Ghost Imaging Experiment With Sunlight Compared to Laboratory Experiment With Thermal Light

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ABSTRACT

A recent article reports on the demonstration of ghost imaging using sunlight which also presents theory for ghost imaging in the atmosphere based on two photon interference.[1] The current paper reviews the experiment from a different context than that presented by Karmakar, Meyers and Shih (KMS).[1] Here we examine data from the KMS sunlight ghost imaging experiment and compare it to ghost imaging produced by true thermal light.

1. INTRODUCTION

The first experimental demonstration of ghost imaging was performed by Pittman *et al.*[2] in 1995 using entangled photon pairs as the light source, inspired by the research of Klyshko.[3–5] In 2003, Shih[6] synthesized the theoretical and experimental research in entangled photon wavefunctions and related them to the nonlocal quantum effects highlighted by Einstein, Podolsky, and Rosen.[7] Later, the observation of lensless near-field ghost imaging was reported by Valencia and Scarcelli *et al.*[8,9] and ghost imaging with true thermal light was demonstrated by Wu *et al.*[10] The first remote ghost imaging experiment was performed by Meyers *et al.*[11] in a form useful for applications. Prior to 2007 Meyers proposed that sunlight could be used as a light source for ghost imaging.[12] In 2012 KMS performed an experiment demonstrating ghost imaging sunlight[1] which also presents theory for

Figure 1. Experimental setup of sunlight ghost imaging experiment contained in a light-tight black box is placed on a sun tracking tripod. A double-slit placed inside the light-tight black box is used here as an object for the experimental demonstration.

ghost imaging in the atmosphere based on two photon interference.[1] Two-photon interference is depicted in Fig.

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2. The 2012 KMS paper investigates the two-photon interference mechanism for sunlight ghost imaging in the atmosphere. This article reviews the KMS experiment in a different context. Here, we examine the data from the KMS sunlight ghost imaging experiment and compare it to laboratory ghost imaging produced by true thermal light.[10, 13]

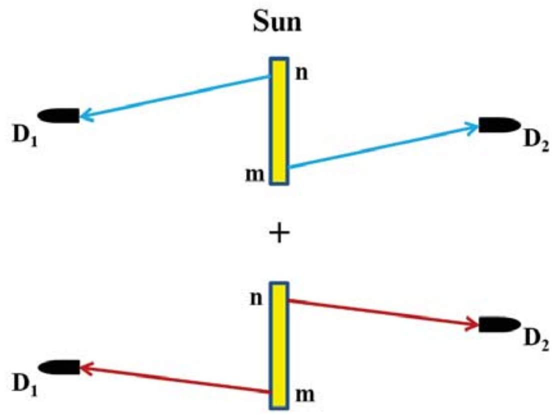

Figure 2. A joint-detection event can be created in two different yet indistinguishable alternative ways.

2. EXPERIMENT

We examine experimental data produced by the KMS experiment[1] and details of the experiment setup can be found in the reference. The setup was placed inside a light-tight black box as shown in Fig. 1. To measure the

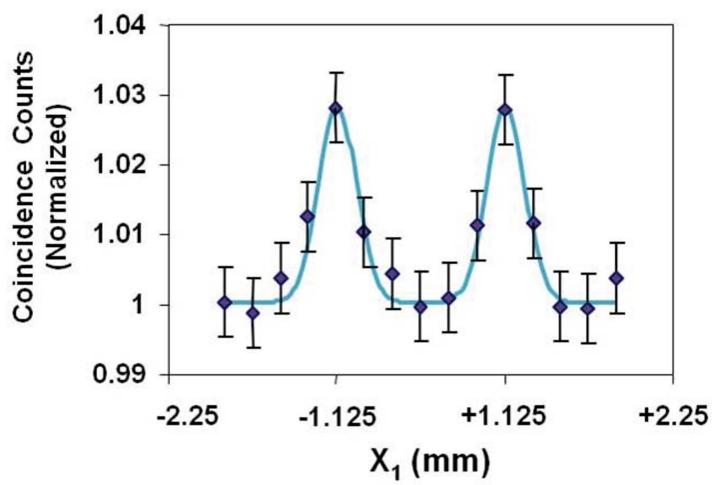

Figure 3. Using the sun as a light source, the image of a double-slit is observed in terms of coincidence counts as a function of the position (X_1) of the input tip of the fiber connected to the scanning detector D_1 where two photodetectors D_1 and D_2 are inserted inside the black box. Blue diamonds on the figure represents the experimental data and the solid (blue) line is the fitting for experimental data.

ghost image using solar illumination a narrow filter was used on the collected sunlight to restrict the bandwidth. Measurements from the KMS experiment are shown in Fig 3. These measurements show the ghost image of a double-slit in terms of coincidence counts between two photon counting detectors, D_1 and D_2, as a function of the position of the scanning fiber tip connected to detector D_1. The detector D_2 acts as a "bucket" detector that measures all the sunlight transmitting through a double slit mask.

3. ANALYSIS

The experiment by Wu *et al.* used two pinholes as the object to be imaged and a hollow cathode Rubidium (Rb) lamp as the incoherent thermal light source.[10]

Table I

Parameters	KMS	Wu
Peak Normalized Coincidence Counts	~ 1.03	~ 1.04
Illumination Coherence Time	$\sim 0.33ns$	$\sim 0.2ns$
Visibility	$\sim 1.4\%$	$\sim 2\%$

Table I shows a comparison of the relevant measurements between the KMS and Wu experiments. The coherence of the filtered sunlight is approximately .33ns while the coherence of the Rb lamp is approximately .2ns. The results shown in Table I indicate that the KMS sunlight field experiment is comparable to the true thermal light laboratory experiment performed by Wu *et al.*

4. CONCLUSION

Though it used sunlight propagating through the atmosphere this ghost imaging experiment produced an image similar to that produced in the laboratory using incoherent light. Thus the prospects for generation of distant higher resolution,[11] "turbulence-free"[16,17] non-local[11] ghost images by sunlight are bright.

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