



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**

**Laboratory: Dynamic Optical System Lab
Institution: Universitat de Barcelona
City, Country: Barcelona, Spain**

Title of the master thesis: Enhanced acousto-optic effect with absorbing molecules

Name and affiliation of the master thesis supervisor: Martí Duocastella Solà, Universitat de Barcelona

Name and affiliation of the co-supervisor (if any):
(for external proposals a co-supervisor chose among the Master Program professors and a collaboration agreement with UPC is needed)

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Keywords:

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

A central quest in science is delivering light deep within inhomogeneous media such as biological tissue. The challenge lies in overcoming light scattering, which typically restricts light delivery depth to 1 mm or below. Several strategies have been developed to address this issue, including wavefront shaping or endoscopy, but they typically come at the cost of loss of spatial or temporal resolution or increased invasiveness. A recently proposed alternative consists of exploiting the acousto-optic effect, namely the changes in refractive index induced by ultrasound⁽¹⁾, directly within the scattering medium. In this case, ultrasound modulation results in an embedded waveguide within the medium, enabling compensation for scattering.^(2–4) Interestingly, the optical properties of the ultrasound-generated waveguide depend on the average static refractive index of the scattering medium – the higher the refractive index, the stronger the ultrasound light-guiding effect.

In this master's thesis, we plan to study methods to increase the static refractive index of a scattering medium by adding absorbing molecules. The rationale is that absorbing molecules at a given waveband can result in an increase in the refractive index at other wavelengths via the so-called Kramers-Kronig relations.



2. Objectives (maximum 1 page):

The main objective of the thesis is to study the effects that absorbing molecules have on the acousto-optic effect in different media. To 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- Simulate the expected refractive index induced by absorbing molecules in a homogeneous medium (water) with and without ultrasound.
- 2- Prepare solutions containing various concentrations of absorbing molecules based on the simulation results.
- 3- Use wavefront sensing to determine the gradient in refractive index induced by ultrasound within solutions prepared in task 1.
- 4- Quantify the improvement in light delivery through a scattering medium that is modulated by ultrasound and doped with the optimized concentration of absorbing molecules.
- 5- Write the thesis.

Additional information (if needed):

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

References:

1. M. Duocastella, S. Surdo, A. Zunino, A. Diaspro, P. Saggau, Acousto-optic systems for advanced microscopy. *JPhys Photonics* **3**, 012004 (2021).
2. B. M. Torà, M. Duocastella, Enhanced light focusing inside scattering media with shaped ultrasound. *Sci. Rep.*, 1–9 (2023).
3. B. Mestre-Torà, M. Duocastella, Parallelized Ultrasound-Guiding for Enhanced Light Delivery within Scattering Media. *ACS Photonics*, 4c01398 (2024).
4. P. Ricci, M. Colom, B. Mestre-Torà, M. Duocastella, Photoacoustics for Direct Light-Guiding Inside Transparent and Scattering Media. *Laser Photon. Rev.*, 2401122 (2025).