Quantumness and its hierarchies in PT-symmetric down-conversion models

Jan Peřina Jr[1], Karol Bartkiewicz[2], Grzegorz Chimczak[2], Anna Kowalewska-Kudłaszyk[2], Adam Miranowicz[2], Joanna K. Kalaga[3], and Wieslaw Leonski[3]

[1]*PJoint Laboratory of Optics, Faculty of Science, Palacký University, 17. listopadu 12, 779 00 Olomouc, Czech Republic*

[2]*Institute of Spintronics and Quantum Information,Faculty of Physics and Astronomy, Adam Mickiewicz University, 61-614 Poznan, Poland*

[3]*Quantum Optics and Engineering Division, Faculty of Physics and Astronomy, University of Zielona Gora, Prof. Z. Szafrana 4a, 65-516 Zielona Gora, Poland*

Abstract: We investigate the hierarchy of quantum correlations in a quadratic bosonic parity-time-symmetric system (PTSS) featuring distinct dissipation and amplification channels [1,2,3]. The hierarchy includes global nonclassicality, entanglement, asymmetric quantum steering, and Bell nonlocality. We elucidate the interplay between the system {physical} nonlinearity---which serves as a source of quantumness---and the specific dynamics of bosonic PTSSs, which are qualitatively influenced by their damping and amplification characteristics. Using a set of quantifiers---including local and global nonclassicality depths, negativity, steering parameters, and the Bell parameter---we demonstrate that the standard PTSS typically exhibits weaker quantumness than its counterparts affected solely by damping or solely by amplification. Both the maximum values attained by these quantifiers and the speed and duration of their generation are generally lower in the standard PTSS. A comparative analysis of three two-mode PTSSs---standard, passive, and active---with identical eigenvectors and real parts of eigenfrequencies, but differing in their damping and amplification strengths, reveals the crucial role of quantum fluctuations associated with gain and loss. Among them, the passive PTSS yields the most strongly nonclassical states. Nevertheless, under suitable conditions, the standard PTSS can also generate highly nonclassical states. The supremacy of the passive PTSS is further supported by its fundamental advantages in practical realizations.

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[2] J. Peřina Jr., A. Miranowicz, J. K. Kalaga, W. Leoński: Unavoidability of nonclassicality loss in PT-symmetric systems, Phys. Rev. A 108, 033512 (2023).

[3] J. Peřina, Jr., A. Lukš, J. K. Kalaga, W. Leoński, A. Miranowicz: Nonclassical light at exceptional points of a quantum PT-symmetric two-mode system, Phys. Rev. A 100, 053820 (2019).