# STABILIZATION OF NEOCLASSICAL TEARING MODES IN TOKAMAKS BY ELECTRON CYCLOTRON CURRENT DRIVE*

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Resistive neoclassical tearing modes (NTMs) will be the principal limit on stability and performance in the ITER standard scenario as the resulting islands break up the magnetic surfaces confining the plasma. Drag from rotating island-induced eddy current in the resistive wall can also slow plasma rotation, produce locking to the wall, and cause loss of the high-confinement H-mode and disruption. NTMs are destabilized by helical perturbations to the pressure-gradient-driven "bootstrap" current. NTMs can be stabilized by applying electron-cyclotron current drive (ECCD) at the island rational surface. Such stabilization and/or preemption is successful in ASDEX Upgrade, DIII-D, and JT-60U, with driven current as little as a few percent of the total plasma current, if the ECCD is kept so narrow that the peak off-axis current density is comparable to the local bootstrap current density. Experiments with either beta ramp-down without ECCD, or at constant beta with ECCD, show that the marginal island width for NTM stabilization is about twice the ion banana width. This is only 1~2 cm in ITER and is much less than the 5~6 cm width 2/1 island that is expected to wall-lock with the low rotation in ITER.[1]

Most experimental work to date uses narrow, cw ECCD; the relatively wide ECCD in ITER may be less effective if it is also cw: the stabilization effect of replacing the "missing" bootstrap current on the island O-point could be nearly cancelled by the destabilization on the X-point if the ECCD is very broad. Modulating the ECCD so that it is absorbed only on the m/n=3/2 rotating island O-point is proving successful in recovering ECCD effectiveness in ASDEX Upgrade when the ECCD is configured for wider deposition.[2]

A recent change in the ECCD launcher scheme in ITER from "remote" to "front" steering has narrowed the expected ECCD considerably. However, the narrower ECCD makes the alignment more challenging. The ECCD is still relatively broad, with current deposition full width half maximum about 5/3 of the marginal island width. This places strict requirements on ECCD alignment, with the cw effectiveness dropping to zero for misalignments as small as 2 cm.

ASDEX Upgrade has used a feed-forward sweep of the toroidal field to get ECCD alignment on the island. JT-60U has used feed-forward sweeps of the launching mirror for the same purpose, followed up by real-time adjustment of the mirror using the electron cyclotron emission diagnostic to locate the island rational surface. In DIII-D, ECCD alignment techniques have proceeded from: (1) adjusting the fixed toroidal field in small steps from shot to shot to maximize the initial island decay rate, to (2) applying "search and suppress" real-time control to find and lock onto optimum alignment (adjusting the field or shifting the plasma major radius in equivalent small steps), to (3) in the absence of an island (and/or after completely suppressing an island) using real-time MHD reconstructions to accurately locate the rational surface for alignment.

The existing experimental alignment results are used to confirm models for the effect of misalignment on the ECCD effectiveness and are then applied to ITER. Tolerances for misalignment will be presented to establish criteria for both the alignment (by moving mirrors) in the presence of an island, and for the accuracy of real-time MHD equilibrium reconstruction in the absence of an island in ITER.

1. R.J. La Haye, et al., Nucl. Fusion **46**, 451 (2006).
2. M. Maraschek, et al., Phys. Rev. Lett. **98**, 025005 (2007).

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