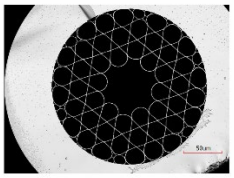
Appel à stage: acronym, title and contact information



Laboratories: Laboratoire de Physique des Plasmas (LPP) and another Laboratory from E4C we are looking for right now

Acronym: **RESOURCE-2**

Title: Hollow-co**RE** fiber absorption **S**pectrosc**O**py (HCF-AS) for miniat**U**re p**R**obing of small densities of IR-absorbing spe**C**i**E**s -2

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Introduction: why continuation?

This project is a continuation of Project RESOURCE financially supported by E4C in spring semester of 2025. We suggested developing an innovative detector of small species, including pollutants like CO2 and NOx, miniaturising the amount of a probe gas. Our request for 2 internships for 32 weeks in total has been accepted by the E4C board (email from E4C from 11/12/2024). The project was very successful, the first prototype has been built on the basis of Raman spectroscopy, the principle of work has been confirmed. Svetlana STARIKOVSKAIA and David PAI were included in the experiment as scientists having permanent positions.

External collaboration with one of unique laboratories in the world producing hollow core fibers, namely GPPMM Group, XLIM Research Institute, CNRS UMR 7252, University of Limoges, 87060 Limoges has been (i) found; (ii) installed and developed on initiative of the two laboratories. Will underline that the project is 100% initiative for the moment (no other financial sources available).

As outcome of the project, (1) Bachelor Ecole Polytechnique Thesis; (2) Abstract + Poster for International Conference of Ionized Gases (ICPIG XXXVI, Aix-en-Provence, 20-25 July 2025), the travel of Bachelor student Mr Vlad-Ștefănuț Radu to ICPIG has been financially supported by E4C; (3) a manuscript of the paper (fast track communication) for Plasma Source Science and Technology (PSST) journal has been prepared:

Vlad-Ștefănuț Radu, Jean-Baptiste Billeau, Kasidapa Polprasarn, Benoit Debord, Ali Al Dhaybi, Denis V Seletskiy, Stephan Reuter, Frédéric Gérôme, David Z Pai, Fetah Benabid and Svetlana Starikovskaia, “Development of a hollow-core fiber spectroscopy technique for miniature probing of plasma-produced species”

Aim of the project:

The aim of the suggested RESOURCE-2 project, after verifying a conception in spring semester 2025, is to develop a prototype of miniature probing spectrometer using hollow-core fibers (HCFs) for gas pollution control.

Financial demand:

12 months of Bachelor Thesis + 20 months of M1/M2 Thesis (5600 € total or 700 /months)

State of art:

The idea to use the core of the hollow cell fiber (HCF) as a gas cells that can guide light over long lengths offering a high level of integration in a practical and compact set-up or device was suggested for the very first time in Nature in 2005 [1]. During the first stage of our project, we found that the first author of this paper is moved to France, Limoges, and is a leader of GPPMM Group, XLIM, at University of Limoges.

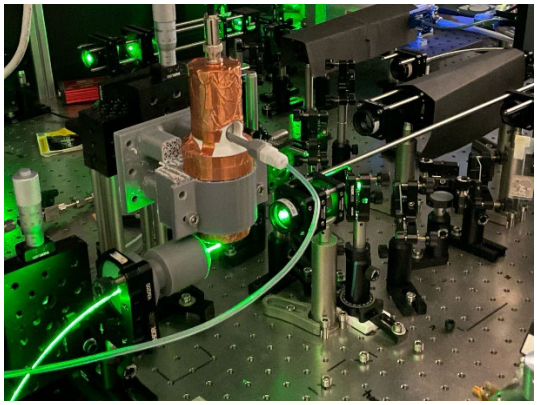

Fig 1: Experiment on enchanced sub-mm Raman spectroscopy using HCF fiber at LPP during RESOURCE project (spring 2025).

Work supported by E4C in 2025, makes a proof of concept, illustrating the possibility to develop a hollow-core fiber spectroscopy technique for miniature probing of plasma-produced species. We have taken a decision to base the experiment on fiber-enhanced Raman spectroscopy, because the group of David PAI at LPP already had Raman installation. The fiber used was a negative curvature hollow-core fiber with a Kagomé lattice cladding. To implement this approach, the guiding properties of the fiber, the measurement principles of the detection method and the dynamics of gas flow inside the fiber were first studied. Based on this analysis, the working device was realized by integrating the fiber into a Raman spectroscopy setup. The enhancement of the Raman signal is demonstrated by comparing the spectra of air with and without the hollow-core fiber, looking in particular at the O_2 and N_2 peaks. Filling the fiber with helium leaded to the disappearance of these peaks, validating the performance of the pumping system.

Methods and approaches:

The suggested technique involves miniature gas sampling into the core of a hollow optical filter followed by IR absorption measurement. Not intended to replace FTIRs, this micro-detector will be designed for specific molecules and miniature multi-point sampling, aiming to control small gas species in laboratory and industrial settings.

We plan to change the detection from Raman, already used in the laboratory, to UV and IR absorption. Keeping in mind that HCFs are mainly developed for IR region, we hope to have an extended list of molecules/radicals absorbing in IR. We have everything at laboratory to measure O3 absorption at 250 nm Hartley band (and the HCF has a transmission window at that region), and we will analyse possibilities of mid-IR sources and detectors. We will appreciate help of any E4C laboratory who is a specialist in IR signals detection.

The planned results for RECOURCE-2 project is (1) a list of species related to climate control and suitable for this diagnostics; (2) a list of pairs “light source-detector” together with measured transparent windows of HCF; (3) prototype of a HCF spectrometer for at least one molecule from the list; (4) demonstration of work of the prototype.

1. Benabid, F. et al., Compact, stable and efficient all-fibre gas cells using hollow-core photonic crystal fibres. Nature 434, 488-491 (2005)