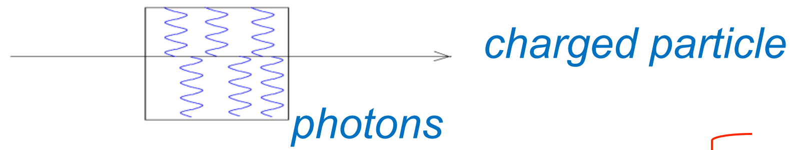
Scintillators



- Charged particle passing through matter distorts
  - atom
  - molecule
  - lattice

- Relaxation of distortion – light emitted

$$p^{\pm} + A \rightarrow p^{\pm} + A^{*}$$
$$A^{*} \rightarrow A + \gamma$$

- Emitted photon may – excite another molecule

Successive excitation & emission – different λ photons

$$p^{\pm} + A \rightarrow p^{\pm} + A^{*}$$
$$A^{*} + B \rightarrow A + B^{*}$$
$$B^{*} + C \rightarrow C^{*} + B$$
$$C^{*} \rightarrow C + \gamma$$

each step $\sim 100\ ps$

whole chain $\sim 1-10\ ns$

- Very fast – good timing resolution

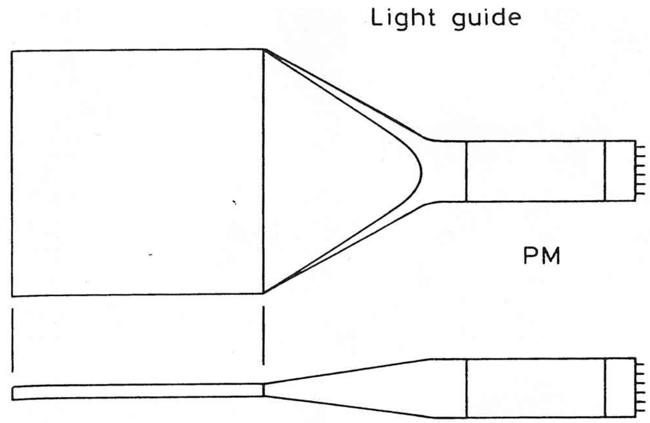


Fig. 9.6. Adapting a flat scintillator sheet to the circular face of a PM with a light guide

- Can be extremely efficient $\frac{dE}{dx} \sim 2\, MeV / cm$

$$1\gamma / 10^2\, eV \text{ lost} \rightarrow 10^4\, \gamma / cm$$

$$\times \text{collection efficiency}$$

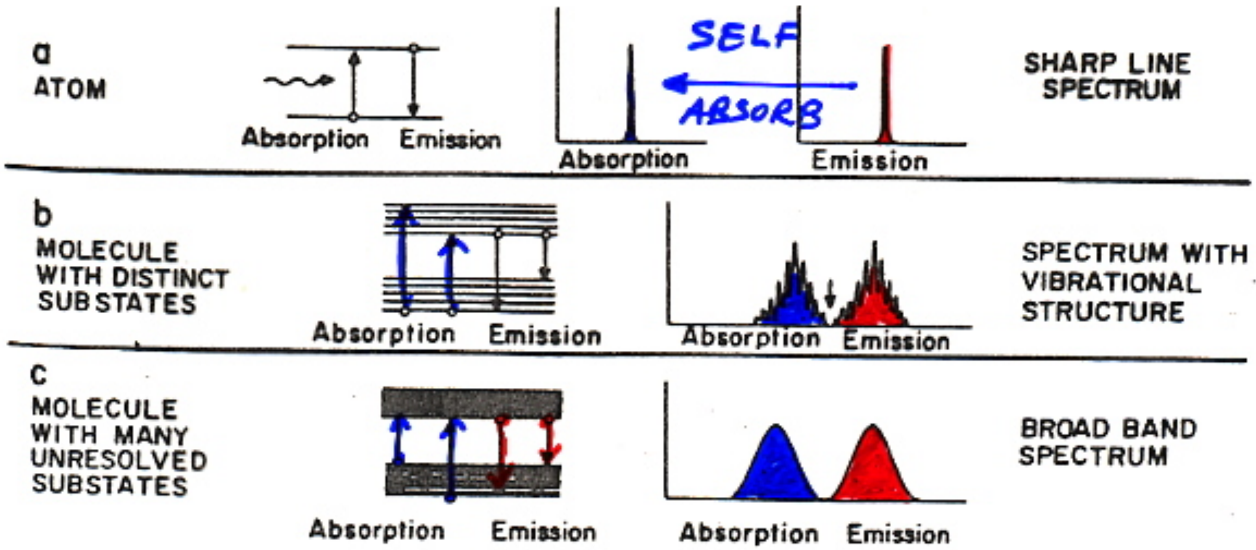
$$\times \text{ photomultiplier efficiency}$$

~ 100 photoelectrons per cm.

- Spatial resolution ~ size of scintillator ~10s cm : 10μ

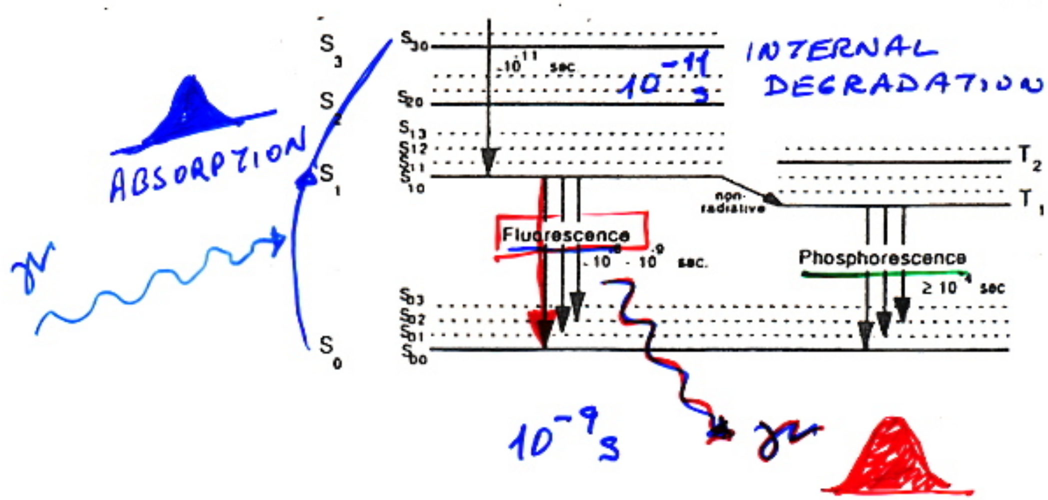
Scintillating fibres

Why are scintillators transparent to emitted light?



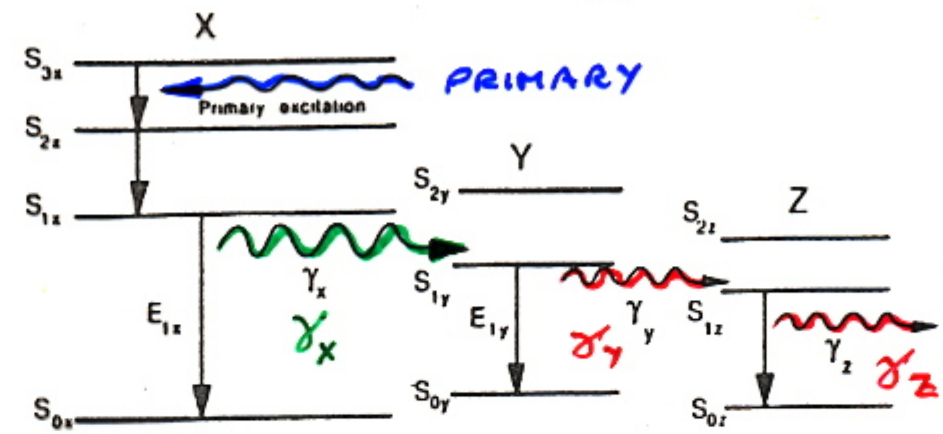
- Stokes shift

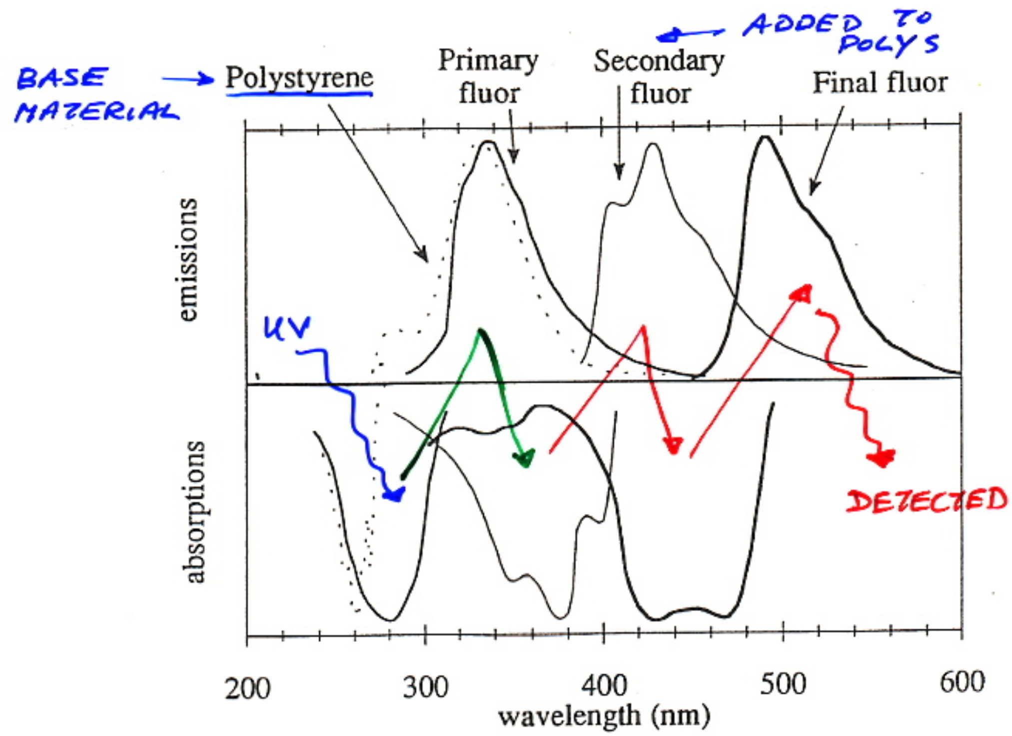
• TIME SCALE OF SCINTILLATION



Wavelength Shifting

• PRIMARY SCINTILLATION MAY BE UNDETECTABLE → UV



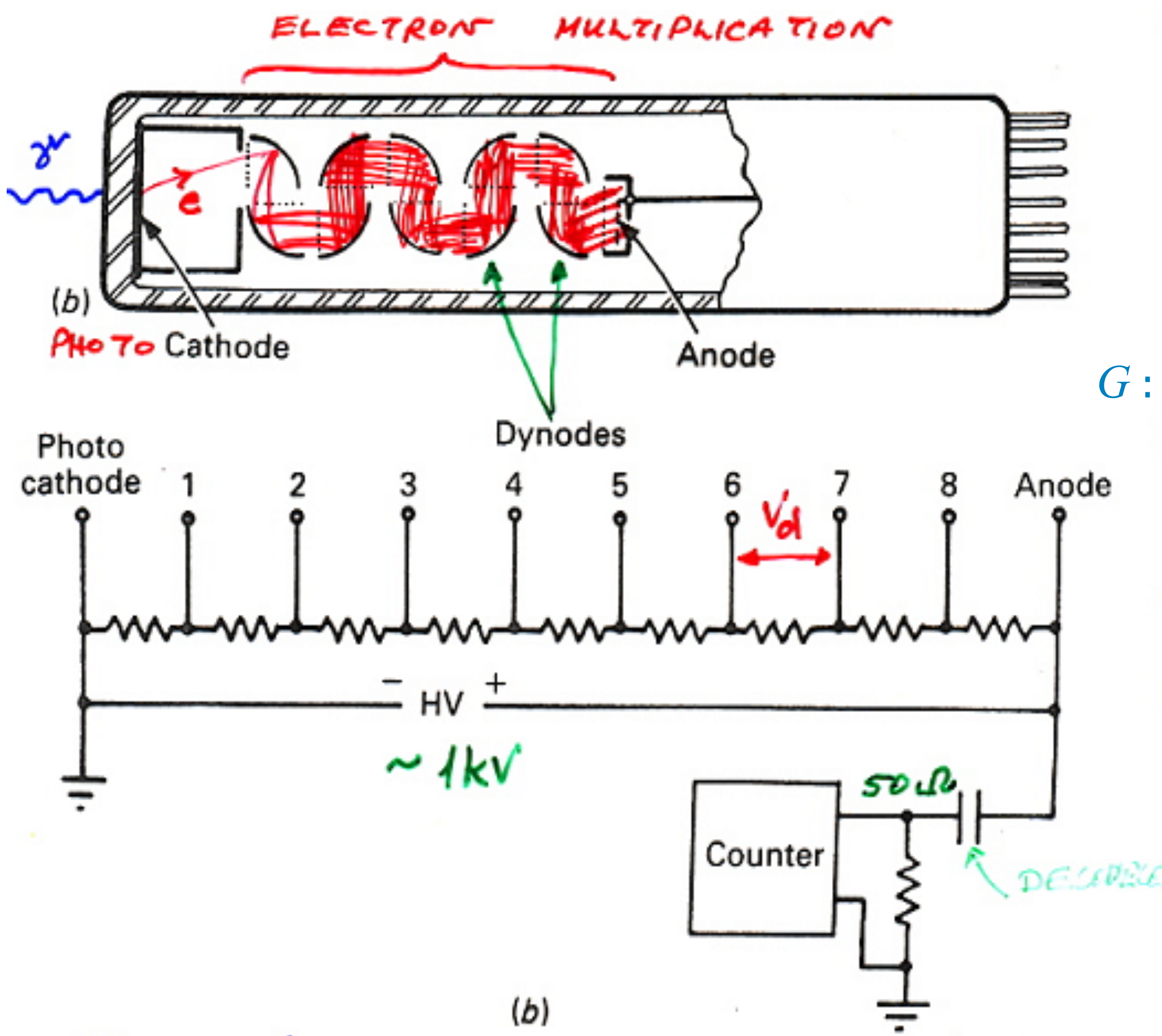


Photomultiplier

$$\text{Gain} = (\text{secondary emission factor } \delta)^N$$

$\delta = kV_d$

number of stages



$G \sim 10^7$ $\quad \dfrac{1 \text{ electron x } 10^7}{10ns} \rightarrow 1mA$

$50\Omega = 50mV$

- Fast
- Low noise
- High gain

PM Sensitivity

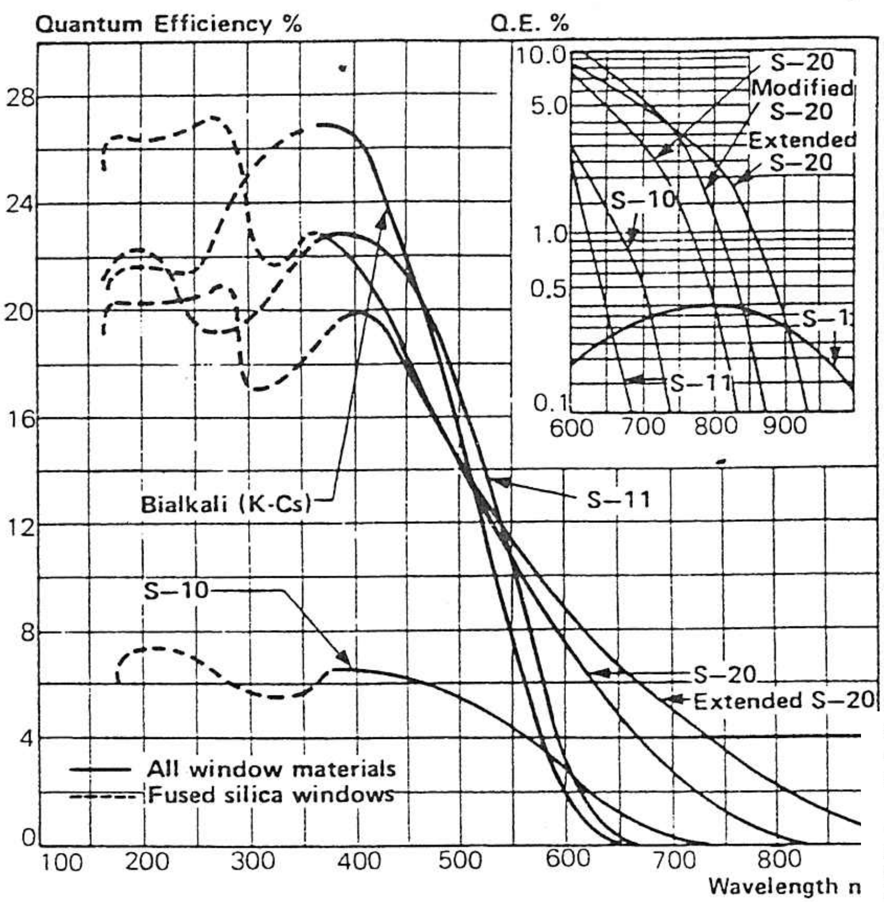
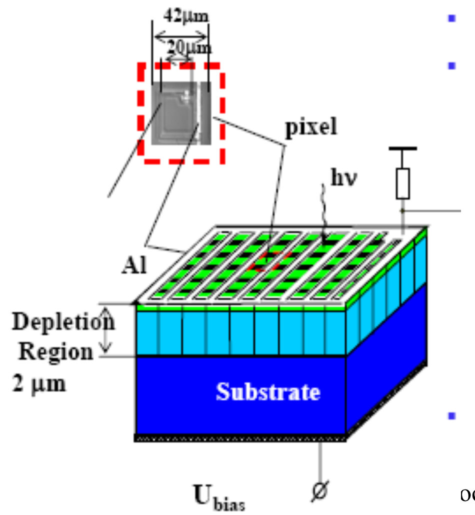


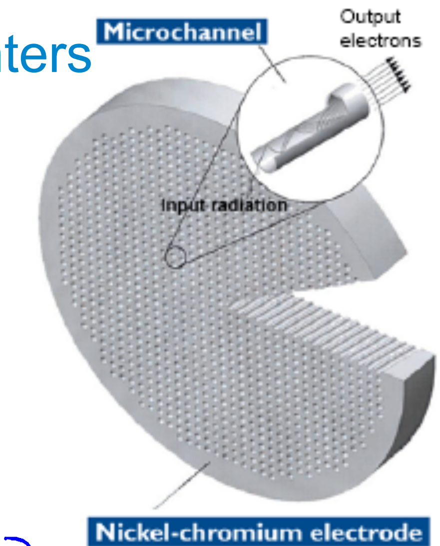
Table 8.1. Photocathode characteristics (from RTC catalog [8.3])

Cathode type	Composition	λ at peak response [nm]	Quantum efficiency at peak
S1 (C)	Ag – O – Cs	800	0.36
S4	SbCs	400	16
S11 (A)	SbCs	440	17
Super A	SbCs	440	22
S13 (U)	SbCs	440	17
S20 (T)	SbNa – KCs	420	20
S20R	SbNa – KCs	550	8
TU	SbNa – KCs	420	20
Bialkali	SbRb – Cs	420	26
Bialkali D	Sb – K – Cs	400	26
Bialkali DU	Sb – K – Cs	400	26
SB	Cs – Te	235	10

Modern Photodetectors

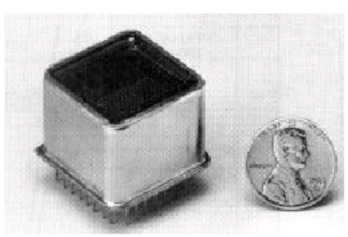
- Micro-channel plates
- Multi-anode pm
- Hybrid pm
- Visible light photon counters





Multi Anode PM

example: Hamamatsu R5900 series.



Up to 8x8 channels.
Size: 28x28 mm^2.
Active area 18x18 mm^2 (41%).
Bialkali PC: Q.E. = 20% at λ_{max} = 400 nm. Gain $\approx 10^6$.