

# Scintillation Products

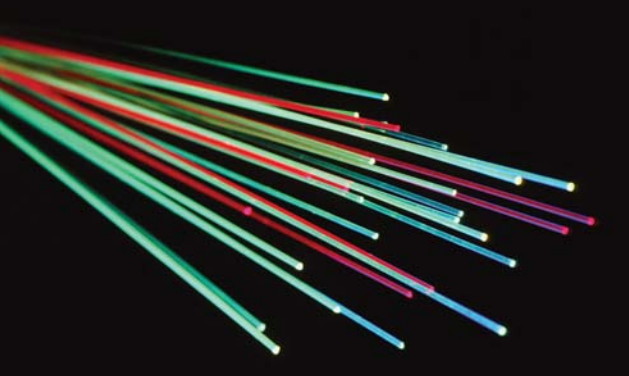


Scintillating  
Optical  
Fibers



SAINT-GOBAIN

CRYSTALS



# Plastic Scintillating Fibers

Saint-Gobain Crystals manufactures a variety of plastic scintillating, wavelength-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

## 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.

## Standard Fibers, Single-clad –

Our standard fibers consist of a polystyrene-based core and a PMMA cladding as diagrammed on page 3. 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 ( $\leq 0.5\text{mm}$ ), 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.

## 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): .....  $4.82 \times 10^{22}$   
 No. of C atoms per cc (core): .....  $4.85 \times 10^{22}$   
 No. of electrons per cc (core): .....  $3.4 \times 10^{23}$   
 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%

### Optical Cladding –

PMMA (polymethylmethacrylate, C<sub>5</sub>H<sub>8</sub>O<sub>2</sub>) 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,  $\geq 0.20\text{mm}$  diameter = 3% of fiber OD
- > Square fiber, 0.20mm to 3mm = 4% of fiber side
- > Square fiber,  $\geq 3.5\text{mm}$  = 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 near the core-cladding interface. For square fibers, the trapping efficiency is 4% and is independent of the scintillation event's location in the fiber.

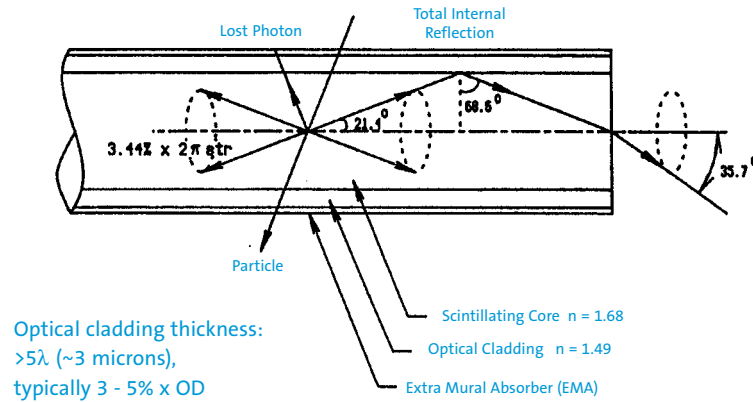
### EMA (Extra Mural Absorber) –

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.

### A Typical Round Scintillating Fiber –



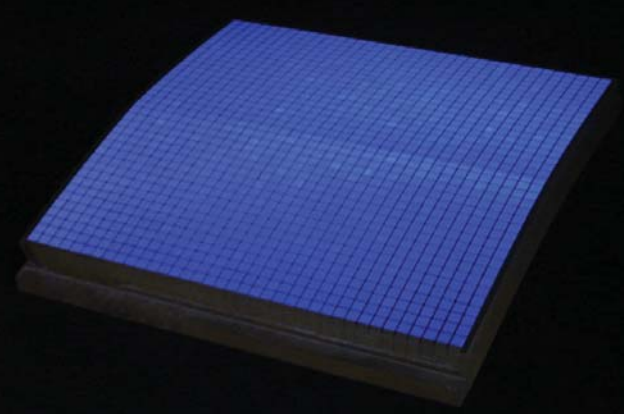
### Standard Sizes and Formulations –

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.

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	1/e Length m*	No. of Photons per MeV**	Characteristics/Applications
BCF-10	Blue	432	2.7	2.2	~8000	General purpose; optimized for diameters $>250\mu\text{m}$
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 radiation 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

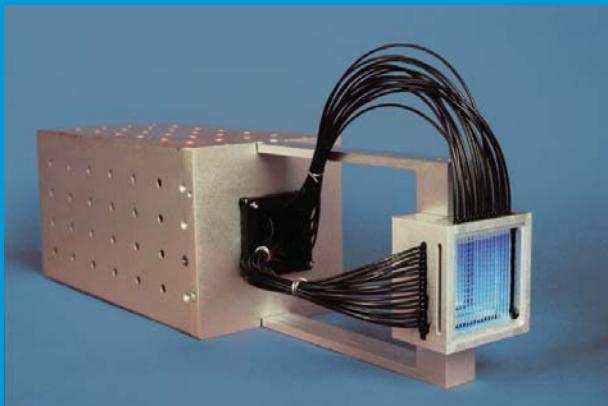
\*\* For Minimum Ionizing Particle (MIP), corrected for PMT sensitivity



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



Position-sensitive ribbon

**Quality Control – Attenuation Length Measurement**

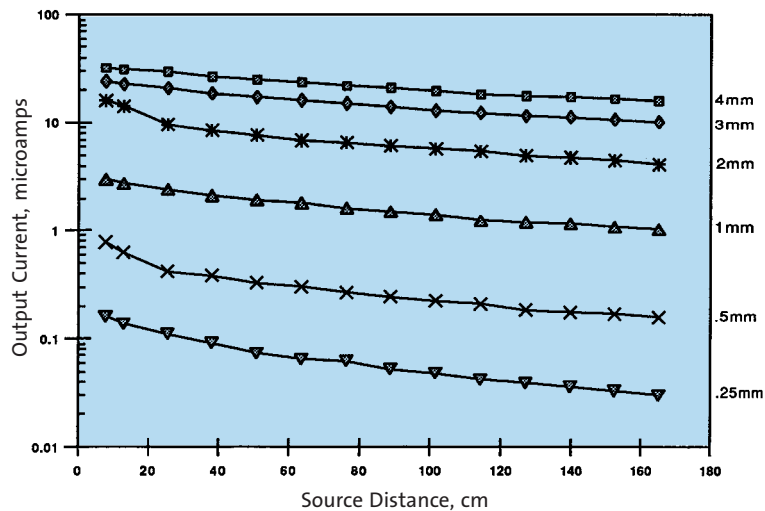
Saint-Gobain Crystals' fiber test station is capable of scanning fiber samples up to five meters in length.

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 <sup>90</sup>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)



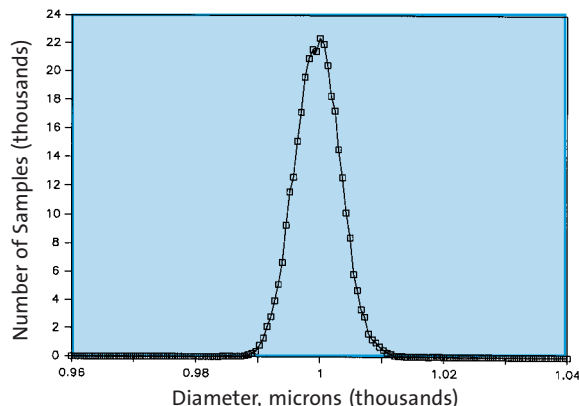
**Quality Control – Dimensional Consistency**

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.

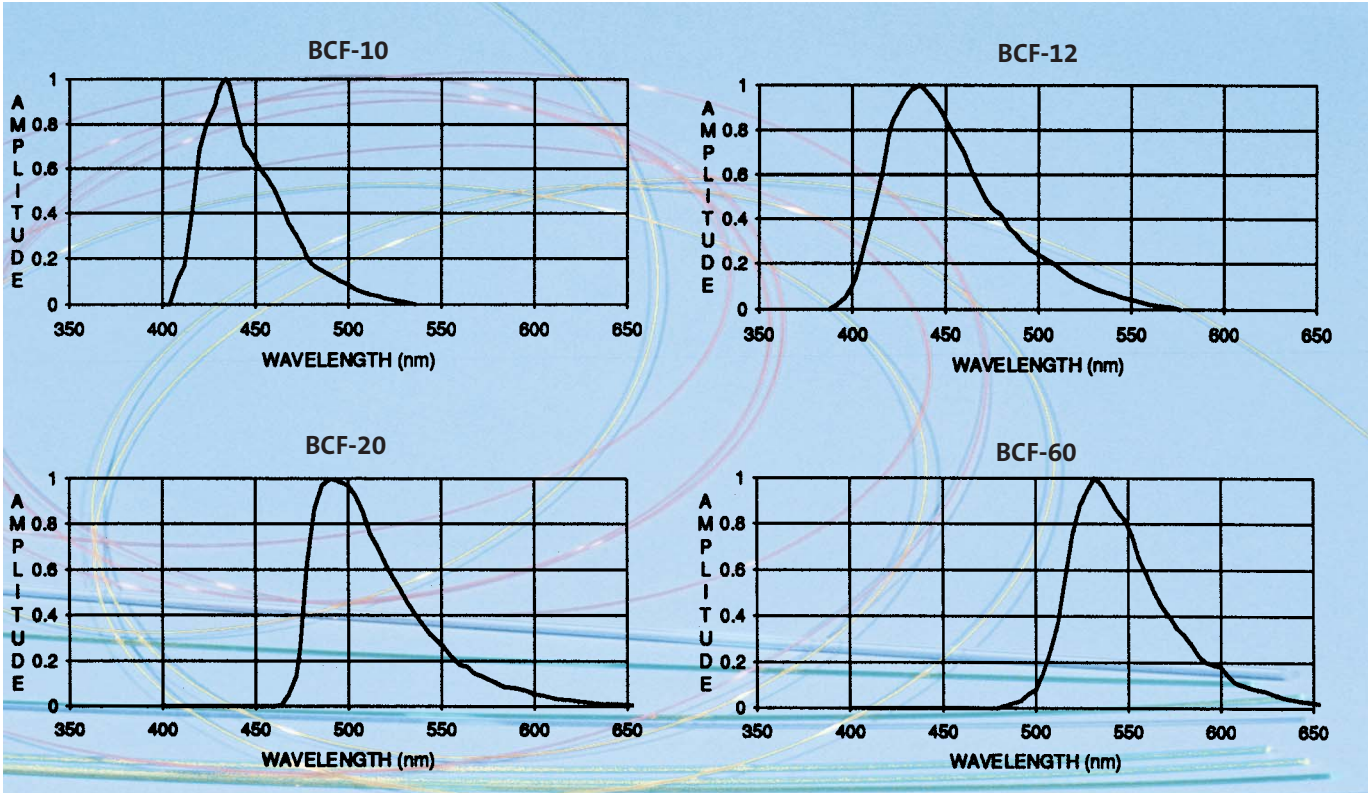
On request, we can quote tighter tolerances for fibers delivered as straight lengths.

**Diameter Sampling**  
(1mm round fiber)

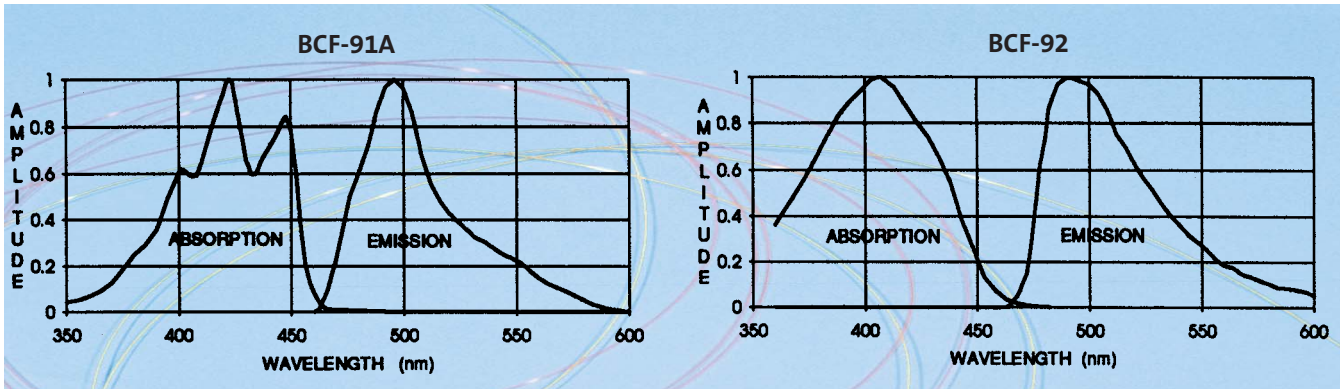


# Technical Data

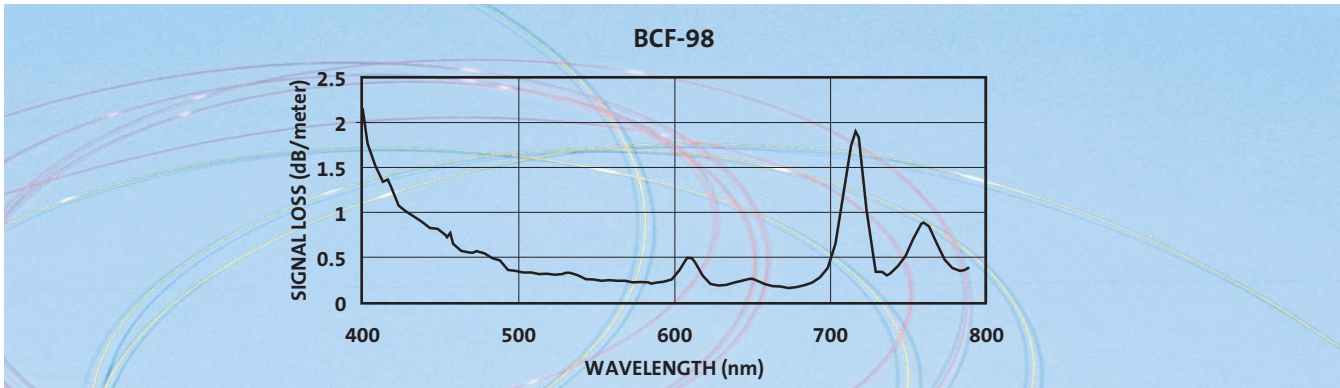
## Emission Spectra –



## Optical Spectra –



## Attenuation vs. Wavelength –



**BICRON®**



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## 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. Saint-Gobain Crystals is a division that includes our Scintillation Products business as well as Photonics and Semiconductor businesses. The Crystals Division employs over 700 people at plants and sales offices throughout the world.

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).

Being a part of Saint-Gobain brings us the long-term industrial strategy and investment benefits of such a dynamic group. There is a coherence centered on materials, applied to increasingly diversified needs. Saint-Gobain encourages research and development and the expansion of relevant technologies and their applications.

For additional Scintillation Products literature or information, call customer service at any of our locations or visit our web site, [www.detectors.saint-gobain.com](http://www.detectors.saint-gobain.com). Products available from Saint-Gobain Crystals, Scintillation Products, include:

- > Inorganic scintillators including NaI(Tl), BGO, CsI, CdWO<sub>4</sub>, and our latest additions – The BrillanCe™ 350 and 380 crystals and PreLude™ 420 scintillator – configured as solids or arrays with or without an integrated light-sensing 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.



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