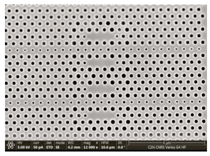
PhD position open

Synchronization in non-Hermitian networks of photonic crystal nanocavities

Scientific project

It has always been sought to reduce or even eliminate optical losses. However, in recent years, another research front has emerged which, instead of eliminating losses, takes advantage of them. This domain is named non-Hermitian photonics and opens the door for the control and design of optical losses to optimize the photonic responses.



Photonic Crystals (PhCs) are well known for enabling efficient construction of photonic nanocavities with small mode volumes and high quality-factors and to couple them to obtain "photonic molecules" with targeted properties.[1-4] Until now, the non-Hermitian aspects were poorly exploited in PhCs,[5] mainly restricted to the investigation of Parity-Time symmetry breaking.

Our engineering approach has enabled fine control of the evanescent coupling between a few adjacent nanocavities[6]. During the PhD we plan to develop large arrays with optimized dissipative coupling. Such non-Hermitian networks will allow exploring several open questions about the link between lattice symmetries (and their spontaneous breaking/restoration) and synchronization of nanolasers, as well as the fundamental limits of the celebrated Kuramoto model to account for synchronization of phase oscillators. More applied driven questions will also address phase locking in laser arrays and active metasurface lasers. The aim of this PhD is thus to explore complex topologies based on an increased number of nanocavities non-Hermitian laser networks. The PhD work will thus include the design and optimization of dissipative coupling as an original development, the fabrication and optical assessment of 1D & 2D networks of coupled nanocavities on 2D PhC platforms. Particular emphasis will be placed on nonlinear dynamic responses and synchronization.

Methods and techniques:

The platform for the design of the different topologies will be the same as for our previous works, *i.e.* III-V semiconductor 2D Photonic Crystal membranes. This will allow to start from solid basis so as the effort will be essentially devoted to: - clever design of dissipative coupling, this will include analytical simplified approach for the optimization of the response and numerical approach for the design of the actual 2D PC geometry; - fabricate them in our clean room facilities and - characterize and study their experimental responses through measurements in the near and far-fields.

Candidate skills:

The candidate should have a solid foundation in optics, be interested in the design of photonic structures and manufacturing in a clean room. A good level of French or English is compulsory as well as skills for teamwork. The candidate must be motivated to participate in exchanges and extended stays in the partner laboratories of the ANR WHEEL project, particularly the LP2N (Institut d'Optique) in Bordeaux.

1) « Spontaneous mirror-symmetry breaking in coupled photonic-crystal nanolasers », Ph. Hamel *et al.* Nature Photonics 9, 311 (2015)
2) **«** Far-from-Equilibrium Route to Superthermal Light in Bimodal Nanolasers », M. Marconi *et al.* Phys. Rev. X 8, 011013 (2018)
3) « Mesoscopic limit cycles in coupled nanolasers », M. Marconi *et al*. To appear in Phys. Rev. Lett (2020)
4) **«** Spontaneous Symmetry Breaking in a Coherently Driven Nanophotonic Bose-Hubbard Dimer **»**, B. Garbin et al. Phys. Rev. Lett. 28, 053901 (2022)
5) « Non-Hermitian zero moder laser in a nanophotonic trimer », K. Ji et al. https://arxiv.org/abs/2302.01809
6) « Photonic molecules: tailoring the coupling strength and sign », S. Haddadi *et al.* Optics Express. 22, 12359 (2014)

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