Microchannel plate cross-talk mitigation for spatial autocorrelation measurements at the single-photon level

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1. Introduction

Single excitation level detectors play a fundamental role in research ranging from optics, atomic physics, nanoscale material science or high-energy physics to *in-vivo* imaging in medicine and biology. In particular recent development in single-photon sensitive cameras lead to major advances in quantum optical technologies [2] and superresolution imaging [3] many of those relying on light intensity correlation measurements.

Among camera technologies scientific metal oxide semiconductor cameras with an image intensifier (I-sCMOS) offer superior read-out speed and low noise. However, the image intensifier (II) introduces a deleterious effect of cross-talk between microchannels in the microchannel plate (MCP), leading to artificial strongly correlated photon counts especially eminent in the single-photon regime. A straightforward solution is to perform a cross-correlation measurement between two separate camera regions by splitting the measured light. Yet this way half of the signal is lost, experimental setup grows more complicated, possibly degrading the measurement quality and effectively the observed camera frame region is reduced by half.

Here we present a method of MCP cross-talk subtraction, which relies on a simple dark counts calibration measurement and allows to reconstruct correct second-order intensity autocorrelation. The method is exemplified with an I-sCMOS camera for pseudo-thermal light autocorrelation and certified by a reference cross-correlation measurement in a Handbury Brown-Twiss like setup.

2. Cross-talk subtraction

Cross-talk can be observed in photon counts $n(x,y)$ autocorrelation $g^{(2)}(x,y;x',y') = \langle n(x,y)n(x',y')\rangle / (\langle n(x,y)\rangle\langle n(x',y')\rangle)$ transformed to the difference coordinates $(x-x', y-y')$. As $g^{(2)}(x-x', y-y')$ is isotropic, we shall focus on the radial dependence $g^{(2)}(r)$. For Poissonian dark counts $g^{(2)}(r) = 1$ is expected, yet due to artificial cross-talk photon counts a range of ca. 26 px (1 px = 15 μm) of increased $g^{(2)}(r) = 1 + c_r(r)/c_a(r)$ can be observed, where $c_r(r)$ is the photon counts covariance multiplied by the number of frames and for the calibration *cal* dark counts measurement corresponds to the cross-talk induced coincidences. With N total photon counts $c_{r,cal}(r)$ can be used to subtract a rescaled portion of coincidences from measured $g^{(2)}(r)$ yielding corrected $g^{(2)}_{corr}(r) = g^{(2)}_{raw}(r) - c_{r,cal}(r)N_{muc}/(c_{r,muc}(r)N_{cal})$ where *muc* refers to the measurement under correction.

Figure 2 depicts a sound agreement of the corrected autocorrelation $g^{(2)}(r)$ for pseudo-thermal light with the reference cross-correlation measurement and a theoretical prediction of $g^{(2)}(r) = 1 + \exp[-r^2/(2\sigma^2)]/M$ for $\sigma = 8$ px, $M = 1.28$.

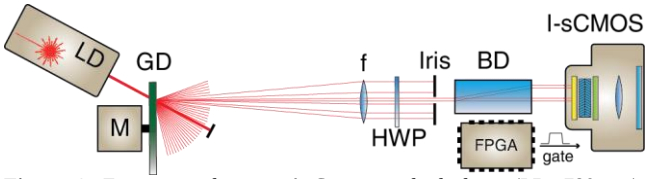

Figure 1: Experimental setup. A Gaussian, diode laser (LD, 780 nm), polarized beam produces pseudo-thermal light when scattered on a rotating ground glass diffuser (GD). I-sCMOS camera placed in the far field (f =250 mm) of GD enables measurement of the second order light intensity correlation function $g^{(2)}(r)$. A beam displacer divides incoming light into two regions on the camera enabling autocorrelation (single camera region) and a reference cross-correlation (*HBT*, two regions) measurements.

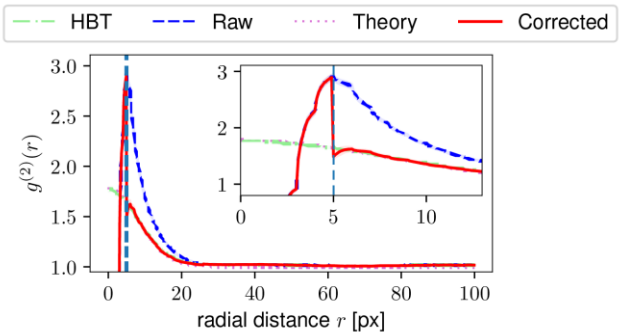

Figure 2: Autocorrelation $g^{(2)}(r)$ measurement (*Raw*) can be compensated ($r \geq 5$ px) for the cross-talk (*Corrected*) yielding a result in a sound agreement with a reference cross-correlation measurement (*HBT*) and the theoretical prediction (*Theory*).

3. Conclusion

Simple cross-talk subtraction method enables precise single-photon level intensity autocorrelation measurements with cameras employing an image intensifier.

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References

[1] Lipka, M., Parniak, M. & Wasilewski, W.. Appl. Phys. Lett. **112**, (2018).

[2] Parniak, M., Dabrowski, M., Mazelanik, M., Leszczyński, A., Lipka, M., & Wasilewski, W. Nature Communications, **8**, (2017)

[3] Israel, Y., Tenne, R., Oron, D., & Silberberg, Y. Nature Communications, **8**, (2017).