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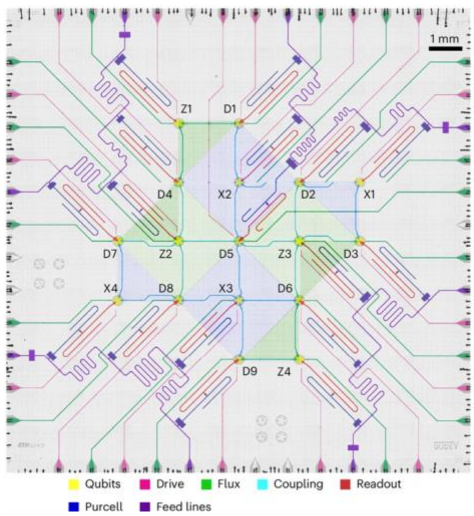
HIGHLIGHTING NEWS

TOWARD FAULT-TOLERANT QUANTUM COMPUTING THROUGH LATTICE SURGURY USING SUPERCONDUCTING QUBITS

A research article published in Nature Physics demonstrates lattice surgery operations between two distance-three repetition codes implemented on a superconducting qubit quantum processor, which addresses a central challenge in quantum computing: performing logical operations between encoded qubits while maintaining active quantum error correction. By operating on encoded repetition code blocks required for lattice surgery, rather on individual physical qubits, the authors show how logical operations can be performed while preserving the error-detecting structure. This achievement represents a key milestone for scalable quantum-error-corrected architectures.

Specifically, in their experiment, a custom superconducting quantum chip contains 17 flux-tunable transmon qubits arranged to support two logical repetition code patches and an intermediate measurement region used for the “split” operation in lattice surgery. In this surface code layout, repeated stabilization through syndrome measurements enables the creation of entangled logical qubits by measuring a boundary column of data qubits and modifying stabilizer measurements. A full stabilizer measurement cycle for the device is completed in approximately 1.66 microseconds, allowing multiple rounds of error detection within the coherence time of the qubits. This fast cycle time is essential for maintaining logical state integrity during lattice surgery operations and demonstrates that encoded qubit manipulation can be performed within the timing constraints of superconducting qubit hardware.

Using this platform, they experimentally implement merge and split lattice surgery primitives between two logical repetition codes and verify the resulting logical-parity correlations through repeated syndrome measurements. These demonstrations establish lattice surgery as a viable method for connecting encoded qubits on superconducting hardware and provide a foundation for scaling toward larger surface code systems, in which logical operations are performed through code-patch interactions rather than direct physical qubit gates, thereby advancing closer to fault-tolerant quantum computation.



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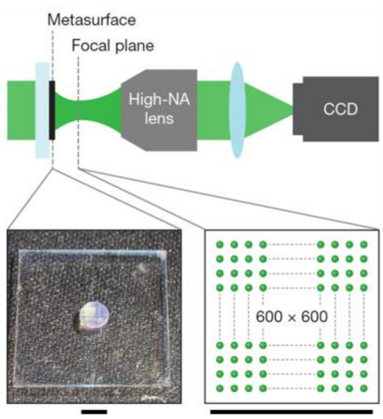
A TOOL OF SCALING NEUTRAL-ATOM QUANTUM SYSTEMS BEYOND 100,000 QUBITS: METASURFACE OPTICAL TWEEZER ARRAYS

Neutral atoms are considered promising candidates for large-scale quantum computing because they function as identical qubits with long coherence times and offer flexible geometric arrangements. These characteristics make them well-suited for quantum simulation, error correction, and scalable computation. However, one of the engineering challenges in quantum computing is both maintaining control and coherence while significantly increasing system size. To address this, researchers combine optical tweezer atom trapping with metasurface-based optical control, enabling laser light to be shaped and distributed efficiently across very large atom arrays. By improving the generation and delivery of optical fields, this approach reduces the hardware complexity that typically grows with system size and facilitates the parallel control of large numbers of atomic qubits.

In experimental demonstrations, the authors implement metasurface optical tweezer arrays by replacing conventional beam-shaping hardware with a flat holographic metasurface that directly shapes and focuses a laser beam into tightly focused trapping sites. A metasurface is a planar optical device composed of subwavelength meta-atoms (nanopillars) that locally control the phase of incoming light, hence generating a two-dimensional array of optical tweezers within a single optical element.

The key scalability advantage stems from the subwavelength pixel size, high diffraction efficiency, and robust power-handling capability of metasurfaces. These features enable the generation of an exceptionally large number of optical traps using a single beam-shaping element. The team experimentally demonstrated a 600 × 600 array of optical tweezer traps and showed that, with realistic laser power and device dimensions, arrays exceeding 100,000 trapped atom qubits are feasible.



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