Sparse deep computer-generated holography for optical microscopy

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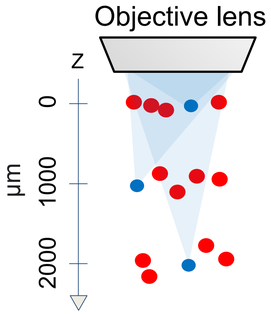
MOTIVATION



Computer generated holography (CGH) applied to optical microscopy is used for photo-stimulation and imaging of multiple neurons in 3D.

Key requirements for CGH-based optical microscopy:

- **Sparse patterns**
- **High contrast**
- **High 3D resolution**

METHODS

- SDCGH utilizes a U-Net in an unsupervised generative approach to create 2D phase masks from targeted 3D intensity patterns. The reconstructed 3D intensity patterns are generated in simulation by using the 2D phase masks as input to the wave propagation model.

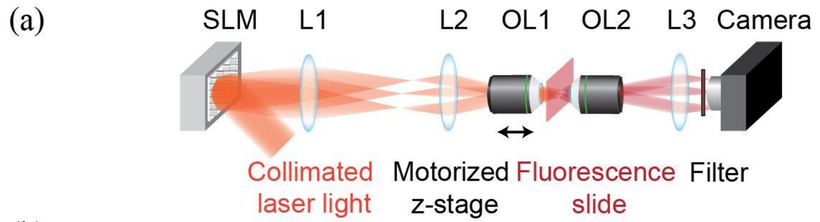
Fraunhofer wave propagation model:

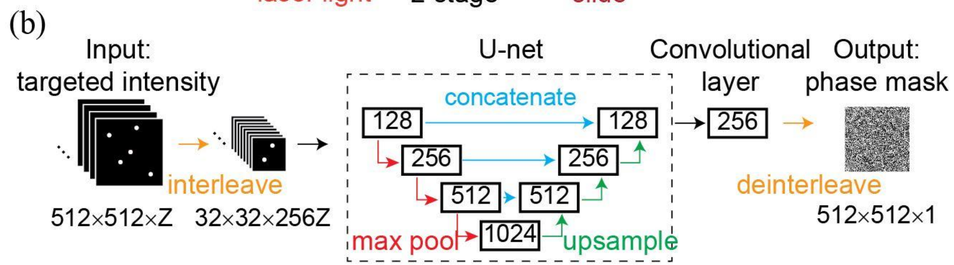
$$P(x,y,z=0) = \frac{1}{i\lambda f}\iint P'_{SLM}(x',y')\exp\left[\frac{-2i\pi(xx'+yy')}{\lambda f}\right]dx'dy'$$

Fresnel wave propagation equation:

$$P(x,y,z) = \frac{e^{ikz}}{i\lambda z}\iint P(x',y',0)\exp\left[\frac{i\pi((x-x')^2+(y-y')^2)}{\lambda z}\right]dx'dy'$$

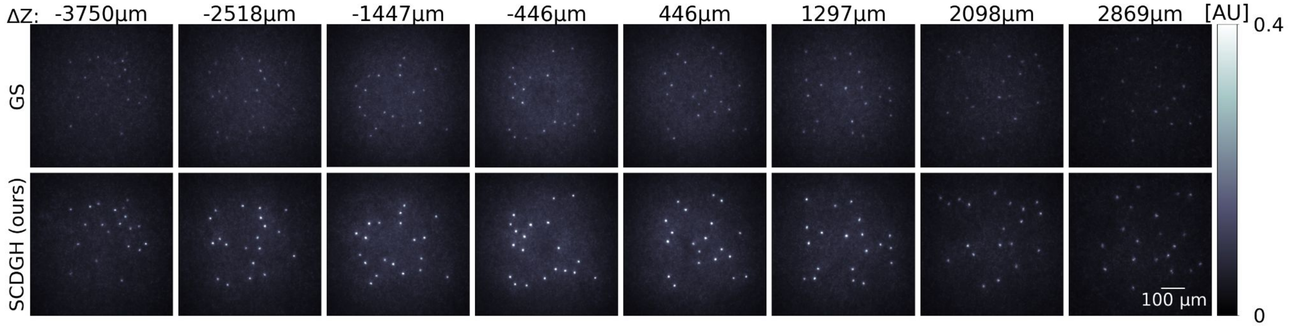
- (a) Schematic diagram of the experimental setup. SLM, spatial light modulator; L, lens. (b) The model architecture.



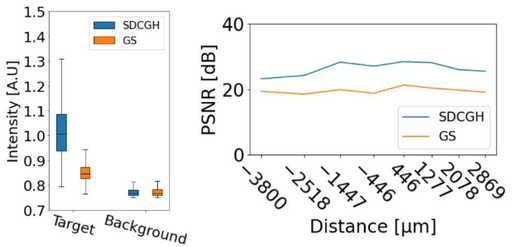


RESULTS

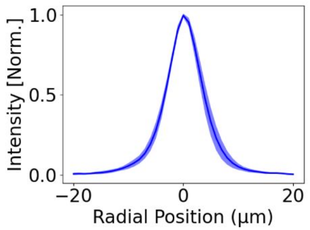
- SDCGH generates 3D intensity patterns with **higher contrast** and performs well across a **large number of z-planes**.



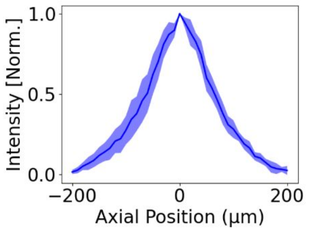
(a) Sparse targets (b) PSNR



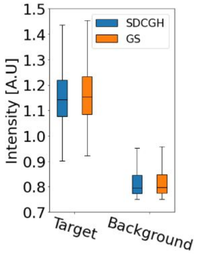
(c) Radial PSF



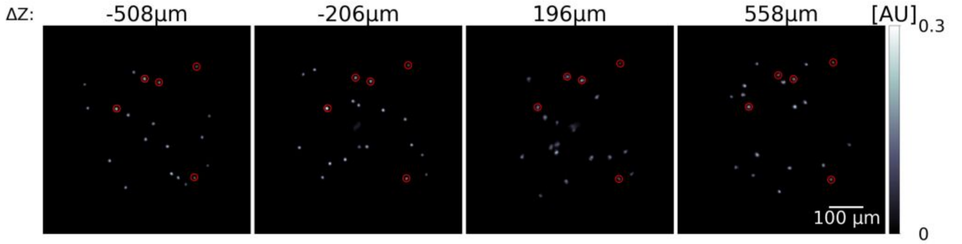
(d) Axial PSF

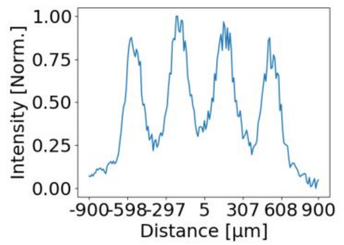


(e) Dense targets



- When points overlap, i.e. have the same (x, y) position across different z-planes, SDCGH is able to generate patterns with **high intensity** on the targeted z-slices while also maintaining desired **low intensity** between defined z-slices.





1. A. Liu, L. Waller, Y. Xue, Sparse deep computer-generated holography for optical microscopy. *arXiv [physics.optics]* (2021), (available at http://arxiv.org/abs/2111.15178).