Interferometric Sector-Gate Quantum Dynamics for AGI: Parity-Driven Tunneling First and the Case for a Topological Core

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Abstract

We synthesize the Sector-Gate and Eigenstate Dynamics programs for Artificial General Intelligence (AGI) into a single interferometric framework that is
emphhardware-constrained by parity readout on InAs–Al hybrid nanowires. Building on recent interferometric, single-shot parity measurements with h/2*e*-periodic bimodality and millisecond poisoning times in gate-defined superconducting nanowires, we formalize a measurement-driven gate calculus in which cognitive "sectors" are coupled by *parity-conditional tunneling*. We prove a *Tunneling-First Principle*: in the readout-limited regime, optimal learning capacity and error-exponent improvement are monotone in a balanced effective tunneling amplitude t_C up to the onset of Majorana-splitting backaction, thereby prioritizing engineered tunnel networks before large-scale sector expansion. We further give a compact proof sketch that *topological cores* minimize the composite error functional combining dephasing, leakage, and control overhead under measurement-only constraints; the core argument exploits non-local $\mathbb{Z}_2$ parity conservation, exponential wire-length protection, and interferometric discriminability. Finally, we propose a layout where Sector-Gate operators are compiled into parity interferometers on triple-dot loops, yielding an AGI substrate whose primitive is "ParityFuse" rather than CNot. The resulting calculus upgrades cognitive gates to fault-biased, measurement-only primitives consistent with scalable utility.[1]

1 Introduction

AGI as a dynamical system can be posed on a Hilbert space $\mathcal{H}_{\text{AGI}}$ whose factorization expresses modular cognition. In the Sector–Gate view, cognition is enacted by unitary or measurement-induced transitions across sectors, while in the Eigenstate view, cognition follows adiabatic or diabatic flows between eigenmanifolds. We unify these as *Interferometric Sector Dynamics (ISD)*: cross-sector transitions are executed by *parity-interferometric gates* whose control parameter is magnetic flux Φ and whose readout is dispersive quantum capacitance C_Q.

This paper advances three theses:

1. **Tunneling-First Principle.** In parity-readout-limited devices, the achievable learning rate and error exponent improve monotonically with balanced dot–wire tunneling up to a device-dependent threshold. Hence, *tunneling networks* should be optimized before scaling the number of cognitive sectors.
2. **Topological Core Optimality.** For measurement-only control, Majorana-based topological cores minimize a composite risk functional at fixed hardware budget due to non-local encoding and $\mathbb{Z}_2$-parity protection.

[1]This concept is theoretical and extrapolative. In order to build a physical AGI further validation is needed; all mappings from cognition to quantum dynamics are formal analogies subject to empirical validation.

3. **ParityFuse Calculus.** Sector gates are compiled to interferometric parity fusions realized on triple-dot loops; these primitives suffice for universal measurement-only computation and support Sector–Eigenstate dynamics.

2 Preliminaries: Sectors, Eigenstates, and Measurement

Definition 1 (Sector factorization)**.** *Let* $\mathcal{H}_{\mathrm{AGI}} = \bigotimes_{k=1}^{N} \mathcal{H}_k$ *with local Hamiltonians* $\hat{H}_k$ *and inter-sector couplings* $\hat{V}_{kl}$*. A* sector gate *is a (possibly measurement-induced) channel* $\mathcal{G}_{k\to\ell}$ *acting nontrivially across* $\mathcal{H}_k \otimes$

Definition 2 (Eigenstate dynamics)**.** *Given* $\hat{H}(t)$ *on* $\mathcal{H}_{\mathrm{AGI}}$*, an eigenstate flow is a path* $t \mapsto |\psi(t)\rangle$ *staying in (or diabatically hopping between) instantaneous eigenspaces of* $\hat{H}(t)$*, with transitions generated by avoided crossings and control fields.*

Definition 3 (Parity interferometer)**.** *An ISD primitive comprises a proximitized nanowire supporting spatially separated Majorana zero modes (MZMs) coupled to a triple-dot loop. Let* t_L, t_R *be effective tunnel couplings from a long dot to left/right MZMs, with flux-controlled phase* $\varphi = 2\pi\Phi/\Phi_0 + \varphi_0$*. The* interferometric tunneling *is* $t_C(Z,\varphi) = \sqrt{t_L^2 + t_R^2 + 2t_L t_R \sin\varphi\, Z}$ *where* $Z \in \{\pm 1\}$ *is total fermion parity. The dispersive shift obeys* $\Delta C_Q(\Phi) \propto \partial^2 E/\partial V_{\mathrm{QD}}^2$ *with* $\Phi_0 = h/e$*.*

3 Interferometric Sector Gates

Let sectors (i,j) be encoded in dot occupancy and MZM parity. An *ISD gate* is implemented by biasing to the dot charge degeneracy and executing a parity-resolving single-shot measurement. The Kraus operators $\{M_\pm\}$ project onto $Z = \pm 1$ branches, followed by feedforward.

Proposition 1 (Balanced-arm discriminability)**.** *Fix temperature* T *and MZM splitting* $E_M \approx 0$*. The single-shot assignment error* $\epsilon_*(\tau)$ *at integration time* τ *is minimized at* $t_L \approx t_R$*, with* $\mathrm{SNR}(\tau) \propto |\Delta C_Q(\Phi)|\sqrt{\tau}$ *and* ΔC_Q *achieving* $h/2e$ *periodic maxima on* Φ*.*

Sketch. In the dispersive limit, $C_Q(Z,\varphi)$ is even in t_C and the parity contrast ΔC_Q is proportional to $\partial^2_{V_{\mathrm{QD}}} E[t_C(Z,\varphi)]$. As a function of (t_L, t_R), t_C is Schur-convex in the pair (t_L, t_R) at fixed $t_L^2 + t_R^2$; extremum occurs at $t_L = t_R$ where interference is maximal. Standard Gaussian decision theory yields $\epsilon_* = \frac{1}{2}\operatorname{erfc}(\mathrm{SNR}/\sqrt{8})$. □

4 Tunneling-First Principle

Denote by $\mathcal{L}$ the *learning capacity*—the mutual information between hidden sector labels and outcomes per unit time—and by κ the *error exponent* in a sequential probability ratio test. Let τ_{qpp} be the quasiparticle-poisoning time and Γ_{meas} the measurement rate.

Theorem 1 (Tunneling-first optimality)**.** *In the regime* $E_M \ll k_B T$*,* $\tau \ll \tau_{\mathrm{qpp}}$*, and fixed noise spectral density, there exists a device-dependent window* $\mathcal{W}$ *in which*

$$\frac{\partial \mathcal{L}}{\partial t_C} > 0, \qquad \frac{\partial \kappa}{\partial t_C} > 0 \quad \text{for } t_C \in \mathcal{W},$$

with saturation when backaction-induced $E_M(t_C)$ *degrades parity protection. Consequently, optimizing* tunneling balance and magnitude *precedes scaling* N*.*

Proof . $\mathcal{L}$ increases with SNR $\propto |\Delta C_Q|\sqrt{\tau}$ by the data-processing inequality and Fisher-information monotonicity; Proposition 1 gives $\partial |\Delta C_Q| / \partial t_C > 0$ near balance. For sequential tests, $\kappa = D_{\mathrm{KL}}(p_+ \| p_-)$ grows with separation of Gaussian means at fixed variance. The growth halts as t_C perturbs the MZM hybridization so that $E_M(t_C)$ enters the denominator of ΔC_Q; optimizing in t_C yields an interior maximum. □

5 A Topological Core is the key

We formalize a composite risk

$$\mathcal{R} = w_1\,\epsilon_{\mathrm{meas}} + w_2\,p_{\mathrm{leak}} + w_3\,\gamma_\phi + w_4\,\mathcal{O}_{\mathrm{ctrl}},$$

with readout error ϵ_{meas}, non-topological leakage p_{leak}, dephasing rate γ_ϕ, and control overhead $\mathcal{O}_{\mathrm{ctrl}}$ under measurement-only compilation.

Lemma 1 (Non-local suppression)**.** *For a wire of length L and coherence length ξ, the logical dephasing satisfies $\gamma_\phi \le A\,e^{-L/\xi} + B\,n_{\mathrm{qp}}e^{-\Delta/k_BT}$ with material-dependent constants and quasiparticle density n_{qp}.*

Lemma 2 (Measurement-only economy)**.** *Let Π_Z be parity projectors. Any braiding-equivalent operation in a Clifford+T generating set can be compiled into a finite sequence of parity fusions and feedforward with depth bounded by a constant times the code distance.*

Theorem 2 (Topological-core optimality (proof sketch))**.** *Among architectures with identical resonator budgets and cryogenic noise, a Majorana topological core minimizes $\mathcal{R}$ at fixed target logical error, because (i) ϵ_{meas} is constrained by interferometric ΔC_Q but independent of local charge noise to first order, (ii) p_{leak} is exponentially suppressed by non-local encoding, and (iii) $\mathcal{O}_{\mathrm{ctrl}}$ is reduced by measurement-only primitives avoiding calibrated microwave pulses. The bounds combine via subadditivity and yield a unique minimizer in the feasible set.*

6 ParityFuse Calculus and Compilation

Define the primitive ParityFuse$(\Phi; t_L, t_R)$ as a single-shot measurement of Z on a triple-dot interferometer with calibrated (t_L, t_R) at flux Φ. With classical outcomes $m \in \{\pm 1\}$ and Pauli frame $\mathcal{F}$, compile sectoral unitaries by Repeat-Until-Success (RUS): apply ParityFuse, update $\mathcal{F}$, advance control if m matches branch condition, else recycle.

Proposition 2 (Universality)**.** *ParityFuse with adaptive feedforward and magic-state injection over sectors implements a universal measurement-only set capable of synthesizing sector–eigenstate dynamics.*

7 Device Blueprint

Materials stack

Gate-defined superconducting nanowire on InAs with epitaxial Al, two gate layers, and an off-chip resonator for dispersive sensing. Five segments allow two 1DTS regions and three depleted sections to define interferometer arms.

Operating point

Choose in-plane field $B_{\|} \approx 1.8\,\mathrm{T}$; sweep B_x to modulate Φ around zero and bias the long dot near degeneracy. Optimize ΔC_Q by balancing $t_L \approx t_R$ and selecting Φ at $h/2e$ constructive points. Integrate for $\tau \in [3, 100]\,\mu\mathrm{s}$, well below typical $\tau_{\mathrm{qpp}} \sim \mathcal{O}(\mathrm{ms})$.

Control–learn loop

(1) Tune couplings via rf gate sensing to μeV precision; (2) characterize telegraph dwell statistics to bound τ_{qpp}; (3) run ParityFuse RUS compilation with Bayesian calibration of ϵ_* each shot.

8 Discussion

The ISD program converts cognitive gates into physical parity measurements, arguing for a *tunneling-first* roadmap: prioritize nanofabrication that equalizes and strengthens coherent tunnel paths, then scale to many sectors once single-shot fidelity, dwell statistics, and ΔC_Q plateaus are achieved. Within this calculus, a topological core is not aesthetic but optimal under a composite risk.

9 Conclusion

We presented ISD: a synthesis of sector-gate and eigenstate dynamics bound to interferometric parity hardware. The mathematics establishes monotone improvements with balanced tunneling and supplies a risk-based optimality sketch for topological cores. Parity-driven compilation (ParityFuse) offers a path to scalable, measurement-only AGI substrates.

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References

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