

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: Unconventional reflexions and transmissions from non-Hermitian metasurfaces

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Keywords: Complex artificial structures, metasurfaces, Non-Hermitian structured materials.

Summary of the subject (maximum 1 page):

Complex artificial metastructures and metasurfaces may lead to unconventional reflections and transmissions. This is a generic research line with three main objectives:

Non-Hermitian reflections. Physical insights and Deep Learning optimization

An inverse-design of non-Hermitian potentials allowed us to obtain asymmetric reflectivities on demand using analytics, Genetic Algorithms and deep learning tools [1,2]. Now we plan to analytically explore metasurfaces based on complex permittivities and find particular asymmetric response, see Fig. 1a) b), for light guidance, beam shaping and totally asymmetric reflections by using deep learning tools.

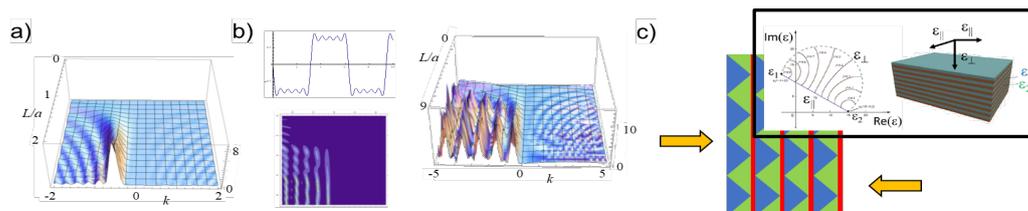


Figure 1: Asymmetric spectral reflectivity as a function of the normalized structure length L/a for a) harmonic b) square complex metasurfaces. c) Dielectric (blue, green) and gain or losses (red) metastructure with polarization dependence. (inset: Effective complex permittivity of a metamaterial as a function of the filling factor and polarization).

Polarization-dependent non-Hermitian metamaterial

We plan to uncover polarization dependent structures with unidirectional reflectionless. Non-Hermitian metamaterial can present a polarization dependence and an asymmetric response because the different effective permittivity of parallel and perpendicular polarizations in a metamaterial as a function of the filling factor, see Fig. 1c). We will theoretically and numerically explore such materials and find applications like light guiding and light localization.

Transitionally invariant metasurfaces

A metasurface may be an easy manufacture and ideal optical component for spatial filtering and without alignment requirements, due to its translational invariance. For instance, it would be extremely useful inside the microlaser intracavity. The device can be modeled as a thin transverse grating in the micron scale in front of a flat mirror (Fig.2a). We will model and numerically analyze translationally invariant metamirrors for light filtering and optimize them for the angular spectrum reduction in the reflected beam, reduction of the beam divergence and other filtering functionalities [3,4]. Non-Hermitian structured transverse gratings in front of mirrors or in microresonators would be applied for the management of not only diffraction but also light diffusion. A particular application would be transverse asymmetric reflections in metamirrors (Fig.2b, 2c). The asymmetric effect can be enhanced in laser cavities by the introduction of non-Hermitian etalons (Fig.2d).

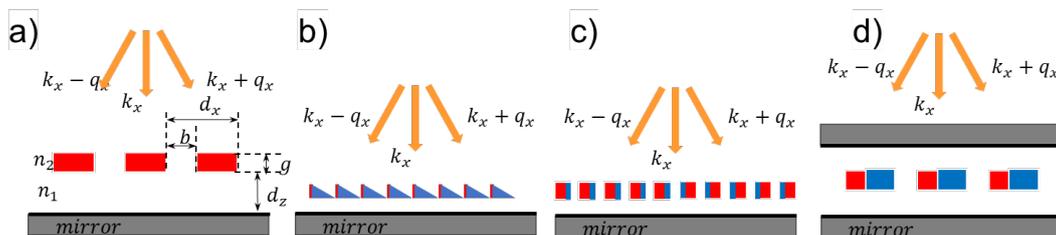


Figure 2: a) Simple transverse index grating in front of a mirror. b) Non-Hermitian grating for asymmetric reflections. c) Axisymmetric non-Hermitian structures for focusing d) non-Hermitian etalons in cavities.

- [1] Ahmed, W. W., Herrero, R., Botey, M., Wu, Y., Staliunas, K. Inverse-design of non-Hermitian potentials for on-demand asymmetric reflectivity. *Opt. expr.* 29, 17001-17010, 2021
- [2] Ahmed, W. W., Herrero, R., Botey, M., Wu, Y., Staliunas, K. Restricted Hilbert transform for non-Hermitian management of fields. *Phys. Rev. Appl.* 14, 044010, 2020
- [3] Wang, P. Y., Herrero, R., Botey, M., Cheng, Y. C., Staliunas, K. Translationally invariant metamirrors for spatial filtering of light beams. *Phys. Rev. A*, 102, 013517, 2020
- [4] Grineviciute, L., Nikitina, J., Babayigit, C., & Staliunas, K. Fano-like resonances in nanostructured thin films for spatial filtering. *Appl. Phys. Lett.*, 118, 131114, 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“. Possibility of joining the DONLL group for a PhD.