Subject: **Experimental study of integrated nanolaser arrays**

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Context:

Non-Hermitian physics provides a theoretical framework for comprehensibly describing the modal properties of resonances emerging from coupling optical resonators. In this context, the concept of exceptional points (EPs) refers to the situation where two or more eigenvalues of a Hamiltonian exactly coalesce, along with the associated eigenvectors [1]. This spectral singularity is a mathematical point associated with a temporary reduction in the system's dimensionality. EPs are associated with a wide phenomenology particularly relevant in photonics, such as the emergence of spatial or spectral non-reciprocity. Gain cavities, in which the system losses can be compensated by pumping an active medium, appear to be excellent candidates for studying these exceptional points. Recently we have demonstrated the presence of EPs in an array of two coupled semiconductor nanolasers interacting through an integrated SOI waveguide [2].

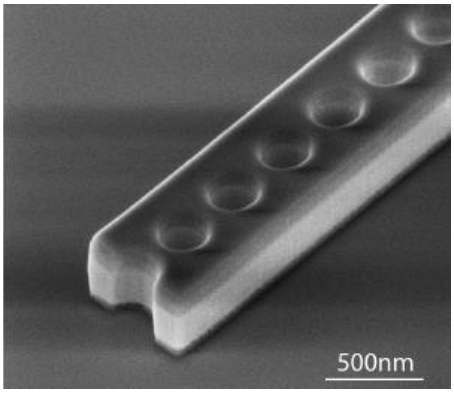

Fig.1 scanning electron micrograph of an Indium-Phosphide photonic-crystal nanolaser integrated on top of a SOI waveguide.

Objectives:

The student will carry experimental investigations of the temporal response of a nanolaser array in the vicinity of exceptional points. Below the laser threshold, the topology of the eigenspectrum will be explored by dynamically encircling EPs. Ring-down experiments using femtosecond pulsed pump laser will reveal the peculiar temporal behavior of coupled resonators set at the EP. Above threshold, the interplay of nonlinear dynamics and non-Hermitian physics is an unexplored field. We expect the emergence of gain-loss competition associated to non-trivial temporal behaviors such as self-pulsing or excitability, with potential benefits for neuromorphic photonic computing.

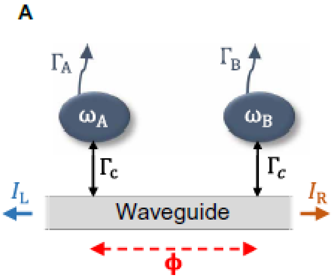

Fig.2 Modal configuration of a waveguide coupled nanolaser array.

The project includes the experimental study of integrated nanolasers with various optical setup using either continuous-wave or pulsed lasers. A theoretical approach will be adopted to describe the experimental results. The student will also explore the modal properties of longer arrays, composed by a large number of nanolasers.

Additional information:

A PhD project can be elaborated on the basis of this Master project. Fundings are already available in the group for that purpose.

References:

[1] Miri, M.-A. & Alù, A. Exceptional points in optics and photonics. Science 363, (2019)

[2] Madiot, G. et al. Harnessing coupled nanolasers near exceptional points for directional emission. Sci. Adv. in press (2024)