

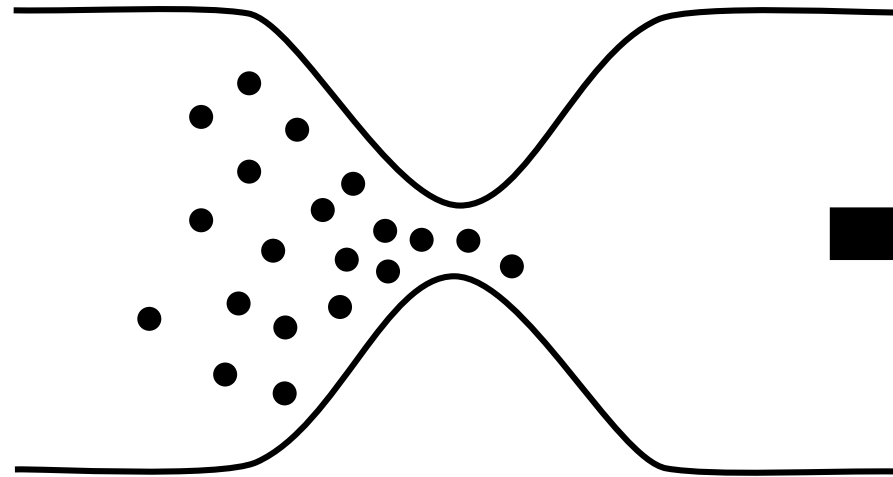
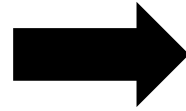
3D fluorescent microscopy at kilohertz volume rate

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Pipeline of compressive imaging

Bottleneck from the optoelectronic device bandwidth
e.g. 800M Pixels/second

Optical
encoding



Computational
decoding



High-dimension datacube



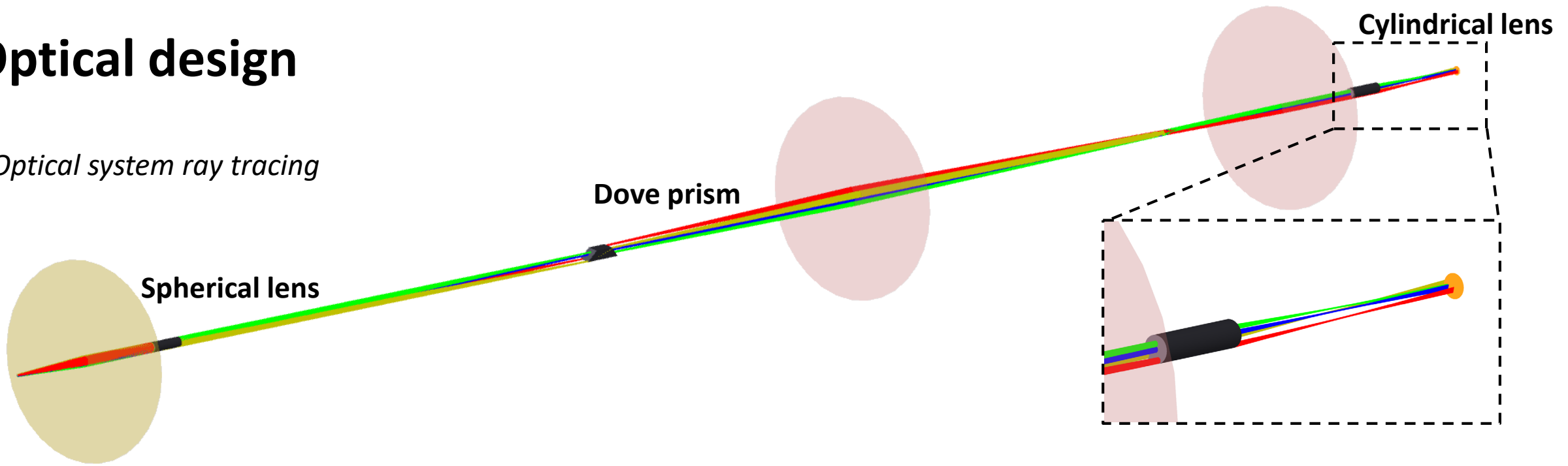
Compressed/Encoded data



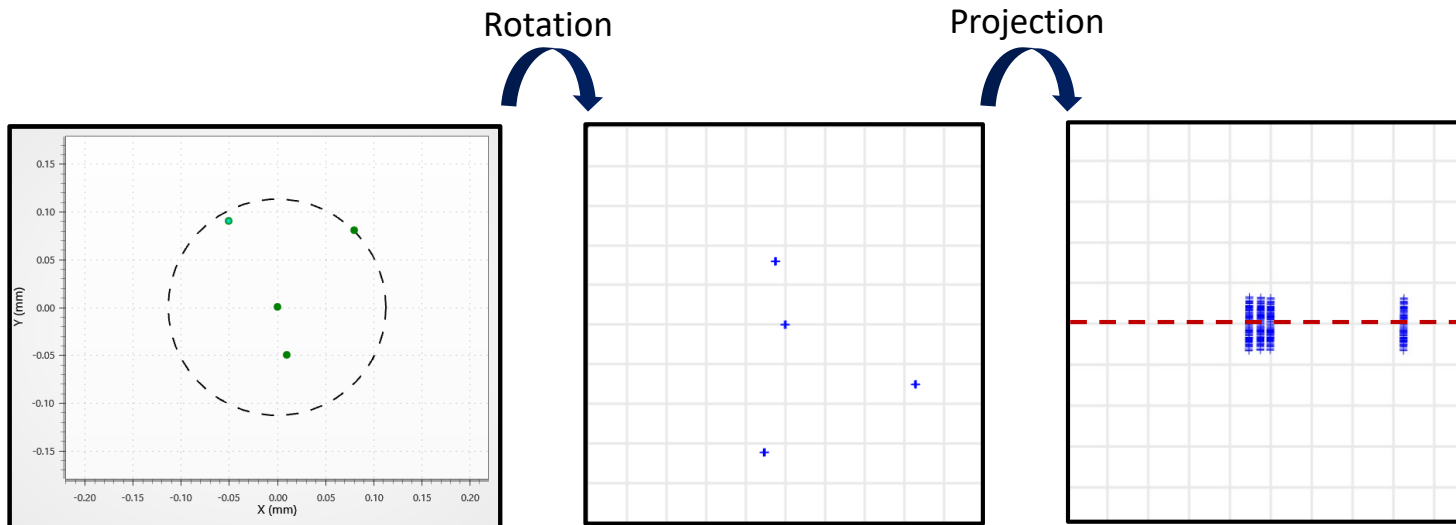
Reconstructed high-dimension datacube

Optical design

Optical system ray tracing

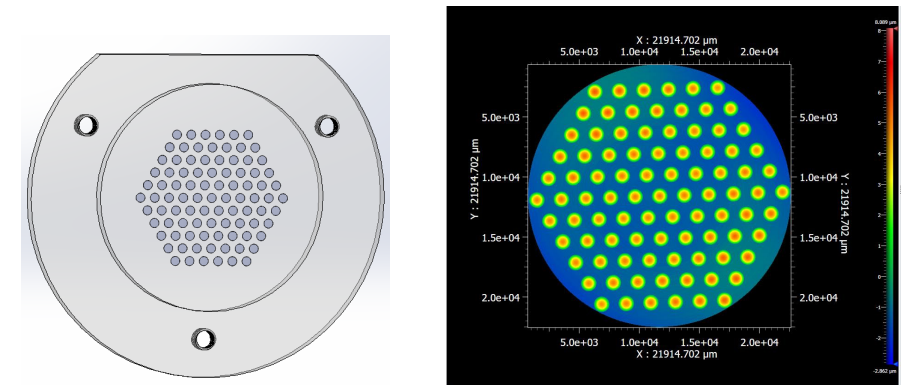


1. Image transformation using optical components



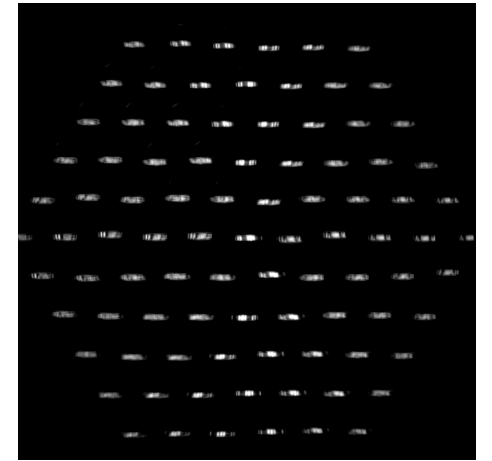
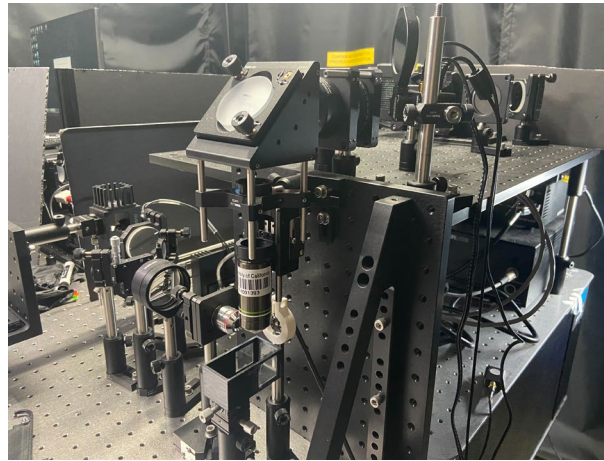
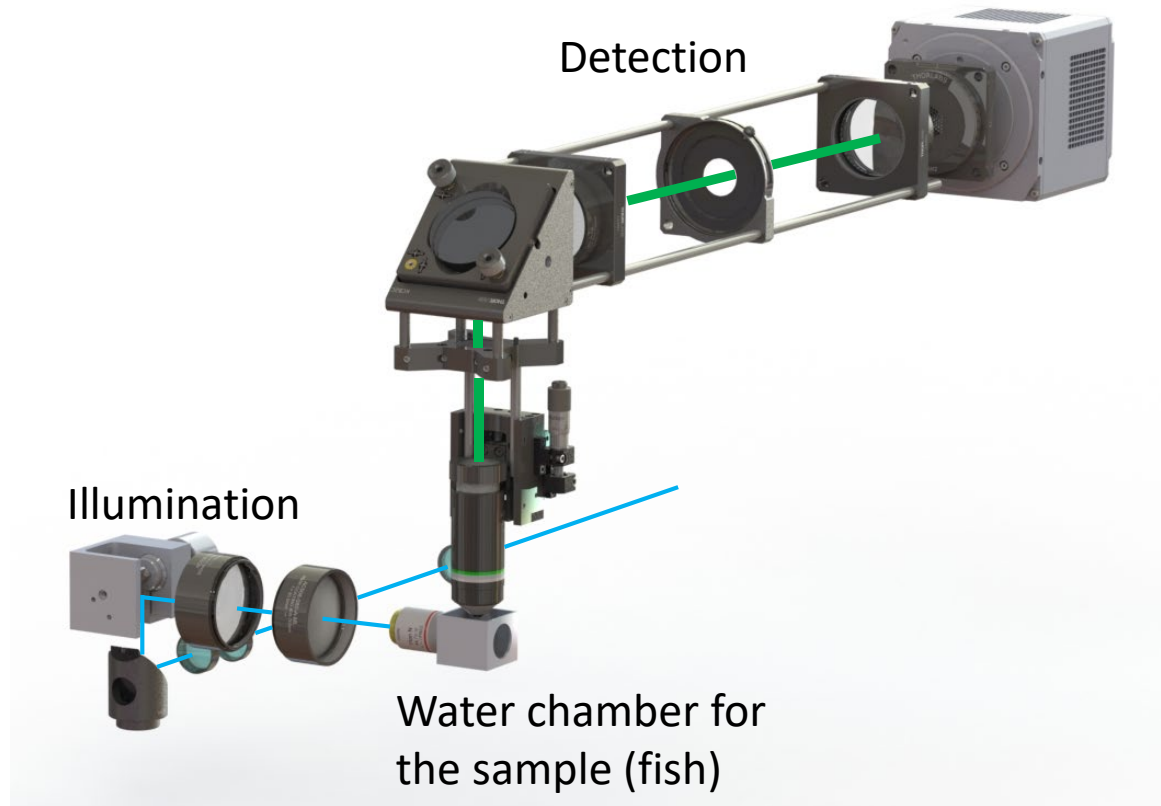
Enable data reduction

2. Lens array fabrication



Enable 3D imaging

Optical system



System parameter	
Field of view (3D)	$450 \times 450 \times 200 \mu m^3$
Spatial resolution (sampling)	$2.32 \mu m$
Temporal resolution	$\sim 8000 \text{ Vols/s}$

Reconstruction algorithm

$$\min_x \|\phi(x)\|, \text{ subject to } b = Ax$$

ϕ is the image prior term; b is the measurement; A is the optical system forward model; x is the solution (e.g., 3D image).

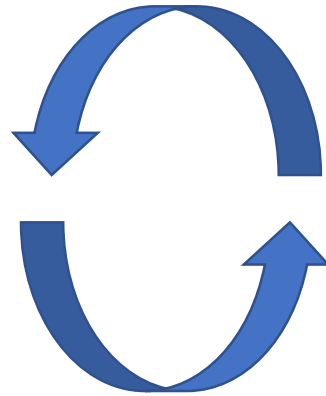
Reconstruction algorithm

$$\min_{x,z} \frac{1}{2} \|x - z\|_2^2 + \lambda \|\Phi(z)\|, \text{ subject to } b = Ax$$

Step 1 Ensure data fidelity

$$\min_x \frac{1}{2} \|x - z\|_2^2, \text{ subject to } b = Ax$$

$$\begin{aligned} x^t &= z^{t-1} + A^T (AA^T)^{-1} (b - Az^{t-1}) \\ &= \text{Projection}(z^{t-1}, b, A) \end{aligned}$$



Step 2 Denoising according image priors

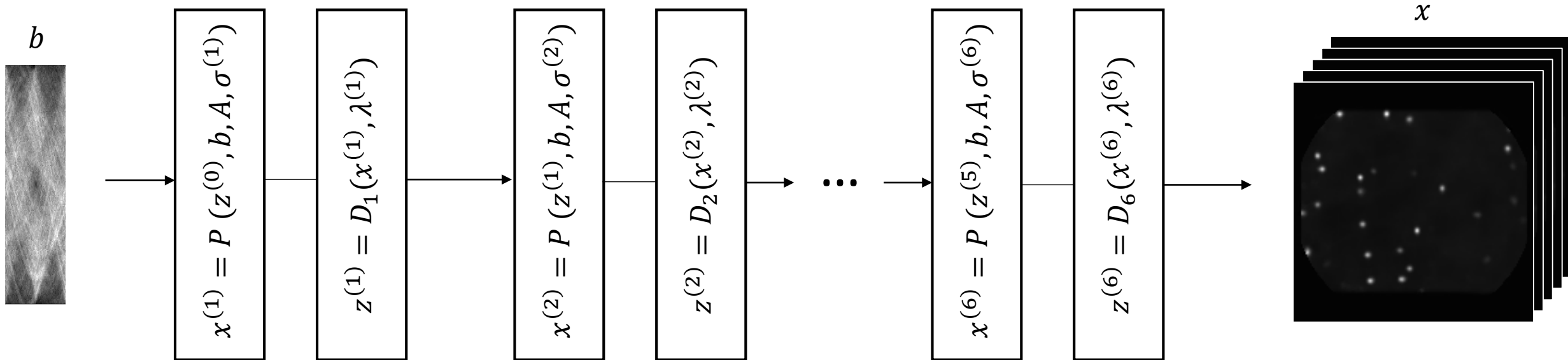
$$\min_z \frac{1}{2} \|x - z\|_2^2 + \lambda \|\Phi(z)\|$$

$$z^t = \text{Denoise}(x^t, \lambda)$$

Iterative optimization to approach the solution x

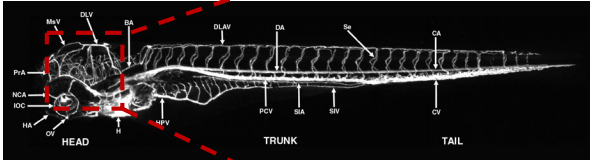
Reconstruction algorithm

Unfold the iterations to add explicit image model constraint to learning-based method

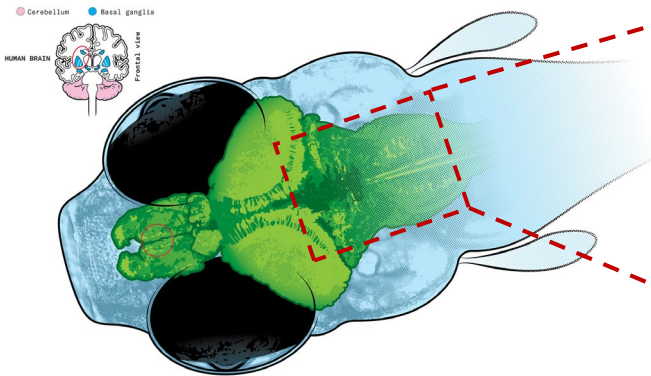
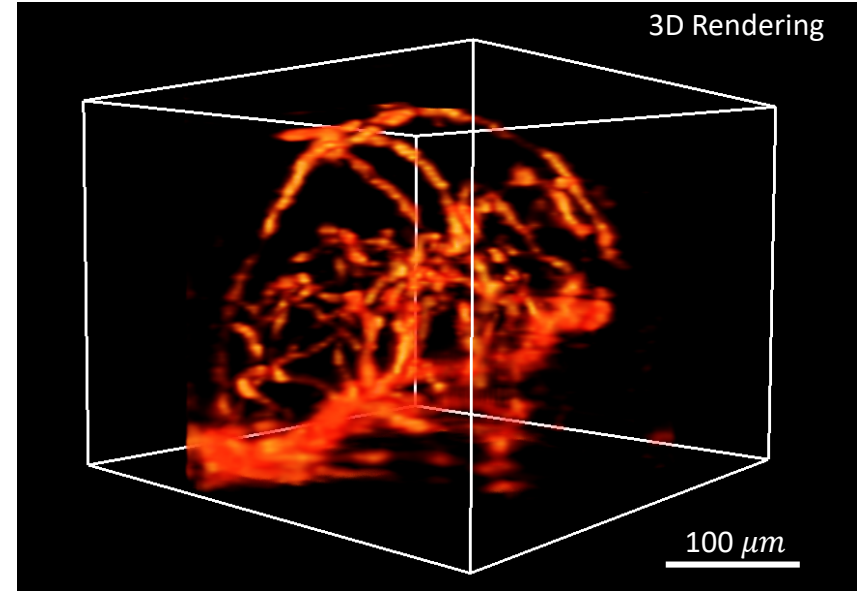
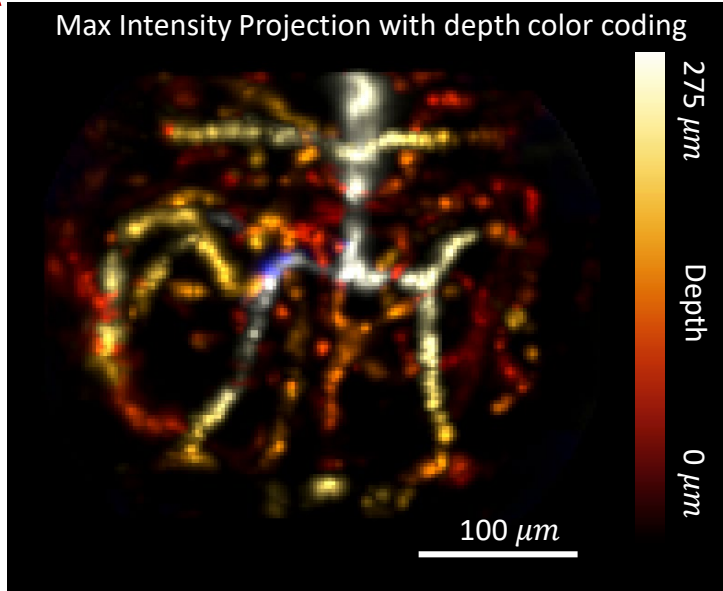


1. Each denoiser D_i is a 2D U-Net with skip connections
2. The x is concatenated with a noise map before denoiser
3. End-to-end training on experimentally acquired data pairs via our home-built system

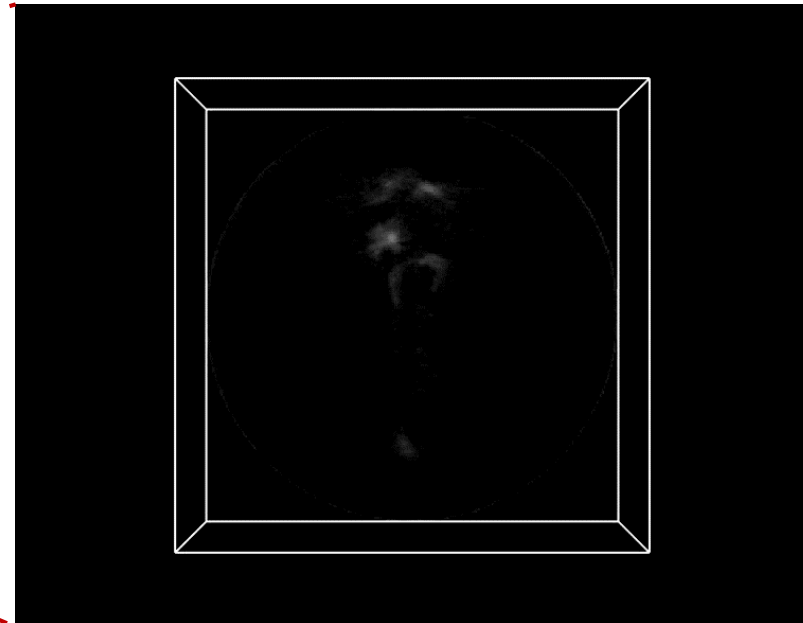
Preliminary results



Tg(flk:mCherry) @ 3dpf
Vasculature



Tg(Elavl3:GCaMP6f) @ 5dpf
Neurons



UCLA

Samueli
School of Engineering

Thank you!