



STANFORD
BIOMEDICAL
OPTICS Group



Ginzton Laboratory &
Department of
Electrical Engineering

Making Good Impressions: OCT Phantoms for System Characterization and Mimicking of Organs

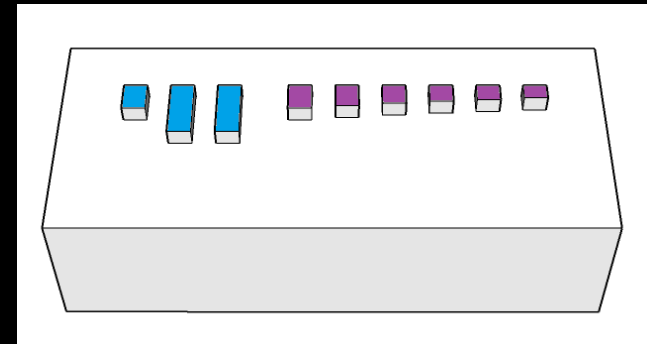
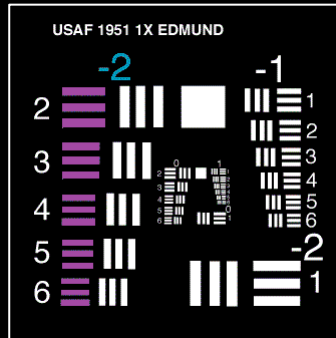
Audrey K Ellebree

M-CERSI Workshop on Optical Phantoms

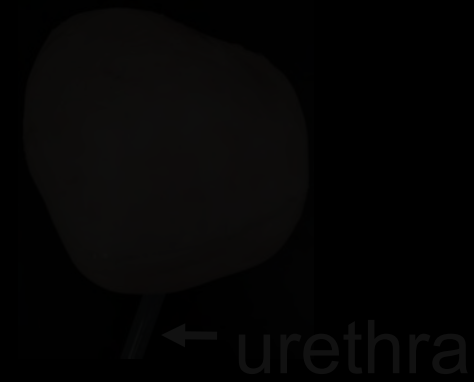
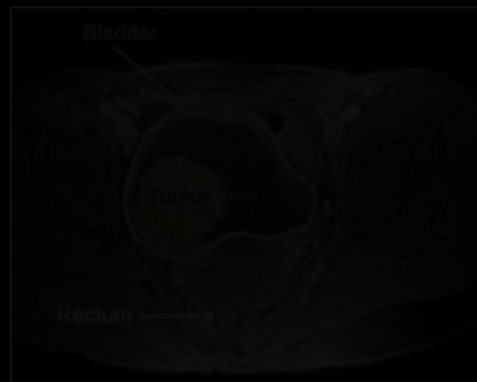
May 21, 2014

Impression-Molding

- System Characterization

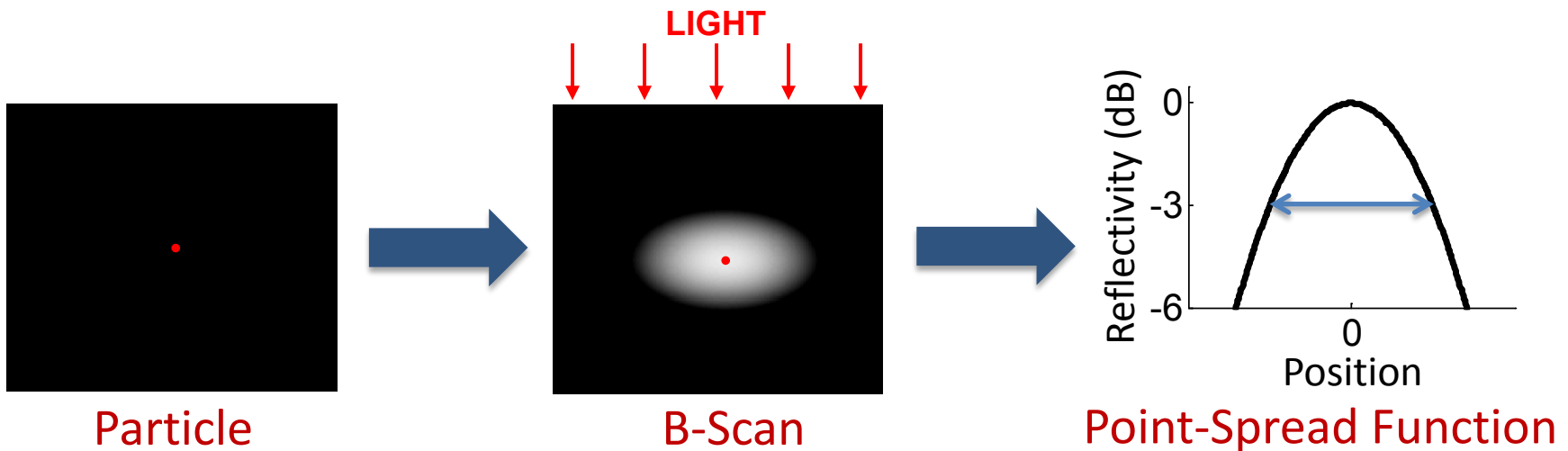
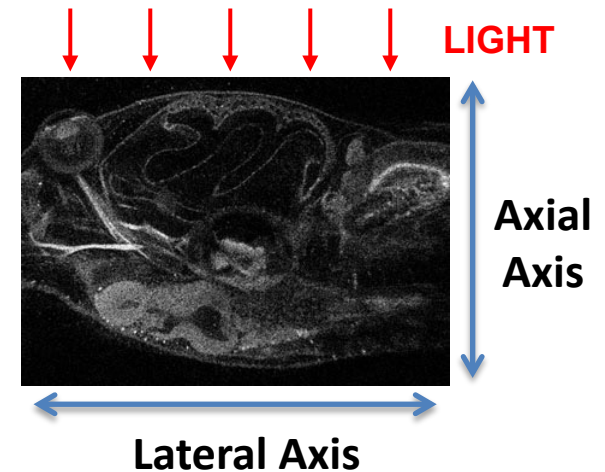


- Organ-Mimicking



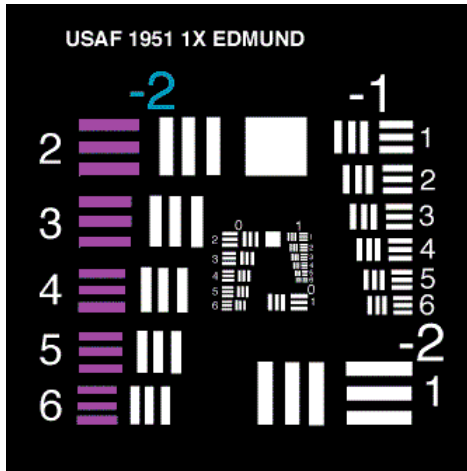
OCT: Decoupled Axial and Lateral Resolution

- **RESOLUTION**: full-width at half-maximum (FWHM) of point-spread function (PSF)
 - **AXIAL** Resolution: $\propto \frac{1}{\Delta\lambda}$ (Source)
 - **LATERAL** Resolution: $\propto \frac{1}{NA}$ (Optics)



Traditional Resolution Measurement

AFTC (Lateral)



Simulated surface scan of AFTC (Edmund Optics)

Mirror (Axial)



Simulated B-scan of mirror

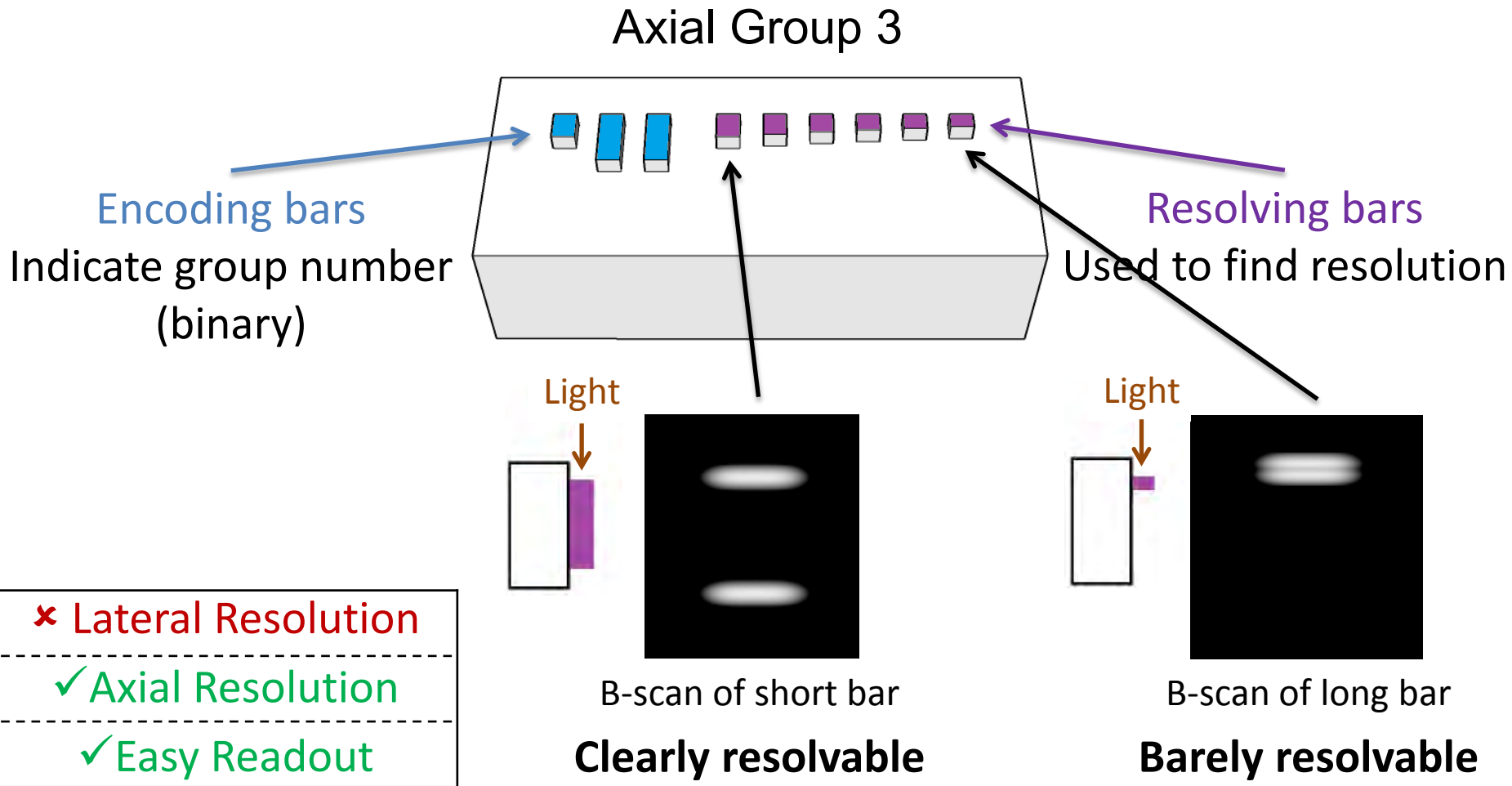
Scattering Particles (Both)



Simulated B-scan of phantom with scattering particles

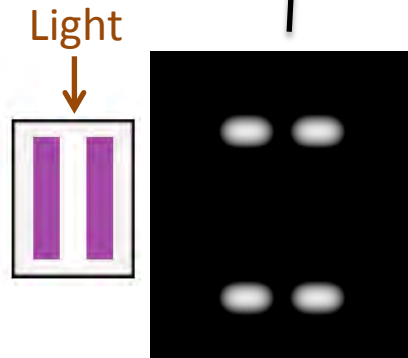
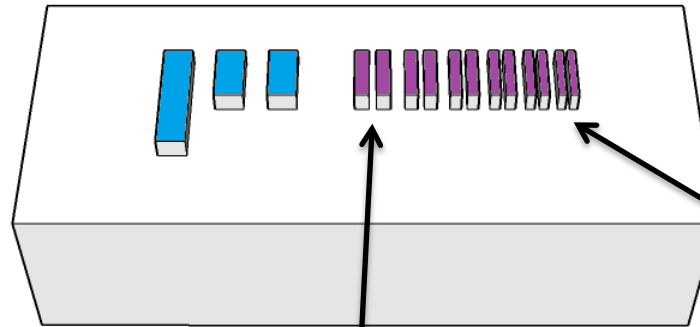
✓ Lateral Resolution	✗ Lateral Resolution	✓ Lateral Resolution
✗ Axial Resolution	✓ Axial Resolution	✓ Axial Resolution
✓ Easy Readout	✗ Easy Readout	✗ Easy Readout

Design of Our Phantom



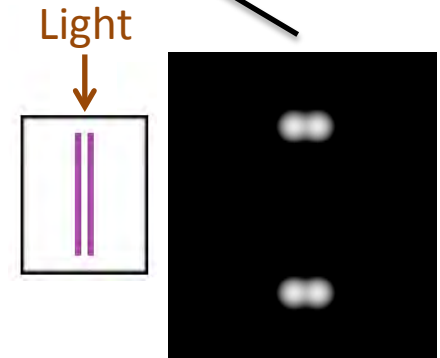
Design of Our Phantom

Lateral Group 4



B-Scan of wide bars

Clearly resolvable



B-Scan of narrow bars

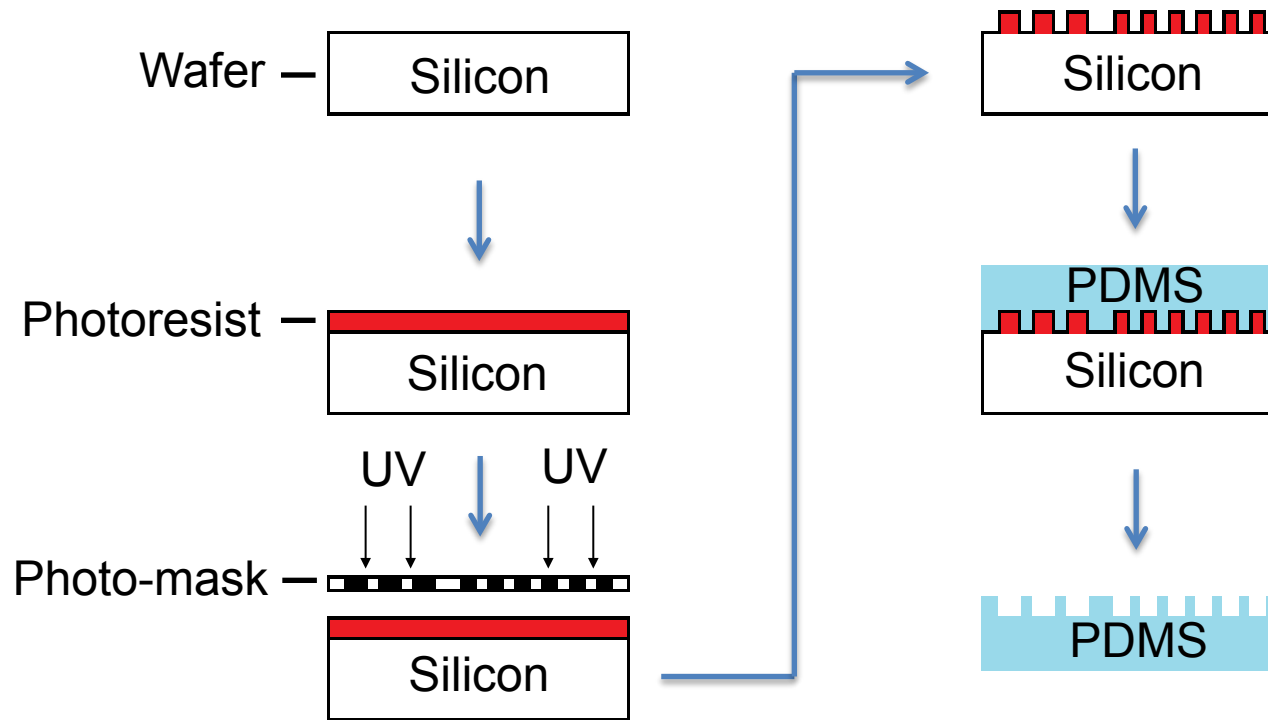
Barely resolvable

✓ Lateral Resolution

✓ Axial Resolution

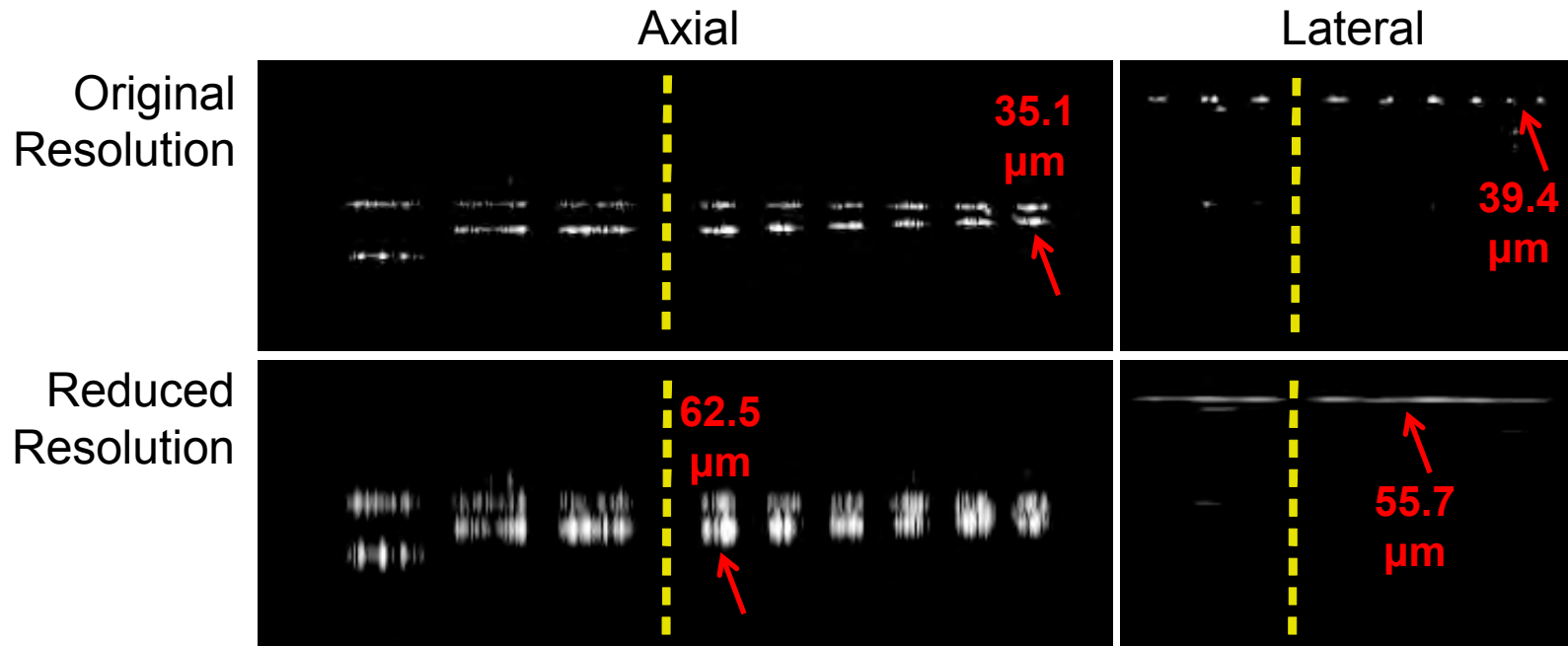
✓ Easy Readout

Fabrication of Phantom



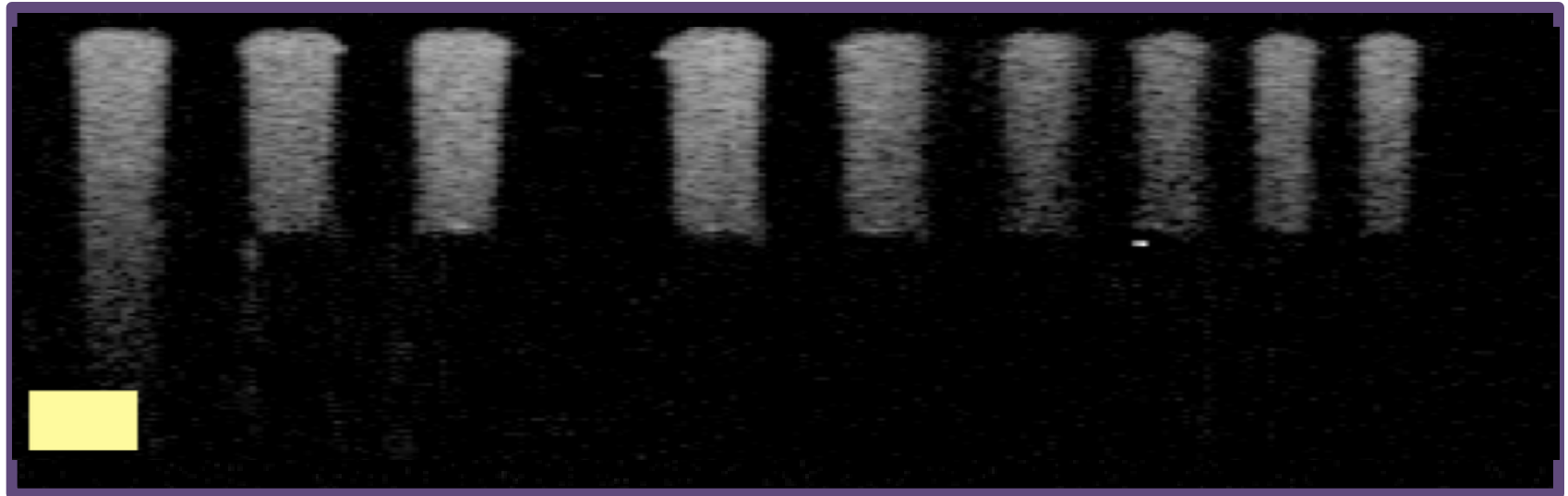
Fabrication process requires only a single photolithography step

Resolution Measurement using Telesto OCT System



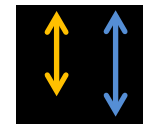
The smallest feature visible in an image is correlated with the resolution of the system

Resolution Measurement using Telesto OCT System: Different Media



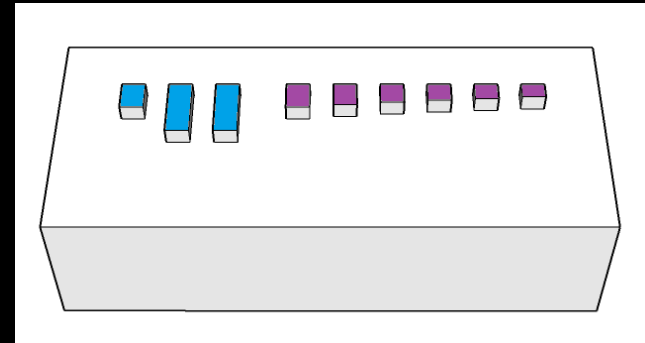
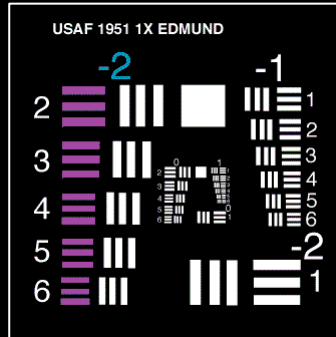
Phantom functional in high refractive index media (water)

- Bar edge reflections are still visible
- Apparent bar length changes



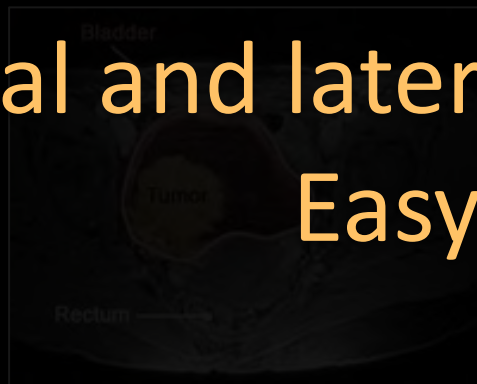
Impression-Molding

- System Characterization



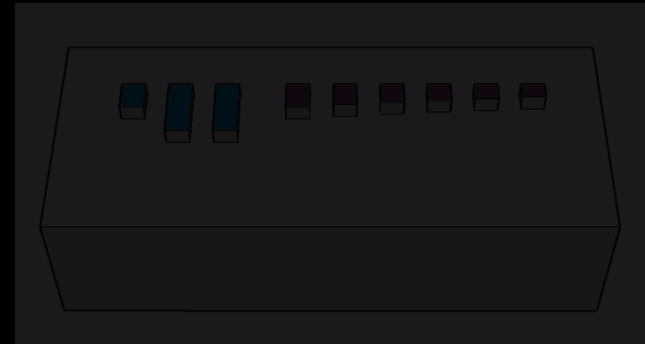
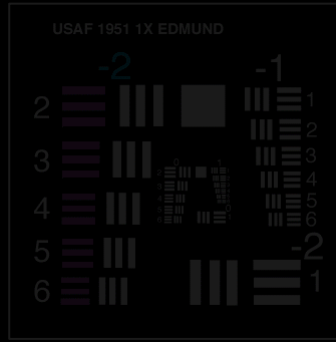
- Organ-Mimicking

Axial and lateral characterization
Easy readout



Impression-Molding

- System Characterization



- Organ-Mimicking



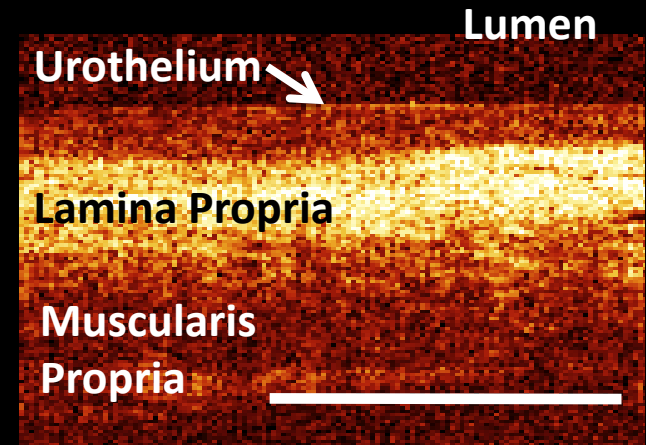
← urethra

Desirable features for bladder phantom

White light cystoscopy



OCT B-scan



- Textured surface morphology
- Vessel patterns
- Compatible with clinical distention equipment
- Realistic non-luminal 3D structure

- Multiple layers with controlled thickness
- Biologically relevant scattering properties

Methods for Phantom Fabrication

Technique	Feature	
Particle dispersion	Optical scattering	Previously Established
3D printing Spin coating Embossing	3D Shape Thin layers Texture	Generalized and Extended
Sandwich molding Inking Off-ratio bonding Material Excision	Thick layers Vessels 3D shape Disease	Newly Introduced

Layer-by-layer phantom assembly

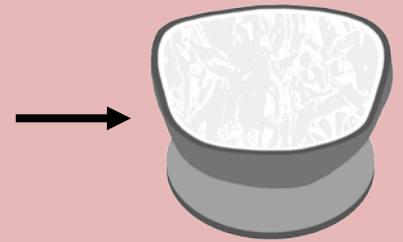
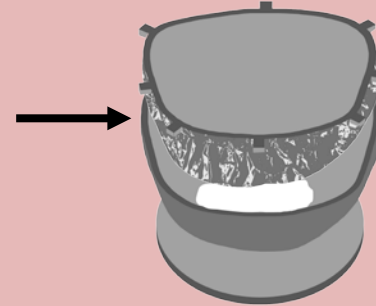
- 1. Muscularis Propria
- 2. Lamina Propria
- 3. Urothelium
- 4. Full bladder

MUSCULARIS PROPRIA

Print Molds

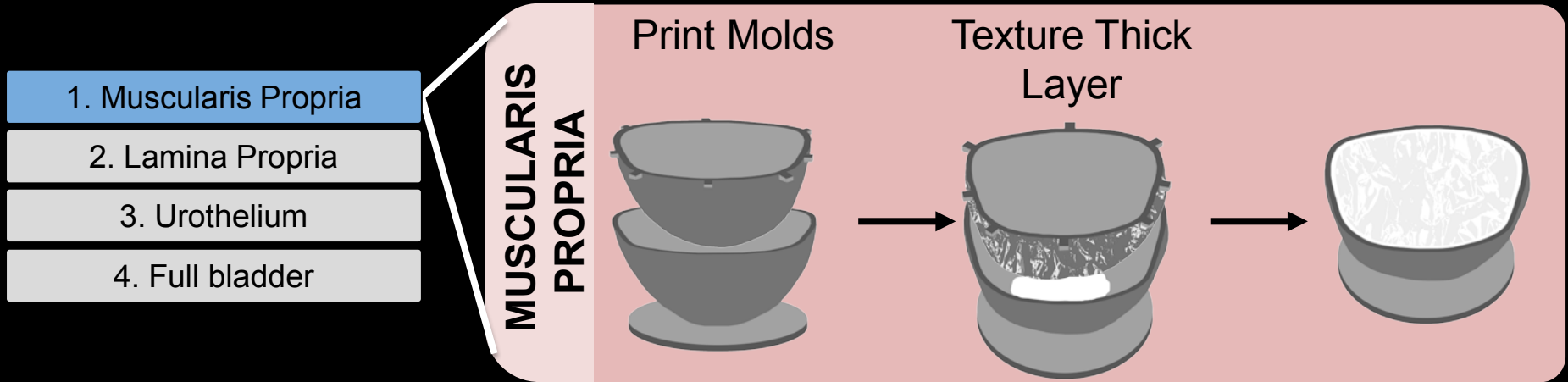


Texture Thick Layer

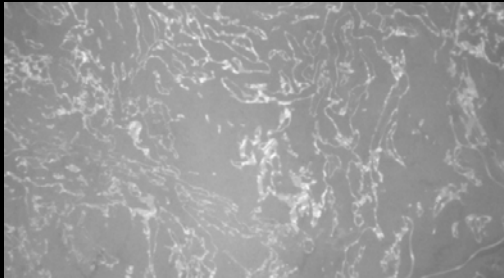


3D printing produces phantoms in a variety of shapes and sizes

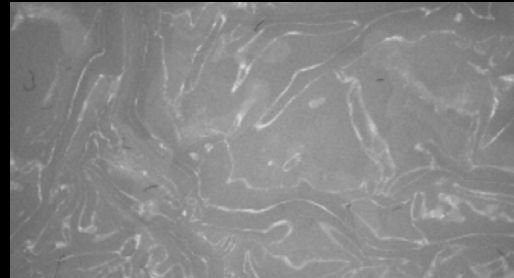
Layer-by-layer phantom assembly



Bladder Tissue



Phantom

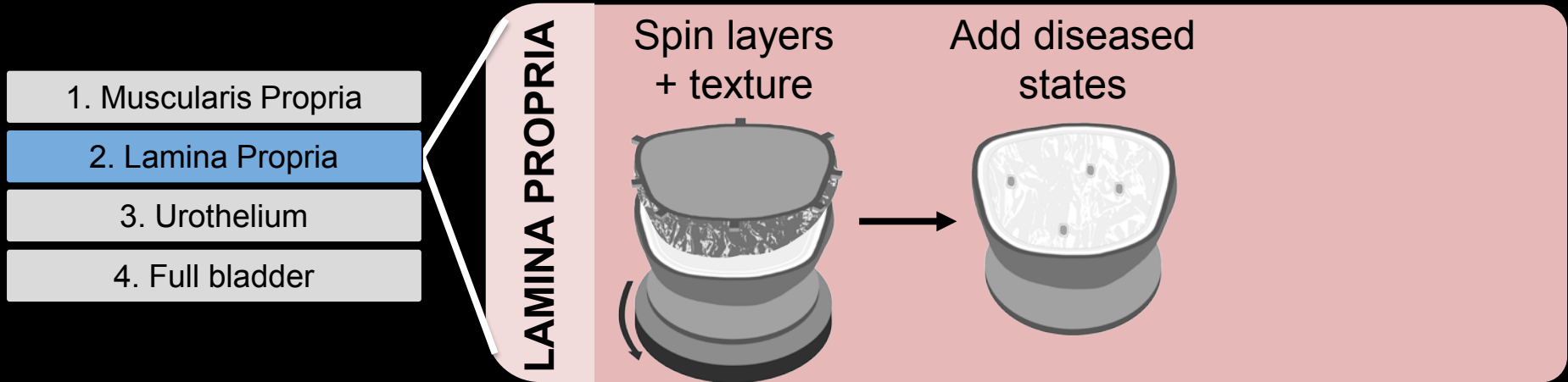


Patterned Texture



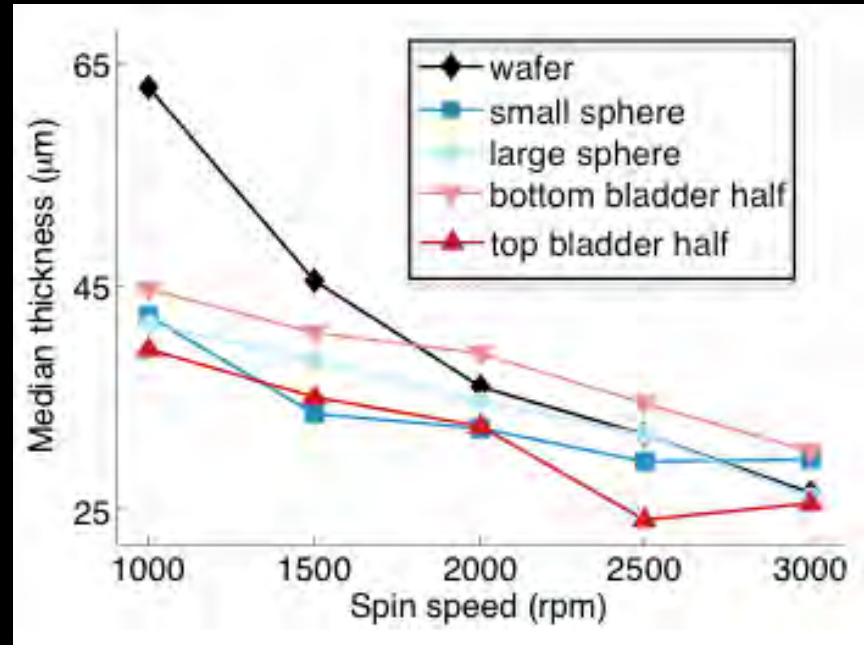
Texture embossing can produce realistic surface morphology and replicate well-defined patterns

Layer-by-layer phantom assembly

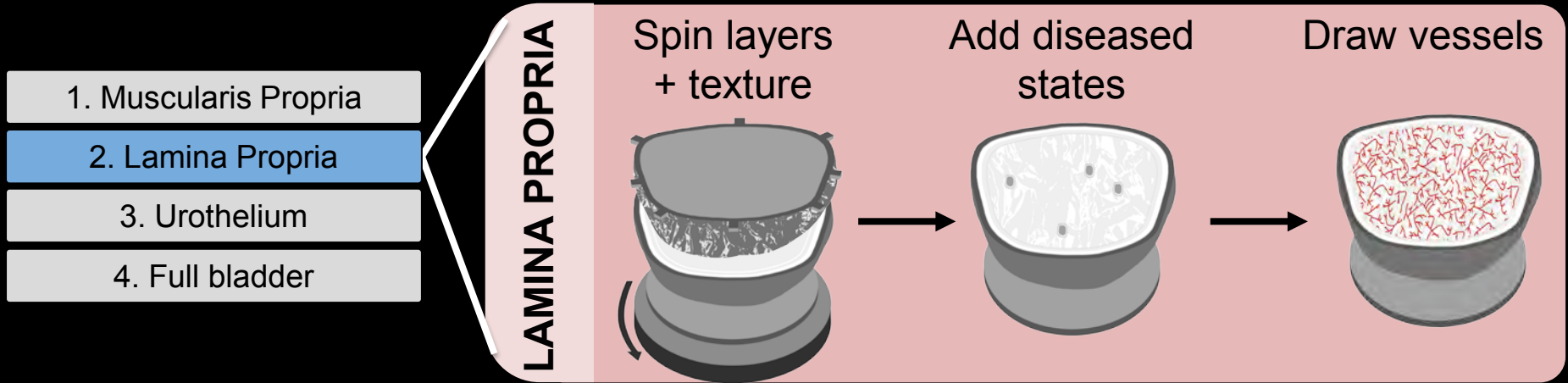


Spin-Coating in 3D:

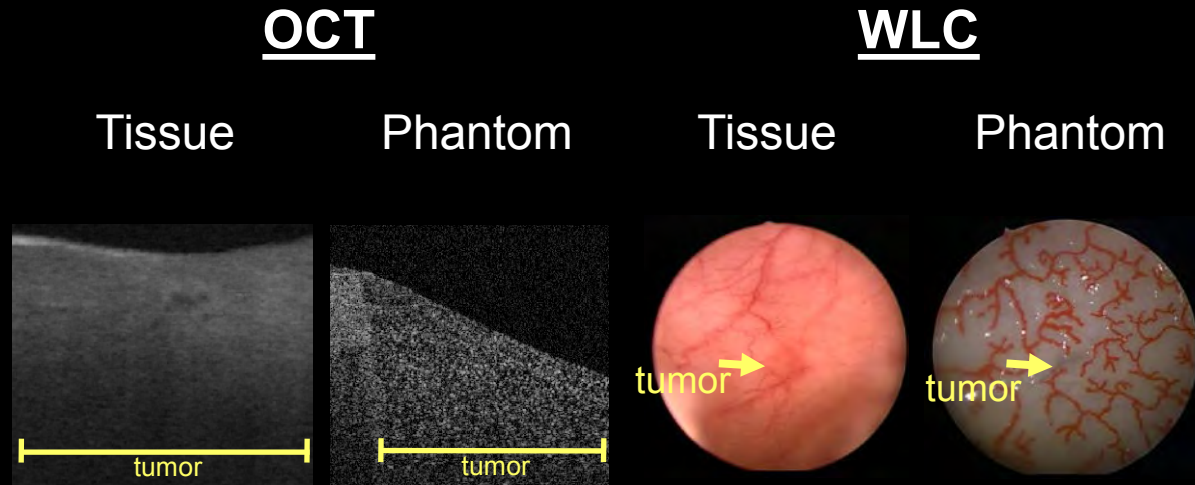
- Thicknesses correlated with spin speed
- Thickness depends on mold shape/size
- Compressed range compared to wafer



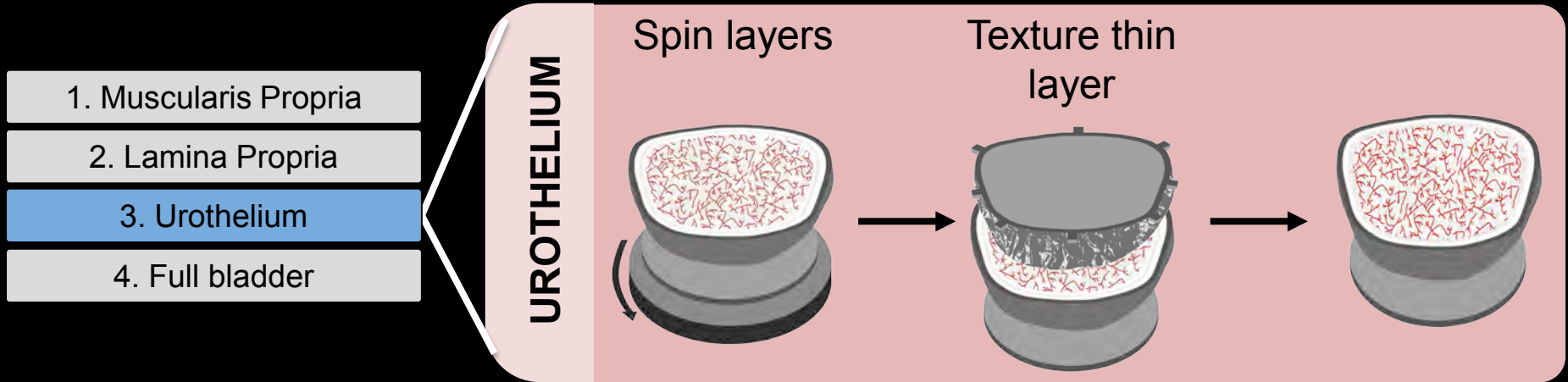
Layer-by-layer phantom assembly



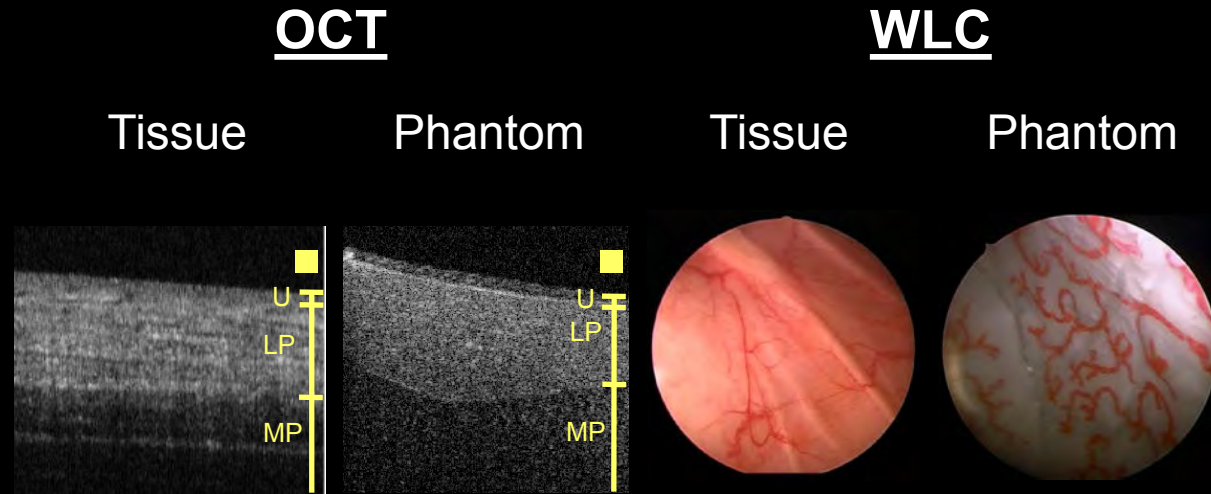
- Phantom mimics appearance of tissue in WL and OCT
- Inking allows persistent appearance of vessels in WLC



Layer-by-layer phantom assembly



- Phantom mimics appearance of tissue in WL and OCT



Layer-by-layer phantom assembly

1. Muscularis Propria

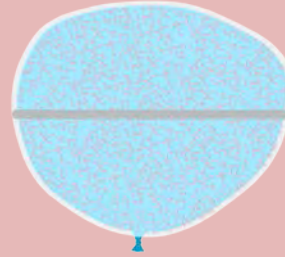
2. Lamina Propria

3. Urothelium

4. Full bladder

FULL BLADDER

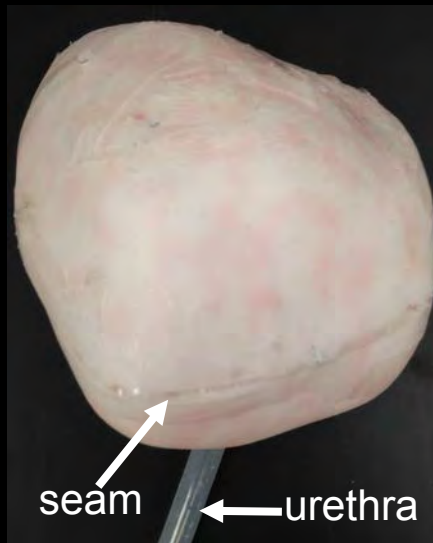
Bond Bladder halves



Bond urethra tubing



The completed phantom has a realistic shape, can be filled with liquid, and is distendable

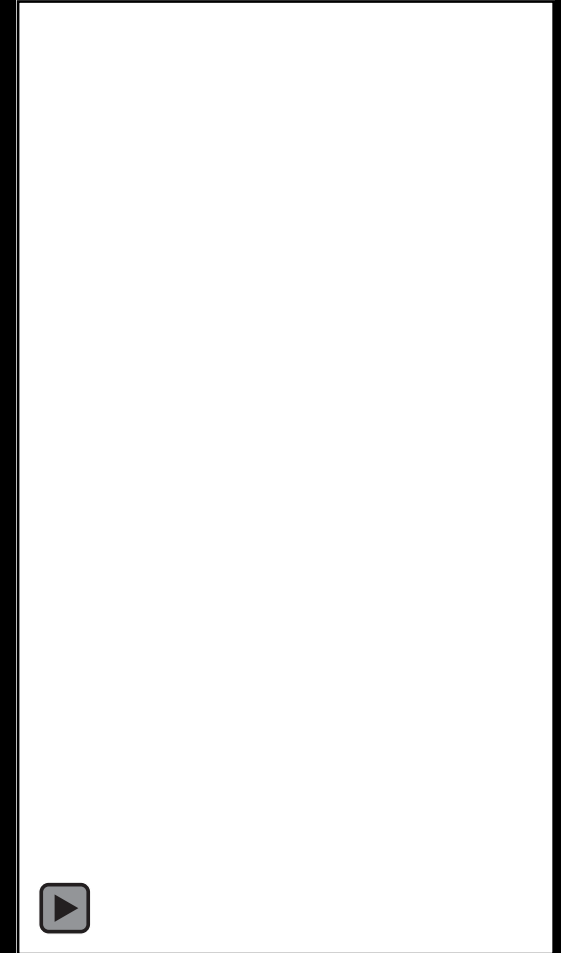


The Phantom in the OR

Cystoscopy

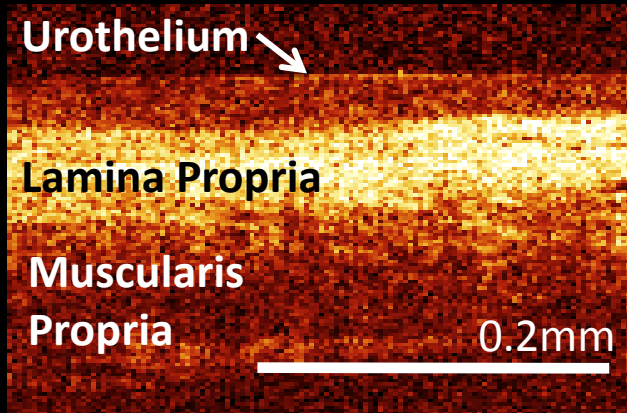


Distention

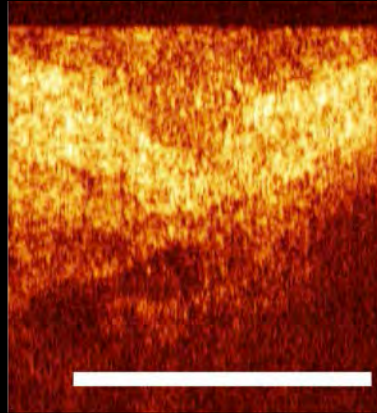


Bladder layers visible with OCT

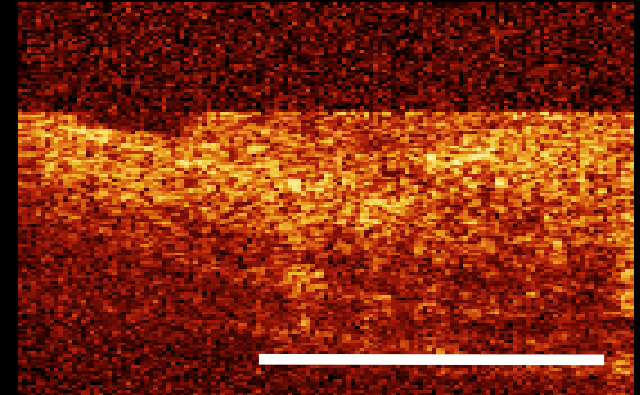
Healthy



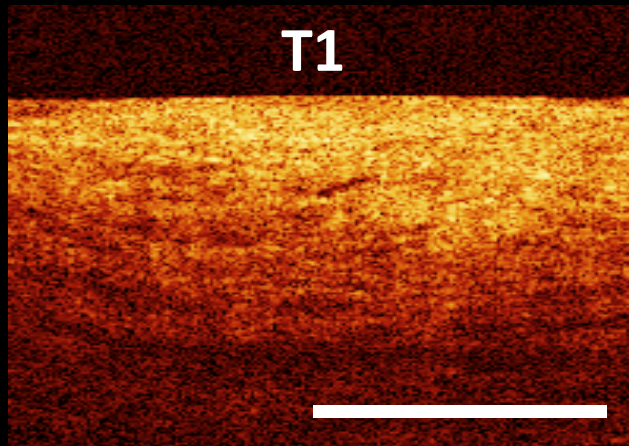
Dysplasia



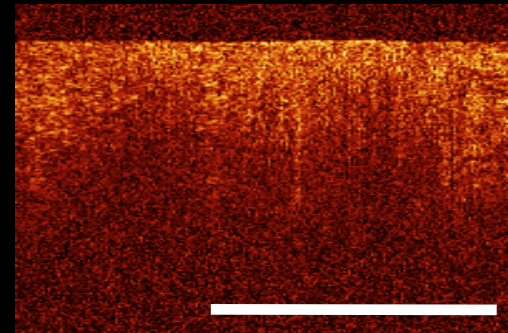
CIS



T1

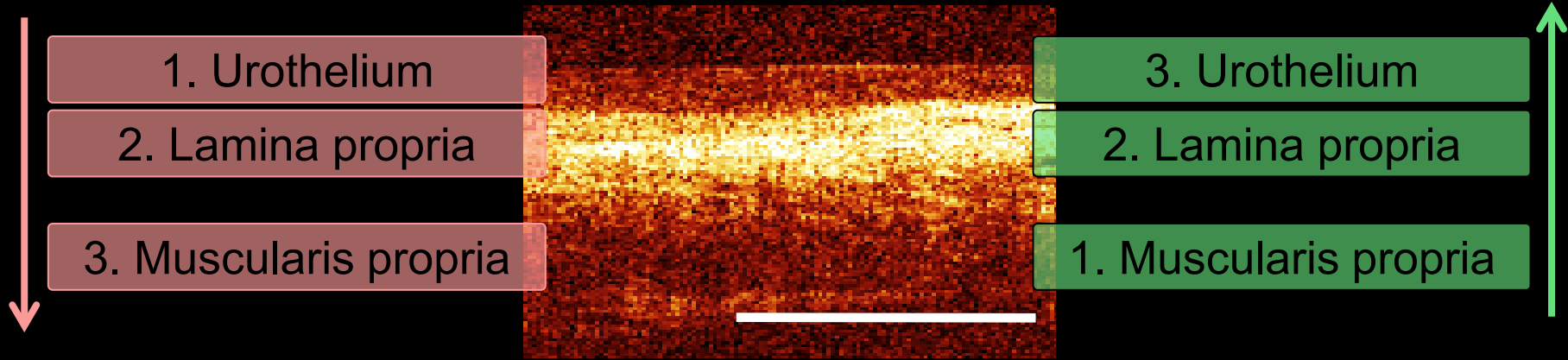


T2



All images from: Schmidbauer, J. et al., "Fluorescence cystoscopy with high-resolution optical coherence tomography imaging as an adjunct reduces false-positive findings in the diagnosis of urothelial carcinoma of the bladder.,"
European urology 56 , 914–9 (Dec. 2009).

Fabricating from the inside → out

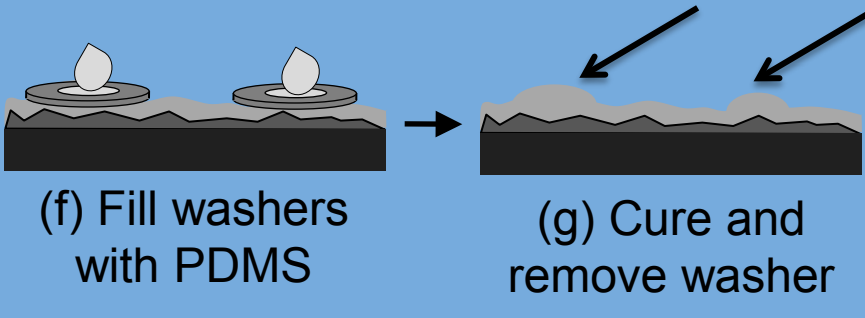


Urothelium

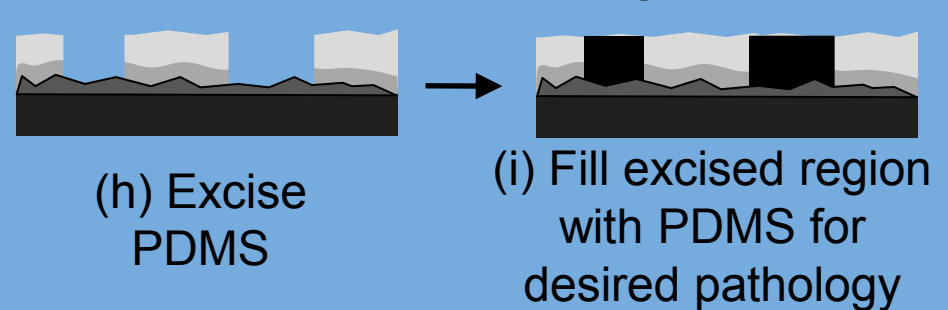
Lamina Propria

Muscularis Propria

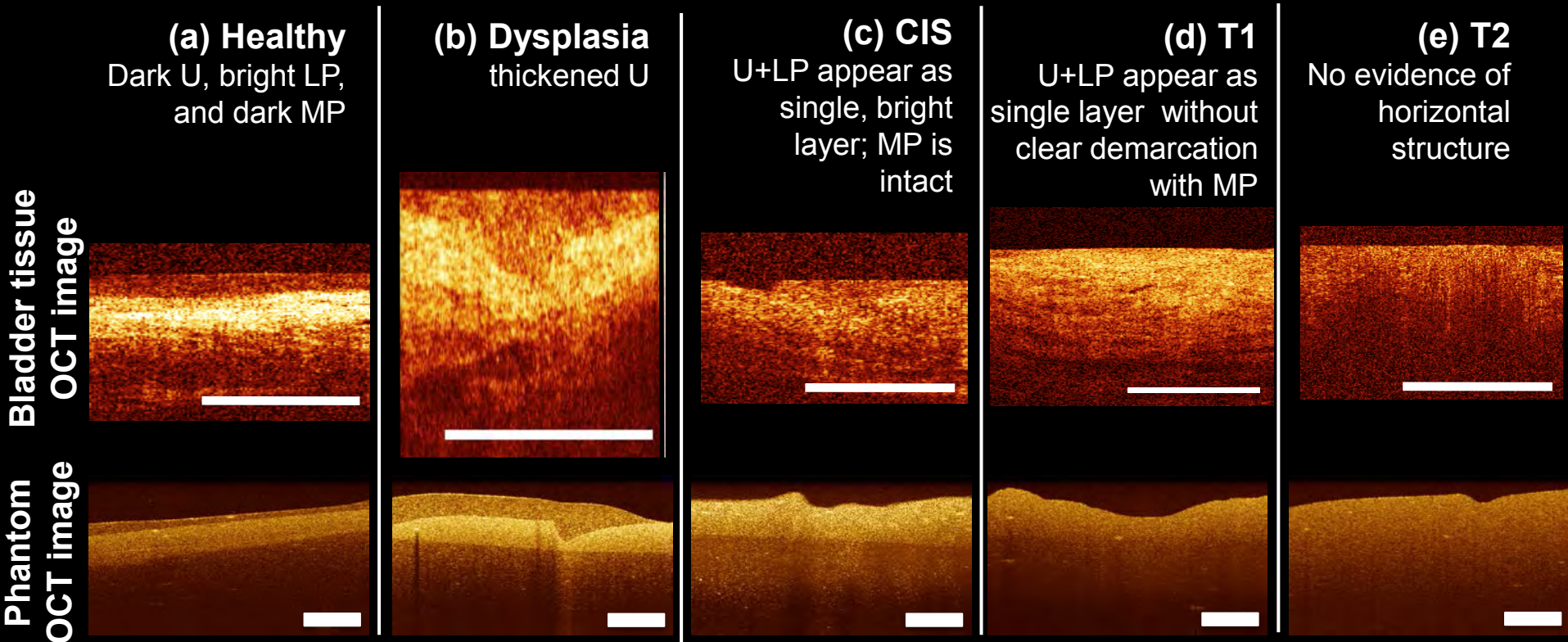
Layer thickening (dysplasia)



Material excision and filling (CIS, T1, T2)



Mimicking of staged cancers



Translating Process to 3D

The Problems:

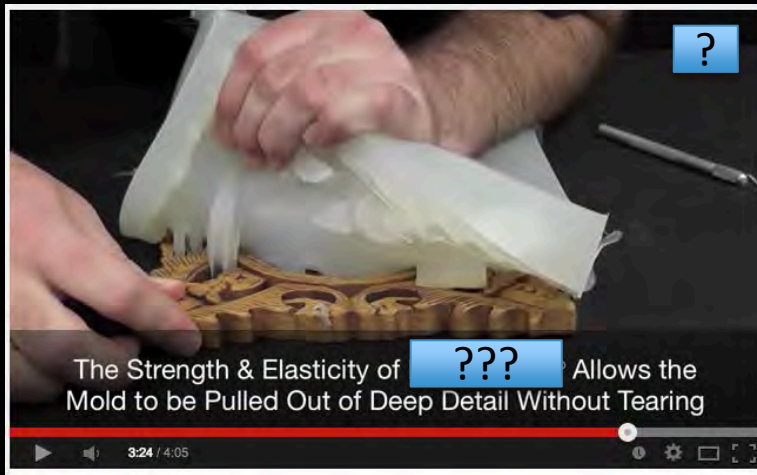
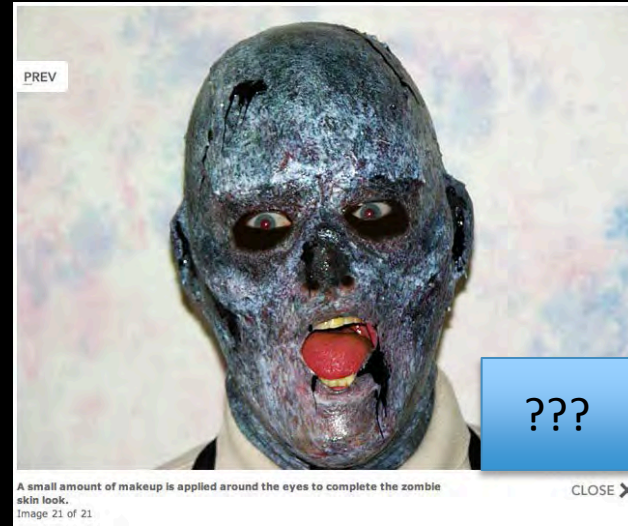
- 1) Building a 3D from from inside → out
- 2) Creating thin layers in 3D context

The Solution:

- 1) New material for optical phantoms
- 2) New Fabrication Process

High elasticity
Optical tunability
Controllable thickness
3D compatability

An alternative material...



Alternative
Methods

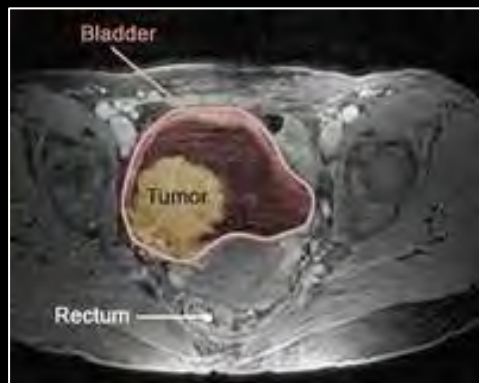


Impression-Molding

- System Characterization

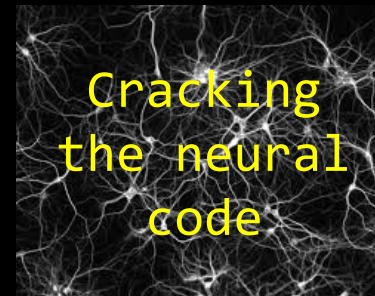
Replicate the 3D morphology of healthy and diseased organs

- Organ-Mimicking



Acknowledgements

- SBO group: GTS, KLL, SK, HL, HS, TM, LZ
- Collaborators: ES, JO, BB, JT, JL
- Research Financial Support



HELLMAN FACULTY
SCHOLARS FUND