Numerical Simulations of Ion Cyclotron Range of Frequency (ICRF) Wave Fields in a Linear Plasma Device

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Abstract

Fusion devices (tokamaks, stellarators) require hundreds of millions degree Celsius temperature to reach the plasma state when the fusion reactions start to occur. Ion cyclotron resonance heating (ICRH) is a method of energy transfer to the ions in the plasma from electromagnetic radiation with a frequency equal to the cyclotron motion frequency of ions in the presence of magnetic field, which is in the range of 30-120 MHz. Main components of an ICRH system are a generator, transmission lines and an antenna placed inside the vacuum vessel of a fusion device. An impedance matching system is also necessary in order to enable the process of power transmission from antenna to plasma. Studies of interactions between ion cyclotron range of frequency (ICRF) radiation and plasma in a configuration representative of a tokamak edge region are carried out on a specialized linear device IShTAR (Ion cyclotron Sheath Test ARrangement). The device is equipped with: 1) a helicon plasma source and magnetic coils to produce a high density, homogeneous, magnetized plasma, 2) an antenna similar to tokamak ICRH antennas, 3) a radially movable manipulator with diagnostic tools: Langmuir probes for electron temperature and plasma density measurements and B-dot probes for radio-frequency (RF) wave magnetic field measurements. Typical operating conditions on IShTAR are: magnetic field of up to 0.2 T in the main chamber and 0.1 T near the helicon source, 10E-4 mbar neutral gas (Argon or Helium) pressure, helicon source power of 3 kW with frequency of 11.76 MHz, ICRF antenna power of 1 kW with 5 MHz frequency. Typical measured parameters are: density of the order 1E16 m^-3 - 1E18 m^-3, electron temperature of few eV and RF B-fields power around 100 mW.
Presented simulation work is intended to support the experimental studies of RF sheaths in front of the ICRF antenna performed on IShTAR. The RF Module of COMSOL Multiphysics® software is used to model the electromagnetic field distribution inside the vessel. Different tasks are addressed, including power losses through the use of a perfectly matched layer (PML), diagnostics calibration, impedance matching tests, and

achievement of coupling conditions equal to experimental and studying the effect of a metallic probe presence inside the plasma.
Evanescent nature of the wave inside the main vacuum vessel ($f = 5$ MHz, $\lambda = 60$ m, characteristic size of vacuum chamber is 1 m) and little wave absorption in plasma determine special conditions for simulations. Instead of the standard PML a new one was created with manually prescribed characteristics. Different tests were performed in simplified geometries first (and in vacuum, without plasma), with further adjustments to the real IShTAR geometry.