High-confinement steady-state operation with quasi-snowflake divertor configuration and active radiation feedback control in EAST

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Advanced divertor configuration and active feedback control of radiated power are two promising solutions to the power exhaust issue in tokamaks, especially for steady-state operations of future fusion reactors. Effective heat load reduction in long-pulse operations with ITER-like tungsten divertor was successfully achieved on EAST in quasi-snowflake (QSF) configuration and active radiation feedback control phase, respectively.

Fully non-inductive steady-state QSF plasmas have been obtained with all the main plasma parameters being very stable, with the longest steady-state shots demonstrated up to 21 s without any sign of instabilities [1], only limited by the technical imposed scenario parameters. A mix of different auxiliary heating power, i.e., ECRH, LHW and ICRH, has been injected up to total 6.2 MW in QSF configuration with top tungsten divertor, without coupling problems. All the discharges were in H-mode with $H_{98} \geq 1$, neither edge D_α nor core impurity accumulation was observed. EAST QSF diverted plasmas have reached an increase of the connection length by ~30% and the flux expansion by a factor of ~3 in the outer strike point region. This QSF configuration is suitable for the superconducting tokamaks with integrated poloidal field system like EAST, which wasn't originally designed for the snowflake divertor configuration. A heat flux reduction, up to a factor of ~ 2.5, was achieved with bottom QSF on the graphite divertor. In all the steady-state QSF discharges, the ELM activity was quiescent, indicating a possible non-linear interaction between the downstream magnetic topology and the upstream kinetic gradients.

By utilizing impurity seeding, assisted with normal divertor gas puff as feedforward and supersonic molecular beam injection (SMBI) as feedback control, the radiation can be effectively controlled with slight degrade of core plasma performance, i.e., the loss of plasma stored energy within 7 - 11%. More importantly, both divertor heat and particle particles were significantly reduced during the active feedback control phase. The radiated power was successfully maintained with the maximum relative control error decreasing from 24% to 13% when the controlled radiated power raised from 0.6 MW to 1.2MW in long-pulse H-mode experiments. In addition, active feedback control of radiation in L-mode plasmas was also performed. In the next step, this radiation feedback control, showing promising potential for heat flux control with good core plasma performance, is planned to be integrated in longer pulse with QSF divertor configuration on EAST.

[1] B. J. Xiao, Z.P. Luo, G. Calabro et al., "A High-confinement Steady-state Plasma with Quasi-snowflake Magnetic Configurations in EAST tokamak", submitted to Nature Phys.