Lighting for photography

CS 448A, Winter 2010

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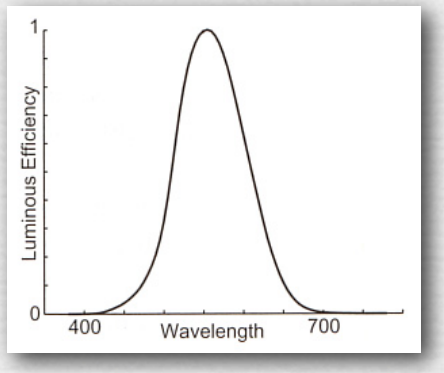
Outline

- measures of light
  - radiometry versus photometry
  - radiant intensity of a point light
  - radiance leaving an area light
  - radiance arriving on a surface
  - irradiance on a surface
- lighting for photography
  - taxonomy of light sources
  - studio lighting
  - lighting for portraiture
  - special lighting problems
  - flash photography

Radiometry versus photometry

- *radiometry* is the study of light w/o considering humans
  - spectroradiometer - power as a function of wavelength
  - radiometer - total power, integrating over all wavelengths
  - measurements include
    - radiant intensity, radiance, irradiance

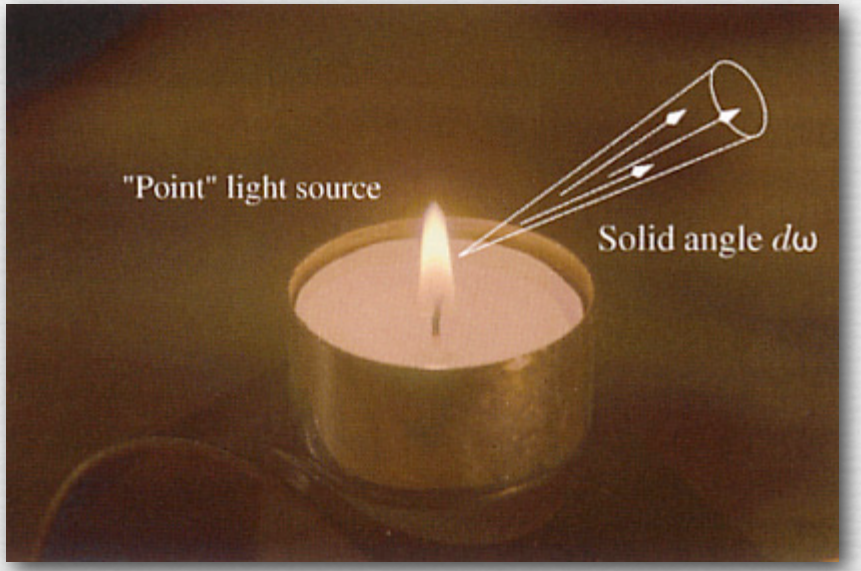
- *photometry* is the study of light as seen by humans
  - spectrophotometer - power we see as a function of wavelength
  - photometer, a.k.a. photographic light meter
  - measurements include
    - luminous intensity, luminance, illuminance
  - relationship to radiometry is given by the luminous efficiency curve



Radiant intensity of a point light

- power given off by the light per unit solid angle

$$I = \frac{P}{\Omega} \qquad \left(\frac{\text{watts}}{\text{steradian}} \right)$$

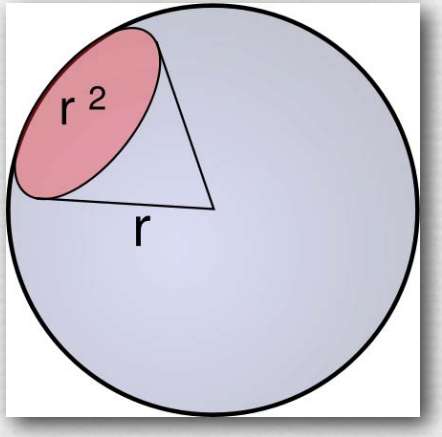


(Reinhard)

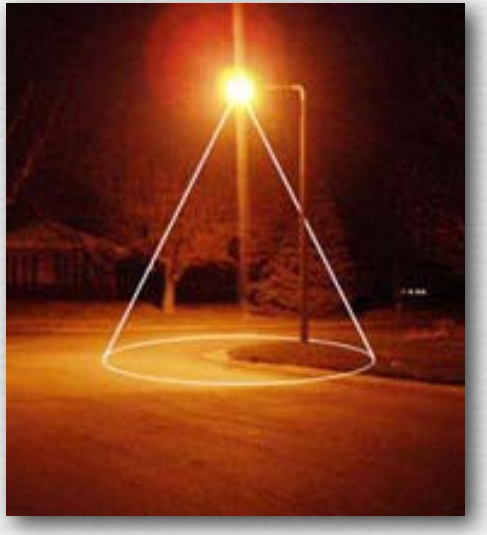
- equivalently, the energy per unit time per unit solid angle
  - 1 watt = 1 joule / second

Steradian as a measure of solid angle

- 1 steradian (sr) is the solid angle such that the area subtended by that solid angle on the surface of a sphere is equal to the sphere's radius^2
  - area of a sphere is $4\pi r^2$, so 1 sr = $r^2 / 4\pi r^2$ ≈ 1/12 of the sphere's surface



(http://www.handprint.com/HP/WCL/color3.html)



- examples
  - circular aperture 65° in subtended diameter
  - square aperture 57° on a side
  - a circle 12.7' in diameter cast by a streetlight 10' high

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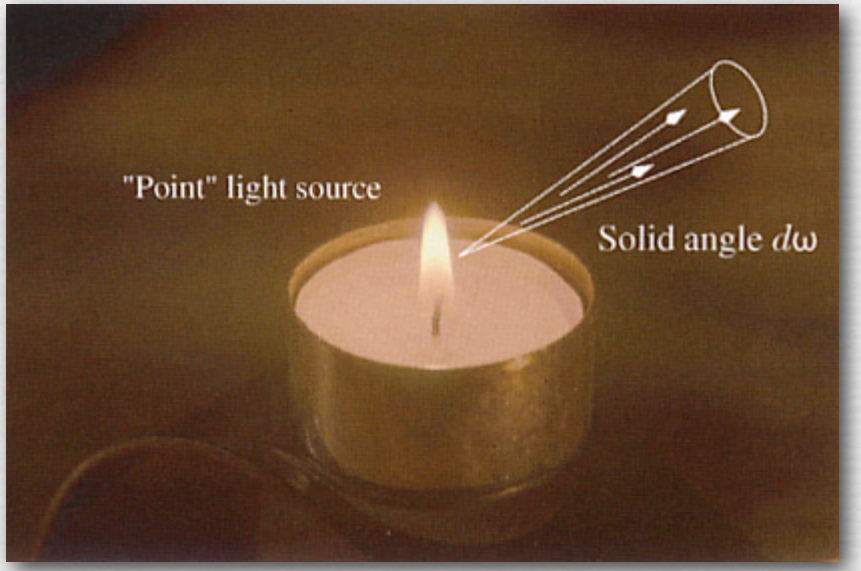

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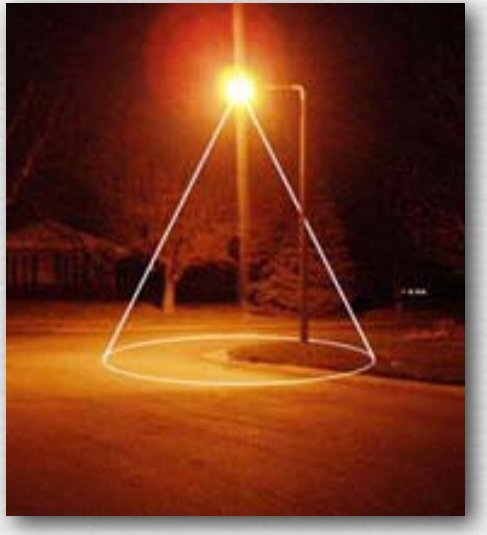

- example
  - 100W light bulb gives off 100 watts over the sphere ÷ 4π sr in a sphere = 8 watts within a 12.7' circle 10' feet from the bulb

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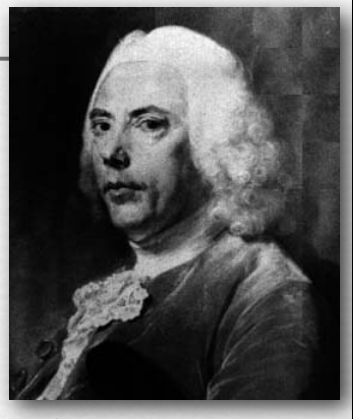


Pierre Bouguer
(1698-1758)

- related photometric concept is luminous intensity (measured in candelas)
  - 1 candela = 1 lumen / sr
- examples
  - a standard Bouguer candle gives off 1 candela
  - a 100W light bulb with a luminous efficiency of 2.6% (the other 97.4% we don't see) gives off 17.6 lumens per watt × 100W ÷ 4π sr in the sphere = 140 candelas

Photography by candlelight

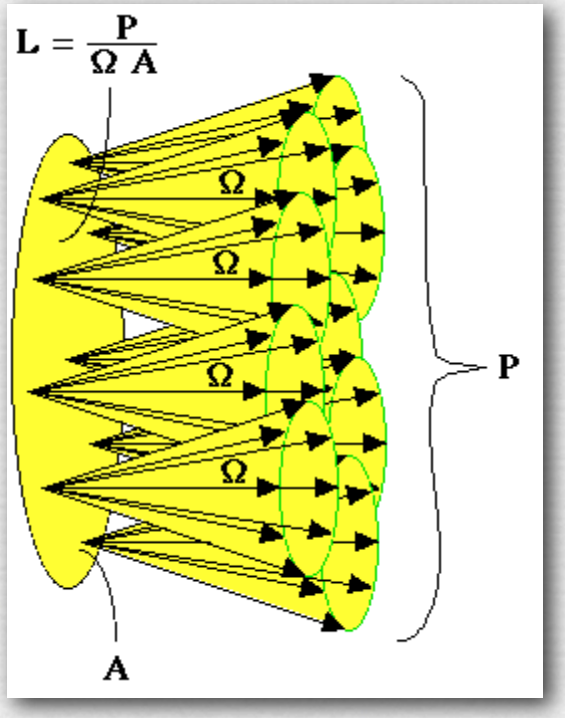
(digital-photography-school.com)

- need SLR-sized pixels, fast lens, tripod, patient subject
  - moderate shutter speed (1/15 sec) and ISO (400)

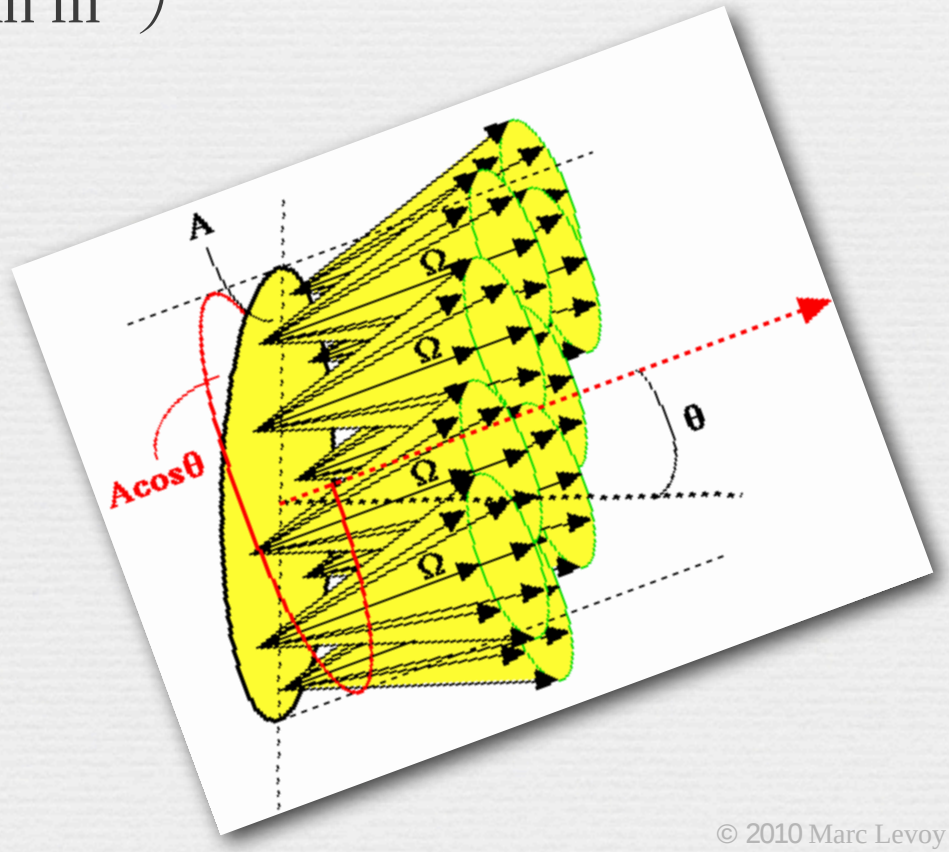
Radiance leaving an area light

- power given off by the light per unit solid angle per unit area, viewed at an angle of θ away from straight-on

$$L = \frac{P}{\Omega A \cos\theta} \qquad \left(\frac{\text{watts}}{\text{steradian m}^2}\right)$$



(http://omlc.ogi.edu/classroom/ece532/class1/radiance.html)



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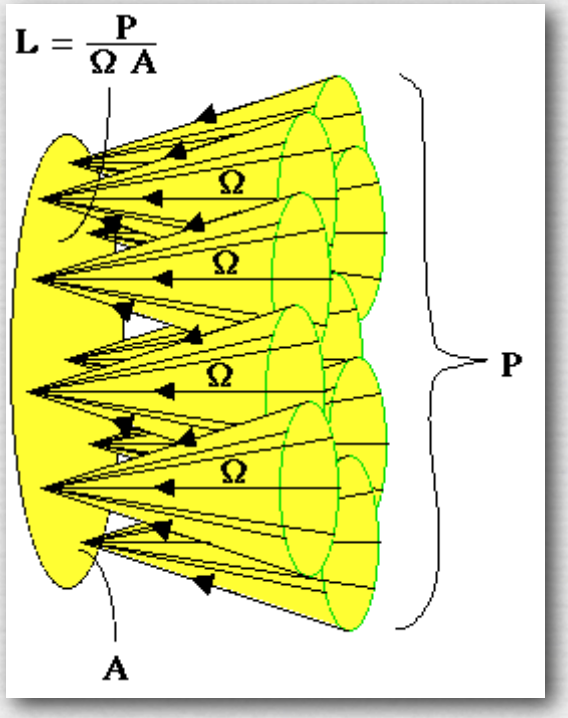
- related photometric concept is luminance (measured in nits) (yup, nits!)
  - 1 nit = 1 candela / m^2 = 1 lumen / sr m^2
- example
  - viewed perpendicularly, a computer display gives off 50-300 candelas per $meter^2$ of the display surface, about the same as a 100W light bulb but spread out

Radiance arriving on a surface

- power arriving on a surface per unit solid angle per unit area, illuminated from a declination of θ

$$L = \frac{P}{\Omega A \cos\theta} \qquad \left(\frac{\text{watts}}{\text{steradian m}^2}\right)$$



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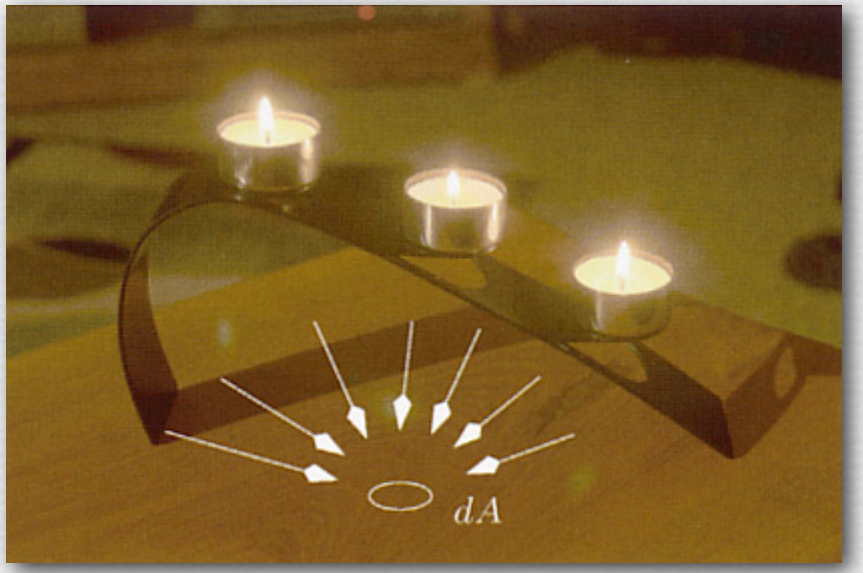
$$L = \frac{P}{\Omega A \cos\theta} \qquad \left(\frac{\text{watts}}{\text{steradian m}^2} \right)$$

- examples (most are from Minnaert)
  - luminance arriving on a surface from a full (overhead) sun is 100,000 candelas/cm^2 (100,000 lumens/sr cm^2)
  - luminance reflected by a diffuse white surface illuminated by the sun is 2 cd/cm^2
  - reflected by a black surface is 0.04 cd/cm^2
  - arriving from a full overhead moon is 0.3 cd/cm^2
  - luminance arriving from a white cloud (fully lit by the sun) is 10 × luminance of the blue sky, a difference of 3.3 f/stops

Irradiance on a surface

- power accumulating on the surface per unit area, considering light arriving from all directions

$$E = \frac{P}{A} \qquad \left(\frac{\text{watts}}{\text{m}^2}\right)$$



(Reinhard)

Irradiance on a surface

- power accumulating on a surface per unit area, considering light arriving from all directions

$$E = \frac{P}{A} \qquad \left(\frac{\text{watts}}{\text{m}^2} \right)$$

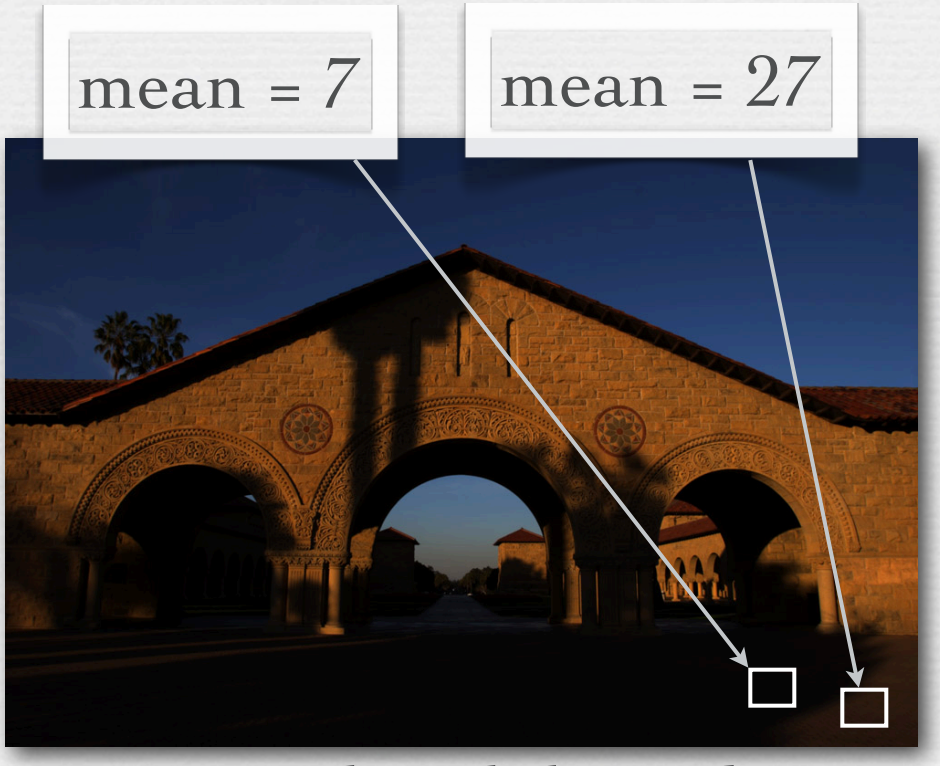
- related photometric unit is illuminance (measured in lux)
  - 1 lux = 1 lumen / m^2
  - British unit is footcandle = 1 candela held 1 foot from surface
- example
  - illuminance from a bright star = illuminance from a candle 900 meters away = 1/810,000 lux

How dark are outdoor shadows?

- luminance arriving on a surface from a full (overhead) sun is 300,000 × luminance arriving from the blue sky, but the sun occupies only a small fraction of the sky
- illuminance on a sunny day = 80% from the sun + 20% from blue sky, so shadows are 1/5 as bright as lit areas (2.3 f/stops)

(Marc Levoy)

JPEG file



RAW, linearly boosted

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  - taxonomy of light sources
  - studio lighting
  - lighting for portraiture
  - special lighting problems
  - flash photography

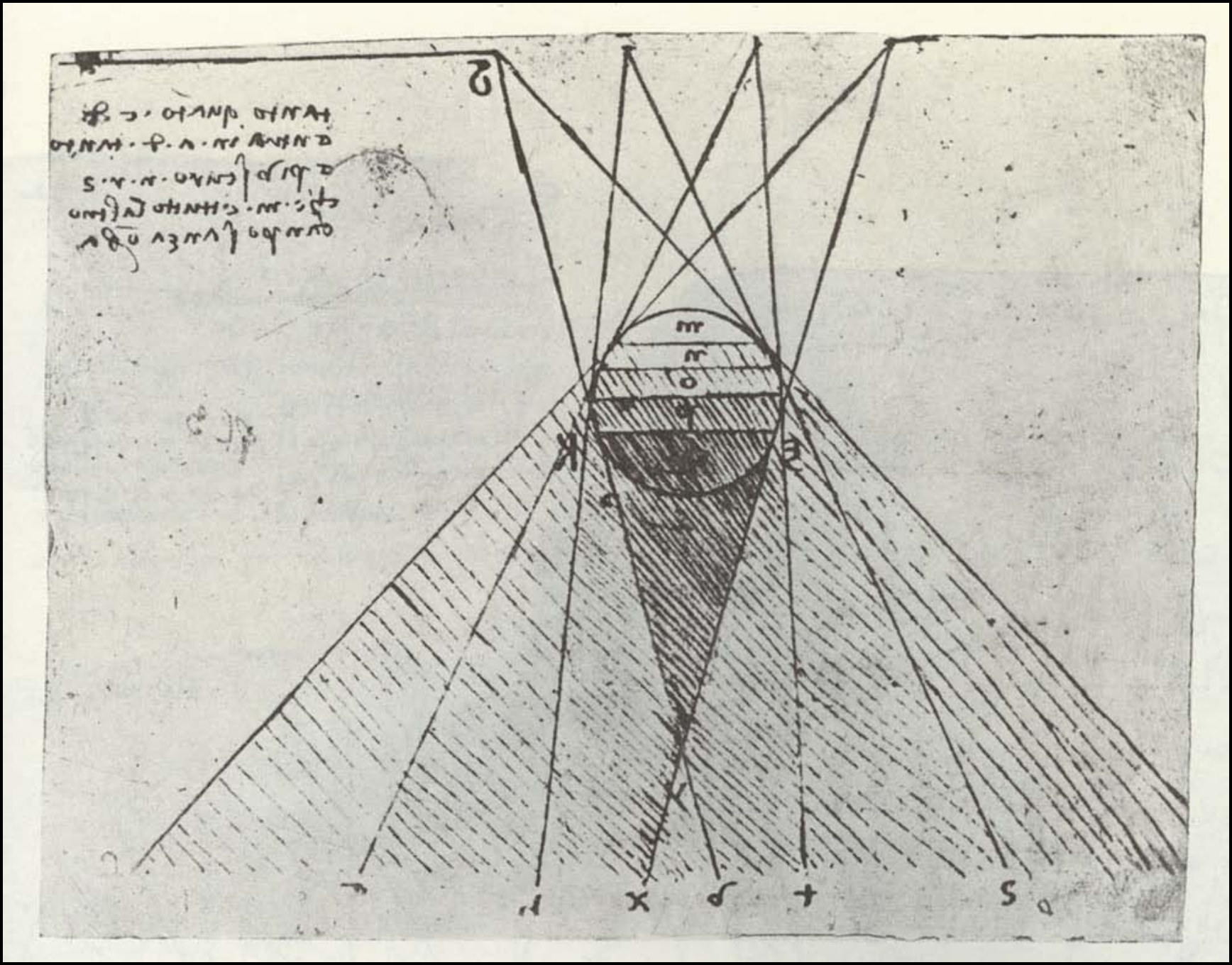
Taxonomy of light sources

[Langer and Zucker, CVPR 1997]

Non-ideal example	*Ideal model*	h_x	h_y	h_p	h_q	dimension
overcast sky	uniform source	∞	∞	∞	∞	4
Cyberware^{TM} scanner		∞	∞	∞	0	3
		∞	∞	0	∞	
fluorescent tube	linear source	∞	0	∞	∞	3
		0	∞	∞	∞	
sunlight	point source at infinity	∞	∞	0	0	2
	uniform distribution of rays in a plane	∞	0	∞	0	2
		0	∞	0	∞	
louvered linear source (see text)	fan of rays perpendicular to a linear source	∞	0	0	∞	2
		0	∞	∞	0	
small panel light	point source	0	0	∞	∞	2
sunlight through crack in doorway	parallel rays in a plane	∞	0	0	0	1
		0	∞	0	0	
rotating spotlight	fan of rays	0	0	0	∞	1
		0	0	∞	0	
spotlight or laser	single ray	0	0	0	0	0

What's different between these two?

(Hunter)



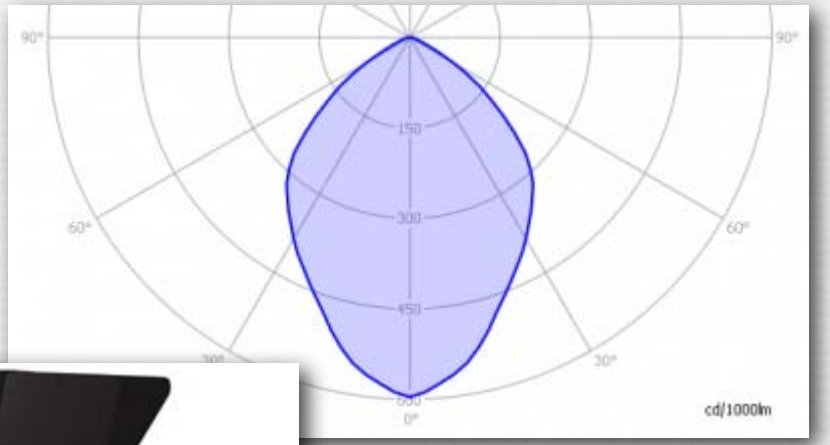
Leonardo, study of umbra and penumbra

Studio lighting

(Kodak)

Adjustments on studio spotlights

goniometric diagram showing luminous intensity at each angle



barn doors

zoom control

filter holder

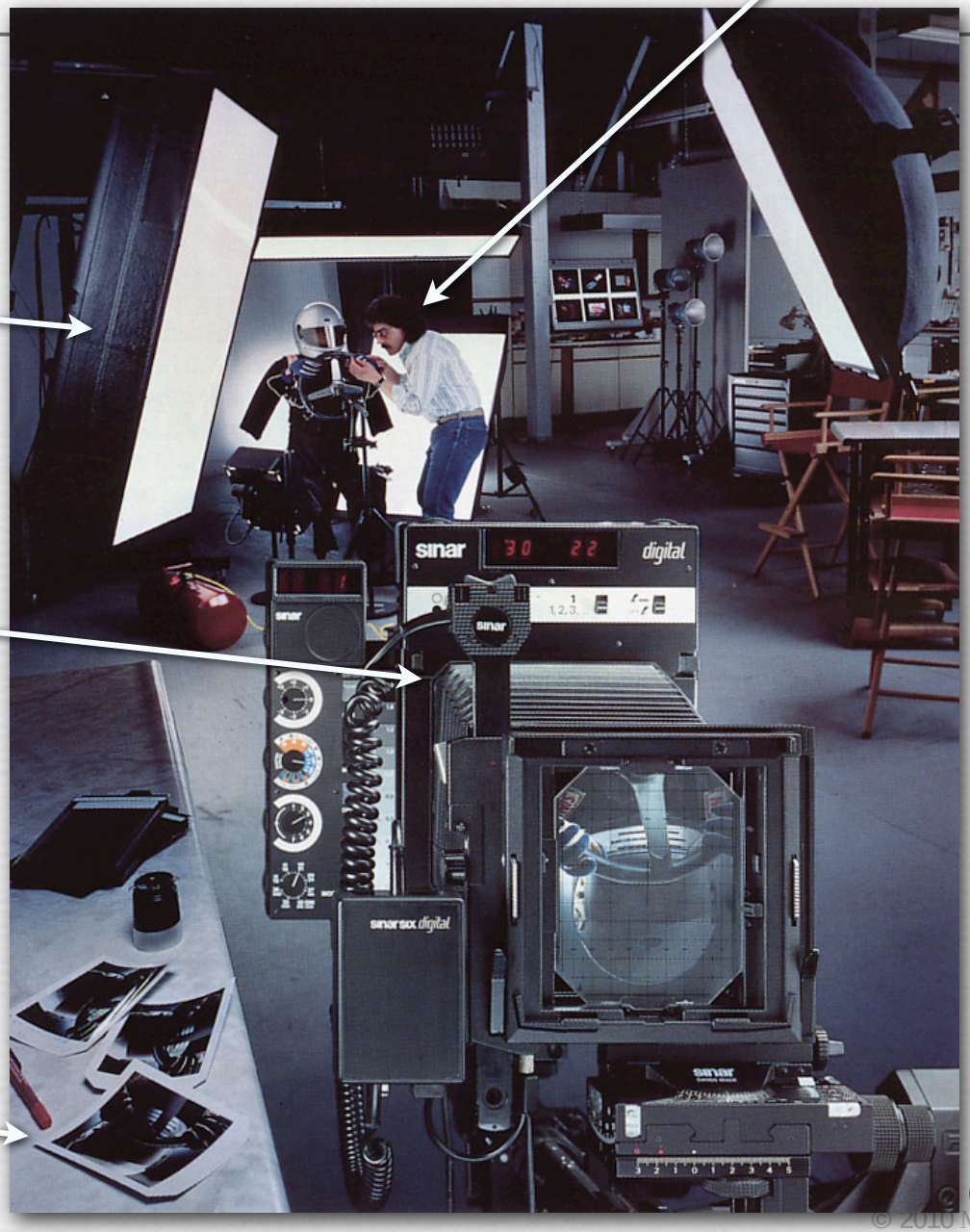
Lighting rigs can be large

1970's haircut

soft box

film view camera with digital light meter

polaroid preview pictures



(Kodak)

Basic portrait lighting

(London)



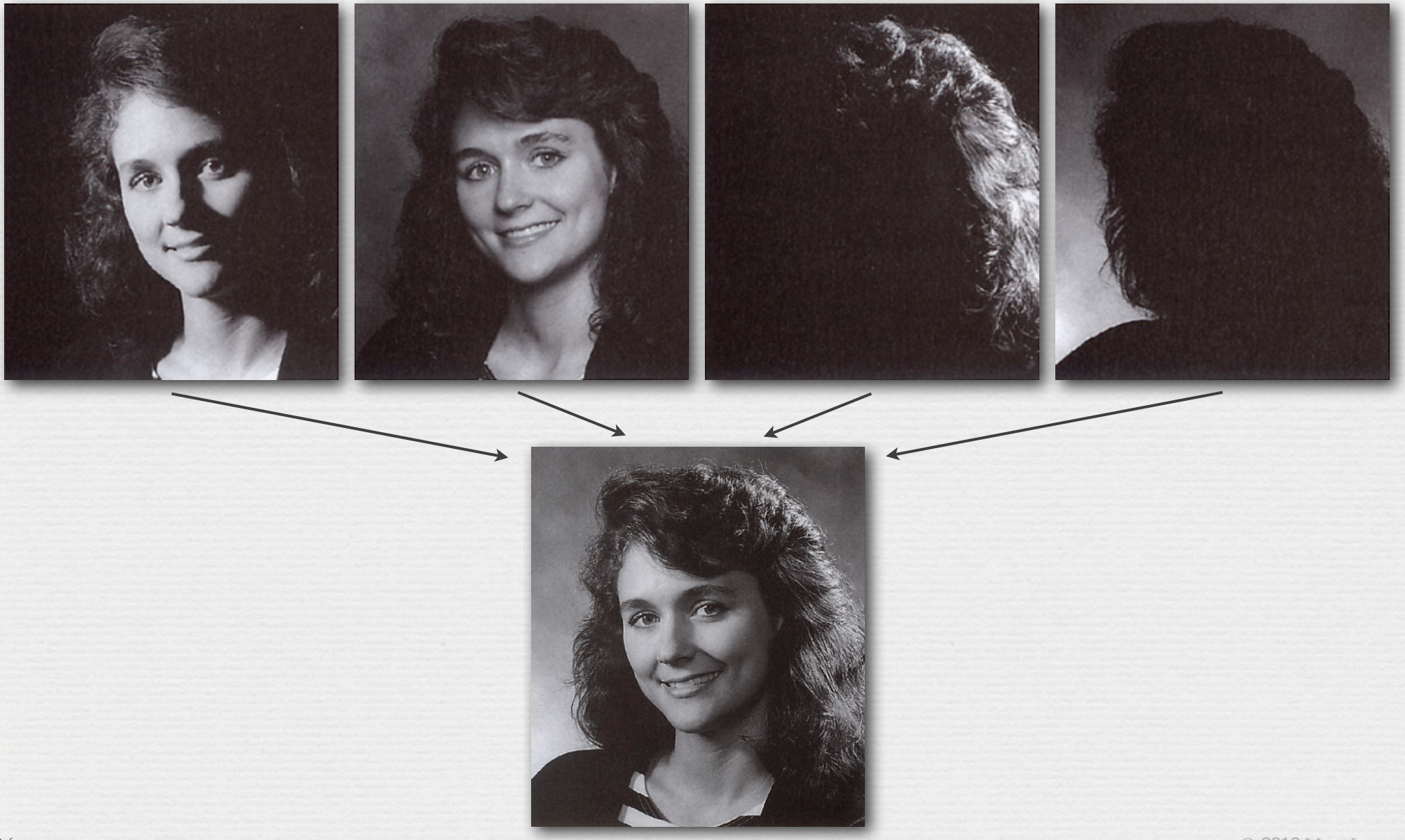




main/key | fill | accent/rim | background

Basic portrait lighting

(London)



Alternative lighting arrangements

- main light on side towards camera - broadens narrow faces
- main light on side of face away from camera - most common
- main light directly in front of face - glamour lighting

broad

short

butterfly

key:fill light ratio

(London)

1:1

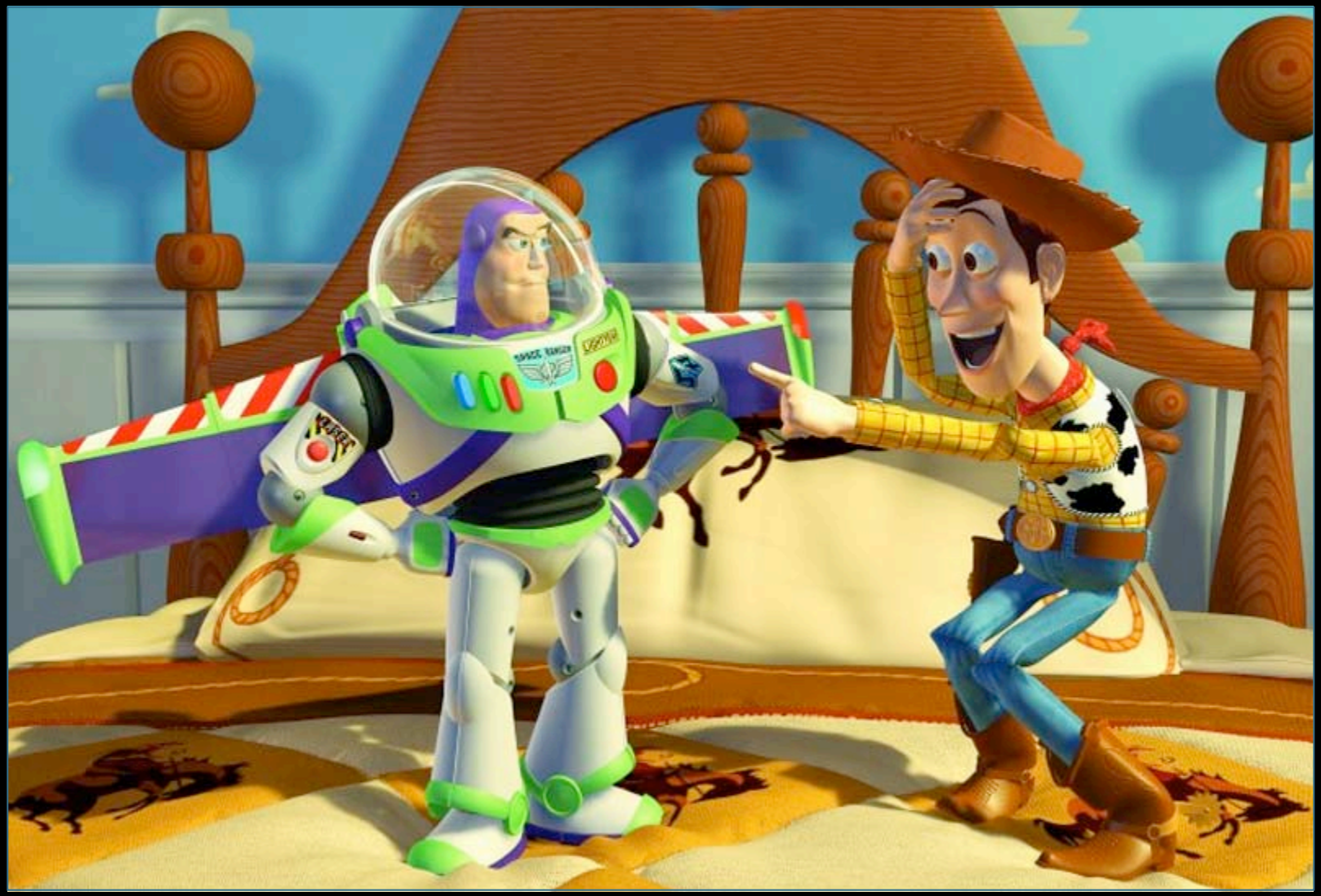
2:1

4:1

8:1

- 8:1 means 3 f/stops (3 doublings)
- think about the mood you want to convey
- the color of the key and fill lights can be different...

Maxfield Parrish, Daybreak, 1922



Pixar, Toy Story, 1995

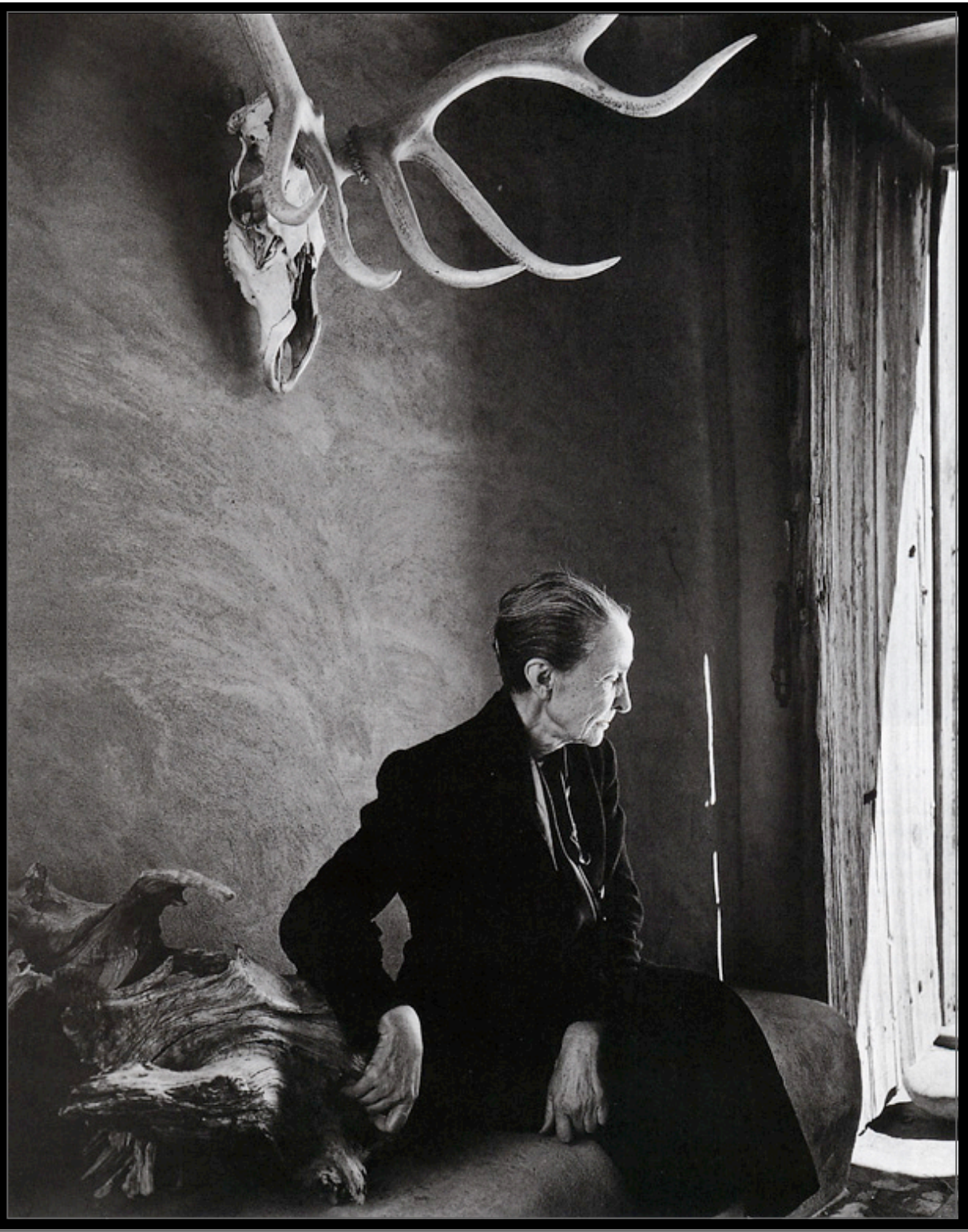
Yousuf Karsh,
Winston Churchill,
1941

Yousuf Karsh,
Audrey Hepburn
1956

Yousuf Karsh,
Peter Lorre,
1946

Photography in available light

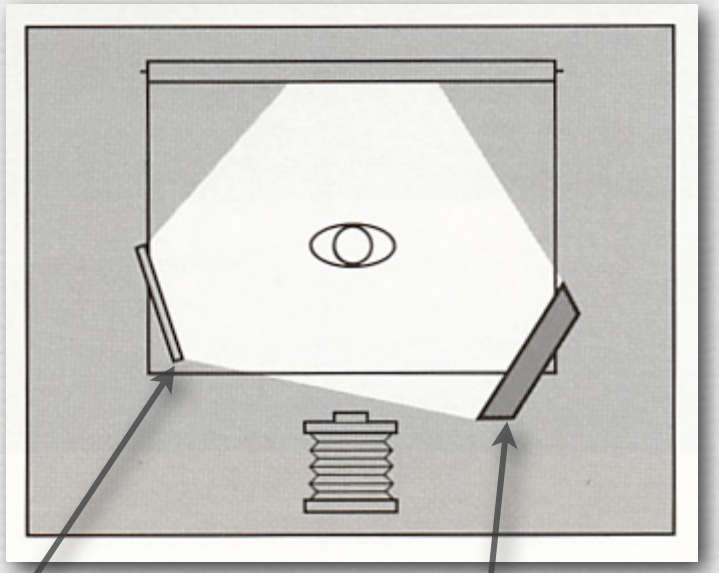
- challenging
- worthwhile
- requires patience and luck
- always carry your camera



Yousuf Karsh,
Georgia O'Keeffe,
1956

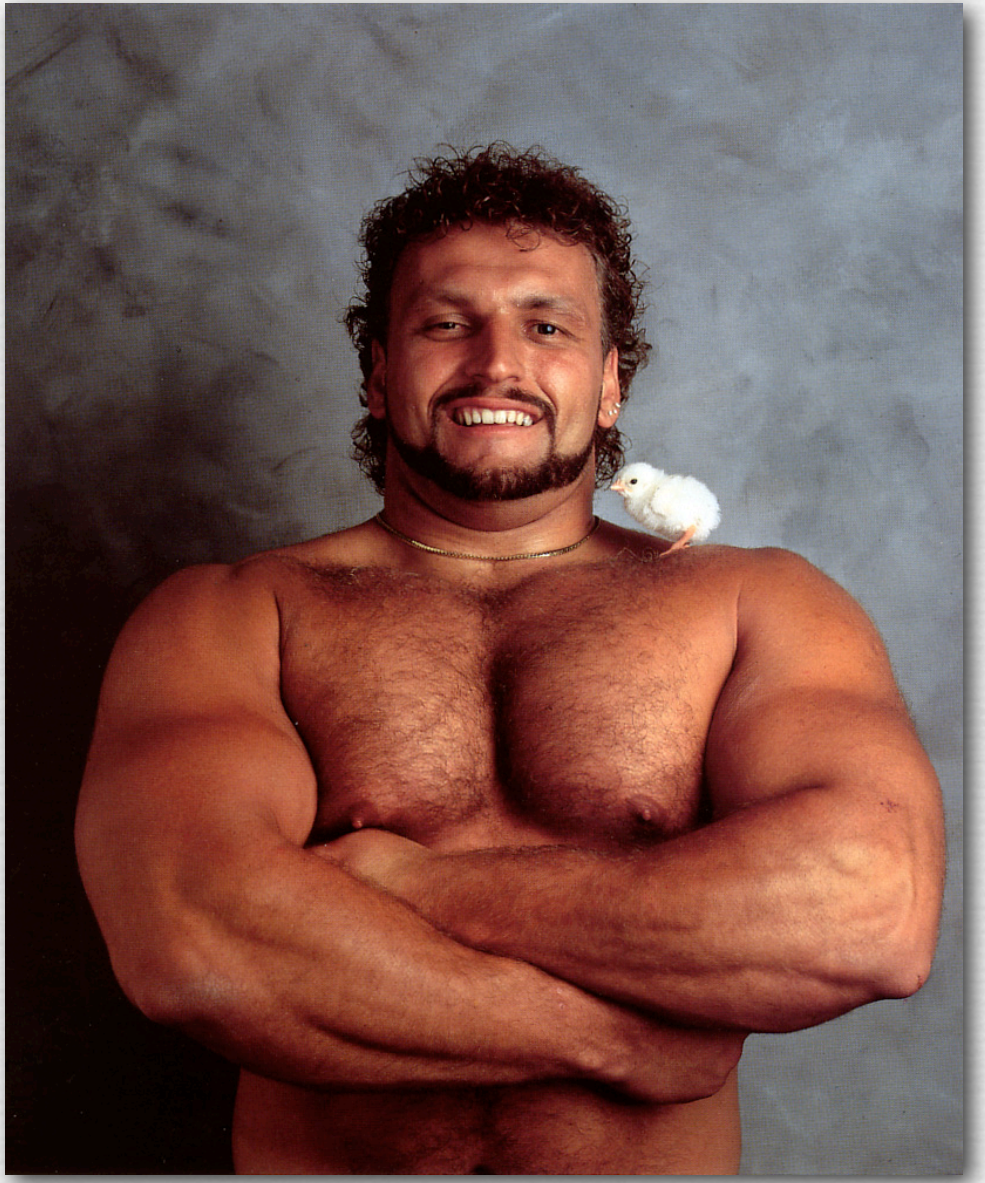
Professional photographic lighting manuals

photographed by
D.W. Mellor



diffuse reflector

diffused spotlight

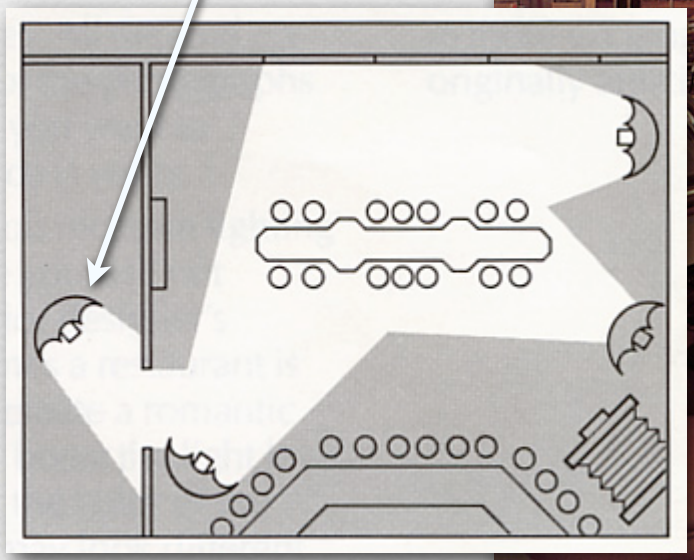


(Kodak)

Special problems: architectural interiors

2-second exposure to show dusk outdoors

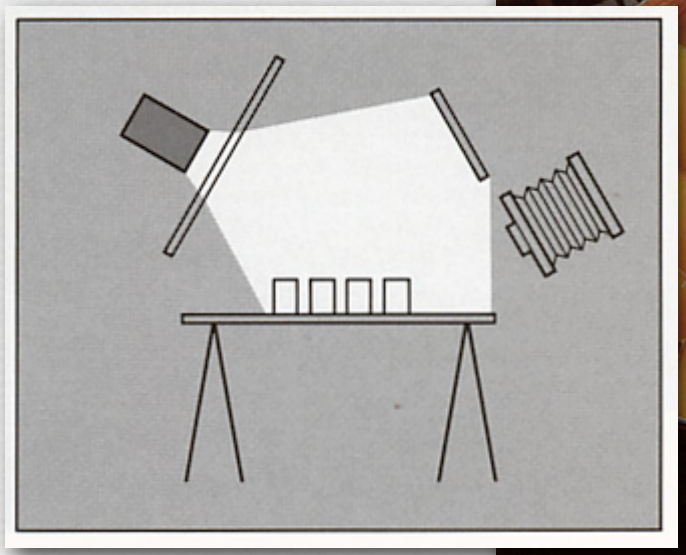
note lighting in 2nd room



(Kodak)

Special problems: food (without breaking FTC laws)

photographed by Richard Fukuhara



(Kodak)

Special problems: surface details

(Hunter)

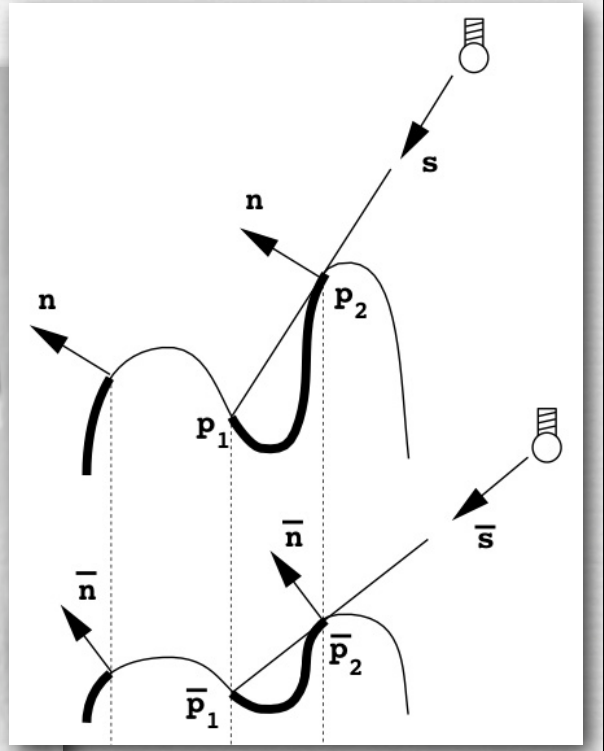
overhead light

grazing light

How is this sculpture lit?

The bas-relief ambiguity

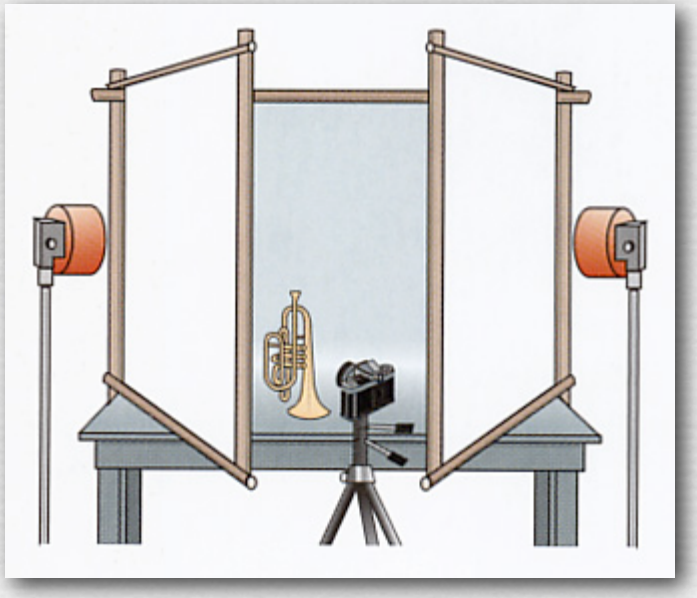
[Belhumeur CVPR 1997]



- changing the depth of an object is equivalent to changing the angle of lighting on it - they produce the same image
  - otherwise, bas-relief sculpture wouldn't work

Special problems: shiny objects

photographed by
Fil Hunter



(London)

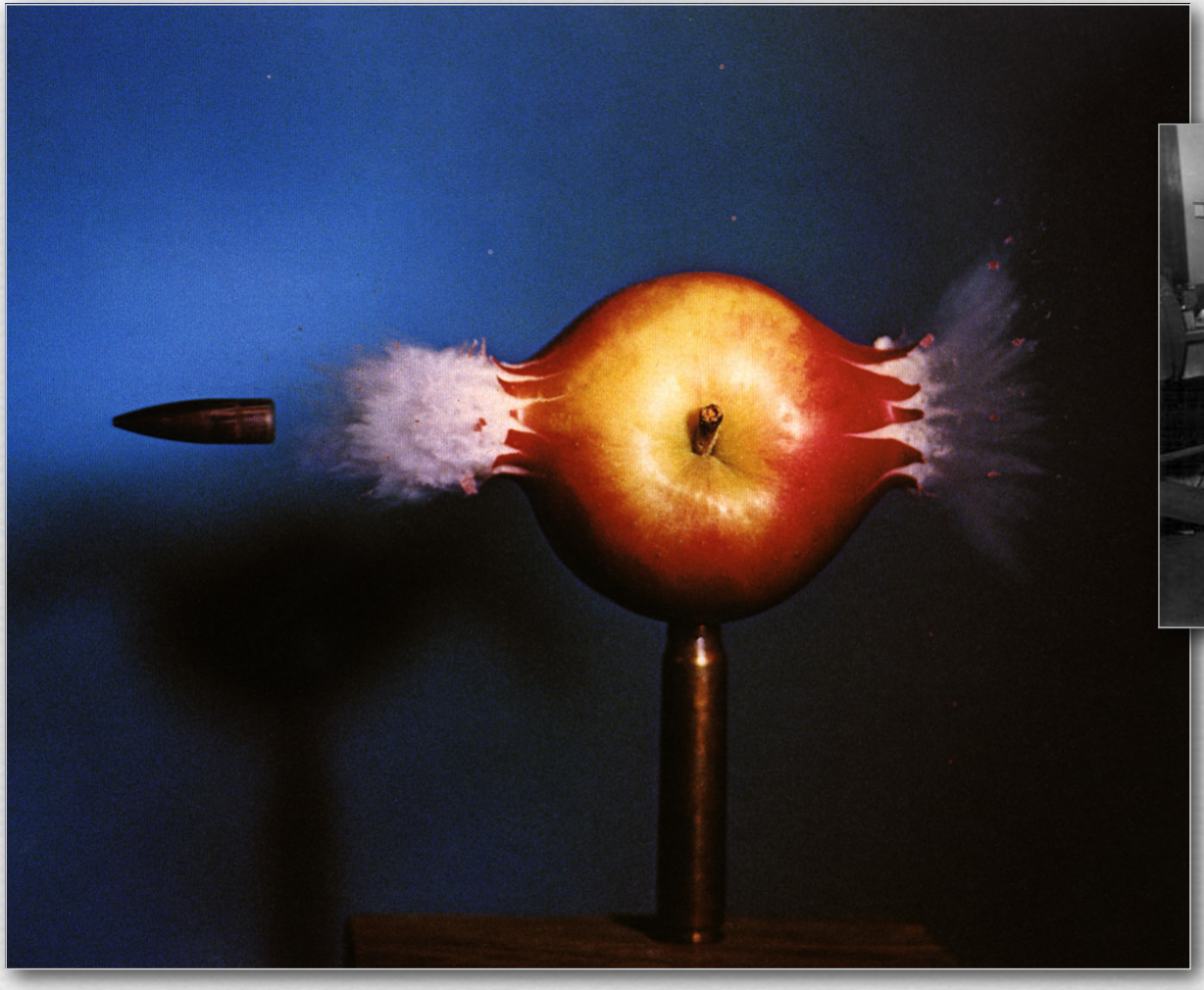
When to use flash?

- freezing the action
- fill-flash
- flash-plus-ambient
- flash as a fill light
- ways to avoid using flash

Lois Greenfield,
dance photography, 1988-

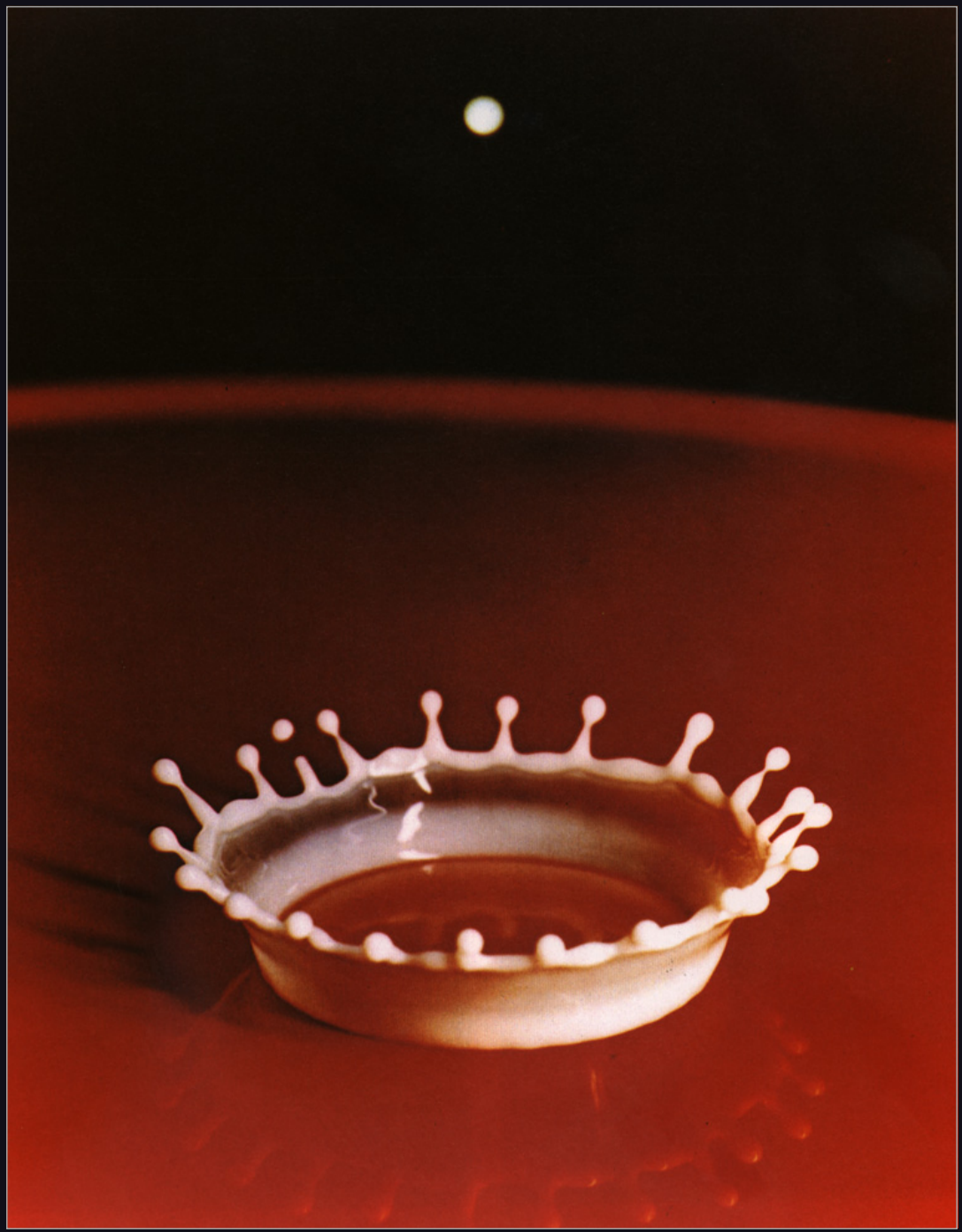
Harold Edgerton:

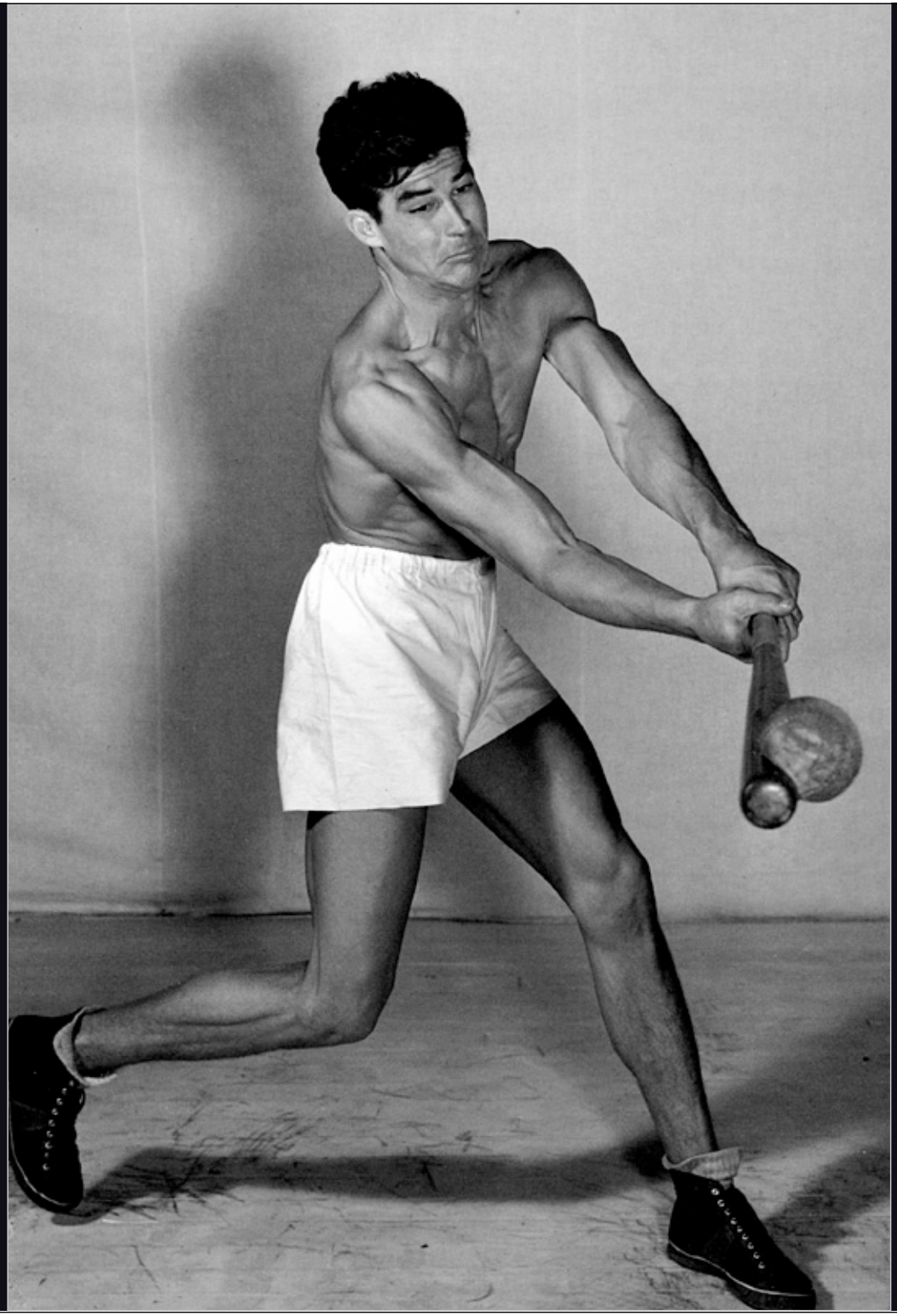
"father" of high-speed photography

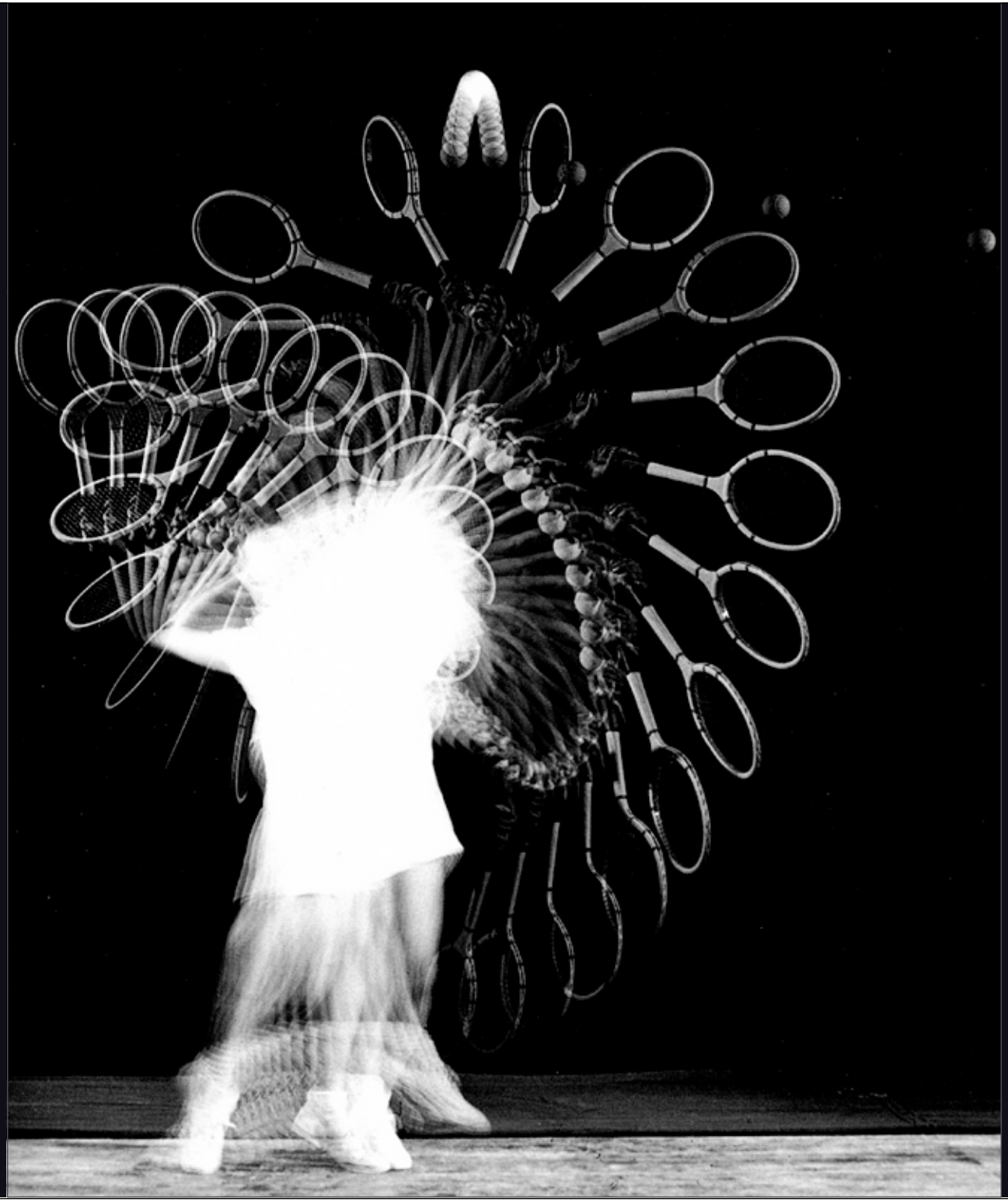


from Stopping Time, 1964

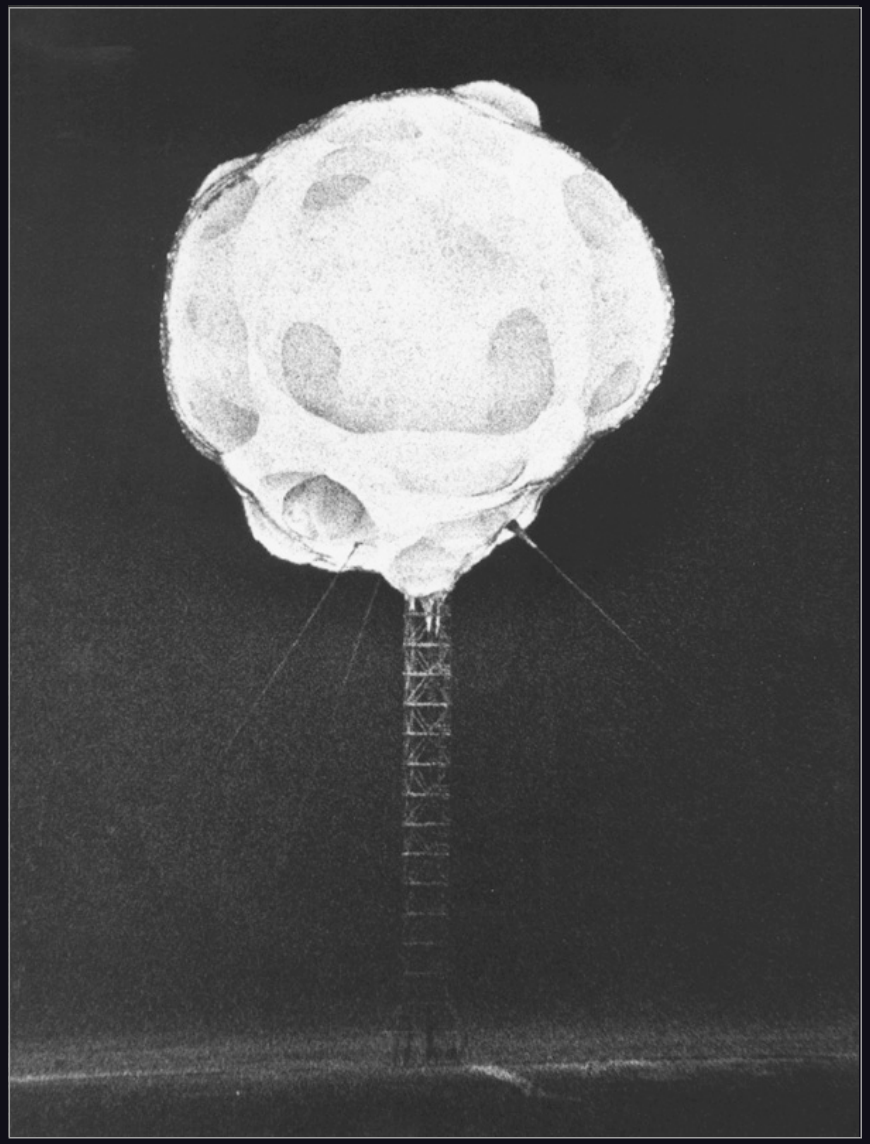
- no shutter
- electronic strobe
- microphone near gun



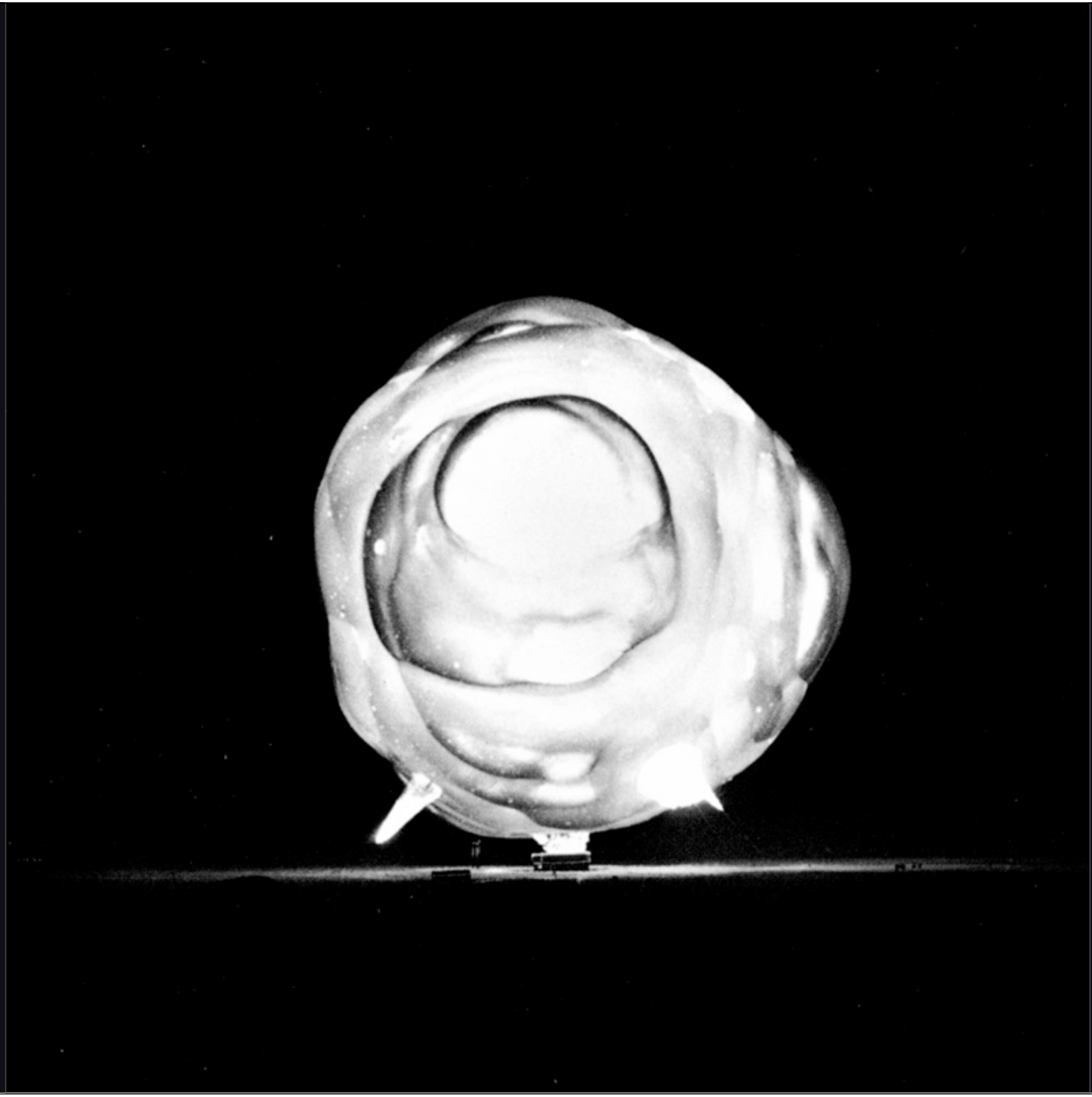


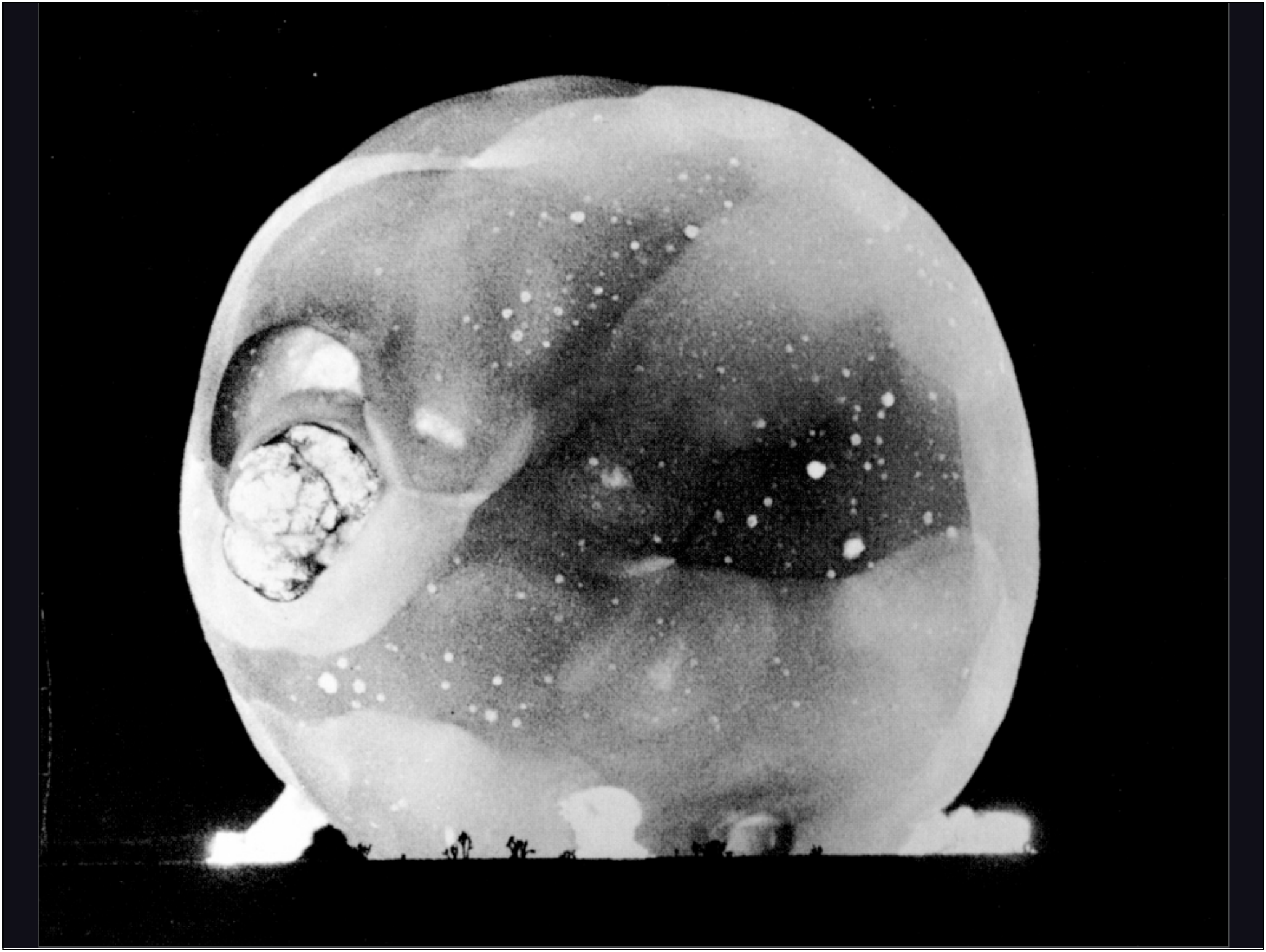


Ultra-high speed photography



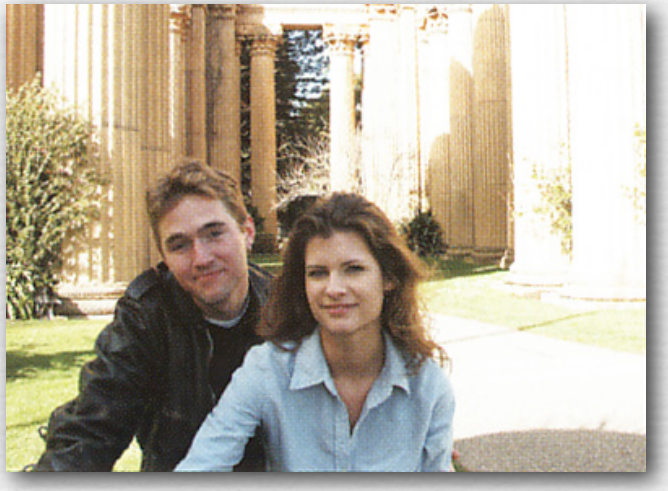
- atomic explosion
- 1/100,000,000 second
- camera was *7* miles away
- telescopic lens



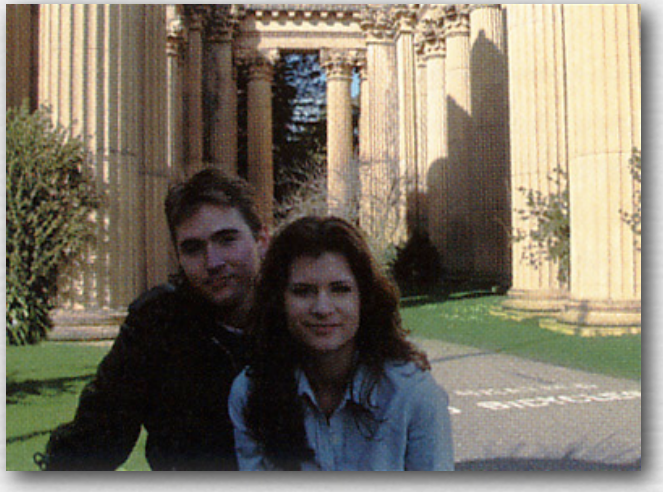


Fill-flash (for brightly lit backdrops)

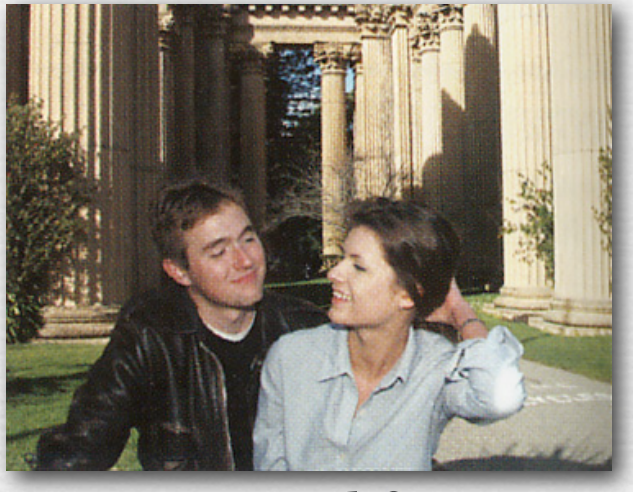
(London)



exposed for foreground



exposed for background



exposed for background, with fill flash

- shorten exposure, then add flash
- could instead use HDR, but that requires multiple shots

Flash-plus-ambient (in low light)

(Ang)

standard flash
exposure

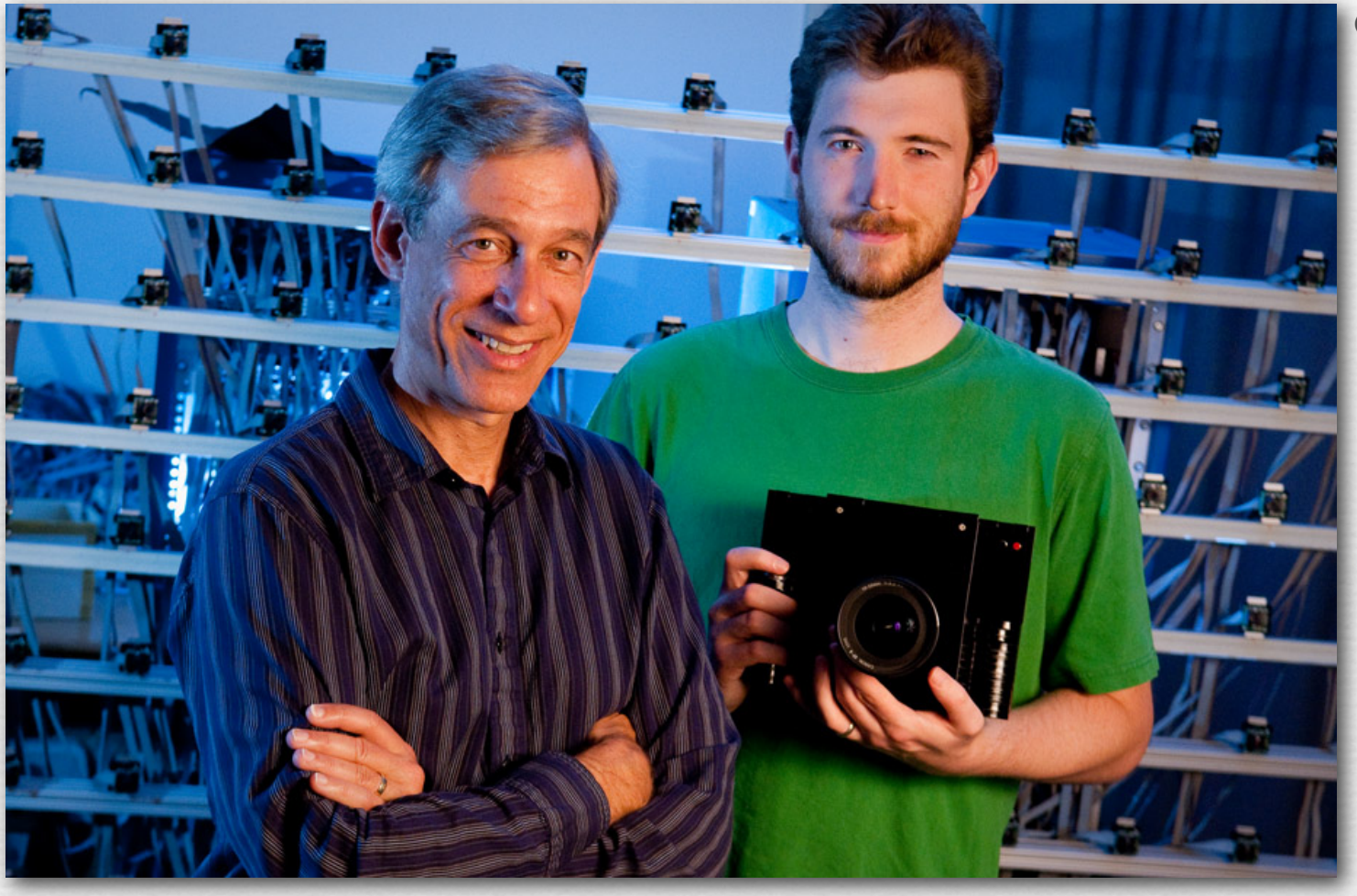
1/4 second
with flash

- use flash, and lengthen exposure
- avoids isolating the foreground from its background

Flash as a fill light

- golden hour sun + off-camera fill flash
  (Canon 5D Mark II, Speedlite 580EX, orange gel)

How was this shot lit?



(Linda Cicero)

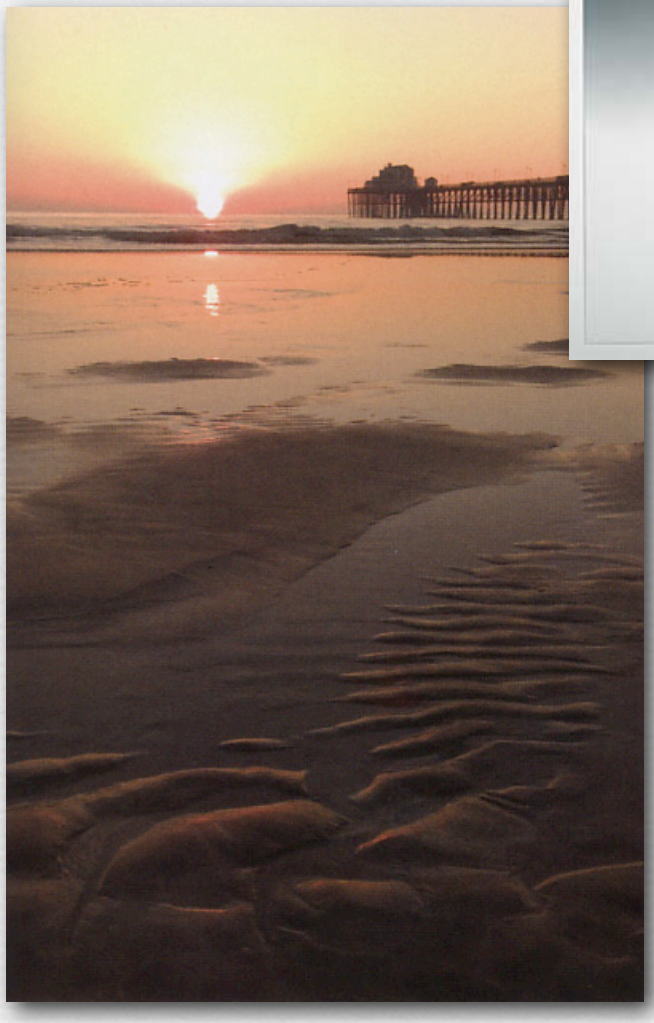
- key flash (on right side of camera) with orange gel & umbrella
  + fill flash (extreme left side of scene) with no gel or diffuser
  + background flash (pointed at back wall) with blue gel

How was this shot lit?

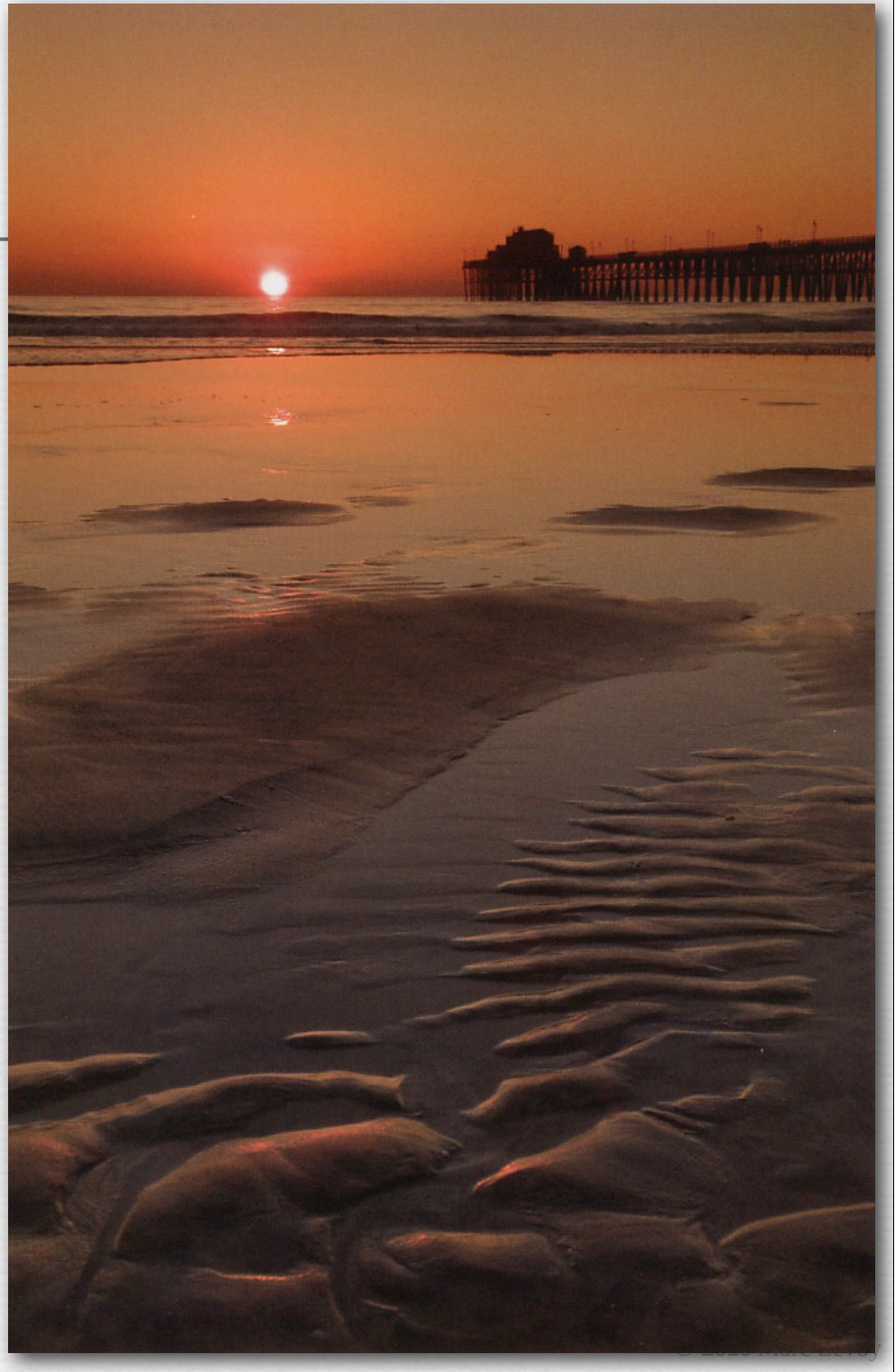
(Fredo Durand)

Avoiding flash

(Peterson)



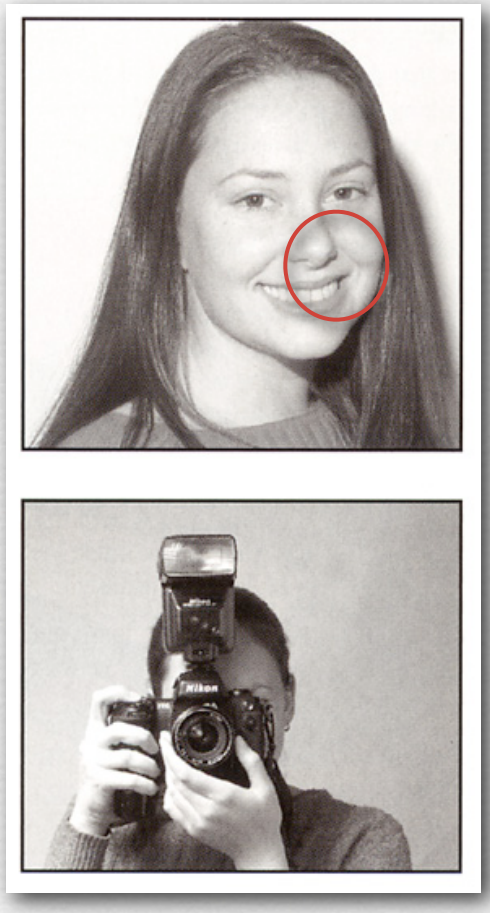
straight shot



with graduated
neutral-density filter

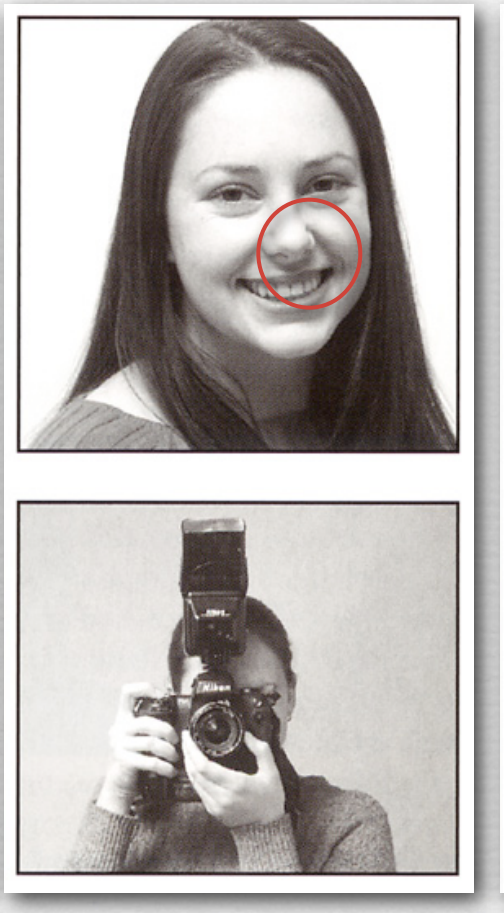
Flash placement

(London)

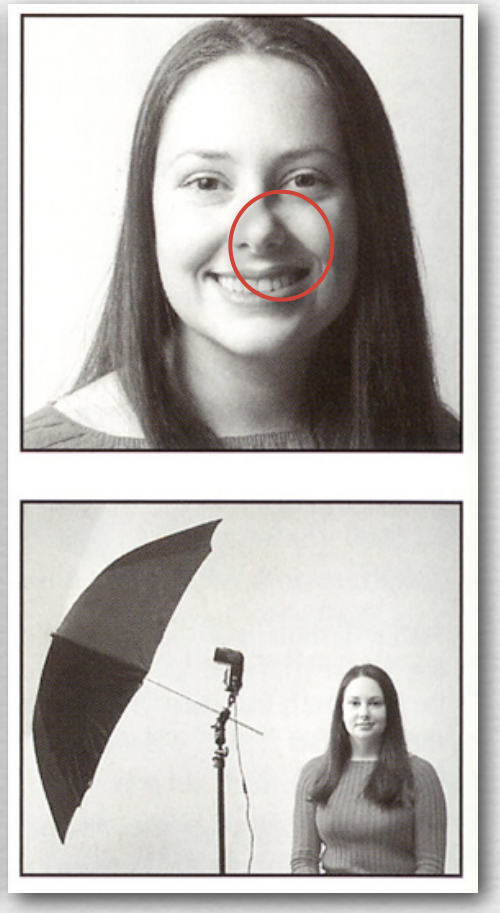


direct flash,
on camera

direct flash,
off camera



bounce flash,
from above



bounce flash,
from the side

Flash technology

(Race Gentry)

1880: flash powder

powdered magnesium +
potassium chlorate +
antimony sulfide

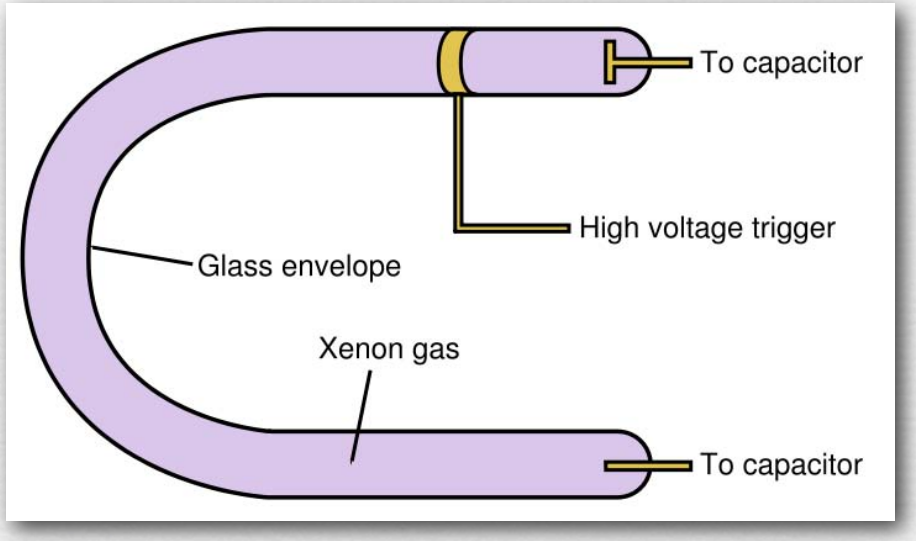
1927: flashbulbs

aluminum foil in oxygen,
later tungsten or zirconium filament
coated in explosive primer paste

1960s: flashcubes

Electronic flash

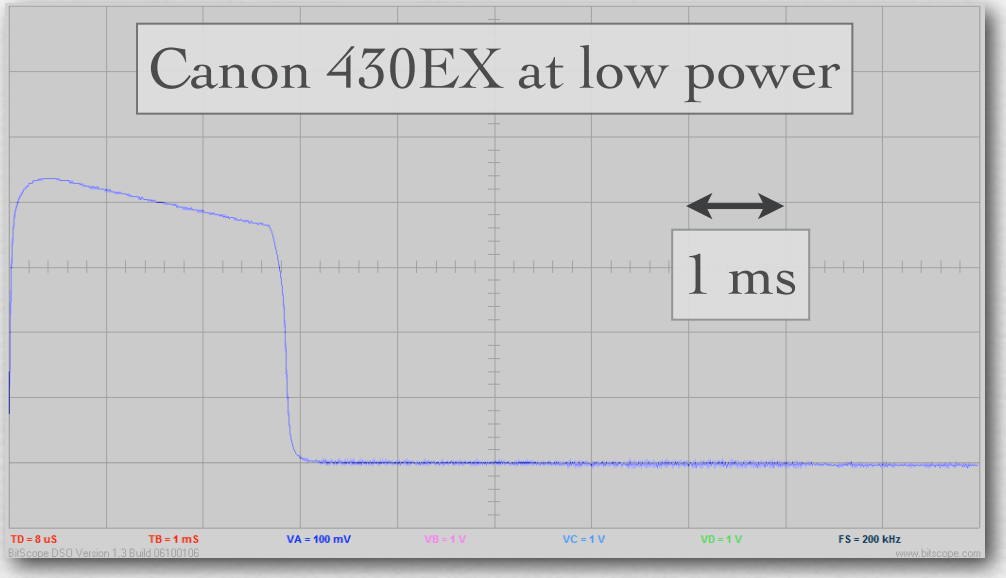
Canon 580EX

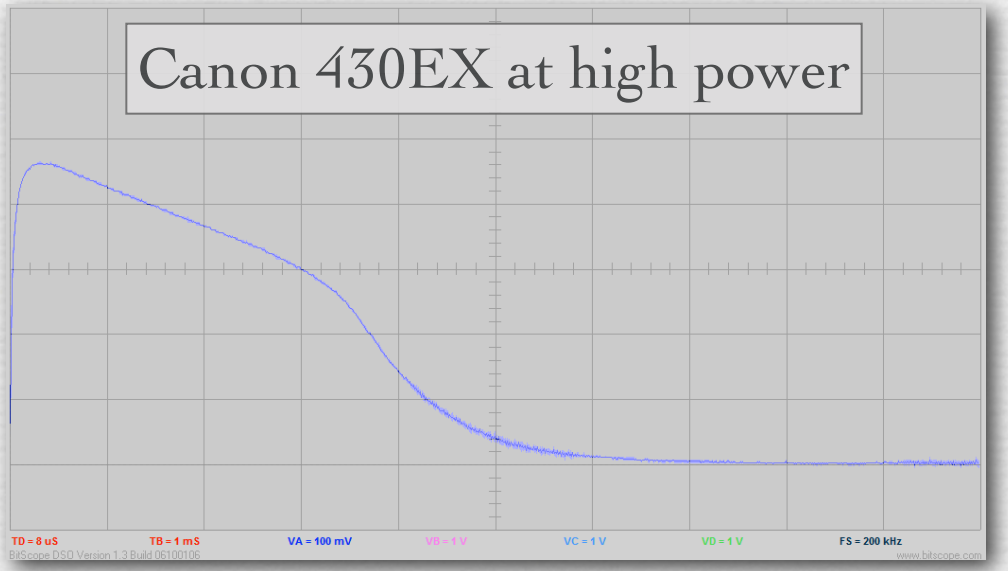


- battery charges up a capacitor (dangerous when disassembled!)
- high-voltage trigger ionizes the gas inside the tube, reducing its resistence to the flow of electricity and causing streamers of ionized gas to form (like "leaders" in lightning)
- the capacitor discharges through the ionized gas, heating it to a plasma state and causing an intense but brief discharge of light

Controlling exposure in flash photography

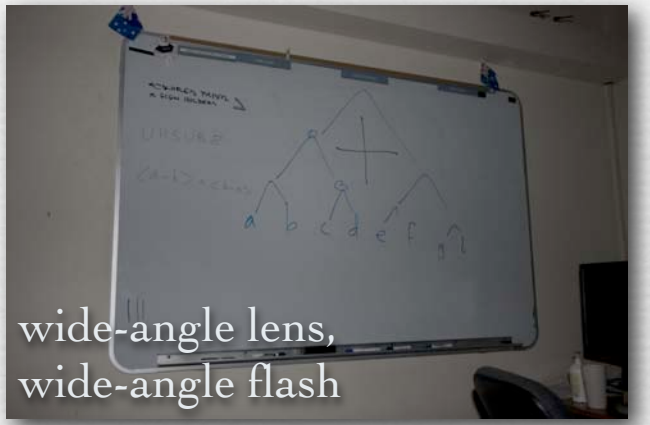
- the luminous intensity of a particular xenon flash tube is fixed
- flash is briefer than the shutter, so you can't use shutter speed to control illuminance on sensor
  - you can still use it to control ambient light
- aperture and ISO affects recording of both flash and ambient light
- instead, adjust duration of the flash pulse

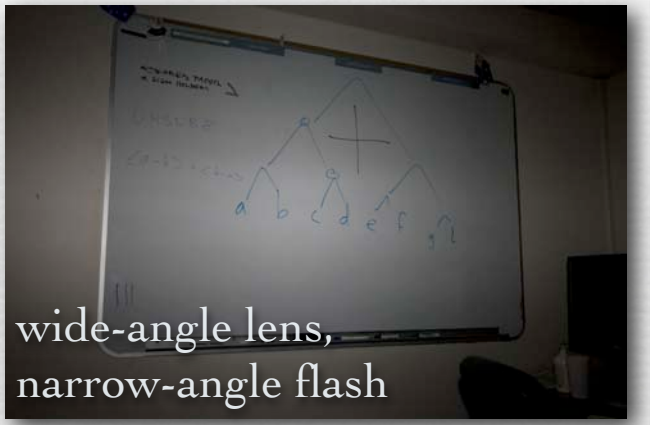




Guide numbers

- flash power is measured in *guide numbers*
  - proper aperture size = guide number / distance to subject
  - varies with focal length for zooming flashes
  - assumes ISO 100


wide-angle lens,
wide-angle flash

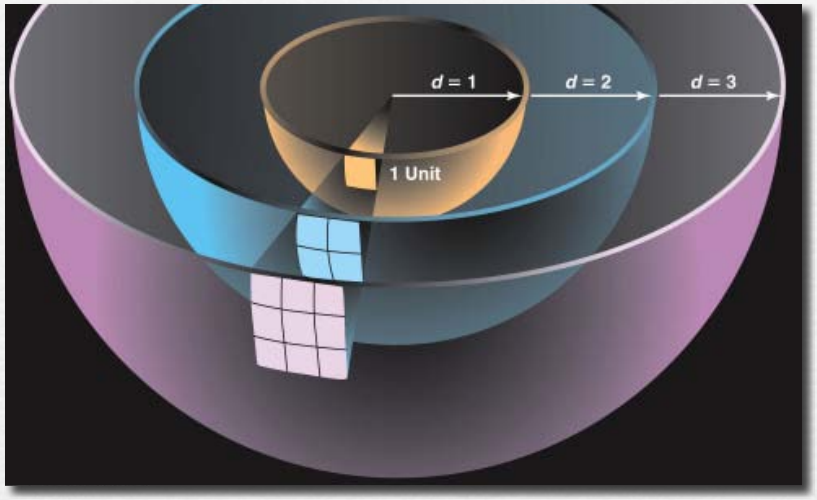

wide-angle lens,
narrow-angle flash

- examples
  - Canon 580 EX hot-shoe flash: guide number 58
  - Nikon D40 pop-up flash: guide number 15
  - Canon SD800 point-and-shoot: guide number 4

4× distance needs
16× as much light

  - for Canon 580EX and a subject 10' away, use f/5.6
  - for Canon 580EX and f/1.4 lens, subject can be 41' away !

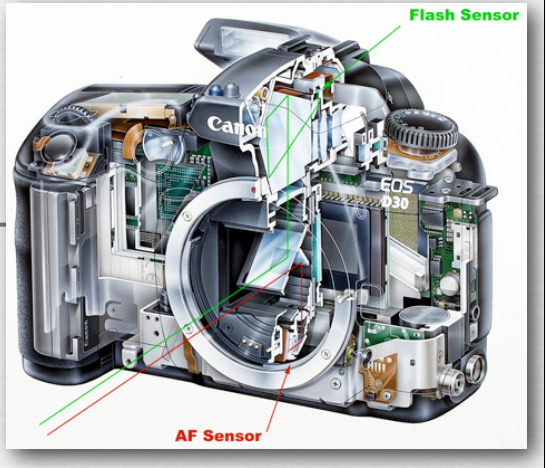
The effect of distance to the subject



(Thomson)

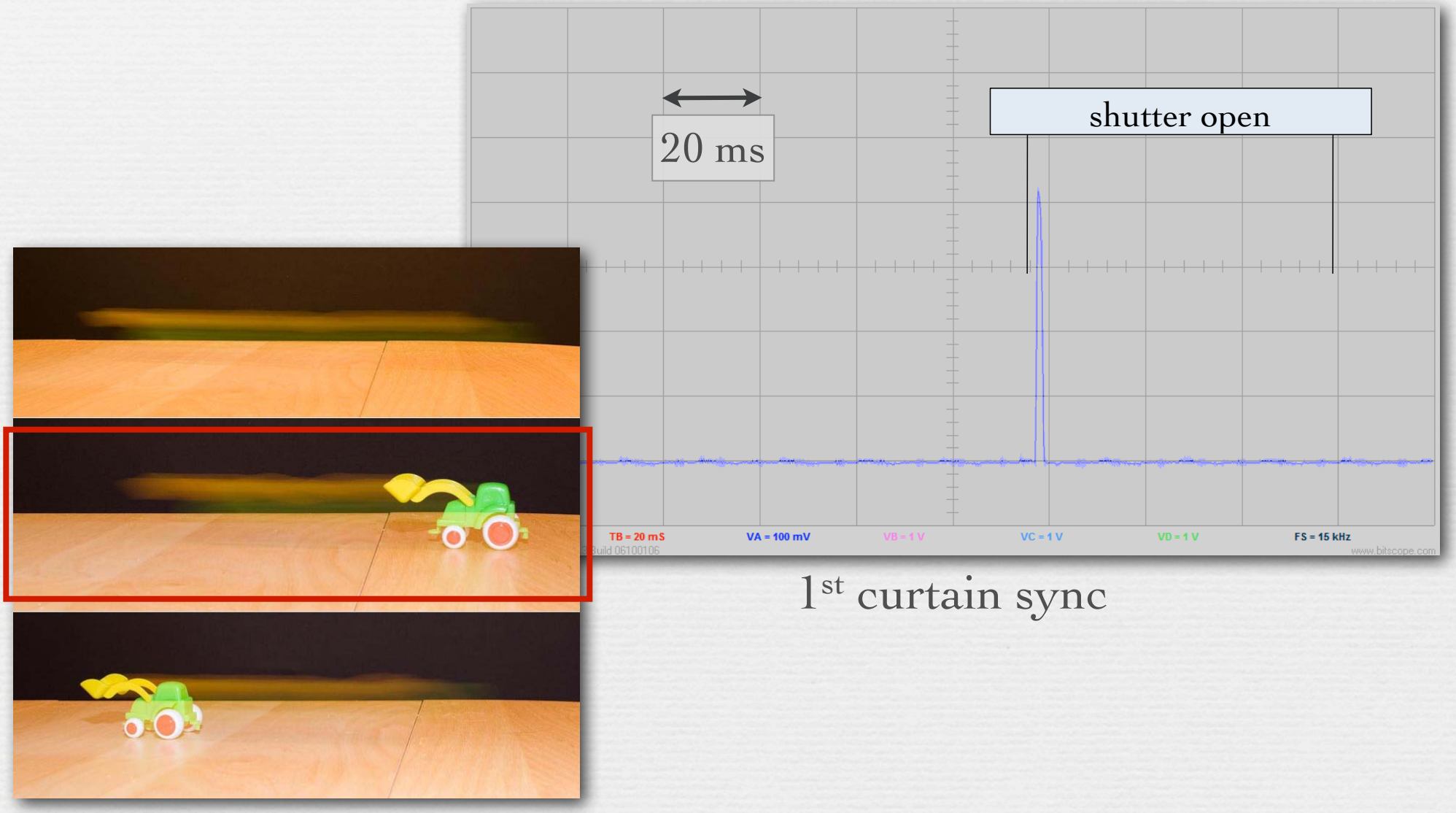
- if you treat flash as a point source, then illuminance (power per unit area) arriving on a subject from the flash falls as d^2
- with respect to a camera pixel, a subject is an area source, so the illuminance arriving on a pixel is independent of d
- hence, under ambient light subjects don't dim with distance from camera, but under flash they dim quadratically !
- to double the distance a flash can reach, you must increase its luminous intensity (power per sr) by 4× !!

Metering for flash photography
(Canon E-TTL or Nikon iTTL, including Nikon D40)



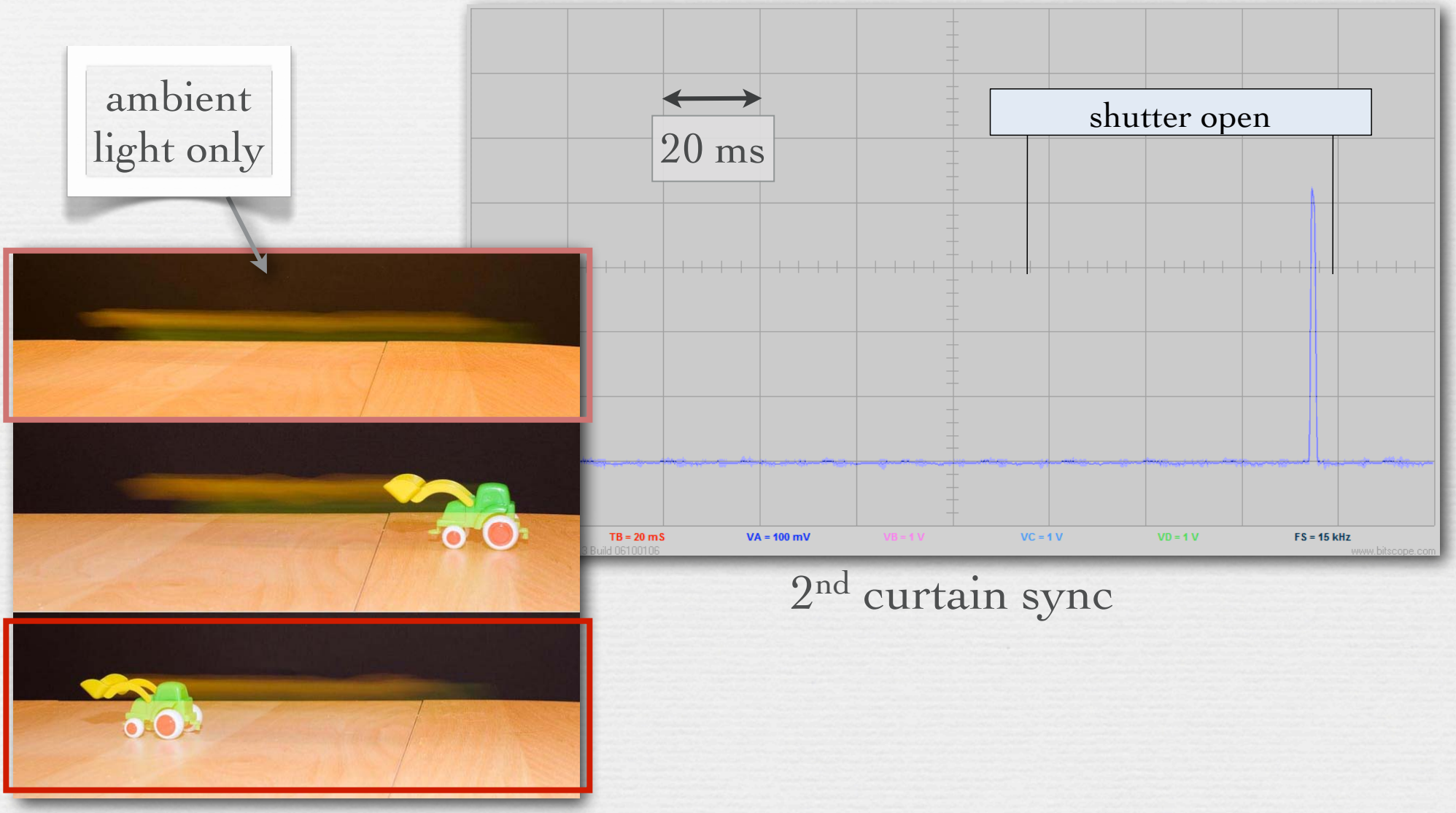
- on shutter half-press, focus under ambient light (or AF assist light) and meter for ambient light
- on shutter press, fire weak preflash and record on flash sensor
- compute some combination of aperture, flash duration, and ISO
  - decision uses multi-point metering of ambient light, multi-point autofocusing, shooting mode, etc.
- flip up mirror, open shutter, and fire flash
- drawbacks
  - fooled by specular objects, scenes that fool metering and focusing,...
  - delay between pre-flash and flash is long enough to cause some people to blink, especially if using 2nd curtain sync

Second-curtain sync

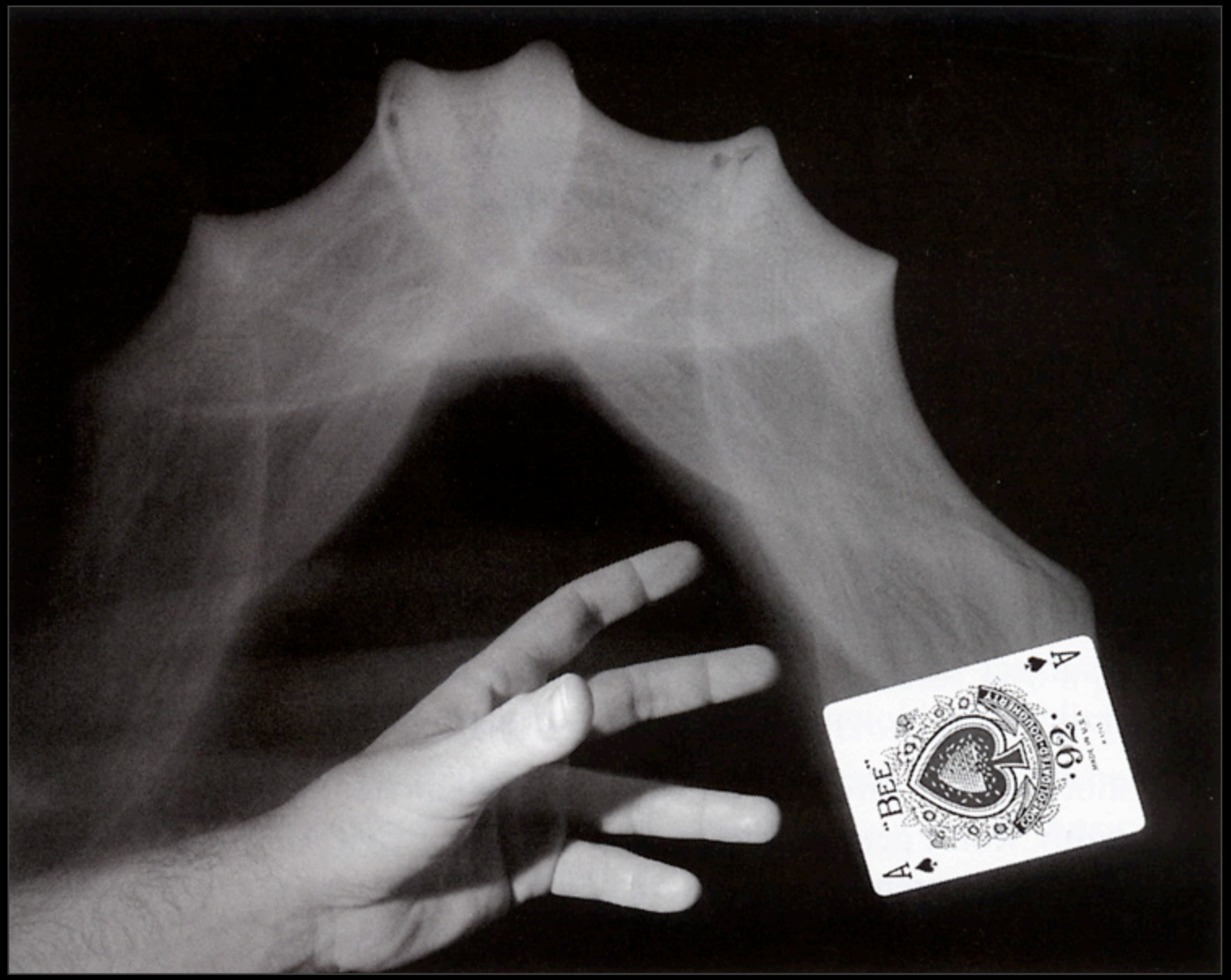


1st curtain sync

Second-curtain sync



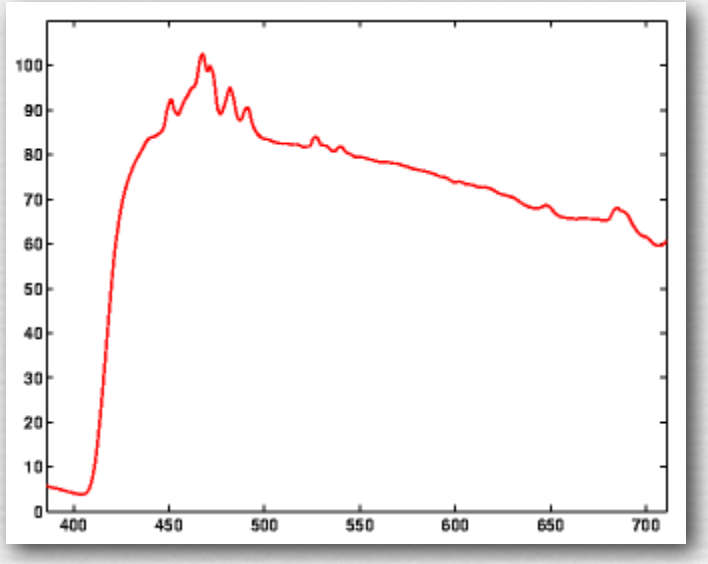
2nd curtain sync



Derrick Story, card flip using second-curtain flash

Color temperature of xenon flash

(graphics.cornell.edu)



- broad spectrum, approximates daylight (6500°K, i.e. D65)
- if mixed with ambient tungsten light, flash will look blue if WB is Tungsten, or background will look orange if WB is Flash
  - can compensate with color correction filter on the flash
  - filters are enumerated in °K of correction
  - filters reduce effective flash power

Problems with flash

- power falls as distance squared
  - subject is too bright
  - background is too dark
- in-camera flash is too close to lens
  - no shadows on subject
  - shadow of lens in wide-angle view
- red-eye
  - worse with in-camera flash
  - worse in low light (pupils are wide open)
  - pre-flash to shrink pupils, which looks better anyway
- shutter speed must be low enough that shutter is completely open
  - 1/90 - 1/250 sec on Canon EOS cameras ("flash synch speed")
  - limits the range of shutter speeds for fill-flash
- don't shoot perpendicularly into glass

Slide credits

- Andrew Adams

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