Control of the Emission of Perovskite Quantum Dots through Plasmonic Coupling for Quantum Photonics

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Lead halide perovskite nanocrystals (NCs) can be synthesized through low-cost solution processing methods,[1] and exhibit high photoluminescence quantum yields and tunable bandgaps. They are currently investigated for a wide range of optoelectronics applications.[2] In particular, they have demonstrated single photon emission with high rates, high purity, and good indistinguishability, making them a promising platform for quantum photonics.[3] However, their optical properties still need to be further improved to enable efficient integration into quantum photonic devices. For this purpose, coupling nanoemitters to plasmonic nanostructures is of great interest, as it has been shown to accelerate spontaneous emission, enhance brightness, and modify the radiation pattern of quantum emitters. This strategy can therefore be extended to perovskite NCs.[4]

First, halide perovskites NCs with the general formula $CsPbX_3$ (X=Br, I) will be studied. Once the optical properties of perovskite quantum dots have been characterized at the single-particle level (photon antibunching, brightness and stability) with a confocal microscope and Hanbury-Brown and Twiss (HBT) set-up, they will be coupled to plasmonic nanostructures. GEMaC has developed a technique for manipulating nano-objects with an AFM Tip. It will be possible to design nanostructures composed of elementary metallic building blocks, such as gold spheres or cubes incorporating a single NC.

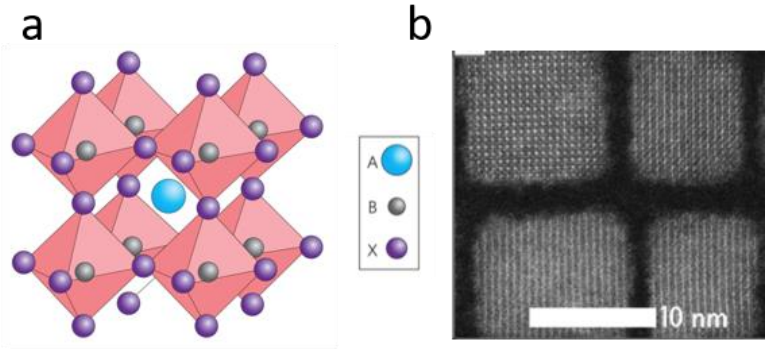

Figure 1 : (a) Perovskite ABX_3 structure (b) HR –STEM image of $CsPbBr_3$ nanocrystals.

Second, the influence of a plasmonic structures will be investigated on thin polymer layers containing NCs ($CsPbI_3$ in particular). These layers will be deposited onto a gold film, and gold nanoparticles of various geometries (such as spheres, cubes and rods) will be spin coated on the polymer layer. The gap plasmon appearing in the polymer layer will induce a strong modification of the NCs emission. In both types of system, the modification of the emission

will be experimentally measured and compared with the reference measurements performed on single NCs without plasmonic structure.

These experimental investigation will be complemented by finite-difference time-domain (FDTD) numerical simulations to characterize the plasmonic structures and quantify their impact on the NCs emission properties, including decay rate, brightness and radiation pattern.

GEMaC is a laboratory conducting research in the field of fundamental physics, condensed matter, and material science. The quantum nanophotonics group is working on nanoemitters, quantum photon sources, and halide perovskites (https://www.gemac.uvsq.fr/oen). The synthesis of the nanoparticles will be carried out in collaboration with Cédric Mayer from LuMIn laboratory, with possible involvement from the candidate. The candidate should have a strong interest in material science and photonics.

References:

[1] Mayer, C. R., Levy-Falk, H., Rémond, M., Trippé-Allard, G., Fossard, F., Vallet, M., Lepeltier, M., Guiblin, N., Lauret, J.-S., Garrot, D. and Deleporte, E. (2022), 'Synthesis of highly calibrated CsPbBr3 nanocrystal perovskites by soft chemistry', *Chemical Communications* **58**(40), 5960--5963.
[2] Dey, A *et al*.(2021), 'State of the Art and Prospects for Halide Perovskite Nanocrystals', *ACS Nano*. **15**(7), 10775—10981.
[3] Kaplan, A. E. K., Krajewska, C. J., Proppe, A. H., Sun, W., Sverko, T., Berkinsky, D. B., Utzat, H. and Bawendi, M. G. (2023), 'Hong-Ou-Mandel interference in colloidal CsPbBr3 perovskite nanocrystals', *Nature Photonics* **17**(9), 775--780.
[4] Shuya N., Zhihui L., Shuo W., Naming Z, Bin Y., Xin W. And Fanghui Z 'Remarkable emission enhancement of CsPbBr3 quantum dots based on an Ag nanoparticle-Ag film plasmonic coupling structure', Optics Express 32, 9276 -2024).

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