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Quantum Fourier Transformation based Coulomb Interaction Simulation

Simulating strongly correlated warm dense matter is an interesting, but a complicated problem. Indeed, even if we reduce the problem by applying Born-Oppenheimer approximations, standard simulation techniques such as density functional theory and quantum Monte Carlo encounter physical and technical challenges when employing classical computer algorithms. Another way is to use analog quantum simulation, however, experimental realization of simulating such a strongly correlated system remains to be a difficult problem. In the digital quantum simulation, we do not know yet, whether this can calculate sufficiently well. The first problem we encounter in this case is modeling Coulomb interaction between particles. This is a difficult task due to the non-local, long range interaction property. Indeed, digital quantum computers are known to be able to apply operations only locally using gates. Here we demonstrate the Coulomb potential can be directly represented in the quantum circuit by probability amplitudes in a continuous fashion in contrast to "classical" digital one. We achieve this result by exploiting the feature of quantum Fourier transformation and continuous probability amplitude. Our result opens a way to simulate physical systems not only to use gates, but also probability amplitudes representing physical observables.

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