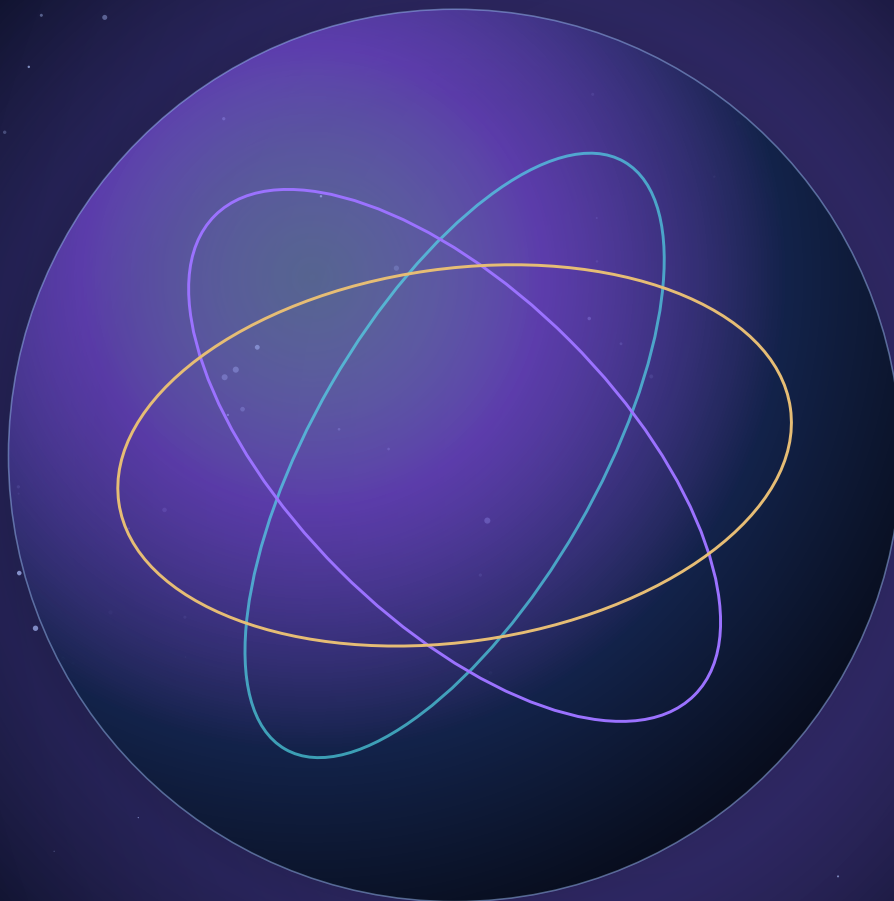




◆ OBSERVATORY ANALYSIS

Error Correction Crosses the Threshold

What Google's below-threshold surface code establishes, and the engineering it leaves in front of the field

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Abstract

A 101-qubit surface-code memory whose logical errors fall as the code grows: the scaling behaviour fault tolerance requires, now demonstrated in hardware. Development: 9 December 2024 · Google Quantum AI and collaborators · Nature, 2024 · Peer-reviewed experiment.

KEYWORDS Quantum Observatory · experiment · L2

Error Correction Crosses the Threshold

The result

Google Quantum AI operated a distance-7 surface-code memory on 101 physical qubits and measured a logical error of 0.143% per correction cycle [1]. Each increase of the code distance by two suppressed the logical error rate by a factor of 2.14, and the logical qubit outlived the best physical qubit on the chip by a factor of about 2.4. Real-time decoding was demonstrated in a separate experiment on the same platform.

What it establishes

For three decades the promise of quantum error correction rested on a threshold theorem: below a certain physical error rate, adding qubits suppresses logical errors instead of multiplying them. This experiment moves that promise from theory into measurement. The suppression factor greater than two is the quantity that matters, because it is what makes larger codes worth building. The result concerns a protected *memory*. Universal computation requires error-corrected logical *gates*, decoding fast enough to keep pace with the hardware and a supply of high-fidelity magic states, none of which this experiment set out to show.

Position in the Civilizational Compute Stack

The result sits at the boundary between L1 (physical capability) and L2 (logical computation). It is the first point at which the stack's lower layers behave as an engineering system rather than a laboratory curiosity.

Why it matters

Once error suppression scales, the questions about quantum computing change character. They stop being questions of possibility and become questions of cost: how many physical qubits per logical qubit, how much energy and cryogenic infrastructure, how fast the decoders, and at what price per logical operation. Those are the variables that will decide who can build and operate fault-tolerant machines, and therefore where quantum capability concentrates.

The open question

How quickly does the cost of a *useful* logical operation fall as platforms scale? QCTM tracks logical gate error, logical gate duration and physical-qubit overhead per logical qubit as separate indicators, reported under stated conditions [2].

Signposts

Logical gate demonstrations on multiple logical qubits; decoder latency below the correction cycle at larger distances; published overhead figures for complete logical operations.

REFERENCES

Sources

1

Google Quantum AI and collaborators. Quantum error correction below the surface code threshold. Nature (2024).

PEER-REVIEWED EXPERIMENT

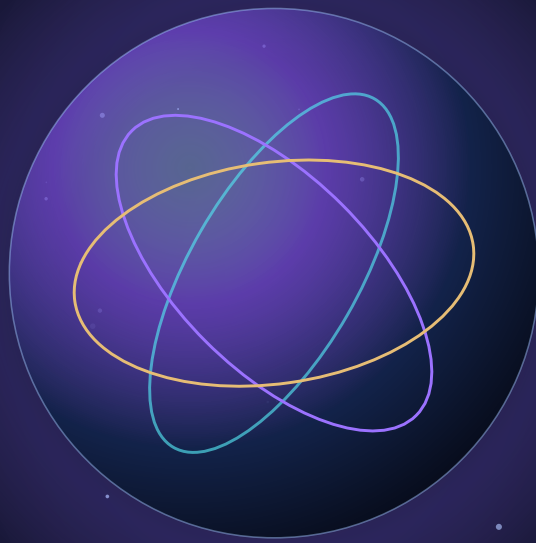
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2

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PEER-REVIEWED REVIEW

<https://www.nature.com/articles/s42254-024-00796-z>



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Physics will decide what becomes computable.
Institutions will decide what becomes of it.