Progress of Physics Understanding for Long Pulse High-performance Plasmas on EAST towards Steady-state Operation of ITER and CFETR

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Significant progress has been achieved along the China's roadmap towards tokamak based fusion energy production. The three-pronged approach towards the Chinese Fusion Engineering Test Reactor (CFETR) will be reported.

Recently, EAST achieved the first demonstration of 100s time scale steady-state H-mode operation with good control of impurity, core/edge MHD stability, heat exhaust using an ITER-like tungsten divertor and pure RF power. Thereafter, with an increase by 20% in heating power, the long-pulse fusion performance was nearly doubled taking advantage of several synergistic effects: electron heating using on-axis Electron Cyclotron Heating (ECH) enhances heating and current drive from Lower Hybrid Waves (LHW) injection, increasing confinement and enabling fully non-inductive operation at higher density (f_{GW} ~80%) and higher poloidal beta (β_P ~2.5). Higher density and poloidal beta increase the bootstrap current fraction and self-consistently broaden current density profile, leading to further increase in confinement. The physics process (RF synergy, core-edge integration, confinement properties, etc.) of the steady-state operation will be illustrated for experiments performed with the following plasma parameters: toroidal magnetic field B_T=2.5T, q_{95}~6.6, elongation k=1.6, poloidal beta β_P ~2, normalized beta β_N ~1.6, and bootstrap current fraction f_{BS} ~50%, maintained for up to 21s with zero-loop voltage. Small ELMs facilitate the RF power coupling in H-mode phase and reduce divertor sputtering/erosion. Zero/low NBI torque, high performance experiments on EAST offer unique contributions to ITER and DEMO.

These results provide key data for validation of heat exhaust, transport and current drive models, and enhance confidence in the fusion performance predictions for CFETR. Recently, a self-consistent steady-state scenario extrapolating the EAST results has been developed using the intergraded modelling. At present, CFETR physics design focuses on optimization of a third-evolution machine: R=7m, a=2m, Bt=6.5-7T, Ip=13MA. Furthermore, a new National Mega Science Project has been recently launched, in support of the engineering development of CFETR and a future DEMO.