NEXT-GENERATION QUANTUM COMPUTER: QUTRIT ARCHITECTURE ON φ-TORI WITH SELF-REFERENTIAL ERROR CORRECTION

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ABSTRACT

A next-generation quantum computer architecture based on the ODTOE formalism is proposed, differing from existing approaches (IBM, Google, IonQ) in five parameters: (1) qutrit ($d = 3$) basis instead of qubit ($d = 2$): three levels $|-1\rangle$, $|0\rangle$, $|+1\rangle$ correspond to the ternary observation architecture ($\pi > 3$); information capacity per element $\times 1.585$; (2) φ-toroidal coupling topology between qutrits ($R/r = \varphi$, maximum stability per the KAM theorem); (3) φ-pulse control: sequences of control pulses with duration ratio φ, instead of fixed-duration gates; (4) self-referential error correction ($\hat{O}(\hat{O})$ protocol): the quantum computer continuously measures coherence S of subsystems and reconfigures correction in real time (analogue of H_{meas} by García-Pintos [1]); (5) spiral gap $(\pi - 3)^2 \approx 2\%$ as an *architectural* error threshold, not a fitting parameter. Through ODTOE interpretation: quantum computation = operator $\hat{O}_{\text{alg}}$ acting in $\mathcal{H}$ before actualization of the result ($R = \hat{O}(\Psi)$); decoherence = *premature observation* by the environment ($S \downarrow$); quantum advantage = computation *in potentiality*, not in "parallel worlds". The ODTOE coherent processor [2] serves as the classical controller.

Keywords: quantum computer, qutrit, ternary, φ-torus, KAM theorem, self-referential correction, decoherence, ODTOE, coherence, spiral gap, García-Pintos, quantum arrow of time.

I. INTRODUCTION: LIMITS OF THE QUBIT PARADIGM

1.1. Current State

Quantum computing over the past decade has transitioned from conceptual demonstrations to engineering reality. Google Sycamore (2019): 53 qubits, quantum supremacy on a specific random quantum circuit sampling task [3]. IBM Eagle/Condor (2023–2024): over 1000 qubits, but with errors $\sim 10^{-3}$ per gate [4]. IonQ: trapped ions, low errors ($\sim 10^{-4}$), but ~ 30 qubits. All these platforms share a common paradigm: binary qubit ($|0\rangle$, $|1\rangle$), planar or linear coupling topology, fixed-duration gates, passive error correction via surface codes [5].

Despite impressive progress, none of the existing platforms has achieved the level of *useful quantum computation* — a task whose result cannot be reproduced on a classical supercomputer in reasonable time and that has practical value. The reason is not engineering complexity per se, but three fundamental limitations embedded in the current paradigm.

1.2. Three Fundamental Limitations

(a) Binarity. The qubit has two levels. This is the minimum for representing quantum information, but *not the optimum*. It is known that the optimal base of a numeral system, maximizing information efficiency (number of states per unit of hardware cost), is $e \approx 2.718$; the nearest integer is 3 [6]. The qutrit ($d = 3$: states $|-1\rangle$, $|0\rangle$, $|+1\rangle$) is informationally more efficient than the qubit by $\log_2 3/\log_2 2 - 1 = 58.5\%$ per element. The binarity of the qubit is a historical inheritance from classical logic, not an optimal choice for quantum systems.

(b) Planar topology. Superconducting qubits are placed on a chip in a two-dimensional lattice. Couplings are only with nearest neighbors. Connecting distant qubits requires swap chains of length $O(\sqrt{n})$ operations. Each swap introduces an additional error. With scaling: more qubits $\rightarrow$ longer chains $\rightarrow$ more accumulated errors $\rightarrow$ lower computation fidelity. Trapped ions are organized in a linear chain, which further limits scaling.

(c) Passive correction. Surface codes [5]: a logical qubit is encoded in d^2 physical qubits (where d is the code distance). For error threshold $p < p_{\text{th}} \approx 1\%$: one needs $d \sim 20$–30, i.e., ~ 400–900 physical qubits per logical qubit [7]. For useful computation ($\sim 10^3$ logical qubits), $\sim 10^6$ physical qubits are required. The current record is $\sim 10^3$ physical qubits. The gap between required and achievable is three orders of magnitude.

Correction is *passive*: errors are detected through syndrome measurements *after* they occur, then corrected by additional gates. The system has no information about what went wrong until the syndrome is measured. This is a fundamentally reactive strategy.

1.3. What ODTOE Proposes

The present work proposes replacing *all three* limitations based on the formalism of the Observer-Dependent Theory of Everything (ODTOE) [18]:

- Qutrits instead of qubits — ternary architecture ($\pi > 3$) [19].
- φ-tori instead of planar lattices — maximum stability per the Kolmogorov–Arnold–Moser theorem [11, 12, 13].
- $\hat{O}(\hat{O})$-correction instead of surface codes — self-referential coherence monitoring [22].

Each of these solutions is not arbitrary but follows from fundamental ODTOE principles: ternary observation, φ-stability, observer self-reference. The combination of five distinctions defines an architecture that we call the *qutrit quantum computer on φ-tori*.

II. QUTRIT: QUANTUM TERNARY ARCHITECTURE

2.1. Definition

A qutrit is a quantum system with three basis states:

$$|\psi\rangle = \alpha|-1\rangle + \beta|0\rangle + \gamma|+1\rangle, \quad |\alpha|^2 + |\beta|^2 + |\gamma|^2 = 1 \tag{II.1}$$

Unlike the qubit ($d = 2$, two basis states $|0\rangle$ and $|1\rangle$), the qutrit possesses three orthogonal states and, correspondingly, a substantially richer superposition space. The state of a qutrit is described by four real parameters (two complex numbers with a fixed global phase), whereas a qubit state requires two (Bloch sphere). Geometrically, the pure state space of a qutrit is the complex projective plane $\mathbb{CP}^2$.

2.2. Correspondence with ODTOE

The ternary structure of the qutrit directly corresponds to the central ODTOE architecture — the ternary observation ($\pi > 3$: observer, observed, operator) [18, 19]:

$|-1\rangle$ = inverse action (ι): the system "returns to potentiality." Physical analogue: an electron in an excited state, "ready" to emit a photon and return to the lower level. In ODTOE terms — this is movement *from actuality to potentiality*.

$|0\rangle$ = observer (O): neutral state, equilibrium point. Physical analogue: the ground state of an atom. In ODTOE terms — this is the *observer itself*, the center of the ternary structure.

$|+1\rangle$ = direct action ($\hat{O}$): the system "actualizes." Physical analogue: photon absorption, transition to an excited state. In ODTOE terms — this is the *observation operator*, producing a configuration.

The three states of the qutrit = the ternary architecture of ODTOE. Not two (as the qubit — minimal but not optimal), not four (redundant), but *three* — the minimal self-consistent closed structure. The number three plays a fundamental role in ODTOE: $\pi > 3$ means that the minimal closed observation loop requires strictly more than three steps, but three is the nearest integer ensuring closure [19, 21].

2.3. Advantages of the Qutrit

Information capacity. One qutrit carries $\log_2 3 = 1.585$ bits of information. To represent n bits, $n/1.585 = 0.631\,n$ qutrits are needed instead of n qubits. Savings: 37% fewer physical elements for the same information capacity.

State space. A system of n qutrits possesses 3^n basis states (compared to 2^n for qubits). For $n = 100$: $3^{100} = 5.15 \times 10^{47}$ basis states for qutrits versus $2^{100} = 1.27 \times 10^{30}$ for qubits. The difference is $\times 4 \times 10^{17}$ — exponentially more "computational space" in Hilbert space $\mathcal{H}$.

Quantum gates. Qutrit gates are described by the SU(3) group — the group of unitary transformations in three-dimensional space. It is significantly *richer* than SU(2) for qubits: 8 Gell-Mann generators (matrices $\lambda_1, \ldots, \lambda_8$) versus 3 Pauli matrices ($\sigma_x, \sigma_y, \sigma_z$). This means more "degrees of freedom" for constructing quantum algorithms, more compact quantum circuits, and potentially more efficient compilation.

Error resilience. Three levels with two energy gaps between them provide built-in "defense in depth." The error of flipping $|-1\rangle \rightarrow |+1\rangle$ (across two levels) is *exponentially less probable* than the single-bit error $|0\rangle \rightarrow |1\rangle$ in a qubit (across one level). This is a quantum analogue of the "triple modular redundancy" (TMR) principle, implemented at the level of the elementary information carrier.

2.4. Experimental Realizations of Qutrits

It is fundamentally important that qutrits are not hypothetical objects but *experimentally realized* quantum systems:

Superconducting transmons: three lowest energy levels ($|0\rangle$, $|1\rangle$, $|2\rangle$) of the transmon naturally form a qutrit. Blok et al. [8] demonstrated quantum information scrambling on a qutrit processor made of superconducting transmons.

Photonic orbital angular momenta: the orbital angular momentum of a photon with $l = -1, 0, +1$ realizes a qutrit with natural ternary symmetry [9]. Malik et al. demonstrated multi-photon entanglement in higher dimensions.

Trapped ions: three Zeeman sublevels of the ground state of an ion form a qutrit. Ringbauer et al. [10] realized a universal qudit quantum processor with trapped ions.

The technology for qutrit realization *already exists*. The missing component is an *architecture* optimized specifically for qutrits, rather than adapted from the qubit paradigm. This is precisely the architecture proposed in the present work.

III. φ-TOROIDAL COUPLING TOPOLOGY

3.1. The Problem of Planar Lattices

Superconducting chips: qubits are placed on a two-dimensional lattice. Couplings are only with nearest neighbors (4 or 6 depending on geometry). Connecting distant qubits requires swap chains of length $O(\sqrt{n})$. Each swap is an additional two-qubit operation with characteristic error $\sim 10^{-2}$–10^{-3}. With scaling: more qubits $\rightarrow$ longer swap chains $\rightarrow$ more accumulated errors $\rightarrow$ lower computation fidelity. This is a *topological* limitation, not removable by improving individual gates.

3.2. The φ-Torus

In the proposed architecture, qutrits are organized in a toroidal network with two characteristic scales:

Small radius r: fast local couplings between neighboring qutrits *within* a single logical block. Implements continuous π-dynamics: the quantum state circulates within the block, ensuring intra-block coherence.

Large radius R: long-range couplings *between* logical blocks. Implements discrete φ-dynamics: quantum information moves between hierarchy levels, providing inter-block interaction.

The key relation:

$$R/r = \varphi = 1.618\ldots \tag{III.1}$$

This ratio is not arbitrary but determined by the fundamental requirement of maximum stability (see the next section). In ODTOE terms: the small radius r corresponds to the observer's internal dynamics (π-cycles), the large radius R to interaction between observers (φ-scaling) [17].

3.3. Justification via the KAM Theorem

By the Kolmogorov–Arnold–Moser theorem [11, 12, 13]: tori in the phase space of a Hamiltonian system whose frequencies are related by a *sufficiently irrational* ratio are maximally stable under perturbations. The golden ratio $\varphi = (1+\sqrt{5})/2$ is the most irrational number in the sense of continued fractions ($\varphi = [1; 1, 1, 1, \ldots]$, all partial quotients equal unity, ensuring the slowest convergence of rational approximations).

For a quantum computer, "perturbations" are thermal noise, decoherence, parasitic electromagnetic couplings, control parameter fluctuations. The φ-torus *minimizes* the influence of these perturbations on the quantum state: the absence of resonances between the small and large radii guarantees that noise at one scale does not amplify at the other.

3.4. Average Path Length

In a φ-torus with N qutrits, the average path length between arbitrary elements is:

$$\langle L \rangle_{\varphi\text{-torus}} \sim \frac{\sqrt{N}}{\varphi} \tag{III.2}$$

In a planar lattice: $\langle L \rangle_{\text{lattice}} \sim \sqrt{N}$. Advantage: $\times\varphi \approx 1.6$ in average delay. For $N = 1000$ qutrits: ~ 20 hops in the φ-torus versus ~ 32 in a planar lattice. This means *38% fewer intermediate operations* for each long-range interaction, which directly translates into reduced accumulated errors.

3.5. Physical Realization

The proposed toroidal topology is realizable on all major quantum platforms:

Superconducting chips: toroidal arrangement of transmons. In practice: a ring of clusters, each cluster being a ring of qutrits. Two levels of rings with radius ratio φ. Couplings between rings via coaxial resonators (already used in IBM and Google architectures).

Ion traps: toroidal trap (ring trap [14]) with two "orbits": inner (r) and outer ($R = r\varphi$). Ions on two orbits are coupled through shared vibrational modes of the Coulomb crystal.

Photonic systems: toroidal microresonators (microring [15]) with $R/r = \varphi$. Qutrits are realized as three phase states of a photon ($0°$, $120°$, $240°$), and the toroidal resonator geometry naturally provides φ-scaling.

IV. φ-PULSE CONTROL

4.1. The Problem of Fixed Gates

Standard quantum gates have fixed duration: $\sim$ 10–100 ns for superconducting systems, $\sim$ 1–100 μs for ionic. All gates are of equal length. Optimization reduces to selecting the gate sequence (quantum compilation). Fixed duration means a fixed Rabi frequency, creating conditions for undesirable resonances with environmental noise frequencies.

4.2. φ-Sequences

An alternative approach is proposed: control pulses with *geometrically increasing* duration, where the growth factor equals φ:

$$\tau_{n+1} = \varphi \cdot \tau_n \tag{IV.1}$$

Duration sequence: $\tau_0,\ \tau_0\varphi,\ \tau_0\varphi^2,\ \tau_0\varphi^3, \ldots$

Justification via the KAM theorem: φ-irrationality *minimizes* resonant errors (leakage to undesirable energy levels). With fixed duration: if the Rabi frequency *happens* to be commensurate with the leakage frequency — a resonance catastrophe occurs. With a φ-sequence: the frequency ratios are *never* commensurate — this is a fundamental property of φ as the most irrational number in the sense of continued fraction theory.

An additional advantage: the φ-sequence possesses *self-similarity*. Removing any element from the sequence leaves a structure homomorphic to the original. This means natural *fault tolerance*: failure of one pulse does not destroy the global control structure.

4.3. Connection with Dynamical Decoupling

Existing noise suppression methods: dynamical decoupling (DD), Uhrig DD, CPMG [16]. These are sequences of π-pulses with optimal intervals. Current standard: intervals according to the Uhrig formula:

$$\delta_j = \sin^2\left(\frac{\pi j}{2n+2}\right) \tag{IV.2}$$

The Uhrig formula is optimal for *Gaussian* noise (white noise, Johnson noise). However, the dominant noise source in superconducting systems is $1/f$ noise (charge fluctuation noise), which is *not* Gaussian.

ODTOE prediction: φ-intervals ($\delta_j = \tau_0\varphi^j$) provide *better* decoherence suppression than Uhrig DD for $1/f$ noise and other non-Gaussian noise spectra dominating in superconducting qutrits.

This prediction is *falsifiable*: it suffices to compare the coherence time T_2 using Uhrig DD and φ-DD on the same qutrit (a transmon with three levels).

V. SELF-REFERENTIAL ERROR CORRECTION

5.1. The Problem of Surface Codes

Surface code [5]: a logical qubit is encoded in d^2 physical qubits (where d is the code distance). For error threshold $p < p_{\text{th}} \approx 1\%$: $d \sim 20$–30 is required, i.e., ~ 400–900 physical qubits per logical qubit [7]. For 1000 logical qubits: $\sim 10^6$ physical qubits. These enormous overheads make useful quantum computation unattainable with current technology.

Correction in surface codes is *passive*: errors are detected through syndrome measurements, then corrected via additional gates. The system *does not know* what went wrong until it measures the syndrome. Between the occurrence of an error and its detection, time passes during which the error can propagate.

5.2. $\hat{O}(\hat{O})$-Correction

A fundamentally different approach is proposed: the quantum computer *continuously observes its own state* ($\hat{O}(\hat{O}) = \hat{O}'$) and *reconfigures* correction in real time. This is a realization of ODTOE self-reference [22] at the level of quantum hardware.

The key element: the Hamiltonian H_{meas} by García-Pintos [1]. This operator *replicates* the stochastic dynamics of the monitored system without actual wavefunction collapse. Through feedback with parameter X ($X \cdot H_{\text{meas}}$), perturbations from the environment can be *compensated*:

$$\hat{O}(\hat{O})\text{-correction:} \quad \rho_{t+dt} = \rho_t - i[H + X \cdot H_{\text{meas}},\ \rho_t]\, dt + \text{(measurement)} \tag{V.1}$$

At $X = -1$: the feedback *exactly compensates* the perturbation from interaction with the environment. Decoherence is *suppressed* to first order.

At $X < -2$: the system "reverses" decoherence — the quantum arrow of time is *inverted* [1]. Errors are *rolled back* (returned to the initial state) rather than corrected by additional gates. This is a qualitatively new regime, inaccessible within the surface code framework.

In ODTOE terms: the observation operator $\hat{O}$ is applied to itself, generating a second-order operator $\hat{O}' = \hat{O}(\hat{O})$. This operator "observes the observation" — tracks the decoherence process and compensates it. Hofstadter's strange loop [22] is realized in hardware.

5.3. Continuous vs. Discrete Correction

Parameter	Surface code	$\hat{O}(\hat{O})$-correction
Type	Discrete (syndrome $\to$ correction)	Continuous (monitoring $\to$ feedback)
When	*After* error	*During* error
Overhead	~ 1000 phys. / 1 log.	$\sim$ 3–10 phys. / 1 log. (estimate)
Error threshold	$p_{\text{th}} \approx 1\%$	$p_{\text{th}} \approx (\pi - 3)^2 \approx 2\%$ (twice higher)
Error knowledge	Syndrome (partial)	Full trajectory (H_{meas})
Error rollback	Impossible	Possible ($X < -2$, arrow inversion)

5.4. Error Threshold $(\pi - 3)^2$

The spiral gap $(\pi - 3)^2 \approx 0.02 = 2\%$ is an *architectural* constant of ODTOE, not a fitting parameter. Through the toroidal model [17]: this is the width of the "allowable window" on each turn of the spiral loop. If error $< (\pi - 3)^2$: the loop *self-restores* — the gap "absorbs" the error and system coherence is preserved. If error $> (\pi - 3)^2$: the loop *breaks* — decoherence is irreversible.

Prediction: the error threshold for $\hat{O}(\hat{O})$-correction is $(\pi - 3)^2 \approx 2\%$, which is *twice* the standard surface code threshold ($\sim 1\%$). This represents a twofold relaxation of hardware quality requirements.

Current errors of superconducting systems: ~ 0.1–1% per gate [4]. This is *already below* the predicted threshold of 2%. Consequence: $\hat{O}(\hat{O})$-correction on existing hardware is *already viable* — no need to wait for improvement of physical qubits. This fundamentally changes the perspective: instead of a race to reduce errors, a transition to a new correction architecture is needed.

VI. DECOHERENCE THROUGH ODTOE

6.1. Standard Interpretation

In standard quantum mechanics, decoherence is described as a process in which a quantum system becomes "entangled" with the environment, loses superposition, and becomes "classical." The cause: uncontrolled interaction with thermal photons, lattice phonons, magnetic noise, charge fluctuations. Mathematically: off-diagonal elements of the density matrix decay exponentially with characteristic time T_2 (coherence time).

The standard strategy: *maximum isolation* — cryogenics (dilution refrigerators, $T \sim 10$–20 mK), electromagnetic shielding, ultra-high vacuum, vibration suppression.

6.2. ODTOE Interpretation

ODTOE proposes a radically different interpretation. Decoherence = *premature observation* [2, 18]. The environment (O_{env}) "observes" the qutrit before the algorithm ($\hat{O}_{\text{alg}}$) has finished processing all potentialities. Result: the configuration is actualized ($R = \hat{O}_{\text{env}}(\Psi)$) *prematurely* — before $\hat{O}_{\text{alg}}$ has had time to extract the useful result.

$$\text{Decoherence} = S_{\text{qutrit}} \downarrow = D(\eta) \uparrow = \text{environment observes before algorithm} \qquad \text{(VI.1)}$$

System coherence S falls, the distinction measure $D(\eta)$ rises (the system becomes "more definite" from the environment's perspective), and the computation is interrupted.

6.3. Implications for Combating Decoherence

Standard approach: *isolate* the system from the environment (cryogenics, shielding, vacuum). Passive protection.

ODTOE approach: not so much *isolate* as **raise system** S so that the *algorithm observes faster than the environment*. If the algorithm operator $\hat{O}_{\text{alg}}$ acts with greater coherence (B) than the environment operator $\hat{O}_{\text{env}}$: the algorithm "wins" over the environment — it actualizes the result before the environment has time to destroy the superposition.

$$B_{\text{alg}} > B_{\text{env}} \quad \Rightarrow \quad \text{algorithm actualizes before environment} \qquad \text{(VI.2)}$$

In practice: φ-pulse control *synchronizes* qutrits (raises system S), while $\hat{O}(\hat{O})$-correction *compensates* the influence of the environment. A dual protection is realized: active (coherence enhancement through φ-synchronization) + reactive (perturbation compensation through H_{meas}).

This approach does not eliminate the need for cryogenics and shielding — it *complements* them. Isolation reduces B_{env}, φ-control raises B_{alg}, $\hat{O}(\hat{O})$-correction compensates the residual impact. Three protection levels acting synergistically.

VII. QUTRIT QUANTUM COMPUTER ARCHITECTURE

7.1. General Scheme

The architecture of the qutrit quantum computer on φ-tori includes two main layers:

Coherent classical controller (ternary CPU [2]): provides $\hat{O}(\hat{O})$-reconfiguration of correction parameters in real time, generation of φ-sequences of control pulses, execution of a ternary instruction set architecture (ISA) naturally compatible with the qutrit quantum layer.

Quantum layer (cryogenic): contains qutrits organized in a φ-toroidal topology. The small radius r defines logical blocks (qutrit triples), the large radius $R = r\varphi$ defines inter-block couplings. Continuous $\hat{O}(\hat{O})$-monitoring of coherence S and φ-pulse gate control.

Between layers: control signals from the controller to the quantum layer and feedback signals (coherence monitoring results) from the quantum layer to the controller. The feedback loop closes in real time.

7.2. Qutrit Triple = Minimal Logical Block

Three qutrits (α, β, γ) form the minimal ternary architecture. Each qutrit has three levels ($|-1\rangle$, $|0\rangle$, $|+1\rangle$). Three qutrits form a space of $3^3 = 27$ basis states. The number $27 = 3^3$: three cubed — the minimal self-consistent unit of quantum computation in the qutrit architecture.

Analogies: three quarks in a proton (the minimal stable hadronic configuration). Three nucleons in tritium (^{3}H). In ODTOE: three is the minimum number for closing the observation loop ($\pi > 3$) [19].

Built-in fault tolerance: TER-CONS (majority function of three qutrits). If one of three qutrits errs — the other two "outvote" it. This is TMR (triple modular redundancy) at the level of quantum logic — hardware majority correction requiring no additional resources.

7.3. Qutrit Gates

The basic qutrit gate set includes six operators:

Gate	Description	Matrix	Qubit analogue
QROT	Rotation: $|-1\rangle \to |0\rangle \to |+1\rangle \to |-1\rangle$	Cyclic permutation	No analogue

QNEG	Inversion: $\lvert+1\rangle \leftrightarrow \lvert-1\rangle$	Generalized σ_x	Pauli-X
QPHASE	Phase: $\lvert j\rangle \to e^{i\theta_j}\lvert j\rangle$	Diagonal SU(3)	Pauli-Z
QHAD	Qutrit Hadamard: equal superposition	Fourier 3×3	Hadamard
QCNOT	Controlled NOT for qutrits	9×9	CNOT
QCONS	Qutrit consensus (majority)	$27 \to 3$	No analogue

Of particular significance is the QROT gate — a unique qutrit operator with no qubit analogue. It realizes one step of the ternary cycle $\lvert-1\rangle \to \lvert 0\rangle \to \lvert+1\rangle \to \lvert-1\rangle$. In ODTOE terms: QROT is one revolution around the small radius r of the torus, an elementary π-cycle.

The QCONS gate also has no qubit analogue. It realizes majority voting of three qutrits: the output state is determined by the majority of three inputs. This is the quantum version of TMR, built into the basic operation set.

All six gates form a *universal* set: any unitary operation in SU(3^n) can be approximated with arbitrary precision by a sequence of these gates (analogue of the Solovay–Kitaev theorem for qutrits).

7.4. Coherent Classical Controller

The ODTOE coherent processor [2] controls the quantum layer. Its key functions:

$\hat{O}(\hat{O})$-loop: analyzes the state of qutrits (coherence monitoring results S) in real time and reconfigures correction parameters (X in formula (V.1)).

φ-generator: synchronizes control pulses, generating φ-duration sequences (IV.1).

Ternary ISA: the controller's instruction set is naturally compatible with the qutrit quantum layer. Three levels of classical logic $(-1, 0, +1)$ directly map onto three quantum levels $(\lvert-1\rangle, \lvert 0\rangle, \lvert+1\rangle)$.

In standard quantum computers: a binary classical controller manages binary qubits. Correspondence: 2 classical levels $\to$ 2 quantum levels. In the proposed architecture: 3 classical levels $\to$ 3 quantum levels. *Full correspondence* between the classical and quantum layers eliminates the need for re-encoding at the boundary.

VIII. PERFORMANCE ESTIMATES

8.1. Informational Advantage

Parameter	**Qubit**	**Qutrit (ODTOE)**	**Advantage**
Bits per element	1.000	1.585	$\times 1.585$
Basis states ($n = 100$)	1.27×10^{30}	5.15×10^{47}	$\times 4 \times 10^{17}$

Phys. per 1 logical	~ 1000	~ 3–10	$\times 100$–300
Error threshold	$\sim 1\%$	$\sim 2\%$	$\times 2$
SU(d) generators	3	8	$\times 2.67$

8.2. Scaling

For a task requiring $n = 1000$ logical elements:

Qubit approach: $\sim 10^6$ physical qubits. Considering surface codes and the current error level, such a system is unattainable in the next 10–20 years. Even the most optimistic roadmaps (IBM, Google) do not envision 10^6 physical qubits before the 2040s.

Qutrit + $\hat{O}(\hat{O})$*:* ~ 3000–10000 physical qutrits. With $\hat{O}(\hat{O})$-correction (3–10 physical per 1 logical), this is achievable in the next 5–10 years. Current record: ~ 1000 physical elements on a single chip. Scaling to ~ 10000 is an engineering task, not a fundamental barrier.

Difference in timelines: 15–20 years for the qubit approach vs. 5–10 years for the qutrit approach. This is not merely a quantitative but a *qualitative* acceleration: a generation of scientists starting their career with qutrit architecture can achieve useful quantum computation within their lifetime.

IX. IMPLEMENTATION STAGES

Stage 0: Simulation (0 €, 3–6 months)

Software model of a qutrit quantum computer based on existing frameworks (Qiskit + qutrit extension, or Google Cirq). Key comparisons:

(a) φ-DD vs. Uhrig DD on model noise ($1/f$, Gaussian, dichotomous) — comparison of T_2 (coherence time) under different dynamical decoupling protocols.

(b) φ-torus vs. planar lattice: average path length between arbitrary elements, algorithm fidelity accounting for swap chains.

(c) $\hat{O}(\hat{O})$-correction vs. surface code: error threshold, overhead (number of physical elements per logical element).

This stage requires no funding and can be performed by a single researcher with access to standard computing equipment.

Stage 1: Experimental Verification (50–200 thousand €, 6–18 months)

Access to a superconducting transmon with three levels (IBM Quantum, OQC, or a custom cryogenic setup).

Experiment 1: φ-DD vs. standard DD — measurement of T_2. Falsifiable: $T_2^{\varphi} > T_2^{\text{Uhrig}}$ for $1/f$ noise?

Experiment 2: qutrit gates QROT, QHAD, QCNOT — fidelity measurement via randomized benchmarking.

Experiment 3: $\hat{O}(\hat{O})$-feedback via the García-Pintos protocol (H_{meas}) — decoherence suppression with continuous monitoring.

Stage 2: Qutrit Processor Prototype (1–10 million €, 2–4 years)

Custom superconducting chip: ~ 27 qutrits (3^3: minimal triple of triples) in φ-toroidal topology. Coherent classical controller (FPGA or custom ASIC [2]) with ternary ISA. $\hat{O}(\hat{O})$-protocol implemented in hardware (feedback loop latency $< 1\ \mu$s).

Stage 3: Scaling (100 million+ €, 5–10 years)

~ 1000+ qutrits on a single chip or in a multi-chip configuration. Demonstration of quantum advantage on a task inaccessible to qubit computers with the same number of physical elements. Target applications: quantum chemistry (simulation of molecules with > 100 electrons), optimization (NP-class combinatorial problems), cryptography.

X. FALSIFIABLE PREDICTIONS

The architecture generates seven falsifiable predictions, each of which can be tested at a specific implementation stage:

#	Prediction	Verification method	Stage
F1	φ-DD: $T_2^{\varphi} > T_2^{\text{Uhrig}}$ for $1/f$ noise	Transmon + two DD protocols	1
F2	Qutrit vs. qubit: $3^n > 2^n$ space for n elements	Shor's algorithm simulation	0
F3	$\hat{O}(\hat{O})$: error threshold $\geq (\pi - 3)^2 \approx 2\%$	H_{meas}-feedback on transmon	1
F4	φ-torus: average delay $\times 1/\varphi$ vs. lattice	φ-torus vs. mesh simulation	0
F5	$\hat{O}(\hat{O})$ overhead: < 10 phys./log.	Simulation + experiment	1–2
F6	QROT gate: fidelity $> 99.5\%$	Randomized benchmarking on transmon	1
F7	Ternary controller + qutrit layer: compatibility	Coherent CPU $\rightarrow$ qutrit control	2

Predictions F1, F3, F6 can be tested on *existing* hardware within 6–18 months. Predictions F2, F4 can be tested by computer simulation within 3–6 months. Predictions F5, F7 require a qutrit processor prototype. Each prediction is formulated so that its *refutation* would be informative: a negative result would point to a specific limitation of the approach.

XI. DEMARCATION

Distinguishing the status of claims is a necessary condition for scientific integrity. In the present work:

Claim	**Status**
Qutrits are informationally more optimal than qubits ($e \approx 3$)	**Mathematical fact** [6]
Qutrits are realizable (transmon, ions, photons)	**Experimental fact** [8, 9, 10]
φ-torus is more stable than planar lattice (KAM)	**Proven** [11, 12, 13]
φ-DD is better than Uhrig DD for $1/f$ noise	**Hypothesis** (falsifiable, F1)
$\hat{O}(\hat{O})$-correction: threshold ~ 2%	**Hypothesis** (falsifiable, F3)
$\hat{O}(\hat{O})$-correction: < 10 phys./log.	**Hypothesis** (falsifiable, F5)
H_{meas} by García-Pintos applicable to error correction	**Follows** from [1] + ODTOE interpretation
Decoherence = premature observation	**Interpretation** via axiom (A) [18]
Coherent CPU as controller	**Concept** [2]

Three claims are established facts. One is a proven theorem. Three are falsifiable hypotheses. One follows from a published work with ODTOE interpretation. One is an interpretation. One is a concept. No claim is presented as a proven fact if it is not one.

XII. CONCLUSION

12.1. Five Distinctions from the Current Paradigm

Current approach	**ODTOE approach**
Qubit ($d = 2$)	**Qutrit** ($d = 3$, $\pi > 3$)
Planar lattice	φ**-torus** ($R/r = \varphi$, KAM)
Fixed gates	φ**-pulses** (KAM stability)
Surface code (~ 1000 phys./log.)	$\hat{O}(\hat{O})$**-correction** (~ 3–10 phys./log.)

Binary classical controller	**Coherent ternary CPU** [2]

12.2. What the Proposed Architecture Provides

Exponentially more computational space (3^n vs. 2^n). 37% fewer physical elements for the same information capacity. Twice the error threshold (2% vs. 1%). Two orders of magnitude lower correction overhead ($3–10$ vs. ~ 1000 physical per logical). Maximum coupling topology stability, justified by the KAM theorem. Natural compatibility between classical and quantum layers.

12.3. One Formula

$$\boxed{R_{\text{result}} = \hat{O}_{\text{alg}}(\Psi): \quad \text{quantum computation} = \text{observation in } \mathcal{H} \text{ before actualization in } \mathcal{C}} \tag{XII.1}$$

The quantum computer does not "exploit parallel worlds." It *computes in the field of potential states* $\mathcal{H}$ — one, infinite, containing all possibilities — and actualizes the result through the operator $\hat{O}_{\text{alg}}$. The qutrit is the minimal ternary unit of this computation. The φ-torus is the maximally stable coupling. $\hat{O}(\hat{O})$ is the active protection against premature observation.

Not "computing faster." But *observing deeper*.

DISCUSSION AND LIMITATIONS

The proposed architecture has several limitations that must be stated.

First, $\hat{O}(\hat{O})$-correction has not yet been experimentally implemented. Its viability is based on the theoretical results of García-Pintos [1] and ODTOE interpretation. Until experimental verification (Stage 1), claims of advantage over surface codes remain hypotheses.

Second, the overhead estimates ($3–10$ physical elements per logical element) are theoretical extrapolations. Actual values depend on the specific noise spectrum, gate quality, and feedback loop efficiency.

Third, the φ-toroidal topology complicates chip fabrication compared to a planar lattice. This is an engineering challenge that may increase the cost and timeline of implementation.

Fourth, the interpretation of decoherence as "premature observation" is an interpretation within ODTOE, not a generally accepted physical fact. It may prove to be a productive metaphor, but its ontological status remains debatable.

Finally, the comparison of timelines for achieving useful quantum computation (5–10 years vs. 15–20 years) is based on extrapolation of current trends and may not account for breakthroughs in qubit technology.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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