Master Thesis Topic

Acoustic modulation of quantum dots in microcavities for GHz-rate single photon sources and optomechanics

Background and Motivation

III-V semiconductor quantum dots (QDs) are the purest single photon sources at cryogenic temperatures. Their emission rate and directionality can be improved by placing them in a photonic environment such as a microcavity (MC) and taking advantage of the Purcell effect. However, the matching of the QD energy with that of the MC is challenging, especially for high-Q MCs. Another challenge is the requirement for the resonant excitation to achieve narrowest linewidth and highest single-photon purity.

The key ideas of the project are to place InAs or GaAs QDs in hybrid Q > 10000 microcavities and use GHz-frequency piezoelectrically excited bulk acoustic waves to realize dynamic Purcell effect. By further shallow patterning of the microcavity we can introduce confined photonic modes with well-defined energies. In this case, we envision that the acoustic modulation of the QD energy will lead to multiple dynamics resonances. Our ultimate goal is to demonstrate on-chip single photon sources triggered at GHz rates as well as new optomechanical devices for microwave-to-optical conversion.

Objective

The main objective of the project is to demonstrate dynamic Purcell effect and GHz-triggered single photon emission in patterned MCs with III-V QDs. You will be working on the following tasks:

1. Needle in a haystack. Using cryogenic photoluminescence, you will identify photonic structures that contain single QDs.
2. Shock to the system. Apply the acoustic wave to demonstrate QD energy and intensity modulation. Tune the acoustic amplitude to observe multiple resonances between QD and confined photonic modes.
3. Quantum light. With the help of correlation measurements, you will demonstrate single photon emission at GHz frequencies.

Methodology

You will use cryogenic (liquid-He) photoluminescence with non-resonant and resonant optical excitation to measure QD emission. Using a radio-frequency generator, you will excite acoustic transducers to generate an acoustic wave and detect dynamic changes in the QD emission energy and intensity. You will learn to measure second-order auto-correlation to study single photon emission from the device.

Expected Outcomes

- Realization of dynamic Purcell control of single photon emission at GHz frequencies
- Demonstration of a novel platform for quantum technologies and getting an invaluable experience along the way.

Skills and Requirements

- Curiosity
- Base knowledge of semiconductor physics and materials

Opportunities and Benefits

- Modern labs with a wide range of experimental techniques.
- Supportive environment with experts for various scientific sub-fields.
- International and culturally diverse community.
- Location in the heart of Berlin with excellent public transport connections.
- Subsidized travel ticket.

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For further details or clarification, please feel free to contact us. Lab tours are also available for interested applicants.