PhD proposal

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Strong coupling of single quantum dot emission within plasmonic antenna modes

ANR Colime

Scientific description:

In the framework of quantum technologies, we aim to develop optical nanosources as elementary building blocks. In that regard, we couple quantum dots to plasmonic antennas in order to improve their fluorescence characteristics such as emission rate or directivity. We achieve a high interaction between the quantum dots and the confined field excited inside the antenna. The objective of our studies is to study how, thanks to a very high confinement and high excitation, the emitters gain specific original quantum properties.

Nanometric semi-conductor colloidal quantum dots, like CdSe/CdS ones, are excellent single photon, stable and bright sources. Their discovery and synthesis has been recently awarded by the Chemie Nobel Price in 2023 given to M. Bawendi, L. Brus and S. Klimov.

When they are excited by an intense laser, we have evidenced radiative emission of multiexciton, acceleration of emission and dramatic spectral broadening. These features couldn't be explained by a standard 2 level system emission model and new interpretations have to be elaborated. In the last years we have developed a statistical model which gives a good description of this phenomena in the steady state regime. The objectives of the internship and thesis are to go further in the pulsed regime and to adapt the model to plasmonic nanoantennas.

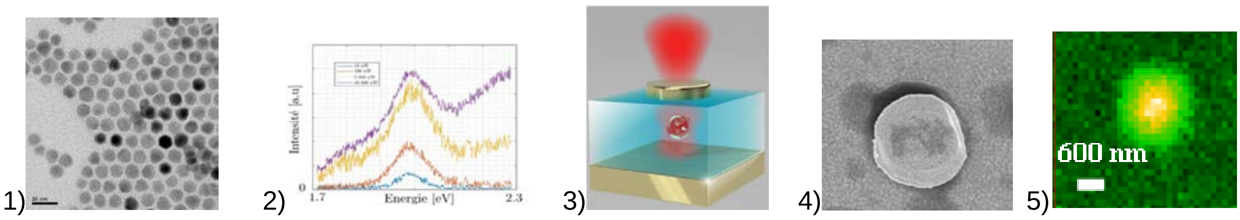

Figure: 1) TEM images of CdSe/CdS quantum dots 2) CdSe/CdS spectra broadening under increasing excitation 3) patch antenna 4) SEM image of patch antenna 5) emission pattern of patch antenna

Experimentally, we couple these single nanoemitters to patch nanoantennas, which consist of a thin dielectric medium sandwiched between a thick gold layer and gold patch. In the preceding years, we have developed lithographic methods making it possible to locate the emitter exactly in the center of the antenna to maximise interaction. We collect the antenna emission in far field by fluorescence microscopy. Thanks to plasmonic modes and high confinement, features observed for single nanocrystal outside the antenna are even reinforced and can be observe at much lower intensity excitation for nanocrystals inside antenna.

During the PhD, the student will study experimentally and theoretically regime of high interaction between field and nanoemitters, either outside the antenna, or within it. We will then investigate and interpretate the quantum properties of this nanosources.

Techniques/methods in use: optical microscopy, spectroscopy, , optical lithography, data analysis, modelling

Funds for the Doctoral thesis: ANR CoLiMe / doctoral school