Simulated Non-Abelian Statistics of Majorana Zero Modes from A Kitaev Lattice

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We simulate the non-Abelian exchange of Majorana zero modes (MZMs) on a quantum computer. Rather than utilizing MZMs at the boundaries of quantum Ising chains, which are typically represented as nonlocal operators on a quantum computer, using a Kitaev lattice allows us to exploit a local representation of MZMs. We detail the protocol for braiding two and four MZMs in terms of the spin Hamiltonian. Projecting this onto a subspace of states that only mix with each other, we extract an effective Hamiltonian which drives a non-Abelian Berry's phase. Using several approximations, we construct a set of gates which mimics this accumulation of non-Abelian phase and apply it to both simulated quantum computers and cloud quantum computers. This is demonstrated by two different methods, firstly by simulating the adiabatic tuning the couplings[1] between MZMs by Trotterising time evolution of the qubit Hamiltonian, and the second by sequences of joint measurements simulating charge parity measurements[2] of two or more MZMs. We believe this to be the first demonstration of a measurement based geometric gate.

References

[1] Karzig *et al.*, Phys. Rev. X **6**, 031019 (2016)
[2] Karzig *et al.*, Phys. Rev. B **95**, 235305 (2017)

Figures

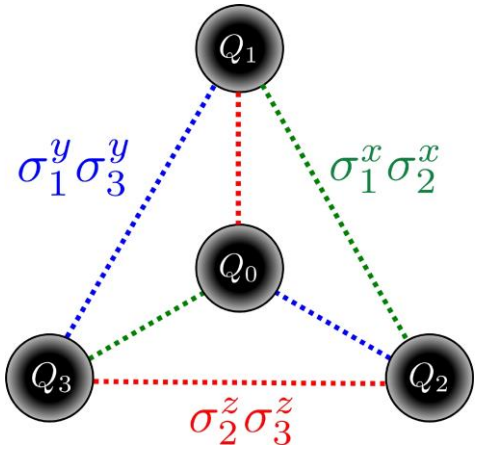

Figure 1: Qubit analogue of a four MZM Y-junction with Kitaev lattice like connectivity

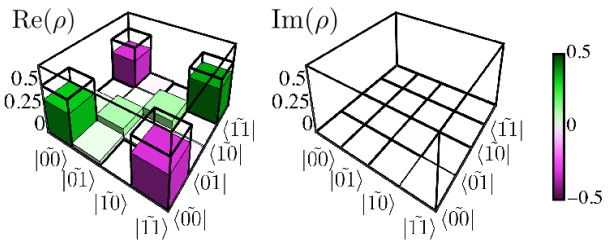

Figure 2: Density matrix output in the logical subspace of the simulated entangling braiding experiment performed on the *ibm_brisbane* processor, corresponding to a 70.1% output state fidelity