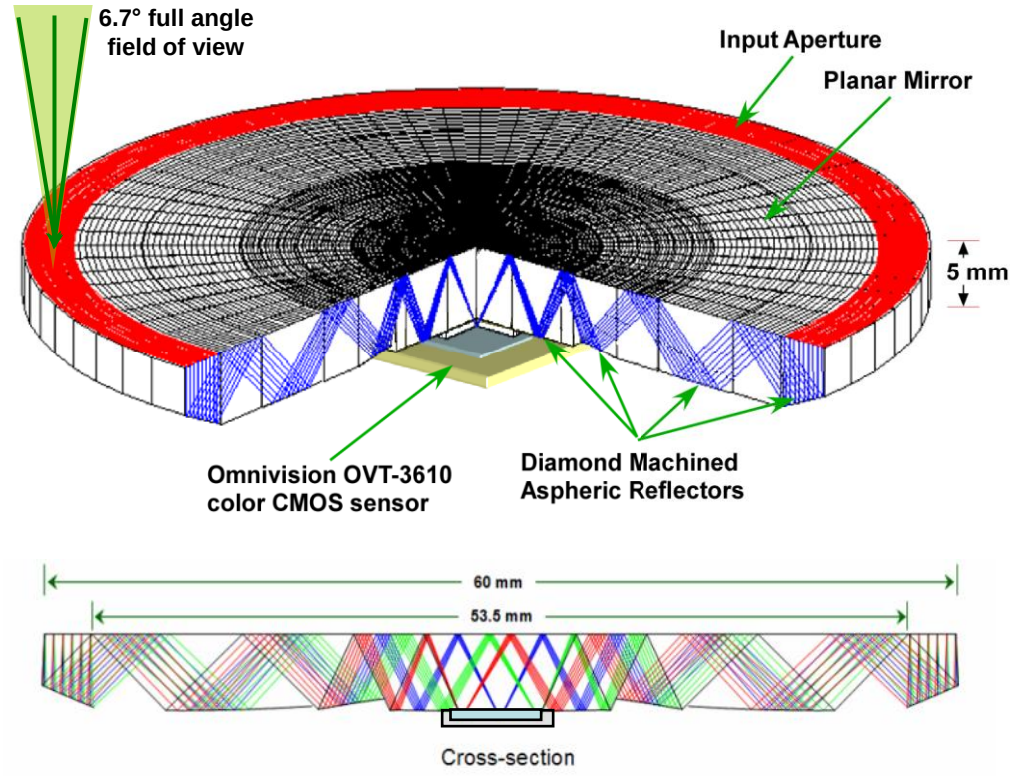
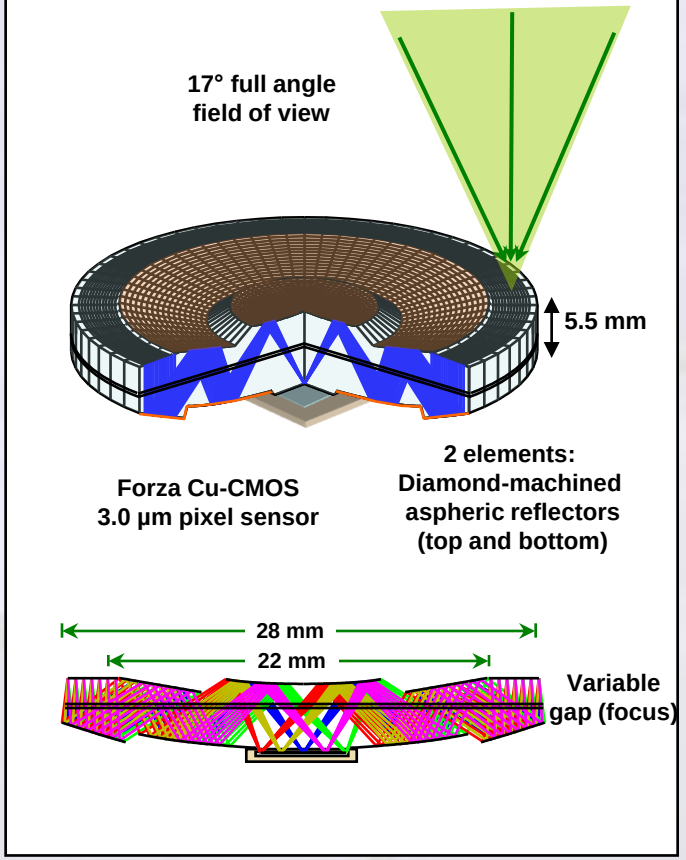
Eight-Reflections vs. Four-Reflections

UCSD Photonics

Eight-Reflection Lens: f = 38 mm



Four-Reflection Lens: f = 19 mm



Four-Reflection lens:

- 2 plano-aspheric elements with index-matched gap
- Variable gap focus adjustment
- Pupil phase coding & smaller focal length for increased depth of field

Result: 75% smaller, 38% aperture eff., 7x solid angle

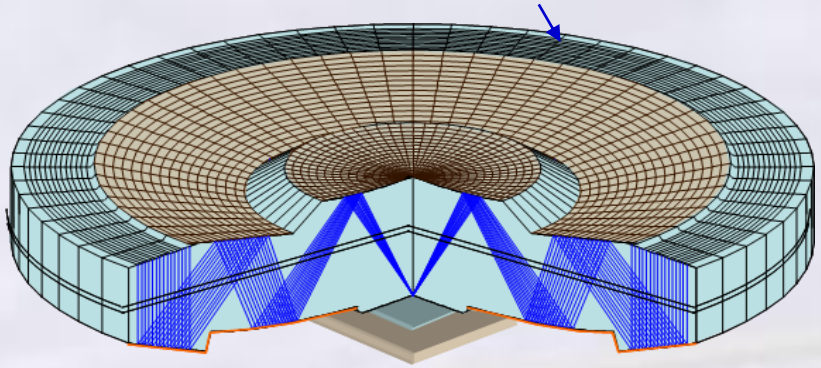
Four-Reflection Adjustable Focus Camera

UCSD Photonics

Four-Reflection Lens:

- **f = 19 mm, F/#$_{eff}$ = 1.15, 17° FOV**
- **1.93 MP Image Sensor (3 µm pixels)**
- **28 mm OD, 5.5 mm thick**
- **0.81 obscuration ratio**
- **Adjustable focus from 3m to infinity**
- **11 µm of lateral color (→ remap RGB planes)**

Input aperture (38% of surface area)



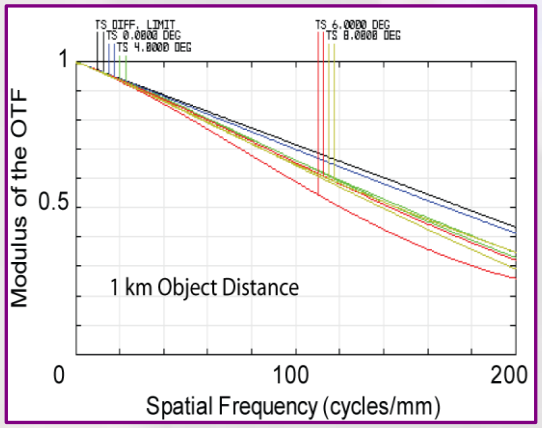
Adjustable Squeeze Focus:

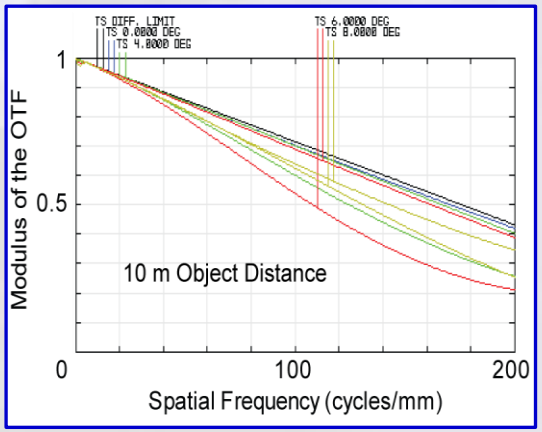
Adjustment range: 14 µm

1 Km

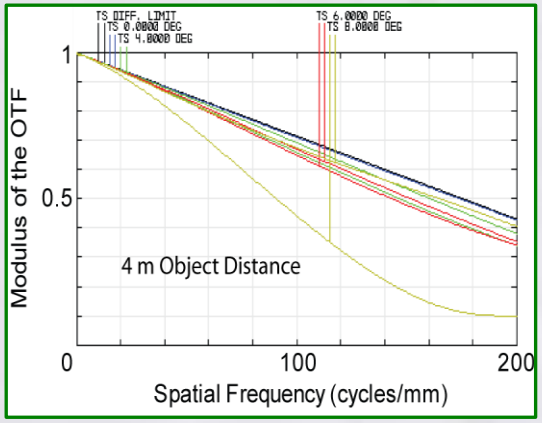
10 m

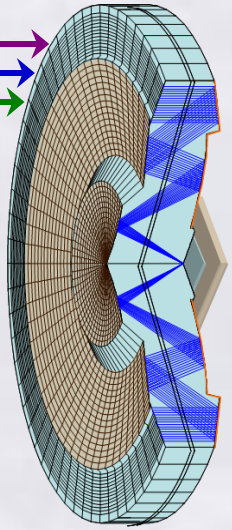
4 m



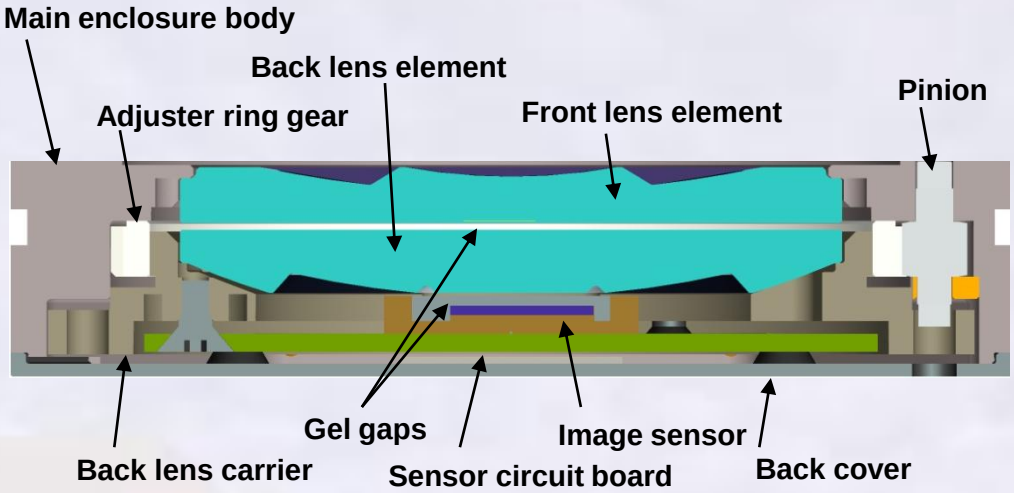


Optimized Design Point

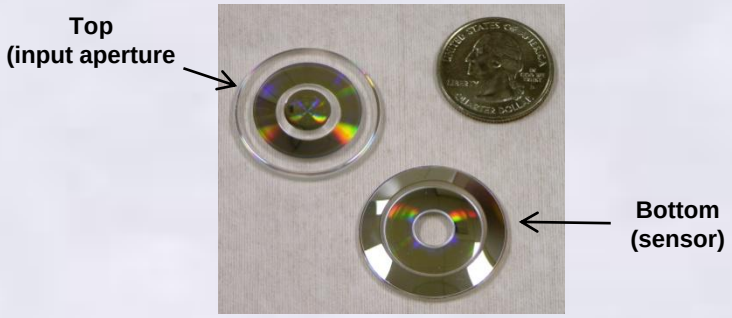


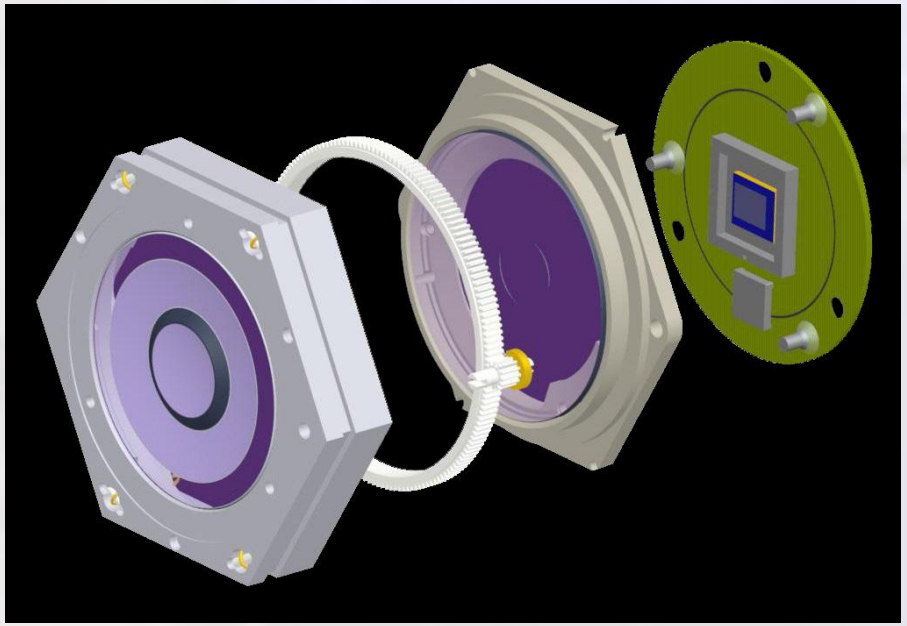


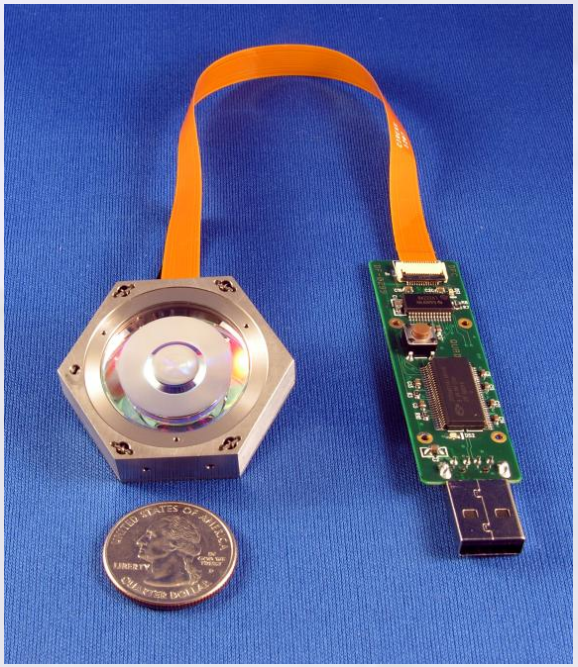
Prototype Optomechanics & Electronics



Diamond turned & coated parts







Ribbon connector high-speed signaling supports full-res video

Connects to USB interface PCB (shown) or multi-camera board

DFC Interactive Camera Environment custom software interface

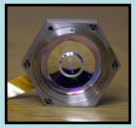
E. J. Tremblay et al., "Ultrathin four-reflection imager" Appl. Opt. **48**, pp. 343-354 (2009)

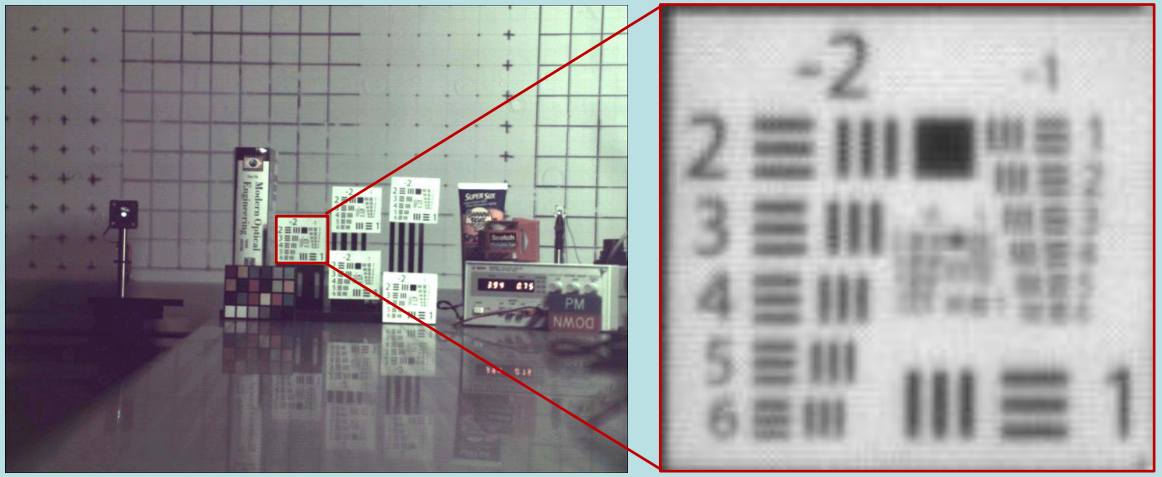
Performance Comparison

UCSD Photonics

Eight-Reflection Camera
6.7° field of view, EFL = 38 mm
Exp: 967 ms w/ gain 10
Depth of Field: ~30 mm

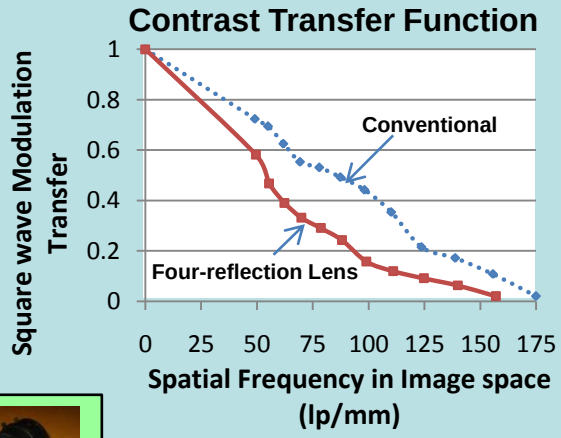
Four-Reflection Camera
17° field of view, EFL = 19 mm
Exp: 40 ms w/ gain ~2
Depth of Field: ~120 mm (4x)

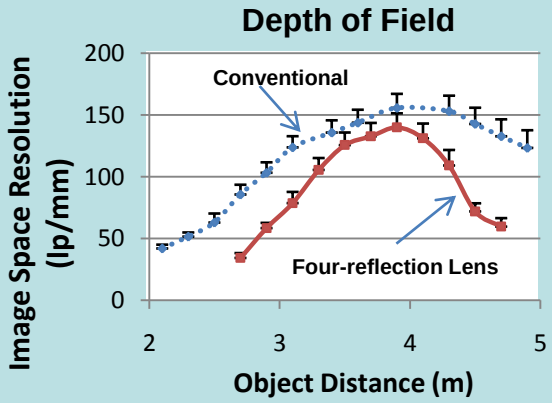




4-Reflection vs. 8-Reflection Summary

- Half Diameter
- 2.5x field of view
- 4x depth of field
- Better sensitivity
- ~Half resolution (due to EFL)

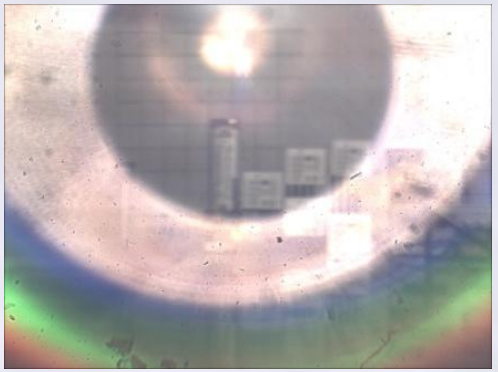




Conventional Comparison:
Sanyo Zoom Lens
F/1.4, EFL = 19 mm

Stray Light in the Four-Reflection Camera

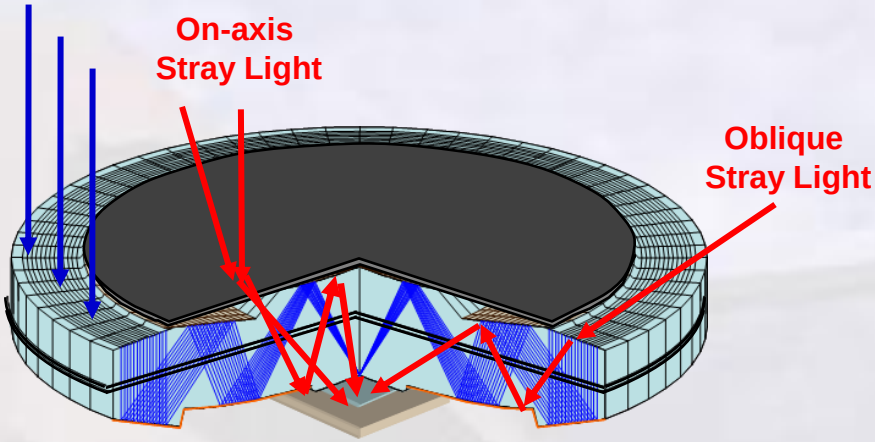
Stray light bench testing by Jason Karp



Bright On-axis Source

A central block is needed to prevent on-axis paths through reflector gaps

Focused Signal



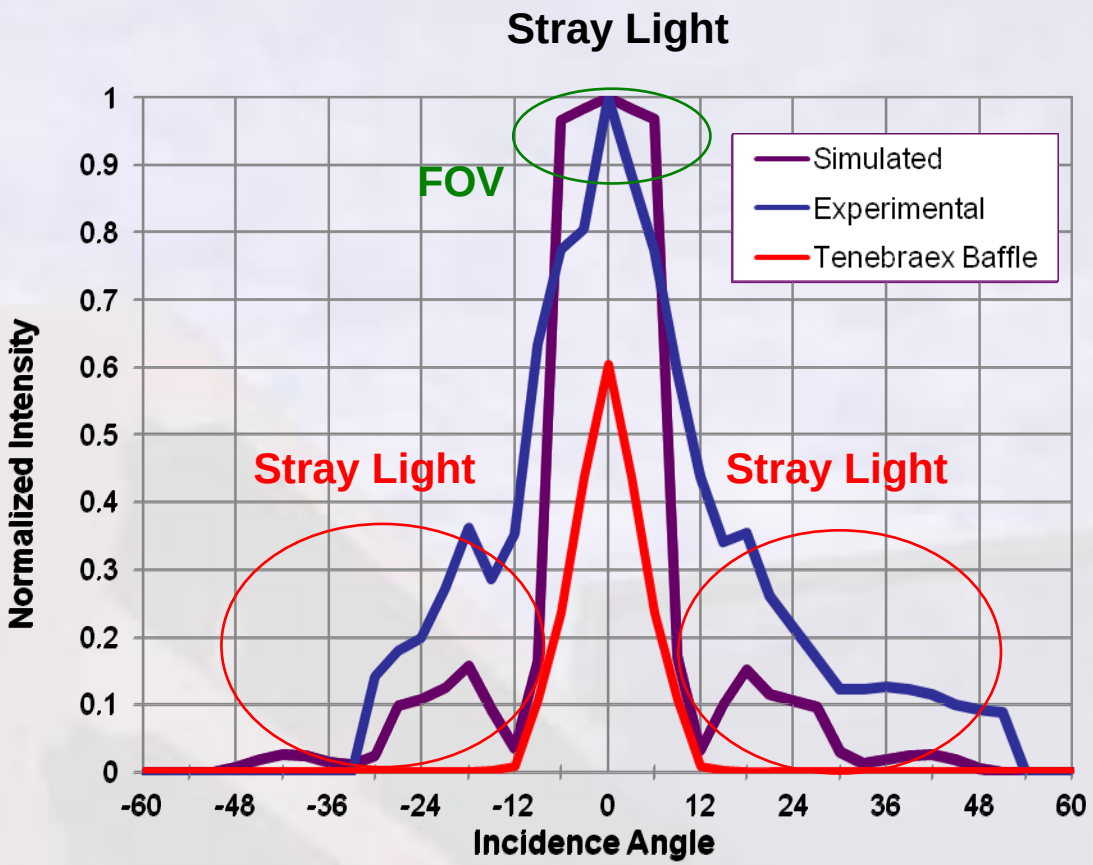
With a central block And no bright Oblique sources

Bright Off-axis Source

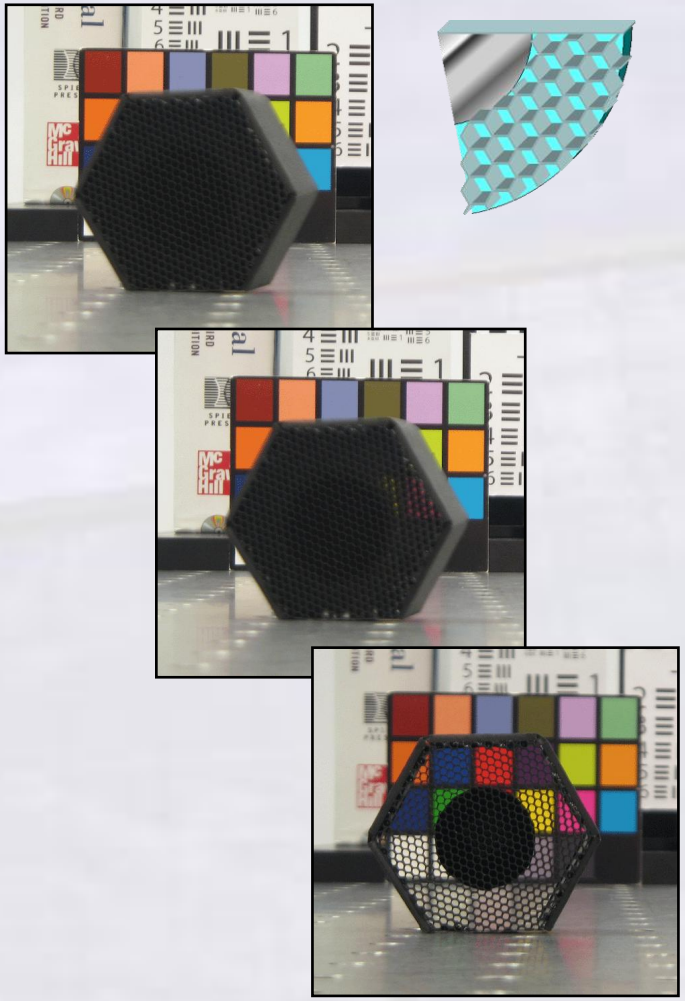
Clear signal to ±8.5° field, Glare shield needed for >±9°

Stray Light in the Four-Reflection Camera

Stray light simulations by Jason Karp



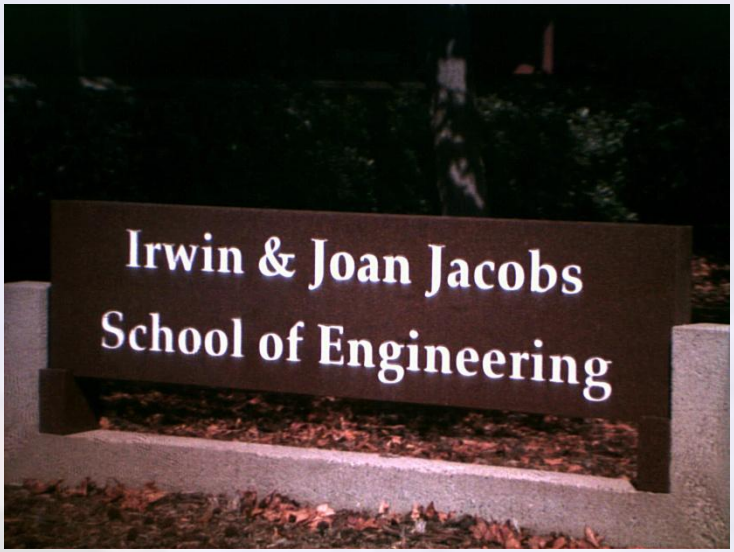
Oblique Light suppression: Commercial Tenebraex "Killflash" glare filter



Origami Optics Graduates from the Lab

UCSD Photonics

Scenes from UCSD campus w/ the 4fold imager: arc-sectioned aperture w/ killflash glare shield)

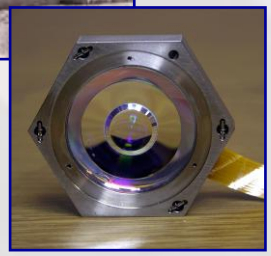


Desert Field Test

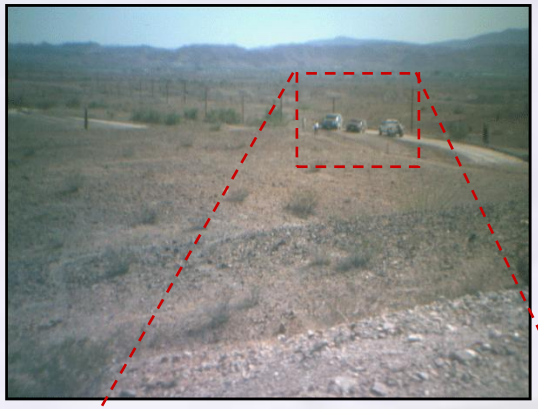
Yuma Proving Grounds, August 15 2007: 50% relative humidity, ground temperature 127°F

Imager concealed in rock pile, focus fixed, aperture stopped to 35° arc: Active optical volume 0.5 cm^3

4 meters



288 meters



473 meters