

A next-generation trapped ion quantum computing system

Yichao Yu

Lei Feng, Liudmila Zhukas, Marko Cetina, Crystal Noel, Debopriyo Biswas,
Andrew Risinger, Alexander Kozhanov, Christopher R Monroe

Monroe Group/Duke Quantum Center

June 2, 2022



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

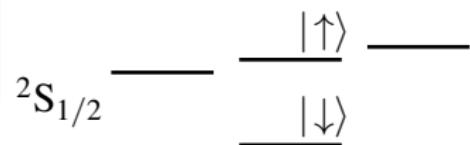
- Long coherence time: $T_2 \approx 1\text{hr}$

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

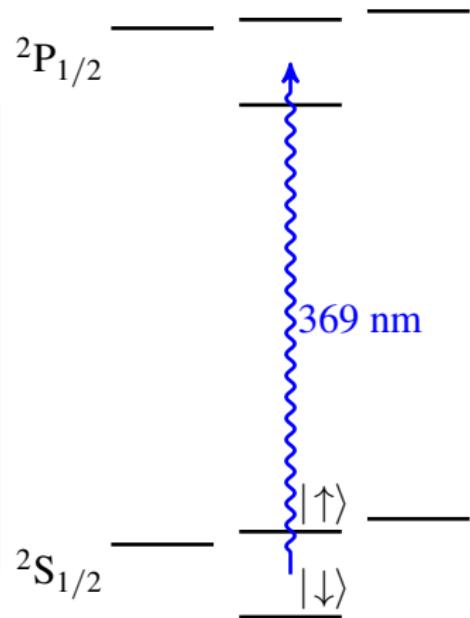
- Long coherence time: $T_2 \approx 1\text{hr}$

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

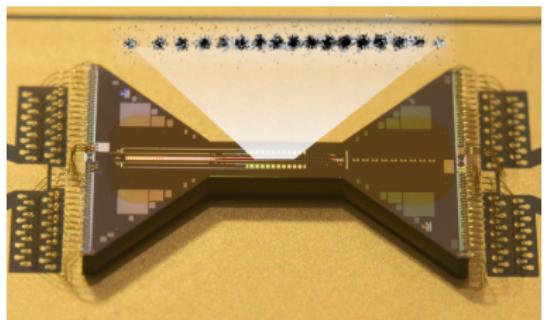
- High fidelity state preparation:
 $> 99.9\%$ in $\approx 10\mu\text{s}$
- High speed and high fidelity readout:
 $> 99.3\%$ in $\approx 100\mu\text{s}$

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

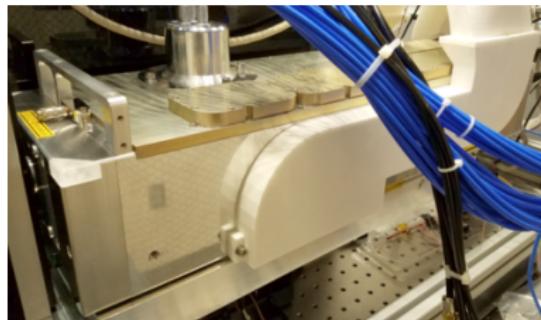
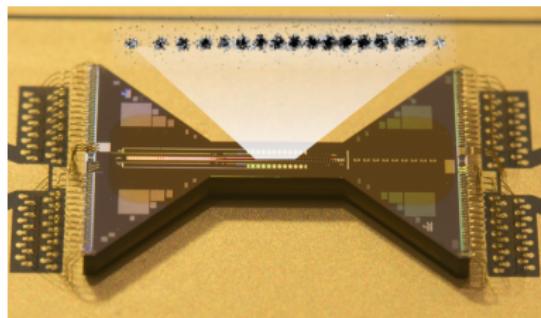
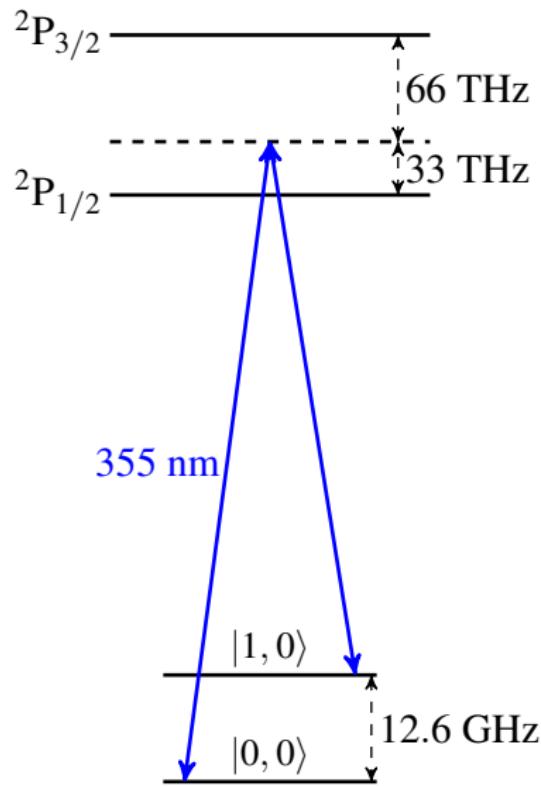
Christensen, et al., NPJ Quantum Inf. 6, 35 (2020)



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



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



1st generation EURIQA system

Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype



- 15-24 qubits
- High fidelity single and two qubit gates
- Universal reconfigurable
- Remote operations

1st generation EURIQA system

Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype



- 15-24 qubits
- High fidelity single and two qubit gates
- Universal reconfigurable
- Remote operations

1st generation EURIQA system

Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype



- 15-24 qubits
- High fidelity single and two qubit gates
- Universal reconfigurable
- Remote operations

1st generation EURIQA system

Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype



- 15-24 qubits
- High fidelity single and two qubit gates
- Universal reconfigurable
- Remote operations

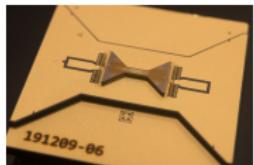
1st generation EURIQA system

Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype

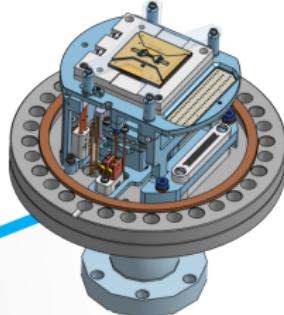


- 15-24 qubits
 - High fidelity single and two qubit gates
 - Universal reconfigurable
 - Remote operations
-
- E06: Programmable N-body interactions with trapped ion qubits
 - E06: Implementing Real-Time Logical Qubit Error Detection & Correction on a Trapped Ion Quantum Computer
 - Q07: Implementation of interactive proofs for quantum advantage on an ion-trap quantum computer
 - U05: Using a trapped ion quantum computer to simulate NMR spectra

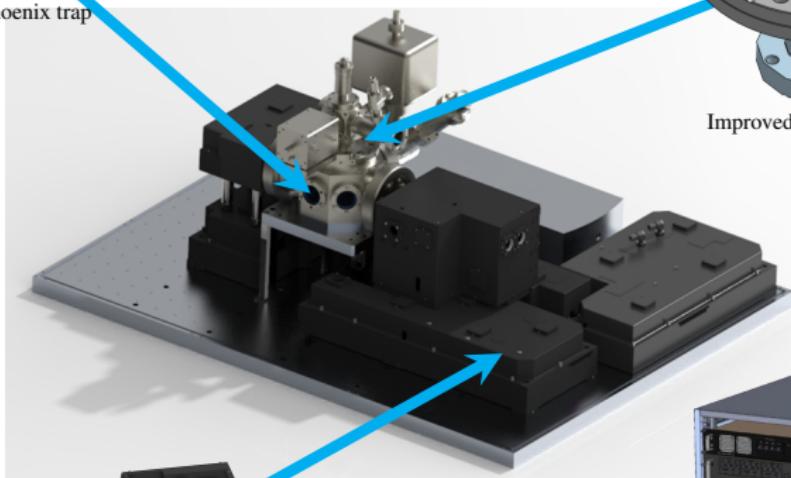
2nd generation EURIQA system



Sandia Phoenix trap



Improved vacuum system



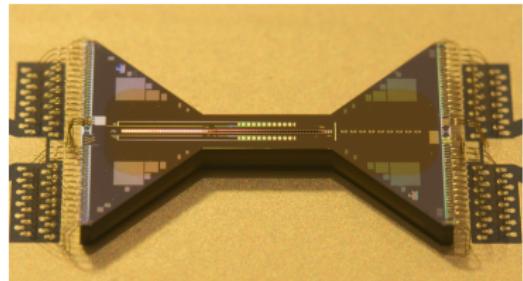
L3Harris Raman beam path



CW lasers

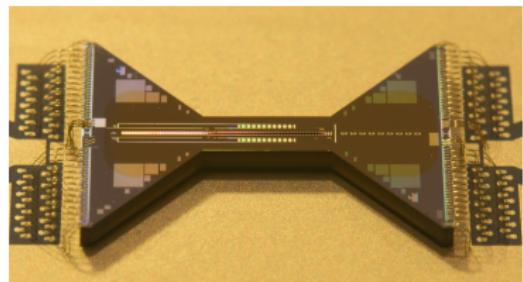
2nd gen EURIQA: Pheonix trap

- Better metallization
 - ▶ Reducing noise
 - ▶ Less charging/photovoltaic effect
- 30 quanta/s @ 3 MHz heating rate
- Segmented outer electrodes
- Better and faster ion loading



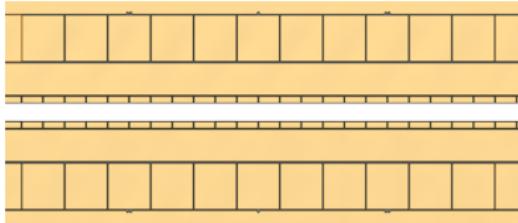
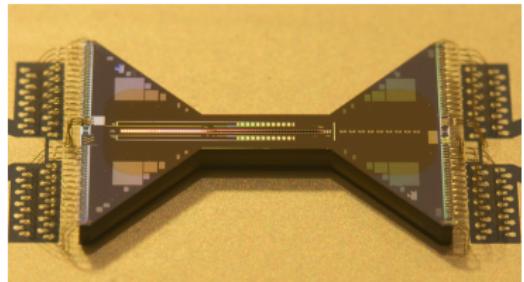
2nd gen EURIQA: Pheonix trap

- Better metallization
 - ▶ Reducing noise
 - ▶ Less charging/photovoltaic effect
- 30 quanta/s @ 3 MHz heating rate
- Segmented outer electrodes
- Better and faster ion loading



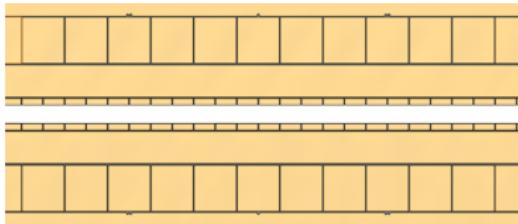
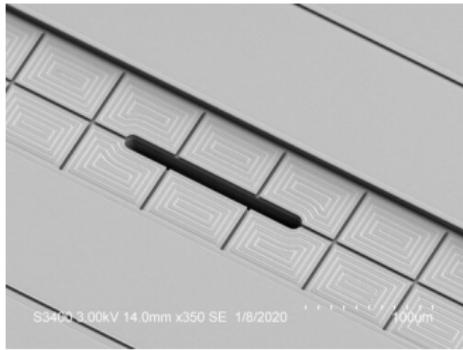
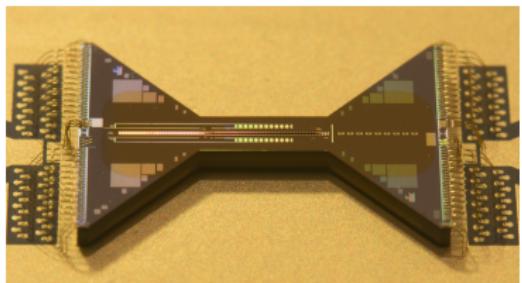
2nd gen EURIQA: Pheonix trap

- Better metallization
 - ▶ Reducing noise
 - ▶ Less charging/photovoltaic effect
- 30 quanta/s @ 3 MHz heating rate
- Segmented outer electrodes
- Better and faster ion loading



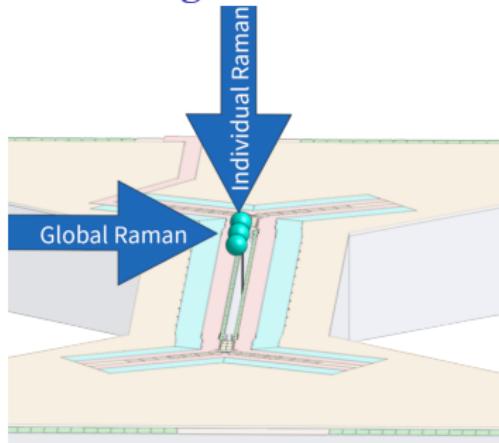
2nd gen EURIQA: Pheonix trap

- Better metallization
 - ▶ Reducing noise
 - ▶ Less charging/photovoltaic effect
- 30 quanta/s @ 3 MHz heating rate
- Segmented outer electrodes
- Better and faster ion loading

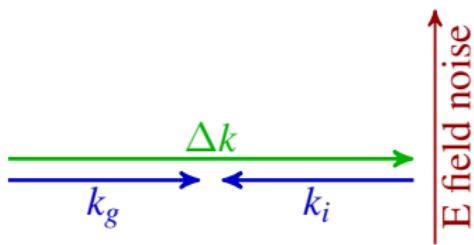
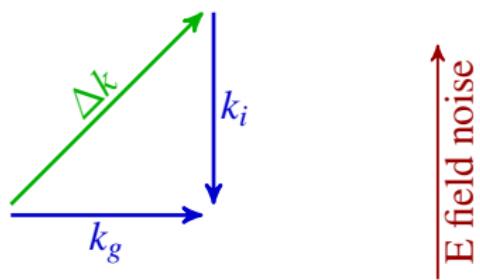
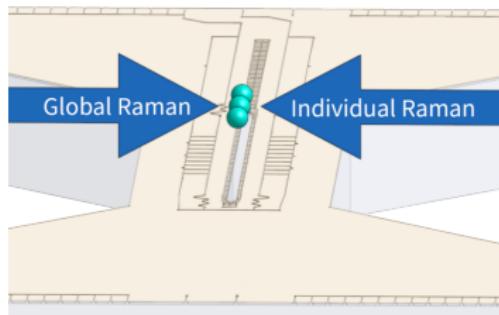


2nd gen EURIQA: Raman geometry

1st gen Raman



2nd gen Raman

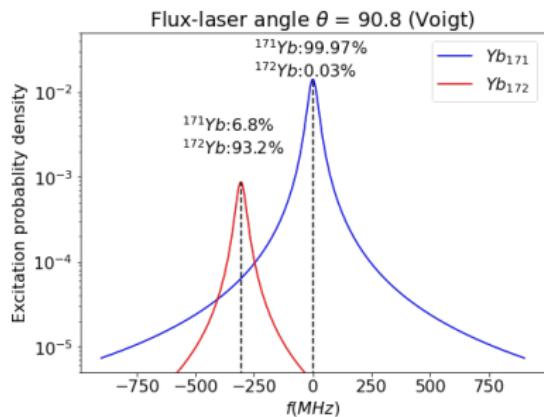


2nd gen EURIQA: New Yb atom source

- Sympathetic cooling with $^{172}\text{Yb}^+$
Cetina, et al., PRX Quantum 3, 010334 (2022)
- New Yb source to enhance loading
of $^{172}\text{Yb}^+$

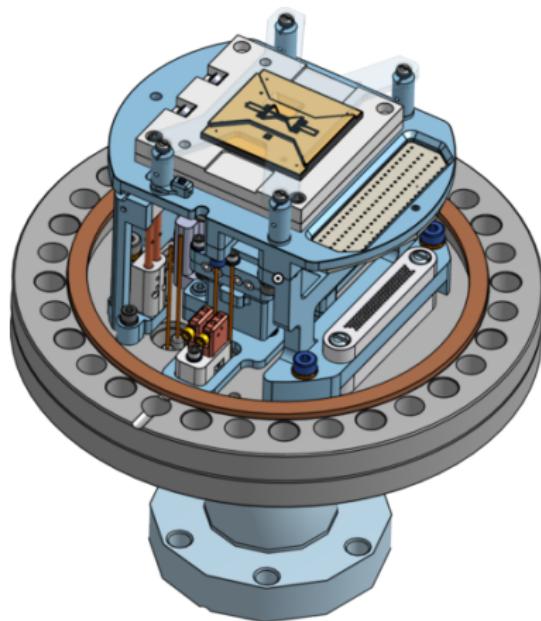
2nd gen EURIQA: New Yb atom source

- Sympathetic cooling with $^{172}\text{Yb}^+$
Cetina, et al., PRX Quantum 3, 010334 (2022)
- New Yb source to enhance loading
of $^{172}\text{Yb}^+$



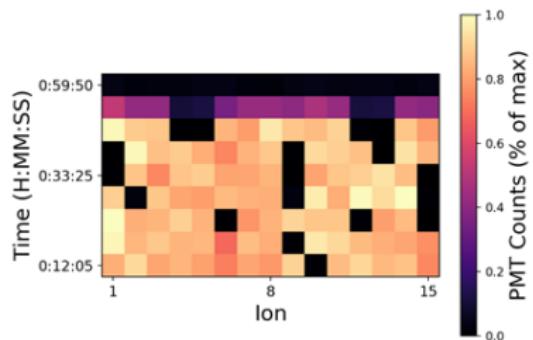
2nd gen EURIQA: Improved vacuum

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



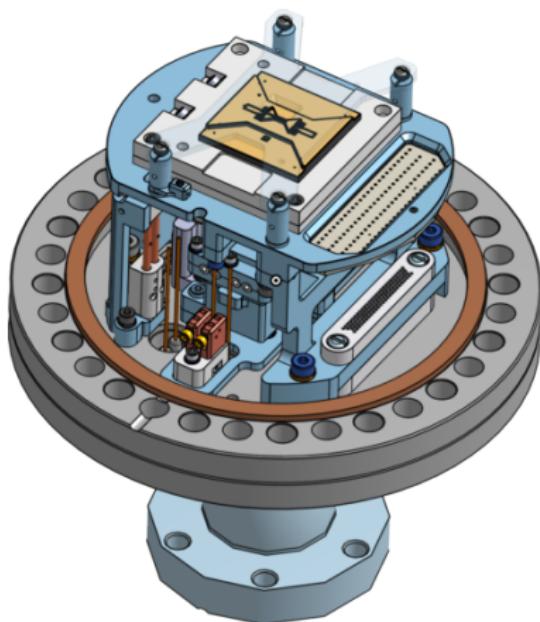
2nd gen EURIQA: Improved vacuum

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



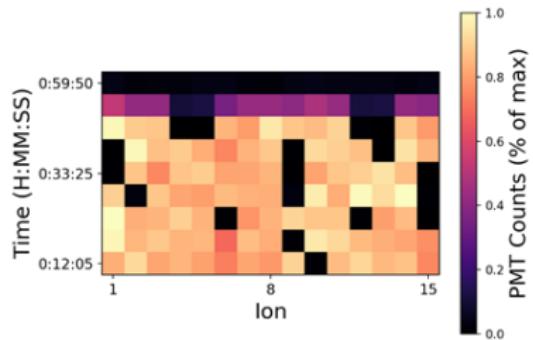
15-ion chain reordering
in 1st gen EURIQA system.
Consistent with 10^{-10} Torr.

Cetina, et al.



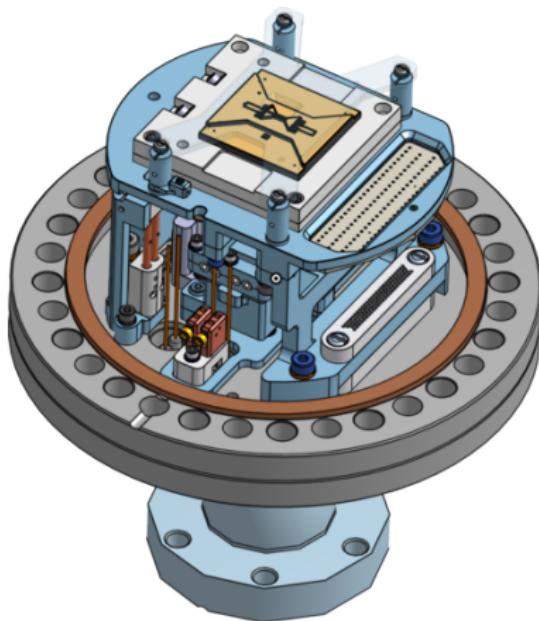
2nd gen EURIQA: Improved vacuum

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

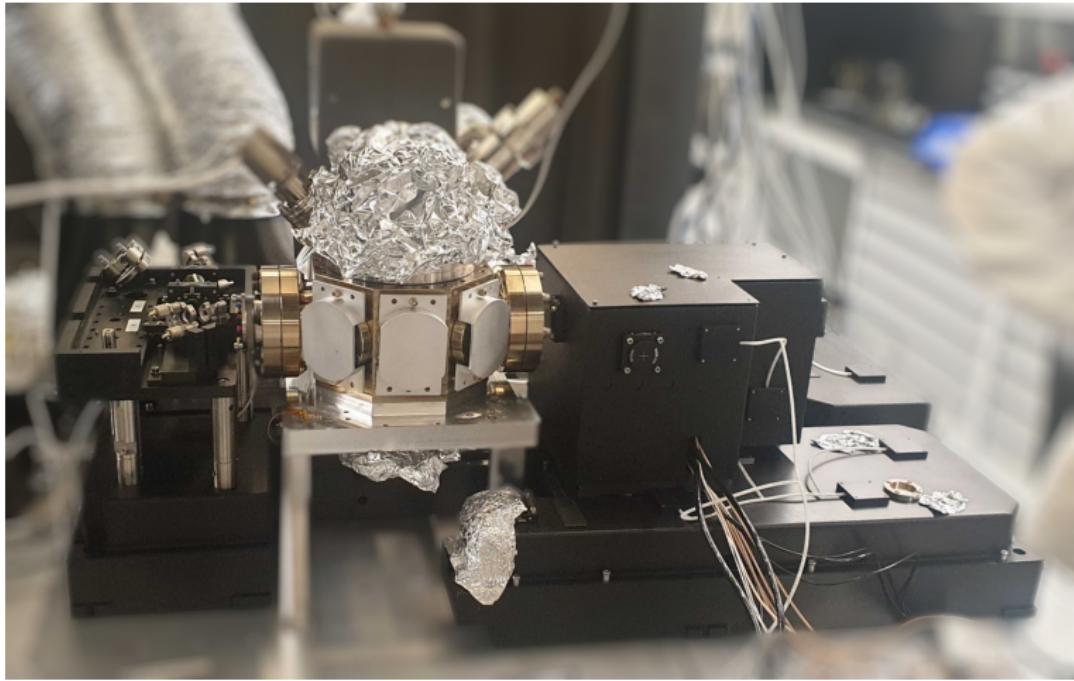


15-ion chain reordering
in 1st gen EURIQA system.
Consistent with 10^{-10} Torr.

Cetina, et al.

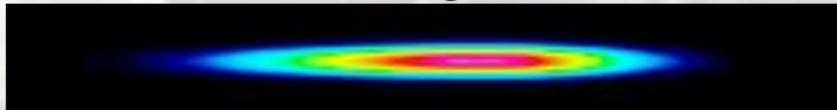


2nd gen EURIQA: Raman beam path

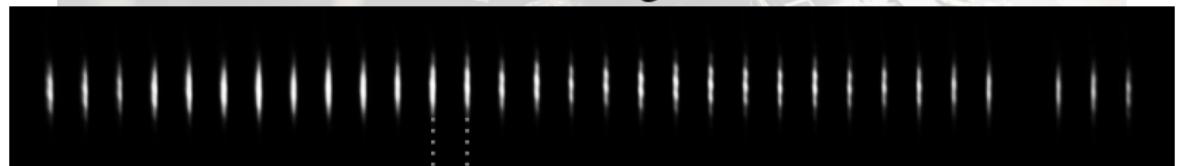


2nd gen EURIQA: Raman beam path

Global addressing Raman beam



Individual addressing Raman beam



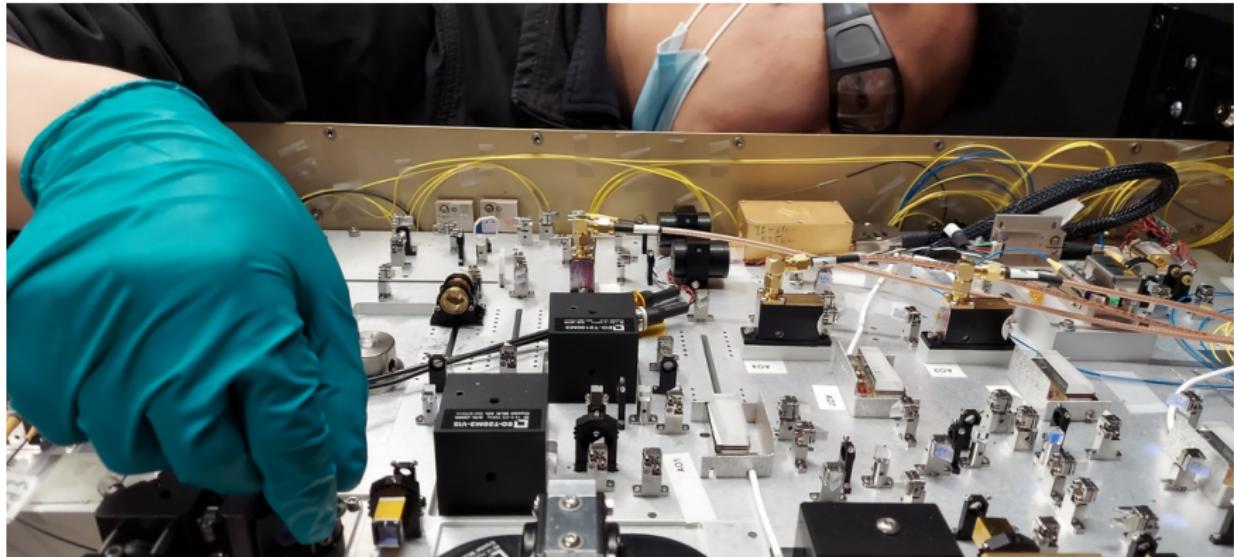
→ ←
 $4.5\mu\text{m}$

2nd gen EURIQA: CW lasers

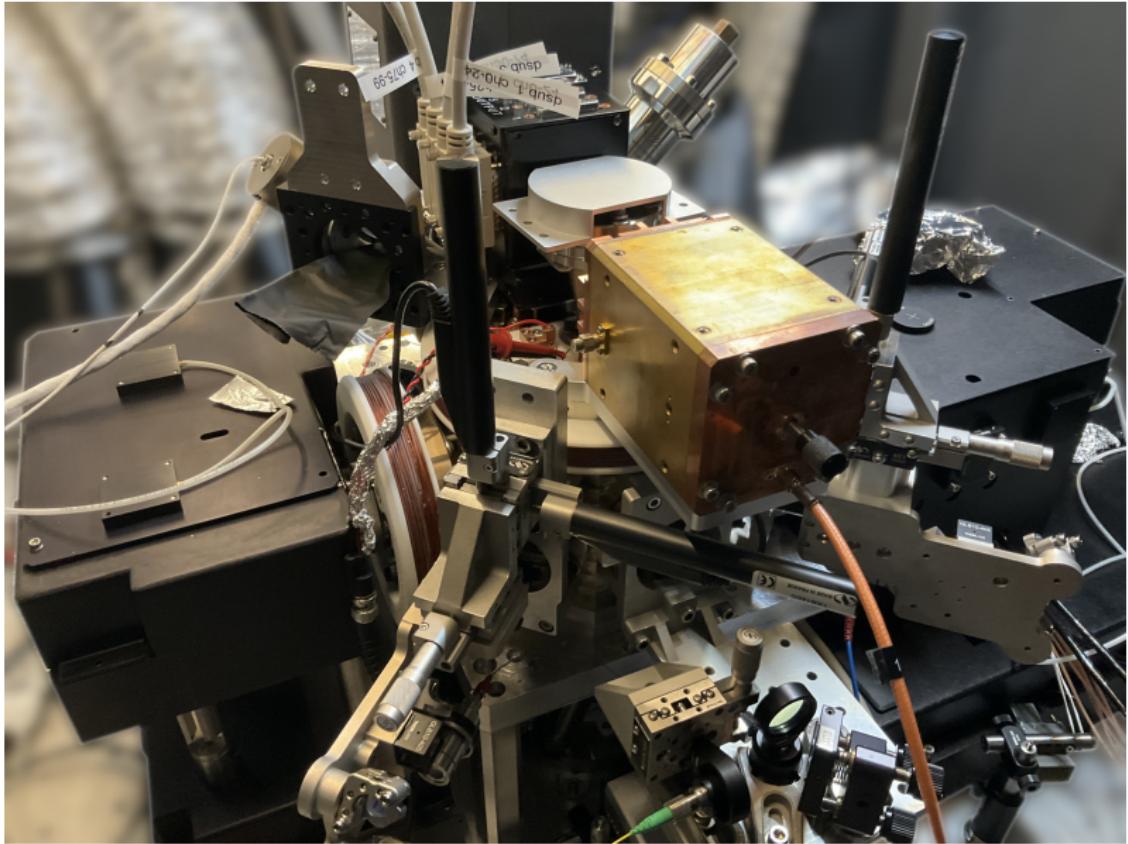
Rack mounted miniaturized beam path
for 369, 399, 780 and 935 nm.



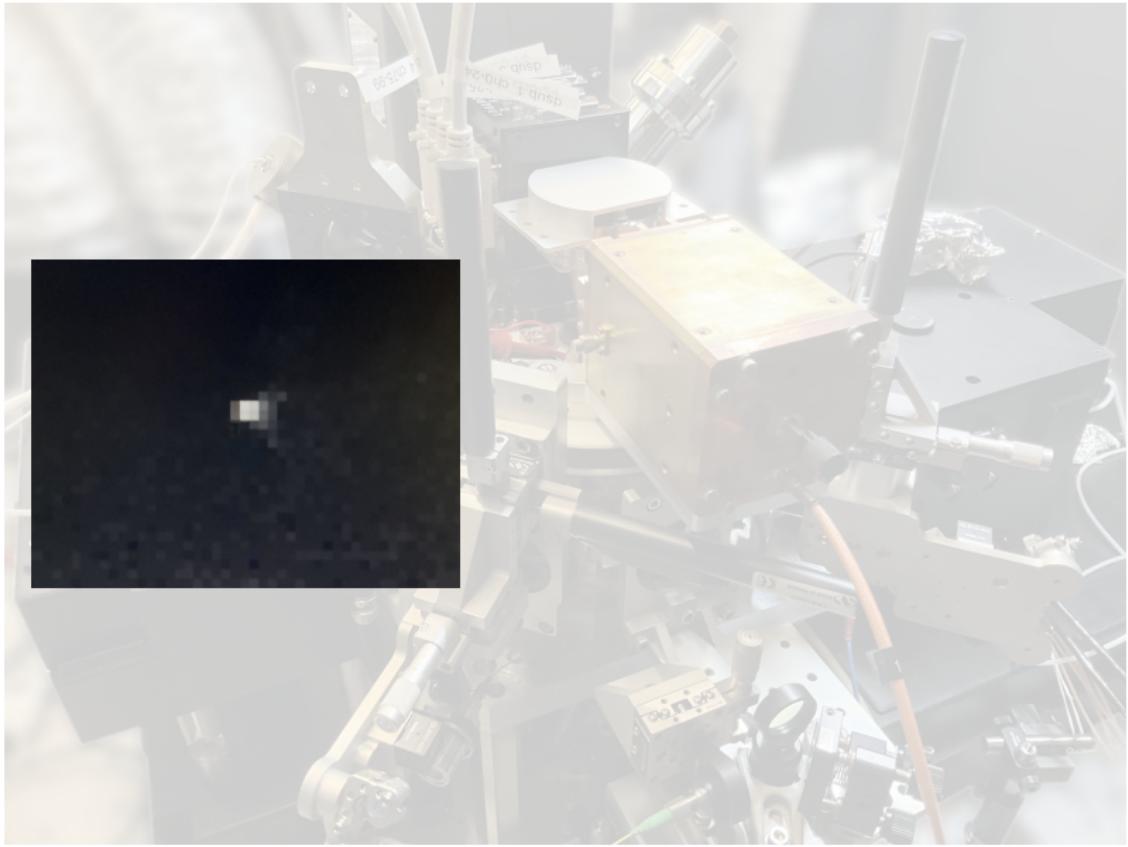
2nd gen EURIQA: CW lasers



2nd gen EURIQA: status and first ion



2nd gen EURIQA: status and first ion



2nd gen EURIQA: status and first ion

