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

MASTER THESIS PROPOSAL

Starting full time from April 2024
Presentation at the end of July or beginning of September 2024

Laboratory: Optical Trapping Lab – Grup de Biofotònica
Institution: Universitat de Barcelona
City, Country: Barcelona, Spain

Title of the master thesis: The Programmable Array Microscope: study of illumination and filtering strategies for optimally trading off speed and confocality

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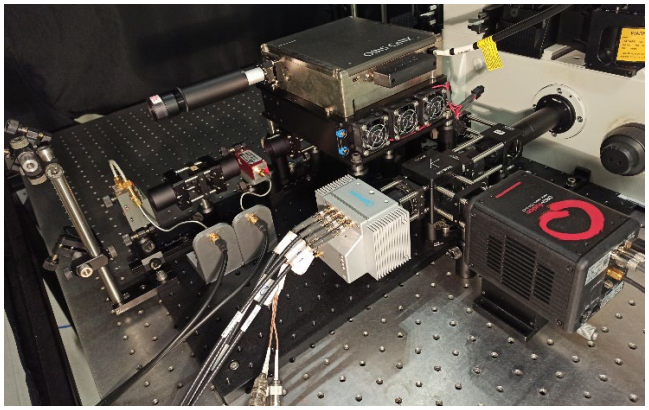
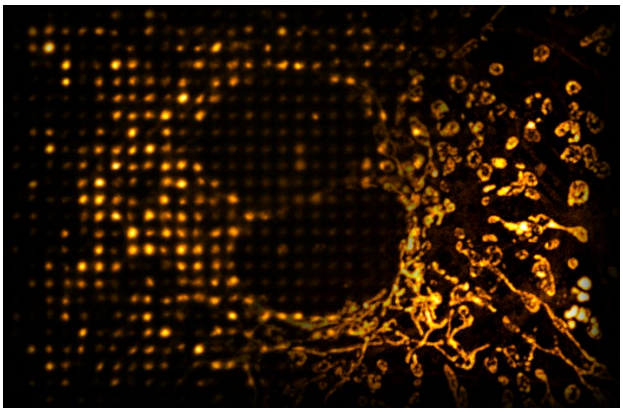
Keywords: Confocal microscopy, fluorescence microscopy, programmable microscope, biophotonics

Summary of the subject (maximum 1 page):

Microscopy for the Life Sciences is a thriving field of research and development, with modern fluorescent microscopes being high technology devices, featuring sophisticated laser illuminators, ultra-sensitive cameras, precise micro-positioning stages or superbly corrected optical systems. However, despite this display of impressive tech, they suffer from a basic inefficiency, which also plague other imaging techniques: the main key performance metrics in microscopy, such as speed, resolution, contrast, or sample innocuity are interdependent magnitudes.
This is known in the field with funny names such as the "eternal triangle of compromise" or the "pyramid of frustration", which essentially mean that one of these magnitudes cannot be maximized without compromising the other ones.
The "compromise" or "frustration" arising from this principle make microscopy manufacturers build instruments that are too specialized (i.e., instruments that excel in one of these metrics but perform rather poorly in the remaining ones), which often require the final users to resort to several instruments for different tasks (e.g., a point scanning confocal for high resolution observations of fixed cells or a spinning-disk, high-speed confocal for live cell imaging), at a large cost, complexity and difficulty.
A much sought-after solution to this dilemma would be the so-called "programmable array microscope" (PAM), a microscope concept coined by the company IBM in 1993, which would incorporate a programmable optical illumination device capable of changing the basic balances between the performance metrics and implement, in a single instrument, multiple imaging modalities.

But that is much easier said than done.
The several practical implementations of this theoretical concept have fallen short of reproducing the performance of the individual instruments that the PAM aims to replace.
In short, known PAMs are generalists but mediocre microscopes and the reason must be found in the inadequacy of the spatial light modulators that drive the programmable core of these multifunctional instruments.
Six years ago, we invented a spatial light modulation technology, based on acousto-optic devices, which has allowed us to build a PAM with the potential to become the first working implementation of this “holy grail” microscope.
We are looking for a motivated student that will help us characterize the performance of our PAM and investigate the switching between illumination modes and filtering algorithms that efficiently trade off speed for confocality/SNR/phototoxicity, by moving through optimal trajectories within the pyramid of frustration.





Objectives:

1) Determination, through simulation and through experimentation with our PAM prototype, of the optimal trade-off trajectories between performance metrics, mainly speed and confocality.
2) Determination of the performance against point-scanning confocals and spinning-disk confocals at the apex points of the trade-off curve. We expect to prove similar or better image quality (confocality) than existing microscopes at the same speed.

Additional information (if needed):
* Required skills: Ideally, the candidate student feels a strong interest in all things biophotonic, especially in modern laser microscopy, and is keen of laboratory work and computer programming for scientific simulation, in Matlab or Python languages (preferably both). Ours is a nice working environment, with modern lab facilities and a convenient location in Barcelona downtown.
* Miscellaneous: Early incorporation welcome.