SAWtrain Research Highlight 1: "Multi-harmonic quantum dot optomechanics in fused $LiNbO_3$–(Al)GaAs hybrids"

We fabricated an acousto-optic semiconductor hybrid device for strong optomechanical coupling of individual quantum emitters and a surface acoustic wave. Our device comprises a surface acoustic wave chip made from highly piezoelectric $LiNbO_3$ and a GaAs-based semiconductor membrane with an embedded layer of quantum dots (see Figure 1).

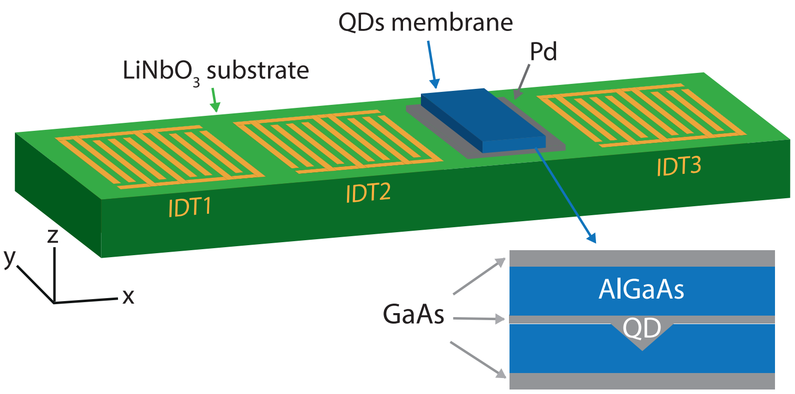

Figure 1: Schematic of the hybrid device composed of a QD membrane transferred by epitaxial lift-off on a $LiNbO_3$ SAW-chip patterned with two delay lines. A schematic of the QD heterostructure is shown in the lower part.

Employing multi-harmonic transducers, we generated sound waves in $LiNbO_3$ over a wide range of radio frequencies, as the Split-52 configuration of the transducers enables excitation of the fundamental SAW and its 2^{nd}, 3^{rd} and 4^{th} harmonics.

The delay line architecture allows us to probe SAW propagation through the GaAs membrane both electrically by the IDTs and optomechanically via the deformation potential coupling of the QDs. The transmission of the SAW across the membrane is measured in the delay line and the dynamic spectral tuning of the QD emission is detected optically. We recorded both effects in parallel as a function of the radio frequency signal applied to the IDT.

The electrically detected SAW transmission is faithfully reproduced in the dynamic spectral broadening of the QD emission signal. Remarkably, we detect the most efficient dynamic spectral tuning for the highest SAW frequencies studied at which the electrically detected transmission is strongly reduced. This finding suggests an increased localization of SAWs inside the epilayer due to a waveguiding effect. This localization increases both the spectral tuning and acoustic losses through scattering at the boundaries of the transferred membrane, giving rise to our experimental observations.

Our experimental findings are also found to be in good agreement with finite element simulations. For moderately high acoustic frequencies, our simulations predict strong optomechanical coupling, making our hybrid device ideally suited for applications in semiconductor-based quantum acoustics.

Publication:
Emeline D. S. Nysten, Yong Heng Huo, Hailong Yu, Guo Feng Song, Armando Rastelli, Hubert J. Krenner, *Journal of Physics D: Applied Physics* **50**, 43LT01 (2017) – Part of *Special Issue on Surface Acoustic Waves in Semiconductor Nanosystems* – doi:10.1088/1361-6463/aa861a

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