

Theory of strong coupling between quantum emitters and propagating surface plasmons

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Abstract

Propagating surface plasmon polaritons (SPPs) are well-known to have both a subwavelength light confinement and long propagation lengths [1]. For this reason, their interaction with quantum emitters (QEs) has attracted great interest recently. The emergence of Strong Coupling (SC) when an ensemble of QE, such as organic molecules and quantum dots, is placed in the vicinity of a metal surface has been experimentally demonstrated [2-4].

In this contribution [5] we present the theoretical foundation of the phenomenon of SC between QEs and propagating SPPs in two-dimensional metal surfaces (see Fig. 1). For that purpose, we develop an ab-initio quantum framework that accounts for the coherent coupling between emitters and surface plasmons and incorporates the presence of dissipation and dephasing self-consistently through an open quantum system formalism. Our formalism is able to reveal the key physical mechanisms that explain the reported phenomenology in the case of disordered ensembles of emitters, and determine the physical parameters that optimize the strong coupling.

Remarkably, the development of this general quantum framework to describe the SC between SPPs and QE enables us to address the fundamental nature (classical versus quantum) of this phenomenon by analyzing the conditions in which photon antibunching could be observed (see Fig. 2).

References

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Figures

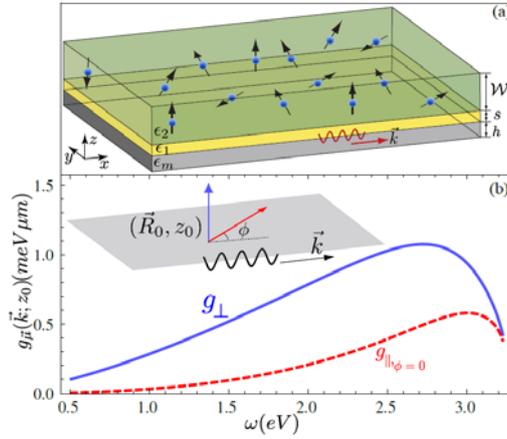


Figure 1. (a) Sketch of the system: N quantum emitters embedded in a dielectric host that is placed on top of a spacer layer and a metal film. (b) Coupling constant between a single emitter and the surface plasmons propagating along the metal surface.

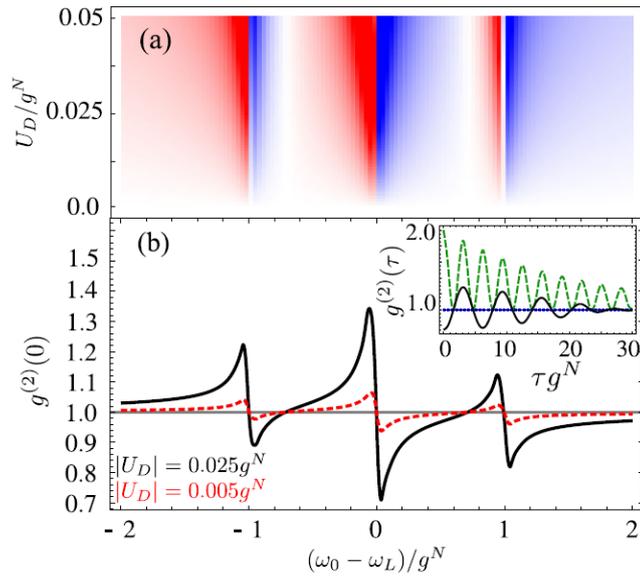


Figure 2. Antibunching. (a) Contour plot of $g^{(2)}(0)$ as a function of the nonlinearity $|U_D|/g_N$ and detuning for the coherently pumped configuration, with system parameters: $s = 10 \text{ nm}$, $W = 10 \text{ nm}$, and $n = 10^6 \text{ m}^{-3}$, which yields $g_N = 50 \text{ meV}$. The color code is 0 blue, 1 white, 2 red. (b) Horizontal cuts of (a) at two fixed nonlinear parameters: $|U_D| = 0.005g_N$ (dashed red) and $0.025g_N$ (solid black). Inset: $g^{(2)}(\tau)$ for a system with $|U_D| = 0.025g_N$ (solid black) and $|U_D| = 0$ for both incoherent pumping (dashed green) and coherent excitation (dotted blue).