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A new paradigm for plasma wave simulations: integration from antenna to core plasma

A flexible and scalable simulation method of the lower hybrid waves demonstrates for the first time ever the integration of the hot core plasma simulation seamlessly with the antennas and the "scrape-off-layer" plasma.

The lower hybrid (LH) wave is a plasma wave extensively used for heating and driving current in fusion plasma experiments. In these experiments, an antenna located at the plasma edge excites the LH waves. The wave propagates towards the plasma core and is absorbed by electrons that are in turn accelerated and produce a net current, which plays a crucial role in the tokamak plasma confinement. In order to interpret the experimental measurements and to predict the outcome of new experiments, numerical simulations of the wave fields are of crucial importance.

Previous work tackled this problem by treating the antenna and the plasma as two separate problems. It was assumed that the antenna is located in vacuum and the effect of having a plasma in front of the antenna was introduced as a boundary condition. The result is an unrealistic virtual boundary which separates the antenna from the plasma. The traditional approach of LH wave simulation for treating the plasma region has been ray-tracing, which approximates the wave as a bundle of "rays" (fig. 1). This approach does not solve Maxwell's equations directly and is known to be questionable in particular regions of the plasma. Solving Maxwell's equations directly while retaining the hot plasma dielectric property has been done by decomposing the wave field into Fourier modes. However, the decomposition requires simplification of antenna structure, and consequently the antenna is approximated by simple wires. This approach also tends to require large computational resources.

To address all of these issues simultaneously, we developed a new procedure for the simulation of LH waves in fusion plasmas. Our approach is based on the finite element method (FEM) and allows the electromagnetic problem to be solved as a whole, from the antenna to the core of the plasma. Even the "scrape-off-layer" region, the low density plasma region surrounding the core plasma, which is critical for several processes involved in the LH waves physics [1], was also seamlessly included in the simulations (fig. 2). The unique result of our work is that the obtained solution satisfies the correct form of the dielectric property of the LH wave, while at the same time keeping the flexibility and the numerical efficiency of the FEM. The scalability required for large scale plasma simulations in reactor sized device has been demonstrated.

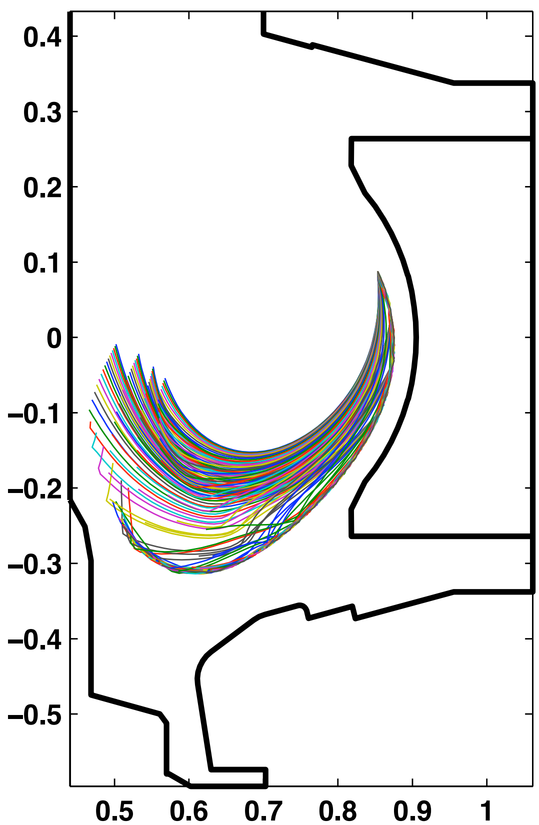

Fig 1: Ray tracing simulation of Alcator C-Mod plasma [1].

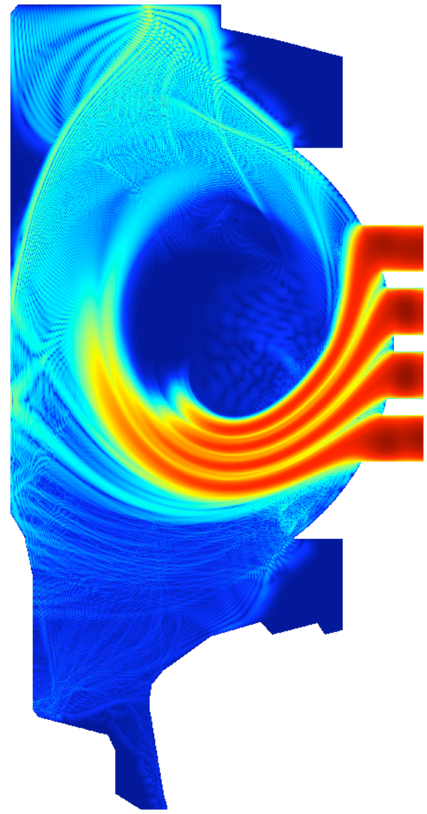

Fig 2: Logarithmic plot of the magnitude of electric field calculated by full wave simulation [2].

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[1] G. M. Wallace, GO4.00008 in this meeting
[2] O. Meneghini, PP8. 00102 in this meeting

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