The Fundamental Limit of Quantum Computation (FLQC)

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Abstract.

This work introduces the concept of the **Fundamental Limit of Quantum Computation (FLQC)** - a precision limit of any quantum computing device arising from the discrete structure of spacetime at the Planck scale. The limit cannot be overcome by any technological progress. Consequences for Shor's algorithm, error correction, and an experimental programme on QPUs at 30–50 mK are discussed.

Preface

Since Turing, computational limitations have been classified as algorithmic or engineering. Quantum computing added a third complexity-theoretic. This work introduces a fourth.

The Fundamental Limit of Quantum Computation (FLQC) is a precision limit of any quantum computing device, arising not from imperfect implementation, but from the discrete structure of spacetime at the Planck scale.

This limit cannot be overcome by any technological progress - just as the speed of light cannot be overcome by any acceleration.

Part I. The Origin of the Limit

1.1 Phase Continuity - the Hidden Assumption

The entire architecture of modern quantum computers rests on one assumption so familiar it has ceased to be noticed: quantum phases are continuous.

The qubit state: $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$, where α and β are complex numbers on the unit circle. Shor's algorithm, Grover's algorithm, the quantum Fourier transform - all exploit phase interference with arbitrary precision. But what if phases are **not continuous?**

1.2 Phase Discreteness from the $\mathbb{Z}^4$ Lattice

In Quantumograph v14, gauge phases on graph edges are physical degrees of freedom of spacetime. The minimum phase step is set by the torus structure:

$$\Delta\theta_{min} = \frac{2\pi}{L}$$

where $\mathbf{L = N^{1/4} = (10^{120})^{1/4} \approx 10^{30}}$ is the linear torus size, $\mathbf{N \leq 10^{120}}$ is the vertex count (Bekenstein–Hawking bound). Phase step: $\Delta\theta_{min} \sim \mathbf{10^{-30}}$ rad.

1.3 Why 10^{-30} Radians Matters

Shor's algorithm for breaking RSA-2048 requires phase precision:

$$\boldsymbol{\Delta\theta_{SHOR}} \sim \frac{2\pi}{2^{2048}} \sim 10^{-617}$$

This is **587 orders of magnitude smaller** than $\Delta\theta_{min}$ ~10^{-30}. Nature does not permit encoding a number with such precision into a qubit phase - not because hardware is imperfect, but because a phase space of the required granularity **does not exist.**

Part II. Formal Definition

2.1 Definition of FLQC

Definition.
The Fundamental (Topological) Limit of Quantum Computation (**FLQC**) is the lower bound on the phase operation error of any physical quantum computing device:

$$\boldsymbol{\varepsilon_{FLQC} \geq \frac{2\pi}{L} \sim \frac{2\pi}{10^{30}} \sim 10^{-30}\ \mathrm{rad}}$$

This error does not depend on device temperature, qubit material, error-correction codes, or number of qubits. It is an ontological constant.

2.2 Critical Temperature T_c

Phase space discreteness becomes observable only below the critical temperature:

$$\boldsymbol{T_c \sim \frac{\hbar\cdot\Delta\theta_{min}}{k_B} \sim 30\text{–}50\ \mathrm{mK}}$$

T^c falls exactly in the operating range of modern superconducting QPUs. This is a **prediction of the theory** testable right now.

2.3 Hierarchy of Quantum Computing Limitations

Type of Limitation	Source	Surmountable?
Engineering	Hardware imperfection, noise	Yes. By better technology
Thermodynamic	Decoherence at T > T_c	Yes. By cooling below T_c
Complexity-theoretic	Algorithmic complexity	Partially. By quantum speedup
Fundamental (FLQC)	Discreteness of spacetime	No/never

Part III. Consequences

3.1 Shor's Algorithm and Cryptography

The FLQC does not make RSA more secure: RSA-2048 as a mathematical object has not changed. The FLQC constrains the breaking tool, not the lock.

Analogy: opening the lock requires a key 10^{-617} mm thick, but nature does not permit manufacturing anything thinner than 10^{-30} mm. The lock is no stronger - **the required tool does not exist.**

The constraint depends on key length n:

- RSA-512: required precision ~10^{-154} rad, gap 124 orders - threat remains
- RSA-2048: required precision ~10^{-617} rad, gap 587 orders - Shor's algorithm physically unrealisable
- Boundary: $n \lesssim 100$ bits above this, FLQC physically blocks Shor's algorithm

3.2 Quantum Error Correction

The FLQC predicts a systematic, uncorrectable error component. As QPUs scale, error-correction codes will encounter a ***floor*** - an error level no correction can reduce below. Detecting this floor is direct experimental evidence of the FLQC.

3.3 Quantum Simulation as a Measurement Tool

A QPU operating below T^c is itself a physical realization of a $\mathbb{Z}^4$-graph fragment. Its systematic errors are a **direct measurement of spacetime structure**. What hinders computation helps physics.

Part IV. Experimental Programme

4.1 What to Measure

1. Implement QFT on n qubits at $T < T_c$. Measure systematic phase deviation as a function of n.
2. Verify: does the deviation grow with n (engineering noise) or remain constant (FLQC)? Constancy is the FLQC signature.
3. Implement random walks on graph directly on QPU. Measure $d_s(\sigma)$: passage through $d_s = 4$ at σ^* is evidence of $\mathbb{Z}^4$ structure.
4. Compare phase errors with $\Delta\theta_{min} \sim 10^{-30}$ rad. Order-of-magnitude agreement confirms FLQC.

4.2 What This Gives Science

- First direct evidence of spacetime discreteness
- A new fundamental technological limit
- Reassessment of quantum computer threats to cryptography
- A new quantum metrology tool

Part V. Phase Resolution, Asymptotic Quantum Algorithms, and the FLQC Constraint

The Fundamental Limit of Quantum Computation (FLQC) has a direct consequence for algorithms whose computational advantage depends on arbitrarily fine phase resolution. The Quantum Fourier Transform (QFT), which forms the basis of Shor's order-finding procedure, is the most direct example.

For an input size M, Shor's algorithm uses a phase-estimation register with approximately $n \approx 2\log_2(M)$ qubits. The controlled phase rotations in the QFT are represented by

$$R_k = \begin{pmatrix} 1 & 0 \\ 0 & e^{2\pi i/2^k} \end{pmatrix}$$

The standard formulation assumes that the phase angle can be implemented with arbitrary precision. Under the FLQC hypothesis this assumption is replaced by a physical resolution limit:

$$\Delta\theta \geq \Delta\theta_{\mathrm{FLQC}} \approx 10^{-30}\ \mathrm{rad}$$

The experimentally implemented operation is therefore not the ideal rotation, but a discretized operation:

$$R_k^{\mathrm{FLQC}} = \begin{pmatrix} 1 & 0 \\ 0 & \exp\left(i \left\lfloor \frac{\theta_{\mathrm{ideal}}}{\Delta\theta_{\mathrm{FLQC}}} \right\rfloor \Delta\theta_{\mathrm{FLQC}} \right) \end{pmatrix}$$

This does not represent ordinary calibration error. It represents a finite resolution of the physical phase space it

For RSA-2048, the required register size is approximately n ≈ 4096 qubits.

The smallest QFT rotations have $\theta_{ideal} = \frac{2\pi}{2^{4096}} \approx\ 10^{-1233} rad.$

This value is many orders of magnitude below the assumed FLQC resolution. Therefore, rotations with sufficiently large k cannot encode additional physical information in the phase degree of freedom. The mathematical circuit continues to exist as an abstract operator sequence, but the corresponding physical implementation may become indistinguishable from an identity operation.

The accumulated effect can be estimated through the fidelity between the ideal and physical QFT states:

$$F = |\langle \psi_{\mathrm{ideal}} | \psi_{\mathrm{act}} \rangle|^2.$$

Approximating the accumulated phase deviations by $\delta\theta_j$,

$$F \approx \prod_j \cos^2(\delta\theta_j)$$

For a systematic phase floor,

$$\sigma^2 \approx n \left(\frac{\Delta\theta_{\mathrm{FLQC}}}{2} \right)^2$$

The resulting interference degradation behaves as:

$$P_{\mathrm{success}} \propto e^{-\sigma^2}$$

The significance of this expression is not the exact numerical coefficient, which depends on the architecture, but the existence of a non-zero asymptotic floor that does not vanish with improved engineering.

This leads to a distinction between two classes of errors. Engineering errors arise from noise sources, control imperfections, thermal fluctuations, and material defects. They can in principle be reduced by improved design. The FLQC contribution would instead remain after these effects are minimized because it originates from the assumed discrete structure of the physical phase space.

The consequence for quantum error correction is a change in interpretation. Standard fault-tolerant schemes assume that arbitrarily small coherent rotations can be represented and projected into correctable error channels. If the physical Hilbert-space realization has a minimum phase granularity, error correction may encounter a lower bound below which additional correction cycles cannot improve the result.

A direct experimental test follows. A QPU operated below the critical temperature range predicted by Quantumograph should be used to implement QFT circuits of increasing depth. The measured systematic phase deviation should be separated into a component that scales with hardware noise and a component that remains constant. A persistent component approaching the predicted order of magnitude would constitute evidence for a fundamental phase-resolution limit.

Note on Interpretation

The FLQC hypothesis does not imply that quantum computation is impossible. It proposes that the ultimate computational capacity of a physical quantum system may differ from the capacity of an abstract mathematical quantum computer. The question is therefore not only whether algorithms exist, but whether the physical universe permits the exact operations assumed by those algorithms.

Conclusion

The Fundamental Limit of Quantum Computation is a physical consequence of the finiteness of the world. Any device existing in discrete spacetime inevitably inherits its granularity.

The precision of computation is bounded by the precision of reality itself.

This can be verified. The equipment exists. The experiment remains to be done.

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References

Shor, P. W. Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer / P. W. Shor // SIAM Journal on Computing. - 1997. - Vol. 26, no. 5. - P. 1484–1509.

Grover, L. K. Quantum mechanics helps in searching for a needle in a haystack / L. K.

Grover // Physical Review Letters. - 1997. - Vol. 78, no. 2. - P. 325–328.
Bombelli, L., Lee, J., Meyer, D., & Sorkin, R. D. (1987). Space-time as a causal set. Physical Review Letters, 59(5), 521–524.
Dawid, R. (2013). String Theory and the Scientific Method. Cambridge University Press.
Fredkin, E. (1990). Digital mechanics: An informal introduction. Physica D, 45(1–3), 254–270.
Wolfram, S. (2002). A New Kind of Science. Wolfram Media.

Materov, S. (2025 - 2026) Quantumograph v13. A Testable Quantum Graph Theory of Spacetime. https://doi.org/10.5281/zenodo.18410313

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