Proposition de SUJET DE STAGE M2R/Ingénieur-3A

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"Hybrid integration of chalcogenides and silicon metamaterials for the mid-IR"

SCIENTIFIC PROJECT:

Mid-infrared (mid-IR) photonics is a key technology for many applications including free-space optical communications, long-range LIDAR, thermal imaging, infrared homing, countermeasures and biochemical sensing. Systems implemented for these applications are typically composed of discrete elements (lasers, modulators, detectors) packaged in rack-size modules. To shrink down the size, weight, power consumption and cost of such systems, photonic integrated circuits (PIC) offer a particularly attractive solution. Leveraging from the availability of high-quality wafer scale silicon thin films, mature patterning capabilities thanks to fabrication advances of the complementary metal-oxide-semiconductor (CMOS) technology and its potential to monolithically integrate electronics and photonics, silicon (Si) has emerged, over the past two decades, as the most prominent waveguide material for the implementation of PIC.

Nanostructures silicon metamaterials developed by the Silicon photonics team at C2N allowed the demonstration of key passive [1] and nonlinear devices [2] in the mid-IR. However, silicon-based PIC, also known as silicon photonics (SiP), does not address all requirements of these emerging applications that would benefit from PIC, especially in mid-IR wavelength range in particular due to its indirect bandgap which prevent efficient light emission.

In this context, recent preliminary results have demonstrated strong rare earth (RE)-doped chalcogenides (ChG) mid-IR emission under "standard" near-IR pumping [3] and the ease of integration of such materials onto Si waveguides [4]. These striking results open a new route to develop broadband and flexible mid-IR sources on silicon photonics by combining ChG wide mid-IR transparency, mid-IR emission from RE ions and fully functional standard silicon photonics platform.

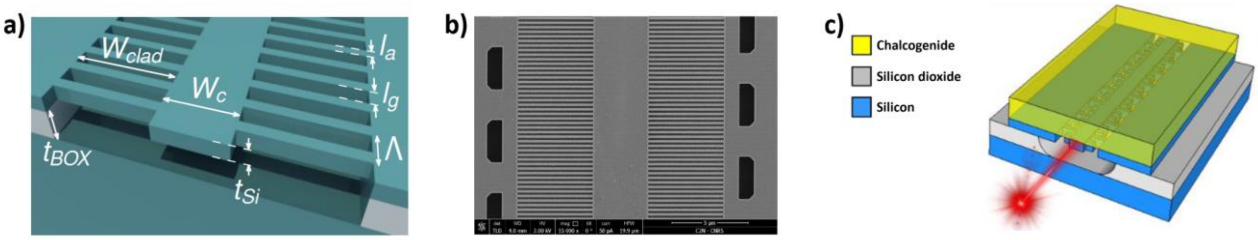

Fig. 1: *Subwavelength metamaterial waveguides for the mid-IR previously developed by the Silicon photonics team in C2N:* ***a)*** *schematic view,* ***b)*** *scanning electron microscope image.* ***c)*** *Schematic view of hybrid integration of chalcogenide on silicon metamaterial waveguide.*

The goal of this internship is to develop nanostructured silicon photonic devices for integration of chalcogenides, targeting applications in light generation in the mid-IR. These devices would be key explore a new approach for the development of on-chip broadband mid-IR sources and tunable lasers by exploiting the hybrid integration of emitting RE-doped ChG with SWG-Si photonics nanostructures.

The research activity will include theoretical study to understand the key parameters governing sub-wavelength engineered waveguides, simulation work to extract main relationships between geometrical parameters and properties of the waveguide, and experimental characterizations of novel sub-wavelength structures with and without chalcogenides. During the internship, the student will be actively involved in the current research activity of the group, collaborating with PhD students, postdocs and researchers of different research backgrounds and nationalities.

This project can be continued and expanded as a PhD within the frame of the national ANR Project KASHMIR.

METHODOLOGY OF THE STAGE

1) Bibliography study: Reading of a pre-selection of the main papers related to the topic, e.g. [5], to understand the physical principles of sub-wavelength engineering.

2) Simulation of sub-wavelength waveguides: Optical and mechanical analysis of sub-wavelength waveguides using commercial software (Lumerical, Comsol) and numerical tools developed by MIT (MEEP, MPB).

3) Experimental characterization of sub-wavelength photonics structures: Linear and nonlinear optical characterizations of novel sub-wavelength waveguides.

VALUED QUALITIES IN THE STUDENT

- Curiosity for novel research experiences and fields.

- Creativity and pro-activity in the search for innovative solutions and approaches.

- Capability to communicate and share results in a multidisciplinary and multi-nationality environment.

BIBLIOGRAPHY RELATED TO THE TOPIC

[1] T. T. D. Dinh et al. “Mid-infrared Fourier-transform spectrometer based on metamaterial lateral cladding suspended silicon waveguides,” Opt. Lett. 47, 810 (2022). https://doi.org/10.1364/OL.450719

[2] T. T. D. Dinh et al. “Dispersive wave control enabled by silicon metamaterial waveguides,” *arXiv:2201.06516* (2022). https://arxiv.org/abs/2201.06516

[3] G. Louvet et al., “Co-sputtered Pr^{3+}-doped Ga-Ge-Sb-Se active waveguides for mid-infrared operation,” Opt. Express 28, 22511 (2020). https://doi.org/10.1364/OE.398434

[4] S. Serna et al., “Engineering third-order optical nonlinearities in hybrid chalcogenide-on-silicon platform,” Opt. Lett. 44, 5009 (2019). https://doi.org/10.1126/science.aar6113