

Center for Quantum Networks

NSF Engineering Research Center



Thrust 2 - Quantum Subsystem Technologies

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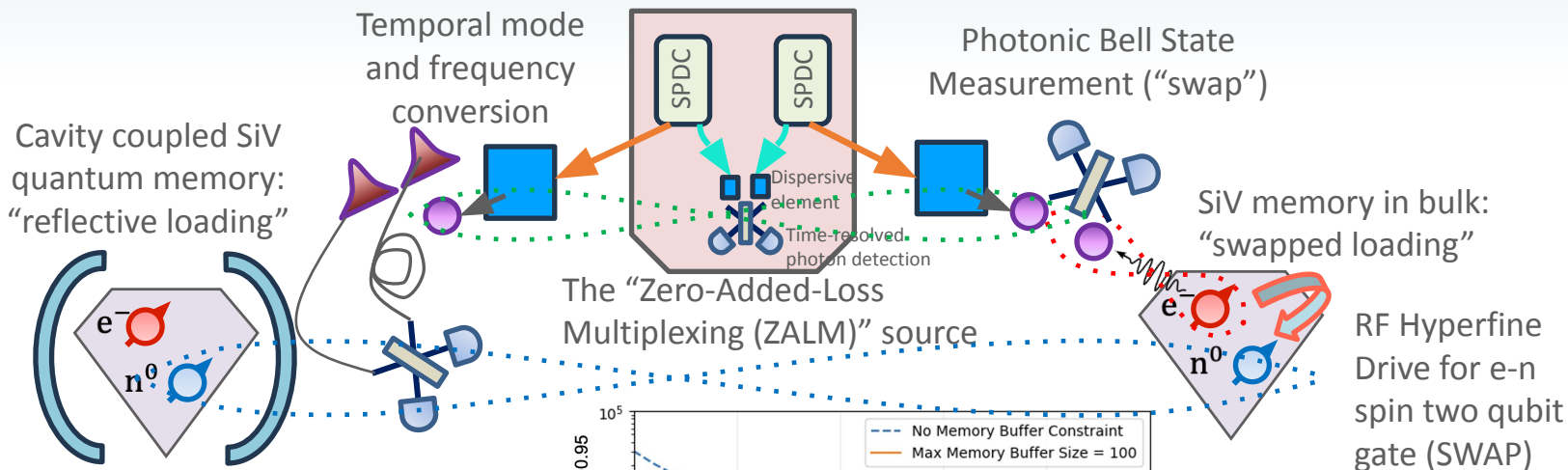
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Subsystem 1: The ZALM



Phys. Rev. Applied 17, 034071 (2022)

Phys. Rev. Lett. 128, 063602 (2022)

Phys. Rev. Applied 19, 054029 (2023)

Phys. Rev. Applied 22, 044014 (2024)

Phys. Rev. Applied 22, 044013 (2024)

C2C paper: Phys. Rev. Research 6, 033317 (2024)

New Award: # 2427047 ExpandQISE: Track 1

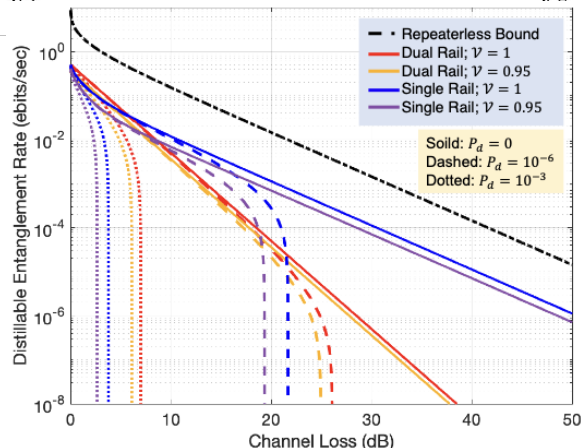
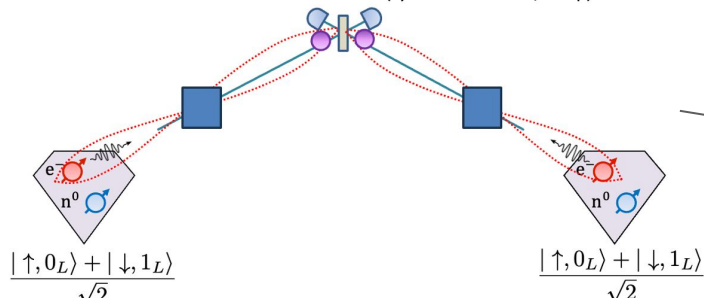
Evaluated detailed extensive models for 6+ different quantum link-architecture alternatives



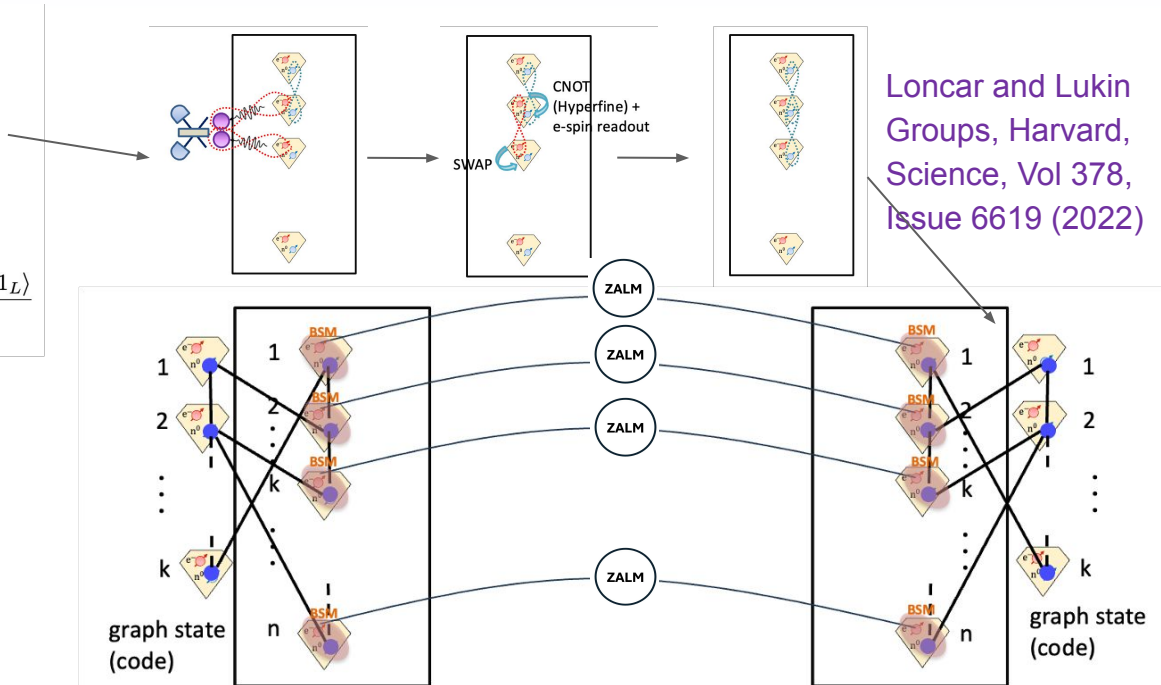
Subsystem 2: Multiplexed entangled SiV module

Subsystem 3: Measurement based ent. distillation

Photonic Bell State Measurement: BSM (synchronous BSM / swap)



Dhara, Englund, Guha, PRR 5, 033149 (2023)



Loncar and Lukin
Groups, Harvard,
Science, Vol 378,
Issue 6619 (2022)

Shi, Patil, Guha

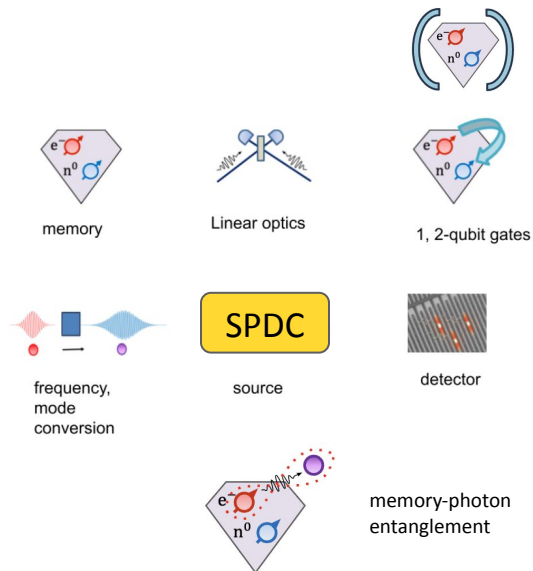
PRX Quantum 6, 010339 (2025)

Physical Review Letters 135, 130803 (2025)

Development Timeline

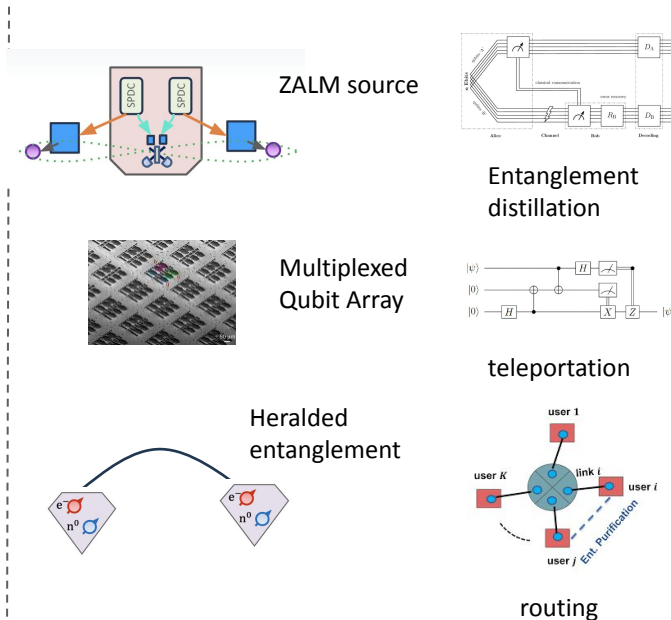
testbeds

Device blocks

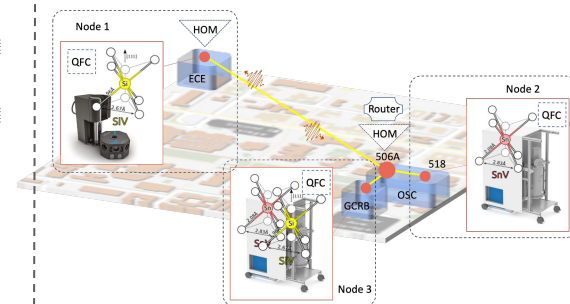


Year 1-4

Functional blocks



Year 5-7

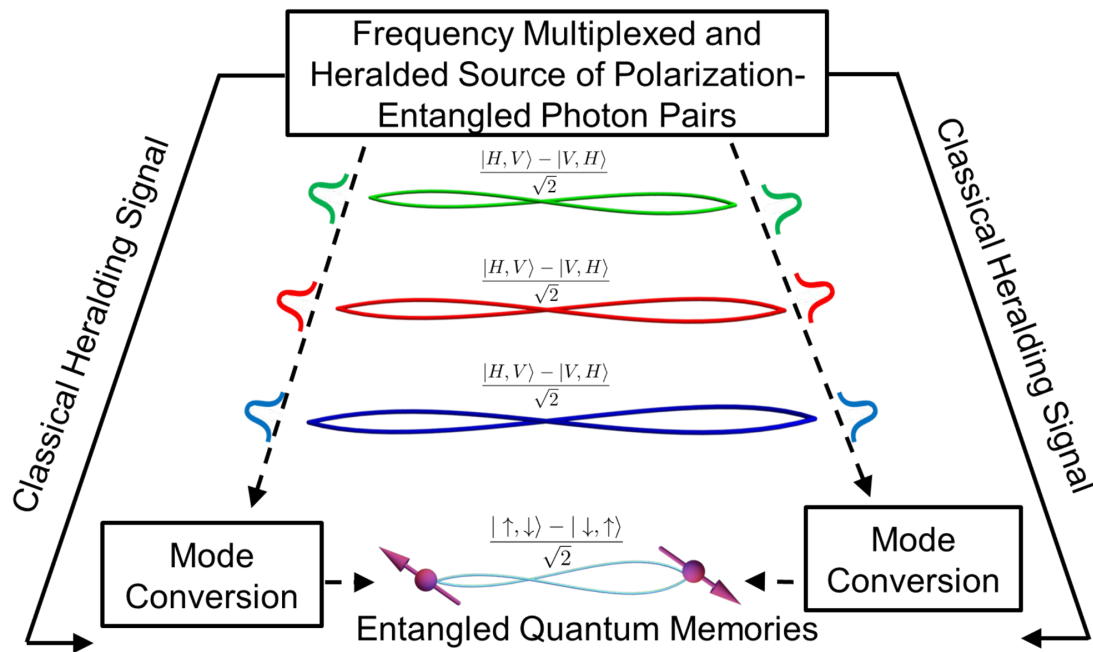


Year 8-10



Zero-added-loss multiplexing (ZALM) scheme

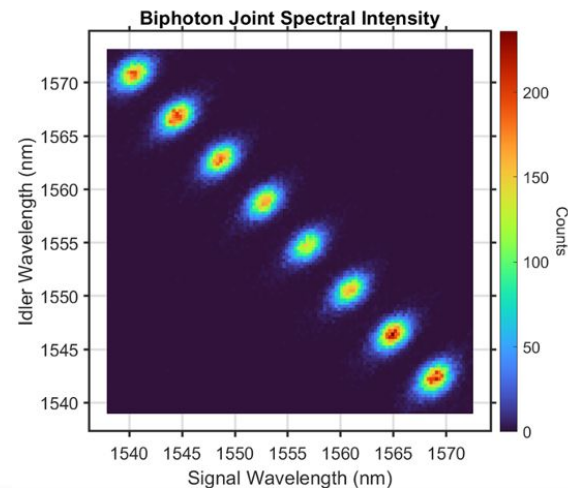
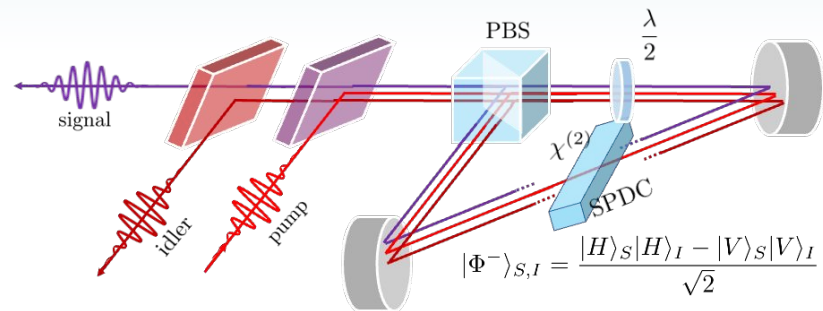
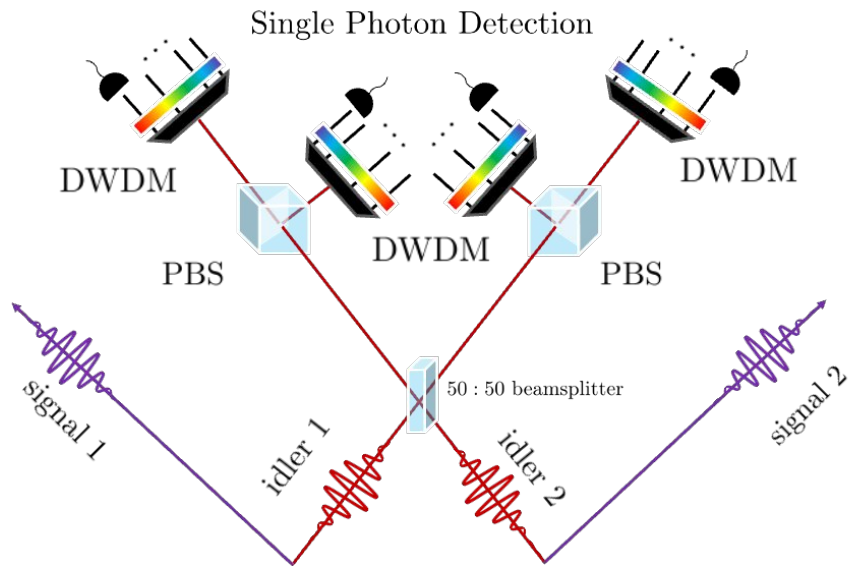
Saikat Guha (UMd) and Dirk Englund (MIT)



Chen, Dhara, Heuck, Lee, Dai, Guha, and Englund, Physical Review Applied 19, 054029 (2023)



ZALM source: Engineered frequency islands



ZALM source: Filtered frequency islands

Analyzed:

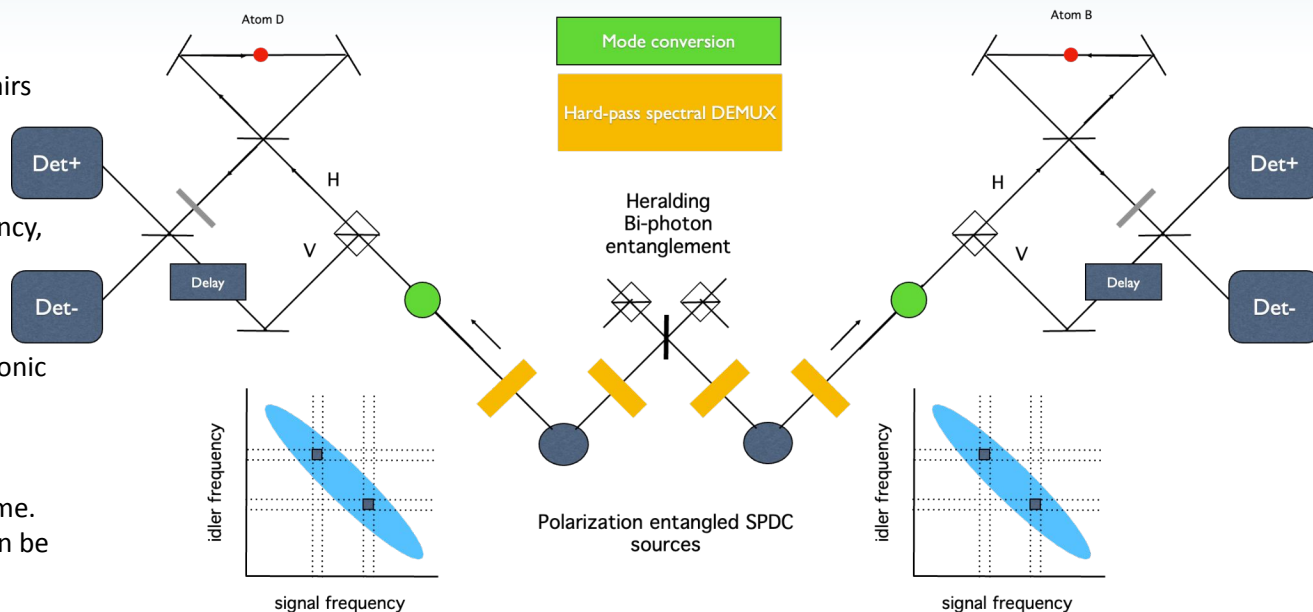
1. ZALM's heralded source of entangled photon pairs
2. loading of the entangled states into pairs of intra-cavity color-center quantum memories,
3. Tradeoffs between distribution rate, heralding probability, heralding efficiency, and entangled-state fidelity.

Findings:

1. Perfect transfer of the entangled photonic state to the quantum memories is possible when the photonic state is bandwidth compressed to reach the memory's narrowband operating regime.
2. Multichannel broadband operation can be analyzed quantitatively.

Ongoing work:

1. Multi-frequency heralding
2. Spectral-temporal pump engineering
3. Optimizing the Frequency-conversion / bandwidth compression trade
4. Joint optimization of source + conversion



Shapiro, Raymer, Embleton, Wong, Smith, Phys. Rev. Appl. **22**, 044014 (2024)
Shapiro, Embleton, Raymer, Smith, arXiv:2507.14427 (2025).

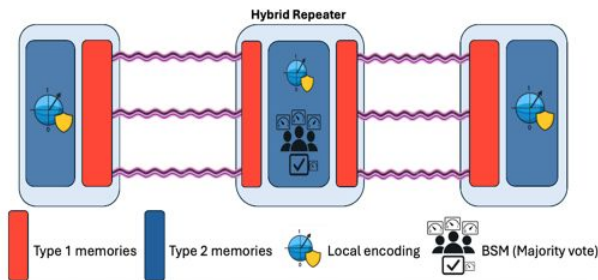
SiV + Ion trap-based hybrid repeaters for encoded entanglement distribution

Goals:

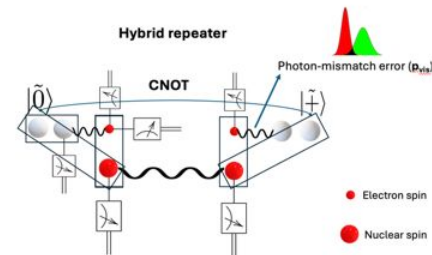
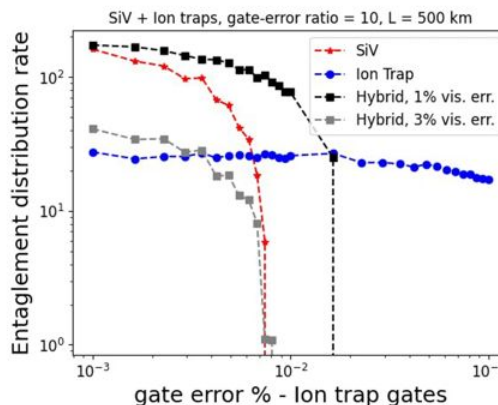
- 1) Improve performance error correction-based entanglement distribution by combining two physical platforms that perform distinct functions.
- 2) Design and optimize hybrid architectures based on SiV and Ion trap qubits.
- 3) Find new optimal pulse level protocols for implementation of such a hybrid encoded repeater architecture.

Challenges:

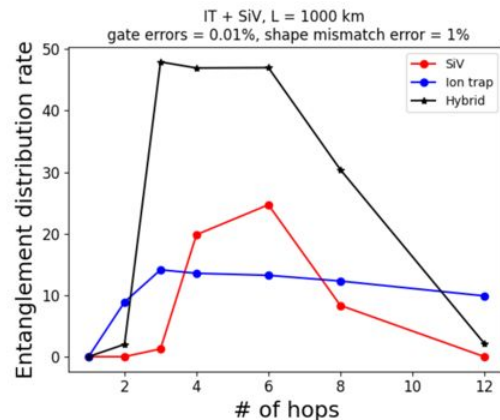
- 1) A tailored model with gate-count level details for color-center and ion-trap based implementation needed to assess real-world performance.
- 2) Important factors like loss and noise from transduction, pulse-shaping challenges need to be included in sims.



Hybrid repeater combines type 1 – “Fast” and type 2 – “high fidelity ops.” platforms



Gate-counts, transduction errors based on physical platform constraints included.

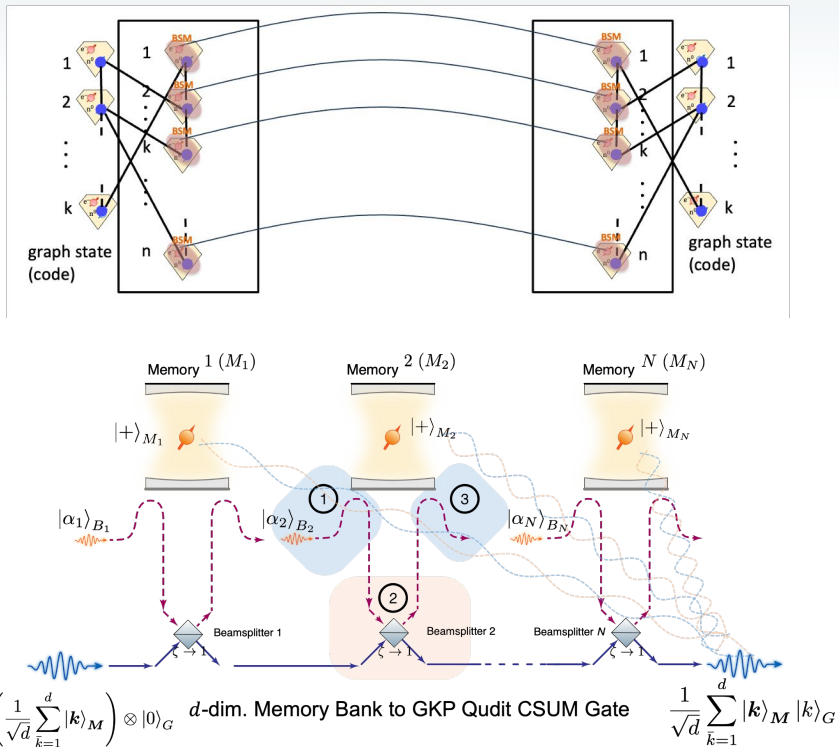


Results:

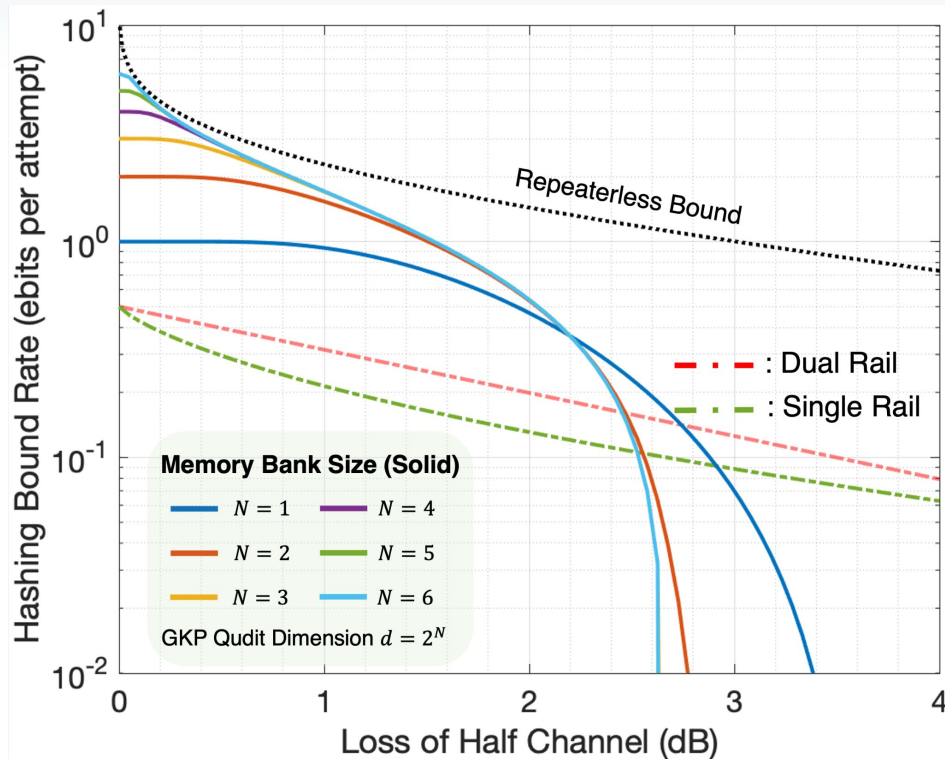
- 1) Hybrid architecture (SiV+Ion trap-based repeaters) outperforms pure (SiV or Ion-based) architectures.
- 2) Optimal choice of # of hops between two error-corrected nodes exists.
- 3) Photon shape mismatch/visibility error plays a deciding role in performance.



High rate entanglement at low loss

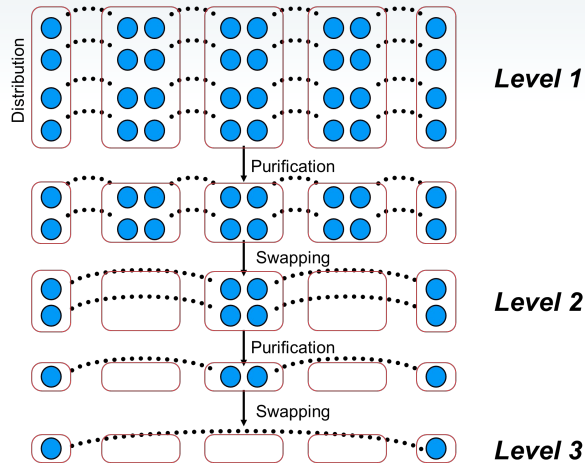


Dhara, Jiang, Guha,
arXiv:2406.04272 (to appear in Optica Quantum 2025)
Phys. Rev. A 112, 012401 (2025)





Code based entanglement distillation



Efficiency:

$$E(F_{in}) = \frac{n_{out}D(F_{out})}{n_{in}D(F_{in})}$$

F – Fidelity

n_{in} – The total number of input Bell States

n_{out} – The total number of output Bell States

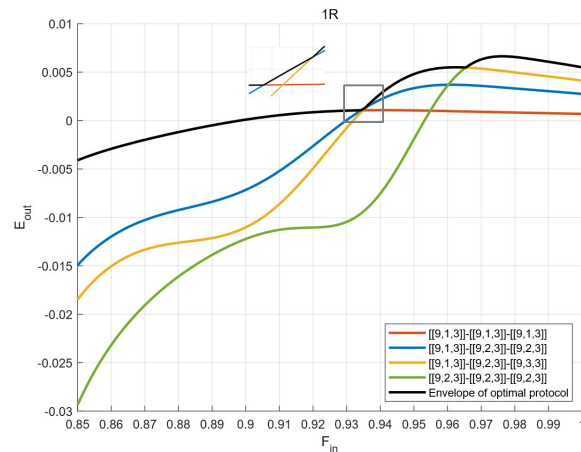
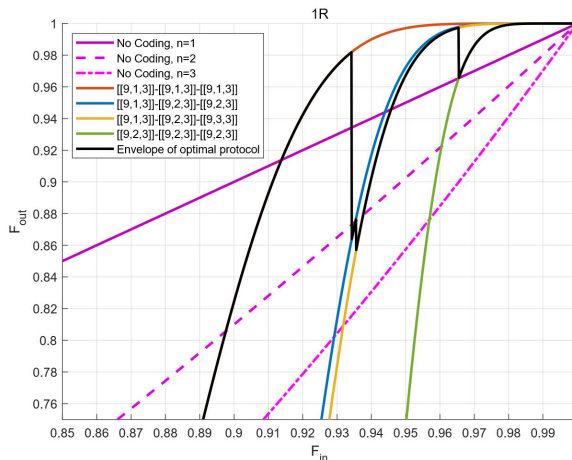
D – Distillable Entanglement

$$D(F) = 1 + F \log_2 F + (1 - F) \log_2 \left(\frac{1 - F}{3} \right)$$

- Adaptive error correction for entanglement distillation
 - Adaptively change the code in the sequence of distillation rounds for a chain of repeaters — gradually increase the rate while limiting error correction capability as fidelity monotonically increases with rounds.
 - This approach jointly optimizes both rate and fidelity (“efficiency” metric).
 - S. Cheng and N. Rengaswamy, 2504.11670

Example of adaptive protocol using $[[9,1,3]]$, $[[9,2,3]]$ and $[[9,3,3]]$ codes

The black line shows the envelope of optimal code sequence as a function of input fidelity

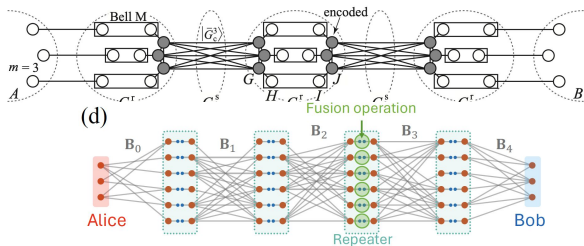




Using spin qubits as a source of photonic graph states for all-photonic repeaters

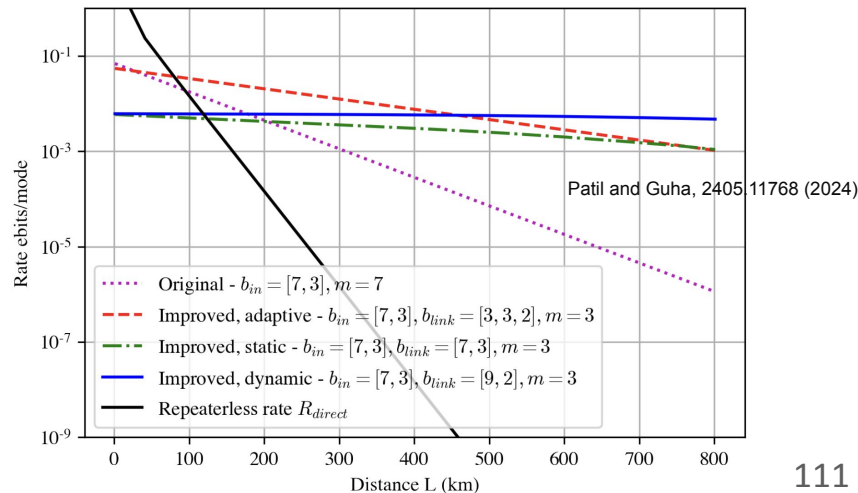
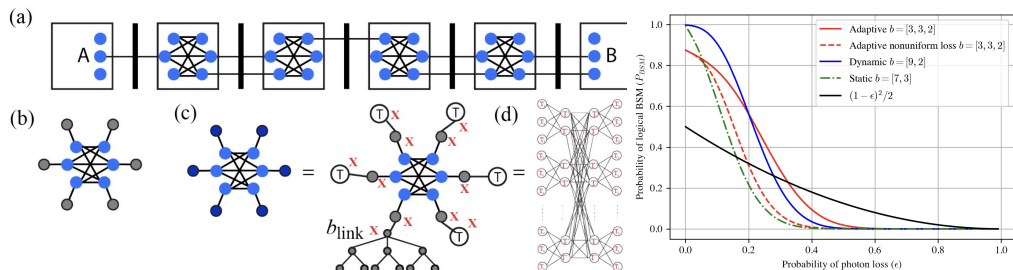
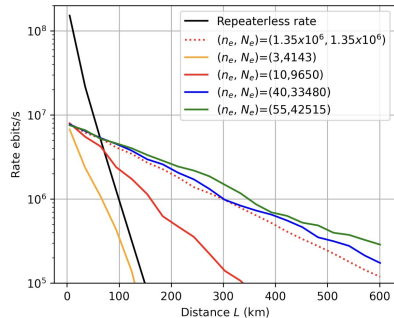
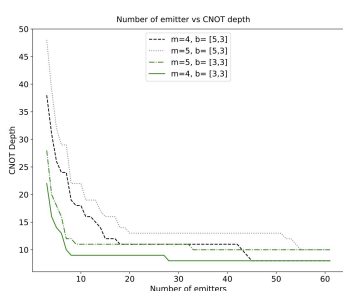
Improved Quantum Repeater Graph States:

Simultaneously entanglement swapping even for probabilistic (optical) Bell measurement.



[CQN Collaboration UChicago + UMass] Li, Googenough, Pozpedek, Jiang, arXiv:2407.01429

Preparation of the graph state using emitters

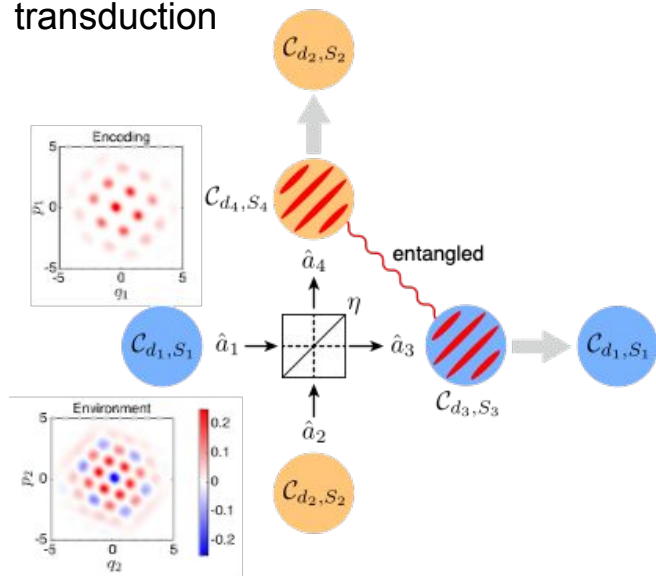




Theoretical Investigation of Quantum Transducers

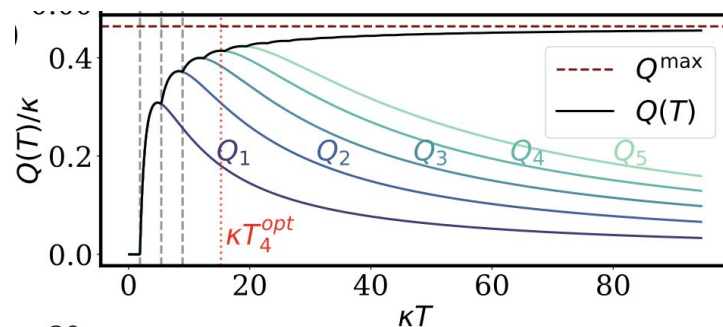
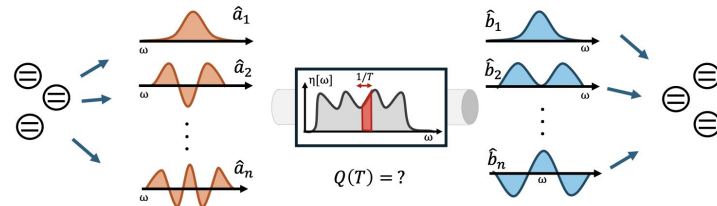
Invent novel quantum transduction protocols enhanced through co-designed QEC

- Inject non-Gaussian (e.g., GKP) state into environmental mode to enhance quantum transduction



Quantify the fundamental limits of practical quantum transduction channels

- Accounting for constraints such as limited bandwidth (B) and finite signal pulse duration (T)





Thrust 2 Integration Across Center

EWD: Raymer organizing Winter school, Smith developed Quantum Masters Internship program at UO, Jiang and Rozpedek organized Quantum Networks Workshop at UChicago, Rengaswamy and Vasic organized Quantum Information Knowledge (QuIK) workshop at IEEE International Symposium on Information Theory in Athens, Greece, involvement of undergrads in research. EWD Fellowship: Quantum Tangram (efficient mapping of quantum circuit to MBQC, <https://arxiv.org/pdf/2210.11465>)

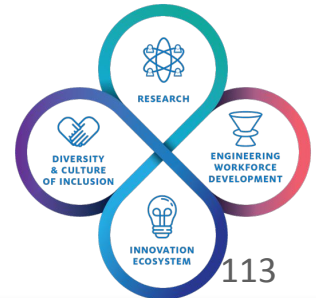
DCI: Recruitment of underrepresented groups at undergrad, grad and postdoc levels to engage in research, high-school student involved in research at UO. Student and faculty involvement in DCI Council, Winter School, the Global Quantum Discussion Group, the SLC Annual Retreat, and other QuESTs and integrated DCI activities

Thrust 1: Collaboration on hybrid networks that include ZALM sources, quantum network tomography; combining error correction based distillation with scheduling policies that can be used for routing

Thrust 3: Collaboration between UO, BYU, MIT and Harvard to address mode conversion; discussions between the groups of Rengaswamy and Berggren about SNSPDs for measurement-based implementation of distillation

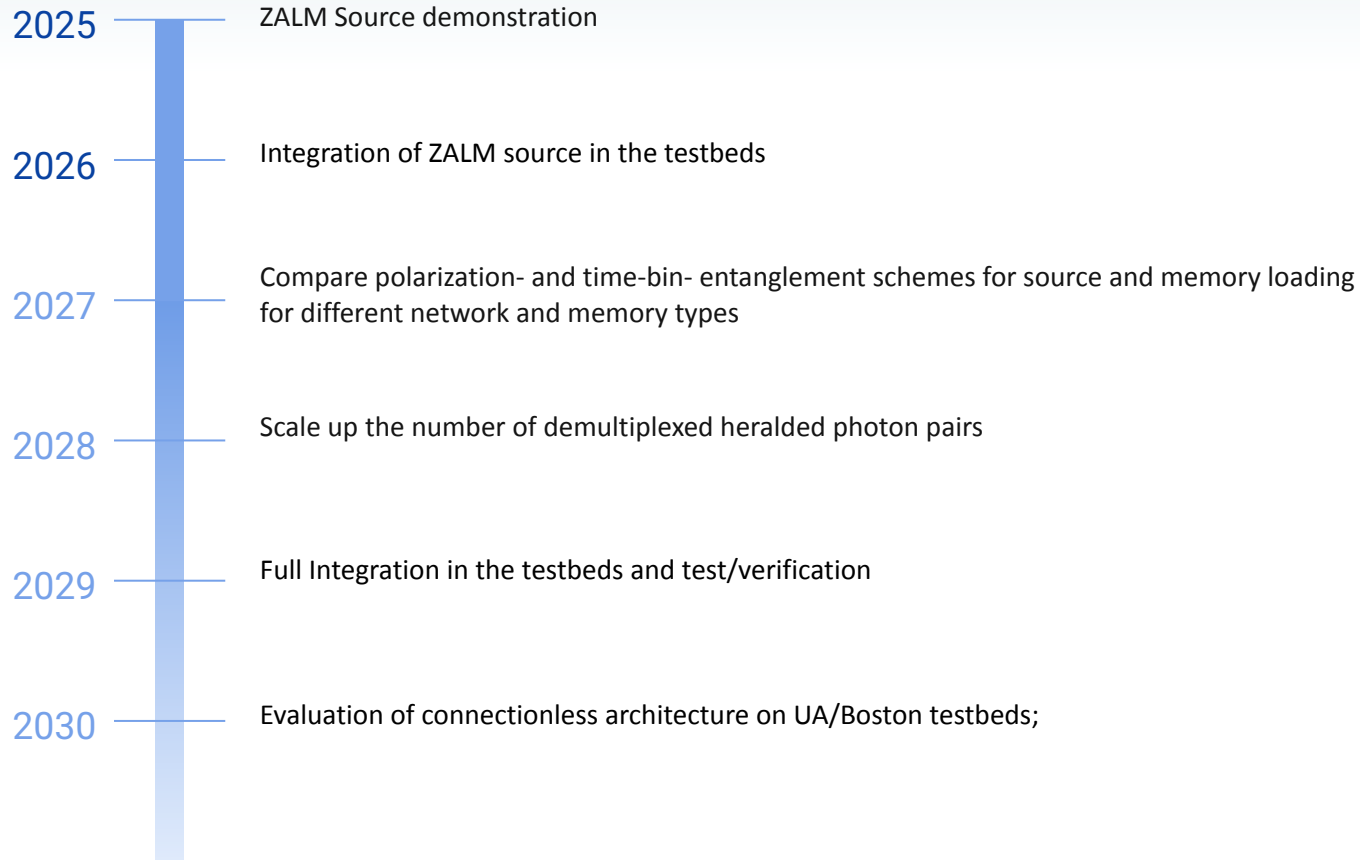
Thrust 4: Smith organized panel discussion on Societal impacts of Quantum Tech at Quantum 2.0 in San Francisco 2025; Smith organized workshop on Societal impacts of Quantum Tech in Spring 2025

IE: Rengaswamy building partnerships with Photonic, Xanadu, and Quantinuum with the help of Jill Allen, UA Director of Industry Engagement



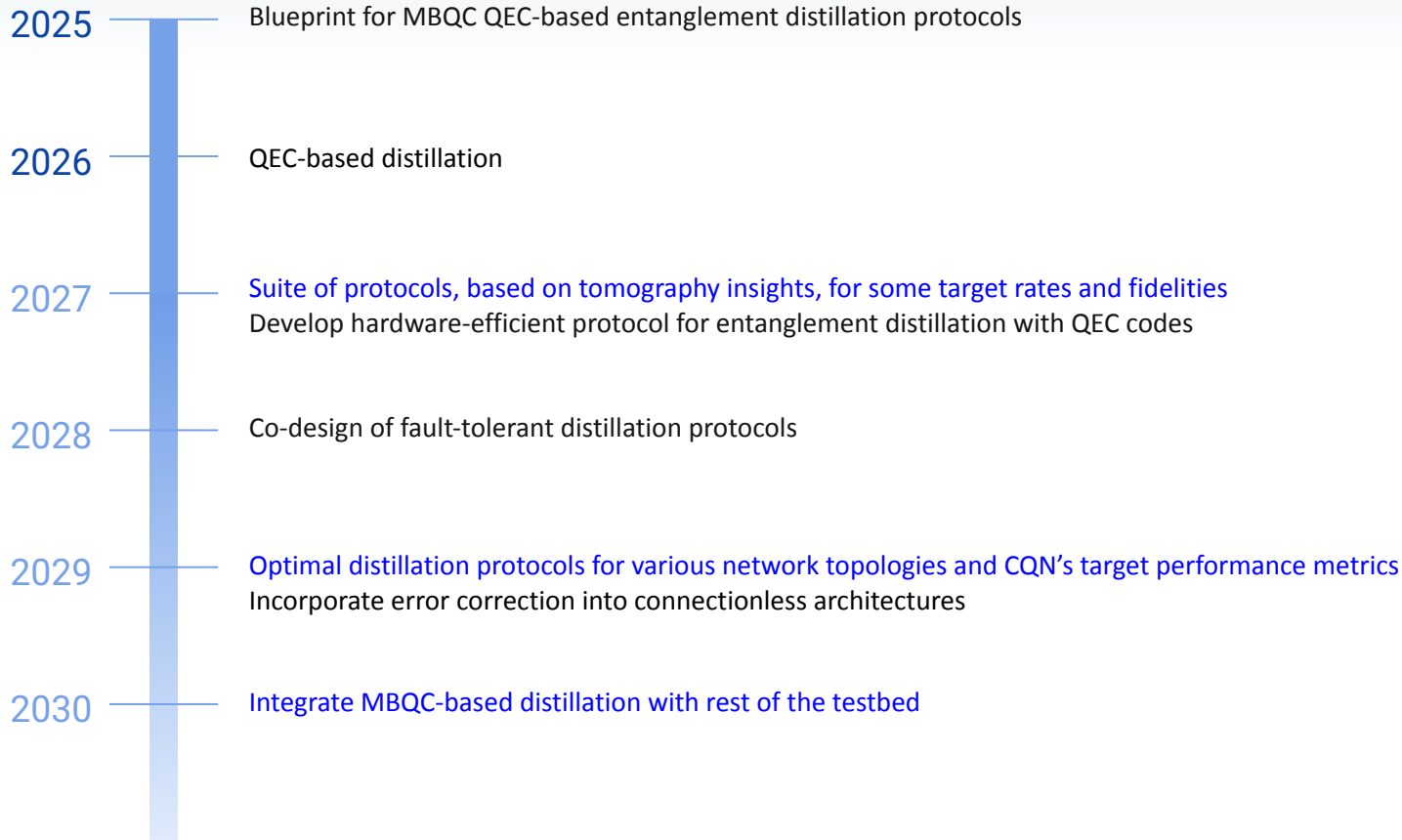


Year 5-10 Major Milestones (Source and mode conversion subsystems)



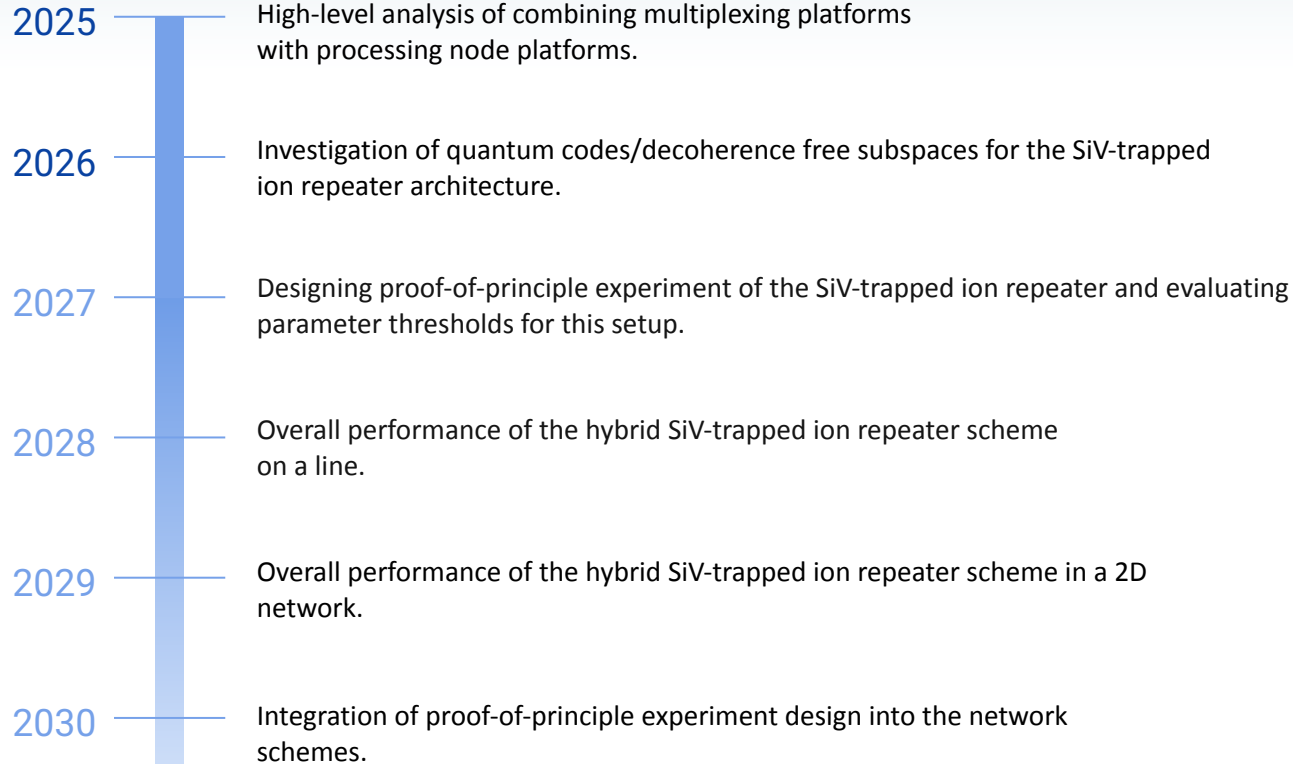


Year 5-10 Major Milestones (Error Correction and distillation Protocols)





Year 5-10 Major Milestones (Physical Layer Repeater Protocols)



Thrust 2 Team

