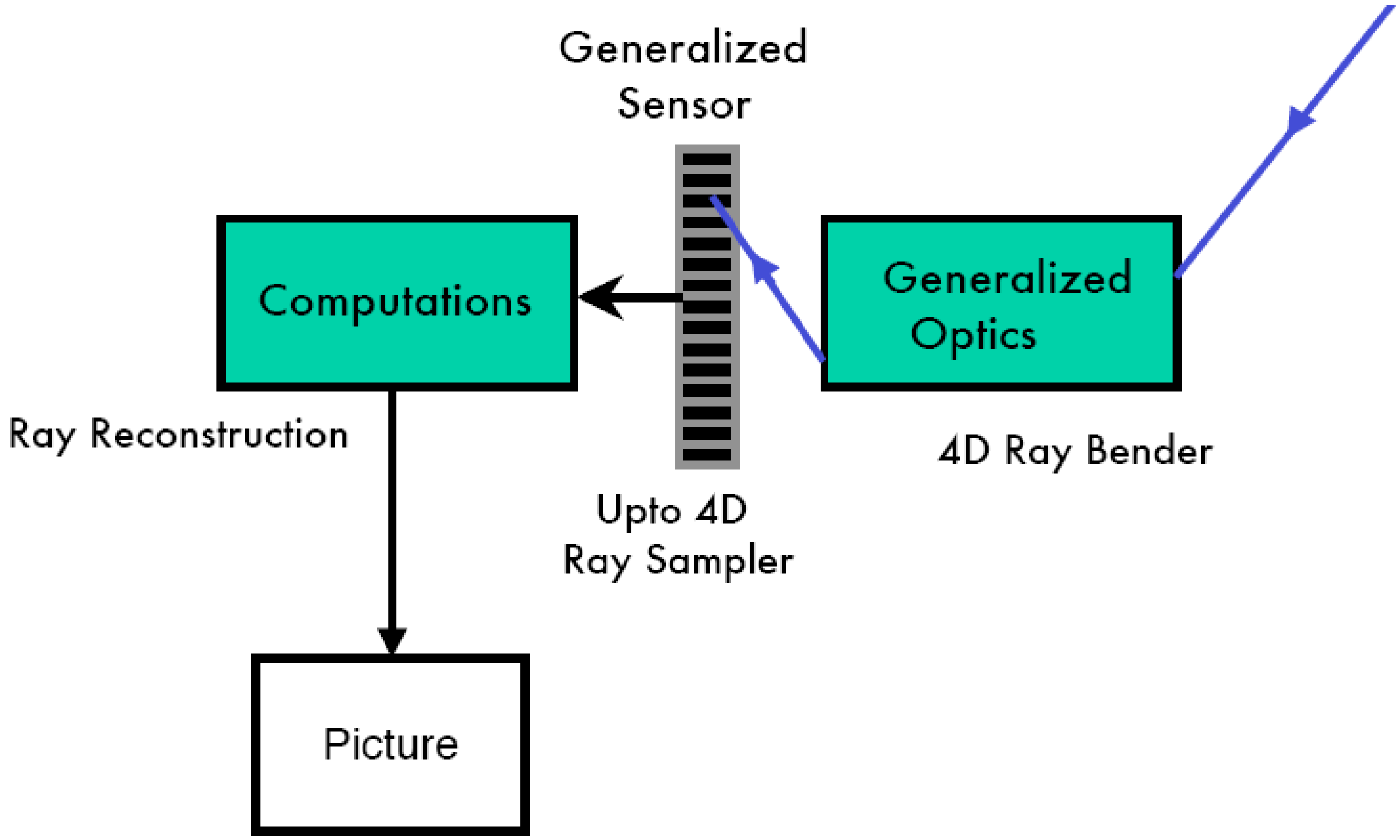
Computational Photography

Dr. Diego Gutiérrez


Generalized
Sensor
Computations
Generalized
Optics
Ray Reconstruction
4D Ray Bender
Upto 4D
Ray Sampler
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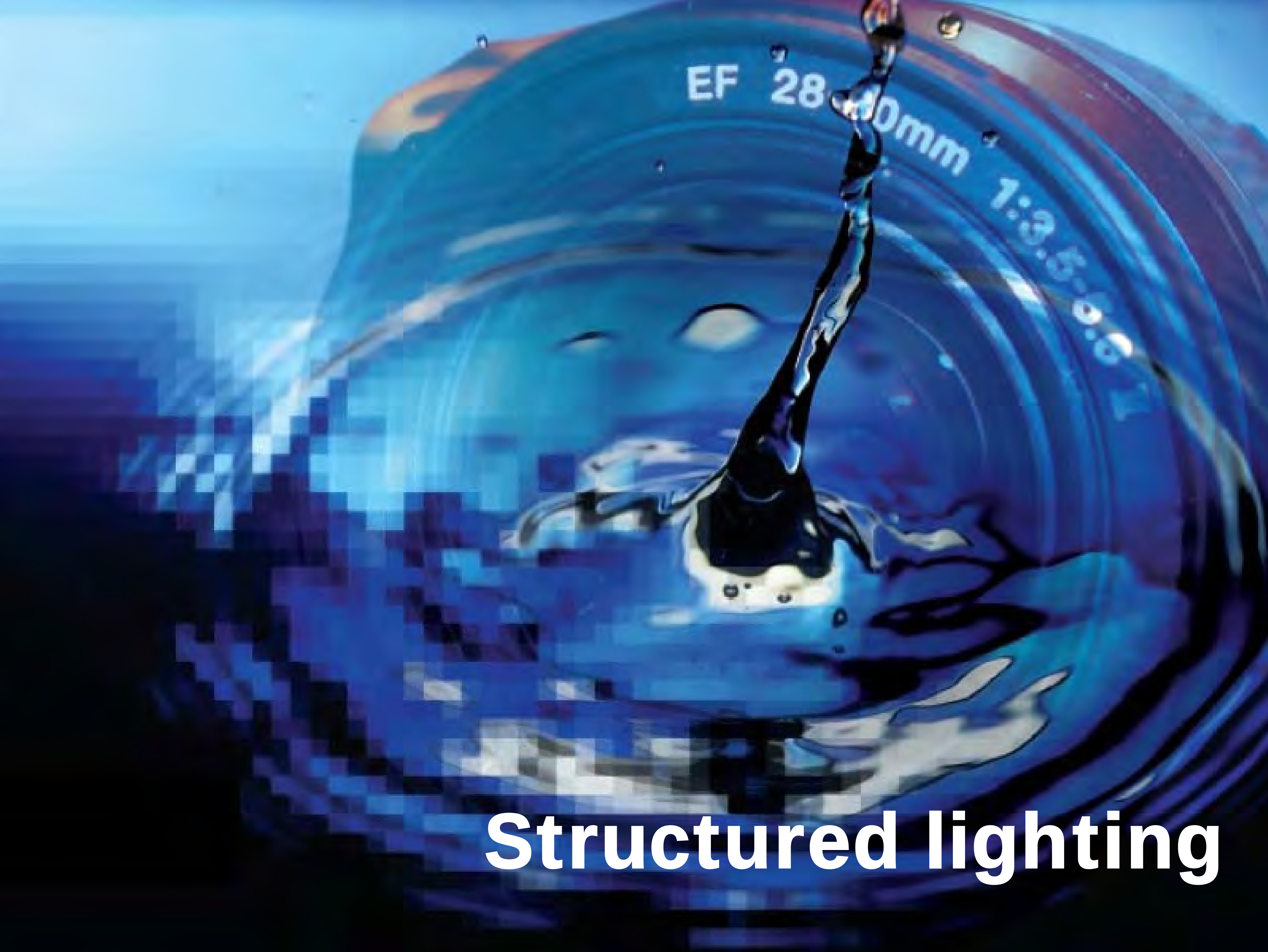

Structured lighting

Fast Separation of Direct and Global Components of a Scene using High Frequency Illumination

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Columbia University

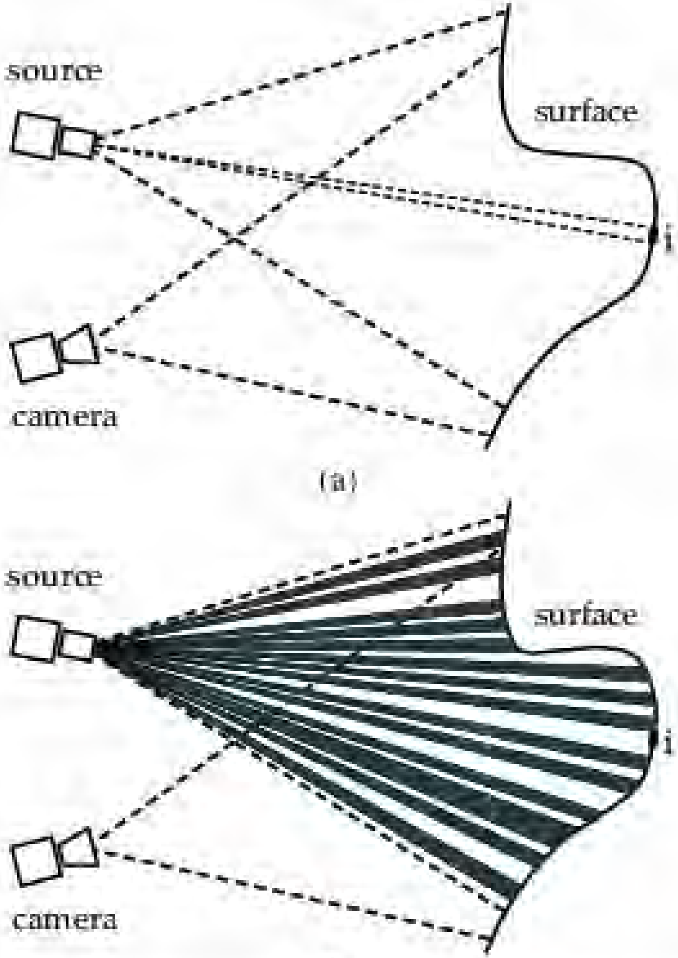
Michael D. Grossberg‡
City University of New York

Ramesh Raskar§
MERL

(a) Scene

(b) Direct Component

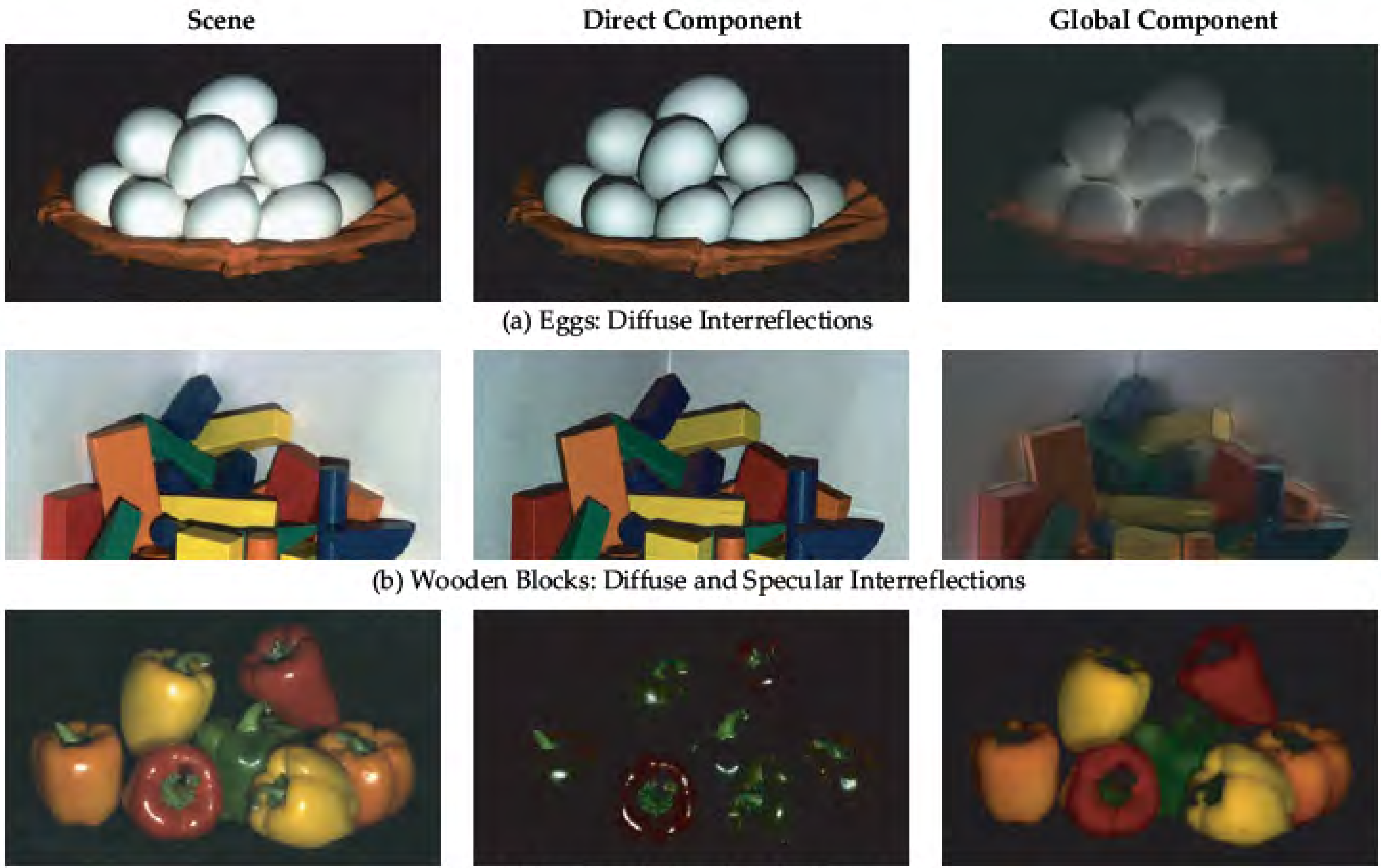
(c) Global Component



(a)

(b)

Figure 3: (a) A simple scenario where the radiance of each patch i includes a direct component due to scattering of light incident directly from the source and a global component due to light incident from other points in the scene. (b) When the source radiates a high frequency binary illumination pattern, the lit patches include both direct and global components while the unlit patches have only a global component. In theory, two images of the scene taken with such an illumination pattern and its complement are sufficient to estimate the direct and global components for all patches in the scene.



(a) Eggs: Diffuse Interreflections

(b) Wooden Blocks: Diffuse and Specular Interreflections

(c) Peppers: Subsurface Scattering

Veiling Glare in High Dynamic Range Imaging

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Stanford University

(a) (b)

Figure 1: *Two HDR captures of a strongly backlit scene, tonemapped for printing. The camera is a Canon 20D. (a) Backlighting produces veiling glare in the camera body and lens, visible as a loss of contrast in the foreground objects. (b) By interposing a structured occlusion mask between the camera and the scene, capturing a sequence of HDR images under different translations of the mask, and applying the algorithm described in Section 4.3, we produce an image with substantially reduced glare.*

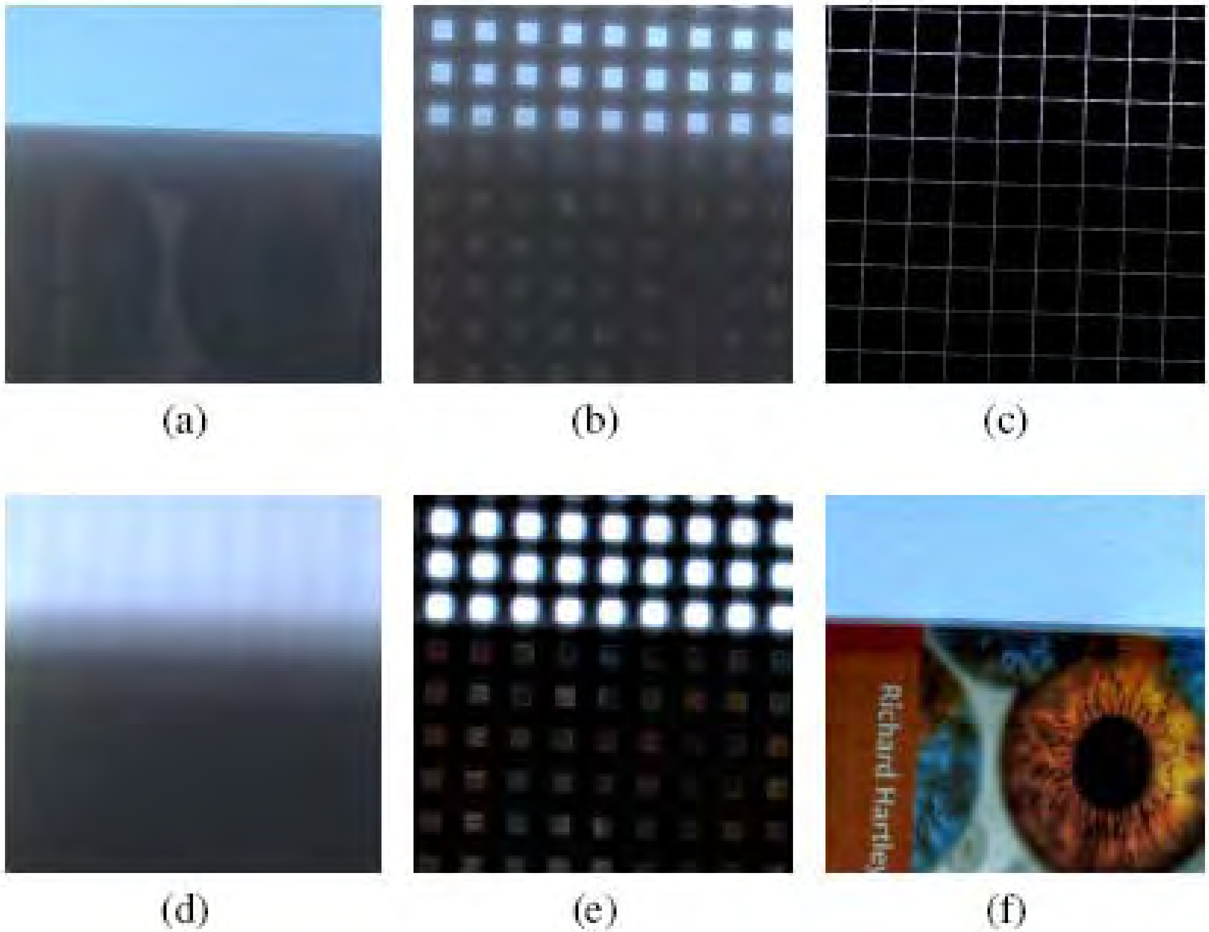
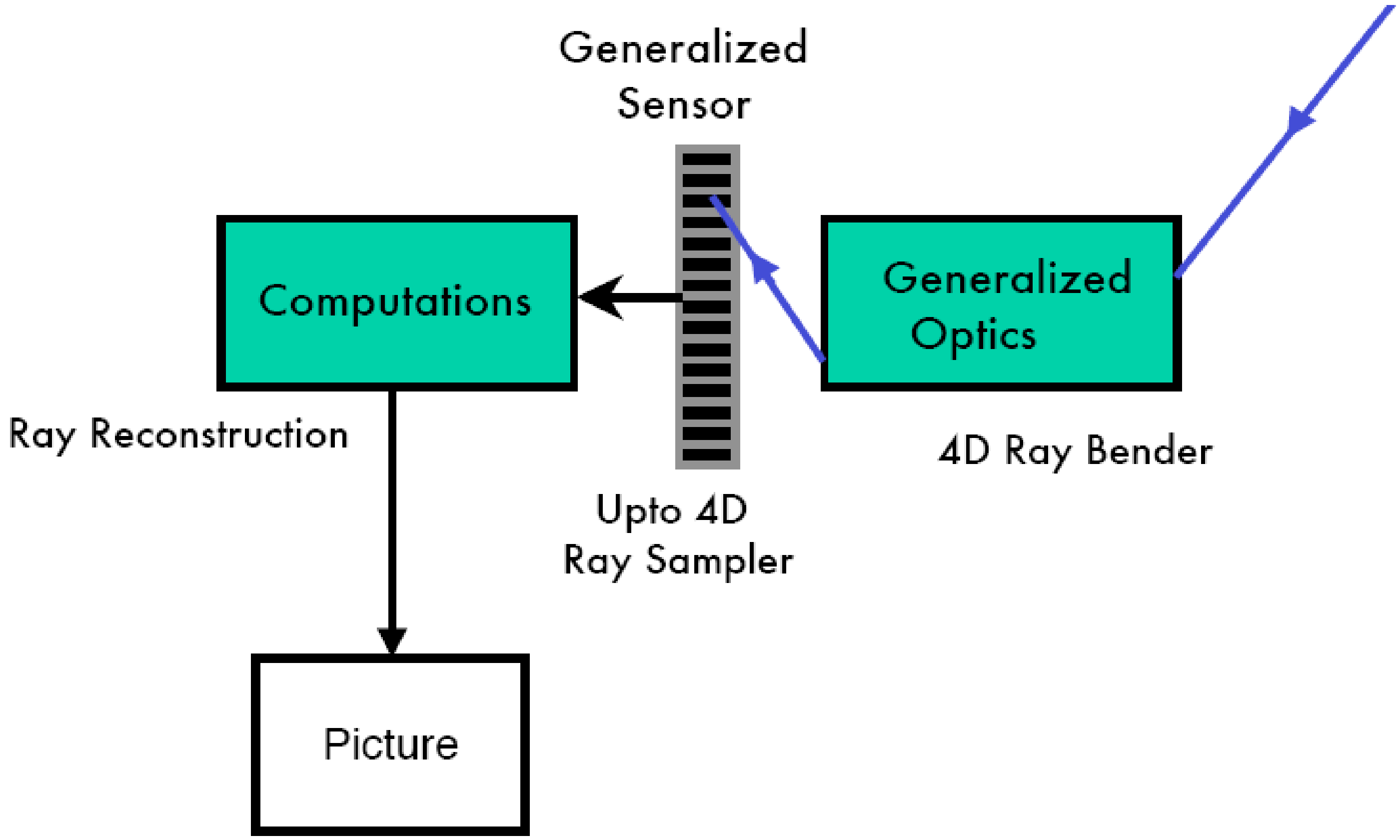


Figure 11: *A closeup of a tonemapped sequence of HDR images formed in interpolating glare removal. (a) Unoccluded original. (b) Single occluded capture* $\mathbf{r}_\phi$*. The occluded regions are extracted to produce (c), the glare-only image* $\hat{\mathbf{g}}_\phi$*. This image is interpolated to form (d), the glare estimate* $\mathbf{g}_\phi$*.* $\mathbf{g}_\phi$ *is then subtracted from (b) to produce (e), the glare-free estimate* $\mathbf{s}_\phi$*. Compositing all* $\mathbf{s}_\phi$ *together forms (f), the complete HDR glare-free image* $\mathbf{s}$*.*

Figure 13: *Tonemapped images of a book in a dark room, against a bright window showing a neighboring building and blue sky, captured with the Canon A640. At the top left is the unmasked HDR capture, and at the top right is our glare-free result. At the bottom is a closeup of corresponding regions from each capture. Compare to the deconvolution result in Figure 6.*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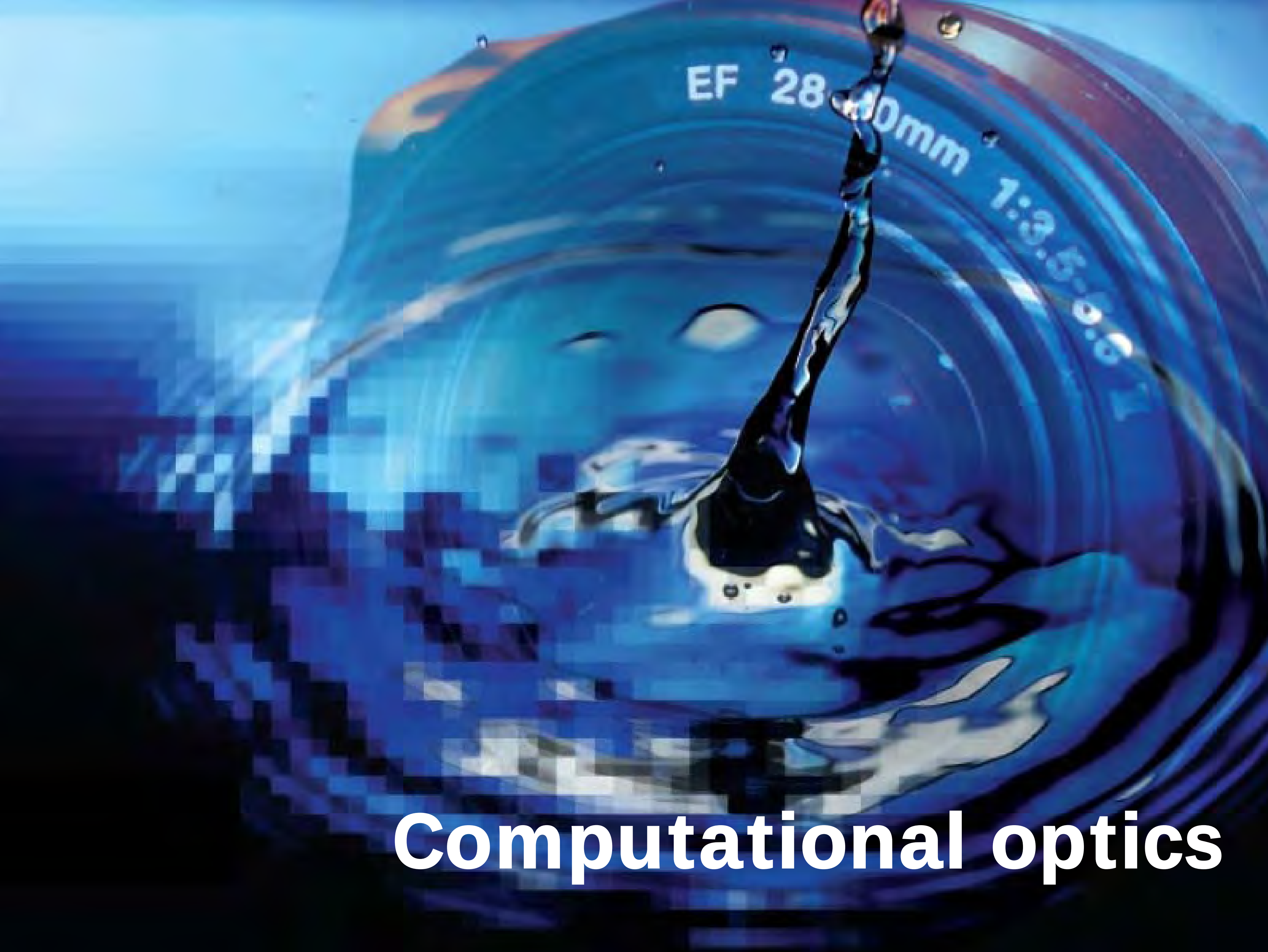
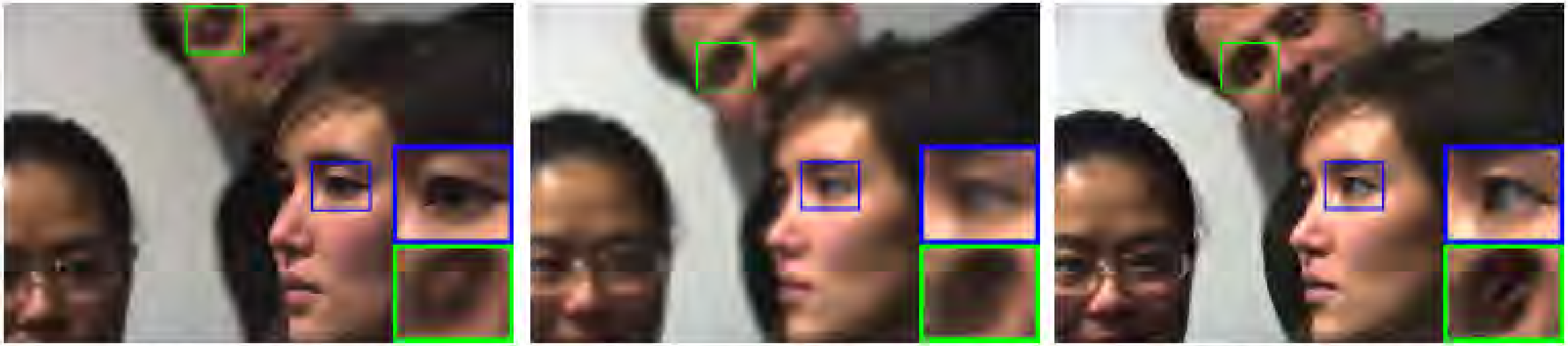


Computational optics

4D Frequency Analysis of Computational Cameras for Depth of Field Extension

Anat Levin[1,2] Samuel W. Hasinoff[1] Paul Green[1] Frédo Durand[1] William T. Freeman[1]
[1]MIT CSAIL [2]Weizmann Institute



Standard lens image | Our lattice-focal lens: input | Lattice-focal lens: all-focused output

Figure 1: *Left: Image from a standard lens showing limited depth of field, with only the rightmost subject in focus. Center: Input from our lattice-focal lens. The defocus kernel of this lens is designed to preserve high frequencies over a wide depth range. Right: An all-focused image processed from the lattice-focal lens input. Since the defocus kernel preserves high frequencies, we achieve a good restoration over the full depth range.*

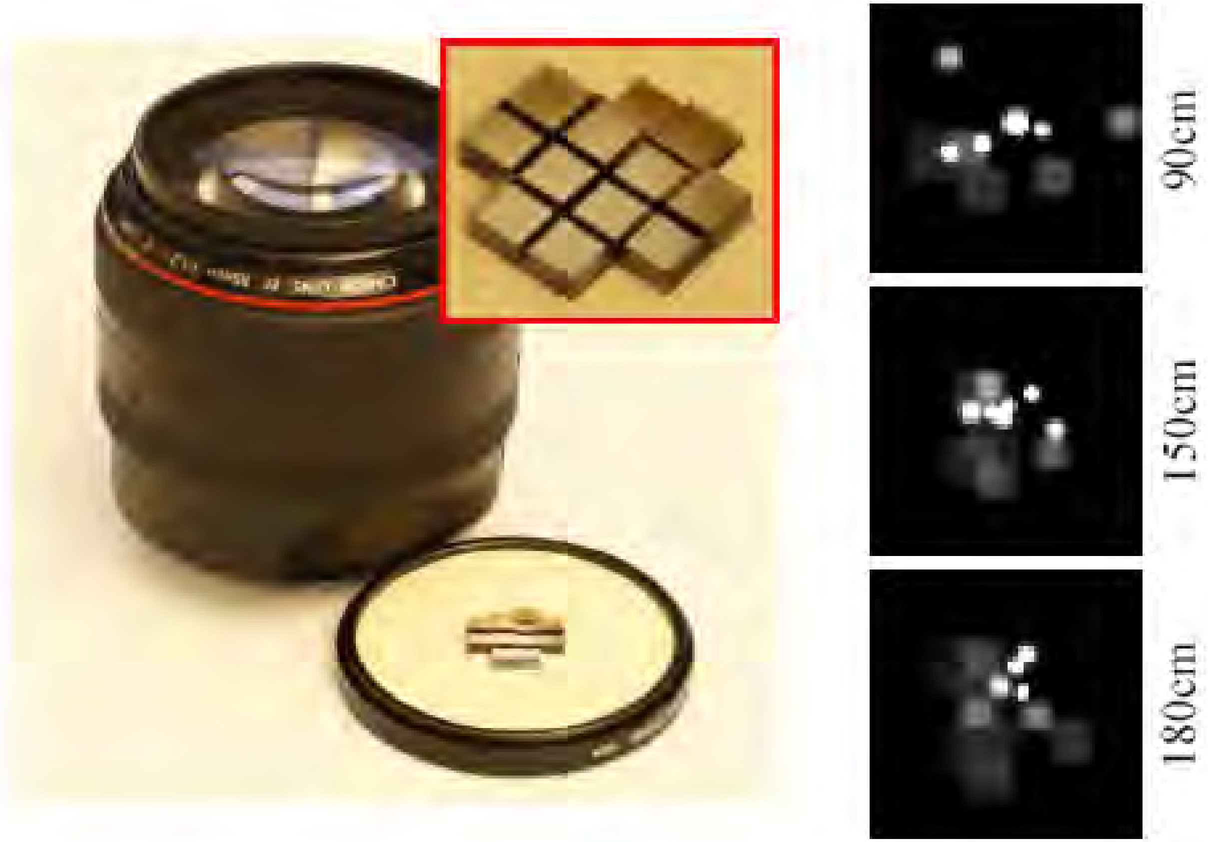


Figure 13: *Our prototype lattice-focal lens and PSFs calibrated at three depths. The prototype attaches to the main lens like a standard lens filter. The PSFs are a sum of box filters from the different subsquares, where the exact box width is a function of the deviation between the subsquare focal depth and the object depth.*

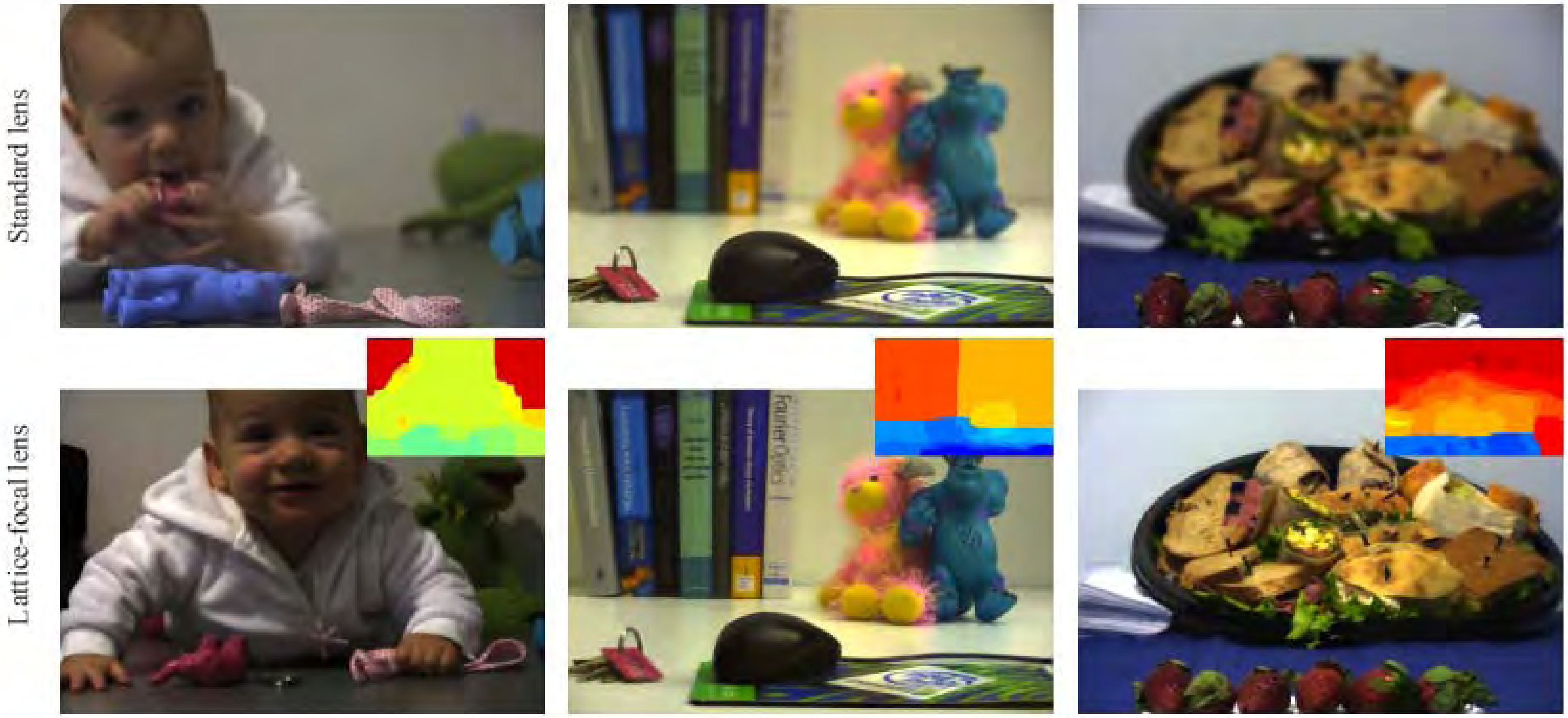
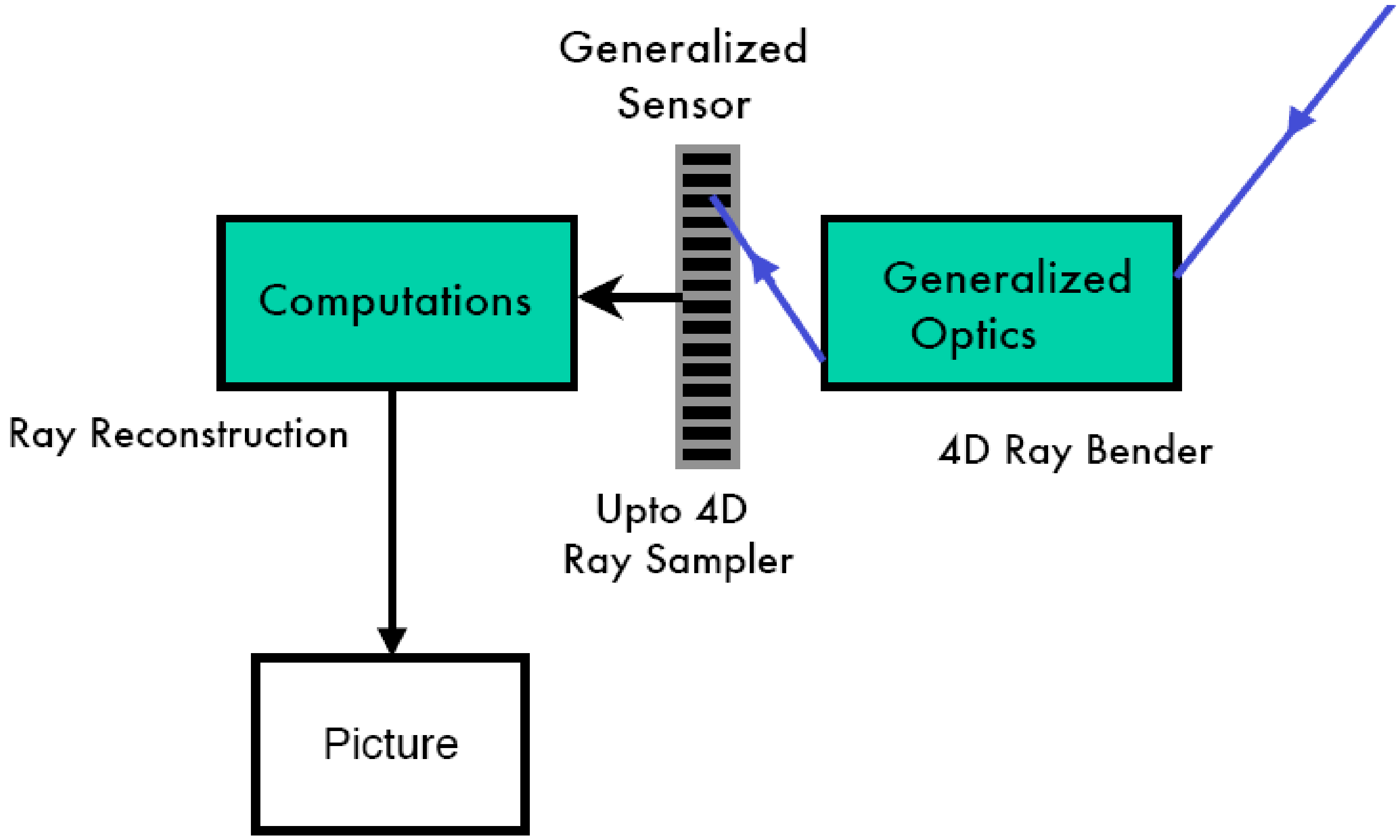


Figure 15: *Partially defocused images from a standard lens, compared with an all-focused image and depth map produced by the lattice-focal lens.*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Deblurring

Recall convolution theorem

- Convolution in space is a multiplication in Fourier
- Note y the observed blurry image and x the original sharp one
- $y = g \otimes x$ in the spatial domain
- $Y = GX$ in the Fourier domain
  - A frequency does not depend on the other ones

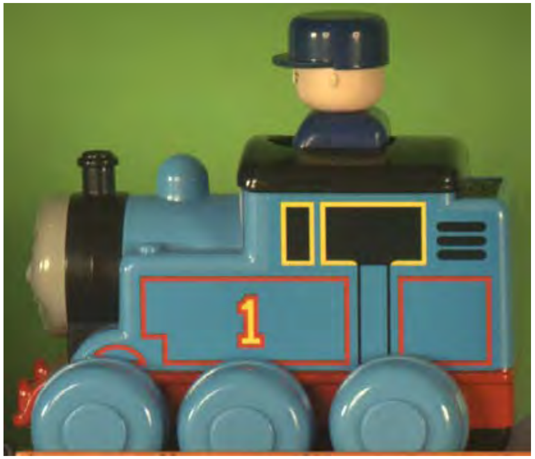
Invert the convolution theorem

- Given $y=g \otimes x$ and g, we seek an estimate x' of x
- How do you invert a multiplication?
  - Division!
- $X'(\omega)=Y(\omega)/G(\omega)$
- DECONVOLUTION IS A DIVISION IN THE FOURIER DOMAIN !
- Which means it is also a convolution in the spatial domain, by the inverse Fourier transform of 1/G

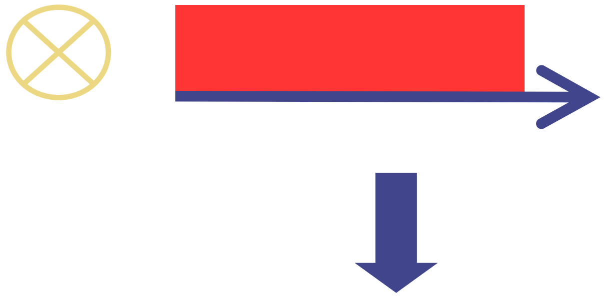
Potential problem?

- Deconvolution is a division in the Fourier domain
- Division by zero is bad!
  - Information is lost at the zeros of the kernel spectrum G

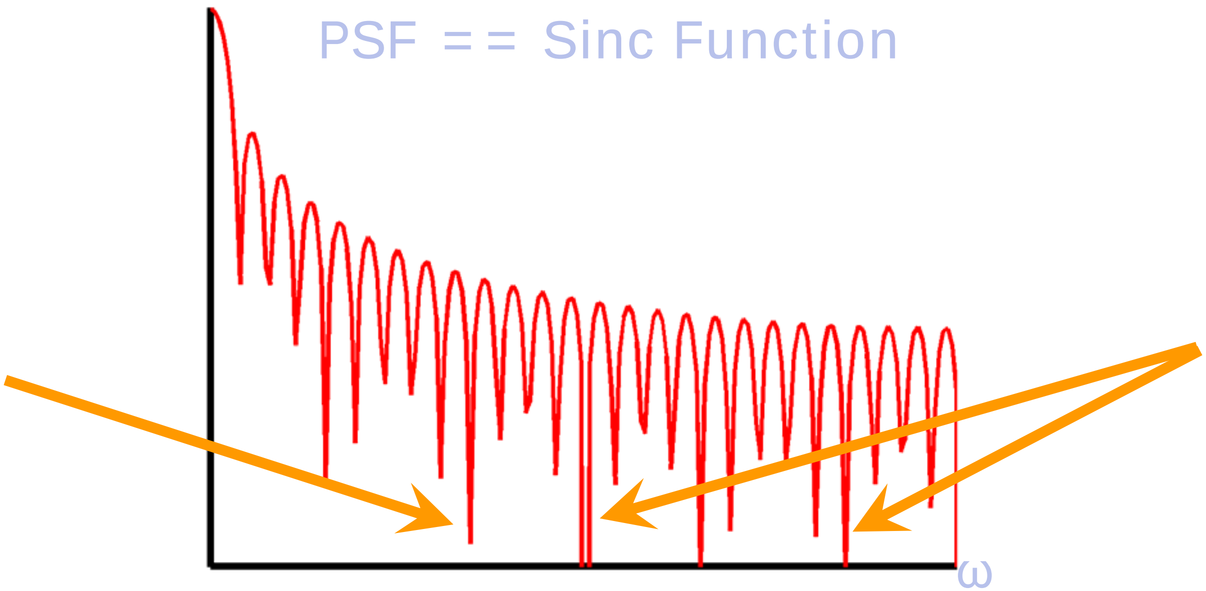
Blurring == Convolution



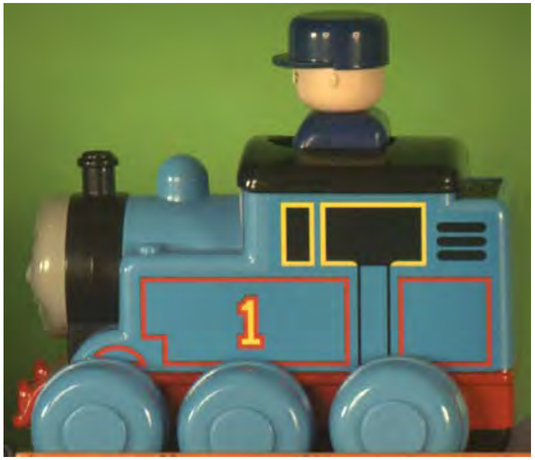
Sharp Photo



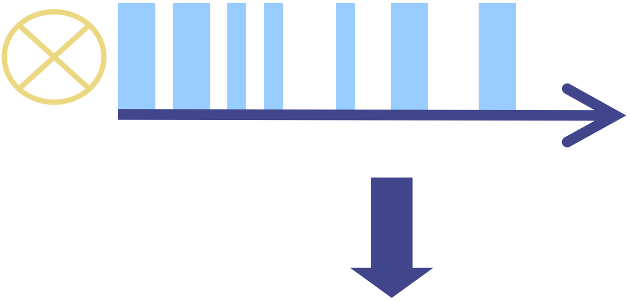
Blurred Photo

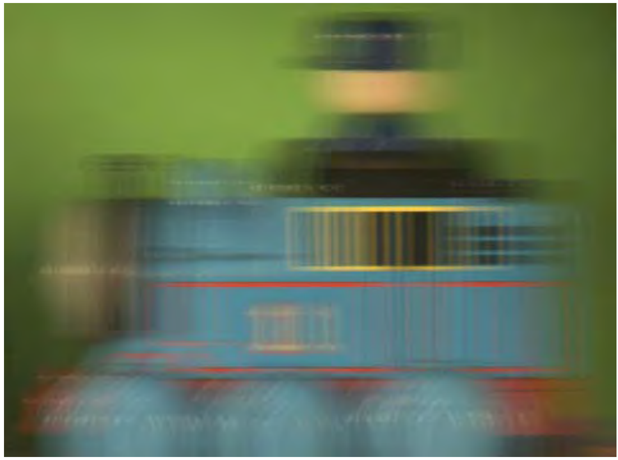


Traditional Camera: Shutter is OPEN: Box Filter

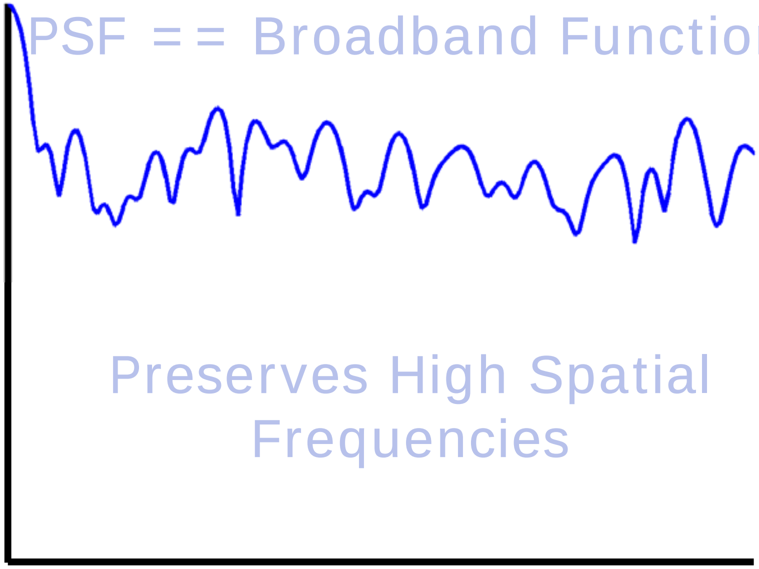


Sharp Photo

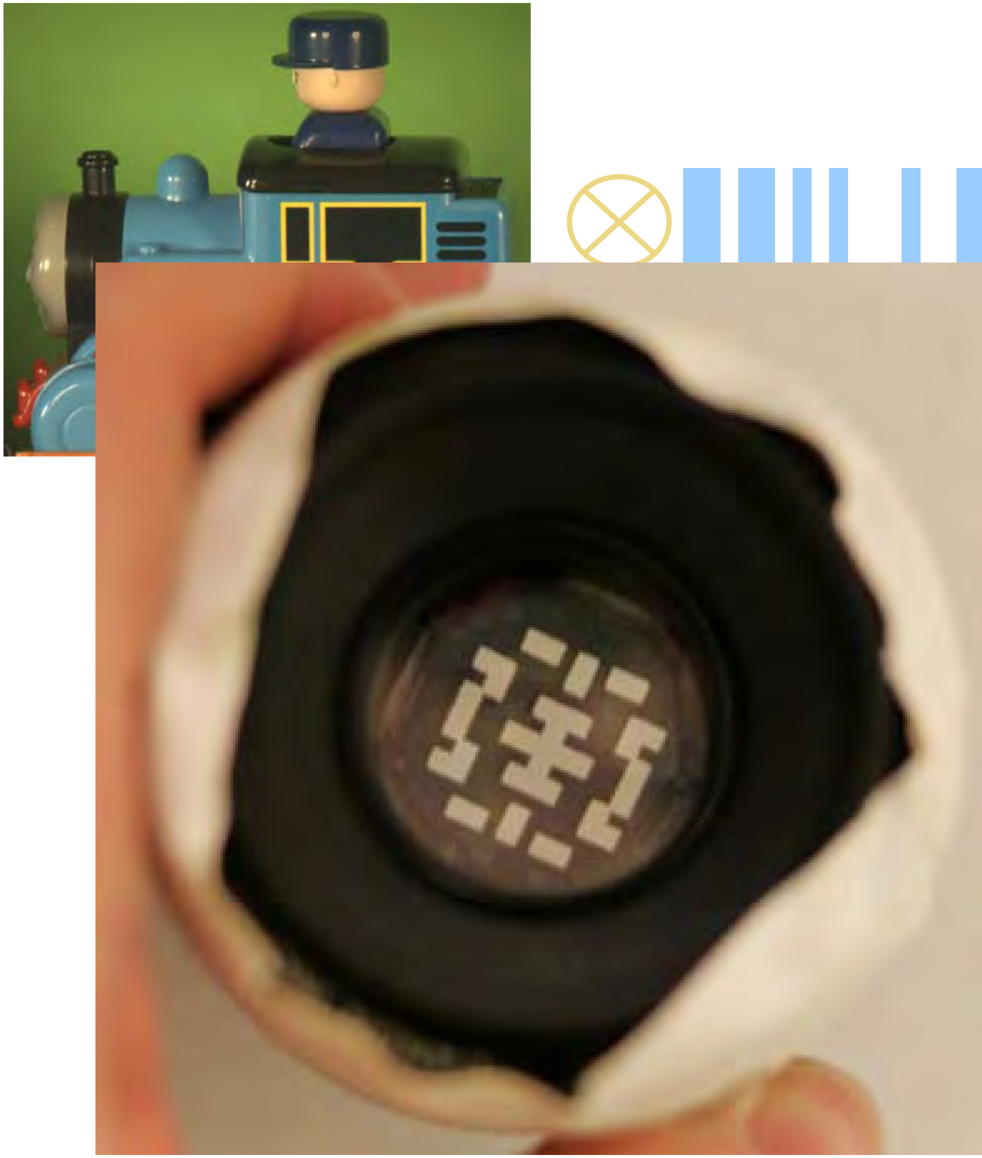




Blurred Photo

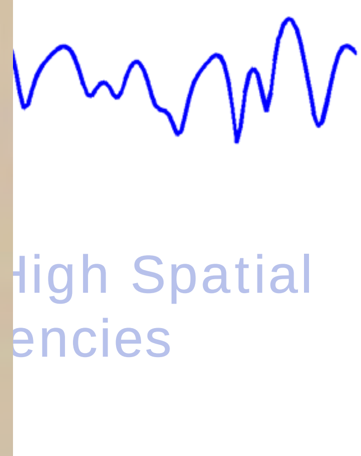


Flutter Shutter: Shutter is OPEN and CLOSED



Blurred Photo

band Function



High Spatial
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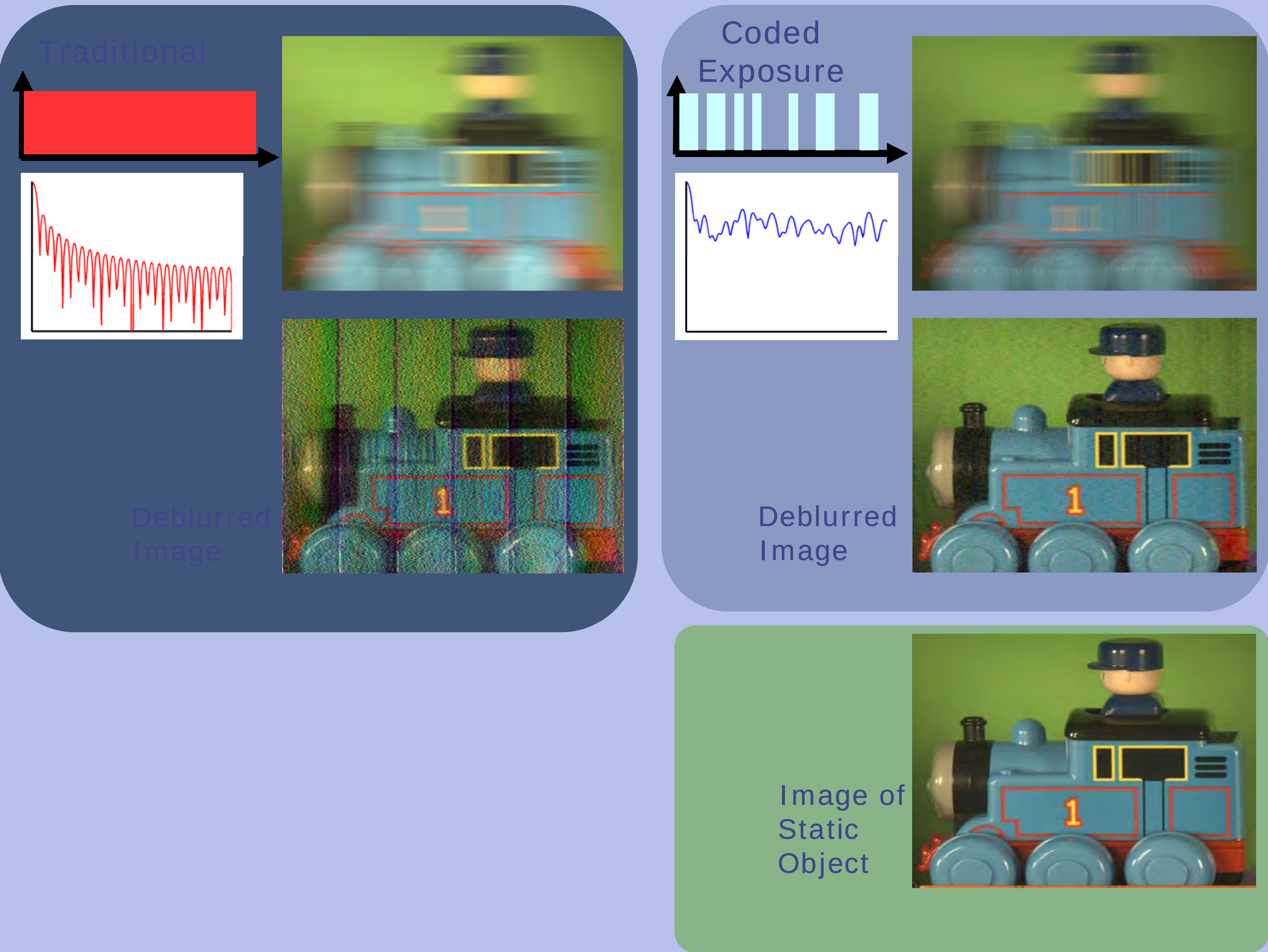
Flutter Shutter: Shutter is OPEN and CLOSED


Traditional
Deblurred Image
Coded Exposure
Deblurred Image
Image of Static Object

Computational processing

Depicting Procedural Caustics in Single Images

Diego Gutierrez
Jorge Lopez-Moreno
Francisco Seron
Jorge Fandos
Mapi Sanchez
Erik Reinhard

Universidad de Zaragoza
University of Bristol

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NEW HORIZONS