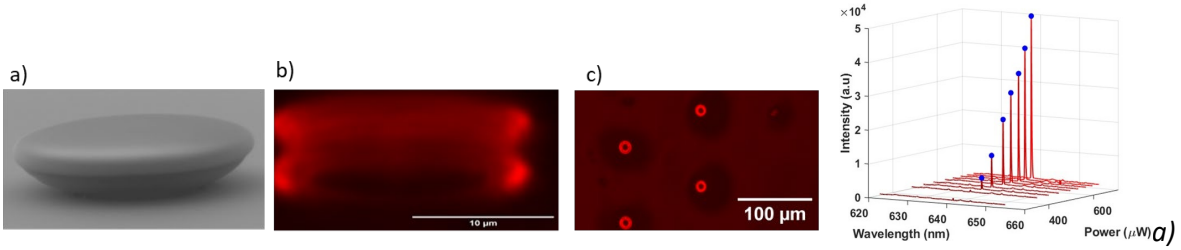
Master thesis proposal

Institut des Nanosciences de Paris
Sorbonne Université, 4 place Jussieu, Paris

Title: Excitonic whispering gallery mode laser in high pumping regime

Keywords: laser, quantum dot, whispering gallery mode, exciton

Scientific description:
In nanophotonics and quantum technologies, photon sources are a ressource which can be integrated into a chip. Cylindrical dielectric microdisks make excellent resonators in which optical gallery modes can propagate at the air/dielectric interface.
Using optical lithography, we have fabricated gallery-mode resonators on which we have deposited fluorescent nano-emitters, colloidal quantum dots. These are CdS/CdSe/CdS semiconductors in a spherical core/shell/shell configuration. Of nanometric dimensions, their fluorescence wavelength depends on their size. They can emit single photons, are resistant to photobleaching and are bright under strong excitation. We have deposited these quantum dots in high concentration on microdisks, in order to achieve a sufficient gain. We were therefore able to create gallery modes excitonic microlasers. [1,2].



microdisk optical cavity C b) Fluorescent gallery mode (side view split by substrate reflection) c) Gallery mode (top view) d) Laser mode and fluorescence spectra

The aim of this internship will be to study these gallery-mode lasers, as a function of their size, shape or when two cavities are coupled. In particular, we will be interested in the behavior of these lasers far from the threshold, when the excitation laser is intense. Under these conditions, the resonant gallery mode intensity is high. If its coupling to the excitons is sufficiently strong, emission will be modified by exciton-photon interaction. We will study these strong coupling configurations in relation to theoretical predictions.

[1] C. Kersuzan et al, *ACS Photonics, 11(4), 1715-1723 (2024)*
[2] C. Kersuzan et al, *ACS Nano, 19, 42, 37444 (2025)*

Techniques/methods in use: fluorescence, microscopy, spectroscopy
Applicant skills: optics and/or nanophotonics

Internship supervisor(s): Agnès Maître, agnes.maitre@insp.jussieu.fr, 01 44 27 42 17
Juliette Lignières , juliette.lignieres@insp.jussieu.fr
Internship location: INSP, Sorbonne université, Jussieu, Tour 22-32, 5th floor

Possibility for a Doctoral thesis: Y , **funding** : Doctoral school

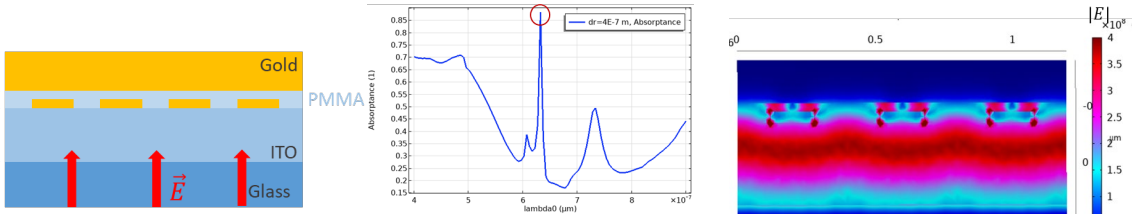
Master thesis proposal

Institut des Nanosciences de Paris
Sorbonne Université, 4 place Jussieu, Paris

Title: Collective resonance of a nano-antennas lattice

Keywords: plasmons, lithography, quantum dots, fluorescence

Scientific description:
Under electromagnetic excitation, metal nano-objects can support collective electron oscillations, known as plasmon waves which allows the nanoparticle to be assimilated to an oscillating dipole that absorbs and scatters light. When illuminated with white light, a resonance (Localised Surface Plasmon Resonance, LSPR) whose center and width, typically a few tens of nanometres, depend on the dielectric constant of the metal, the shape of the nanoparticle and on the dielectric environment of the nanoparticle. This property makes it possible to create sensitive sensors based on the detection of LSPR resonance shifts when the nanoparticle's environment changes. However, the sensitivity of these sensors is limited by the width of the LSPR resonance. To increase sensitivity, these nanoparticles can be positioned as a lattice on a substrate. Given the periodicity of this arrangement, the first order diffraction of incident light at a given wavelength can propagate in the plane of the array resulting in a much thinner resonance used to increase the sensitivity of the sensor. This resonance is called Surface Lattice Resonance (SLR).
As part of this internship, we will fabricate arrays of gold nanoparticles above a gold mirrors, enabling us to observe collective resonance of such antennas lattice. We will characterize them optically and optimize the parameters to maximize the signal and its spectral finesse. In a second step, we will deposit CdSe/CdS quantum dots that resonate or do not resonate with the SLR modes, and study how their emission is modified by the resonance.



Figue 1: a) scheme of the antenna lattice, b) absorptance spectrum, c) resonance

Techniques/methods in use: electron beam lithography, spectroscopy, microscopy, fluorescence,

Applicant skills: skills in optics and/or nanophotonics

Internship supervisors:

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- Hugo Saint Olive, hugo.saint-olive@insp.jussieu.fr

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Possibility for a Doctoral thesis: Y , funding : Doctoral school

Master thesis proposal

Institut des Nanosciences de Paris
Sorbonne Université, 4 place Jussieu, Paris

Strong coupling for a colloidal quantum dot inside a plasmonic nano-antenna

Keywords: fluorescence, quantum dot, plasmonics, strong coupling

Scientific description:

CdSe/CdS core/shell quantum dots are excellent bright nano-emitters. At room temperature, under low excitation power they behave as high quantum efficiency single photon source thanks to the electronic confinement and efficient Auger processes leading to the recombination of a single exciton. They can be analysed as a simple two-level system and their emission linewidth is approximately $\Delta\lambda \approx 20$ nm. However, by increasing the excitation power, emission spectrum broadens dramatically up to $\Delta\lambda \approx 150$ nm (Fig1a). Moreover, the emission intensity grows non-linearly with increasing excitation power [1][2]. The two- levels system paradigm fails for interpreting those features. In this view, we have successfully developed a model based on the radiative recombination of multiple excitonic levels within a single nanocrystal , relying on statistical description[3] of electron and hole populations in a quasi-equilibrium and Bayesian analysis.

Patch plasmonic nanoantennas consist of a thin dielectric medium sandwiched between a thick gold layer and gold patch. In the preceding years we have developed protocols in order to locate single quantum dots inside antenna. We have demonstrated that for a quantum dot inside such antenna, the absorption cross section is increased by 3 order of magnitude. Therefore such an antenna/ quantum dot system is a good candidate for achieving strong coupling, a regime for which quantum dots emission and cavity resonance cannot be considered independently anymore.

During the internship, the student will start developing bright optical nanosources by coupling nanoemitters to plasmonic antennas. He/she will fabricate then and study by confocal optical microscopy the fluorescence (emission rate and spectrum, directivity,…). The final objective is to achieve the regime of strong coupling regime between the emitter and the confined field excited inside the antenna. Thanks to a high confinement and excitation, the emitters should gain specific original quantum properties.

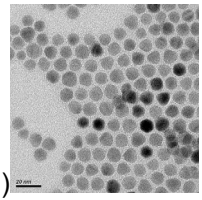
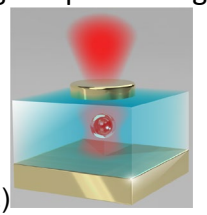
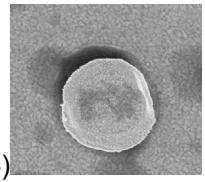
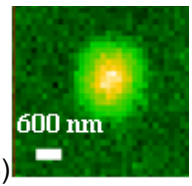
1)  2)  3)  4) 

Figure: 1) TEM images of CdSe/CdS nanocrystals 2) patch antenna 3) SEM image of patch antenna 4) emission pattern of patch antenna

References

[1] A.R Dhawan, et al. (2020) Light: Science & Applications, 9(1), 1-9., [2] A. R Dhawanet al (2022), Advanced Materials, 34(11), 2108120, [3] P. Wurfel. (1982) 15(18), 3967.

Techniques/methods in use:, optical microscopy, optical lithography, spectroscopy

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Possibility for a Doctoral thesis: Y , funding : Doctoral school