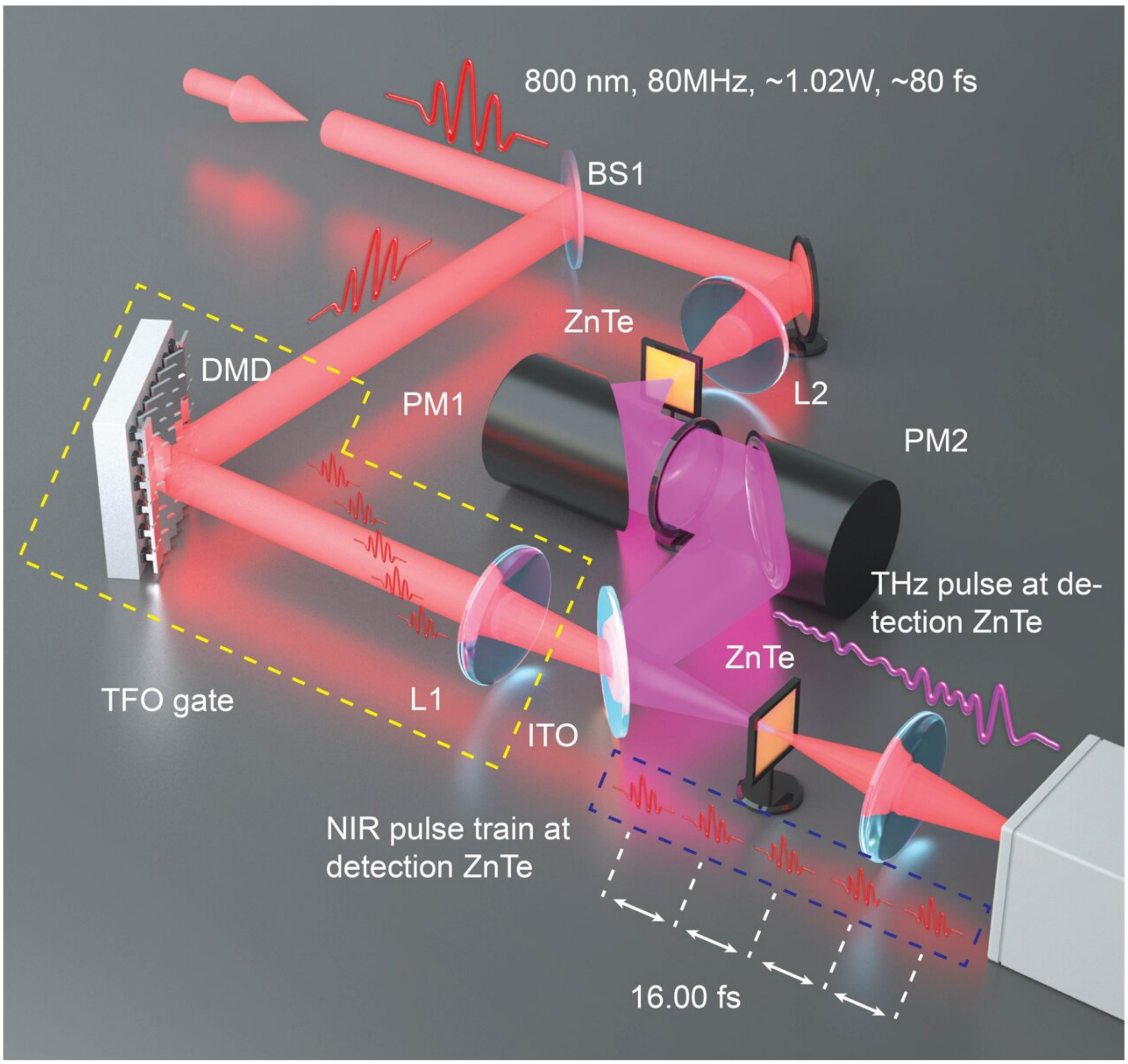
New technique speeds measurement of ultrafast pulses

September 24 2021



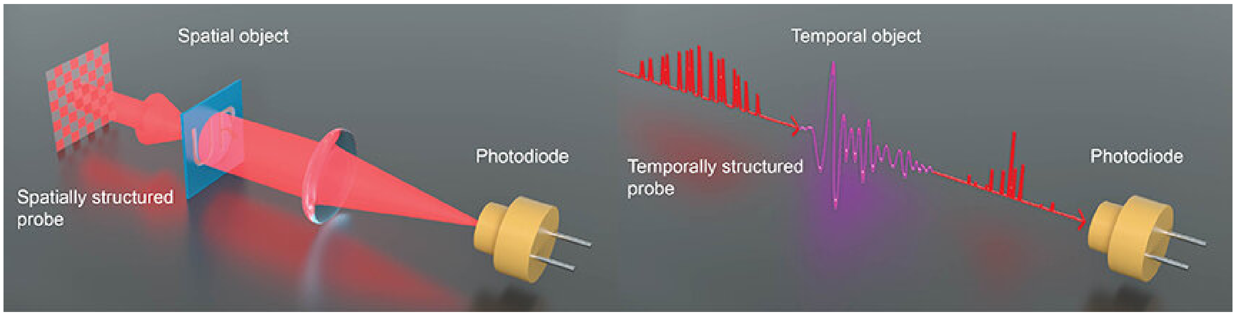
Schematics of the experimental setup showing a temporal fan out (TFO) gate represented by the yellow dashed box, which includes a digital micromirror device. The propagation direction of prepared input ultrafast pulse, originating in blue dashed box, is shown in pink. Dark red lines represent the corresponding pulse front. Credit: Jiapeng Zhao

When we look at an object with our eyes, or with a camera, we can automatically gather enough pixels of light at visible wavelengths to have a clear image of what we see.

However, to visualize a quantum object or phenomenon where the illumination is weak, or emanating from nonvisible infrared or far infrared wavelengths, scientists need far more sensitive tools. For example, they have developed single-pixel imaging in the spatial domain as a way to pack and spatially structure as many photons as possible onto a single pixel detector and then create an image using computational algorithms.

Similarly, in the time domain, when an unknown ultrafast signal is either weak, or in the infrared or far infrared wavelengths, the ability of single-pixel imaging to visualize it is reduced. Based on the spatio-temporal duality of light pulses, University of Rochester researchers have developed a time-domain single-pixel imaging technique, described in *Optica*, that solves this problem, detecting 5 femtojoule ultrafast light pulses with a temporal sampling size down to 16 femtoseconds. This time-domain analogy of the single-pixel imaging shows similar advantages to its spatial counterparts: a good measurement efficiency, a high sensitivity, robustness against temporal distortions and the compatibility at multiple wavelengths.

Lead author Jiapeng Zhao, a Ph.D. student in optics at the University of Rochester, says possible applications include a highly accurate spectrographic tool, demonstrated to achieve 97.5 percent accuracy in identifying samples using a convolutional neural network with this technique.



Comparison of single-pixel imaging, at left, and time-domain single-pixel imaging (TSPI) at right. In a typical single-pixel imaging configuration the photodiode detector has only one pixel and hence provides no spatial resolution. In TPSI, the photodiode, which lacks the temporal bandwidth to resolve ultrafast signals by itself, works as the “single-pixel” detector in the time domain and is used in conjunction with a programmable temporal fan-out gate based on a digital micromirror device. Credit: Jiapeng Zhao

The technique can also be combined with single-pixel imaging to create a computational hyperspectral imaging system, says Zhao, who works in the Rochester research group of Robert Boyd, professor of optics. The system can greatly speed up the detection and analysis of images at broad frequency bands. This could be especially useful for medical applications, where detection of nonvisible light emanating from human tissue at different wavelengths can indicate disorders such as high blood pressure.

"By coupling our technique with single pixel imaging in the spatial domain, we can have good hyperspectral image within a few seconds.

That's much faster than what people have done before," Zhao says.

More information: Jiapeng Zhao et al, Compressive ultrafast pulse measurement via time-domain single-pixel imaging, *Optica* (2021). DOI: 10.1364/OPTICA.431455

Provided by University of Rochester