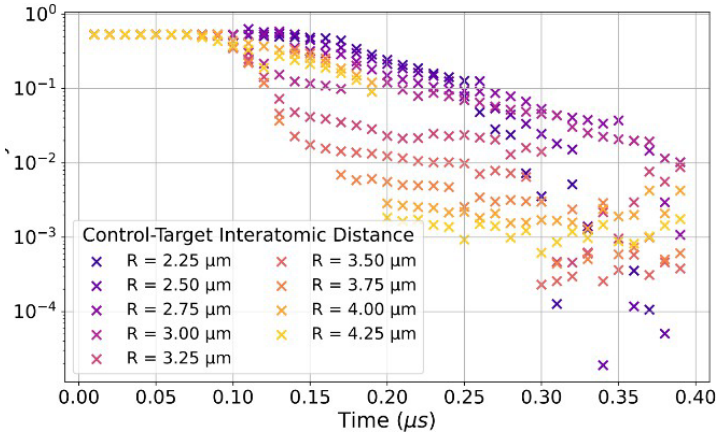
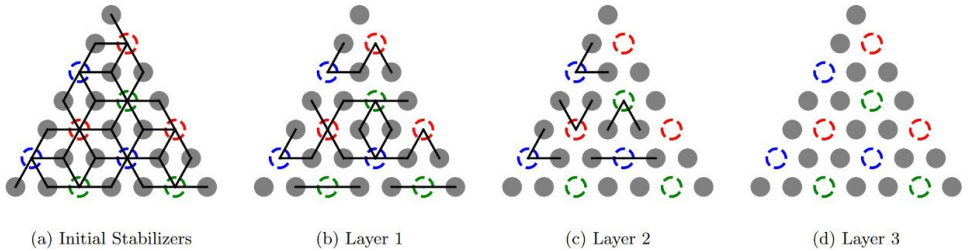
Multi-Target Rydberg Gates via Spatial Blockade Engineering



Gate fidelity versus time for varying atom-atom radii. Intermediate radii achieve high fidelity rapidly, while smaller or larger radii require longer evolution times.



Color-coded stabilizer scheduling over time cycles, showing how larger multi-qubit gates reduce the number of required cycles.

S. Stein, C. Liu, S. Kan, E. Crane, Y. Ding, Y. Mao, A. Schuckert, and A. Li, "Multitarget Rydberg gates via spatial blockade engineering," Phys. Rev. Res. 8, 013254 (2026). DOI:10.1103/k72m-9tn8

Scientific Achievement

Geometric control of Rydberg blockade enables single-control, multi-target, low-overhead $C(Z^{\otimes N})$ gates with CZ-like durations and >99% simulated noisy fidelities for N=2,3

Significance and Impact

Multi-target entangling gates can substantially reduce stabilizer-measurement depth in quantum error correction, the most important protocol for fault tolerance.

Research Details

- Introduced a geometric Rydberg-blockade scheme to realize asymmetric interactions.
- Designed single-control multi-target $C(Z^{\otimes N})$ gates (CZZ, CZZZ) using optimized global pulses with CZ-like gate times using machine learning.
- Achieved >99% simulated fidelity for N=2,3 under realistic noise, including Rydberg decay and atomic positions.
- Demonstrated up to 50% reduced stabilizer-measurement depth via scheduling optimization over the color code, with cycle reductions enabled by multi-target gates, and application to future quantum error correcting code implementation and design.

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- **NQISRC Intellectual Role:** *Collaborator*
- **NQISRC Funding Role:** *Majority*
- **Explanation of Funding Institution Contributions**
  - Quantum Algorithms and Architecture for Domain Science (QuAADS), Laboratory Directed Research and Development (LDRD) Initiative, Pacific Northwest National Laboratory (PNNL)
  - U.S. Department of Energy (DOE), Office of Science, National Quantum Information Science Research Centers, Quantum Science Center (QSC)
  - Pacific Northwest National Laboratory (PNNL), operated by Battelle for DOE (Contract DE-AC05-76RL01830)
  - Oak Ridge Leadership Computing Facility (OLCF), DOE Office of Science User Facility (Contract DE-AC05-00OR22725)
  - U.S. Department of Energy (DOE), Office of Science, National Quantum Information Science Research Centers, Quantum Systems
  - National Energy Research Scientific Computing Center (NERSC), DOE Office of Science User Facility (Contract DE-AC02-05CH11231)