Quantum Holographic Imaging by Entangled Photons

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The idea that the photons that have never visited an object can record its holographic image at a distant place cannot be realized by any classical means but by quantum entanglement of twin photons [1, 2]. Even though this idea of quantum holographic imaging is very attractive, it does not work for usual scattering objects, but works for absorbing objects leaving its complementary holographic images.

In the pioneering work of A. F. Abouraddy *et al.* [1, 2], two distinct single-photon probability densities for two-photon imaging are introduced.

When a planar source emits light in a pure two-photon state, the probability density of observing idler photon B at y_1 on output plane after passing through an optical process, regardless of the state of photon A, is the ordinary single-photon probability density $p_{\rm B}(y_1)$ and $p_{\rm A}(x_1)$ is defined in a similar manner.

The probability density of detecting idler photon B at y_1 after an optical process with the coincident detection of signal photon A at any location after an optical process, including the scattering process from an object that we want to image, is called the marginal probability density $\overline{p}_{\rm B}(y_1)$.

Summation over all possible scattering output is realized by the so-called 'bucket' detector, which collects all the scattered photons without any spatial resolution.

When the two-photon source is not an entangled one, the ordinary single-photon probability density is obviously equal to the marginal probability density. For an entangled two-photon source, the two probability densities are not equal to each other when the process that signal photon A goes through has some absorbing channels since the ordinary probability density does not contain any information of the optical process that the signal photon A experiences, while the marginal one contains coherent information of absorbing channels.

The marginal probability density is complementary to the absorbing channels; an example of

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Babinet's principle. In Pittman *et al.*'s experiment [3], much simpler than this coherent imaging, the idler photons in one optical system are gated by their twin signal photons that pass through an aperture on the other optical system and leave the enlarged image of the aperture on the output plane of the idler's side. In this case, the signal photons that do not pass through the aperture but are bounced back could be interpreted being absorbed by the non-aperture part. Thus the enlarged image of the aperture is nothing but the image of the complementary to the non-aperture (absorbing) part, that is, the aperture itself.

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