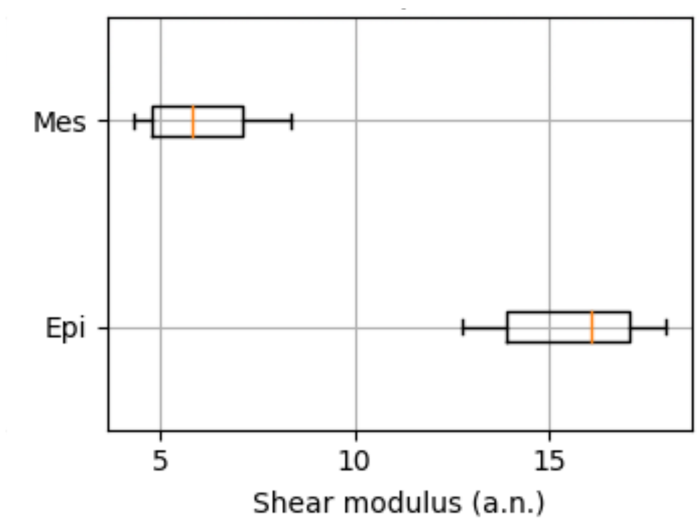
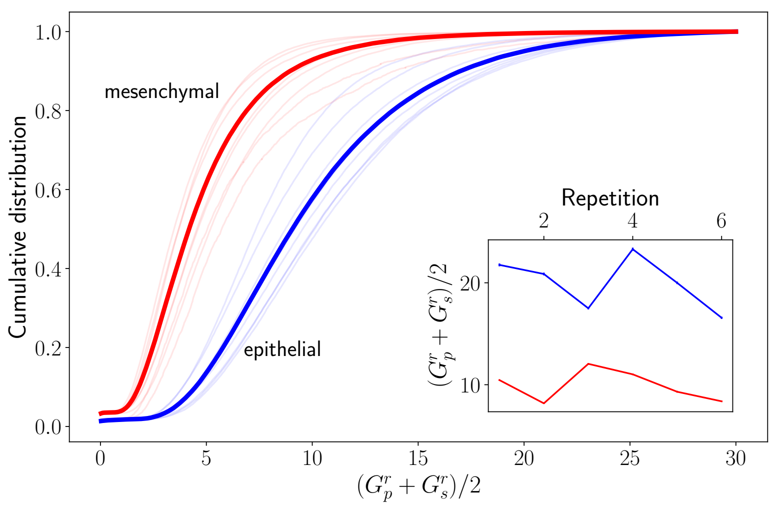
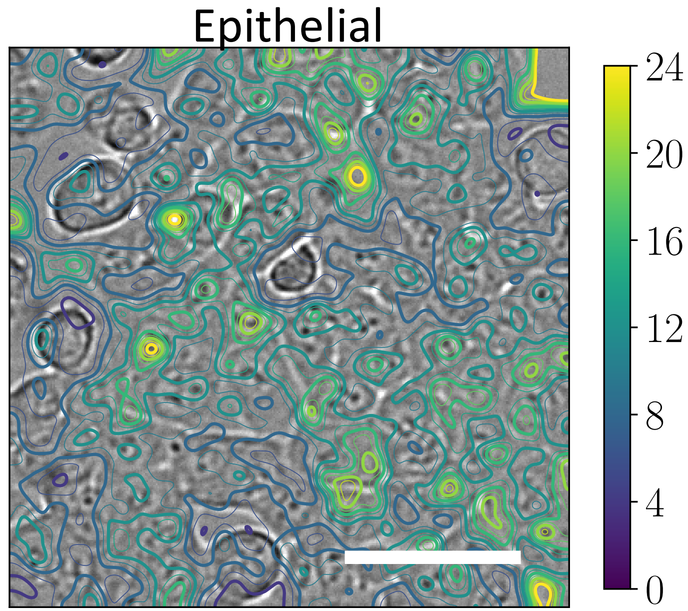
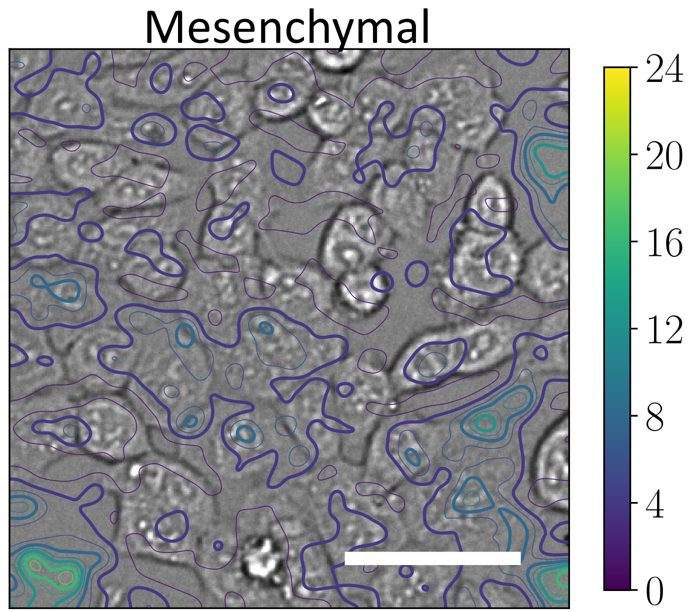
EMT & shear modulus

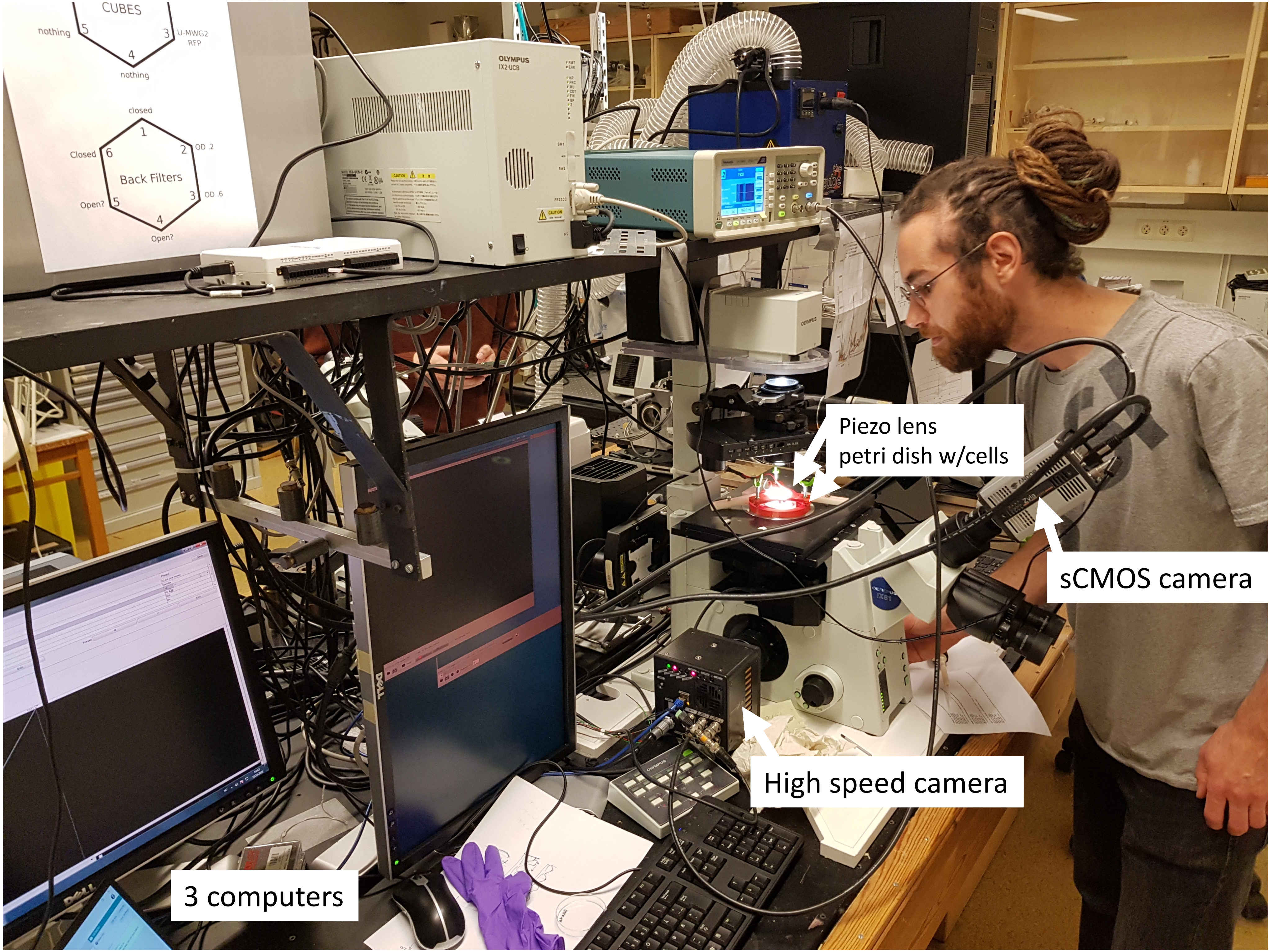
Shear wave frequency ~30 kHz (“passive” cytoskeleton)
Cells used: HCT116 (colon carcinoma)
TNF treatment induces EMT (Epithelial-mesenchymal transit
→ TNF treated should be mesenchymal





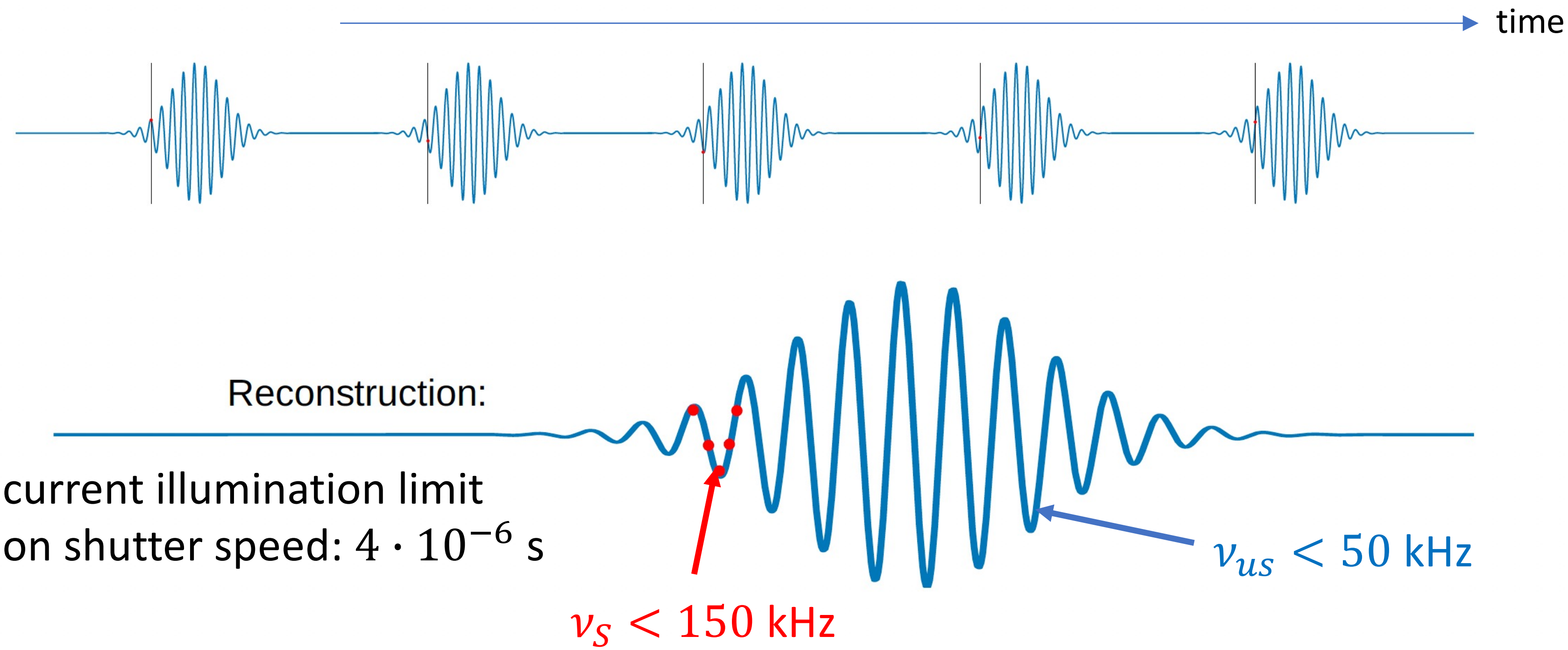






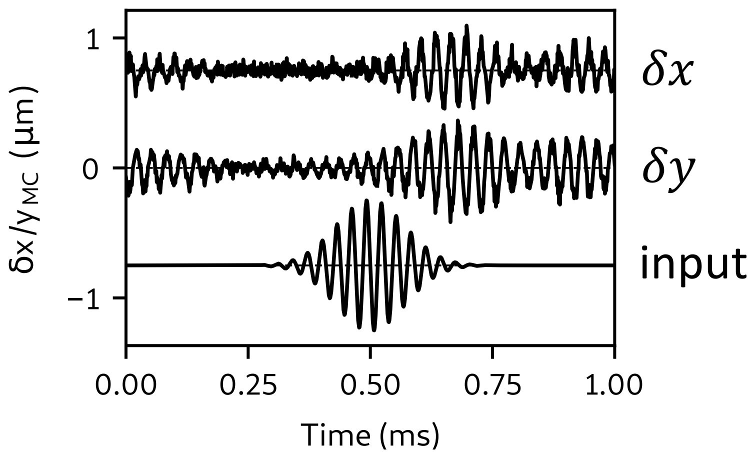
CUBES
nothing
U-MWG2
RFP
nothing
closed
Closed
Back Filters
OD .2
OD .6
Open?
Open?
OLYMPUS
IX2-UCB
Piezo lens
petri dish w/cells
sCMOS camera
High speed camera
3 computers

STROBOSCOPIC IMAGING - PRINCIPLE



current illumination limit
on shutter speed: $4 \cdot 10^{-6}$ s

Digital image correlation (DIC)



Digital Image Correlation

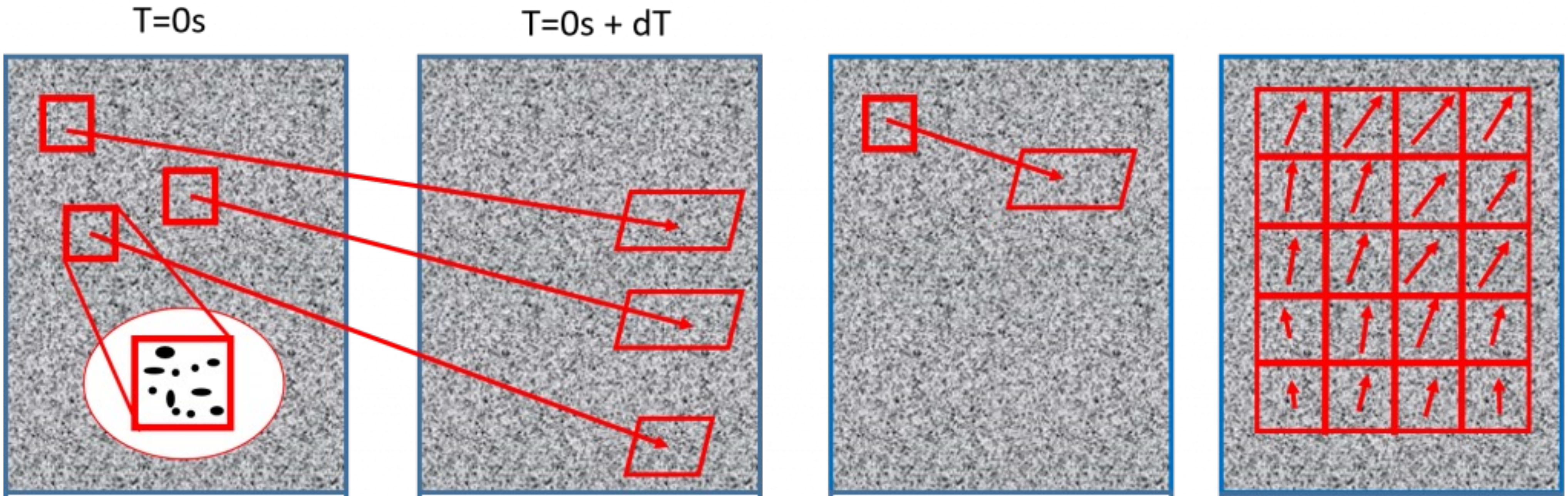


Image is divided into image subsets	The correlation algorithm follows the movement of each subset in consequtive images	A displacement vector is obtained for each subset	Full field strains can be calculated from the displacement vectors

$$\Delta x = \Delta y = 2.5\mu m$$

$$\delta_x(x, y)$$
$$\delta_y(x, y)$$

$$\gamma_s = \frac{\partial \delta_x}{\partial y} + \frac{\partial \delta_y}{\partial x}$$
$$\gamma_p = \frac{\partial \delta_x}{\partial x} + \frac{\partial \delta_y}{\partial y}$$

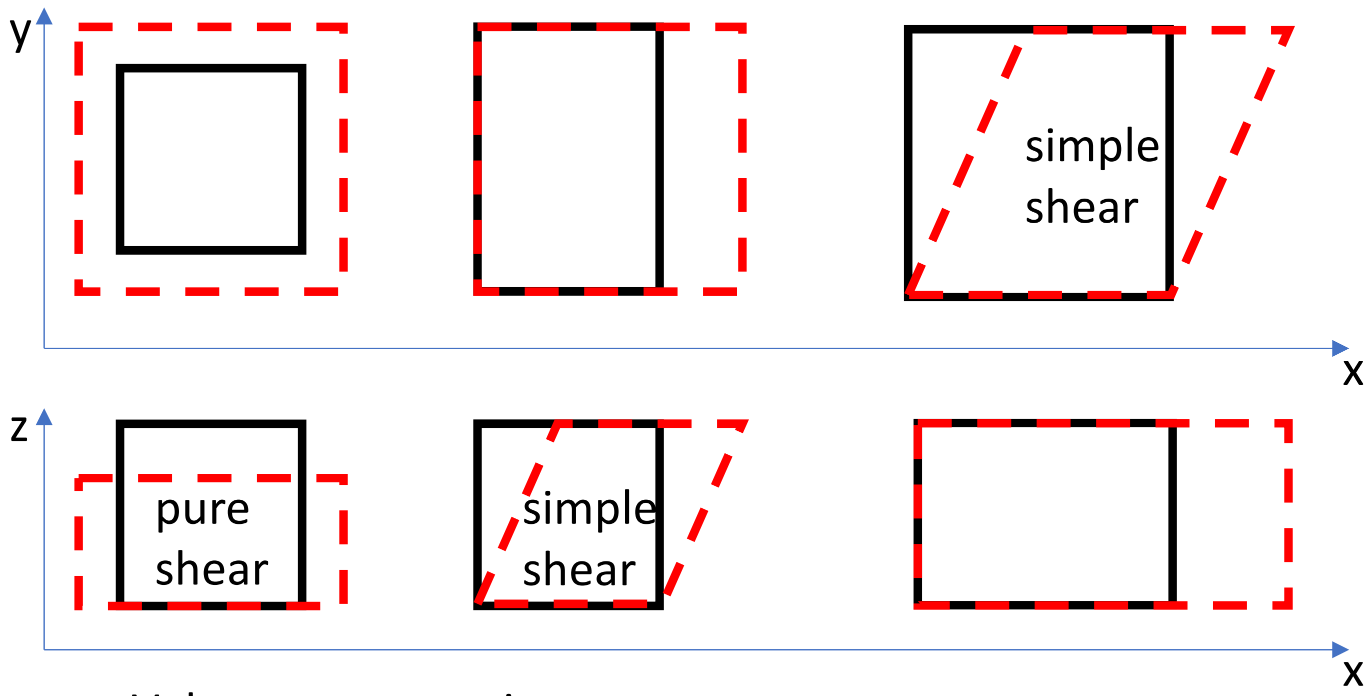
Shear and apparent volumetric strain

$$\gamma_p = \frac{\partial \delta_x}{\partial x} + \frac{\partial \delta_y}{\partial y}$$

$$\gamma_s = \frac{\partial \delta_x}{\partial y} + \frac{\partial \delta_y}{\partial x}$$

Area change = apparent volume change

Area conserved

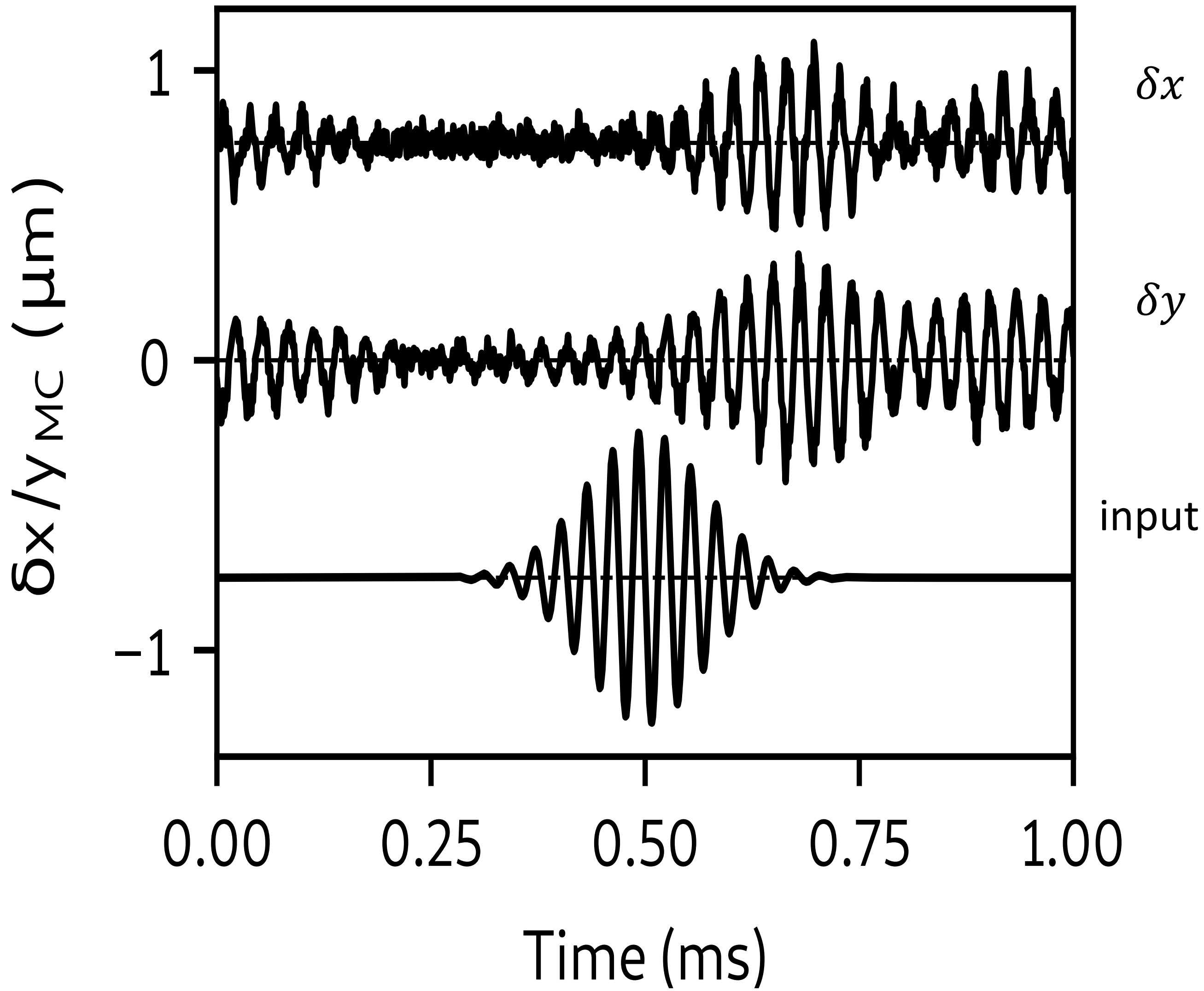


Volume conservation

$$\gamma_p \approx \gamma_s$$

Homodyne detection

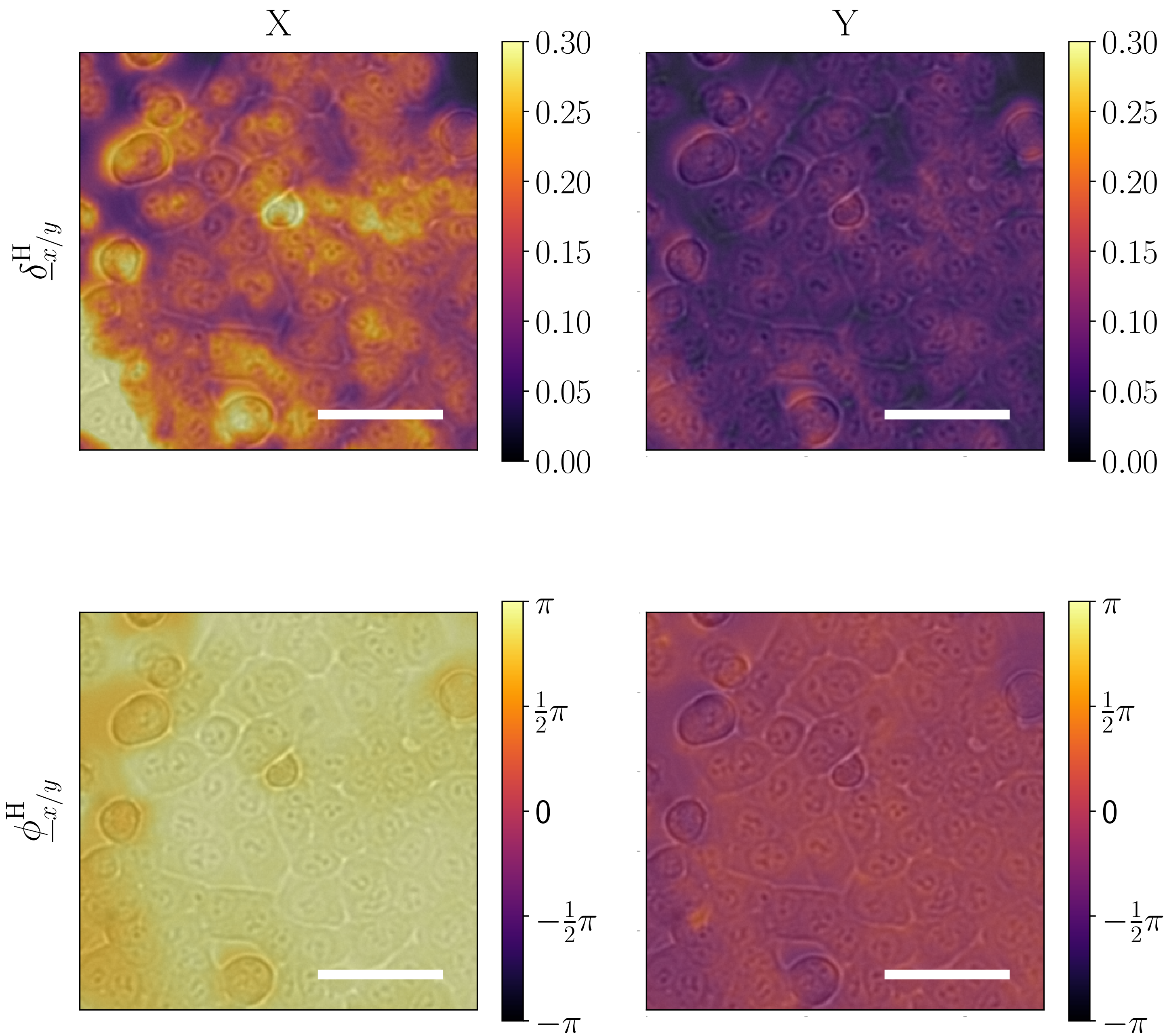
Single frequency excitation – same frequency detection



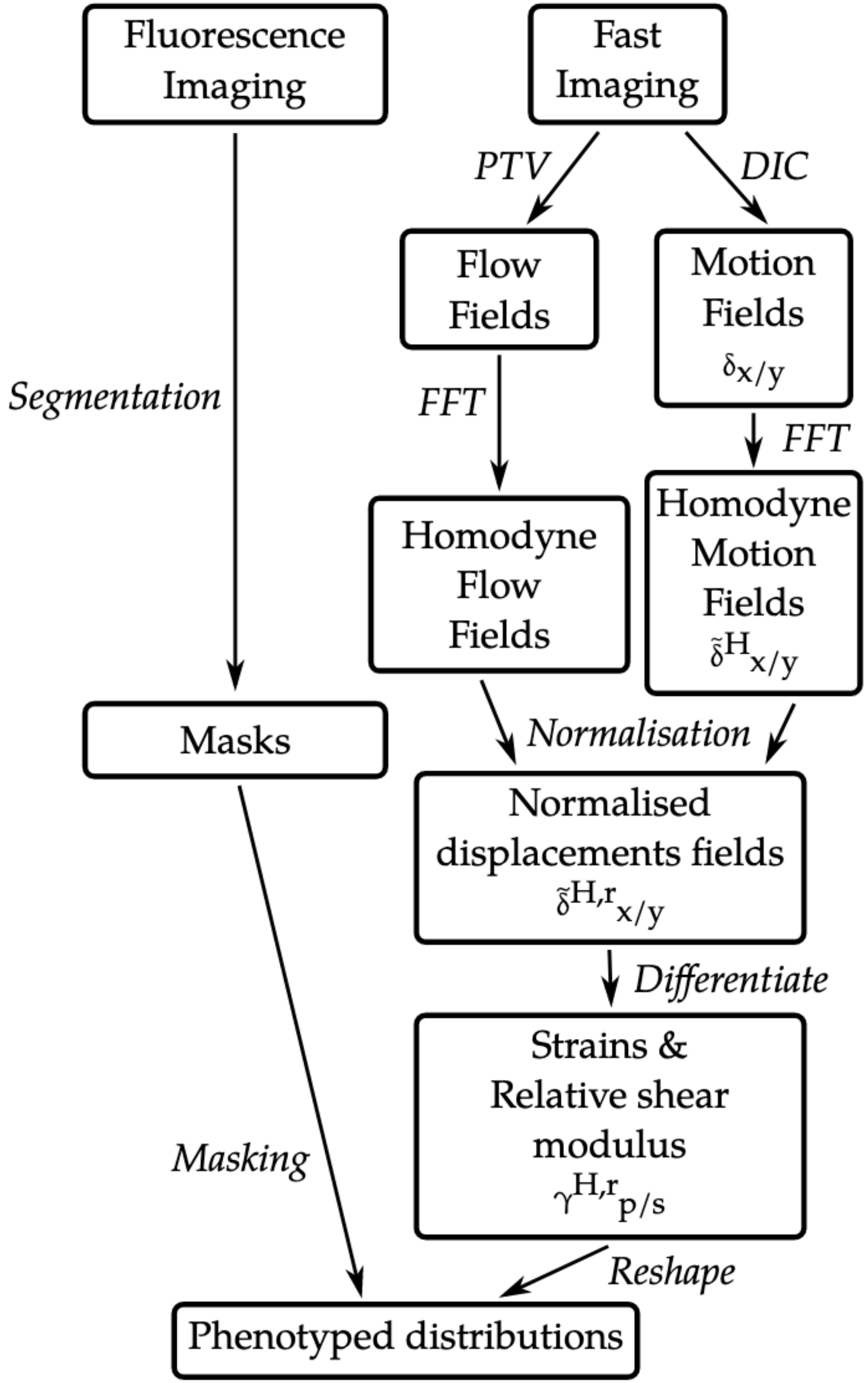
Homodyne detection

Using Fast Fourier Transform (FFT) of the displacements $\tilde{\delta}_{x/y}(f) = \underline{\delta}_{x/y} \mathrm{e}^{i\phi_{x/y}}$, where i is the imaginary unit, are computed. An homodyne detection is then performed by only keeping the amplitude and phase at the carrier frequency f_0:

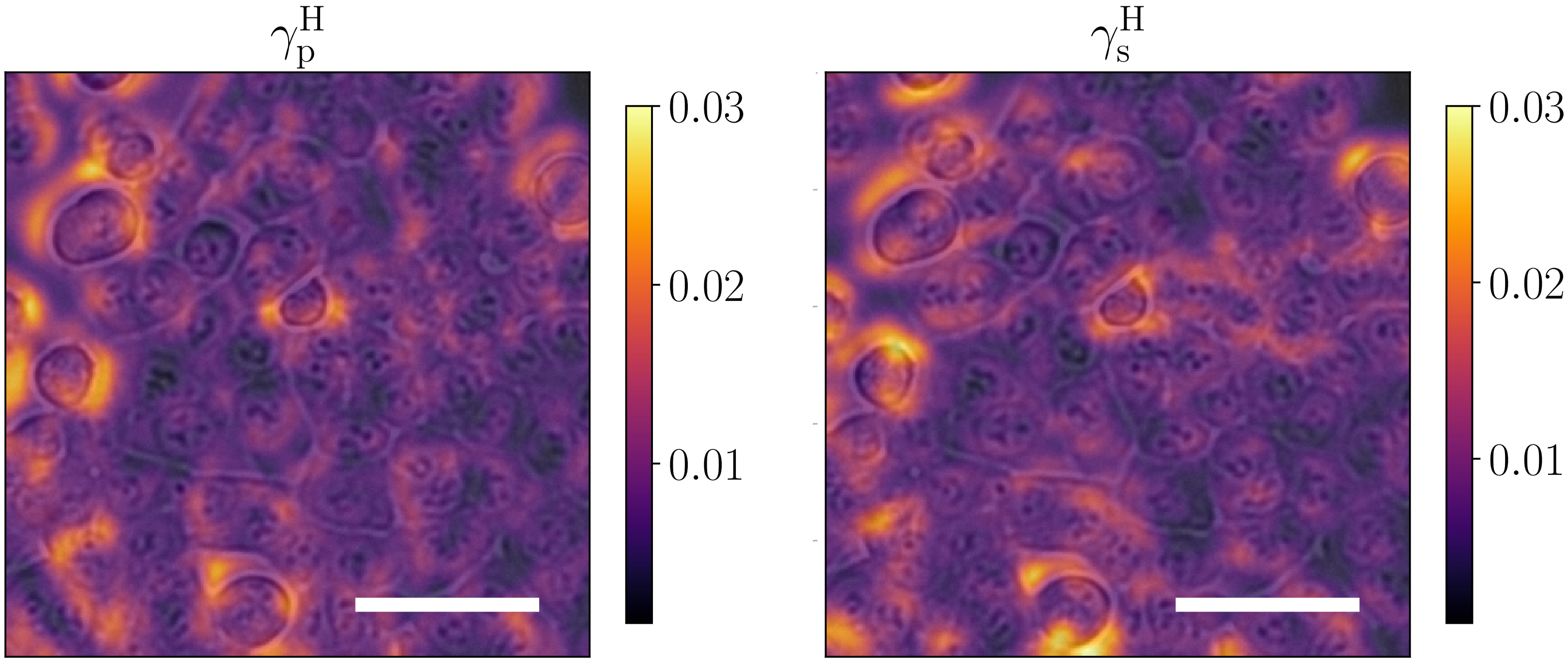
$$\tilde{\delta}^{\mathrm{H}}_{x/y} = \underline{\delta}^{\mathrm{H}}_{x/y} \mathrm{e}^{i\phi^{\mathrm{H}}_{x/y}} = \tilde{\delta}_{x/y}(f = f_0) \qquad (3)$$



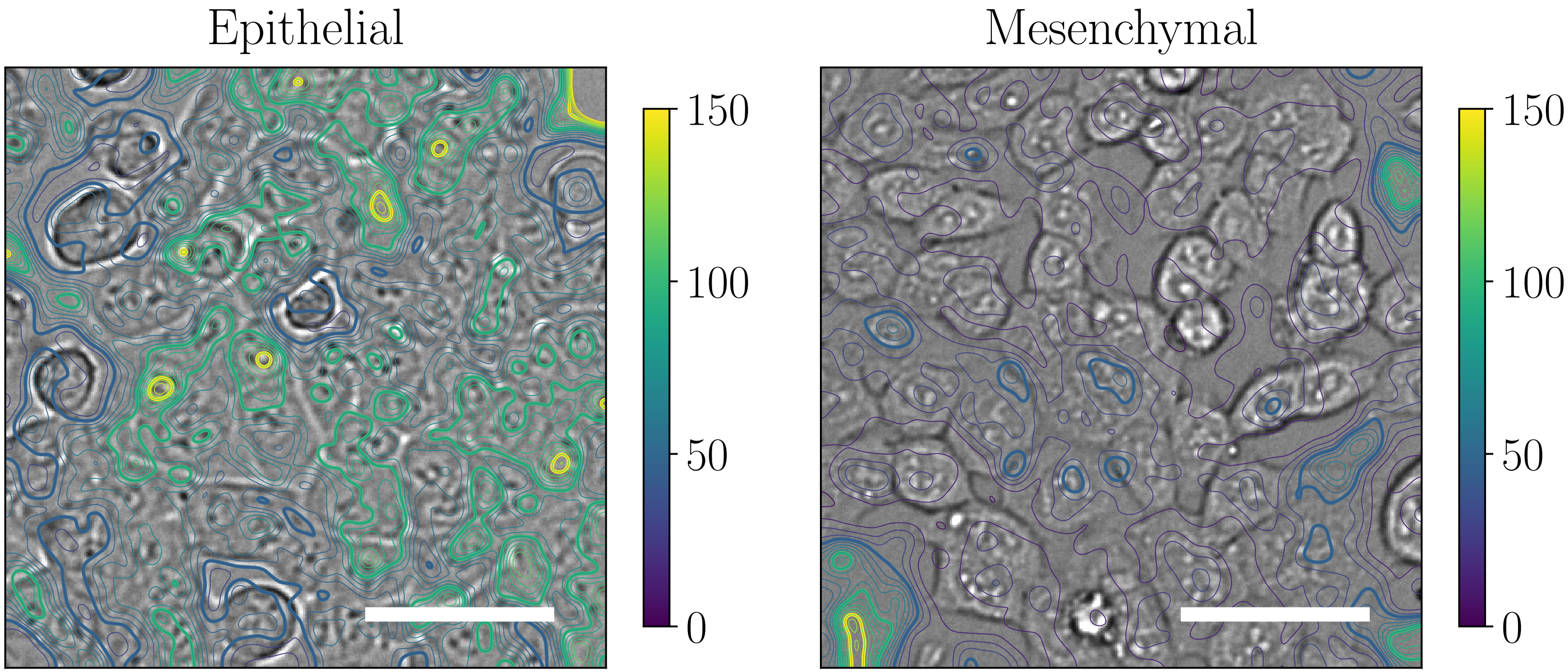
X
Y
$\underline{\delta}^{\mathrm{H}}_{x/y}$
$\underline{\phi}^{\mathrm{H}}_{x/y}$
0.30
0.25
0.20
0.15
0.10
0.05
0.00
π
$\frac{1}{2}\pi$
0
$-\frac{1}{2}\pi$
$-\pi$

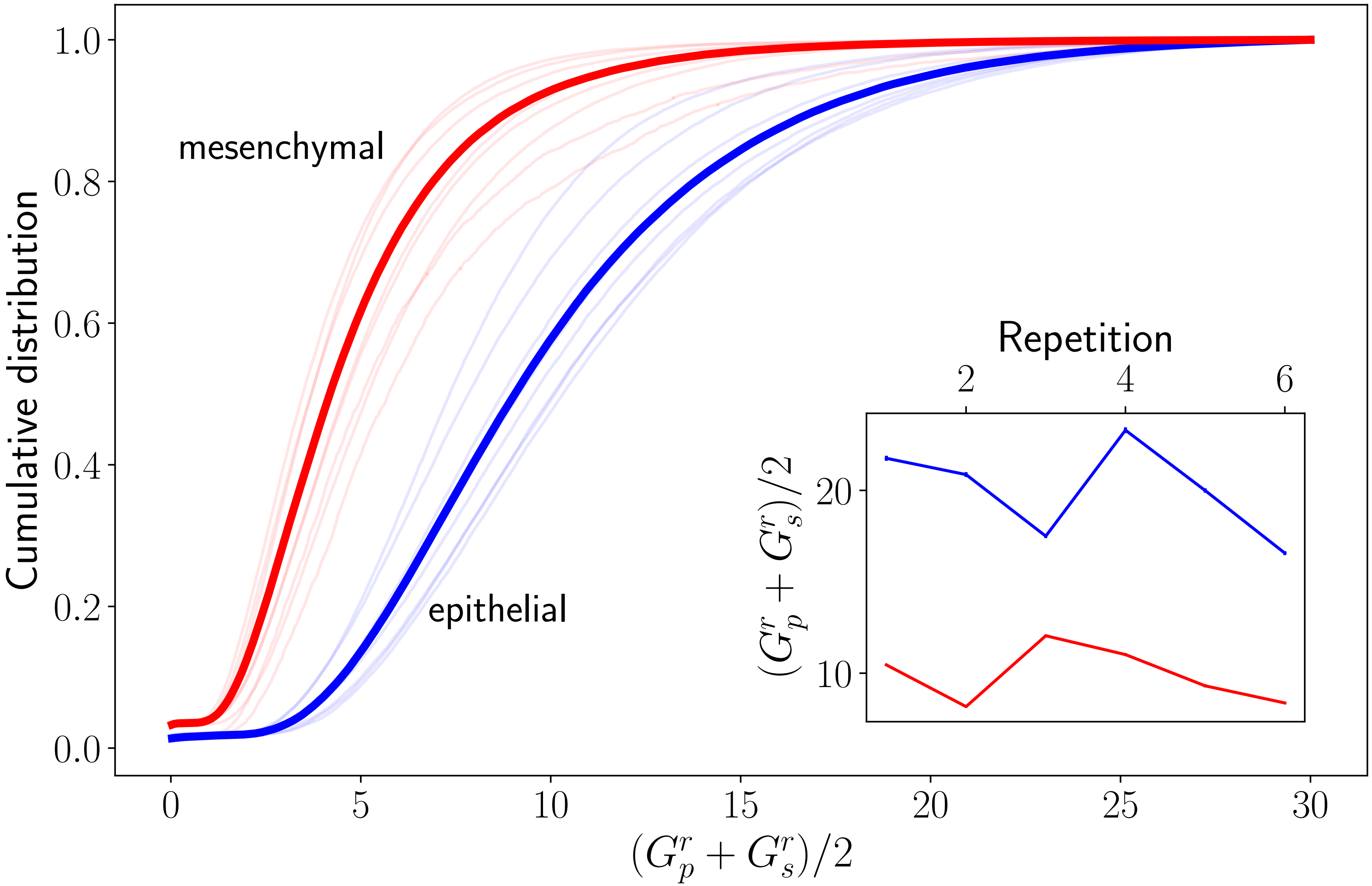

Fluorescence Imaging
Fast Imaging
PTV
DIC
Flow Fields
Motion Fields
$\delta_{x/y}$
Segmentation
FFT
FFT
Homodyne Flow Fields
Homodyne Motion Fields
$\tilde{\delta}^{H}{}_{x/y}$
Masks
Normalisation
Normalised displacements fields
$\tilde{\delta}^{H,r}{}_{x/y}$
Differentiate
Strains & Relative shear modulus
$\gamma^{H,r}{}_{p/s}$
Masking
Reshape
Phenotyped distributions

Homodyne strains



Moduli





Cumulative distribution
1.0
0.8
0.6
0.4
0.2
0.0
mesenchymal
epithelial
0
5
10
15
20
25
30
$(G_p^r + G_s^r)/2$
Repetition
2
4
6
$(G_p^r + G_s^r)/2$
20
10