Topic 7: Numerical simulation of electromagnetic waves in anisotropic media: absorbing boundary conditions and domain decomposition methods

Submitter: Modave Axel
Laboratory: UMA

In computational plasma physics and nanophotonics, it is necessary to be able to simulate numerically the time-harmonic electromagnetic wave propagation in anisotropic media. This is typically done with the help of the Finite Element Method, which, in particular, allows to handle wave propagation in heterogeneous media. However, such simulations present several computational challenges:

1. In many applications, the wave propagation problems are defined on large or infinite areas, while the domain of interest is rather small. Thus, the computational domain must be truncated. This, in turn, requires a use of an appropriate technique at the artificial boundary of the domain to represent the outward propagation of waves (e.g. absorbing boundary conditions, perfectly matched layer, exact transparent boundary conditions). However, the design of the techniques that are accurate, robust and computationally inexpensive is rather difficult, and had been a subject of active research during last 30 years.

2. The finite element discretization of time-harmonic problems leads to large-scale sparse linear systems that are difficult to solve with standard algebraic solvers. Appropriate domain decomposition methods are currently being developed to accelerate the solution of these linear systems. The construction of these methods relies on boundary operators used in absorbing boundary conditions.

The goal of this project is to develop, to analyze and to validate novel artificial boundary operators for the numerical simulation of electromagnetic waves in anisotropic media. Mathematically, the problems we consider are described by time-harmonic Maxwell equations with elliptic tensors of dielectric permittivity and magnetic permeability. The following questions will be studied during the post-doctoral research project:

1. Construction of low-order (and, prospectively, high-order) absorbing boundary conditions for anisotropic media. The standard properties of these conditions will be studied (i.e. well-posedness of the boundary value problems and accuracy of the solution). Numerical simulations with a finite element method will be performed to assert the accuracy of the conditions.

2. The developed boundary operators will be tested in transmission conditions to accelerate the convergence of domain decomposition methods. Depending on the candidate, mathematical analyses and numerical studies of the obtained domain decomposition methods will be performed.

The candidate will be mentored by Patrick Ciarlet (ENSTA Paris), Maryna Kachanovska (INRIA) and Axel Modave (CNRS, main contact). The research will be done in the POEMS laboratory (CNRS/INRIA/ENSTA), inside the Applied Mathematics Unit of ENSTA Paris.