INFRARED COMPONENTS

www.lasercomponents.com

“Nearly every week I got new or improved lasers on my desk for testing. Improved or even new detectors are very rare.“

Peter Kaspersen


Patrick Paul, CEO

Infrared Tradition

Dear Reader,

Since its founding in 1982, LASER COMPONENTS has specialized in IR components with a focus on infrared detectors, and over time our collective know-how has become extensive. Customers now profit from our in-house production facilities world-wide. We have had the luxury of bringing aboard specialists that are more familiar with the market than ever before, providing their expertise in R&D and production.

We offer IR detectors that implement different technologies making it possible for our customers to always find their ideal solution; and depending on the application, one technology may be more ideal than the other. LASER COMPONENTS also offers individual assistance, a service not always available from other manufacturers and vital for custom products.

IR WORKshop

We can proudly say that we launched an international platform for IR technologies in 2012. Every 2 years we welcome experts at our headquarters in Olching to participate at a workshop that focuses on IR detectors for commercial applications, IR components, corresponding peripherals and their applications. It is a global event limited to 80 attendees from Asia over Russia to the USA and of course, Europe.

www.ir-workshop.info

Starting from 2017 the 4th IR WORKshop will also be held in the USA, helping to close the geographical gap between those working towards a brighter future for the future of IR technologies. Our 2018 event will be held again in Munich, Germany.

With this catalog, we welcome you to the IR world of LASER COMPONENTS.

Yours

Patrick Paul
CEO

CONTENT

In-House Manufacturing

LASER COMPONENTS Detector Group

Founded in 2004
Located in Tempe, Arizona, USA

Dragan Grubisic

The LASER COMPONENTS Detector Group with its CEO Dragan Grubisic started with the production of Avalanche Photodiodes in 2004, and with his experience in xInGaAs materials our PIN photodiodes were subsequently developed.

Our latest technologies were launched in 2015, with Detector Group opening a development division and production plant for PbS and PbSe detectors. LASER COMPONENTS has now become the technology leader in PbS/PbSe manufacturing; developing new detectors and inventive fabrication techniques. "We can truly say that we are advancing the state of the art." mentioned Dragan Grubisic.

xInGaAs & InAs PIN Photodiodes

Our detector group manufactures lattice matched InGaAs as well as extended InGaAs PIN photodiodes. On top of this, we now provide extended InGaAs linear arrays with features, such as auto-zero bias for all pixels as standard.

PbS & PbSe Detectors

PbS and PbSe differ in typical spectral range from 1000 to 3500 nm for PbS and from 1000 to 5500 nm for PbSe, and these detectors are provided in cooled and uncooled configurations for a variety of applications.

Questions to Dragan Grubisic, CEO

Q: What has been your first experience with infrared?
A: I started working with Ge, InGaAs and InAs single element detectors in 1983.

Q: Has there been somebody like an infrared guide to you?
A: Processing of infrared detectors has been and still is a kind of "black magic" so I mostly worked on my own developing fabrication and passivation processes for those infrared detectors with initial support by a Senior Chemist at Judson Infrared Inc. and later on by an infrared expert who was one of the first engineers working at Santa Barbara Research Centre.

Q: What has changed in the infrared over the years?
A: In terms of device structures the trend is from single element detectors toward the linear and 2D arrays and in packaging from LN_2 dewars to modern TE-cooled and/or room temperature housings. Also significant amount of work has been invested in new quaternary materials with intention to replace MCT (Mercury Cadmium Telluride) material system in hope to yield better detectors with wider sensitivity coverage, which would extend TE-cooling packaging to detectors covering even longer part of the infrared spectrum.

Q: Basically, your infrared products are based on mature technologies. Do you think, there is still any innovation possible?
A: As I mentioned above, fabrication of many infrared detectors is still far from being fully understood not even talking about being optimized. Looking at the performances, i.e. D* vs. wavelength charts, there is still a lot of room to improve existing state of the art as well as achieve further advances in reliability and process reproducibility of such detectors.

Q: Is there anything specific on your location or your country? Does it have any influence on the company?
A: One of the biggest US Universities ASU, very strong in technical sciences is next door to us and with that we have an easy access to highly educated engineers, technical support and semiconductor characterization facilities.

Q: Please imagine your company and/or your products as some sort of "art object or performance". What is your first association?
A: I have a feeling we are on a space ship who has just jumped into wrap speed.... However, my engineers tell me that a Rembrandt painting would be a good symbol: It just uses fine lines.

Q: How do you think IR technologies have evolved from 2015 – 2017?
A: Technically, alternative semiconductor materials came up in the 3–5 µm range that work well at peltier cooling.

In-House Manufacturing

Lance Feldman

LASER COMPONENTS Pyro Group

Founded in 2014
Located in Stuart, Florida, USA

In 2014 the LASER COMPONENTS group expanded its infrared detector activities and acquired the majority ownership of a U.S. based think tank and manufacturer lead by Alan Doctor, a well-known pioneer in the field of IR, who was the first CEO of LASER COMPONENTS Pyro Group for more than 3 years. LASER COMPONENTS Pyro Group is now lead by our new CEO Lance Feldman, who has been manufacturing pyroelectric detectors for over more than a decade.

The LASER COMPONENTS Pyro Group facility was moved in 2015, not only expanding their production capacities enormously but also introducing the newest assembly and testing equipment.

LASER COMPONENTS Pyro group focuses in pyroelectric detectors based on $LiTaO_3$ and DLaTGS crystals for advanced applications in gas analysis, safety, FTIR spectroscopy, and process control.

Our mission is to bring competition into former monopoly markets, driving innovation and growth. Beside technical improvements in areas like microclimate and filter selection we are introducing our new range of differential pyroelectric detectors. We believe that the differential will have major impact in the manufacturing industry, pushing towards more rugged and higher performing detectors.

Questions to Lance Feldman, CEO

Q: What has been your first experience with infrared?
A: My first experience with Infrared occurred while I was still in Middle School, when motion sensors moved from Ultrasound to Infrared; the dramatic reduction of false positives, reduction in cost, giving rise to the commercialization of burglar alarms. I was fascinated with the technology and the reduction of these false positives utilizing Infrared.

Q: Has there been somebody like an infrared guide to you?
A: In 2008 I was approached by Alan Doctor who is well known in the IR community. He taught me the science of manufacturing pyroelectric devices. This was different to any previous experience as I learned the details of how each component operates and integrates. We created new techniques for manufacturing and moving the production of these devices forward.

Q: What has changed in the infrared over the years?
A: Over the past several years I have witnessed a move to hand held devices requiring lower power consumption. The advent of the smartphone and "Apps" for detection has really fueled some great discussions about where the technology is heading.

Q: Basically, your infrared products are based on mature technologies. Do you think, there is still any innovation possible?
A: Absolutely. There are always ways to improve in both the applications, and the processes in which to produce what the market requires. Curiosity without the binds of practicality, will always be a driving force of innovation.

Q: Please imagine your company and/or your products as some sort of "art object or performance". What is your first association?
A: LASER COMPONENTS Pyro Group's influence on Pyroelectric Detection with the Differential will be no different than what Andy Warhol did for the art community of the 60's and 70's. Possibly, the Ramones in the world of music the past 40 years. A true Paradigm shift in the technology.

Q: What has been changed in the infrared from 2015 to 2017?
A: The personalization of applications for this technology and possible infringements on that technology. Infrared effects everyone whether they know it or not. On Tuesday, June 28, 2016, Apple was granted a new patent, entitled "Systems and methods for receiving infrared data with a camera designed to detect images based on visible light." The patent essentially discloses a method for a smartphone's camera to receive data over infrared waves — data that could alter functionality of the phone. Since the grant of the patent there has been a viral outpouring of articles on using this technology to disable photography and video capture, particularly at live concerts, political gatherings, and theater events. While this apparently invasive tech may be something to keep an eye on, it's important to consider if this can be implemented tomorrow, in a future Phone, or device further down the road. How soon should we start to worry? What technology will allow for detection and, defense of such invasive applications?

In-House Manufacturing

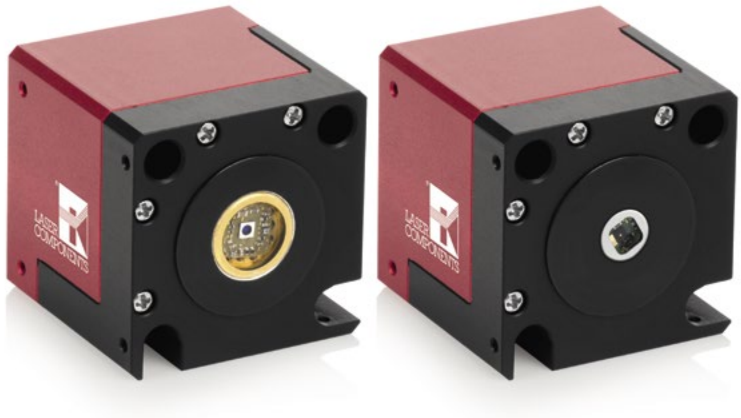
Dr. Lars Mechold

LASER COMPONENTS GmbH

Founded in 1982
Located in Olching, Germany

The LASER COMPONENTS GmbH is the headquarter of the whole LASER COMPONENTS Group, and is where our optoelectronic department is located. More than 10 engineers work on inter-divisional products and technologies in the Munich suburb.

For our IR products a product family for testing and lab applications is currently being developed, dubbed the "CUBE". As well as CUBE's, we can now also offer our miniature FTIR Reference laser module. Housed in our popular CUBE format the InGaAs, Pyroelectric, PbS, and PbSe detectors will become availabe as well as corresponding IR emitters.



Questions to Dr. Lars Mechold, CTO

Q: What has been your first experience with infrared?
A: During my PhD I used to work in the field of high resolution spectroscopy in molecular plasmas.

Q: Has there been somebody like an infrared guide to you?
A: Yes, my former supervisor Prof. Röpcke at the Leibniz Institute for Plasma Science and Technology. He introduced me to a new field and its fabulous possibilities.

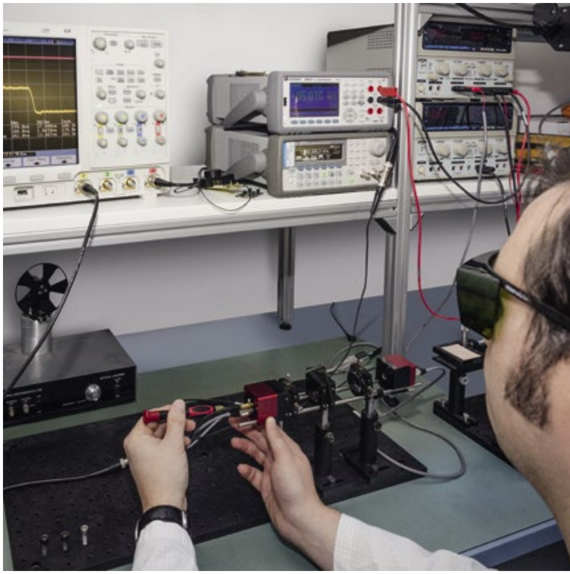
Q: What has changed in the infrared over the years?
A: Lead-salt lasers disappeared and QCL arised. There are new laser sources available. Fortunately more and more applications find themselves to their main spectral range in the IR. On the other hand more devices are produced to be used in medicine. Ophtalmology and skin treatment use wavelengths between 2 and 3 µm.

Q: Basically, your infrared products are based on mature technologies. Do you think, there is still any innovation possible?
A: It is never too late to think new ways. Innovation appears when creative people talk to each other.

Q: Is there anything specific on your location or your country? Does it have any influence on the company?
A: Munich area involves perfect logistic possibilities for travelling, business and scientific interaction. LASER COMPONENTS is part of the industrial advisory board of the master studies in photonics at the Munich University of Applied Science. Every two years our main exhibition LASER World of Photonics is held in Munich. On the other hand Bavaria has beautiful places and is rich in traditions to be explored.

Q: Please imagine your company and/or your products as some sort of "art object or performance". What is your first association?
A: It is the company maypole.

Q: What has been changed in the infrared from 2015 to 2017?
A: We became an established manufacturer of infrared detectors! We did bring real competition into some markets and came up with sound innovations like the differential pyroelectric detector as well.



Variety of IR Detectors

LASER COMPONENTS offers a broad spectrum of IR components that implement different technologies. Gas measurements, for example, can be carried out using both PbS/PbSe or pyroelectric detectors. Depending on what exactly needs to be measured, one technology is more ideal than the other. Here you will find a general comparison of the technologies.

To receive the best measurement result it is mostly neccessary to test different technologies. That's the aim of our IR application development kit.

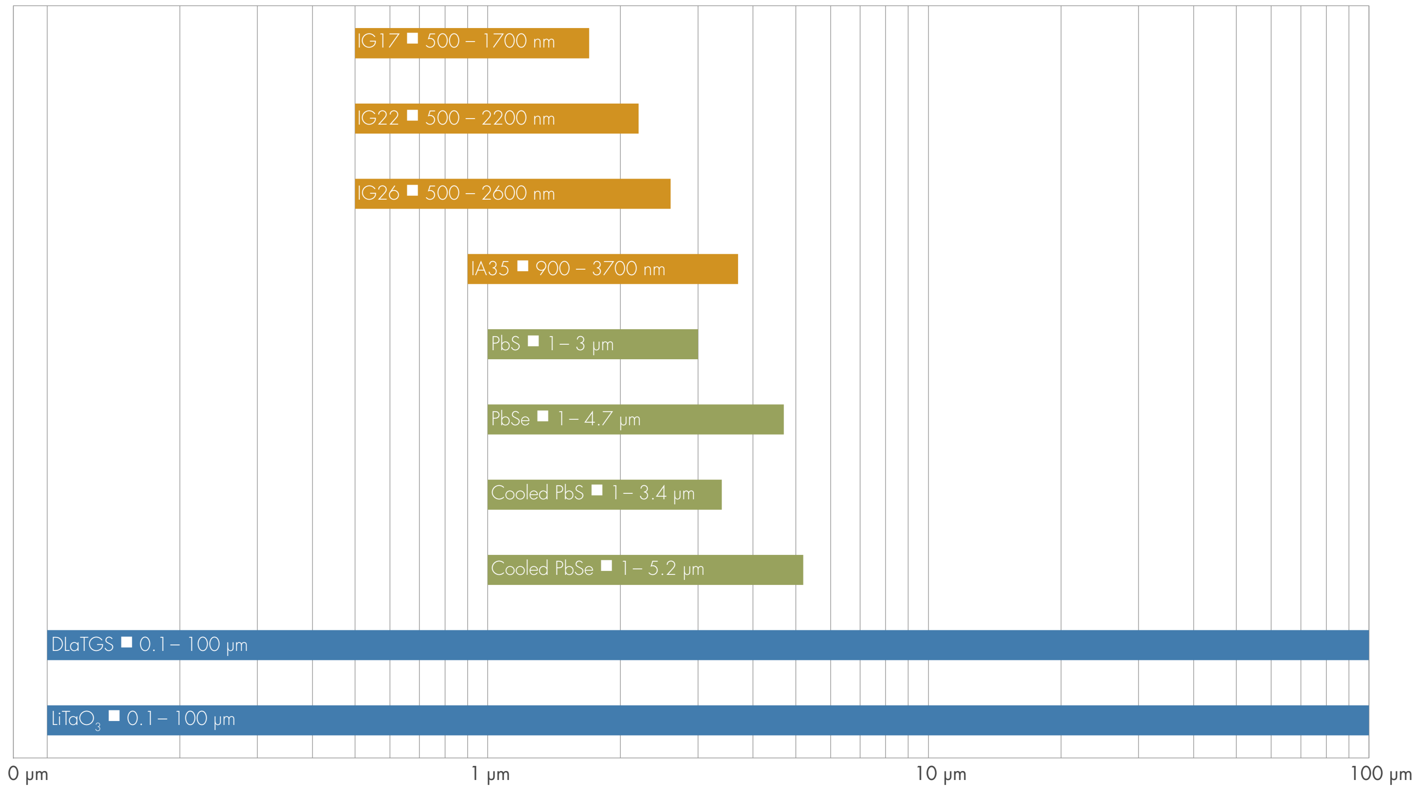


Fig 1: Spectral response of different detector materials

Detectivity D*

The Detectivity D* describes the quality of a detector with the following definition:

D* represents the signal-to-noise ratio for a certain electrical frequency and bandwidth if 1 Watt of radiation power reaches a detector surface of 1 cm². The higher the D* value is, the better the detector is. NEP describes the noise equivalent power.

$$D^* [\mathrm{cm}\sqrt{\mathrm{Hz}}\,\mathrm{W}^{-1}] = \frac{\sqrt{\text{active detector surface}}}{\text{NEP}}$$

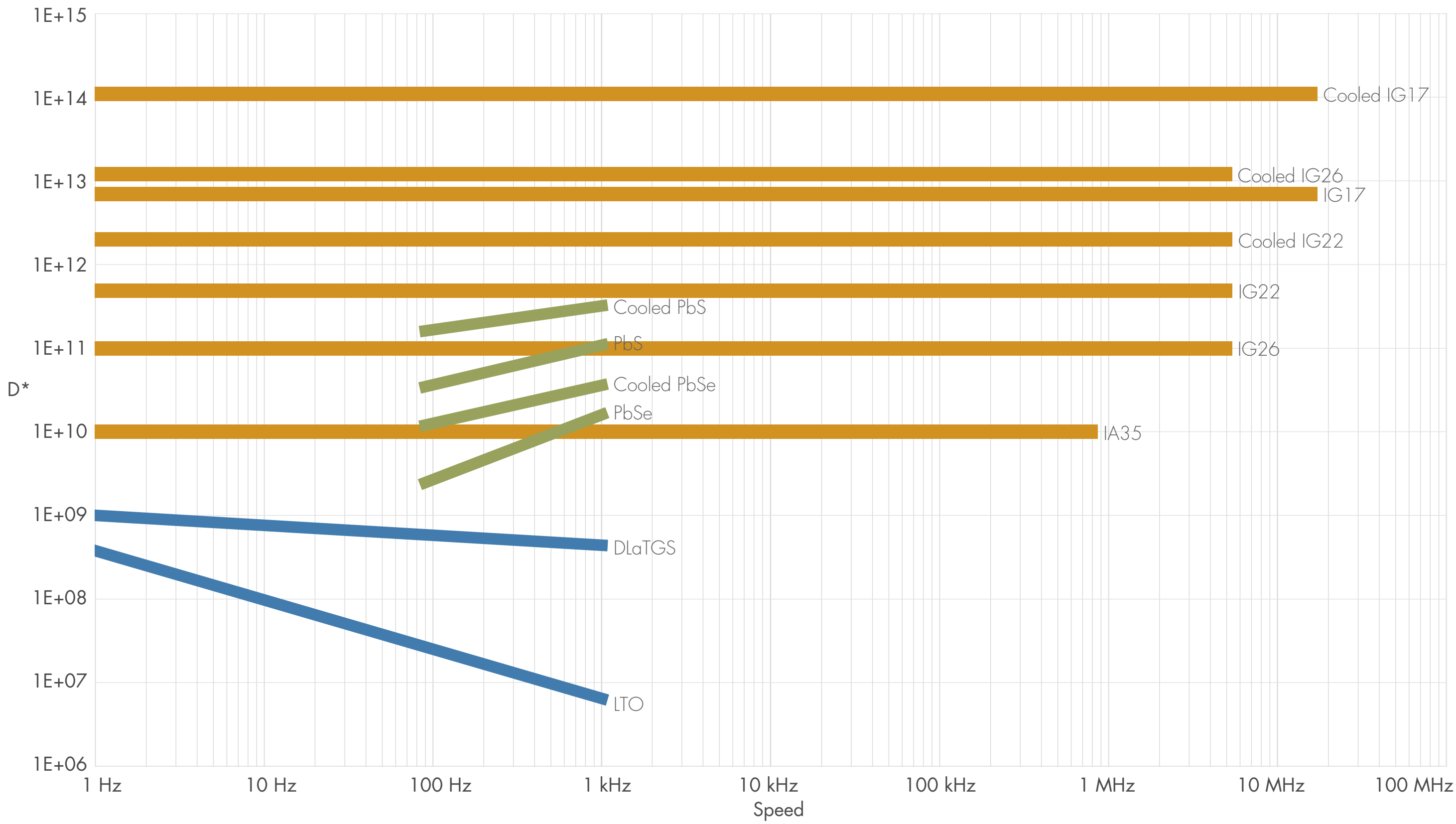


Fig 2: D* vs speed for different detector materials

Philosophy

Application Driving Innovation

At LASER COMPONENTS, we understand that it is not the component manufacturers who drive worldwide innovation, but rather those who use our products. Therefore, we make sure to keep our finger on the pulse of new technologies, whether via. one of our annual international IR WORKshop events; where we bring together academics and industrial innovators from all fields around the world together, to share their combined knowledge at our HQ in Munich or at Arizona State University in the USA.

We are also a manufacturer that is dedicated to working with customers to produce detectors optimised for customer specific applications; working through several iterations to nail down the optimum specification. We are happy once we achieved a simple and clean solution!

We also understand that you want more than "just a salesperson" when looking for your next solution, and therefore our sales engineers go the extra mile to be informed about our technologies, always keeping in close contact with our development teams, academics, and even going as far as building detectors themselves at one of our annual training days!

Infrared Locomotive

We are actively pushing progress in the infrared community. In 2011, we felt that the commercial infrared community seems a little sleepy and decided to start a series of IR WORKshops one year later. Nowadays, the activity level at infrared technologies has increased and commercial breakthroughs will follow.

We have brought serious competition into market segments which have been dominated by one company for a long period.

It has been clear to us that sooner or later; MEMS technologies will become a major driver of growth in the infrared. Very likely these technologies will need detector chips rather than packaged devices. We have been open to this idea all the time and support MEMS makers whenever possible.

Making the Unquantifiable, Quantifiable.

Our engineering philosophy is simple. Experience. Throughout our manufacturing facilities we have a combined experience of over 100 years in the Infra-Red. We have people from many expertise's coming together in the same place, sharing their ideas across many different sensor platforms. The sensors we sell and manufacture may be mature technologies; but we have endeavoured to bring the processes and understanding of the underlying mechanisms into the 21st century. Often bucking against market trends. We are turning the previous "magic" of Lead Salt detectors, which have been known for their "bucket chemistry" production methods in the past; into an exact science using state of the art analysis equipment. Not only do we have a better idea of our manufacturing process and how best to control them, but we now have a better understanding of the materials underlying quirks, which have puzzled those in the field for decades.

We have also made an exciting development in the field of pyroelectric detectors, mainly with the release of our new differential/double ended pyroelectric detector. With the use of a differential amplification scheme, we have been able to achieve a D* of ~1×10^9 Jones with LTO pyroelectrics based on standard LTO wafers. This level of performance has only before been reached with special ultrathin LTO chips, or differing materials such as TGS.

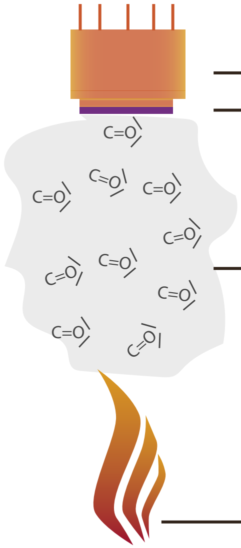
Traditionally detectors are characterized by their D* (specific detectivity), which is a figure of merit used to characterise performance. The higher this number, the "better" the detector. This is quite understandable with defence related thermal imaging as a major technology driver; in this application, all that is desired is to "see" an event. However, in most commercial applications an event must be quantified, implying that the signal is directly proportional to the illumination; therefore, the detector must be linear. In general, reliable linearity specifications are rarely found on datasheets. We are working hard to change this for the better, but it is a rocky road.

Firstly, you need to be able to measure linearity precisely, quickly, and repeatedly over several decades. This could be a topic for a conference on its own! However, we have decided to follow the methods of the telecoms industry, using similar test equipment; allowing us to measure linearity directly over more than 6 decades @1.55 µm. Of course, this is not ideal for characterisation of mid-wave infrared detectors, but it is a sound start and we will add linearity specifications over the years.

Secondly, discussions regarding linearity is not commonplace at conferences and in papers. The reason might be (besides all practical problems of measurement) that there might be a trade-off among performance and linearity, and materials that appear to be superior (like MCT) are a little bit less superior when taking nonlinearity into account. So far this is just a suspicion due to a lack of detailed data.

Dear readers of this catalog: Please help us in our fight for more transparency in the world of infrared detectors and keep on asking speakers, authors and other catalog makers for linearity data. Standardization has always been the base for commercial growth. There is absolutely no reason why infrared technologies should be any different.

Applications



IR detectors and emitters are used for many different applications such as flame detection, gas monitoring, and medical gas analysis or protein measurement. They are also used in incubators or for the inspection of surfaces.

Flame Detection

Flames are often detected in two different ways: high frequency flicker detection, or by detecting the molecules of the gasses given off in combustion such as CO_2. Combustion detection often uses a technique called non-dispersive infrared (NDIR), looking at the light emitted or absorbed by a gas with respect to a reference channel (See application section "Gas Analyzer" for more information). In flame detection, the emission of light at discrete wavelengths is measured, as at hot temperatures gasses emit the same wavelength of light as they absorb.

Flame Control

In today's environmentally friendly industrial climate, if your industrial processes requires the burning of fuels the most efficient flame must be used; producing as little unwanted pollutants as possible. IR detectors are often used to monitor these products of combustion and fuel/air mixtures are adjusted to achieve the most efficient flame, producing less pollution and reducing fuel consumption.

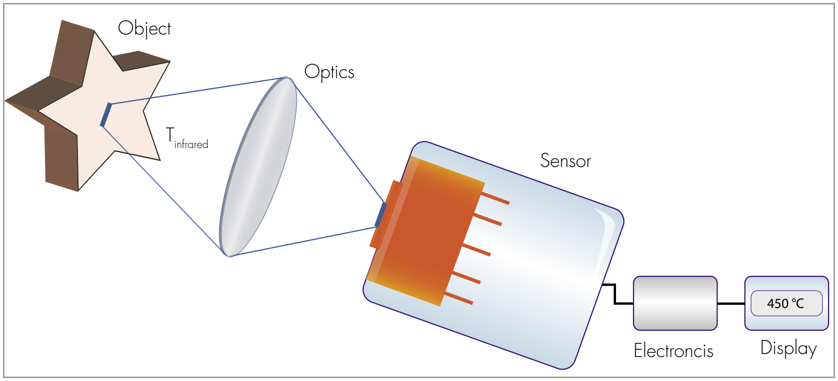
Detectors Used for Flame Detection

Pyroelectric detectors are one of the most common detectors used to detect flames by characterizing the products of combustion. By using a 4 channel pyroelectric detector redundant information can be gained in order to eliminate false alarms. LASER COMPONENTS pyroelectric detectors patented production methods also give reduced microphonics giving you more accurate results.

For more demanding situations PbSe can be used at 4.3 µm, having the advantage of a higher D* and high frequency operation.

Applications

This technique is used at offshore production platforms or ships, at refineries, production facilities, compressor stations, turbine enclosures, airport water curtains, and many more situations.

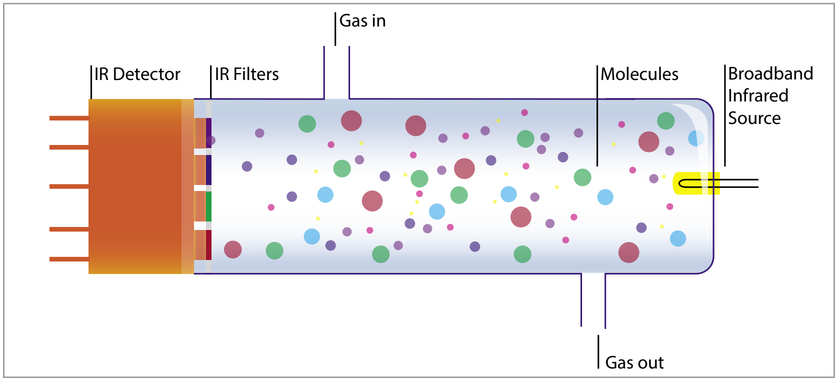


Non-Contact Temperature Measurement

Everything emits heat in the form of blackbody radiation, and this can be exploited to measure the temperature of an object without ever having to physically touch what you are trying to measure. By knowing the emissivity of the object you are trying to measure and the amount of infrared energy emitted the temperature of the object can be calculated using the Stefan-Boltzmann law.

The type of detector used in non-contact temperature measurement varies due to many factors, but one of the largest influences is the temperature of the object you wish to detect. Hotter objects emit light at shorter wavelengths to cooler objects so the correct wavelength range must be chosen based on modeling (using Plank's and Wein's Laws) and experimentation. However, IR non-contact methods of temperature detection are most suitable for materials with a high emissivity. Materials with a high reflectivity such as gold, silver and aluminum are very hard to analyze as measured values would not represent their true temperature in the presence of background sources.

Non-contact temperature measurement is very important for quality assurance in industry for monitoring the processes in glass, plastics, and steel manufacturing; as well as environmental monitoring in geological applications.
LASER COMPONENTS concentrates on supplying detectors and arrays globally to manufacturers of pyrometers for unique applications.



Did you already know

Everyone knows that Google uses street view cars to show 360° panoramas of many places worldwide. Nearly unknown is the fact that the cars are equipped with a measurement technology to measure methane gas leaks.
Leak detection is very important in our days as gas leaks can lead to explosions, and even small leaks cause smog condition and global warming. [1]

Gas Analyzers

One of the most common uses for IR detectors is gas analysis (especially pyroelectric detectors). Most gases have their own "absorption lines" at different frequencies of light and are targeted; using the Beer-Lambert Law to calculate the concentration. Unlike spectroscopic methods like Raman, absorption spectroscopy allows you to not only determine what gas is present; but also the concentration.

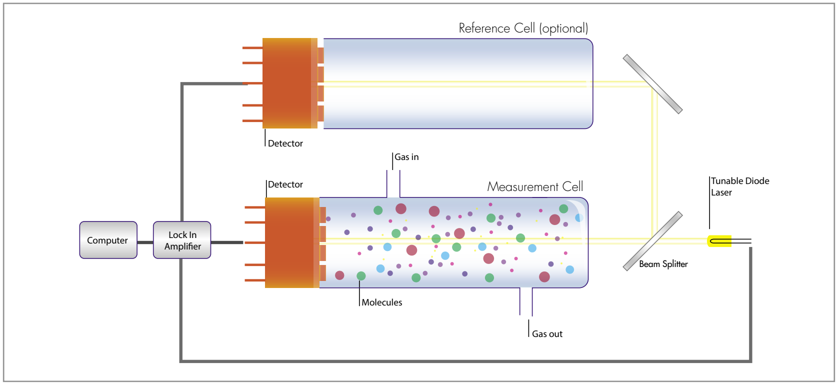
Non-Dispersive Infrared (NDIR)

NDIR is by far the most commonly used gas detection method today due to its simplicity. Gas is passed through a measurement cell where a broadband IR source is used to emit light through the cell to a detector. The detector uses IR optical filters to filter the light into an "active channel" at the absorption wavelength of the target gas and a reference channel. One of the most common gasses that is detected via this method is CO_2 at approx. 4.3 µm.

The advantage of NDIR comes from the strength of absorption in the mid IR compared to methods in the NIR. This strong absorption allows relatively low concentrations of gas to be detected with small path lengths and inexpensive components. LASER COMPONENTS can provide detectors that have more than one channel with many filter options, one channel as a reference and the rest for the gasses you would like to detect. We now offer a filter that enables infrared humidity measurements in many applications.

NDIR is also not without its challenges: selection of the correct filters to minimize crosstalk combined with the angular and temperature dependence these filters can cause undesired results. LASER COMPONENTS has years of experience in this field, and our standard selection of filters has been carefully chosen to help you easily find the best filters for your application.

[1] Authority: http://techpresident.com/news/25215/google-street-view-cars-deployed-measure-methane-gas-leaks



Tunable Laser Diode Spectroscopy (TDLS)

TDLS is a highly sensitive detection technique capable of resolving low gas concentrations down to ppb. A tunable laser diode such as a DFB or VCSEL is used with PIN detectors and optics to target very narrow absorption bands. Popular applications in the NIR are oxygen, water vapour, methane and ammonia detection. TDLS has several advantages over NDIR including: faster acquisition times, high S/N ratio, and the ability to target specific gasses in a family. The disadvantage is that TDLS analysis is expensive compared to NDIR, despite pricing is decreasing. Applications in MWIR and LWIR are catching up due to progress at laser sources.

TDLS takes advantage of the fact that modern semiconductor lasers can be tuned in wavelength via temperature or current tuning, allowing scanning over individual gas absorption lines. Measurements can be referenced via the two zero values either side of the absorption line. By subtracting your reference values or monitoring the ratio between the signals detected to the original intensity the gas concentration can be determined via spectral analysis.

LASER COMPONENTS supplies detectors, optics and lasers to manufacturers of specialist TDLS equipment.

! Did you already know

Did you know human skin has been used as a part of an infrared detection scheme for TDLS spectroscopy?

A group from Frankfurt Johann Wolfgang Goethe-University has developed a method of glucose detection based on photothermal deflection. A pulsed QCL is used on the skin, and due to the LWIR absorption characteristics of glucose the skin absorbs a certain amount of light; heating it up. This energy is transferred to a prisim via contact changing the refractive index and hence the total internal reflection. This minor change is then monitored by a second low cost probe laser. A spectrum can them be taken by tuning the QCL over a wide range giving the concentration of glucose present in the blood.[1]

[1] Authority:
Pleitez M. et al., Photothermal deflectometry enhanced by total internal reflection enables non-invasive glucose monitoring in human epidermis. Analyst (2014) DOI: 10.1039/c4an01185f

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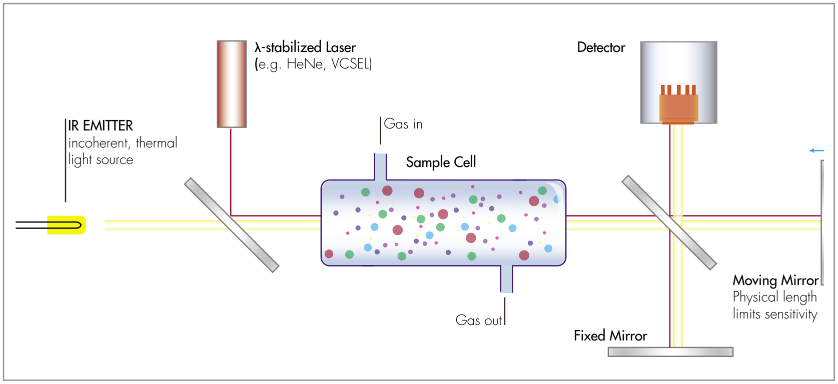


Schematic drawing of a FTIR spectrometer

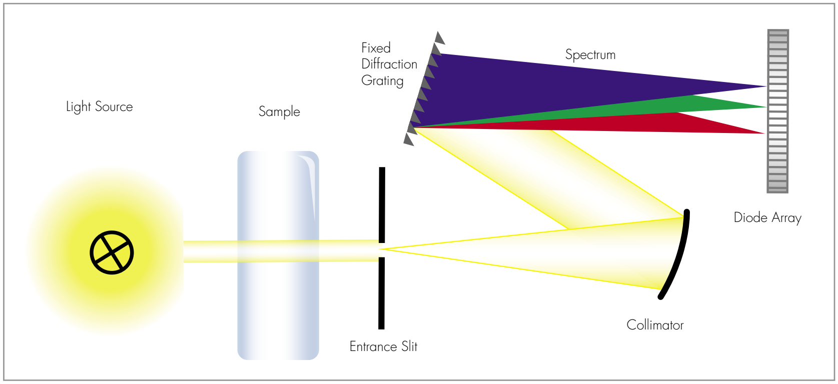
Spectrometers

Spectrophotometry is an incredibly powerful method of analyzing a sample for the presence of many unknown constituents in a single measurement, provided that the absorption features are in the wavelength range of the detector used. IR spectrometry is used worldwide for any application where needing to know what chemicals and gasses are present, such as environmental and urban gas monitoring, security, forensics, quality control, and biomedical analysis.

Spectrometers can be built with many different methods using arrays, single point detectors, monochromators, prisms, gratings, etc.

FTIR

FTIR spectroscopy, better known as FTIR; is the method for collecting spectral data over a wide range with a high spectral resolution. Unlike traditional spectroscopy techniques using prisms, gratings, or monochromatic sources, FTIR uses a broadband source in combination with a Michelson interferometer using wave interference to generate each individual wavelength. A Fourier transform is used to manipulate the mirror position to the specific wavelength. The precision of these scans is highly dependent on an accurate frequency reference, often provided by a known laser source.



Array Spectrometers

As IR detector technology advances with larger wafers, increased responsivity, and better assembly techniques; IR arrays have seen a large decrease in price allowing them to be used in many more applications than ever before. The advantage of using an array over a monochromator or a FTNIR is as the entire spectrum can be captured in one measurement allowing for much faster acquisition times; and as there is no need for moving parts, array spectrometers can be made to be very small and robust. Miniaturized and rugged spectrometers opens the door for applications not before possible, such as spectroscopic analysis from UAVs.

Laser Power Monitoring

Laser Power monitoring is a direct and trivial application for any light detector. However there is one major difference between detectors used in power meters, and those used in power monitoring; detectors for power monitoring are not calibrated to a specific power level. In power monitoring applications a detector is used to produce a feedback loop between the output of a laser and the electronics used to control it, producing a stabilized output power. Although this might sound simple, care has to be taken so a detector is not over saturated and the laser is within the detectors range of linearity. This is why beamsplitters or side reflections are used to only observe a small fraction of the laser light.

Choosing the Right Detector

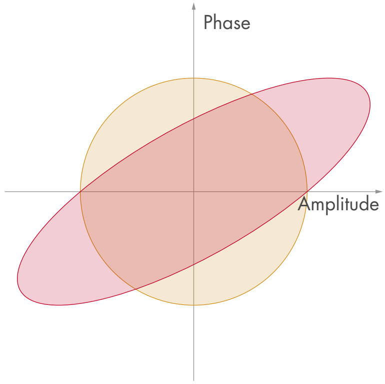
In most power monitoring applications the smallest photodiode will be more than enough to do the job; however, if you are looking to record the absolute power (even in arbitrary units) then larger area photodiodes are recommended. Care also has to be taken to select the right spectral range, and effects of temperature are taken into account.

InGaAs or Silicon?

For lasers in the 900 – 1000 nm region silicon is still a popular choice of detector for power monitoring despite the fact that its responsivity is heavily temperature dependent in this spectral range. InGaAs on the other hand has a far better temperature coefficient over this spectral band, with our IG17 series having a temperature coefficient of <0.1%/K. With the same coefficient becoming an entire order of magnitude less with our IG22 chemistry.

Pyroelectric

A high speed version with integrated OpAmp can be a sound option for applications up to a few kHz in cases where semiconductor based detectors are unsuitable.



How squeezed states effect the uncertainty regions of photons

- Circular Uncertainty Region of Glauber States of Light
- Uncertainty Region of Squeezed States of Light

Squeezed States

Most experiments into quantum metrology run into the same problems, mainly that most detection setups are limited in sensitivity due to the quantum noise floor. This is thanks to the uncertainty principle, where the precision of the complimentary variables x (position) and ρ (momentum) has a fundamental limit:

$$\sigma_\chi \sigma_\rho \geq \frac{\hbar}{2}$$

Which essentially describes that the more you know about a particles position, the less you know about its momentum; and vice versa. Applications such as gravitational wave interferometry are dependent on the uncertainty principle to be able to achieve the incredibly low noise floor for their experiments.

Squeezed states of light can be used in these applications to be able to overcome this quantum noise inherent to photons, even overcoming the noise of Glauber (coherent) states; meaning that by using this little quirk of quantum optics, you can achieve uncertainty regions which are less than the circular uncertainty regions of Glauber states. Or, the uncertainty region is "squeezed". The overall area of the region stays the same, but one of the axes is pushed together; increasing your accuracy for this measurement while sacrificing the accuracy of the other. A visual representation of this is shown in the figure.

To generate a squeezed state of light, you must first have an incredibly stable and coherent state of light, then via the use of some non-linear optics (optical parametric oscillator); one pumping photon produces 2 photons which are entangled. A good way to think about how this effects your noise measurement is to think of 2 dice. When you throw the dice, they might land in the same area but the values of the dice will be different and random (an unknown quantity); the values on the dice are your "quantum noise" effecting the accuracy of your overall measurement. Imagine the entangled photon pairs as a pair of dice that always throw doubles; you always know that the dice will have an equal value (much like entangled photons), so any changes to the value of the dice would have come from an outside influence.

Recently, our high QE photodiodes were used to detect 15dB squeezed states of light[i] for the first time ever; a world record achievement for quantum optics; requiring an incredibly sensitive detector.

(i) Vahlbruch et. Al – Detection of 15dB Squeezed Stated of Light and their Application for the Absolute Calibration of Photoelectric Quantum Efficiency PRL 117, 110801 (2016)

InGaAs PIN Photodiodes

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You can also give us a call!

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Nordic Countries	+46 31 703 7173
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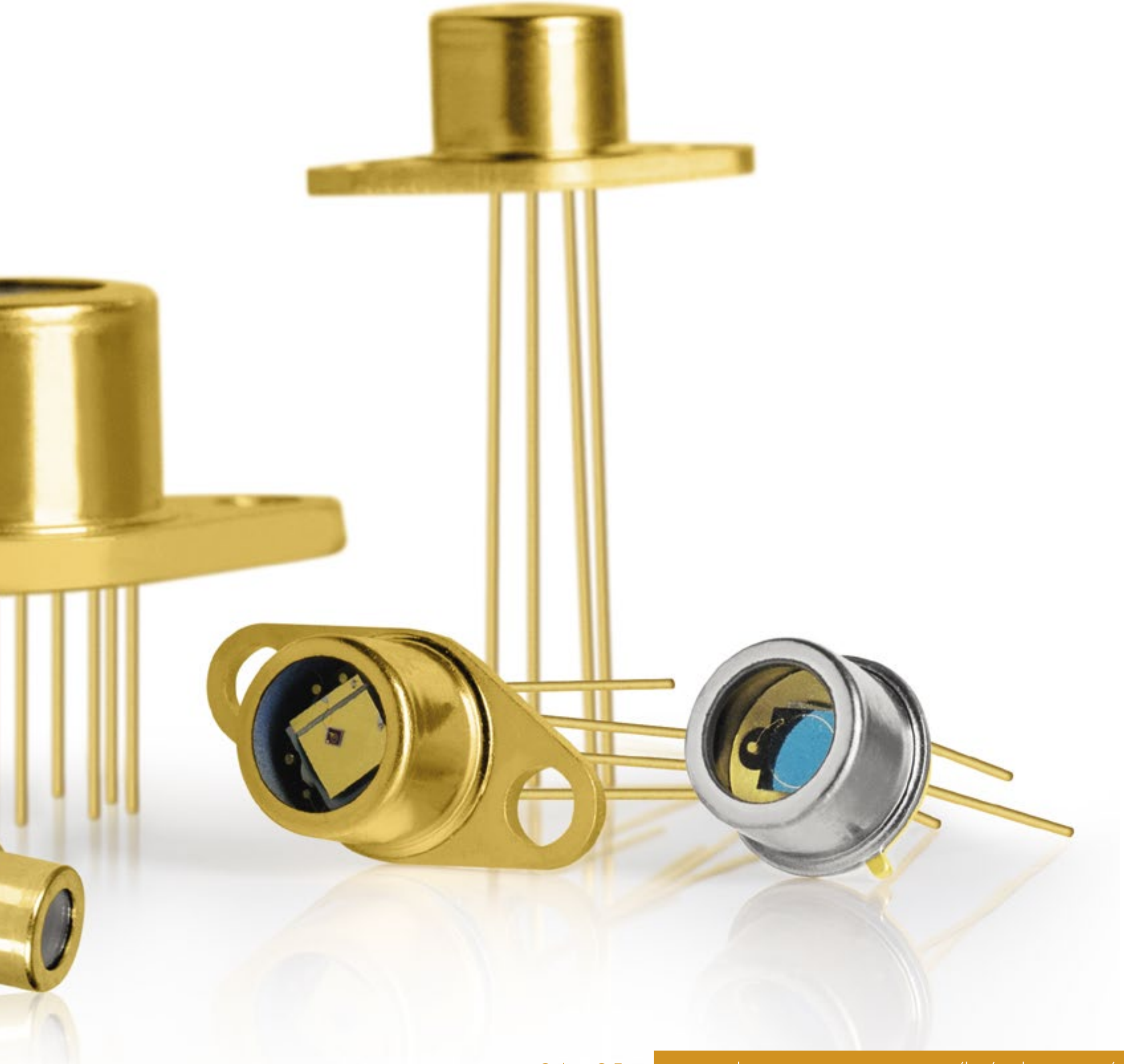
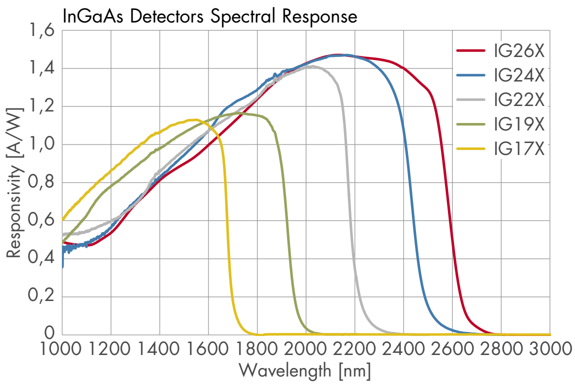


Tech Notes & Basics

InGaAs
Indium Gallium Arsenide Photodetectors are composed of two III–V semiconducting materials. They not only have applications in electronics but also in optoelectronics.

The wavelength range is enormous:
InGaAs λ = 500 nm – 1700 nm
x-InGaAs λ = 500 nm – 2600 nm



Quantum Detectors – Photovoltaic Type

InGaAs PIN photodiodes are photovoltaic quantum detectors, converting an optical infrared signal to an electrical signal. Our InGaAs PIN photodiodes are panchromatic with a sensitivity range from 500 nm up to 2600 nm.

Physical Principles
The semiconductor material absorbs incident IR photons in the intrinsic region, generating electron hole pairs which are collected at external electrodes.

Materials
Photovoltaic detectors can consist of many different materials, e.g. Ge, InAs, InGaAs, or extended InGaAs.

Advantages of InGaAs PIN Detectors

Compared to other photovoltaic materials InGaAs has numerous advantages:

- Fast response times
- High quantum efficiency
- Low dark current and low noise

Further advantages are

- Perfect for short wavelengths
  Our InGaAs PIN detectors are suited for measurements in the shorter wavelength range as they have a high sensitivity in this area.
- Eliminated off area response
- Linear at high incident of power densities
- High shunt resistance

Absolute Maximum Ratings

		Min.	Max.
Storage Temperature [°C]		-55	+125 / +80[c]
Operating Temperature [°C]		-40	+85 / +60[c]
Reverse Bias, cw [V]		-	1 / 10[b] / 0.25[c]
Forward Current, cw [mA]		-	1 / 10[c]
Soldering Temperature, 5 sec. [°C]		-	260
ESD Damage Threshold, Human Body Model Class[a]: 0 / 1A[b], [V]		0 / 250[b]	<250 / <500[b]
TE Cooler Voltage [V]	T7	-	0.8
	T9	-	3.7
TE Cooler Current [A]	T7	-	1.9
	T9	-	1.2

[a]ANSI/ ESD STM5. 1-2007 [b] for IG17 only [c] for IA35 only

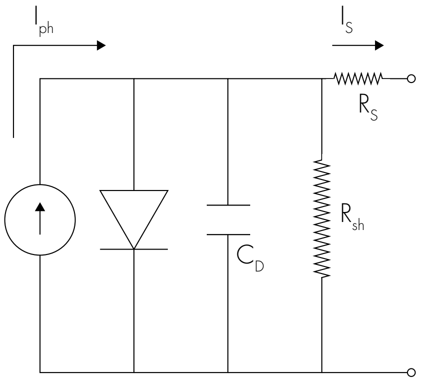
Part Number Designation

Our product nomenclature allows you to see at a glance what's what – details are given below.

	Type	Diameter	Package Style
C- Chip only	IG17X	250 — 250 µm	S4i — TO-46, isolated
	IG19X	500 — 500 µm	S4ix — TO-46, no window
	IG22X	1000 — 1 mm	G1i — TO-39, isolated
	IG24X	1300 — 1.3 mm	G1ix — TO-39, no window
	IG26X	2000 — 2 mm	T7 — TO-37, single stage TEC
		3000 — 3 mm	T9 — TO-66, dual stage TEC
			L5 — TO-46 with lens
			M2 — 2 pad PCB SMD (large volume)

Standard window: Borosilicate glass
Other window materials and coating options are available on request

Note: Not every IG type is available in every chip diameter.



I_{ph} = Current generated by incident photons
C_D = Detector junction capacitance
R_{sh} = Detector shunt resistance
R_S = Detector series resistance
I_S = Output signal current

Fig 1: Equivalent circuit of a photodiode

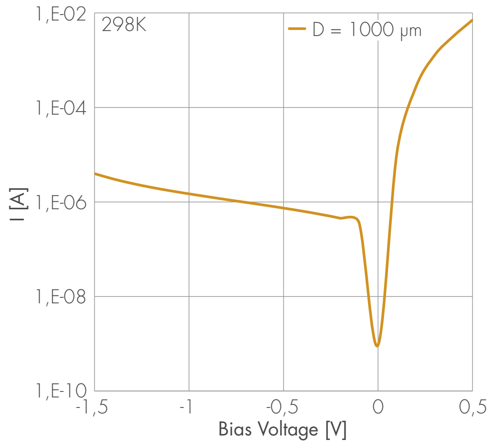


Fig 2: The importance of 0V bias

Technical Note on Basis of Photovoltaic Detectors

Technology Basics

A semiconductor material absorbs light when the photon energy is larger than the band gap energy of the semiconductor. The absorbed photons generate mobile charge carriers. The generated carriers modify conductivity of the semiconductor in a photoconductive detector, while they are collected as a current in a photovoltaic detector.

Photovoltaic detectors are an excellent choice in many applications due to their high sensitivity, fast response, low noise and wide dynamic range. Our photovoltaic detectors are pin junction photodiodes. The mobile carriers generated in and close to the junction's depletion region are quickly transported to the contacts by the internal electric field where they form a measurable current. The ratio of the measured current and the input light power is a major characteristic of a detector called **responsivity** (Amps/Watt). The responsivity is a function of wavelength, temperature and optical matching at the air/photodetector interface. Temperature changes affect the responsivity at the long wavelength portion of the spectral response, largely due to temperature induced changes in the detector's material band gap energy (cut-off). Antireflective coating (AR) films are usually applied to the detector surface to increase the fraction of the light penetrating into the junction which increases the responsivity by approximately 25%.

Equivalent Circuit Diagram

The equivalent circuit of a photodiode (Fig. 1) consists of a current source Iph, an ideal diode, a shunt resistance R_{sh}, a capacitance C_d and a series resistance R_s. The current I_{ph} is due to the photogenerated mobile charges and thus is proportional to the intensity of the absorbed light. The shunt resistance is the second most critical component of the circuit that needs to be as large as possible to minimize the noise and maximize the portion of the I_{ph} current (signal current I_S) available externally for measurement. Large shunt resistance values are generally associated with small values of the dark current I_d. The dark current is the component of the signal current not generated by light and it is usually a small fraction of the total signal current. The series resistance value is very small (typically 1 Ohm) to have a negligible voltage drop for light power levels generally up to 10 mW and so to maintain the linearity of the photodiode response. A diode photodetector has the best performance when its load is a "short circuit", in line with its current source model.

The Importance of 0V Bias

Biasing photodiodes is a very common practice, especially in industries that favor speed over the overall sensitivity of the photodiode; such as telecoms. However, LASER COMPONENTS' photodiodes are designed for sensing applications, where most of our users need to squeeze every last bit of performance; especially in low light conditions using the detectors in a photovoltaic regime. One of these important specifications is the Dark Current.

Figure 2 shows how even a small amount of overall biasing voltage can seriously effect the level of dark current in the device, resulting in noise. Even 10µV can increase the dark current significantly, especially for x-InGaAs photodiodes!

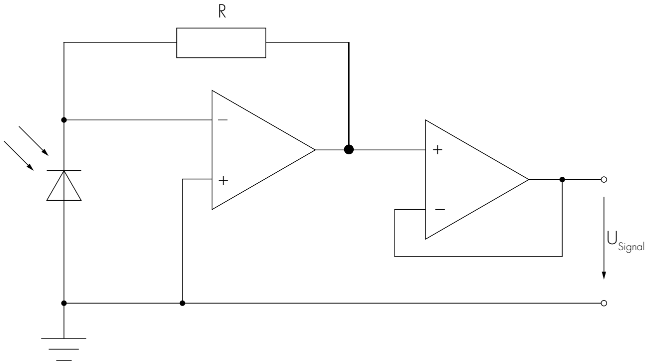


Fig 3: Typical transimpedance amplification circuit

We always recommend that care is taken to include measures to ensure that our photodiodes are operated at 0V bias with some form of voltage correction circutry.

Amplifier Selection

The transimpedance amplifier (Fig. 3) is the recommended preamplifier circuit for a photodiode because it best approximates the "short circuit" load. The op amp of the transimpedance amplifier keeps the photodiode detector near zero volt bias ("short circuit") and directs the signal current through the feedback resistor R_F. The amplifier output voltage is the voltage drop across the feedback resistor equal to the product of the signal current and the feedback resistance, thus converting the photodetector's signal current to a voltage signal that can now be easily digitized, transmitted or further amplified depending on the application. The feedback capacitor is added to limit the amplifier gain and noise at high frequencies.

Proper selection of the op amp is essential for achievement of the high performance transimpedance amplifier operation. The desired op amp characteristics are high DC gain, high unity gain-(gain bandwidth product) frequency, low bias currents, low offset voltage and low current and voltage noise. The op amps with a JFET input stage are recommended because of their exceptionally low current noise, low voltage noise and very low bias currents and offset voltages. In the past, when selecting the op amp, one had to consider whether the shunt resistance is high or low and match the op amp noise characteristics accordingly; however, currently available low noise JFET input stage op amps make such considerations unnecessary.

Selecting Photodiodes

Photodiode selection for a particular application is a compromise of two conflicting considerations: selecting a small band gap energy photodiode detector that responds to widest possible infrared wavelength range that at the same time has very high shunt resistance to minimize the noise and dark current. However, the semiconductor physics makes it unavoidable that the smaller the band gap energy of a semiconductor material, the smaller the shunt resistance (and the larger the dark current) of the photodiodes made from the material. That's why one has commercially available many different photodiodes with slightly different cut off wavelengths (band gap energies) in the same semiconductor material family, such as various InGaAs compositions.

The shunt resistance depends exponentially on the ratio of the band gap energy and absolute temperature

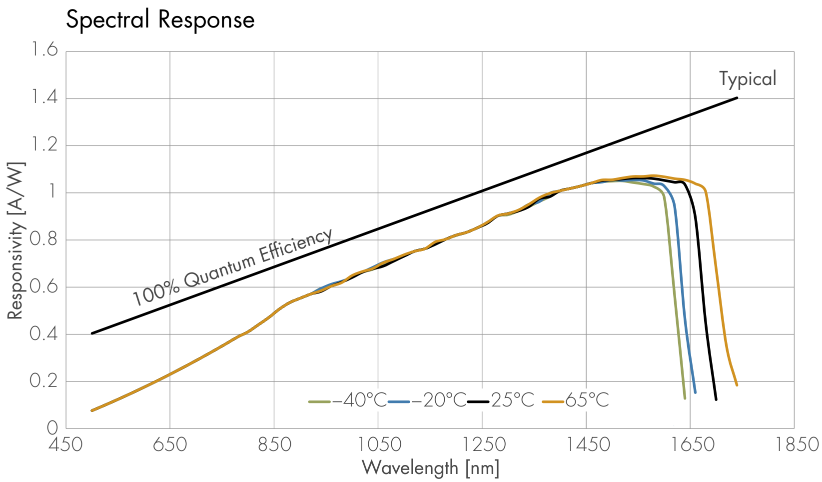
$$R_{sh} \sim \exp(E_g/kT).$$

so lowering the temperature of the diode increases its shunt resistance. Exploiting this relationship, photodiodes for high end applications are frequently operated at reduced temperature, down to roughly -50°C to increase the shunt resistance and improve the noise.

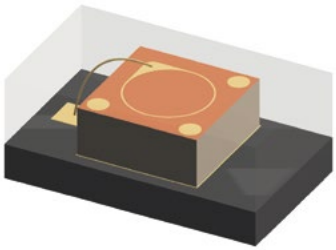
Active surface area of the photodiode is another parameter subject to compromise in diode selection since larger active area increases the photogenerated current but also lowers the shunt resistance.

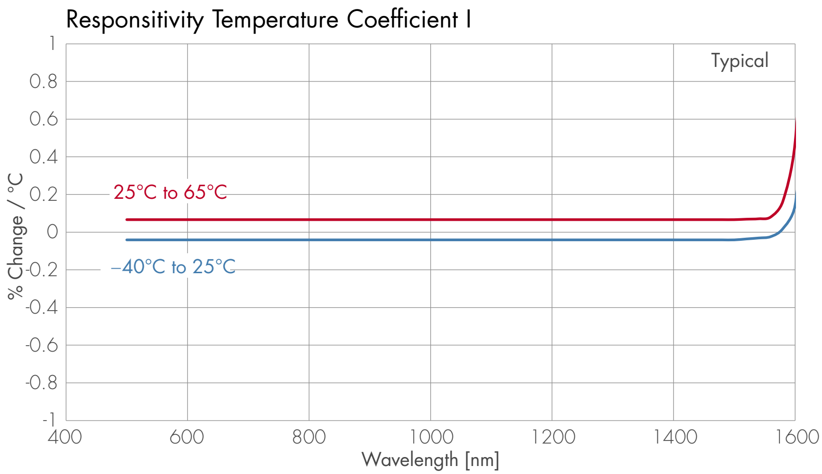
IG17 Series

InGaAs Photodiodes (cut off @ 1.7 μm)



High Volume Option
IG17X1000M2 / IG17X250M2





Note: InGaAs makes an ideal replacement for Silicon photodiodes at NIR wavelengths for power monitoring applications (e.g. at 1064 nm) due to the increased linearity

Basic Characteristics, Specifications @ 25°C[c]

Part Number	50% Cut off Wavelength[a] [μm]	Peak Wavelength[a] [μm]	Peak Responsivity[a,b] [A/W]		Responsivity [A/W]					
					@ 520 nm[a,b,d]		@ 1300 nm[a,b]		@ 1500 nm[a,b]	
		Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.
IG17	1.65	1.55 ± 0.1	0.9	1.05	TBD	0.1	0.77	0.91	0.8	1.0

[a] Parameter tested on batch level at T = 25°C. [b] Responsivity measured at 0 V Bias. [c] Data are prior to window integration [d] Preliminary data

Electro-Optical Characteristics, Specifications @ 25°C

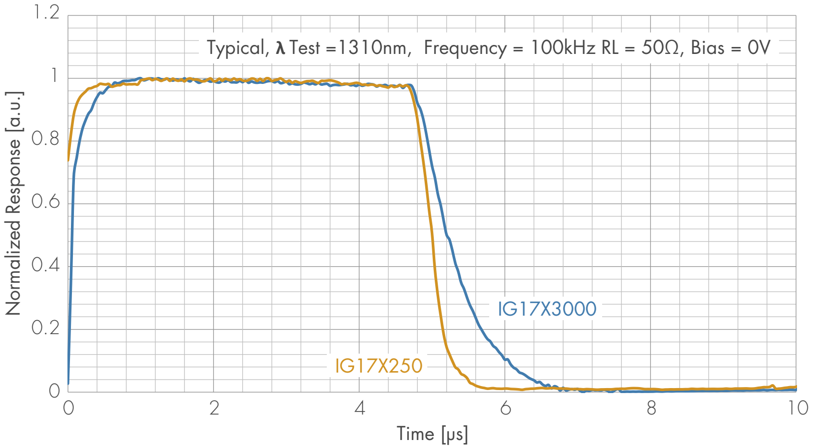
Part Number	Diameter [µm]	Shunt Impedance @ V_R= 10 mV[b] [MOhm]		Dark Current @ V_R= 5 V[b] [nA]		Peak D* [a] f = 1 kHz [cm Hz$^{1/2}$/W]		Peak NEP[a] f = 1 kHz [W/Hz$^{1/2}$]		Capacitance @ V_R= 0 V[a] [pF]	Forward Voltage [V]
		Min.	Typ.	Typ.	Max.	Min.	Typ.	Max.	Typ.	Typ.	Typ.
IG17X250S4i	250	200	830	0.1	1	5.0 E+12	1.0 E+13	1.0 E-14	5.0 E-15	15	0.73
IG17X500S4i	500	60	200	0.3	2	3.8 E+12	7.0 E+12	1.8 E-14	1.0 E-14	60	
IG17X1000S4i	1000	20	100	1	8	3.1 E+12	7.0 E+12	3.2 E-14	1.4 E-14	215	
IG17X1300S4i	1300	10	45	2	20	2.5 E+12	5.3 E+12	4.5 E-14	2.1 E-14	305	
IG17X2000G1i	2000	6	20	3	30	2.4 E+12	4.4 E+12	5.8 E-14	3.2 E-14	700	
IG17X3000G1i	3000	4	12	10	75	2.4 E+12	4.2 E+12	7.1 E-14	4.1 E-14	1550	

[a] Parameter tested on batch level [b] Parameter 100% tested

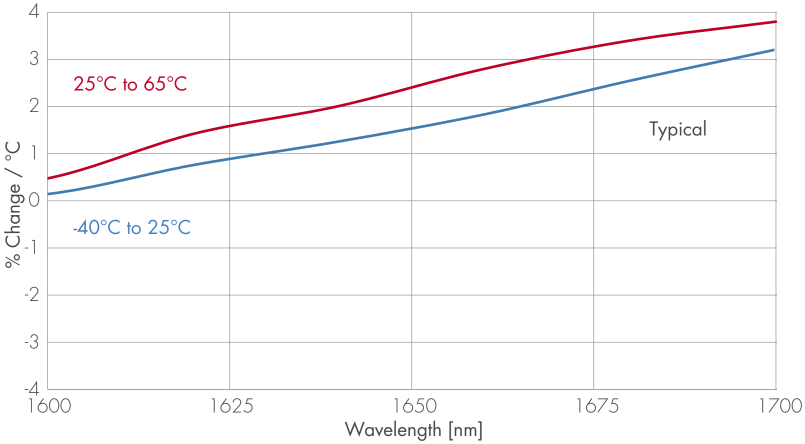
Thermoelectrically Cooled InGaAs Detectors

Part Number	Diameter [µm]	Operating Temperature [°C]	Shunt Impedance @ V_R= 10 mV[b] [MOhm]		Peak D* [a] [cm Hz$^{1/2}$/W]	Peak NEP[a] [W/Hz$^{1/2}$]	Capacitance @ V_R= 0 V[a] [pF]
			Min.	Typ.	Typ.	Typ.	Typ.
IG17X1000T7	1000	-20	750	2750	4.1E+13	2.1E-15	215
IG17X1300T7	1300		360	1500	4.0E+13	2.9E-15	305
IG17X2000T7	2000		180	530	3.6E+13	4.9E-15	700
IG17X3000T7	3000		65	295	4.1E+13	6.6E-15	1550
IG17X1000T9	1000	-40	5000	19000	1.1E+14	7.9E-16	215
IG17X1300T9	1300		2000	10000	1.1E+13	1.1E-15	305
IG17X2000T9	2000		1100	4000	1.0E+13	1.7E-15	700
IG17X3000T9	3000		200	400	4.9E+13	5.5E-15	1550

[a] Parameter tested on batch level [b] Parameter 100% tested

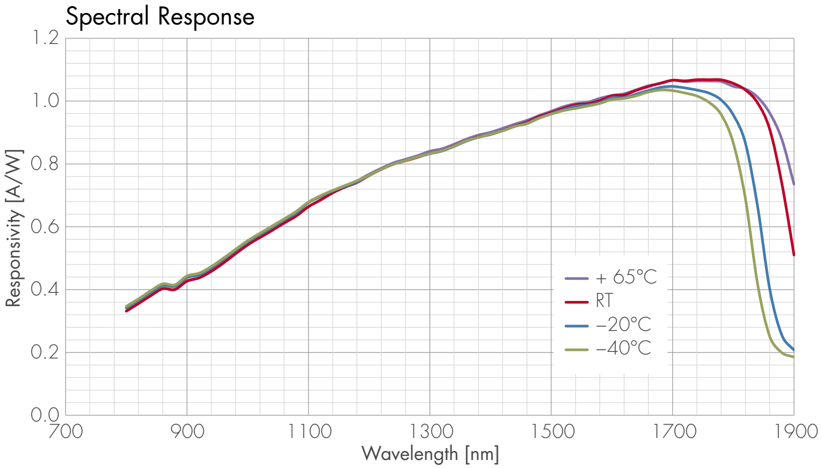


Sample Pulse Response



Responsivity Temperature Coefficient

Linearity



IG19 Series

Extended InGaAs Photodiodes (cut off @ 1.9 µm)

Basic Characteristics, Specifications @ 25°C[c]

Part Number	50% Cut off Wavelength[a] [µm]	Peak Wavelength[a] [µm]	Peak Responsivity[a] [A/W]		Responsivity [A/W]					
					@ 520 nm[a,d]		@ 1500 nm[a]		@ 1700 nm[a]	
		Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.
IG19	1.87	1.75	1.1	1.15	TBD	0.1	0.77	0.96	0.9	1.05

[a] Parameter tested on batch level at T = 25°C. [b] Responsivity measured at 0 V Bias. [c] Data are prior to window integration [d] Preliminary data

Electro-Optical Characteristics, Specifications @ 25°C

Part Number	Diameter [µm]	Shunt Impedance @ V_R= 10 mV[b] [MOhm]		Dark Current @ V_R= 0.25 V[b] [nA]		Peak D* [a] [cm $Hz^{½}$/W]		Peak NEP[a] [W/$Hz^{½}$]		Capacitance @ V_R= 0 V[a] [pF]
		Min.	Typ.	Typ.	Max.	Min.	Typ.	Typ.	Max.	Typ.
IG19X250S4i	250	8.0	16	5	50	1.2 E12	1.7 E+12	2.9 E-14	4.1 E-14	60
IG19X1000S4i	1000	0.8	1.6	40	400	7.6 E+11	1.1 E+12	0.9 E-13	1.3 E-13	1040

[a] Parameter tested on batch level [b] Parameter 100% tested

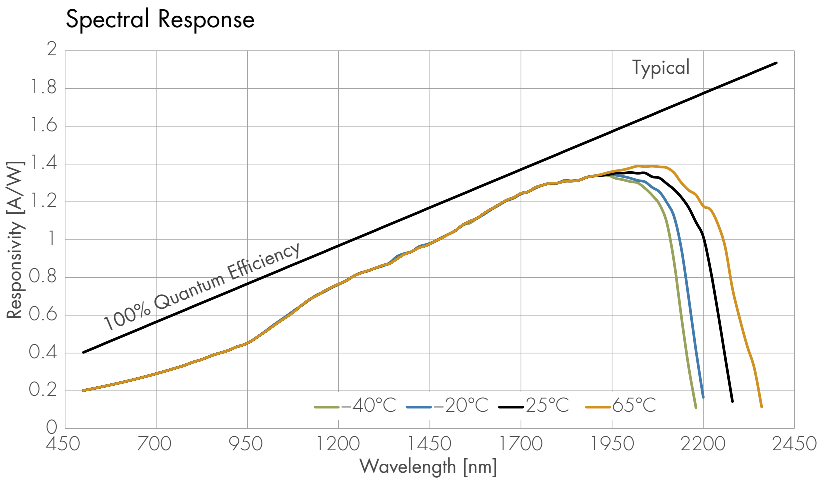
Thermoelectrically Cooled InGaAs Detectors

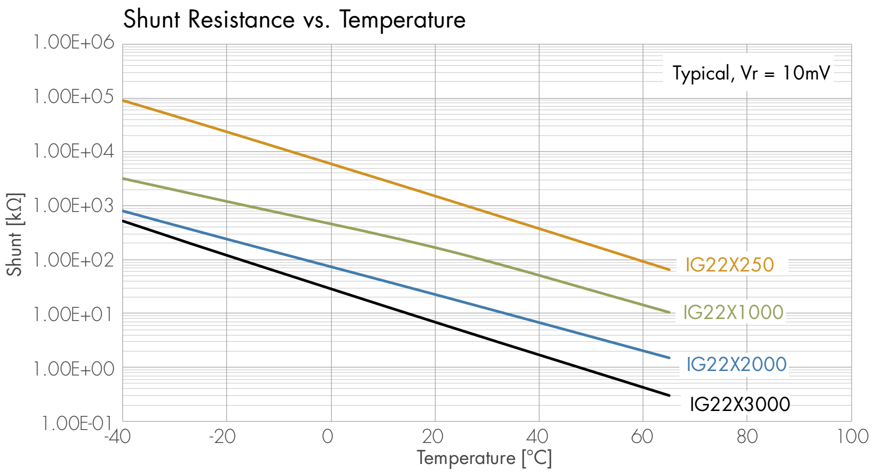
Part Number	Diameter [µm]	Operating Temperature [°C]	Shunt Impedance @ V_R= 10 mV[b] [MOhm]		Peak D* [a] [cm $Hz^{½}$/W]	Peak NEP[a] [W/$Hz^{½}$]	Capacitance @ V_R= 0 V[a] [pF]
			Min.	Typ.	Typ.	Typ.	Typ.
IG19X1000T7	1000	-20	10	105	8.8E+12	1.1E-14	1040
IG19X1000T9	1000	-40	160	400	1.5E+13	6.6E-15	1040

[a] Parameter tested on batch level [b] Parameter 100% tested

IG22 Series

Extended
InGaAs Photodiodes
(cut off @ 2.2 µm)





Note: For applications where shunt resistance needs to be matched, our InGaAs photodiode's shunt resistance can be tuned via. Temperature.

Basic Characteristics, Specifications @ 25°C[c]

Part Number	50% Cut off Wavelength[a] [µm]	Peak Wavelength[a] [µm]	Peak Responsivity[a,b] [A/W]		Responsivity [A/W]					
					@ 520 nm[a,b,d]		@ 1300 nm[a,b]		@ 1500 nm[a,b]	
		Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.
IG22	≥ 2.15	1.95 ± 0.1	1.15	1.40	TBD	0.1	0.74	0.92	0.87	1.09

[a] Parameter tested on batch level at T = 25°C. [b] Responsivity measured at 0 V Bias. [c] Data are prior to window integration [d] Preliminary data

Electro-Optical Characteristics, Specifications @ 25°C

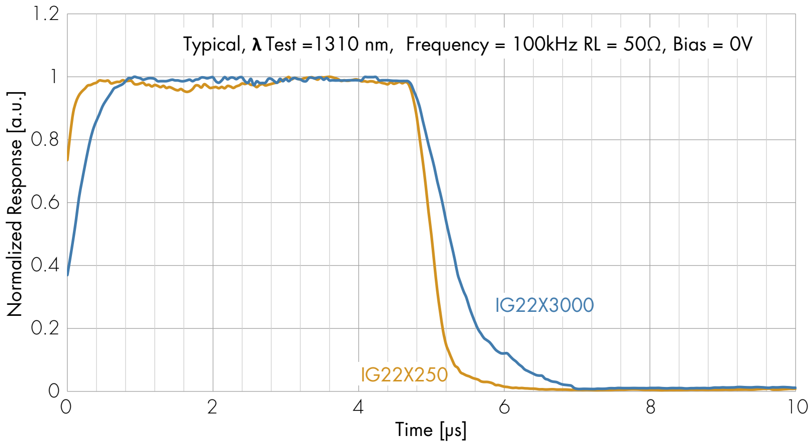
Part Number	Diameter [µm]	Shunt Impedance @ V_R= 10 mV[b] [kOhm]		Dark Current @ V_R= 5 V[b] [µA]		Peak D* [a] f = 1 kHz [cm Hz^{½}/W]		Peak NEP[a] f = 1 kHz [W/Hz^{½}]		Capacitance @ V_R= 0 V[a] [pF]	Forward Voltage [V]
		Min.	Typ.	Typ.	Max.	Min.	Typ.	Max .	Typ.	Typ.	Typ.
IG22X250S4i	250	500	1000	0.05	0.5	3.1 E+11	4.5 E+11	1.6 E-13	1.1 E-13	40	0.56
IG22X500S4i	500	200	600	0.1	1	2.8 E+11	4.9 E+11	2.5 E-13	1.4 E-13	160	
IG22X1000S4i	1000	60	300	0.2	2.5	2.2 E+11	4.9 E+11	4.6 E-13	2.0 E-13	650	
IG22X1300S4i	1300	25	150	0.5	5	1.6 E+11	4.0 E+11	7.1 E-13	2.9 E-13	1100	
IG22X2000G1i	2000	12	40	1	10	1.3 E+11	2.5 E+11	1.0 E-12	5.6 E-13	1750	
IG22X3000G1i	3000	4	12	5	50	9.8 E+10	1.7 E+11	1.8 E-12	1.0 E-12	5200	

[a] Parameter tested on batch level at T = 25°C. [b] Parameter 100% tested.

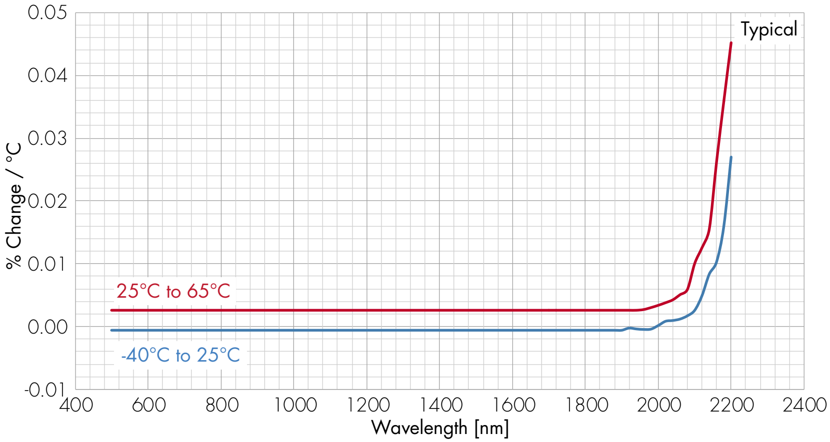
Thermoelectrically Cooled InGaAs Detectors

Part Number	Diameter [µm]	Operating Temperature [°C]	Shunt Impedance @ V_R= 10 mV[b] [kOhm]		Peak D* [a] [cm Hz^{½}/W]	Peak NEP[a] [W/Hz^{½}]	Capacitance @ V_R= 0 V[a] [pF]
			Min.	Typ.	Typ.	Typ.	Typ.
IG22X250T7	250	-20	11000	23500	1.2E+12	1.8E-14	40
IG22X1000T7	1000		600	1200	1.0E+12	8.1E-14	650
IG22X2000T7	2000		120	240	9.8E+11	1.8E-13	1745
IG22X3000T7	3000		62	190	1.3E+12	2.0E-13	5200
IG22X250T9	250	-40	48000	90000	2.7E+12	8.3E-15	40
IG22X1000T9	1000		1600	3200	2.0E+12	4.4E-14	650
IG22X2000T9	2000		400	800	2.0E+12	8.8E-14	1745
IG22X3000T9	3000		260	610	2.6E+12	1.0E-13	5200

[a] Parameter tested on batch level [b] Parameter 100% tested

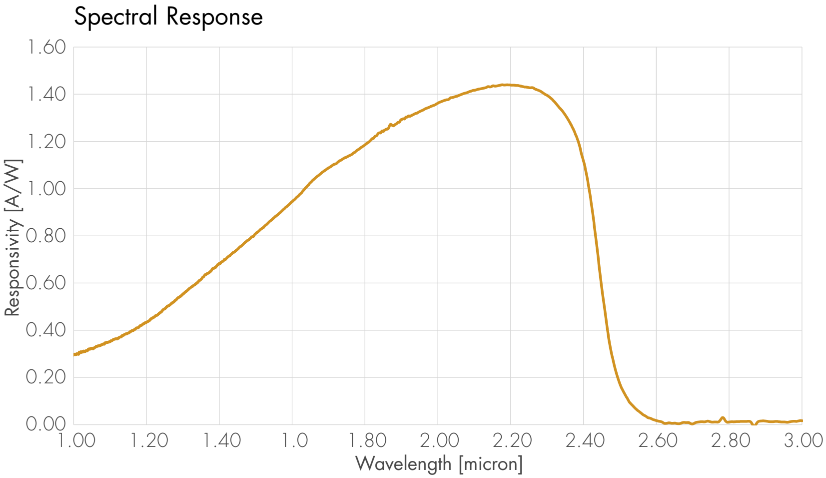


Sample Pulse Response



Responsivity Temperature Coefficient

Linearity



IG24 Series

Extended InGaAs Photodiodes (cut off @ 2.4 µm)

Basic Characteristics, Specifications @ 25°C[c]

Part Number	50% Cut off Wavelength[a] [µm]	Peak Wavelength[a] [µm]	Peak Responsivity[a,b] [A/W]	
		Typ.	Min.	Typ.
IG24	≥2.35	2.20	1.25	1.40

[a] Parameter tested on batch level at T = 25°C. [b] Responsivity measured at 0 V Bias. [c] Data are prior to window integration

Electro-Optical Characteristics, Specifications @ 25°C

Part Number	Diameter [µm]	Shunt Impedance @ V_R= 10 mV[b] [kOhm]		Dark Current @ V_R= 0.25 V[b] [µA]		Peak D* [a] f=1 kHz [cm Hz$^{1/2}$/W]		Peak NEP[a] f=1 kHz [W/Hz$^{1/2}$]		Capacitance @ V_R= 0 V[a] [pF]
		Min.	Typ.	Typ.	Max.	Min.	Typ.	Typ.	Max.	Typ.
IG24X250S4i	250	120	240	0.2	2.5	1.6 E+11	2.4 E+11	2.1 E-13	3.0 E-13	60
IG24X500S4i	500	40	80	0.6	7.5	1.3 E+11	1.9 E+11	3.6 E-13	5.2 E-13	140
IG24X1000S4i	1000	10	20	2.5	25	0.9 E+11	1.4 E+11	7.2 E-13	1.1 E-12	1040

[a] Parameter tested on batch level [b] Parameter 100% tested

IG26 Series

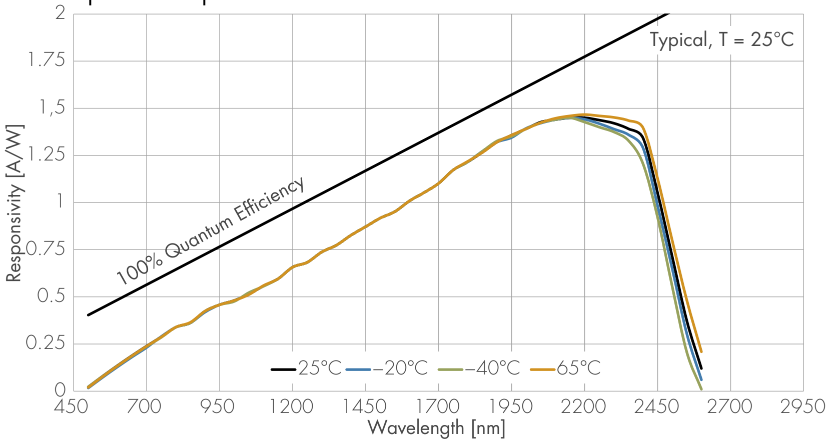
Extended InGaAs Photodiodes (cut off @ 2.6 µm)

Did you know?

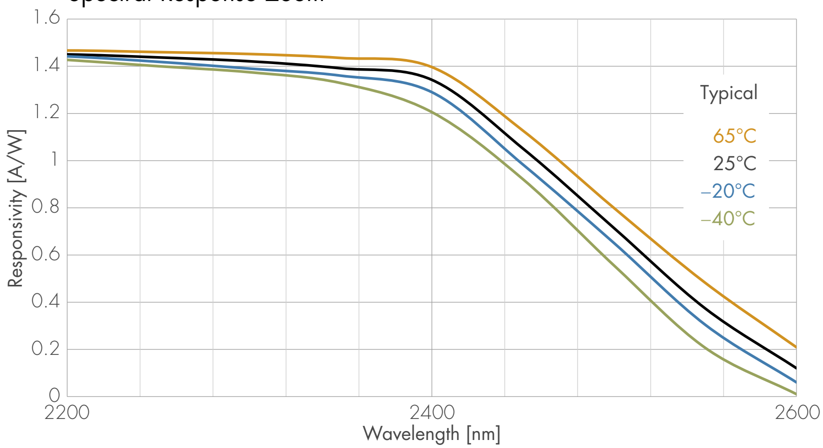
The rise time of photodiodes is proportional to the capacitance of the photodiode itself. The higher the capacitance, the longer the rise time.

Our IG26 series capacitance is identical to our IG22 series, and therefore the rise time and bandwidth is identical.

Spectral Response



Spectral Response Zoom



Basic Characteristics, Specifications @ 25°C[c]

Part Number	50% Cut off Wavelength[a] [µm]	Peak Wavelength[a] [µm]	Peak Responsivity[a,b] [A/W]		Responsivity [A/W]					
					@ 520 nm [a,b,d]		@ 1600 nm [a,b]		@ 1900 nm[a,b]	
		Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.
IG26	≥2.45	2.25 ± 0.1	1.30	1.50	TBD	0.1	0.7	1.0	1.08	1.36

[a] Parameter tested on batch level at T = 25°C. [b] Responsivity measured at 0 V Bias. [c] Data are prior to window integration [d] Preliminary data

Electro-Optical Characteristics, Specifications @ 25°C

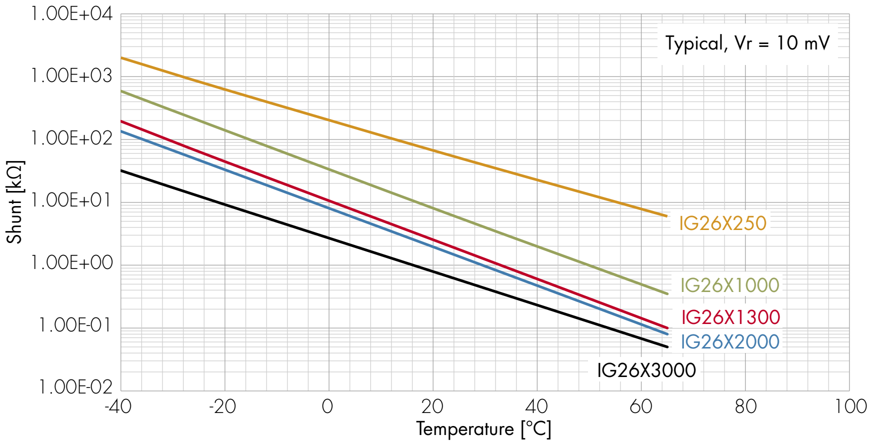
Part Number	Diameter [µm]	Shunt Impedance @ V_R= 10 mV[b] [kOhm]		Dark Current @ V_R= 5 V[b] [µA]		Peak D* [a] f= 1 kHz [cm Hz½/W]		Peak NEP [a] f= 1 kHz [W/Hz½]		Capacitance @ V_R= 0 V[a] [pF]	Forward Voltage [V]
		Min.	Typ.	Typ.	Max.	Min.	Typ.	Max.	Typ.	Typ.	Typ.
IG26X250S4i	250	25	60	2	8	8.3 E+10	1.2 E+11	6.0 E-13	4.2 E-13	35	0.48
IG26X500S4i	500	10	25	4	25	7.4 E+10	1.2 E+11	1.0 E-12	6.0 E-13	140	
IG26X1000S4i	1000	3	9	8	75	5.7 E+10	1.0 E+11	1.8 E-12	1.0 E-12	580	
IG26X1300S4i	1300	1	4	15	150	3.7 E+10	7.6 E+10	3.0 E-12	1.5 E-12	1040	
IG26X2000G1i	2000	0.6	1.5	30	300	3.6 E+10	5.8 E+10	3.9 E-12	2.4 E-12	1920	
IG26X3000G1i	3000	0.25	0.7	75	750	2.8 E+10	4.8 E+10	6.0 E-12	3.6 E-12	3200	

[a] Parameter tested on batch level [b] Parameter 100% tested

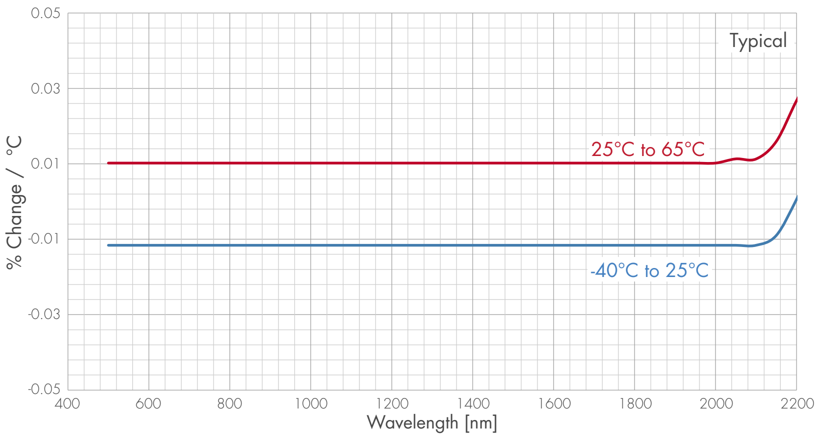
Thermoelectrically Cooled InGaAs Detectors

Part Number	Diameter [µm]	Operating Temperature [°C]	Shunt Impedance @ V_R= 10 mV[b] [kOhm]		Peak D* [a] [cm Hz½/W]	Peak NEP[a] [W/Hz½]	Capacitance @ V_R= 0 V[a] [pF]
			Min.	Typ.	Typ.	Typ.	Typ.
IG26X250T7	250	-20	300	625	1.9 E+11	1.2 E-13	35
IG26X1000T7	1000		80	140	3.6 E+11	2.4 E-13	580
IG26X1300T7	1300		15	44.5	2.6 E+11	4.3 E-13	1040
IG26X2000T7	2000		13	33	3.5 E+11	5.0 E-13	1925
IG26X3000T7	3000		3.5	9.2	2.8 E+11	9.6 E-13	3200
IG26X250T9	250	-40	1000	2000	4.0 E+11	5.6 E-14	35
IG26X1000T9	1000		300	590	7.4 E+11	1.2 E-13	580
IG26X1300T9	1300		65	195	5.5 E+11	2.0 E-13	1040
IG26X2000T9	2000		60	135	7.1 E+11	2.5 E-13	1920
IG26X3000T9	3000		15	32	5.2 E+11	5.1 E-13	3200

[a] Parameter tested on batch level [b] Parameter 100% tested

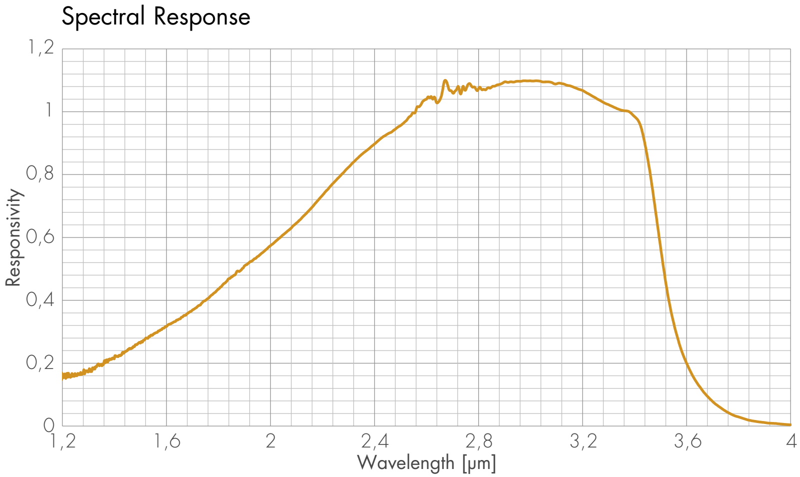


Shunt Resistance vs. Temperature



Responsivity Temperature Coefficient

Linearity



IA35

InAs Photodiode (cut off @ 3.5 µm)

Basic Characteristics, Specifications @ 25°C

Part Number	20% Cut off Wavelength[a] [µm]	Peak Wavelength[a] [µm]	Peak Responsivity[a] [A/W]		Responsivity [A/W]					
					@ 900 nm[a]		@ 2800 nm[a]		@ 3200 nm[a]	
		Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.
IA35	3.50	2.8	0.95	1.08	n.a.	0.1	0.95	1.05	n.a.	0.90

[a] Parameter tested on batch level. [b] Parameter 100% tested

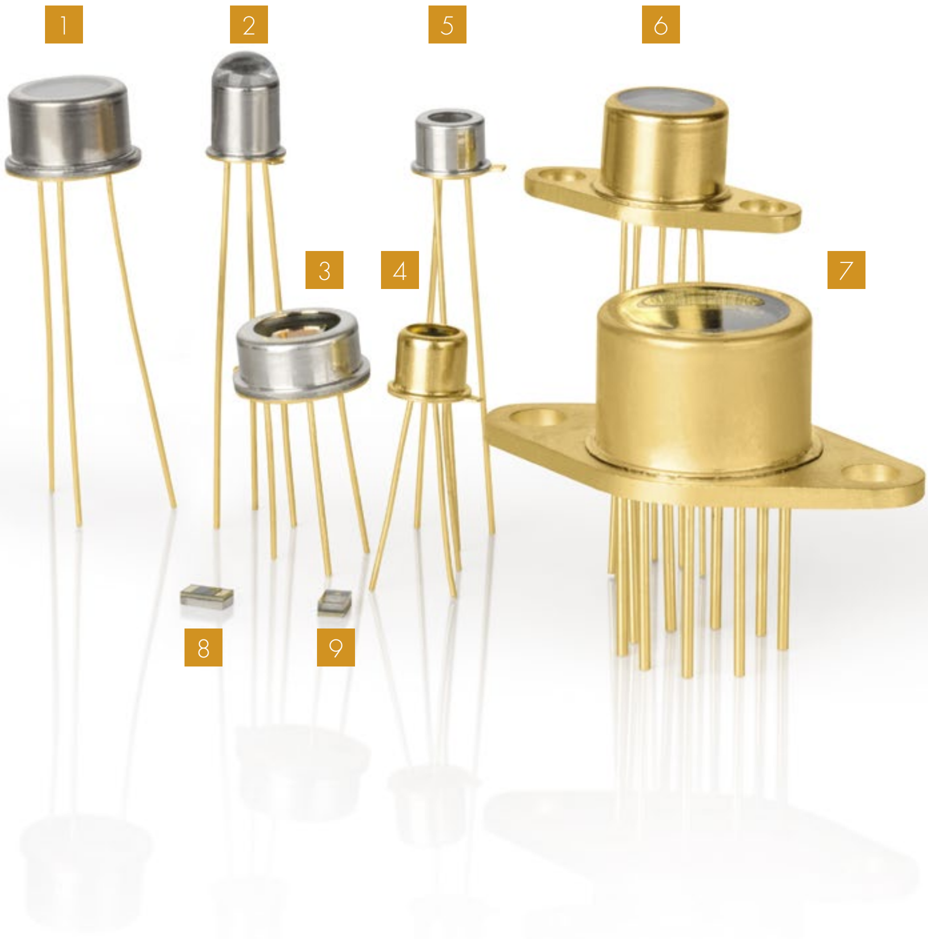
Electro-Optical Characteristics, Specifications @ 25°C

Part Number	Diameter [µm]	Shunt Impedance @ V_R= 10 mV[b] [Ohm]		Dark Current @ V_R= 0.1 V[b] [mA]		Peak D* [a] [cm Hz$^{1/2}$/W]	Peak NEP[a] [W/Hz$^{1/2}$]	Capacitance @ V_R= 0 V[a] [pF]
		Min.	Typ.	Typ.	Max.	Min.	Typ.	Typ.
IA35S500S4i	500	450	700	0.15	1	1.0 E10	6.0 E-12	1000

[a] Parameter tested on batch level [b] Parameter 100% tested

Packaging

1. TO-39
2. TO-46 Lens Cap
3. TO-39, No Window
4. TO-46, No Window
5. TO-46
6. TO-37
7. TO-66
8. 2-Pad PCB SMD
9. Chip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PbS Detectors
PbSe Detectors

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Tech Notes

PbS and PbSe

Lead Sulfide, PbS and Lead Selenide, PbSe detectors are both IV–VI semiconductors. We manufacture them as polycrystalline detectors that need to be biased.
They have similar characteristics but differ in the wavelength region:

PbS λ = 1000 – 3300 nm
PbSe λ = 1000 – 5300 nm

Background

The photoconductive properties of PbS were first discovered by Kutzscher in 1930s and at the time it was the first infrared semiconductor material, with military and commercial production of PbS starting in the mid 1940s. Later, Cushman showed that PbSe also had the same photoconductive properties covering the 3–5 µm region.

Further improvements helped to expand the commercial market causing the lead salt boom in the 1950s until the 1970s; however, academics had now shifted their focus more towards MCT detectors. Lead salt detectors are now seen as a mature technology, but despite all technical competition from InGaAs, extended InGaAs, InAs, MCT, superlattices and similar materials PbS and PbSe based detectors are still a popular choice:

- PbSe is still one of the best MWIR detectors on the market for high performance without cooling.
- PbS provides the best price/performance ratio in large active areas for the SWIR region.

PbS-/PbSe- detectors manufactured by LASER COMPONENTS are manufactured via wet chemical precipitate deposition on quartz substrates: A polycrystalline film is deposited onto the substrate by generating a chemical reaction between the materials. Additives and catalytes are added to control the rate of growth and consequently the attributes of the film, with multiple layers built up in order to maximize D* and passivation overcoatings providing chemical stabilization. A rigorous control of deposition parameters is required in order to achieve optimum composition and performance characteristics; this is achieved with state of the art computer control of the deposition process and has been a core process development at LASER COMPONENTS Detector Group.

Some groups around the world have tried, and do make lead salt detectors with modern sputtering technologies; but surprisingly, these detectors do not match the uncooled performance which has been achieved by our wet chemistry process. The reasons for this are not well understood and would require further material research, this research would be very beneficial as depositing PbS/PbSe via. sputtering works very well on silicon substrates. The use of silicon substrates would allow lead salt detectors to have the potential to be used for high end monolithic MEMS devices and may cause the popularity of PbS/PbSe detectors to boom again!

Most recently a Belgium research group has demonstrated a completely different approach to make PbS based photodiodes[i]: Using "spraying" technology based on quantum dot concepts in order to make a photodiode at 1.45 µm. So far, the performance of those detectors is still lacking. However, it is a cheap process and a new approach.

(i) P.E. Malinowski et al., SWIR detection with thin film photodetectors based on colloidal quantum dots, 43rd Freiburg Infrared Colloqium, March 14–15, 2017

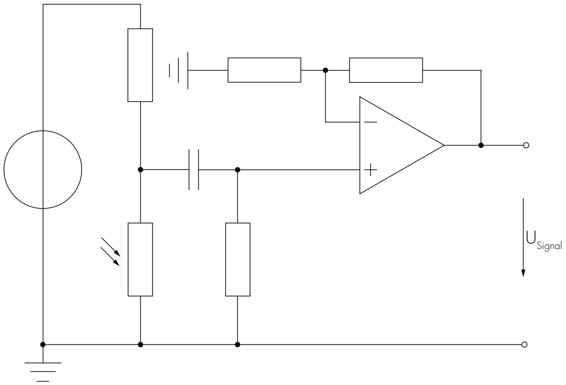


Fig 1: Typical operating circuit for IV–VI photoconductors.

Basic Principle

Recent research by LASER COMPONENTS has now shown that contrary to previous beliefs the main mechanism for PbS PbSe is not so much traditional band migration; but rather impurity trap transport in the bands. This complex mechanism causes a complex spectral response and longer response times due to an inherent time constant involved with this mechanism.

To extract a useful signal from these detectors, we can exploit this phenomenon. As light falls on the detector the electron flow increases increasing the materials conductivity; and inversely, reducing its resistance. By using a load resistor (typically 1MΩ, as matching the detectors dark resistance will ensure the best results) is placed in series with the detector as a voltage divider, and a bias voltage is applied. As the resistance of the detector changes, the electronic characteristics of a voltage divider are used to measure the "output". Debate continues as to whether this mode of operation is the most suitable operation method for PbS and PbSe detectors, with the Microbolometer FPA community discussing the S/N ratio advantages of current related methods.

Biasing

Our PbS and PbSe detectors are photoconductive and require a biasing voltage to operate, increasing the bias voltage increases signal and noise respectively[ii]. A minimum bias voltage is needed to overcome system noise and a maximum voltage cannot be exceeded due to runaway thermal effects. Historically the optimum biasing voltage has been 50V/mm with the maximum being roughly double, but progress in modern electronics means that lower voltages can now be used without making compromises in the performance. LASER COMPONENTS corporate research is looking into the trade-offs.

(ii) Please note, that a PbS crystal with gold contact was the first solid state semiconductor diode ever constructed, first investigated in the 1870s. Parasitic diode effects may be present at very low biasing voltages, which are not recommended.

Noise

The two dominant types of noise in a PbS or PbSe detector are generation-recombination noise and 1/f noise, which is why historically detector specifications are given at 1kHz to represent optimum performance. However we understand that more often than not these detectors are used at lower operation frequencies which is why LASER COMPONENTS lists D* values for operation at 90 Hz as well. As a rule of thumb, you can expect a threefold increase in noise at 90 Hz when compared to 1 kHz.

Basics

Temperature

Although PbS and PbSe are famous for their performance at room temperature in comparison to other detector technologies, the effect temperature has on the detectors themselves is incredibly important and effects the behavior of the detectors in many different ways.

Lead Salt detectors have a temperature coefficient around 4%/K, and although the can operate without a cooler it is recommended that some form of temperature stabilization is implemented; be it a peltier cooler or not. For devices with a peltier cooler, PbS and PbSe detectors experience an increase in their peak wavelength response the more they are cooled, an effect commonly taken advantage of through the use of coolers with differing ΔT values to help fine tune the peak wavelength response and increase responsivity. This effect is generally not well understood despite being exploited for decades as it has not been well documented due to the stochastic nature of the polycrystalline structure and wide spread manufacturing variations.

A consequence of this increased responsivity due to cooling is subtle, but still important. Photoconductive detectors' time carrier lifetimes (and hence, time constants) are directly proportional to responsivity. As you cool your device you will see an increased signal due to a responsivity increase, but your device will also become slower; the opposite is true when the device is heated as it will speed up with reduced signal. Following this responsivity/carrier lifetime relation, PbS has higher performance than PbSe by roughly one order of magnitude, but is also slower with the time constant being roughly 200 μs compared to 4 μs at room temperature.

Visible and UV Light

Visible and UV light can effect PbS and PbSe detectors over time, causing a degradation of the active elements or effecting the detector performance. To ensure that reliable and repeatable results are achieved the detectors should be stabilized in a controlled area which is darkened and at the same temperature they will be operated at for 24 hours prior to testing.

Currently LASER COMPONENTS still recommends using sapphire windows instead of uv-vis blocking silicon windows for several reasons:

1. Sapphire provides a better spectral range and transmission than silicon windows
2. The effects of visible light can be managed with proper handling
3. Sapphire is extremely robust
4. Silicon needs to be coated for optimum transmission

Although our standard parts use sapphire windows, we can also offer hard coated silicon windows with improved transmission in the 3–5.5 μm range for our PB55 series.

Absolute Maximum Ratings

		Min.	Max.
Storage Temperature [°C]	PbS	-70	+85[b]
	PbSe	-85	+100[b]
Operating Temperature [°C]	PbS	-65	+75
	PbSe	-75	+90
Soldering Temperature, 5 sec. [°C]		-	+250 (at pins only)
ESD Damage Threshold, Human Body Model Class 3B[a], [V]		8000	

[a] ANSI/ ESD STM5. 1-2007 [b] operation for short-term up to storage temperature may not damage the device. It could take longer time to recover to normal operation.
The TE-Cooler ratings are listed in the datasheets

Part Number Designation

Our product nomenclature allows you to see at a glance what's what – details are given below.

Type

PB25	uncooled PbS detector
PB27	cooled PbS detector
PB30	ultimate cooled PbS detector
PB45	uncooled PbSe detector
PB50	cooled PbSe detector
PB55	ultimate cooled PbSe detector

Window

S	sapphire
G	glass
A	Si 1.5 – 5 µm
B	Si 1.2 – 3.5 µm
X	no window
Z	Specials
C	Si 1.7 µm LWP

Element Size[a]

1010	1.0 x 1.0 mm^2
2020	2.0 x 2.0 mm^2
2050	2.0 x 5.0 mm^2
3030	3.0 x 3.0 mm^2
5050	5.0 x 5.0 mm^2
6060	6.0 x 6.0 mm^2

Cooling

T1	1stage
T1S	1stage superior
T2	2stage
T2S	2stage superior
T3	3stage

Package

4	TO-46
6	TO-8 with flange
7	TO-37
8	TO-8
9	TO-39

Cap[b]

S	short
M	medium
L	long
X	special
SD	short with integrated LED (Note: "D" is for Diode)

[a] for rectangular elements: Space between electrodes first
[b] see separate datasheet for details

PB25 Series

Uncooled ESWIR Semiconductor Detectors (cut off @ 3.0 µm)

The PB25 series is a collection of uncooled polycrystalline biased single element PbS detectors that operate at room temperature with a 20% cut-off of 3.0 µm. This series is widely used in analytic, safety and radiometric applications.

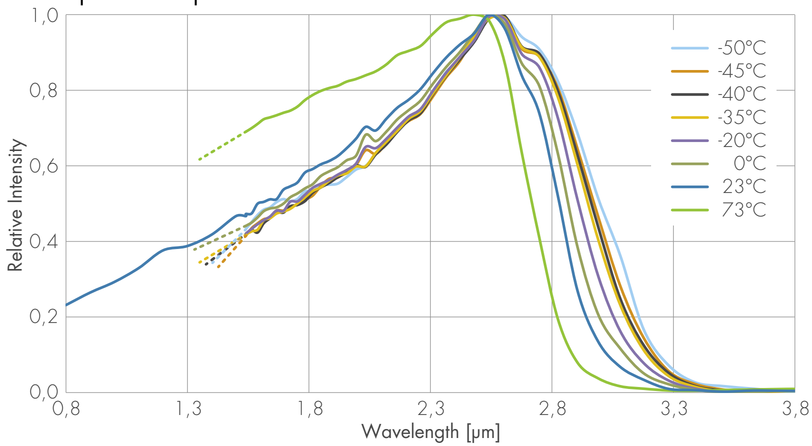
You may notice that extended InGaAs photodiodes such as the IG22 and IG26 series provide greater D* than PbS detectors, so why would anybody still use PbS detectors?

PB25 detectors are still unmatched when it comes to price vs performance and spectral range for large area detectors, making them still the ideal choice of detector even though the technology is over 70 years old!

Features

- Spectral range from 1 to 3.0 µm
- State of the art performance
- 100% test data provided

Spectral Response for PB25



Basic Characteristics, Specifications @ 23°C

Part Number	Element Size [mm]	Aperture Size [mm]	Features	20% Cut-off Wavelength [b] [µm]	Peak Wavelength [b] [µm]	Peak Responsivity [ac] [V/W]		Time Constant [b] [µs]		Optional Package Versions
				Typ.	Typ	Min.	Typ.	Typ.	Max.	
PB25S10104S	1.0 x 1.0	dia. 3.0	TO-46, short cap	3.0	2.4	560000	800000	200	400	TO-39
PB25S20209S	2.0 x 2.0	dia. 6.35	TO-39, short cap	3.0	2.4	280000	400000	200	400	medium cap
PB25S20509S	2.0 x 5.0	dia. 6.35	TO-39, short cap	3.0	2.4	TBD	105000[d]	TBD	TBD	medium cap
PB25S30309S	3.0 x 3.0	dia. 6.35	TO-39, short cap	3.0	2.4	185000	260000	200	400	medium cap
PB25S50508M	5.0 x 5.0	dia. 9.5	TO-8, medium cap	3.0	2.4	110000	160000	200	400	
PB25S60608M	6.0 x 6.0	dia. 9.5	TO-8, medium cap	3.0	2.4	90000	140000	200	400	

Further Versions in progress

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Chopping frequency is 650 kHz. [b] Parameter not 100% tested. [c] Without filter/window
[d] Measured with 0.5 MOhm load

Electro-Optical Characteristics, Specifications @ 23°C

Part Number	Element Size [mm]	Noise Density (rms) [a] [µV/Hz$^{1/2}$]		Peak D* [abc] [cm Hz$^{1/2}$/W]		Peak D* [ac] [cm Hz$^{1/2}$/W]		Dark Resistance [MOhm/square]		
		@ 90 Hz [b]	@ 650 Hz	@ 90 Hz	@ 90 Hz	@ 650 Hz	@ 650 Hz			
		Typ.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Max.
PB25S10104S	1.0 x 1.0	4.2	1.4	2.5 E+10	3.5 E+10	8.0 E+10	1.1 E+11	0.25	0.8	2.5
PB25S20209S	2.0 x 2.0	4.2	1.4	2.5 E+10	3.5 E+10	8.0 E+10	1.1 E+11	0.25	0.8	2.5
PB25S20509S	2.0 x 5.0	TBD	TBD	TBD	2.3 E+10 [d]	TBD	7.0 E+10 [d]	0.20	0.50	0.80
PB25S30309S	3.0 x 3.0	TBD	TBD	2.5 E+10	3.5 E+10	8.0 E+10	1.1 E+11	0.25	0.8	2.5
PB25S50508M	5.0 x 5.0	TBD	TBD	2.2 E+10	3.0 E+10	7.0 E+10	9.0 E+10	0.2	0.8	2.5
PB25S60608M	6.0 x 6.0	TBD	TBD	2.2 E+10	3.0 E+10	7.0 E+10	9.0 E+10	0.2	0.8	2.5

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Bandwidth of test setup is 1 Hz. [b] Parameter not 100% tested. [c] Without filter/window
[d] Measured with 0.5 MOhm load

PB27 Series

Cooled Standard ESWIR Semiconductor Detectors (cut off @ 3.3 μm)

The PB27 series is a collection of TE cooled polycrystalline biased single element PbS detectors that operate at -25°C to -35°C with a 20% cut-off of 3.3 μm. This series is widely used in analytic, safety and radiometric applications especially when large active areas are requested.

Features

- Spectral range from 1 to 3.3 μm
- State of the art performance
- 100% test data provided

Cooling Characteristics

Part Number	Element Size [mm]	Typ. Detector Operating Temperature [b] [°C]	Max. Cooler Power	Delta T @ max. Cool [°C]		Optional Package Versions
			Typ.	Min.	Typ.	
PB27S1010T17M	1.0 x 1.0	-25	1.0 V @ 1.2 A	45	50	TO-8
PB27S2020T17M	2.0 x 2.0	-25	1.0 V @ 1.2 A	45	50	TO-8
PB27S3030T17M	3.0 x 3.0	-25	1.0 V @ 1.2 A	45	50	TO-8
PB27S5050T1S6M	5.0 x 5.0	-25	1.8 V @ 1.2 A	45	50	TO-8
PB27S6060T1S6M	6.0 x 6.0	-25	1.8 V @ 1.2 A	45	50	TO-8
PB27S2020T26L	2.0 x 2.0	-35	0.9 V @ 1.2 A	55	60	TO-8
PB27S3030T26L	3.0 x 3.0	-35	0.9 V @ 1.2 A	55	60	TO-8

[b] Valid with sufficient heat sinking only!

Basic Characteristics

Part Number	Element Size [mm]	Aperture Size [mm]	Features	20% Cut-off Wavelength [b] [µm]	Peak Wavelength [b] [µm]	Peak Responsivity [ac] [V/W]		Time Constant [b] [µs]	
				Typ.	Typ	Min.	Typ.	Typ.	Max.
PB27S1010T17M	1.0 x 1.0	dia. 6.35	1 stage cooling (1.2 W), TO-37, medium cap	3.3	2.6	1300000	1950000	800	1600
PB27S2020T17M	2.0 x 2.0	dia. 6.35		3.3	2.6	650000	975000	800	1600
PB27S3030T17M	3.0 x 3.0	dia. 6.35		3.3	2.6	430000	650000	800	1600
PB27S5050T1S6M	5.0 x 5.0	dia. 9.5	1 stage cooling superior, TO-8 flange, medium cap	3.3	2.6	260000	390000	800	1600
PB27S6060T1S6M	6.0 x 6.0	dia. 9.5		3.3	2.6	215000	325000	800	1600
PB27S2020T26L	2.0 x 2.0	dia. 9.5	2 stage cooling (1.5 W), TO-8 flange, large cap	3.3	2.6	660000	1000000	1250	2500
PB27S3030T26L	3.0 x 3.0	dia. 9.5		3.3	2.6	440000	660000	1250	2500

Further Versions in progress

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Chopping frequency is 650 Hz. [b] Parameter not 100% tested. [C] Without filter/window

Electro-Optical Characteristics

Part Number	Element Size [mm]	Noise Density (rms) [a] [µV/Hz$^{1/2}$]		Peak D* [abc] [cm Hz$^{1/2}$/W]		Peak D* [ac] [cm Hz$^{1/2}$/W]		Dark Resistance [MOhm/square]		
		@ 90 Hz [b]	@ 650 Hz	@ 90 Hz	@ 90 Hz	@ 650 Hz	@ 650 Hz			
		Typ.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Max.
PB27S1010T17M	1.0 x 1.0	TBD		3.5 E+10	6.0 E+10	1.0 E+11	1.65 E+11	1.5	3.0	10
PB27S2020T17M	2.0 x 2.0			3.5 E+10	6.0 E+10	1.0 E+11	1.65 E+11	1.5	3.0	10
PB27S3030T17M	3.0 x 3.0			3.5 E+10	6.0 E+10	1.0 E+11	1.65 E+11	1.5	3.0	10
PB27S5050T1S6M	5.0 x 5.0			2.5 E+10	5.0 E+10	8.0 E+10	1.5 E+11	1.5	3.0	10
PB27S6060T1S6M	6.0 x 6.0			2.5 E+10	5.0 E+10	8.0 E+10	1.5 E+11	1.5	3.0	10
PB27S2020T26L	2.0 x 2.0			5.0 E+10	0.9 E+10	1.5 E+11	2.75 E+11	2.5	5.0	15
PB27S3030T26L	3.0 x 3.0			5.0 E+10	0.9 E+10	1.5 E+11	2.75 E+11	2.5	5.0	15

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Bandwidth of test setup is 1 Hz. [b] Parameter not 100% tested. [C] Without filter/window

All specifications apply at or near max. cooling temp. with heat sink at +25°C.

PB30 Series

Cooled Ultimate ESWIR Semiconductor Detectors (cut off @ 3.4 µm)

The PB30 series is a collection of TE cooled polycrystalline biased single element PbS detectors that operate at -45°C to -55°C with a 20% cut-off of 3.4 µm. This series is widely used in analytic, safety and radiometric applications.

Features

- Spectral range from 1 to 3.4 µm
- State of the art performance
- 100% test data provided

Cooling Characteristics

Part Number	Element Size [mm]	Typ. Detector Operating Temperature [c] [°C]	Max. Cooler Power	Delta T @ max. Cool [a] [°C]		Optional Package Versions
			Typ.	Min.	Typ.	
PB30S1010T2S6L	1.0 x 1.0	-50	1.8 V @ 1.2 A	70	75	TO-8
PB30S2020T2S6L	2.0 x 2.0	-50	1.8 V @ 1.2 A	70	75	TO-8
PB30S3030T2S6L	3.0 x 3.0	-45	1.8 V @ 1.2 A	65	70	TO-8
PB30S6060T2S6L	6.0 x 6.0	-35	1.8 V @ 1.2 A	55	60	TO-8

[a] Values are valid for TO-66 and TO-8 packages. [c] Valid with sufficient heat sinking only!

Basic Characteristics

Part Number	Element Size [mm]	Aperture Size [mm]	Features	20% Cut-off Wavelength [b] [µm]	Peak Wavelength [b] [µm]	Peak Responsivity [ac] [V/W]		Time Constant [b] [µs]	
				Typ.	Typ	Min.	Typ.	Typ.	Max.
PB30S1010T2S6L	1.0 x 1.0	dia. 9.5	2 stage (2.5 W) cooling, TO-8 flange, large cap	3.4	2.7	1500000	2200000	1750	3500
PB30S2020T2S6L	2.0 x 2.0	dia. 9.5		3.4	2.7	750000	1100000	1750	3500
PB30S3030T2S6L	3.0 x 3.0	dia. 9.5		3.4	2.7	500000	730000	1750	3500
PB30S6060T2S6L	6.0 x 6.0	dia. 9.5		3.3	2.6	240000	360000	1750	3500

Further Versions in progress

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Chopping frequency is 650 kHz. [b] Parameter not 100% tested. [C] Without filter/window

Electro-Optical Characteristics

Part Number	Element Size [mm]	Noise Density (rms) [a] [µV/Hz$^{1/2}$]		Peak D* [abc] [cm Hz$^{1/2}$/W]		Peak D* [ac] [cm Hz$^{1/2}$/W]		Dark Resistance [MOhm/square]		
		@ 90 Hz [b]	@ 1 kHz	@ 90 Hz	@ 90 Hz	@ 1 kHz	@ 1 kHz			
		Typ.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Max.
PB30S1010T2S6L	1.0 x 1.0			7.0 E+10	1.6 E+11	2.2 E+11	3.2 E+11	3.0	6.0	20.0
PB30S2020T2S6L	2.0 x 2.0			7.0 E+10	1.6 E+11	2.2 E+11	3.2 E+11	3.0	6.0	20.0
PB30S3030T2S6L	3.0 x 3.0			7.0 E+10	1.6 E+11	2.2 E+11	3.2 E+11	3.0	6.0	20.0
PB30S6060T2S6L	6.0 x 6.0			3.5 E+10	8.0 E+10	1.0 E+11	2.5 E+11	3.0	6.0	20

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Bandwidth of test setup is 1 Hz. [b] Parameter not 100% tested. [C] Without filter/window

All specifications apply at or near max. cooling temp. with heat sink at +25°C.

PB45 Series

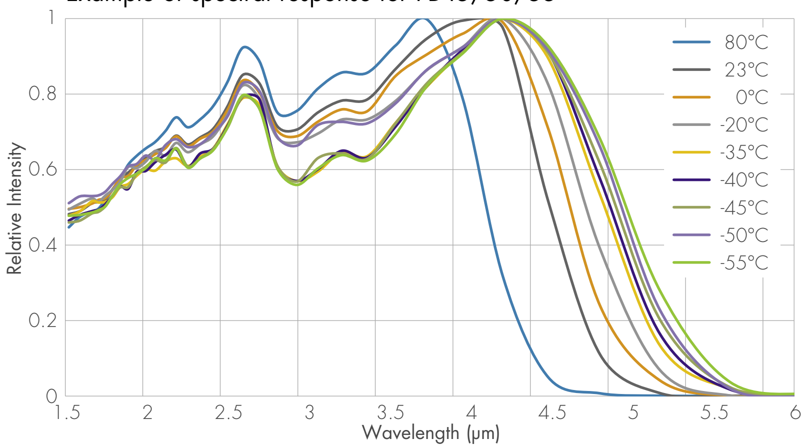
Uncooled MWIR Semiconductor Detectors (cut off @ 4.7 µm)

The PB45 series is a collection of uncooled polycrystalline biased single element PbSe detectors that operate at room temperature with a 20% cut-off of 4.7 µm. This series has been designed for demanding analytic, medical and radiometric applications.

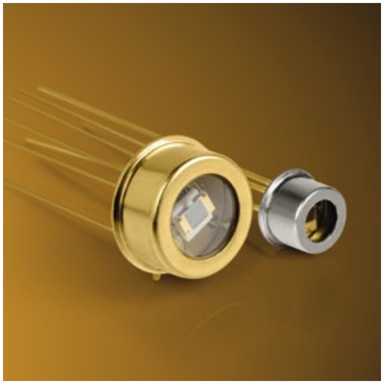
Features

- Spectral range from 1 to 4.7 µm
- State of the art performance
- 100% test data provided

Example of spectral response for PB45/50/55*



*Spectral Responsivity Modulation is "Substrate Enhanced". This means that not all photons are initially captured by the absorbing region. A portion of the light passes the absorber, travels through the quartz substrate, is reflected, and passes through the substrate again until it is finally captured by the PbSe material. Therefore, the detailed spectral responsivity curve is a little complex since it is a product of the infrared absorption of the active material itself, the substrate and once again the active material. Older literature curves tend to hide this feature for simplicity reasons. Please note, that a spectrally simple curve can be generated on special request by blackening the backside of the substrate. However, the drawback of blackening is less signal.



Basic Characteristics, Specifications @ 23°C

Part Number	Element Size [mm]	Aperture Size [mm]	Features	20% Cut-off Wavelength [b] [µm]	Peak Wavelength [b] [µm]	Peak Responsivity [ac] [V/W]		Time Constant [b] [µs]		Optional Package Versions
				Typ.	Typ	Min.	Typ.	Typ.	Max.	
PB45S10104S	1.0 x 1.0	dia. 3.0	TO-46	4.7	4.0	21000	42000	4	10	TO-39, short cap
PB45S20209S	2.0 x 2.0	dia. 6.35	TO-39, short cap	4.7	4.0	10500	21000	4	10	Medium cap
PB45S30309S	3.0 x 3.0	dia. 6.35		4.7	4.0	7000	14000	4	10	Medium cap
PB45S50508M	5.0 x 5.0	dia. 9.5	TO-8, medium cap	4.7	4.0	4200	8400	4	10	–
PB45S60608M	6.0 x 6.0	dia. 9.5		4.7	4.0	3500	7000	4	10	-

Further Versions in progress

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Chopping frequency is 1 kHz. [b] Parameter not 100% tested. [c] Without filter/window

Electro-Optical Characteristics, Specifications @ 23°C

Part Number	Element Size [mm]	Noise Density (rms) [a] [µV/$Hz^{1/2}$]		Peak D* [abc] [cm $Hz^{1/2}$/W]		Peak D* [ac] [cm $Hz^{1/2}$/W]		Dark Resistance [MOhm/square]		
		@ 90 Hz [b]	@ 1 kHz	@ 90 Hz	@ 90 Hz	@ 1 kHz	@ 1 kHz			
		Typ.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Max.
PB45S10104S	1.0 x 1.0	2.1	0.7	4.0 E+09	6.0 E+09	1.2 E+10	1.8 E+10	0.1	0.8	2.5
PB45S20209S	2.0 x 2.0	2.1	0.7	4.0 E+09	6.0 E+09	1.2 E+10	1.8 E+10	0.1	0.8	2.5
PB45S30309S	3.0 x 3.0	2.1	0.7	4.0 E+09	6.0 E+09	1.2 E+10	1.8 E+10	0.1	0.8	2.5
PB45S50508M	5.0 x 5.0	2.1	0.7	3.0 E+09	4.0 E+09	0.9 E+10	1.2 E+10	0.1	0.8	2.5
PB45S60608M	6.0 x 6.0	2.1	0.7	3.0 E+09	4.0 E+09	0.9 E+10	1.2 E+10	0.1	0.8	2.5

[a] Measured with 500 K blackbody. Bias is 50 V/mm with 1 MOhm load in series. Chopping frequency is 1 kHz. [b] Parameter not 100% tested. [c] Without filter/window

PB50 Series

Cooled Standard MWIR Semiconductor Detectors (cut off @ 4.9 µm)

The PB50 series is a collection of TE cooled polycrystalline biased single element PbSe detectors that operate at -25°C to -35°C with a 20% cut-off of 4.9 µm. This series has been designed for demanding analytic, medial and radiometric applications.

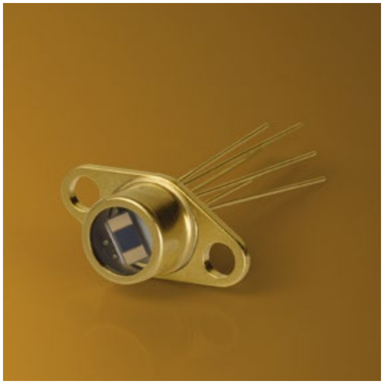
Features

- Spectral range from 1 to 4.9 µm
- State of the art performance
- 100% test data provided

Cooling Characteristics

Part Number	Element Size [mm]	Typ. Detector Operating Temperature [b] [°C]	Max. Cooling	Delta T @ max. Cool [°C] [a]		Optional Package Versions
			Typ.	Min.	Typ.	
PB50S1010T17M	1.0 x 1.0	-20	1.0 V @ 1.2 A	45	50	TO-8
PB50S2020T17M	2.0 x 2.0					
PB50S3030T17M	3.0 x 3.0					
PB50S1010T26L	1.0 x 1.0	-35	0.9 V @ 1.2 A	55	60	TO-8, TO-37
PB50S2020T26L	2.0 x 2.0					
PB50S3030T26L	3.0 x 3.0					

[a] Values are valid for TO-66 and TO-8 packages. Delta T is typically reduced by 5 K for TO-37 packages. [b] Valid with sufficient heat sinking only!



Basic Characteristics

Part Number	Element Size [mm]	Aperture Size [mm]	Features	20% Cut-off Wavelength [b] [µm]	Peak Wavelength [b] [µm]	Peak Responsivity [ac] [V/W]		Time Constant [b] [µs]	
				Typ.	Typ	Min.	Typ.	Typ.	Max.
PB50S1010T17M	1.0 x 1.0					48000	72000		
PB50S2020T17M	2.0 x 2.0	6.35	1 stage cooling (1.2 W), TO-37, medium cap	4.8	4.2	24000	36000	8	20
PB50S3030T17M	3.0 x 3.0					16000	24000		
PB50S1010T26L	1.0 x 1.0					79000	120000		
PB50S2020T26L	2.0 x 2.0	9.5	2 stage cooling (1.5 W), TO-8 flange, large cap	4.9	4.3	39500	60000	10	25
PB50S3030T26L	3.0 x 3.0					26300	40000		

Further Versions in progress

[a] Measured with 500 K blackbody. Bias is 30 V/mm with 1 MOhm load in series. Chopping frequency is 1 kHz. [b] Parameter not 100% tested. [C] Without filter/window

Electro-Optical Characteristics

Part Number	Element Size [mm]	Noise Density (rms) [a] [$\mu V/Hz^{1/2}$]		Peak D* [abc] [cm $Hz^{1/2}$/W]		Peak D* [ac] [cm $Hz^{1/2}$/W]		Dark Resistance [MOhm/square]		
		@ 90 Hz [b]	@ 1 kHz	@ 90 Hz	@ 90 Hz	@ 1 kHz	@ 1 kHz			
		Typ.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Max.
PB50S1010T17M	1.0 x 1.0									
PB50S2020T17M	2.0 x 2.0	TBD	TBD	5.3 E+9	1.1 E+10	1.6 E+10	3.2 E+10	0.5	4.0	10.0
PB50S3030T17M	3.0 x 3.0									
PB50S1010T26L	1.0 x 1.0									
PB50S2020T26L	2.0 x 2.0	TBD	TBD	5.5 E+9	1.1 E+10	1.7 E+10	3.2 E+10	1.0	5.0	15.0
PB50S3030T26L	3.0 x 3.0									

[a] Measured with 500 K blackbody. Bias is 30 V/mm with 1 MOhm load in series. Bandwidth of test setup is 1 Hz. [b] Parameter not 100% tested. [c] Without filter/window

All specifications apply at or near max. cooling temp. with heat sink at +25°C.

PB55 Series

Cooled Ultimate MWIR Semiconductor Detectors (cut off @ 5.2 µm)

The PB55 series is a collection of TE cooled polycrystalline biased single element PbSe detectors that operate at -45°C to -55°C with a 20% cut-off of 5.2 µm. This series has been designed for demanding analytic, medical and radiometric applications.

Features

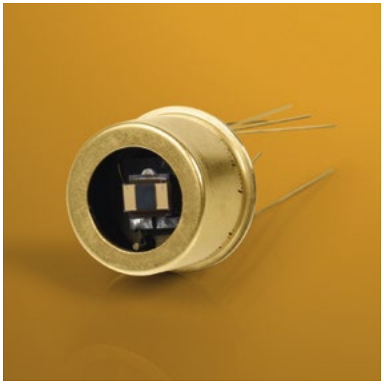
- Spectral range from 1 to 5.2 µm
- State of the art performance
- 100% test data provided

Cooling Characteristics

Part Number	Element Size [mm]	Typ. Detector Operating Temperature [c] [°C]	Delta T @ max. Cool [a,b] [°C]		Optional Package Versions
			Min.	Typ.	
PB55S1010T2S6L	1.0 x 1.0	-50	70	75	TO-8
PB55S2020T2S6L	2.0 x 2.0	-50			
PB55S3030T2S6L	3.0 x 3.0	-45			
PB55S5050T2S6L	5.0 x 5.0	-45			
PB55S6060T2S6L	6.0 x 6.0	-45			

[a] Values are valid for TO-66 and TO-8 packages. [b] Max. cooling: 1.8 V @ 1.2 Amps (typical).

[c] Valid with sufficient heat sinking only!



Basic Characteristics, Specifications

Part Number	Element Size [mm]	Aperture Size [mm]	Features	20% Cut-off Wavelength [b] [µm]	Peak Wavelength [b] [µm]	Peak Responsivity [ac] [V/W]		Time Constant [b] [µs]	
				Typ.	Typ	Min.	Typ.	Typ.	Max.
PB55S1010T2S6L	1.0 x 1.0	9.5	2 stage (2.5 W) cooling, TO-8 flange, large cap	5.2	4.6	120000	180000	12	30
PB55S2020T2S6L	2.0 x 2.0					60000	90000		
PB55S3030T2S6L	3.0 x 3.0					40000	60000		
PB55S5050T2S6L	5.0 x 5.0					24000	36000		
PB55S6060T2S6L	6.0 x 6.0					20000	30000		

Further Versions in progress

[a] Measured with 500 K blackbody. Bias is 30 V/mm with 1 MOhm load in series. Chopping frequency is 1 kHz. [b] Parameter not 100% tested. [c] Without filter/window

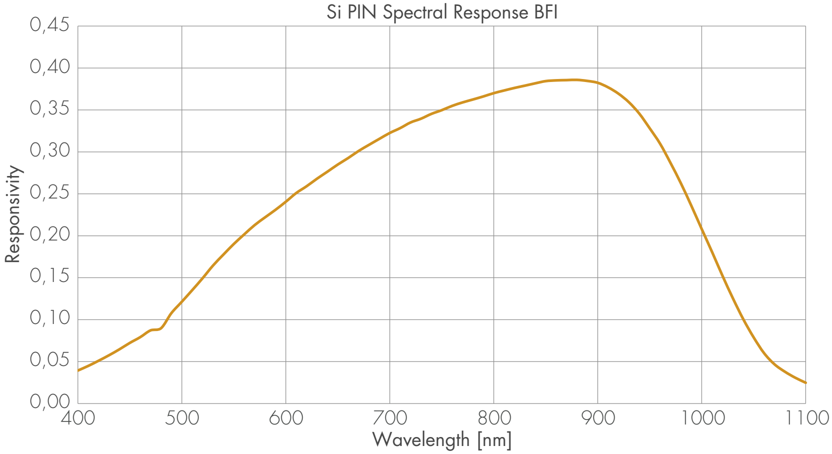
Electro-Optical Characteristics

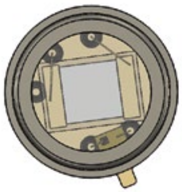
Part Number	Element Size [mm]	Noise Density (rms) [a] [µV/Hz$^{1/2}$]		Peak D* [abc] [cm Hz$^{1/2}$/W]		Peak D* [ac] [cm Hz$^{1/2}$/W]		Dark Resistance [MOhm/square]		
		@ 90 Hz [b]	@ 1 kHz	@ 90 Hz	@ 90 Hz	@ 1 kHz	@ 1 kHz			
		Typ.	Typ.	Min.	Typ.	Min.	Typ.	Min.	Typ.	Max.
PB55S1010T2S6L	1.0 x 1.0	TBD	TBD	7.0 E+9	1.2 E+10	2.2 E+10	3.6 E+10	1.0	6.0	20
PB55S2020T2S6L	2.0 x 2.0									
PB55S3030T2S6L	3.0 x 3.0									
PB55S5050T2S6L	5.0 x 5.0			6.8 E+9	1.0 E+10	1.8 E+10	3.2 E+10			
PB55S6060T2S6L	6.0 x 6.0			6.8 E+9	1.0 E+10	1.8 E+10	3.2 E+10			

[a] Measured with 500 K blackbody. Bias is 30 V/mm with 1 MOhm load in series. Bandwidth of test setup is 1 Hz. [b] Parameter not 100% tested.
[c] Without filter/window All specifications apply at or near max. cooling temp. with heat sink at +25°C.

Specials

Figure showing the extended spectral range added via the addition of a Si photodiode.





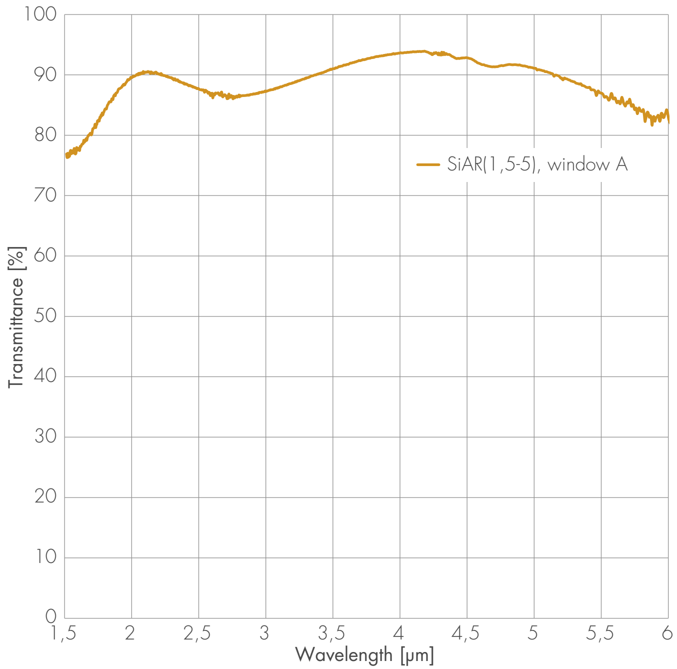
We manufacture novel Lead Salt devices based on unique applications, 2 examples of this are our Lead Salt/Silicon photodiode sandwich detectors which bring visible detection to PbS detectors; and our combined LED & PbS/PbSe detector for simultaneous illumination and detection. Both of these devices are available to purchase. Our LED packages combine an 2x2mm PbS/PbSe chip (performance data on previous pages) with a 970nm LED.

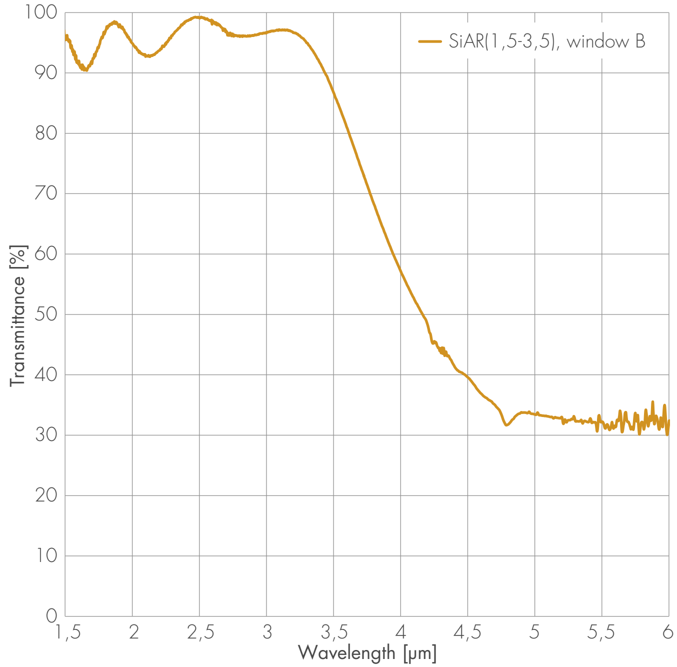
LED Optical and Electrical Characteristics

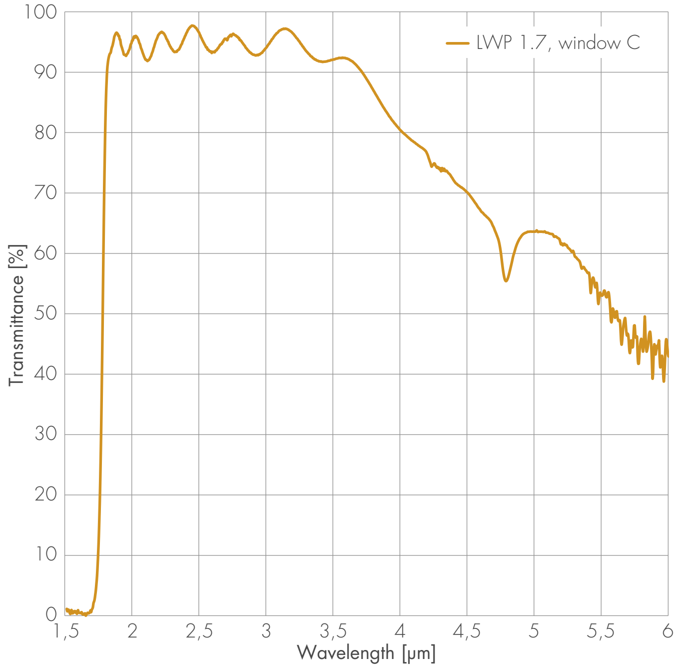
Part Number	Forward Voltage V_F @I_F = 20mA [V]		Reverse Current I_R @I_R = 5V [μA]	Output Power ϕ_e @I_F = 20mA [mW]		Peak Wavelength λ_p @I_F = 20mA [nm]	FWHM $\lambda_{0.5}$ @I_F = 20mA [nm]	Switching Times t_r, t_f @I_F = 20mA [ns]
	Typ.	Max.	Max.	Min.	Typ.	Typ.	Typ.	Typ.
PB25C20209SD								
PB25S20209M	1.25	1.45	10	1.8	2	970	35	15; 20
PB45C20209SD								

T_{amb} = 25, unless otherwise specified

Filters and Windows







Packaging

1. TO-8 with copper flange (equal to TO-66)
2. TO-46
3. TO-8 L-Cap
4. TO-8 M-Cap
5. TO-37 L-Cap (also available as S- & M-Cap)
6. TO-39 M-Cap
7. TO-39 S-Cap


1
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2

Pyroelectric Detectors

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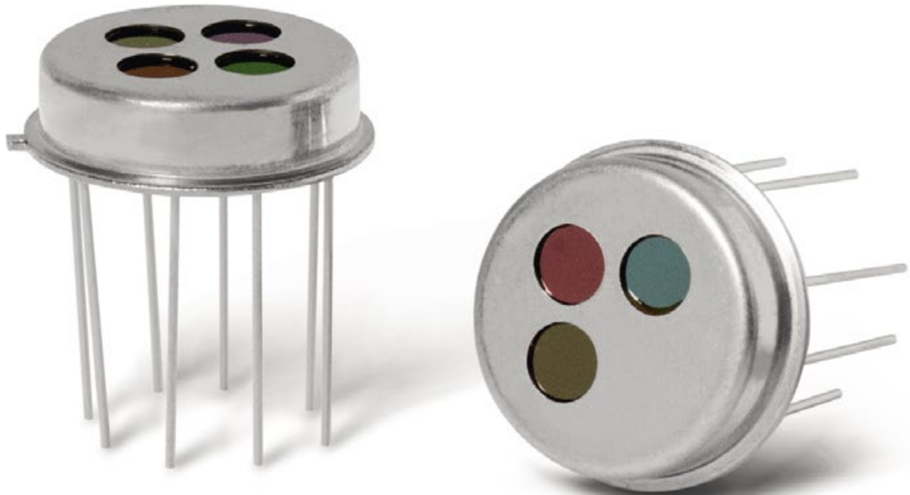


Thermal Detectors

A pyroelectric IR detector is a thermal detector in that it responds to the change in heat (IR radiation) absorbed on its surface. Thermal detectors are polychromatic with a very wide spectral bandwidth.

Physical Principles

The nature of a pyroelectric effect is that in a highly ordered crystal (or ceramic) a temperature change in the crystal causes its atoms to move slightly out of position thus rearranging its electric charge; which is measured via. electrodes on its surfaces.

Materials

The pyroelectric effect is found in many materials. The most commonly used materials are

- DLaTGS - Deuterated L-Alanine doped Triglycine Sulphate
- LTO - Lithium Tantalate
- PZT - Lead Zirconate Titanate

The performance of PZT is lacking compared to the other materials - that's why LASER COMPONENTS only uses DLaTGS and LTO for pyroelectric elements.

Material	Pyro. Coef. [Coul/cm² °K (x 10^{-8})]	C_v [Joules/cm³ °K]	K	AC Resisitivity [Ohms @ 1 kHz. (x 10^{10})]	Curie Temp. [°C]	Fig. of Merit Normalized (VM)
DLA	4.1	2.5	21	2.4	62	5.472
LTO	2.3	3.16	51	3.6	610	1.000
PZT	4.0	3.1	250	.007	290	0.374

Fig. 1: The properties of different pyroelectric materials used today

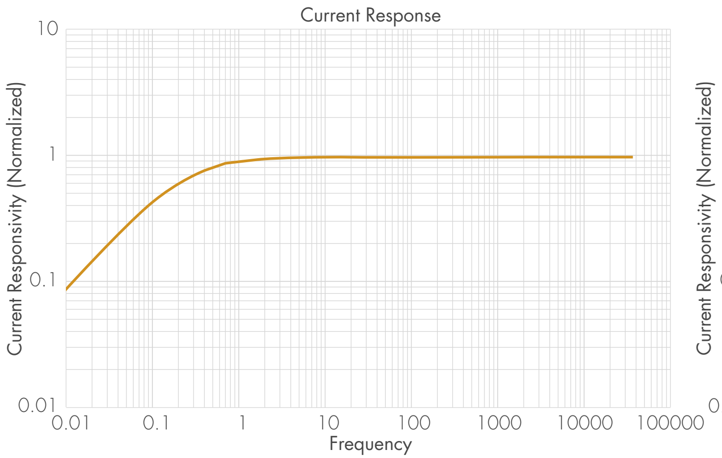


Fig. 2: Graph showing normalised current response with relation to frequency

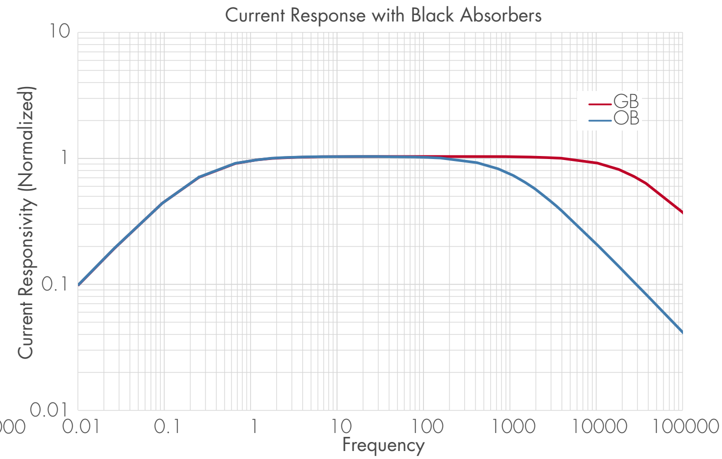


Fig. 3: Graph showing normalised current responses of LCPG's "Organic Black" and "Gold Black" coatings

Measurement Principle

The actual sensor's signal output is a change in the charge present on the active elements surface - it is caused by the temperature gradient dT/dt as it is changing its temperature. The change in charge with time dq/dt is the electric current (Amperes):

$$dq / dt = I \ [A]$$

And where charge on the plates of the pyroelectric element (acting like a capacitor) can be characterised by:

$$q = \rho Ad \Delta T$$

Where:
q = Charge produced (Coul.)
ρ = Pyrolelectric Coefficient (C/cm^2 °K)
Ad = Area of detectionelement (cm^2)

As you can see, as the relationship between current and charge is dependent on changing temperature (dt), when there is no change in temperature there is no current production. Pyroelectric detectors are AC detectors.

We can go into further depth regarding the underlying physics behind pyroelectric detectors, but we do not have enough room in this catalog! Please check our website for a more in depth analysis.

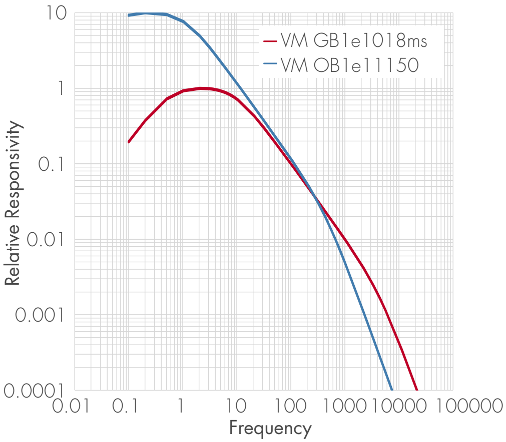
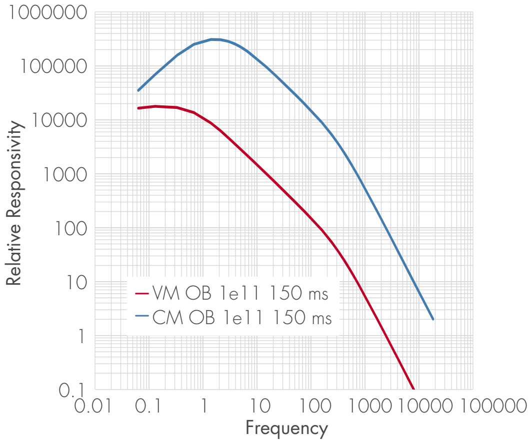


Fig. 4 (left): Graph comparing the frequency response of 2 VM detectors

Fig 5 (right): Graph comparing responsivity compared to frequency for 2 identical detectors, with one using CM amplification (blue) and the other using VM (red)



Frequency Response

As we just learned, pyroelectric detectors cannot be used in DC operations. But that prompts the question… Just how fast can I push my pyroelectric sensor? The answer involves many different factors which will be looked at briefly here. Again, please visit our website for a more in-depth analysis.

The frequency response of a pyroelectric detector can be distilled down into these factors:

1. Thermal properties of the pyroelectric crystal
   a. The thermal conductivity of the crystal & mounting scheme
   b. The thermal mass of the absorber
2. The frequency response of the preamplifier
   a. The value of the feedback resistor in current mode
   b. The value of the load resistor in voltage mode

The low frequency response of a pyroelectric detector is controlled by the thermal conductivity of the crystal and the mounting scheme.

At LASER COMPONENTS Pyro Group the thermal time constant can be adjusted from <5 msec to 350 msec via. material and mounting method. The higher your thermal time constant, the better your device will perform at lower frequencies. A typical current response curve for an unblackened element with a 150 msec time constant can be seen in Fig. 2

The high frequency response of a pyroelectric is controlled using by the thermal mass of the absorbing coating on the surfaces of the crystal. Although from the graph below you might first assume that this has a detrimental effect on the frequency response, please remember that this is a normalised graph; and the black coatings greatly improve the absorption of IR radiation increasing D* significantly. We provide 2 coatings: Organic, high thermal mass black (for low speed applications) and "Gold Black" for high speed, high performance applications.

The next factor for frequency response of the output signal (or Voltage Responsivity) is the preamplifier, which is a function of both the Current Responsivity described above and the preamp gain:

$$\text{Voltage responsivity (V/W)} = \text{Current Responsivity (A/W)} \times \text{Preamp Gain } (V_{out}/V_{in})$$

Where preamp gain can be described as:

$$V/W = A/W * \frac{R}{\sqrt{(1+(\omega RC)^2}}$$

Where:

R = Load Resistor (VM) or Feedback Resistor (CM)

C = Detector Capacitance (VM) or Stray Capacitance (CM)

We will now compare 2 different Voltage mode detectors. One with a low thermal mass and lower load resistor, and another with a high thermal mass and high load resistor. (Fig. 4)

As you can see, the detector with the larger resistor and thermal mass (blue) has a much larger low frequency response, whereas the detector with a lower resistor and thermal mass (red) has a better high frequency response.

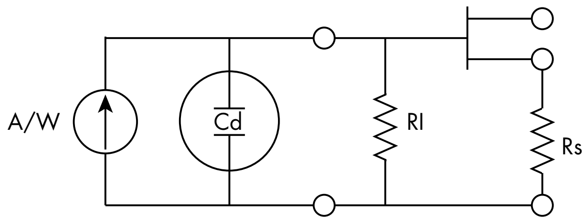


Fig. 6: Typical voltage mode operational circuit (source follower)

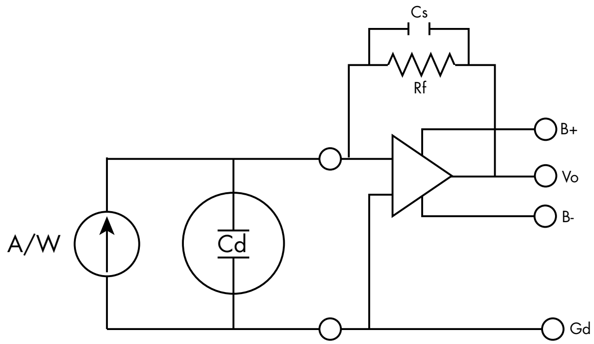


Fig. 7: Typical current mode operational circuit

Noise in Pyroelectric Detectors

Full notes regarding noise in pyroelectric detectors can be found on our website under application notes. Noise in pyroelectrics is a complex matter, but well understood. The main noise drivers in pyroelectric detectors are:

1. Johnson noise in the load or feedback resistor
2. Current (shot) noise from the input leakage of the integrated JFET or Opamp
3. Voltage noise of the JFET or Opamp
4. Dielectric loss or loss tangent (from the series or parallel resistance associated with the detectors electrodes)

Electric Circuit

A pyroelectric detector is modelled as a current source [A/W] in parallel with a capacitor [Cd]. These high impedance sensors must be coupled to an impedance matching amplifier, either a FET follower (voltage mode) or a transimpedance amplifier (current mode). There are certain trade-offs in choosing the VM or CM configuration.

Voltage Mode

JFET-based voltage mode has been widely available for a long time; however, it has critical disadvantages and is now only usually used experienced users; producing a relatively low signal on a strongly temperature-dependent offset. But this mode of operation also has some advantages: JFETs are cheap and the amplification is flexible. Fig. 6 shows a typical voltage mode circuit.

Current Mode

In current mode, a high signal is produced on a low offset with relatively low temperature dependence. Current Mode, whilst not a "new" breakthrough; has recently become much more viable and affordable due to the advances in semiconductor manufacturing, allowing for small and low power Opamps to be manufactured. The low output impedance of Opamps leads to additional EMI advantages. Fig. 7 shows a typical current mode circuit.

For high-end designs at low frequencies similar values for D* are achieved as with voltage mode. However, unlike voltage mode detectors current mode detectors have a very large output (due to the large transimpediance gain), which means they can be used to directly drive post-processing electronics like microprocessors, without the use of a pre-amplification stage[i]. This makes them ideal for modern applications and those new to the detectors, slashing your development time.

Temperature Fluctuation Compensation (TFC)

There is a common misconception that TFC elements (or "blind") elements add an active, temperature stabilising solution to a detector; protecting you from drift over slow, long temperature changes. This is unfortunately incorrect. TFC protects against instantaneous changes to the microclimate temperature, and helps to stabilise the active element and reduce the ringing of the signal, bringing the detector back to normal operation.

TFC does reduce the responsivity by a factor of 2 in the voltage mode with parallel compensation. In current mode the signal remains unchanged by TFC. However, TFC in current mode attenuates the tendency toward natural oscillation, thus allowing a larger amplification.

(i) Please note, that a buffer amplifier might be requested in case of very low power OpAmps.

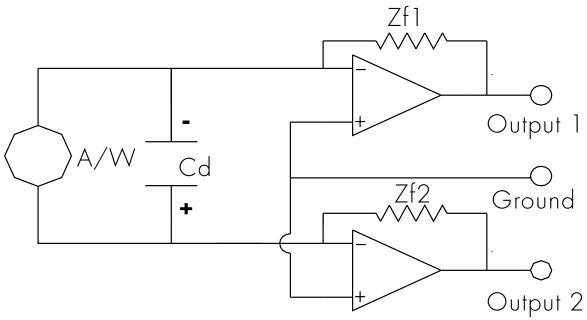


Fig.8: Circuit diagram of our CM based Differential Pyroelectric Detector

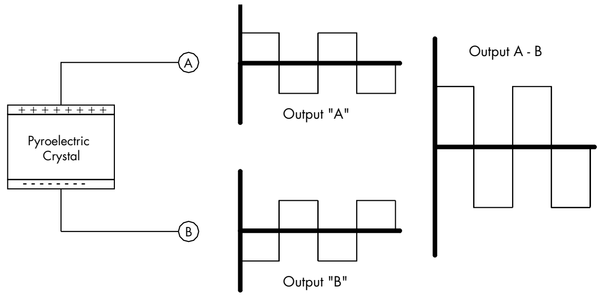


Fig. 9: Demonstration of the effect on signal when both outputs are subtracted.

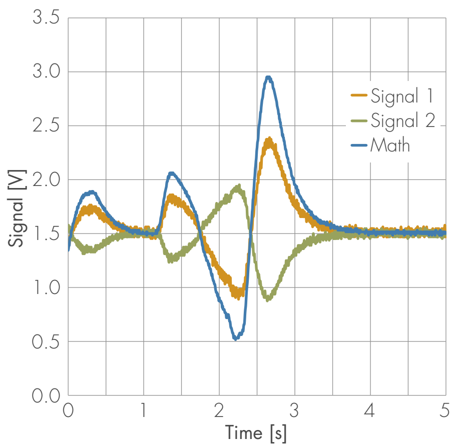
Differential Pyros

Unlike their thermopile cousins, pyroelectrics are still single-ended detectors; making them susceptible to electromagnetic interference from non-detector related noise. Processor clocks, line interference, and other sources of electromagnetic noise can still be coupled to their output causing unnecessary headaches during design phases of new equipment. LASER COMPONENTS not only has developed a new and unique pyroelectric connection method to eliminate electromagnetic interference, our new, patented detector configuration (Fig.8) improves the signal to noise ratio by approximately 1.4!

When charges are generated on the pyroelectric crystal, both positive and negative charges are generated on opposite sides (Fig. 9). Both sides of the crystal produce opposing signals of equal magnitude, and by using our unique scheme we can subtract the signals from each other (using a differential or instrumentation amplifier) eliminating the common mode noise from outside sources, but effectively doubling the output!

Although our detector signal increases twofold, our noise increases by a factor of only √2; **resulting in an overall signal to noise improvement of approximately 1.4**. When both channels are combined the net noise voltage becomes:

$$VnD=\sqrt{((VnT_1)^2+(VnT_2)^2)}$$



In Figure 10 we used one of our differential detectors and introduced common mode noise in the form of a 50Hz signal. As you can see signal 1 and signal 2 both demonstrate the noise; whereas the mathematically subtracted output does not. As well as giving a significantly increased output, the common mode noise has been eliminated.

Because this detector is also based on our Current Mode architecture, our differential detectors can be directly inputted in to modern ADCs and microcontrollers where this subtraction can be done in software; allowing you to cut out pre-amplification stages from your design, and cut down on development costs!

Fig. 10: Graph showing common mode noise eliminated via. our differential detector

Absolute Maximum Ratings

		Min.	Max.
Storage Temperature [°C]		- 25	+ 85
Operating Temperature [°C]	$LiTaO_3$	- 20	+ 85
	DLaTGS	-20	+ 55
Soldering Temperature (5 sec.) [°C]		+ 280	+ 300
ESD Damage Threshold, Human Body Model Class ...* [V]		0	<250

* ANSI/ESD STN5. 1-2007

Part Number Designation

Our product nomenclature allows you to see at a glance what's what – details are given below.

Material	Type	Channels	Versions	Micro	Element Size	Filter Code

Material

L	$LiTaO_3$
LD	$LiTaO_3$ differential
D	DLaTGS
DD	DLaTGS differential

Type

0	chip only
1	current mode
2	current mode + TFC
3	voltage mode
4	voltage mode + TFC

Channels

1	single
2	dual
3	triple
4	quad

Versions

Version

Micro

X	standard
M	ultra low micro
T	TEC
C	ultra low microphonics + TEC

Element Size

1000	∅ 1.0 mm
1300	∅ 1.3 mm
2000	∅ 2.0 mm
3000	∅ 3.0 mm
1010	1.0 x 1.0 mm²
1810	1.8 x 1.0 mm²
2020	2.0 x 2.0 mm²
3030	3.0 x 3.0 mm²

Filter Code

See separate datasheet

Note:

- TFC: temperature fluctuation compensation
- Low Micro: reduced microphonic effect

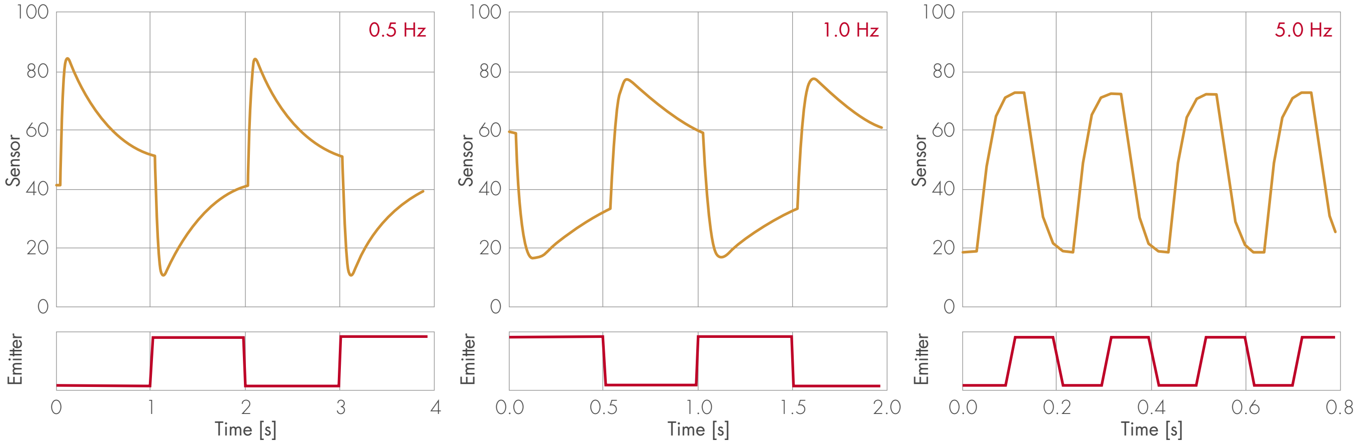
L11, L21 Series

LTO Single Channel CM Pyro Detectors

- $LiTaO_3$
- Single element
- Current mode
- Integrated OpAmp (or JFET)
- TFC optional
- Trend towards low power OpAmp

Basic Characteristics, Specifications

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Supply Current @1MOhm	Speed
					Max	Recommended		
L1100X2020	2.0 x 2.0	5.0 x 5.0	TO-39 3 pin	n	2.7 – 10	3	30μA	Low
L1120X2020	2.0 x 2.0	5.0 x 5.0	TO-39 4-Pin	n	26	±6V	0.9mA	High
L2100X2020	2.0 x 2.0	5.0 x 5.0	TO-39 3 pin	y	2.7 – 10	3	30μA	Low
L2110X2020	2.0 x 2.0	5.0 x 5.0	TO-39 4-Pin	y	±16	±5	150μA	Low

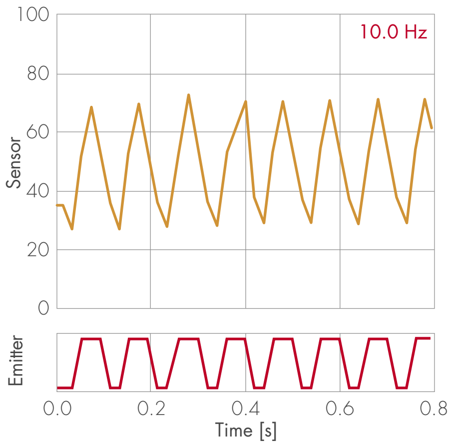


Lithium Tantalate ($LiTaO_3$/LTO) is the most widely used pyroelectric material in many non-dispersive applications, and as power monitors for pulsed laser systems due to its relatively high performance and low cost compared to other thermal detectors.

Traditionally voltage mode devices have always been used for pyroelectrics; not because of performance, but because of the availability of small and reliable transimpedance amplifiers available on the market. Semiconductor manufacturing processes now allows for this with current mode devices providing some distinct advantages over voltage mode, especially for new users.

Detector Signal at Different Frequencies
The signal form depends on the frequency of the IR radiation source. Real-time data from our IR applications kit with a single mode CM detector (results vary from model to model).

- Easy system integration
- Short development times
- Increased performance at higher frequencies
- High signal with low offset
- Low temperature dependence
- Low output impedance reduces EMI effects



Electromechanical Characteristics

Part Number	Responsivity @500K [V/W, 10Hz]		Max Noise Density [RMS, 10Hz]	D* @ 500K [Jones, 10Hz]		FOV [Deg]
	Min	Typ		Min	Typ	
L1100X2020	30.000	40.000	25µV	3.00 E+8	4.00 E+8	70
L1120X2020	20	25	500nV	7.00 E+6	1.00 E+7	70
L2100X2020	100.000	150.000	60µV	4.50 E+8	6.00 E+8	70
L2110X2020	100.000	150.000	50µA	5.00 E+8	7.00 E+8	70

LD11,
LD21 Series

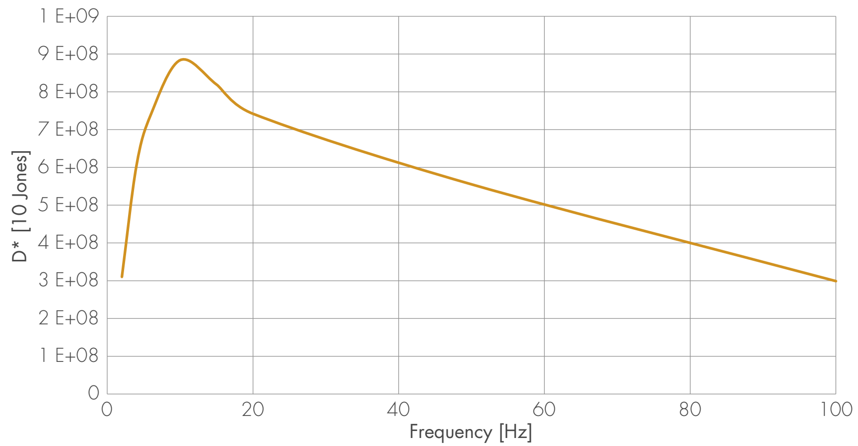
LTO Differential
Single Channel
CM Pyro Detectors

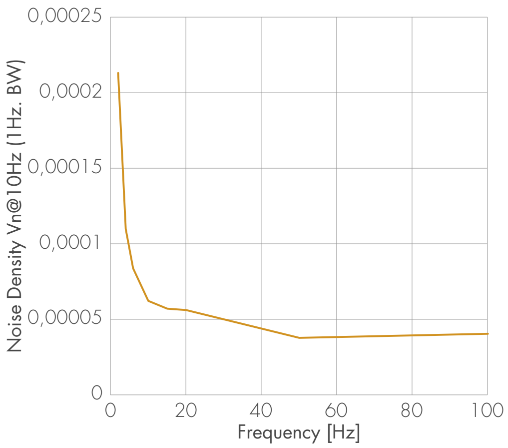
- $LiTaO_3$ Double ended output
- Single element
- Current mode
- Integrated OpAmp
- TFC

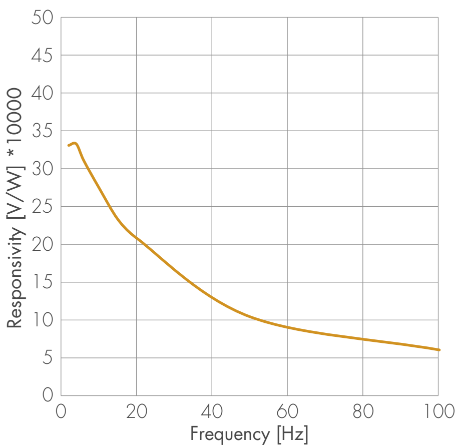
MORE MODELS COMING SOON !

Basic Characteristics, Specifications

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Supply Current @1MOhm	Speed
					Max	Recommended		
LD2100X2020	2.0 x 2.0	5.0 x 5.0	TO-39 4-Pin	y	2.7 - 10	3	1mA	Low







Pyroelectric crystals simultaneously generate positive and negative charges on opposite faces, and our LD2100 detectors exploit this with a new amplification scheme.

The LD2100 series is based on our best-selling L2100 series CM current mode detector, and we plan to bring other differential versions of our detectors to market in due course.

We now can produce a pyroelectric detector that not only gives you double the sig-nal compared to a single ended detector when used with a differential amplifier, but the noise only increases by √2. This produces an improvement in signal to noise ratio of around 1.4.

Pyroelectric detectors with a differential amplifier have two additional advantages: External interference signals are eliminated by signal subtraction. Thus, they can be used in critical environments with electric fields. Furthermore, the LD2100 series makes simple wiring possible, by allowing you to connect the signal outputs directly to the inputs of an differential AD converter.

Electromechanical Characteristics

Part Number	Responsivity @500K [V/W, 10Hz, 1 Hz BW]		Max Noise Density [RMS, 10Hz]	D* @ 500K [Jones, 10Hz]		FOV [Deg]
	Min	Typ		Min	Typ	
LD2100X2020	240,000	280,000	70	8.00 E+08	1.00 E+09	70

L31, L41 Series

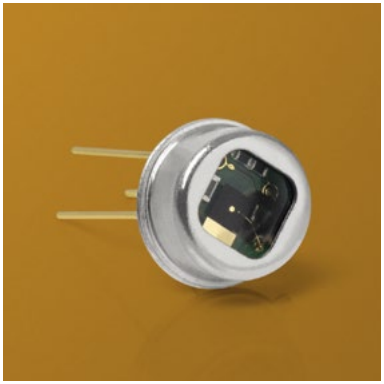
LTO Single Channel VM Pyro Detectors

- $LiTaO_3$
- Single element
- Voltage mode
- Integrated JFET
- TFC optional

Basic Characteristics, Specifications

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Speed
					Max	Recommended	
L3100X2020	2.0 x 2.0	5.0 x 5.0	TO39 3-pin	n	30	9	Low
L4100X2020	2.0 x 2.0	5.0 x 5.0	TO39 3-pin	y	30	9	Low

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Speed
					Max	Recommended	
L3151X1000	∅ 1	∅ 5.3	TO39 4-pin	n	25	9	High
L3151X1300	∅ 1.3						
L3151X2000	∅ 2						
L3151X3000	∅ 3						



Voltage mode Lithium Tantalate devices are what every experienced user of pyroelectric detectors will be most familiar with, and FET source follower based detectors being the most common.

Voltage mode detectors are recommended for long term users of pyroelectrics, due to the relatively low signal and strong temperature dependence when compared to current mode devices. However, voltage mode amplification is affordable, and provides a very flexible form of amplification.

- For experienced users
- Flexible and affordable amplification
- Well documented
- High low frequency response

Electromechanical Characteristics

Part Number	Responsivity @500K [V/W, 10Hz]		Max Noise Density [RMS, 10Hz, 1Hz BW]	D* [Jones, 10Hz, 500k]		FOV [Deg]
	Min	Typ		Min	Typ	
L3100X2020	340	400	150nV	6.00 E+08	9.00 E+08	70
L4100X2020	160	200	130nV	4.00 E+08	5.00 E+08	70
Part Number	Responsivity @1000K [V/W, 1kHz]		NEP [W/√Hz]	D* [Jones, 1kHz, 1000k]		FOV [Deg]
	Min	Typ		Min	Typ	
L3151X1000[a]	TBC	17	1.60 E-09	6.00 E+07	9.00 E+07	45
L3151X1300[a]	TBC	10	2.00 E-09	6.00 E+07	1.00 E+08	40
L3151X2000[a]	TBC	6	3.00 E-09	6.00 E+08	1.00 E+08	35
L3151X3000[a]	TBC	2	5.00 E-09	5.00 E+07	8.00 E+07	25

[a] Metal block

L1x, L2x Series

LTO Multi Channel CM Pyro Detectors

- $LiTaO_3$
- Multi channel elements
- Current mode
- Integrated OpAmp
- TFC optional
- Trend towards low power

Basic Characteristics, Specifications

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Supply Current @1MOhm	Speed
					Max	Recommended		
L1200X1810	1.8 x 1.0	2.7 x 1.8	TO-39 4-Pin	n	2.7 – 10	3	150µA	Low
L2200X1810	1.8 x 1.0	2.7 x 1.8	TO-39 4-Pin	y	2.7 – 10	3	150µA	Low
L2400X2020	2.0 x 2.0	∅ 3.5, 4-hole	TO-8 8-Pin	y	2.7 – 10	3	300µA	Low
L2410X2020	2.0 x 2.0	∅ 3.5, 4-hole	TO-8 8-Pin	y	±16	±5	300µA	Low

Multi-channel detectors are most commonly found in gas sensing applications as when combined with narrow bandpass IR filters targeted at specific gas lines; incredibly compact gas sensors can be made based on NDIR detection methods.

Our L1x/2x is available with up to 4 channels with integrated filters, allowing for detection of up to 3 gasses simultaneously (3 active channels + 1 reference channel) and any one of our standard filters or custom filters can be fitted. Current mode devices have a very distinct advantage over voltage mode devices when made into multi-channel detectors. OpAmps when compared to JFETs have a much lower temperature dependence, resulting in a significantly reduced temperature drift between elements when compared to voltage mode operation.

- Available in 2, 3 or 4 channel configurations
- Wide selection of standard filters
- Compact designs
- Greatly improved temperature drift between elements when compared to voltage mode

Electromechanical Characteristics

Part Number	Responsivity @500K [V/W, 10Hz]		Max Noise Density [RMS, 10Hz, 1 Hz BW]	D* @ 500K [Jones, 10Hz]		FOV [Deg]
	Min	Typ		Min	Typ	
L1200X1810	25,000	35,000	20μV	2.00 E+08	3.00 E+08	20[a]
L2200X1810	60,000	120,000	50μA	3.00 E+08	5.00 E+08	20[a]
L2400X2020	90,000	120,000	65μA	6.00 E+08	7.50 E+08	45
L2410X2020	90,000	120,000	65μA	6.00 E+08	7.50 E+08	45

[a] wider available

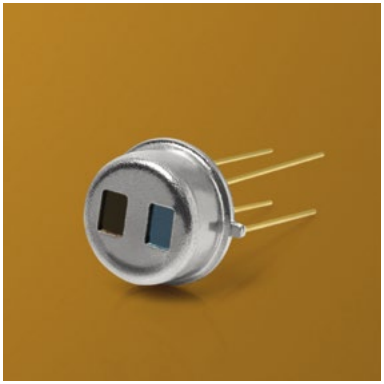
L3x, L4x Series

LTO Multi Channel VM Pyro Detectors

- $LiTaO_3$
- Multi channel elements
- Voltage mode
- Integrated JFET
- Optional with TFC

Basic Characteristics, Specifications

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Speed
					Max	Recommended	
L4200X1810	1.8 x 1.0	2.7 x 1.8	TO39 4-pin	y	30	9	Low
L3400X2020	2.0 x 2.0	∅ 3.5, 4-hole	TO8 12-pin	n	30	9	Low
L4400X2020	2.0 x 2.0	∅ 3.5, 4-hole	TO8 12-pin	y	30	9	Low



Multi-channel detectors are most commonly found in gas sensing applications as when combined with narrow bandpass IR filters targeted at specific gas lines; incredibly compact gas sensors can be made based on NDIR detection methods.

Our L3x/4x devices are also available with up to 4 channels allowing for detection of up to 3 gasses simultaneously (3 active channels + 1 reference channel) and any one of our standard filters or custom filters can be fitted.

Our voltage mode devices are available in many well know configurations, and can be directly integrated into existing designs and electronics.

- Available in 2, 3 or 4 channel configurations
- Wide selection of standard filters
- Compact designs
- Common configurations available

Electromechanical Characteristics

Part Number	Responsivity @500K [V/W, 10Hz]		Max Noise Density [RMS, 10Hz, 1Hz BW]	D* @ 500K [Jones, 10Hz]		FOV [Deg]
	Min	Typ		Min	Typ	
L4200X1810	320	360	120	4.50 E+08	5.00 E+08	20[a]
L3400X2020	300	360	150	4.20 E+08	1.00 E+09	45
L4400X2020	160	200	120	4.50 E+08	1.00 E+09	45

[a] wider available

D31, D41 Series

DLaTGS Single Channel VM Pyro Detectors

- DLaTGS
- Single element
- Voltage mode
- Integrated JFET

Basic Characteristics, Specifications

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Speed
					Max	Recommended	
D3110X2010	2.0 x 1.0	∅ 5.3	TO39 4-pin	n	25	9	Low
D3110X2000	∅ 2.0	∅ 5.3	TO39 4-pin	n	25	9	Low

Part Number	Element Size [mm]	Aperture Size [mm]	Package	TFC	Suply Voltage [V]		Speed
					Max	Recommended	
D3151X1000	∅ 1.0	∅ 5.3	TO39 4-pin	n	25	9	High
D3151X1300	∅ 1.3	∅ 5.3	TO39 4-pin	n	25	9	High
D3151X2000	∅ 2.0	∅ 5.3	TO39 4-pin	n	25	9	High
D3151T1000	∅ 1.0	∅ 5.3	TO37 8-pin	n	25	9	High
D3151T1300	∅ 1.3	∅ 5.3	TO37 8-pin	n	25	9	High
D3151T2000	∅ 2.0	∅ 5.3	TO37 8-pin	n	25	9	High

Our D 31/41 series of Voltage Mode DLaTGS detectors are aimed at legacy customers who use DLaTGS or TGS in existing FTIR applications and devices, it is recommended that new developments take advantage of our selection of differential current mode, or differential voltage mode devices.

DLaTGS (deuterated L-alanine-doped triglycine sulphate) has some advantages over TGS, mainly the increased curie temperature of 61°C (10 K higher). This is achieved via. the process of deuteration, the complete replacement of all hydrogen atoms by deuterium atoms.

Additional doping increases the sensitivity of detectors and prevents permanent depolarisation when heating beyond the Curie temperature.

- Improved curie temperature when compared to TGS
- DLaTGS D* typically 2.5 times higher than LTO
- TEC available for elevated temperature operation
- No permanent depolarization
- Ideal for existing FTIR designs
- Many well-known configurations available

Electromechanical Characteristics

Part Number	Responsivity [V/W, 10Hz, 1000K]		D* [Jones, 10Hz, 1000K]		NEP [W/√Hz]	FOV [Deg]
	Min	Typ	Min	Typ		
D3110X2010	TBC	3200	9.00 E+08	1.00 E+09	TBC	35
D3110X2000	TBC	2000	9.50 E+08	1.50 E+09	TBC	35

Part Number	Responsivity [V/W, 1kHz, 1000K]		D* [Jones, 1kHz, 1000K]		NEP [W/√Hz]	FOV [Deg]
	Min	Typ	Min	Typ		
D3151X1000	TBC	100	1.80 E+08	2.50 E+08	4.10 E-10	45
D3151X1300	TBC	60	2.00 E+08	2.70 E+08	4.50 E-10	40
D3151X2000	TBC	30	2.10 E+08	2.80 E+08	6.00 E-10	35
D3151T1000	TBC	100	1.80 E+08	2.50 E+08	4.00 E-10	80
D3151T1300	TBC	60	2.00 E+08	2.70 E+08	4.50 E-10	75
D3151T2000	TBC	30	2.10 E+08	2.80 E+08	6.50 E-10	70

Filters and Windows

The pyroelectric detector configuration is concluded with an appropriate window or filter specification.

Depending on the application, the filter/window defines the spectral sensitivity of the pyroelectric element, also providing a reliable hermetic sealing of the optical interface between the detector and its environment.

Please note that if pyroelectric detectors are required without any filter or window, we cannot offer any warranty on the functionality of the device.

The detector designation includes the filter/window description via codes according to the following tables.

Numbers are used for filters (see table 1) for applications that require a large aperture/field of view e.g. flame detection. Here the detector aperture is normally 5 x 5 mm^2 for single channel detectors.

Letters are used for filters in applications where a small aperture is sufficient. Here the aperture is 3.5 x 3.5 mm^2 (for single elements in TO-39 can).[i]

For the windows (see table 2) in general the aperture is 5 x 5 mm^2 for single channel detectors. However other apertures are available on request.

Please note: For development purposes our filters are also available mounted in round holders that fit over standard TO-39 caps (single elements).

(i) The small aperture is the standard option for narrow bandpass filters. A larger aperture gives more signal; However, selectivity might be compromised due to angular shifts and instrument calibration may become more difficult.

General Specifications

Thickness	0.4 – 0.7 mm
Blocking	Up to 10 µm[a]
Surface Quality	MIL-F-48616
Environmental quality	acc. to MIL-F-48616 (Temperature §4.6.9.1, Humidity §4.6.8.2, Moderate abrasion §4.6.8.3, Adhesion §4.6.8.1, Solubility and Cleanability §4.6.9)

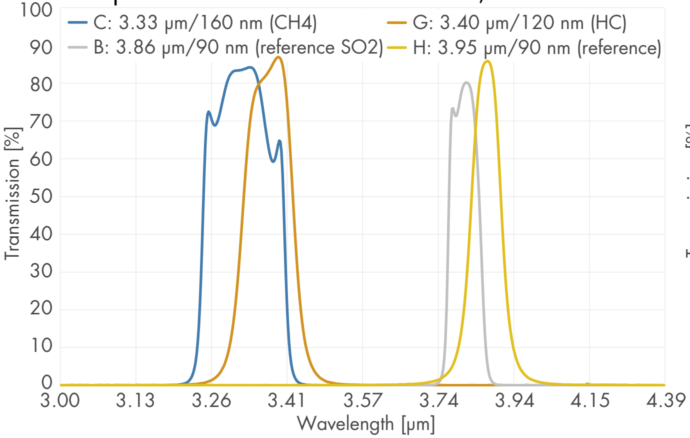
[a] U filter up to 13µm

Standard Gas Sensor Filters

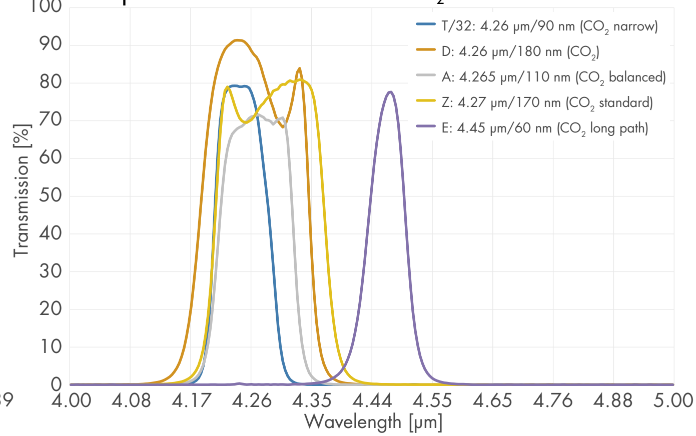
	Code*	Application	CWL [µm]	HPBW [µm]	Angle shift @ AOI 15° [nm]	Temperature shift [nm/K]
NBP 3.33–160 nm	C | 35	CH_4 - Methane	3.33 ± 20 nm	160 ± 20 nm	≤ -20	< +0.50
NBP 3.40–120 nm	G | 40	HC	3.40 ± 30 nm	120 ± 20 nm	≤ -25	< +0.25
NBP 3.86–90 nm	B | 41	Reference for SO_2 mixtures	3.86 ± 30 nm	90 ± 20 nm	≤ -20	< +0.50
NBP 3.95–90 nm	H | 34	Reference	3.95 ± 35 nm	90 ± 10 nm	≤ -15	< +0.50
NBP 4.26–90 nm	T | 32	CO_2 narrow	4.26 ± 20 nm	90 ± 20 nm	≤ -20	< +0.50
NBP 4.265–110 nm	A | 42	CO_2 easy calibration	4.265 ± 20 nm	110 ± 20 nm	≤ -20	< +0.50
NBP 4.26–180 nm	D | 33	CO_2	4.26 ± 20 nm	180 ± 20 nm	≤ -40	< +0.25
NBP 4.27–170 nm	Z | 43	CO_2 standard	4.27 ± 30 nm	170 ± 20 nm	≤ -20	< +0.50
BP 4.30–600 nm	F | 30	flame	4.30 ± 50 nm	600 ± 50 nm	≤ -20	< +0.50
NBP 4.45–60 nm	E | 44	CO_2 long path	4.45 ± 20 nm	60 ± 20 nm	≤ -20	< +0.50
NBP 4.66–180 nm	I | 39	CO centered	4.66 ± 30 nm	180 ± 20 nm	≤ -20	< +0.50
NBP 4.74–140 nm	K | 37	CO flank	4.74 ± 20 nm	140 ± 20 nm	≤ -20	< +0.50
NBP 5.3–180 nm	L | 31	NO	5.3 ± 40 nm	180 ± 20 nm	≤ -25	< +0.60
NBP 5.78–180 nm	M | 38	H_2O in gas mixtures	5.78 ± 40nm	180 ±20nm	≤ -22	< +0.60
NBP 7.3–200 nm	U | 45	SO_2	7.3 ± 40nm	200 ± 30nm	≤ -30	< +0.80
NBP 7.91–160 nm	S | 46	Methane in gas mixtures	7.91 ± 50nm	160 ± 30nm	≤ -30	< +0.80
BP 9.50–450 nm	O | 36	Alcohol	9.50 ± 60nm	450 ± 60nm	≤ -40	< +1.00

* Letter for small aperture / Number for large aperture
Note: For gas measurement applications the small aperture is standard due to selectivity. Large aperture is standard in flame applications.

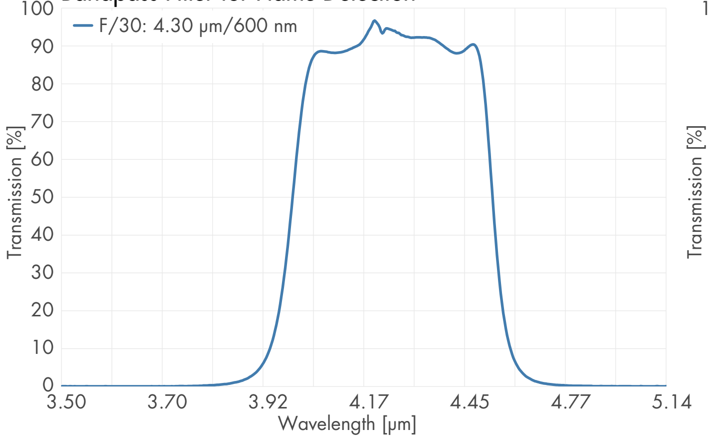
Bandpass Filters for Detection of Methane, HC and References



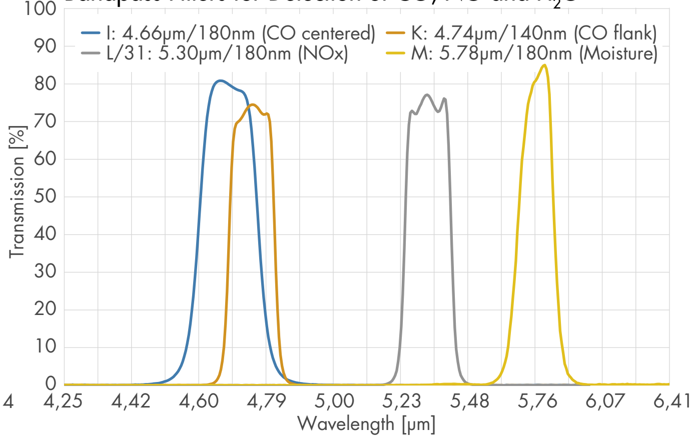
Bandpass Filters for Detection of CO_2



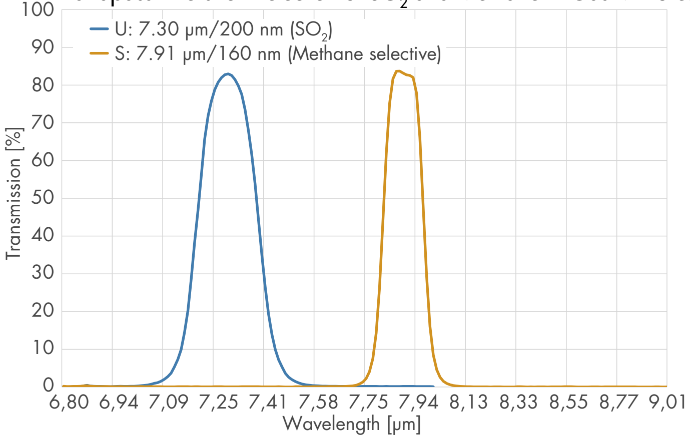
Bandpass Filter for Flame Detection



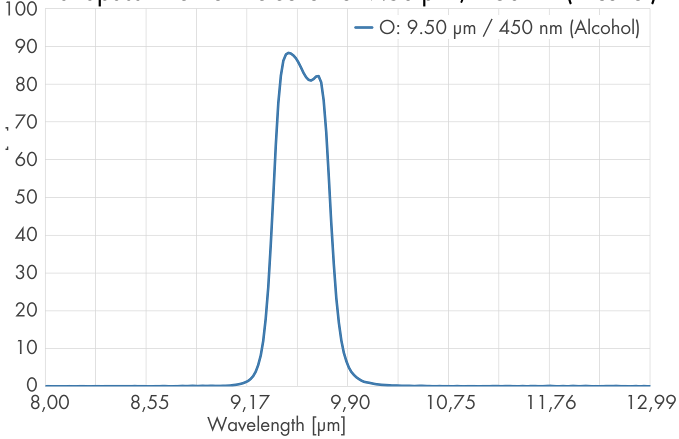
Bandpass Filters for Detection of CO, NO and H_2O



Bandpass Filters for Detection of SO_2 and Methane in Gas Mixtures



Bandpass Filter for Detection of 9.50 µm / 450 nm (Alcohol)



Standard Windows

Code	Name	Thickness [mm]	Description	Transmission Range / Coating Range	Notes
b1*	BaF2	0.4	Barium fluoride	UV–12 µm	
c1*	CaF2	0.4	Calcium fluoride	UV–9 µm	
k1	KBr protected	1.0	Potassium bromide, protected	UV–25 µm	
k2	KBr uncoated	1.0	Potassium bromide, uncoated	UV–25 µm	Water-soluble
l1	Si LWP 7.5µm	0.55	Silicon longwave-pass filter		Cut on (5 %) ~ 7.22 µm 50% point ~ 7.5 µm
s1	Si uncoated	1.0	Silicon uncoated	2–56 µm	
s2	Si 3–5	0.5	Silicon AR coated, hard	3–6 µm	T (3–6 µm) > 90 % T (3.4 µm) > 99 %
w1	Si WBP (8-14µm)	0.55	Silicon bandpass filter	8–14 µm	T ave (9–13 µm) > 75 %
z1*	ZnSe A/R (2-14µm)	0.5	Zinc Selenide AR-coated, wedged	2–14 µm	
z2*	ZnSe wedged	0.5	Zinc Selenide wedged	0.6–16 µm	

Available Options

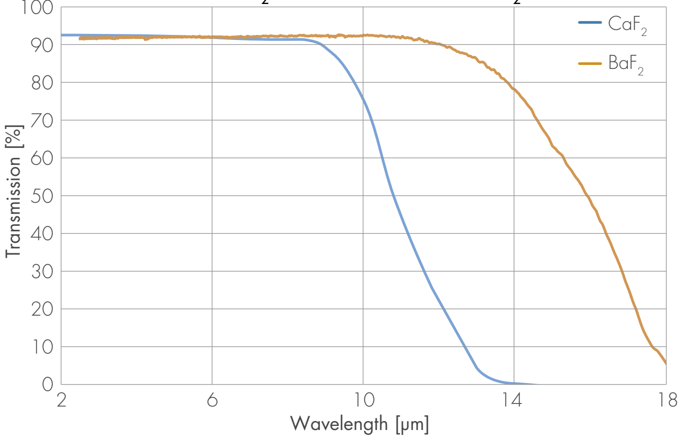
Code	Name	Thickness [mm]	Description	Transmission Range	Notes
a1*	Sapphire	0.4	Sapphire uncoated	UV–5 µm	
d1	CVD Diamond	0.15		UV–100 µm	
i1	CsI	1.0	Caesium Iodide	UV–50 µm	Water-soluble
p1	HDPE	0.8	High density polyethylene		
Y			without window		No warranty!!

Example:
LT……-b1: Detector with Barium Fluoride window, 0.4 mm thick.

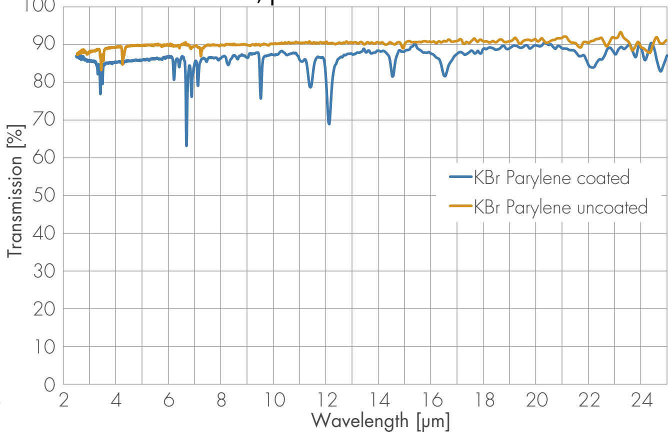
Notes: Transmission ranges are typical values and are not specified as this is a material property.

* Available as soldered version on request.

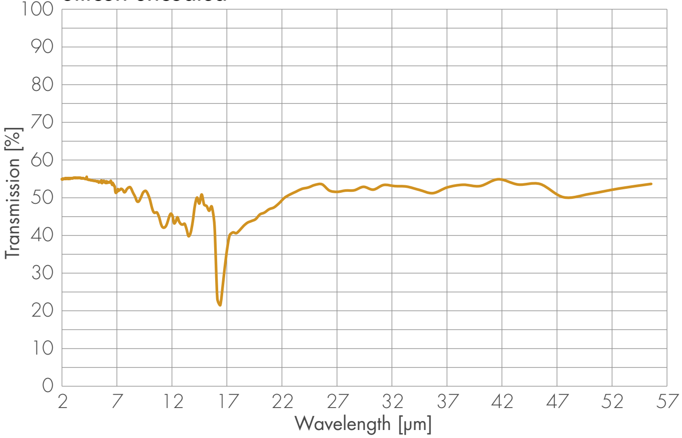
Barium fluoride BaF_2 & Calcium fluoride CaF_2



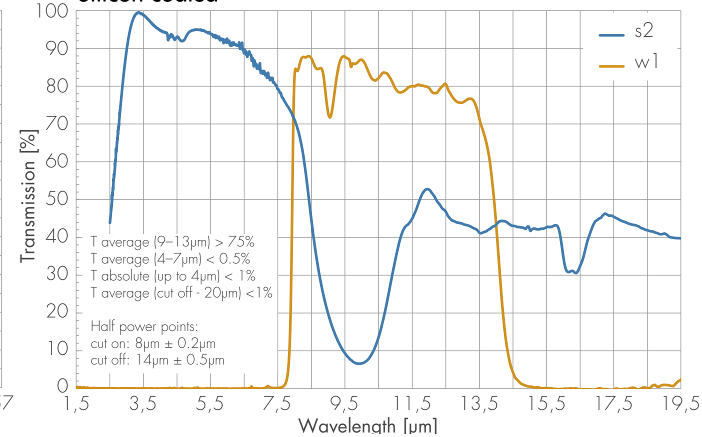
Potassium bromide, protected & uncoated



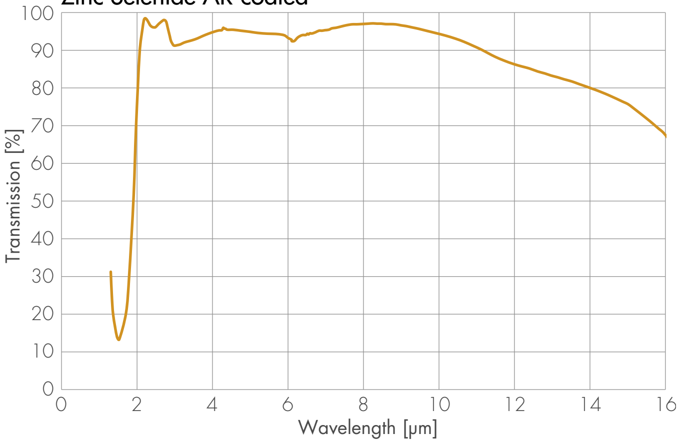
Silicon uncoated



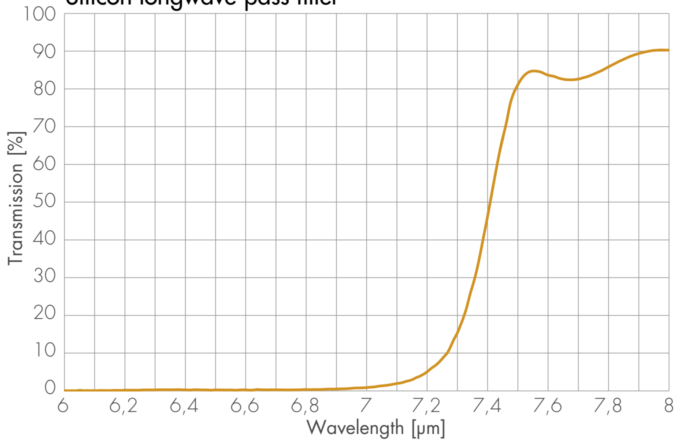
Silicon coated



Zinc Selenide AR-coated



Silicon longwave-pass filter



Packaging

1. TO-39 small aperture 3.5 x 3.5 mm^2
2. TO-39 large aperture 5 x 5 mm^2
3. TO-39 Dual channel
4. TO-39 round aperture
5. TO-8 4 channel small aperture
6. TO-8 4 channel large aperture


1
2
3
4
5
6

(x-) InGaAs Line Arrays

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Tech Notes & Basics

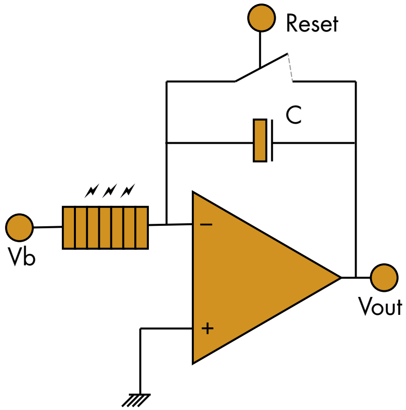


Fig. 1: A capacitive feedback is used in a CTIA instead of a fixed resistance. The capacitance size is the well size.

Please note, that the scheme has been simplified so that the parasitic capacitance of the photodiode itself has been neglected. This parasitic effect is present and needs to be lowered by the manufacturer by proper design and manufacturing processes.

Multiplexed (muxed) InGaAs line arrays with spectral range up to 1.7 µm became available and useful for industrial spectroscopy around the mid-90s.

So-far they have always been hybrid devices, consisting of a InGaAs linear array and a "Read Out Integrated Circuit" (ROIC) connected to each other either via wire-bonding or part of a flip chip design. The main drivers for this setup are: telecoms (DWDM-monitoring), process control, and non-invasive glucose monitoring. All these applications have made their way into SWIR except for glucose monitoring[a]. Using Muxed arrays allowed for:

- High speed, high throughput measurements
- Spectral snapshots, as the whole spectrum is taken simultaneously and not sequentially
- Using the array combined with the rugged optics used by instrument manufacturers, resulted in excellent long term performance with low drift.

It took at least another decade until "good" extended line arrays with spectral range up to at least 2 µm appeared on the market.

Let us assume, a user does have experience in operating single element InGaAs photodiodes. What is different to him with a multiplexed line array? At first, the array takes snapshots. So, the user needs to set an illumination time (integration time) and a sensitivity (Gain, Well Capacity) by software. He also needs to decide on the number of snapshots and the time interval inbetween snapshots. The purpose of multiple snapshots is noise reduction. The number of snapshots per second is called frame rate and is usually different from model to model. Please note, that this catalog includes the new XLIN-FC series which enables up to 400.000 snapshots with up to 2048 pixels within one second which will be a milestone. At second, the user has no access to the "naked" photodiode pixel itself, it is always the combination of photodiode and ROIC that he sees. The ROIC is always a compromise and therefore in many cases the ROIC is a limitation as well: For instance, people are used to the fact that InGaAs photodiodes itself are linear over appr. 10 decades. Here is the point: The signal will be linear over 2 to 3 decades of illumination intensity only in a typical InGaAs line array at a given combination of settings.

Let us have a more detailed look into the electronics that drives a pixel. At first, the signal needs to be amplified: The most common approach is to use a CTIA (Capacitive Transimpedance Amplifier) design (see Fig. 1). The amplifier consists of a variable capacitance charge well that integrates the current from the photodiode for a length of time referred to as the integration time. The transimpedance, R_T and hence the gain of the amplifier is dependent on the full charge well size (FW), and the integration time, t_{int}.

$$R_T \sim t_{int} / FW$$

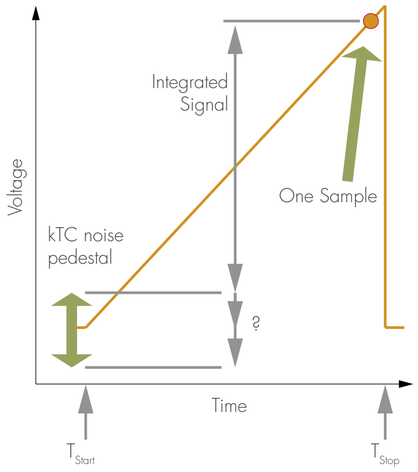
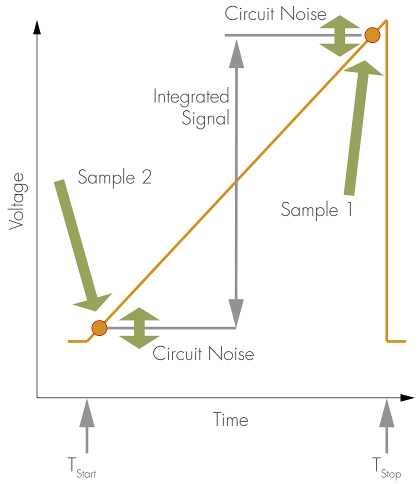


Fig.2 (left): kTC noise will shift with the integration slope.

Fig.3 (right): Double sampling can eliminate kTC noise pedestal.



The well is a "room" to collect charges with the following tradeoff: The bigger, the better for SNR; the smaller, the better for responsivity. It must also be taken into account, that the "room" size is limited and large charge packets fit into large wells only. Therefore, it makes sense to offer a variety of well sizes in order to find an optimum match for a given application.

At the end of a snapshot the well is sampled and a voltage is measured. Question: Is this voltage due to "good" charges only? The answer is: No! There is a kTC noise pedestal and a smaller circuit noise contribution , that are included in this sample. (see Fig. 2).

As an alternative, 2 samples can be taken: One at the start of the slope, another at the end (see Fig. 3). When these 2 samples are taken on the same slope, and the same capacitor, this is called "Correlated Double Sampling" (CDS)[b].

However, some noise is still there and, if the application does allow for it, it can be statistically improved by taking multiple snapshots and averaging them.

Another strategy to fight against noise are "Anti-Alias Noise Filters" which are incorporated into the ROIC. This limits the noise bandwidth of the front end amplifier which can be summed up during the sampling process.

It has become pretty common practice in the spectroscopic community to take a certain number of dark snapshots, average them and call the calculated standard deviation "noise". This is not correct from a scientific viewpoint, but it seems to match users experience in a number of practical cases, especially when people use InGaAs line arrays with cut-offs longer than 1.7 µm. People do see that the well is partially filled up with "bad" charges due to dark current. This effect gets stronger with increasing chip temperature and of course longer integration times. Dark current requires a bias voltage to be applied across the diode, this bias can be the input offset of the amplifier. When the bias/offset voltage zero, then dark current would not flow. To achieve this some ROIC's have "Auto-Zero" functionality which zeros out the amplifiers offset voltage during every reset interval.

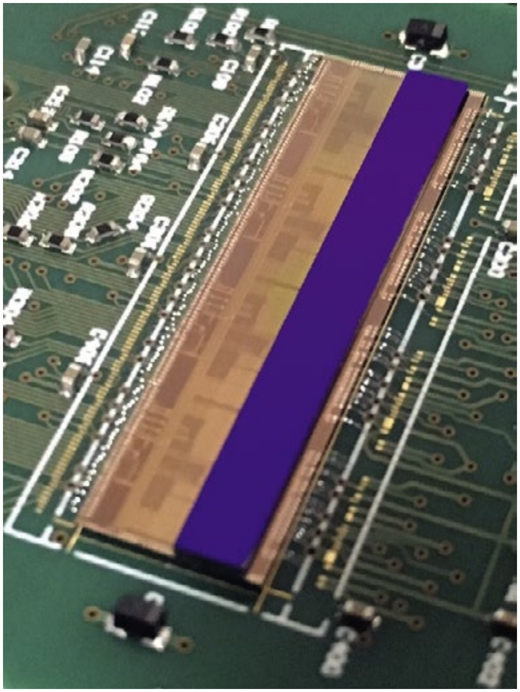
Acknowledgement: We are thankful to Patrick Merken, Xenics, for vital contributions including the figures.

[a] Per today's knowledge, glucose monitoring needs to be performed in the fingerprint region in order to design a reliable universal instrument.

[b] CDS was a breakthrough in InGaAs line array development despite slowing down the readout process. Internal records indicate the first successful customer test report on CDS in the fall of 1996. LASER COMPONENTS has been deeply involved with this development in two ways: Firstly, we were at the front line of innovation as the German sales organization for our US manufacturing partner and secondly, the project manager of our US partner at this point in in time was Dragan Grubisic. He is now the CEO of LASER COMPONENTS Detector Group.

XLIN-FC

InGaAs Line Scan Sensors



High speed SWIR line-scan detector with rectangular or square pixels manufactured by Xenics in Belgium. Accurate and/or fast spectroscopic, OCT and imaging applications.

The XLIN-FC InGaAs line-scan sensors are a hybrid assembly of an array of InGaAs photodiodes connected to a state-of-the art amplifying multiplexer. The sensors come in a hermetically sealed package with anti-reflective coated windows and delivered with a Thermo-Electric Cooler (TE1), resulting in a further reduction of the dark current. There are three resolution offerings of 512, 1024 and 2048 pixels.

The architecture consists of stitched arrays based on 512-pixel modules. They are electrically identical and independent. Each has its own sequencer, output buffers, SPI interface etc. This stitched architecture enables high speed design with limited power consumption.

Evaluation board with software will become available.

Features

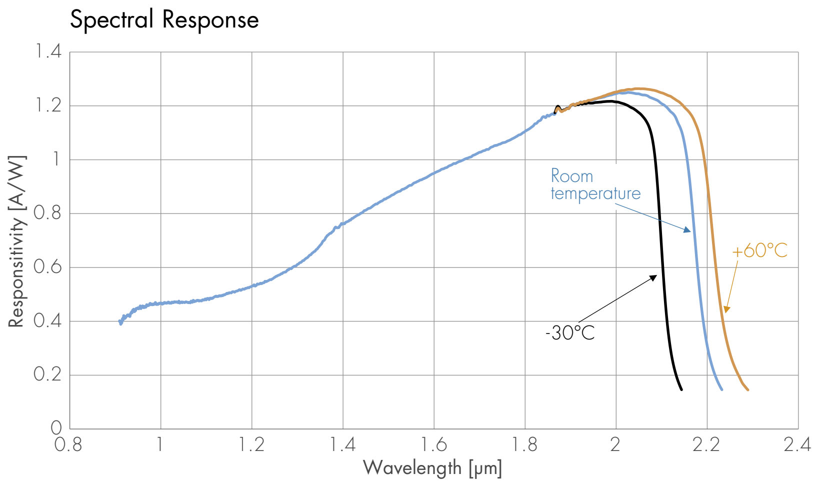
- Complete update of XLIN-Series
- Ultra high speed 400 kHz line rate
- High sensitivity
- Reduction of parasitic capacitance by flip chip process
- TE1 cooling for thermal stabilization
- Rectangular pixel design optimized for spectroscopy (R-series)
- Square pixel design optimized for imaging (SQ-series)
- Five Gain settings

Specifications

Array Specifications	XLIN-FC-512R	XLIN-FC-1024R	XLIN-FC-2048R
Array Characteristics			
Type	InGaAs		
# Outputs	2/4 outputs (selectable per 512 module)		
Spectral band	0.9 to 1.65 µm		
# Pixels	512 x 1	1024 x 1	2048 x 1
Pixel pitch	12.5 µm		
Pixel height	250 µm		
InGaAs array length	6.4 mm	12.8 mm	25.6 mm
Line rate	400 kHz (Max)		
Integration time	1.4 µs (Min)		
Operating modes	Integrate While Read (IWR)		
Dark current	TBD		
Thermo-electric cooler	TE1		
Pixel operability	99.5%	99%	98%
Detector Characteristics			
Peak sensitivity wavelength	1.6 µm		
Peak quantum Efficiency	TBD		
Gain Capacitor Characteristics			
Gain settings	TBD		
Pixel well depth	62 Ke$^-$/300 Ke$^-$/1500 Ke$^-$/8 Me$^-$/40 Me$^-$		
Dynamic range	TBD		
Electrical Specifications			
Power supply voltage	3.3 V		
Power consumption (without TEC)	0.3 W	0.6 W	1.2 W
Physical Characteristics			
Operational temperature range	- 40 °C to 65 °C		
Storage temperature range	- 40 °C to 85 °C		

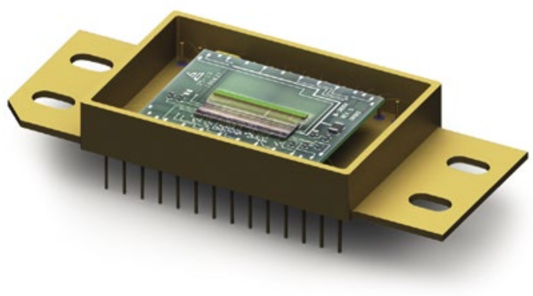
IG22 Series Line Arrays

Extended InGaAs Linear Array Sensors (cut off @ 2.15 µm)



Features

- 20 % cut off wavelength ≥ 2.15 µm (@ -40°C)
- Optimized thermal design results in 55 K temperature difference against room temperature with 2 stage TEC cooling
- Auto zeroing of input offset (< 100 µV) results in reduced dark pattern
- Eight selectable gains
- Built in antialias filtering
- Correlated double sampling
- 50 µm pitch
- CMOS - ROIC



The IG22 extended InGaAs line sensors are designed for use in process control, general IR-spectroscopy, food and pharmaceutical control.

Operation at 0°C chip temperature should be fine for most applications. This means that applications at 50°C ambient are within reach easily. At high flux density applications even operation with chip at room temperature is possible.

Absolute Maximum Ratings

	Min.	Max.	Units
Storage Temperature	-55	+125	°C
Operating Temperature	-40	+85	°C
Vdd	-	6	V
Any Pin	-	Vdd +0.5, Vss -0.5	V
Soldering temperature, 5 sec.	-	260	°C
ESD Damage Threshold, Human Body Model Class 1A*	250	<500	V
TE Cooler Voltage	-	2.4	V
TE Cooler Current	-	6.0	A

* ANSI/ESD STN5. 1-2007

Specifications @ 0°C Detector Temperature

Array Specifications	IG22X50250L28-256TEC
Array Characteristics	
Type	x-InGaAs
# Outputs	selectable / differential
Spectral band	0.8 to 2.15 µm
# Pixels	256 x 1
Pixel pitch	50 µm
Pixel height	250 µm
InGaAs array length	12.8 mm
Line rate	3 kHz (Max)
Operating mode	Integrate Then Read (ITR)
Photoresponse nonuniformity, 10 ms, 1V	±5% typical, ±10% max.
Thermo-electric cooler	TE2
Pixel operability	99.5%
Detector Characteristics	
Peak responsivity wavelength	1.95 µm
Peak responsivity	1.20 A/W
Gain Capacitor Characteristics	
Gain settings	8 steps
Pixel well depth	From 2 Me^- to 250 Me^-
Dynamic range	TBD
Electrical Specifications	
Power consumption (without TEC)	60 mW

Sweet Spots for IG22 Line Array Operation

	0.1 ms	1 ms	5 ms	20 ms	50 ms
33°C	4800		2600		600
20°C	5200	5100	4450		1100
0°C	4750	4700	4600	4200	
-20°C	5130	5000	4850		4500

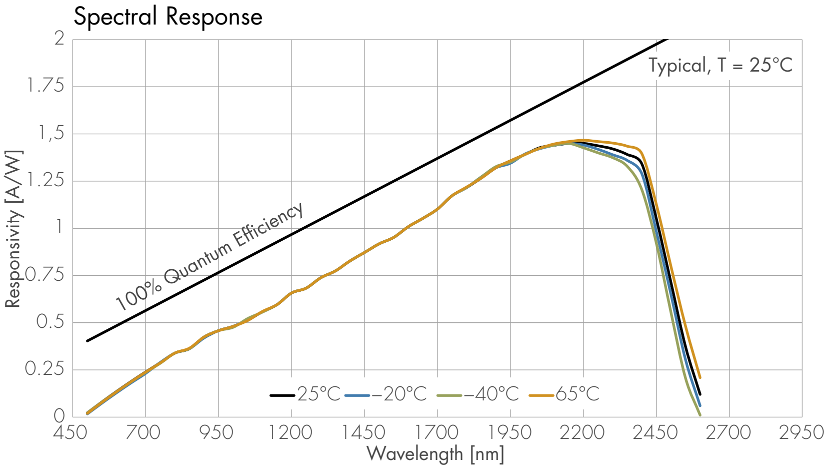
This table shows areas marked in green where the user can expect spectroscopic performance, i.e. a dynamic range of at least 4000. This table has been generated with the following procedure: We did choose the lowest gain setting, i.e. 16 pF.
We took 100 dark scans at each temperature – integration time combination. The scans have been averaged and standard deviation has been calculated. Finally, dynamic range has been calculated as 2.5 V, which is maximum possible signal, divided by the noise.

! Search strategy for optimum settings:

1. Choose 16 pF gain.
2. Choose a detector temperature that is convenient for your application.
3. Choose integration time within the green sweet spot area such, that the maximum signal in the snapshot is around 2 V for the following reason: There is something like an event horizon at a signal level of typically 10 mV and users should try to stay away as much as possible from this boundary if they want collect precise raw data. The boundary is very likely due to a combination of nonlinearity and noise effects. A detailed analysis of the mechanisms behind does require ultra precise tools and will take some time. However, it is our intention to get better understanding of this phenomenon in the future in order to develop a strategy for improvement.
4. In case this is not possible, please select a colder detector temperature and wait for stabilization. This will extend your sweet spot. Please choose longer integration time.
5. In case this still fails, please try to choose a larger gain step by step for finetuning. Please be cautious, since at the edge of the sweet spot the number of useful gain settings is limited. Note: Please verify, that your optical alignment is at optimum already.
6. Please check, if your application allows to take more scans,
   i.e. try for improvement by statistic.

IG26 Series Line Arrays

Extended InGaAs Linear Array Sensors (cut off @ 2.5 µm)



The IG26 extended InGaAs line sensors are designed for use in process control, general IR-spectroscopy, food and pharmaceutical control.

Operation at -20°C chip temperature will give the customer usual spectroscopic performance until integration times of up to 2.5 ms. Further cooling will extend the spectroscopic exposure time.

Features

- 20 % cut off wavelength ≥ 2.50 µm (@ -20°C)
- Optimized thermal design results in 55 K temperature difference against room temperature with 2 stage TEC cooling
- Auto zeroing of input offset (< 100 µV) results in reduced dark pattern
- Eight selectable gains
- Built in antialias filtering
- Correlated double sampling
- 50 µm pitch
- CMOS - ROIC

Absolute Maximum Ratings

	Min.	Max.	Units
Storage Temperature	-55	+125	°C
Operating Temperature	-40	+85	°C
Vdd	-	6	V
Any Pin	-	Vdd +0.5, Vss -0.5	V
Soldering temperature, 5 sec.	-	260	°C
ESD Damage Threshold, Human Body Model Class 1A*	250	<500	V
TE Cooler Voltage	-	2.4	V
TE Cooler Current	-	6.0	A

* ANSI/ESD STN5. 1-2007

Specifications @ -20°C detector temperature

Array Specifications	IG26X50250L28-256TEC
Array Characteristics	
Type	InGaAs
# Outputs	selectable / differential
Spectral band	0.8 to 2.50 µm
# Pixels	256 x 1
Pixel pitch	50 µm
Pixel height	250 µm
InGaAs array length	12.8 mm
Line rate	3 kHz (Max)
Operating mode	Integrate Then Read (ITR)
Photoresponse nonuniformity, 10 ms, 1V	±5% typical, ±10% max.
Thermo-electric cooler	TE2
Pixel operability	99%
Detector Characteristics	
Peak responsivity wavelength	2.2 µm
Peak responsivity	1.23 A/W
Gain Capacitor Characteristics	
Gain settings	8 steps
Pixel well depth	From 2 Me^- to 250 Me^-
Dynamic range	TBD
Electrical Specifications	
Power consumption (without TEC)	60 mW

Sweet Spots for IG26 Line Array Operation

	0.1 ms	1 ms	5 ms	50 ms
0°C	4600	2300	700	330
-10°C	4400	3600	1350	
-20°C	5150	4800	2800	360

This table shows areas marked in green where the user can expect spectroscopic performance, i.e. a dynamic range of at least 4000. This table has been generated with the following procedure: We did choose the lowest gain setting, i.e. 16 pF. We took 100 dark scans at each temperature – integration time combination. The scans have been averaged and standard deviation has been calculated. Finally, dynamic range has been calculated as 2.5 V, which is maximum possible signal, divided by the noise.

! Search strategy for minimum noise:

1. Situation: Optimum settings have been chosen within the sweet spot and everything should be fine. However, the snapshot is still noisy.
2. Suspicion: Performance is limited by optical noise.
3. Proof of suspicion:
   a. Take at least 100 scans per measurement including dark.
   b. Take measurement and average and subtract dark average pixel by pixel. Let us call this curve "BEFORE"
   c. Dim the light source slightly (for instance by a factor of 2) and make sure that spatial and spectral distribution remains exactly the same. Note: This is the critical point and not easy to achieve!
   d. Take measurement with dim light. Analog procedure to 3.b. Call this curve "DIM".
   e. The ratio of BEFORE and DIM should be exactly 2, i.e. a straight line according to the dim factor.
   f. Calculate average and standard deviation of this line. Note: Do not use pixels with signal below 100 mV in the BEFORE curve for this calculation.
   g. If the standard deviation is within approximately 1%, i.e. 0.02 in the example, your optical setup is very likely ok.
   h. In case the deviation being significantly larger than 1%, it is very likely that optical noise is a problem.
   i. This might be due to stray light effects. As a thumb rule, please try to illuminate the line sensor as direct as possible, avoid out of area effects and suppress travelling light. Check for coherence effects. Check, if your light source is noisy and can be changed.
   j. In case nothing helps, the most simple strategy to fight against such noise effects is statistic, i.e. more scans and hence a longer measurement time. Please note that there are limitations to that improvement strategy as well. It works as long as white noise dominates. However, drift processes in spectroscopic systems start to dominate after a certain measurement time in most cases. They can be due to the source, the device under test, the optical path or whatever. It has become common procedure in the community of diode laser absorption spectroscopists to use Allan variance analysis for system performance optimization and to calculate the "Allan-Werle plot". This strategy should work in spectroscopic applications that use InGaAs line arrays as well. A good description of this method is given in (i). The name of the plot is because of David Allan, who invented this statistic method, and Peter Werle, who made it popular in the spectroscopic community

(i) P.W. Werle et al, Signal processing and calibration procedures for in situ diode-laser absorption spectroscopy. Spectrochimica Acta Part A 60 (2004) 1685-1705

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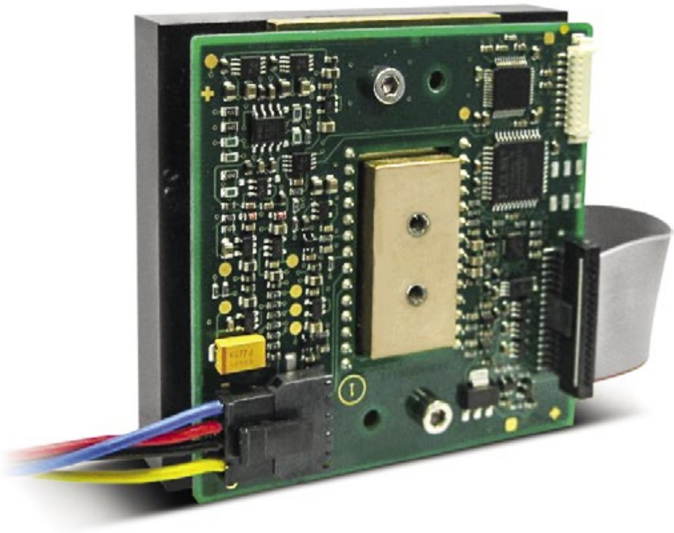


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TEESS

Tempe Electronics & Software Set

IG22 and IG26 x-InGaAs line arrays are complex parts that require a complex and precise drive electronics. Usually, large users design their own circuit. However, small to mid-size users in many cases do prefer to purchase the electronics as well. Unfortunately, our devices will not work with traditional InGaAs drive electronics that have been available on the market so far due to inherent improvements and modifications.

So, we had to close this gap quickly with a high performance, reliable and user friendly new device. Of course, this is impossible without experienced partners. Therefore, we decided to team up with a company that has more than 2 decades of experience in electronics and software for spectroscopy and one advanced user in addition.

The finished drive electronics is "Made in Germany" and we named it TEESS (Tempe Electronics & Software Set). This shall remind people that the line arrays, which are driven by this set, are manufactured at our facility located in Tempe, AZ.

The TEESS set consists of the following components:

- Sensor board (without housing) (Fig 1)
- Main processing and control unit (Fig 2)
- Software for control and data analysis
- Cable set
- Sub heatsink (Fig 3)

TEESS does support thermoelectric cooling.

Fig 1: Backside of a sensor board PCB. There is a 28 pin socket at the top side that fits to the detector.

Sensor board

The sensor board is a separate PCB board that converts the analog output signals to digital. It houses the array physically, communicates with the main unit and interfaces with the optics and the heat sink.

The sensor board does have holes, which fit to optics manufactured by Polytec GmbH, located in Waldbronn, Germany and by Carl Zeiss Spectroscopy GmbH, located in Jena, Germany[i].

(i) Different optics must be integrated by adapters that use the holes that are already there.

Fig. 2: Main processing and control unit

The detector will be shipped separate and must be integrated by the user with usual ESD precautions.
The basic idea of integration can be seen best by looking at Figure 4.
A detailed description can be downloaded separately.

The sensor board is plug and play with the main processor and control unit and the software. Communication protocol is available for OEM customers on special request and under NDA.

Fig. 3: The sub heatsink has to be attached to the bottom of the detector with a small amount of thermal epoxy. A thermally conductive adhesive tape can be an alternative. It is a flexible thermal interface from the detector to a larger heatsink, which has to be chosen and installed by the user.

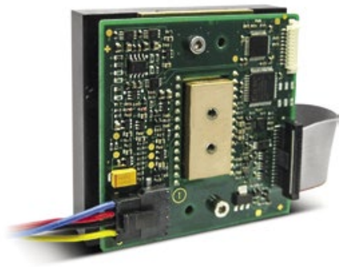

Fig 4: The sub heat sink has been attached to the bottom of the detector and is ready to interface to a larger heat sink(i). The detector itself is hidden in this picture. Its pins have been plugged into a socket without mechanical stress. A custom optics has been applied to the top side of the detector by using screws and an additional submount. Care has been taken to make a stress release and not to bend the detector.

(i) It makes sense to choose a removable thermal connection. This can be achieved by just applying a small amount of thermal epoxy or by using "Thermally Conductive Adhesive Transfer Tapes".

Main processing and control unit (MPCU)

The MPCU is the smart link inbetween the sensor board and the user PC (and even more). The unit offers all necessary interfaces and displays in a clear design and enables straightforward integration into custom instruments. Temperature controller is included as well.

The heart of the MPCU unit is based on powerful XILINX Virtex 4 technology in combination with IBM Power PC which is ideal for spectroscopic applications. Data acquisition and sensor control is separated from first data handling. Therefore, it is possible to send preprocessed data to a PC app via LAN/WLAN quickly. A data buffer up to 2000 data sets enables continuous and lossless data acquisition and streaming even for kinetic applications.

Hardware Characteristics

Architecture	Virtex-4 FPGA with PowerPC
Data buffer	2000 spectra
Size of aluminum housing	6.5 cm x 10.5 cm x 17.0 cm
Features	
Integration Time	0.1 ms to 10 sec
Measuring Modes	Single, Multiple, Continous
Kinetic Mode with independent time bases	Yes
Trigger Options	External digital input with up to 50Hz. By time. By Software
Shutter and lamp control	Yes
On-board diagnostic system	Yes. Temperature, voltage, current etc
Communication	
Data transmission	Ethernet TCP/IP 10/100/1000 MBit/s
IP adress	DHCP or programmable
Galvanically isolated digital I/O	32
RS-232 for control of external devices	2
Status Display	8 x LED
Electrical and environmental specifications	
Storage temperature	-10°C to + 60°C (no condensation)
Operating temperature	+5°C to + 50°C
Power consumption with TEC	25 W
Operating voltage	5 V DC

Software

The TEESS software has been written for plug and play operation of the MPCU and the sensor board. It has 3 basic functions:

- Organization of MPCU and sensor control
- Organization of data acquisition
- Data evaluation

TEESS Software

Instrument control	
Array parameters	Integration time, temperature, average, measurement range, well size
Standard measuring modes	Single, multi, continous
Kinetic mode	Yes. Up to 4 independent time bases.
Trigger options	Yes. Timer, digital I/O, event etc.
Synchronisation & control of optical accessories	Possible.
Data handling and storage	
Representation for transmission and absorbance	Yes.
User definable normalization and calibration	Yes.
File formats	SPC, UVD/3D, ASCII
Data viewer	Yes. Math options and Excel export.
Advanced features	
User defined processing	Yes. By script language.
Trend analysis	Yes.
Multivariate data analysis	Yes. With module, i.e. CAMO.
Concentration, Film Thickness, Color Analysis	Yes.
Minimum requirements	
CPU	Pentium IV processor or better
Operating System	Windows 7 SP1 (32 & 64 bit)
Memory	4 GB
Available Disc Space	500 MB
Graphics adapter	Standard graphics
Screen resolution	1024 x 768 pixel at least

Specials

info@lasercomponents.com

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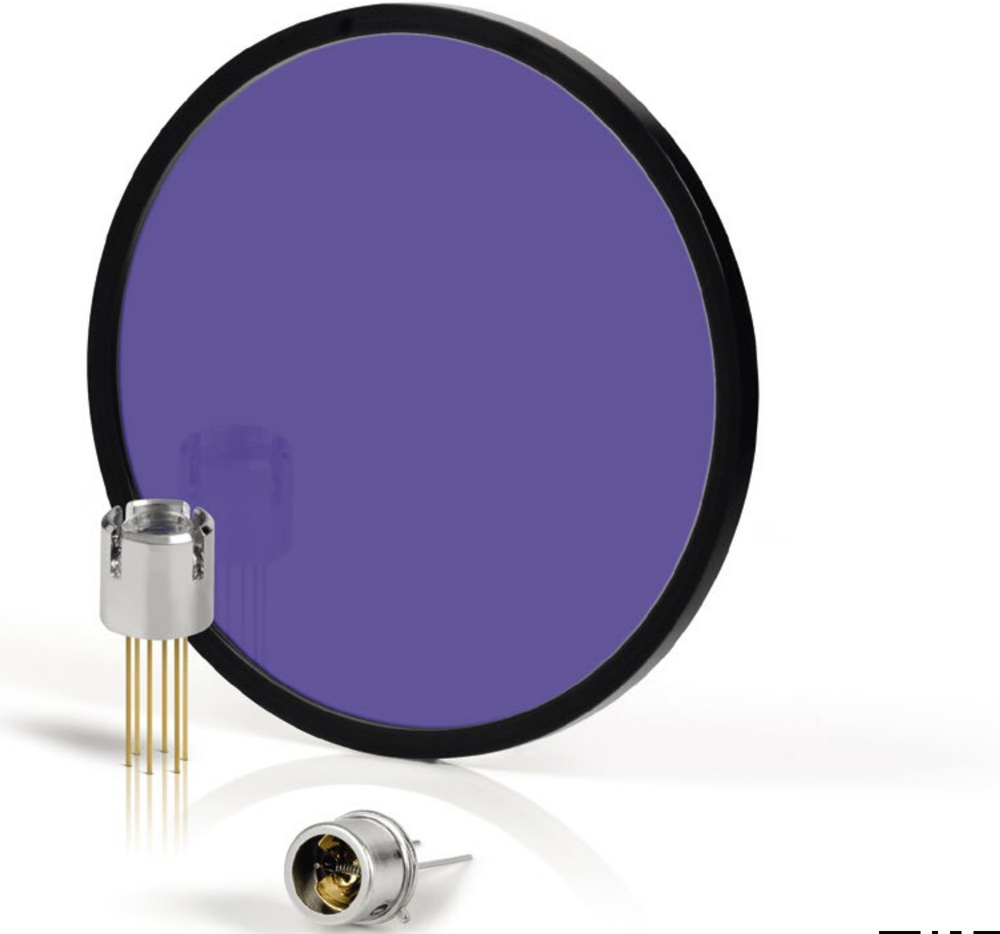

IR Emitters

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Model	Pk Volts	Pk Current (A)	Pk Power (W)	Window
Pulsable/Steady State Tungsten Filament Source (TO-8)				
EP-3872	2.20	1.10	2.40	Sapphire
EP-3962	2. 60	1.05	2.70	Sapphire
EP-3963	3.00	1.00	3.00	Sapphire
EP-3964	3.50	1.00	3.50	Sapphire
EP-3965	3.50	2.00	7.20	Sapphire
EP-4317	5.00	2.10	10.50	Sapphire
Pulsable/Steady State NiCr Filament Source (TO-8)				
EF-852X*	2.00	1.30	2.60	■
EF-853X*	3.00	1.30	4.40	■
Steady State Kanthal Filament Source (TO-8)				
EK-827X	1.20	1.08	1.30	■
EK-837X	1.40	1.75	2.45	■
EK-852X	3.00	1.48	4.40	■
EK-862X	3.50	2.40	8.40	■
Steady State Kanthal Filament Source (TO-3)				
EK-343X	4.00	2.96	11.84	■
Steady State Kanthal Filament Source (TO-5)				
EK-527X	1.20	1.08	1.30	■
EK-537X	1.40	1.75	2.45	■

Notes: Shortened "Point Source" filaments are available for all EK-style IR sources
Custom IR sources are available upon request

* Add an "R" to include Reflector

Window Options

■ = X	0	1	2	3
	No Window	Sapphire	CaF2	ZnSe

Thermal Emitters

HelioWorks manufactures a wide range of black body infrared emitters primarily for the OEM market. Our products are used in near infrared (NIR) spectroscopy, non-dispersive infrared (NDIR) gas detectors for medical and industrial applications including: CO, CO_2, alcohol, hydrocarbon and other noxious gases, and many other applications.

Infrared Radiation

The infrared spectrum is invisible and starts at approx. 800 nm. It is divided into near-infrared (NIR) from 750 – 1400 nm, the short-wavelength IR (SWIR) from 1400 – 3000 nm, the mid-infrared (MIR) from 3000 – 8000 nm, the long-wavelength IR (LWIR) from 8 – 15 µm, and the far infrared (FIR) that starts at 15 µm.

Thermal emitters can be approximated as black body emitters with varying emissivities based on the material used.

Types of IR Emitters

There are two general types of IR Emitters: pulsable sources and steady state elements.

EK Series - Steady State Emitters

- Operating temperatures 900°C ... 1050°C
- Kanthal Filament with Emissivity of 0.7
- Various window options available
- Internal Gold Plated Parabolic Reflector
- Industry Standard TO Package
- Inert Gas Backfill

EP Series - Pulsable Emitters

- Operating temperatures up to 1700°C
- Tungsten Filament
- Sapphire Window
- Operates in Pulsed or Steady State Mode
- Internal Gold Plated Parabolic Reflector
- Industry Standard TO-8 Package

EF Series - Pulsable Emitters

- Operating temperatures up to 700°C
- Filament has uniform emitting area
- Emissivity is 0.88
- Various window options available
- Operates in Pulsed or Steady State Mode
- Industry Standard TO-8 Package
- NiCr Filament
- Large temperature change, ΔT, during pulsing

HQE Detectors

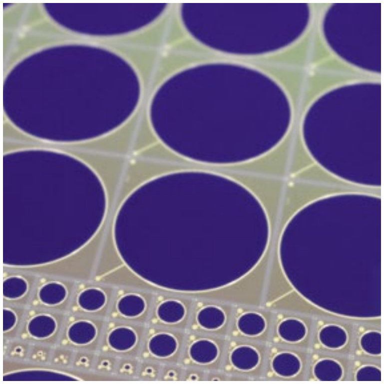
Features

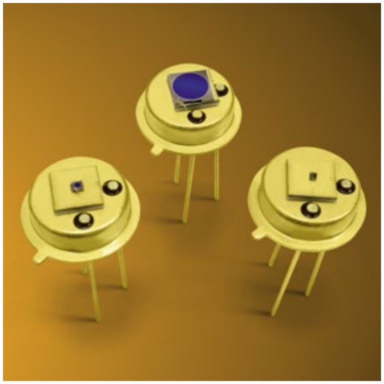
- Quantum efficiency ≥99% (99.5% typically)
- Screened for microdefects
- Delivered with removable cap
- Anode and cathode isolated from ground

Our High Quantum Efficiency (HQE) photodiodes haven been provided to a number of research organizations around the world. Customers have achieved record breaking results especially in squeezed light applications. These photodiodes are typically tailored to a specific wavelength, angle of incidence and polarization.

Specifications, Typical Values

Part Number	Diameter [μm]	Dark curent @-2,5V	Capacity @-2,5V, 1MHz	Bandwith	Responsivity [A/W]
IGHQEX0060	60	100 pA	500 fF	1.5 GHz	1.14
IGHQEX0080	80	200 pA	1 pF	800 MHz	1.14
IGHQEX0100	100	300 pA	2 pF	400 MHz	1.14
IGHQEX0300	300	500 pA	8 pF	100 MHz	1.14
IGHQEX0500	500	800 pA	14 pF	35 MHz	1.14
IGHQEX2000	2000	25 nA	180 pF	500 kHz	1.14
IGHQEX3000	3000	60 nA	400 pF	350 kHz	1.14





Maximum Ratings

Max forward current	10 mA
Max reverse Voltage	-15 V
Operating Temperature	-20 .. 85 °C

Typical AR-Coatings

Wavelength: 1064 nm AOI: 20° s-Polarization (TE)
Wavelength: 1064 nm AOI: 10° p-Polarization (TM)
Wavelength: 1550 nm AOI: 20° s-Polarization (TE)

other AR coatings possible

LC-V Series

Frequency Reference Laser Diode Module

Features

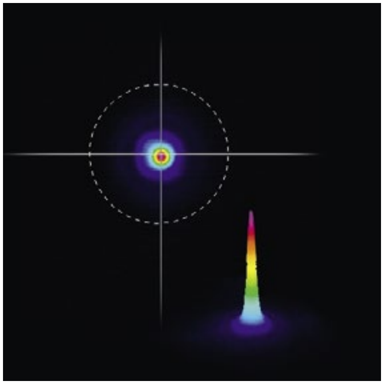
- 850 nm SM VCSEL with Side Mode Suppression Ratio in excess of 10 dB
- Integrated Peltier element for temperature stabilization
- Circular and Gaussian beam
- Integrated aspheric lens
- Precision alignment

Spectrometers like FTIR and FTNIR need a permanent frequency reference. Historically, this application has been dominated by HeNe lasers as their frequency is a constant natural frequency. However, it is a bulky expensive part that uses lots of power, with people always looking for smart alternatives. The Single Mode VCSEL has always been a good candidate due to its inherent Gaussian beam profile, low cost, and stability. The development of polarization locked VCSELs paved the road for its breakthrough as a reference source.
However, due to inherent temperature & current tuning coefficients, and the demanding specifications for optical precision it is a tricky part to manufacure. We do recommend to use the laser at less than 2.0 mW for ultimate stability. This specific laser chip is used as it features a relatively large laser cavity. This this is complimented by a smaller carrier density and hence less aging effects.

Specifications

Beam Profile	Circular, Gaussian
Wavelength [nm]	850 ±10
Typical Tuning Coefficients	0.06 nm/K, 0.4 nm/mA
Output Power @ 23°C [mA]	2.0 @ 2.3 (nominal)
Supply Voltage Laser Diode @ 23°C [V]	2.6
Typical Beam diameter @ 1 m [mm]	0.9
Divergence [mrad]	< 1.2
Pointing direction error [mrad]	< 10 (relative to housing)[a]
Integrated TEC	Single Stage, 0.3 W (With Heat sink)
Thermistor	10 kOhm Chipthermistor
Header	6 pin TO-39
Dimensions	9.7 mm length x 10 mm dia, 23.2 mm total length with pins
Housing	Aluminum, not hermetic
Product designation	LCV-850-2.0-C-TEC

[a] tighter tolerances on request.

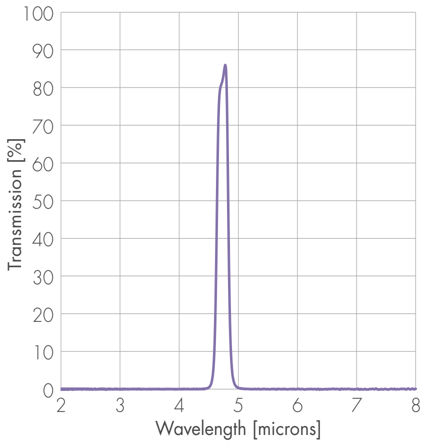


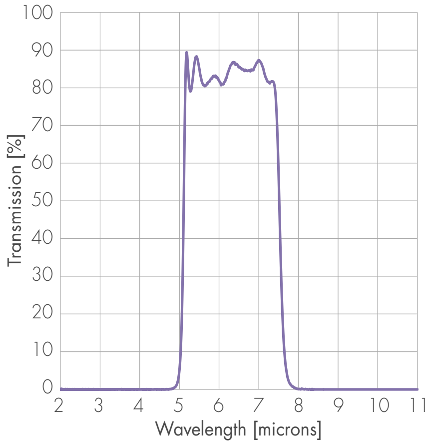
Absolute Maximum Ratings

	Min.	Max.
Storage temperature [°C]	-10	+60
Chip operating temperature [°C][a]	+15	+60
Laser Reverse Voltage [V]		5
Forward Laser Current [mA]		6.0
Soldering Temperature 5 sec [°C]		260
ESD Damage Threshold Laser:	Human Body Model Class 2: Min 2000 V (ANSI/ESD STM5.1-2007)	
TE Cooler allowable Voltage [V]		0.3
TE Cooler allowable Current [A]		1.0

[a] Note: No condensation on chip!

IR Filters





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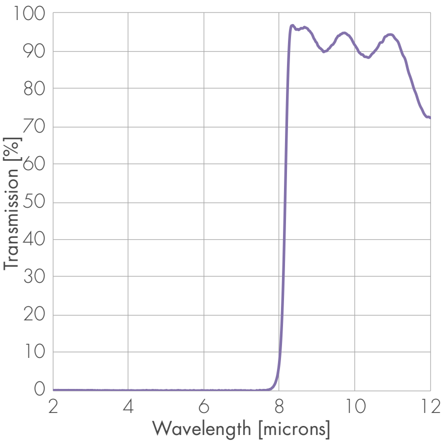
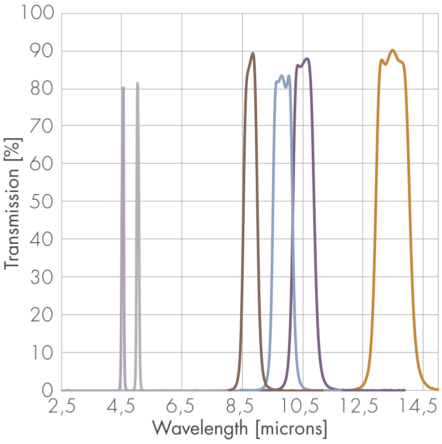
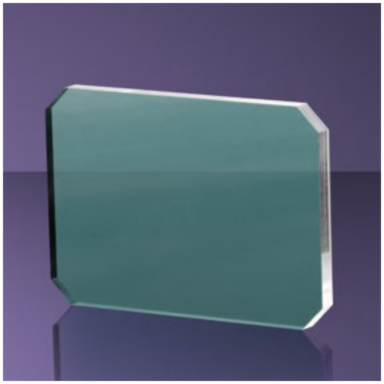
Narrow Bandpass Filters are designed to isolate a narrow region of the infra-red spectrum. This is accomplished using a complex process of constructive and destructive interference. Narrow band pass filters have bandwidths (measured at half-peak transmittance levels) less than 6% of the centre of wavelength value. When ordering, the bandwidth can be expressed as a percentage of the centre wavelength, or can be given in microns. The filters exhibit high peak transmission (typically greater than 60%) combined with high attenuation levels outside the passband (typically less than 0.1%).

This **Wide Bandpass Filter** highlights NOC's ability to create high wavelength filters while still maintaining the steep slopes and flat top that are becoming ever more important in the industry.

The filters exhibit high average transmission in the passband (typically greater than 70%) and very low transmission levels outside the passband (typically less than 0.1 %). This type of filter is particularly useful for isolating the 3–5 µm or 8–12 µm atmospheric windows and finds widespread use in thermal imaging/human body sensor applications.







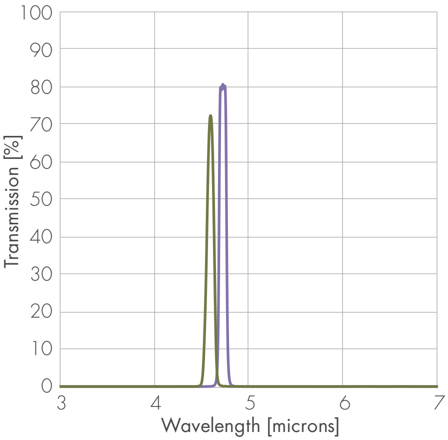
Long Wave Pass Filters (also referred to as edge filters) are constructed from stacks of thin layers. They are distinguished by a sharp transition from a zone of rejection to a zone of transmission. The rejection region extends to below 0.3 µm and the transmission region typically extends to greater than twice the wavelength of the edge position.

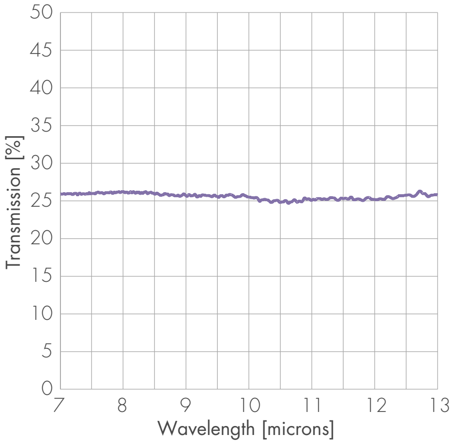
IR Semiconductor Filters

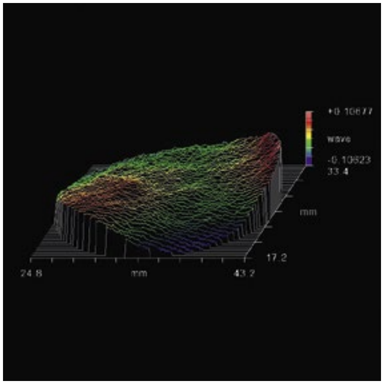
These are not strictly speaking thin film filters but are based on the band structure of the semiconductors. The material is AR coated + polished and available in Si, GaAs, Ge or InAs.

Specials. A range of special purpose narrow band filters for gas and vapour analysis are generally available ex-stock at very competitive prices. Specifications are based on general customer requirements and experience over many years, although tighter tolerances, different bandwidths and filters for other gas bands are available on request.

Beamsplitter 4.74 µm at AOI 45°







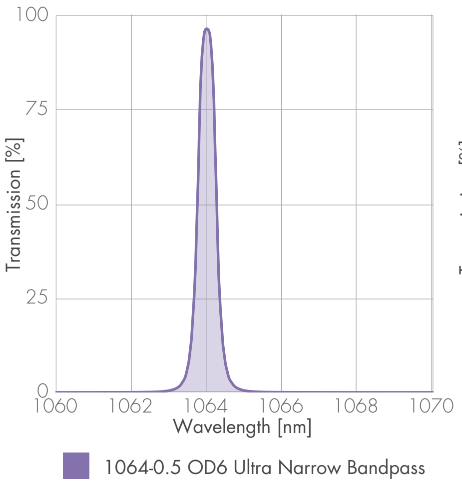
IR Neutral Density Filters

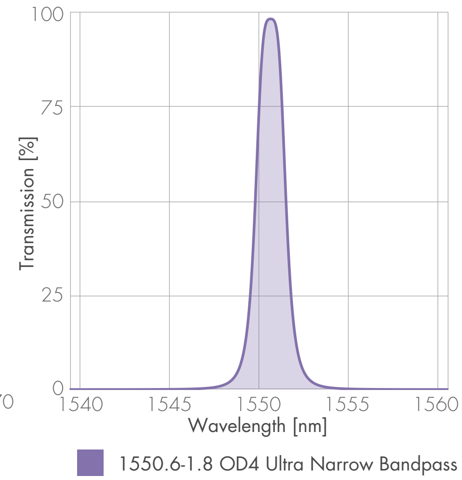
Neutral IR gray filters are used for the broadband attenuation of infrared radiation, and are largely produced according to customer specifications. A metallic coating is responsible for the attenuation of light via reflection or absorption.

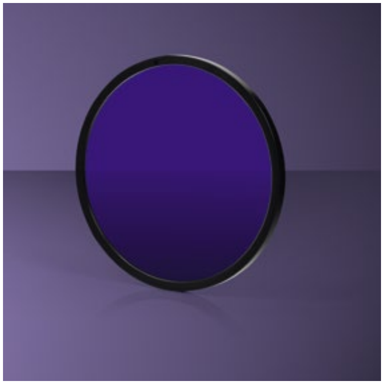
Depending on the required wavelength range (up to 14 μm), substrates such as fused silica, sapphire, germanium, or silicon are used. IR ND filters are classified by optical density (OD) in the range from 0.1 to 2.0, and shape of the curve across the wavelength range can be considered as linear.

Low Stress Manufacturing Process

When a thin-film hard coating is deposited onto a substrate, the stress of the coating causes the substrate to bend. This coating stress induced curvature can result in image distortion. Traditionally, this curvature can be minimized by the use of a thicker substrate or by a backside compensation coating. However, both of these options come with drawbacks. Therefore, Alluxa has developed a low-stress manufacturing process that produces ultra-flat dichroics and mirrors without the need for backside compensation. The dichroic filter in the figure above refers to another dichroic which is identical in terms of spectral response, coating thickness, and both substrate thickness and material. However, the filter produced using the low-stress process is flatter by nearly one order of magnitude than the filter manufactured using standard methods.







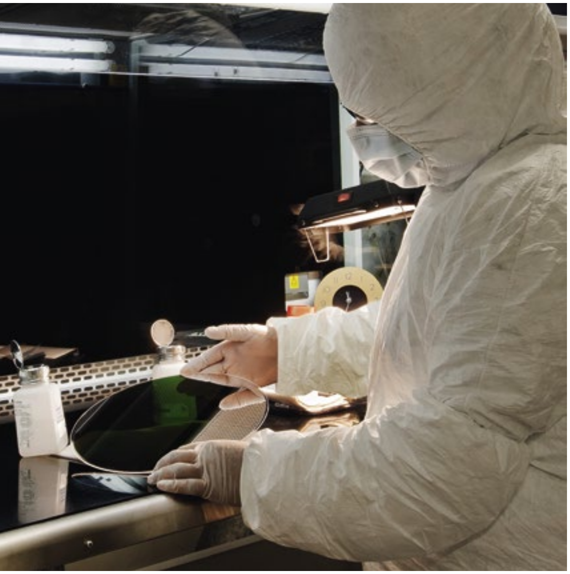
Ultra Narrow Bandpass Filters are ideal for use as laser line, laser cleanup, or laser excitation filters in applications such as fluorescence microscopy, flow cytometry, and DNA sequencing. Alluxa is the only manufacturer offering FWHM bandwidths as narrow as 0.1 nm

- Up to >98% peak transmission
- Fully blocked out of band range up to OD10 by design
- Multicavity designs for square spectral performance
- CWL tolerances as tight as 0.05 nm or less
- Transmitted Wavefront Error (TWE) as low as 0.01 wave RMS/inch (measured at 632.8 nm)

Ultra Narrow NIR Filters for Communication

- Highest peak transmission > 90% (95% typical between 1000 nm and 2000 nm)
- Fully blocked - OD3, OD4, or OD6 from 200 nm to 2000 nm (30 dB to 60 dB)
- 'Squarest' passbands in the industry 2, 3, 5, 7+ cavity filters
- Specializing in large formats Diameters up to 300 mm

Special Partner



Company Brief:
Alluxa, Inc.

Founded in 2007
Located in Santa Rosa, California, USA

Alluxa is a rapidly growing manufacturer of dielectric filters with traditional focus on wavelengths from 0.25 µm to 2 µm.

Inhouse Processes

- Thin film coating, glass coring and singulation
- Design and fabrication of thin-film coating equipment

Philosophy

- Every job can be handled by all of the coaters
- Custom solutions to the most challenging optical coating problems at competitive pricing
- Major investments into measurement tools
- Automation whenever it gives an advantage
- 24-7 production

Milestones

- ISO 9001 accreditation in 2008
- Sales agreement with LASER COMPONENTS GmbH in 2015

- Time Zone: Pacific Time

Questions to Peter Egerton,EVP Business Development

Q: What has been your first experience with infrared?
A: Personally, I stepped into LWIR it just recently. My first experience with the IR photonics was in the telecom space in the late 1990's and 2000's. We were engaged to do some coatings in the 8 – 12 µm region and came up with a really nice process with some good results. However, LWIR is still relatively new for us as a company. Near infrared has been part of our daily business since the company was founded.

Q: Has there been somebody like an infrared guide to you?
A: Apart from you Joe? Yes, our CEO Mike Scobey has decades of experience in the IR throughout his career.

Q: What has changed in the infrared over the years?
A: My first answer is: Not much, at least not in terms of the coatings. There have always been just a handful of players you run into inside US. New players are needed and that is what brought us into the wavelength region to develop a coating process. We hope to push the boundaries of performance as we mature in the wavelength range.

Q: Basically, infrared products have been based on mature technologies. Do you think, there is still any innovation possible?
A: Yes of course! Innovation is always in concert with customer needs and we have some customers with very demanding requirements. As a result, we developed our long wave IR coating process as a mixture of our proprietary coating technologies. As far as near infrared is concerned, we are targeting for more layers that result in better performance in combination with faster deposition without compromising basic quality. We are focusing on things that can be made at reasonable pricing as well as things that will challenge the process. Not all potential innovations in our industry do make their way into production though. Just remember the discussion on rugate designs few years ago: They are dificult to make and therefore expensive and still exotic. This is one reason why we do not use this approach.

Q: Is there anything specific on your location or your county? Does it have any influence on the company?
A: Our culture is close to Silicon Valley and has strong roots in Ca

Q: Please imagine your company and/or your products as some sort of art object or performance or even music. What is your first association?
A: Good question, I never thought about this before. My first association is wine, since Sonoma county is a wine country. It takes lots of passion and precision to make a good product. Isn't good wine a form of art as well?

Q: How do you think IR industry and technologies have evolved from 2015 2017?
A: There is a little bit more demand in the mid and long wave. However, so far it is primarily government and defense jobs. Technology transfer into the commercial space needs to catch up.

Special Partner

Company Brief:
Northumbria Optical Coatings Limited

Founded in 1994
Located in Boldon, United Kingdom

NOC is supplier of dielectric filters in the wavelength range from ~2 µm to 20 µm.

- In-house Processes:
  Thin film coating, polishing and cutting of optical materials and metrology
- First product shipped:
  Narrow Band Filter, CWL 4.62 µm on a Germanium substrate

Milestones:

- Doubling of floorspace in 2003 and again in 2013 to 10.000 sqft
- ISO accreditation September 2006
- Acquisition of FK Optical in 2011
- Establishment of Polishing and Cutting Departments in 2013
- State-of-the-art cutting capabilities from 2014
- 2015 – Investment into new test equipment for the metrology department (Zygo Interferometer)
- 2016 / 2017 – Coating machine upgrades

- Time zone: Greenwich Mean Time

Questions to the Team

Q: What has been your first experience with infrared?
A: To most, infrared radiation is first understood as "light that cannot be seen, but can be felt", or, put another way, "heat". Those of us trained in Chemistry also recognise that infrared spectroscopy can be used as an analytical tool. For NOC, manufacturing of infrared filters can be traced to collaboration between the Thin Film Division at Grubb Parsons in the North East of England, and UK academics the early 1960s. Together, these co-workers developed an understanding of infrared thin film filter technology, which has percolated through the subsequent generations of NOC.

Q: Has there been somebody like an infrared guide to you?
A: The company's knowledge-base is derived from the activities of Angus MacLeod, who joined Grubb Parsons Thin Film Division in 1963. MacLeod's publications and design programmes continue to underpin NOC's capabilities.

Q: What has changed in the infrared over the years?
A: Recent years have seen expansion of applications of infrared filters into key areas such as medicine and diagnostics. Regulatory challenges have also arisen; the RoHS and REACH directives have a limiting effect on selection of coating materials. End-users are also requesting enhanced durability for applications in harsher conditions, as well as improved attenuation outside the pass band to support more sensitive analytical techniques. NOC endeavours to stay ahead of the game in anticipating such changes and improvements.

Q: Basically, your infrared products are based on mature technologies. Do you think, there is still any innovation possible?
A: We continue to strive for manufacturing efficiencies which deliver price reductions and shorter lead times. The company has a dedicated R&D function, which is addressing the new challenges described above.

Q: Is there anything specific on your location or your country? Does it have an influence on the company?
A: The current location owes much to the heritage of the North East of England, which has historical strengths in glassmaking and engineering.

Q: Is there any picture or imagination that exists, that says something important about your company while it does not show directly the employees, the company building and also not the products?
A: This is not an easy question at all, but indeed there is such an imagination. We think of a cloud that contains hazardous gases. IR based instruments can help to protect people and environment.

Q: How do you think infrared technologies have evolved from 2015–2017?
A: We have noticed a considerable change in customer specifications for tighter tolerances, better blocking densities and flatter more parallel substrates, we believe a number of these owe to the improvement of detectors, electronics and the strive for precision.

Special Partner

Xenics
Infrared Solutions

Company Brief:
Xenics

Founded in 2000
Located in Leuven, Belgium

Xenics is manufacturer of infrared cameras and array detectors for OEM users.

- In-house Materials and Processes: Si, InGaAs
- In-house Processes: ROIC design and fabrication
- First Product: Xeva camera, InGaAs based, TE1 cooling
- SWIR OEM Components:

  2014: Muxed regular InGaAs line arrays up to 2048 pixels
- 2014: Sales agreement with LASER COMPONENTS

- Time zone: Central European Time

Questions to the Team

Q: What has been your first experience with infrared?
A: During early development in imec, we implemented our detector arrays in our home-grown MBE layer stack, and combined them with our readouts. This work was based on our research on III-V laser detector structures, which allowed us to move towards integrated detector arrays.

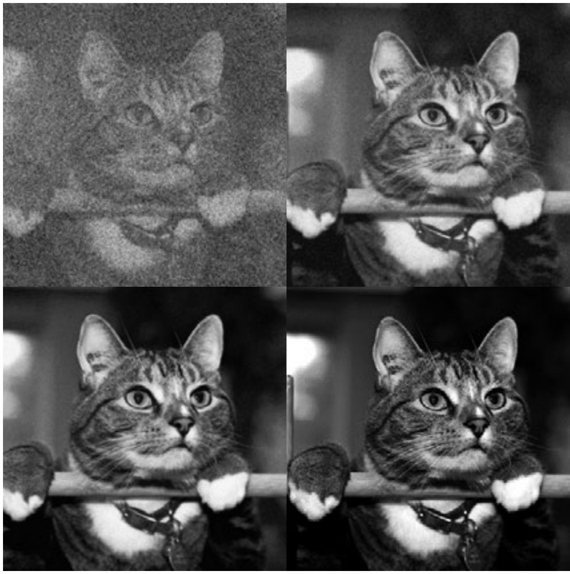
Q: Has there been somebody like an infrared guide to you?
A: Basically, it was Professor Gustaaf Borghs, who initiated the idea of implementing detector devices in III-V material in imec. As such he can be considered the "mental" founder of our company.

Q: Basically, your infrared products are based on mature technologies. Do you think, there is still any innovation possible?
A: We believe this innovation will be based on important differentiators like readout technology with integrated smart technology (system on chip), which will allow users to interface with an infrared detector array very much as if it were a CMOS sensor. Many aspects of light detection have not or only partially been explored, like for example polarization sensitivity. These factors should allow further innovation and development of new types of products.

Q: Is there anything specific on your location or your country? Does it have any influence on the company?
A: We are close to Leuven and imec, and have a fast and efficient link to people and new technology. This is of vital importance for Xenics, as it allows continuous product innovation combined with the necessary expertise to build up know-how and sustain our growth.

Q: Please imagine your company and/or your products as some sort of "art object or performance". What is your first association?
A: In a certain way, there is no better art than nature. All our cameras are named after wild cats, and moreover cats can be associated with infrared cameras. For example, cats can see in the dark;

Q: How do you think infrared technologies have evolved from 2015–2017?
A: In particular between 2015 and 2017, we have seen significant price reductions for various infrared technologies, including SWIR. More and more suppliers are also shifting their focus from only R&D and defense, to also include industrial applications.



Special Partner

HELIOWORKS
"Out Shines All Others"

Company Brief:
Helioworks, Inc.

Founded in 2003
Located in Santa Rosa, California, USA

Helioworks, Inc. is manufacturer of pulsed and steady state infrared lamps.

- In-house Materials: Tungsten, Kanthal and NiCr
- First product: Steady state Kanthal based emitter (2003)

Milestone:

Patent on tungsten filaments was granted on 17th October 2006

- Time zone: Pacific Time

Questions to Don Wood, CEO

Q: What has been your first experience with infrared?
A: Watching a chicken roasting under IR lamps in a restaurant window as a 5 or 6 year old. My father explained that the heat was infrared.

Q: Has there been somebody like an infrared guide to you?
A: Got started by learning to design IR coatings at Optical Coating Laboratory Inc. (OCLI).

Q: What has changed in the infrared over the years?
A: It has transitioned from largely military to include consumer applications.

Q: Basically, your infrared products are based on mature technologies. Do you think, there is still any innovation possible?
A: Definitely! At the time IR technology was considered "mature" I obtained two US patents for innovative new product applications.

Q: Is there anything specific on your location or your country? Does it have an influence on the company?
A: Good supply of innovative, creative employees and applicants.

Q: Please imagine your company and/or your products as some sort of "art object or performance". What is your first association?
A: The rising sun in the early morning, which is our company logo as well.

Product Changes

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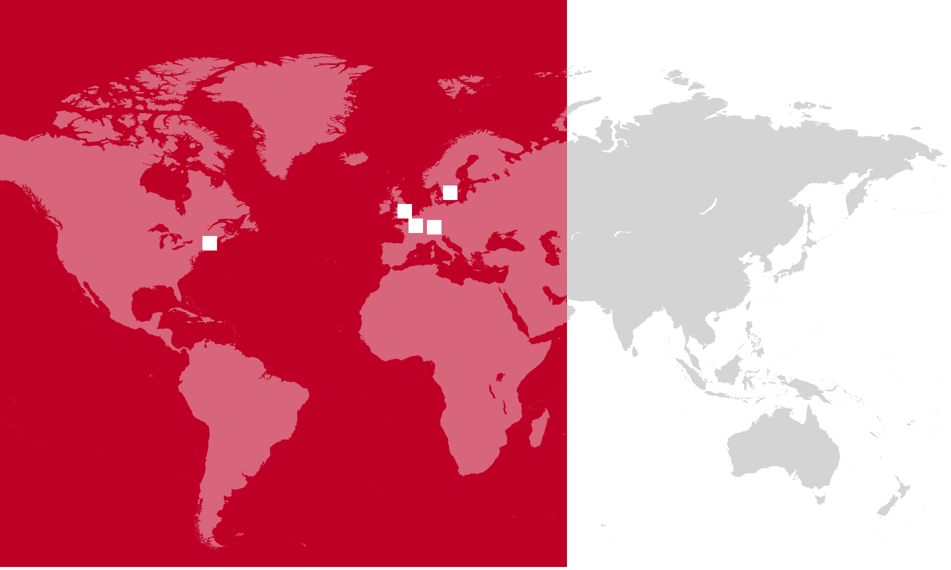

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