

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

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IARPA



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

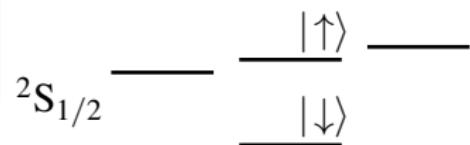
- Long coherence time: $T_2 \approx 1\text{hr}$

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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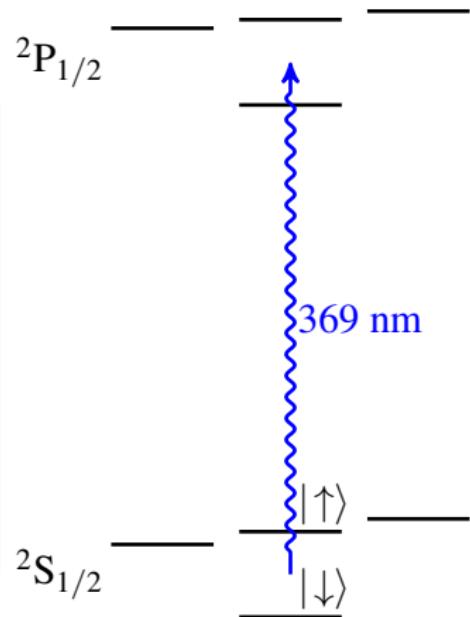
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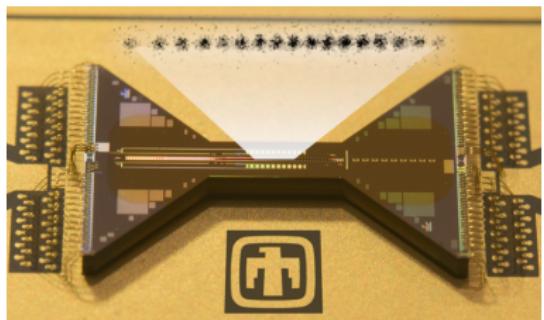
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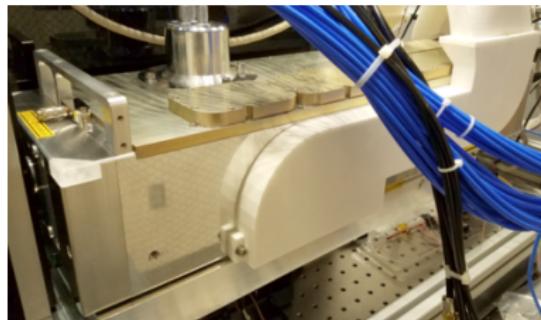
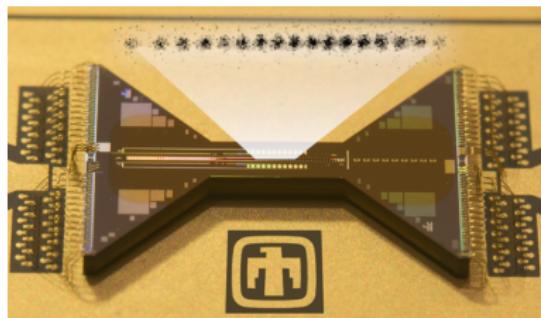
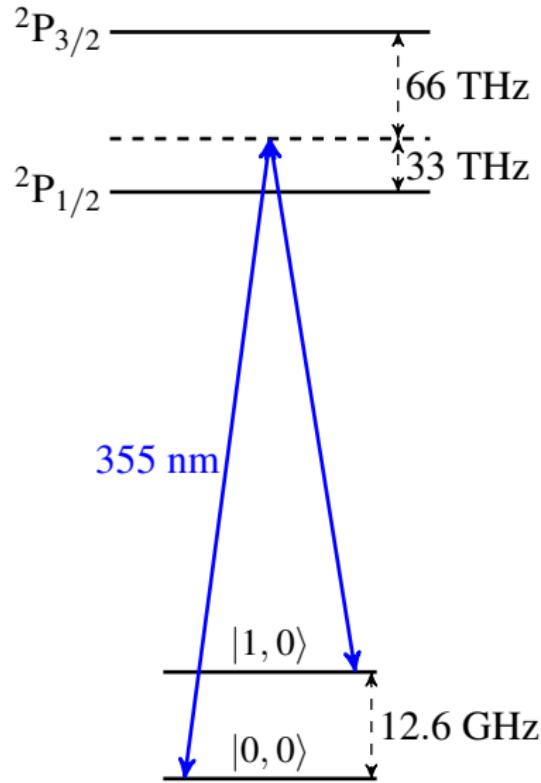
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1st generation EURIQA system

Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype



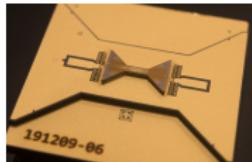
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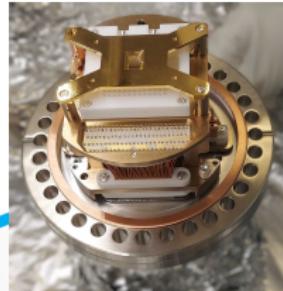


- 15-24 usable qubits
- High fidelity single (99.9 %) and two-qubit (99 %) gates

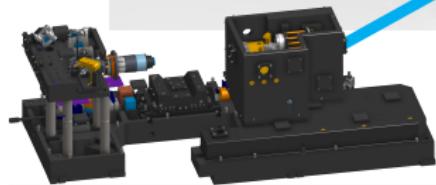
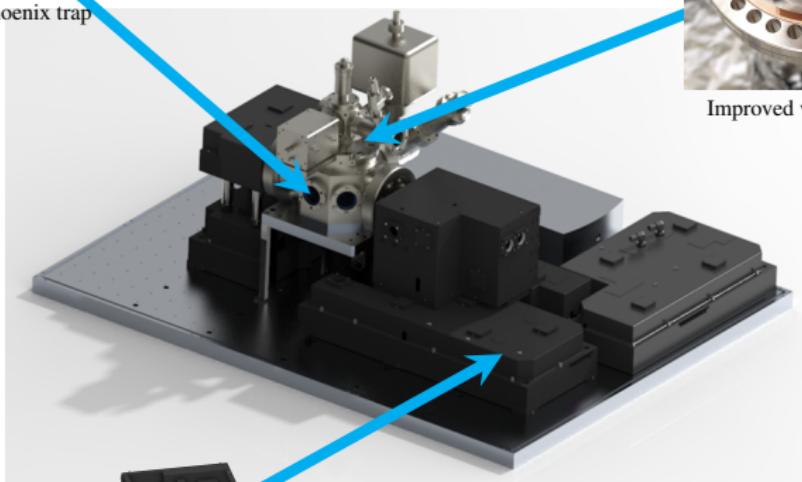
2nd generation EURIQA system



Sandia Phoenix trap



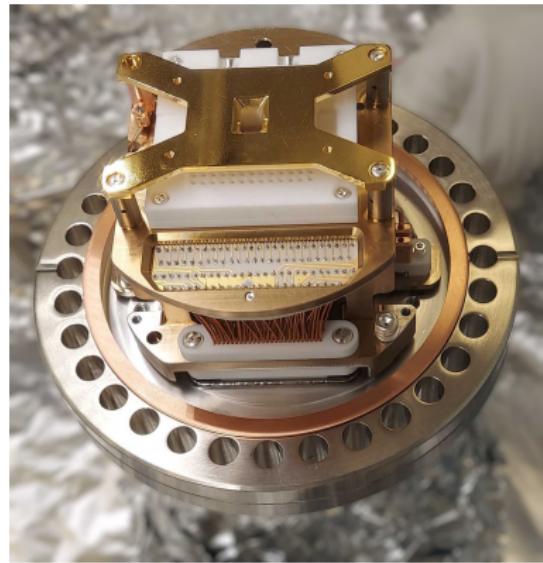
Improved vacuum system



L3Harris Raman beam path

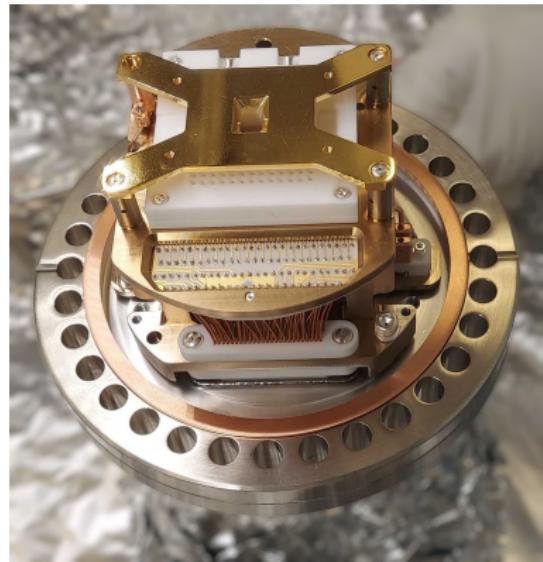
2nd gen EURIQA: Improved vacuum

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



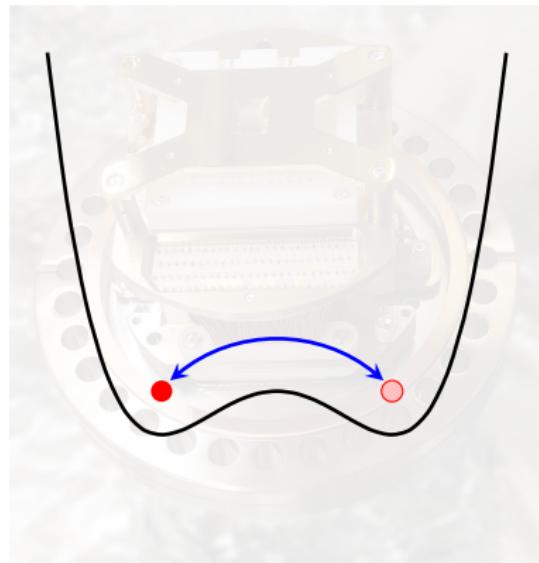
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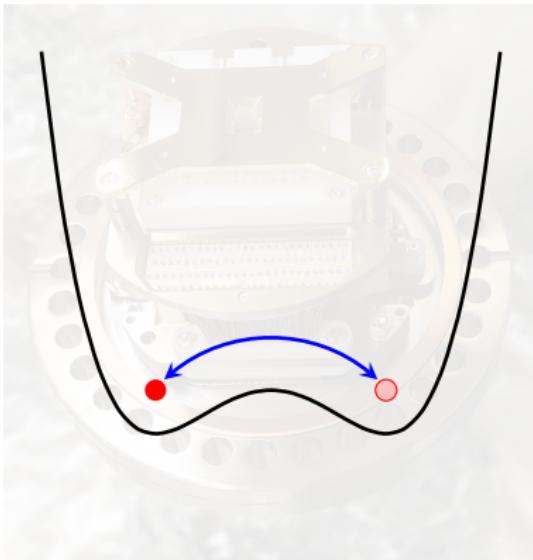
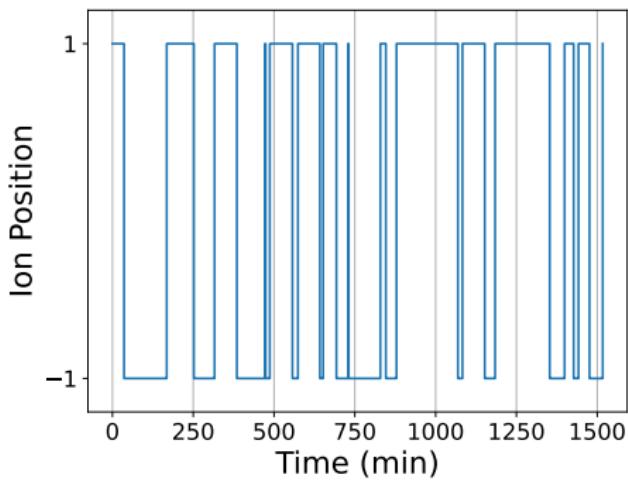
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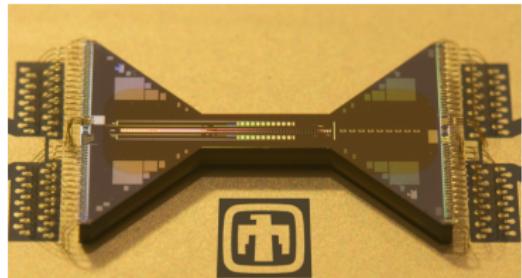
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2nd gen EURIQA: Phoenix trap

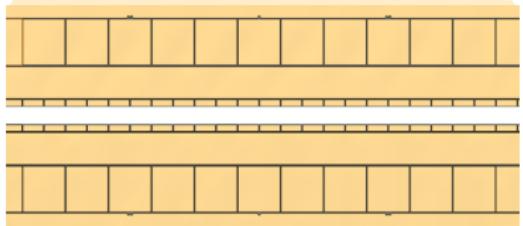
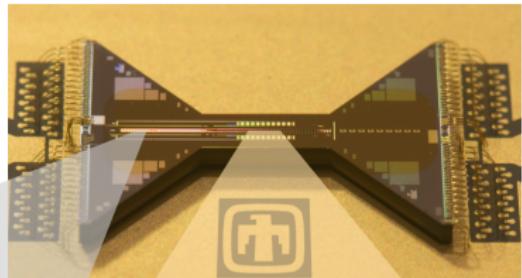
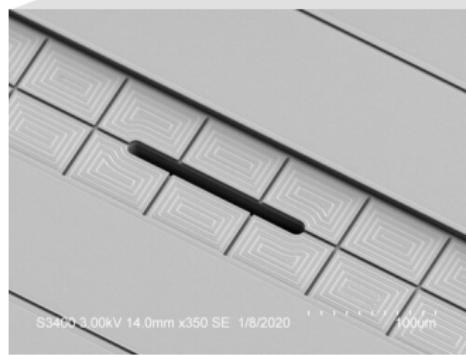
- Better loading and chain control
- Reduced surface electrical noise
3x less heating compared to EURIQA-1



F01.00038 The Quantum Scientific Computing
Open User Testbed (QSCOUT)

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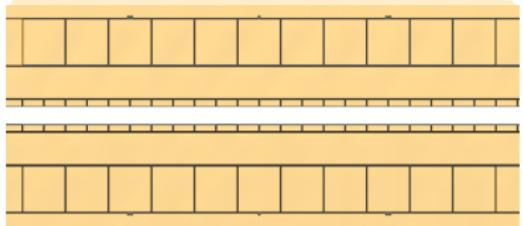
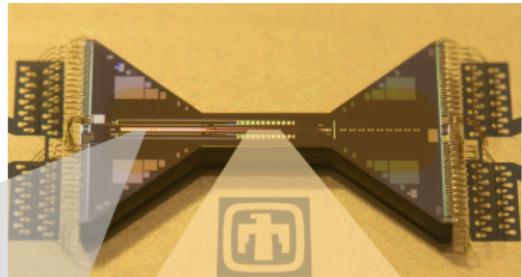
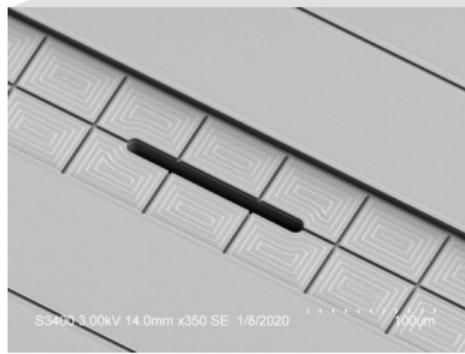


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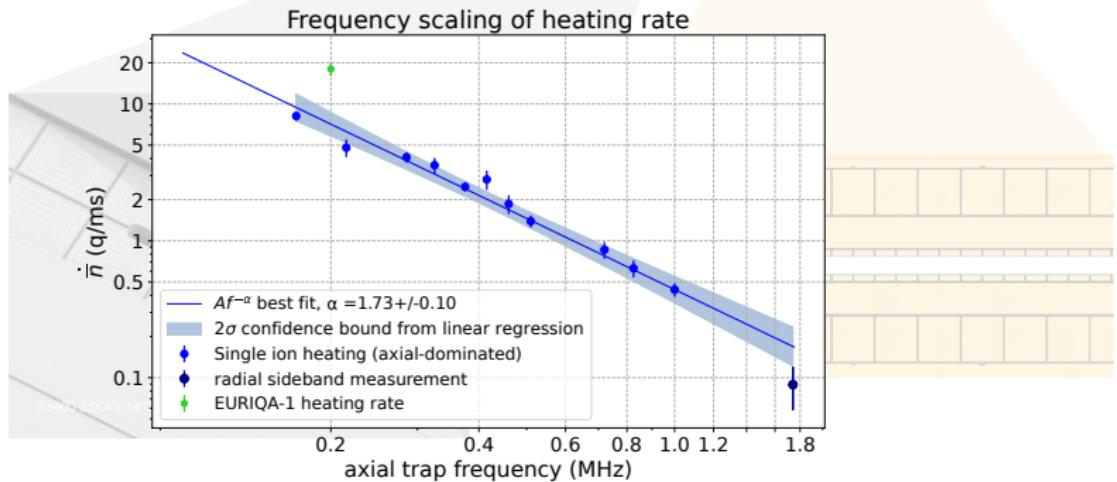
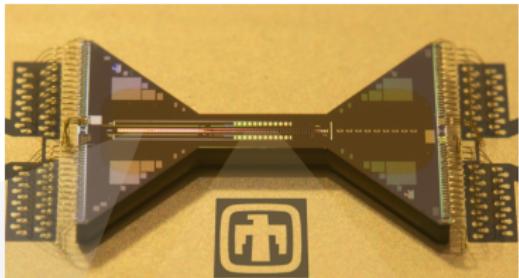
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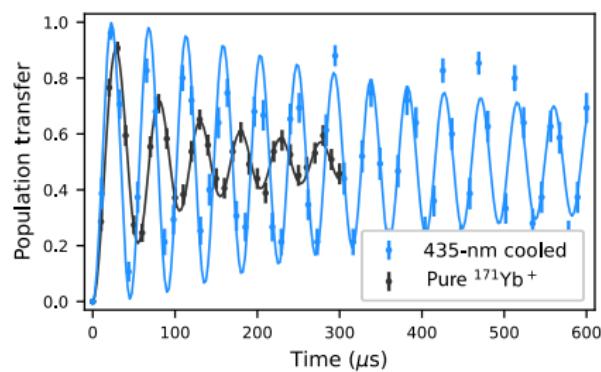
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2nd gen EURIQA: New Yb atom source

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

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

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

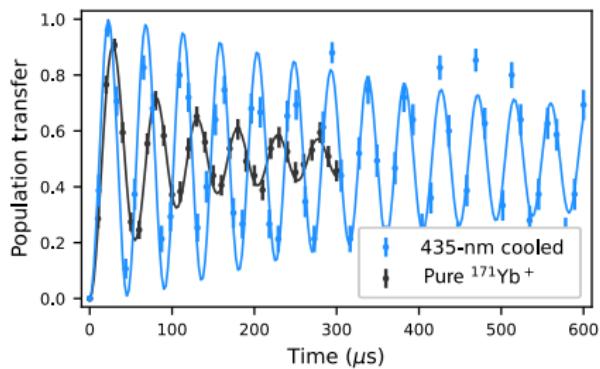
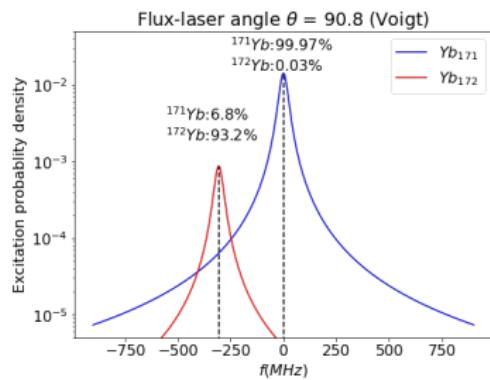


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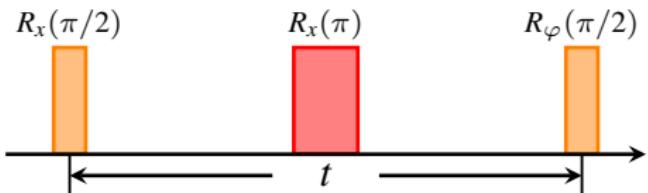
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2nd gen EURIQA: Qubit coherence

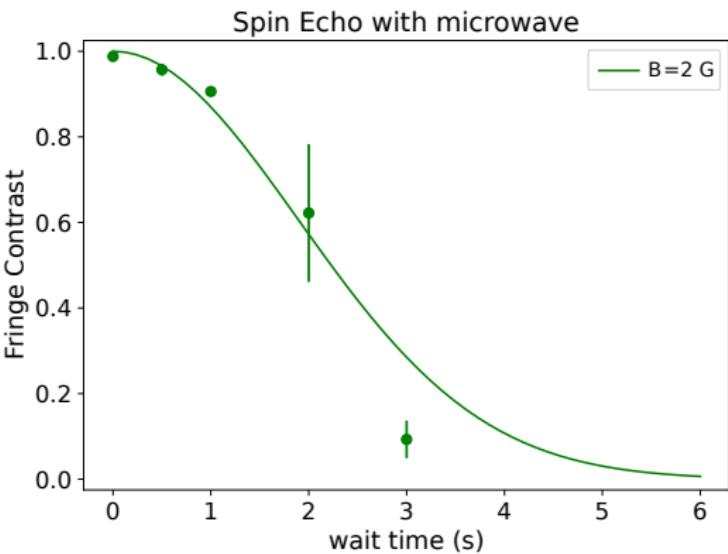
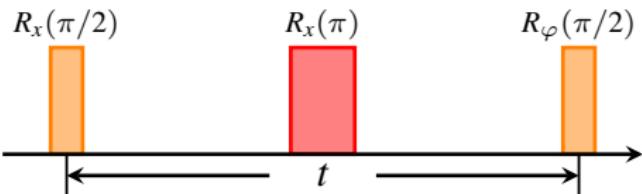
- Ramsey with spin-echo using microwave
- $T_2 = 2.68(36)$ s
(Can be further improved with shielding)



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2nd gen EURIQA: Imaging system



- NA=0.63 lens.
- 32 channel fiber bundle for individual detection.
- Crosstalk between neighboring channels: 0.05%

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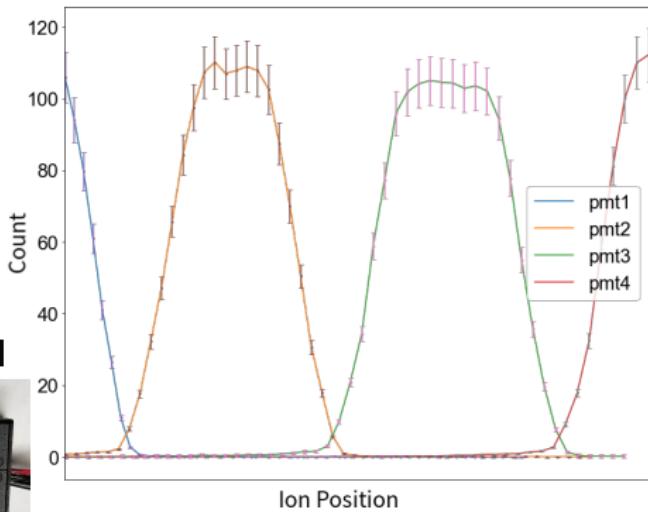
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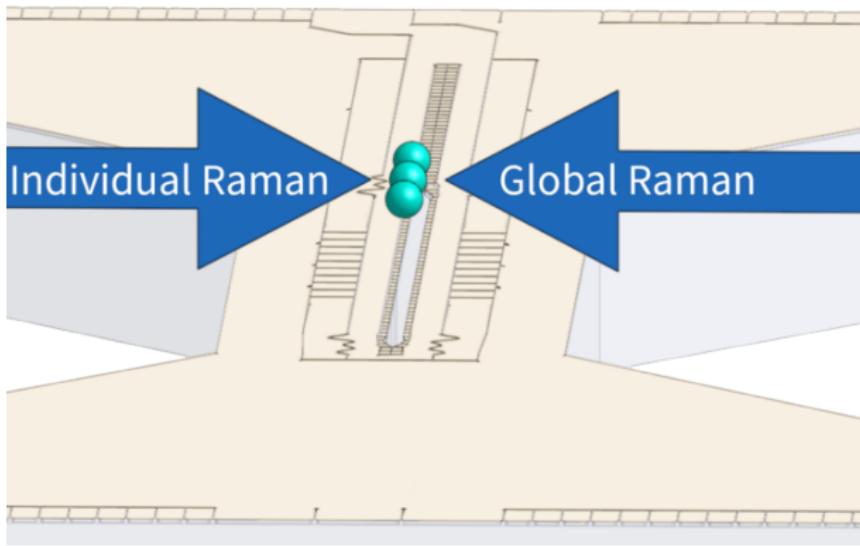
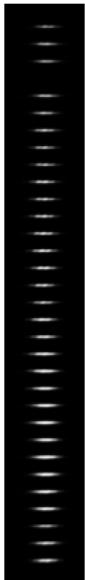


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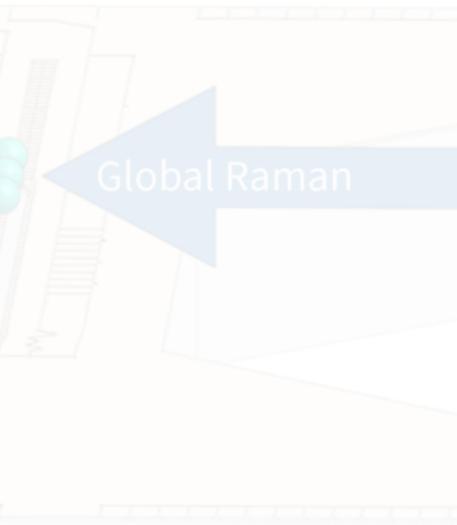
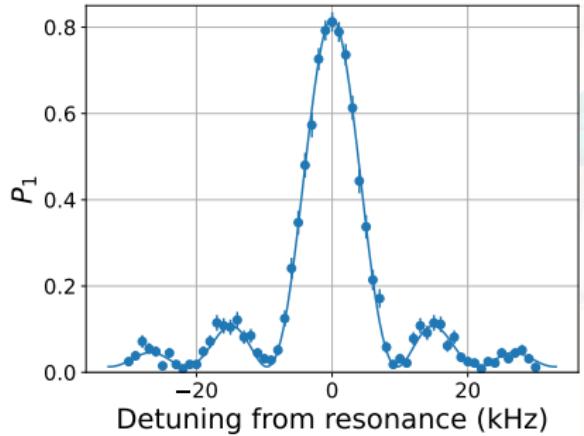
2nd gen EURIQA: Raman addressing

- Counter-prop global and individual beams
 - Cross-beam Raman signal
 - Individual addressing
- Nearest neighbor crosstalk: 2%.



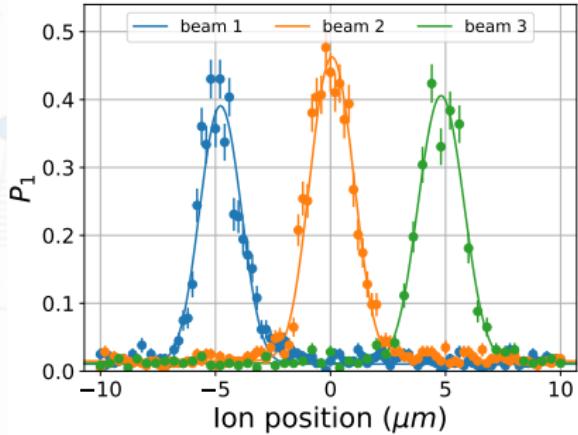
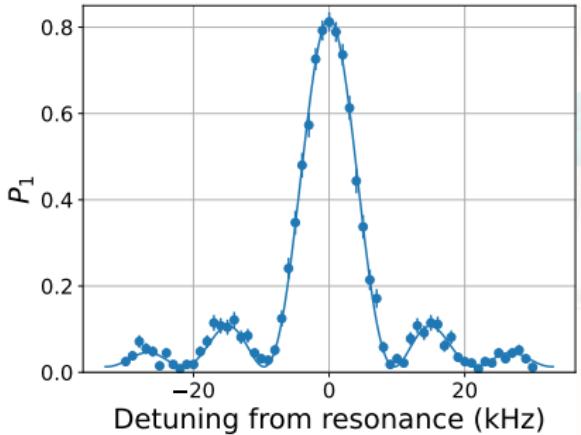
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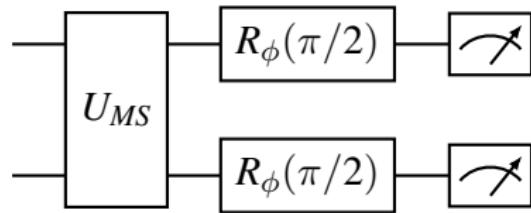


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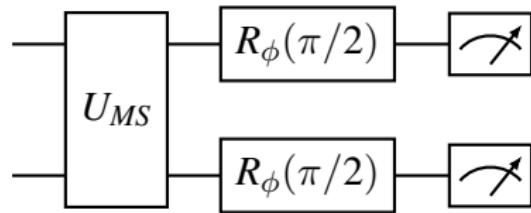
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2nd gen EURIQA: Mølmer-Sørensen Gate



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Christopher R Monroe



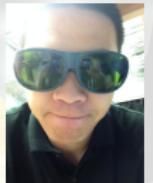
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