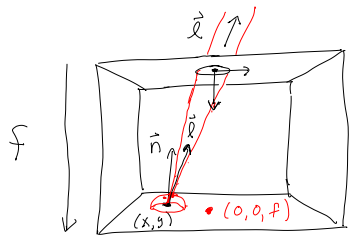
lecture 7

Camera response, color

Thin lens model (camera)



Let A be the aperture (lens diameter), so lens area is $\frac{\pi A^2}{4}$.

$$E(x,y) = L(\vec{\ell}) \frac{(\text{area of lens})(\vec{n}\cdot\vec{\ell})^4}{f^2}$$

$$= L(\vec{\ell}) \frac{\pi}{4} \left(\frac{A}{f}\right)^2 (\vec{n}\cdot\vec{\ell})^4$$

Camera f-number (f-stop)

$$E(x,y) = L(\vec{\ell}) \frac{\pi}{4} \left(\frac{A}{f}\right)^2 (\vec{n}\cdot\vec{\ell})^4, \qquad N = \frac{f}{A}$$

$$\sim \left(\frac{1}{N}\right)^2$$

$N = 1.4, 2, 2.8, 4, 5.6, 8, 11$

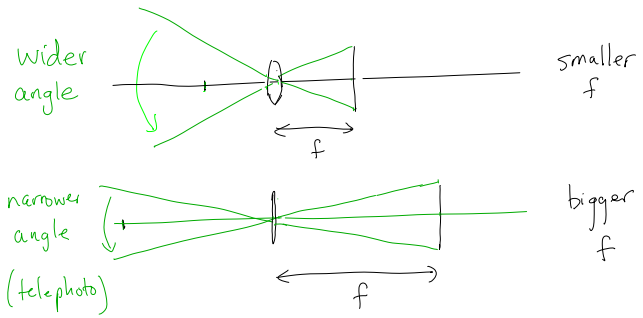
$= \sqrt{2}, \sqrt{4}, \sqrt{8}, \sqrt{16}, \sqrt{32}, \sqrt{64}, \sqrt{128}$

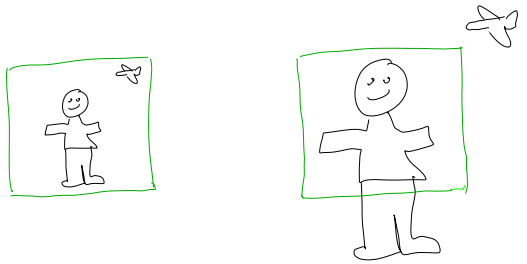
$$N = \frac{f}{A}$$

$\Rightarrow$ two ways to change N

Change f with A fixed

$$E(x,y) = L(\vec{\ell}) \frac{\pi}{4} \left(\frac{A}{f}\right)^2 (\vec{n}\cdot\vec{\ell})^4, \qquad N = \frac{f}{A}$$



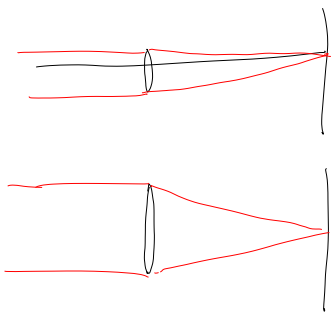


small f (wide angle)

large f (telephoto)

Same set of rays is spread out over larger sensor area $\Rightarrow$ darker

Change A with f fixed



Exposure

image irradiance $E(x,y)$ — $\frac{\text{light energy}}{\text{time} \times \text{area}}$

exposure time t

exposure $E(x,y) \cdot t$ — $\frac{\text{light energy}}{\text{unit area}}$

Shutter Speed ($\frac{1}{t}$)

Typical t

$\ldots, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{16}, \frac{1}{32}, \frac{1}{64}, \frac{1}{128}, \frac{1}{256}, \frac{1}{512}, \ldots$

Typical shutter speed $\frac{1}{t}$ (on camera dial)

$\ldots, 2, 4, 8, 15, 30, 60, 125, 250, 500, \ldots$

Exposure

$$E(x,y)\ t = L(\vec{l})\ \frac{\pi}{4}\left(\frac{A}{f}\right)^2 (\vec{n}\cdot\vec{l})^4 \cdot t$$

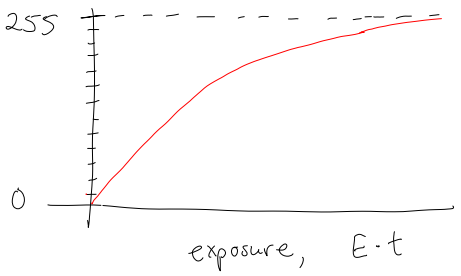
$\frac{A}{f}$: $\frac{1}{N^2}$ ↑ ; t: $\frac{1}{1/t}$ ↑

increase N (by decreasing A) ⇒ $E(x,y)\cdot t$ fixed
decrease $\frac{1}{t}$ (increase t)

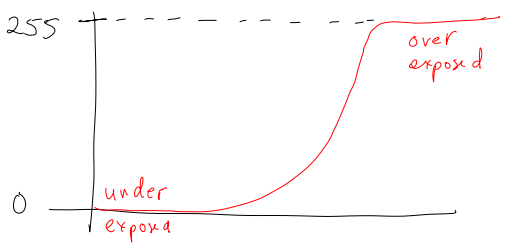
increase N (by increasing f) ⇒ EEK! size change (more complicated)
decrease $\frac{1}{t}$ (increase t)

Camera Response (Tone Mapping)

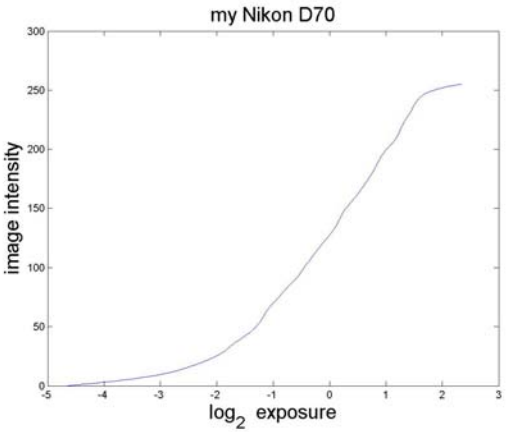
$$T(E(x,y)\cdot t) \rightarrow \{0,1,\ldots,255\}$$



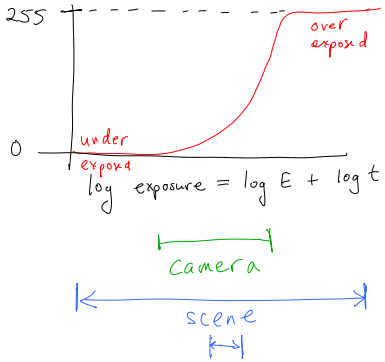
Camera Response

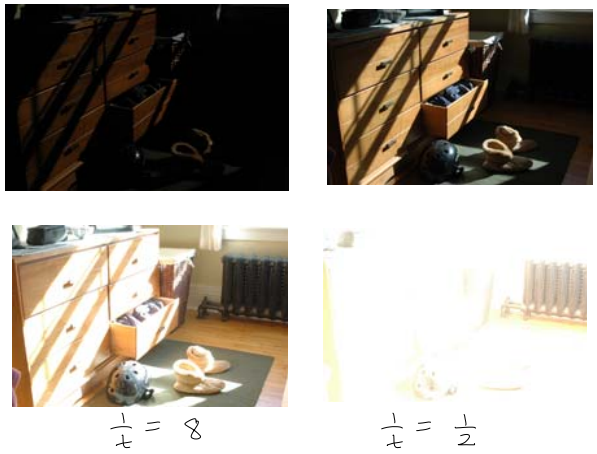


log exposure = log E + log t

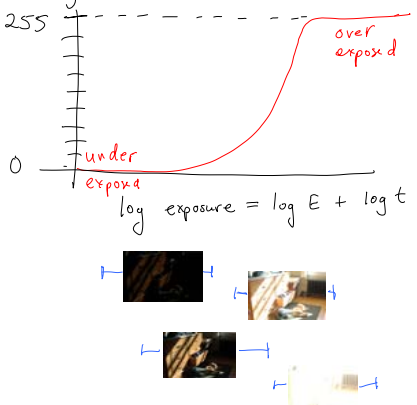


Dynamic Range.





Dynamic Range.



High Dynamic Range Imaging

Given
- $T(E(x,y)\cdot t) \rightarrow \{0,1,\ldots,255\}$
- image intensities $I_t(x,y)$ for many shutter speeds $1/t$

Compute

$$E(x,y)\cdot t = T^{-1}(I_t(x,y))$$

For each (x,y) use an image such that $0 \ll I(x,y) \ll 255$

Color

radiance $L(x, \vec{\omega}, \lambda)$

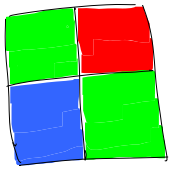
irradiance $E(x, \lambda)$

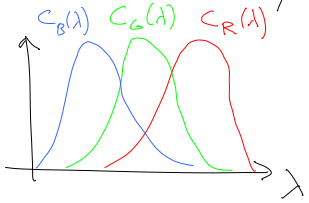
3D scene point

BRDF $\rho(x, \omega_{in}, \omega_{out}, \lambda)$

image irradiance $E(x, y, \lambda)$

Pixel (Bayer pattern)





$$E_{RGB}(x,y) = \int c_{RGB}(\lambda)\, E(x,y,\lambda)\, d\lambda$$

↑ 3 intensities per pixel