Master 1 internship - Coherent quantum emitter coupled to a nanophotonic waveguide

Overview

Institution: Sorbonne University - Ecole Normale Supérieure - CNRS - Laboratoire Kastler Brossel
Team: Nanophotonics team - Hanna Le Jeannic, Alberto Bramati, Quentin Glorieux
Location: Jussieu campus. Paris, France
Duration: 3-6 months
Websites: www.quantumoptics.fr and www.lejeannic.quantumoptics.fr/

Quantum emitters coupled to Nanophotonics waveguides

Photons have long been favored as carriers of information due to their non-interacting nature. Traditionally, atoms have served as the primary means to manipulate and process quantum information carried by photonic qubits. However, recent groundbreaking advancements in solid-state emitters such as color centers, quantum dots, and molecules have ushered in a new era of highly coherent interaction with light, akin to atomic-level interactions.

Moreover, the seamless integration of solid-state emitters into nanophotonic structures has unlocked the potential for achieving remarkably efficient light-matter interactions [1]. Amongst them, nanofibers have attracted attention due to their guided evanescent field that enables efficient coupling of emitters placed at their vicinity. This breakthrough not only facilitates the creation of high-performance single-photon sources but also enables the exciting prospect of photon-photon interactions[2].

Within the nanophotonic research team at LKB, we have cultivated expertise in the production of nanofiber waveguides and their precise coupling with solid-state emitters [3, 4]. This specialized focus empowers us to drive advances in single-photon quantum information processing

Internship Description

In this exciting research project, we are embarking on a journey to explore new frontiers in quantum optics by coupling molecules to a nanofiber waveguide. While our group has previously focused on coupling quantum dots to nanofibers, we are now expanding our horizons to investigate the unique potential of molecules as highly stable and coherent emitters, particularly at low temperatures. Molecules possess distinct advantages as quantum emitters. Unlike quantum dots, which can be susceptible to environmental perturbations, molecules offer exceptional stability and coherence characteristics at cryogenic

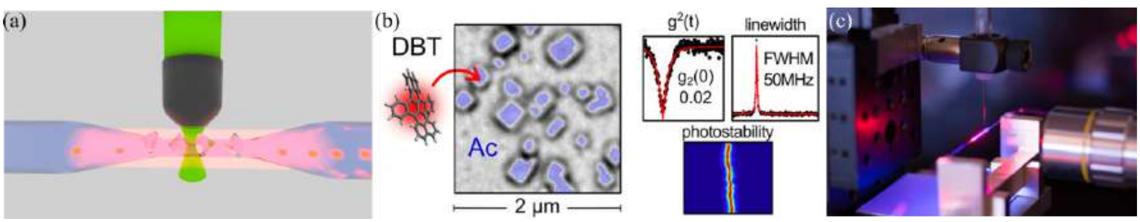

Figure 1: (a) Illustration of the concept. Single emitters deposited on a nanofiber emits photons directly in the nanofiber. (b) Nanocrystals of Anthracene containing single DBT molecules and their performance as a single photon source. From [5]. (c) Photography of the setup showing the deposition of single emitters onto the nanofiber

temperatures. This enhanced stability and coherence make them ideal candidates for generating single photons with exceptional fidelity, an essential requirement for emerging quantum technologies.

With a collaboration with the University of Florence in Italy, we have access to nanocrystals containing single molecules [5]. By coupling molecules to a nanofiber waveguide, we aim to harness their inherent coherence properties to achieve highly efficient and coherent single photon generation. The resulting single photons will serve as fundamental building blocks for quantum communication, quantum computing, and quantum cryptography applications. The project will present a range of challenges, including precise deposition of single nanocrystals on the nanofiber, integration of the system in a cryostat, characterizing the quantum state of emitted photons, and optimizing the photon extraction process.

In addition to single photon generation, coupling molecules to a nanofiber also opens up the possibility of exploring interactions between these coherent photons and individual atoms-like quantum emitters. This aspect of the project holds immense potential for quantum information processing.

Key Responsibilities:

- **Quantum Emitter deposition** Fabricated optimized nanofibers and develop a technique to deposit a single nanocrystal containing a single molecule onto the nanofiber
- **Nanofiber Waveguide Coupling:** Modelize the system using FDTD simulation. Investigate methods to increase the coupling of the quantum emitter to the nanofiber waveguide to enhance photon extraction and propagation.
- **Experimental Setup:** Contribute to the design, construction, and maintenance of the experimental setup for the research project.
- **Characterization and Measurement:** Perform measurements and characterizations to assess the quality and coherence of single photons generated.
- **Collaboration:** Collaborate with other researchers and team members to share insights, solve problems, and advance the project's goals.

How to Apply - Contact Us

For inquiries or more information about this internship or to apply for this internship, please contact us directly at hanna.le-jeannic@cnrs.fr.

Nanophotonics group at LKB

We are a group of friendly and welcoming scientists and we aim to create **an inclusive and supportive research environment.** We strongly believe in the value of diversity and inclusion in the field of quantum physics and we encourage **women and/or individuals from underrepresented minority groups** to apply for this internship.

References

[1] H. L. Jeannic, A. Tiranov, J. Carolan, T. Ramos, Y. Wang, M. H. Appel, S. Scholz, A. D. Wieck, A. Ludwig, N. Rotenberg, L. Midolo, J. J. García-Ripoll, A. S. Sørensen, and P. Lodahl, "Dynamical photon-photon interaction mediated by a quantum emitter," *arXiv*, Dec. 2021.

[2] P. Türschmann, H. Le Jeannic, S. F. Simonsen, H. R. Haakh, S. Götzinger, V. Sandoghdar, P. Lodahl, and N. Rotenberg, "Coherent nonlinear optics of quantum emitters in nanophotonic waveguides," *Nanophotonics*, vol. 8, pp. 1641–1657, Oct. 2019.

[3] S. Pierini, M. D'Amato, M. Goyal, Q. Glorieux, E. Giacobino, E. Lhuillier, C. Couteau, and A. Bramati, "Highly Photostable Perovskite Nanocubes: Toward Integrated Single Photon Sources Based on Tapered Nanofibers," *ACS Photonics*, vol. 7, pp. 2265–2272, Aug. 2020.

[4] M. Joos, C. Ding, V. Loo, G. Blanquer, E. Giacobino, A. Bramati, V. Krachmalnicoff, and Q. Glorieux, "Polarization Control of Linear Dipole Radiation Using an Optical Nanofiber," *Phys. Rev. Appl.*, vol. 9, p. 064035, June 2018.

[5] S. Pazzagli, P. Lombardi, D. Martella, M. Colautti, B. Tiribilli, F. S. Cataliotti, and C. Toninelli, "Self-Assembled Nanocrystals of Polycyclic Aromatic Hydrocarbons Show Photostable Single-Photon Emission," *ACS Nano*, vol. 12, pp. 4295–4303, May 2018.