A next-generation trapped ion quantum computing system

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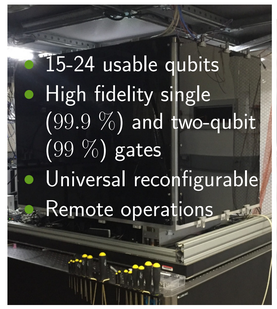
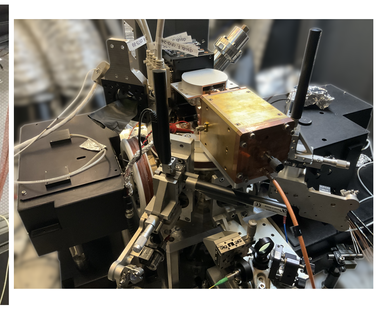
Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype

1st Generation

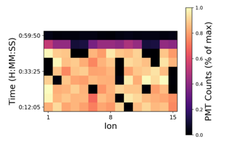


2nd Generation



Vacuum System

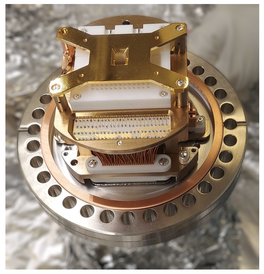
- Vacuum fired components
- Reduce ion-chain reordering rate
- 10^{-11} Torr measured pressure



15-ion chain reordering in 1st gen EURIQA system.

Consistent with 10^{-10} Torr.

Cetina, et al.

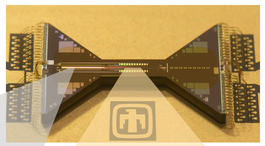


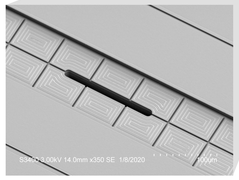
Phoenix Surface Trap

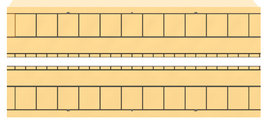
- Better metallization
  - Reducing noise
  - Less charging/photovoltaic effect

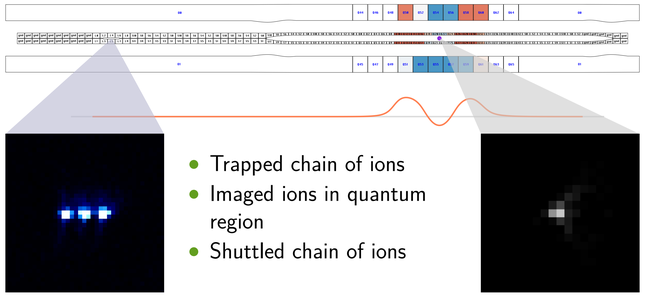
  30 quanta/s heating rate @ 3 MHz

  Measured by Sandia
- Segmented outer electrodes
- Better and faster ion loading



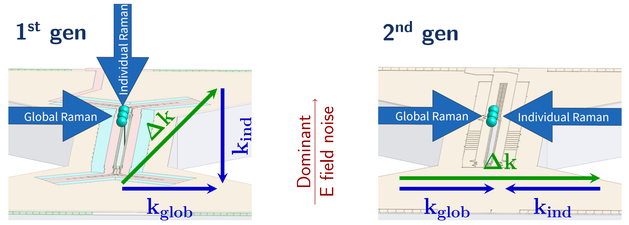


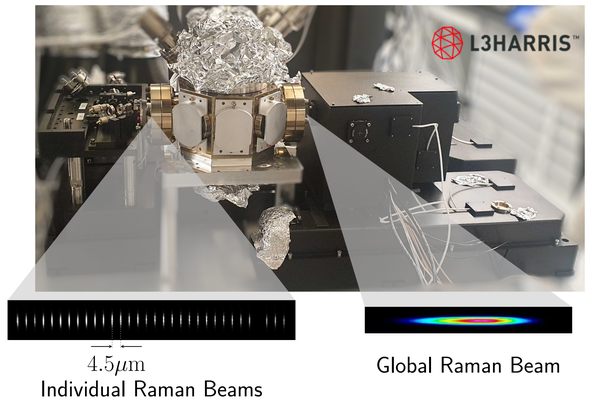




- Trapped chain of ions
- Imaged ions in quantum region
- Shuttled chain of ions

Raman System

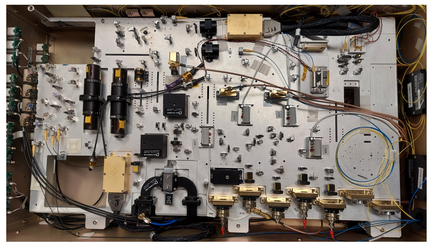




Individual Raman Beams

Global Raman Beam

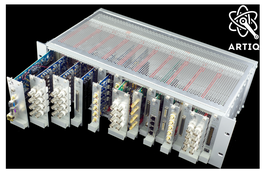
Miniaturized 369/399/780/935nm Beam Path



Control System

ARTIQ

- Artiq software
- Sinara hardware



RFSoC/Pentek

- integrated pulse-level control
- phase synchronization

Duke Artiq Extensions

- modular control software
- system code organization

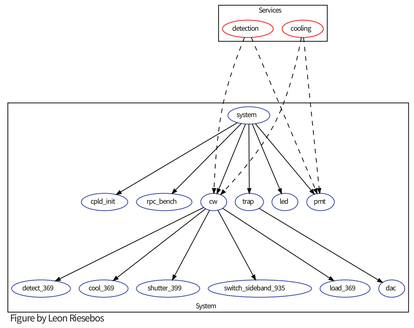
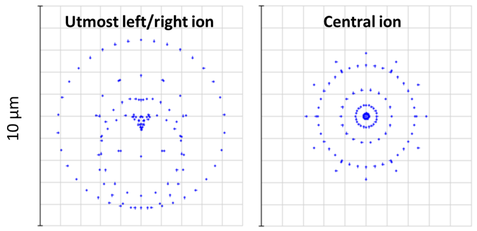
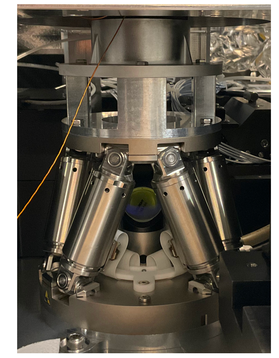


Figure by Leon Riesebos

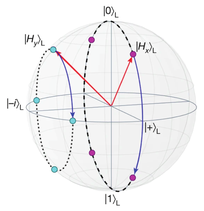
Imaging System

- Imaging system for 32 ions, fixed 4.5 μm spacing between ions
- Two stage imaging system with a total magnification of 27
- Minimized instrumental crosstalk by coupling fluorescence from each ion to the individual PMT module (Hamamatsu, H10682-210)
- PhotonGear optical lens design (0.63 NA) mounted on PI Hexapod for precise positioning
- Zemax simulations: the resulting Strehl ratio is > 0.95 for all 32 ions in the chain





Applications



- Universal Quantum Computer
- 20+ qubits and high fidelity
- Quantum simulations of many body physics
- Quantum chemistry
- Quantum gravity
- Nuclear theory
- Quantum Error Correction