WeLight@HKU

Seeing Beyond RGB

Neural Optics for Stereo RGBD and Hyper-spectral Imaging

Yifan (Evan) Peng

HKU EEE & CS

Apr 2025

Images from public domain

Applications are different, imagers & ISPs are not

Co-design of Optics, Sensing, and Algorithms

optics

+

sensing

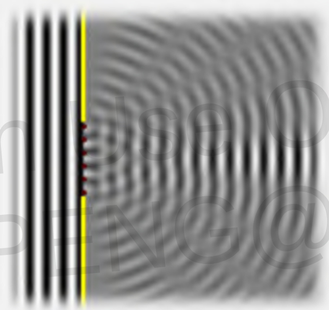
+

computation

Ray optics → Wave optics

Diffractive Optical Elements

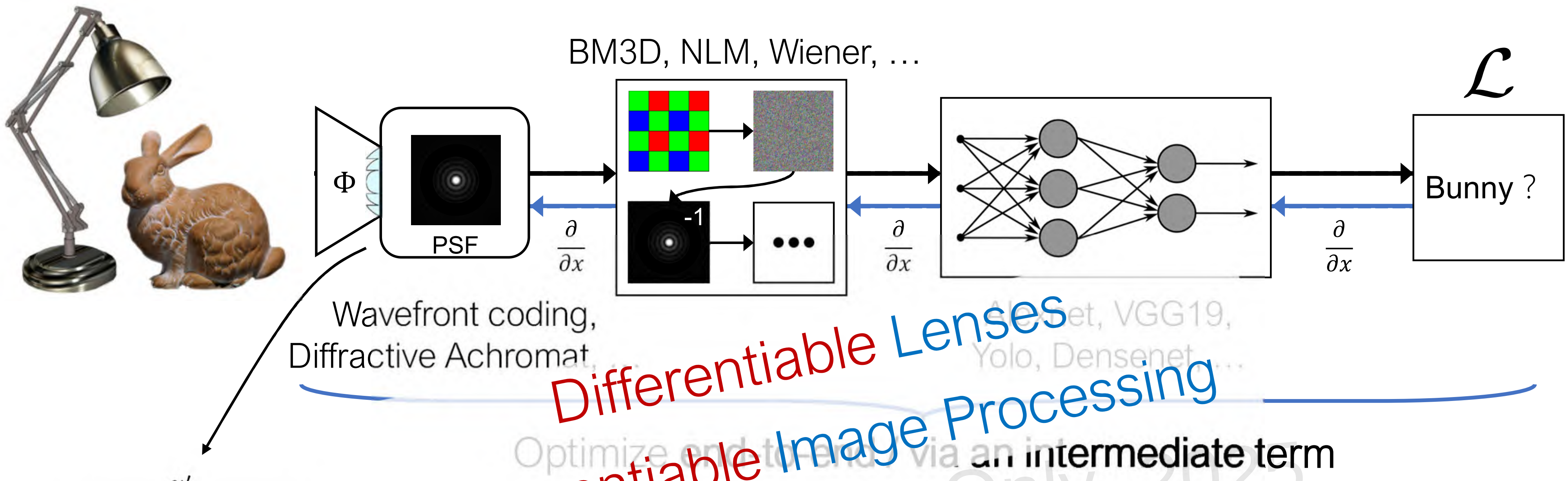
- *thin & lightweight structure*
- *large & flexible design space*
- *availability of mass fabrication*
- *color dispersion (downside)*

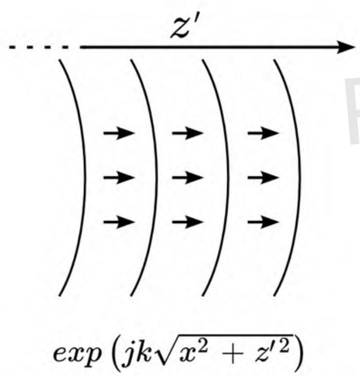


Promising platform for imaging & visual computing apps.

Images from public domain

Neural Optics for Domain-specific Apps. Imaging





- Performance & robustness gains
- Domain-specific hardware w/ reduced cost
- New design space: The "*BunnyCam*"

* *End-to-end optimization of optics and image processing for achromatic extended depth of field and super-resolution imaging, V Sitzmann*, S Diamond*, Y Peng*, et al. – ACM TOG, 2018.*

Differentiable Cameras for Domain-specific Apps.


End-to-end Optimization of Optics and Image Processing for Achromatic Extended Depth of Field and Super-resolution Imaging

VINCENT SITZMANN*, Stanford University
STEVEN DIAMOND*, Stanford University
YIFAN PENG*, The University of British Columbia and Stanford University
XIONG DUN, King Abdullah University of Science and Technology
STEPHEN BOYD, Stanford University
WOLFGANG HEIDRICH, King Abdullah University of Science and Technology
FELIX HEIDE, Stanford University
GORDON WETZSTEIN, Stanford University

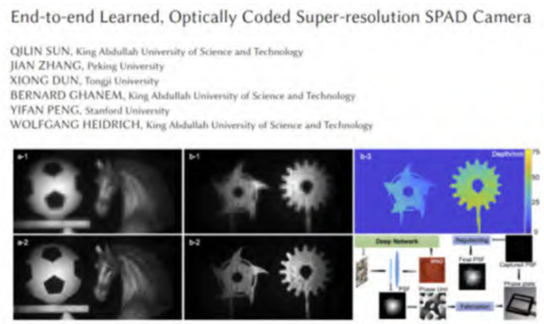
Single-shot Extended DOF
ACM TOG '18


Deep Optics for Single-shot High-dynamic-range Imaging

Christopher A. Metzler Hayato Ikoma Yifan Peng Gordon Wetzstein
Stanford University

Abstract

Single-shot HDR Imaging
IEEE CVPR '20


End-to-end Learned, Optically Coded Super-resolution SPAD Camera

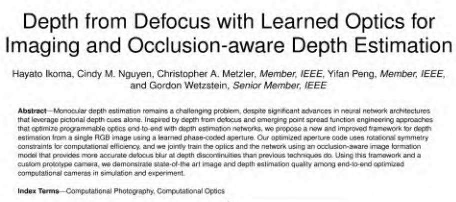
QILIN SUN, King Abdullah University of Science and Technology
JIAN ZHANG, Peking University
XIONG DUN, Tongji University
BERNARD GHANEM, King Abdullah University of Science and Technology
YIFAN PENG, Stanford University
WOLFGANG HEIDRICH, King Abdullah University of Science and Technology

Super-resolution SPAD Camera
ACM TOG '20; IEEE CVPR '18


Learned Large Field-of-View Imaging With Thin-Plate Optics

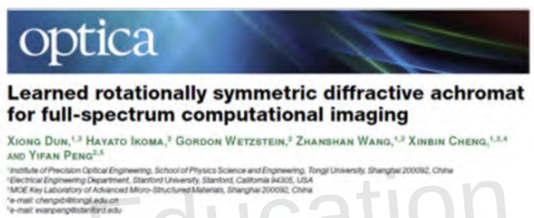
YIFAN PENG*, Stanford University
QILIN SUN*, King Abdullah University of Science and Technology
XIONG DUN*, King Abdullah University of Science and Technology
GORDON WETZSTEIN, Stanford University
WOLFGANG HEIDRICH, King Abdullah University of Science and Technology
FELIX HEIDE, Princeton University

Large FOV & Lightweight
OSA OE '15; ACM TOG '19


Depth from Defocus with Learned Optics for Imaging and Occlusion-aware Depth Estimation

Hayato Ikoma, Cindy M. Nguyen, Christopher A. Metzler, Member, IEEE, Yifan Peng, Member, IEEE, and Gordon Wetzstein, Senior Member, IEEE

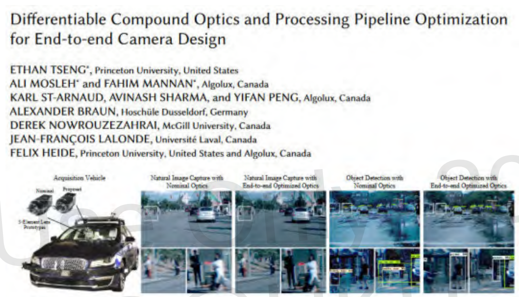
AiF & Depth Estimation
IEEE ICCP '21


optica

Learned rotationally symmetric diffractive achromat for full-spectrum computational imaging

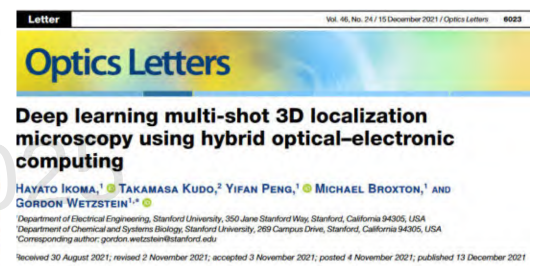
Xiong Dun, Hayato Ikoma, Gordon Wetzstein, Zhanshan Wang, Xinbin Cheng, and Yifan Peng

Full-spectrum & Lightweight
OSA Optica '20; ACM TOG '16


Differentiable Compound Optics and Processing Pipeline Optimization for End-to-end Camera Design

ETHAN TSENG*, Princeton University, United States
ALI MOSLEH* and FAHIM MANNAN*, Algolux, Canada
KARL ST-ARNAUD, AVINASH SHARMA, and YIFAN PENG, Algolux, Canada
ALEXANDER BRAUN, Hochschule Dusseldorf, Germany
DEREK NOWROUZEZAHRAI, McGill University, Canada
JEAN-FRANÇOIS LALONDE, Université Laval, Canada
FELIX HEIDE, Princeton University, United States and Algolux, Canada

Differentiable Compound Optics
ACM TOG '21


Letter Vol. 46, No. 24 / 15 December 2021 / Optics Letters 6023

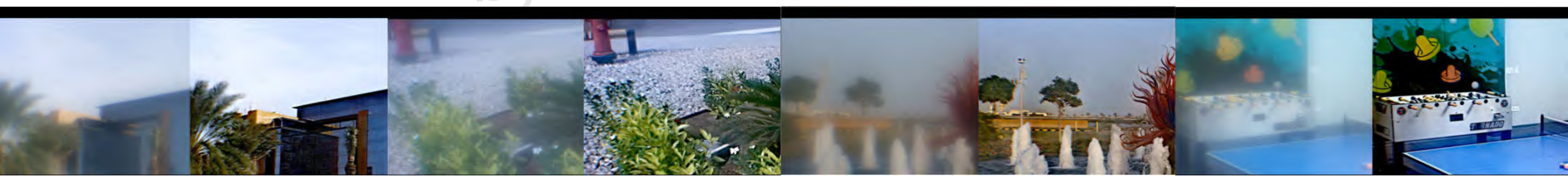
Optics Letters

Deep learning multi-shot 3D localization microscopy using hybrid optical–electronic computing

Hayato Ikoma, Takamasa Kudo, Yifan Peng, Michael Broxton, and Gordon Wetzstein

Received 30 August 2021; revised 2 November 2021; accepted 3 November 2021; posted 4 November 2021; published 13 December 2021

3D Microscopy Imaging
OSA OL '21

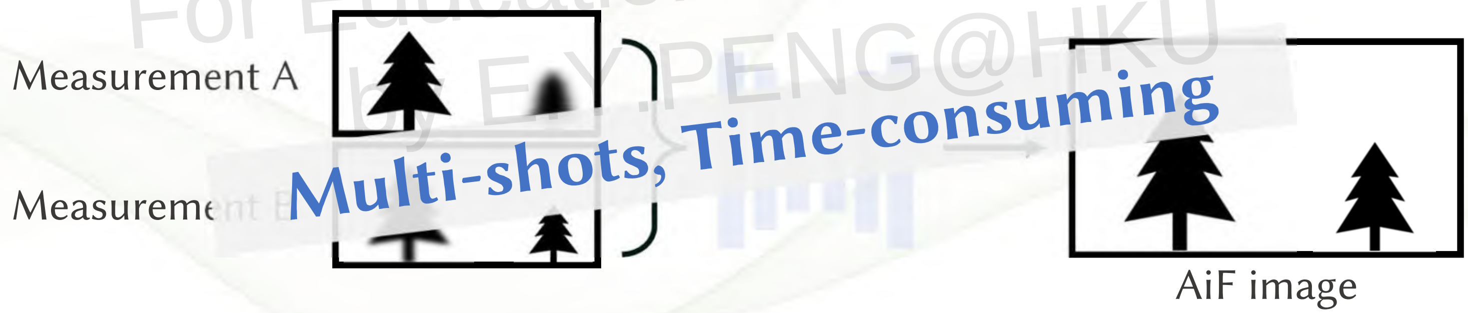


Issues in RGBD Imaging...

A. Monocular Image Reconstruction

Snapshot Depth from Defocus

Multi-focus Image Fusion



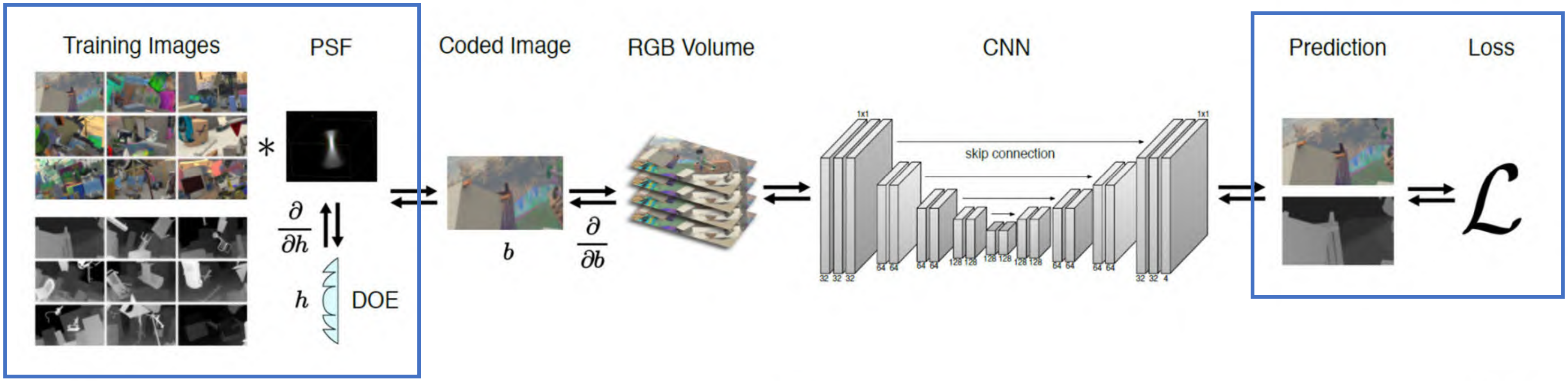
Issues in RGBD Imaging...

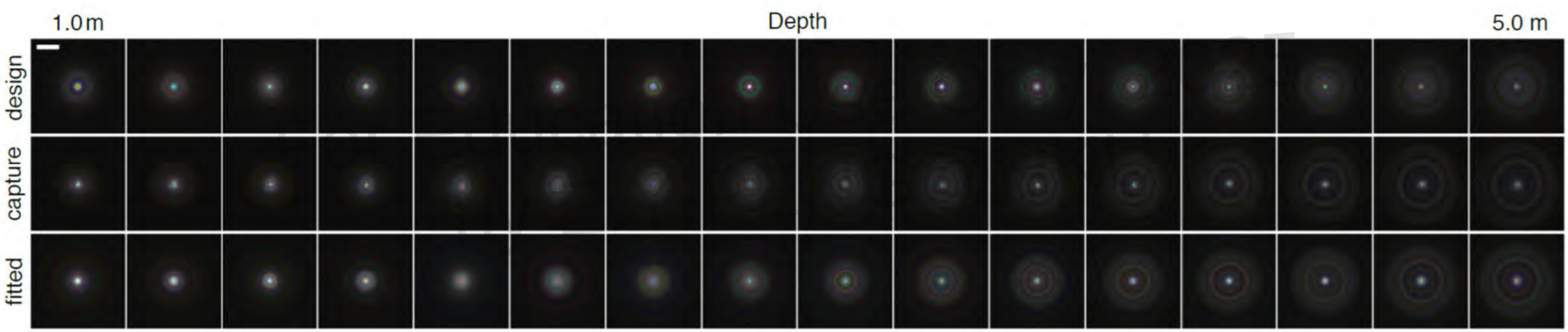
B. Conventional Stereo Matching

Left Measurement　　Estimated disparity　　Distortion caused by blur

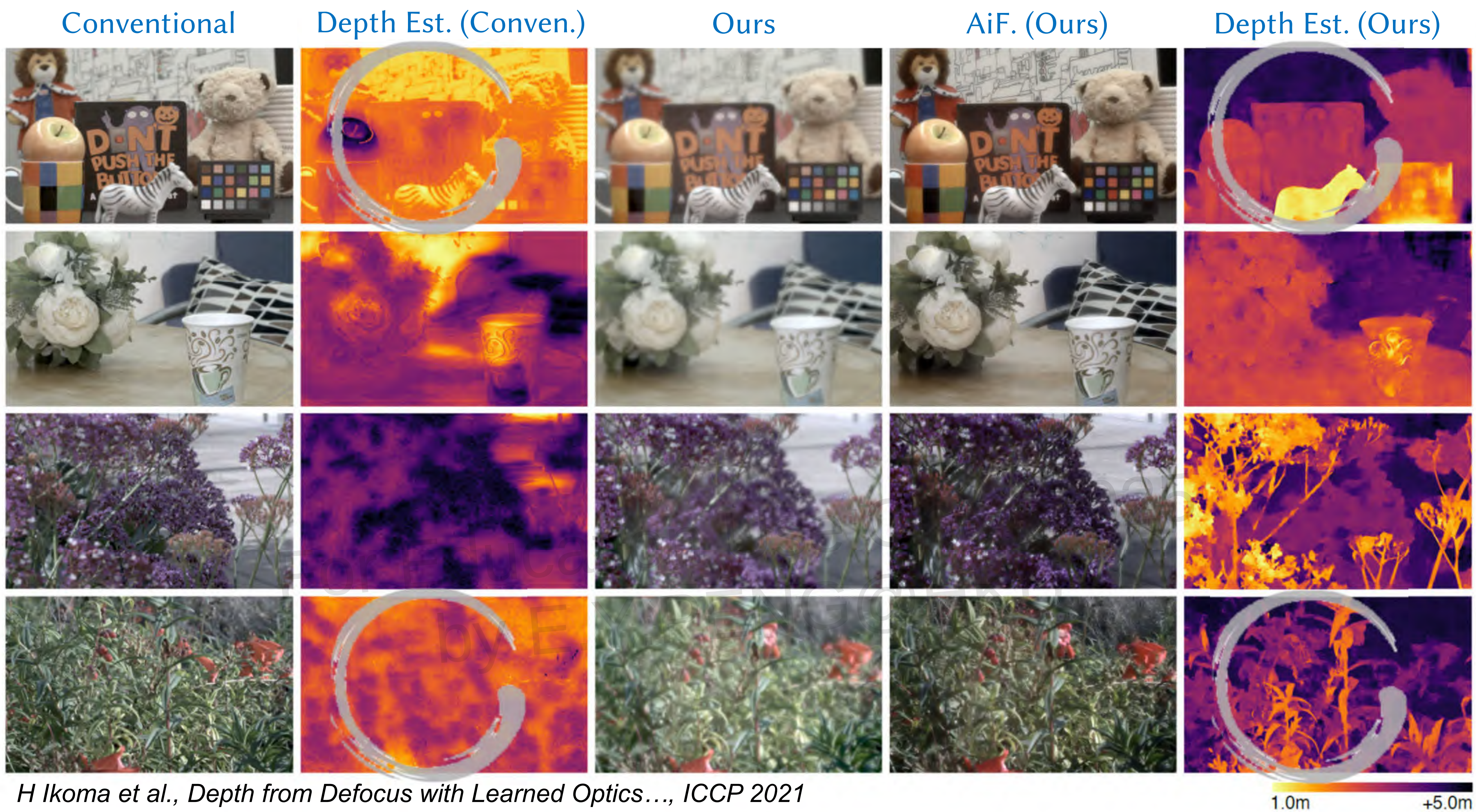
Binocular-Encoding Optics?

Monocular Depth Estimation and All-in-focus Imaging



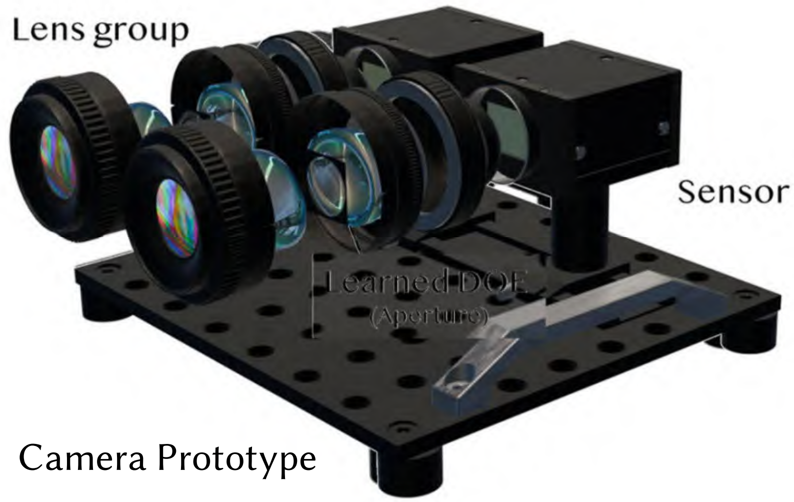


* Depth from Defocus with Learned Optics for Imaging and Occlusion-aware Depth Estimation,
H Ikoma, C Nguyen, C Metzler, Y Peng, G Wetzstein– IEEE ICCP, 2021.



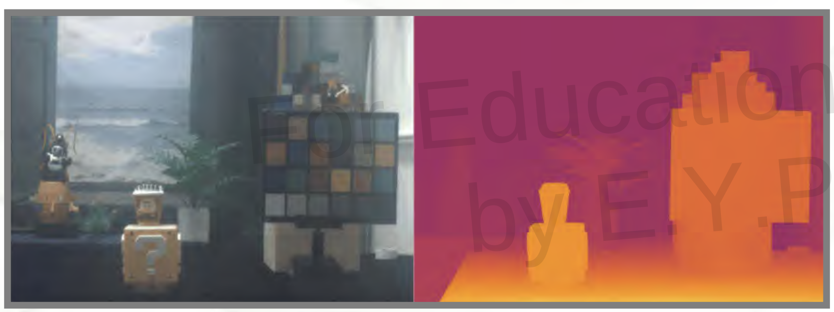
H Ikoma et al., Depth from Defocus with Learned Optics…, ICCP 2021

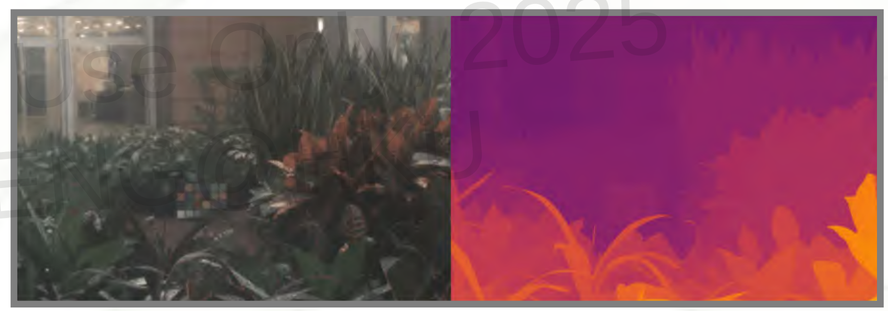
Learned Binocular-Encoding Optics for RGBD Imaging



Camera Prototype


Learned Diffractive Optical Element (DOE)


Reconstructed RGB Estimated Depth

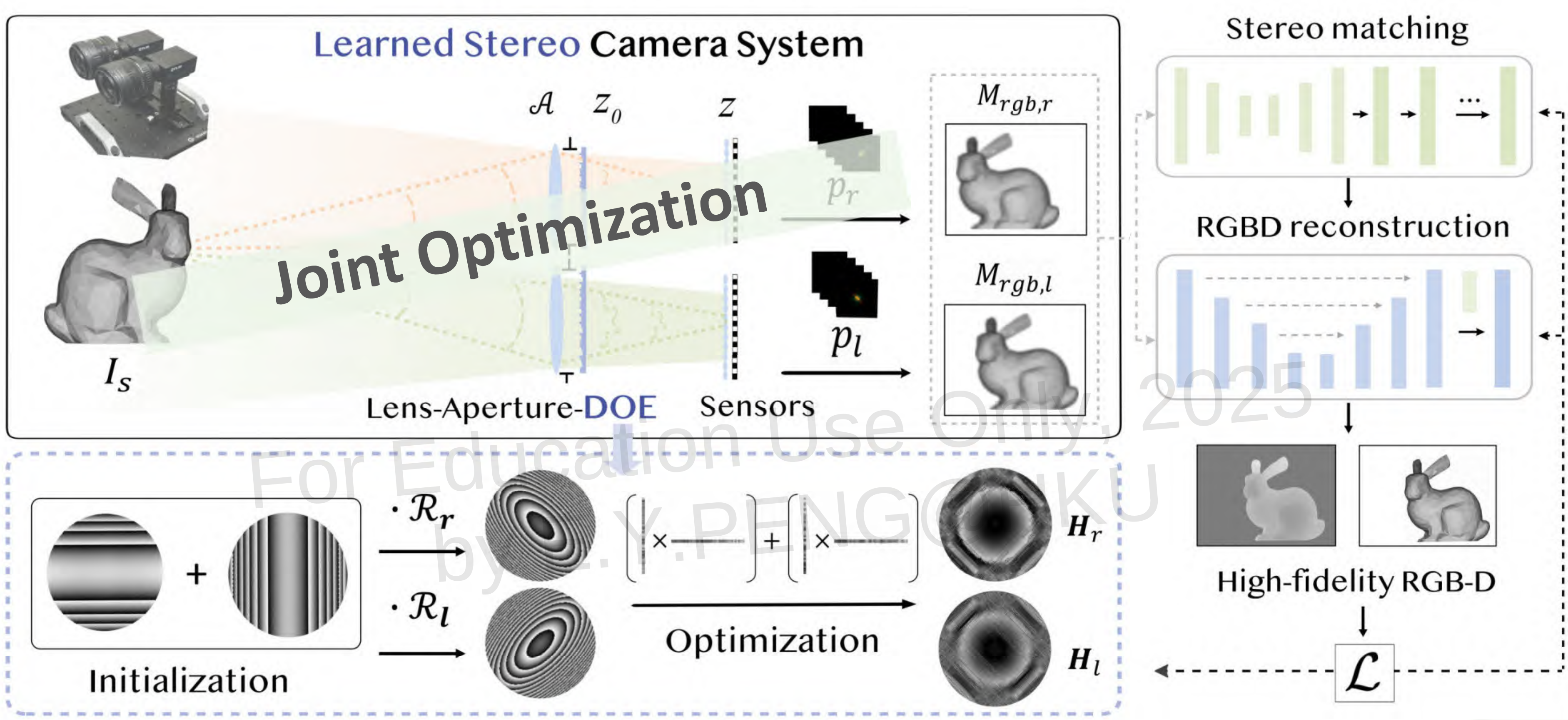

Reconstructed RGB Estimated Depth

* *Yuhui Liu, Liangxun Ou, Qiang Fu, QHadi Amata, Wolfgang Heidrich, Yifan Peng, IEEE CVPR, 2025 (Oral)*

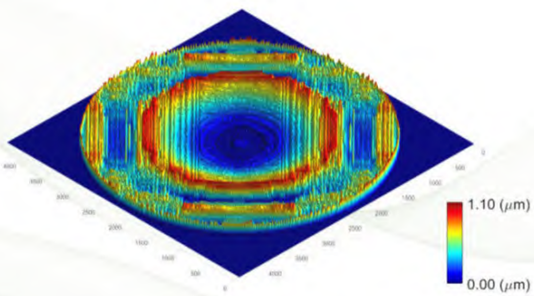
KAUST

Learned Binocular-Encoding Optics for RGBD Imaging

Pipeline

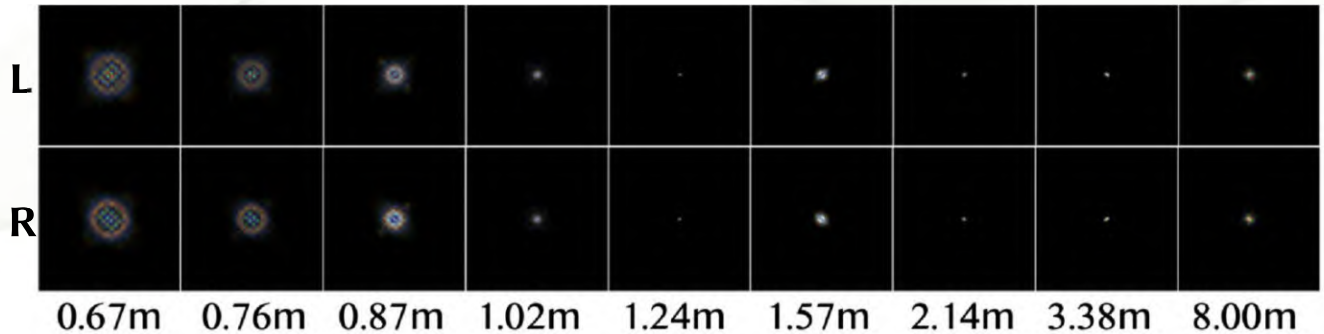


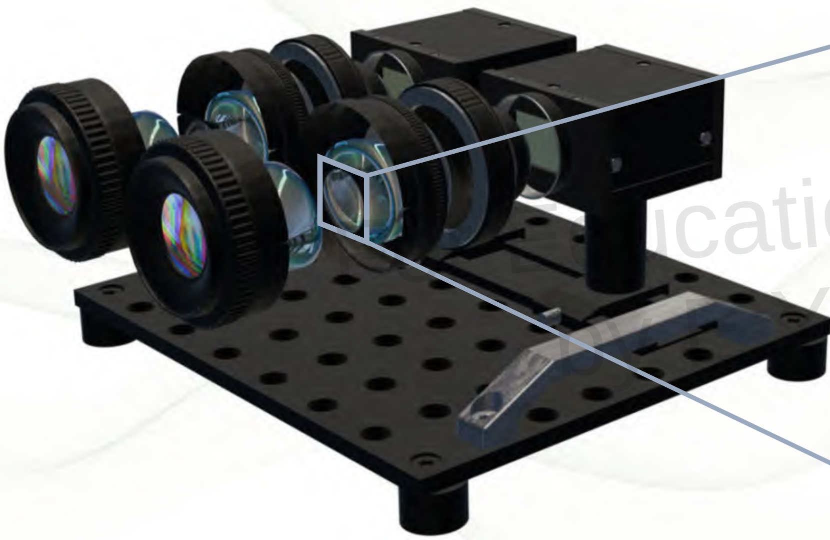
Customized Camera Prototype



3D Profile of Left DOE

PSFs



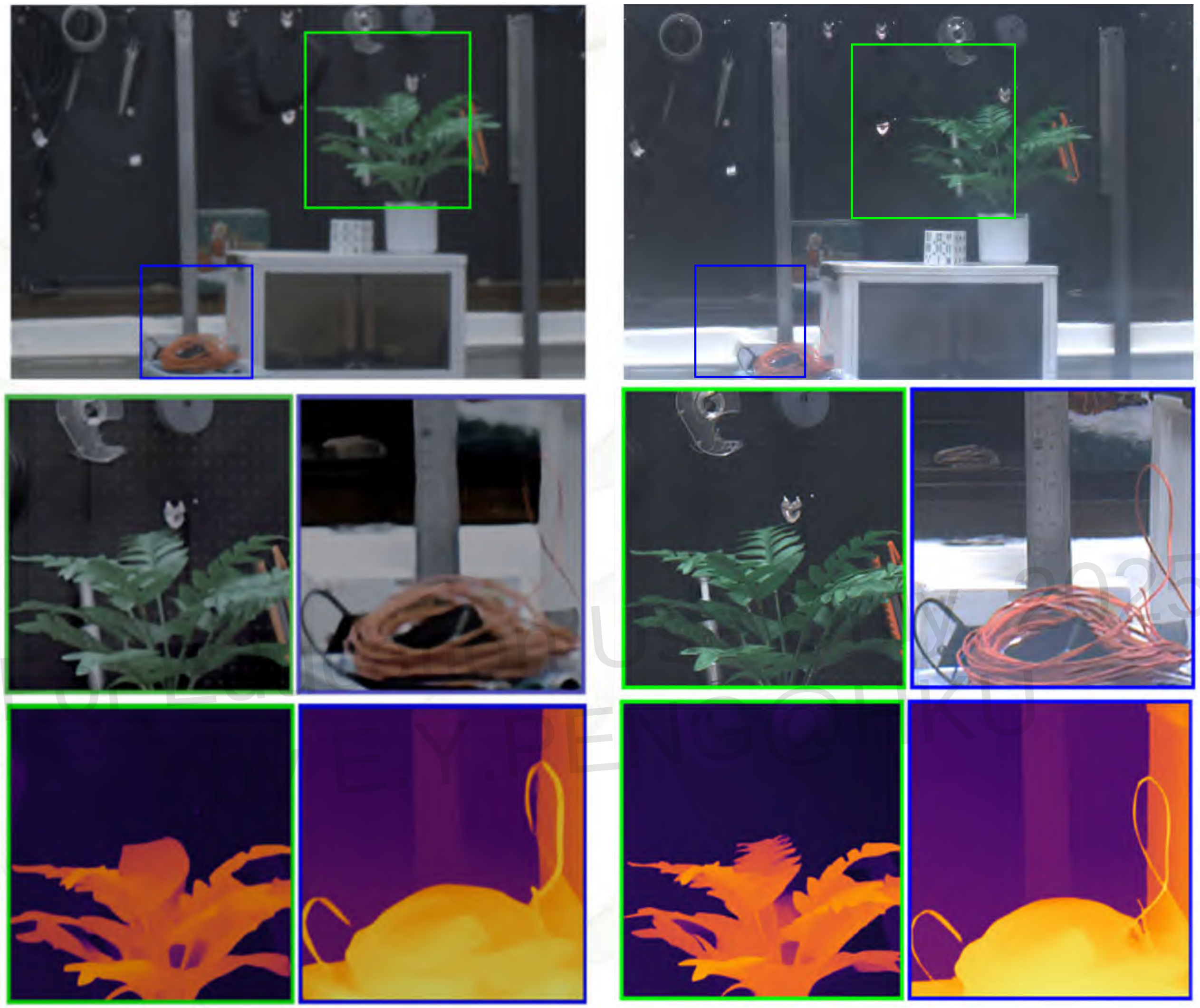


Experimental Results

Conventional Lens

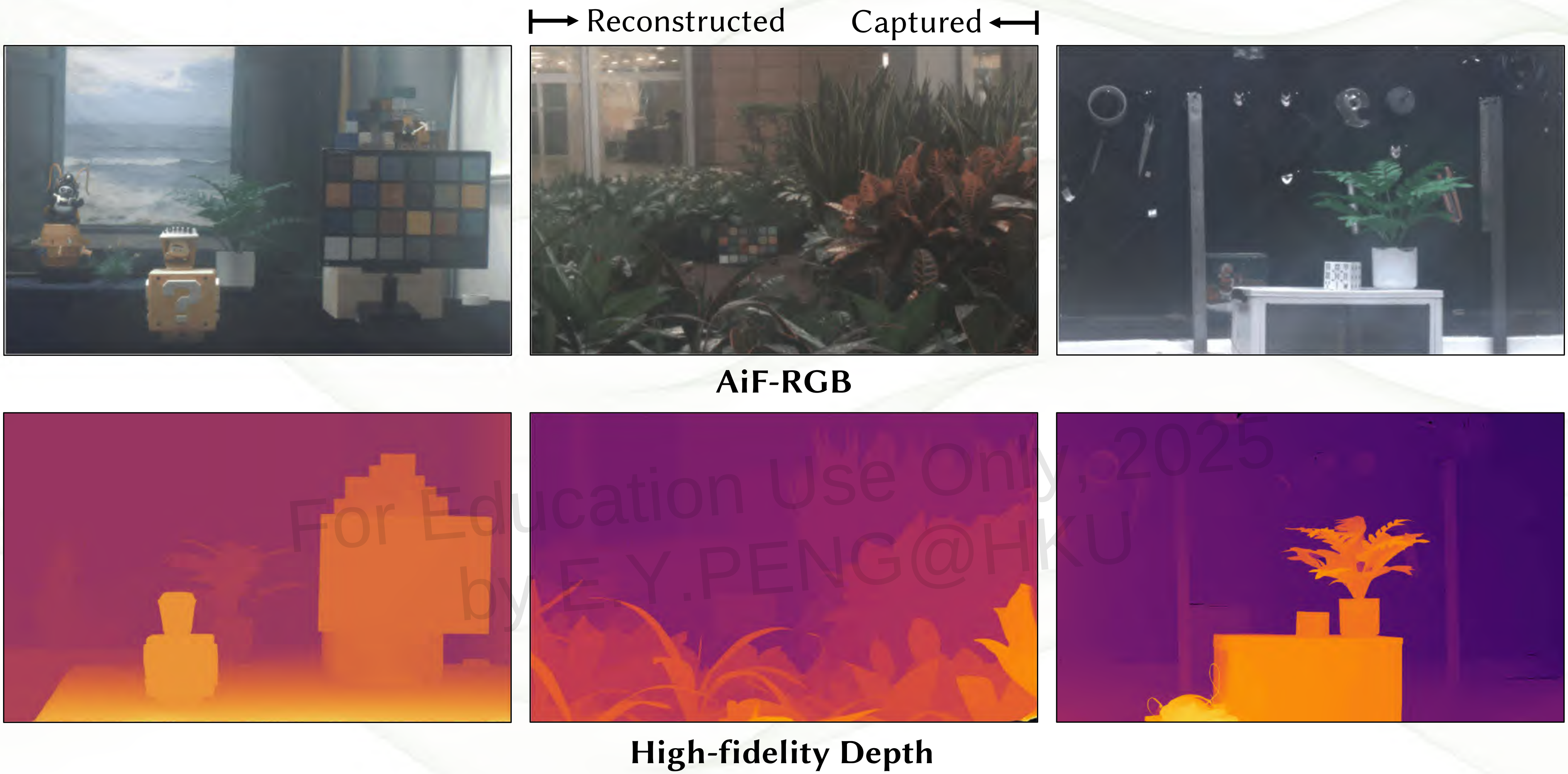
AiF-RGB

Depthmap



Lens w/ rank2-coded DOE

Experimental Results

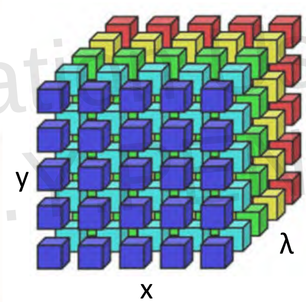


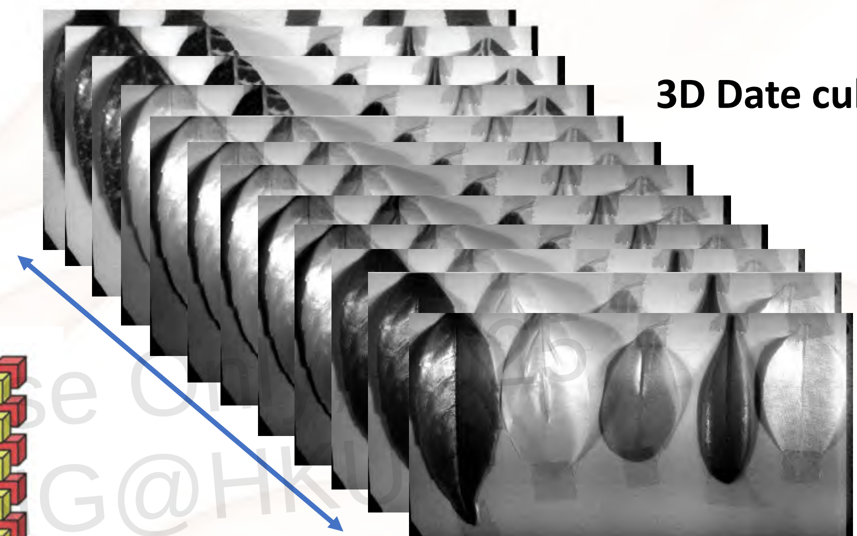
Why Snapshot Hyperspectral Imaging

Application scenario: Identify which leaves are fake.

Approach: Hyperspectral imaging.

RGB imaging





3D Date cube

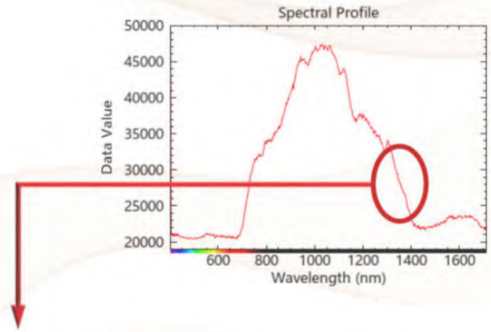
Hyperspectral imaging

Why Snapshot Hyperspectral Imaging

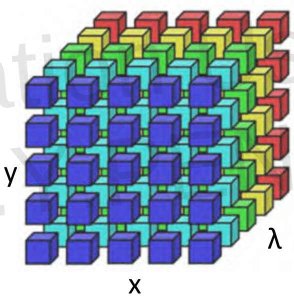
Application scenario:

Identify which leaves are fake.

Approach: Hyperspectral imaging.



RGB imaging



Hyperspectral imaging

Hyperspectral date cube (3D) beyond sensor capability (2D).

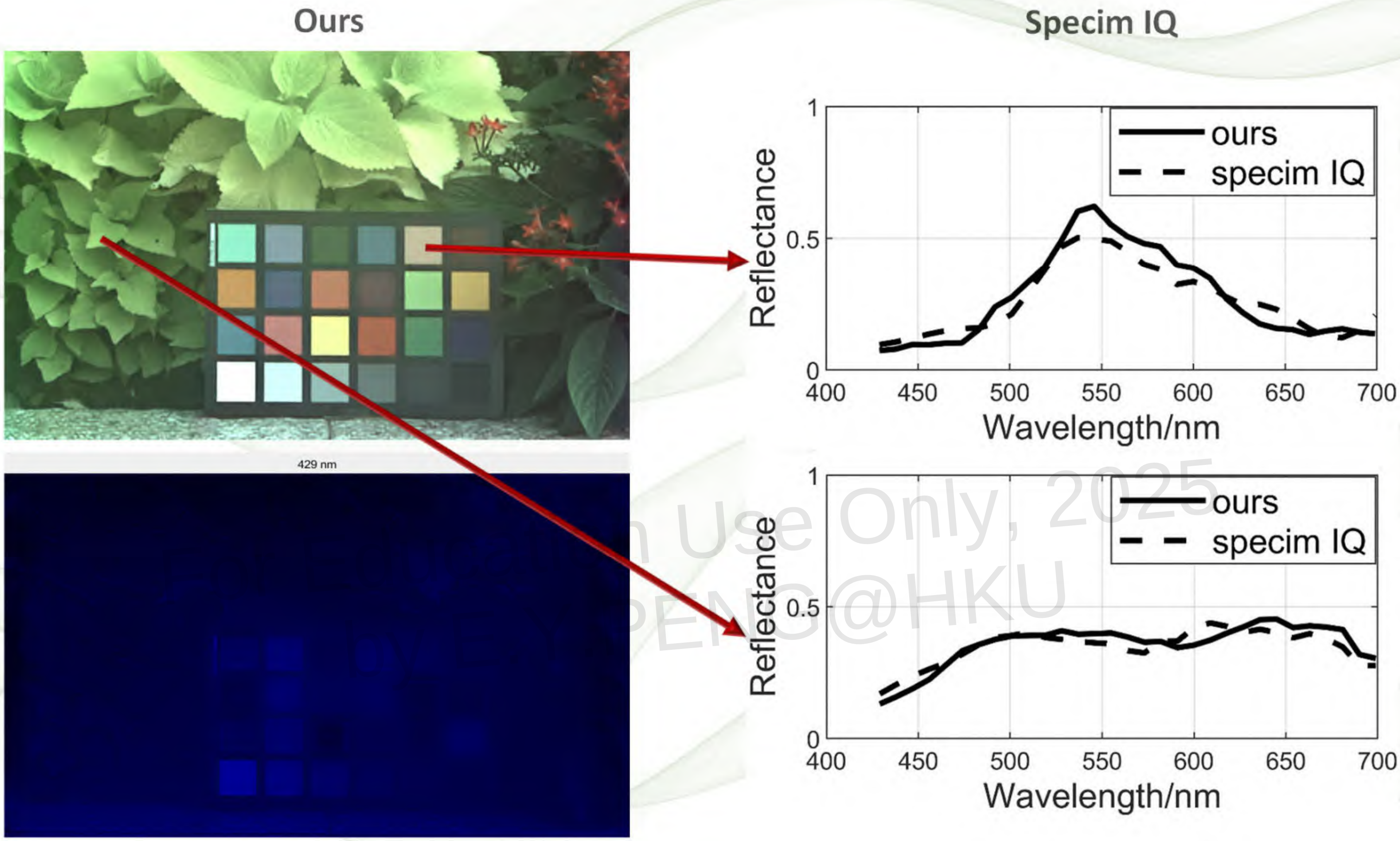
Learned Multi-aperture Color-coded Optics for Snapshot Hyperspectral Imaging

(a) Color Coded DOE Array Camera (b) Reconstructed RGB Image (c) Reconstructed Hyperspectral Images (zoom-in)

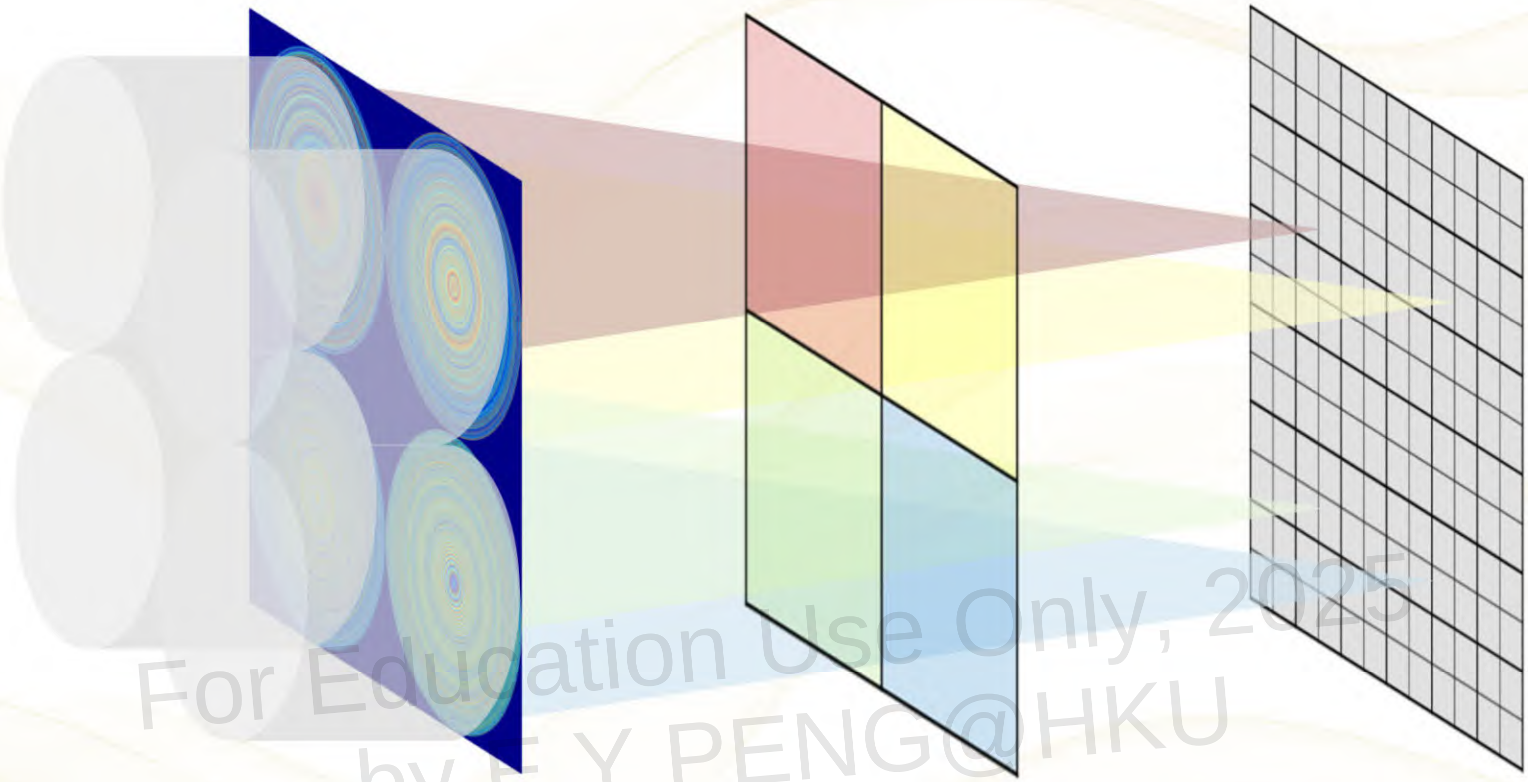
https://whywww.github.io/ArrayHSI/

Zheng Shi*, Xiong Dun*, Haoyu Wei, Siyu Dong, Zhanshan Wang,
Xinbin Cheng, Felix Heide, Yifan Peng, ACM TOG, 2024

RGB and Hyperspectral Imaging Results Highlight



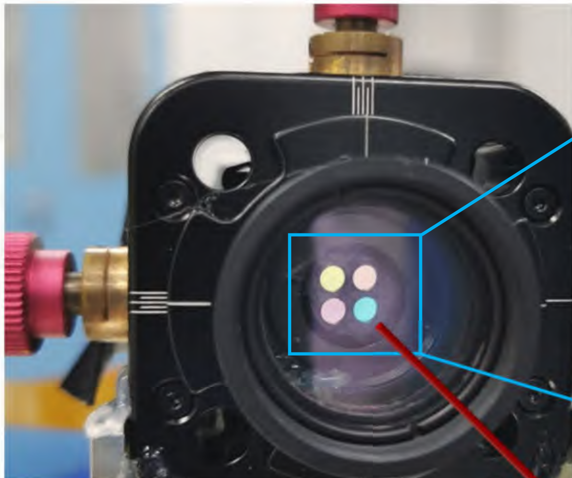
Tech Flow Overview



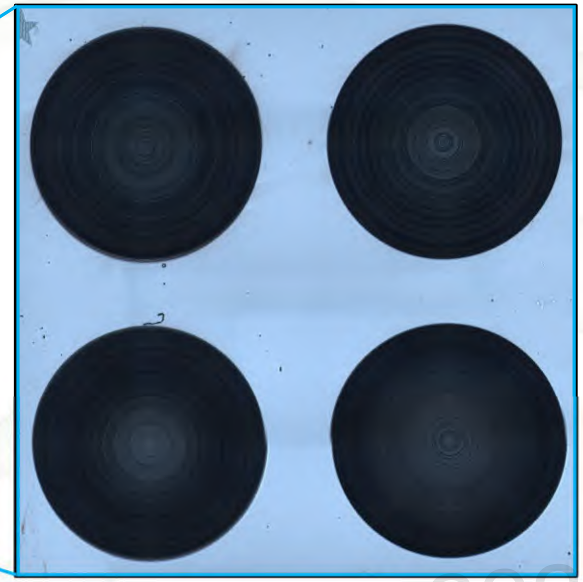
Spatial and spectral coding are fully **decoupled**

Aperture-wise filter also avoids the high cost of customized Bayer filter

Camera Prototype

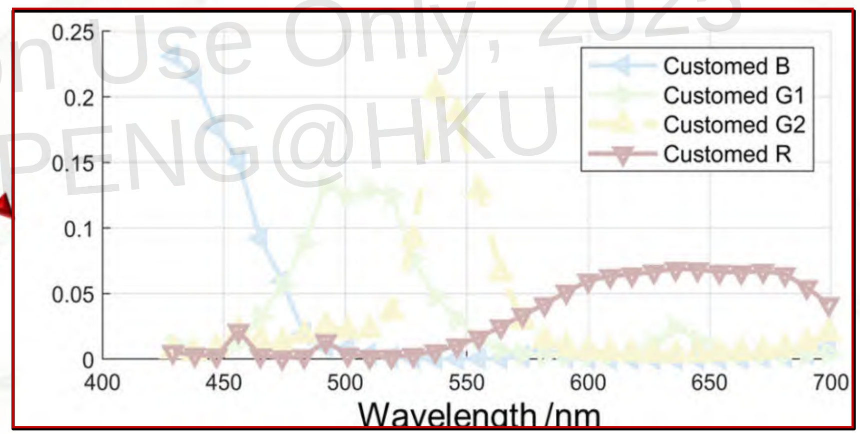


Aperture size: 3mm
EFL: 20mm
FOV: 20°



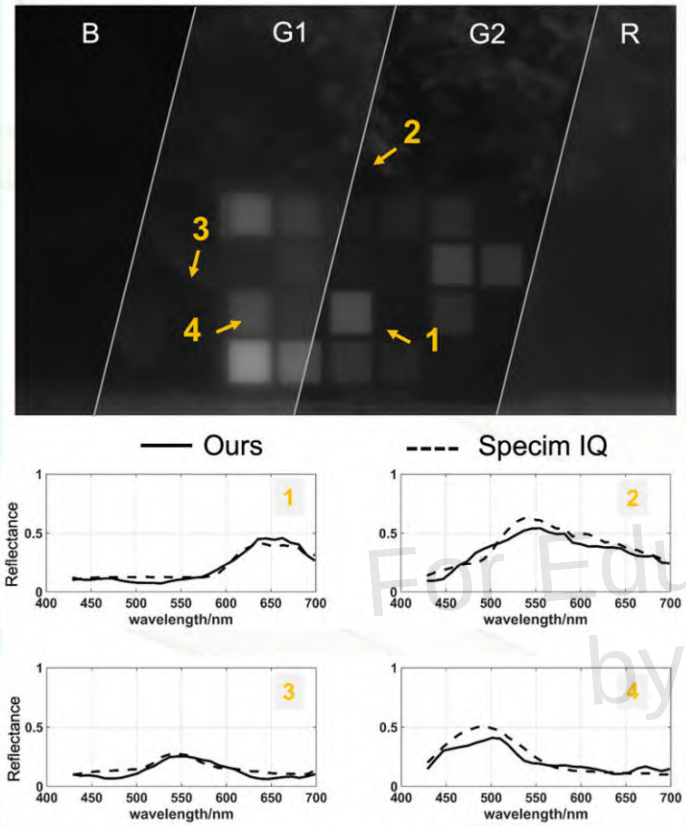
Microscope image of the DOE array

Customed spectral response curves

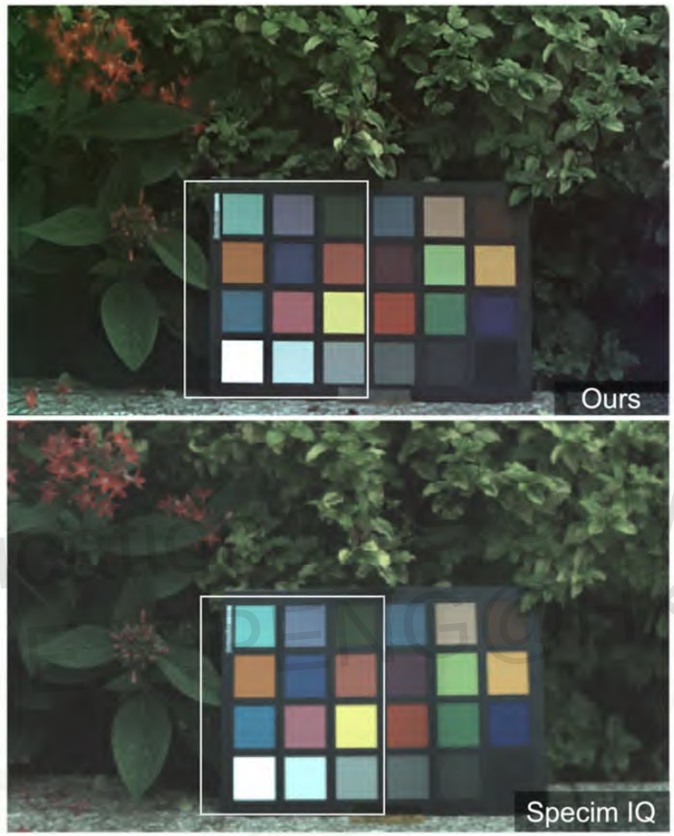


ACM TOG, 2024

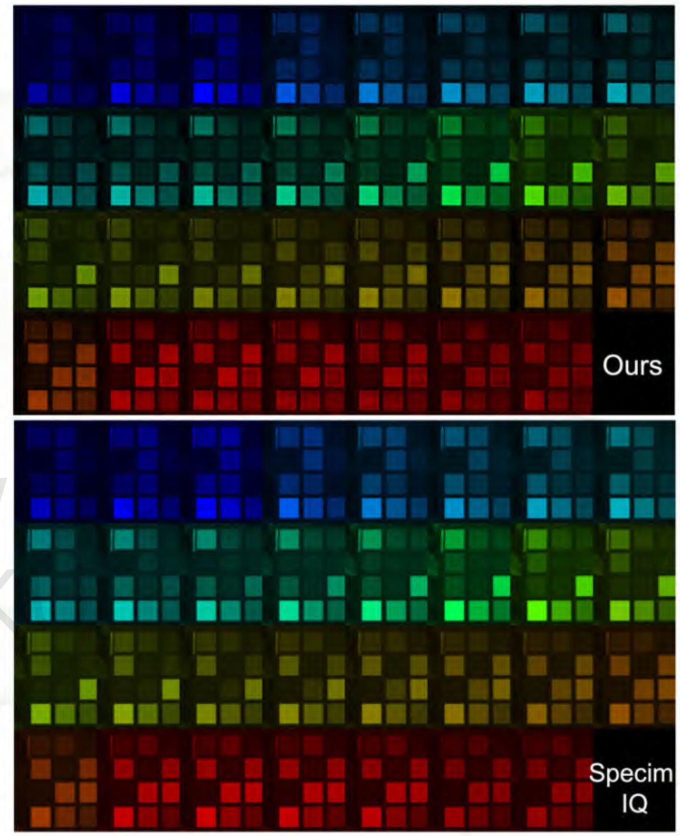
Experimental Results



RGB image



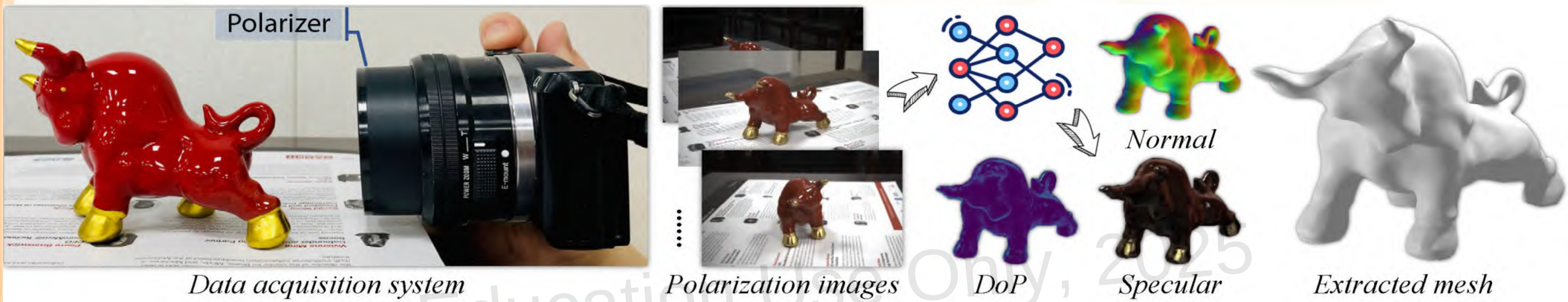
HSI images

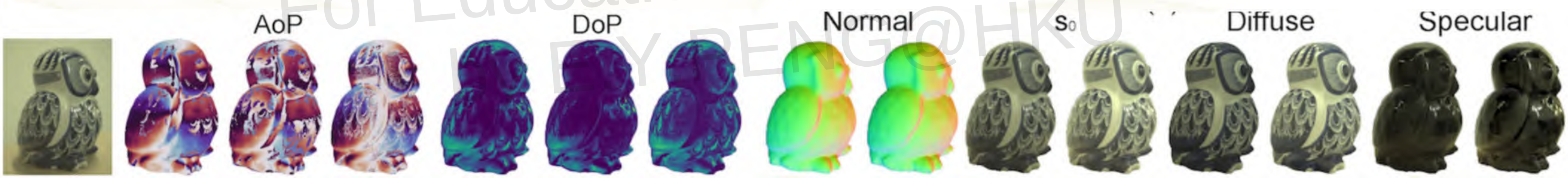


ACM TOG, 2024

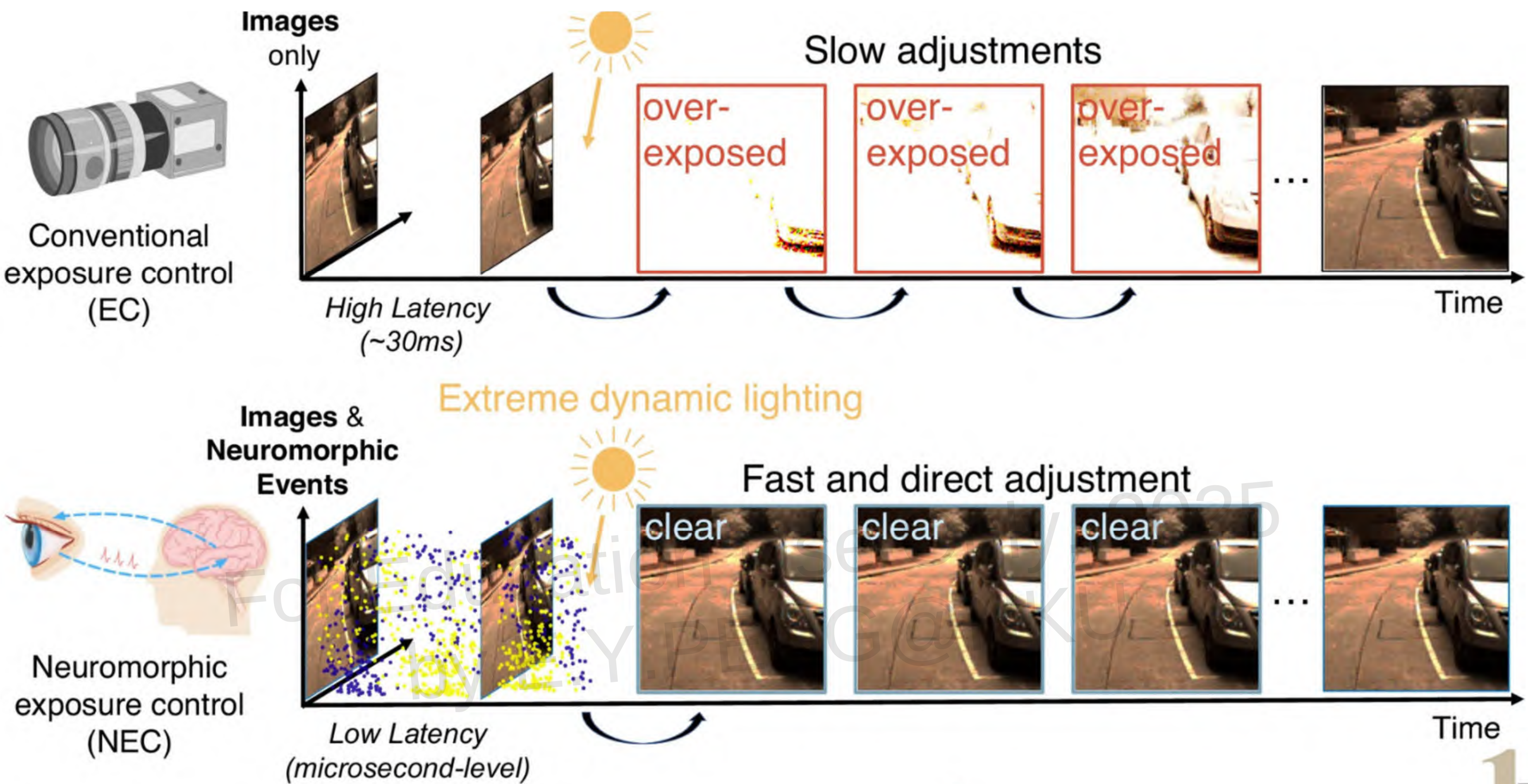
Glossy Object Reconstruction with Polarization Cues

- ***Cost-effective*** polarized acquisition: RGB camera + single linear polarizer
- A single polarized image per view + NeRF + E2E polarization rendering
  = Accurate reconstruction & radiance decomposition



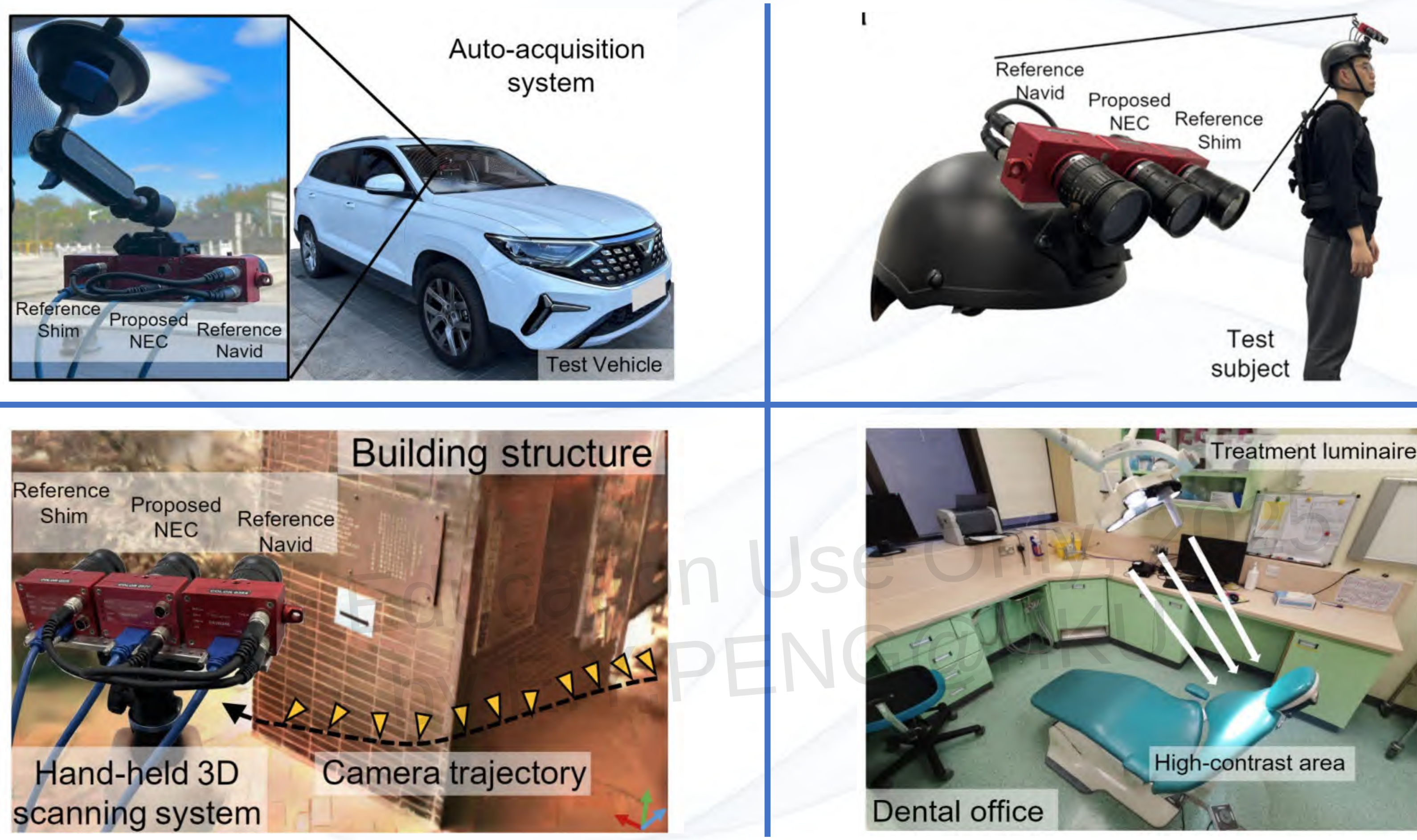


* *Bojian Wu, Yifan Peng, Ruizhen Hu, and Xiaowei Zhou, IEEE CVPR, 2025 (Highlight)*



Conventional
exposure control
(EC)
Images
only
High Latency
(~30ms)
Slow adjustments
over-
exposed
over-
exposed
over-
exposed
...
Time
Extreme dynamic lighting
Neuromorphic
exposure control
(NEC)
Images &
Neuromorphic
Events
Low Latency
(microsecond-level)
Fast and direct adjustment
clear
clear
clear
...
Time

Machine Vision in Extreme Bright: Embodied Neuromorphic Synergy



* *Lin et al. Seeing in Extreme Bright: Embodied Neuromorphic Synergy for Lighting-robust Machine Vision, Nature Comms., 2024*

Take-home Messages (**Imaging** Beyond RGB)

Why ?

Thinner, lighter products

Large, flexible design

Optimal visual performance

How ?

Wave propagation (DOE or Freeform lens)

Auto-tuning & Data-driven advances

Physics + AI **differentiable** optimization

What ?

Possibly compact form factor optics

High-definition image reconstruction

Domain-specific visual & sensory applications

WeChat Official Account: ***IntelligentOptics***

Intelligent **O**ptics **S**haring

感知 | 计算

成像 | 显示

Thank You

evanpeng@hku.hk

Thank You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VISUAL COMPUTI
15 – 16 April 2025
10:00 a
Multi-purpose Zone Room 1, 3/F, M
The University of Hong Kong (HKU
Chair: Prof. Evan Y. Peng @ HKU EEE
ACKNOWLEDGEMENT:


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VISUAL COMPUTING 2025
15 – 16 April 2025
10:00 am
Multi-purpose Zone Room 1, 3/F, Main Library,
The University of Hong Kong (HKU)
Chair: Prof. Evan Y. Peng @ HKU EEE x CS
FISVC2025
Details & Registration
www.eee.hku.hk/20250415
WORKSHOP OBJECTIVES
• Encourage Innovative Spirit
• Promote Excellence and Sustain Quality
• Strive for Improvement
• Connect Communities
Meet Our Speakers!
David FORSYTH
University of Illinois Urbana-Champaign (UIUC)
The Joy of Latents: What Image Generators "Know" and Don't "Know", and Why It Matters
Xiaojuan QI
The University of Hong Kong (HKU)
Learning 3D Representations from Videos
Hongzhi WU
Zhejiang University (ZJU)
Differentiable Acquisition of Appearance and Geometry
Taku KOMURA & Hongbo FU
HKU & HKUST
ACM SIGGRAPH Asia 2025 Pitching
Wenzheng CHEN
Peking University (PKU)
Open-World Rain Simulator
He SUN
Peking University (PKU)
Diffusion Posterior Sampling for Computational Imaging with Inaccurate Priors or Physics
Yinqiang ZHENG
The University of Tokyo (UTokyo)
Security Concerns on Visual AI beyond RGB Domain
Tianfan XUE
The Chinese University of Hong Kong (CUHK)
Computational Photography in the Age of Foundation and Generative Models
Yuanmu YANG
Tsinghua University (THU)
Flat-Optics for Imaging with Extended Information
Ping TAN
Hong Kong University of Science and Technology (HKUST)
Towards Better Gaussian Splatting: Enhancing Geometry and Volumetric Rendering
Seung-Hwan BAEK
Pohang University of Science and Technology (POSTECH)
Computational Imaging for Graphics, Vision, Robotics, and Science
• Closing Remarks: Prof. Kaibin HUANG, Head of HKU-EEE

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