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Quantum electrodynamics with polaritons in 2D materials

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Abstract: The description of several light-matter interaction phenomena at the nanoscale requires a quantum description of the electromagnetic field. This task is complicated when the electromagnetic field does not exist in a vacuum, but permeates a dielectric medium. In this case, the photons of the electromagnetic field couple to the dielectric degrees of freedom, giving origin to hybrid quasiparticles, which are referred to as polaritons. In order to describe polaritons, one must quantize the electromagnetic field in the presence of a dispersive material medium. However, the standard quantization approach does not work in the presence of dispersion. In this talk, we will describe a quantization approach that solves this issue. Our method allows us to, in principle, quantize polaritons in dispersive media with arbitrary geometry. The description of quantum polaritons in terms of modes allows to isolate the physical response of polaritons, from other radiative modes or lossy effects. In Ref. [1], we used the method to describe the decay rate of a quantum emitter due to graphene plasmon-polariton emission. Comparing the plasmon-polariton emission with the full decay rate, we conclude that, in certain conditions, the decay rate is dominated by emission of plasmons. We also used our quantization method to study the coupling of nitrogen-vacancy color centers mediated by exciton-polaritons hosted by two-dimensional transition metal dechalcogenides [2]. We find that by controlling the separation between two nitrogen-vacancy color centers, we can bring the emitters into the superradiant regime.

References

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[2] J. C. G. Henriques. B. Amorim and N. M. R. Peres, Phys. Rev. B 103, 085407 (2021).

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