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

MASTER THESIS PROPOSAL

Dates: April 2025 – July or September 2025

Laboratory: BiOPT lab and Wavefront Engineering group, Departament de Física Aplicada
Institution: Universitat de Barcelona (UB)
City, Country: Barcelona, Spain

Title of the master thesis: Dynamic characterization and multi-wavelength optimization of a Pockels cell for real-time super-resolution microscopy

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Keywords: Super-resolution microscopy, depletion microscopy, fluorescence microscopy, vortex beams, doughnut beams, polarization control.

Summary of the subject: Advanced optical microscopy techniques are widely used in the life sciences. Fluorescence microscopy is an essential tool for studying biological processes at cellular and molecular scales. However, optical microscopy is fundamentally limited in spatial resolution due to the phenomenon of diffraction, which prevents the observation of structures smaller than approximately 200 nm. To overcome this limitation, non-optical technologies such as electron microscopy and, more recently, atomic force microscopy have been proposed since the mid-20th century. Nevertheless, these techniques lack the versatility of visible light-based microscopy, which is more compatible with molecular biology labelling methods.

The development of super-resolution microscopy in the early 21st century has enabled the diffraction barrier to be overcome using purely optical approaches. Techniques, such as STED, RESOLFT, and SIM, achieve nanometre-scale resolutions but face challenges when analysing biological processes on short timescales. Image reconstruction from point-by-point scanning of the sample makes video-rate imaging impractical. In this project, we will use a custom-developed microscope that employs acousto-optic deflectors (AODs) to parallelize multiple beam modes for illuminating and scanning biological samples. Building on this technology, this work aims to improve the switching time between Gaussian and doughnut illumination modes by integrating a Pockels cell into the experimental setup.

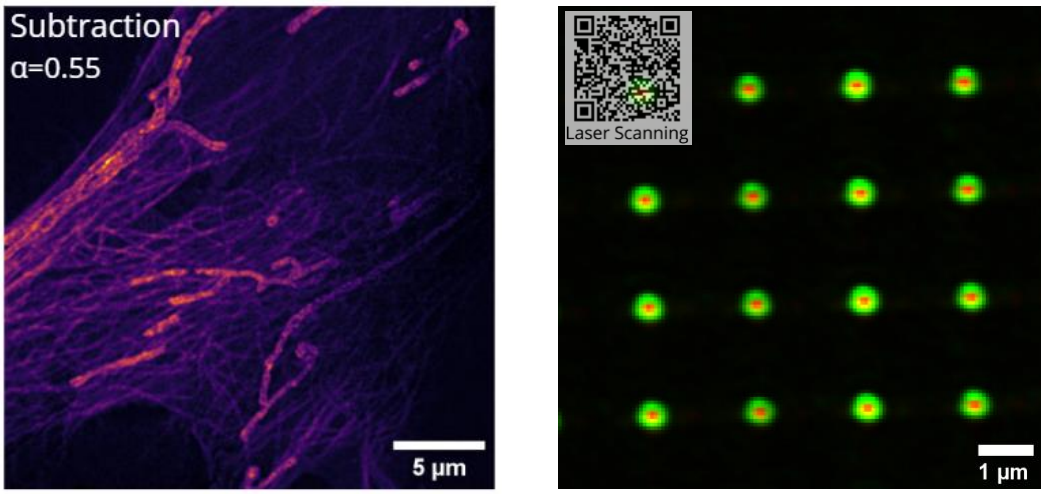

Figure 1. *Imaging of mitochondria in huFIB cells obtained with our subtraction microscope and parallelised structureed illumination scheme for Gaussian and doughnut beams. QR link.*

Objectives: This project aims to characterize the performance of a Pockels cell integrated into a super-resolution microscope developed by our research group over the past few years. The study will focus on investigating the dynamic behaviour of the Pockels cell and its effects on the polarization state of the laser beam in both collimated and focused configurations. To demonstrate fast switching between illumination modes (e.g., doughnut and Gaussian beams), the Pockels cell will be implemented in our subtraction microscope, enabling the acquisition of video-rate images. Additionally, the project will examine the cell's response across various wavelengths to ensure compatibility with multi-colour microscopy, facilitating applications where specific wavelengths are used to highlight distinct cellular structures.

Additional information:

* Required skills: Disposition for experimental work in a microscopy lab, interested in biophotonics, proficient in a computer language with preference for Matlab, Python and LabVIEW.
* Miscellaneous: Early incorporation is possible.