Internship proposal (2025)

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"2D- material-augmented nonlinear silicon photonics"

Research project description:

The integration of various materials and the possibility of realising a wide range of optical functions on a chip through the advanced miniaturisation of guided optics in silicon photonics offer very broad opportunities for a continuum of studies ranging from fundamental physics to applications **[1]**. A recent trend of the field has been devoted to the investigation of second and third-order optical nonlinearities of the available materials for the realization of integrated light optical sources, including frequency comb **[2]** or supercontinuum **[3]** sources. In the race to exploring new phenomena and implement key on-chip functionalities (e.g. light emission, light modulation, beam stearing, etc), the list of available materials is a key point. The set of most classical materials available in silicon photonics includes Si itself, with additionally SiO_2, and Si_3N_4 or silicon-rich nitride. The properties of these materials have been pushed to their limits, enabling a high-level of integration and the realization of complex circuits (e.g. see **[4]**). To go beyond, other approaches are now necessary.

In this context, the **topic of the research proposal** consists in contributing to the **exploration of the possible use of two-dimensional mono-atomic materials (graphene, MoS_2, WS_2) with a view to overcoming limitations of silicon or silicon nitride photonic structures**. By integrating 2D materials on photonic waveguides, as illustrated in a particular configuration in **Fig. 1**, it is possible to exploit some of their exceptional physical properties to control the propagation of guided modes, whose interaction (overlap) with 2D materials can be exploited and optimised. This approach opens up a vast field of possibilities, ranging from the study of the physical properties of 2D materials to applications. **The intern candidate will focus in particular on the study of the third-order non-linear optical properties of these materials, with a view to demonstrating optical pulse compression in hybrid optical waveguides coated with 2D materials** **[5]**. A series of studies aiming at understanding the influence of the number of atomic monolayers and to propose, produce and characterise hybrid optical waveguides and photonic structures based on this integration approach will be carried out.

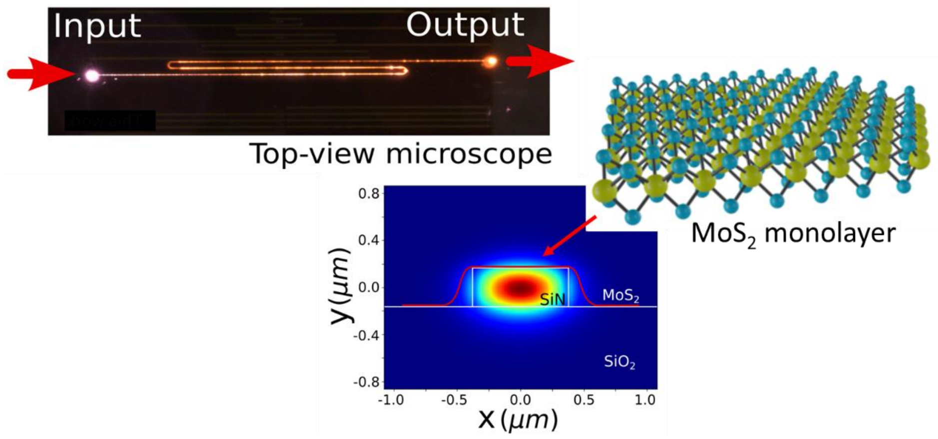

Fig. 1: General principle for the integration of nanomaterials with silicon photonic waveguides

Objective 1: Design and characterize optical hybrid waveguides (silicon nitride based)
Objective 2: Characterize their effective third-order nonlinearity (Kerr like)
Objective 3: Explore schemes to realize optical pulse compression based on these waveguides (from >1ps down to 200fs or below)

The research facilities:
The candidate will be hosted by the "Minaphot" group at C2N (https://minaphot.c2n.universite-paris-saclay.fr/en/). The research environment comprises the clean room facilities of C2N and the simulation and experimental setups of the Minaphot group (see **Fig. 2**).

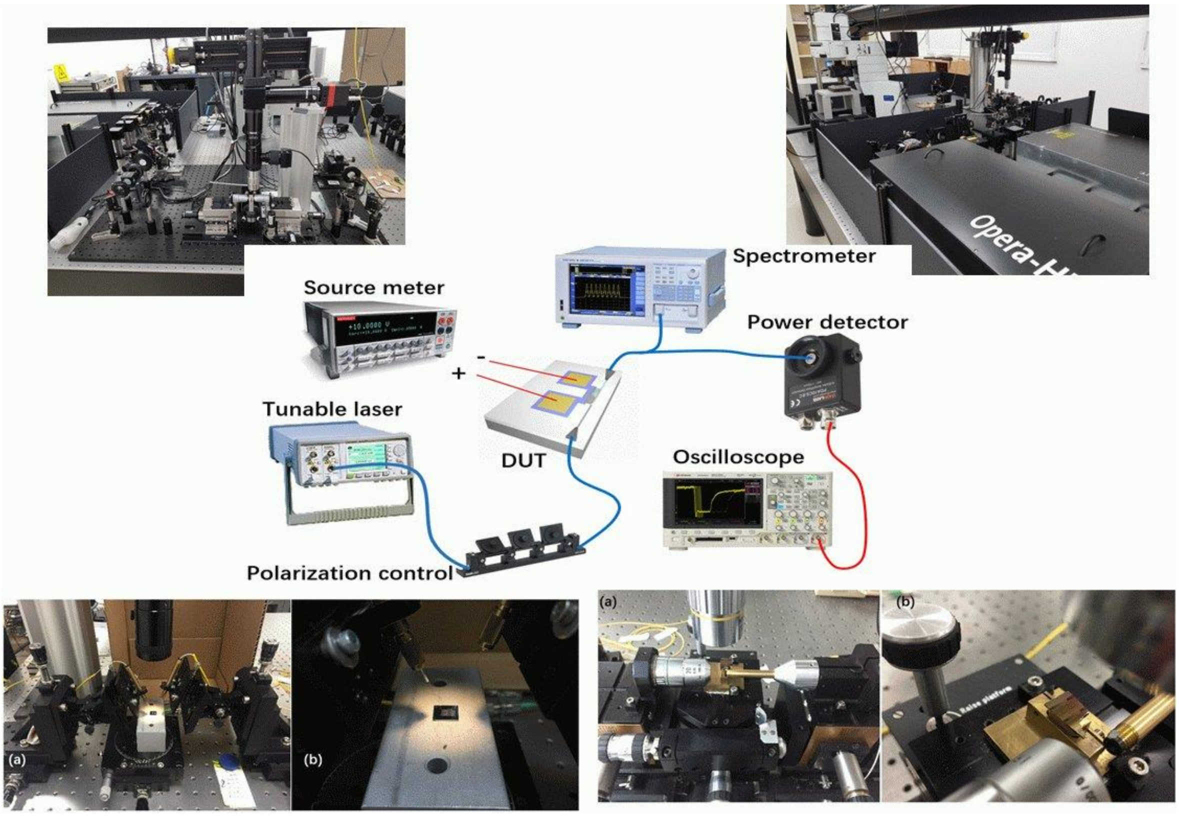

Fig.2: Some illustrations of the experimental facilities available at the C2N laboratory host team / UPSaclay-CNRS.

What we expect from you:

- Enthusiasm and strong involvement in your project, a growing autonomy
- Taste for Optics&Photonics, including experiments AND simulation
- Ability to communicate and work in a group, an open-minded attitude and an ability to conduct a project by addressing questions to relevant people around you

For any questions, to ask for references, and to apply:

eric.cassan@universite-paris-saclay.fr

References:

[1] **"Roadmap on silicon photonics"**
David Thomson, Aaron Zilkie, John E Bowers, Tin Komljenovic, Graham T Reed, Laurent Vivien, Delphine Marris-Morini, Eric Cassan, Léopold Virot, Jean-Marc Fédéli, et al.
Journal of Optics 18 (7), 073003, https://iopscience.iop.org/article/10.1088/2040-8978/18/7/073003

[2] **"Octave-spanning dissipative Kerr soliton frequency combs in Si3N4 microresonators"**
M. H. P. Pfeiffer, C. Herkommer, J. Liu, H. Guo, M. Karpov, E. Lucas, M. Zervas, T. J. Kippenberg
Optica 4 (7), 684 (2017) , https://doi.org/10.1364/OPTICA.4.000684

[3] **"Supercontinuum generation in a nonlinear ultra-silicon-rich nitride waveguide"**
Cao, Y., Sohn, BU., Gao, H. et al
Scientific Reports **12**, 9487 (2022). https://doi.org/10.1038/s41598-022-13734-9

[4] **"Silicon nitride passive and active photonic integrated circuits: trends and prospects"**
Chao Xiang, Warren Jin, and John E. Bowers
Photonics Research 10, A82-A96 (2022), https://doi.org/10.1364/PRJ.452936

[5] **"Hybrid integration of 2D materials for on-chip nonlinear photonics"**
Vincent Pelgrin, Hoon Hahn Yoon, Eric Cassan, Zhipei Sun
Light: Advanced Manufacturing (2023), 4:14 - https://doi.org/10.37188/lam.2023.014