Towards the control of delocalized states of interacting emitters

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Optical resolution of solid-state single quantum emitters at the nanometer scale is a challenging step towards the control of delocalized states formed by strongly and coherently interacting emitters, and for efficient and deterministic coupling of emitters to photonic or plasmonic nanostructures.

I will describe a simple super-resolution optical nanoscopy method operating at cryogenic temperatures, which is based on optical saturation of the excited state of single fluorescent molecules with laser-shaped beams. Sub-5 nm resolution in the transverse plane and 20 nm resolution in the longitudinal direction have been achieved. Combining this approach with single molecule super-localization techniques, we could perform the study of coherent interactions between single emitters and manipulate their degree of entanglement.

The second part of my talk is dedicated to the hybridization of quantum emitters and plasmonic nanostructures in order to achieve long-range qubit entanglement. Recent theoretical studies suggest that the plasmonic field mainly acts as a communication bus allowing for intense cross-talking between emitters, and leading to the formation of collective states known as superradiant states. In such regime the synchronized dipoles radiate at an increased rate which scales with the number of emitters, as in the case of the Dicke superradiance. Yet, experimental evidence of plasmonic superradiance is still lacking mainly because of difficulties to engineer systems with precise control of the number and positions of emitters around a metallic nanostructure.

I will present our experimental investigations of plasmonic superradiance in nanohybrids constituted of a gold core capped with a silica shell grafted with fluorescent dyes. Single particle studies revealed that the average decay rate scales with the number of grafted emitters, in agreement with theoretical predictions. Observation of plasmonic superradiance at room temperature opens questions about the robustness of collective states against decoherence processes in the condensed matter.

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