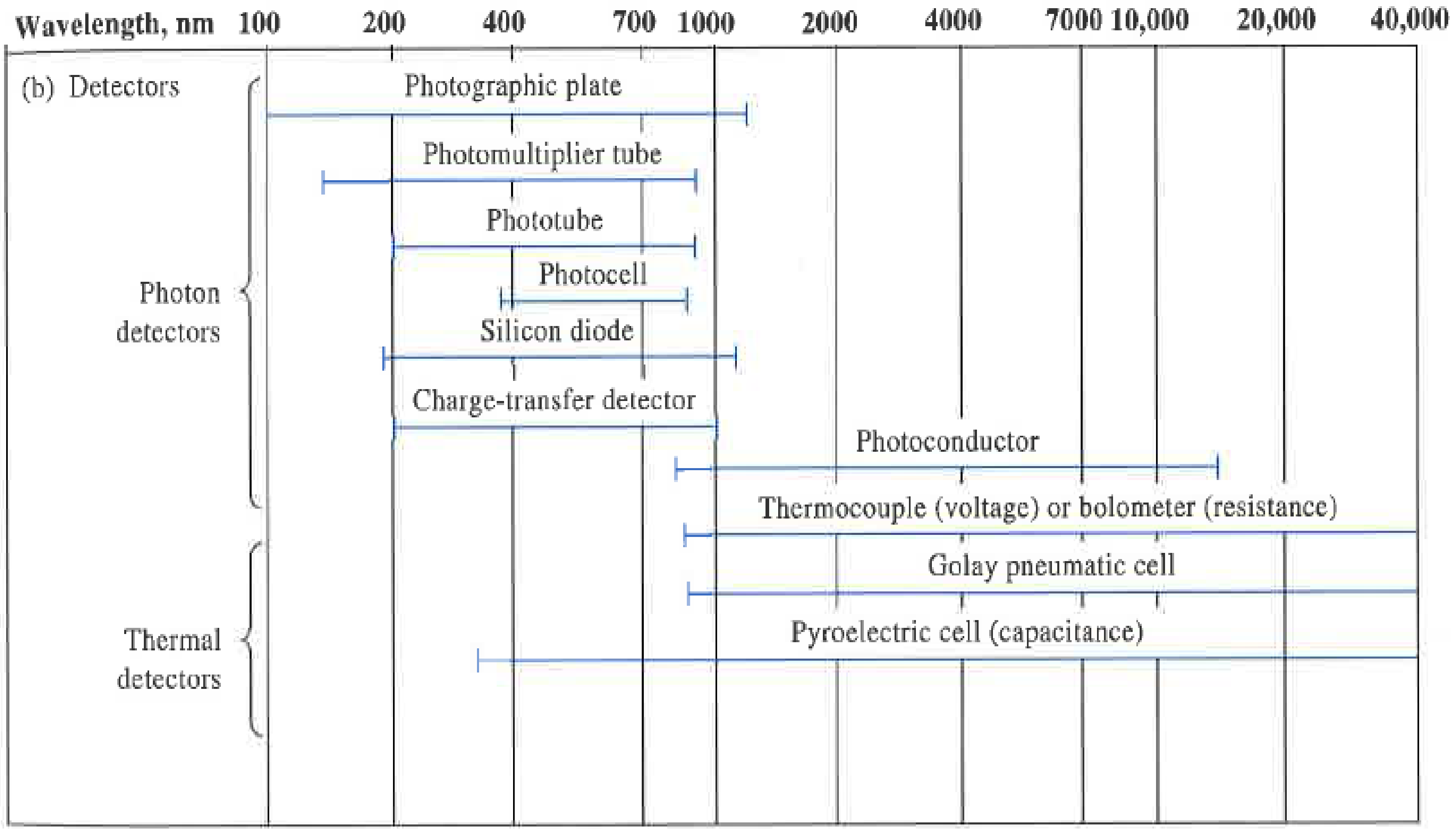
Radiation Transducers



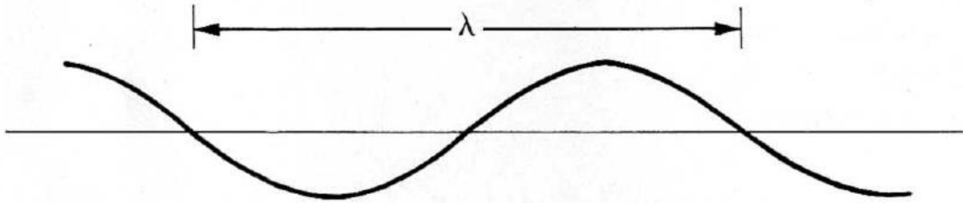
Radiation Transducers

$E = h\nu$

h = Planck's constant
ν = frequency
c = velocity of light under vacuum

$$\lambda = \frac{c}{\nu}$$

Combining these two equations shows that the electromagnetic energy is reciprocally related to the wavelength; *i.e.*, the *highest* energies are associated with the *shortest* wavelengths.



Units of Wavelength

1 Angstrom (Å) $= 1 \times 10^{-8}$ cm
1 Nanometer (nm) $= 1 \times 10^{-7}$ cm
1 Micron (μ) $= 1 \times 10^{-4}$ cm

Units of Energy

3×10^{14} Hz $= 10{,}000$ cm^{-1}
3×10^{14} Hz $= 1.239$ eV
3×10^{14} Hz $= 28.58$ Kcal per mole

Radiation Transducers

Region	*Frequency*	*Wavelength*	*Units of Energy*	*Molecular and Atomic Processes*
Radiofrequency	3×10^{5} to 3×10^{9} Hz	10^{-1} to 10^{3} m	1×10^{-5} to 0.1 cm^{-1}	Molecular rotations in solids and liquids
Microwave	3×10^{9} to 3×10^{11} Hz	10^{-1} to 10^{1} cm	0.1 to 10 cm^{-1}	Molecular rotations in gases
Infrared	3×10^{11} to 4×10^{14} Hz	0.75 to 1×10^{3} μ	10 to 13,300 cm^{-1}	Molecular vibrations
Visible	4×10^{14} to 8.6×10^{14} Hz	350 to 750 nm	13,300 to 38,600 cm^{-1}	
Ultraviolet	8.6×10^{14} to 3×10^{15} Hz	100 to 350 nm	3.5 to 12.5 eV	Electronic transitions involving outer orbitals
X-ray	3×10^{15} to 3×10^{18} Hz	1 to 10^{4} Å	12.5 eV to 12.5 keV	Electronic transitions involving inner orbitals
Nuclear	3×10^{18} to 3×10^{22} Hz	10^{-4} to 1 Å	12.5 keV to 125 MeV	Changes in nuclear energy levels

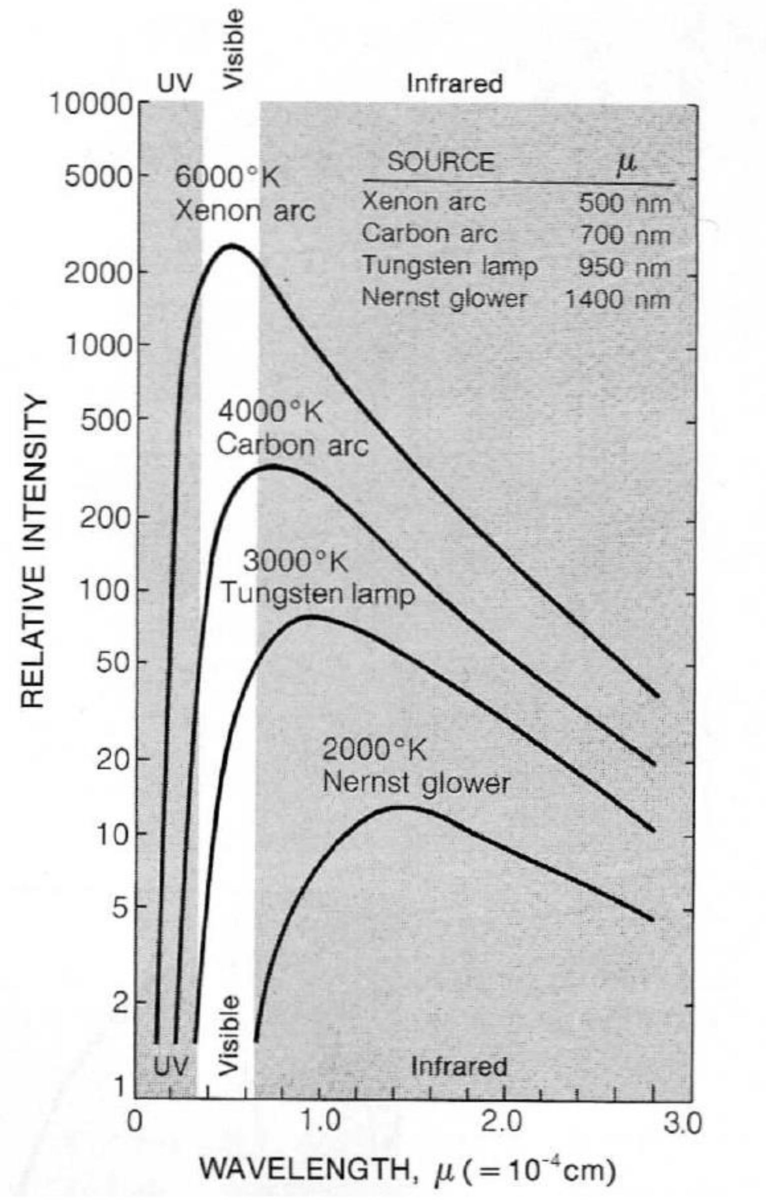
1. The energy of the particular radiation under study dictates the choice of the transducer
2. The choice of optical materials to be used depends on its transparency to that radiation. Glass window is transparent to visible light, but opaque to UV radiation. Thus measurement of UV radiation cannot be made if the transducer is contained in an envelop of window glass

Radiation Transducers

Increased radiation temperature is associated with:

1. Increased number of photon per unit time
2. Increased photon energy

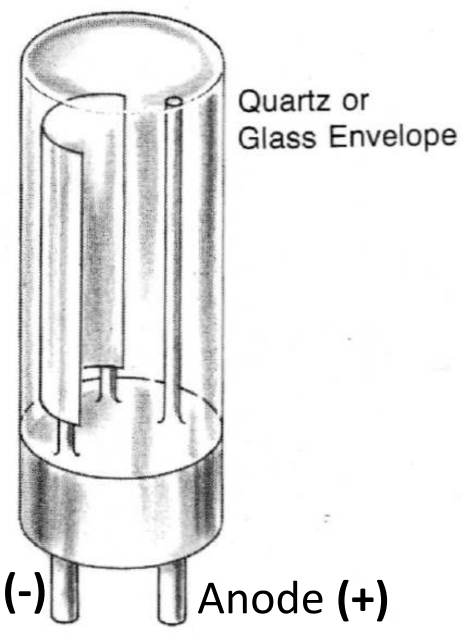
Cool sources (e.g., Nernst glower) are relatively week intensity, and emit long wavelength
Hot sources (e.g., Xenon arc) are of high intensity and emit higher energy shorter wavelengths



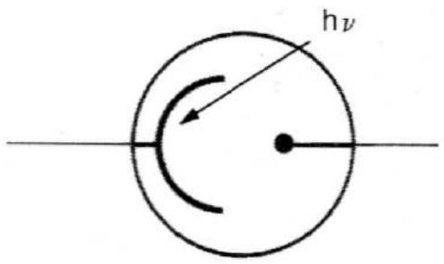
Radiation Transducers - Phototubes

Phototubes

1. Large photocathode and anode
2. Light striking at the photocathode cause electrons to be ejected
3. The ejected electrons are attracted to the anode, held at a voltage which is positive with respective to the cathode
4. Current resulting from this photoelectric effect is proportional to the number of photons striking the surface
5. The ease with which the electrons are ejected is related to the work function of the metal employed.
6. For a given metal surface, response is higher for short-wavelength photons; longer wavelength radiations have less energy, and must strike electrons that already excited in order to eject them
7. Thus the phototube is useful only in the UV and lower visible regions
8. Modification of the surface material can however permit the use of phototubes throughout the visible region.

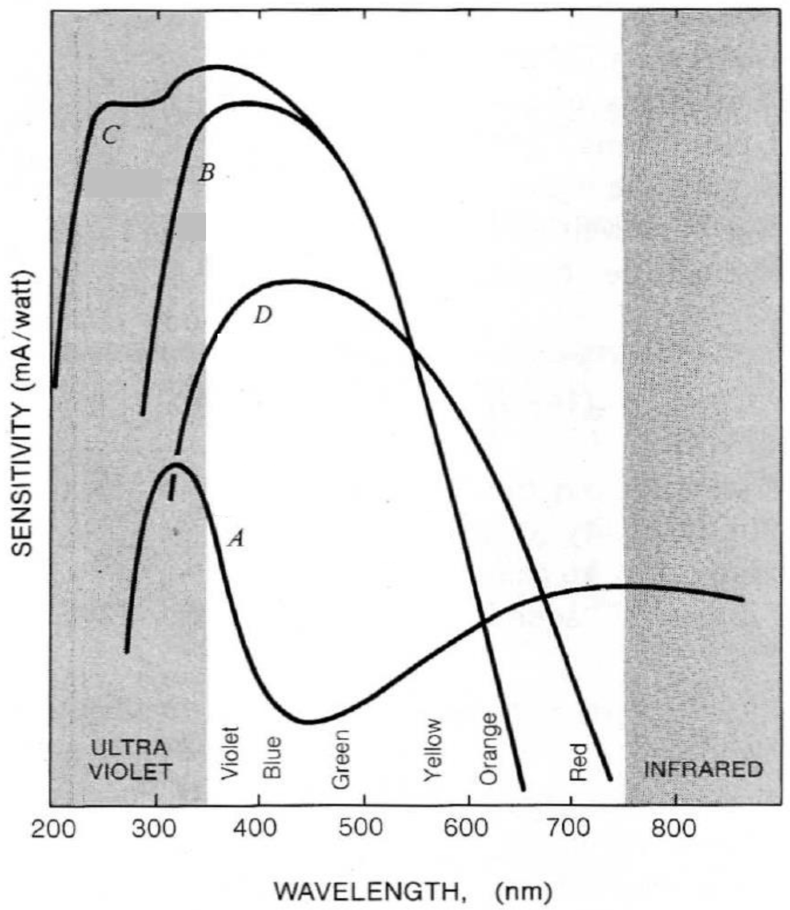


Vacuum Phototube

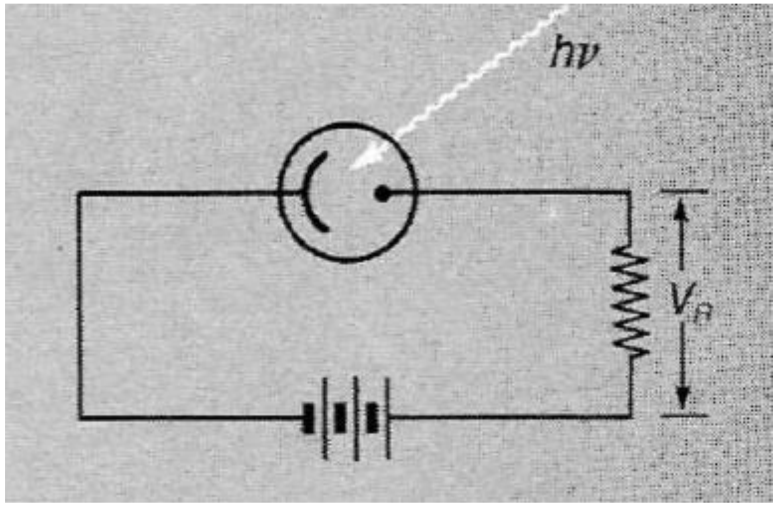


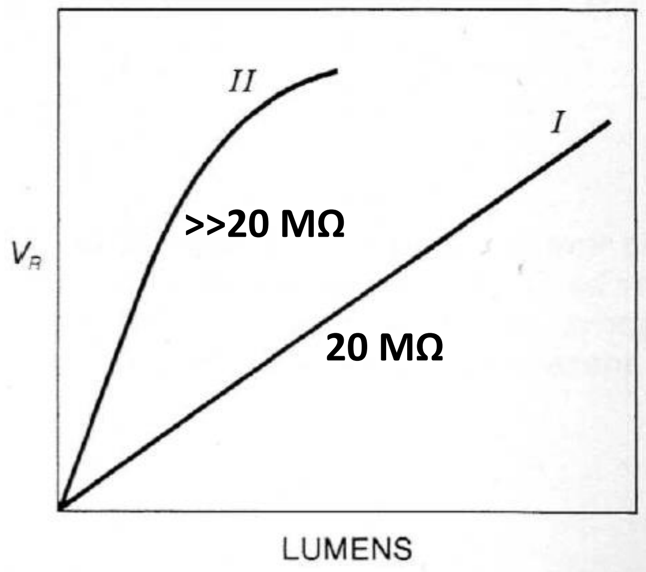
Electronic Symbol of Vacuum Phototube

Radiation Transducers - Phototubes



Labels in Figure	**Cathode Material**	**Useful λ Range**
A	Ag–O–Cs	500–1000 nm
B	Cs–Sb	300–620
C	Cs–Sb	200–620
D	Ag–Bi–O–Cs	330–720



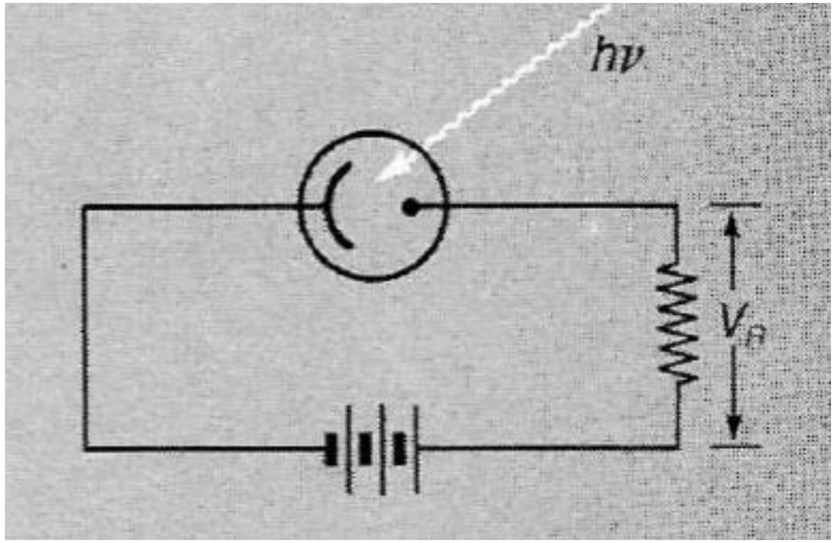


LUMENS $= CA/d^2$

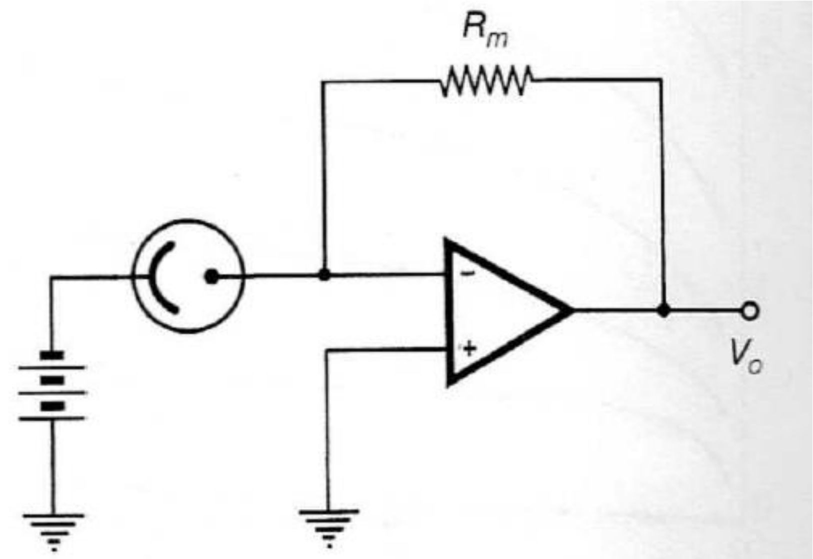
C = source strength (in candlepower)
A = area illuminated
d = distance from source to area

Voltage generated across the resistor must be small compared with the applied voltage. This places a limit on the resistor if linear response is desired

Radiation Transducers - Phototubes



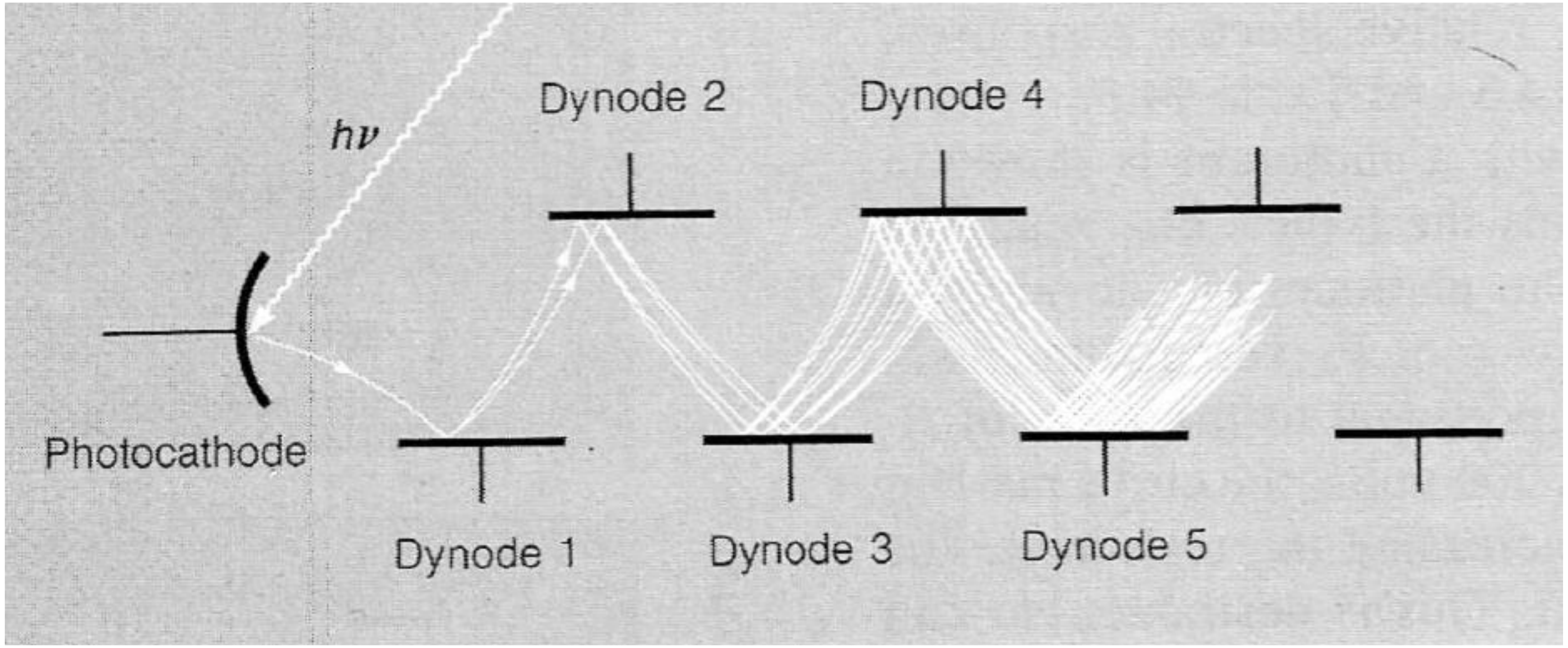
To increase sensitivity of the phototube, gas-filled phototubes are used. Response from this gas-filled phototube is however non-linear, which limits accurate measurements.



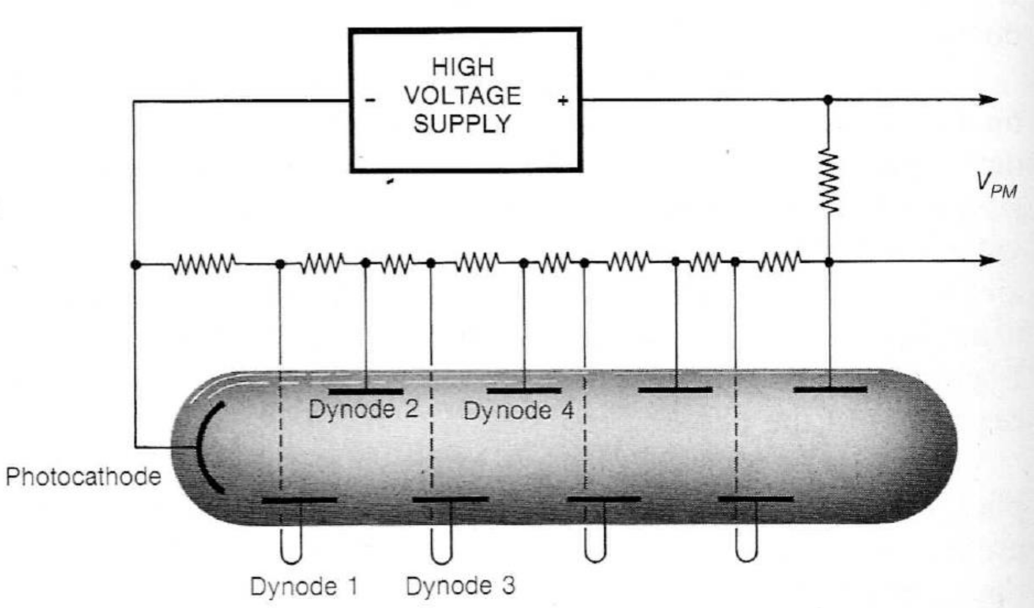
The use operational amplifiers solves the non-linearity and inaccuracy measurement problems. In this configuration, the anode is kept at a virtual ground, which isolates the applied voltage from the one developed in the measuring resistor

$$\mathbf{V_o = - R_m \times Photocurrent}$$

Radiation Transducers – Photomultiplier

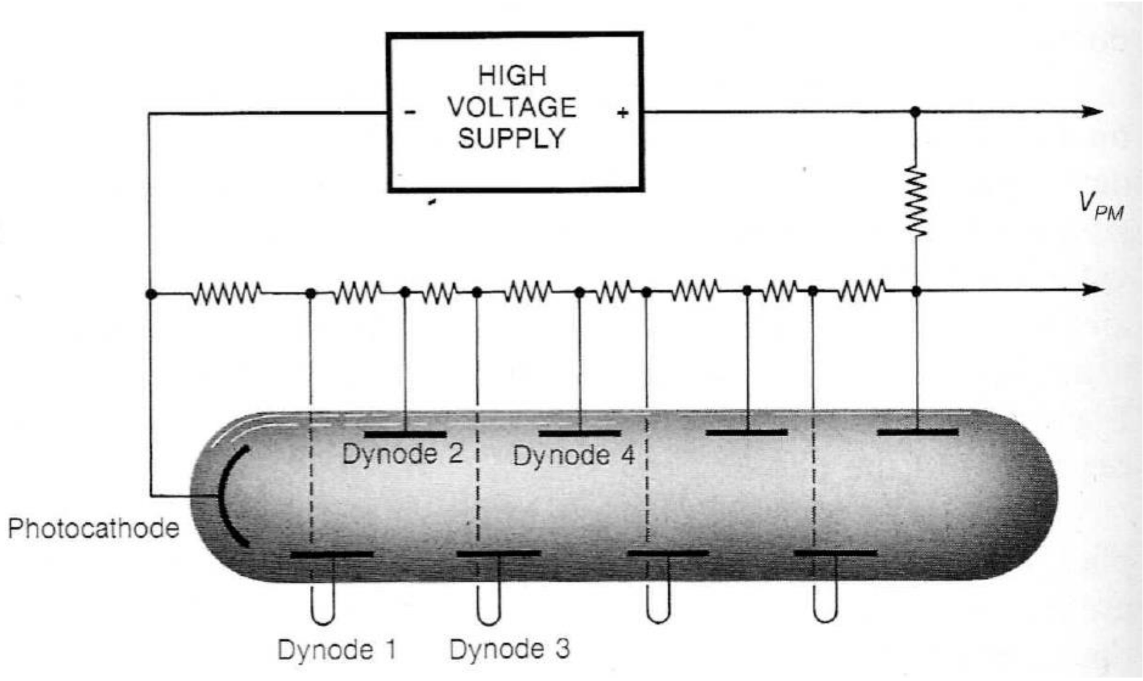


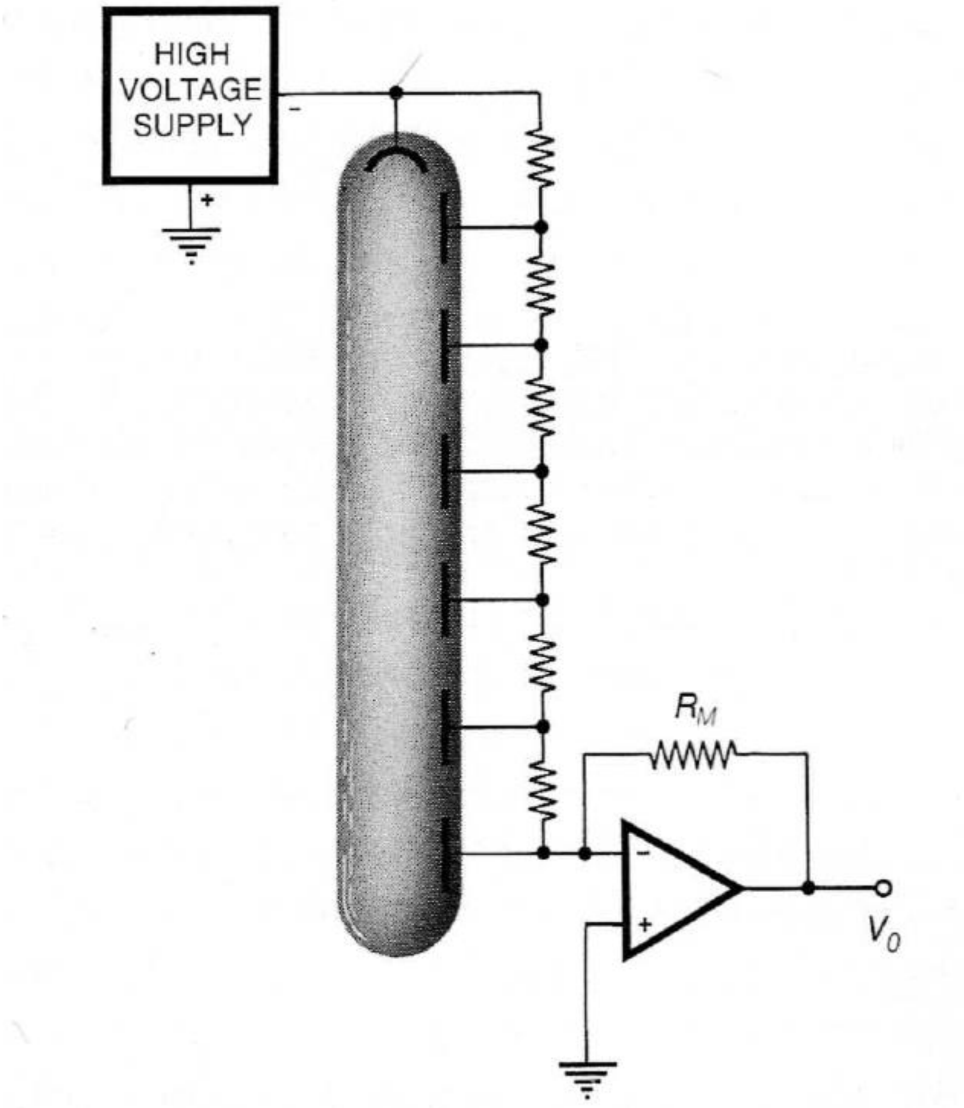
Amplification is done within the envelop of the tube
Typically nine dynodes are used, and each dynode is held at a voltage more positive than the preceding one



The mode of applying different and increasing voltage to dynodes

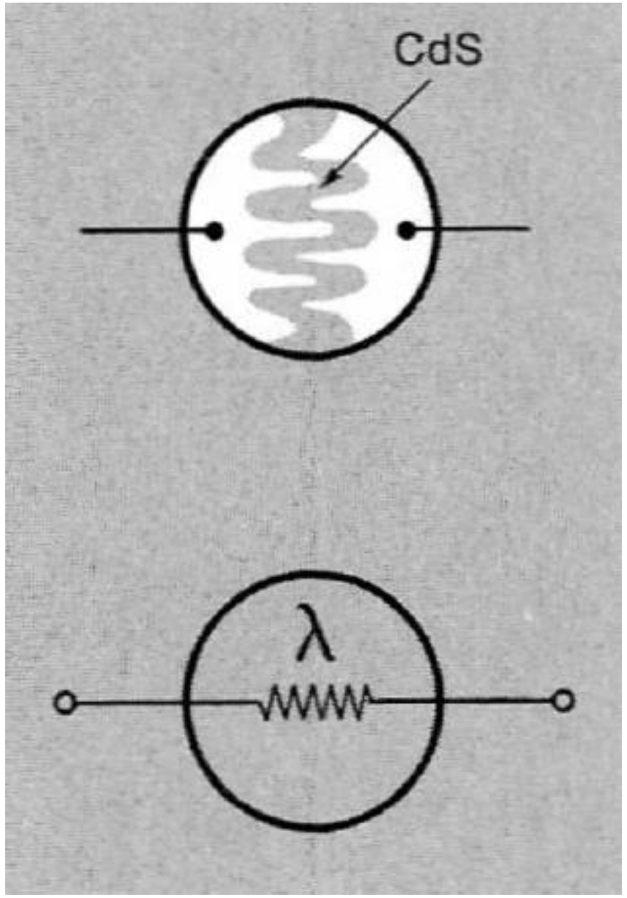
Radiation Transducers – Photomultiplier





$Vo = - R_m$ x Photocurrent

Radiation Transducers – Photoconductivity



Most sensitive detector for IR radiation

The conductivity of the material (CdS or PbS) is changed when exposed to light

Electron is freed (not ejected) by radiant light to move about in the crystal structure, thus decreasing the resistance of the material between two electrodes

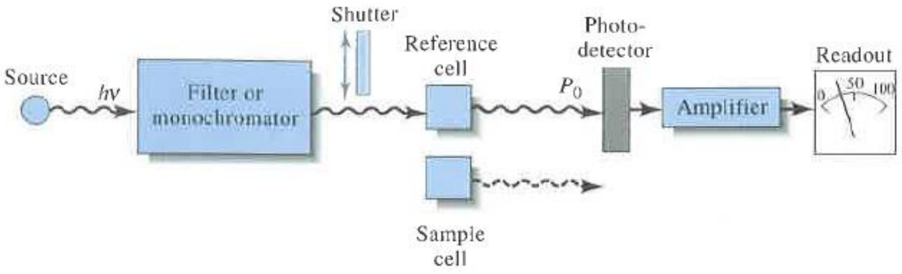
Cooling is necessary to suppress noise arising from thermally induced transitions among closely lying energy elevels

Radiation Transducers – Photoconductivity

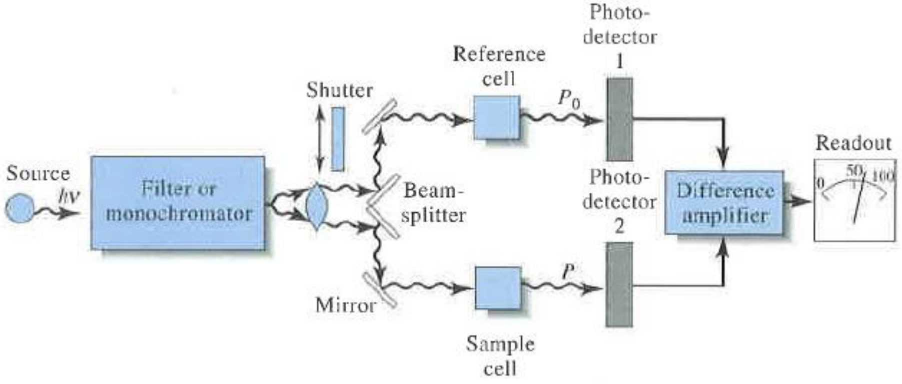
Transducer Type	*Response Time*	*Output*	*Auxiliary Equipment*	*Sensitivity*	*Transducer Impedance*	*Size*	*Wavelength Region*
1 Phototube	1 μsec	*I*	voltage source	medium	high	moderate	150 to 1500 nm
2 PM tube	1 μsec	*I*	high voltage source	high	high	moderate	200 to 1000 nm
3 Photoconductivity Cell	10 μsec	*R*	none	medium	medium	small	350 to 4000 nm
4 Photovoltaic cell	10 μsec	*V*	none	medium	low	small	350 to 750 nm
5 Phototransistor	<1 μsec	*I*	none	medium	high	small	250 to 1100 nm
6 Bolometer	1 msec	*R*	current source and amplifier	low	low	small	1 to 40 μ
7 Thermocouple	10 msec	*V*	amplifier	low	low	small	1 to 40 μ

Typical Spectrophotometric Configurations

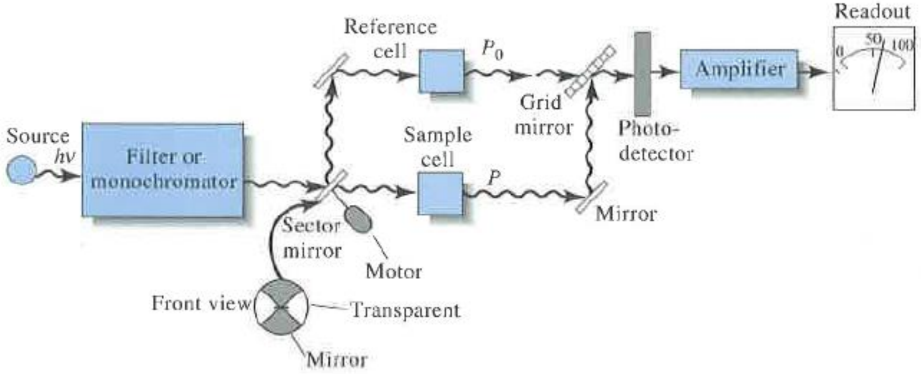
(a) Single-beam instrument

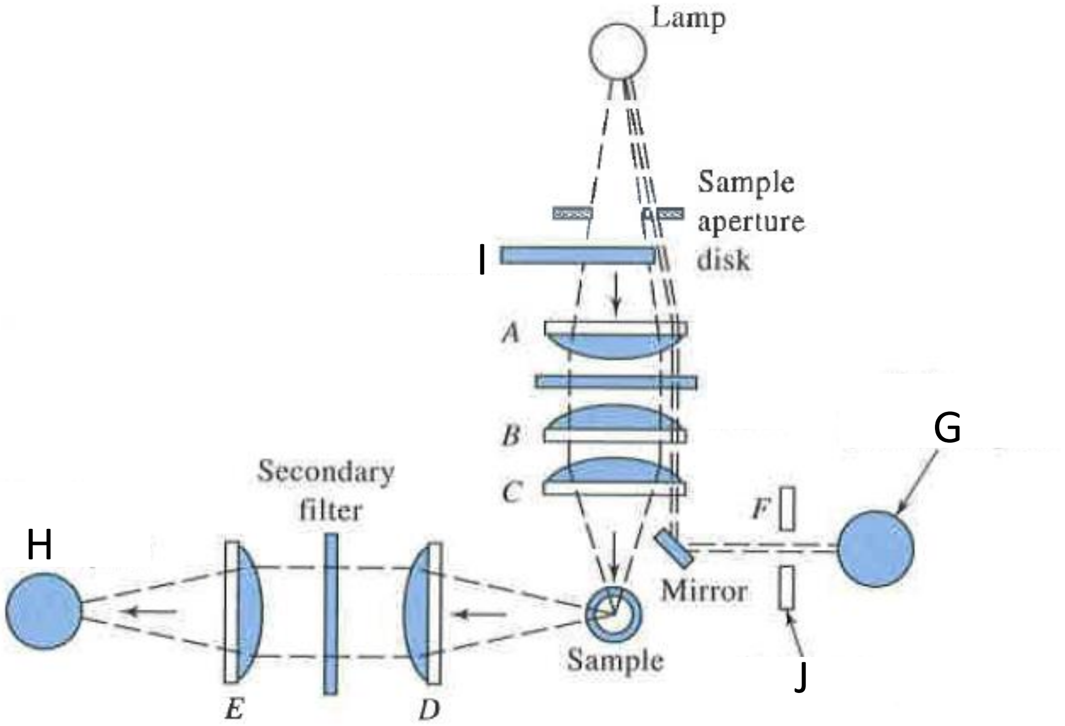


(b) Double-beam-in-space instrument

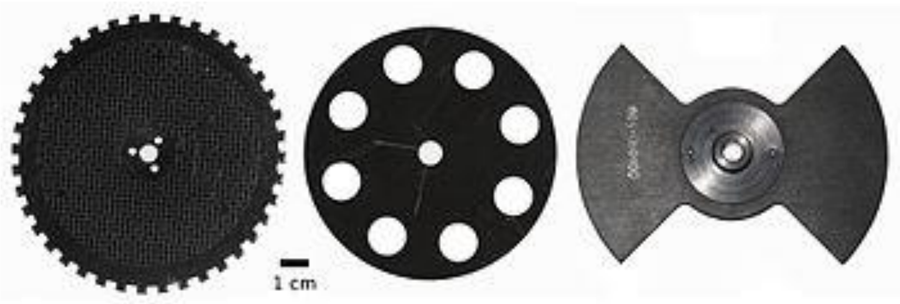


(c) Double-beam-in-time instrument





Optical Choppers/Shutter



An optical chopper is a device which periodically interrupts a light beam. Three types are available: variable frequency rotating disc choppers, fixed frequency tuning fork choppers, and optical shutters.

Frequency modulation allows selective signal amplification be means of lock-in amplifiers