Transparent Camera
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Why Hard?

• Counter-intuitive?
• How does the sensor accept light?
• How to stop stray light if case is transparent?

Proposed Solution

• Coatings on
  • Case and sensor are complementary
  • Lens and sensor are the same: No need of coating on lens
  • Spatial gap (1) in the sensor
  • No coating in the gap
  [1] Transparent display

• Transparency is minimum when eye looks through the case and sensor
  • Transparency = wavelength fill factor × sensor gap spatial fill factor

• How to improve transparency?
  • (1) Wider bands in the case and narrower bands in the sensor’s filter \(\rightarrow\) noisy
  • Or some overlap \(\rightarrow\) stray light leads to an offset, strong photon noise
  • (2) Wider gap in the sensor \(\rightarrow\) larger holes in the image
  • Tradeoff between transparency and image quality

Implementation

Coating on the sensor

Coating on the case

Absorptive filter

Spatial gap (10μm, No filter)

400

700

wavelength (nm)

Sensor

Captured image

Reconstructed image

Image Restoration

Image quality

After U-net based reconstruction

Before reconstruction

Wavelength fill factor

High-based

Low noise

Gap fill factor

Case gap

Spatial vs. wavelength fill factor

Other Implementations?

Captured Image

Reconstruction

Sensor

Case

Coating on the sensor

Coating on the case (Absorptive)

RGB/(NIR+NUV) separation

Interference-based filter leads to strong reflection

Polarizer leads to stay light noise and low transparency

Vibration sensor?

Combined with Others

• Orthogonal to other camera types, and thus can be combined, like pinhole camera, lensless camera, thin camera, and tiny camera

Image quality vs. transparency

Ground truth

Pixel walls high wall

Case doesn’t even need it

Sensor only exposes to light when case shutter is on

Case is by LCD-based shutter (fast on and off)

LCD-based shutter

Pixels with high wall

Best image quality given transparency

Case gap

Sensor

Implementation

Spatial Coatings

Counter Case

Transparent fish has evolved for 140 million years...

Transparent cellphone

Lens

Sensor

Case

Size of the camera is not to scale