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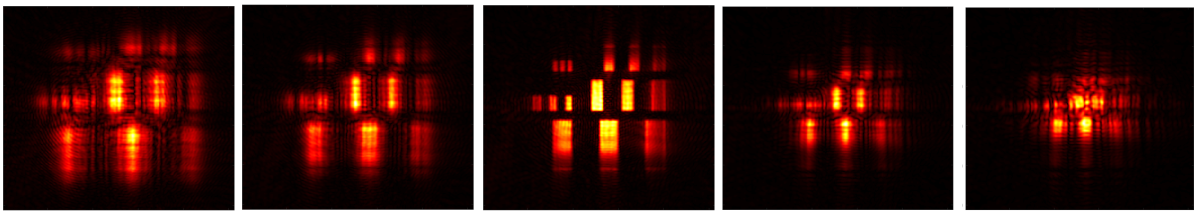
Assignment 1: Phasor-field Non-Line-Of-Sight Imaging

Single-frequency NLOS imaging

Efficient single-frequency RSD propagation

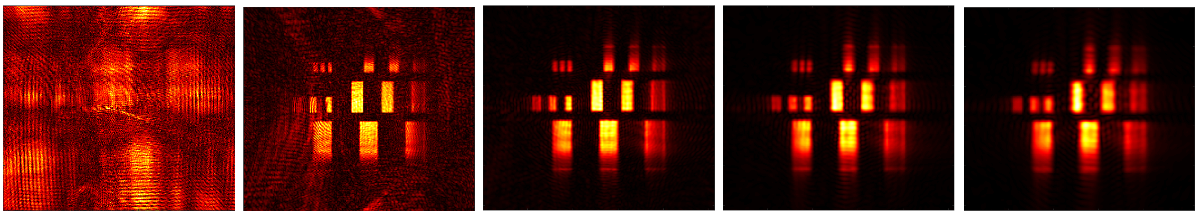
Spatial convolution and the frequency convolution produce identical reconstructions, but the FFT-based implementation is faster because its runtime is independent of the chosen voxel size and it preserves full output quality, but in the frequency convolution it is needed to do the RSD propagation for different focal planes to create a volume reconstruction as the spatial convolution of the last lab. The following results have been tested with $\lambda_c=4\cdot\Delta x$:



z=0.3 z=0.4 z=0.5 z=0.6 z=0.7

Effect of λ_c

Above ($\lambda_c>4\Delta x$) the image blurs, at $\lambda_c=4\ \Delta x$ resolution is optimal and below it ringing artifacts and speckle appear from unsupported high-frequency components. The following results have been tested with z=0.5:

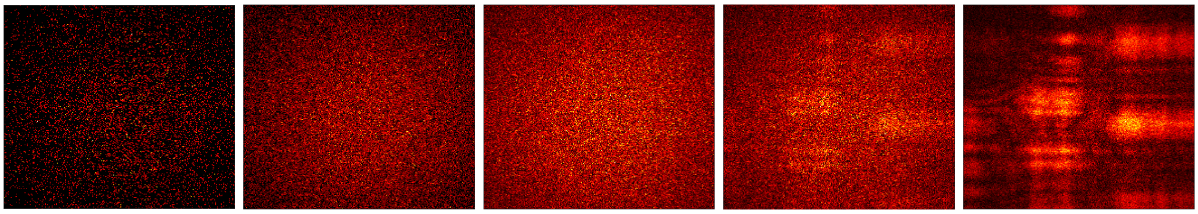


$\lambda_c = 1\cdot\Delta x$ $\lambda_c = 2\cdot\Delta x$ $\lambda_c = 4\cdot\Delta x$ $\lambda_c = 6\cdot\Delta x$ $\lambda_c = 8\cdot\Delta x$

Sensitivity to signal degradation

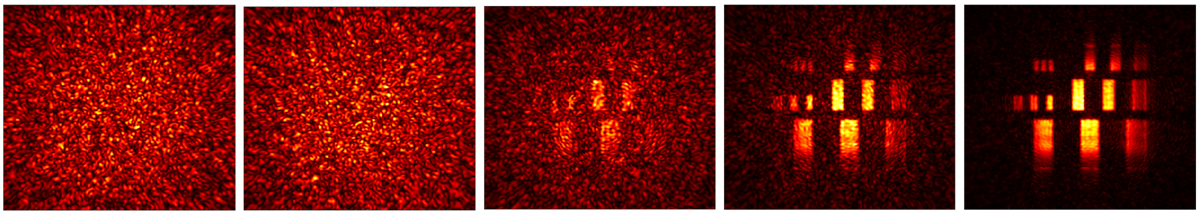
Reconstructing with Poisson-noise photon counts p shows that $p < 10^6$ yields severe contrast loss; $p \approx 10^6$ recovers main features with speckle, while $p \geq 10^7$ matches noise-free quality. The following results have been tested with $\lambda_c=4\cdot dx$ and z=0.5:

H omega:



10k 100k 1M 10M 100M

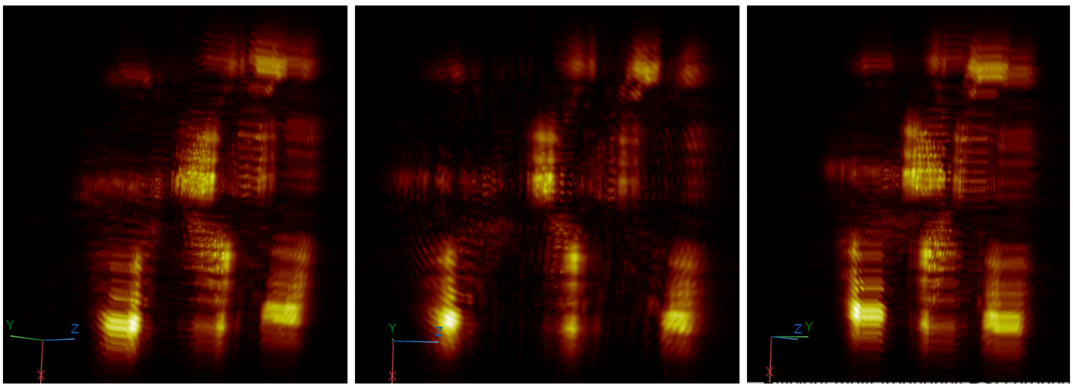
Reconstruction:



10k 100k 1M 10M 100M

Multiple focal planes

It is a reconstruction with 20 slices spanning z = 0.3–0.7 m using the same RSD propagation, shifting the virtual plane for each. Only the slice at z = 0.5 m appears sharply focused; all others show blurred edges and lower contrast. Stacking these into a 3D volume and applying a maximum-intensity projection reveals a bright layer at the object depth.



Left side Front side Right side

Multi-frequency RSD propagation

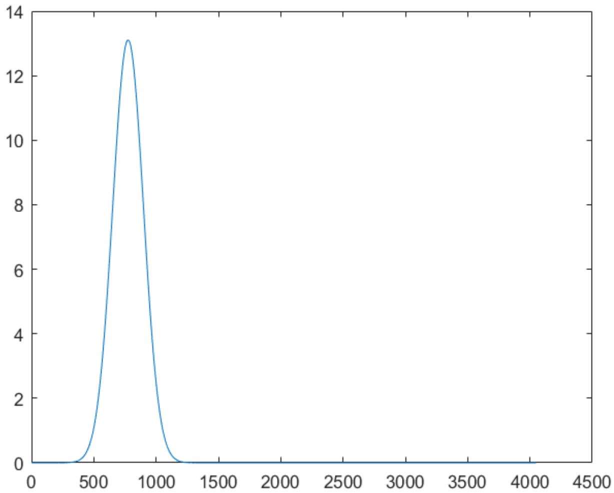
Efficient multi-frequency RSD propagation

By computing the temporal FFT of $H(x_l,x_s,t)$ to obtain $H(x_l,x_s,\Omega)$. For each frequency Ω, we apply two RSD propagations—laser-to-relay and relay-to-virtual plane—by multiplying with the shifted function kernel in the spatial-frequency domain. Summing f(x_v,Ω) over all Ω yields a volumetric backprojection with enhanced depth resolution.

Narrow-band NLOS imaging using virtual pulsed illumination

Computing P(Ω) via FFT of the Gaussian-windowed pulse. Retaining only bins where |P(Ω)| > $1e^{-3}$ (others are negligible), speeding up computation.

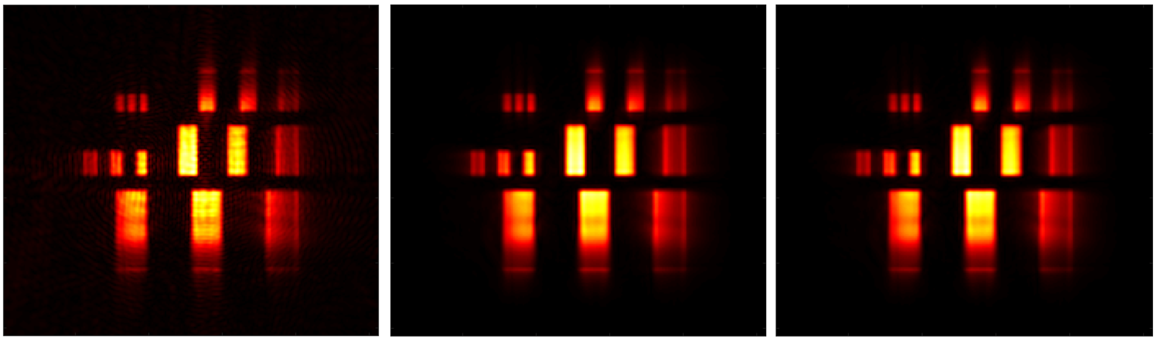
Below is a plot of |P(Ω)| versus FFT frequency-bin indices (from fftfreq), highlighting the bins above the $1e^{-3}$ threshold used for propagation.



Results

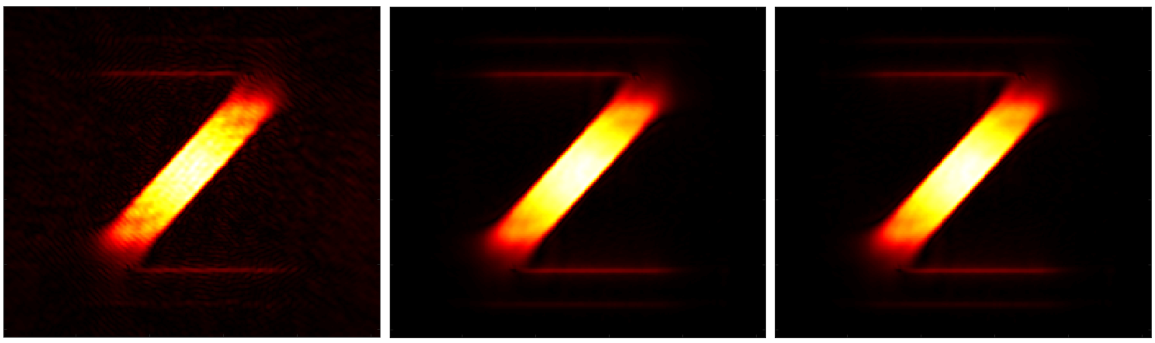
The following results have been tested with the usaf and Z datasets in single frequency (**SF**), multiple frequency (**MF**) and narrow band multiple frequency (**NB**), all with the same parameters $\lambda_c=4\cdot\Delta x$ and z=0.5:

USAF dataset:



SF MF NB

Z dataset:



SF MF NB