Open Systems & Quantum Information

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High-order photon-number correlations: a resource for the characterization and the application of quantum states

Abstract: Correlations play a fundamental role in the investigation of optical coherence, in connection with quantum state characterization, to define nonclassicality and for the enhancement of ghost-imaging protocols. Usually, correlation functions are defined in terms of normal ordered operators and result in expressions that are not accessible by realistic direct detection schemes. We thus define and derive the analytical expression of correlation functions at any order by only using quantities that can be experimentally accessed by direct detection, taking into account the non-unit quantum efficiency of the detection scheme. We show their usefulness in fully characterizing a multimode twin-beam state in comparison with classical states and, in particular, we introduce a nonclassicality criterion based on a simple linear combination of high-order correlation functions. From the experimental point of view, we implement a direct detection scheme based on hybrid photodetectors to experimentally investigate high-order correlations for detected photons. Our scheme is self-consistent, allowing the estimation of all the involved parameters (quantum efficiency, number of modes and average energy) directly from the same experimental data. Results are in very good agreement with theory, thus suggesting the exploitation of our scheme for reliable state characterization in quantum technology. In particular, we show that high-order correlations actually represent a useful discriminating tool of the nature of the state and demonstrate that, at increasing correlation order, the differences between classical and quantum states become more and more evident.

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