Spinning A Fusion Plasma Using Static Magnetic Fields

First observation of plasma acceleration driven by the application of static non-axisymmetric magnetic fields, with resulting improvement in the global energy confinement time.

Toroidal rotation benefits tokamak plasmas by flow shear stabilization of turbulence and suppression of macroscopic plasma instabilities. However, a self-heated fusion reactor plasma will have little or no toroidal momentum injection. On the other hand, toroidal momentum sinks will exist in a burning plasma, including torques from unavoidable magnetic non-axisymmetries (field errors).

Although the braking effect of static magnetic field asymmetries is well known, recent theory [A.J. Cole, C.C. Hegna, J.D. Callen, Phys. Rev. Lett. 99, 065001 (2007)] predicts that a particular type of magnetic asymmetries can lead instead to an *increase* in rotation toward a "neoclassical offset" rate. Recent experiments at the DIII-D National Fusion Facility in San Diego, by a team of researchers from General Atomics, Princeton Plasma Physics Laboratory, and Columbia University, have provided the first experimental confirmation [A.M. Garofalo et al., to be published in Phys. Rev. Lett.] of this surprising result.

By using DIII-D's capability to vary the toroidal momentum injection relative to the direction of the plasma current (using combinations of beams of neutral deuterium atoms oriented in both directions), the scientists prepared discharges with a variety of plasma rotation conditions. While maintaining constant neutral beam torque, they applied nonresonant magnetic fields of toroidal mode number n=3 using a modular set of non-axisymmetric coils inside the tokamak's vacuum vessel, (Fig. 1). When discharges were prepared with a steady co-rotation (rotating in the same direction as the plasma current), the application of n=3 fields slowed that rotation appreciably, indicating that the nonresonant field torque competes with the torque from the neutral beams. When discharges were prepared with a small steady counter (opposing the plasma current) rotation, the n=3 fields accelerated that counter rotation toward a value in accord with the predictions of Cole, Hegna, and Callen. When discharges were prepared with a steady counter rotation larger than the predicted offset rotation, the n=3 fields slowed the rotation toward the same lower, offset value. The magnitude, direction, and radial profile of the observed offset rotation are consistent with theory. This offset rotation might be expected to improve confinement through rotational shear stabilization, as well as to partially or completely suppress MHD instabilities, including the Resistive Wall Mode, that appear at the very high plasma pressures required for steady-state, high fusion performance operation of ITER or a future power plant.

Work supported by the U.S. Department of Energy under DE-FC02-04ER54698.

Contacts: A.M. Garofalo, General Atomics (858) 455-2123, garofalo@fusion.gat.com
M.R. Wade, General Atomics (858) 455-4165, wade@fusion.gat.com

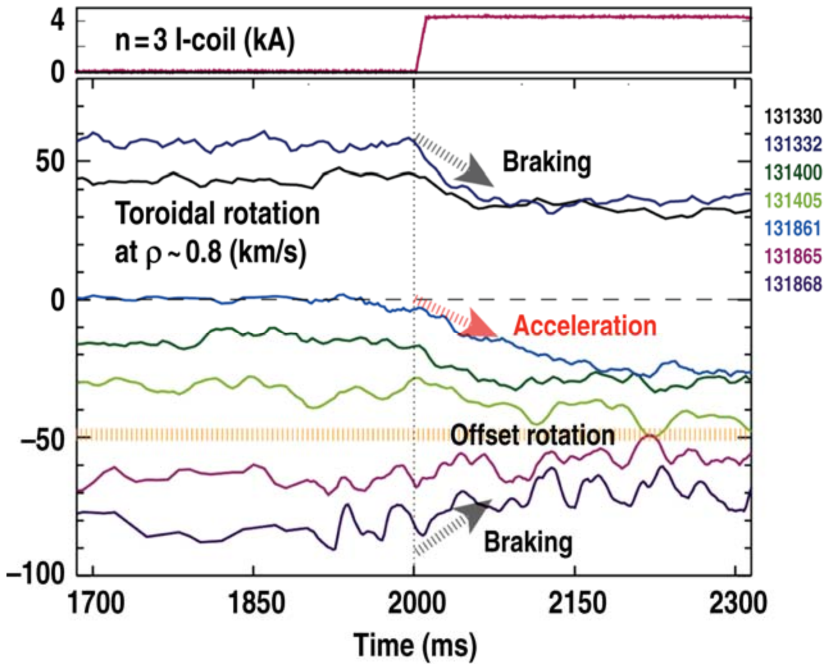

Fig. 1. The effect of a large nonresonant n=3 field applied to plasmas with different initial toroidal rotation depends on the initial rotation and tends to relax the toroidal flow to an "offset" flow in the direction counter to the plasma current (negative rotation in the figure), consistent with neoclassical theory. Shown are (a) the amplitude of n=3 I-coil current producing the nonresonant magnetic field, and (b) the toroidal rotation evolution measured at a fixed location inside the plasma (near the edge) for discharges with different initial rotation (different color lines).