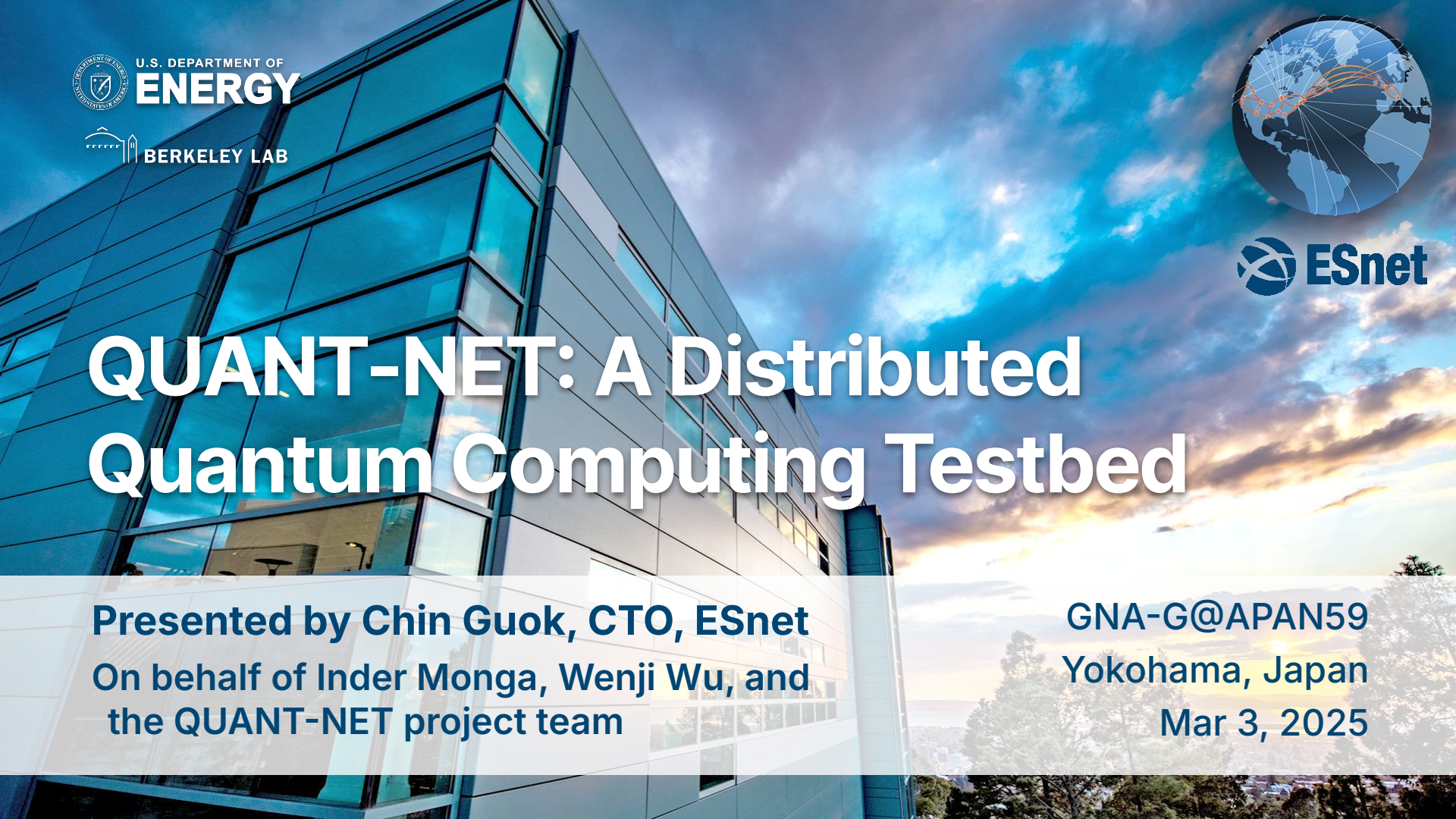

QUANT-NET: A Distributed Quantum Computing Testbed

Presented by Chin Guok, CTO, ESnet

On behalf of Inder Monga, Wenji Wu, and the QUANT-NET project team

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Yokohama, Japan

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  - **Inder Monga (PI)**, Ezra Kissel, Erhan Saglamyurek
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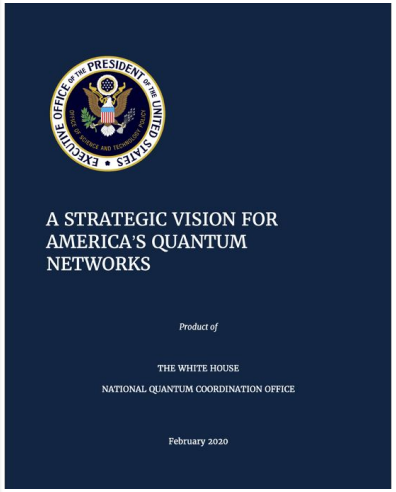
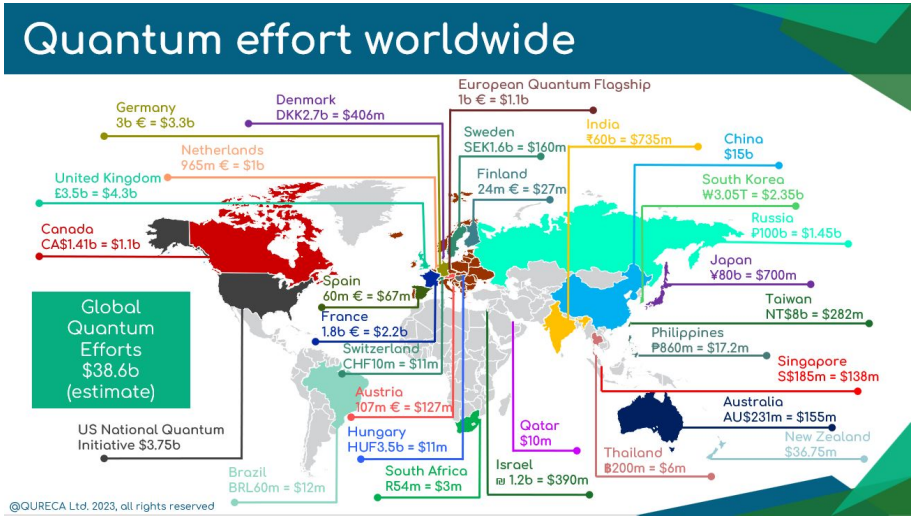
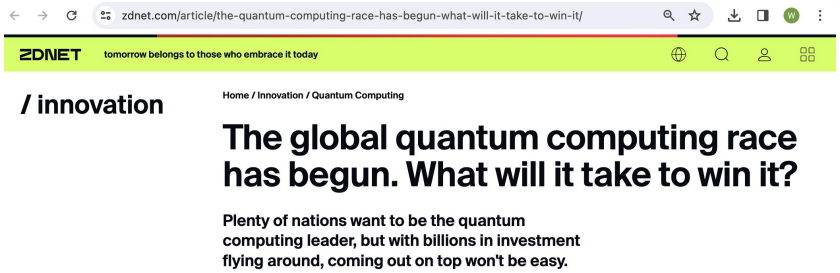
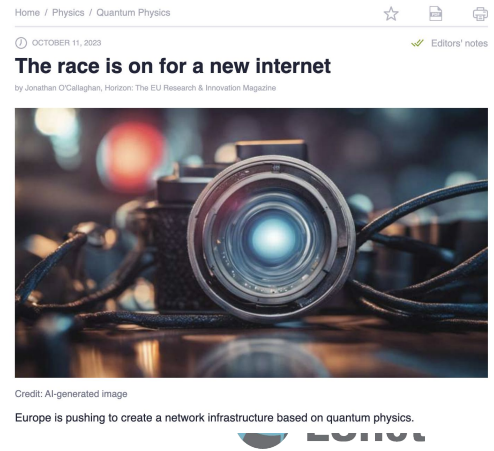
- **The University of Innsbruck**
  - Tracy Northup, Viktor Messerer

Quantum Computing and Networking is a Worldwide Initiative and Race

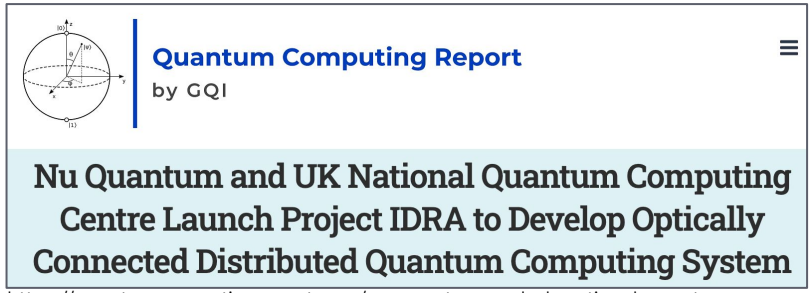




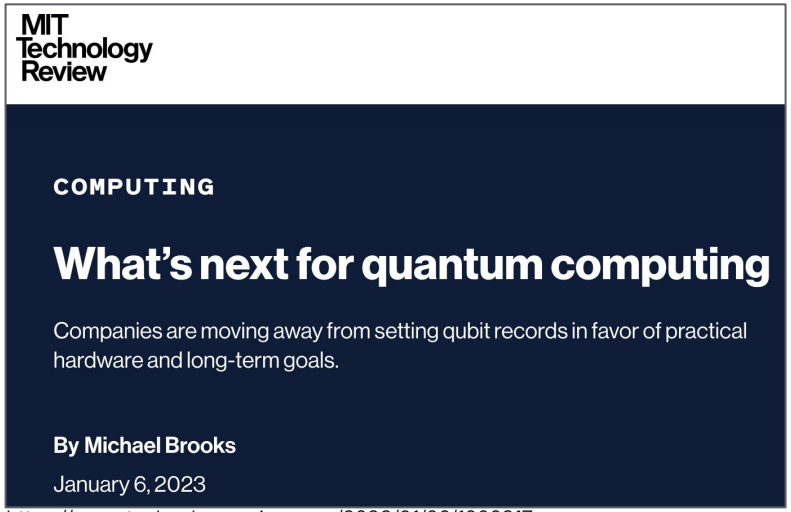




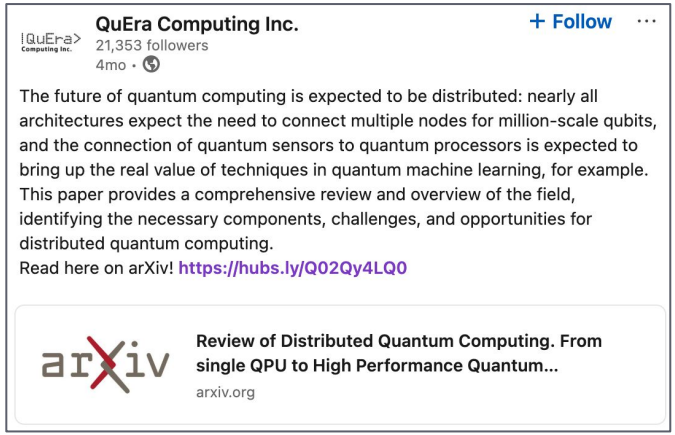
The Future of Quantum Computing is Distributed



https://quantumcomputingreport.com/nu-quantum-and-uk-national-quantum-computing-centre-launch-project-idra-to-develop-optically-connected-distributed-quantum-computing-system/



https://www.technologyreview.com/2023/01/06/1066317/whats-next-for-quantum-computing/



https://www.linkedin.com/posts/quera-computing-inc_review-of-distributed-quantum-computing-activity-7250467672381927425-7V-n/

https://thequantuminsider.com/2024/06/18/google-is-looking-for-proposals-to-push-boundaries-in-distributed-quantum-computing/

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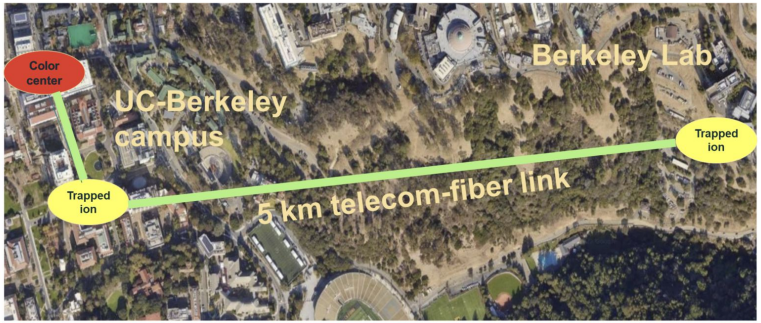
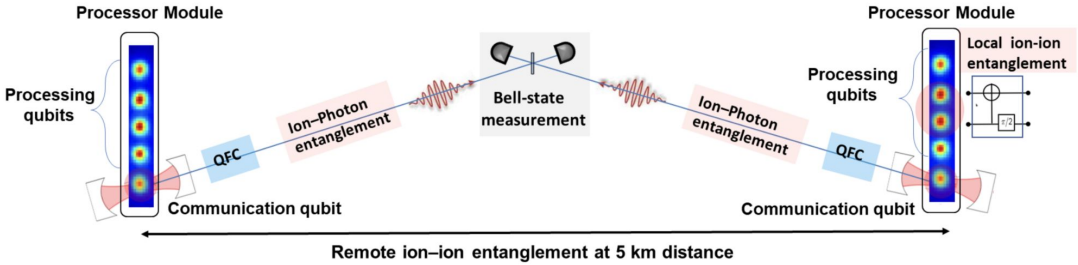
The QUANT-NET Testbed

- A DOE/ASCR funded quantum network research project (Oct 2021 - Oct 2026)
  - Berkeley Lab, UC Berkeley, Caltech, the University of Innsbruck
- Project goals:
  - Develop a three-node quantum networking testbed system at Berkeley demonstrating the basic elements of distributed quantum computing, quantum repeaters, and quantum hybrid systems based on the trapped ion and color center technologies.
  - Architect and implement scalable quantum network protocols, control, and monitoring for the testbed



A three-node quantum networking testbed at Berkeley



Distributed quantum computing between remote trapped-ion nodes

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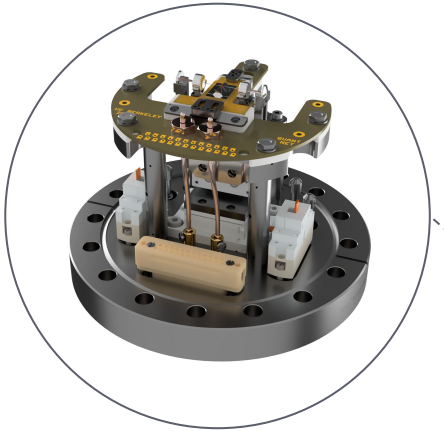
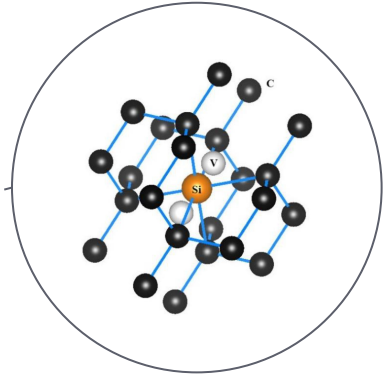
QUANT-NET Focus Areas

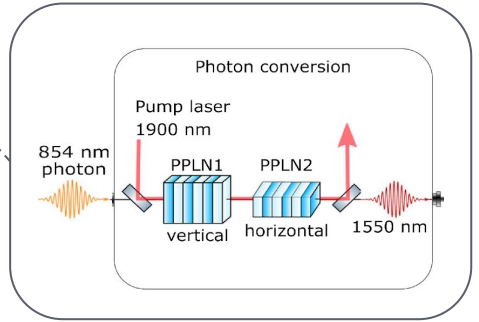


Repeater-friendly **Ion Trap Quantum Computing** Node

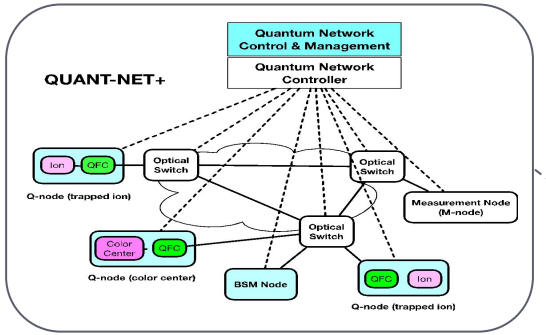
Native telecom photon source and Quantum memories using **Silicon Color Centers**



Efficient **Quantum Frequency Conversion** Technologies



Scalable Quantum Network **architecture, control and management plane**



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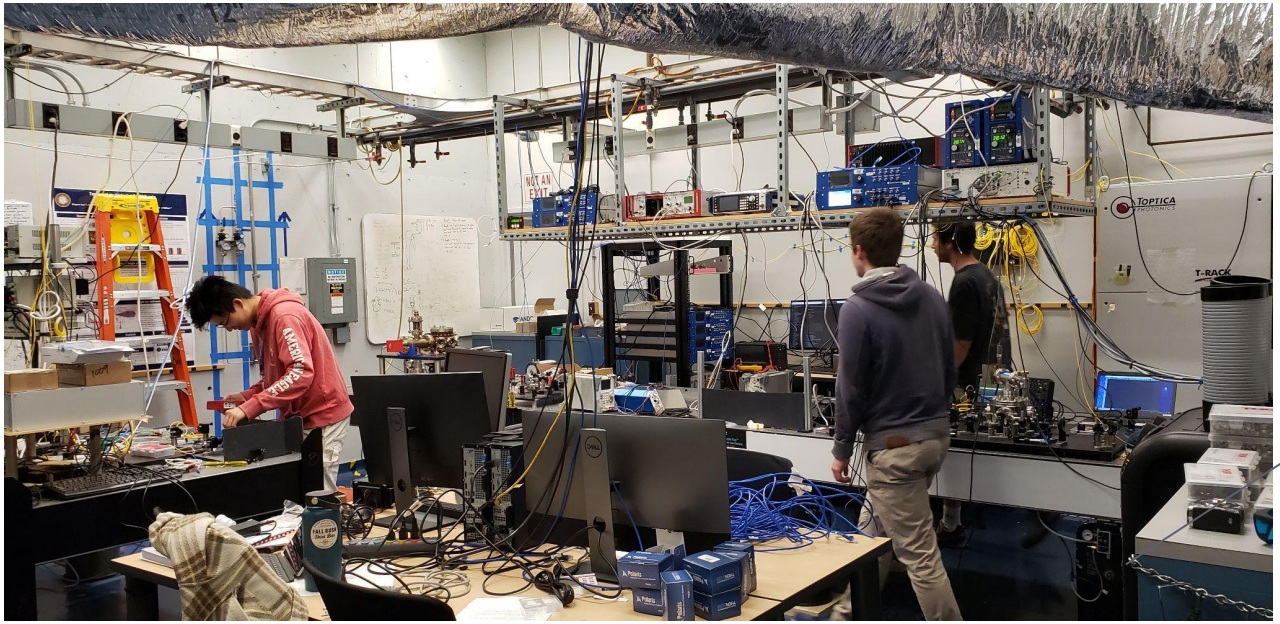
Why the QUANT-NET approach is unique and important

- Distributed quantum computing “scale out” architecture within the data center
  - Entanglement distribution and quantum networking can provide ability to scale out before quantum repeater technology is mature
- Primary research focus is to improve the fidelity and rate of entanglement
  - Broader project research agenda includes quantum repeater research and entanglement across hybrid platforms (color centers)
- Testbed approach provides an end-to-end research proofpoint as well as a platform for continual experimental improvement
  - Systems approach: building the software stack along with the hardware
- Seamless integration with software simulation platforms allows rapid testing of a variety of research approaches
  - And test for scalability

Quantum Node at LBNL



High Performance Laminar Flow Isolator

- 10+ lasers for ion trapping/cooling, qubit manipulation, and Q-networking experiments
- Ultra stable reference cavities + high bandwidth locking electronics
- Ion-trap apparatus and 2x Artiq based control systems
- Fiber-based and free-space BSM and detection system with SNPDs (x5)

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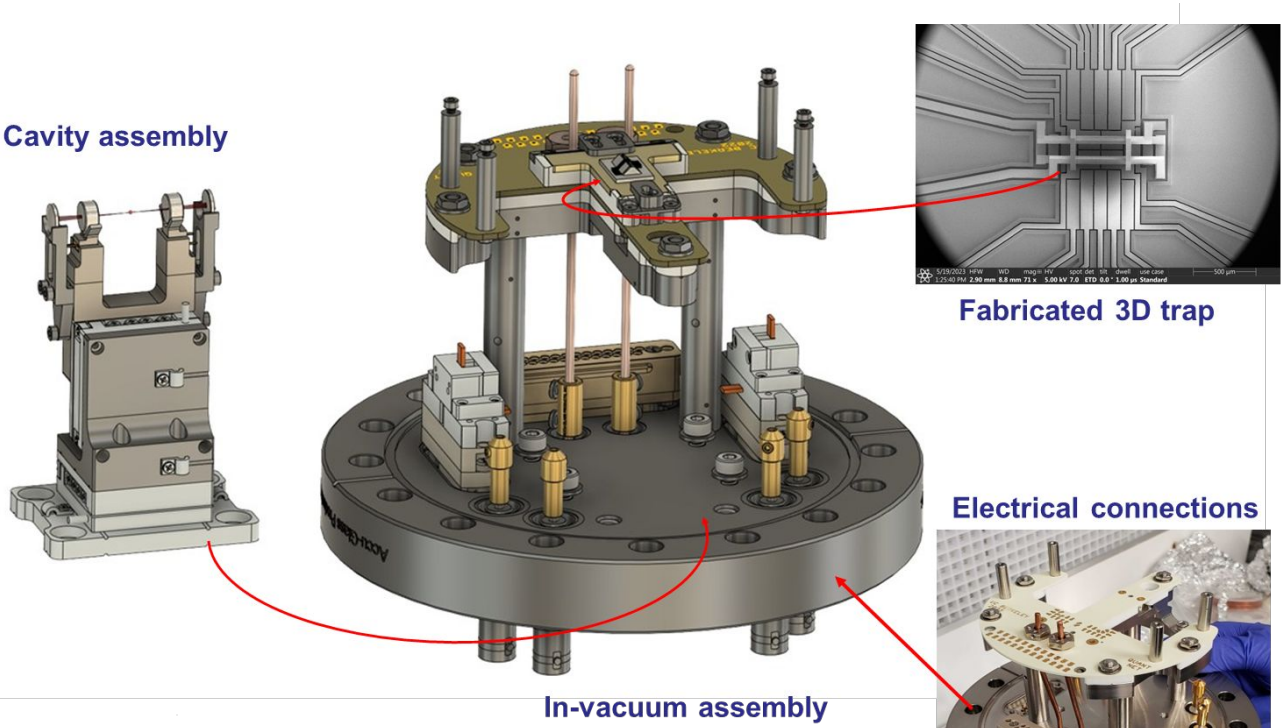
Ion-trap Q-node design and construction



Pioneering implementation of a ion-cavity
3-D microfabricated technology

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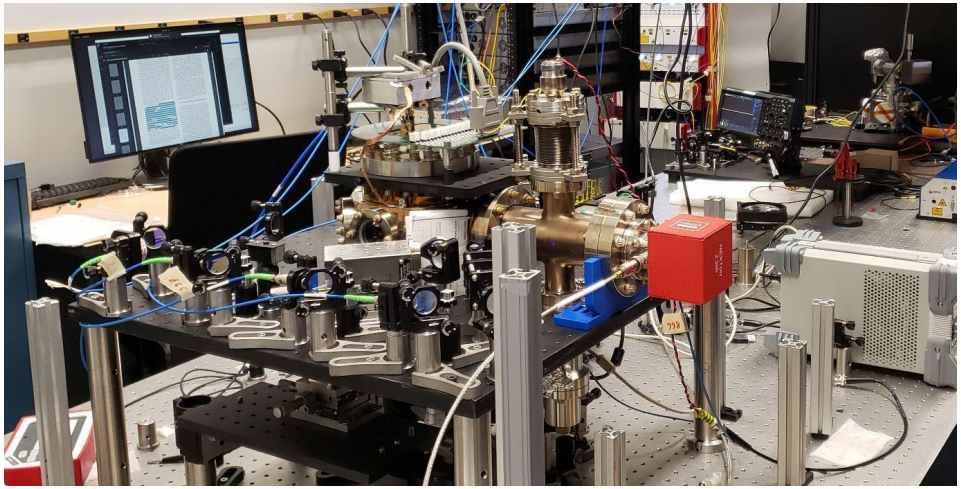
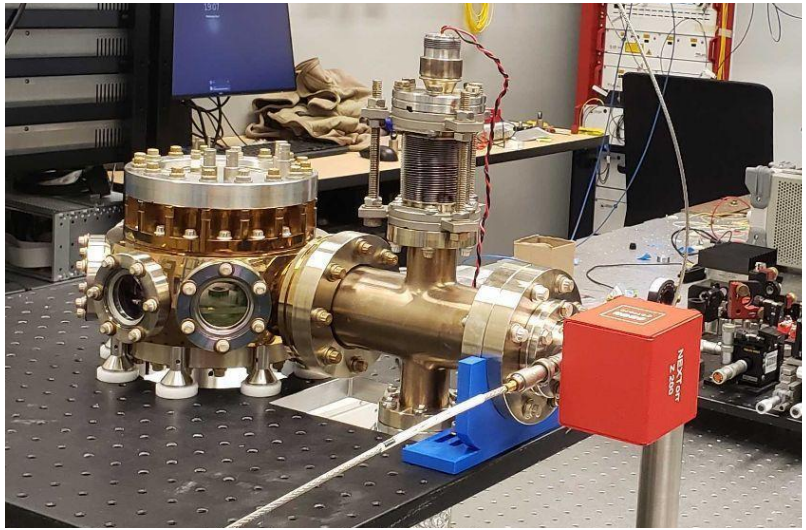
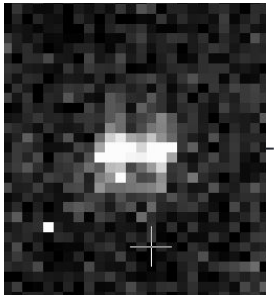
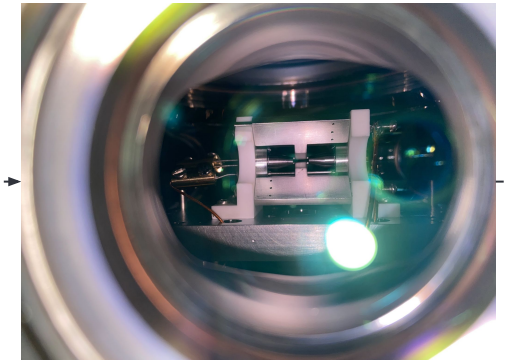
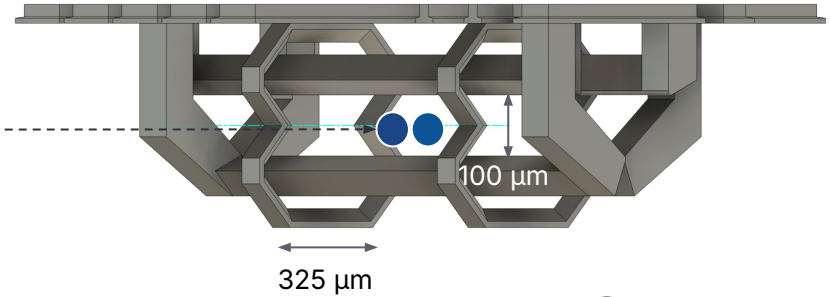
Ion-trapping with 3D micro-trap











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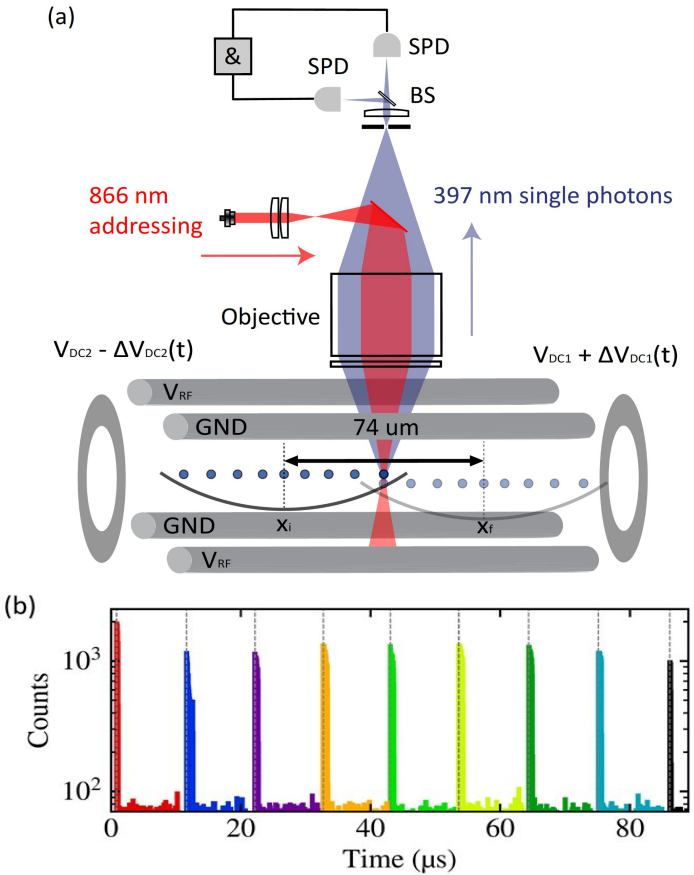
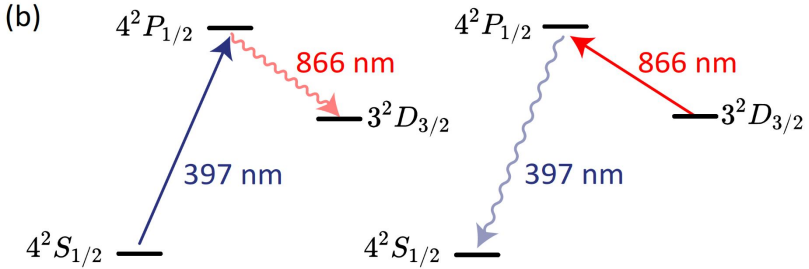
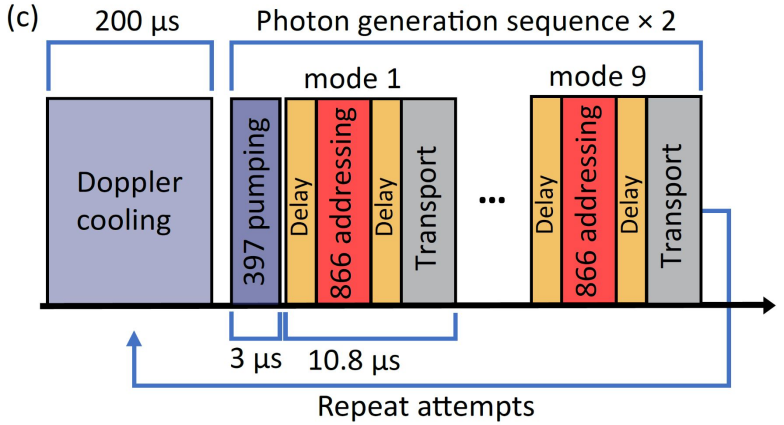
Multiplexed ion-photon interface to increase rate of entanglement







Y. Wu et al.; arxiv:2405.10501

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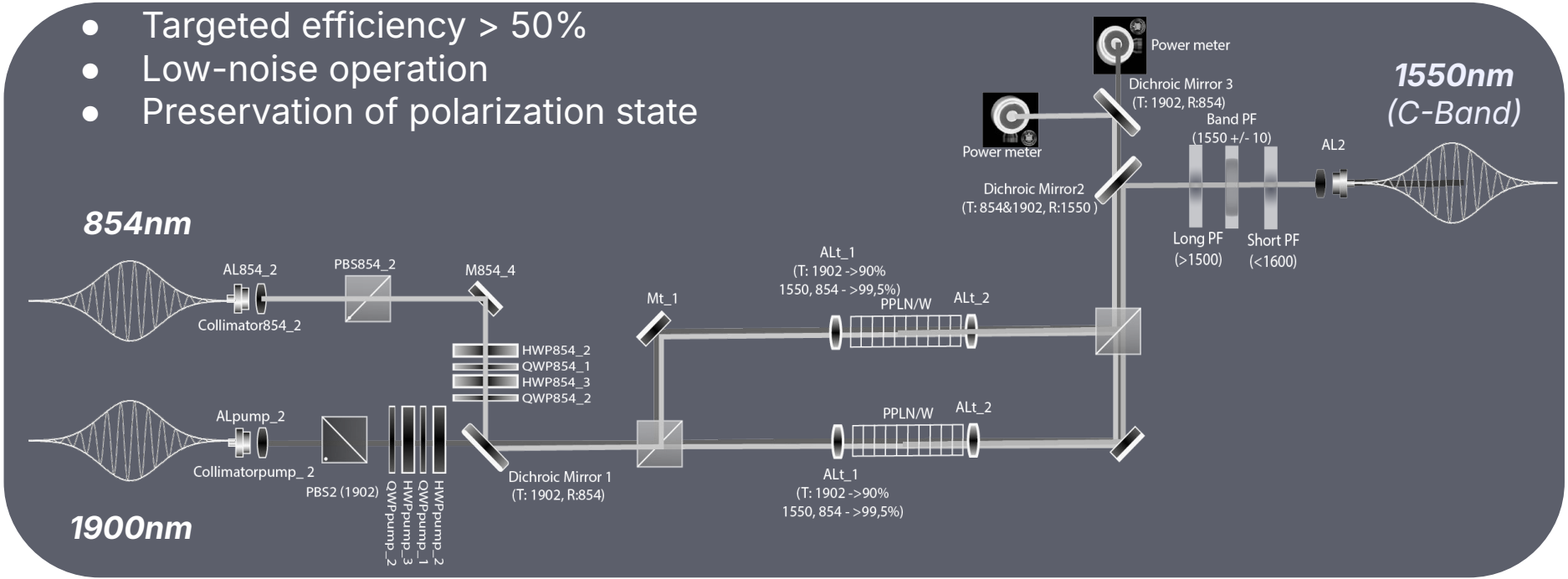
Efficient conversion to telecom frequency

- 854 nm → 1550 nm conversion
- Targeted efficiency > 50%
- Low-noise operation
- Preservation of polarization state



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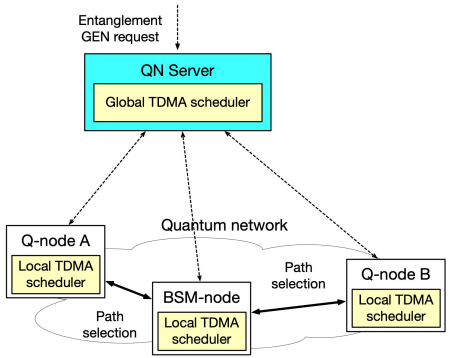
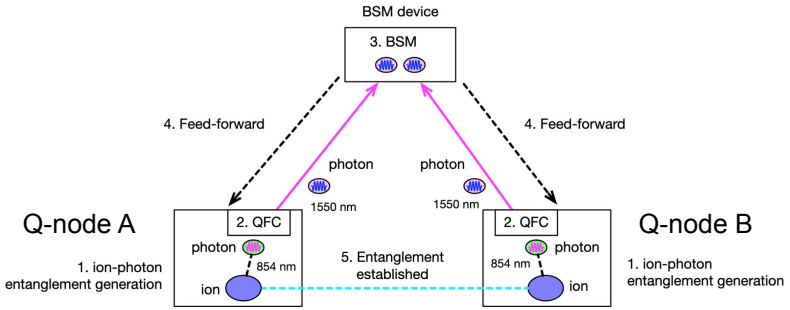
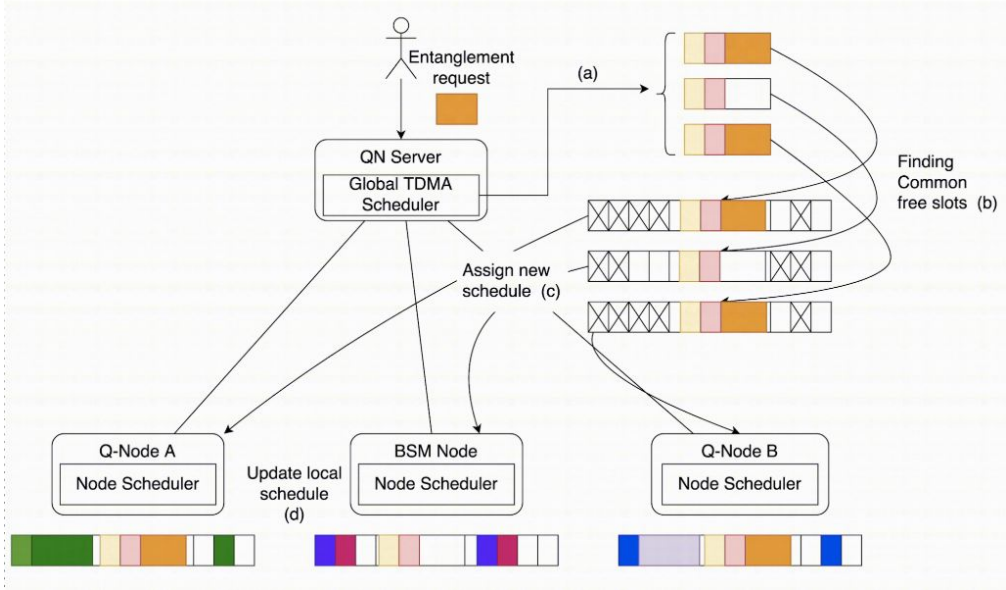
Two-level control framework - support synchronized operations



1. Quantum network topology



2. Remote ion-ion entanglement generation process



3. How the control framework supports such a process

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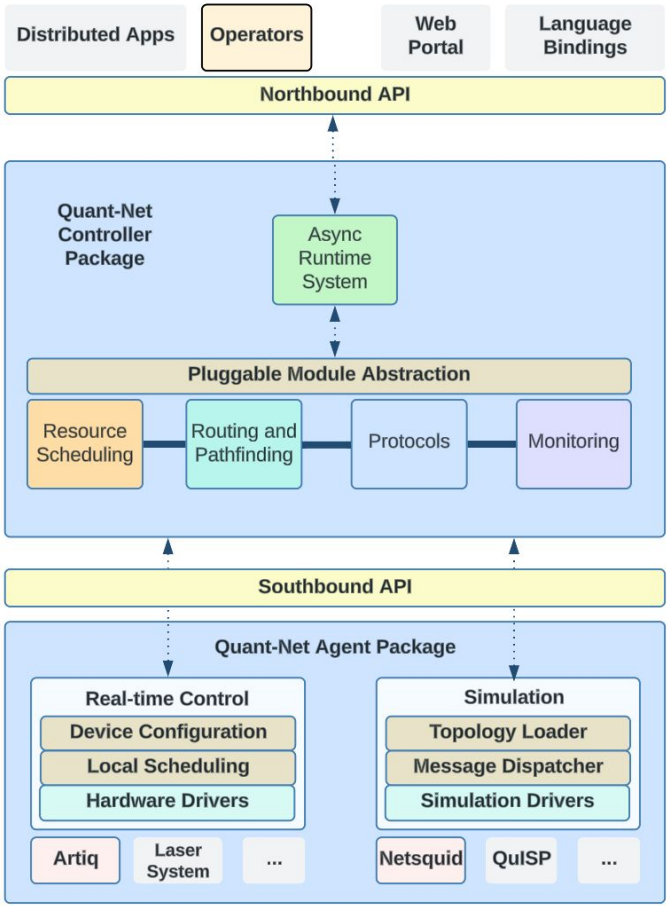
Two-level control framework - an open plug-in design (1/2)



- A framework for exploring a range of quantum networking approaches
  - A modular, extensible software platform
  - Support both real hardware and simulation
- Create an opportunity for the quantum network community to evolve together

Allow for dynamic insertion of new services and functionalities in the control plane

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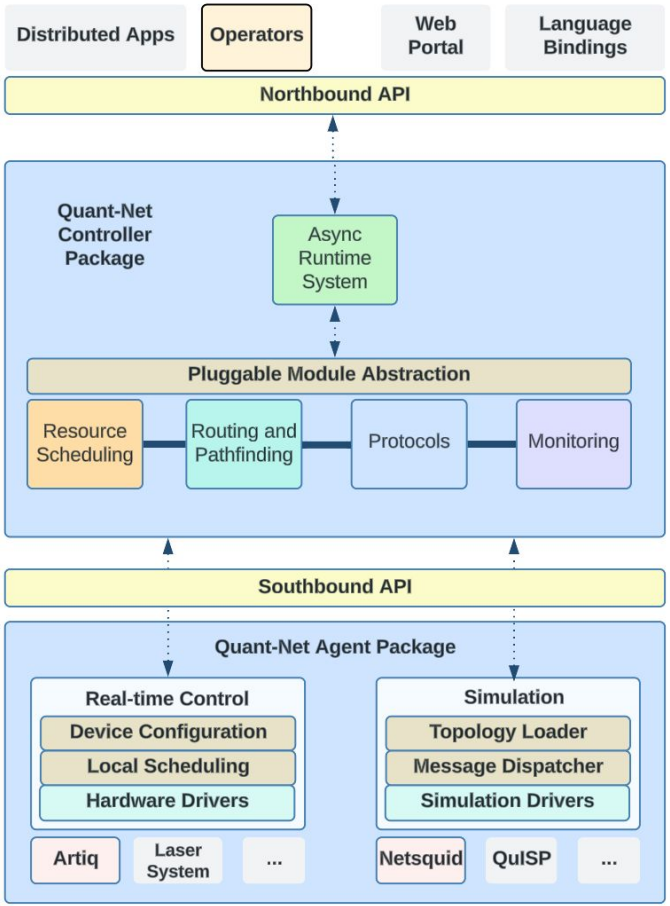
Two-level control framework - an open plug-in design (2/2)



Service/protocol interface and protocol plugin support (Northbound)

- Entanglement generation
- Teleportation
  - Data teleportation, gate teleportation
- Multi-party quantum state generation

Controller and device interactions (Southbound)

- Agent hardware abstraction layer with a number of implemented device drivers
- Pluggable agent command interpreters to define protocol behavior
- Agent local scheduling (with DAG traversal)
- Device monitoring with measurement schema

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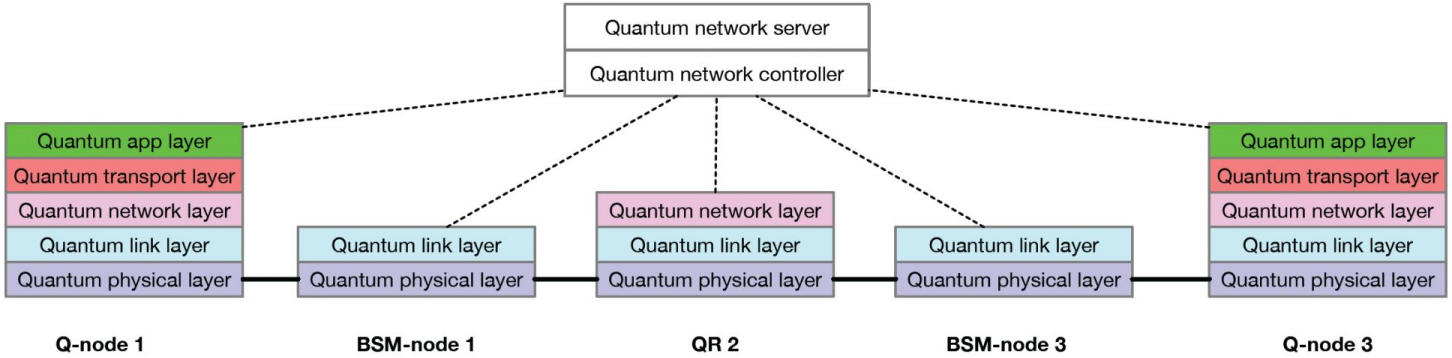
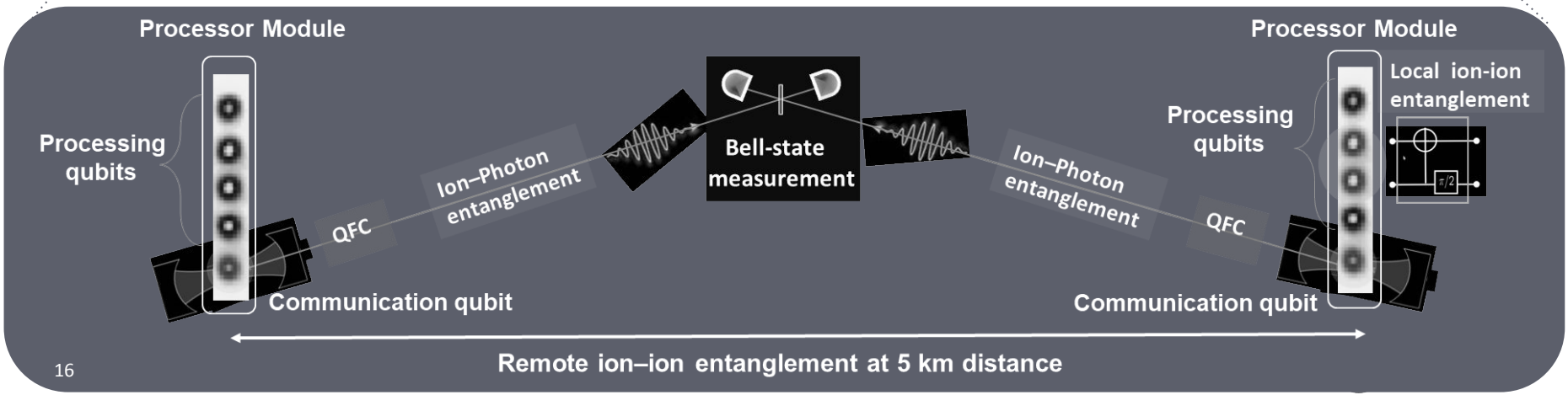
Bringing all the layers together





Learn more about QUANT-NET

quantnet.lbl.gov

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