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

MASTER THESIS PROPOSAL

Starting full time from April 2026
Presentation at the end of July or beginning of September 2026

Laboratory: DONLL group , Nonlinear Dynamics, Nonlinear Optics and Lasers
Institution: Universitat Politècnica de Catalunya
City, Country: Terrassa, Catalunya

Title of the master thesis: Stabilization of microlasers

Name of the master thesis supervisor and co-supervisor: Ramon Herrero, Kestutis Staliunas
Email address: ramon.herrero@upc.edu
Phone number: 34 937398523
Mail address: TR14, planta 1, porta 108, edifice Gaia, Rambla Sant Nebridi 22, Terrassa

Keywords: Semiconductor Lasers, Stabilization, Spacetime modulations, PT-symmetry, Non-Hermiticity

Summary of the subject (maximum 1 page):

The most commonly used semiconductor microlasers, Edge Emitting Lasers (EEL) and Vertical Cavity Surface Emitting Lasers (VCSEL), suffer from a poor beam quality of the emission due to the lack of an intrinsic transverse mode selection and this limits their possible applications. Moreover, such lasers are often combined in arrays to obtain high powers and their coupling enhances instabilities.

Spatial modulations inside the laser cavity can control the laser complex spatiotemporal dynamics to shape the beam profile and obtain clean beams. Different techniques have been proposed in our research group to attain this purpose based on intracavity filtering, on modulations of the refractive index and gain/loss [1,2,3] on the localization of the generated field [4,6] and on the management of the coupling between laser arrays [5]. Further, these techniques do not need light coherence so could even be applied to other light sources like RCLEDs.

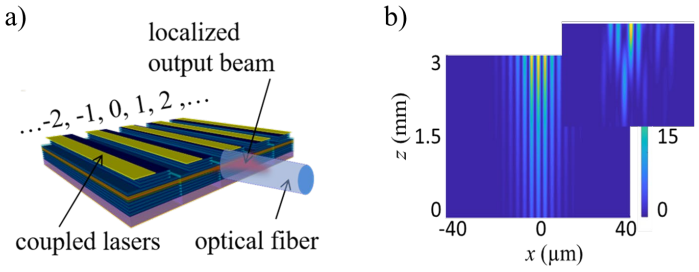

***Figure** a) Coupled EEL semiconductor laser array. b) Localized and regularized intracavity field (inset: non-controlled field)*

We now theoretically explore the simultaneous spatial modulations in transverse and longitudinal directions for the stabilization of multimode lasers. The non-Hermitian modulations in transverse and longitudinal space appears to be very interesting for laser control as they could symmetrically select transverse and longitudinal modes, symmetrically acting to forward and backward fields for particular parameters. Similar non-Hermitian spatial modulations can be applied to laser arrays, inducing asymmetric transverse couplings to stabilize the ensemble. This line is now in collaboration with the Monocrom company for the EEL case and a Master Thesis student would be very welcome.

Further, we started the study of spatiotemporal modulated lasers. Its implementation would consider modulations of both, the refractive index of the intracavity medium as well as the pumping parameters modulated in time and transverse space. Temporal modulations of the laser are possible by optically pumping with two slightly different light frequencies to obtain temporal modulations. Interesting time scales will be localized on the order of GHz, corresponding to the characteristic response time of the population of charge carriers and at the order of the resonator frequency to achieve active mode locking effects.
Both research lines are inside the Research Project PID2022-138321NB-C21.

Objectives:
The objectives are the theoretical and numerical study of space-time modulated lasers and laser arrays with non-Hermitian spatial modulations, and to write a paper.

[1] R. Herrero, M. Botey, M. Radziunas, K. Staliunas, K. Beam shaping in spatially modulated broad-area semiconductor amplifiers, *Opt. Lett.*, 37, 5253-5255, 2012
[2] M. Radziunas, M. Botey, R. Herrero, K. Staliunas, Intrinsic beam shaping mechanism in spatially modulated broad area semiconductor amplifiers, *Appl. Phys. Lett.* 103, 132101, 2013
[3] W. W. Ahmed, S. Kumar, J. Medina, M. Botey, R. Herrero, and K. Staliunas, Stabilization of broad-area semiconductor laser sources by simultaneous index and pump modulations, *Opt. Lett.* 43, 2511-2514, 2018
[4] J. Medina, M. Botey, R. Herrero, and K. Staliunas, Stabilized narrow-beam emission from broad-area semiconductor lasers, *Phys.Rev. A* 101, 033833, 2020
[5] J. M. Pardell, R.Herrero, M. Botey, and K. Staliunas, Non-Hermitian arrangement for stable semiconductor laser arrays, *Opt. Expr.* 29, 23997-24009, 2021
[6] M.Plukys, L.Grineviciute, J.Nikitina, D.Gailevičius, K.Staliunas, "Polarization enhancement in Nd:YAG microchip laser with Meta-Mirror output coupler," Opt. Lett. **50**, 4666-4669, 2025

Additional information (if needed):
* Recommended skills: Programming (C++, MatLab,..)

* Miscellaneous: This study is in the framework of a Project “Exploring complex spacetime systems for light control“ (PID2022-138321NB-C21) inside the coordinated project “Exploring complex spacetime systems for unconventional light and sound wave control“ with UPV and international collaborations of the DONLL group involving several photonic companies from Lithuania and Catalonia. Possibility of joining the DONLL group for a PhD.