Travelling through scattering tissue with far less light

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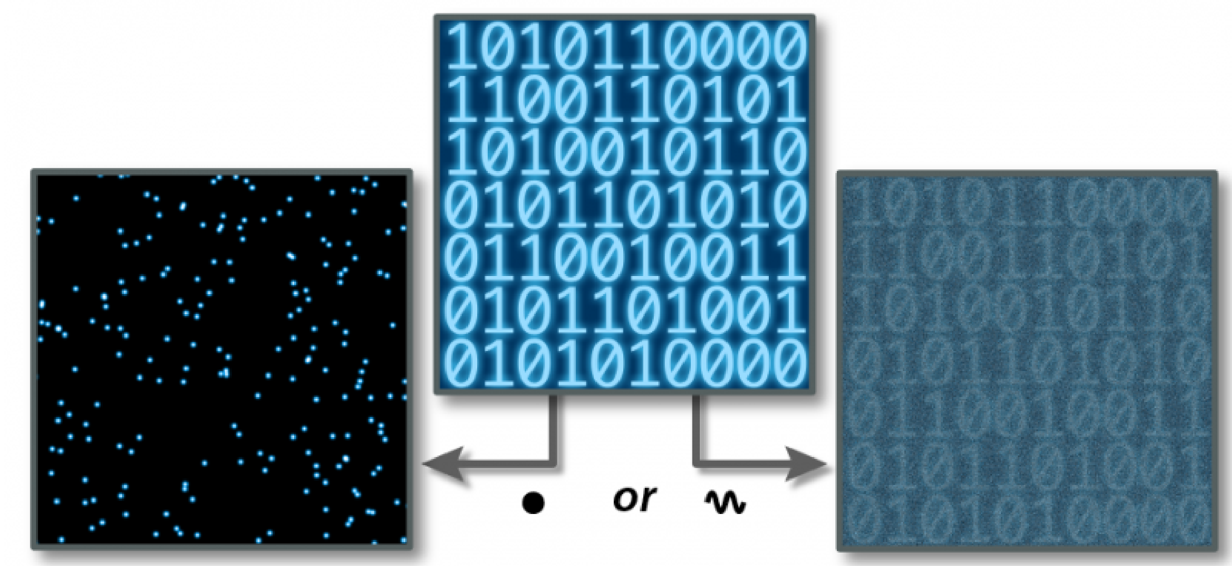

Seeing light as only particles, an speckled image would be the result, while by including the wave character, the fully reconstructible image (right) is formed. Credit: University of Twente

Medical applications of light, looking inside human tissue, often are limited by the highly scattering nature of tissue. Inuitively, a lower limit of one photon per camera pixel is assumed. Scientists of the University of Twente in The Netherlands and Caltech in Pasadena, USA, prove that the lower limit is actually much lower, thus opening possibilities of going deeper into tissue with less light.

How do you send light through scattering tissue and how much light do you actually need for that? One photon per pixel of the camera would be the lower limit, you might say. Remarkably, you can go much lower, researchers of UT and Caltech show in *Physical Review Letters*.

Although light has promising biomedical applications, for example for measuring blood circulation or tracing tumors, the depth is limited by the heavy scattering of the tissue. How much light do you actually need? The new results of researchers of the University of Twente in The Netherlands and Caltech in Pasadena, shows that the intuitive lower limit of one photon per pixel actually is not the lower limit. Thanks to the wave character of light, even a few thousandth of a photon per pixel is sufficient. For several reasons, this is good news, as you can't simply use more light: too much of it can damage the tissue.

Back tracing

The small amount of light that finds its way through tissue, has travelled a complex path. It is scattered many times, but eventually finds a way out. If you manage to go back along this path, you know what waveform is needed to send light through tissue with success. Although you don't know the exact path in that case, you do know that there is a path: you calculate the result back to the source. In this way it is also possible to focus light inside tissue, enabling looking through tissue or deeper inside the brain.

Counterintuitive

Imagine no more than 1000 photons traveling through tissue, while the camera chip has 200.000 pixels. The first thought is that just 1000 pixels receive light, showing an occasional 'speckle' here and there. This is not the correct assumption, however. Different pixels can, at the same time, register the information of one single photon. As light is a wave as well, one photon can travel different paths. The phase of the light falling on the camera pixels, is always a combination of the actual signal and a reference source. Even with an 'unequal ratio' of pixels and photons, the full image is available and can be calculated back to the source. Although the image has less contrast, it remains possible to reconstruct it. That is something you wouldn't expect seeing photons as separate particles. This counterintuitive result proves that you need far less light to go deeply into tissue. This is good news for applications in new imaging techniques, for example hybrid techniques that use a combination of light and ultrasound.

More information: Optical phase conjugation with less than a photon per degree of freedom. arxiv.org/abs/1610.04553

Provided by University of Twente

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