Phase space approach to quantum enhanced loss estimation with un-symmetric photon annihilated correlated light

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Abstract: We have studied theoretical un-symmetric multi-photon annihilated twin beam states and demonstrated their quantum advantage for loss estimation over coherent states and thermal states in both with and without per photon exposure scenarios.

Phase-space distributions, such as the Wigner functions, are known as an important tool for signal processing, and image reconstruction from the transmission profile of an object. In this work, we have theoretically obtained the Wigner distribution function of an un-symmetric multi-photon annihilated twin beam state (TWB) as a probe passing through an absorbing sample which can be analogously obtained experimentally by performing Homodyne measurements. These states are generated by subtracting photons locally from one mode of the TWB using a very low reflective beam splitter. Finding a close form expression of marginals of quantum states other than photon number states is not so easy task and their importance has not yet been widely studied. We calculated marginal probability from the measured Wigner distribution which carries object information and subsequently Fisher information is calculated from the marginals. We have demonstrated that un-symmetric photon annihilated twin beam states at low mean number of photons resemble high photon number states with increase in the number of annihilated photons which are more robust to noise and losses Results are presented up to three photon annihilation which show remarkable quantum advantage over coherent states at low light illumination.

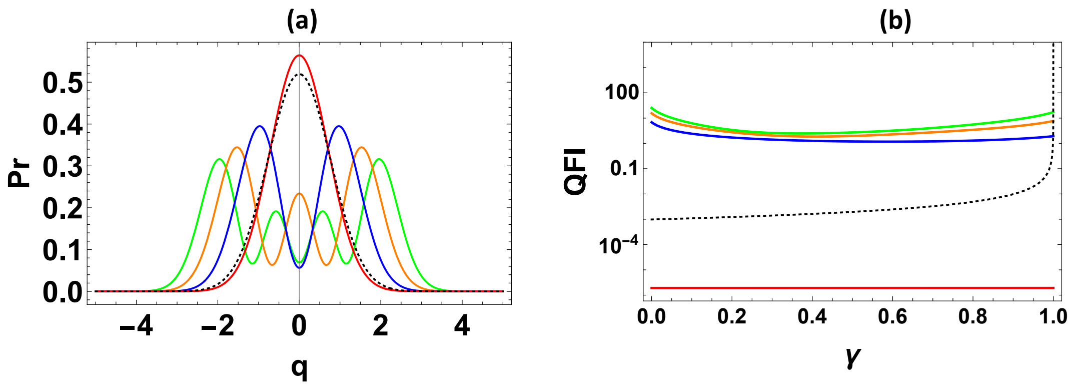

Fig. 1 Blue, orange and green curves correspond to one, two and three photon annihilated twin beam state respectively. Red, and black dotted curves show the performance of thermal and coherent state respectively. Average number of photons per mode is 0.01 and the detection loss is 2%: (a) Marginal probability as a function of position, (b) Quantum Fisher information versus absorption coefficient γ of the sample.

Coherent states outperform photon annihilated states at high losses as expected. Photon annihilated states provide quantum advantage in loss and phase estimations through joint photon number difference measurements. In contrast to joint photon number difference measurement which is difficult to maintain outside of laboratory set up, our approach does not require joint photon number difference measurement, so it may be useful for long range loss estimation of low absorbing objects.

References

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