Electro-optic transduction approaching kHz throughput in the quantum regime

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Entanglement distribution among quantum processors need to be faster than the lifetimes of the quantum memories that are being linked. Therefore, devices capable of high signal transfer rate while maintaining sufficiently low noise are key for their realization. One promising candidate for this task are electro-optic (EO) transducers, which combine the high speed and advanced control capabilities of superconducting qubits with the robustness and range of optical links. Here we present measurements of an EO transducer, based on a 3D microwave cavity coupled to a whispering gallery mode optical resonator. Using a design based on Ref. [1], incorporating different materials and coupling strength, we achieved high signal throughput, quantified as conversion efficiency x bandwidth x duty cycle, while keeping the input-referred added noise N_{add} < 1 (quantum-enabled regime). We achieved two orders of magnitude improvement with respect to previous EO transducers [2] and comparable with the highest quantum-enabled results for the on-chip approach [3]. Furthermore, we present multiplexing results, where frequency conversion efficiency remains within the same order of magnitude, for optical modes spaced over a 25 MHz frequency range.

References

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[2] R. Sahu, W. Hease, A. Rueda, G. Arnold, L. Qiu, & J. M. Fink, Nature communications, 13 (2022) 1276

[3] H. Zhao, W. D. Chen, A. Kejriwal, & M. Mirhosseini. Nature Nanotechnology, 20 (2025) 602–608

Figures

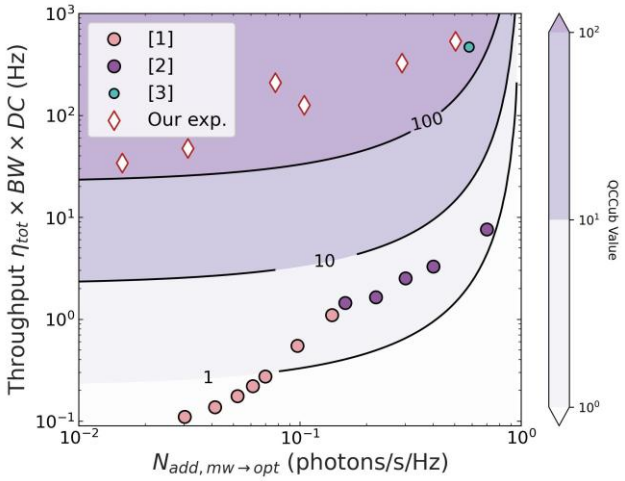

Figure 1: Throughput as function of the N_{add} for our experiment, as well ass for previous transducer designs. Contours indicate the quantum channel capacity upper bound (QCCub) of 1, 10, and 100 Hz.

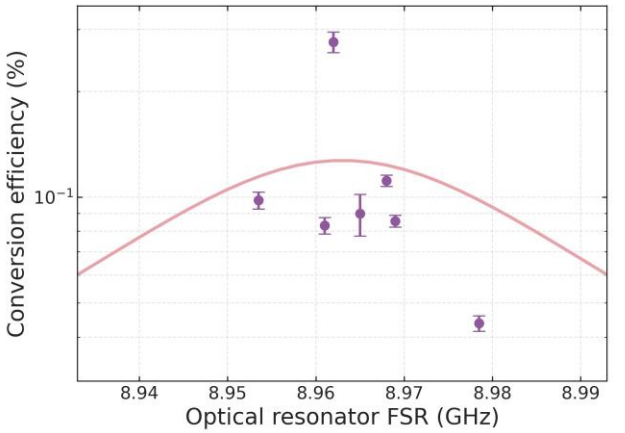

Figure 2: Total conversion efficiency for different optical modes at the same intracavity pump photon number ~ 10^{16}. The red plot indicates the microwave mode bandwidth for the possible conversion range.