Effect of Collisionality and Detachment Onset on the Scrape-off Layer Heat Flux Profiles in NSTX*

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During the final run campaigns of NSTX, it was shown experimentally that the inter-ELM scrape-off layer (SOL) width, λ_q varied inversely with the poloidal magnetic field at the outer midplane, such that $\lambda_q \propto B_{pol,\,omp}^{-1.6}$ under attached, boronized, low gas puffing conditions [1]. An international database was compiled to better understand how λ_q scales with tokamak major radius, injected power and plasma current and found that for ITER $\lambda_q \sim 1$ mm under attached conditions [2]. This narrow λ_q leads to untenable heat fluxes on the divertor for ITER. A dissipative – e.g. high collisionality – divertor solution is required to maintain tolerable heat fluxes to the divertor.

In NSTX inter-shot evaporative lithium wall conditioning was utilized to control collisionality. The addition of lithium wall conditioning had the effect of reducing divertor and mid plane neutral pressure, far-SOL ion saturation current as well as divertor D_α emission [3]. Outer strike point (OSP) heat fluxes were measured utilizing a unique dual-band infrared thermography [4] to compensate for the reduced surface emissivity introduced by the use of lithium wall conditioning. λ_q and S, the diffusive parameter in the Eich fitting function of the deposited heat flux [5], both show a reduction of up to 66% when large amounts (> 300 mg) of Li evaporation are used for inter-shot wall conditioning as shown in Figure 1a and 1b respectively. λ_q is found to increase linearly with upstream density similar to other tokamaks [6]. During the secular density rise of a standard NSTX discharge [7], the rate of rise of λ_q with respect to upstream density increased five times faster under boronized conditions as compared to lithium. The S parameter also increases linearly with upstream density but at a much slower rate than λ_q and is independent of the wall conditioning technique employed.

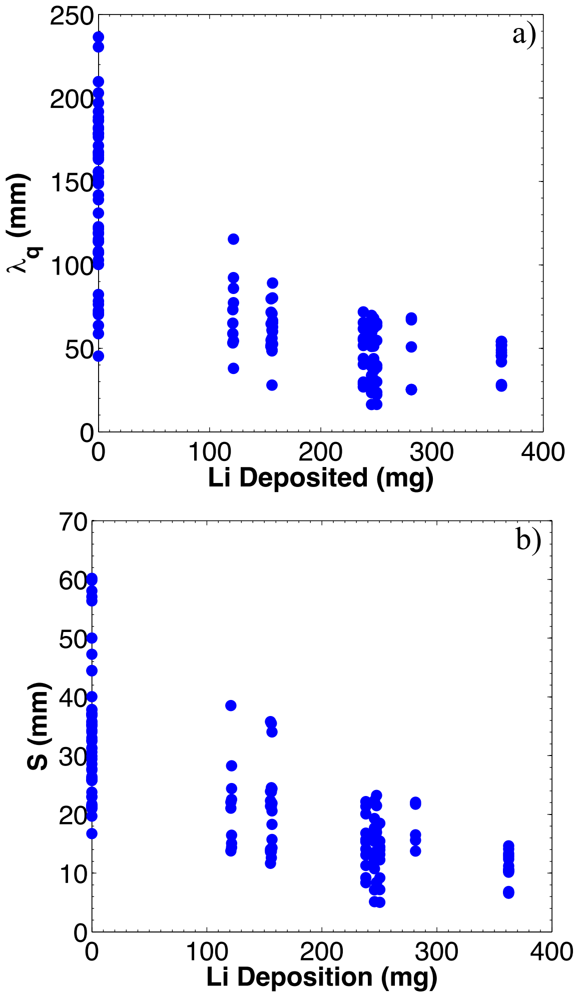

Figure 1: a) λ_q and b) S Eich fit parameters for inter-ELM and ELM-free outer strike point heat flux profiles as a function of inter-shot lithium deposition.

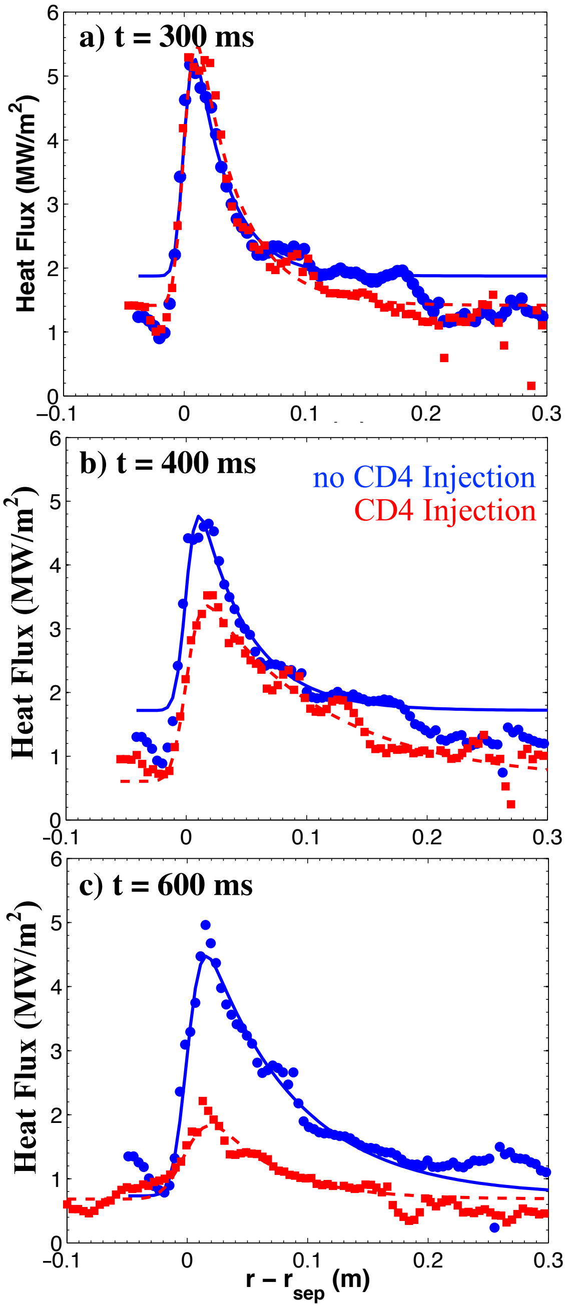

Figure 2: Averaged (12 ms window), ELM-free outer strike point heat flux profiles a) before CD_4 injection, b) during and c) approximately 100 ms after CD_4 injection had ended.

Conversely, to increase divertor collisionality, CD_4 gas injection into the SOL was employed. Figure 2 shows two NSTX discharges: one with and one without divertor CD_4 gas injection. Prior to divertor gas injection, the OSP heat flux profiles were comparable (Fig. 2a). However, approximately 100 ms after CD_4 injection began, shown in Fig. 2b, the peak heat flux was reduced while λ_q increased to over 100 mm from 30 mm prior to CD_4 injection with the increase in λ_q correlated in time with rising divertor C-II emission. Conversely, no response in the S parameter was observed until after 600 ms when oscillations in divertor D_α and heat flux were observed as the outer strike point approached complete detachment. Shown in Fig. 2c, CD_4 injection had ceased for approximately 100 ms and peak heat flux remained low, 2 MW/m^2, compared to 5 MW/m^2 in the reference case. λ_q had returned to approximately 30 mm similar to the reference discharge. Preliminary heat flux measurements from NSTX-U will be presented and implications for a dissipative divertor in a future Fusion Nuclear Science Facility (FNSF) discussed.

*This work was supported by DoE Contracts: DE-AC05-00OR22725, DE-AC52-07NA27344 and DE-AC02-09CH11466.

[1] T.K. Gray, et al., J. Nucl. Mater. 415 (2011) S360
[2] T. Eich, et al. Nucl. Fusion. **53**(9) (2013) 093031
[3] R. Maingi, et al., J. Nucl. Mater. 463 (2015) 1134
[4] A.G. McLean, et al., Rev. Sci Instrum. **83**(5) (2012) 053706
[5] T. Eich, et al., Phys. Rev. Lett. 107 (2011) 215001
[6] B Sieglin, et al., Plasma Phys. Controll. Fusion. 55 (2013) 124039
[7] V.A. Soukhanovskii, et al., J. Nucl. Mater. 390-391 (2009) 1901