Certification of quantum non-Gaussianity and Wigner function negativity of photonic detectors

Josef Hloušek
Jan Grygar, Jaromír Fiurášek, and Miroslav Ježek.

Department of Optics, Palacký University Olomouc, 17.listopadu 12, 77146, Olomouc, Czechia.

hlousek@optics.upol.cz

Nonclassical states of light are of fundamental importance in quantum optics, optical quantum communication, quantum information processing, and quantum metrology. An important subclass of nonclassical states is represented by states with negative Wigner function and quantum non-Gaussian (QNG) states. Several criteria and witnesses for detection of QNG states have been established [1], and the quantum non-Gaussian character of various sources of nonclassical light has been demonstrated experimentally [2].

Similarly to characterization of non-classical properties of quantum states we can investigate nonclassicality of positive operator-valued measure (POVM) elements Π that describe the studied quantum measurement device. State-of-the-art methods for characterizing photonic detectors and their nonclassicality are indirect. They typically require a full detector tomography with many probing states.

We propose a new efficient procedure for direct certification of nonclassical features of photonic detectors requiring only three classical probe states – either two thermal states and the vacuum state or three thermal states [3]. We demonstrate the feasibility of the proposed certification method by experimentally verifying the quantum non-Gaussianity and the negativity of the Wigner function of a single-photon avalanche diode. Furthermore, we confirm the quantum non-Gaussian character of a photon-number resolving detector from single-photon to seven-photon measurement elements. We also find that the injection of classical background noise into the detector may reduce the measurement time required for reliable confirmation of quantum non-Gaussianity. Our results enable direct certification of the strong nonclassicality of quantum detectors.

References

[1] *R. Filip and L. Mišta, Jr., Phys. Rev. Lett. 106, 200401 (2011).*
[2] *I. Straka et al., npj Quantum Inf. 4, 4 (2018).*
[3] *J. Hloušek et al., Journal, Phys. Rev. Lett. 126, 043601 (2021).*

Figures

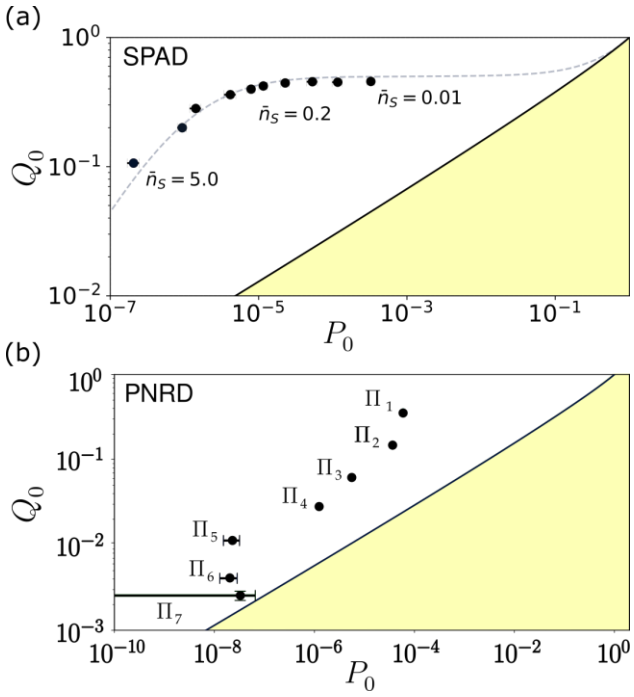

Figure 1: *Quantum non-Gaussianity certification: (a) single-photon avalanche diode for various mean photon numbers of the probe thermal states, and (b) photon-number-resolving detector for POVM elements up to 7. Quantum non-Gaussianity is certified for points lying outside the yellow area.*