Glossary of terms

General definition

$Hg_{1-x}Cd_xTe$: Known also as Mercury Cadmium Telluride (MCT), CdHgTe, (Cd,Hg)Te or Mercadtel, an alloy of CdTe and HgTe. Change of the CdTe to HgTe ratio (composition or x-value) can be used to tune optical absorption cut-off wavelength in the wide range from ultraviolet (UV) to deep infrared (IR). Cooling shifts the cut-off wavelength towards long wavelengths. Detectors from VIGO System (VIGO for short) are based on complex graded gap MCT structures optimized for MWIR (3-5 µm) and LWIR (8-14 µm) ranges.

Detector formats

Square and rectangular formats are used for PC, PEM and PV devices. Round shapes are also used for some PV devices. Custom shapes are available on request.

Photovoltaic detectors (PV or PVM)

Photovoltaic devices (photodiodes) are semiconductor structures with one (PV) or multiple (PVM) homo- or heterojunctions. Absorbed photons produce electron-hole pairs, resulting in external photocurrent. Reverse bias voltage may be applied to increase differential resistance, reduce the shot noise, improve high frequency performance and dynamic range. Reverse bias may increase responsivity in some devices. Unfortunately, at the expense of flicker (1/f) noise in most cases. PV detectors are more vulnerable to electrostatic discharges than photoconductors.

Photoelectromagnetic detectors (PEM)

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

Photoconductive detectors (PC)

Photoconductive Devices (PC) are 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 voltage change by applying a constant current bias. The optimum bias current is specified in the Final Test Report and depends on the detector size, operating temperature and spectral characteristics.

Detector parameters

Responsivity- width product: $R_v w$

The voltage responsivity of PC and PEM is inversely proportional to the width of detectors. Therefore the normalized responsivity can be expressed as the responsivity-width product.

Current and voltage responsivity: R_i, R_v

$$R_i(\lambda)=\frac{current\ signal(\lambda)d\lambda}{incident\ power(\lambda)d\lambda} \quad \text{(in A/W)}$$

$$R_v(\lambda)=\frac{voltage\ signal(\lambda)d\lambda}{incident\ power(\lambda)d\lambda} \quad \text{(in V/W)}$$

Current responsivity is typically used for description of photovoltaic detectors and voltage responsivity for description of photoconductors and photoelectromagnetic detectors.

Dark current: I_{dark}

The current that flows in a photodetector when it is not receiving any light. It may increase as the temperature rises.

The small amount of current that flows through a photonic semiconductor device when it is not operating. Also known as leakage current.

Maximum bias current: I_{max}

The maximum current that can flow through a photoconductive or photovoltaic detector without a risk of its damage.

Noise current and noise voltage: I_n, V_n

Root mean square noise current or voltage.

$$I_n=\sqrt{\overline{I_n^2(t)}} \qquad V_n=\sqrt{\overline{U_n^2(t)}}$$

Noise current and noise voltage density: i_n, v_n

$$i_n=\frac{I_n}{\sqrt{\Delta f}} \qquad v_n=\frac{V_n}{\sqrt{\Delta f}}$$

1/f corner frequency

Flicker or 1/f noise is a frequency dependent noise. Its power is proportional to $\frac{1}{f^b}$ where b ~ 1. Below the corner frequency the noise of detectors is dominated by flicker noise.

Normalized detectivity: D*

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 bandwidth. The higher the D* value, the better the detector.

$$D^*=\frac{R_i}{i_n}\sqrt{A}=\frac{R_v}{v_n}\sqrt{A} \quad \text{in cmHz}^{1/2}\text{/W}$$

Operating temperature: T

Detector active element temperature.

Optical area: A

The area from which the incident radiant power is collected.

For immersed detector it is different from physical detector area (see Optical immersion chapter).

Detector capacitance C_i

Parallel capacitance in the detector structure.

Spectral response
Spectral responsivity or spectral detectivity. In detector data sheets it is presented as Rv(λ), Ri(λ) or D*(λ). It can be characterized by cut-on, cut-off, optimum and peak wavelength.

Peak wavelength: λ_{peak}
λ_{peak} is a wavelength of detector maximum responsivity.

Optimum wavelength: λ_{opt}
The wavelength a device is optimized for. Typically longer than $\lambda_{peak.}$

Cut-on Wavelength: λ_{con}
λ_{con} is the shortest wavelength at which a detector responsivity reaches 10% of the peak value.

Cut-off wavelength: λ_{coff}
λ_{coff} is the longest wavelength at which a detector responsivity reaches 50% of the peak value.

Resistance–area product: RA
Area-normalized detector resistance. Typical photodiodes (PV series) resistance decreases proportionally to their area increase. Therefore, the normalized resistance can be expressed as the RA. In contrast, the PVM series devices are characterized by sheet resistance.

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

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

The time constant is related to 10 – 90% rise time t_r:

$$t_r=2.2\tau$$

Series resistance: R_s
Parasitic resistance in photodiodes. Its contribution to the total diode resistance may be significant for long wavelength and near room operating temperatures diodes, especially with large active area.

Sheet resistance: R_{sq}
The normalized resistance expressed in ohm/square. It is used to normalize the resistance for different size devices with non-square active area

$$R_{sq}=\frac{Rw}{l}$$

Detector module & preamplifier parameters

Output voltage responsivity: R_V
The output voltage divided by incident optical power on the detector.

Output voltage swing: V_{out}
The maximum and minimum voltages where preamplifier works in linear range.

GND
Point of zero potential. For standard preamplifiers is common power supply and signal ground.

Cut-On frequency: f_{lo}
a minimum frequency at which a module responsivity (or preamplifier gain) reaches -3dB of the peak value.

Cut-Off frequency: f_{hi}
a maximum frequency at which a module responsivity (or preamplifier gain) reaches -3dB of the peak value.

Output noise
Noise voltage at preamplifier output.

Average output noise density

$$V_n=\sqrt{\frac{\int_{f_1}^{f_2} V_{out}^2(f)\,df}{f_2-f_1}}$$

Noise measurement frequency: f_0
frequency at which output voltage noise is measured selectively.

Output noise density at specific frequency $V_n(f_0)$
Noise voltage density measured at a given frequency.

Transimpedance: T_r
current to voltage conversion factor (ratio).

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

Preamplifier input noise current: i_n
noise current generated by equivalent current source in parallel with ideal preamplifier input.

Preamplifier input noise voltage: e_n
noise voltage generated by equivalent voltage source in series with ideal preamplifier input.

Total input noise current: I_{in}
Parameter taking into consideration all noise sources related to the input.

$$I_{in}=\sqrt{(i_{PA}^2+i_d^2)}=\frac{V_{n0}}{T_r}$$

Output impedance: R_{out}
equivalent impedance exhibited by its output terminals.

Load resistance: R_L
optimal resistance of the load: amplifier's or the measurement device's.

Output voltage offset: V_{off}
DC component of the output voltage.

Power supply voltage: V_{sup}
supply voltage required for correct preamplifier operation. ±20% tolerance is allowed.

Power supply current: V_{sup}
supply current consumption during correct preamplifier operation.

Coupling type
Preamplifier coupling type. It may be AC for alternate current or DC for direct current.

Power supply input (+) and (-)
polarity of the power supply related to the ground. Swapping supply connectors may lead to module damage.

Temperature sensor inputs
Temperature sensor pins – might be connected with any polarity.

TEC supply input (+) and (-)
Supply polarity for the TEC. Those pins are floating, which means they are not connected to the GND.

TE cooling

Detector cooling reduces noise, increases responsivity and, in some devices, improves high frequency response. Two, three and four stage TE coolers are available TE cooler (TEC) is biased with DC power. All specifications are given for 300K heat sink temperature.

The coolers are characterized by:

Maximum temperature difference ΔT_{max}
ΔT_{max} rated at Q=0, at other Q the ΔT should be estimated as $\Delta T=\Delta T_{max}(1-Q/Q_{max})$

Optimum current: I_{opt}
Supply current giving the highest temperature difference (ΔT_{max}) at the specified conditions stated in detector test data sheet.

Maximum TEC voltage: V_{max}
Voltage drop at ΔT_{max}.

Maximum heat pumping capacity: Q_{max}
Q_{max} rated at ΔT=0, at other ΔT cooling capacity should be estimated as $Q=Q_{max}(1-\Delta T/\Delta T_{max})$

Standard TE coolers parameters:

	2TE	3TE	4TE
$T_{detector}$, K	~230	~210	~195
V_{max}, V	1.3	3.6	8.3
I_{max}, A	1.2	0.45	0.5
Q_{max}, W	0.36	0.27	0.28
ΔT_{max}, K	92	114	125

Temperature Sensor

The built-in thermistor serves as a sensor of the detector operation temperature. The maximal power dissipated by the thermistor should not exceed 0.2 mW—and for accurate temperature measurement, the power should be reduced to <0.03 mW. TE-cooled detectors are equipped with thermistor type TB04-222 as a standard. Resistance – temperature characteristics of the sensors are shown in Table.

Resistance vs temperature for TB04-222 Thermistor

T [K]	R_{th}[Ω]
180	1146.9
181	1048.6
182	959.6
183	879.1
184	806.1
185	739.8
186	679.6
187	624.9
188	575.1
189	529.7
190	488.3
191	450.6
192	416.1
193	384.6
194	355.7
195	329.3
196	305.1
197	282.9
198	262.5
199	243.7
200	226.5
201	210.6
202	196
203	182.5
204	170.1
205	158.6
206	148
207	138.2
208	129.2
209	120.8
210	113
211	105.8
212	99.1
213	92.9
214	87.1
215	81.8
216	76.8
217	72.2
218	67.8
219	63.8
220	60.1
221	56.6
222	53.3
223	50.2
224	47.4
225	44.7
226	42.2
227	39.9
228	37.7
229	35.6
230	33.7
231	31.9
232	30.2
233	28.6
234	27.1
235	25.7
236	24.4
237	23.2
238	22
239	20.9
240	19.9
241	18.9
242	18
243	17.1
244	16.3
245	15.5
246	14.8
247	14.1
248	13.4
249	12.8
250	12.2
251	11.7
252	11.1
253	10.6
254	10.2
255	9.7
256	9.3
257	8.9
258	8.5
259	8.1
260	7.8
261	7.5
262	7.2
263	6.9
264	6.6
265	6.3
266	6
267	5.8
268	5.6
269	5.4
270	5.1
271	4.9
272	4.7
273	4.6
274	4.4
275	4.2
276	4.1
277	3.9
278	3.8
279	3.6
280	3.5
281	3.4
282	3.2
283	3.1
284	3
285	2.9
286	2.8
287	2.7
288	2.6
289	2.5
290	2.4
291	2.4
292	2.3
293	2.2
294	2.1
295	2.1
296	2
297	1.9
298	1.9
299	1.8
300	1.7
301	1.7
302	1.6
303	1.6
304	1.5
305	1.5
306	1.4
307	1.4
308	1.4
309	1.3
310	1.3
311	1.2
312	1.2
313	1.2
314	1.1
315	1.1
316	1.1
317	1
318	1
319	0.98

Temperature Sensor

The built-in thermistor serves as a sensor of the active element temperature. The maximal power dissipated by the thermistor should not exceed 0.2 mW and for accurate temperature measurement, the power should be <0.03 mW.

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 housing, it must be firmly attached to the heat sink (Figs. 1 a and b). Heat sinking via the mounting screw or via the detector housing cylindrical walls is not sufficient (Figs. 1 c and d). A thin layer of heat conductive epoxy or silicone grease should be applied to improve thermal contact between detector housing and heat sink.

A heat sink thermal resistivity of ~2 K/W is typically required for the most two-stage and three-stage Peltier coolers. Four stage cooler require ~1 K/W.

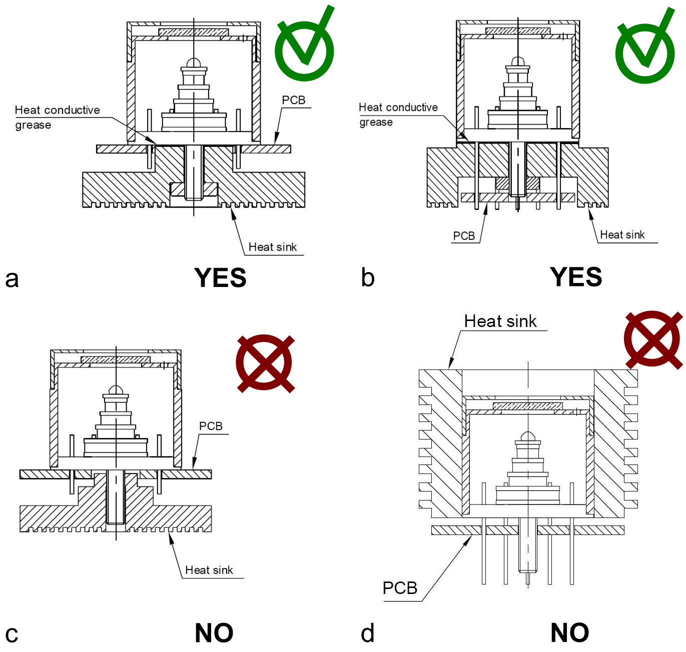

Fig. 1: Heat dissipation from TE cooled detector

TEC Controllers

VIGO System offers the standard thermoelectric cooler controller STCC-04 and the miniature thermoelectric cooler controller MTCC-01.

Temperature sensor inputs

Temperature sensor pins – might be connected with any polarity.

TEC supply input (+) and (-)

Supply polarity for the TEC. Those pins are floating, which means they are not connected to the GND.

Maximum TEC controller output current: I_{tec}

Maximum current that is provided by the controller to the TEC.

Maximum TEC controller output voltage: V_{tec}

Maximum voltage that is provided by the controller to the TEC.

Ripple of output current

It is a small unwanted residual periodic variation of the direct current (dc) output of a power supply (or other device) which has been derived from an alternating current (ac) source. This ripple is due to incomplete suppression of the rectified (dc) waveform within the power supply.

Output current of the built-in power supply

maximum current that can be delivered by power supply to the preamplifier, usually +/-100mA.

Series resistance of the connecting cable

material parameter - resistance of the supply cable. It depends on cable length.

Settling time of the set detector temperature

the time taken by the cooling system to reach appropriate temperature of the detector

Maximum voltage across TEC element

maximum voltage for TEC supplying.