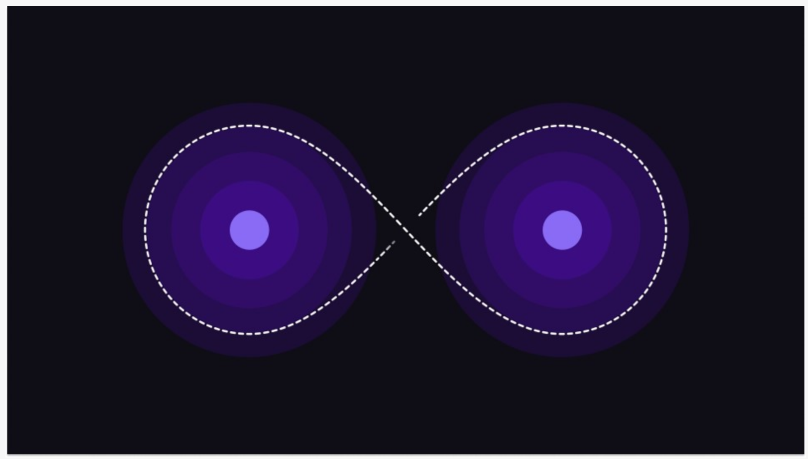
Q-CTRL Achieves Computational Gains in Generation of Long-Range Entanglement Enhanced by Error Detection

Two record-setting demonstrations leveraging low-overhead error detection deliver enhanced computation and the largest entanglement generation up to 75 qubits



LOS ANGELES, CA, UNITED STATES, May 29, 2025 /EINPresswire.com/ -- Q-CTRL, the global leader in quantum infrastructure software, announced two record-setting demonstrations that redefine what can be achieved with long-range entanglement generation. These results, captured in the company's paper published in PRX Quantum, showcase a novel approach to boosting the performance of quantum computers by combining error suppression techniques with error detection, a central building block of quantum error correction.

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>
> *Doug Finke, Chief Content Officer at Global Quantum Intelligence*

Quantum error correction (QEC) is a foundational technique that protects fragile quantum information from errors caused by noise and hardware imperfections, making it essential for scalable, reliable quantum computing. Progress in experimental QEC demonstrations has been rapid; however, fully error-corrected calculations remain difficult to implement on today's hardware, often delivering limited performance gains at high resource costs.

Similarly, generating large-scale quantum entanglement – a key resource for quantum computing and communication – has remained a significant challenge due to noise and device constraints. Entanglement is part of the 'secret sauce' of quantum computers, but it is also one of their most difficult properties to create and maintain. In the future, many quantum algorithms will rely on entanglement to perform computation.

Previous demonstrations of large-scale entangled state preparation often relied on logical encoding, leading to a high overhead in both qubit count and shot count due to a large discard rate. In this work, Q-CTRL has overcome both hurdles through a strategic application of QEC primitives without logical encoding, yielding significant advantages on superconducting processors while only requiring a modest overhead.

The team at Q-CTRL presents two key demonstrations by leveraging error-detection strategies:

The first sets a new state-of-the-art in the implementation of a long-range CNOT gate using a novel teleportation protocol based on unitary preparation of a GHZ state, followed by a unitary disentangling step. This approach has the advantage that the final state of the disentangled qubits reveals errors that have occurred during the application of the gate. (See Chart 1 image and description)

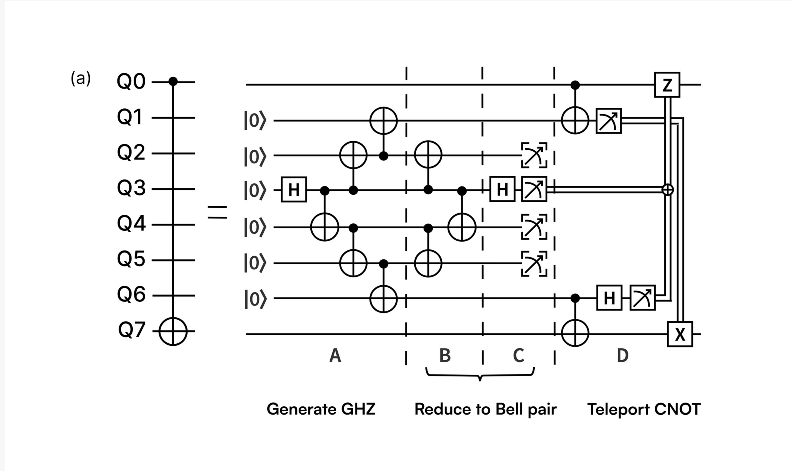

Chart 1: With this approach, Q-CTRL performed a long-range CNOT, achieving over 85% fidelity across up to 40 lattice sites, outperforming state-of-the-art alternatives on superconducting processors.

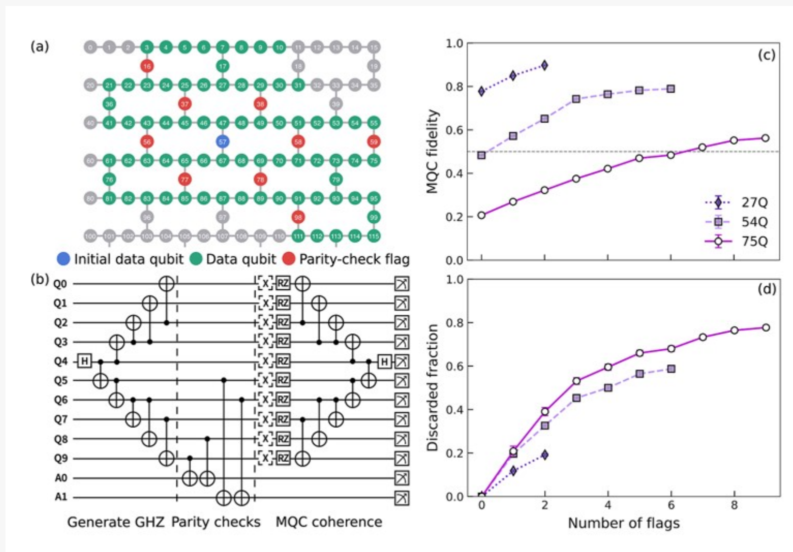

Chart 2: Using this resource-efficient routine with Q-CTRL's deterministic error-suppression, the team achieved genuine multipartite entanglement for up to 75 qubits, verified in terms of multiple-quantum coherence (MQC) fidelity—a record in the published literature.

Second, Q-CTRL generated large GHZ states using a protocol that allows for the integration of sparse error detection through ancillary stabilizer measurements. In quantum computing, a Greenberger–Horne–Zeilinger (GHZ) state is a special type of entangled state involving three or more qubits that are perfectly correlated across all qubits. (See Chart 2 image and description)

Most other methods discard almost all shots at large scales, whereas Q-CTRL observes a comparatively low discard rate, where over 80% of the shots are kept in the case of generating a

27-qubit GHZ state and over 21% in the 75-qubit state. These results demonstrate that incorporating QEC primitives on the physical level can deliver a substantial net improvement in the capability of a near-term quantum computer relative to the best alternative.

“This work demonstrates that QEC primitives, even without full logical encoding, can offer significant computational advantages with only modest resource overhead,” said Yuval Baum, Head of Quantum Computing Research. “By designing smart protocols, leveraging intrinsic symmetries and combining strategic error detection, we achieve high-fidelity long-range CNOT gates and generate a 75-qubit GHZ state with genuine multipartite entanglement—the largest reported to date. These results suggest that meaningful benefits from QEC are already accessible on current-generation hardware.”

“These demonstrations of Q-CTRL’s innovative and efficient use of an approach that combines error suppression with error detection show how these techniques can create the largest GHZ state to date, as well as enable long-range, high-fidelity CNOT gates that can be useful in quantum networking,” said Doug Finke, Chief Content Officer at Global Quantum Intelligence (GQI). “Such an approach may represent an interim step between the NISQ and the full Fault Tolerant Quantum Computing (FTQC) eras that could allow users to experience quantum advantage earlier than expected. We look forward to seeing how this approach will continue to develop and be put to use in real applications in the near future.”

These record-setting results underscore Q-CTRL's commitment to fundamental research that makes quantum technology useful today. With limited qubit and runtime resources in the near term, it is helpful to consider the adoption of low-overhead quantum error correction (QEC) subroutines on the physical level without the need for QEC encoding. By combining error suppression and error detection, this novel paradigm is a step toward useful quantum computing and represents a new building block to the growing quantum error-reduction toolkit.

These achievements contribute directly to the global effort to build more robust and powerful quantum computers, accelerating the timeline for achieving quantum advantage.

Access the full technical manuscript for more information:
https://doi.org/10.1103/PRXQuantum.6.020331

About Q-CTRL
Q-CTRL is a key player in the global quantum technology industry as a category-defining business for AI-powered quantum infrastructure software. Leading quantum computing hardware providers integrate its performance-management software with their superconducting and silicon-based platforms to deliver unprecedented capabilities to end users. The company’s global leadership in quantum sensing for defense and dual-use was featured in The New York Times. Q-CTRL also developed Black Opal, an award-winning edtech program that enables users to quickly learn quantum computing.

Founded by Michael J. Biercuk in November 2017, Q-CTRL has assembled the world's foremost team of expert quantum-control engineers, providing solutions to global quantum technology leaders, including Fortune 500 companies, startups, national research labs, and academic institutions. The company has international headquarters in Sydney, Los Angeles, San Francisco, Berlin, and Oxford.

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