Quantifying Fidelity and Entanglement in Two-Qubit Teleportation via a Quantum Communication Channel of Spin-1/2 Ising-Heisenberg Lieb Lattices

Elham Shahhosseini Shahrabadi
Jozef Strečka

Department of Theoretical Physics and Astrophysics, Faculty of Science, P. J. Šafárik University, Park Angelinum 9, 040 01 Košice, Slovakia

elham.shah.hosseini@student.upjs.sk
elham.shhoseini@gmail.com

Abstract

This work investigates the realization of quantum teleportation for arbitrary two-qubit entangled states using a quantum communication channel established by two Heisenberg dimers embedded within two independent spin-1/2 Ising-Heisenberg Lieb lattices [1]. To quantify the efficiency of the protocol, we evaluate the system's ability to preserve bipartite entanglement via concurrence, allowing for a precise comparison between the input and output states to characterize the robustness of the quantum communication channel [2.3]. Furthermore, we rigorously determine the teleportation fidelity and average fidelity, examining how thermal fluctuations and interaction ratios at zero magnetic field impact the performance of the teleportation protocol. Our investigation explores the efficiency of teleporting an arbitrary entangled two-qubit state through this quantum communication channel by specifically analysing the temperature dependence of both the channel concurrence and the output concurrence for specific and generalized input states. It is shown that both fidelity of quantum teleportation as well as bipartite entanglement of the quantum communication channel display pronounced changes when the system is driven through a continuous thermal phase transition.

References

[1] J. Strečka, and M. Jaščur, Physical Review B, **66**, 174415 (2002).
[2] J. Strečka, F. Benabdallah, and M. Daoud, Phys. Scr., **100,** 095112 (2025).
[3] A. Ghannadan, and J. Strečka, Chinese Journal of Physics, 89 (2024).

Acknowledgment
Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V02- 00021.