Transition to a helical core equilibrium in a toroidal plasma

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The reversed-field pinch (RFP) equilibrium, like the tokamak [1], has been shown computationally to bifurcate into an alternate equilibrium that has a three-dimensional (3D) helical core with closed flux surfaces that are thought to provide superior plasma performance [2]. In the normal state, multiple tearing modes with similar amplitude appear as a result of current-driven instability and nonlinear coupling, creating a stochastic magnetic field in most of the plasma volume that degrades confinement. The closest experimental analog of the theoretically predicted bifurcated helical state occurs when one mode spontaneously grows large, obtaining an amplitude an order-of-magnitude bigger than the secondary modes. Under these conditions, the axisymmetric magnetic equilibrium evolves into a single helical axis where the bulk current merges with the current in the *O*-point of the dominant mode forming helical flux surfaces in the core region. The first direct measurements of the internal magnetic field structure and the temporal evolution associated with the transition to a helical equilibrium in the core of a magnetically-confined toroidal plasma are reported. Non-perturbing measurements are accomplished using a combined fast Faraday rotation diagnostic and interferometer that allows simultaneous detection of both density and the magnetic field. Evidence for symmetry breaking is seen in the line-integrated density measurements and their reconstructions to obtain the local density distribution. Polarimetric measurements of the Faraday rotation profile identify a non-axisymmetric structure and resolve the transition to the 3D helical state. The non-axisymmetric geometry is consistent with results from a 3D equilibrium reconstruction. Concurrent with this transition to a core 3D helical equilibrium is an improvement in energy and particle confinement.

[1] W. A. Cooper *et al.,* Phys. Rev. Lett. **105**, 035003 (2010)

[2] J. M. Finn *et al.,* Phys. Fluids B **4**, 1262 (1992)