Single-shot Hyperspectral-Depth Imaging with Learned Diffractive Optics

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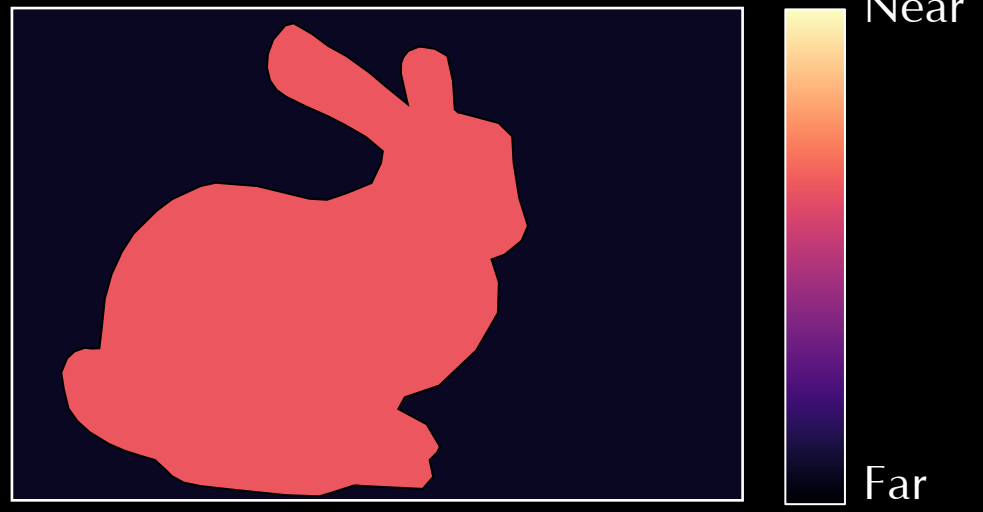
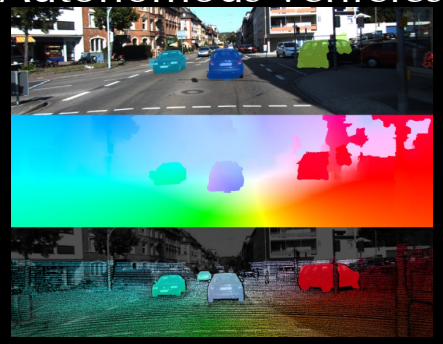
Depth Imaging



Depth

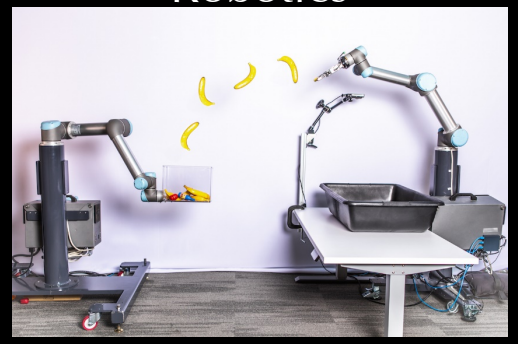
Depth

Autonomous vehicles



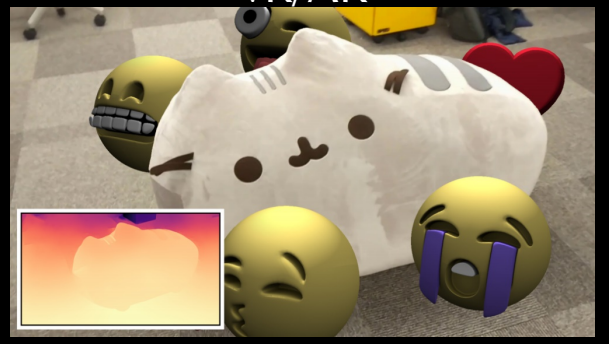
[Menze and Geiger, CVPR15]

Robotics



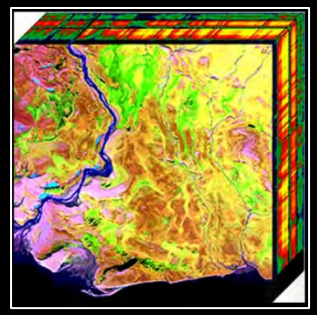
[Zeng et al., RSS19]

VR/AR



[Holynski and Kopf, TOG18]

Hyperspectral Imaging

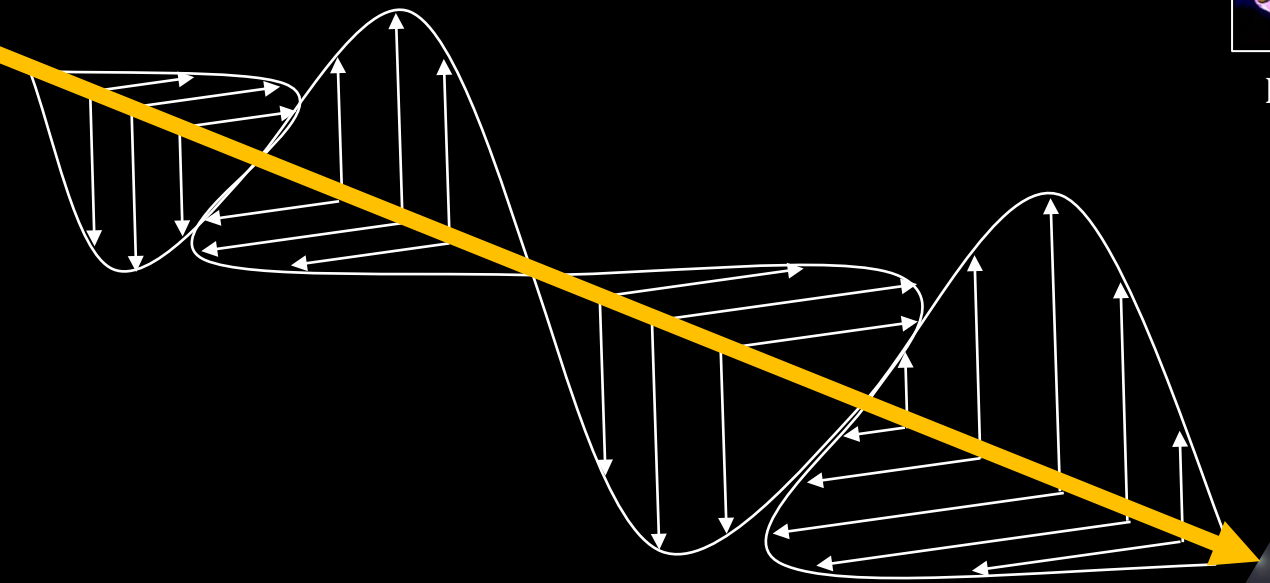


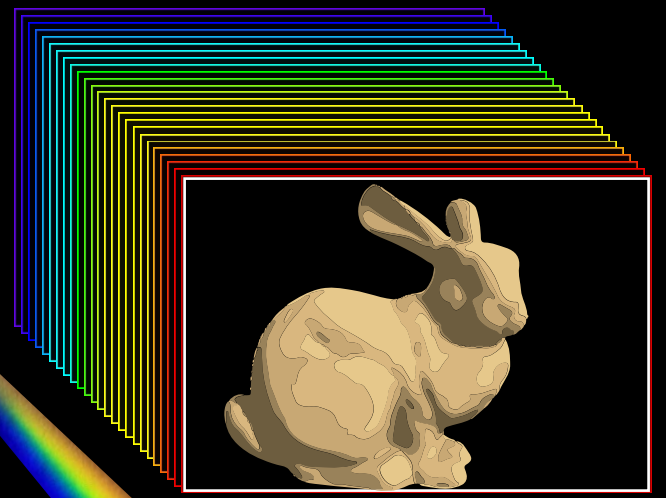
Plant resources development

Pharmaceutical ingredient analysis

Food quality control measurement

Beauty / Cosmetics





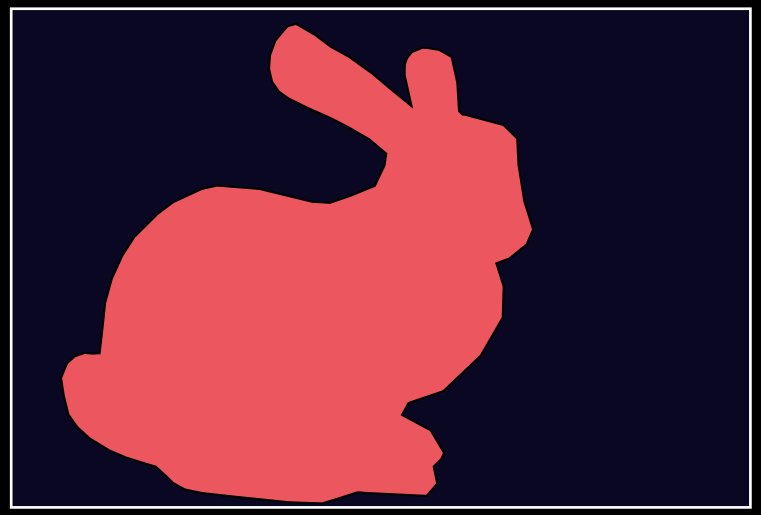
Hyperspectral image

RGB

Depth Imaging

↓

Geometric understanding



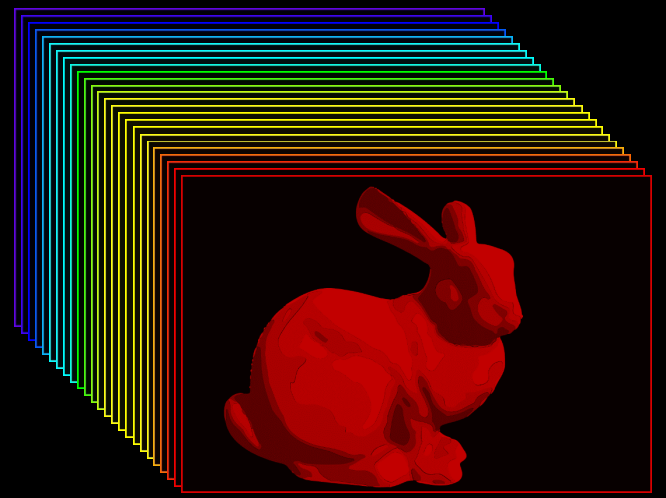
Depth

+

Hyperspectral Imaging

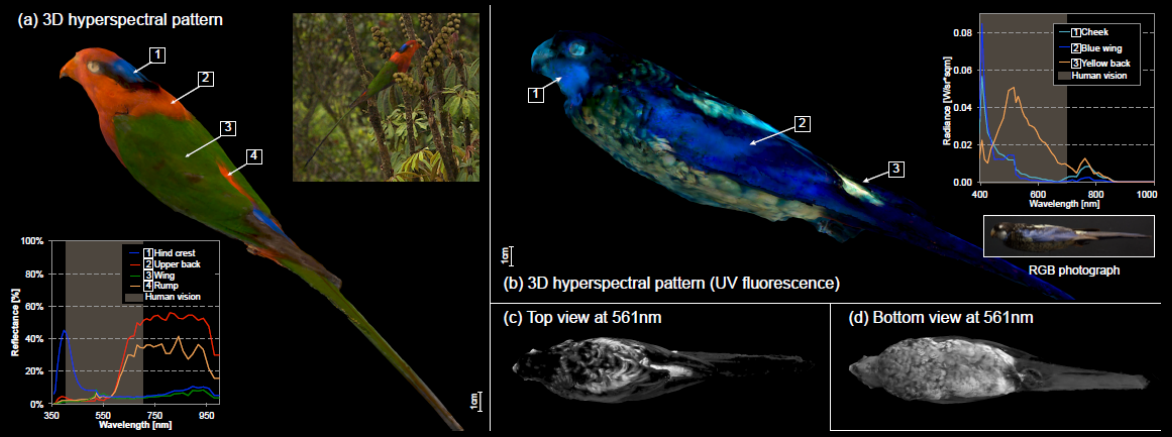
↓

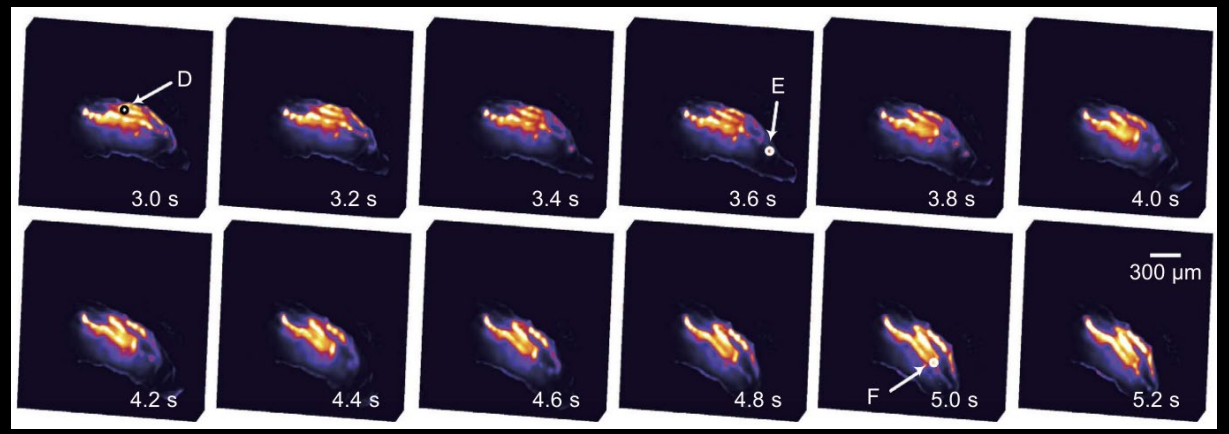
Material understanding

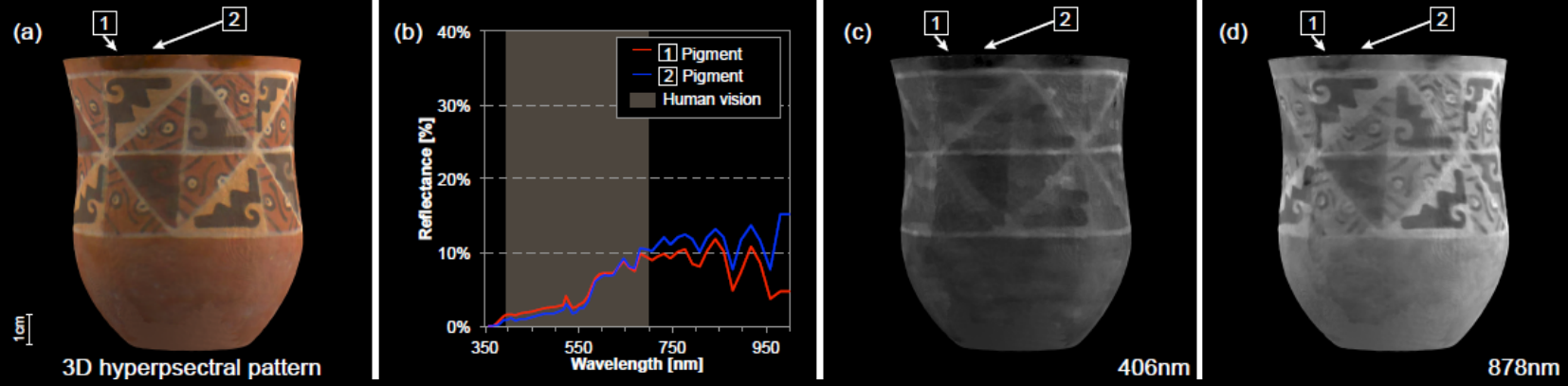


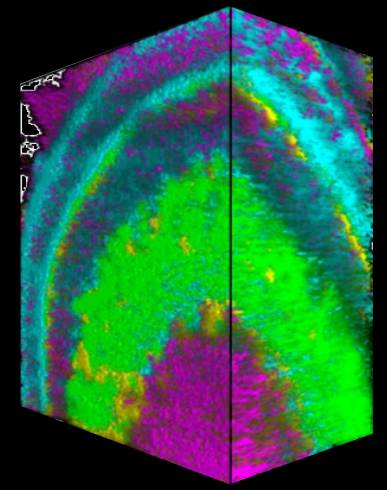
Hyperspectral image

Hyperspectral-Depth Imaging





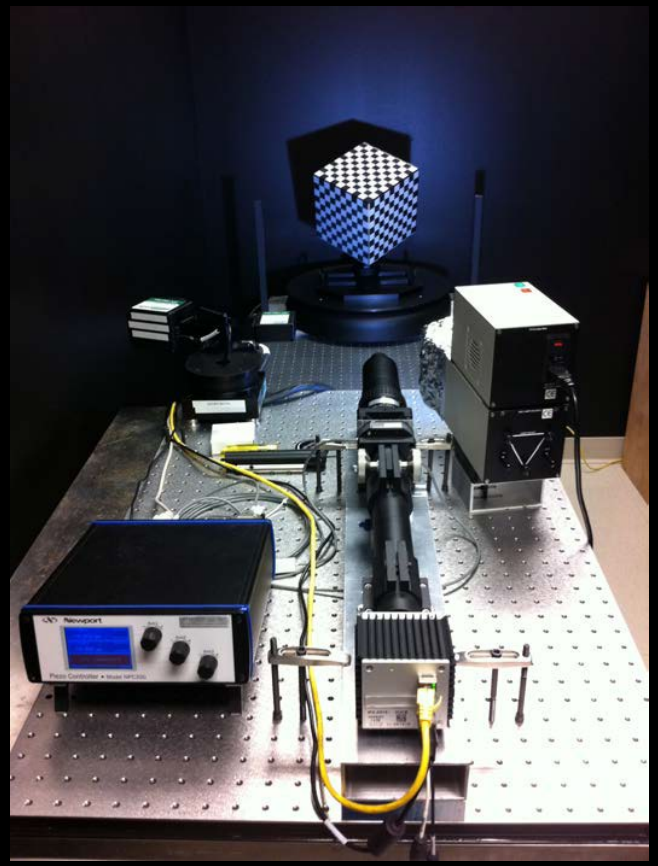


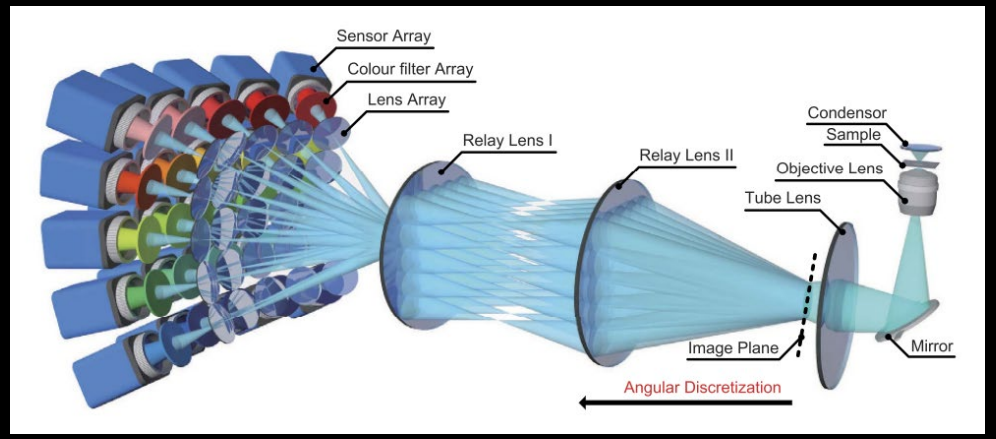


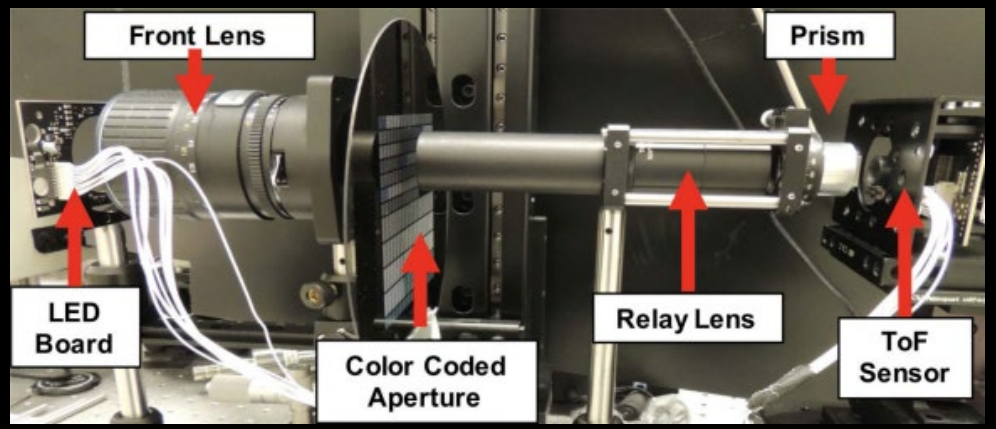
[Kim et al., 2012], [Wu et al., 2015], [Hedde et al., 2021]

Hyperspectral-Depth Imaging

- Combinatorial system
  - Hyperspectral imager + depth imager



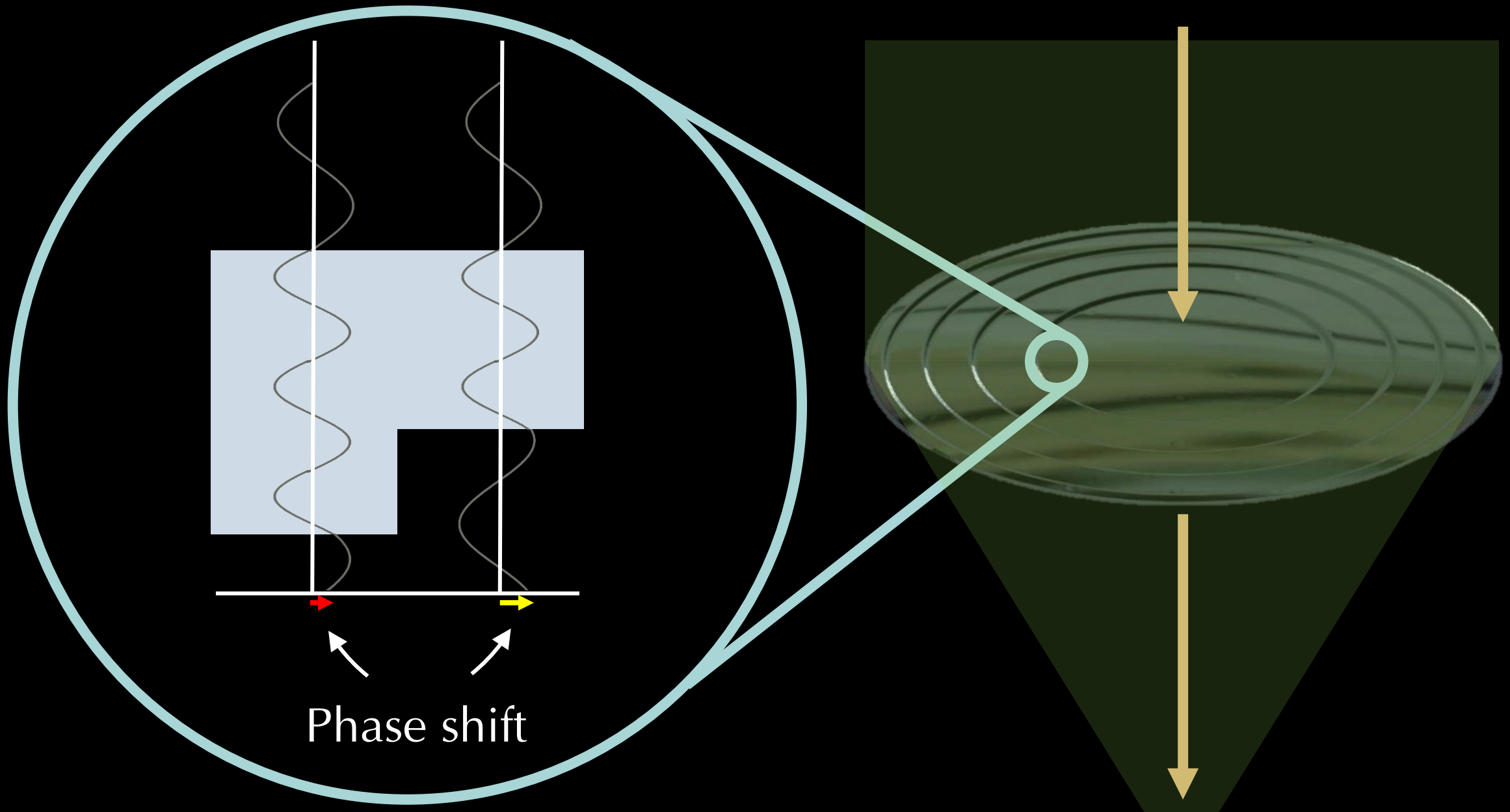




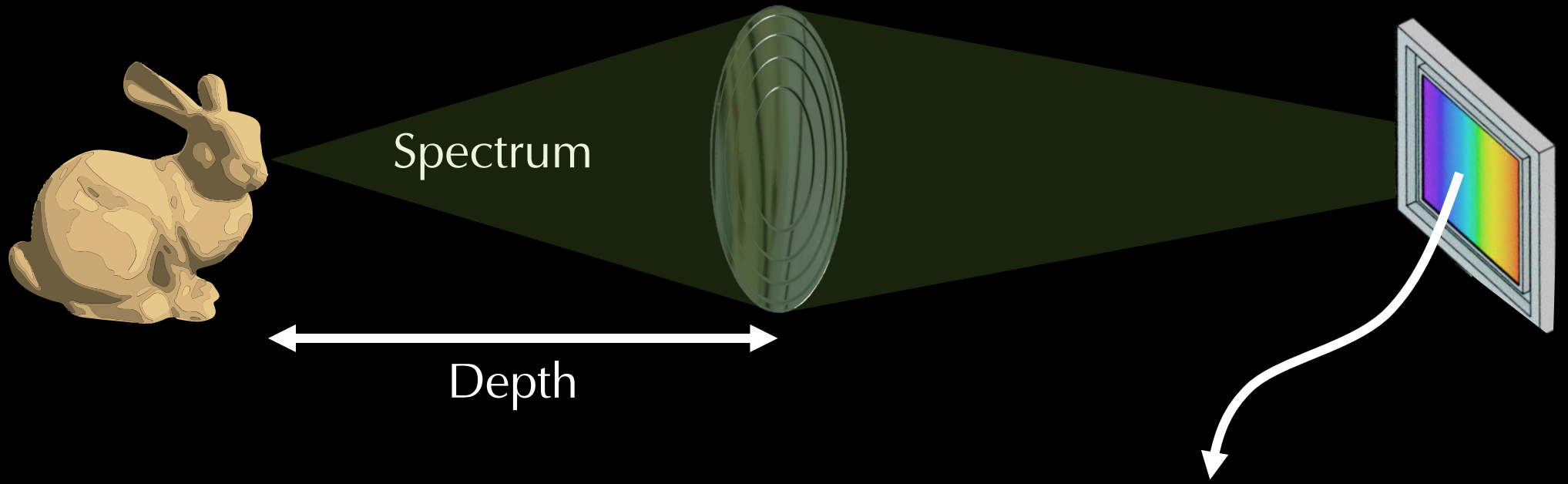
High system complexity
- Form factor
- Cost
- …

[Kim et al., 2012], [Wu et al., 2016], [Rueda-Chacon et al., 2020]

Diffractive Optical Element (DOE)

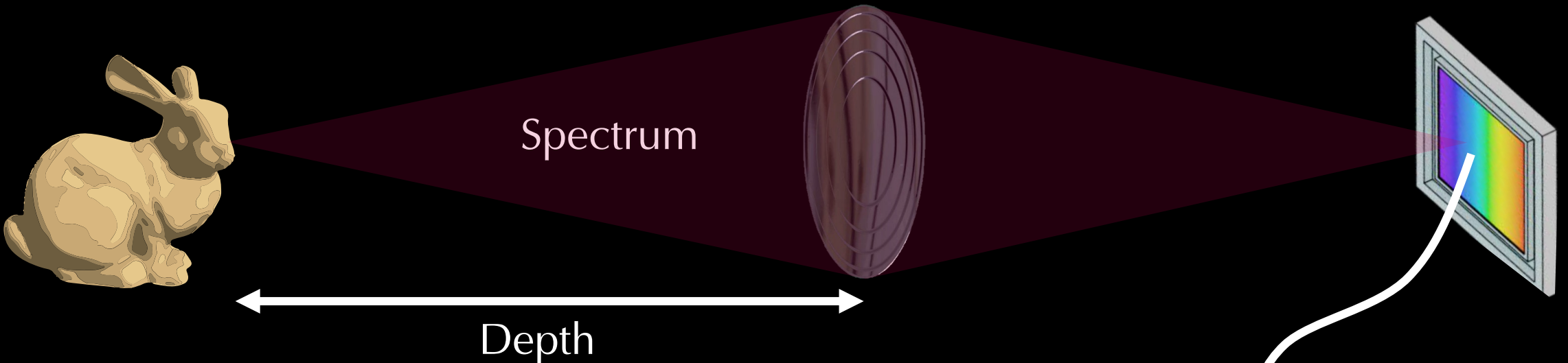


Point Spread Function from a DOE



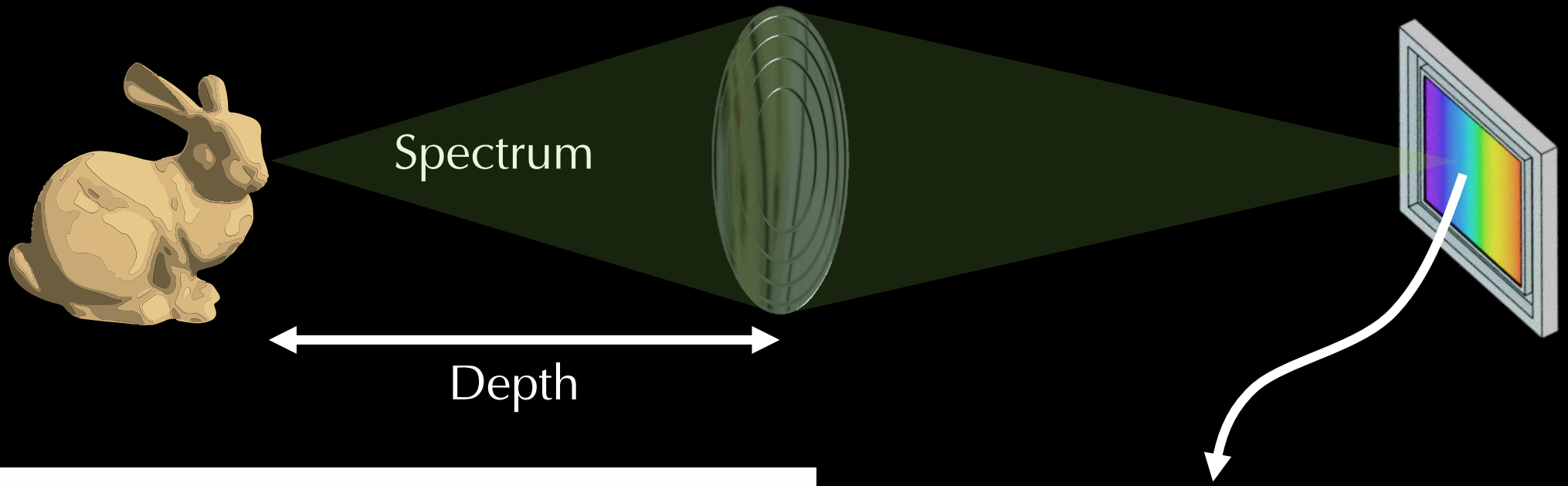
$$PSF = \left|F\left(Ae^{\phi_{scene}+\phi_{DOE}+\phi_{focal}}\right)\right|^2$$

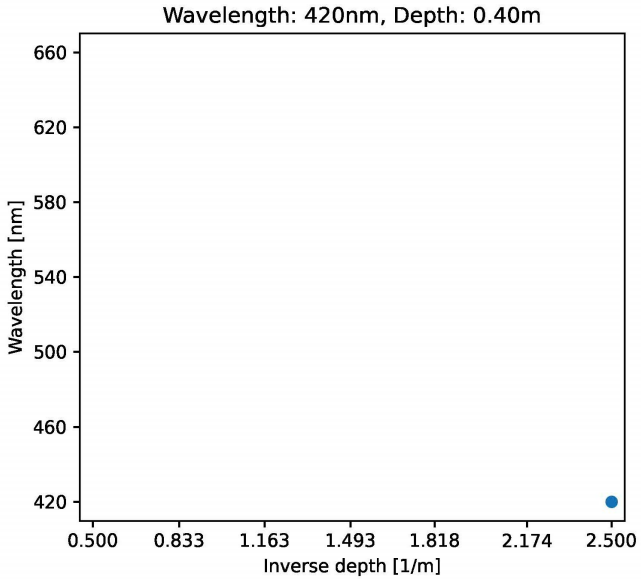
Point Spread Function from a DOE

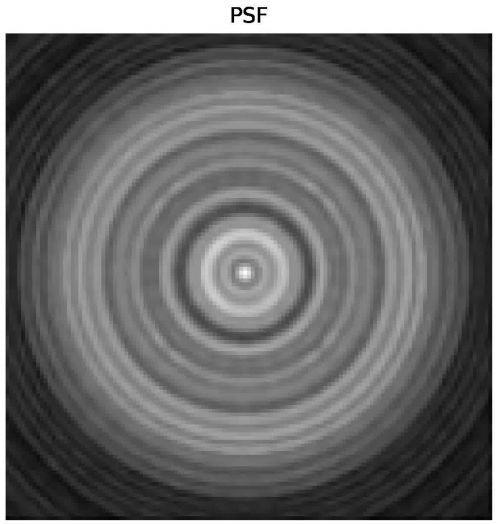


$$PSF = \left|F\left(Ae^{\phi_{scene}+\phi_{DOE}+\phi_{focal}}\right)\right|^2$$

Point Spread Function from a DOE



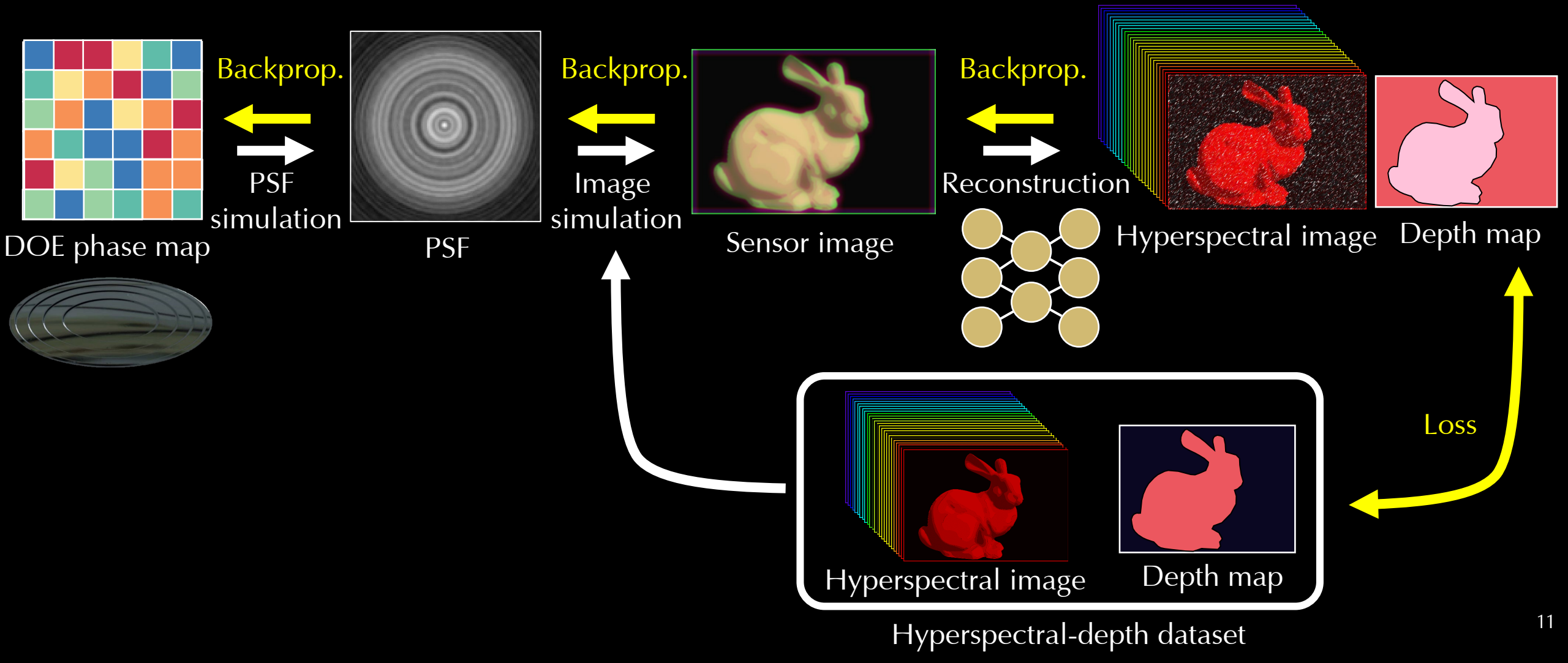




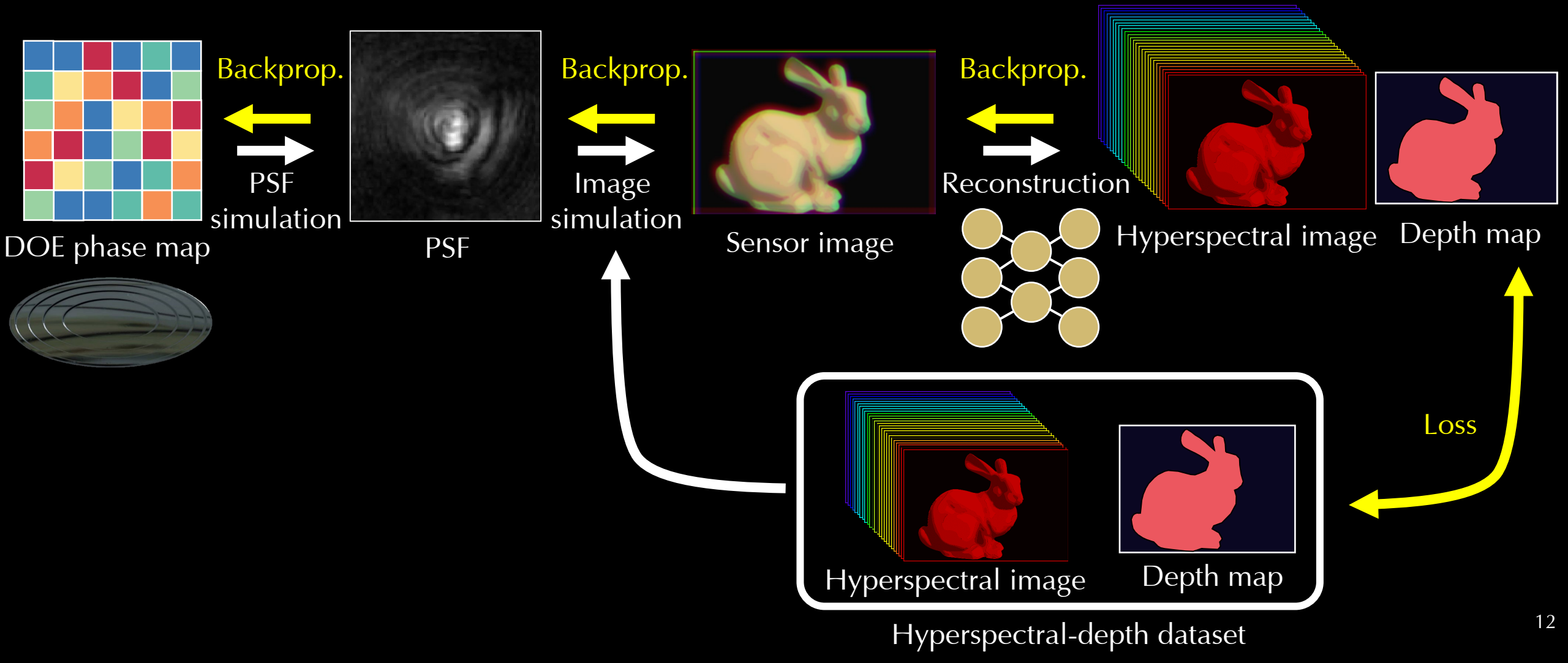
$$PSF = \left|F\left(Ae^{\phi_{scene}+\phi_{DOE}+\phi_{focal}}\right)\right|^2$$

What is a good DOE for reconstructing depth and spectrum?

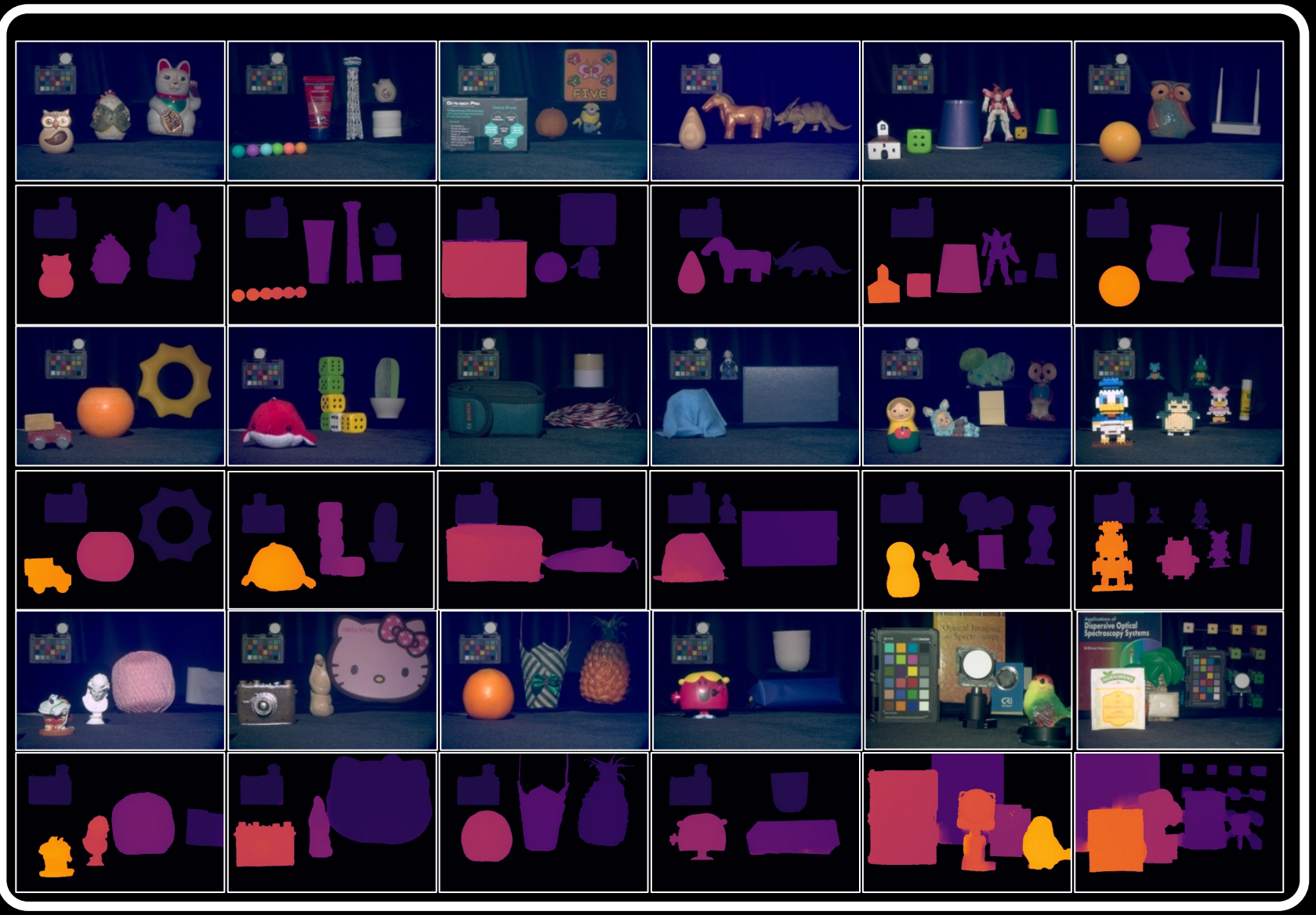
Learning the DOE for Hyperspectral-depth Reconstruction



Learning the DOE for Hyperspectral-depth Reconstruction



Hyperspectral-depth Dataset



Dataset-acquisition setup

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

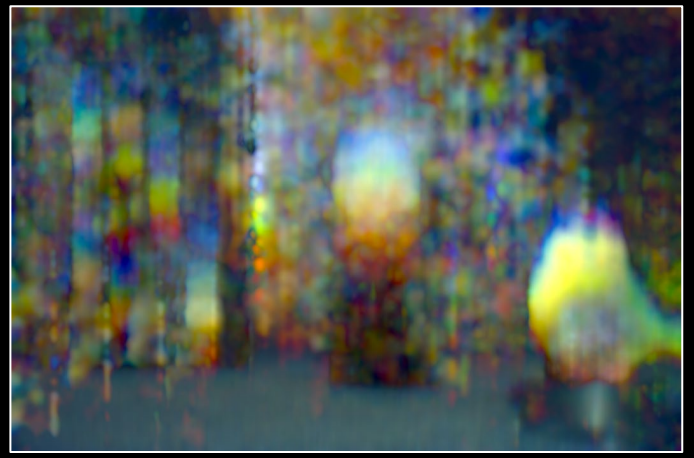
Synthetic Results

Ground truth

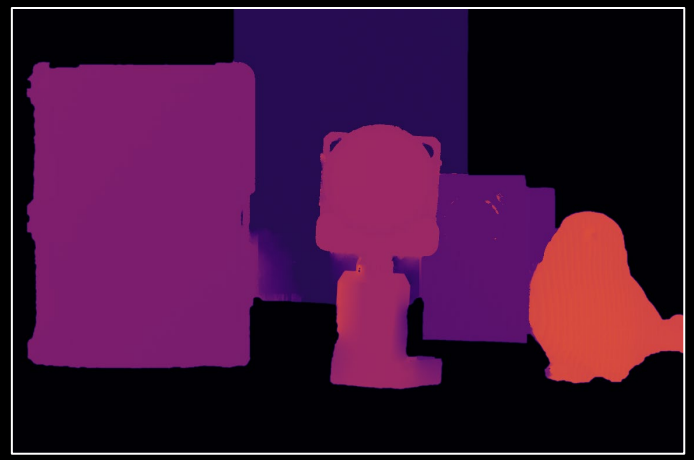
Feng et al.

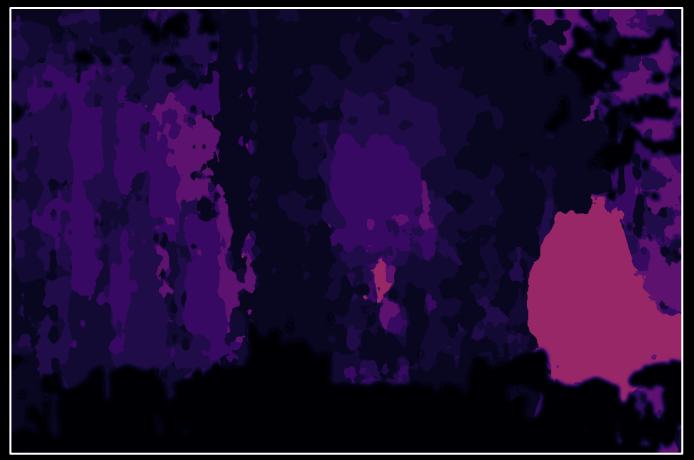
Ours

Hyperspectral image



Depth map

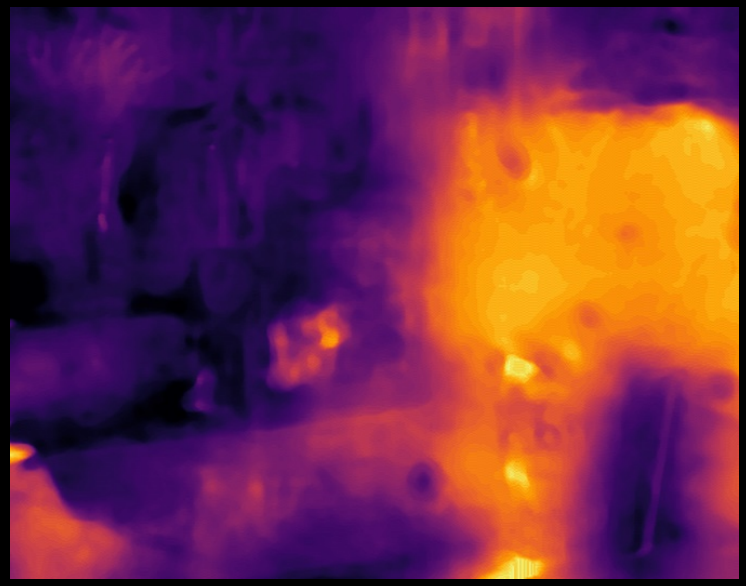




Real Results

Fabricated DOE

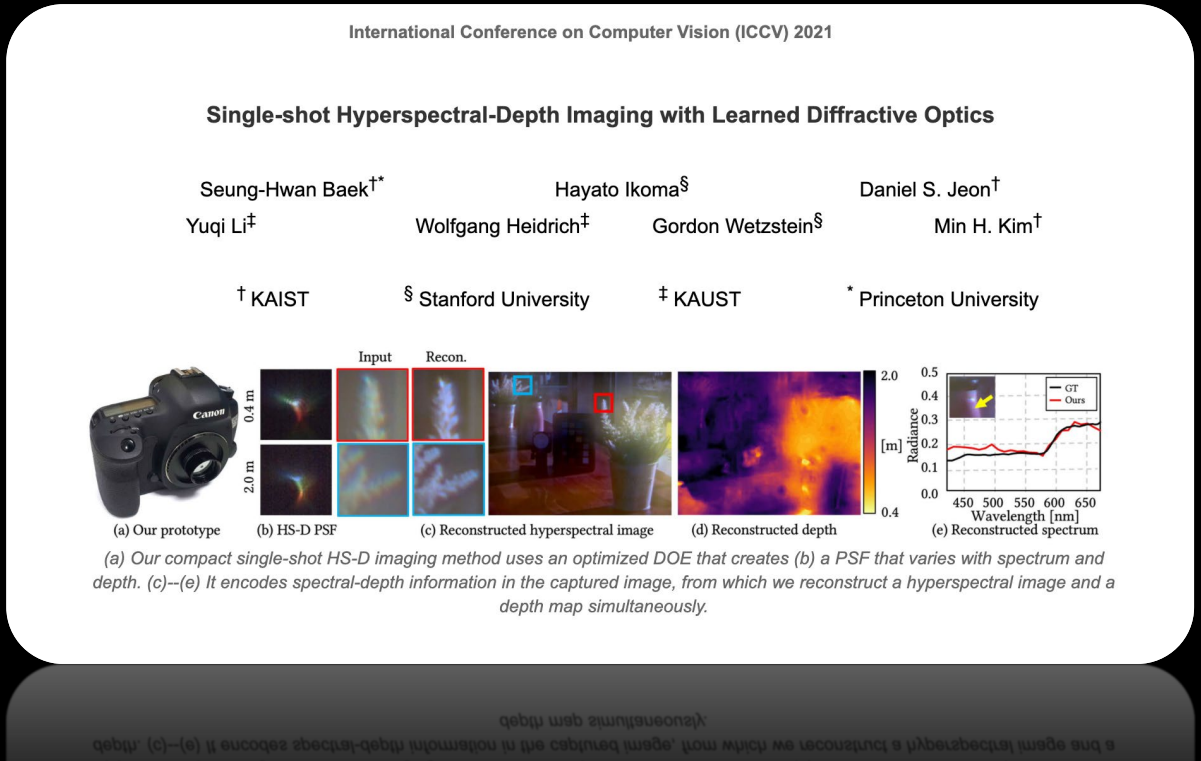
Hyperspectral image



Depth map

Conclusion

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



Project website

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