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Phase-dependent correlations for quantum information

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During the last decade, phase-averaged coherent states, namely the states obtained by randomizing the phase of coherent states, have been successfully used to enhance the security of communication channels in quantum key distribution protocols [1–3]. For such applications, the high degree of accuracy in the phase-randomization process is one of the main requirements and thus a good estimation of the randomization quality is in general desirable. In principle, this task can be obtained by completely characterizing the state, for instance by reconstructing its density matrix or its Wigner function. Nevertheless, the achievement of this goal is not straightforward, as it typically involves interferometric techniques, long acquisition sessions and non-trivial data processing [4–6].

To prove whether an optical state is endowed with a defined phase or not, here we propose a different method that consists in displacing the state under investigation with a coherent field and then mixing the resulting state with the vacuum at a beam splitter. The intensities at the two outputs of the beam splitter are then measured and pulse-by-pulse intensity correlations are calculated [7]. The resulting values of correlations depend on the existence of phases. The theoretical description of this scheme is derived in the general case, in which a phase sensitive state is displaced by a coherent field. To prove the robustness of the method from the experimental point of view, we show the results obtained by characterizing a class of non-trivial phase-sensitive states that can be obtained as the sum of two mixtures of coherent states with a 180 deg-difference in phase. We demonstrate that such states, which we call brackets states, are endowed with phase-dependent intensity correlations, except for a particular choice of parameters that reduces them to the phase averaged coherent states, which are phase-insensitive.

The experimental data, in excellent agreement with the theoretical prediction, were obtained in the mesoscopic photon-number domain by means of a direct detection scheme involving a pair of hybrid photodetectors [8]. Thanks to the photon-resolving capability of these detectors, our experimental scheme can be also exploited to implement quantum state discrimination protocols to be used for secure communication [9]. In fact it allows us to generate coherent states with a 180 deg-difference in phase that are displaced by a coherent field with the same amplitude. The investigation of the statistical properties as well as the error probability calculated on the shot-by-shot outcomes offer the possibility to obtain optimized state discrimination strategies in the presence of noise.

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