Imaging through Partially Occluding Media
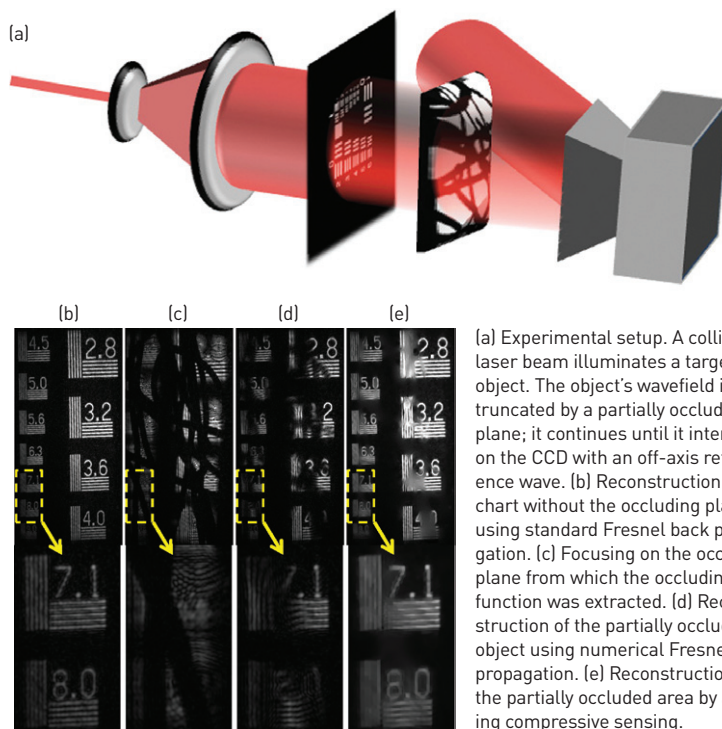## Using Compressive Sensing

The imaging of a partially occluded target object is an active area of research.[1,2] It is usually addressed using multi-aperture systems in which different views of the object can be revealed by applying synthesis algorithms. These techniques often require substantial scanning and are limited by the numerical aperture of a single perspective, which may yield low-resolved object details.

We present a method that can be implemented with a single shot and single aperture holographic and computational reconstruction.[3] Object recovery was recast as a compressive sensing (CS) problem, where the sensing mechanism is based on the free space propagation of the object's wavefield. CS is a joint signal acquisition-reconstruction paradigm that has gained much attention because it provides a framework for reconstructing highly subsampled signals.

Digital holography is an efficient object sensing scheme when combined with CS; a signal can be reconstructed from a subsampled Fresnel/Fourier hologram.[4] This motivated us to try recovering an object whose wavefield was partially blocked by the occluding environment.

For the experiment, we recovered an Edmund Optics 1951 USAF transmission resolution chart, which was illuminated by a HeNe laser beam at 632 nm. We used a twisted, blackened barb wire as partially opaque media and an off-axis setup to record the hologram. By numerically refocusing the wire plane, we evaluated its structure and found that approximately 59 percent of the resolution chart's field was obscured.

The figure shows reconstruction results for a non-occluded object (as a reference), numerical focusing on the occluding plane, and the occluded object reconstructed via standard numerical back propagation and CS. The reconstruction with the CS approach reveals details that are lost in the reconstruction with numerical back propagation.

We treated the occluding object as planar and binary. Given the physical properties of the media (e.g., opacity percentage and physical structure), one can theoretically determine the minimal number of objects that can be reconstructed.[3] That is demonstrated in our online video. Since the analytical results also apply to complex media, the method can be used to recover objects behind turbid media.[5] OPN

(a) Experimental setup. A collimated laser beam illuminates a target object. The object's wavefield is then truncated by a partially occluding plane; it continues until it interferes on the CCD with an off-axis reference wave. (b) Reconstruction of chart without the occluding plane using standard Fresnel back propagation. (c) Focusing on the occluding plane from which the occluding function was extracted. (d) Reconstruction of the partially occluded object using numerical Fresnel back propagation. (e) Reconstruction of the partially occluded area by applying compressive sensing.

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