# X-Mask: Improving Soft-Edge Occlusion in Optical See-Through Displays with Cross-Shaped Pinholes


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Background

# Transparent Virtual Object in OST-HMDs

**Conventional OST-HMD**

Transparent teapot

**Occlusion mask**

**Occlusion Display**

Physically block the incoming light

Background

# Transparent Virtual Object in OST-HMDs

**Conventional OST-HMD**

Transparent teapot

**Occlusion mask**

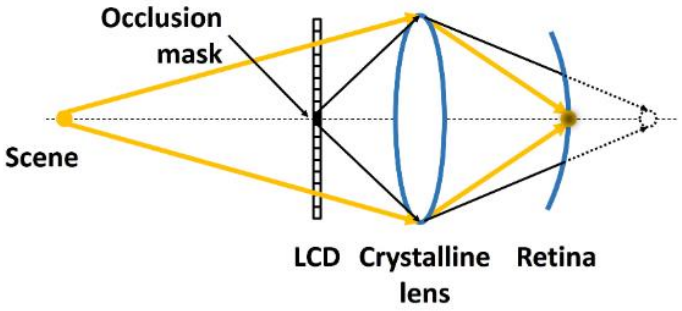
**Occlusion Display**

Solid teapot with depth cue

# Background
# Soft-Edge and Hard-Edge Occlusion

**Soft-edge occlusion**

Compact but blurry

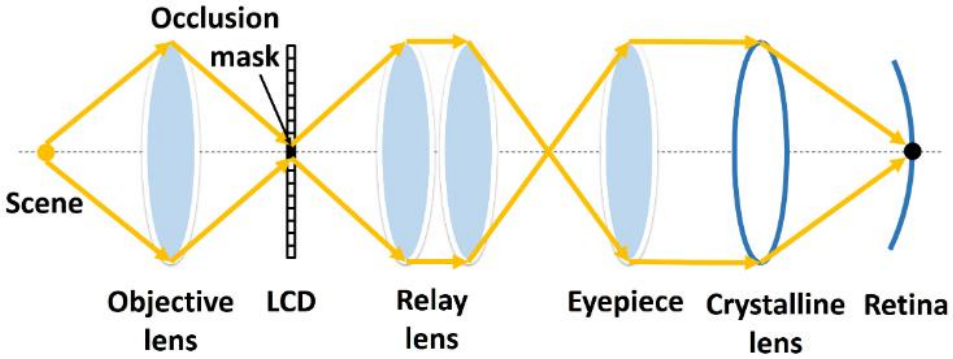



Defocused occlusion mask

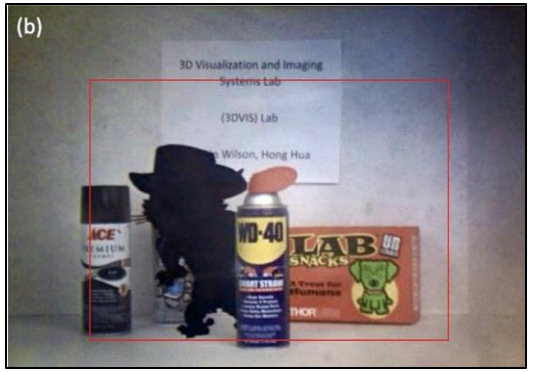

(Itoh et al., 2017)

**Hard-edge occlusion**

Sharp but bulky



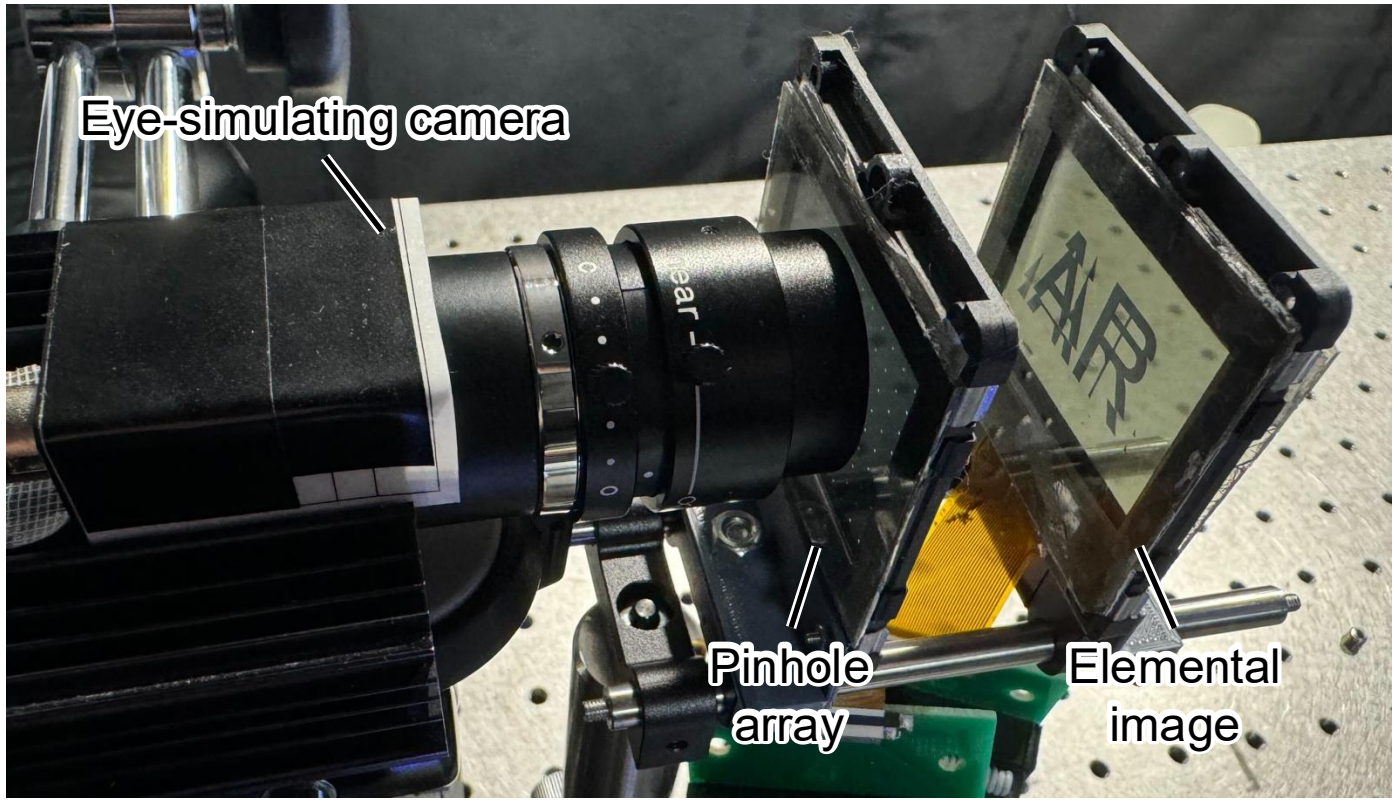

Lenses align focus for both scene and occlusion mask




(Wilson & Hua, 2021)

Previous Work

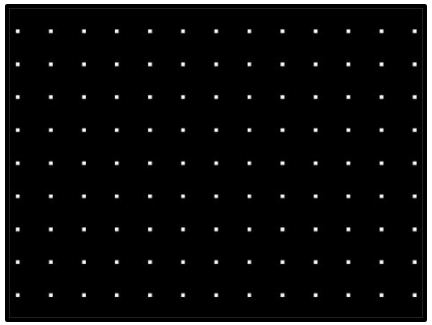
# Pinhole-Array-Based Displays



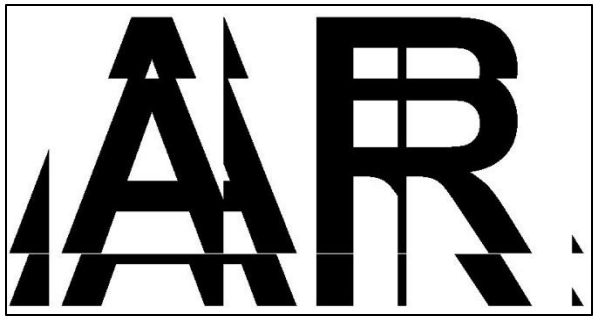

Xiaodan Hu, et al. “Pinhole Occlusion”, *IEEE VRW 2024*

## PA as a lensless solution

- Pinhole = tiny apertures
  → all-in-focus
- Multiple pinholes
  → brighter image
- But split views
  → need elemental images

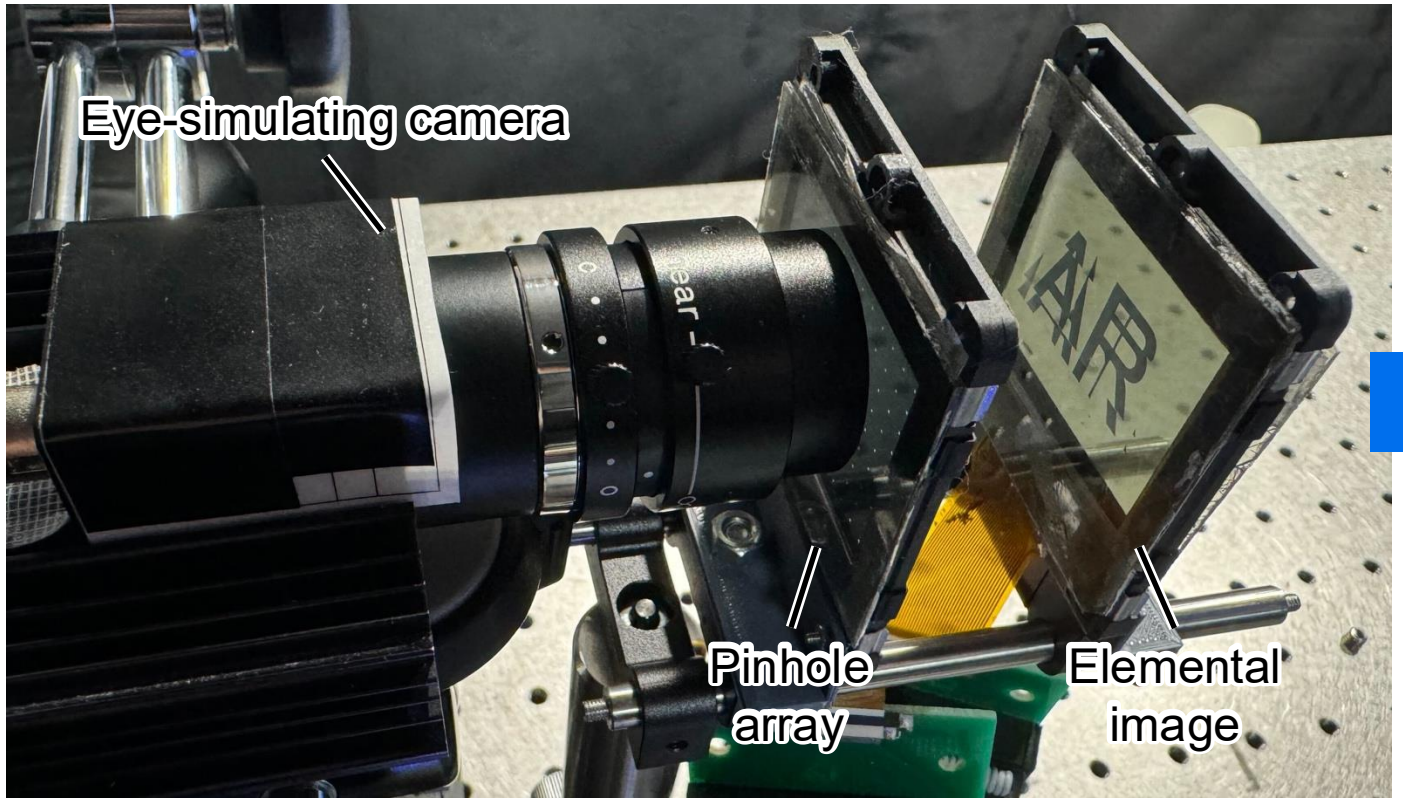


Pinhole array

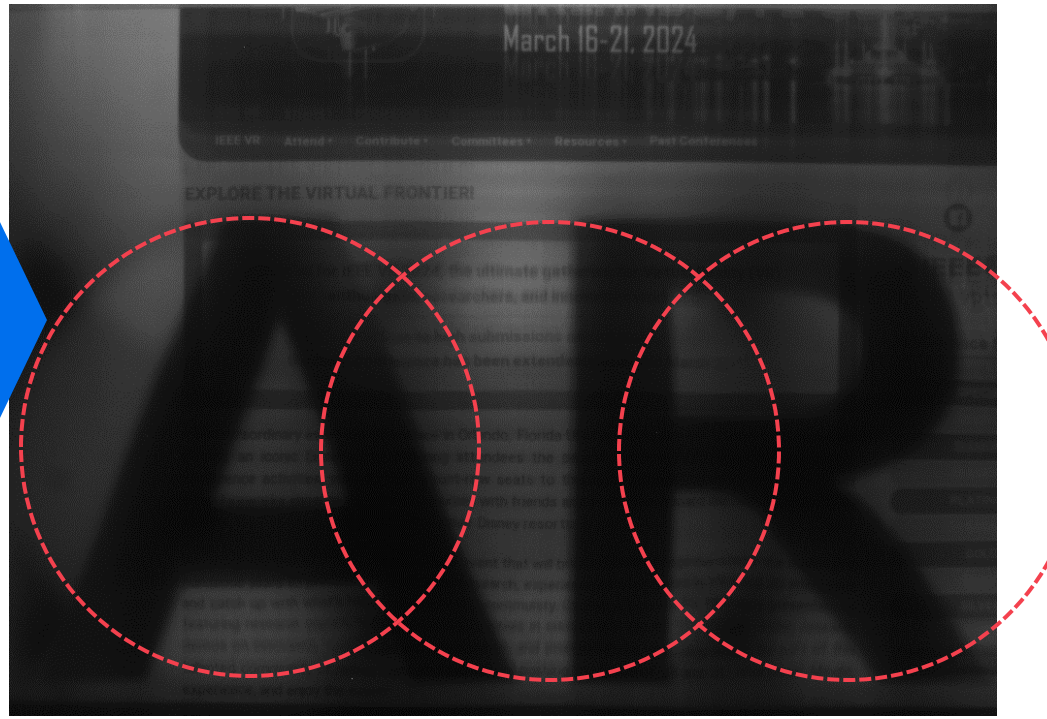


Elemental images

# Previous Work
# Artifacts Caused by Defocused Pinholes




Sharper! Artifacts!



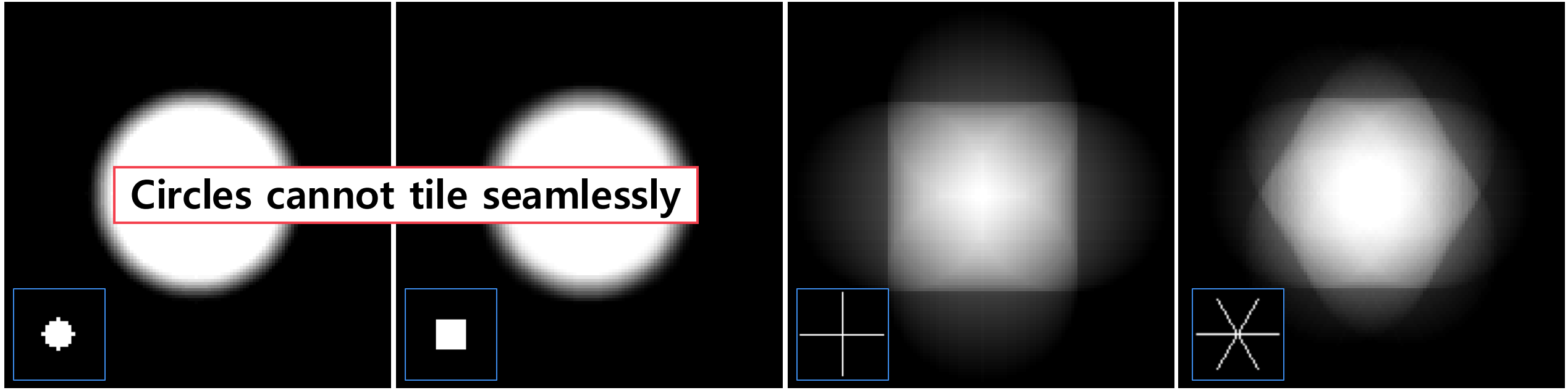

Xiaodan Hu, et al. "Pinhole Occlusion: Enhancing Soft-Edge Occlusion Using a Dynamic Pinhole Array." *IEEE VRW 2024*

## Proposed Method

# X-Mask: Cross-Shaped Pinholes

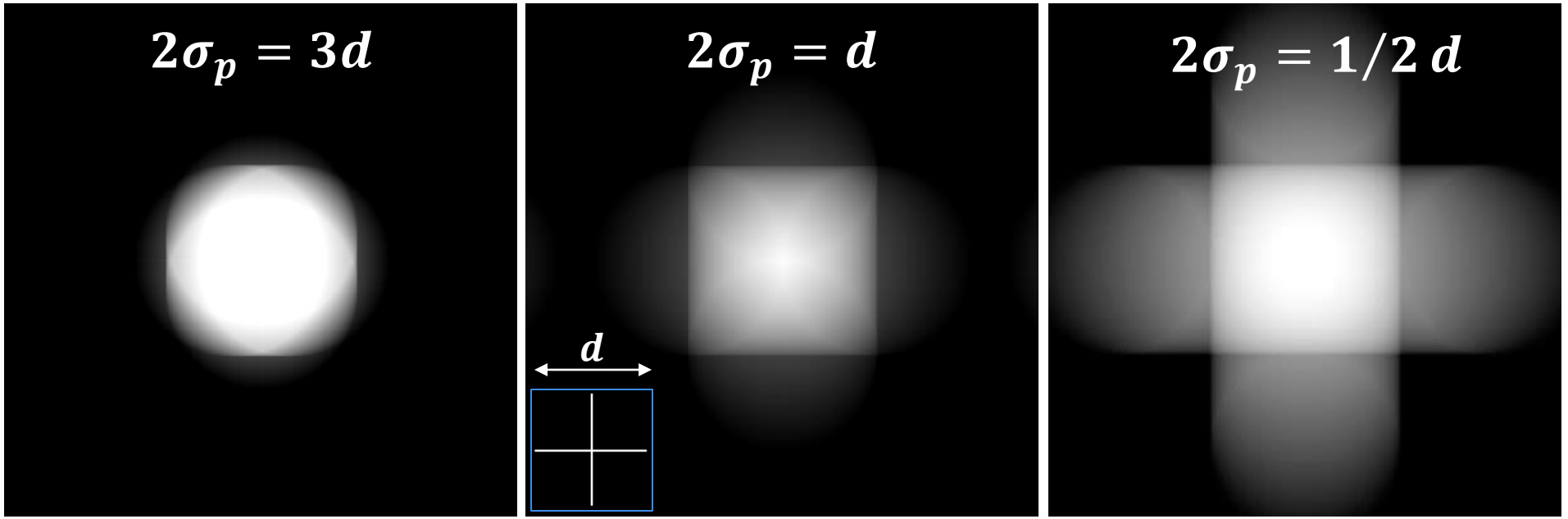
1 mm 4 mm

**Blur = Convolution of pinhole pattern and pupil aperture**



Proposed Method

# Relation Between Line Length & Squareness




$d < 2\sigma_p \rightarrow$ round

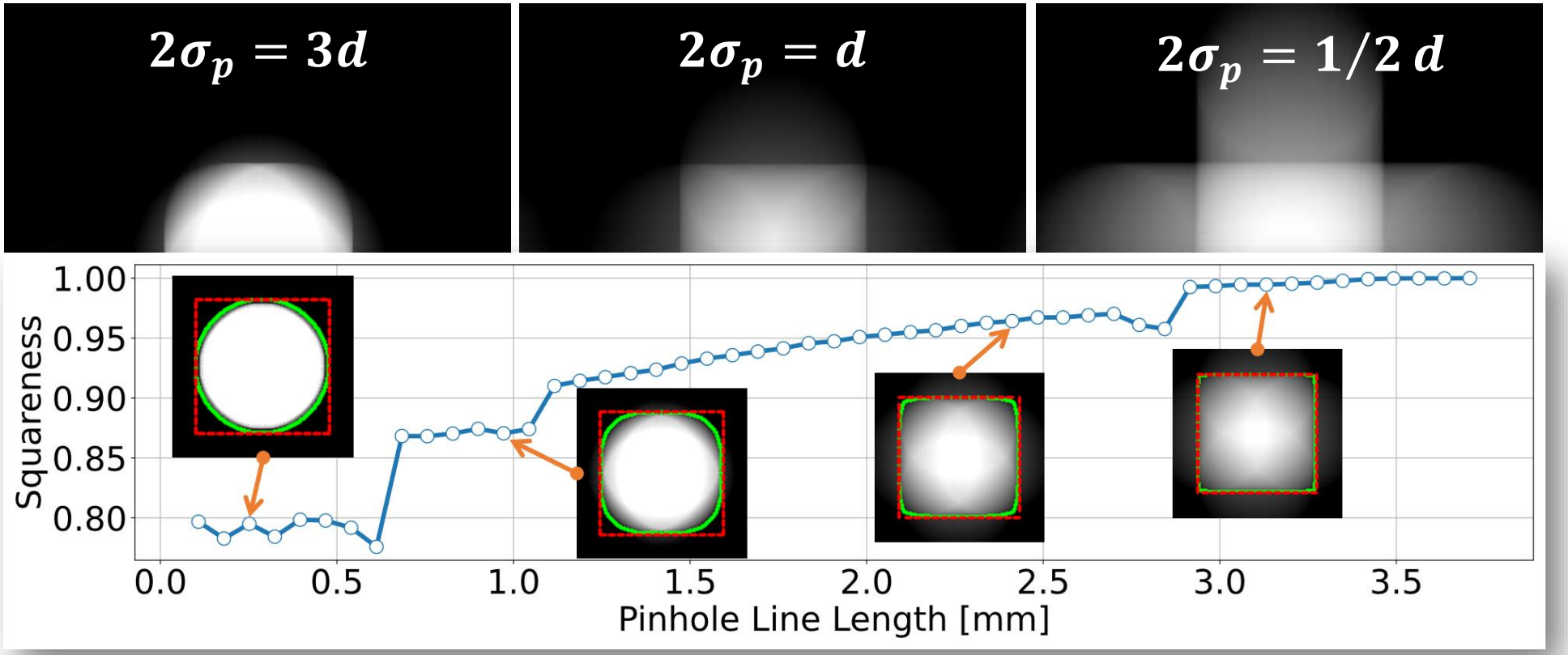
$d = 2\sigma_p \rightarrow$ square

$d > 2\sigma_p \rightarrow$ cross

$\sigma_p$ : pupil radius

Proposed Method

# Relation Between Line Length & Squareness




$d < 2\sigma_p \rightarrow$ round

$d = 2\sigma_p \rightarrow$ square

$d > 2\sigma_p \rightarrow$ cross

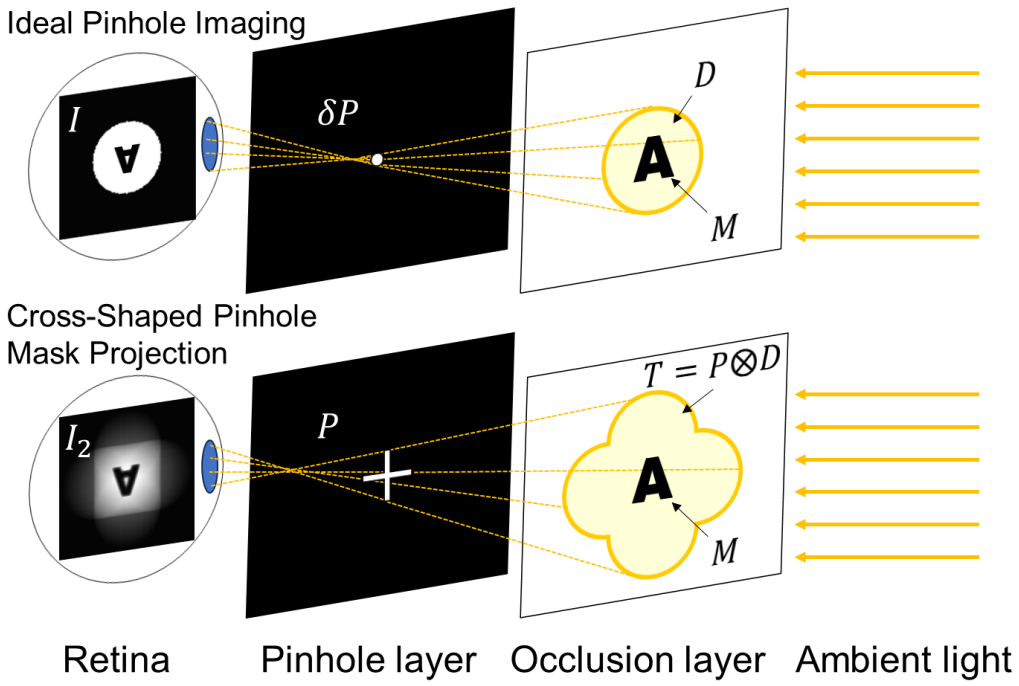
$\sigma_p$ : pupil radius

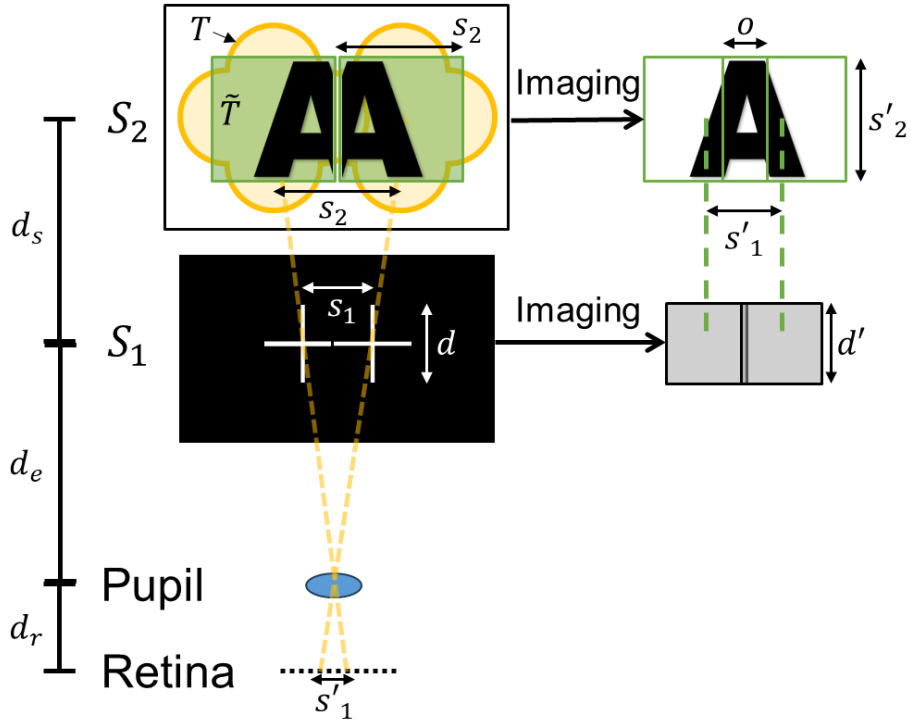
**Squareness = blur contour / min. bounding square**

**(via Sobel edge)**

# Proposed Method

# Elemental Occlusion Mask

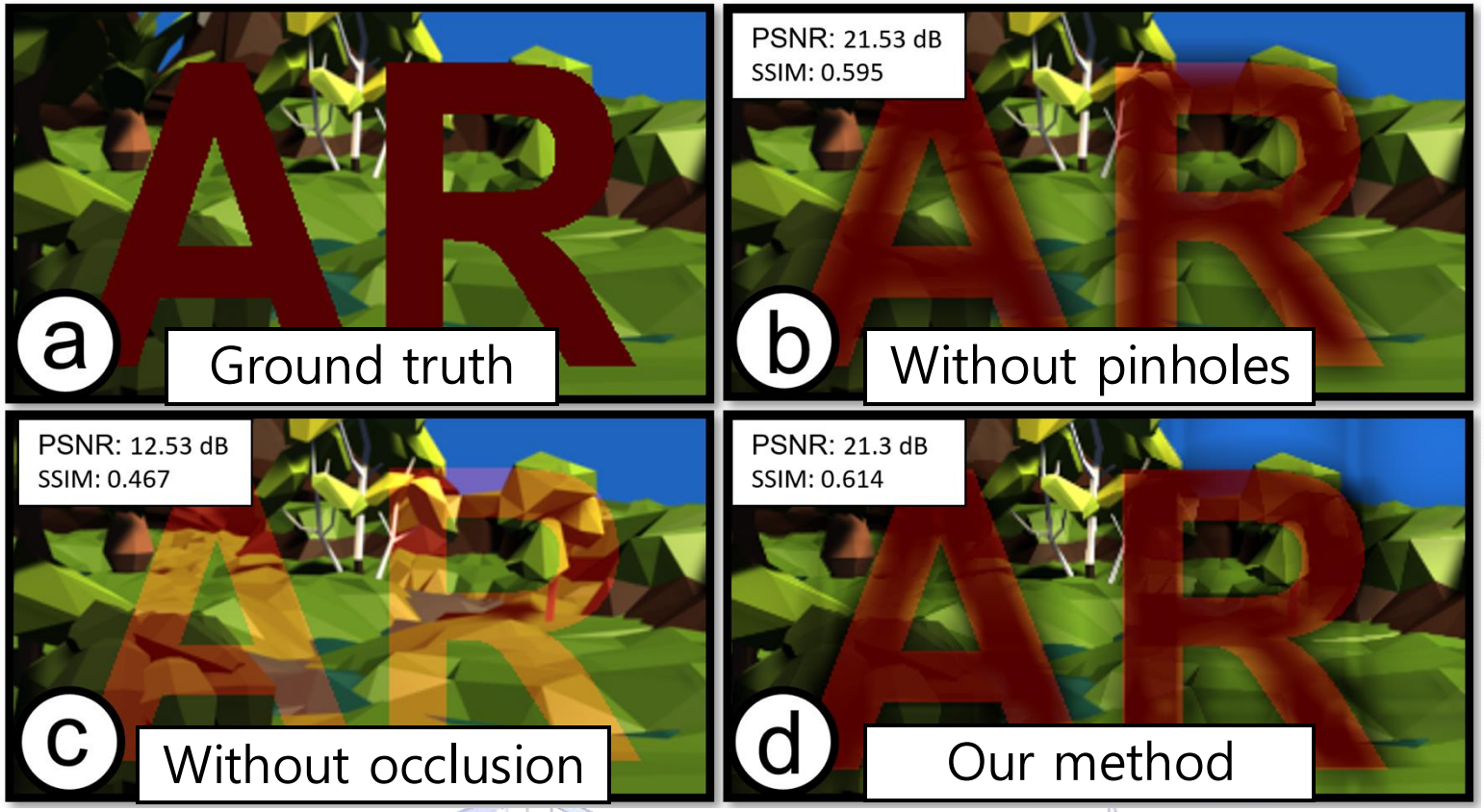


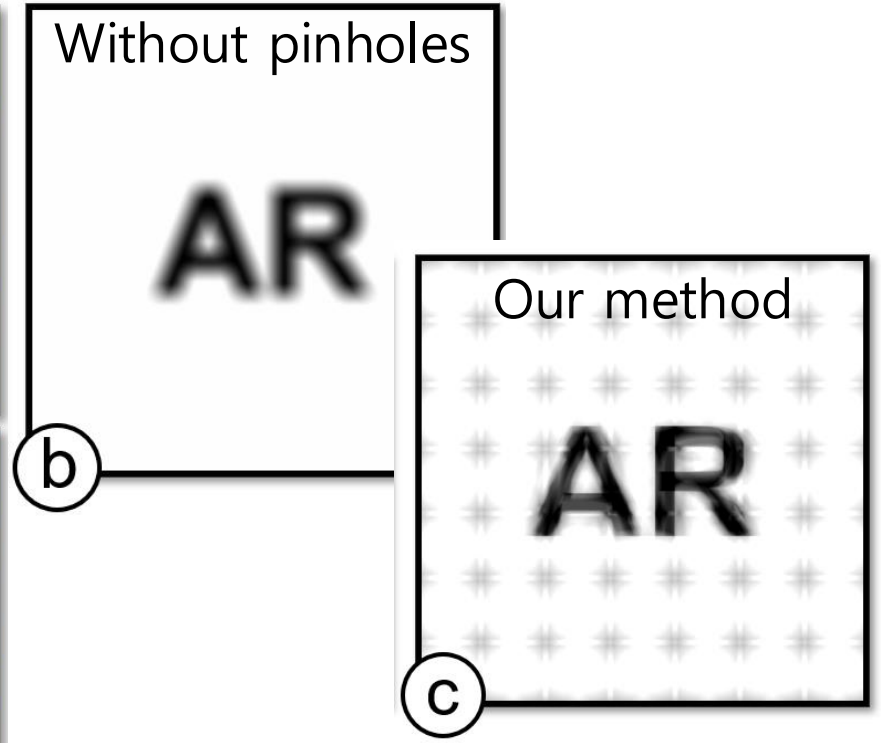



Results

# Simulation Results

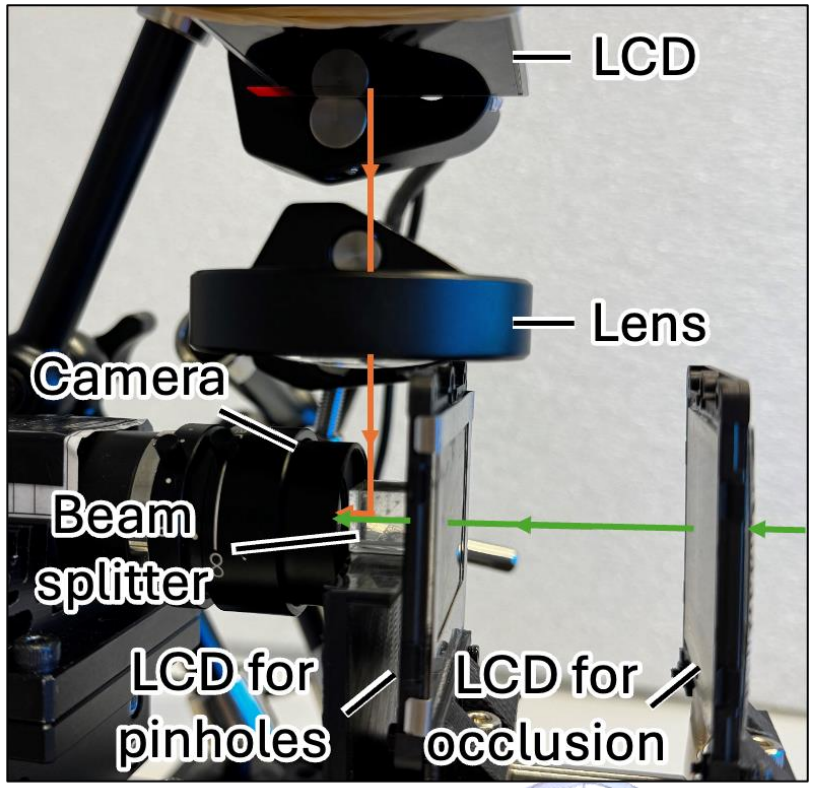
**Pupil size: ~4 mm**
**Focusing distance: 1 m**

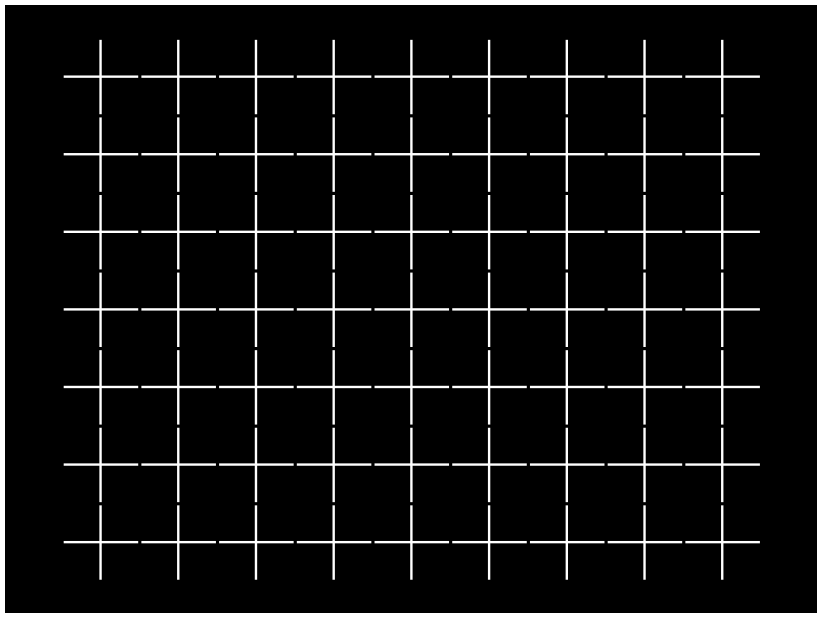


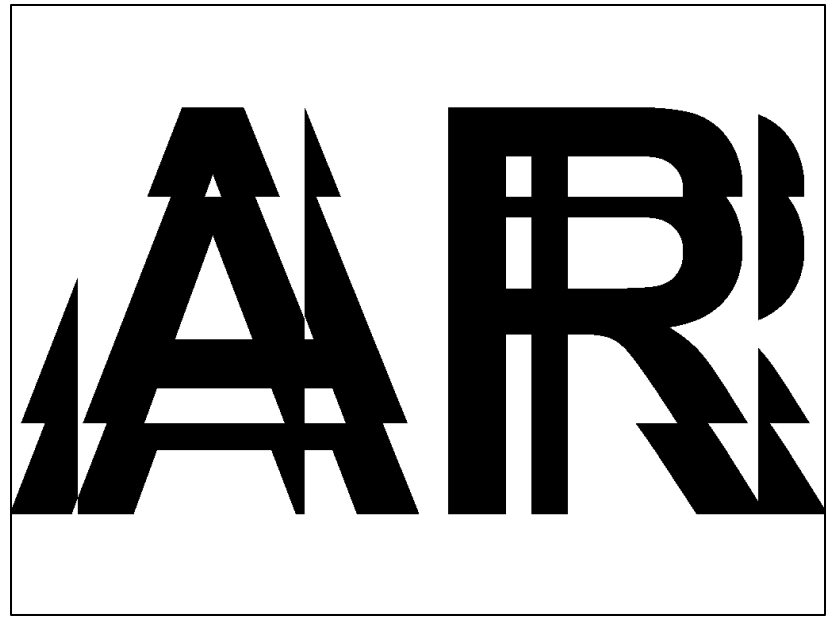

**Remove background**

# Experimental Setups



Pinhole array

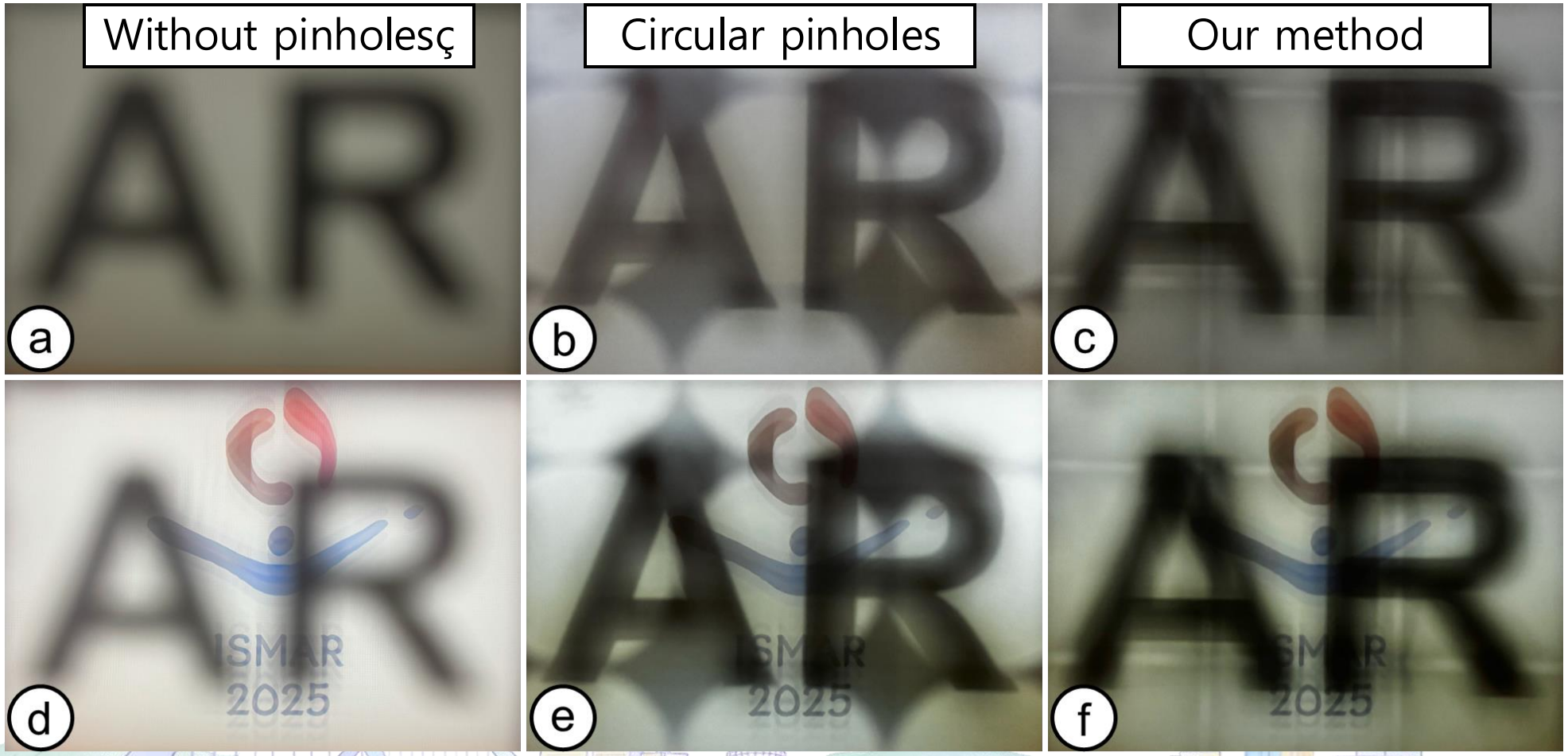


Elemental masks

Results

**Aperture size: ~4 mm**
**Focusing distance: 2 m**

# See-Through Results: Mask Only



Results

Aperture size: ~4 mm
Focusing distance: 2 m

# See-Through Results: + Virtual Image

Without pinholes

Circular pinholes

Our method

# Limitations and Discussion

- **Limitations:**
  - Crosstalk
  - Low brightness
  - Diffraction of transparent LCDs
- **Discussion:**
  - Integrating with eye tracking
  - Consider human visual perception

# Summary

- **X-Mask**: lensless occlusion with cross-shaped pinholes
- **Sharper edges** + **uniform tiling** on retina
- **Validated** in simulation & prototype
- **Lightweight, practical for OST-HMDs**

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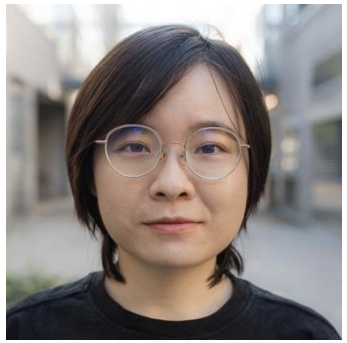

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