



Offre n°2024-07306

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

Type de contrat : Fixed-term contract

Niveau de diplôme exigé : Graduate degree or equivalent

Fonction : PhD Position

A propos du centre ou de la direction fonctionnelle

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 regional 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.

Contexte et atouts du poste

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.

Mission confiée

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.

Principales activités

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. Cuffe 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. Elsayy, 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. Elsayy, 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. Taflov and S.C. Hagness. Computational electrodynamics: the finite-difference time- domain method - 3rd ed. Artech House Publishers (2005)

Compétences

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

Avantages

- 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

Rémunération

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)

Informations générales

- **Thème/Domaine** : Numerical schemes and simulations
- **Ville** : Sophia Antipolis
- **Centre Inria** : [Centre Inria d'Université Côte d'Azur](#)
- **Date de prise de fonction souhaitée** : 2024-10-01
- **Durée de contrat** : 3 years
- **Date limite pour postuler** : 2024-04-28

Contacts

- **Équipe Inria** : [ATLANTIS](#)
- **Directeur de thèse** :
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A propos d'Inria

Inria est l'institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 215 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3900 scientifiques pour relever les défis du numérique, souvent à l'interface d'autres disciplines. L'institut fait appel à de nombreux talents dans plus d'une quarantaine de métiers différents. 900 personnels d'appui à la recherche et à l'innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 200 start-up. L'institut s'efforce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l'économie.

Attention: Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d'autres canaux n'est pas garanti.

Consignes pour postuler

Sécurité défense :

Ce poste est susceptible d'être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L'autorisation d'accès à une zone est délivrée par le chef d'établissement, après avis ministériel favorable, tel que défini dans l'arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l'annulation du recrutement.

Politique de recrutement :

Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.