Type-II Quantum Computing Using Superconducting Qubits

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Most algorithms designed for quantum computers will not best their classical counterparts until they are implemented with thousands of qubits. For example, the factoring of binary numbers with a quantum computer is estimated to be faster than a classical computer only when the length of the number is greater than about 500 digits [1]. In contrast, the Factorized Quantum Lattice-Gas Algorithm (FQLGA) [2] for fluid dynamics simulation, even when run on a quantum computer significantly smaller than the one just discussed, has significant advantages over its classical counterparts.

The FQLGA is the quantum version of classical lattice-gases (CLG)[3]. CLG are an extension of classical cellular automata with the goal of simulating fluid dynamics without reference to specific microscopic interactions. The binary nature of the CLG lattice variables is replaced for the FQLGA by the Hilbert space of a two-level quantum system. The results of this replacement are similar to that of the lattice-Boltzmann model, but with a couple of significant differences [4]. The first is the exponential decrease in required memory. The second is the ability to simulate arbitrarily small viscosities.

We have recently developed two implementations of the algorithm for the 1D diffusion equation using the PC qubit. The first consists of initializing the qubits while keeping them in their ground state, and then performing the collision by quickly changing their flux bias points and then performing a single $\pi/2$ pulse (Figure 1). This initialization technique could prove quite useful, since relaxation effects are avoided, but the way we have implemented the collision is not easily generalized to other collisions. A more general collision implementation was then developed by decomposing the unitary collision matrix into a sequence of single qubit rotations and coupled free evolution. The single qubit rotations then also serve to initialize the fluid’s mass density.

![Figure 1: Simulation of the FQLGA for 1D diffusion is pictured (o) alongside simulation of the first proposed implementation (+). The expected diffusion of a gaussian is observed.](image)

REFERENCES: