Universität Münster

Aktuelle Fragen der Nanophysik

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Fast acoustic modulation of QD in optomechanical cavity: towards GHz-rate single-photon sources

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Engineering of optical degrees of freedom, e.g., the photonic density of states, of a two-level single-photon (SP) emitter underpins a possibility of realizing bright deterministic SP sources (SPSs) [1]. Complementary tailoring of mechanical degrees of freedom, opens a pathway towards dynamical functionalities unattainable in static scenarios, e.g., fast manipulation of energy levels [2] and Floquet engineering of quantum emitters [3].

I will present about our hybrid system, where we combined cavity quantum electrodynamics with QDs and GHz-frequency cavity optomechanics on a monolithic III-V based platform with the ultimate goal of realizing on-demand generation of high-purity SPs with GHz emission rates. To this end, we integrated InAs QDs in a patterned optomechanical AlGaAs microcavity (MC) designed to enhance coupling of co-localized 300 THz optical and 6 GHz acoustic modes to QDs. Optical states with well-defined discrete energies were created by the lateral confinement of photons in µm-sized traps defined lithographically in the MC spacer [4]. We used piezoelectric bulk acoustic wave transducers, fabricated on top of the MC, to precisely control the amplitude of the strain of a standing longitudinal bulk acoustic wave (BAW) with frequency tunable in the 3-13 GHz range [5]. Then, we demonstrated tunable strain-modulation of the QD transition energy by BAWs up to 13 GHz providing the mechanism for fast control of the QD-cavity detuning. For the BAW frequency around 6 GHz, corresponding to the MC acoustic mode, the QD energy is periodically shifted through a spectrally narrow ($Q \approx 1500$) confined photonic mode leading to an appreciable enhancement of the QD emission due to the dynamic Purcell effect [6]. We numerically explored time-evolution of the QD-cavity system under modulation and identified conditions that could enable GHz SP rates.

In the future, we plan to combine high-Q cavities ($Q > 5000$) with deterministic fabrication of photonic traps [7] to realize scalable III-V SPSs with on-chip acoustic clocks generating indistinguishable high-purity SPs with GHz rates under continuous wave optical excitation.

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[5] D. H. O. Machado *et al.*, Phys. Rev. Appl. **12**, 044013 (2019) doi: 10.1103/PhysRevApplied.12.044013.
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