

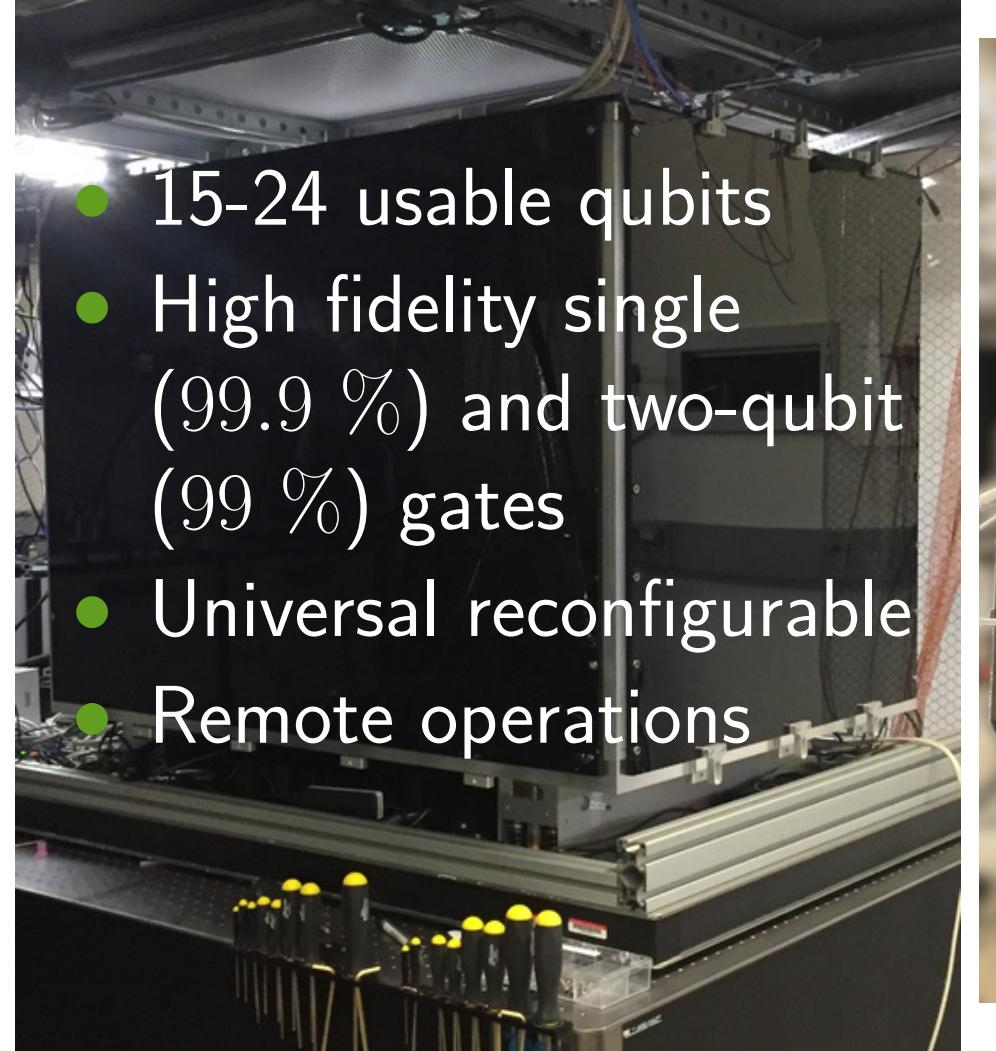
# A next-generation trapped ion quantum computing system

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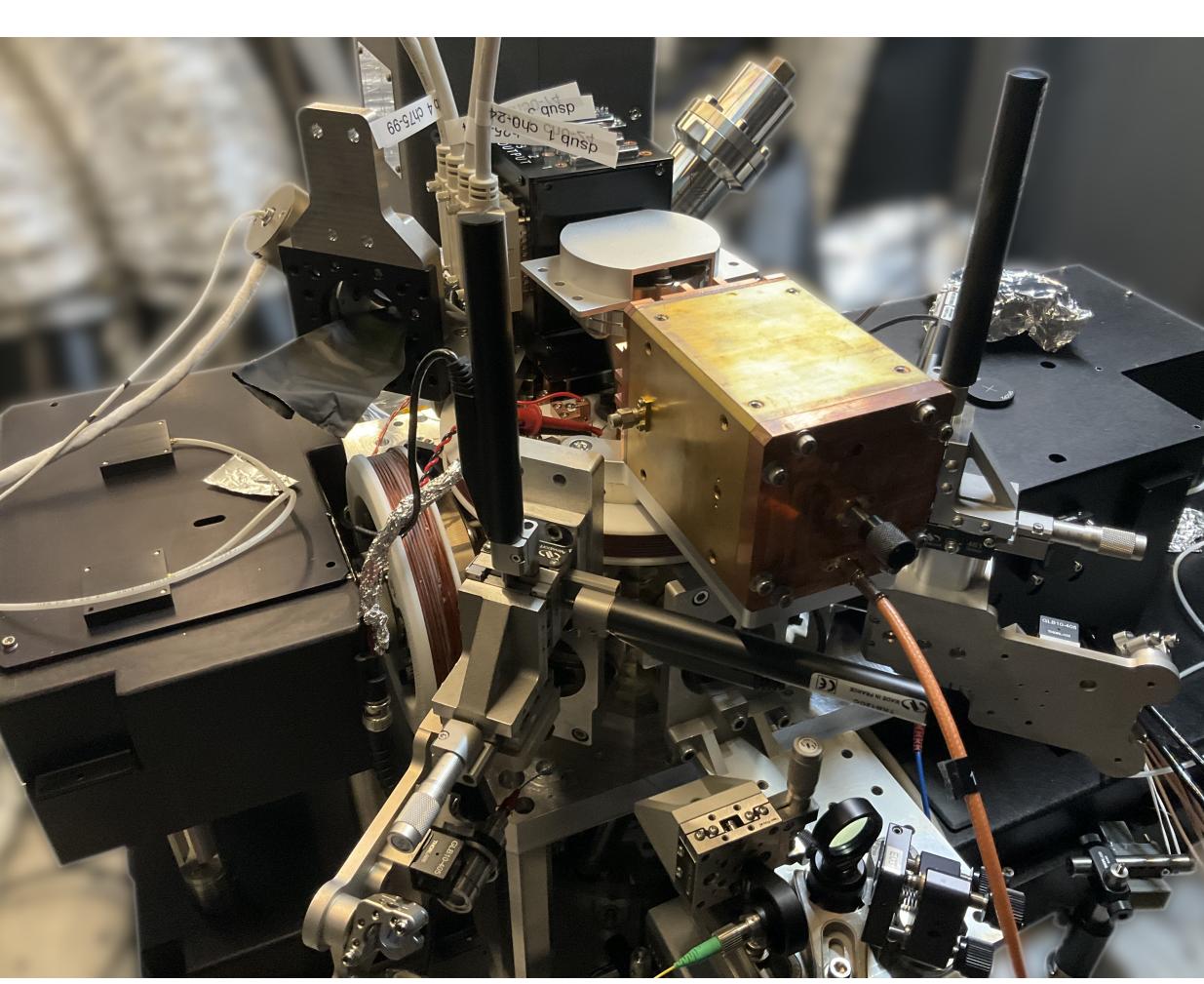
## Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype

### 1<sup>st</sup> Generation



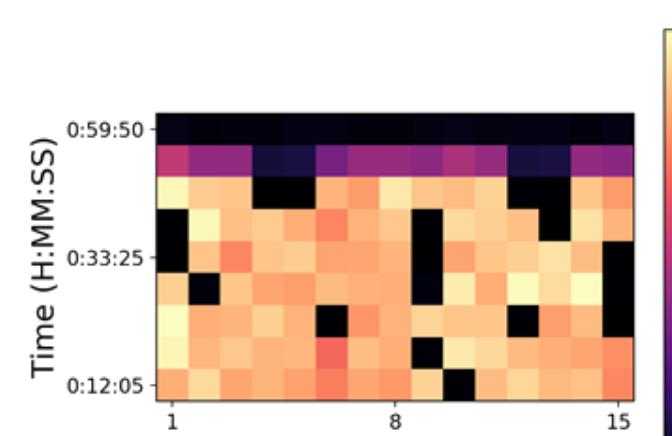
- 15-24 usable qubits
- High fidelity single (99.9 %) and two-qubit (99 %) gates
- Universal reconfigurable
- Remote operations

### 2<sup>nd</sup> Generation



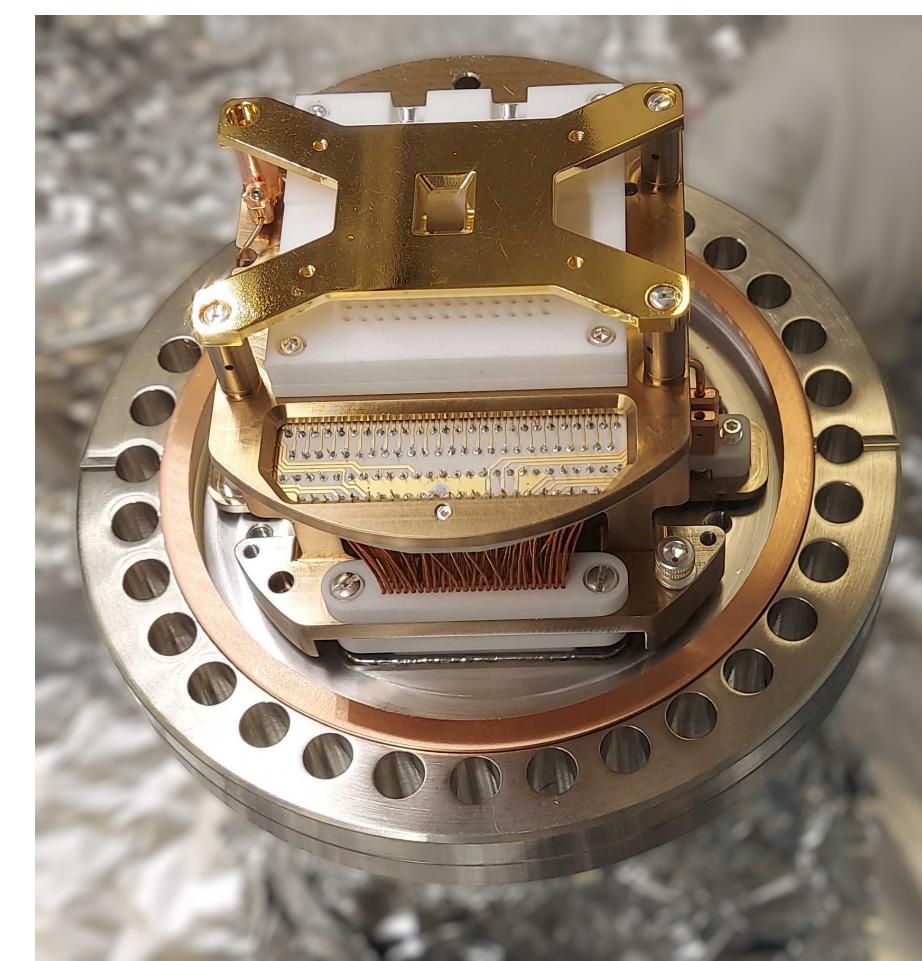
## Vacuum System

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



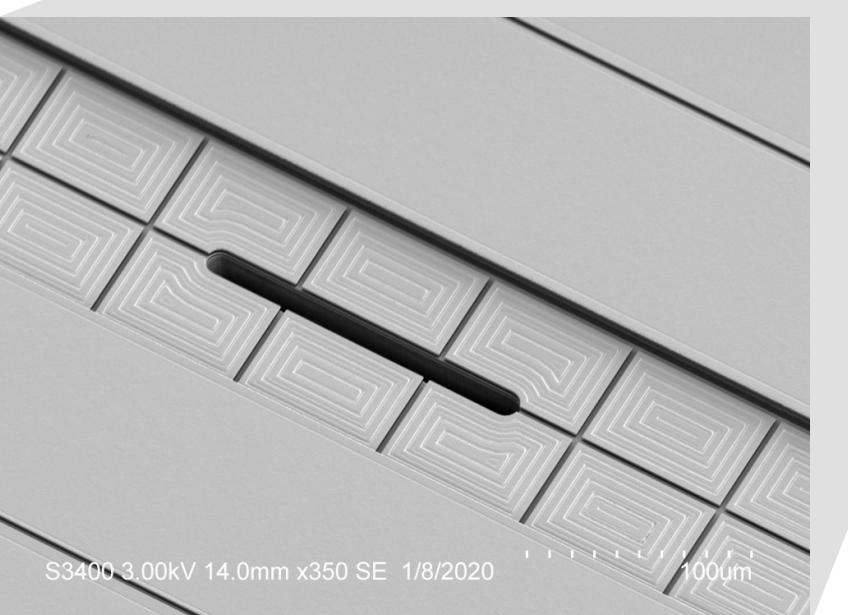
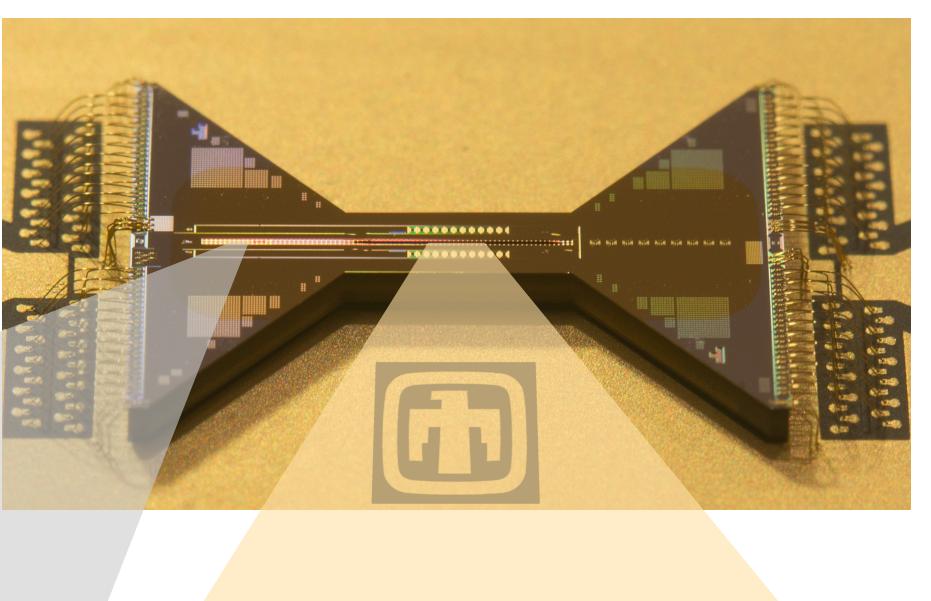
15-ion chain reordering in 1<sup>st</sup> gen EURiQA system.  
Consistent with  $10^{-10}$  Torr.

Cetina, et al.

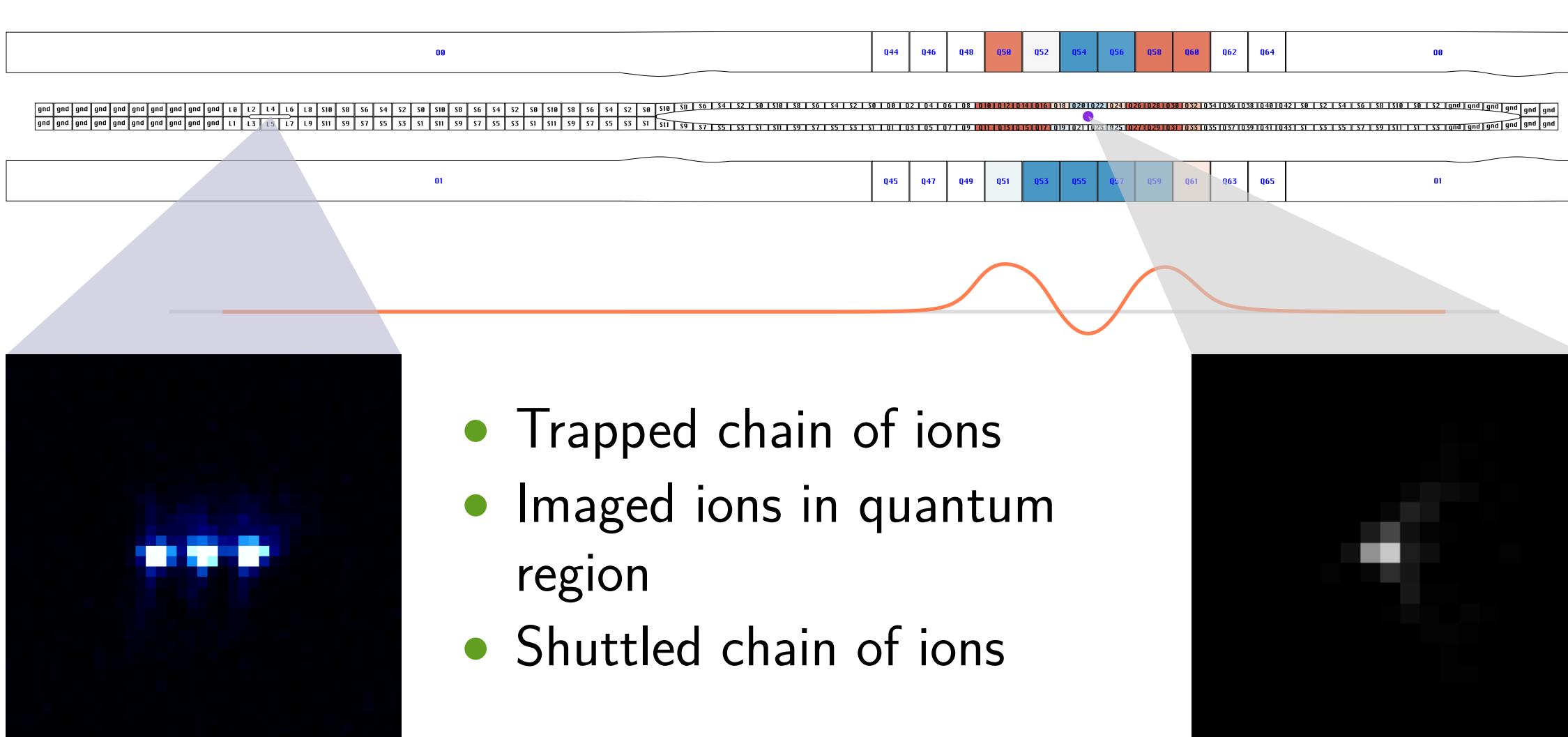


## Phoenix Surface Trap

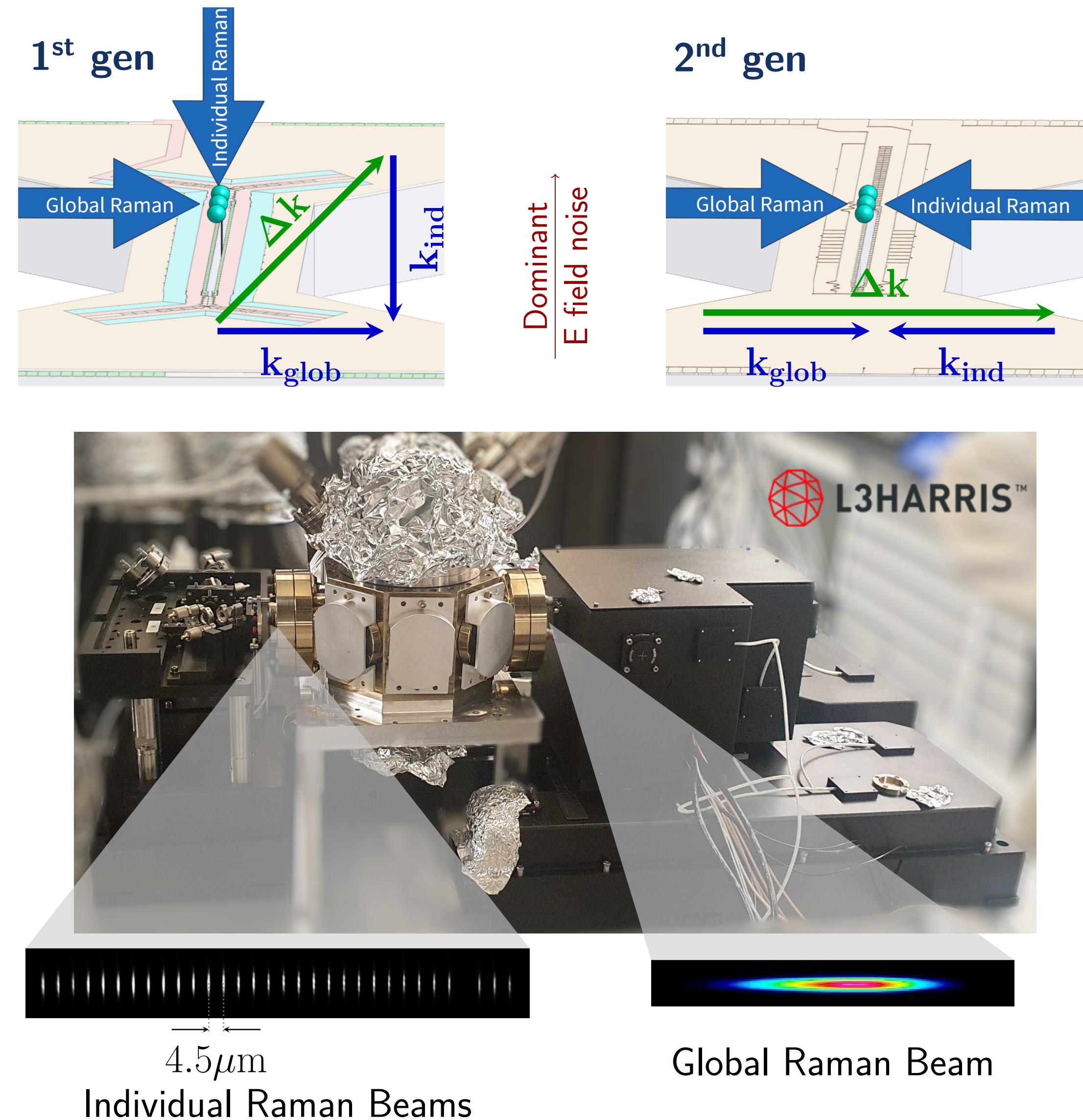
- Better metallization
  - Reducing noise
  - Less charging/photovoltaic effect
- 30 quanta/s heating rate @ 3 MHz  
Measured by Sandia



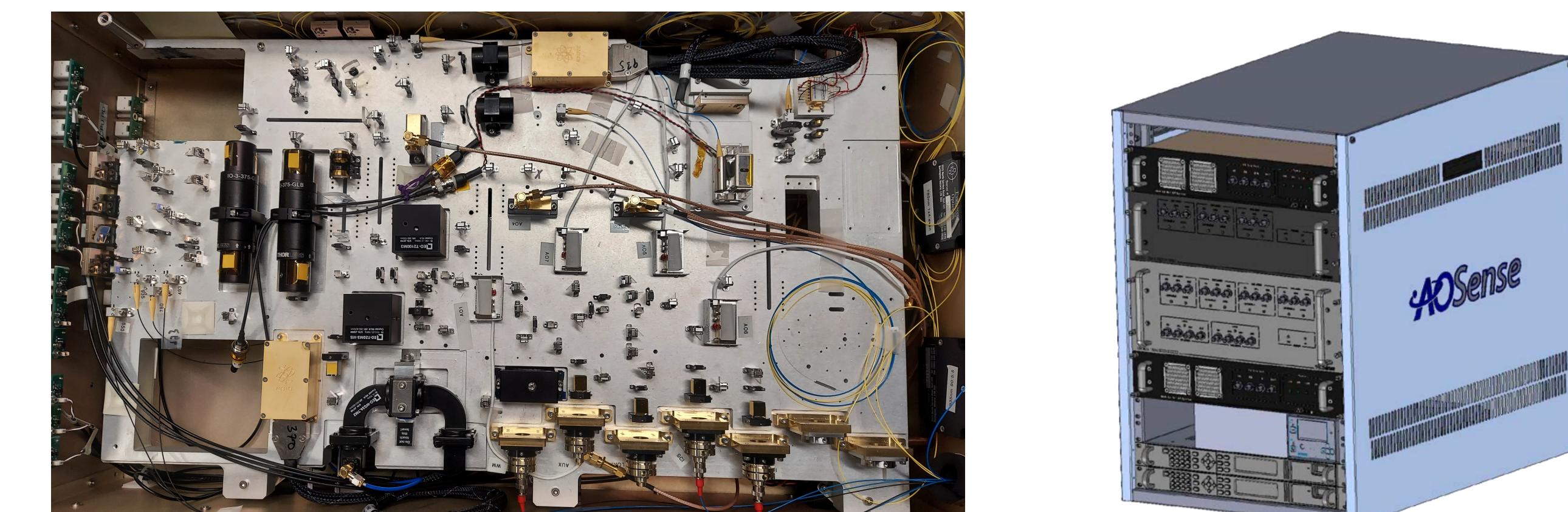
- Trapped chain of ions
- Imaged ions in quantum region
- Shuttled chain of ions



## Raman System



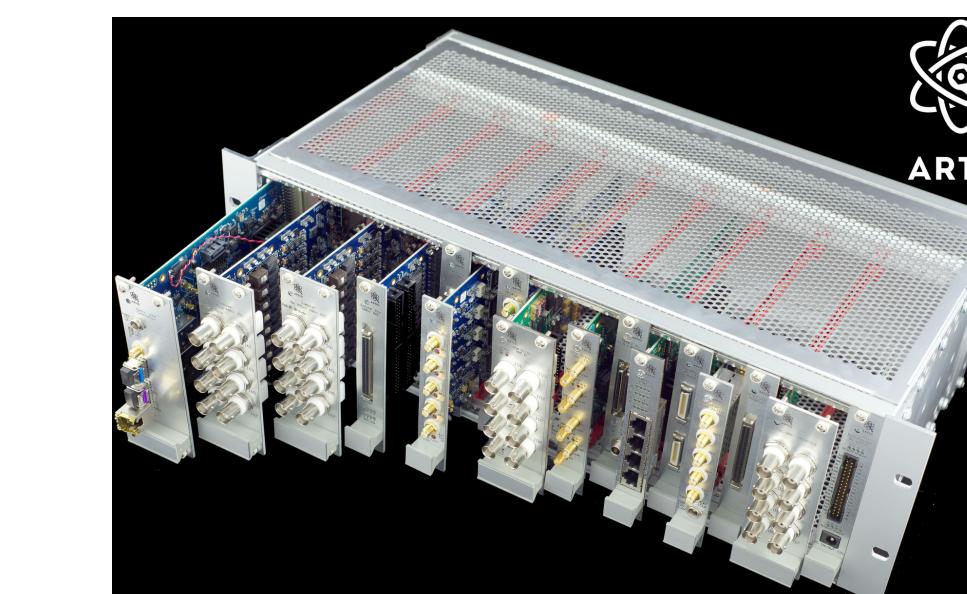
## Miniaturized 369/399/780/935nm Beam Path



## Control System

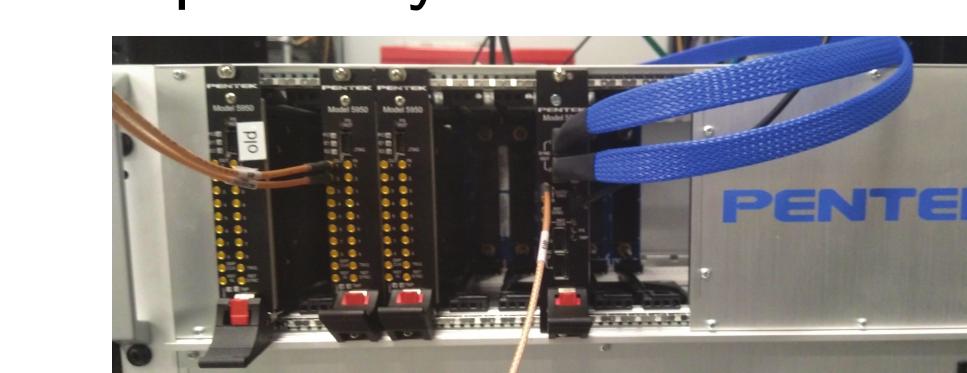
### ARTIQ

- Artiq software
- Sinara hardware



### RFSoC/Pentek

- integrated pulse-level control
- phase synchronization



### Duke Artiq Extensions

- modular control software
- system code organization

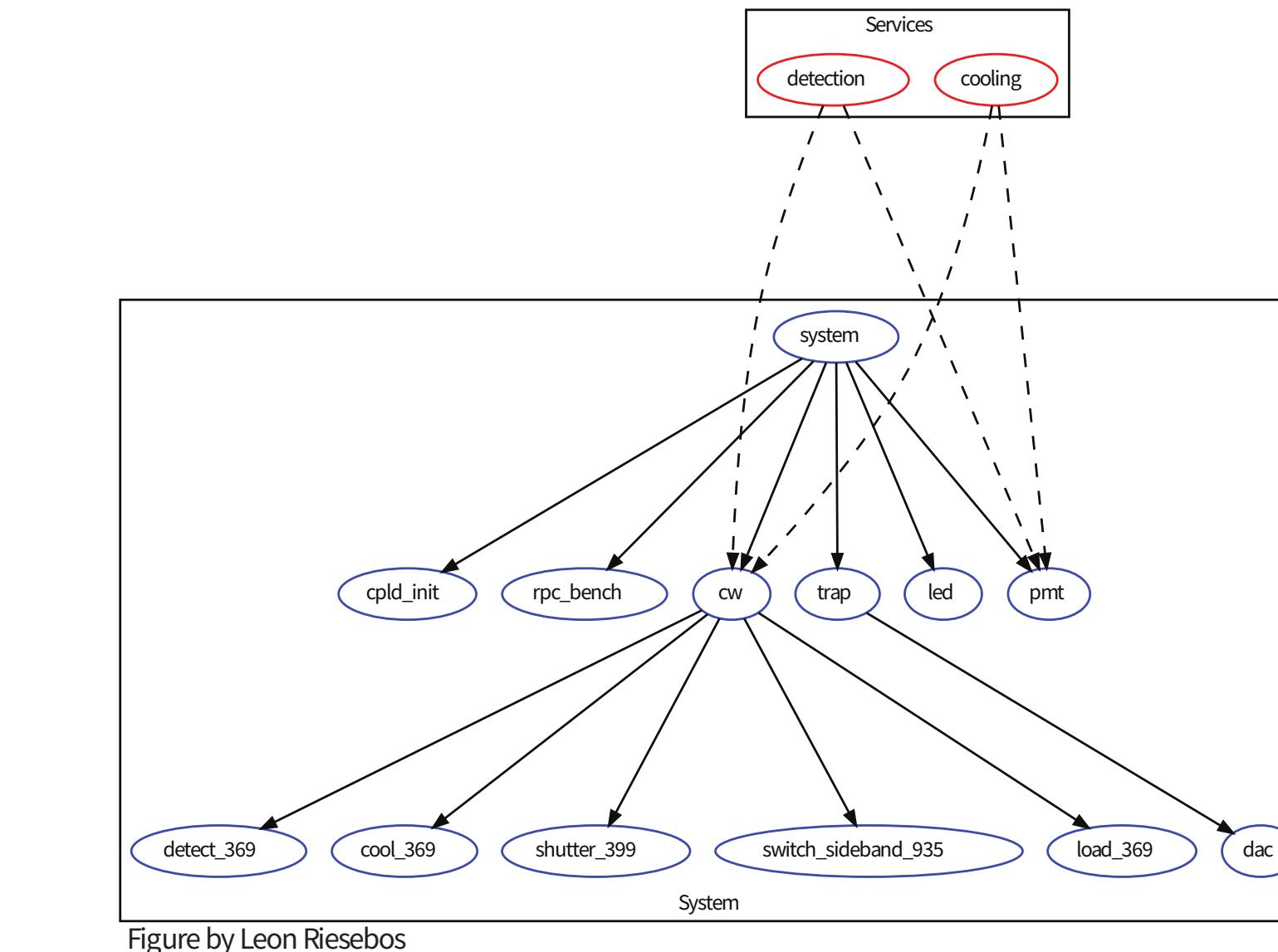
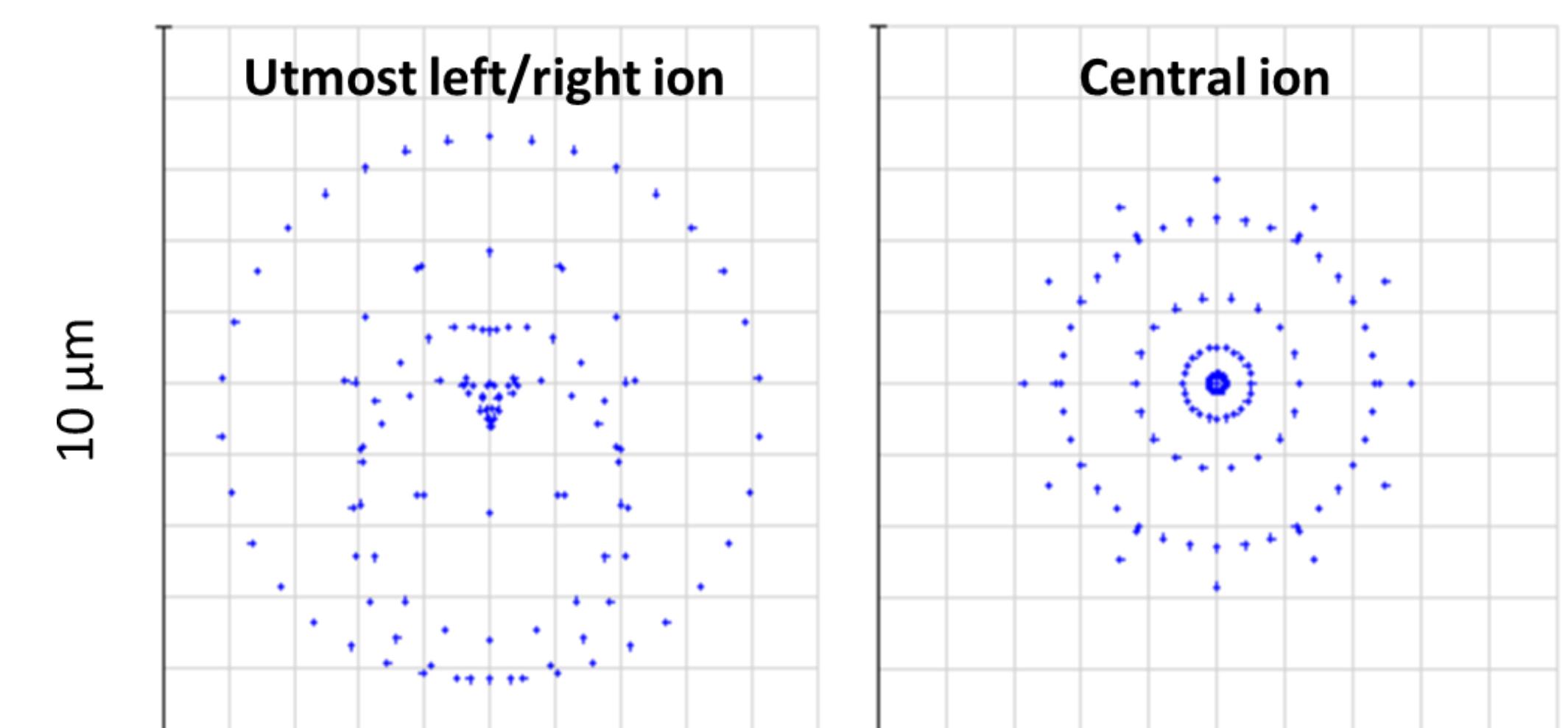


Figure by Leon Riesenb

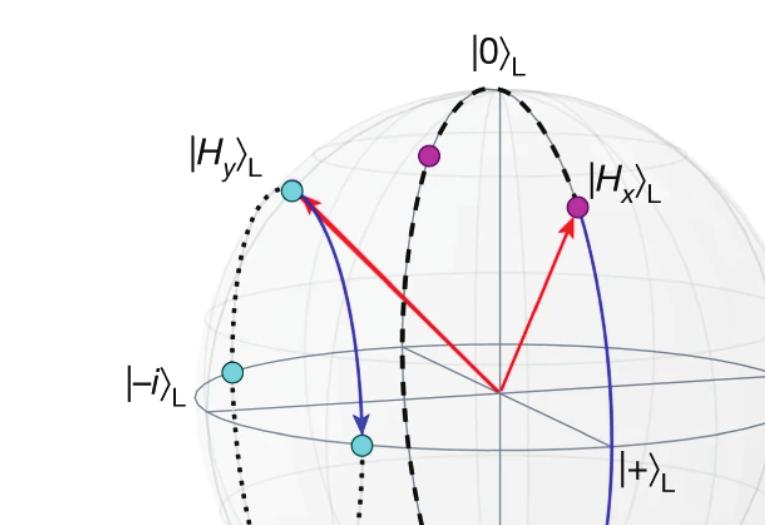
## Imaging System



- Imaging system for 32 ions, fixed 4.5  $\mu\text{m}$  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

