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 to the plasma boundary has been found to have significant impact on the plasma performance in tokamaks. As the present plan for ITER relies on the use of non-axisymmetric magnetic perturbation for ELM suppression [1], the effect of these 3-D fields on the divertor heat and particle footprints is of substantial interest for the divertor power handling. In National Spherical Torus Experiment (NSTX), the intrinsic error fields are found to induce the splitting of strike point (SP) for heat and particle flux profiles to form multiple striations on the divertor plate surface. This can be further perturbed by the externally applied 3-D magnetic perturbation. When the 'intrinsic' SP splitting occurs, both the heat and particle flux profiles broaden and this leads to a higher total power received by the divertor plates. 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, thus the integral power stays largely unchanged across the application. The observed SP splitting has been compared with a vacuum field line tracing for n=1 and n=3 cases and showed good agreement. The inclusion of plasma response inside the separatrix in the field line tracing did not alter the predicted footprints at the divertor targets substantially.

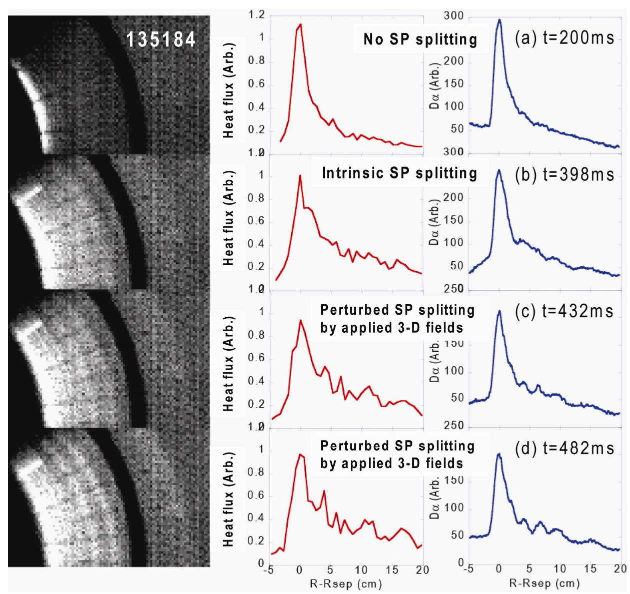

Fig.1 Raw IR images of lower divertor plates from the top of NSTX (left column), measured heat flux (middle), and D_α (right) profiles taken at different time slices for a discharge with n=3 3-D fields applied from t=400ms, showing (a) no strike point splitting at earlier stage, (b) intrinsic strike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

NSTX has 6 coils at the midplane outside the vessel, capable of generating n=1, 2, and 3 fields. A high speed infrared (IR) camera [2] has been used to investigate the effect of the applied 3-D perturbation fields on the heat flux profiles [3]. A modest level of SP splitting is usually observed in NSTX even before the 3-D field application. This is thought to be due to the intrinsic error fields and the divertor profiles broaden once this intrinsic SP splitting occurs (compare row (a) and (b) in Fig. 1). The splitting becomes stronger (see row (c)) when perturbed by the external 3-D fields. Note that this becomes even stronger with time, see row (d), as the 3-D fields penetrate into the plasma. The location of some of the intrinsic striations before the n=3 3-D field application is found to agree with that of the perturbed ones after the application, implying that the 3-D field perturbation augmented the n=3 component of the intrinsic error fields. It is also found that the peak heat and particle flux values at the separatrix are largely unaffected across the 3-D field application.

The 'perturbed' 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 agree well with the observation (see Fig. 2 for an n=3 case), suggesting that the role of internal plasma response in the perturbed SP splitting may be minor. The time response of the perturbation is as fast as the applied field penetration time through the vacuum vessel, τ_{vessel}~3-4ms. The upper pedestal electron temperature and density profiles show quick (<15ms) reduction after the 3-D field application but the electron collisionality (ν^*_e) is not found to change substantially. The SP splitting observed in the heat flux profile in NSTX occurred in pedestal ν^*_e of 1-2. This is comparable to the DIII-D result, where it is only observed for ν^*_e >0.5 [4, 5].

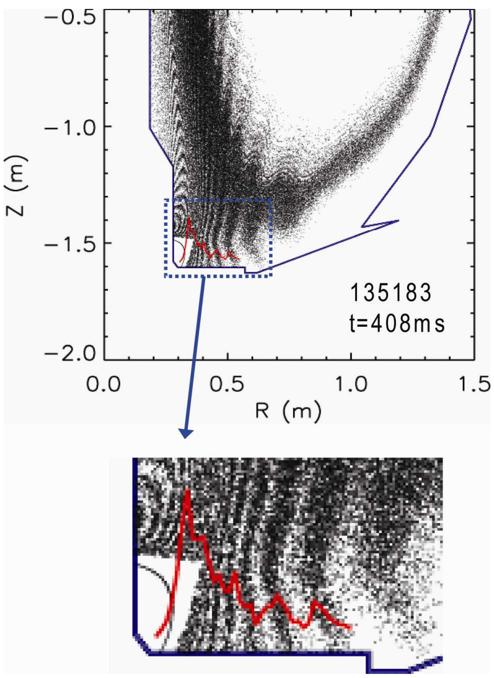

Fig. 2 Magnetic footprints on the divertor target, calculated by a vacuum field line tracing code for the toroidal location of the IR camera at φ=225º, with the measured heat flux profile overlaid (red)

The radial location of the local maxima and the width of striations increase non-linearly, with increasing distance from the separatrix. The striation widths are larger than the values from the field line tracing, consistent with the expectation that the plasma diffuses radially inside each of the invariant manifolds created by the strike point splitting. Note that 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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