Divertor heat and particle flux profile modification during 3-D field application in NSTX

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The application of small, 3-D magnetic field perturbations produced by internal or external coils has been found to have significant impact on the plasma performance in tokamaks. As the present plan for the International Thermonuclear Experimental Reactor (ITER) relies on the use of non-axisymmetric magnetic perturbation for ELM suppression [1], the effect of these 3-D fields on the heat and particle footprints on the divertor plates is of substantial interest for the divertor protection. Modification of heat and particle flux profiles, *i.e.* the splitting of strike point (SP) to form multiple striations at the target, is induced by intrinsic error fields and this is amplified by the externally applied 3-D magnetic perturbation. When the intrinsic SP splitting occurs, both the heat and particle profiles are broadened and this leads to a higher integral power exhausted from the core. The additional modification of the profiles by the applied 3-D fields causes higher local peak values in the profiles but does not make a significant change either in the separatrix value or in the overall profile width, and thus the integral power stays largely unchanged across the application. The observed SP splitting has been compared with field line simulations for n=1 and n=3 cases and showed good agreement. The inclusion of internal plasma response in the simulation did not affect the result substantially.

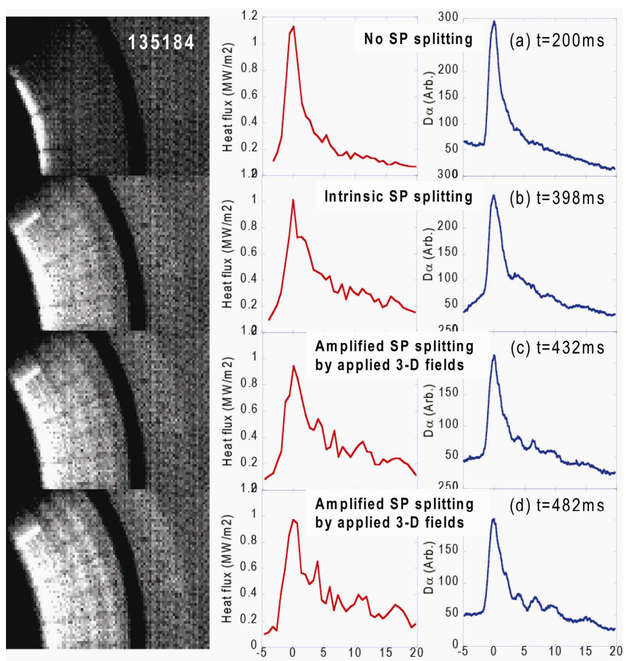

Fig.1 Raw IR images of lower divertor plates from the top of NSTX (left column), measured heat flux (middle), and D_α (right) profiles taken at different time slices for a discharge with n=3 3-D fields applied from t=400ms, showing (a) no strike point splitting at earlier stage, (b) intrinsic strike point splitting 2ms before the 3-D field application, (c) and (d) amplified splitting by the applied 3-D fields. Note that the amplification becomes stronger with time as the 3-D fields penetrate into the plasma

NSTX has 6 coils at the midplane outside the vessel and is capable of generating n=1, 2, and 3 fields [2]. The applied 3-D fields are predicted to generate the so-called ‘lobes’, which is equivalent to the SP splitting. This is observed as

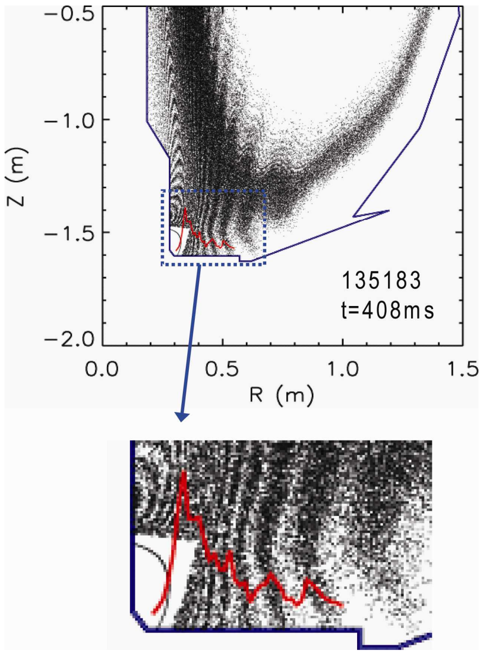

Fig. 2 Magnetic footprints on the divertor target, calculated by a vacuum field line tracing code for the toroidal location of the IR camera at φ=225º, with the measured heat flux profile overlaid (red)

striations in the measured particle, *i.e.* D_α, and heat flux profiles at the divertor plates. It is observed that the SP splitting occurs even before the 3-D field application. This is thought to be due to the intrinsic error fields (EF). Once the SP splitting occurs, the divertor profiles become broader than without the splitting (see Fig. 1 for an n=3 field application case). The location of local peaks in the divertor profiles due to the intrinsic EF (Fig.1 (b)) and applied 3-D fields (Fig.1 (c) and (d)) agrees with each other quite well, indicating that the primary component of the intrinsic EF may be n=3 in this case. It is also found that the peak heat and particle flux values at the separatrix are not much changed by the 3-D field application.

The 'amplified' SP splitting by the applied 3-D fields was simulated by a vacuum field line tracing code for n=1 and n=3 cases. It is found that the location and spacing of the simulated split strike points well agree with the observation (see Fig. 2 for an n=3 case), suggesting that the role of plasma response in the amplification may be minor. The time response of the amplification is as fast as 3-4ms and is consistent with the field line penetration time through the vacuum vessel, τ_{vessel}~3-4ms. The pedestal electron temperature and density profiles show noticeable reduction by the applied 3-D fields but the electron collisionality (ν^*_e) is not found to change substantially. The SP splitting observed in the heat flux profile in NSTX occurred also in quite low pedestal ν^*_e (~0.2-0.3) compared to the DIII-D result, where it is only observed for ν^*_e >0.5 [3, 4].

The radial location of the local maxima and the width of striations increase, stronger than linearly, with increasing distance from the separatrix. The striation widths are larger than the values from the field line tracing, which is consistent with anticipation because the plasma would diffuse radially inside the lobes, while the vacuum field line tracing does not consider the plasma transport. The amplitude of coil current affects the magnitude of the local peaks and valleys in the profile but does not change the spacing and width of the striations.

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References:

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