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Contents

Conference presentations and posters

I. Novikau, I. Y. Dodin, E. A. Startsev, I. Joseph, **Quantum algorithms for simulating dissipative linear and nonlinear dynamics of plasmas.** Invited talk at the 66th Annual Meeting of the APS Division of Plasma Physics, Atlanta, Georgia.

Quantum computing (QC) has the potential to speed up classical simulations of plasma dynamics, which requires dealing with large amounts of high-dimensional data, by leveraging quantum superposition and entanglement. Yet, due to the intrinsically linear and unitary nature of quantum mechanics, modeling dissipative nonlinear (NL) dynamics has required significant development. **We have derived explicit quantum algorithms (QAs) for modeling plasma physics including the linear dynamics of cold fluid waves in plasmas, electromagnetic waves, and diffusion, and have begun to develop QAs for nonlinear dynamics.** In this talk, we discussed the new QAs, various techniques for encoding classical systems into quantum circuits, and their potential for quantum speedup. QAs for dissipative dynamics are usually based on the transformation of nonunitary initial-value problems into a system of linear equations which then can be solved by a quantum linear solver such as the quantum singular value transformation. Another recent method that we have explored, the Linear Combination of Hamiltonian Simulations algorithm, provides an explicit encoding in terms of multiple unitary evolution operators and thereby avoids matrix inversion. Nonlinear dynamics is especially challenging for quantum computers due to the no-cloning theorem which forbids copying unknown quantum states. This results in an exponential growth of resources when any iterative QA is applied to a NL problem. The Koopman—von Neumann (KvN) formulation allows one to embed a NL system into a linear problem that describes the linear evolution of the wavefunction and, hence, the probability distribution function. **We present the first explicit KvN-based QA for simulating NL dynamics and the initial application of this method to representative test cases**.

Publications

Novikau I., Dodin I.Y., Startsev E.A., **Encoding of linear kinetic plasma problems in quantum circuits via data compression**, Journal of Plasma Physics. 2024;90(4):805900401, doi:10.1017/S0022377824000795

We propose an algorithm for encoding linear kinetic plasma problems in quantum circuits. The focus is on modelling electrostatic linear waves in a one-dimensional Maxwellian electron plasma. The waves

are described by the linearized Vlasov–Ampère system with a spatially localized external current that drives plasma oscillations. This system is formulated as a boundary-value problem and cast in the form of a linear vector equation to be solved by using the quantum signal processing algorithm. The latter requires encoding of a matrix in a quantum circuit as a sub-block of a unitary matrix. We propose how to encode in a circuit in a compressed form and discuss how the resulting circuit scales with the problem size and the desired precision.