



**Offer #2023-06381**

## **PhD Position F/M Fast solvers for studying light absorption by nanostructured imagers**

**Contract type** : Fixed-term contract

**Level of qualifications required** : Graduate degree or equivalent

**Other valued qualifications** : Master in applied mathematics or scientific computing

**Fonction** : PhD Position

**Level of experience** : From 3 to 5 years

### **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 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.

### **Context**

The exploitation of nanostructuring in order to improve the performance of CMOS imagers based on microlens grids is a very promising avenue. In this perspective, numerical modeling is a key component to accurately characterize and optimize the absorption properties of these complex imaging structures which are intrinsically multiscale (from the micrometer scale of the lenses to the nanometric characteristics of the nanostructured material layers). The present PhD project is proposed in the context of a collaboration between the Atlantis project-team of Inria research center at Université Côte d'Azur and STMicroelectronics (CMOS Imagers division of the Technology for Optical Sensors department) in Crolles. A Cifre funding will support this project.

The objectives of the project are to design (1) a fast electromagnetic simulation approach based on a model reduction technique, to characterize numerically the light trapping in digital imagers exploiting nanostructured pixels and, (2) a multi-objective optimization strategy of the geometrical characteristics of the nanostructuring in order to simultaneously maximize the light absorption in a pixel and to minimize the crosstalk phenomenon between neighboring pixels. For the first time, in addition to the rigorous methods for solving Maxwell's equations, we will be able to benefit from an alternative simulation approach based on model reduction. This new approach can be used in an optimization process and the expected gain in total computation time would be between 10 to 1000.

### **Assignment**

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.

The core of the present study is concerned with reduced-order modeling for time-domain electromagnetic wave propagation problems. In short, reduced-order models (ROMs) are simplifications of high fidelity, complex models. They capture the behavior of these source models so that one can quickly study a system's dominant effects using minimal computational resources. The starting point will consist on some preliminary works and contributions that the team has obtained during the recent years by considering a particular reduced-order modelling technique known as the proper orthogonal

decomposition (POD) method.

In the POD approach, a reduced subspace with a significantly smaller dimension is constructed by a set of basis vectors extracted offline from snapshots that are extracted from simulations with a high order DGTD method. By doing so, a non-intrusive POD-based ROM has been developed for the solution of parameterized time-domain electromagnetic scattering problems. The considered parameters are the electric permittivity and the temporal variable. By using the singular value decomposition (SVD) method, the principal components of the projection coefficient matrices (also referred to as the reduced coefficient matrices) of full-order solutions onto the RB subspace are extracted. A cubic spline interpolation-based (CSI) approach is proposed to approximate the dominating time- and parameter-modes of the reduced coefficient matrices without resorting to Galerkin projection. The generation of snapshot vectors, the construction of POD basis functions and the approximation of reduced coefficient matrices based on the CSI method are completed during the offline stage. The RB solutions for new time and parameter values can be rapidly recovered via outputs from the interpolation models in the online stage. In particular, the offline and online stages of the proposed RB method, termed as the POD-CSI method, are completely decoupled, which ensures the computational validity of the method. Starting from these previous contributions, the present study will aim at two objectives: on one hand, the efficiency improvement, as well as the development of the proposed non-intrusive ROM methodology for three-dimensional (3d) parameterized time-domain electromagnetic scattering problems; on the other hand, the study of possible strategies for dealing with geometrical parameters.

Moreover, the recruited PhD student will also be exposed to alternative physics-based alternative numerical modeling in the framework of modal approaches developed at STMicroelectronics. These modal type methods are part of the reference simulation methods routinely in this industrial context.

## Main activities

- Bibliography study on data-driven ROM
- Analysis of our previous works
- Getting started with existing Python codes for the POD-CSI method in the 2d case
- Specification and development (in Fortran 2003 and Python) of a POD-CSI software for 3d problems
- Adaptation of the 3d POD-CSI software to high performance computing systems
- Extension of the existing POD-CSI approach for handling geometrical parameters
- Detailed assessment of the novel ROM methodologies by considering practical scattering problems
- Writing of scientific publications

## Skills

Technical skills and level required :

- Master or engineering degree in numerical mathematics or scientific computing
- Sound knowledge of numerical analysis for PDEs
- Basic knowledge of physics of electromagnetic wave propagation

Software development skills : Python and Fortran 2003, parallel programming with MPI and OpenMP

Relational skills : team worker (verbal communication, active listening, motivation and commitment)

Other valued appreciated : good level of spoken and written english

## 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 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
- Contribution to mutual insurance (subject to conditions)

## Remuneration

Duration: 36 months

Location: Sophia Antipolis, France

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** : 2023-10-02
- **Duration of contract** : 3 years
- **Deadline to apply** : 2024-06-30

## Contacts

- **Inria Team** : [ATLANTIS](#)
- **PhD Supervisor** :  
Lanteri Stéphane / [Stephane.Lanteri@inria.fr](mailto: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.