Directed and enhanced photoluminescence of quantum nanoemitters using all-dielectric nanoantennas

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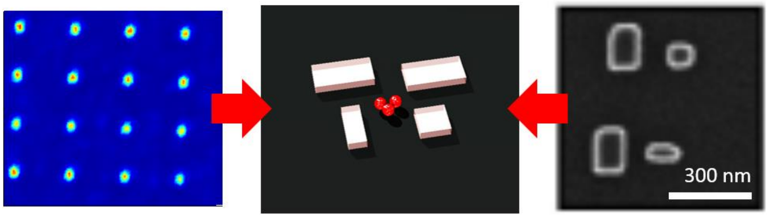
- Multidisciplinary topic based on the expertise of two laboratories from Toulouse.
- Funding by INSA Toulouse – CNRS for 3 years 2018-2021

KEY WORDS : single photon sources, colored centers, nanodiamond, quantum dots, dielectric nanostructures, directed assembling, nanoxerography, Atomic Force Microscopy (AFM), time-resolved optical microscopy, photon correlation, numerical simulation of optical properties.

Introduction and context - High-index dielectric nanostructures sustain electric and magnetic resonances in the visible. These resonances make possible a strong localization and enhancement of the field in the vicinity of the nanostructures, leading to a strong modification of the photonic local density of states. Consequently, the light emission by quantum emitters positioned in the near field of these structures can be controlled (enhancement, directivity, etc). In addition, the interferences between these resonances of low or high order allow for the manipulation of specific properties of light like the directivity of the scattered light in the far field. This topic is a growing field of research which is now challenging Plasmonics.

Topic - The main objective of this thesis is the production and the study of hybrid photonic systems made of silicon nanoantennas and fluorescent nanoparticles, allowing for enhancement and directivity control of the light emitted by these quantum emitters. This approach is essential for the development and the control of single photon emitters at nanoscale.



Left : 20x20 µm² confocal image of the luminescence of quantum dots clusters fabricated by AFM nanoxerography. Center: artistic view of a small cluster of quantum emitters placed at the center of a Si nanoantenna. Right: SEM image of a crystalline Si nanoantenna fabricated by e-beam lithography (LAAS-CNRS).

In this thesis, the fluorescent emitters will be semiconductor core-shell quantum dots and/or nanodiamonds hosting colored centers, both in solution, with typical diameters of few tens of nanometers.

The dielectric nanoantennas will be fabricated by ebeam lithography on silicon on insulator (SOI) substrates thanks to an active collaboration with the LAAS laboratory at Toulouse. Moreover, the geometry of these dielectric nanostructures will be optimized by the mean of electrodynamic simulations available at CEMES (Green dyadic method (GDM) coupled to an evolutionist optimization multi-objectives algorithm).

The spatial and quantitative positioning of the fluorescent emitters above the dielectric nanoantennas will be performed by a directed assembling technic called AFM nanoxerography. This technic has been developed in the Nanotech team of LPCNO. It relies on the local injection of electrostatically charged dots by the mean of an AFM tip which is polarized when positioned above the areas of interest (dielectric nanoantennas). These charged dots will act as selective electrostatic traps for the emitters.

Once the emitter-antenna hybrid systems are done, the spatial distribution of the photonic local density of states will be measured by mapping the photoluminescence of the emitters. The directivity will be assessed by back-focal plane imaging. These optical characterizations will be performed at CEMES.

We look for – The candidate will hold a Master degree or an equivalent diploma in condensed matter physics, nanotechnologies, colloids with a solid background in general physics, electromagnetism and optics.
The PhD student will be hosted by the Nanotech team of LPCNO and the NeO team of CEMES at Toulouse. The candidate will follow a multidisciplinary training, both experimental and theoretical, on (i) the electric and topographic modes of the AFM microscopy, (ii) the process of micro/nanodeposition related to the nanoxerography technic, (iii) the methods of electrodynamics simulation, (iv) the optical characterization at the single photon scale (quantum regime)

The candidate will have strong skills in experimental research, which will partly take place in the clean room of the Nanotech team of LPCNO, and/or prior experience in optical and/or AFM microscopies. Dynamism, scientific curiosity and rigor are the key words to carry out this project.

Contact - Interested? Please contact Laurence Ressier (Professor, LPCNO) and Aurélien Cuche (CNRS Researcher, CEMES)
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