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Quantum Simulation of Particles in External Fields

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Quantum computing in the last few years has seen fast growth, making it one of the most active research areas of today. This thesis investigates one of their applications, the simulation of the dynamics of charged particles in strong laser fields in the Strong Field Quantum Electrodynamics (SFQED) regime. Quantum algorithms that decompose the Time Evolution Operator into discrete quantum gates using both the Lie-Trotter product formula and Quantum Fourier Transforms, enabling the simulation of particle interactions in diverse external fields. The use of Walsh Functions enables the implementation of time-dependent vector potentials, more specifically Sauter pulses and oscillatory plane waves, on a quantum circuit, overcoming the challenge of representing continuous functions like cosines and hyperbolic tangents on digital quantum computers. The proposed algorithms were validated through 2D simulations comparing Classical and Quantum Trotterization, demonstrating that the quantum approach accurately reproduces expected physical behaviors, such as wave packet spreading and oscillatory drift, matching theoretical calculations. Future work aims to extend these methods to full plane wave potentials without dipole approximations, refine error analysis, and implement the algorithms on actual quantum hardware.

Field of Research/Work

Quantum Information, Science, and Technology

Author: MARIANO, José (Instituto Superior Técnico - University of Lisbon / GoLP)