CYlinks and CYgluons: Interactions in Meta-Quantum Computing

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Abstract

We propose a formal description of *CYlinks* and *CYgluons*, the interaction structures in the Meta-CY Quantum Computing framework. CYlinks represent couplings between CYbits, defined by embeddings into Calabi–Yau (CY) subspaces, while CYgluons describe higher-order interactions between the links themselves, analogous to gluons in quantum chromodynamics (QCD). We present mathematical definitions, operator formalisms, research roadmap, and perspectives for computational applications.

1 Introduction

In the Meta-CY Quantum Computing framework, CYbits are quantum states defined on CY manifolds. To build computation, CYbits must interact. These interactions are not limited to pairwise couplings, but may themselves form networks of higher-order dynamics. We call these structures CYlinks (direct connections) and CYgluons (link-link interactions).

2 Definition of CYlinks

Let M be a CY manifold, discretized as a graph $G = (V, E)$. For two CYbits at points $p_i, p_j \in M$, define a CYlink as an operator

$$H_{link}(i, j) = w_{ij}\, \psi^\dagger(p_i)\psi(p_j) + h.c., \tag{1}$$

with weight

$$w_{ij} = f(\mathrm{dist}_M(p_i, p_j),\ \mathcal{T}_{ij}), \tag{2}$$

where $\mathcal{T}_{ij}$ encodes topological data of the embedding subspace.

2.1 Graph Laplacian Form

The total link Hamiltonian can be expressed as:

$$H_{links} = \sum_{(i,j)\in E} w_{ij}(\psi^\dagger(p_i)\psi(p_j) + h.c.). \tag{3}$$

This generalizes standard adjacency-based interactions to CY-dependent weights.

3 CYgluons: Interactions Between Links

CYlinks themselves may interact, forming higher-order couplings. Define a CYgluon operator acting on two links (i, j) and (k, l):

$$H_{gluon}((i,j),(k,l)) = g_{ijkl}\,\psi^\dagger(p_i)\psi(p_j)\psi^\dagger(p_k)\psi(p_l), \tag{4}$$

where

$$g_{ijkl} = g(\mathcal{T}_{ij}, \mathcal{T}_{kl},\ \mathrm{Hom}(M)). \tag{5}$$

Here g_{ijkl} depends on overlaps of CY subspaces and homological relations.

3.1 Total Hamiltonian

The global system Hamiltonian is then

$$H = \sum_i H_{CYbit}(i) + \sum_{(i,j)} H_{link}(i,j) + \sum_{(i,j),(k,l)} H_{gluon}((i,j),(k,l)). \tag{6}$$

4 Research Roadmap

4.1 Stage I: CYlink Formalism

1. Define explicit w_{ij} for simple CY (tori T^n, K3).
2. Compute spectra of CYlink Hamiltonians.
3. Relate w_{ij} to CY topology.

4.2 Stage II: CYgluon Structures

1. Introduce g_{ijkl} based on overlaps of CY subspaces.
2. Test consistency with gauge-like symmetries.
3. Explore analogy with QCD color charges.

4.3 Stage III: Combined Dynamics

1. Simulate CYbit networks with CYlinks and CYgluons.
2. Study stability and error correction properties.
3. Explore emergent computational phases.

5 Perspectives

- **Computational Power:** CYlinks and CYgluons provide new interaction structures, potentially enhancing expressive capacity.
- **Error Correction:** CYgluon couplings may stabilize logical states via higher-order redundancies.
- **Physics Analogy:** Formal similarity with gauge field theories suggests extensions to CY gauge groups.

6 Conclusion

CYlinks and CYgluons extend the Meta-CYbit model by introducing structured interactions between CYbits and between their couplings. This offers a foundation for novel quantum computational architectures grounded in Calabi–Yau geometry.

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