

## 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:** 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

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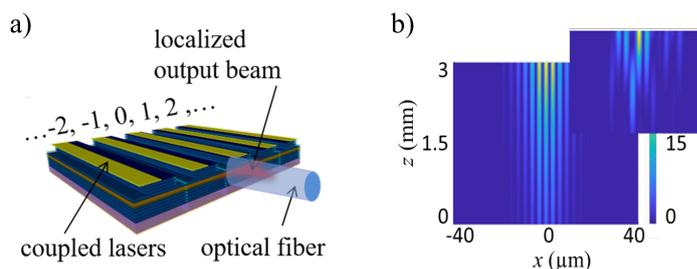
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**Keywords:** Semiconductor Lasers, Stabilization, Spacetime modulations, PT-symmetry, Non-Hermiticity

### 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] 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 emitted field.*



We now explore spatiotemporally 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 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. Further, the combination of temporal modulations and non-Hermitian modulations in transverse space are also possible in lasers as they act symmetrically to forward and backward fields. Similar non-Hermitian spatial modulations can be applied to laser arrays, inducing asymmetric couplings to stabilize the ensemble.

### 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

### 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“ and international collaborations of the DONLL group involving several photonic companies from Lithuania and Catalonia. Possibility of joining the DONLL group for a PhD.