

More computational light transport



15-463, 15-663, 15-862
Computational Photography
Fall 2017, Lecture 23

Course announcements

- Sign-up for final project checkpoint meeting.
 - Moved to Monday-Tuesday,
 - Email me if you cannot make it then.
- Any questions about homework 5?

Overview of today's lecture

- Direct and global illumination.
- Direct-global separation using high-frequency illumination.
- Direct-global separation using epipolar probing.
- Energy-efficient epipolar imaging.

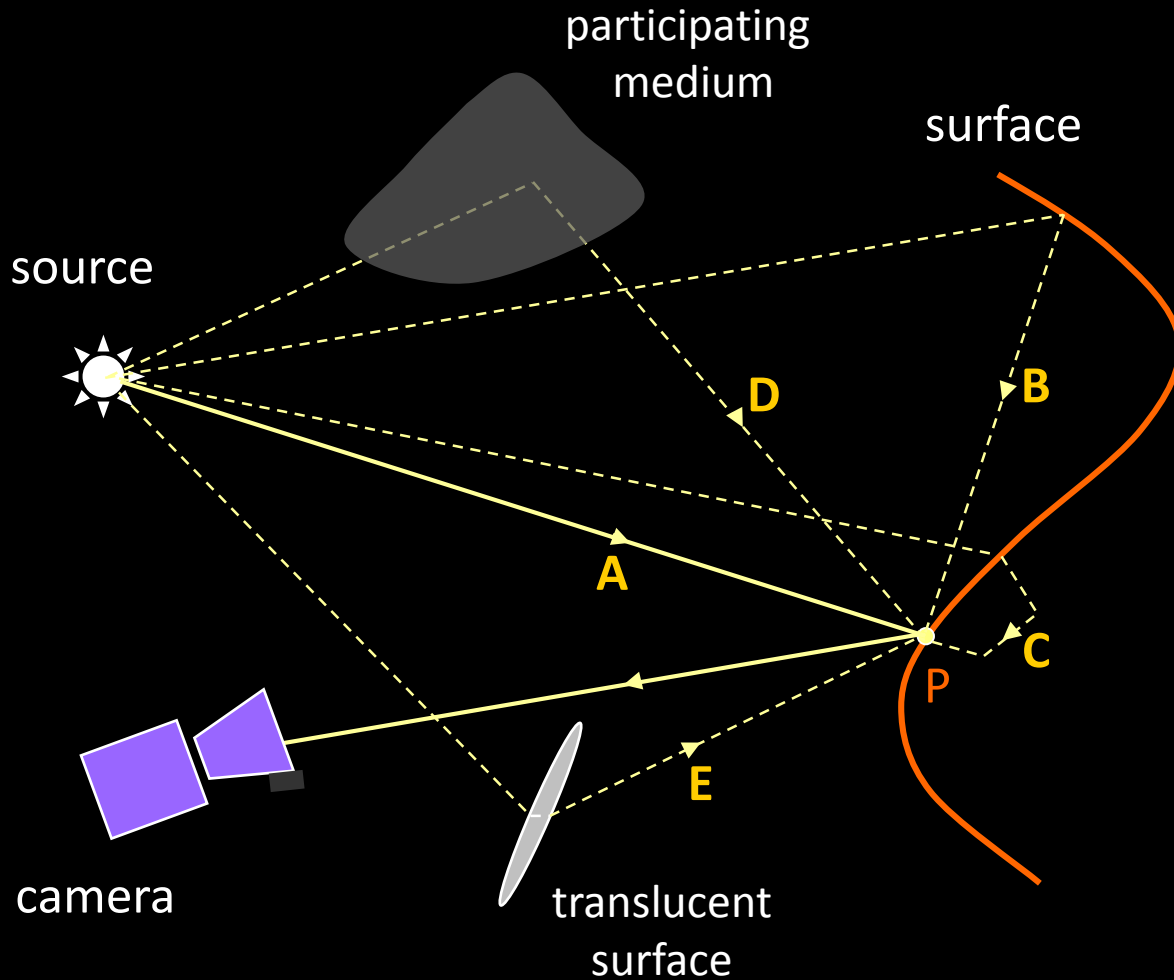
Slide credits

These slides were directly adapted from:

- Shree Nayar (Columbia).
- Matthew O'Toole (Stanford).

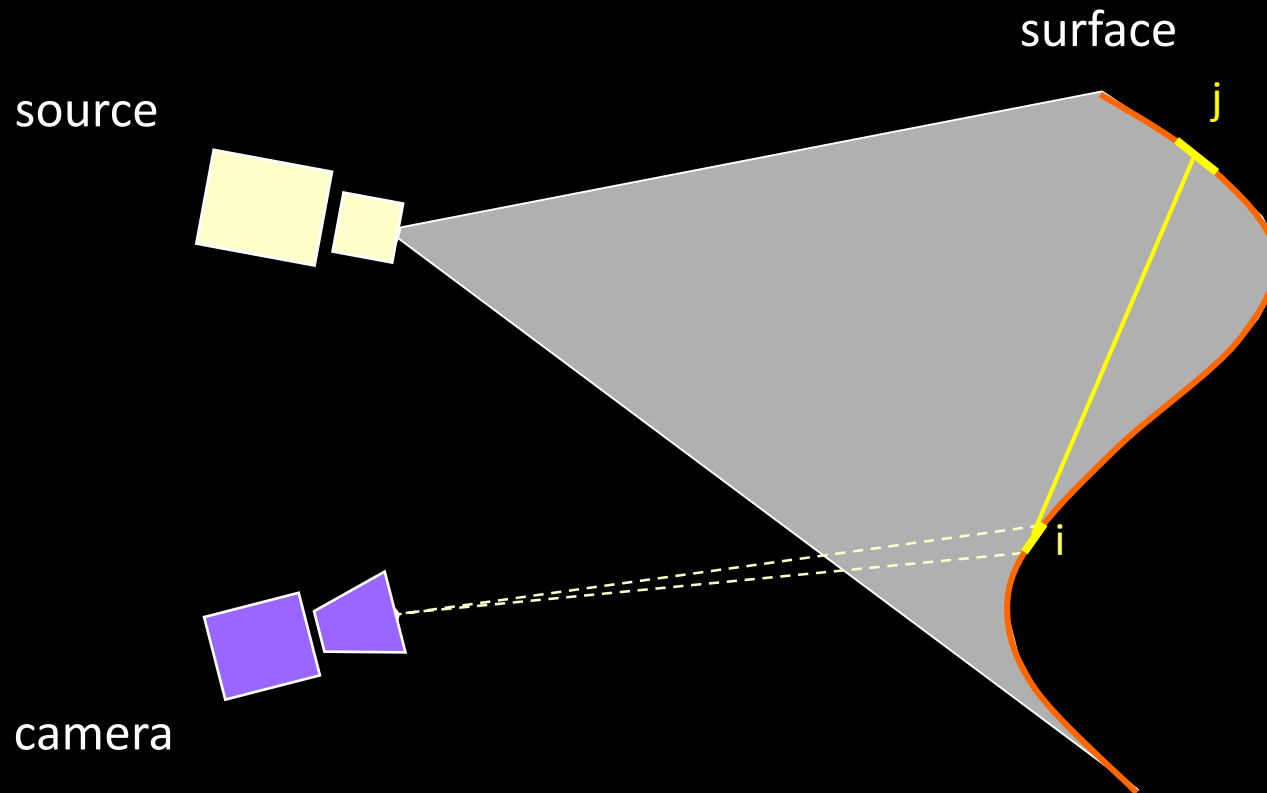
Direct and global illumination

Direct and Global Illumination



- A : Direct
- B : Interreflection
- C : Subsurface
- D : Volumetric
- E : Diffusion

Direct and Global Components: Interreflections



$$L[c, i] = L_d[c, i] + L_g[c, i]$$

radiance

direct

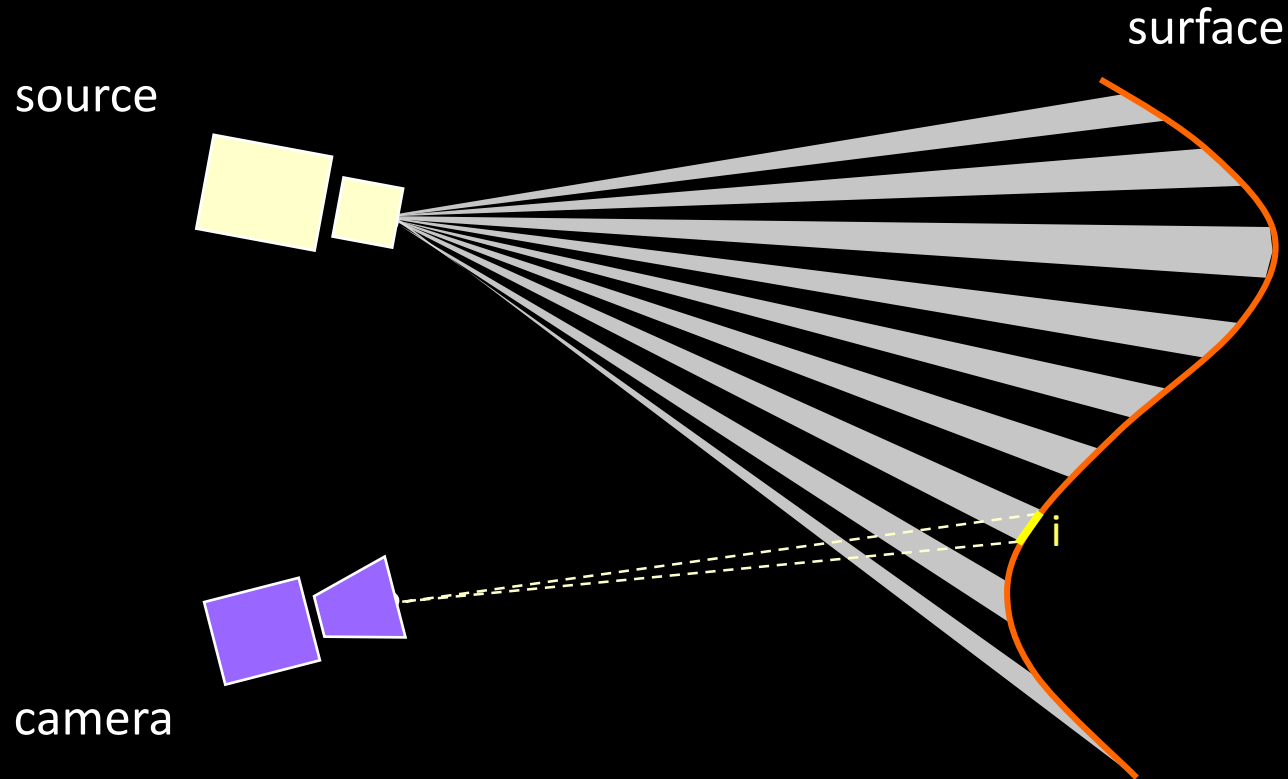
global

$$L_g[c, i] = \sum_P A[i, j] L[i, j]$$

BRDF and geometry

Direct-global separation using high-frequency illumination

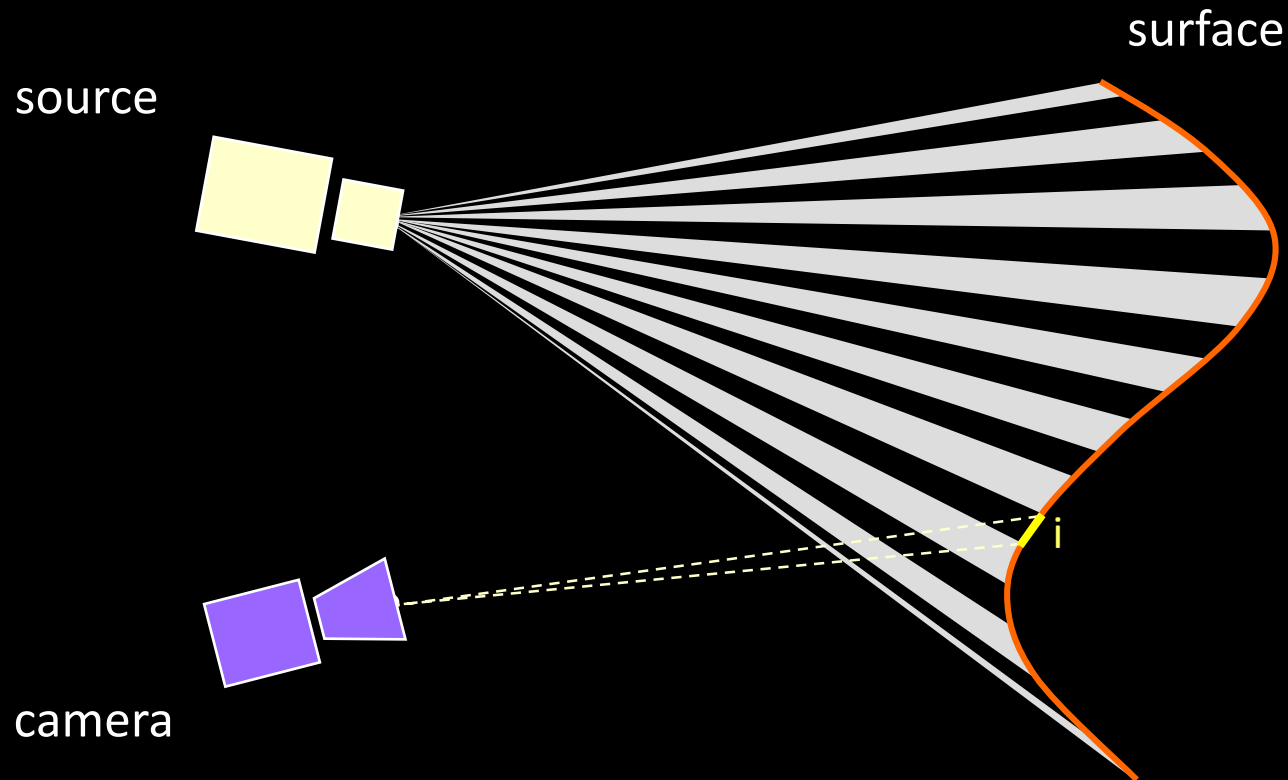
High Frequency Illumination Pattern



$$L^+[c, i] = L_d[c, i] + \alpha L_g[c, i]$$

fraction of activated source elements

High Frequency Illumination Pattern



$$L^+[c, i] = L_d[c, i] + \alpha L_g[c, i]$$

$$L^-[c, i] = (1 - \alpha) L_g[c, i]$$

fraction of activated source elements

Separation from Two Images

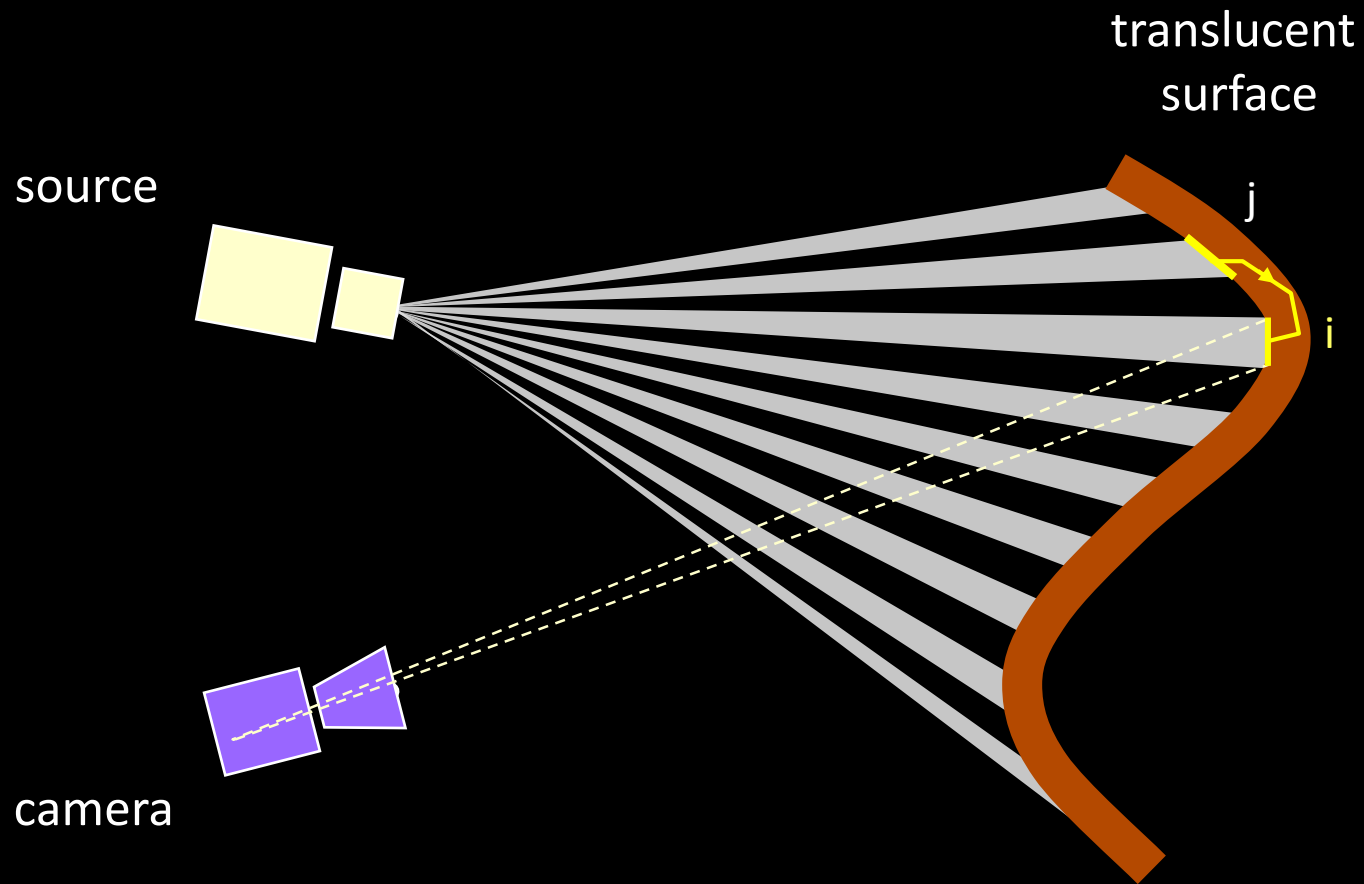
$$\alpha = \frac{1}{2}:$$

$$L_d = L_{\max} - L_{\min}, \quad L_g = 2L_{\min}$$

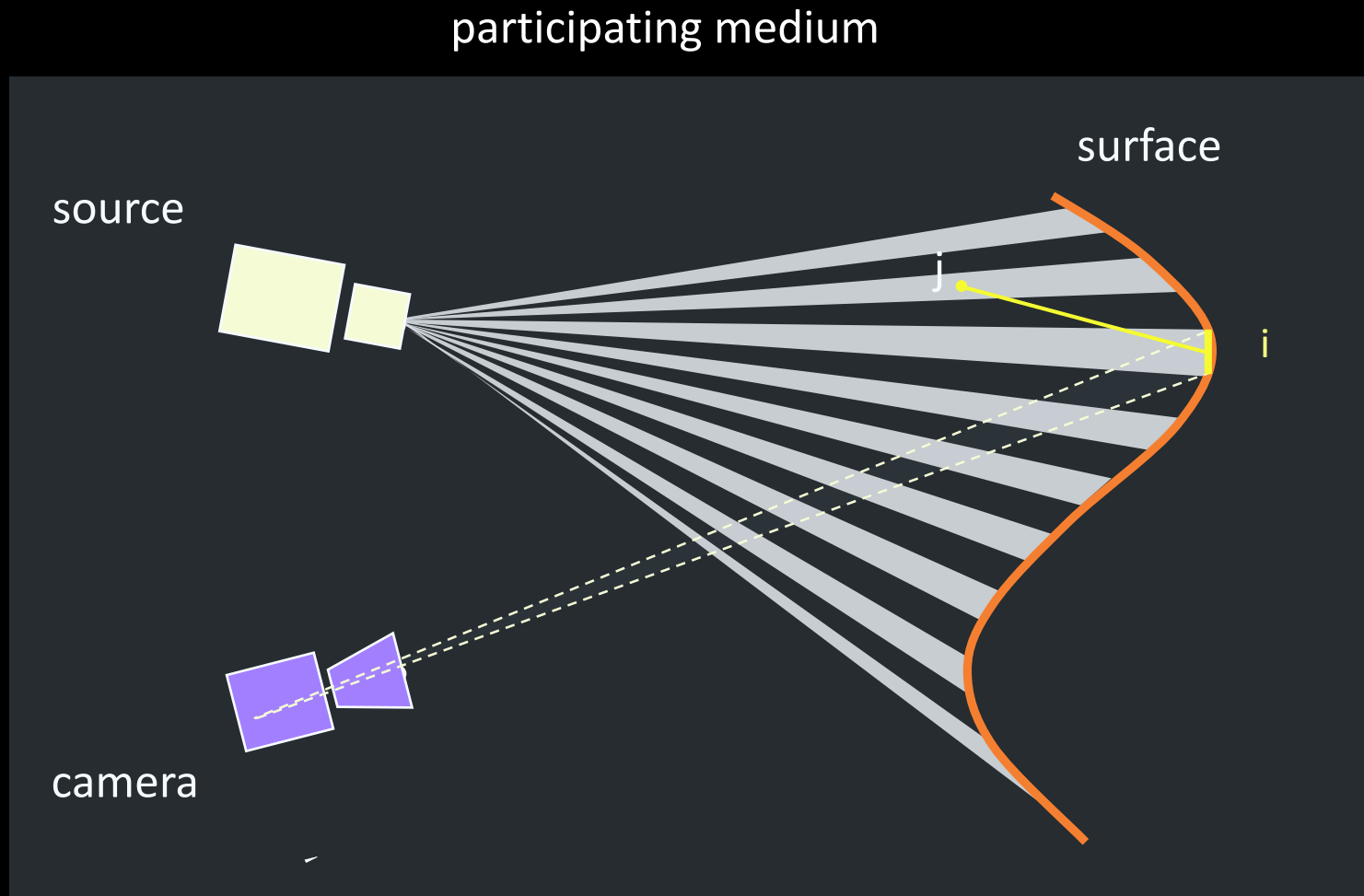
direct

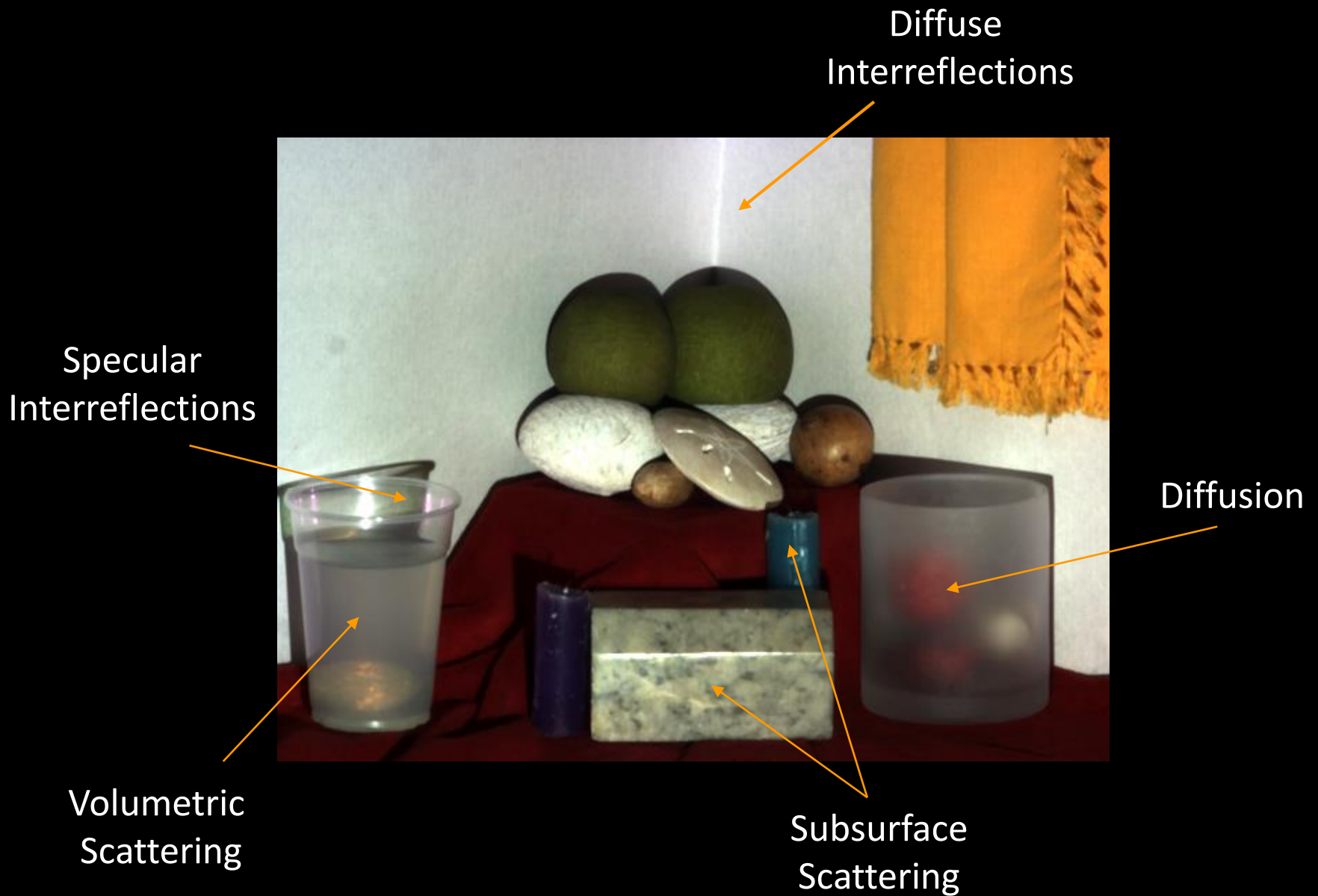
global

Other Global Effects: Subsurface Scattering

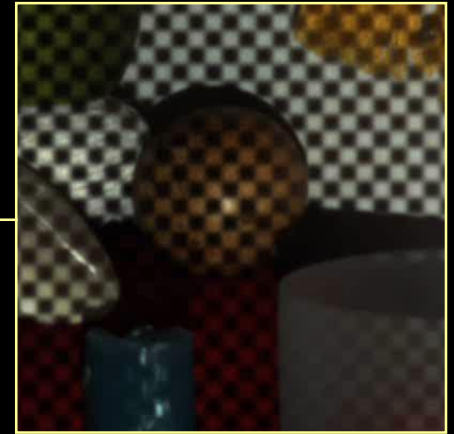
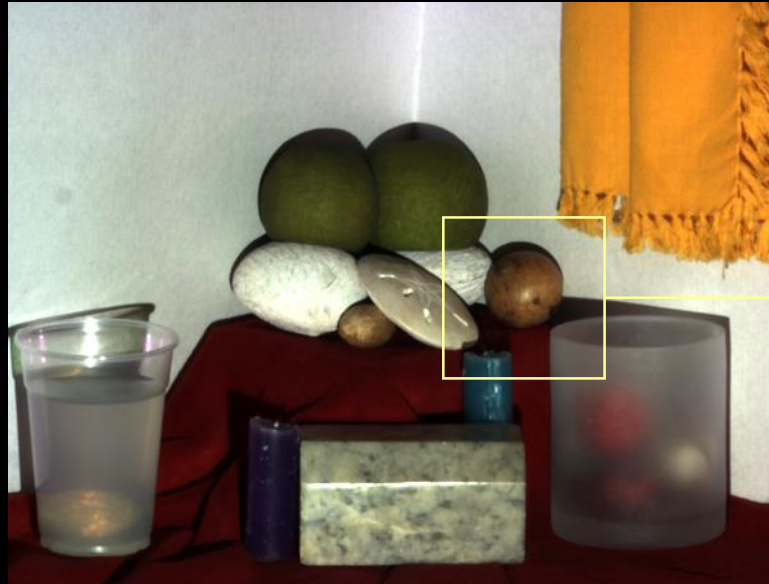


Other Global Effects: Volumetric Scattering





Scene



Direct

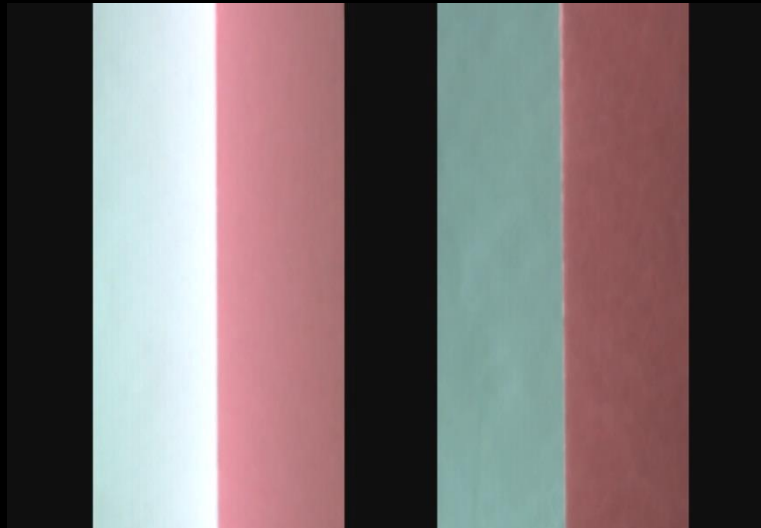


Global

V-Grooves: Diffuse Interreflections

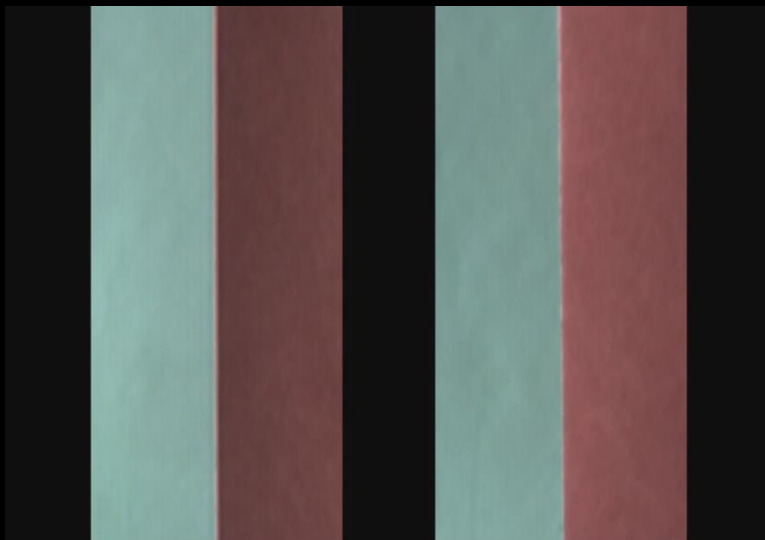
concave

convex

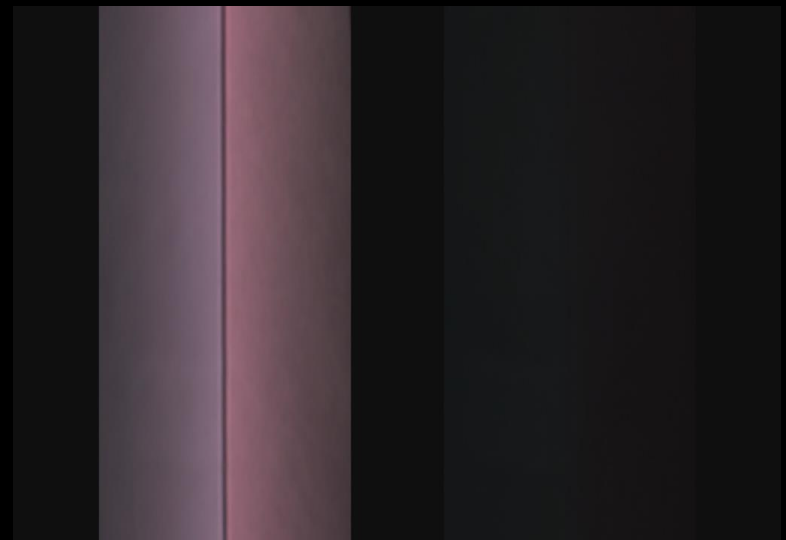


Psychophysics:

Gilchrist 79, Bloj et al. 04



Direct



Global

Real World Examples:

Can You Guess the Images?

Eggs: Diffuse Interreflections

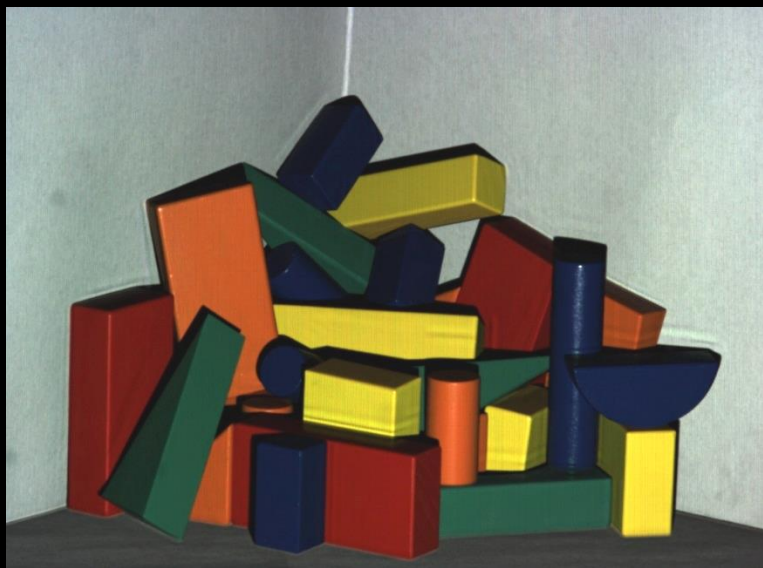
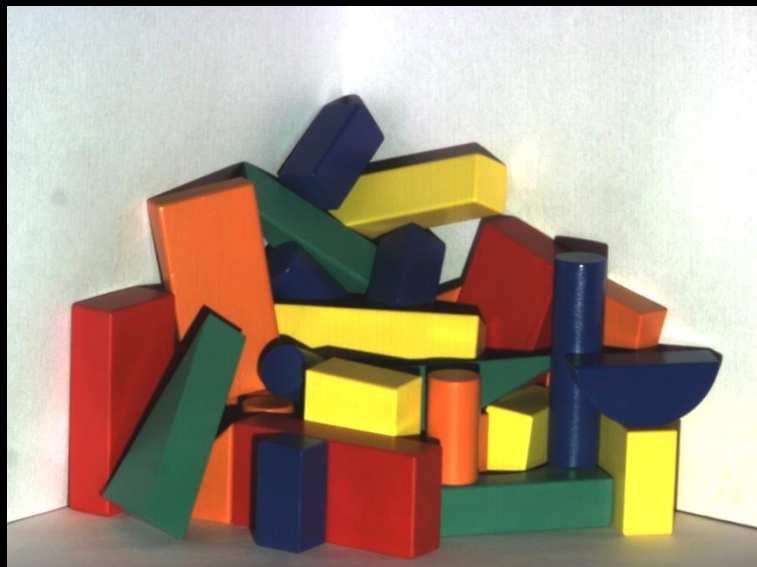


Direct



Global

Wooden Blocks: Specular Interreflections

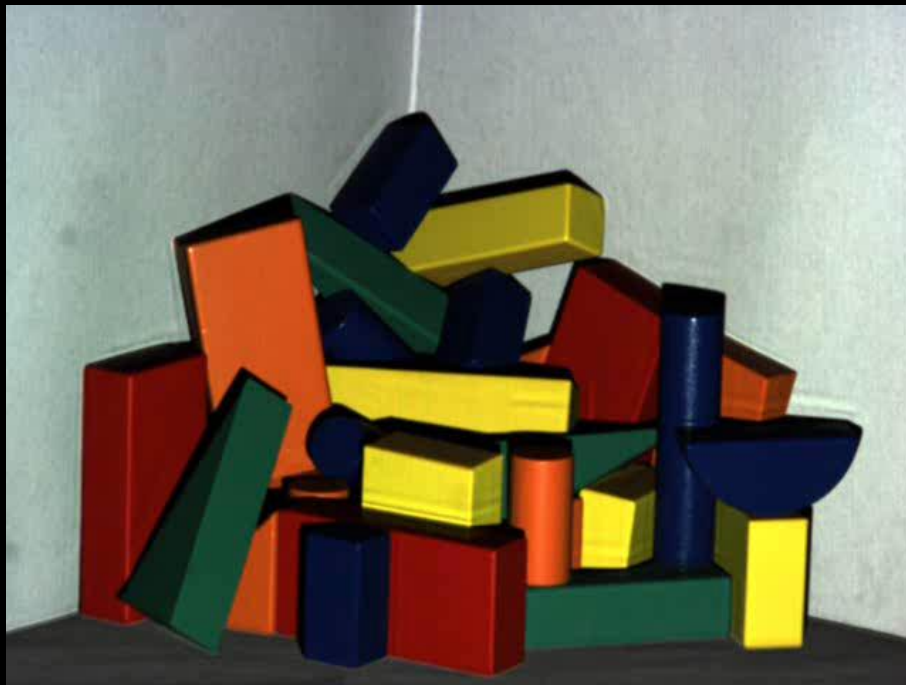


Direct



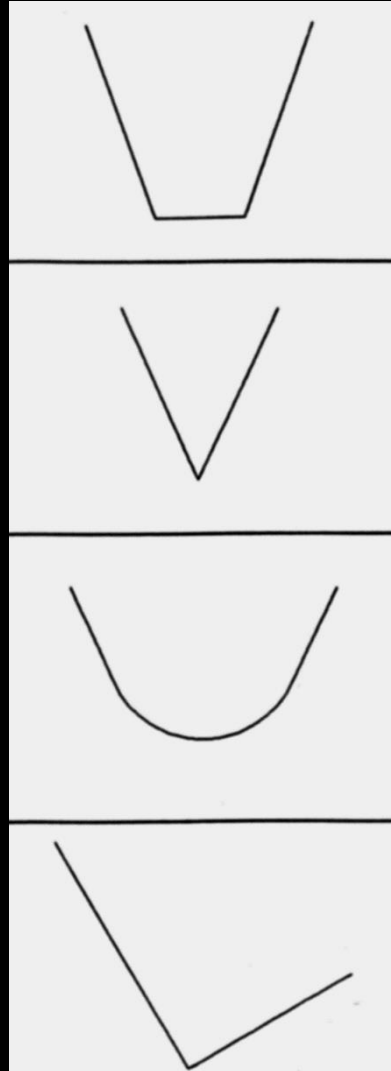
Global

Novel Images

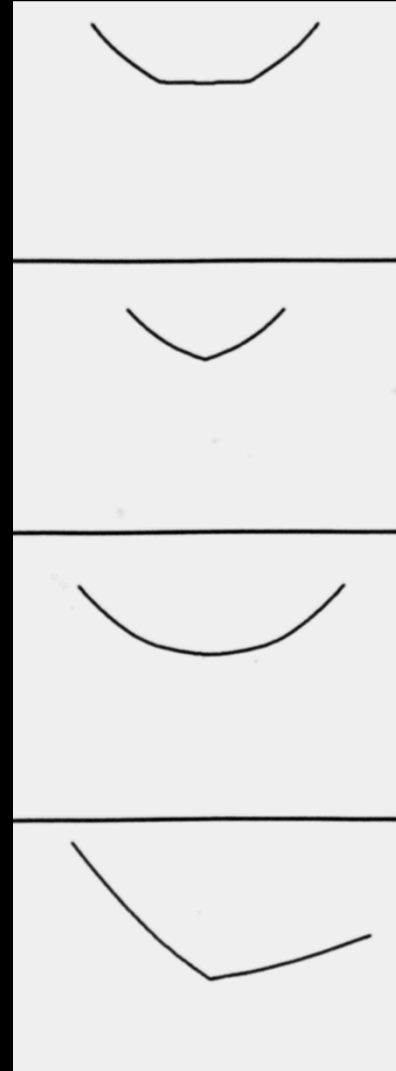


Photometric Stereo: The Pseudo Shape

Actual Shape
($\rho = 0.95$)



Pseudo Shape



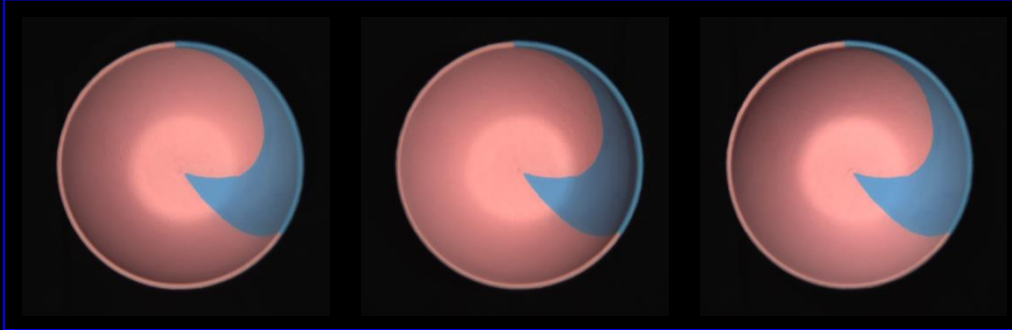
Photometric Stereo using Direct Images

Source 1

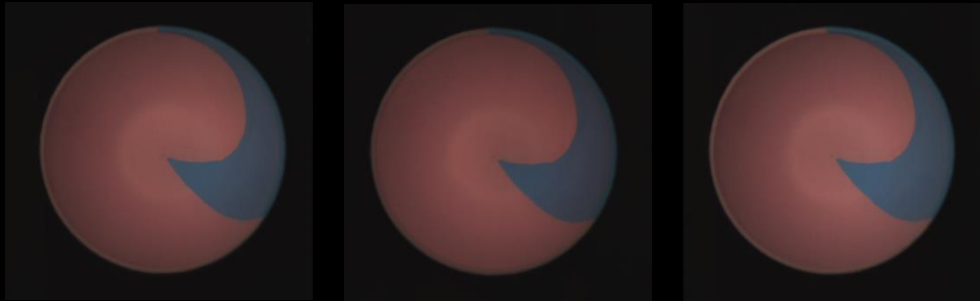
Source 2

Source 3

Bowl



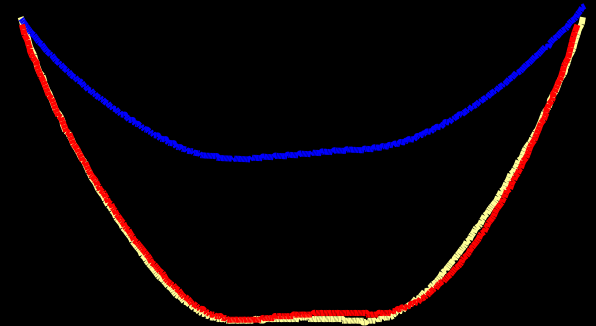
Global



Direct

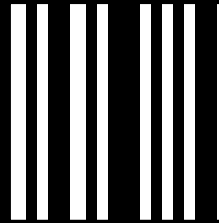


Shape



Variants of Separation Method

- Coded Structured Light



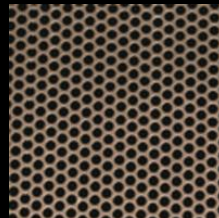
- Shifted Sinusoids



- Shadow of Line Occluder



- Shadow of Mesh Occluders



Building Corner



Stick



Shadow

3D from Shadows:
Bouguet and Perona 99

$$L_d = L_{\max} - L_{\min} , \quad L_g = L_{\min}$$

direct

global

Building Corner

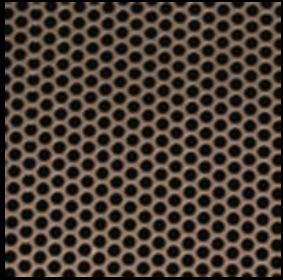


Direct



Global

Shower Curtain: Diffuser



Mesh



Shadow

$$L_d = L_{\max} - \beta L_{\min}, \quad L_g = \beta L_{\min}$$

direct

global

Shower Curtain: Diffuser

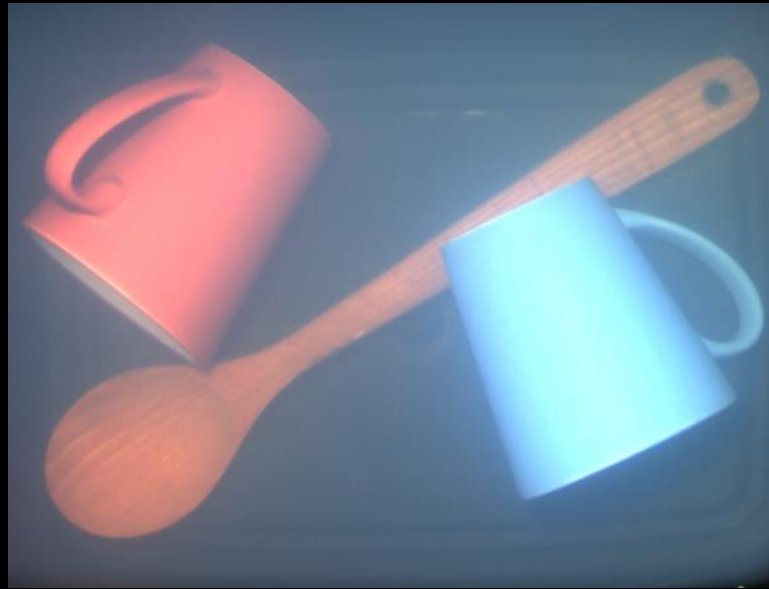


Direct



Global

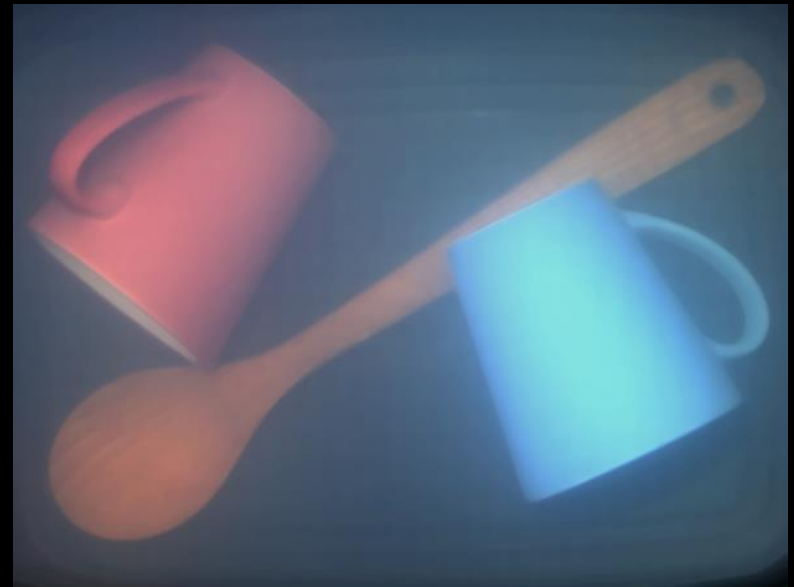
Kitchen Sink: Volumetric Scattering



Volumetric Scattering:
Chandrasekar 50, Ishimaru 78



Direct

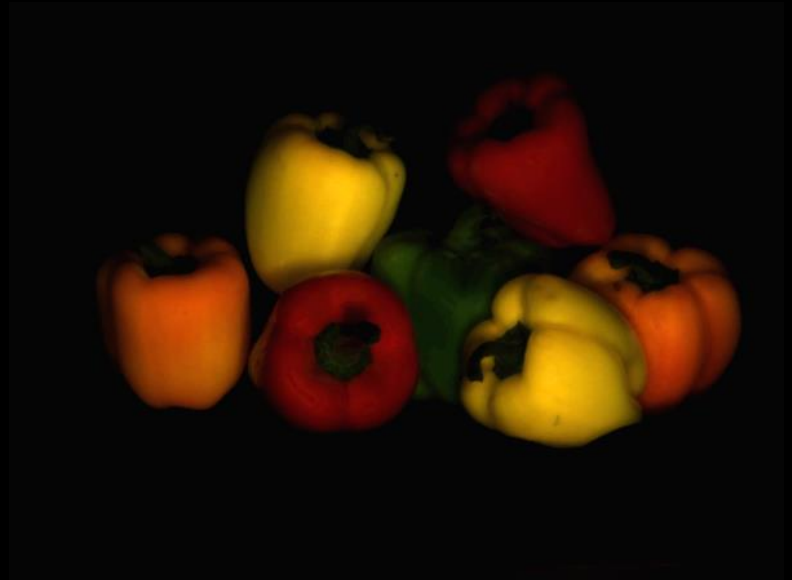


Global

Peppers: Subsurface Scattering

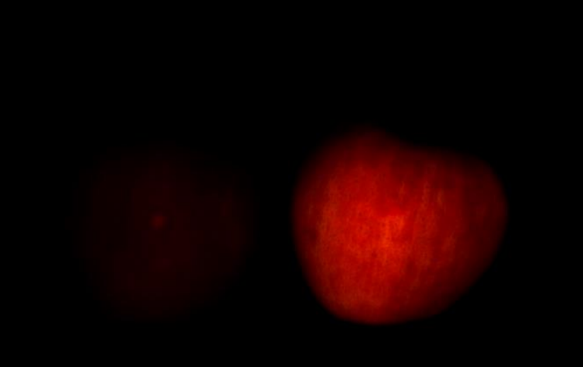
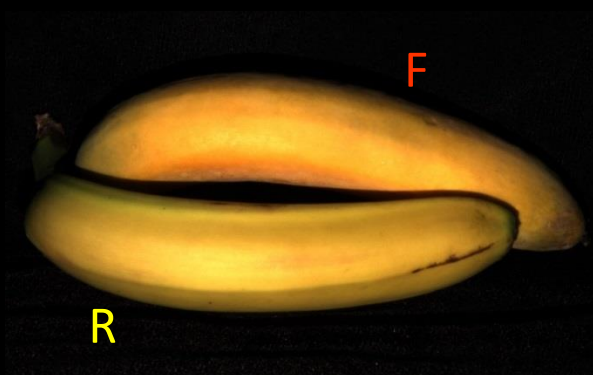


Direct



Global

Real Fake



Direct

Global

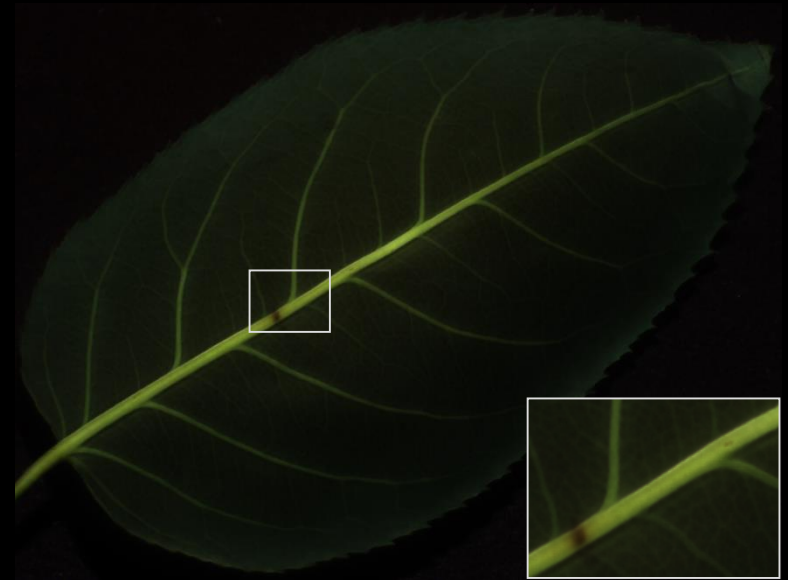
Tea Rose Leaf



Leaf Anatomy: Purves et al. 03



Direct

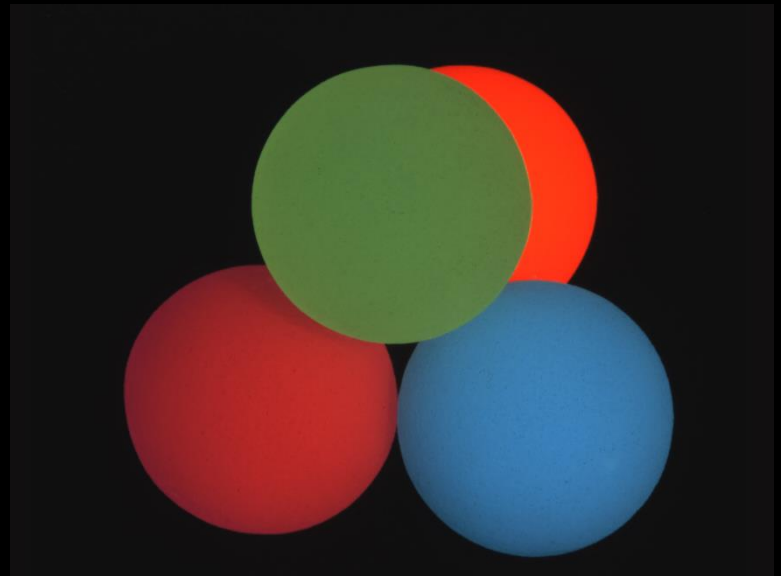


Global

Translucent Rubber Balls

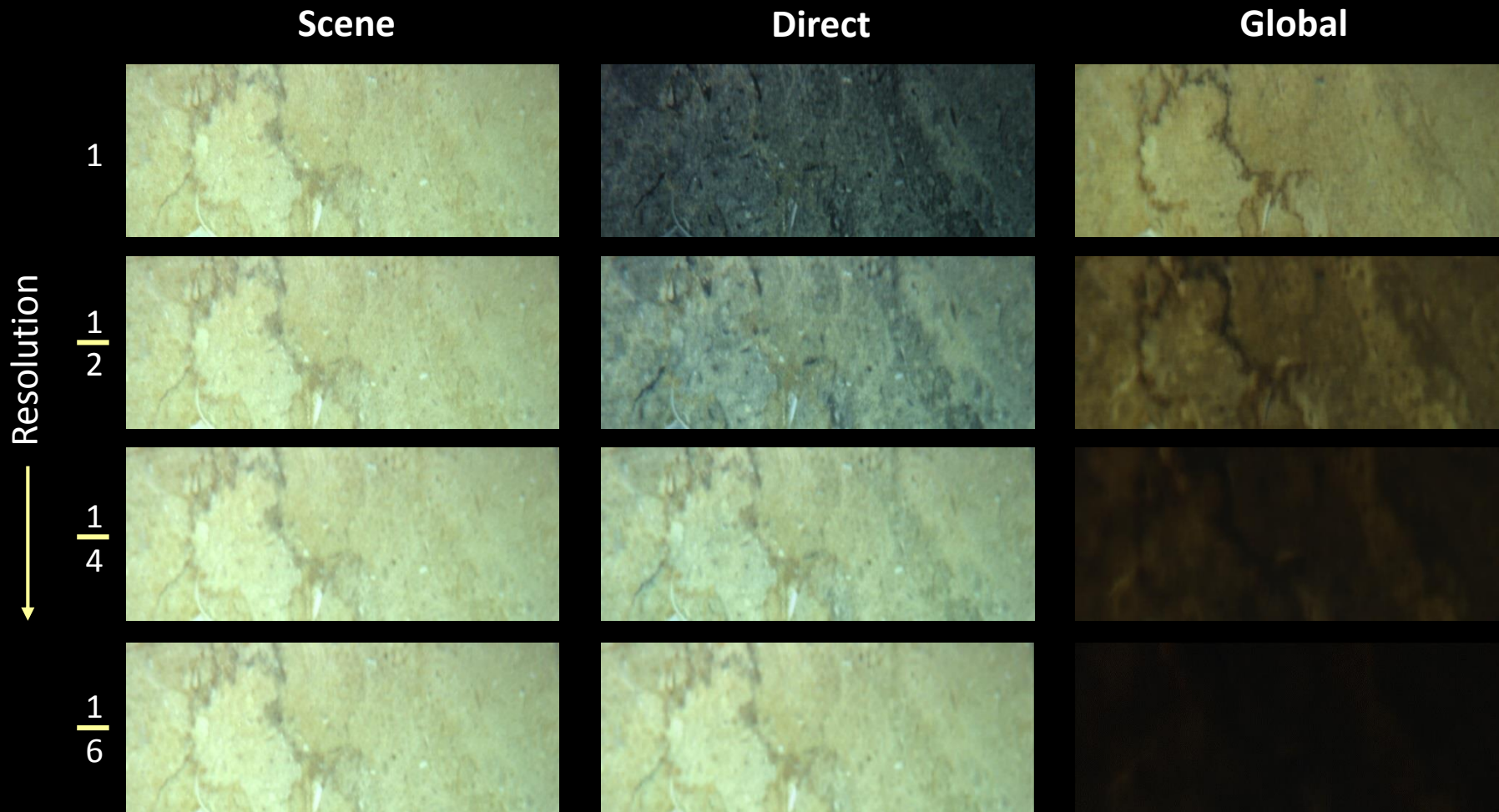


Direct



Global

Marble: When BSSRDF becomes BRDF



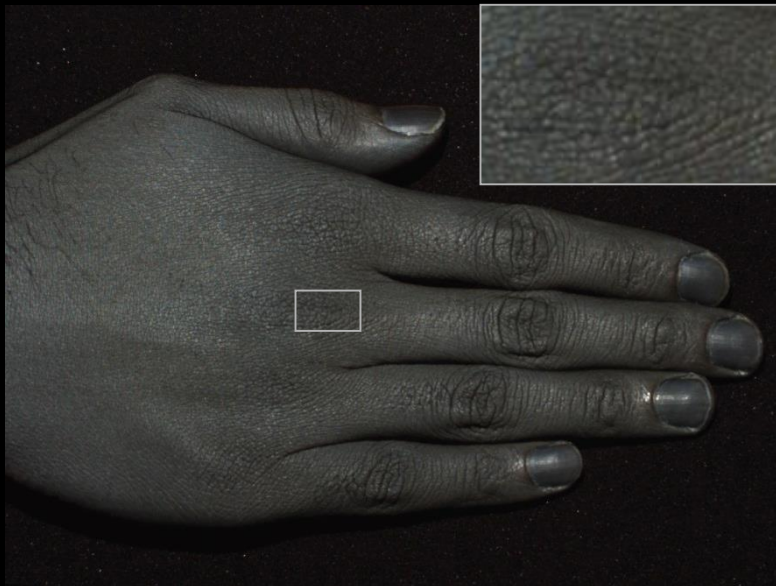
Subsurface Measurements:

Jensen et al. 01, Goesele et al. 04

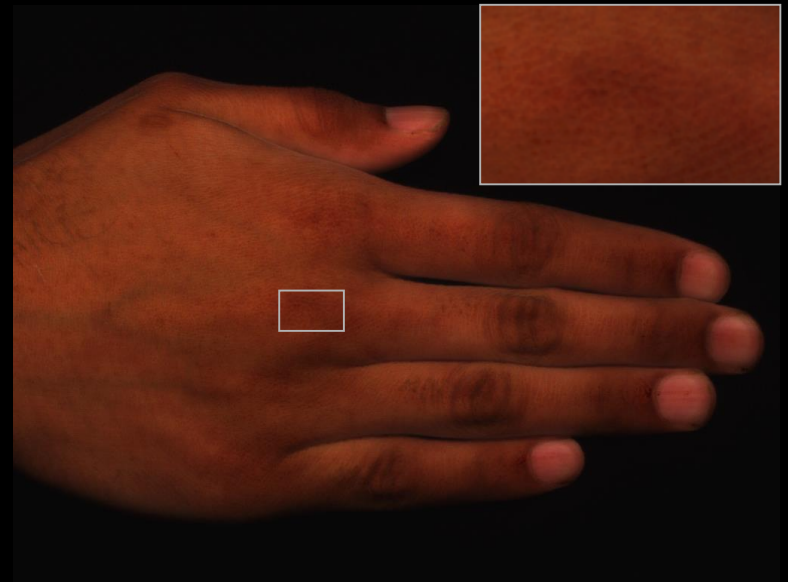
Hand



Skin: Hanrahan and Krueger 93,
Uchida 96, Haro 01, Jensen et al. 01,
Igarashi et al. 05, Weyrich et al. 05



Direct



Global

Hands



Afric. Amer.
Female



Chinese
Male



Spanish
Male



Afric. Amer.
Female



Chinese
Male



Spanish
Male



Afric. Amer.
Female



Chinese
Male

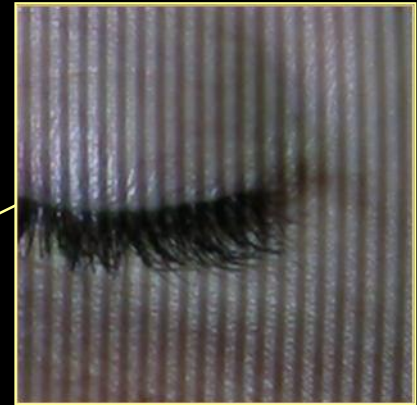
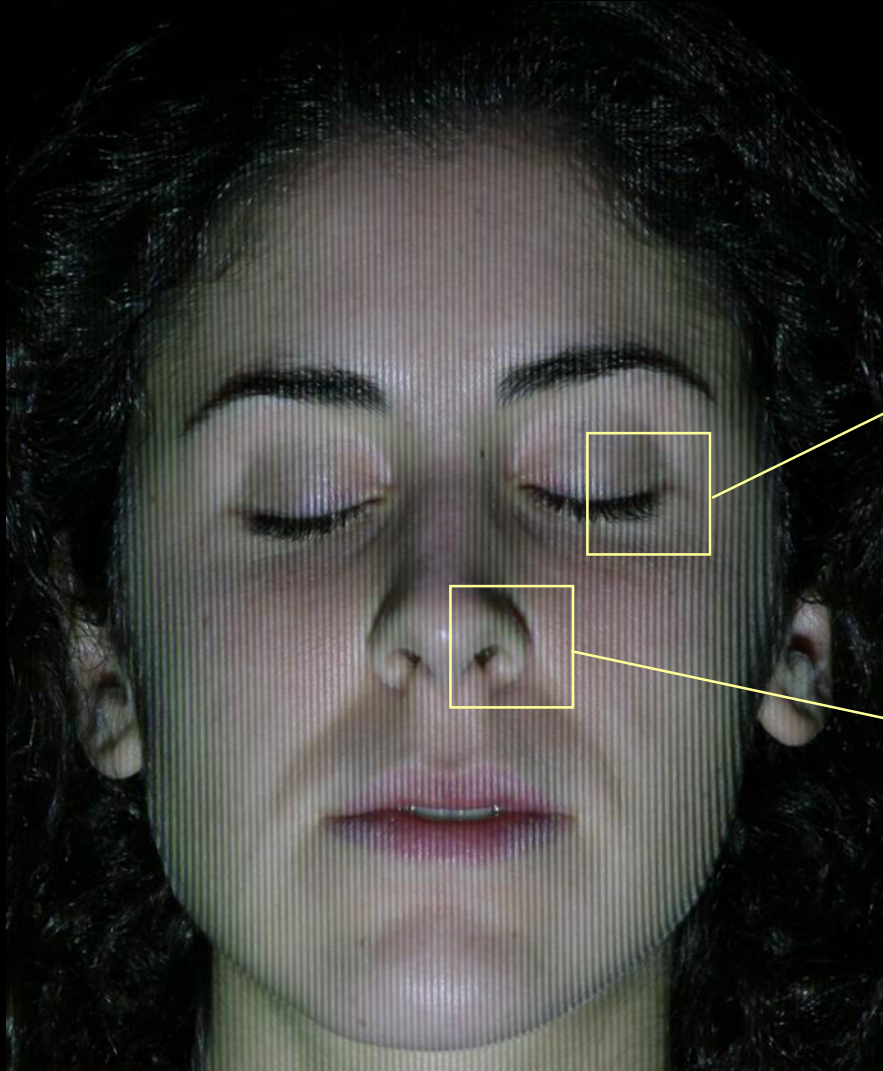


Spanish
Male

Direct

Global

Separation from a Single Image



Face



Direct



Global



Sum

Blonde Hair



Hair Scattering: Stamm et al. 77,
Bustard and Smith 91, Lu et al. 00
Marschner et al. 03



Direct

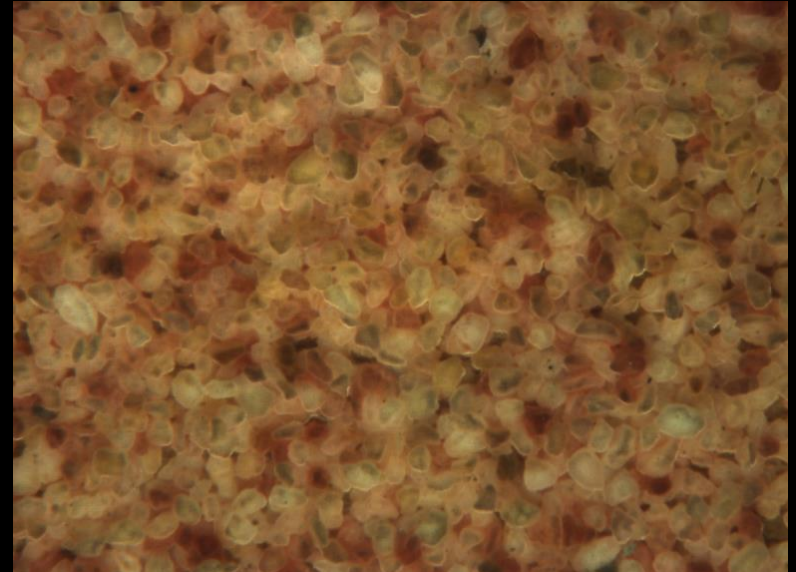


Global

Pebbles: 3D Texture



Direct



Global

Pink Carnation



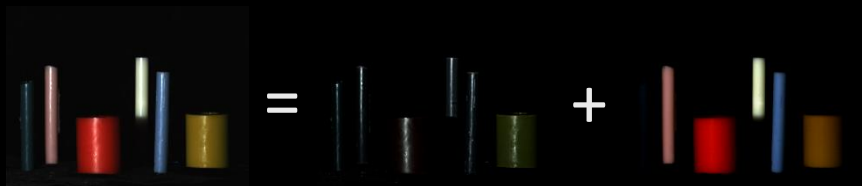
Spectral Bleeding: Funt et al. 91



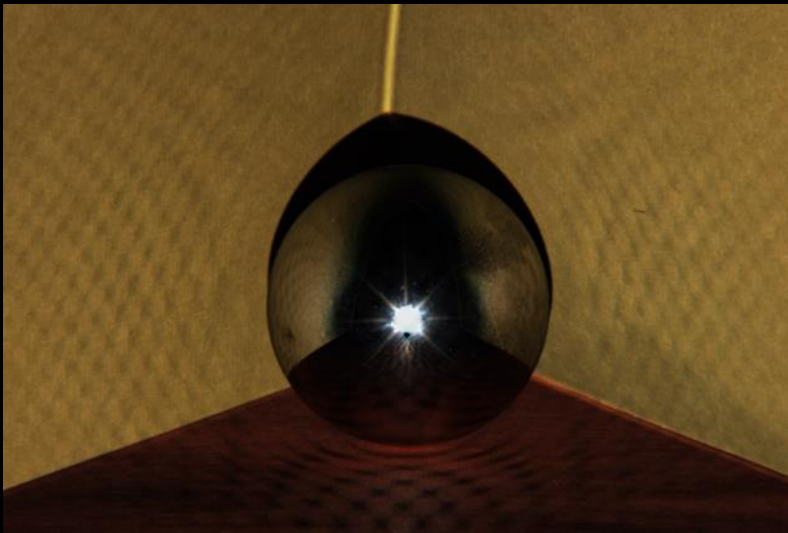
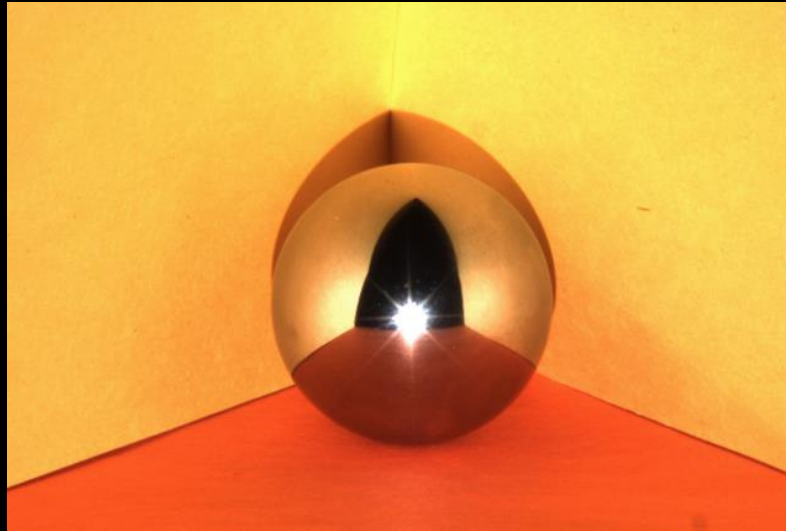
Direct



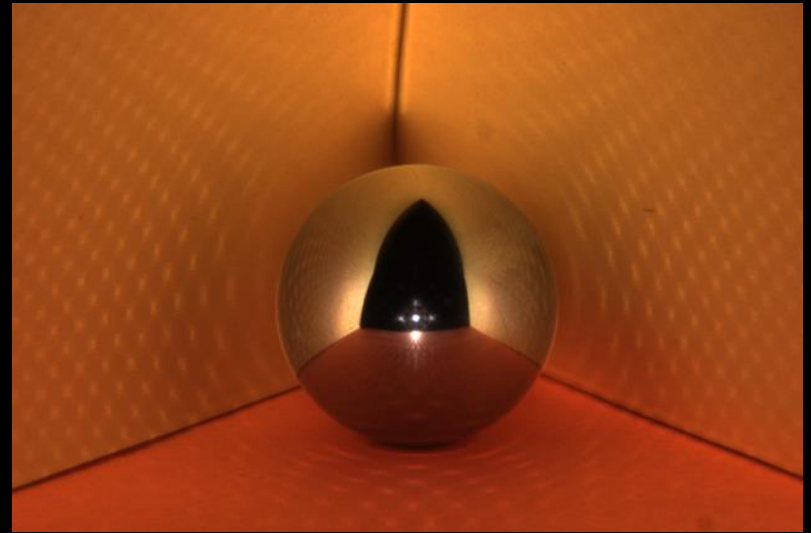
Global



Mirror Ball: Failure Case



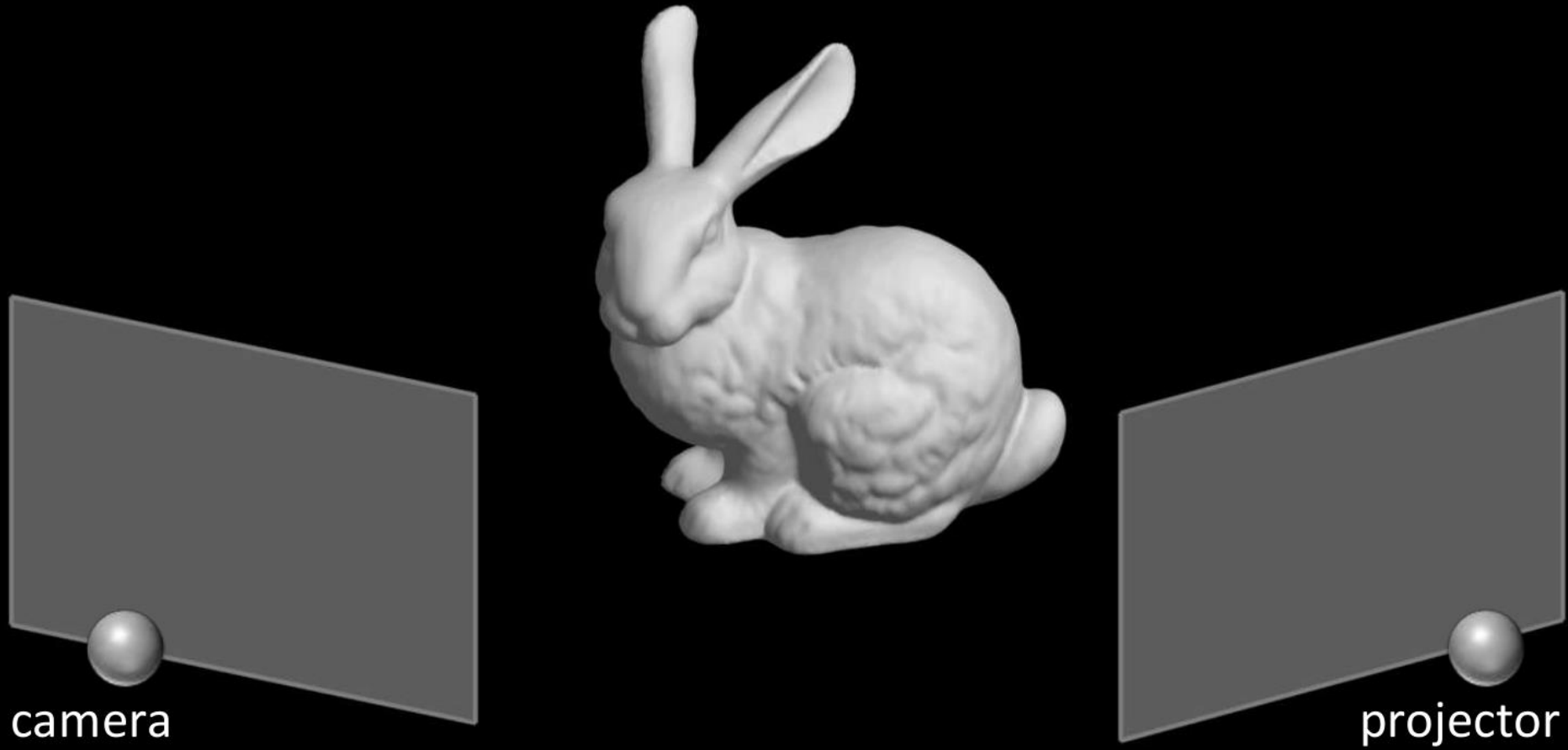
Direct



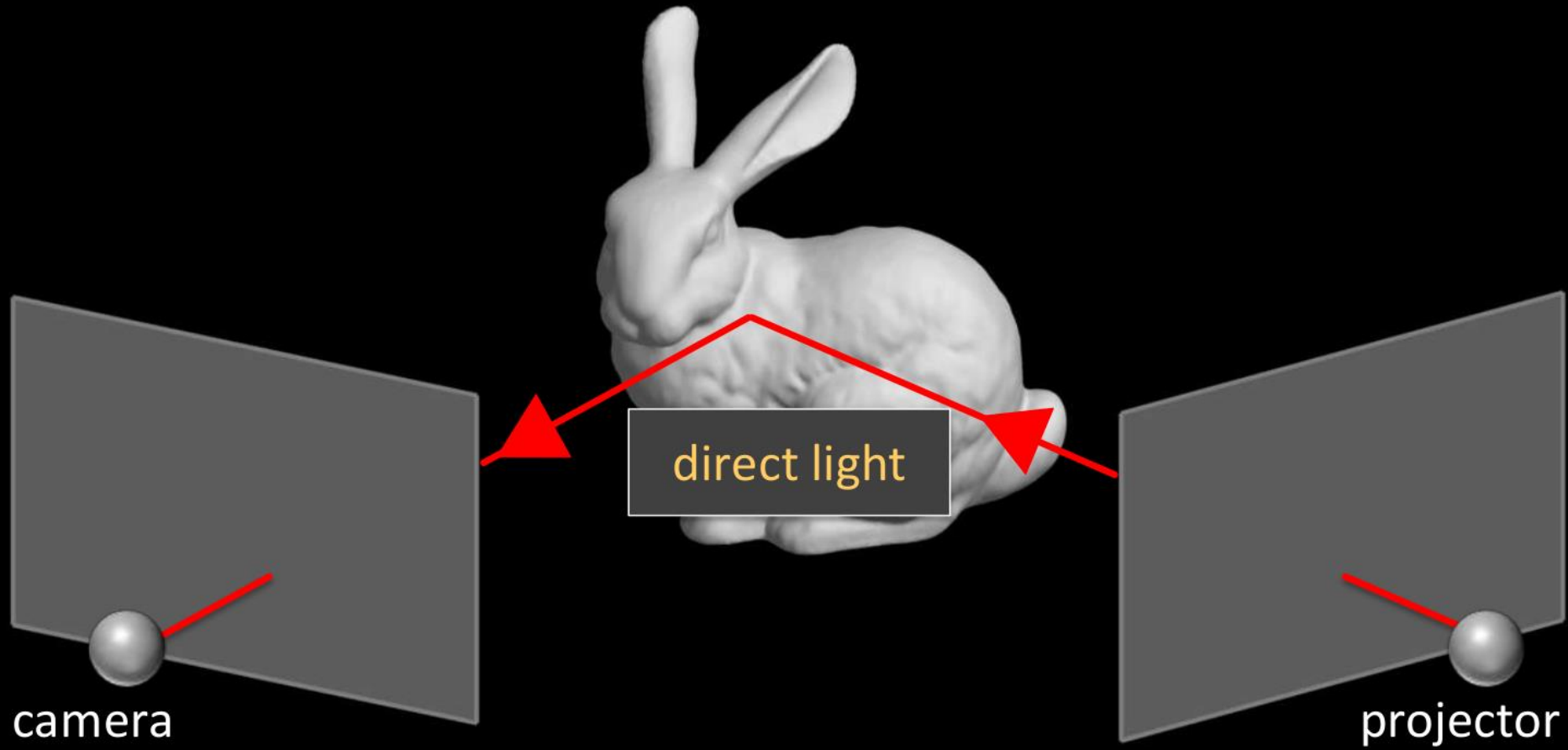
Global

Direct-global separation using epipolar
probing

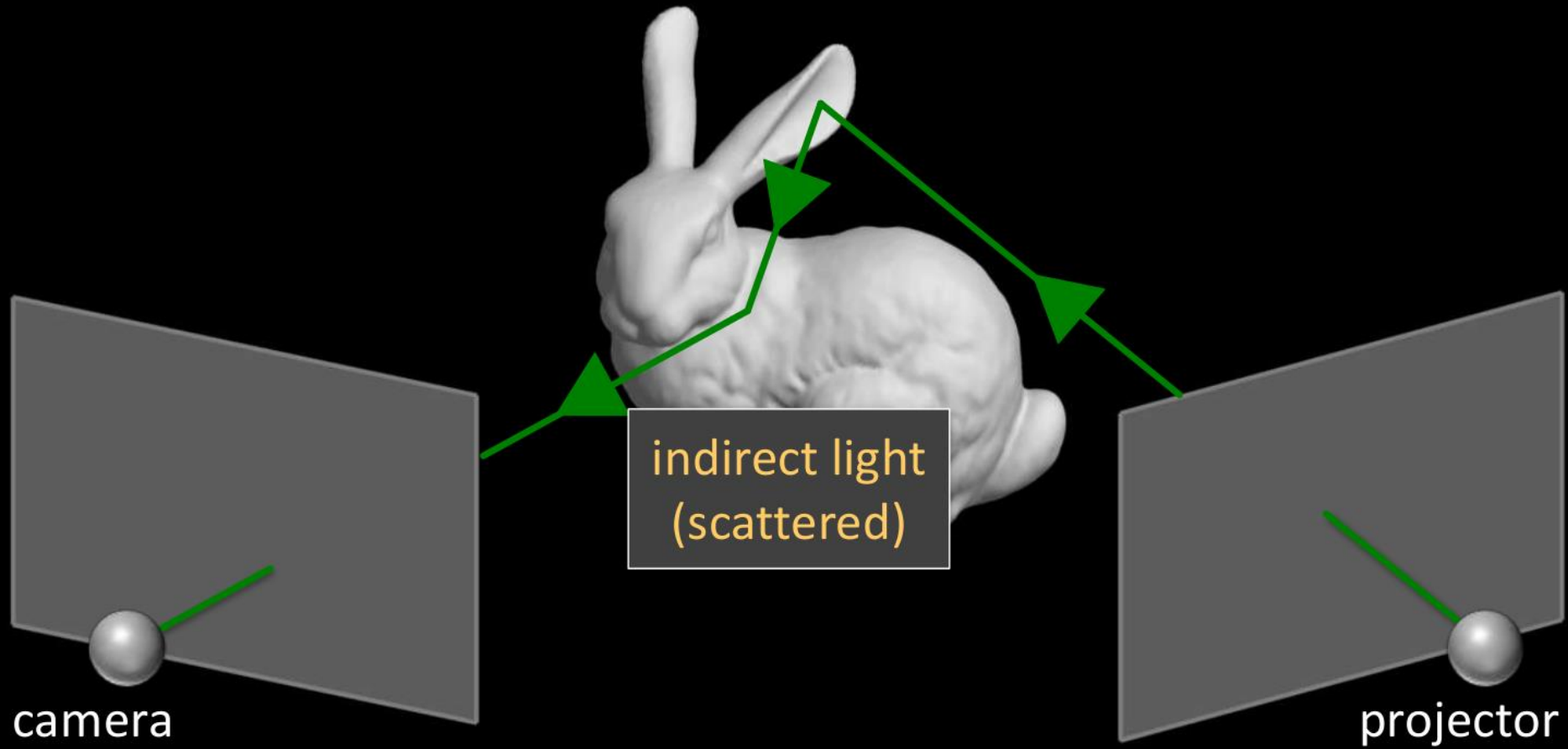
basic light paths



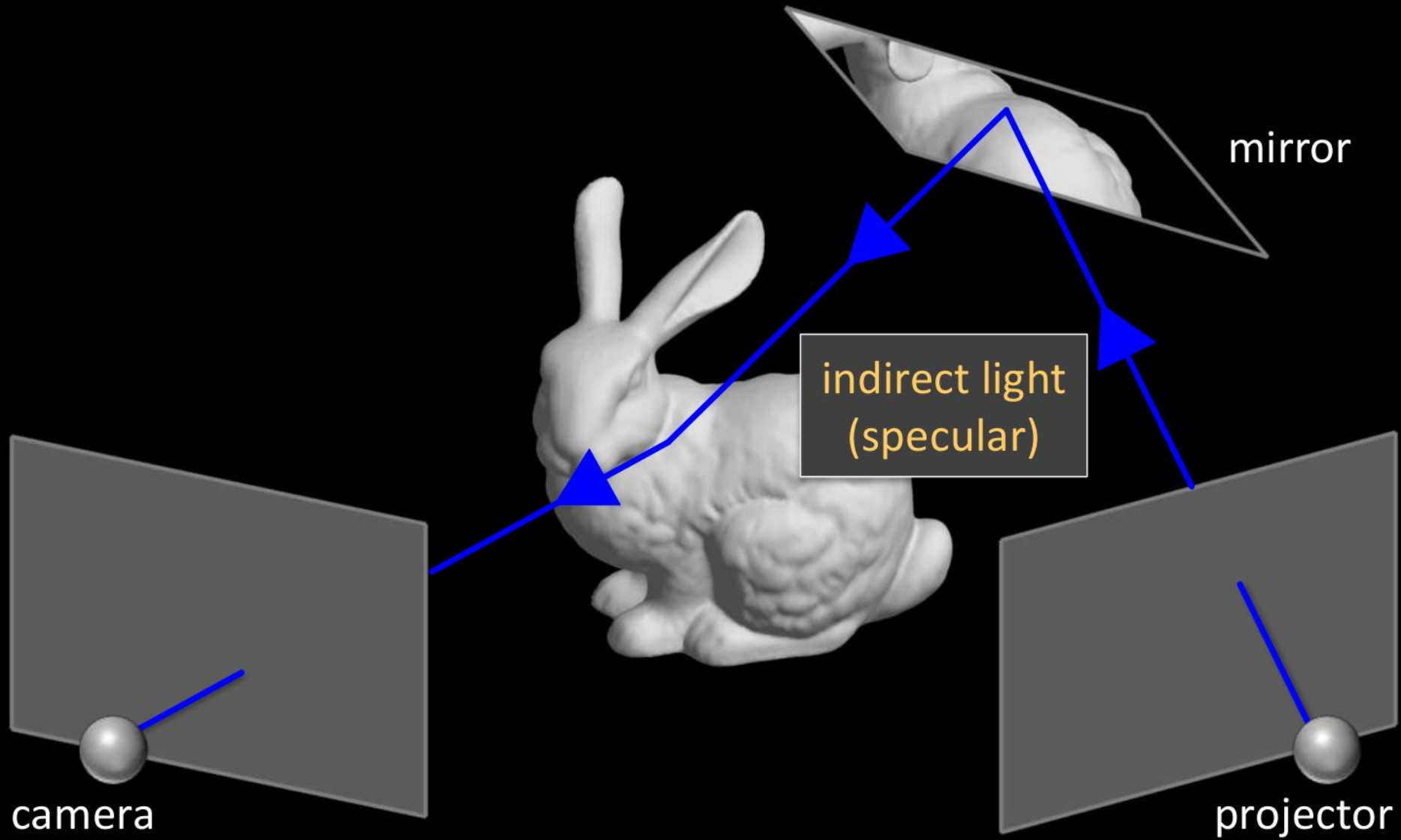
basic light paths



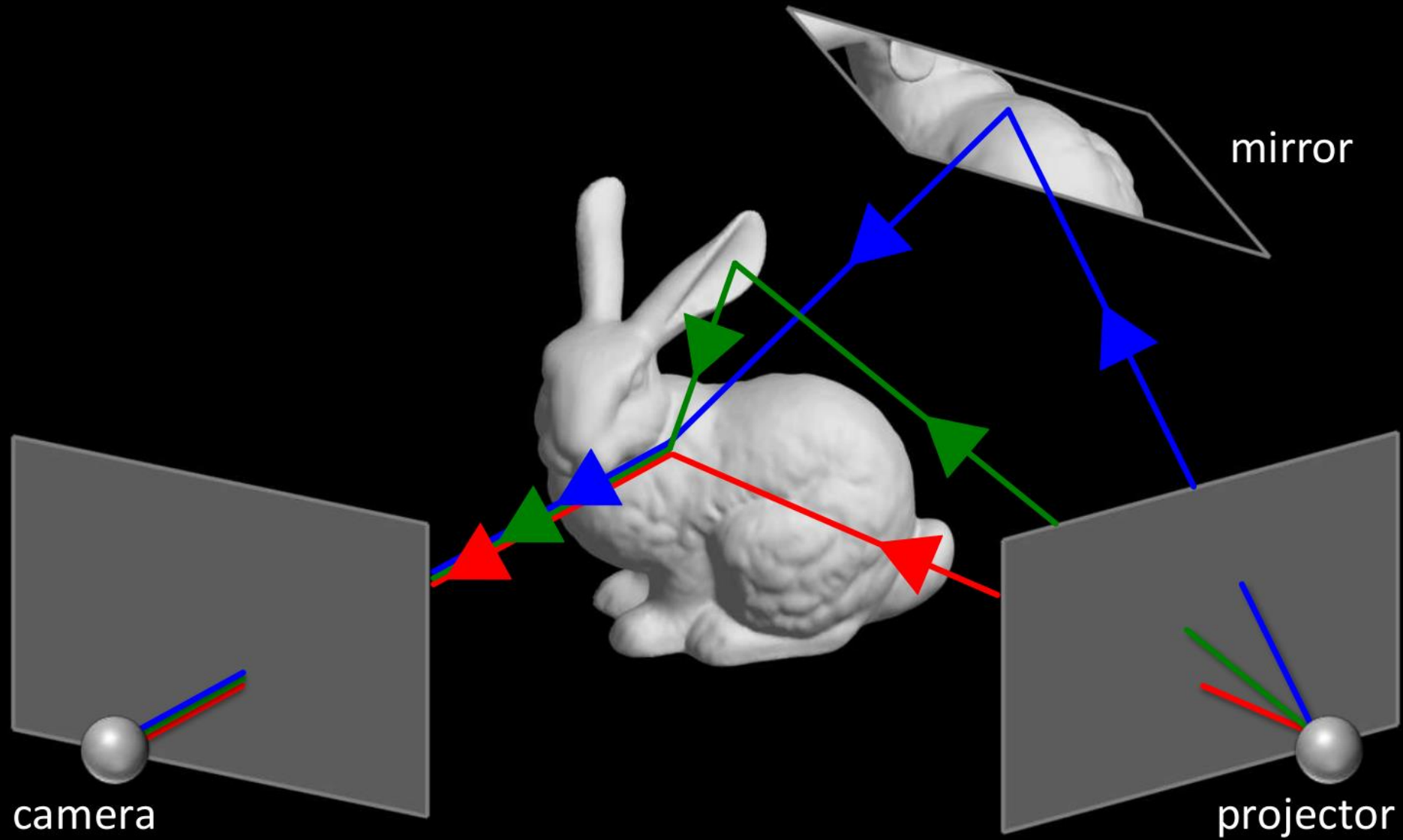
basic light paths



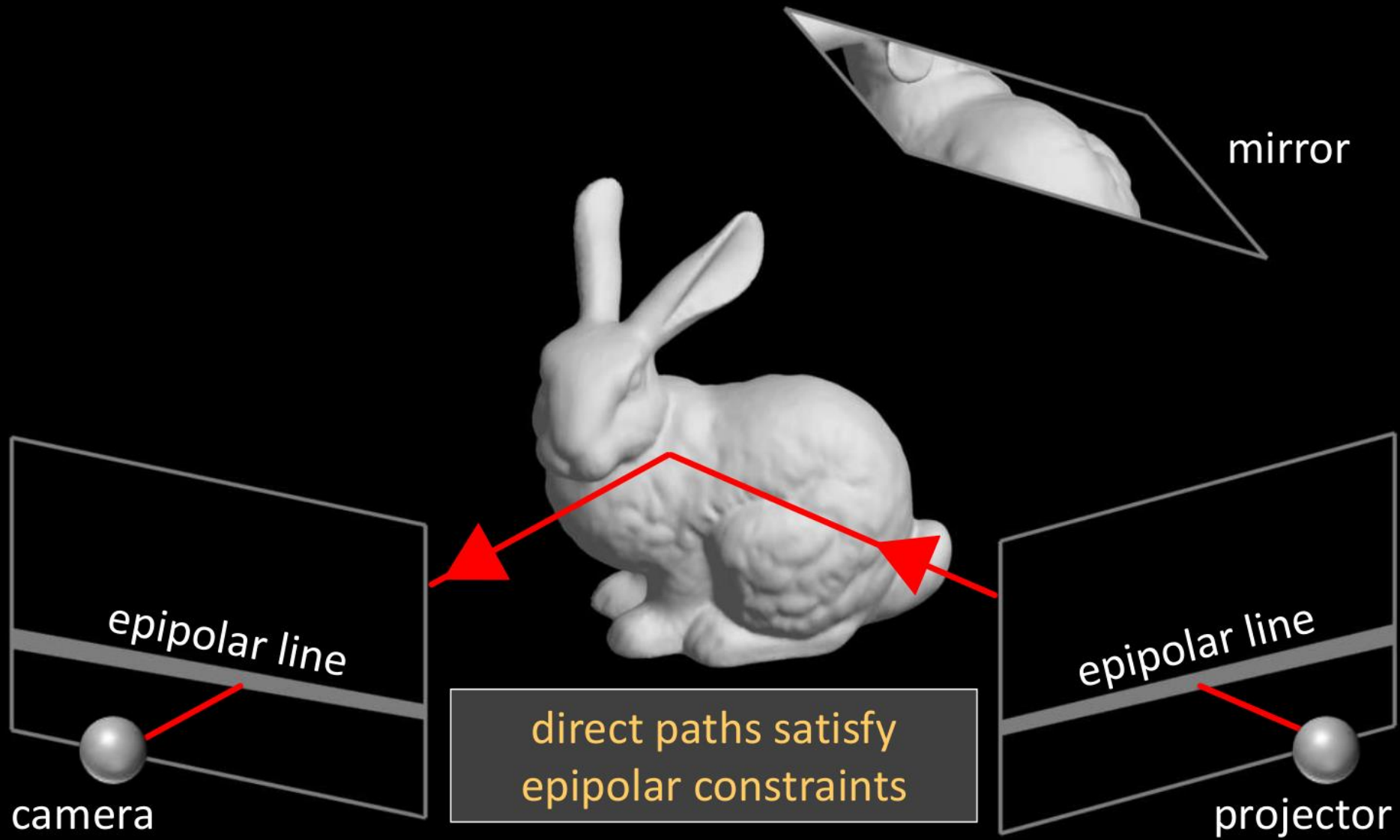
basic light paths



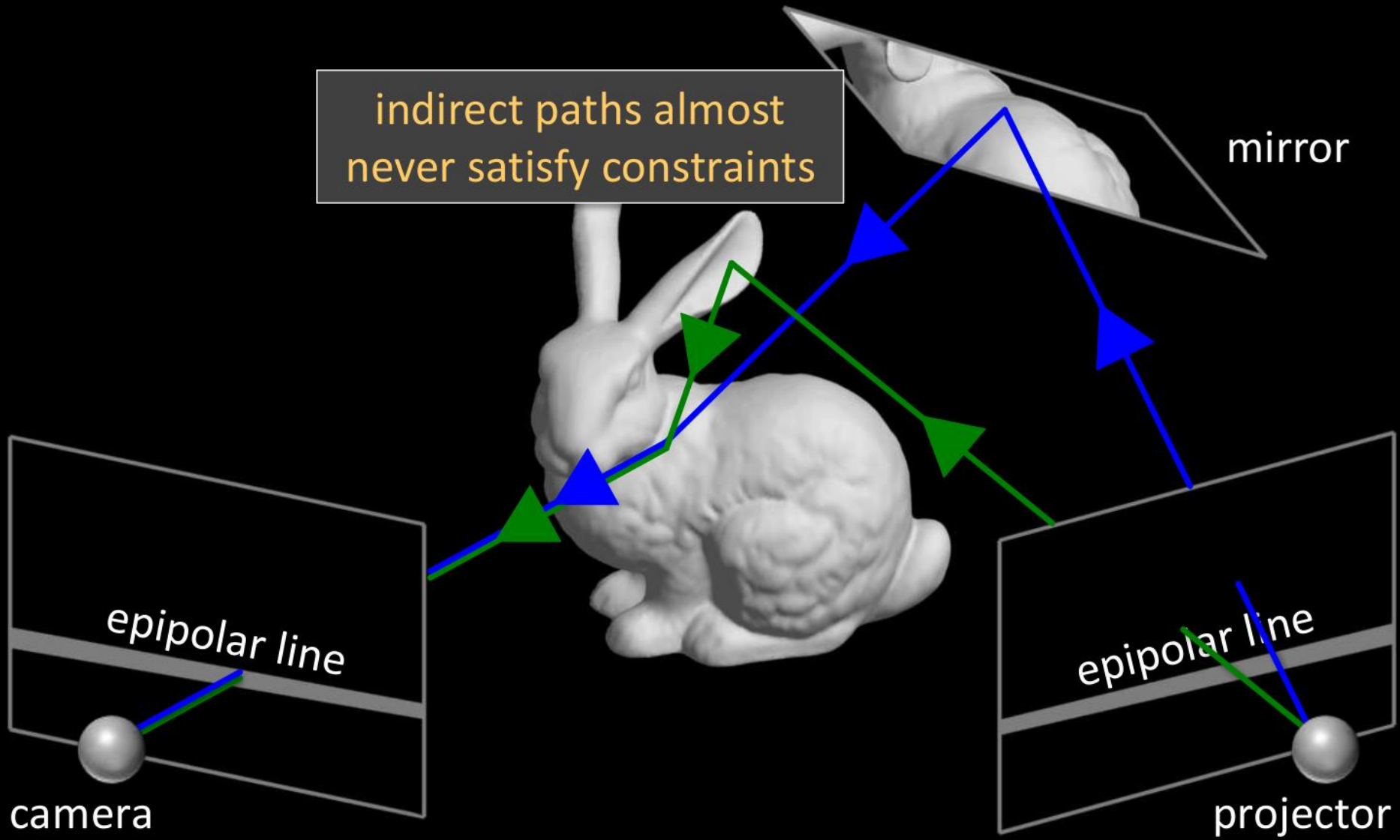
basic light paths



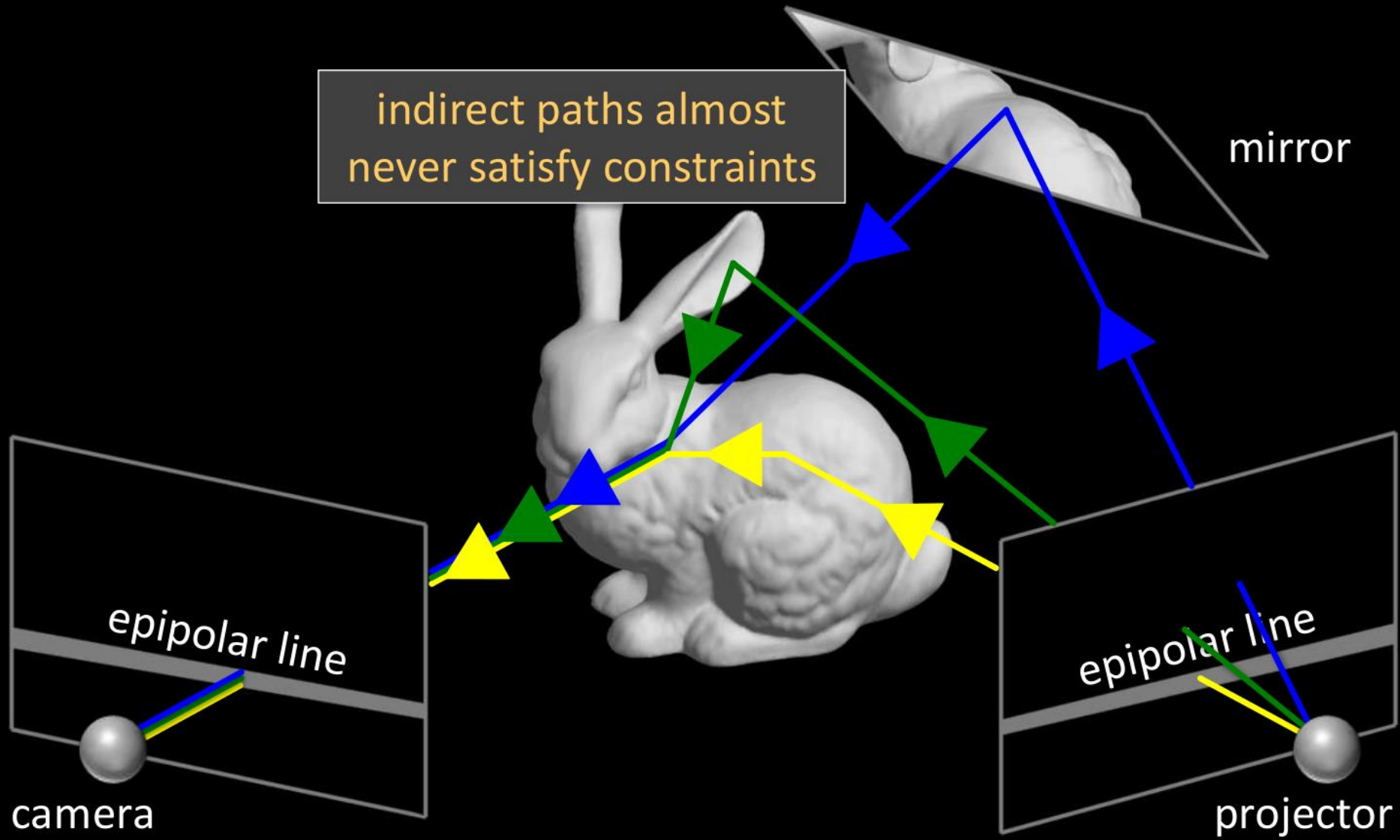
epipolar constraint & light transport



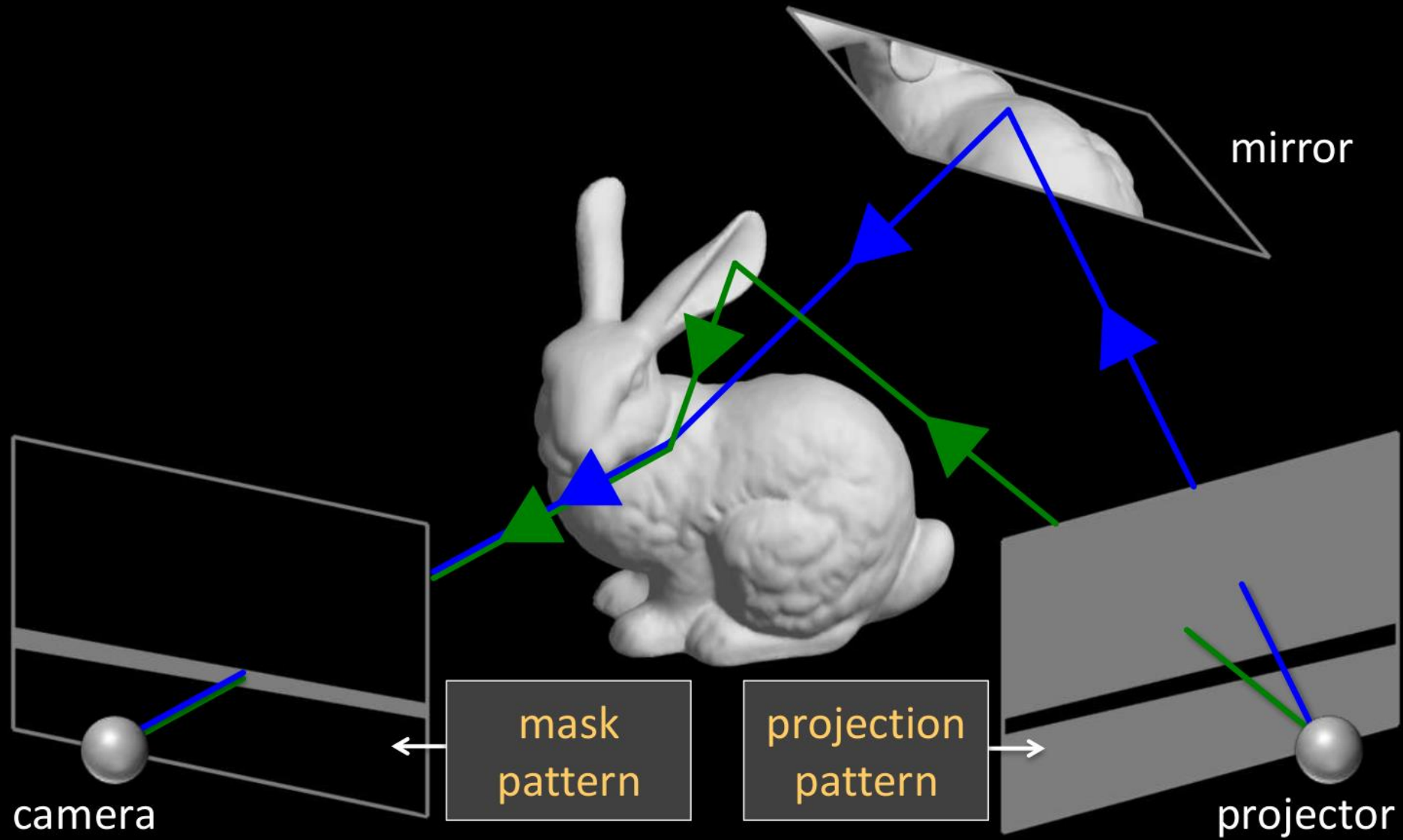
epipolar constraint & light transport



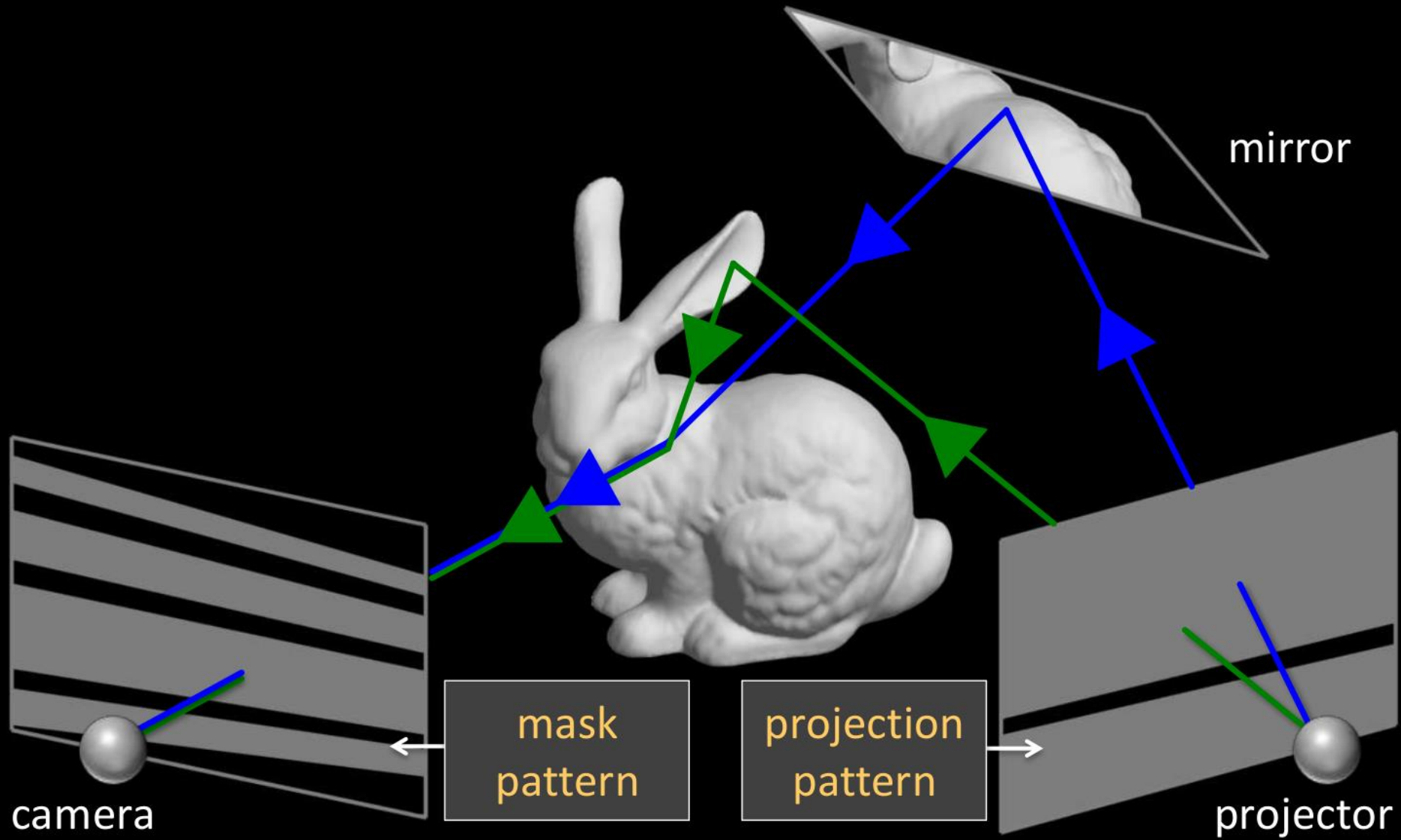
epipolar constraint & light transport



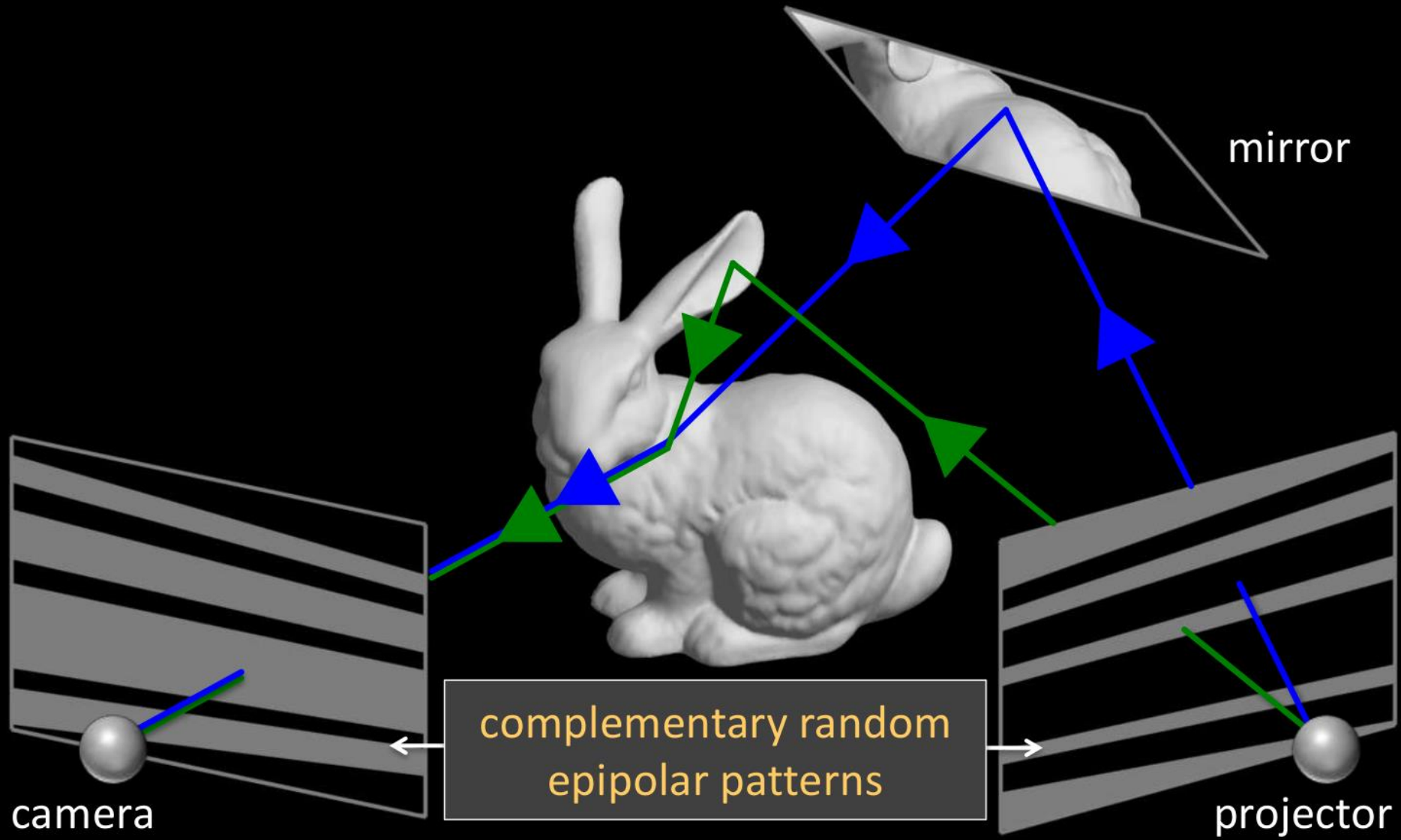
blocking epipolar paths with patterns & masks



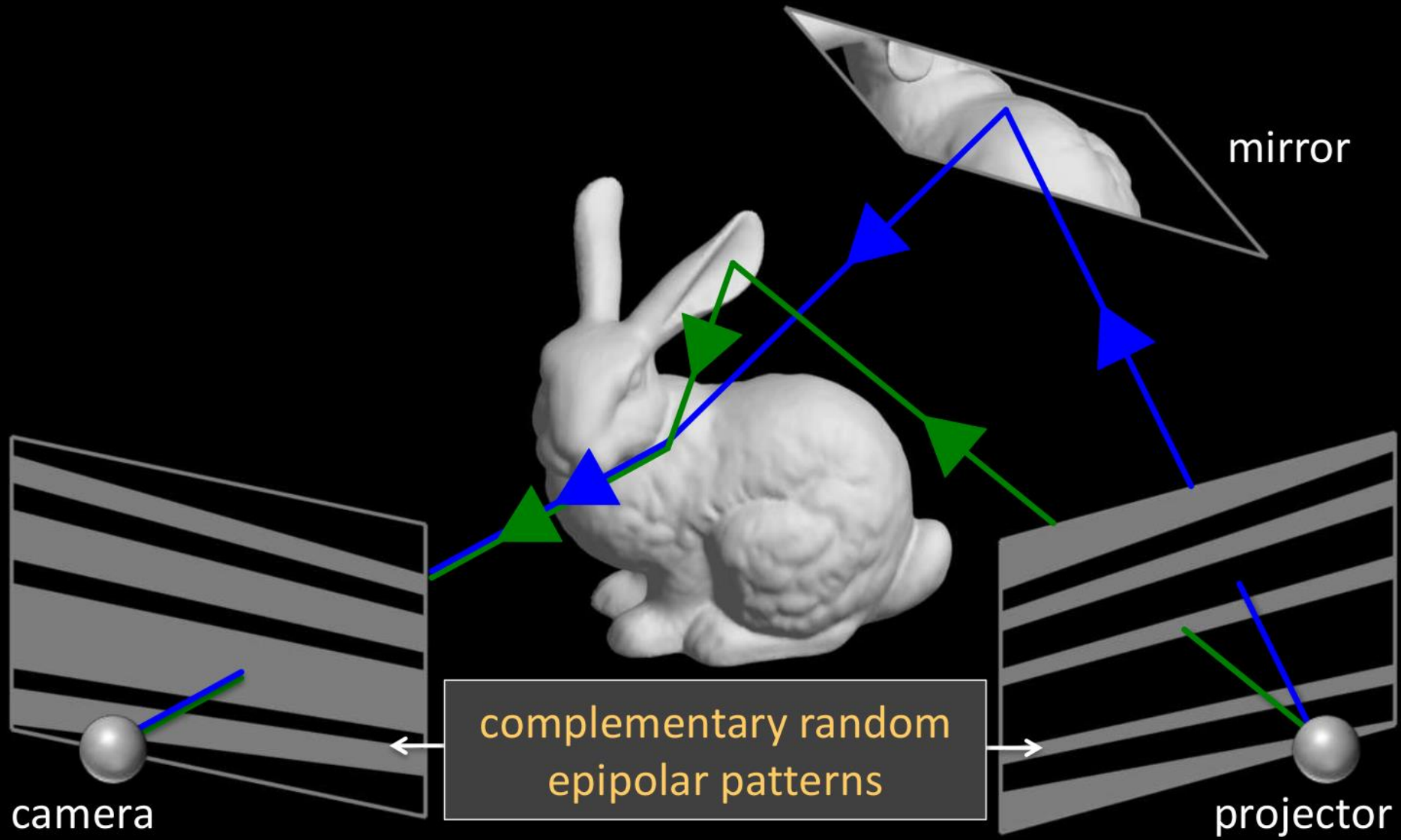
blocking epipolar paths with patterns & masks



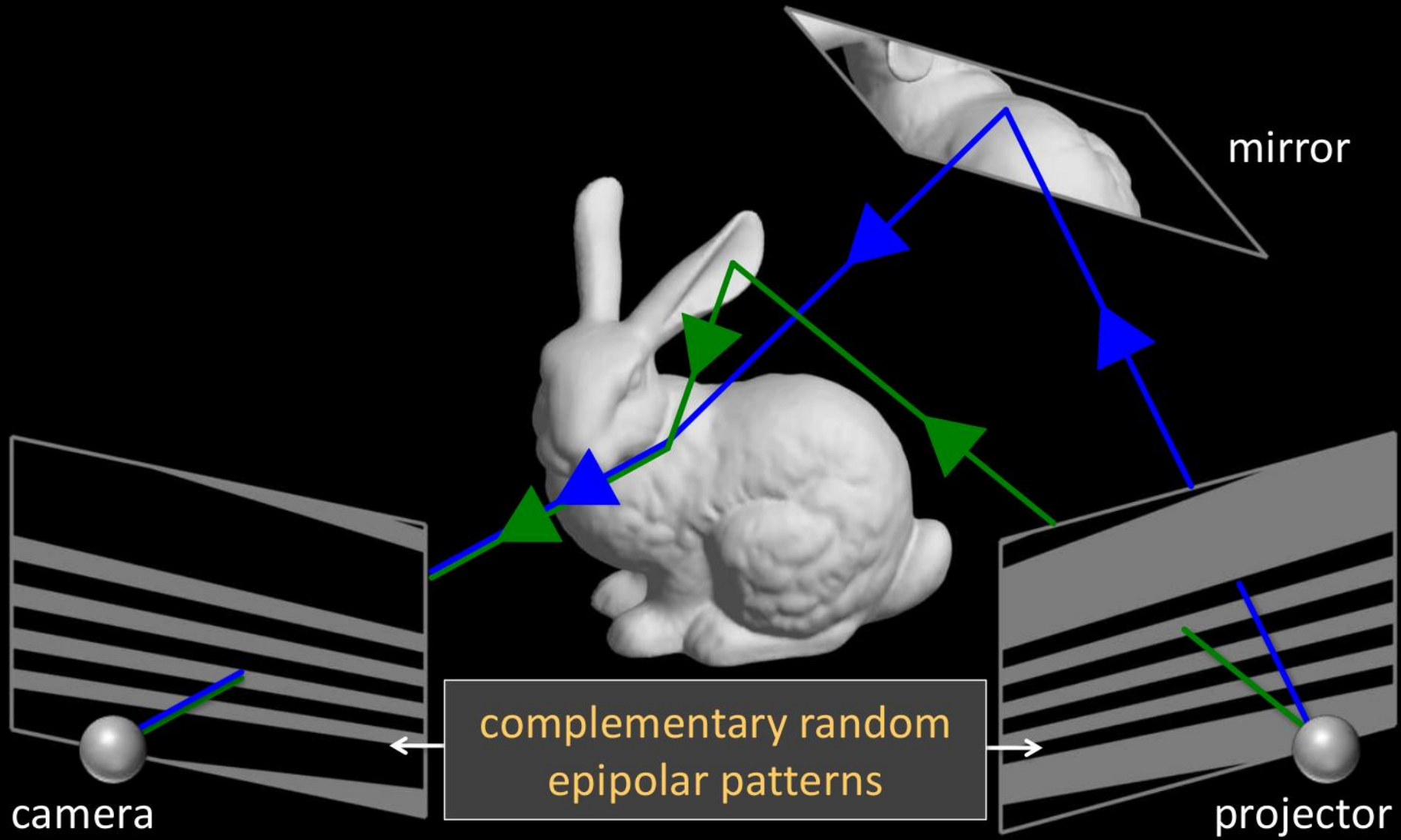
blocking epipolar paths with patterns & masks



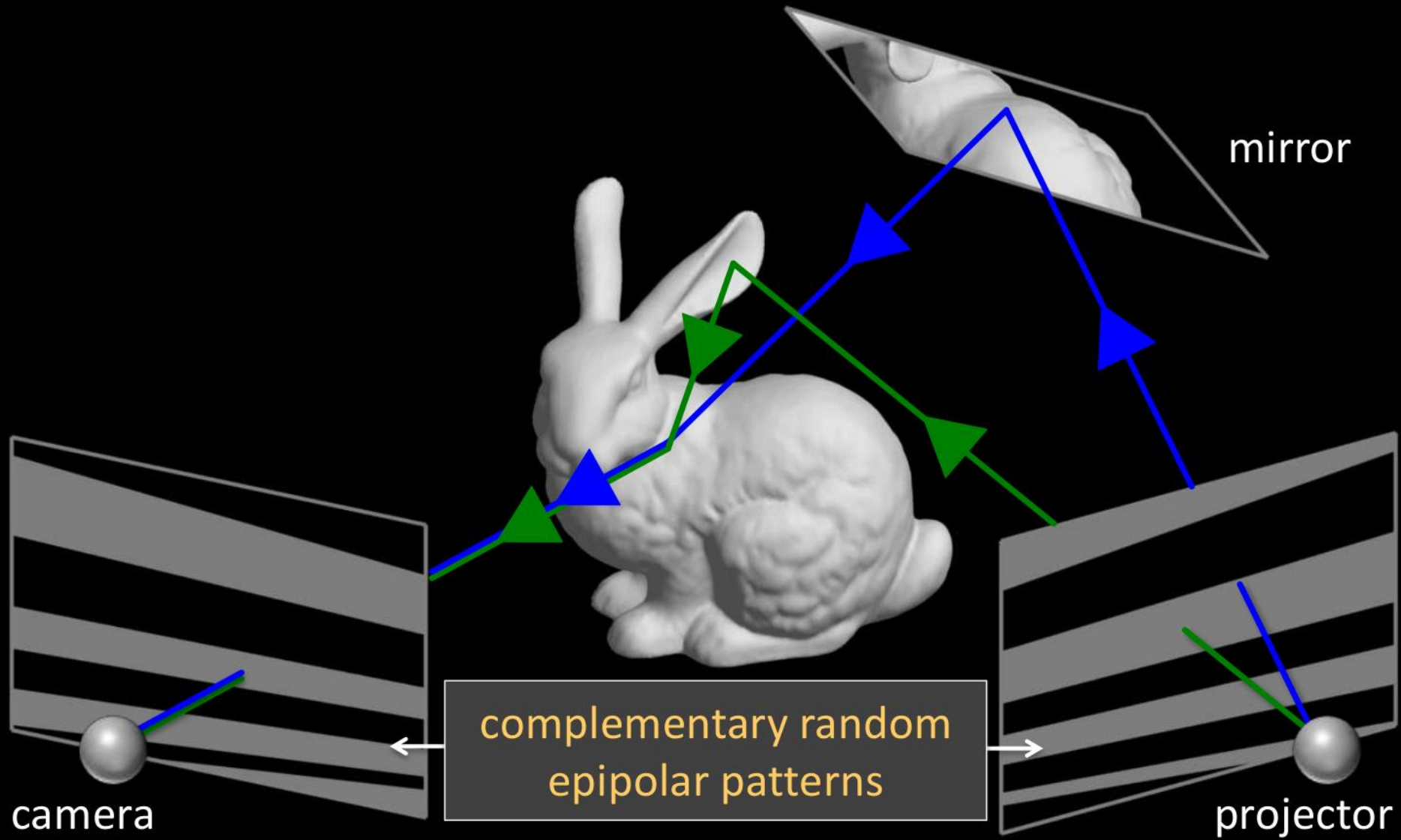
blocking epipolar paths with patterns & masks



blocking epipolar paths with patterns & masks

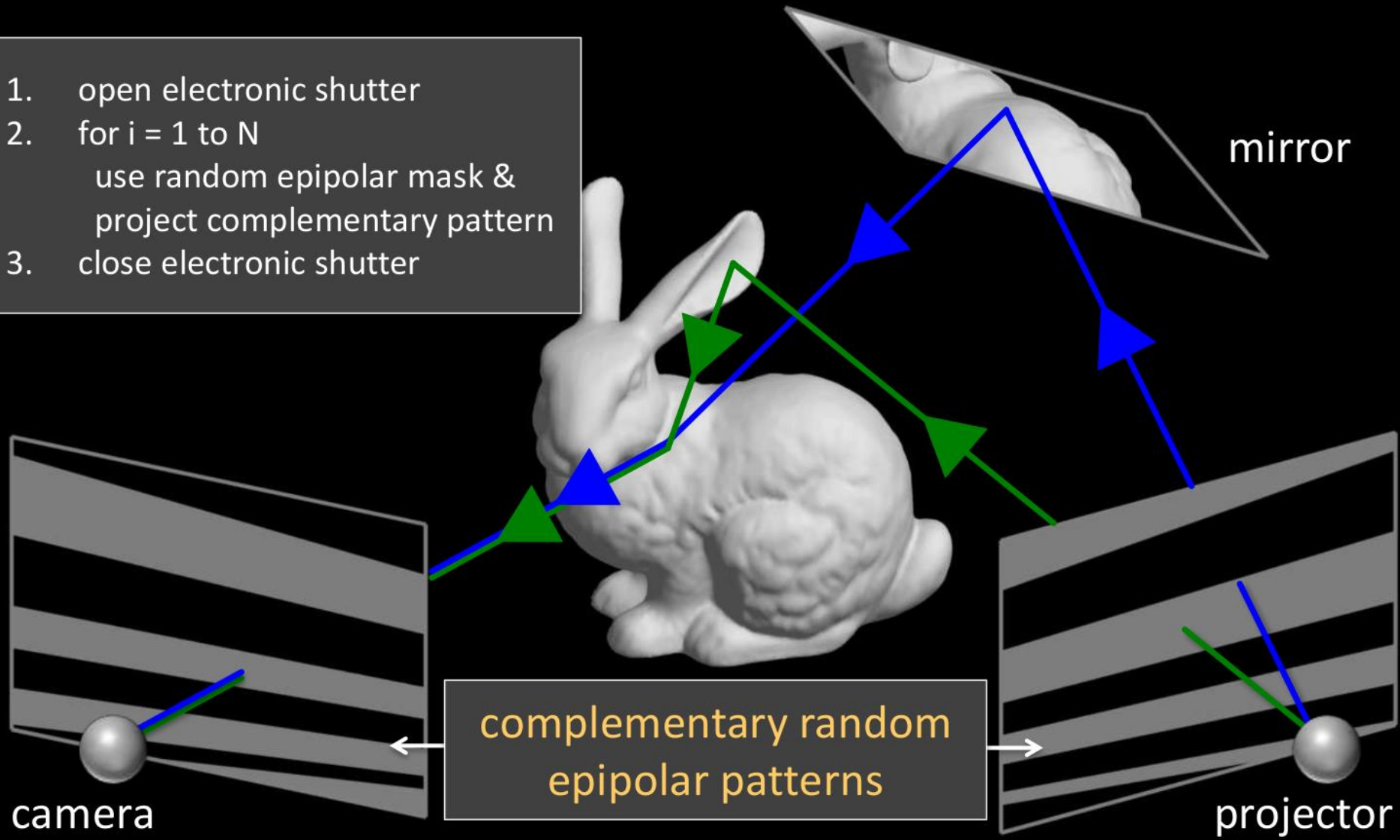


blocking epipolar paths with patterns & masks



blocking epipolar paths with patterns & masks

1. open electronic shutter
2. for $i = 1$ to N
use random epipolar mask &
project complementary pattern
3. close electronic shutter





top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only





top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only





top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only



top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only



top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only





top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only





top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only





top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only



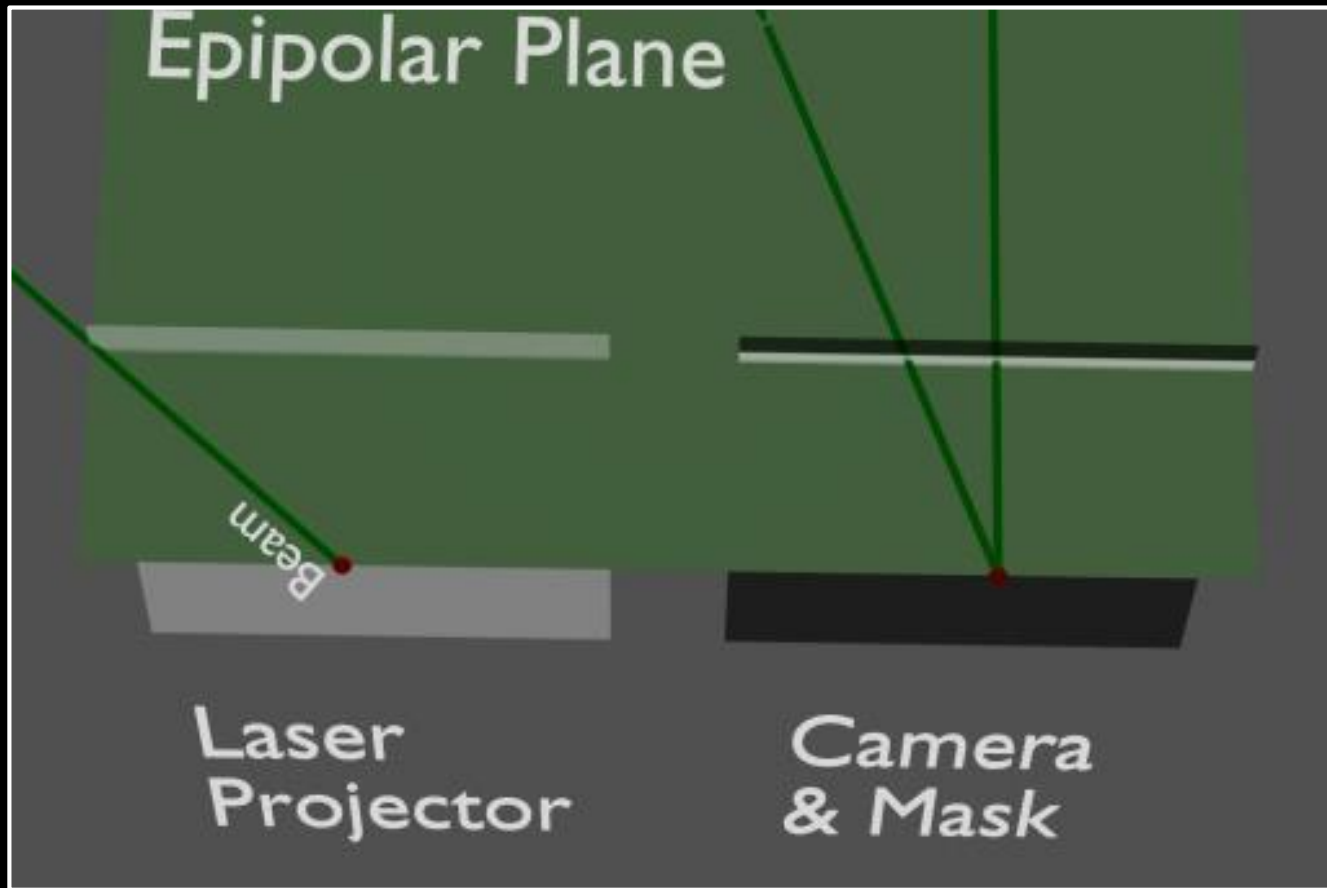


top-left: conventional
top-right: indirect-only
bottom-right: epipolar-only

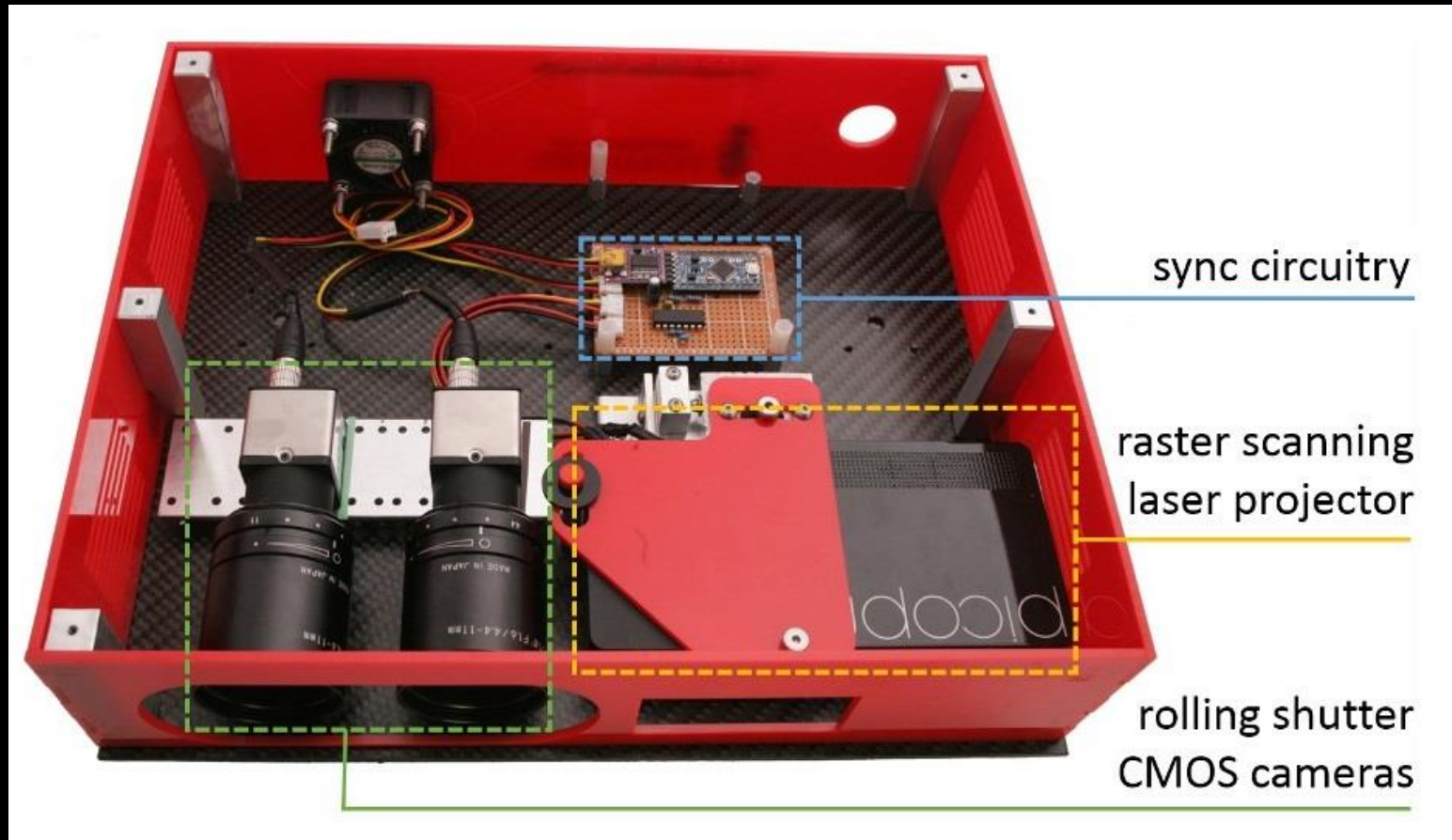


Energy-efficient epipolar imaging

Energy-efficient transport parsing



Energy-efficient transport parsing

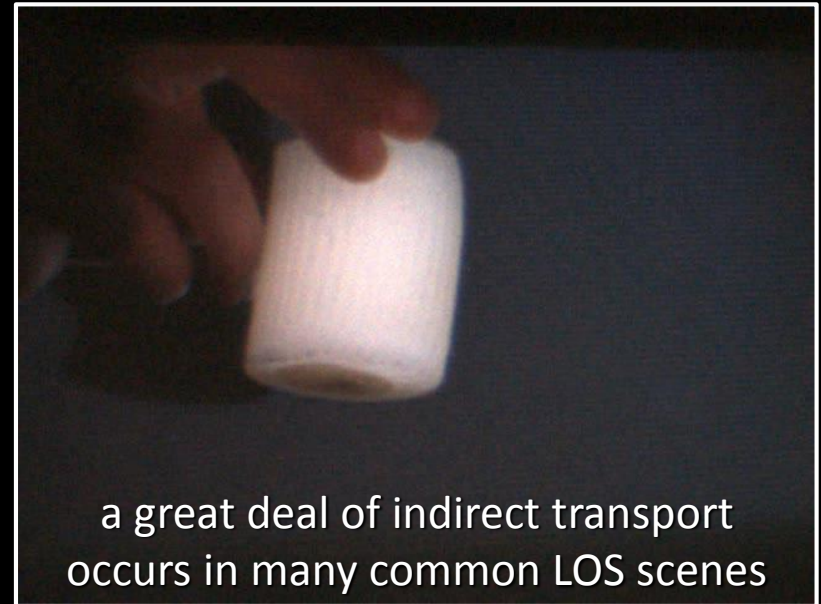


all paths

```
graph TD; A[all paths] --> B[planar (mostly direct)]; A --> C[non-planar (always indirect)];
```

planar (mostly direct)

non-planar (always indirect)

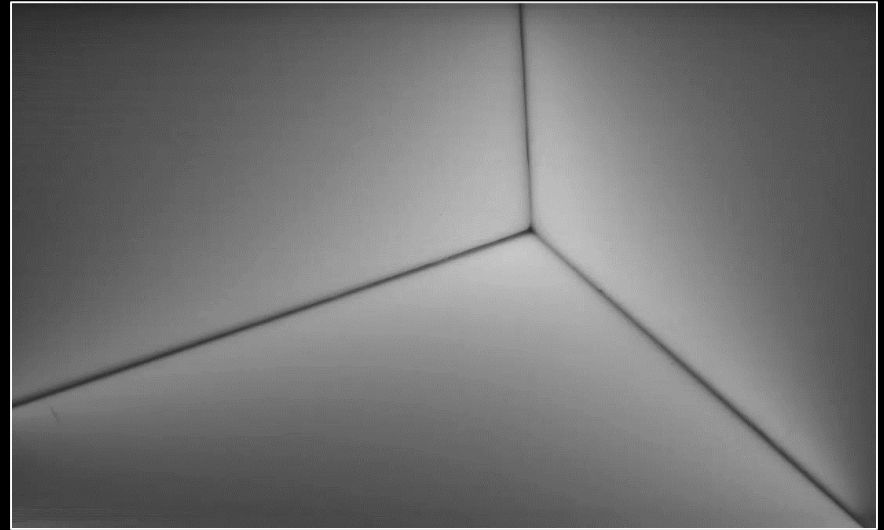
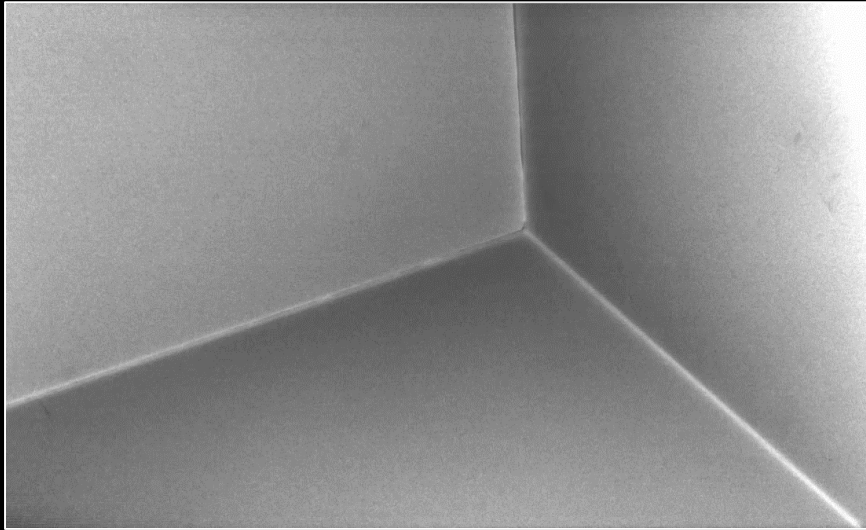


a great deal of indirect transport
occurs in many common LOS scenes

all paths

planar (mostly direct)

non-planar (always indirect)



References

Basic reading:

- Nayar et al., “Fast separation of direct and global components of a scene using high frequency illumination,” SIGGRAPH 2004.
the paper on separation of direct and global illumination using high-frequency illumination.
- O’Toole et al., “Primal-dual coding to probe light transport,” SIGGRAPH 2012.
- O’Toole et al., “3d shape and indirect appearance by structured light transport,” CVPR 2014.
these two papers introduce the concepts of light transport probing and epipolar probing, as well as explain how to use primal-dual coding to achieve them.
- O’Toole et al., “Homogeneous codes for energy-efficient illumination and imaging,” SIGGRAPH 2015.
this paper shows how to efficiently implement epipolar imaging with a simple projector and camera.

Additional reading:

- Seitz et al., “A theory of inverse light transport,” ICCV 2005.
this early paper shows a way to *exactly* decompose light transport by number of bounces, under certain assumptions for the imaged scene.
- Chandraker et al., “On the duality of forward and inverse light transport,” PAMI 2011.
- Reddy et al., “Frequency-space decomposition and acquisition of light transport under spatially varying illumination,” ECCV 2012.
these two papers have additional analysis about the relationship between direct and global illumination and illumination frequency.