Advanced Techniques for Neoclassical Tearing Mode Control by Electron Cyclotron Current Drive in DIII-D*

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Novel techniques have been developed in DIII-D for (1) control of rapidly rotating neoclassical tearing modes (NTMs) and (2) control of NTMs that have locked to a residual error field or the resistive wall. Electron cyclotron current drive (ECCD) has been successful at suppression of NTMs in present tokamaks, but will face new challenges in ITER where NTMs are expected to be more prone to locking. In order to avoid locking, rotating islands must be controlled at small widths that are expected to be narrower than the ECCD deposition. Under these conditions, modulated ECCD is predicted to stabilize more efficiently than continuous current drive. (1) A new technique developed at DIII-D detects the island using oblique electron cyclotron emission with a line of sight equivalent to that of the ECCD. This removes much of the uncertainty in mapping the island structure from the detector to the current drive location. This method was used both to measure the radial alignment between ECCD and the island, and to synchronize the modulation in phase with the island O-point, successfully stabilizing an NTM with mode numbers m/n=3/2. (2) If islands do grow large enough to lock, locked mode control will be necessary for recovery or avoiding disruption in ITER. A potential difficulty associated with locking is that the mode can lock in a position not necessarily accessible to ECCD. To obviate this problem, magnetic perturbations were used for the first time to unlock and reposition a locked m/n=2/1 mode in order to bring it in view of the gyrotron beam, leading to a significant reduction in island size. Once unlocked, magnetic perturbations were also used to sustain and control the mode rotation, which has the potential for easier ECCD modulation.

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