MEMBER OF ECREAM

European Cluster of Research projects for Environmental and Agri-food Monitoring

https://ecream.eu

Symphony

SYMPHONY newsletter 2

Jul-2025

- Development of a one chip fluidic for gas identification from microTEC
- Micro-spectrometers at CSIC
- SOI photonics platform development at KTH and CNRS

More information is available on the project website https://symphonyproject.eu

This photo shows a scanning electron microscope image of the metamaterial-based ultra-broadband TE_0 to TE_2 mode exchanger. [Image courtesy of CSIC.]

Consortium

cnrs · Aristotle University of Thessaloniki · ST · VIVID COMPONENTS · RESOLUTE PHOTONICS · bert · CYRIC · KTH VETENSKAP OCH KONST · microTEC Gesellschaft für Mikrotechnologie mbH · CSIC · Sensair

Please join the SYMPHONY LinkedIn group to keep up with project updates!

https://www.linkedin.com/company/symphony-project

Coordinator	Carlos Ramos	Université Paris Saclay - CNRS	carlos.ramos@c2n.upsaclay.fr
Admin	Bruce Napier	Vivid Components Germany	bruce@vividcomponents.co.uk

Funded by the European Union

This project has received funding from Horizon Europe, the European Union's Framework Programme for Research and Innovation, under Grant Agreement No. 101135523 (SYMPHONY). Funded by the European Union. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union. The European Union cannot be held responsible for them.

Development of a one chip fluidic for gas identification

microTEC Gesellschaft für Mikrotechnologie mbH

Physical principles

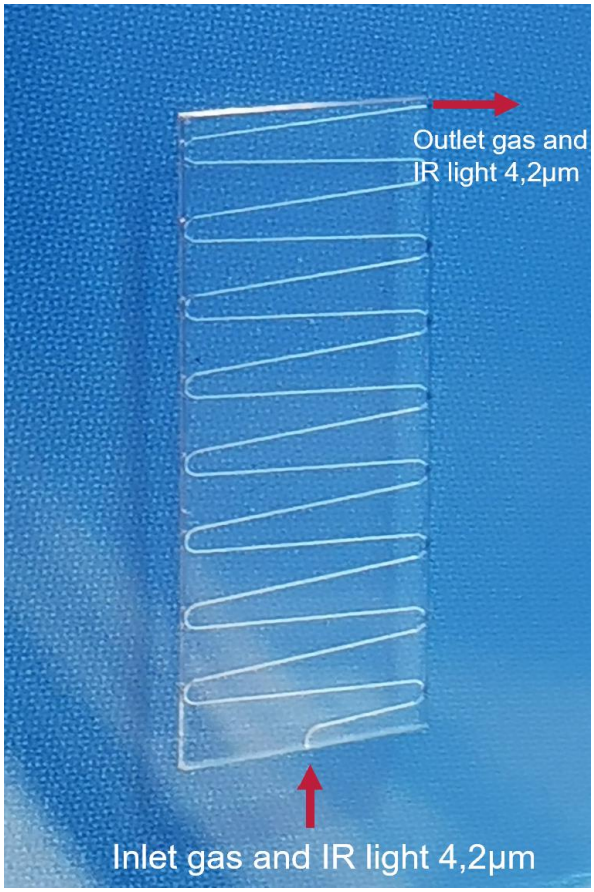
Gases exhibit characteristic light absorption when photon energies match quantum mechanical transitions. While atoms show discrete absorption lines—such as the sodium D-line at 589 nm—molecules display broader absorption bands in the infrared range due to vibrational and rotational transitions, such as CO_2 at 4.3 µm. These absorption features follow quantum mechanical selection rules and are influenced by pressure broadening and Doppler effects.

Sensor design and operating principle

The sensor features a hollow waveguide fabricated using Rapid Micro Product Development (RMPD) 3D printing. The inner surfaces of the waveguide are metallised through Physical Vapor Deposition (PVD). This design allows the simultaneous propagation of both light and gas within the waveguide. When the gas absorbs light, the medium heats up, creating a chimney effect that induces convective gas flow against gravity. The velocity of this flow correlates with the gas's absorption characteristics.

Measurement techniques

At the waveguide output, a spectral analysis of the transmitted light is conducted to identify the gas. Simultaneously, the flow dynamics are characterised by measuring the temperature difference between the waveguide inlet and outlet. An optoacoustic detection system complements these methods: a pulsed laser generates pressure waves either in the metallised channel walls or directly in the gas. These pressure waves are detected with the laser on the metallisation of the wave guide wall, capturing their propagation characteristics such as travel time and amplitude. The combination of spectroscopic, thermal, and acoustic measurements enables high-precision gas analysis.



Fluidic chip for gas identification.

Manufacturing advantages

The RMPD 3D printing technique allows precise fabrication of complex microchannel geometries, with cross-sections tailored to the desired optical cut-off wavelength. Subsequent PVD metallisation ensures optimal optical properties and enhances optoacoustic signal generation. This manufacturing approach facilitates cost-effective mass production while maintaining high measurement accuracy.

For more information please contact
Reiner Goetzen
goetzen@microtec-d.com

Funded by the European Union

First results

A chip 5 × 15 × 1 mm^3 with a 10 × 10 μm^2 channel metallised with silver has a length of 90 mm and is irradiated with light 850 nm from a VCSEL. There is air in the optical hollow waveguide. The voltage measured at the output with a photodiode result in an attenuation of 2.2 dB/cm.

Applications

This innovative gas sensor is particularly suited for environmental monitoring, industrial process control, and medical diagnostics. Its compact design and integrated measurement methods offer significant advantages over conventional gas sensors in terms of functionality, precision, and scalability.

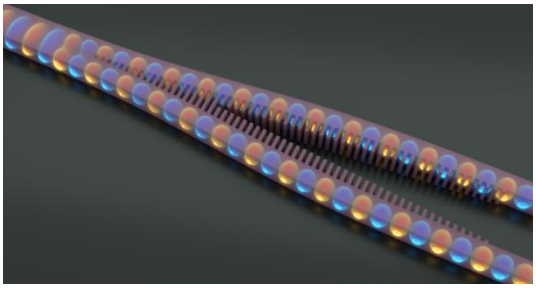
Silicon photonics micro-spectrometers

CSIC

In the first year of the SYMPHONY project, the CSIC team focused on developing key silicon photonics components aimed at enhancing the performance of on-chip micro-spectrometers. The devices—a subwavelength-engineered Y-junction power splitter and a mode exchanger—were designed to address fundamental needs such as low-loss operation, robustness against fabrication deviations, and efficient handling of multiple modes and polarisations.

SWG-engineered Y-junction power splitter

The team developed a novel multimode Y-junction power splitter incorporating two tailored subwavelength grating (SWG) regions [1]. This design enables smooth modal evolution and significantly reduces losses typically caused by the abrupt index transition at the junction tip. Its experimental validation demonstrated excellent performance, with insertion losses below 0.2 dB for TE_0 and TE_1 modes, and below 0.4 dB for the TM_0 mode over a 250 nm bandwidth, along with high resilience to ±10 nm fabrication deviations.

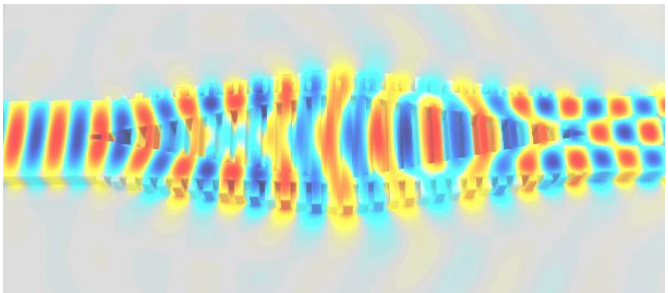


Three-dimensional schematic of the SWG-assisted Y-junction comprising two S-shaped arms and an SWG-metamaterial-assisted transition.

Compared to the state-of-the-art, the device exhibits the broadest experimentally validated bandwidth for a multimode, dual-polarisation power splitter on the silicon-on-insulator platform—while maintaining low loss and a compact footprint.

TE_0–TE_2 Mode Exchanger

An innovative mode exchanger composed of two mirrored Y-junctions connected via an SWG metamaterial region [2] was also developed within the framework of the SYMPHONY project. The integration of SWG nanostructures in the design enable precise control of mode exchange through different propagation constants in the arms and metamaterial and takes advantage of dispersion engineering to broaden the operating bandwidth.



Real part of the electric field (E_y) propagating along the device showing TE_0 to TE_2 conversion.

Measurements confirmed insertion loss below 0.4 dB and extinction ratio exceeding 18 dB across nearly 150 nm bandwidth, which represents the broadest reported bandwidth for TE_0–TE_2 mode conversion. This efficient mode manipulation offers promising capabilities for bimodal sensing and enhanced light–analyte interaction.

Outlook

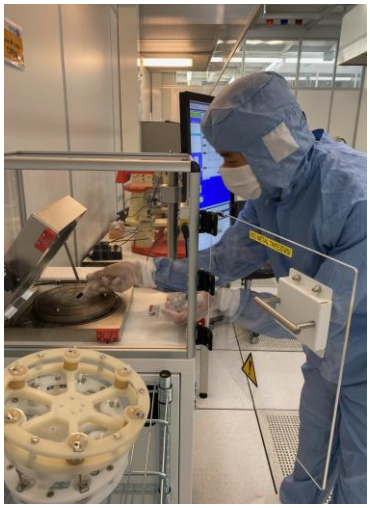
These photonic building blocks address key challenges in micro-spectrometer systems, including low-loss operation, fabrication robustness, and efficient mode and polarisation handling. Their performance supports improved signal-to-noise ratio, spectral resolution, and scalable integration. Both devices are now patented and have attracted initial interest from two Spanish companies.

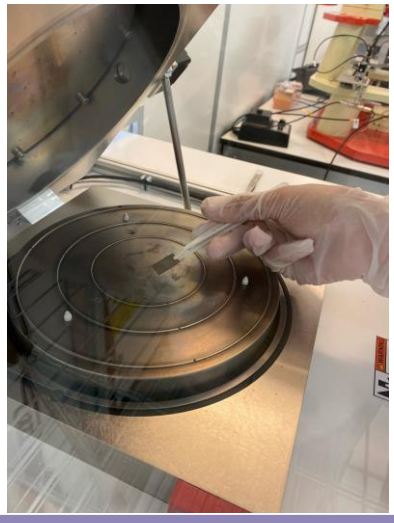
[1] R. Fernández de Cabo *et al.* "Broadband mode exchanger based on subwavelength Y-junctions," Nanophotonics **13** (2024): 4037-4045. (2024). https://doi.org/10.1515/nanoph-2024-0291

[2] R. Fernández de Cabo, Raquel *et al.* "Extending the spectral operation of multimode and polarization-independent power splitters through subwavelength nanotechnology," Optics & Laser Technology **181** 111921 (2025). https://doi.org/10.1016/j.optlastec.2024.111921

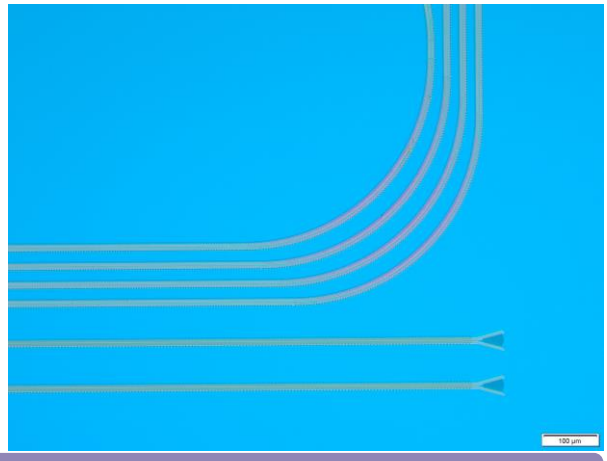
Silicon-on-insulator photonics platform

In the SYMPHONY project, both near- and mid-infrared photonics technologies are being advanced to enable next-generation optical sensing solutions. The teams at KTH Royal Institute of Technology and CNRS are leading the development of a mid-infrared suspended silicon-on-insulator (SOI) photonics platform, specifically designed for high-performance gas sensing. A key innovation is the integration of on-chip thermal emitters made from molybdenum disilicide ($MoSi_2$), a robust ceramic material known for its excellent heating properties and stability at high temperatures. This platform leverages the state-of-the-art silicon photonics technology, ensuring compatibility with mature fabrication processes while achieving low optical losses and strong light-matter interaction. The suspended SOI structure further enhances performance by enabling efficient mid-infrared propagation and interaction with target gases. KTH's contributions are central to SYMPHONY's goal of pushing the boundaries of mid-infrared photonics in environmental and industrial sensing technologies.





[Left and centre] The KTH team at work in the lab
[Below] Example of SOI waveguides fabricated at KTH.



For more information please contact: Pen-Sheng Lin pslin@kth.se

Funded by the European Union