Extension of the I-mode confinement regime to 8 tesla on Alcator C-Mod*

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A crucial need for fusion devices is to achieve sufficiently high energy confinement, without the large transient heat loads typical of H-mode with Type I ELMs. The I-mode regime has a strong energy transport barrier, without a particle barrier, and is naturally free of ELMs. Particle confinement is at the L-mode level, which also avoids accumulation of impurities that may arise from plasma-surface interactions. Key questions remain for extrapolation of I-mode to reactors, notably the conditions needed to access the regime, and to maintain it without transitions to H-mode or L-mode. Experiments on the Alcator C-Mod tokamak have extended I-mode to the full range of field and current, B_T=2.8-8 T and I_p= 0.55-1.7 MA, and show that the regime becomes more robust against transitions to H-mode at higher fields. This is due to weak dependence of the L-I power threshold on B_T, while the upper range of power while staying in I-mode increases more strongly with field [1]. At 8 T, no discharges transitioned to H-mode even at maximum-available ICRH power (5 MW). I-mode discharges feature strong temperature pedestals, with T_e and T_i over 1 keV, and L-mode density pedestals. An E_r well, intermediate between L-mode and H-mode discharges, also develops. Several interrelated features in pedestal turbulence and flows are observed, including a low frequency GAM (10's of kHz), a high frequency 'weakly coherent mode' (few hundred kHz), and reduction in turbulence between these ranges. Some of these fluctuations may extend into the SOL.

The different characteristics of I-mode vs H-mode pose new questions and challenges for boundary solutions. While the elimination of transient heat loads due to ELMs is a major advantage, the stationary heat flux on the outer strike point can remain high, similar to L-modes and H-modes, with extremely narrow λ_q (<1 mm) at high poloidal field [2]. Because I-mode is usually accessed with ion $B\times\nabla B$ drift away from the active X-point, reversing ExB SOL flows, heat fluxes can also be high on the inner strike point [3]. Total power to the dominant divertor target has been significantly reduced by operating in near balanced configurations, with $|\delta r_{sep}|$ smaller than ~1.5 mm [1], but reducing the instantaneous *peak* heat-flux on any one target remains a challenge since the heat-flux widths are so small [3]. Combining I-mode with a detached divertor also remains an outstanding challenge [4]. Prospects for and needed research on the I-mode regime will be summarized.

[1] A.E. Hubbard *et al*, Nucl. Fusion 57 (2017) 126039.
[2] D. Brunner *et al*, submission to this conference.
[3] J. L. Terry *et al*, J. Nucl. Materials 438 (2013) S212 ; also submission to this conference.
[4] M.L. Reinke *et al*, submission to this conference.

This work was supported by US DoE cooperative agreements DE-SC0014264 and DE-FC02-99ER54512 on Alcator C-Mod, a DoE Office of Science user facility.