Mitigation of Type-I ELMs with *n* =2 Fields on JET

Y. Liang[1a], P. Lomas[2], I. Nunes[2]. M. Gryaznevich[2], M. N. A. Beurskens[2], S. Brezinsek[1], J. Coenen[1], P. Denner[1], Th. Eich[3], L. Frassinetti[4], S. Gerasimov[2], D. Harting[1], S. Jachmich[5], A. Meigs[2], J. Pearson[1], M. Rack[1], S. Saarelma[2], B. Sieglin[3], Y. Yang[1], L. Zeng[1], and JET-EFDA contributors[*]
JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

[1]Forschungszentrum Juelich GmbH, Association EURATOM-FZ Juelich, Institut für Energie- und Klimaforschung - Plasmaphysik, Trilateral Euregio Cluster, D-52425 Juelich, Germany
[2]EURATOM/CCFE Fusion Association, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK
[3]Max-Planck-Institut für Plasmaphysik, EURATOM-Assoziation, D-85748 Garching, Germany
[4]Association EURATOM-VR, Fusion Plasma Physics, EES, KTH, SE-10044 Stockholm, Sweden
[5]Association EURATOM-Belgian State, Koninklijke Militaire School - Ecole Royale Militaire, B-1000 Brussels Belgium

A reliable method for Edge Localized Modes (ELMs) control is needed for ITER to handle the peak heat load onto the plasma facing components. The recently obtained results from several tokamaks (DIII-D, AUG, JET, MAST, NSTX) have shown that magnetic field perturbations can either completely suppress ELMs, or affect the frequency and size of the type-I ELMs in a controllable way, preserving good global energy confinement. The coil systems in these devices include different designs, e.g. in-vessel off-midplane coils and external midplane coils, and provide different poloidal, *m*, and toroidal, *n*, mode number spectra as well as different radial profiles. To date, suppression of the type-I ELMs has only been achieved by using in-vessel off-midplane coils in DIII-D (*n*=3) [1] and AUG (*n*=2) [2]. On JET, the type-I ELM frequency in low collisionality (ν^*_e~0.1) H-mode plasmas has been increased by a factor up to 5 when applying static *n* = 1 or 2 fields produced by four external midplane error field correction coils (EFCC) [3-5]. This generates an open question: ***What is the limitation for ELM control/suppression with external midplane coils?***

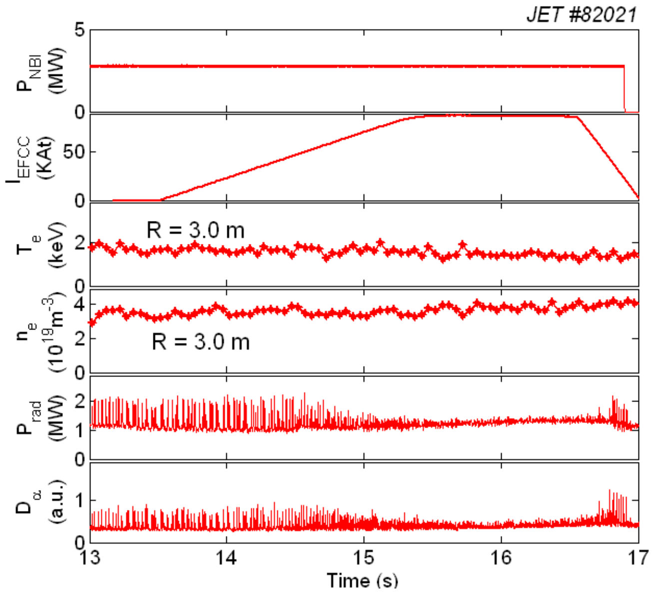

Figure 1. Overview of a type-I ELM mitigation experiment on JET. The traces from top to bottom are the NBI input power (P_{NBI}), the EFCC coil current (I_{EFCC}), the plasma central electron temperature (T_e) and densities (n_e) measured at R = 3.0m, the total plasma radiation power (P_{rad}), and the D_α signals measured at the inner divertor.

Recently, JET EFCC power supply system has been enhanced with a coil current up to 96kAt (twice than before). Strong mitigation of type-I ELMs has been observed with application of the *n* = 2 field in high collisionality (ν^*_e=2.0) H-mode plasma on JET tokamak with ITER-like wall.

[a] Email address: y.liang@fz-juelich.de
[*] See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejeon, Korea

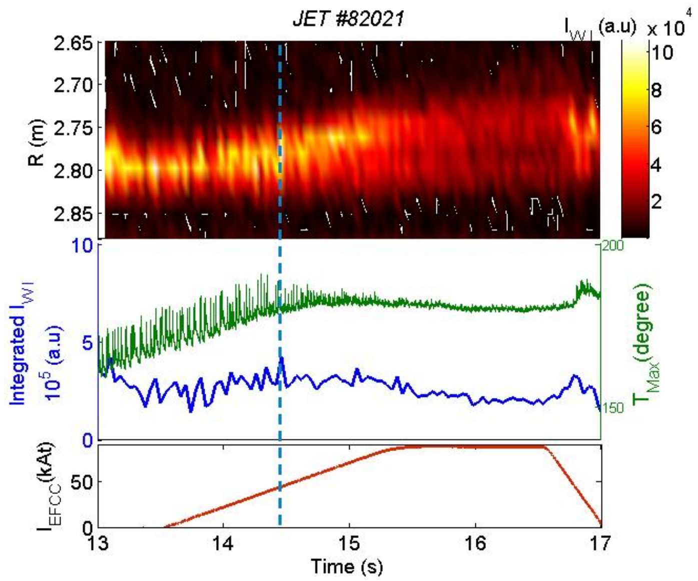

Figure 2, Time evolutions of intensity profile of W I emission ($I_{W\,I}$), integrated W I emission, and Maximal surface temperature on the outer divertor plate, and the EFCC coil current.

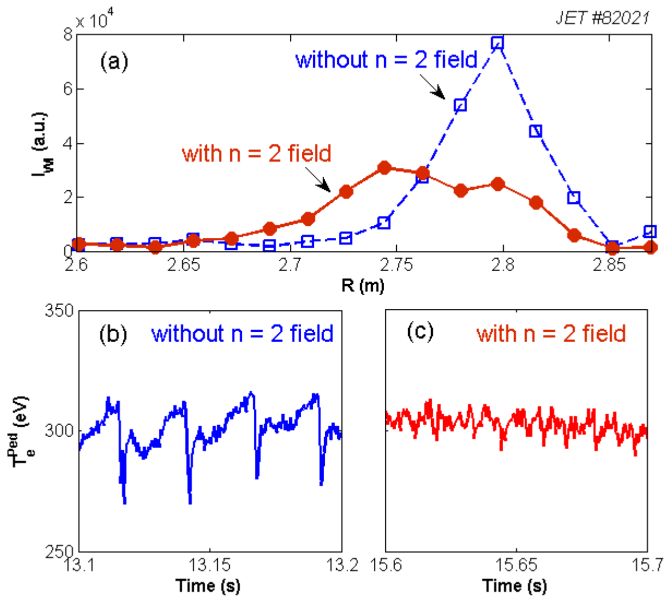

Figure 3, a) Radial profiles of W I emission ($I_{W\,I}$) averaged in (blue) t=13s-13.5s and (red) t=15.5s-16.5s, and time evolution of the pedestal electron temperature measured b) with and c) without n=2 fields.

Figure 1 shows an example of mitigation of type-I ELMs with n = 2 fields on JET. The pulse had a toroidal magnetic field of B_t = 1.85 T and a plasma current of I_p = 1.2 MA, corresponding to an edge safety factor of q_{95} = 4.8. The type-I ELM H-mode was sustained for 5 seconds by the Neutral Beam Injection (NBI) with an input power of 2.6 MW. The target plasma had a low triangularity shape ($\delta_{average}$= 0.26). To avoid impurity influx, a strong gas puffing with a rate of 4×10^{21} electron/s was applied during the NBI heated phase. The n = 2 perturbation field created by the EFCCs has a slow ramp-up for 2 s, and a flat top for 1 s which is a factor of ~4 longer than the plasma energy confinement time. As soon as the EFCC coil current, I_{EFCC}, reached a critical value of 44 kAt the ELM frequency started to increase. Further increase of the I_{EFCC}, the type-I ELMs with frequency of ~ 45 Hz was replaced by high frequency (few hundreds Hz) small ELMs as seen in Fig. 3 b) and c). There is no drop in the core electron density (even increasing slightly during the EFCC flat top phase) and temperature during the application of the n = 2 field even with I_{EFCC} up to 88 kAt. In addition, the influence of the n = 2 field on the edge pedestal can be neglected. The H-factor (H98y) in this high collisionality target plasma is 0.65 only, and it is weakly influenced during application of n = 2 fields.

During the normal type-I ELM H-mode phase, the maximal surface temperature (T_{max}) on the outer divertor plate was overall increasing and associated with large periodical variation due to the type-I ELMs as seen in Fig. 2. However, during an application of the n = 2 field, T_{max} was saturated and has only small variation in few degrees due to the small mitigated ELMs. Splitting of the outer strike point has been observed during the suppression of the type-I ELMs as seen in Fig. 3 a).

References:

[1] T. Evans *et al.* Nature Phys. 2, 419 (2006).
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[3] Y. Liang *et al.* Phys. Rev. Lett. 98 265004 (2007).

Topic: EX-S

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Recently, strong mitigation of Type-I Edge Localized Modes (ELMs) has been observed with application of the *n* = 2 field in high collisionality (ν^*_e=2.0) H-mode plasma on JET tokamak with ITER-like wall. In this experiment, the EFCC power supply system has been enhanced with a coil current up to 88kAt (twice than before). With an *n* = 2 field, the large type-I ELMs with frequency of ~ 45 Hz was replaced by the high frequency (few hundreds Hz) small ELMs. No density pump-out was observed during an application of the *n* = 2 field. The influence of the *n* = 2 field on the core and the pedestal electron pressure profiles is within the error bar and it can be neglected.

During the normal type-I ELM H-mode phase, the maximal surface temperature (T_{max}) on the outer divertor plate was overall increasing and associated with large periodical variation due to the type-I ELMs. However, during an application of the *n* = 2 field, T_{max} was saturated and has only small variation in few degrees due to the small mitigated ELMs. Splitting of the outer strike point has been observed during the strong mitigation of the type-I ELMs.