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Multisampling Compressive Video Spectroscopy

Daniel S. Jeon Inchang Choi Min H. Kim

Korea Advanced Institute of Science and Technology (KAIST)

VISUAL COMPUTING Lab

Fake or Real?

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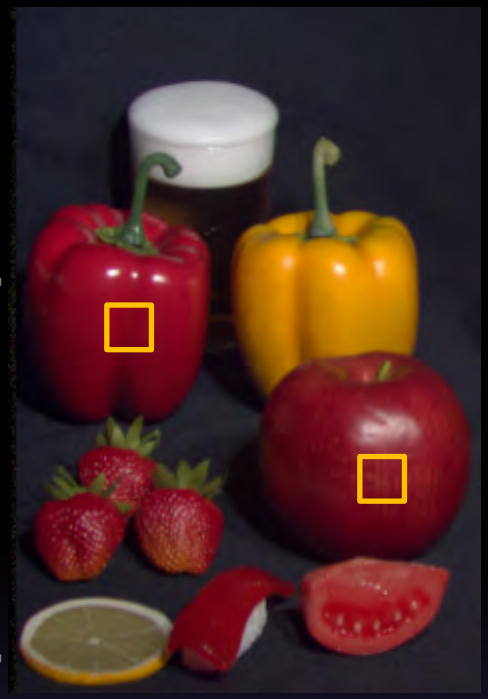
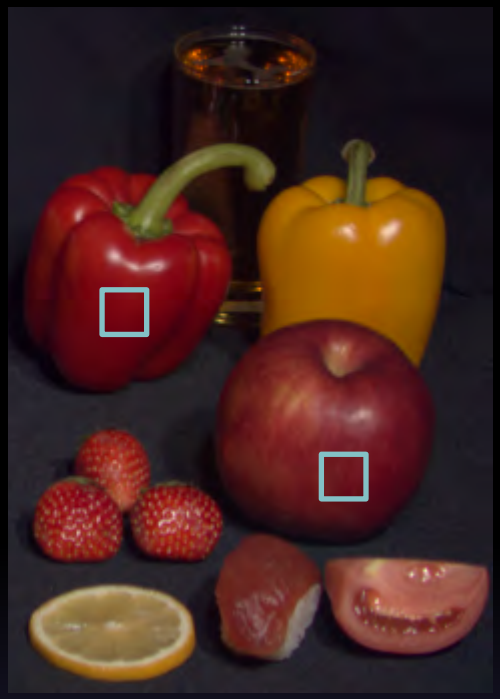
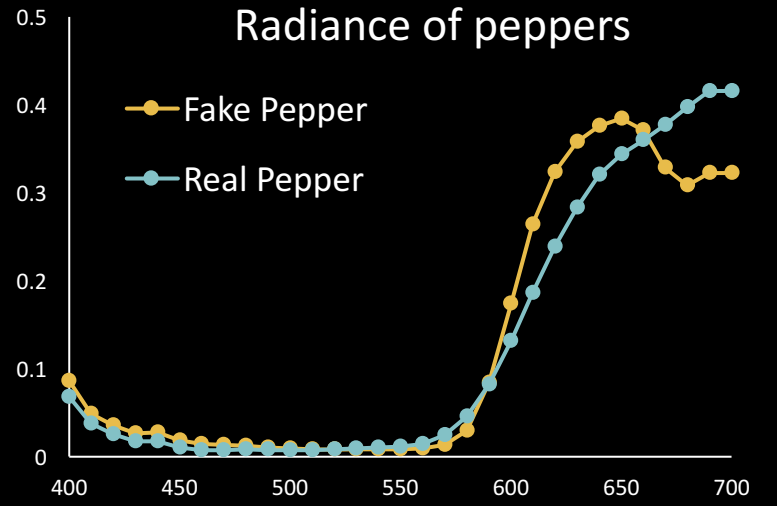


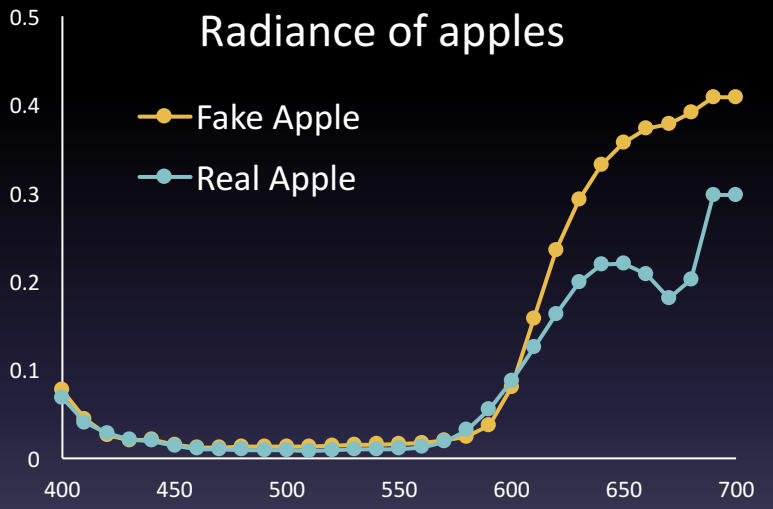
[Yasuma et al. 2008]

Fake



Real





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Hyperspectral Imaging

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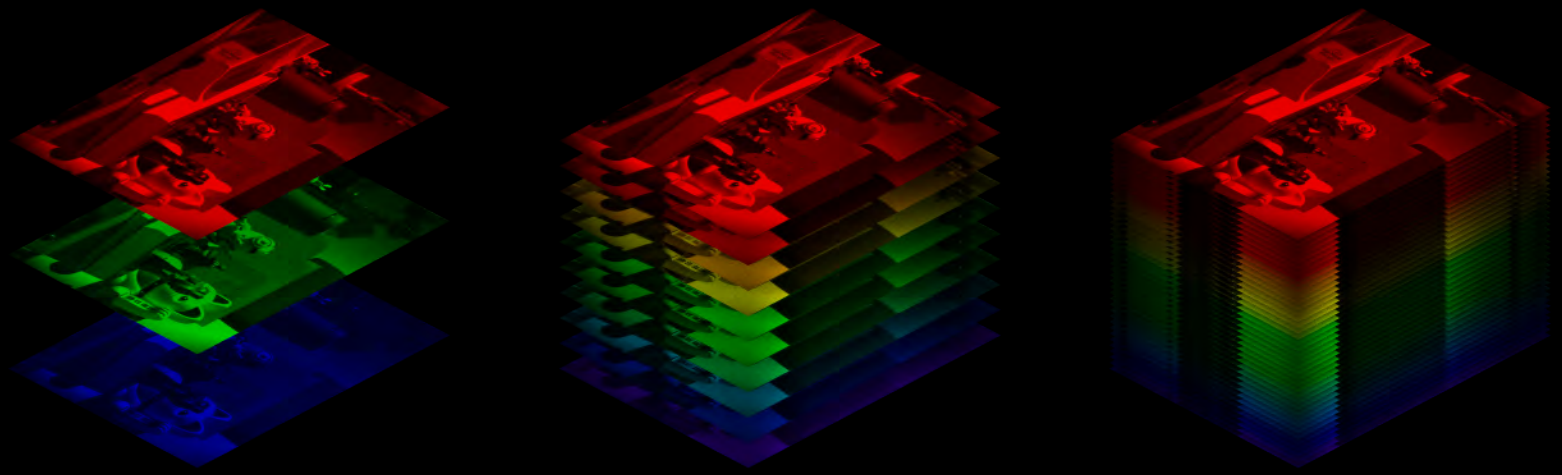

RGB Imaging	Multispectral Imaging	Hyperspectral Imaging
3 channels	<~30 channels	≥~30 channels

Spectroscopy Imaging

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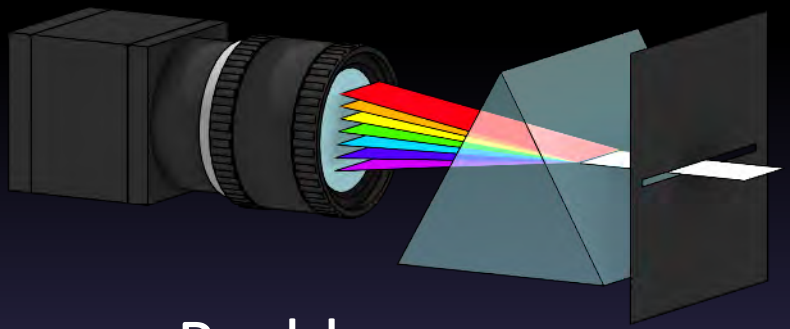
Bandpass filter

[Mansouri et al. 2007]

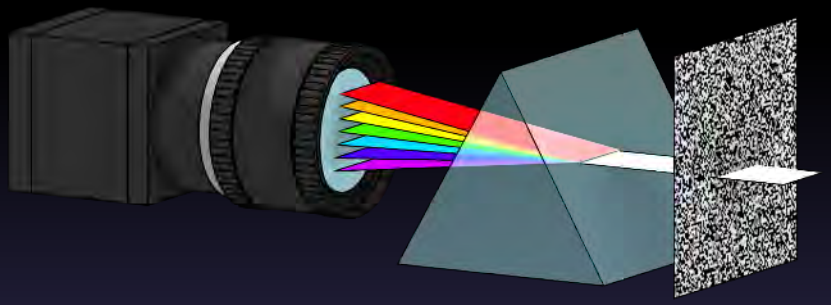
LCTF (liquid crystal tunable filter)

[Attas et al. 2003]



Pushbroom

[Brusco et al. 2006]



CASSI

[Wagadarikar et al. 2008]

Multisampling CASSI

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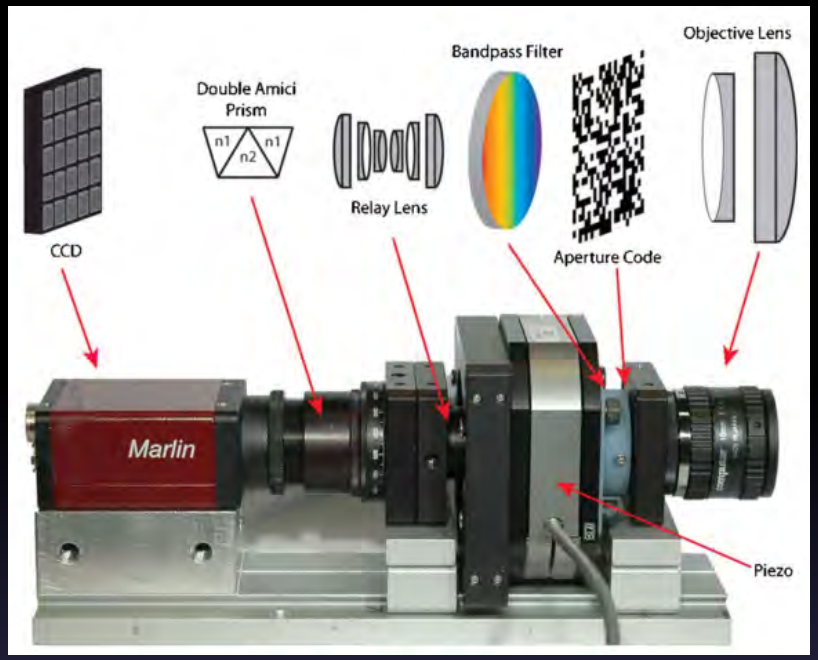
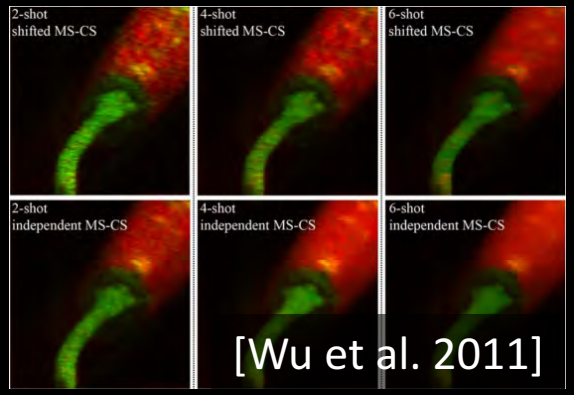
Mask shifting using piezo translation stage

[Kittle et al. 2010]

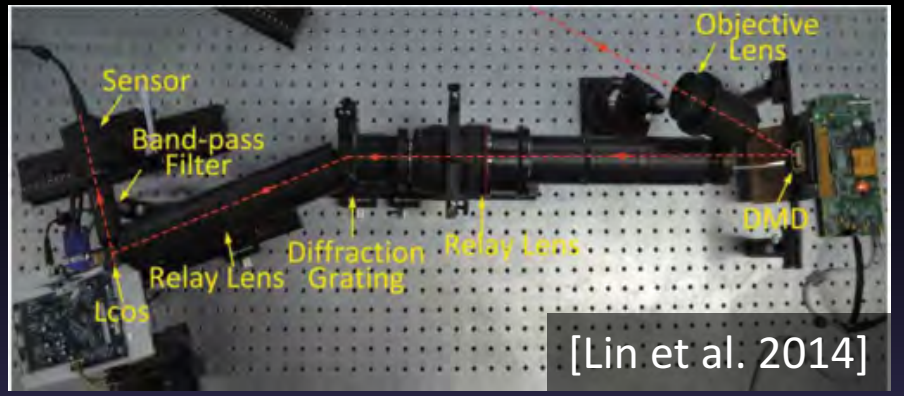


DMD (digital-micromirror-device)



[Wu et al. 2011]

LCoS (liquid crystal on silicon)



[Lin et al. 2014]

Multisampling CASSI systems require multiple captures

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Goal

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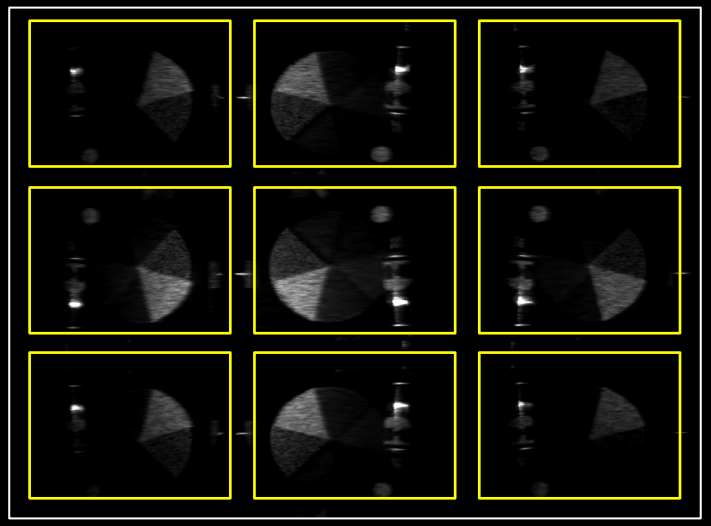
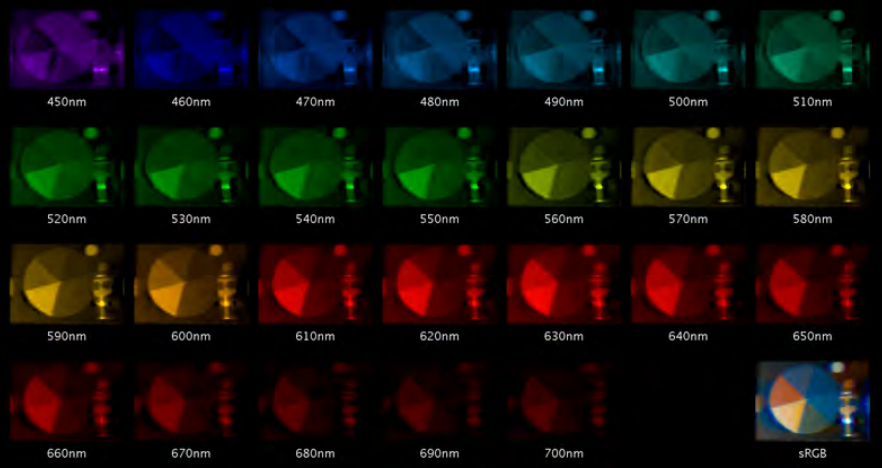
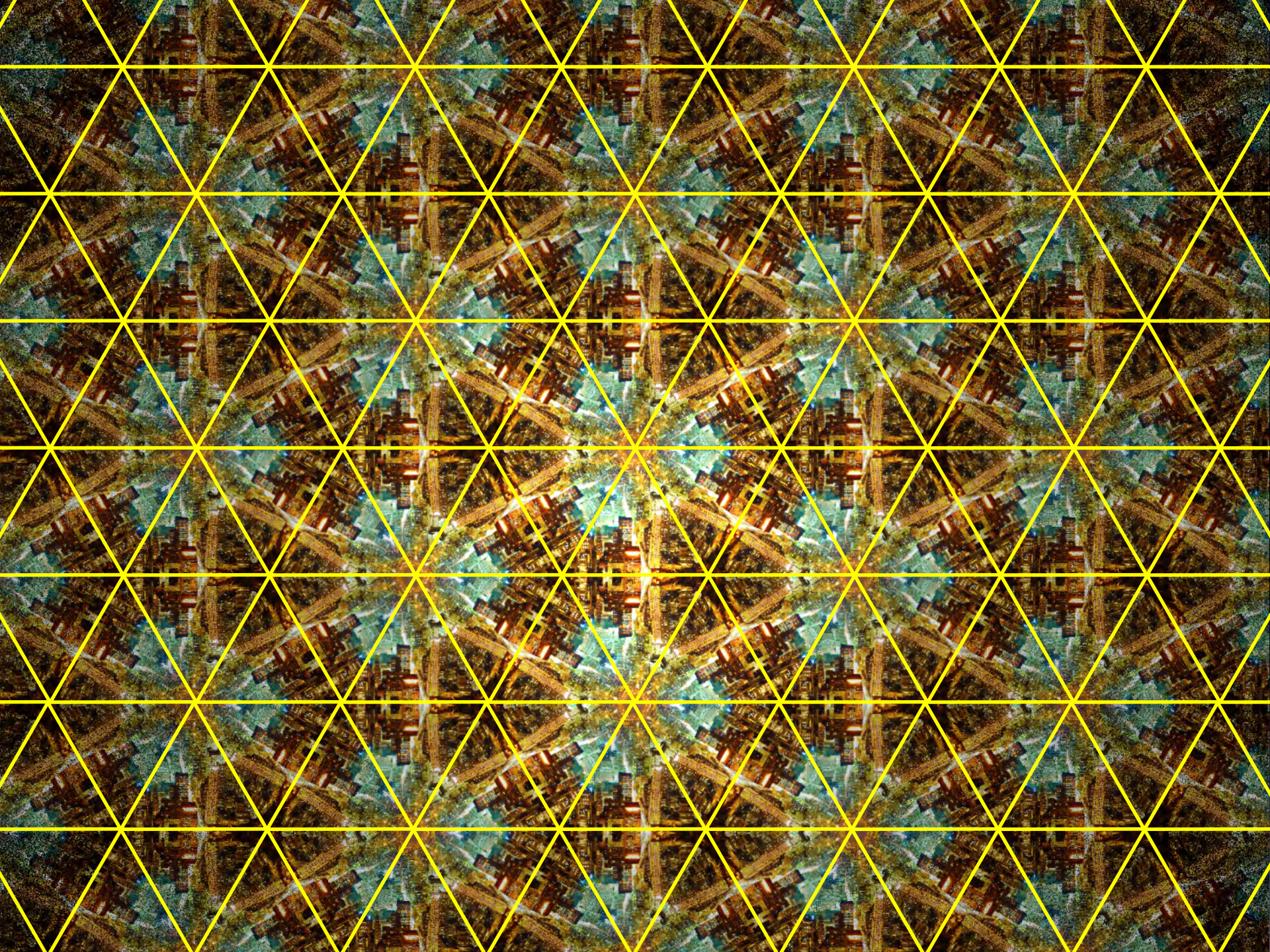
Single coded input



Hyperspectral video



- Multisampling compressive imaging
  - → High spectral resolution
  - → High spatial resolution
- Single snapshot hyperspectral imaging
  - → Video spectroscopy



Key Idea

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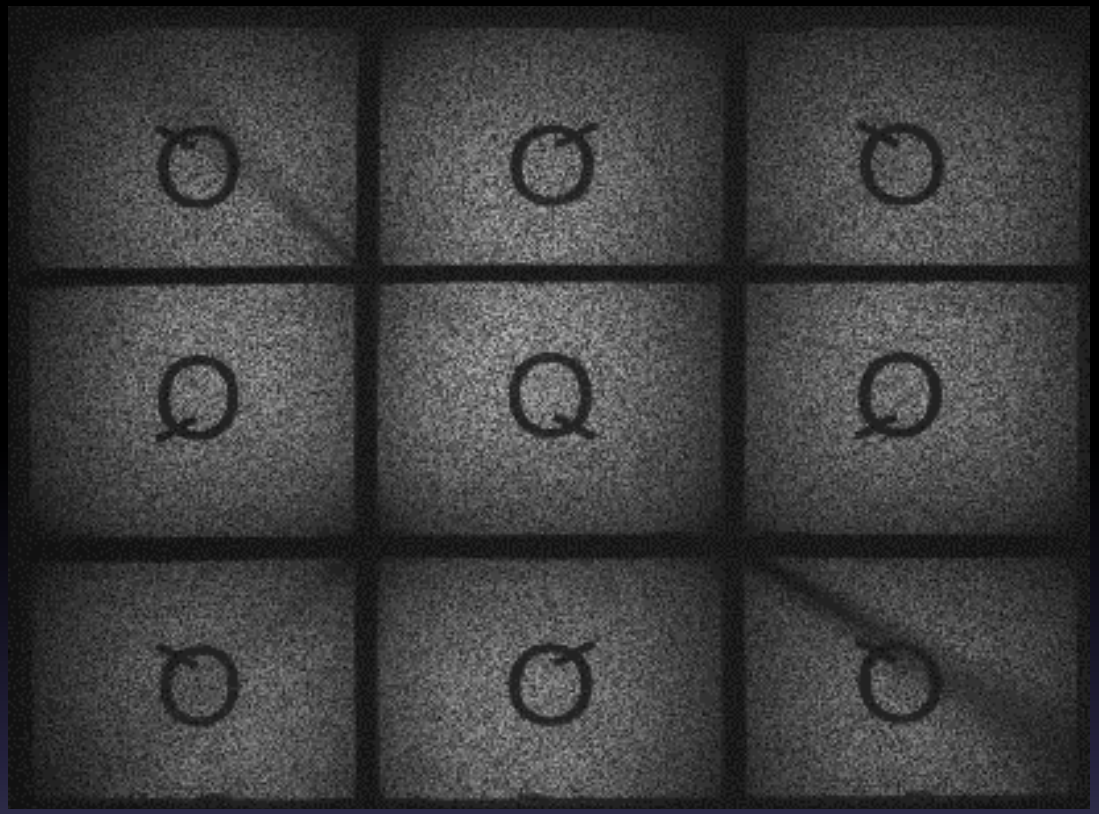
- Coded aperture snapshot spectral camera

- Multisampling

➔ Kaleidoscope



System Setup

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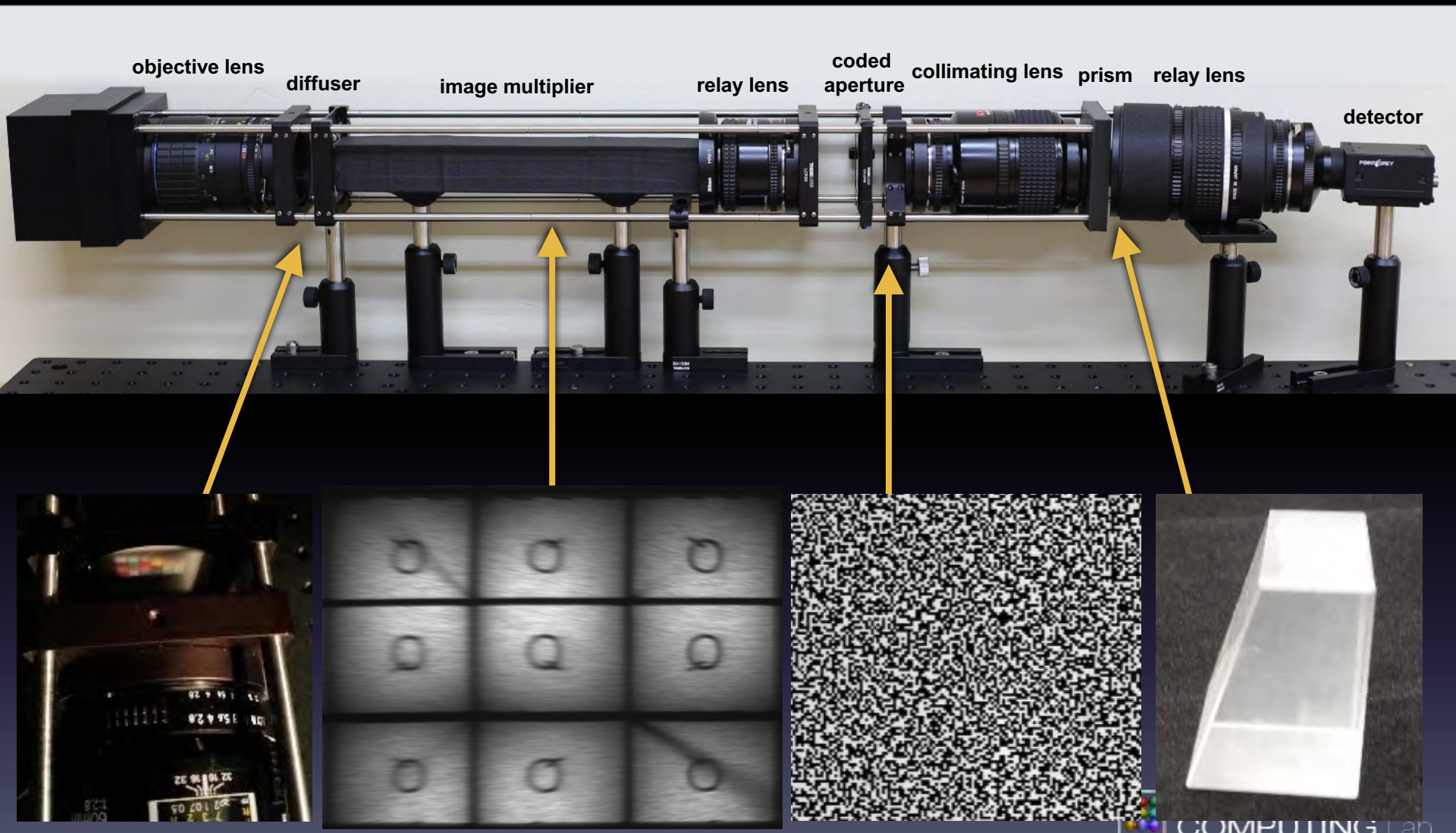
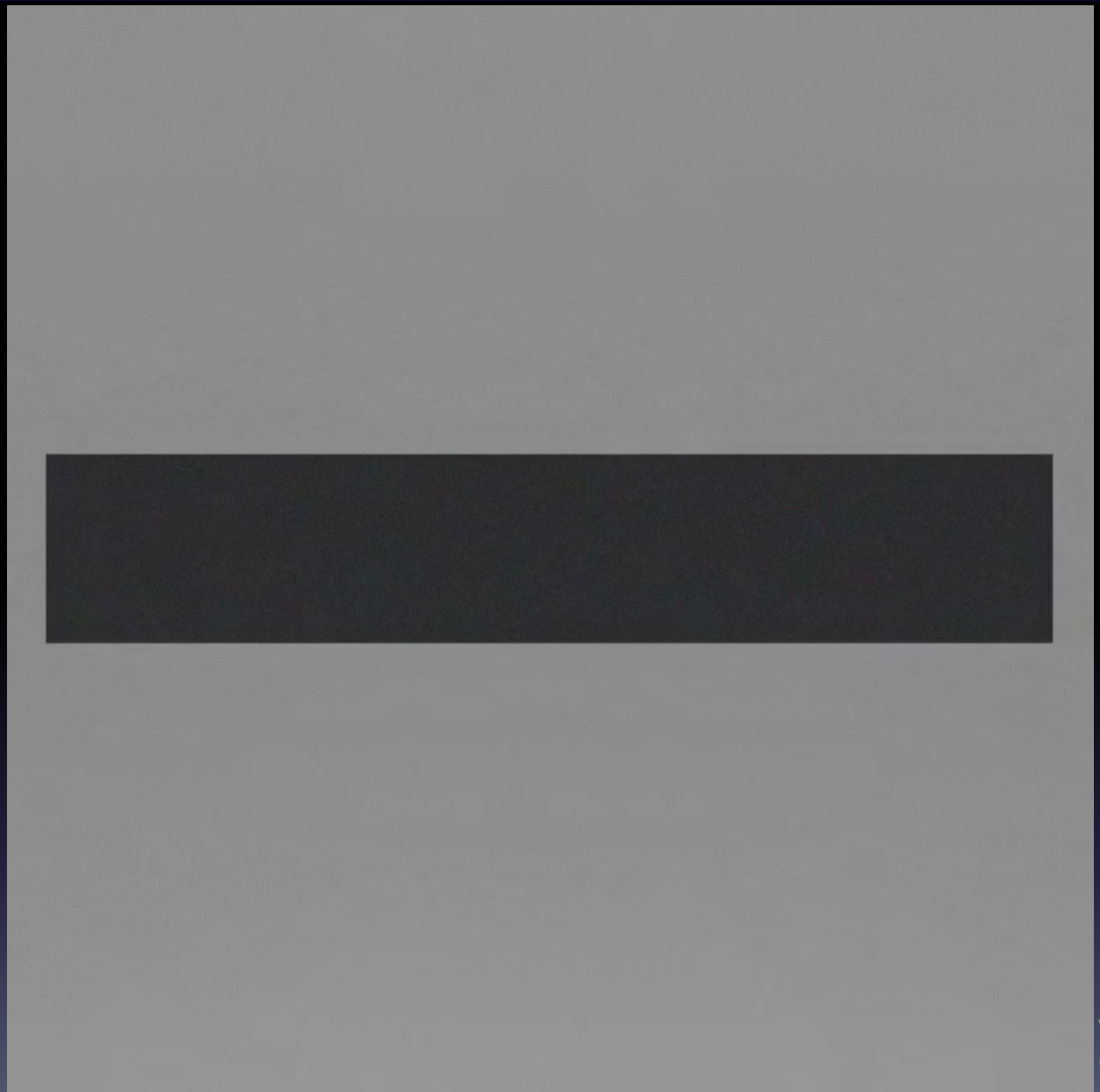
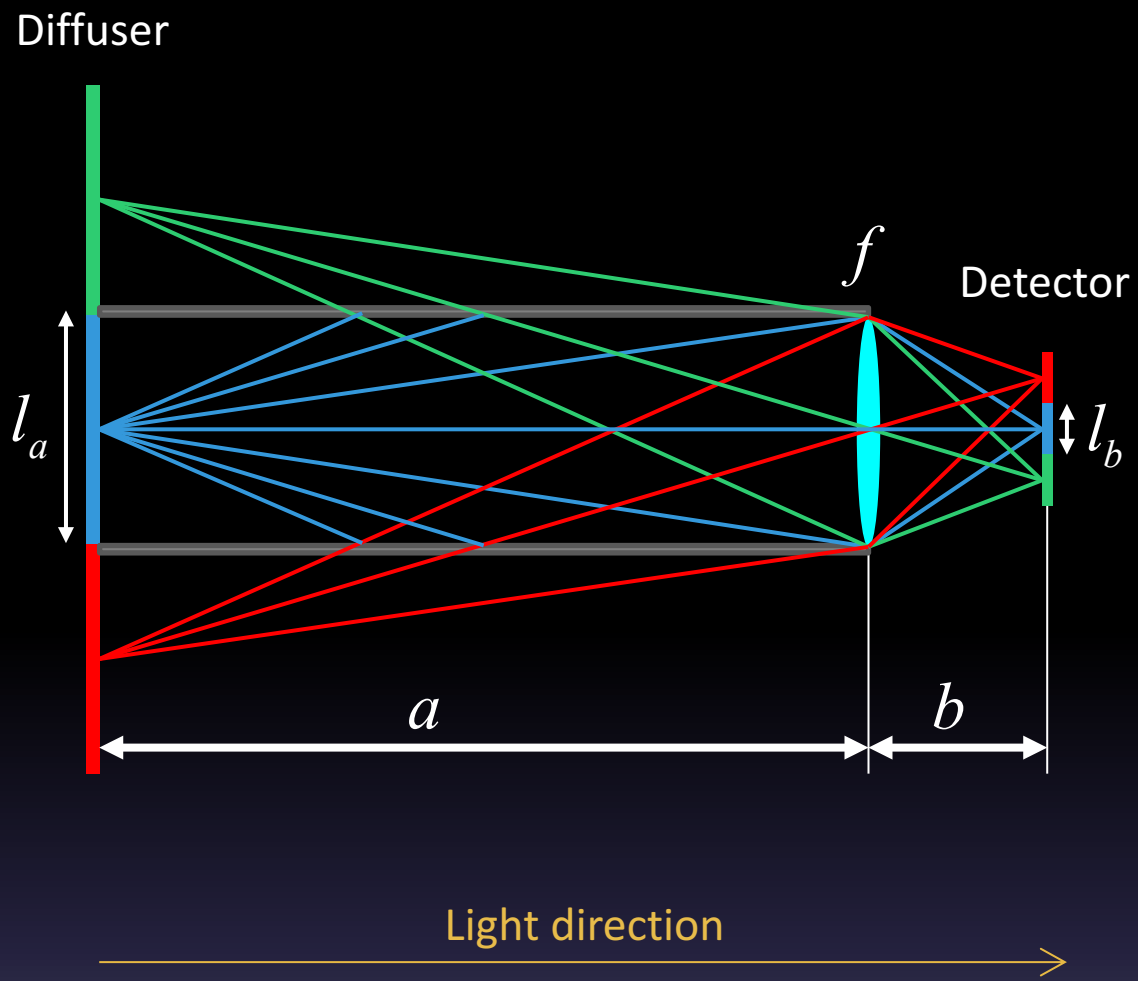


Examine Kaleidoscope



View Multiplication



m : maginification

$$m = \frac{b}{a} = \frac{1}{a/f - 1}$$

$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$$

Effect of Diffuser

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With diffuser

Without diffuser

Raw Input Video

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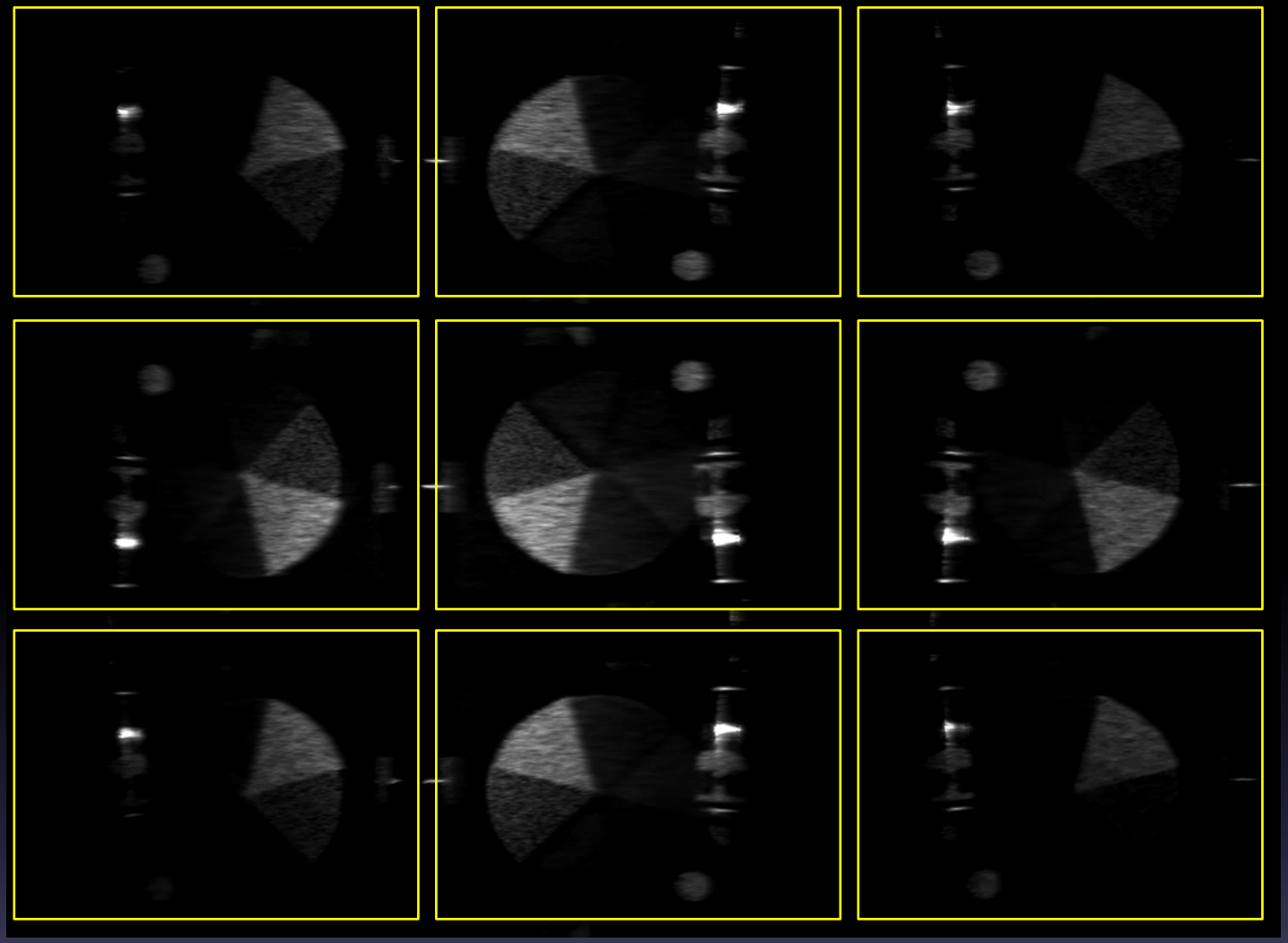

Geometric Calibration - Homography

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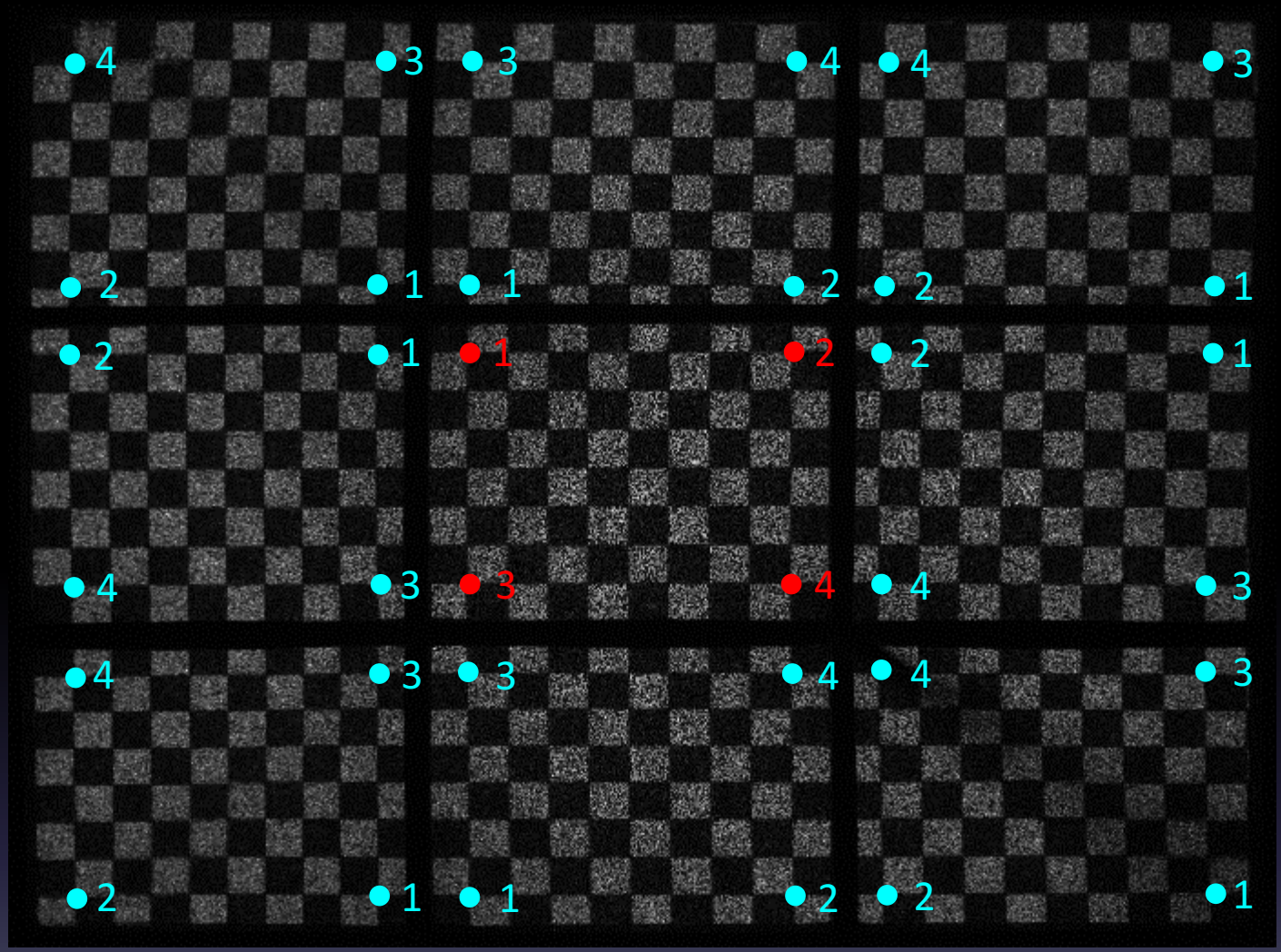

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Geometric Calibration - Optical Flow

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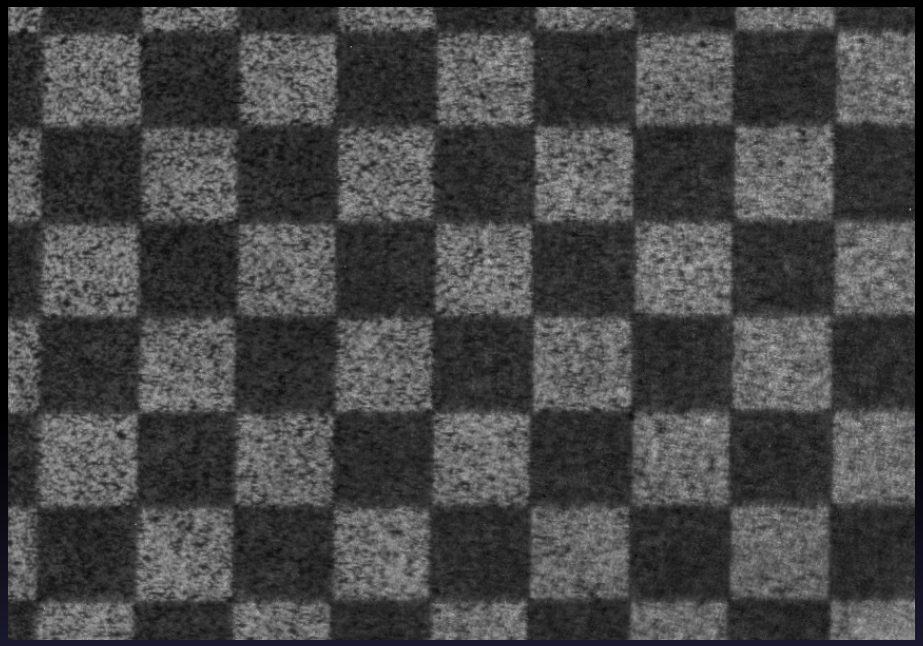
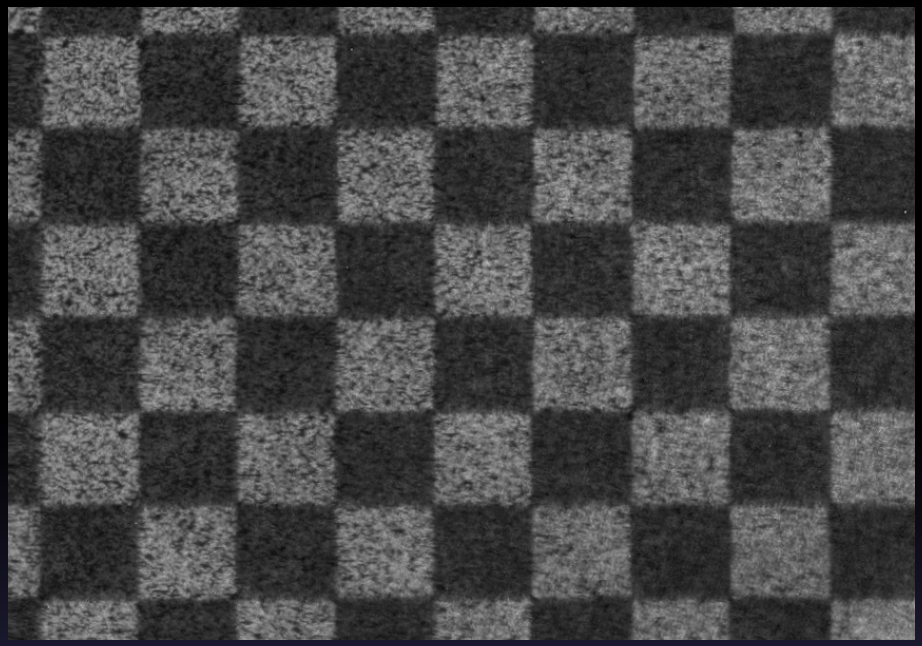
Before apply optical flow



After apply optical flow



Animated 5 views

Geometric Calibration - Dispersion Direction

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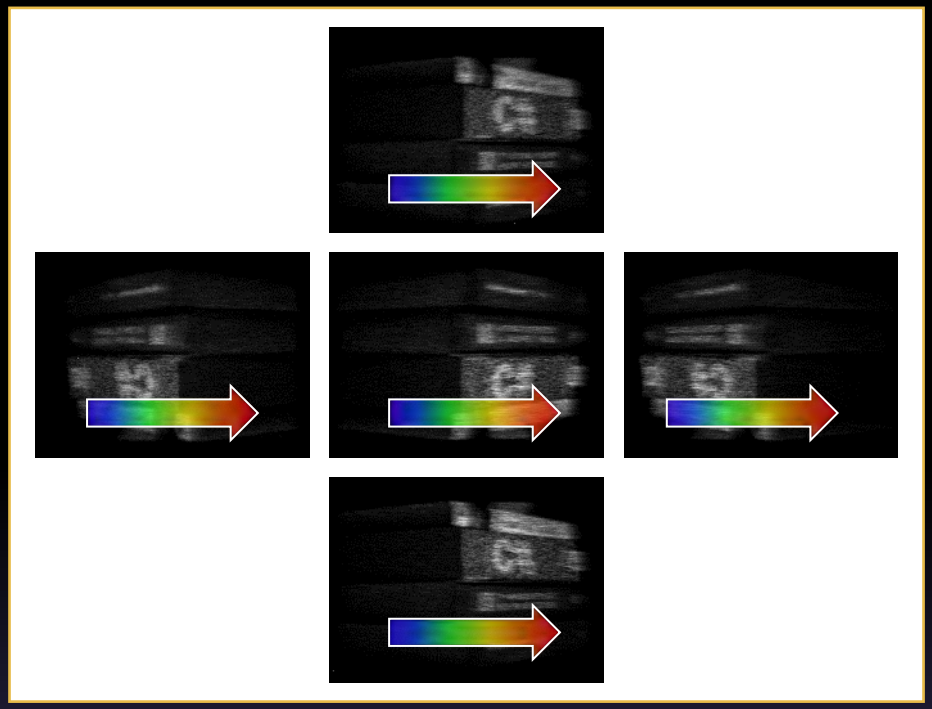
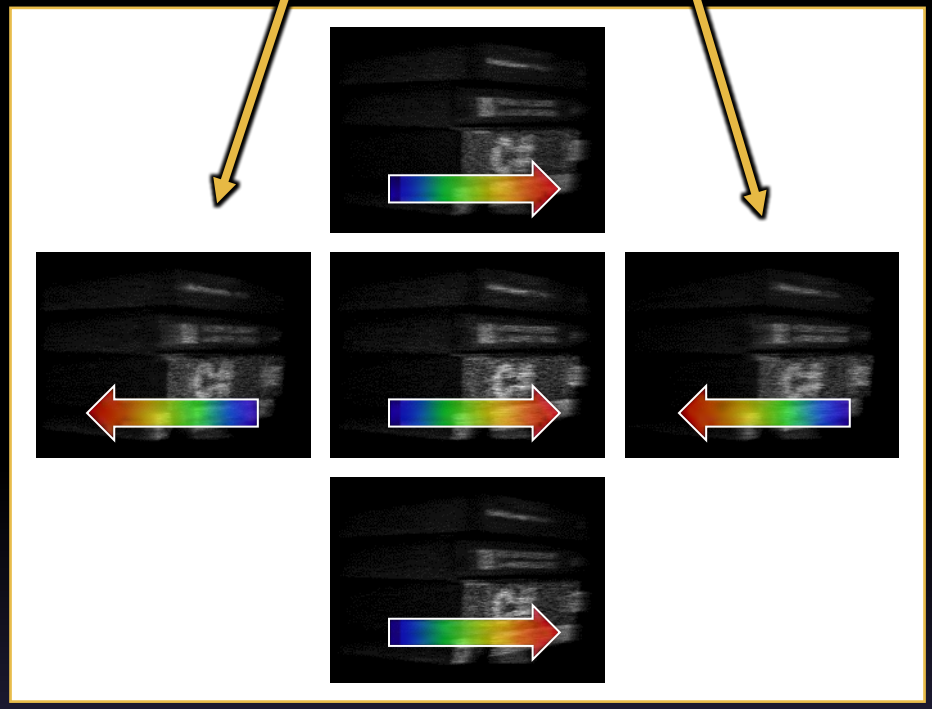


Captured images



Aligned images

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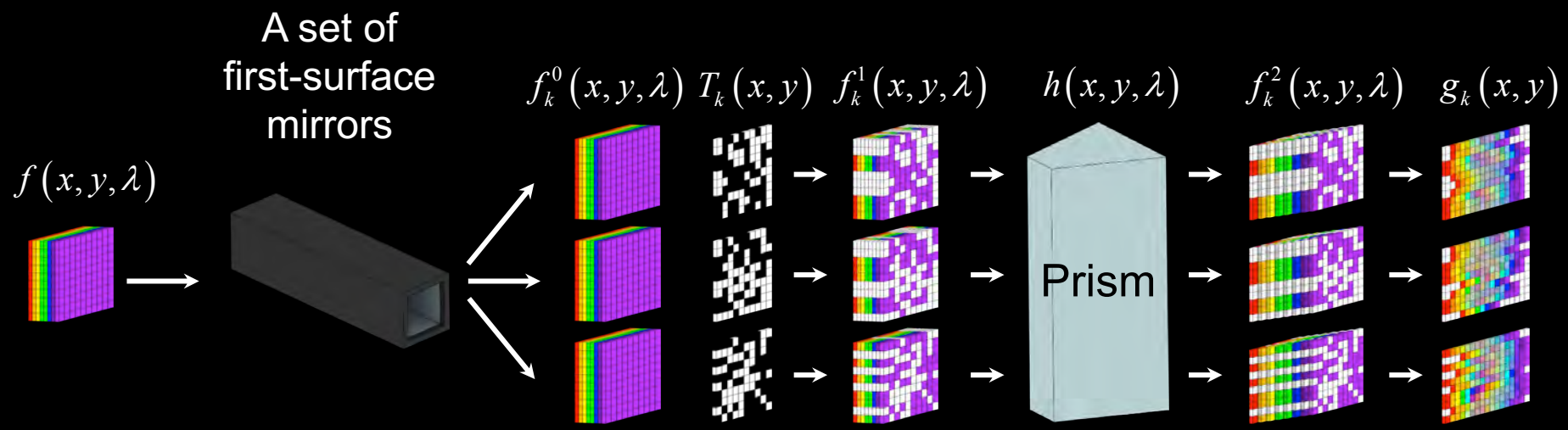
Image Reconstruction



$$g_k(x,y) = \int_\Lambda \iint \underbrace{h(x' - \phi_k(\lambda), x, y', y, \lambda)}_{\text{Dispersion}} \underbrace{T_k(x,y)}_{\text{Mask}} \underbrace{f_k^0(x,y,\lambda)}_{\text{Incident}} dx'dy'd\lambda$$

Coded Aperture

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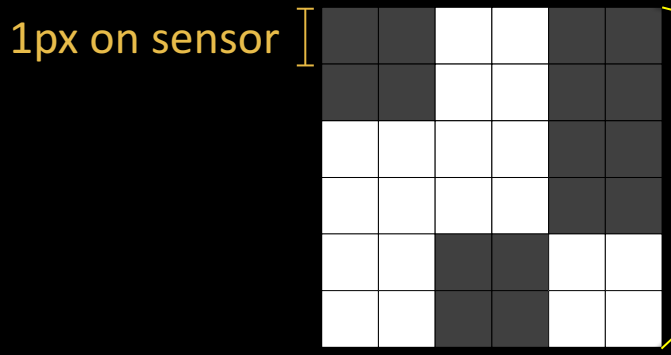
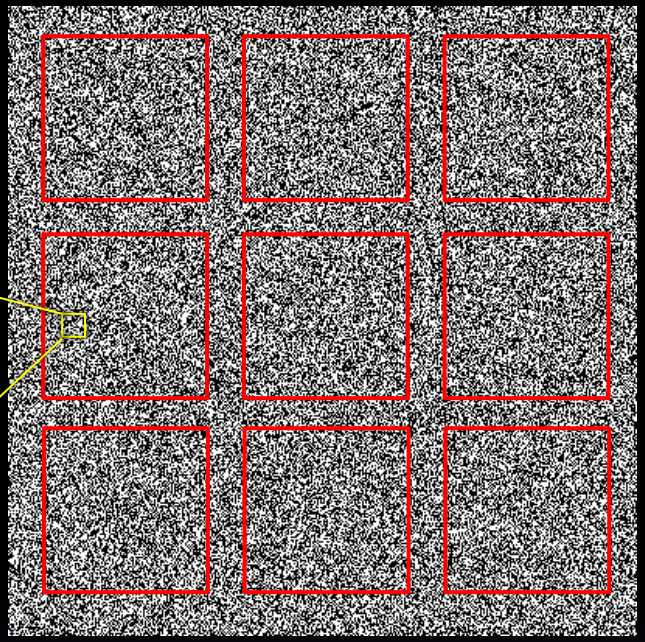
Coded aperture specs

- Random binary patterns
- corresponds to two-by-two pixels



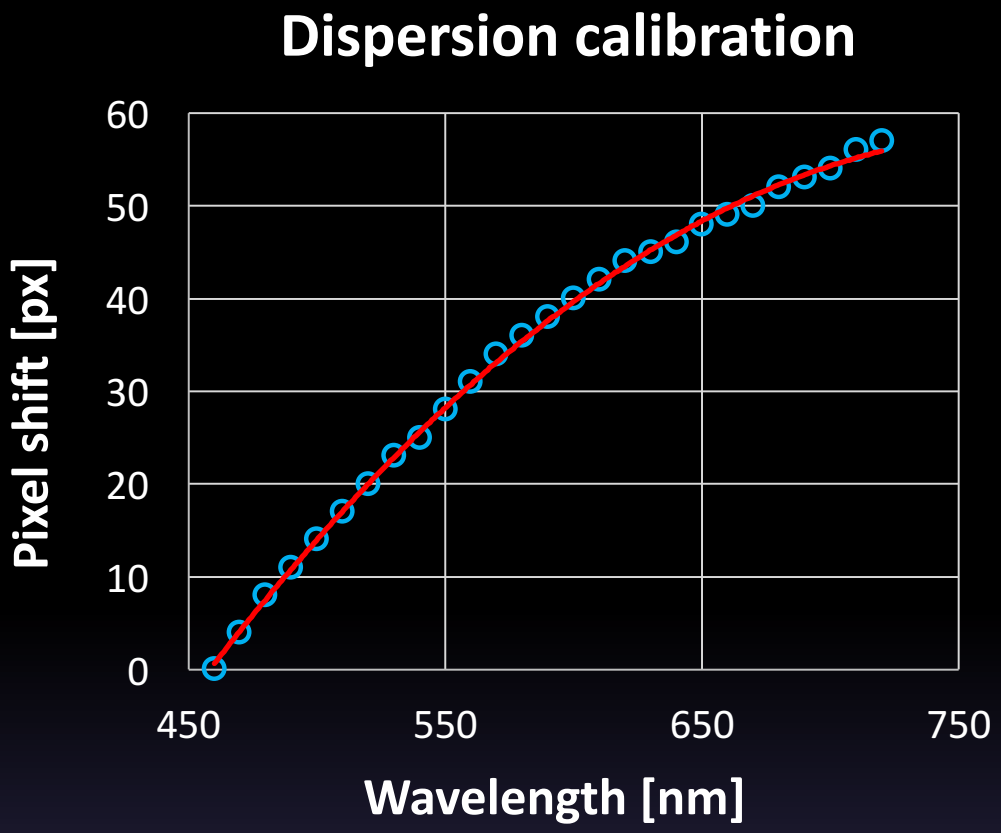


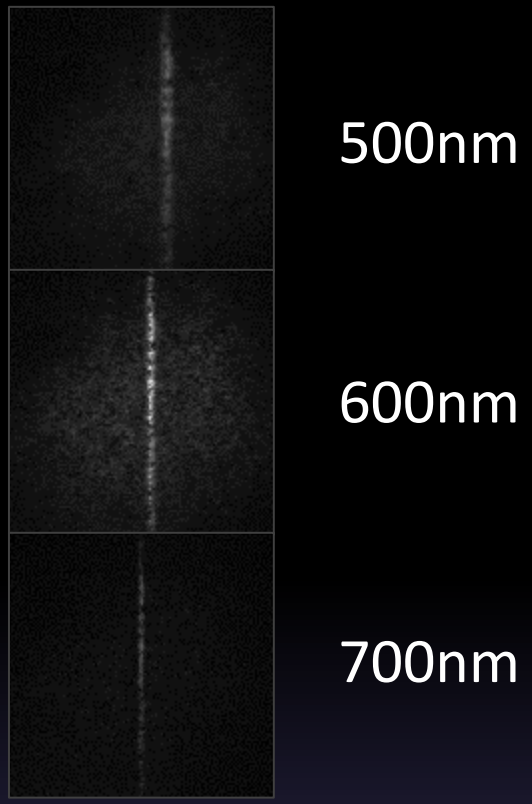
Each 9 view pass through different coded aperture patterns

→ Enable multisampling

$$T_k(x,y) = \sum_{i,j} \mathbf{T}_{ijk} \,\mathrm{rect}\left(\frac{x}{\Delta} - i, \frac{y}{\Delta} - j\right)$$

Prism Dispersion





$$f_k^2(x,y,\lambda) = \iint h(x' - \phi_k(\lambda), x, y', y, \lambda) f_k^1(x,y,\lambda) dx' dy'$$

Dispersed light Dispersion Coded light

Reconstruction

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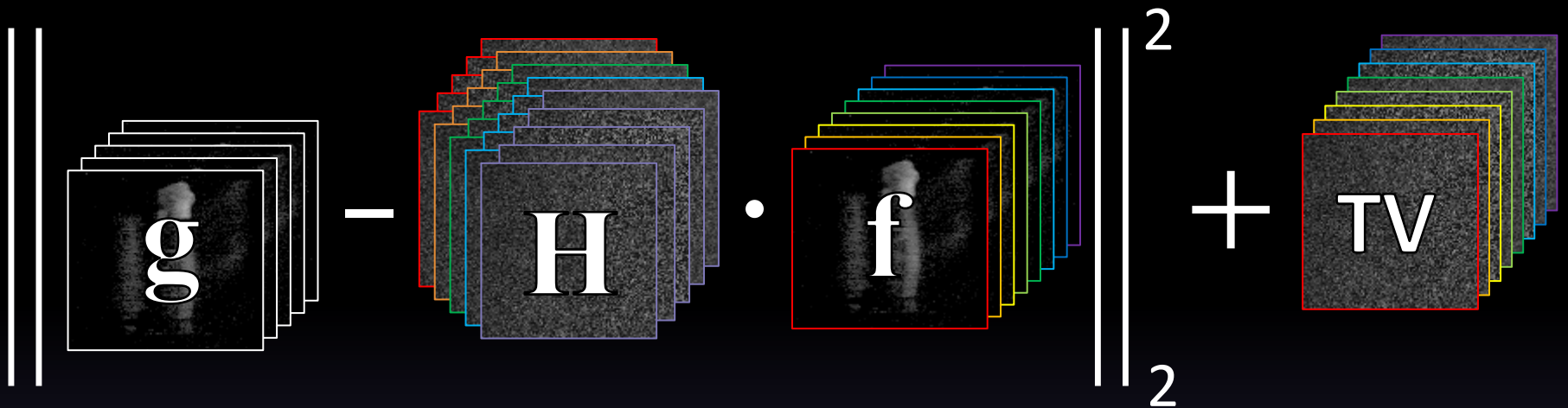
- Minimizing an objective function with total variation

  [Bioucas-Dias and Figueiredo 2007]



Detector input (3D)

Light modulation (4D)

Hyperspectal Image (3D)

Regularizing Sparsity (3D)

View Multiplication

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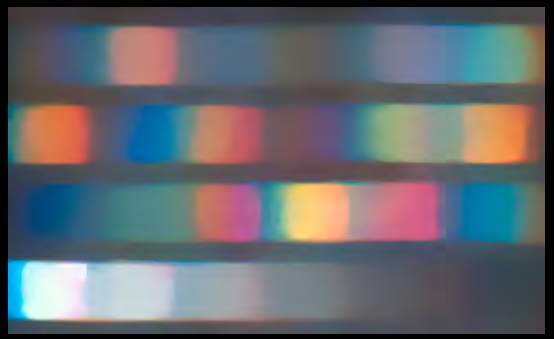
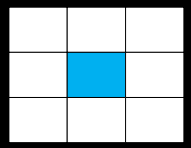
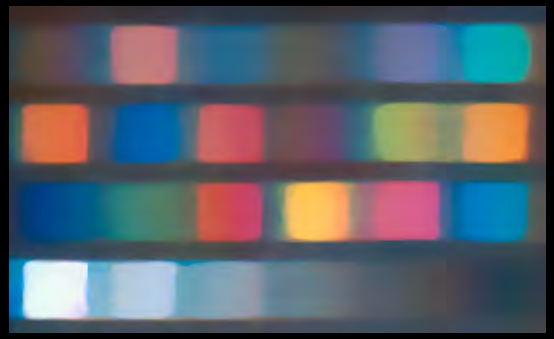
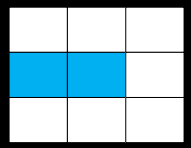


1 view

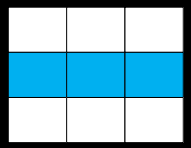




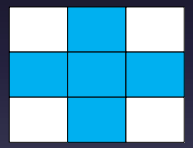
2 views

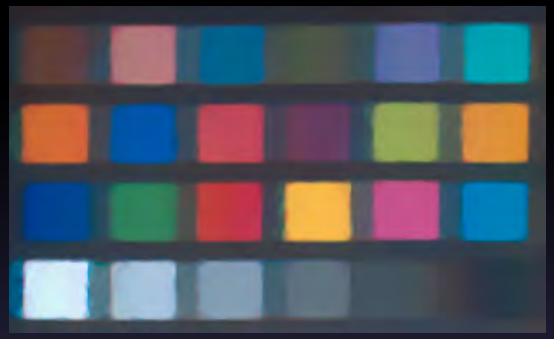


3 views

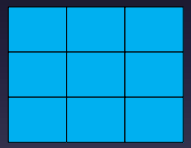


5 views





9 views



reference

(synthetic images)

Dispersion Direction

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5 views without dispersion inversion

PSNR: 28.20
SSIM: 0.88

5 views with dispersion inversion

PSNR: 30.45
SSIM: 0.91

reference

(synthetic images)

Multiview Tradeoff

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1 (full)

1	2	3
4	5	6
7	8	9

1	2	3
4	5	6
7	8	9

PSNR: 27.84
SSIM: 0.88

PSNR: 23.42
SSIM: 0.77

PSNR: 31.29
SSIM: 0.92

reference

(synthetic images)

Comparison

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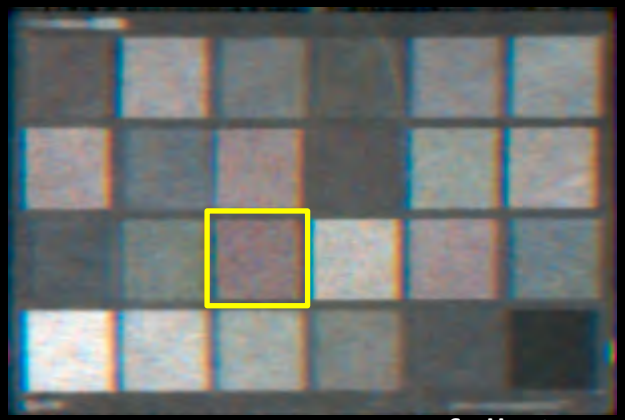
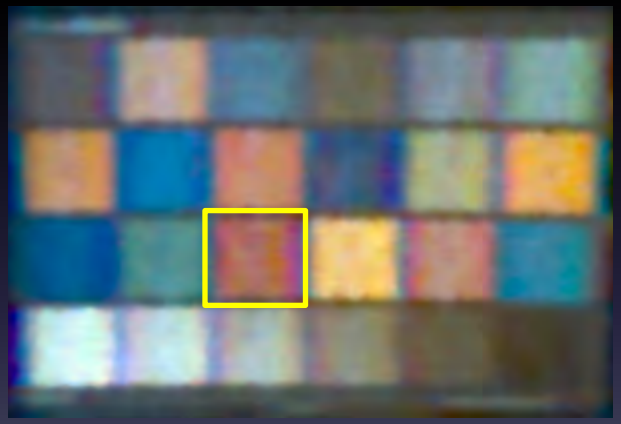
Traditional CASSI

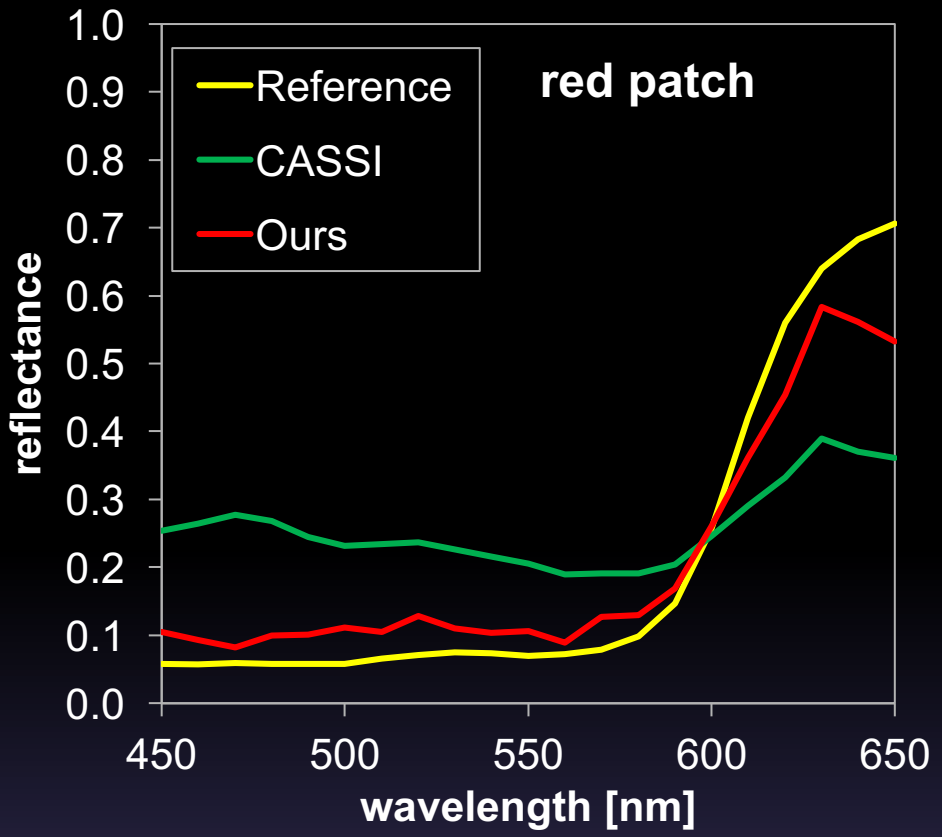


1 full view

Our multisampling CASSI



5 views



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Results

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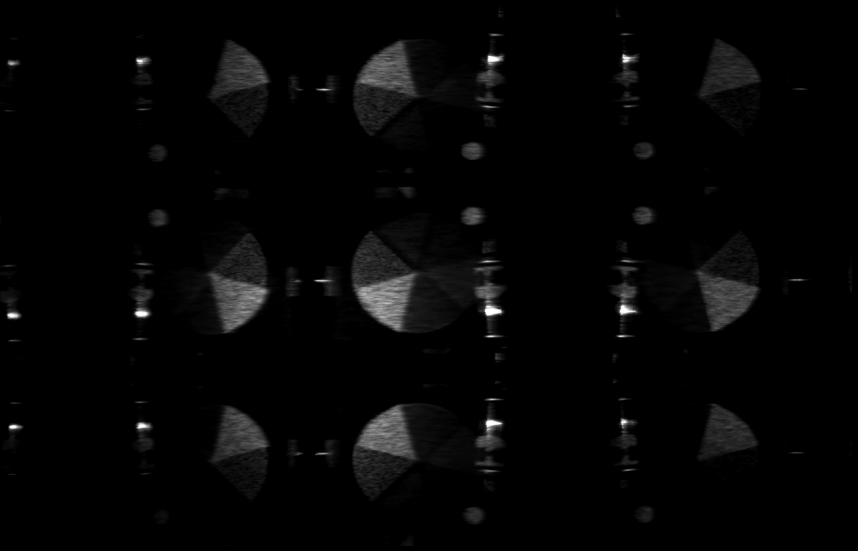
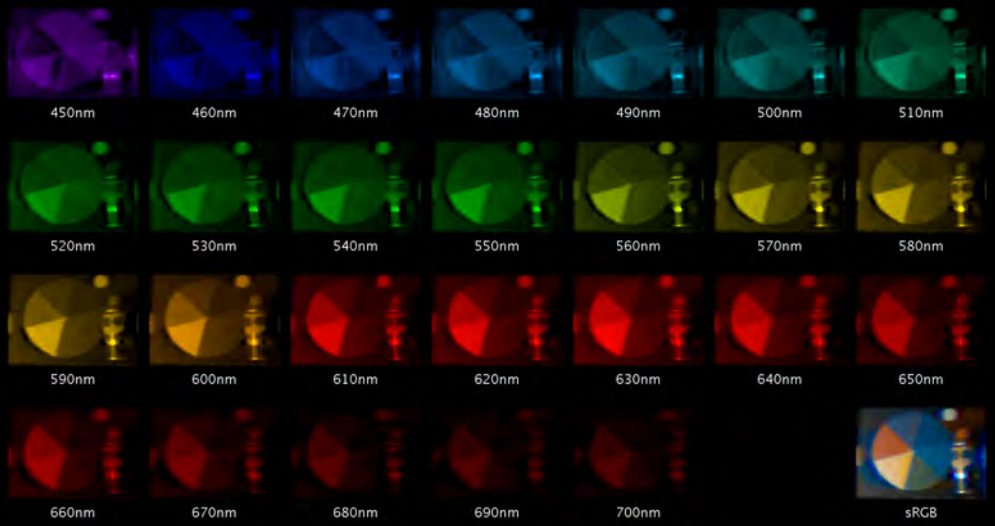
Input

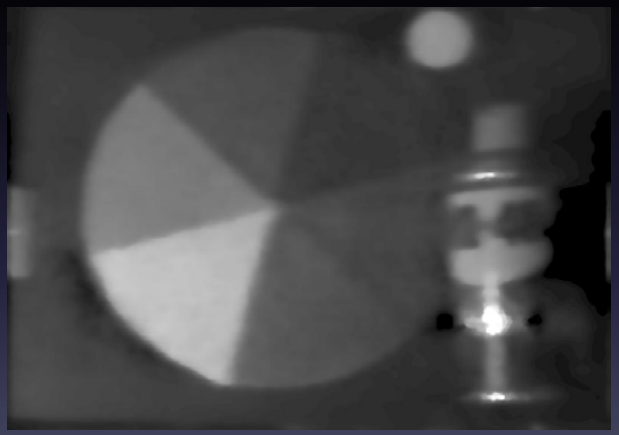


Reconstructed hyperspectral video



sRGB video

Wavelength at 600nm



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Results

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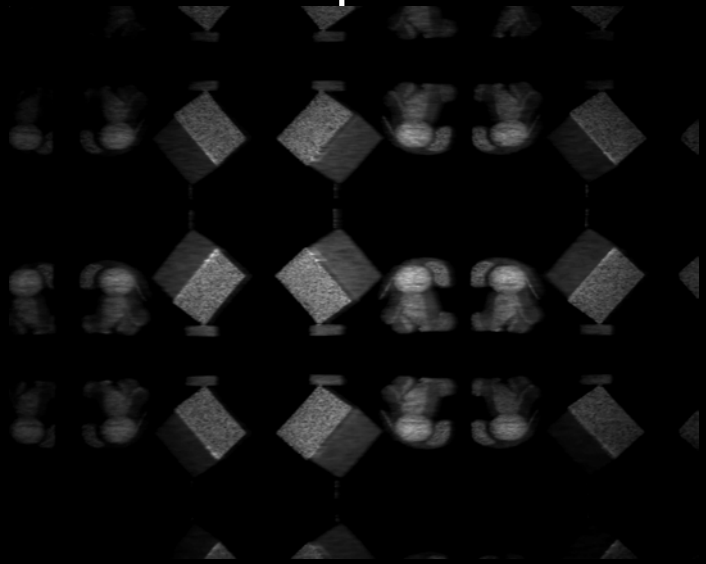
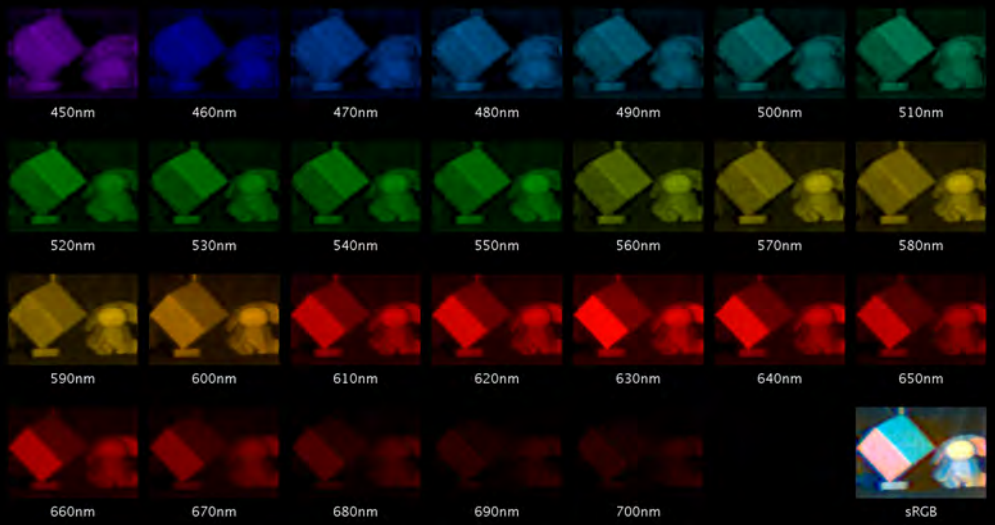
Input



Reconstructed hyperspectral video



sRGB video

Wavelength at 600nm

VISUAL COMPUTING Lab

Results

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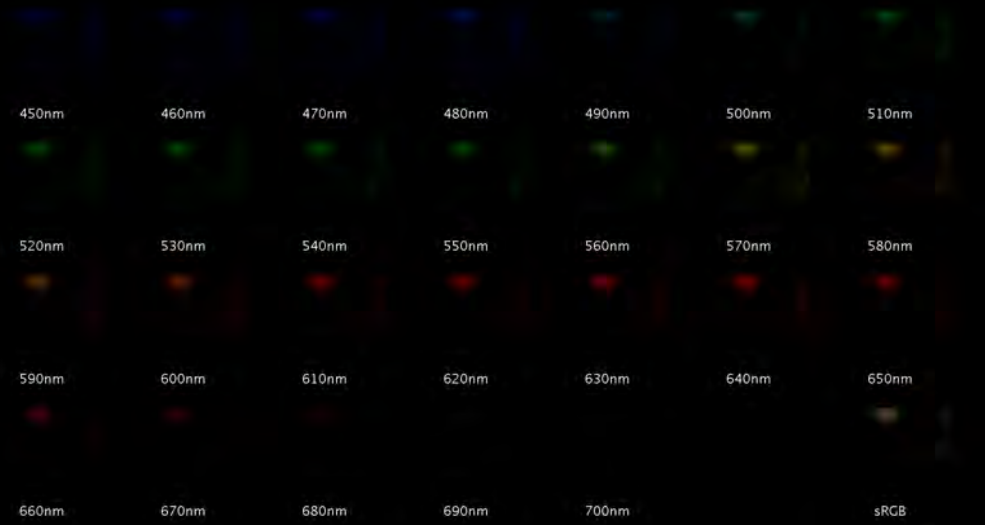
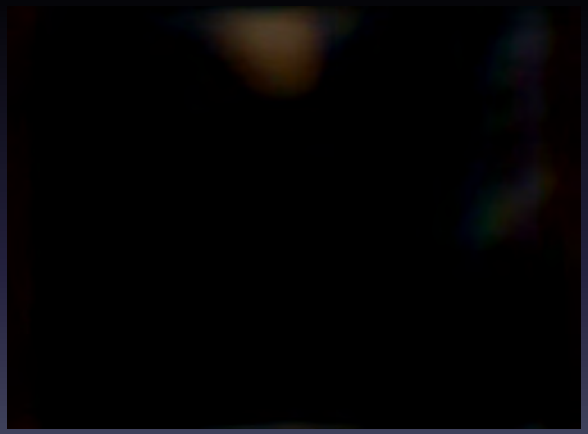
Input

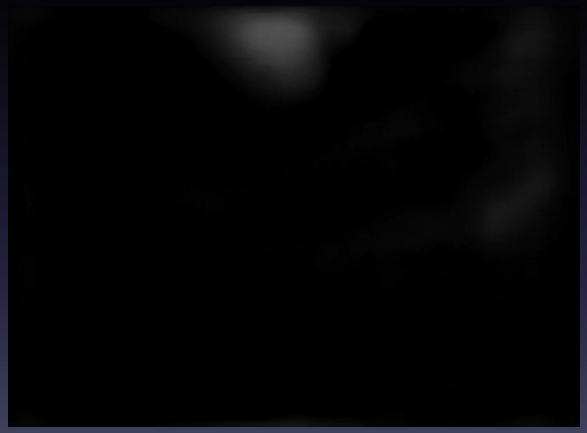
Reconstructed hyperspectral video



sRGB video



Wavelength at 600nm



VISUAL COMPUTING Lab

Results

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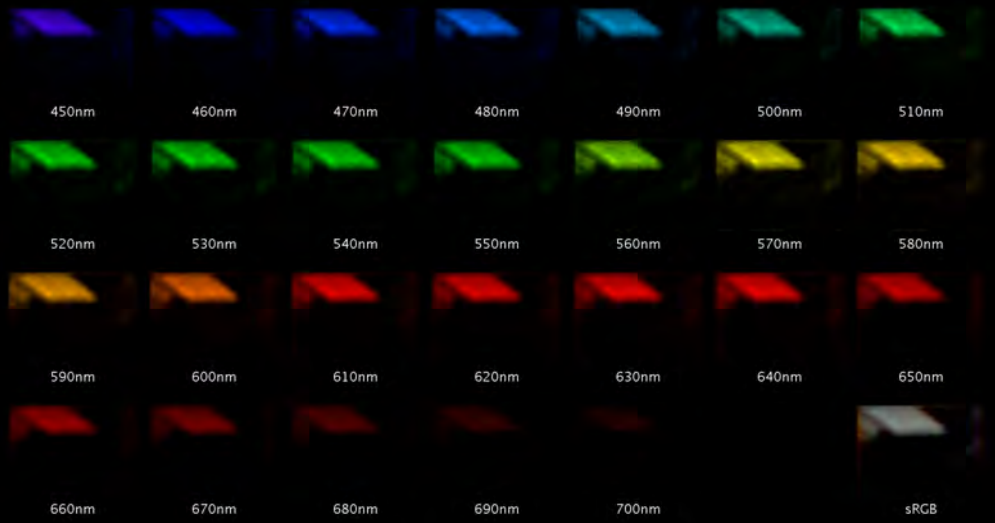
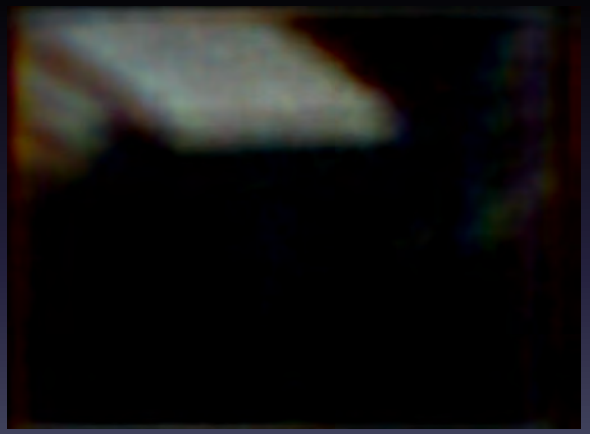
Input

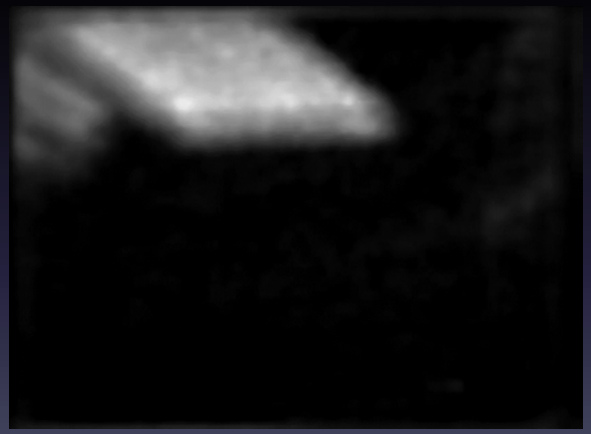
Reconstructed hyperspectral video



sRGB video



Wavelength at 600nm



VISUAL COMPUTING Lab

Discussion

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- Tradeoff between spatial and spectral resolution
  - Significantly enhance spectral resolution
  - Sacrifice sensor resolution
- Misalignment of copied views gives a critical reconstruction problem
- Alternatives for TV-L1 optimization

Conclusion

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- Single snapshot-based design
- Hyperspectral video acquisition
- High spectral resolution
- By coupling multisampling and compressive imaging

Acknowledgements

- Korea National Research Foundation (NRF) grants (2013R1A1A1010165 and 2013-M3A6A6073718)
- Korea ICT R&D program of MSIP/IITP (10041313)

Thank you