Master in Photonics – "PHOTONICS BCN"
Master ERASMUS Mundus "EuroPhotonics"

MASTER THESIS PROPOSAL

Full time from April 2026 (it can start part time from February 2026)
Presentation date to be chosen: end of July or beginning of September 2026

Note: The main Master Thesis supervisor has to be a professor of the Master in Photonics program. One co-supervisor (internal or external) can be defined. Main Supervisor is responsible for the subject of the proposal and has to give continuous support to the student (research development, Report writing and presentation preparation). For external proposals a co-supervisor from the Master program and a collaboration agreement with UPC are needed. You can find all information about the Master Thesis process in our webpage.

Laboratory: Quantum Nano-optoelectronics group
Institution: ICFO
City, Country: Castelldefels (Barcelona), Spain

Title of the master thesis: Electrical Infrared Spectroscopy with Graphene for Compact and Selective Gas Sensing

Name and affiliation of the master thesis supervisor: Prof. Dr. Frank Koppens
Name and affiliation of the co-supervisor (if any): Dr. Ediz Herkert
(for external proposals a co-supervisor chose among the Master Program professors and a collaboration agreement with UPC is needed)
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Keywords: Infrared spectroscopy, gas sensing, 2D materials, graphene, optoelectronics

1. **Summary of the subject (maximum 1 page):**

   Gas sensing plays a vital role in applications ranging from environmental monitoring to medical diagnostics. Optical methods based on infrared (IR) absorption spectroscopy are particularly promising due to their high selectivity, compactness, and cost efficiency. Among them, Fourier-transform infrared (FTIR) spectroscopy provides broadband spectral information that enables the detection of multiple gas species simultaneously.

   However, conventional FTIR systems are often bulky and limited in speed and sensitivity, which restricts their use in portable or real-time sensing applications. Recent developments in our group have shown that these limitations can be overcome by integrating surface-enhanced infrared absorption (SEIRA) with two-dimensional (2D) materials, such as graphene and hexagonal boron nitride (hBN) [1,2]. The resulting electrical-SEIRA (eSEIRA) platform

combines the functionalities of a SEIRA substrate and an infrared photodetector in a single compact chip.

This master's project aims to implement and characterize a compact FTIR-based gas sensor using the eSEIRA platform. The focus will be on the integration and optimization of optical and electronic components and the setup and calibration of a gas mixing system that enables accurate testing of the sensor with known gas concentrations.

The student will work hands-on in the laboratory, aligning and testing optoelectronic components, and characterizing the eSEIRA platform for a wide range of gas mixtures. The final goal is to demonstrate a compact and sensitive gas sensing system capable of detecting volatile organic compounds (VOCs) with high specificity, sensitivity, and fast response times.

Objectives (maximum 1 page):

- Implement and refine a compact FTIR setup for the eSEIRA platform.
- Integrate, align, and optimize optical and electronic components for mid-infrared measurements.
- Assist in setting up and calibrating a gas mixing system capable of generating accurate gas mixtures in the ppm range.
- Design and test a custom gas cell compatible with the eSEIRA chip.
- Characterize the eSEIRA sensor to selected gases (e.g., acetone, isopropanol, ethylene).

Additional information:

Required skills:

- Optics and photonics: Understanding of infrared spectroscopy and interferometric techniques (e.g., FTIR).
- Laboratory experience: Experience with optical alignment, spectroscopy setups, or electronic instrumentation is desirable.
- Gas handling: Experience in working with gas cells and flow controllers is an advantage.
- Data analysis: Basic skills in Python for basic measurement automation and data processing.
- Background: Motivation for experimental research in nanophotonics, spectroscopy, or optoelectronics.

References

[1] Castilla, S., Agarwal, H., Vangelidis, I. *et al.* Electrical spectroscopy of polaritonic nanoresonators. *Nat Commun* **15**, 8635 (2024).

[2] Bylinkin, A., Castilla, S., Slipchenko, T.M. *et al.* On-chip phonon-enhanced IR near-field detection of molecular vibrations. *Nat Commun* **15**, 8907 (2024).