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Published in:

11th International Workshop on Nonlinear Optics and Excitation Kinetics in Semiconductors

Publication date:

2012

[Link back to DTU Orbit](#)

Citation (APA):

Madsen, K. H., Nielsen, P. K., Kreiner-Møller, A., Stobbe, S., Nysteen, A., Mørk, J., & Lodahl, P. (2012). Non-Markovian phonon dephasing of a quantum dot in a photonic-crystal nanocavity. In 11th International Workshop on Nonlinear Optics and Excitation Kinetics in Semiconductors (pp. 82)

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Non-Markovian phonon dephasing of a quantum dot in a photonic-crystal nanocavity

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Single quantum dots (QDs) can be embedded in nanocavities in order to enhance the interaction with a single mode of the electromagnetic field, thereby making them candidates for applications in quantum information systems. In this work [1], we investigate the coupling between single QDs and localized modes in photonic crystal (PC) cavities. From measurements of the detuning-dependent decay rate of a QD embedded in an L3 PC cavity we find a surprisingly broadband enhancement of the decay rate, cf. Fig. 1, which cannot be explained using the standard approach of a dissipative Jaynes-Cummings (JC) model. Similar measurements on a single QD tuned through an Anderson localized (AL) mode [2] in a PC waveguide show that in this system the decay rates closely follow the JC model.

We introduce a novel microscopic model taking the interaction with longitudinal-acoustic (LA) phonons into account. Using this model, we are able to explain the broadband enhancement in an L3 cavity, and the quantitative difference compared to the AL-cavity arises from a larger background decay rate in the AL-cavity due to the presence of leaky radiation modes. The concept of the effective phonon density of states (DOS) is introduced, which determines the rate of phonon-assisted spontaneous emission. If, e.g., the QD is blue-detuned from the cavity mode, the QD can emit a photon into the cavity mode by emitting the residual energy as a phonon [3]. Our microscopic model allows us to extract the effective phonon DOS, that turns out to agree with a model for bulk phonons.

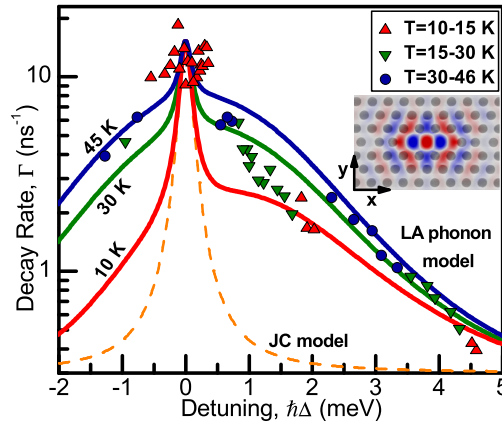


Figure 1: Measured detuning dependence of the decay rate of a QD tuned through resonance of the L3 cavity. The coupling range is much broader than predicted by the JC model (dotted orange curve) and very well described by the microscopic theory including LA phonons (solid curves) shown for different temperatures. Inset shows a SEM image of a cavity, with the simulated E_y -profile of the cavity field.

References

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- [2] L. Sapienza *et al.*, *Science* **327**, 1352 (2010).
- [3] P. Kaer *et al.*, *Phys. Rev. Lett.* **104**, 157401 (2010).