EXC-Confinement

The evolution of the edge pedestal structure and turbulence spatial scale during the ELM cycle on NSTX

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Fusion performance of ITER is predicted to be proportional to the square of the pedestal pressure height [1]. The reference scenario for the ITER H-mode is projected to be in the Type I edge localized mode (ELMy) regime where the maximum pedestal pressure is reached leading to an enhancement of the fusion gain. Recent experiments on National Spherical Torus Experiment (NSTX) in ELMy H-mode regimes showed that the pedestal pressure height builds up and reaches saturation during the last 30% of the ELM cycle in high triangularity discharges. Furthermore, the pedestal pressure width is also found to increase while the pressure gradient is clamped early in the ELM cycle. These characteristizations of the pedestal structure (height, width, and gradient) dynamics are consistent with the peeling ballooning description of the ELM cycle, and are in agreement with observations in large aspect ratio tokamaks. We measured, for the first time the evolution during an ELM cycle, ion-scale microturbulence consistent with instabilities of the type ion temperature gradient –ITG (and hybrid ITG/trapped electron mode TEM) - and/or kinetic ballooning mode – KBM - in the pedestal region, which could potentially limit the pedestal gradient.

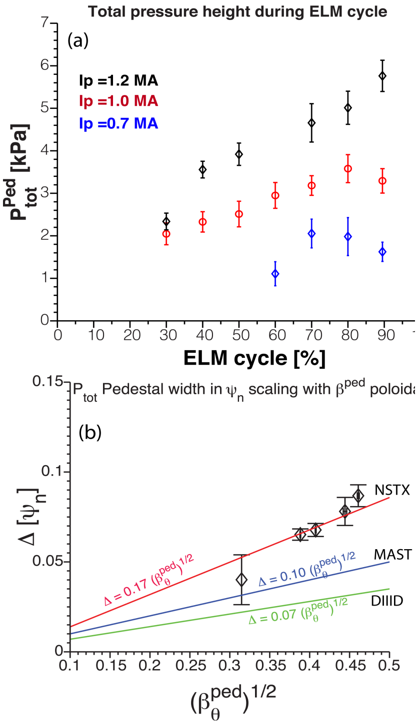

Figure 1: Pedestal structure scalings: (a) Pedestal height dynamics during the ELM cycle showing saturation prior to the onset of ELM in low and medium Ip. (b) the pedestal width scaling with poloidal β and comparision with scalings observed in different machines.

The pedestal pressure evolution during the ELM cycle for three different plasma currents is shown in figure 1(a). We observe a clear buildup of the pedestal height before the onset of ELMs for high plasma current (I_p). In the lower I_p case, however, this buildup saturates during the last 30% of the ELM cycle [2]. The pedestal width and gradient show similar dynamics with gradient being clamped early on during the ELM cycle and the width saturating during the last part of ELM cycle. The clamping of the gradient has been hypothesized [3] to be due to instabilities like KBMs. This hypothesis is consistent with the width-poloidal β experimental scaling shown in figure 1(b). In fact, this scaling is expected if the pressure gradient is limited by KBMs, which increase the transport in the pedestal region in order to limit the pressure gradient [3]. While this width scaling has been observed in other tokamaks, the observed width in NSTX is 2.4 larger than DIII-D and C-Mod, and 1.7 larger than MAST. A large pedestal width would yield a large bootstrap current with beneficial effects on the overall energy confinement.

Using turbulence diagnostics, we probe the spatial scales present during the inter-ELM phase in order to understand the role of microturbulence in limiting the pedestal gradient. Measurements of the density fluctuations at the pedestal top show $k_\theta\rho_i$ spanning 0.1 to 0.2 and the fluctuations propagating in the ion diamagnetic direction [4]. These are obtained by characterizing the poloidal structures of microturbulence present during the inter-ELM phase using the BES system [5]. The poloidal correlation lengths (see figure 2(a)) are obtained from two-point correlation measurements between multiple adjacent points in the poloidal direction at the pedestal top. We observe small changes in the poloidal correlation length evolution during the ELM cycle. The direction of propagation of the fluctuations in the laboratory frame was determined to be in the ion diamagnetic direction (once the Doppler shift is removed as shown in figure 2(b)). Given the measurements of the poloidal correlation lengths of the fluctuations at the pedestal top, and the propagation direction, we show that the dominant fluctuations in the pedestal region during the inter-ELM phase are consistent with ion scale turbulence (e.g., ITG, hybrid ITG/TEM, and/or KBM).

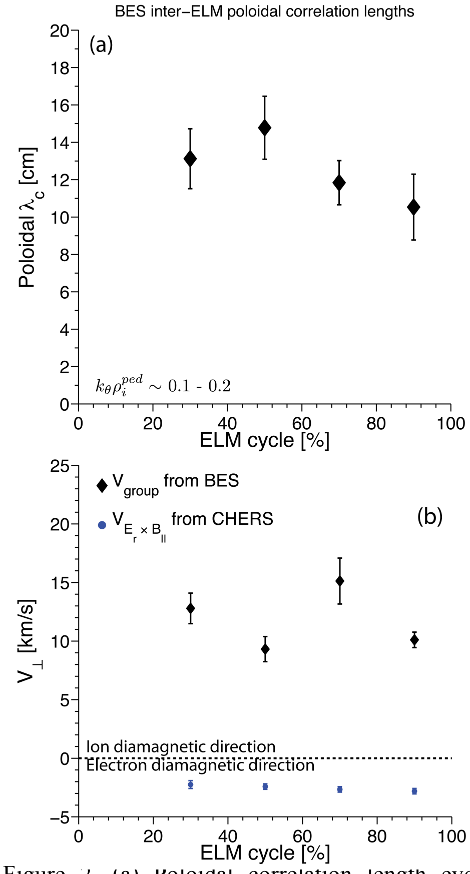

Figure 2. (a) Poloidal correlation length evolution during the inter-ELM phase at the pedestal top. (b) Perpendicular velocity measurements using both BES and charge exchange recombination spectroscopy (CHERS) systems.

While within uncertainties the inter-ELM evolution at the pedestal top of theoretical microinstability parameters (e.g., R/L_{Ti} , R/L_{Te} , R/L_{ne}, ν_e^*) are found to vary less than few percent, we observe that R/L_{Te} is overall 60% larger than R/L_{Ti} and greater (6 times) than R/L_{ne}. Out of these theoretical parameters, only the electron pedestal β (by way of the pedestal height) shows continuous increase during the ELM cycle. With the electron drive R/L_{Te} being larger than R/L_{Ti}, electron-type microturbulence such as hybrid ITG/TEM are not to be ruled out. Distinguishing between ITG, hybrid ITG/TEM, or KBM, however, is not possible with the present data and would require both linear and nonlinear modeling of the edge pedestal, which is currently being pursued. The experimental observations represent the first indications that the fluctuations during the ELM cycle at the pedestal top exhibit spatial scale of ion-scale microturbulence. Finally, these observations could potentially provide an understanding of the mechanism limiting the pedestal gradient during the ELM cycle, which is critical for ITER and next-step devices. *Work supported in part by U.S. DOE contract DE-AC02CH11466.*

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