

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: LPENS

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Internship location: 24 rue Lhomond 75005 Paris

Thesis possibility after internship: YES

Funding: NO

If YES, which type of funding:

Near field cavity quantum electrodynamics with telecom nano emitters.

The scientific project focuses on coupling nano-emitters to optical micro-cavities, which has a multitude of potential applications. Such coupling enables the modification of "natural" emitter properties through phenomena like the Purcell effect; which enhances the spontaneous emission rate and the efficient funneling of photons into a single optical mode. These effects are particularly valuable for quantum telecommunication. Moreover, this technique allows the generation of coherent light-matter superpositions (polaritons), paving the way for advanced photonic functionalities such as few photon non-linearity or quantum logic gates. The strength of light-matter coupling depends on the ratio Q/V where V denotes the cavity mode volume and Q denotes the quality factor of the system. Two main strategies exist to maximize this figure of merit: the plasmonic route, which is restricted by Ohmic losses in the metal, yet with the mode volume being significantly sub-wavelength, and the dielectric resonator route, which can attain very high 'Q', yet with a mode volume not smaller than $\sim \lambda^3$ due to the diffraction limit.

Our project aims to combine both approaches by designing and fabricating modified dielectric cavities that exhibits high Q-factor and deeply sub-wavelength volumes, achieved through a near field approach. These cavities will be used to couple solid-state nano-emitters (organic color centers in carbon nanotubes, graphene or perovskite quantum dots [3]) that behave like artificial atoms, for quantum technology applications. In fact, by utilizing the discontinuities of the electric field at the center of a particular dielectric bow-tie antenna, it is possible to generate an anomaly in the E field resulting in an extremely small effective mode volume, with virtually no lower limit [1]. The price to pay is a limited extension of the mode in the z direction which puts this approach at the border of near-field optics.

Efficient coupling between the nano-emitter and the cavity requires two key conditions: the emitter has to be positioned in the cavity field maximum (spatial matching), and the cavity has to be resonant with the emitter (spectral matching). To fulfill these requirements, our team has developed open-cavity system over several years, where one mirror is fabricated on the tip of an optical fiber [2,4]. The spatial and spectral matching are naturally obtained by moving this fiber. In this project, the bow-tie dielectric antenna will be fabricated on the tip of the fiber. All the necessary experimental equipment to conduct the experiments is readily available within our team. The core focus of this internship is to design, nanofabricate and benchmark the dielectric antennas.

Subsequent developments within the PhD project will involve coupling the antennas to an appropriate quantum emitter while investigating advanced quantum optics effects.

[1] Choi et al, PRL 118 223605 (2017) .

[2] Jeantet et al, PRL 116 247402 (2016).

[3] He et al, Nat. Mat. 17 663 (2018).

[4] Borel et al, ACS photonics,10, 2839 (2023).

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