The study of Weakly Coherent Modes and Pedestal Relaxation Events during the I-mode regime

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Abstract: This paper investigates key observations and simulations in I-mode regime, particularly focusing on weakly coherent modes (WCM) and pedestal relaxation events (PREs). WCM was successfully determined its poloidal wavenumber range from the conventional reflectometer on EAST tokamak. During the L-mode to I-mode transition, the line-averaged density remained stable, while significant changes were observed in Electron Cyclotron Emission (ECE) signals at the boundary. These changes, characterized by increased differences between edge channels, coincided with the appearance of WCM and a rise in boundary electron temperature. Statistical results showed an inverse relationship between the central frequency of WCM and q95. Simulation results aligned with experimental data, demonstrating that the simulated WCM's central frequency and radial distribution closely correspond to regions with strong electron temperature gradients. Cross-correlation analysis of simulated fluctuations indicated that WCM is likely triggered by electron temperature fluctuations. I-mode occasionally exhibits minor events known as PRE, which transiently elevate heat deposition on divertor targets. These PREs have been observed on ASDEX-U and Alcator C-Mod. BOUT++ simulations, using real experimental equilibrium and profiles, were conducted. Employing peeling and ballooning (P-B) simulations within the three-fields model, stable outcomes distinguished PREs from type-I ELMs. The 6-field nonlinear simulation successfully reproduced I-mode PREs qualitatively and quantitatively, with PRE characteristics, including time scales, WCM frequency, and features of precursor oscillations, all showing excellent agreement with experimental observations. Turbulence and transport analysis revealed that drift-Alfvén Wave (DAW)-driven turbulence is the major trigger of PREs. These findings enhance the understanding of plasma behavior in advanced operating modes, providing insights into the modulation of high-frequency density fluctuations and the mechanisms behind transient events in I-mode plasmas.

Keywords: I-mode, detachment, BOUT++ simulation, WCM, PRE