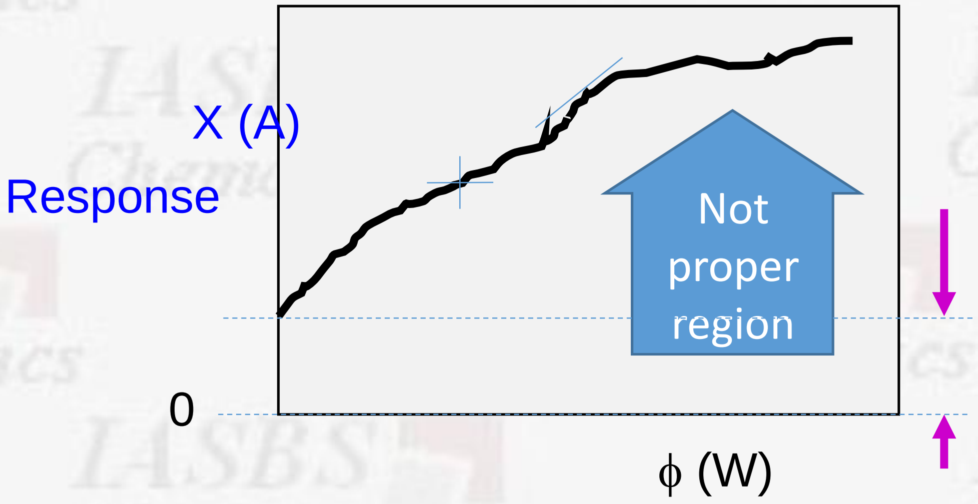
4-4 Optical Transducers

Transducers characteristics

Responsivity: $R(\lambda) = X_{rms}$ (A) / ϕ_{rms} (w)

(at particular λ, ϕ, temperature and voltage)

Sensitivity: $Q(\lambda) = dX/d\phi$



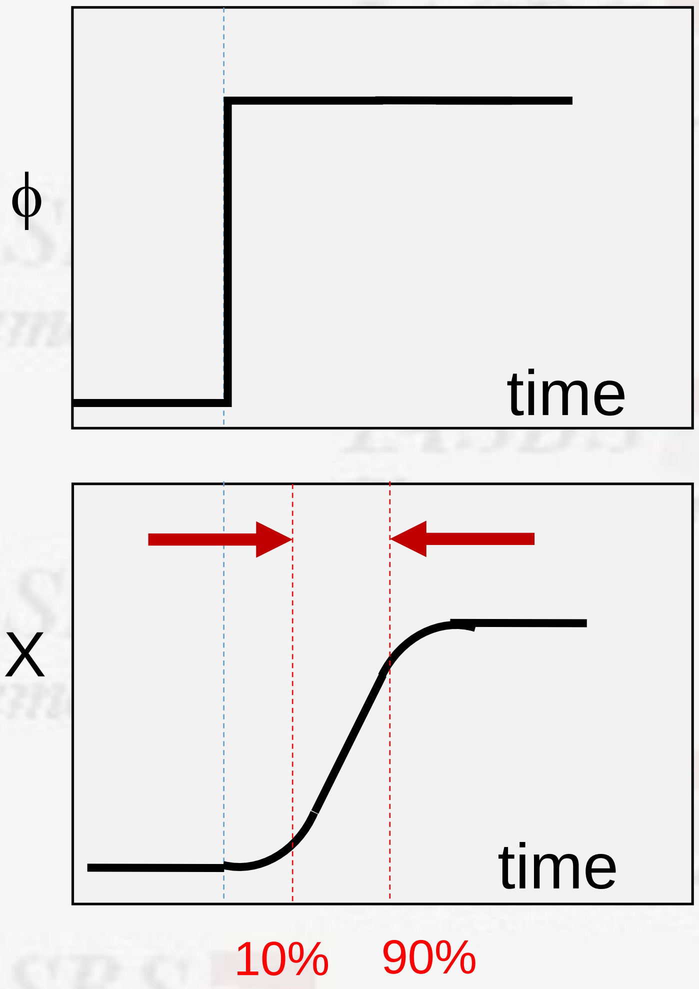
Degradation: long term change in Q.

Hysteresis: change in Q after a pulse of ϕ

Dark signal: $i_{dark} \pm \sigma_{dark}$

Output signal in absence of radiation.
(Thermal, ...)

Response Speed



Rise time

$\tau = 1/\ 2\pi\ f$

f: max response frequency

Output domain

Analog: Intansity vs time
vs frequency

Digital: No of pulses vs time

Noise equivalent power

Sinusoidal input radiation (ϕ_{NEP}) with

σ_{NEP} or ϕ_{NEP} (W) $\propto \sigma_{dark}$ (A)

ϕ_{NEP} (W) $= \sigma_{dark}$ (A) $/ R(\lambda)$

Example:

- for PMT ϕ_{NEP}= 1e-5 W
- for PT ϕ_{NEP}= 1e-1 W

Detectivity:

$D = 1/ \phi_{NEP}$

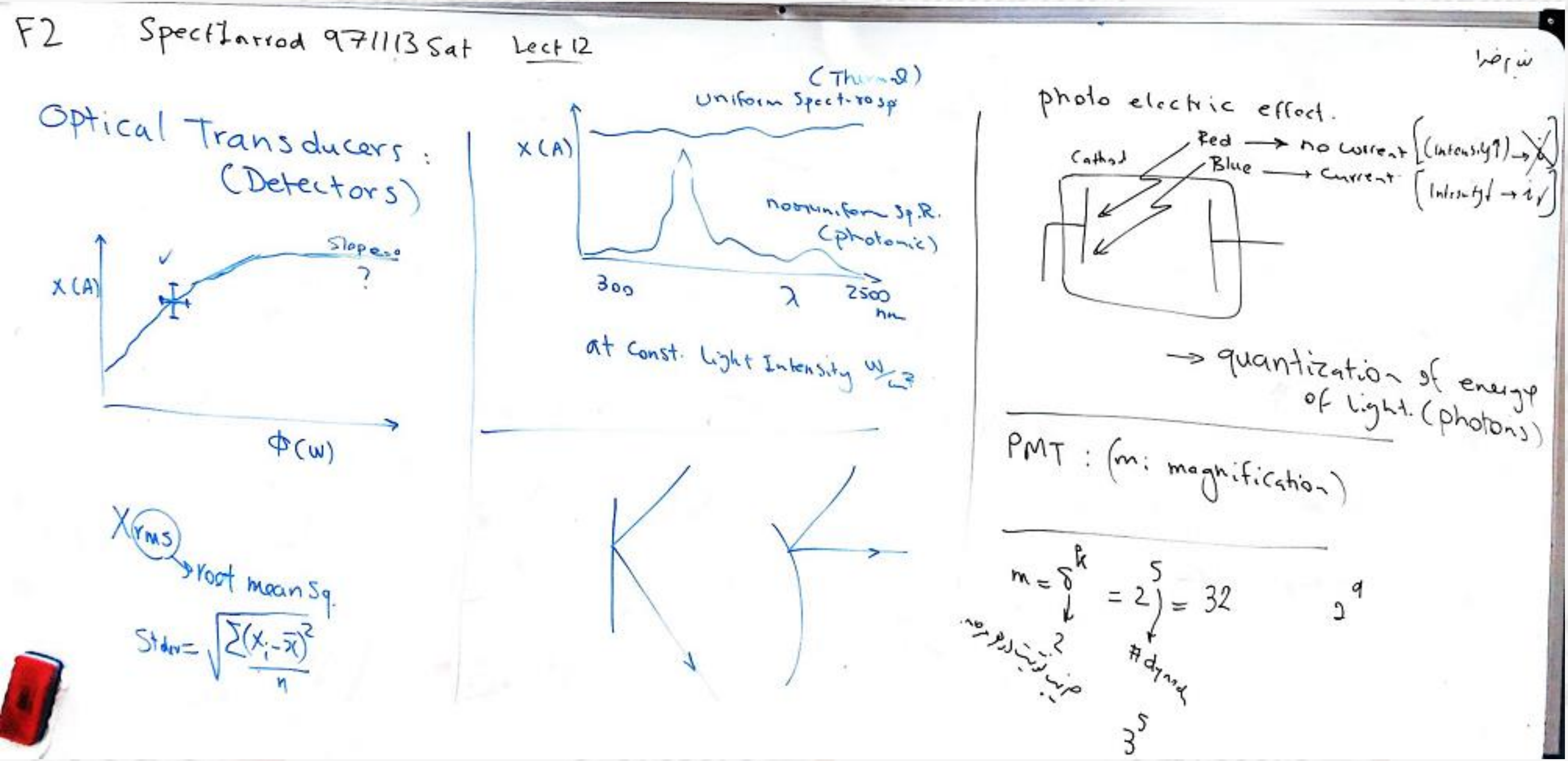
(similar to LOD)

Normalized Detectivity:

$D^* = D\,(A\,\Delta f)^{1/2}$

A: detector area (cm^2)

Δf : noise equivalent bandwidth (Hz)


F2 Spect Iarrod 971113 Sat Lect 12
Optical Transducers: (Detectors)
X(A)
Slope=0
?
Φ(W)
X(rms) → root mean Sq.
Stdev = √(Σ(Xi − x̄)²/n)
(Thermal)
Uniform Spect. resp
X(A)
nonuniform Sp.R. (photonic)
300
λ
2500 nm
at Const. Light Intensity W/cm²
photo electric effect.
Cathod
Red → no current
Blue → current
→ quantization of energy of light. (photons)
PMT: (m: magnification)
m = δ^k = 2^5 = 32
#dynod
3^5

Transducers (Detectors)

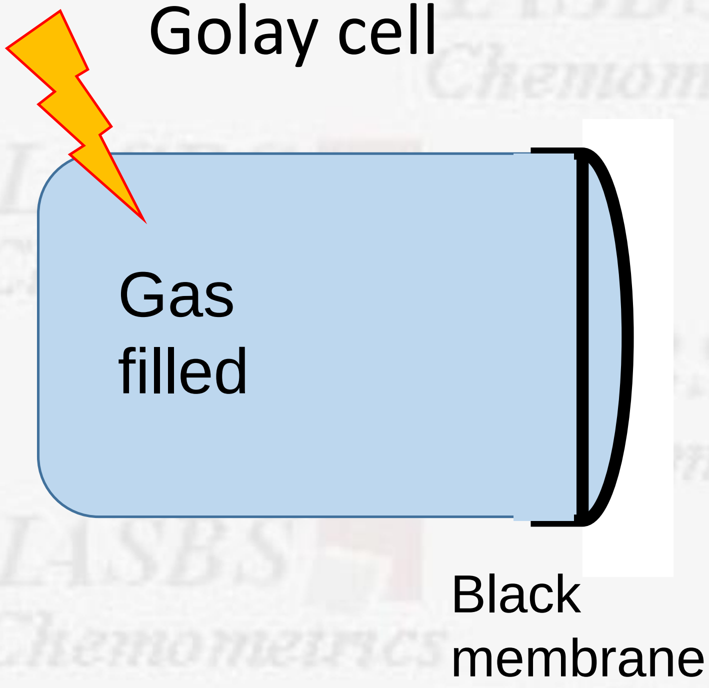
- Thermal : -Uniform spectral response
  (proportional to total energy, and not to photon energy),
  -Low response speed
  -Low sensitivity.

- Photonic: - Non uniform spectral response (f(λ))
  - High response speed,
  - High sensitivity

Thermal detectors

Pneumatic

Golay cell

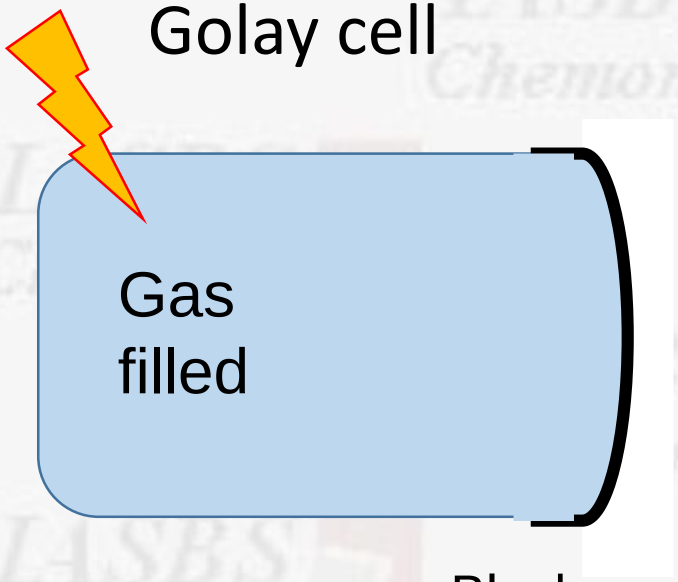


- High spectral range (1000µm)
- high D*

Thermal detectors

Pneumatic

Golay cell



Black
membrane

- High spectral range (1000μm)
- high D*

Thermocouple

Contacting Al foil to filled tooth with metallic amalgam, you feel the voltage

Black sheet light absorber → change in V(T) at metal junction (μV)

- Response to : 0.8 to 40 μm
- Response time: high (Response speed: low)

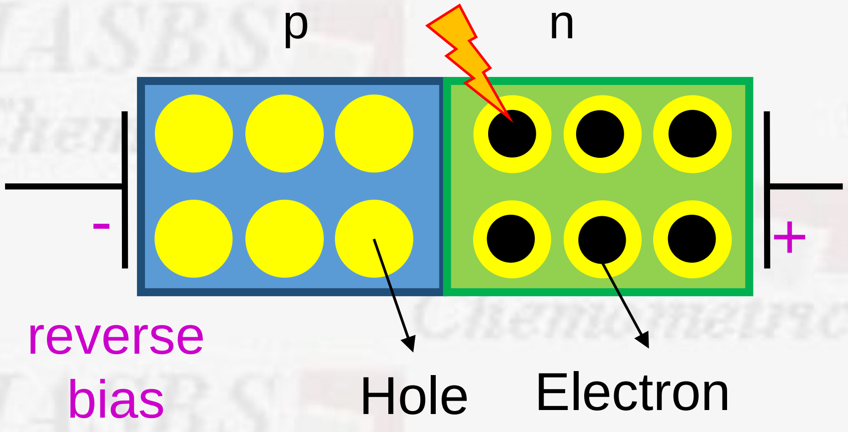
- Uniform spectral response (advantage).
- No bias voltage.

Thermal detectors

Thermistor

(Bolometer)

Diode + voltage difference



Reverse bias: low conductivity

+light → Temp ↑ →
e s to holes → Conductivity

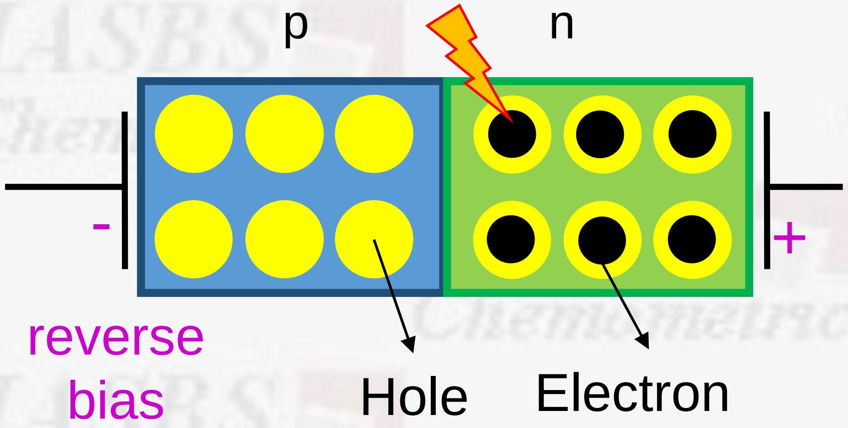
1e-6 to 1e-1 W/cm^2
0.8 to 40.0 μm, Resp time ↑

Thermal detectors

Thermistor

(Bolometer)

Diode + voltage difference

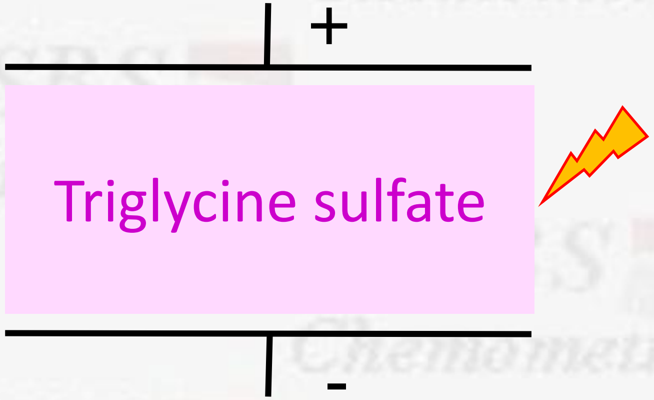


Reverse bias: low conductivity

+light → Temp ↑ →
e s to holes → Conductivity

1e-6 to 1e-1 W/cm^2
0.8 to 40.0 μm, Resp time ↑

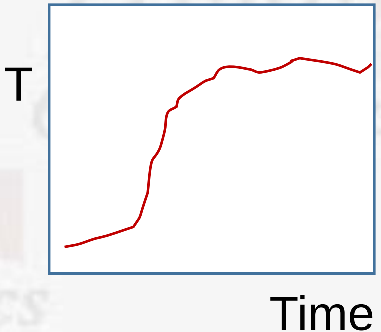
Pyroelectric



Pulse of light → dT/dt → dE (pot difference)

R(λ) = 1e4 V/W !!
linear range: 1e-16 to 1e-1 W/cm2 !!

- 0.3 to 1000 μm



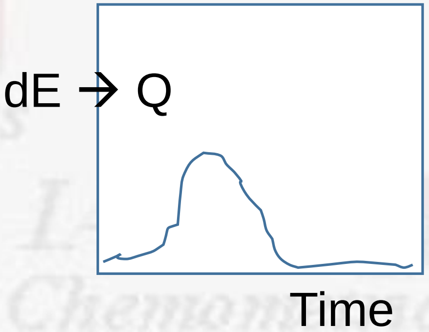


TABLE 4-5

Thermal detector characteristics

Type	D^* (cm $Hz^{1/2}$ W^{-1})	$R(\lambda)$[a]	Linear range[b]	Spectral range (μm)	Time constant (ms)	Output
Pneumatic	2×10^9	Not applicable	10^{-8}–10^{-6} W (1%)	0.8–1000	2–30	Displacement or capacitance
Thermocouple	10^9	5–25 V W^{-1}	6×10^{-10}–6×10^{-8} W (0.1%)	0.8–40	10–20	Voltage
Thermistor bolometer	$1.1 \times 10^9 \sqrt{\tau}$	~10^3 V W^{-1}	10^{-6}–10^{-1} W cm^{-2} (5%)	0.8–40	1–20	Resistance change
Pyroelectric	3×10^8	10–10^4 V W^{-1}	10^{-6}–10^{-1} W cm^{-2} (5%)	0.3–1000	See footnote c	Current

[a]Voltage responsivity for thermistor assumes constant current of 10 mA; voltage responsivity for pyroelectric detector assumes load resistance of 10 MΩ (10 V W^{-1}) to 10^4 MΩ (10^4 V W^{-1}).

[b]Percentages refer to maximum deviations from linearity in the range shown.

[c]Electrical τ depends on load resistance; thermal τ determines low-frequency response.

Photon detectors

Vacuum phototube

-Evacuated glass

-Photocathode: Cs_3Sb

if incident $\lambda < \lambda_{threshold}$

→ e escapes from cathode

$\lambda_{threshold} = hc/E_{work\ function}$

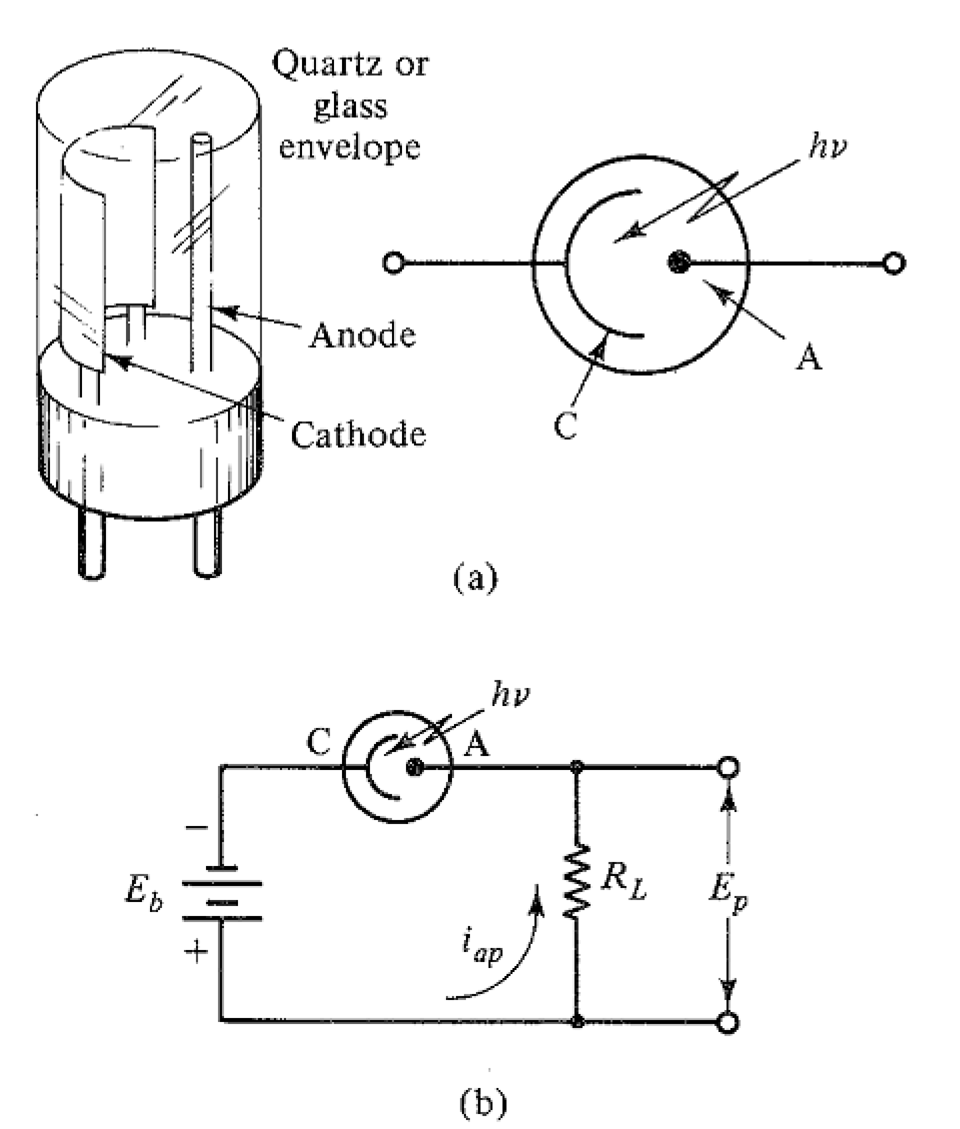


Photo Multiplier Tube

- Gain $m=10^7$ e in eah anode pulse

  (10^{-12} coulomb in 5 nsec)

  or 320 mA

I. Average anodic photo current:

$i_{ap} = m\ \eta\ i_{cp} = m\ \eta \int \phi_\lambda\ R(\lambda)\ d\lambda$

(W) (A/W)

η: collection fraction

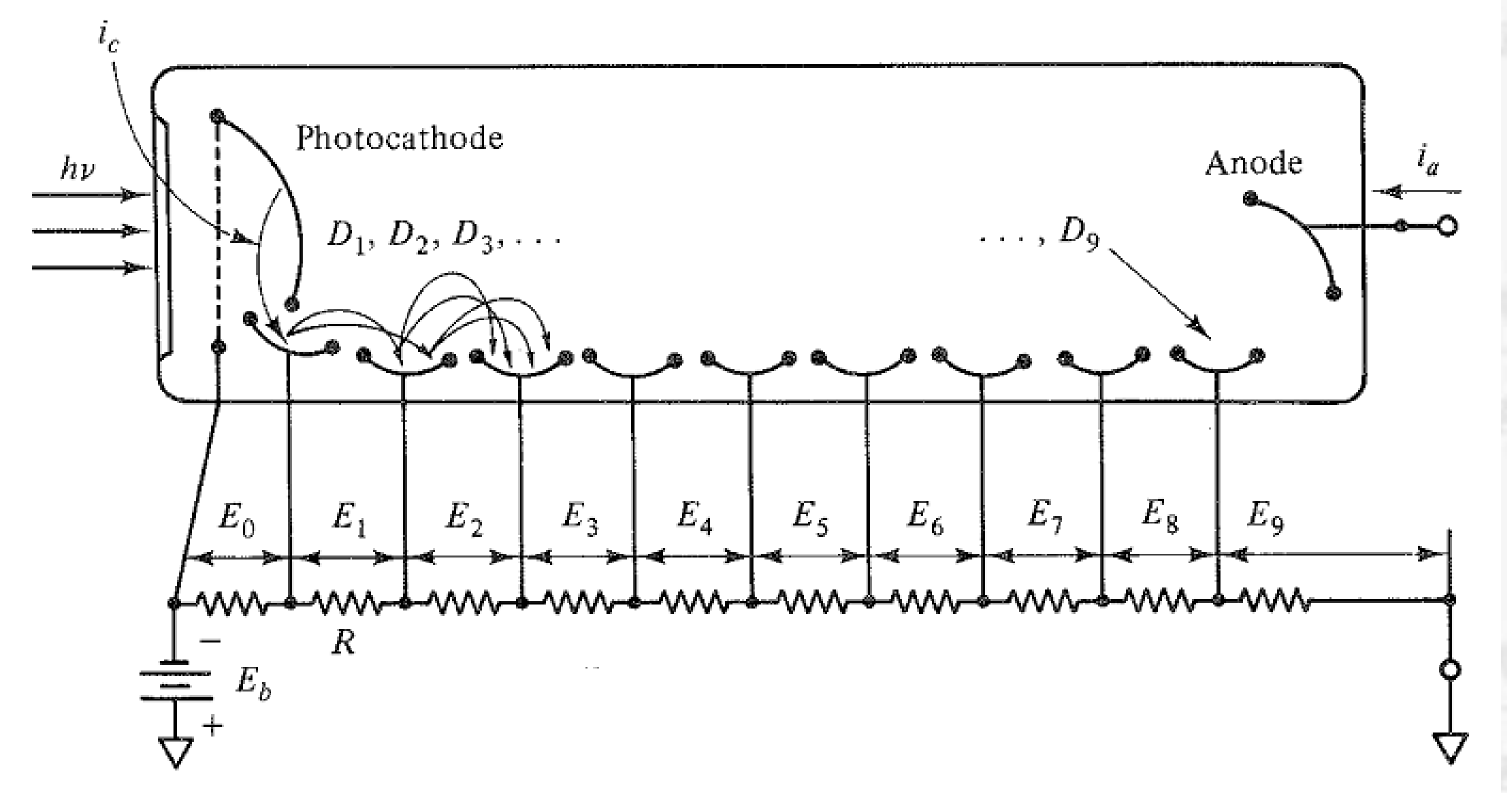
$R(\lambda) \propto \lambda$

II. photon counting (# pulses/sec)

$r_{ap} = \eta\ r_{cp} = \eta \int \phi_\lambda\ K(\lambda)\ d\lambda$

(e/photon)

r_{ap}: anodic photon pulse rate



$m = \delta^k$

δ: Stage gain

k: # dynodes (5 to 11)

m vs Eb :
log-log is linear

Fatigue:
light intensity↑→ sensitivity loss

Hysteresis: intense intensity change → unpredicted response

Photon detectors

Photo Multiplier Tube

Cathodic responsivity curves

Dark current: ~ 1e-7 A

1. Thermal (removed by cooling)
2. Radiation: (remove by shielding)
3. Eb(opt) (changed by m)

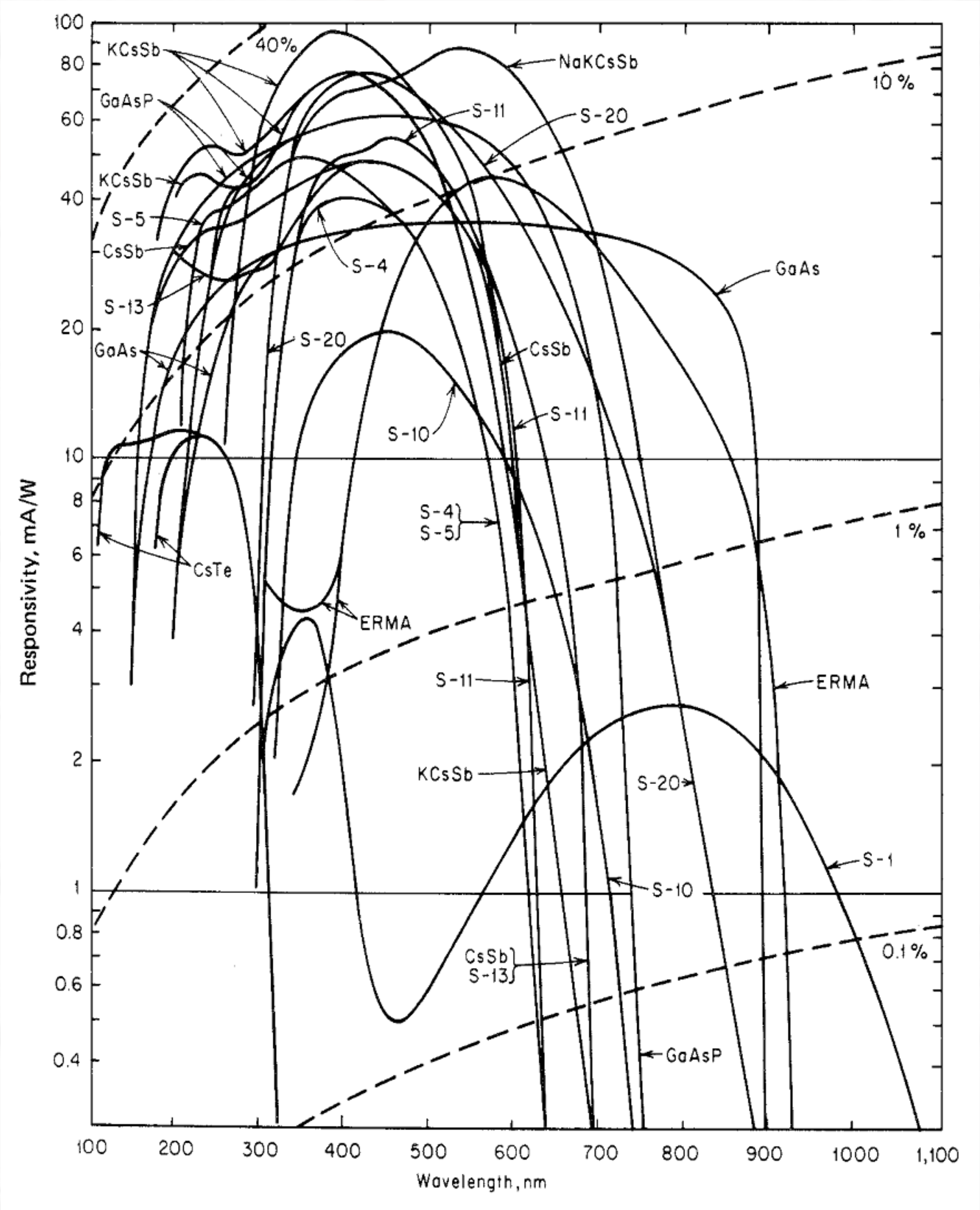
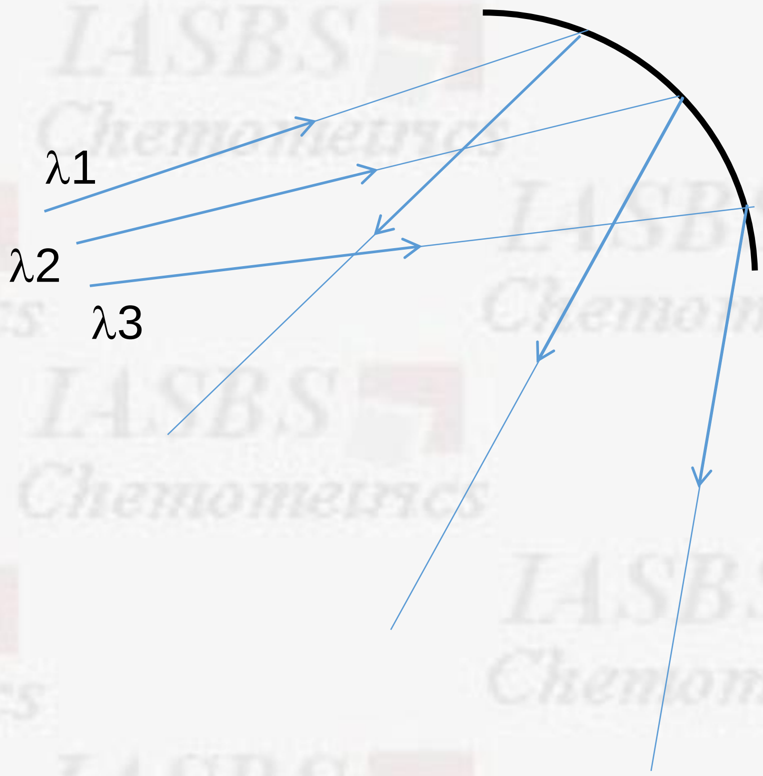


Image dissector tube (IDT)

Different incident angles of different wavelengths from a grating

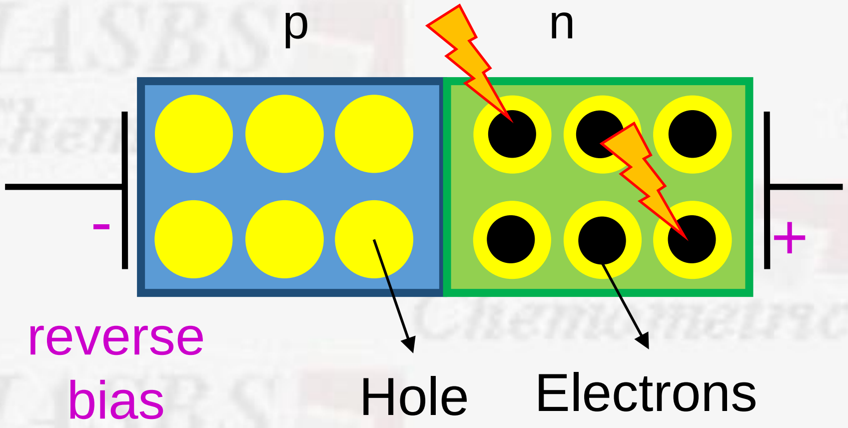
results in

different angles for emitting electrons

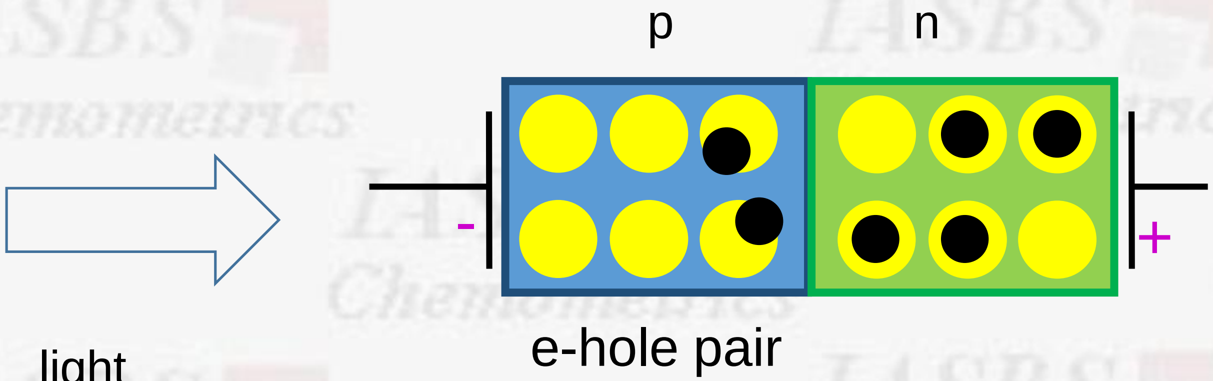


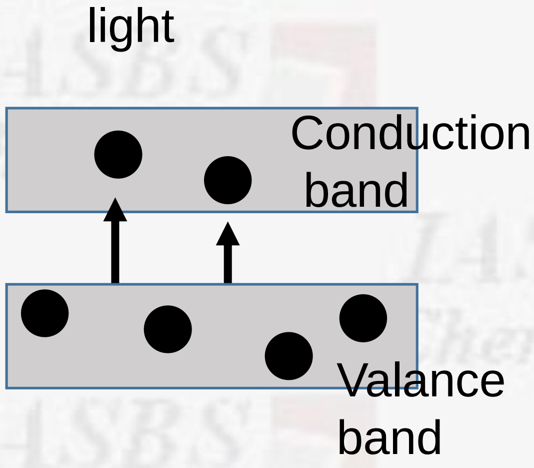
Photodiodes

Diode + voltage difference



All in
valance
band

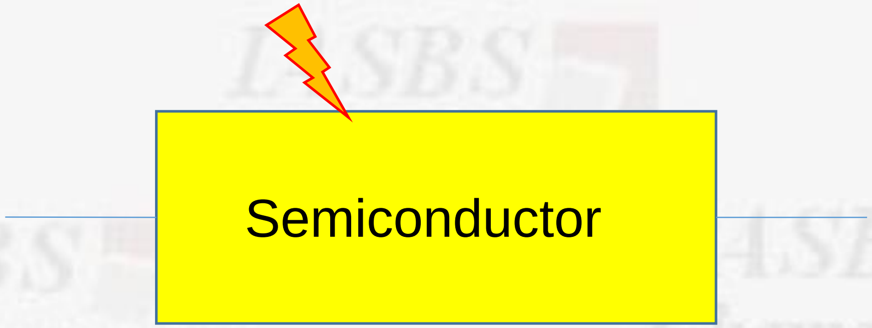




Conductivity

sensitivity <PMT

Photoconductive cells



No PN junction

light → e- hole pair → conductivity

lower Resistance

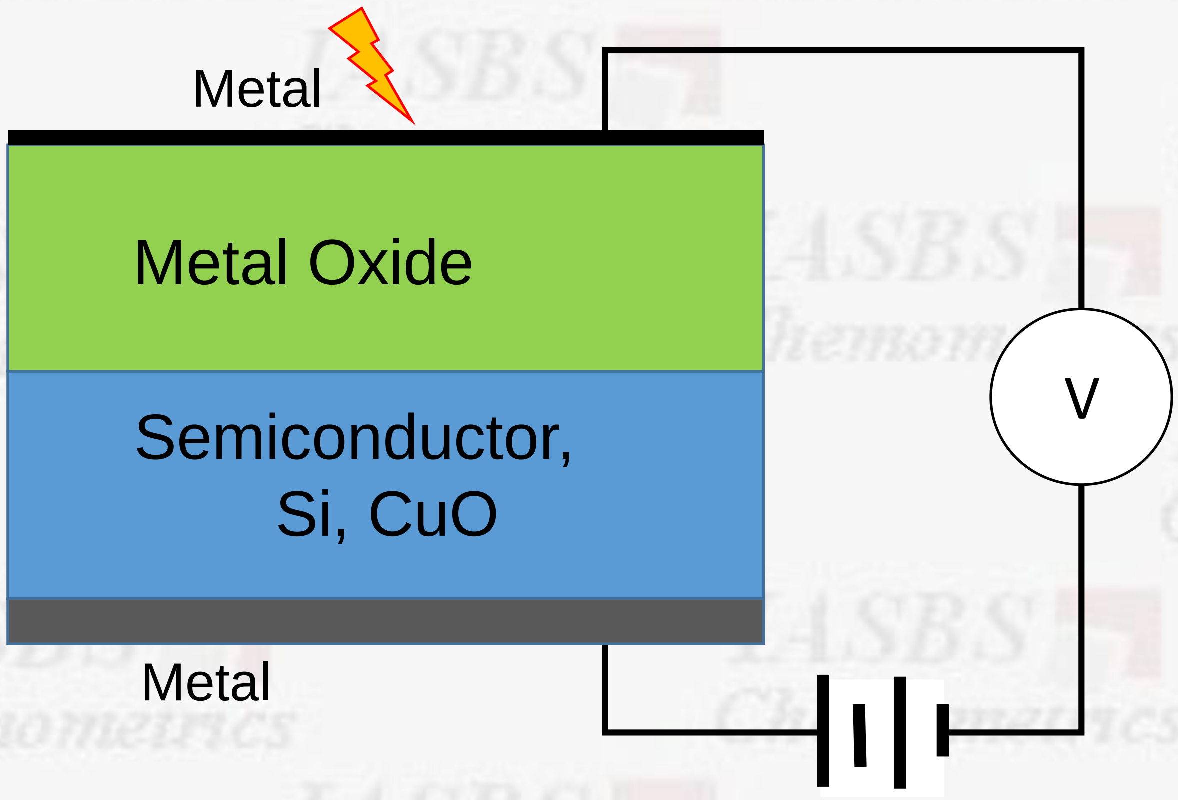
PbSe
PbS (NIR)

CdS: Photographic light meters

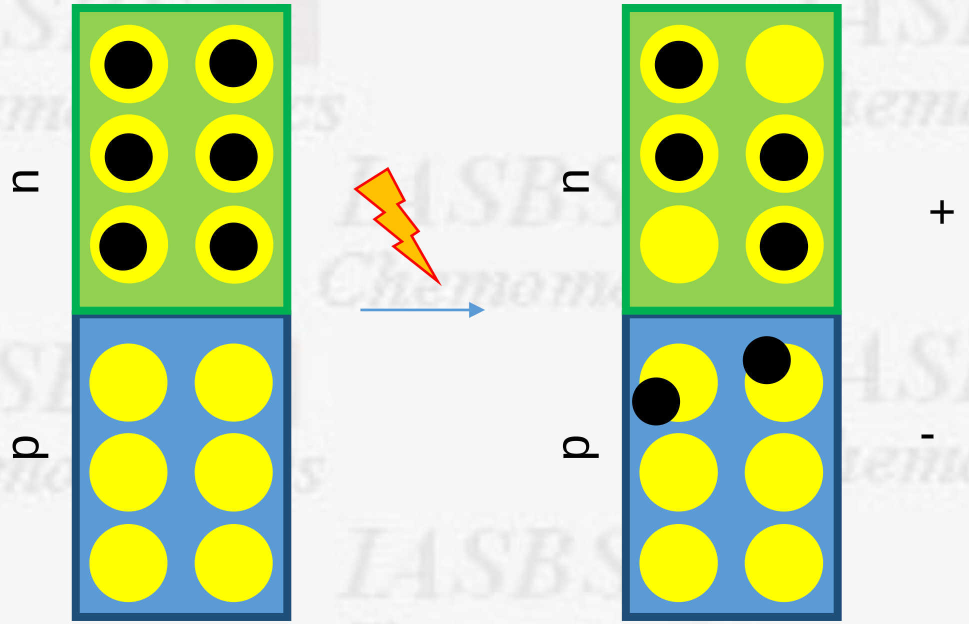
Spectral response: not flat

Photon detectors

Photovoltaic cells



Charge separation
→ Voltage



Se: for simple colorimeters
Si: for Solar cells

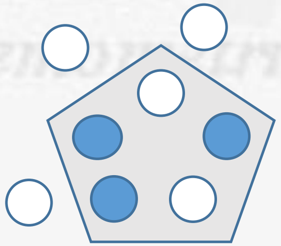
Multichannel detectors

- Photographic detectors
- Photodiode arrays
- charge coupled devices (CCD)

Photographic plate

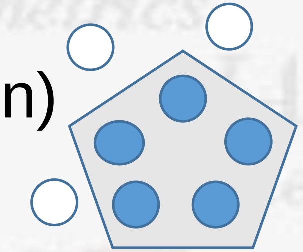
AgX crystals (in emultions)

↓ Photon



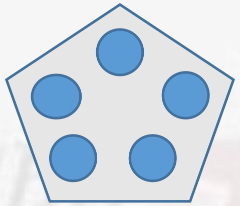
Ag clusters (Ag and Ag^+ in crystals)

↓ Development (internal amplification)



Exposed crystals (All Ag in crystals)

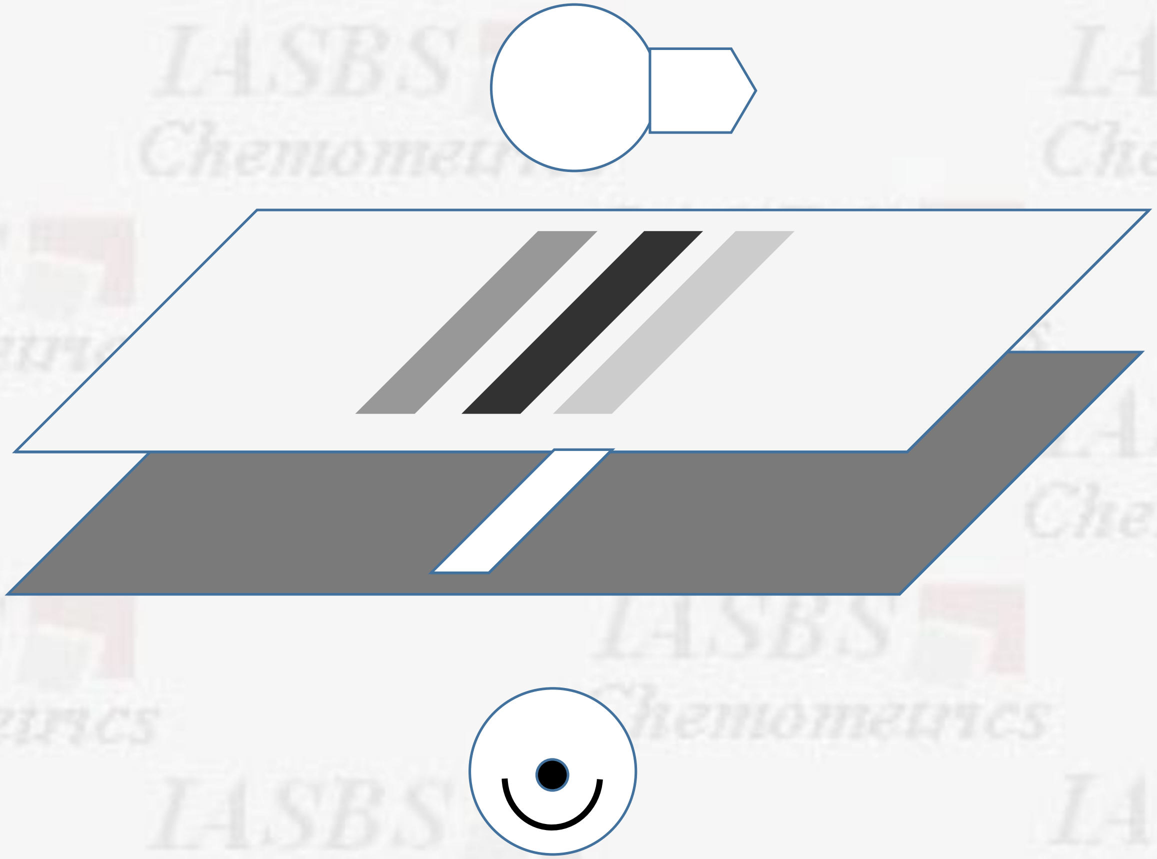
↓ Complexation of Ag^+



Ag+ are removed

↓ Into Densitometer

Densitometer



Developed film

1. time ↑
   (Camera is less time consuming)
2. linearity ↓

Advantages:

- Sensitivity (< 100 photons)
  - -light intensity
  - -Exposure time (integrity).