



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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Acknowledgements

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- **Berkeley Lab**

- Lavanya Ramakrishnan, You-Wei Cheah
- **Inder Monga (PI)**, Ezra Kissel, Erhan Saglamyurek
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Caltech

- **Caltech**

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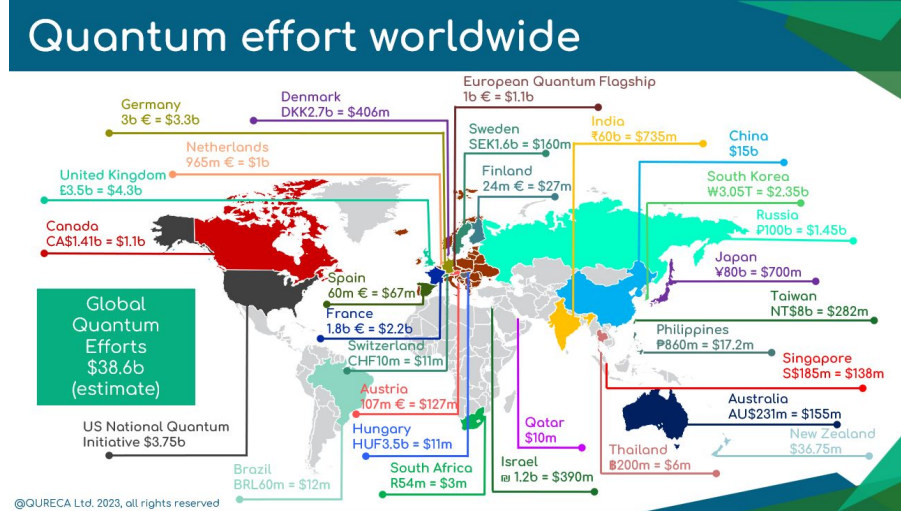
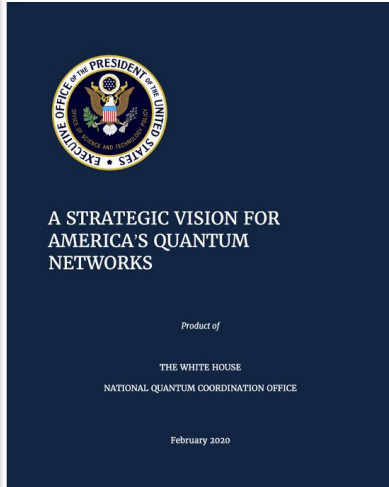


**universität
innsbruck**

- **The University of Innsbruck**

- Tracy Northup, Viktor Messerer

Quantum Computing and Networking is a Worldwide Initiative and Race



Home / Physics / Quantum Physics

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👍 Editors' notes

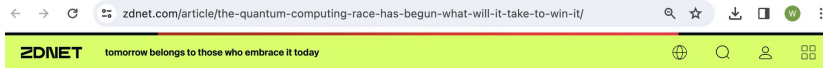
The race is on for a new internet

by Jonathan O'Callaghan, Horizon: The EU Research & Innovation Magazine



Credit: AI-generated image

Europe is pushing to create a network infrastructure based on quantum physics.



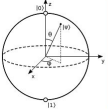
/ innovation

Home / Innovation / Quantum Computing

The global quantum computing race has begun. What will it take to win it?

Plenty of nations want to be the quantum computing leader, but with billions in investment flying around, coming out on top won't be easy.

The Future of Quantum Computing is Distributed




Quantum Computing Report

by GQI

Nu Quantum and UK National Quantum Computing Centre Launch Project IDRA to Develop Optically Connected Distributed Quantum Computing System

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




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The future of quantum computing is expected to be distributed: nearly all architectures expect the need to connect multiple nodes for million-scale qubits, and the connection of quantum sensors to quantum processors is expected to bring up the real value of techniques in quantum machine learning, for example. This paper provides a comprehensive review and overview of the field, identifying the necessary components, challenges, and opportunities for distributed quantum computing.


Read here on arXiv! <https://hubs.ly/Q02Qy4LQ0>



Review of Distributed Quantum Computing. From single QPU to High Performance Quantum...

arxiv.org

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



COMPUTING

What's next for quantum computing

Companies are moving away from setting qubit records in favor of practical hardware and long-term goals.

By Michael Brooks
January 6, 2023

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



Google Is Looking For Proposals To Push Boundaries In Distributed Quantum Computing

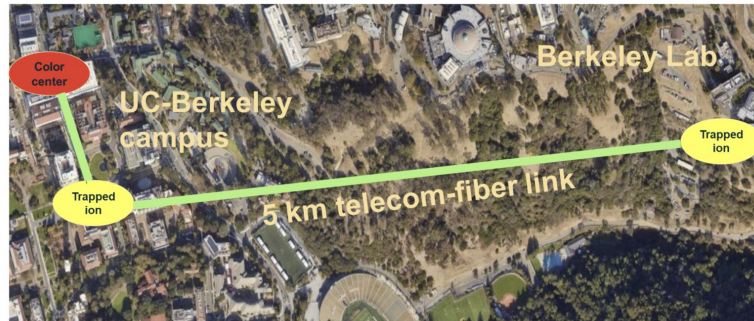
Research Matt Swayne • June 18, 2024

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

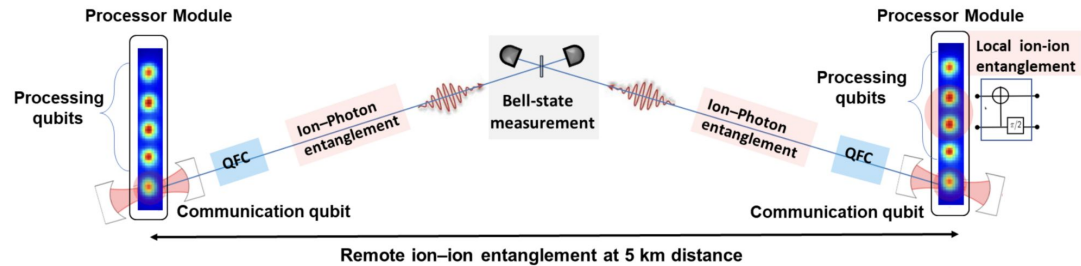


The QUANT-NET Testbed

- 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

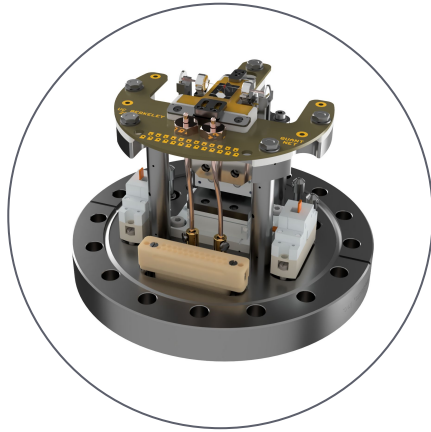


A three-node quantum networking testbed at Berkeley



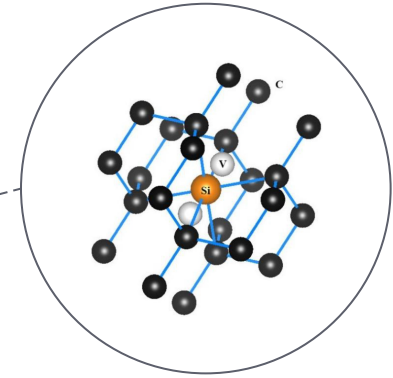
Distributed quantum computing between remote trapped-ion nodes

QUANT-NET Focus Areas

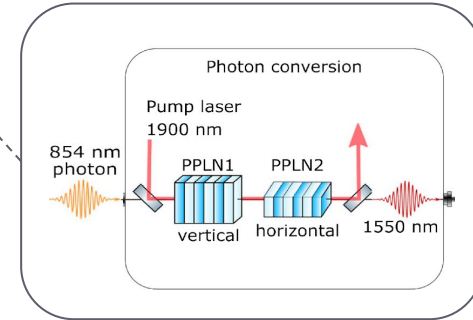


Repeater-friendly
**Ion Trap
Quantum
Computing
Node**

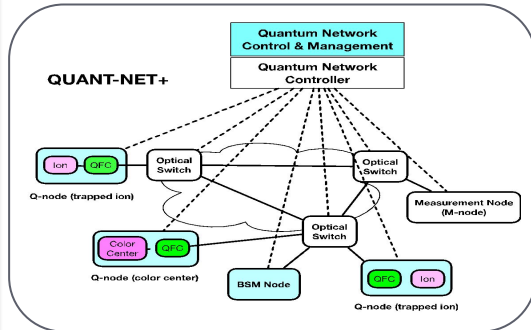
Native telecom
photon source
and Quantum
memories using
**Silicon Color
Centers**



Efficient
**Quantum
Frequency
Conversion
Technologies**



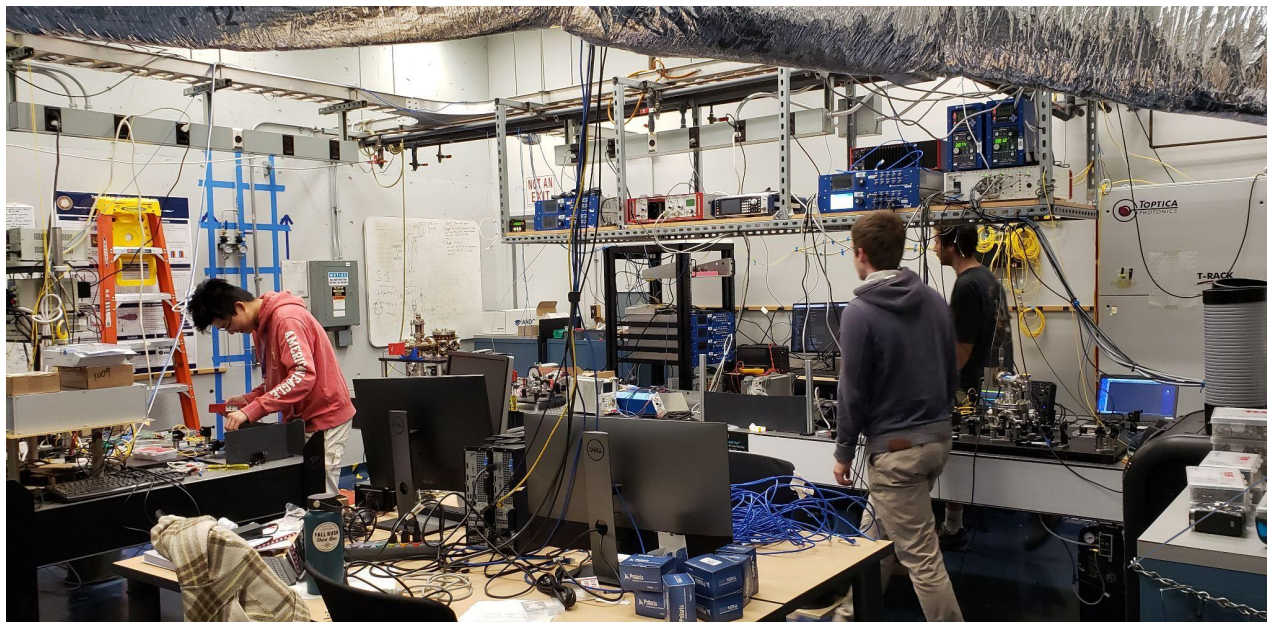
Scalable
Quantum
Network
**architecture,
control and
management
plane**



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



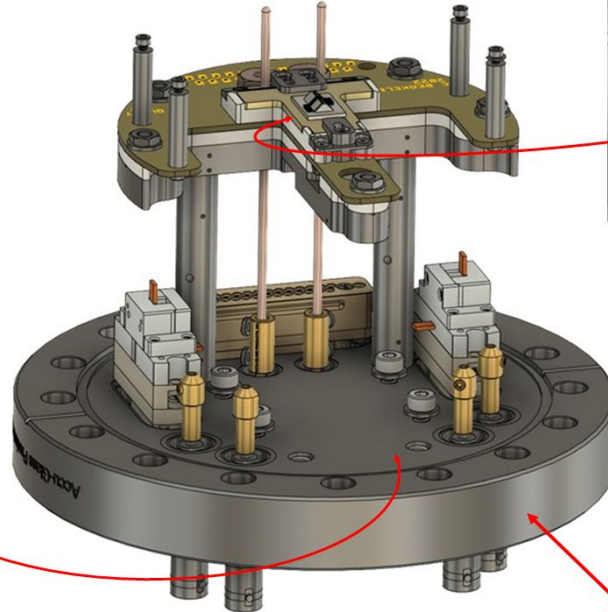
High Performance
Laminar Flow
Isolator



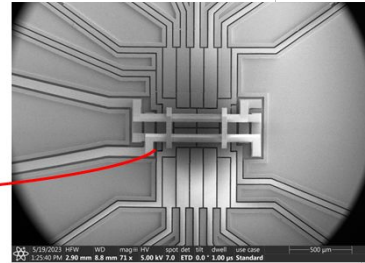
- 10+ lasers for ion trapping/cooling, qubit manipulation, and Q-networking experiments
- Ultra stable reference cavities + high bandwidth locking electronics
- Ion-trap apparatus and 2x Artiq based control systems
- Fiber-based and free-space BSM and detection system with SNPDs (x5)

Ion-trap Q-node design and construction

Cavity assembly

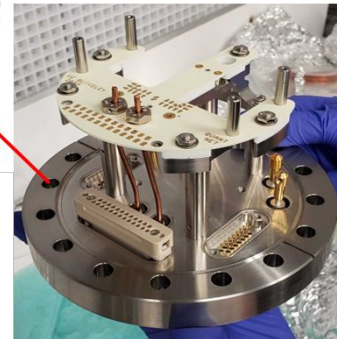


In-vacuum assembly



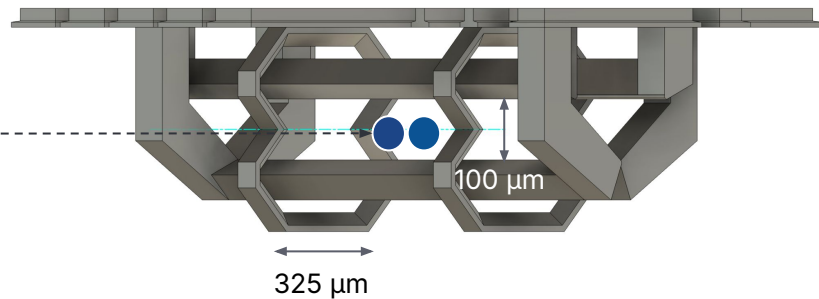
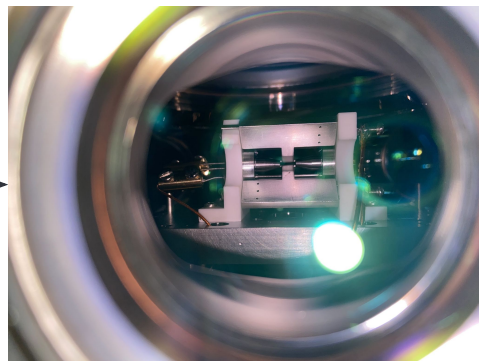
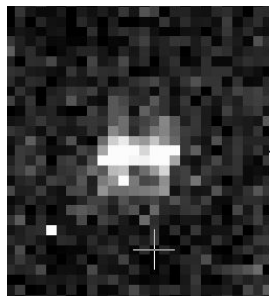
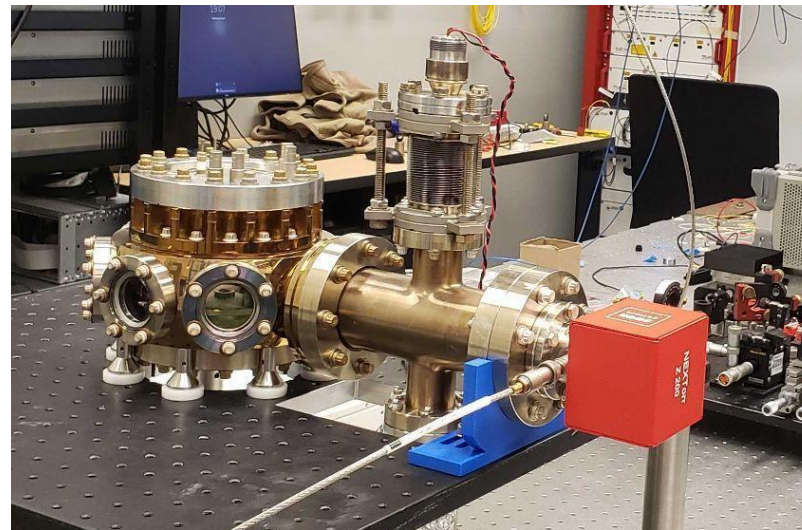
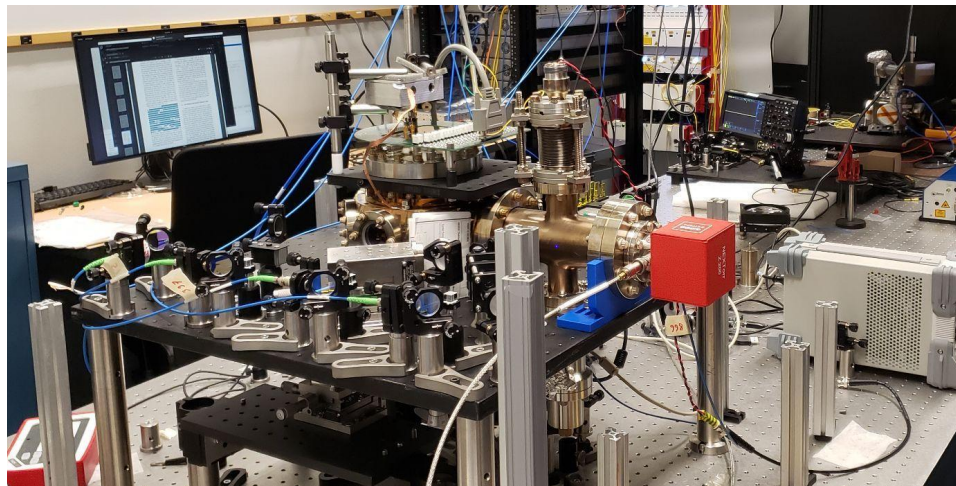
Fabricated 3D trap

Electrical connections

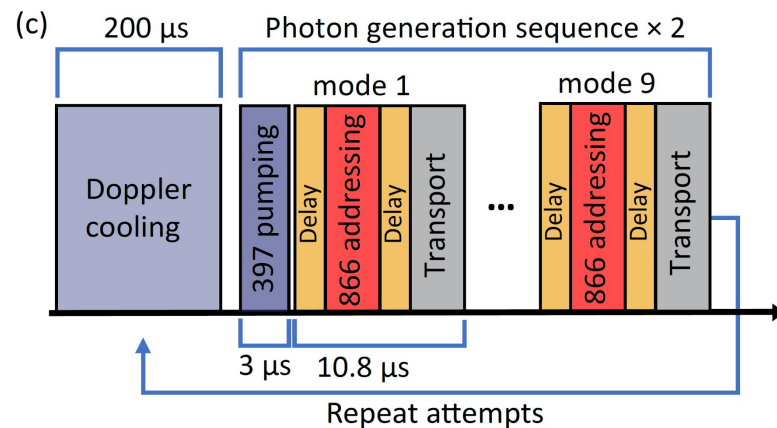
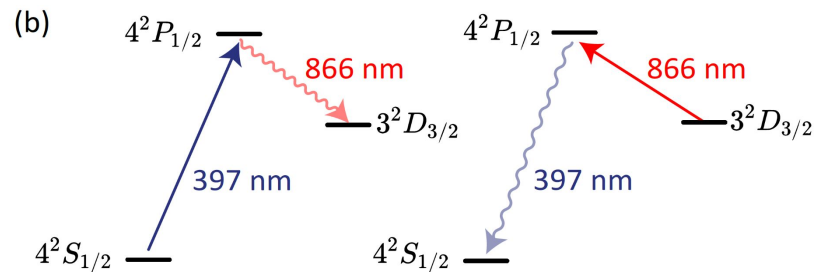
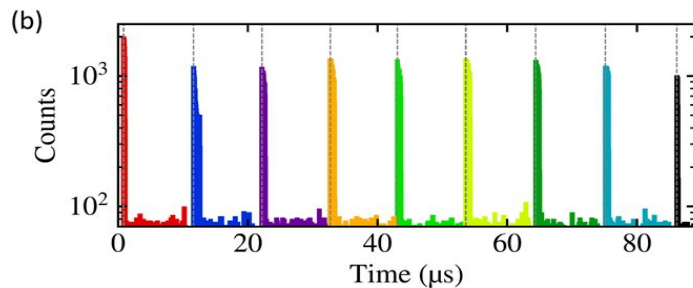
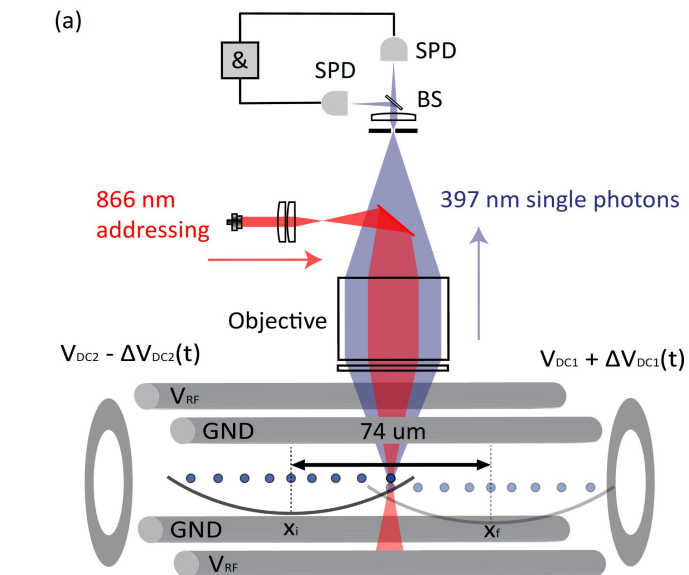


Pioneering implementation of a ion-cavity
3-D microfabricated technology

Ion-trapping with 3D micro-trap

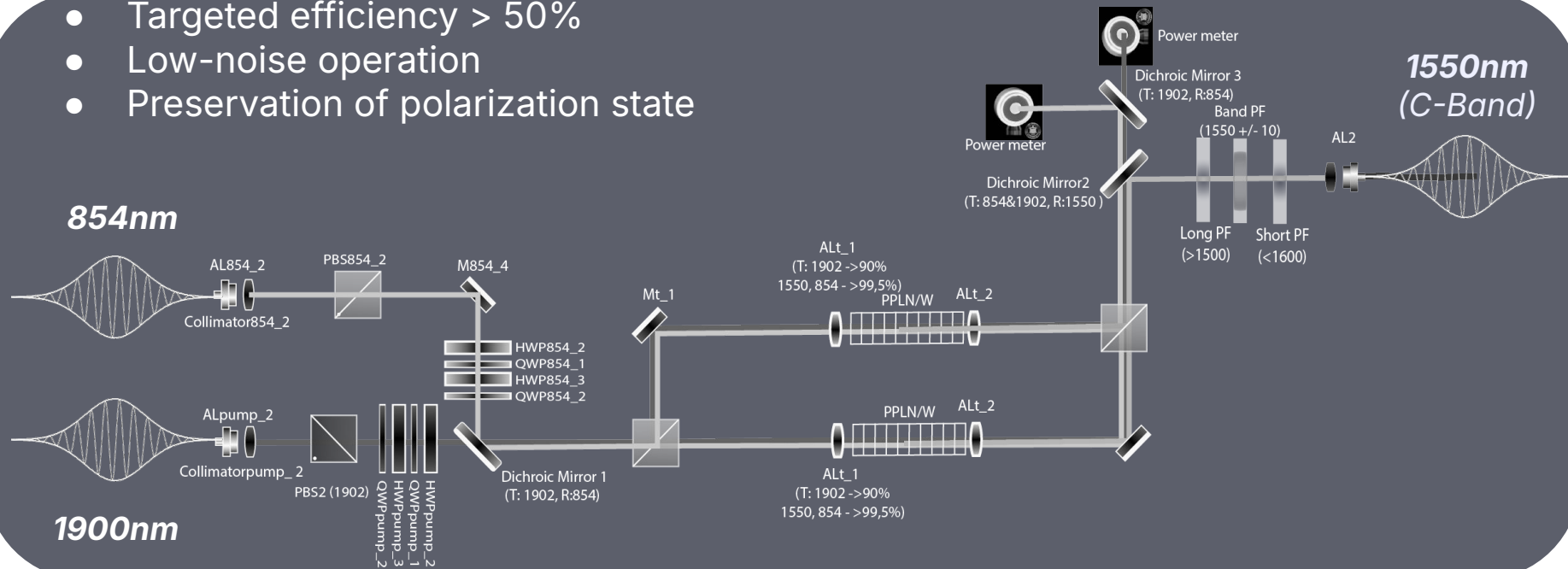


Multiplexed ion-photon interface to increase rate of entanglement

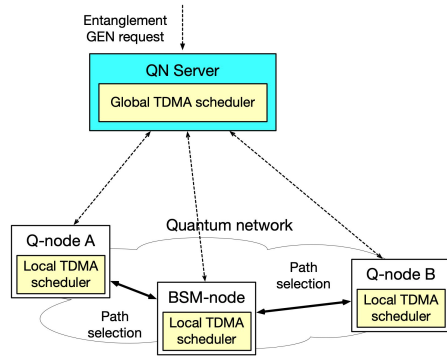


Efficient conversion to telecom frequency

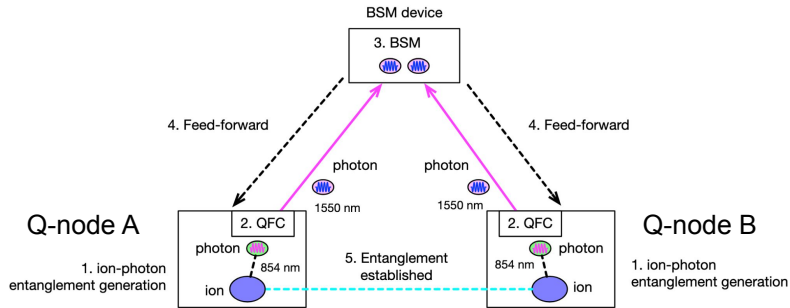
- 854 nm \rightarrow 1550 nm conversion
- Targeted efficiency > 50%
- Low-noise operation
- Preservation of polarization state



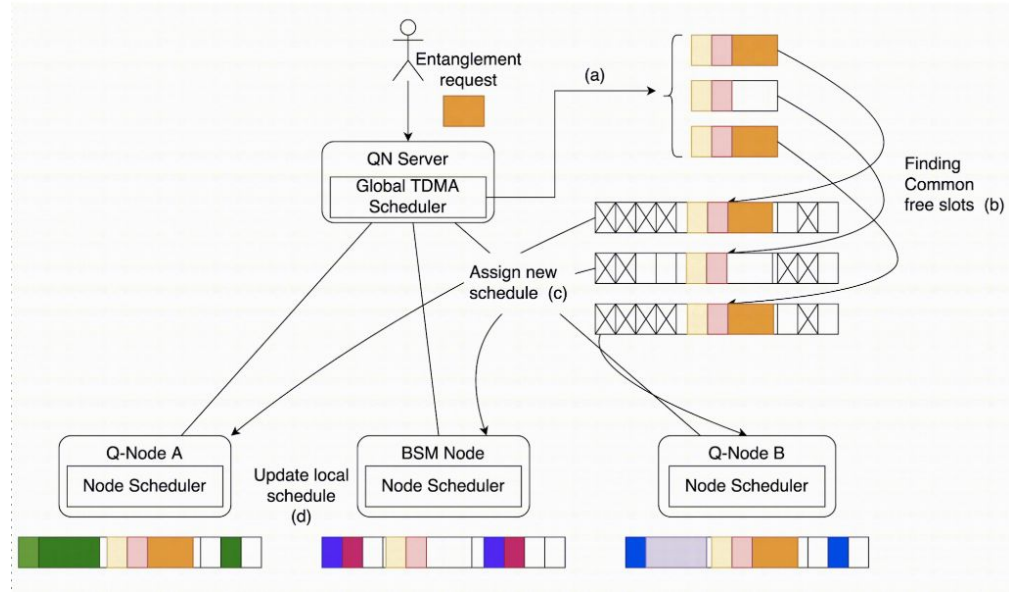
Two-level control framework - support synchronized operations



1. Quantum network topology

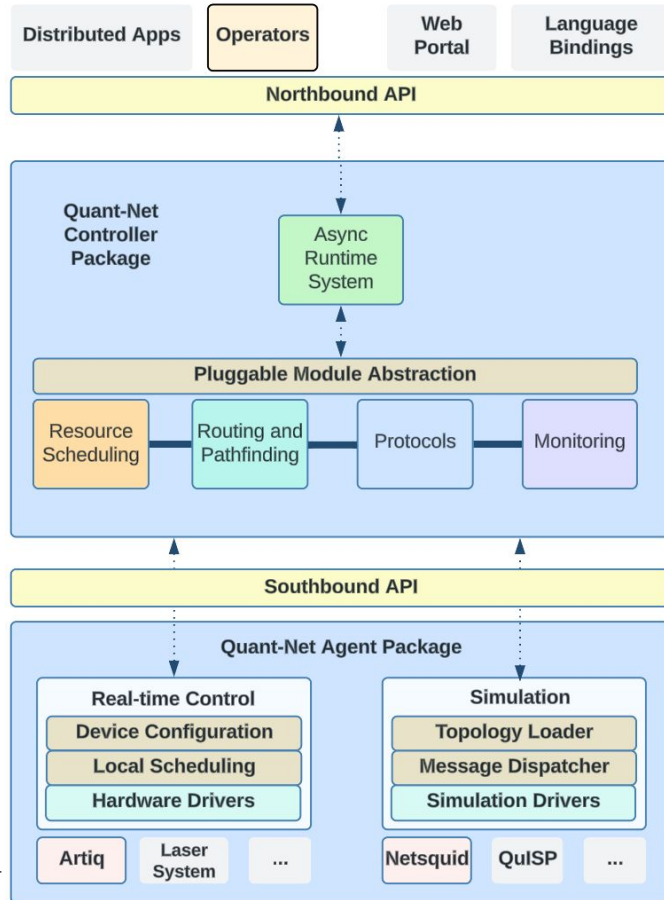


2. Remote ion-ion entanglement generation process



3. How the control framework supports such a process

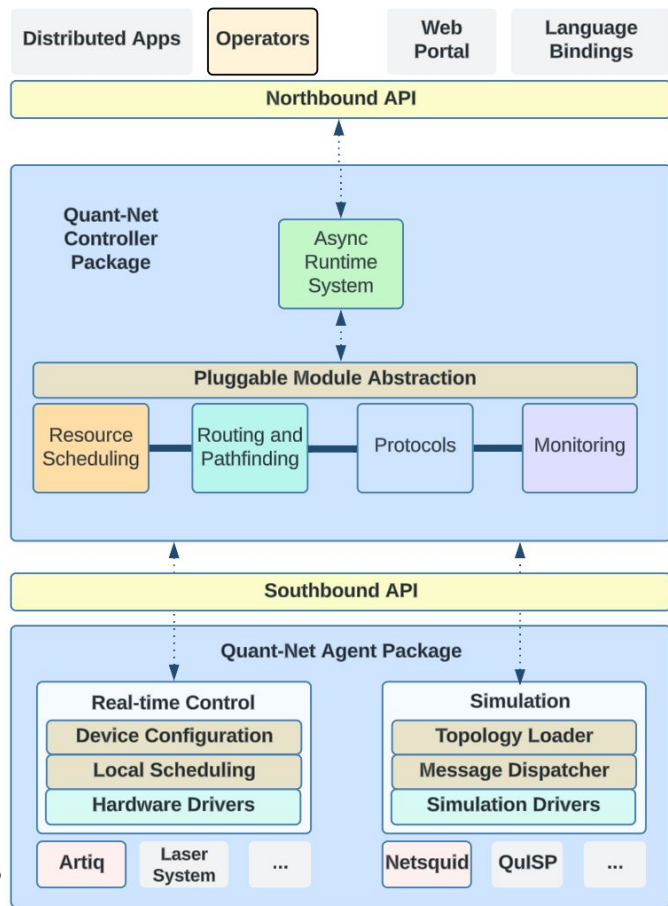
Two-level control framework - an open plug-in design (1/2)



- 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

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



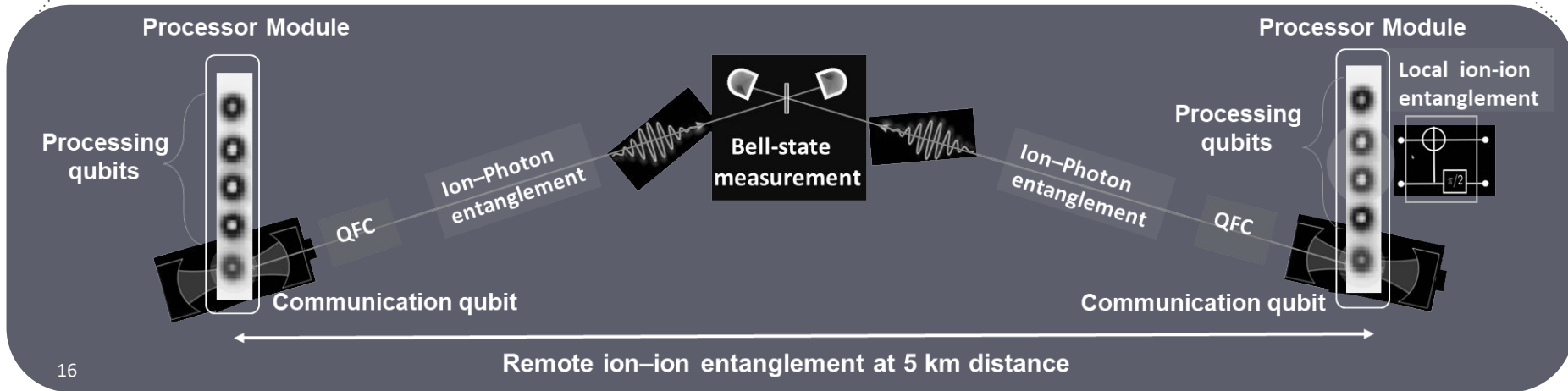
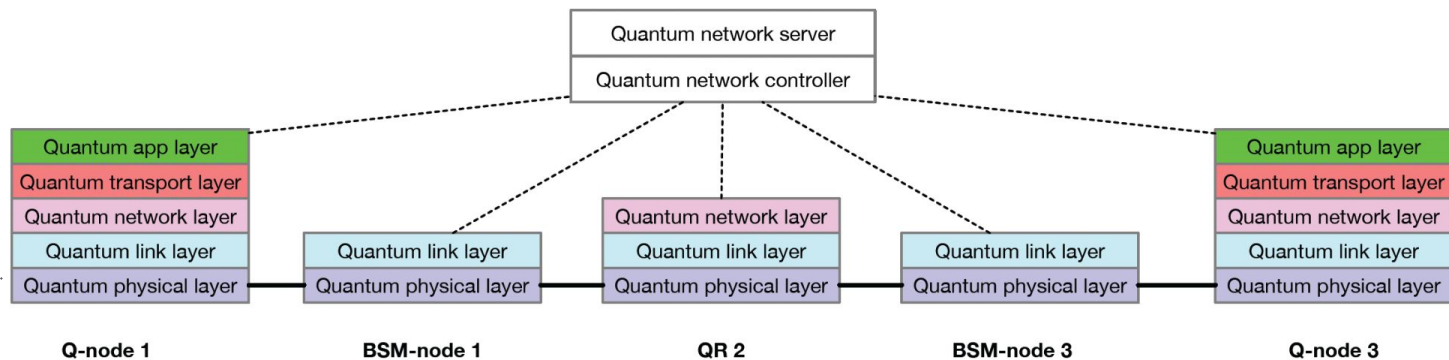
Service/protocol interface and protocol plugin support (Northbound)

- 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

Bringing all the layers together

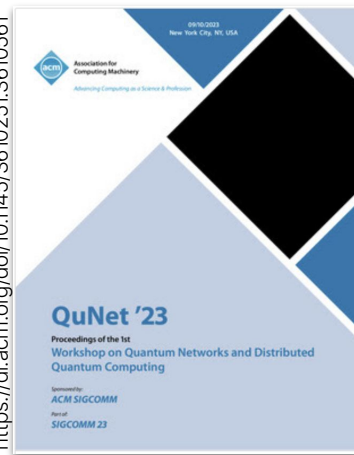


Learn more about QUANT-NET



quantnet.lbl.gov

https://dl.acm.org/doi/10.1145/3610251.3610561



QUANT-NET: A testbed for quantum networking research over deployed fiber

Authors: Inder Monga, Erhan Saglamyurek, Ezra Kissel, Hartmut Häffner, Wenji Wu [Authors Info & Claims](#)

QuNet '23: Proceedings of the 1st Workshop on Quantum Networks and Distributed Quantum Computing • September 2023 • Pages 31–37 • <https://doi.org/10.1145/3610251.3610561>

on History

Check for updates



quantum network research testbed funded by the U.S. Department of
establish this network between two sites, Lawrence Berkeley National
California, Berkeley, connected with an entanglement swapping
nd managed by a quantum network protocol stack. On top of this
strate the research team will implement the most basic building blocks
outing and quantum repeater by teleporting a controlled-NOT gate
quantum computation nodes. This paper presents QUANT-NET, its

QUANT-NET Leadership



**Inder
Monga**
Berkeley Lab
(PI)



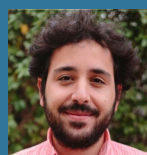
**Hartmut
Häffner**
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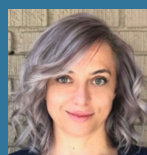
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