Polarization-Preserving Quantum Frequency Conversion for Trapped-Ions in the MARQI Network

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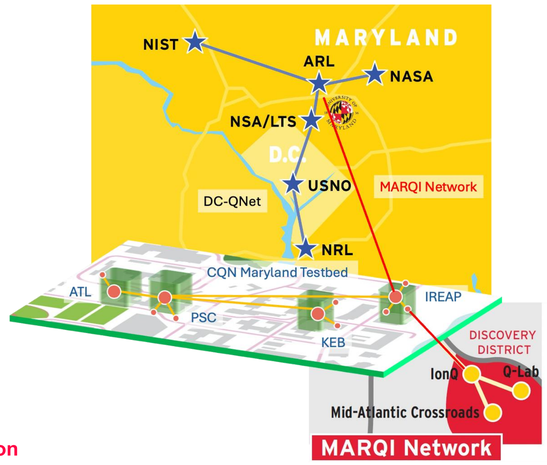
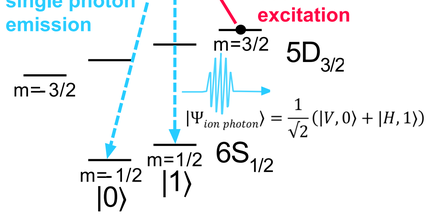
Motivation

Trapped Ions in the MARQI network: Ba^+ ions are used as communication qubits in quantum networking architectures due to their strong-dipole transition and ease of ion-photon entanglement generation [1].

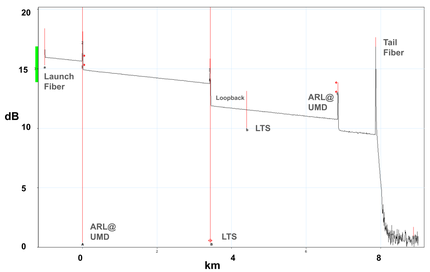


Entangled photon generation



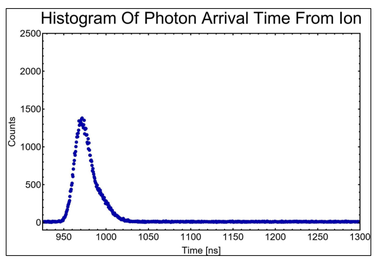
Quantum Frequency Conversion (QFC): Extending the networking range and integrating with other quantum-ready components typically require QFC [2-5]. For polarization-entangled photonic qubits, polarization-preserving QFC is necessary.

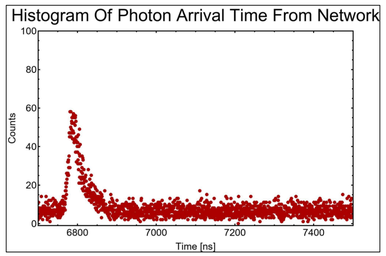
MARQI Network Deployed Fiber Measurements



OTDR for an 8-km roundtrip deployed fiber to LTS (MAX), measured at the JQI hub.

Ion-emitted photon transmission through an 11-km deployed fiber, where the ion's temporal statistics are preserved.

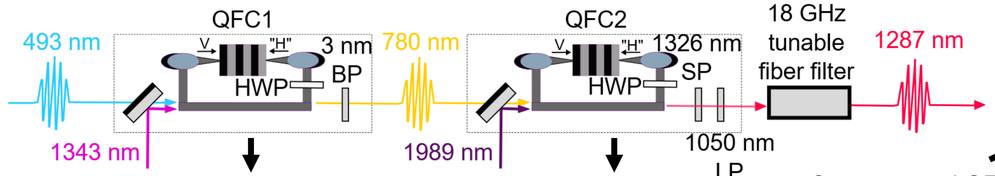


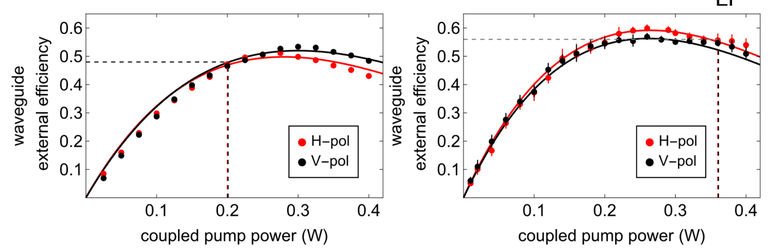


Polarization-Preserving Quantum Frequency Conversion to O-band

We use two stages of polarization-preserving quantum frequency conversion from 493 nm to the O-band at 1283 nm for telecom networking.

- This two-stage conversion scheme allows intermediate 780-nm photons for storage and hybrid networking with Rubidium systems.
- We anticipate **three orders of magnitude improved SNR** over our prior work converting to the telecom C-band [2,6].





QFC1 and QFC 2 waveguide conversion efficiencies

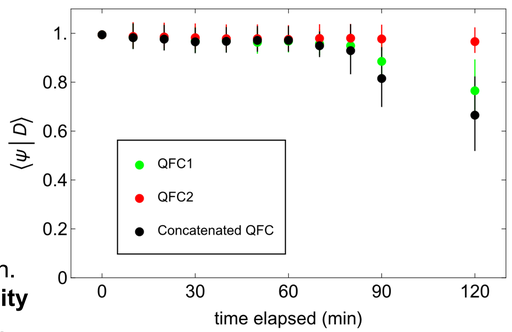
- Periodically-poled lithium niobate (PPLN) in Sagnac-type configuration.
- Operate at **34% fiber-to-fiber conversion efficiencies** for each stage.

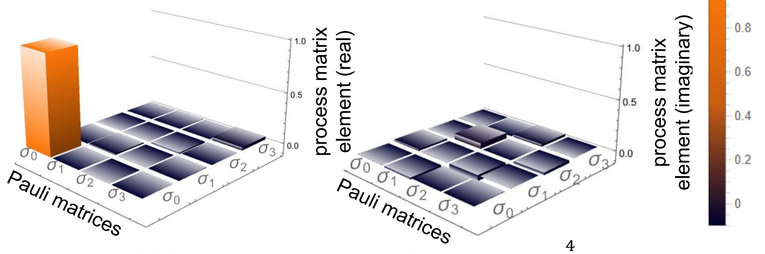
Projected O-band Ion-Photon Entanglement Rates and Fidelities, based on [7]

	rates	fidelity
493 nm	137 s^{-1}	> 0.93(2)
780 nm	45 s^{-1}	> 0.84(2)
1287 nm (projected)	15 s^{-1}	> 0.7(5)

Concatenated QFC polarization stability

- Characterized by injecting CW light at Diagonal polarization.
- **> 60 minutes stability** without recalibration.





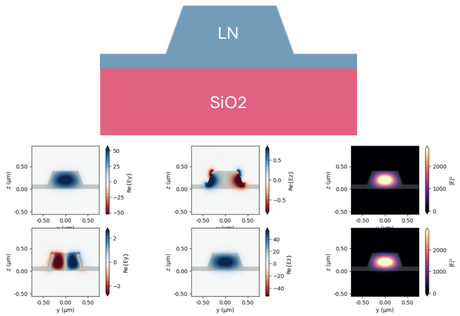
Concatenated QFC process matrix χ_{mn}[8]

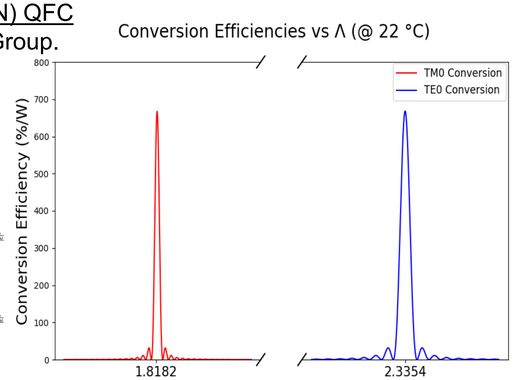
- Characterized using a CW source.
- **Process fidelity: ≥ 97.(0)%.**

$$\rho_{out} = \sum_{m,n=1}^{4} \chi_{mn} \sigma_n \rho_{in} \sigma_m^{\dagger}$$

Next-Generation Polarization-Preserving QFC in Thin-Film Lithium Niobate

Prototyping thin-film lithium niobate (TFLN) QFC devices in collaboration with the Loncar Group.





- Tighter mode confinement can **increase relative efficiency** & reduces overhead
- Greater support of complex integration allows for optimized couplers with **lower insertion loss**
- Leveraging full nonlinear susceptibility tensor allows for **unidirectional polarization diversity**

References

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