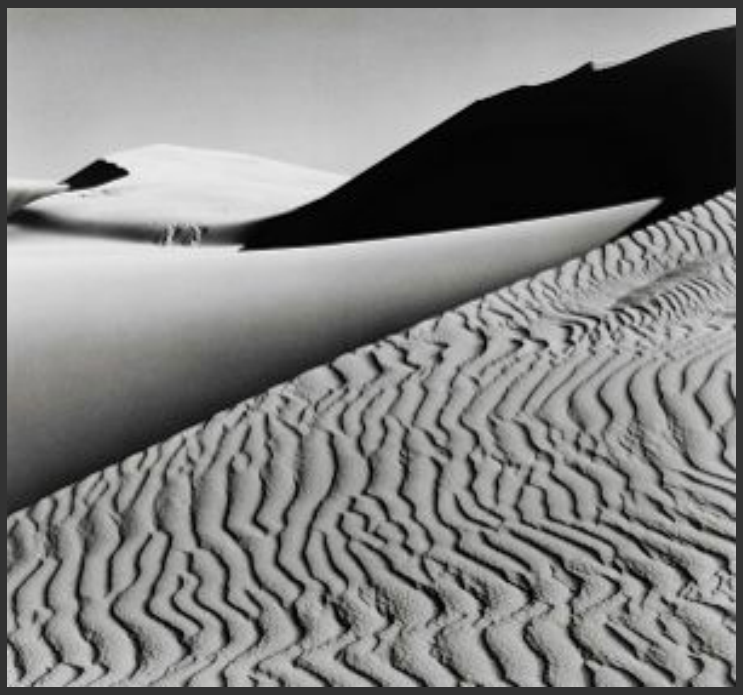
cameras



ansel adams

cs148 / 1 july 2014

why study real cameras?

"star wars episode 1: the phantom menace", george lucas/20th century fox (1999)

"barry lyndon", stanley kubrick/warner bros. (1975)

american cinematographer, march 1976.
http://imgur.com/a/mkDGR

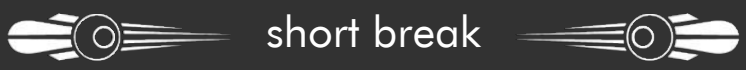
heavily-modified Mitchell BNC cameras

Zeiss 50mm f/0.7 lenses
developed by NASA for satellite photography

push process: changes contrast, film sensitivity

lens optics

camera anatomy & demo

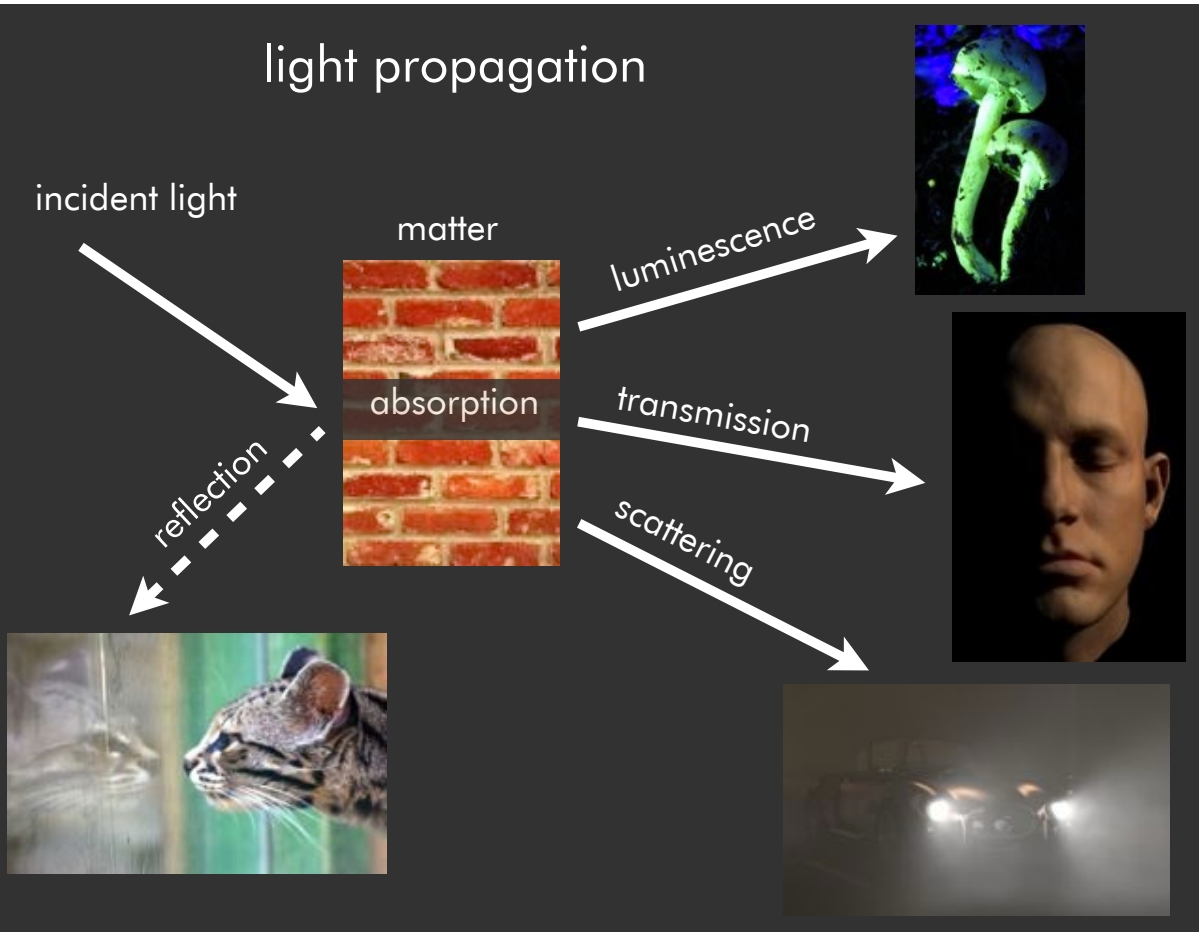


modern cameras

cameras in simulation

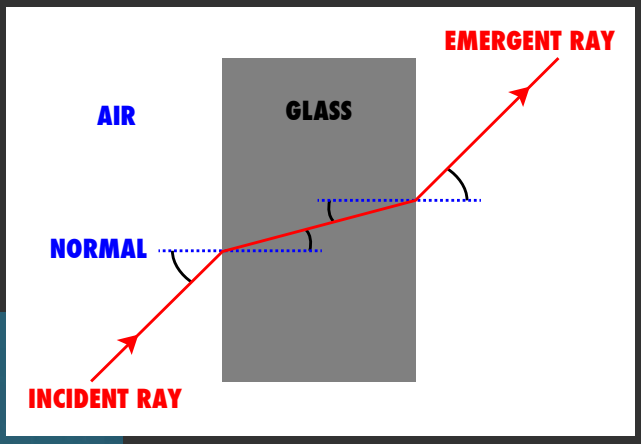
wrap up

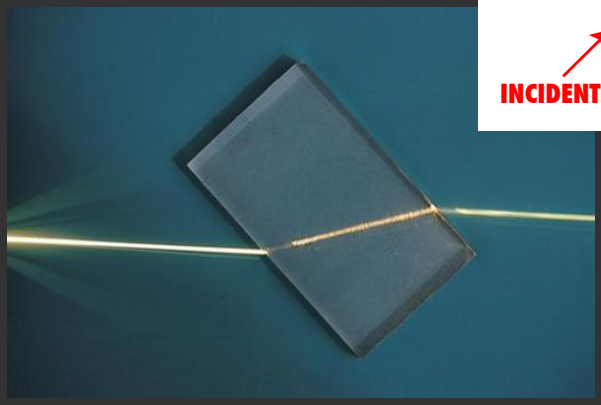
light propagation



refraction

transmitted light will change direction (refract) when it passes from one material to another





refractive index

material property
(proportional to nuclear density)

how much slower does light propagate through this material than it would through free space?

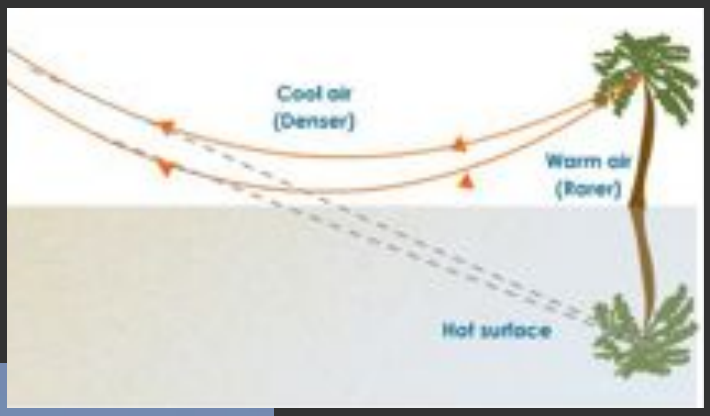
$$\eta = \frac{c}{v}$$

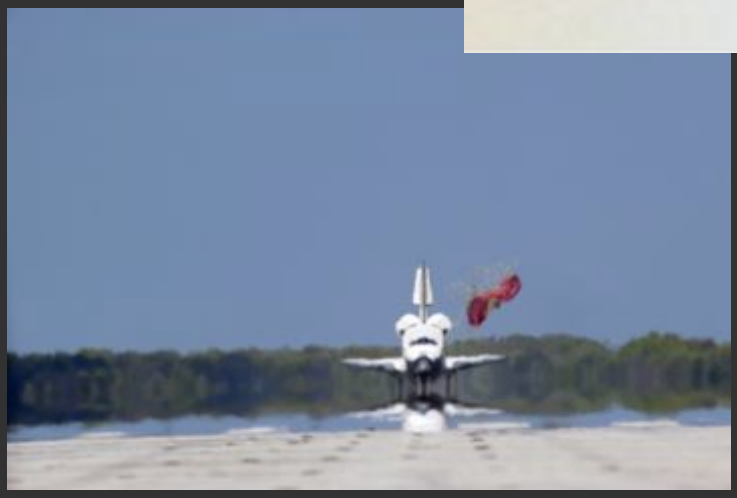
example refractive indices, η

air	1.00
water	1.33
ethanol	1.36
crown glass	1.52
diamond	2.42

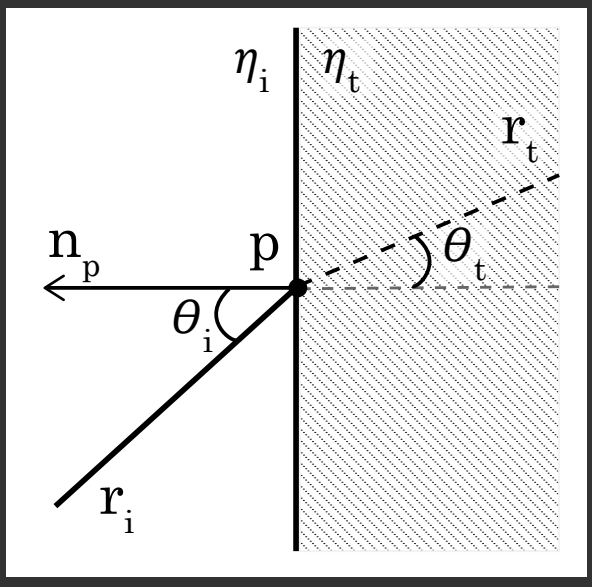
D

mirage is caused by reflection off the interface between layers of warmer and cooler air with different η





snell's law

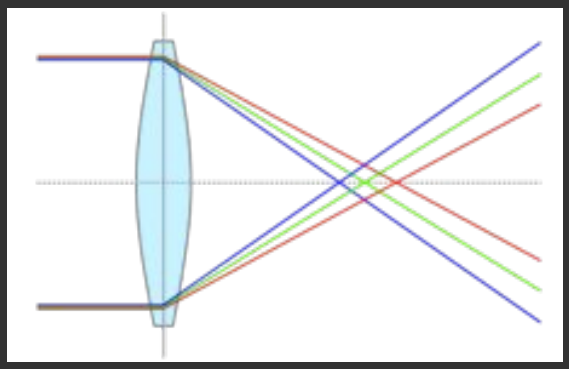


$$\eta_i \sin\theta_i = \eta_t \sin\theta_t$$

$$\frac{\eta_i}{\eta_t} = \frac{\sin\theta_t}{\sin\theta_i}$$

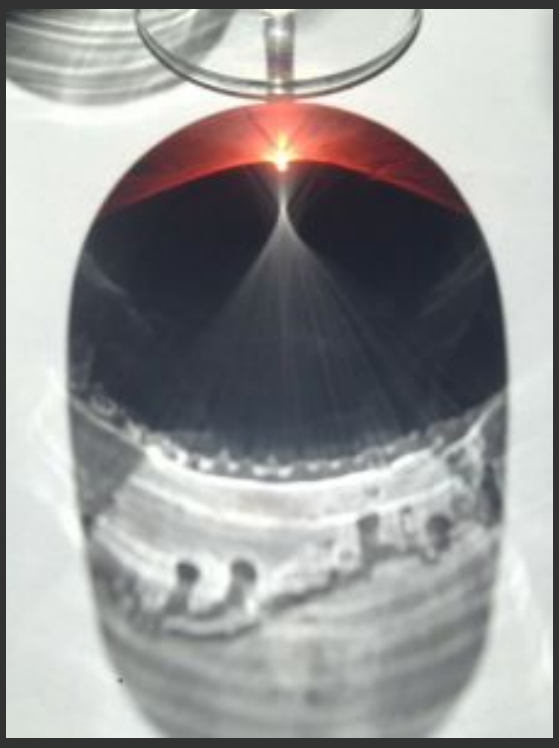
change in angle depends on surface orientation and refractive index

refraction is wavelength dependent



glass, $\eta = 1.5$

diamond, $\eta = 2.4$



caustics, lensing effects across multiple interfaces.

lens optics

camera anatomy & demo

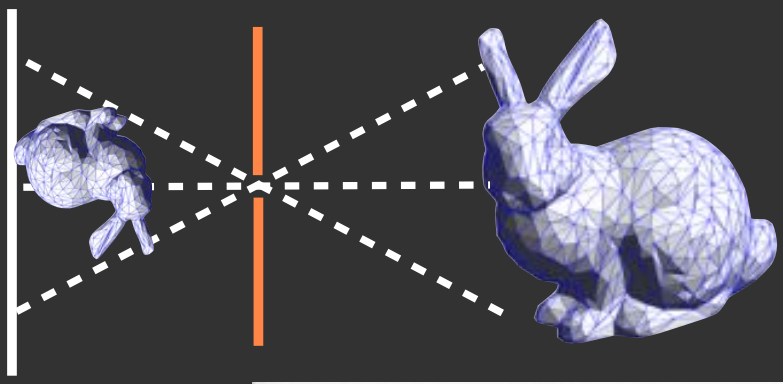
short break

modern cameras

cameras in simulation

wrap up

a simple camera



a simple camera

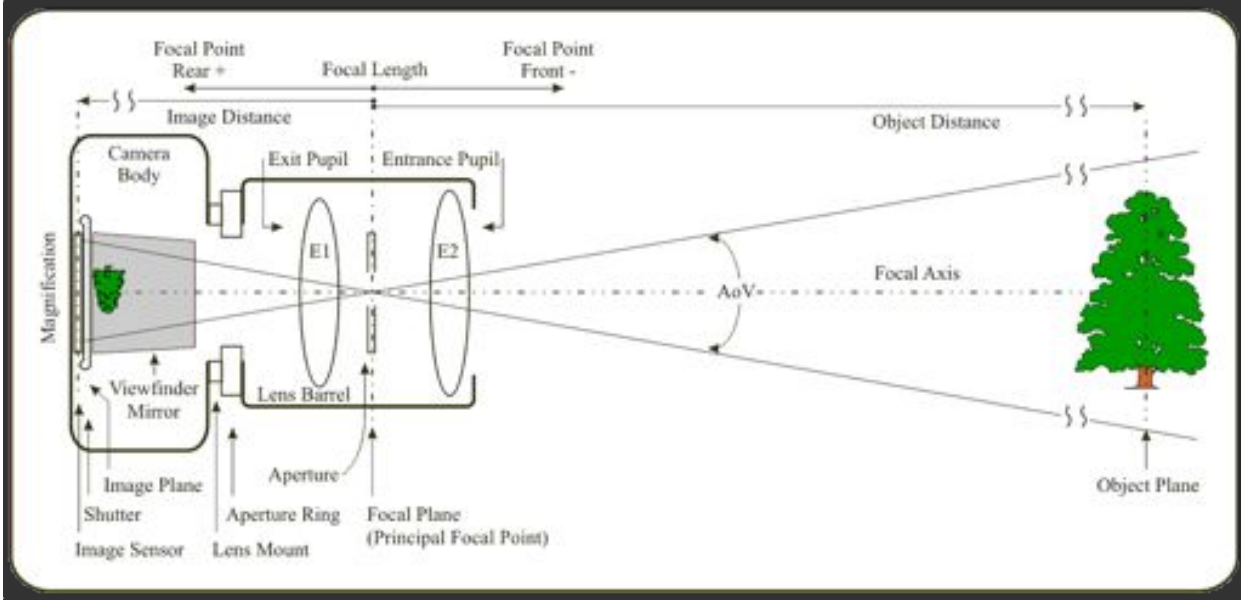


image controlled by:

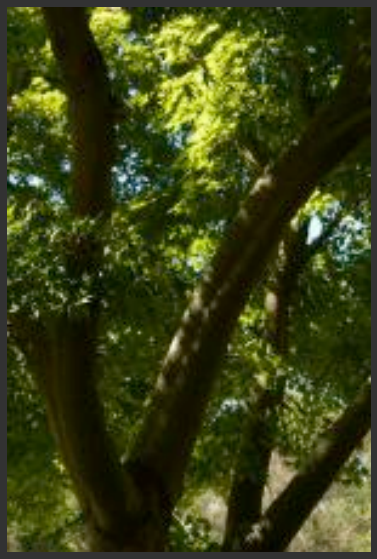
ISO
how sensitive is the film to light?

shutter speed
how long is the aperture open?

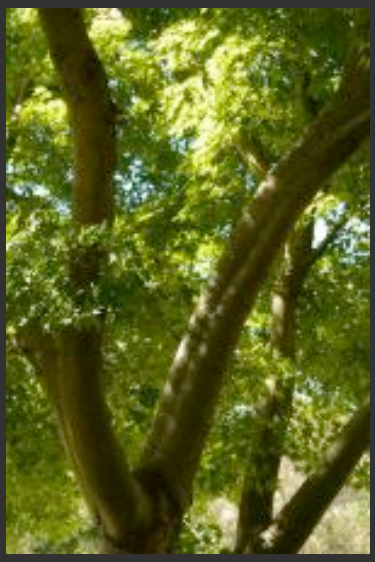
focus distance
where is the film plane?

aperture
how much light is coming into the camera?

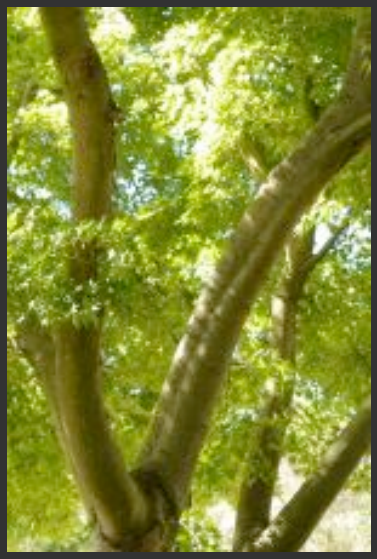
lens
how is incoming light being bent between the scene and the film plane?



ISO 800



ISO 1600



ISO 3200

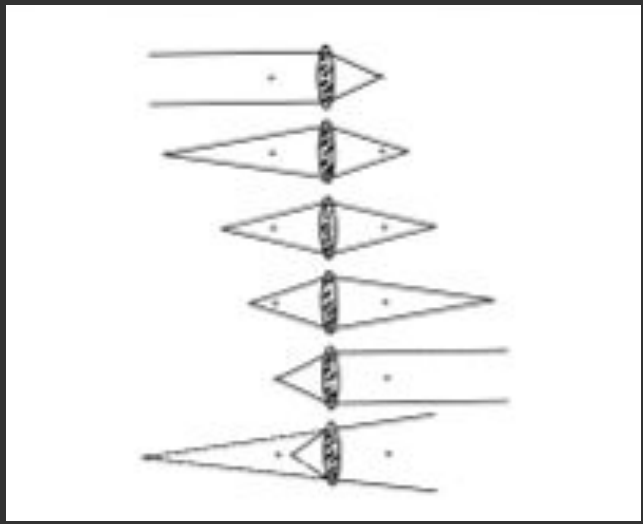
shutter speed

1/125″

1/10″

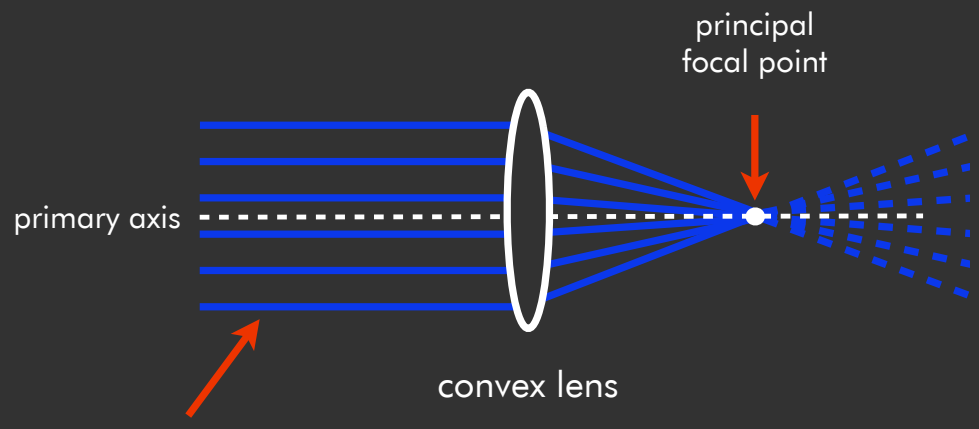
1/1000″

focusing



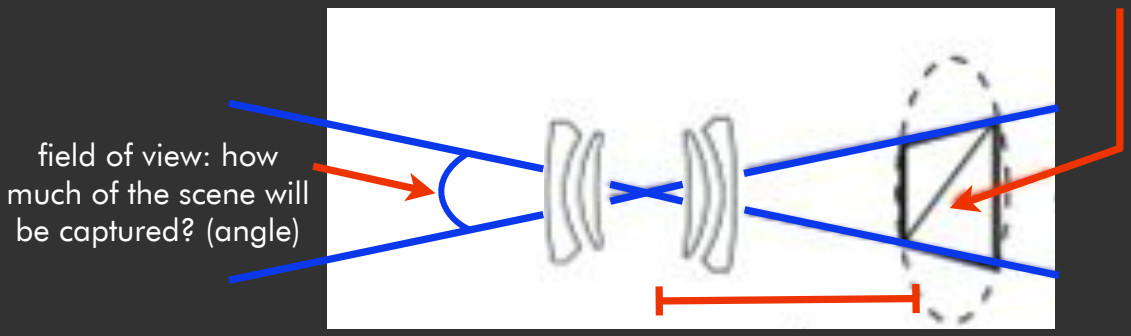
to focus: move lens relative to backplane
(or, move backplane relative to lens)

lenses



field of view

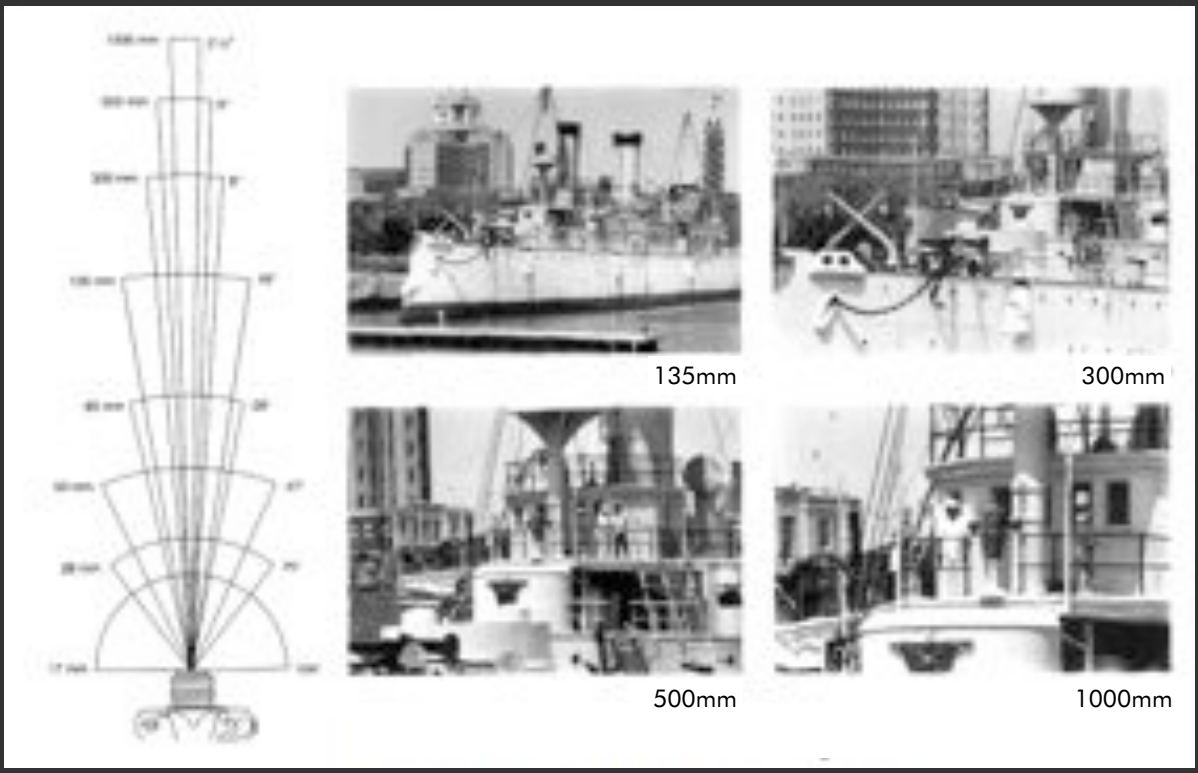
film diagonal: how big
is the sensor/film? (mm)



focal length:
distance between the lens and the image
sensor when the subject is in focus (mm)

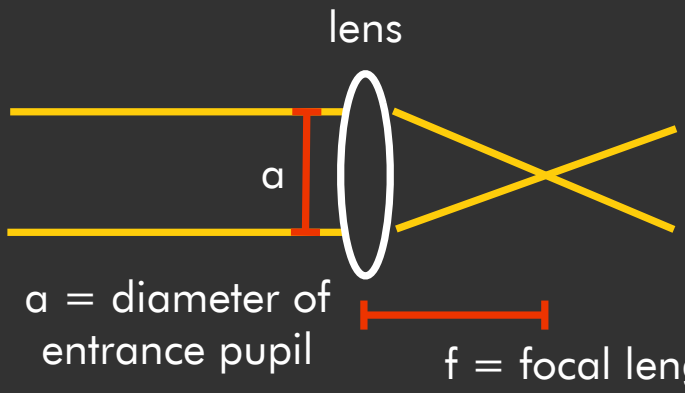
$$\tan\frac{f.o.v}{2} = \frac{\frac{1}{2}filmdiag}{f}$$

for a given film size: short focal length ⟹ wide field of view, low magnification
long ⟹ narrow field of view, high magnification



from London and Upton, "Photography"

aperture and exposure

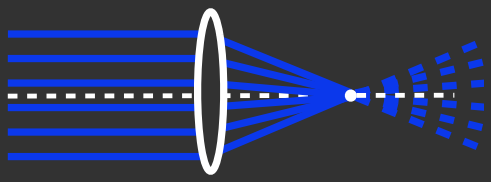


f-stop, N

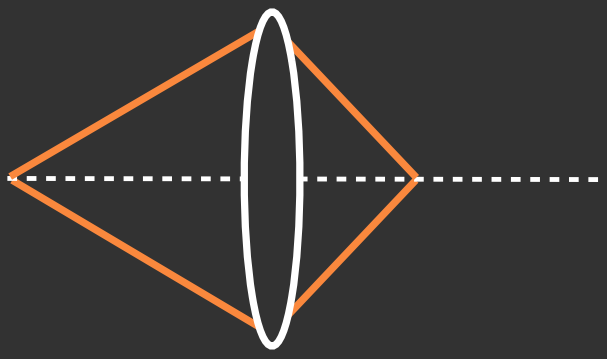
$$N = \frac{f}{a}$$

Exposure is proportional to the area^2 :

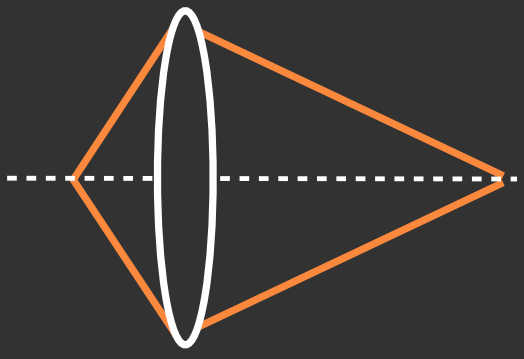
$$\mathrm{E} \propto \frac{a^2}{f^2}$$



focusing at infinity

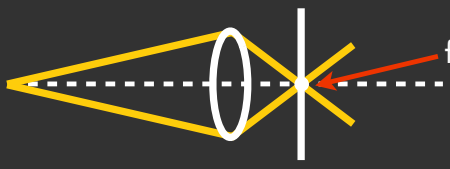


object far

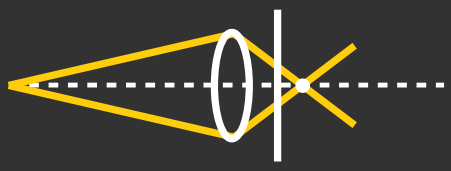


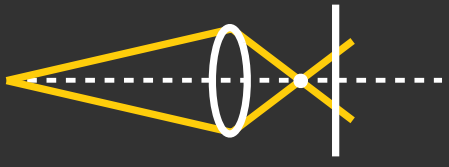
object near

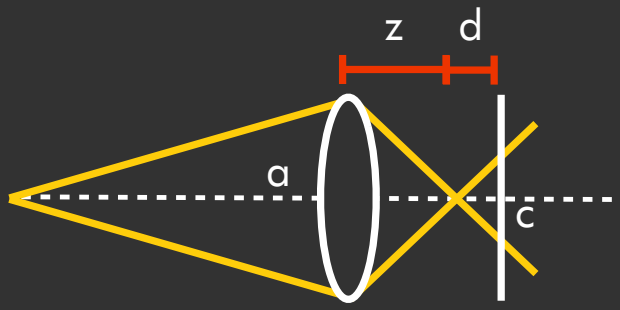
circle of confusion



focus point





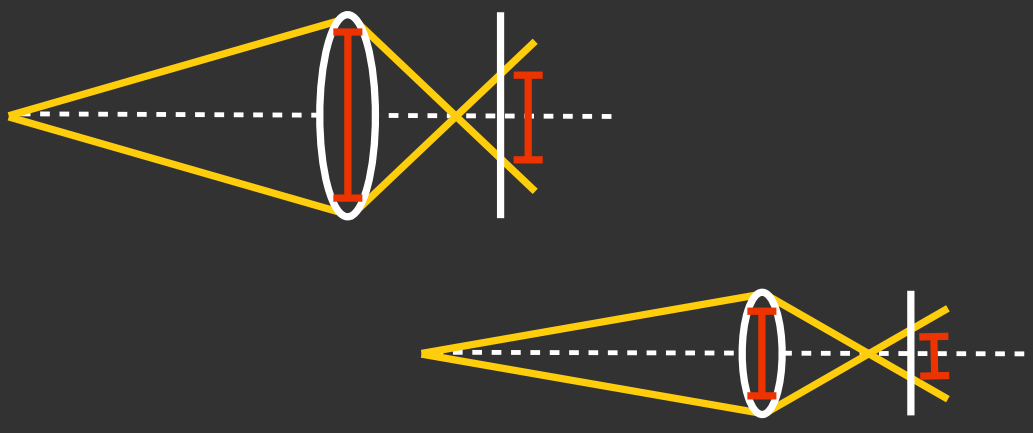


back plane

circle of confusion:
proportional to the size of the aperture

$$\frac{c}{a} = \frac{d}{z}$$

circle of confusion



circle of confusion:
proportional to the size of the aperture

$$\frac{c}{a} = \frac{d}{z}$$

depth of field

f/3.5 f/7.1 f/14

thought experiment

demo: 8x10” view camera

photos: jim breeden

lens optics

camera anatomy & demo

short break

modern cameras

cameras in simulation

wrap up

film ⟹ digital sensors

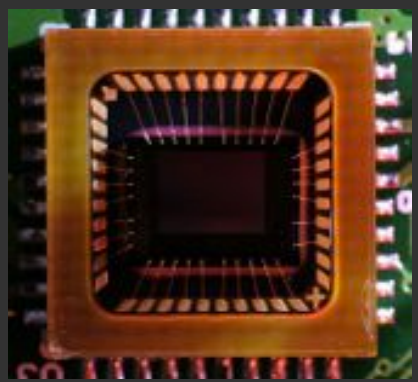
boyle and smith (1969), bell labs.
nobel prize (2009)

photons converted to electrical charges, stored in capacitors.

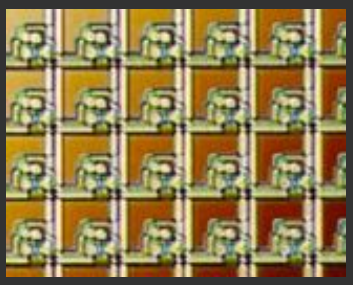
more photons? higher charge.

charges read off, filtered to produce an image

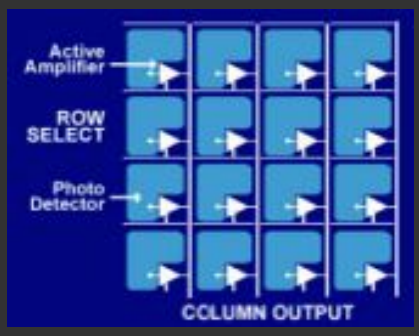
charge coupled devices (CCDs)



film ⟹ digital sensors



active pixel sensor
(APS/CMOS)



development 1960s-90s

big push for consumer devices by JPL spinoff Photobit Corp (1995)

pixels are "active" because each has its own amplifier

CCD vs. CMOS

CCD	CMOS
global shutter	rolling shutter
pixels captured in columns	pixels captured individually
slightly better resolution	cheaper
slightly more power	slightly less power

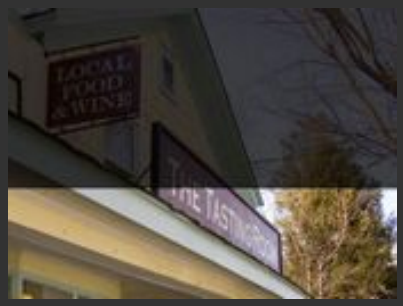
more info: http://www.bhphotovideo.com/c/find/newsLetter/Comparing-Image-Sensors.jsp

CCD

panning causes blur

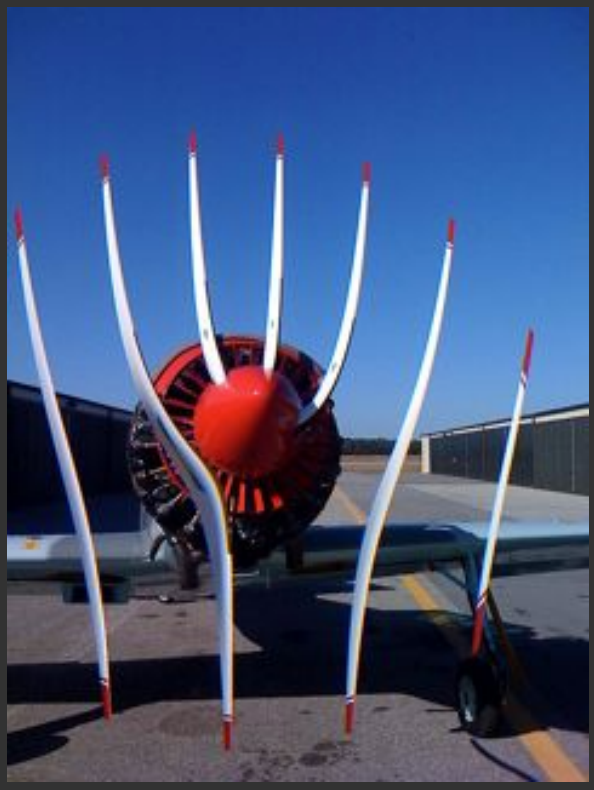
vertical smear

CMOS



flashes can cause
uneven lighting effects

panning causes shearing



rolling shutter

sensors: bigger is better

example: 6 megapixel camera

36mm x 24 mm (DSLRs)
- ~10 µm pixel size
- larger size gathers more light
- low noise (lots of photons)

¼" (point and shoot)
- ~1.5 µm pixel size
- smaller size, less light
- more noise

modern digital cameras

phase one

digital backs

canon EOS rebel

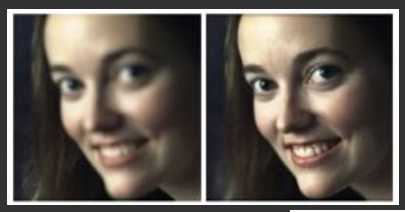
digital SLR

iphone 5, samsung pixon

mobile phones

depth cameras

microsoft kinect



lytro

light field photography

light field photography

record pixel values

record ray values

traditional cameras:

capture the amount of light striking each region of the image plane

insight:

by recording the direction of each ray of light, the image can be refocused after it is captured

light field photography

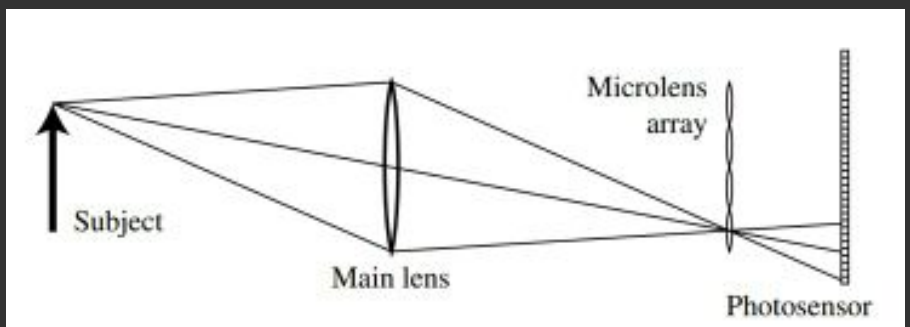
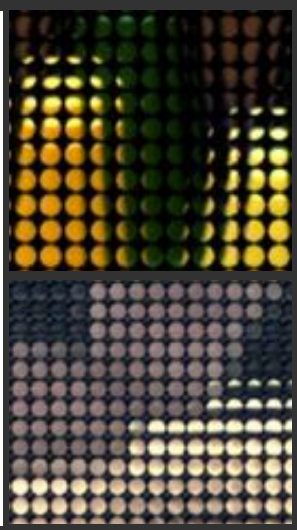
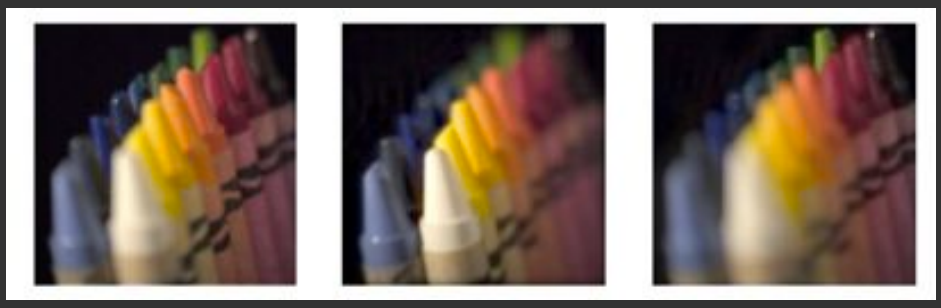


Figure 1: Conceptual schematic (not drawn to scale) of our camera, which is composed of a main lens, microlens array and a photosensor. The main lens focuses the subject onto the microlens array. The microlens array separates the converging rays into an image on the photosensor behind it.



Ng et al., "Light Field Photography with a Hand-held Plenoptic Camera"

light field photography



advantages:

refocusing
low-light photography
depth images
...?

lytro illum: coming soon!

lens optics

camera anatomy & demo

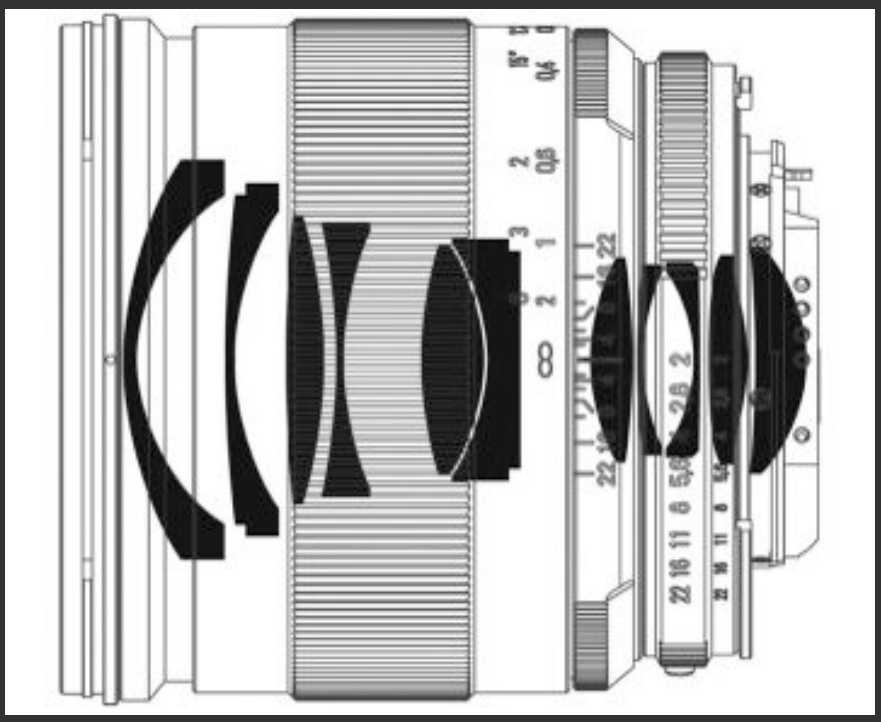
short break

modern cameras

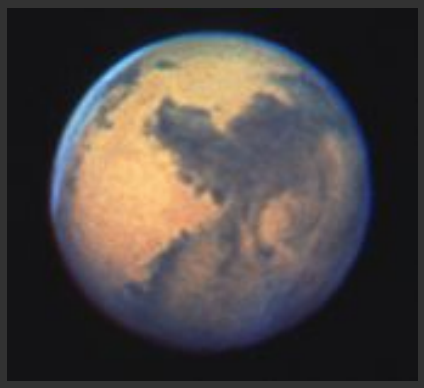
cameras in simulation

wrap up

real camera lenses



chromatic aberration

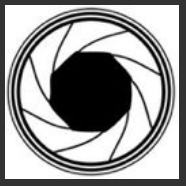


no lens is perfect!

a historical bottleneck for telescopes & microscopes

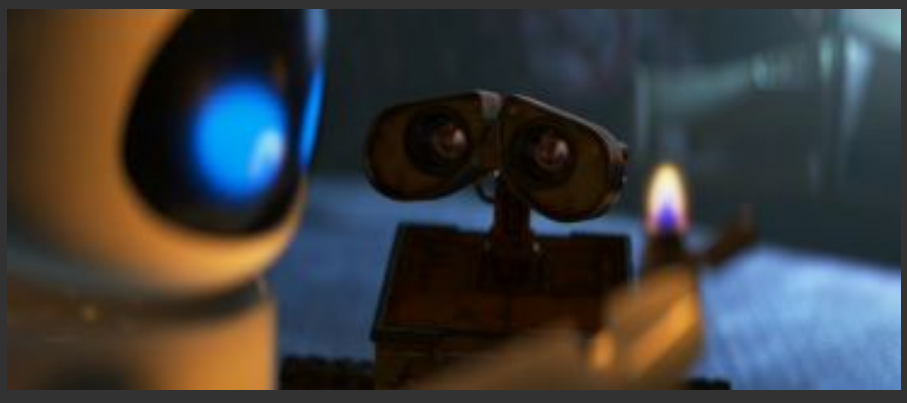
lens flare

bokeh



ratatouille, PIXAR, 2007

wall-e, PIXAR, 2008



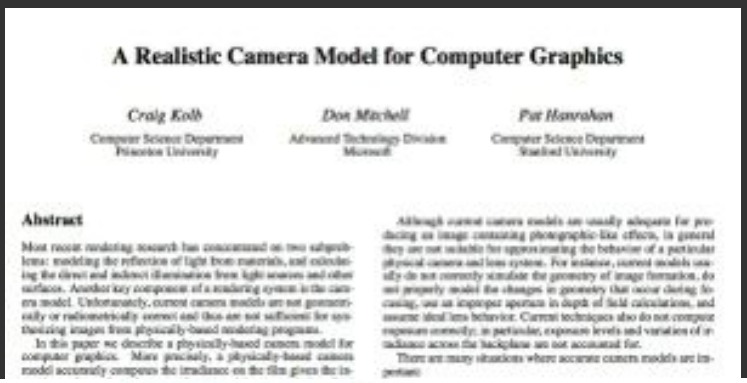
motion blur

star shaped bokeh

http://renderman.pixar.com/view/motion-blur-and-depth-of-field

simulating real camera lenses

assignment out thursday!



A Realistic Camera Model for Computer Graphics

Craig Kolb — Computer Science Department, Princeton University

Don Mitchell — Advanced Technology Division, Microsoft

Pat Hanrahan — Computer Science Department, Stanford University

Abstract

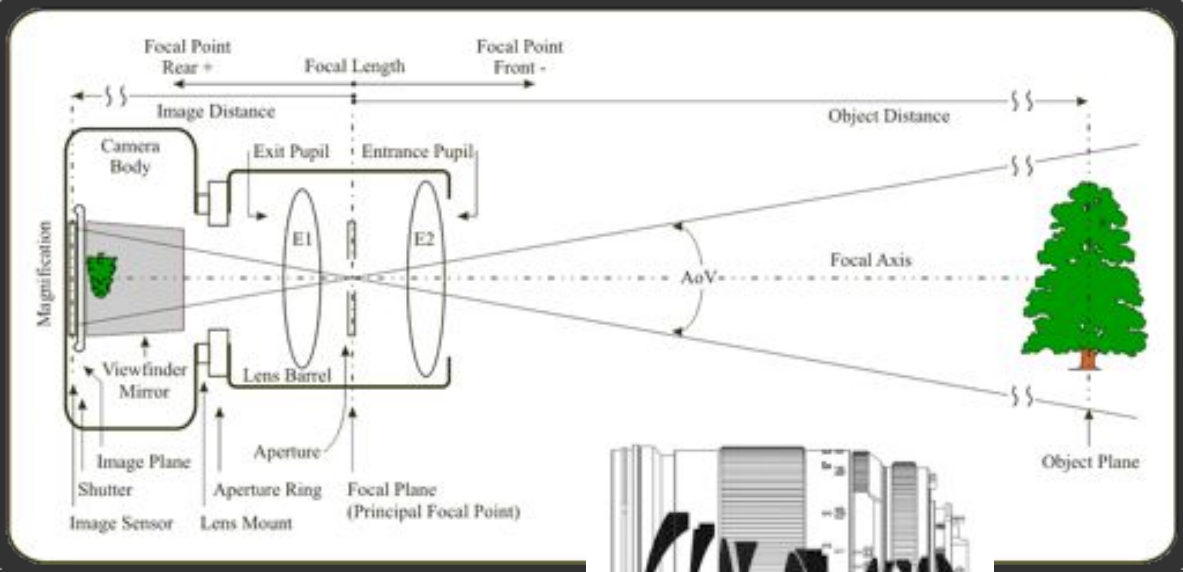
Most recent rendering research has concentrated on two subproblems: modeling the reflection of light from materials, and calculating the direct and indirect illumination from light sources and other surfaces. Another key component of a rendering system is the camera model. Unfortunately, current camera models are not geometrically or radiometrically correct and thus are not sufficient for synthesizing images from physically-based rendering programs.

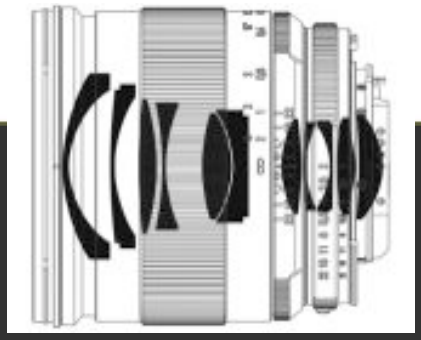
In this paper we describe a physically-based camera model for computer graphics. More precisely, a physically-based camera model accurately computes the irradiance on the film given the in-

Although current camera models are usually adequate for producing an image containing photographic-like effects, in general they are not suitable for approximating the behavior of a particular physical camera and lens system. For instance, current models usually do not correctly simulate the geometry of image formation, do not properly model the changes in geometry that occur during focusing, use an improper aperture in depth of field calculations, and assume ideal lens behavior. Current techniques also do not compute exposure correctly; in particular, exposure levels and variation of irradiance across the backplane are not accounted for.

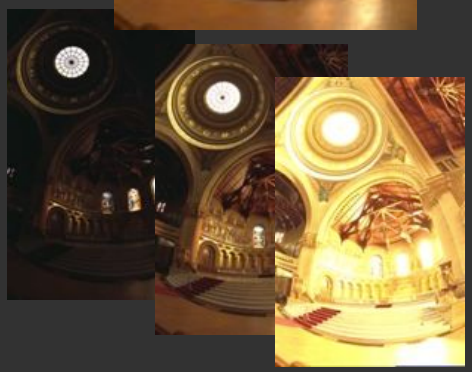
There are many situations where accurate camera models are important

trace rays through camera elements by finding their intersections with lens elements, calculating outbound direction from Snell's law





further topics



high-dynamic range imaging

tilt-shift photography

lens optics

camera anatomy & demo

short break

modern cameras

cameras in simulation

wrap up

things to remember

refraction, η, and snell's law

field of view depends on film size, focal length

exposure depends on aperture, shutter speed

circle of confusion

modern camera technology

simulating real camera lenses

Tim Jenison

NewTek:
Video Toaster (video production software)
& Lightwave 3D

movie night

"Tim's Vermeer"

johannes vermeer:
the first CS148 student?
you be the judge.

movie night

"Tim's Vermeer"

wednesday

6pm@ Gates 104

popcorn and cookies!

for next time:

reading response:
Shirley Ch. 3

assignment 1
due thursday night

movie night
poll on Piazza