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EDGE PEDESTAL CONTROL IN QUIESCENT H-MODE DISCHARGES IN DIII-D USING CO PLUS COUNTER NEUTRAL BEAM INJECTION

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Edge Pedestal Control in Quiescent H-Mode Discharges in DIII-D Using Co Plus Counter Neutral Beam Injection Ex-C

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Quiescent H-mode (QH-mode) plasmas in DIII-D with co plus counter neutral beam injection have demonstrated active control of the edge pedestal that can be used to optimize the edge conditions in future burning plasma devices such as ITER. Burning plasmas impose significant, conflicting constraints on the edge pedestal. To maximize fusion power, the edge pedestal pressure must be as high as possible. However, to eliminate damage to divertor components caused by impulsive heat loads due to edge localized modes (ELMs), the edge pressure must be limited to a value below that set by the peeling-ballooning mode stability limit. In addition, helium ash removal demands sufficient edge particle transport; ELM-induced particle transport could provide this were it not for the heat load problem. ELM-free QH-mode plasmas have demonstrated that all these requirements can be met simultaneously in discharges which operate with constant density and radiated power. As is illustrated in Fig. 1, experiments with co plus counter neutral beam injection show that altering the torque input to QH-mode plasmas allows continuous adjustment of the pedestal density, pressure and particle transport over a range of about a factor of 2 while maintaining the ELM-free state. This active control capability allows operation near but below the ELM stability boundary. These plasmas exhibit edge particle transport more rapid than that produced by ELMs while operating at reactor relevant pedestal beta (β^{ped} ~ 1%) and collisionality ($\nu_i^* = 0.1$) [1]; pedestal densities up to 1/2 the Greenwald density have been achieved.

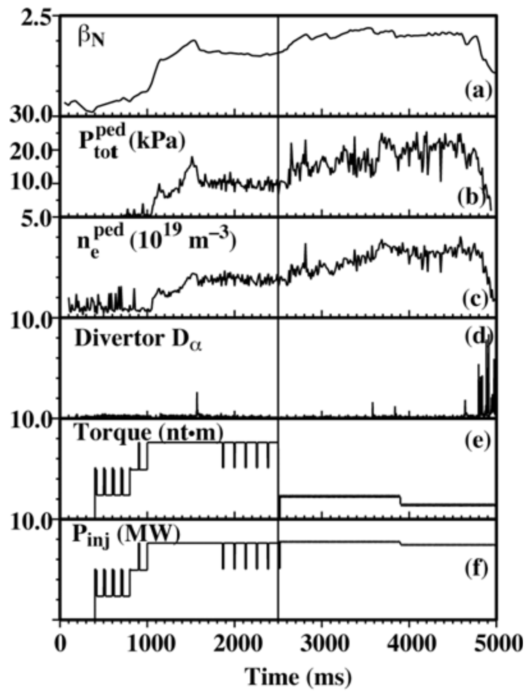

Fig. 1. Time history of (a) normalized beta, (b) total pedestal pressure, (c) pedestal electron density, (d) divertor D_α intensity, (e) total input torque and (e) input power for QH-mode discharge with a torque scan. Torque is positive in the direction opposite the plasma current.

The essential feature distinguishing QH-mode from standard ELMing H-mode is the presence of an edge-localized electromagnetic mode, the edge harmonic oscillation (EHO). The EHO provides increased particle transport [1], which prevents ELMs by keeping the edge pressure below the peeling-ballooning mode boundary [2]. The EHO is spontaneously generated by the plasma itself and requires no external coils to generate a perturbed magnetic field as is necessary, i.e., for ELM suppression via resonant magnetic perturbations (RMP) [3]. Unlike RMP ELM suppression, there are no known resonant edge *q* effects on the EHO.

The QH-mode is a different operating mode than the EDA H-mode on C-Mod [4]; the EHO is quite different than the quasi-coherent mode [4] and QH-mode has no known maximum power limit [5].

The extra EHO-induced particle transport can be adjusted by changing the input torque to the plasma, thus altering the plasma rotation. As is shown in Figs 1 and 2, the edge density and pressure then increase, leading to an overall increase of plasma stored energy of ≈35% in the best cases seen to date. As the profiles in Fig. 2 reveal, this increase is due to a change in the edge pedestal.

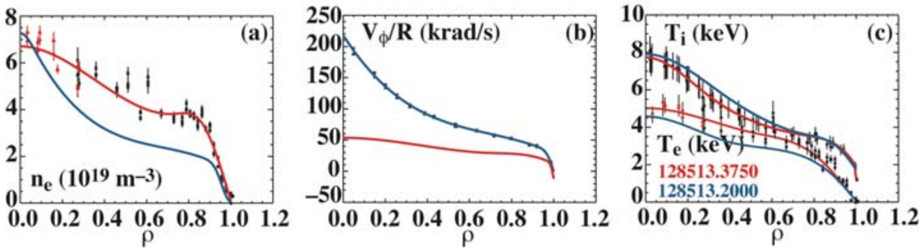

Fig. 2. Plasma profiles for discharge in Fig. 1 for low torque period (red) and high torque period (blue).

As is illustrated in Fig. 3, edge stability calculations using the ELITE code [6,7] show that the QH-mode operating point is near the peeling boundary. Much of the physics of the EHO is consistent with a model in which the EHO is an edge kink-peeling mode that is destabilized by shear in the edge toroidal rotation at an edge current density slightly below that on the standard ELM boundary [2]. EHO saturates by dragging on the wall, reducing the rotational drive.

Peeling-ballooning stability calculations have been used as a guide in developing the best plasma shape. To maximize the pedestal pressure, a shape with the best ballooning stability is preferred. This also eases the need for edge transport control, since less transport increase is needed to hold the edge pressure below the ballooning limit. The high-triangularity, double-null divertor shape shown in Fig. 3 was chosen after detailed edge stability calculations revealed its superior stability to peeling-ballooning modes [8]. The improvement in the stability limits over a single-null shape is clearly demonstrated in Fig. 3 by the difference between the yellow line and the blue region.

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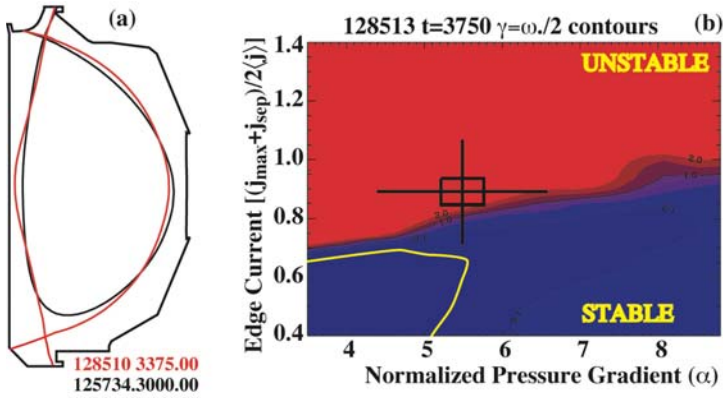

Fig. 3. (a) Plasma shape for double-null discharge in Fig. 1 (red) and for an upper single null discharge used in previous QH-mode experiments, (b) peeling-ballooning stability diagram with the data point showing the operating point for the DND discharge in Fig. 1 during the low torque period. Also shown in (b) is the stability boundary for the single-null plasma (yellow).

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