Ghost imaging in the time domain could revolutionize the imaging of disturbance-sensitive signals

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The conventional approach to decode information carried by ultrafast optical signals that propagate in optical fibers employs fast detectors that convert the temporal intensity variations of a light beam into an RF electrical signal. This technique is at the core of ultrafast optical communications, enabling the transmission of information at speeds exceeding several billion bits per second. A team led by Professor Goëry Genty from the Optics Laboratory at the Tampere University of Technology in collaboration with Professor Ari T. Friberg from the University of Eastern Finland now demonstrates how ultrafast pulses that carry information over durations shorter than 1 billionth of a second can be detected without actually 'seeing' those pulses directly. The results were obtained within the framework of the 'Temporal correlation imaging' project funded by the Academy of Finland.

"Ghost imaging is an all-new physical imaging method that enables us to image a target by correlating two beams of light, neither of which contains image information. One beam sees the object and measures the overall output, while the other is in no contact with the object although its space distribution is measured. When these measured intensities are correlated, the image of the target magically appears, 'like a ghost'," Friberg explains.

In their experiments, the team transposed the concept of ghost imaging into the time domain to produce the 'image' of an ultrafast signal in the form of short optical pulses by correlating in time the intensity of two light beams, neither of which independently carries information about the signal. The key element was to use a laser source with random intensity fluctuations at a time scale of a picosecond, a feature which is generally highly detrimental for the standard transmission of information. By correlating these fluctuations with the total power of the modulated signal, it was possible to reconstruct a perfect copy of the ultrafast signal.

"Even more fascinating", says Professor Genty, "is the fact that the technique is completely insensitive to distortion that the signal may experience due to dispersion, nonlinearity, or attenuation, for example." To demonstrate this inherent property associated with ghost imaging, the researchers have scrambled the information carried by the optical pulses using a multi-mode fiber whose large dispersion spreads the individual pulses in time to the extent that they start overlapping and thus prevent the information from being faithfully retrieved with a conventional fast detector. When the ghost imaging approach was used, the team showed that a perfect replica of the original signal could be obtained and the information could be recovered.

The method is scalable, it can be integrated on-chip, and it offers great promise for the dynamic imaging of ultrafast waveforms with applications in communications, remote sensing and ultrafast spectroscopy.

More information: Piotr Ryczkowski et al. Ghost imaging in the time domain, *Nature Photonics* (2016). DOI: 10.1038/nphoton.2015.274

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