POEMS laboratory, CNRS, Inria, ENSTA Paris, Institut Polytechnique de Paris, Palaiseau (France)

Postdoctoral fellowship

Hybridizable discontinuous finite element method for time-harmonic electromagnetism in complex media

Laboratory: POEMS *(UMR 7231)* @ Palaiseau *(France)*
Supervisors: Dr Axel Modave *(CNRS researcher)* and Prof. Patrick Ciarlet *(ENSTA Paris)*
in collaboration with Dr Théophile Chaumont-Frelet *(Inria Researcher, Atlantis)*

Duration: 1 year *(potentially extended for another year)*
Starting: Ideally September/October 2023
Funding: Project ElectroMATH *(CIEDS)*

Key words: Numerical simulation; Finite element method; Electromagnetic waves; Numerical analysis; Scientific computing

General context

Numerical tools simulating electromagnetic wave propagation phenomena are intensively used in academia and industry to address important challenges, such as electromagnetic compatibility testing, the design of metamaterials, or the study of waves in plasma. Numerical schemes based on ***finite-element methods*** (FEMs) have proven their ability to address realistic problems. Nevertheless, the discretization of time-harmonic problems with FEMs leads to large sparse linear systems that are difficult to solve. Important efforts have been provided by the community to design and to study ***novel discretization and domain decomposition methods*** in order to accelerate the solution procedures.

The postdoctoral fellow will be part of the ***ElectroMATH project*** *(funded by CIEDS)*, whose the general goal is to contribute to the mathematical and numerical study of electromagnetic wave problems with complex/anisotropic media *(e.g., plasmas, metamaterials, ...)* and/or complex configurations *(e.g., coupling interface, waveguide, ...)*. More specifically, the postdoctoral fellow will contribute to a research axis dedicated to the design and the analysis of novel numerical schemes and HPC strategies for solving large-scale time-harmonic problems.

POEMS is a joint lab associated with CNRS, Inria and ENSTA Paris with 16 academic permanents and approximatively 20 non-permanents researchers. The research activities of POEMS are mainly dedicated to the mathematical and numerical study of wave propagation problems, including aspects related to mathematical analysis, numerical simulation and high-performance computing.

Description of the postdoctoral research project

A novel hybridizable discontinuous Galerkin finite element approach, called CHDG, has been recently proposed in [3] for time-harmonic scalar wave problems. The CHDG method relies on a standard upwind scheme that is hybridized by using characteristic variables at the interface between the elements. The resulting reduced system has interesting properties for efficient solution procedures with standard iterative methods. In particular, the reduced system can be solved with a fixed-point iteration and the convergence of the CGNR iteration is nearly as fast as the convergence of the GMRES iteration. Therefore, CHDG is a good candidate to address large-scale realistic problems.

The goal of this project is to develop/study a CHDG approach for time-harmonic electromagnetic problems. In a progressive approach, the postdoctoral fellow will propose a CHDG formulation based on a standard upwind scheme written for the Maxwell equations. The resulting scheme will then be studied, similarly to what has been proposed in [3] for scalar wave problems. Depending on the results and the interests of the fellow, several extensions may be considered: The resulting scheme may be implemented and tested in a `C++` research code developed as part a the WavesDG project [link]; Extensions to deal with

anisotropic media of increasing complexity (see e.g., [1]) could be investigated. The general class of elliptic anisotropic media, which has been studied in the PhD thesis of D. Chicaud [2], is targeted.

Profile of the candidate

We are looking for a candidate with a PhD in Applied Mathematics, or a PhD in Engineering with strong skills/interests on mathematical and numerical aspects. Good knowledge on wave-like PDEs, finite element methods and scientific programming are expected. Knowledge of standard discontinuous Galerkin methods is an asset.

We are interested by motivated/rigorous candidates having both theoretical and practical skills/interests. Don't hesitate to contact us for more information!

Practical information for application

Interested candidates should send an application letter along with a full CV, copies of the PhD reports and reference letters *(if any).*

- Dr Axel Modave *(CNRS researcher, POEMS)* [axel.modave@ensta-paris.fr ; website] *(main contact person)*
- Prof. Patrick Ciarlet *(ENSTA Paris, POEMS)* [patrick.ciarlet@ensta-paris.fr ; website]
- Dr Théophile Chaumont-Frelet *(Inria researcher, Atlantis)* [theophile.chaumont@inria.fr ; website]

References

[1] Assous, Ciarlet, Labrunie (2018). *Mathematical Foundations of Computational Electromagnetism*. Springer [manuscript]

[2] Chicaud (2021). *Analysis of time-harmonic electromagnetic problems in elliptic anisotropic media*. PhD at Institut Polytechnique de Paris [manuscript]

[3] Modave, Chaumont-Frelet (2022). A hybridizable discontinuous Galerkin method with characteristic variables for Helmholtz problems. Submitted for publication [preprint]

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