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# The Impact of n=2 Resonant Magnetic Perturbations on Limiter H-mode Plasmas in TEXTOR

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## Introduction

The application of resonant magnetic perturbations to produce stochastic magnetic fields is regarded as one possible option to control ELMs in future fusion devices such as ITER. The feasibility of such a concept has been shown at the tokamak DIII-D at ITER-like collisionalities [1]. So far, the physical mechanisms behind the ELM suppression are not fully understood. Therefore, for extrapolation of such a scenario, studies of transport in stochastic edge plasmas are required. In this context, the impact of the mode spectrum of the perturbations on transport and structure formation is of special importance. In the follwowing, we report on experimental results of limiter H-mode plasmas in the tokamak TEXTOR under the influence of the Dynamic Ergodic Divertor (DED) in the $m/n = 6/2$ base mode configuration.

## Limiter H-mode scenario in TEXTOR

The power threshold to access H-mode conditions in TEXTOR [2] is considerably larger than predicted for the H-mode in poloidal divertor tokamaks, which is related to larger convective heat losses out of the confined plasma in limiter configuration compared to divertor configurations (cf. [3] for a further discussion). The L-H power threshold in TEXTOR amounts to a total input power of 1.5 - 2 MW at $B_t = 1.3$ T and 3.0 - 3.8 MW at 1.9 T depending on the wall conditions. With the L-H transition we observe ELMs at frequencies in the range of 300- 1300 Hz (increasing with pedestal collisionality). So close to the power threshold one would expect type-III ELMs but an unambiguous identification couldn't be made so far in TEXTOR because of the lack of input power to go substantially over the threshold. The formation of the pedestal structure is most pronounced in the density profile. Note, that access of H-mode conditions requires in

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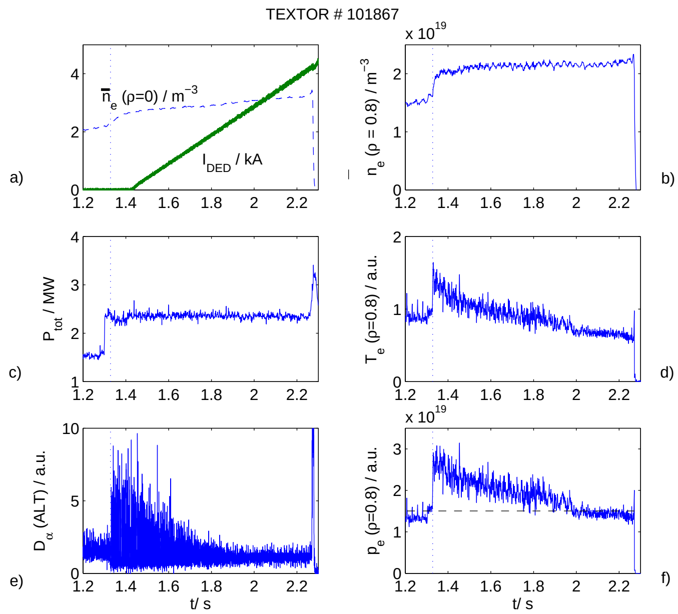


Figure 1: *Response of the plasma edge properties to a slow ramp-up of the perturbation current in the 6/2 base mode configuration: a) line averaged central electron density (dashed) and perturbation current (solid line), b) line averaged electron density at $\rho = 0.8$ at the LFS, c) total input power, d) the electron temperature at the HFS at $\rho = 0.8$, e) $D_\alpha$ emission in front of the ALT limiter at the LFS, f) product of line averaged electron density at $\rho = 0.8$ at the LFS and the electron temperature at the HFS at $\rho = 0.8$ as a measure of the pedestal pressure*

general a horizontal shift of the plasma column towards the high field side by 3-7 cm. Under these conditions the plasma is limited by the inner wall covered with carbon tiles prior to the application of the resonant magnetic perturbations. When the perturbation is applied, divertor strike zones are formed on the inner wall.

## Experimental results of the limiter H-mode under the influence of the DED

Experiments in the 6/2 base mode configuration of the DED have shown a significant impact of the magnetic perturbations on the plasma edge properties and ELMs associated with the edge pedestal. In this configuration every four neighboring of the 16 helical perturbation coils at the high field side are switched in parallel for the DC operation of the coils discussed in this paper. An example is shown in Fig. 1 ($B_T = 1.3$ T/ $I_p = 245$ kA, $R = 1.70$m / $a = 0.43$m, $q_a = 3.4$). The L-H transition occurs at 1.33s (vertical dotted line) about 30 ms after the onset of the full heating power (panel c)) with the onset of high frequency ELMs (panel e)) at about 350 Hz. With increasing perturbation current we observe a rather smooth decrease of the particle bursts while the height of the pedestal pressure represented in panel f) is reduced at the same time. This reduction is caused by a reduction of the pedestal temperature (panel d), from the HFS and only given in relative units as not absolute ECE calibration is available for $B_T = 1.3$T) rather than by a reduction of the pedestal density (panel b), line averaged density from interferometric measurements at the LFS) by the resonant magnetic perturbations. When the ELMs are completely diminished at about $t = 1.9$ s, also the pedestal pressure is almost reduced back to L-mode level (horizontal dashed line in panel f)).

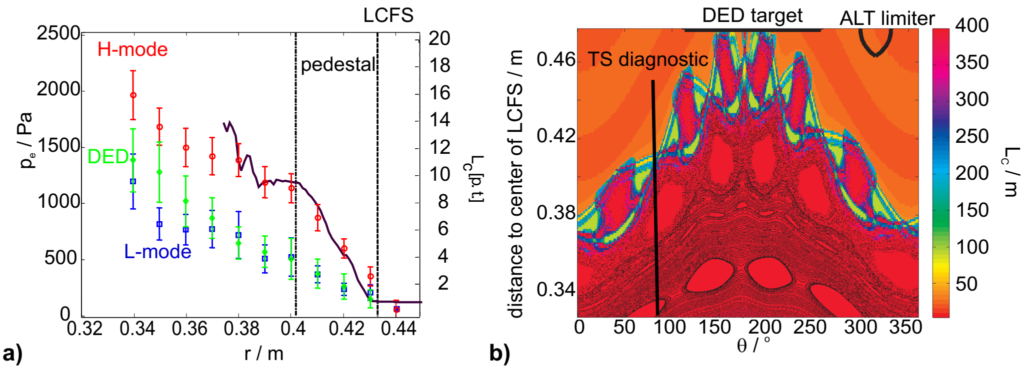


Figure 2: *a) Edge electron pressure profiles for L-mode (blue squares, 102158), H-mode (red circles, 102161) and with DED (green diamonds, 102168) together with connection length to wall in poloidal turns, b) Laminar plot at toroidal section of TS diagnostic.*

Fig. 2a) shows the electron pressure profiles measured with the multi pulse TS scattering diagnostic at TEXTOR mapped onto minor radius. As this diagnostic only delivers one burst of pulses per discharge we compare three discharges similar to ♯ 101867 shown in figure 1. In the L-mode reference (blue squares) the profile has been taken prior to the L-H transition (10 pulses of the burst averaged), for the H-mode case (red circles) we averaged 3 pulses prior to an ELM crash and for the discharge, where a constant perturbation current of $I_{DED}$ = 3kA was applied during the H-mode phase, we again averaged over 10 pulses. In the H-mode phase we observe a region with a steepened pressure gradient of approximately 20kPa/m over about 3 cm pedestal width. The pedestal collisionality amounts to $\nu_e^* = 1.1$. Under the influence of the DED the pressure profile is flattened back to L-mode level, consistently with the evolution displayed in fig. 1, the ELMs have disappeared with the loss of the H-mode pedestal.

We want to compare the change of the pressure profile with application of DED to the magnetic topology calculated with a field line tracing code using a vacuum approximation of the perturbation field. Fig. 2b) shows the Poincaré plot of the perturbation overlayed to a color contourplot of the connection length to the wall. The vertical path of the laser beam, along which the profiles are measured, is indicated. It is inclined because the major radius of the laser path ($R = 1.85m$) is different to the major radius of the plasma ($R$ = 1.70m). We note that an ergodic zone with remanent islands is formed in the region of the pedestal characterized by long connection lengths. Here, we expect an increase of the effective radial particle and heat transport because of the diffusion of field lines, causing the observed flatting of the pressure profile. In contrast, in laminar regions with short connection lengths we observed a strong drop of the pressure and a steepening of profiles because of a dominant parallel transport to the wall [4].

Fig. 3 summarizes the pedestal characteristics at $B_T$ = 1.9T, ($Ip$ = 310kA, $R_0$ = 1.71m, $a$ = 0.44m) in an edge operational diagram where we plot the electron temperature at the pedestal (from ECE diagnostics) against the electron density at the pedestal (deduced from the Abel inverted profiles of the HCN interferometer), both parameters determined at the LFS about 3 cm inside of the LCFS and ELM averaged. The interpolation of the electron density profiles poses some uncertainty onto the deduced pedestal density (the spatial separation of the HCN channels contributing to the profile construction is only 5 cm. The observed changes of the pedestal parameters, however, going from L- to H-mode and the relaxation of the pedestal pressure back to L-mode levels caused by the DED are in line with what had been observed with the TS scattering diagnostics at $B_T = 1.3$T: The transition from L- to H-mode is most pronounced in the density channel while pressure relaxation with DED (data points refer to both steady and ramped perturbation currents) is mainly caused by a temperature drop. We relate the latter finding to the positive impact of the DED on particle confinement generally seen in L-mode plasmas which are shifted towards the HFS (cf. discussion in [2]). Such a behavior is in contrast to the density pump- out under the influence of the DED which is observed in TEXTOR once the plasma is shifted towards the LFS. There, the laminar zone is much reduced in width with respect to the ergodic zone. Density pump- out has also been found in experiments using RMPs to affect ELMs in both DIII-D [1] and JET [5]. Recent experiments in the $m/n = 3/1$ base mode configuration confirmed earlier findings [2], that only a small operational window to influence edge transport and stability exists for edge safety factors $q_a < 4$, as 2/1 tearing modes are excited by the n=1 external error field [6].

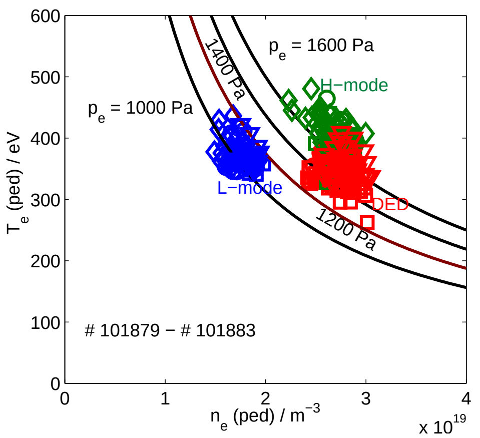


Figure 3: *Edge operational diagram of the limiter H-mode at $B_T = 1.9\,T$*

## Summary and conclusions

Edge pressure profiles can be controlled by the DED in limiter H-mode plasmas. However, no operational window could be found so far where the H-mode pedestal is maintained but the ELMs are suppressed. In the 6/2 base mode configuration the edge pedestal is steadily reduced with increasing perturbation together with ELM size until the plasma is finally driven back to L-mode. A density pump-out has not been observed under these conditions where the near field of the DED directs the plasma onto the inner wall along laminar flux tubes. These results emphasize the importance of the magnetic topology for particle transport.

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