PhD position in ultrafast optics at the Nice Institute of Physics (2024 Q4)

Femtosecond mid-infrared driver for nanophotonic accelerators

CONTEXT - Ultra-short sources have opened up the field to a considerable number of applications such as high-precision machining, multi-photon microscopy, or X-UV generation through high harmonic generation. Among the most recent and most spectacular achievements is the acceleration of charged particles by sub-picosecond pulses focused on nanostructures. This new approach could cut the costs and the footprint of current particle accelerators and path the road to compact and affordable accelerators [1]. Still, practical applications in science, medicine or industry require average currents which are not yet within the reach of current chip devices. Substantial progress has been made in this area in recent years, fueled by a growing international collaboration of universities, national laboratories, and companies. One promising research direction is to work with a high-repetition-rate mid-infrared driver and large nanophotonic channels to maximize the average electron flux.

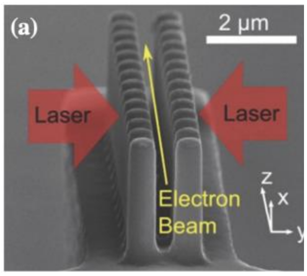

Figure 1. Dielectric laser accelerator structure based on the dual-pillar

This research topic is one of the focuses of VISUAL, a large-scale European project (4 M€, 4 years) that aims to develop a versatile femtosecond source for biomedical imaging, micro-structuration and electron acceleration. The main objective of the VISUAL proposal is to scale up the average power of high-repetition-rate Ytterbium lasers (60 MHz, 60 W, 1 µJ/pulse, <300 fs), provide advanced modulation features (pulse on demand, burst mode) and push forward the wavelength tunability of ultrafast sources up to the thermal infrared. To achieve the defined objectives, the VISUAL consortium relies on a wide range of multi-disciplinary expertise, ranging from industrial ultrafast lasers advanced photonic crystal fiber, extreme nonlinear optics to nanophotonics and cutting-edge microscopy. The consortium covers three European countries (Poland, Germany, France) and includes both private and public partners, among which are the CNRS (France) and the Friedrich Alexander University (FAU, Erlangen, Germany). The FAU is at the forefront and birth of acceleration of electrons in nanostructures [1, 2]. The CNRS gathers three research units (PHLAM in Lille, Femto-ST in Besançon and INPHYNI in Nice) which are in charge, within VISUAL, of drawing photonics fibers and developing a high-power mid-infrared ultrafast driver for the FAU.

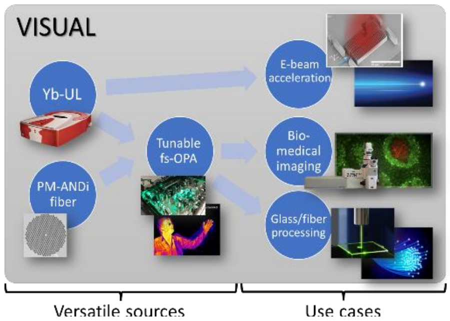

Figure 2. Overview of the VISUAL project.

RESEARCH PROGRAM – The research project aims to develop an infrared light source to drive the generation of ~MeV electron beams by electron acceleration in dielectric periodic structures. The expected output is a disruptive table-top source of MeV-electrons with high brightness. The research program comprises: (1) the design and the study of a mid-infrared difference-frequency generation (DFG) pumped by a VISUAL Ytterbium laser, (2) the assessment of the damage threshold of Silicon nanostructures provided by the FAU, and (3) electron acceleration experiments at FAU.

Objective 1: mid-infrared driver - The envisioned driver at 3 µm relies on two unique building blocks, both developed within the context of VISUAL: a high-average-power and high-repetition-rate ultrafast laser at ~1030 nm provided by an industrial partner, and a polarization-maintaining all-normal-dispersion (ANDi) photonic fiber drawn at CNRS. The combination of these devices allows the generation of a broad, coherent and ultra-stable supercontinuum ranging from ~0.7 µm to ~1.4 µm [3]. By intra-pulse frequency-difference (IDFG) between pairs of components (e.g. ~0.88 µm and ~1.25 µm), mid-infrared (e.g. ~3 µm) will be generated and amplified in a set of nonlinear crystals ($LiNbO_3$, $LiGaS_2$, GaSe…). Given the high average power of the driving laser (60 W, 60 MHz), a high-flux mid-infrared beam of few-cycle pulses is expected, with features (average power, wavelength tunability) that should reach or exceed the state of the art [4, 5]. Although not related to the field of electron acceleration, the pulses generated by IDFG will form a mid-infrared frequency comb of high brightness.

The latter will be studied, in connection with the astrophotonics team at INPHYNI, in the context of optical interferometry.

Objective 2: LIDT of nanostructures - So far, nanophotonics-based particle acceleration has only been performed at repetition rates in the range of up to 200 kHz. We will hence investigate how the high repetition rate, high power, laser pulses developed under in this project can be used for laser-driven particle acceleration, and which currents are achievable. For this, we will first measure the laser-induced damage thresholds (LIDTs) of high-performance Silicon nanostructures at various repetition rates / interaction regimes (burst mode) and at different wavelengths. These measurements will be done at INPHYNI in collaboration with FAU.

Objective 3: electron acceleration - Laser acceleration experiments will be conducted at FAU with the mid-infrared driver developed at INPHYNI. Based on the measured LIDT, the FAU will conceive a structure optimized for mid-infrared driver. The structure and the optical feeding setup will be optimized to couple the maximum laser pulse energy. This includes conceiving and building the required pulse front tilting setup, matched to both the electron initial energy and the design gradient, as well as a cylindrical focus system.

TASKS AND RESPONSIBILITIES

- Demonstrate a high level of commitment and personal initiative to undertake the necessary efforts to ensure good progress in the research project, which includes the development of the research methodology, the analysis and communication of the research results;
- Be aware of, and adhere to, the generally accepted norms of responsible conduct of research: document your work, promoting open science through research data management, respect the intellectual property rights relating to concepts and findings of CNRS or any other relevant institution, proper care of materials and equipment etc;
- Together with your supervisor, build a plan for your PhD program: research-related training and activities, as well as soft skills. These will help advance the quality and efficiency of your research and prepare you for a professional career. You ensure that the activities in the context of the doctoral program are completed within the proposed deadlines;
- Follow the training sessions (90 hour-standard course) of the ED.SFA PhD program of the Université Côte d'Azur, attend the induction /welcome meeting and the symposium of the ED.SFA;
- Supervise Bachelor/Master theses and tutoring students.

WHAT DO YOU HAVE TO OFFER?

You hold a MSc. (or equivalent) in physics, have done an experimental master project (or equivalent) in an optical, atomic, molecular or high-energy physics lab. Other skills and documents that would benefit your application are:

- hands-on experience with experimental techniques used in ultrafast optics, such as electronics, lasers, fibers, optics;
- working knowledge of a programming language (Python, Matlab or equivalent);
- good English oral and written communication skills;
- good French oral and written communication skills are not mandatory but are appreciated.

To foster diversity in our research group, we will especially appreciate applications from groups underrepresented in science.

OUR OFFER

We offer a temporary contract of **3 years**, starting at the **beginning of September 2024**, latest. You will be enrolled in the ED.SFA PhD program of the Université Côte d'Azur. The gross monthly salary is **~XXXX €.**
The student will work closely with a multidisciplinary team of scientists and instrumentation experts. and will have access to state-of-the-art laboratory facilities and collaborative partnerships with leading international astronomical institutions. Besides the salary and a challenging environment, we offer you: 5 weeks of holidays, a complete educational program for PhD students with multiple courses on topics and soft skills, help with accommodation, partial coverage of public transport costs etc.

ABOUT THE NICE INSTITUTE OF PHYSICS

The Nice Institute of Physics is a mixed research unit (UMR 7010) affiliated with the University Côte d'Azur (UCA) and the French National Center for Scientific Research (CNRS). INPHYNI's activities are structured around three, principal axes: waves and quantum physics, photonics and nonlinear physics, complex fluids, and biophysics. Projects developed around these topics cover theoretical, fundamental, and experimental aspects as well as applications. These projects benefit especially from the support of technological platforms and technical shared services. Université Côte d'Azur (UCA) now includes 17 major academic establishments around the historic university core to create one of France's top 10 research-intensive universities. UCA was awarded the prestigious 'Initiatives of Excellence' certification label, which highlights the quality of its research and ensures that it has a high visibility international profile.

CONTACT AND JOB APPLICATION

If you feel the profile fits you, and you are interested in the job, we look forward to receiving your application. Please submit your application apply online via the button below and by email to:

nicolas.forget@inphyni.cnrs.fr

Applications should include the following information:

- a detailed CV including the months (not just years) when referring to your education and work experience;
- a letter of motivation;
- the name and email address of at least one reference who can provide a letter of recommendation.

The first interview will usually be held within a few weeks of the reception of an application from a suitable applicant.

PREREQUISITES - Master's degree with experience in ultrafast optics, nonlinear optics, integrated optics or physics. Please provide a CV, a cover letter, and a description/report of a significant project/work you have done in the last few years.

CONTACTS – Nicolas Forget, Research Director at InPhyNi, nicolas.forget@inphyni.cnrs.fr
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[1] K. J. Leedle et al., "Phase-dependent laser acceleration of electrons with symmetrically driven silicon dual pillar gratings," Opt. Lett., vol. 43, no. 9, pp. 2181–2184, 2018.
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[4] C. Gaida, et al., "Watt-scale super-octave mid-infrared intrapulse difference frequency generation." Light: Science & Applications 7.1 (2018): 94.
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