Quantum Internet Seminar

October 20-21, 2025

@Nihonbashi Innovation Center, NICT (Tokyo, Japan)

Diamond-based Quantum Internet

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Professor, Yokohama National University

Director, Quantum Information Research Center

Acknowledgements

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総務省の委託研究事業「ICT重点技術の研究開発プロジェクト グローバル量子暗号通信網構築のための研究開発 グローバル量子暗号通信網構築のための研究開発」JPMI00316および「量子インターネット実現に向けた要素技術の研究開発」(JPMI00316)

JSTの戦略的創造研究推進事業(CREST)「量子状態の高度な制御に基づく革新的量子技術基盤の創出」JPMJCR1773および「先端国際共同研究推進事業(ASPIRE)」(JPMJAP24C1)

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によって実施した成果を含みます。

Quantum Information Center

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Hideo Kosaka

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Anton Myalitsin

International PR
Adjunct Teaching Staff

Annelies Volders

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Intellectual Property Producer

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Kai Mueller

TUM

Company

Visiting Professor

Yu Mimura

FURUKAWA ELECTRIC

Visiting Associate Professor

Mamiko Kujiraoka

TOSHIBA

Partnership

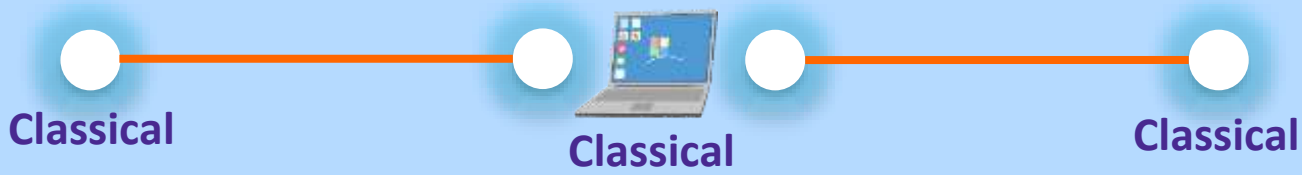
UTokyo-IIS
RIKEN
QST
Universität ulm
University of Stuttgart Germany

Joint Research

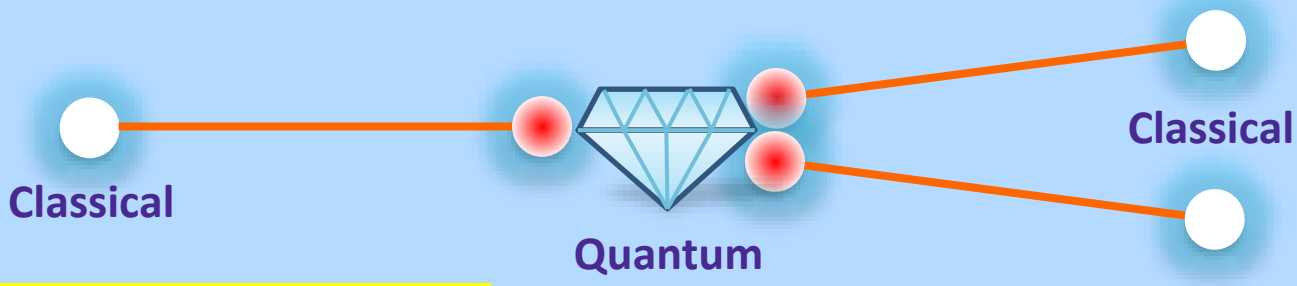
NICT
FURUKAWA ELECTRIC
QUTech

Development Steps toward Quantum Internet

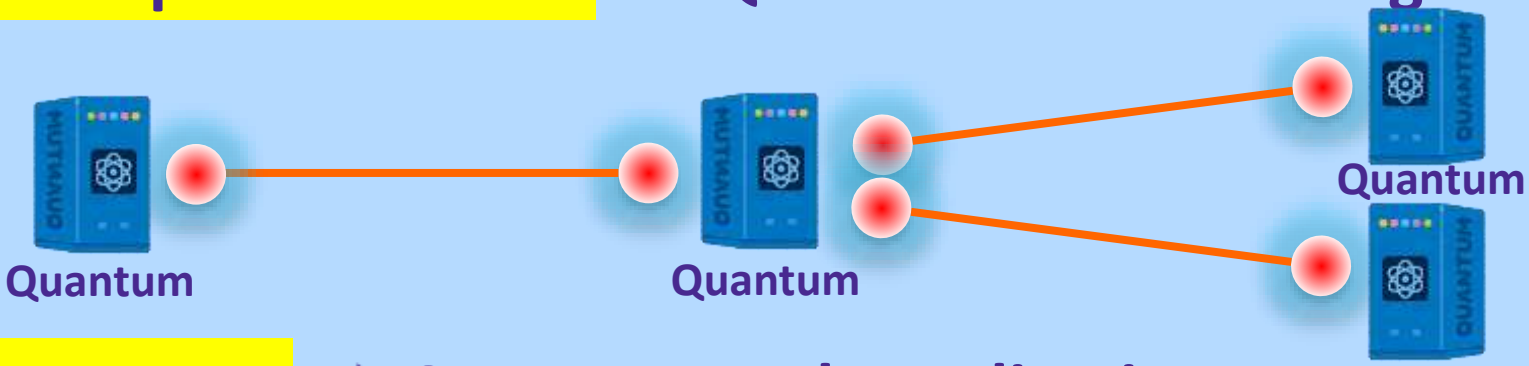
0. Trusted-node QKD network ➡ Classical node protection



1. Quantum Repeater network ➡ Classical data exchange



2. Quantum Computer network ➡ Quantum data exchange

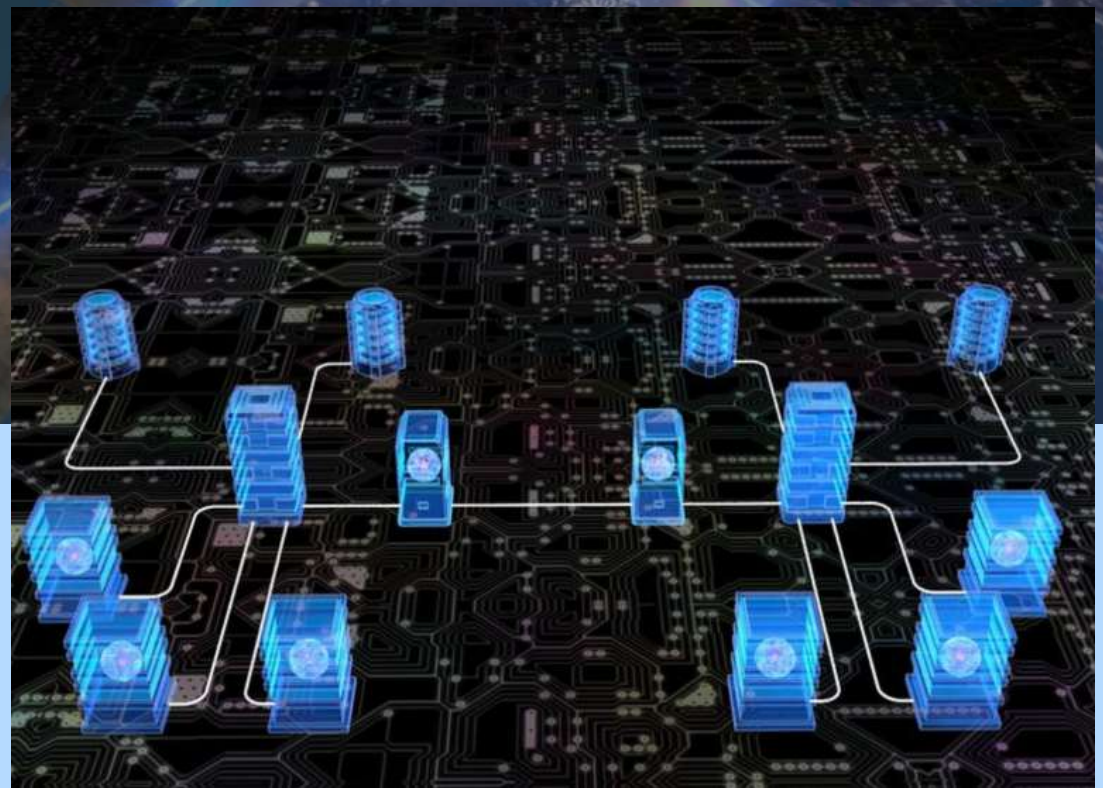


3. Quantum Internet ➡ Quantum Web application

Quantum Internet Alliance

Quantum Internet Alliance

Building a global Quantum Internet made in Europe



https://quantuminternetalliance.org/

Generations of Quantum Network

Error type	Method	1G	2G	3G
Loss error	Heralded entanglement	✔	✔	
	QEC with logical qubits			✔
Operation error	Heralded purification	✔		
	QEC with logical qubits		✔	✔
		Not very useful (Almost done?)	Maybe useful (Just started)	Quantum Internet

Scientific Reports **6**, 20463 (2016)

Development Roadmap of Q. Network in US

At least 3 years earlier than in Japan

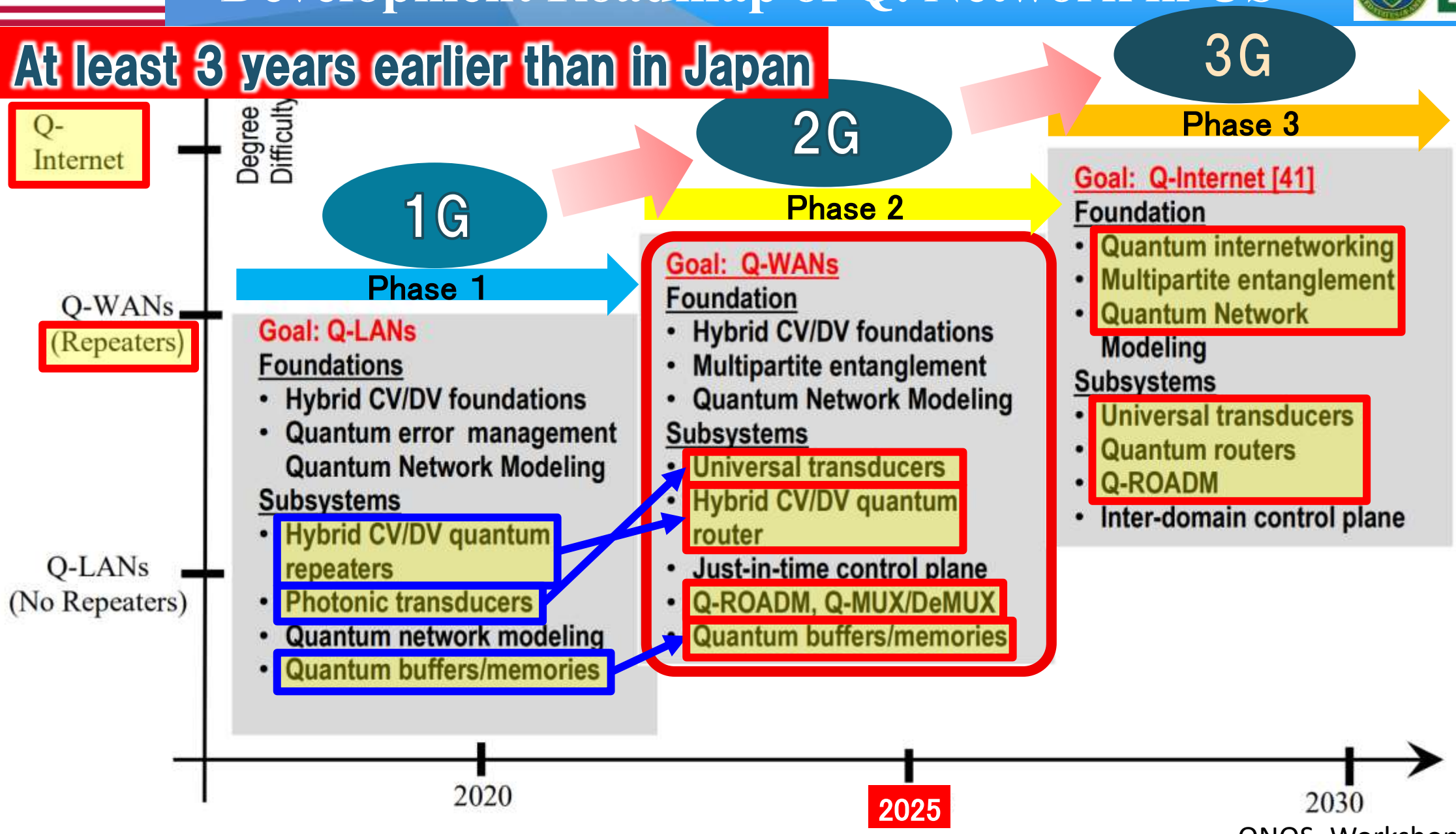
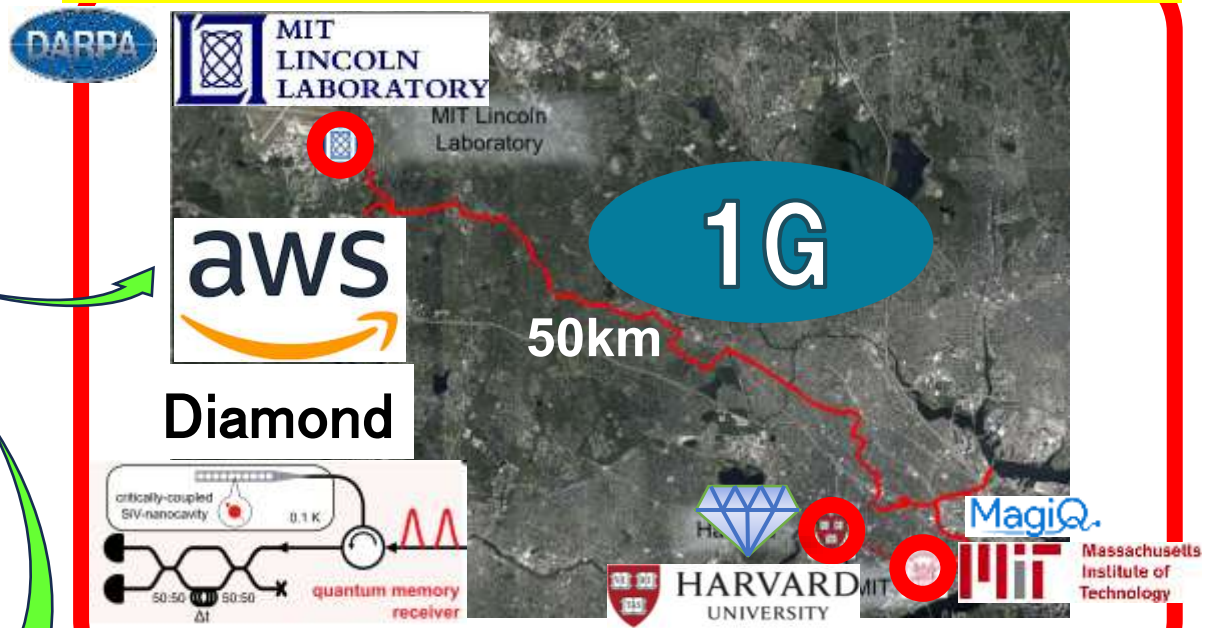


Figure 7: Transparent optical Quantum networks evolution in the open science

Development of Q. Network

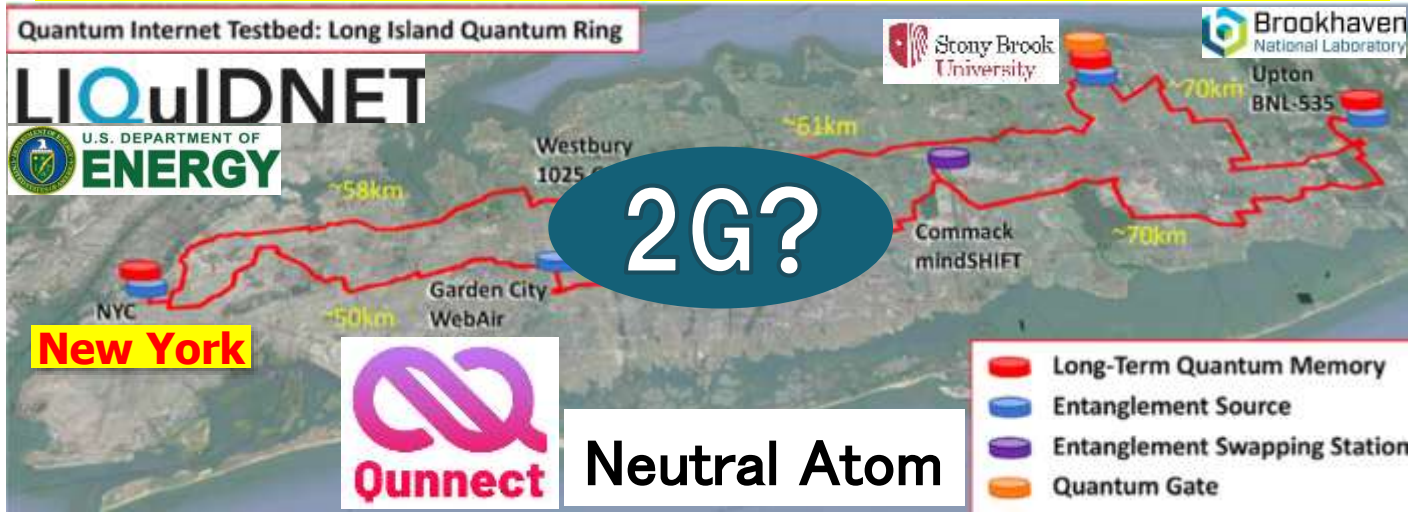
Boston-Area Quantum Network (BARQNET)



arXiv:2310.01316 arXiv:2307.15696v1 arXiv:2307.08619v1

DC Quantum Network (DC-Qnet)

Long Island Quantum Repeater Network (LIQuIDNET)



Development of Diamond-based Quantum Repeater

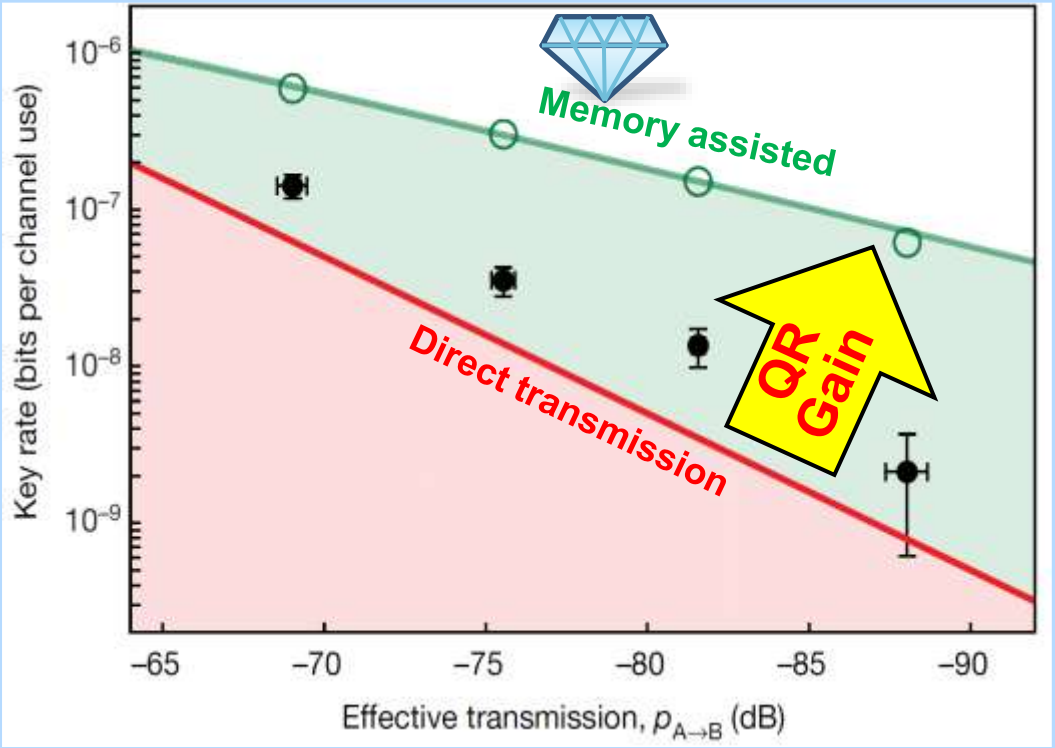
1G

2020: First Demonstration of Break-Even Advantage of QR

HARVARD UNIVERSITY

Mikhail Lukin
Marko Loncar
(Harvard)

nature

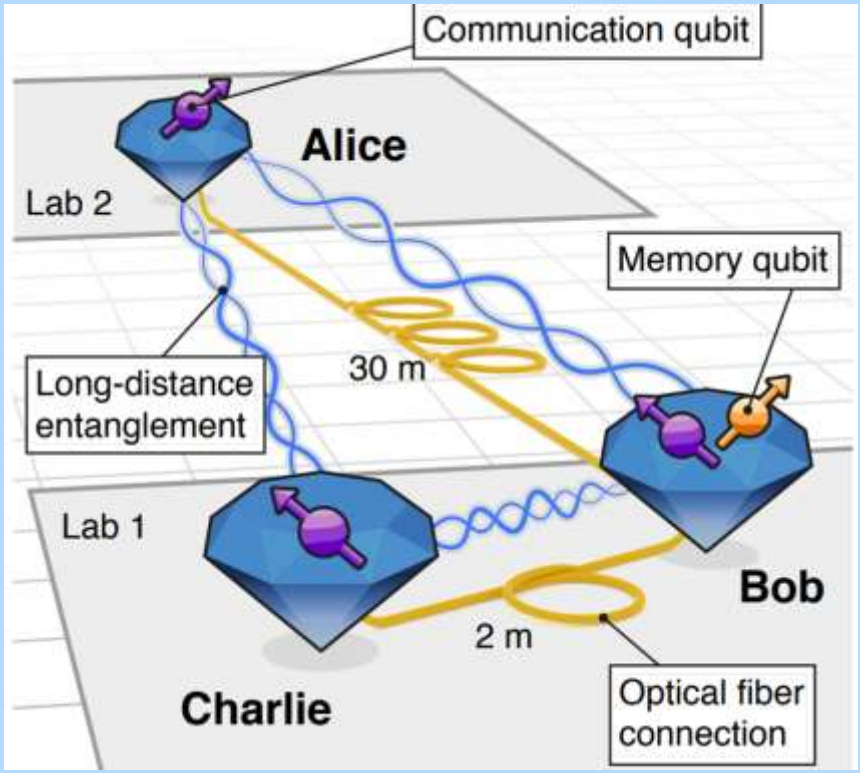


2021: First Demonstration of Three-Node QR

Science

TU Delft QuTech

Ronald Hanson
(QuTech / TU Delft)



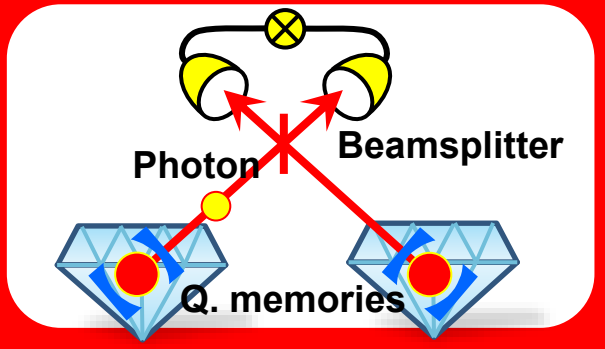
M. Pompili et.al. , Science 372, 259–264 (2021)

Three Types of Diamond QR

1G

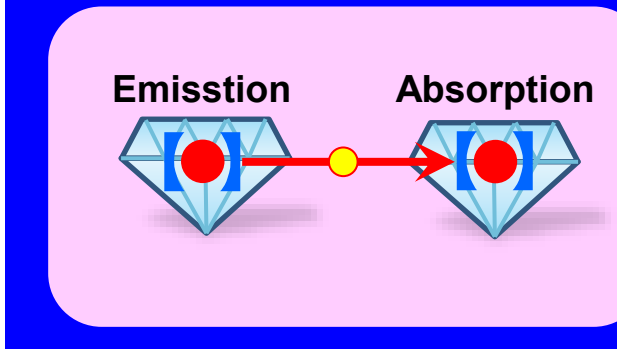
TU Delft

Photon Interference



YNU

Emission-Absorption



HARVARD UNIVERSITY

Photon Scattering

Efficient entanglement generation
Requires phase synchronization

No need for phase synchronization
Inefficient entanglement generation

Field Demonstration of a Diamond Quantum Network

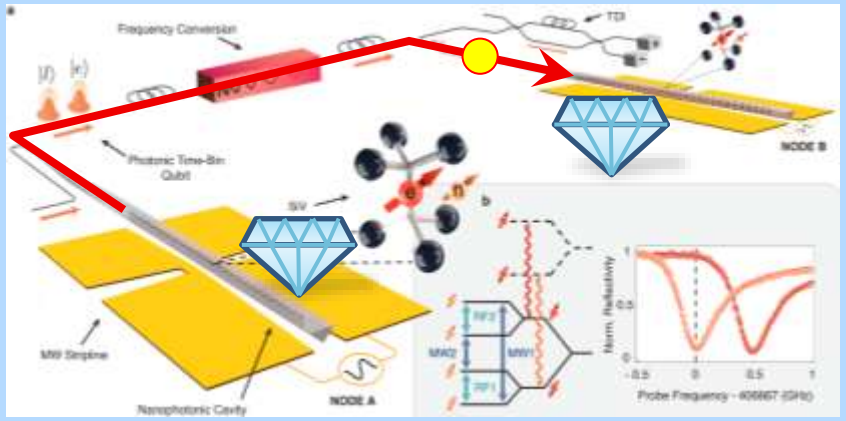
1G

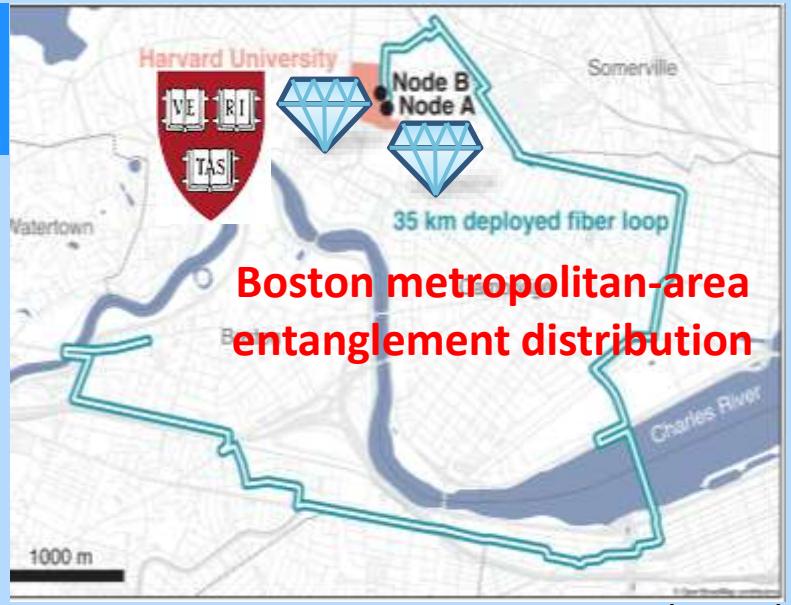
2023

Between two diamond SiVs
over 35 km (field demonstration) 0.0002Hz

HARVARD UNIVERSITY

Mikhail Lukin
Marko Loncar
(Harvard)





Nature 629, 573 (2024)

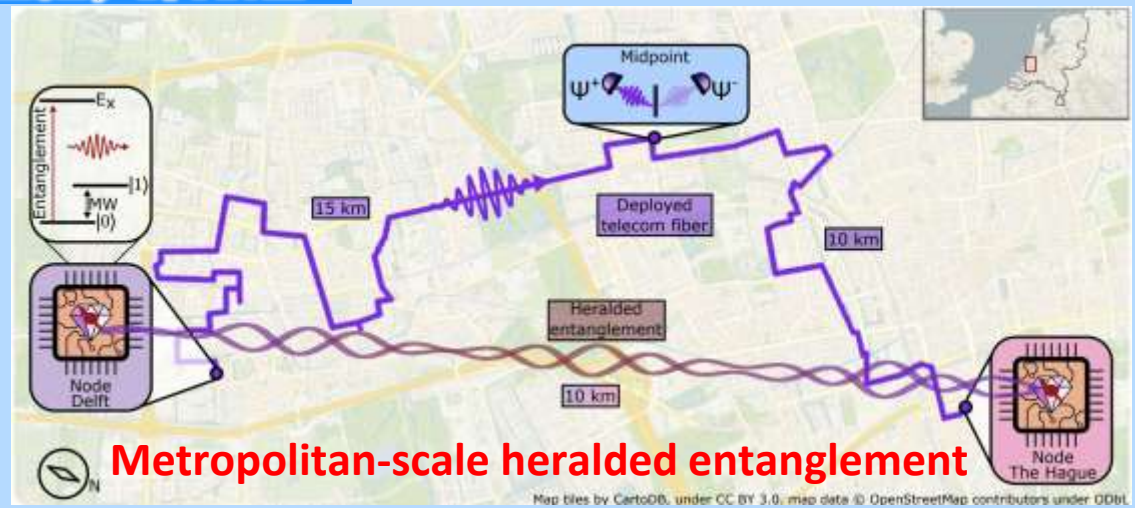
2024

Between two diamond NVs
over 25 km (field demonstration) 0.48Hz

Science Advances, 10, 44 (2024)

QUTech

Ronald Hanson
(QuTech /
TU Delft)

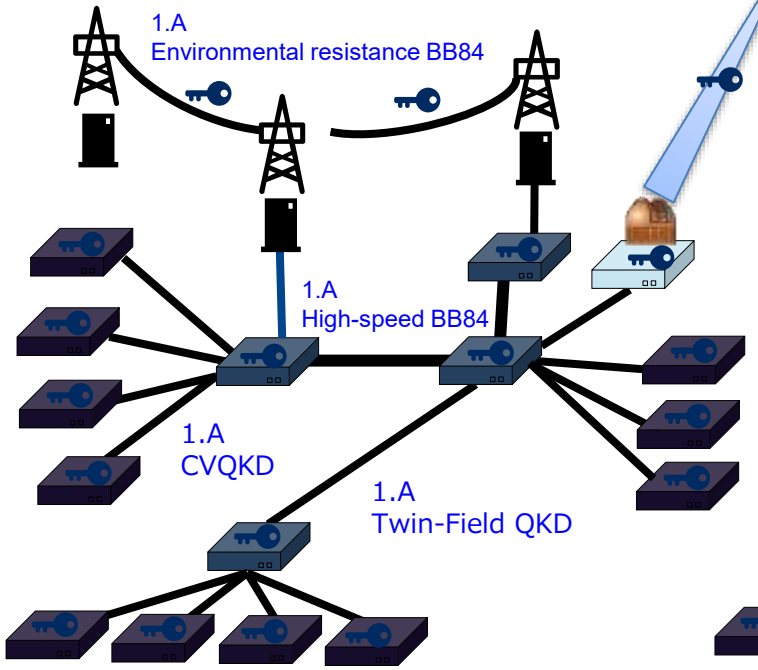


MIC: Priority ICT Technologies - Global QKD Network

JPMI00316

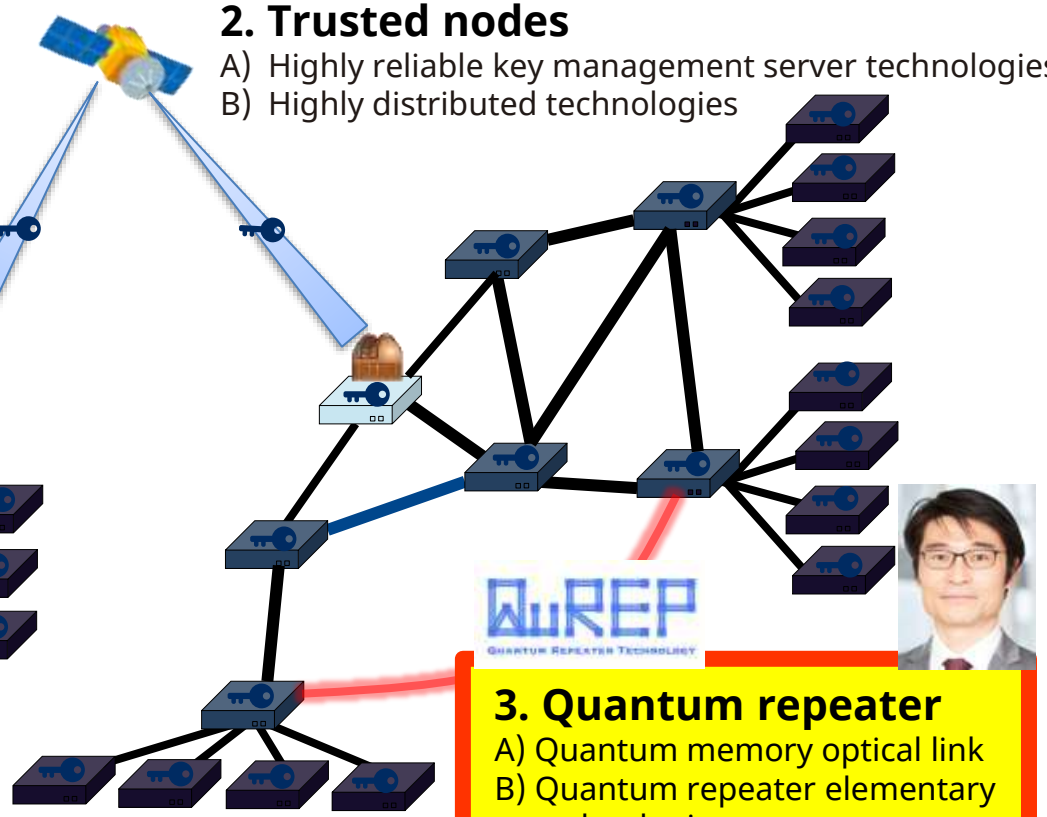
1. Quantum crypto link

A) High-performance quantum cryptography
B) Photon detection



2. Trusted nodes

A) Highly reliable key management server technologies
B) Highly distributed technologies



QuREP
Quantum Repeater Technology

3. Quantum repeater

A) Quantum memory optical link
B) Quantum repeater elementary technologies

4. Network operation

A) Network control and management

4 Companies

TOSHIBA
FURUKAWA ELECTRIC
NEC
HAMAMATSU

3 National Institutes

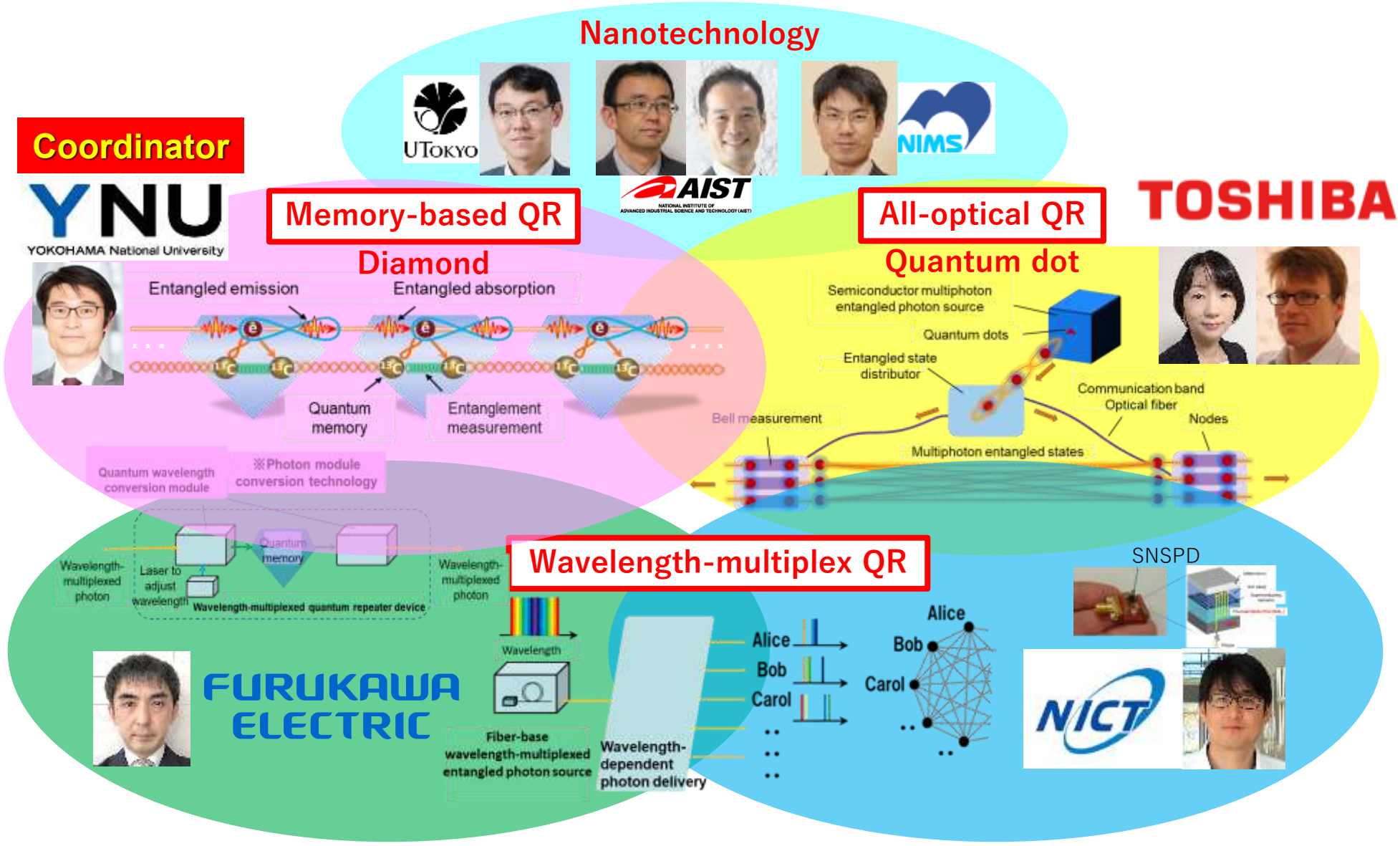
NICT
AIST
NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)
NIMS

4 Universities

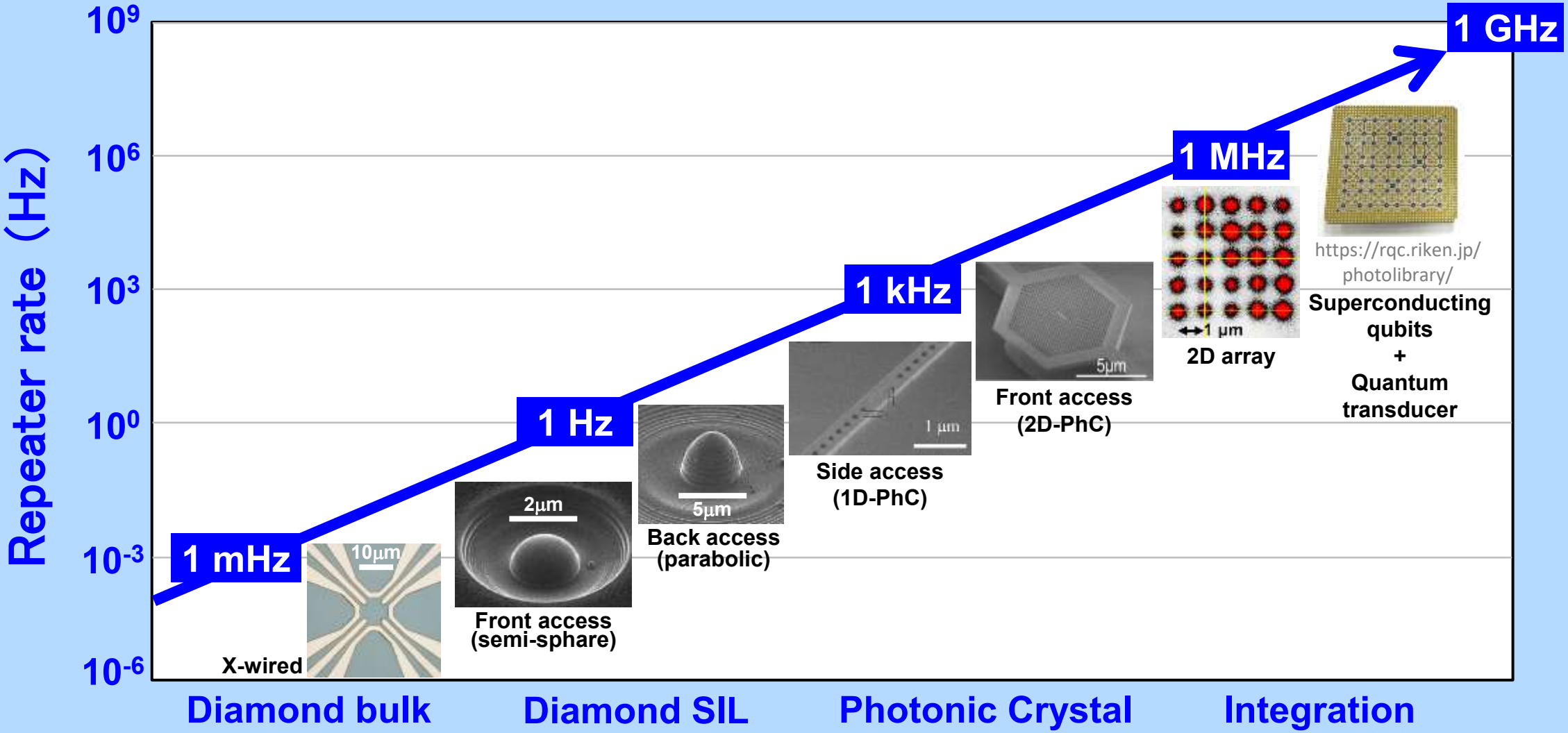
YNU
YOKOHAMA National University
UTokyo
HOKKAIDO UNIVERSITY
GAKUSHUIN UNIVERSITY

Subject III: Quantum Repeater Project

JPMI00316

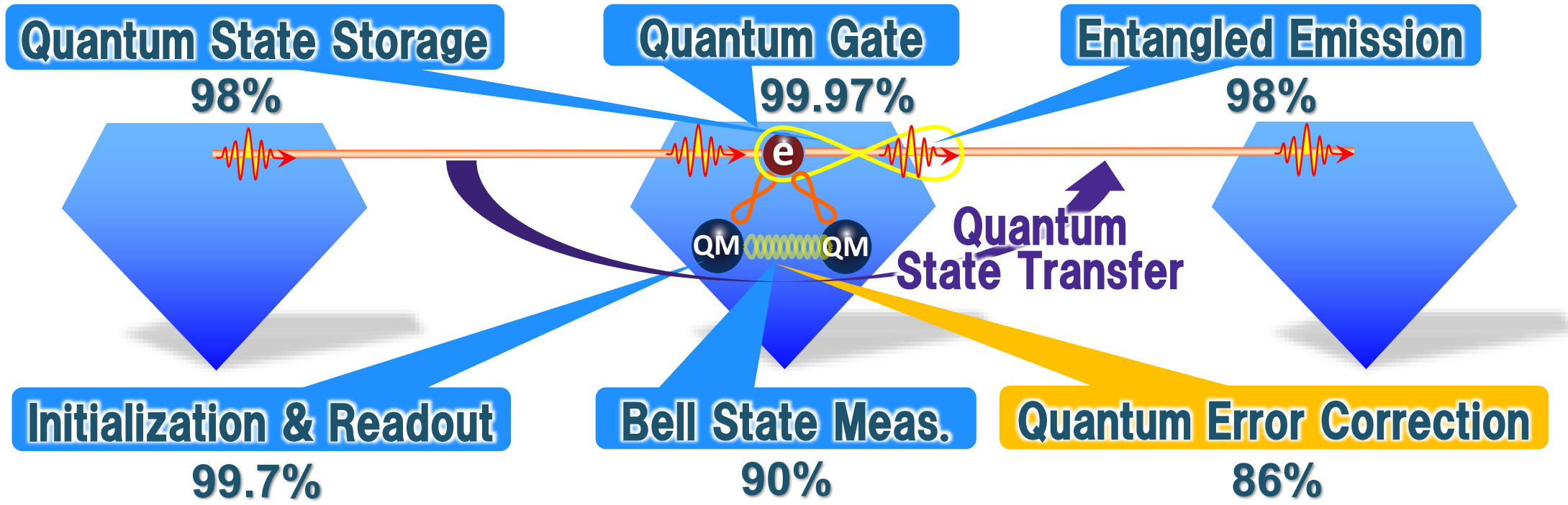


Development Steps for Diamond-QR Device

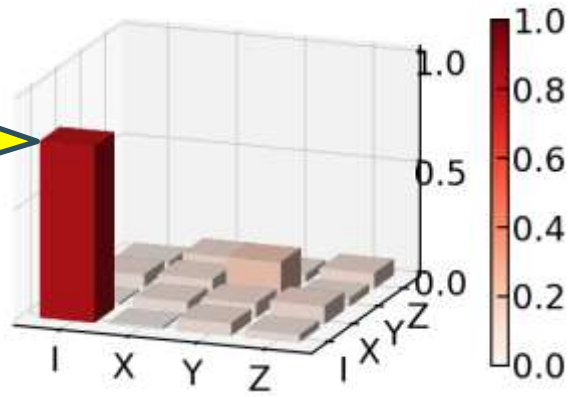


Proof-of-principle Demonstration of Diamond QR

1G



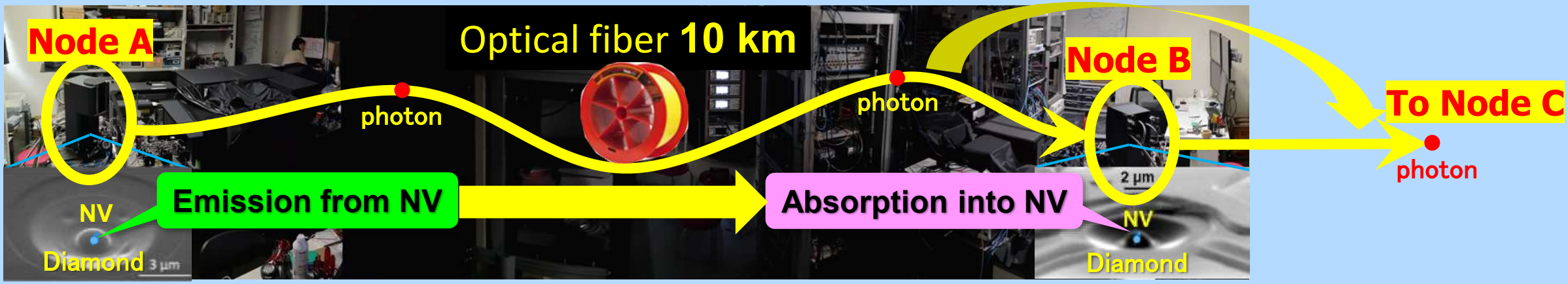
Fidelity of QR Process: 87% on average



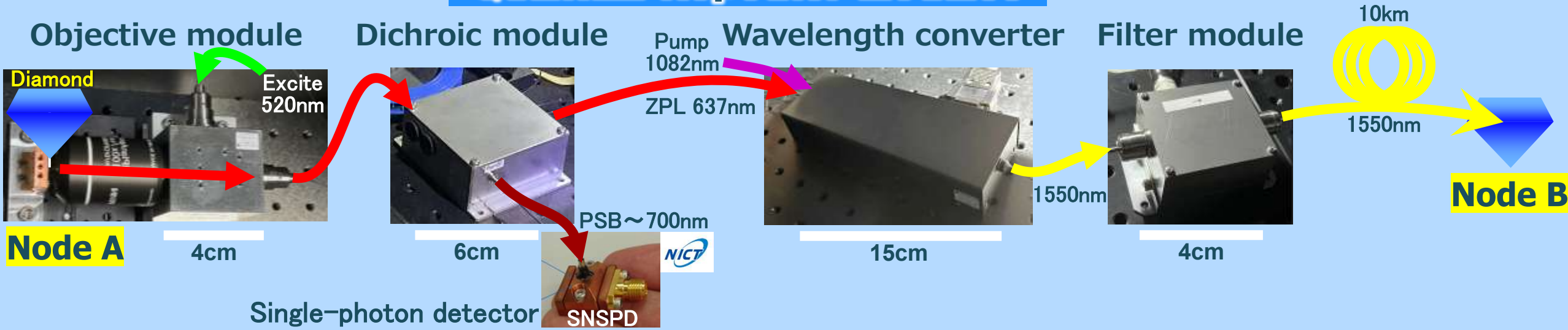
Quantum Process Tomography of Quantum State Transfer

10-km in-lab demonstration of Diamond-QR

1G

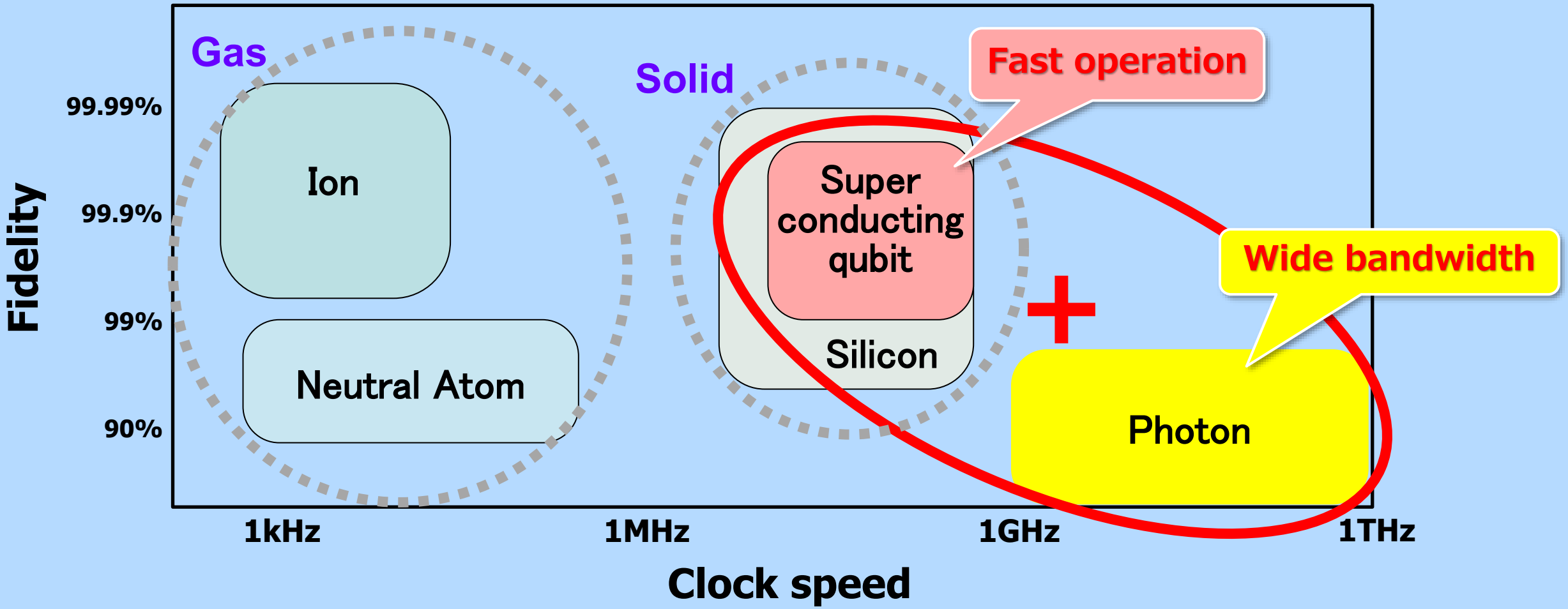


Quantum Repeater Modules

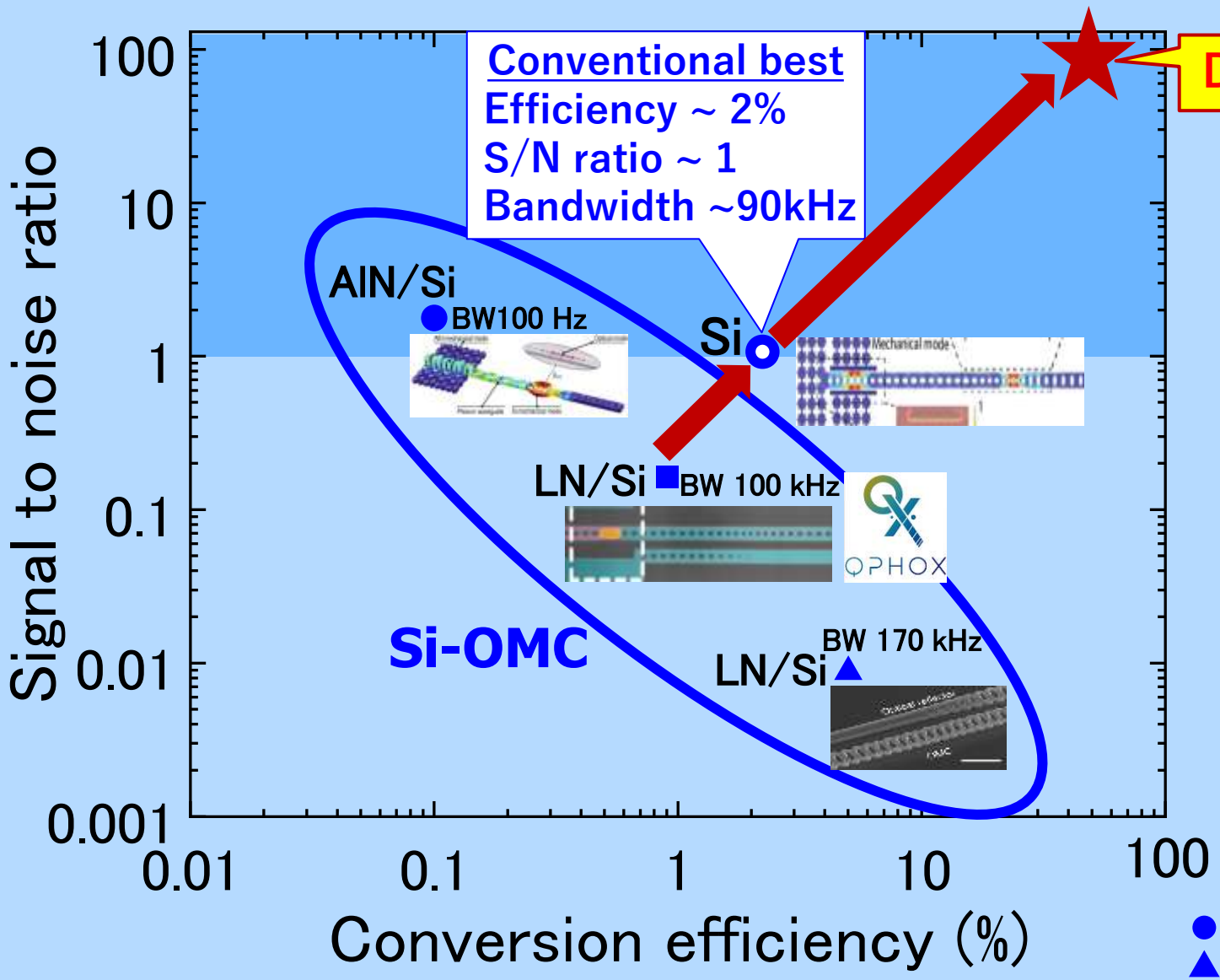


Quantum Computer Network

3G



Quantum Transducers for Interconnecting SC & Photonic qubits



Diamond-OMC

QiC

Key players

M. Lukin & M. Loncar
(Harvard)

D. Englund
(MIT)

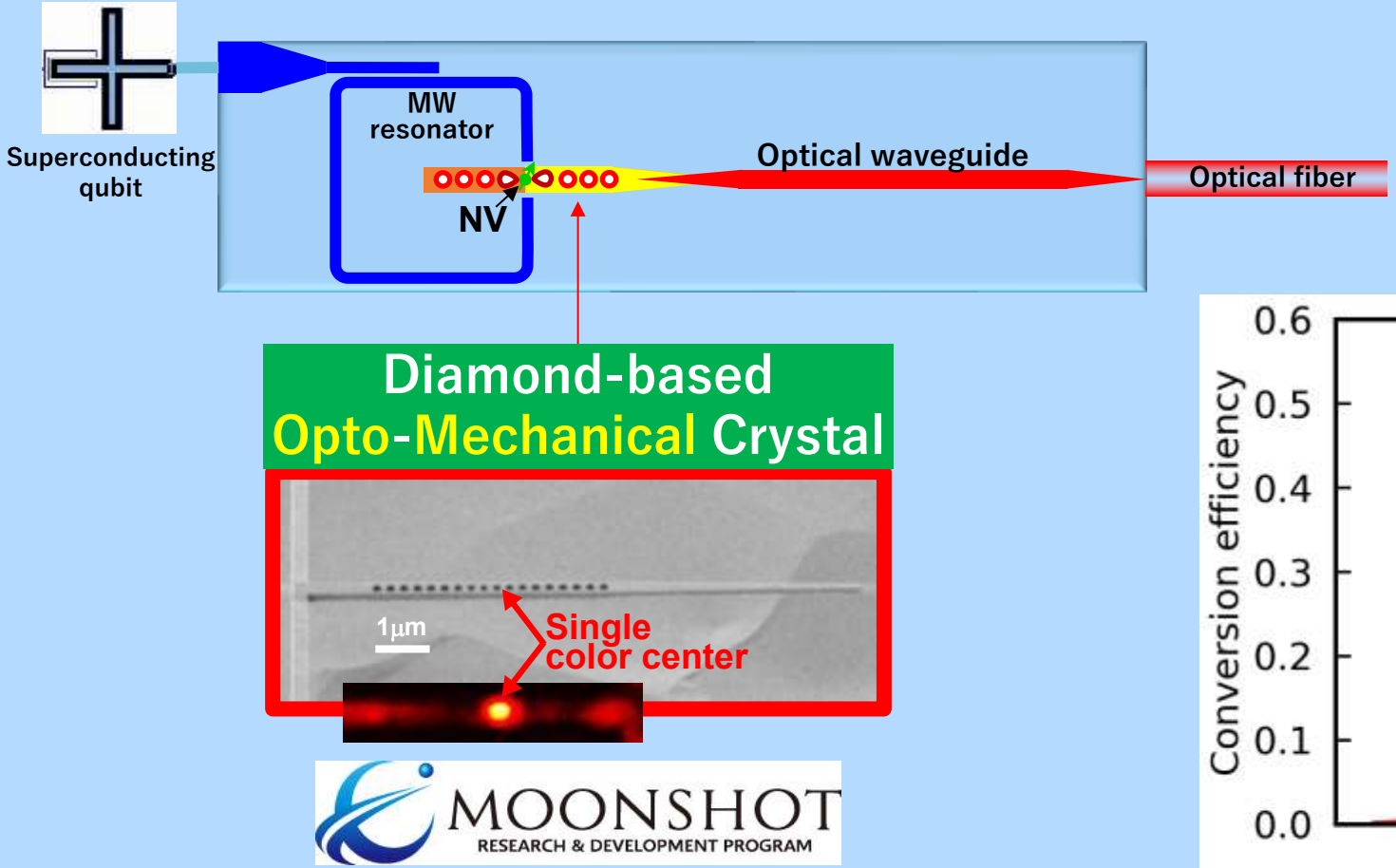
S. Naeini & J. Vuckvic
(Stanford)

R. Hanson & T. Taminiau
(TU Delft - QuTech)

A. B. Jayich
(UCSB)

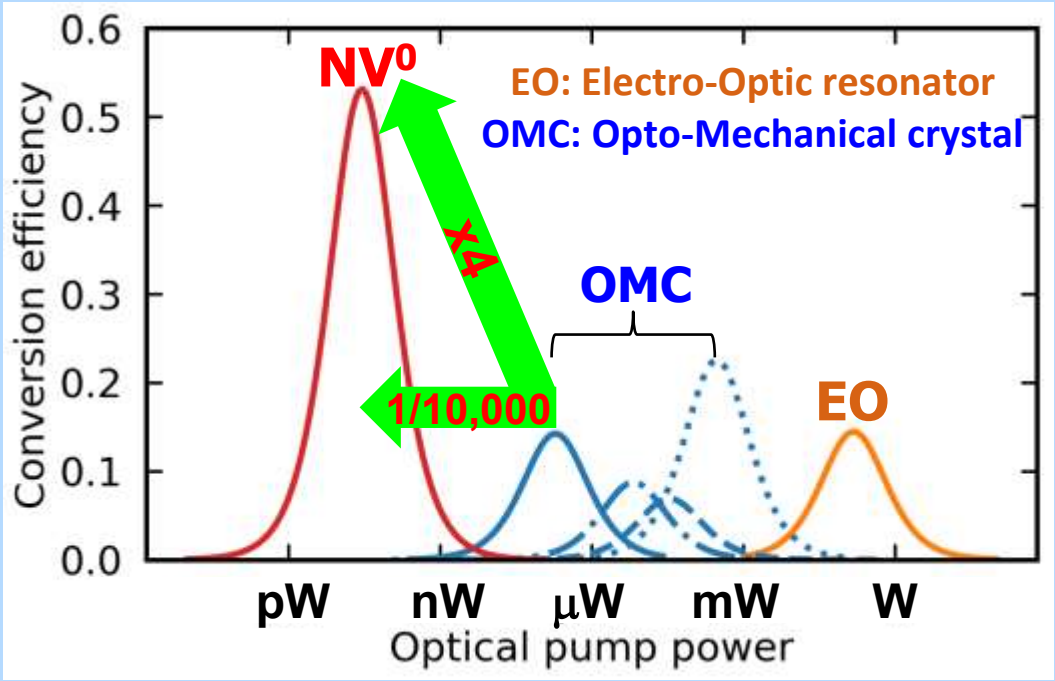
● Mirhosseini & **Painter**, Nature 588, 599 (2020)
▲ Jiang & **Naeini**, Nature Physics 19, 1423 (2023)
■ Weaver, **Groblacher** & Stockill, Nat. Nano. 19, 166 (2024)
○ Zhao & **Mirhosseini**, Nature Nano. 20, 602 (2025)

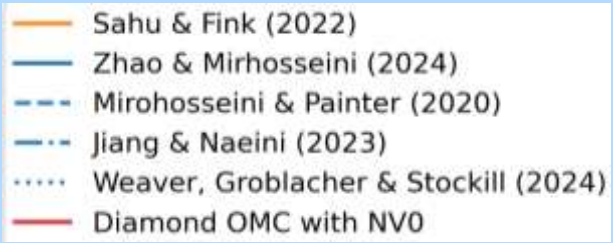
Diamon-based Microwave-to-Optical Quantum Transducer



MOONSHOT
RESEARCH & DEVELOPMENT PROGRAM

Kosaka project
(JPMJMS2062)





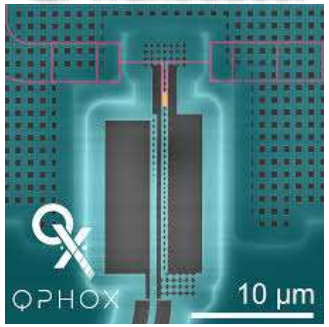
Towards Quantum Computer Network

3G?

AFRL
AIR FORCE RESEARCH LABORATORY

Potential interactions of quantum technology areas in a network

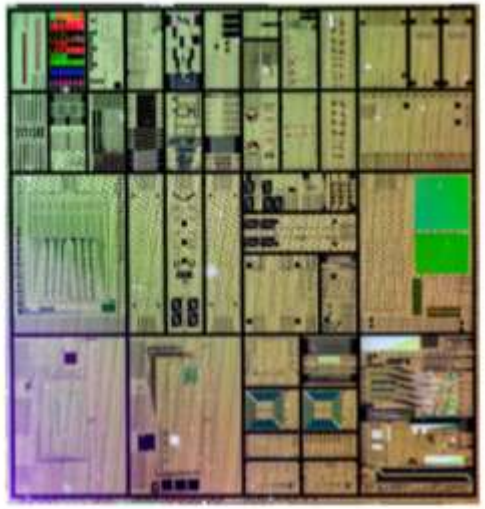
Q. Transducer



High fidelity teleportation To ote Nodes

QPHOX

Microwave-telecom quantum interface



Error Correction

Optical Q. computer

PsiQuantum

Trapped Ion-telecom quantum interface

Diamond Q. Transducer

Superconducting Q. Computer

IBM

rigetti

Rapid quantum logic processing, QRAM

Ion-SC quantum interface

Long-term quantum memory

Ion Q. Computer

IONQ

Quantum Computer Network Test Bed

3G?

AFRL
AIR FORCE RESEARCH LABORATORY

rigetti

Superconducting Q. Computer

MONTANA STATE UNIVERSITY
QCORE

Quantum Network

ORCA COMPUTING

Optical Q. computer

Morrow said MSU is the world's first university to have a Rigetti Novera superconducting quantum computer on site, and it's the first university in the U.S. with an ORCA photonic quantum computer. QCORE has one of only five quantum network test beds in the world and, according to Morrow, is one of only seven organizations in the world to house two different types of quantum computers: photonic and superconducting.

Global Collaboration Toward Quantum Data Centers

nu QUANTUM

Technology Impact About us

25.02.2025

Nu Quantum launches Quantum Datacenter Alliance with Cisco, NTTData, OQC, QphoX, Quantinuum, QuEra

Superconducting

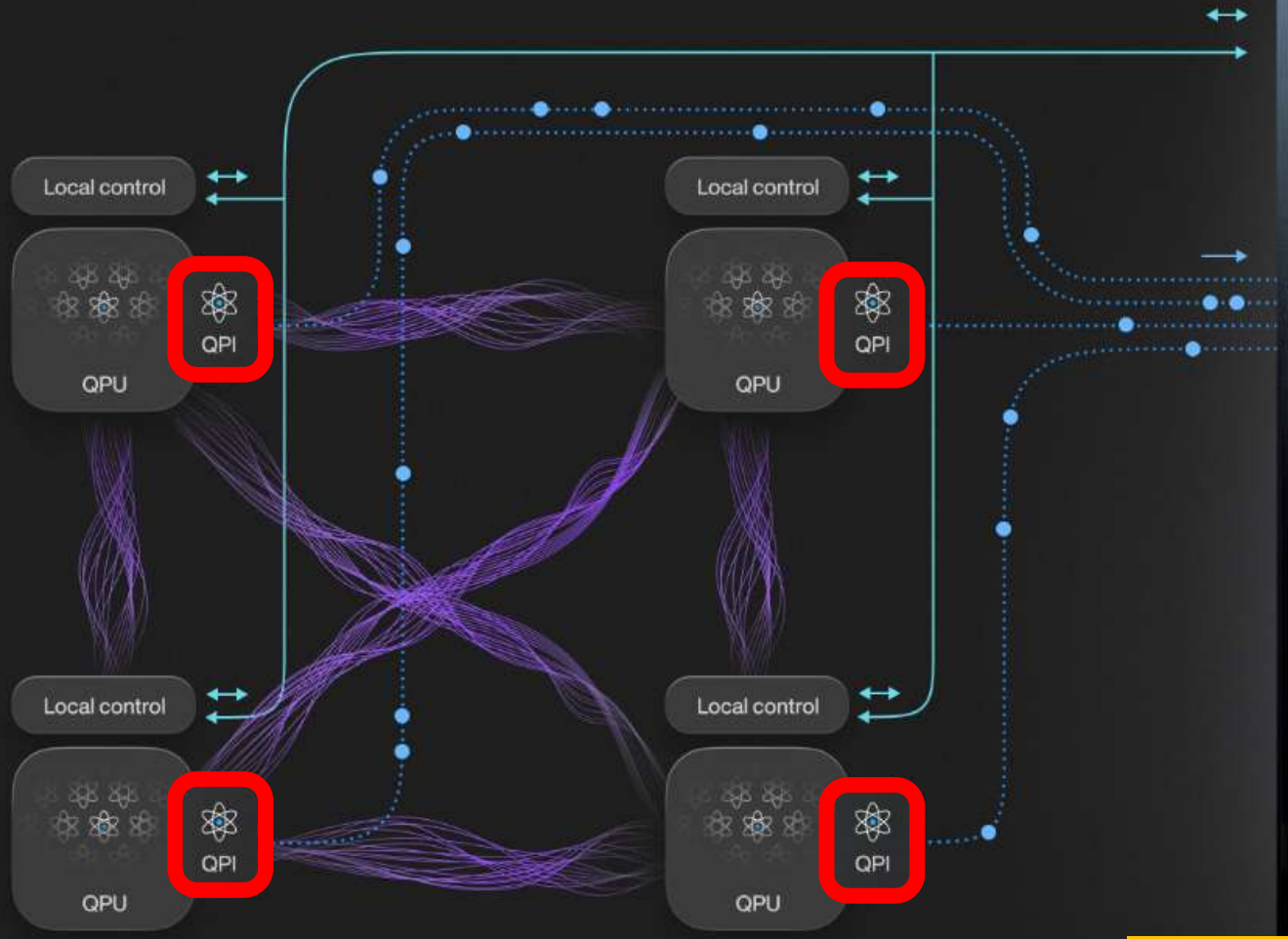
Ion

Neutral atom

nu QUANTUM

Our vision for distributed quantum computing

3G?



Quantum Networking Unit

QPI:
Qubit-Photon Interface

↔ Ultra-low latency classical channel

High fidelity quantum photonic channel (optical fibre)

On demand entanglement resource generation

Summary

- We successfully demonstrated the proof-of-principle of a diamond-based quantum repeater.
- We successfully achieved modularization of the diamond quantum repeater.
- By using quantum computers as quantum routers with quantum transducers, we can realize the quantum internet.