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Overview of KSTAR

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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. First of all, a new advanced scenario was 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). It is demonstrated effective use of the H&CD with instrumented plasma control and shaping parameters became a key to access to the advanced operation scenarios such as high $_p$, high l_i, high q_{min}, hybrid, internal transport barrier (ITB) and low q_{95} operation. 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 (H_{89} ~ 2) both in limited and USN configuration, a low qmin 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.

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Recent KSTAR 3D experiments have focused on several ITER-relevant issues, such as divertor heat flux broadening in 3-row vs 2-row resonant magnetic perturbations (RMPs) on ELM-crash suppression, RMP-driven ELM-crash-suppression on ITER-like low P_{NBI} (~3.2-3.4) and the characterization of ELM-crash suppression window in terms of normalized electron collisionality (H_{89}) and plasma toroidal rotation (q_{95}) at pedestal top. Strong up-down asymmetry in 3-row configuration was identified and effect of the kink/anti-kink configuration was also clarified for ELM suppression in LSN plasmas. We have demonstrated the ISS-compatible RMP control in KSTAR using n=2, +900 phasing RMP, although the ISS has been more vulnerable to mode-locking than typical KSTAR configuration. A detailed study of the KSTAR database (where RMP configuration of all the discharges belongs to n=1, +900 phasing) showed that the ELM-crash suppression phase in KSTAR is in the range of 0.2 < ν_e^* < 1.2 and V_{tor}> 40 km/s. During the ELM suppression phase, coexistence of filamentary mode and smaller scale turbulent eddies at pedestal with broad-range of wave number (ν_e^*<1.1 V_{tor} and frequency (f<100 kHz) is identified by ECE imaging (ECEI) and strong energy exchange of the filamentary and turbulent modes was measured. The bicoherence analysis of the edge harmonic oscillations (EHOs) at natural ELM-less mode shows that there is a strong nonlinear interaction between EHOs, and the nonlinear interaction of EHOs has a significant effect on the ELM structure and dynamics.

Cross-validation between the advanced diagnostics and the modeling provides new insight on the basic transport process at KSTAR. For example, in the recent MHD-quiescent KSTAR plasmas non-diffusive avalanche-like electron heat transport events are observed by the ECEI and these observations have been successfully reproduced by gyrokinetic simulations indicating the broad range of spatial scales up to the minor radius. In addition, various studies utilizing the KSTAR fluctuation diagnostics demonstrated the importance of the turbulence characteristics in plasma rotation and confinement. 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 k (FIDA) diagnostics.

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.

Lastly, the research plan in near term will be addressed with the machine upgrades. KSTAR will focus on the development of the DEMO/ITER relevant operational scenario, i.e., high-beta steady-state operation with benign MHD activities which will require robust plasma control in strong shaping, control of MHD modes and thorough analysis of the fundamental physics processes. In these regards, KSTAR upgrades will includes extensive NBI (off-axis, 6MW) & RF (Helicon CD, 4MW) heating & current drive capabilities and the installation of new tungsten divertors with active cooling.

References:
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