Lithium Niobate Devices for Quantum Processors

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Microwave-frequency superconducting circuits are currently being used to build the first coherent and scalable quantum machines with tens to hundreds of quantum bits. It is expected that these systems will be soon complex enough to perform tasks beyond the reach of current technology. In moving current systems to larger scales, we face several daunting challenges. The current level of coherence achieved in superconducting quantum devices, though enough to enable fault-tolerant operation, can only do so with a significant amount of overhead for error correction. Meanwhile, the superconducting quantum machines today are rapidly becoming the most complex coherent microwave frequency circuits that have ever been realized. To facilitate scaling microwave quantum machines, it is fruitful to consider classical information processing systems. In the domain of conventional coherent microwave systems, acoustic filters and resonators are ubiquitous. They have played a key role in high-frequency circuits and systems for decades and can be found in every mobile phone and laptop because of their high-quality factor and small size compared to electromagnetic components. The clear application of these microwave acoustic systems to the quantum domain has motivated experimental efforts to extend the success of acoustic devices to the quantum realm. In a series of remarkable experiments, thin-film, surface, and bulk acoustic wave resonators made of piezoelectric materials have coupled gigahertz acoustic resonators with varying levels of confinement to superconducting circuits. Similarly, almost all classical information processing systems involve the conversion of information across the electromagnetic spectrum. For example, to realize a large-scale quantum machine, it is exceedingly likely that we may need to implement a quantum network connecting independent nodes. To achieve quantum connectivity across medium to long distances, it is natural to consider optical photons and consequently, quantum-limited frequency converters between optical and microwave frequencies.

Lithium niobate is a particularly exciting platform for realizing these key capabilities that enable scaling of quantum machines. In this talk, I will present our experimental results on the integration of superconducting qubits, and high-Q photonic systems and nanomechanical/nanophotonic integrated devices etched out of lithium niobate. I will also offer our vision for a “quantum acoustic processor” [1,2], which is a more programmable and hardware-efficient approach to quantum information processing.