2018-00586 - Post-doctoral position: Black-hole plasmonic waves in dispersive electromagnetic components

Level of qualifications required: PhD or equivalent
Fonction: Post-Doctoral Research Visit

About the research centre or Inria department
Located at the heart of the main national research and higher education cluster, member of the Université Paris Saclay, a major actor in the French Investments for the Future Programme (Idex, LabEx, IRT, EquipeX) and partner of the main establishments present on the plateau, the centre is particularly active in three major areas: data and knowledge; safety, security and reliability; modelling, simulation and optimisation (with priority given to energy).

The 450 researchers and engineers from Inria and its partners who work in the research centre’s 31 teams, the 100 research support staff members, the high-level equipment at their disposal (image walls, high-performance computing clusters, sensor networks), and the privileged relationships with prestigious industrial partners, all make Inria Saclay Île-de-France a key research centre in the local landscape and one that is oriented towards Europe and the world.

Context
Previous theoretical studies carried out by POEMS team have shown that a scatterer made of an idealized material, with a real valued negative permittivity, can absorb some energy, although no dissipation is considered in the material. This strange fact is due to the so-called black-hole plasmonic waves that propagate towards the edges of the scatterer, carrying some energy. Since black-hole waves approach the corners but never reach them, this energy is definitely trapped by the corners of the scatterer. One consequence of this phenomenon in the frequency domain is the hyper-singular and hyper-oscillating behavior of the electromagnetic field at the corner (it is no longer in $L^2$), which requires a new approach for both the mathematical analysis and the numerical method. A solution has been previously developed for the scalar 2D case, relying on Mellin theory and Kondratiev Sobolev spaces for the analysis, and on a combination of finite elements and Perfectly Matched Layers (PMLs) at the corners, for the numerical simulations.

References:
On the use of Perfectly Matched Layers at corners for scattering problems with sign-changing coefficients

Radiation condition for a non-smooth interface between a dielectric and a metamaterial
Anne-Sophie Bonnet-BenDhia, Lucas Chesnel and Xavier Claeyss

Assignment
We propose to pursue this study in two main directions:

1 - Study black-hole resonances in dispersive materials. In practice, negative permittivity can occur only in dispersive material. We would like to investigate and compute the complex leaky modes associated to the black-hole phenomenon. Indeed, this phenomenon is responsible for an interval of essential spectrum. Leaky modes correspond to the poles of the analytic extension of the resolvent across this part of the spectrum. The classical method to compute them is precisely to use PMLs which move the essential spectrum in the complex plane and reveal leaky modes. The particularity of the present situation is the fact that the essential spectrum is a bounded interval instead of a semi-infinite line.

2 - Study black-hole waves at 3D edges or corners. It has been already observed in the case of a circular cone that two black-hole waves can exist, instead of only one in 2D. But the case of a cone with a polygonal base cannot be treated analytically: it requires the numerical resolution of an unusual sign-changing Laplace Beltrami eigenvalue problem. Concerning the numerical method, the extension of the PML technique to 3D corners has to be developed.
Main activities
1 - Development of a 2D test case for black-hole resonances: choice of the PML model, derivation of a mathematical formulation, implementation in the XLiFE++ library, treatment of the non-linear eigenvalue problem, test campaign in order to exhibit complex resonances.

2 - Black-hole waves at 3D corners. Only the scalar model will be considered. Derivation of a mathematical formulation, numerical study of the sign-changing Laplace Beltrami eigenvalue problem, derivation of adapted PML technique.

Skills
A good knowledge of basic notions of functional analysis for PDEs (variational formulations in particular) and of associated finite element methods is required.

Some competencies in spectral theory and in C++ language would be appreciated

Benefits package
- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities

Remuneration
Monthly gross salary: 2,653 euros