Master thesis proposal

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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.

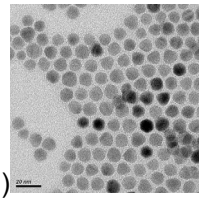
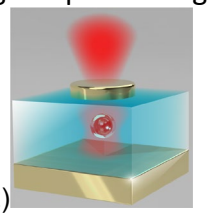
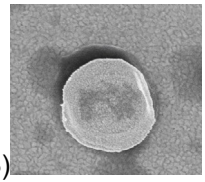
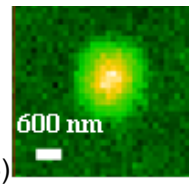
1)  2)  3)  4) 

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

Internship supervisors:

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