Label-free imaging of refractive index
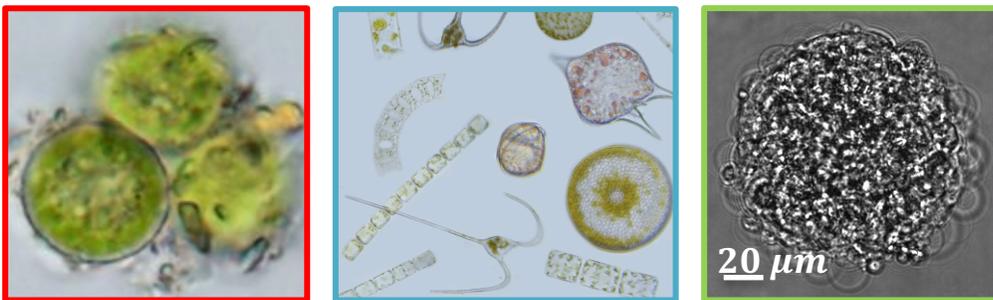
Snow algae[1,2]

Phytoplankton[3]

$20\ \mu m$

Organoid Development[4]

Climate modeling

Imaging System

Collimated, expanded light source

Objective Pupil Plane $P(k)$

Camera $y(r)$

Phase Spatial Light Modulator at Fourier Plane $M_i(k)$

Sample $x(r)$

2D angle-scanning mirror

Objective lenses (0.8 NA, 50x)

Linear polarizer

Pixel

Zernike

Defocus

Formulate as an optimization problem to solve:

$$x(r)^* = \mathrm{argmin}_{x(r)} \left| \left| \mathcal{F}^{-1}\{M_i(k)P(k)\mathcal{F}\{S_i\{x(r)\}\}\} \right| - \sqrt{y_i(r)} \right|_2^2$$

Combine pupil coding and classic tomography system to reduce required data

Measured images are more varied with pupil coding

Limited Illumination Angles
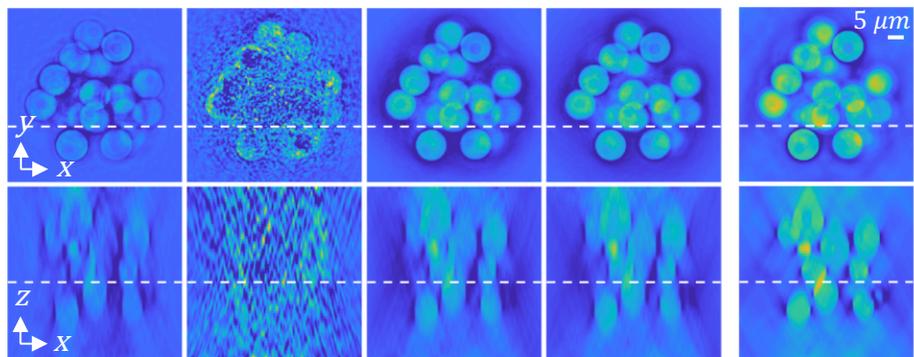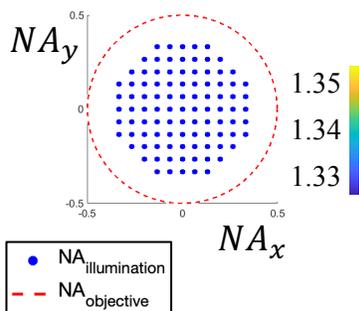
NA_y

NA_x
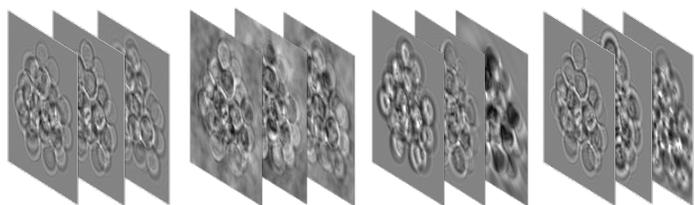
No coding   Pixel   Zernike   Defocus

NA-filtered Ground Truth

$5\ \mu m$

y, x

z, x

- NA$_{illumination}$
- NA$_{objective}$

1.35
1.34
1.33

Data reduced by 45%

Cast as machine learning problem to optimize pupil coding

Learnable pupil coding θ

Images $y^{(n)}$

Volume $x^{(N)}$

1st   2nd   ...   Nth $\mathcal{L}$

Ground Truth

[1] Kvíderová, Jana. (2012). Czech Polar Reports. 2. 8-19. 10.5817/CPR2012-1-2. [2] Dr. Chaincy Kuo, LBNL [3] Dr. Colleen Durkin, MLML [4] David Allen Joy & Dr. Todd McDevitt, UCSF