Optical Interfaces for Scalable Qubit Operation

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Abstract

Cryogenic quantum processors based on technologies such as superconducting qubits have made great strides in qubit count and computing potential. Nevertheless, to tackle practical applications, processors will need to scale up by orders of magnitude. Two major barriers to expansion are heat dissipation via input/output lines and cryogenic amplifiers [1]. Transferring signals via optical fiber eliminates these heat loads and has great potential to facilitate larger quantum processors in cryogenic systems [2,3].

In this work we demonstrate qubit control and readout via optical signals. We extract the readout signal via an integrated microwave-to-optics transducer. Using high-power demolition readout we achieve a single shot readout fidelity of 81% [4]. Our converter is nanofabricated on a chip and dissipates less than 1% of the power of a conventional HEMT amplifier.

In a separate demonstration, we deliver qubit control signals via a fixed array of cryogenic photodiodes [2]. During operation the active heat load of our link remains substantially below the passive heat load of coaxial cabling, while featuring added noise that does not measurably excite the qubit. Together these two approaches highlight the feasibility of microwave-over-fiber and hence quantum processors exceeding 1000 qubits in a dilution refrigerator.

References

[1] Raicu et al. arXiv:2502.01945 (2025)
[2] Lecocq et al. Nature, 591, (2021) 575
[3] Delaney et al. Nature, 606,(2022) 489
[4] van Thiel et al. Nat. Phys., (2025)

Figures

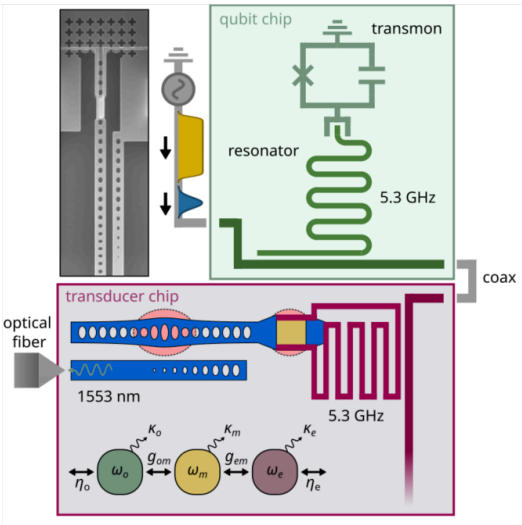

Figure 1: Simplified optical readout of a transmon qubit with a modular transducer.