Internship research project (2026)

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" AI aided methods for nonlinear integrated silicon photonics: from numerical modelling to optical bench experiments"

Research project description:

The internship proposed topic lies in the field of integrated silicon photonics [1]. The integration of various materials and the possibility of realising a wide range of functions through the advanced miniaturisation of **integrated photonics** offer very broad opportunities for a continuum of studies ranging from fundamental physics to applications in surface footprints of the mm^2 comprising easily hundreds of integrated components and complex circuits for light path and manipulation. In another direction, the realisation of nonlinear optical functions has been the source of previous scientific works from the creation of a ruby laser in 1960 to very recent developments aimed at creating attosecond lasers by generating high harmonics used to probe the fundamental electronic and spin processes of matter. **Nonlinear optics** has also led to a wide range of applications, including the modulation/switching or processing of optical signals, analysis of the surface of materials, optical imaging, medical treatments, etc. The work carried out has historically been developed in free-space optics, then in optical fibres. Merging the two fields of the photonic integration and nonlinear optics has raised a strong interest in recent years, paving the way for various demonstrations including supercontinuum generation, the realization of stable frequency combs spanning over one octave [2], etc. Planar integrated photonics based on platforms like Si, SiN, or AlGaAs enable tight mode confinement and long interaction lengths, making them excellent candidates for exploiting optical nonlinearities (e.g., Kerr, χ^2, two-photon absorption). These effects underpin key functions such as Frequency comb generation, supercontinuum generation, nonlinear wavelength conversion (FWM, SHG, DFG), all-optical signal processing, quantum photon pair generation. However, **realizing efficient nonlinear processes on-chip is not straightforward**. Device performance depends on many strongly coupled parameters, and **analytic design is often insufficient**. Moreover, realistic nonlinear photonic devices involve **multiple geometric parameters** (e.g., waveguide width, height, gap, curvature radii, grating periods) **and material properties**. Nonlinear efficiency also depends simultaneously on phase matching, mode confinement, group-velocity dispersion (GVD), coupling coefficients, and loss.
The proposed research topic will aim at developing **AI assisted numerical modelling of nonlinear optical phenomena in silicon photonics** [3]. Owing to the complexity of the cascade of nonlinear physical effects arising in a realistic device, **AI can indeed find unconventional geometries** (e.g., multi-section tapers, asymmetric waveguides, coupled resonators) that human intuition might overlook. These studies will take into account **data scarcity**. High-quality nonlinear simulation data are indeed expensive to generate, and most datasets are too small or too narrow to train robust large AI models. **Dimensionality reduction** of the set of opto-geometrical parameters **in case of nonlinear problems** will be explored. Physical constraints (symmetries, conservation laws, modal structure) may also reduce the effective degrees of freedom compared to raw geometric parameter count.

Two kinds of structures will be primarily considered: i) Arbitrary shape photonic waveguides, which width profiles can be optimized to target dedicated physical effects; ii) Coupled photonic crystal cavities systems capable of generating combs of frequencies for FWM experiments.

We are seeking a **motivated Master's intern** to join our team and contribute to the AI-assisted numerical modelling of nonlinear optical effects in integrated photonics. This internship offers the opportunity to develop models leveraging both your technical skills and creativity to explore innovative solutions in nonlinear photonics.

Your tasks will include:

- Designing and optimizing photonic structures through advanced numerical simulations and AI algorithms, with a focus on nonlinear optical phenomena.

- Generating GDS masks using Python scripts to prepare structures for electron-beam lithography, ensuring precision in the fabrication process.
- Observing clean room fabrication even if direct hands-on fabrication may be limited by time constraints of the internship period.
- Participating to experiments on optical benches to characterize the physical properties of the fabricated devices, validating theoretical predictions with real-world measurements.

We are looking for a student eager to work at the intersection of theory, simulation, and experiment, with a strong interest in integrated photonics and nonlinear optics. We encourage applicants who are proactive, detail-oriented, and open-minded.

For any question, you can send an email to eric.cassan@universite-paris-saclay.fr

Our web page: https://minaphot.c2n.universite-paris-saclay.fr/en/

References:

[1] **"Roadmap on silicon photonics"**
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[2] **"Octave-spanning dissipative Kerr soliton frequency combs in Si_3N_4 microresonators"**
M. H. P. Pfeiffer, C. Herkommer, J. Liu, H. Guo, M. Karpov, E. Lucas, M. Zervas, T. J. Kippenberg
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[3] **"Interfacing Nanophotonics with Deep Neural Networks:AI for Photonic Design and Photonic Implementation of AI**
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