Doctoral dissertation

Resonance fluorescence of a solid-state quantum emitter with fluctuating transition energy

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ABSTRACT

This PhD thesis comprises a series of three thematically related publications. The aim of this work is to theoretically investigate the impact of fluctuations in a solid-state semiconductor on the resonance fluorescence (RF) spectrum of an emitter embedded within the material.

RF has found numerous applications in studying the properties of solid-state emitters (particularly quantum dots) and in generating light with desirable properties for quantum information science. Specifically, RF is used in miniaturized, on-chip quantum hybrid systems, in which an acoustically modulated quantum dot acts as a transducer between acoustic and optical signals. Nevertheless, the optical properties of the emitter, and consequently its RF spectrum, are adversely affected by environmental noise, which is inevitable in solid-state systems. Therefore, to develop high-quality quantum devices, it is necessary to quantitatively study these influences on the emitter.

Firstly, telegraph and white noise were modeled, and the resulting changes in the RF spectrum and the intensities of its individual spectral lines were calculated. Subsequently, the white noise model was extended to the situation of an emitter modulated by surface acoustic waves, as is the case in quantum hybrid systems. It has been quantitatively shown how noise limits the effective acoustic control of light scattering on the emitter, and the stability requirements for the acoustical signal to remain resolvable in the RF spectrum have also been defined. Finally, the environmental noise was modeled as acoustic phonons. In this case, a Fano profile was discovered in the RF spectrum, the existence of which depends on the ambient temperature and the strength of the phonon–emitter coupling.

In conclusion, in this PhD thesis, various types of noise have been modeled, identifying characteristic parameters that can be used to quantitatively describe the impact of a given type of fluctuation on the shape of the RF spectrum. The obtained results will be useful in diagnosing the types of noise affecting experimentally-tested semiconductor emitters. In the case of an acoustically modulated emitter, this dissertation paves the way for research on the impact of noise on correlations, including the second-order correlation, between specific spectral bands. In turn, the model of the emitter interacting with acoustic phonons can be extended in the future to other types of phonons, for instance, those occurring in two-dimensional materials.