Compact and controllable STRONGly-coupled NANOsources of light (STRONG-NANO)

Laboratories involved	L2n (UTT, CNRS), CINTRA (NTU Singapour, Thales, CNRS)
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This master internship and its objectives, illustrated if Fig. 1, will benefit from a new granted ANR project that is coordinated by Renaud Bachelot: STRONG-NANO (2023-2026). The project will be carried out in collaboration with the CINTRA laboratory (Thales/CNRS/NTU Singapore) where Cuong Dang is an expert in strong coupling for nanophotonics [Yu20]. Within this international context, the master student will have the possibility to continue with a 3-year PhD thesis (grant already obtained).

Strong light-matter coupling is a new tool for molecular, photonic and material engineering [Bit19, Sam21] and plays a key role in several fields of physics and technology such as: lazing processes, non-linear optics, quantum information, light emission, photochemistry and exciton transport.

Nowadays, despite the numerous reported strong coupling demonstrations involving hybrid plasmonic nanosources, there are still three crucial requirements to be satisfied: i) precise spatial position of quantum emitters of different colors at the plasmonic hot spots, ii) excitonic emitters with strong oscillation strength, iii) controlled coupled nanosystem, including systems at the single particle level, allowing for the assessment of the efficiency of the coupled quantum system.

The master student will join a research team to address the above challenges by using plasmon-induced photopolymerization [Ge20, Ge22] for taking a new step forward: trapping in a controlled way one or a few strong excitonic nano-object (CdSe 2D nanoplatelets) in the vicinity of plasmonic nanostructures, resulting in strongly coupled light-emitting nanodevices at the single particle level, including single photon emitters.

C. Dang demonstrated that such strong excitonic nano-objects of giant Rabbi splitting energy can easily lead to strong coupling with metal nanocavities (silver nanocubes) [Yu20]. However, he could not control the spatial distribution of the nanoplatelets (or their number) in the vicinity of the nanocubes. Using the unique method of nano-positioning developed at L2n [Ge20, Ge22], the master student is expected to take part in the achievement of new breakthroughs.

More particularly, the project is associated to three objectives:

i) Fabricating and characterizing the strongly coupled hybrid system consisting of ensemble of CdSe nanoplatelets and a single plasmonic nanocavity of different natures (nanocubes, bowties, bipyramids,..in gold, silver, aluminum,..). We expect a plasmonic polariton light source at a sub-λ scale with Rabi-energy > 500 meV. The anisotropy of the active medium will be exploited to command the strength of the strongly coupled hybrid system (see Fig. 6(b)) with the polarization of the incident optical field

ii) Achieving coupling between a single nanoplatelet and a plasmonic nanocavity and studying transition from weak to strong coupling regime at room temperature

iii) Utilizing the strongly coupled (single small nanoplatelet/plasmonic nanocavity) system to demonstrate reliable on-demand single-photon sources with $g2(0)<0.1$ and number of photons per pulse > 0.5 (the quantum efficiency of the coupled system).

Ultimately, we will try to couple the strongly coupled nanosystem to integrated photonic waveguides, for getting a fist prototype of an integrated functional nanosystem. The L2n Lab has got a strong experience about this issue [Xu20].

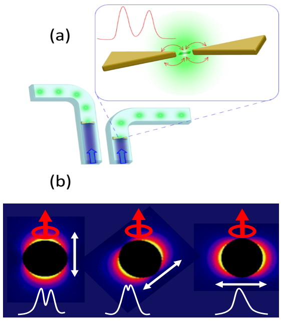

Fig. 1. Strong coupling at the single particle level. Main objectives: (a) Compact sources, including one-photon source, consisting of a strongly coupled single nanoplatelets/plasmonic structure (inset) that can also be integrated into photonic waveguides. (b) For a fixed position of the emitter (already controlled by plasmonic photo-polymerization), the excitation of the emitter can be tuned with the incident polarization. From left to right: strong excitation (strong coupling), middle excitation, weak excitation (weak coupling): the strength of the involved oscillators can be controlled, and the strong coupling can be consequently remotely tailored.

References

[Bit19] O. Bitton et al. Quantum dot plasmonics: from weak to strong coupling. Nanophot. 8, 559 (2019); [Ge20] D. Ge et al. Hybrid plasmonic nano-emitters with controlled single quantum emitter positioning on the local excitation field. Nature Comm. 11, 3414 (2020); [Ge22] D. Ge et al. Advanced hybrid plasmonic nano-emitters using smart photopolymer. Photonics Research 10 (7) 07001552 (2022); [Sam21] A.D Sample et al., Strong coupling between plasmons and molecular excitons in metal–organic frameworks Publication date. Nano lett. 21, 7775 (2021) [Xu20] X. Xu et al. Towards the integration of nanoemitters by direct laser writing on optical glass waveguides. Photon. Res. 8, 1541 (2020); [Yu20] J. Yu et al. Strong Plasmon-Wannier Mott Exciton Interaction with High Aspect Ratio Colloidal Quantum Wells. Matter 2, 1550 (2020);

Examples of Knowledges and Skills that are likely to be acquired during the internship

Knowledges: (nano)optics, material science, solid state physics, nanoplasmonics, excitonics
Skills/experience: optical characterization, sample preparation, micro-nano fabrication. Experience in electromagnetic simulation