Impact of resonant magnetic perturbations on the MAST pedestal

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Abstract

The application of RMPs causes a perturbation of the plasma edge which produces a toroidal variation in the shape and position of the edge transport barrier observed at different sectors using Thomson scattering (TS) and a linear D_α camera. The impact that the strength of the applied RMP has on the toroidal perturbation is examined by varying the coils current and the distance between the plasma and the RMP coils. The application of RMP also causes an increase in ELM frequency known as mitigation. The magnitude of the toroidal perturbation is compared with the mitigated ELM frequency and the pedestal behaviour in discharges for both n=4 and n=6 RMP configurations. To examine the impact of RMPs on performance, the plasma pressure pedestal just before an ELM crash is examined as it varies with applied RMP coil current and ELM frequency. ELM affected area as a function of mitigated frequency is also examined to determine the nature of the lower particle loss per ELM at high mitigated ELM frequency. During an RMP induced density pump out, a drop in core plasma density is typically observed. With careful refuelling it has been possible to replace the core density loss in recent experiments [1]. This results in a change in the gradient inside the separatrix, shown elsewhere to change ELM losses [2]. On MAST the RMP system consists of 18 in-vessel coils (6 upper and 12 in the lower row) [3], allowing for the application of RMPs with toroidal mode numbers $n = 1,2,3,4$, and 6, with currents up to 1.4kA per coil.

Induced Toroidal Perturbation

When RMPs are applied to the MAST plasma it is observed that there is a change in the edge transport barrier (ETB) of the plasma. This is due to the induced corrugation of the plasma edge which matches the

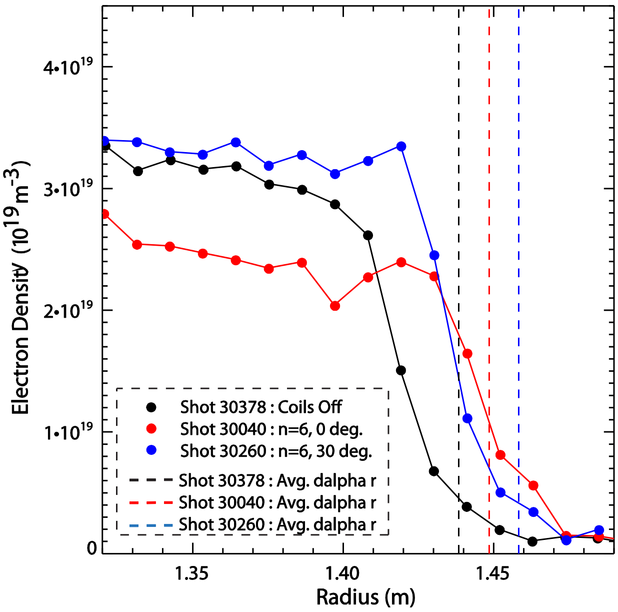

Figure 1: The n_e pedestal and Dα peak radial position as a function of RMP phase.

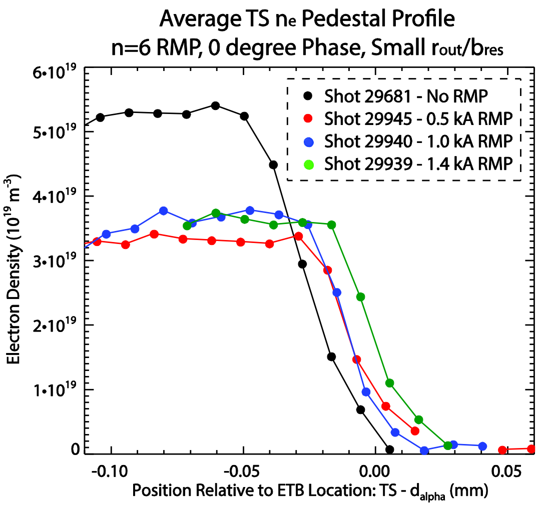

Figure 2: TS $\boldsymbol{n_e}$ profiles with respect to the relative ETB location for n = 6 RMP.

toroidal mode number of the applied RMP perturbation. The size of the shift in the ETB location (measured using the linear-$D\alpha$ camera in conjunction with the TS profiles), varies with the size of the RMP coil current. The position of the observed ETB location shifts outwards or inwards depending on the RMP applied. This shift due to the RMP coils is a local effect based on the position of the diagnostic, relative to the phase and mode number of the perturbation (Figure 1). The total observed shift is due to this effect and the response of the plasma control system.

Figure 2, shows a set of similar discharges with only the strength of the $n = 6$ perturbations changing. When the coil current increases the effective outward shift of the average pedestal position also increases. These profiles are obtained by averaging the n_e TS profiles for each discharge during the last 25% of the ELM cycle in a time window covering from 0.50s to 0.60s, where the RMPs are at their designated current value and the plasma current (I_P), is not ramping down. The averaged n_e pedestal is plotted with respect to the radial position relative to the peak Dα.

MAST has the flexibility to allow for operations where the plasma edge is moved outward to be in closer proximity to the RMP coil, which in turn amplifies the effect of the perturbation on the plasma. In the $n = 4$ discharges, the outboard plasma pedestal is incrementally moved outwards towards the vessel wall radially from 1.38m to 1.41m. When the plasma boundary is moved into closer proximity to the RMP coils, an increase in ELM mitigation is observed. Comparing the $n = 4$ results those of the investigated $n = 6$ discharges, a similar trend is

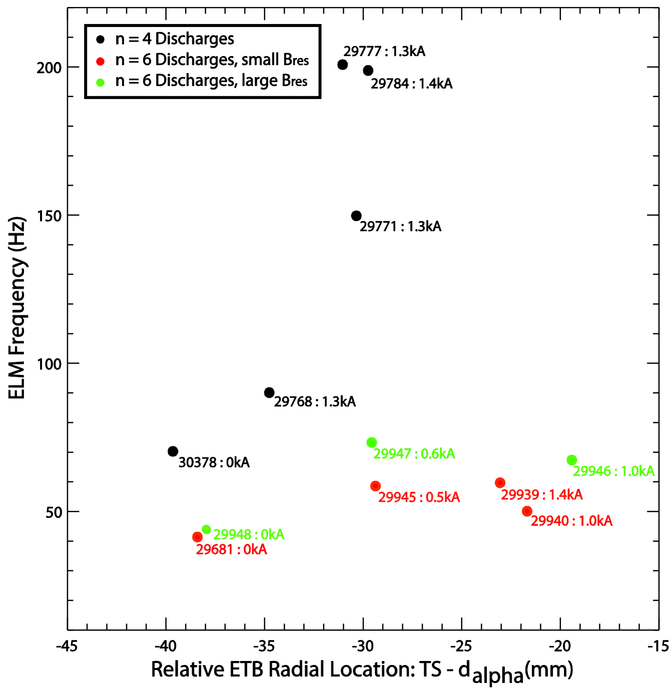

Figure 3: ELM frequency as a function of the relative ETB location and how they scale with ELM coil current.

observed. In the $n = 6$ discharges the plasma position was kept constant while varying the RMP coil current from 0 to 1.4kA. This is shown in Figure 3, where either pushing the plasma outward, closer to the RMP coils with a fixed coil current or increasing the coil current at a fixed plasma position, the ELM frequency increases, resulting in an increase in ELM mitigation.

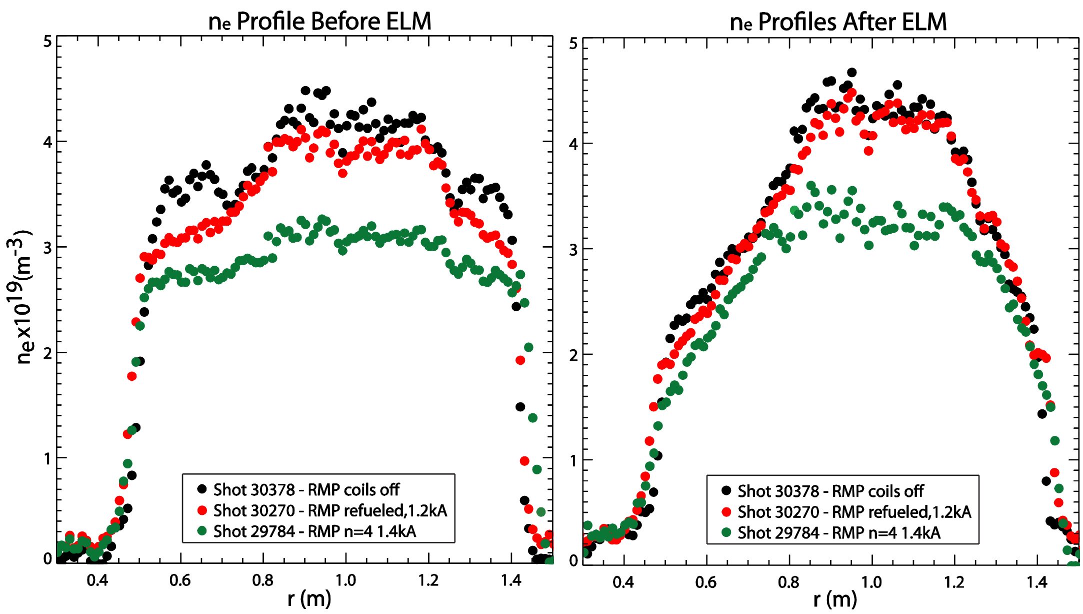

Figure 4: The $\boldsymbol{n_e}$ profiles before (left) and after (right) an ELM event for two RMP shots, one with strong refuelling, with both shots compared to a coils-off reference discharge.

ELM Affected Area

The ELM frequency is increased as a result of the applied RMP field, resulting in smaller (ΔW) ELMs. While RMPs are applied and achieve a substantial level of ELM mitigation, there is a density pump-out observed in the edge and core of the plasma that causes a reduction in the plasma confinement. It is possible to replace the lost pedestal density with strong gas refuelling at the edge. In this comparison, three shots are examined to highlight both the impact of RMPs on the ELM affected area and the influence of strong refuelling, comparing RMP discharges with and without this refuelling to a shared coils-off reference discharge (Figure 4). The effect of the applied RMPs is evident in Figure 5, where it is shown when the perturbation is applied, a decrease in the density loss per elm event is observed. This decrease can be related to the decrease in the peak pedestal height

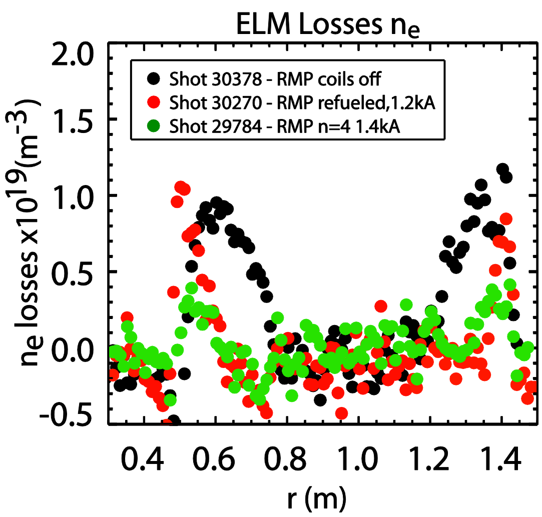

Figure 5: Electron density ($\boldsymbol{n_e}$) losses for the two highly ELM mitigated shots with and without strong refuelling and their coils-off reference.

prior to the ELM event, as highlighted in Figure 6. In shot 30270 where the density pump out is mostly compensated for by the additional refuelling the density loss per ELM at the edge is similar in profile to the loss observed in the RMP discharge without additional refuelling. Even with an overall reduction in the ELM losses, the refuelled discharge is observed to have edge peak n_e losses similar to that of the coils off reference. However with strong refuelling, there is an observed increase in the confinement compared to the $n = 4$ example with a similar level of ELM mitigation, shown in Figure 7. The level of ELM mitigation is shown by the size and frequency of the Dα signal spikes associated with ELMs, an estimate of the plasma energy loss by the drops in the plasma energy measured at the time of an ELM. The focus has been on the n_e pedestal behaviour. This is due to $\Delta T_{e,ped}$ showing little change with the application of RMPs in the examined discharges, adding no additional information in the current state of the examination.

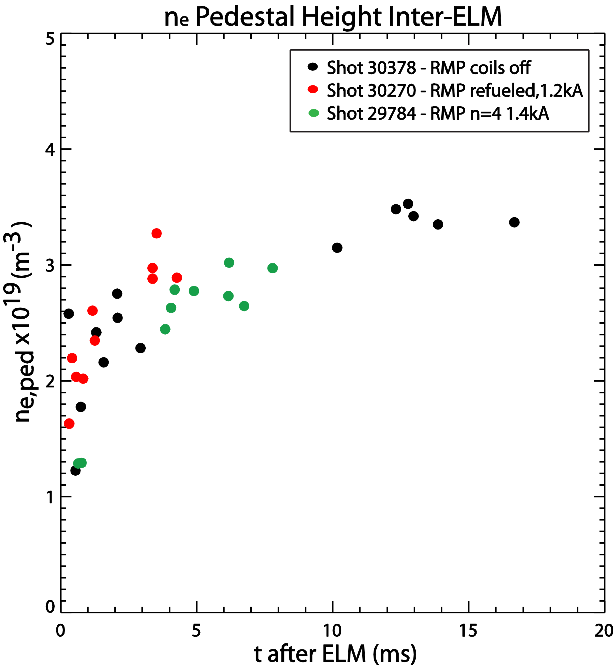

Figure 6: The n_e pedestal height evolution over the inter ELM period, capturing values building up to and just after an ELM event.

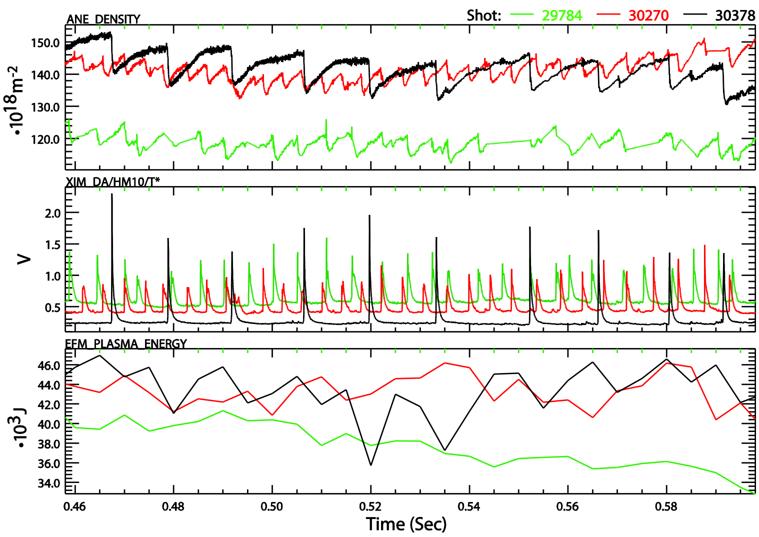

Figure 7: Comparison of average line density, Dα signal, and plasma energy to compare level of ELM mitigation.

References

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