Progress On Modulated Broad ECCD Suppression of 2/1 NTMs in DIII-D

Presented by
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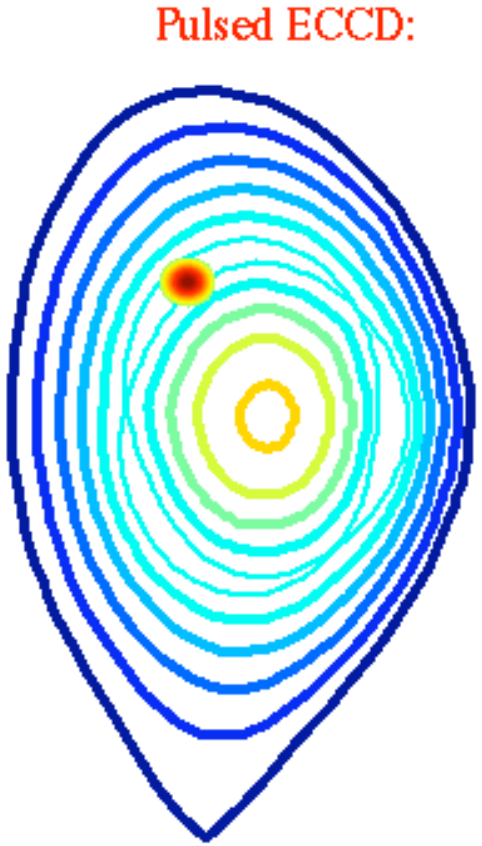
General Atomics



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Why, How, And What Has Happened

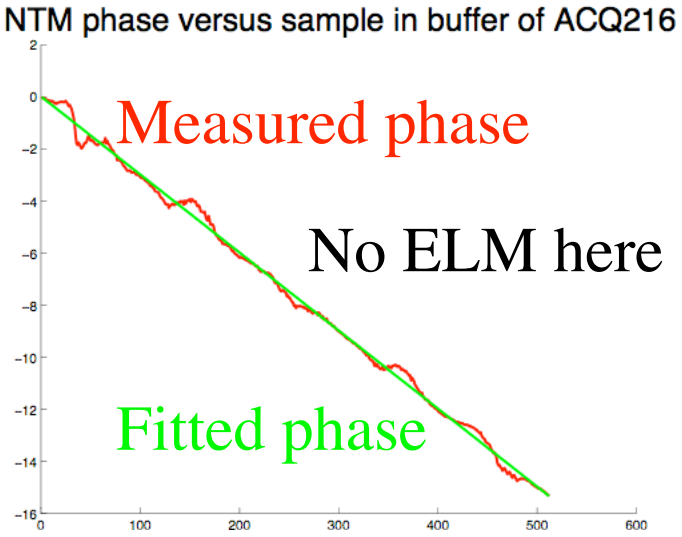
- **Incentive**
  - Quantify how modulation affects suppression rate and perhaps in more detail how the rate depends on toroidal angle between ECCD and O-point
- **Control method**
  - Algorithm for NTM phase detection using Mirnov probes is used to modulate ECCD
- **Results**
  - A few hundred ms of modulated ECCD was applied in piggy back experiment. Some Mirnov signals were not working but modulation nonetheless acceptable.

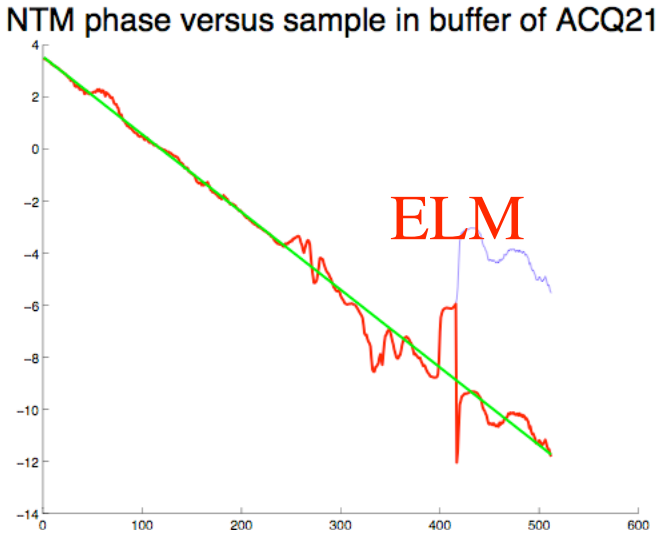
Modulation Based On Real-Time Mirnov Analysis

- Toroidal array of 7 Mirnov probes sampled at 1 MHz
- Data buffered in digitizer, buffer size is 512 samples
- Fourier decomposition made into n = 1, 2, 3 based on the 7 signals for the 512 samples
- Straight line is fit to phase versus time (algorithm for ELM noise discrimination included in this analysis)
- Pulse train sent to gyrotrons based on assumption of constant frequency during time for analysis

Mirnov analysis Discriminates Noise Features

Figures show measured phase in red and fitted phase in green. The graph on the right contains noise feature which is well discriminated by a special algorithm.





Great Precision and Accuracy Can Be Reached

- **Precision** or random error depends mostly on control system latency which is presently a bit high. Rotation is jerky requiring a latency of <100 μs (presently 1 ms). Noise and other MHD (ELMs) can also play a role but a clever algorithm can minimize this influence.

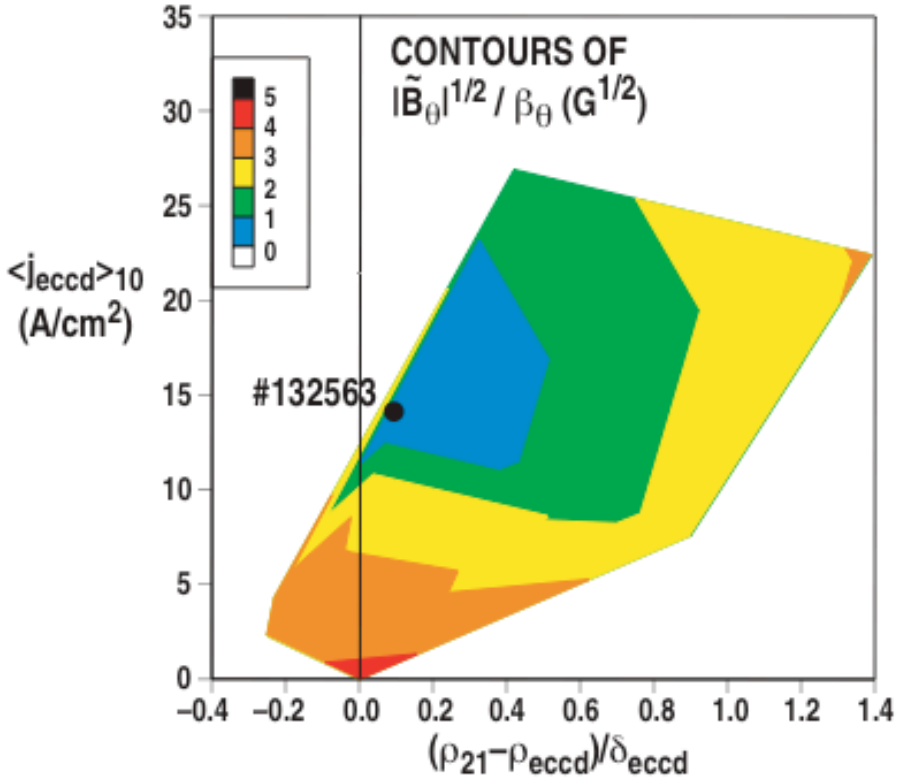
- **Accuracy** or systematic error depends on (mainly poloidal aspect of) phase mapping between ECCD point and Mirnov probes. Mapping done with Toray, EFIT and/or oblique ECE. Other time/phase delays are not issues.

Modulation Did Not Work In First Experiments But cw-ECCD Data Obtained

Alignment by decreasing BT in time approaches $\Delta\rho = 0$ from positive side

★ all cw and modulated 2008 data used

. . . modulated phase is assumed incoherent



#132563 100% STAB

1.84 MW cw

ITER shape

$q_{95} = 4.5$

$\beta_N = 1.86$

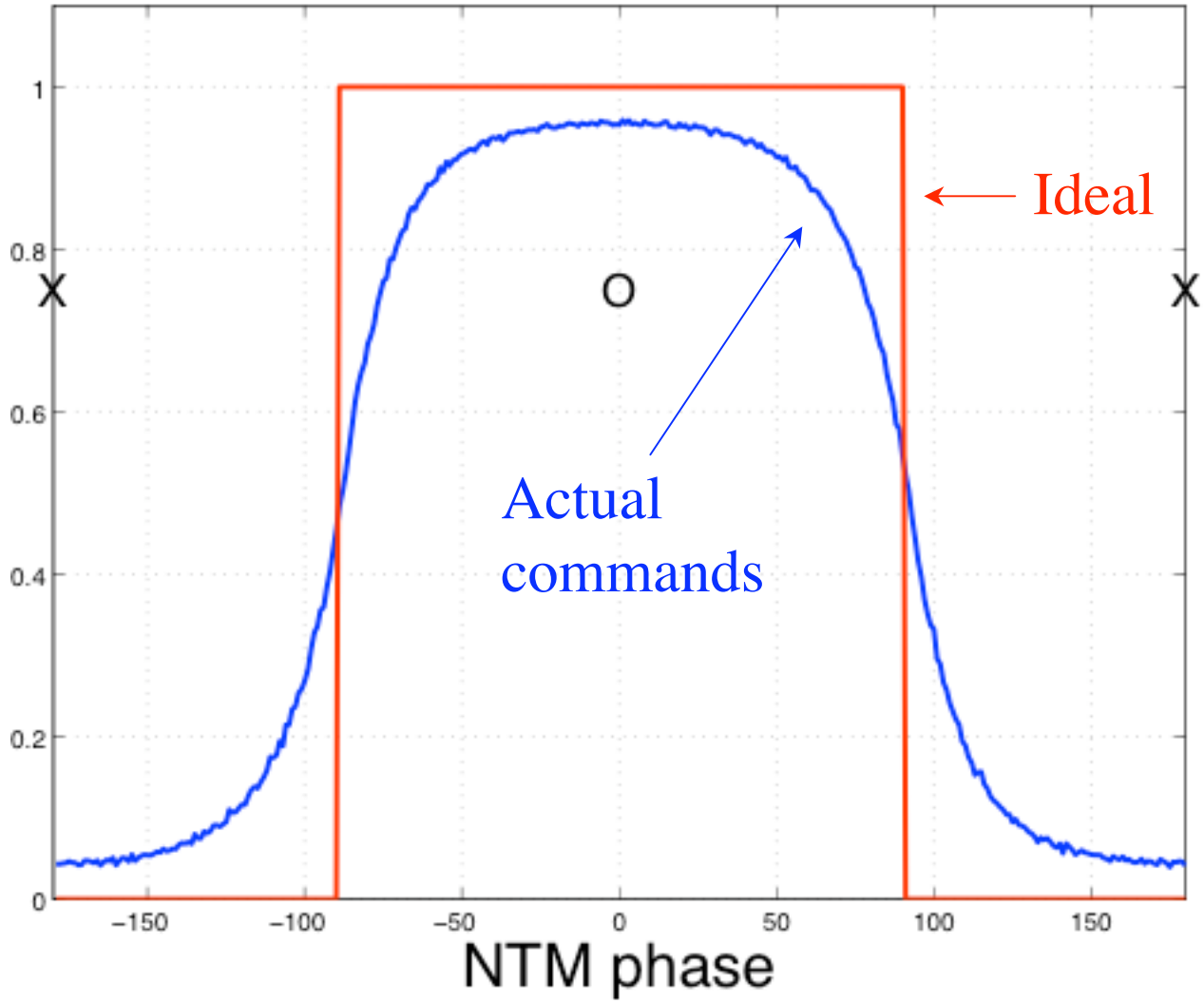
$j_{eccd}/j_{boot} \approx 2.0$

$w_{sat}/\delta_{eccd} \approx 1.9 > 1$

$w_{marg}/\delta_{eccd} \approx 0.7 < 1$

$w_{marg} \approx 1.7\, \varepsilon^{1/2} \rho_{\theta i}$

Control Now Fully Operational With Fairly Coherent Modulation



Graph showing how often the command was correct in a test.

The difference between ideal case in red and actual in blue is almost entirely caused by the control system latency of 1 ms

Summary

- A target plasma has been developed with low enough rotation frequency and a cw-ECCD power scan was acquired.
- Modulation of ECCD using Mirnov signals now fully operational. Only thing left is to get the data.
- Future work is to incorporate oblique ECE in the control system for radial alignment and for phase mapping during modulation.