Experimental Techniques of Optics

Spring 2015 PHYC 476,477, 302L

University of New Mexico

http://www.optics.unm.edu/sbahae/Optics Lab/

OPTICAL SENSORS TUTORIAL

Mansoor Sheik-Bahae

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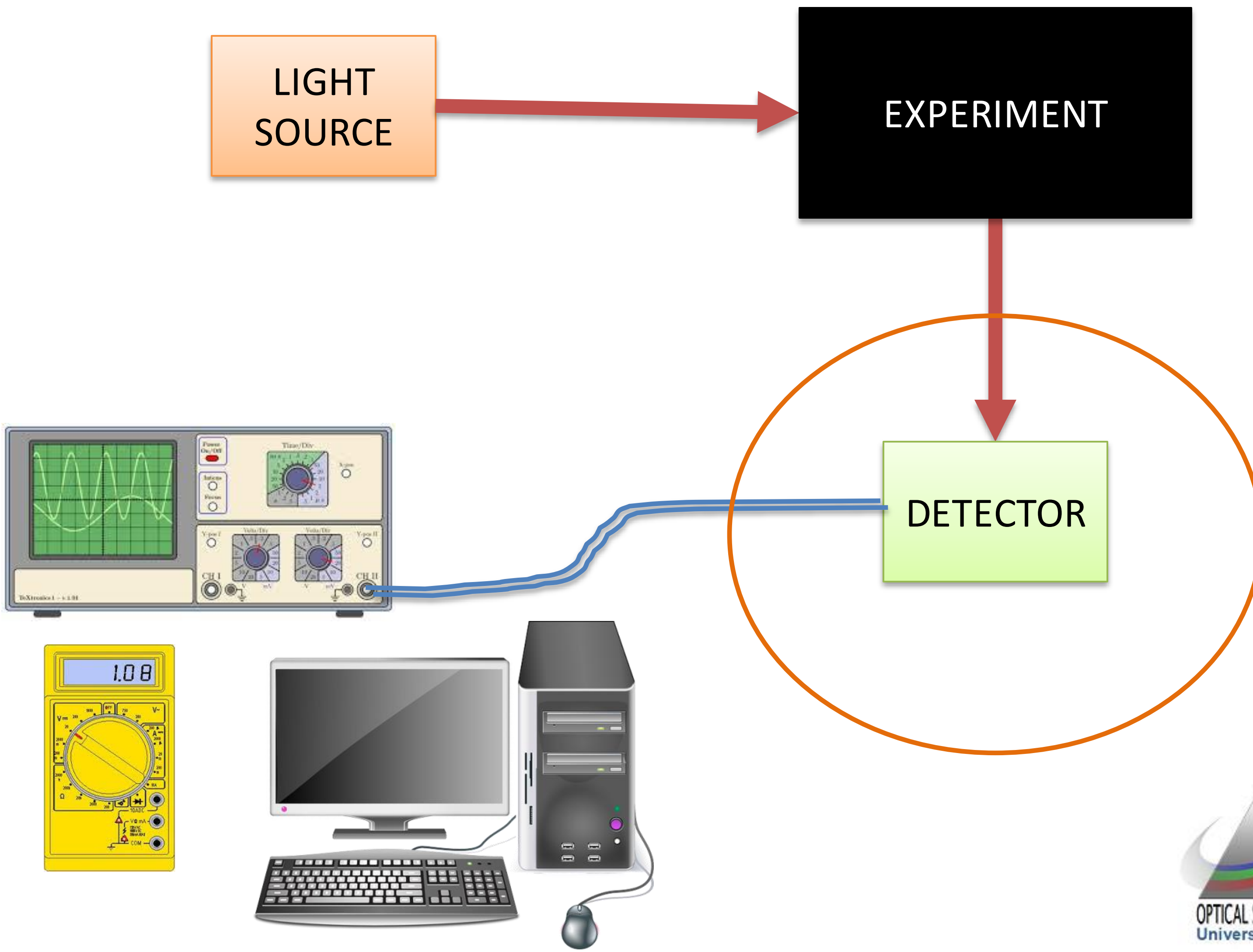
IN ANY OPTICS EXPERIMENT



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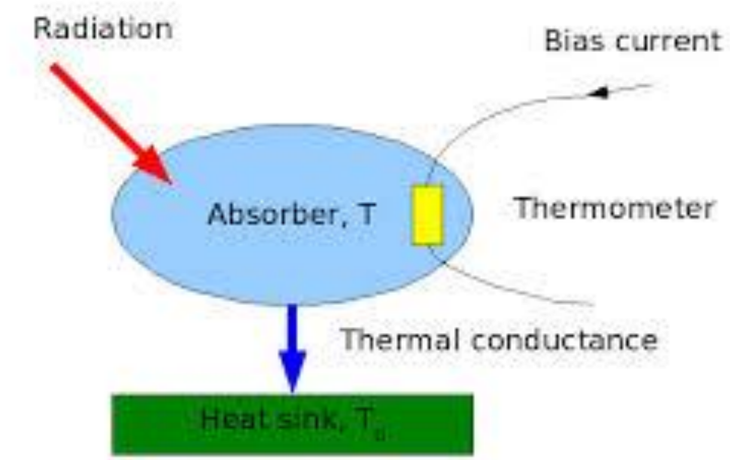
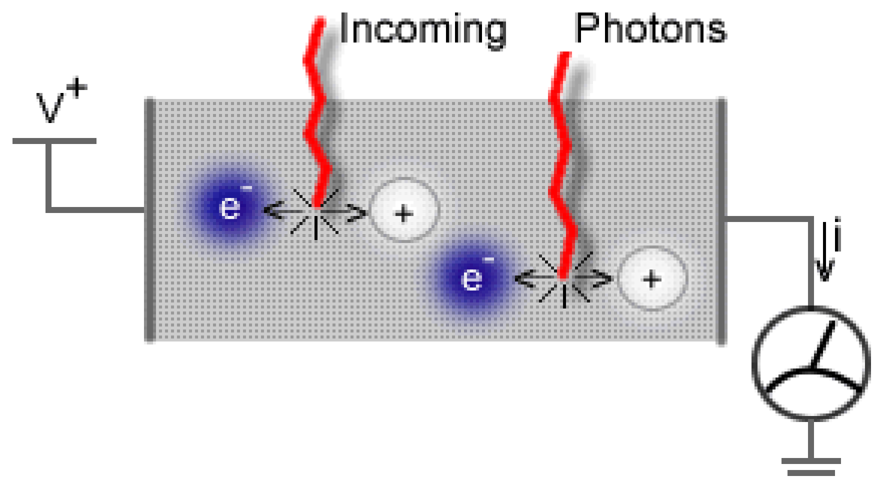
Detector Types (mostly)

- **Thermal**



- **Quantum**



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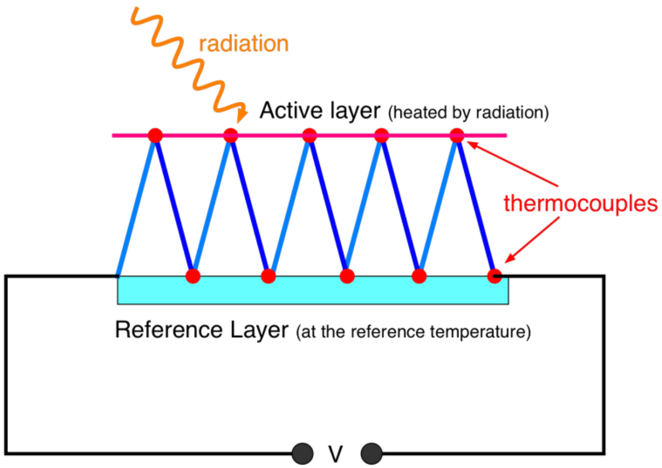
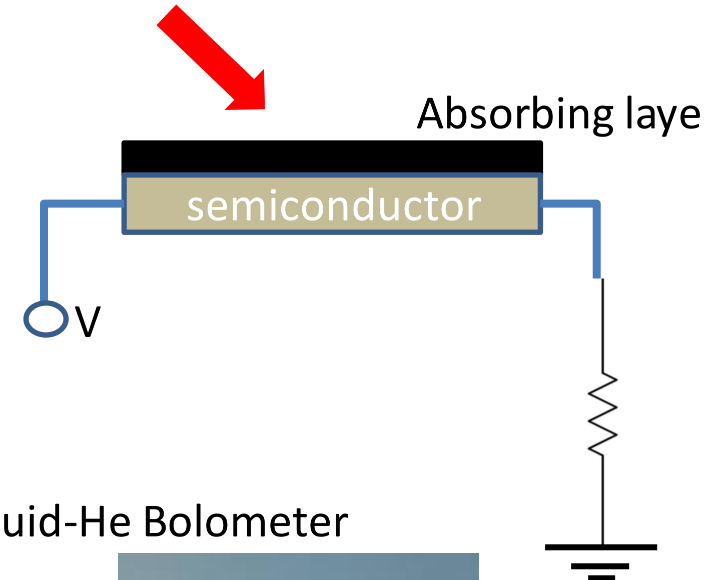
Thermal (Bolometric) Optical Detectors





Example: Power Meters

Liquid-He Bolometer

Response time: SLOW! 10-100 Hz

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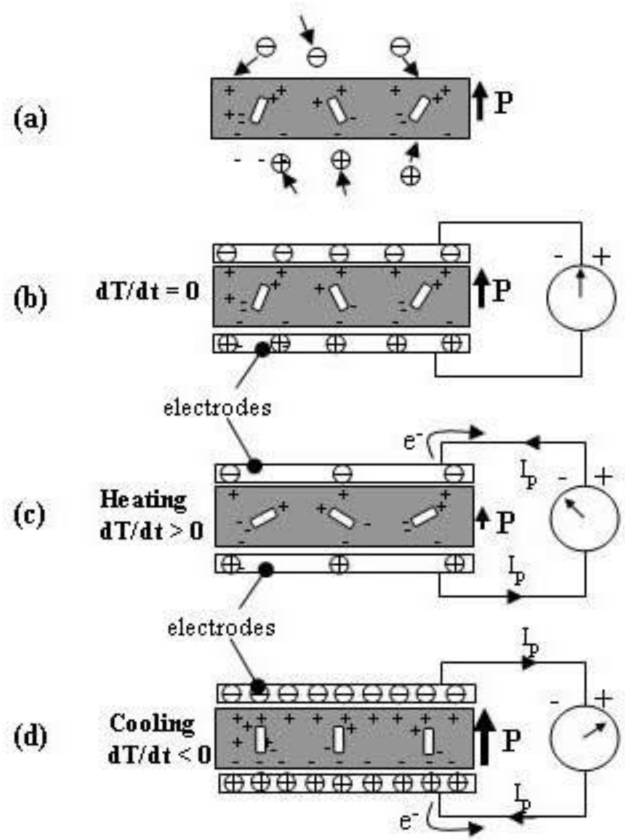
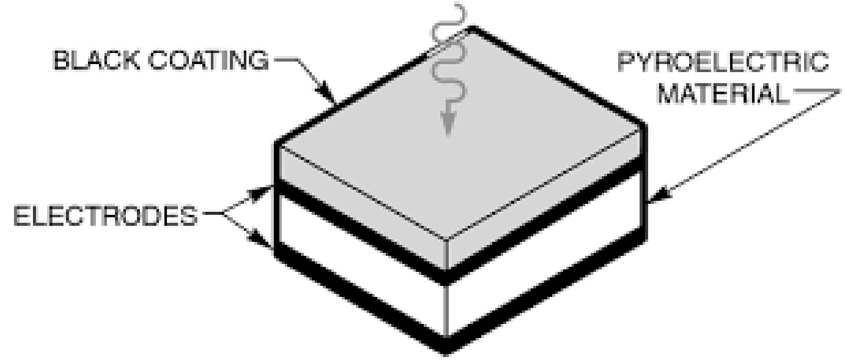
Thermal (Bolometric) Optical Detectors

Pyroelectric Effect





Only measures AC (pulses, etc.), Can have fast rise time

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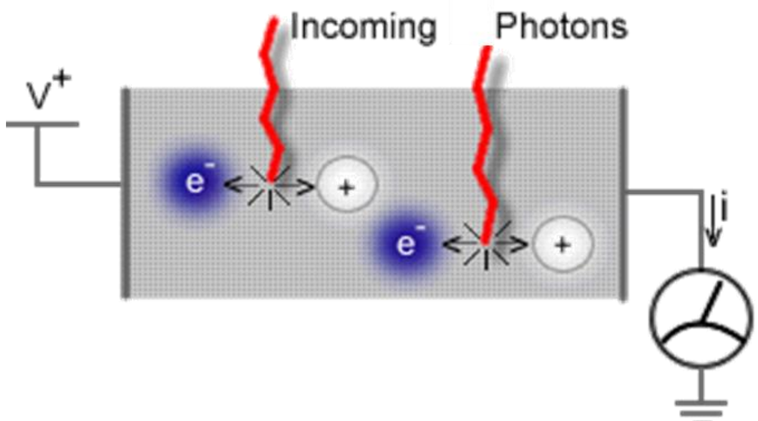
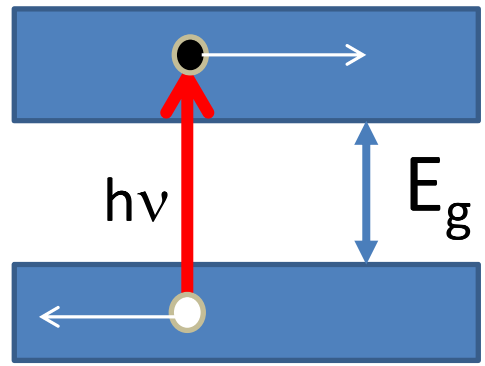
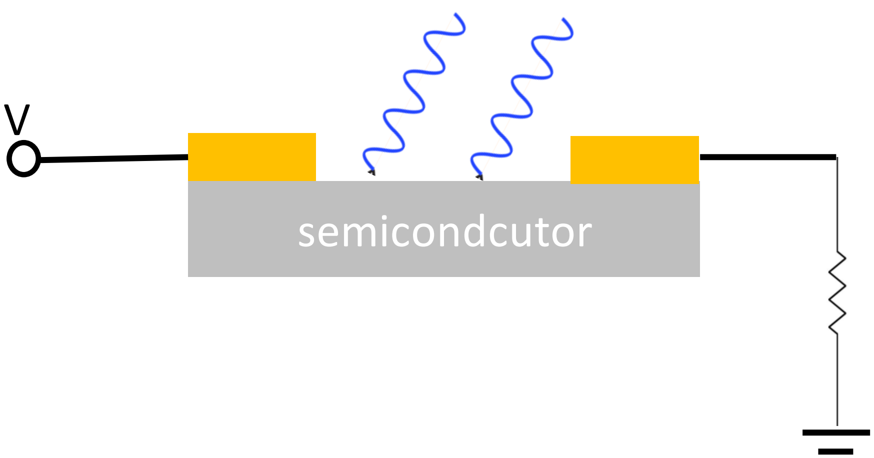
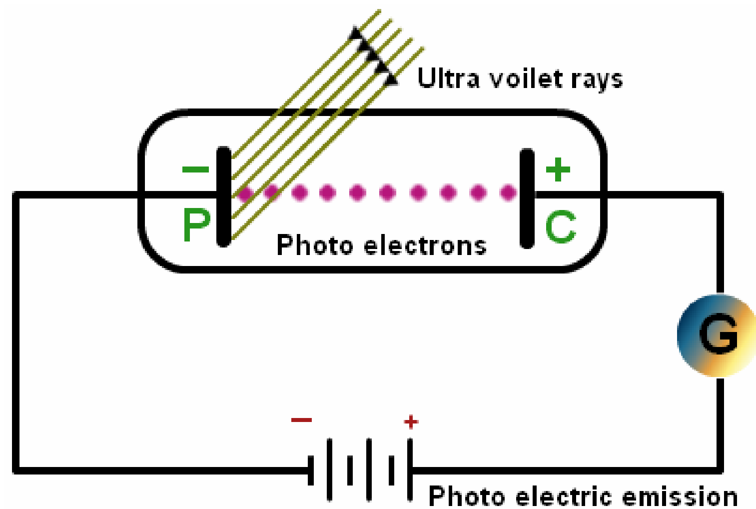
Quantum (Photon) Detector









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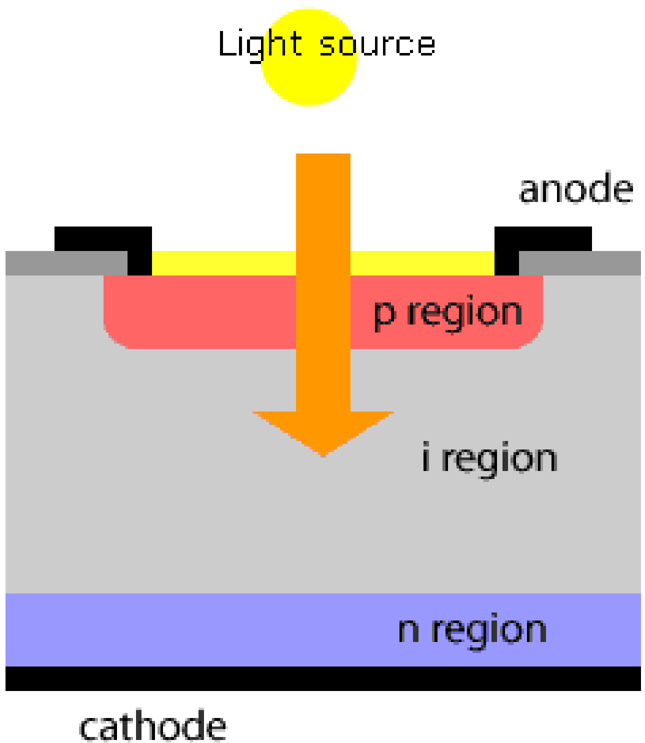
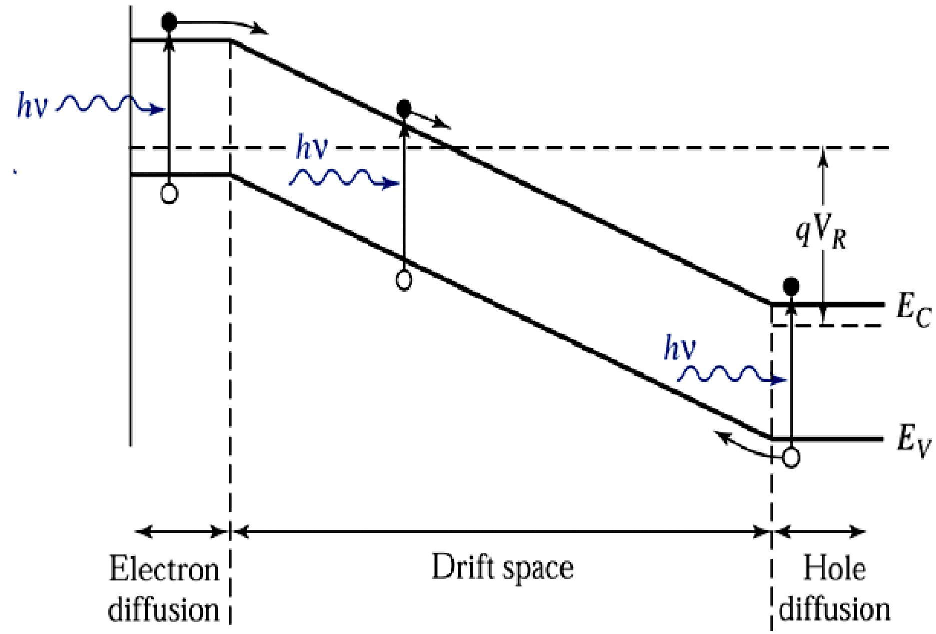
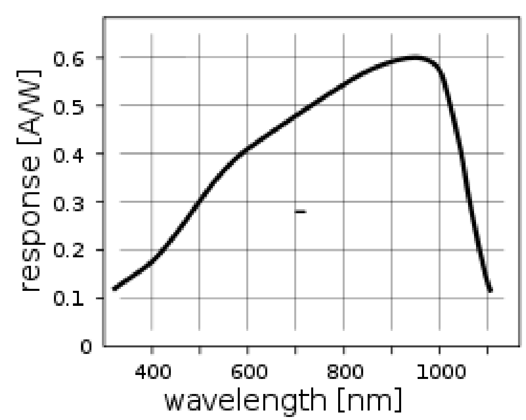
Quantum (Photon) Detector

The photodiode



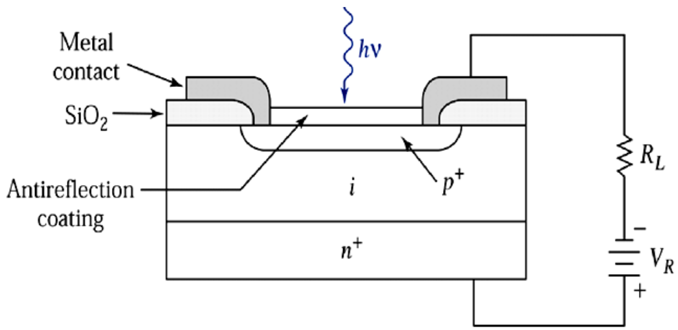


$$\Re = \frac{I_P}{P_0} = \frac{\eta q}{h\nu} \quad [A/W]$$

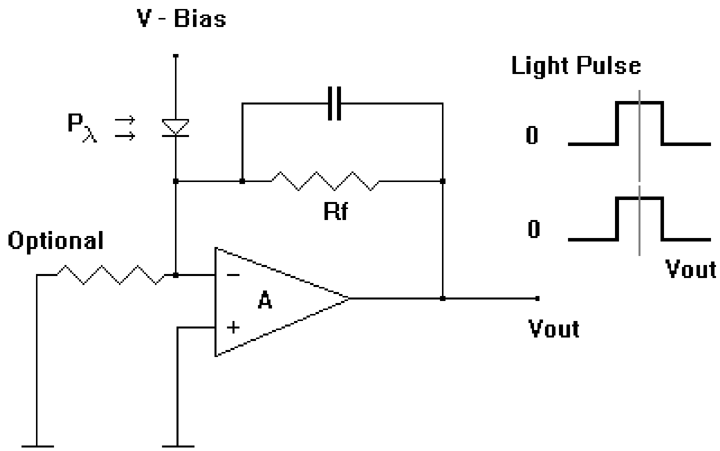


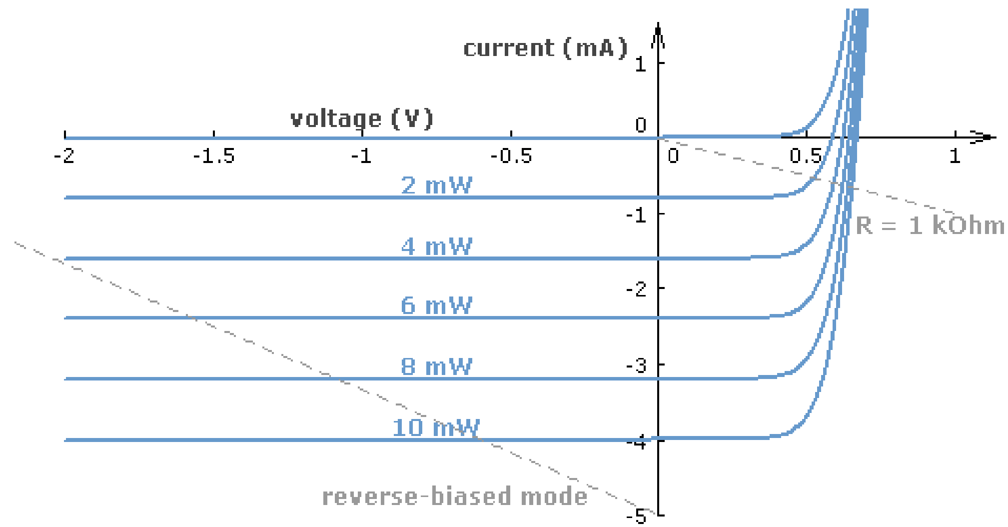
Quantum (Photon) Detector

The photodiode

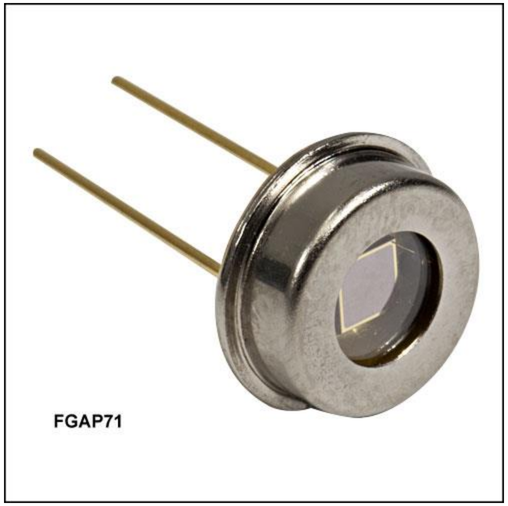


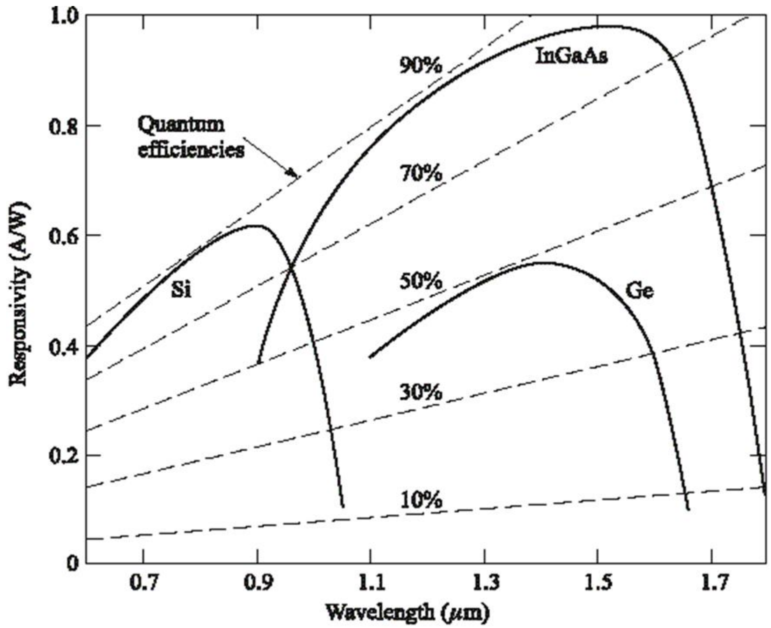
Negative Bias Circuit





Photodiodes





$$\Re = \frac{I_P}{P_0} = \frac{\eta q}{h \nu} \quad [A/W]$$

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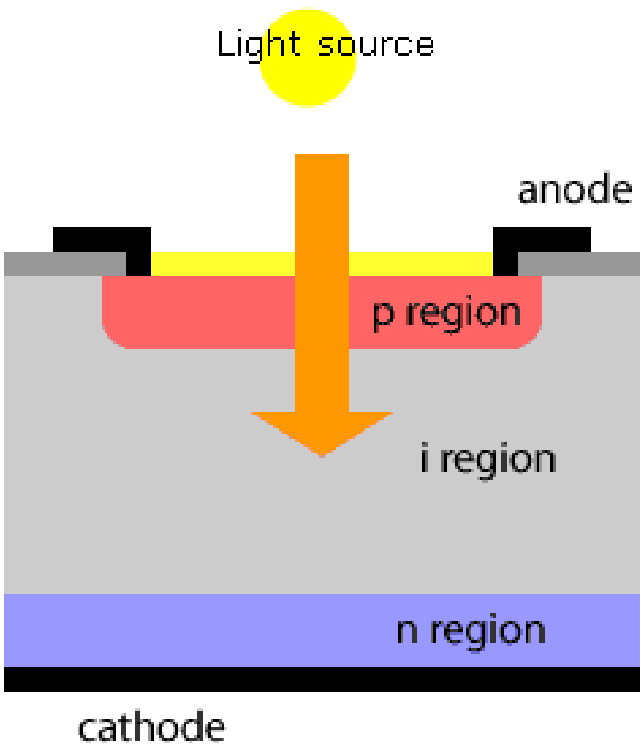
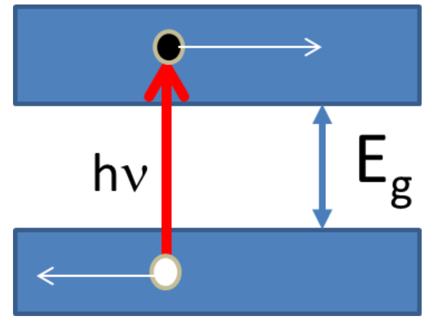
Quantum (Photon) Detector

The Response Time





Ultimately depends on two responses :

1- transit time $t_d = \frac{w}{v_d}$ — w: Width of depletion region; v_d: Drift velocity

and

2- RC time

$$t_{RC} = R \times C_{total}$$

Fast detectors have smaller area!

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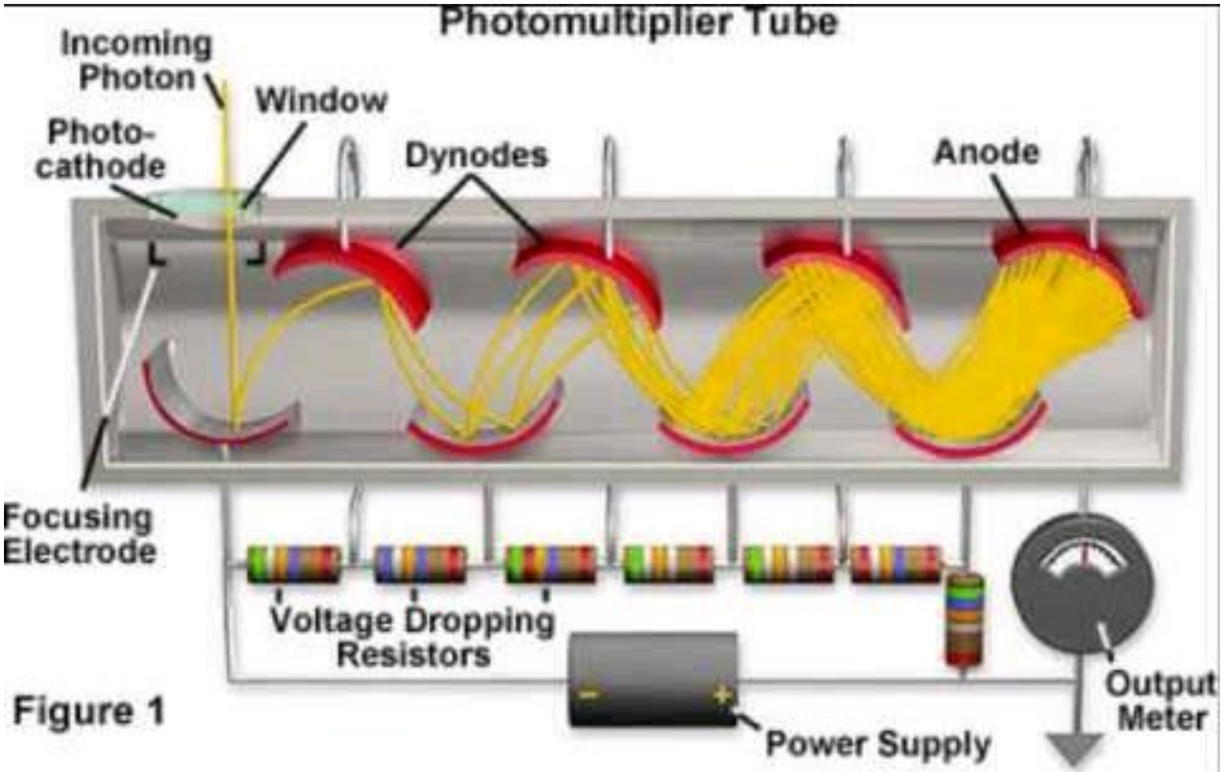
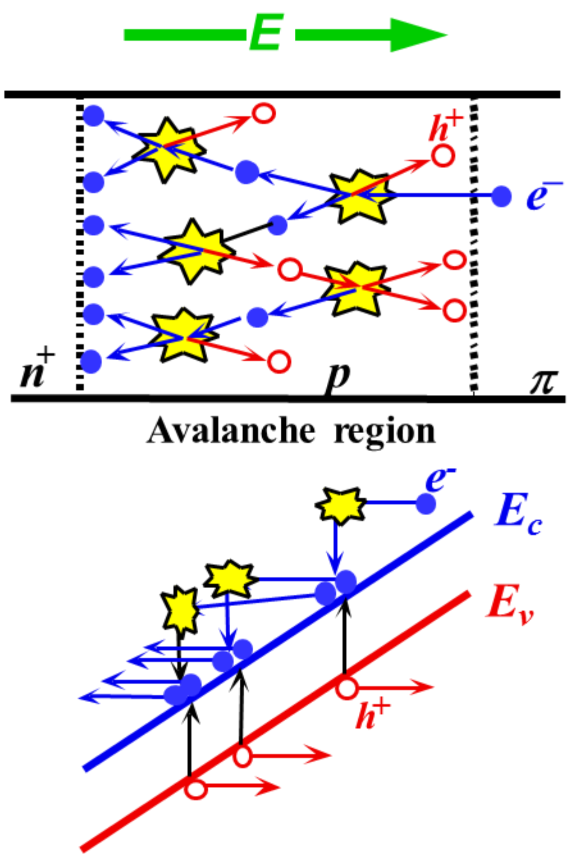
Photomultiplier Tubes (PMT)

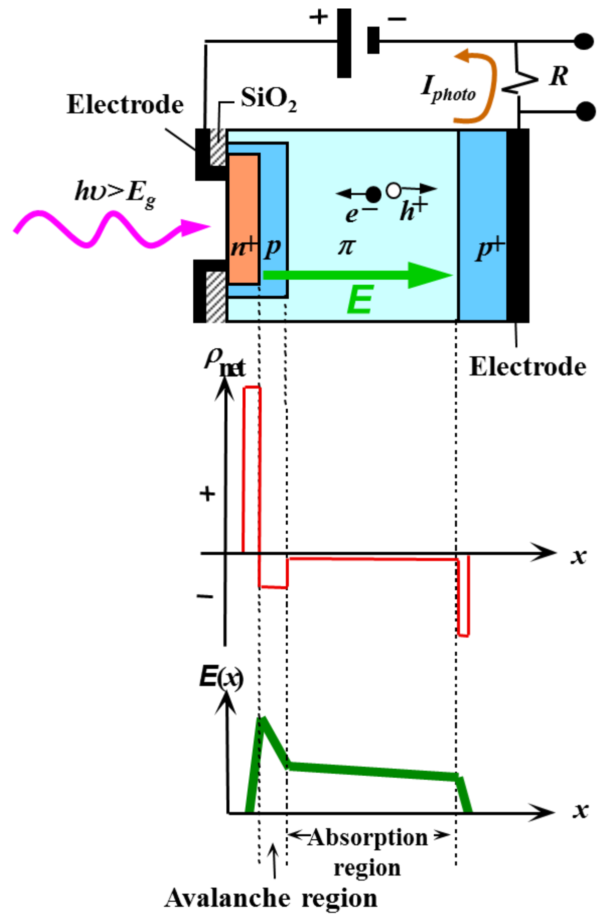


- High gain (10^7)
- Low noise
- Fast (ns)
- Single-photon sensitivity
- Large area

High voltage (kV)

Avalanche Photodiodes (APD)





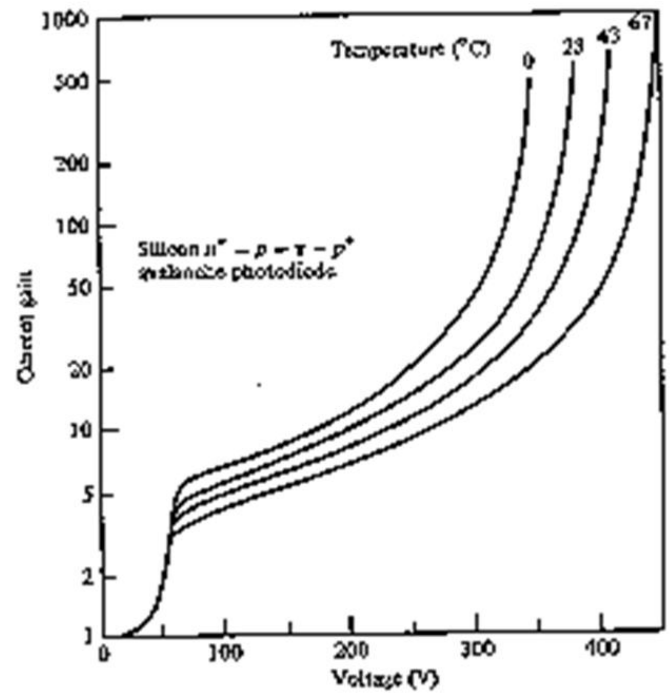
APD

Gain <10^6 (100-1000 typical)

$$\Re_{APD} = \frac{\eta q}{h\nu} M = \Re_0 M$$

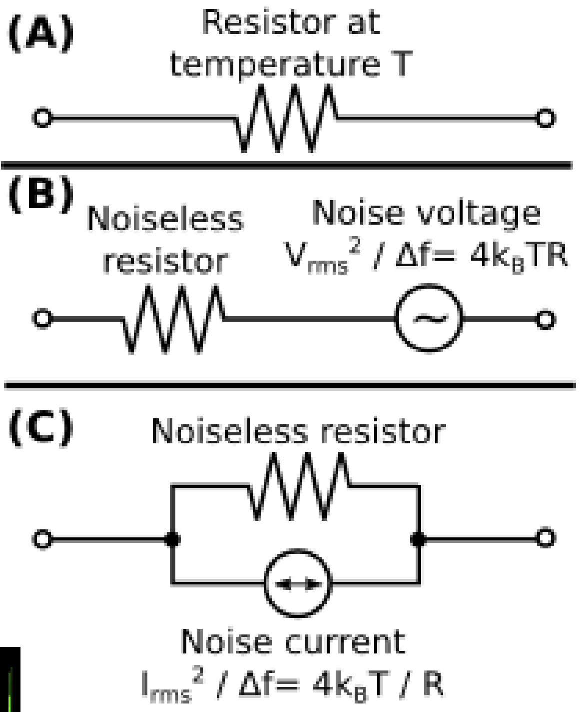
Small area

Photodiode	λ_{range} nm	λ_{peak} nm	R at peak A/W	Gain	Rise time ns	I_{dark}
Si APD	400-1100	830-900	40-130	10-100	0.1	1-10nA
Ge APD	700-1700	1500-1600	4-14	10-20	0.1	1-10μA
InGaAS APD	800-1700	1500-1600	7-18	10-20	0.07-0.1	10-100nA



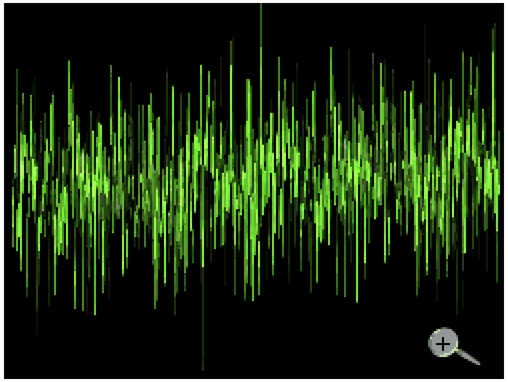
Thermal (Johnson) Noise (dark current)

$$\left\langle i_T{}^2 \right\rangle = \sigma_T{}^2 = \frac{4k_B TB}{R_L}$$

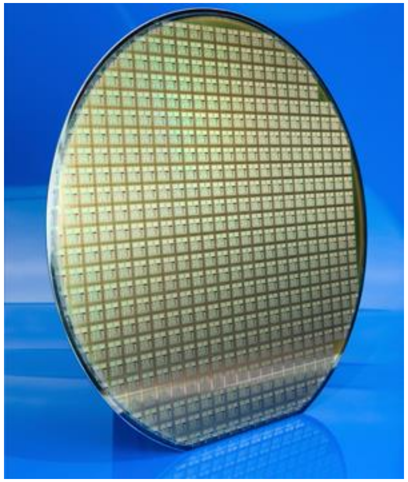


$$v_n = \sqrt{k_B T / C}.$$

Noise of capacitors at 300 K		
Capacitance	Voltage	Electrons
1 fF	2 mV	12.5 e⁻
10 fF	640 µV	40 e⁻
100 fF	200 µV	125 e⁻
1 pF	64 µV	400 e⁻
10 pF	20 µV	1250 e⁻
100 pF	6.4 µV	4000 e⁻
1 nF	2 µV	12500 e⁻

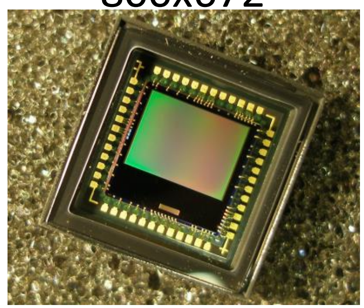


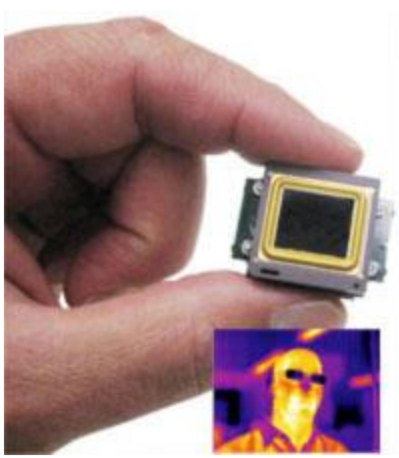
Finally, few words on cameras



-2D sensor arrays
-individually addressable (CMOS cameras)
-Thermal or quantum pixels

800x672





Si micro-bolometer array