ELM Mitigation Through Magnetic Perturbation generated by Divertor Biasing Current on the HL-2A Tokamak

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Controlling the large heat flux on the divertor target is a critical issue for fusion reactor design. It is however challenging to install and utilize these coils in fusion reactor environment, due to space limitations and high neutron fluxes [1]. Development of a simple, flexible and robust syetm for heat flux control is therefore much desirable and also urgent.

Recently, a divertor biased target system, with 2 × 2 array of plates, has been designed, constructed and installed on the HL-2A tokamak [2]. When the applied voltage U_{BT} increases from ~ 0 V to ~ 60 V, ELM mitigation appears after 20ms. Before that, splitting of the divertor strike points has been observed, in the presence of currents driven by the divertor biased target system and flowing in the scrape-off layer (SOL) region. The ELM induced ion saturation current (Jsat) extends from $Z \simeq -81$ cm to $Z \simeq -86$ cm. When the SOL currents exceed a critical value, the secondary strike point at $Z \simeq -85$ cm appears. Meanwhile, the peak position of Jsat induced by ELMs moves up.

Power spectrum of electron density fluctuations in r=0.34m near the plasma edge measured by BES indicates that the bias-driven magnetic perturbation significantly enhances the power spectrum in the high-frequency (30–50 kHz) range whereas the peaked power spectrum around 40 kHz. The magnetic perturbation generated by the divertor biasing current mitigated the edge localized mode (ELM) in high-confinement mode plasmas through affecting the heat flux pattern on the divertor target plate. Toroidal modeling with the magnetohydrodynamic code shows that the magnitude of the dominant resonant magnetic field perturbation including the plasma response, generated by an 80 A biasing current in SOL, is comparable to that produced by the ELM control coils in HL-2A. The magnetic field topology mapping and the thermal particle orbit tracing, both inside the plasma and in the SOL region, confirm the divertor strike point splitting effect. In coclusion, these results clearly indicates that ELMs can be mitigated by the biasing technique for the case studied here.

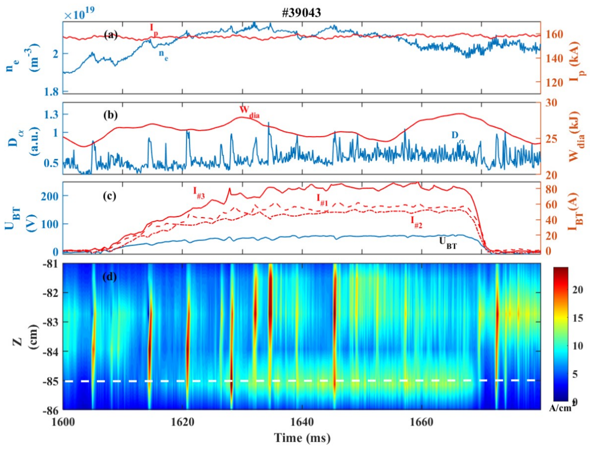

Figure 1. Effects of the biased targets on the ELM behavior and the divertor heat flux in HL-2A H-mode discharge 39043. Shown on left panels are time traces for (a) the electron density ne (in blue) and the toroidal plasma current Ip (in red), (b) intensity of the D_α emissions (in blue) in the outer divertor and the plasma stored energy Wdia (in red), (c) the biasing voltage U_{BT} and the bias-driven SOL current $I_{\#1} - I_{\#3}$, and (d) the spatiotemporal distribution of the ion saturation current density on the outer divertor target.

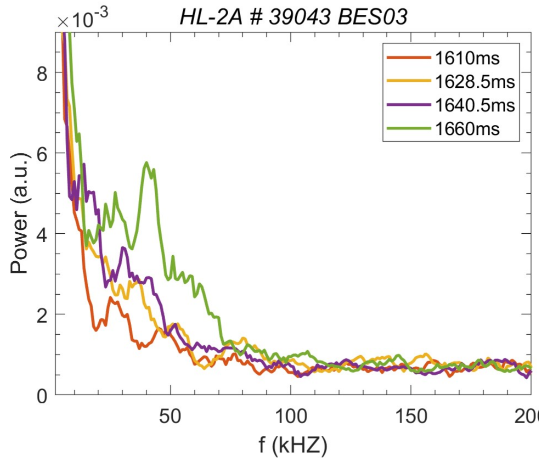

Figure 2. Power spectrum of electron density fluctuations in r = 0.34m from 1610 ms to 1660 ms near the plasma edge measured by BES

References

[1] S. J. Zinkle, Phys. Plasmas 12, 058101 (2005).

[2] B. Cui et al., Fusion Eng. and Des. 173, 112963 (2021).