Quantum Super Computers

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Quantum Computers

- **Grover's algorithm**
  - Brute-force search time: $2^N \rightarrow 2^{N/2}$
  - optimizers/MIP/AI training
- **Shor's algorithm**
  - Integer-factorization time: $\sim 2^{\sqrt[3]{N}} \rightarrow \sim N^2$
- **Quantum chemistry**
  - Development of pharmaceuticals
- **Quantum simulations**
  - Room temperature superconductors
- **Quantum astronomy**
  - Imaging the surface of expolanets

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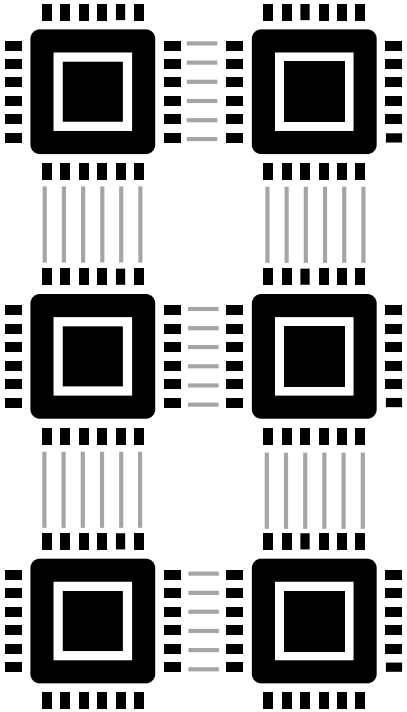
Quantum Networks
Trapped Ions
Quantum Cryptography
Quantum Nanophotonics

NISQ – noisy intermediate scale

	(NISQ) Quantum Computer	Super-Computer = network of processors
Advantage:	? **Speed-up** $\propto \exp(\gamma N_{Qubit})$ for noisy computers	✓ **Scalable (cost** $\propto$ **resources)** ✓ **Capacity** $\propto exp(\gamma t)$
Processor capacity:	Neven's Law* (→ up to few 1000 noisy qubits, or 10s of error corrected qubits)	Moore's Law*
Network capacity:		Keck's Law*

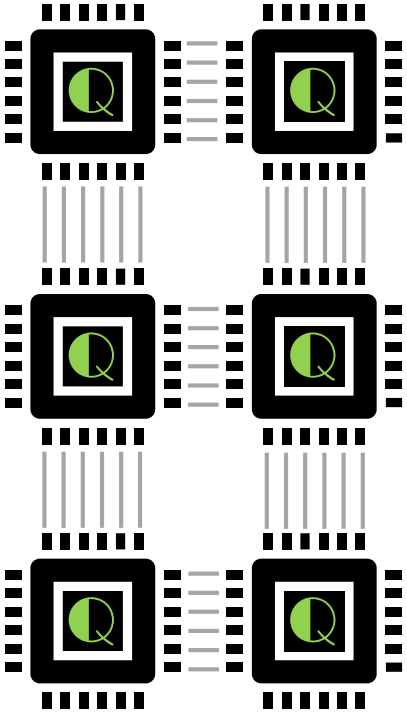
"**NISQ** era"



* Exponential improvement in time

beyond intermediate scale

	Quantum *Super* Computer = network of Q-processors	Super-Computer = network of processors
Advantage:	✓ **Speed-up** $\propto \exp(\gamma N_{Qubit})$ ✓ **Scalable (cost $\propto$ resources)** ✓ **Capacity** $\propto exp(\gamma t)$	✓ **Scalable (cost $\propto$ resources)** ✓ **Capacity** $\propto exp(\gamma t)$
Processor capacity:	Neven's Law*	Moore's Law*
Network capacity:	**Required beyond NISQ**	Keck's Law*

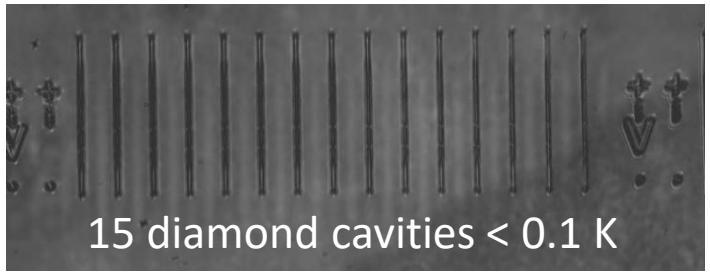


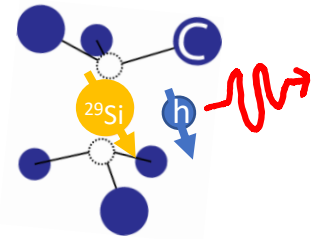
* Exponential improvement in time

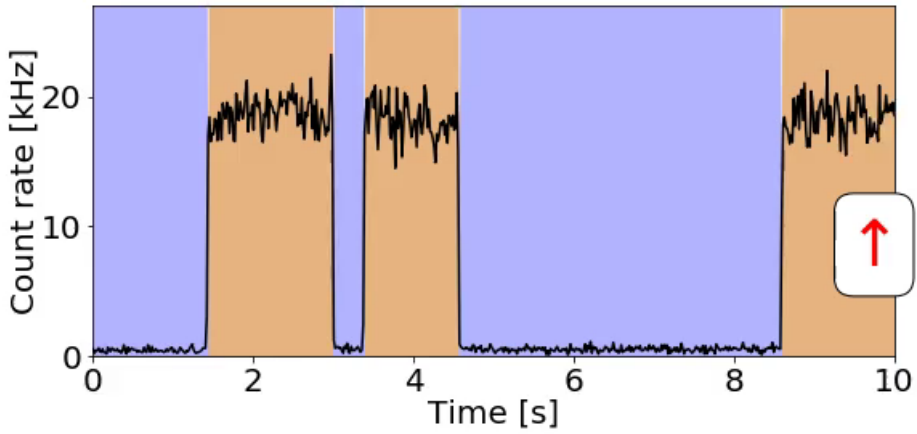
Quantum Network Interfaces

- Nanophotonic Diamond Processors
  - Scalable technology, excellent network interfaces
  - @UHH: expand # of qubits, explore Q-networks

See also:
Bhaskar et al., Nature 2020,
Stas et al., Science 2022

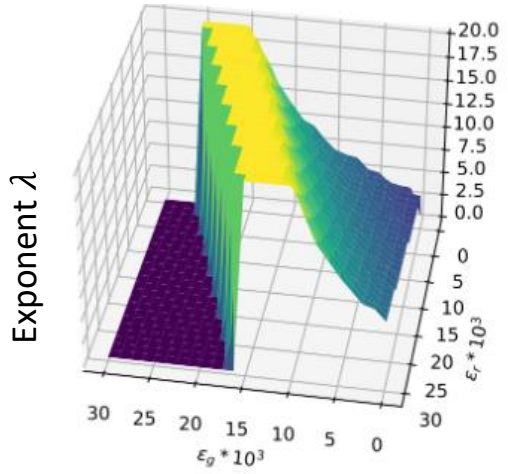






- Network Theory (Airbus + UHH)
  - Resource optimized network operation

See also:
Dawar et al., https://doi.org/10.48550/arXiv.2410.10512



Quantum Network Interfaces

- With EleQtron/NXP/parityQC

  Conventional optical interfaces

See also: https://q-sea.de/

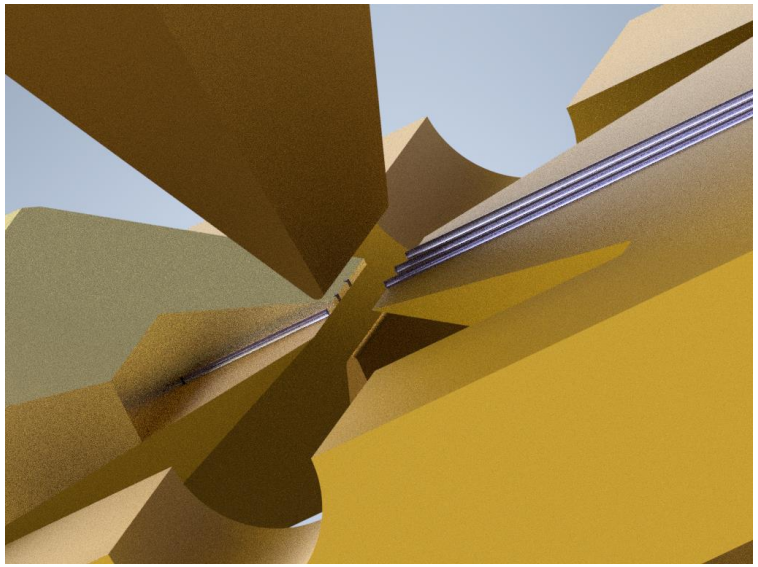
©QSea

- IonLinQ

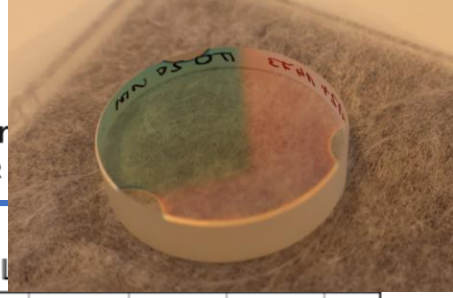
Purcell-enhanced network interfaces

To trapped ion quantum computers

See also:
https://www.quantentechnologien.de/forschung/foerderung/nachwuchswettbewerb-quantum-futur/ionling.html



IonLinQ – conductive mirrors



Trapped Ions:

✓long coherence

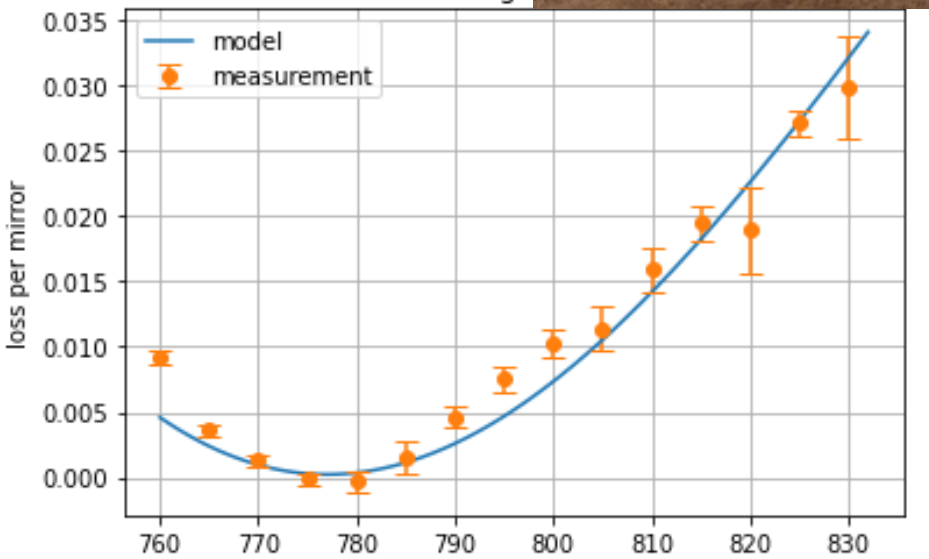
✓high fidelity gates

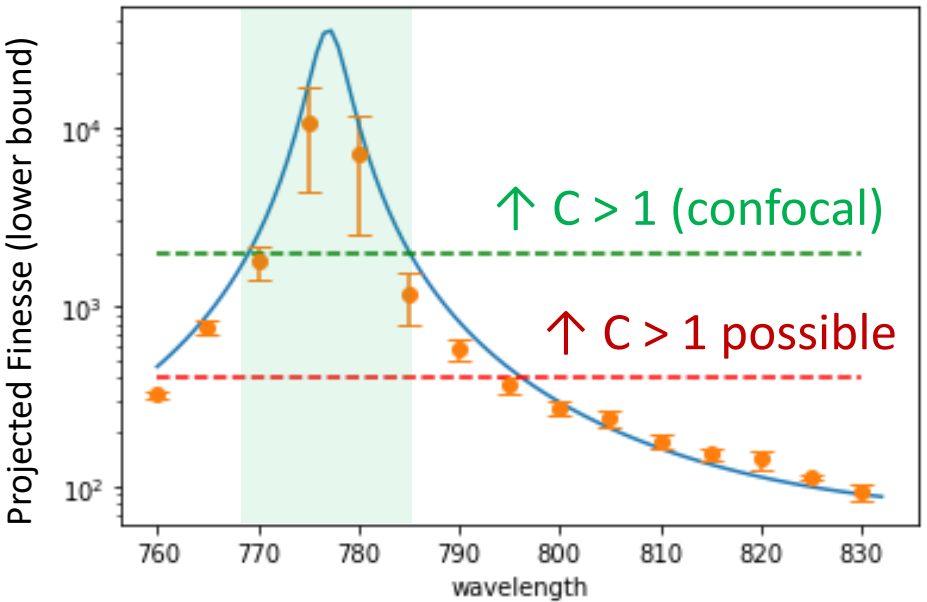
✓“network ready” optical transitions

Charge-noise sensitive

Solution:

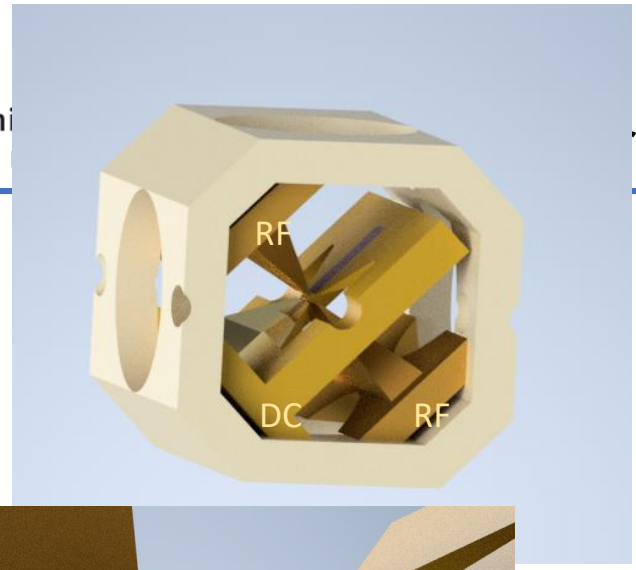
- Conductive mirrors – no shielding needed
- Engineered mode density suppresses optical absorption

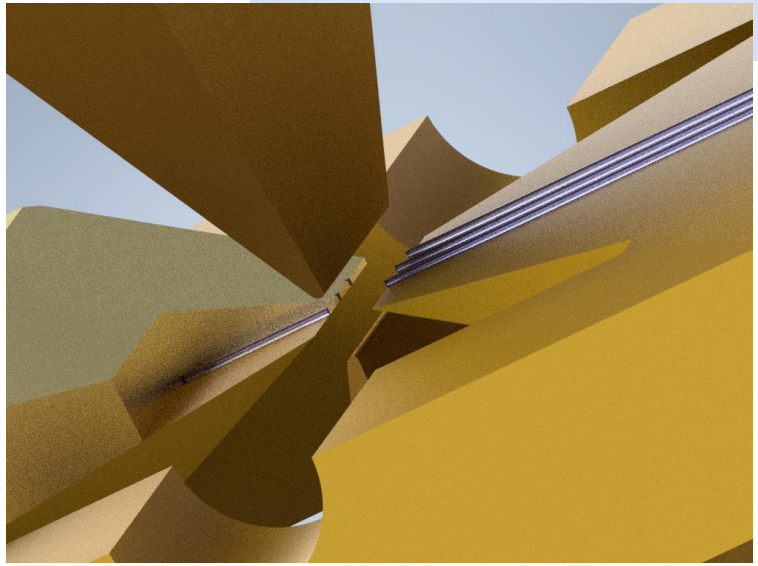




IonLinQ – “Plug-and-play” network adapter

- Integrate in *established processors* – linear trap
- Processor-compatible ion: **Barium 138**
  - Popular secondary/communication ion
  - Visible (493nm), *fast* ground state transition
  - Favorable branching ratio (sub-µs pumping)
  - Outlook: $^{171}Yb^{+}$ sympathetic cooling, $^{133}Ba^{+}$
- Monolithic integration
  alignment free operation





NUMBER 14 PHYSICAL REVIEW LETTERS 6 OCTOBER 1986

Observation of Quantum Jumps

Th. Sauter, W. Neuhauser, R. Blatt, and P. E. Toschek[(a)]
I. Institut für Experimentalphysik, Universität Hamburg, D-2000 Hamburg, Federal Republic of Germany
(Received 12 May 1986)

We have recorded the laser-excited resonance fluorescence of one to three Ba^{+} ions and observed Bohr's "quantum jumps" when an ion decayed to the metastable $^2D_{5/2}$ state, suddenly

PHYSICAL REVIEW A, VOLUME 65, 053401

Raman cooling and heating of two trapped Ba^{+} ions

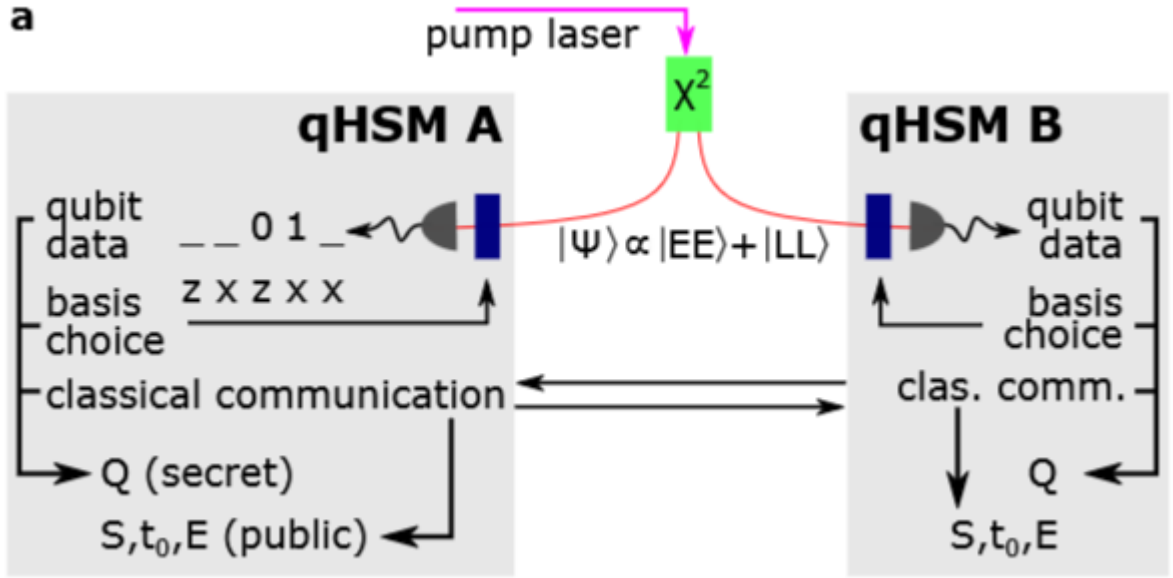
D. Reiß, K. Abich, W. Neuhauser, Ch. Wunderlich, and P. E. Toschek
Institut für Laser-Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany
(Received 15 March 2001; published 12 April 2002)

Quantum Cryptography

- Quantum Thermodynamic Security bounds

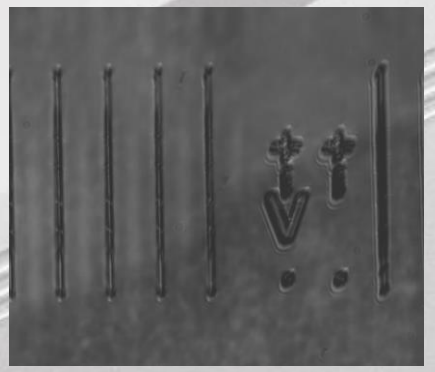
$$W \gtrsim \sqrt{2^N p}\,\frac{\hbar}{t}$$

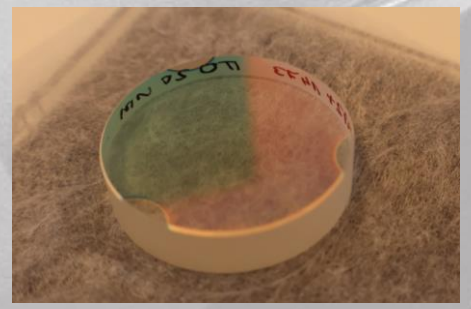
- Scalable quantum-secured cryptography

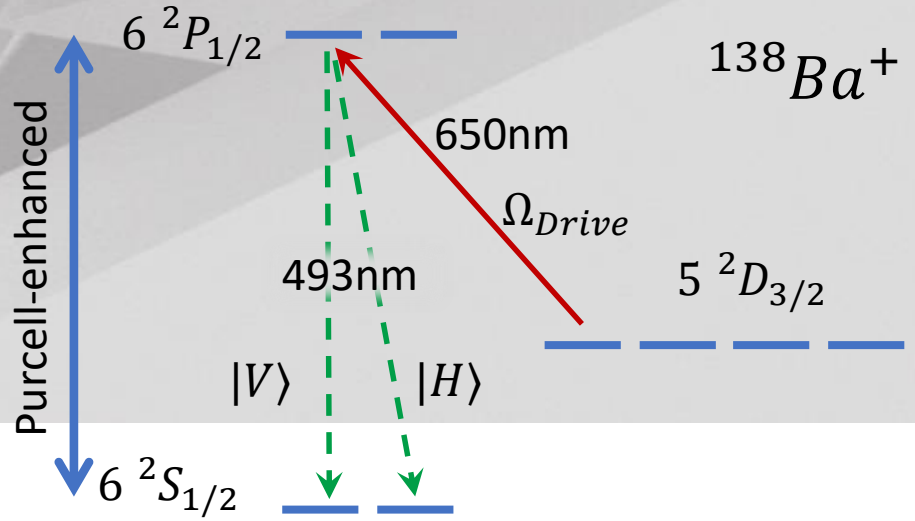


Thank you for your attention

- Quantum Super Computer
- Diamond Nanophotonics
- “Plug-and-play” network adapter for ion traps







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EU/HH