9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Effects of RMP on edge-core turbulence spreading and coupling in a tokamak plasma

Lai Wei[1], G. Ren[1], Z. X. Wang[1], J. Li[2], and F. Yu[3]

[1] School of physics, Dalian University of Technology, [2] Southwestern Institute of Physics, Chengdu, [2] School of Mathematical Sciences, Dalian University of Technology

e-mail (speaker): laiwei@dlut.edu.cn

The micro-turbulence transport, especially the edge–core turbulence spreading in tokamak plasmas, is closely related to the high-confinement mode operation of the advanced fusion devices. In this report, the electromagnetic features of the edge–core turbulence spreading are systematically investigated via a five-field Landau fluid model including the resonant magnetic perturbations (RMP) effect.

Multiple eigenstates of the ion-temperature-gradient (ITG) mode, kinetic ballooning modes (KBM), and electron drift wave instability (DWI) are obtained by the eigenvalue problem solver. In the low β regime, the dominant one is found to be the high order DWI corresponding to the unconventional ballooning mode structure with multiple peaks in the poloidal position, in contrast to the conventional modes that peak at the outboard mid-plane, and has been verified through initial value simulation. In the high β regime, the dominant eigenmodes in the core and edge region are the conventional and unconventional kinetic ballooning modes (KBM) respectively.

In the nonlinear simulation, an inward turbulence spreading phenomenon during the quasi-saturation phase of the edge turbulence is clearly observed. The inward speed of the turbulence energy front in the high β regime is much faster than that in the low β regime. It is interestingly found that the speed of the turbulence energy front increases with the increase of the plasma β in the low β regime, while it is almost unchanged in the high β regime. Evolution of the ion temperature perturbations are given in Fig. 1. It is identified that the turbulence spreading in the low and high β regimes are determined by the nonlinear dynamics and the linear toroidal coupling respectively.

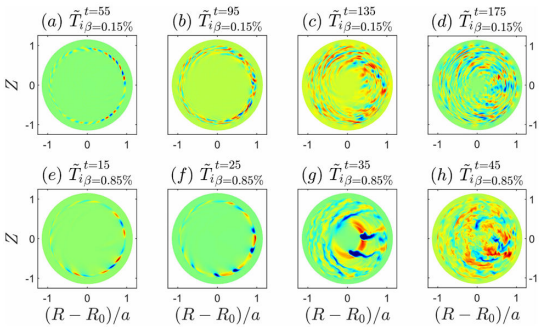

Figure 1. Evolution of the ion temperature perturbations for β=0.15% and β=0.85%. The upper snapshots taken at (*a*) t = 55, (*b*) t = 95, (*c*) t = 135, and (*d*) t = 175 for the case of β=0.15%. The lower snapshots taken at (*e*) t = 15, (*f*) t = 25, (*g*) t = 35, and (*h*) t = 45 for the case of β=0.85%.

Roles of RMP in the turbulence spreading from the edge to the core region of a tokamak are also investigated. When the amplitude of RMP is low, the intensity of the electromagnetic turbulence increases with the increase of RMP amplitude, and the corresponding speed of inward turbulent spreading also increases. As the amplitude of RMP at the boundary exceeds a certain threshold, the long-wavelength fluctuations around the resonance surface can be excited due to forced magnetic reconnection. It will cause magnetic island chains near the low helicity resonant surface, resulting in locally strong shear flow at the magnetic island separatrix, as shown in Fig. 2. The observed shear flow can break the radially elongated vortex structures of the turbulent fluctuation. Thus, the inward turbulence spreading can be blocked by this shear flow, and the saturation level of turbulence intensity in the core region declines. When the helicity of the externally RMP field approaches the resonance surface in the pedestal region, intermittent transport phenomena will occur, and the inward pinch of the particles can be clearly observed.

References

[1] L. Wei, G. Ren, Z. X. Wang, J. Li and F. Yu, "*Electromagnetic drift wave instability in tokamak plasmas with strong pedestal gradient*", 2023 *Nucl. Fusion* **63** 096001

[2] G. Ren, L. Wei, J. Li and Z. X. Wang, "*Effect of resonant magnetic perturbation on edge–core turbulence spreading in a tokamak plasma*" 2024 *Nucl. Fusion* **64** 056016

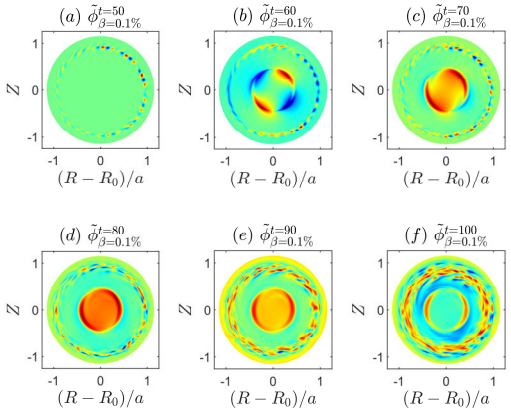

Figure 2. Evolution of the electrostatic potential with a RMP field of the long-wavelength fluctuations for β=0.1%.