Benchmarking A Neutral-Atom Quantum Computer

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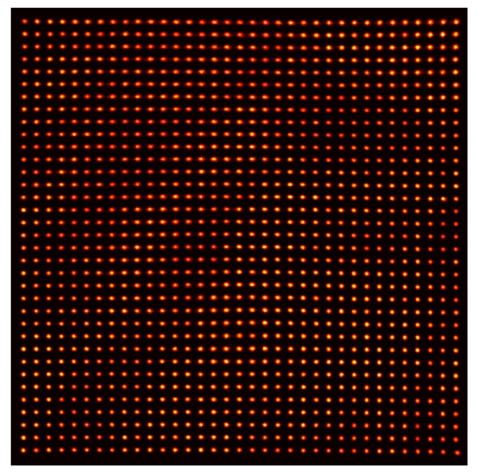
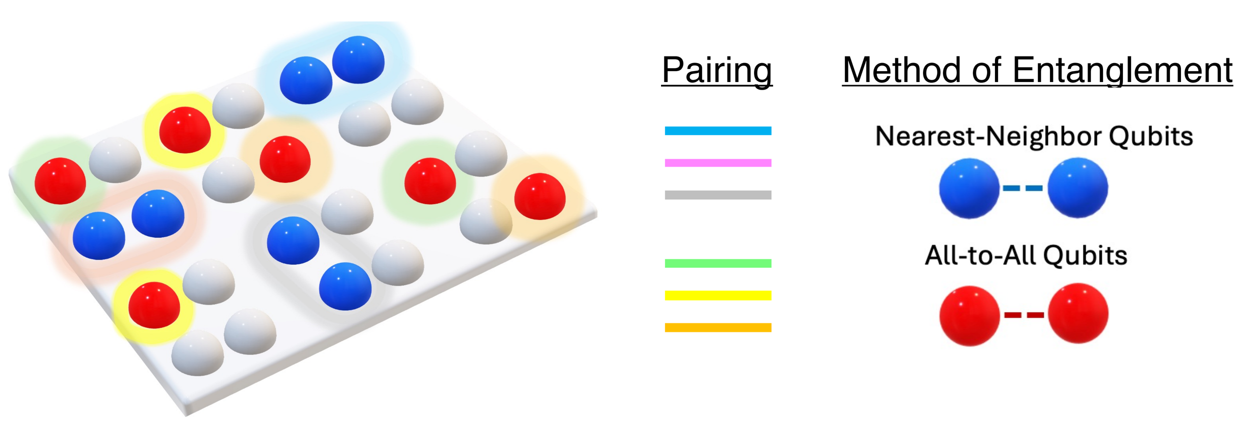
BACKGROUND

Several qubit arrangements have been proposed for a scalable quantum computer using neutral atom quantum computing arrays. (*Right*: Lattice of entangled Cesium atoms)

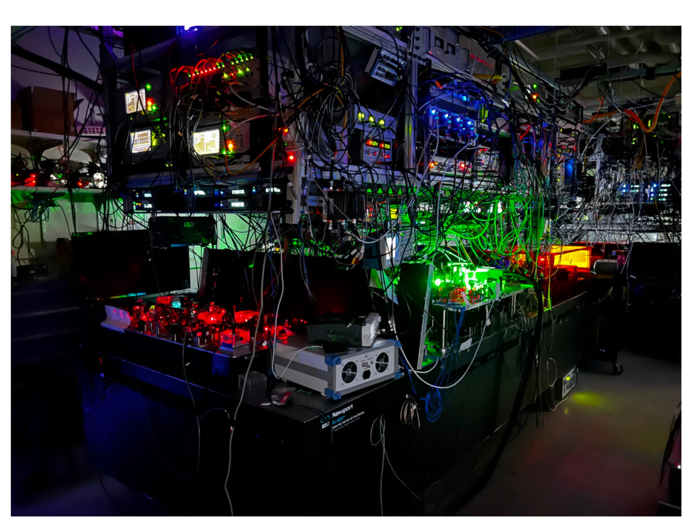


Cesium atoms can be entangled using lasers to manipulate data using qubits.

There are two major kinds of atomic entanglement: *all-to-all* and *nearest-neighbor*. We hypothesize that all-to-all connectivity significantly increases data fidelity.



OBJECTIVES



Our work developed a mathematical, computer based noise model which models sources of noise found in the experimental lab quantum processor.

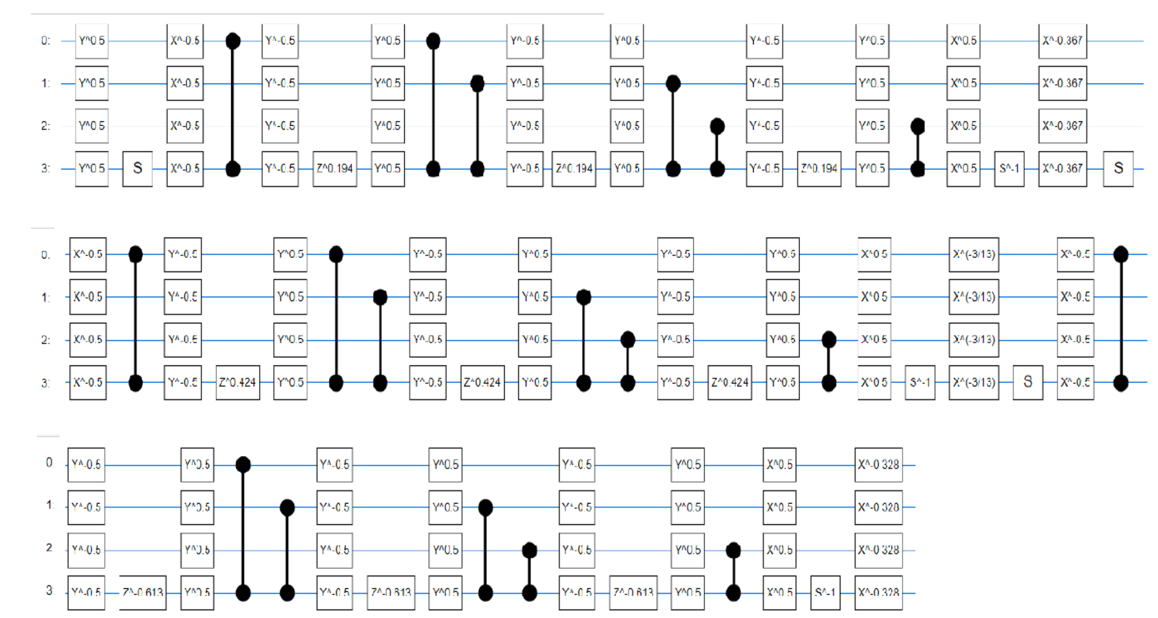
Our research objectives were threefold:

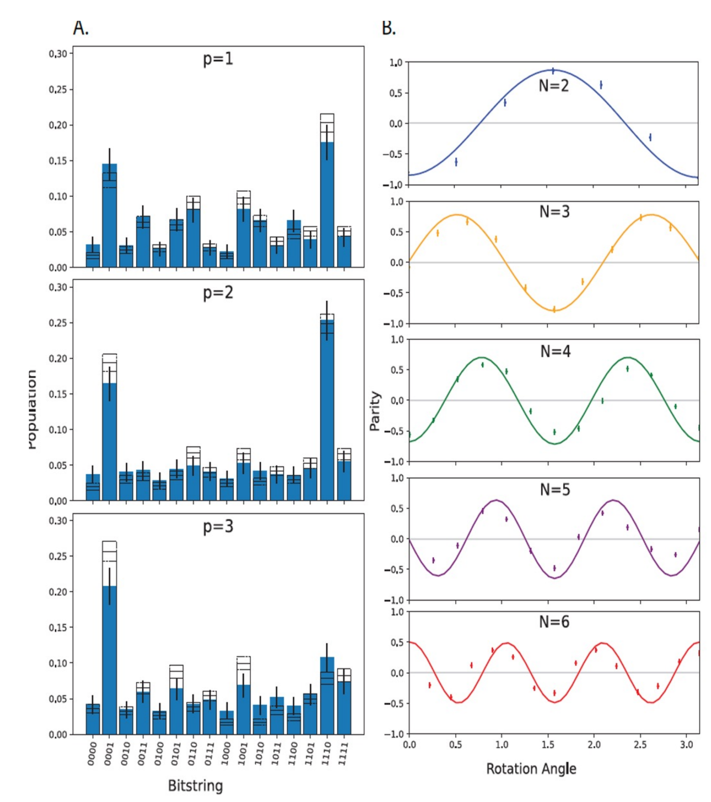
- Develop and benchmark a software-based quantum computer simulator to run different Cesium-based qubit configurations and lattice sizes
- Using simulator, determine if all-to-all vs. nearest neighbor entanglement arrangements make difference in data fidelity
- Explore and model scalability using the simulator

With the simulator, we can model different experiments before reconfiguring the sensitive laser table.

METHODS

- (*Right*) Circuit diagram of four qubit simulated circuit used in benchmarking experiments
- Circuit diagram shown in Inverse Quantum Fourier Transform format

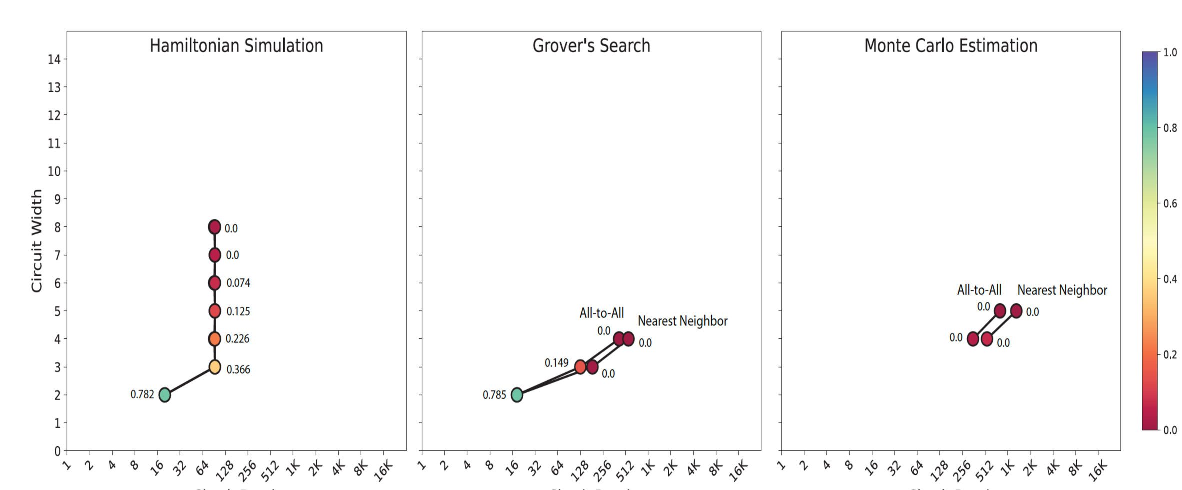


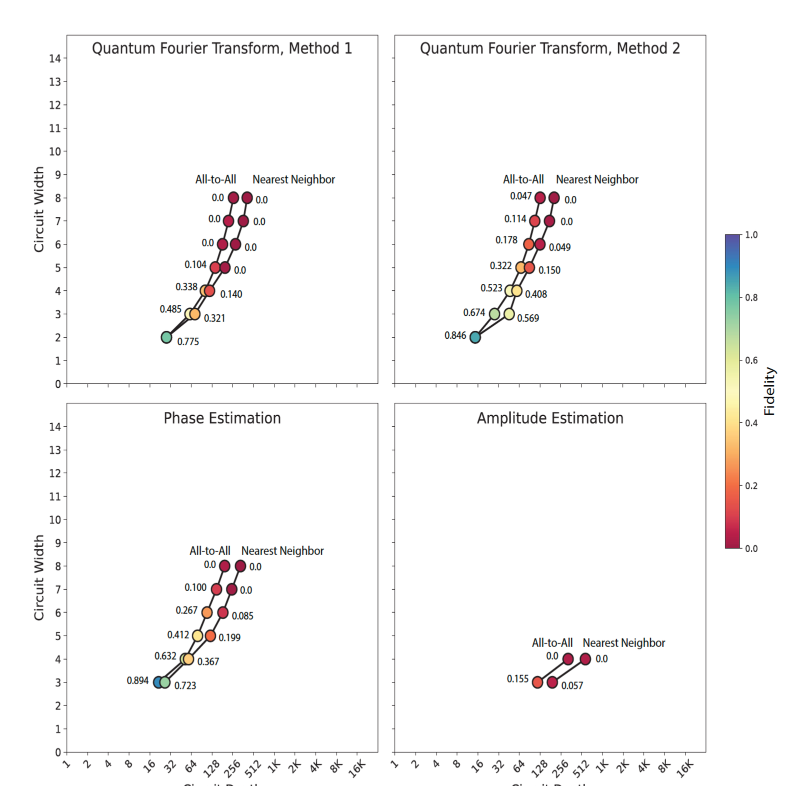


- (*Left*) Column A - Results of four qubit algorithm simulation, with unfilled bars representing experimental data; blue fill being simulated data. Results highly correlated, demonstrating low noise margins.
- Column B - Parity oscillation curves of 2-6 qubit GHZ states. Data points represent experimental data; solid-colored curves represent simulated data.

RESULTS

- (*Right*) Simulation results for Hamiltonian simulation, Grover's search, and Monte Carlo estimation
- For Hamiltonian simulation there was negligible difference between all-to-all and nearest-neighbor circuits



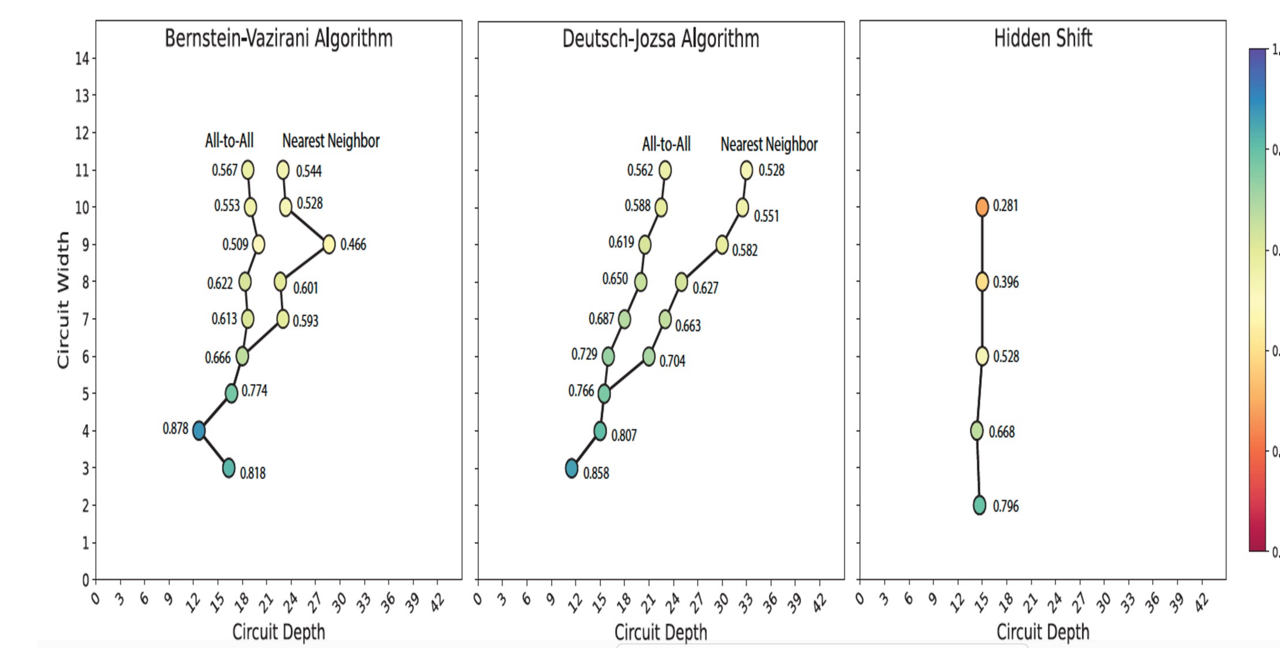


- (*Left*) Simulation results for the phase estimation, amplitude estimation, and both Quantum Fourier Transform benchmarks
- Simulator runs Bernstein-Vazirani & Deutsch-Jozsa circuits with up to five qubits having greater than 70% fidelity; Hidden Shift circuit up to four qubits exceeds > 60% fidelity
- Accuracy well-maintained at increasing qubit counts simulated up to 11-qubit implementations

CONCLUSIONS

Using completed and benchmarked simulator, experimental results support our hypotheses that:

1. Neutral-atom quantum computers demonstrate growing evidence that they are scalable (in these simulations up to 11-qubits)
2. All-to-all qubit array topologies offer 10-15% better data fidelity versus nearest-neighbor entanglement configurations
3. Inverse Quantum Fourier Transform fidelity increased by 13% within the 3-5 qubit range, peaking at a 17% increase using a five-qubit implementation



KEY REFERENCES

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