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SCINTILLATORS-SiPM COUPLING

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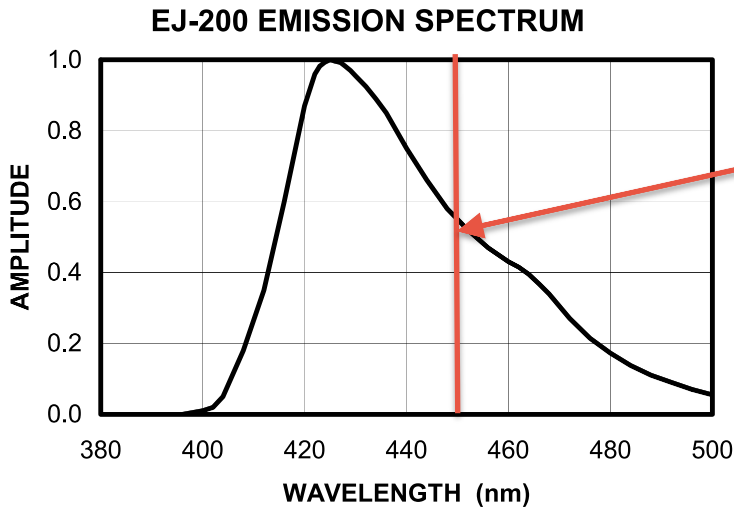
SCINTILLATOR ←→SIPM

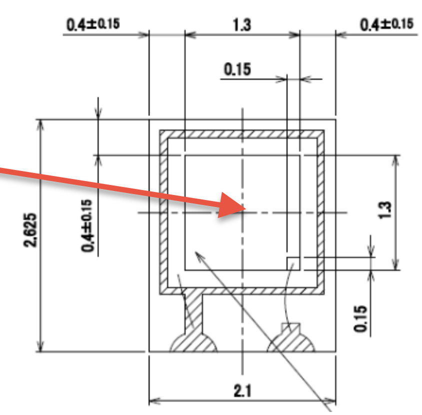
1st PROBLEM: EJ-200 peak emission spectrum do not match S18825 peak sensitivity



S18825 PEAK SENSITIVITY WAVELENGTH

2nd PROBLEM: EJ-200 strip section do not match the S18825 sensitive area

- Scintillation strip section area = 6.4x10 mm^2
- SipM active area = 1.3x1.3 mm^2

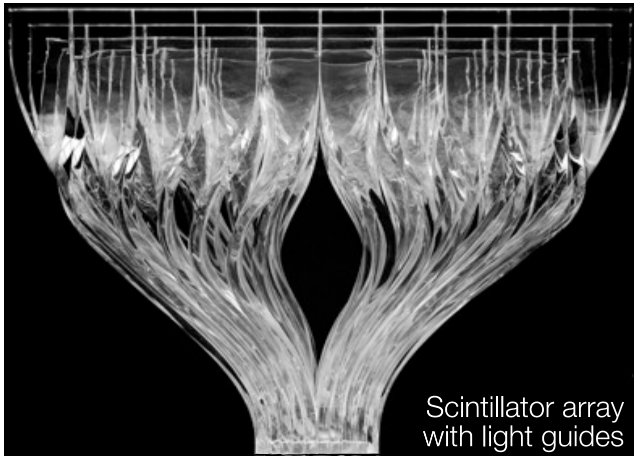


READOUT HAS TO BE ADAPTED TO GEOMETRY AND EMISSION SPECTRUM OF SCINTILLATOR

GEOMETRICAL ADAPTATION → LIGHT GUIDES (I)

PLASTIC (PLEXIGLASS) LIGHT PIPES OFTEN ARE USED WITH PLASTIC SCINTILLATORS TO:

- Provide a PMT mounting surface
- Guide the scintillating light to the photocathode
- Back-off the PMT where the scintillator is in a strong magnetic field
- Minimize pulse height variation



THE COUPLING A SCINTILLATOR TO A PHOTODETECTOR THROUGH A LIGHT GUIDE IS GENERALLY USED TO COUPLE A LARGE AREA CRYSTAL TO A SMALL AREA DETECTOR

- Save money
- Reduce electronic noise when using photodiodes

BUT THE EFFICIENCY OF LIGHT TRANSMISSION IS LIMITED BY

- The angle of total reflection
- The conservation of phase space → $\Delta X \Delta \theta$ (Liouville's theorem)

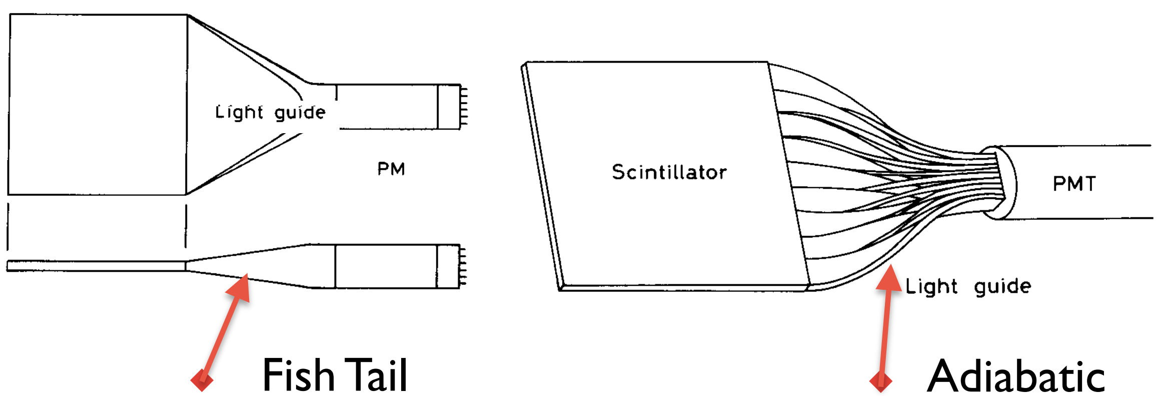
GEOMETRICAL ADAPTATION → LIGHT GUIDES (II)

Conservation of phase space means that the flux of photons per unit area and per unit solid angle is constant throughout a given medium [D. Marcuse, BSTJ 45 (1966) 743, Applied Optics 10/3 (1971) 494]. Consequently, no optical coupling scheme relying on reflection or diffraction alone can transmit photons from a large source to a small detector with full efficiency.

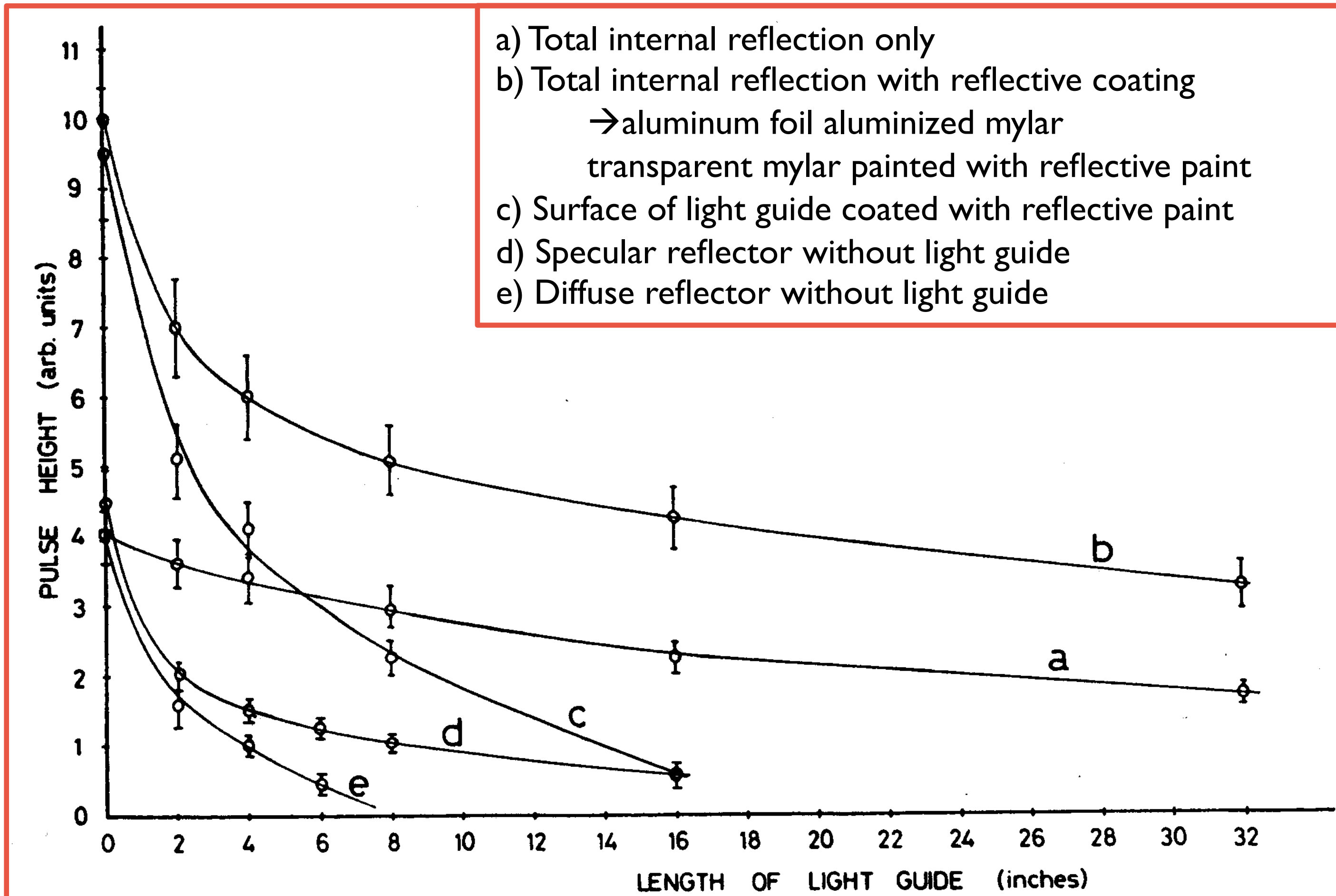
This limitation can be overcome by wavelength shifters, that absorb the incident light and re-emit photons, thereby redefining the phase space element.

TYPICAL LIGHT PIPES GEOMETRIES INCLUDE:

- Right Cylinders - used when the light pipe diameter is the same as the scintillator diameter
- Tapered Cones - are transition pieces between square-to-round or round-to-round cross-section "Fish Tail" - are transition pieces from thin, rectangular cross-sections to round cross- sections
- Adiabatic - provide the most uniform light transmission from the scintillator exit end to the PmT; the cross-sectional areas of the input and PMT faces are equal



GEOMETRICAL ADAPTATION → LIGHT GUIDES (III)

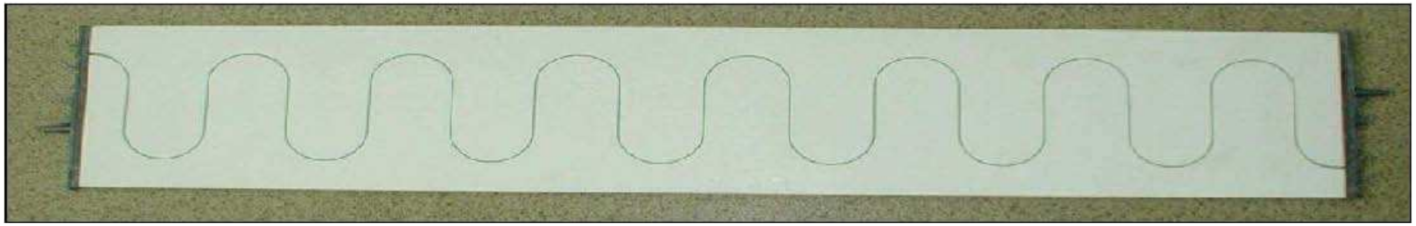


a) Total internal reflection only
b) Total internal reflection with reflective coating
→aluminum foil aluminized mylar
transparent mylar painted with reflective paint
c) Surface of light guide coated with reflective paint
d) Specular reflector without light guide
e) Diffuse reflector without light guide

THE SOLUTION: FIBERS EMBEDDED ON SCINTILLATOR

WLS FIBERS EMBEDDED ON SCINTILLATOR PROS:

- Allow to avoid cumbersome light guide
- Collect scintillation light, shift it to longer wavelength and pipe it to photodetector
- Elude (partially) Liouville Theorem because the shift to longer waveforms correspond to a "cooling" of the light (reduced phase space)



NEVETHELESS BECAUSE LIOUVILLE THEOREM

→ the total area of the cross-section along a light guide cannot be reduced without light losses

The fiber minimum bending radius must satisfy the relation:

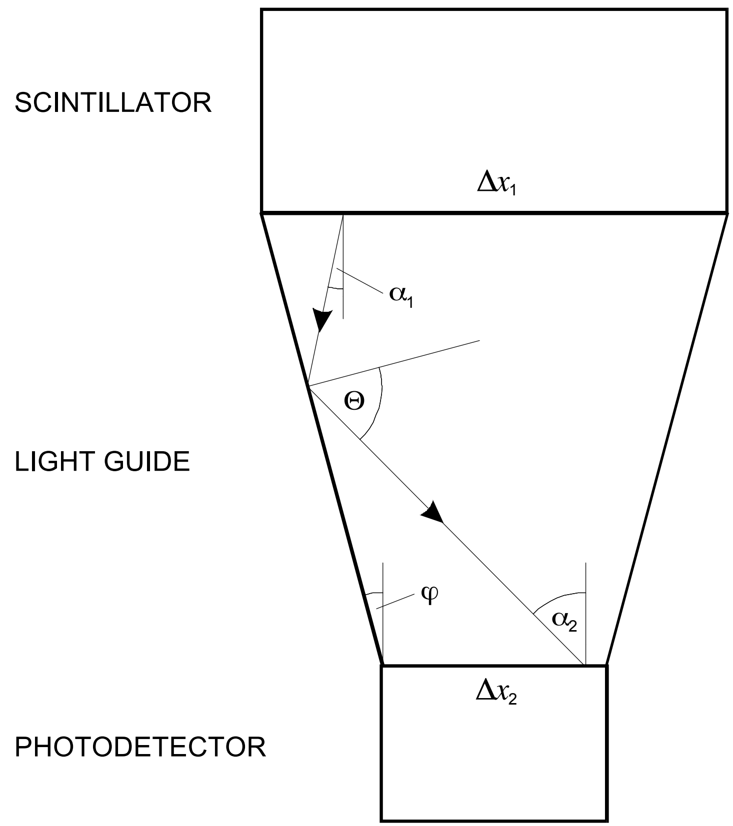
$$n^2 - 1 \geq \left(d/2r + 1 \right)^2$$

- d = fiber diameter
- n = refractive index
- r = bending radius

BIBLIOGRAPHY

[1] J.B. Birks, The Theory and Practice of Scintillation Counting, New York, 1964
[2] G.F. Knoll, Radiation Detection and Measurement, New York, 1989
[3] Sarkis Abrahamian, Fiber Optic training guide
[4] Scintillation Detectors, Particle Detection via Luminescence, Heidelberg University [http://www.kip.uni-heidelberg.de/~coulon/Lectures/Detectors/Free_PDFs/Lecture4.pdf
[5] Scintillation detectors, Spieler [http://www-physics.lbl.gov/~spieler/physics_198_notes/PDF/III-Scint.pdf]
[6] Scintillation + Photo Detection [http://www.helsinki.fi/~www_sefo/accelerators/lectures/acc_exp08_7_091208.pdf]
[7] Organic Scintillation Materials [Saint-Gobain Crystals]

SPARE – TOTAL REFLECTION



TOTAL REFLECTION

- To be reflected the incident angle must be $\sin\Theta \geq \frac{n_{ext}}{n}$

  n_{ext}=refractive index of external medium and n = refractive index of light guide
- If external medium is air n_{ext}= , then $\sin\Theta \geq \frac{1}{n}$
- If light guide is gradually narrowed with an angle φ the

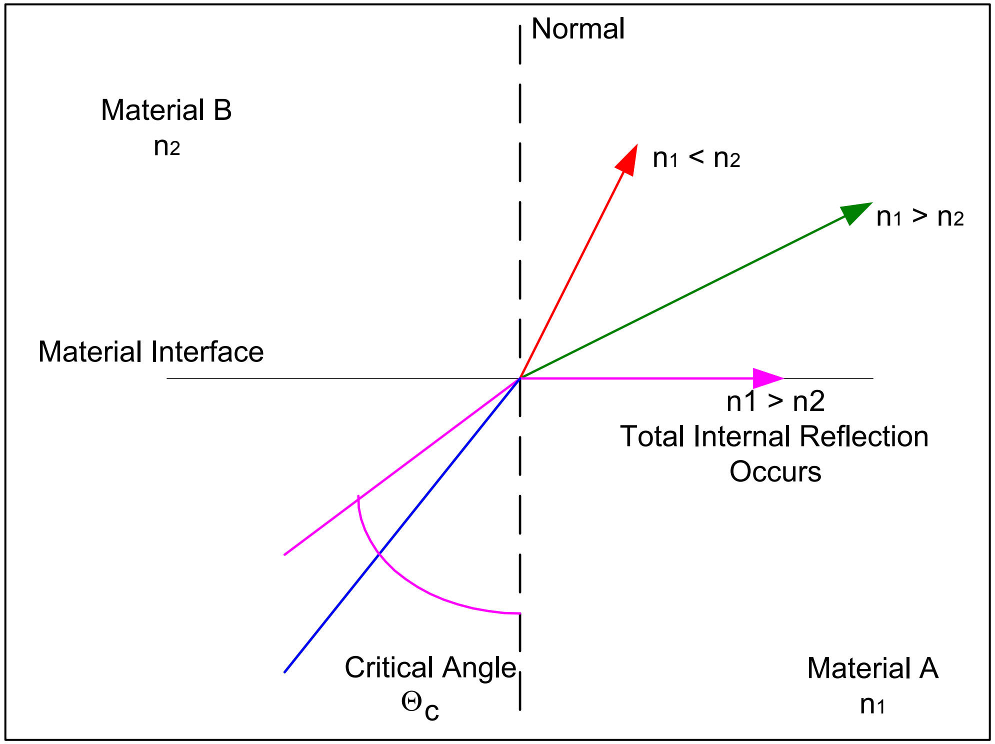
  photon limit angle for total reflection is $\frac{\pi}{2} + \varphi - \Theta$

  (it is also the maximum angle at the light guide output)

SPARE – OPTICAL FIBERS: TOTAL INTERNAL REFLECTION (I)

Behavior of a ray of light passing through two media of different refractive indexes n_1 and n_2

- $n_1 > n_2$: the ray of light is is bent away from from the line perpendicular to the media mating surface
- $n_1 < n_2$: the ray of light is is bent toward the line perpendicular to the media mating surface
- If $n_1 > n_2$ TOTAL INTERNAL REFLECTION occurs and the ray of light is deflected by an angle θ_C travelling along the interface. If the angle is bigger than θ_C the ray is reflected back into the medium.



SPARE – OPTICAL FIBERS: TOTAL INTERNAL REFLECTION (II)

TOTAL INTERNAL REFLECTION → $\theta \geq \theta_C$ and $\theta_C = \arcsin(n_2/n_1)$