A next-generation trapped ion quantum computing system

Yichao Yu

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Monroe Group/Duke Quantum Center

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

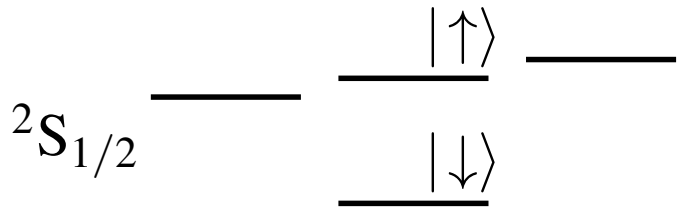
- Long coherence time: $T_2 \approx 1\text{hr}$

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

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

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

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



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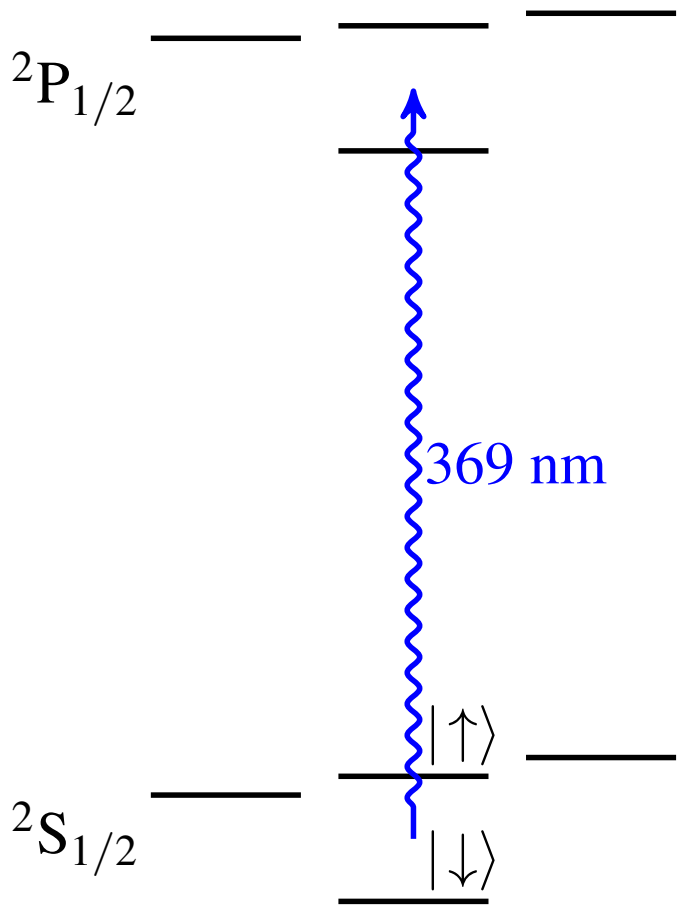
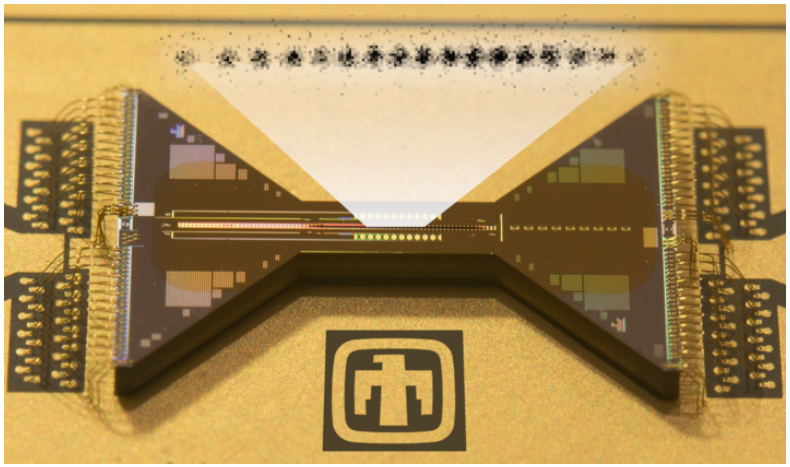


$^{171}Yb^{+}$ chain and coherent manipulation



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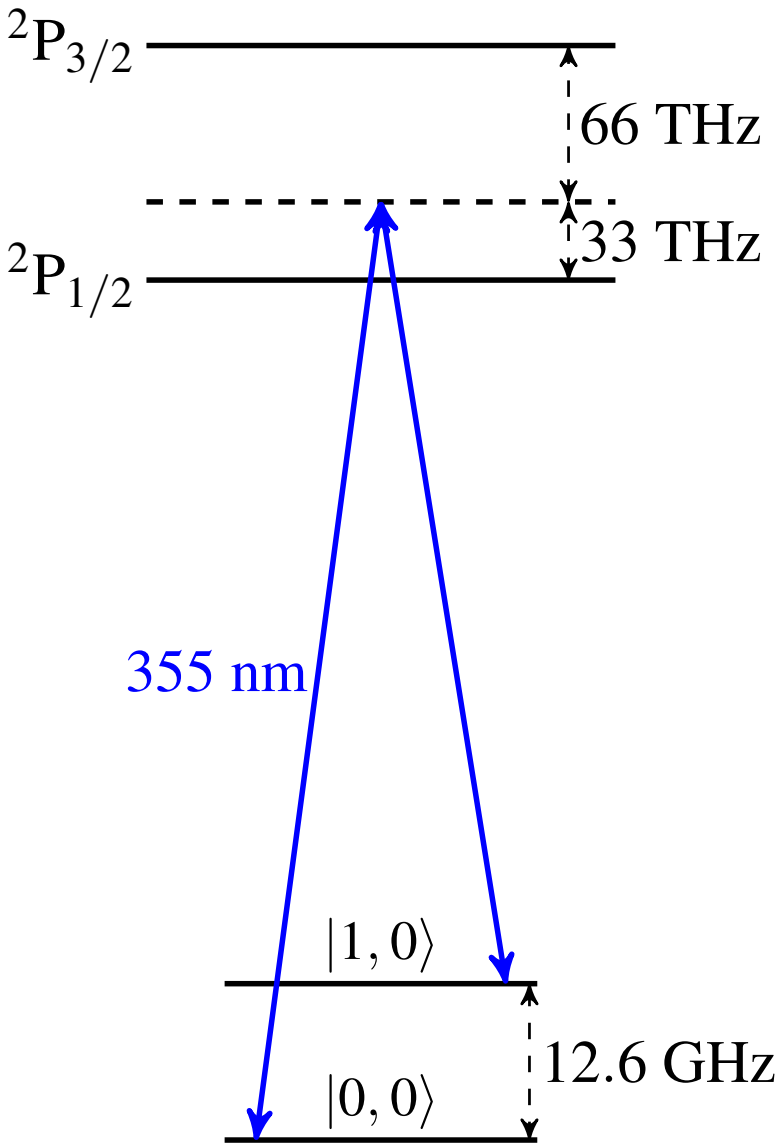

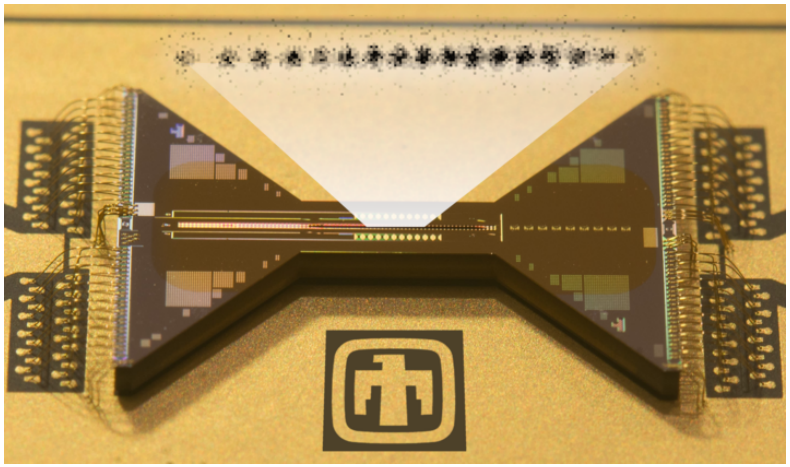

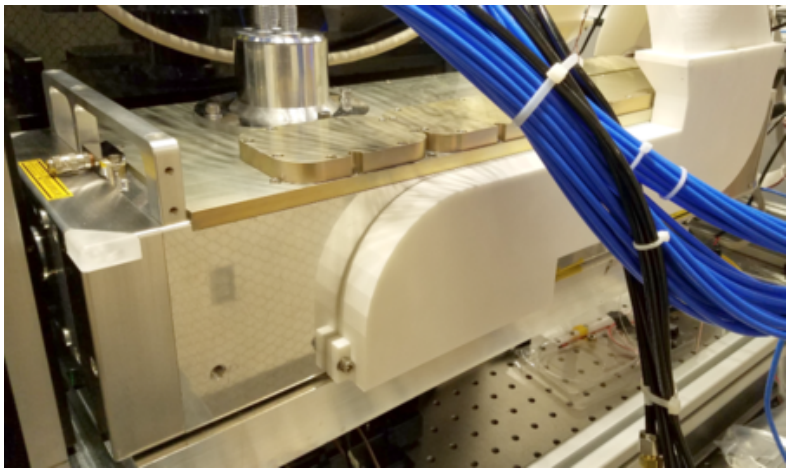

1st generation EURIQA system

Error-corrected **U**niversal **R**econfigurable **I**on-trap **Q**uantum **A**rchetype

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

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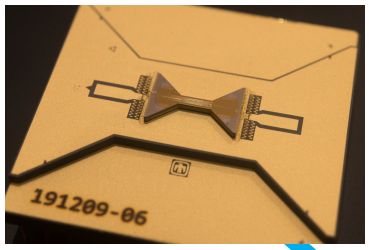
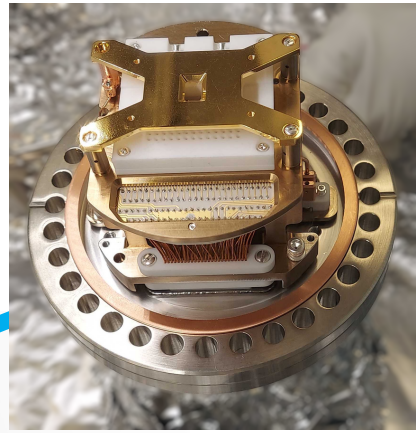
- E06: Programmable N-body interactions with trapped ion qubits
- E06: Implementing Real-Time Logical Qubit Error Detection & Correction on a Trapped Ion Quantum Computer
- Q07: Implementation of interactive proofs for quantum advantage on an ion-trap quantum computer
- U05: Using a trapped ion quantum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

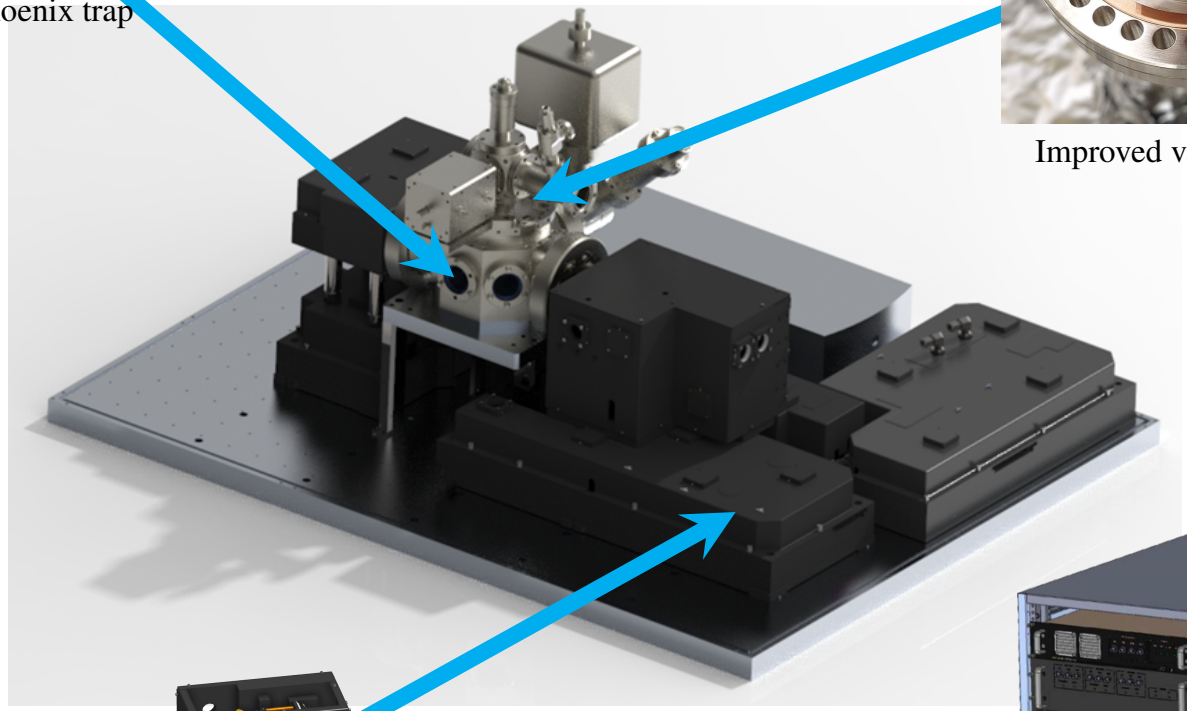
2nd generation EURIQA system

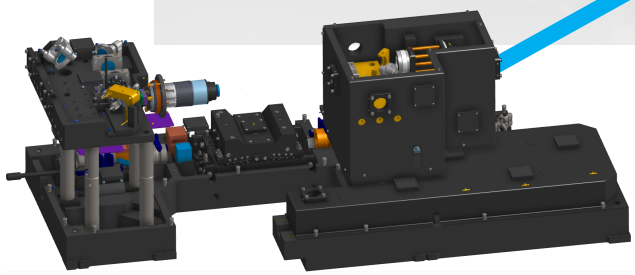


Sandia Phoenix trap



Improved vacuum system





L3Harris Raman beam path

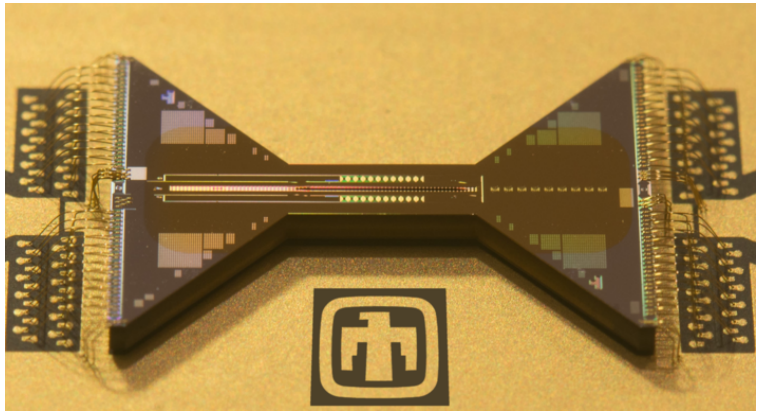
CW lasers

2nd gen EURIQA: Phoenix trap

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

  30 quanta/s heating rate @ 3 MHz

  Measured by Sandia
- Segmented outer electrodes
- Better and faster ion loading



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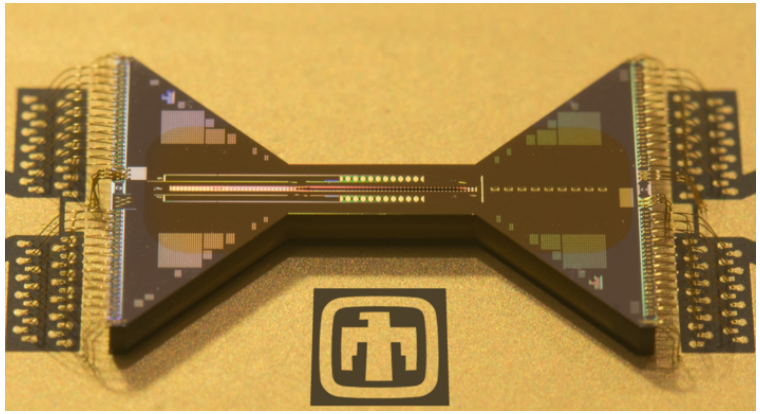

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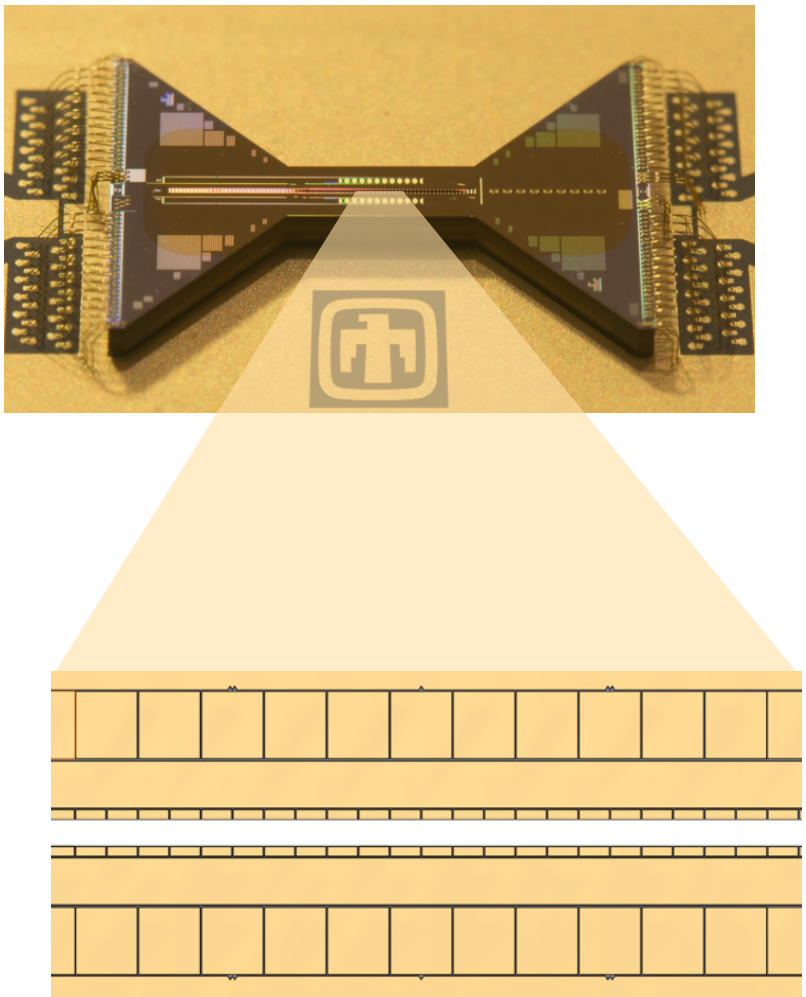

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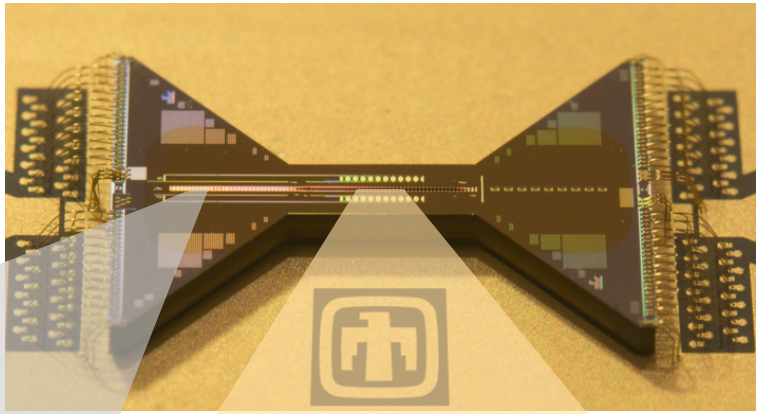
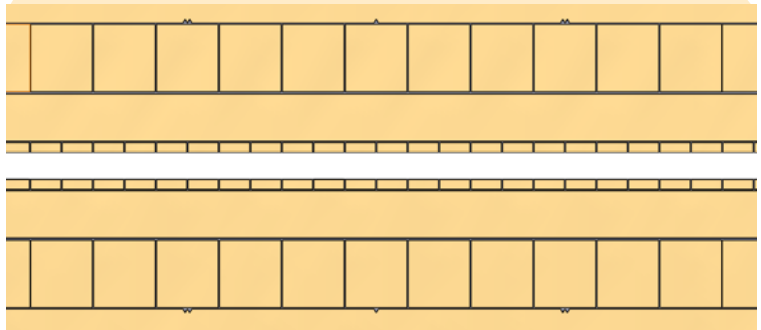
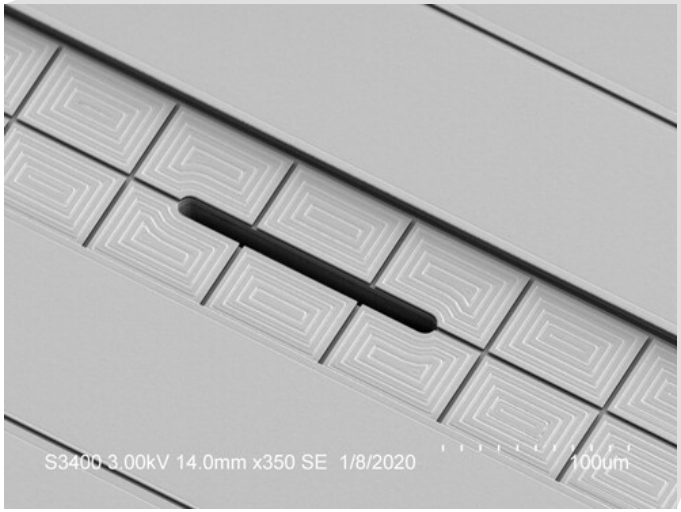
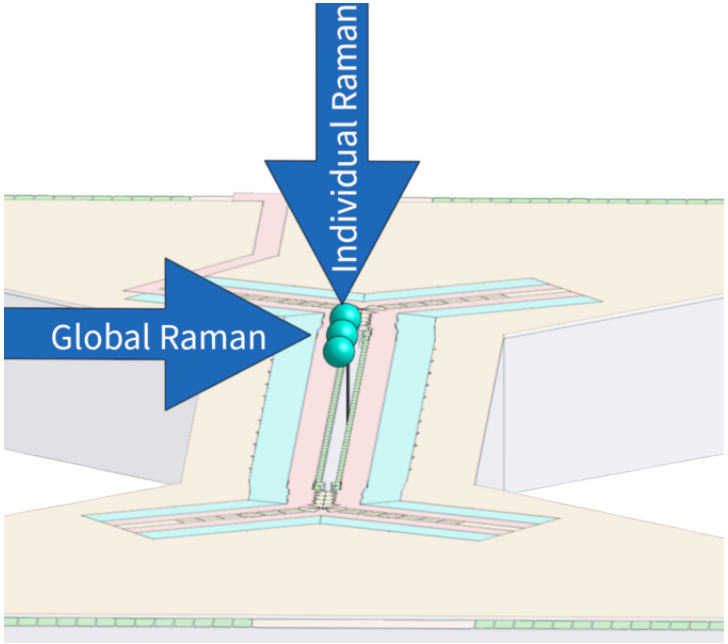


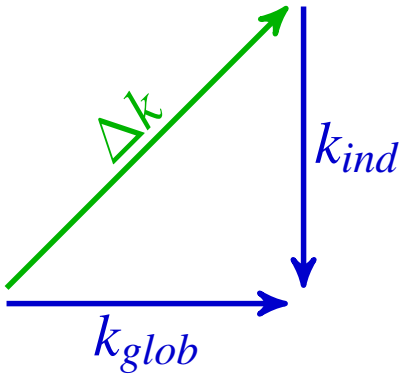




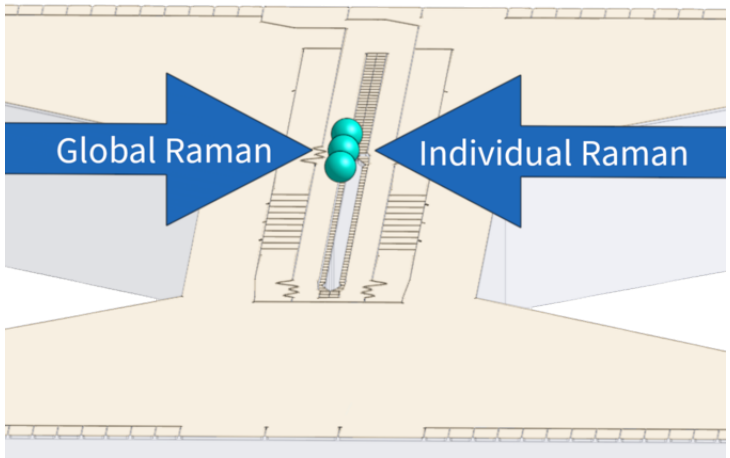
2nd gen EURIQA: Raman geometry

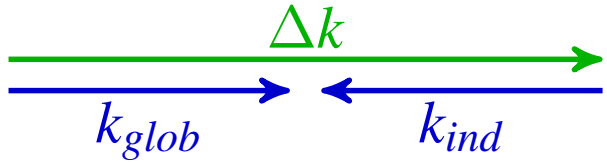
1st gen Raman





2nd gen Raman



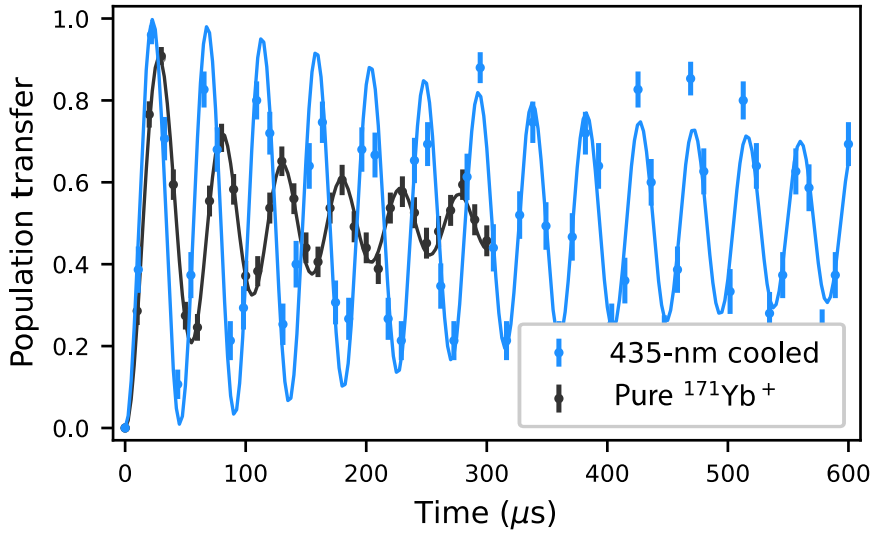


2nd gen EURIQA: New Yb atom source

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

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

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



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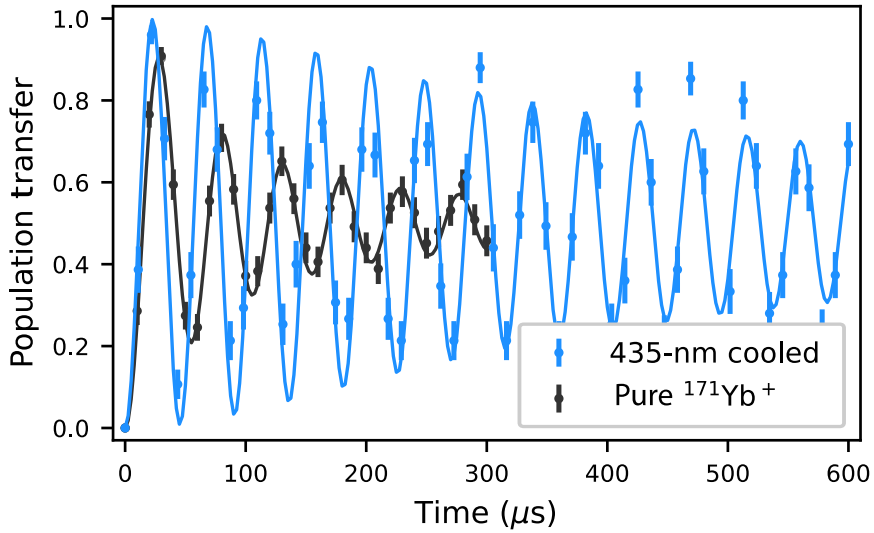
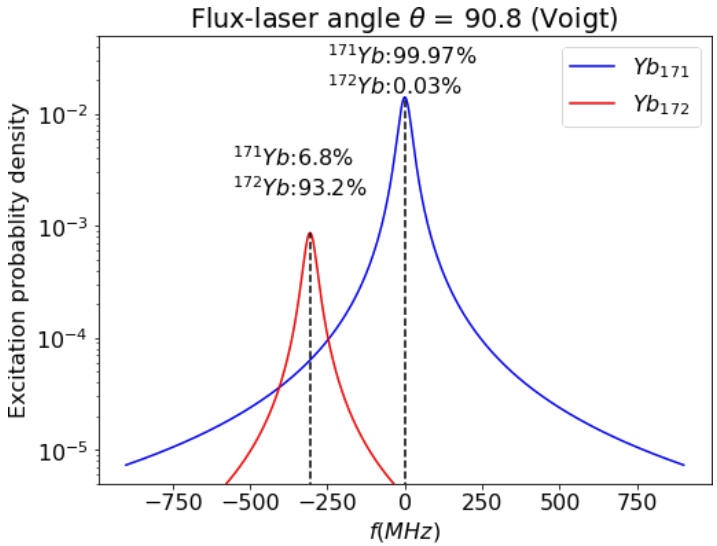
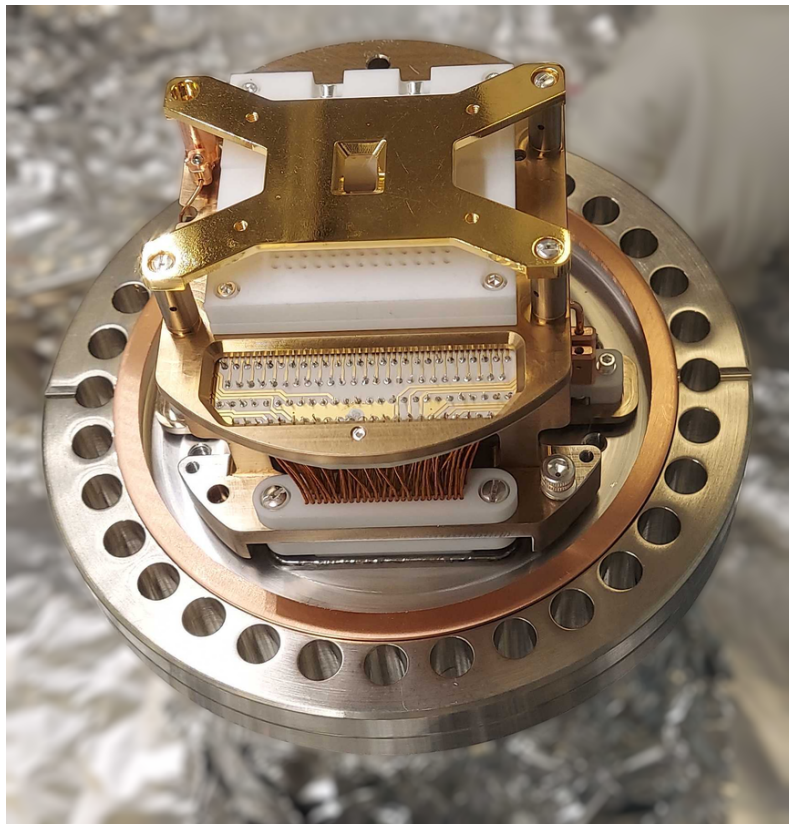




2^{nd} gen EURIQA: Improved vacuum

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



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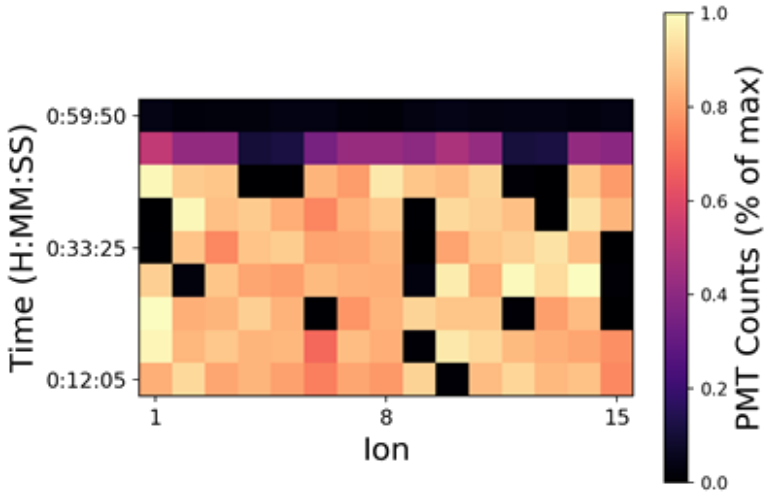
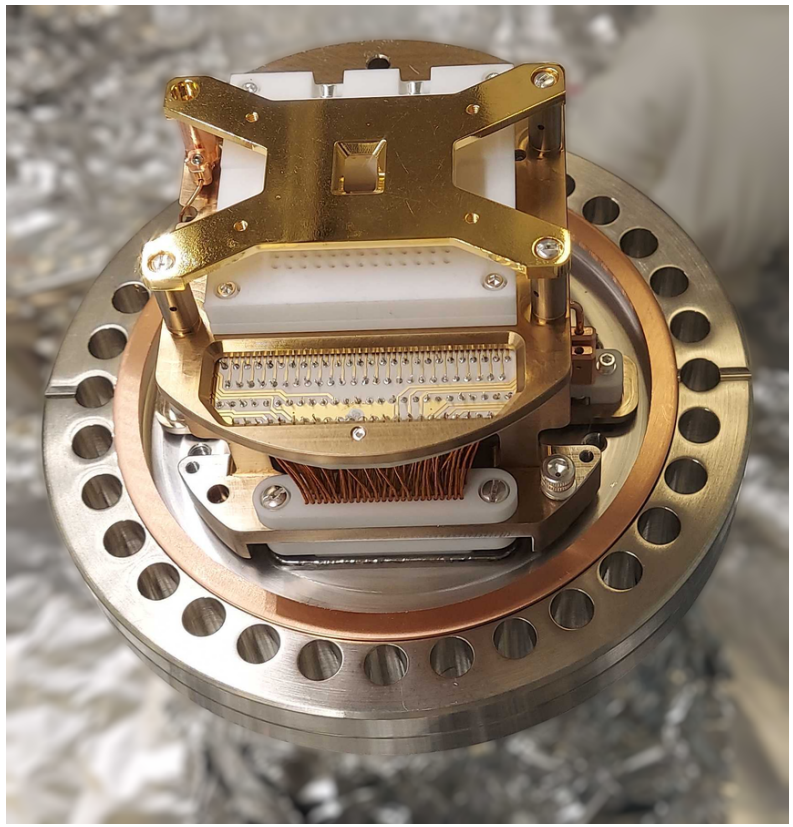


15-ion chain reordering
in 1st gen EURIQA system.
Consistent with 10^{-10} Torr.

Cetina, et al.



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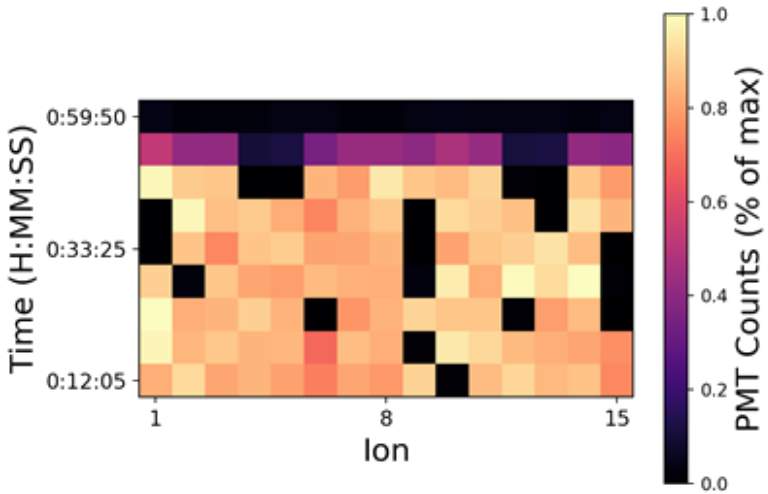

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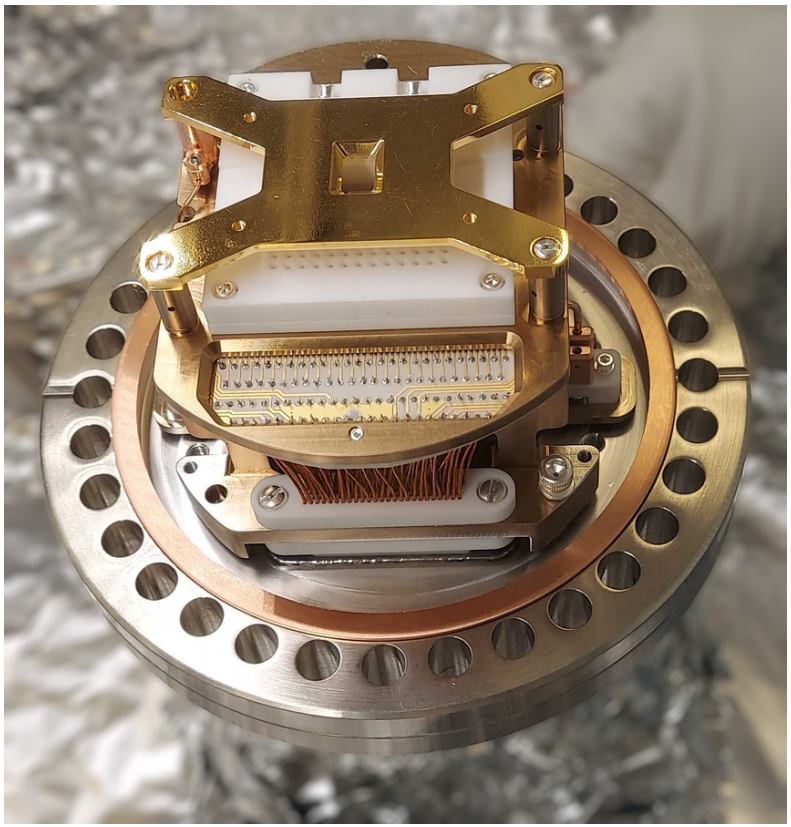
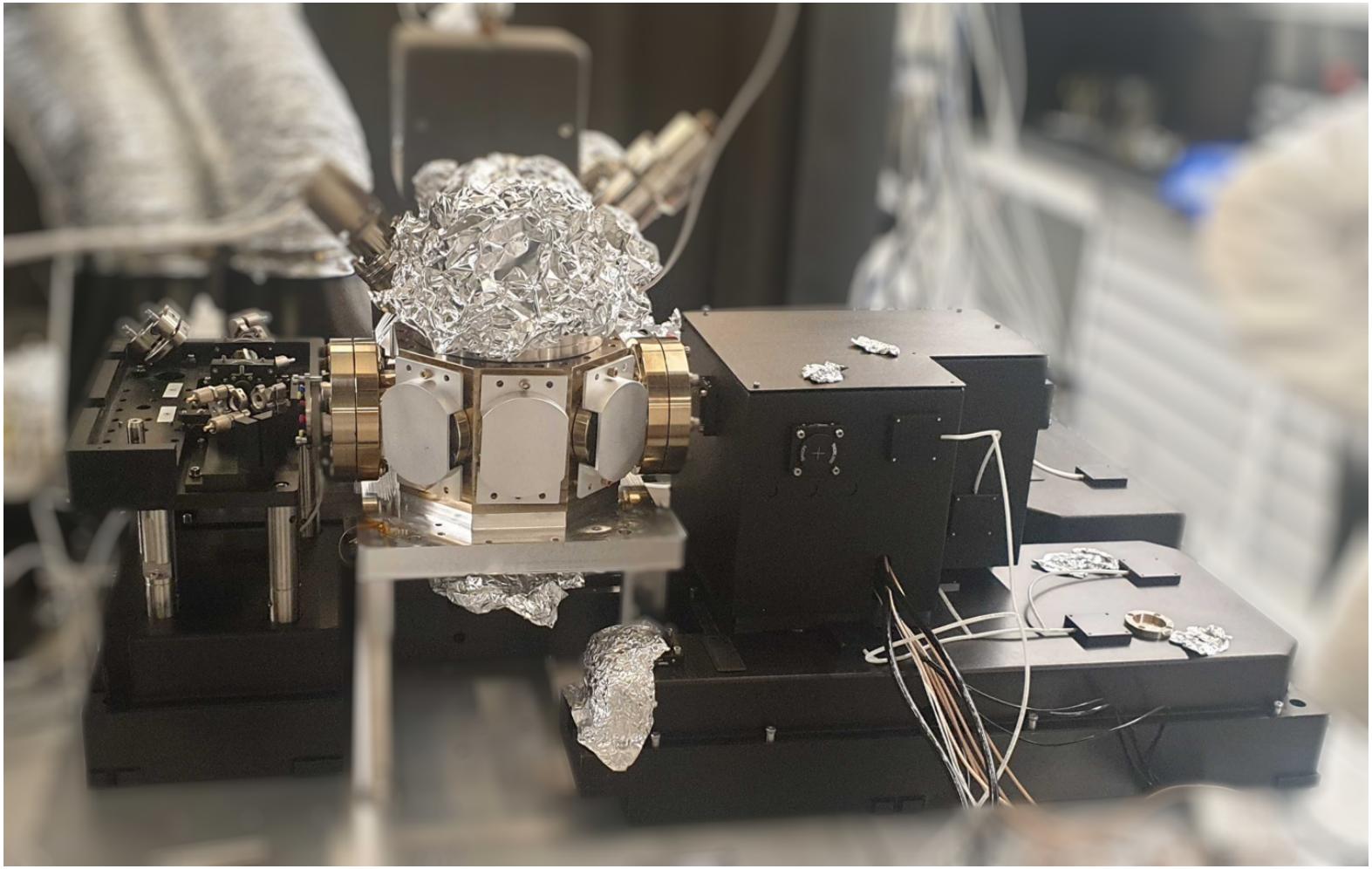


2nd gen EURIQA: Raman beam path

L3HARRIS™



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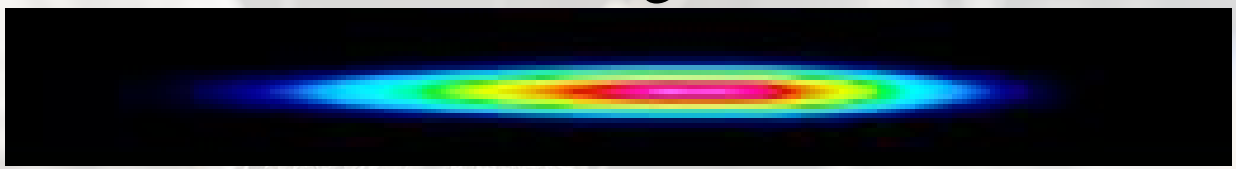
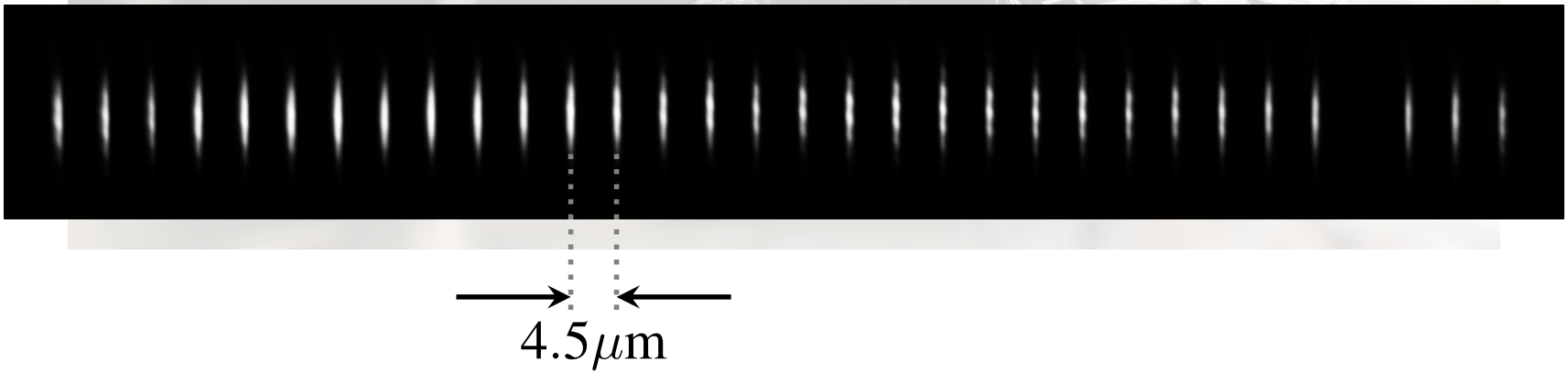
Global addressing Raman beam

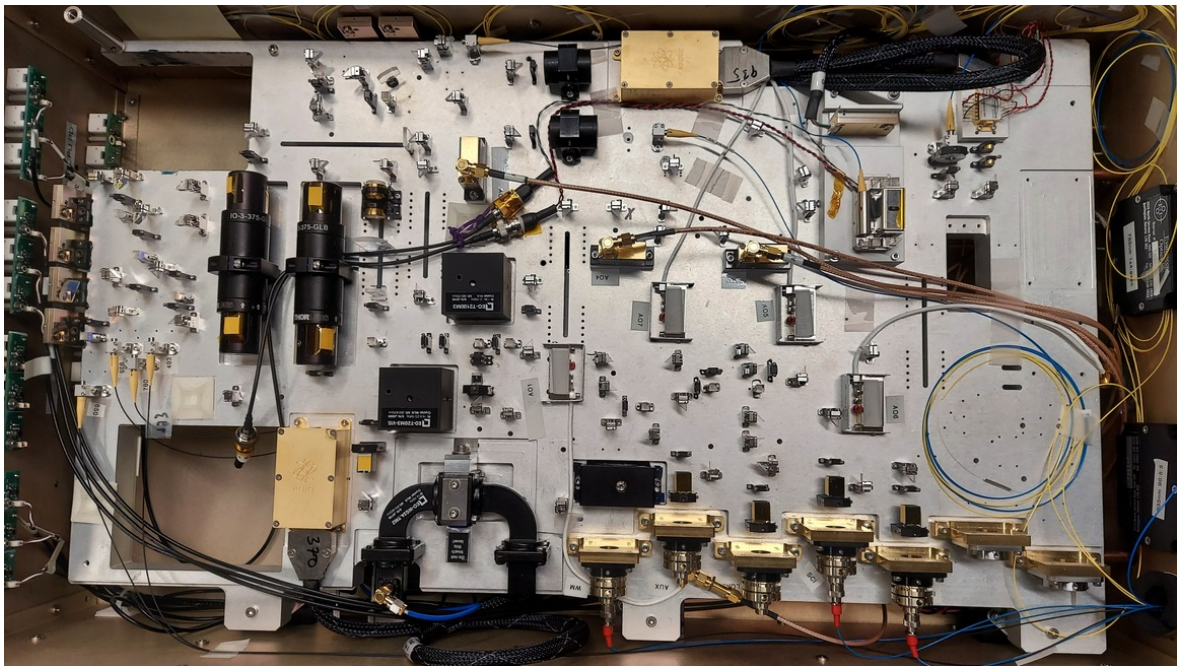


Individual addressing Raman beam



2nd gen EURIQA: CW lasers

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



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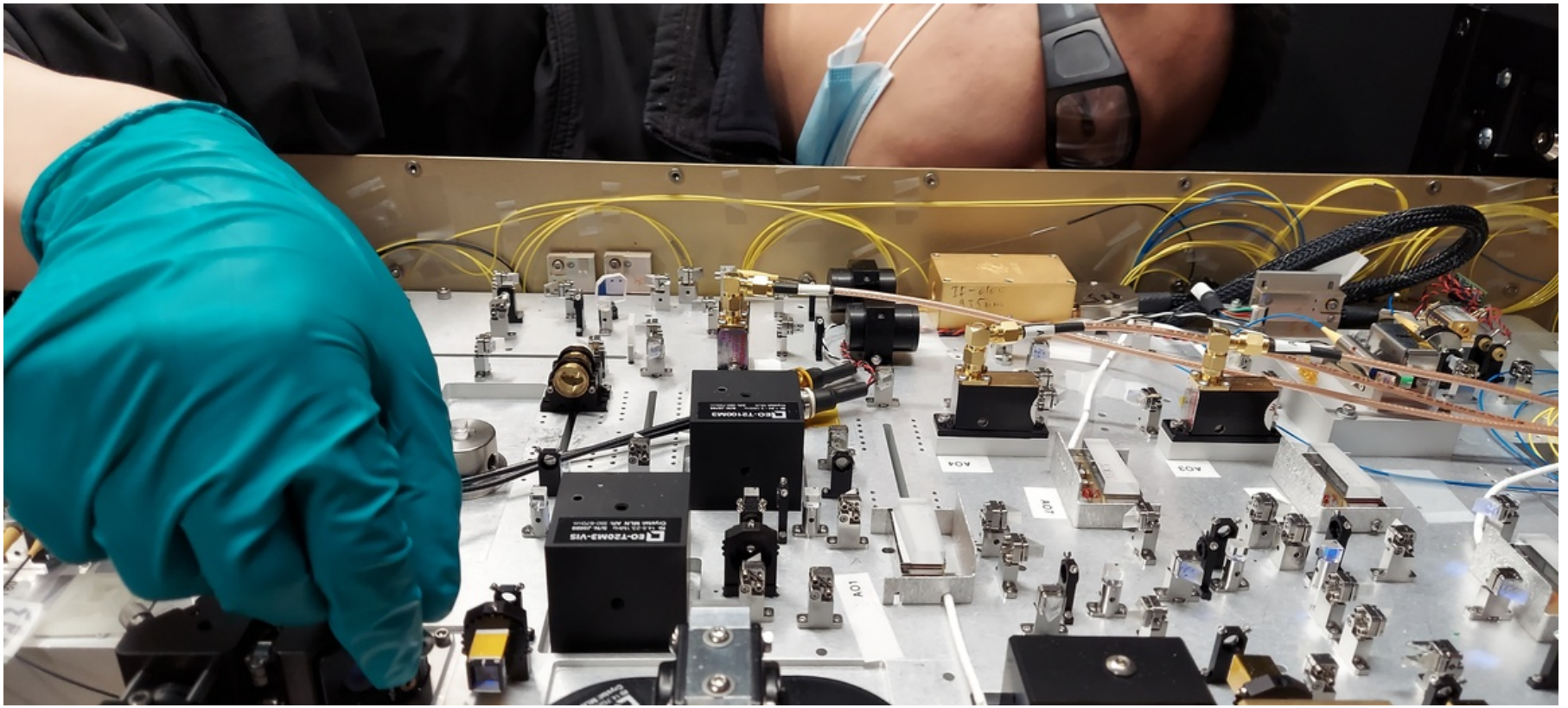
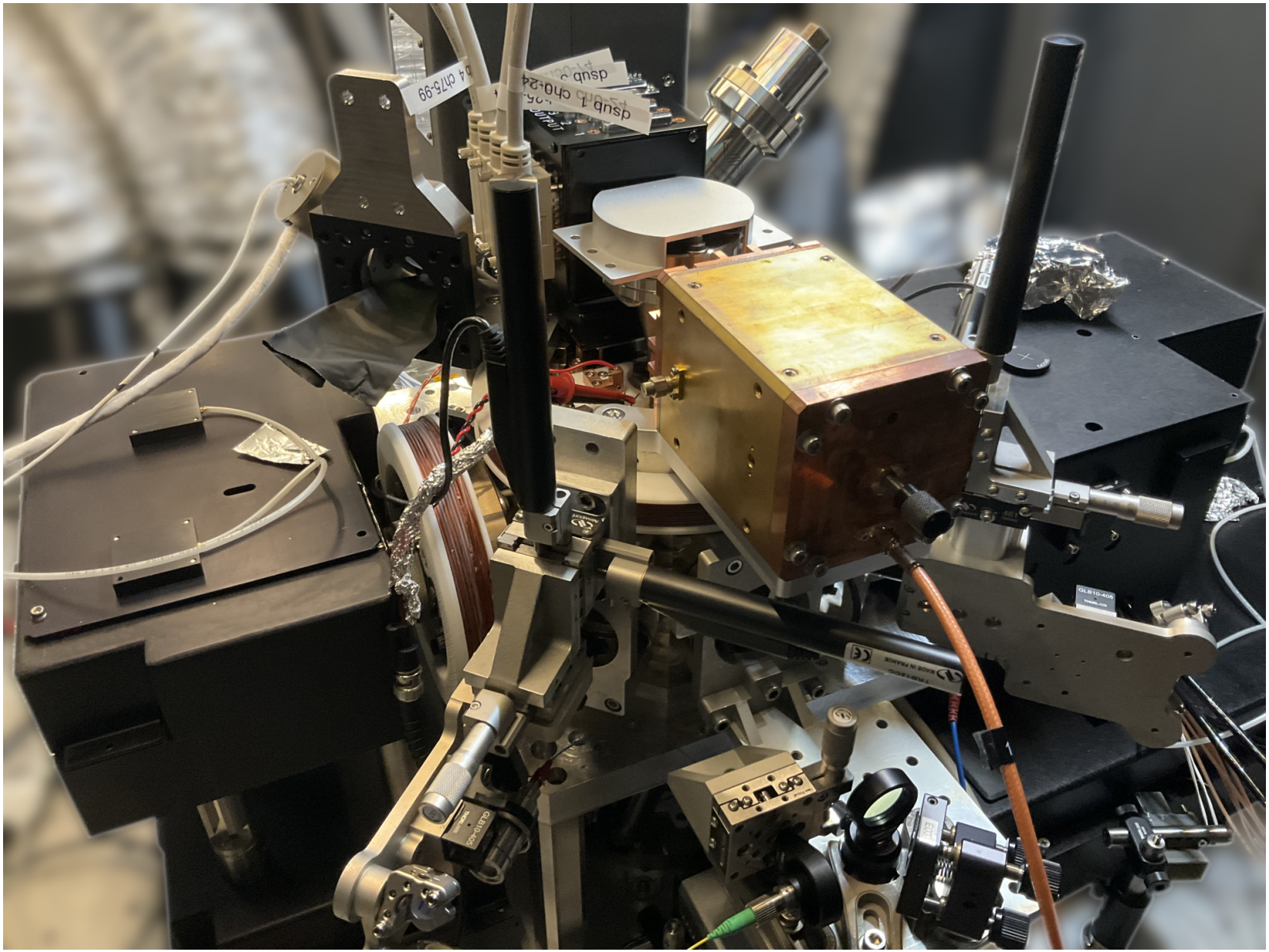


2nd gen EURIQA: status and first ion



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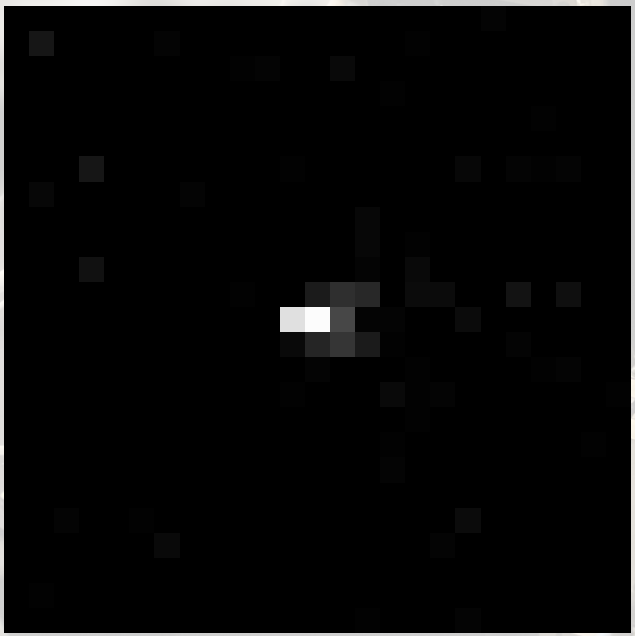

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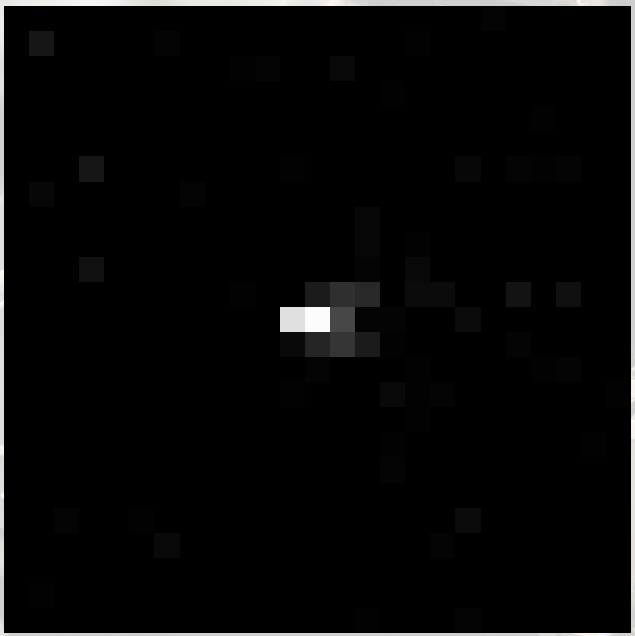

Christopher R Monroe

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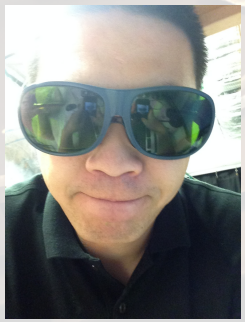

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