Fundamental cavity-waveguide interplay in cavity QED

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Interfacing solid-state emitters with photonic structures is a key strategy for developing highly efficient photonic quantum technologies [1]. Such structures are often organised into two distinct categories: nanocavities and waveguides. However, any realistic nanocavity structure simultaneously has characteristics of both a cavity and waveguide, which is particularly pronounced when the cavity is constructed using low-reflectivity mirrors in a waveguide structure with good transverse light confinement. In this regime, standard cavity quantum optics theory breaks down, as the waveguide character of the underlying dielectric is only weakly suppressed by the cavity mirrors.

In this work [2], we present a quantum optical model that captures the transition between a high-Q cavity and a waveguide, allowing consistent treatment of waveguides, lossy resonators, and high quality cavities. Our model constitutes a bridge between highly accurate optical simulations of nanostructures [3] and microscopic quantum dynamical calculations. This way, the quantum properties of generated light can be calculated, while fully accounting for the electromagnetic properties of the nanostructure. The generality of this theory enables us to identify an optimal regime of operation for quantum dot single-photon sources, which simultaneously harnesses the high efficiency of a waveguide and the phonon- suppressing spectral structure of a cavity [4,5].

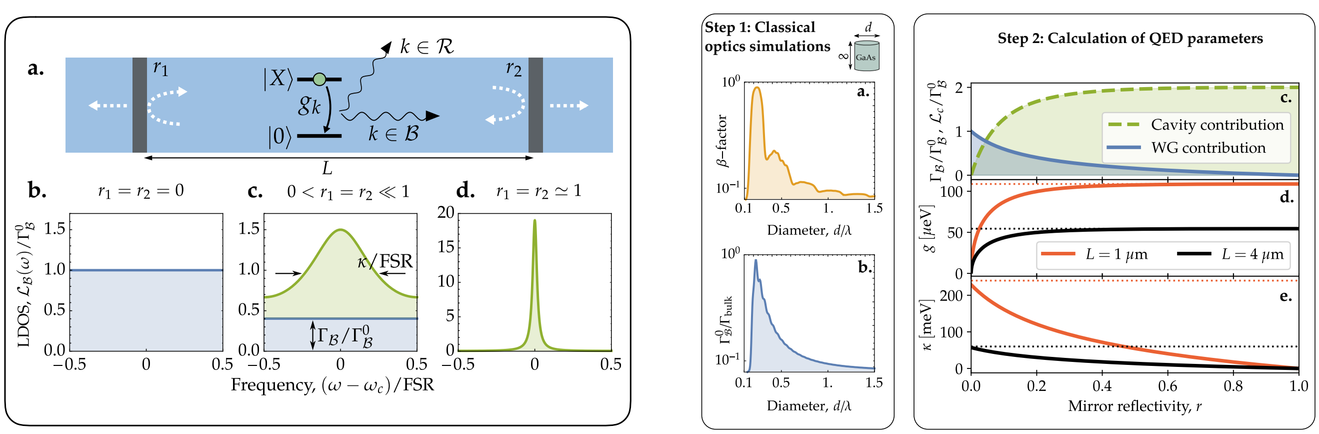

Figure 1: **(Left) a.** Schematic of a two-level emitter in a waveguide structure with two mirrors forming a Fabry-Perot cavity. **b–d.** Optical local density of states (LDOS) vs. frequency, scaled with the free spectral range (FSR), at the position of the emitter for mirrors with weak, intermediate and high reflectivity, respectively. **(Right) a, b.** β-factor and spontaneous emission rate into infinitely long waveguide. **c.** Cavity and waveguide contributions to LDOS when mirrors are introduced to the structure. **d, e.** Cavity-emitter coupling rate and cavity decay rate.

References

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