Quantum Imaging with Undetected Photons[1]

Gabriela Barreto Lemos

Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Austria.

Vienna Center for Quantum Science and Technology, Austria

Quantum effects have led to novel concepts that overcome classical possibilities. Of these interaction-free measurement and high-contrast ghost imaging have received notable attention. Here, we present an imaging concept that goes beyond both possibilities. Our experiment uses spontaneous parametric down conversion, but requires no coincidence detection. It relies on the indistinguishability of the possible sources of a photon that illuminates the imaged object, but remains undetected.

Our technique is based on a very unusual interferometer introduced more that twenty years ago[2]. A 532 nm laser coherently illuminates two separate down-conversion crystals. If a photon pair is created in the first crystal, a 1550 nm undetected photon passes the sample to be imaged, and its mode is made identical to that of a 1550 nm undetected photon created in the second crystal. The sister 810 nm amplitudes from both crystals are combined at a beam splitter. When the two 810 nm amplitudes are indistinguishable, interference can be observed on a single-photon sensitive camera. The image is revealed in the interference of the two signal amplitudes, which never encountered the object. The image of an absorptive object arises because the object acts as a detector creating position dependent "which-source" information. We also show images of pure phase objects that are either opaque or invisible to the detected photons. On the other hand, our cameras are blind to the photons probing the object.

We can learn rich new physics by exploring the relevant experimental parameters and observing the unusual and counterintuitive phenomena that make this a unique interferometric setup and a rich platform for the investigation of quantum optics and quantum information.

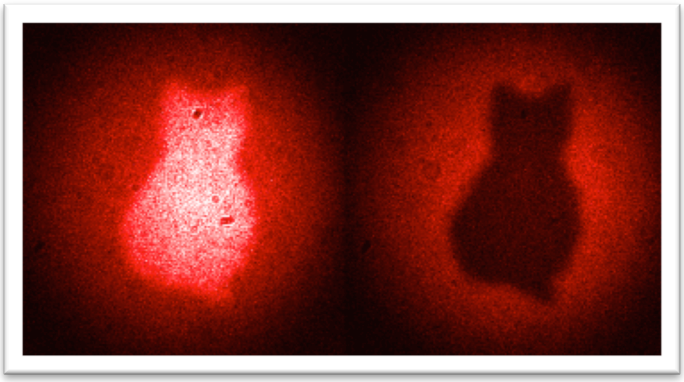

Figure 1. The image of a cardboard cut-out illuminated with undetected 1550 nm photons is observed in the interference visibility of the 810 nm photons which do not interact with the object. These are the two outputs of the interferometer.

[1] G.B. Lemos, V. Borish, G. Cole, S. Ramelow, R. Lapkievicz, A. Zeilinger. Nature 512, 409 (2014)
[2] X. Y. Zou, L. J. Wang, L. Mandel. Phys. Rev. Lett. 67, 318 (1991).