Scintillation Products

Scintillation Materials and Assemblies

SAINT-GOBAIN
CRYSTALS

Contents —

POCKET

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About Saint-Gobain Crystals

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 reinforces Saint-Gobain's commitment to the development of high performance materials.

Saint-Gobain Facts –

- Established in 1665.
- The first major project was the production of the mirrors for the famous Hall of Mirrors in Versailles Palace.
- Today the Saint-Gobain group is listed among the 100 largest industrial groups worldwide.
- Produces 30 billion glass bottles each year.
- Supplies half of Europe's cars with glass.
- Insulates one-third of all USA homes.

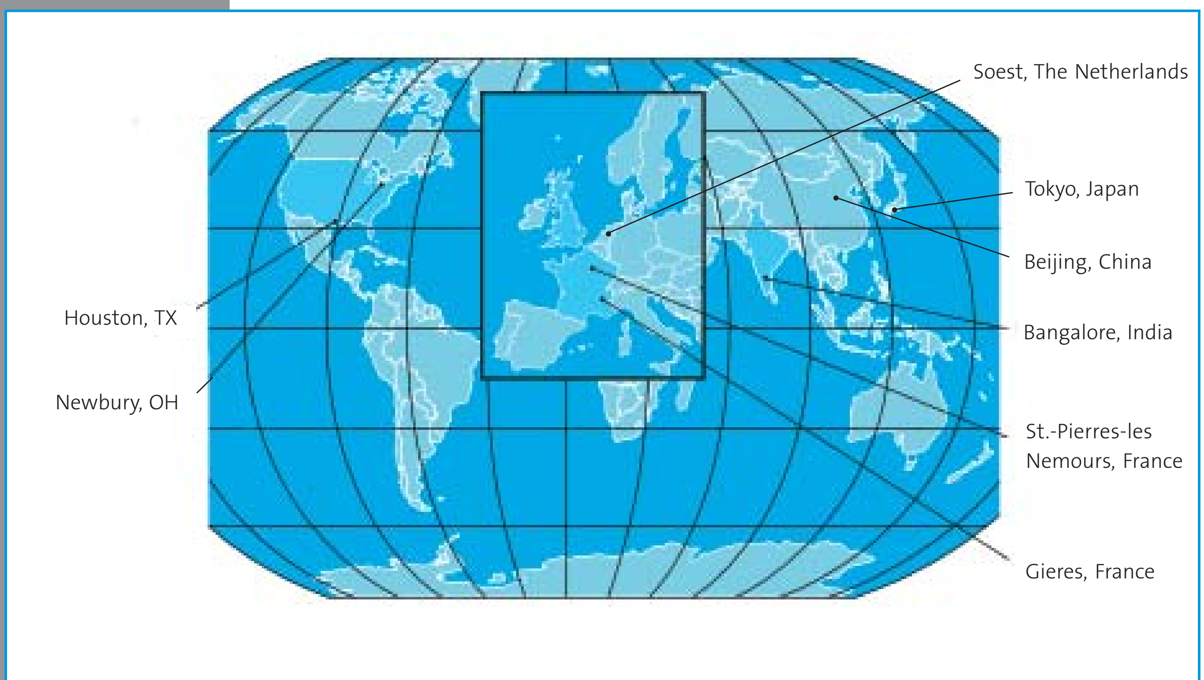
The Scintillation Products business of the Crystals Division is a combination of companies that have been prominent in crystal growth or in radiation detection and measurement.

Notable names include: Bicron, Crismatec, Harshaw/STI and NE Technology (inorganic and organic scintillators and detectors); Gamma Laboratories and TGM Detectors (gas-filled radiation detectors).

The objective of the Scintillation Products group is to take a proven technology forward to meet tomorrow's needs. We have successfully accomplished this for many industries, such as in the development of ruggedized assemblies that withstand the high vibration, high temperature environments of today's "Measurement While Drilling" oil well logging applications. We continue to make a significant contribution working with OEM customers to develop medical and industrial detectors to meet new specifications for innovative applications.

Saint-Gobain Crystals is considered to be the leader in scintillation technology and is the largest producer of sodium iodide crystals in the world. We have now developed several new scintillators with *enhanced* properties – the BrilLanCe™ 350 and 380 crystals and the PreLude™420 crystal.

This brochure presents the basic properties of our scintillation materials as well as mechanical features of our various standard and specialty detector designs. Many of the detector configurations listed in this catalog are standard detectors that can be modified to meet your requirements or are detectors designed for a specific application.



Materials, Markets and Applications

We offer product and technology solutions to a varied customer base. Scintillators were originally used in nuclear research. As early as 1944, researchers were successfully detecting ionizing radiation with a phosphor coupled to a photomultiplier tube. Since then, many practical commercial applications have been developed in nuclear medicine, oil exploration, health physics, security/safeguards and industry.

Our philosophy has been to develop basic design and assembly concepts that can be integrated into a virtually limitless array of sizes and geometries dependent upon the radiation you need to detect and the conditions and constraints of your application. The ultimate end-use and performance specifications determine crystal choice, housing material, optical window material, light-sensing device, and so on. More specific information on dimensions, geometries and performance can be obtained from Saint-Gobain Crystal's technical staff or from technical literature on our website.

Medical Applications –

Gamma Cameras
PET Scanners (Positron Emission Tomography)
PEM (Positron Emission Mammography)
PET/SPECT
CT Scanners (Computed Tomography)
Surgical Probes
BMD (Bone Mass Densitometry)
RIA (Radioimmunoassay)
Whole Body Counting

Industrial Applications –

Contamination Monitoring
Non-destructive Evaluation
Cargo Inspection
Luggage Inspection
Gauging
Thermal Neutron Activation Analysis

Physics Research Applications –

Spectroscopy
Calorimetry (HEP)
Astrophysics

Geophysical Applications –

Wireline Logging
MWD (Measurement While Drilling)
Multiphase Flow Analysis
Aerial (large area) Survey

Saint-Gobain Crystals' Radiation Sensors Applications Matrix

Sensor	<20 kev X-ray	20 to 100 keV X-ray	100keV to 5MeV γ-ray	5 to 300 MeV γ-ray	300MeV + γ-ray	Thermal neutron	Fast neutron	Alpha	Beta	Charged particles	Fast timing, high rate
NaI(Tl)	•	•	•	•	•					•	
CsI(Tl)	•	•	•	•	•					•	
CsI(Na)	•	•	•	•	•					•	
CsI(Pure)			•	•	•					•	•
BrilLanCe™ 350	•	•	•	•	•					•	•
BrilLanCe™ 380	•	•	•	•	•					•	•
CaF_2(Eu)		•	•					•	•	•	
BaF_2		•	•	•	•		•			•	•
BGO		•	•	•	•					•	
$CdWO_4$	•	•	•	•	•					•	
YAP(Ce)	•	•	•	•	•			•	•	•	•
PreLude™ 420	•	•	•	•	•						•
Organic Solids		•	•			•	•	•	•	•	•
Organic Liquids		•	•			•	•			•	•
Lithium Glasses		•	•	•		•		•		•	•
Proportional Counters	•	•	•	•			•	•	•		
G-M Tubes	•	•	•	•				•	•		
He-3 Tubes						•					

Saint-Gobain Scintillators – Properties

Scintillator	Light yield (photons/keV)	Light ouput (%) of NaI(Tl) bialkali PMT	Temperature coefficient of light output (%/C) $25^{o}C$ to $50^{o}C$	1/e Decay time (ns) ($10^{-3}\mu s$)	Wavelength of maximum emission γm (nm)	Refractive index at γm	Thickness to stop 50% of 662 keV photons (cm)	Thermal expansion (/C) x 10^{-6}	Cleavage plane	Hardness (Mho)	Density g/cm³	Hygroscopic	Comments
NaI(Tl)	38	100	-0.3	250	415	1.85	2.5	47.4	<100>	2	3.67	yes	General purpose; excellent energy & good time resolution
Polyscin^R NaI(Tl)									none				Polycrystalline NaI(Tl); for extra strength
CsI(Tl)	54	45	0.01	1000	550	1.79	2	54	none	2	4.51	slightly	High Z; rugged; good match to photodiodes & red PMT
CsI(Na)	41	85	-0.05	630	420	1.84	2	54	none	2	4.51	yes	High Z; rugged; good match to bialkali PMT
CsI(pure)	2	4-6	-0.3	16	315	1.95	2	54	none	2	4.51	slightly	High Z; fast emission
BGO	8 - 10	20	-1.20	300	480	2.15	1	7	none	5	7.13	no	High Z; compact detector; low afterglow
BaF_2	1.8	3	0	0.6 - 0.8	220(195)	1.54	1.9	18.4	<111>	3	4.88	slightly	Fast component for fast time resolution
	10	16	-1.1	630	310	1.50	1.9	18.4	<111>	3	4.88	slightly	Slow component
CaF_2(Eu)	19	50	-0.33	940	435	1.47	2.9	19.5	<111>	4	3.18	no	Low Z; α & β detection
$CdWO_4$	12 - 15	30-50	-0.1	14000	475	~2.3	1	10.2	<010>	4 - 4.5	7.9	no	High Z; low afterglow; for use with photodioides
BrilLanCe™ 350 $LaCl_3$(Ce)	49	70-90	0.7	28	350	~1.9	2.4	11	<100>		3.79	yes	General purpose; best energy & fast time resolution
BrilLanCe™ 380 $LaBr_3$(Ce)	63	130	0	26	380	~1.9	1.8	8	<100>		5.29	yes	General purpose; best energy & fast time resolution
PreLude™ 420 $Lu_{1.8}Y_{.2}SiO_5$(Ce)	32	75	0.04	41	420	1.81	1.1	–	none		7.1	no	Bright; high Z, fast, dense; excellent time resolution
ZnS(Ag)	~50	130	-0.6	110	450	2.36	–	–	–	–	4.09	no	Multicrystal; 15μ stops 5.5 MeV (n detection with ^{6}Li)
YAP(Ce), $YAlO_3$ (Ce)	18	40	-0.1	27	350	1.94	1.7	~80	none	8.5	5.55	no	Low Z; rate of change of light output w/temperature is small
YAG(Ce), $Y_3Al_5O_{12}$(Ce)	8	15	–	70	550	1.82	2	~80	none	8.5	4.55	no	β; X-ray counting; electron microscopy

Standard Assemblies

Saint-Gobain Crystals offers four basic detector designs: a packaged scintillator, a scintillator integrally mounted to a light-sensing device [such as a photomultiplier tube (PMT)], a scintillator with a demountable PMT and a scintillator array. Each of those basic detector configurations can be designed with one or more of the various options listed. To discuss which options may suit your application, contact our customer service department.

Detector Assembly Options –

- Rectangular and other shapes
- Light-sensing device selection
- Integrated, low-background voltage divider and preamplifier bases
- Thin aluminum or beryllium radiation entrance windows
- Special flanges, O-rings, mounting fixtures or other modifications
- End well and transversal well geometries
- Low background stainless steel or copper containers and other components

Basic Packaged Scintillator –

The packaged scintillator is basically a scintillation crystal mounted in a low-mass metal container (usually aluminum). For NaI(Tl) and other hygroscopic crystals, the package is hermetically sealed. Reflector material is placed between the scintillator and the container walls. An optical window is incorporated into one end. A wide variety of sizes and shapes (including curved and rectangular) can be produced. This type of detector requires a user-supplied, externally-coupled light-sensing device.

Packaged scintillators are appropriate for certain experimental or manufacturing situations where different scintillator-PMT combinations may be required on a regular basis.

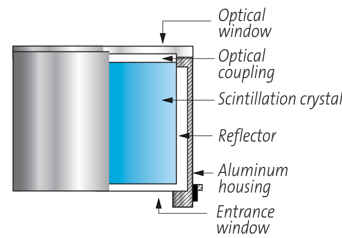
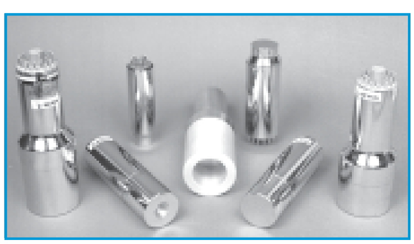


Illustration of Basic Packaged Scintillator

Integrally Mounted Scintillator/Light-sensing Device Assembly –

In this integral design, the light-sensing device (usually a PMT) is optically coupled directly to the scintillator. The scintillator is mounted in a container (usually aluminum) and a mu-metal shield is fitted over the PMT. The detector package is hermetically sealed when a hygroscopic scintillator, such as NaI(Tl) is used. The scintillator container and mu-metal shield are sealed together to form a low-mass and light-tight housing for the detector.

This design usually yields better and more consistent energy resolution. Therefore, these are the detectors of choice for spectroscopy and radioisotope assay.



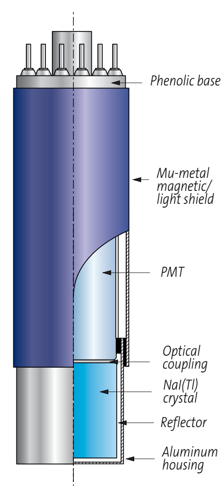


Illustration of Integrally Mounted Scintillator/PMT Assembly

Standard Assemblies

Demountable Scintillator/PMT Assembly –

The demountable designs are scintillator-photomultiplier tube (PMT) combinations that allow the removal of the PMT(s) without disturbing the scintillator package. The scintillator is mounted with appropriate reflector material in a low-mass metal container with an optical window for each PMT. The magnetic light shield of each PMT is mechanically fastened to the flange or other mounting hardware on the scintilator container.

This configuration is well-suited for applications requiring the use of a crystal larger than 5" in diameter or imaging applications.

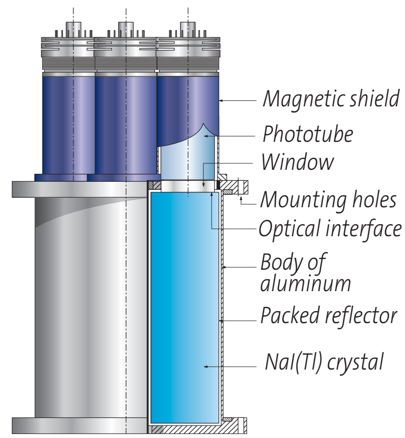
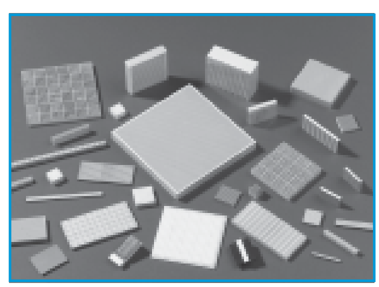


Illustration of NaI(Tl) Detector Assembly with Demountable Photomultiplier Tubes

Crystal Arrays –

Many of our scintillation materials can be used for small-pixel arrays. The continuing demand for better resolution and the availability of improved, position-sensitive light sensors has pushed the development of arrays. They are now widely used in medical, security and industrial imaging.

For detailed information on our arrays products, request our brochure "Scintillation Crystal Arrays and Assemblies."



Detector Assembly Considerations–

- Radiation to be Measured:
  - Alpha
  - Beta
  - Gamma
  - X-ray
  - Photon
  - Neutron
- Scintillator Assembly Configuration
  - Scintillator material
  - Housing material
  - Geometry
  - Crystal size
  - Overall detector size
- Environmental Considerations
  - Temperature
  - Shock
  - Vibration
  - Magnetic field
  - Pressure/Vacuum
  - Background radiation
- Performance Specifications
  - Energy range of interest
  - Pulse height resolution (PHR)
  - Uniformity
  - Efficiency
  - Count rate range
  - Detector background
  - Coincidence resolving time (CRT)
- Light-sensing Device
  - Photomultiplier tube (PMT)
  - Photodiode (PD)
  - Microchannel plate (MCP)
- Electronics
  - Voltage divider
  - Built-in high voltage
  - Dynode tap
  - Preamplifier

Specialized Assemblies

Some applications require specific designs, such as a phoswich detector for low energy gamma counting in a high energy background or a ruggedized design for operation in harsh environments. Shown below are some of our specialized assemblies.

Well Designs –

End wells and through-side wells are used when the application requires high detection efficiency, e.g., for counting applications such as RIA (Radioimmunoassay) and Compton suppression. The design depends on energies of interest and performance criteria.

Ruggedized Designs –

Ruggedized units, developed for the oil well service industry, are designed to withstand high temperatures and/or shock and vibration. Epoxy seals are not used in this type of detector. The design can incorporate an all-welded assembly, stainless steel housing and proprietary interface loading. Ruggedized detectors are built to survive in temperatures from -55°C to +205°C and in extreme shock and vibration environments.

The NxGen Ti™ detector, our "next generation" ruggedized assembly, has a titanium alloy housing, which makes it possible to package a larger crystal into a standard footprint. The benefits include increased efficiency and count rate.

Harsh Environment Designs –

Detectors can be modified or custom designed to operate outside the laboratory environment. Your specific requirements may include use in one or more of these environments: extreme cold, vacuum, elevated temperatures, under water or severe mechanical shock and vibration.

Pulser Designs –

Building a reference light source into a detector assembly is a common way to stabilize gain. The light source produces a peak in the spectrum outside the region of interest. The system adjusts the gain to keep this peak's position constant in the measured spectrum. Depending upon your requirements, we can supply detectors with any of the following as the reference light source: (1) an ^{241}Am light pulser; (2) an LED imbedded in the optical window; (3) a fiber optic cable with an external LED or (4) a radioactive source (e.g. ^{137}Cs).

Flat NaI(Tl) Detector Plate
Application: Nuclear Medicine Imaging

Ruggedized Detectors
Application: Downhole Well Logging

Plastic and NaI Detectors, Gas Tubes
Application: Safeguards

Probe
Application: Medical

CsI(Tl)/NaI(Tl) Phoswich Detector
Application: Whole Body Counting

Phoswich Designs –

A phoswich ("phosphor sandwich") is a combination of scintillators with dissimilar pulse shape characteristics optically coupled to each other and to a common PMT (or PMTs). Pulse shape analysis is used to distinguish the signals from the two scintillators, identifying in which scintillator the event occurred. Phoswich detectors were developed to detect low-intensity, low-energy gamma rays, X-rays, as well as alpha and beta particles efficiently in a higher-energy ambient background.

A phoswich detector can also be used in a detector telescope to detect and identify particles.

Low Background Designs –

For low level activity measurements, it is necessary to reduce the detector background by selecting materials exhibiting the lowest natural radioactivity: (1) low background and very low background scintillator; (2) quartz window instead of the standard glass window; (3) stainless steel, copper or low background aluminum for the housing; (4) specific reflector material and other selected components; (5) PMT selected for low background.

Thin Entrance Window Designs (for low energies) –

Low energy gamma and X-ray applications call for specific crystal thickness, entrance window type and entrance window thickness. The typical energy range for an assembly with a beryllium entrance window is 3 to 100 keV and 10 to 200 keV for an assembly with an aluminum entrance window.

Other Specialized Detector Designs –

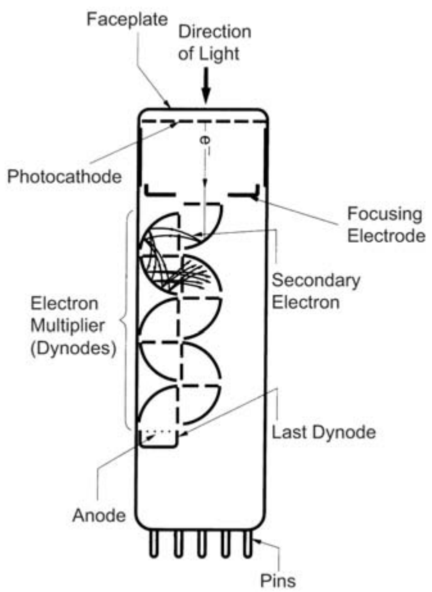
- Large spectrometers
- Annular shields
- Flat and curved detector plates for nuclear medicine applications: SPECT, PET and Planar imaging
- Position-measuring detector bars
- Pair spectrometers
- Neutron detectors

Light-sensing Devices

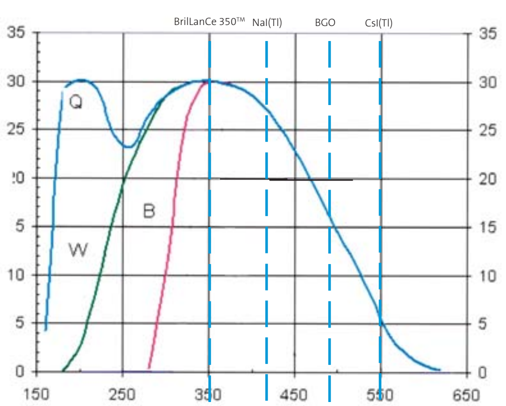
Light-sensing devices are used to convert the light created in the scintillator into a suitable measurable analog signal. The primary light sensors in use today are photomultiplier tubes (PMT) and photodiodes (PD).

The choice of the most appropriate sensor for a particular detector will be made on the basis of the following criteria:

- emission spectrum of the scintillator
- required nuclear performance
- mechanical and environmental constraints
- geometry
- cost



Shown are the main elements of a photomultiplier tube. For details about the specific performance of PMTs, please refer to the PMT manufacturer's literature. (Illustration courtesy of Hamamatsu Corporation)



Maximum emission points of various scintillators compared to quantum efficiency of a bialkali ETI9266 PMT with (B)Borosilicate, (W)UV glass and (Q)Quartz face plates (Q.E. data courtesy of Electron Tubes, Inc.)

Photomultiplier Tube (PMT) –

The energy resolution, coincidence resolving time (CRT) and stability of a scintillation detector depend to a great extent upon the PMT. The selection of the proper type is fundamental to a good detector design. PMTs are sensitive to magnetic fields. A mu-metal shield provides adequate protection from the earth's magnetic field.

Important parameters that need to be taken into consideration when choosing a PMT are:

• **Photocathode spectral response** of the PMT. The most commonly used PMTs have a bialkali photocathode. Bialkali material has a broad spectral response from 170nm to 560nm. Photocathode spectral response should match the emission spectrum of the scintillator used.

• **Current amplification (gain)** of the PMT. Gain depends on the number of dynodes and the dynode structure (Venetian blind, circular cage, box and grid, linear focused), the nature of the emissive material and the interdynode voltage. Various other factors such as temperature in the environment and count rate can affect the gain of a PMT. A typical PMT has a gain of 1 million (10^6).

Photodiode (PD) –

Another way to detect the scintillation light is by using a silicon photodiode. This is a semiconductor device consisting of a thin layer of silicon in which the light is absorbed and free charge carriers (electrons and holes) are created. They are collected at the anode and the cathode of the diode.

When these photodiodes are optically coupled to a scintillation crystal, the scintillation light pulse generates a small charge pulse in the diode.

In contrast to PMTs, photodiodes operate at lower bias voltages, typically less than 100V. Photodiodes are thin, rugged and insensitive to magnetic fields. Furthermore, the output signal from a photodiode is very stable and constant with temperature. There is no charge amplification in the device so the selection of a low noise preamplifier is critical for good performance.

We have developed a photodiode scintillation detector consisting of a scintillation crystal, a photodiode, and a special preamplifier – all in one small unit.

Other Types of Sensors –

Avalanche photodiode (APD) – An APD is a special type of photodiode that can withstand voltages up to several hundred volts. The high voltage generates an avalanche effect. Primary charge carriers are accelerated enough to release additional charge carriers along the collection path.

Hybrid photodiode (HPD) – An HPD is similar in design to a PMT. The main difference is that all dynodes and the anode are removed and replaced by a silicon diode. HPDs show an excellent single photon detection capability and have good linearity and timing characteristics.

Microchannel Plate (MCP) - The interaction of a photon in an MCP produces a charge pulse of electrons that emerge from the rear of the plate.

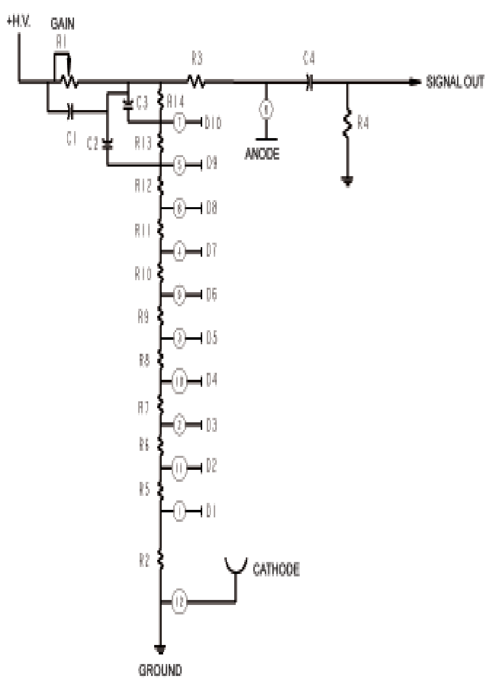
Wavelength Shifter Bar - A WLS bar absorbs light at one wavelength and emits it isotropically at a longer wavelength.

Position Sensitive Photomultiplier Tube (PSPMT) - NaI(Tl) and BGO pixellated materials lend themselves well to the use of a PSPMT due to the emission wavelength of less than 480nm.

High Voltage Electronics

Voltage dividers and voltage divider/preamplifiers allow for the supply of proper voltage distribution to the light-sensing device, such as a photomultiplier tube, and for the transmission of the signal to your system electronics. These devices can be plugged onto or hard-wired to the light-sensing device. For complete information on design considerations, request our "Bases, Voltage Dividers and Preamplifiers" information sheet.

Schematic of standard 12-pin voltage divider



Voltage Divider for PMTs–

A standard voltage divider distribution is usually specified by the PMT manufacturer for each photomultiplier tube. However, such a standard configuration is not always the optimum one for a specific application.

The voltage divider can be custom designed to take into account the photomultiplier characteristics and the performance if specific gain, linearity or timing is a requirement.

Options:

- Gain potentiometers allow for precision adjustments to balance pulse heights from two or more PMTs.
- A focus potentiometer and dynode output can be added on specific request.
- A dynode tap output is used to provide a linear signal when a phototube is operated at such a high gain that anode output is non-linear. This is often the case with fast-timing phototubes.

Voltage Divider/Preamplifier Combinations for PMTs–

The charge delivered at the output of the photomultiplier must be converted to a voltage pulse. This is done by a preamplifier.

In addition, a preamplifier:

- Maximizes the signal/noise. The preamplifier has to be located close to the detector.
- Operates as a line driver to send the signal to the main amplifier, which can be a distance from the detector.
- Provides an output pulse to be fed to the spectroscopic amplifier consistent with the NIM standard. Typically, the decay time is 50µs.

Electronics for Photodiodes –

Unlike a PMT, there is no charge amplification in the photodiode itself so the charge pulses are very small (typically several femto Coulombs). For this reason, the noise of the photodiode/preamplifier combination is a significant factor in the performance of the device. The noise prohibits the use of photodiode scintillation detectors at very low energies (several tens of keV X-rays or γ-rays.)

Since the noise of a photodiode increases with its active surface area, detectors employing small (10x10mm^2 or smaller) diodes have a better energy resolution than those equipped with larger diodes.

The signal from a photodiode scintillation detector amounts to several mV per MeV γ. Additional pulse processing electronics are needed to amplify the signal further. A standard spectroscopy amplifier with a gain of a few thousand can be used for this purpose.

Photodiode scintillation detectors require bias supplies, typically less than 100V.

Standard Features of Saint-Gobain Plug-on* or Hard-wired Voltage Dividers –

- Positive (+) high voltage operation (Negative (-) high voltage is an option)
- BNC connector for signal output
- SHV connector for high-voltage supply input
- 800 to 1200 VDC (may be higher or lower depending upon the specific PMT)
- Gain potentiometer
- Focus potentiometer (14 pin only)

*The advantage of a plug-on voltage divider is that it can be removed and used on other detectors.

Detector Warranty Information

Each Saint-Gobain Crystals' scintillation detector is manufactured from high quality crystal, processed to obtain the best possible performance and assembled and packaged in accordance with advanced design and engineering techniques. Each detector assembly is tested prior to shipment and is accompanied by a data sheet bearing the performance specifications of the detector at the time of shipment. These records are permanently maintained by us for future reference. Below is the warranty for standard detectors. Other warranties may apply depending on product type.

Our Capabilities

Purification and Growth –

By processing our raw materials in-house, we can control performance, especially light output, and quality consistency.

Manufacturing Control –

Precision machining is done in a technologically advanced fabrication shop. Detectors and arrays are assembled in clean rooms, in dry boxes or dry rooms, as required, in our facility.
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Performance Testing –

Detector and array performance can be tested during and following assembly. We maintain advanced and specialized test equipment to simulate actual use.

Manufacturing Support –

Through years of various application experience, we can help you with the selection of crystal, light-sensing device and electronics. Custom engineering and design assistance is available.

Inorganic Scintillation Detectors –
Saint-Gobain Crystals will repair or replace, at no charge, any detector which fails within a period of two years from date of shipment* as a result of faulty construction or failure of the hermetic seal(s).

This warranty does not apply to any detector which fails as a result of abuse or exposure to a non-laboratory environment. A normal laboratory environment is defined as air at normal pressure and any humidity, at a temperature between +40°F and +110°F (+4°C to +43°C) which temperature does not change at a rate greater than 15°F (8°C) per hour and which does not heat or cool any region of the detector such as to produce a temperature gradient of greater than 5°F (3°C) across the affected region.

Detector assemblies designed for use in specific applications where severe environmental conditions may be encountered carry a specific warranty. Please contact sales/ customer service for further explanation of warranties.

*one year for BrilLanCe™ series detectors

Photomultipliers (PMTs) –
For photomultipliers, we pass on to the customer the PMT manufacturer's standard warranty, which in most cases is one year.

General Information –
This warranty applies only to the original purchaser of the detector and only to product with serial numbers still legible. This warranty does not apply to any detector which fails as a result of abuse or exposure to a non-laboratory environment. This warranty does not apply if the product has been modified or altered without our express written approval.

Saint-Gobain Crystals' obligation hereunder shall be limited to the repair or replacement, at our option, of any detector or any part thereof which, upon receipt and examination, proves to have been defective within the specified warranty period. We are not responsible for damages of any kind including incidental or consequential damages. To the extent permitted by law, this warranty is in lieu of all other warranties, express or implied, and constitutes the fulfillment of Saint-Gobain Crystals' obligations to the purchaser.

Scintillation Products
Scintillation Materials
and Assemblies

BICRON®

crismatec®

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

- Plastic scintillators available as rods, blocks, ingots, thick and thin sheets, tubing and spheres.
- Scintillating optical fibers which can be assembled into ribbons, arrays or complete detectors.
- Liquid scintillators as detectors or as bulk material.
- Geiger-Mueller and He-3 proportional counters.

SAINT-GOBAIN CRYSTALS

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(12-04)