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Tight tests for nonclassicality

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An optical state is considered nonclassical if its density operator cannot be represented as a statistical mixture of coherent states. This definition renders prominent phenomena such as sub-Poissionian statistics of photon counts or quadrature squeezing nonclassical. However, determining whether an optical state is nonclassical is a challenging task since it requires tomographic reconstruction of its density operator. A more practical approach is to understand whether given measurement statistics could be in principle simulated by a mixture of coherent states.

The detection of nonclassicality of measurement statistics is still a nontrivial task. Mathematically, a set of all classical statistics for a given set of measurements represents a convex hull of statistics exhibited by coherent states. This enables one to apply hyperplane separation theorem in order to test nonclassicality of measurement statistics. Each direction in the space of statistics is considered a normal of a hyperplane that touches the convex hull and divides the space into two parts. If statistics under consideration is not in the same halfspace as the hull, one can conclude that it is nonclassical.

Considering all possible directions in the statistics space can be a computationally expansive task. Fortunately, one can identify a minimal set of useful directions such that all other directions need not be considered in order to determine nonclassicality. Each direction corresponds to a tight inequality whose violation implies nonclassicality. [1]

[1] V. S. Kovtoniuk, et al., PRA 109, 053710 (2024)

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