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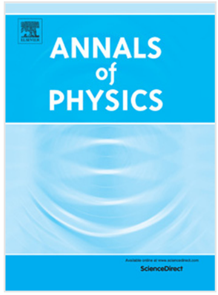

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Optimal control of fast and high-fidelity quantum state transfer in spin-1/2 chains

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Abstract

Spin chains are promising candidates for quantum communication and computation. Using quantum optimal control (OC) theory based on the Krotov method, we present a protocol to perform quantum state transfer with fast and high fidelity by only manipulating the boundary spins in a quantum spin-1/2 chain. The achieved speed is about one order of magnitude faster than that is possible in the Lyapunov control case for comparable fidelities. Additionally, it has a fundamental limit for OC beyond which optimization is not possible. The controls are exerted only on the couplings between the boundary spins and their neighbors, so that the scheme has good scalability. We also demonstrate that the resulting OC scheme is robust against disorder in the chain.

Keywords: Quantum state transfer, Quantum control, Spin dynamics

1. Introduction

One of the major challenges on the road to practical quantum computers is the trustworthy transfer of quantum information between different nodes in quantum networks [1]. The problem of state (or information) transfer has accepted considerable attention in the last decade. The parts for an infrastructure that can speedily and robustly transport qubit states between sites where qubit operations can be performed may be considered to be quantum channels for quantum information transfer. In this respect, spin chains have been designed as quantum channels [2–13] for transferring information. The use of spin chains for this task has been regarded in the context of various physical systems. Realizations of spin chains may connect nitrogen-vacancy registers in diamond [9] or entangle inner states of an array of ultracold atoms restricted to an optical lattice [14]. Arrays of capacitively coupled flux qubits have also been shown to be suitable for quantum state transfer (QST) [15]. several systems of this class have been investigated in order to improve their capability for the state transmission. High-quality quantum information transport is essential for most practical models of quantum computation. For example, local control only on the boundary spins in either a random unpolarized chain [16] or an initialized chain [9] can build a great advancement of the transmission fidelity from one end to the opposite end. Perfect state transfer (PST) could be realized using accurately engineering spin-spin coupling configurations in the chain [4, 11, 17–21]. However, Such proposal is extremely challenging at present, being an inaccessible task for long channels that possess a great number of control parameters and are progressively sensitive to shortcomings as the number of spins grows [11, 12].

In general, it is demonstrated that we can just only control two boundary couplings rather than the whole system to achieve an optimized state transfer. The straightforward control strategy may involve only the boundary (sender and receiver) spins that are connected via the channel. Recently, it has been

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