Fundamental properties of devices for quantum information technology

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This thesis reports a theoretical investigation of the influence of the electron-phonon interaction on semiconductor cavity quantum electrodynamical systems, specifically a quantum dot coupled to an optical microcavity. We develop a theoretical description of the decay dynamics of the quantum dot interacting with the cavity and the phonons. It is shown that the presence of the phonon interaction, fundamentally changes the spontaneous emission decay behavior of the quantum dot. Especially in the regime where the quantum dot-cavity spectral detuning is significantly larger than any linewidth of the system, the effect of the phonon interaction is very pronounced. A simple approximate analytical expression for the quantum dot decay rate is derived, which predicts a strong asymmetry with respect to the quantum dot-cavity detuning at low temperatures, and allows for a clear interpretation of the physics. Furthermore, a study of the indistinguishability of single photons emitted from the coupled quantum dot-cavity system is performed, with special emphasis on non-Markovian decoherence due to the phonon interaction. We show that common theoretical approaches fail to predict the degree of indistinguishability, on both a qualitative and quantitative level, for experimentally relevant parameters regimes. The important role of non-Markovian effects in the shorttime regime, where virtual processes dominate the decoherence of the quantum dot-cavity system, is emphasized. Importantly, our investigations lead to a maximum achievable degree of indistinguishability, a prediction which eludes common approaches.

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