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**First observation of unstable global pressure limiting instability with toroidal mode numbers greater than one.**

S.A. Sabbagh, J.E. Menard, D.A. Gates, A.C. Sontag, et al.

*Experiments on NSTX show the existence of pressure-limiting resistive wall modes (RWMs) with multiple toroidal mode numbers, as the plasma pressure is pushed beyond the stability limit without mode control. This is an important step toward developing successful MHD mode control for application in experiments such as ITER.*

The n > 1 toroidal mode structure of unstable resistive wall modes has been measured for the first time in NSTX experiments. Tokamak plasma studies to date have restricted focus on the stabilization of n = 1 resistive wall modes. The existence of n > 1 unstable modes means that they must be considered in the stabilization techniques applied to the plasma. Understanding the effects of the mode on the plasma and methods of stabilization are important for stable plasma operation at increased beta, including the advanced operational regime of ITER.

The ultra-high beta operation (volume averaged toroidal beta up to 40%) and reduced aspect ratio in NSTX are expected by theory to contribute to destabilization of a broader n spectrum. The passive stabilizing plates and new, non-axisymmetric field coils on the device allow control of the instability, and plasma rotation - which is directly linked to RWM stabilization.

Tokamak plasmas suffering unstable RWMs with n > 1 have been a theoretical concern for a decade. Demonstrating the experimental existence of the mode with n components greater than 1 is a significant milestone in the multi-year global mode stabilization research planned for, and conducted on NSTX. It is an important stepping stone in the development of an effective, active stabilization system to stabilize these modes at the low rotation speeds expected in ITER.

The mode spectrum and dynamics for discharges showing pure RWM mode growth, and mode rotation during growth are shown in Fig 1. Mode growth and associated beta collapse occur in a few wall times, $\tau_w$ (about 5 ms). The $B_p$ sensor array shows nearly simultaneous growth of $n$ = 1-3 mode components in Fig 1a at a peak toroidal beta of 35% with no apparent mode rotation. A plasma displaying mode rotation is shown in Fig 1b. The measured mode rotation frequency of 120 Hz is of order $O(1/\tau_w)$ and in the direction of plasma rotation. The mode rotation significantly slips behind the measured edge plasma rotation frequency of 2 kHz, consistent with expectations of the Fitzpatrick-Aydemir theory [Nucl. Fusion **36** (1996) 11].

Time-evolved ideal MHD stability assuming no stabilizing wall for $n$= 1 - 3 modes was computed for these plasmas with DCON using EFIT equilibrium reconstructions. Fig. 1(a,b) shows that just before RWM mode growth, both plasmas are calculated to exceed the computed $n$ = 1 - 3 ideal no-wall beta limit – a necessary (but not necessarily sufficient) condition for RWM instability. Fast camera images support the toroidal asymmetry and macroscopic scale of the mode. Visible light emission (Fig. 2a) from the plasma shown in Fig 1a is compared to the DCON computed perturbed magnetic field normal to the surface in Fig. 2(b-c), combining the $n$ = 1-3 components based on the measurement, but exaggerated by a factor of 10 to more readily show the mode shape. MHD mode calculations, supported by soft X-ray measurements at two toroidal positions, confirmed the broad reach of the mode across the plasma. DCON calculations show the mode to be ballooning - being significantly larger on the outboard portion of the plasma.

The physics of RWM stabilization, damping of stabilizing plasma rotation, amplification or phase shifting of device error fields by stable RWMs all depend on the toroidal mode spectrum. The importance of n > 1 modes shows that the NSTX plan to investigate n > 1 phenomena should continue to be carried out. As an example, at present, 2005 data is being analyzed to determine the effects of n > 1 on plasma rotation damping. For the future, the impact of n > 1 instabilities will be factored into the implementation of stabilization mechanisms for this instability.

S. A. Sabbagh (sabbagh@pppl.gov), J.E. Menard (jmenard@pppl.gov), D.A. Gates (dgates@pppl.gov), A.C. Sontag (asontag@pppl.gov). Progress in this area will be presented in several NSTX papers at the upcoming 2005 Meeting of APS DPP.

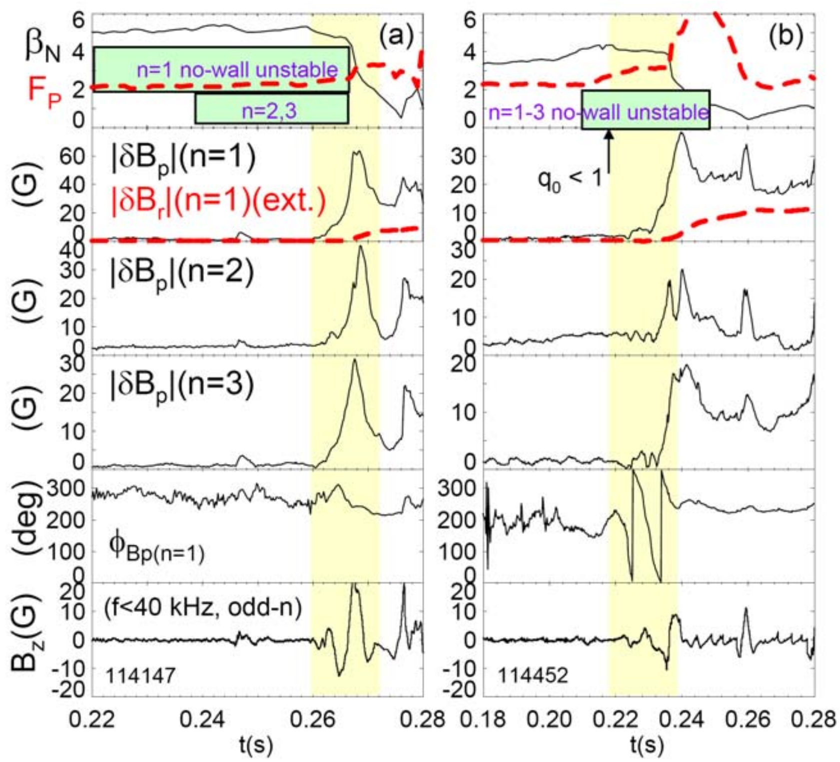


Figure 1. RWM toroidal mode spectrum and dynamics for (a) pure growth and (b) mode rotation during growth. The evolution of $\beta_N$, pressure peaking factor, $F_p$ (dashed line), amplitude of n = 1-3 components of mode-generated $B_p$ (internal to vacuum vessel), n=1 $B_r$ (external to vacuum vessel; dashed line), phase of n = 1 mode-generated $B_p$, and integrated pickup loop data measuring the vertical field, $B_z$, for odd-n MHD modes are shown. The computed ideal MHD no-wall stability for n = 1-3 is also shown.

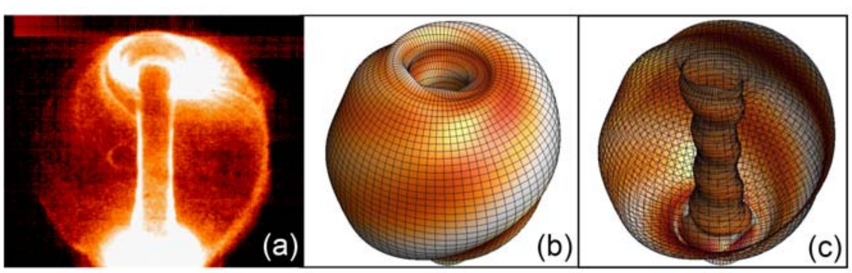


Figure 2. Visible light emission (a) and DCON computed normal perturbed field (b,c) for the unstable RWM with toroidal mode number n = 1-3 shown in Figure 1 (discharge 114147) at t = 0.268s.