

# A next-generation trapped ion quantum computing system

Yichao Yu

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Monroe Group/Duke Quantum Center

June 1, 2022



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

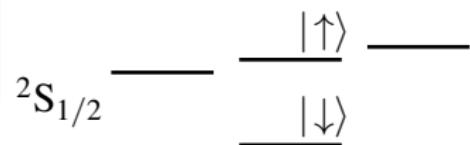
- Long coherence time:  $T_2 \approx 1\text{hr}$

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)



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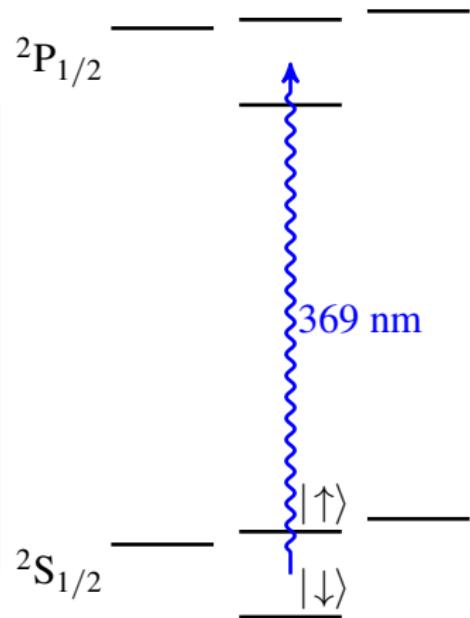
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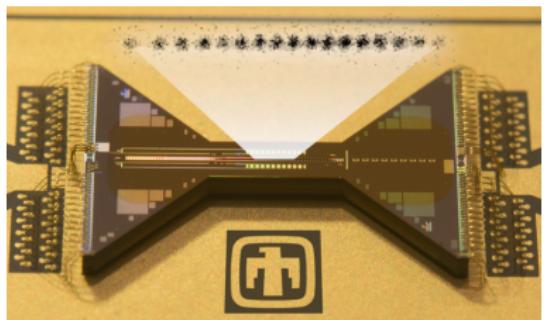
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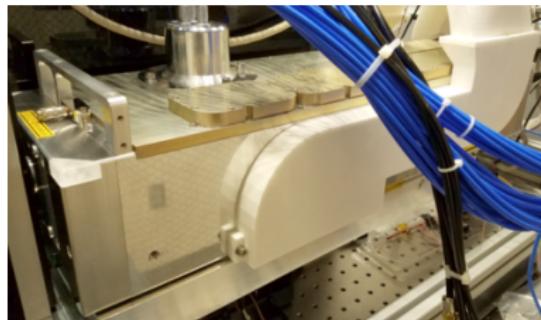
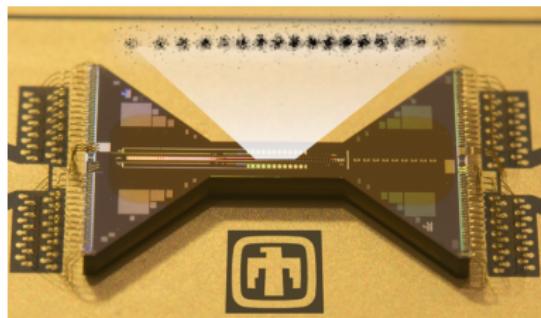
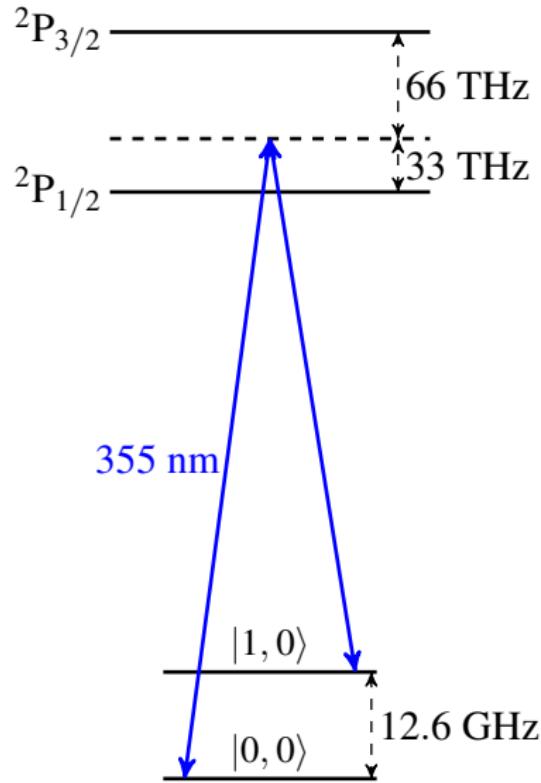
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# $^{171}\text{Yb}^+$ chain and coherent manipulation



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# 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

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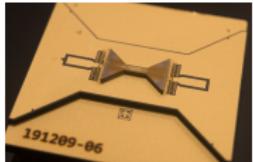
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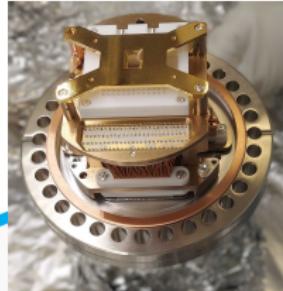


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- E06: Programmable N-body interactions with trapped ion qubits
  - E06: Implementing Real-Time Logical Qubit Error Detection & Correction on a Trapped Ion Quantum Computer
  - Q07: Implementation of interactive proofs for quantum advantage on an ion-trap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

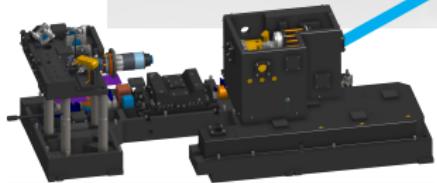
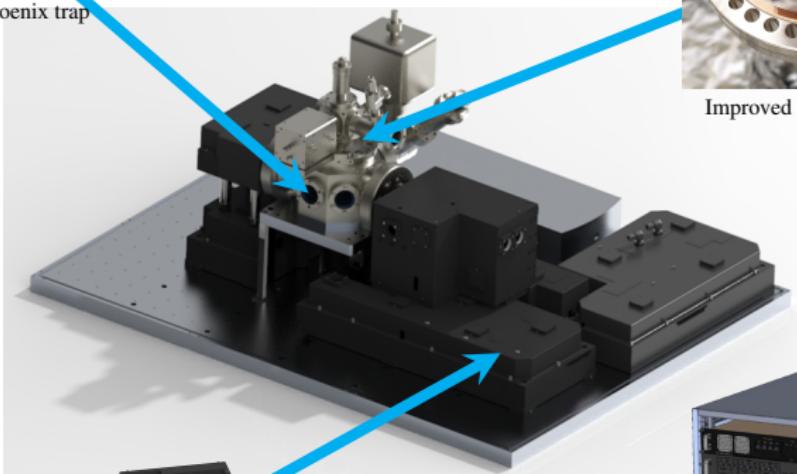
## 2<sup>nd</sup> generation EURIQA system



Sandia Phoenix trap



Improved vacuum system



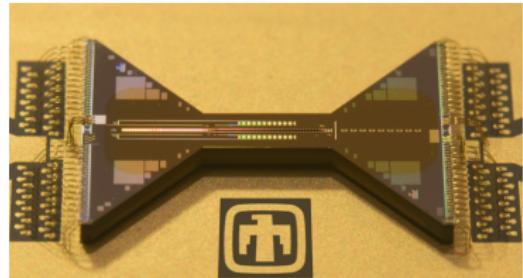
L3Harris Raman beam path



CW lasers

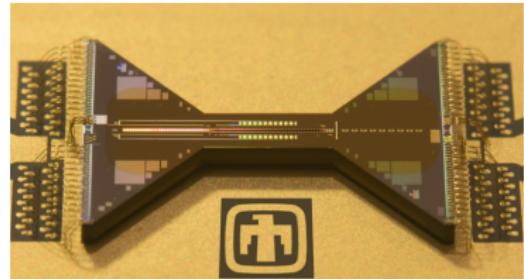
## 2<sup>nd</sup> gen EURIQA: Phoenix trap

- 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



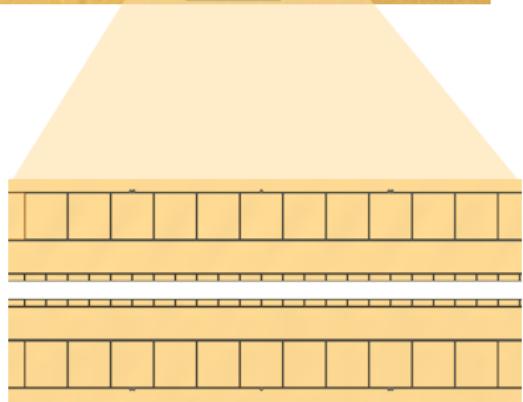
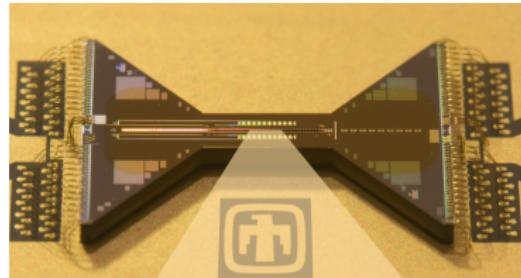
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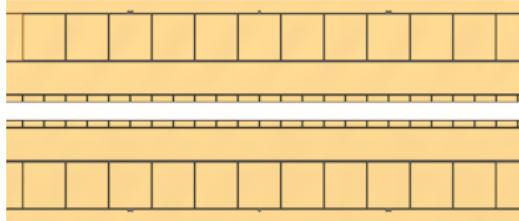
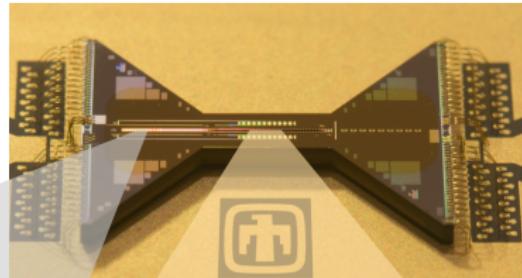
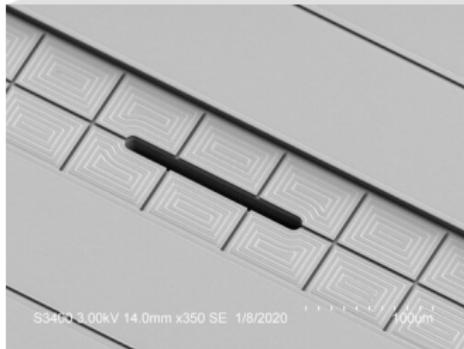
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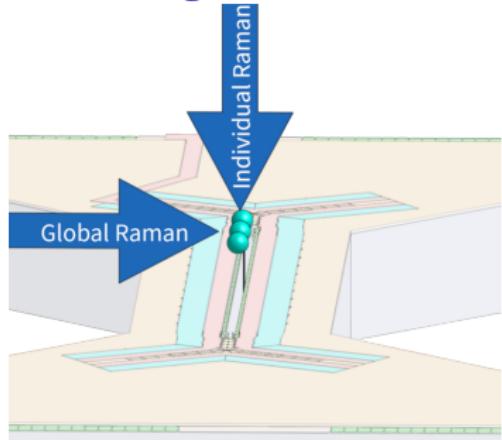
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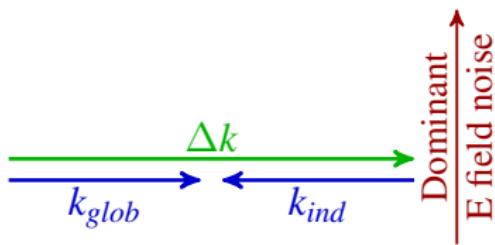
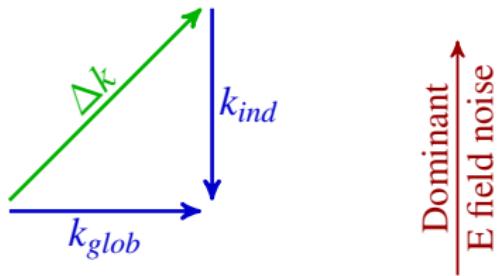
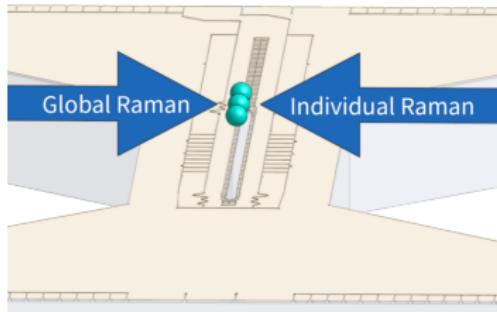


## 2<sup>nd</sup> gen EURIQA: Raman geometry

1<sup>st</sup> gen Raman



2<sup>nd</sup> gen Raman

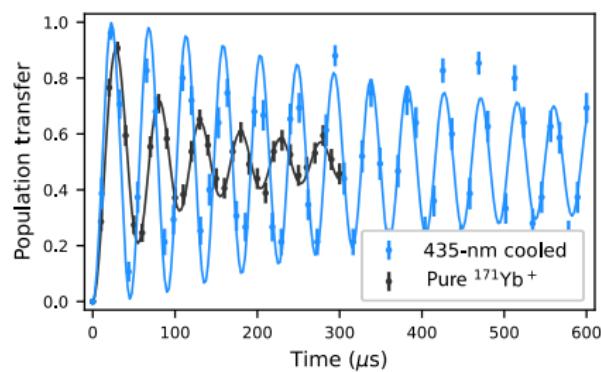


## 2<sup>nd</sup> gen EURIQA: New Yb atom source

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

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

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

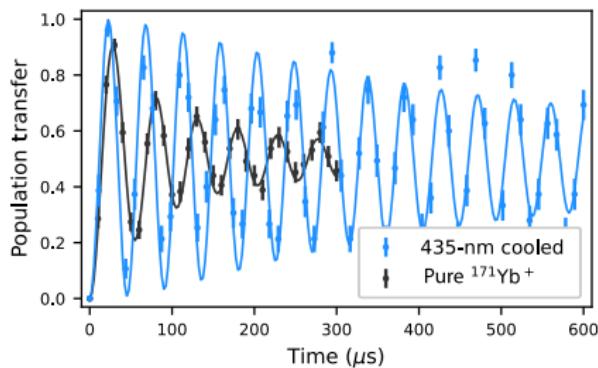
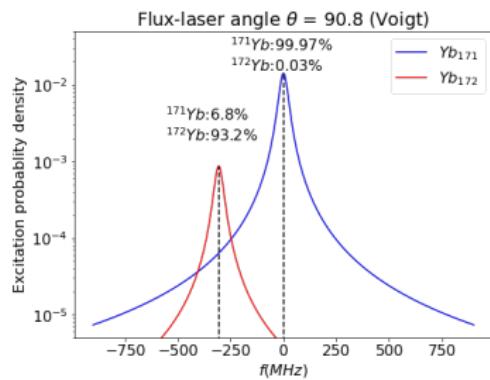


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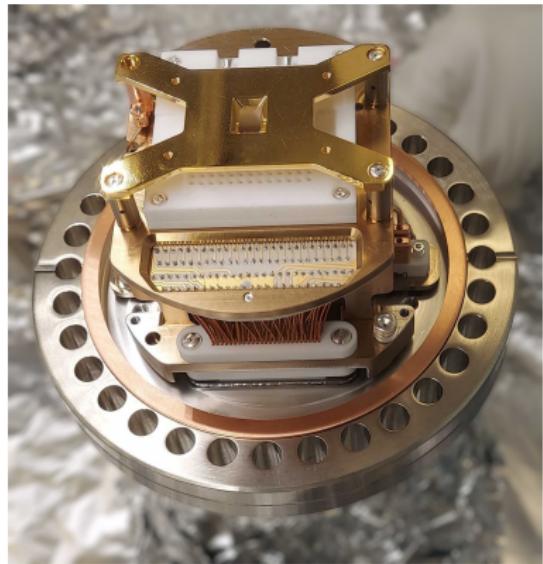
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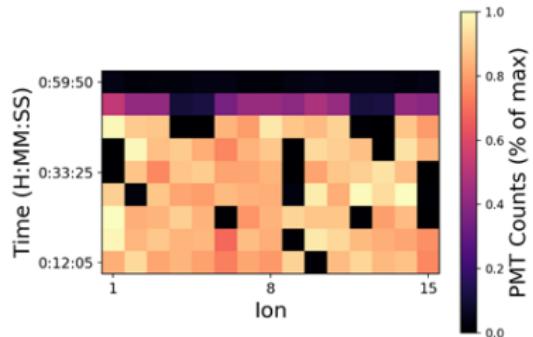
## 2<sup>nd</sup> gen EURIQA: Improved vacuum

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



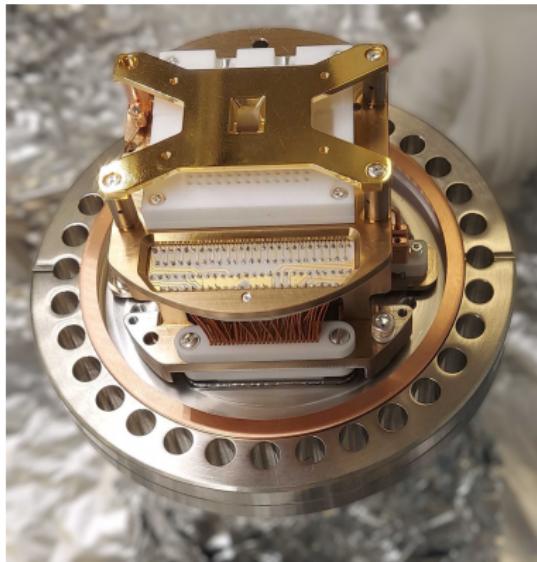
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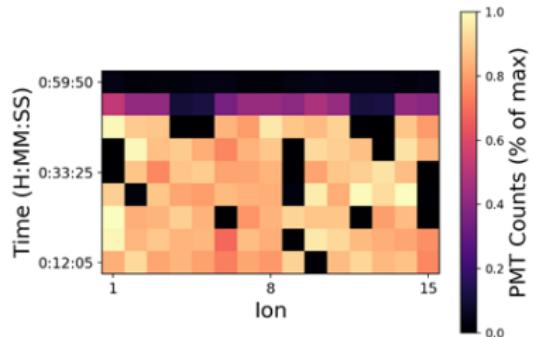
15-ion chain reordering  
in 1<sup>st</sup> gen EURIQA system.  
Consistent with  $10^{-10}$  Torr.

Cetina, et al.



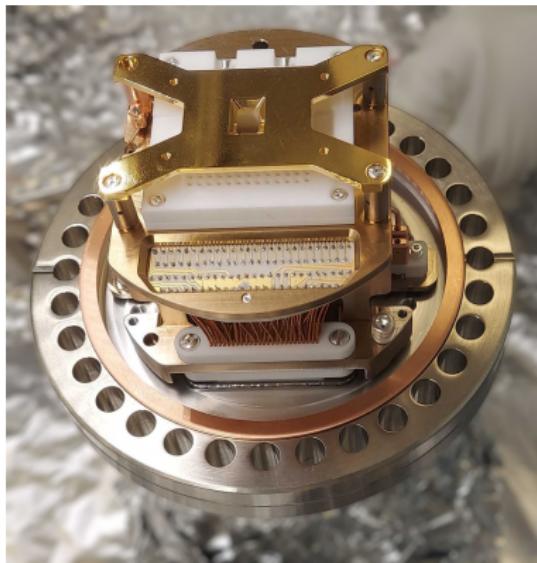
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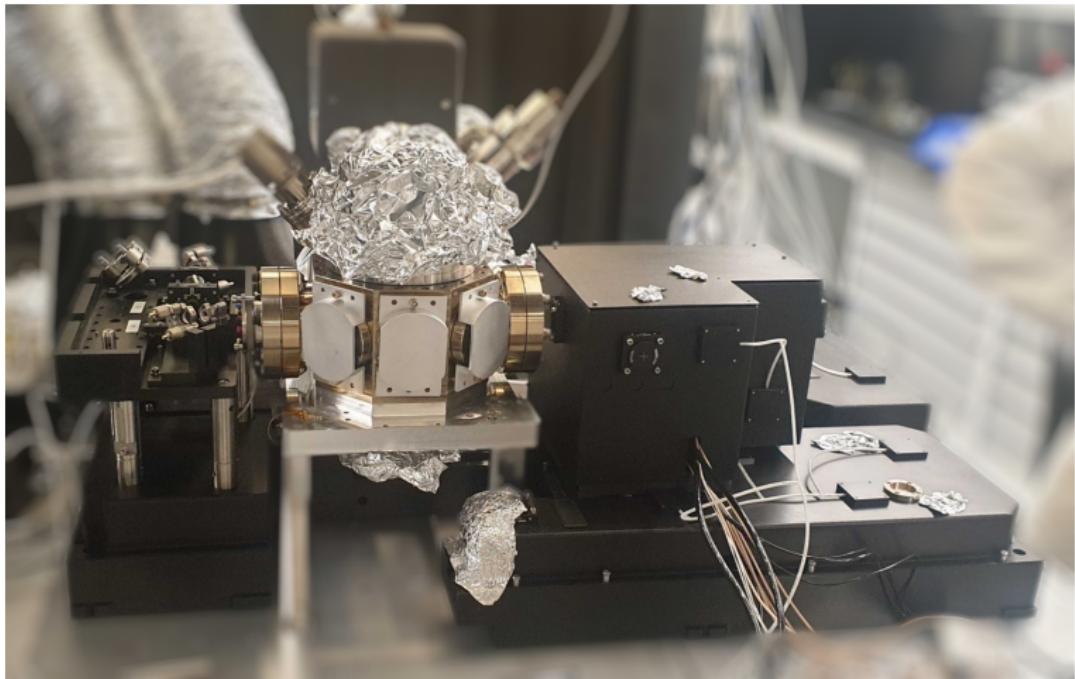


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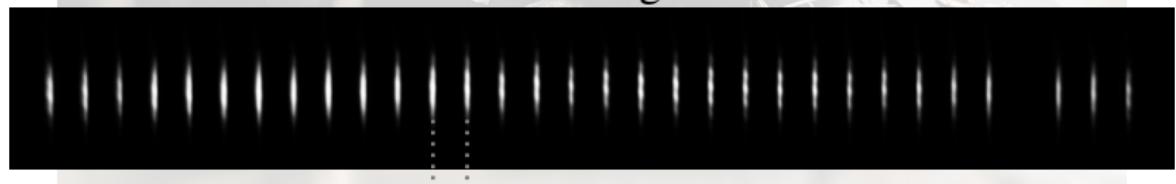
## 2<sup>nd</sup> gen EURIQA: Raman beam path



Global addressing Raman beam



Individual addressing Raman beam



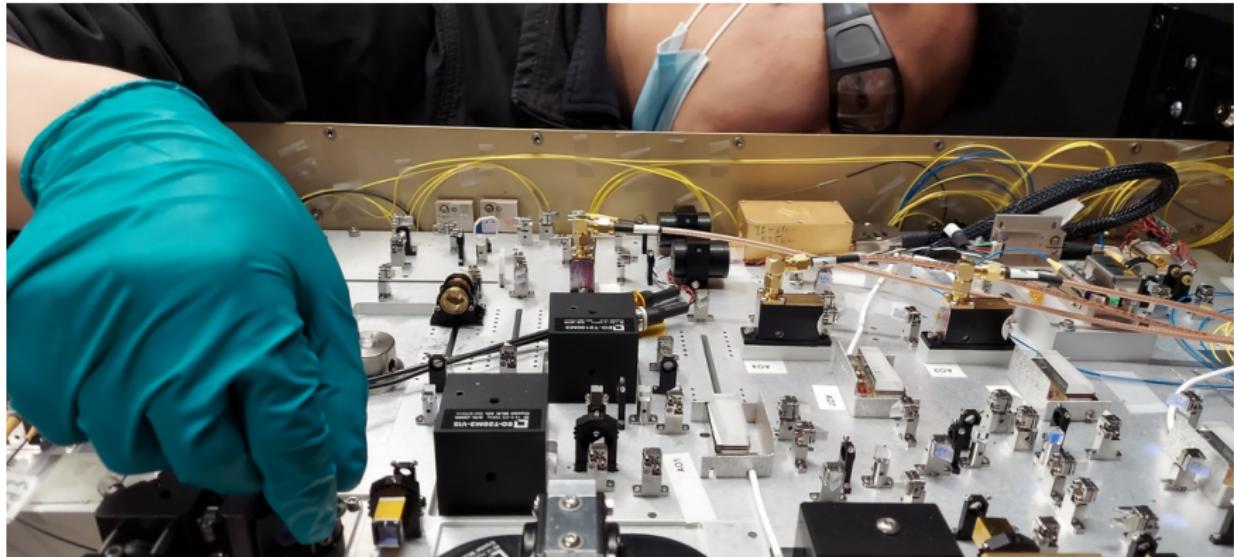
4.5 $\mu\text{m}$

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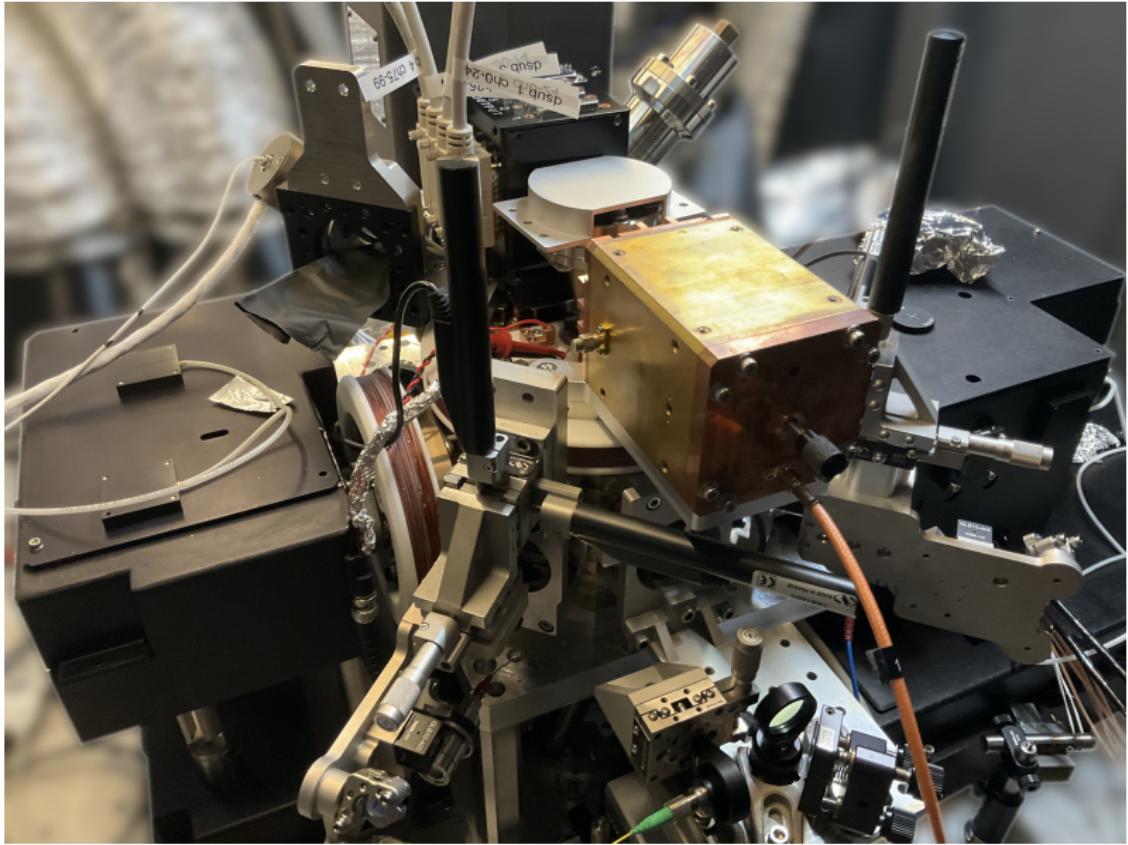
Rack mounted miniaturized beam path  
for 369, 399, 780 and 935 nm.



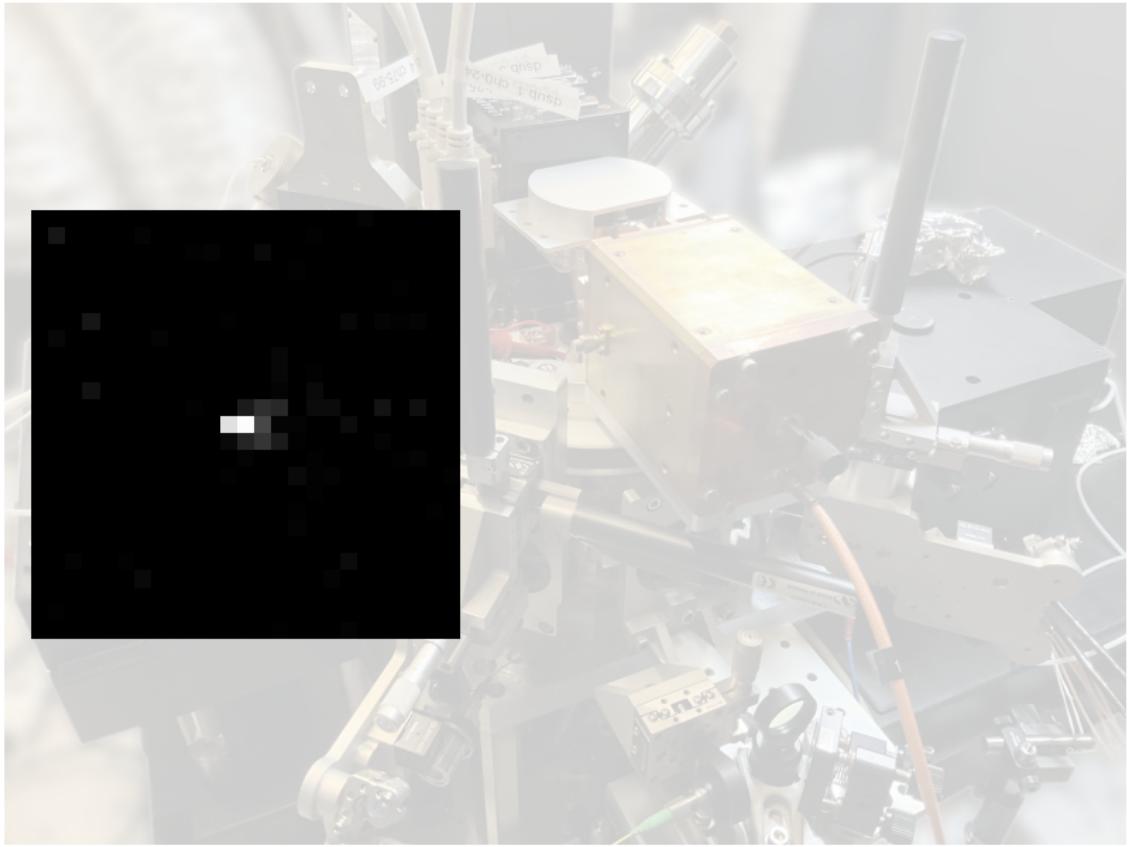
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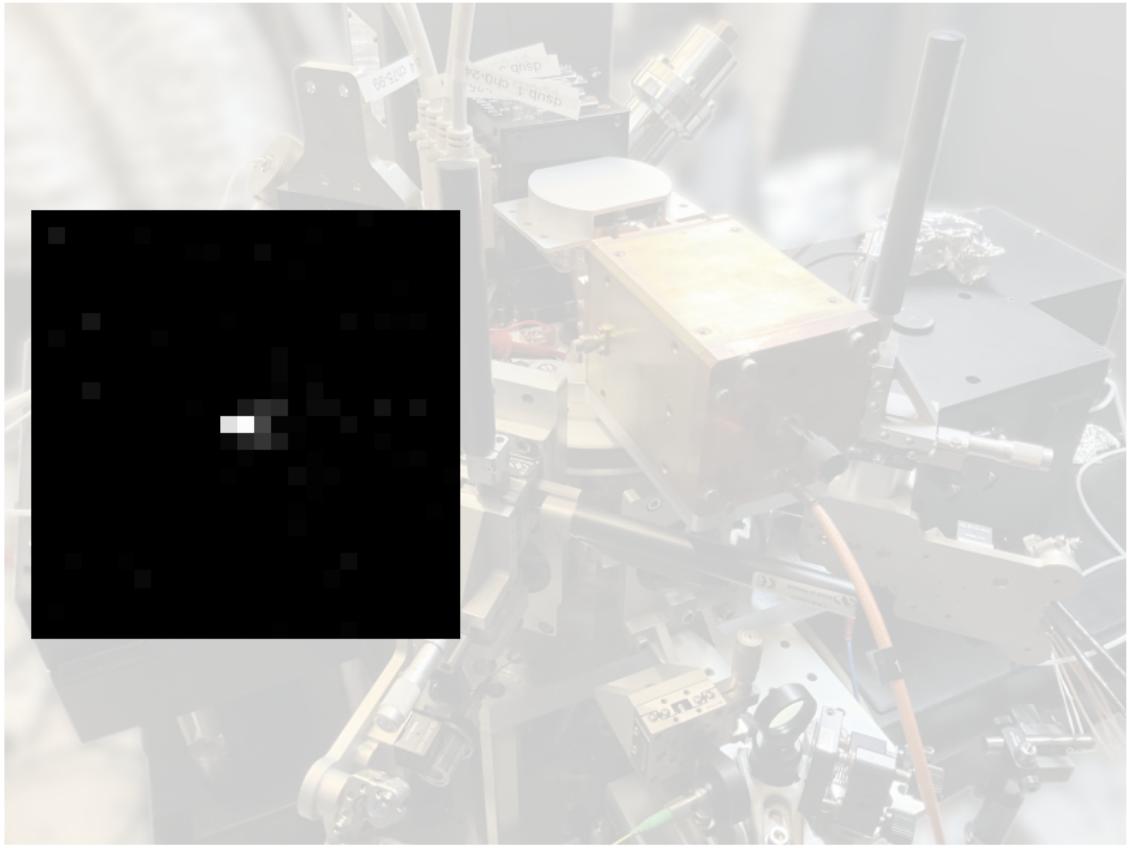
## 2<sup>nd</sup> gen EURIQA: status and first ion



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