Advanced Control of Neoclassical Tearing Modes in DIII-D with Real-time Steering of Electron Cyclotron Current Drive

A.S. Welander\textsuperscript{1}, E. Kolemen\textsuperscript{2}, R.J. La Haye\textsuperscript{1}, N.W. Eidietis\textsuperscript{1}, D.A. Humphreys\textsuperscript{1}, J. Lohr\textsuperscript{1}, S. Noraky\textsuperscript{1}, B.G. Penaflor\textsuperscript{1}, R. Prater\textsuperscript{1}, and F. Turco\textsuperscript{3}

\textsuperscript{1}General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA
\textsuperscript{2}Princeton Plasma Physics Laboratory, Princeton, NJ 08543-0451, USA
\textsuperscript{3}Columbia University, New York, NY 10027, USA

New techniques developed on DIII-D suppress neoclassical tearing modes (NTMs) by using steerable mirrors to deposit electron cyclotron current drive (ECCD) on the rational $q$-surface. In a recent advance, the plasma control system can now operate in “catch and subdue” mode by (1) detecting the onset of a growing mode ($m/n=3/2$ or 2/1), (2) deciding to turn on the gyrotron power, (3) moving the mirrors for complete prompt stabilization, and (4) actively tracking island-ECCD alignment to maintain suppression.

Precise alignment can be maintained even when the $q$-surface moves or the EC beam refraction changes. The $q$-surface is tracked by real-time equilibrium reconstructions (that include measurements of the motional Stark effect) and the ECCD position is tracked by real-time beam refraction estimates. In addition three different algorithms can be employed to fine-tune alignment when NTMs occur. The first method adjusts ECCD alignment in steps until the island decays fast enough. The second method sweeps the alignment to find the optimum and then aims the mirrors there. The third method pulses the gyrotrons and uses measurements of electron cyclotron emission to compare where the resulting temperature pulses are located relative to the temperature fluctuation node from a rotating NTM.

Experimental results and future directions in minimizing both the peak and average EC power needed for robust disruption-free control of NTMs will be presented.

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