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Improvement of the magnetic configuration in the RFP through successive bifurcations

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An ohmic RFP must have a helical deformation, which according to MHD simulations may be of either of two types connected through a bifurcation: stationary with a single helicity (SH) or fluctuating in time with a multiple helicity. Experiments in RFX-mod, the largest RFP, show that the plasma reaches Quasi-SH (QSH) states that come closer to SH when the last closed flux surface is made more toroidally symmetric, and by increasing plasma current. The SH configuration corresponds to a helical equilibrium, like the stellarator, but it is ruled by magnetic self-organization. In QSH, magnetic chaos partially degrades ideal SH. QSH may be of either of two types connected through a saddle-node bifurcation: with or without an island. Resilience of QSH states to chaos increases when the magnetic island is suppressed. We report the experimental observation of separatrix suppression in a QSH state, with the improvement of the electron temperature profile and of core confinement. RFX-mod has been coming steadily closer to this state by improving the magnetic boundary through feedback control of MHD modes, and by increasing the current up to the present record value of 1.6 MA. The spontaneous occurrence of this state, dubbed Single Helical Axis (SHAx), is observed at plasma current $I > 1$ MA if the ratio between the amplitude of the dominant and of the secondary modes exceeds a threshold. The thermal helical structure, that covers up to 30 % of the volume, reaches temperatures in 1 keV range. Steep T_e gradients build in the core, with values of $R/L_{Te} \sim 20-30$, comparable to those of tokamak electron transport barriers. SHAx states provide the best RFX-mod electron temperature and confinement. Simulations of test particle transport confirm the improvement. This result paves the way for further improvements, towards a RFP with confinement suitable for a reactor.

¹in collaboration with RFX-mod team