Complete Suppression of the m/n = 2/1 Neoclassical Tearing Mode Using Radially Localized Electron Cyclotron Current Drive on DIII–D and the Requirements for ITER

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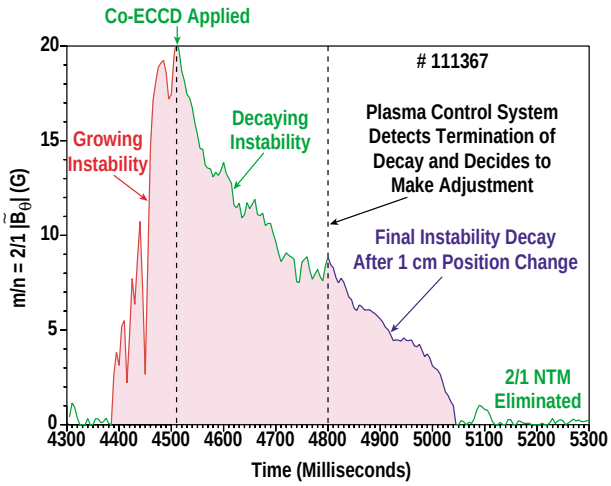
DIII–D experiments demonstrate the first automatic, real-time control of the location of a narrow beam of microwaves to completely suppress and eliminate a growing tearing mode at the q=2 surface. Long wavelength tearing modes such as the m/n = 2/1 instability are particularly deleterious to tokamak operation. Confinement is seriously degraded by the island, plasma rotation can cease (mode-lock) and disruption can occur. The neoclassical tearing mode (NTM) is maintained by a helically-perturbed bootstrap current and can be stabilized by replacing the "missing" bootstrap current in the island O-point by precisely located co-electron cyclotron current drive (ECCD). The DIII–D plasma control system is put into a "search and suppress" mode that makes small radial shifts (in about 1 cm steps) in the ECCD location based on minimizing the Mirnov amplitude.

The suppression of tearing modes in DIII-D was carried out in high performamce, long-pulse discharges with β_N = 2.7, H_{89P} = 2.6, q_{95} = 4.3 and $f_{bs} \approx 0.35$. These discharges are referred to as a hybrid scenario as they have sufficient bootstrap current to significantly reduce the volt-sec consumption but not enough for full noninductive steady state. The hybrid scenario promises to be a robust, long-pulse operating regime for physics and engineering tests on ITER, highlighting the importance of stabilizing the 2/1 NTM.



Applying and adjusting the precise position of co-ECCD stops the growth of a long wavelength tearing mode and then completely eliminates it.

The requirements on the ECCD for complete island suppression in DIII-D are well-modeled by the modified Rutherford equation. The ECCD needs for a prototype hybrid scenario in ITER will be described in reference to: 1) the necessary ratio of peak electron cyclotron current density j_{ec} to bootstrap current density j_{bs} at q = 2, 2) the optimum current drive width, and 3) the total ECCD current I_{ec}. Such requirements are needed as input for the design of an ECCD system for ITER.

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