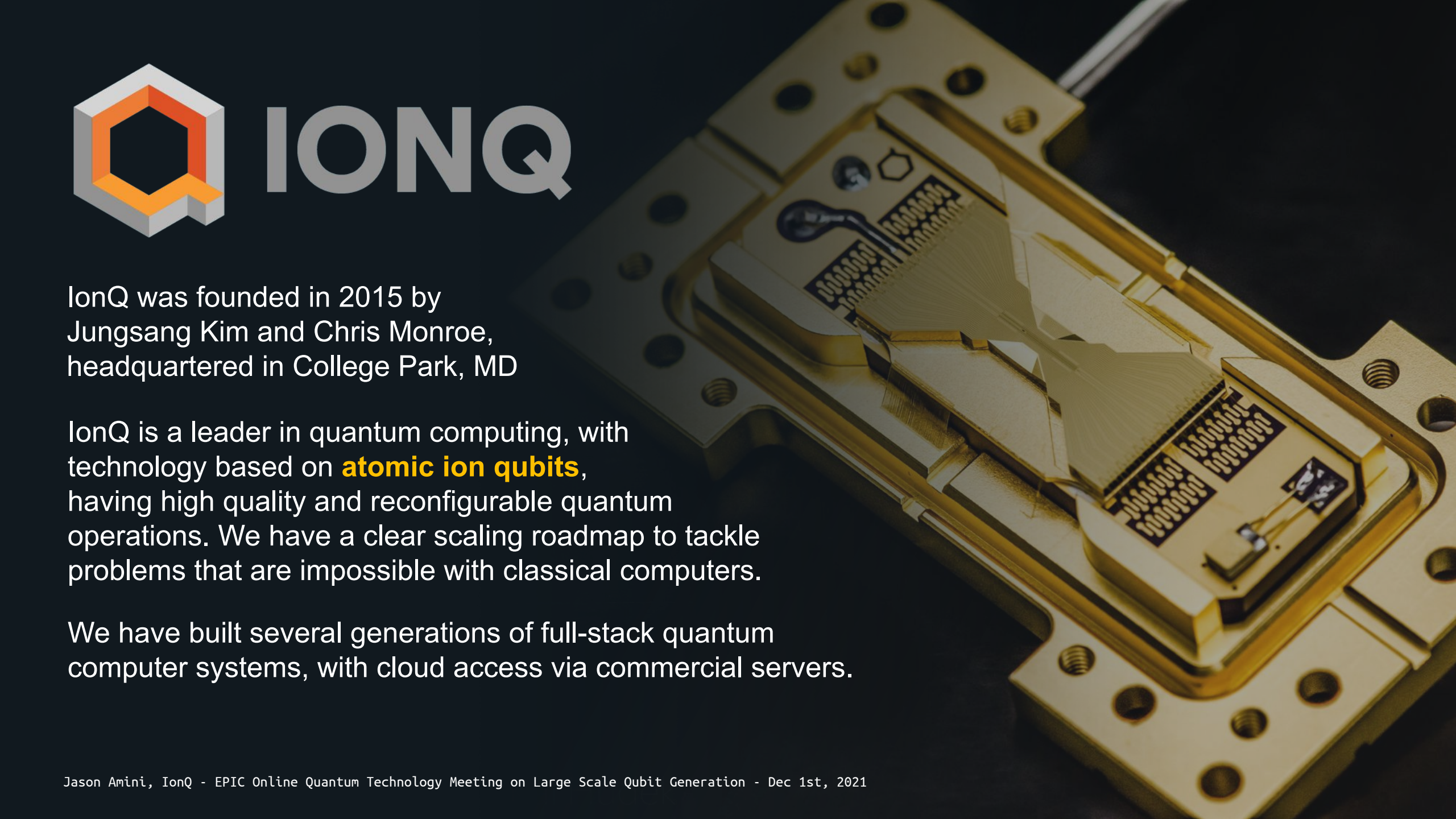
IONQ

Modular Scaling via Photonic Interconnects

EPIC Online Quantum Technology Meeting on Large Scale Qubit Generation

Dec 1st, 2021



IONQ

IonQ was founded in 2015 by Jungsang Kim and Chris Monroe, headquartered in College Park, MD

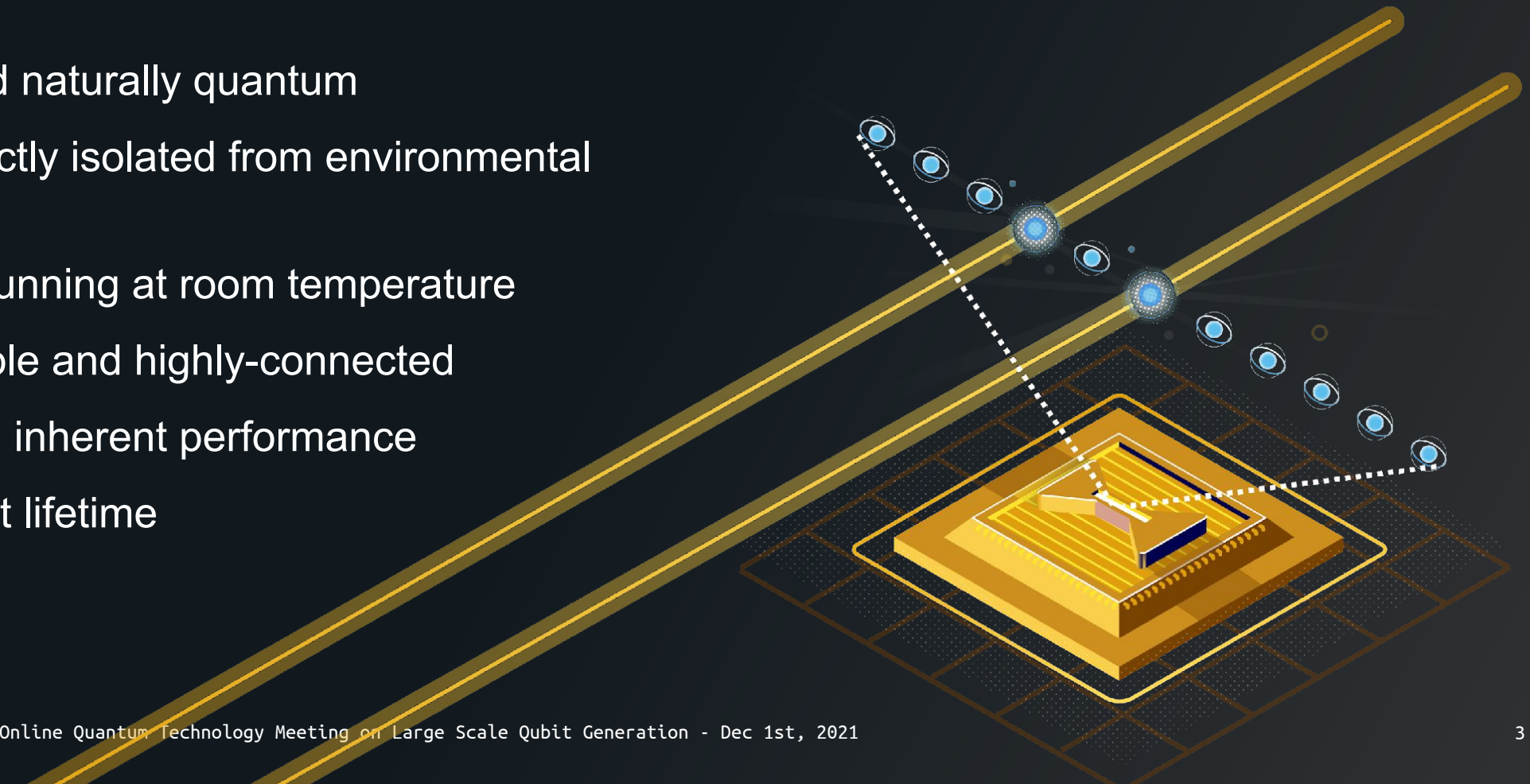
IonQ is a leader in quantum computing, with technology based on **atomic ion qubits**, having high quality and reconfigurable quantum operations. We have a clear scaling roadmap to tackle problems that are impossible with classical computers.

We have built several generations of full-stack quantum computer systems, with cloud access via commercial servers.

Trapped Atomic Ion Quantum Computer

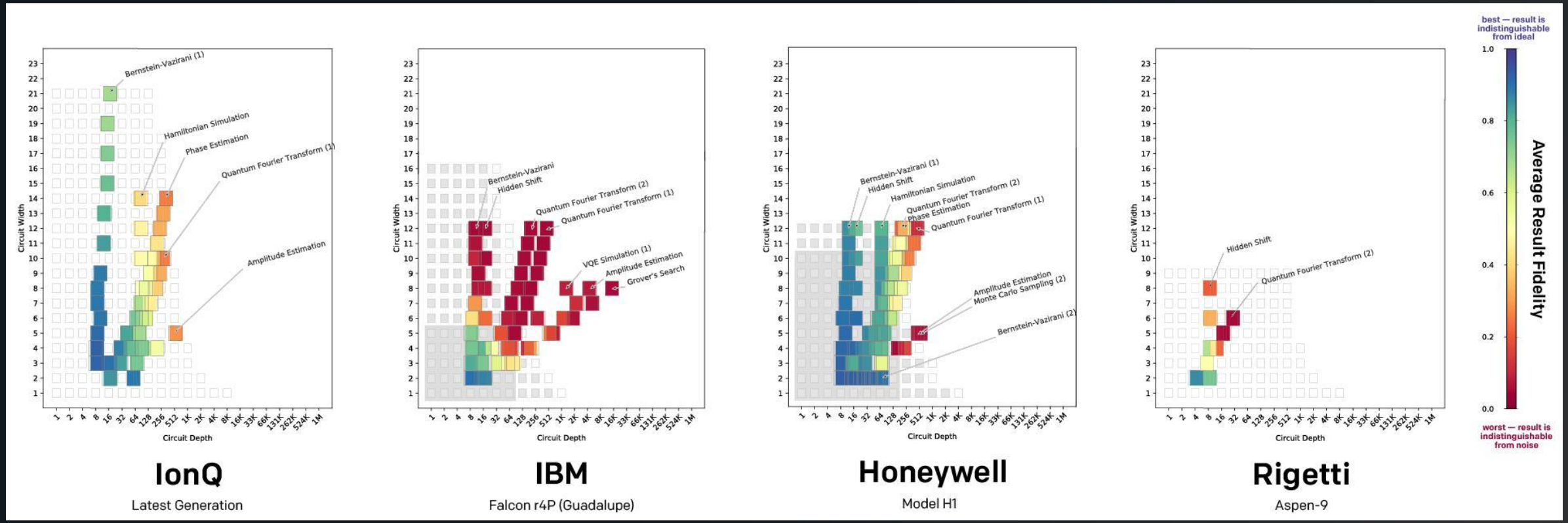
Individual atomic ion qubits in an electromagnetic trap are well-isolated, allowing for nearly perfect idle qubit performance

- identical and naturally quantum
- nearly perfectly isolated from environmental influences
- capable of running at room temperature
- reconfigurable and highly-connected
- unparalleled inherent performance
- longest qubit lifetime



Benchmarking

IonQ's Latest System Outperforms Competitors

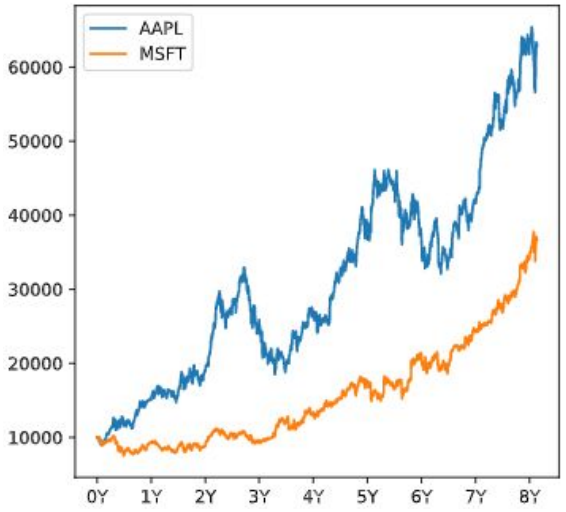


Application-Oriented Performance Benchmarks for Quantum Computing, arXiv 2110.03137 (2021)

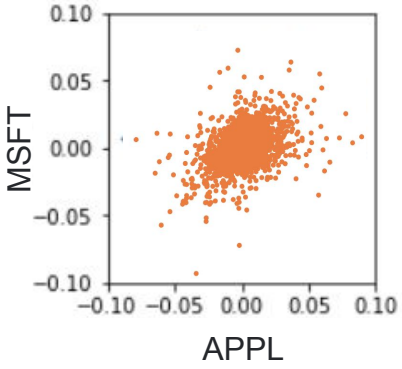
Applications

Generative Quantum Learning for Financial Applications

Input time series of two stock prices



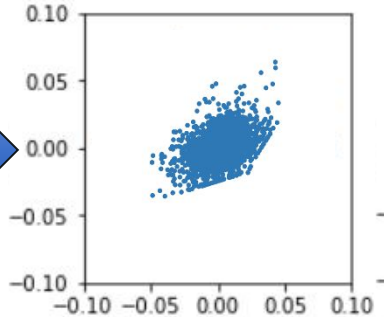
Target Distribution from training data



Generate multivariate distribution (copulas) of the stocks

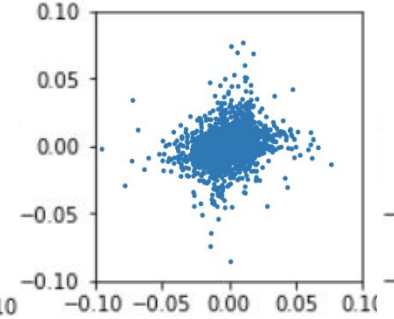
QGAN: Quantum Generative Adversarial Network
QCBM: Quantum Circuit Born Machine

Classical GAN



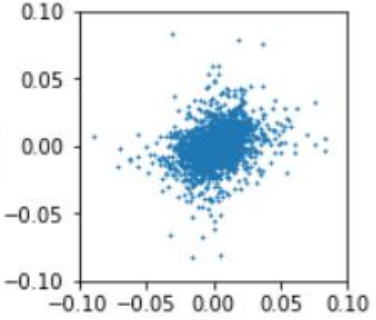
20,000 Iterations

Quantum GAN



1,000 Iterations

Quantum CBM



26 Iterations

FCAT FIDELITY CENTER for APPLIED TECHNOLOGY℠

IONQ

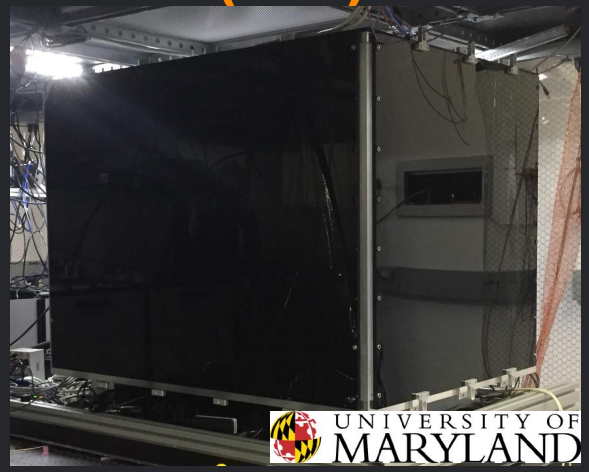
Youtube: "Quantum Sampling: The Fastest Path to Advantage"

Generative Quantum Learning of Joint Probability Distribution Functions, arXiv 2109.06315 (2021)

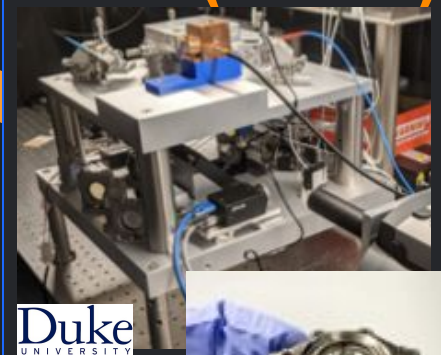
IonQ's path to scaling

2016 (10m)

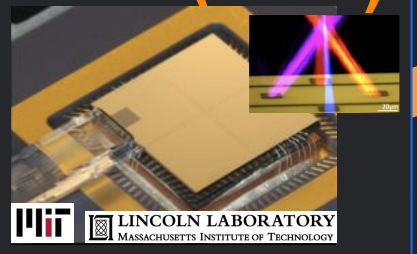
2018 (2m)

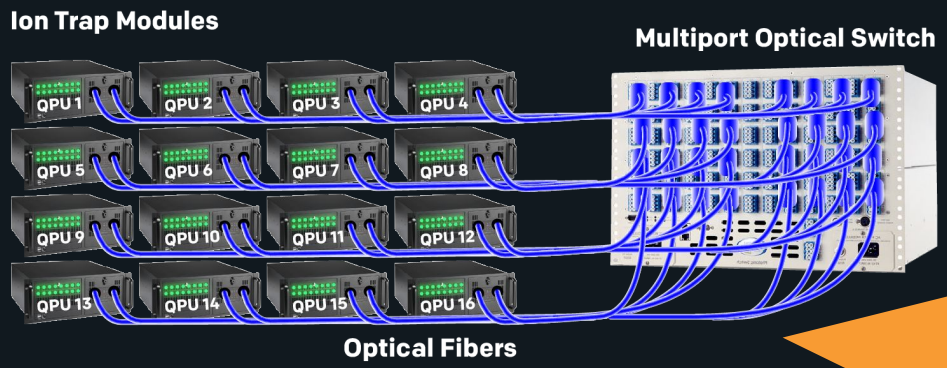


2021 (10cm)



2023 (1cm)





System scaling: Photonic interconnects

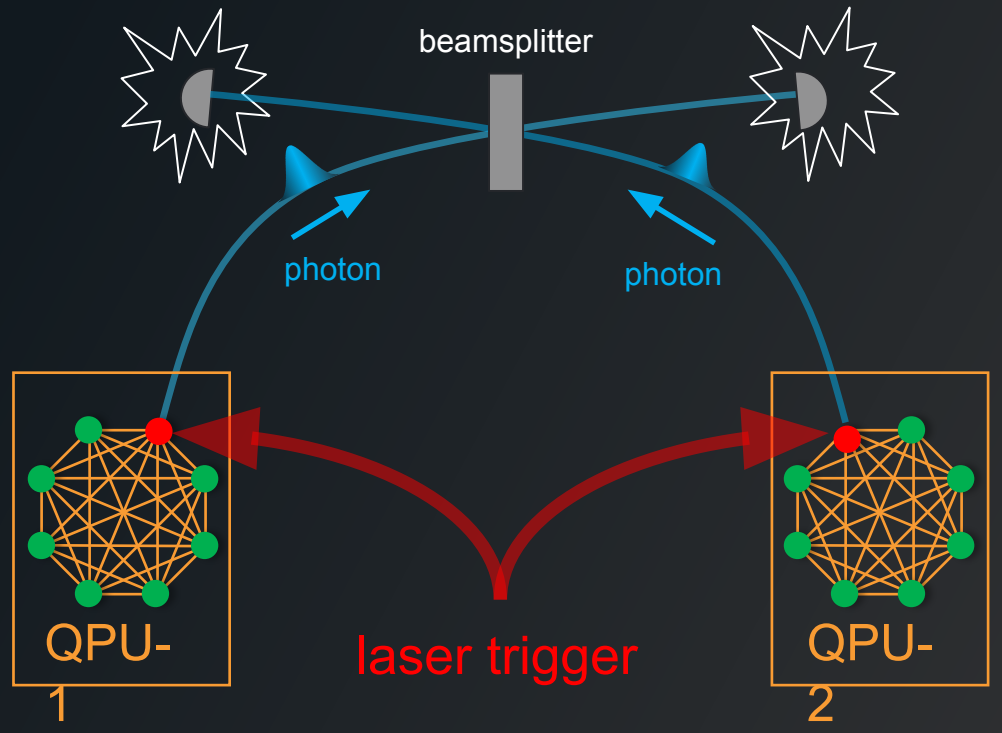
Entangling ions in separate systems

Inter-QPU link relies on an interference between indistinguishable photons emitted by the target atomic ion qubits

Requires multiple species (different elements or isotopes) to eliminate crosstalk

Memory qubit

Communication qubit



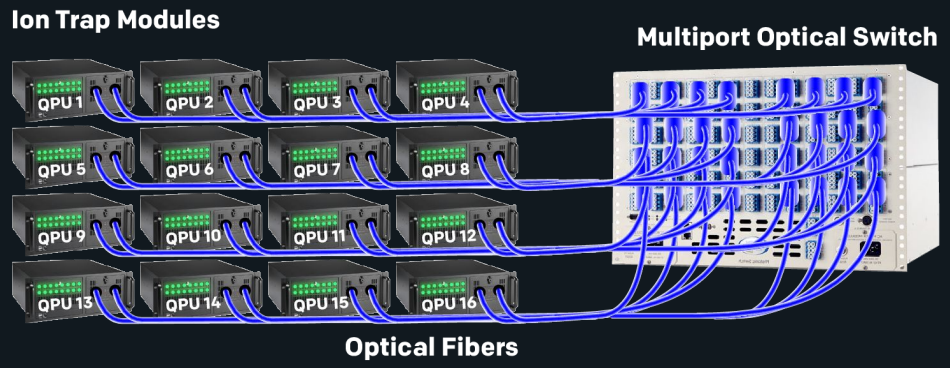
Hong, Ou, Mandel, PRL 59, 2044 (1987)
Y.H. Shih & C. O. Alley, PRL 61, 2921 (1988)
Simon & Irvine, PRL **91**, 110405 (2003)
L.-M. Duan, et. al., QIC **4**, 165 (2004)
Y. L. Lim, et al., PRL **95**, 030505 (2005)

2007: **Trapped Ions** [Nature 449, 68–71]
2013: **Trapped Neutrals** [PRL 110, 140403]
2014: **NV-diamond** [Science 345, 532]
2015: **Quantum Dots** [Nature Phys. 12, 218]
2016: **Superconductors** [PRX 6, 031036]

System scaling: Photonic interconnects

Switching and photonic interconnects

IonQ QPUs can be networked using photonic interconnects and existing photonic and optical fiber switching technology.

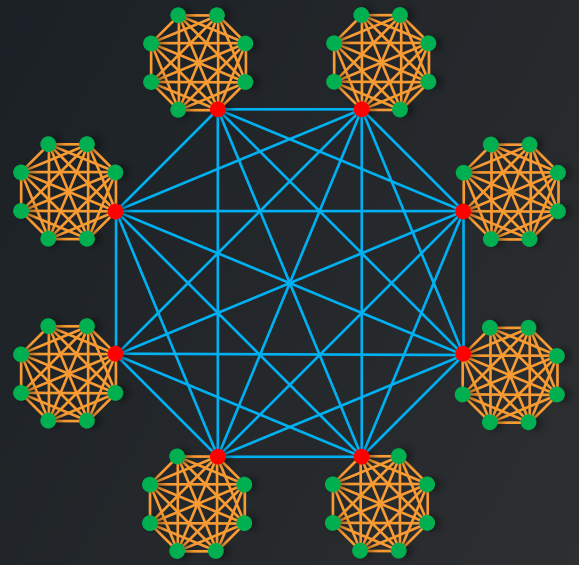


This modular approach allows for indefinite scaling of individual QPUs to form a more powerful quantum system.

Reconfigurable multiport optical switch allows for full modular connectivity between all qubits.

Unique to the IonQ architecture

8 × 8 QPU network: 2,016 random access connections

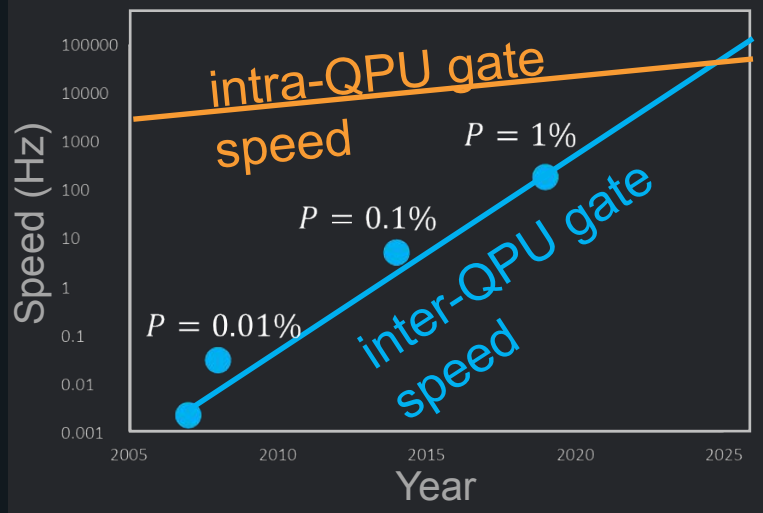


Duan and Monroe, *Rev. Mod. Phys.* **82**, 1209 (2010)
Li and Benjamin, *New J. Phys.* **14**, 093008 (2012)
Monroe, et al., *Phys. Rev. A* **89**, 022317 (2014)

System scaling: Photonic interconnects

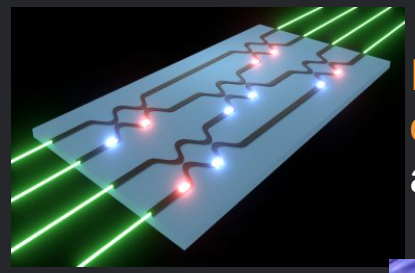
Boosting interconnect speed

Inter-QPU connection speed is currently 1/50 of intra-QPU speed, but is catching up fast

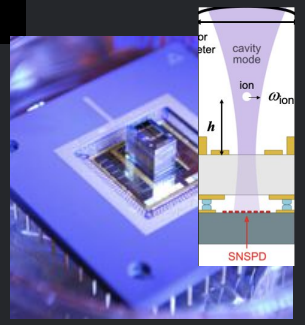


UMD: Nature 449, 68–71 (2007)
UMD: Nature Phys. 11, 37 (2015)
Oxford: PRL 124, 110501 (2020)

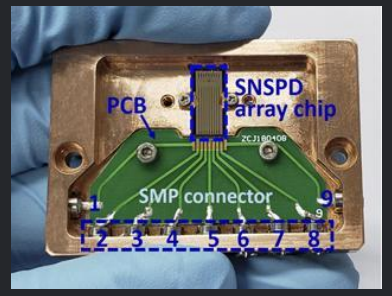
Leverage photonics tech



Integrated optics delivery and collection



Integrated optical cavities



Integrated SNSPD detectors

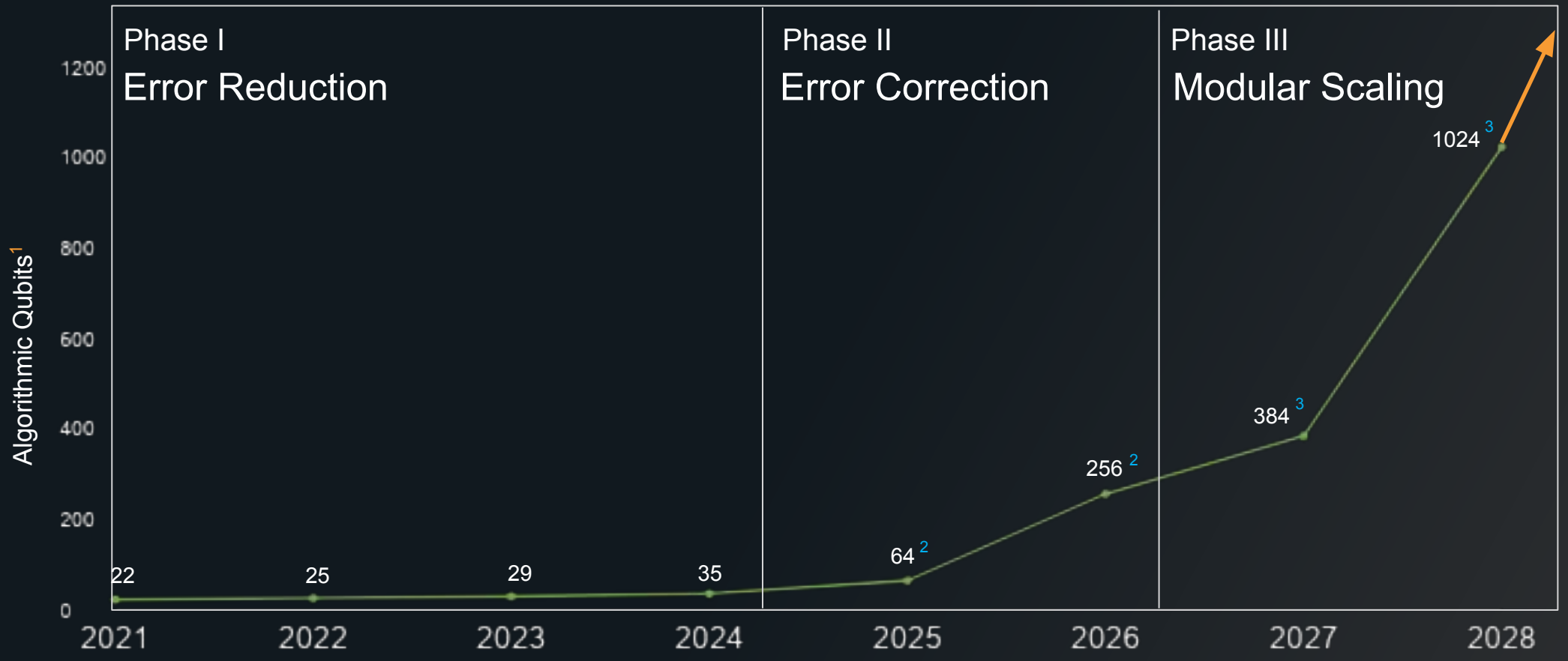
And scale!

1,100-port photonic switch
Jungsang Kim, Bell Labs (2002)

IonQ Technology Roadmap

Scaling the number of algorithmic qubits[1]

1 Algorithmic qubit number defined as the effective number of qubits for typical algorithms, limited by the 2Q gate fidelity
2 Employs 16:1 error-correction encoding
3 Employs 32:1 error-correction encoding



On Oct 1, 2021 IonQ was listed on the NYSE as the first public pure-play quantum computing company, with a $2 billion market capitalization.