Post doctoral position

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Mid-IR photonic integrated circuits

Mid-infrared (mid-IR) spectroscopy is a nearly universal way to identify chemical and biological substances, as most of the molecules have their vibrational and rotational resonances in the mid-IR wavelength range. The development of mid-IR photonic circuits on silicon chips has recently gained a lot of attention, as it could offer high performance, low cost, compact, low weight and power consumption photonic circuits. Among the different materials available in silicon photonics, germanium (Ge) and silicon-germanium (SiGe) alloys with a high Ge concentration are particularly interesting because of the wide transparency window of Ge extending up to 15 µm.

In this context, we aim at demonstrating breakthrough in the field of mid IR photonic integrated circuits based on Ge-rich SiGe materials. The main achievements obtained in the recent years are described below:

- It has been demonstrated that a Ge-rich graded SiGe platform relying on a graded SiGe layer epitaxially grown on Si substrate, presents definitive advantage in terms of mid-IR photonics platform, as a single waveguide can be used with low propagation losses **in an unprecedent wavelength range, up to 11 wavelengths, for both TE and TM polarization** [1].

- A whole set of passive devices has then been demonstrated: (i) Optical spectrometers working in a wide mid-infrared spectral range have been developed using a **classical Fourier-transform approach** [2], leading to the first on-chip spectrometer **working from 5 to 8.5 µm wavelength.** (ii) a new spectrometer has then been proposed **to overcome the tradeoff between bandwidth and resolution of classical approaches**. To this end, the spatial heterodyning of Mach Zehnder arrays is combined with optical path tuning by thermo-optic effect. A mid-infrared SiGe spectrometer was then demonstrated with a resolution better than 15 cm^{-1} and a bandwidth of 603 cm^{-1} near 7.7 µm wavelength with a 10 MZI array [3]. Finally resonators have been investigated in different configurations, based on racetrack devices and Bragg grating based Fabry-Perot cavities corresponding to the first integrated resonators reaching 8 µm wavelength [4,5]

- Active devices is a challenge to achieve a complete mid-IR photonics platform. As a preliminary step towards the implementation of a high-performance integrated modulator in the mid-IR regime, all-optical modulation has been demonstrated [6]. **This first experimental demonstration of optical modulation in a mid-IR PIC**, carried out in long wave infrared (LWIR) regime confirms theoretical free-carrier electro-absorption predictions paves the way for efficient electrically driven optical modulators. On another side on-chip broadband light sources are of significant interest for compact sensing devices. In that regard, supercontinuum generation offers a mean to efficiently perform coherent light conversion over an ultrawide spectral range, in a single and compact device. **On-chip two-octave supercontinuum generation in the mid-infrared wavelength, ranging from 3 to 13 µm** and covering almost the full transparency window of germanium has been demonstrated recently [7]. Such an ultrawide spectrum is achieved thanks to the unique features of Ge-rich graded SiGe waveguides, which allow second-order dispersion tailoring and low propagation losses over a wide wavelength range. This results also rely on the use of a Ge-rich approach which benefits from a large Kerr coefficient and tight confinement, thus, enhancing the nonlinear processes.

As a next step we would like to develop active devices in the mid-IR, that can have a strong impact for all applications. Both electro-optic and non-linear devices are targeted. Furthermore the combination of Quantum Cascade Lasers (QCL) with Silicon-Germanium (SiGe)-based mid-IR photonic integrated circuits (PIC) benefiting from both on-chip optoelectronic devices and optical non-linear functionalities will be targeted.

The research activity will include:

- **theoretical study and electro/optical simulations** (linear and non-linear devices)
- **clean room fabrication**
- **experimental characterizations** using mid-IR optical bench existing in the group

The repartition between the three aspects can be tuned as a function of the Post-Doc researcher skills and motivation. The post-doc researcher will be actively involved in the current activity of the group, collaborating with PhD students, and researchers of different research backgrounds and nationalities. The work is done in the framework of a collaboration with L-Ness lab (Politecnico di Milano) and IES (Université de Montpellier).

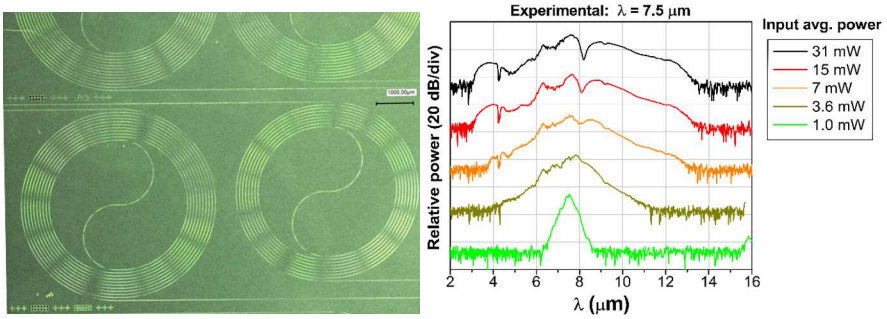

Fig. 1: left: picture of integrated mid-IR photonic integrated circuit based on Ge-rich SiGe platform / right: Output power spectral density experimentally measured in a 5.5 mm-long waveguide for different input average power values at 7.5 μm fixed wavelength. For the sake of clarity, each trace has been shifted by 30 dB.

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