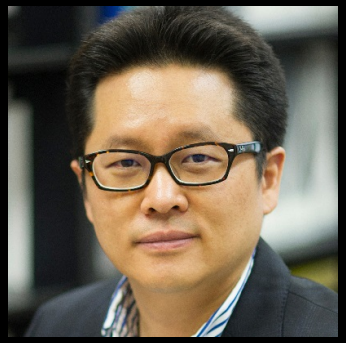
SIGGRAPH ASIA 2016 MACAO

Simultaneous Acquisition of Microscale Reflectance and Normals





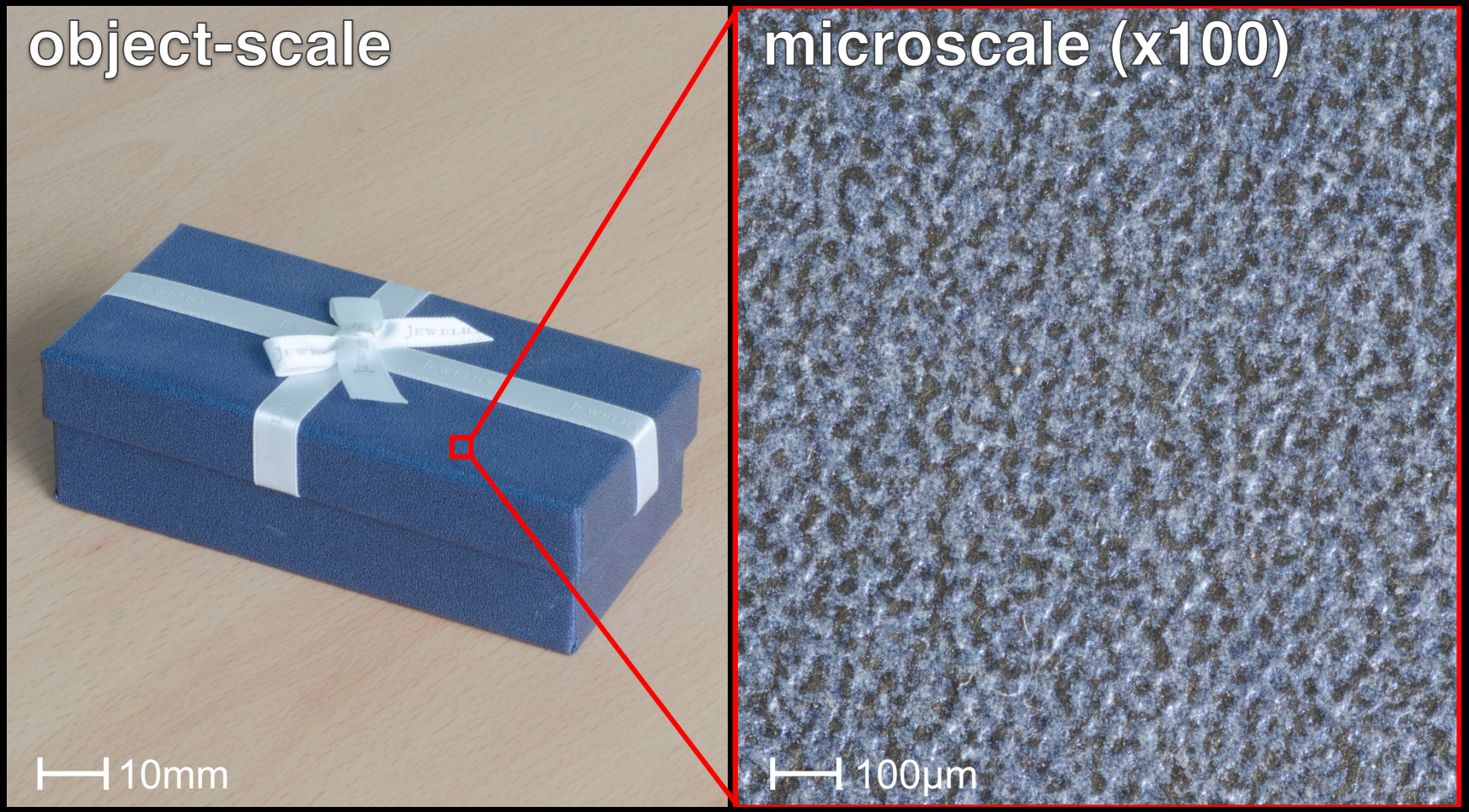


Giljoo Nam[†] Joo Ho Lee[†] Hongzhi Wu[§] Diego Gutierrez[*] Min H. Kim[†]

[†]KAIST [§]Zhejiang University [*]Universidad de Zaragoza, I3A

Material Appearance

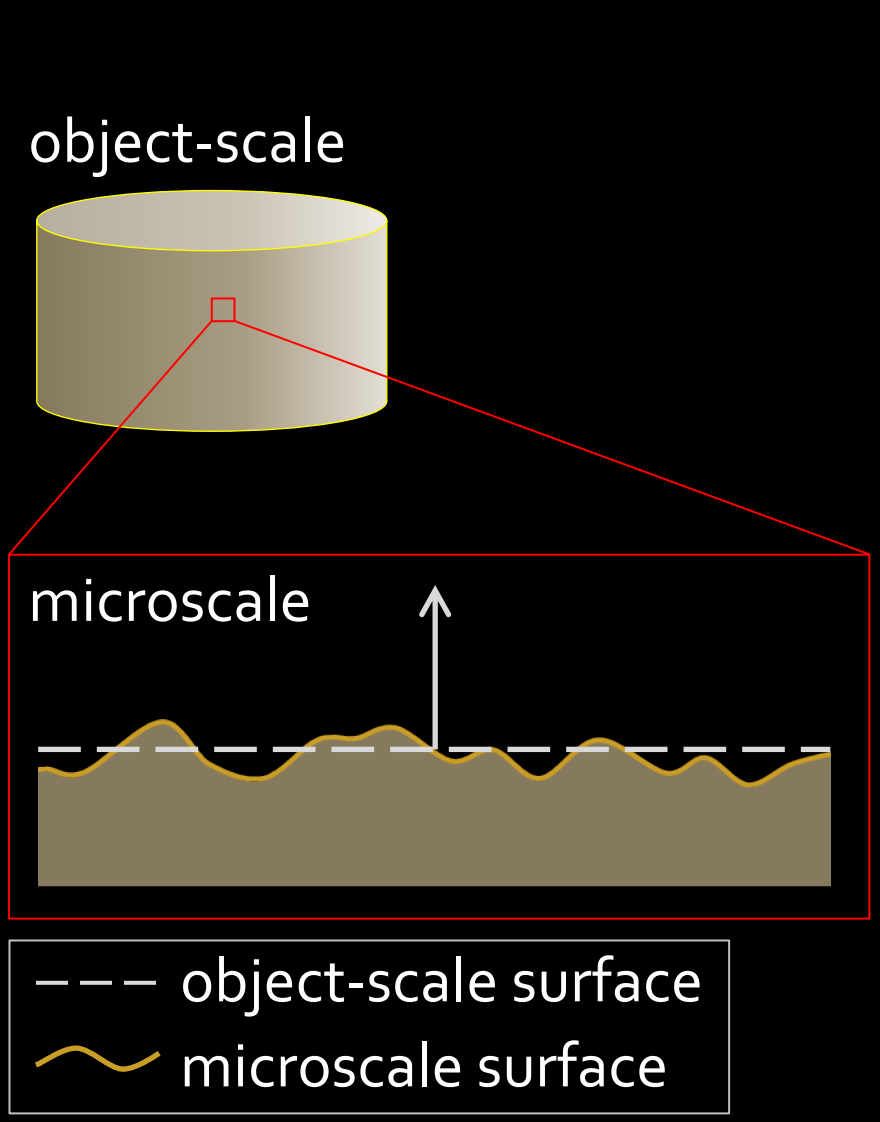
- Microscale material appearance is significantly different from object-scale appearance

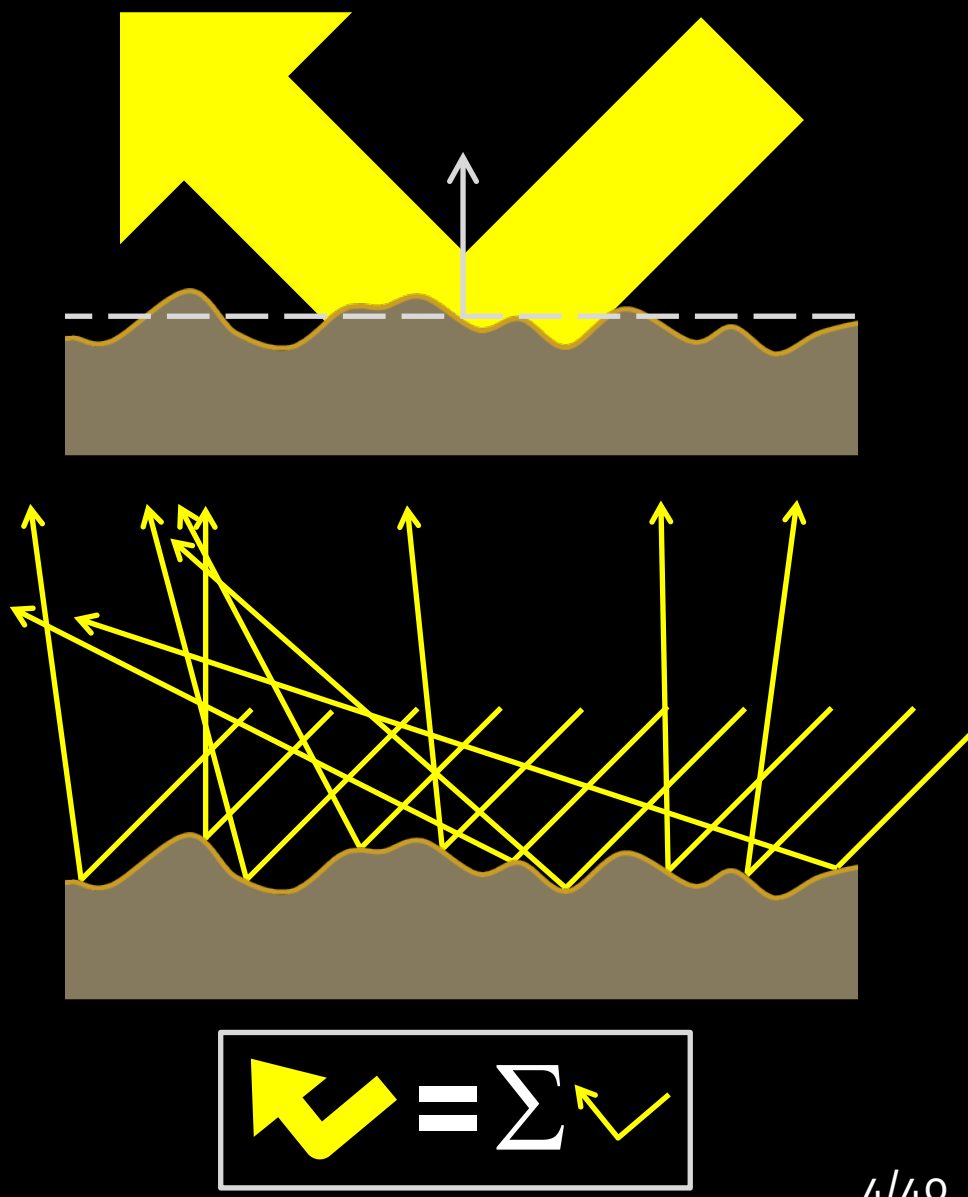


Material Appearance

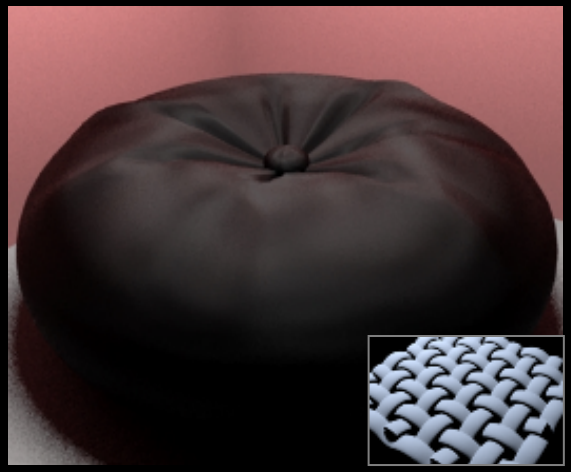
- Microscale material appearance is significantly different from object-scale appearance

Microfacet Theory

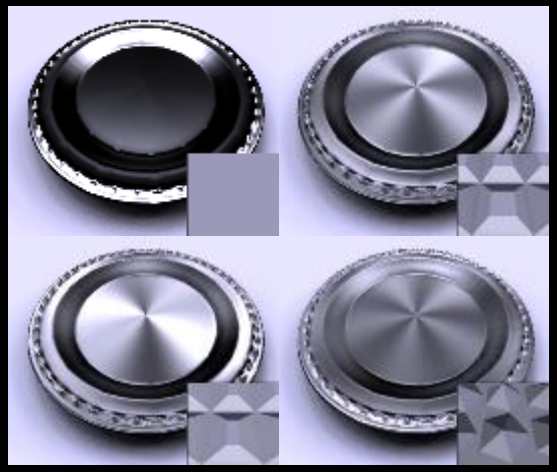




Microfacet Theory for Rendering

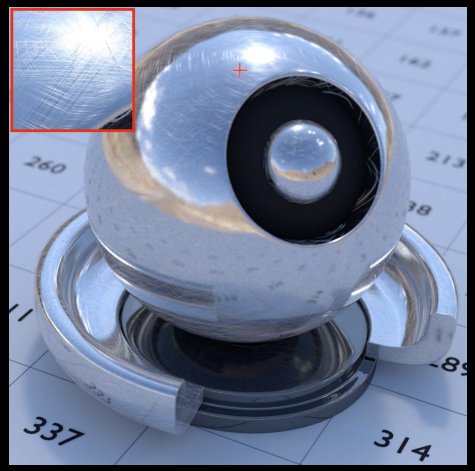


[Westin et al. 1992]

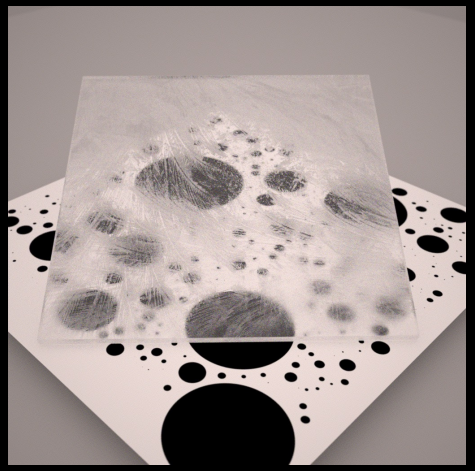


[Wu et al. 2011]

[Jacob et al. 2014]



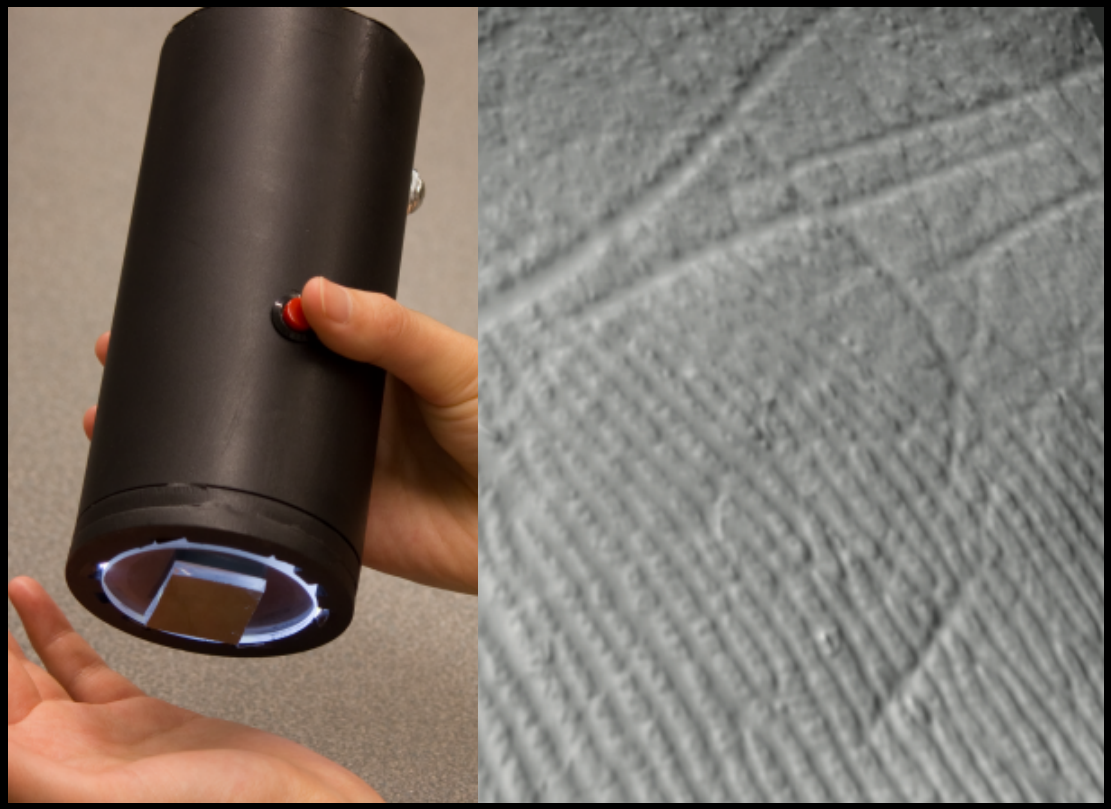
[Raymond et al. 2016]



[Heitz et al. 2016]

[Yan et al. 2016]

Microscale Geometry



[Johnson et al. 2011], GelSight

Motivation

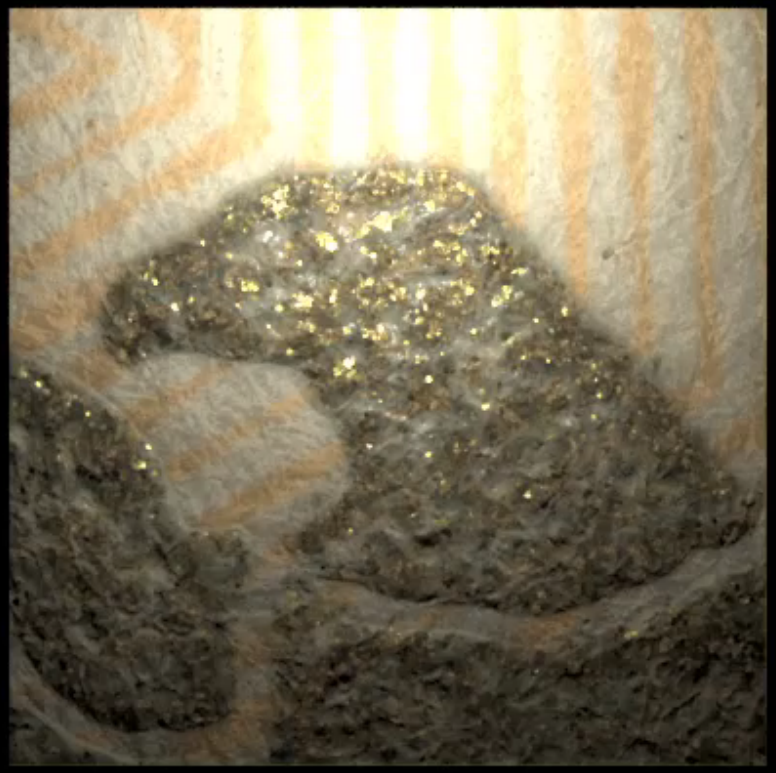
No actual measurement of **microscale material appearance** yet!

Motivation

No actual measurement of **microscale material appearance** yet!

Simultaneous acquisition of microscale reflectance and normals

Microscale Appearance Rendering

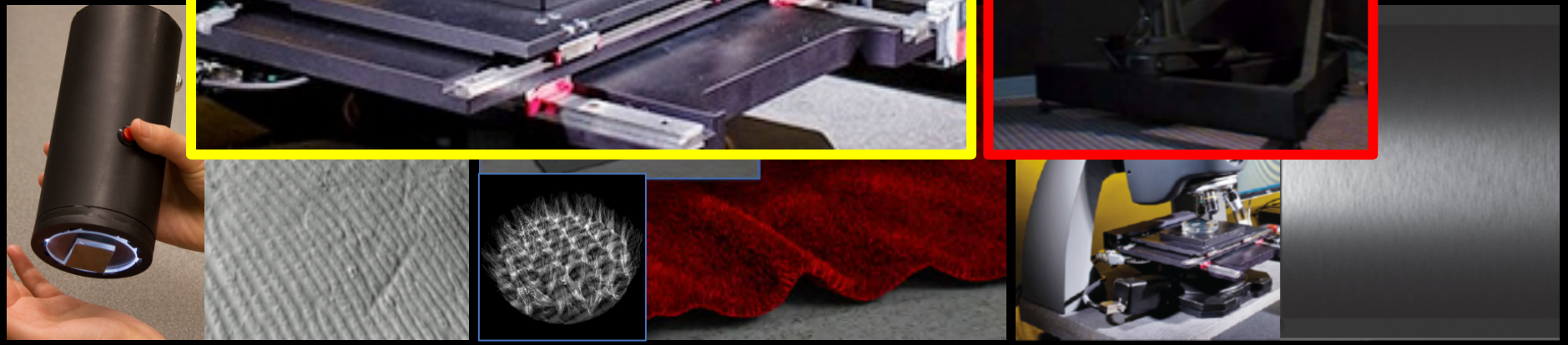


Previous Work

- Reflectance and shape measurement (object-scale)

[A 014]

- Micr



[Johnson et al. 2011] [Zhao et al. 2011] [Dong et al. 2015]

Contributions

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Acquisition System

SVBRDF Estimation

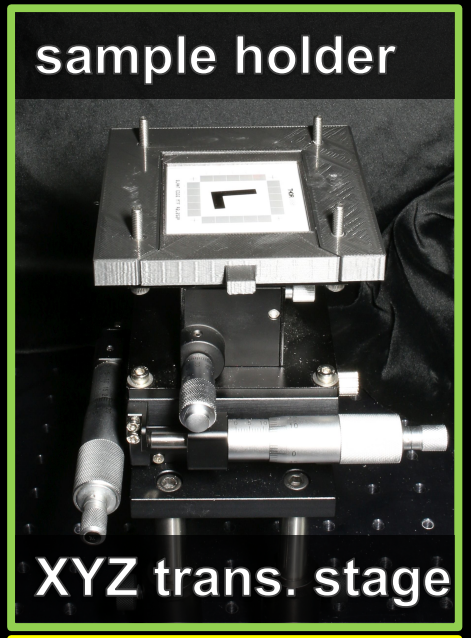
Microscale Dataset

Applications

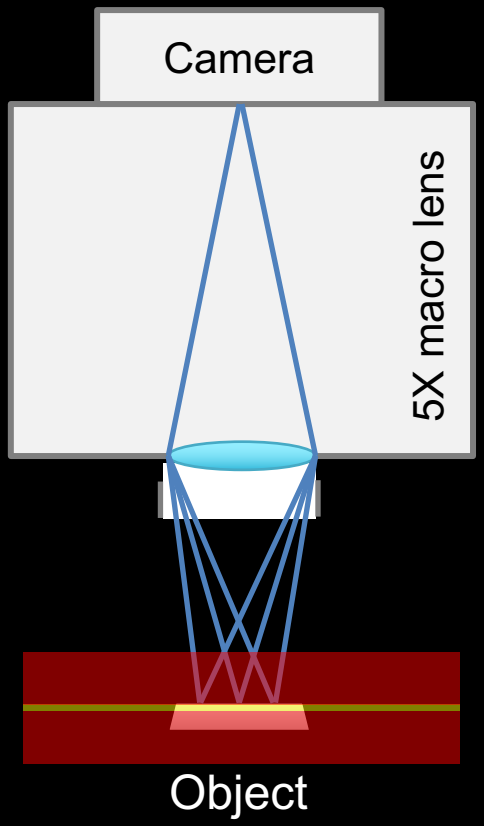
Microscale Material Appearance

ACQUISITION SYSTEM

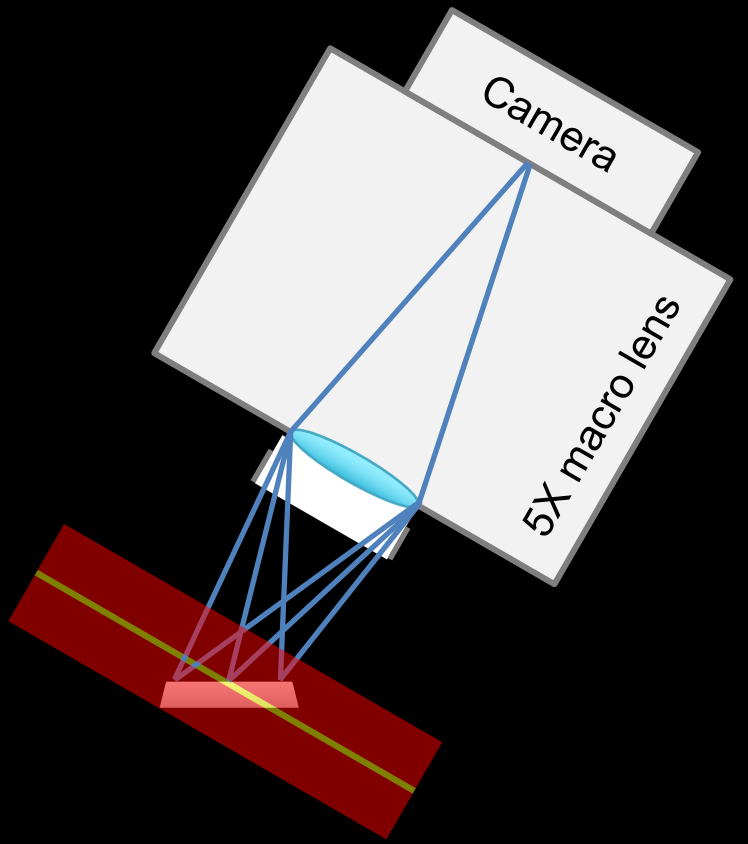
Microscale Acquisition System



Microscale Acquisition System



Shallow Depth-of-Field
(~100μm)

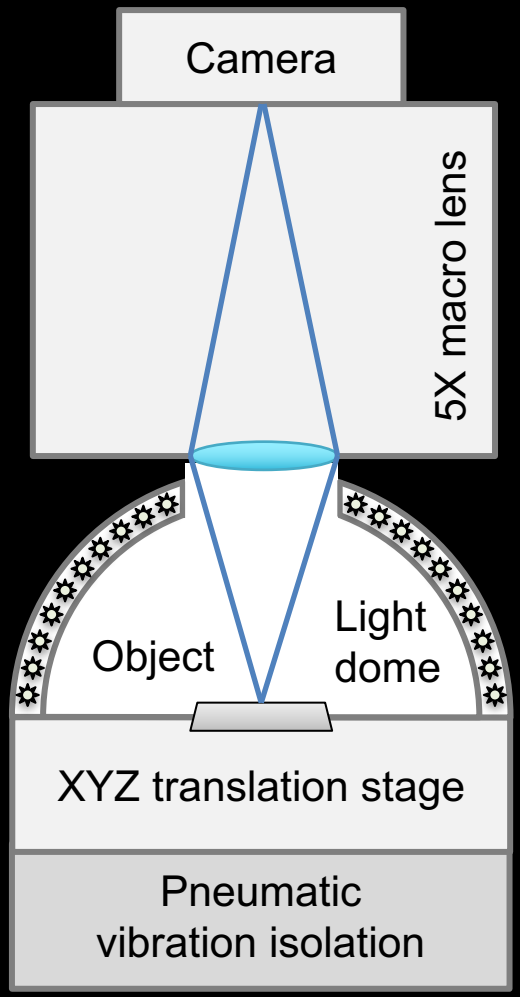


Out-of-focus image

Out-of-focus region

In-focus plane

Microscale Acquisition System

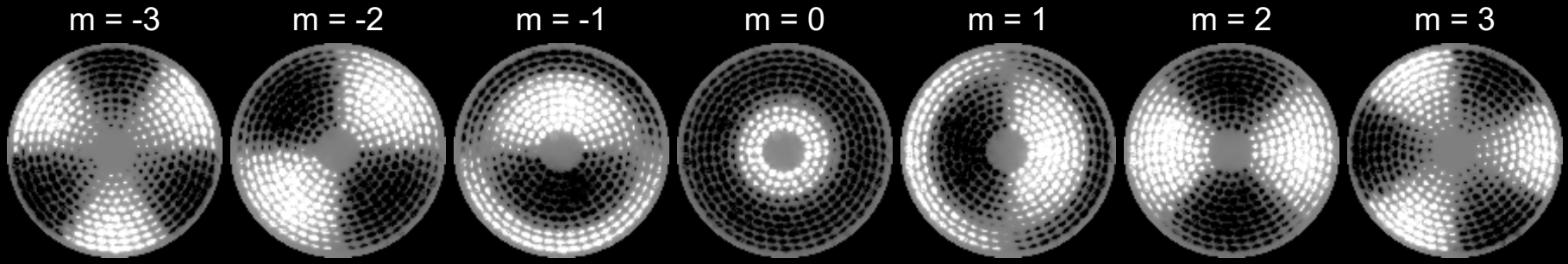


Pixel resolution: 620nm

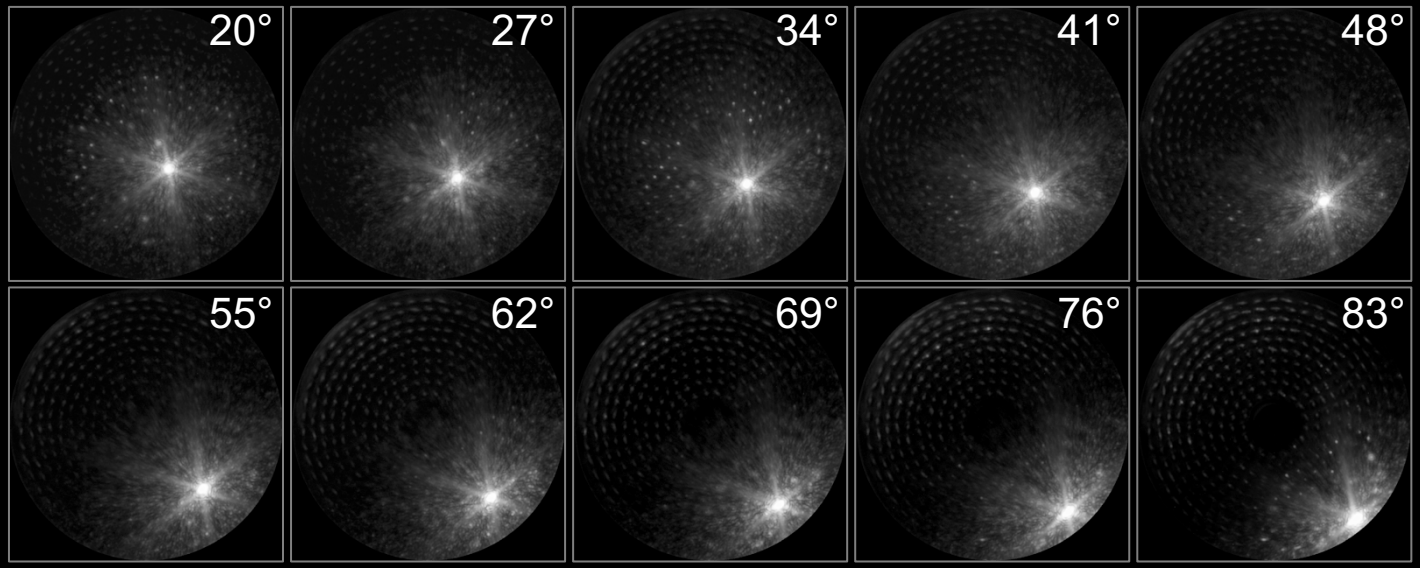
Effective resolution: ~1.98μm

Illumination Structure

- Spherical harmonics illumination at level 3



- Point illumination



Microscale Material Appearance

SVBRDF ESTIMATION

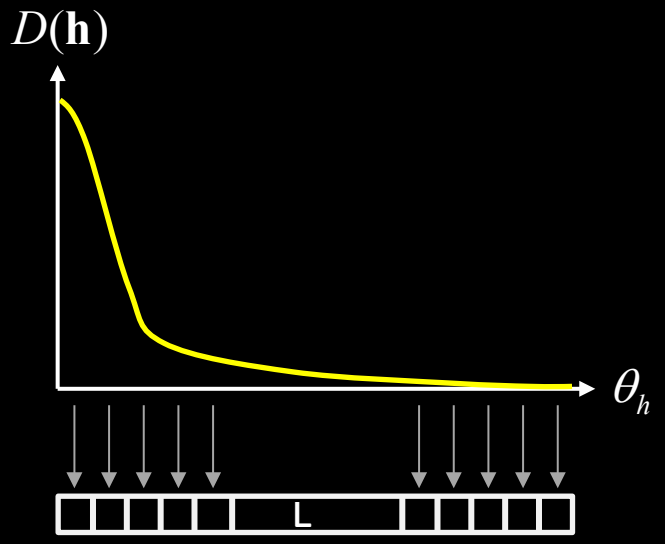
BRDF Representation

$$R(\mathbf{o},\mathbf{i}) = \frac{1}{\pi}\rho_d + \rho_s \frac{D(\mathbf{h})G(\mathbf{n},\mathbf{o},\mathbf{i})F(\mathbf{h},\mathbf{i})}{4(\mathbf{n}\cdot\mathbf{o})(\mathbf{n}\cdot\mathbf{i})}$$

[Torrance and Sparrow, 1967]

$D(\mathbf{h})$: Normal Distribution Function (NDF)

1) Parametric model for sub-micron scale is unknown
2) Data-driven representation has better expressive power than parametric models



1D array with 90 coefficients

BRDF Representation

$$R(\mathbf{o},\mathbf{i}) = \frac{1}{\pi}\rho_d + \rho_s \frac{D(\mathbf{h})G(\mathbf{n},\mathbf{o},\mathbf{i})F(\mathbf{h},\mathbf{i})}{4(\mathbf{n}\cdot\mathbf{o})(\mathbf{n}\cdot\mathbf{i})}$$

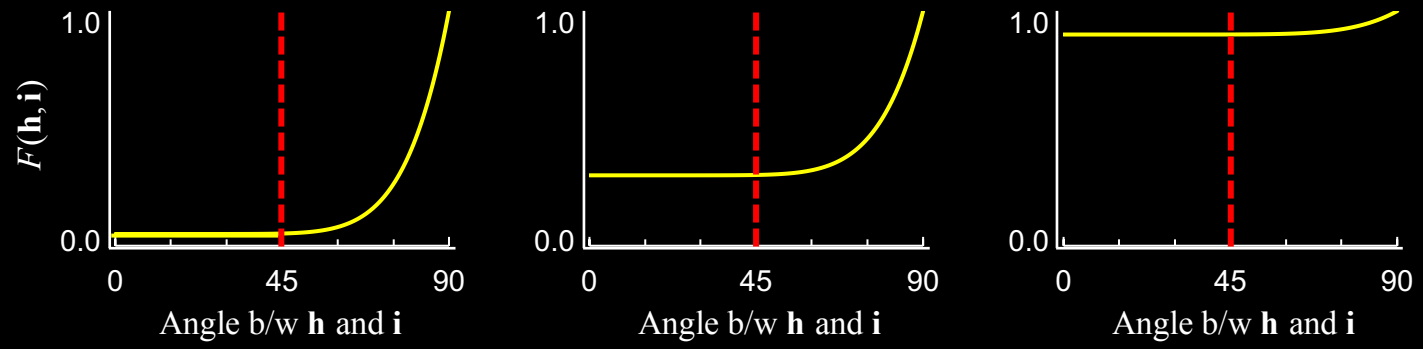
[Torrance and Sparrow, 1967]

$G(\mathbf{n},\mathbf{o},\mathbf{i})$: Shadowing/Masking

$G(\mathbf{n},\mathbf{o},\mathbf{i})$ from $D(\mathbf{h})$ [Ashikhmin, 2000]

$F(\mathbf{h},\mathbf{i})$: Fresnel

$F(\mathbf{h},\mathbf{i}) = \text{constant}$



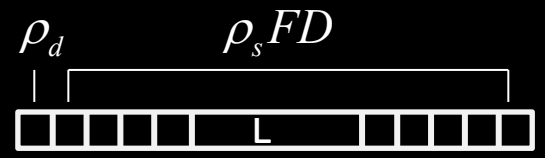
BRDF Representation

$$R(\mathbf{o},\mathbf{i}) = \frac{1}{\pi}\rho_d + \rho_s \frac{D(\mathbf{h})G(\mathbf{n},\mathbf{o},\mathbf{i})F(\mathbf{h},\mathbf{i})}{4(\mathbf{n}\cdot\mathbf{o})(\mathbf{n}\cdot\mathbf{i})}$$

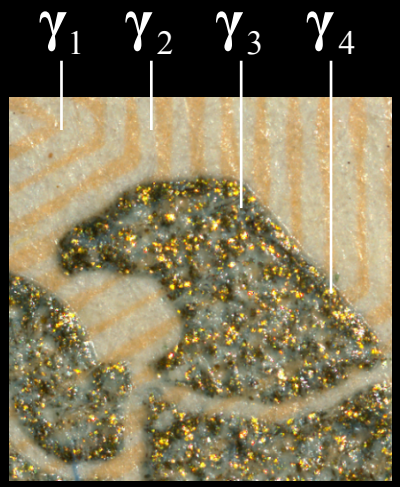
[Torrance and Sparrow, 1967]

- Reflectance property

$$\gamma = [\rho_d, \rho_s FD] \in \mathbb{R}^M$$



1D array of 90 coefficients



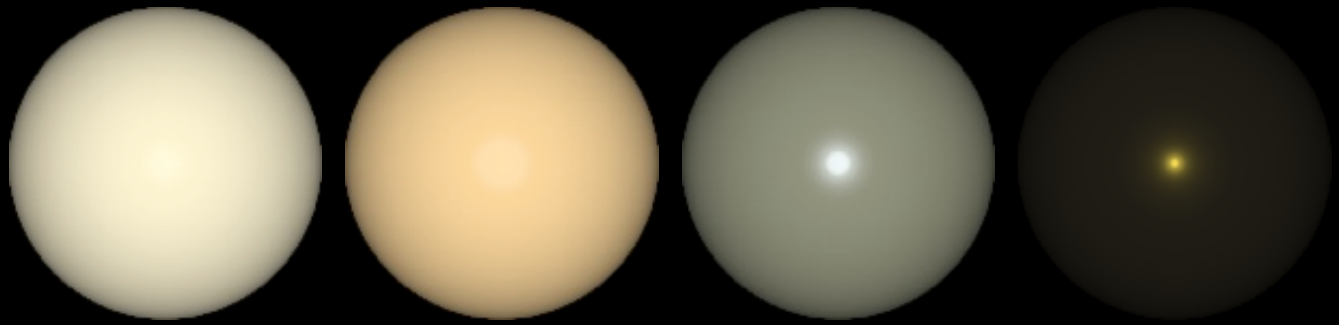
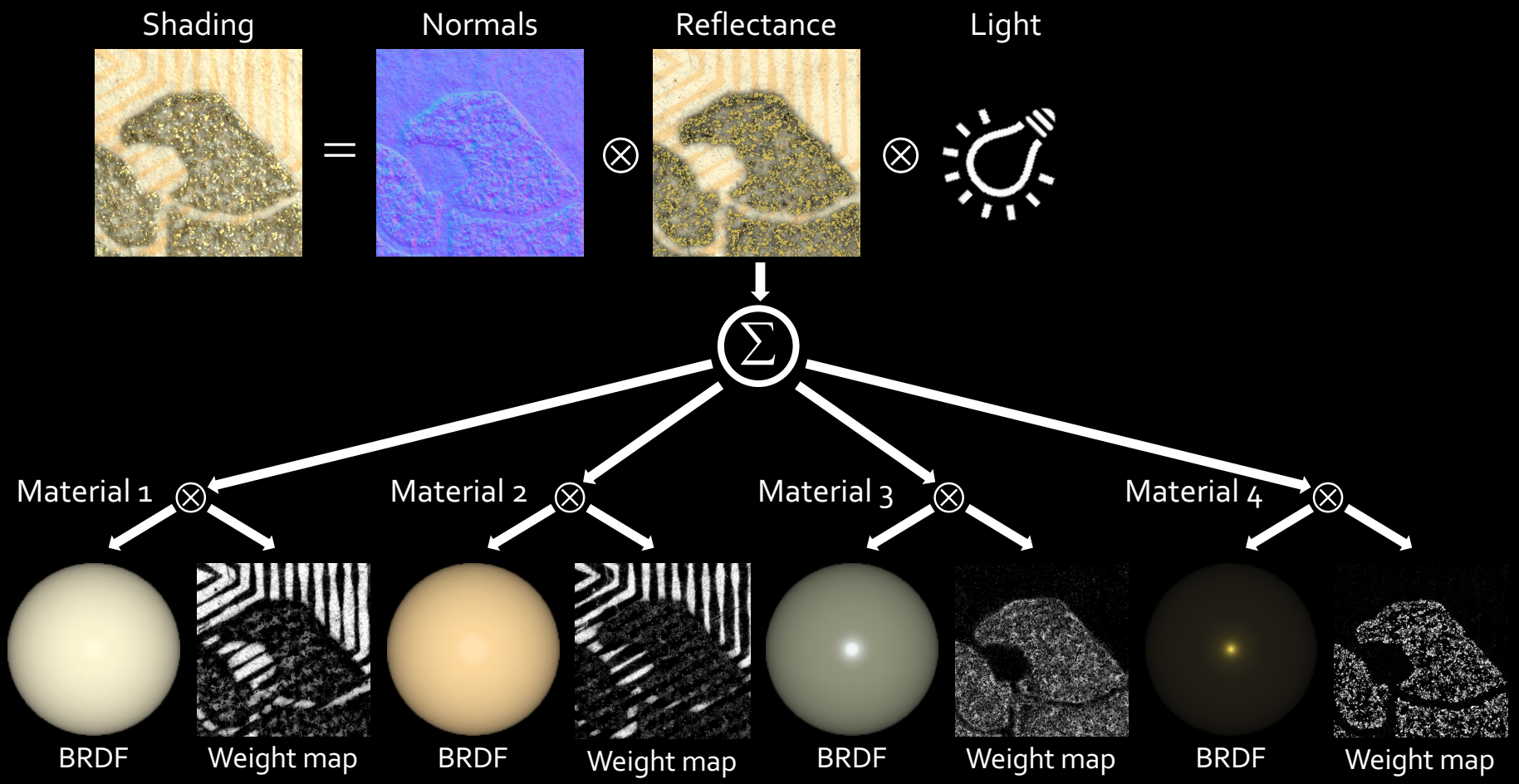
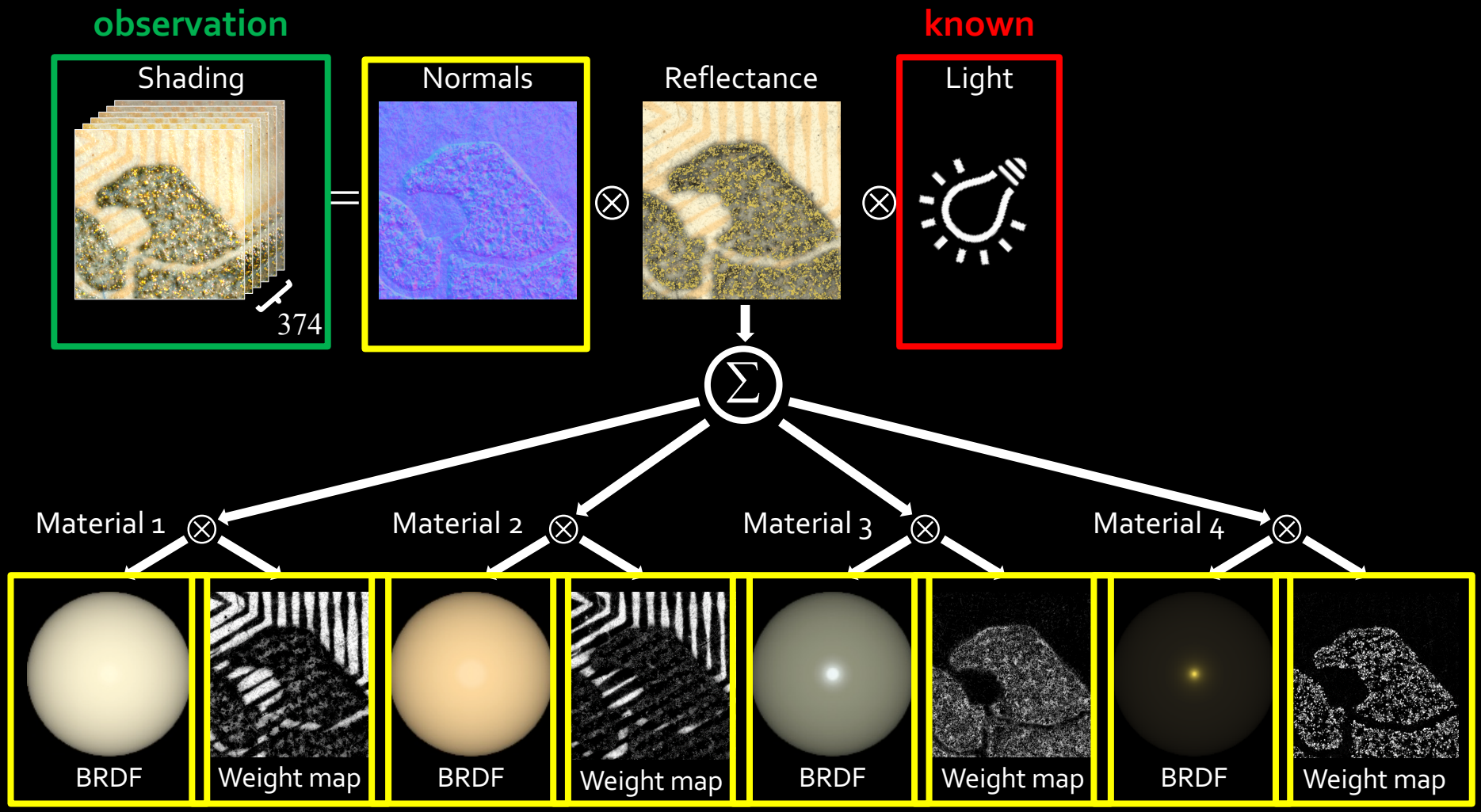


Image Formation



Alternating Optimization

- Solve for one unknown factor, while keeping the rest fixed.



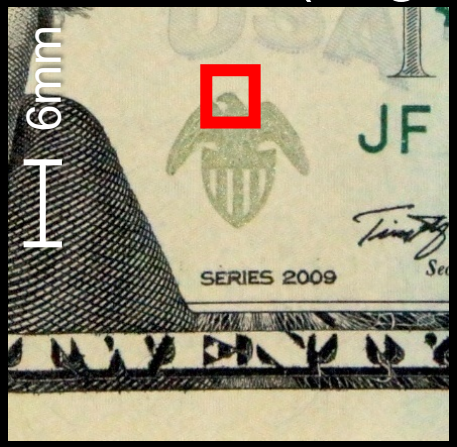
Microscale Material Appearance

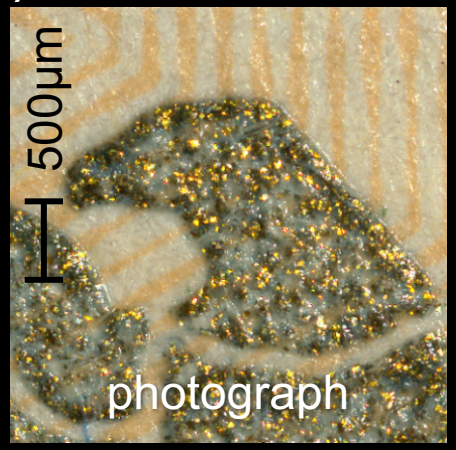
MICROSCALE DATASET

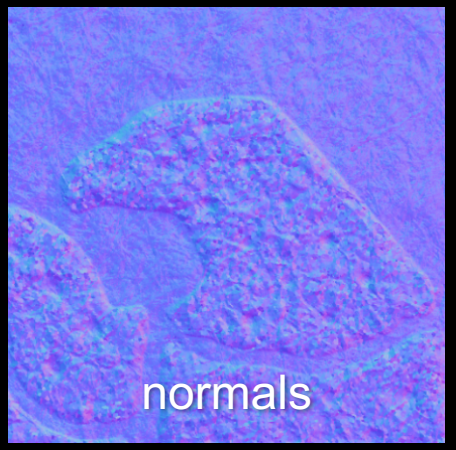
Microscale Dataset #1

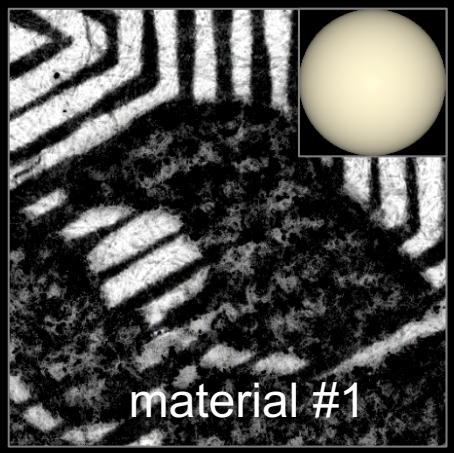
SIGGRAPH ASIA 2016 MACAO

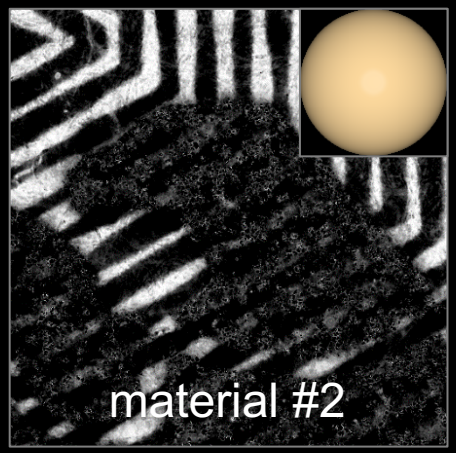
Dollar bill (eagle)

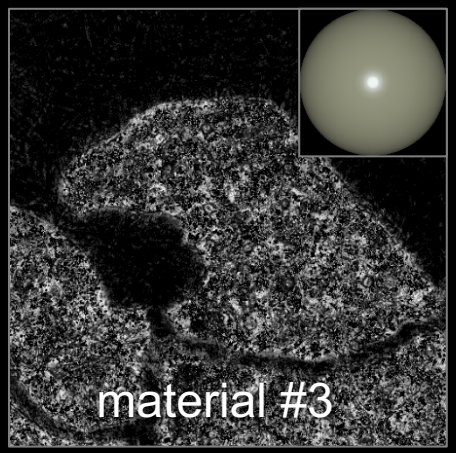


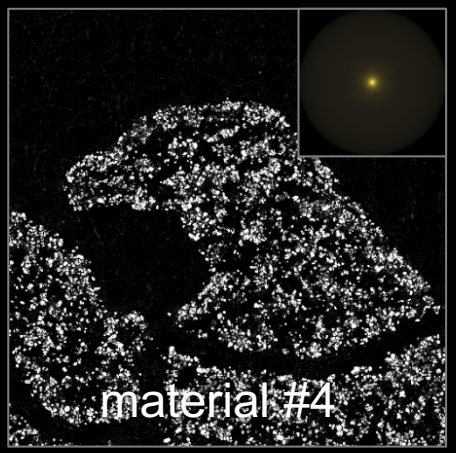






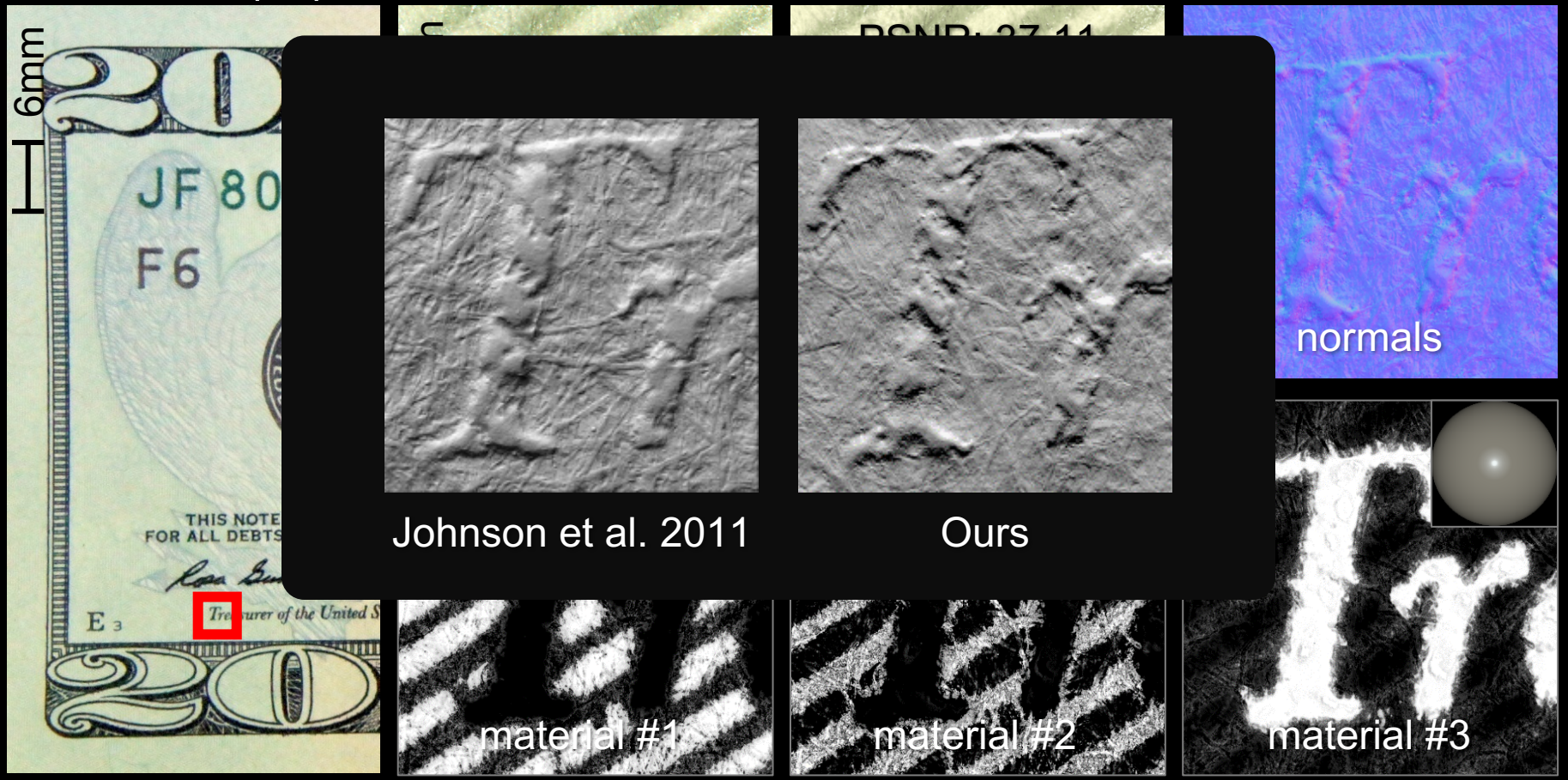






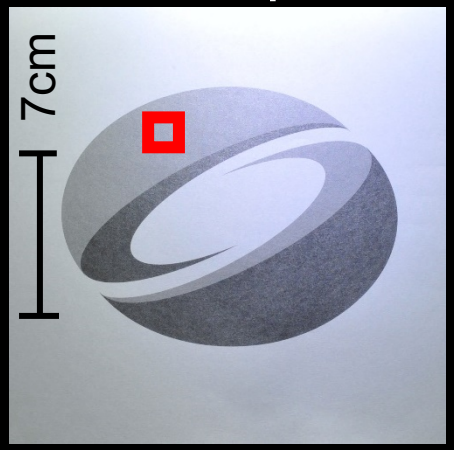
Microscale Dataset #2

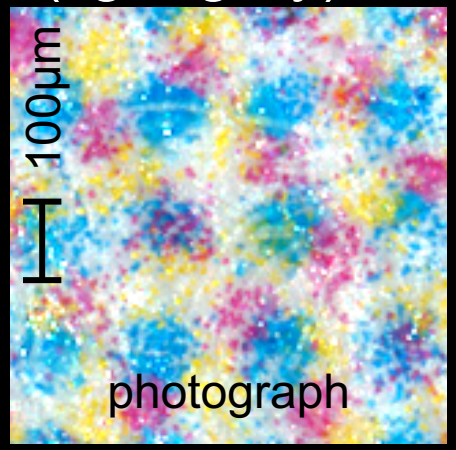
Dollar bill (Tr)

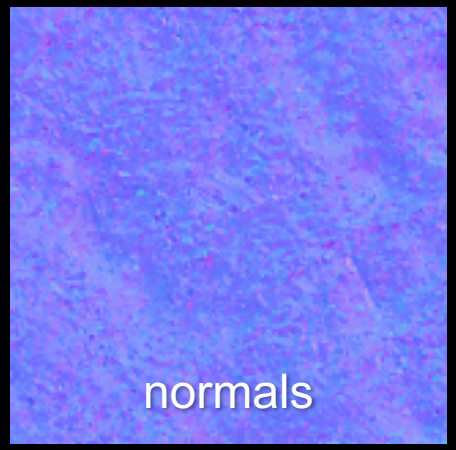


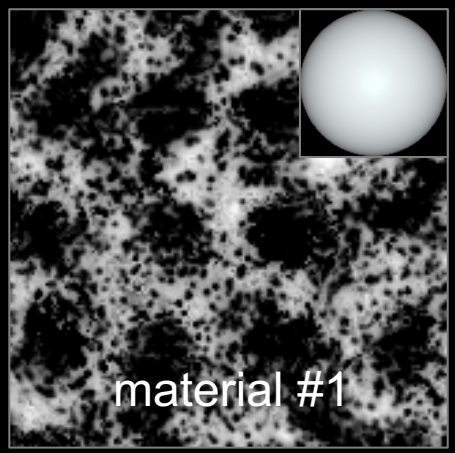
Microscale Dataset #3

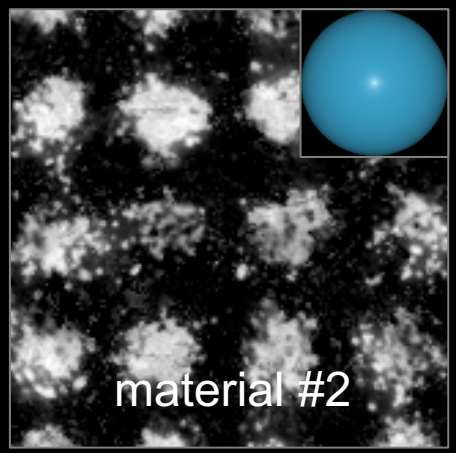
Halftone printout (light gray)

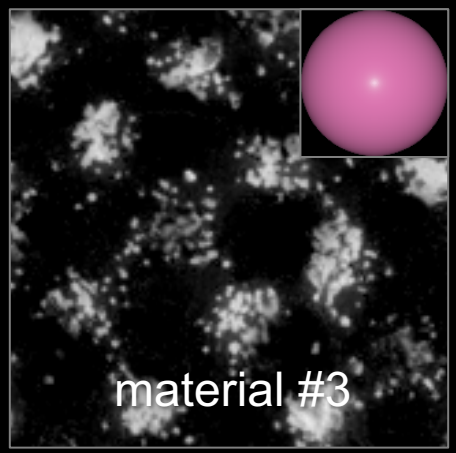


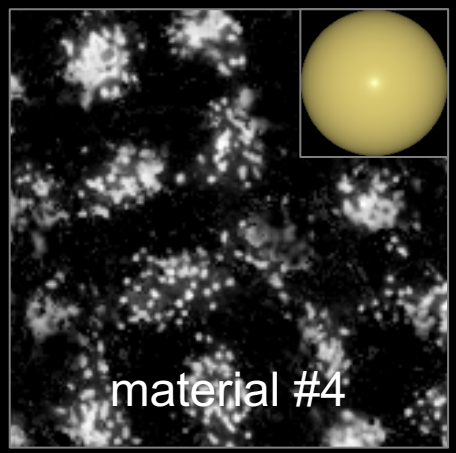










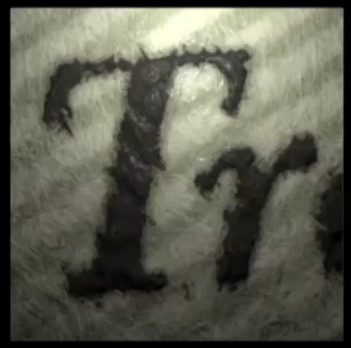


Microscale Dataset

- More datasets will be available on our website.

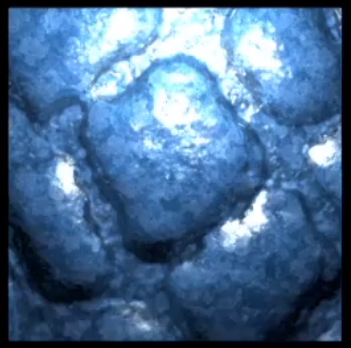
  http://vclab.kaist.ac.kr/siggraphasia2016p2/

Dollar bill (eagle)



Dollar bill (Tr)

Leaf



Blue notebook

Halftone printout

Copper coin

Leather

Textile

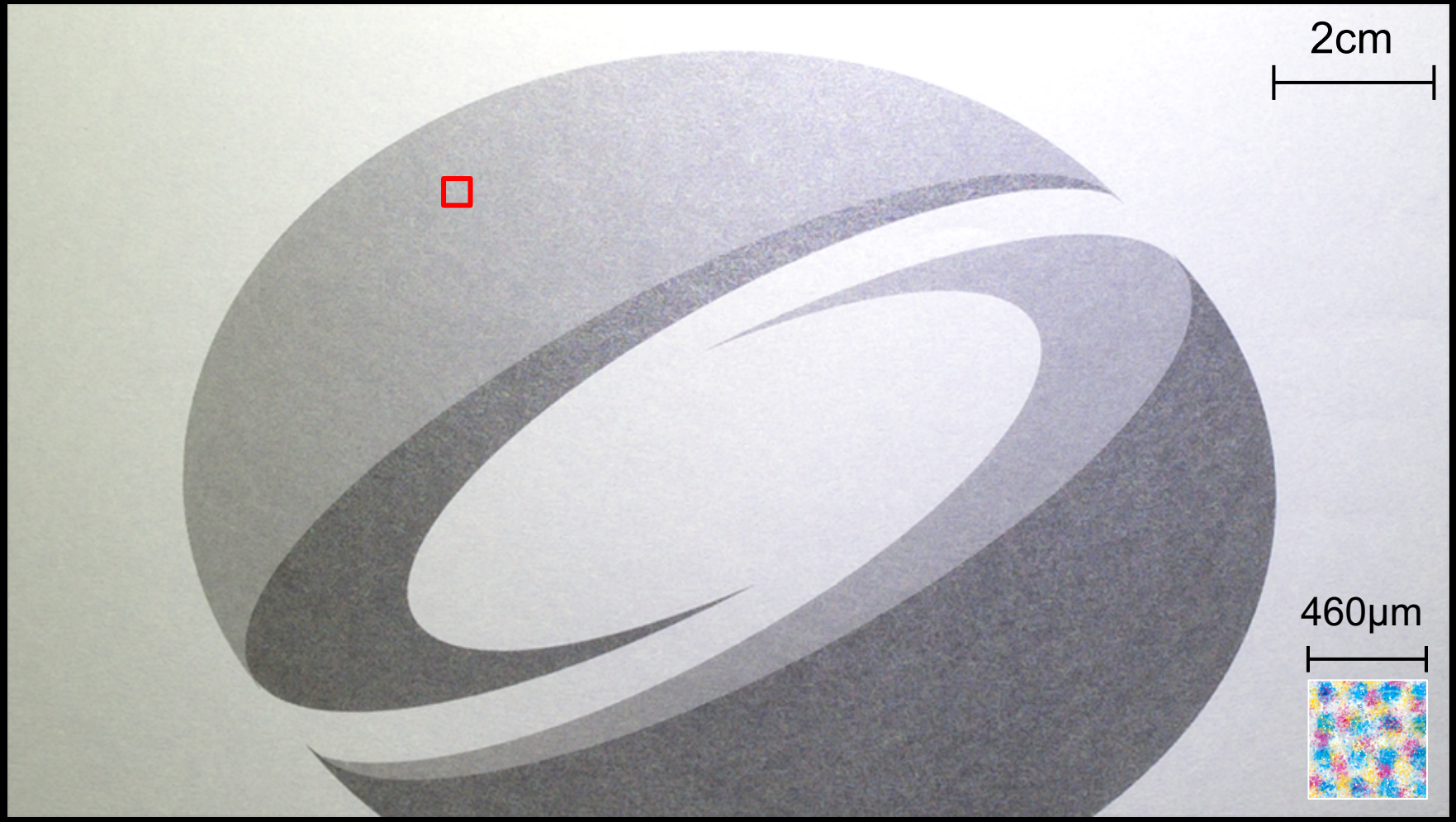
Microscale Dataset

Microscale Material Appearance

APPLICATIONS

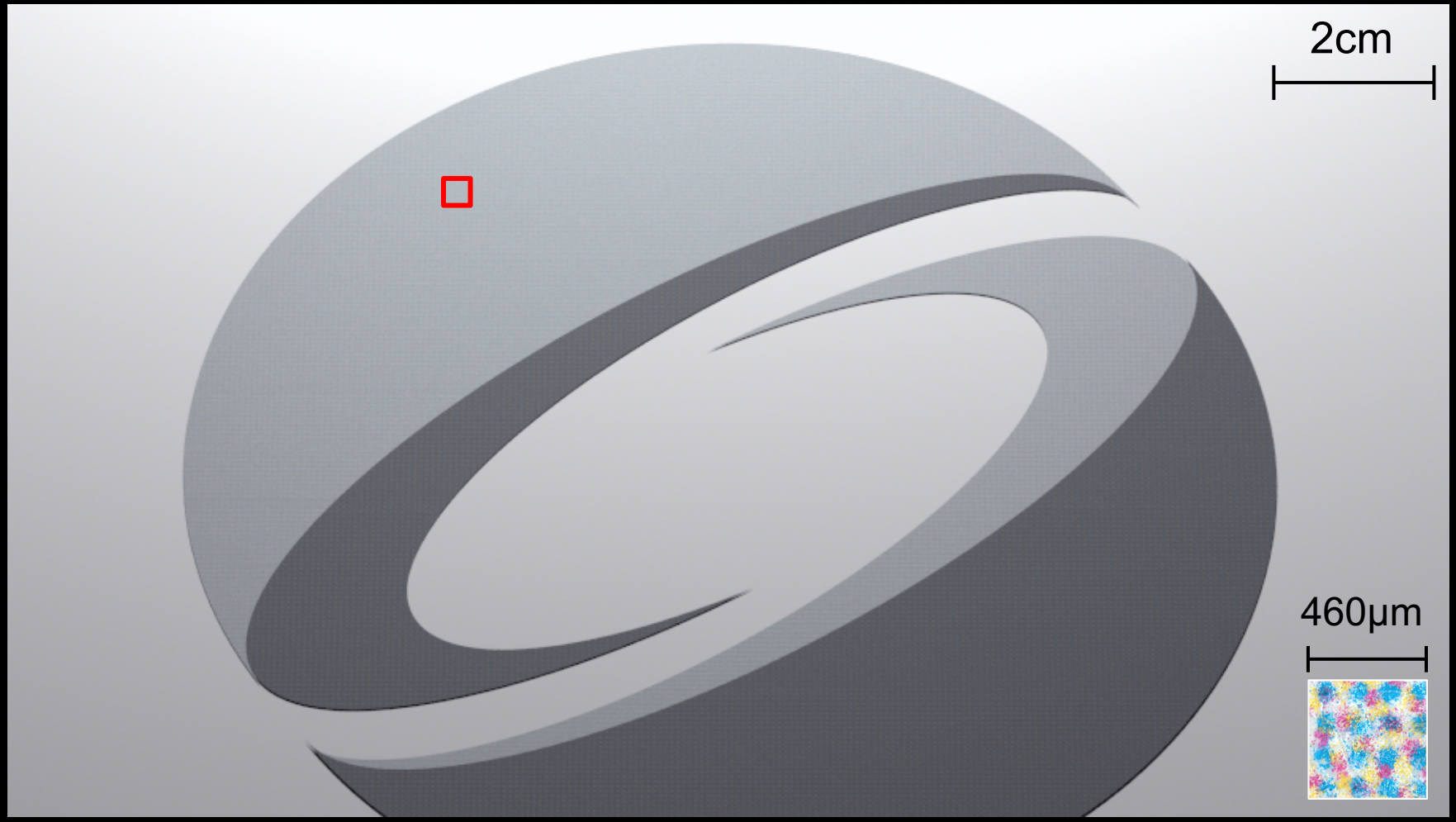
Biscale Appearance Editing

- Photograph



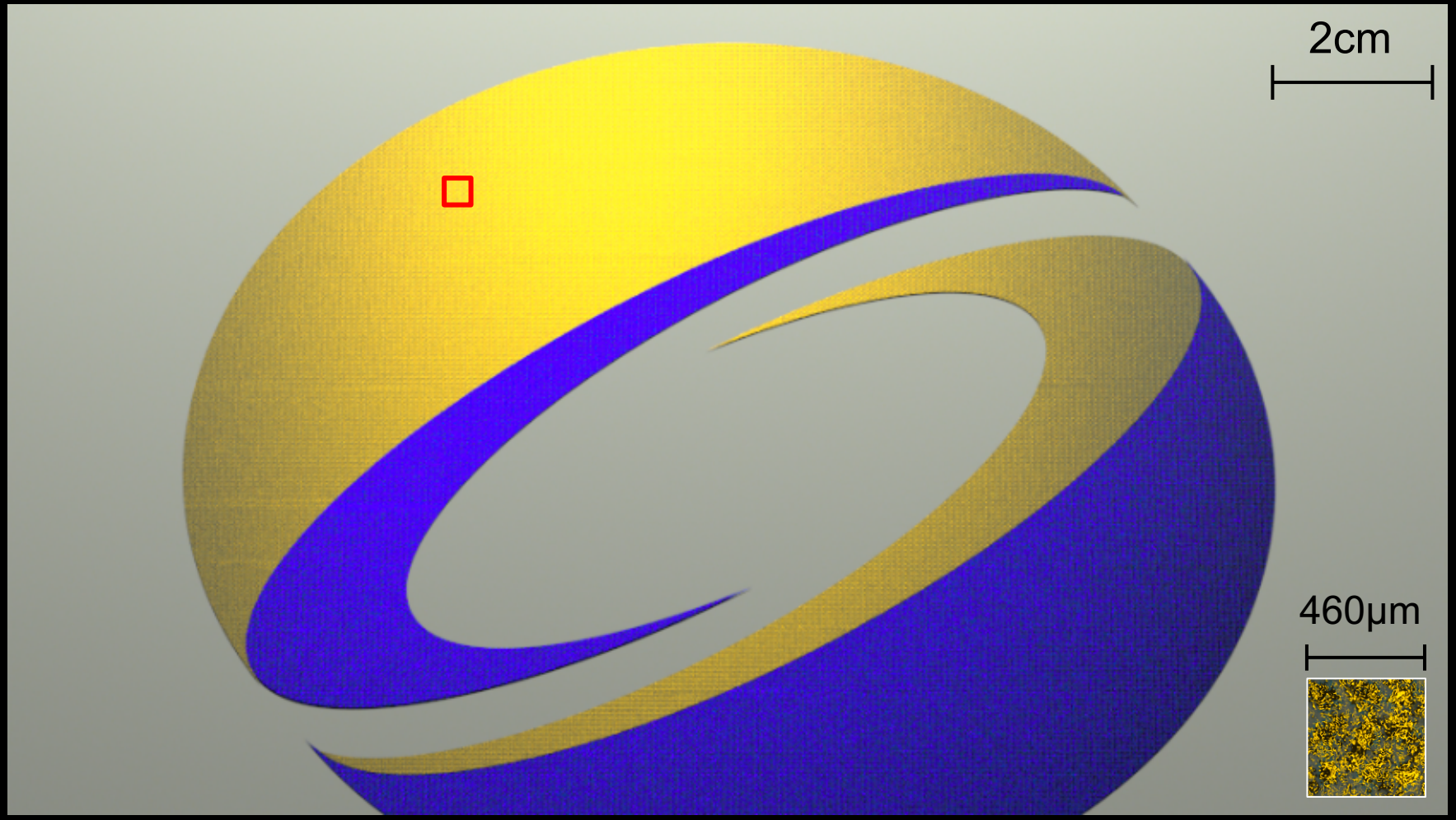
Biscale Appearance Editing

- Rendering



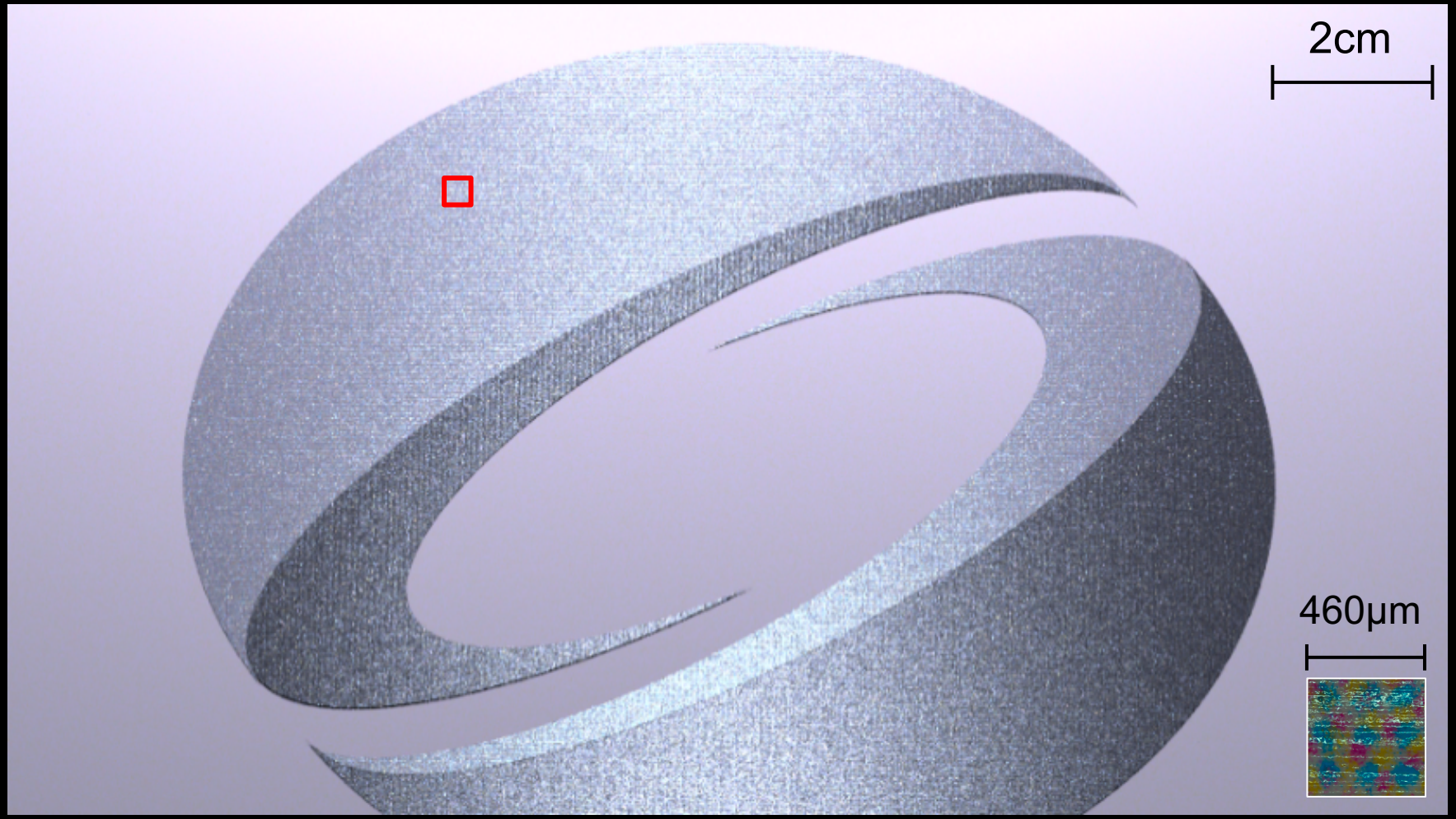
Biscale Appearance Editing

- Microscale BRDF editing



Biscale Appearance Editing

- Microscale BRDF and normal editing



Biscale Appearance Editing

- Rendering

Biscale Appearance Editing

- Microscale BRDF editing

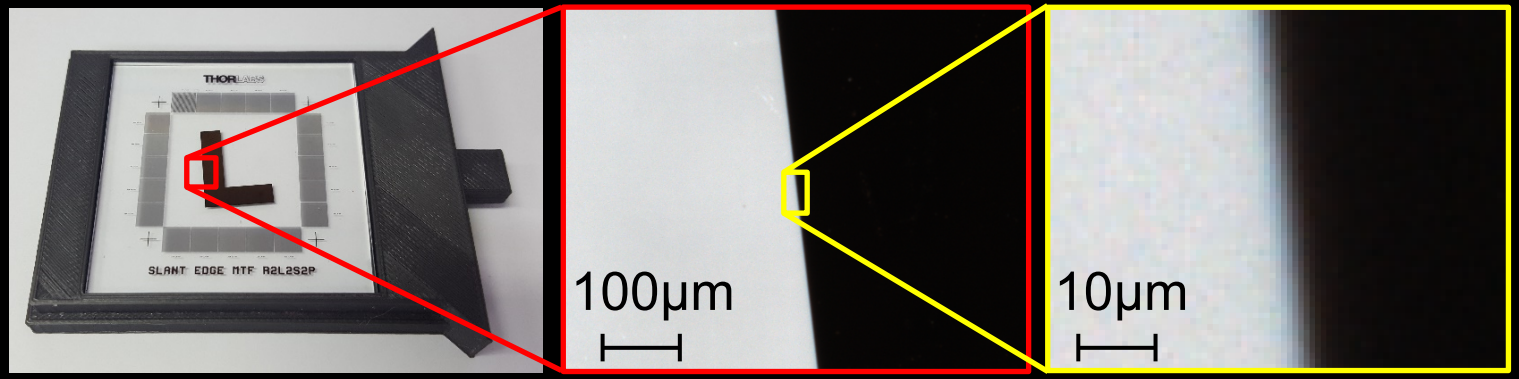
Biscale Appearance Editing

- Microscale BRDF and normal editing

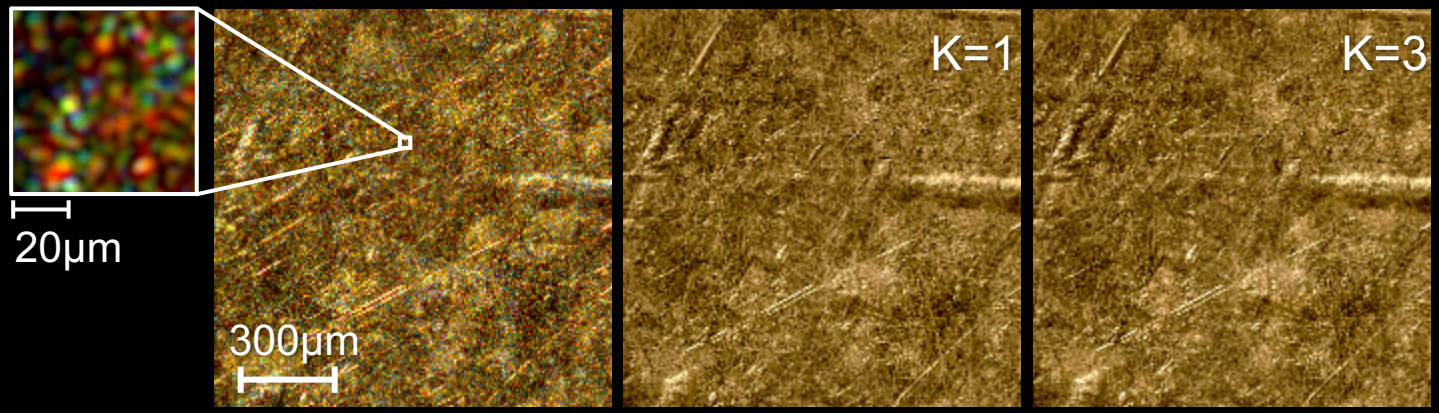
DISCUSSION

Limitation

- Diffraction limit
  - Imaging resolution: 620nm
  - Effective resolving power: ~1.98μm



- Huygens-Fresnel principle



Conclusion

- A hardware system and related algorithms for simultaneous acquisition of microscale reflectance and normals
- First time that this information is simultaneously captured at such small scale.

Thank You

- Datasets will be available on our website

  http://vclab.kaist.ac.kr/siggraphasia2016p2/