

A next-generation trapped ion quantum computing system

Yichao Yu

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Monroe Group/Duke Quantum Center

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

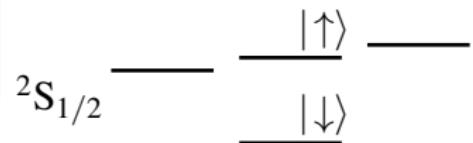
- Long coherence time: $T_2 \approx 1\text{hr}$

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)



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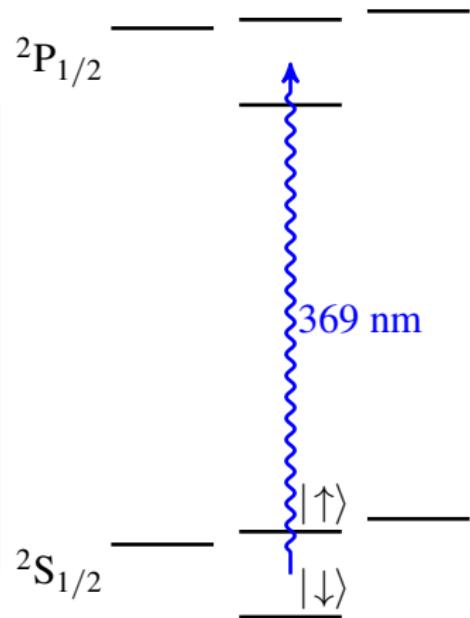
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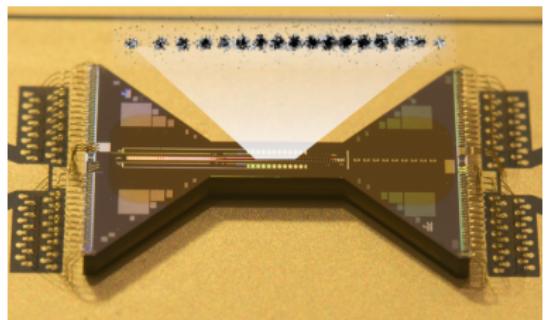
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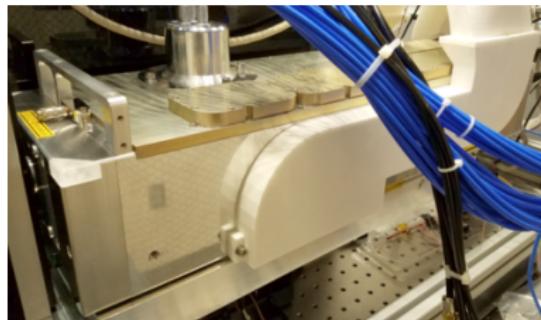
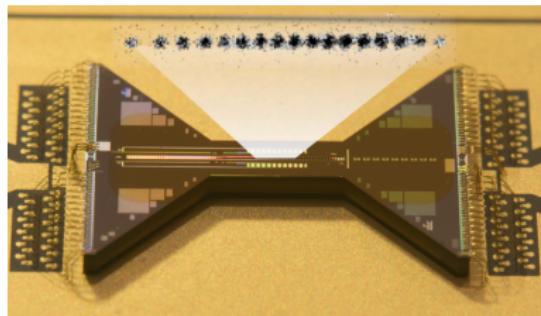
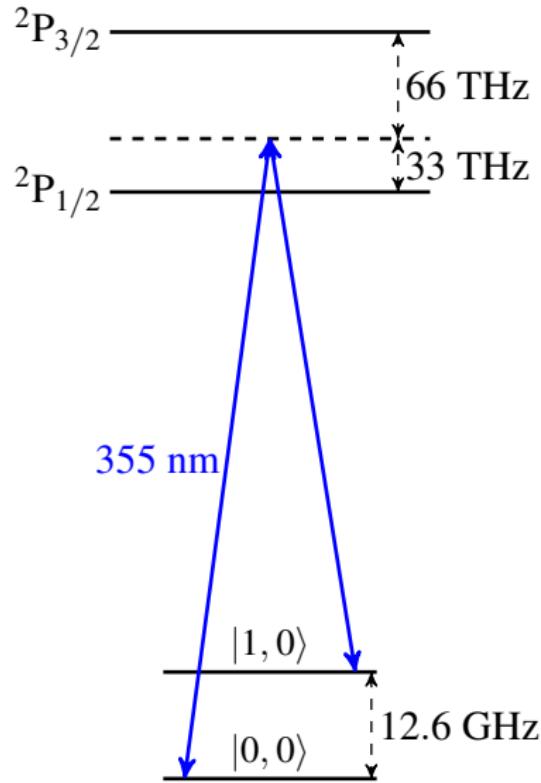
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$^{171}\text{Yb}^+$ chain and coherent manipulation



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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

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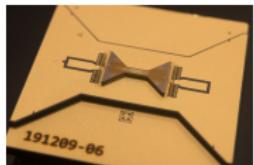
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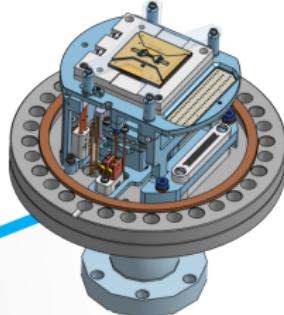


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-
- E06: Programmable N-body interactions with trapped ion qubits
 - E06: Implementing Real-Time Logical Qubit Error Detection & Correction on a Trapped Ion Quantum Computer
 - Q07: Implementation of interactive proofs for quantum advantage on an ion-trap quantum computer
 - U05: Using a trapped ion quantum computer to simulate NMR spectra

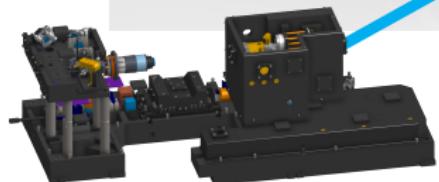
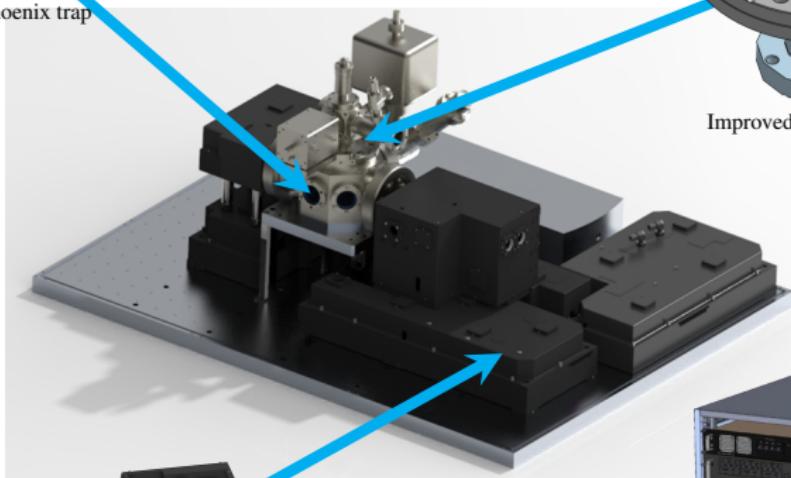
2nd generation EURIQA system



Sandia Phoenix trap



Improved vacuum system



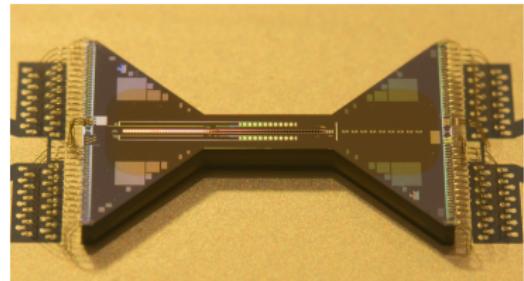
L3Harris Raman beam path



CW lasers

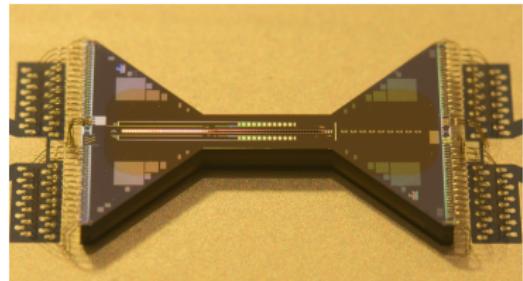
2nd gen EURIQA: Phoenix trap

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



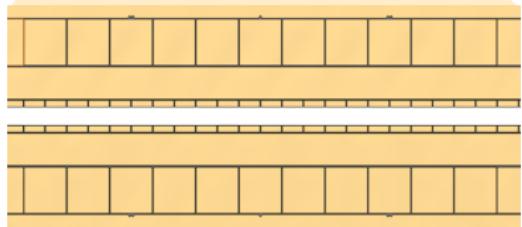
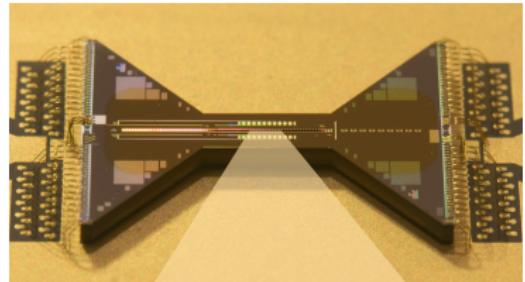
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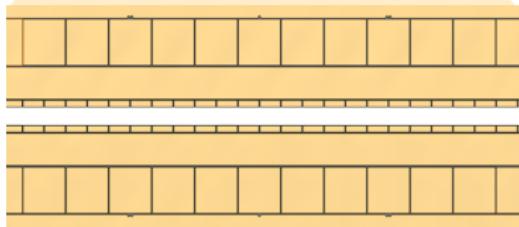
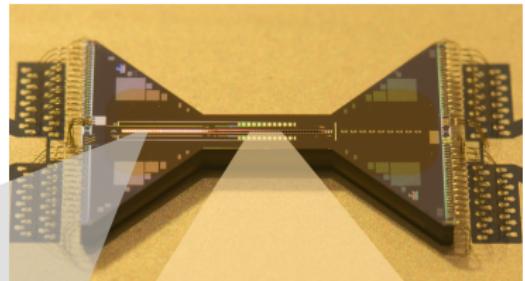
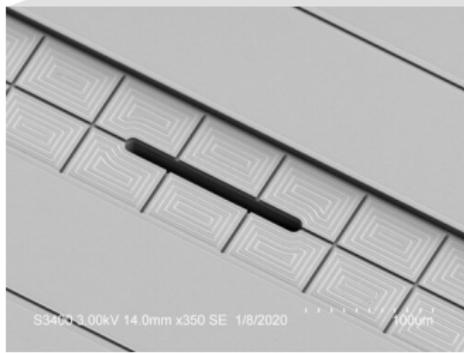
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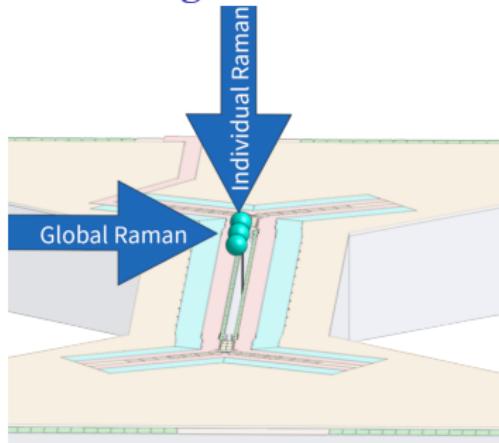
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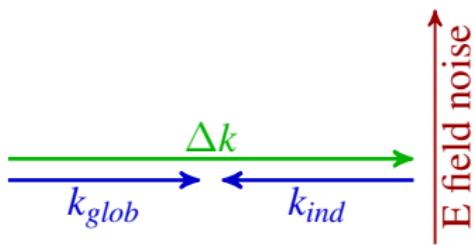
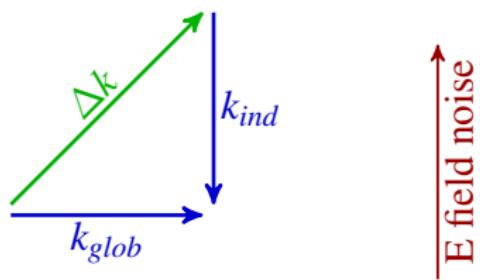
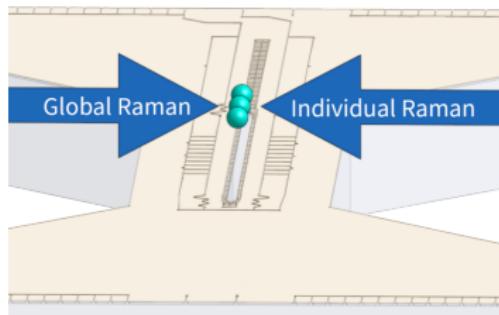


2nd gen EURIQA: Raman geometry

1st gen Raman



2nd gen Raman

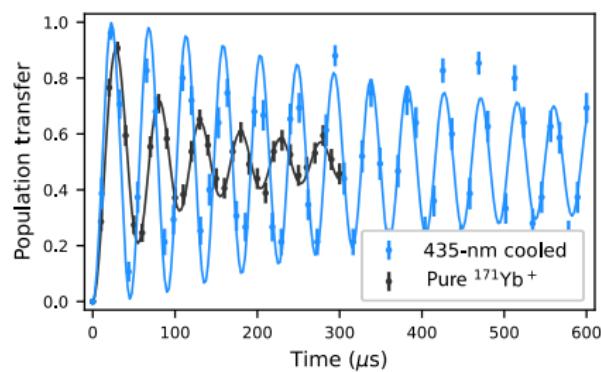


2nd gen EURIQA: New Yb atom source

- Sympathetic cooling with $^{172}\text{Yb}^+$

Cetina, et al., PRX Quantum 3, 010334 (2022)

- New Yb source to enhance loading of $^{172}\text{Yb}^+$

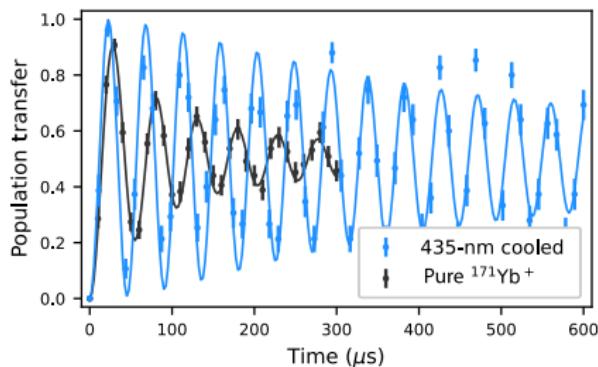
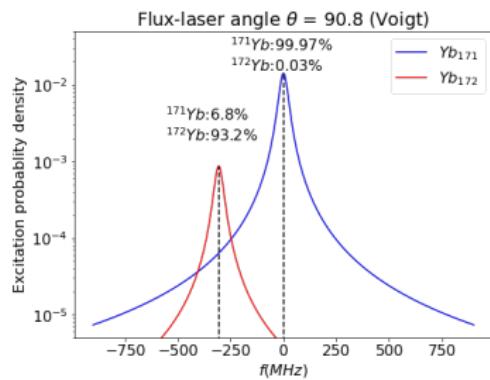


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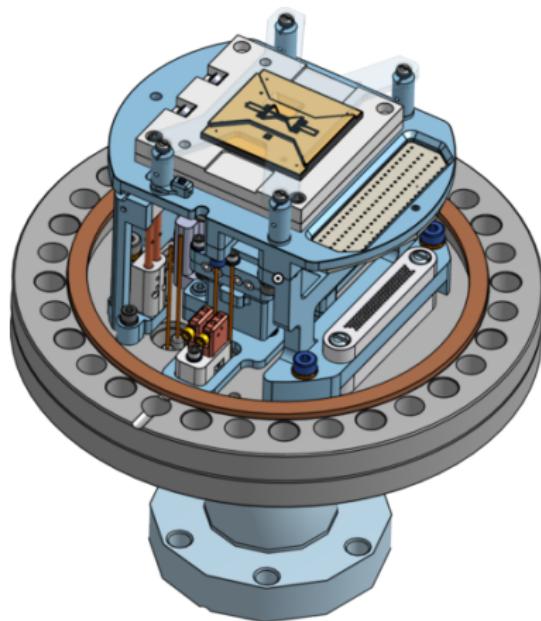
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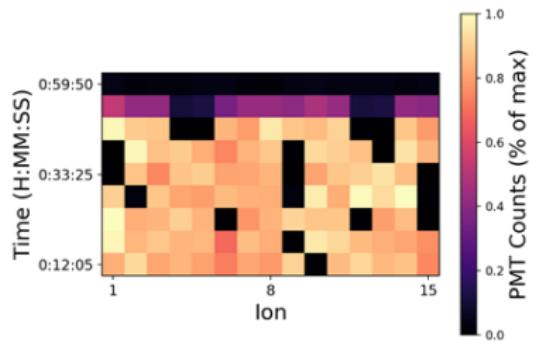
2nd gen EURIQA: Improved vacuum

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



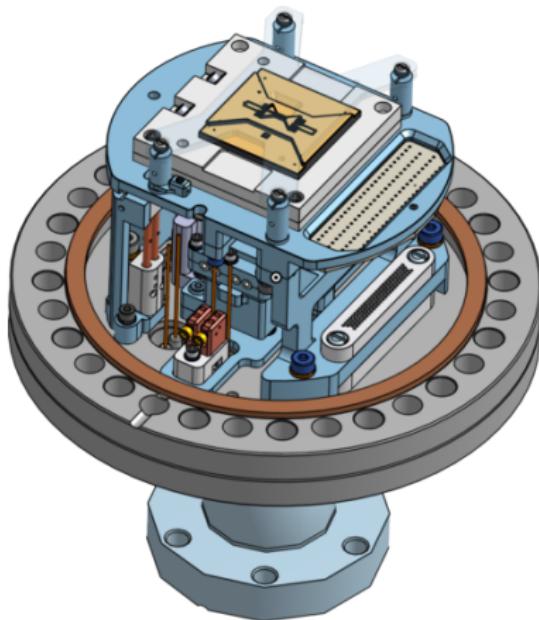
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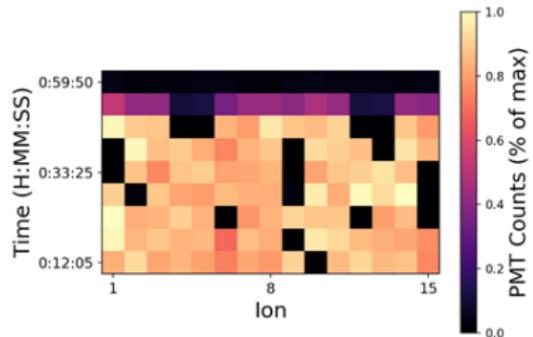
15-ion chain reordering
in 1st gen EURIQA system.
Consistent with 10^{-10} Torr.

Cetina, et al.



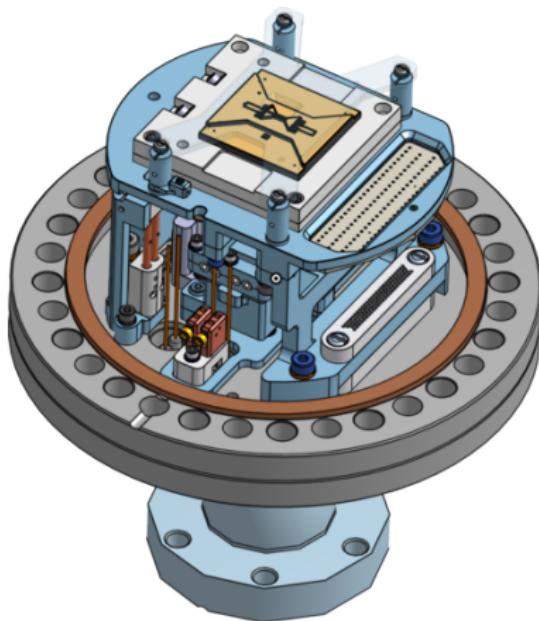
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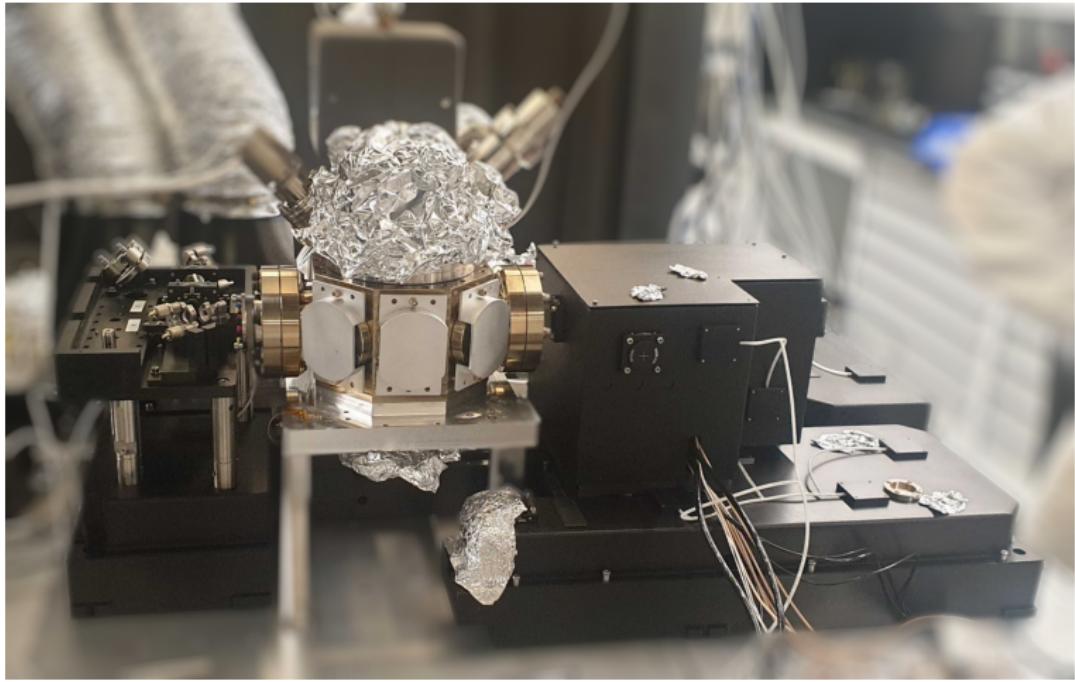


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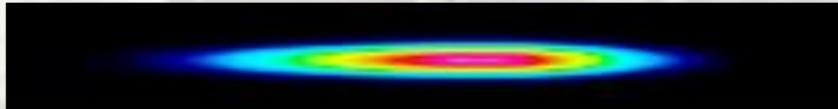


2nd gen EURIQA: Raman beam path

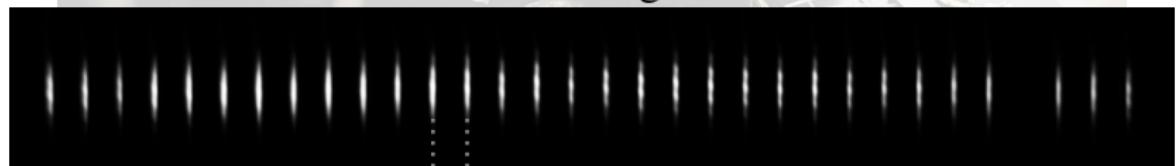


2nd gen EURIQA: Raman beam path

Global addressing Raman beam



Individual addressing Raman beam



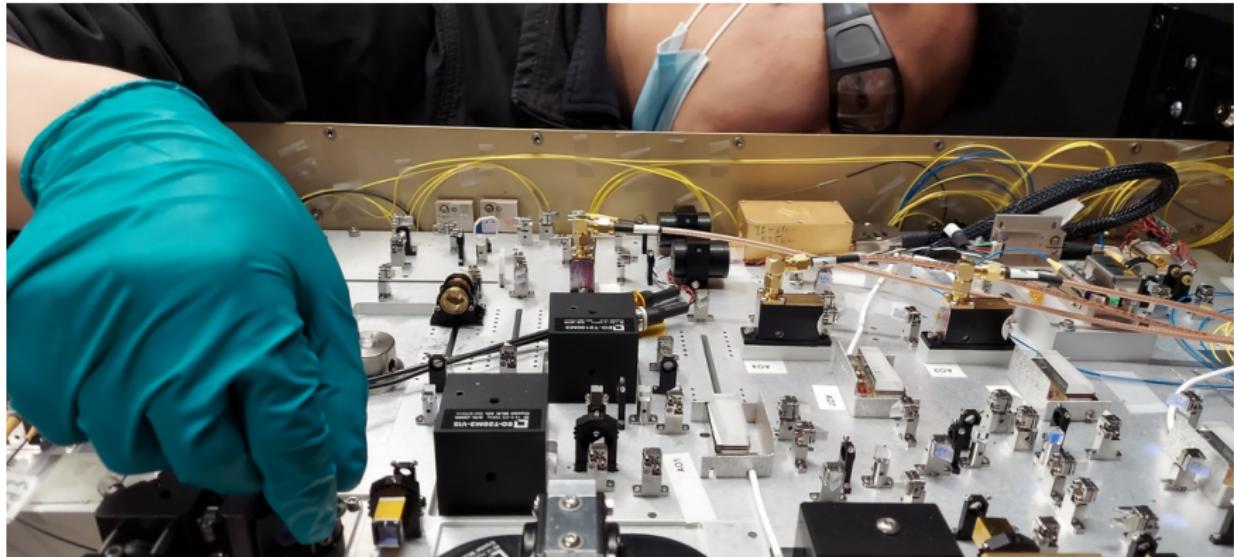
→ ←
 $4.5\mu\text{m}$

2nd gen EURIQA: CW lasers

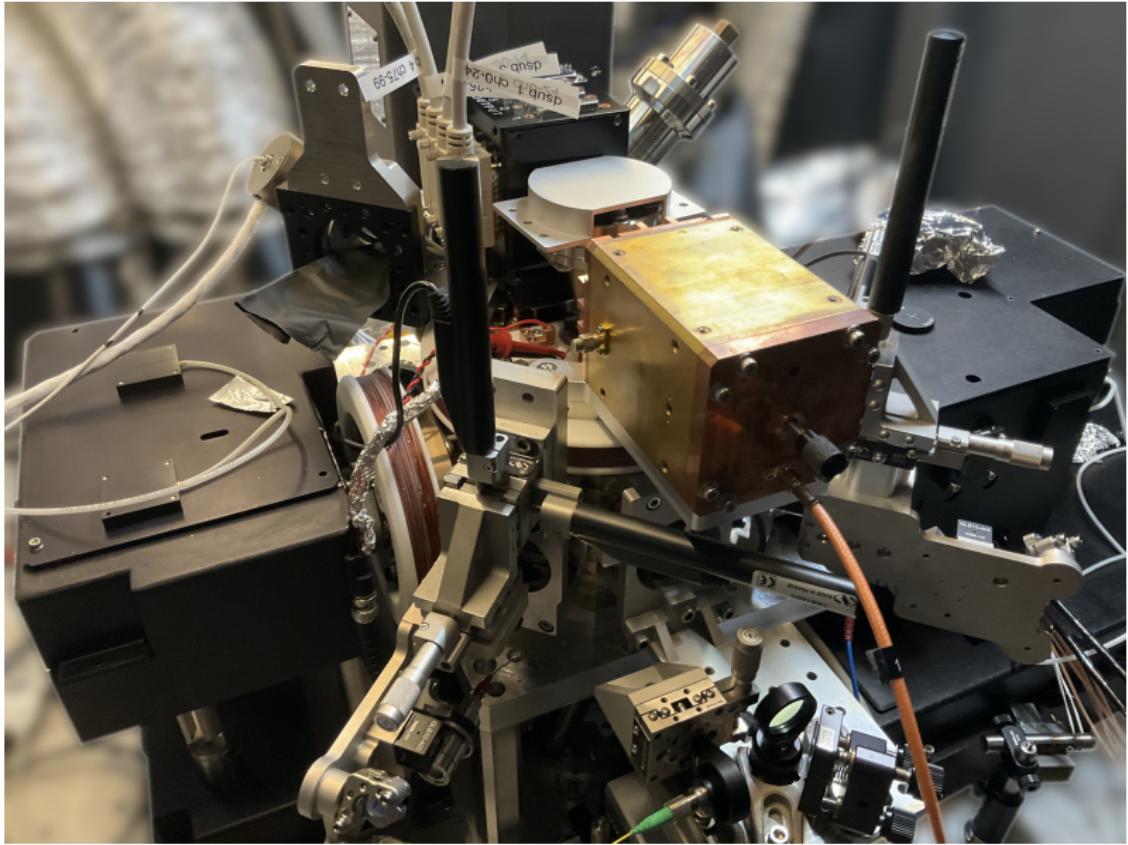
Rack mounted miniaturized beam path
for 369, 399, 780 and 935 nm.



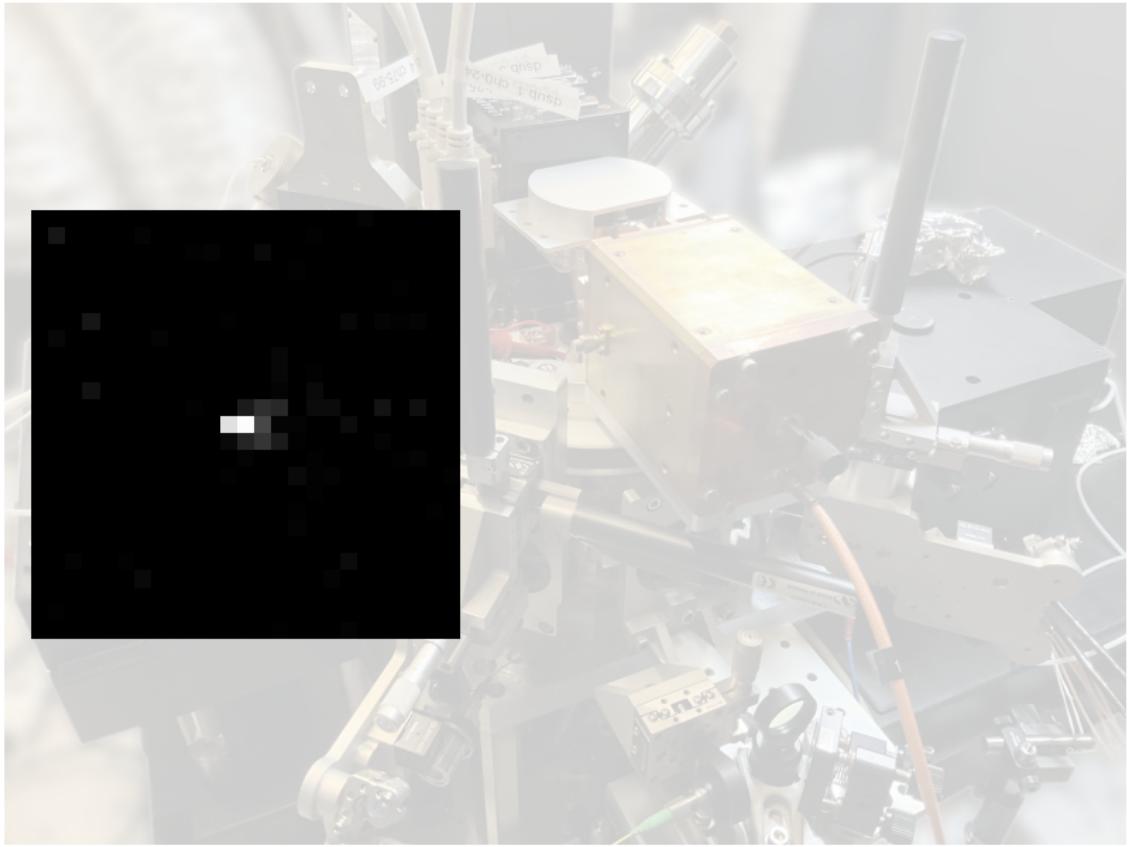
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2nd gen EURIQA: status and first ion



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