Mesh Field Theory – Lecture 06: Mesh Phase Estimation and Frequency Readout

From First Principles: Causal Oscillation and Collapse

1. Introduction

Phase estimation is a central operation in quantum algorithms — used in order-finding, eigenvalue detection, and periodicity extraction.

In standard quantum computation, this is performed with controlled-U gates and inverse quantum Fourier transforms.

In Mesh, phase estimation emerges from the **frequency of causal coherence oscillation** in a Mesh qubit — and is read out via divergence collapse.

This lecture explains how Mesh qubits store, accumulate, and reveal frequency information — **physically, not symbolically.**

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2. Frequency as Physical Structure

In Mesh, a qubit with locked twist and coherent support behaves like a field oscillator:

$$\phi(x,t) = 2\pi\theta t + \phi_0(x) \quad \Rightarrow \quad \vec{C}(x,t) = \nabla\phi(x,t)\cdot\chi(x,t)$$

The parameter $\theta \in [0,1)$ represents the unknown frequency we wish to extract.

Unlike symbolic phases in QM, θ is **real** — encoded in the wave's causal evolution.

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3. Clock Qubits: Frequency Amplifiers

To extract θ, prepare n Mesh clock qubits. Each is exposed to $\vec{C}_\psi(x,t)$, the oscillator carrying the phase.

Each clock field accumulates phase proportional to time and position:

$$\phi_k(x,t) = 2\pi 2^k \theta t$$

Thus:

- Clock 0 accumulates θ - Clock 1 accumulates 2θ - ... - Clock $n-1$ accumulates $2^{n-1}\theta$

This is implemented by configuring phase velocity gradients — not symbolic control gates.

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4. Causal Interference Across Clock Fields

After exposure, each clock qubit now contains a coherence vector:

$$\vec{C}_k(x,t) = \nabla\phi_k(x,t)\cdot\chi(x,t)$$

Interference occurs across clock qubits — real scalar products cause reinforcement or cancellation based on shared phase alignment.

Constructive alignment:

$$\vec{C}_k \cdot \vec{C}_l > 0 \quad \Rightarrow \quad \text{phase match}$$

Destructive:

$$\vec{C}_k \cdot \vec{C}_l < 0 \quad \Rightarrow \quad \text{phase conflict}$$

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5. Readout via Collapse Geometry

Each Mesh clock qubit exists in a bounded region. As phase accumulates and interference intensifies:

$$\Gamma(x,t) = \nabla \cdot \vec{C}(x,t) \quad \text{rises}$$

Collapse occurs when:

$$\Gamma(x,t) > \Gamma_{\text{crit}}$$

This collapse location is tied to the phase offset — allowing us to infer the value of θ.
In binary: collapse at region k means the k-th bit of θ is 1.
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6. Worked Example: 2-Bit Mesh Phase Estimate

Let $\theta = 0.10_2 = 0.5$
Then:

$$\phi_0 = 2\pi(2^0) \cdot 0.5t = \pi t \phi_1 = 2\pi(2^1) \cdot 0.5t = 2\pi t$$

After evolution:
- $\vec{C}_0$ has direction reversal (phase $= \pi$) $\rightarrow$ divergence $\uparrow$ - $\vec{C}_1$ has full-cycle coherence $\rightarrow$ no divergence
Collapse:
- Clock 0 collapses $\rightarrow$ bit = 1 - Clock 1 does not collapse $\rightarrow$ bit = 0
Recovered value: $\theta = 0.10_2 = 0.5$
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7. Ensemble Statistics (Mesh vs QM)

In QM, phase estimation is probabilistic. In Mesh, each collapse is deterministic per field geometry — but repeated runs with slightly varied initial conditions yield:

$$\text{Distribution of bit strings } \{b_1, b_2, \dots\} \Rightarrow \text{ensemble converges to } \theta$$

Thus:
- Mesh is deterministic per run - But still produces statistical convergence
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8. Comparison to Quantum Phase Estimation (QPE)

— Feature — Quantum QPE — Mesh Phase Estimation — ———————————————— — Phase accumulation — Controlled unitaries — Physical frequency accumulation — — Interference — Amplitude overlap — Coherence vector alignment — — Readout — Measurement and inverse QFT — Divergence collapse at clock regions — — Statistics — Born rule — Causal ensemble variation — — Output — Bit string encoding θ — Bit string from collapse pattern —
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9. Summary

Phase estimation in Mesh is:

- Real: frequency is encoded in causal oscillation - Physical: no gates or projective measurement - Deterministic: collapse arises from divergence - Accurate: multiple runs yield convergent results

Mesh extracts frequency from structure — not from symbol.

Next: Mesh modularity and periodicity — the foundation for Simon and Shor.