POST-DOCTORAL FELLOWSHIP

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 (France).
- Funding by the Institute of Quantum technologies in Occitanie for 18 months 2021 (starting 09/01)

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

Introduction and context - In the context of the worldwide effort on quantum technologies, the development and the control of single photon sources are one of the most important stakes for quantum communication, either for long-range or on-chip applications. Recently, high-refractive index dielectric resonators, typically silicon nanostructures, have attracted increasing interest since they sustain electric and magnetic resonances in the visible that make possible a strong localization and enhancement of the field, leading to a strong modification of the photonic local density of states [1]. Consequently, the light emission by quantum emitters positioned in the near field of these structures can be controlled (enhancement, directivity). These properties, along with a weaker dissipation than in plasmonic systems and compatibility with CMOS technologies, make Si nanostructures a unique platform to investigate the classical to quantum optics transition in coplanar devices.

Topic - The main objective of this project is the production and the study of assembly of hybrid systems made of optimized silicon nanoantennas and quantum nanoemitters, allowing for enhancement and directivity control of the single photons emitted by these sources. This approach is essential for the development and the control of robust and integrated single photon sources at nanoscale for quantum communication.

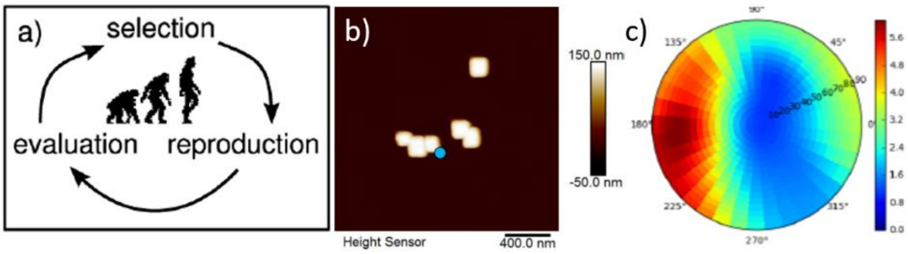

Figure 1: (a) Schematic of the evolutionary optimization (eo). (b) AFM image of an eo-optimized Si nanoantenna, made of silicon blocks, fabricated by e-beam lithography. (c) Simulated diagram of emission in the back-focal plane for a dipolar quantum emitter positioned at the center of the antenna shown in (b) where the blue dot shows the position of the dipole). Photons are preferentially emitted at 180°.

In this project, the quantum emitters will be colored centers in colloidal nanodiamonds, with typical diameters of few tens of nanometers [2]. NV centers will be preferentially used, but others colored centers available at CEMES will be considered too (collaboration with an academic partner). These different emitters will be systematically characterized by optical methods on operational time-resolved confocal microscopes at CEMES. Wavelength-dependent lifetime measurements and intensity correlation will be used to analyze their temporal dynamics.

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 as shown if Figure 1 (Green dyadic method (GDM) coupled to an evolutionist optimization (eo) multi-objectives algorithm) [3].

The spatial and quantitative positioning of the fluorescent emitters above the dielectric nanoantennas will be performed by a directed assembly technique called AFM nanoxerography [4,5]. This technique has been developed in the Nanotech team of LPCNO. It relies on the local injection of electrostatically charged dots by the mean of a polarized AFM tip positioned above the areas of interest (dielectric nanoantennas). These charged dots will act as selective electrostatic traps for the emitters. The two labs (CEMES and LPCNO) involved in that project recently demonstrated the deterministic and reproducible positioning of nanodiamonds on a flat SiO2/Si film (Figure 2).

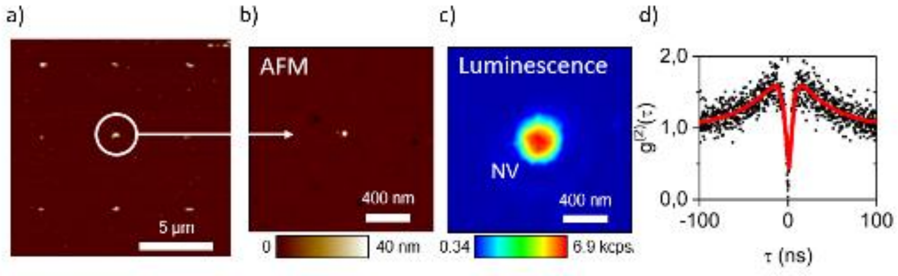

Figure 2: (a-b) Large-scale AFM images of an assembly of nanodiamonds fabricated by AFM nanoxerography. (c) Confocal image of the luminescence of the nanodiamond shown in (b). (d) Autocorrelation $g^{(2)}(t)$ *function recorded on the nanodiamond in (b) and (c). The photon antibunching at zero-delay is the signature of a single NV center in the diamond particle.*

Once the emitter-antenna hybrid systems are done, the wavelength- and (dipole) orientation-dependent modification of the photodynamics of the emitters will be measured by 2D mapping of the time-resolved photoluminescence. The directivity will be assessed by back-focal plane imaging. These optical characterizations will be performed at CEMES on state-of-art time-resolved confocal microscopes. The experimental results will be systematically supported by simulations based on the Green Dyadic Method.

We look for – The candidate will hold a PhD diploma in nano-optics, plasmonics, nanotechnologies, or near-field probes with a solid background in general physics, electromagnetism and light-matter interaction. The postdoctoral fellow will be hosted by the NeO team of CEMES and the Nanotech team of LPCNO at Toulouse (France). The candidate will be involved in the experimental aspects of (i) the electric and topographic modes of the AFM microscopy, (ii) the process of micro/nanodeposition related to the nanoxerography technique, (iii) the optical characterization at the single photon scale (quantum regime), and to the theoretical aspects of (iv) the methods of electrodynamics simulation and of the design of the structures by eo algorithm. The candidate will have strong skills in experimental research, and/or prior experience in optical and/or AFM microscopies. Autonomy, dynamism, scientific curiosity and rigor are the key words to carry out this project.

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References related to the projet

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