Dependences of the divertor and midplane heat flux widths in NSTX

T.K. Gray[1], R. Maingi[1], J. Surany[2], J.-W. Ahn[1], A.G. McLean[1] and the NSTX Team

[1]Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA
[2]Princeton University, Princeton, NJ 08543 USA

Email: tkgray@pppl.gov

Divertor heat flux plays a crucial role in the lifetime of plasma facing components (PFCs), and it's profiles are correlated to the heat transport through the scrape-off layer (SOL) and cross-field transport in the edge plasma. Spherical tokamaks in particular have high heat fluxes due to their compact geometry. Divertor performance and lifetime ultimately impact the overall performance of all fusion reactors. Here we report the dependences of National Spherical Torus Experiment (NSTX) lower divertor heat flux profiles, measured using ELM-averaged infrared thermography, on a wide range of discharge and plasma shapes. Of special interest is how the heat flux profile scales as plasma current and beam power are increased. For example, the proposed center stack and heating power upgrade to NSTX is predicted to have equal or greater peak divertor heat flux than in ITER. These measurements therefore provide confirmation of necessary heat flux handling techniques in the NSTX through magnetic flux expansion and evaporative coatings on the PFC surface.

Previously it was found[1] that the SOL heat flux widths (λ_q^{mid}, magnetically mapped from the divertor profiles obtained from thermography) decreased with increasing I_p, and were relatively independent of P_{NBI} at high P_{NBI}, in discharges with low divertor triangularity $\delta \sim 0.5$. Here we have extended the studies to higher triangularity of $\delta \sim 0.7$, extending and confirming the previous trends up to 1.2 MA. Specifically we find that the midplane heat flux width λ_q^{mid}, as defined by[2], contracts with increasing plasma current in low triangularity discharges from $\geq$2 to $\sim$1 cm as shown in Figure 1b. At higher triangularity, as shown in Figure 1b, the same relative trend is observed with a 50%

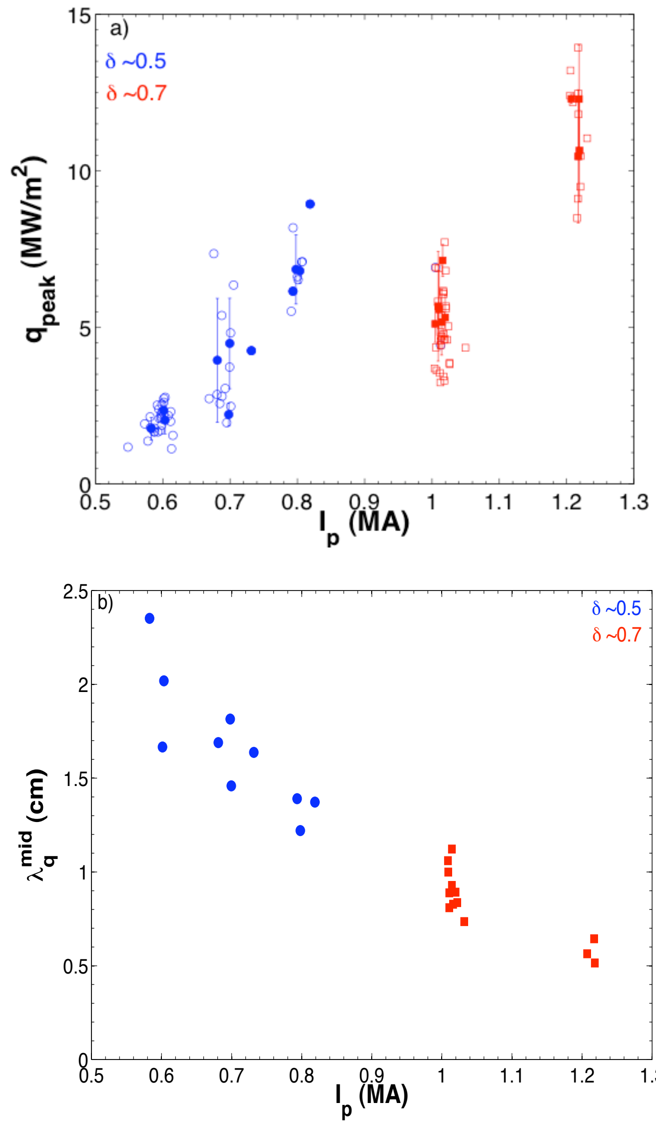

Figure 1: The measured a) peak heat flux, q_{peak} and b) heat flux width mapped to the midplane, λ_q^{mid} as a function on increasing plasma current for low (blue) and high (red) triangularity discharges.

contraction in λ_q^{mid} when the plasma current is increased from 1 to 1.2 MA. In addition, a detailed study of the dependence of the heat flux on flux expansion has shown that the divertor heat flux footprint λ_q^{div} increases ~ linearly the magnetic flux expansion, f_{exp} over a range of f_{exp} = 10-40. This leads to a strong reduction of the peak heat flux as shown in Figure 2a, where the peak heat flux is reduced from 8 to 2 MW/m^2 as the magnetic flux is expanded from 10 ≤ f_{exp} ≤ 40. When λ_q^{div} is mapped to the midplane as shown in Figure 2b however, λ_q^{mid} shows little dependence on f_{exp} with λ_q^{mid} nearly constant at 1 cm over the same range of f_{exp}.

Finally, we note that NSTX utilizes lithium coatings to condition its graphite plasma facing components[3]. This results in ELM-free discharges[4], leading to a further contraction of the heat flux profile. While uncertainty in the emissivity for lithium coated graphite plasma facing surfaces limits a direct comparison of the magnitude of the heat flux profile, the relative change in radial profile shape from pure graphite to a lithium coated surface is still applicable. New measurements with a 2-color infrared camera that will account for lithium emissivity differences, as well as new experiments with the liquid lithium divertor will be reported.

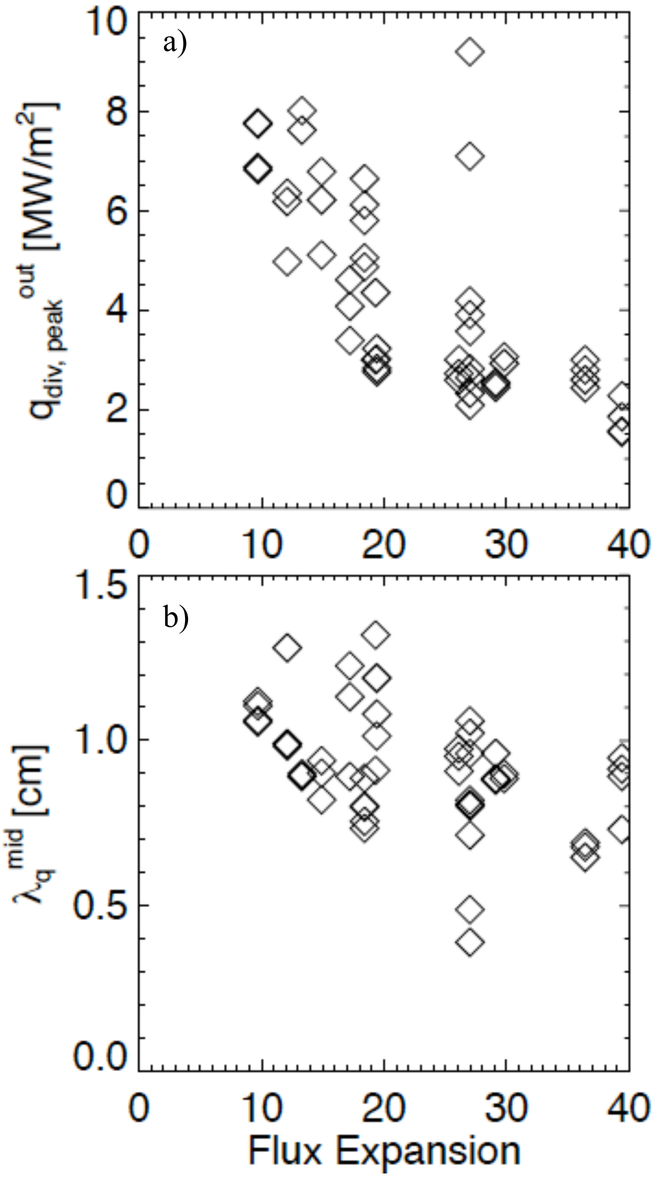

Figure 2: a)Peak heat flux decreases as flux expansion increases, while the b)heat flux width, mapped to the midplane, λ_q^{mid} is shown to be invariant with increasing flux expansion.

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