

COL7655

Foundations of Visual Computing

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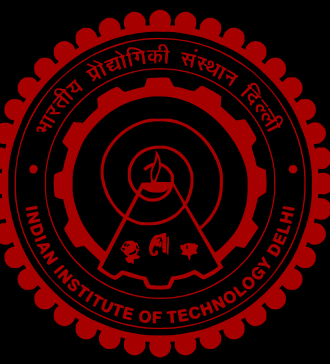
COL7655

Image Formation

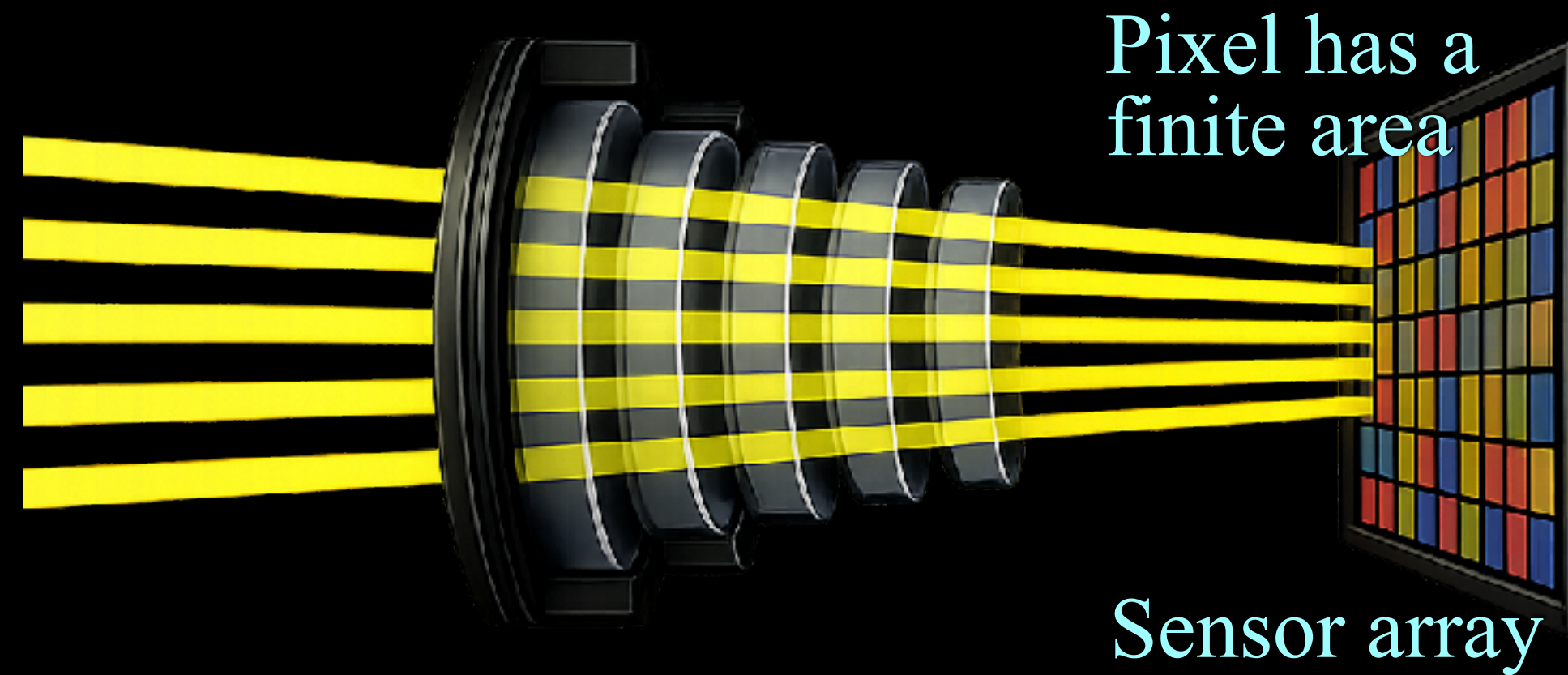
Thanks to Chetan Arora for help with slides

Image Formation

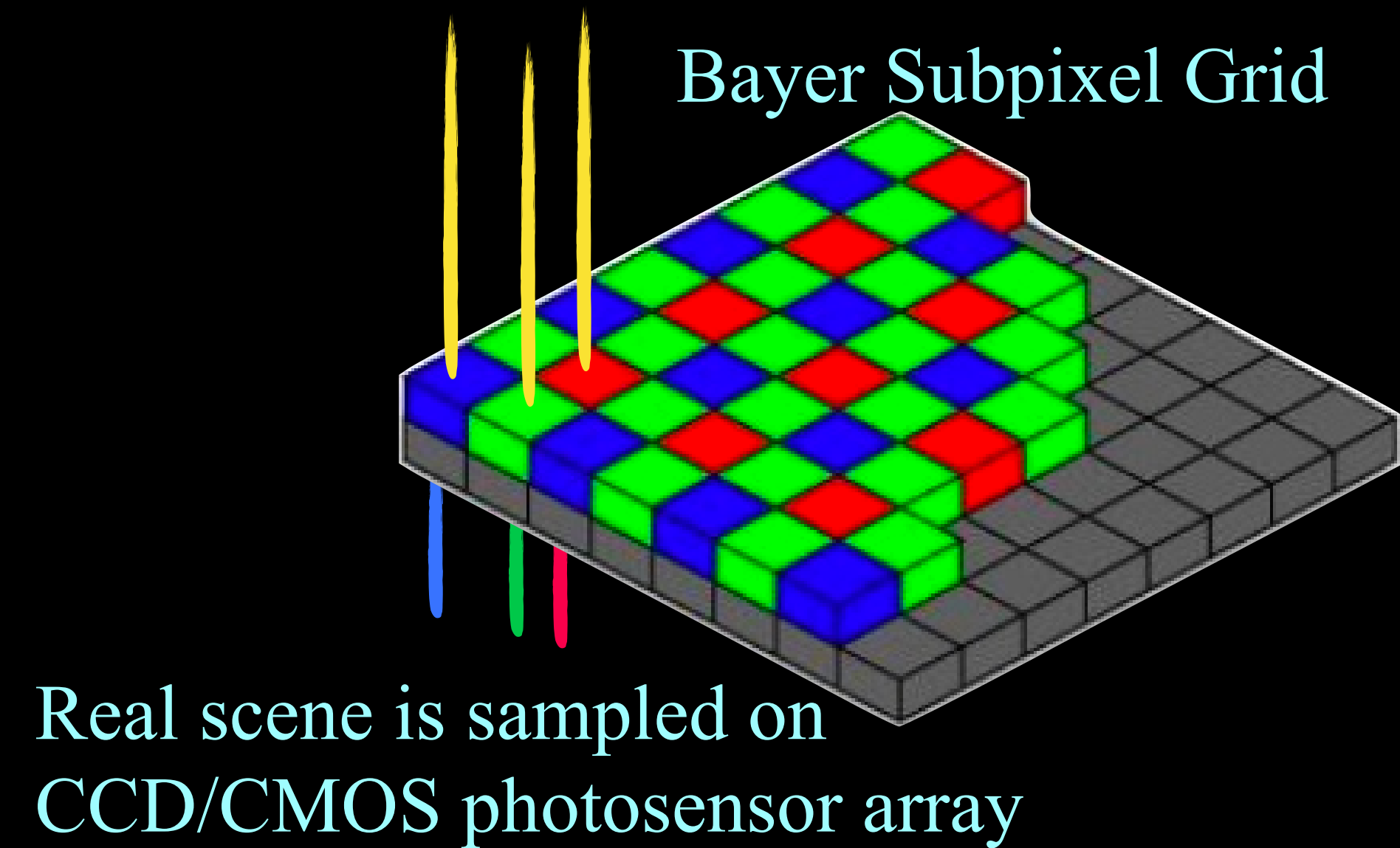
A visual pipeline



Continuous
Scene



File rendered on screen
with samples rendered
as finite area pixels



May be saved in a file,
one color per sample

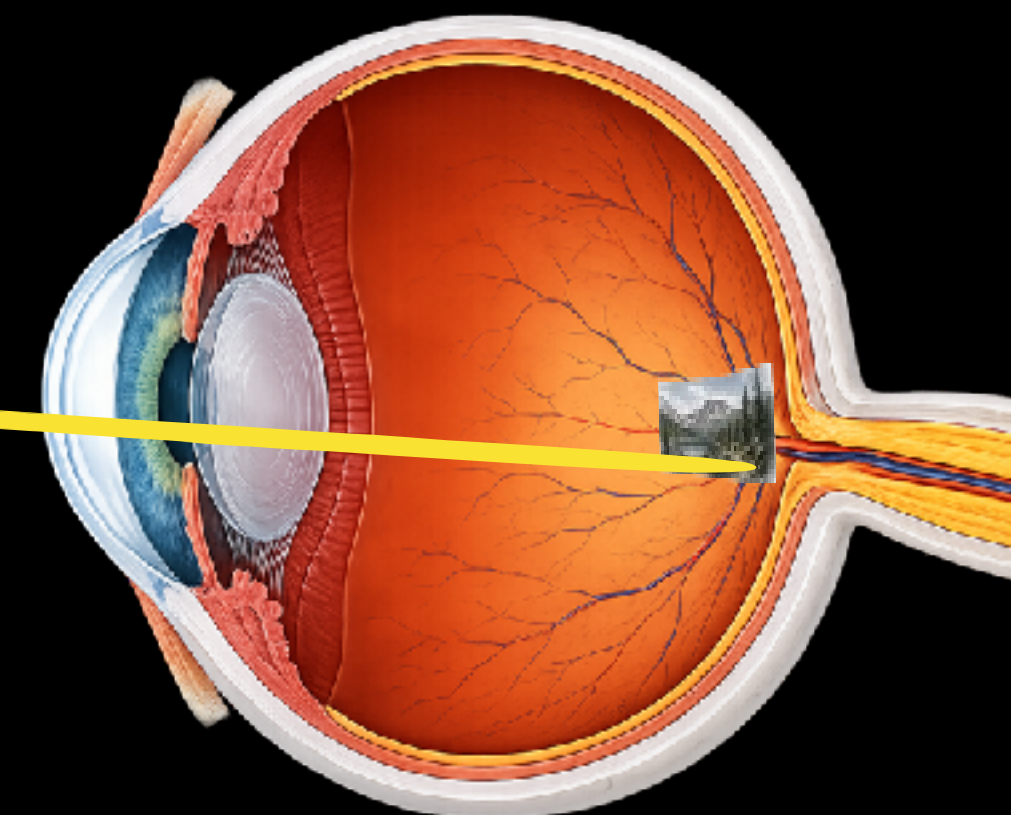
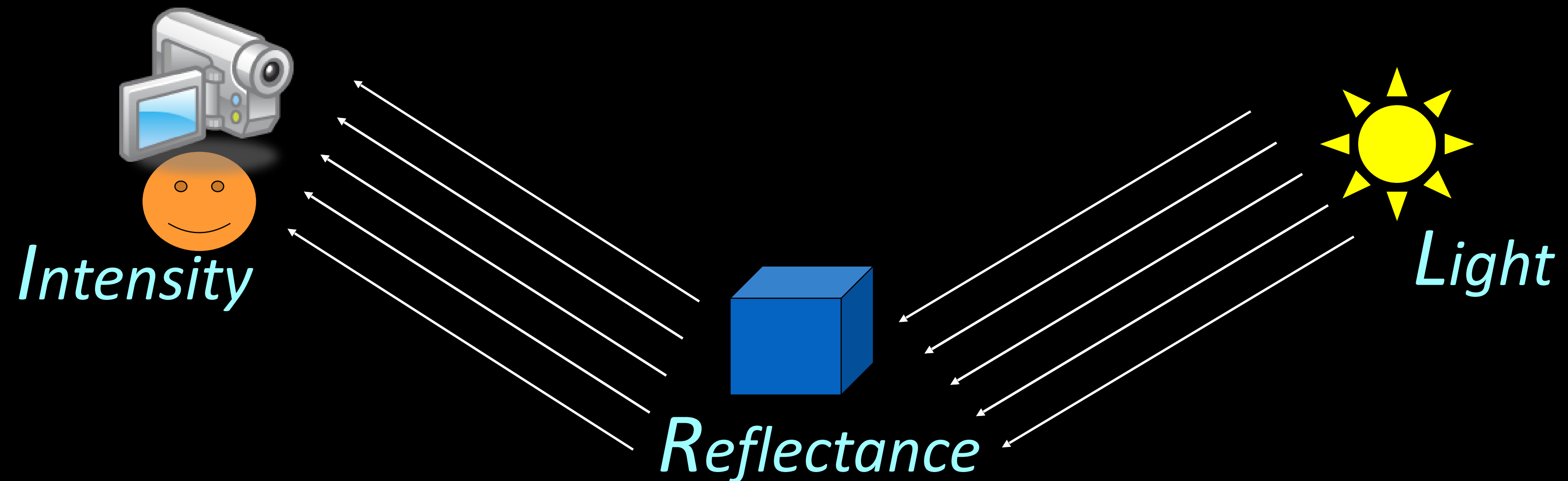


Image Formation: Luminance

- Light is emitted by light source
- Light is reflected from objects
- Reflected light is sensed by eye or by camera



Camera Parameters

- Composition (Location, direction)
- Focus
- Aperture
- Shutter speed
- ISO/Exposure
- White balance
 - Shift chromaticity on temperature-tint axis)

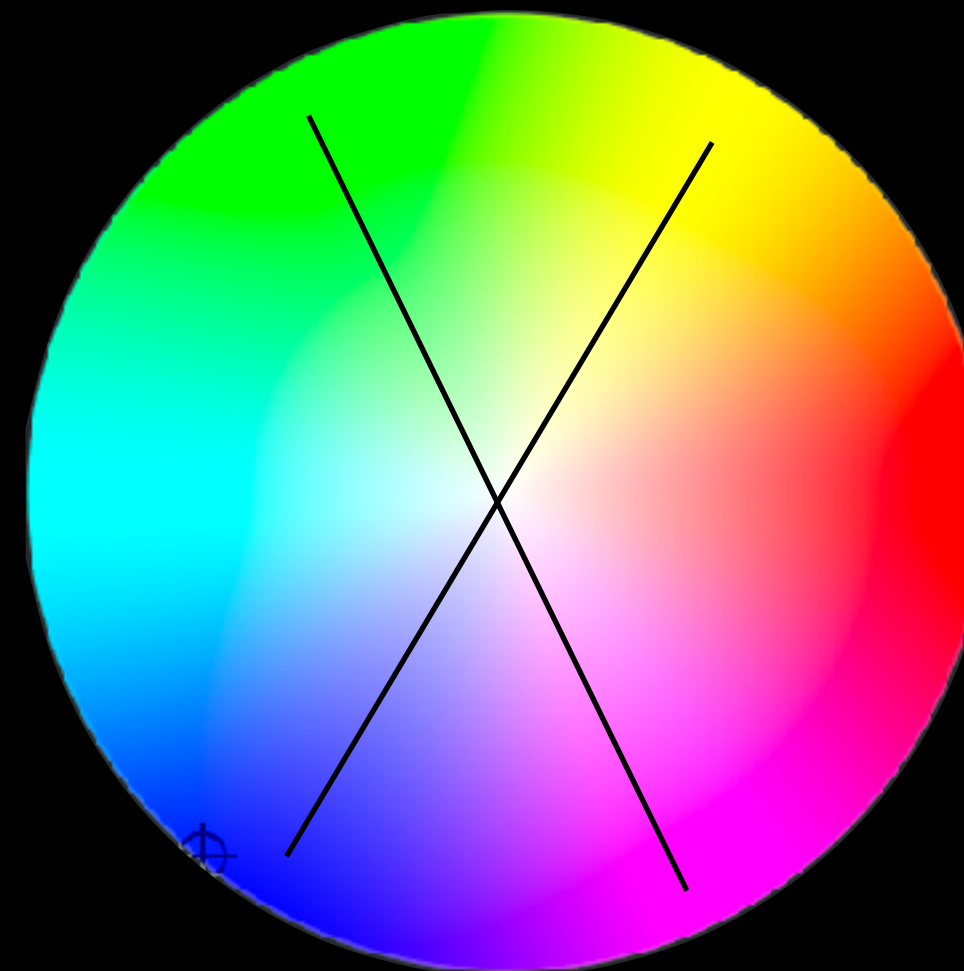
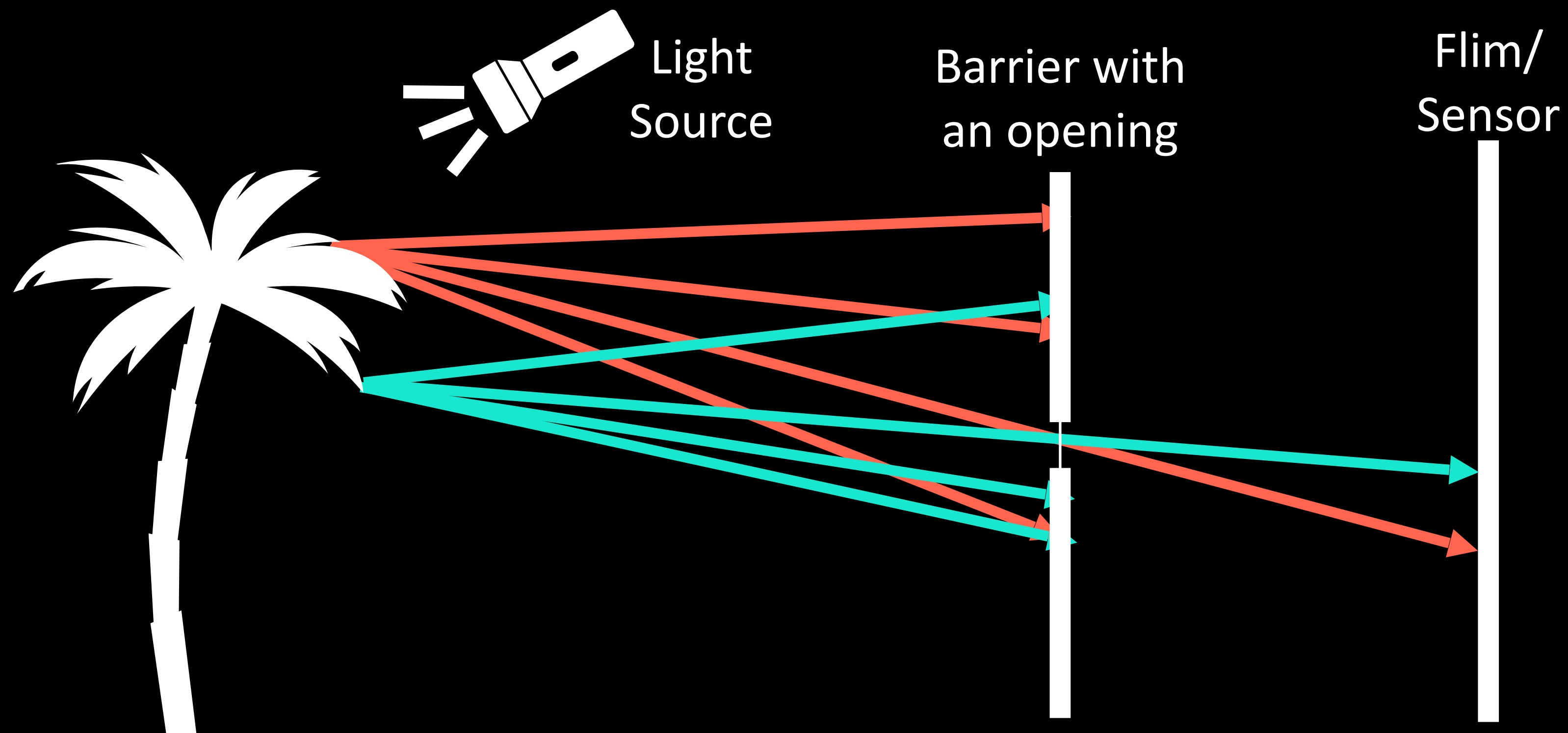


Image Capture

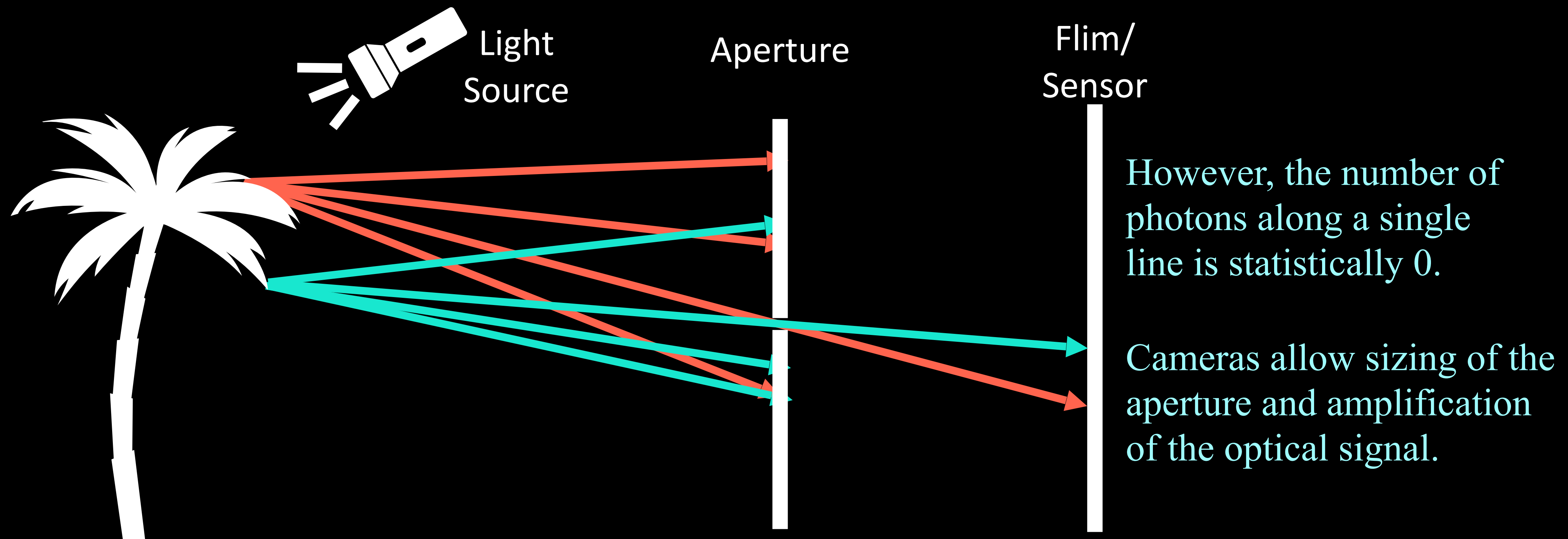
- A barrier with an opening (aperture) and a film plane

Opening has to be *shuttered* close except when taking a picture



Aperture Size

- If the aperture is a mathematical “pinhole,” light from only a single mathematical direction reaches any point on the film, and that light carries the color of its mathematical point of origin



Aperture Size

- As the aperture grows in size, one point on the film can sense light from multiple directions a finite amount of light per sensor location, but also a mixture of photons from multiple reflectors, aka *blur*

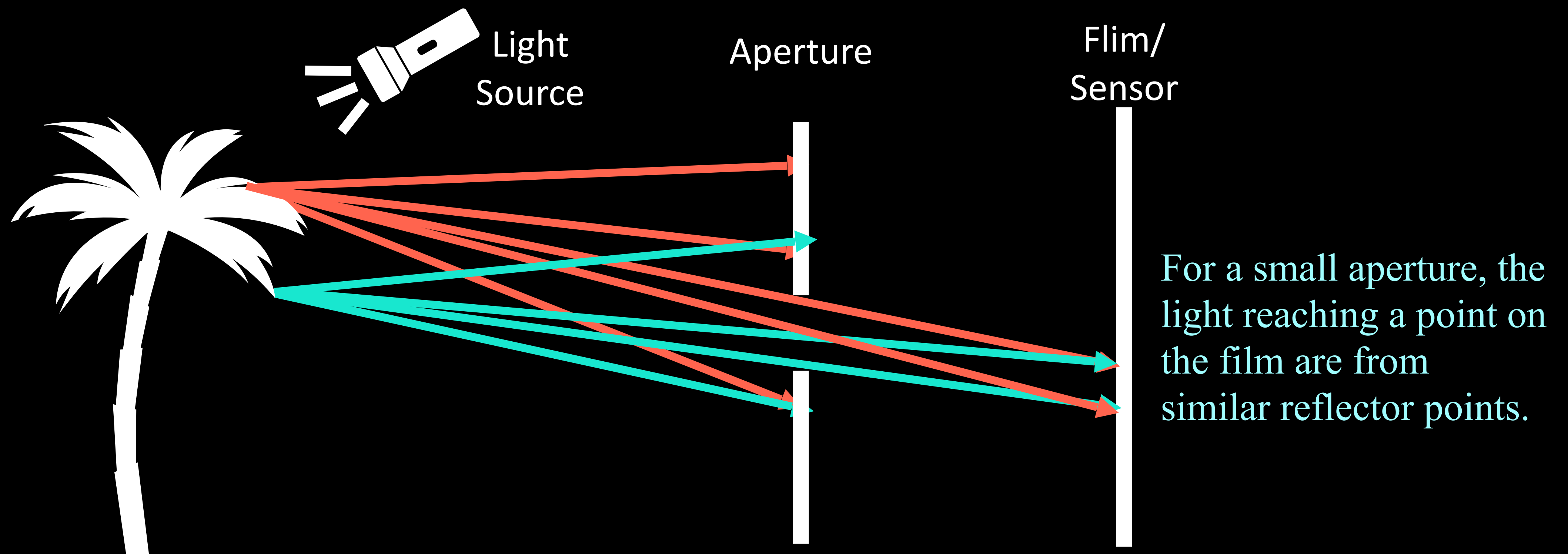
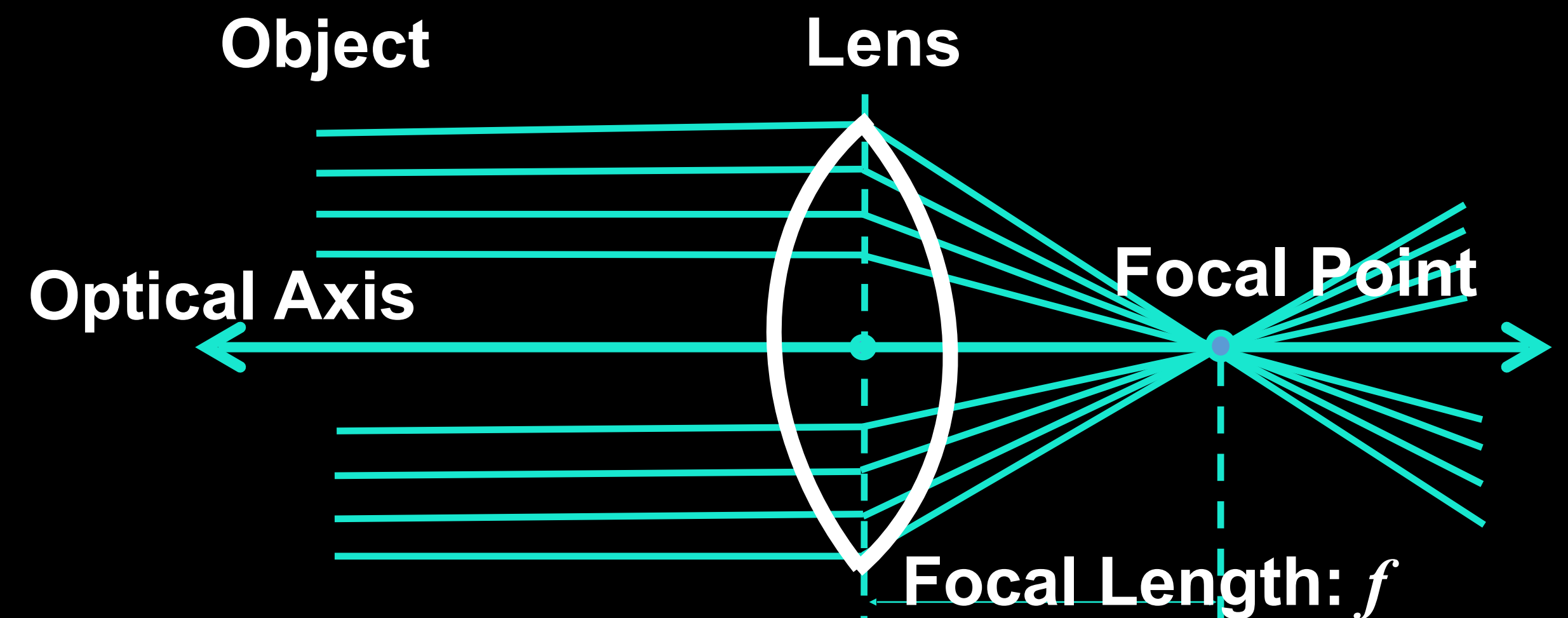
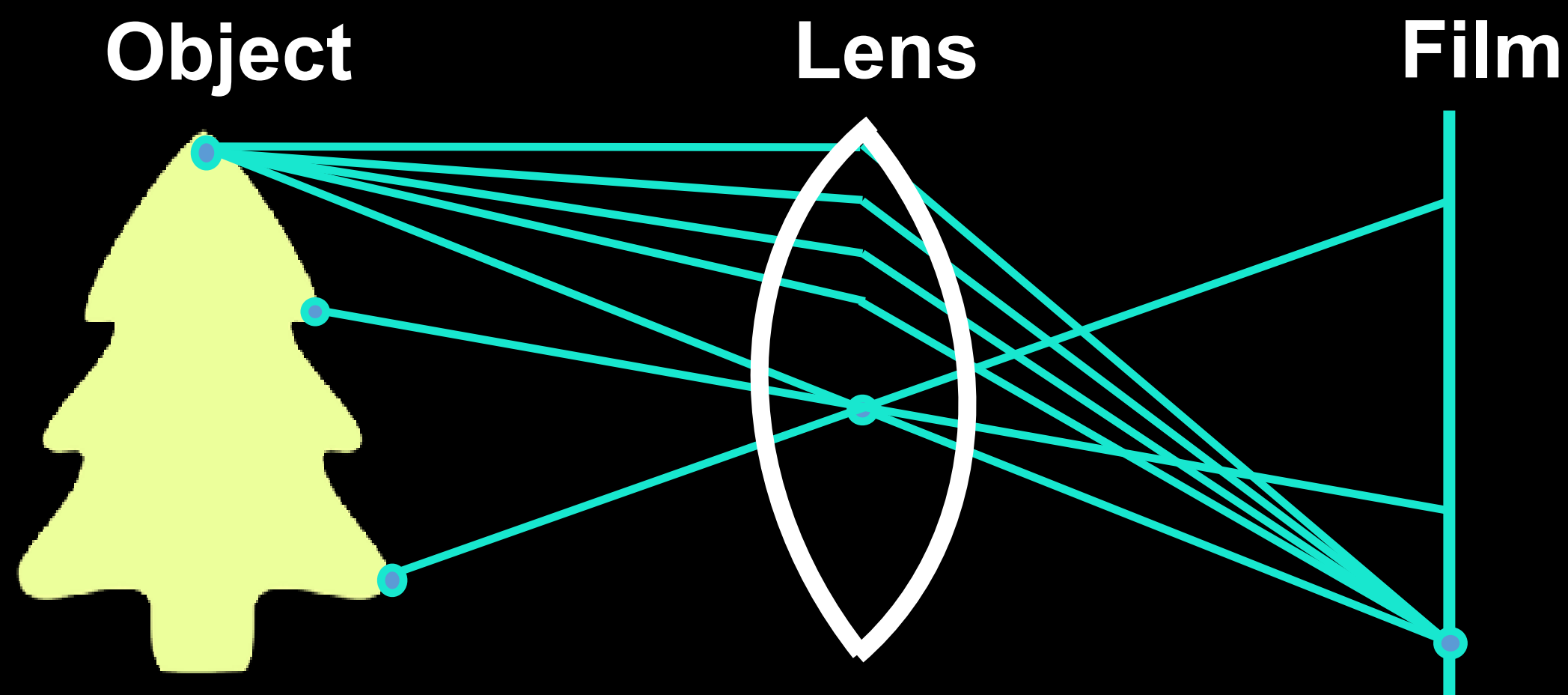
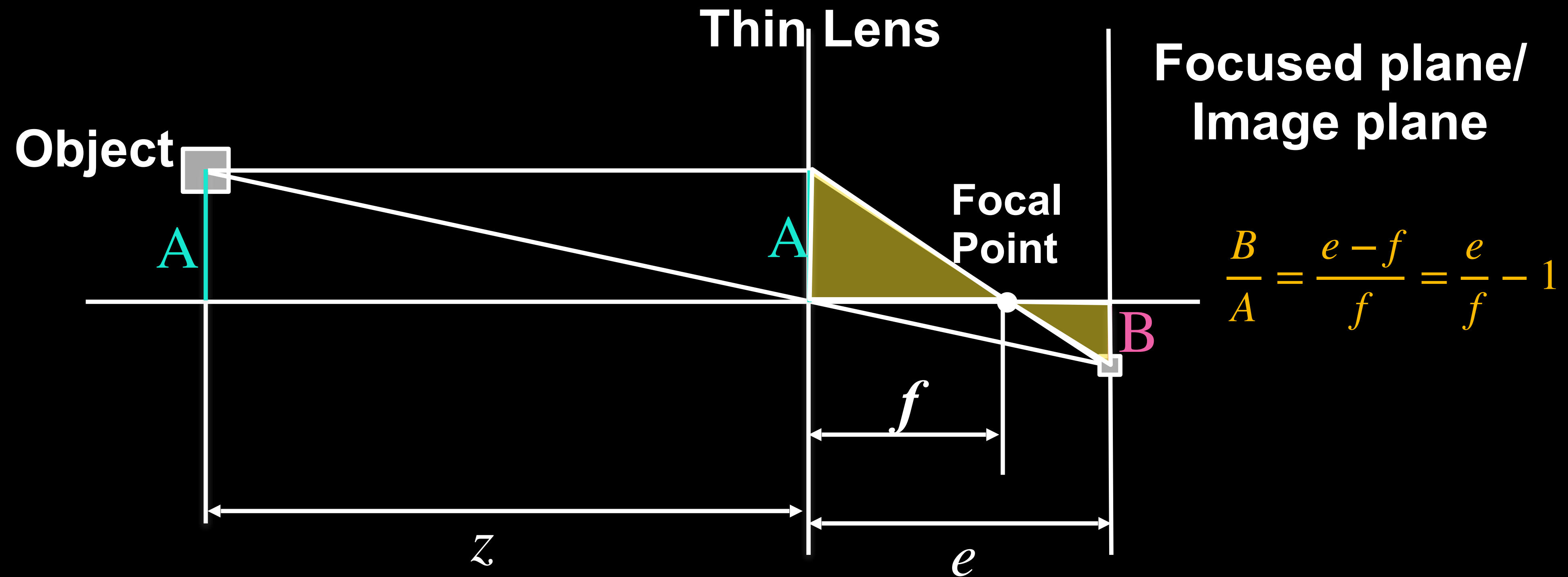


Image Capture using a Converging Lens

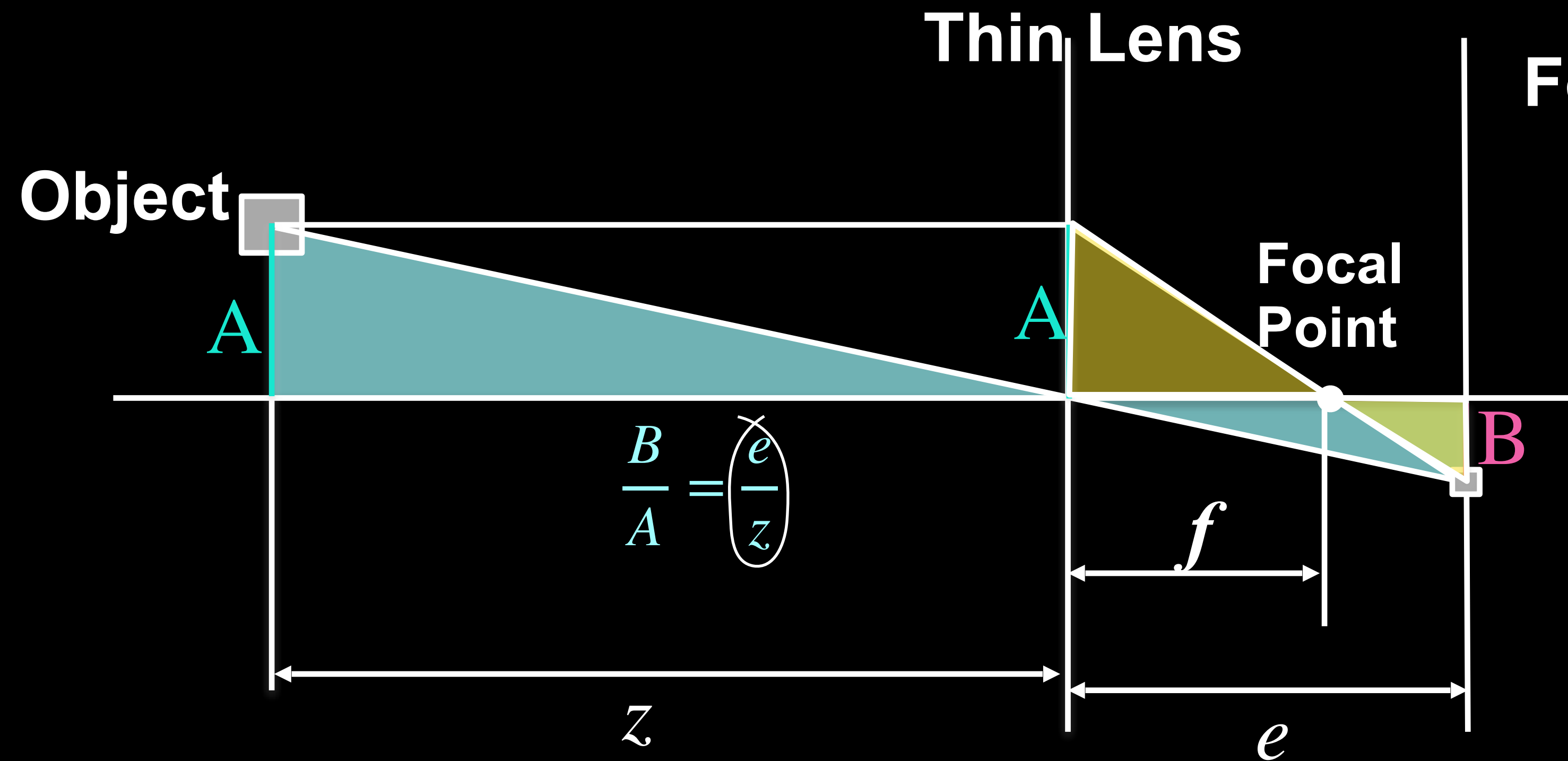
- A lens focuses light onto the film
- Rays passing through the 'Optical Center' are not deviated
- All rays parallel to the 'Optical Axis' converge at the 'Focal Point'



Thin Lens Equation



Thin Lens Equation



Focused plane/
Image plane

$$\frac{B}{A} = \frac{e-f}{f} = \frac{e}{f} - 1$$

$$\frac{e}{z} = \frac{e}{f} - 1 \Rightarrow \frac{1}{f} = \frac{1}{z} + \frac{1}{e}$$

Given a fixed f and e , z gets fixed

For a sharp image

Blur Circle

What if the image plane is not at the ideal distance from the lens?

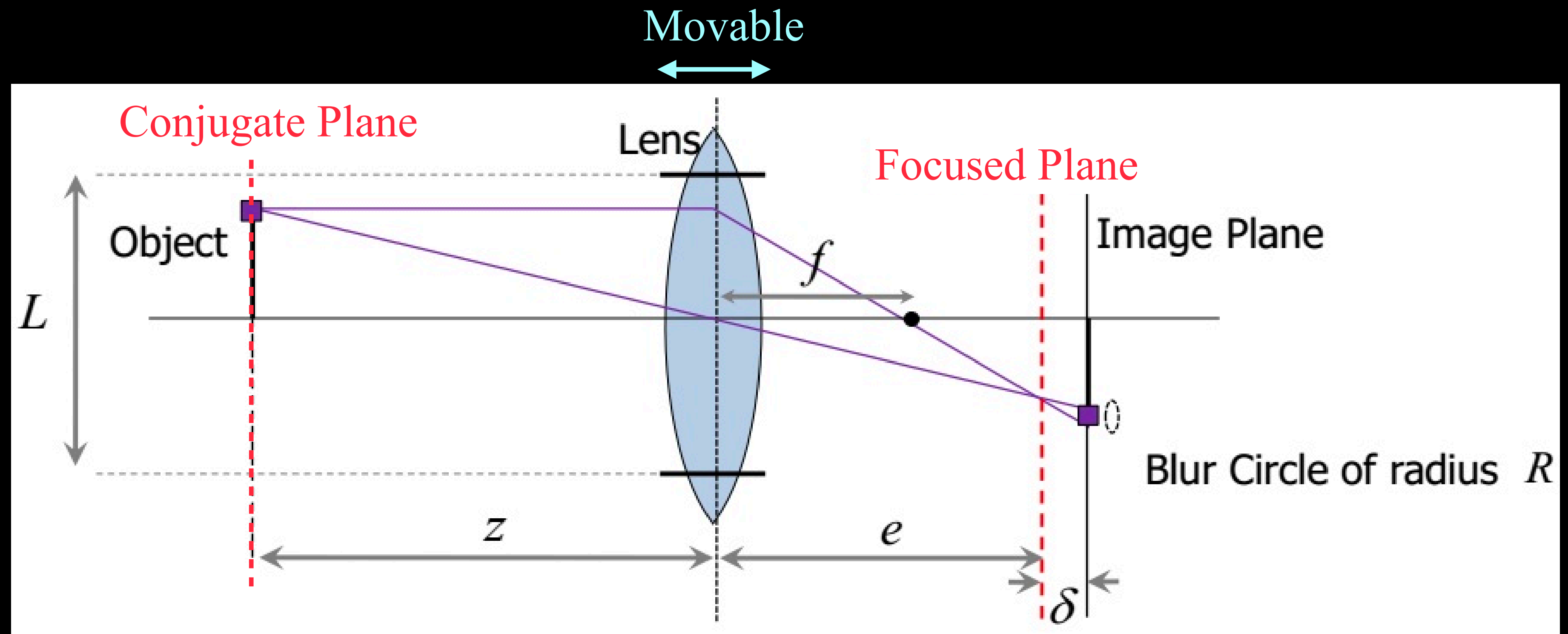
- Object is out of focus and Blur has radius: $R = \frac{L\delta}{2e}$

- Small L (pinhole) results in small R

- OK if R is smaller than pixel size

- For any $(e + \delta)$ and f and, only a single z is in focus

$$\frac{1}{f} = \frac{1}{z} + \frac{1}{e}$$



Focus and Depth of Field (DOF)

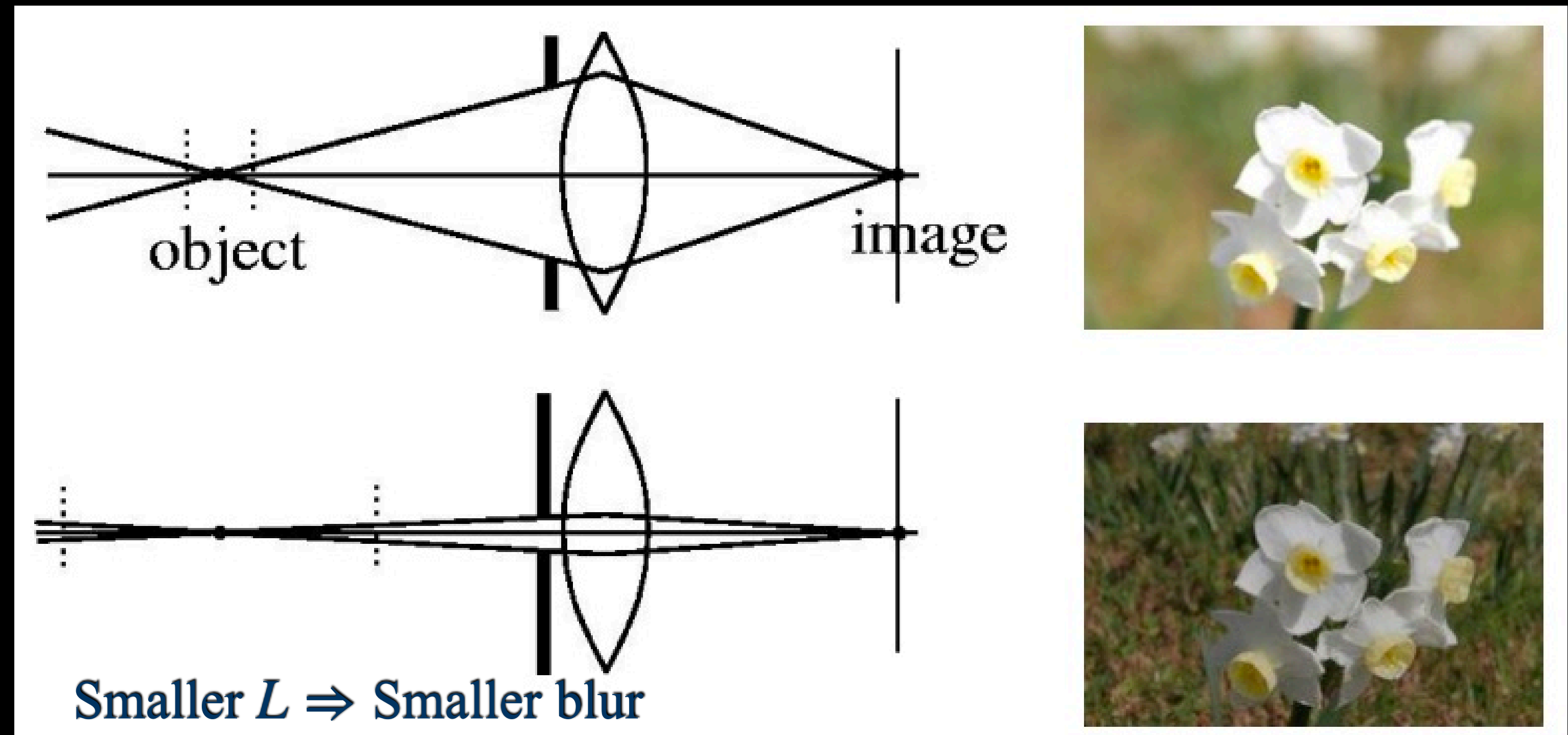
- Although a fixed lens can focus at only one depth, z , at a time, the decrease in sharpness is gradual on either side of ideal z
- Within a range of depths, DOF, the blur is generally ‘imperceptible’ (depending on pixel size)



DOF and Aperture

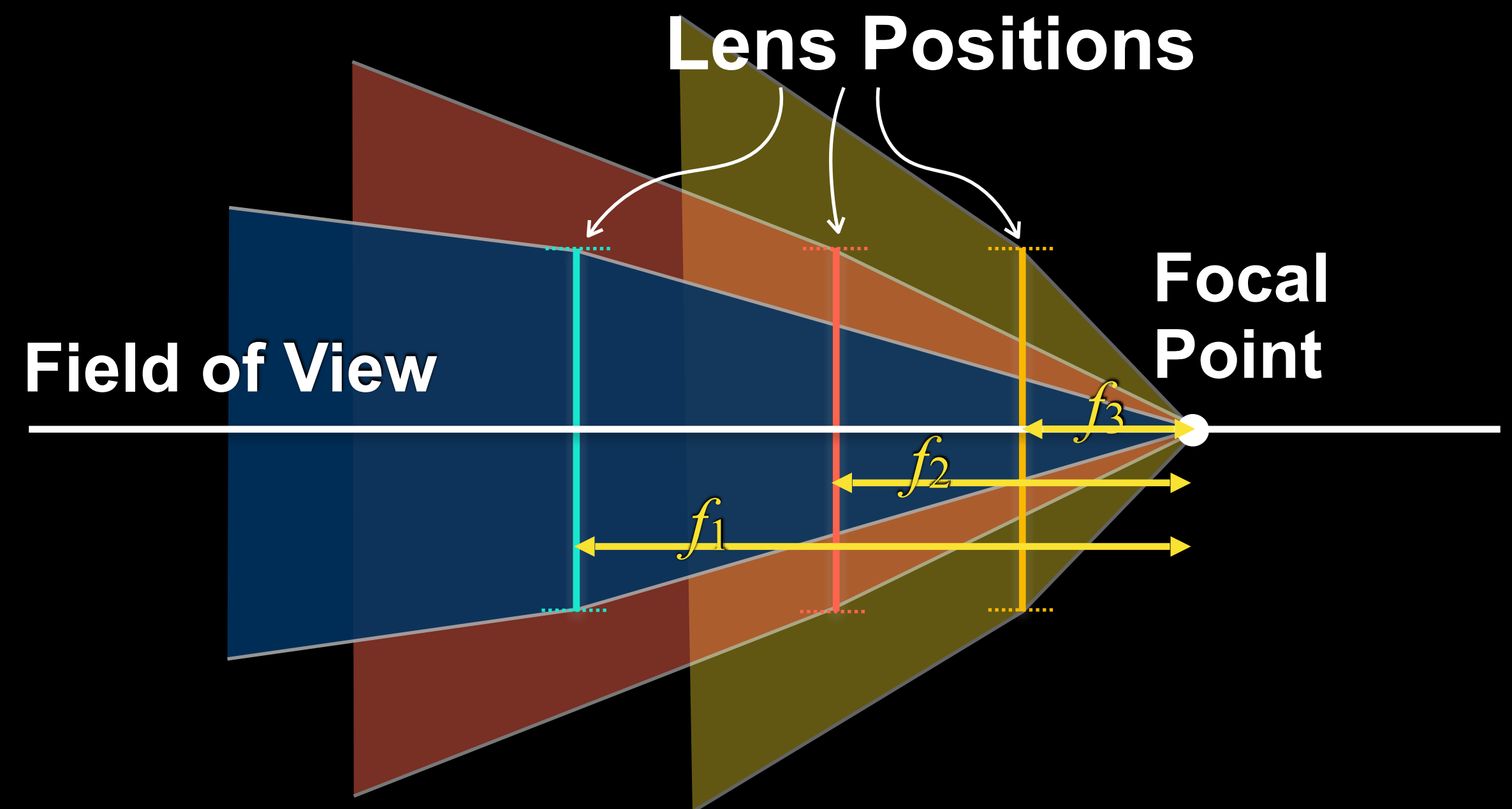
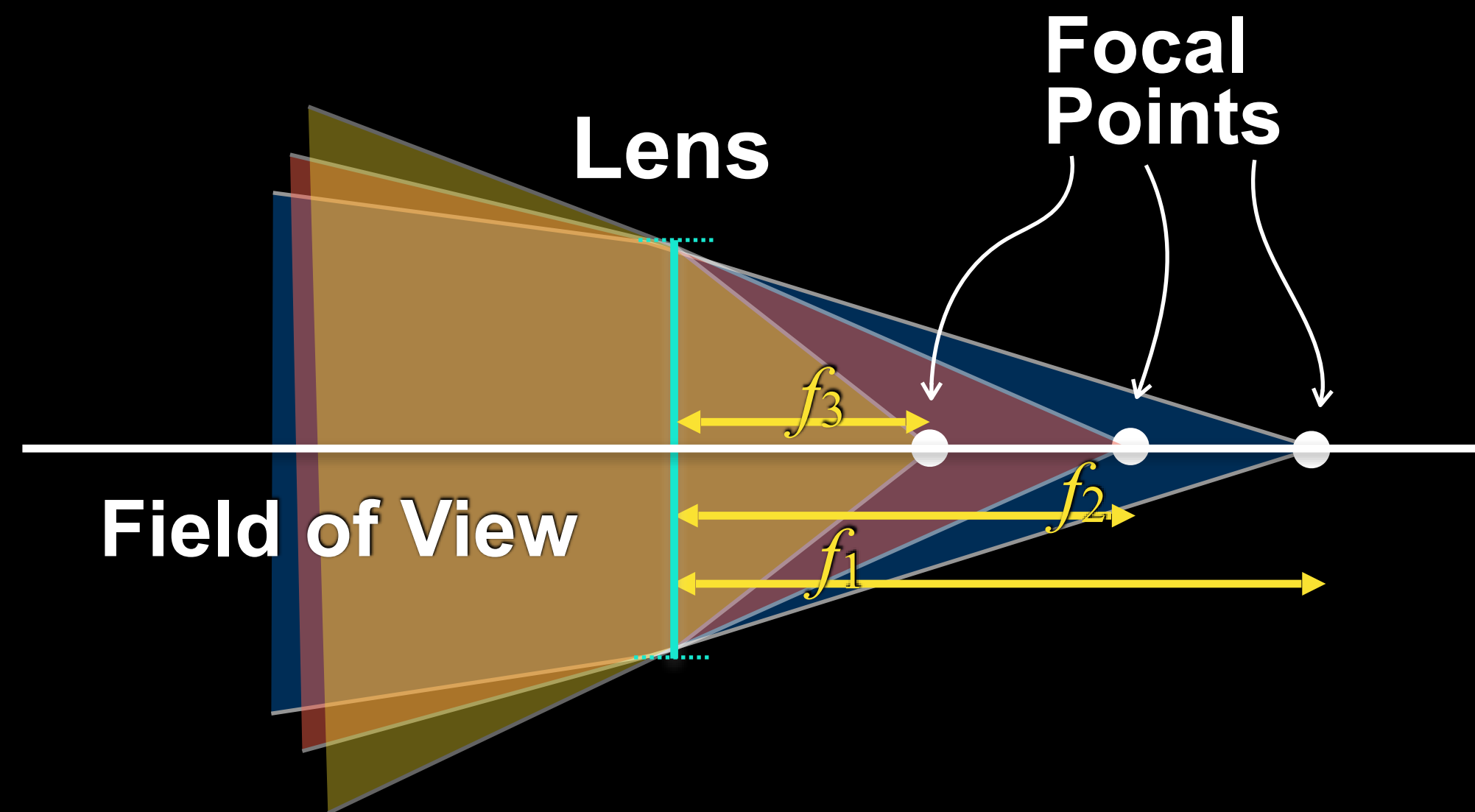
Aperture size affects the depth of field

- A smaller aperture increases DOF, the range in which the object appears approximately in focus but reduces the amount of light entering the camera



Focal Length and Field of View (FOV)

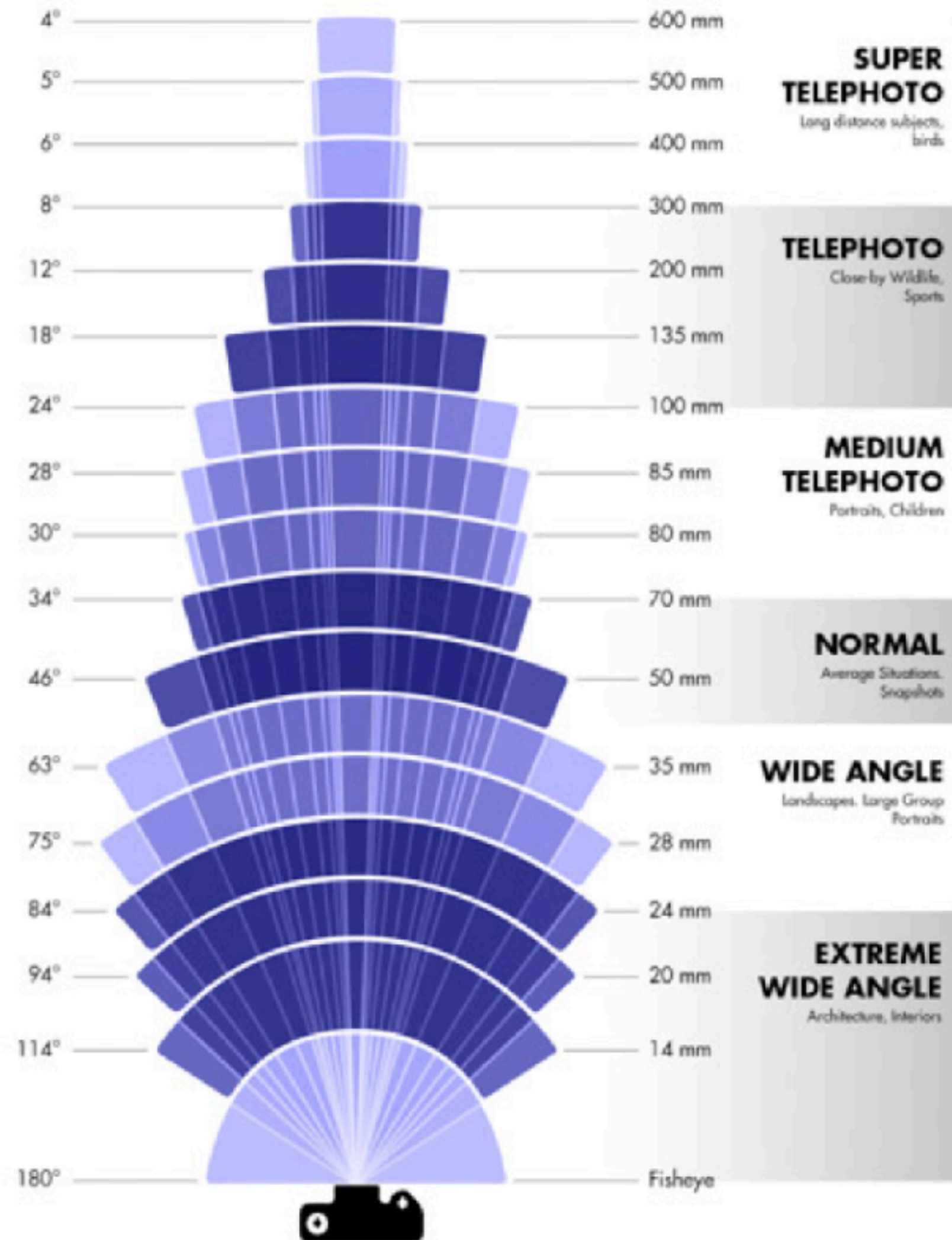
- As f gets smaller, FOV increases, image becomes more “wide angle” capturing more of the world
- And *vice versa*



Focal Length and Field of View (FOV)

FOCAL LENGTH

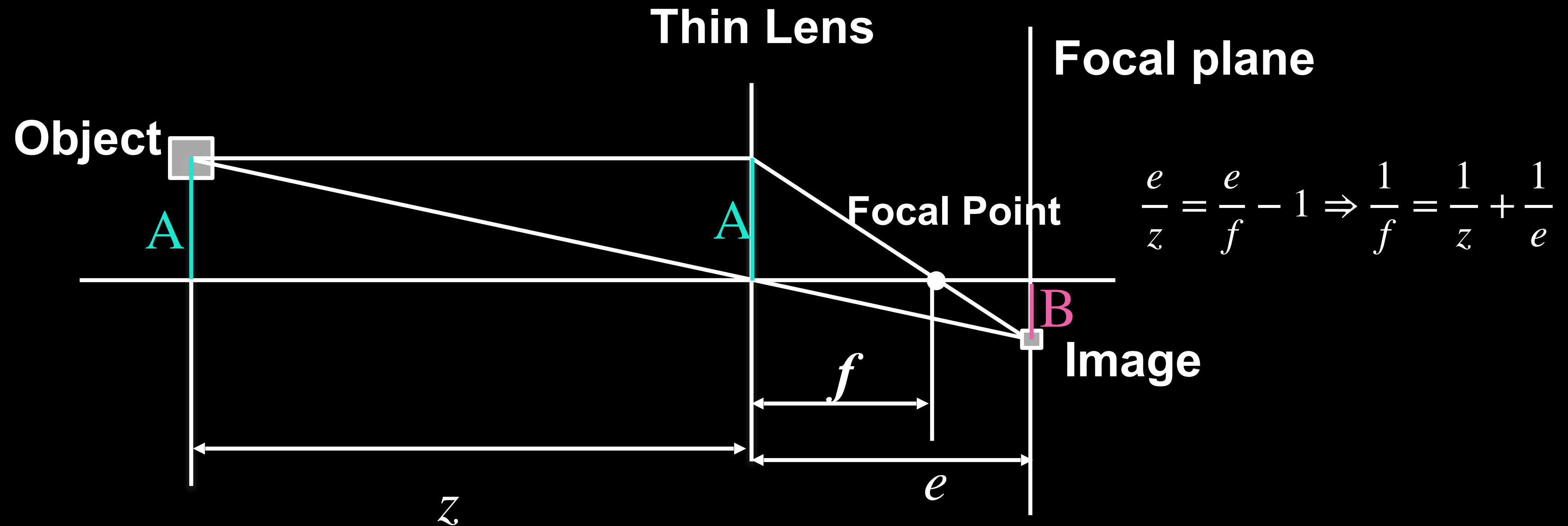
& ANGLE OF VIEW



LENS TYPES



CameraHarmony

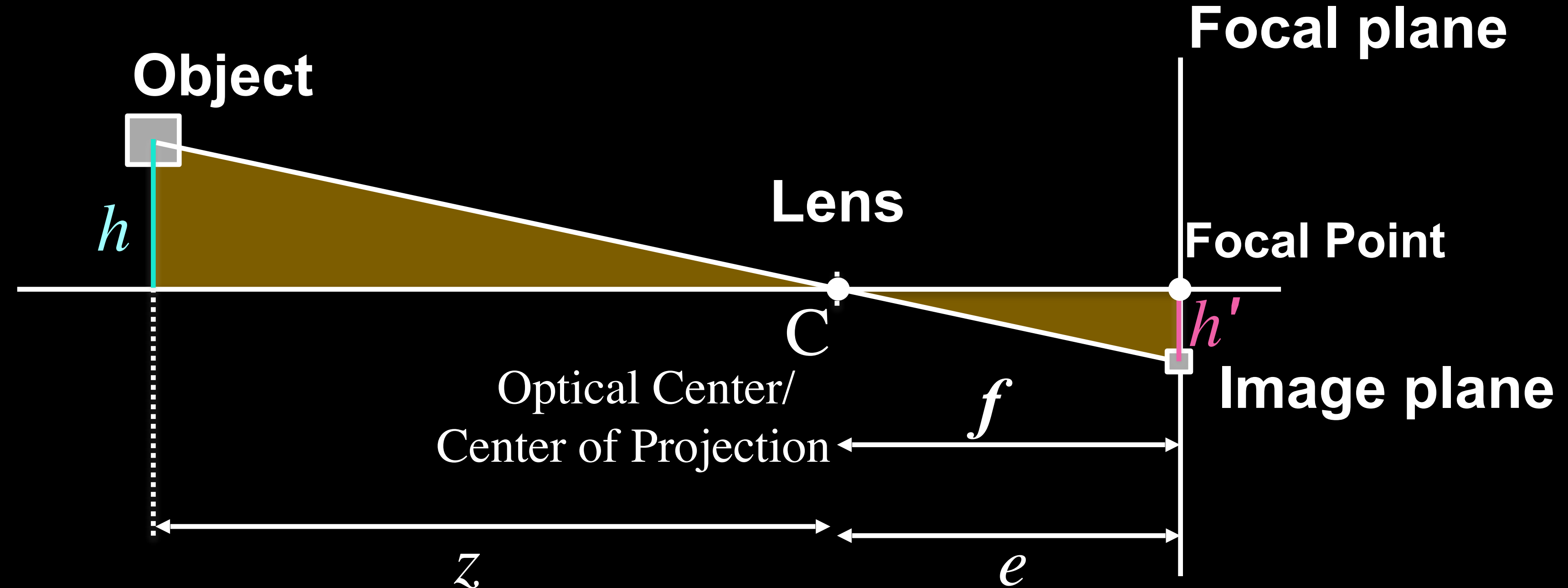


Pinhole Camera Approximation

- Consider $z \gg f$

$$\frac{1}{f} = \frac{1}{z} + \frac{1}{e} \Rightarrow \frac{1}{f} \approx \frac{1}{e} \Rightarrow f \approx e$$

$$\frac{h}{h'} = \frac{f}{z} \Rightarrow h' = \frac{f}{z}h$$



- Effectively, brings objects at infinity into perfect focus: true pinhole means all objects are in focus
- The dependence of the size of an object's image on its depth (i.e. distance from the camera) is known as **perspective**

Perspective Effects

- Far away objects appear smaller



Perspective Effects

- Parallel lines in the world intersect in the image at a “vanishing point”

