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HIGHLIGHTING NEWS

UTOKYO AND IBM PUSH QUANTUM ALGORITHMS TOWARD REAL-WORLD ADVANTAGE

Quantum computing is maturing beyond theory, but realizing its full potential depends on powerful algorithms as much as on hardware. Researchers at the University of Tokyo and IBM Quantum are leading this charge with the development of Krylov quantum diagonalization (KQD), a novel algorithm for finding the ground states of complex quantum systems.

Ground states—the lowest-energy configurations of a system—are fundamental to understanding physics, chemistry, and materials science. Classical supercomputers struggle to calculate these states efficiently for large, interacting systems. KQD leverages the quantum computer itself to handle the most computationally demanding parts of the task: generating Krylov subspaces, a mathematical tool introduced by Aleksey Krylov in 1931 that isolates the essential structure of large matrices. By evolving qubits that represent these subspaces, the quantum device can converge exactly to the ground state, producing precise results with fewer errors than previous methods like the variational quantum eigensolver (VQE).

The KQD framework has also inspired sample-based Krylov quantum diagonalization (SKQD), which combines Krylov subspace decomposition with sampling techniques for faster, scalable solutions. While KQD excels in condensed-matter simulations, sample-based variants perform well in chemistry, positioning these algorithms as promising routes toward near-term quantum advantage.

As IBM and other companies prepare fault-tolerant machines, including the upcoming IBM Quantum Starling in 2029, algorithms like KQD ensure that today's quantum computers can already deliver valuable insights, bridging the gap between current capabilities and the future of scalable, real-world quantum computing.

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STAR-LATTICE SUPERCONDUCTING ARCHITECTURES FOR EFFICIENT QUANTUM ERROR DETECTION

Achieving scalable and industrially relevant quantum computation critically depends on the implementation of quantum error correction (QEC). In a recent open-access article published in PRX Quantum, Vigneau et al. report a significant experimental advance by demonstrating quantum error detection using a novel superconducting-qubit architecture based on a qubit–resonator star topology.

This work addresses long-standing architectural challenges associated with implementing QEC codes beyond the surface code, particularly color codes and quantum low-density parity check (qLDPC) codes.

The authors introduce a six-qubit star lattice architecture in which four data qubits and two ancilla qubits are coupled via tunable couplers to a shared central resonator. This design provides effective local all-to-all connectivity and high operational parallelism within a planar geometry, features that are difficult to achieve in conventional square-grid superconducting processors. Such enhanced connectivity is essential for efficiently measuring high-weight and overlapping stabilizers required by advanced QEC codes.

As an experimental benchmark, the team implements the ⟦4,2,2⟧ color code, encoding two logical qubits into four physical qubits while simultaneously and repeatedly measuring both X- and Z-type stabilizers. Logical state characterization is performed using the classical shadow tomography framework, enabling accurate estimation of logical fidelities, purities, and acceptance probabilities.

The reported results demonstrate logical state fidelities exceeding 96% for all cardinal logical states, with some states approaching 99.9%. Importantly, repeated error-detection cycles yield logical lifetimes that surpass those of the best individual physical components in the device. Logical error-per-cycle rates are measured in the range of 0.25% to 0.91%, remaining below the error probability of the underlying two-qubit gates. The authors further demonstrate the preparation and preservation of a logical Bell state, confirming that entanglement can be maintained at the logical level over multiple error-detection cycles.

Beyond this proof-of-principle demonstration, the study outlines a clear scaling pathway. By tiling star units into larger lattices and incorporating flag qubits, the architecture is well positioned to support higher-weight stabilizers and more efficient QEC codes. Overall, this work establishes star-lattice superconducting architectures as a promising route toward fault-tolerant quantum computing.

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