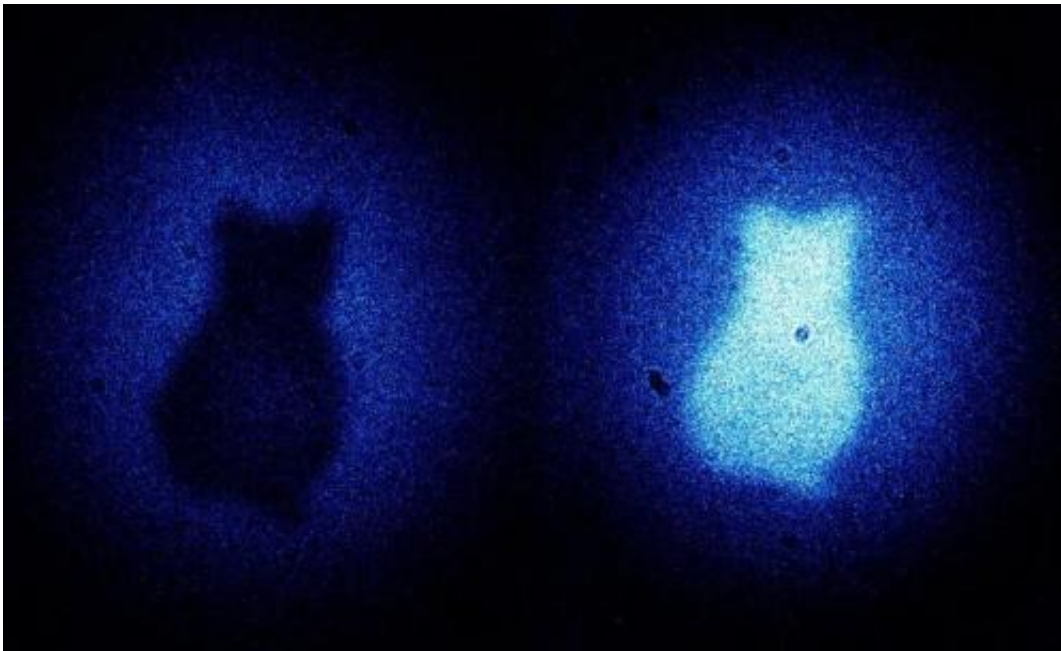


Picturing Schrodinger's cat: Quantum physics enables revolutionary imaging method

August 28 2014



The cats represent the famous Schrödinger cat paradox, in which a quantum cat closed in a box can be dead and alive at the same time. The dark and light cat bodies are images of a cardboard cut-out. They arise due to destructive and constructive quantum interference, respectively. In this experiment the photons that interact with the cardboard cut-out are not detected, while the images are obtained by detecting only photons that never interact with the object. Credit: Gabriela Barreto Lemos

Researchers from the Institute for Quantum Optics and Quantum

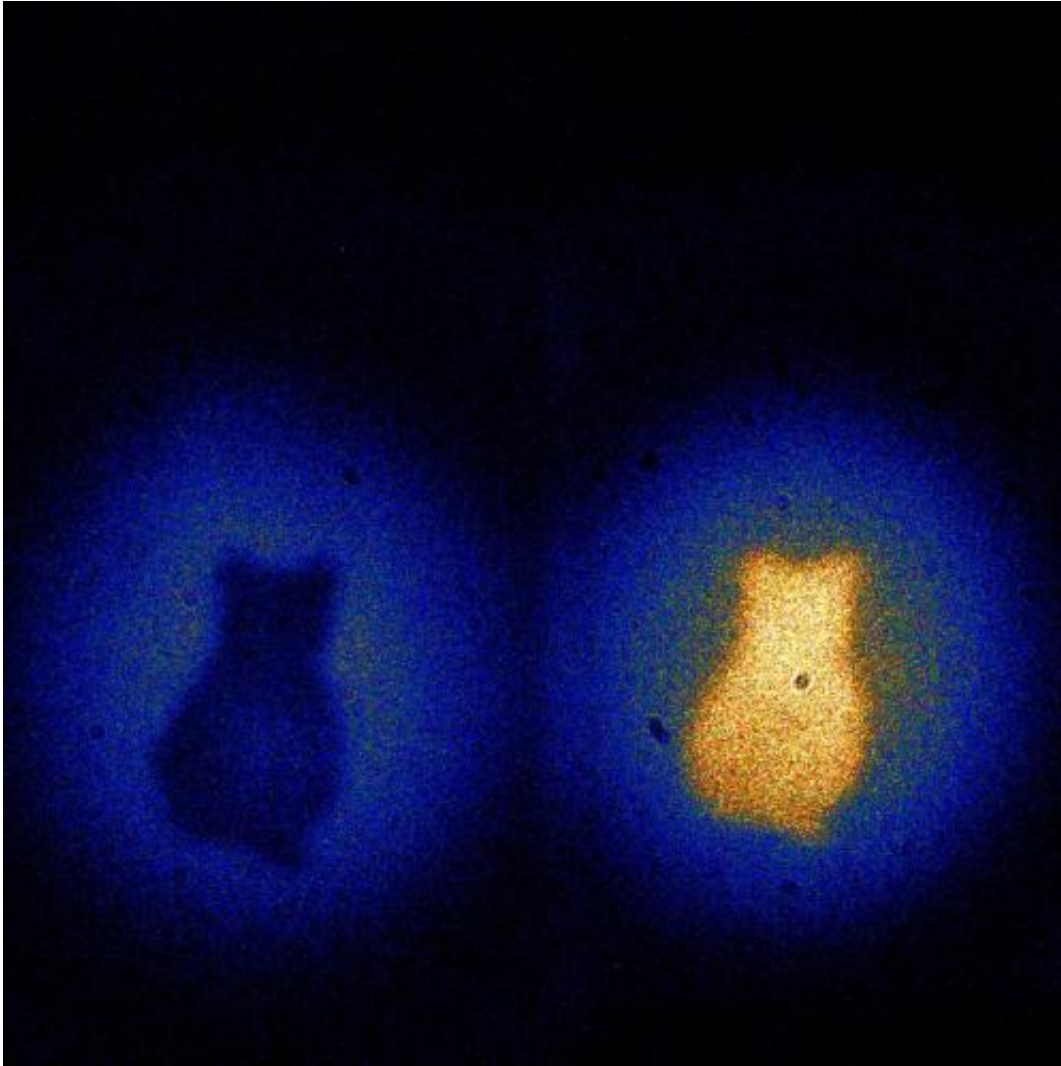
Information (IQOQI), the Vienna Center for Quantum Science and Technology (VCQ), and the University of Vienna have developed a fundamentally new quantum imaging technique with strikingly counterintuitive features. For the first time, an image has been obtained without ever detecting the light that was used to illuminate the imaged object, while the light revealing the image never touches the imaged object.

In general, to obtain an image of an object, one has to illuminate it with a [light](#) beam and use a camera to sense the light that is either scattered or transmitted through that object. The type of light used to shine onto the object depends on the properties that one would like to image. Unfortunately, in many practical situations, the ideal type of light for the illumination of the object is one for which cameras do not exist.

The experiment published in *Nature* this week for the first time breaks this seemingly self-evident limitation. The object (e.g. the contour of a cat) is illuminated with light that remains undetected. Moreover, the light that forms an image of the cat on the camera never interacts with it. In order to realise their experiment, the scientists use so-called "entangled" pairs of photons. These pairs of photons - which are like interlinked twins - are created when a laser interacts with a non-linear crystal. In the experiment, the laser illuminates two separate crystals, creating one pair of twin photons (consisting of one infrared photon and a "sister" red photon) in either crystal. The object is placed in between the two crystals. The arrangement is such that if a photon pair is created in the first crystal, only the infrared photon passes through the imaged object. Its path then goes through the second crystal where it fully combines with any infrared photons that would be created there.

With this crucial step, there is now, in principle, no possibility to find out which crystal actually created the photon pair. Moreover, there is now no information in the infrared photon about the object. However,

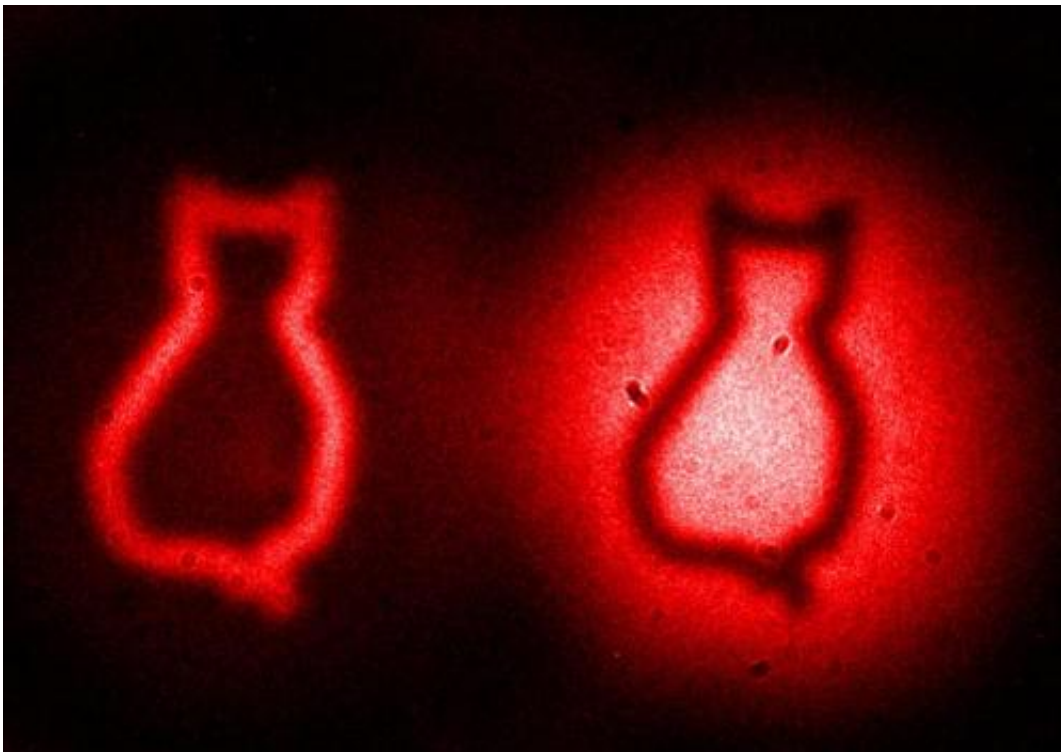
due to the quantum correlations of the entangled pairs the information about the object is now contained in the red photons - although they never touched the object. Bringing together both paths of the red photons (from the first and the second crystal) creates bright and dark patterns, which form the exact image of the object.



The cats represent the famous Schrödinger cat paradox, in which a quantum cat closed in a box can be dead and alive at the same time. The dark and light cat bodies are images of a cardboard cut-out. They arise due to destructive and constructive quantum interference, respectively. In this experiment the photons that interact with the cardboard cut-out are not detected, while the images are

obtained by detecting only photons that never interact with the object. Credit: Gabriela Barreto Lemos

Stunningly, all of the infrared photons (the only light that illuminated the object) are discarded; the picture is obtained by only detecting the red photons that never interacted with the object. The camera used in the experiment is even blind to the infrared photons that have interacted with the [object](#). In fact, very low light infrared cameras are essentially unavailable on the commercial market. The researchers are confident that their new imaging concept is very versatile and could even enable imaging in the important mid-infrared region. It could find applications where low light imaging is crucial, in fields such as biological or medical imaging.



The cats represent the famous Schrödinger cat paradox, in which a quantum cat

closed in a box can be dead and alive at the same time. The dark and light cat body outlines are images of an etched piece of silicon. They arise due to destructive and constructive quantum interference, respectively. In this experiment the photons that interact with the silicon are not detected, while the images are obtained by detecting only photons that never interact with the object.
Credit: Gabriela Barreto Lemos

More information: "Quantum imaging with undetected photons": Gabriela Barreto Lemos, Victoria Borish, Garrett D. Cole, Sven Ramelow, Radek Lapkiewicz, Anton Zeilinger. *Nature*, 2014. [DOI: 10.1038/nature13586](https://doi.org/10.1038/nature13586)

Provided by University of Vienna

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