Quantum plasmonics: strong-coupling between quantum emitters and surface plasmon polaritons

A. Gonzalez-Tudela[1], P.A. Huidobro[1], L. Martín-Moreno[2], FJ. García-Vidal[1], C. Tejedor[1]

[1] *Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, 28049, Madrid, Spain*
[2] *Instituto de Ciencia de Materiales de Aragón and Departamento de Física de la Materia Condensada, CSIC-Universidad de Zaragoza, E-50009, Zaragoza, Spain*

Propagating surface plasmon polaritons (SPPs) are well-known to have both a subwavelength light confinement and long propagation lengths [1]. Experimental evidence of the existence of Strong-Coupling(SC) between Quantum Emitters (QEs) and two-dimensional (2D) SPPs metallic systems [2], has not been accompanied by any rigorous theoretical interpretation.
We present a fully quantum mechanical description [3] of SPPs coupled to either one or many QEs in terms of a master equation for the density matrix containing both SPP's and excitstions of the QE's.
We start with single QE case determining the coupling to SPP's in a 2D geometry without the use of any fitting. We explore the parameters (lifetime, separation between QE and the surface, …) in which this SC regime could emerge. In this case, our main result is that SC appears when the SPP dispersion relation is extremely flat and coexisting with strong dissipation at the metal.
Then we study an ensemble of N QE's (Fig. 1) which requires the introduction of a collective mode for the excitations of the QE's. The main novelty of it resides in the fact that each QE contributes to the collective mode depending on its distance to the metallic surface. We incorporate the presence of dephasing and excitation mechanisms into the theoretical framework in order to be as close as possible to the experimental situation. Our formalism is able to reveal the key physical mechanisms that explain the reported phenomenology and also to determine the physical parameters that optimize the strong coupling (Fig. 2) [3].
Finally, we make predictions for experiments that could determine unambiguously, quantum effects. In particular, we show that coherent pumping of the SPP's with a well defined momentum produces a measurable second order coherence function $g^{(2)}(0)<1$ (Fig. 3) [3].

[1] T. W. Ebbesen *et al*, Physics Today **5**, 44 (2008).
[2] J. Bellessa *et al*, PRL. **93**, 036404 (2004), P. Vasa *et al*, PRL **101**, 16801 (2008). T. K. Hakala *et al* PRL. 103, 053602 (2009)
[3] A. Gonzalez-Tudela *et al,* PRL in press.

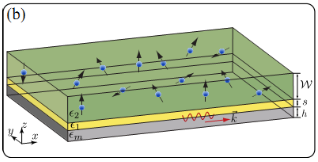

Fig. 1

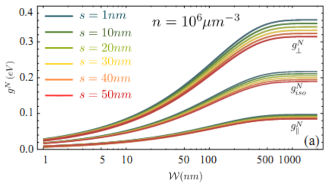

Fig. 2

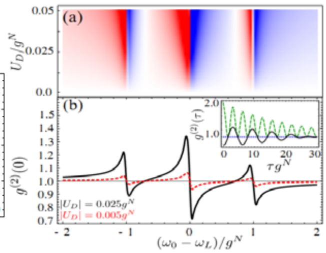

Fig. 3