Full field measurement of spatial correlated photon pairs with an EMCCD camera

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Abstract

The spatial correlations between the photon pairs produced by spontaneous parametric down conversion (SPDC) have been investigated in a number of different configurations over the last two decades [1]. The high dimensionality of the transverse spatial degrees of freedom (DOF) of the photon pairs can be explored either by projections onto a discrete (infinite) basis, such as the LG modes, or by using a continuous basis defined by the transverse position or momentum of the photons. For instance, it has been shown that their transverse position and momentum display EPR-type correlations [2]. Despite the continuous and unbounded nature of both these bases, the most common measurements to date have relied upon the scanning of a single avalanche photodiode or a very small number of individual detectors. This sequential scanning or small number of detectors negates any information capacity advantage in the use of spatial states.

Recent years have seen a rapid advance in imaging technologies, particularly for low light levels. Of these technologies the highest quantum efficiency is achieved using electron multiplying CCDs (EMCCD). Developments in low noise EMCCD cameras suggest they are capable of greater than 80% quantum efficiencies and if operated in an ultra-low light environment whilst being maintained at low temperatures, can provide single photon sensitivity [3]. EMCCDs have been used in measurements of sub-shot-noise correlations of intensity fluctuations [4, 5] as well as in intensity correlations measurements [6] in the far field of the photon pairs from SPDC.

Here we report the observation of spatial correlations from SPDC using an EMCCD camera in both the image and far-field planes of the down conversion crystal. We pump a BBO crystal at 355nm with a few milli-Watts of optical power and use a simple lens system to relay the down-converted light to an EMCCD array which can be positioned in either the image plane or the far-field of the crystal. Our photon flux is around 1/100 per pixel, which approximately doubles the signal obtained when the light is blocked. We typically record 100,000 individual frames and then sum the auto-correlation of the individual frames. We observed intensity correlation and anti-correlation in the image and far-field planes, respectively. In both cases we make the correlations more visible by subtracting a background which is obtained as the average correlation obtained between successive frames. Using this approach we are able to visualize the strength of the correlations in both position and momentum, showing a variance product nearly one order of magnitude below the classical limit in both x and y directions.

Fig. 1. Measured marginal probability (left) for image-plane measurements, and for far-field measurements (right).

References