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Quantum computing approach to wave propagation in plasmas

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The prospect that quantum computers could be exponentially faster than conventional computers has motivated our research on the application of quantum information science to plasma physics. Quantum computers leverage quantum parallelization, entanglement, and superposition to speed up computations. In developing algorithms for quantum computers there are two particular postulates of quantum mechanics that need to be kept in mind. The first specific postulate is that quantum bits (qubits) are entities that exist in complex Hilbert space. In contrast, classical bits are binary objects. The second postulate is that the time evolution of the state of a physical system is given by the Schrödinger equation, and the evolution operators are unitary. Consequently, the electromagnetic fields are state vectors in a Hilbert space and the evolution equations, that is, Maxwell equations, have to be in a form similar to the Schrödinger equation.

We will discuss our approach to formulating a unitary form of Maxwell equations for electromagnetic waves in dielectrics and in cold magnetized plasmas [1-4]. Based on these theoretical constructs, we have developed discrete qubit lattice algorithms which are suitable for quantum computing. Qubit lattice algorithms are an interleaving sequence of entanglement and streaming operators, which, to second order in grid spacing, reproduce the Schrödinger-like form of Maxwell equations. A desirable feature of quantum lattice algorithms is that they can be implemented and tested on presently available supercomputers. We have simulated propagation of wave packets in dielectrics and their scattering by spatially localized dielectric objects. Since the unitary representations of Maxwell equations are in the time domain, just as is the Schrödinger equation, the scattering phenomena is more insightful and relevant compared to the static, frequency domain, boundary value studies.

We will review the theoretical approaches that have been undertaken to express Maxwell equations as unitary evolution equations. Additionally, we will display results from simulations based on qubit lattice algorithms.

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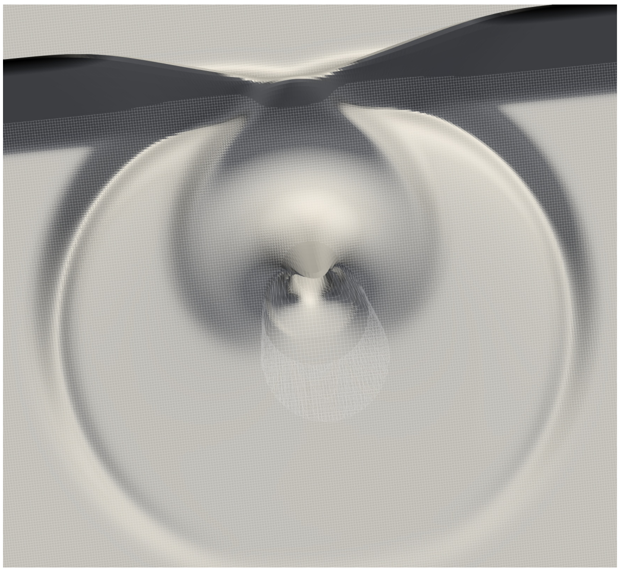

Figure 1: The scattering of an electromagnetic pulse by a dielectric cylinder in 2-dimensional configuration space. This is a snapshot at a time when the pulse has passed by the cylinder.

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