Virtual ghost imaging: New technique enables imaging even through highly adverse conditions

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Ghost imaging (GI), and its even more oddly named cousin virtual ghost imaging (VGI), seem to contradict conventional wisdom by being able to image an object by simply counting photons in a "light bucket." This non-intuitive technique, however, can lead to better images when conditions are less than ideal. In a first-of-its-kind demonstration, a team of researchers from the U.S. Army Research Laboratory in Adelphi, Md., and the University of Maryland in Baltimore, captured reflected photons from a highly specialized laser beam to create a VGI image of a remote target.

In the case of VGI, reflection does not refer to a mirror image of an object. Rather it is merely the individual reflected photons of light that are counted with a single-pixel camera known as a light bucket.

"Virtual ghost imaging is an amazing tool," says Ronald Meyers, a quantum physicist with the U.S. Army Research Laboratory, in a paper published in the American Institute of Physics' journal Applied Physics Letters. "Because we are no longer bound by the need to collect spatial information – as is necessary in a typical camera – we can produce an image in some rather adverse and highly obscured conditions."

In normal ghost imaging, harnessing information to make an image is a two-step process. First, you analyze the light source, which could be the sun or a lamp, with a charge-coupled device (CCD) camera. You then

use a second detector, a light bucket, to count the reflected photons. By combining the data from the light source with the properties of the collected photons, an image can be created.

The trick to making an image from photons that contain no spatial information lies in physics related to "entanglement," a property of light that Einstein referred to as "spooky action at a distance." Through entanglement, photons (individual packets of light) can share a certain degree of information. This property is already being developed for specialized communications and computers.

Virtual ghost imaging is a more self-contained and robust application of this phenomenon. For example, in VGI, one light source was a laser that produced an incredibly coherent beam of light known as a Bessel beam. Bessel beams, unlike normal laser beams, produce concentric-circle patterns. If a portion of the beam is blocked or obscured along its trajectory, the original pattern eventually reforms. "Bessel beams are self-healing and provide an important tool in virtual ghost imaging," said Meyers. "Even after passing through distortions or a mask, the same well-defined ring shapes reemerge." So long as enough photons make it to the target and back to the single-photon detector, it's possible to construct an image.

In their proof-of-concept demonstration, the researchers compared a Bessel beam's VGI imaging capabilities with that of a normal "Gaussian" laser beam. Their target was the letters "ARL." The light was then reflected back to the single pixel bucket detector. The researchers conducted this same test several times, placing different objects or an obscuring medium in the paths of the two light beams. In each case – whether passing through an offset aperture, cloudy water, or heat distortion – the Bessel beam reformed to produce a recognizable VGI image. The Gaussian beam produced a much less faithful image, and, in the case of the offset aperture, produced virtually no image at all.

"What this demonstrates is that by combining virtual ghost imaging with a highly diffraction-free coherent light source like a Bessel beam, it's possible to probe through conditions that would normally thwart other imaging technologies," Meyers says.

According to the researchers, potential spin-offs of ghost imaging and virtual ghost imaging include applications in Intelligence-Surveillance-Reconnaissance (ISR), medical imaging, and quantum computing.

More information: "Virtual Ghost Imaging through Turbulence and Obscurants using Bessel Beam Illumination" is published in *Applied Physics Letters*.

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