Experimental evidence of plasmonic superradiance

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Hybridization of quantum emitters and plasmonic nanostructures has attracted much attention over the last years, due to their interest in the design of plasmon-based nanolasers [1] or to achieve long-range qubit entanglement [2].

Recent theoretical studies [3,4] 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 predicted to scale with the number of emitters as it is the case for the Dicke superradiance [5]. Yet, experimental evidence is still lacking to support the theory of plasmon-mediated superradiance. This is a due to the difficulty to create a system with precise control over the number of emitters and their relative distance to the structure.

In this work, we experimentally investigate the plasmonic superradiance from the fluorescence characterization of organic emitters near a metal nanosphere at room temperature. A silica shell acts as a spacer between the grafted emitters and the Au core. An ensemble study of Rhodamine B-nanohybrids revealed that the average decay rate scales with the number (N) of grafted emitters, in agreement with theoretical predictions [3]. This trend was confirmed by single particle statistics on Atto532-nanohybrids with a different core diameter. Furthermore, the slope with N increases dramatically as the emitters are closer to the core. According to our knowledge, we show here for the first time the direct evidence of plasmon-mediated superradiance. This observation of plasmonic superradiance at room temperature opens questions about the robustness of these collective states against decoherence mechanisms which are of major interest for potential applications.

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