Efficient Reconstruction of Holographic Lens-Free Images by Sparse Phase Recovery

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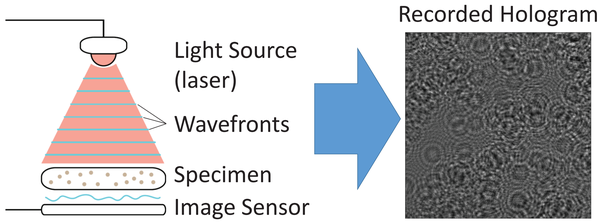
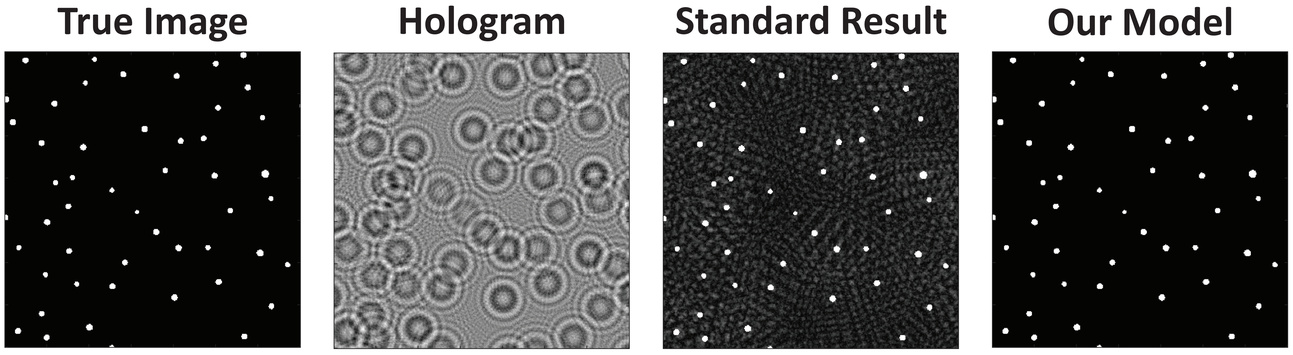
Lens-Free Holographic Imaging

- Coherent light is passed through specimen.
- Resulting diffraction pattern is recorded.
- Image is reconstructed via post-processing.



The Reconstruction Problem

- **Standard approach**: Back-project recorded diffraction pattern to the image plane.
- **Problem**: The image sensor only records the amplitude of the diffraction pattern.
- **Standard Result**: The **"Twin-Image" artifact** corrupts the reconstructed image.
- **Our Model**: Use sparse priors to reconstruct image and estimate missing phase.



Our Model

$$\min_{\{X_j\}_{j=1}^D, W, k} \frac{1}{2}\|H \odot W - k\mathbf{1} - \sum_{j=1}^{D} T(z[j]) * X_j\|_F^2 + \lambda \sum_{j=1}^{D} \|X_j\|_1 \quad \text{subject to} \quad |W| = 1$$

$H \in \Re^{m \times n}$: Hologram

$W \in \mathbb{C}^{m \times n}$: Phase Estimate

$\mu \in \mathbb{C}$: Background Estimate

$z \in \Re^D$: Vector of Focal Depths

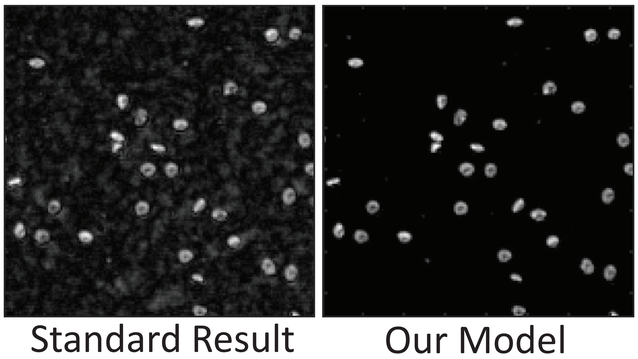
$T(z[j]) \in \mathbb{C}^{m \times n}$: Diffraction Tranfer Function at Depth $z[j]$

$X_j \in \mathbb{C}^{m \times n}$: Reconstructed Image at Depth $z[j]$

Single Depth Reconstructions

- **Closed form updates** for each variable via alternating minimization.
- **Quick convergence** in a small number of iterations (~15 iterations).
- **Efficient implementation** on GPU and reconstruction of (2048x4096) image in **<1sec**.

Reconstructions of Human Blood

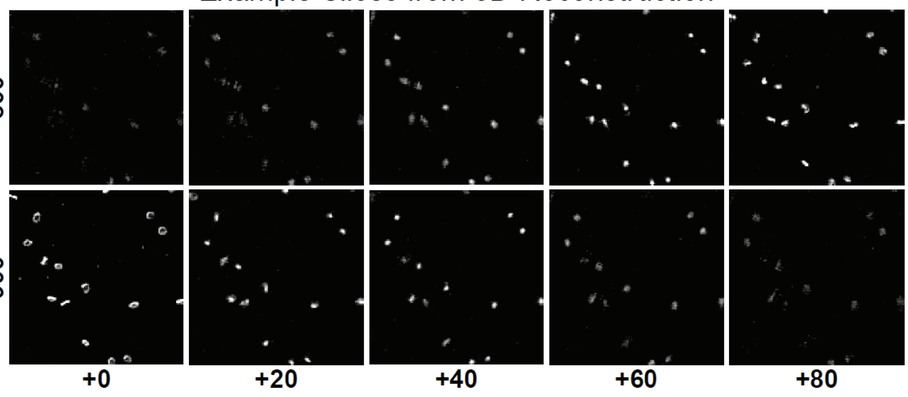


Standard Result | Our Model

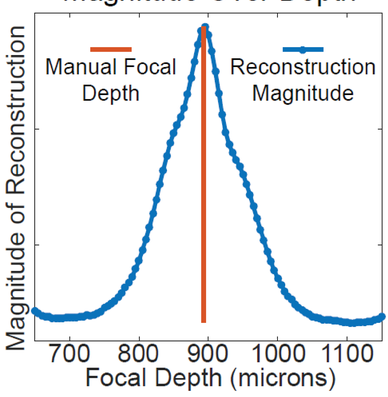
Multi Depth Reconstructions

- **Robustly** finds the focal depth of objects in the specimen.
- Variable updates via alternating accelerated proximal gradient descent.

Example Slices from 3D Reconstruction



Magnitude Over Depth



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