Meta-CY Quantum Computing: Spectral Graphs on Calabi–Yau Manifolds

Evgeny Monakhov
VOSCOM Research Initiative

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1. Central Idea

This work introduces a computational framework in which information carriers are defined not only as qubits or qudits but as wavefunctions on Calabi–Yau (CY) manifolds. The approach combines CY geometry with spectral graph theory.

1.1 CYbit

For a Calabi–Yau manifold M of complex dimension k, a *CYbit* is defined as

$$\psi \in L^2(M, \mathbb{C}^d), \tag{1}$$

with d being the local dimension (qudit-like).

1.2 CY Graphs

A system of CYbits can be represented by a graph $G = (V, E)$ embedded in M. Edge weights are determined by distances and topological cycles:

$$w_{ij} = f(\mathrm{dist}_M(p_i, p_j), \mathrm{Top}(M)). \tag{2}$$

1.3 Spectral Laplacian

The Laplacian on such a graph encodes both metric and topological properties of M. Eigenvalues and eigenvectors define possible energy states and transitions.

2. Motivation

- Classical computers: bounded by 10^{12} ops/s.
- Quantum computers: 2^n states from qubits.
- Qudits: d^n states with $d > 2$.
- CYbits: exponential extension via CY structure.

3. Formal Structure

- Hilbert space: $L^2(M, \mathbb{C}^d)$.
- Graph representation: adjacency operator A.
- Hamiltonian:
$$H = -\Delta_{CY} + V + H_{\text{int}}$$
where Δ_{CY} is the Laplacian on CY.

4. Scaling Potential

System	Local dimension	$n = 10$ sites
Qubits (2D)	2	$2^{10} \sim 10^3$
Qudits ($d = 10$)	10	10^{10}
CY-3D ($m = 10$)	10^3	10^{30}
CY-6D ($m = 10$)	10^6	10^{60}

5. Research Roadmap

1. Theoretical definitions: CYbits, CYlinks, Laplacians.
2. Mathematics: mirror symmetry, invariants, topology of CY.
3. Simulations: spectral numerics for torus T^2, T^3.
4. Experimental: prototypes with $d = 3 - 5$ photonic or ion states.
5. Long-term: scalable CY quantum computation.

6. Conclusion

This proposal formulates a new paradigm of quantum information: *Meta-CY Quantum Computing*. It unites CY geometry, topology, and spectral graphs to vastly extend computational capacity.