INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique de l'ENS (LPENS)
CNRS identification code: UMR 8023

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Web page: https://www.lpens.ens.psl.eu/recherche/quant/equipe-01/
Internship location: LPENS, 24 rue Lhomond, 75005 Paris

Thesis possibility after internship: YES
Funding: YES   If YES, which type of funding: ANR

Cavity-enhanced superfluorescence of perovskite nanocrystals superlattices

Since their first synthesis in 2015, perovskite nanocrystals have attracted much attention due to their easy and cheap large-scale fabrication and excellent optical properties. In particular, they have become promising nanoemitters for optoelectronics[1] and quantum optics[2] due to their high radiative quantum yields and high purity single photon emission up to room temperature. In 2018, a major breakthrough was made when superfluorescence was demonstrated in superlattices of $CsPbBr_3$ nanocrystals at low temperature[3]. Superfluorescence is a well-known phenomenon in atomic physics in which emitters can emit light synchronously through their long-range interaction, resulting in accelerated and bright coherent emission. However, superfluorescence has only been demonstrated in a few solid-state systems due to the difficulty of obtaining identical individual emitters at high densities within a superstructure. In this context, colloidal semiconductor nanocrystals[4] are indeed an excellent seed material for the fabrication of superlattices, as they can be synthesised with narrow size dispersion and high concentration. The integration of perovskite superlattices into optimised optical microcavities is now a crucial step towards the enhancement of superfluorescence by cQED effects in these emergent systems. The cavity will thus provide a new tool to explore the rich physics of superfluorescence by tuning the key element responsible for superfluorescence, i.e. the dipole-dipole coupling, and to enhance superfluorescence. This could ultimately lead to low-threshold superfluorescence lasing.

In the Nano-Optics group, an original and flexible fibered Fabry-Perot microcavity has been designed specifically for solution-processed nanoemitters to enhance their emission via cQED effects[5]. The fundamental optical properties of single perovskite nanocrystals have been investigated[6] and their cavity coupling has been successfully achieved[7]. The main goal of the internship/PhD is to efficiently couple a superlattice of perovskite nanocrystals to this flexible microcavity. The optical properties of the superlattices synthesised at LuMIn laboratory (in the framework of an ANR project) will first be studied in free space configuration by micro-photoluminescence experiments to characterise the spectral and temporal superfluorescence features. A fibered microcavity will then be adapted to the perovskite superlattices to compare the emission of a single superlattice in free space and in cavity configuration. It is likely that the cavity mediates the dipole-dipole coupling to a longer length, leading to an increase in the number of nanocrystals involved in the superfluorescence and hence to superfluorescence enhancement.

[1]Kovalenko et al., Science 358, 745 (2017); [2]Kaplan et al., Nature Photonics 17, 775 (2023); [3]Rainò et al., Nature 563, 671 (2018); [4]Chemistry Nobel Prize 2023 awarded to Bawendi, Brus, Yekimov "for the discovery and synthesis of quantum dots"; [5]Borel et al., ACS Photonics 10, 2839 (2023); [6]Amara et al., Nano Lett. 23, 3607 (2023) & Nano Lett. 24, 4265 (2024); [7]Said et al., in preparation.

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