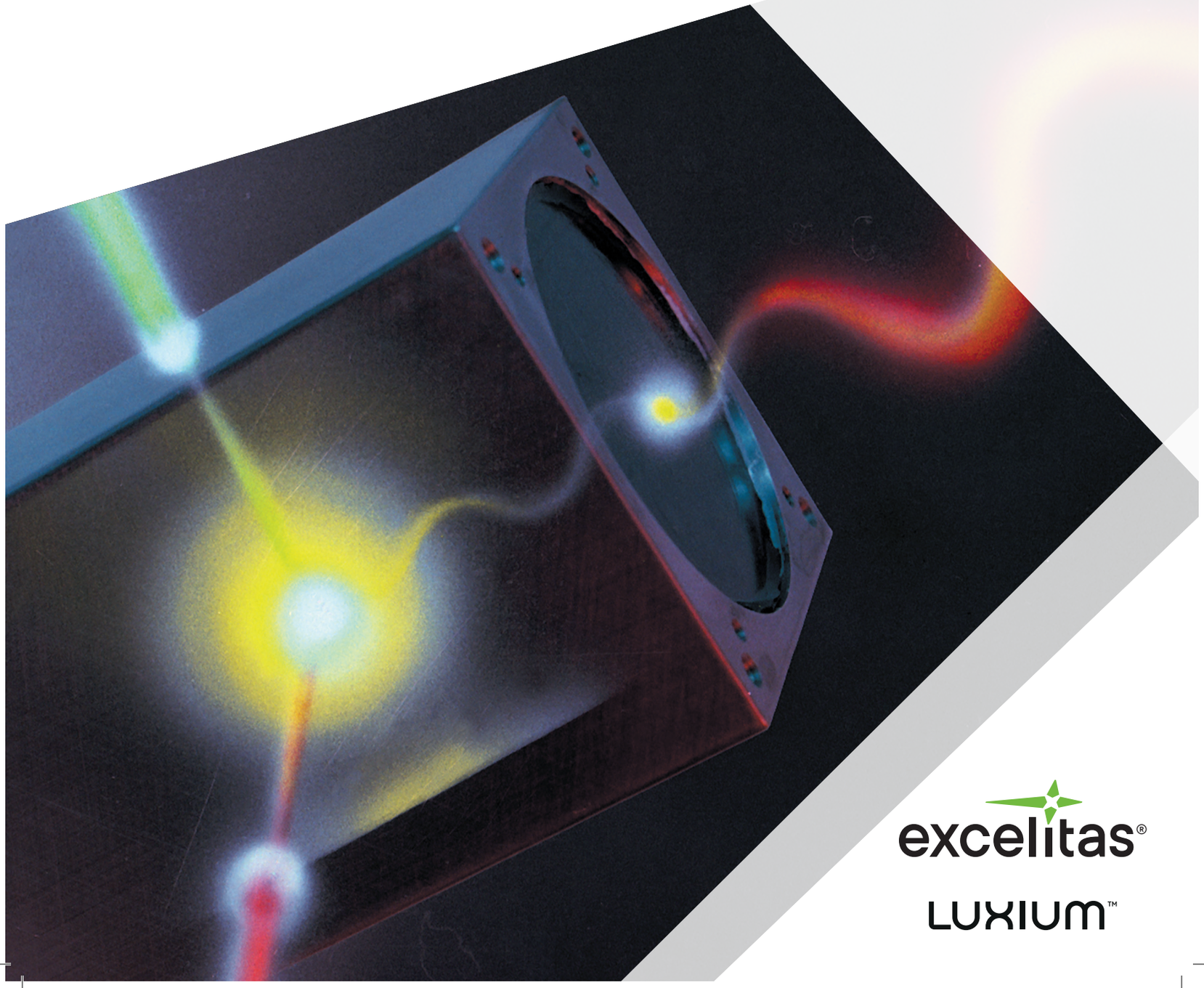
Luxium™ Scintillation Materials & Assemblies



excelitas®

LUXIUM™

About Luxium™ Scintillation Materials & Assemblies

Luxium™ Scintillation Materials & Assemblies build on the combined heritage of several pioneering companies in crystal growth, radiation detection, measurement technologies, and opto-mechanical products. This portfolio brings together decades of expertise from renowned brands including Bicron®, Crismatec®, Harshaw®, NE Technology® (inorganic and organic scintillators and detectors), Gamma Laboratories®, and Saphikon® (sapphire products).

Today, as part of Excelitas Technologies, the Luxium™ portfolio supports OEM customers and researchers worldwide by developing advanced scintillation products and radiation detection solutions for the Energy, Medical, Security, Industrial, Defense, and Semiconductor markets. These solutions enable customers to meet demanding performance requirements and develop innovative new applications.

Luxium™ Scintillation Materials & Assemblies are recognized as a global leader in scintillation technology and include the world's largest production capacity for sodium iodide (NaI(Tl)) crystals, delivering the quality, consistency, and reliability trusted by customers worldwide.

This brochure presents the basic properties of our radiation detection products and the mechanical features of various standard and specialty designs. Many of the products incorporate scintillation materials, both inorganic crystals and organic solids and liquids, where absorption of ionizing radiation leads to a corresponding burst of light that can be detected and measured to characterize the radiation.

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.

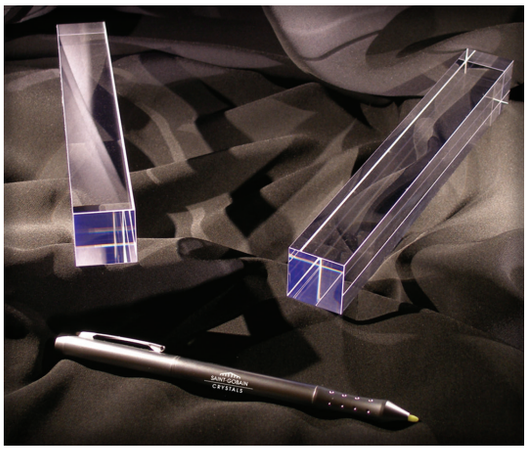
Worldwide locations:

- Bengaluru, India
- Beijing, China
- Gieres, France
- Hiram, Ohio
- Milford, New Hampshire
- St.-Pierre-les Nemours, France
- Tokyo, Japan

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.



Medical Applications –
SPECT and Planer Imaging
PET Scanners (Positron Emission Tomography)
CT Scanners (Computed Tomography)
Surgical Probes
BMD (Bone Mass Densitometry)
RIA (Radioimmunoassay)
Whole Body Counting

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

Security Applications –
Nuclide Identification
Cargo Scanners
Luggage Scanners
Portal Monitoring

Industrial Applications –
Contamination Monitoring
Non-destructive Evaluation
Nuclear Gauging
Thermal Neutron Activation Analysis

Physics Research Applications –
Spectroscopy
Calorimetry (HEP)
Astrophysics

Scintillation Materials & Assemblies Applications Matrix

Sensor	<20 kev X-ray	20 to 100 keV X-ray	100keV to 5MeV γ-ray	> 5 MeV γ-ray	Thermal neutron	Fast neutron	Alpha	Beta	Charged particles	Fast timing, high rate
NaI(Tl)	•	•	•	•					•	
$LaBr_3$	•	•	•	•					•	•
LYSO	•	•	•	•						•
CsI(Tl)	•	•	•	•					•	
CsI(Na)	•	•	•	•					•	
CsI(Pure)			•	•					•	•
CaF_2(Eu)		•	•				•	•	•	
BaF_2		•	•	•		•			•	•
BGO		•	•	•					•	
$CdWO_4$	•	•	•	•					•	
Organic Solids		•	•		•	•	•	•	•	•
Organic Liquids		•	•		•	•			•	•
Lithium Glasses		•	•	•	•		•		•	•

Material & Geometry Capabilities

We offer an industry leading variety of scintillators and detectors. We also continue to develop new scintillators internally and with outside partners to meet current and future market needs.

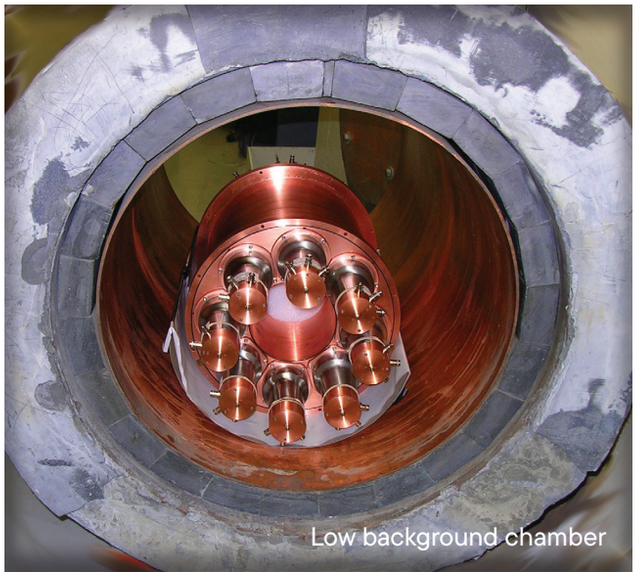
We have developed internal raw material chemistry capabilities and growth processes for most of these materials. By processing our raw materials in-house, we can control performance, especially light output, and quality consistency.
In addition, We have developed unique cutting, shaping and packaging equipment and facilities. This allows us to form scintillators into almost any shape that could be asked for, including:

Cylinders	Annuli	Pixels
Cubes	Curved	Arrays
Bars	Well	Large Format
Plates	Spheres	Near Net Shape

After shaping, our manufacturing facilities are equipped with the environment and climate conditions compatible with the material characteristics to prevent any degradation during the assembling process. Our long experience in packaging hygroscopic materials provides assurance that detectors will continue to perform in the field for many years.

We can provide higher level electronic and mechanical assemblies to speed introduction to market and to ensure proper system performance, especially with testing of the higher level assemblies.

When production levels move from low volume prototyping to high volume production, we have industry-leading capacity in sodium iodide and other primary scintillators. This ensures that partnership with us will allow for smooth ramp up with successful market introductions.


Low background chamber

ENGINEERING TEST CAPABILITIES

We have test equipment to allow for thorough testing of detectors, including laboratory environments as well as extreme conditions. In addition, there are significant process controls to ensure that tests are repeatable, accurate and consistent from test system to test system. The test systems include:

- Vibration systems with simultaneous nuclear performance test capability. These include capability for concurrent temperature cycling (-40°C to +200°C).
- Shock test system
- Temperature (-70°C to +180°C) and humidity test chambers, including automated plateau station (-40°C to 205°C).
- X-Ray Test System for afterglow
- Low background chamber with nuclear performance test capability
- Multi-PMT Gamma Camera Flood Imager
- PSPMT Tubing
- All traditional nuclear measurements (e.g. coincidence, background, pulse shape)

Luxium™ Scintillation Materials – Physical Properties of Common Inorganic Scintillators

Scintillator	Light yield (photons/keV)	Light ouput(%) of NaI(Tl) bialkali pmt	Temperature coefficient of light output(%/C) 25°C to 50°C	1/e Decay time(ns)	Wavelength of max emission lm(nm)	Refractive index at lm	Thickness to stop 50% of 662 keV photons (cm)	Thermal expansion (/C)x10^{-6}	Density g/cm^3	Hygroscopic	Comments
$LaBr_3$(Ce+Sr)	73	190	0	25	385	~2.0	1.8	8	5.08	yes	Ultimate energy resolution (2.2% @ 662keV)
$LaBr_3$(Ce)	63	165	0	16	380	~1.9	1.8	8	5.08	yes	General purpose, excellent energy resolution
CLLB $Cs_2LiLaBr_6$(Ce)	43	115		180 / 1100	420	~1.85	2.2	--	4.2	yes	Dual Gamma-Neutron detection, excellent
NaI(Tl)	38	100	-0.3	250	415	1.85	2.5	47.4	3.67	yes	General purpose, good energy resolution
NaI(Tl+Li)	35	100	-0.3	240, 1.4μs 230. 1.1μs	419	1.85	2.5	47.4	3.67	yes	Neutron-Gamma Scintillator
$LaCl_3$(Ce)	49	70-90	0.7*	28	350	-1.9	2.3	11	3.85	yes	General purpose, good energy resolution
CsI(Na)	41	85	-0.05	630	420	1.84	2	54	4.51	yes	High Z, rugged
LYSO $Lu_{1.8}Y_2SiO_5$(Ce)	33	87	-0.28	36	420	1.81	1.1	--	7.1	no	Bright, high Z, fast, dense, background from ^{176}Lu activity
CdWO4	12-15	30-50	-0.1	14000	475	~2.3	1	10.2	7.9	no	Low afterglow, for use with photodioides
CaF2(Eu)	19	50	-0.33	940	435	1.47	2.9	19.5	3.18	no	Low Z, α & β detection
CsI(Tl)	54	45	0.01	1000	550	1.79	2	54	4.51	slightly	High Z, rugged, good match to photodiodes
BGO	8 - 10	20	-1.2	300	480	2.15	1	7	7.13	no	High Z, compact detector, low afterglow
YAG(Ce)	8	15	--	70	550	1.82	2	~8	4.55	no	β-ray, X-ray counting, electron microscopy
CsI(Pure)	2	4-6	-0.3	16	315	1.95	2	54	4.51	slightly	High Z, fast emission
BaF2	1.8	3	0	0.6-0.8	220(195)	1.54	1.9	18.4	4.88	slightly	Fast component (subnanosecond)
	10	16	-1.1	630	310	1.50	1.9	18.4	4.88	slightly	Slow component
ZnS(Ag)	~50	130	-0.6	110	450	2.36	--	--	4.09	no	Coated on BC-400 or acrylic for α detection

The data presented are believed to be correct but are not guaranteed to be so.
Please see individual data sheets for full details at https://luxiumsolutions.com

Revised May 2018

Standard Assemblies

We offer 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.

Basic Packaged Scintillator –

The packaged scintillator is 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 cylindrical 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.

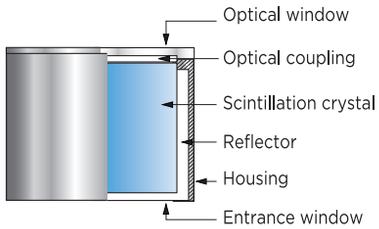


Illustration of Basic Packaged Scintillator

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.

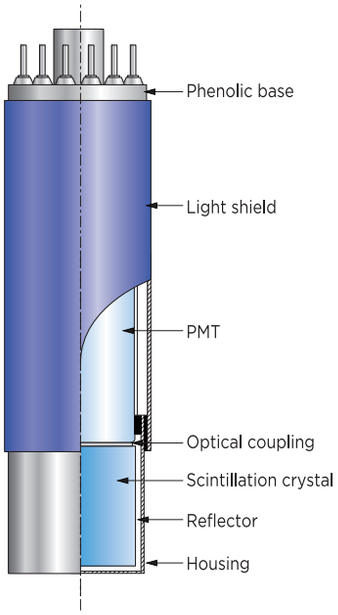
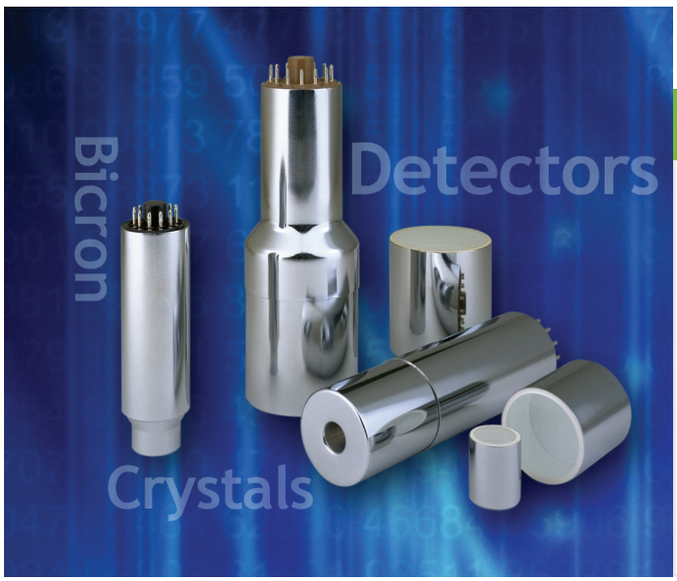


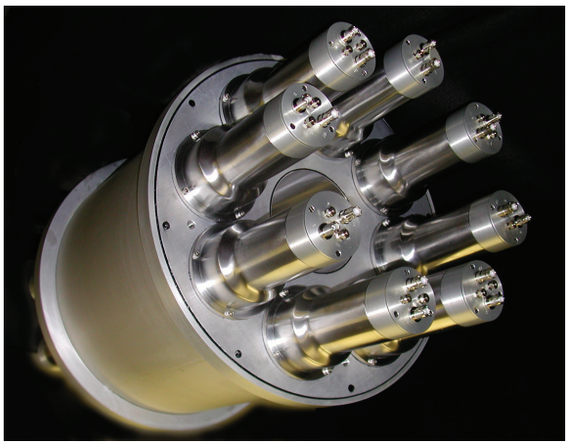
Illustration of Integrally Mounted Scintillator/PMT Assembly



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

Standard Assemblies



DETECTOR ASSEMBLY CONSIDERATIONS –

- **Radiation to be Measured:**
  - Alpha
  - Beta
  - Gamma
  - X-ray
  - 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)
  - Solid State PMT (SSPM)
  - Position Sensitive PMT (PSPMT)
  - Photodiode (PD)
  - Avalanche Photodiode (APD)
  - Microchannel plate (MCP)
- **Electronics**
  - Voltage divider
  - Built-in high voltage
  - Dynode tap
  - Preamplifier

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.

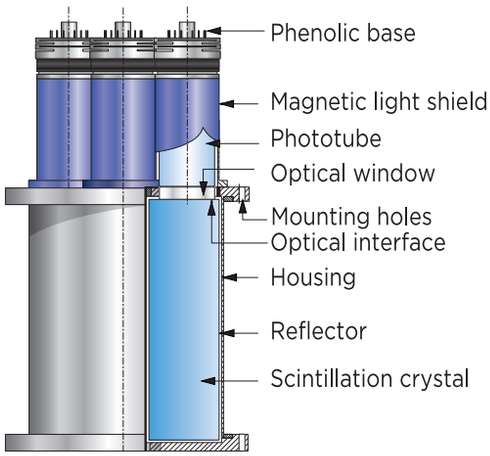
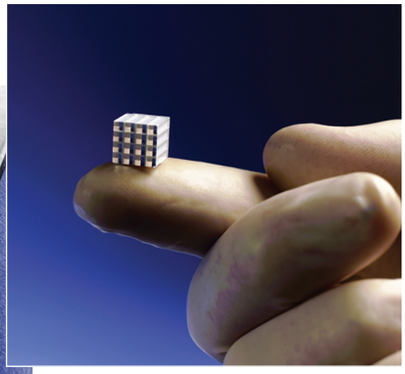


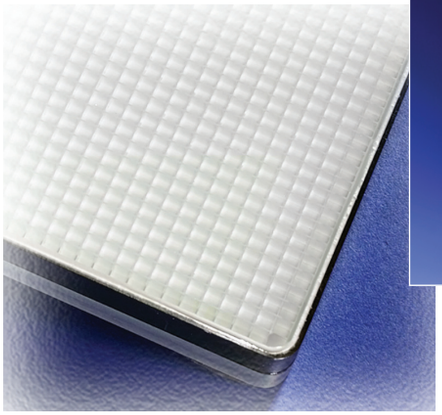
Illustration of NaI(Tl) Detector Assembly with Demountable Photomultiplier Tubes

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, access our "Scintillation Crystal Arrays and Assemblies" brochure on our website – *www.luxiumsolutions.com*





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 or titanium alloy 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.

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 or LED 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).

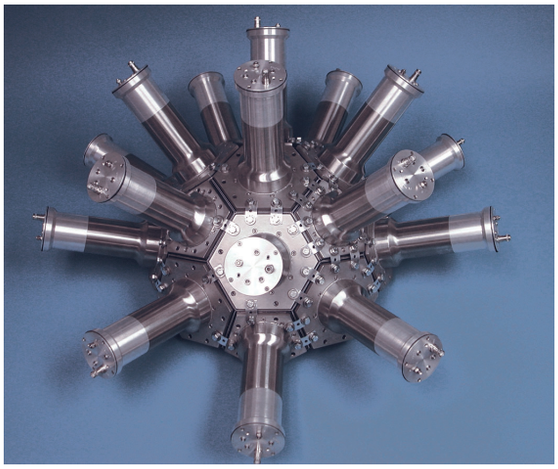
Phoswich Designs –
A phoswich ("phosphor sandwich") is a combination of scintillators with dissimilar pulse shape characteristics optically coupled to each other and to a common PMT (or PMTs). Pulse shape analysis is used to distinguish the signals from the two scintillators, identifying in which scintillator 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
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
- Position-measuring detector bars
- Pair spectrometers
- Neutron detectors



Luxium™ NaI(Tl) Detector "Crystal Ball"
Application: Nuclear Physics



Luxium™ $LaBr_3$(Ce) Detector
Application: Aerospace

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).

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:

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

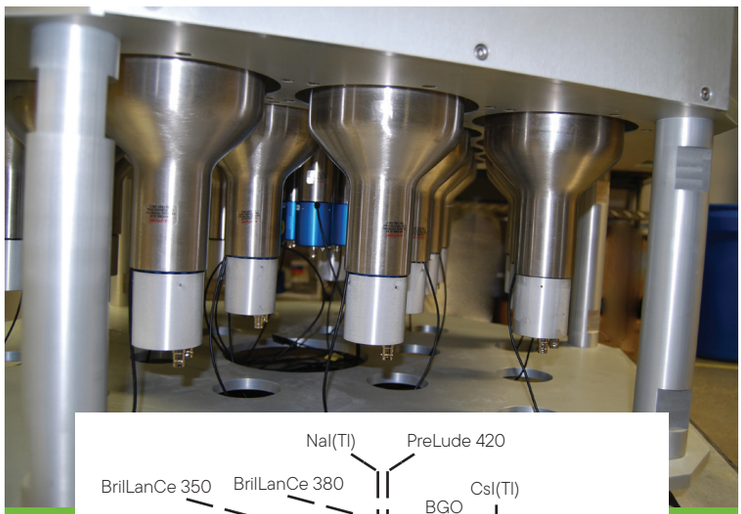
Other Types of Sensors –
Avalanche photodiode (APD) – An APD is a special type of photodiode that can withstand voltages up to several hundred volts. The high voltage generates an avalanche effect. Primary charge carriers are accelerated enough to release additional charge carriers along the collection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

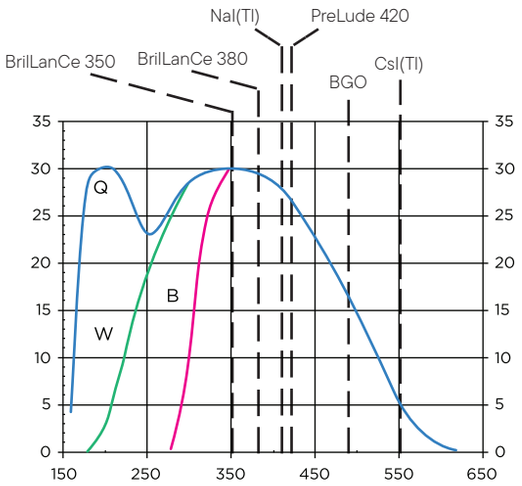
Solid-State Photomultiplier (SSPM) – An SSPM is an array of small pixels (typically a few tens of μm), each consisting of a Geiger-mode avalanche photodiode coupled to a quenching resistor. It is fundamentally a photon-counting device, as each pixel is operated in a binary, on/off, mode to indicate the presence or absence of a photon. SSPMs offer gains comparable to that of a traditional PMT, to which they are a light-weight, compact, low-bias alternative. SSPMs are also insensitive to magnetic fields. Their properties typically vary with temperature. Depending on the SSPM, the output signal can be analogue or digital.

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.

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.





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.)

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

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 in an integrated package. For complete information on design considerations, request our "Voltage Dividers Design Considerations" information sheet.

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.

A 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, operates as a cable 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.

Integrated High Voltage Power Supply –

The high voltage power supply contains a voltage divider, charge-sensitive preamplifier and power supply assembled in one package. It is optimized to work with our Scintillation detectors.

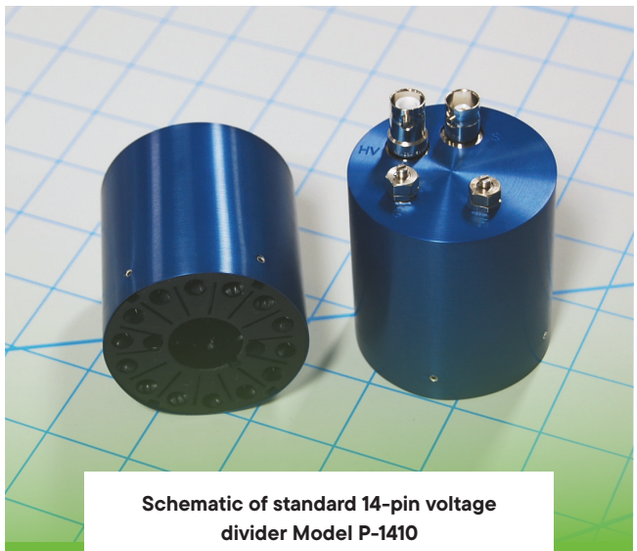
Electronics for Photodiodes –

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.)

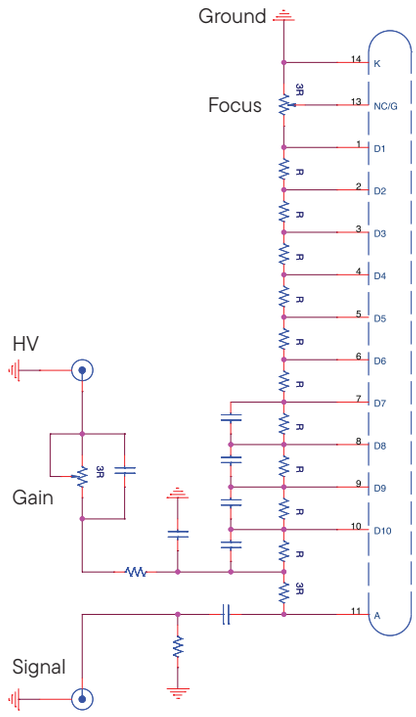
Since the noise of a photodiode increases with its active surface area, detectors employing small (10x10mm^2 or smaller) diodes have a better energy resolution than those equipped with larger diodes.

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.



Schematic of standard 14-pin voltage divider Model P-1410



Standard Features of Luxium™ Solutions Voltage Dividers

- Positive HV max: 1500V
- Anode load resistor: 1MOhm (nominal)
- Anode output: AC coupled
- RoHS compliant
- BNC connector for signal connector
- SHV connector for high voltage

Options available:

- Fully Transistorized
- Negative high voltage
- 8-Stage option for 14-pin only
- Conformal coating for high humidity
- Dynode out

Detector Warranty Information

Each Luxium™ 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 typically 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.

Inorganic Scintillation Detectors –

Excelitas 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.

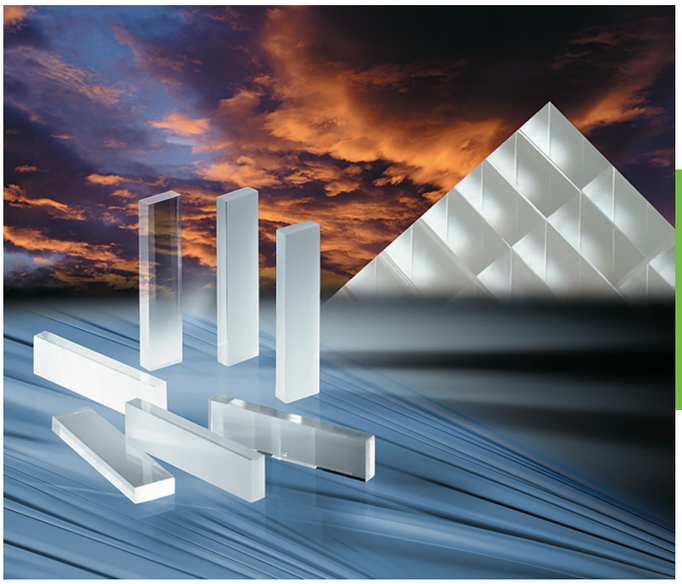
Photomultipliers (PMTs) –

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.

Excelitas' 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 Excelitas' obligations to the purchaser.



Luxium™ Scintillation Materials & Assemblies are produced under a Quality Management System for design and manufacturing of chemical compounds, crystals, and detectors, which complies with the requirements of ISO 9001:2008

For additional product literature or information, call customer service at any of our locations or access our website document library – www.luxiumsolutions.com

It's what's Inside *that* Counts®

excelitas®

For a complete listing of our global offices, visit www.excelitas.com/locations

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