PhD position

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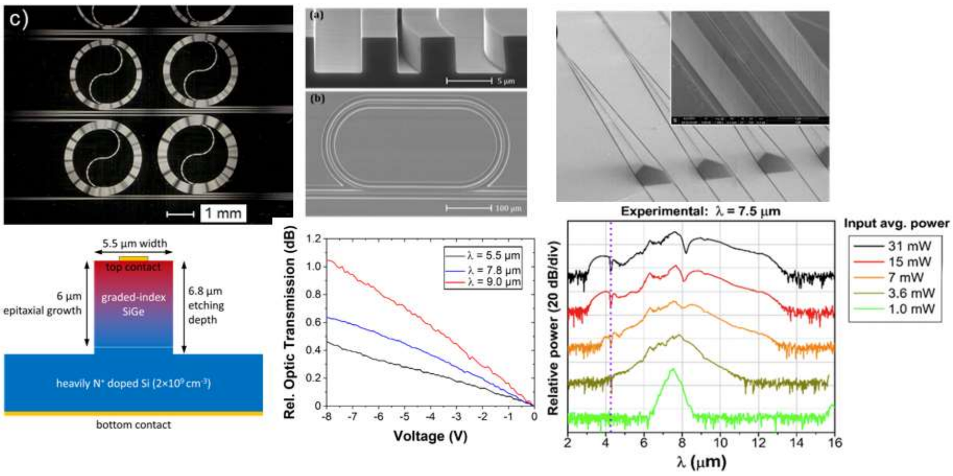
Integrated mid-IR photonics for sensing and astrophotonics

Mid-infrared (mid-IR) spectroscopy is a universal way to identify chemical and biological substances. Indeed, when interacting with a light beam, most molecules are responsible for absorption at specific wavelengths in the mid-IR spectrum, allowing to detect and quantify small traces of substances. In the recent years there has been a lot of efforts towards the miniaturization and/or the integration of mid-IR spectrometers. This would allow not only to reduce the size, cost and weight of the systems but also to open new opportunities based on the integration of complex optical functions. Applications are foreseen in a large range of domains, from fundamental physics including the analysis of biochemical reactions or the study of the universe, to the large scale commercialisation of compact chip scale sensors, for example for gas leak detection systems.

Ge-rich SiGe photonics has been developed in our group in the recent years, in strong collaboration with Politecnico Di Milano. It has been 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, integrated resonators have been obtained. Then, the demonstration of large bandwidth optical source on chip based on non-linear optical effects of SiGe waveguides, and the realization of optoelectronic devices (modulator and photodetector) complete the photonics platform.



Examples of SiGe mid IR photonics circuits (SEM view, schematic view and experimental results)

In this context the objective of the PhD is **to explore the potential of mid-IR SiGe photonics circuits for two promising applications, i.e. the development of compact sensors for gaz sensing [1] and the exploration of the potential of SiGe photonics for astrophotonics** [2].

The main challenges that have been identified up to now are listed hereafter:

- For optical sensing applications, the coupling of the mid-IR photonics circuits with a compact electrically driven QCL pump laser source will be a key aspect to demonstrate. Furthermore a “sensing” part on the photonic circuits, where light will interact with the medium to analyse will be developed. Among the different possibilities, the use of subwavelength structures, pedestal waveguides or suspended thin films with a large evanescent field fraction will be investigated.

- Astrophotonics is the use of photonic techniques and devices to manipulate the collection and processing of light for the purpose of improving the ability to probe and hence understand the universe. Simple devices such as on chip couplers and / or spectrometers operating in the deep mid-IR wavelengths can already have a clear impact on astronomical instruments. In this field, the main challenge will be related with the optical losses that will have to be reduce at maximum.

Within the PhD, different strategies will be explored, to solve each of these different challenges. The research activity will include:

- theoretical study, optical and electro-optical simulations, device designs
- clean room fabrication including definition of process flows, and mask designs
- experimental characterizations of passive and active devices within mid-IR optical bench

The work will be developed in strong collaboration with Politecnico Di Milano, while collaboration with experts in sensing and astrophotonics will be looked for during the PhD.

[1] Jane Hodgkinson and Ralph P Tatam 2013, Meas. Sci. Technol. 24 012004
[2] Lucas Labadie, A report on the status of astrophotonics for interferometry and beyond, arXiv:2208.05380