

# The Potential of Light Fields

## -for imaging and beyond-

Oliver Bimber

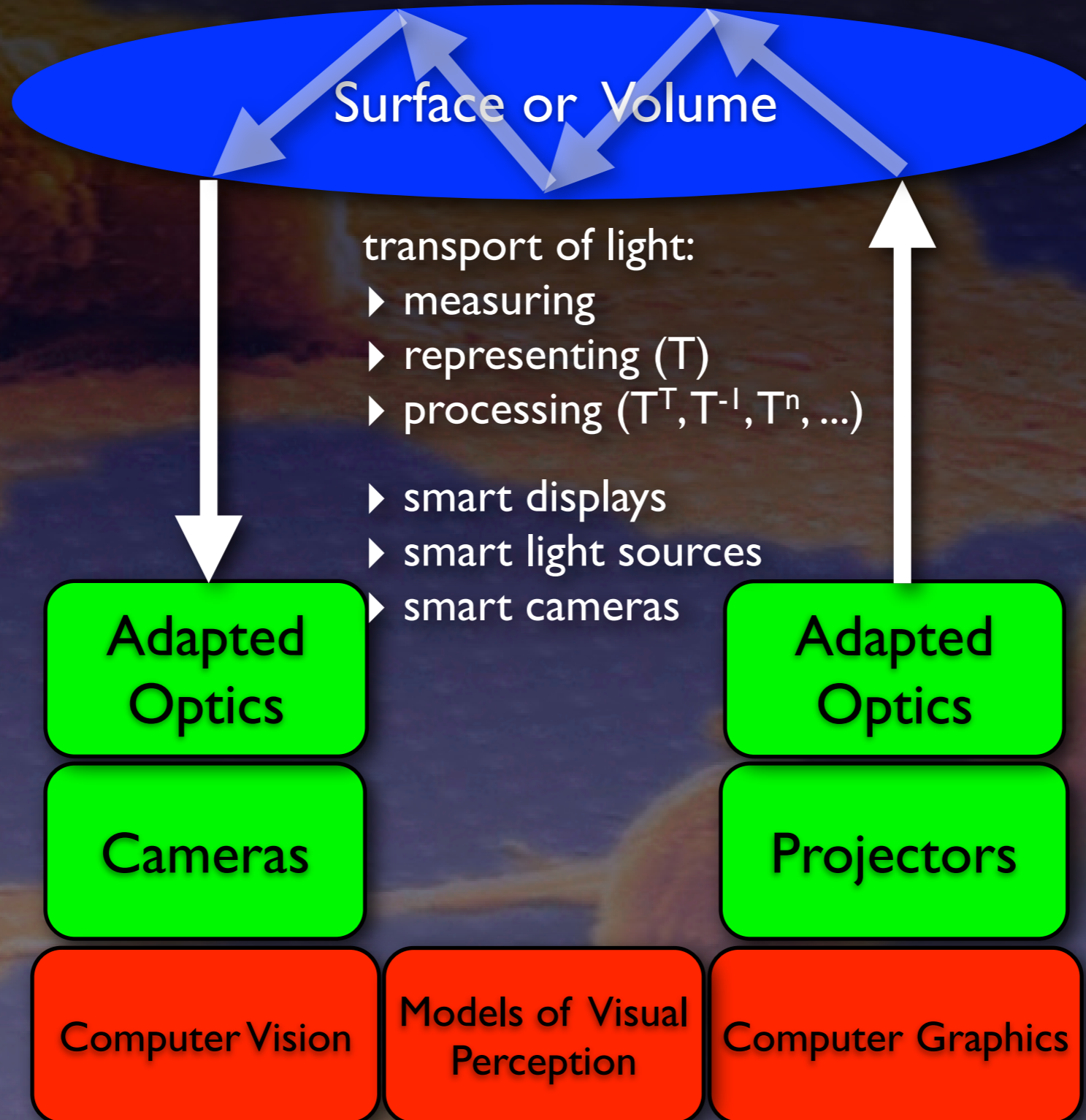
*Institute of Computer Graphics  
Johannes Kepler University, Linz*

# Projector-Camera Systems

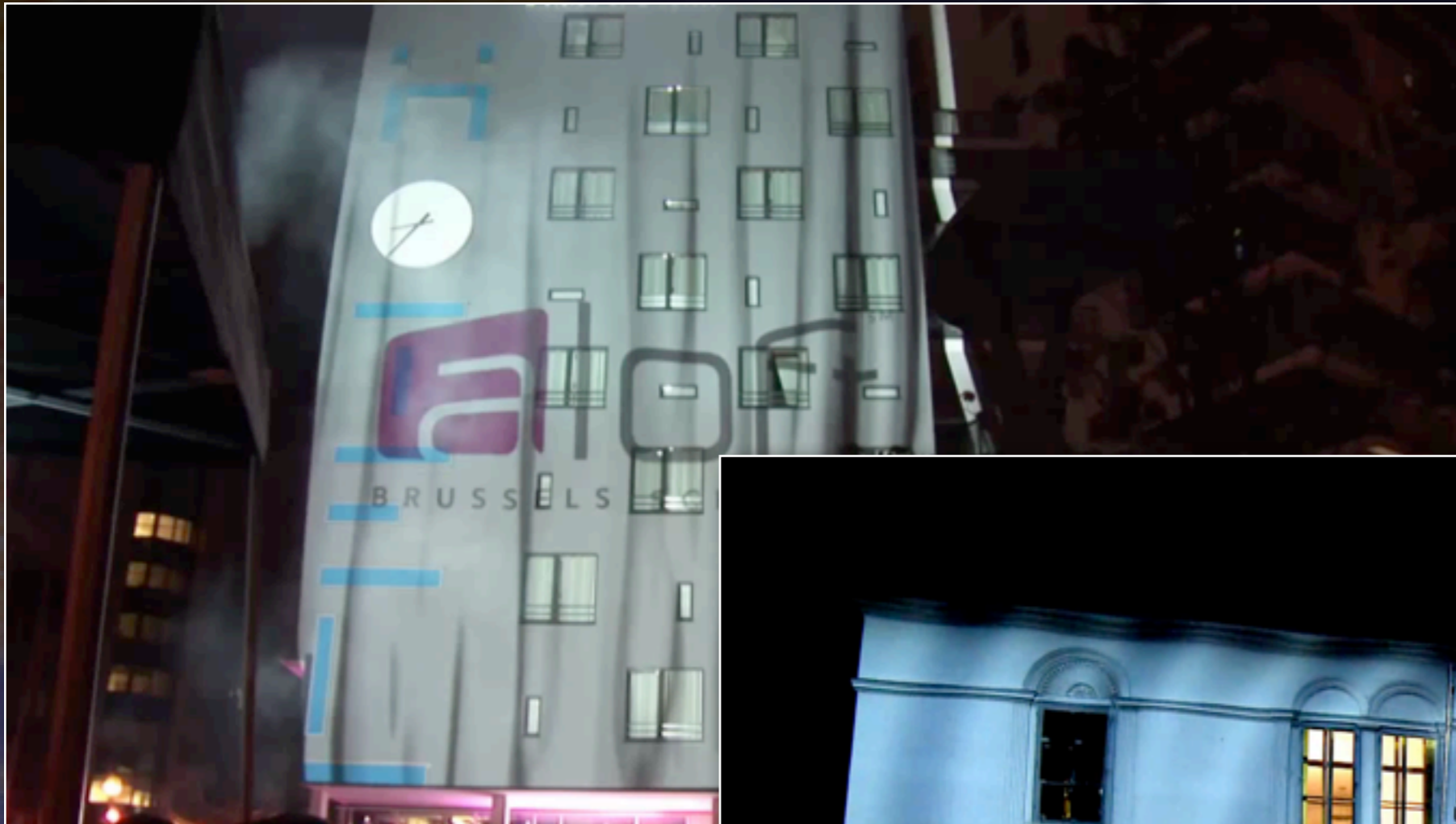
# The Projection-Screen Dilemma



# Projector-Camera Systems



# SmartProjector™



ALOFT hotel Brussels Schuman, 2010



Schloß Paars, 2010



# SmartProjector™



Loreley, 2009



Castle Altena, 2009

# SmartProjector™



EON, 2010



# SmartProjector™



IVETE-Show Madison Square Garden, New York, 2010



Essence Music Festival, New Orleans, 2010

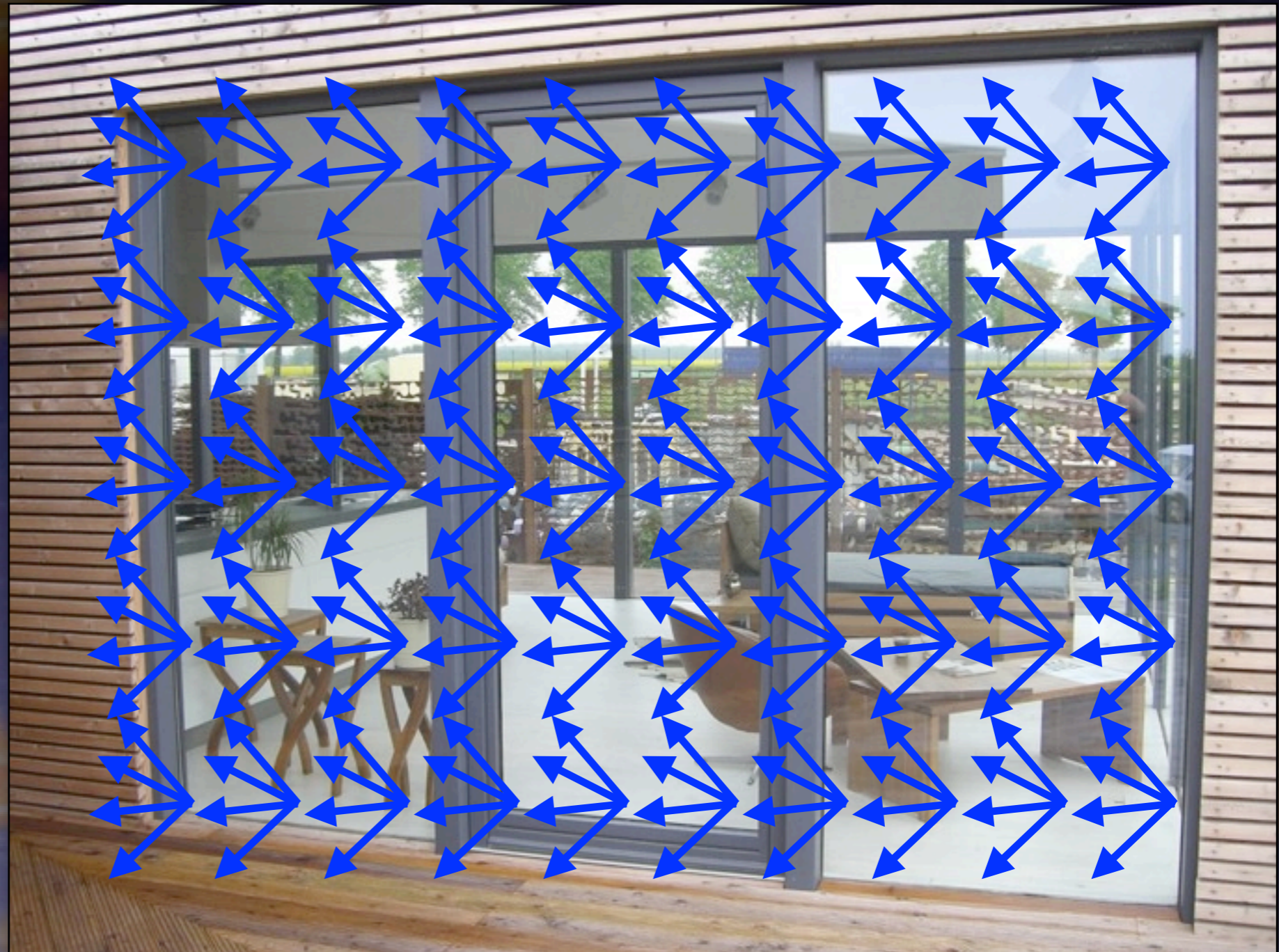
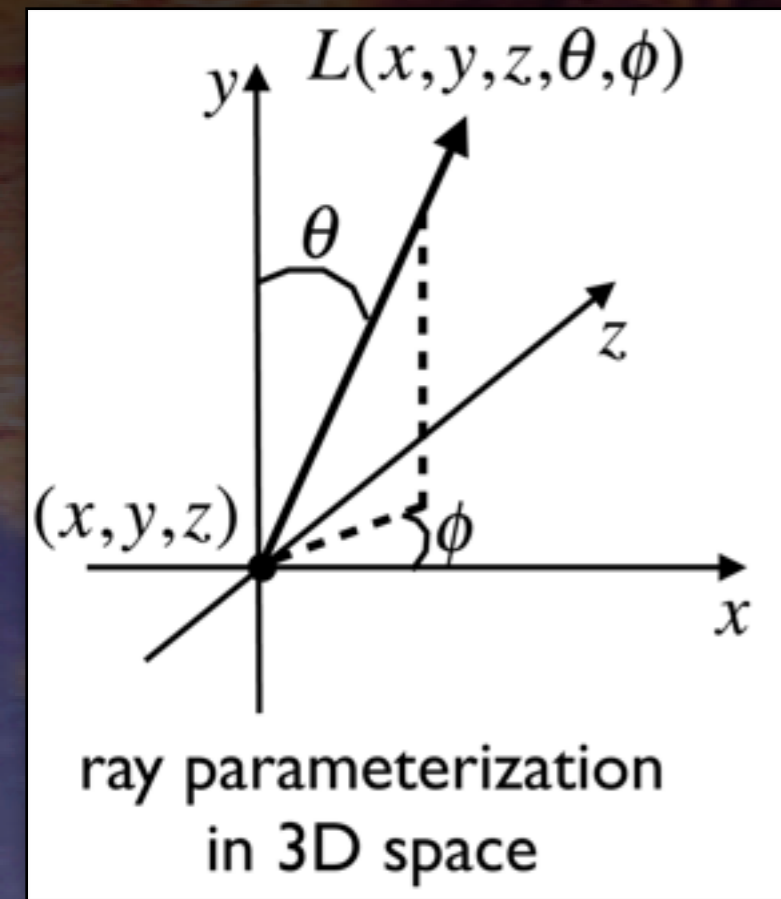


# SmartProjector™

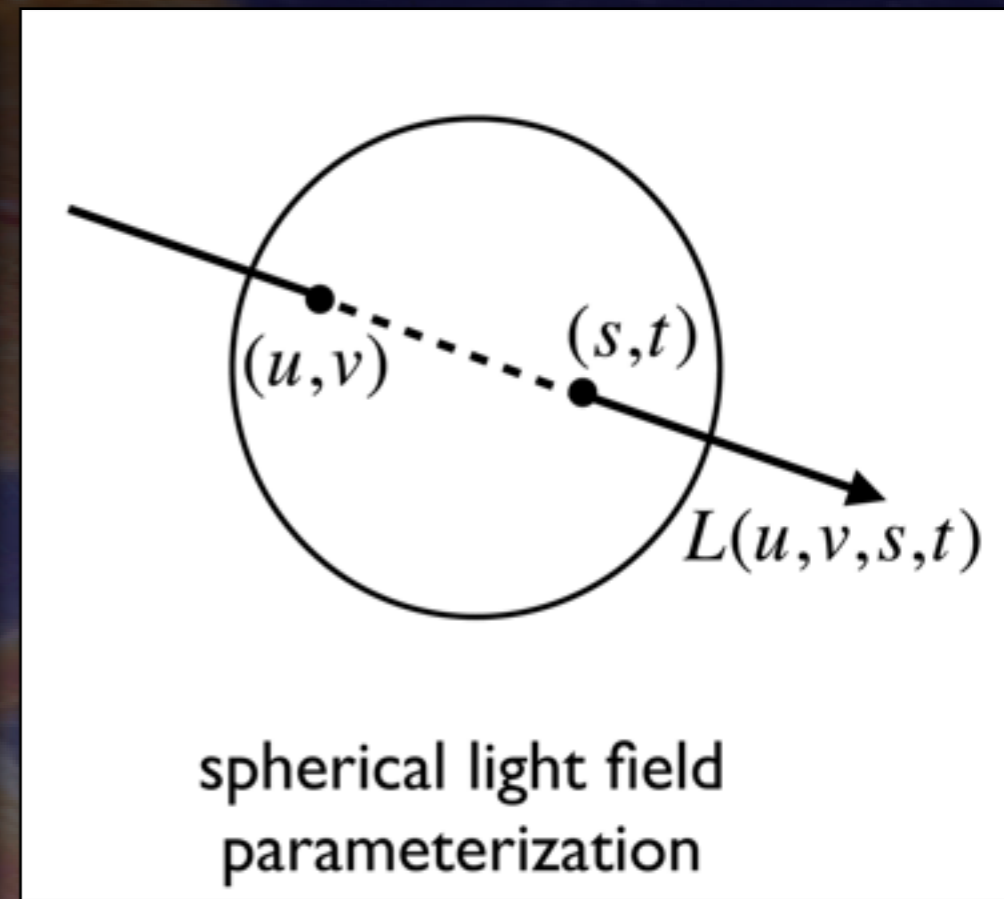
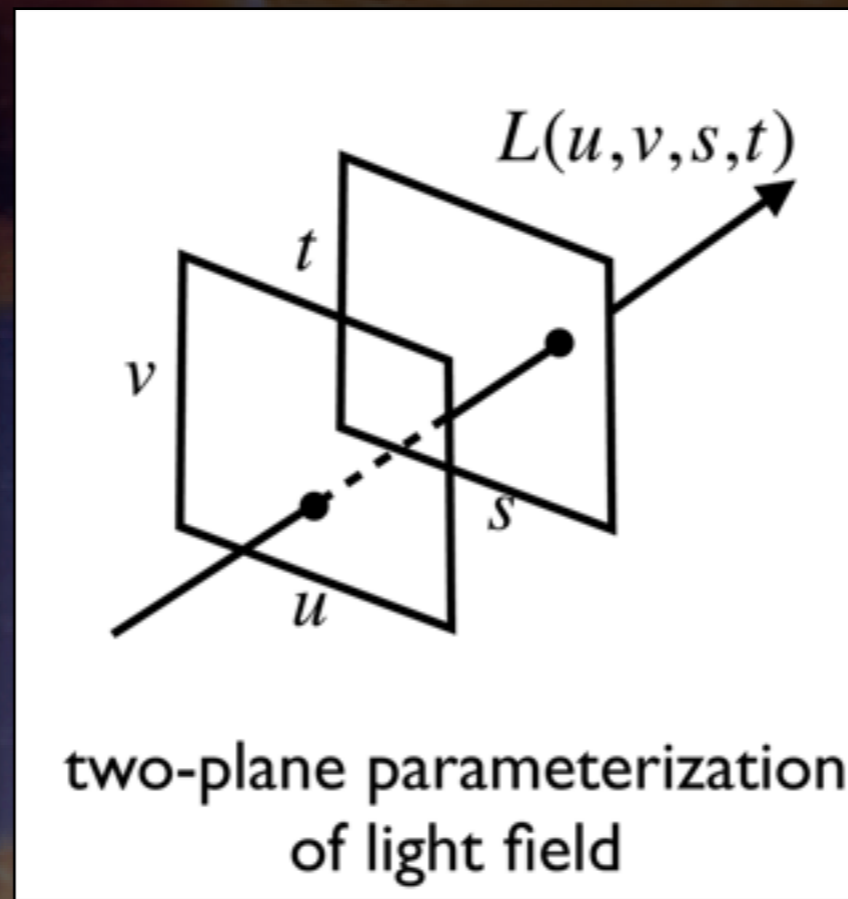
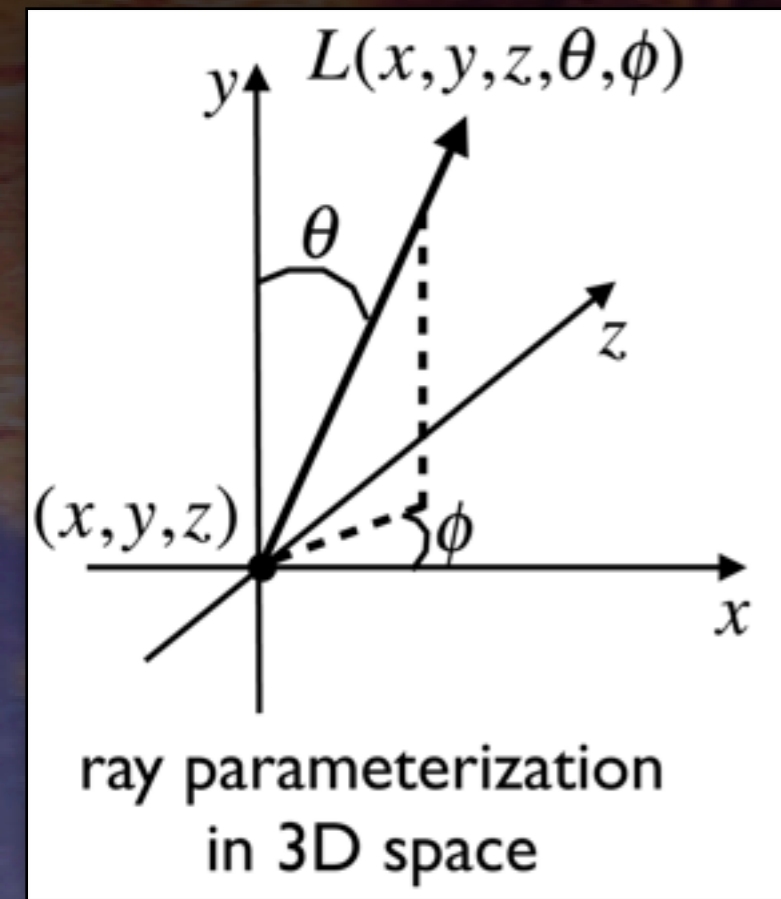


# Light Fields

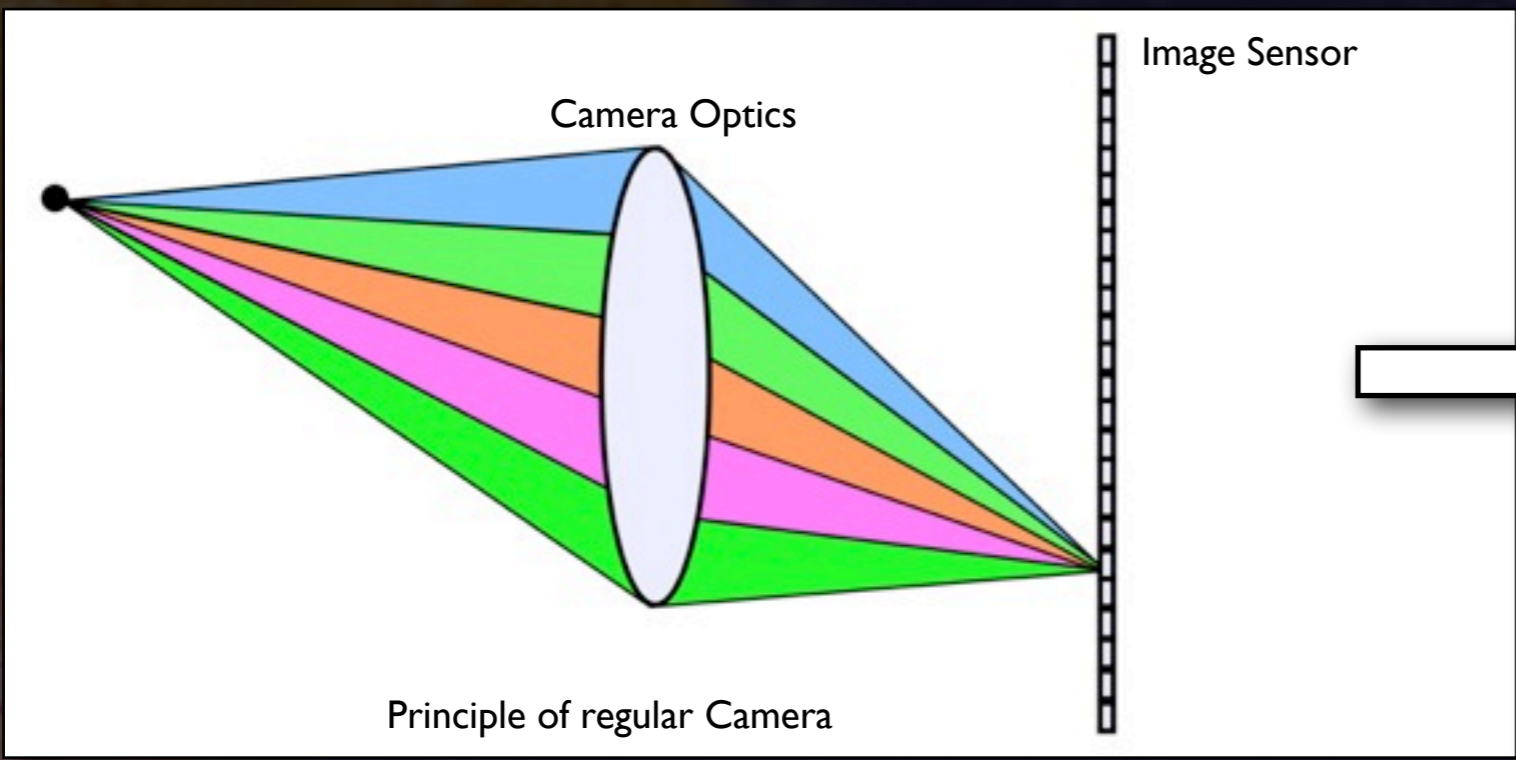
# What are Light Fields?



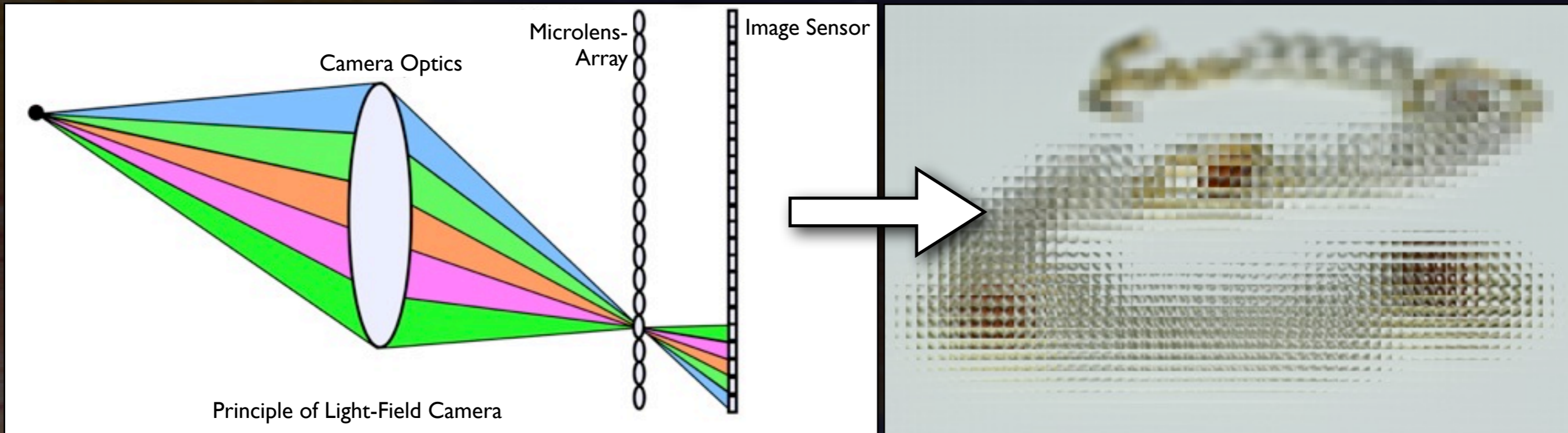
# What are Light Fields?



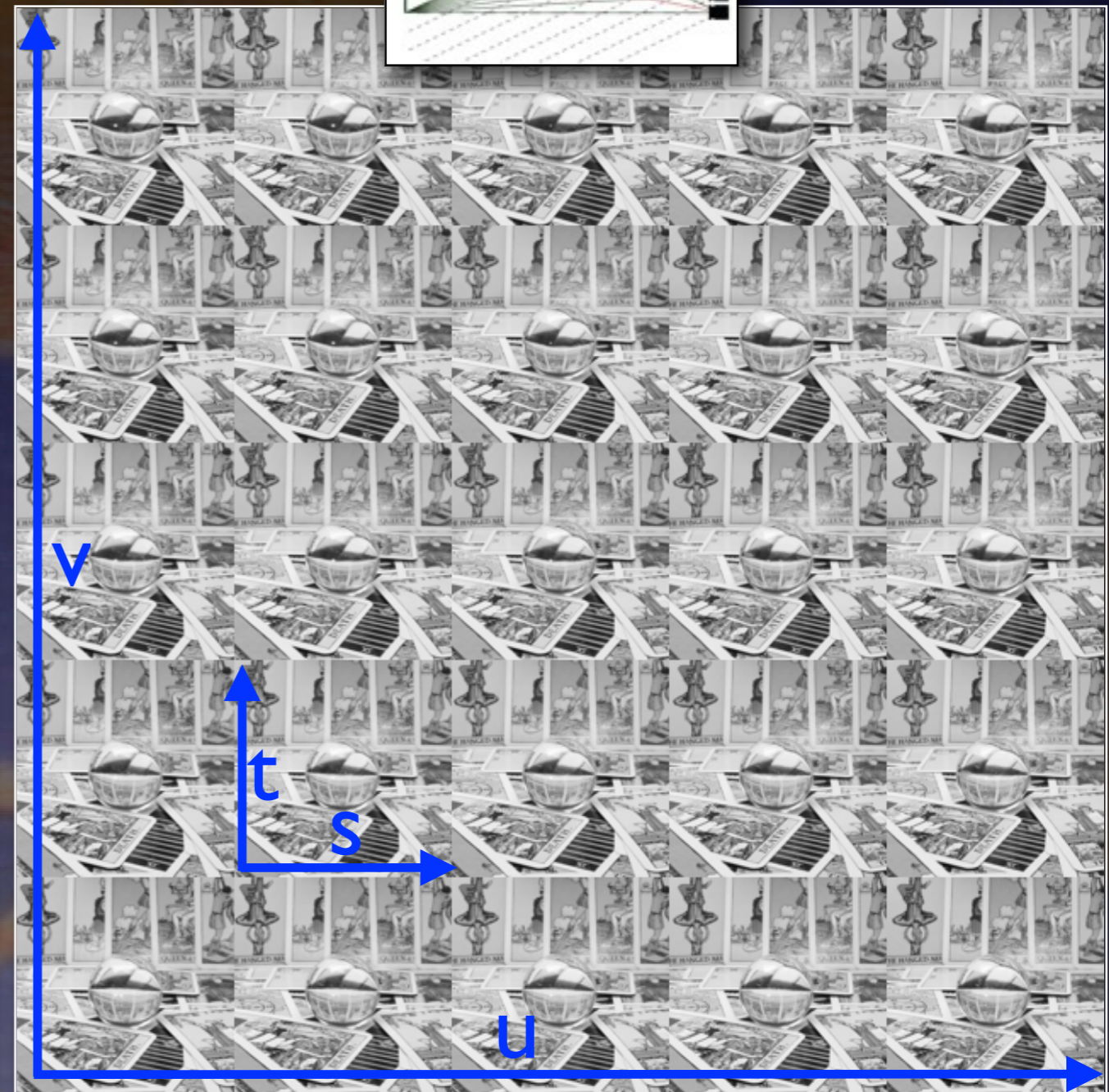
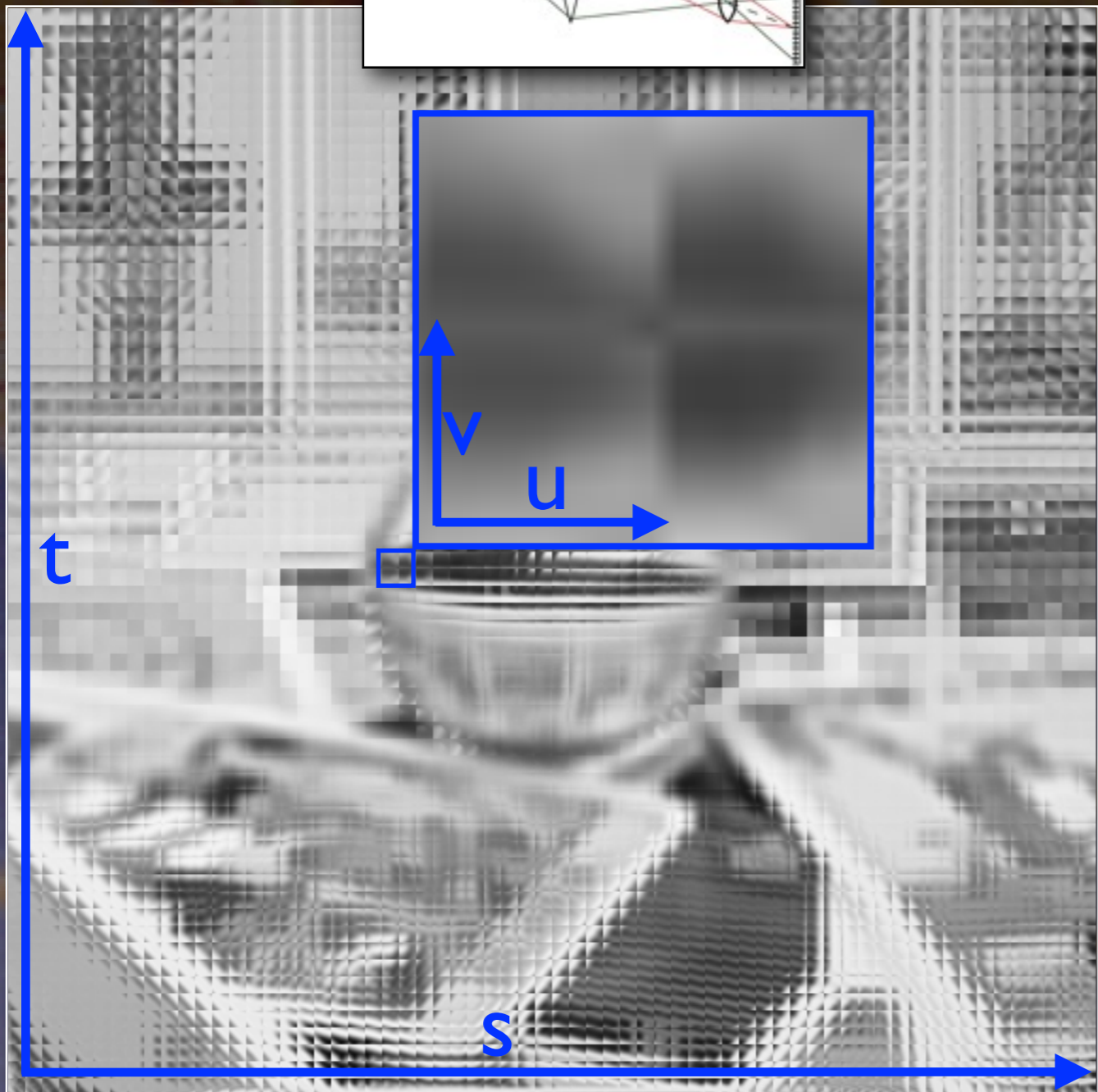
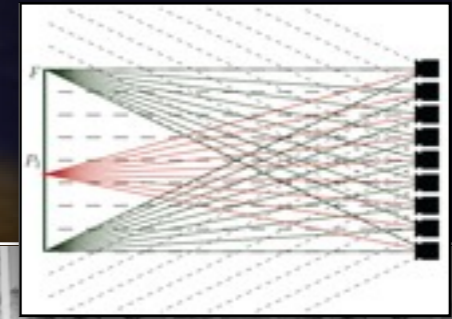
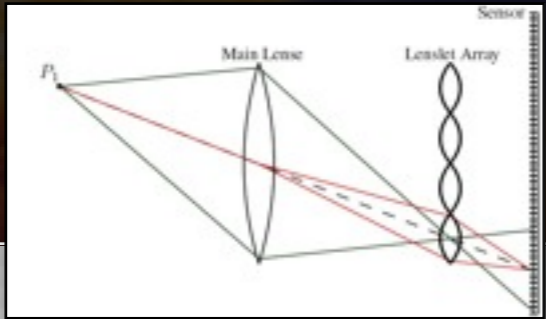
# What does a Camera Capture?



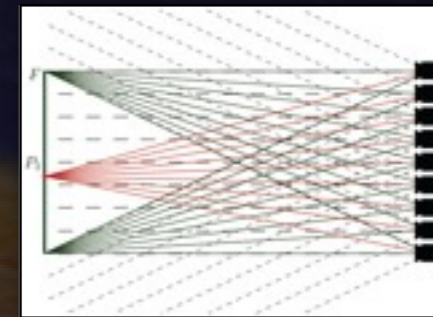
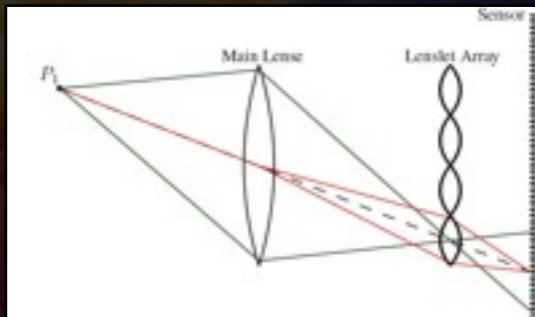
# What are Light Field Cameras?



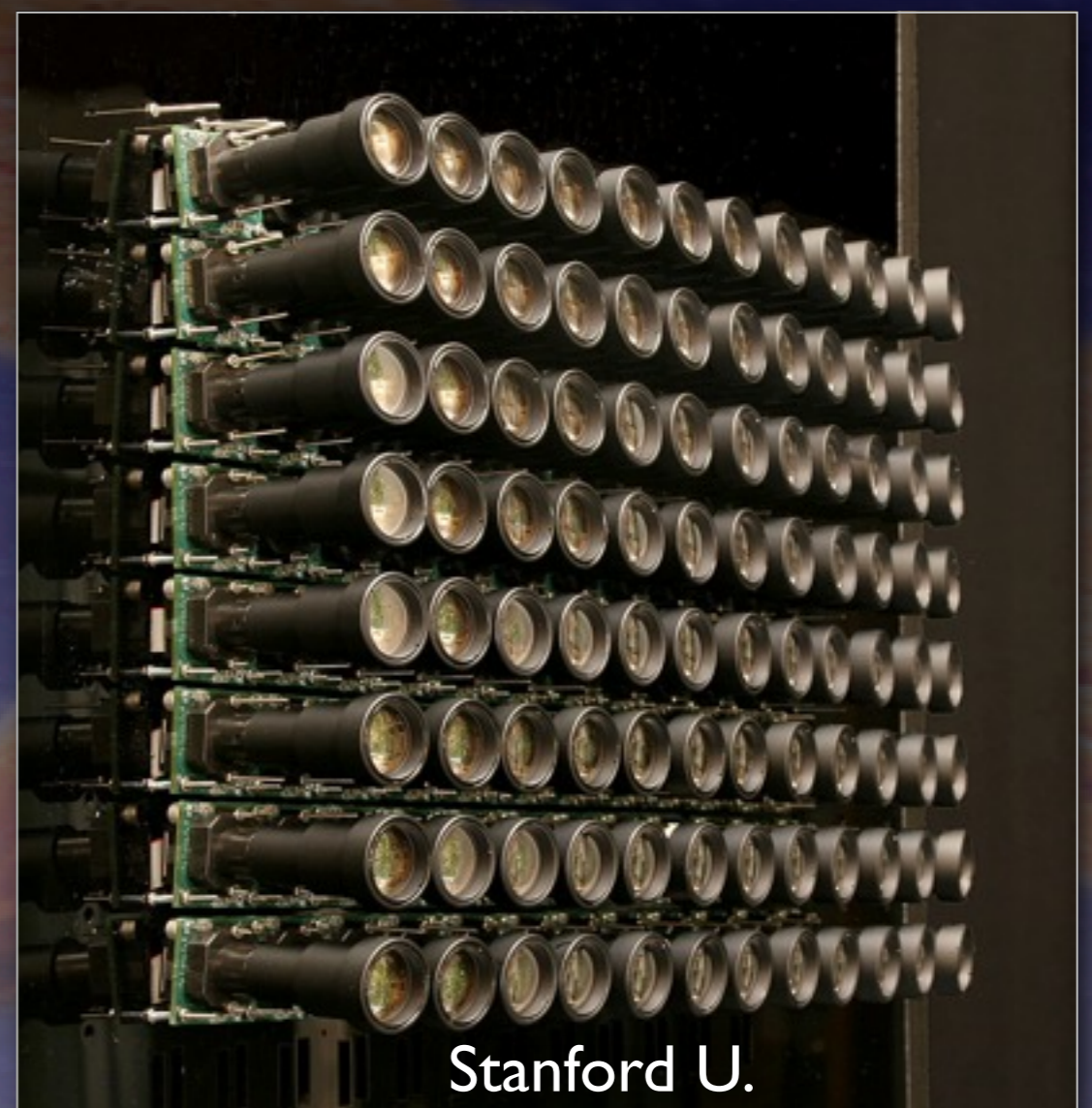
# What are Light Field Cameras?



# What are Light Field Cameras?



Lytro



Stanford U.



# What are Light Field Cameras?



Lytro



Raytrix

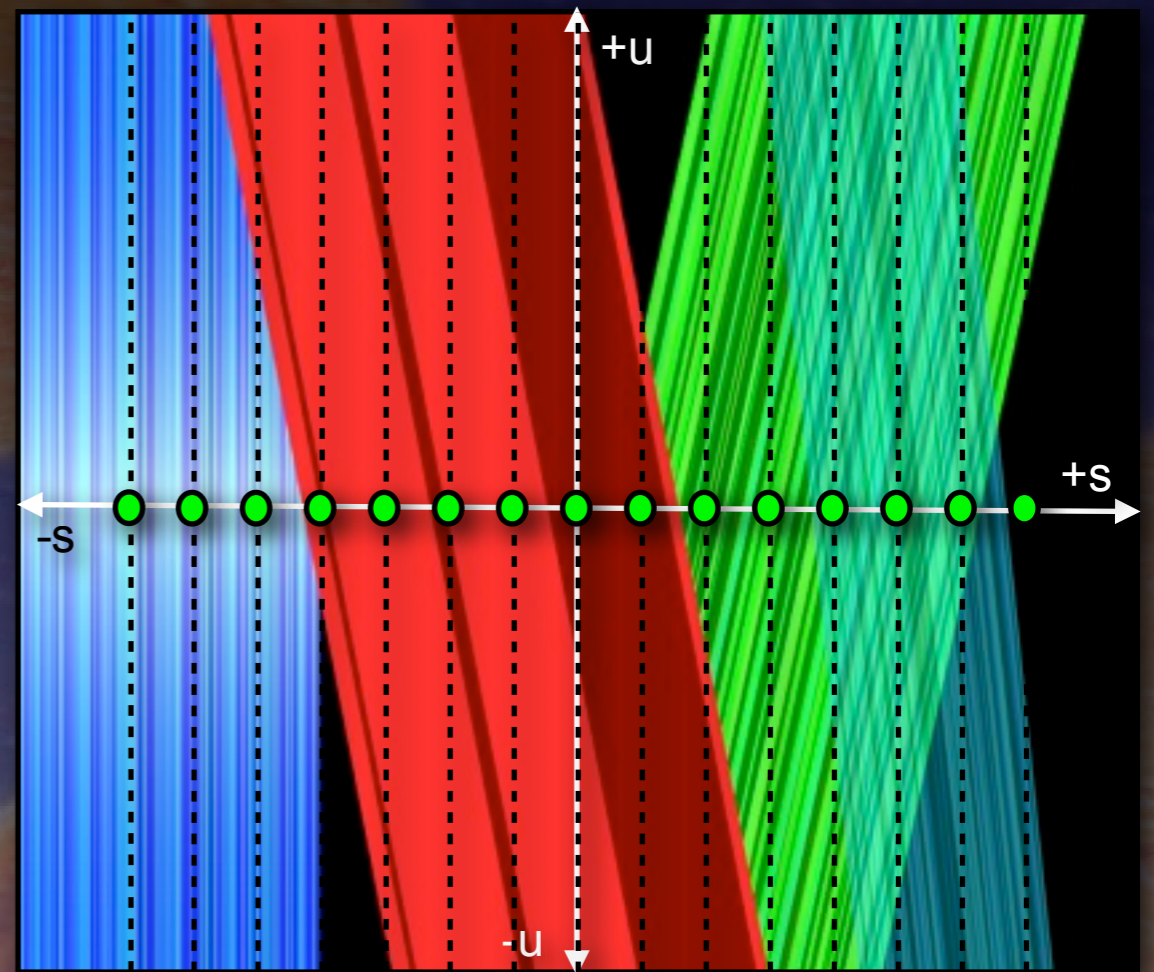
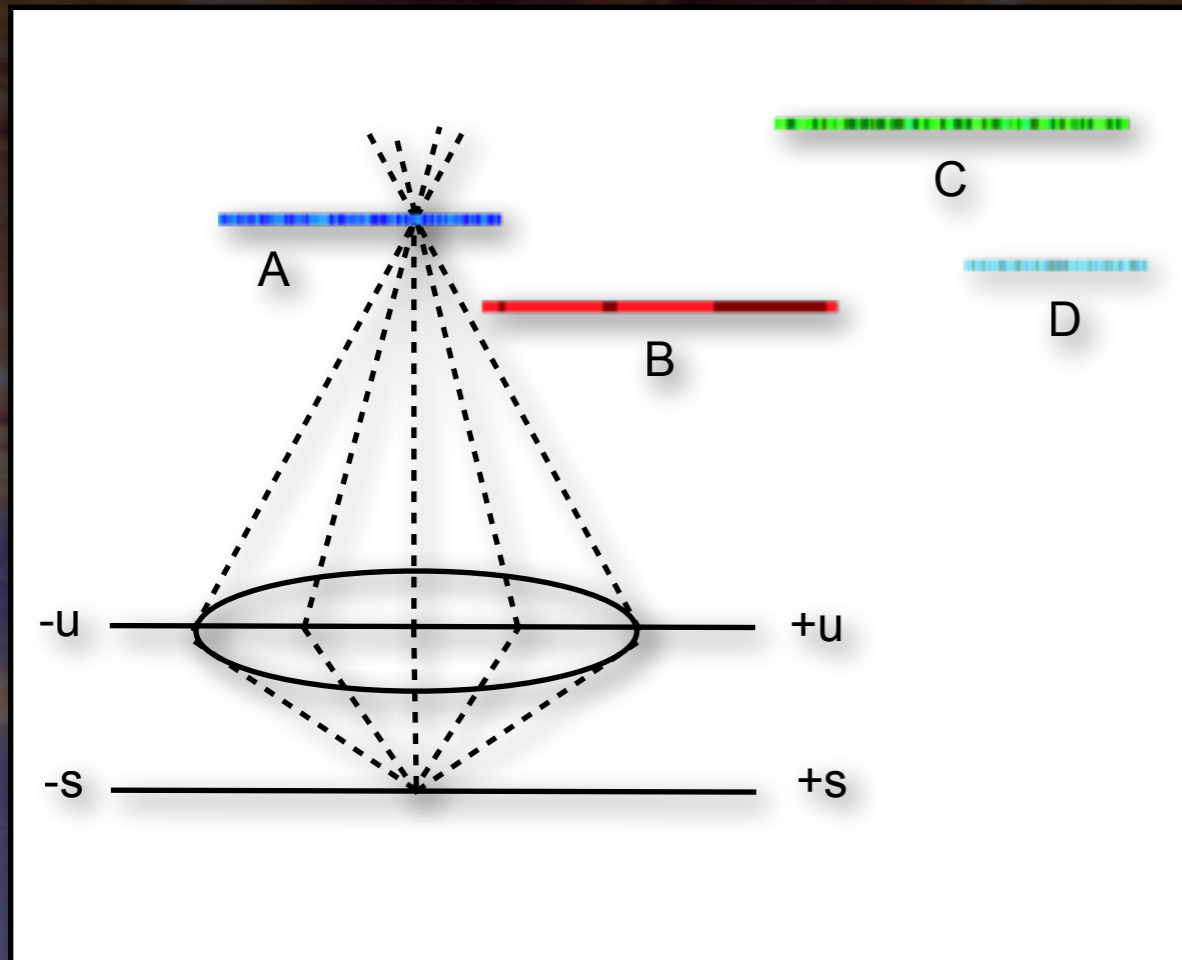


Adobe

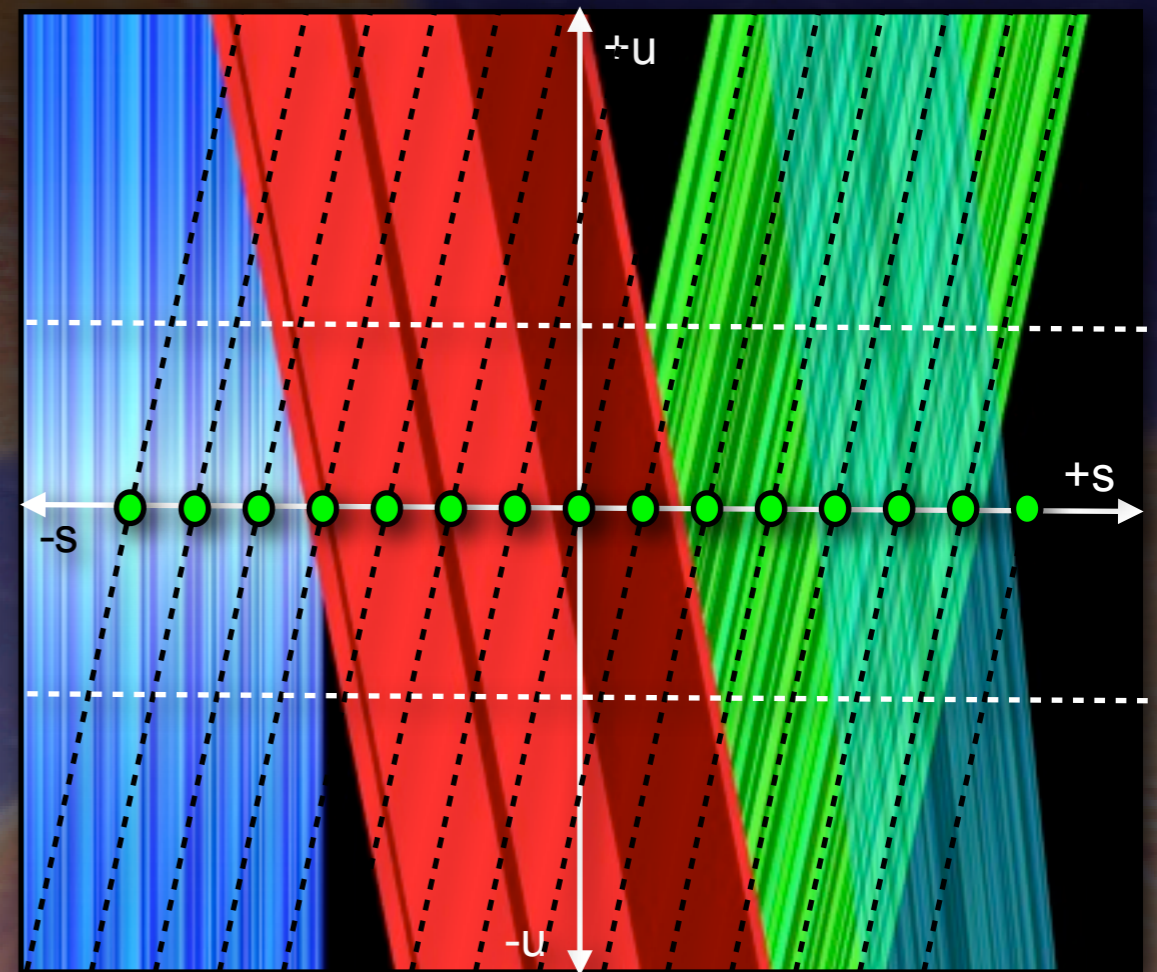
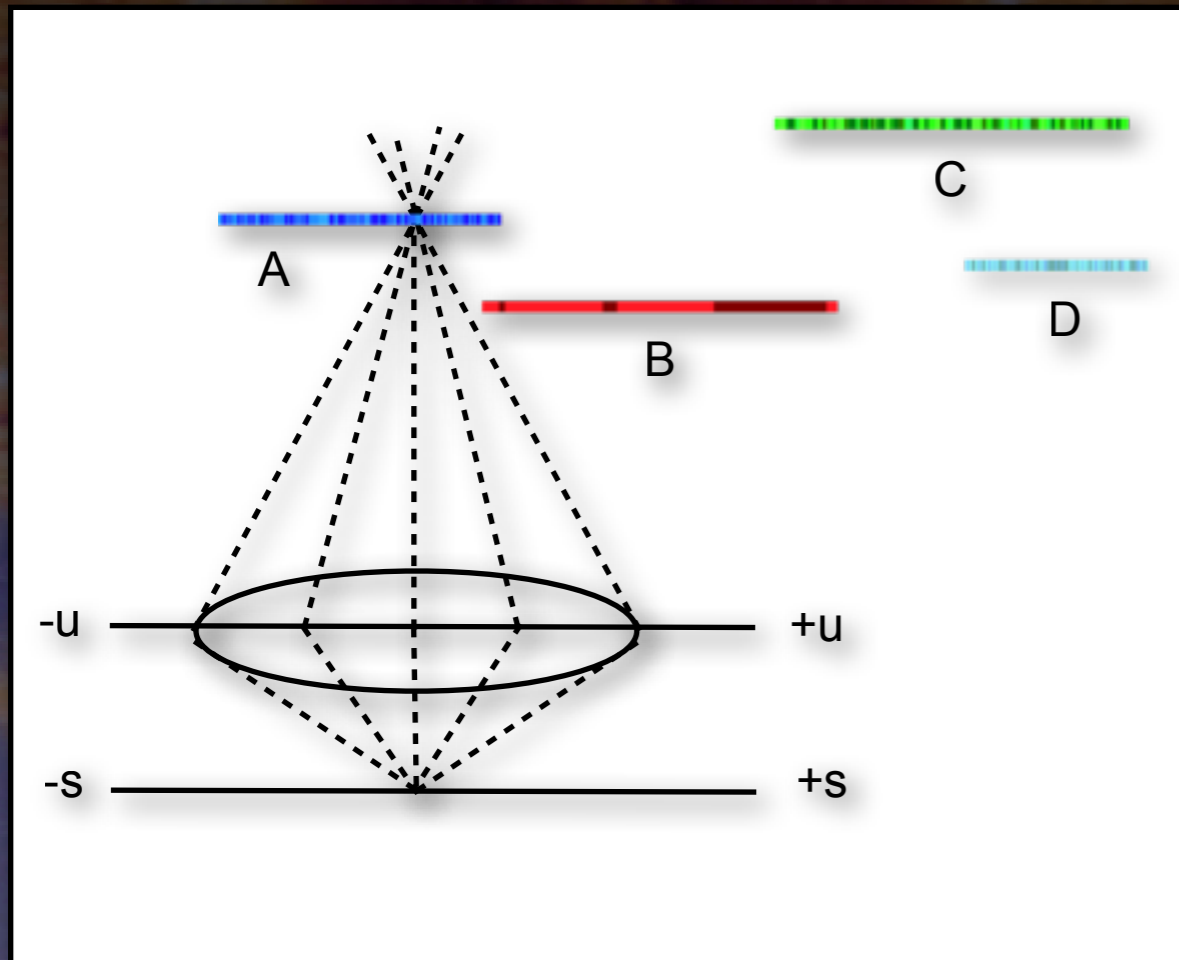
# Light-Field Rendering



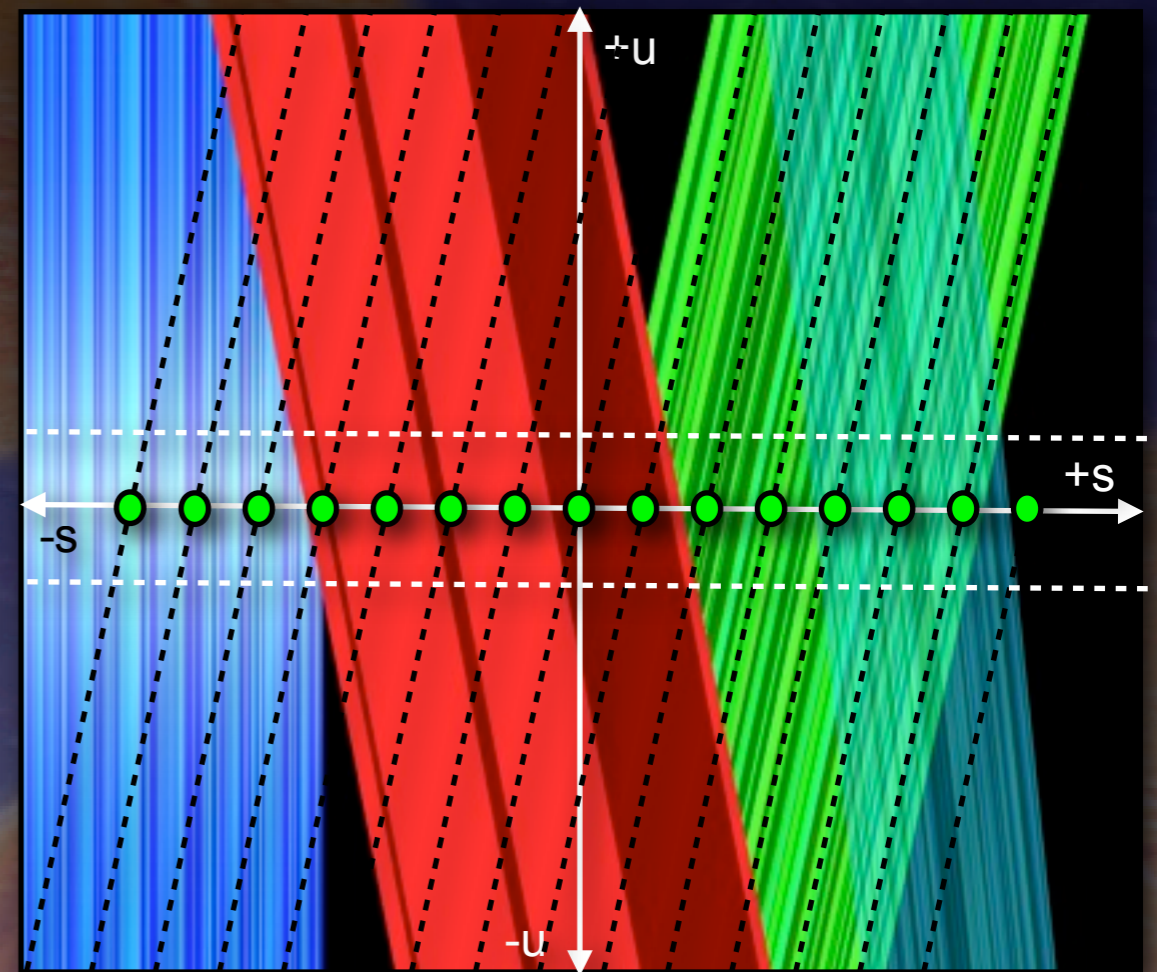
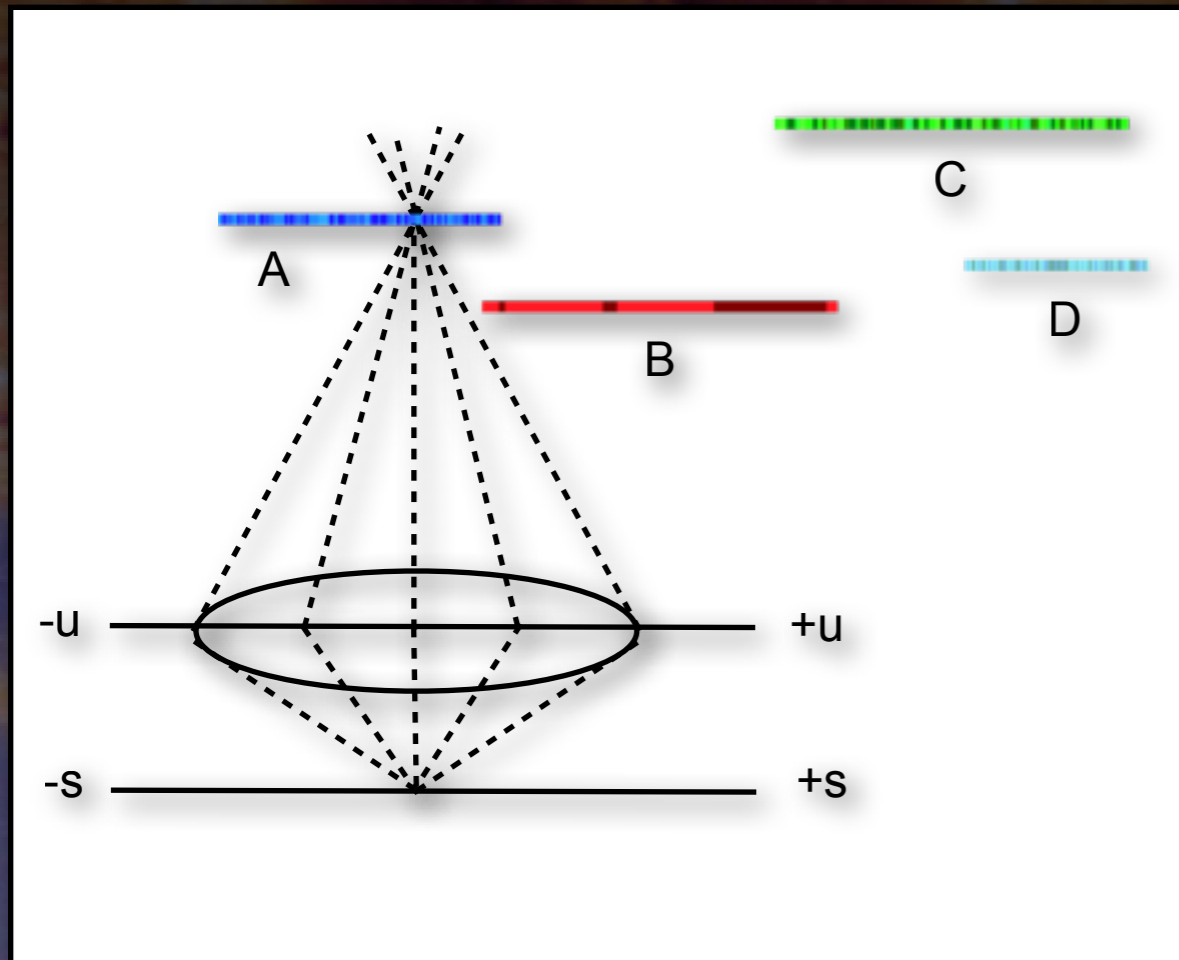
# Synthetic Aperture Reconstruction



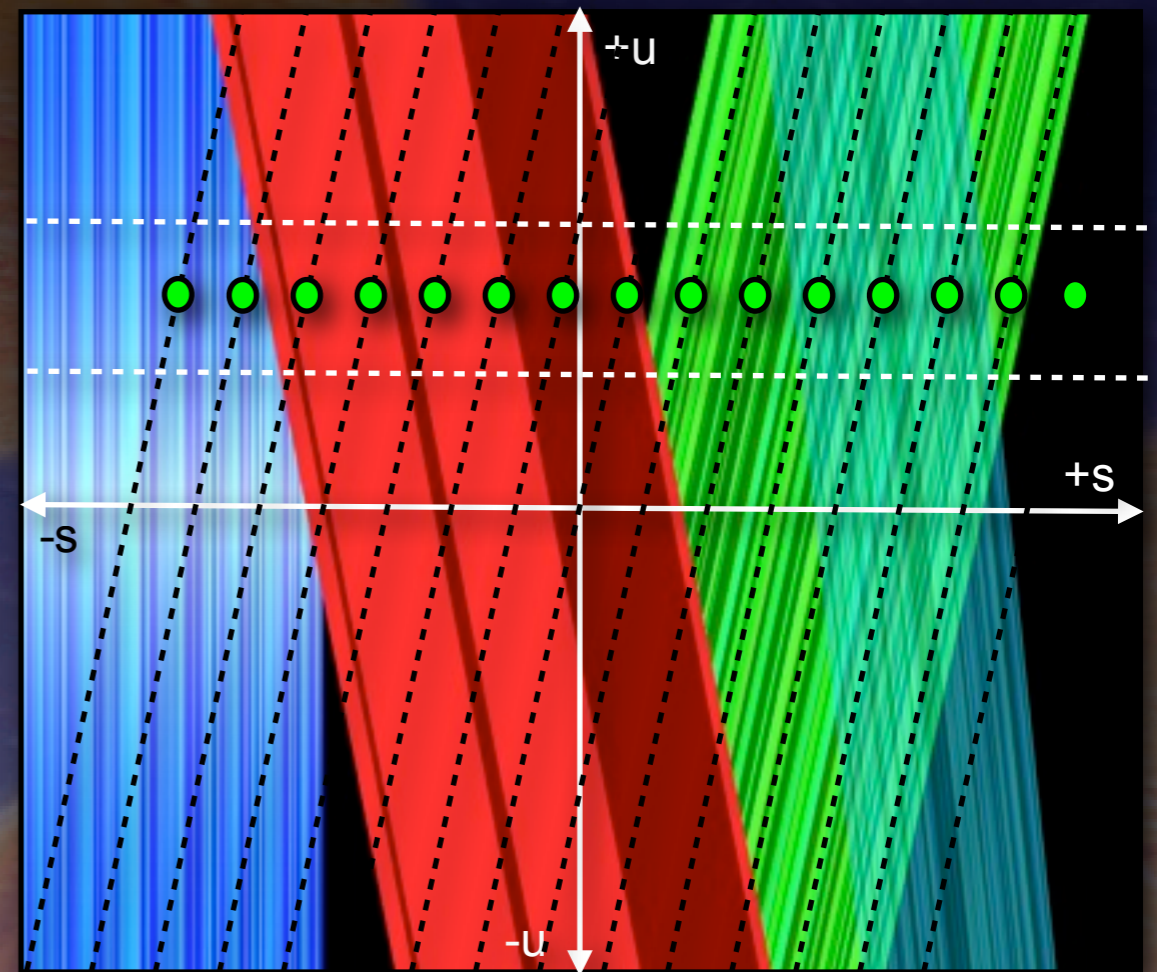
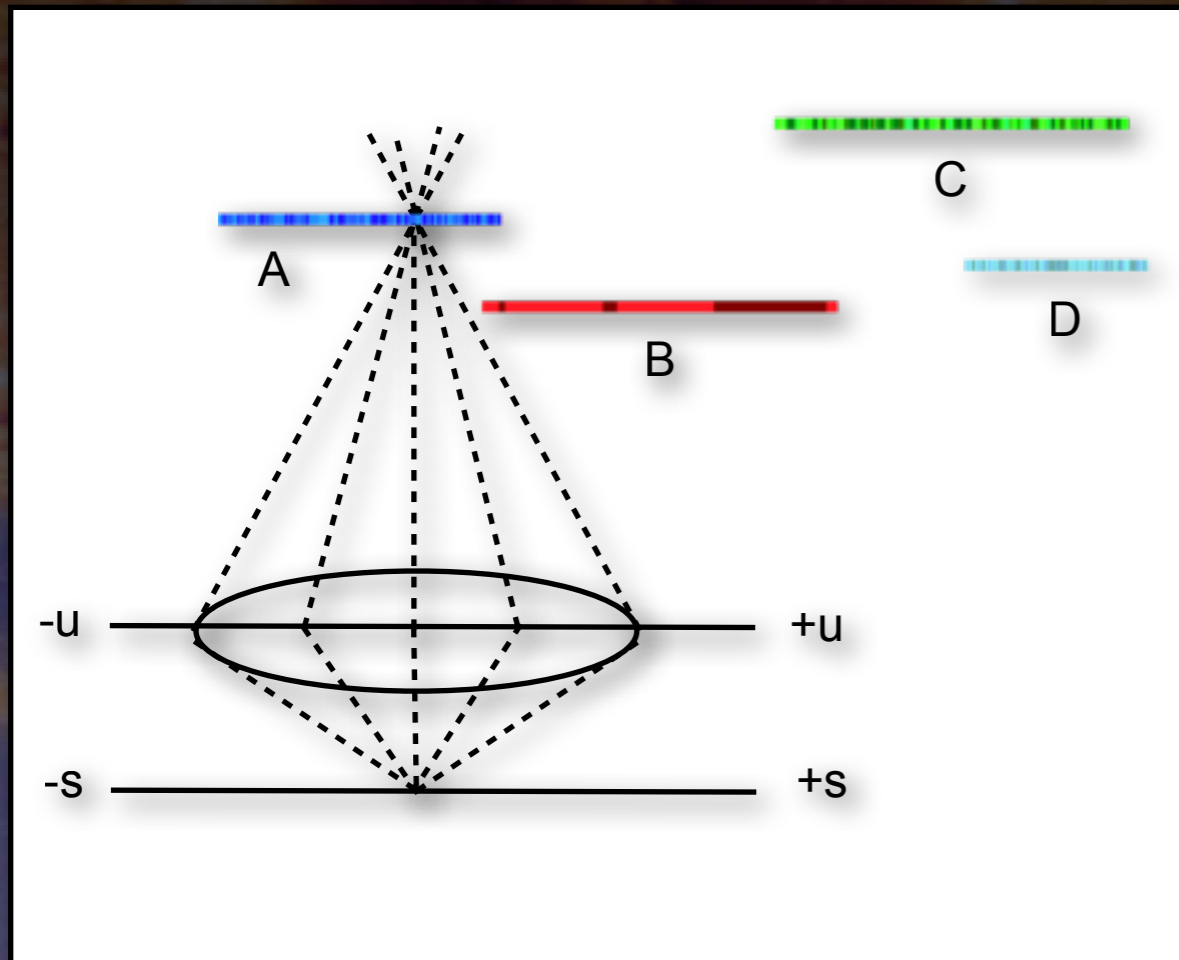
# Synthetic Aperture Reconstruction



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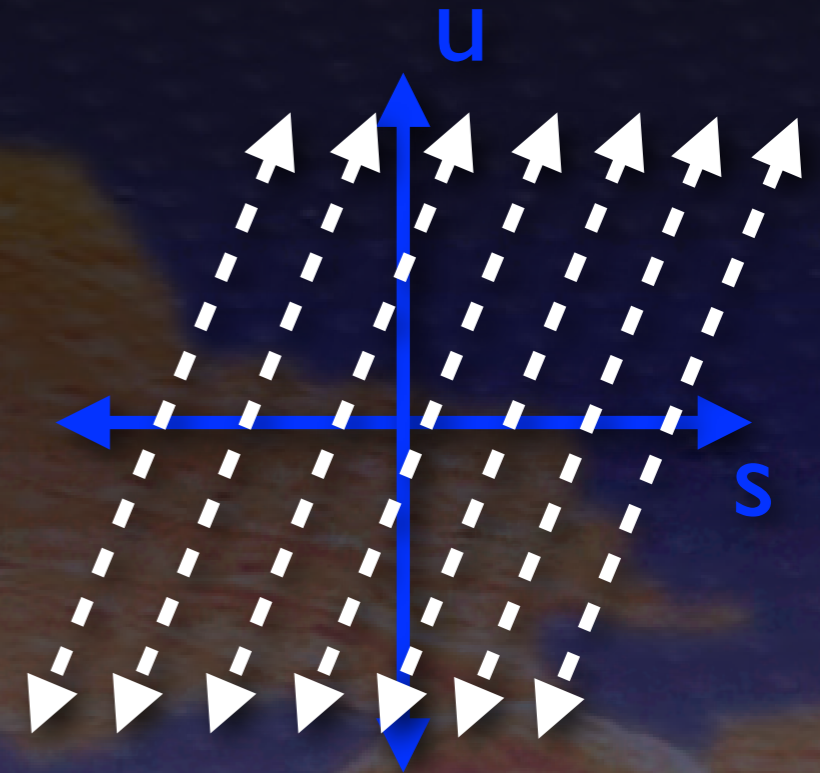
# Synthetic Aperture Reconstruction



# Spatial vs. Frequency Domain

- **Spatial Domain:**

- 4D light field is sheared and integrated on 2D image plane



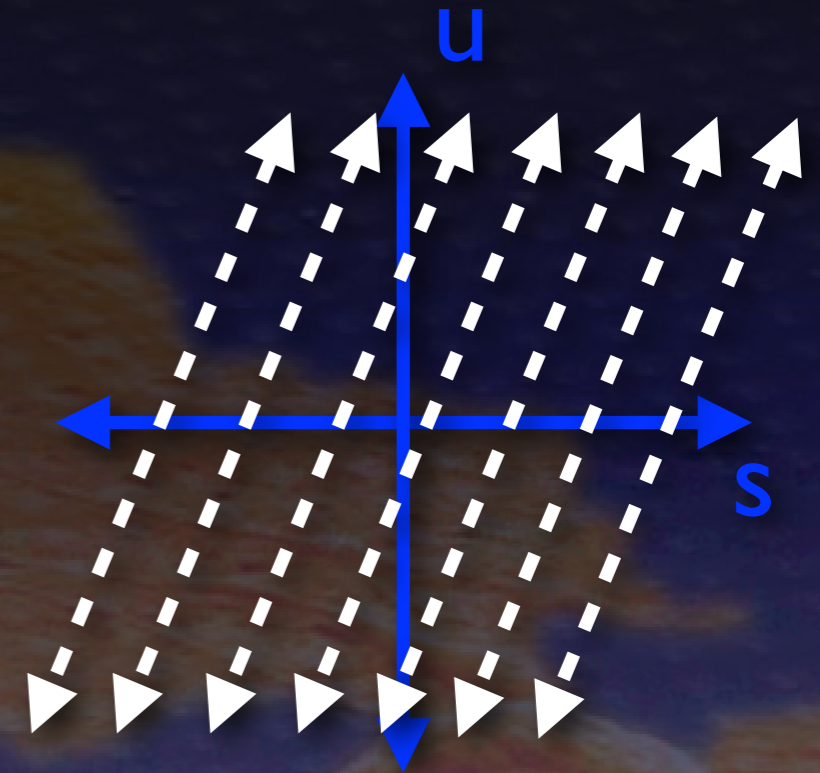
# Spatial vs. Frequency Domain

- **Spatial Domain:**

- 4D light field is sheared and integrated on 2D image plane

- **Projection-Slice Theorem:**

- projecting a higher-dimensional signal onto a lower-dimensional slice and Fourier-transforming it, is the same as Fourier-transforming higher-dimensional signal and take the slice, that is perpendicular to the integral direction in spatial domain





# Spatial vs. Frequency Domain

- **Spatial Domain:**

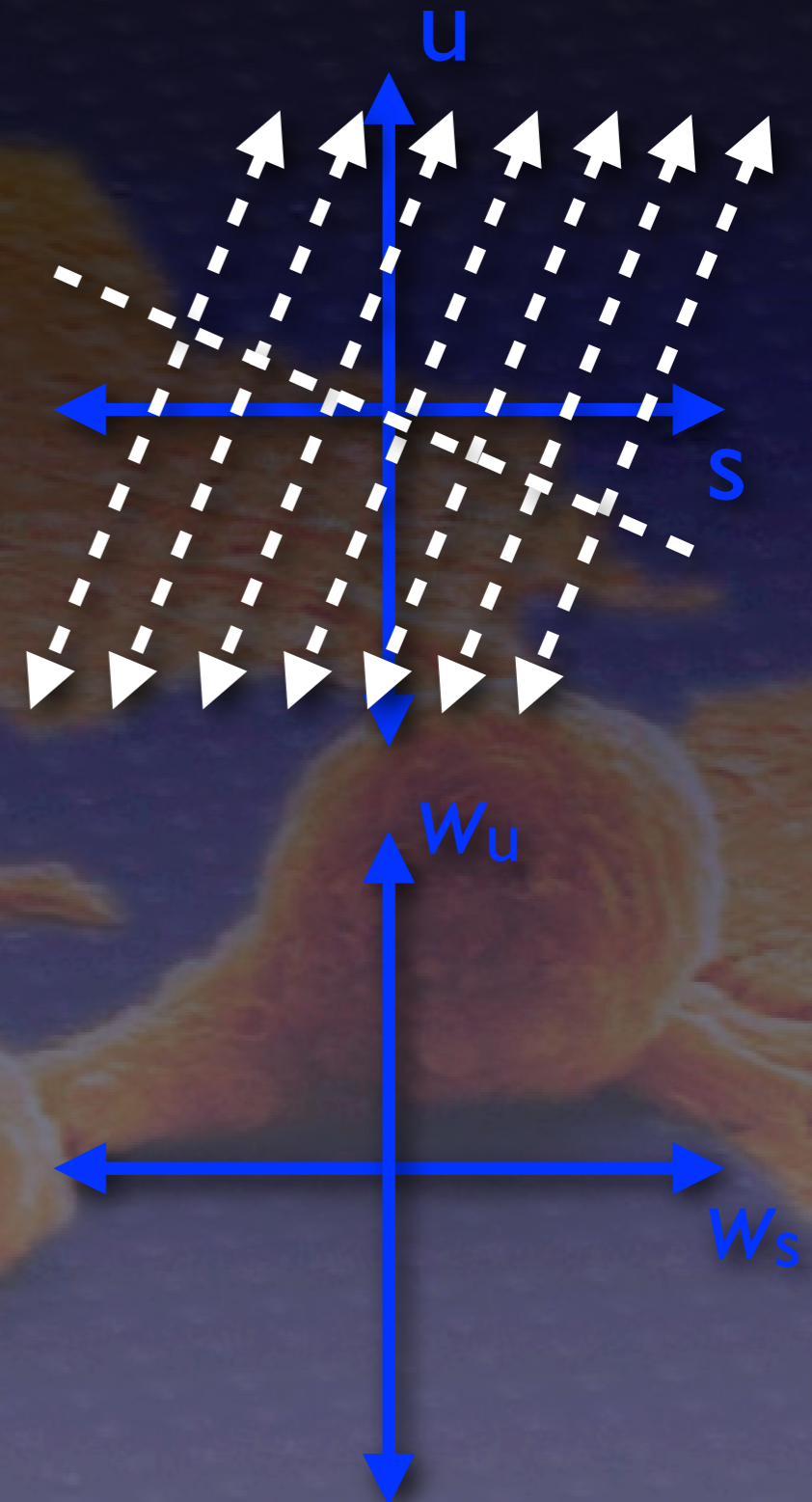
- 4D light field is sheared and integrated on 2D image plane

- **Projection-Slice Theorem:**

- projecting a higher-dimensional signal onto a lower-dimensional slice and Fourier-transforming it, is the same as Fourier-transforming higher-dimensional signal and take the slice, that is perpendicular to the integral direction in spatial domain

- **Frequency Domain:**

- Fourier-transform 4D light field, take 2D slice, inverse Fourier-transform 2D slice



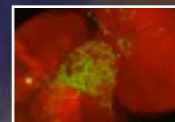
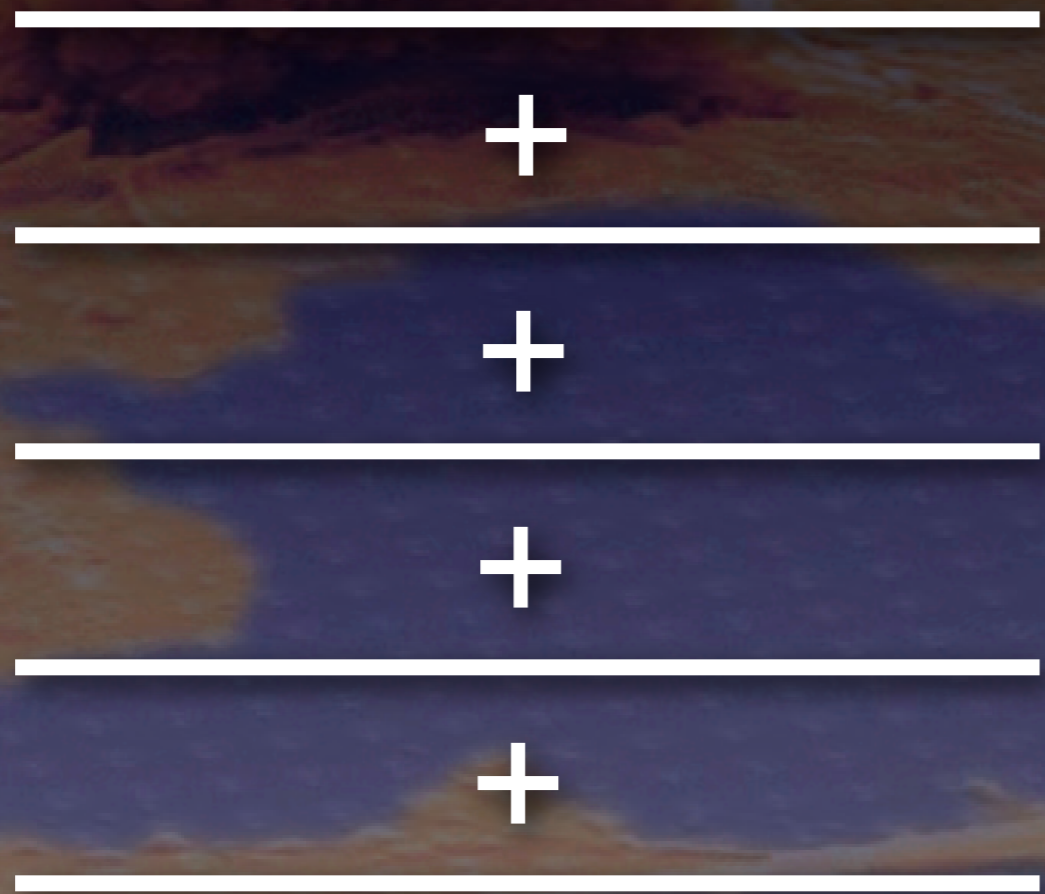
# Focal Stacks and Z-Stacks

deconvolution

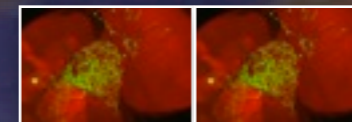
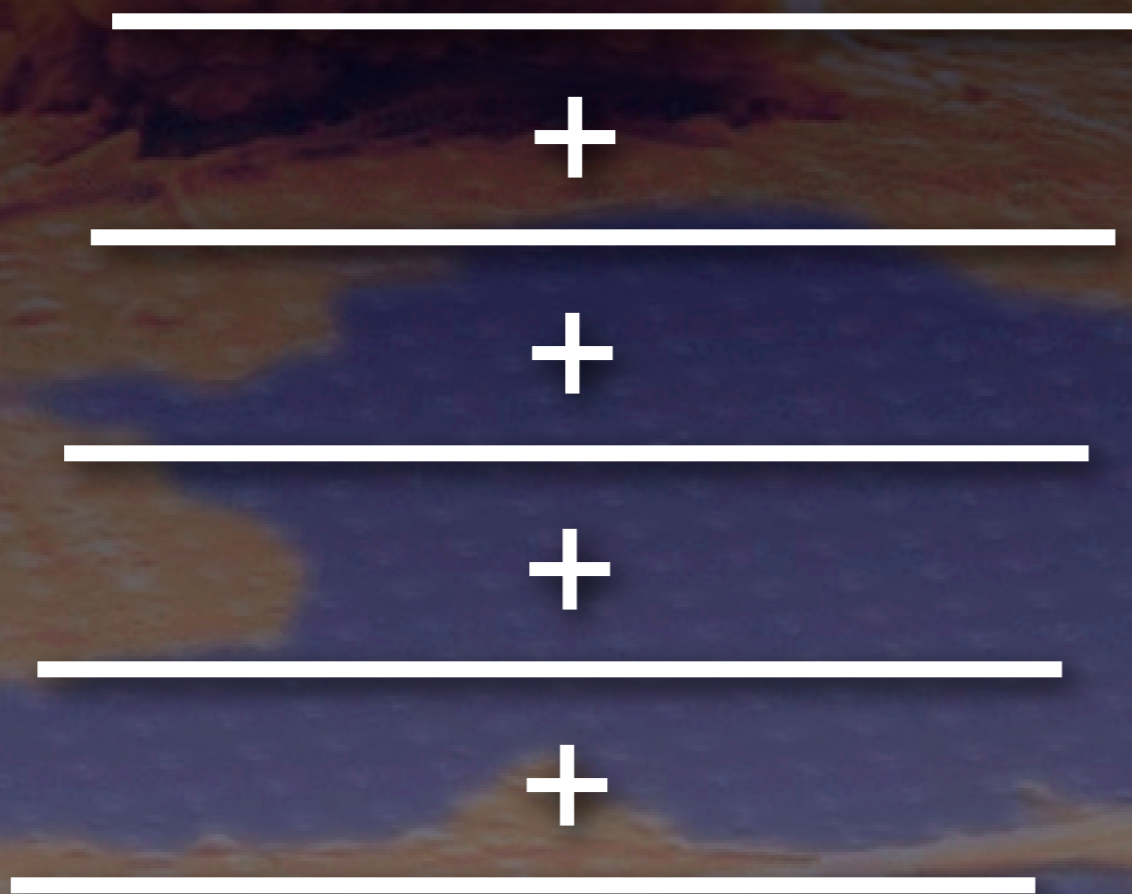


convolution

# Z-Stacks to Light Fields



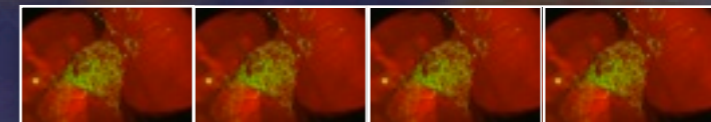
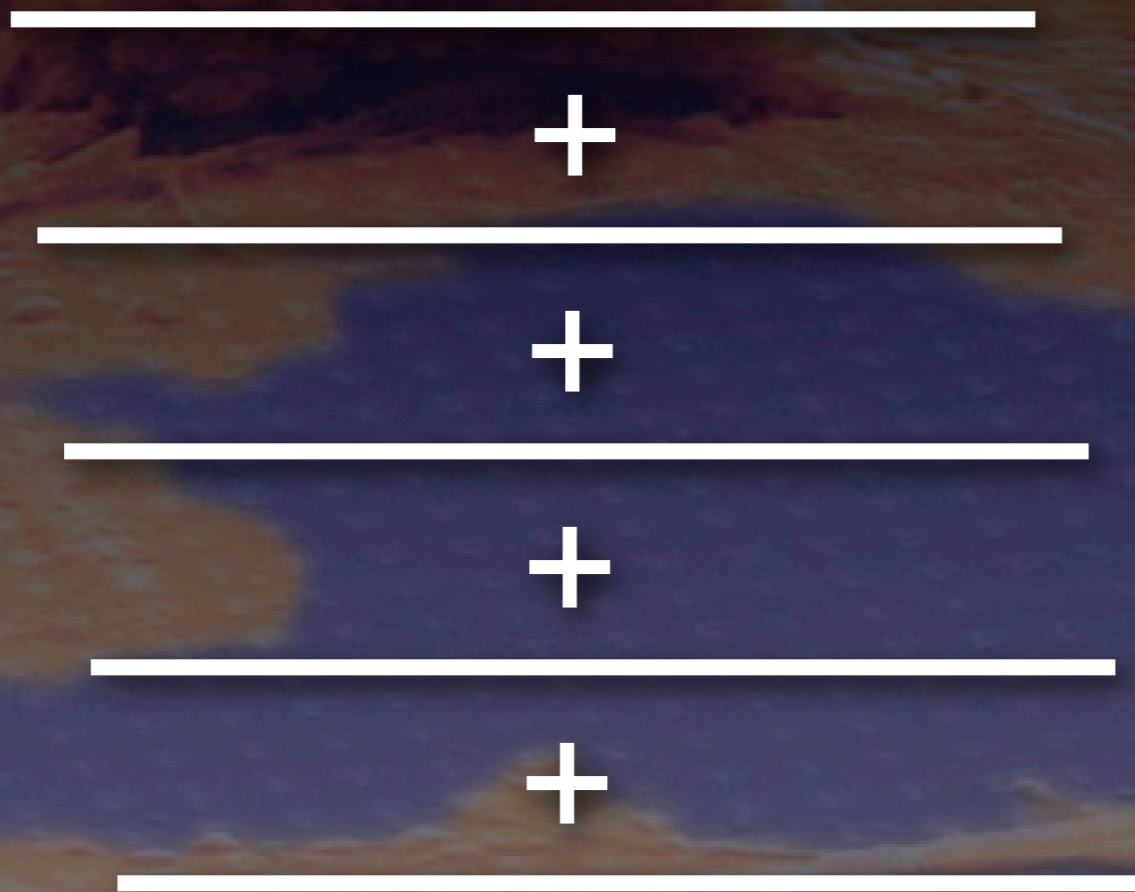
# Z-Stacks to Light Fields



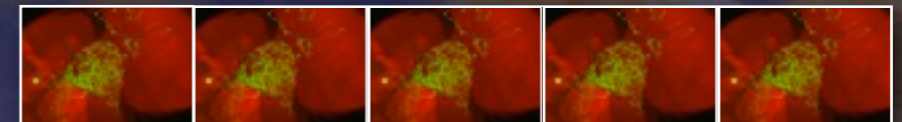
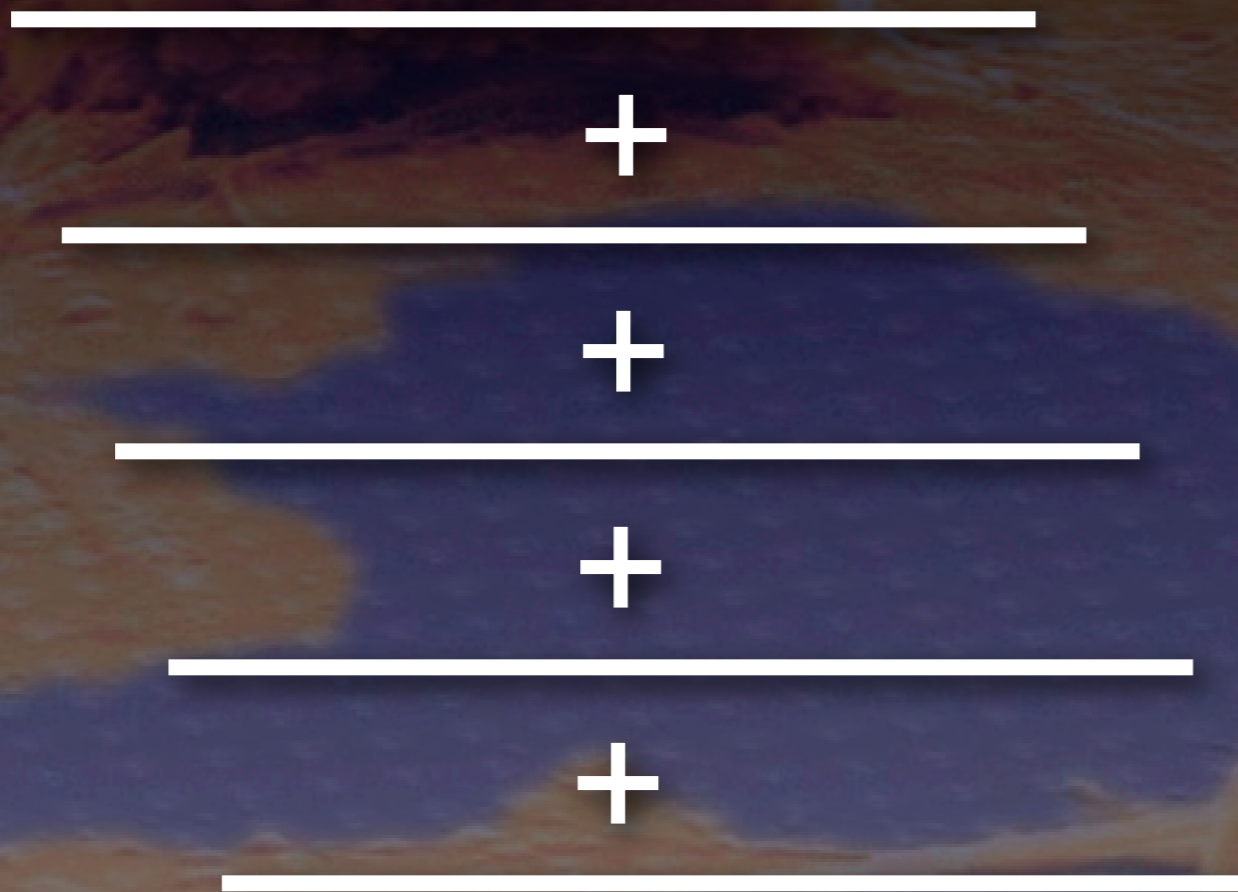
# Z-Stacks to Light Fields



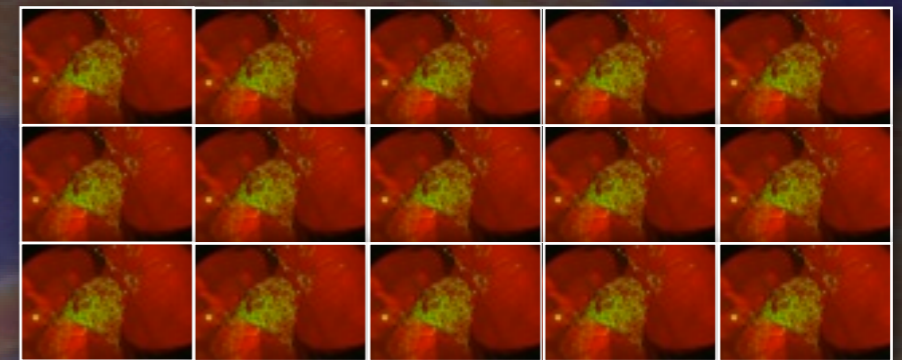
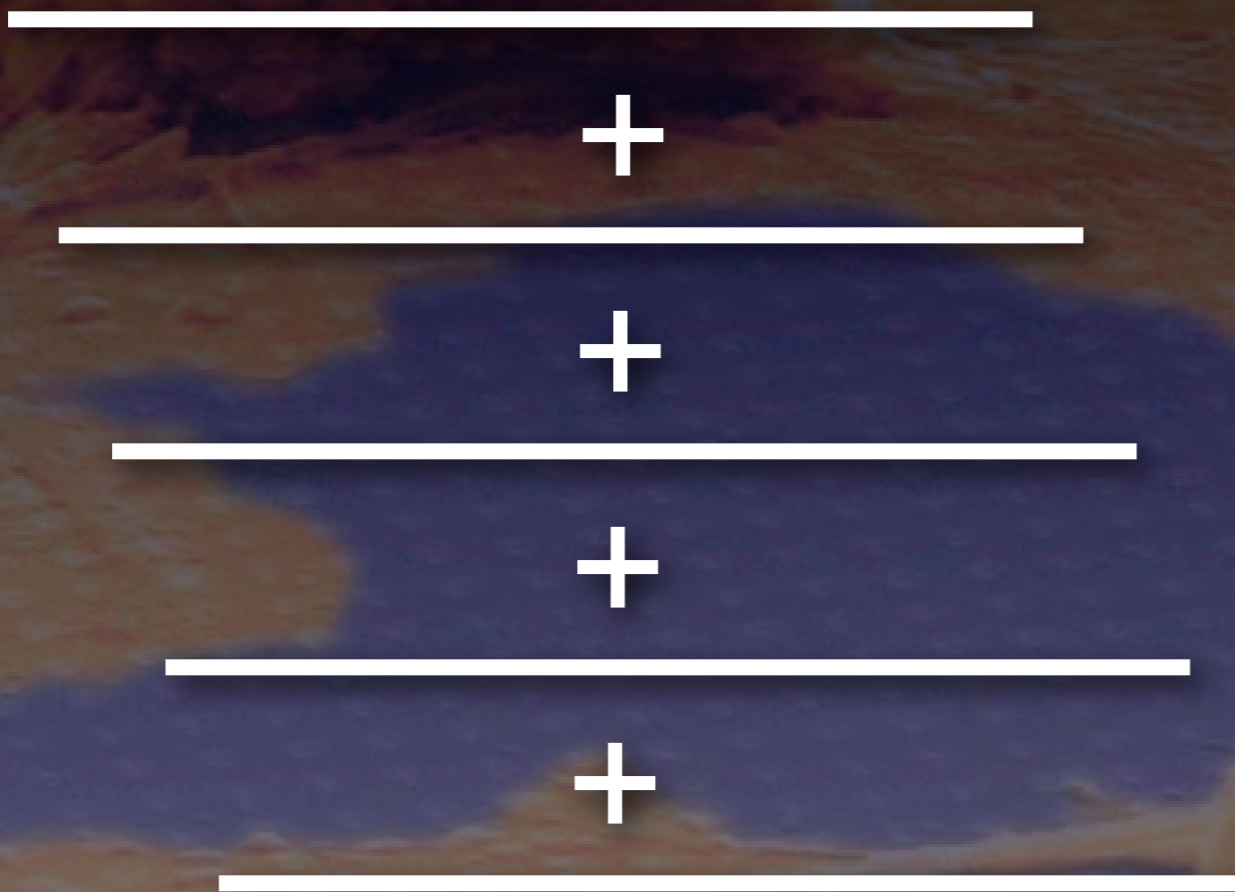
# Z-Stacks to Light Fields



# Z-Stacks to Light Fields

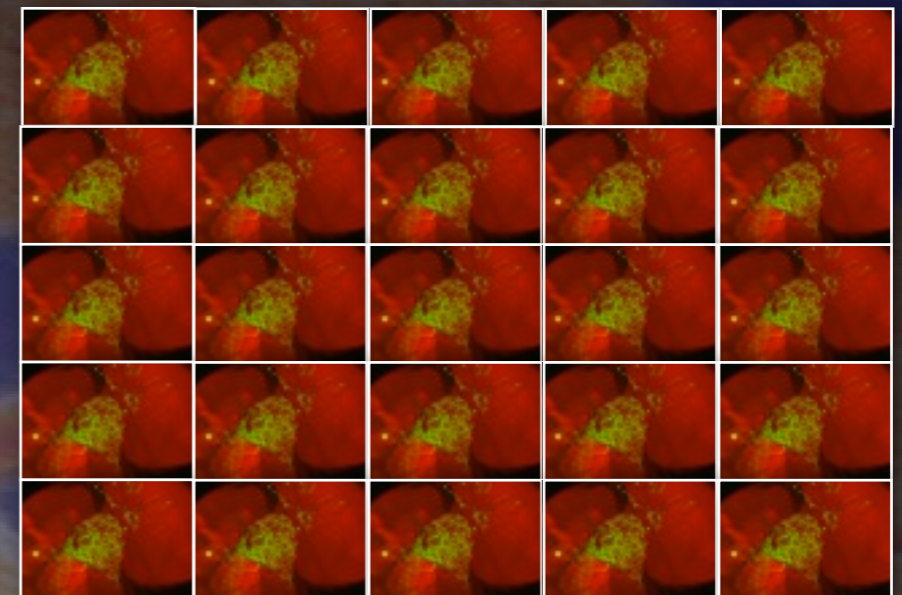


# Z-Stacks to Light Fields

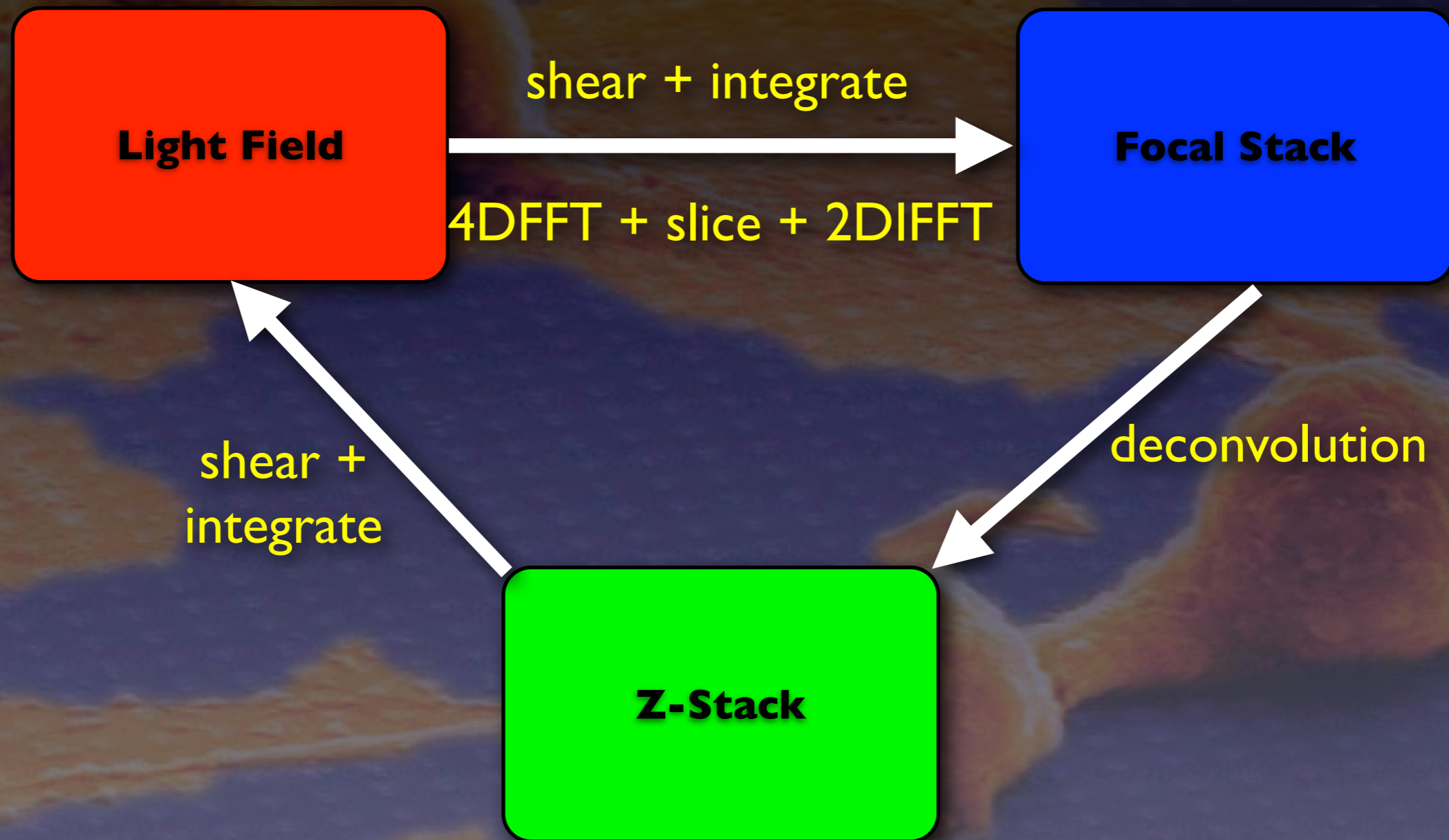




# Z-Stacks to Light Fields



# Transformations



# Light-Field Processing

# Image Retargeting

Retarget col seam: twoPeopleSea.jpg



MERL (Siggraph 2007)

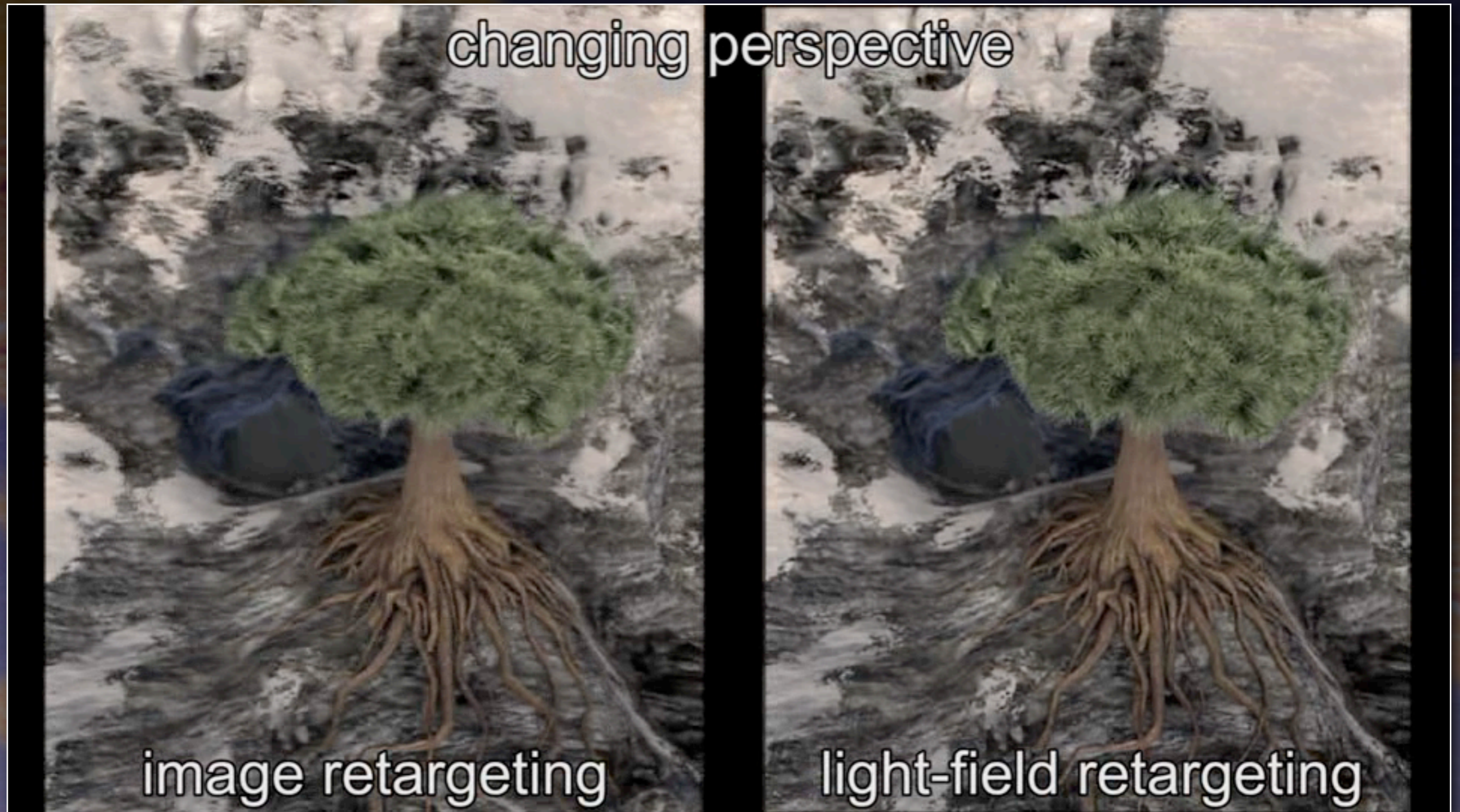
# Image Retargeting



MERL (Siggraph 2007)



# Light-Field Retargeting



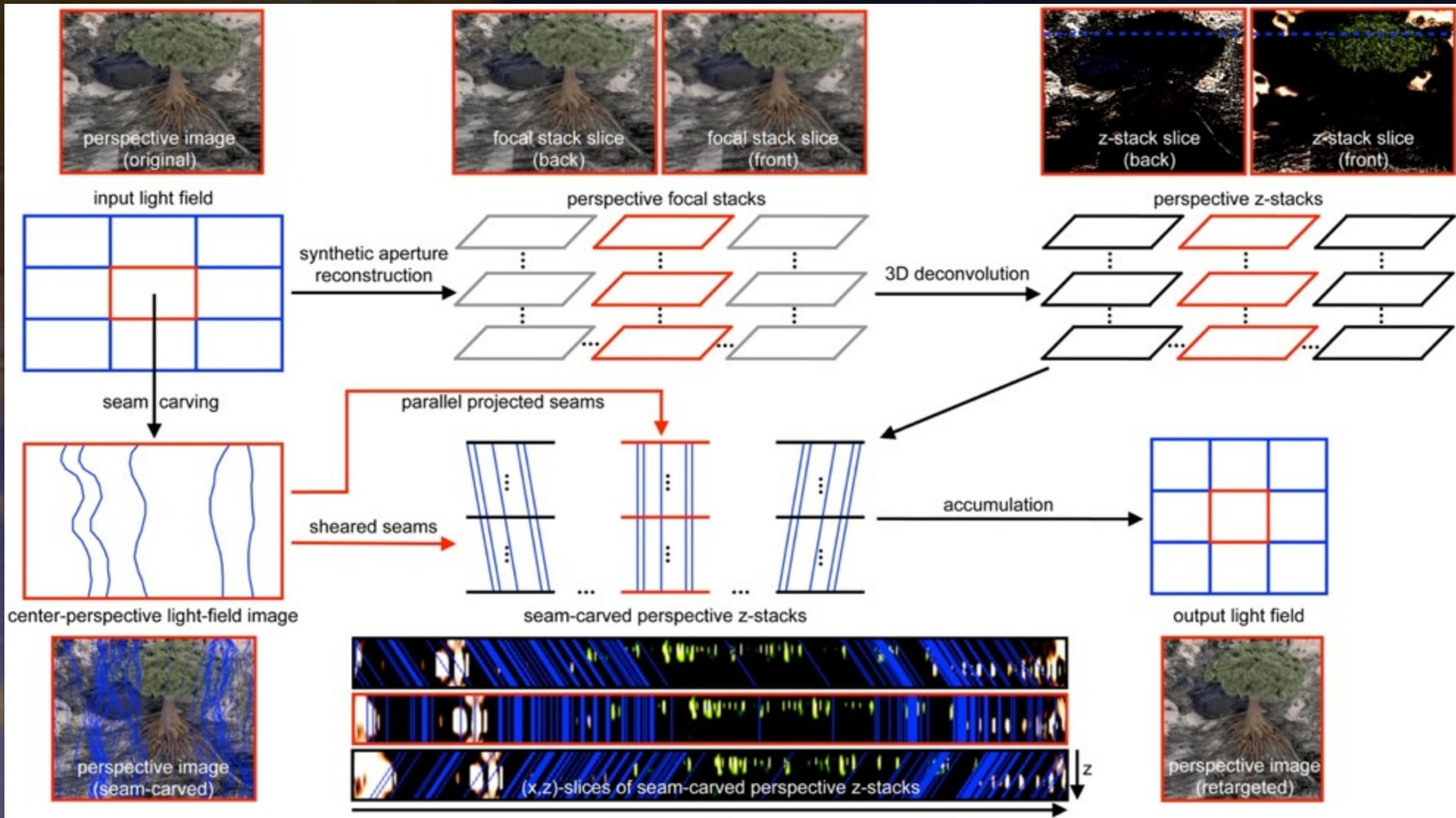
Siggraph 2011, Eurographics 2012

# Light-Field Retargeting



Siggraph 2011, Eurographics 2012

# Light-Field Retargeting

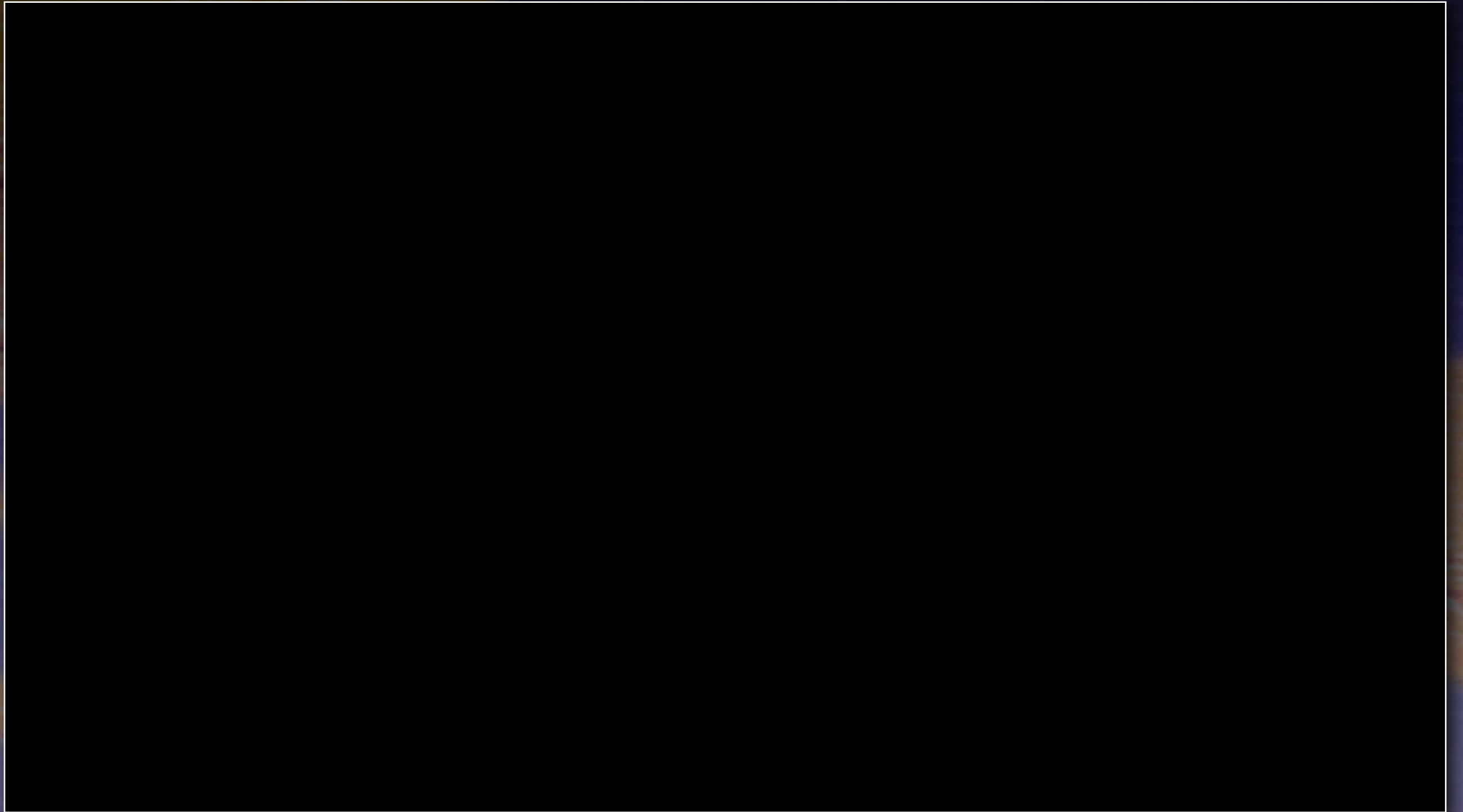


Siggraph 2011, Eurographics 2012



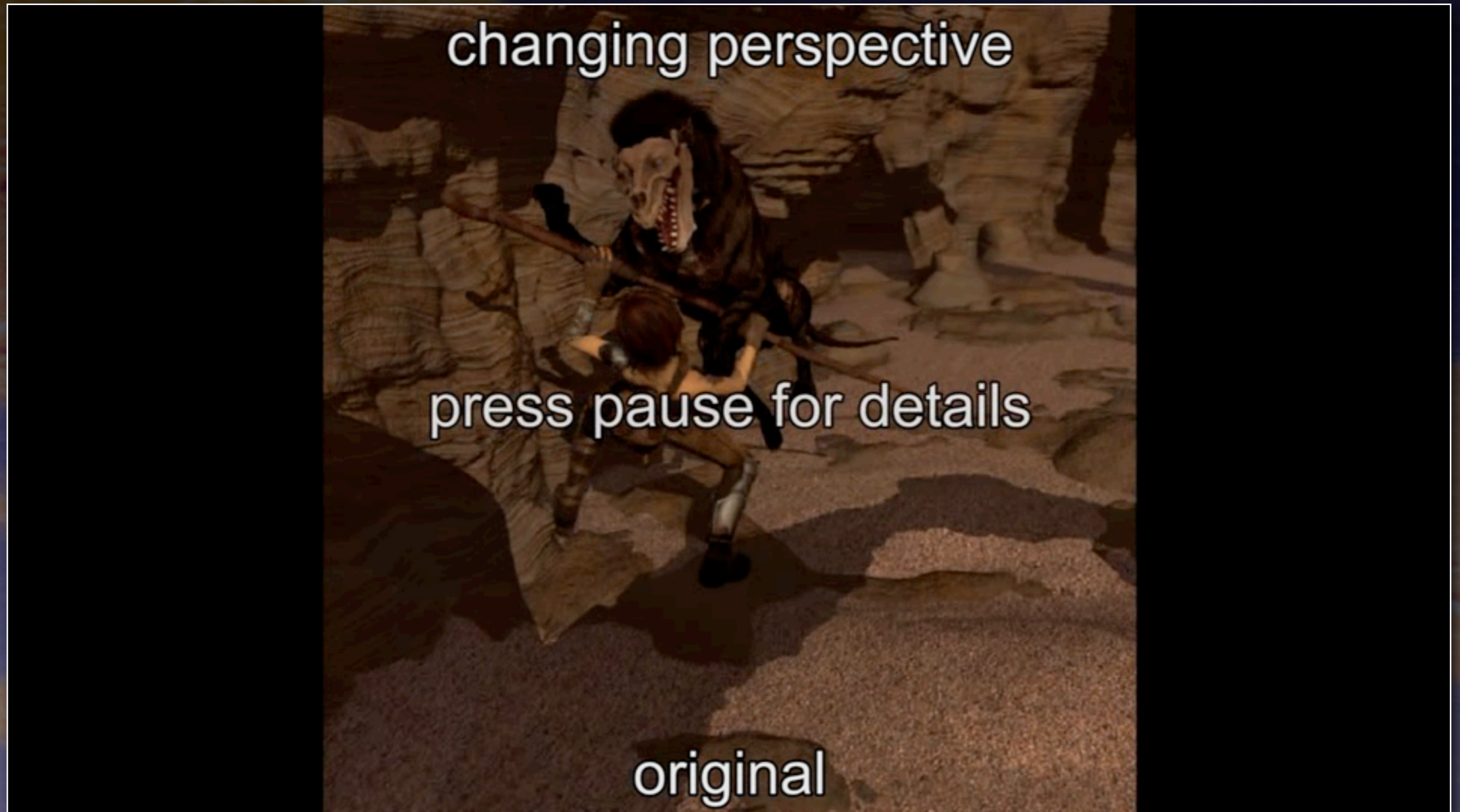


# Light-Field Retargeting



Siggraph 2011, Eurographics 2012

# Light-Field Retargeting



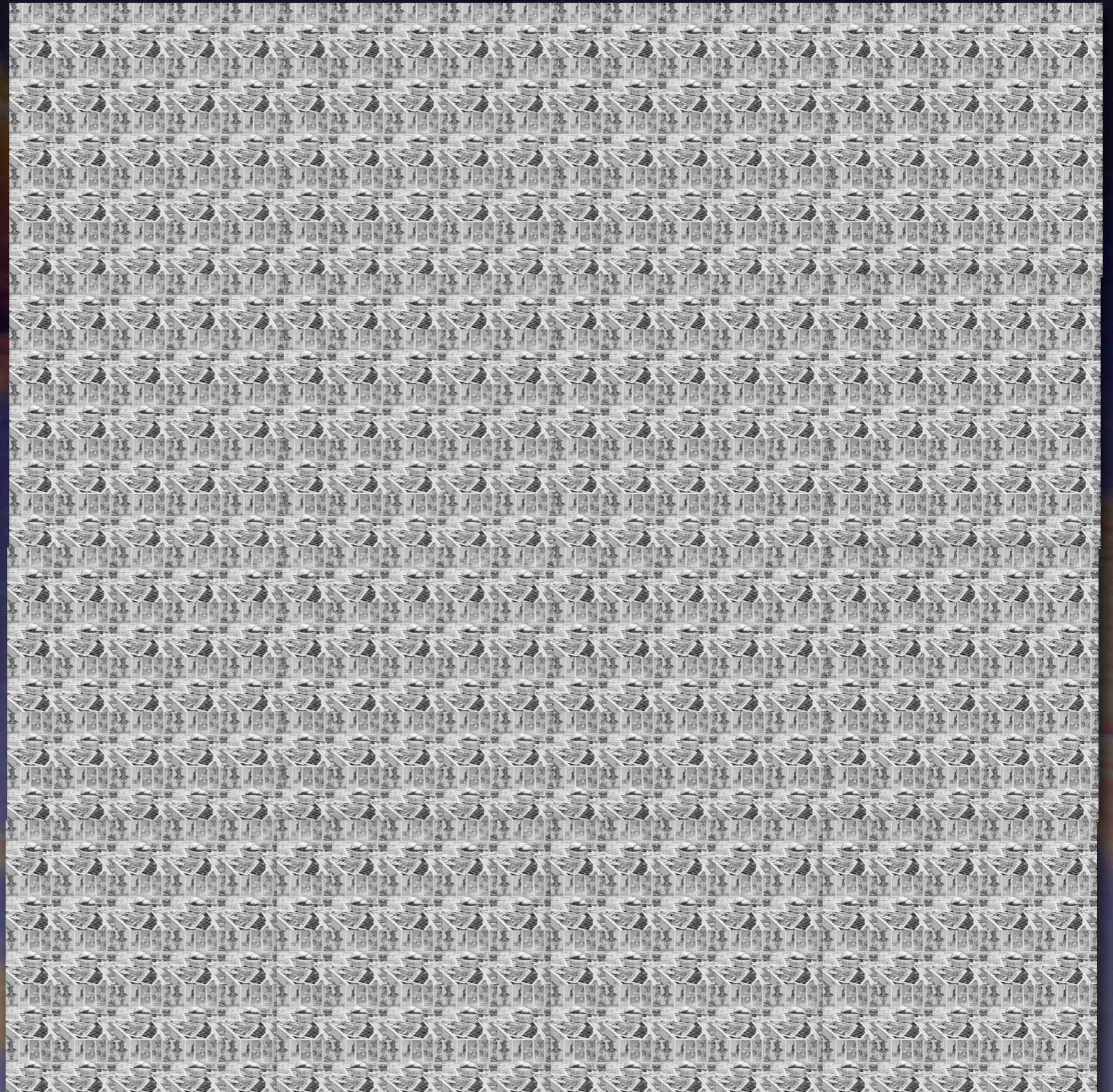
Siggraph 2011, Eurographics 2012

# Complexity of Light Fields

$2k \times 2k = 12.6\text{MB}$



$20 \times 20 \times 2k \times 2k = 5\text{GB}$



# Light-Field Caching

With 450MB available graphics memory...



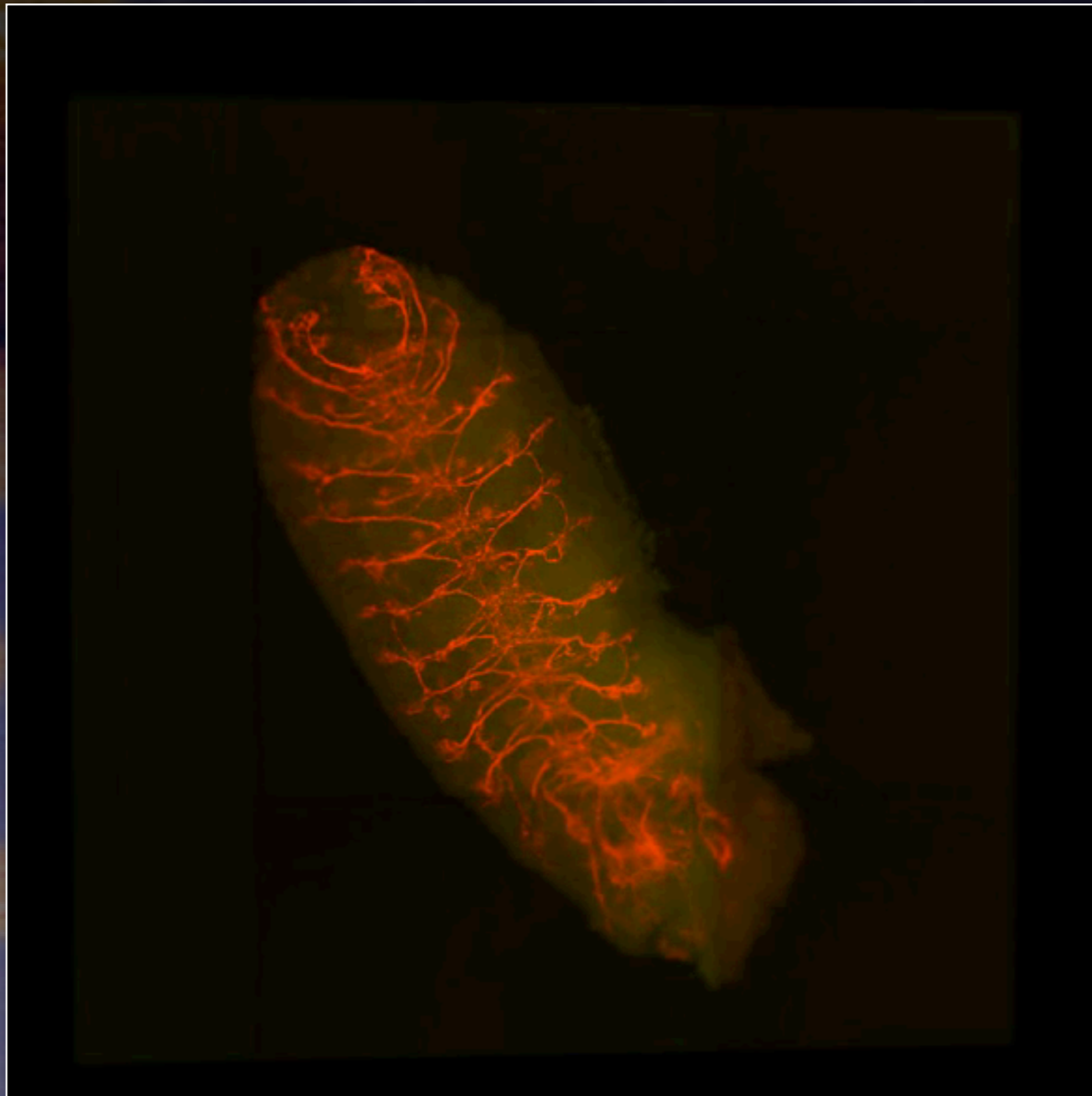
# Visualization of Large Datasets



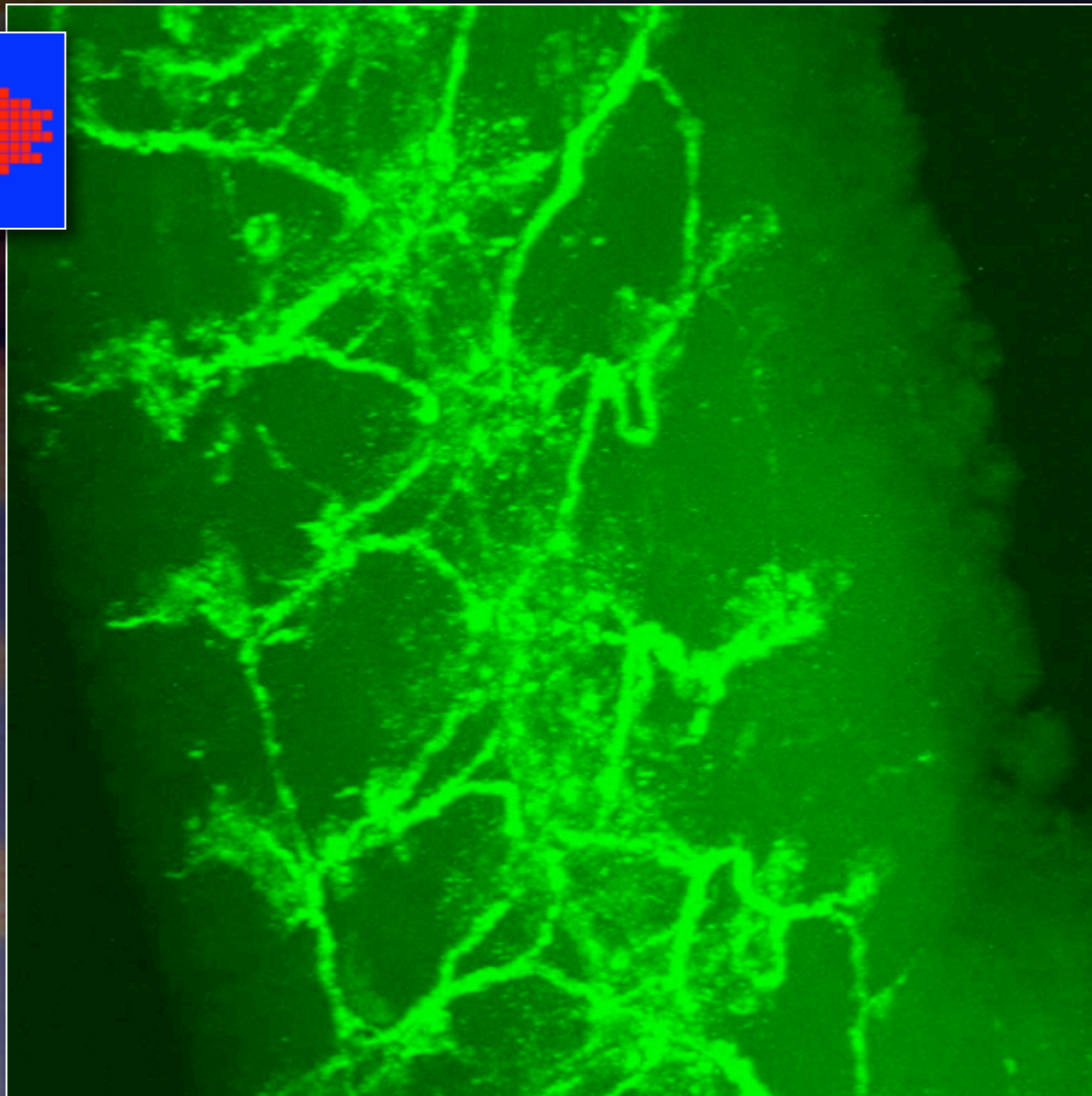
# Visualization of Large Datasets



# Visualization of Large Datasets



# Visualization of Large Datasets



green: new volume rendering (full resolution)

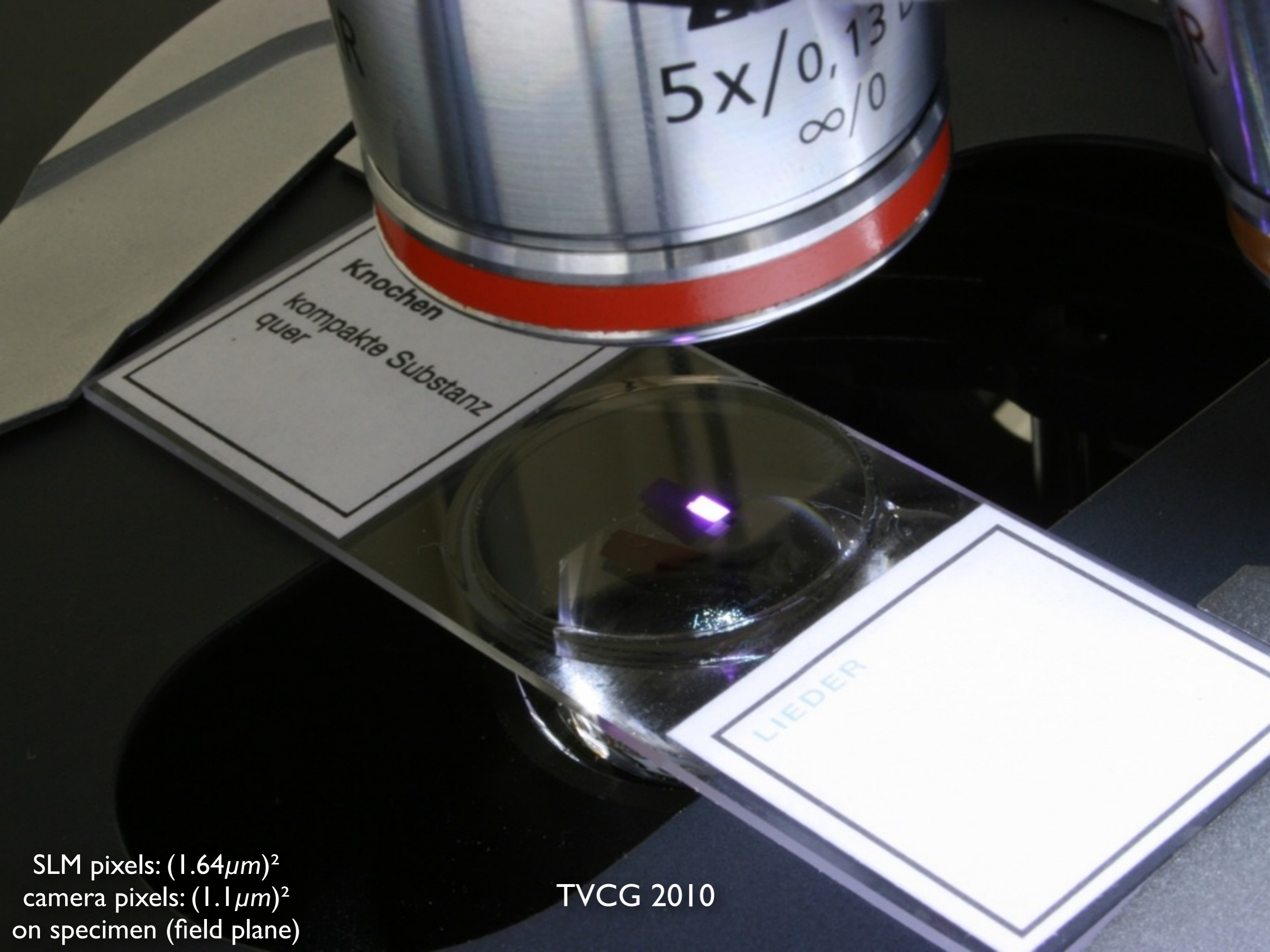
red: new volume rendering (low resolution)

gray: cached light-field rendering (full resolution)

blue: cached light-field rendering (low resolution)



# Light-Field Imaging and Illumination



5x/0,13  
∞/0

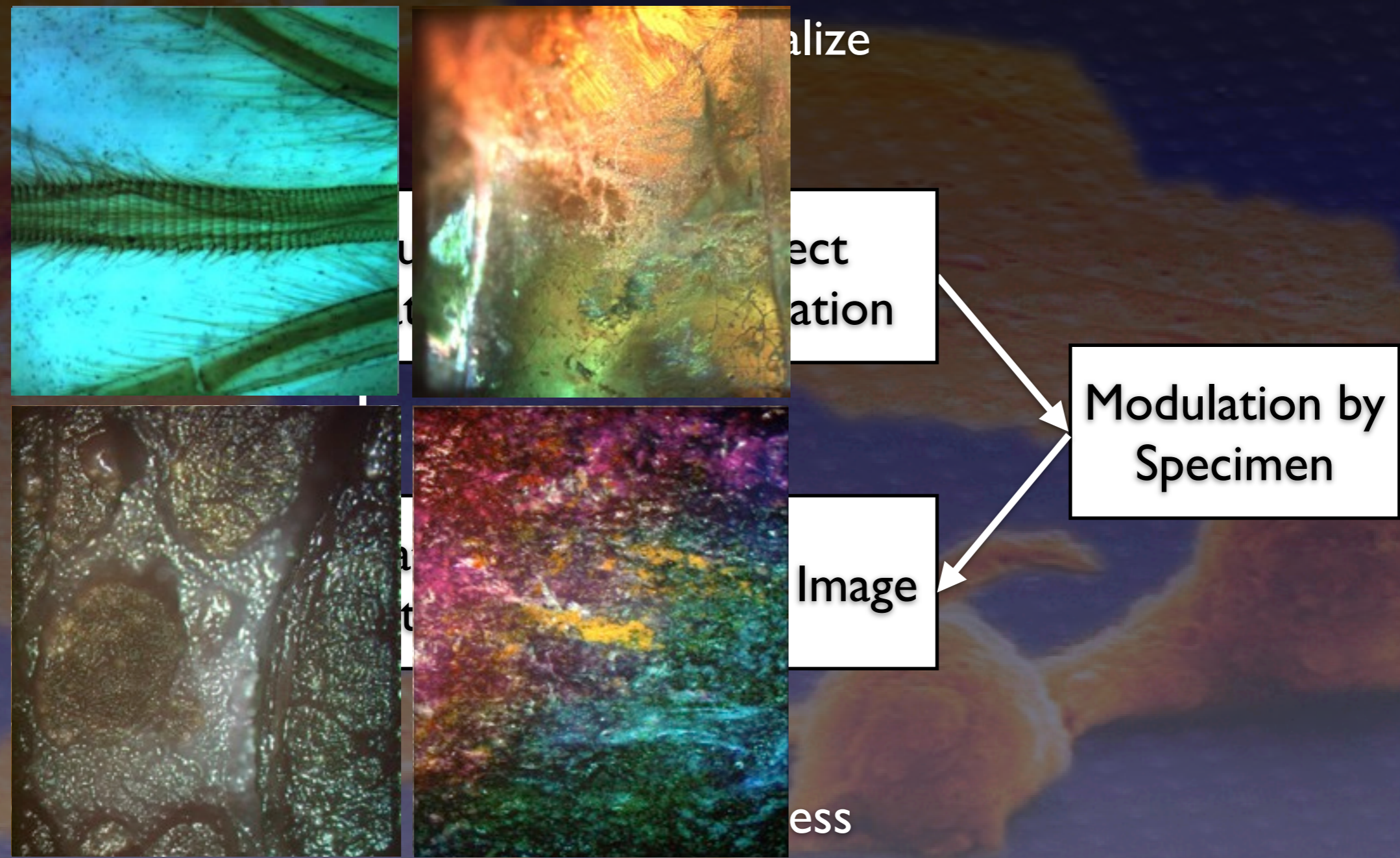
Knochen  
kompakte Substanz  
quer

LIEDER

SLM pixels:  $(1.64\mu\text{m})^2$   
camera pixels:  $(1.1\mu\text{m})^2$   
on specimen (field plane)

TVCG 2010

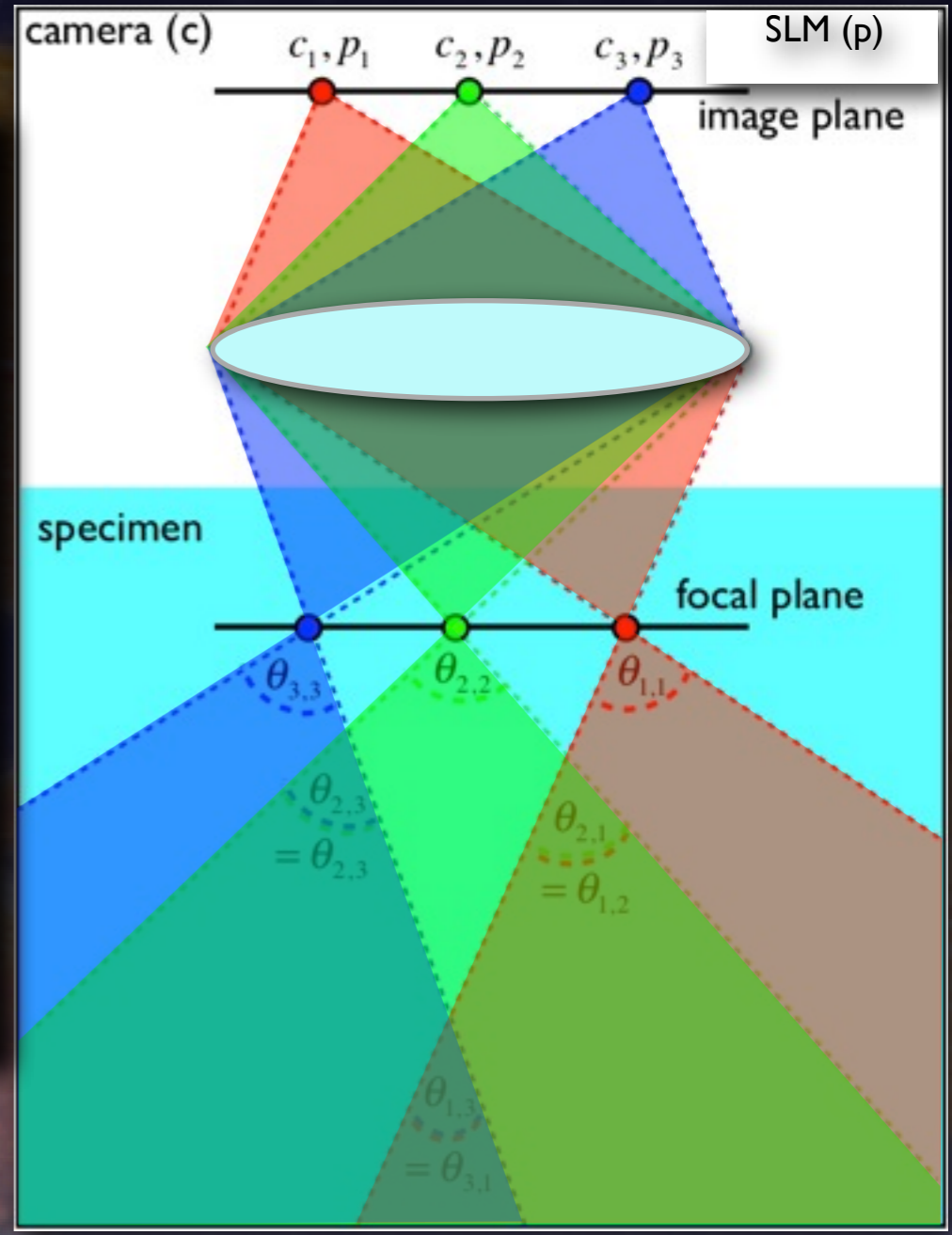
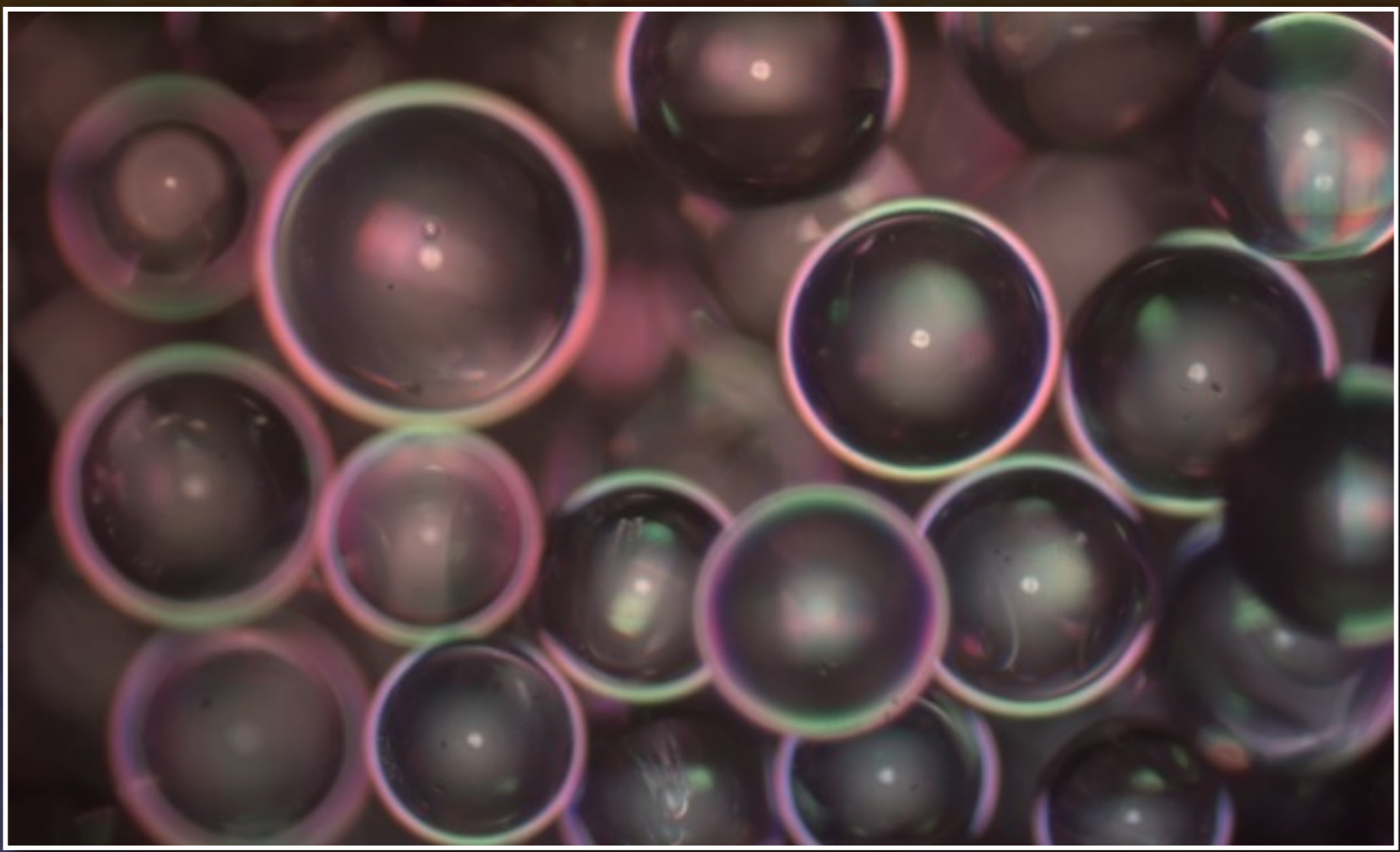
# Closed-Loop Feedback Illumination



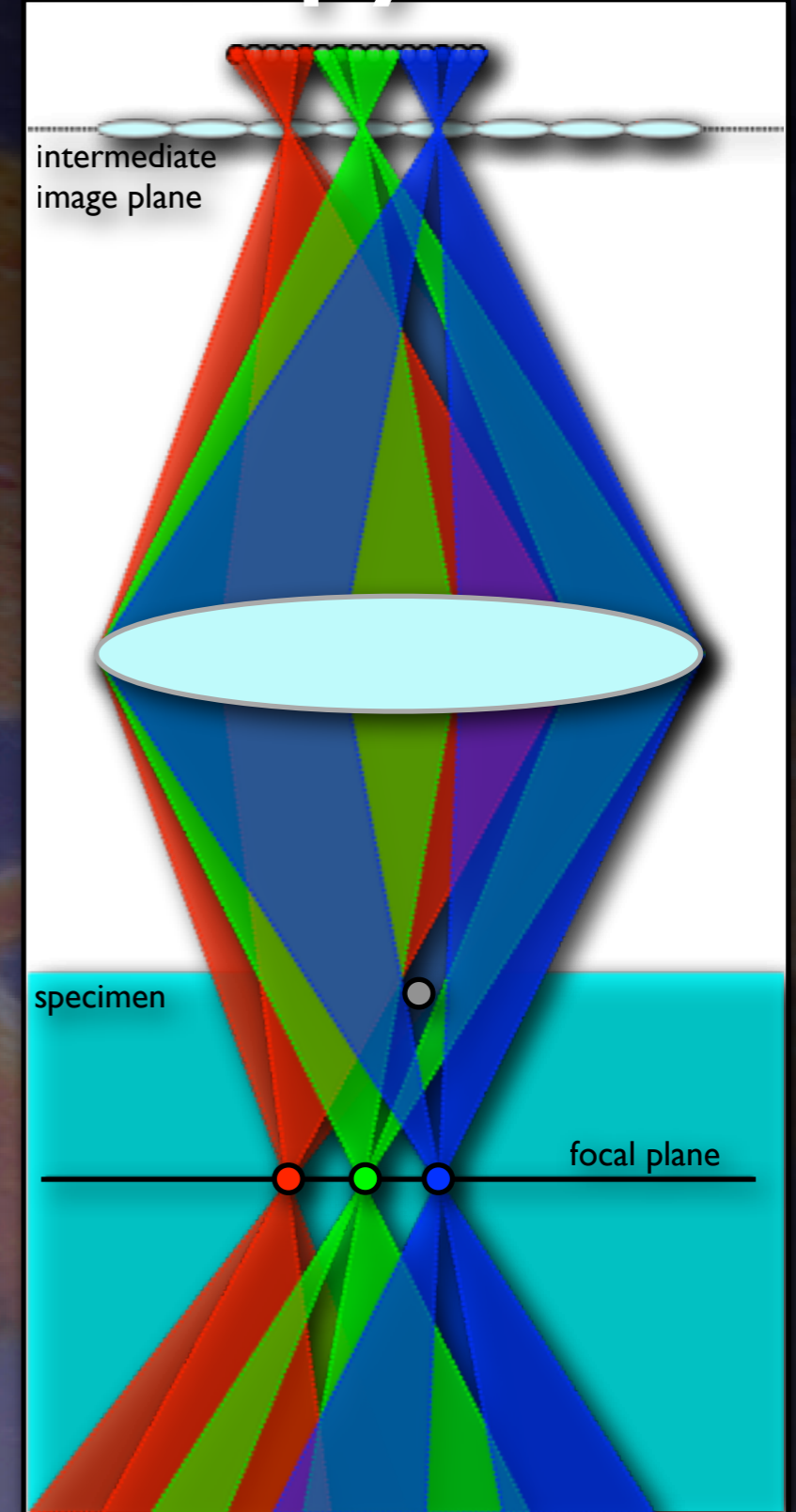
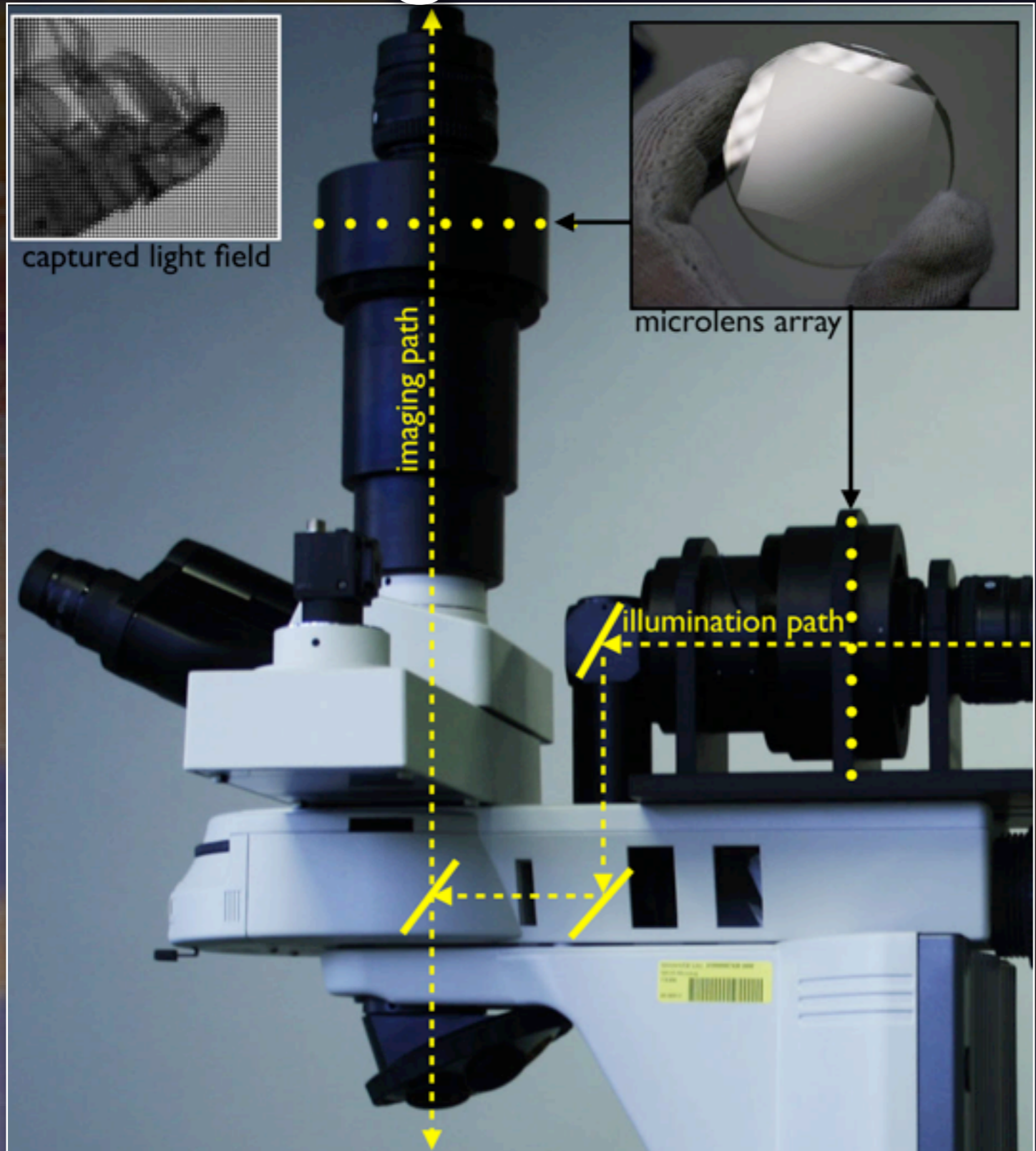
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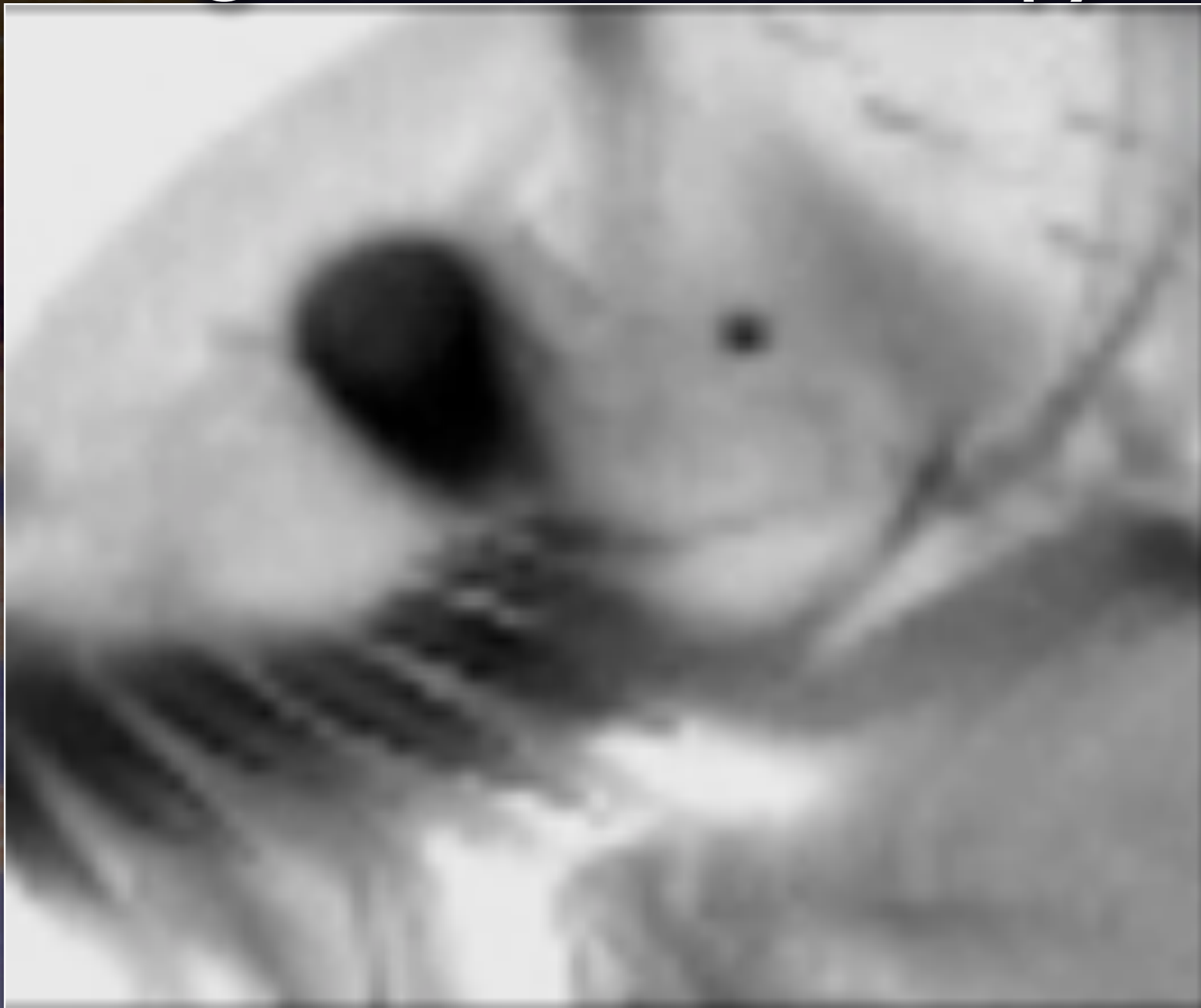
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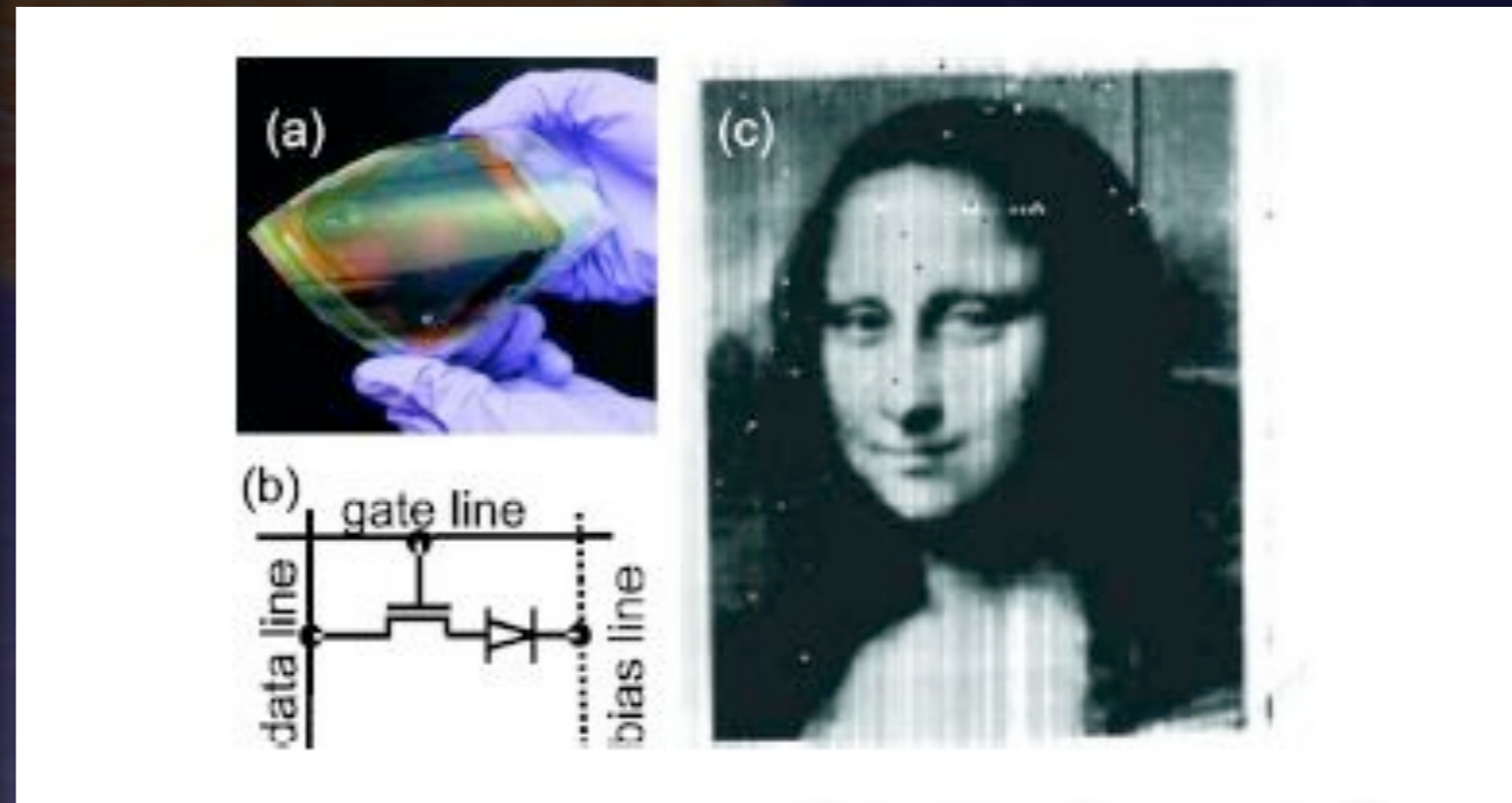
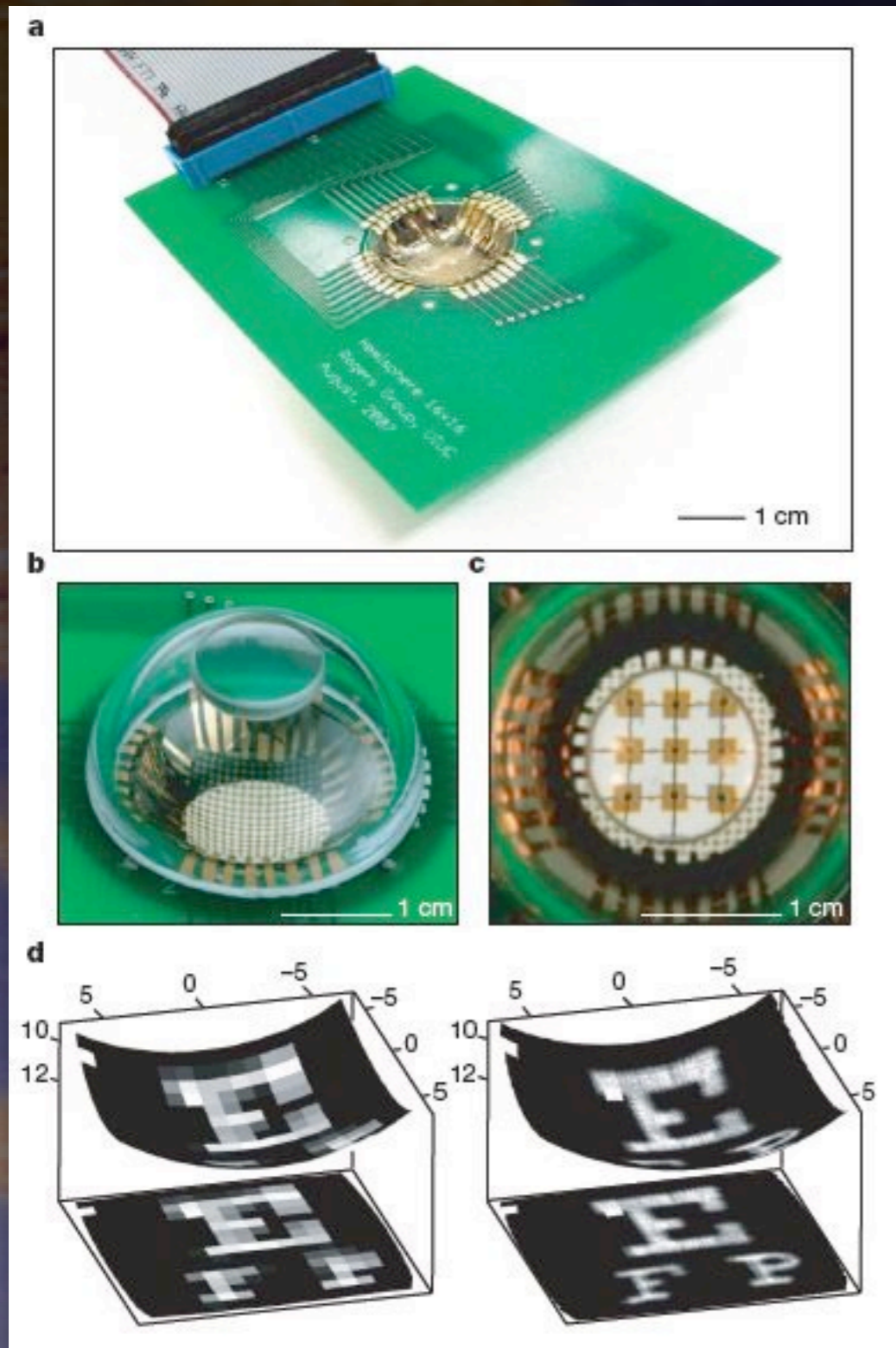
# Light-Field Microscopy



# Light-Field Microscopy



# Flexible and Transparent Image Sensors

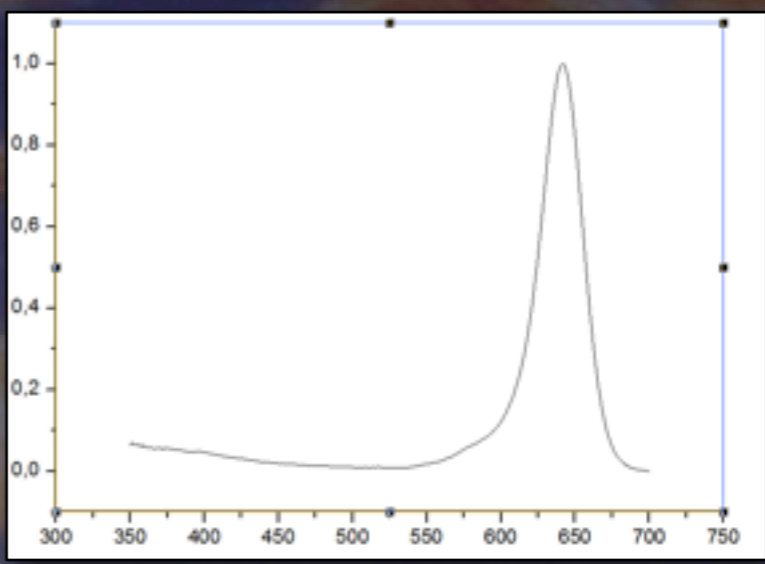
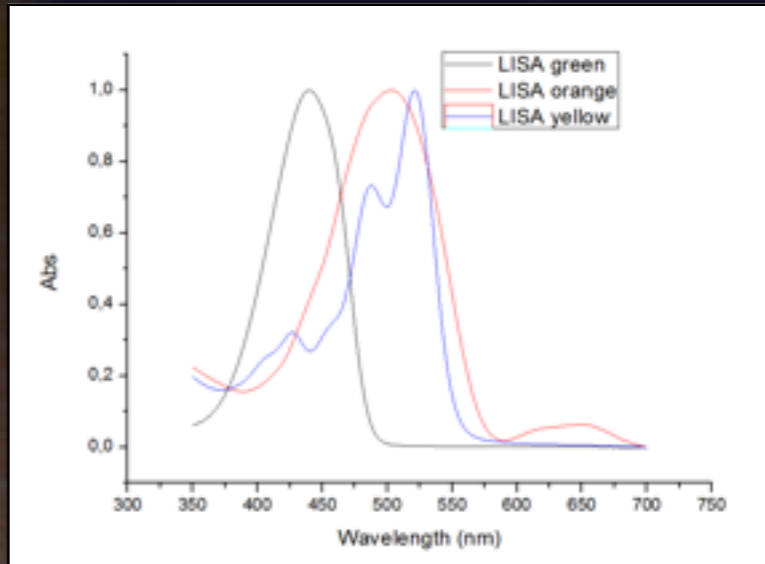
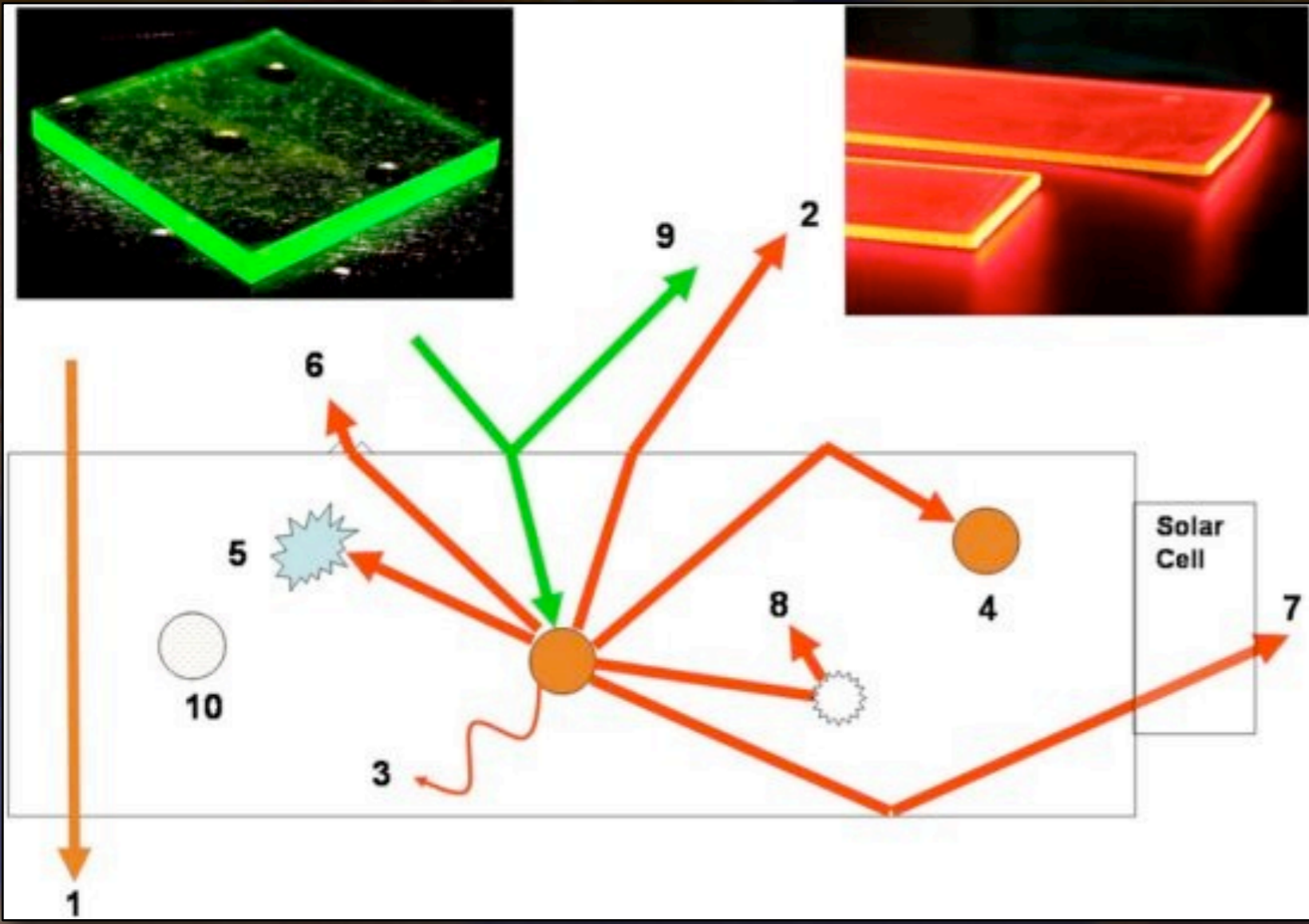


Palo Alto Research Center  
(Applied Physics Letters 2008)

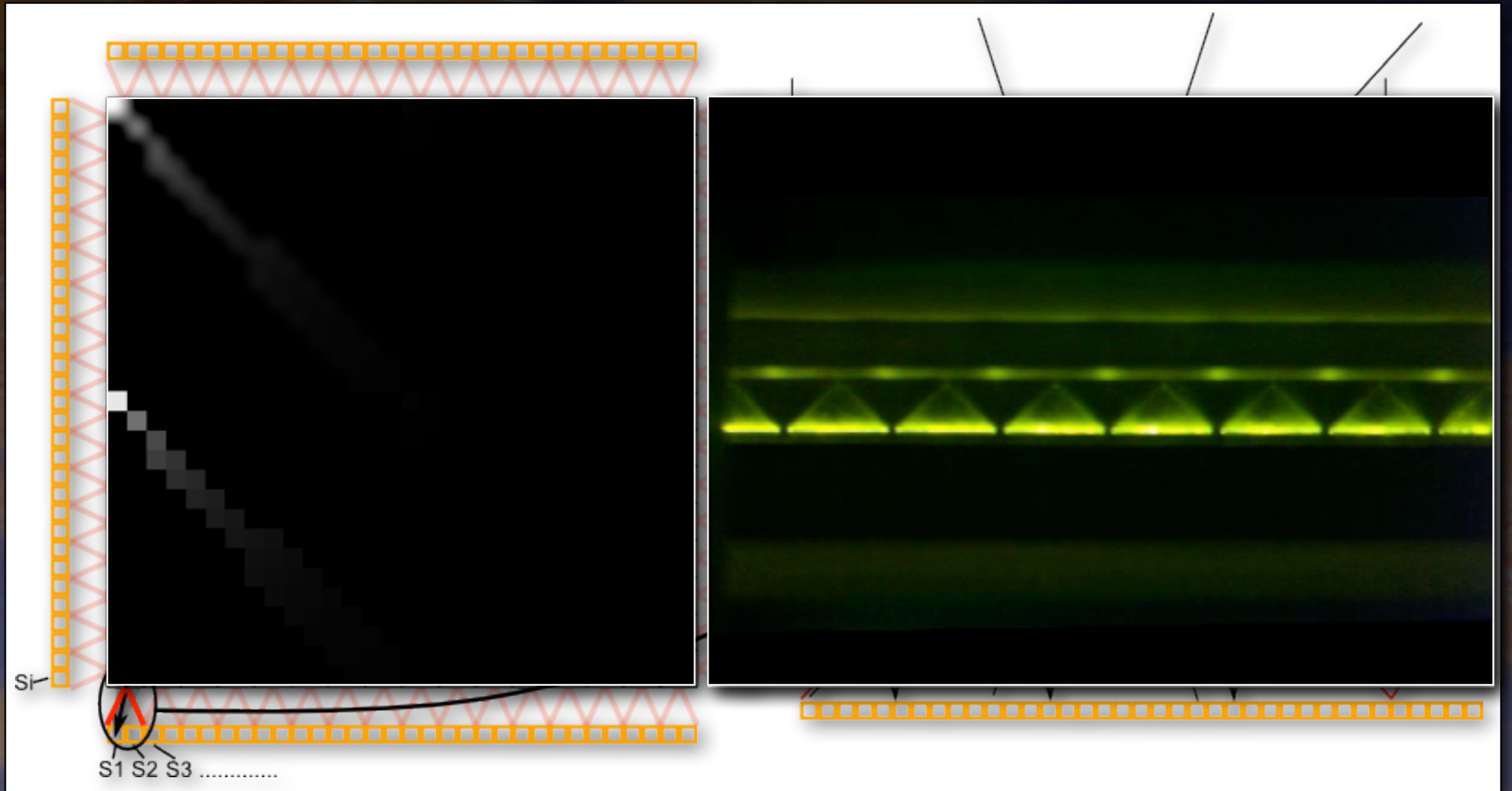
University of Illinois  
(Nature 2008)



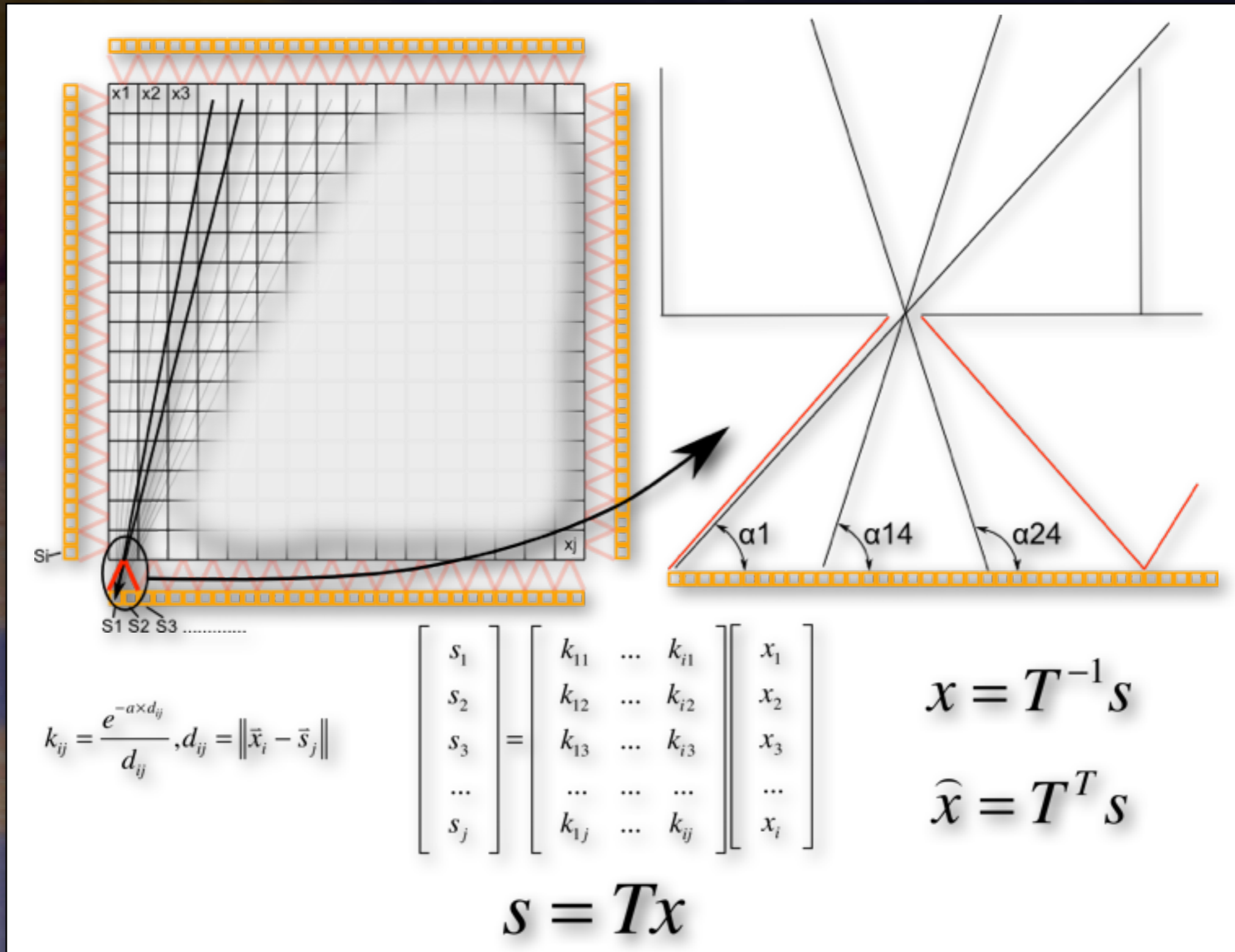
# Luminescent Concentrators



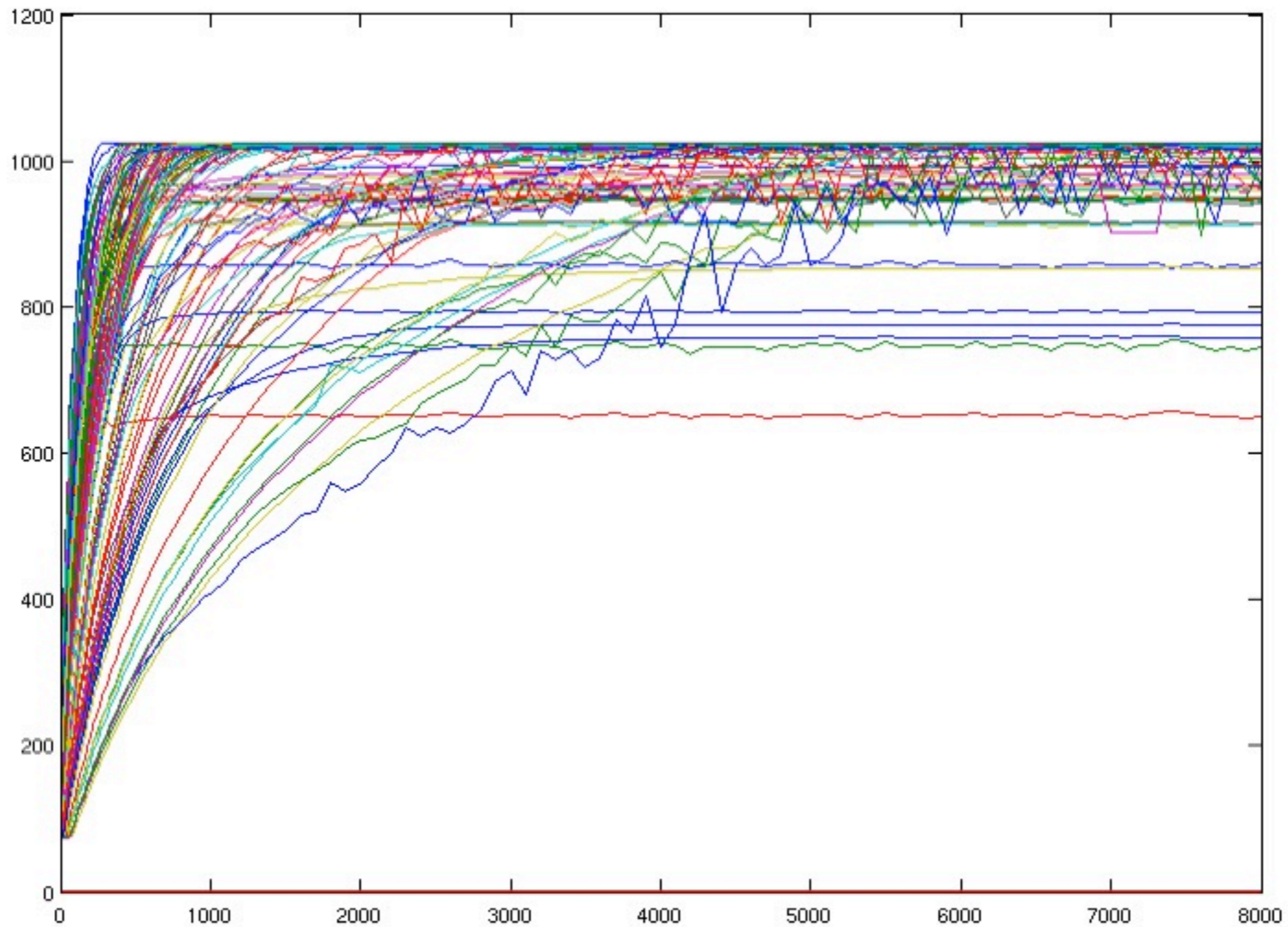
# 2D Light-Field Camera



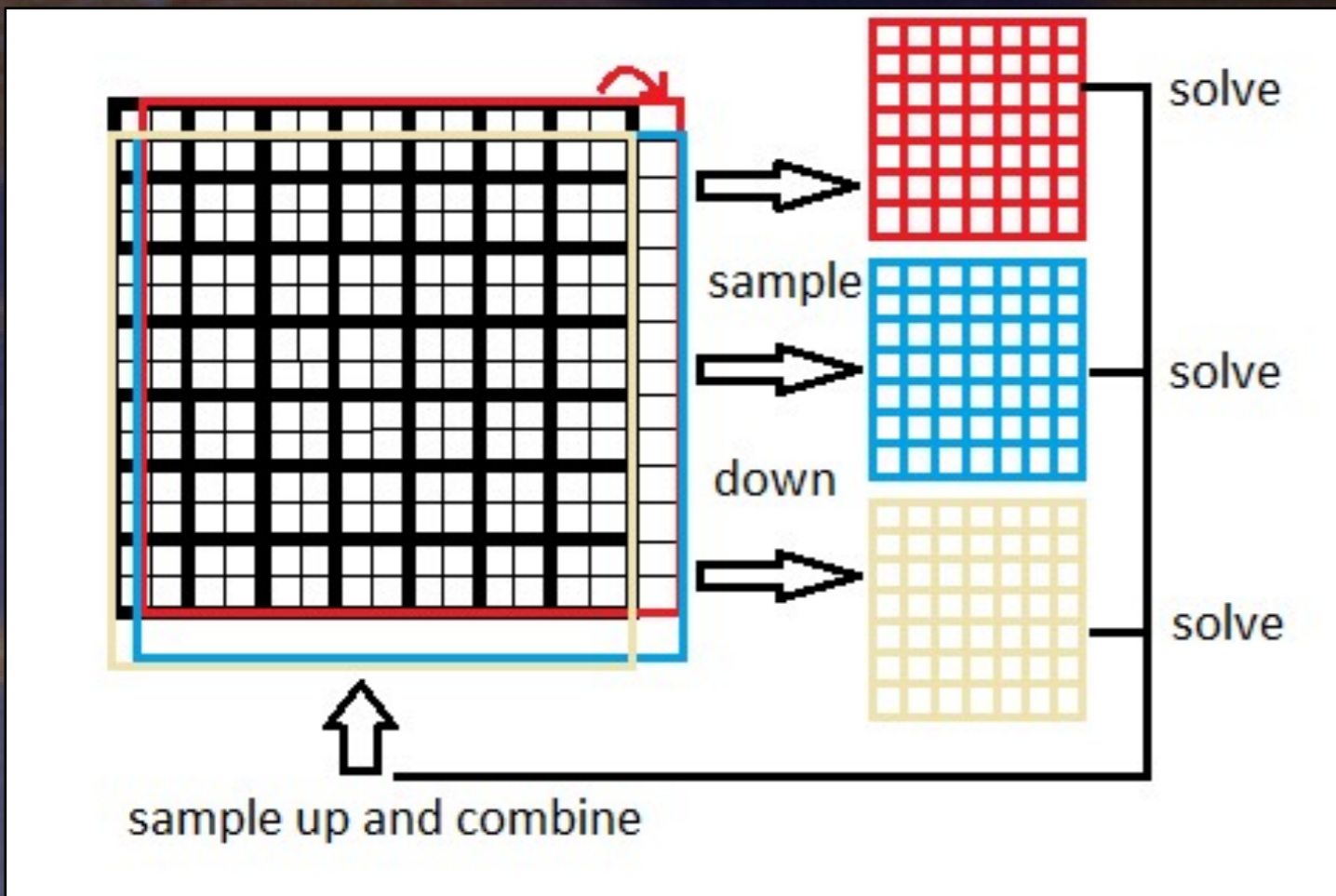
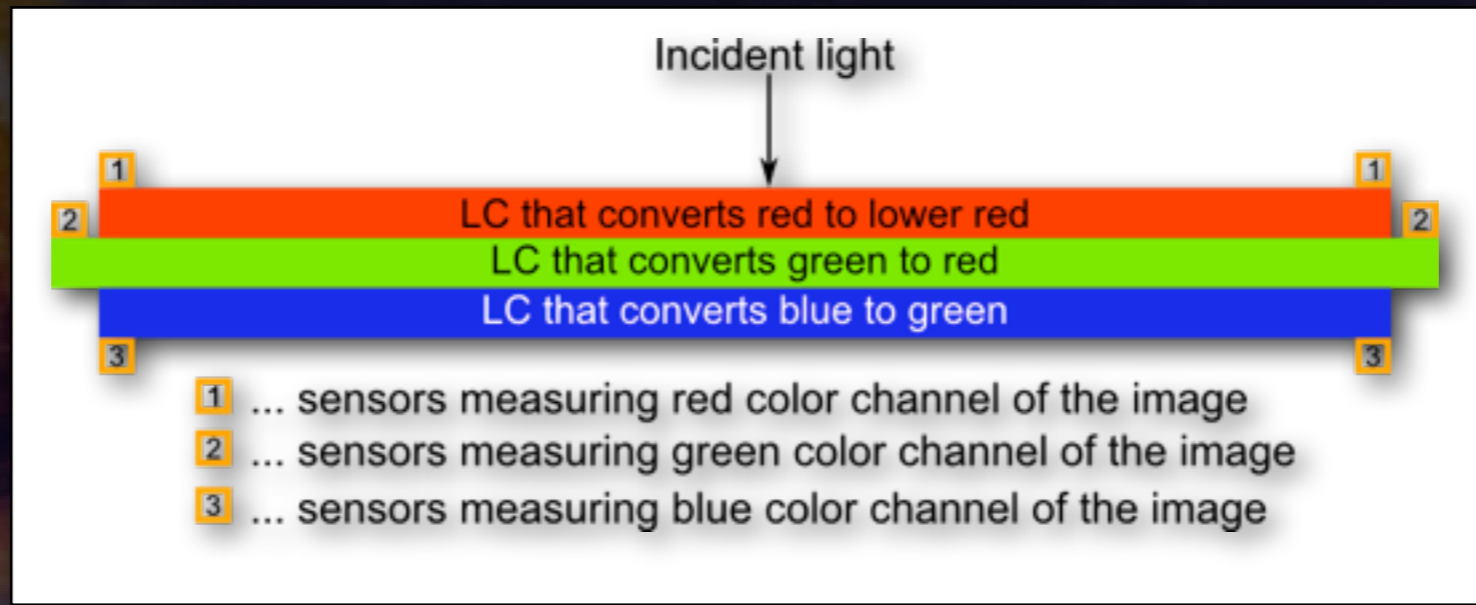
# Image Reconstruction



# Current Results



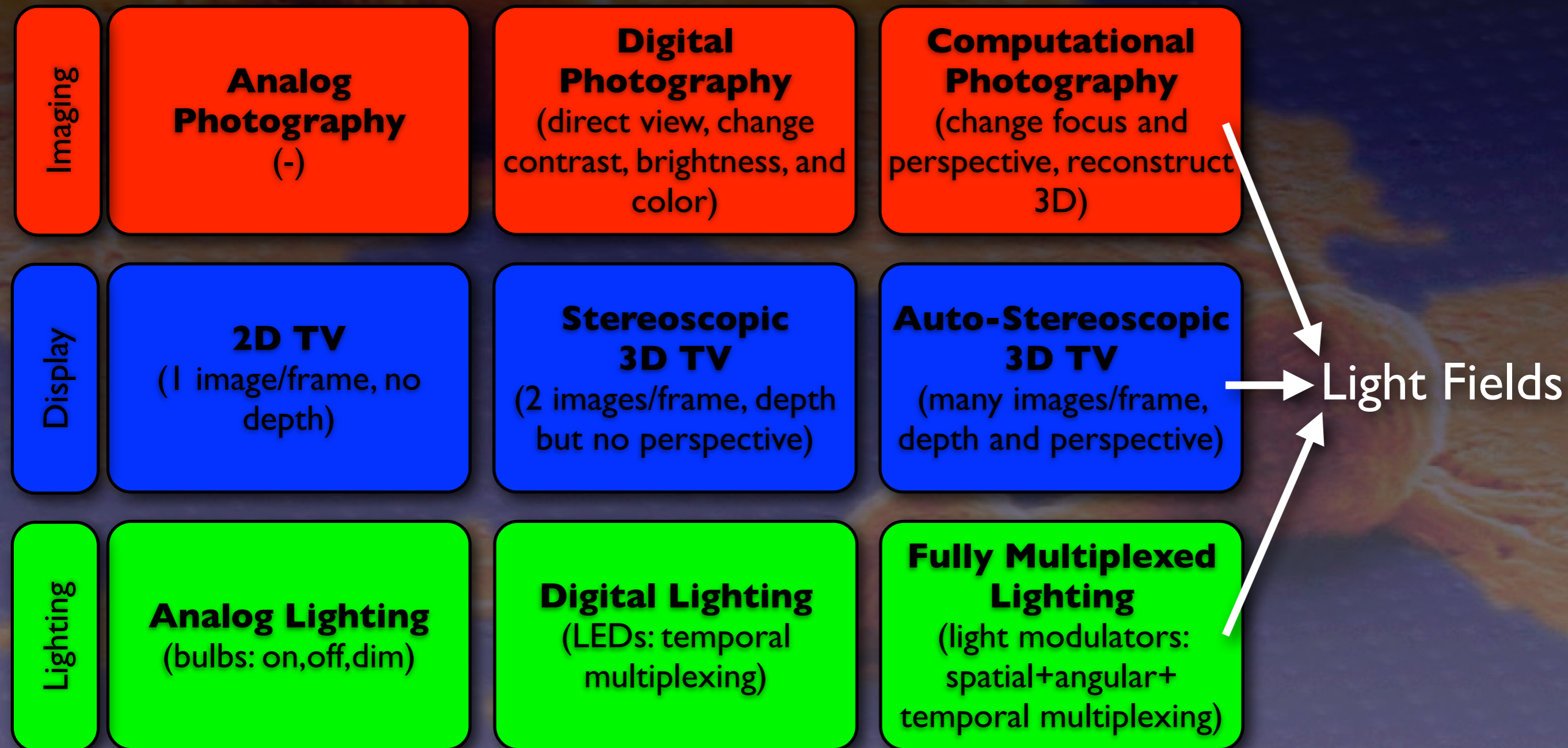
# Color and Superresolution



# Where is the Potential?

# Where is the Potential?

we are here now



# What are the Challenges?



# What are the Challenges?

- Imaging?



Lytro

# What are the Challenges?

- Imaging?
  - maybe not...



Lytro

# What are the Challenges?

- Imaging?

- maybe not...

- Displays?



Lytro



Polarization Field Display

UBC (Siggraph Asia, 2011)

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Lytro

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Polarization Field Display

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UBC (Siggraph Asia, 2011)

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Lytro

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Polarization Field Display

UBC (Siggraph Asia, 2011)

- Processing?

- definitely!

# Where is the Potential for AR/MR?

- **Imaging: light-field camera instead of normal camera**
  - consistent and adaptable rendering (occlusion, illumination, focus, etc.)
  - improved tracking and registration
  - etc.



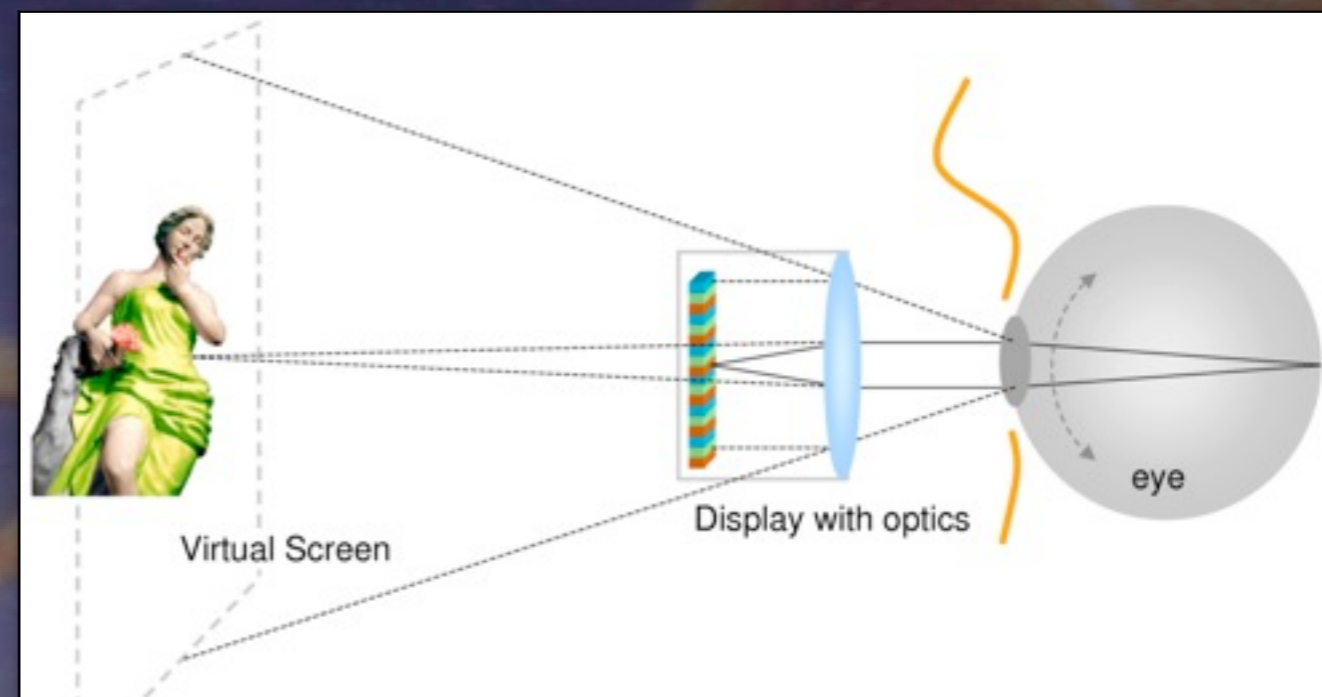
# Where is the Potential for AR/MR?

- **Imaging: light-field camera instead of normal camera**

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- improved tracking and registration
- etc.

- **Displays: light-field displays instead of normal displays**

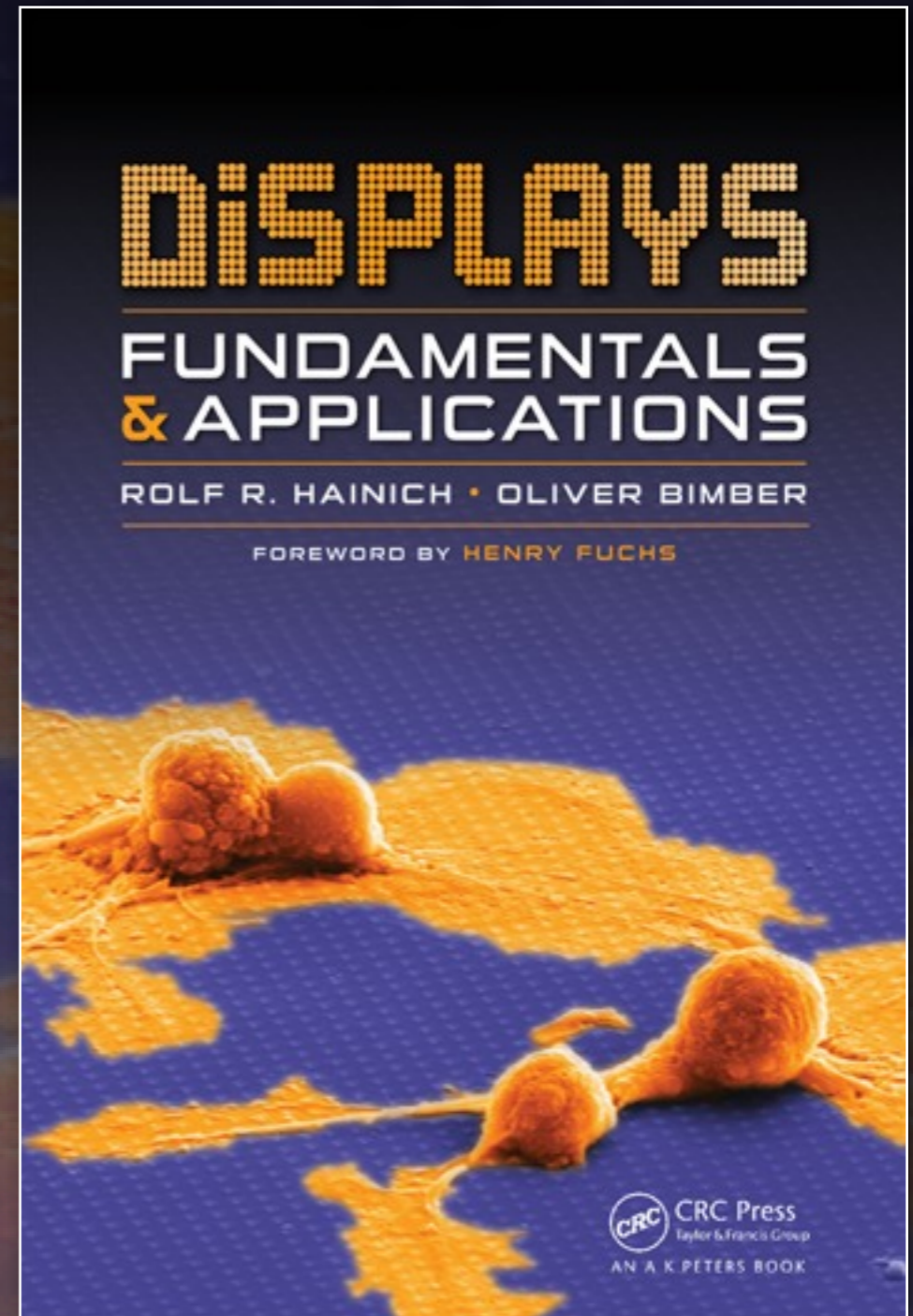
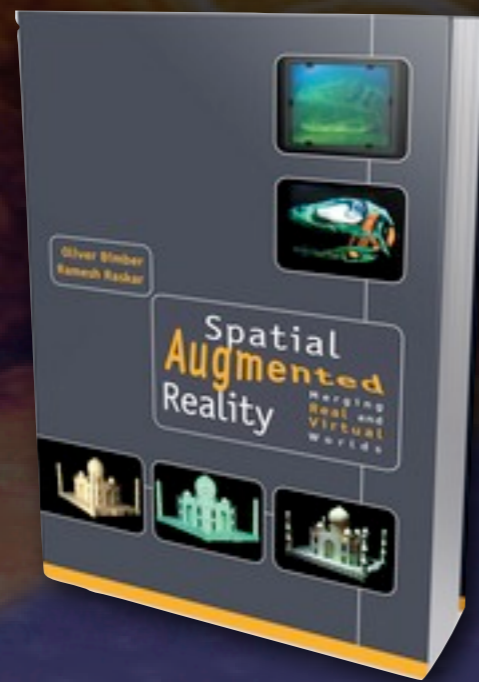
- consistent and adaptable focus
- improved eye-tracking
- etc.





[www.displaysbook.info](http://www.displaysbook.info)

[www.jku.at/cg](http://www.jku.at/cg)



Thank You!