Photodetection

•Many examples of light signals

sensors such as scintillators, Cerenkov radiation, ...

lasers for telecommunications, cable TV, local or wide area optical network

optoelectronic technology is rapidly growing field with innumerable applications, eg:

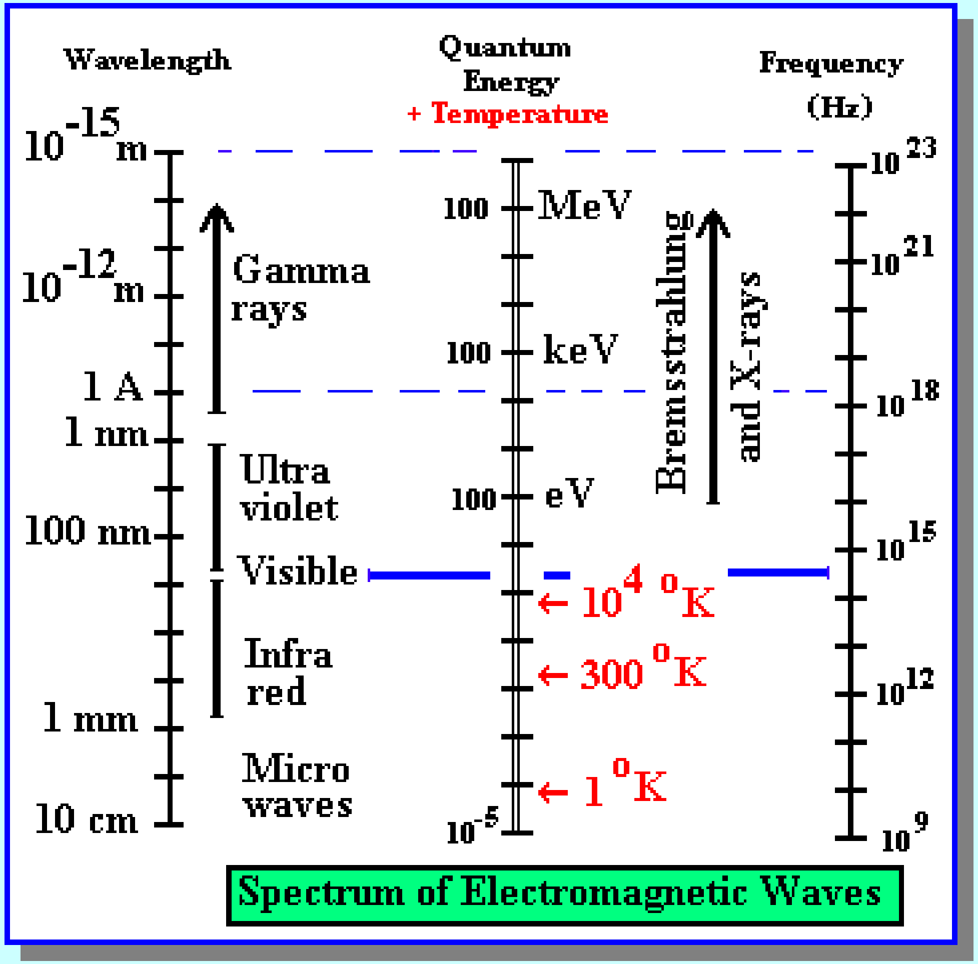
optical computing
holographic memories
consumer electronics and data storage (CDs, etc)

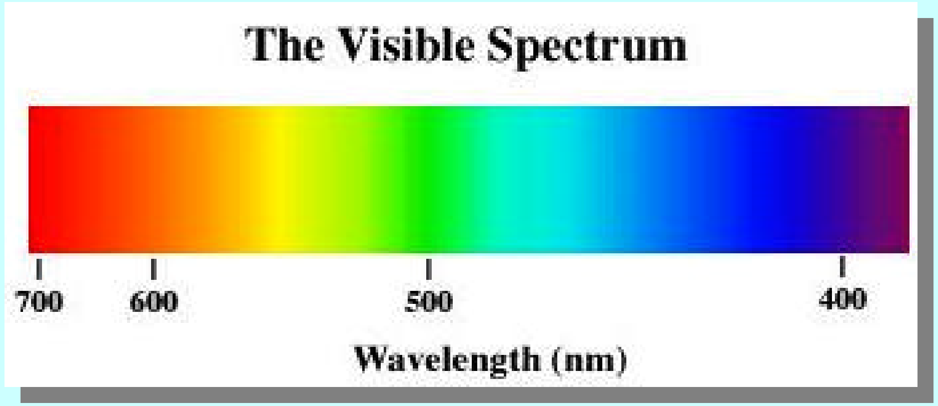
•What types of sensor are available for photonic measurements?

•What are the requirements?

•What properties and limitations do they have?

Reminder - Electromagnetic spectrum





- $\lambda = c/\nu = hc/E$ $\lambda\ [\mu m] = 1.24/E\ [eV]$

0.2µm = 6eV	ultra-violet
0.5µm = 2.4eV	visible
1µm = 1.24eV	infra-red
10µm = 0.12eV	far-IR

- Wide range of photon wavelengths and energies to be covered!

  should not expect a single sensor for all applications

Photomultiplier

•Most common light sensor - simple structure

electrodes enclosed, in vacuum, in glass envelope

many sizes and shapes

•Photocathode - thin metal coating on inside of entrance window

semi-transparent (& fragile)

photon absorbed and converted to electron, small k.e.

e^- diffuses to surface and escapes

•Electron capture region

E field shaped to transport e- to first dynode

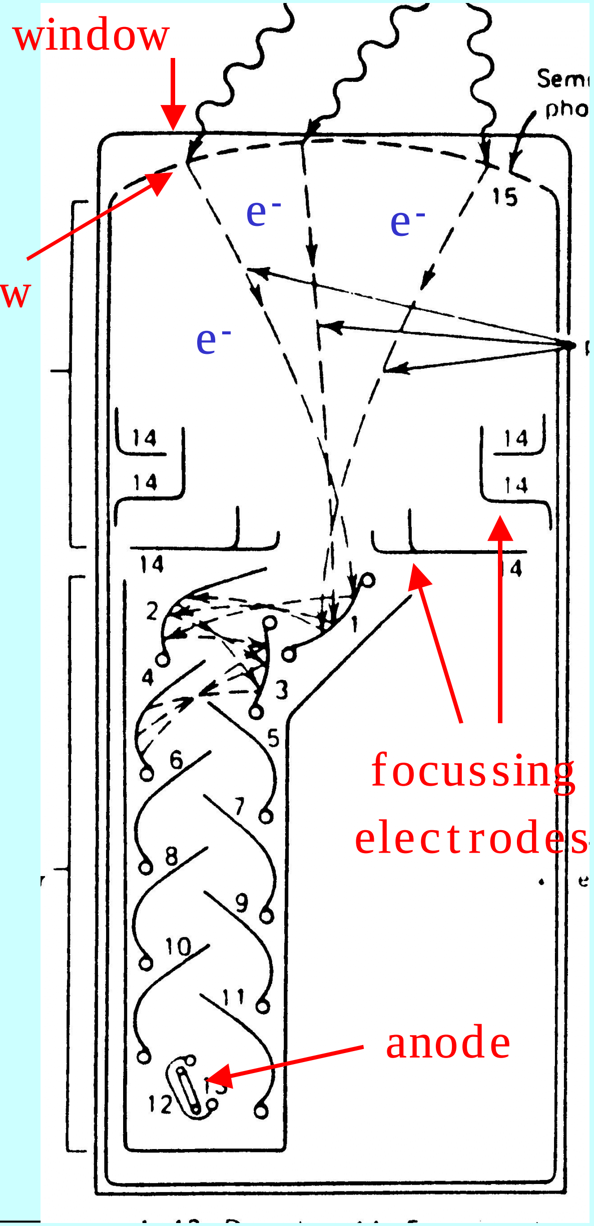
•Dynodes - electron multiplier chain

e^- accelerated in E field

strikes dynode and ke. releases more e^- = amplification

•Anode

after several amplification stages, -> current signal



Photomultipliers

Photomultiplier operation

•Bias dynodes by applying voltages

typically ~100V stage

G_{stage} ~ ke of incident electron

•simplest arrangement: resistor potential divider

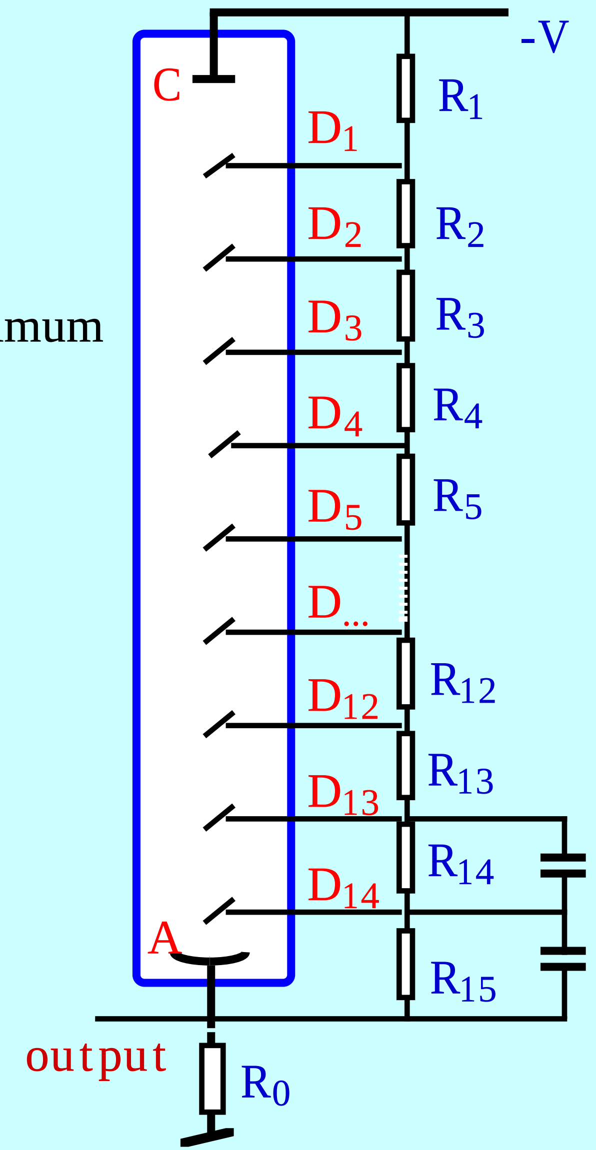
usually add capacitors in final stages, where current is maximum

can add Zener diodes for stability

•Choice of components

first stage is often largest ΔV for maximum gain

$I_{chain} \gg I_{peak\ signal}$



Characteristics

- photocathode- determines wavelength sensitivity and quantum efficiency

QE = N_e/incident photon

3-4 eV alkali metals
1.5-2eV bi-alkali

Signal = G_{total} x QE x ε_{photon} x $\varepsilon_{electron}$

ε_{photon} = fraction of photons reaching cathode

$\varepsilon_{electron}$ = electron collection efficiency

photocathode type	$\Delta\lambda$ (nm)	λ_{max} (nm)	QE (%)	name
Ag-O-Cs	300-1100	800	0.4	S1
Bi-Ag-O-Cs	170-700	420	6.8	S10
Cs_3-Sb-O	160-600	390	19	S11
Na_2-K-Sb-Cs	160-800	380	22	S20
K_2-Cs-Sb	170-600	380	27	bialkali

- try to match sensitivity to source, eg scintillator spectrum

- very sensitive to magnetic field

electrons are low energy and E field is limited

- stable high voltage required

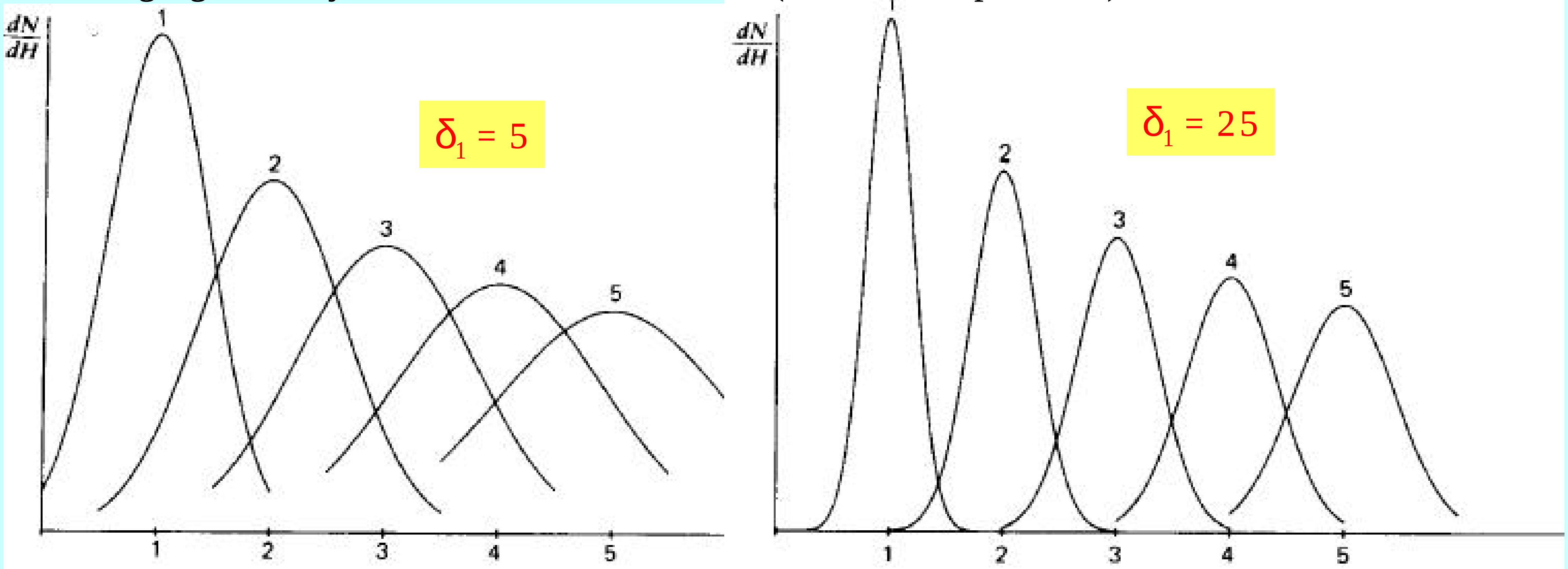
since gain $G_{total} \sim G_{stage}^N \sim \Delta V^N \sim (V/N)^N$

Sensitivity

•Approximate picture - each stage increases signal by factor δ_{stage}

Single and multiple electron signals can be distinguished depending on dynode gain

stage gain subject to Poisson statistics (ie. random process)



signal in photoelectron equivalents

•if gain is high, first stage dominates

Signal = $N_e\delta_1\delta_2\delta_3\delta_4\ldots\ \delta_N$

Noise

•Photomultipliers often described as noiseless sensor - but...

noise arises from thermionic emission of electrons from cathode and dynodes

dark count rates of ~kHz or more possible - can be minimised in several ways

if signal can be observed in coincidence with another signal

very often possible, eg particle crosses several detectors

cooling tube

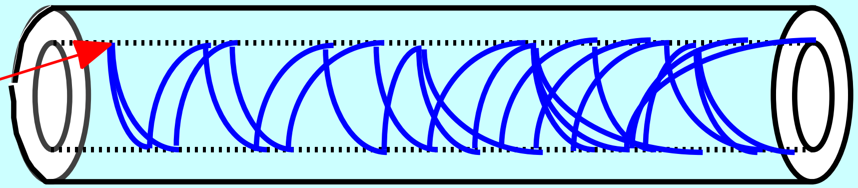
minimise dark current

discriminating amplitude of signal -

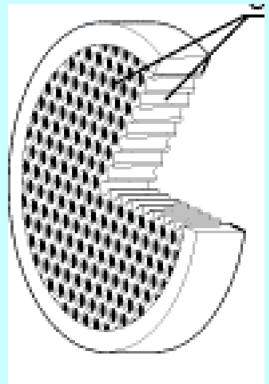
noise pulses generated after first stage will be smaller amplitude

Channel plate

- Hollow tube of high resistivity glass coated internally with secondary electron emitter
  - apply potential difference along tube -> multiplication
  - pack series of tubes as bundle ~ few cm^2



- Intrinsically spatially sensitive
  - to avoid too many channels read out with resistive anodes, strips or CCD



- Use "chevron" arrangement to avoid positive ion feedback
  - could damage tube

- Applications
  - image intensifier - very compact low light detection
  - spatial imaging - β isotopes
  - fast timing - transit time short, and dispersion smaller