Aktuelle Fragen
der Nanophysik

Montag, 16.05.2022 um 15:15 Uhr
HS 2, Wilhelm-Klemm-Str. 10

Hybrid $LiNbO_3$-(Al)GaAs devices for quantum dot optomechanics


© Dr. Emeline Nysten

Dr. Emeline Nysten
WWU Münster
Physikalisches Institut

Acoustic phonons couple easily to many excitations present in condensed matter which makes them ideally suited for the design and realization of hybrid quantum systems. In this context, surface acoustic waves (SAWs), mechanical waves confined to the surface of solid-state substrates and generated by interdigital transducers (IDTs) on piezoelectric substrates, have been proven to be a useful tool for the control of quantum systems [1]. In parallel, semiconductor quantum dots (QDs) also have been considered as an essential part of future quantum systems and technologies as an optically active and addressable two-level system and as an efficient source of single and indistinguishable photons. Here, we focus on the control of optically active semiconductor QDs by the mechanical strain field of a SAW through the deformation potential coupling. The strength of this interaction can be quantified by a coupling parameter just like for many hybrid quantum devices, in this case, it is the optomechanical coupling parameter γ_{OM} linking the modulation of the emission energy to the surface displacement of the SAW.

Our goal is to increase the optomechanical coupling between the two systems. For this purpose, we used the so-called epitaxial lift-off technique to release a QD membrane from its GaAs substrate and transfer it onto a $LiNbO_3$ SAW-chip to fabricate hybrid III-V semiconductor-$LiNbO_3$ devices.

The coupling of the surface acoustic waves to the membrane is studied first through finite element simulations which show an increased optomechanical coupling parameter due to a localization of the SAW field inside the membrane for increasing SAW frequency. The simulations results are confirmed by measurements on a fabricated hybridized SAW sample. The coupling of the wave to the membrane is quantified by measuring both the SAW signal transmitted across the hybridized delay line and the optomechanical response of the dots inside the epilayer [2].

To further increase the sound-matter coupling, the epilayer was transferred inside a SAW resonator cavity where both the electrical reflection of the resonator and the optomechanical coupling of the dots to the resonator modes were recorded [3]. We investigated the subject further by incorporating the QDs inside superconducting surface acoustic wave resonators at high frequencies.

Finally, the transferred epilayer can be patterned into more complex photonic structures such as ring resonators and their access waveguides. The interaction between the SAW, the QDs and the resonators was measured and analyzed. The emergence of phononic resonances is observed and these resonances show an interesting non-linear behavior which is analyzed in more detail.

[1] Delsing et al Journal of Physics D: Applied Physics, 52(35):353001 (2019)
[2] Nysten et al Journal of Physics D: Applied Physics, 50(43):43LT01 (2017)
[3] Nysten et al Applied Physics Letters, 117(12):121106 (2020)