Single helicity: a new paradigm for the reversed field pinch

The reversed field pinch (RFP) is a configuration for magnetic confinement akin to the tokamak, but its toroidal field has an amplitude comparable to the poloidal one, and reverses in the outer region. Recent progress in experiments and theory open an exciting path beyond the standard paradigm that a bath of magnetic turbulence is intrinsic to the RFP. In RFX, the largest present RFP experiment located in Italy, the existence of plasma states with a hot helical core has been proven by soft X-ray tomography. Such states have been seen transiently in several RFP's, but also permanently in discharges in RFX. This last fact makes these states germane to the stationary single helicity (SH) states displayed by three dimensional viscoresistive MHD simulations. These simulations also display multiple helicity (MH) states whose features, in particular magnetic chaos, are analogous to the traditional turbulent state of RFP plasmas. The numerical MH states bifurcate to SH ones when dissipation is increased. The SH states correspond to an integrable magnetic field with good flux surfaces, a feature favourable to good confinement. A natural chaos healing mechanism makes them resilient to chaotic perturbations when fully reconnected. SH states are not Taylor states, but they may be viewed as the nonlinear state of a resistive kink mode stabilised by the toroidal field reversal. A low aspect ratio looks promising for obtaining SH states. The boundary conditions imply the existence of helical boundary currents. These currents cannot properly flow in the shells of present RFP's unless a good correction of the radial MH error field is performed. This suggests an evolution of the RFP into a forced SH RFP which still produces most of the confining magnetic field by plasma currents, and which is intermediate between the tokamak (because of the toroidal current) and the stellarator (because of helical external windings).
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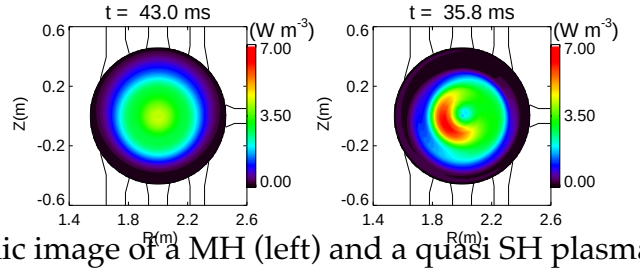

Soft X-ray tomographic image of a MH (left) and a quasi SH plasma in RFX