Scintillation Products

Scintillating Optical Fibers

SAINT-GOBAIN
CRYSTALS

Plastic Scintillating Fibers

Saint-Gobain Crystals manufactures a variety of plastic scintillating, wave-length-shifting and light-transmitting fibers used for research and industry.

Scintillating fibers are well-suited for such applications as:

- Neutron imaging
- Particle discrimination
- Calorimeters
- Cosmic ray telescopes
- Real-time imaging systems
- Flow cells
- Tracking detectors

Single-clad Fibers Properties

Core material	Polystyrene
Core refractive index	1.60
Density	1.05
Cladding material	Acrylic
Cladding refractive index	1.49
Cladding thickness, round fibers	3% of fiber diameter
Cladding thickness, square fibers	4% of fiber size
Numerical aperture	0.58
Trapping efficiency, round fibers	3.44% minimum
Trapping efficiency, square fibers	4.4%
No. of H atoms per cc (core)	4.82×10^{22}
No. of C atoms per cc (core)	4.85×10^{22}
No. of electrons per cc (core)	3.4×10^{23}
Radiation length	42 cm
Operating temperature	-20°C to +50°C
Vacuum compatible	Yes

Multi-clad Fibers Properties

Second cladding material	Fluor-acrylic
Refractive index	1.42
Thickness, round fibers	1% of fiber diameter
Thickness, square fibers	2% of fiber size
Numerical aperture	0.74
Trapping efficiency, round fibers	5.6% minimum
Trapping efficiency, square fibers	7.3%

Standard Fibers, Single-clad –

Our standard fibers consist of a polystyrene-based core and a PMMA cladding as diagrammed on page 4. External EMA (optional) is often used to eliminate optical crosstalk.

The scintillating core contains a combination of fluorescent dopants selected to produce the desired scintillation, optical and radiation-resistance characteristics. Often, one property is enhanced while another is mildly compromised. In small fibers ($\leq$ 0.5mm), the fluor concentration is increased, usually at the expense of light attenuation length.

Scintillation efficiency is generally kept near maximum, which for BCF-10, BCF-12 and BCF-20 is 2.4% (nominal). This means that these fibers yield about 8,000 photons per MeV from a minimum ionizing particle. The trapping efficiency, however, permits the collection of less than 4% of the photons for passage down the fiber.

Multi-clad Fibers –

This special class of fibers has a second layer of cladding that has an even lower refractive index and, thus, permits total internal reflection at a second boundary. The additional photons guided by multi-clad fibers increase the output signal up to 60% over conventional single-clad fibers. All of Saint-Gobain Crystals' fibers can be supplied in either single-clad or multi-clad variations.

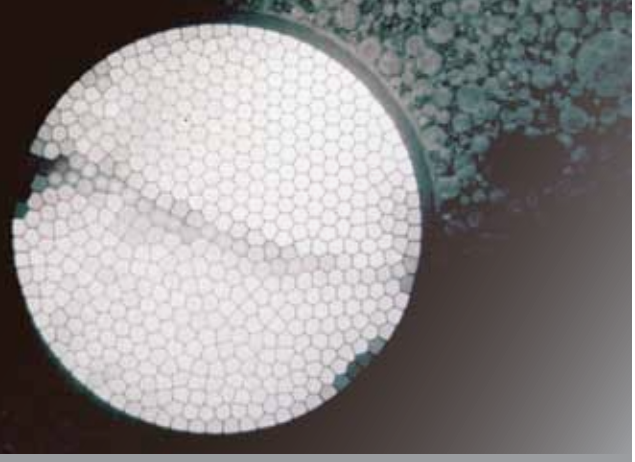
Product Development Timeline –

1989 Introduced various formulations of fibers to the already established plastics product line. Developed clad, plastic scintillating fiber capability.

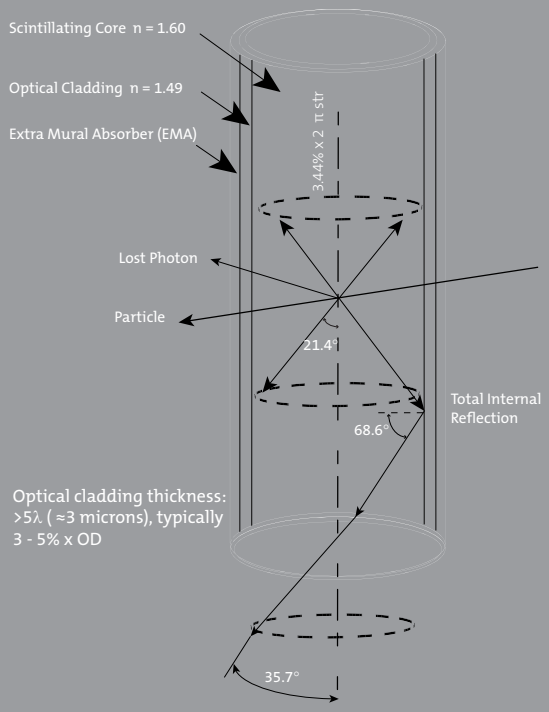
1991 Development of plastic fiber arrays.

1992 Development of blue-emitting fibers with enhanced radiation resistance and green-emitting fibers with fast decay times.

2000 Development of new techniques for specialized fiber arrays.



A Typical Round Scintillating Fiber



Optical cladding thickness: >5λ (≈3 microns), typically 3 - 5% x OD

Optical Cladding –

PMMA (polymethylmethacrylate, $C_5H_8O_2$) is the standard cladding material for Saint-Gobain Crystals' fibers. It has a density of 1.2 g/cc and a refractive index of 1.49. Standard thicknesses are:

- Round fiber, ≥0.20mm diameter = 3% of fiber OD
- Square fiber, 0.20mm to 3mm = 4% of fiber side
- Square fiber, ≥ 3.5mm = 2% of fiber side

The refractive indices of the core and cladding and the cross section of the fiber determine the trapping efficiency.

In round fibers, the trapping efficiency also depends on the distance between the fiber axis and the scintillation event. The trapping efficiency of Saint-Gobain Crystals' round fibers ranges from 3.4% for events occurring at the fiber axis to ~7% for events ne.. the core-cladding interface. For square fibers, the trapping efficiency is 4% and is independent of the scintillation event's location in the fiber.

EMA (Extra Mural Absorber) –

White or black coatings may be applied to the outer fiber surface primarily to eliminate crosstalk among closely packed fibers. Our coatings are typically 10 to 15 microns thick.

An EMA coating decreases the overall signal intensity obtained from a fiber, irrespective of its length. This effect is greatest with black EMA, as well as with short fibers. The coating can interfere with useful light-piping in the cladding. Black EMA applied at the near end of fibers can be used to flatten out position dependent response. White EMA is used in the construction of short fiber imaging bundles.

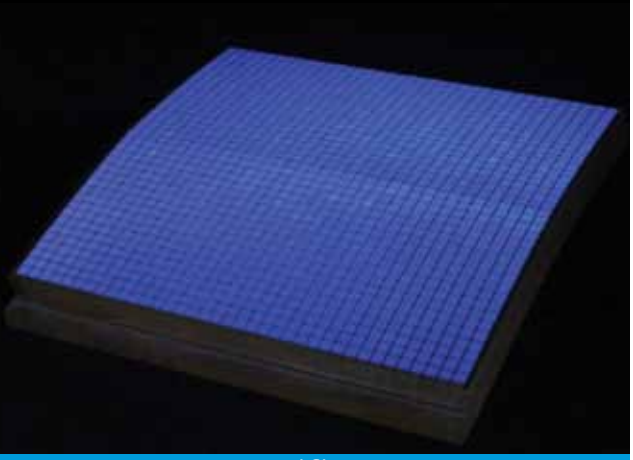
Standard Sizes and Formulations –

Standard sizes range from 0.25mm to 5mm square or round cross sections. We can supply fiber as pre-cut straight canes or on spools (for the smaller cross sections), as well as as an assembly. Below are the properties of our standard fiber formulations.

Specific Properties of Standard Formulations

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	1/e Length m*	# of Photons per MeV**	Characteristics / Applications
BCF-10	blue	432	2.7	2.2	~8000	General purpose; optimized for diameters >250µm
BCF-12	blue	435	3.2	2.7	~8000	Improved transmission for use in long lengths
BCF-20	green	492	2.7	>3.5	~8000	Fast green scintillator
BCF-60	green	530	7	3.5	~7100	3HF formulation for increased hardness
BCF-91A	green	494	12	>3.5	n/a	Shifts blue to green
BCF-92	green	492	2.7	>3.5	n/a	Fast blue to green shifter
BCF-98	n/a	n/a	n/a	n/a	n/a	Clear waveguide

* For 1mm diameter fiber; measured with a bialkali cathode PMT
** For Minimum Ionizing Particle (MIP), corrected for PMT sensitivity

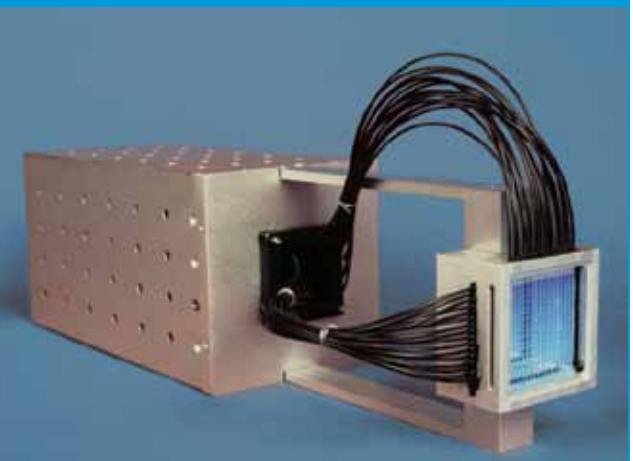


Focused fiber array

Types of Fiber Assemblies Available –

- Single ribbons as wide as 300mm and as long as 3200mm
- Multilayered ribbons up to 4 layers thick
- Coherent imagers of round or square fiber
- Ribbons with precision alignment to MA-PMT's
- Crossed fiber arrays
- Flow cells
- Detectors with long, flexible sheathed bundles

Beam profile monitor with orthogonal fiber ribbons



Quality Control – Attenuation Length Measurement

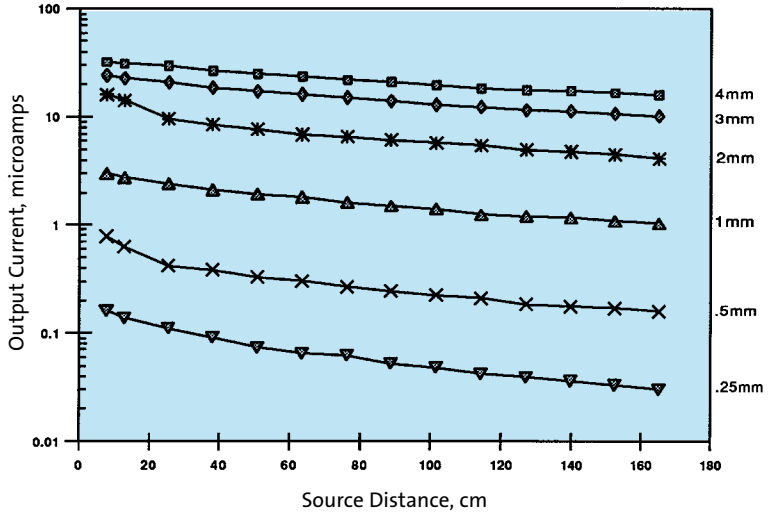
Saint-Gobain Crystals' fiber test station is capable of scanning fiber samples up to five meters in length.

In the standard test, one end of a three meter sample is polished and held in a fixture so that the polished end butts against the window of an end-on, bialkali photocathode photomultiplier tube. The other end is rough cut and blackened to eliminate back reflections.

The test station is equipped with an ^{90}Sr beta source that excites the fiber. A precision track and servo motor insure a fixed geometry and position control to 1mm. The signals from the PMT are digitized and recorded by the computer.

Derivation of the 1/e length is through a least squares analysis of data points 1 to 3 meters from the PMT. The results are reproducible within 5%.

Typical Output Current for Various Fiber Diameters
(Blue fiber with bialkali cathode PMT)

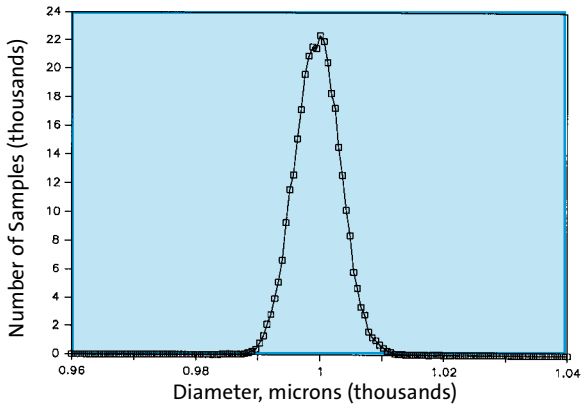


Quality Control – Dimensional Consistency

All pulling towers are equipped with laser-gauge size measurement and a positive feedback control system. The standard tolerance for round fibers is 2% of the fiber diameter, 3% of the fiber width for square fibers.

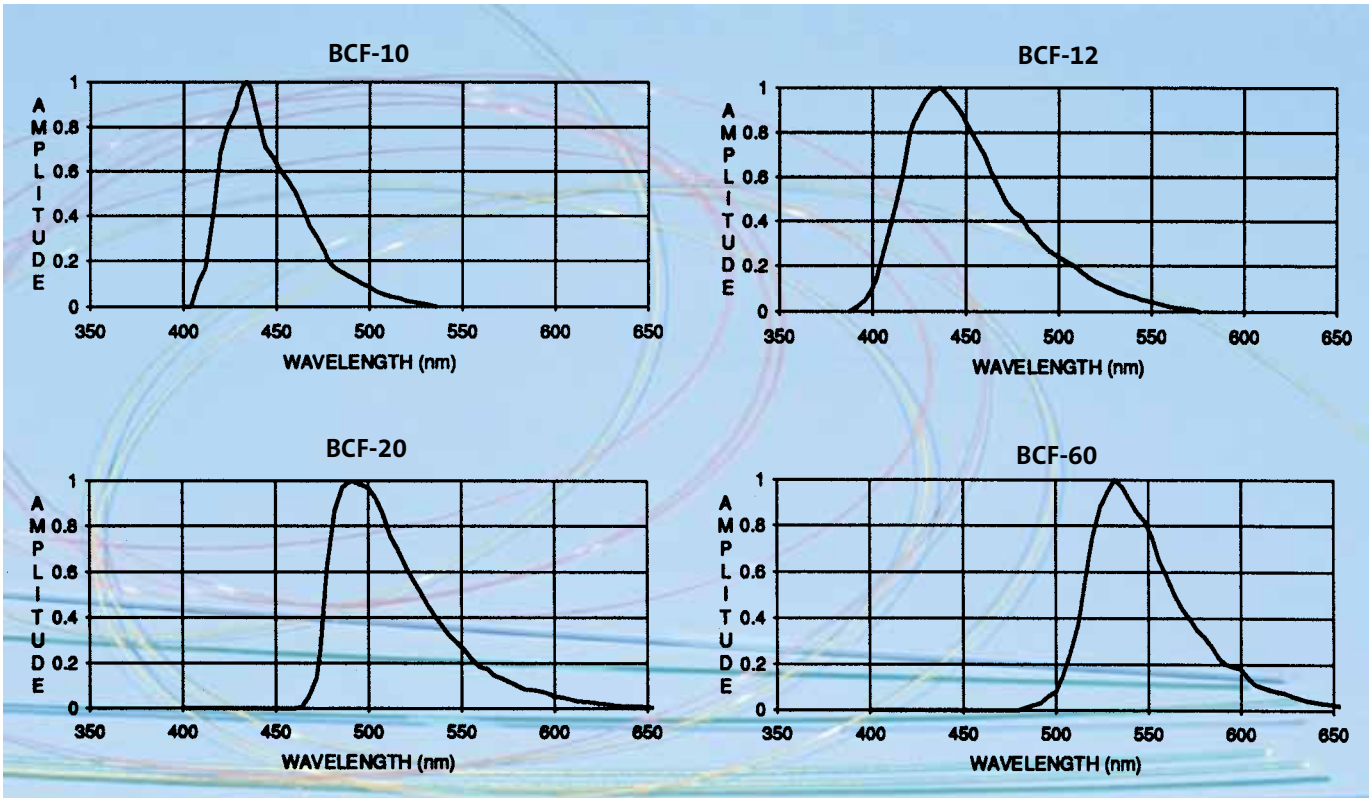
On request, we can quote tighter tolerances for fibers delivered as straight lengths.

Diameter Sampling
(1mm round fiber)

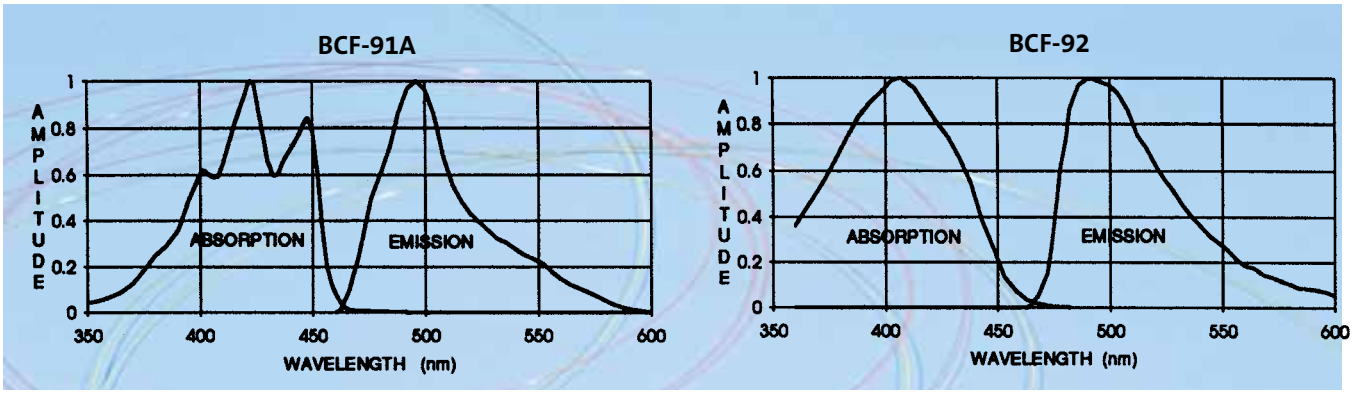


Technical Data

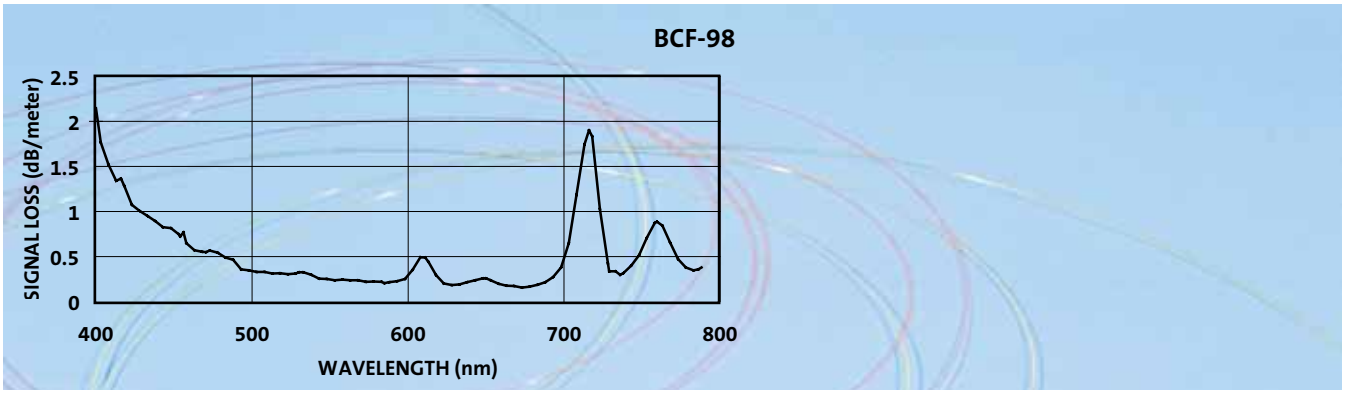
Emission Spectra –



Optical Spectra –



Attenuation vs. Wavelength –



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BICRON®

About Saint-Gobain

Saint-Gobain is a global leader in the manufacture and development of engineered materials such as glass, insulation, reinforcements, containers, building materials, ceramics and plastics. The formation of the Crystals Division reflects Saint-Gobain's commitment to the development of high performance materials.

The Scintillation Products business of the Division is a combination of companies that have been prominent in crystal growth or in radiation detection and measurement. Notable names include: Bicron® and Crismatec (inorganic and organic scintillators and detectors); Gamma Laboratories and TGM Detectors (gas-filled radiation detectors).

For additional product literature or information, call customer service at any of our locations or access our website document library – www.detectors.saint-gobain.com. Other radiation detection products available from Saint-Gobain Crystals include:

- Inorganic scintillators including NaI(Tl), BGO, CsI, $CdWO_4$, BrilLanCe™ 350 ($LaCl_3$) and BrilLanCe™ 380 ($LaBr_3$) crystals and PreLude™ 420 (LYSO) scintillator – configured as solids or arrays with or without an integrated photo readout device.
- Plastic scintillators available as rods, blocks, ingots, thick and thin sheets, tubing and spheres.
- Liquid scintillators as detectors or as bulk material.
- Geiger-Mueller and He-3 proportional counters.

(06-11)