SCIENCES SORBONNE UNIVERSITÉ

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Master thesis proposal

INSP INSTITUT DES NANOSCIENCES DE PARIS

Campus PMC (Jussieu)
Director: M. Marangolo

Superfluorescence of semiconductor quantum light nano-emitters

Keywords: quantum dots – quantum wells (semiconductor nanoparticles), fluorescence microscopy, exciton interactions, quantum optics and single photons

Semiconductor quantum dots are very bright, stable and versatile light nano-sources with more and more applications in bio-imaging, lighting, TV displays and quantum information (as rewarded by the 2023 Nobel prize). In terms of fundamental physics, their discrete dipole states (ruled by quantum confinement) present quantum optical properties analog to "artificial atoms". They can be, much more easily than trapped atoms, observed by fluorescence microscopy at the level of a *single* nanoparticle.

Chains of semiconductor quantum wells, synthesized and assembled by our collaborators at the Chemistry Lab of ENS de Lyon (fig. 1(a)), constitute a good model system to explore interactions between nano-emitters. For instance, we have shown that, due to near-field dipole-dipole interactions (known as FRET), energy migrates between platelets over record distances of 500 nm (fig. 1(b)).

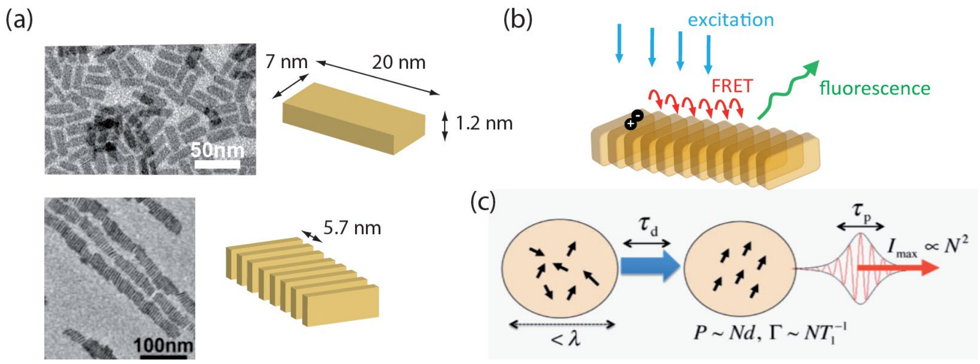

Figure 1 : (a) TEM images of CdSe colloidal quantum wells (nanoplatelets) and chains of quantum wells – synthesis B. Abecassis and B. Wagnon, ENS de Lyon [Ouzit et al., ACS Photonics 2023]. (b) Mechanism for FRET exciton diffusion : an exciton (electron-hole pair) is created in a given emitter, then diffuses by FRET energy transfer and recombines elsewhere with photon emission. (c) **Superfluorescence schematic [K. Cong et al, 2016] : initially incoherent dipoles develop a coherence and a macroscopic dipole, then after this build-up time they all interfere constructively and radiate very intensely and, thus, very fast.**

The topic of the internship is to examine whether these structures can also exhibit **superfluorescence**, a mechanism by which incoherently excited dipoles, because of their coupling to the electromagnetic field, spontaneously develop a coherence and interfere constructively (fig. 1(c)), leading to accelerated emission and original properties for emission correlations and directionality. We will probe the luminescence of chains of CdSe nanoplatelets under various excitation powers and temperatures and analyze the emission properties (dynamics, photon correlations) in order to identify manifestations of superfluorescence. The experiments are led in collaboration with a group of theorists in quantum many-body physics.

⇨ *A few reference papers by the group :*
Jiawen Liu et al., Nano Lett. 20, 3465 (2020)
Zakarya Ouzit et al., ACS Photonics 10, 421 (2023)
Zakarya Ouzit et al., J. Phys. Chem. Lett. 14, 6209 (2023)

Techniques/methods in use: Photoluminescence microscopy, spectroscopy, single-photon detection, cryogenic temperatures, numerical simulations
Applicant skills: Motivation for experimental work, organization, preferably some basic knowledge in optics

Internship supervisor(s) : Laurent COOLEN, laurent.coolen@insp.jussieu.fr
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Internship location: Campus Pierre et Marie Curie (place Jussieu), 22-32-5th floor, office 519

Possibility for a Doctoral thesis: Yes (application to Ecole doctorale + ANR)