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Quantum Transduction at SQMS

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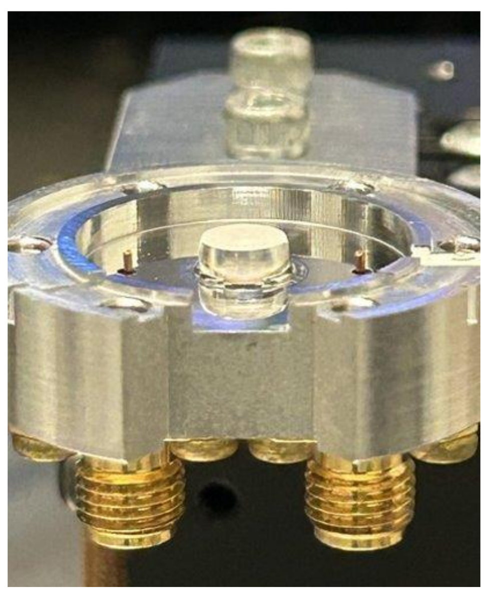
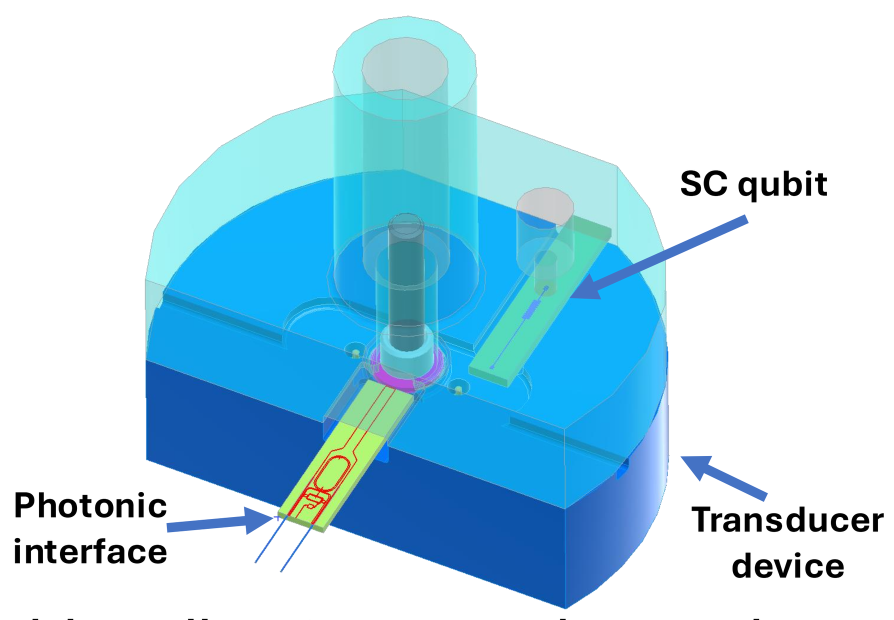
Overview

Microwave-optical transduction aims at enabling high-fidelity conversion of quantum information between microwave and optical frequencies. Our research targets the development of a three-dimensional quantum transducer, serving as an interface between superconducting quantum devices and optical-fiber based quantum networks. Our transducer leverages high-quality (high-Q) microwave and optical cavities to achieve high conversion efficiency with low added thermal noise. Furthermore, we propose protocols for time-bin quantum state transfer and quantum repeaters based on our transduction architecture, applicable for scalable quantum networks.

EO Transduction Device

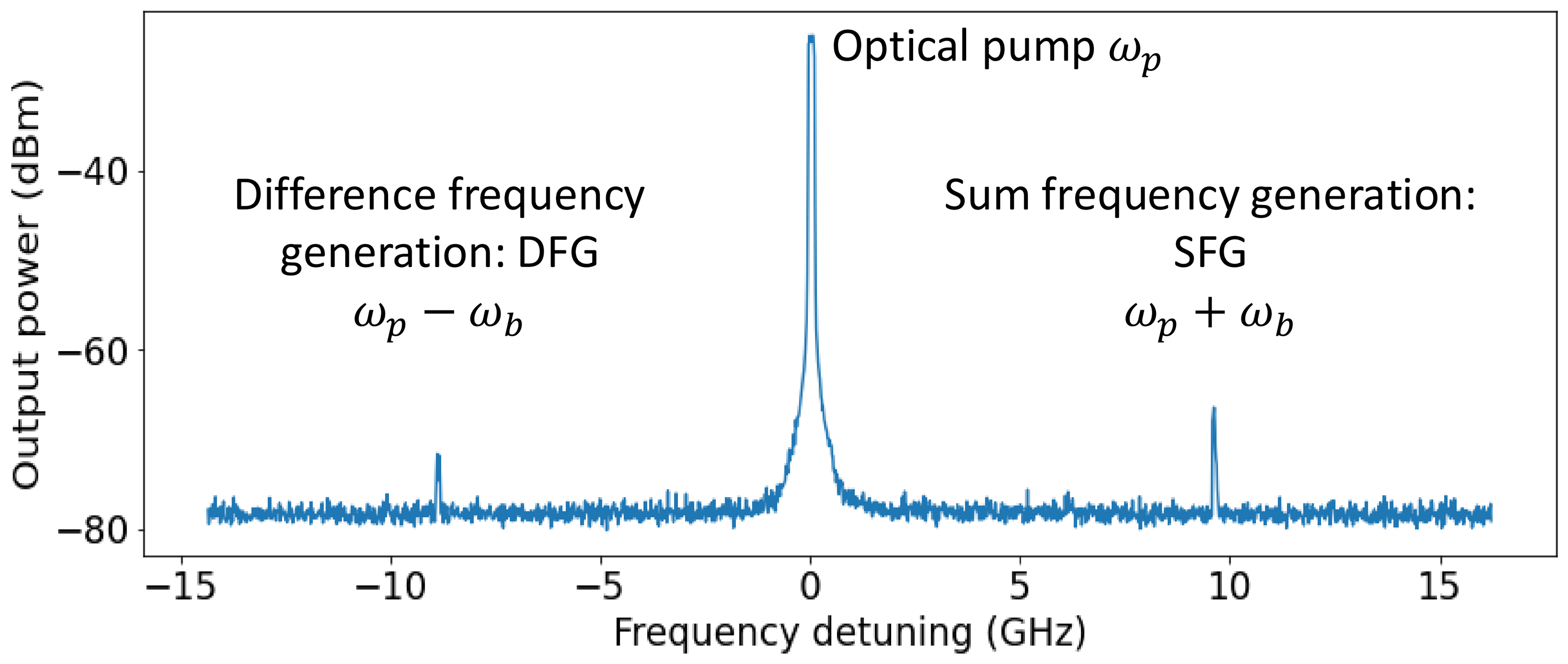
Lithium niobate optical cavity within a high-Q superconducting radiofrequency (SRF) cavity.





The electro-optic effect provides direct conversion and two-mode squeezing through three-wave mixing.

$$H = \hbar g_{eo}\left(a_p a_s^\dagger b + a_p^\dagger a_s b^\dagger\right) + \hbar g_{eo}\left(a_p a_s^\dagger b^\dagger + a_p^\dagger a_s b\right).$$

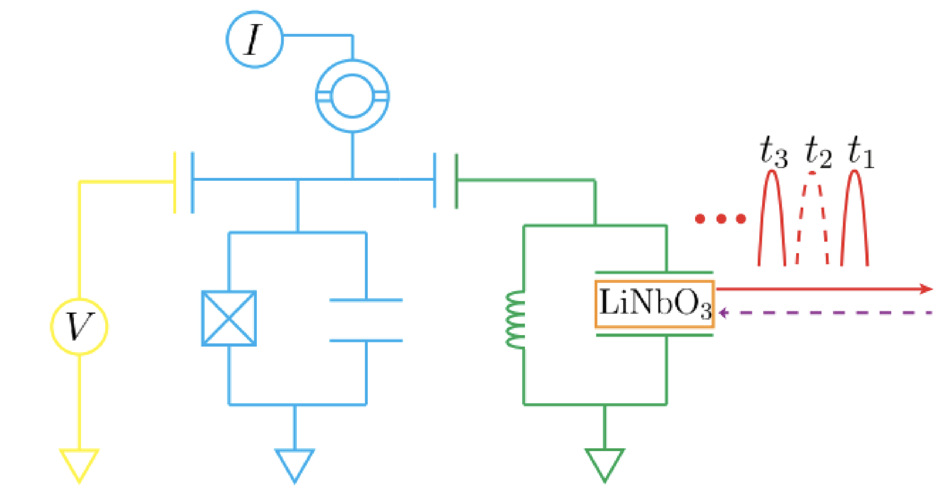


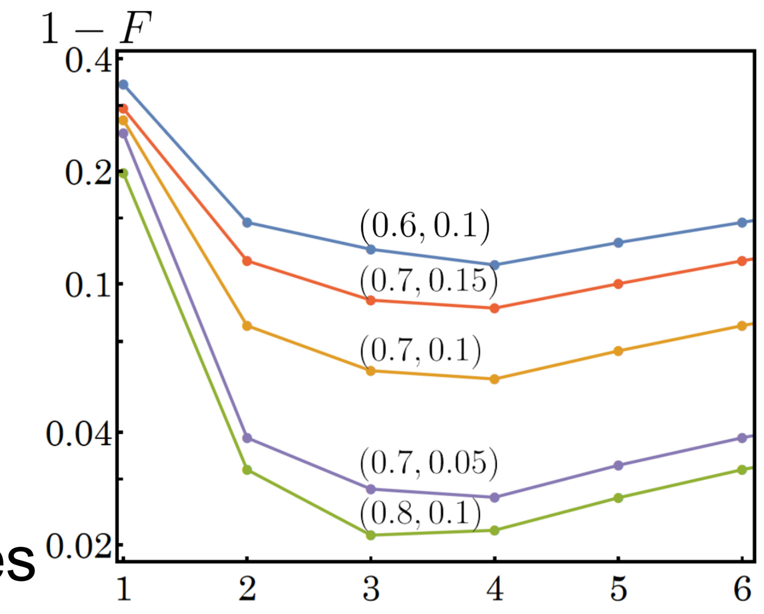
Estimated figures of merit

Parameters	Estimate
Single-photon microwave-optical coupling rate	$2\pi \times 46.75$ Hz
Microwave Quality Factor	10^5
Cooperativity	0.58
Conversion Efficiency	Up to 50%
Operating Bandwidth	100KHz
Pump Power	<1mW

npj Quantum Inf **8**, 149 (2022)

Remote Entanglement via Time-Bin States

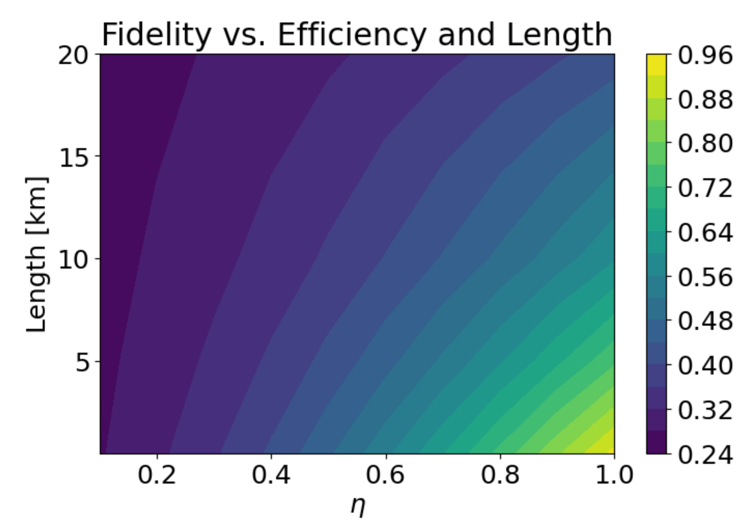


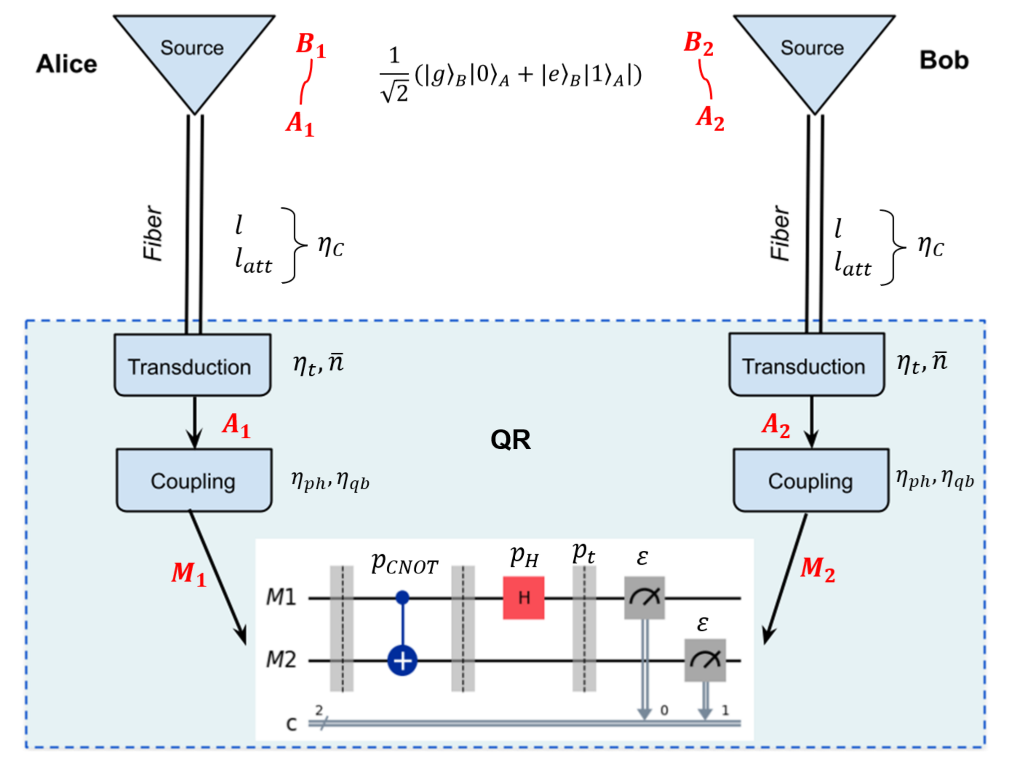


J. Wu et al., arXiv:2506.15277 (2025), *under press*

- Multi-time bin encoding suppresses quantum channel.
- Fidelity is limited by decoherence
- Compatible with a variety of platforms

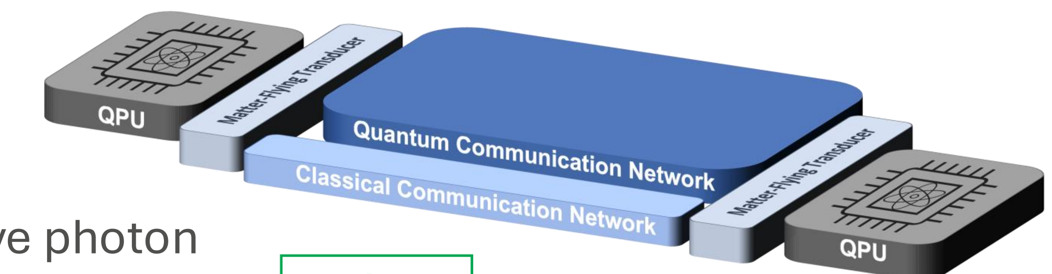
Quantum Repeaters

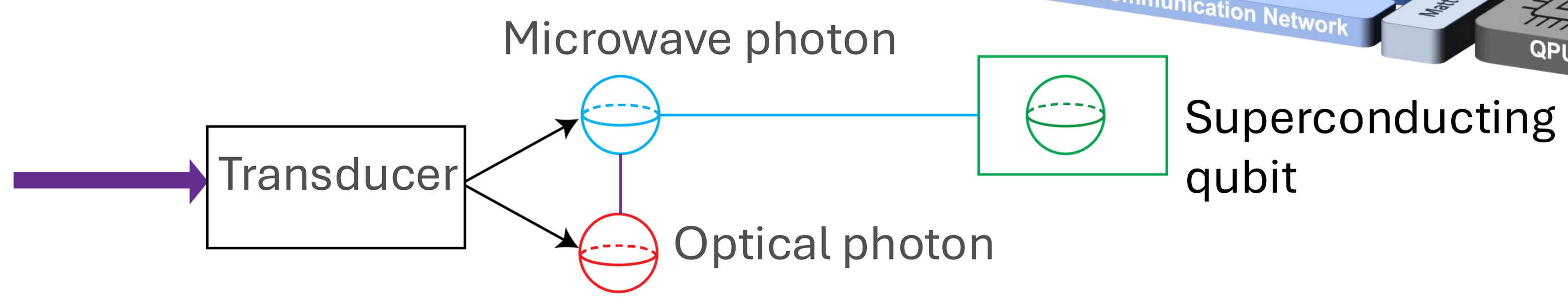




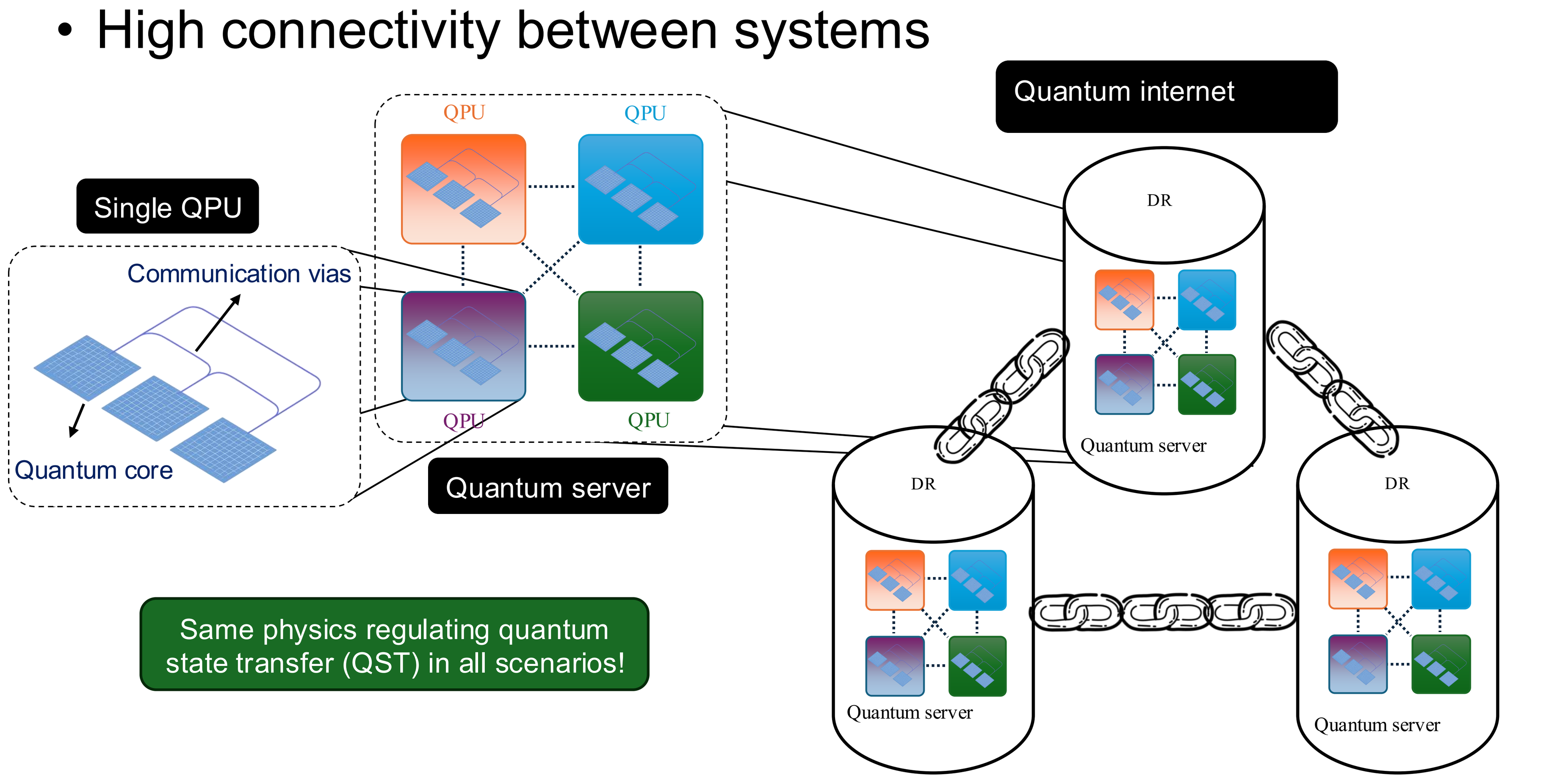
- Optical photons carrying quantum information arrive at the QR node via optical fibers
- Conversion to microwave photons via the transducer.
- Microwave photons interact with qubits in a cQED setup.
- Swapping or distillation using high-fidelity gates.

Quantum Networks





- Modular architectures allow larger devices built from smaller units
- Advancing protocols for entanglement generation between the transmon qubit and optical time bins
- Fault-tolerant scaling of error-corrected modular devices
- High connectivity between systems



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