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Investigation of Surface Acoustic Wave Dynamics at Cryogenic Temperatures for Quantum Device Applications

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Surface acoustic waves (SAWs) offer potential for next-generation quantum technologies, including spin current generation, control of magnetization dynamics, and hybrid SAW–skyrmion platforms for qubit manipulation. Although SAW devices have long been used as RF filters, signal processors, and sensors, their operation in extreme environments remains underexplored. This work studies the frequency response of SAW devices at ultralow temperatures and under high magnetic fields, while also investigating hybrid coupling between SAWs and surface plasmon polaritons (SAW–SPP).

SAW devices are designed on 128° YX-cut lithium niobate, selected for its strong piezoelectric response and high electromechanical coupling. Devices use 50 finger pairs with 2 μm width and a 8 μm wavelength in the HF range, and a 300 μm aperture for improved acoustic confinement. Equivalent circuit models including IDT capacitance, motional branches, acoustic delay, and matching networks are implemented in Mathcad and LTSpice, with COMSOL Multiphysics simulations used for validation.

Cryogenic analysis shows reduced phonon scattering modifies velocity, attenuation, and coupling, shifting resonance and increasing Q. High magnetic fields and integrated metal–dielectric interfaces enable study of magneto-acoustic effects and SAW–SPP interactions, establishing a multiphysics framework linking RF, acoustic, cryogenic, and plasmonic behavior for compact, high-Q, field-tunable quantum and sensing platforms.

Academic or Professional Status

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