PhD project: Subwavelength silicon photonic nanostructures for applications in the near-IR and mid-IR

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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 [4]. 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 [5,6]. 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 [6]. **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).

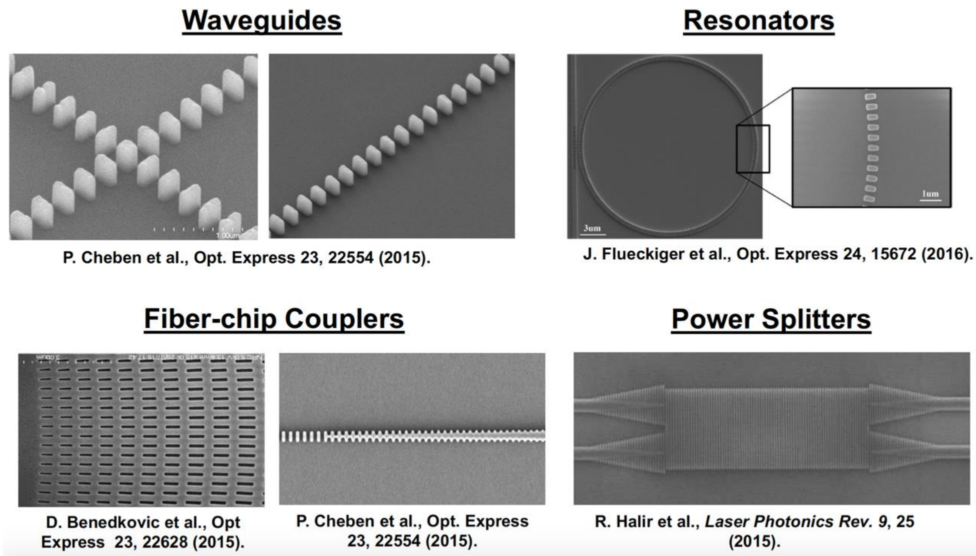

Fig. 1: Examples of key building blocks based on sub-wavelength engineering, with performances and functionalities that go far beyond what is possible with standard approaches.

The goal of this PhD is to develop new types of sub-wavelength nanostructured silicon photonics devices, targeting ultra-wideband operation and enhanced light-matter interactions.

This work will be done in the framework of the ANR project MIR-Spec, in close collaboration with ST-Microelectronics (www.st.com) and start-up mirSense (www.mirsense.com)

The research activity will include:

- Theoretical study of sub-wavelength engineered devices (using commercial software) extract main relationships between geometrical parameters and properties of the waveguide.

- Fabrication of nano-structured Si photonics devices in our clean-room facilities.

- Experimental characterization of linear and nonlinear properties of developed devices.

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. Soref. "Mid-infrared photonics in silicon and germanium," Nat. Photon. 4, 496 (2010). https://doi.org/10.1038/nphoton.2010.171

[5] M. Maldovan, "Sound and heat revolutions in photonics," Nature 503, 209–217 (2013). https://doi.org/10.1038/nature12609

[6] E. Kittlaus, et al. "Large Brillouin amplification in silicon," Nat. Photon 10, 463–467 (2016). https://doi.org/10.1038/nphoton.2016.112

[7] 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