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Active and Passive Experiments to Control the Helical Boundary of Wall-Stabilized Tokamak Plasma

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We report high-resolution detection of the time-evolving, three-dimensional (3D) magnetic structure of wall-stabilized tokamak discharges in the HBT-EP device[1]. The time-evolution of unstable and saturated wall-stabilized external kink modes are studied in detail with and without applying magnetic perturbations with non-axisymmetric control coils[2,3]. Naturally occurring external kinks are composed of independent helical modes that are seen to modulate each other in time[4]. For limited discharges produced with a rapid plasma current ramp, strong multimode kink behavior is excited whenever modes resonate with the edge safety factor, $q(a)$, $m/n = 3/1$ and $6/2$. In contrast, when the plasma boundary is diverted, we show for the first time that kink mode dynamics becomes dominated by a single mode in agreement with expectations from ideal MHD[1]. We observed the dynamic, multimode structure of plasmas with a distributed array of more than 200 magnetic sensors[5], with high-speed videography of the plasma-wall interactions, and with soft x-ray detectors. Naturally occurring external kinks and resistive wall modes (RWM) are excited with plasma current ramps, and we find the kink mode amplitude and dynamics depends strongly on the position of the adjustable wall and on the application of magnetic feedback[6]. Additionally, experiments are underway with a newly installed adjustable ferritic wall[1] that will enable systematic investigations of multimode kink dynamics as the separation between the ferritic wall and the plasma changes, and will also allow first tests of active control of the ferritic resistive wall mode (FRWM) using high-speed, multiple-input, multiple-output control[7]. Initial experiments with rapidly rotating external kink modes show wall stabilization in the presence of a close ferromagnetic wall ($r/a \sim 1.07$). Future experiments with slower plasma rotation are expected to see reduced wall stabilization due to ferritic effects.

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