Project Fact Sheet: Interface-Constrained Dynamics and Coherence Framework

AuraCoreCF Research Group

March 2026

1 Project Overview

This fact sheet summarizes the "Interface-Constrained Dynamics and Coherence" theoretical framework, developed by AuraCoreCF Research Group in January 2026. The theory proposes that physical interfaces (e.g., measurement instruments with finite resolution) actively shape quantum coherence, geometry, and dynamics through equivalence classes over microstates. It unifies information theory, quantum mechanics, and emergent geometry, with testable predictions in interferometry and Bell tests. **Key Objectives:**

- Formalize coherence as interface-relative distances.
- Derive gauge structures and decoherence from equivalence classes.
- Provide falsifiable predictions for apparatus-dependent effects.
- Explore implications for quantum gravity, entanglement, and technology.

Status: Theoretical and phenomenological; supported by simulations matching experimental bounds (e.g., visibility in high-mass interferometry). Not yet experimentally confirmed, but consistent with data up to m* ¿ 10,000 amu.

2 Key Personnel and Timeline

- **Principal Investigator:** AuraCoreCF Research Group
- **Development Period:** January 2026 (initial papers)
- **Current Phase:** Simulation validation (QuTiP-based modeling of decoherence); proposed experimental tests in 2026–2027 (e.g., upgraded LUMI/KDTLI interferometers).
- **Future Milestones:** Reanalyze existing data (e.g., Fein et al., 2019); run Bell tests with varying resolution d; seek funding for km-scale setups.

3 Methodology and Core Concepts

The framework models interfaces as quantum instruments inducing equivalence relations, leading to fiber-bundle geometry and Fisher-information penalties. **Interfaces and Equivalence Classes:**

Interface I maps microstates Φ to observables: $\Phi \sim \Phi'$ if $I(\Phi) = I(\Phi')$. Physical space: $M_{\text{phys}} = M_{\text{micro}}/\sim$, a principal G-bundle.

Coherence Measures:

Intrinsic: $C_Q(\rho) = \inf_{\sigma \in R} D(\rho \| \sigma)$, where $D(\rho\|\sigma) = \text{Tr}[\rho(\log\rho - \log\sigma)]$ and $R = \{\sigma : L_{\text{int}}(\sigma) = 0\}$. Operational: $C_I(\rho; M) = \frac{1}{1+D_{\text{KL}}(p_\rho^M \| p_{\text{ref}}^M)}$.

Emergent Geometry:

Connection A_μ for covariant derivatives: $D_\mu = \partial_\mu + A_\mu$. Curvature: $F_{\mu\nu} = [D_\mu, D_\nu]$. Leading EFT penalty: $\int \mathrm{Tr}(F^2)$ (Yang-Mills-like).

Decoherence Channel:

Action penalty: $S_C = -\frac{\hbar^2}{8m^*}\int (\nabla\rho)^2/\rho$. Master equation: $\frac{d\rho}{dt} = -\frac{i}{\hbar}[H,\rho] - \frac{\eta\hbar}{8m^* d^4}[x,[x,\rho]]$, with $\eta \approx 1/8$.

4 Key Equations and Predictions

Visibility Suppression (Talbot-Lau Geometry):

Path separation: $\Delta x \approx \lambda_{dB} L/d$; at resonance, $\Delta x \approx qd$. Visibility: $V/V_{QM} = \exp\left[-\frac{\eta\hbar t}{8m^* d^2}(\Delta x/d)^2\right]$ (for $\Delta x \sim d$). Scaling: Fixed $\Delta x \to \ln V \propto -1/d^4$; Talbot mode $\to -1/d^2$.

Bell-State Demonstration:

State under dephasing: $\rho(p) = \frac{1}{2}(|00\rangle\langle 00| + |11\rangle\langle 11|) + \frac{c(p)}{2}(|00\rangle\langle 11| + \text{h.c.})$, $c(p) = (1-2p)^2$. Z: $C_I = 1$ (constant); X⊗X: C_I decreases.

Experimental Bounds:

From Fein et al. (2019): d=266 nm, t≈7.51 ms, V≥0.90 → m* ≥ 1000–8000 amu (η=1/8 to 1).

5 Simulation Results

Using QuTiP to solve the master equation for a two-path interferometer (Talbot-like, $\Delta x = d$, $\eta = 1/8$, m*=1.66×10^{-24} kg, t=7.51 ms):

At d=266 nm: V ≈ 0.90 (matches bound). Varying d (100 nm, 200 nm, 266 nm, 500 nm, 1 μm): V ≈ [0.475, 0.830, 0.900, 0.971, 0.993]. Finer d increases decoherence, unique signature.

6 Implications and Risks

Scientific Impact: Unifies QM and geometry; resolves entanglement "spookiness"; predicts d-dependent effects falsifiable in near-term experiments. **Technological Implications:**

Quantum computing: Limits from intrinsic decoherence; opportunities in interface-optimized sensors. AI/Complex Systems: Charge-bounded entanglement for robust networks. Challenges: May cap scalable QC; requires redesigning experiments.

Risks and Mitigation: Theory is phenomenological; if no effects seen, m* bounds tighten. Propose simulations first, then hardware tests.

7 References

Thomas, C. (2026). Various papers on interface-constrained coherence. Fein et al. (2019). Nature Physics.