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Overview of KSTAR resolving key physics and engineering issues for ITER and beyond

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As a continuous effort for the development of steady-state high performance operation scenario, there has been significant progress in 2019 campaign including long-pulse extension, high ion temperature, and advanced scenario development in KSTAR.

KSTAR[1,2] program has been focused on resolving the key physics and engineering issues for ITER and future fusion reactors utilizing unique capabilities of KSTAR. new advanced scenarios were developed targeting steady-state operation based on the early diverting and heating during the ramp-up phase of plasma current and significant progress has been made in shape control to address the MA level of plasma current and stationary ITER-similar shape (ISS). We have made significant progress in developing plasma shape control early in the plasma startup which is non-trivial for ITER and DEMO. Modifications to the final current profile have been found to result in significant impact on global energy confinement. The examples of advanced scenarios are shown in Figure 1. The stationary ITB (fig 1a) is successfully reproduced with comparable confinement as H-mode level (H89 ~ 2) both in limited and USN configuration, a low q_{min} scenario (fig 1b) is developed based on early diverting and delayed core heating approach and finally stable long-pulse H-mode operation (fig 1c) was extended upto 88 sec.

Recent KSTAR 3D experiments have focused on several ITER-relevant critical issues, such as divertor heat flux broadening in various resonant magnetic perturbations (RMPs) on ELM-crash suppression, RMP-driven ELM-suppression on ITER-like low q_{95} (~3.2-3.4) and ELM-crash suppression window in terms of normalized electron collisionality and plasma toroidal rotation at pedestal top. Strong up-down asymmetry in polodal configuration was identified and effect of the kink/anti-kink configuration was also clarified for ELM suppression in lower single-null plasmas. During the ELM suppression phase, coexistence of filamentary mode and smaller scale turbulent eddies at pedestal top with broad-range of wave number ($k_\theta < 1.1\ \mathrm{cm}^{-1}$) and frequency ($f < 100\ \mathrm{kHz}$) is identified by ECE imaging (ECEI) and strong energy exchange of the filamentary and turbulent modes was experimentally identified. The bicoherence analysis of the edge harmonic oscillations (EHOs) at natural ELM-less mode reveals that there is a strong nonlinear interaction among EHOs, and the nonlinear interaction of EHOs has a significant effect on the final ELM structure and dynamics.

KSTAR provided unique demonstration on the performance of symmetric multiple Shattered Pellet Injections (SPIs) which is the main strategy of ITER for disruption mitigation. It was shown successfully the current quench rate changes proportionally as the time difference varies from several percent to several tens of percent of the thermal quench (TQ) duration (1~2 ms) and it was demonstrated that peak density was increased twice with dual SPIs compared with a single SPI and energy can be radiated when multiple SPIs are injected simultaneously, as planned in ITER.

Cross-validation between the advanced diagnostics and the modeling provides new insight on the basic transport process at KSTAR. The extensive study of the intrinsic rotation in Ohmic plasmas found a clear link between the counter-current toroidal rotation direction and the quasi coherent mode (QCM) which is measured by the Microwave Imaging (MIR). The improved confinement in the low rotation experiment was correlated with the suppression of the broadband (~200 kHz) ECEI fluctuations, and Collective Thomson Scattering provides a detailed measurement on the high-k density turbulence which is suppressed during the typical LH transition. Finally, strong interaction between fast-ion and EP driven MHD mode was identified with Fast ion D**α** (FIDA) diagnostics.

References

[1] G.S. Lee et al, Nucl. Fusion 40 575 (2000) 575
[2] H. K. Park et al, Nucl. Fusion 59 (2019) 112020 (13pp)

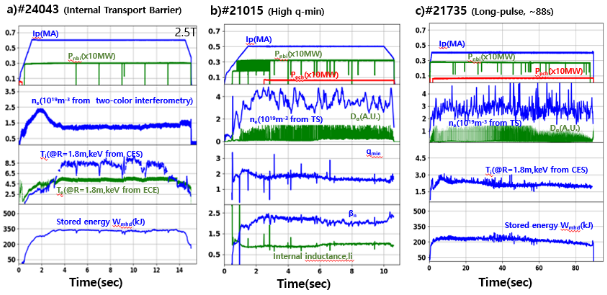

Figure 1. Examples of the advanced scenarios at KSTAR a) Stationary ITB discharge with P_{NBI}~3MW with H_{89}~2. b) Low q-min scenario with early heating c) long-pulse H-mode discharge lasted upto ~ 88 sec.