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Fast Imaging of Transients and Coherent MHD Modes in DIII-D[1]

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Fast framing cameras and new signal processing techniques yield images of plasma instabilities in DIII-D with unprecedented detail, including the first visible-light images of neoclassical tearing modes (NTMs). These images of both transient and coherent MHD activity are providing new understanding of the physical processes and new opportunities for comparison to theory. During edge-localized modes (ELMs), rotating filaments following helical magnetic field lines with effective toroidal mode number n ranging from <10 to 35 are rapidly ejected with radial velocity ∼500 m/s into the region outside the separatrix. Visible images of the midplane region show that multiple ejected filaments interact with the outer wall in rapid succession during a single ELM. In high-density plasmas, the outer midplane ELM signal always precedes the divertor ELM signal, which is consistent with the model of a coupled peeling-ballooning instability driving ELMs. In lower density plasmas, however, the midplane and divertor ELM signals appear simultaneously, showing qualitatively different ELM behavior. The fast camera is used in separate studies to record rotating $m/n = 2/1$ NTMs using visible bremsstrahlung emission. High-resolution 2D images of the mode amplitude and phase are obtained by Fourier filtering each pixel's time series at the mode frequency. Inside the $q = 2$ surface, the measurements show excellent agreement with NTM modeling, and the magnetic island width is found by comparing to a synthetic camera diagnostic applied to simulations. Additional structure seen in the camera measurements outside the $q = 2$ surface may require nonlinear, multi-mode modeling to explain.

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