

Advancing Ion Cyclotron Resonance Heating with improved simulations and novel antenna concepts

Abstract

In contemporary fusion experiments, Ion Cyclotron Resonance Heating (ICRH) is a fundamental method for heating plasma, and due to intrinsically low coupling, ICRH antennas play a critical role. This points to two complementary issues: the importance of numerical tools to accurately predict their behaviour, and the research into novel antenna concepts.

A few codes are available in the reference scientific community for simulating antenna performance under Ion Cyclotron (IC) conditions, with accurate 3D geometry and realistic plasmas. The TOPICA code is among the most widely recognised and utilised. This code employs an integral-equation method with 3D geometry and a 1D slab hot-plasma approximation derived from integration with the FELICE plasma code.

In this work, the TOPICA code was updated with a new, more performing version of FELICE, and thoroughly tested.

With TOPICA equipped with the new version of FELICE we then addressed an issue that has in recent years risen to relevance: the presence of Lower Hybrid Resonance (LHR) in low-density region near the antenna.

It appears that a self-consistent account of LHR is not possible within the current plasma description framework; hence, ways to stabilise the solution and remove the related artefacts are crucial, and so is the study of sensitivity to the stabilisation approaches. After a careful study, we have proposed specific figures of merit to highlight the effect on the simulations.

As for innovative antenna concepts, we studied resonant antennas that can inherently exhibit a very low reflection coefficient (and, ideally not requiring an external matching circuit). This happens in a narrow band, though, and we have introduced the concept of tunable self-resonant antennas. The concept has been fully designed to work for the DTT experiment, with design optimisation, frequency

analysis, and load resilience study; the design has been fully tested in front of a realistic plasma using TOPICA. The results indicate that this innovative design presents a promising pathway to further enhance ICRH performances.