

Experimental implementation of a device-independent dimension test for quantum systems using genuine temporal correlations

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Abstract

We investigate experimentally temporal correlations of measurement outcomes on a qudit. We obtain correlations violating bounds given for a qubit and use these correlations to certify a lower bound on the qudit dimension. The qudit is encoded into hyperfine states of a single laser-cooled $^{171}\text{Yb}^+$ -ion trapped in a segmented micro-structured linear Paul trap.

Spatial correlations between quantum systems are a thoroughly investigated topic and a growing number of applications of spatial entanglement in quantum information science and quantum metrology has been conceived. In comparison to spatial correlations, temporal correlations that appear in sequential measurements of a quantum system are still a fairly fresh and up to recently a somewhat neglected field of research. As these correlations depend on the quantum system's dimension, a device-independent measurement scheme has been devised that witnesses the dimension of the system through the violation of temporal inequalities [1]. Using the hyperfine manifold of a single $^{171}\text{Yb}^+$ ion stored in a micro-structured 3D linear Paul trap [2], we observe temporal correlations between two consecutive measurements of hyperfine states and the violation of the above-mentioned inequalities. This serves to certify a lower bound for the dimension of the quantum system used in these experiments [3]. Extending measurement sequences to length three, we demonstrate an even stronger violation and show that the genuine temporal correlation scheme goes beyond the prepare-and-measure schemes.

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- [2] P. Kaufmann, T. F. Gloger, D. Kaufmann, M. Johanning and Ch. Wunderlich, *Phys. Rev. Lett.* 120, 010501 (2018).
- [3] C. Spee, H. Siebeneich, T. F. Gloger, P. Kaufmann, M. Johanning, Ch. Wunderlich, M. Kleinmann and O. Gühne, arXiv:1811.12259v1 [quant-ph].