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Robustness of improved error field suppression in long-pulse discharges

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Jon Menard, PPPL

Advanced Scenarios and Control TSG Group Review

Princeton Plasma Physics Laboratory

March 20, 2008

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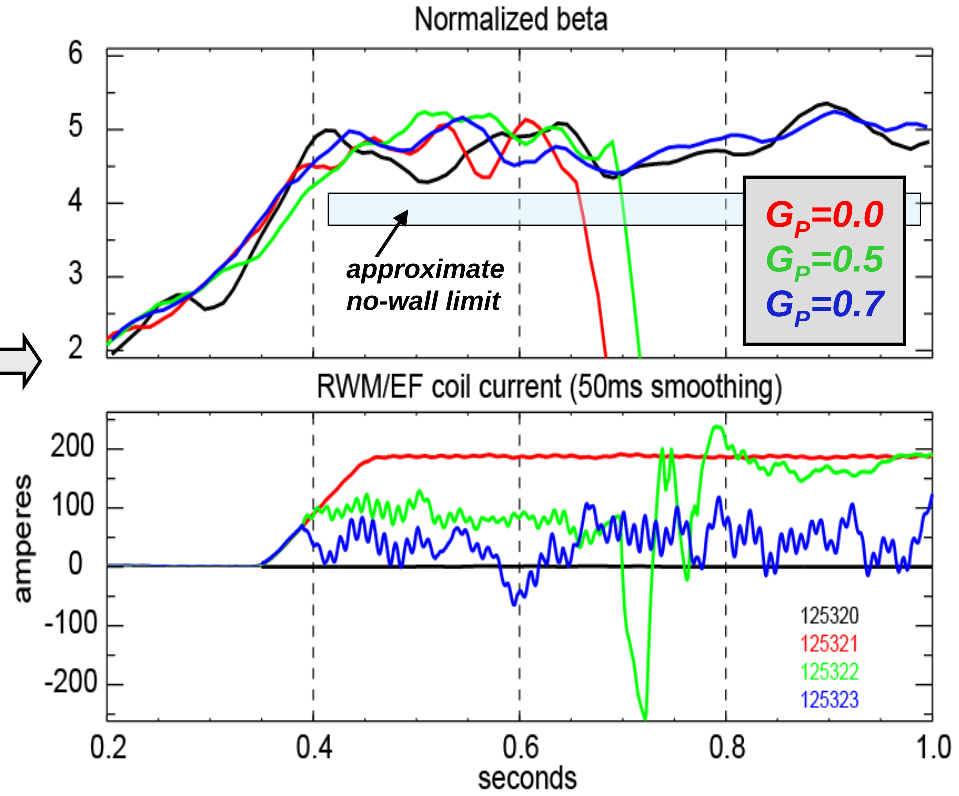
In 2007, using optimized B_P sensors in control system allowed feedback to provide most/all n=1 error field correction at high β

- **Previous n=1 EF correction required a priori estimate of intrinsic EF**
- Additional sensors → detect modes with RWM helicity → increased signal to noise
- Improved detection → higher gain → **EF correction using *only feedback on RFA***

EFC algorithm developed in FY07:

- Use time *with minimal intrinsic EF* and RWM stabilized by rotation
- Intrinsic Ω_ϕ collapse absent in 2007 → **purposely apply n=1 EF to reduce rotation, destabilize RWM**
- Find corrective feedback phase that reduces applied EF currents
- Increase gain until applied EF currents are nearly completely nulled and plasma stability restored

- **Then turn off applied error field (!)**



→ *Use same gain/phase settings to suppress RFA from intrinsic EF **and** any unstable RWMs*

High gain, phase difference δ=270° between measured U/L avg B_P & applied B_R optimal → can we optimize control further?

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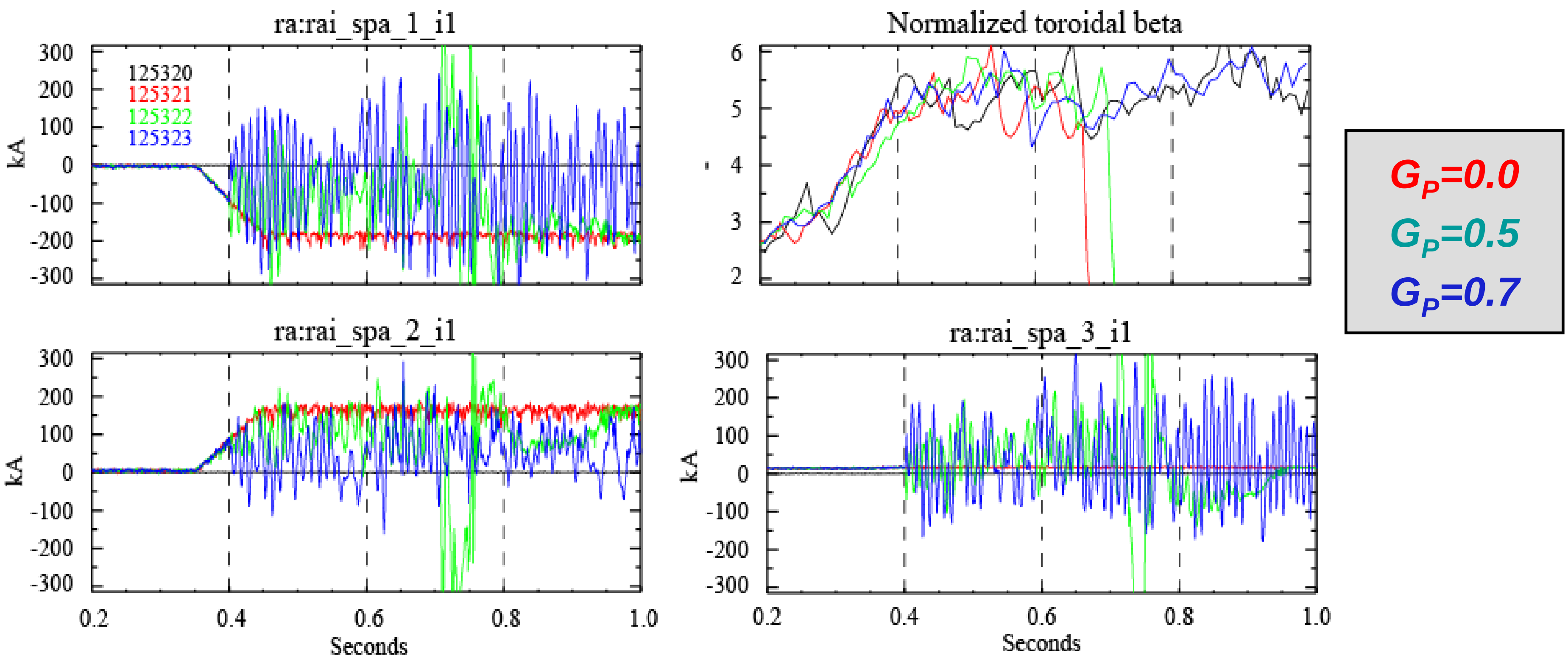
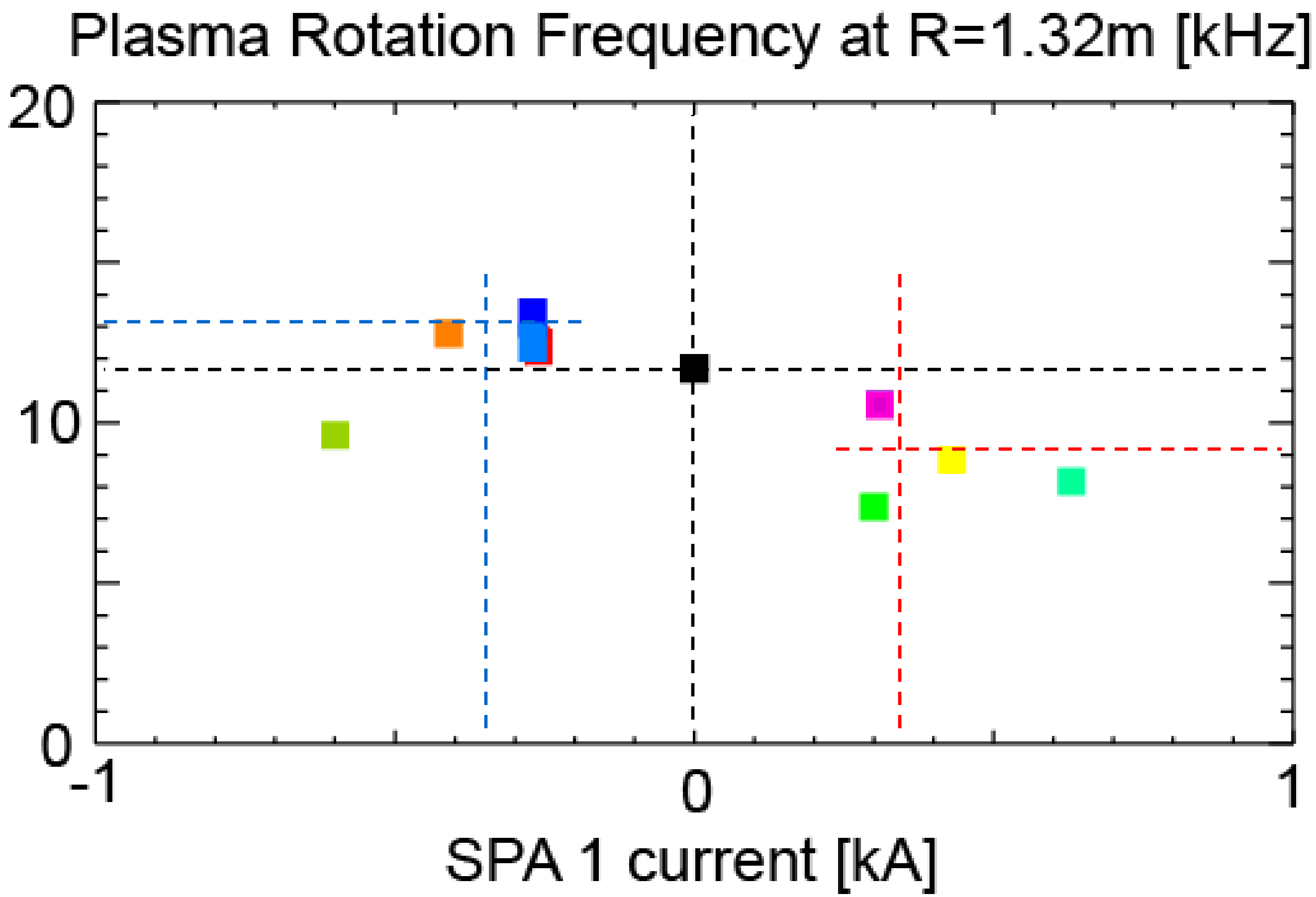


- Higher gain beneficial for improved RFA suppression – G_P >> 1 possible?
  - Goal - Factor of 2 gain increase w/o loss of controller stability
- Significant increase in AC control power evident at higher gain
- More optimal controller? - LPF at SPA request to reduce noise…?

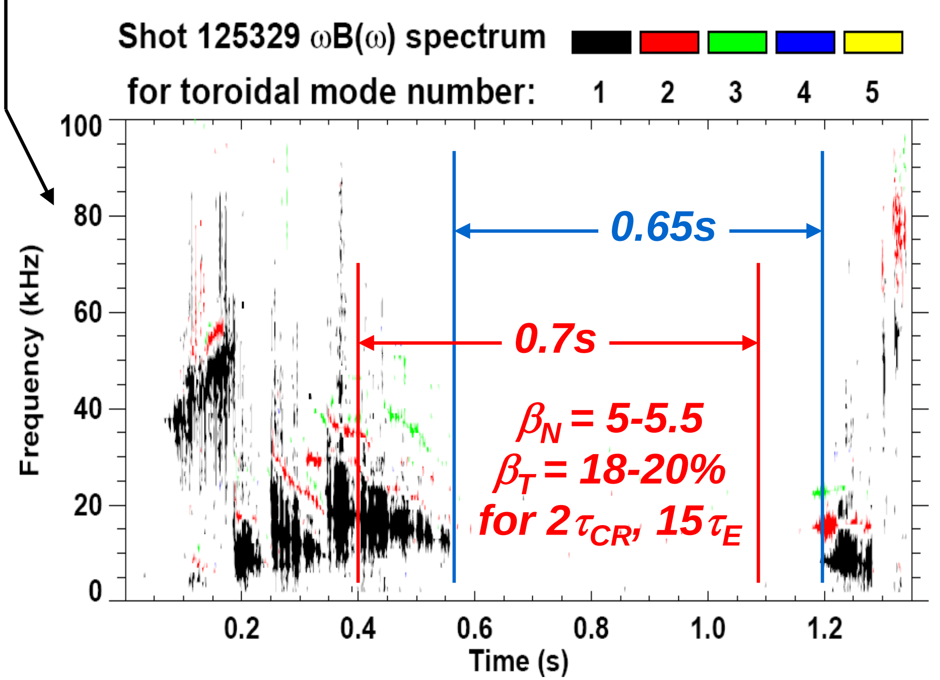
Outboard Ω_ϕ changes by 30-40% with n=3 polarity flip

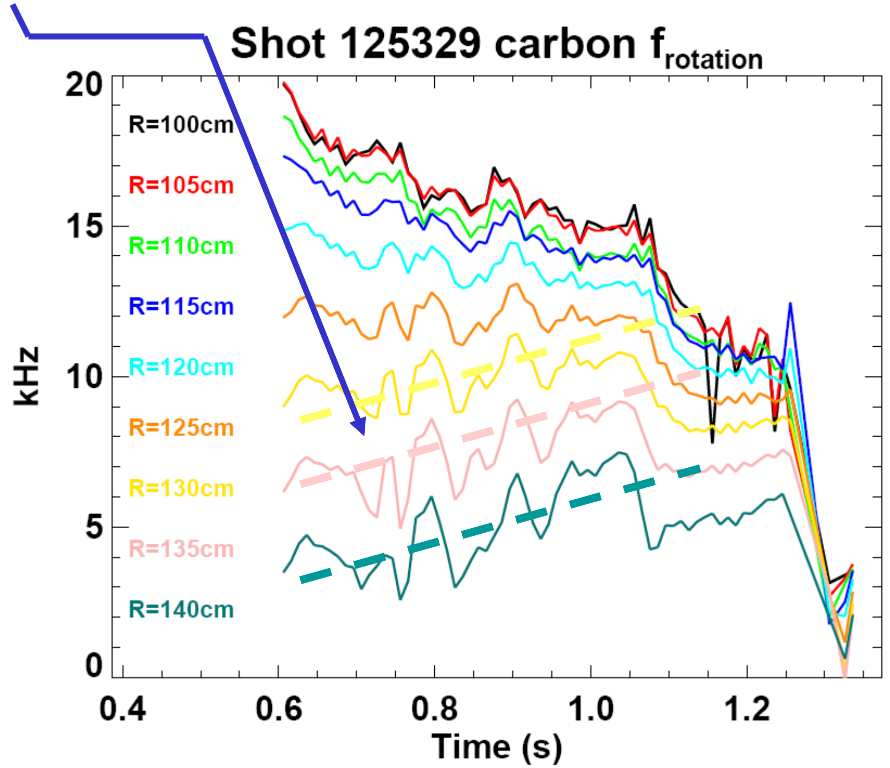
- Optimal n=3 current magnitude = 300-400A
- Coil shape data indicates VF coil (PF5) produces some n=3 EF
  - Need to assess if PF5 EF is consistent with empirical correction below



Simultaneous multiple-n correction improves performance
(Optimized feedback control of n=1 B_P RFA + pre-programmed n=3 correction)

- Record pulse-length at I_P=900kA, with sustained high-β
- Long period free of core low-f MHD activity
- Plasma rotation sustained over same period
  - Core rotation decreases with increasing density (f_{GW} → 0.75), but…
  - R > 1.2m rotation slowly ***increases*** until large ELM at t=1.1s





For reference: $\tau_{CR} \approx 0.3s$, τ_E=40-50ms

Goal: Extend optimal EFC to wider range of scenarios and I_P
Methodology/shot plan:

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Optimize n=1 RFA suppression controller

- Start from 2007 reference, increase RWM control gain until system is unstable to determine highest stable value **(5 shots)**
- After implementation of LPF in RWM control algorithm, with gain at highest stable value, increase LPF time-constant τ_{LPF} from 0 to:
  - 1ms, 3ms, 10ms, 30ms, 100ms (2 shots for each τ_{LPF}) **(10 shots)**
- For τ_{LPF} where AC RMS control power is reduced by factor 2-4, increase gain again and determine highest stable value **(5 shots)**

Determine optimal n=3 EFC gain relative to I_{PF5} and/or I_P

- Scan plasma current and optimize n=3 EFC for each
- 900kA already optimized above → Use 700kA and 1.2MA targets
  - Assume n=3 EFC proportional to I_P → scan gain: x 1, 2, 0.5, 0, -1 **(12 shots)**
- Implement gains in PCS EFC algorithm for all experiments **(2 shots)**