RAVEN
Ultra high resolution atmospheric sensors

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THE PROJECT

RAVEN will develop two innovative miniaturised gas sensor modules—one covering the VIS-SWIR range and the other the MIR range—to detect multiple pollutants and greenhouse gases (CO_2, CO, O_3, CH_4, N_2O, CH_3OH, NH_3, NO_2) at ppb-level sensitivity. These modules will be combined into a compact, energy-efficient multi-sensing system that leverages on-chip high-power dual-supercontinuum light sources and quantum-inspired data analysis for enhanced selectivity and low power consumption. This all-in-one solution will help Europe meet the objectives of the EU Green Deal while advancing the bloc's photonic technology capabilities.

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Welcome to the first RAVEN project newsletter!

As we head into summer, we're excited to celebrate RAVEN's first anniversary. Over the past year, our consortium has made strong progress across several key work packages—from breakthroughs in optical source technology to advances in data processing and sensor chip development.

Here's a quick look at what we've achieved so far:

In Work Package (WP) 1: Supercontinuum source development (PIC1), PICOPHOTONICS (PICO) has made significant strides in the development of the first preliminary microchip laser source for the RAVEN system. The latest version of the source delivers substantially increased maximum power while improving overall system stability by nearly an order of magnitude. These improvements are critical for enabling robust performance in compact sensing devices. As part of this advancement, **PICO** has delivered the first dual-wavelength laser to project partners working on supercontinuum development. Furthermore, efforts to develop a compact, dual-wavelength microchip source have yielded great results in generating a novel design for a microchip laser. This innovation has shown excellent performance and has now been filed for patent protection, marking a significant technical achievement in the RAVEN project.

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In WP2: Sensing chip development (PIC2), several partners are advancing the development of RAVEN's sensor chip and optical waveguide components.

At **Grenoble INP** (**G-INP**), researchers have designed and fabricated a 1-meter-long spiral waveguide on an ion-exchange glass platform (Fig.1) . The waveguide operates in single mode at 1550 nm, with low propagation losses of just 0.3 dB/cm. The spiral waveguide will be a key component of the PIC2 sensing chips, designed for use in harsh environments. It will be integrated with a Bloch Surface Wave platform to target gas detection within the 600 to 1700 nm spectral range.

At **Jean Monet University** (**UJM**), the focus is on developing grating in/out coupler to enable efficient coupling between waveguide modes and Bloch Surface Wave modes. So far, a first design using a high-index grating has been developed, which enables excitation via the -1^{st} diffraction order. This approach has shown promising efficiency, achieving a coupling length under 1 mm. By the end of the year, **UJM** will collaborate closely with **G-INP** to experimentally characterise the grating outcoupler on glass waveguides.

In RAVEN, **Polytechnic University of Turin** (**POLITO**) is responsible for developing the sensing chip (PIC2), specifically focusing on designing the multilayer structure that supports Bloch Surface Waves at the targeted wavelengths of 670 nm and 710 nm. In the past year, they have designed and simulated a one-dimensional photonic crystal (1DPC) capable of supporting BSWs at these wavelengths. Through dispersion and sensitivity analyses, **POLITO** has identified an optimal multilayer configuration: a stack of nine alternating SiO_2 and TiO_2 layers (excluding the termination layer), with individual layer thicknesses of 110 nm for SiO_2 and 80 nm for TiO_2 (Fig.2). The structure is capped with a 25 nm TiO_2 termination layer. This configuration delivers strong surface wave excitation and sensitivity for gas detection at the desired wavelengths (Fig. 3).

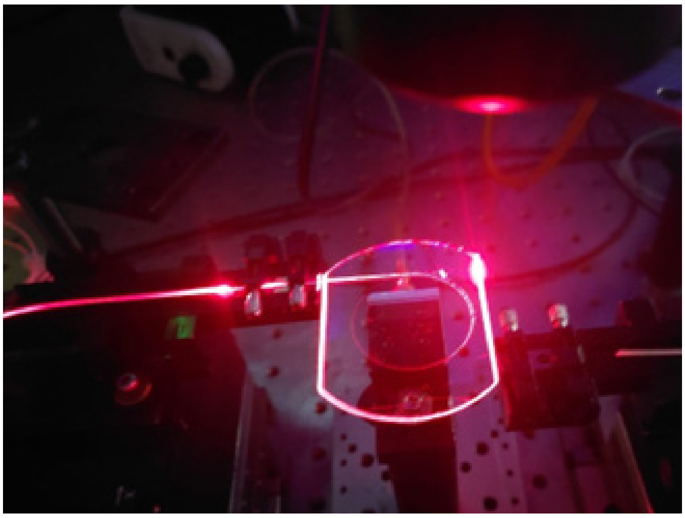

Fig.1: Spiral waveguide designed at G-INP.

Fig.2: Schematic of the 1DPC structure.

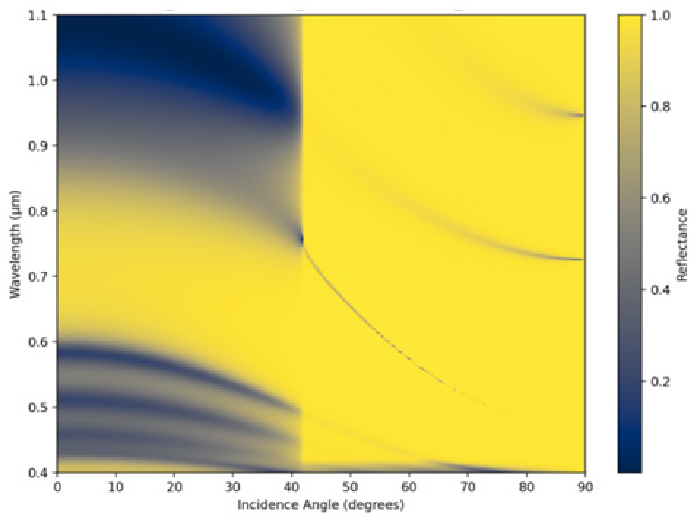

Fig.3: Reflectance as a function of wavelength and incident angle for the 1DPC.

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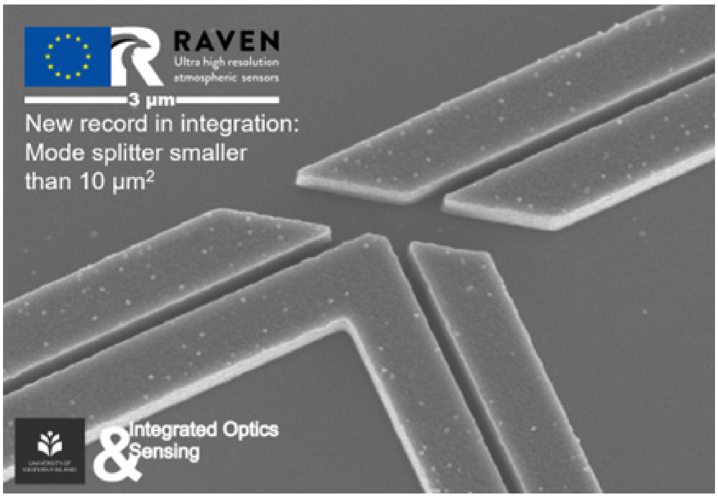
In WP3: Data processing chip development (PIC3), **University of Eastern Finland** (**UEF**) is leading the development of the optical data processing chip. Using a hybrid polymer–titania platform, **UEF** has fabricated waveguides with high light confinement properties. This technology ensures that light will remain within the waveguide even in tight bends and small structures. Based on this waveguides, **UEF** has successfully developed Mach–Zehnder interferometers occupying less than 10 µm² and capable of comparing two signals (see image below). These interferometers form the building blocks of RAVEN's future smart processing chip, which will be capable of on-chip optical signal comparison and



advanced spectral data analysis.
In WP3, **nanoGUNE** has been focusing on analysing absorption spectra of atmospheric gases under various environmental conditions, using datasets sourced from public databases. By applying data preprocessing methods such as filtering, scaling, interpolation, and correlation analysis, the team has selected robust datasets for developing multiparametric regression models. A partial least squares regression approach was used to establish the foundation for interpreting RAVEN's sensor outputs. In addition, **nanoGUNE** has developed a new machine learning algorithm that segments spectra, compares them to known reference patterns, and uses a voting mechanism to classify signals. This approach has shown significant improvements in detection accuracy, sensitivity, and overall performance in laboratory tests compared to traditional spectral analysis techniques, as shown in tests using spectral data from nanoGune lab.
Lastly, in WP3, our team at the **University of Gdańsk (UG)** has contributed deep theoretical insights from quantum metrology to guide the optimisation of the RAVEN sensor system. In any sensing setup, three key components define how efficiently information about a sample can be extracted: the probe (in this case, an electromagnetic field), the interaction mechanism (e.g., a sensing chip based on Bloch Surface Waves), and the measurement process. Using the concept of Fisher information—a metric that quantifies how much information can be gained from a single measurement—the **UG** team assessed various detection strategies. Their analysis showed that heterodyne measurements enable significantly more precise estimates of pollutant concentrations than conventional intensity or phase-shift methods. However, while powerful, heterodyne detection is not always quantum-optimal. The team is now focused on refining the measurement scheme further, aiming to approach the ultimate precision limits set by quantum mechanics.

We hope you enjoyed this closer look at the exciting progress made during the first year of the RAVEN project!

Stay connected with us through our website and social media channels for the latest news, updates, and insights about our project partners as we continue to push the boundaries of environmental sensing technology.

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