

A next-generation trapped ion quantum computing system

Yichao Yu

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Grant Eberle, Alexander Kozhanov, Christopher R Monroe

Monroe Group/Duke Quantum Center

Oct 16, 2023



IARPA



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

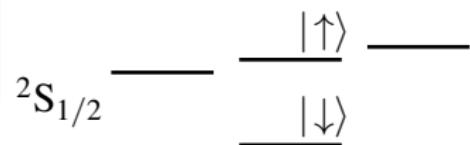
- Long coherence time: $T_2 \approx 1\text{hr}$

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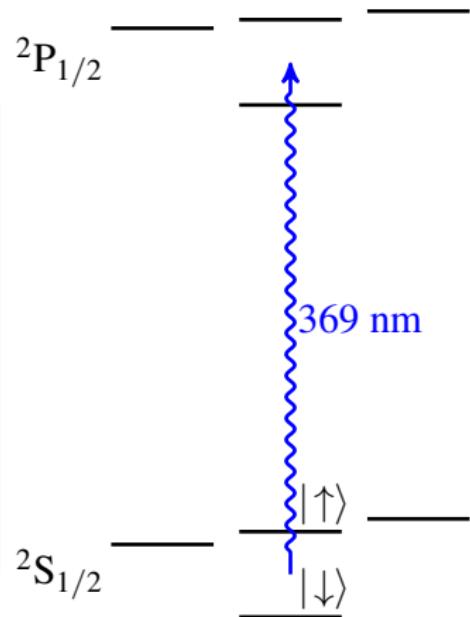
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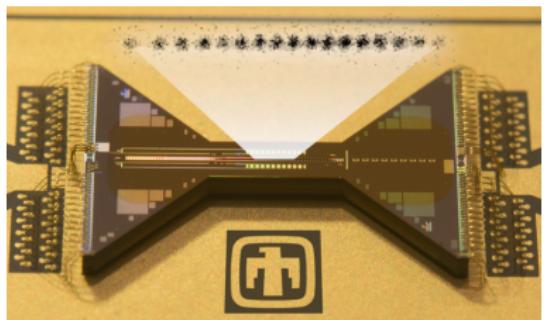
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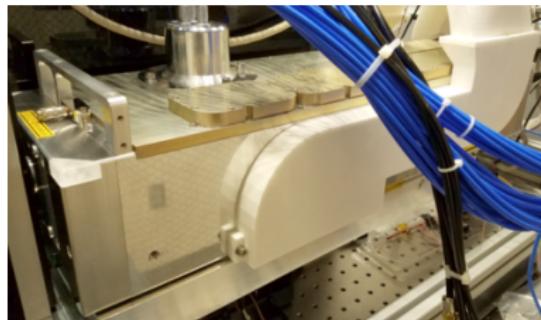
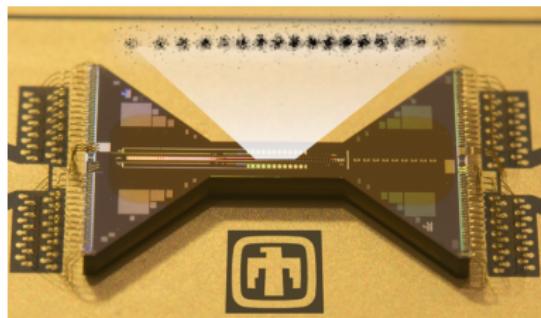
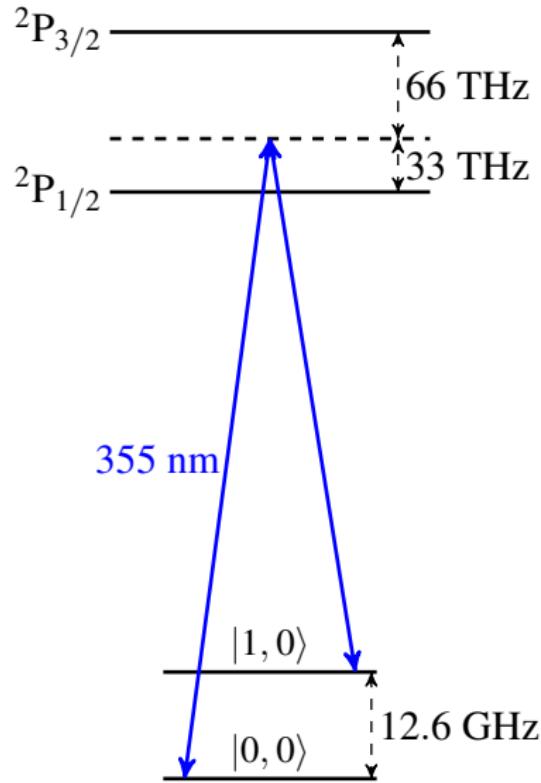
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$^{171}\text{Yb}^+$ chain and coherent manipulation



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1st generation EURIQA system

Error-corrected Universal Reconfigurable Ion-trap Quantum Archetype



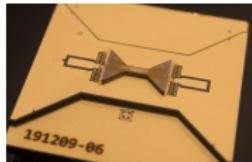
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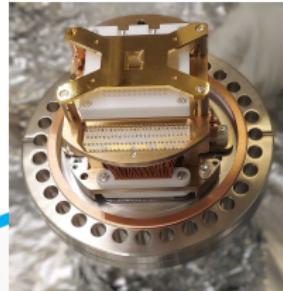


- 15-24 usable qubits
- High fidelity single (99.9 %) and two-qubit (99 %) gates

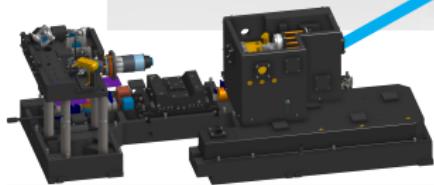
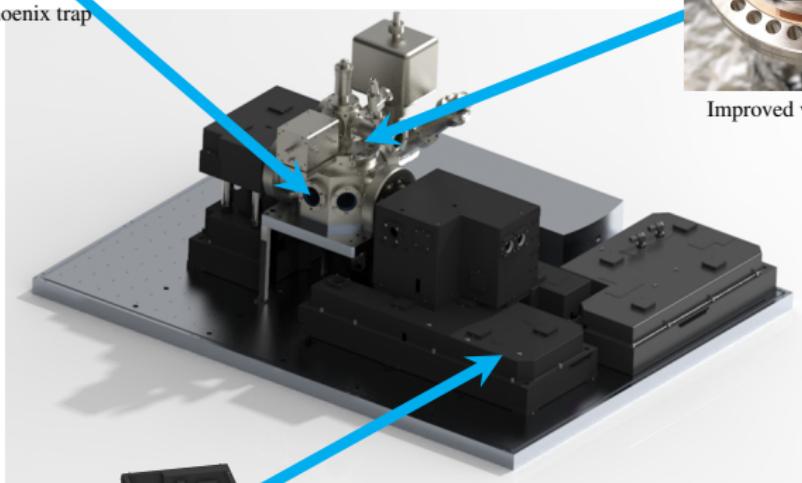
2nd generation EURIQA system



Sandia Phoenix trap



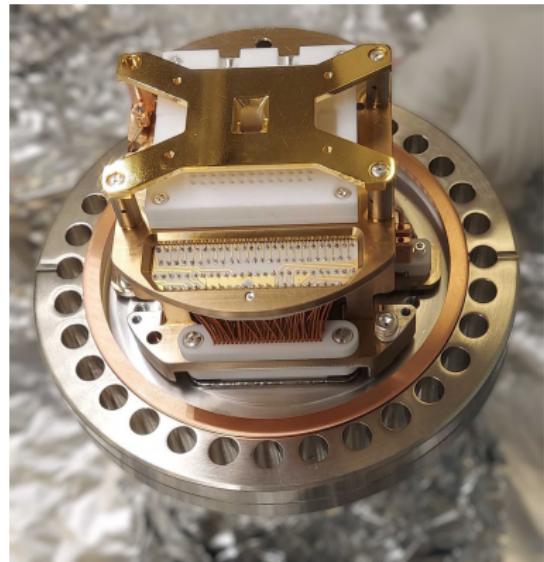
Improved vacuum system



L3Harris Raman beam path

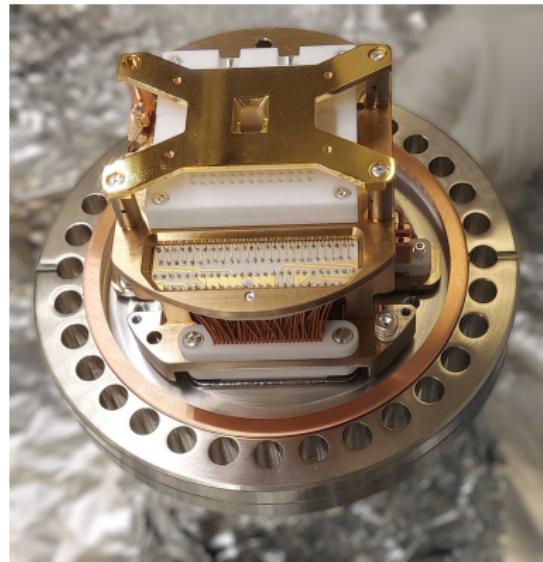
2nd gen EURIQA: Improved vacuum

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



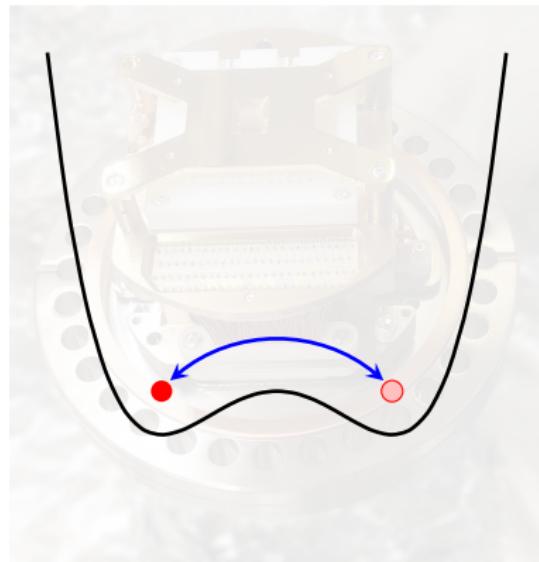
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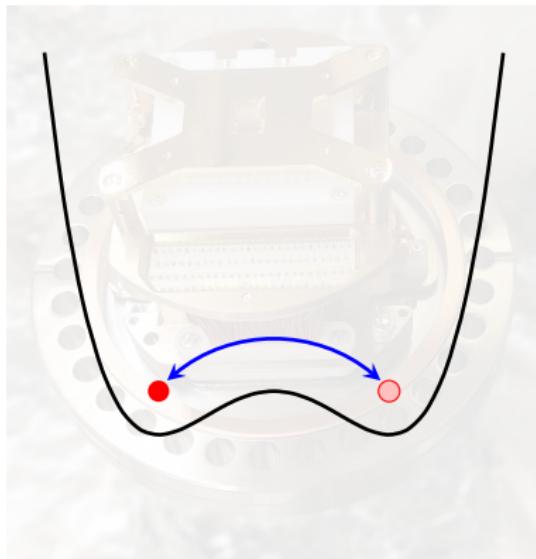
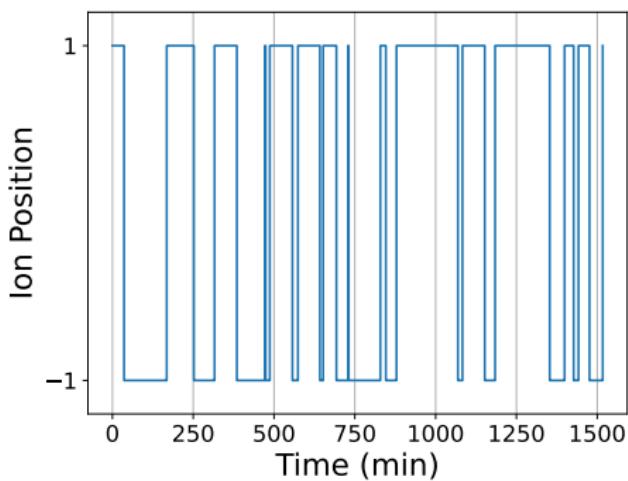
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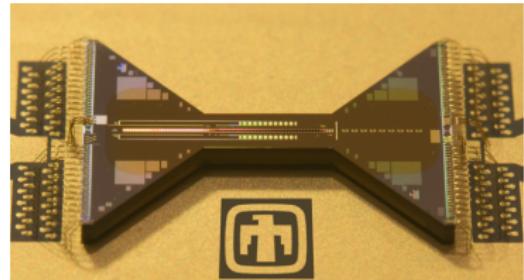
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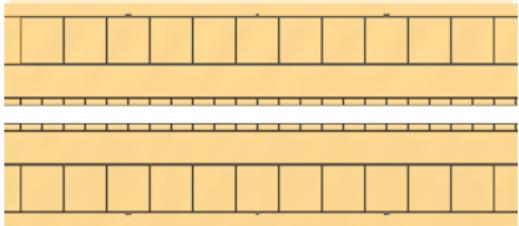
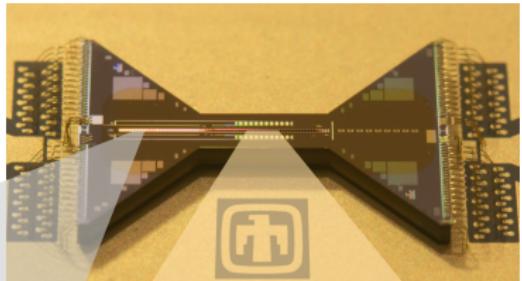
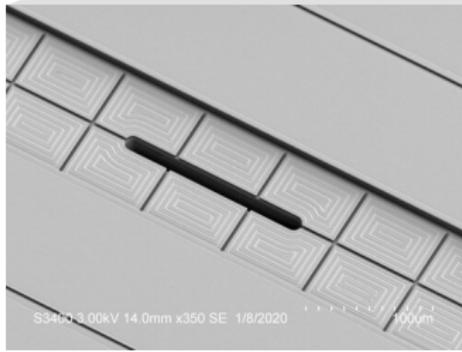
2nd gen EURIQA: Phoenix trap

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



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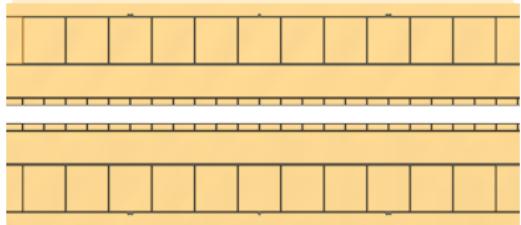
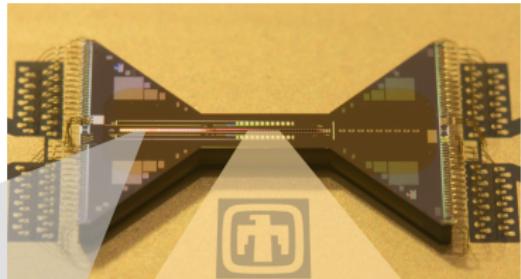
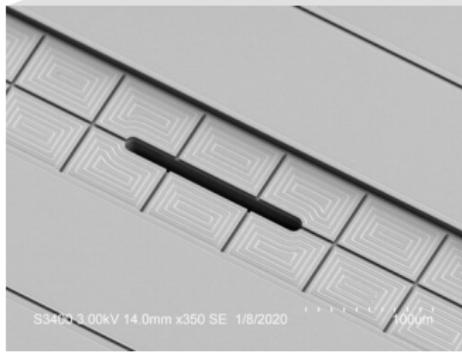
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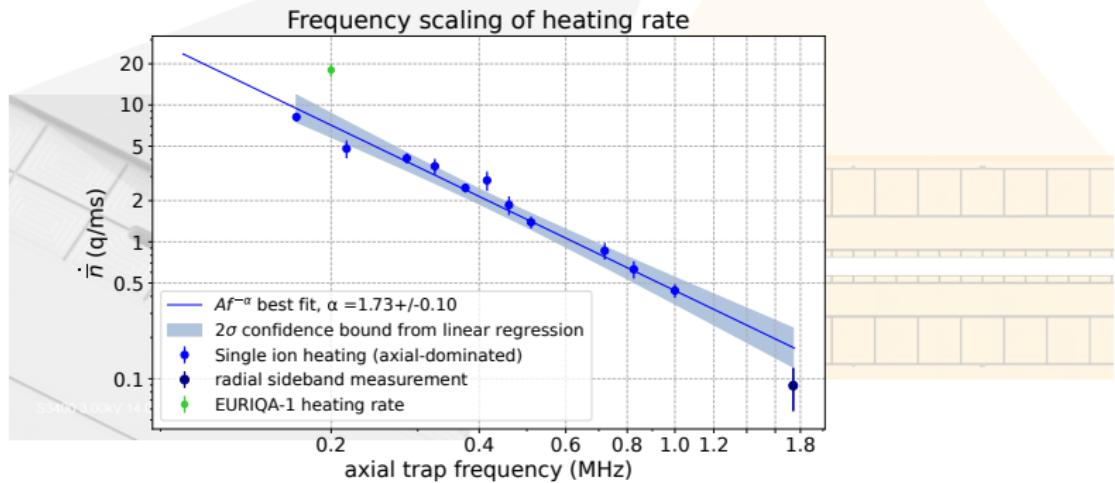
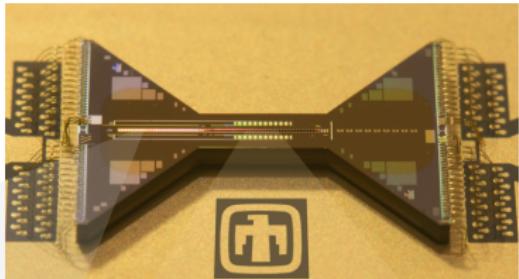
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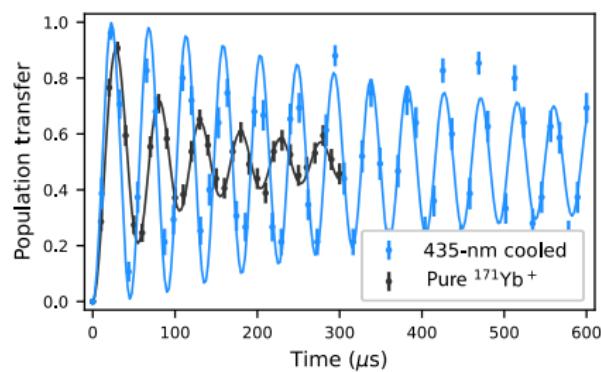


2nd gen EURIQA: New Yb atom source

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

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

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

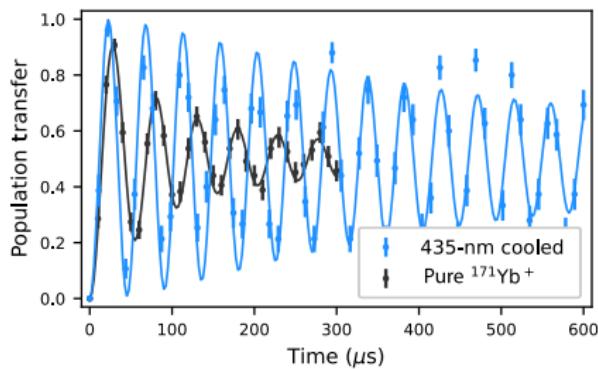
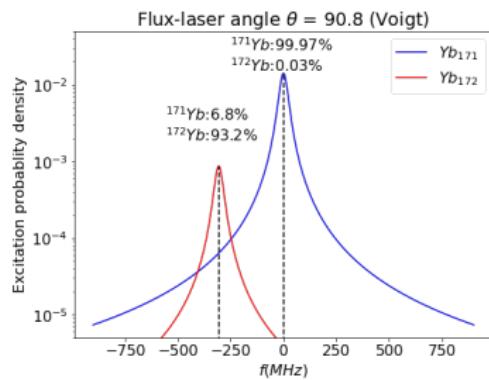


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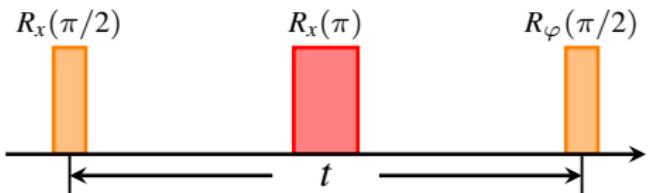
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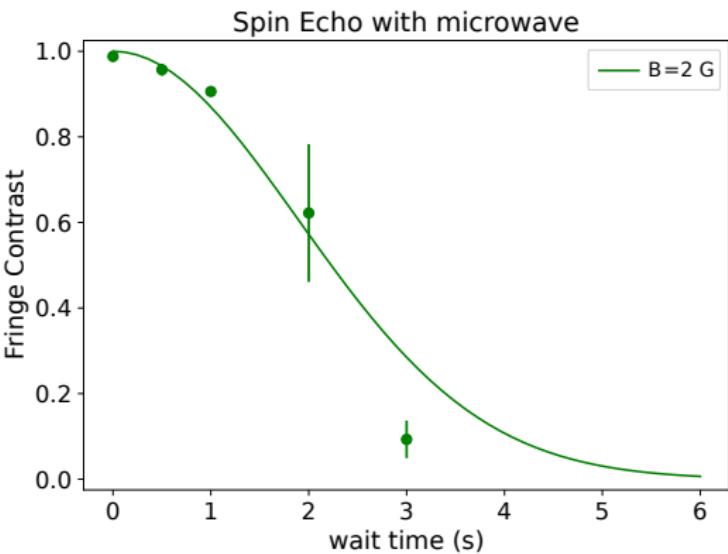
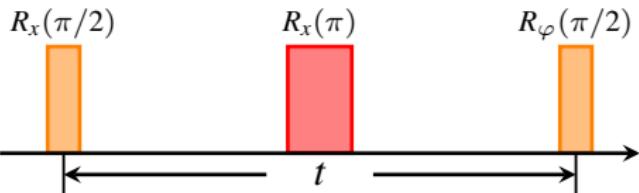
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- Ramsey with spin-echo using microwave
- $T_2 = 2.68(36)$ s
(Can be further improved with shielding)



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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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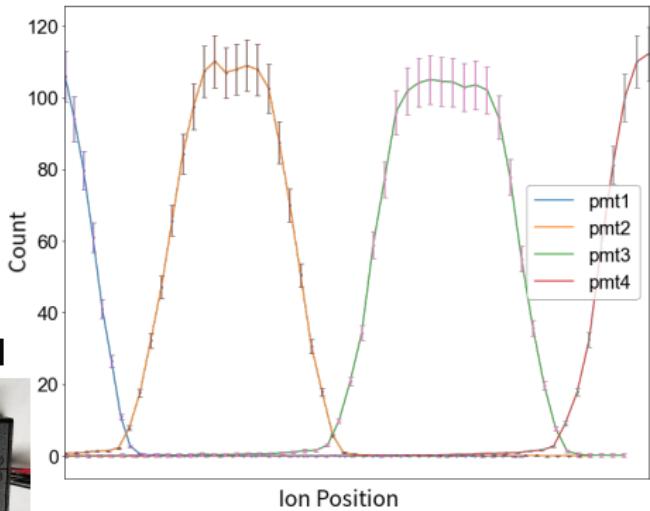
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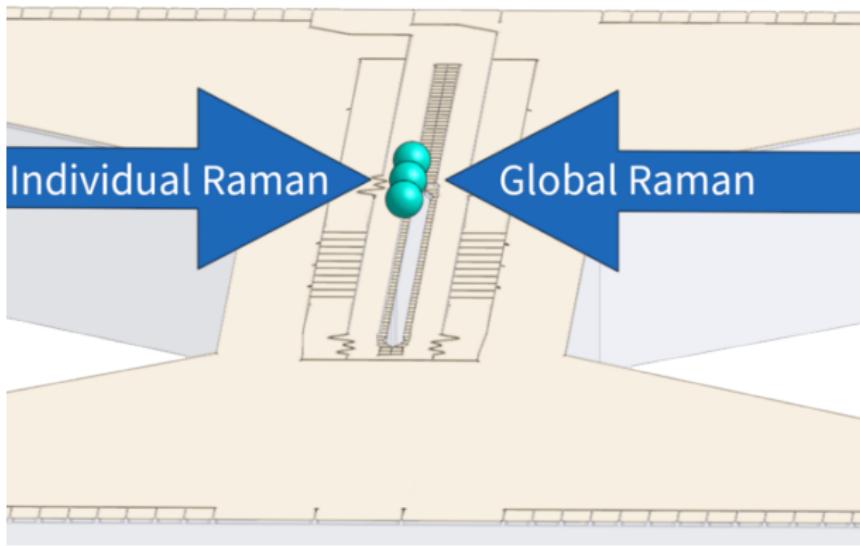
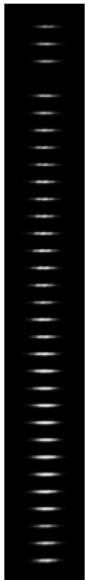


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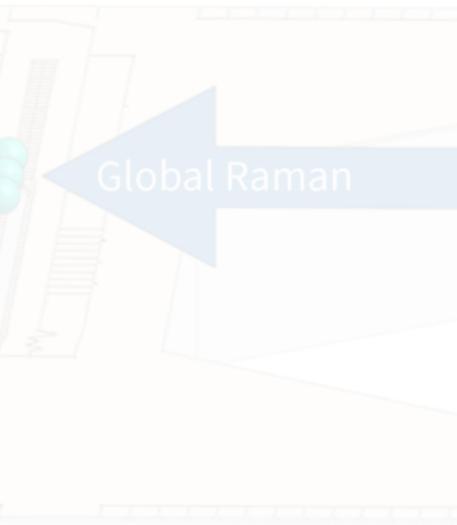
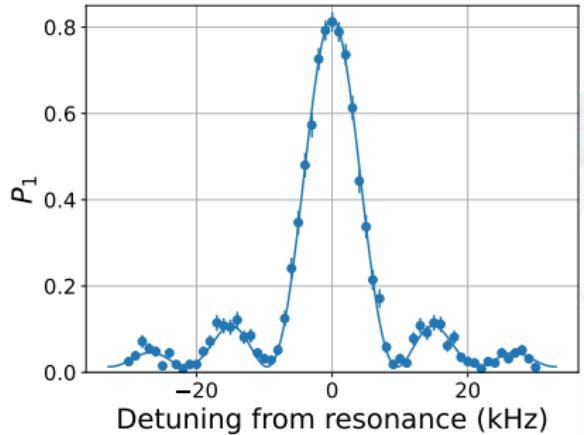
2nd gen EURIQA: Raman addressing

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



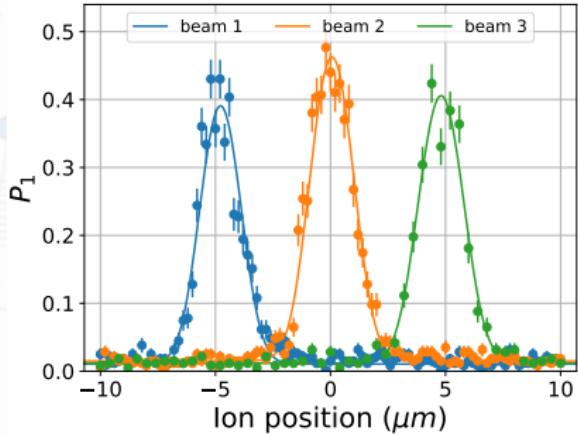
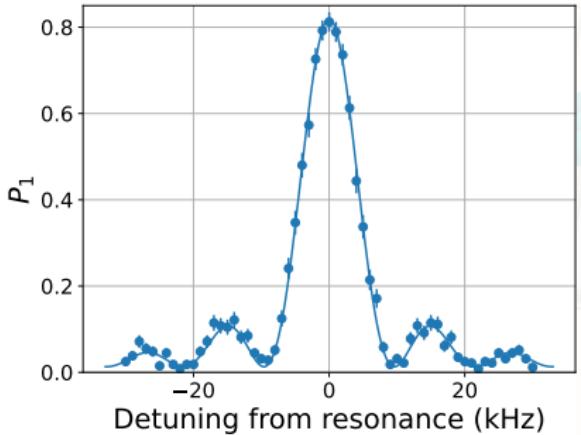
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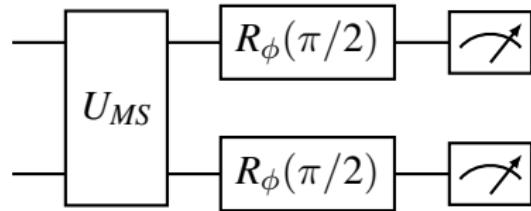


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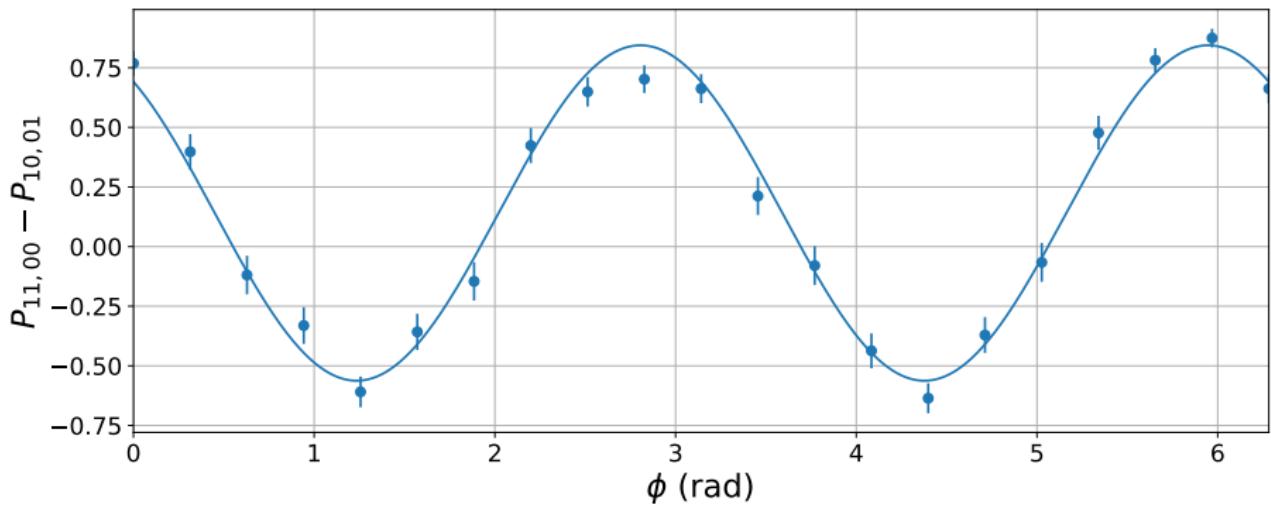
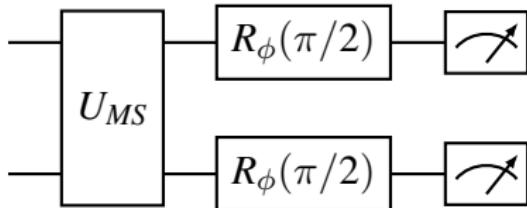
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Christopher R Monroe



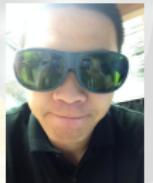
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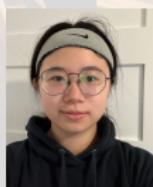
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