Optimizing direct single-photon Wigner-function measurement

Petr STEINDL[1]
H. Lam[1], J. Alvarez[1], K. Laverick[2], I. Maillette de Buy Wenniger[3], S. Wein[4], A. Pishchagin[4], Thi-Huong Au[4], S. Boissier[4], A. Lemaitre[1], D. Fioretto[1,4], A. Auffèves[2], P. Senellart[1]
[1]*C2N, Photonics Department, 10 Bd Thomas Gobert, 91120 Palaiseau, France*
[2]*Majulab, University of Singapore, Singapore 117543*
[3]*Imperial College London, Quantum Optics and Laser Science, Exhibition Rd, London SW72BX, UK*
[4]*Quandela, 7 Rue Léonard de Vinci, 91300 Massy, France*
petr.steindl@cnrs.fr

Direct Wigner function (WF) measurement [1] based on photon-number counting is a sensitive method to characterize continuous-variable resource states in the discrete variables context. This method is based on direct photon-number measurement after quantum interference of the target state with a weak laser. In contrast to the more established homodyne measurement [2], the direct measurement enables to quantify the displacement and distinguish it from optical loss. This displacement together with a precise characterization of optical losses is essential to reconstruct the WF, as pioneered with heralded single photons [3]. We use a deterministic true single-photon source based on a semiconductor quantum dot (QD) device [4] to improve the direct WF reconstruction precision and its resource demand. First, we demonstrate efficient homodyne photon-correlation techniques to optimize the mode-matching of the local oscillator to the single-photon wavepacket based on monitoring the photon bunching. By tailoring laser light in different degrees of freedom, we maximize the overlap up to 77% [5]. This represents a record value reported with semiconductor-QD sources, slightly limited by the mismatch between the temporal profile of the two fields and the low-frequency charge noise of the single-photon source.
Second, in Fig. 1, we compare two different acquisition methods to reconstruct the target-state photon-number distribution by either from pseudo-photon number resolving (PPNR) detection with four parallelized detectors or zero-photon (ZP) detection probability under controlled and calibrated attenuation derived from single-detector clicks [6]. After optical loss and mode-matching corrections of the measured signal, we, for the first time, reconstruct the single-photon WF. The maximum-likelihood Wigner reconstruction fed with the ZP dataset enables retrieval of the expected WF, even up to relatively high displacement, where the PPNR method fails for limited photon-number resolution [3] despite using three more detectors. Even under demultiplexing into more detectors, the precision of the PPNR-based WF reconstruction remains limited due to the exponentially longer acquisition time of higher-order correlations.

References

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Figures

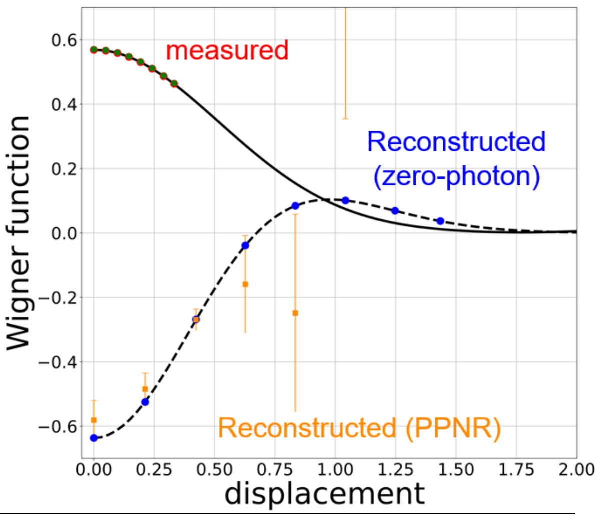

Figure 1: Comparison of reconstructed single-photon WF.