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Quantum Transduction for Networked Quantum Computation

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Abstract/Résumé

Quantum transduction between microwave and optical frequencies enables the interconnection of microwave-frequency quantum processors through low-loss optical channels at room temperature. This talk will detail how nanoscale mechanical oscillators can provide an effective intermediary between the widely separated frequency bands, enabling conversion with sufficiently low noise and high efficiency to transduce a quantum state.

The physical carrier of quantum information plays a crucial role in how the information is processed, communicated and measured. Encoding quantum information in microwave-frequency photons has allowed for the development of circuit [1] and spin-based [2,3] quantum information processing. These architectures allow for on-chip scaling of qubit numbers, and have resulted in world-leading devices in terms of qubit count and performance fidelity, however require milliKelvin-scale temperatures to operate. On the other hand, optical photons at telecom wavelength are a natural carrier for quantum information, benefitting from particularly low loss rates in optical fibers [4], an effectively noise-free environment at room temperature and near-unity efficiency single-photon detection technology.

Interconverting quantum states between the microwave and frequency domains will enable the quantum information processed by many quantum computers to be - for the first time - brought out of the cryogenic environment and routed over long distances to other systems. This process will allow for both networked quantum computing architectures, as well as the inclusion of quantum processors in future long-distance quantum communication networks.

Nonetheless, transducing a quantum state between the microwave and optical domains places stringent requirements on the performance of the conversion hardware, in particular the efficiency and the added noise levels. While many solutions with different conversion mechanisms exist, at QPhoX we focus on using a mechanical intermediary in the conversion chain [5]. Confined mechanical states can form high-efficiency interfaces with both microwave and optical frequency photons, mediating the conversion process without requiring excessive optical powers.

In this talk I will provide a background to the field of quantum transduction, and discuss how the unique challenges involved in converting the frequency a quantum state over five orders of magnitude motivate the design, fabrication and operation of our quantum transducers. I will cover progress we have made in this direction [6], how our solution compares to complementary approaches, and the remaining developments in the field. I will also cover the use-cases of the technology we are currently targeting, and how they set new benchmarks for the transducers to be of practical use.

References

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