Job vacancy #2023-05862

PhD Position F/M Designing highly efficient ultrafast dynamical metasurface for LIDAR applications

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

Level of experience : From 3 to 5 years

About the research centre or Inria department

Inria is a national research institute dedicated to digital sciences that promotes scientific excellence and transfer. Inria employs 2,400 collaborators organised in research project teams, usually in collaboration with its academic partners.
This agility allows its scientists, from the best universities in the world, to meet the challenges of computer science and mathematics, either through multidisciplinarity or with industrial partners.
A precursor to the creation of Deep Tech companies, Inria has also supported the creation of more than 150 start-ups from its research teams. Inria effectively faces the challenges of the digital transformation of science, society and the economy.

Context

The present postdoctoral project is part of a collaborative project between the Atlantis project-team from the Inria Research Center at Université Côte d'Azur, (2) CRHEA in Sophia Antipolis, France, and (3) LAAS in Toulouse France.

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

Metasurfaces are engineered materials that can precisely control the behavior of electromagnetic waves by using subwavelength-sized elements called meta-atoms. These meta-atoms can be designed to exhibit specific electromagnetic responses, which allows metasurfaces to manipulate the properties of light waves in a highly controlled manner. Metasurfaces can be divided into two main categories: passive and active. Passive metasurfaces have a fixed response to incident electromagnetic waves, meaning that their functionality is set during fabrication and their geometrical parameters are tuned to achieve the desired response. Active metasurfaces, on the other hand, can actively change their response in real-time by incorporating active materials such as phase change materials, liquid crystals, or materials with electro-optical response. This allows for dynamic manipulation of light waves upon the application of external stimuli, achieved by spatially modulating the permittivity of the nano-resonators. However, designing efficient active metasurfaces is challenging because the refractive index modulation response is often not sufficient to achieve the necessary conditions for wavefront control, especially for materials with ultrafast response. This usually requires a deep understanding of the topological resonance behavior and careful numerical modeling to achieve full phase modulation with high amplitude response in a single unit-cell configuration.

he main goal of this PhD project is to use numerical methods to optimize the design of active nanostructures in order to achieve the highest possible phase modulation and amplitude response. The optimization process will focus on adjusting the dimensions and shapes of meta-atoms and will take into account the limitations of the active materials used. For passive metasurfaces, different resonators with different shapes are used to achieve the desired phase profile, but in an active system, all resonators in a microcell will have the same shape but will be modulated differently by applying different voltages. As a result, a more advanced optimization method is needed to account for the effects of near-field coupling and fabrication errors.

The second perspective objective is to design metasurface configuration achieving the ultrafast light modulation, in the order of a fraction of the optical frequency. This offers exceptional peculiar perspective applications in particular with the emerging innovative space-time metasurfaces modulations [EL22, ST22]. In the present Ph.D. project, we aim at **first developing the appropriate modeling** tools for solving **Maxwell's equations with space-time** material variations relying on advanced high-order methods. Besides, we aim at deploying the advanced tools and benefiting from our experience in the field of metasurface [MELS19, MELS21, MELS22, MELS23] for optimizing **spatiotemporal metasurfaces** at optical and NIR regimes and achieve exceptional and exotic functionalities at the optical frequency speed.

This study will exploit a numerical methodology that has previously been used successfully for passive cases [MELS19, MELS21]. This method consists of two components: a global optimization method based on statistical learning for the outer loop, and a fullwave solver for the inner loop to accurately evaluate a given design. The outer loop, which is driven by the Efficient Global Optimization (EGO) method, explores the predefined design space in an efficient manner to minimize the number of calls to the fullwave solver. The inner loop relies on the Discontinuous Galerkin Time-Domain (DGTD) method, which combines high order discontinuous finite elements for space discretization with an explicit time-stepping method for time integration of the 3D time-domain Maxwell equations. The DGTD method [Viq15] is accurate, efficient and easy to implement.

[MELS19] M. 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. Elsawy, A. Gourdin, M. Binois, R. Duvigneau, D. Felbacq, S. Khadir, P. Genevet an S. Lanteri, *Multiobjective statistical learning optimization of RGB metalens*, ACS Photonics, Vol. 8, No. 8, pp. 2498–2508 (2021)

[MELS22] M. Elsawy, M. Binois, R. Duvigneau, S. Lanteri, and P. Genevet, *Optimization of metasurfaces under geometrical uncertainty using statistical learning*, Optics Express 29(19), 29887–29898 (2021)

[MELS23] M. Elsawy, C. Kyrou, E. Mikheeva, R. Colom, J-Y Duboz, K. Zangeneh Kamali, D. Neshev, S. Lanteri and P. Genevet, *Universal active metasurfaces for ultimate wavefront molding by manipulating the reflection singularities*, https://hal.science/hal-03864817/ (2022)

[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. 458–1482 (2022)

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

[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)

Skills

Academic background: Ph.D. in applied mathematics or scientific computing or electrical engineering.

Required knowledge and skills

- Theory and methodology: computational electromagnetics, finite element methods for PDEs, numerical optimization
- Programming: Fortran 2008, Python, MPI, OpenMP

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

Gross Salary per month: 2051€ brut per month (year 1 & 2) and 2158€ brut per month (year 3)

General Information

- **Theme/Domain :** Numerical schemes and simulations
  Scientific computing (BAP E)
- **Town/city :** Sophia Antipolis
- **Inria Center :** Centre Inria d'Université Côte d'Azur

- **Starting date :** 2023-09-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-05-31

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.