OVERVIEW OF RECENT EXPERIMENTAL RESULTS ON EAST IN SUPPORT OF ITER NEW RESEARCH PLAN

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Experimental Advanced Superconducting Tokamak (EAST) has made an important advance by achieving a record H-mode plasma over 1066-second with the total injected energy up to 3.05GJ. With this result EAST, has become the first tokamak that can operate with a pulse length in thousand-second scale, with plasma temperatures in the tens of million degrees Celsius and self-driven current, as foreseen for the ITER Q ≥ 5 long-pulse and steady state scenarios. Significant advancements have been made in the development of long-pulse H-mode on EAST in physics and technologies, as illustrated in Figure 1. These include progress in RF H&CD with low momentum input, a reactor-like metal wall, active control of stationery and transient divertor heat flux and particle exhaust, plasma wall interaction and particle balance, magnetic configuration and equilibrium stability in long duration.

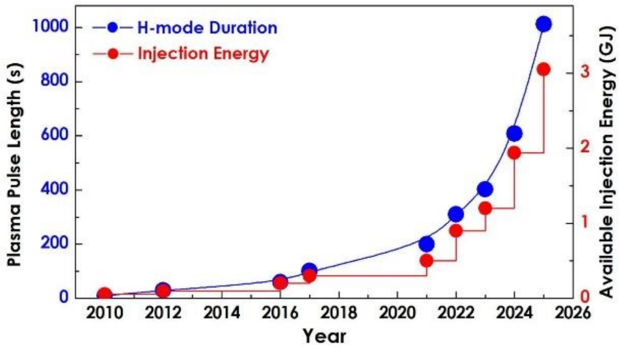

Fig 1 Progress of LPO for H-mode in EAST

A series of solutions to mitigate the challenges faced by long pulse H-mode plasma over 1066s pulse is shown in Figure 2. The configuration is a lower single null, with the strike point on the tungsten divertor. A poloidal beta of β_P = 2.0 was achieved with a total RF power of 3 MW, including P_{LHCD} =1.1 MW and P_{ECRH}=1.9 MW. A flux loop in the high-field side mid-plane was actively controlled to maintain zero loop voltage, ensuring fully non-inductive plasma. A grassy ELM regime was achieved with the outer strike point on the horizontal target, facilitating efficient RF power coupling and reducing W sputtering/erosion. A fully non-inductive CD with electron density at 60% of the Greenwald density, confinement enhancement factor H_{98y2} is greater than

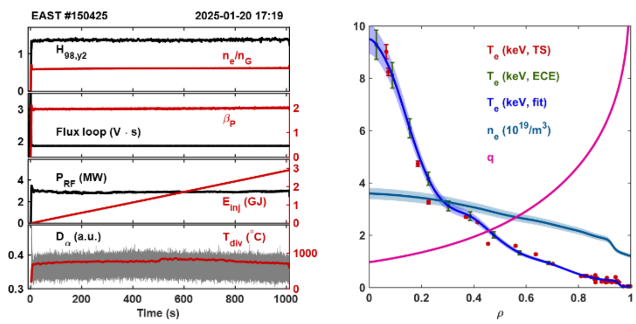

Fig 2 Time histories of EAST long-pulse H-mode discharge (Left), (a) $H_{98,y2}$ and electron density n_e/n_G, (b) Poloidal flux and β_P, (c) RF power and total injected energy, (d) Divertor temperature (IR) and D_α emission. Electron density and temperature, current profile (Right).

1.3 due to the electron temperature internal transport barrier (e-ITB). Transport analysis shows that a high bootstrap current fraction is about ~50%, and it can be stably maintained in high β_p scenario. Low Z materials wall coating and real-time powder injections were applied to improve particle control capability. No W impurity accumulation was observed throughout the discharge.

The synergy effects between on-axis ECRH and LHCD play a crucial role in maintaining high confinement in electron channel. It enables the EAST program to address plasmas with high electron temperature gradient research. The long pulse H-mode discharge with e-ITB is nonlinear self-organization, emerging near the magnetic axis in a positive magnetic shear without momentum injection. This long-term stability provides an opportunity to understand the abnormal energy fluxes driven by turbulence and self-organized evolution. Additionally, off-axis ECRH has been investigated to enhance plasma performance, with turbulence reduction correlates with an evolved weak/negative magnetic shear.

The wall materials evolution has been investigated by plasma-wall integrated modeling. The results reveal that a lithium (Li)-enriched layer can develop underneath the surface of the divertor's tungsten material. This multilayered structure significantly influences local particle recycling processes, thereby affecting the distribution of edge plasma. Experimental results show that the intensity peak of Li I line is situated below the equatorial plane, the decrease in impurity sputtering on limiter, which gradually reduced the impurity inventory on the wall surface.

In support of the R&D requirement for the ITER new research plan, a dedicated set of joint ITER-EAST experiments have been performed on optimization and characterization of boronization, plasma start-up on the tungsten limiter, and the impact of W on the H-mode operational space with and without boron coatings. The related key technical and scientific challenges will be addressed, focusing on core-edge integration in high performance steady-state operation scenarios with metallic wall compatibility. EAST demonstrated a stationary ELM-free H-mode regime sustained for 50-100 seconds with simultaneous feedback-controlled divertor detachment. Effective Type-I ELM suppression has been achieved using n=2 RMP, these results verify a good compatibility of radiative divertor operation by injecting nitrogen (N_2). A lower density limit for accessing ELM suppression using n=4 RMP was also observed.

Furthermore, to improve plasma fusion performance with W-Divertor/W-limiter utilizing B-coating, experiments have been done on EAST with dominant ion heating by combining high power NBI and impurity seeding. It is found that the central ion temperature (Ti) can be increased to ~10keV at moderate density. In this high-Ti peak regime, multi-scale instabilities will be described to provide a clear picture of the interaction between turbulence behaviors and impurity transport in the plasma core.

Detailed physics and technologies with upgrade of EAST capabilities towards future fusion reactors such as the ITER-relevant configuration also will be presented. Work was supported in part by the National MCF Energy R&D Program (2022YFE03050000).