Elettra Sincrotrone Trieste

The ESS WS OFE

Sandi Grulja

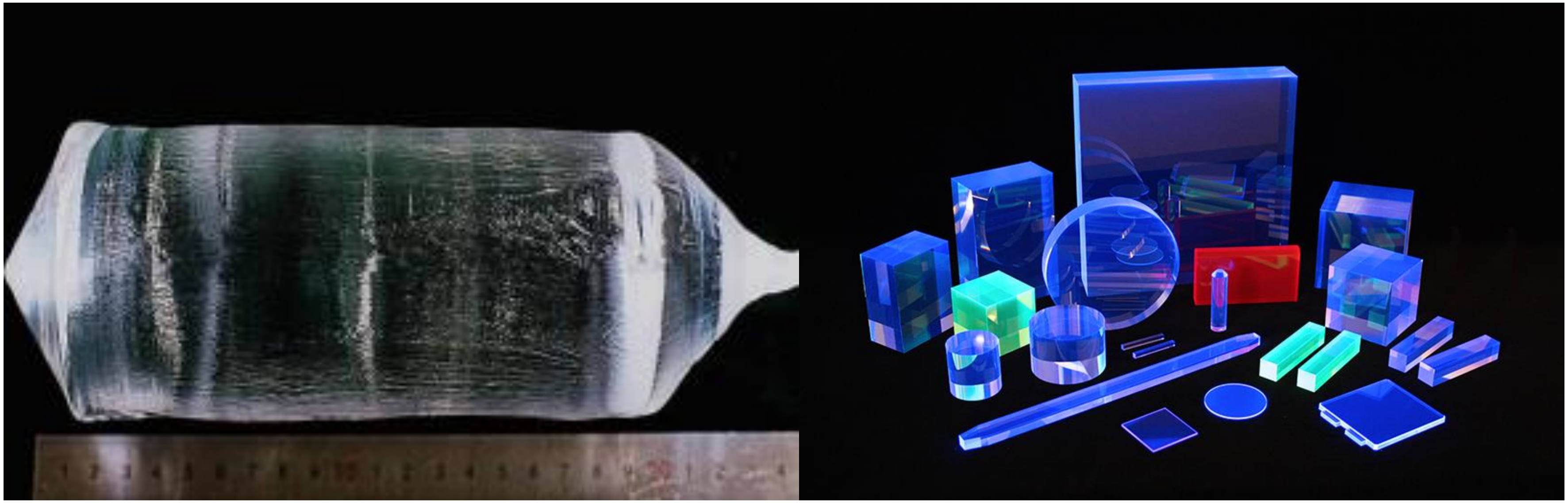
Themes:

- Scintillator – physics and application
- OFE assembly and electric test

Scintillators

What are they ?

A scintillator is a luminescent material when struck by an incoming particle, absorb its energy and re-emit the absorbed energy in the form of light.

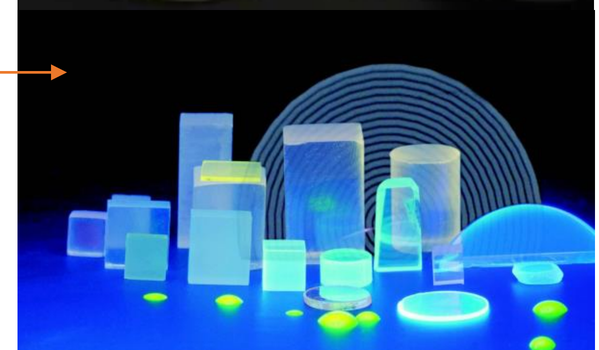


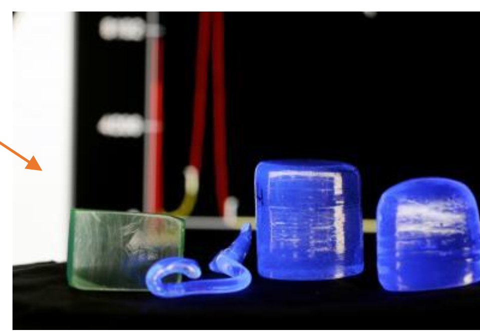
Depending on the material the relaxation from excited state back down to lower states is delayed from a few nanoseconds to hours. This is also called after-glow process

Scintillators

Types of scintillators

- Organic crystals
  - Aromatic hydrocarbon - C_6H_6
  - Anthracene - C14H10
  - Stilbene - C14H12
  - Naphthalene - C10H8
- Organic liquids
- Plastic scintillators
  - Polyethylene naphthalate - $C_{14}H_{10}O_4$
- Inorganic crystals
  - Thallium – sodium iodide – NaI (Tl)
- Gaseous scintillators
- Glasses

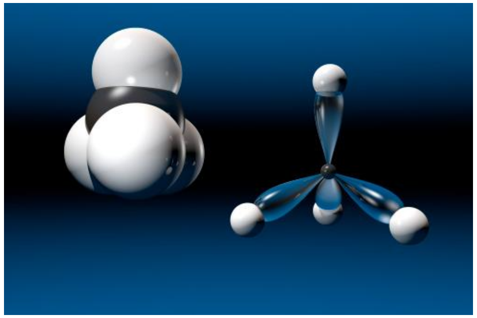


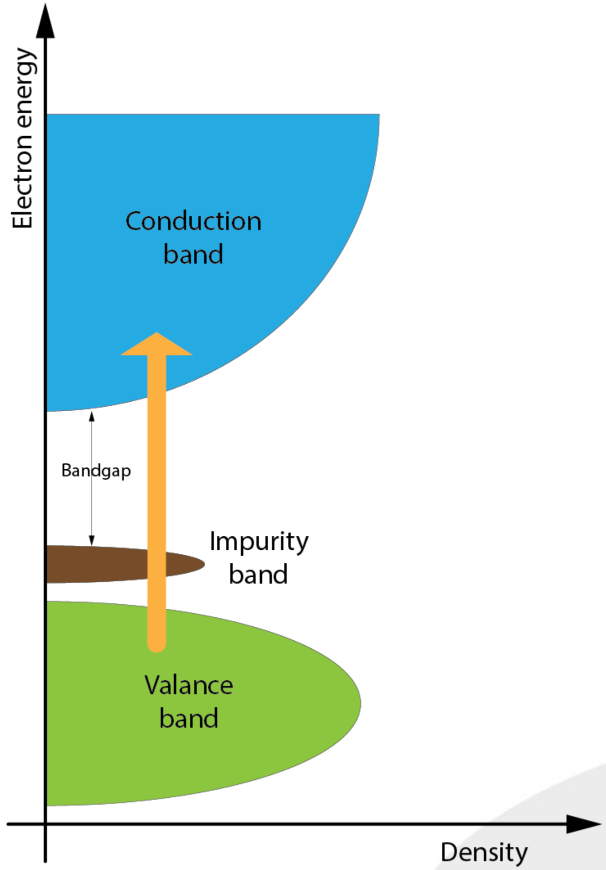


Physics of Scintillations

In organic scintillators transitions of free valence electrons associated with molecule produce scintillation light.
The struck particle excite molecule electrons. These excitations immediately decay without the emission of radiation (internal degradation) and emit a scintillation photon or fluorescence.

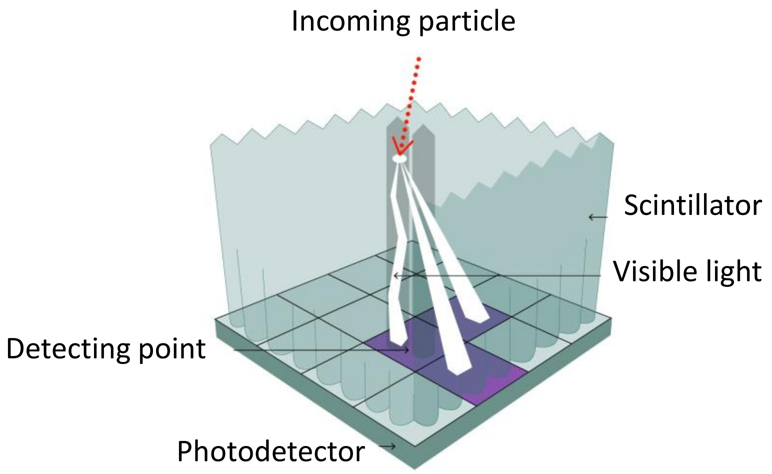
In inorganic scintillators the scintillation process is due to the electronic band structure in crystals and not molecular. The particle that struck the crystal excite an electron from the valence band to conduction band or to the band below the conduction band - energy gap. This leaves a hole behind in the valence band.
The electron - hole pairs freely wander thru the crystal until they are captured by impurity. In this way de-excite and emit scintillation light. The activator or impurities are chosen so that the emitted light is in the visible range where photodetectors are effective.

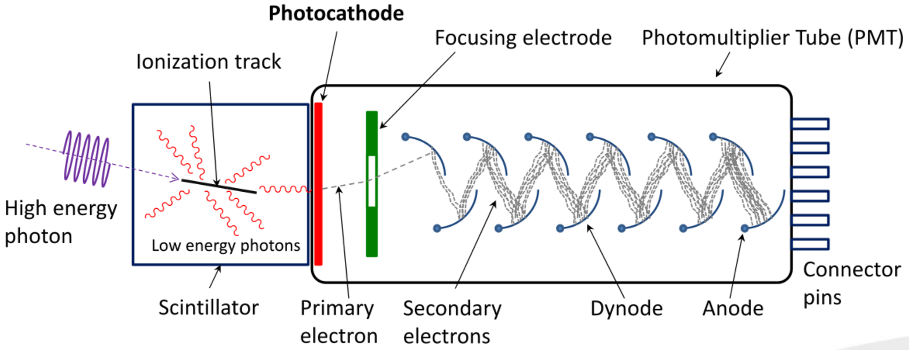




Scintillation detector

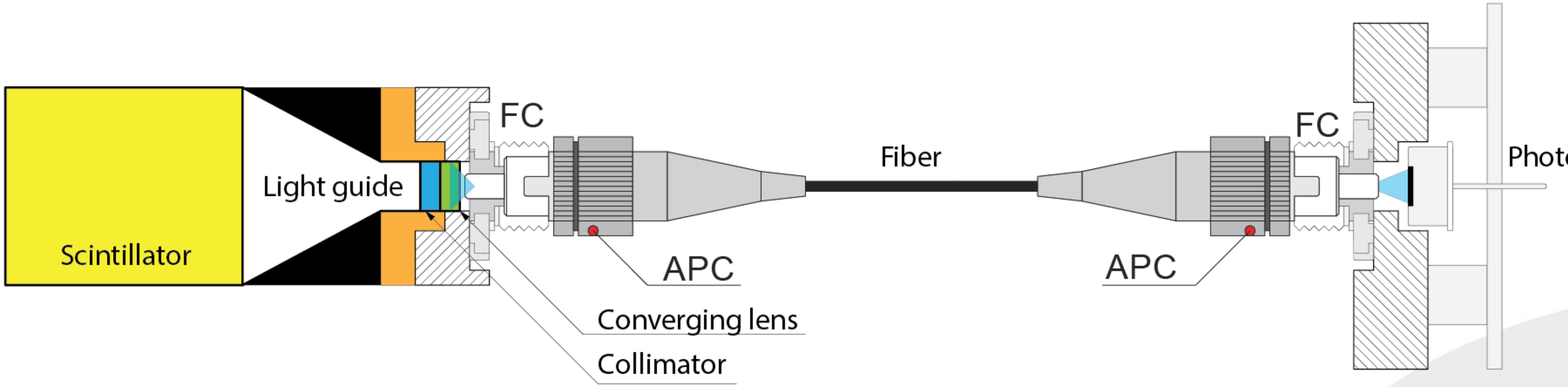
- A scintillation detector is a union of scintillator and electronic light sensor.
- The light emitted by the scintillator is absorbed by the silicon photodiodes.
- Incoming photons excite charge carriers directly in the silicon.
- The silicon carriers or the photodiode current is converted and amplified to electric signal.
- Reversed biased avalanche photodiodes with sufficient voltage operate in avalanche mode and are sensitive to a single photons.





Light guides

Once the light is produced in a scintillator must be collected and transported to the optic detector. For this purpose Optic Light Guides are used to transmit illumination. OLG interface with scintillator to transfer light in a usable manner.



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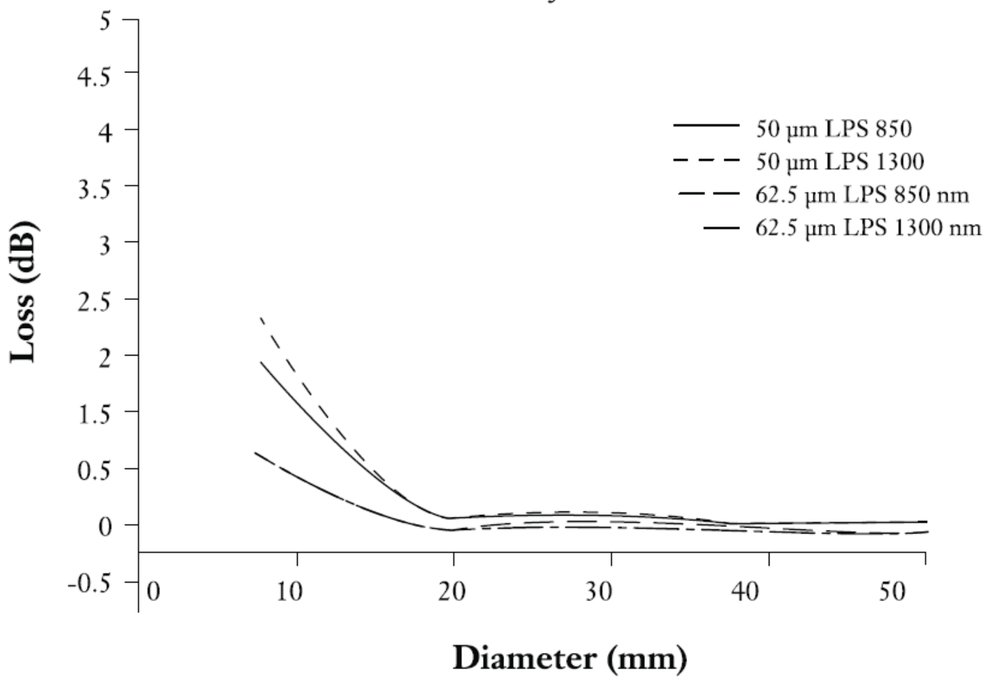
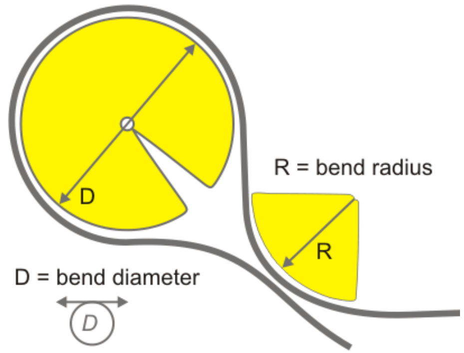
Fibers

Attenuation or loss in optical fibers basically refers to the loss of power. During transit, light loses some photons, this reduce their amplitude. Attenuation is specified in decibels per kilometer. The degree of attenuation depends on the wavelength of light transmitted.

Comparison of 50 and 62.5 μm Multimode Fiber Bend Loss using FOTP 62 Method A with Launch Procedure B of FOTP 50



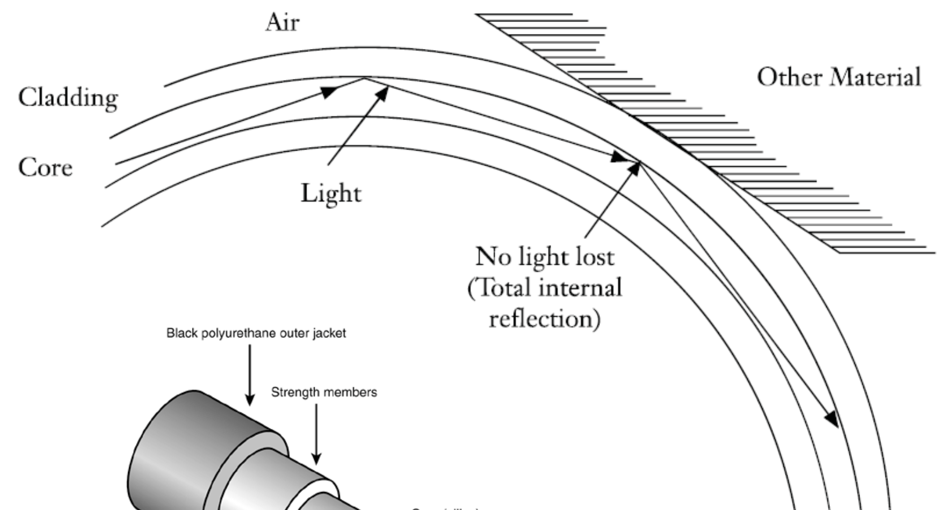
Cable bend radius

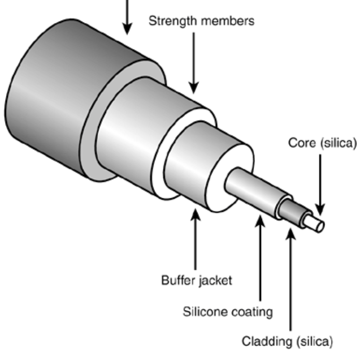


Normally a banding radius is 15 x the fiber diameter

$$n_c^2(r,\theta) = n^2(r) + \frac{2n_1^2}{R}\, r\cos\theta$$

Local refractive index

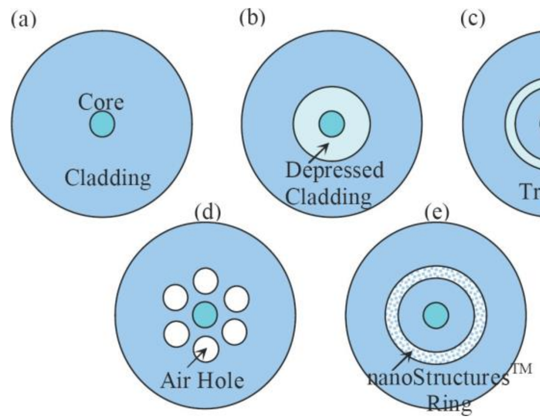




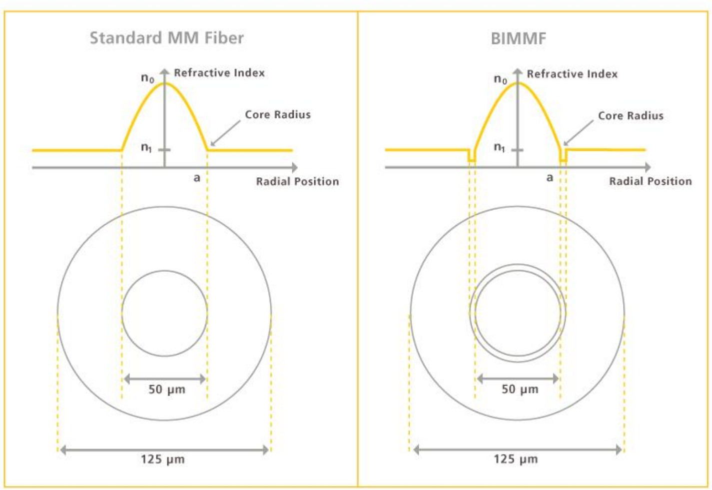
DNV·GL ISO 9001

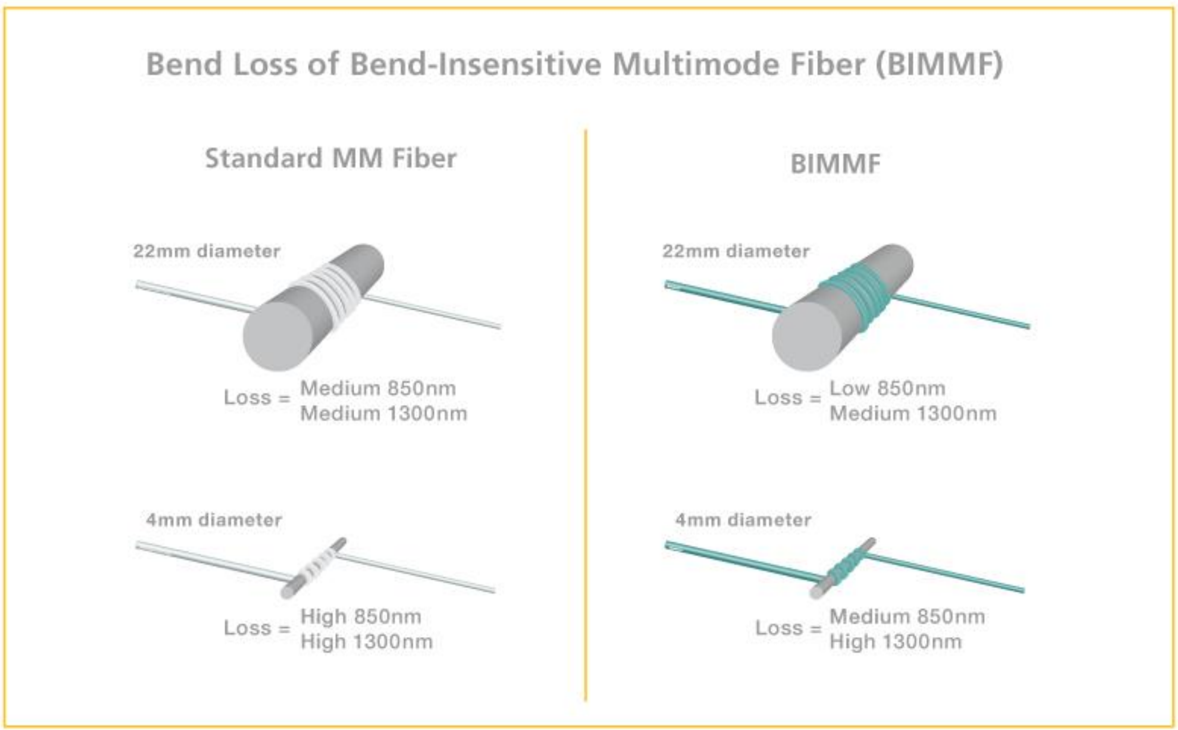
DNV·GL OHSAS 18001

Bend insensitive optical fibers



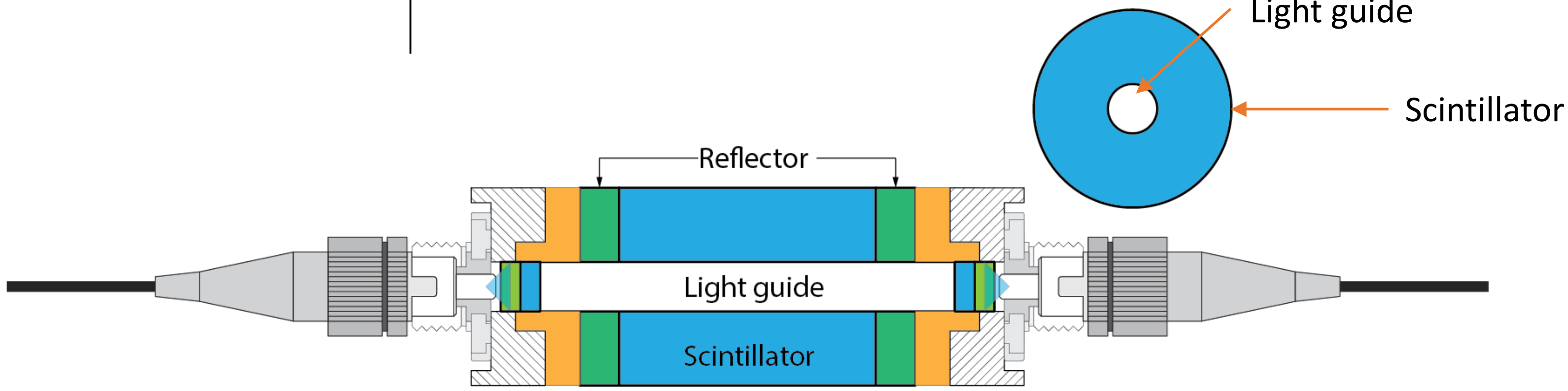
Fiber designs for reducing bending loss: (a) reduced mode field diameter (MFD) design; (b) depressed-cladding design; (c) trench fiber design; (d) hole-assisted design; and (e) nanoStructures design.





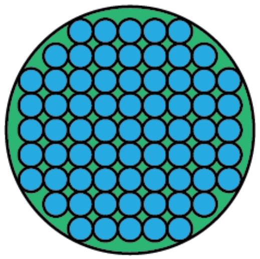
The same as standard multimode but there is an added layer of glass between the core and the cladding

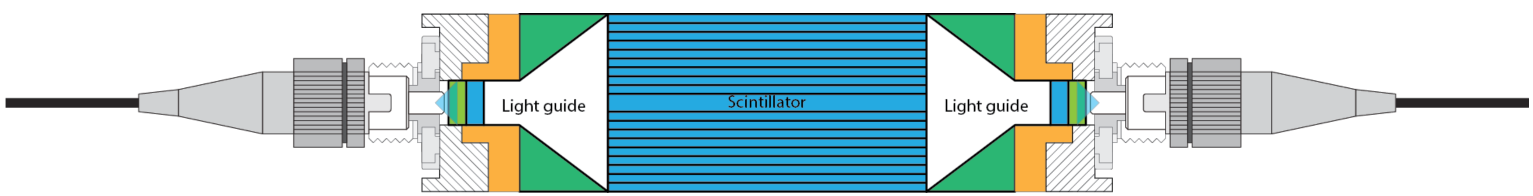
Scintillators and light guides coupling



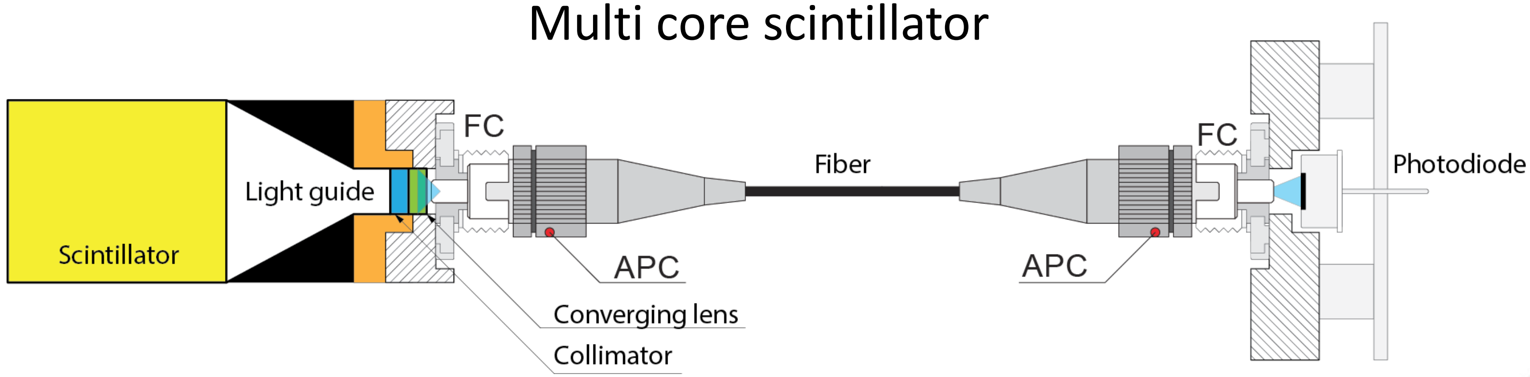
Single cylinder scintillator

Array of scintillators in form of cylinder





Multi core scintillator



Rectangular scintillator

Scintillators and bend insensitive optical fibers manufacturers

Bend insensitive optical fibers

http://www.fujikura.co.jp/eng/

https://www.corning.com/worldwide/en.html

https://www.newport.com/f/bend-insensitive-single-mode-fibers

Scintillators and light guides

http://www.crystals.saint-gobain.com/products/crystal-scintillation

http://www.eljentechnology.com/

http://www.crytur.com/

http://www.amcrys.com/

http://www.canberra.com/products/detectors/scintillation-detectors.asp

http://www.made-in-china.com/manufacturers/scintillator.html

The ESS WS Optical Front End

Sandi Grulja

Optical Front End

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Technical specifications

OFE tech specifications:

- low-voltage noise JFET-input stage

- Power supply	-5V to +5V
- High Gain Bandwidth Product	1.6 GHz
- High Bandwidth	275 MHz
- Slew Rate	700 V/µs
- Operating Temperature Range	–40° C to 85° C
- Low-Input Offset Voltage	±250 µV
- Low-Input Bias Current	2 pA
- Low-Input Voltage Noise	4.8 nV/√Hz
- Input noise current	1.8 pA/√Hz
- High-Output Current	70 mA
- Output voltage range	0 to - 4.5 V
- Optical power sensitivity	1nW
- Optical power range	1nW – 60uW

Si Photo Diode (PD) Hamamatsu S1226-44BQ

- Photo sensitivity area	3.6 x 3.6 mm
- Operating temperature	-20 to +60 deg. C
- Spectral response range	190 to 1000 nm
- Peak sensitivity wavelength	720 nm
- Photosensitivity	0.36 A/W
- Dark current	10 pA
- Terminal capacitance	500 pF

Avalanche Si Photo diode (APD) Hamamatsu S5544

- Photo sensitivity area	fi 3.0 mm
- Operating temperature	-20 to +60 deg. C
- Spectral response range	200 to 1000 nm
- Peak sensitivity wavelength	620 nm
- Photosensitivity	0.42 A/W
- Dark current	Typ 1 nA max 30 nA
- Terminal capacitance	120 pF
- Break down voltage	typ 150V max 200V

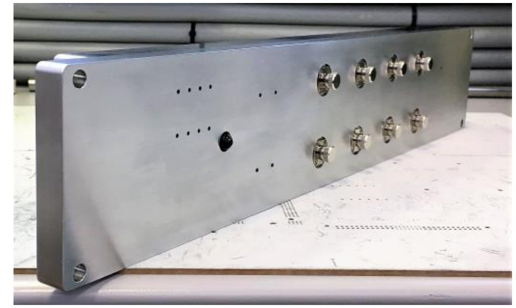
Power Supply

- Main power supply (BE)	-5V / +5V
- Main current max	-100 mA / +200 mA
- Bias High Voltage (BE)	0 V to max +200V must be software limited to +150V
- Internal Bias High Voltage	0 V to max +200V

Mechanical specifications

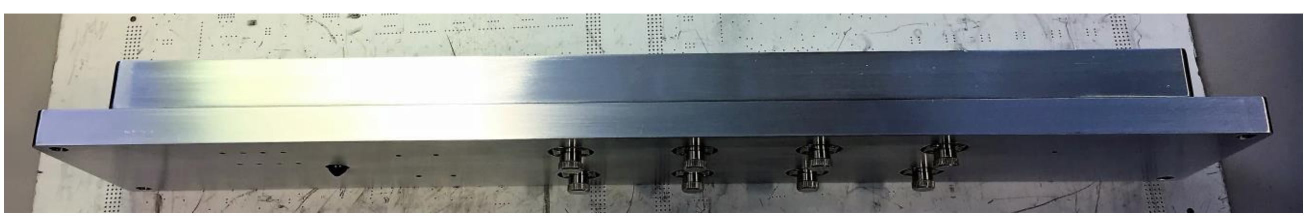
- Aluminum milled unibody case	
- Mechanical dimension	19 inch 1U rack mount case W-483mm H-88mm D-50mm
- Weight	1934.35 g

Optical Front End



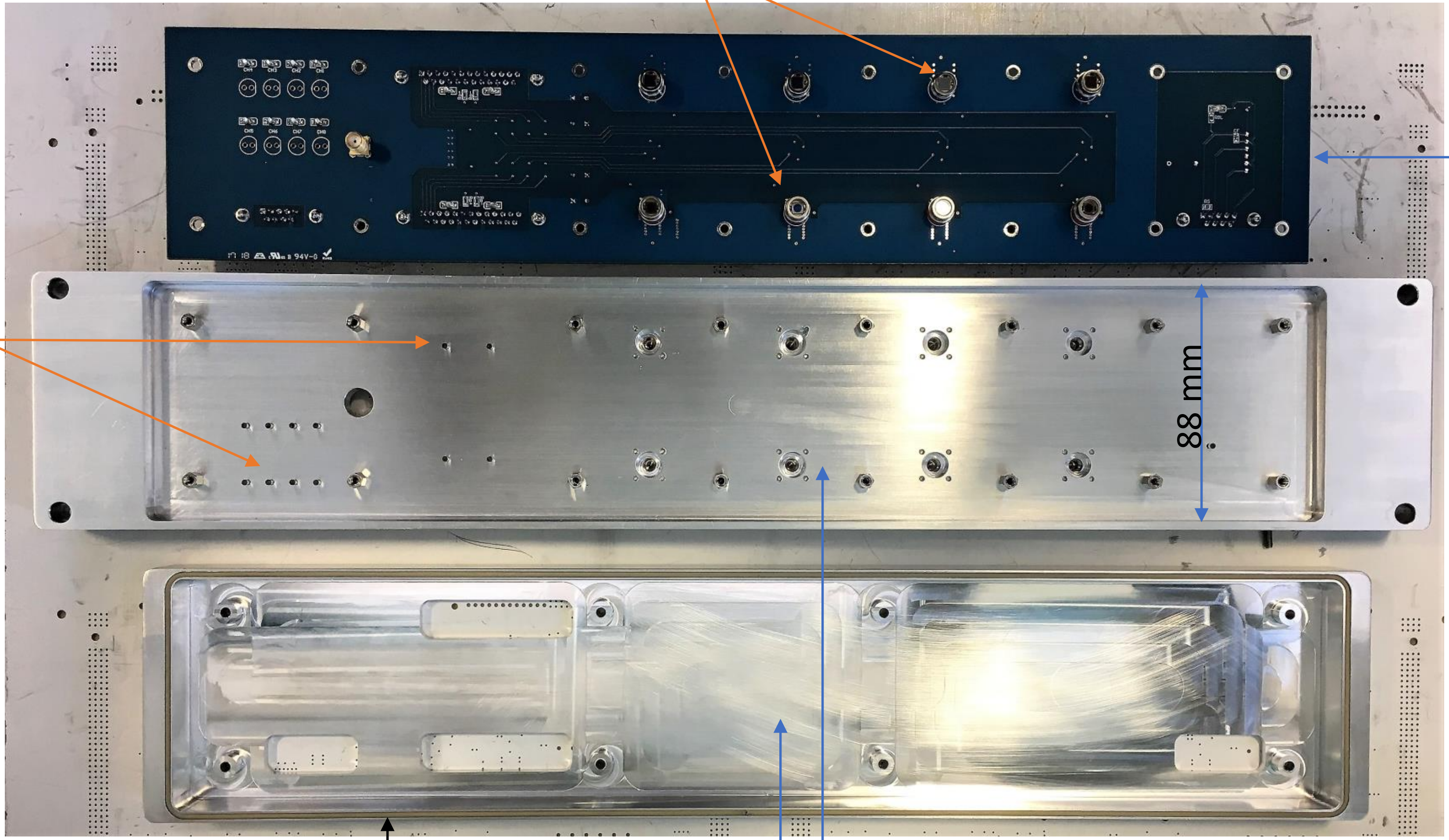
Aluminum milled body

Connections on the back



Slim and compact design

Optical Front End hardware

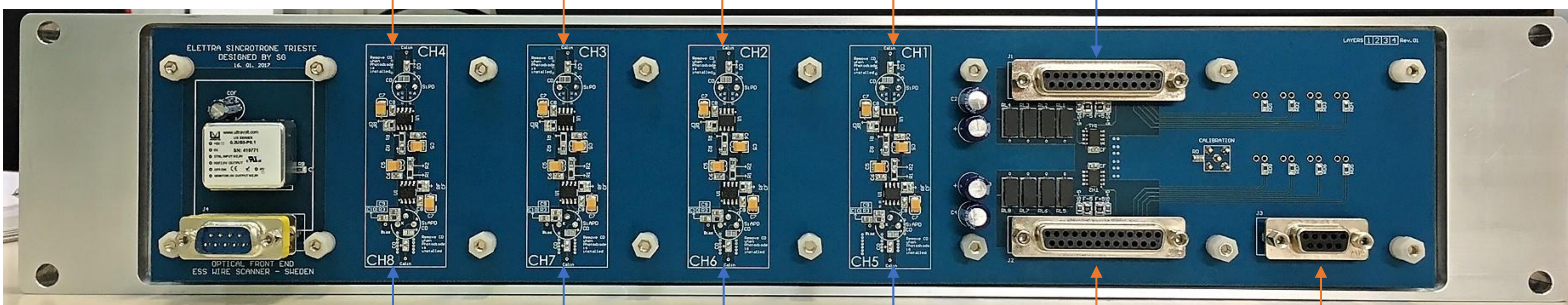


Optical Front End hardware

Assembled OFE electronics in Aluminum milled body

SiPD amplifier

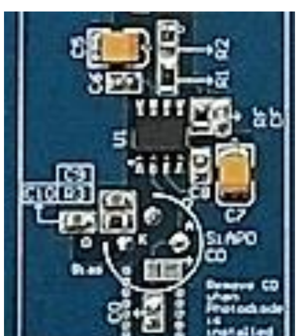
Back End controlled PS, CH selector, and Signal Output



Internal HV for biasing voltage controlled source

SiAPD amplifier

Back End controlled PS, HV biasing, CH selector, Signal Output and Temp measurement



Assembled detail

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Optical Front End light measurement

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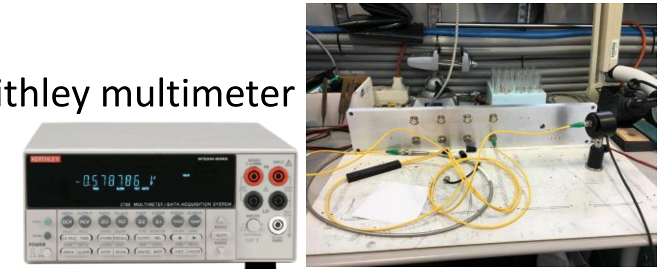
Keithley multimeter



With SiPD 1nW light power easily measured

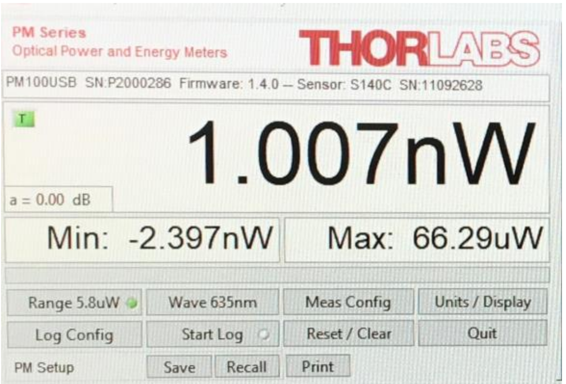
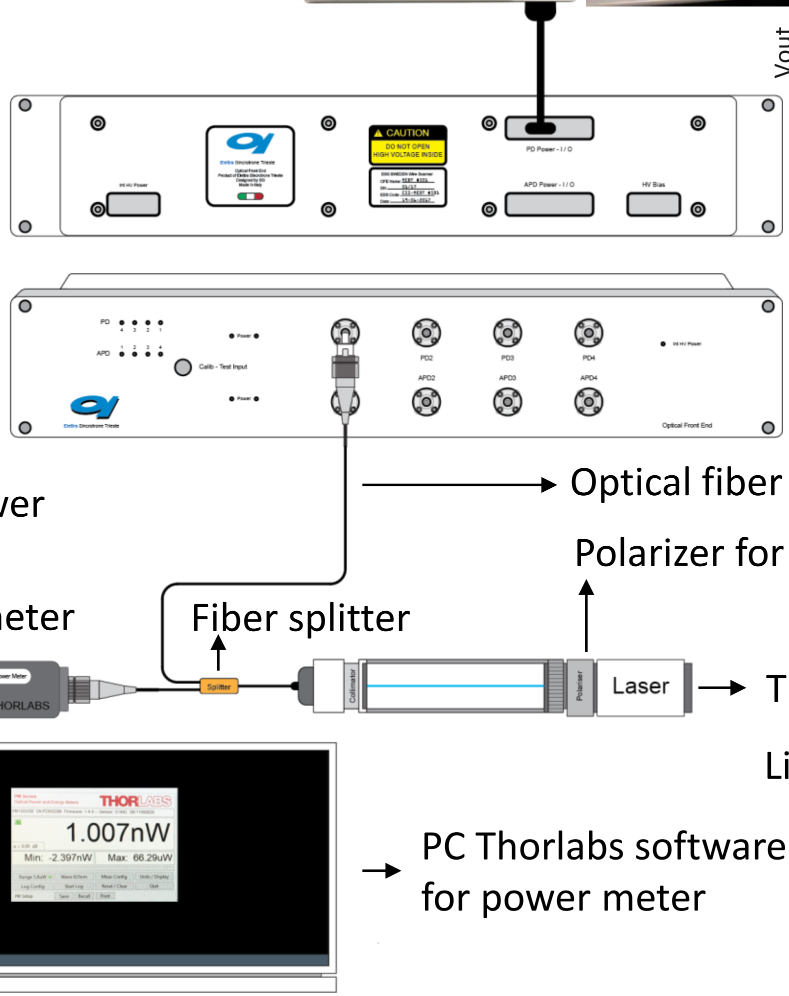


Image of the measured light power



Optical fiber

Polarizer for light power regulation

Thorlabs power meter

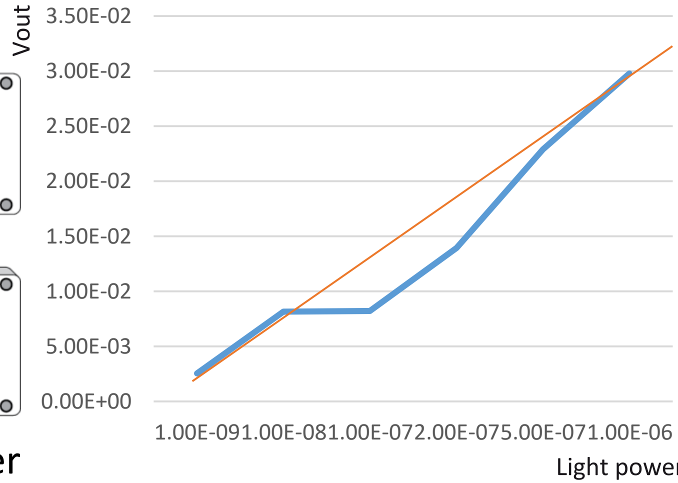
Fiber splitter

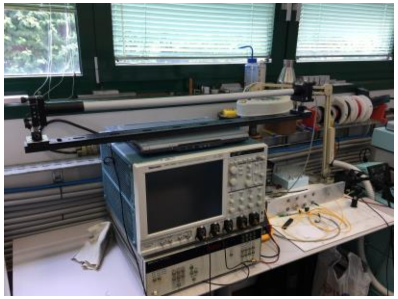
Thorlabs 1 mW - 670 nm laser

Light power from 1nW to 60 uW

PC Thorlabs software for power meter

SiPD output





Thank you !