

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 ($R=2\text{m}$, $a=0.46\text{m}$), in high-current discharges ($I_p > 1\text{MA}$, $n/n_G < 0.3$), an almost monochromatic magnetic spectrum spontaneously develops, with $m/n=1/7$ the dominant mode rotating at a toroidal frequency of $\sim 20\text{Hz}$. 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 δ_{sec} that can be comparable to the dominant one, $\delta_{1/7}$, 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: L_{cw} . 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 L_{cw} 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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