

Single-shot Hyperspectral-Depth Imaging with Learned Diffractive Optics

Seung-Hwan Baek^{1,2} Hayato Ikoma³ Daniel S. Jeon¹ Yuqi Li⁴
Wolfgang Heidrich⁴ Gordon Wetzstein³ Min H. Kim¹



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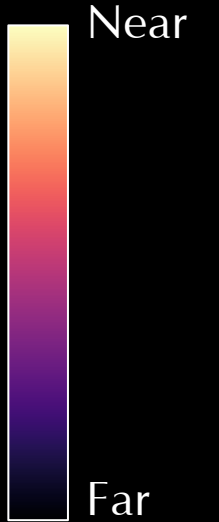
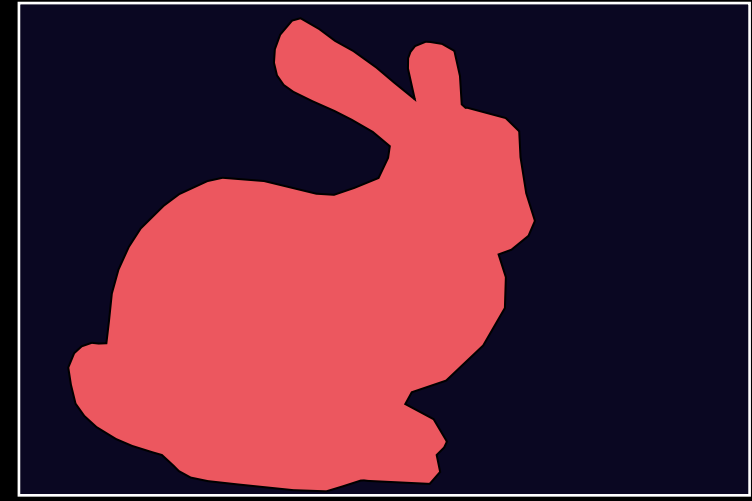


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جامعة الملك عبد الله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Depth Imaging

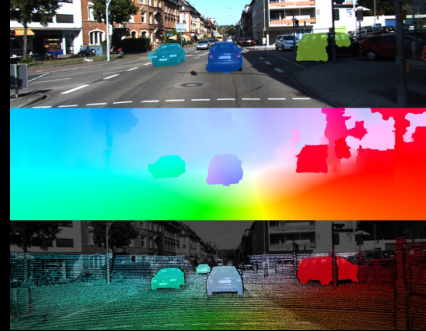


Depth

Depth



Autonomous vehicles



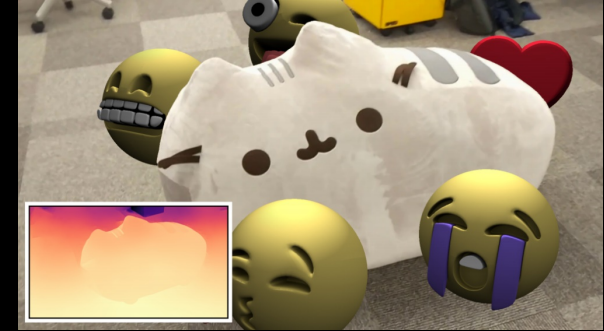
[Menze and Geiger, CVPR15]

Robotics



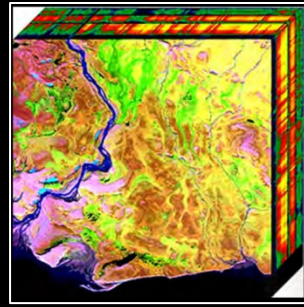
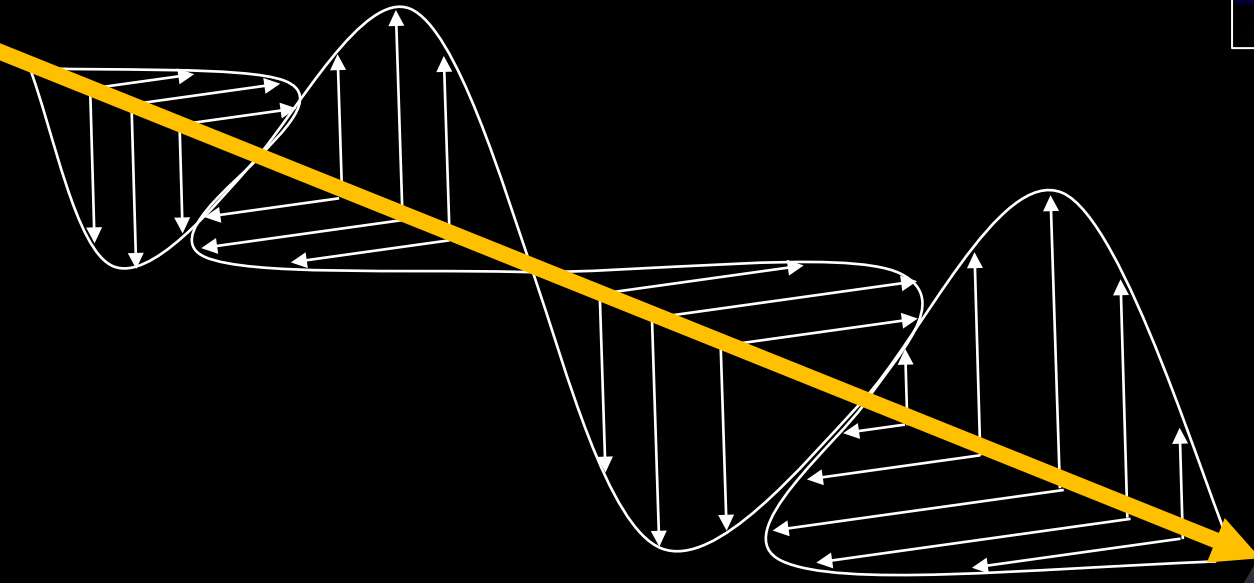
[Zeng et al., RSS19]

VR/AR



[Holynski and Kopf, TOG18]

Hyperspectral Imaging



Plant resources development



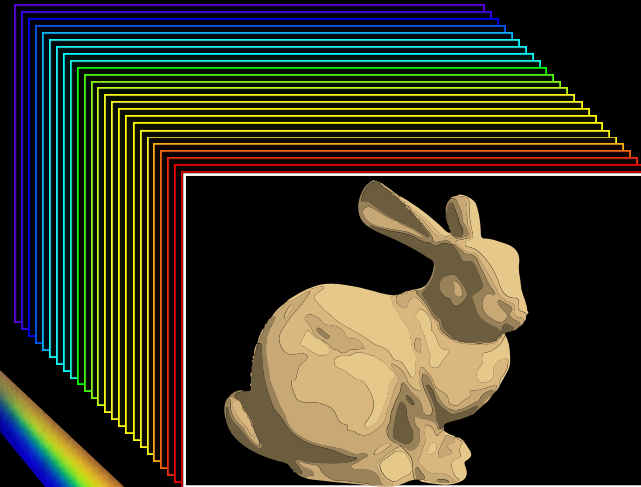
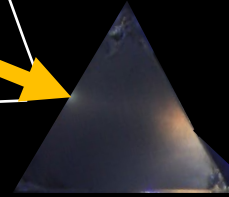
Pharmaceutical ingredient analysis



Food quality control measurement



Beauty / Cosmetics

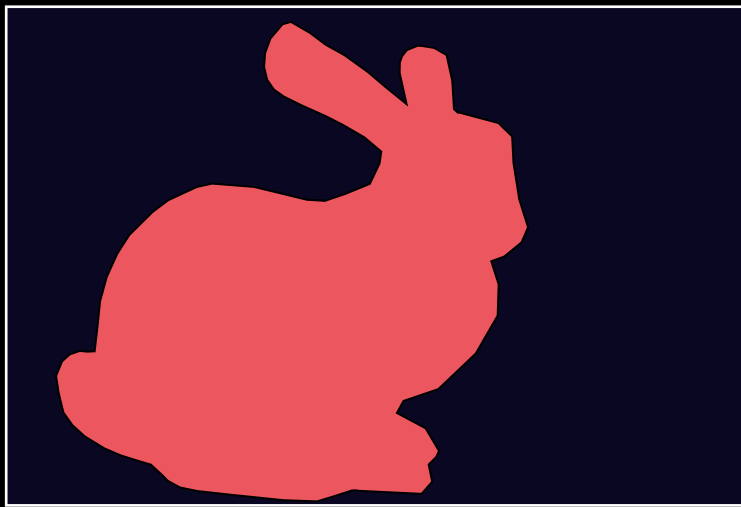


Hyperspectral image

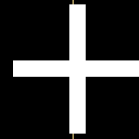
Depth Imaging



Geometric understanding



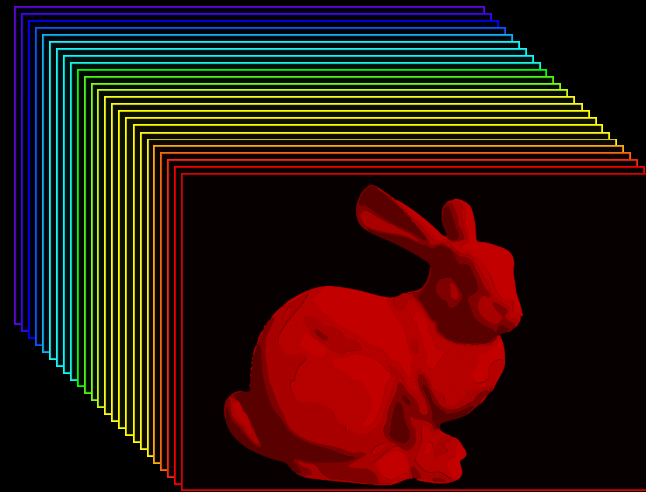
Depth



Hyperspectral Imaging



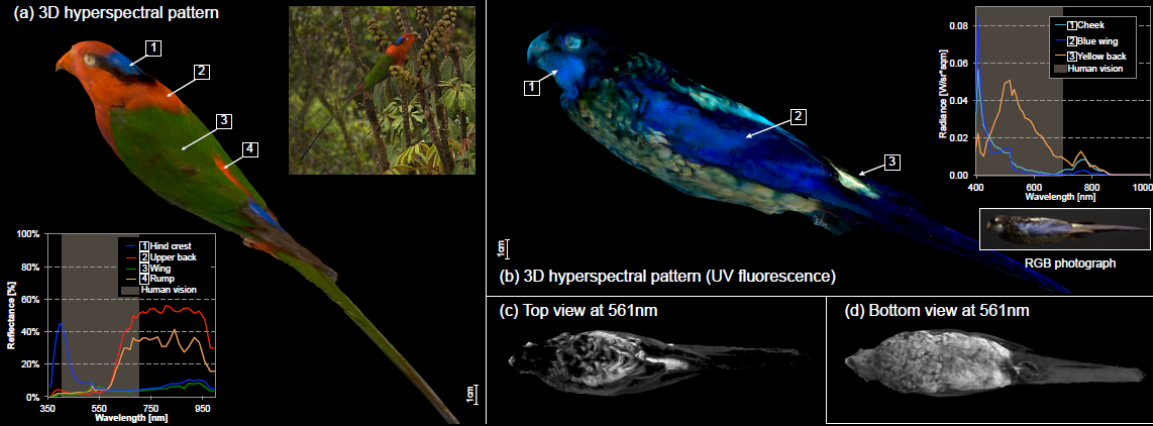
Material understanding



Hyperspectral
image

Hyperspectral-Depth Imaging

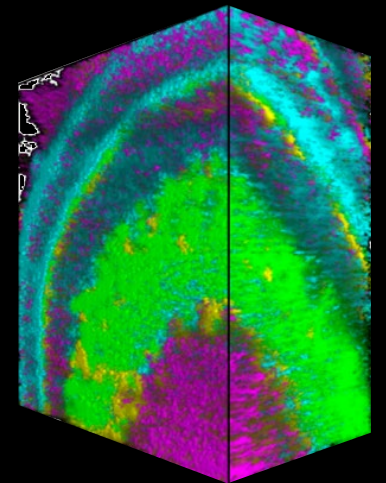
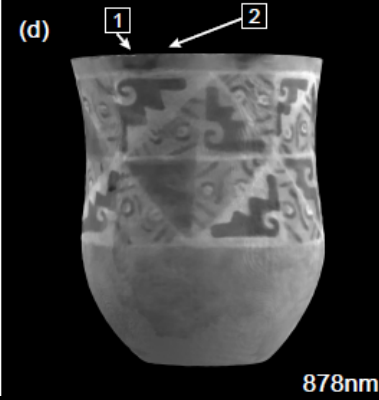
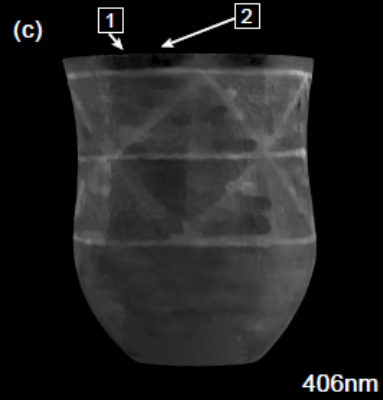
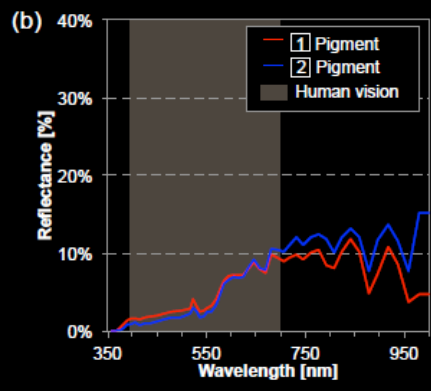
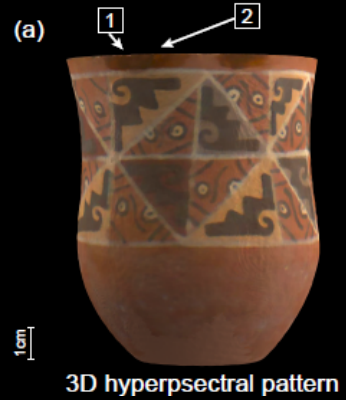
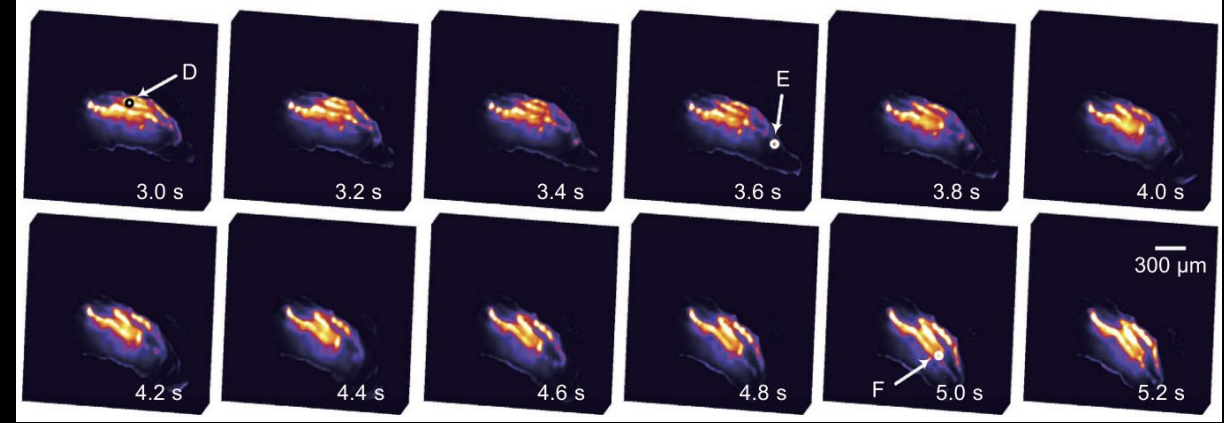
(a) 3D hyperspectral pattern



(b) 3D hyperspectral pattern (UV fluorescence)

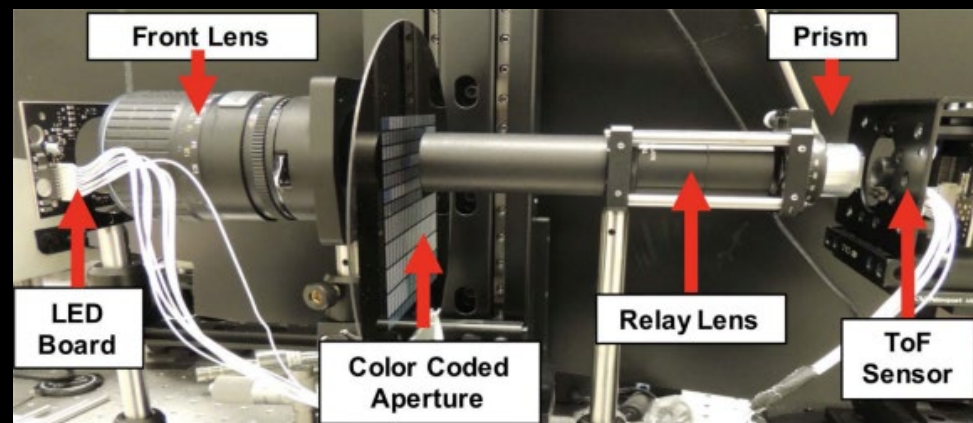
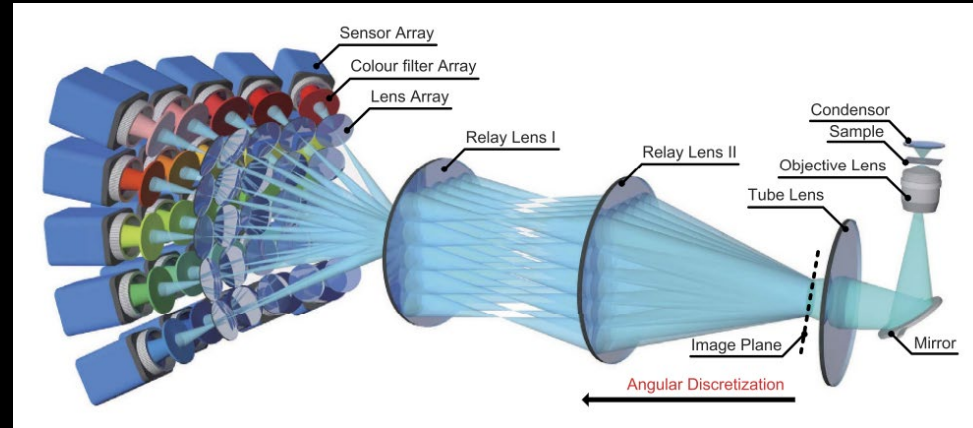
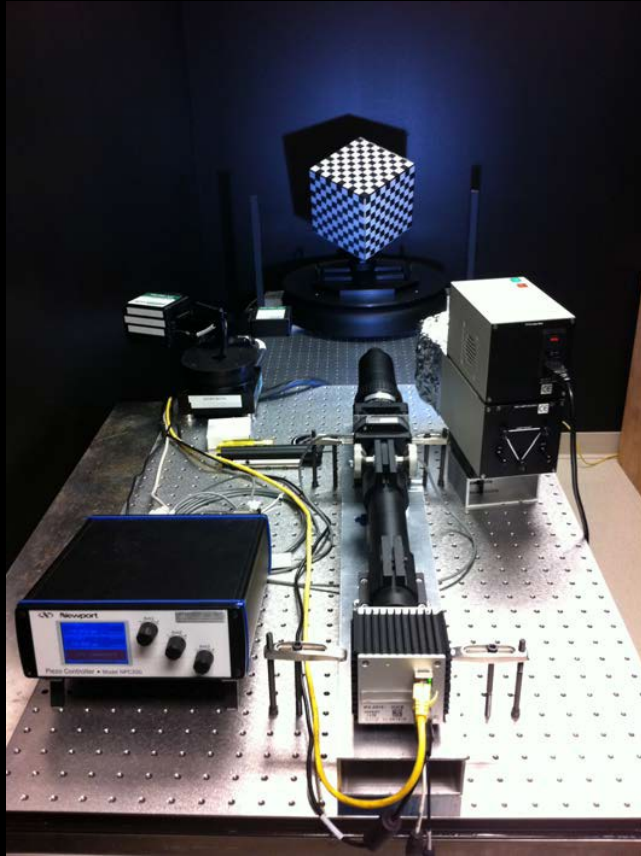
(c) Top view at 561nm

(d) Bottom view at 561nm



Hyperspectral-Depth Imaging

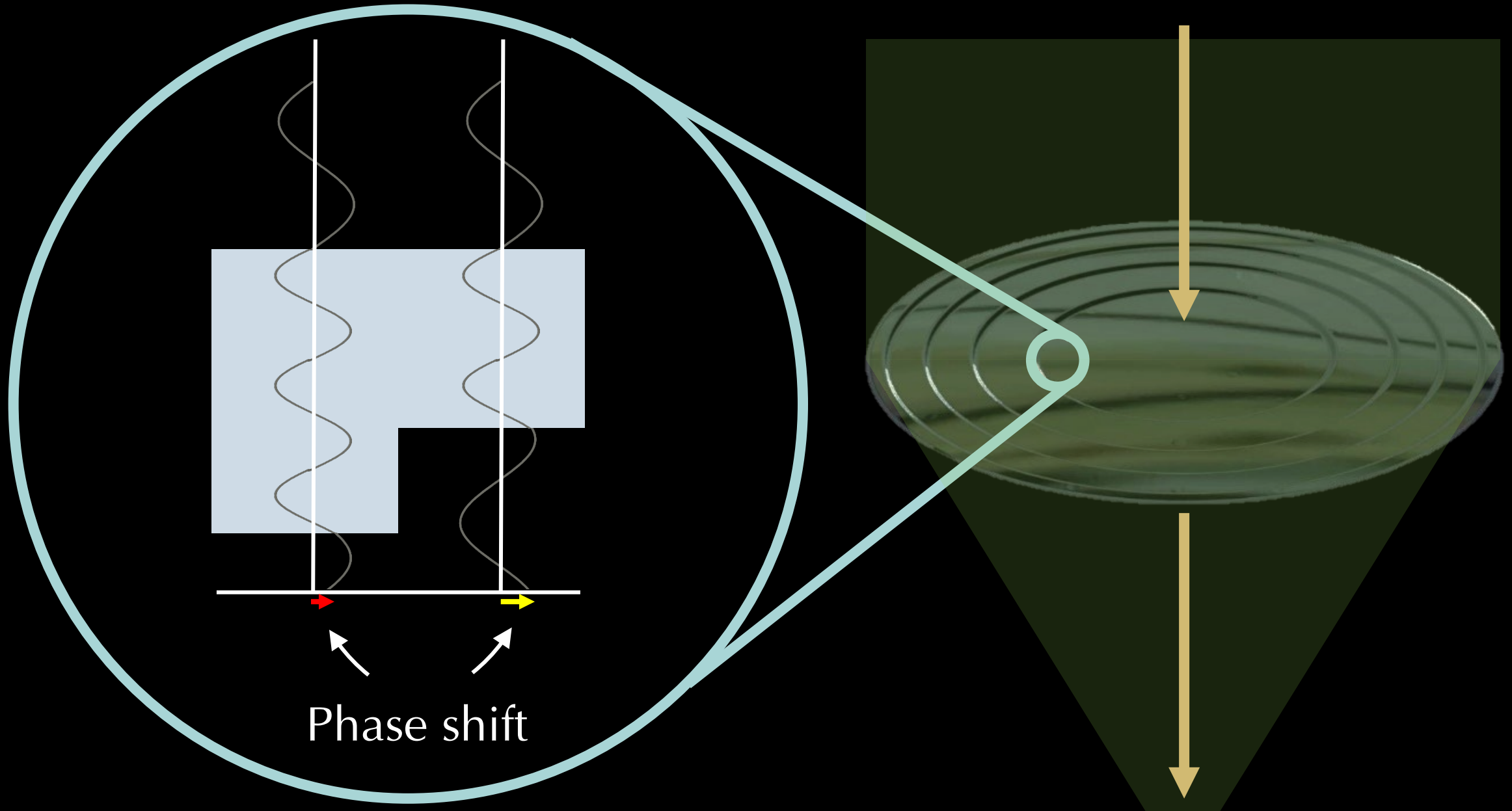
- Combinatorial system
 - Hyperspectral imager + depth imager



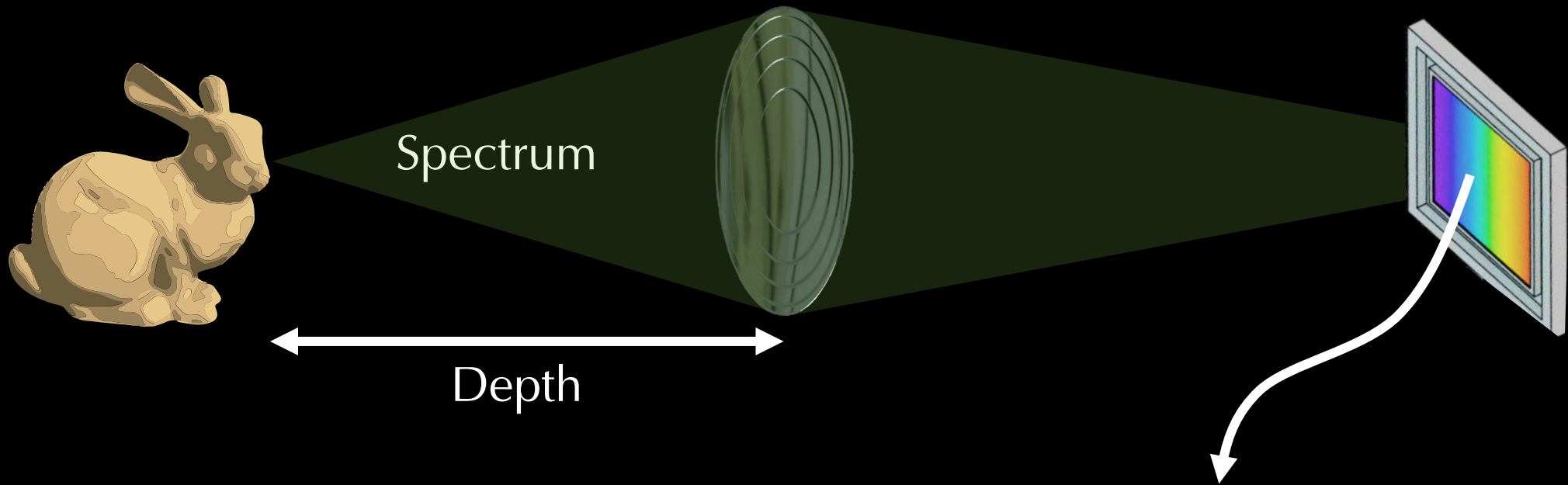
High system complexity

- Form factor
- Cost
- ...

Diffractive Optical Element (DOE)

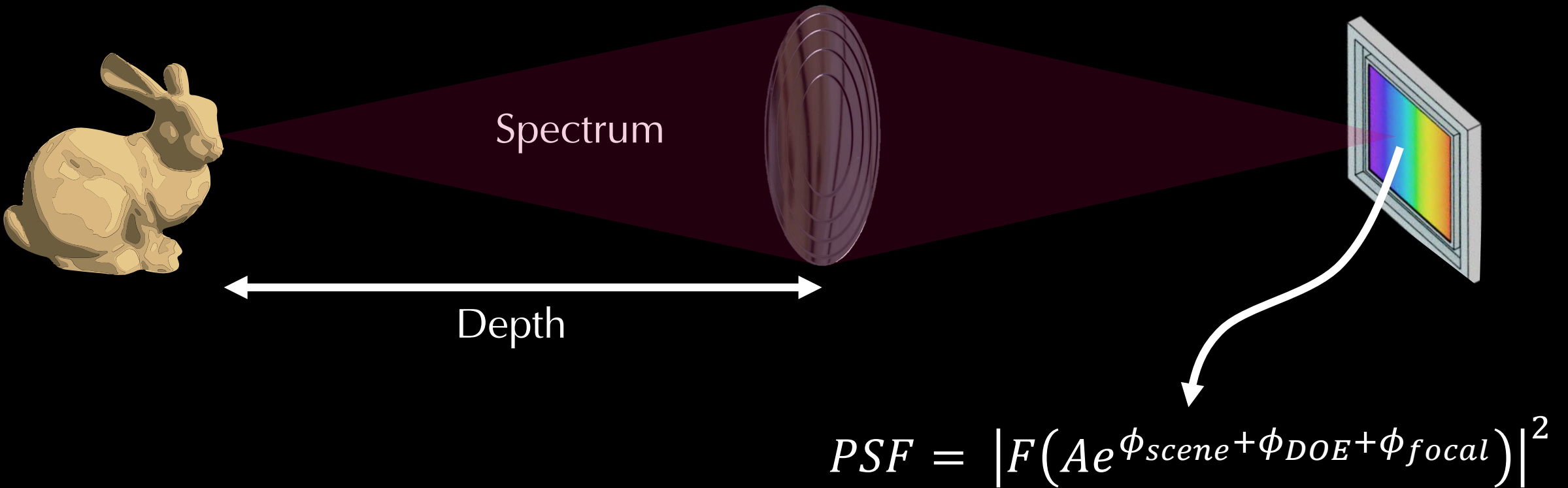


Point Spread Function from a DOE

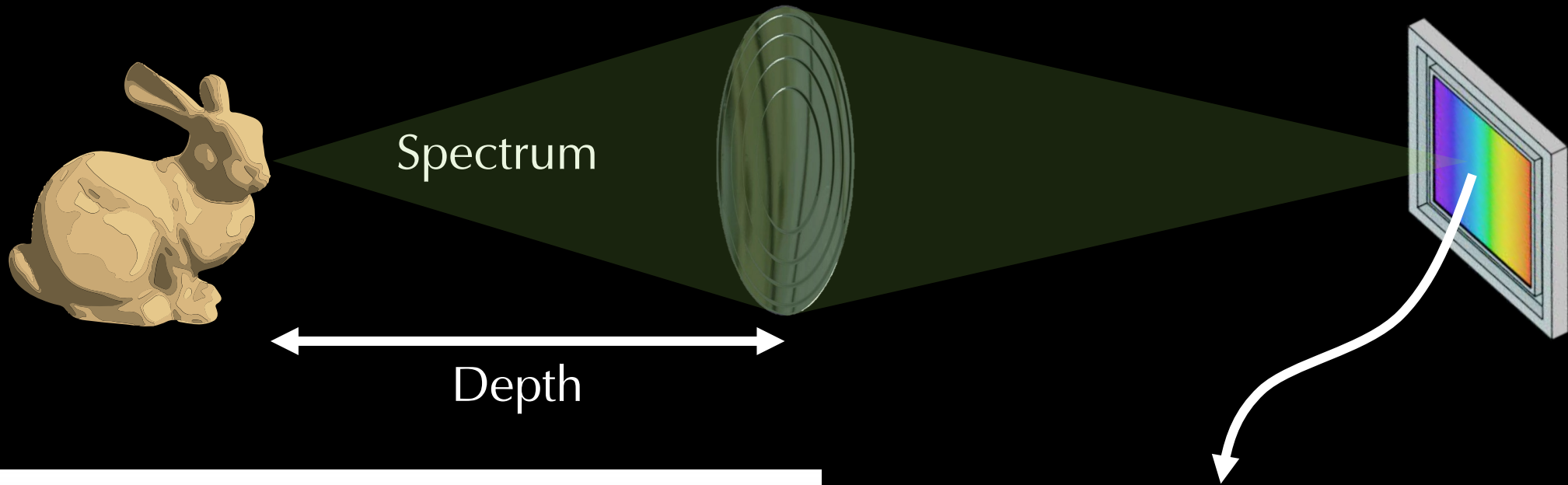


$$PSF = |F(Ae^{\phi_{scene} + \phi_{DOE} + \phi_{focal}})|^2$$

Point Spread Function from a DOE



Point Spread Function from a DOE

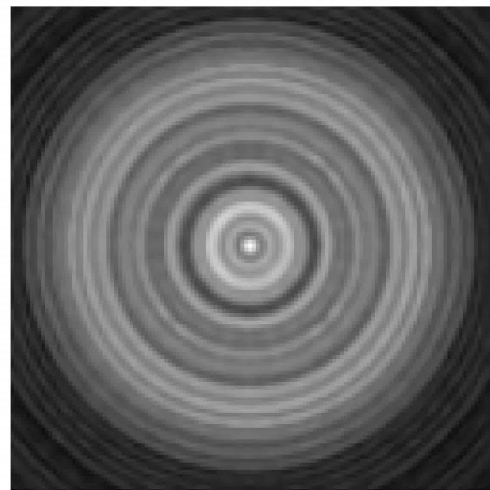
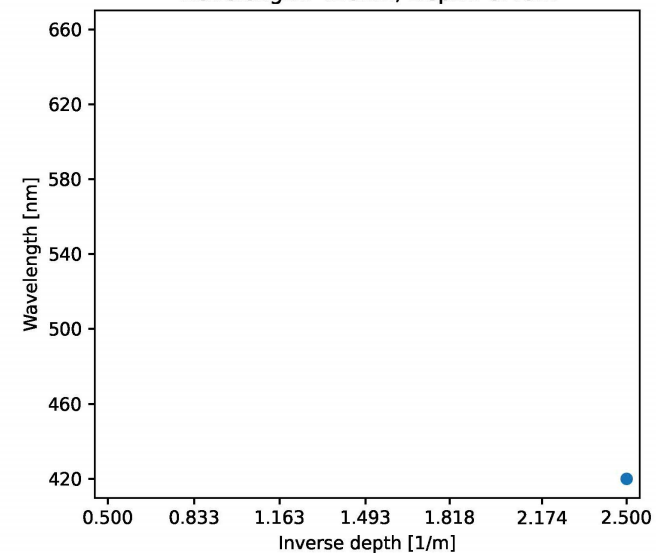


$$PSF = |F(Ae^{\phi_{scene} + \phi_{DOE} + \phi_{focal}})|^2$$

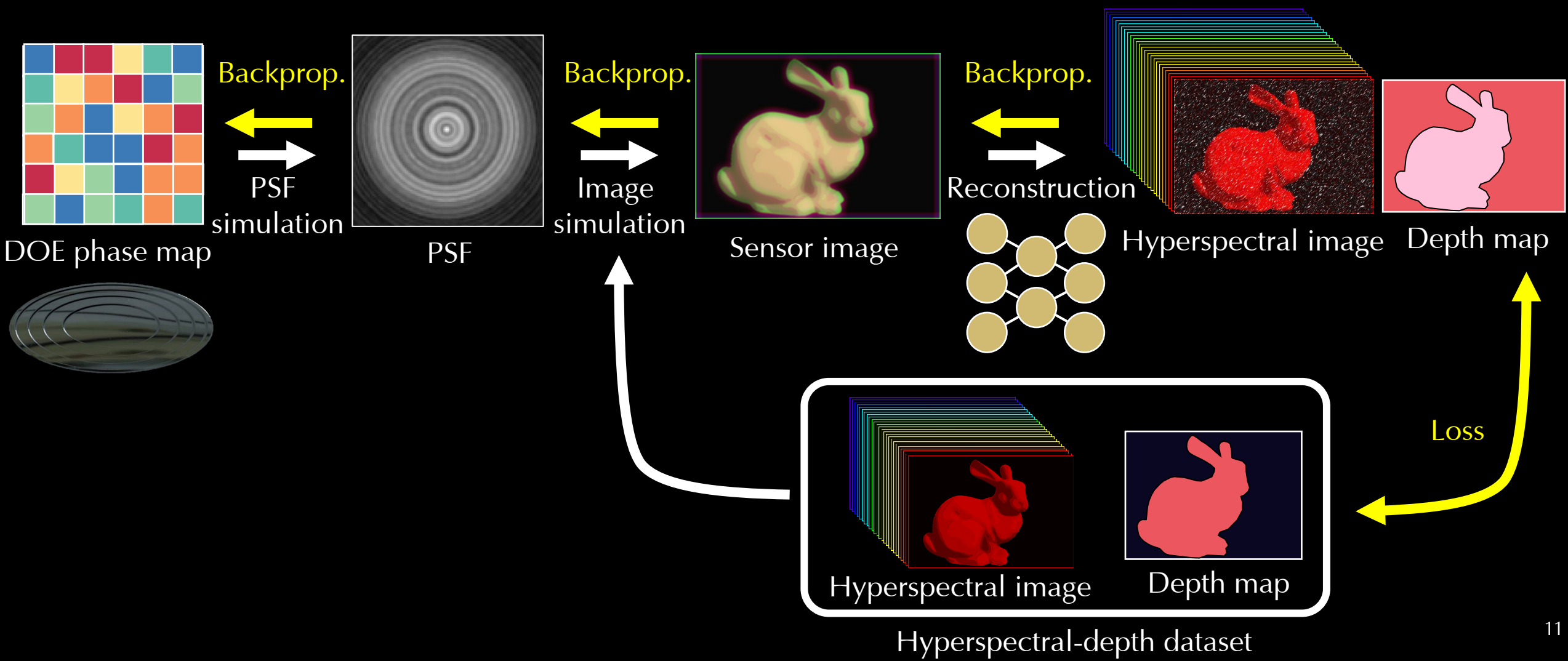
What is a good DOE for reconstructing depth and spectrum?

Wavelength: 420nm, Depth: 0.40m

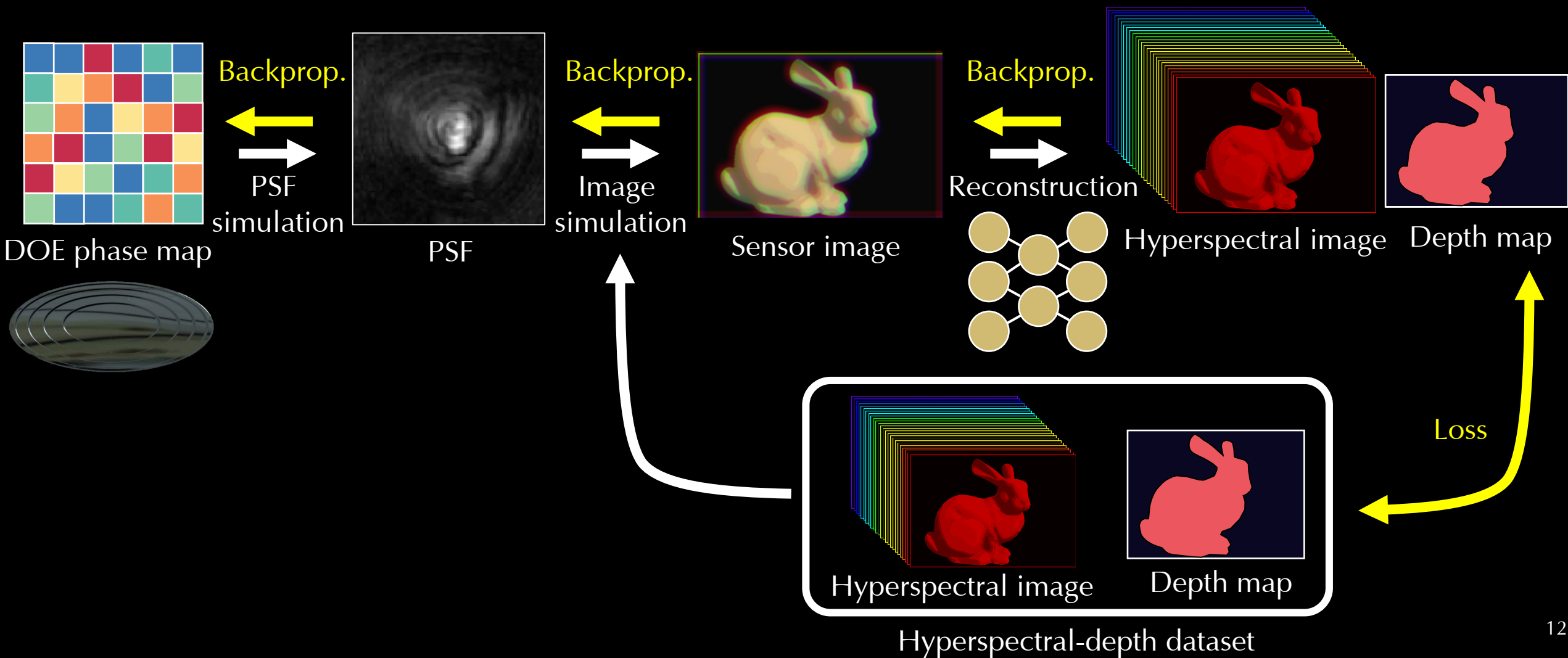
PSF



Learning the DOE for Hyperspectral-depth Reconstruction



Learning the DOE for Hyperspectral-depth Reconstruction



Hyperspectral-depth Dataset



Dataset-acquisition setup

*Dataset is available in <http://vclab.kaist.ac.kr/iccv2021/>

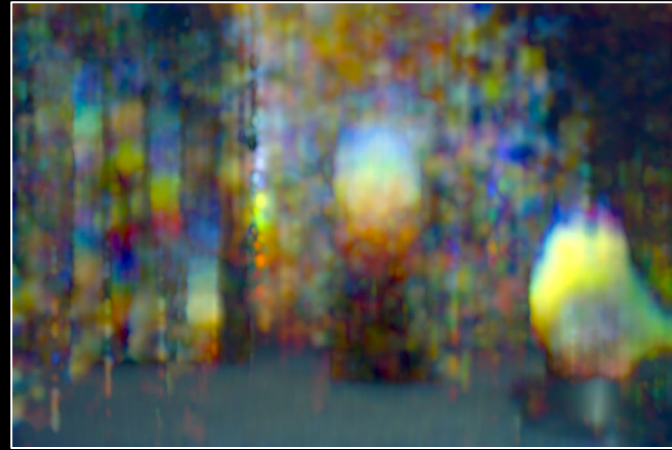
Synthetic Results

Hyperspectral image

Ground truth



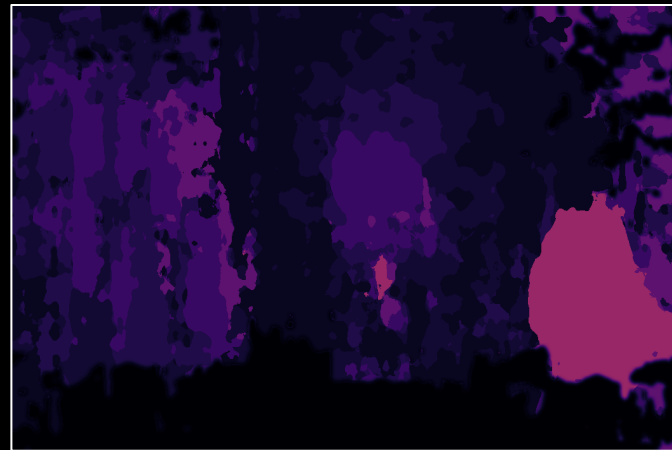
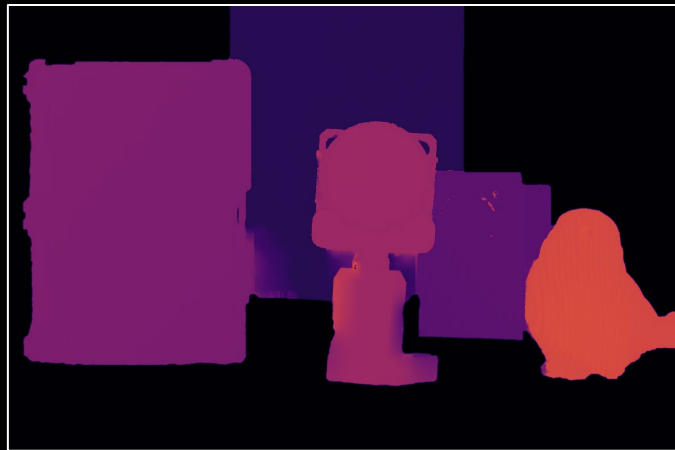
Feng et al.



Ours

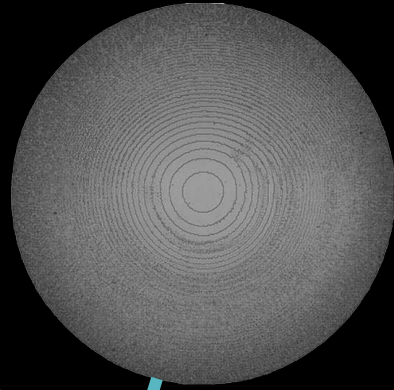


Depth map

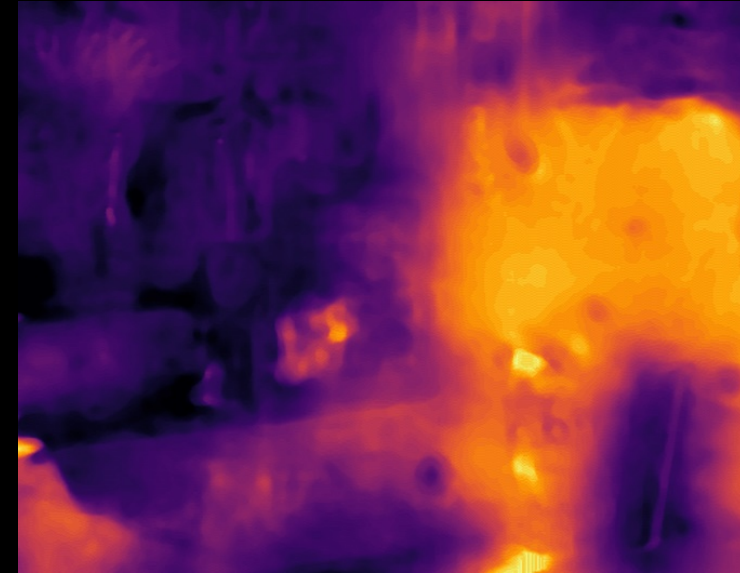


Real Results

Fabricated DOE



Synthetic aperture image



Depth map

Conclusion

- Single-shot hyperspectral-depth imaging using a DOE
- First hyperspectral-depth image dataset

International Conference on Computer Vision (ICCV) 2021

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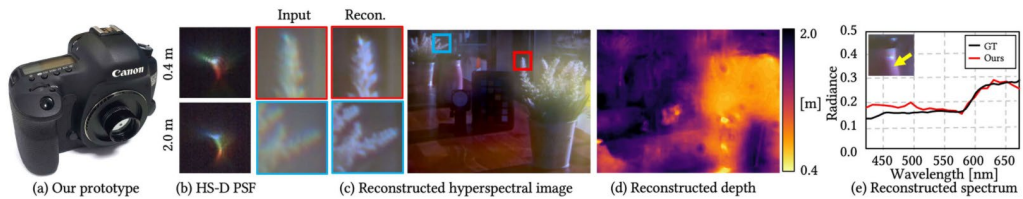
Min H. Kim[†]

[†] KAIST

[§] Stanford University

[‡] KAUST

^{*} Princeton University



(a) Our compact single-shot HS-D imaging method uses an optimized DOE that creates (b) a PSF that varies with spectrum and depth. (c)–(e) It encodes spectral-depth information in the captured image, from which we reconstruct a hyperspectral image and a depth map simultaneously.

Project website

- <http://vclab.kaist.ac.kr/iccv2021/>