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Effect of separatrix density on ELM instability in long-pulse H-mode plasmas on EAST

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One critical issue for achieving stationary high-confinement mode (H-mode) operation of the next-step tokamak fusion reactors is to control the transient heat load induced by large-amplitude edge-localized modes (ELMs) without significant degradation of the plasma performance. Although various small/no ELM H-mode regimes have been achieved on present tokamaks, a detailed physics understanding of these regimes is not yet available. Effective and robust control of large-amplitude ELMs still awaits better understanding of the ELM characteristics for extrapolation to future fusion reactors. In this contribution, analysis of ELM instability in minute-scale long-pulse H-mode discharges on EAST and active control of large-amplitude ELMs by changing the strike point location will be presented. It has been suggested that separatrix density plays an important role in ELM instability, which is thought to be helpful to improve our understanding on the ELM instability and facilitate the long-pulse H-mode operation on EAST.

In minute-scale long-pulse H-mode discharges conducted in 2017 campaign on EAST, it has been repetitively observed that the edge fuel recycling level might gradually decrease after the plasma current flattop sustained to a certain time, accomplished by the decrease in separatrix density and subsequent trigger of large-amplitude ELMs, which would induce large transient heat load on the divertor target plates and restrict the high-performance long-pulse operation. Pedestal stability analysis suggests that the decrease in separatrix density leads to an increase in the pedestal density gradient and thus higher pedestal pressure gradient and higher peak current density, which is thought to be the main reason for destabilizing medium-n peeling-ballooning modes (PBMs) and triggering the large-amplitude ELMs. By numerical scan of separatrix density, it has been found that there is a certain range of separatrix density making medium-n PBMs unstable in the pedestal region. When further increasing or decreasing the separatrix density, the medium-n PBMs might become more stable. In addition, ideal ballooning mode would become unstable at the pedestal foot region with a high separatrix density, which is thought to facilitate the achievement of small ELMs. Active control of large-amplitude ELMs by changing the strike point location has been performed with newly developed lower tungsten divertor characterized by a right-angled corner at the outer divertor in the 2021 campaign on EAST. The experimental results show that the separatrix density could be significantly enhanced as well as the scrape-off layer (SOL) density when the strike point moves to the horizontal target plate away from the corner. At the same time, large-amplitude ELMs are successfully mitigated and the plasma energy confinement performance remains unchanged. SOLPS simulation suggests that there is a high ionization source in the SOL region near outer midplane when the strike point is located on the horizontal target plate away from the corner, providing a strong fueling near separatrix and thus significantly raising separatrix density, which facilitates to trigger ballooning instabilities at the pedestal foot region and thus achieve the small ELM regime.

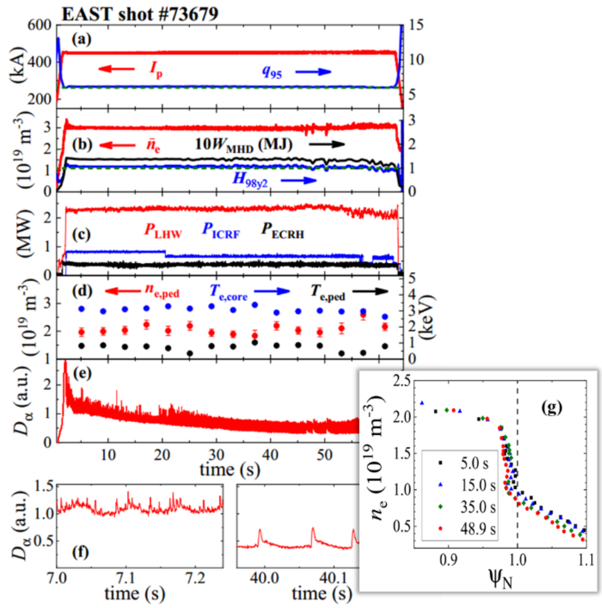

Fig. 1. Large-amplitude ELMs appear in the minute-scale long-pulse H-mode discharges on EAST.

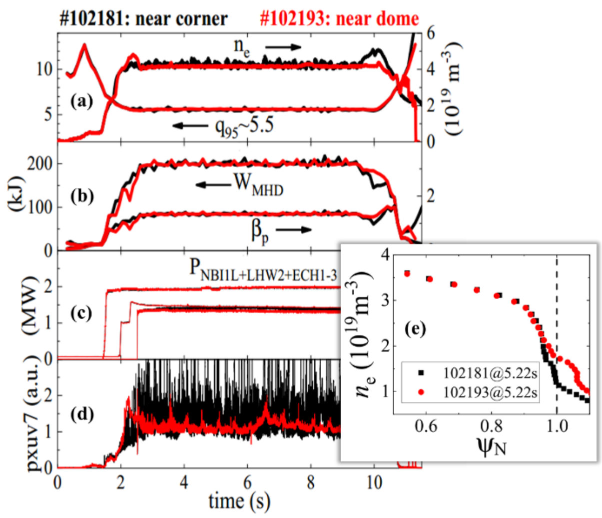

Fig. 2. Active control of large-amplitude ELMs by changing the strike point location has been achieved with newly designed lower tungsten divertor on EAST.