



# A next-generation trapped ion quantum computing system

Yichao Yu

Liudmila Zhukas, Lei Feng, Marko Cetina, Crystal Noel, Debopriyo Biswas,  
Andrew Risinger, Vivian Zhang, Keqin Yan, Bahaa Harraz  
Grant Eberle, Alexander Kozhanov, Christopher R Monroe

Monroe Group/Duke Quantum Center

June 7, 2023



# $^{171}\text{Yb}^+$ qubit

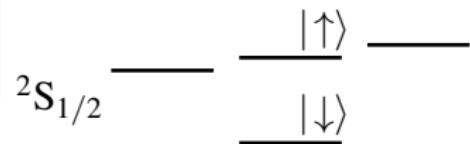
- Long coherence time:  $T_2 \approx 1\text{hr}$

Wang, et al., Nat Commun 12, 233 (2021)

- High fidelity state preparation:  
 $> 99.9\%$  in  $\approx 10\mu\text{s}$
- High speed and high fidelity readout:  
 $> 99.3\%$  in  $\approx 100\mu\text{s}$

Harty, et al., PRL. 113, 22051, (2014)

Christensen, et al., NPJ Quantum Inf. 6, 35 (2020)



# $^{171}\text{Yb}^+$ qubit

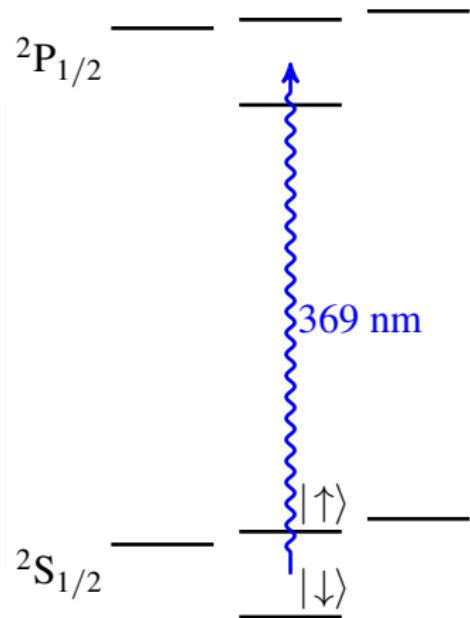
- Long coherence time:  $T_2 \approx 1\text{hr}$

Wang, et al., Nat Commun 12, 233 (2021)

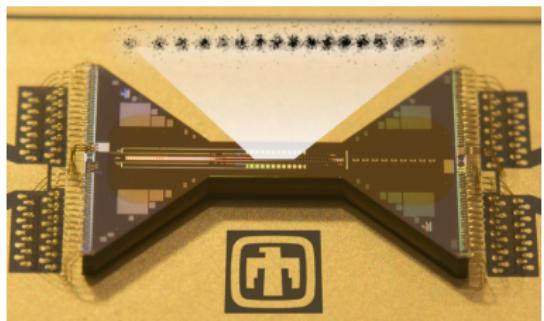
- High fidelity state preparation:  
 $> 99.9\%$  in  $\approx 10\mu\text{s}$
- High speed and high fidelity readout:  
 $> 99.3\%$  in  $\approx 100\mu\text{s}$

Harty, et al., PRL. 113, 22051, (2014)

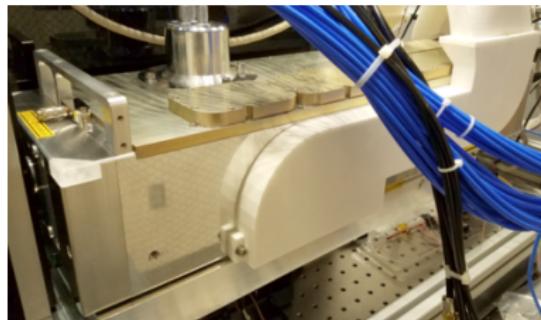
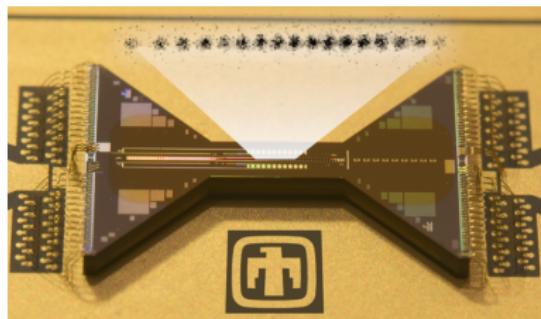
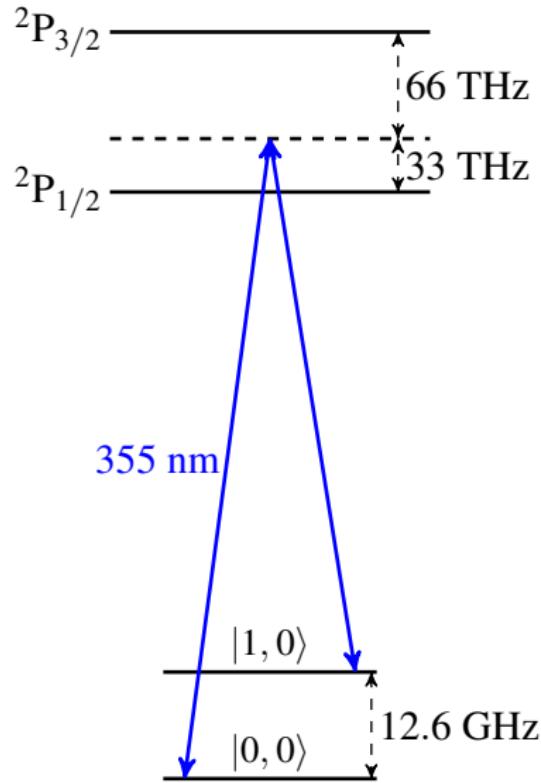
Christensen, et al., NPJ Quantum Inf. 6, 35 (2020)



# $^{171}\text{Yb}^+$ chain and coherent manipulation



# $^{171}\text{Yb}^+$ chain and coherent manipulation



# 1<sup>st</sup> generation EURIQA system

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



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

# 1<sup>st</sup> generation EURIQA system

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



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

# 1<sup>st</sup> generation EURIQA system

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



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

# 1<sup>st</sup> generation EURIQA system

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



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

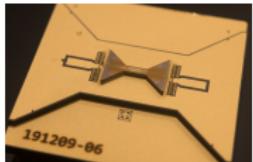
# 1<sup>st</sup> generation EURIQA system

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

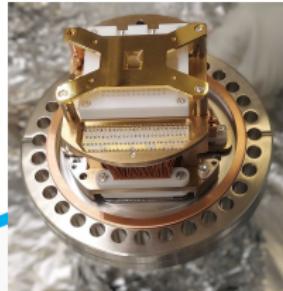


- 15-24 usable qubits
- High fidelity single (99.9 %) and two-qubit (99 %) gates
- Universal reconfigurable
- Remote operations
- K02: Quantum Simulations and Computations with Ion Trap Systems
- Z05: Search for Millicharged Dark Matter with Trapped-Ion Quantum Processor

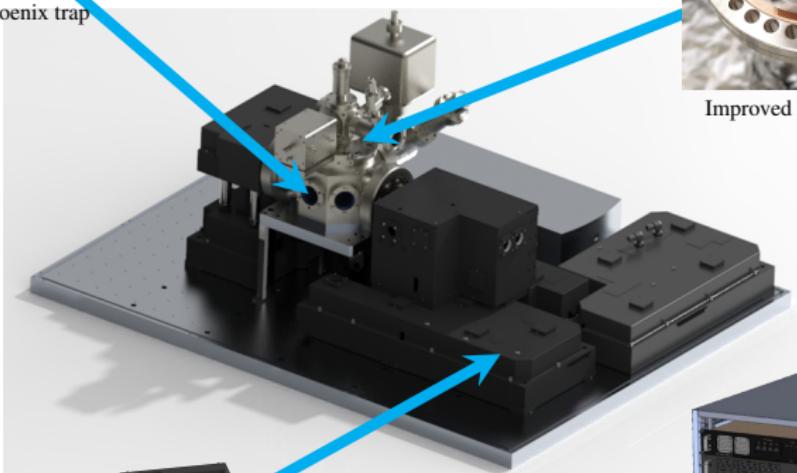
## 2<sup>nd</sup> generation EURIQA system



Sandia Phoenix trap



Improved vacuum system



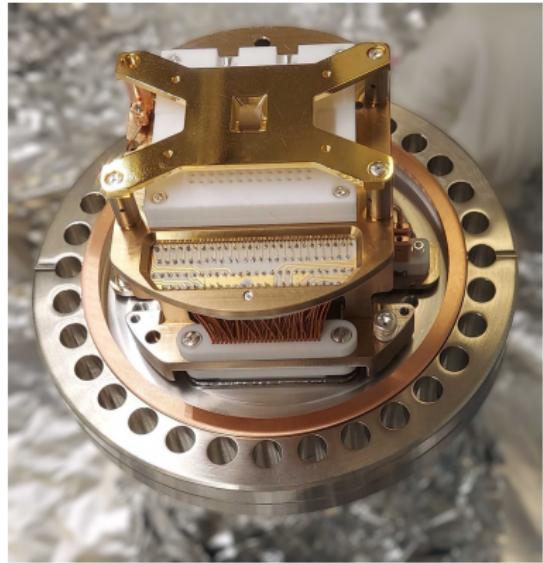
L3Harris Raman beam path



CW lasers

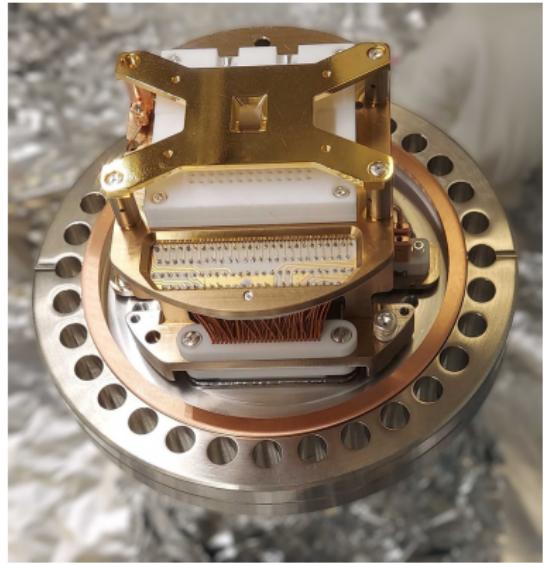
## 2<sup>nd</sup> gen EURIQA: Improved vacuum

- Vacuum fired components
- Reduce ion-chain reordering rate
- $1.32(21) \times 10^{-11}$  Torr measured pressure



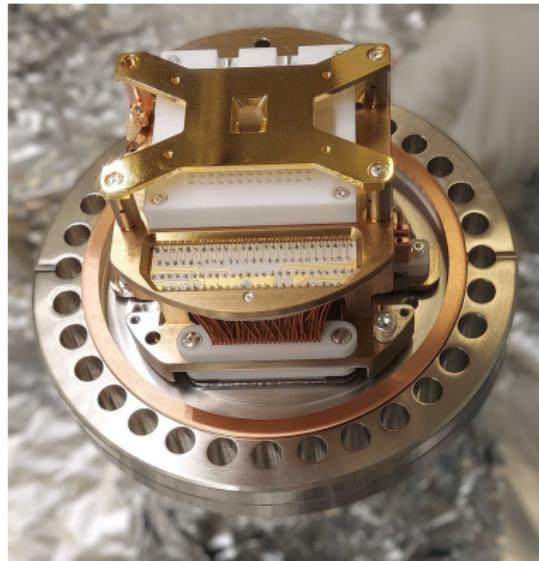
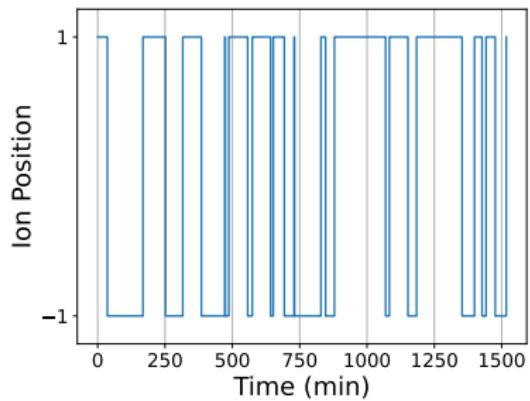
## 2<sup>nd</sup> gen EURIQA: Improved vacuum

- Vacuum fired components
- Reduce ion-chain reordering rate
- $1.32(21) \times 10^{-11}$  Torr measured pressure



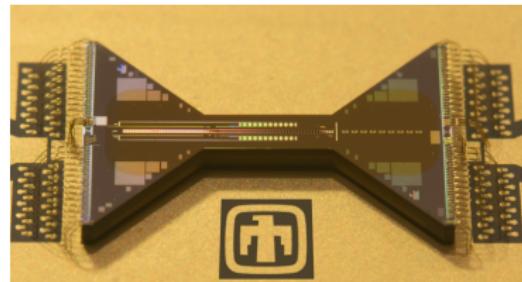
## 2<sup>nd</sup> gen EURIQA: Improved vacuum

- Vacuum fired components
- Reduce ion-chain reordering rate
- $1.32(21) \times 10^{-11}$  Torr measured pressure



## 2<sup>nd</sup> gen EURIQA: Phoenix 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

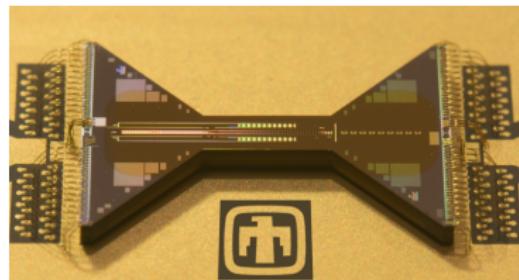


## 2<sup>nd</sup> gen EURIQA: Phoenix trap

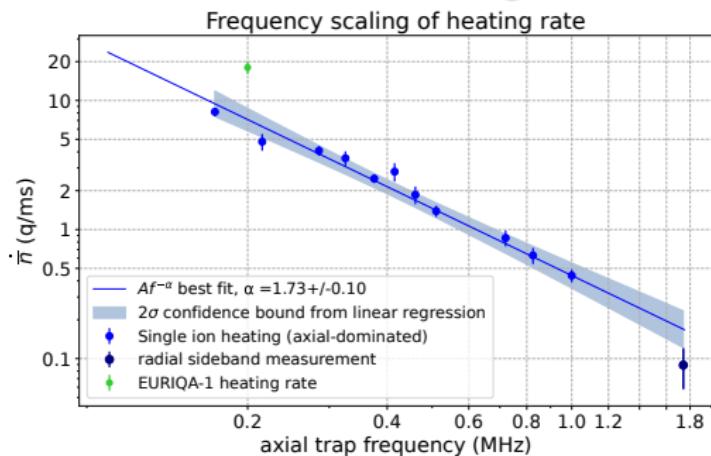
- Better metallization
  - ▶ Reducing noise
  - ▶ Less charging/photovoltaic effect

30 quanta/s heating rate @ 3 MHz

Measured by Sandia

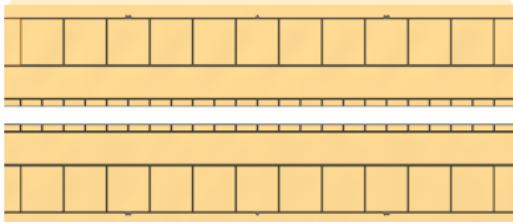
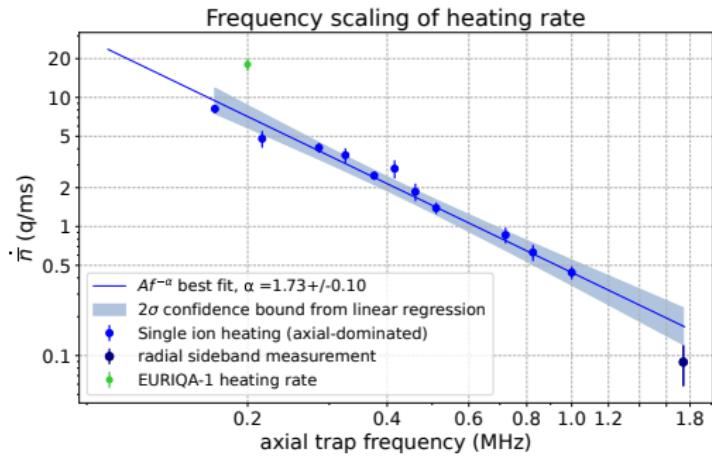
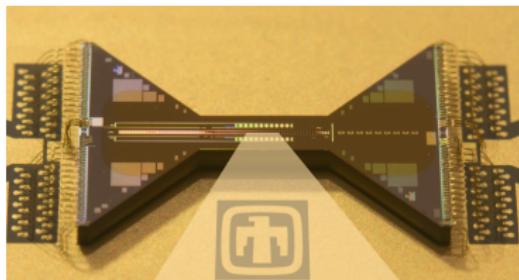


- Segmented outer electrodes
- Better and faster ion loading



## 2<sup>nd</sup> gen EURIQA: Phoenix 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



## 2<sup>nd</sup> gen EURIQA: Phoenix 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

