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

ICRF wave heating simulation integrating with SOL plasma based on FEM

[1]Zhuo-Qi Liu, [2]Jia-Hui Zhang, [1]Feng Wang, [1]Zheng-Xiong Wang

[1] School of Physics, Dalian University of Technology, Dalian, Liaoning Province, People's Republic of China

[2]School of Aerospace Science and Technology, Xidian University, Xi'an, Shaanxi Province, People's Republic of China

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

As an AAPPS-DPP standard, we do not need to add your postal address.

In numerical simulations of the ion cyclotron range of frequencies (ICRF) wave heating scheme, core solvers usually focus on wave propagation and absorption mechanisms within the core plasma region. However, the realistic scrape-off layer (SOL) plasma is usually simplified due to the limitations of Fourier decomposition have resulted in challenges concerning discretization mesh and computational resources, thereby complicating the simulation of realistic SOL plasma. Thus, we apply a finite elements method (FEM) based on the approach of Vallejos, to simulate ICRF wave heating to account realistically for SOL plasma of the EAST. It is observed that a kind of cavity mode occurred for the case of low parallel wave number, in the presence of the density pedestal neat the last closed flux surface. Besides, a proxy mechanism is employed in the SOL region to explore the impact of unknown complex interaction mechanisms, such as radio-frequency (RF) sheath dissipation, slow wave propagation, lower hybrid resonance, and surface wave propagation. It is found that cavity mode also occurred for the case of low values of proxy mechanism. We have also conducted 3D full-wave simulation of ICRF wave heating based on FEM. To consider the 3D filed effects, a realistic and detailed antenna geometry of the newly designed ICRF antennas on EAST is included. In this 3D model, the core region, SOL region, and ICRF antennas is treated as a unified computational region, which is difficult to realize in the solvers based on Fourier decomposition.

Using the fast magnetosonic wave in an ion cyclotron range of frequencies (ICRF) to heat ions and electrons in the plasma core has been demonstrated an efficient way on EAST and other tokamaks. This poster reports the recent advancements in the first developed three-dimensional (3D) full-wave model of ICRF wave heating based on finite element methods (FEM). This model is an extension of previous work by Zhang et al (J.H. Zhang et al 2022 Nucl. Fusion 62 076032). To consider the 3D field effects, a realistic and detailed antenna geometry of the newly designed ICRF antennas on EAST is integrated with a 3D core plasma and a detailed 3D scrape-off layer (SOL) plasma geometry in this 3D full-wave model.

Compared to the full-wave codes based on Fourier methods, such as TORIC and AORSA, FEM-based full-wave codes have ability to accurately describe the ICRF antennas and other asymmetric geometries. Besides, FEM-based codes have the potential to mimic ICRF waves in the core and edge plasma regions, simultaneously. Combining these two computational regions is important to improve understanding of wave-plasma interactions and core-edge coupling. Commonly, the core and edge regions are treated as two separate computational regions in 3D ICRF simulations. For instance, HIS-TORIC extended the TORIC core solver to incorporate the edge region, which is solved using the FEM discretization. However, this approach may have limitations in self-consistent calculations. In this first developed 3D full-wave model, the core plasma, SOL plasma, and ICRF antennas are treated as a unified computational region. The development of this new 3D full-wave model is believed to perform valuable analysis of ICRF experimental results from EAST and provide important references for future experimental campaigns.

References

[1] Z. Q. Liu, J. H. Zhang, Z. X. Wang et al, Eur. Phys. J. Spec. Top., in print (2025)

[2] Z. Q. Liu, J. H. Zhang et al, Plasma Sci. Tech. 26, 105103 (2024)

[3] J. H. Zhang et al, Nucl. Fusion 62, 076032 (2022)

[4] J. H. Zhang et al, Nucl. Fusion 63, 046015 (2023)