Theory of quantum devices in the ultra-strong light-matter coupling regime

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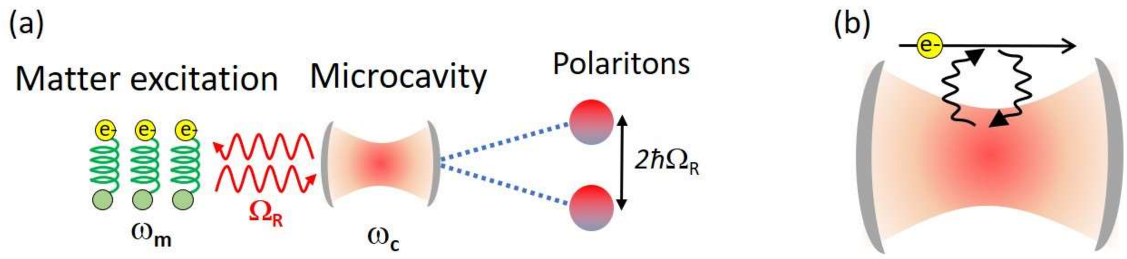
The absorption and emission of light in an optoelectronic device are often considered as perturbative phenomena, which are treated in a single-particle picture. However, when the emitter (absorber) is inserted in a microcavity, the light-matter interaction is no longer a perturbative process. Energy is periodically exchanged with the microcavity at a frequency Ω_R, and the systems enters the strong coupling regime, where the cavity mode is split into two light-matter coupled (polariton) states separated by energy $2\hbar\Omega_R$ (Fig.(a)). The last decade has seen the emergence of yet stronger interaction regime, where the coupling constant Ω_R becomes comparable to the frequency of the matter excitation, ω_m. This regime with Ω_R/ω_m~1 is known as "ultra-strong" light-matter coupling and sets new frontiers for cavity quantum electrodynamics [1]. Indeed, coupling with light can be so strong, that it leads to important changes of the material properties of the coupled system, such as its electrical conductivity [2].



Recently, we developed a theoretical model that allows exploring the photocurrent generated in detectors operating in the ultra-strong light-matter coupling regime [3] (Fig. (b)). This model has been extended to the case of non-linear generation in such devices [4]. As an intern, the candidate will work in a close collaboration with an experimented student in order to express the optical rectification in such devices, in order to understand the impact of the ultra-strong coupling regime in such device. Depending on the availability of the candidate, she/he can also work on modelling of a simple electromechanical system in the regime of ultra-strong coupling. The Ph.D. work will focus on exploring the quantum fluctuations in devices in the regime of ultra-strong coupling, and on devising possible experiments in order to access them.

[1] A. F. Kockum, A. Miranowicz, S. De Liberato, S. Savasta and F. Nori, Nature Reviews Physics **1**, 19–40 (2019).

[2] E. Orgiu, et al. Nature Materials **14**, 1123 (2015).

[3] F. Pisani et al., Nature Comm. **14**, 3914 (2023).

[4] T. Kriguer, under submission, (2024).