DPP13-2013-000734

Abstract for an Invited Paper
for the DPP13 Meeting of
the American Physical Society

Edge Localized Modes (ELMs) in Tokamaks[1]

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Beginning with the first observation of high confinement (H-mode) in a tokamak nearly three decades ago, high performance regimes have been accompanied by sudden and periodic expulsions of magnetic flux, heat and particles. These edge localized modes (ELMs) result when the edge pressure gradient builds to exceed an MHD stability limit, resulting in a complex nonlinear 3D instability with localized flux reconnection and expulsion of plasma filaments much akin to a solar flare. While ELMs have beneficial effects in controlling density and impurity buildup in the core plasma, the sudden release of plasma onto open field lines can result in the deposition of several MJ/m^2 within several hundred microseconds onto plasma facing surfaces, representing one of the great challenges for future burning plasma tokamaks. To understand, predict, and eventually control the evolution of the ELM instability, a wide range of physical processes must be taken into account. While the onset of the ELM is well described by a linear MHD model of pressure and current gradients, the ELM quickly grows nonlinearly with local reconnection of core plasma onto open field lines and rapid radial propagation of plasma filaments. These features lead to an intense plasma-material interaction with a complex pattern of deposition. Nonlinear models are now able to capture key aspects of this complex behavior through simulation in realistic 3D geometry. Promising prospects for controlling the ELM include enhancing transport to arrest the edge pressure buildup, instigating a saturated mode to prevent explosive growth, or triggering modes with more modest amplitude using external perturbations. Thus, this fascinating physics and exciting progress ranges from fundamental science to the challenge in burning plasma devices such as ITER.

[1]Supported by the US Department of Energy under DE-FC02-04ER54698.