Control of Neoclassical Tearing Modes in DIII-D


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Real-time Mirror Steering Keeps ECCD Well Aligned With NTM For Efficient Suppression

Electron cyclotron current drive (ECCD)

Neoclassical Tearing Mode (NTM)

Mirror controlled to keep ECCD on NTM resonant q-surface

RF beam

Gyrotron
Mirrors Respond Quickly And Accurately To Commands

Normally mirror angle is within uncertainty of the command

Several layers of safety ensure the mirrors don’t move too far

$Z_q$ is where $q=3/2$ intersects EC resonance
Accurate Alignment Of ECCD Found By Detailed Analysis Of Measurements Combined With Fine-Tuning Algorithm

- q-surface position from equilibrium reconstructions based on external and internal field measurements
- Controlled mirror
- Refraction from estimator that uses interferometer densities

Three options to fine-tune alignment when NTM in plasma and ECCD on:

- Adjust in steps until sufficient suppression
- Sweep to find where suppression maximized
- Analyze electron cyclotron emission to find signatures of rotating NTM and ECCD (ECCD signature created by pulsing gyrotrons)
Flowchart For NTM Control

- Active Tracking
  - Adjust mirrors when beam refraction changes or q-surface moves
  - Analyze magnetics to find NTMs
  - ECCD can be on all the time or only in event of NTM

- NTM?
  - Yes
    - Add ECCD?
      - Yes
        - Gyrotrons ON
          - Fine-tuning algorithm
            - Scan for best alignment with steps or a sweep, or analyze ECE
Preemptive ECCD Promptly Suppresses NTMs

- 3/2 NTMs triggered at 2.5 and 2.8 sec immediately stabilized by ECCD
- 4/3 NTM at 2.8 seconds not stabilized
Turning On ECCD When NTM Detected Can Also Give Rapid Suppression (Called **Catch & Subdue** Method)

- Early detection critical for rapid suppression
- ECCD should be off again after suppression in this scenario but stayed on in this case
- 3/2 NTMs at 2 and 3.75 seconds
When NTM Grows Despite ECCD, Tuning Alignment With The **Target Lock** Algorithm Can Achieve Suppression

- Decision to sweep ECCD at 3.2 seconds
- Upward sweep 3.25–3.65 seconds
- Best suppression found slightly before dip
- Correction applied at 3.65 seconds

![Active Tracking with misalignment](image)

![Graph showing ECCD and 3/2 surface suppression](image)
Present Status And Plans For The NTM Control System

• **Status**
  – Mirror steering is fast, precise actuator for aligning ECCD-NTM
  – Alignment maintained as q-surface and refraction changes
  – Automatic fine-tuning of alignment when needed
  – Option to turn on ECCD when NTM appears (Catch & Subdue)

• **Plans**
  – Control of several modes, e.g. 3/2 & 2/1
  – **Catch & Subdue** to also turn off ECCD after NTM suppressed

See also E. Kolemen U07.00004 Thursday afternoon