Violation of the KCBS Inequality Using Polarized Biphoton Qutrits

A. Shaham and H. S. Eisenberg
Racah Institute of Physics, Hebrew University of Jerusalem,
Jerusalem 91904, Israel

The KCBS pentagram inequality is a Bell-type inequality which tests whether given outcomes of measurements performed on Spin-1 systems, are compatible with a description of a joint-probability distribution ("hidden variables model") [1]. Violation of this inequality refutes the existence of such a distribution, testifies that quantum mechanics results cannot be reproduced by any non-contextual hidden variables model (the Kochen-Specker theorem), and thus confirms the context-dependent nature of quantum mechanics.

In this work, we generated photon pairs which represent three-level quantum systems (biphoton qutrits), and measured their KCBS value. The biphotons were generated in the process of spontaneous parametric down conversion, where the information was encoded in the polarization degree of freedom. We used the projection protocol suggested in [1], and adjusted it to the real scenario where some of the biphotons are distinguishable. Our results $(2.17 \pm 0.04 \geq 2)$ indicate a KCBS violation by more than four standard deviations, and thus support the contextual description of quantum mechanics.

Next, we investigated the affects of decoherence on the KCBS value of the generated qutrit state: The qutrit state, was passed through a dephasing and a 2-field quantum channels [2], with controlled amount of noise. From the output state density matrix, we calculated the maximal KCBS value that the state can exhibit. We compared it to the maximal possible violation of the CHSH inequality, that implies on the state's non-locality, conditioned on the separation of the photon-pair to two different ports. The results, as a function of the noise parameter *P*, are shown in Fig. 1. The ability of the biphoton to violate the KCBS inequality is more fragile to noise than the ability to exhibit non-locality, as expected [3]. We believe that this study will be useful to any practical realization of contextual based-on quantum technologies in the future.

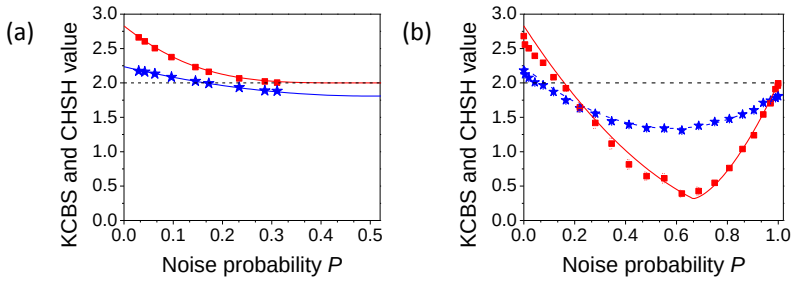

Fig. 1. The KCBS (stars) and the CHSH (squares) values as a function of the noise probability *P* of a 1-field (dephasing) channel (a), and a 2-field decohering channel (b). Solid lines represent the theoretical predictions.

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[2] A. Shaham and H. S. Eisenberg, Phys. Rev. A **83**, 022303 (2011).
[3] A. Soeda, P. Kurzyński, R. Ramanathan, K. Modi and D. Kaszlikowski, Phys. Rev. A **87**, 022120 (2013).