

PhD Proposal

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Location : Laboratoire Photonique Numérique et Nanosciences, UMR 5298, Institut d'Optique Graduate School, Bordeaux.

Subject : Toward Controlled Molecular Entanglement

Strong light matter interaction has been extensively studied in the last decades and tremendous experimental and theoretical efforts have been devoted to tailor and enhance this interaction by placing emitters close together at a nanometric distance, at the vicinity of a nanostructure where the electric field is exalted. In solid state physics, single emitters, such as single molecules, quantum dots, defects in diamond are good candidates to realize optical qubits as they can easily be manipulated with light, coupled to nano-devices or use in photon-based quantum information processing schemes.

Among all of these emitters, organic molecules are nearly ideal quantum emitters, emitting single indistinguishable photons [1], which makes them ideal candidates for basic building blocks of a quantum logic gate. To be fully operational, this gate requires a strong interaction between emitters. However, the dipole-dipole interactions occurs at short-range, well below the diffraction limit. New optical approaches to manipulate delocalized states formed by interacting emitters are therefore needed.

Recently, we developed a simple super-resolution optical microscopy method operating at cryogenic temperatures and obtained a sub 10-nm resolution [2,3]. In this PhD Work, we will propose to use this modality to reveal the rich space-frequency signatures of the coherent coupling and to manipulate, on demand, the degree of entanglement of such a system.

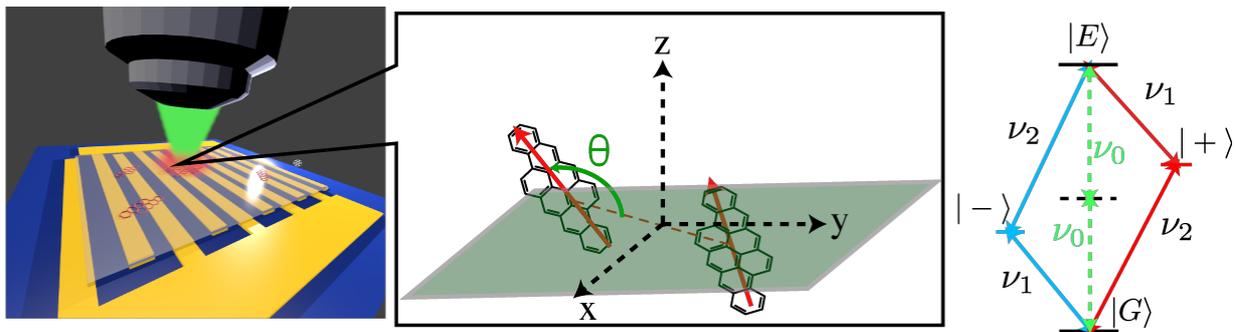


Figure 1 : Molecular entanglement proposal. A highly doped crystal containing interacting molecules will be placed above a micro-patterned electrode comb. The generated electric field, shifts the energy levels of the coupled pair and modify the degree of entanglement of the two intermediate states ($|-\rangle$ and $|+\rangle$).

References related to this project :

- [1] Trebbia, J. B., Tamarat, P. & Lounis, B. Indistinguishable near-infrared single photons from an individual organic molecule, *Phys Rev A*, (2010).
- [2] Yang, B., Trebbia, J. B., Baby, R., Tamarat, P. & Lounis, B. Optical nanoscopy with excited state saturation at liquid helium temperatures. *Nature Photonics* 9, 658–662 (2015).
- [3] Trebbia, J. B., Baby, R., Tamarat, P. & Lounis, B. 3D optical nanoscopy with excited state saturation at liquid helium temperatures. In preparation (2019).

Recent publications :

- Ming Fu *et al.*, “Unraveling exciton–phonon coupling in individual FAPbI₃ nanocrystals emitting near-infrared single photons”. *Nat. Commun.*, **2018**.
- Veshchunov, *et al.* “Optical manipulation of single flux quanta”, *Nat. Commun.*, **2016**.
- Veshchunov, *et al.*, “Direct Evidence of Flexomagnetoelectric Effect Revealed by Single-Molecule Spectroscopy”, *PRL*, **2015**.
- Yang, B, ... Trebbia J. B., Lounis B., “Polarization effects in lattice-STED microscopy”, *Faradays Disc.*, **2015**.