Ghost imaging with engineered quantum states unveiling rotated objects

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Conventional ghost imaging aims at reconstructing any given object by means of spatially correlated photons. Our work highlights the importance of the selection of the quantum states that are used for such reconstructions, showing how the object can be rotated, or even doubled, by properly engineer the spatial correlations each of the photons possess.

Traditional ghost imaging experiments exploit position correlations between correlated states of light [1]. These correlations occur directly in spontaneous parametric down-conversion (SPDC), and in such a scenario, the two-photon state usually used for ghost imaging is symmetric. Here we perform ghost imaging using an anti-symmetric state, engineering the two-photon state symmetry by means of Hong-Ou-Mandel interference, as shown in the setup of Fig. 1. We use both symmetric and anti-symmetric states and show that the ghost imaging setup configuration results in object-image rotations depending on the state selected. Further, the object and imaging arms employ spatial light modulators for the all-digital control of the projections, being able to dynamically change the measuring technique and the spatial properties of the states under study.

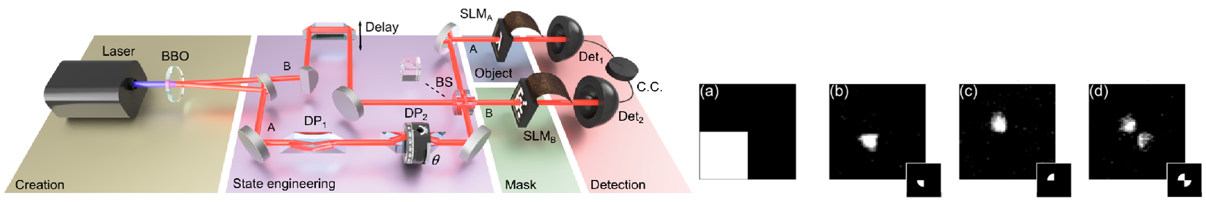

FIG. 1 Setup in the left. **(a)** Object. **(b)** Conventional ghost imaging (GI). **(c)** Rotated GI. **(d)** Counter-rotated GI.

An example of the rotation effect is given in Figs. 1**(a-d)**, where we can appreciate how the object given in **(a)** can be normally reconstructed using the conventional ghost imaging techniques but performing the projections with SLMs in **(b)**. We can induce a rotation in **(c)** by rotating the Dove prisms, and a double rotation in **(d)** if a beam splitter is introduced prior their spatial projections. The results are in perfect agreement with the theory and confirm the image rotation and image `doubling' because of the state preparation and filtering steps [2].

This image invariance under rotations could play a role in future applications where the study of the innate geometric symmetry of an object is important, or it may find application in the field of quantum communication, wherein one could ascertain the centre of an SPDC beam source and align a system accordingly by using the counter-rotated reconstructed object.

[1] T.B. Pittman, Y.H. Shih, D.V. Strekalov, A.V. Sergienko, *Phys. Rev. A* **52**, R3429 (1995).

[2] N. Bornman, S. Prabhakar, A. Vallés, J. Leach and A. Forbes, *New J. Phys.* (accepted).