Using 3D Fields to Control Islands, Aid ECCD-Stabilization and Measure Error-Fields in DIII-D*

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3D static or rotating magnetic fields were applied in the DIII-D tokamak to control the rotation and toroidal phase of magnetic islands. This aided the stabilization of “Locked Modes” (LMs) by modulated or continuous Electron Cyclotron Current Drive (ECCD) and permitted measuring intrinsic Error Fields (EFs) through analyzing the non-uniform rotation of islands subject to uniformly rotating applied perturbations.

In a first set of experiments, static perturbations forced the rotating precursor of a LM to directly lock in a special position. In that position, the island O-point was accessible to localized, continuous ECCD that rapidly and completely stabilized it and avoided a disruption. ECCD was more efficient than simple EC heating in the O-point, and ECCD in the X-point was destabilizing, as expected. LM suppression permitted recovery of high beta and high confinement, and no loss of H-mode. Complete LM stabilization was observed in slowly rotating plasmas, for balanced neutral beam injection (NBI). For unbalanced NBI, instead, the LM was often unlocked and accelerated by the NBI torque before being completely suppressed by the ECCD.

In a second set of experiments, rotating perturbations were used to unlock the island or catch it when still rotating, and sustain its rotation at up to 300 Hz. This was obtained both in feed-forward as well as by a feedback controller originally designed for resistive wall modes. In some discharges the mode amplitude was observed to decrease as the rotation speed increased to above the inverse wall time, as expected. Additionally, ECCD was added to some discharges. The ECCD was modulated synchronously with the driven rotation of the island, and resulted in more rapid stabilization when selectively applied to the island O-point.

In the third set of experiments, we exploited the fact that LMs tend to align to the resultant of resonant intrinsic EFs, applied EF corrections (EFCs) and other applied perturbations, and are also affected by non-resonant and viscous torques. As a result, they rotate non-uniformly in the presence of uniformly rotating perturbations. This non-uniform rotation was used to infer the EFs and optimize the EFCs, in good agreement with existing “compass scan” techniques, but within a single discharge. The method is promising for initial ITER operation, when lack of full auxiliary heating systems makes existing techniques based on rotation or plasma amplification unsuitable.

Electromagnetic torques acting on the island were taken into account for interpreting its toroidal phase. These include torques exerted by the wall, EFs, EFCs, applied perturbations, and other islands. When all effects were considered, the calculated island rotation agreed very well with the measurements. Conversely, when all torques were calculated except one, it was possible to infer that one torque by the difference between calculations and measurements. Finally, synthetic diagnostics were developed that, based on the island size, shape, location and dynamics, predict or reconstruct magnetic signals in very good agreement with the actual signals.

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