the latter enabling measurements of the main ion species. Compared to the impurity toroidal rotation, which exhibits a local minimum at the plasma edge during the inter-ELM phase, the edge main ion toroidal rotation has a much less pronounced dip and is rather flat. During the ELM the main ion toroidal rotation in the pedestal drops by about 5-10 km/s. This is in contrast to the behaviour of the impurity toroidal rotation, which shows a flattening of the toroidal dip feature.
Integrated modelling of the various transport channels allows us to shed light on the dynamic behaviour of the transport coefficients during the ELM cycle. The analyses reveal that the ion heat transport is at the neoclassical level before the ELM crash in the region where the edge ion temperature gradient is maximal. Further inwards, the ion heat transport is about a factor of 4-5 above the neoclassical level. Two possible mechanisms for the additional energy transport in the electron channel (electron temperature gradient modes and neutral ionization) that could cause the delay in the ∇T_e recovery, were studied. The energy loss due to ionization of neutrals was found to be insignificant, while ETGs cannot be excluded. The dominant effect comes from the depletion of energy caused by the ELM. The local sources and sinks for the electron channel in the steep gradient region are much smaller compared to the energy flux arriving from the pedestal top, indicating that the core plasma may dictate the local dynamics of the ∇T_e recovery during the ELM cycle.

[1] M. Cavedon et al, PPCF **59** 105007 (2017)
[2] F. Mink et al, NF **58** 026011 (2018)
[3] F. M. Laggner et al, PPCF **58** 065005 (2016)