

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

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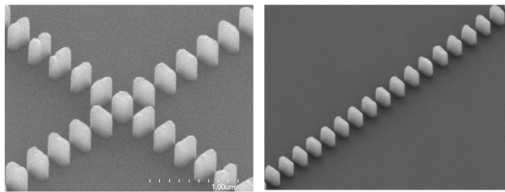
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Driven by the impressive development in the nanofabrication technologies and the nanoscale engineering, **silicon photonics has rapidly become the platform of choice for on-chip integration of high performing photonic devices**. At the beginning, these 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 [4,5]. 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 [6,7]. Specifically, stimulated Brillouin scattering is being investigated, targeting key functionalities in all-optical circuits and microwave photonics signal processing.

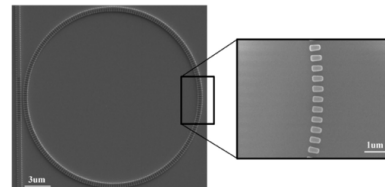
In this context of new applications, new wavelength ranges and new physical phenomena, researches in sub-wavelength engineering of Si structures can play a key role. Patterning Si with features smaller than half of the wavelength (well within the capabilities of standard large volume fabrication processes) has proven to be a simple and powerful tool to tailor material properties [8,9]. **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 state-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).

Waveguides



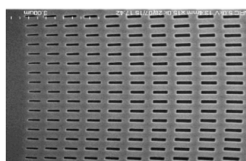
P. Cheben et al., Opt. Express 23, 22554 (2015).

Resonators

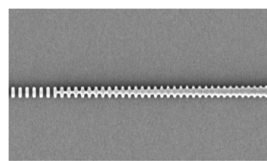


J. Flueckiger et al., Opt. Express 24, 15672 (2016).

Fiber-chip Couplers

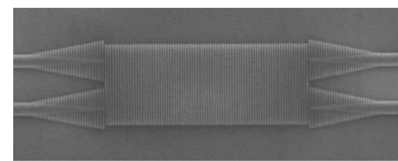


D. Benedkovic et al., Opt Express 23, 22628 (2015).



P. Cheben et al., Opt. Express 23, 22554 (2015).

Power Splitters



R. Halir et al., Laser Photonics Rev. 9, 25 (2015).

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 National 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

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- [9] 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>