June 2024 Newsletter

THE PROJECT

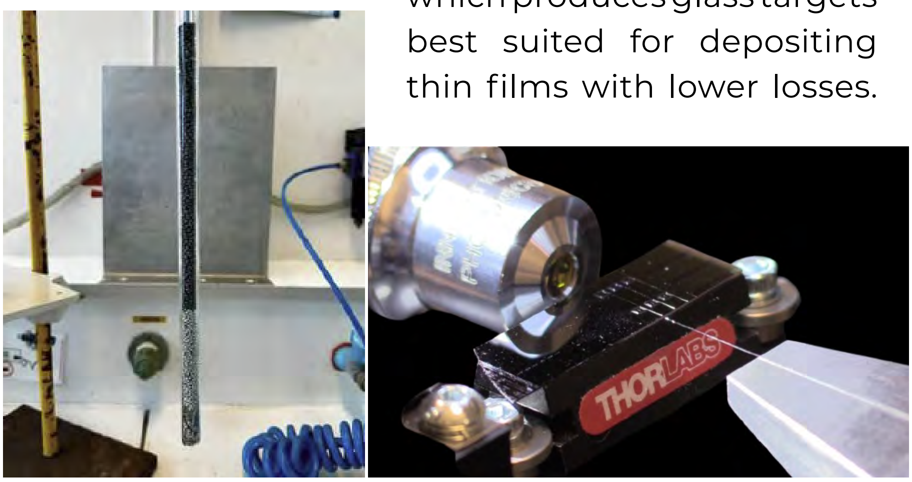
IBAIA will develop four innovative sensor modules to detect microplastics, organic chemicals, nutrient salts, and heavy metals, as well as measure salinity and physicochemical parameters. These sensors will be designed, tested, and integrated into a modular, advanced multi-sensing system. This system will provide a versatile, all-in-one solution for various users, addressing the growing demand for enhanced water quality monitoring to meet the objectives of the European Green Deal.

The project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement number 101092723/IBAIA. UK participants in Horizon Europe Project IBAIA are supported by UKRI grant number 10062902.

Funded by the European Union

Enabling mid-IR technology for the detection of organic molecules in water

The IBAIA research teams at CNRS-UR1, UP, Ifremer, Cedre, Scirpe, mirSENSE, and VIGO have been working on a chalcogenide-based **mid-IR** platform for detecting organic molecules in water using mid-infrared spectroscopy with evanescent waves. Developing this mid-IR sensor involves overcoming challenges related to minimising losses in the waveguides. To address these challenges, the IBAIA team is improving the quality of the glass target by optimising the fabrication process and glass composition, and reducing the roughness of the waveguide sides. Currently, the team is comparing the results from two different glass target fabrication methods - preparation from purified precursors and double distillation process - to determine which produces glass targets best suited for depositing thin films with lower losses.



Left: Preparation of the glass rod for the double distillation process. **Right:** waveguide on the prepared glass substrate and the optic bench environment.

Work is also ongoing on the prototype of the mid-IR sensor, focusing on the development and integration of its various components: the quantum-cascade laser (QCL) array, Chalcogenide glass waveguides, and the detector.

mirSENSE has been working on the laser design and has developed and characterised a High Heat Load (HHL) package for the QCL, which includes efficient thermal management. Meanwhile, VIGO has been working on the detector component and optimisation of the QCL structure.

HHL package prototype developed for the QCL in the mid-IR sensor module.

Development of interferometry-based sensors on oxide glass thin films in water

The IBAIA teams at UEF, TAU, and UP are developing key components for **VIS-NIR sensor** to enhance salinity measurements and microplastic detection.

At UP, efforts focus on fabricating and characterising erbium-doped tellurite thin films. By using radiofrequency magnetron sputtering, thin films with the desired thickness of the order of several hundred nanometers could be obtained while preserving the chemical composition to the extent that the deposition parameters are well controlled, particularly for the power density. Characterisation techniques included X-ray diffraction, atomic force microscopy, profilometry, transmission spectroscopy, variable angle spectroscopic ellipsometry, scanning electron microscopy with energy-dispersive X-ray analysis, and luminescence spectroscopy.

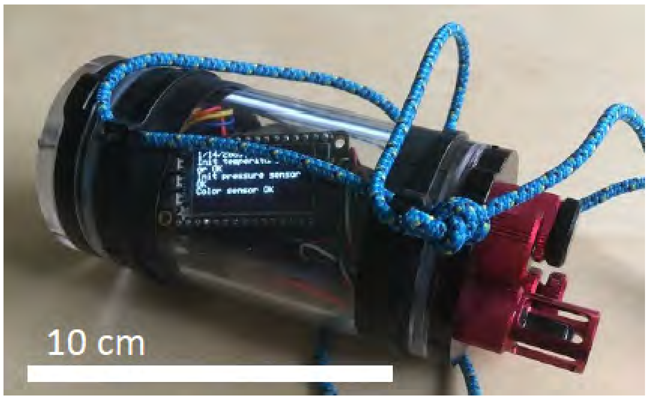
TAU has been developing oxide glass targets incorporating high concentrations of rare earth ions, particularly Er^{3+}, to enhance visible and NIR emission. They created new Er^{3+}-doped tellurite glasses with Ag_2O to improve thermal stability and reduce OH content, enhancing their spectroscopic properties.

At UEF, significant progress has been made in designing and fabricating a Mach-Zehnder interferometer (MZI). This MZI, built on a strip-loaded TiO_2 platform on an oxidized silicon wafer, features a novel design with large openings in the sensing region. This innovation increases sensitivity by using the analyte as the loading strip, allowing it to outperform conventional MZIs. The next steps will involve finalizing the design and conducting further experimental demonstrations to showcase its capabilities.

Tailored optodes and low-cost sensors for physico-chemical parameter (pH, O_2, CO_2) measurements

The CNRS-LAAS team has been developing prototypes of an oxygen optode that relies on phase shift measurements. This device features separate compartments for electronics and optics, making integration straightforward. Additionally, since the optode sensor will be submerged in water, waterproofing is guaranteed with a PDMS casing.

Testing conducted in the lab has included characterisation and comparison with a commercial portable reader, demonstrating excellent alignment in readout results.



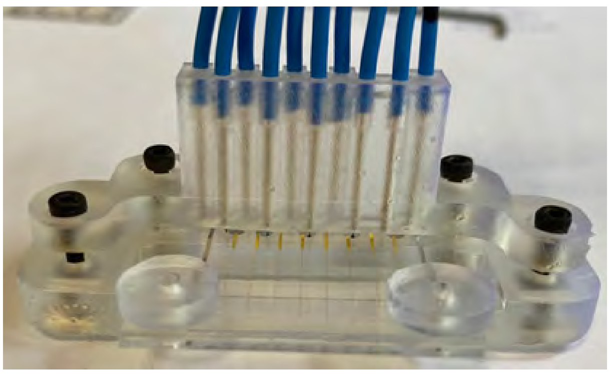
Oxygen optode readout field-deployable prototype.

Extensive review has also been done at UDE on optode sensor spots for CO_2 and pH, including the development of a plastic matrix film for photostability improvement.

The next steps for the O_2 optode will involve PCB fabrication, design of the 3D printed water-tight enclosure and field validation of the updated prototype. For CO_2 and pH optodes, work will be done on evaluating the optical filters and optoelectronic components and producing a readout device prototype.

Electrochemical sensor modules for metallic trace element and nutrient monitoring in complex water

IBAIA teams at BRGM, CNRS-UR1, Klearia, and Ifremer are collaborating on developing an electrode platform for electrochemical sensing of As, Cd, phosphate, and nitrate. Their work so far has been focusing on: (1) downsizing Au macro-electrodes to micro-electrodes and assessing the impact this has on As and nitrate sensitivity; (2) manufacturing and characterising C macro and microelectrodes, comparing them with AU microelectrodes, and (3) nanoelectrode assemblies.



IBAIA’s electrochemical sensor prototype.

Next steps involve Au and C microelectrode array production, achieving Cd detection on Bi modified C electrode and phosphate detection on Cu modified C electrode, combining electrochemistry to RAMAN spectroscopy, and Cu and Au nanoelectrode studies.

Where can you connect with IBAIA?

Date	Location	Details
June 05-07, 2024	NANOTECH France 2024, Paris, France	UMONS will present their work on the development of fluorine-free superhydrophobic surfaces, which is part of the IBAIA sensor functionalization work.
June 23-28, 2024	ICOOPMA 2024, Pardubice, Czechia	CNRS-UR1 will chair a session and present their work at IBAIA on both the functionalization of the mid-IR sensor and the sensor itself. TAU will present the research on Er^{3+} doped tellurite glasses.
Aug 25-28, 2024	ICG 2024, Incheon, Republic of Korea	TAU will present the research on Er^{3+} doped tellurite thin films.

Recent publications

Doughan, I., Oyemakinwa, K., Ovaskainen, O. and Roussey, M., 2024. Strip-loaded Mach–Zehnder interferometer for absolute refractive index sensing. *Scientific Reports*, 14(1), p.3064.

Guo, T.L., Li, F. and Roussey, M., 2023. Dielectric Cavity-Insulator-Metal (DCIM) Metamaterial Absorber in Visible Range. *Nanomaterials*, 13(8), p.1401.

Peiponen, K.E., Kanyathare, B., Hrovat, B., Papamatthaiakis, N., Hattuniemi, J., Asamoah, B., Haapala, A., Koistinen, A. and Roussey, M., 2023. Sorting microplastics from other materials in water samples by ultra-high-definition imaging. *Journal of the European Optical Society-Rapid Publications*, 19(1), p.14.

Project partners