Quantum Technologies with Hybrid Plasmonic Cavities

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With the advent of the Second Quantum revolution [1], there is an increased interest from the society and large investing companies to exploit the advantages of quantum mechanics to outperform applications of standard classical processes.
One of the bottlenecks of current quantum technologies is their limitation to form faster and on-demand sources of entanglement; the intrinsic ingredient to perform quantum computing and sensing. One way to control and speed up these nonclassical generations, limited currently to GHz clock rates (i.e. microwaves), is by enhancing the optical interaction of well-defined quantum levels, or so-called qubits, with nanophotonic microcavities [1]. The optical modes supported by these dielectric devices typically reach large enhancements because of their long photon lifetimes and high-quality factors (Q~1000). Moreover, most of the light emitted by these systems channels into a single cavity mode, facilitating its efficient collection through, for example, a photonic waveguide. More recently, plasmonic nanoparticles have become a promising route offering new strategies to mold and manipulate ultrafast quantum interactions. Instead of retaining photons for very long, metallic nanostructures can confine their energy in volumes well below the diffraction limit (V~ 10 nm^3) [2], thus achieving unprecedented coupling strengths above THz rates.

However, both photonic microcavities and plasmonic nanocavities present important flaws. The formers are limited in their mode volume and, although they can exhibit large Q-factors, they are often extremely sensitive to minor fabrication errors and changes in temperature or the environment. The latter suffer from strong dissipative losses, which limit their quality factor and therefore the entrance into strong light-matter couplings necessary for the formation of polaritons with several few quantum emitters. For these quantum polaritonic applications, one would like to have access to QED cavities combining a large Q-factor, small modal volume, high robustness to imperfections, and a well-behaved emissivity. A recent strategy has become a new state-of-the art to realize such devices, consisting in the combination and hybridization of both photonic and plasmonic elements into single QED cavities, what is called *hybrid plasmonic cavities* [4,5].

In this TFM project, it will be explored the properties of hybrid plasmonic cavities to generate single photons and coupling between N quantum emitters. By means of numerical and analytical methods, we will explore the enhancing limits of these systems and explore their ability to create the necessary ingredient for quantum optical applications, i.e. entanglement. Last but not least, it will be explored the nonclassical properties of the generated light to perform quantum sensing.

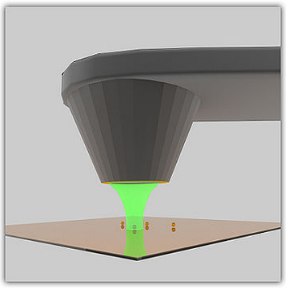

Illustration of a hybrid plasmonic cavity from reference [4].

[1] European Quantum Flagship, https://qt.eu/
[2] A. V. Kavokin et al., *Microcavities* (Oxford University Press, 2007).
[3] R. Sáez-Blázquez et al., Phys. Rev. A 98, 013839 (2018).
[4] Kelkar, H. et al. Phys Rev Appl 4, 054010 (2015).; Gurlek, B., Sandoghdar, V. & Martín-Cano, D., ACS Photonics 5, 456–461 (2017)
[5] I. Medina et al. arXiv:2008.00349v1 (2020)