Proposition de SUJET DE STAGE M2R/Ingénieur-3A

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"Subwavelength nanostructured Si photonic devices"

SCIENTIFIC PROJECT:

Driven by the impressive development in the nanofabrication technologies and the nanoscale engineering, **silicon photonics has rapidly become the platform of choice for on-chip integration of high performing photonic devices**. At the beginning, these photonic circuits mainly targeted the realization of ultra-wideband transceivers for datacom applications, e.g. in big datacenters. However, this enormous technology development has opened new opportunities for Si photonics beyond datacom, with a growing interest in sensing [1], microwave photonics [2] and quantum photonics [3] applications. Aiming to meet the requirements of these envisioned applications, Si photonics is expanding its frontiers by exploring wider wavelength ranges and new physical phenomena. On the one hand, a great effort is being devoted to increase the operation wavelength from the near-infrared towards the mid-infrared, thus covering the full Si transparency window, between 1.1 μm and 8 μm wavelengths. This new wavelength range holds the promise to create exciting new opportunities, e.g. in absorption spectroscopy and nonlinear photonics. On the other hand, light-sound (photon-phonon) interactions in Si waveguides is raising a growing interest. Specifically, stimulated Brillouin scattering is being investigated, targeting key functionalities in all-optical circuits and microwave photonics signal processing.

In this context of new applications, new wavelength ranges and new physical phenomena, researches in sub-wavelength engineering of Si structures can play a key role. Patterning Si with features smaller than half of the wavelength (well within the capabilities of standard large volume fabrication processes) has proven to be a simple and powerful tool to tailor material properties [4,5]. **This innovative approach releases new degrees of freedom that allow unprecedented flexibility in the design of light-matter interactions, chromatic dispersion and light propagation in general.** Indeed, sub-wavelength engineering has already been used to demonstrate stat-of-the-art performance in several key devices, including low loss waveguides and crossings, micro-resonators, fiber-to-chip grating couplers and power splitters (see Fig. 1).

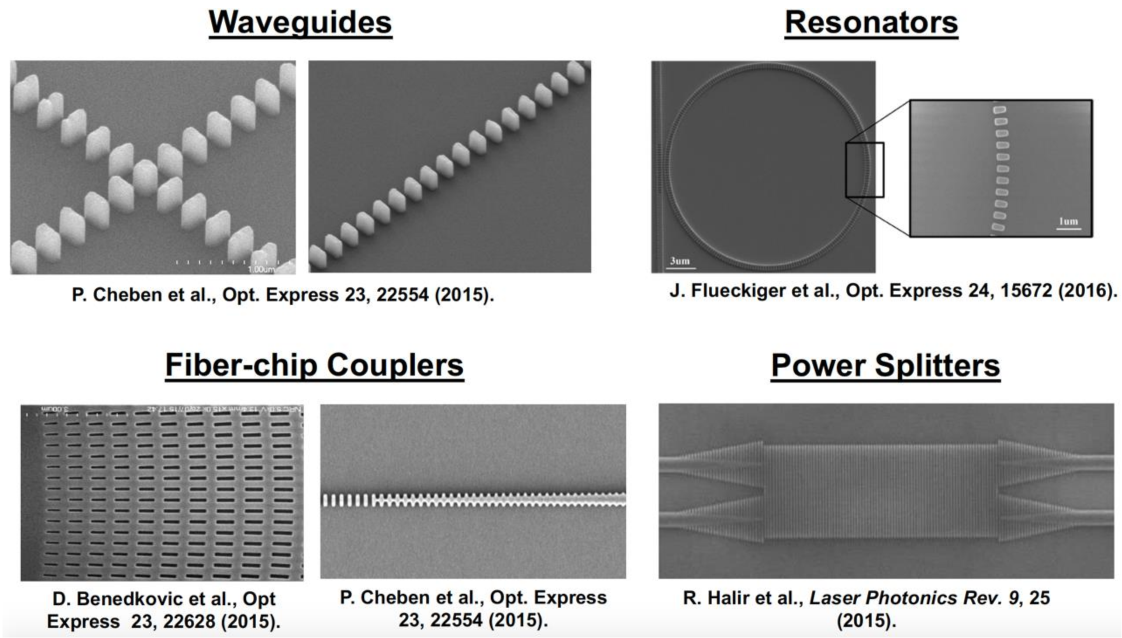

Fig. 1: Examples of key building blocks based on sub-wavelength engineering, with performances and functionalities that go far beyond what is possible with standard approaches.

The goal of this internship will be to model, design and experimentally characterize new types of sub-wavelength nanostructured silicon photonics devices, targeting ultra-wideband operation and enhanced light-matter and light-sound interactions.

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. 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 within the frame of a PhD (ANR, European Union, or European Research Council projects).

METHODOLOGY OF THE STAGE

1) Bibliography study: Reading of a pre-selection of the main papers related to the topic, e.g. [4], to understand the physical principles of sub-wavelength engineering.

2) Simulation of sub-wavelength waveguide structures: 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] M.-C. Estevez, et al. “Integrated optical devices for lab-on-a-chip biosensing applications,” Laser Photonics Rev. 6, 463–487 (2012). https://doi.org/10.1002/lpor.201100025

[2] J. Capmany, and D. Novak, “Microwave photonics combines two worlds,” Nature Photon. 1, 319–330 (2007). https://doi.org/10.1038/nphoton.2007.89

[3] J. W. Silverstone, et al. "On-chip quantum interference between silicon photon-pair sources," Nat. Photon. 8, 104–108 (2014). https://doi.org/10.1038/nphoton.2013.339

[4] R. Halir, et al. “Waveguide sub-wavelength structures: a review of principles and applications,” Laser Photonics Rev. 9 (1), 25-49 (2015). https://doi.org/10.1002/lpor.201400083