Camera & Image

Dr. Tushar Sandhan

Introduction

Introduction

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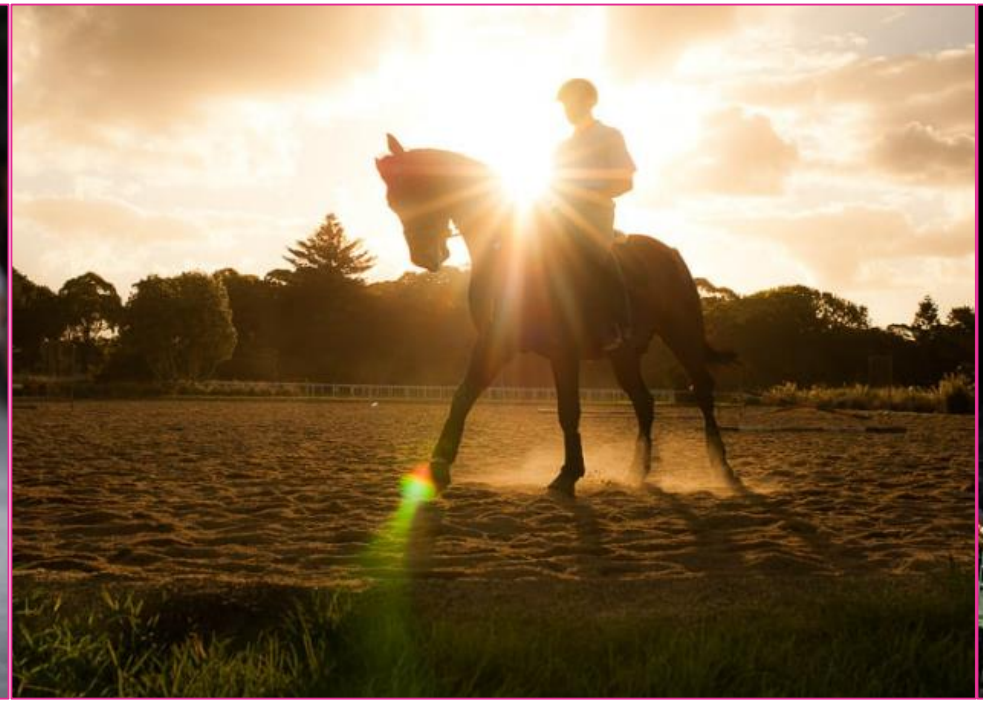
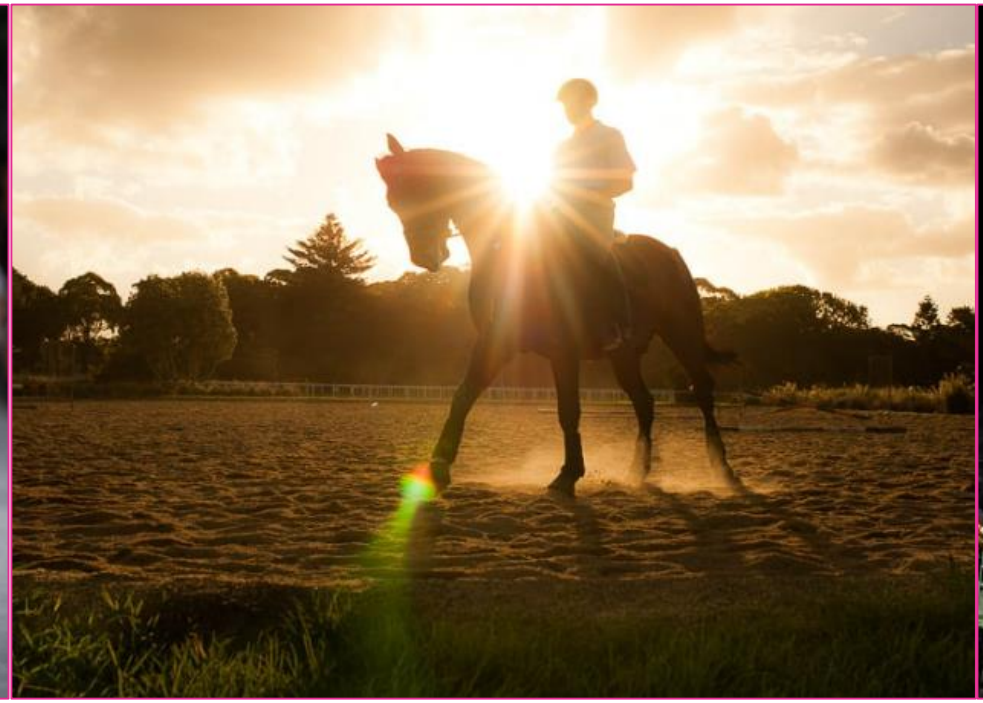


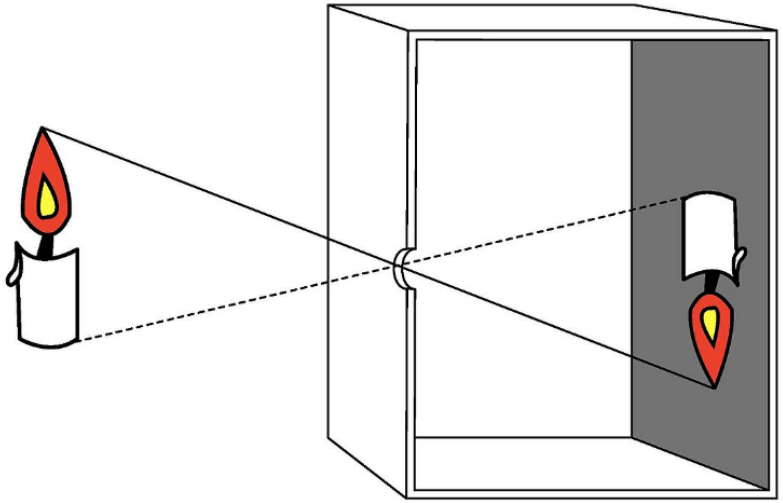
Introduction

- Focus
- Colors
- Motions



Aperture

- Pinhole camera
  - without lens
  - tiny aperture
  - no lens distortions
  - everything appears in focus
    - ∞ DOF



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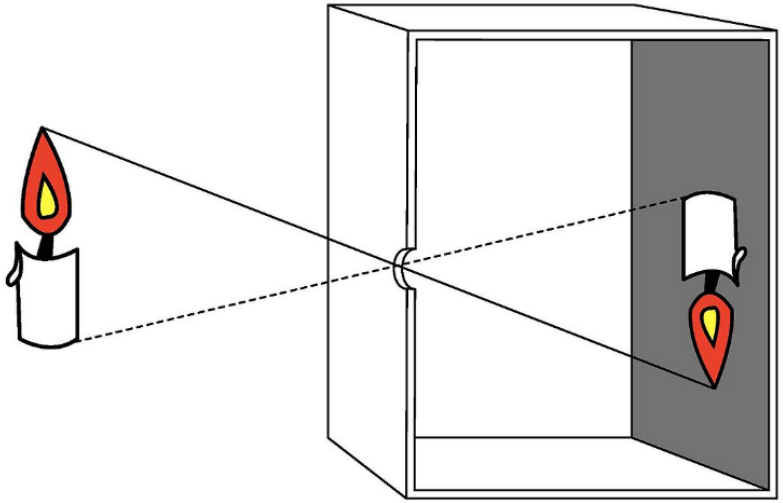

- Photography camera
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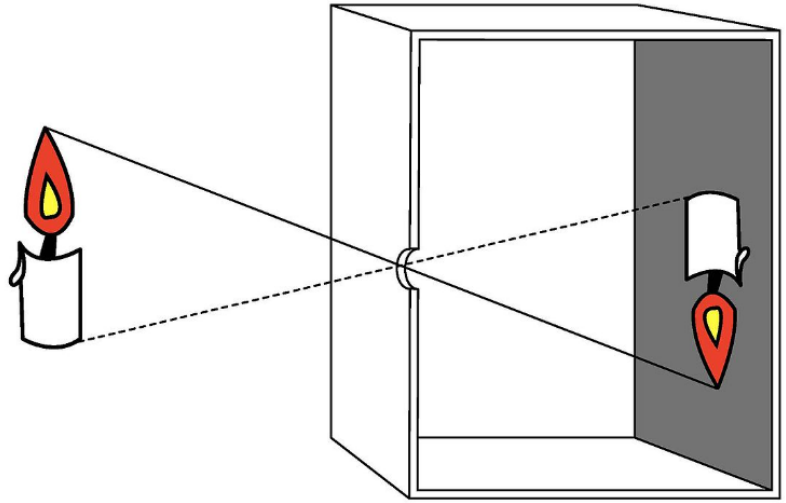

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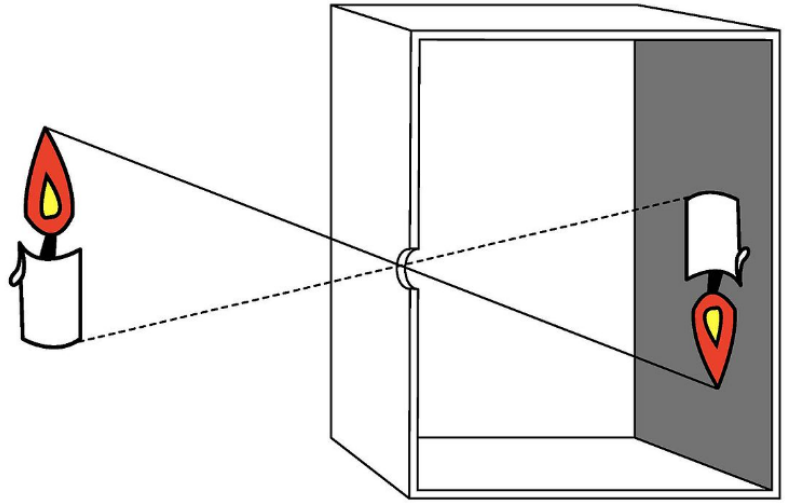

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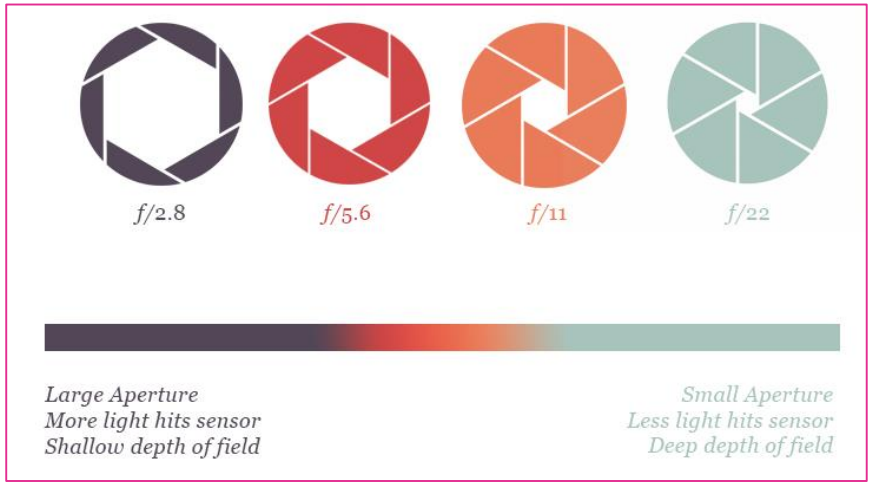
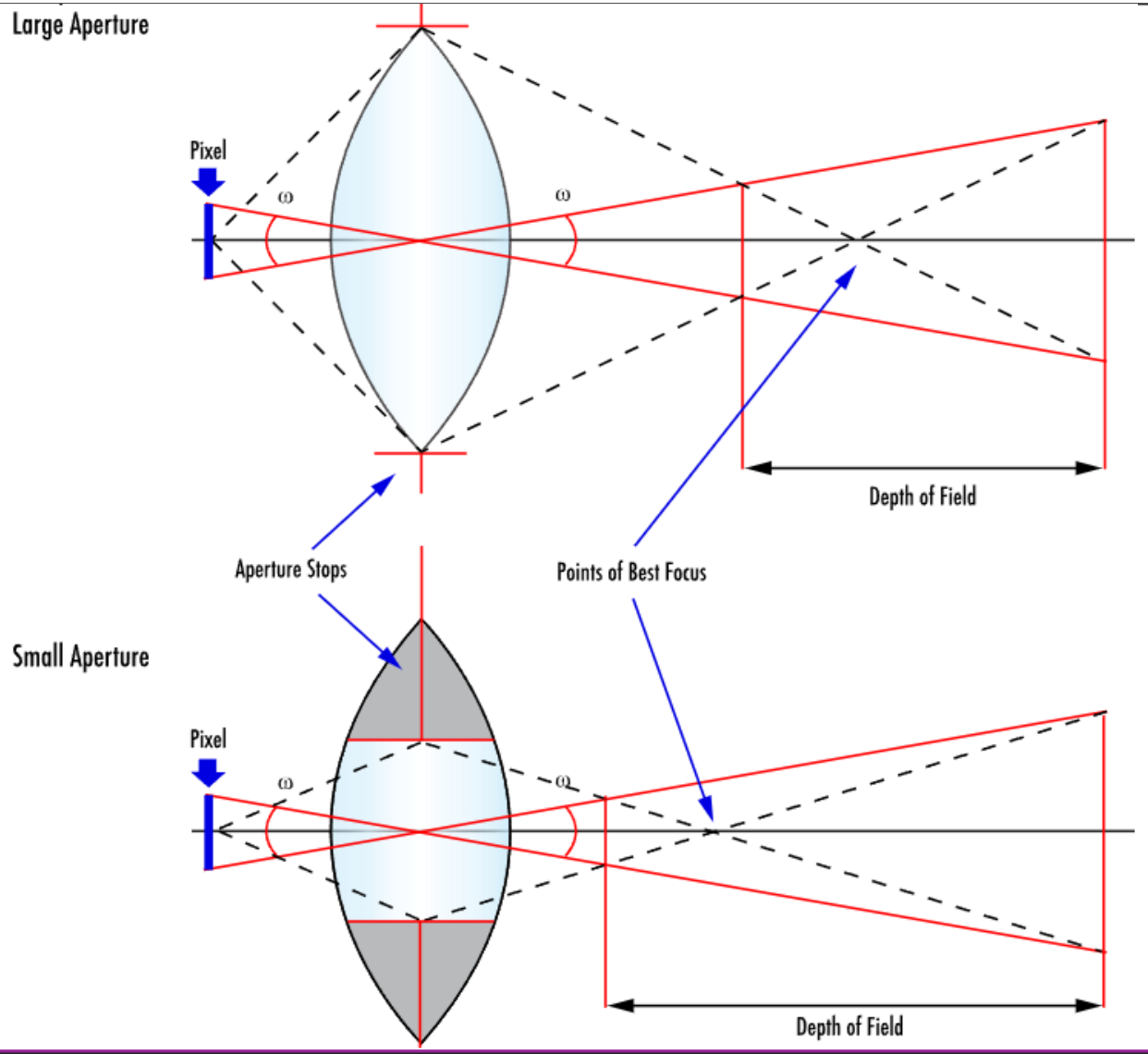


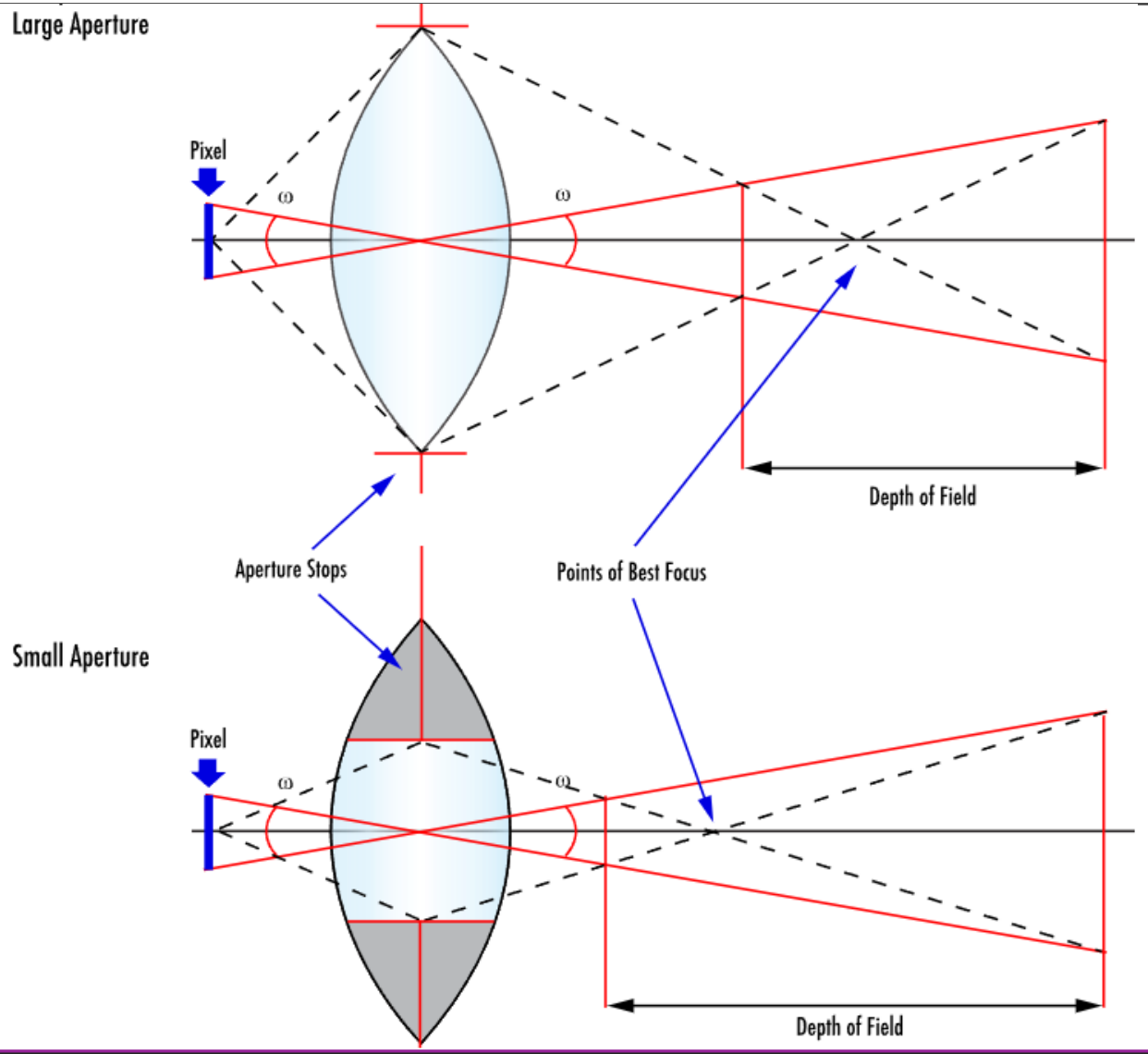
Aperture

- Depth of Field
  - aperture ↓ : DOF ↑



Aperture

- Depth of Field
  - aperture ↓ : DOF ↑
- Shutter
  - optical ON OFF
  - motion ↑ : speed ↑



Sensors

- Passive (self-generated sensors)
  - ➢ Not require external power
  - resistors
  - capacitors
  - inductors, transformers
  - antennas
  - diodes

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    - LED
    - solenoid
    - LiDAR
    - LCD

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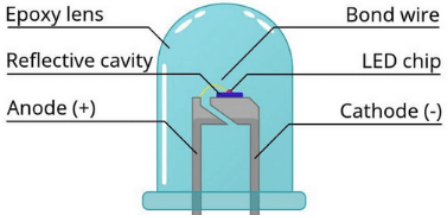

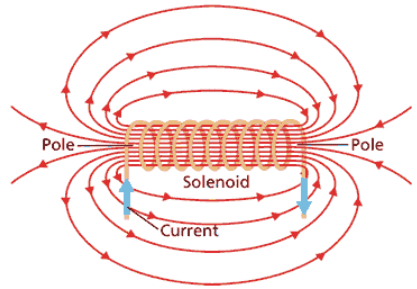

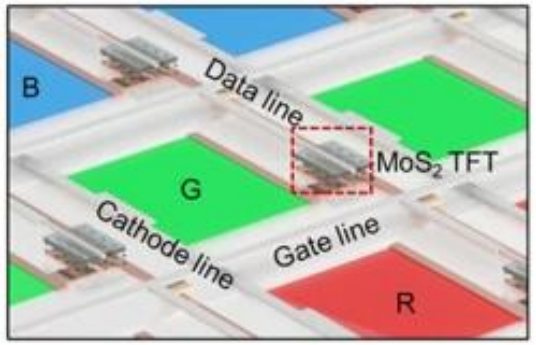

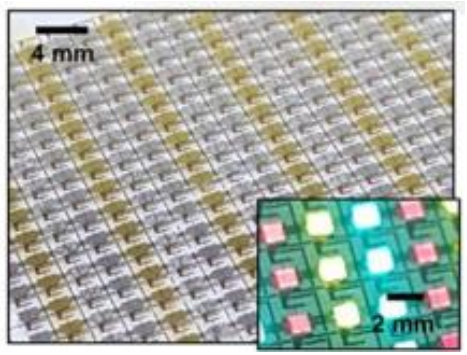

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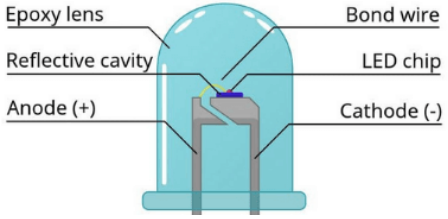
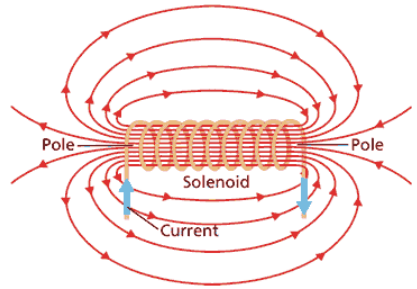
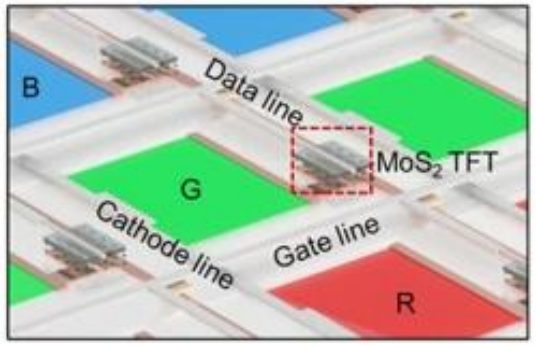
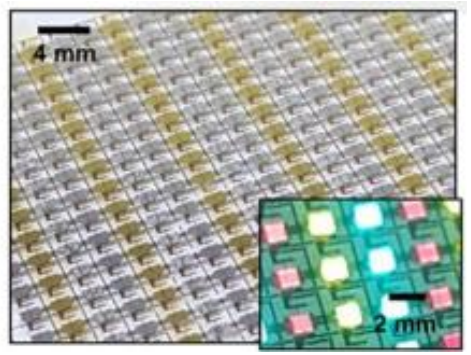
- Which are energetically more efficient?
  - ➢ Nature's choice



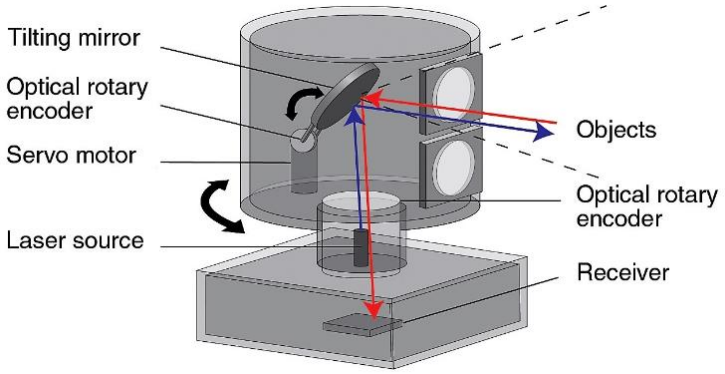






Active sensing

- Precision
  - elevation mapping
- Safety
  - autonomous driving (LIDAR)
  - leader?



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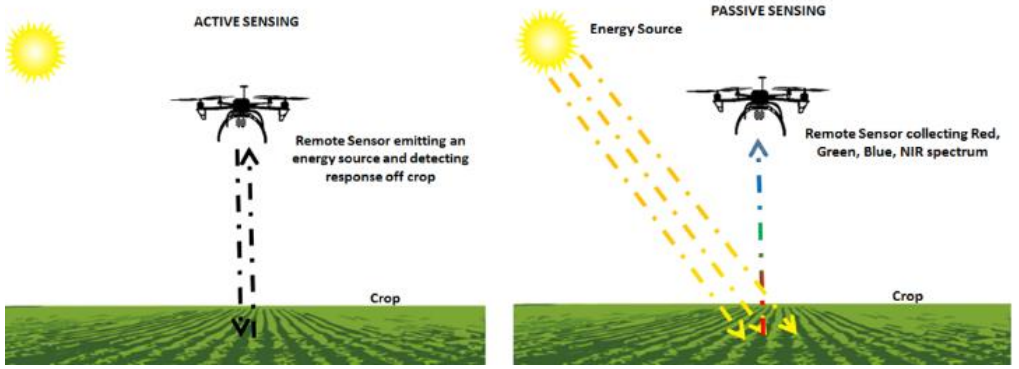
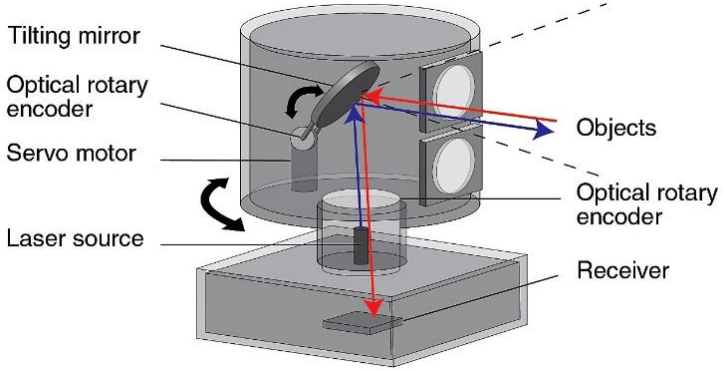
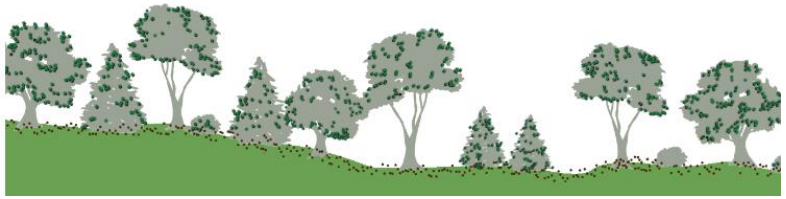






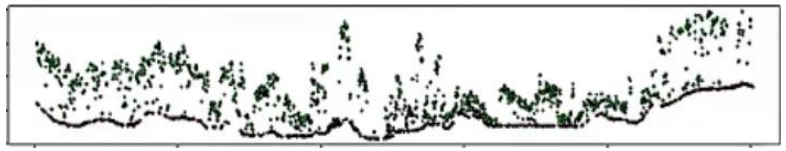
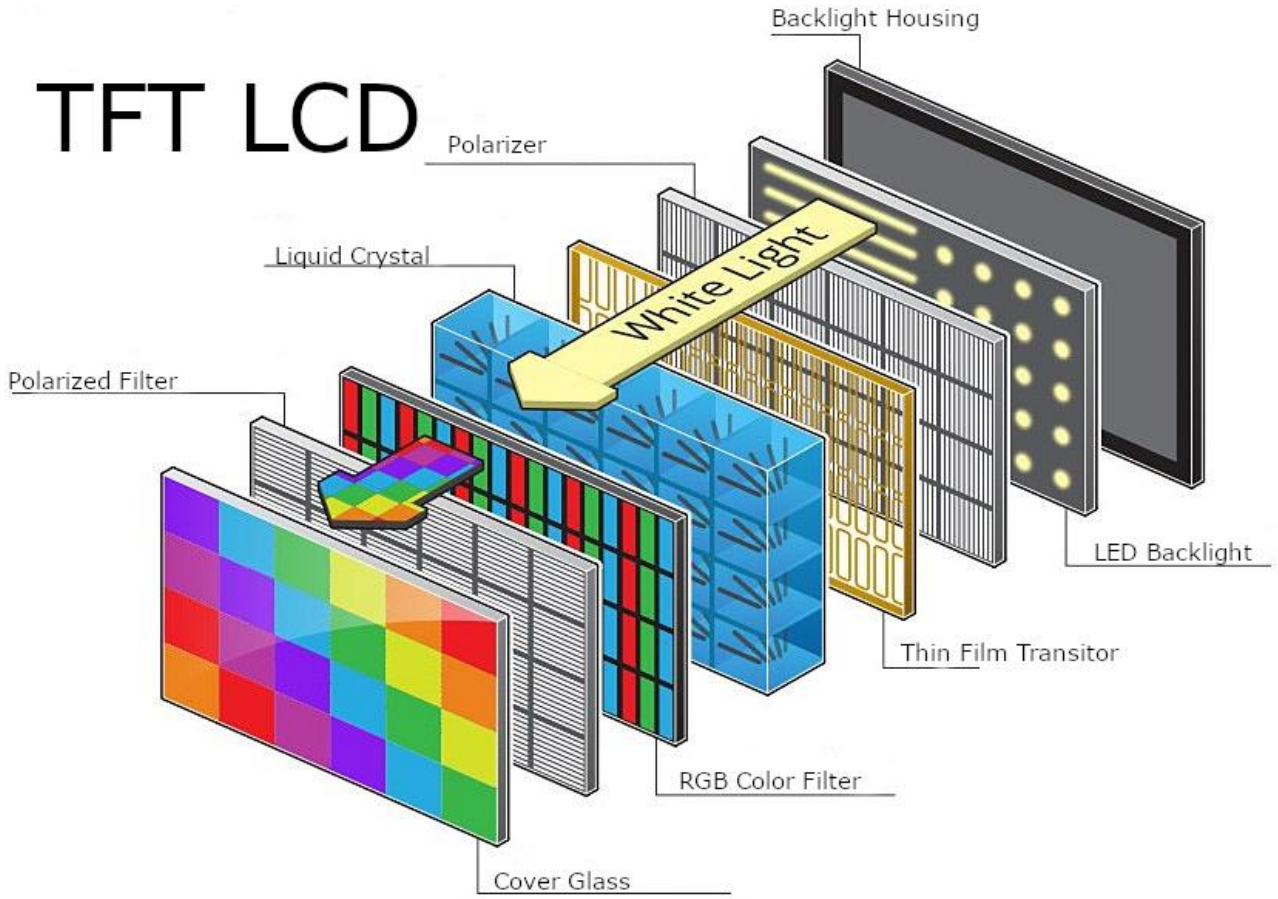


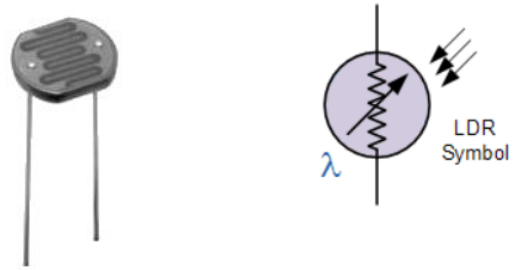
Image display

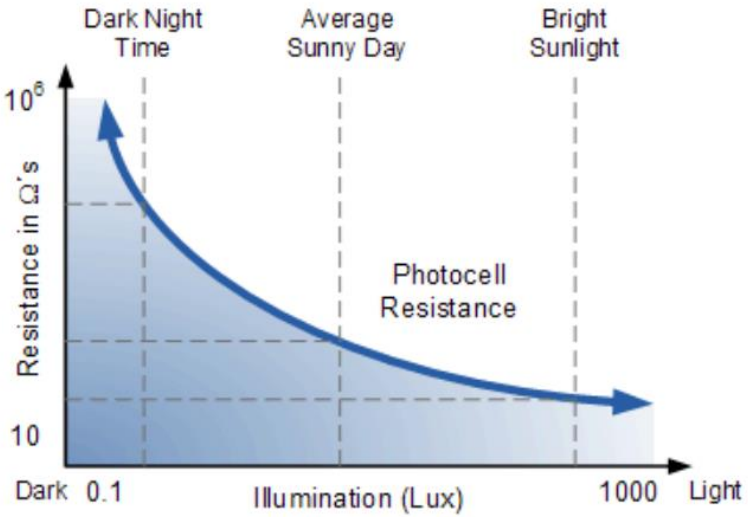
- Active
  - LCD
    - twisted nematic liquid
    - rotate the polarization of linearly polarized light
  - thin film transistors



Light sensing elements

- LDR
  - light dependent resistor
  - cadmium sulphide (CdS)
  - long response time
  - alarm detector?





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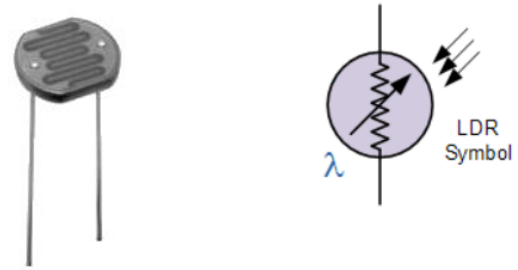

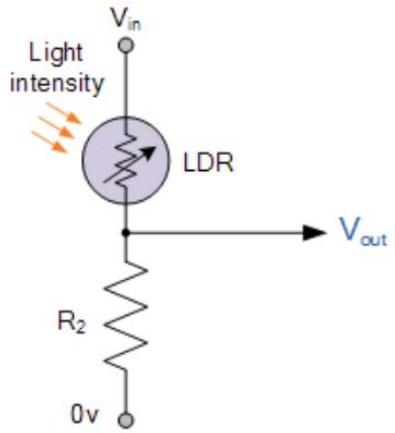

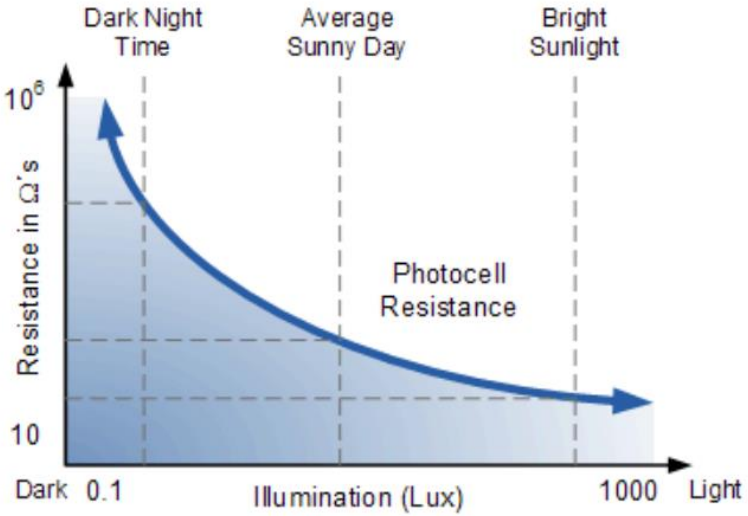

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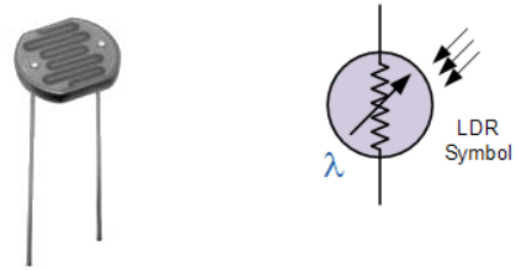
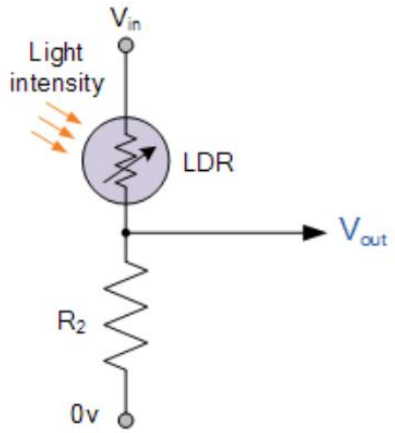
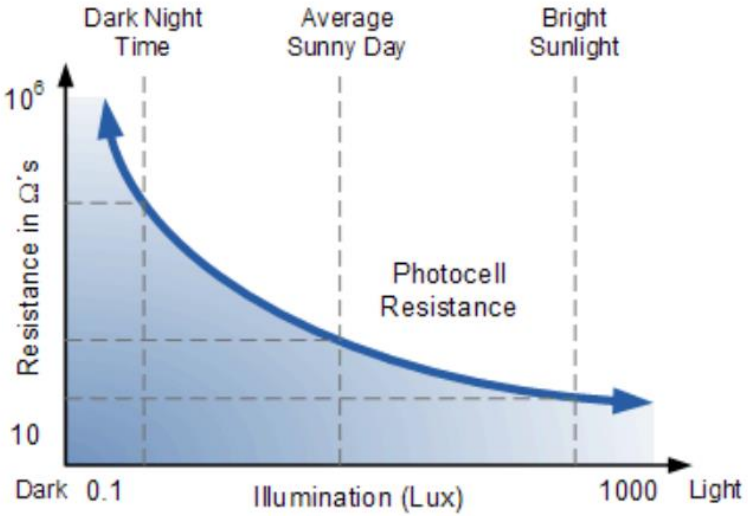




$$V_{out} = V_{in} \frac{R_2}{R_2 + R_{LDR}}$$



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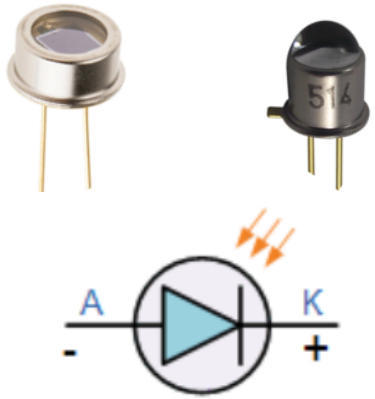
  - usual PN junctions
  - more responsive to longer λ (IR)
  - response time: nanosec
  - cameras, scanners, fax machines, light meters, DVD drives



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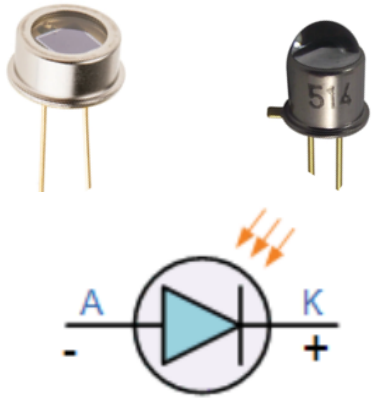

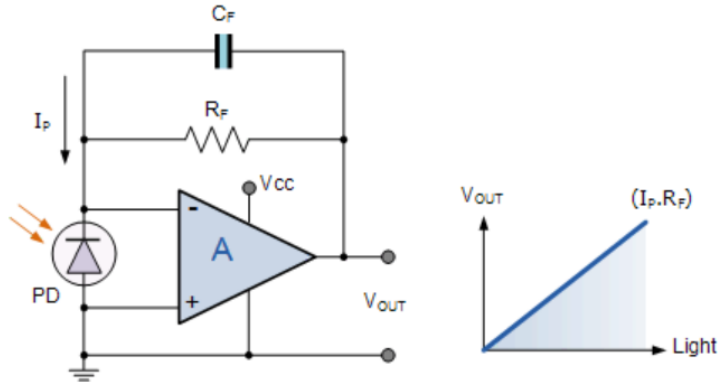

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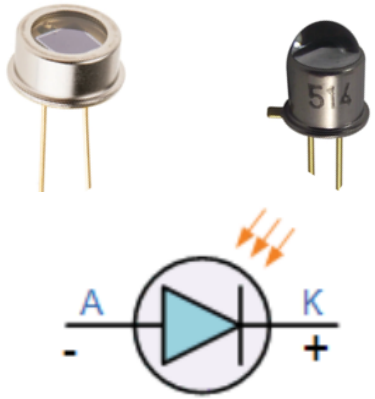

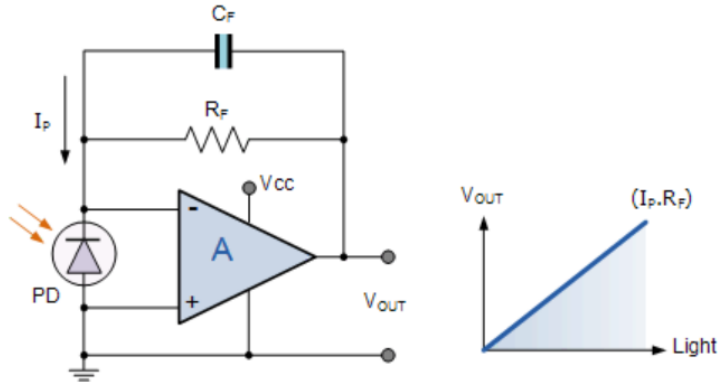

- Phototransistor
  - e.g. photodiode with inbuilt amp.
  - 100times more current gains than photodiodes
  - bipolar NPN transistor with optional base
  - opto-isolators, opto-switches fibre optics

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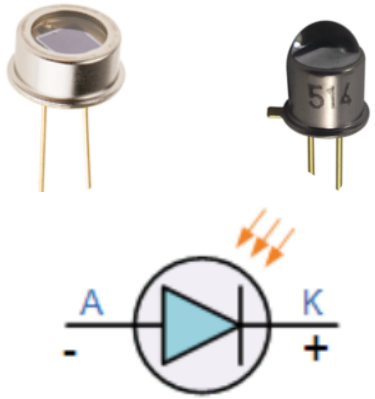

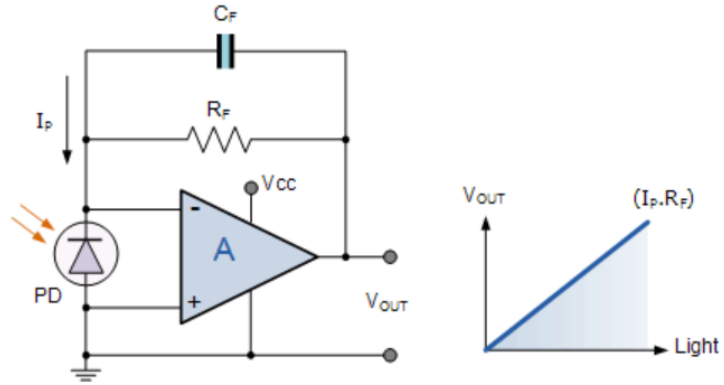

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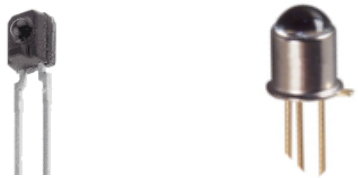

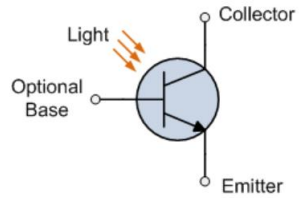

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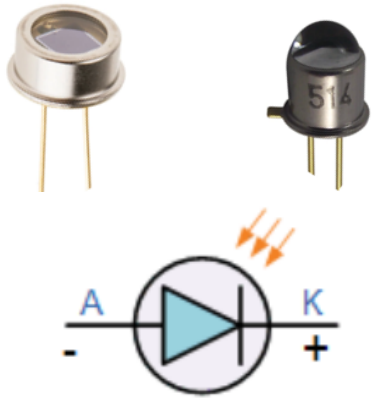

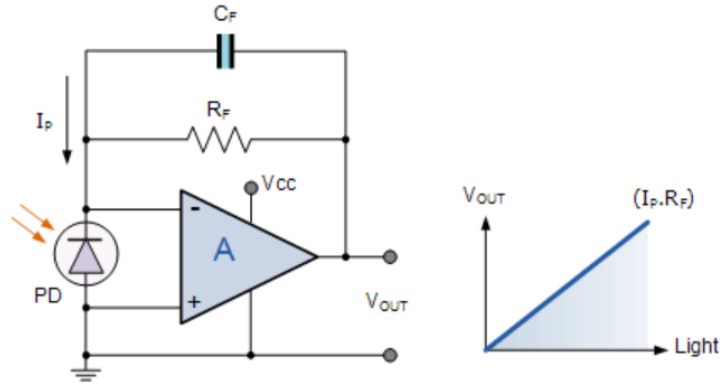

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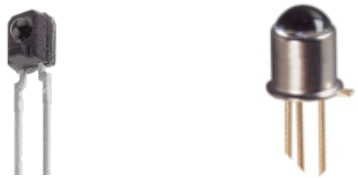

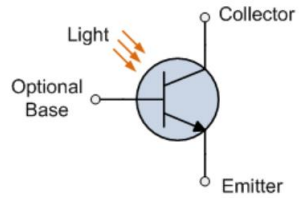

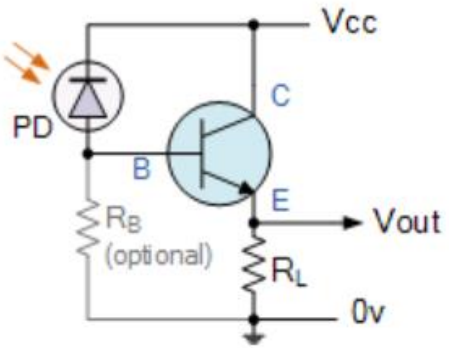

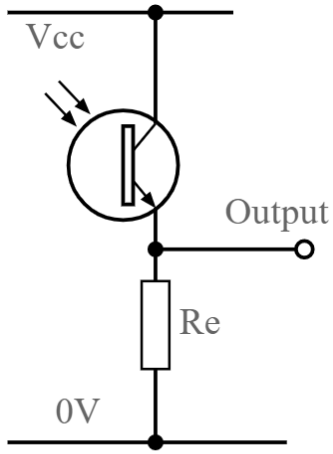

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  - reduced dynamics range
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Light focusing element

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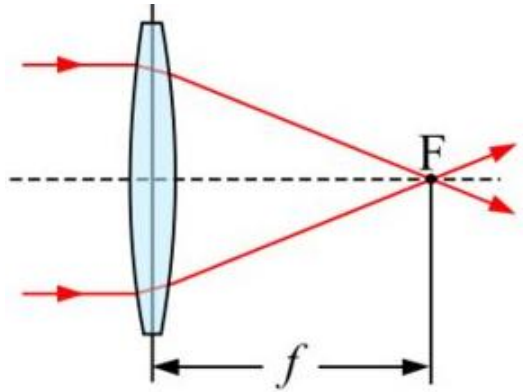

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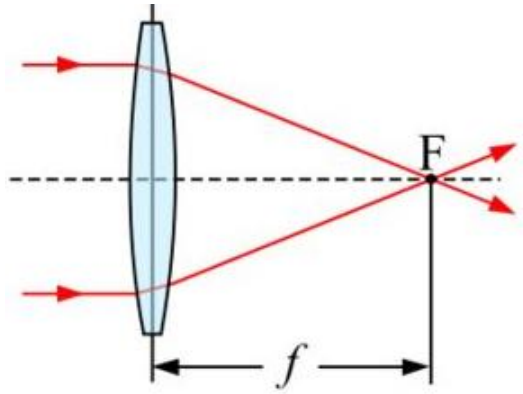
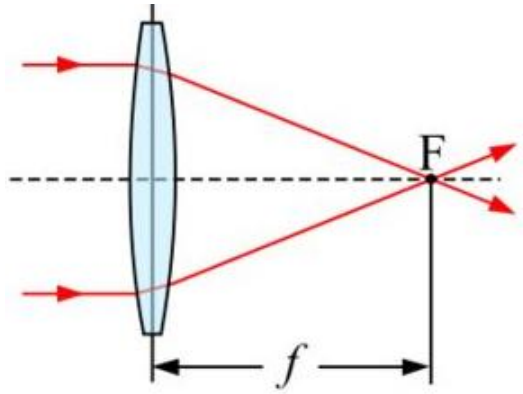


$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)d}{nR_1R_2}\right]$$

f is the focal length of the lens
n is the refractive index
R_1 R_2 radius of curvature
d is the thickness of the lens

Light focusing element

- Lens
  - Lensmaker's eq



$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n-1)d}{nR_1R_2}\right]$$

f is the focal length of the lens
n is the refractive index
R_1 R_2 radius of curvature
d is the thickness of the lens

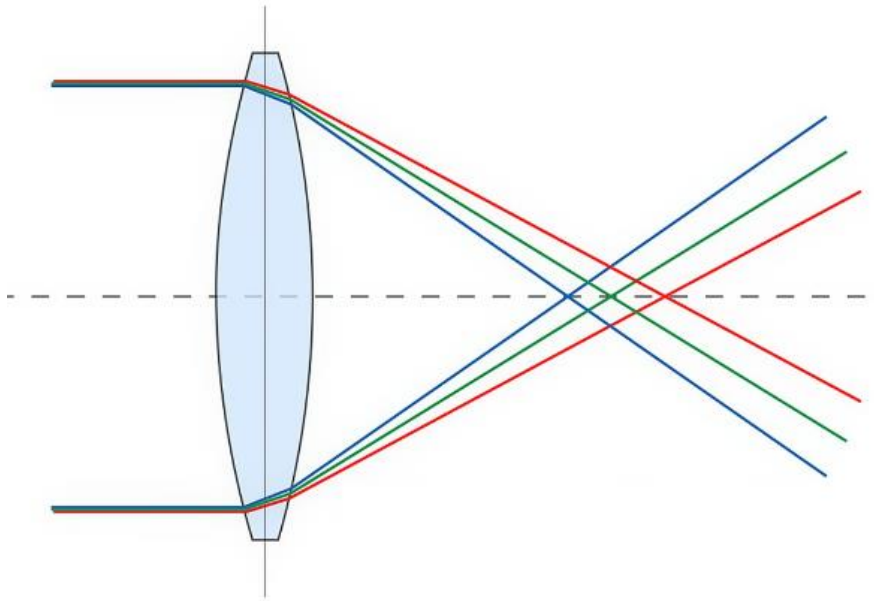
- Refractive index

$$n(\lambda) = A + \frac{B}{\lambda^2}$$

A, B: material constants.

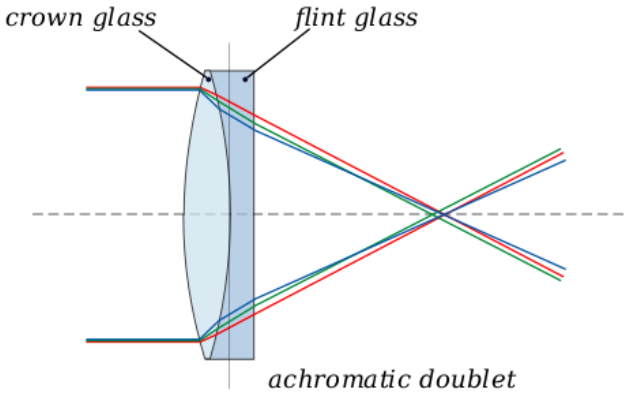
Single lens

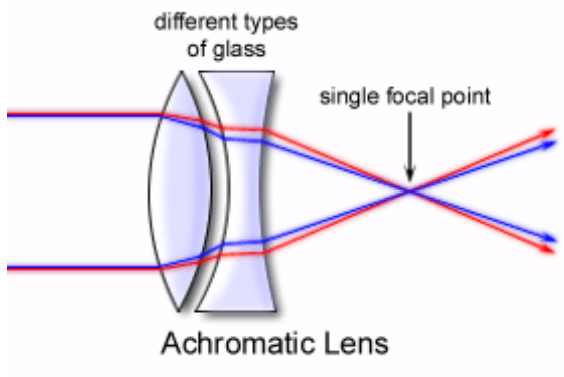
- Chromatic aberrations
  - failure of lens to focus
    all colors to the same point
  - fringes of color at image boundaries

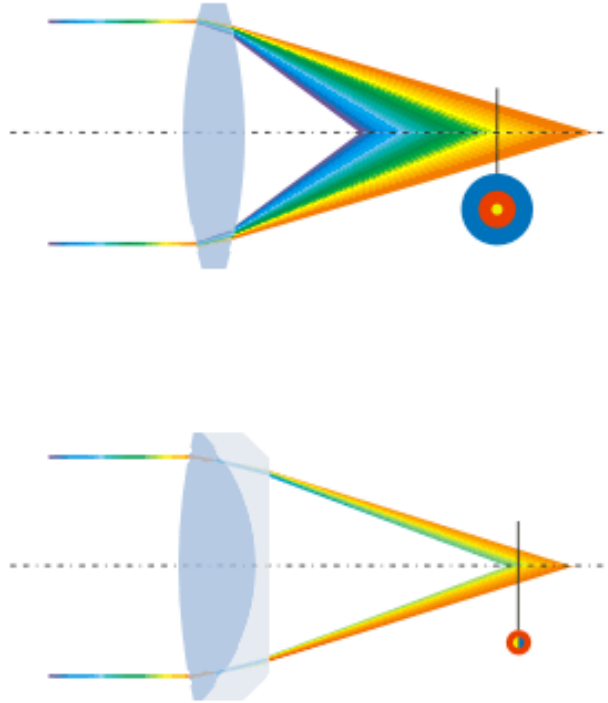


Double lens

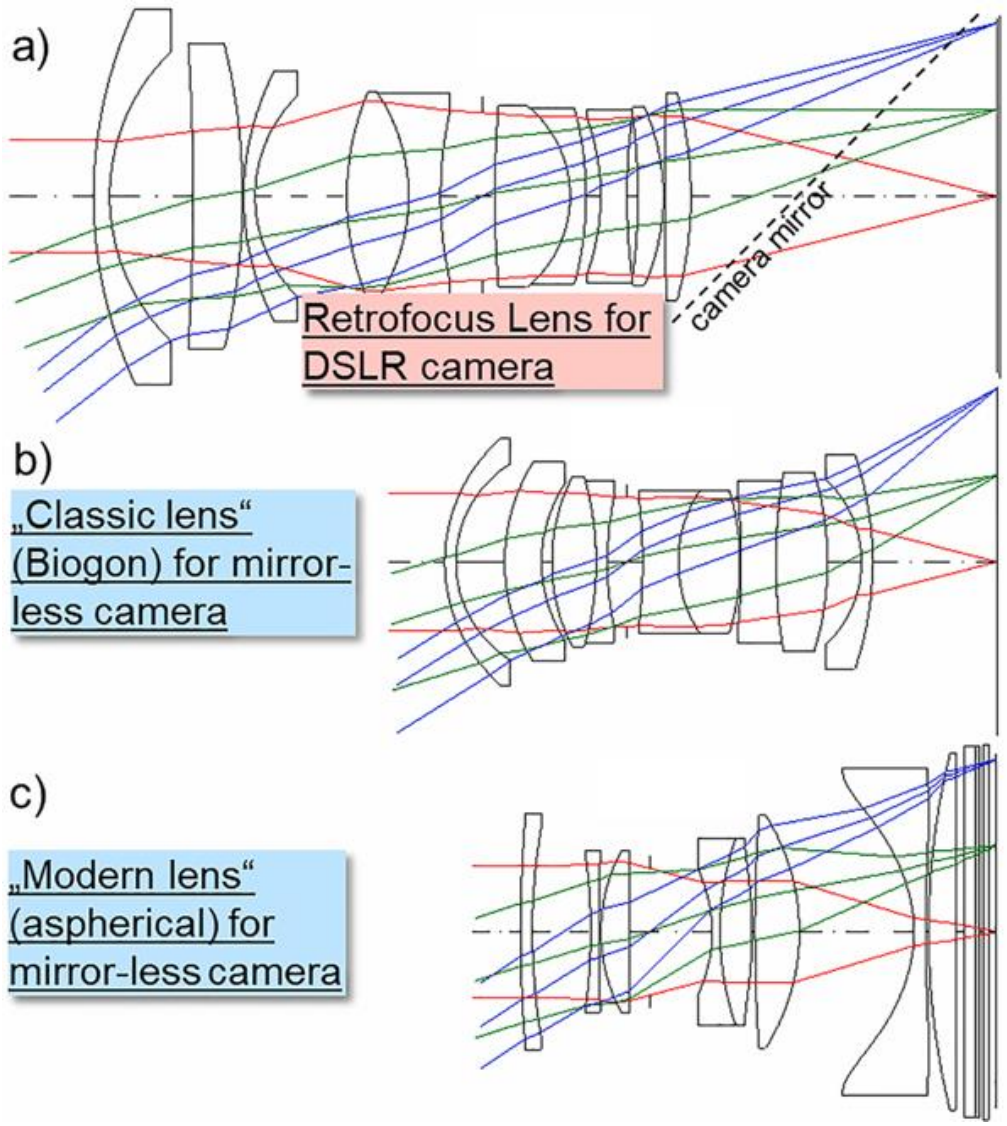
- Achromatic doublet
  - Littrow doublet : $R_1 = R_2$, $R_3 = -R_2$
  - Fraunhofer doublet: small air between R_2, R_3
    - more degree of freedom in design



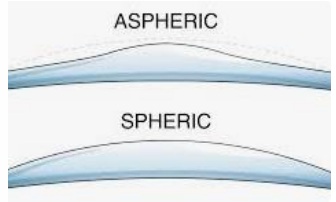




Multi-Lens



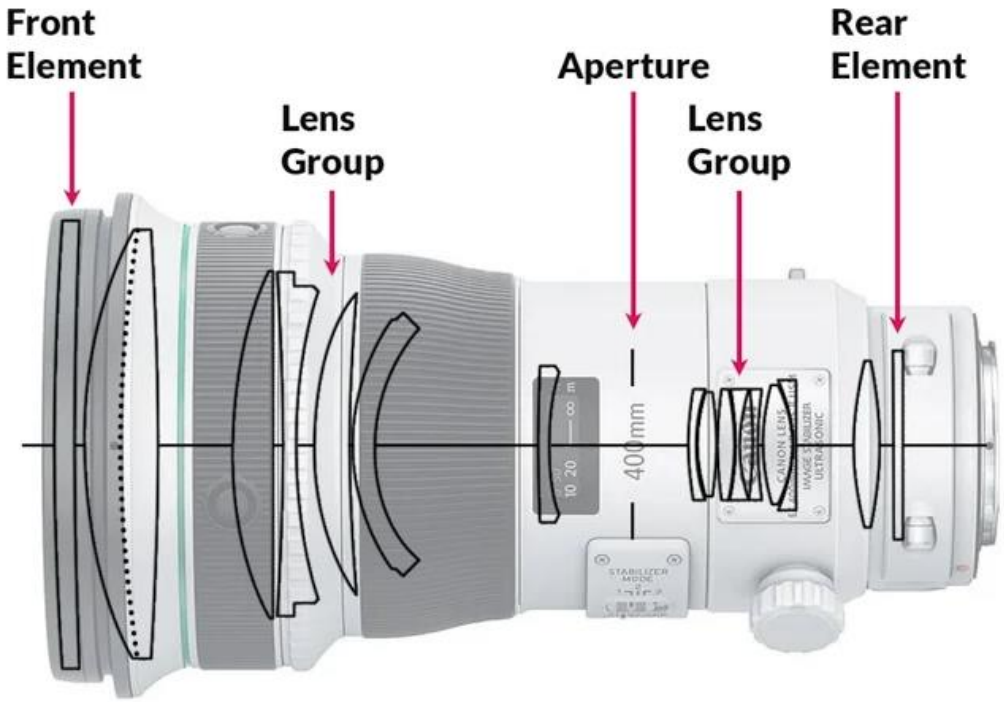
DSLR (digital single line reflex)

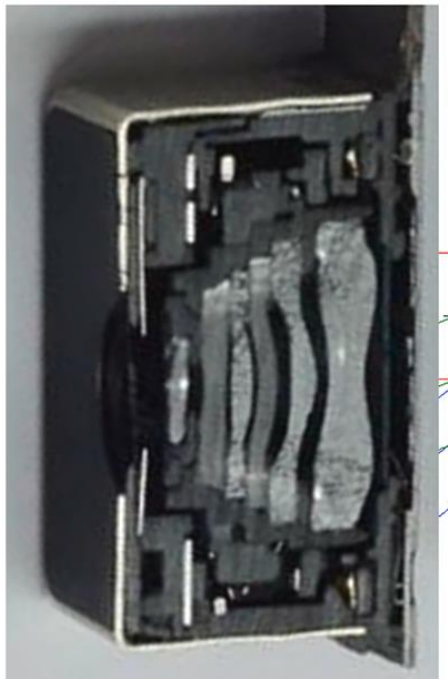


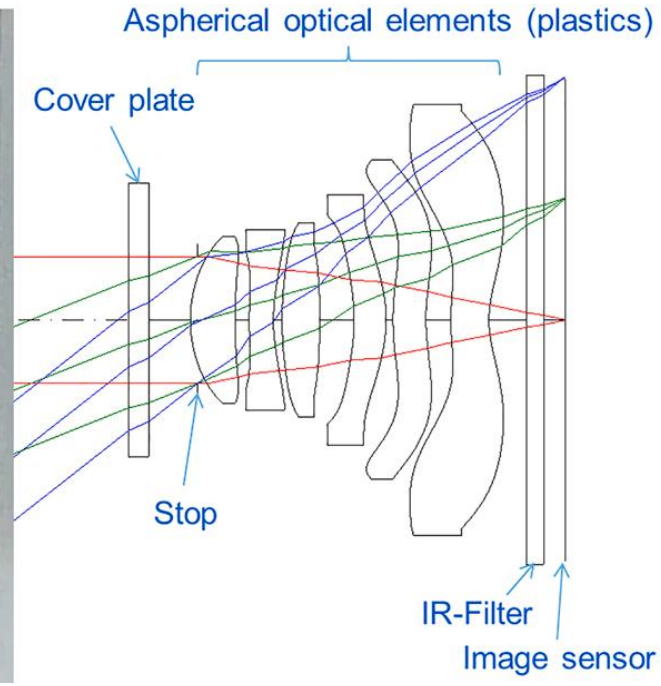
mirror-less system camera

Cameras

- Eagle Vs Hummingbird







High precision lens

- Scientific and precision imaging




Image sensing

- Array sensor
  - 1D, 2D

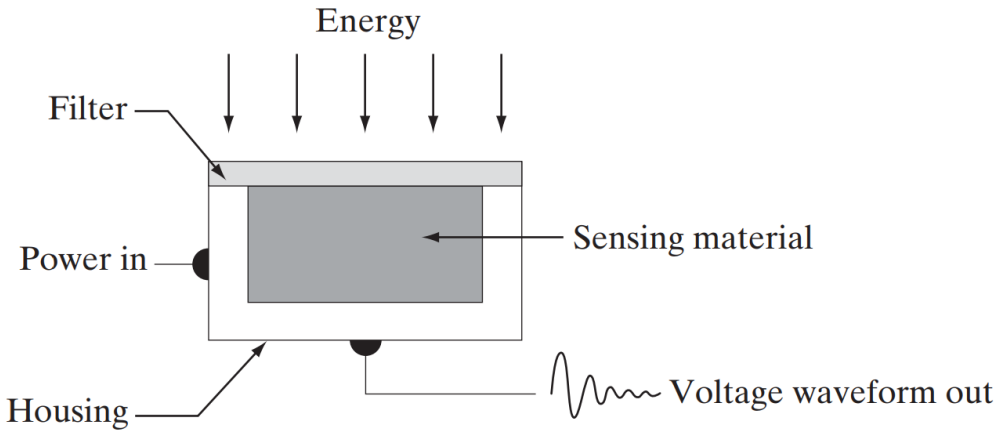
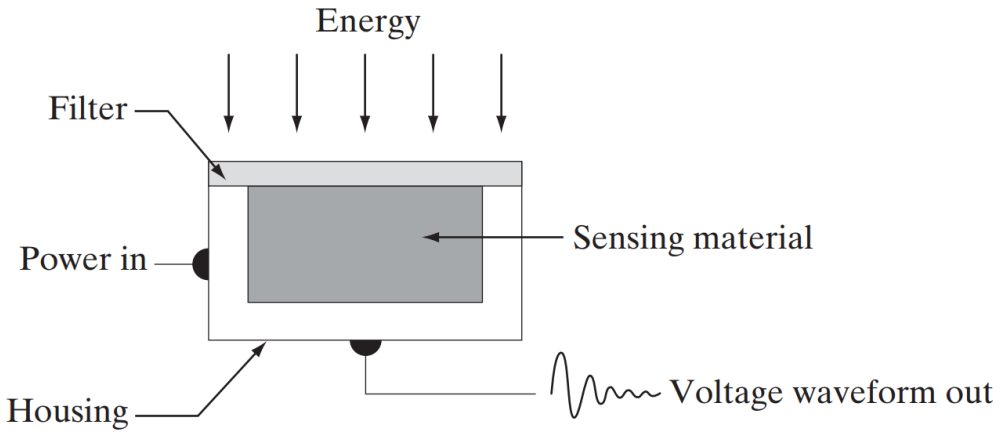


Image sensing

- Array sensor
  - 1D, 2D



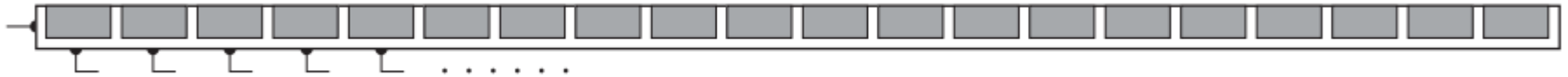
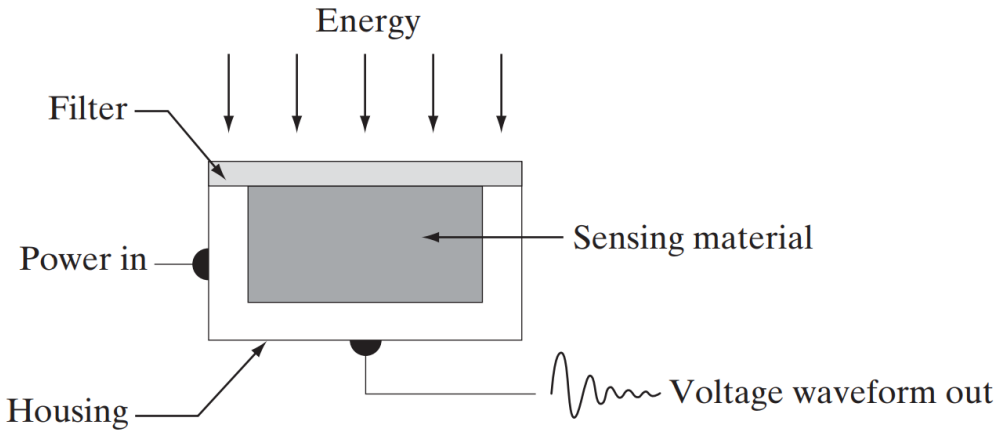


Image sensing

- Array sensor
  - 1D, 2D



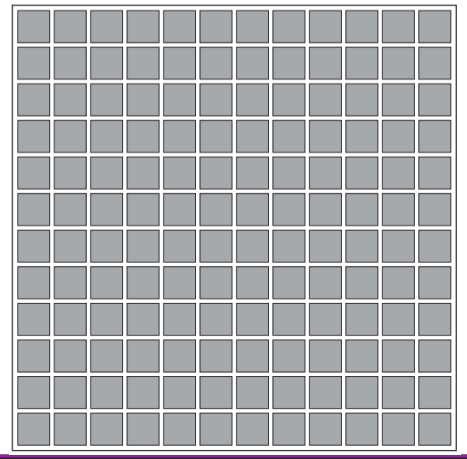
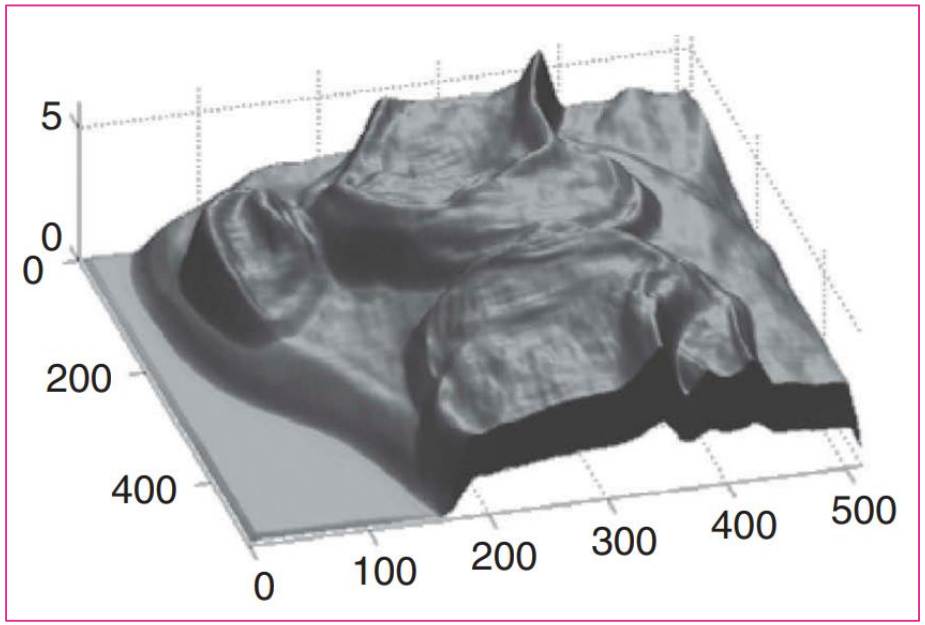
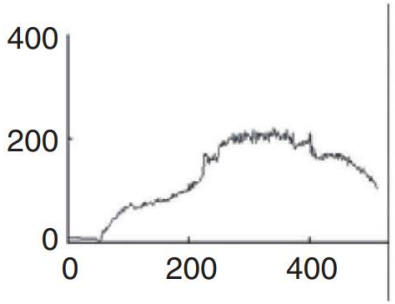


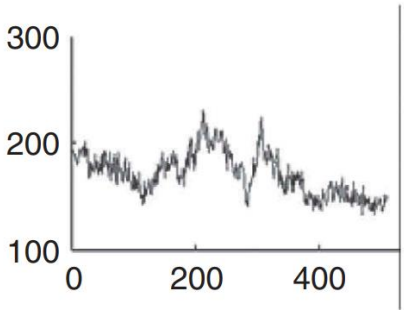
Image representations



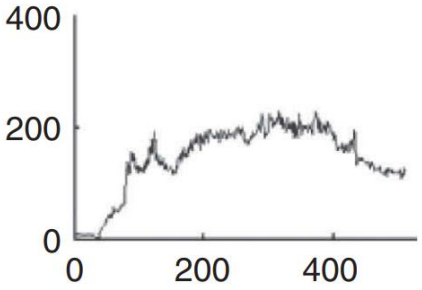
(a)



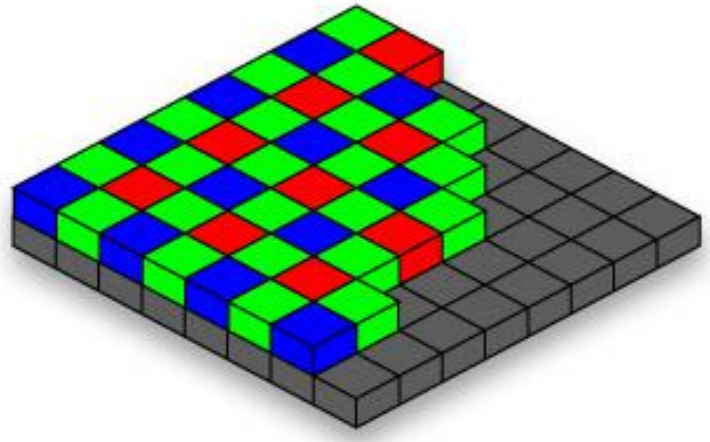
(b)



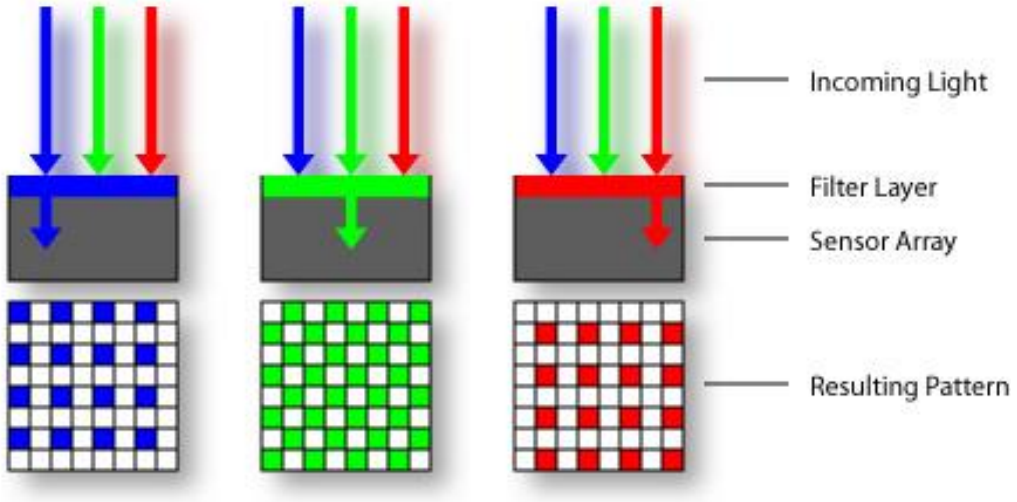
(c)



Color sensing

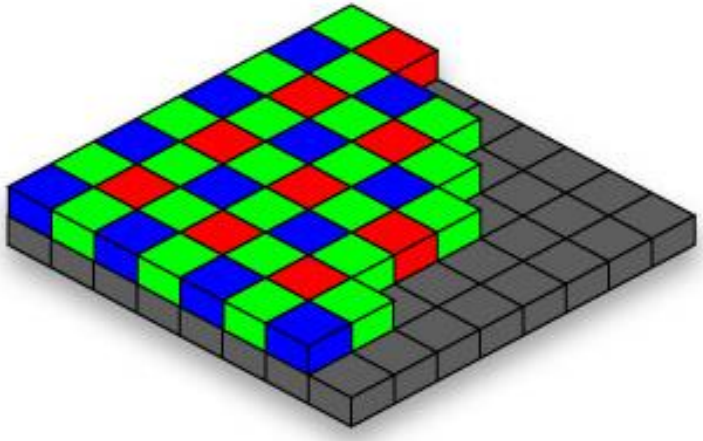


Bayer pattern



Color sensing

Estimate the color



Bayer pattern

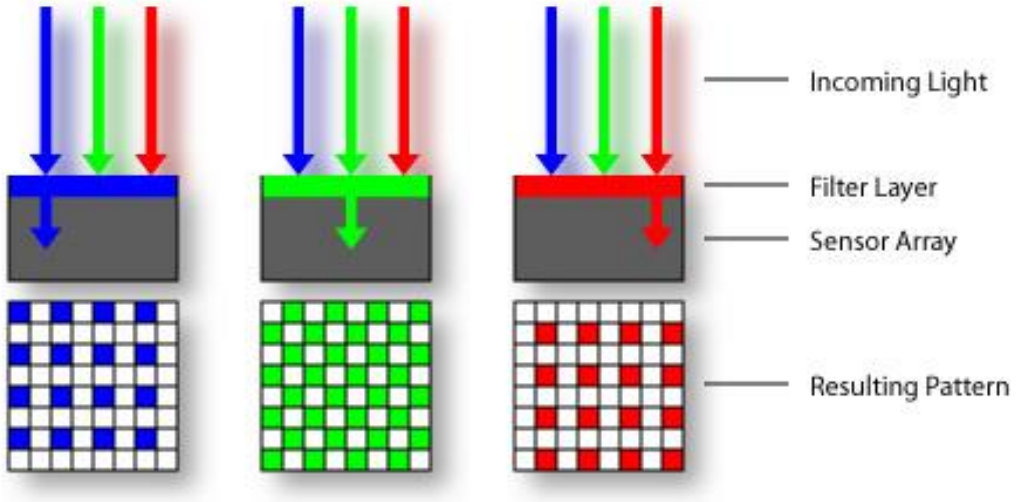
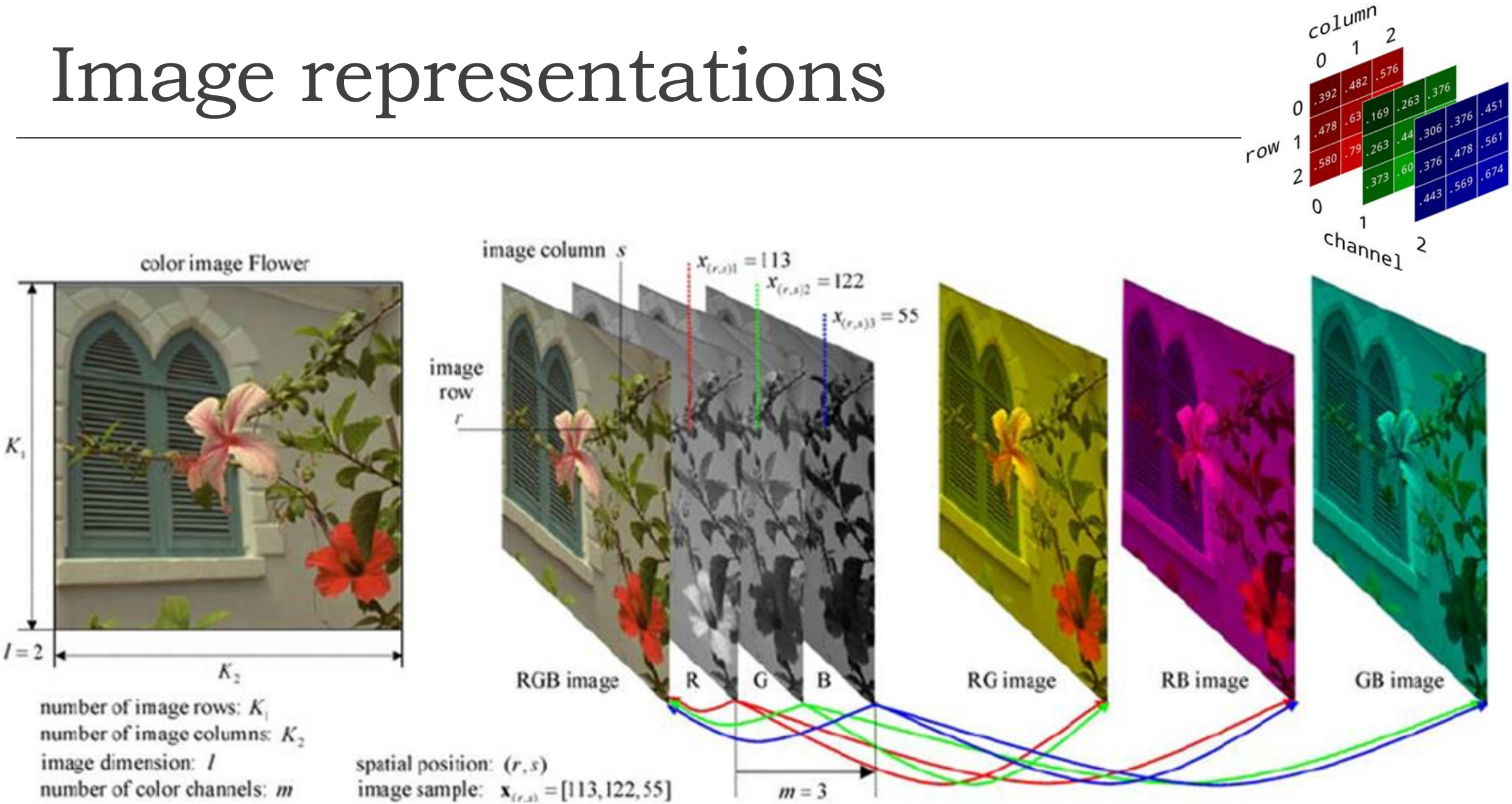


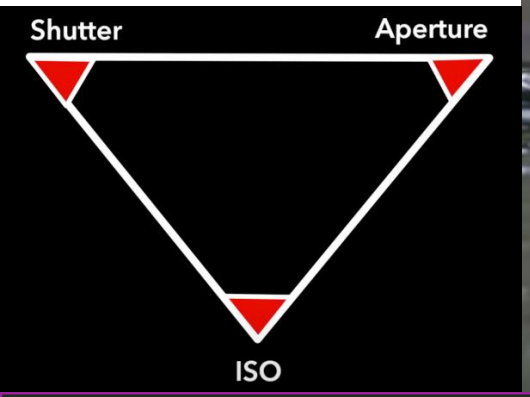
Image representations



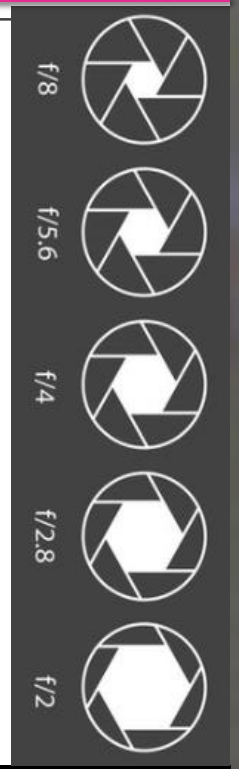
credit: K. Plataniotis

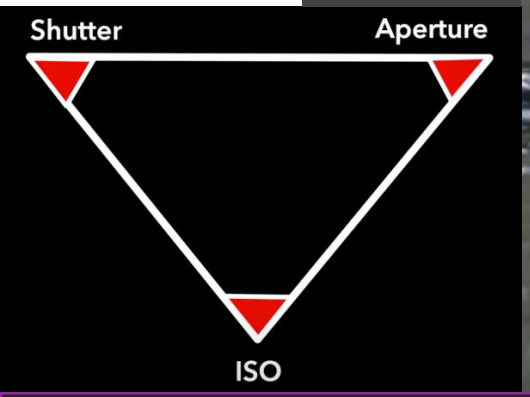
The Exposure Triangle

The Exposure Triangle

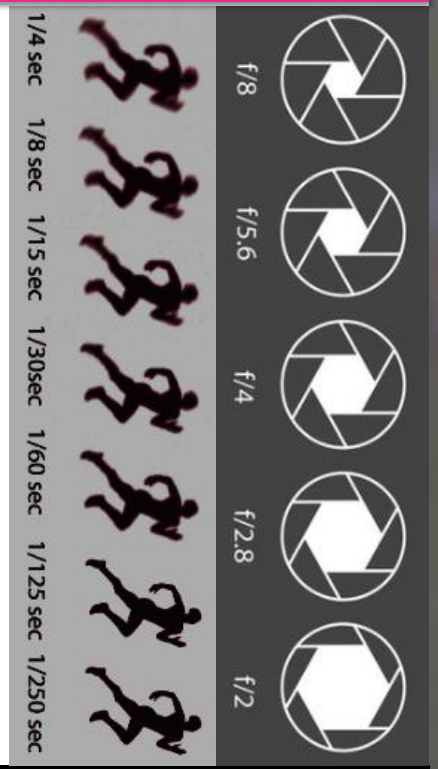


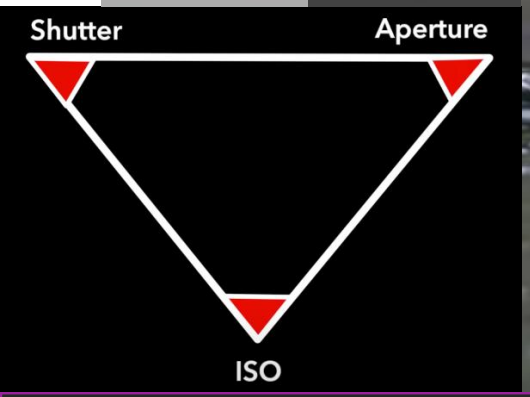
The Exposure Triangle



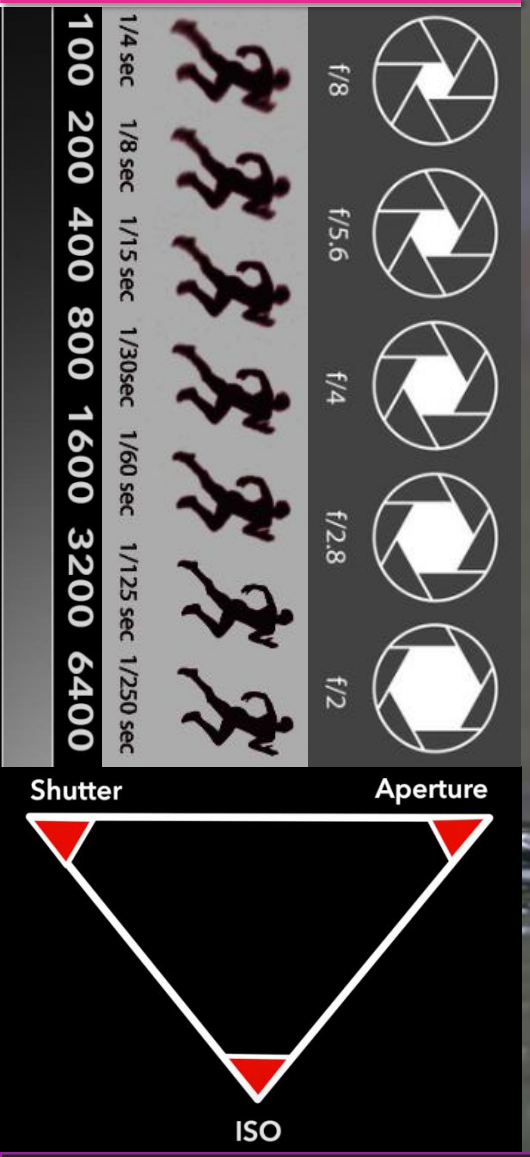


The Exposure Triangle





The Exposure Triangle



Conclusion

- Camera systems
- Image representation

Conclusion

- Camera systems
- Image representation

❑ Camera systems
- Aperture
- Lens
- Shutter
- Light sensors

❑ Digital image representation
- Grey
- Color
- Matrix (tensor)