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Quantum Algorithm for QED

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The general simulation of Quantum Field Theory scales exponentially with the spatial volume, which makes the sizable computation possible only through the quantum computer. The standard quantum algorithm for the scalar field theory has long been developed, where the scalar field is simple enough to admit an obviously optimal qubit approximation to the continuum theory. When extending to the gauge theory, we are confronted with more constraints and limits. Here we present a standard qubit approach for the Quantum Electrodynamics, an Abelian gauge field theory in 3+1 dimension. The extra constraint, the Gauss's law, is dissolved by the fact that when the implementation is completely gauge invariant, the Gauss's law will be satisfied automatically. In light of this, the exact gauge transformation is enabled only by the gauge link, so the approach is also in the shape of the Wilson or Kogut-Susskind lattice theory. We have set up both 2+1 and 3+1 dimensional lattices, and tested out the codes on IBM quantum platforms. In the framework, we have also investigated the quantum error mitigation methods and found that in comparison to the post-selection method, the calibration method works better in the situation.

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