Internship Offer (M2) – Generating nonclassical states of light using waveguide quantum electrodynamics

We are seeking a motivated and talented **Master's (M2) student** for a research internship focused on **theoretical quantum optics**. The internship will involve exploring the interaction between a laser field and a quantum emitter to calculate the quantum photonic states that can be generated through this interaction.

Overview

Title: Generating nonclassical states of light using waveguide quantum electrodynamics
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: 4-6 months
Deadline for applications: December
Websites: www.quantumoptics.fr and www.lejeannic.quantumoptics.fr/

Project Overview:

Photons have long been favored as information carriers due to their non-interacting nature. Traditionally, atoms have been 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 and enable to completely reshape few photon pulses [1].

If so far most of the effort in the solid-state has been towards the generation of single photons, recent proposals suggest that the interaction of light with a single two-level emitter could also produce highly nonclassical states when coupled to photonic waveguides[2, 3].

This internship will focus on studying the evolution of quantum states when a few photons (e.g., from a weak laser) interact with a two-level quantum emitter (atom, molecule, or quantum dot), which is critical for quantum computing, communication, and sensing. We aim to model realistic systems (e.g., imperfect emitters or couplings) and explore how varying interaction parameters (detuning, input field) might generate nonclassical states like squeezed states or even cat or GKP states, and under what conditions this can be achieved.

The project will involve:

- Modeling and simulating the interaction between a few photon field and quantum emitters using a recently developed approach. [2]

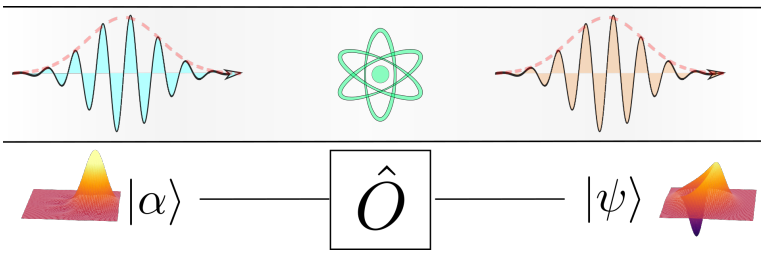

Figure 1: Concept idea: a few photon coherent state (i.e. an attenuated laser) interacts with a quantum emitter in a waveguide and enable the creation of a nonclassical quantum state, with a Negative Wigner function.

- Investigating how different parameters (detuning, coupling, decoherence) affect the quantum states produced.
- Propose an experimentally viable approach to generate interesting quantum states of light using single solid states emitters in a nanophotonic waveguide.

This work will contribute to a better understanding of quantum state manipulation, a fundamental topic in advancing quantum technologies.

Key Responsibilities:

- Perform theoretical analysis and calculations.
- Develop and implement computational models for simulating quantum interactions.
- Analyze and interpret the results in the context of quantum state generation.
- Collaborate with the research team and contribute to group discussions.
- Document findings and potentially contribute to academic publications.

Candidate Profile:

- Currently enrolled in a **Master's program (M2)** in **Quantum Mechanics**, **Optics**, or a related field.
- Familiarity with **quantum optics** and/or **quantum information** is a plus.
- Experience with **computational tools** (in particular Python).

Benefits:

- Hands-on experience in cutting-edge research in quantum physics.
- Possibility to contribute to scientific publications.
- Possibility of going on in Ph.D (experimental)

Application:

For inquiries or more information about this internship or to apply for this internship, don't hesitate to get in touch with us directly at hanna.le-jeannic@cnrs.fr. Please submit your CV, a brief cover letter explaining your interest in the position, and your academic transcripts.

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.

We look forward to receiving your application!

References

[1] H. Le 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] A. H. Kiilerich and K. Mølmer, "Quantum interactions with pulses of radiation," *Phys. Rev. A*, vol. 102, p. 023717, Aug. 2020.

[3] K. Kleinbeck, H. Busche, N. Stiesdal, S. Hofferberth, K. Mølmer, and H. P. Büchler, "Creation of nonclassical states of light in a chiral waveguide," *Phys. Rev. A*, vol. 107, p. 013717, Jan. 2023.