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Rationale: As an important part of the fusion research programme of China, the key mission of the HL-2A tokamak is to explore physics involved in advanced tokamaks. Most of the important subjects of fusion physics, such as turbulence and transport both in low and high confinement regimes, have been investigated through the progressive improvement of the many subsystems of HL-2A. This contribution will highlight most of the recent research achievements on the roles of electrostatic and electromagnetic turbulence in plasma transport, the effect of flows on turbulence, nonlinear interaction of multi-scale instabilities (micro-turbulence, mesoscale fluctuations, and large scale MHD activities).

Talk Title: On turbulence and multi-scale interactions in low and high confinement plasmas of the HL-2A tokamak

Short abstract: Nonlinear interaction and multi-scale physics are crucial in the physical understanding of the turbulence and transport in complex nonlinear system of fusion plasmas. In the HL-2A tokamak, the turbulence and related transport have long been foci of intensive studies. Significant progress on the roles of electrostatic and electromagnetic turbulence in plasma transport, the effect of flows on turbulence, nonlinear interaction of multi-scale instabilities has been obtained, recently. The synchronization of geodesic acoustic modes (GAMs) and magnetic fluctuations is identified in the edge plasmas of the HL-2A tokamak. The temporal evolutions of the mesoscale electric fluctuations and the magnetic fluctuations clearly show the frequency entrainment and the phase lock between the GAM and the m/n = 6/2 magnetic fluctuations. The results indicate that GAMs and magnetic fluctuations can transfer energy through nonlinear synchronization. Such nonlinear synchronization may also contribute to low-frequency zonal flow formation, reduction of turbulence level, and thus confinement regime transitions. The nonlinear interaction between GAM and turbulence can also be externally stimulated by supersonic molecular beam injection, which plays an important role in initiating the L-H transition. In HL-2A H-mode plasmas, quasicoherent modes have been observed in the pedestal region, which regulate the pedestal transport. In addition, a broadband electromagnetic (EM) turbulence has been observed in the edge plasma region. It is driven by the density gradient of edge self-accumulated impurities. The nonlinear interaction is responsible for the generation of the broadband spectrum. Furthermore, the interaction between large-scale MHD modes and turbulence has been investigated in HL-2A. The results indicate that both the perpendicular flow and the density fluctuation level are modulated by the intrinsically rotating tearing mode near the island boundary and the multi-scale interactions via the nonlinear modulation process might enhance the plasma transport. The study helps to understand the nonlinear interaction mechanisms between cross-scale instabilities and their roles in transport and confinement in magnetically confined plasmas.

List of related published papers

[1] K. J. Zhao, Y. Nagashima, P. H. Diamond *et al* 2016 *Phys. Rev. Lett.***117** 145002
[2] W. L. Zhong, Y. Shen, X. L. Zou *et al* 2016 *Phys. Rev. Lett.***117** 045001.
[3] W.L. Zhong, Z.B. Shi, Y. Xu *et al* 2015 *Nucl. Fusion* **55** 113005
[4] K. J. Zhao, Y. Nagashima, P. H. Diamond *et al* 2017 *Nucl. Fusion* **57** 076036
[5] W. L. Zhong, X.L. Zou, Z.B. Shi *et al* 2016 *Plasma Phys. Control. Fusion* **58** 065001 (*Highlight*)
[6] W. L. Zhong, X.L. Zou, J.M. Gao *et al* 2017 *Plasma Phys. Control. Fusion* **59** 014030
[7] W. Chen, M. Jiang, Y. Xu *et al* 2017 *Nucl. Fusion* **57** 114003
[8] M. Jiang, W.L. Zhong, Y. Xu *et al* 2018 *Nucl. Fusion* 58 026002
[9] Y. Shen, J.Q. Dong, A.P. Sun *et al* 2018 *Nucl. Fusion* **58** 014004