The effect of feedback-controlled divertor nitrogen seeding on the boundary plasma and power exhaust channel width in Alcator C-Mod

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The scrape-off layer (SOL) power channel width, λ_q, is projected to be ~0.5 mm in power reactors, based on multi-machine measurements of divertor target heat fluxes in H-mode [1,2]. However, these measurements were performed at low levels of divertor recycling and radiant heat dissipation, allowing the heat flux 'footprint' at the divertor target to be interpreted as a measure of the 'upstream' λ_q. Important questions therefore arise: Does upstream λ_q change with the level of divertor dissipation and/or the degree to which the divertor target plate is electrically connected to the upstream SOL? Theory indicates that electrical connection to the divertor target can play a role in SOL turbulence, e.g., parallel currents can reduce blob polarization and transport [3]; sheath potentials can impose $E\times B$ shear, regulating turbulence [4]. We report results from Alcator C-Mod in which feedback controlled nitrogen seeding in the divertor was used to systematically vary divertor dissipation in a series of otherwise identical L-mode plasmas at three plasma currents: 0.55, 0.8, 1.1 MA, with 5.3 Tesla toroidal field. Core plasma density was chosen so as to place the divertor in a sheath-limited heat flux regime prior to nitrogen injection. Outer midplane profiles were recorded with a scanning Mirror Langmuir Probe; divertor plasma conditions were monitored with 'rail' Langmuir probe and surface thermocouple arrays. Key observations are:

(1) In all cases, N_2 seeding resulted in a factor of ~10 reduction in divertor target plate heat fluxes while maintaining core plasma conditions relatively unchanged;
(2) In all cases, divertor target conditions near the strike point changed from sheath-limited to high-recycling, attaining partial detachment;
(3) In all cases, net parallel current densities to the target plate – driven by Pfirsch-Schülter and thermoelectric currents – were reduced by over an order of magnitude;
(4) Despite these dramatic changes in divertor conditions, upstream λ_q remained largely unchanged, within statistical uncertainties.

We interpret observation (3) to indicate that an order-of-magnitude variation in the 'electrical connection' between target plate and upstream SOL was obtained. The results have important implications for our understanding of boundary plasma transport and for advanced divertors:

- Divertor dissipation does not reduce peak heat flux densities entering from 'upstream'.
- Divertor plasma conditions, including sheath boundary conditions, do not play a defining role in the physics of cross field transport in the near SOL region.
- Upstream λ_q will be largely unaffected by advanced divertor details – leg length, flux expansion, x-points.
- Divertor fan width can be designed based on empirical λ_q scaling.

[1] T. Eich, *et al.*, Nucl. Fusion **52** (2013) 093031; [2] D. Brunner, *et al.*, this conference; [3] O.E. Garcia, *et al.*, Phys. Plasmas (2006) 082309; [4] F. Halpern, *et al.*, Nucl. Fusion **57** (2017) 03400.

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