Offer #2024-07306

PhD Position F/M [DOCT2024-ATLANTIS] Advanced numerical modeling for time-varying metasurface modulation

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

About the research centre or Inria department

The Inria centre at Université Côte d'Azur includes 37 research teams and 8 support services. The centre's staff (about 500 people) is made up of scientists of different nationalities, engineers, technicians and administrative staff. The teams are mainly located on the university campuses of Sophia Antipolis and Nice as well as Montpellier, in close collaboration with research and higher education laboratories and establishments (Université Côte d'Azur, CNRS, INRAE, INSERM ...), but also with the regiona economic players.
With a presence in the fields of computational neuroscience and biology, data science and modeling, software engineering and certification, as well as collaborative robotics, the Inria Centre at Université Côte d'Azur is a major player in terms of scientific excellence through its results and collaborations at both European and international levels.

Context

Atlantis is a joint project-team between Inria and the Jean-Alexandre Dieudonné Mathematics Laboratory at Université Côte d'Azur. The team gathers applied mathematicians and computational scientists who are collaboratively undertaking research activities aiming at the design, analysis, development and application of innovative numerical methods for systems of partial differential equations (PDEs) modelling nanoscale light-matter interaction problems. In this context, the team is developing the DIOGENeS [https://diogenes.inria.fr/] software suite, which implements several Discontinuous Galerkin (DG) type methods tailored to the systems of time- and frequency-domain Maxwell equations possibly coupled to differential equations modeling the behaviour of propagation media at optical frequencies. DIOGENeS is a unique numerical framework leveraging the capabilities of DG techniques for the simulation of multiscale problems relevant to nanophotonics and nanoplasmonics.

Assignment

The last ten years have seen an impressive amount of work aimed at developing thin metamaterials to control the wavefront of light and design planar photonic devices. The concept of the metasurface is at the heart of almost all discoveries in this field. Metasurfaces are arrays of optically thin elements, called meta-atoms or nanoresonators, that enable optical behaviors distinctly different from those observed in conventional three-dimensional metamaterials. However, most of the planar photonic devices proposed to date are based on passive metasurfaces whose functions are fixed during fabrication. In other words, the geometrical characteristics of nanoresonators are set a priori to achieve the desired optical functionality. However, modern applications require dynamic manipulation of light waves through the application of external stimuli. In general, this is achieved by fixing the geometrical characteristics of the nano-resonators and forming the metasurface building blocks from active materials such as phase-change materials, liquid crystals or electro-optically responsive materials. In a passive metasurface, the refractive index of the nano-resonators is modulated in space while remaining fixed in time. On the other hand, the ultrafast modulation of light, on the order of a fraction of the optical frequency, offers exceptional prospects for applications, particularly with the emerging innovative concept of space-time modulated metasurfaces.

Main activities

Numerical modeling is an essential path to study space-time metasurface modulation. Generally speaking, one needs to model rigorously inside Maxwell's equations heterogeneous materials with time-varying response. The well-known Finite-Difference-Time Domain (FDTD) method [TH05] has been considered for this task, but the existing works are rather rare and limited to simple applications [Liu04]. The FDTD method solves the time-domains Maxwell equation on a structured (Cartesian) grid. FDTD is a conceptually simple and computationally efficient numerical method but its accuracy is limited when dealing with complex geometries and in the presence of multiscale features such as the ones raised when modeling the interaction of an electromagnetic wave with space-time modulated materials. Alternative approaches making use of an unstructured (finite element type) grid. The Discontinuous

Galerkin Time-Domain (DGTD) method [Viq15] is such an approach, which is nowadays very popular in the computational electromagnetic community. DGTD can be viewed as a blending of classical (continuous) finite element and finite volume methods, merging the best of these two families of methods (i.e. high order accuracy, flexibility with regards to the type of mesh used for discretization of complex objects, etc.). The DGTD fullwave solver introduced in [Viq15] is one component of the DIOGENeS software suite.

In the present Ph.D. project, a first objective will be to formalize and develop the appropriate modeling for solving Maxwell's equations with space-time material variations. In particular, we will rely on and extend the high order DGTD method initially introduced in [Viq15]. The second objective will be to apply the developed rigorous fullwave DGTD solver to the study and design of space-time modulated metasurfaces. For that purpose, we will benefit from our experience in the field of passive metasurface design [MELS19, MELS21] for optimizing spatiotemporal metasurfaces at optical and NIR regimes, and achieve exceptional and exotic functionalities at the optical frequency speed. This Ph.D. will take place in the Atlantis project-team at the Inria research center at Université Côte d'Azur in Sophia Antipolis. Moreover, this Ph.D. project will be conducted in close collaboration with our physical partners for the indispensable physical interpretation and potential applications.

[GE11] N. Yu, P. Genevet, M.A. Kats, F. Aieta, J.-P. Tetienne, F. Capasso and Z. Gaburro, « Light propagation with phase discontinuities: generalized laws of reflection and refraction », Science, Vol. 334, pp. 333–337 (2011)

[HAS14] D. Lin, P. Fan, E. Hasman and M.L. Brongersma, « Dielectric gradient metasurface optical elements », Science, Vol. 345, pp. 298-302 (2014)

[EL22] E. Mikheeva, C. Kyrou, F. Bentata, S. Khadir, S. Cueff and P. Genevet. « Space and time modulations of light with metasurfaces: recent progress and future prospects », ACS Photonics, Vol. 9, No. 5, pp. 1458–1482 (2022)

[ST22] S. Taravati and G. V. Eleftheriades, « Microwave space-time modulated metasurfaces », ACS Photonics, Vol. 9, No. 2, pp. 305-318 (2022)

[GX19] X. Guo, Y. Ding, Y. Duan and X. Ni , « Nonreciprocal metasurface with space–time phase modulation », Light: Science & Applications, Vol. 8, No. 123 (2019)

[MELS19] M.M.R. Elsawy, S. Lanteri, R. Duvigneau, G. Brière, M.S. Mohamed and P. Genevet, « Global optimization of metasurface designs using statistical learning methods », Scientific Reports, Vol. 9, No. 17918 (2019)

[MELS21] M.M.R. Elsawy, A. Gourdin, M. Binois, R. Duvigneau, D. Felbacq, S. Khadir, P. Genevet and S. Lanteri. « Multiobjective statistical learning optimization of RGB metalens », ACS Photonics, Vol. 8, No. 8, pp. 2498–2508 (2021)

[Viq15] J. Viquerat. Simulation of electromagnetic waves propagation in nano-optics with a high-order discontinuous Galerkin time-domain method. Ph.D. thesis, University of Nice-Sophia Antipolis (2015)

[Liu04] X. Liu. The use of the FDTD method for electromagnetic analysis in the presence of time-varying media. PhD thesis, University of Ottawa (2024)

[TH05] A. Taflove and S.C. Hagness. Computational electrodynamics: the finite-difference time- domain method - 3rd ed. Artech House Publishers (2005)

Skills

Typical profile: MSc in scientific computing, modeling and simulation.

Skills :

- Basic knowledge of numerical resolution of PDEs for computational physics
- Introduction to finite difference / finite volume / finite element methods
- Basic knowledge of electromagnetism
- Software development using Fortran 95 and Python

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Remuneration

Duration: 36 months

Location: Sophia Antipolis, France
Gross Salary per month: 2100€ brut per month (year 1 & 2) and 2190€ brut per month (year 3)

General Information

- **Theme/Domain :** Numerical schemes and simulations
- **Town/city :** Sophia Antipolis
- **Inria Center :** Centre Inria d'Université Côte d'Azur
- **Starting date :** 2024-10-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-04-28

Contacts

- **Inria Team :** ATLANTIS
- **PhD Supervisor :**
  Lanteri Stéphane / Stephane.Lanteri@inria.fr

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.