FDTD full-wave simulations for microwave-plasma interactions

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One of the most robust methods to describe electromagnetic wave propagation, such as microwave propagation, is the full-wave solution, since Maxwell's equations are exactly solved. The drawback of this approach is that it is computationally demanding. Consequently, caution during development, as well as coding optimisation is required. Based on Yee's algorithm [1], a 2D Finite-Difference Time-Domain (FDTD) full-wave code is currently being developed. It simulates microwave propagation through a similar-sized (to the beam) atmospheric plasma, which is confined in a glass quartz tube [2]. The electric and magnetic field components are evolved with the leapfrog method in both time and space. The plasma current density from the linearised fluid equation of motion is also evolved and accounts for plasma effects. Essentially, this method leads to an explicit calculation of **E**, **B** and **J** for each time step. An example of the probing beam's electric field at the end of the simulation is plotted in figure (1).

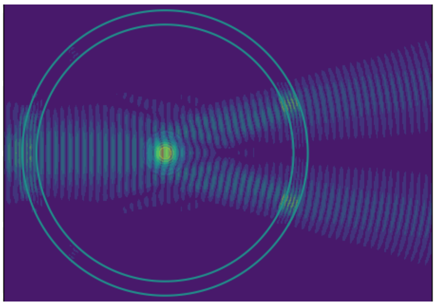

Figure 1: *Beam propagation to quartz tube and plasma*

In order to simulate actual experimental set-ups, large domain grid size and thus computational time are required. Therefore, the code is OpenMP parallelised. In the simulations, a microwave beam is propagating across a quartz tube and a circular plasma. After this interaction, the spatial profile of the power is monitored in a receiving antenna plane, and it is shown how the shape depends on both, the plasma density profile and its peak density. By comparing the results with measurements at a plasma torch, the actual plasma shape can be deduced. Based on the results of this FDTD code, a novel microwave interferometry approach is developed, which allows to also estimate the plasma density shape, apart from the line-integrated density that results from conventional interferometry [3]. Finally, the numerical model, which can be extended to 3D, will be applied to scenarios at the edge of the TJ-K stellarator device, which is located at the Institute of Interfacial Process Engineering and Plasma Technology of the University of Stuttgart.

References

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[2] M. Leins *et al*, Contrib. Plasma Phys. **54**, 1 (2014)

[3] I.H. Hutchinson, Principles of Plasma Diagnostics, Cambridge University Press (2002)