4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Nonlinear MHD physics in KSTAR uncovered through advanced diagnostics

Gunsu S. Yun[1]
[1] Department of Physics, Pohang University of Science and Technology

e-mail (speaker): gunsu@postech.ac.kr

It was a simple idea to confine high-temperature plasmas for sustained nuclear fusion reactions using toroidally symmetric magnetic fields called "tokamak" configuration. Half a century later, that still remains a challenging goal albeit significant progresses in understanding the underlying tokamak plasma physics such as fluid/kinetic instabilities and particle/energy transport processes. To put it simple, the challenge is two-fold: the difficulty of engineering to achieve a perfect axisymmetry and the fact that improved confinement increases the probability of severe instabilities.

The high-precision engineering of the KSTAR tokamak achieved a nearly axisymmetric magnetic field configuration [1], making it an ideal test-bed for experimental studies on the intrinsic deviations from the axisymmetry and the response to external perturbations [2,3]. A suite of advanced diagnostics have been developed on the KSTAR to assist the study of MHD and turbulence physics, including the electron cyclotron emission imaging (ECEI) systems [4], the microwave imaging reflectometry [5], and the fast RF spectroscopic system [6]. These diagnostics have provided high resolution data on MHD, turbulence, and wave phenomena with unprecedented details for a wide region of the plasma cross-section, which led to the discoveries of many intriguing phenomena. The examples include the quasi-stable modes in the core [7–9], the emergence of non-eigenmode filamentary perturbation in the edge of H-mode plasmas [10–12], and the interaction amongst turbulence [6,13], MHD modes [14,15], and ion cyclotron harmonic waves [16,17]. A notable feature of the quasi-stable modes and the non-eigenmode perturbations is their role on the plasma stability. For the core quasi-stable modes, linear and nonlinear MHD simulations [8, 9] showed that flat safety factor (q) profile with q=1 is a necessary condition for the generation of quasi-stable modes, suggesting that relaxation events in the core would lead to fully relaxed state. In the edge of H-mode plasmas, the emergence of a non-eigenmode perturbation is related to the weakening of turbulent fluctuations [13] and enhancement of ion cyclotron harmonic waves [6, 16], and its burst initiates the relaxation of the pedestal. It is demonstrated that external magnetic perturbation can enhance the turbulence level and thereby suppress the non-eigenmode perturbation, which in turn prevents the pedestal relaxation (aka ELM crash). The characteristics of the MHD modes, turbulence, and waves identified by these diagnostics are eliciting novel theoretical developments for the study of nonlinear dynamics in magnetically confined plasmas beyond the conventional linear stability analysis.

References

[1] Y. In et al, Nucl. Fusion 55 (2015) 043004
[2] Y.M. Jeon et al., Phys. Rev. Lett. 109 (2012) 035004
[3] G.S. Yun et al., Phys. Plasmas 19 (2012) 056114
[4] G.S. Yun et al., Rev. Sci. Instrum. 85 (2014) 11D820
[5] W. Lee et al., Nucl. Fusion 54 (2014) 023012; Plasma Phys. Control. Fusion 60 (2018) 115009
[6] M.H. Kim et al., Nucl. Fusion 58 (2018) 096034
[7] G.S. Yun et al., Phys. Rev. Lett. 109 (2012) 145003
[8] G.H. Choe et al., Nucl. Fusion 55 (2015) 013015; Nucl. Fusion 58 (2018) 016038
[9] Y. Nam et al, Nucl. Fusion 58 (2018), 066009
[10] G.S. Yun et al., Phys. Rev. Lett. 107 (2011) 045004
[11] J.E. Lee et al., Scientific Reports 7 (2017) 45075
[12] Y.M. Oh et al., AIP Adv. 8 (2018) 025224
[13] J. Lee et al., Phys. Rev. Lett. 117 (2016) 075001
[14] M.J. Choi et al, Nucl. Fusion 57 (2017) 126058; Nucl. Fusion 59 (2019) 086027
[15] G. Kim et al., Plasma Phys. Control. Fusion 60 (2018) 035009; Plasma Phys. Control. Fusion 61 (2019) 055001
[16] B. Chapman et al., Nucl. Fusion 57 (2017) 124004; Nucl. Fusion 58 (2018) 096027
[17] S. Thatipamula et al., Plasma Phys. Control. Fusion 62 (2020) 035004;