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Pauli Stabilizer Models of Twisted Quantum Doubles, and a New Quantum Cellular Automaton

by

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ALL INTERESTED ARE WELCOME

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Abstract

We construct a Pauli stabilizer model for every Abelian topological order that admits a gapped boundary in two spatial dimensions. Our primary example is a Pauli stabilizer model on four-dimensional qudits that belongs to the double semion (DS) phase of matter. The DS stabilizer Hamiltonian is constructed by condensing an emergent boson in a Z4 toric code. We show that the construction of the DS stabilizer Hamiltonian generalizes to all twisted quantum doubles (TQDs) with Abelian anyons. This yields a Pauli stabilizer code on composite-dimensional qudits and implies that the classification of topological Pauli stabilizer codes extends beyond stacks of toric codes—in fact, exhausting all Abelian anyon theories that admit a gapped boundary.

We use this technique to construct a novel three-dimensional quantum cellular automaton (QCA) based on a system with short-range entangled bulk and chiral semion boundary topological order. We argue that either the QCA is nontrivial, i.e., not a finite-depth circuit of local quantum gates. Our QCA is obtained by first constructing the Walker-Wang Hamiltonian of a certain premodular tensor category, and then condensing the deconfined bulk boson. We show that the resulting Hamiltonian hosts chiral semion surface topological order in the presence of a boundary and can be realized as a non-Pauli stabilizer code on qubits, from which the QCA is defined. Our results support the conjecture that the group of nontrivial three-dimensional QCAs is isomorphic to the Witt group of non-degenerate braided fusion categories.

References:
PRX Quantum 3, 010353 (2022) (https://doi.org/10.1103/PRXQuantum.3.010353)
PRX Quantum 3, 030326 (2022) (https://doi.org/10.1103/PRXQuantum.3.030326)

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