INTERNSHIP PROPOSAL

(One page maximum)

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Thesis possibility after internship: **YES**
Funding: **SECURED** If YES, which type of funding: **Institut Quantique Occitan**

Superradiance of optical phonons in hexagonal boron nitride

The objective of the project is to observe the luminescence of 2D optical phonons, and to study their superradiance during the 2D-3D crossover of the light-matter interaction. Phonons are the quanta of vibrations in a crystalline lattice. When a solid-state system is subjected to an external excitation, its relaxation to thermodynamic equilibrium generates non-equilibrium phonons, which propagate and encounter scattering events at the origin of heat diffusion. The phonon relaxation dynamics is thus mostly non-radiative, and phonons are usually considered only as a dissipative reservoir.

We intend to demonstrate that phonons can also generate light. Following our recent paper bringing the evidence for a radiative efficiency of order 10% for optical phonons in monolayer boron nitride [Cas22], we aim at detecting and controlling the luminescence of non-equilibrium phonons in hexagonal boron nitride. Our strategy relies on experiments in this 2D material by means of our scanning confocal cryo-microscope operating from the UV-C to the mid-IR spectral ranges [Cas16,Cal19,Val20,Rou21]. A key aspect of the project will be to study the build-up of superradiant phonons as a function of the number of atomic layers. Superradiance appears as a key resource for the observation of the luminescence of non-equilibrium phonons with the perspective of reaching radiative efficiency of order unity [Cas22b].

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[Cas16] G. Cassabois, P. Valvin, and B. Gil, Nat. Phot. 10, 262 (2016).
[Cal19] J. Caldwell, I. Aharonovich, G. Cassabois, J. Edgar, B. Gil, and D . Basov, Nat. Rev. Mat. 4, 552 (2019).
[Val20] P. Valvin, T. Pelini, G. Cassabois, A. Zobelli, J. Li, J. H. Edgar, and B. Gil, AIP Adv. 10, 075025 (2020).
[Rou21] A. Rousseau, L. Ren, A. Durand, P. Valvin, B. Gil, K. Watanabe, T. Taniguchi, B. Urbaszek, X. Marie, C. Robert, and G. Cassabois, Nano Lett. 21, 10133 (2021).
[Cas22b] G. Cassabois, G. Fugallo, and B. Gil, Phys. Rev. Res. 4, L032040 (2022).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: **YES** Soft Matter and Biological Physics: NO
Quantum Physics: **YES** Theoretical Physics: NO