INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de physique de la matière condensée
CNRS identification code: UMR7643
Internship director'surname: Clément Livache / Alistair Rowe
e-mail: clement.livache@polytechnique.edu Phone number: 01 69 33 46 54
Web page: https://pmc.polytechnique.fr/spip.php?article623&lang=en
Internship location: Ecole polytechnique, Route de Saclay 91120 Palaiseau
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ED

Single Quantum Dot Nano-LEDS using Scanning Tunneling Luminescence

Colloidal quantum dots (CQDs) are semiconductor nanoparticles that, due to their size (2-20 nm), fall in the quantum confinement regime. As such, they exhibit optical properties that can be continuously adjusted over a wide wavelength range, from the infrared to the ultraviolet (Fig. 1a),[1] and are efficient, room-temperature single photon sources at room temperature.[1,2] Recently, diluted CQDs were integrated in electrical transport layers, allowing for observation of electrically-injected single-photon emission.[3] However, the charge injection pathway is very complex in such devices as they involve a very large ensemble of CQDs, and brightness is very low as single photon purity is achieved by collecting photons from a very limited area.[4]

In this internship, we propose to use scanning tunneling electroluminescence microscopy (STLM)[5,6] to probe electronic and optical properties of CQDs with unprecedented nanoscale resolution, in effect realizing a true single-CQD LED inside a STM equipped with light collection optics. The goals are:

(1) probe the local electronic density of states of single CQDs using tunneling spectroscopy, and correlate this with STLM electroluminescence and with ensemble optical spectroscopy;
(2) build a Hanbury-Brown & Twiss interferometer to observe single photon emission excited by tunnel currents in single CQDs;
(3) provide an accurate description of the charge injection mechanism.

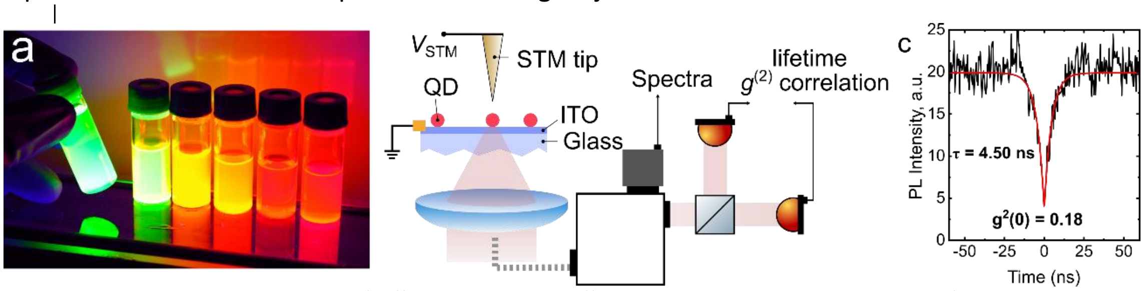

Figure 1. (a) CdSe colloidal quantum dots of different sizes emit at different wavelengths thanks to quantum confinement (b) Principle of STLM single-photon experiment with CQDs. STM tip ensures local injection of current, local electroluminescence is collected in transmission by a lens and spectrally analyzed with an amplified camera. (c) Electrically-injected single photon source purity measurements in a dilute CQD LED device.

The candidate will perform:

- Visible and near-IR CQD nanofabrication, material characterization
- Fabrication and optimization of single-particle sample, single particle optical spectroscopy
- Exploration of CQD surface chemistry and sample architecture for STM experiments
- Construction and adaptation of an HBT interferometer compatible with STLM measurements
- Experiment design, automation, data analysis (LabView, Python…)

(1) Pietryga et al. *Chem. Rev.* **2016**, *116*, 10513–10622.
(2) Proppe et al. *Nat. Nanotechnol.* **2023**, *18*, 993–999.
(3) Lin et al. *Nat. Commun.* **2017**, *8*, 1132.
(4) Deng et al. *Nat. Commun.* **2020**, *11*, 2309.
(5) Hahn et al. *Phys. Rev. B* **2018**, *98*, 045305.
(6) Sauty et al. *Phys. Status Solidi B* **2023**, *260*, 2200365.

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