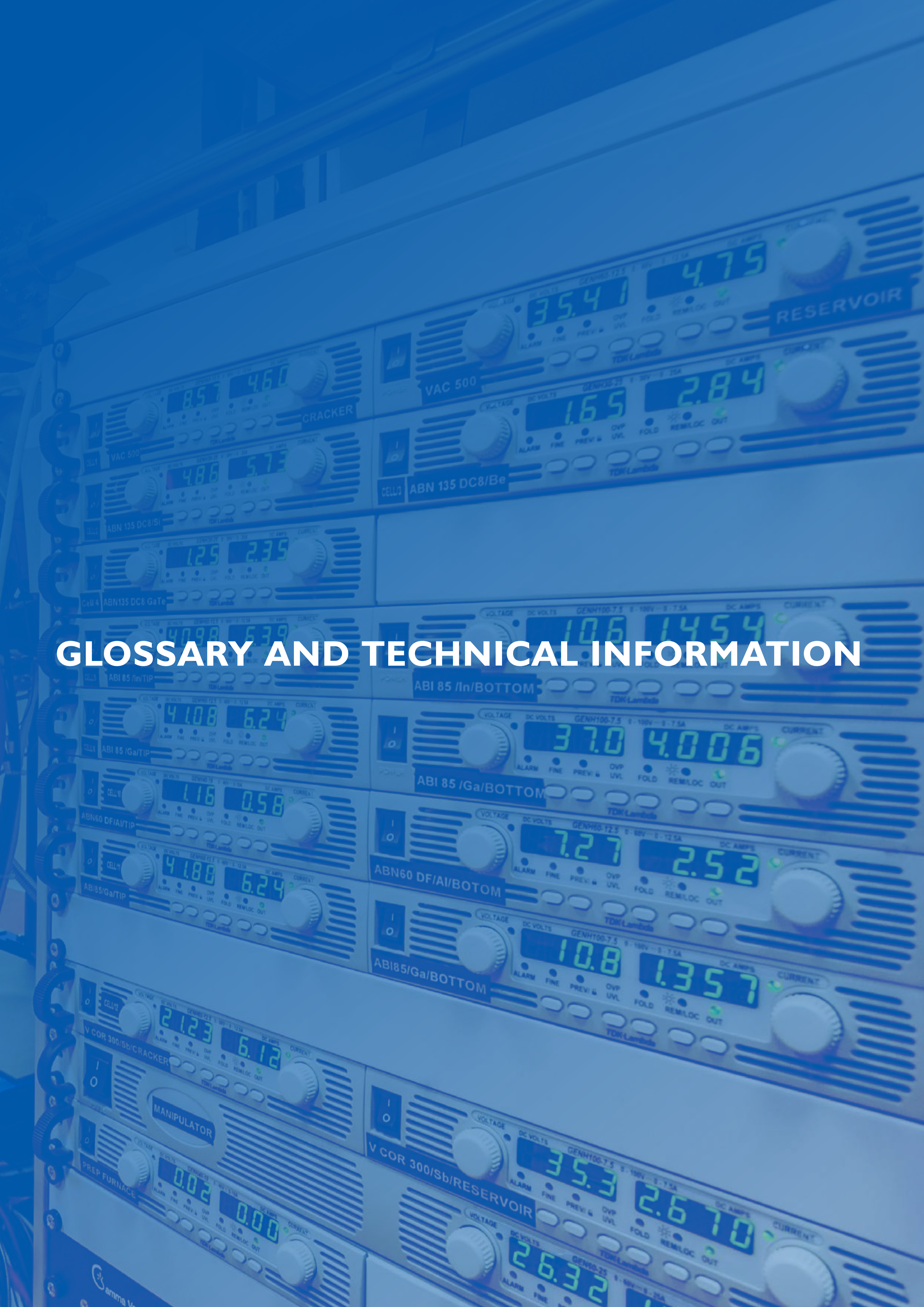

GLOSSARY AND TECHNICAL INFORMATION

Glossary

Infrared detectors

Infrared photodetectors are semiconductor electro-optical devices that convert infrared radiation into an electrical signal.

Photoconductive detectors PC

Photoconductive detectors based on the photoconductive effect. Infrared radiation generates charge carriers in the semiconductor active region decreasing its resistance. The resistance change is sensed as a current change by applying a constant voltage bias. The devices are characterized by near linear current-voltage characteristics. The electric field E in photoconductors is constant across the device. It equals ratio of bias voltage Vb and distance between contacts L:

$$E = \frac{V_b}{L}$$

The optimum bias voltage is specified in the Final test report (supplied with each VIGO device) and depends on detector size, operating temperature and spectral response.

Photovoltaic detectors PV, PVM

Photovoltaic detectors (photodiodes) are semiconductor structures with one (PV) or multiple (PVM), homo- or heterojunctions. Absorbed photons produce charge carriers that are collected at the contacts, resulting in external photocurrent. Photodiodes have complex current voltage characteristics. The devices can operate either at flicker-free zero bias or with reverse voltage. Reverse bias voltage is frequently applied to increase responsivity, differential resistance, improve high frequency performance and increase the dynamic range. Unfortunately, at the expense of flicker noise 1/f in most cases.

Photovoltaic detectors are more vulnerable to electrostatic discharges than photoconductors.

Photoelectromagnetic detectors PEM

Photovoltaic detectors are based on the photoelectromagnetic effect based on spatial separation of optically generated electrons and holes in the magnetic field. The devices do not require electrical bias and show no flicker noise 1/f. The PEM devices are typically used as fast, uncooled detectors of the long wavelength radiation.

Active element material $Hg_{1-x}Cd_xTe$

$Hg_{1-x}Cd_xTe$ also known as Mercury Cadmium Telluride, MCT, HgCdTe, (Cd, Hg)Te or MerCardTel. It is a variable band gap alloy, commonly used for fabrication of photodetectors with tunable spectral response.

Active element material $InAs_{1-x}Sb_x$

$InAs_{1-x}Sb_x$ also known as Indium Arsenide Antimonide or InAsSb is another variable band gap alloy used for fabrication of photodetectors with tunable spectral response.

Active area A, mm×mm

The physical area of a photosensitive element, the active region that converts incoming optical radiation into electric output signal.

$$A = W\text{ (width)} \times L\text{ (length)}.$$

In photoconductors L is a distance between contacts

Optical area A_o, mm×mm

The apparent optical area of the detector which is "seen". It is equal to physical area of the detector active element unless an optical concentrator is used. The optical detector area can be significantly magnified in detectors supplied with optical concentrators, i.e. immersion microlenses. For more information please see chapter *Optical immersion technology*.

$$A_o = W_o\text{ (width)} \times L_o\text{ (length)}.$$

Cut-on wavelength λ_{cut-on} (10%), μm

The shorter wavelength at which a detector responsivity reaches 10% of the peak value.

Peak wavelength λ_{peak}, μm

The wavelength of detector maximum responsivity.

Cut-off wavelength $\lambda_{cut-off}$ (10%), μm

The longer wavelength at which a detector responsivity reaches 10% of the peak value.

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Normalized detectivity D*, cm·Hz$^{1/2}$/W

The signal-to-noise ratio (SNR) at a detector output normalized to 1 W radiant power, a 1 cm^2 detector optical area and a 1 Hz noise bandwidth.

Noise equivalent power NEP, nW/Hz$^{1/2}$

The incident power on the detector generating a signal output equal to the 1 Hz bandwidth noise output. Stated another way, the NEP is the signal level that produces a signal-to-noise ratio (SNR) of 1.

Photocurrent I_{ph}

Photocurrent is the current generated by infrared radiation, which is not in thermal equilibrium with detector. For small irradiation, the photocurrent is proportional to incident radiation power P.

$$I_{ph} = R_i \cdot P$$

R_i is the current responsivity.

Current responsivity R_i, A/W

Current responsivity is the ratio of photocurrent and power of radiation. The current responsivity is typically measured for monochromatic radiation (the spectral current responsivity) and blackbody radiation (the blackbody current responsivity). The responsivity typically remains constant for weak radiation and tends to decrease with more strong radiation.

Current responsivity-active area length product Ri·L and current responsivity-optical area length product $R_i \cdot L_O$, A·mm/W

The current responsivity of unbiased PEM, PVM and biased (with constant electric field E) PC detectors is proportional to the reciprocal active area length L (optical area length L_O). Therefore, the current responsivity $R_i \cdot L$ ($R_i \cdot L_O$) is used to compare devices of various formats.

Another normalized current responsivity, $R_i \cdot L/E$ ($R_i \cdot L_O/E$), is used to compare responsivity of photoconductive detectors of various format, and operating with different electric fields

.

Time constant τ, ns

Typically, detector time response can be described by the one pole filter characteristics. Time constant is the time it takes detector to reach 1/e 37% of the initial signal value. The time constant is related to the 3dB high cut-off frequency f_{hi}:

$$\tau = 1/(2\pi \cdot f_{hi})$$

Time constant for one pole filter is related to 10-90% rise time tr:

$$t_r = 2.2 \cdot \tau$$

Bias voltage-active area length ratio V_b/L, V/mm

Normalized photoconductive bias voltage for nonimmersed detectors.

Bias voltage-optical area length ratio V_b/LO, V/mm

Normalized photoconductive bias voltage for immersed detectors.

Flicker noise 1/f

It is a frequency dependent noise. It occurs in any biased devices.

1/f noise corner frequency f_c, Hz

Frequency, at which the low frequency noise equals to the white noise (e.g. the Johnson or shot noise), the flicker noise dominates at $f < f_c$.

Resistance-active area product R·A, Ω·cm^2

Normalized detector resistance for nonimmersed photovoltaic detectors. It is used to compare photodiodes with different sizes of active areas, in which dynamic resistance decreases proportionally to the detector active area.

Resistance-optical area product $R \cdot A_O$, Ω·cm^2

Normalized detector resistance for immersed photovoltaic detectors. It is used to compare photodiodes with different sizes of optical areas, in which dynamic resistance decreases proportionally to the detector optical area.

Active element temperature T_{det}, K

The detector active element temperature.

Acceptance angle Φ, deg

Acceptance angle is the maximum cone angle at which incoming radiation can be captured by a detector. Radiation coming from a larger angle will not reach the detector. In systems without external objectives, acceptance angle and field of view (FOV) are identical.

Infrared detection modules

Detection module integrates detector, preamplifier, thermoelectric cooler, and other components (detector biasing circuit, heat dissipation system, optics etc.) in a common package. The operation of detection modules can be described in similar way as for detectors, by specifying their spectral and frequency characteristics of responsivity and detectivity.

Voltage responsivity R_v, V/W

The output voltage divided by optical power incident on the detector. For spectra measurements in can be expressed as:

$$R_v(\lambda) = R_i(\lambda)\cdot K_i$$

Low cut-off frequency f_{lo}, Hz

The minimum frequency at which a detection module gain reaches -3dB of the peak value or 0 for DC coupling devices.

High cut-off frequency f_{hi}, Hz

The maximum frequency at which a detection module gain reaches -3dB of the peak value. f_{hi} of the preamplifier may differ from f_{hi} of the detection module.

Noise measurement frequency f_0, Hz

Frequency at which output voltage noise density is measured selectively.

Transimpedance K_i, V/A

Current to voltage conversion ratio:

$$K_i = \frac{V_{out}}{I_{in}}$$

Current signal I_{in}, A

Current signal from photodetector when exposed to incident radiant power.

Output noise voltage density v_n, nV/Hz$^{1/2}$

Noise voltage density measured at preamplifier output.

Output impedance R_{out}, Ω

Impedance that appears in series with the output from an ideal amplifier.

Load resistance R_L, Ω

Resistance of the detection module's load.

Output voltage V_{out}, V

Output signal of the detection module.

Output voltage offset V_{off}, mV

Output DC voltage of the detection module without input signal.

Power supply input $+V_{sup}$ and $-V_{sup}$, V

Supply voltage required for correct detection module operation.

Power supply current I_{sup}, mA

Supply current consumption during correct detection module operation.

GND

Point of zero potential. It is common power supply ground and signal ground.

Ambient operating temperature T_a, °C

Ambient temperature during test measurements.

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Thermoelectric coolers and thermoelectric cooler controllers

Active element temperature T_{det}, K

The detector active element temperature.

Maximum thermoelectric cooler current I_{max}, A

Maxiumum current resulting in greatest ΔT_{max}.

Maximum thermoelectric cooler voltage V_{max}, V

Maxiumum voltage drop resulting in greatest ΔT_{max}. Maximum heat pumping capacity Q_{max}, W

Qmax rated at $\Delta T = 0$. At other ΔT cooling capacity should be estimated as $Q = Q_{max} \cdot (1 - \Delta T/\Delta_{Tmax})$.

Maximum temperature difference ΔT_{max}, K

ΔTmax rated at $Q = 0$. At other Q the temperature difference should be estimated as $\Delta T = \Delta T_{max} \cdot (1 - Q/Q_{max})$.

Temperature stability, K

It indicates the possible error in the temperature on the thermoelectric cooler.

Temperature readout stability, mK

It indicates the possible error in readout of the temperature of the thermoelectric cooler provided by controller.

Detector temperature settling time, s

The time taken by the cooling system to reach appropriate temperature of the detector active element.

Maximum TEC output current, A

Maximum current that is provided by the controller to the thermoelectric cooler.

Output voltage range, V

Range of voltage on output of module.

Power supply voltage V_{sup}, VDC

Supply voltage required for correct thermoelectric cooler controller operation.

Power supply current I_{sup}, mA

Supply current required for correct thermoelectric cooler controller operation.

Series resistance of the connecting cable, Ω

Material parameter. It is resistance of the supply cable. It depends on the cable length.

Detector’s packages and infrared windows

	Package type	Cooling	Window	Detector type
	BNC	uncooled	no	PC, PCI, PV, PVI, PVM, PVMI
	TO39	uncooled	no	PC, PCI, PV, PVI, PVA, PVIA, PVM, PVMI
	PEM-SMA	uncooled	yes	PEM, PEMI
	PEM-TO8	uncooled	yes	PEM, PEMI
	TO8	uncooled	no	PCQ, PVMQ
	TO8	TE cooled	yes	PC-2TE, PC-3TE, PC-4TE PCI-2TE, PCI-3TE, PCI-4TE PV-2TE, PVA-2TE, PV-3TE, PV-4TE PVI-2TE, PVIA-2TE, PVI-3TE, PVI-4TE PVM-2TE PVMI-2TE, PVMI-3TE, PVMI-4TE
	TO66	TE cooled	yes	PC-2TE, PC-3TE, PC-4TE PCI-2TE, PCI-3TE, PCI-4TE PV-2TE, PVA-2TE, PV-3TE, PV-4TE PVI-2TE, PVIA-2TE, PVI-3TE, PVI-4TE PVM-2TE PVMI-2TE, PVMI-3TE, PVMI-4TE

Uncooled detectors are typically provided in BNC or TO39 packages without the window.

The exception are the specialized PEM packages. Due to magnetic circuit incorporated into the package, 3° wedged zinc selenide anti reflection coated (wZnSeAR) window is supplied to protect against external pollution. There are two versions of packages dedicated for photoelectromagnetic detectors:

- PEM-SMA with SMA signal output connector which makes it convenient in use,
- PEM-TO8 on TO8 header which enables integration with VIGO preamplifier

Encapsulation

Thermoelectrically cooled detectors are mounted in metal packages: TO8 and TO66 sealed with IR windows. The packages are filled with dry, heavy, noble gases (Krypton / Xenone mixture) of low thermal conductivity. Water vapor condensation is prevented by humidity absorber container mounted inside the package and careful polymer sealing. For low temperature fluctuation anti-convection shields is also apply.

Infrared windows

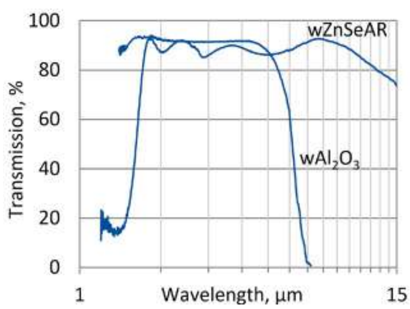
We provide two types windows as a standard:

- 3° wedged sapphire (wAl_2O_3)
- 3° wedged zinc selenide anti-reflection coated (wZnSeAR)

3° wedge prevents „fringing” – unwanted interference effects.

Material	Hardness, kg/mm²	Wedging	Anti-reflection coating	Symbol
sapphire	1370	3°	no	wAl_2O_3
zinc selenide	120	3°	yes	wZnSeAR

Spectral transmission of wAl_2O_3 and wZnSeAR windows (typical example)



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Thermoelectric cooling

Some of VIGO devices are provided with thermoelectric cooling. Cooling of infrared detectors reduces noises, increases responsivity, shifts the cut-off wavelength toward longer wavelengths (in HgCdTe detectors) and toward shorter wavelengths (in InAs / InAsSb detectors).

Two-, three- and four-stage thermoelectric coolers are available. Operation of TE coolers is based on Peltier effect. Thermoelectric coolers are supplied with DC power supply.

Temperature control

Thermoelectrically cooled detectors are equipped with built-in thermistor to provide precise control an measurements of detector active element temperature.

The electricity applied to between terminals of thermistors should be under the maximum power dissipation at 25°C (100 mW) not to destroy the thermosensor. For the measurement of resistance, the power should not exceed 1 mW.

The relation between the resistance and the temperature:

$$R_T = R_{T0} \exp\left(\beta \cdot \frac{T_0 - T}{T \cdot T_0}\right)$$

RT_0 = 2.2 kΩ ± 3% at T_0 = 298 K

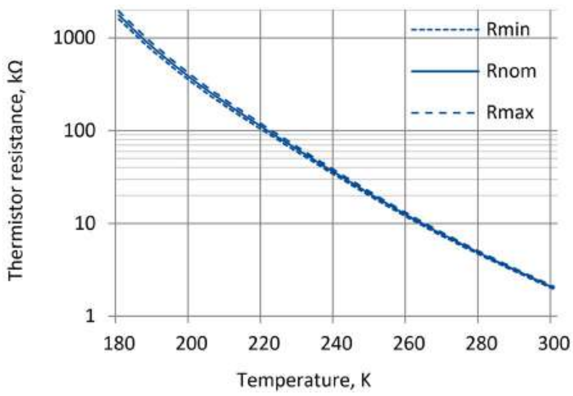
β = 3500 K ± 1

Thermoelectric coolers parameters*)

Parameter	Cooling		
	2TE	3TE	4TE
Active element temperature T_{det}, K	~230	~210	~195
Maximum TEC voltage V_{max}, V	1.3	3.6	8.3
Maxium TEC current I_{max}, A	1.20	0.45	0.40
Maximum heat pumping capacity Q_{max}, W	0.36	0.27	0.28

*) *– Depend on temperature of the hot side of the TE cooler. Typically specified for 300 K.*

Thermistor characteristics



Resistance vs. temperature of thermistor

T, K	T, °C	R_{min}, k	R_{nom}, k	R_{max},k
180	-93	1594.97	1757.95	1935.84
182	-91	1336.02	1469.90	1615.75
184	-89	1124.16	1234.66	1354.81
186	-87	950.46	1042.11	1141.58
188	-85	807.57	883.99	966.78
190	-83	689.57	753.62	822.88
192	-81	591.68	645.64	703.89
194	-79	510.07	555.75	604.98
196	-77	441.68	480.54	522.34
198	-75	384.05	417.25	452.91
200	-73	335.23	363.71	394.26
202	-71	293.65	318.17	344.43
204	-69	258.05	279.23	301.88
206	-67	227.41	245.76	265.36
208	-65	200.91	216.85	233.85
210	-63	177.89	191.77	206.55
212	-61	157.81	169.92	182.79
214	-59	140.22	150.80	162.03
216	-57	124.76	134.02	143.83
218	-55	111.14	119.25	127.83
220	-53	99.10	106.21	113.72
222	-51	88.44	94.67	101.25
224	-49	78.98	84.44	90.21
226	-47	70.57	75.37	80.42
228	-45	63.09	67.30	71.73
230	-43	56.42	60.12	64.01
232	-41	50.49	53.74	57.15
234	-39	45.19	48.05	51.04
236	-37	40.47	42.98	45.61
238	-35	36.26	38.47	40.77

T, K	T, °C	R_{min}, k	R_{nom}, k	R_{max},k
240	-33	32.51	34.45	36.47
242	-31	29.16	30.87	32.64
244	-29	26.18	27.68	29.24
246	-27	23.51	24.84	26.21
248	-25	21.14	22.30	23.51
250	-23	19.02	20.05	21.11
252	-21	17.13	18.04	18.98
254	-19	15.45	16.25	17.07
256	-17	13.95	14.65	15.38
258	-15	12.61	13.23	13.87
260	-13	11.41	11.96	12.53
262	-11	10.34	10.83	11.33
264	-9	9.38	9.82	10.26
266	-7	8.52	8.91	9.31
268	-5	7.75	8.10	8.45
270	-3	7.07	7.37	7.69
272	-1	6.45	6.72	7.00
274	1	5.89	6.13	6.38
276	3	5.38	5.60	5.83
278	5	4.93	5.13	5.32
280	7	4.52	4.69	4.87
282	9	4.15	4.30	4.46
284	11	3.81	3.95	4.09
286	13	3.50	3.63	3.75
288	15	3.22	3.33	3.45
290	17	2.96	3.06	3.17
292	19	2.73	2.82	2.91
294	21	2.51	2.59	2.68
296	23	2.32	2.39	2.46
298	25	2.13	2.20	2.27

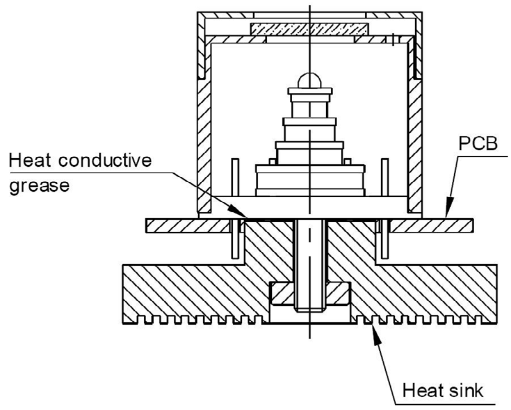
Heat sinking

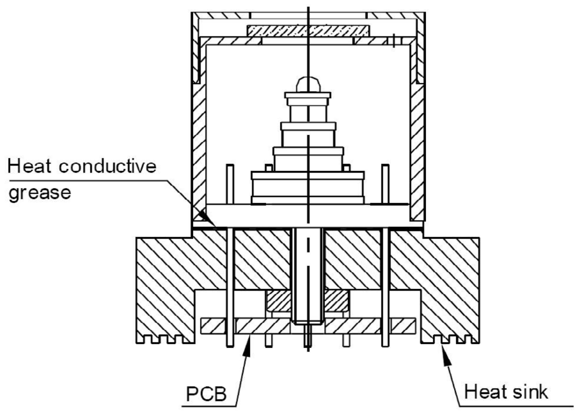
Suitable heat sinking is necessary to dissipate heat generated by the Peltier cooler or excessive optical irradiation. Since heat is almost 100% dissipated at the base of the detector header, it must be firmly attached to the heat sink.

A thin layer of heat conductive epoxy or silicon (thermal) grease should be used to improve thermal contact between the detector header and the heat sink to maximize heat transfer. Heat sinking via the detector cilindrical cap or via the mounig screw is not sufficient.

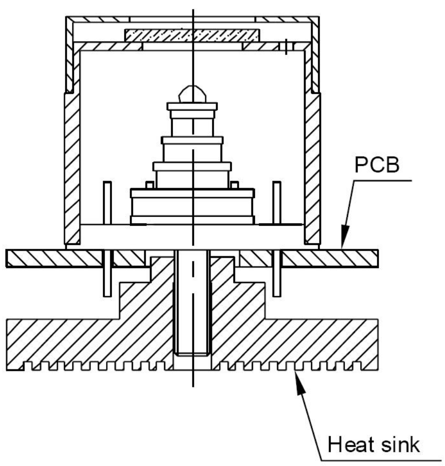
A heatsink thermal resistance of ~2 K/W is typically recommended for the most 2TE and 3TE coolers. For 4TE cooler, heatsink thermal resistance ~1 K/W is recommended.

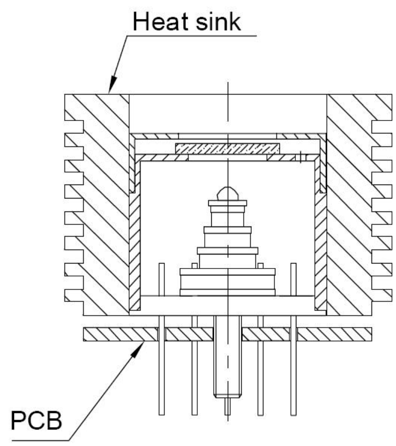
Correct heatsink placement





Incorrect heatsink placement





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Optical immersion technology

In order to improve performance and get the best signal-to-noise ratio of the devices, optical immersion technology may be applied. It is successfully use in all types VIGO detectors.

Optical immersion it is monolithic integration of detector active element with hyperhemispherical microlens (deafult). It makes optical linear size of detector active area 11 times larger compared to its physical size. This results in improvement of detectivity D* by one order of magnitude. Also detector electric capacitance Cd is reduced by a factor of two orders of magnitude compared to conventional detector of the same optical area. Acceptance angle is reduced to ~36° – the microlens naturally shields background radiation which is one of the factors of noise. Hemispherical microlens is available as a custom option.

Optical power limitations for optically immersed detectors are more restrictive than for detectors without immersion microlens – for more information please see chapter Precautions for use.

Optically immersed detectors parameters

Parameter	Microlens shape			
	Hemisphere*)		Hyperhemisphere	
	Theory	GaAs	Theory	GaAs
Distance L	R	R	R·(n+1)	4.3·R
d / d'	n	3.3	n^2	10.9
$D^*imm / D^*_{non\text{-}imm}$	n	3.3	n^2	10.9
Aceptance angle Φ	180°	180°	2arcsin(1/n)	~36°

**) Custom option*

n – refractive index of microlens material (GaAs), n = 3.3

d – optical (apparent) detector size

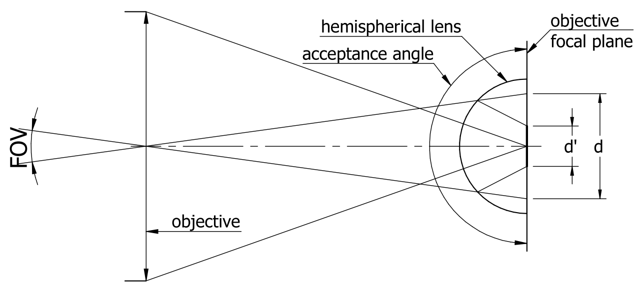
d' – physical detector size

R – lens radius

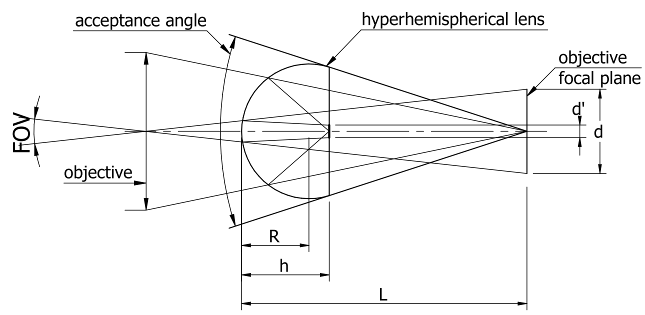
L – lens face to objective focal plane distance

h – lens thickness, h = R+ R/n

Function and properties of hemisphere microlens



Function and properties of hyperhemisphere microlens



Precautions for use

Operating temperature

A detector should be operated at its optimal temperature given in the Final test report (delivered with every device).

Maximum voltage

Do not operate the photovoltaic detector at higher bias voltages than suggested in the Final test report (delivered with every device).

Be careful using ohmmeters for photovoltaic detectors!

Standard ohmmeters may overbias and damage the detector. This is especially true for small physical area or SWIR photovoltaic detectors. Bias of 10 mV can be used for resistance measurements of any type of detector. Ask for conditions of I-V plot measurements!

Usage

Devices can operate in the 10% to 80 % humidity, in the –20°C to +30 °C ambient temperature range. Operation at >30°C ambient may reduce performance for standard Peltier coolers.

Ask for devices that can operate in the +30°C to +80°C ambient temperature range.

Storage

The following conditions should be fulfilled for safe and reliable operation of detector:

- store in dark place, 10% to 90% humidity and –20°C to +50°C temperature,
- avoid exposing to the direct sunlight and strong UV/VIS light as this may result in degradation of the detector performance,
- avoid electrostatic discharges at leads therefore, the devices should be stored having leads shorted.

Beam power limitations

Damage thresholds, specified as integrated power of incoming radiation:

- For devices without immersion microlens irradiated with continuous wave (CW) or single pulses of more than 1 μs duration, irradiated power on the active area must not exceed 100 W/cm^2.The irradiance of a pulse shorter than 1 μs must not exceed 1 MW/cm^2.
- For optically immersed detectors irradiated with CW or single pulse longer than 1 μs irradiance on the apparent optical active area must not exceed 2.5 W/cm^2. The irradiance of the pulse shorter than 1 μs must not exceed 10 kW/cm2.
- For repeated irradiation with pulses shorter than 1 μs, the equivalent CW irradiation, average power over the pulse-to-pulse period should be less than the CW damage threshold according to equation:

$$\text{equivalent CW radiation power density} = \frac{\text{pulse peak power}}{\text{focus area}} \cdot \text{pulse duration} \cdot \text{repetition rate}$$

Saturation thresholds vary by detector type and can be provided upon request.

Handling

Particular attention should be paid to not scratch a surface of the window. A damaged window may entirely degrade the detector performance. Excessive mechanical stress applied to the package itself or to a device containing the package may result in permanent damage. Peltier element inside thermoelectrically cooled detectors is susceptible to mechanical shocks. Great care should be taken when handling cooled detectors.

Cleaning window

Keep the window clean. Use a soft cotton cloth damped with isopropyl alcohol and wipe off the surface gently if necessary.

Mechanical shocks

The Peltier elements may be damaged by excessive mechanical shock or vibration. Care is recommended during manipulations and normal use. Drop impacts against a hard surface are particularly dangerous.

Shaping leads

Avoid bending the leads at a distance less than 2 mm from a base of the package to prevent glass seal damage. When shaping the leads, maximum two right angle bends and three twists at the distance minimum 6 mm from the base of the package.

Keep the leads of the detecting element shorted when shaping!

Soldering leads

IR detectors can be easily damaged by excessive heat. Special care should be taken when soldering the leads. Usage of heat sinks is highly recommended. Tweezers can be used for this purpose; when soldering, clamp a lead at a place between the soldering iron and the base of the package. To avoid destructive influence of ESD and other accidental voltages (e.g. from a non-grounded soldering iron) rules for handling LSI integrated circuits should be applied to IR detectors too. Leads should be soldered at +370 °C or below within 5 s.

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