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Quantum-classical transition in optical twin beams and experimental applications to quantum metrology

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The discrimination between quantum and classical states, besides its very important and deep conceptual relevance, has also recently received much attention due to the development of quantum technologies. On one side, it represents a fundamental point for the studies concerning the transition between quantum and classical world, one of the most intriguing research sectors in the foundations of physics. On the other side it is an important tool when comparing results that can be achieved with quantum and classical protocols.
Considering the experimental interest in the frame of quantum optics, in a recent paper [1], we have considered different "quantumness"quantifiers applied to the study of quantum-classical transition in seeded parametric down-conversion (PDC): the noise reduction factor (NRF), the Lee parameter, and the logarithmic negativity. It emerges a general understanding of the hierarchy of these three quantifiers in this optical systems. Moreover, we have focused our analysis towards an operational approach linked to measurement schemes, basically showing that these quantifiers can be estimated just measuring the photon numbers in the two beams, and their correlation.
On the other side, in the last years in our laboratories, we realized several quantum enhanced measurement protocols exploiting twin beams, where the improvement over the corresponding classical protocols is directly related to the NRF, that quantify the sub-shot noise properties of the source. In particular, we will describe the sub-shot-noise quantum imaging (SSNQI) scheme [2], and the quantum illumination (QI) [3]. The first one allows to obtain a almost noise-free image of a weak absorbing object placed in one branch of PDC just subtracting the correlated noise pattern measured un the other branch, while all the classical schemes, based for example on a split thermal beam, are limited by the unavoidable shot noise.

Fig. 1: Error probability of discriminating if the target is present or not in function of the number photons Nb of the background. TW and TH stand for TWin beams and THermal split beams respectively, while Mb is the number of independent modes of the multi-thermal background

The QI protocol is devoted to the detection of a weak reflecting target immersed in a extremely noisy background. In this case we elaborated a measurement scheme allowing performances which are orders of magnitude higher than the classical counterpart (see Fig.1). Furthermore, the most intriguing observation is that the quantum advantage does not disappear even if the signature of "quantumness"is completely destroyed by the noise introduced at the measurement stage.

References

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