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Quantum Lattice Gas Representation for Vector Solitons

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Abstract

The study of solitons has impacted such diverse fields as plasma physics, neuclear/particle physics, molecular biology, geology, meteorology, oceanography, astrophysics, cosmology, semi-conductor physics and even to the study of protein systems and neurophysiology

There is much interest in developing algorithms for quantum computers - computers that (theoretically) can yield exponential speed-up over classical computers because of their ability to utilize quantum superposition of states. The classical binary bit is now replaced by a qubit as the basic building block. By ingenious methods, it is believed possible to sustain phase coherence over millions of globally entangled qubits for sufficiently long time intervals so that classically intractable problems (e.g., the factoring of large composite numbers, or the simulation of large many-body quantum systems) can be solved. These types of quantum computers can be designated as Type-I and have yet to be built. However, it is much simpler to develop quantum computers that only require qubit entanglement over short ranges and for short times. Thus these quantum computers would involve large parallel arrays of small quantum computers, with each quantum computing node embodying only a small set of qubits, and a classical communication network connecting the nodes. This quantum architecture has been designated as a Type-II quantum computer. While exponential speed-up is now restricted to those steps involving quantum entanglement, this is an excellent and ideal stepping stone to the future Type-I computer. Moreover, Type-II macroscopic scale computers exist (e.g., using liquid-state NMR technology) and implemented to solve some simple quantum algorithms (e.g., the solution of the diffusion equation).

We determine quantum lattice gas representations for NLS and KdV that are unconditionally stable and ideal for implementation (and parallelization) on a hybrid quantum-classical computer as well as on a classical computer. In particular results will be shown for both the integrable (cubic) NLS as well as the non-integrable NLS which yields soliton turbulence. Vector solitons of the Manakov type will also be considered.