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Helical plasma-wall interaction in the RFX-mod: effects of high-n mode locking

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The edge of toroidally confined plasmas can be characterized by the presence of magnetic perturbations (MP) with helicity m/n, with m and n the poloidal and toroidal mode numbers, respectively. In the Reversed Field Pinch (RFP) RFX-mod device (R=2m, a=0.46m), in high-current discharges (Ip>1MA, n/nG<0.3), an almost monochromatic magnetic spectrum spontaneously develops, with m/n=1/7 the dominant mode rotating at a toroidal frequency of ~20Hz. This mode produces a helical equilibrium called quasi-single helicity (QSH). In this new equilibrium, which stands apart from the standard, chaotic RFP state, also the shape of the edge plasma is influenced, with a helical 1/7 plasma wall interaction (PWI). Were the QSH perfectly monochromatic, the edge would show a helical scrape-off layer (SOL) with good confinement properties, as shown in previous works on RFX. Unfortunately, the QSH is disturbed by the presence of high toroidal harmonics with 7 < n < 20 ("secondary modes"). These secondary modes, with amplitude one order of magnitude smaller than the dominant n=7 one, interact each other with a constructive interference, called mode or phase locking: the result is a local radial magnetic deformation ⊠sec that can be comparable to the dominant one, ⊠1/7, due to the 1/7 mode. From the point of view of particle transport, the presence of the phase locking translates in a localized decrease ("hole") in the helical pattern of the connection length to the wall: Lcw. This happens because magnetic field lines, in the vicinity of the locking, are deformed in large poloidal lobes (homoclinic tangles) hitting the plasma-facing components (PFCs), a mechanism similar to the toroidal "fingers"observed in tokamak divertors during RMP application.
A smoother magnetic boundary is expected in the upgraded RFX-mod, where the magnetic deformation decreases by a factor 2-3. Initial estimates show that the local "hole"of Lcw should be strongly reduced by halving the secondary mode amplitude: this is a promising perspective for the RFP helical state performance.

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