Beam Me Up: Implicitly Learned Neural Phase Functions for Point Spread Function Engineering in Optogenetics

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Introduction

- Recently, non-invasive neural stimulation has become a key goal in optogenetics
- Near-infared (NIR) lasers can penetrate deep within the brain
- Spatial light modulator (SLM) in a 4f optical system controls how light focuses by engineering the system's point spread function (PSF) (Fig. 1)

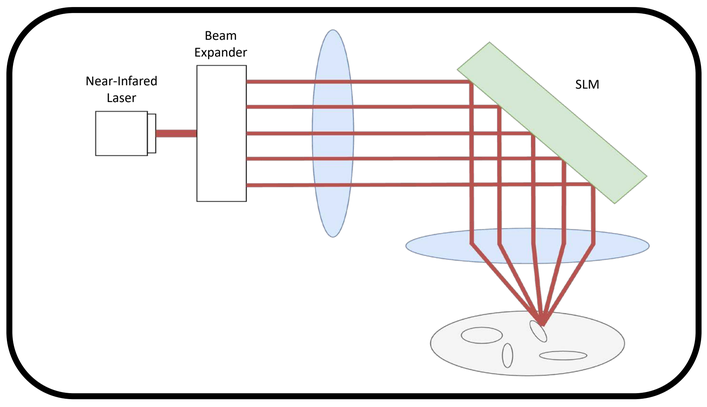

Figure 1. Simplified optogenetics setup with 4f system.

Methods

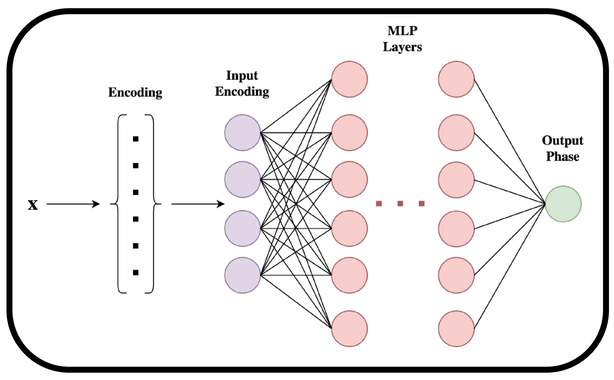

Figure 2. MLP architecture.

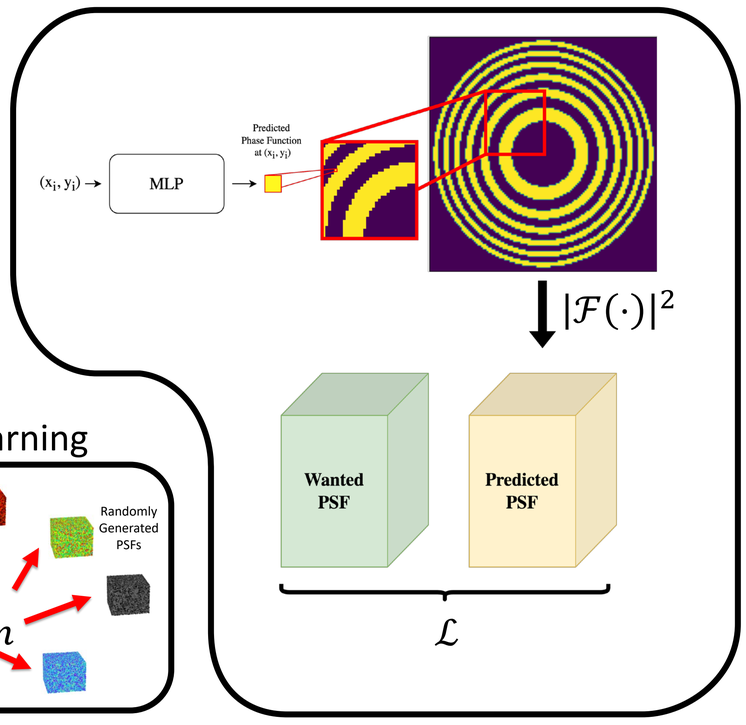

Figure 3. Model training structure.

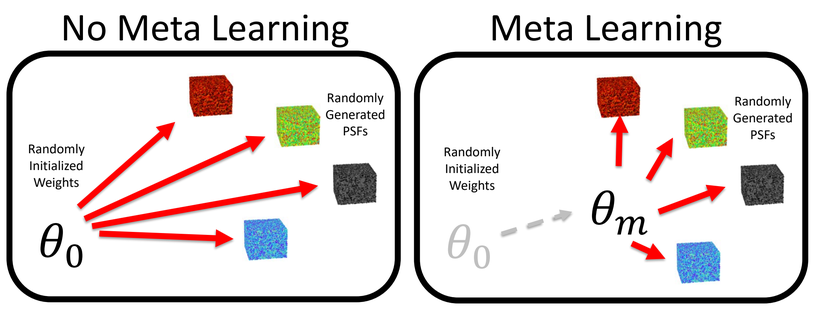

Figure 4. Meta-learning improves weights initialization.

Results

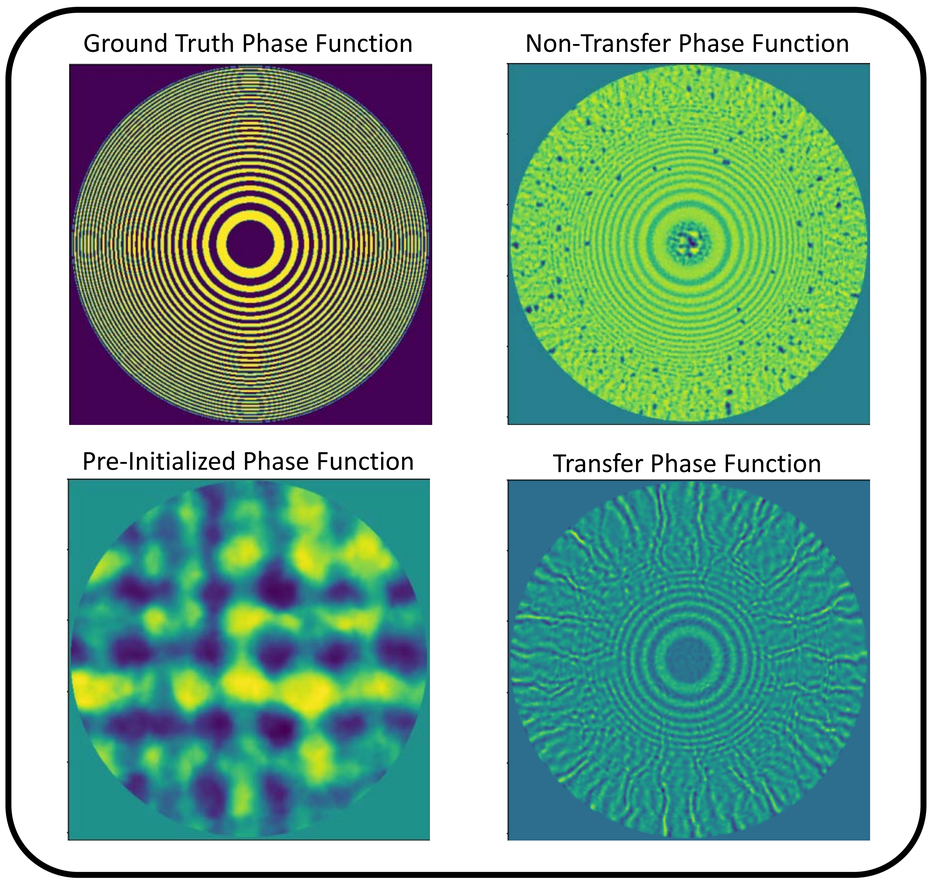

Figure 5. Comparison of multi-focal phase functions learned with different learning types.

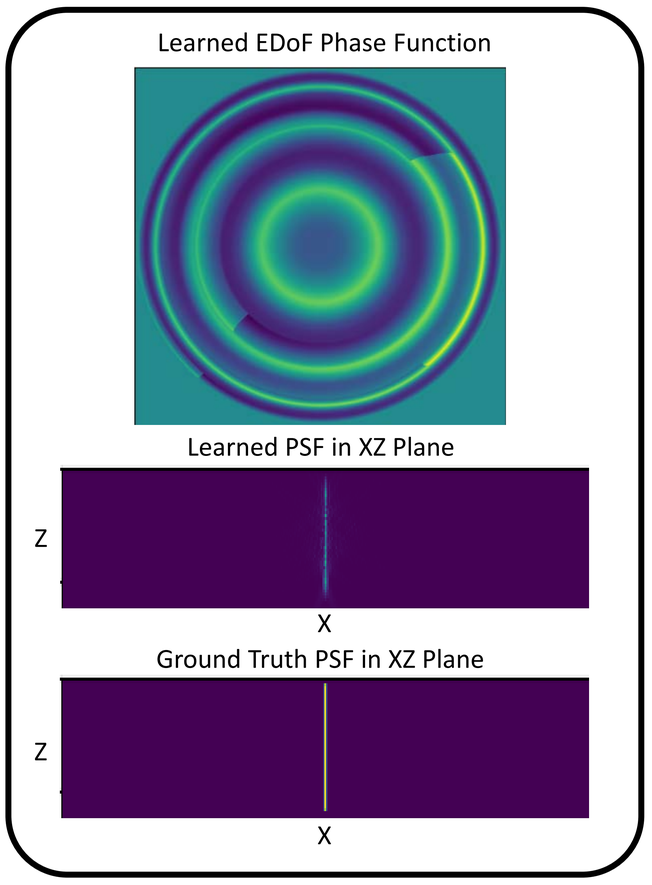

Figure 6. Model learns an ideal extended depth of field (EDoF) PSF.

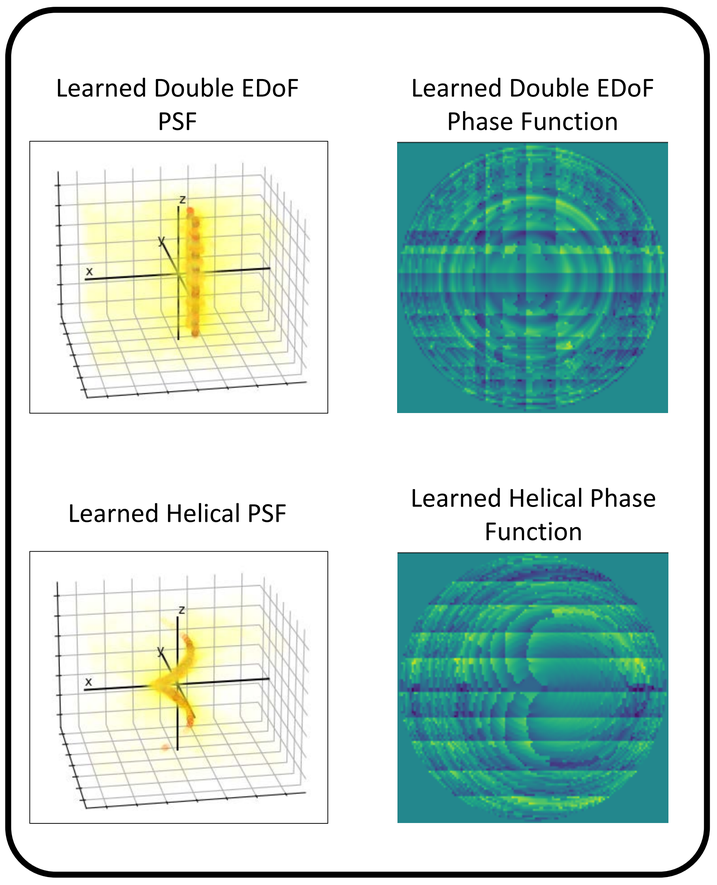

Figure 7. Model learns arbitrary PSFs.

Discussion & Conclusions

- Our implicit neural representation approach succeeds in learning both provided pupils and ideal PSFs (Fig. 5-6).
  - We further show that our method is very robust and is able to learn arbitrary PSFs (Fig. 7).
- Our transfer learning approach reduces noise in the learned pupil (Fig. 5).
- **Next Steps**
  - Transfer learning shows significant promise due to better convergence and reduced training time.
  - With a strong initialization it may be possible to produce PSFs in real-time in order to adapt to rapidly changing conditions.
  - Since the problem of phase retrieval is very ill-posed, the loss landscape of the neural network is highly oscillatory. An adversarial approach (i.e. using a discriminator network) to model training may improve convergence and yield better results.
  - Progressively increasing the predicted grid resolution may also improve convergence by encouraging model to learn major features first.

References

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