4 GLOSSARY AND TECHNICAL INFORMATION

4.1 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 the ratio of bias voltage V_b 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. A 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 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 bandgap alloy, commonly used for the fabrication of photodetectors with a 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 bandgap alloy used for the fabrication of photodetectors with a tunable spectral response.

Active area A, mm×mm

The physical area of a photosensitive element is the active region that converts incoming optical radiation into the 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 is "seen". It is equal to the 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 (Chapter **Optical immersion technology**).

$$A_O = W_O \text{ (width)} \times L_O \text{ (length)}.$$

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

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

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 generates 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}

The photocurrent is the current generated by infrared radiation, which is not in thermal equilibrium with the 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 $R_i \cdot L$ 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 the responsivity of photoconductive detectors of various formats and operate with different electric fields.

Time constant τ, ns

Typically, detector time response can be described by the one-pole filter characteristics. The time constant is the time it takes the 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}:

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

The time constant for one pole filter is related to 10-90% rise time t_r:

$$t_r = 2.2 \cdot \tau$$

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/L_O, 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·cm²

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·cm²

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

The 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 a 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 is divided by the optical power incident on the detector. For spectra measurements 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

The 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_{Load}, Ω

Resistance of the detection module's load.

Output voltage V_{out}, V

The 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

The 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 a common power supply ground and signal ground.

Ambient operating temperature T_a, °C

Ambient temperature during test measurements.

THERMOELECTRIC COOLERS AND THERMOELECTRIC COOLER CONTROLLERS

Active element temperature T_{det}, K

The detector active element temperature.

Maximum thermoelectric cooler current I_{max}, A

Maximum current resulting in greatest ΔT_{max}.

Maximum thermoelectric cooler voltage V_{max}, V

Maximum voltage drop resulting in greatest ΔT_{max}.

Maximum heat pumping capacity Q_{max}, W

Q_{max} rated at $\Delta T = 0$. At other ΔT cooling capacity should be estimated as

$$Q = Q_{max} \cdot (1 - \Delta T/\Delta T_{max}).$$

Maximum temperature difference ΔT_{max}, K

ΔT_{max} 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 a readout of the temperature of the thermoelectric cooler provided by the controller.

Detector temperature settling time, s

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

Maximum TEC output current, A

The maximum current that is provided by the controller to the thermoelectric cooler.

Output voltage range, V

Range of voltage on the output of the module.

Power supply voltage V_{sup}, VDC

The 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.