SCINTILLATORS-SiPM COUPLING

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

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

- Scintillation strip section area = 6.4x10 mm²
- SipM active area = 1.3x1.3 mm²

**READOUT HAS TO BE ADAPTED TO GEOMETRY AND EMISSION SPECTRUM OF SCINTILLATOR**
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)
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
III. Scintillation Detectors

- Variation of pulse height with length of light guide
  - 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

Although peak light output can be improved by reflective coatings, this only obtains with short light guides. Critical that surface of light guide be smooth.
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)

NEVERTHELESS 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:

\[ n^2 - 1 \geq \left( \frac{d}{2r} + 1 \right)^2 \]

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

[http://www.kip.uni-heidelberg.de/~coulon/Lectures/Detectors/Free_PDFs/Lecture4.pdf]
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TOTAL REFLECTION

- To be reflected the incident angle must be \( \sin \Theta \geq \frac{n_{ext}}{n} \)
  
  \[ n_{ext} = \text{refractive index of external medium and } n = \text{refractive index of light guide} \]

- If external medium is air \( n_{ext} = 1 \), then \( \sin \Theta \geq \frac{1}{n} \)

- If light guide is gradually narrowed with an angle \( \varphi \) the photon limit angle for total reflection is \( \frac{\pi}{2} + \varphi - \Theta \)

(it is also the maximum angle at the light guide output)
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 bent away from the line perpendicular to the media mating surface.
- $n_1 < n_2$: the ray of light 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 $\theta_C$ travelling along the interface. If the angle is bigger than $\theta_C$ the ray is reflected back into the medium.
Light is confined within the core of the optical fiber through total internal reflection. To understand the phenomenon of total internal reflection and how it is responsible for the confinement of light in an optical fiber consider a ray of light incident on the fiber core as shown in figure 4.

Light enters the core of the optical fiber and strikes the core/cladding interface at an angle $\theta$. If this angle is greater than the critical angle (i.e. $\theta \geq \theta_c$ where $\theta_c = \arcsin(n_2/n_1)$) then the ray will reflect back into the core thus experiencing total internal reflection. This ray of light will continue to experience total internal reflection as it encounters core/cladding interfaces while propagating down the fiber.

\[
\text{TOTAL INTERNAL REFLECTION} \rightarrow \theta \geq \theta_c \text{ and } \theta_c = \arcsin(n_2/n_1)
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