Proposition de SUJET DE STAGE M2R/Ingénieur-3A

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"Neuromorphic silicon photonic circuits for smart gas sensors"

SCIENTIFIC PROJECT:

Air pollution poses a great environmental risk to health, accounting for nearly half a million premature deaths each year in Europe. Ubiquitous, real-time air quality monitoring could reduce the negative impact of pollution. However, air pollution monitoring generally relies on costly (k€ range), complex stationary equipment, that limits its widespread deployment. **The Silicon Photonics team at C2N leads a new European project, SYMPHONY that aims at developing a new technology combining different silicon photonics platforms and silicon microelectronics** to enable the implementation of dense networks of cloud-connected, low-cost (< 100 €), and portable (5-80 cm^3 size) easy-to-use smart sensors, capable of multi-target detection in air pollution monitoring. The SYMPHONY consortium comprises well-established industrial actors, including a large company in optical gas sensing (Senseair), SMEs in the internet of things (CyRIC), packaging (microTEC), photonic integrated system development (Resolute Photonics), a large silicon microelectronics and photonics foundry (STMicroelectronics), together with research-related institutions, which are pioneers in the fields of silicon photonics (C2N), on-chip spectroscopy (CSIC), mid-IR sensing (KTH), and neuromorphic photonics and deep learning algorithms (AUTH).

SYMPHONY will address this challenge by making key developments in silicon photonics, neuromorphic circuits, artificial intelligence (AI), integration, and packaging, while exploiting state-of-the-art silicon microelectronics for ultra-low power edge computing with AI, and the connected sensor network for spatially-resolved analysis and prediction.

The envisioned SYMPHONY sensing platform (see Fig. 1) relies on a network of remote smart sensors, connected to the cloud for processing and analysis of large amounts of data, e.g., for spatially resolved analysis or correction/calibration/reconfiguration of remote sensors. The smart sensors implement optical absorption spectroscopy for multi-gas monitoring. Different silicon photonic technology platforms are used to cover a wide spectral range. The detection of target molecules is performed by a neural network implemented in the remote sensors (edge computing) comprising photonic and microelectronic modules. Silicon neuromorphic photonic integrated circuits (PICs) collect optical absorption information, conduct initial processing and translate this information into electrical signals.

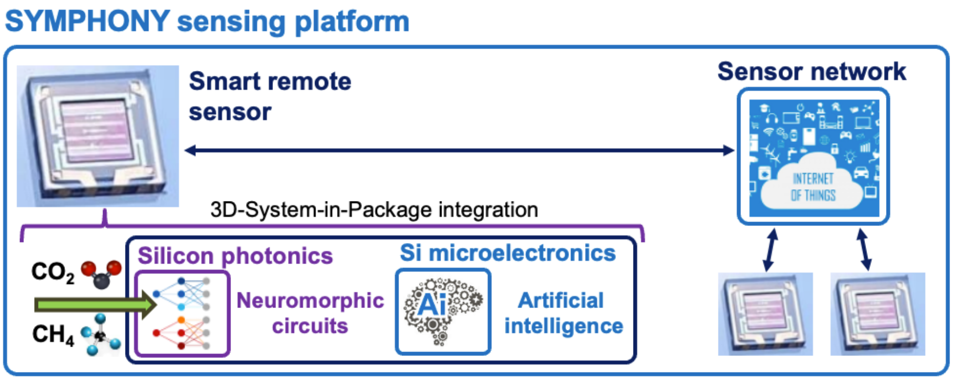

Fig. 1: The SYMPHONY sensing platform: cloud-connected network of smart sensors harnessing silicon photonics, silicon microelectronics and AI to provide low-cost miniaturized multi-target detection for applications in environmental monitoring, industrial process control and safety.

The goal of this internship will be to study different architectures for the implementation of photonic neural networks and algorithms compatible with the envisioned SYMPHONY scheme. Simplified models of Si sensors will be combined with deep learning algorithms develop pattern recognition tools for advanced detection and processing functionalities.

This stage project can be continued and expanded as a PhD within the frame of the European collaborative project SYMPHONY. The PhD and will include theoretical study to understand the major limitations of current silicon photonics sensors and the basics of deep learning algorithms. Also, a modelling and simulation works will be carried out to develop simplified models of the sensors, generate meaningful training data and develop deep-learning models. The student will be also actively involved in the current research activities of the group, collaborating with PhD students, postdocs and researchers of different research backgrounds and nationalities.

METHODOLOGY OF THE STAGE

1) Bibliography study: Reading of a pre-selection of the main papers related to the topics of silicon photonics sensors and deep learning algorithms, e.g. [1-5].

2) Modelling of silicon photonics sensors: numerical simulations and constituent equations will be used to develop simplified model of silicon photonic sensors that allows fast analysis and generation of meaningful datasets to train deep learning algorithms.

3) Simulation of deep learning algorithms: deep learning models will be developed and trained to allow detection and classification of data provided by the simplified model of Si photonic sensor.

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

[1] A. Herrero-Bermello et al. "On-chip Fourier-transform spectrometers and machine learning: a new route to smart photonic sensors," Opt. Lett. 44, 5840 (2019).

[2] T. T. D. Dinh et al. "Silicon photonic on-chip spatial heterodyne Fourier transform spectrometer exploiting the Jacquinot's advantage," Opt. Lett. 46, 1341 (2021).

[3] D. González-Andrade et al. "Broadband Fourier-transform silicon nitride spectrometer with wide-area multiaperture input," Opt. Lett. 46, 4021 (2021).

[4] F. Ottonello-Briano et al. "Carbon dioxide absorption spectroscopy with a mid-infrared silicon photonic waveguide," Opt. Lett. 45, 109 (2020).

[5] T. T. D. Dinh et al. "Mid-infrared Fourier-transform spectrometer based on metamaterial lateral cladding suspended silicon waveguides," Opt. Lett. 47, 810 (2022).