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

MASTER THESIS PROPOSAL

Starting full time from April 2025
Presentation at the end of July or beginning of September 2025

Laboratory: Dynamic Optical Systems Lab and Molecular Bionics
Institution: Universitat de Barcelona and IBEC
City, Country: Barcelona, Spain

Title of the master thesis: Tracking of active diffusion swimmers using light-sheet microscopy

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Keywords: optical microscopy, chemotaxis, microfluidics

Summary of the subject (maximum 1 page):

The movement of organisms toward or away from specific chemicals, a process known as chemotaxis, is a predominant tactic among unicellular organisms to perform tasks as relevant as gathering nutrients, evading toxins, or forming colonies and biofilms. Chemotaxis holds promise as a therapeutic route: by designing exogenous chemical gradients, drug-carrying nanoparticles can be guided to targeted locations inside an organ or tissue. Unfortunately, the characterization of the chemotactic effects on nanoparticles can be challenging. In this case, the nanoparticles act as swimmers that are constantly and randomly moving, and only when exposed to a chemical gradient, they self-propel and slightly change their trajectory. Such an active diffusion process has been so far characterized using fluorescence confocal microscopy. However, the point-by-point scanning nature of this technique impedes reaching high imaging speeds. As a result, only averaged two-dimensional trajectories of swimmers can be reconstructed – insufficient to properly quantify chemotaxis effects.

Objectives: The main goal of this master’s thesis is to implement a light-sheet microscope to characterize the active diffusion of nanoparticles when exposed to a chemical gradient inside a microfluidic chamber.
The achieve this overall objective, we have organized the work plan into five different tasks, which will occur sequentially through a 4-month period, as detailed next.

1) Quantify the imaging performance (point spread function) of an already existing light-sheet microscope (LSM) by imaging static sub-diffracted particles.
2) Optimize the current LSM to accommodate the specific demands imposed by the microfluidic chamber.

3) Characterize the single particle tracking localization precision achieved with the modified LSM for fixed nanoparticles undergoing a known trajectory, and compare experimental results with the theoretical values expected using the Cramer Rao lower bound.
4) Measure the mean square displacement over time of swimmers inside the microfluidic chamber with and without a chemical gradient.
5) Write the thesis

Additional information (if needed):

A **5-month scholarship** is available for the candidate.
* Required skills: the candidate is expected to show an interest in multidisciplinary subjects, and basic programming in Python and MATLAB.