



UNIVERSITAT POLITÈCNICA  
DE CATALUNYA  
BARCELONATECH

**UAB**  
Universitat Autònoma  
de Barcelona



UNIVERSITAT DE  
BARCELONA

**ICFO**  
The Institute  
of Photonic  
Sciences



Erasmus+

## **Master in Photonics – “PHOTONICS BCN” Master ERASMUS Mundus “EuroPhotonics”**

### **MASTER THESIS PROPOSAL**

**Dates:** April 2022 – July or September 2023

**Laboratory:** Dynamic Optical System Lab (Department of Applied Physics)

**Institution:** Universitat de Barcelona

**City, Country:** Barcelona, Spain

**Title of the master thesis:** Encoded illumination for high-speed optical microscopy

**Name of the master thesis supervisor and co-supervisor:** Martí Duocastella; co-supervisor Salvador Bosch

Email address: [marti.duocastella@ub.edu](mailto:marti.duocastella@ub.edu)

Phone number: 622906820

Mail address: Departament de Física Aplicada, C/Martí i Franquès 1, 08028 Barcelona, Spain

**Keywords:** optical microscopy, fast imaging, single-pixel camera

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

Optical imaging techniques are the tool of choice for characterizing fast processes at the sub-micrometer scale in areas as relevant as materials science, industrial inspection, fluid dynamics, and biology. However, current microscope architectures offer an inherent trade-off between spatial resolution, imaged area, and acquisition speed. Several techniques exist capable of acquiring dozens of images per second using camera-based microscopes with thousands of pixels, but achieving faster imaging speeds without sacrificing spatial resolution remains challenging. This limitation in the amount of spatiotemporal data that can be collected from samples is currently hindering the understanding of a myriad of key phenomena, ranging from light-matter interactions to brain functioning.

The goal of this master thesis is to address this issue and develop a new microscope capable of acquiring millions of frames per second (fps) at diffraction-limited resolution and over a significantly large imaged area. Our central idea is to combine a camera with only a single pixel but a very fast timing response (picoseconds), with encoded illumination consisting of thousands of flickering spots, each with different but known modulation frequency and spatial coordinates. By demultiplexing the acquired signal in a post-processing step, high-resolution images will be retrieved, at a rate only limited by the lowest modulation frequency of the illumination spots.



UNIVERSITAT POLITÈCNICA  
DE CATALUNYA  
BARCELONATECH

**UAB**  
Universitat Autònoma  
de Barcelona



UNIVERSITAT DE  
BARCELONA

**ICFO**  
The Institute  
of Photonic  
Sciences



Erasmus+

The thesis is divided into five distinct parts, which will occur sequentially through a 4-month period, as detailed next. 1) Design of the light encoding system and simulations. 2) Experimental implementation of the system into an existing optical microscope. 3) Characterization of the optical performance of the new microscope by measuring the point spread function with fluorescent nano-beads. 4) Proof of concept consisting of imaging a moving object. 5) Writing of the thesis.

**Additional information (if needed):**

\* Required skills : the candidate is expected to show an interest in multidisciplinary subjects, and basic programming in Python or Matlab.