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Flying a fusion plasma straight and level when stabilizing plasma flow is reduced

First stabilization of large-scale instabilities at low plasma flow in high performance, spherically-shaped plasmas.

Just as an airplane needs sufficient airflow over its wings to remain in flight, high performance magnetic fusion plasmas in the National Spherical Torus Experiment (NSTX) have needed sufficient plasma flow through the magnetic field to avoid large-scale instabilities and keep the plasma hot and confined. However, reduced flow speeds are expected in burning plasmas in ITER, and thus techniques to stabilize the large-scale instabilities in the absence of rapid rotation are needed to maintain steady, burning plasma operation in advanced ITER operating conditions. Scientists from Columbia University and the Princeton Plasma Physics Laboratory (PPPL) have recently installed an active stabilization system and have demonstrated plasma stabilization at reduced flow speeds [1] on NSTX, located at PPPL.

NSTX plasmas typically have high flow speeds, which keep the plasmas stable at plasma pressure (beta) levels exceeding stability limits for slowly-rotating, or non-rotating plasmas. A relatively small, steady, and more bumpy magnetic field was applied to the equilibrium magnetic field to reduce the plasma flow [2] to simulate the slower flow speeds in ITER. Like air brakes in an aircraft, this magnetic field slows the flow in controlled manner, allowing for controlled experimental conditions to conduct the active stabilization experiments.

The plasma instability that was actively controlled, a “resistive wall mode” (RWM), had a toroidal mode number, n, of unity. A long-standing question regarding $n = 1$ stabilization is whether or not the $n = 2$ RWM would tap the energy of the system and become unstable. While stable $n = 2$ RWM activity was measured, the actively stabilized plasma did not suffer an unstable $n = 2$ RWM. Variation of feedback stabilization parameters showed $n = 1$ mode excitation or suppression, depending on whether or not the parameters were set favorably. In certain cases, the $n = 1$ mode became unstable by deforming poloidally, an important consideration for stabilization system design. Future experiments will assess the effect of using various sensor combinations on RWM active stabilization performance.

This work will be presented in an invited talk by Dr. S.A. Sabbagh of Columbia University at the APS-DPP meeting in Philadelphia, PA, October 30 to November 3, 2006.*

*Invited paper VI2.00001, "Active Resistive Wall Mode Stabilization in Low Rotation, High Beta NSTX Plasmas"
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References:
[1] S.A. Sabbagh, R.E. Bell, J.E. Menard, et al., *Phys. Rev. Lett.* **97** (2006) 045004.
[2] W. Zhu, S.A. Sabbagh, R.E. Bell, et al., *Phys. Rev. Lett.* **96** (2006) 225002.

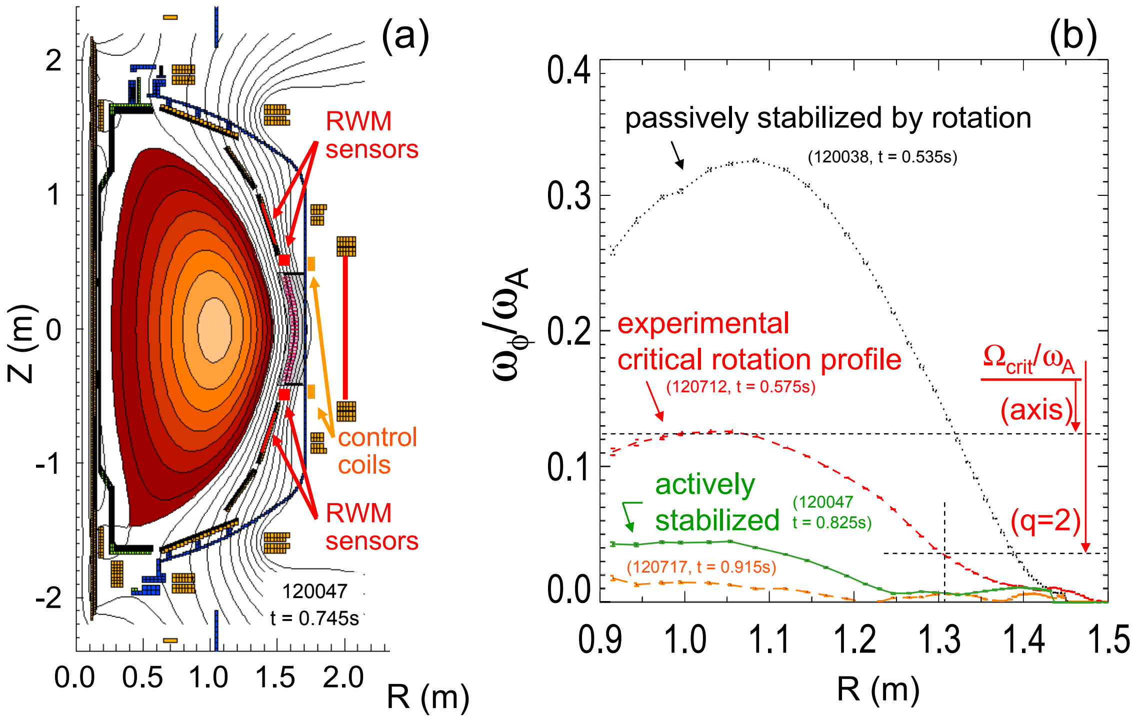

Fig. 1 Actively stabilized plasma equilibrium and rotation profiles. Shown are (a) NSTX cross-section with plasma equilibrium, RWM sensor positions and control coil locations, (b) plasma rotation frequency normalized to Alfven frequency vs. major radius for plasmas that are rotationally stabilized, are at RWM marginal stability (critical rotation, Ω_{crit}), and are actively stabilized.

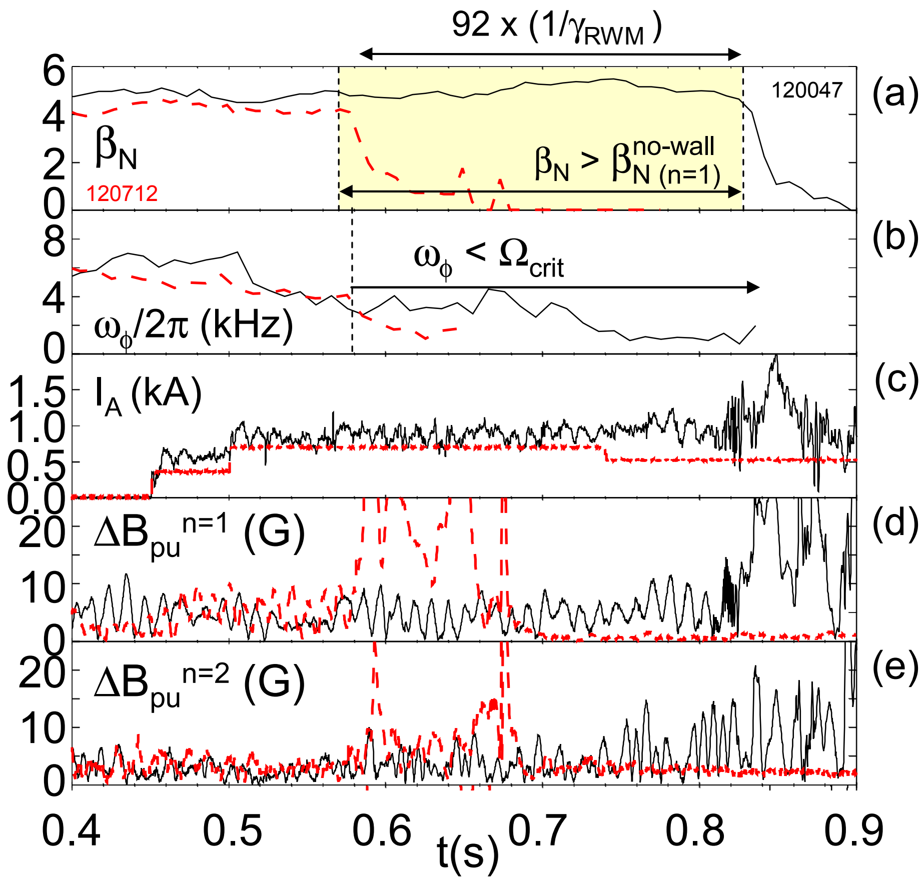

Fig. 2 RWM active feedback stabilization in low rotation plasmas. Solid curves: actively stabilized plasma with rotation ω_ϕ significantly below Ω_{crit}, dashed curves: RWM unstable plasma at $\omega_\phi/\Omega_{crit}$ = 1 with active feedback turned off, dotted curves: (upper two frames) actively stabilized plasma suffering a beta collapse from an internal n = 2 plasma mode. Shown are the evolution of (a) β_N, (b) ω_ϕ near q = 2, (c) current in representative non-axisymmetric control coil, (d) and (e) measured n = 1 and 2 mode amplitude (B_p sensors).