PhD position

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Brillouin optomechanics in Silicon germanium photonics circuits

Brillouin scattering is a nonlinear optical phenomenon based on the interaction between light and the mechanical modes of a structure. Brillouin scattering allows the generation of new optical frequencies, and is of great interest for the generation of **ultra-stable microwave signals or for opto-microwave conversion**. **Optomechanics, or the coupling between optical mode and mechanical mode**, has recently seen a lot of attention in silicon photonics community, the idea being to benefit from high-volume and low-cost manufacturing techniques [1-4]. However, silicon-on-insulator guides, commonly used in silicon photonics, do not have naturally a good confinement of mechanical modes, while **Germanium is expected to offer good optical and mechanical mode confinement simultaneously** [5].

In parallel, Ge-rich SiGe photonics has been developed in our group in the recent years, in strong collaboration with Politecnico Di Milano. First works targeted mainly electro-optical devices in the near IR range exploiting Ge quantum well structure [6]. More recently it was demonstrated that **graded index SiGe waveguide can be used in a large wavelength range in the mid-IR,** and a large range of passive building bloc including Mach Zehnder interferometers or integrated resonators have been obtained [7]. Then, the demonstration of large bandwidth optical source on chip based on non-linear optical effects of SiGe waveguides [8], and the realization of optoelectronic devices (modulator and photodetector) recently completed the photonics platform [9].

In this context, the objective of the work is to study Germanium on silicon structures, which seem promising for simultaneous confinement of optical and mechanical modes.

In this context, the goal of the PhD project is to study and develop a novel platform for Brillouin optomechanics, relying in SiGe waveguides on Si substrates. Different strategies will be employed to achieve simultaneously mechanical and optical confinement, and innovative devices will be developed based on the research findings.

The research activity will include:

- **Modeling of the photonics devices** (optical, mechanical, electro-optical simulation using commercially available software and developing code interfaces (python/matlab)
- Design and fabrication of the devices in in-house clean room
- **Experimental characterizations** of the devices, using near IR and mid-IR optical benches

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References

[1] Raphaël Van Laer, Bart Kuyken, Dries Van Thourhout , Roel Baets , Interaction between light and highly confined hypersound in a silicon photonic nanowire, Nature Photonics volume 9, pages 199–203 (2015)

[2] Gustavo S. Wiederhecker ; Paulo Dainese ; Thiago P. Mayer Alegre, Brillouin optomechanics in nanophotonic structures, APL Photonics 4, 071101 (2019), https://doi.org/10.1063/1.5088169

[3] Benjamin J. Eggleton, Christopher G. Poulton, Peter T. Rakich, Michael. J. Steel and Gaurav Bahl, Brillouin integrated photonics, Nature Photoenics, 2019, 664, (2019)

[4] Paula Nuno Ruano, Jianhao Zhang, David Gonzalez-Andrade, Daniele Melati, Eric Cassan, Pavel Cheben, Laurent Vivien, Norberto Daniel Lanzillotti-Kimura, and Carlos Alonso-Ramos, Stimulated Forward Brillouin Scattering in

[5] C. Wolff, R. Soref, C.G. Poulton, and B.J. Eggleton, Germanium as a material for stimulated Brillouin scattering in the mid-infrared, Optics Express, 22 (25), 30735 (2014)

[6] D. Marris-Morini, P. Chaisakul, M-S Rouifed, J. Frigerio, D. Chrastina, G. Isella, S. Edmond, X. Le Roux, J-R. Coudevylle, L. Vivien, Towards low energy consumption integrated photonic circuits based on Ge/SiGe quantum wells, Nanophotonics. Volume 2, Issue 4, 279-288, DOI: 10.1515/nanoph-2013-0018, (2013)

[7] Natnicha Koompai, Thi Hao Nhi Nguyen, Victor Turpaud, Jacopo Frigerio, Virginia Falcone, Stefano Calcaterra, Luca Lucia, Adel Bousseksou, Raffaele Colombelli, Jean-Rene Coudevylle, David Bouville, Carlos Alonso-Ramos, Laurent Vivien, Giovanni Isella, Delphine Marris-Morini, Long wave-infrared integrated resonators in the 7.5-9 μm wavelength range, Applied Physics Letters,123 (3) (2023)
https://hal.science/hal-04149167

[8] M. Montesinos-Ballester, C. Lafforgue, J. Frigerio, A. Ballabio, V. Vakarin, Q. Liu, J. M. Ramirez, X. Le Roux, D. Bouville, A. Barzaghi, C. Alonso-Ramos, L. Vivien, G. Isella, and D. Marris-Morini, On-Chip Mid-Infrared Supercontinuum Generation from 3 to 13 μm Wavelength, ACS Photonics, 7, 3423-3429, (2020)
https://hal.science/hal-04077434

[9] Thi Hao Nhi Nguyen, Victor Turpaud , Natnicha Koompai , Jonathan Peltier , Stefano Calcaterra , Giovanni Isella, Jean-René Coudevylle , Carlos Alonso-Ramos , Laurent Vivien , Jacopo Frigerio and Delphine Marris-Morini
Integrated PIN modulator and photodetector operating in the mid-infrared range from 5.5 μm to 10 μm
Nanophotonics, (2023)
https://hal.science/hal-04419849