ELM mitigation using the recently installed active in-vessel coils at ASDEX Upgrade

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For the 2011 campaign in-vessel coils have been installed in ASDEX Upgrade which allow the application of a magnetic perturbation with a mode number of up to n=2. If the peripheral plasma density is above a critical value, the n=2 perturbation leads to a strong mitigation of type-I edge localized modes (ELMs). This is found independent of whether the resonant perturbation field is maximized or minimized. The particle confinement increases in ELM mitigation phases, i.e. no density 'pump-out' is observed. Pellets are used to fuel these plasmas up to densities 1.5 x the Greenwald limit with high fuelling efficiency, while also pellet-triggered ELMs are suppressed by the magnetic perturbations.

1. Introduction

In ITER, the type-I ELMy H-mode is foreseen to be the basic operational scenario. The activity of edge localized modes (ELMs) presents the risk of overloading the plasma facing components. Thus, a way of reliably suppressing or mitigating ELMs is required to guarantee the success of ITER and later reactors. One way to do this could be additional coils close to the plasma that introduce non-axis-symmetric, magnetic perturbations.

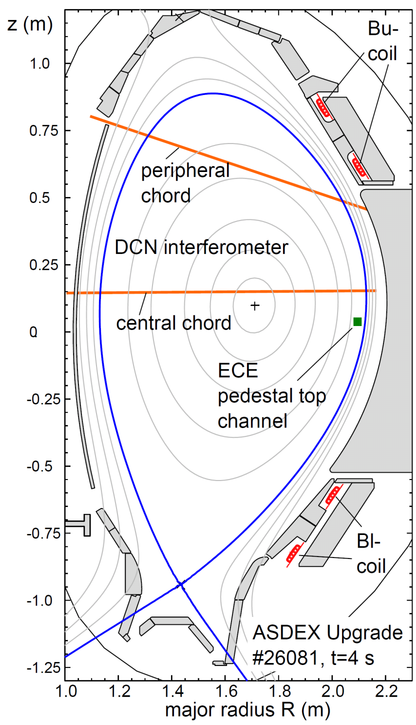

Fig. 1 Cross-section of ASDEX Upgrade indicating the location of perturbation coils and diagnostics

In the present work, results on ELM mitigation employing such perturbation coils in ASDEX Upgrade are presented. More details about the described experiments can be found in [1,2].

2. Experiment and Observations

In 2010, eight in-vessel coils, labelled perturbation coils in the following, were installed in the ASDEX Upgrade tokamak. They are mounted close to the plasma, as can be seen in Fig. 1. The perturbation coils form an upper and a lower ring each of which consists of four coils. In Fig. 1, the upper and lower coils are labelled Bu-coils and Bl-coils, respectively. The wiring allows for the application of magnetic perturbations of up to n=2, while at each toroidal position the Bu-coils either create a perturbation field that has the same direction as that of the Bl-coils (even) or the opposite direction (odd).

First results demonstrate that ELM mitigation is possible in the n=2 configuration. The mitigation is found only above a critical electron density n_{crit}. When the coils are switched on and the plasma density is above n_{crit} the type-I ELMs become less frequent and are replaced by smaller ELM-like instabilities within a few energy confinement times. The change of ELM type leads to a small increase of plasma density, while the temperatures are slightly decreased. No considerable effect on the stored energy is observed and neither the high-Z nor the low-Z impurity levels are changed. All observations so far suggest that n_{crit} shows a linear dependence on the toroidal plasma current which can be expressed as a minimum Greenwald fraction of approx. 0.65. Further parameter dependencies, on safety factor and plasma shape, are under investigation. When perturbation coils are applied and the pedestal density is above the threshold, type-I ELMs disappear and give way to a minor ELM-like edge instability. The collapse of pedestal parameters at each ELM is much reduced and thus, the power load due to the ELM is rather small in both of the divertors. In Fig. 2, the corresponding measurements are presented. The application of the perturbation fields leads to an increase of the baseline power-load at the outer divertor, while at the inner divertor the baseline level is slightly decreased. In any case, the large excursions that are observed during type-I ELMy phases are eliminated by the perturbation fields.

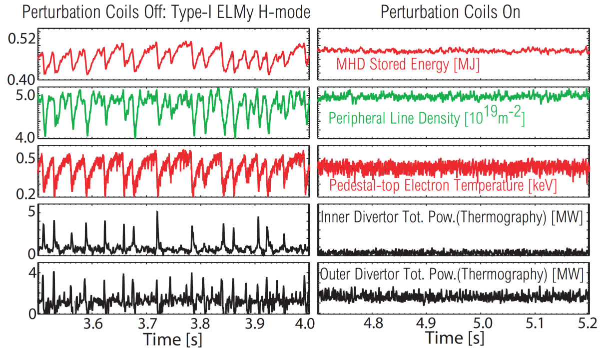

Fig. 2 Comparisons of stored energy, edge density, edge temperature and the divertor power loads for type-I ELMs and mitigated ELMs

ELM-mitigated phases are characterised by a slight increase in particle confinement and no degradation of energy confinement as compared with the no coil reference phase. No large ELMs are induced by injected pellets if the perturbation fields are applied, while with perturbation coils off ELMs are triggered as generally observed in ELMy H-mode [3]. A train of pellets has been employed to push the plasma density to 1.5 times the Greenwald density, while type-I ELMs remained mitigated by the application of the perturbation fields.

The access condition for the ELM-mitigated regime is not found to be dependent on the relative alignment of magnetic field lines and the perturbation field structure applied by the coils (resonant/non-resonant). In the pedestal, the profiles of electron temperature, electron density, ion temperature, toroidal and poloidal rotation exhibit no obvious difference to the cases without perturbation coils. At the same time, strike line splitting is observed in the divertor demonstrating an influence of the perturbation coils at radii outside of the separatrix.

Up to now the plasma rotation was not found to influence the ELM mitigation effect. Thus, it is unclear what the interconnections between plasma rotation, the penetration of the magnetic perturbations and the effect on the ELMs are.

3. Discussion

The observations reported in the present work are remarkable, because they add additional phenomenology to the observations at other experiments [4-7]. New aspects are the fact that for most of the cases neither density pump-out, nor confinement degradation are observed in the phases during which ELMs are influenced by the magnetic perturbations. This is connected to the fact that the kinetic profiles are not degraded by the perturbation fields. The latter suggests that field line stochastization is not playing a major role inside of the separatrix. However, it is possible that the observations described in the present work relate to a density regime that was not investigated in detail by other experiments up to now. At DIII-D, the existence of a high-collisionality regime was mentioned earlier [4], in which ELM-mitigation but not ELM-suppression was possible. However, ELM suppression in plasmas corresponding to the DIII-D low collisionality regime [5] has not been found as yet in ASDEX Upgrade. Current experimentation aims to match dimensionless parameters and fuelling and pumping parameters in both machines. The ASDEX Upgrade in-vessel coil set is now upgraded by installation of another eight coils to allow n=4 resonant and non-resonant perturbations. This upgrade allows the investigation of effects due to the details of the field structure on ELM mitigation.

It should be noted that for the discovered high-density regime, no satisfactory theory is available to describe the observations. Even if the regime is related to the high-collisionality regime observed at DIII-D, it is unclear how the perturbation coils can affect the ELM-stability in the observed way.

References

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