

Dictionary-based phase retrieval for space-time super resolution using lens-free on-chip holographic video

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Northwestern
ENGINEERING



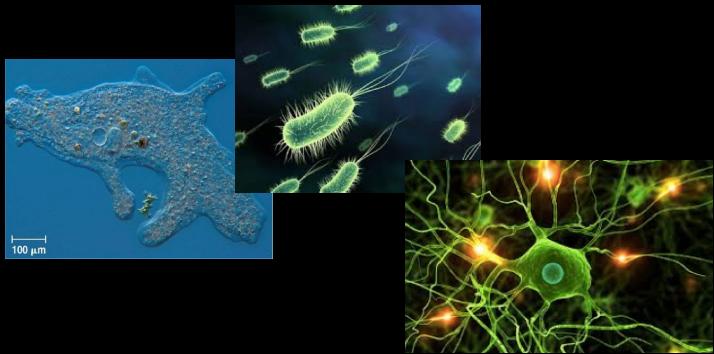
comp



photo



lab



non-invasive

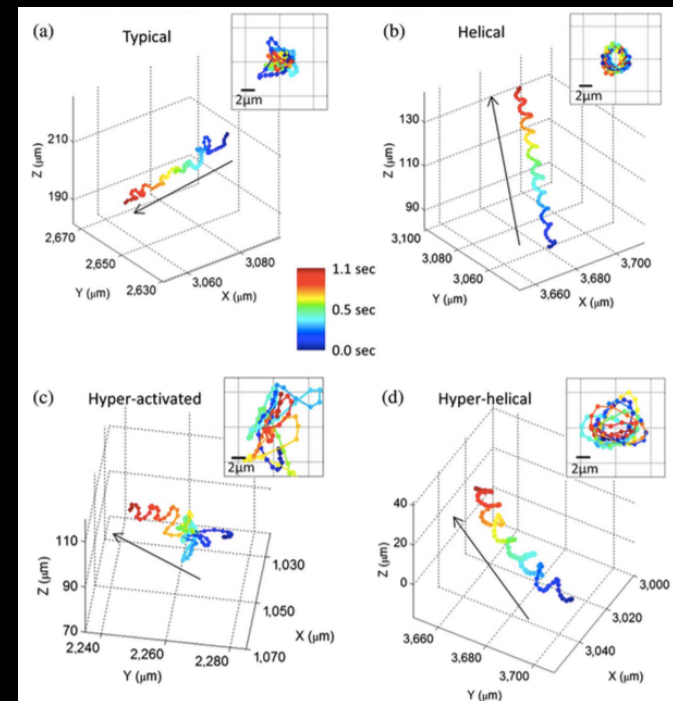
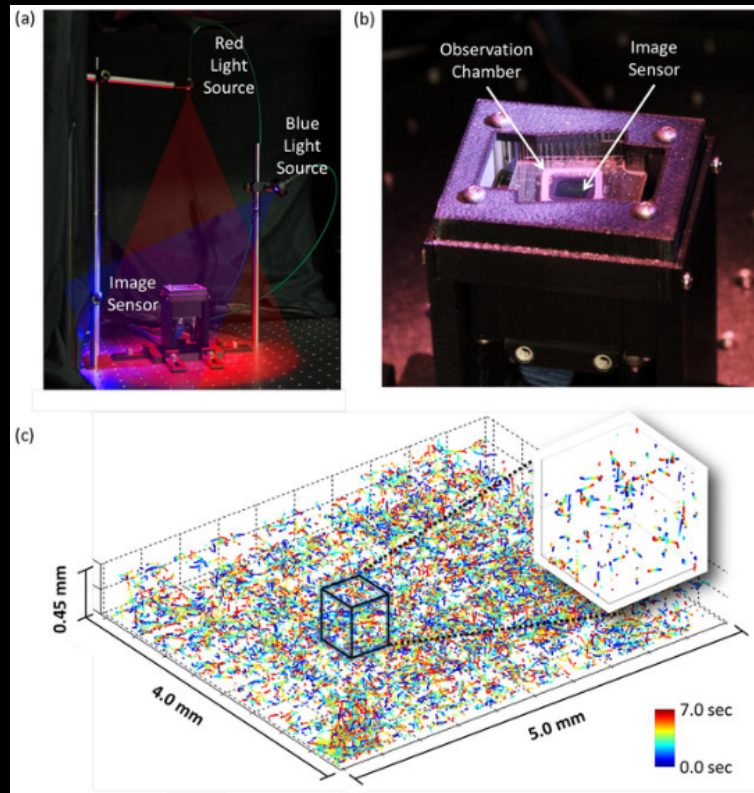
large field-of-view



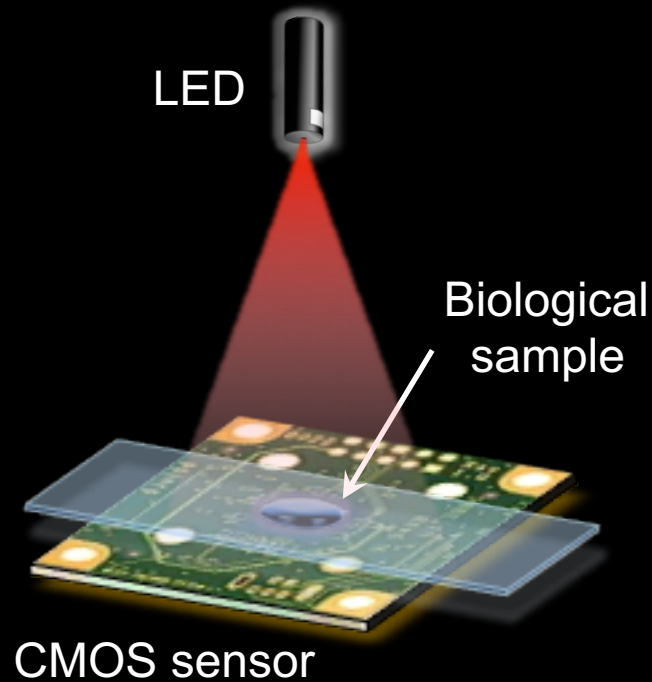
high speed

localization

sperm, protozoa, etc.



lens-free on-chip video



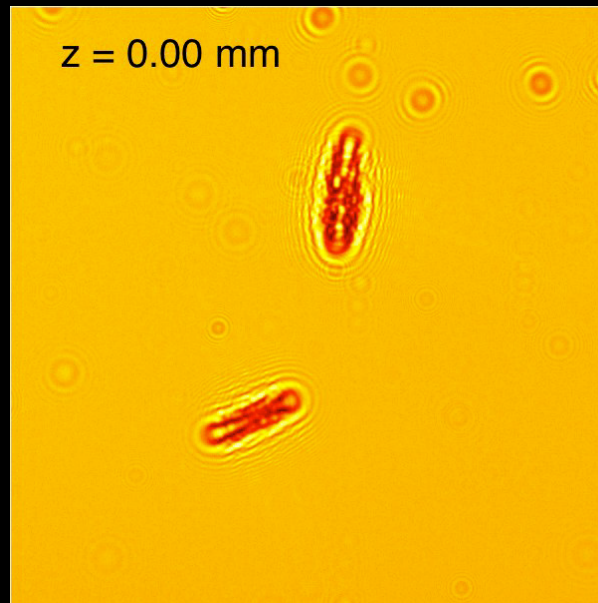
Blepharisma



large Field-of-View, compact, cost-effective
2.2x2.2 μm pixel resolution

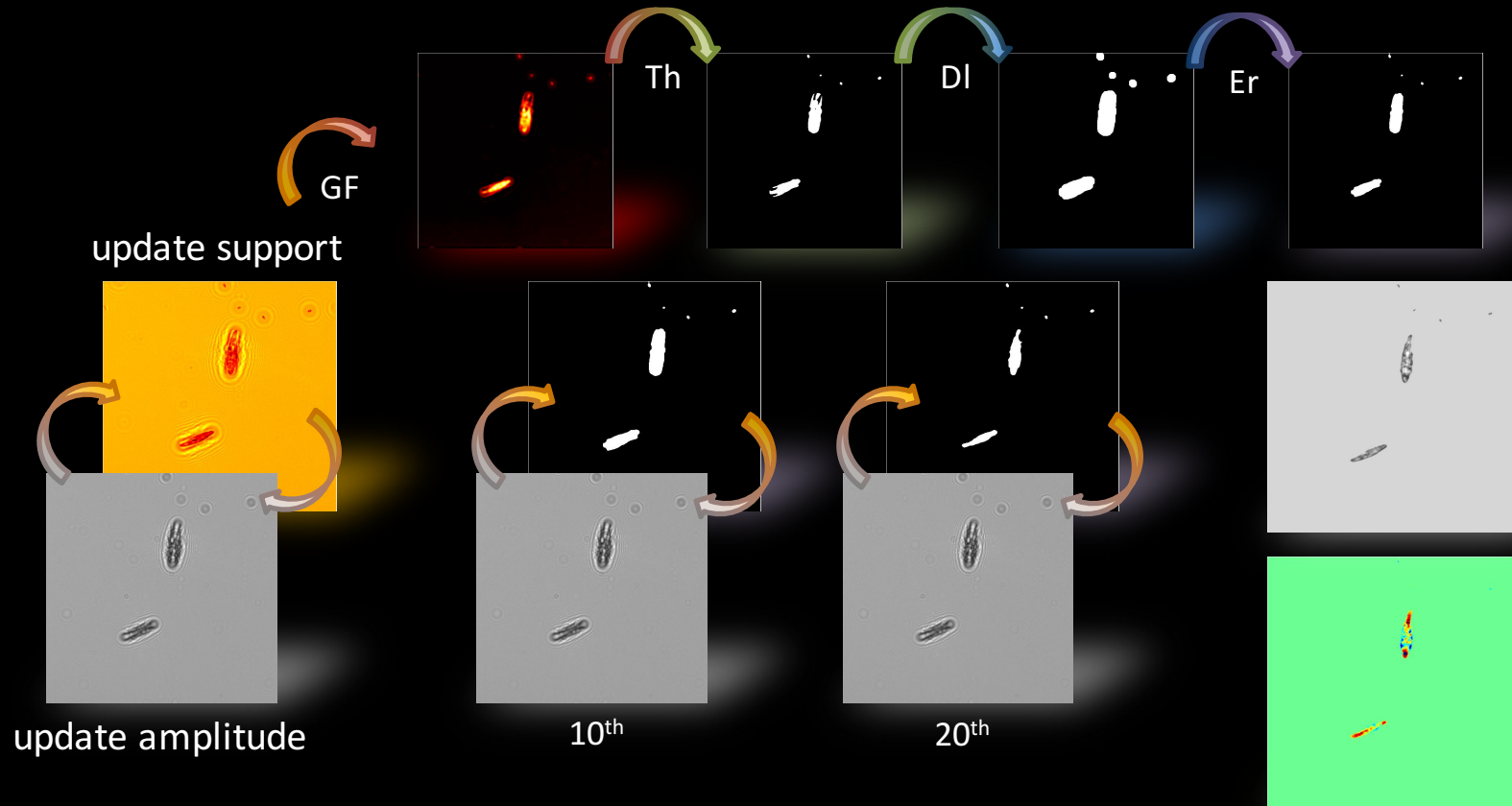
from hologram to object – phase retrieval

$$\text{back propagation } H(x,y;z) = \mathfrak{F}^{-1} \left\{ \mathfrak{F}\{E(x,y)\} [k_x, k_y] \exp [iz\sqrt{k^2 - k_x^2 - k_y^2}] \right\} [x,y]$$



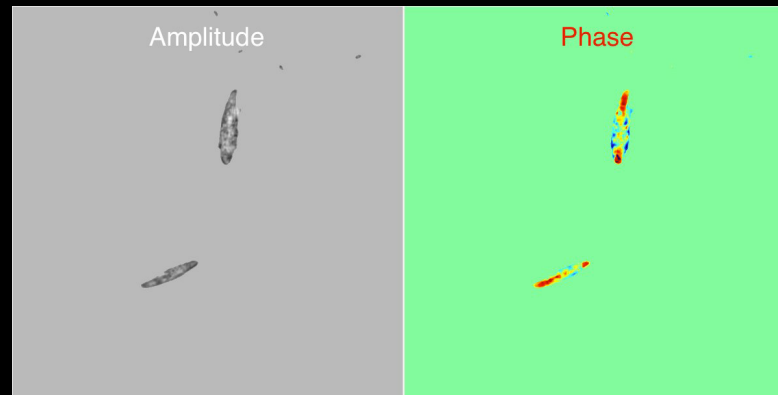
refocusing

from hologram to object – phase retrieval

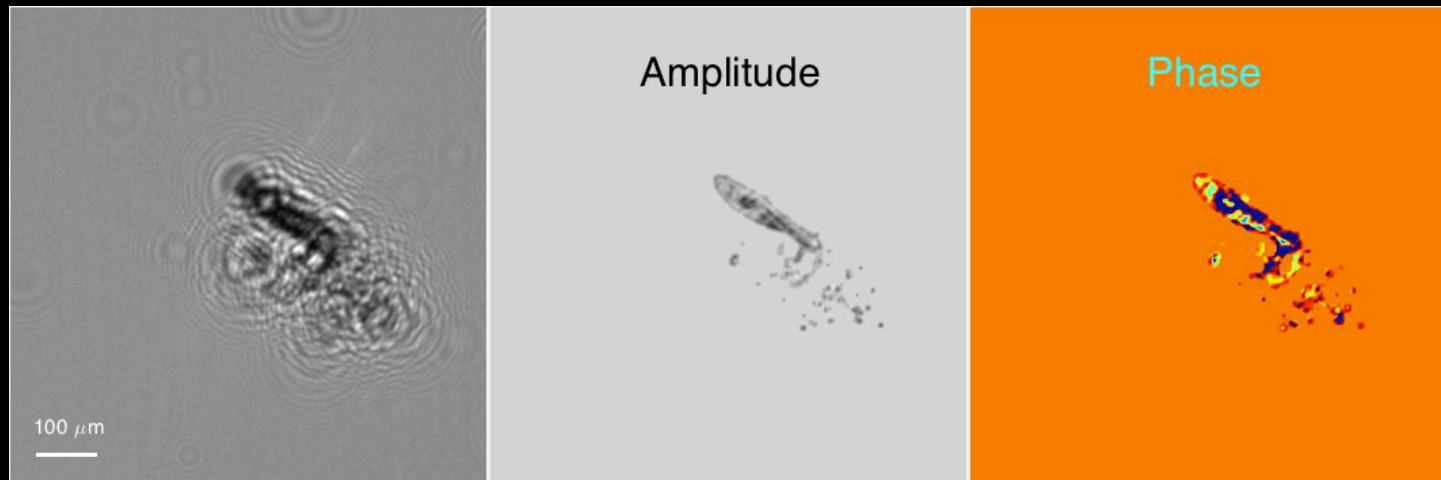


GF: Gaussian Filtering Th: Thresholding DI: Dilation Er: Erosion

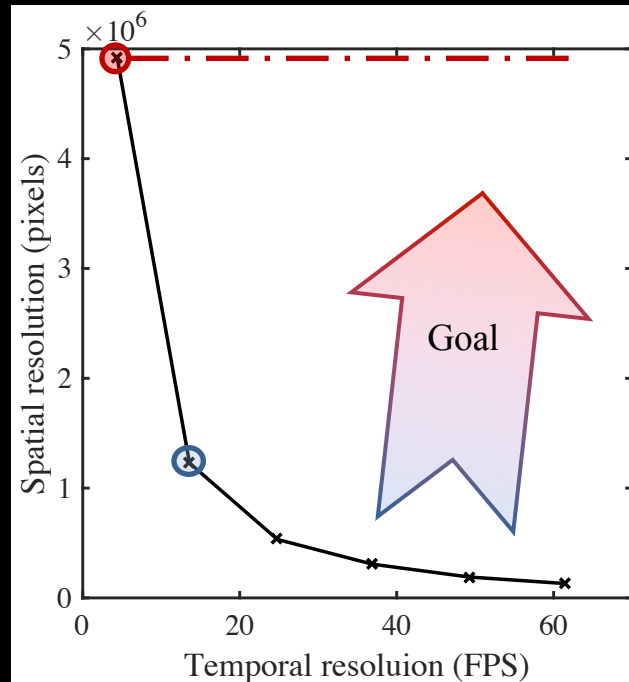
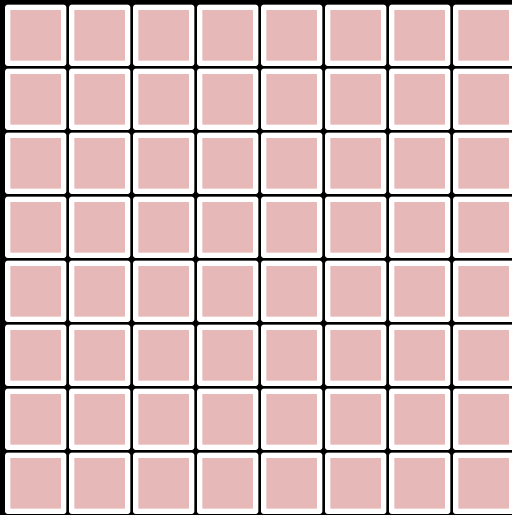
Blepharisma



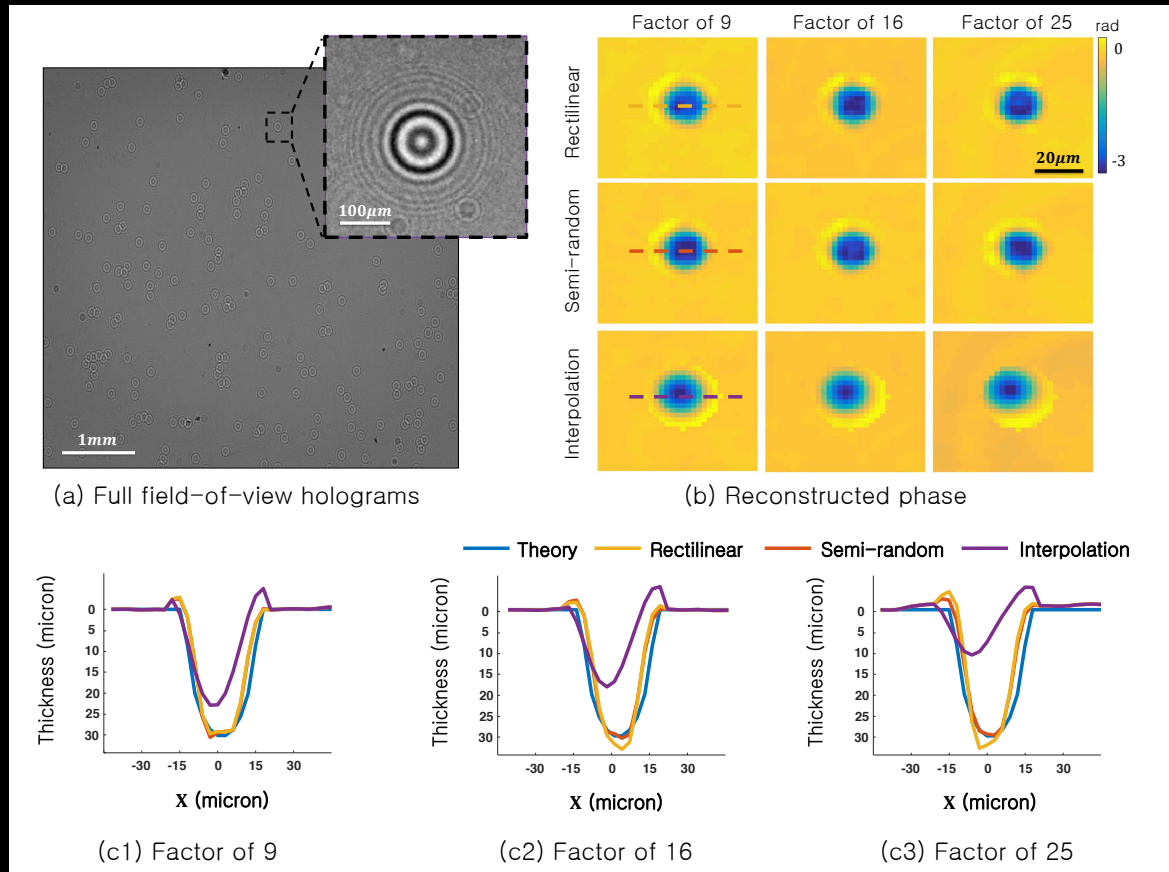
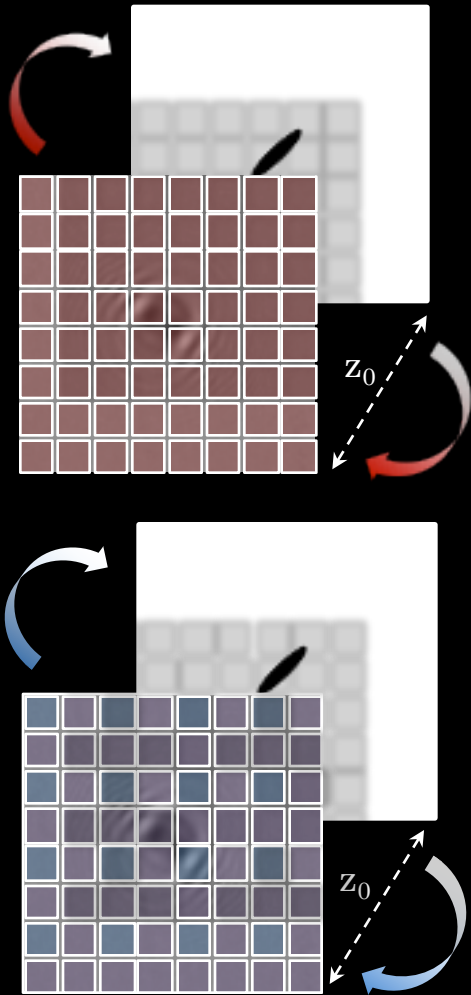
Paramecium



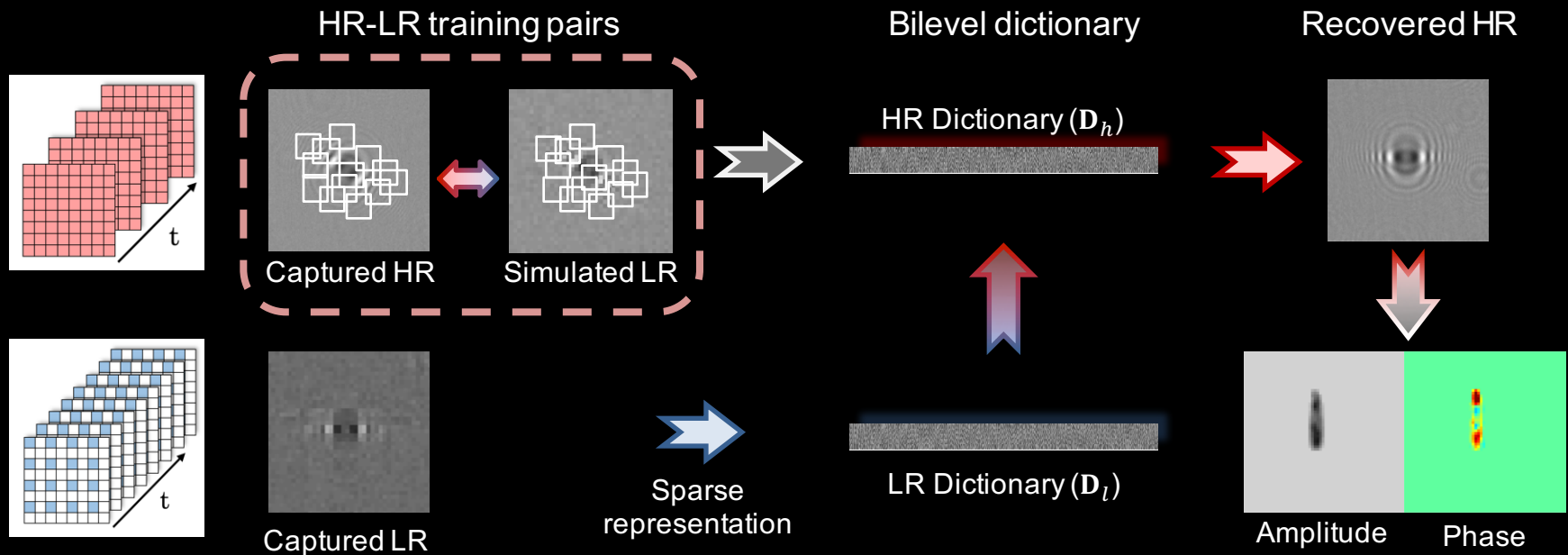
temporal resolution enhancement



subsampled phase retrieval

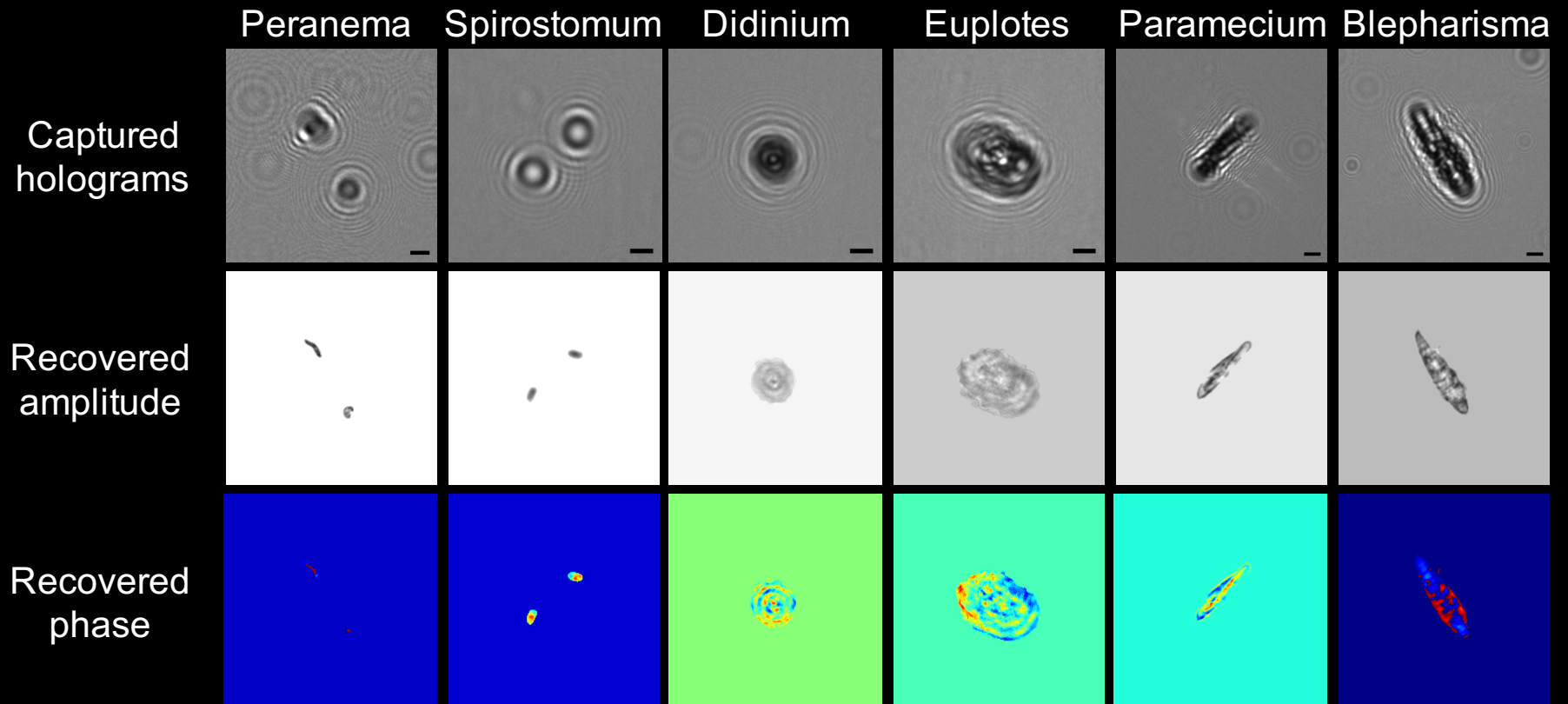


lens-free on-chip dictionary?

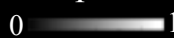
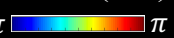


$$\begin{aligned} & \min_{\mathbf{D}_l, \mathbf{D}_h} \sum_{i=1}^N \frac{1}{2} \|\mathbf{H}_i - \mathbf{D}_h \alpha_i^H\|_2^2 \\ & s.t. \alpha_i^H = \arg \min_{\alpha_i^L} \frac{1}{2} \|\mathbf{L}_i - \mathbf{D}_l \alpha_i^L\|_2^2 + \lambda \|\alpha_i^L\|_1 \\ & \|\mathbf{D}_h(:, k)\|_2 \leq 1, \|\mathbf{D}_l(:, k)\|_2 \leq 1, k = 1, \dots, m \end{aligned}$$

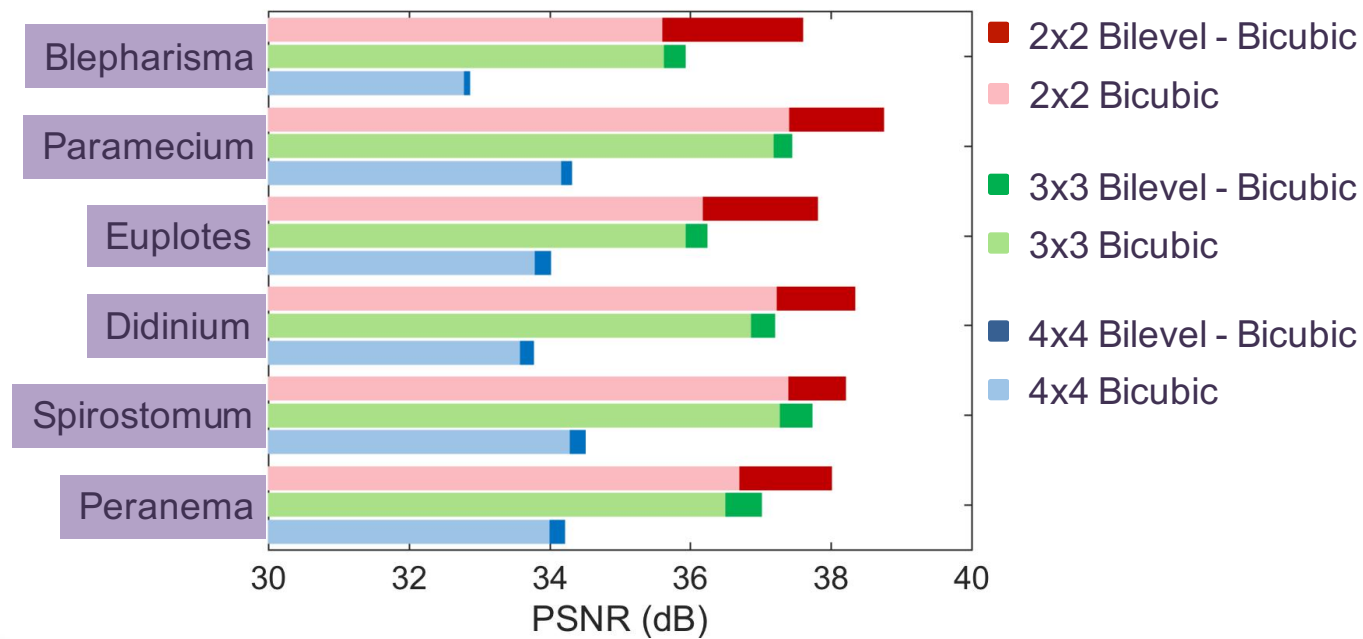
data collection



$44\mu\text{m}$ Amplitude Phase (rad)

 0  1 $-\pi$  π

results – numerical subsampling



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Full resolution

2x2

3x3

4x4

SPR

PSNR

23.31

23.04

21.20

20.65

20.01

19.92

Bicubic

PSNR

23.52

24.00

21.62

22.28

20.02

21.36

Bilevel

PSNR

28.62

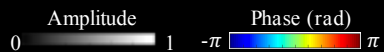
25.78

25.57

24.04

21.60

21.93



results – experimental videos recovery

2x2



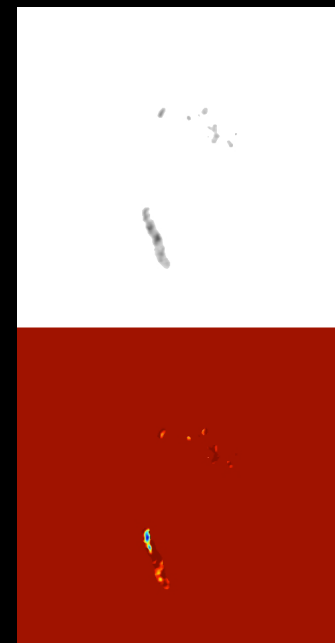
13.6 FPS

3x3



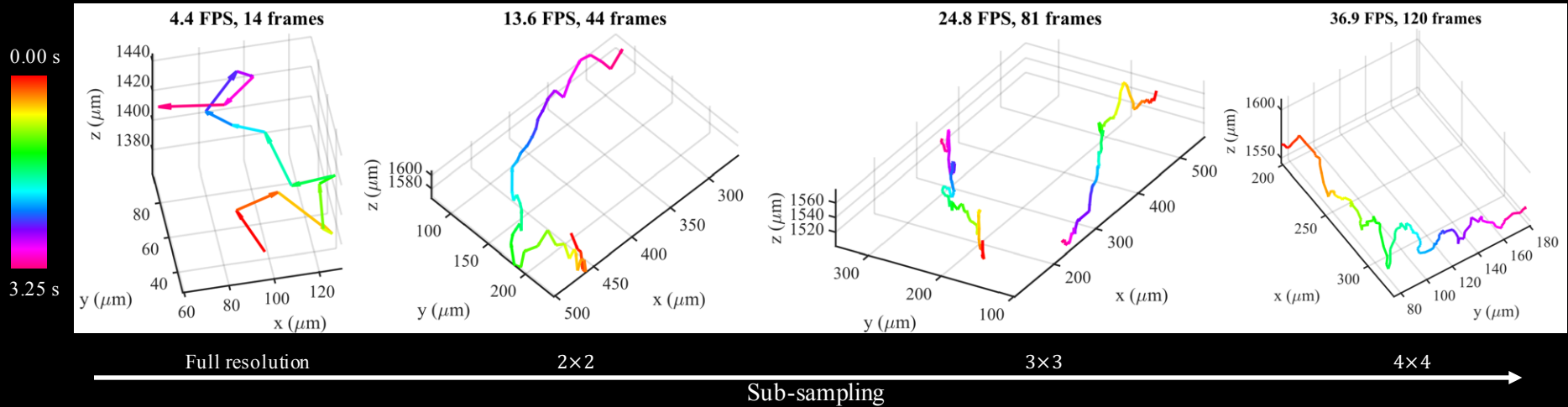
24.8 FPS

4x4



36.9 FPS

results – 3D tracking of Euglena



summary

- used holographic lens-free on-chip video for monitoring in vivo biological samples;
- used single frame subsampling for temporal resolution enhancement;
- constructed a bilevel dictionary for recovering subsampled holograms;
- performed phase retrieval on recovered holograms;

Thanks for your attention!

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