Topic: EX-C

Electron Temperature Perturbation Studies on the National Spherical Torus Experiment (NSTX)*

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A primary energy loss mechanism on NSTX is apparently through the anomalously high electron thermal transport. [1] Therefore, characterizing and understanding electron transport and thermal diffusion is important in the quest for improved performance in NSTX. In the past, this thermal transport has been characterized using the propagation of small heat pulses generated by sawtooth crashes to probe the radial electron heat conduction coefficient, χ_e. [2-4] While high performance NSTX discharges generally operate sawtooth-free with q(0) > 1, other techniques can be used to create temperature perturbations, thus allowing the determination of the perturbed electron transport coefficient, e.g. lithium pellet injection (LPI) from the low field side and edge localized modes (ELMs) at the plasma edge.

Both of these phenomena cause a small, prompt, crash of the edge electron temperature, which then initiates a cold pulse front that propagates radially inwards towards the plasma core. In fact, the characteristics of the cold pulse from the pellet and the ELM are strikingly similar in both the time scales of the propagation and the magnitude of the perturbation of the electron temperature. In each case, the cold pulse propagates to the core on time scales of ~2-3 ms, and can cause a reduction in the central electron temperature of 10-30%. Another common characteristic is the relative insensitivity of the global electron density profile to these perturbations. While ELM events do cause a reduction of the edge impurity density “ears” that are a common feature of the hollow density profiles of NSTX H-mode plasmas, LPI causes instead a slight enhancement of these density “ears” from the ablation of the pellet at the plasma edge; however, in both cases the global electron density profile is largely unchanged. This difference at the plasma edge is also a good indication that, while the subsequent perturbations are similar, the LPI induced perturbations and ELMs are distinct events, i.e. the pellet injection is not causing an ELM.

The general behavior of the cold pulse has been documented with multipoint Thomson scattering (MPTS) using a varying time window between laser pulses. NSTX plasmas are overdense for electron cyclotron emission (ECE) due to the low B_t; hence, the soft X-ray (SXR) system is the main diagnostic tool for measuring the details of the cold front propagation. A consequence of the generally unperturbed density profile is that the change in SXR emission is roughly proportional to the change in electron temperature. Figure 1a shows the time evolution of the relative change of the SXR intensity profile during an ELM and the subsequent cold pulse propagation. Figure 1b shows the electron temperature and density before the ELM and during the cold pulse as indicated. The electron temperature profile shows the perturbation almost to the magnetic axis, while the electron density profile shows only a slight global increase and the aforementioned reduction of the impurity density “ears”.

(a) (b)

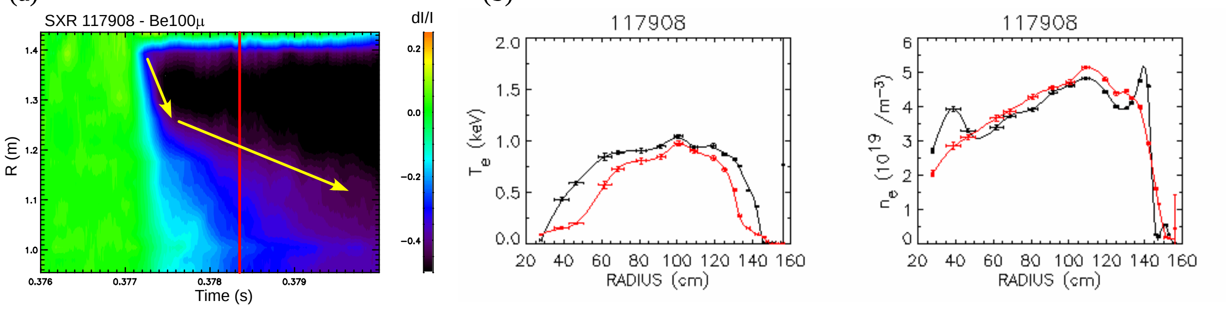

Figure 1: (a) relative change in the SXR profile filtered with a 100μ Be filter, red line indicates MPTS timing, yellow arrows indicate speed of propagation of the perturbation (b) MPTS electron temperature and density pre-ELM (black) and post-ELM (red)

Of particular interest is that the cold pulse has reduction in the propagation speed inside R ~1.3m. In fact, when the simple sawtooth model for electron thermal transport is applied [4], the perturbed χ_e is calculated at a few hundred m^2/s for $\rho > 0.4$ which is in the region of relatively high electron temperature gradient, and few tens of m^2/s for $\rho < 0.4$, the region of flat electron temperature profile (Fig. 2). This trend appears contrary to that typically obtained from power balance calculations in the NSTX H-mode, where χ_e outside $\rho >$ 0.5 (high T_e gradient region) is generally lower than that inside (low T_e gradient). This suggests again that, as discussed in [5], perturbed and steady state transport can be quite different.

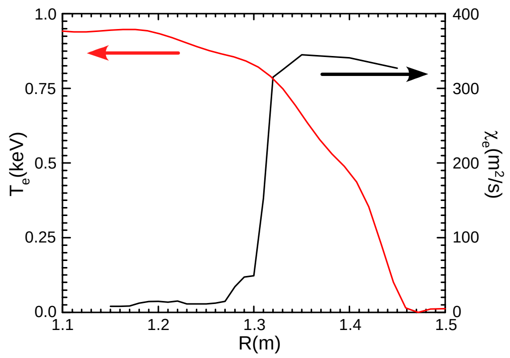

Figure 2: radial electron heat conduction coefficient, χ_e, and corresponding MPTS electron temperature profile

Further study will compare these results to other models, such as the critical gradient model, and expand the analysis to other plasma regimes. Specifically, plasma discharges with slightly reduced plasma current have demonstrated some “resistance” to the central propagation of the cold pulse, i.e. the perturbation was limited to the outermost ~10cm of the plasma. Detailed results from a new multi-energy SXR system and dedicated experiments will be presented.

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