NTM Stabilization with ECCD in JT-60U

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Real-Time NTM Stabilization

Real-time NTM stabilization system has been developed.

1. Coarse estimation of mode location
2. Fine tuning using $T_e$ profile
3. EC mirror steering

- Calculation: 10ms
- Mirror scan: $\Delta R_{dep}/\Delta t \sim 10\text{cm/s}$
A 3/2 NTM at high beta ($\beta_N=1.5$, $\beta_p=1.1$) has been completely stabilized with the real-time system.

- $\beta_N$ increased by the stabilization, and even after the EC turn-off
  - Confinement improvement
    - (H$89$: 1.8 $\rightarrow$ 1.9; HH$y2$: 1.0 $\rightarrow$ 1.1)
Perturbation decreases asymmetrically during the stabilization.

- Just after the EC injection,
  - $T_e$ at HFS: decrease
  - $T_e$ at LFS: increase
  - Asymmetry ... future work

- Rapid decrease in island width at 8.3s:
  - Consistent with the modified Rutherford eq.

![Graph showing $\beta_N$, $w$ vs. time, and $(\gamma R/\gamma) d\gamma/dt$ with and without EC injection.]

- $T_e$ map with island width, peak, and center annotations.

- $\beta_N$ vs. time graph with markers indicating $w_{sat}$: ~7.5s and ~8.3s.

- $w$ vs. time graph showing $w$ without and with EC.
Real-time NTM stabilization system has been upgraded and applied to experiment.
- Real-time plasma shape calculation & coarse estimation of mode location were implemented.
- Real-time NTM detection & mirror steering of EC injection were demonstrated.
- Complete stabilization of NTM in finite beta region was obtained.
- Increase in $\beta_N$ and H-factor was achieved.

Stabilization process has been measured in detail.
- Rapid decrease in the island width after the slow decrease is consistent with the modified Rutherford equation.
- Asymmetry in electron temperature perturbation profile is remained as a future work.