Proposition de SUJET DE STAGE M2R/Ingénieur-3A

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"Subwavelength silicon photonics for applications in the near-IR and mid-IR"

Silicon photonics has emerged as a key technology for sensing applications, including medical diagnostics, hazard detection, air and water quality monitoring, or industrial process control [1]. On-chip photonic sensors based on evanescent field detection have demonstrated high sensitivity, label-free, and real-time operation [1]. However, they rely on chemical or biological functionalization of the chip surface to yield the detection specificity. This complicates device integration and compromises durability and reusability of the sensors. **A promising alternative approach is absorption spectroscopy**. By monitoring the spectral characteristics of the light propagating through a medium, it is possible to identify the absorption peaks associated to the fingerprints of the present elements [2]. The analysis of this spectrum provides high-precision information of the nature and concentration of these elements. The mid-Infrared (mid-IR) wavelength range, between 2 µm and 20 µm, contains the strongest absorption peaks of many chemical and biological substances, such as industrial gases (CO_2, CH_4, NH_3), bacteria (Campylobacter, Salmonella) or glucose. Hence, **mid-IR absorption spectrometers have a unique potential to perform high-precision, label-free, real-time detection of multiple target molecules within a single sensor**.

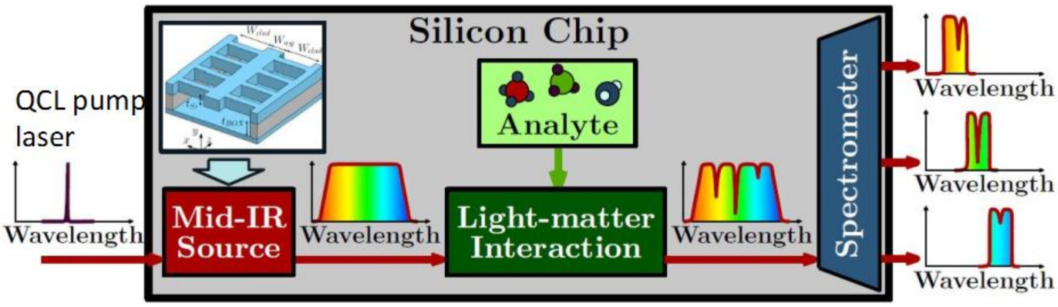

Fig. 1: Schematic view of mid-IR SOI absorption spectrometer.

Mid-IR free-space absorption spectrometers have demonstrated detection with outstanding precision and versatility. However, they are bulky and high-cost, precluding their use in widespread high-volume applications. On-chip integration would provide superior robustness and reduced cost. The high-quality materials and the mature high-volume fabrication processes of the silicon-on-insulator (SOI) platform provide an immense potential for the development of high-performance, and low cost mid-IR photonic circuits. Unfortunately, despite the wide Si transparency range (1.1 µm - 8 µm wavelength), the mid-IR operation of SOI is strongly limited by the absorption of the buried oxide (BOX) layer beyond 3.6 µm wavelength [3].

The goal of this stage is to use **subwavelength silicon nanostructures** to locally remove the BOX layer, and exploit the full Si transparency range up to 8 µm, thereby outperforming current state of the art. **The novel optical properties found in these structures, along with the capability to control their optical responses, has opened new prospects for controlling and manipulating light in planar waveguide circuits** [4,5,6].

Figure 1 schematically describes the envisioned mid-IR absorption spectrometer on SOI platform. A narrowband quantum cascade laser (QCL) pump is injected into the Si chip (using efficient grating couplers), to feed a nonlinear spectral broadening source, e.g. supercontinuum. Then, this wideband light is marked with the absorption fingerprints of the target molecules, and a wavelength filter array is used to retrieve this spectral information, enabling precise detection and quantification.

The goal of this stage is to design, model and characterize 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) **and <u>can be extended into a PhD</u>**.

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.

<u>VALUED QUALITIES IN THE STUDENT</u>

- 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.

<u>BIBLIOGRAPHY RELATED TO THE TOPIC</u>

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