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

Title of the master thesis:
Model-based control of multifrequency acousto-optic beam array generation

Name and affiliation of the master thesis supervisor: Estela Martín Badosa
Name and affiliation of the co-supervisor (if any): Mario Montes Usategui
(for external proposals a co-supervisor chose among the Master Program professors and a collaboration agreement with UPC is needed)
Email address: estela.martinb@ub.edu
Phone number: 934021143
Mail address: Facultat de Física, c/ Martí i Franquès, 1, 08028 Barcelona

Keywords: acousto-optic deflectors (AODs), crystal optics, non-linear acousto-optic effects, beam array generation

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

Acousto-optic deflectors (AODs) are ultrafast devices for laser beam steering and are widely used in applications such as laser marking, optical tweezers, and optical microscopy. In an AOD, the deflection angle of a laser beam is proportional to the frequency of a radiofrequency (RF) signal applied to a piezoelectric transducer, which generates acoustic waves propagating inside an optically transparent crystal. These acoustic waves act as a diffraction grating for the incident light. When multiple RF frequencies are applied simultaneously, multiple diffracted beams are produced at distinct angles, enabling the simultaneous generation of several laser spots. This capability allows for increased scanning rates and parallelized optical processing, producing one-dimensional arrays with a single AOD and two-dimensional arrays using two orthogonally oriented AODs. Multifrequency acousto-optic diffraction has therefore become increasingly relevant for applications such as structured illumination microscopy and emerging quantum technologies.

However, multifrequency operation introduces non-linear effects in the acousto-optic interaction, leading to the generation of intermodulation products and other unwanted diffraction orders. These effects manifest as spurious light and non-uniform intensity distributions among the desired laser spots, limiting performance and image quality. A common approach to mitigate these effects relies on experimental feedback loops, where images of the multi-spot pattern are analyzed and the RF amplitudes are iteratively adjusted to equalize spot intensities. While effective, this method is time-consuming and impractical for dynamic or automated applications.

In this work, we propose a modeling-based approach to correct for non-linearities in multifrequency acousto-optic diffraction without relying on experimental calibration.

2. Objectives (maximum 1 page):

The main objective of this project is to accurately predict the response of an acousto-optic deflector operating in the multifrequency regime and to synthesize optimized RF signals that compensate for nonlinear effects a priori. This approach aims to enable uniform and controllable multi-spot beam array generation, thereby improving the practicality of AOD-based beam steering systems for high-speed and high-precision optical applications.

To achieve this goal, the coupled-wave equations governing the acousto-optic interaction will be solved numerically in the multifrequency regime. A physical model of the acousto-optic deflector will be developed to predict the intensity distribution of multifrequency diffraction patterns and to design optimized RF excitation signals. Experimental measurements will be performed to validate the model predictions and to evaluate the intensity uniformity of the resulting beam arrays.

Additional information (if needed):

* Required skills:

- Experience with numerical computing in Python or MATLAB
- Interest in crystal optics and nonlinear optics
- Interest in theoretical modeling of wave–matter interactions

* Miscellaneous: an early start is welcome.