Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: LPENS
CNRS identification code: UMR 8023
Internship director'surname: Yannick Chassagneux & Christophe Voisin
e-mail:yannick.chassagneux@ens.fr christophe.voisin@ens.fr Phonenumber:0608759235
Web page:
Internship location: ENS, 24 rue Lhomond 75005 Paris

Thesis possibility after internship: YES
Funding: EDPIF

Deep sub-wavelength dielectric cavities for cavity quantum electrodynamics with nano-emitters.

Coupling nano-emitters to optical micro-cavities has a wide range of applications: among them the possibility to modify "natural" properties such as spontaneous emission (the so-called Purcell effect: acceleration of the spontaneous decay rate and efficient funneling of photons into a single optical mode, with applications for quantum telecommunication). It can also be used to generate coherent superposition of light and matter states (polaritons), which open the door to many advanced photonic functionalities, such as the few photon non-linearity, quantum gates… The strength of light-matter coupling depends crucially on the ratio Q/V where V is the cavity mode volume and Q is the lowest quality factor of the system. Two main routes are presently pursued to maximizes this figure of merit : the plasmonic route, where Q is limited by Ohmic losses in the metal, but where the mode volume can be strongly sub-wavelength and the dielectric resonator route, that can have very high Q but where the mode volume is usually no smaller than $\sim\lambda^3$.

Here, we propose to get the best of both approaches by designing and fabricating modified dielectric cavities (hence with high Q) with deep sub-wavelength volume. These cavities will be used for coupling solid state nano-emitters such as carbon nanotubes, graphene quantum dots, perovskite quantum dots, 2D transition metal dichalcogenides… In fact, the usual limitation of mode volume to $\sim \lambda^3$ in micro-cavities is a consequence of the diffraction limit, but this holds only for uniform dielectric environment. By using the discontinuities of the electric field at interfaces and using a specific antenna geometry, it is possible to create an anomaly in the E field leading to an extremely small effective mode volume, with virtually no lower limit [1].

Coupling an emitter to a cavity requires two additional conditions: the emitter has to be in the cavity field maximum (spatial matching), and the cavity has to be resonant with the emitters (spectral matching). To fulfilled these requirement we choose from several years to work with open-cavities, 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 fibered mirror. The cavity that we propose to develop here can be decomposed in two part: the outer part will be similar with a fibered cavity and will gives the high Q factor, the spectral and spatial matching. The inner part will be a dielectric structure (with a bow tie shape) fabricated on the tip on the fiber, leading to the E-field anomaly and thus to the sub-wavelength volume.

All the experimental environment needed to conduct these experiments is already available in our team; the core of the project for this internship is the design, nanofabrication and benchmarking of the dielectric antennas. Further developments in the PhD project include the coupling to an appropriate quantum emitter and investigation of advanced quantum optics effects.

[1] Choi et al, PRL 118 223605 (2017) .
[2] Jeantet et al, PRL 116 247402 (2016).
[3] Jeantet et al Nano Lett. 17 4184 (2017).
[4] X. He et al, Nat. Mat. 17 663 (2018).

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