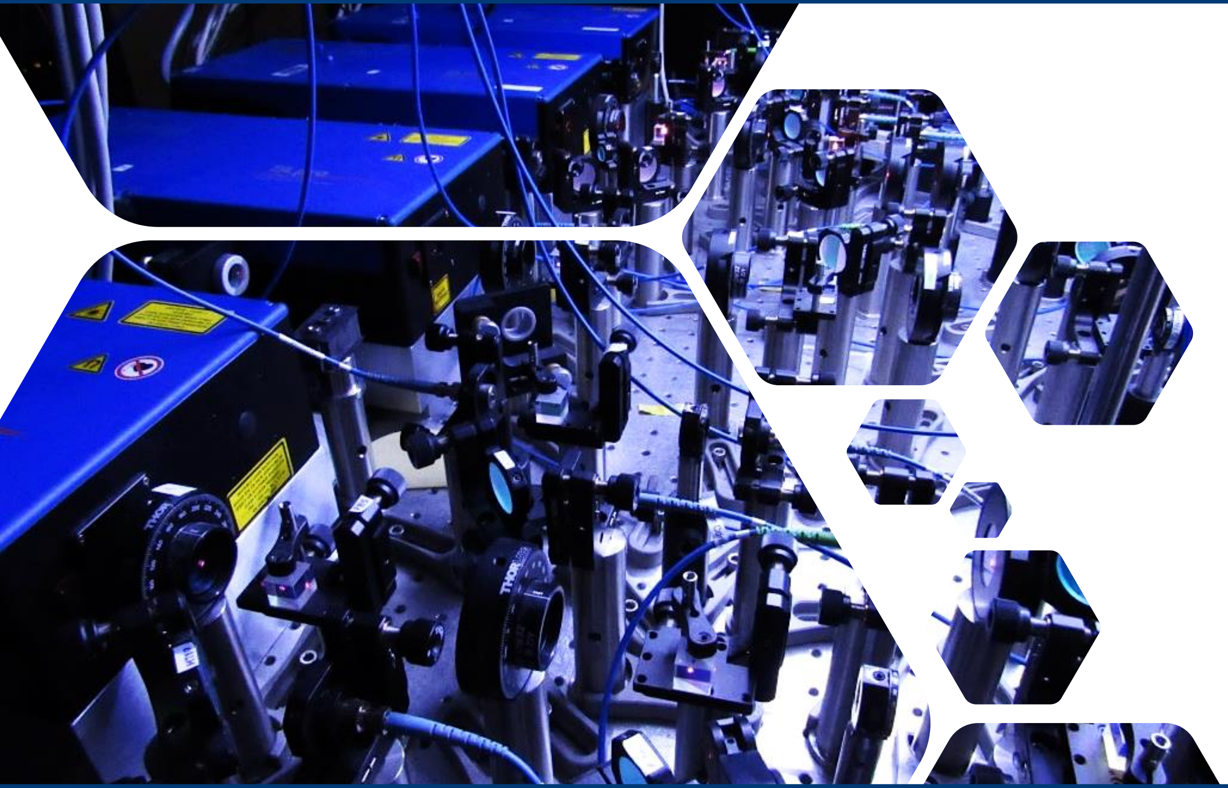


Practical Quantum Networking at Room Temperature

Qunnect Inc.

Enabling The Quantum Internet

www.qunnect.inc

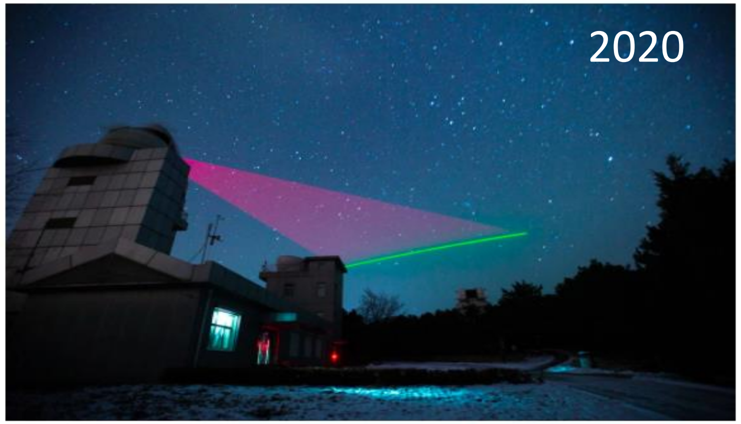
Mehdi Namazi

Co-founder and CSO

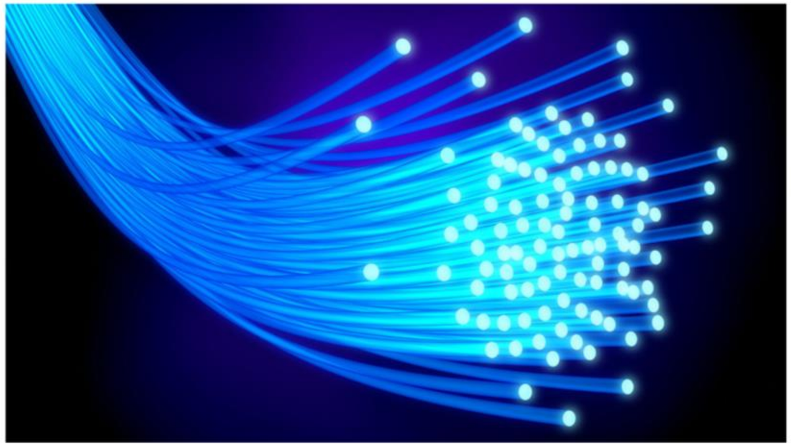
The Global Effort

China Reports Progress in Ultra-Secure Satellite Transmission

Researchers enlisted quantum physics to send a "secret key" for encrypting and decrypting messages between two stations 700 miles apart.



A quantum communication ground station in Xinglong, in northern China, in 2016, communicating with the quantum satellite Micius, the world's first. Jin Liwang/Xinhua, via Alamy Live News



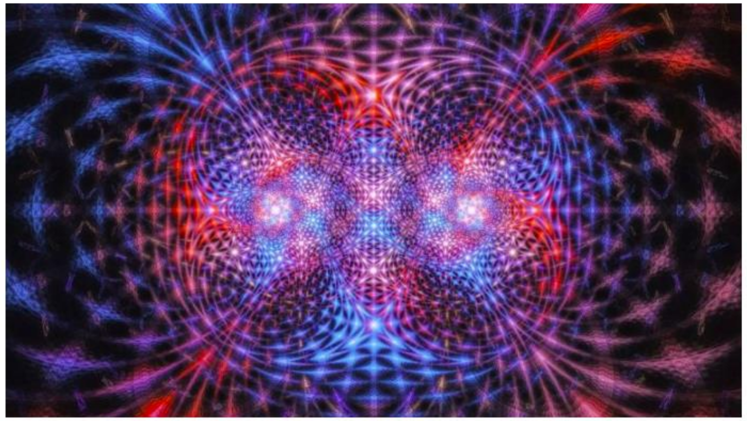
Physicists used a special technique to help photons travel further down standard optical fibers. HENRIK500/ISTOCK

Quantum internet closer as physicists stretch spooky link between atoms

U.S. Department of Energy Unveils Blueprint for Quantum Internet

TOPICS: Brookhaven National Laboratory DOE Quantum Information Science University Of Chicago

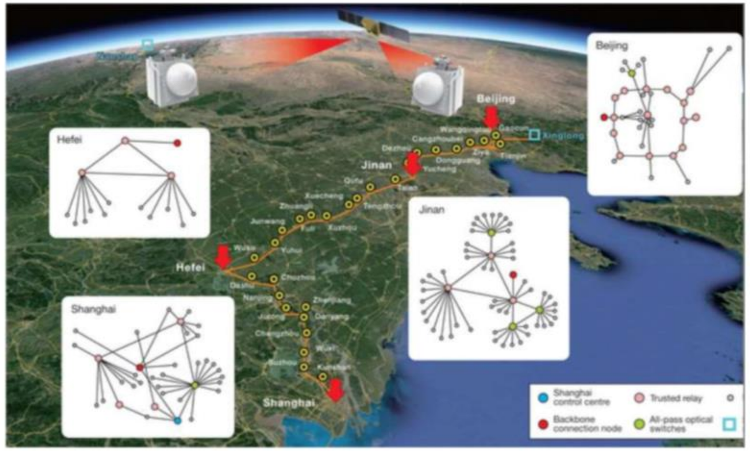
By BROOKHAVEN NATIONAL LABORATORY AUGUST 1, 2020



Nationwide effort to build quantum networks and usher in new era of communications. Credit: Image by UChicago

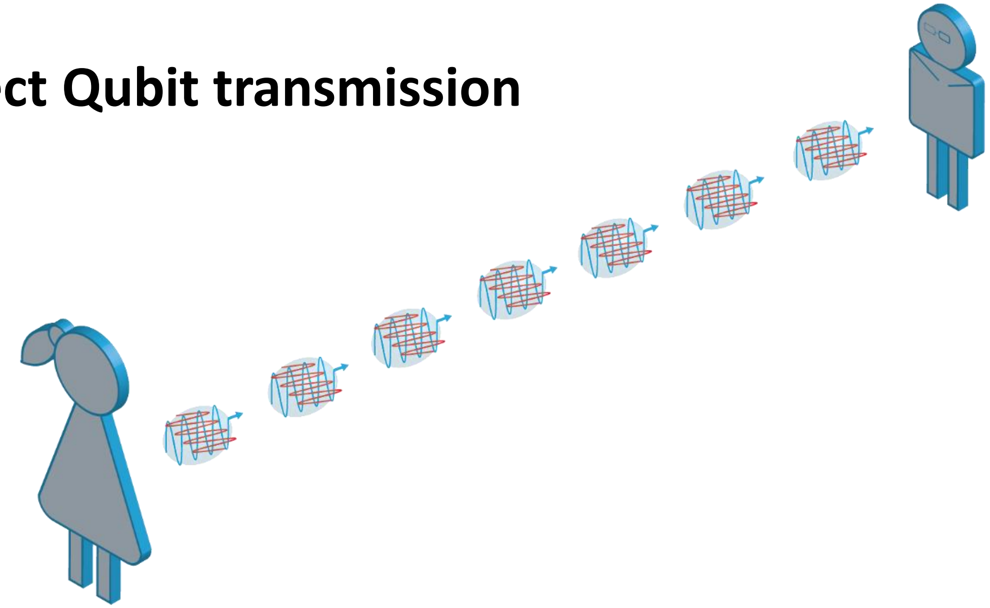
The world's first integrated quantum communication network

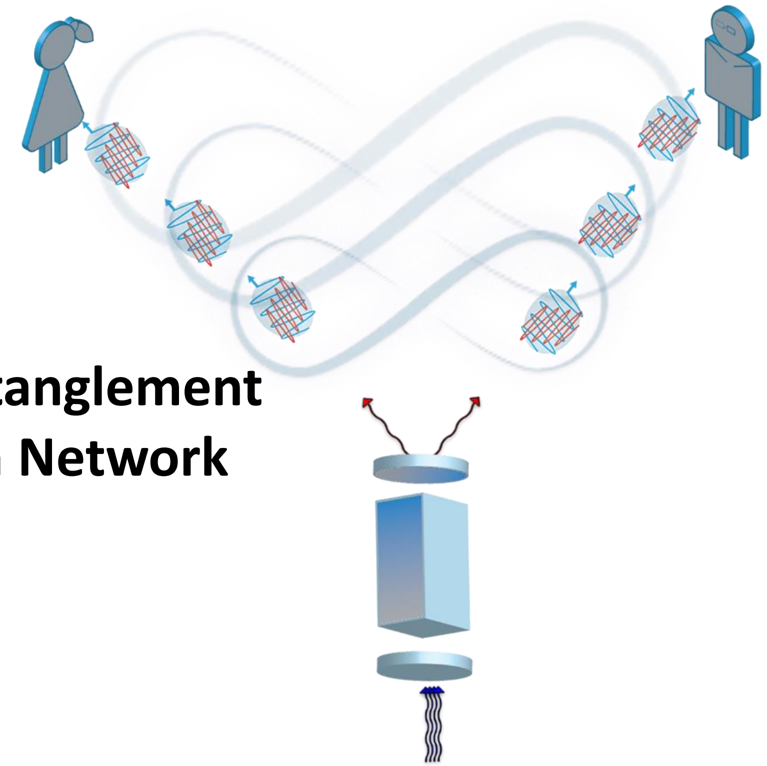
by University of Science and Technology of China



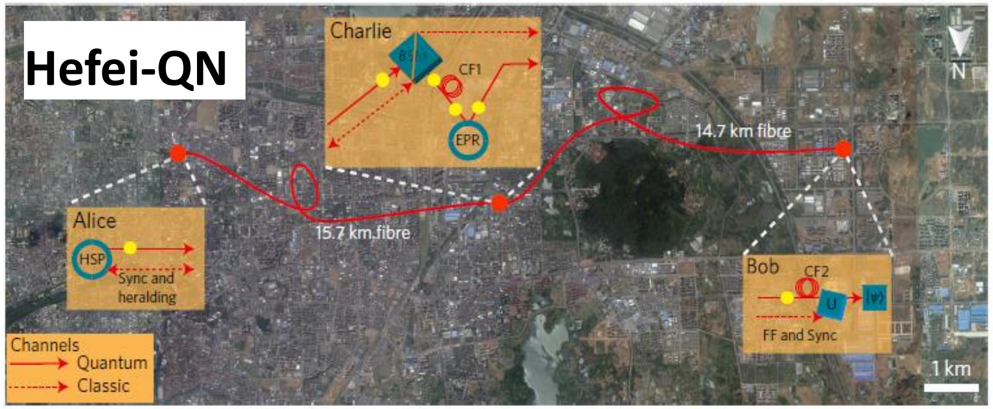
Q-Network Evolution

Direct Qubit transmission





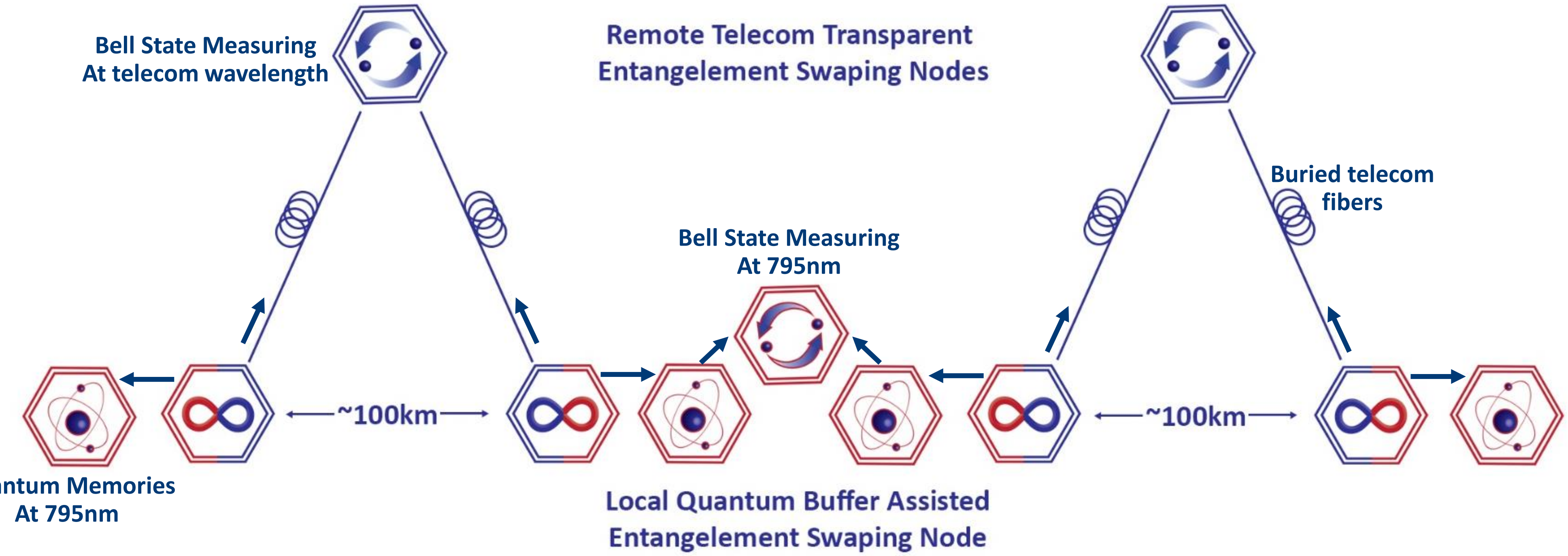
Quantum Entanglement Distribution Network



Distributing Entanglement

Our Technology Roadmap

Qunnect is aiming to develop “Bichromatic Buffered Quantum Repeaters”:



Critical advantages:

-Entanglement distribution rate increase due to the buffering capability of quantum memories

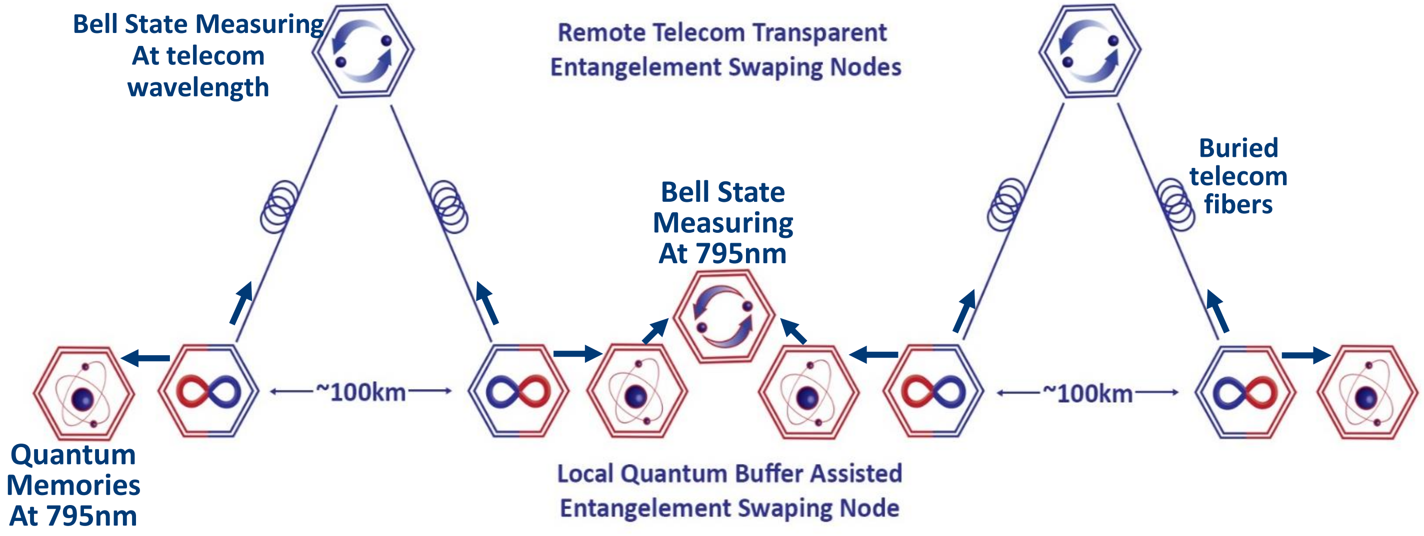
-Optically transparent on the fiber lines, allowing for hybrid classical-quantum networks

-Minimal need for heralding elements and No need for frequency conversion

-Fully scalable through multiplexing, all devices operate at room temperature and are cost efficient

Proprietary

Our Technology Roadmap



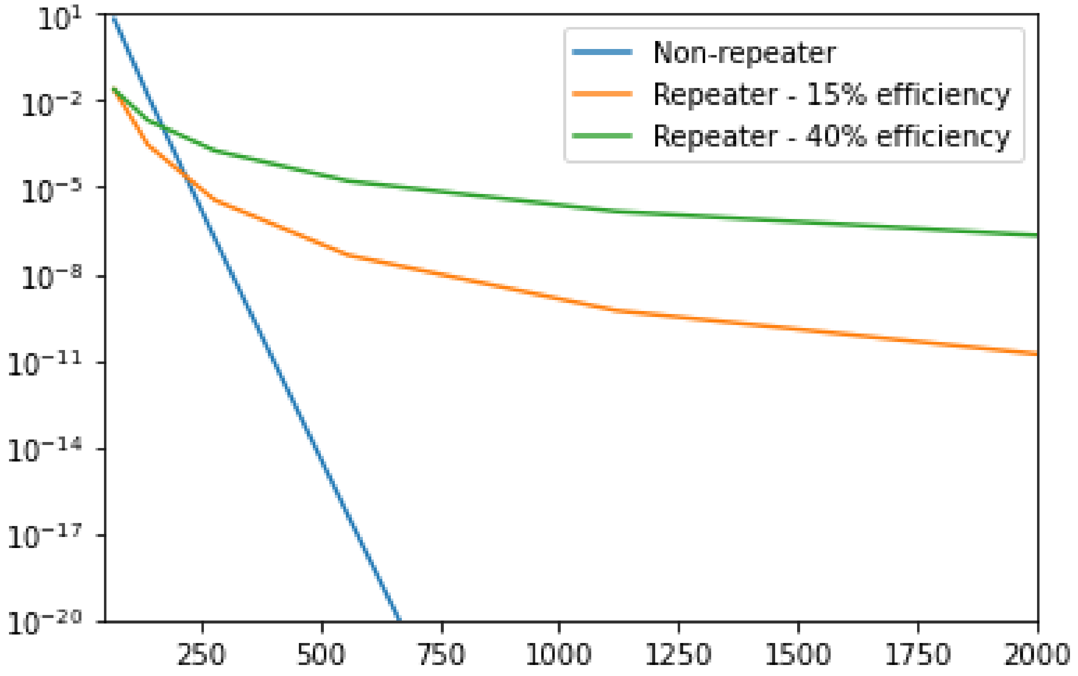
$$T_e = \bar{n}_L T_0 + \sum_{l=1}^{L} \frac{\bar{n}_L}{\bar{n}_{l-1}} 2^{l-1} T_0 = n_L T_0 \left[1 + \sum_{l=1}^{L} \frac{2^{l-1}}{\bar{n}_{l-1}} \right]$$

$$\bar{n}_l = \bar{n}_{l-1} \frac{3 - 2P_{es}}{(2 - P_{es})P_{es}} \quad P_0 = p_{pair}^2 10^{-2L_0/\alpha} QE^2$$

$$T_0 = \frac{L_0}{1/3c}$$

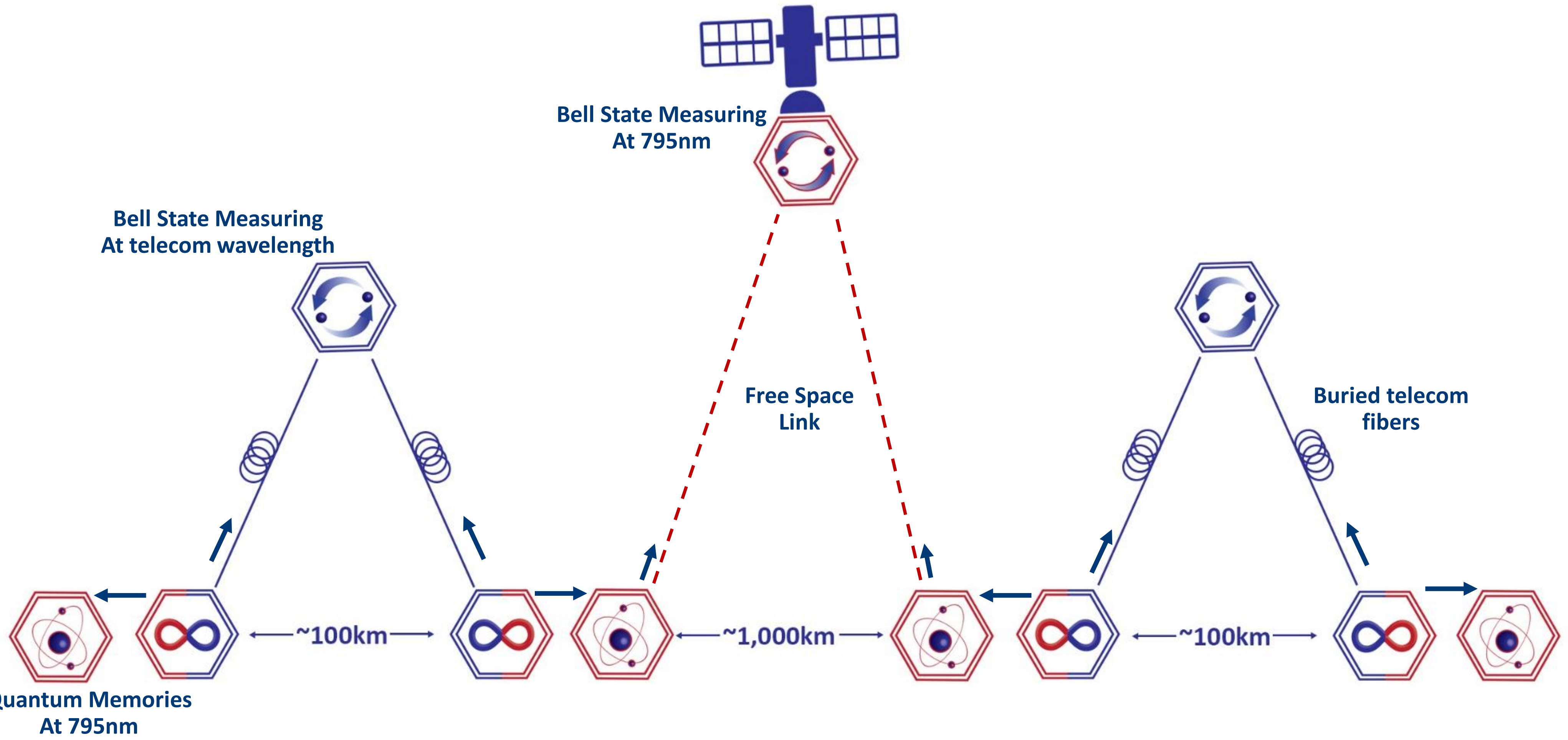
$$P_{es} = \eta_{mem}^2 QE_{atomic}^2$$

For an elementary repeater scheme with:
Fiber length of 35km
Source pair production probability of 0.05
Fiber attenuation of 0.3 dB/km
Detector efficiency of ~0.85
->Without Multiplexing<-



Future Hybrid Networks

As a long-term vision, the proposed quantum repeater protocol can be extended to ultra-long-distance fiber based and satellite-based quantum networks



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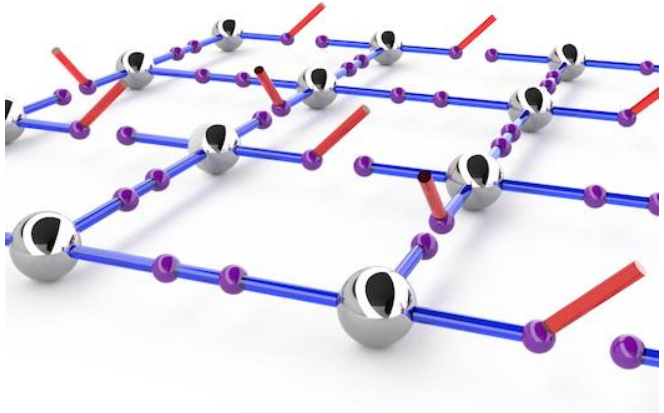
Q Network Key Challenges

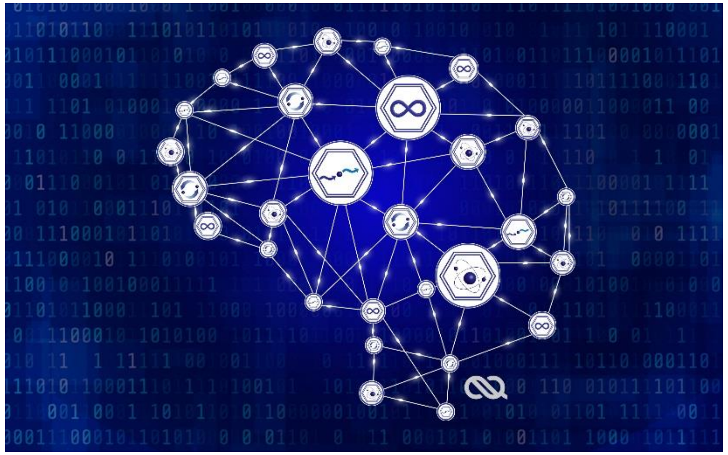
To realize field deployable quantum networks, we must first answer these questions:

How to build robust Q devices, reliable for years?



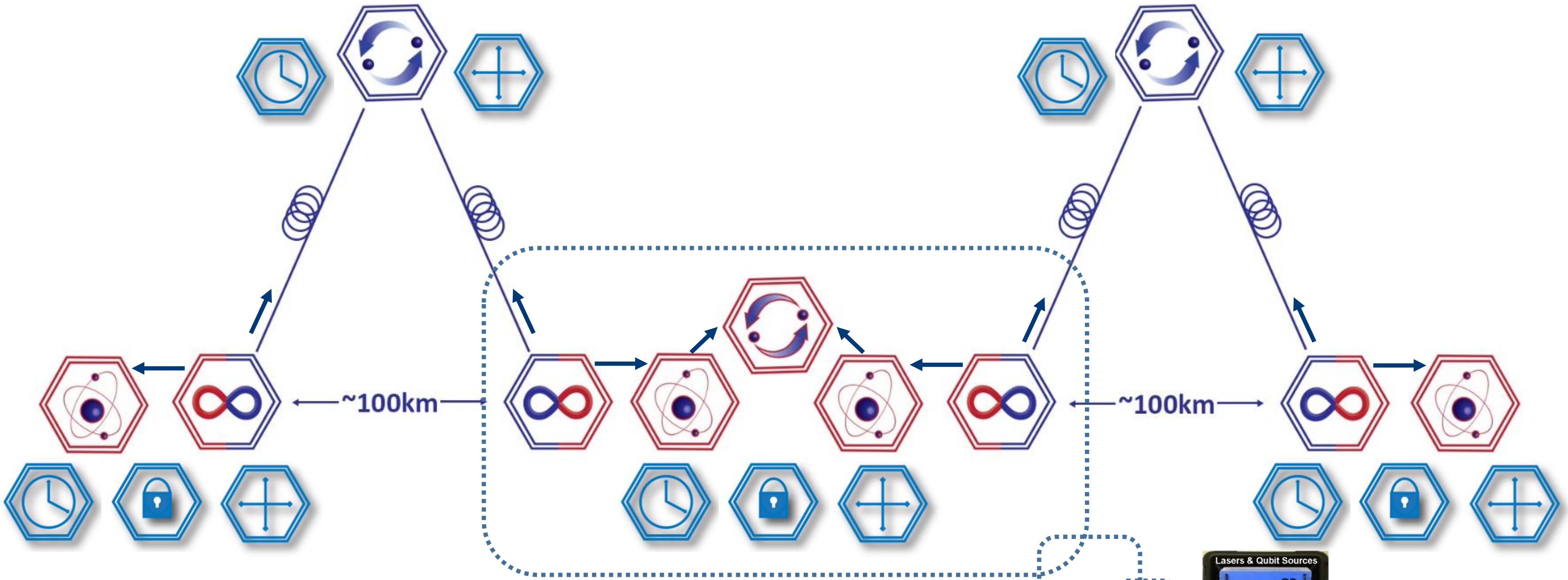
How to build compatible Q devices for different tasks in a Q network?

How to make telecom network quantum friendly?



How to develop the protocols for classical-quantum interfaces and network control?

Quantum Support Hardware



Qu-Lock: Multi-Laser Lock Box

Qu-Sync: <ns Time Synchronization

Qu-APC: Automated Polarization Compensation

Qunnect's Qu-Rack modules for telecom fiber hubs

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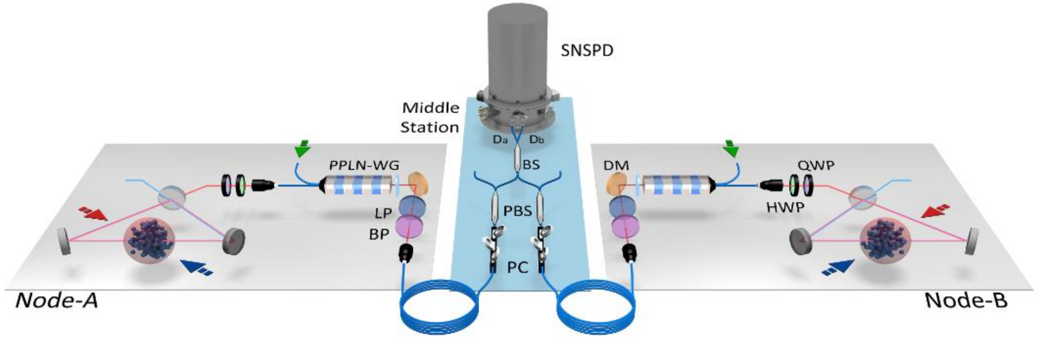
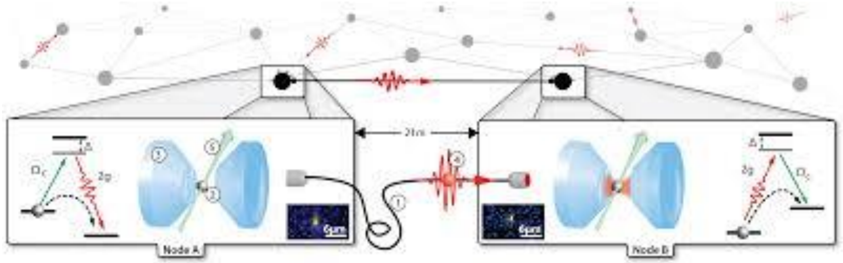
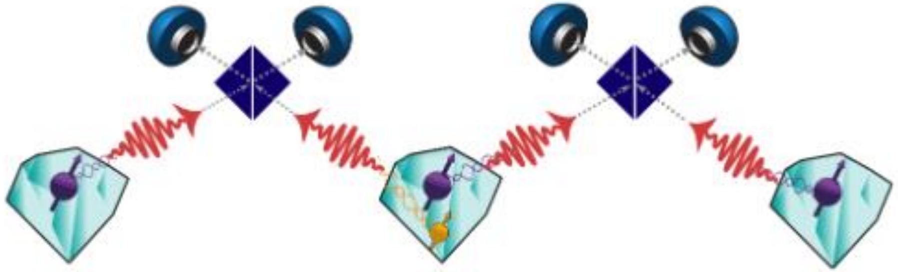
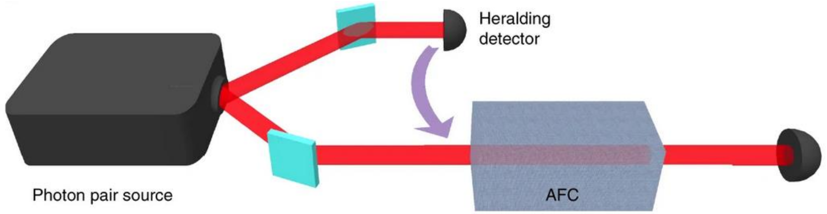
Qu. Light-Matter Interfaces



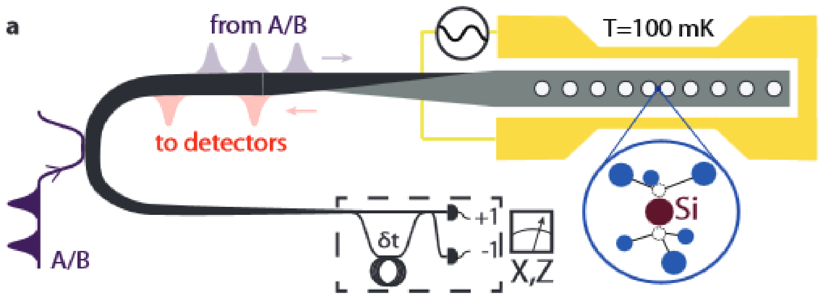
(Atomic ensembles: USTC China, Barcelona, Caltech)


(Single-atoms: MPQ, Munich)

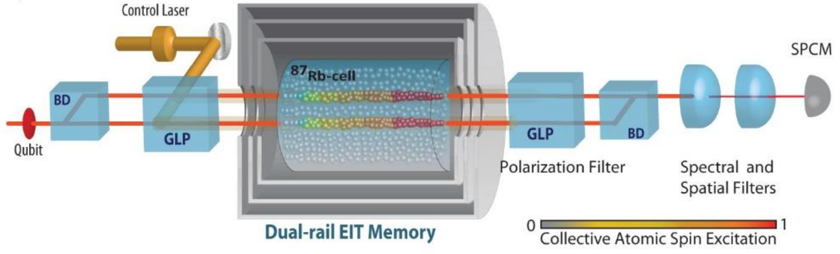

(NV Diamond centers: TU Delft, Chicago/Argonne)



(Rare-earth doped crystals: MPQ, Caltech)

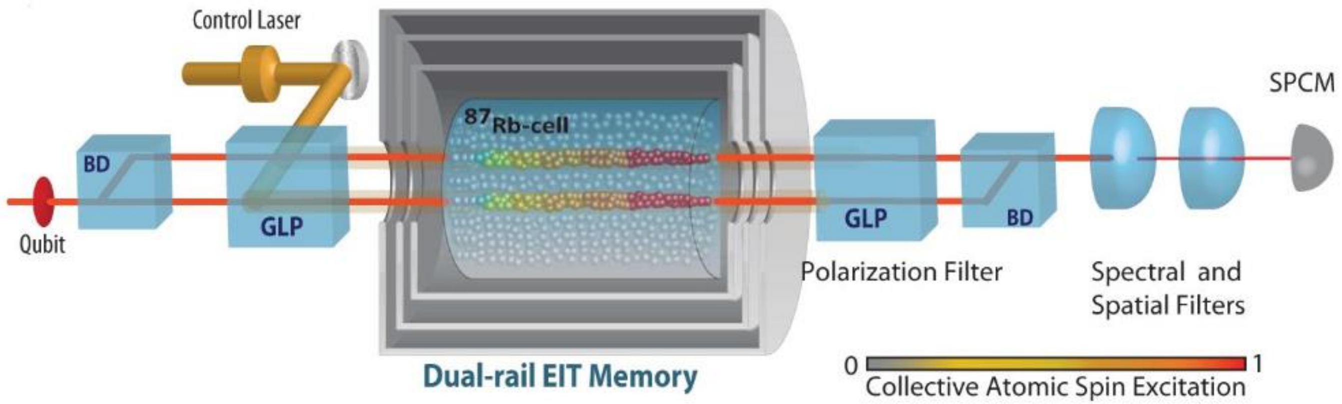


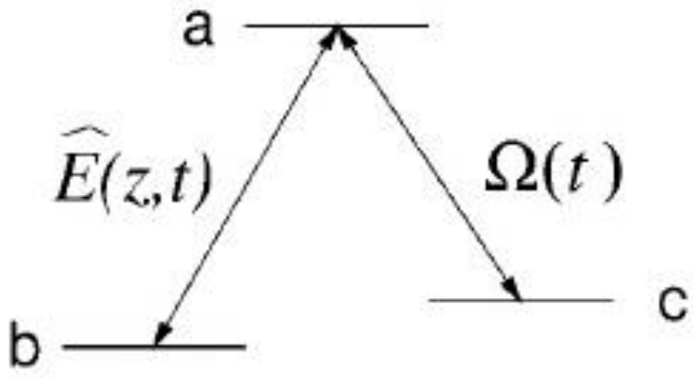
(SiV centers: MIT, Harvard, USA)

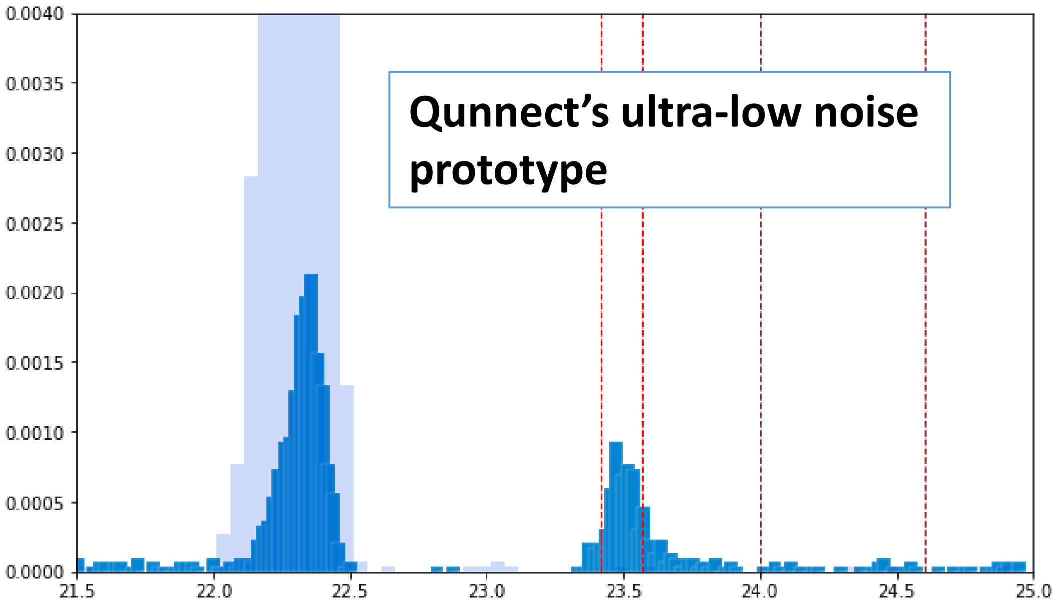


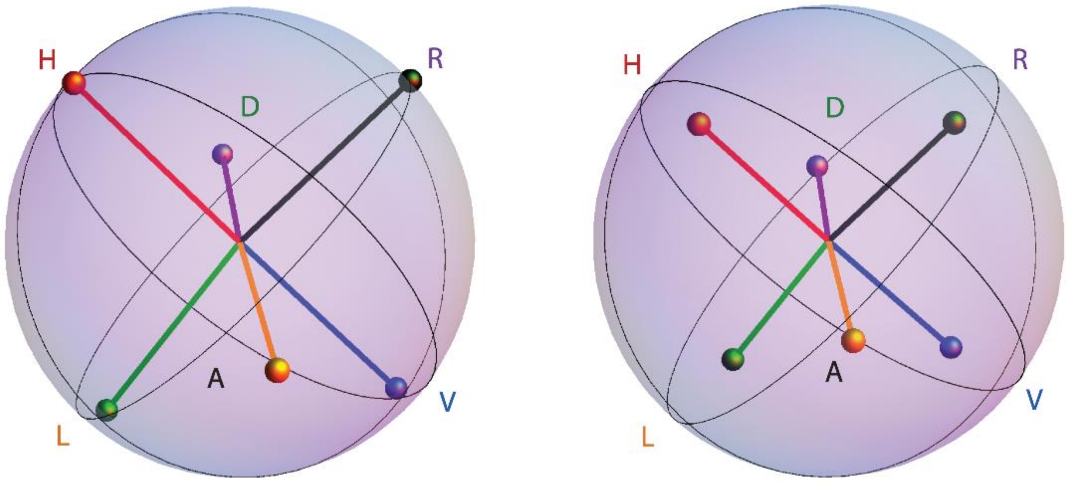
(Room temperature ensembles: SBU, Oxford)

EIT-based RT Q Memory







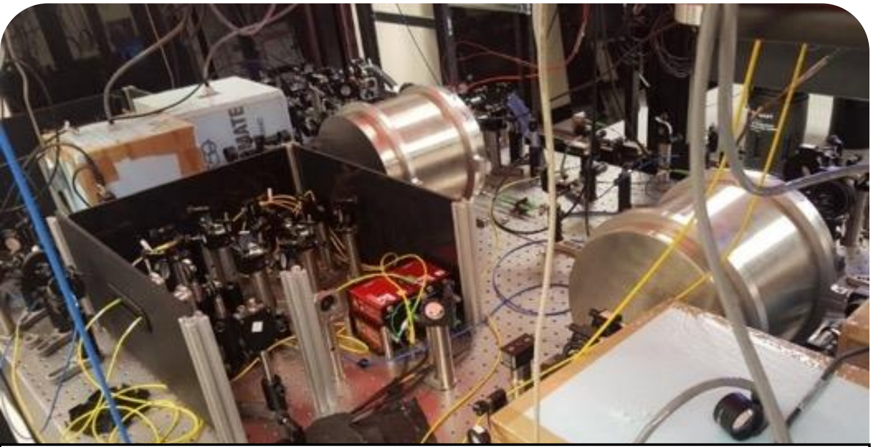


Input polarization states

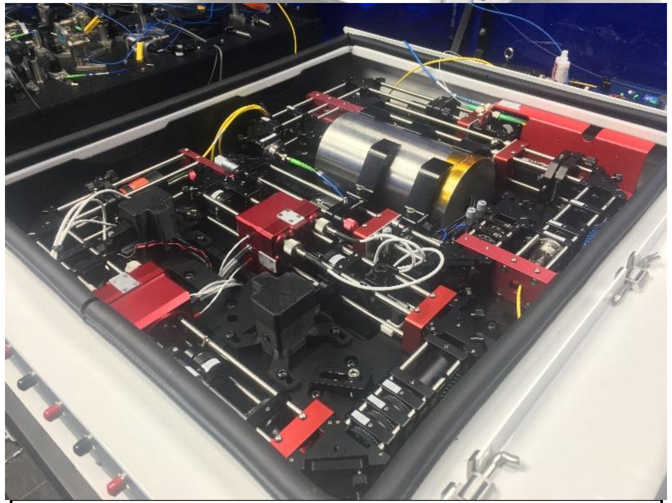
Stored polarization states

Phys. Rev. Applied 8, 034023 (2017). Scientific Reports 5, 7658 (2015).

Field-Deployable Qu-Mem



2017: Two table-top quantum memories,
Stony Brook University QIT Lab
72”x48”



2020: Mark-Alpha
for research customers
26”x24”x8”

2020: Mark-Beta
for mid-scale qu. networks
22”x19”x3.5”

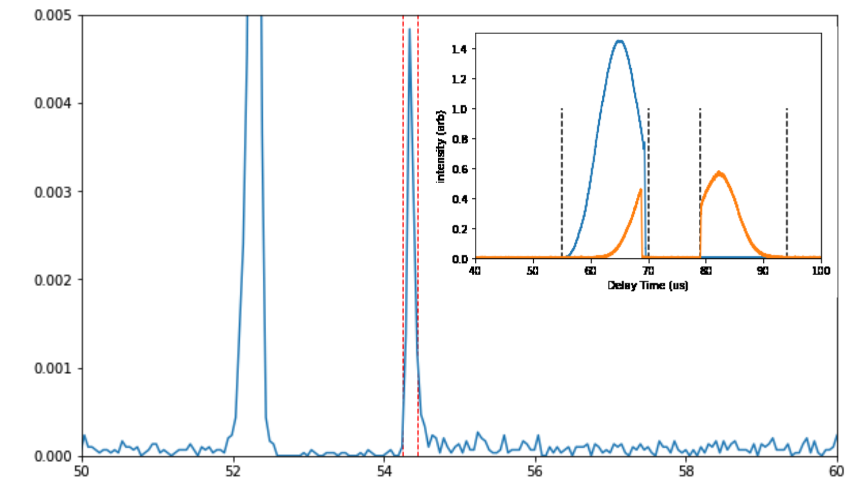
PCT/US19/24601, 05/2019, National Filings US, CA, EU, AU, SK, JP; PCT WO2019/191442, Priority date 9/11/2018

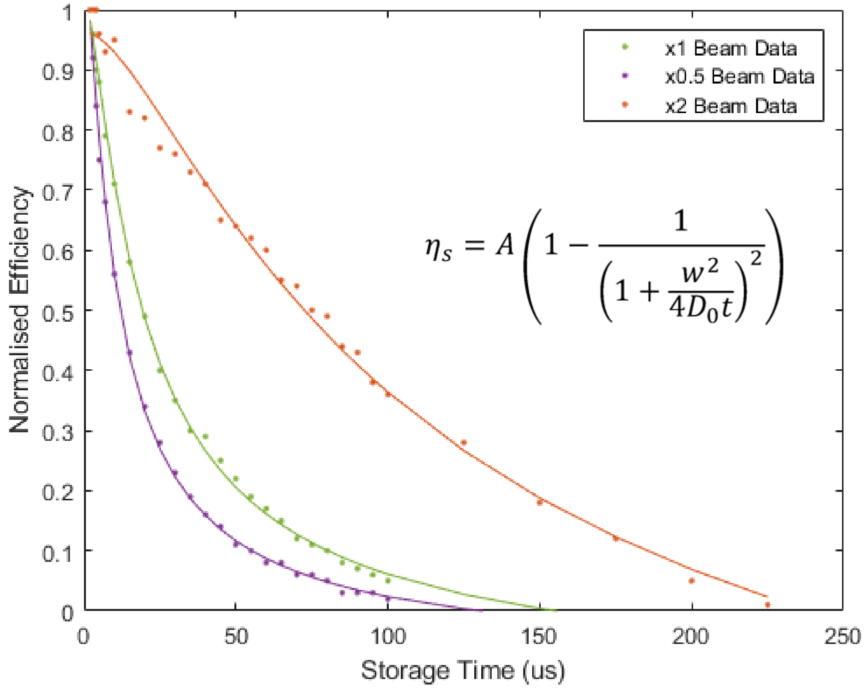
Proprietary

M.Beta Target Performance

Our team of physicists, engineers and firmware/ML experts work together not only to improve the quantum performance of our modules but also to engineer more robust systems and develop a support software suite for long-term usability of our quantum memories in the field

Mem Generation	Mark Alpha	Mark Beta	Mark1 (Q4,22)
Fidelity (SNR)	87% (2.9)	>95% (>15)	>98% (>25)
Storage eff	~5%	~5%	>40%
Transmission	~5%	>30%	>40%
Coherence time	40us	>100us	>500us
Stability	>10hrs	>week	>month
Supp. Software	None	Auto temp adj	Auto optimizer





PCT/US19/24601, 05/2019, National Filings US, CA, EU, AU, SK, JP; PCT WO2019/191442, Priority date 9/11/2018

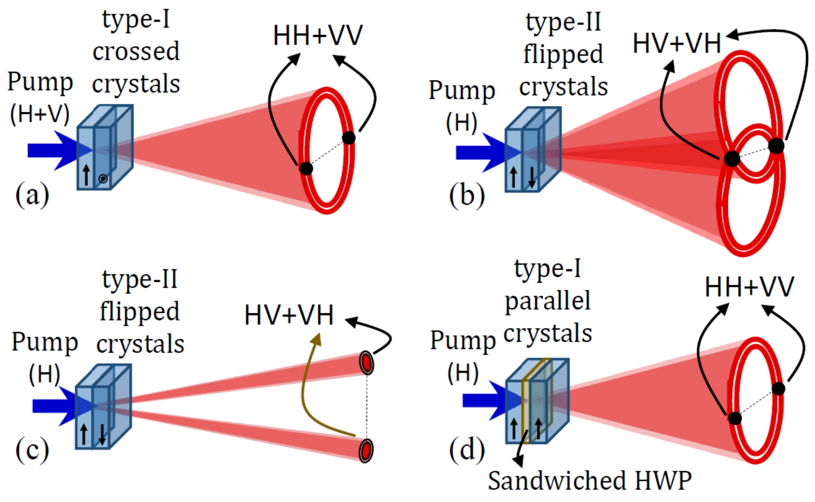
Proprietary

Commercial Ent. Sources

Most commercial ent. sources are based on the SPDC process in nonlinear crystals.

Typical performance parameters:
- ~100kHz photon pair generation rate
- ~10nm photon linewidths (~2-10THz)
-Single wavelength operation

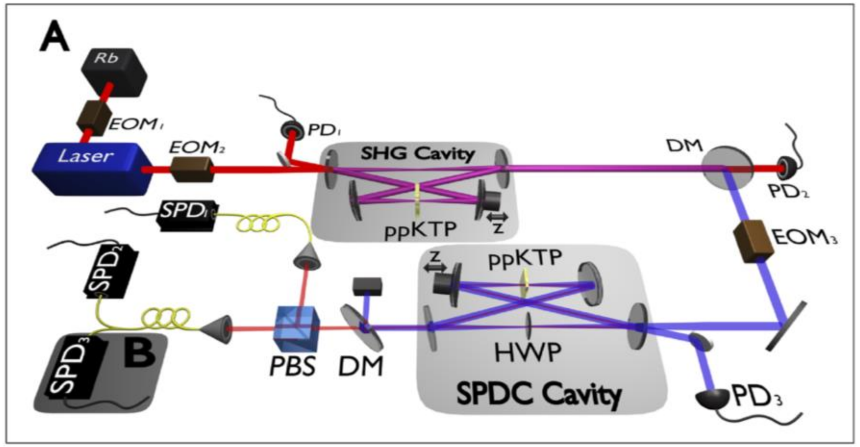
Pain points: Very broadband, single wavelength



One way to solve the linewidth issue is by using Cavity enhanced sources.

State of the art:
Linewidth ~1MHz
Rate ~5KHz
Efficiency ~20%

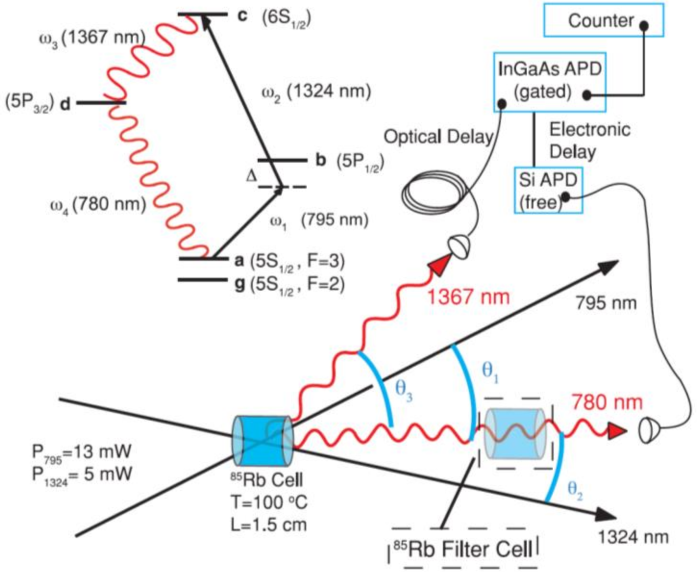
Pain points: Complex, Low rate, hard to scale



APL Photonics 1, 096101 (2016)

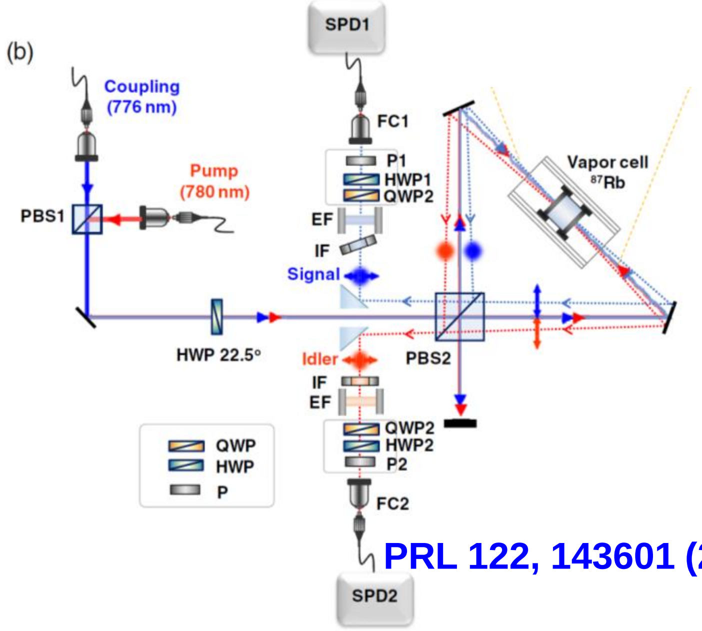
Light-Matter Sources

It is also possible to use Spontaneous Four Wave Mixing in atoms to create pairs of photons, on resonance with atomic transitions while the photon linewidth is significantly narrower than the SPDC sources



PRA 82, 053842 (2010)

SFWM in atomic systems can be used to create bicolor photons that are entangled in polarization space. The wavelength of the generated photons can be tuned by picking suitable atomic transitions

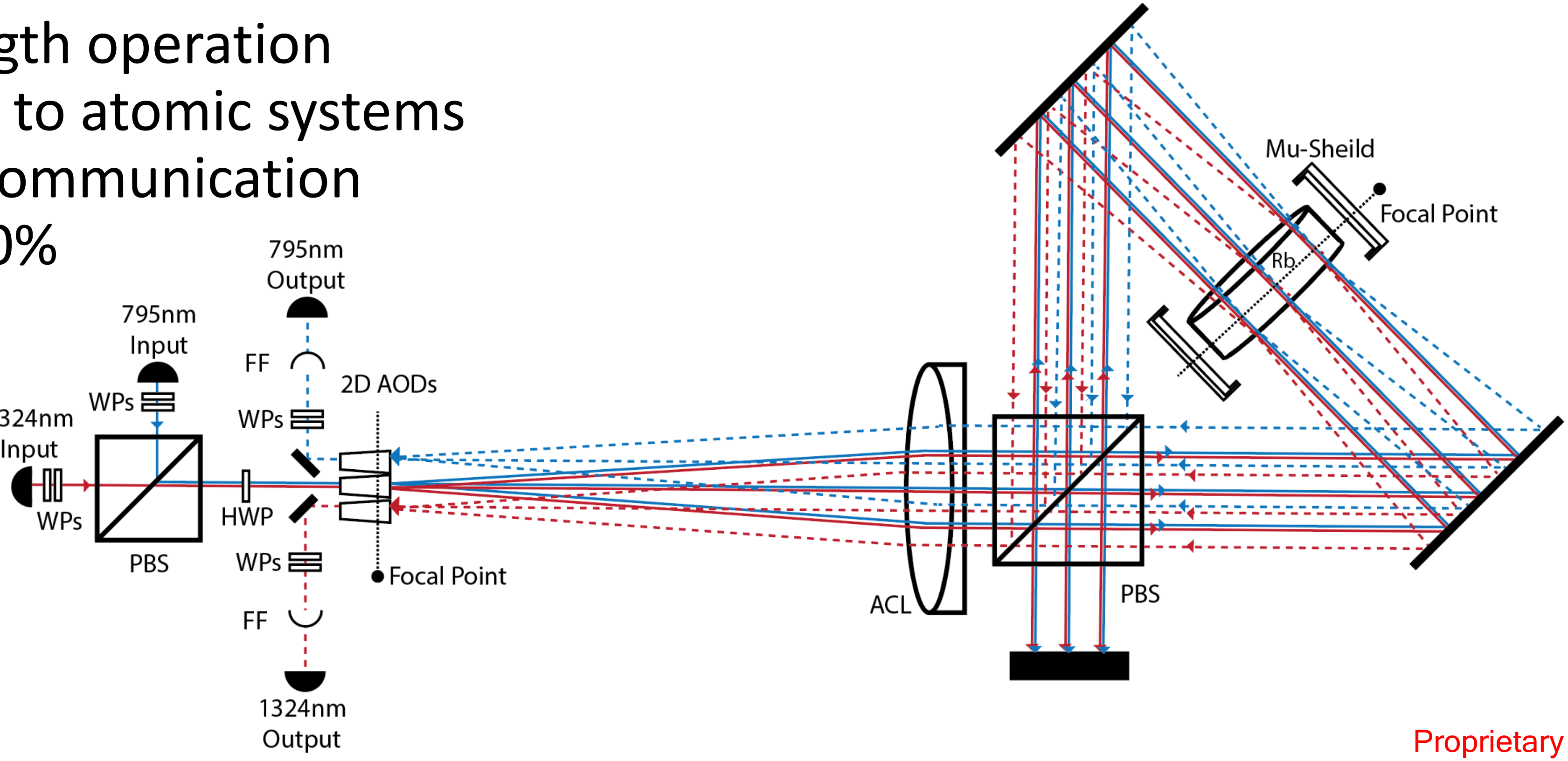


PRL 122, 143601 (2019)

Our approach: Hi-Waves

Qunnect is combining Sagnac interferometer with multiplexing to create bichromatic polarization entangled photons via atomic four wave mixing

Target performance parameters:
-100-1,000kHz photon pair generation rate
-Sub-100MHz photon linewidth
-1320nm and 795nm wavelength operation
-Maximum coupling efficiency to atomic systems
-Compatible with free-space communication
-Heralding efficiency of ~10-20%



Proprietary

Key Challenges

Qu-Memory:

- -Merging together a truly high performance memory with low loss
- -Assuring the long term (5yrs+) stability / Space ready design
- -Achieving the above two items together with multiplexing

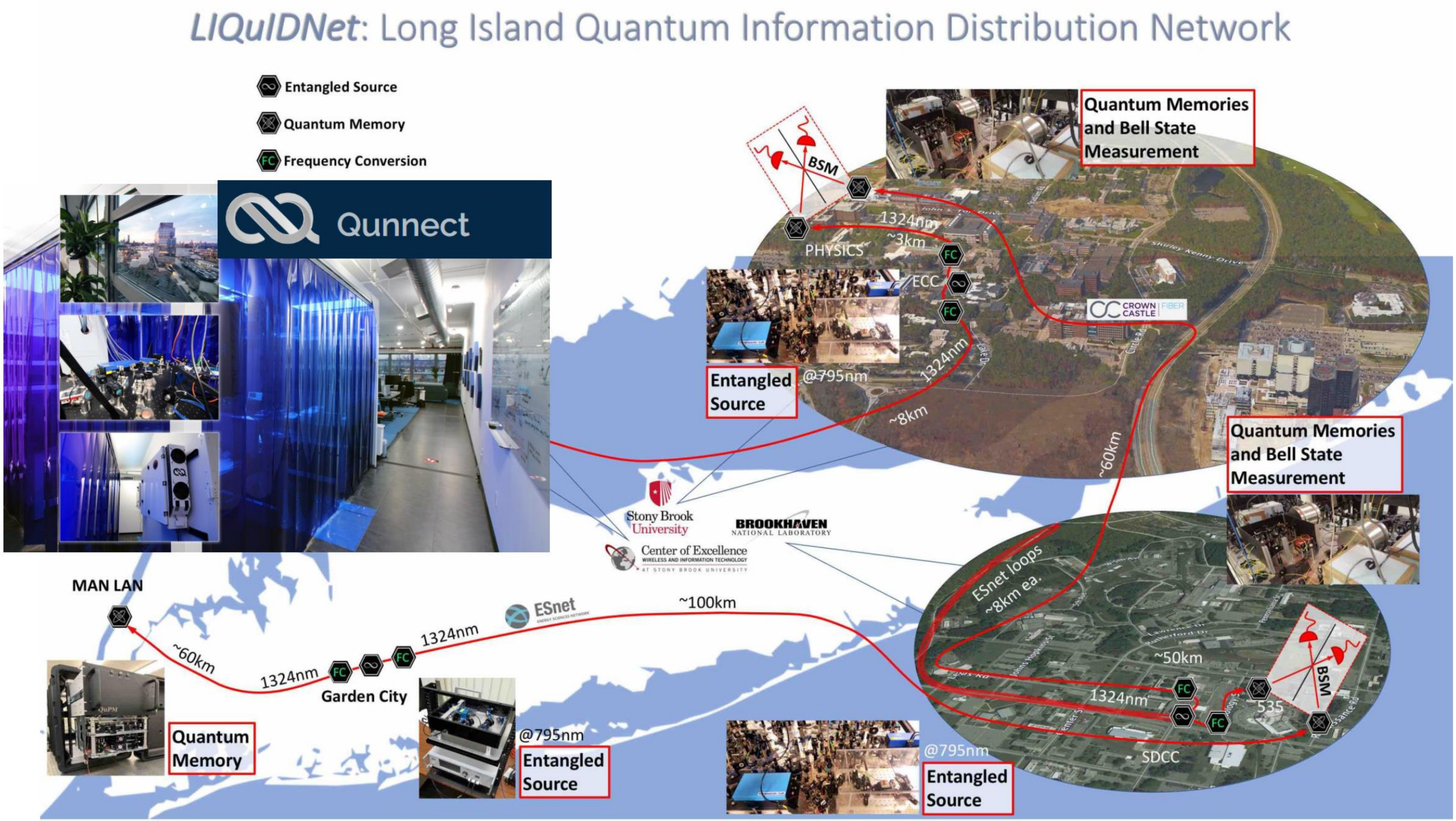
Qu-Source:

- -Increase the rate without affecting the heralding efficiency and the g2

Qu-Repeater:

- -Efficient interface of the source-memory
- -Protocol development and the digital support layer
- -Stability of a distributed network with many quantum devices

Future Field-Testing Plans



Qunnect

Building Hardware for Real-World, Scalable, Quantum Networking

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Fordham U.
Novawave

Kris Kearton
Ret. US Navy
Cyber Command

Thank you for your time!

QUANTONATION

ACCELERATE New York Seed Fund

U.S. DEPARTMENT OF ENERGY

U.S. AIR FORCE SBIR STTR

NSF

Center of Excellence WIRELESS AND INFORMATION TECHNOLOGY AT STONY BROOK UNIVERSITY

Clean Energy Business Incubator Program AT STONY BROOK UNIVERSITY

NEWLAB

SUNY RF The Research Foundation for

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