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Mapping and measuring large-scale photonic correlation with single-photon imaging: supplementary material

KE SUN[1], JUN GAO[1,2], MING-MING CAO[1], ZHI-QIANG JIAO[1,2], YU LIU[1], ZHAN-MING LI[1,2], EILON POEM[3,4], ANDREAS ECKSTEIN[3], RUO-JING REN[1,2], XIAO-LING PANG[1,2], HAO TANG[1,2], IAN A. WALMSLEY[3], AND XIAN-MIN JIN[1,2,*]

[1]School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China
[2]Synergetic Innovation Center of Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei, Anhui 230026, China
[3]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK
[4]Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 7610001, Israel
[*]Corresponding author: xianmin.jin@sjtu.edu.cn

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This document provides supplementary information to "Mapping and measuring large-scale photonic correlation with single-photon imaging," https://doi.org/10.1364/OPTICA.6.000244, giving a comprehensive comparison be-tween COSPLI and singe-pixel detectors in the main text.

A COMPREHENSIVE COMPARISON BETWEEN COSPLI AND SINGE-PIXEL DETECTORS

In this work, we propose a new detecting method rather than a new setup. This method is not only to count the number of photons, but to use ICCD to actually "see" the photons and their correlations on the screen. Joint spectrum is just one applied example of this method. This method is not only a better use of the current technology, but a process of extracting useful correlation information from non-negligible noise even when the signal to noise ratio is quite low.

Our joint spectrum experiment is a two-dimensional example since all the photon spots form two parallel straight line on the screen. Our method has the ability to measure correlations of genuine 2D patterns, especially large-scale correlation measurements and multiphoton correlation measurements, with one commercial accessible setup, which is experimentally intractable by simply moving the APD n×m times or economically unfeasible to build such large APD array (the point to point single pixel coupling is also technically very challenging). Let alone as the system scale increases, the combination of all the possible correlation will certainly saturate the memory of current field-programmable gate array (FPGA) based counting modulus.

The performance of our method is currently limited by the quantum efficiency of the image intensifier and the sensor, the decay time of phosphor and the readout frame rate.

The total quantum efficiency of the ICCD we used is less than 10% at the wavelength of 780nm which can be attributed to two factors, namely, the efficiency of the image intensifier and the sensor. The current quantum efficiency of image intensifier is the bottleneck for all single-photon imaging devices. The efficiency of the sensor is related to the phosphor type. By choosing suitable phosphor, the efficiency of the sensor can be higher than 90% (like Princeton Instrument Kuno). However, when considering the common efficiency of APD ($60\% - 70\%@780nm$) and the coupling loss to single mode fibers, we find that the total efficiency of these two methods are comparable with the state of arts of current technology.

The saturation level is also related to the phosphor type. The current phosphor is P43, which has a rather long decay time like 2ms. Due to our research into the phosphor, the fastest decay time of available phosphor is $80ns$ level, which is enough for the current quantum information processing experiment.

In fact, the real bottleneck of our method is the frame rates where the maximum rate is 28 frames/s in our current experiment. Though the repetition rate of generating photon pairs is more than 106 pairs/s, the short slab is the camera rather than the photon source. We can solve the problem by updating the imaging systems. The top-notch IsCMOS camera has the ability to reach 700 frames per second when the region of interest (ROI) is set to be 128*128 pixels (the size we used in experiments). Technology of intensified camera is developing quickly and therefore this method possesses a great potential to play a more important role in the future experiments.

In the long term, we believe that the advantages given by our method is higher than single pixel detectors, which can serve as the appealing candidate for large-scale quantum information processing measurement in the near future.