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Quantum Algorithms for Efficient Classical Plasma Simulation[1]

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Quantum computers show promise to solve some computational problems exponentially faster than classical computers. This naturally includes the simulation of quantum many-body systems, yet quantum algorithms can also achieve speedups for problems unrelated to quantum physics. For example, a large speedup may be obtained if a computational problem can be mapped to a quantum system. We successfully apply that strategy to a specific kinetic plasma physics problem: linear Landau damping [1]. We find that a set of variables describing this system evolves unitarily, which allows us to develop and test a quantum algorithm that can simulate this evolution efficiently. Our algorithm has a computational complexity only logarithmic in the number of grid points, but also has a cost factor of 1/E, where E is the measurement error. Extensions to higher dimensions and electromagnetics appear straightforward, but incorporating nonlinearity is more challenging. We introduce techniques for mapping nonlinear dynamical systems to infinite-dimensional, linear dynamical systems. When the resulting linear system can be truncated, yielding a finite linear system, quantum algorithms can be applied to perform the associated evolution. We discuss conditions under which such an approach can accurately and efficiently reproduce outputs for nonlinear dynamical systems. Progress on applying this strategy to the Vlasov-Poisson system will be reported. [1] A. Engel, G. Smith, and S. E. Parker, Quantum algorithm for the Vlasov equation, Phys. Rev. A 100, 062315 (2019).

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