PDA40, PDA41, PDA42
PDA43, PDA44, PDA45
SiPM Amplified Detectors

User Guide



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Chapter 1 Safety

1.1 Precautions

Please read the instruction manual carefully before operating your SiPM Amplified Detector. All statements regarding safety and technical specifications will only apply when the unit is operated correctly.

Refer to this User's Guide whenever the following symbols are encountered on the SiPM Amplified Detector and Power Supply.



Caution
Only with written consent from Thorlabs may changes to single components be carried out or components not supplied by Thorlabs be used.

The safety of any system incorporating the equipment is the responsibility of the assembler of the system.

If equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

This instrument should be kept clear of environments where liquid spills of condensing moisture are likely. It is not water resistant. To avoid damage to the instrument, do not expose it to spray, liquids, or solvents.



Caution
This equipment is intended for laboratory use only and is not certified for medical applications, including but not limited to, life support situations.

Transportation and delivery may cause the SiPM Amplified Detector to be warm or cool upon receipt. Please wait for the device to reach room temperature before attempting to operate.



Warning: Risk of Electrical Shock
This product is powered directly from the LDS12B AC-DC power supply provided with the unit. Do not substitute this power supply. If you need a replacement power supply, contact Thorlabs.

Dangerous voltage exists within the power supply. Do not tamper with or open the supply under any circumstances. Doing so may expose lethal voltage to personnel and will void the warranty of the power supply and device it is connected to.

The LDS12B power supply has a three-position line switch that must be set to match the voltage of your local mains power source.

If the voltage selector switch is set to the wrong voltage, the power supply may be damaged or the SiPM Amplified Detector may be damaged, or both. Always ensure that the line voltage selector switch is set correctly before plugging the power supply into mains power.

1.2 Product Care

Handle the system with care during transportation and unpacking. Bumping or dropping the device can damage the unit or lower its performance. To ensure proper care and operation of your SiPM Amplified Detector, please follow the handling instructions below.

- Do not store or operate in a damp, closed environment.
- Do not use solvents on or near the equipment.
- Keep away from dust, dirt, and air-borne pollutants (including cigarette smoke). The device is not designed for outdoor use. Protect the equipment from rain, snow, and humidity.
- Do not expose to mechanical or thermal extremes. Protect the equipment from rapid variation in temperature.
- Handle all connectors with care. Do not use unnecessary force as this may damage the connectors.
- Clean using a soft, lint free cloth. Use of isopropyl alcohol is permitted, however do not immerse in any liquid or solvent.
- Clean any accessible optical surfaces with an appropriate optics grade tissue or cloth.

1.2.1 Service

Only trained and approved Thorlabs' personnel should service this product, including the power supply. Please contact Thorlabs' Technical Support at **techsupport@thorlabs.com** and a member or our team will be happy to assist you.

1.2.2 Accessories and Customization

All amplified detectors are supplied with one LDS12B power supply and a line cord that matches your country's connector style.

Warning: Risk of Electrical Shock
The LDS12B power supply has a three-position line switch that must be set to match the voltage of your local AC mains power source.

The power supply must be connected to a properly grounded AC mains connection.

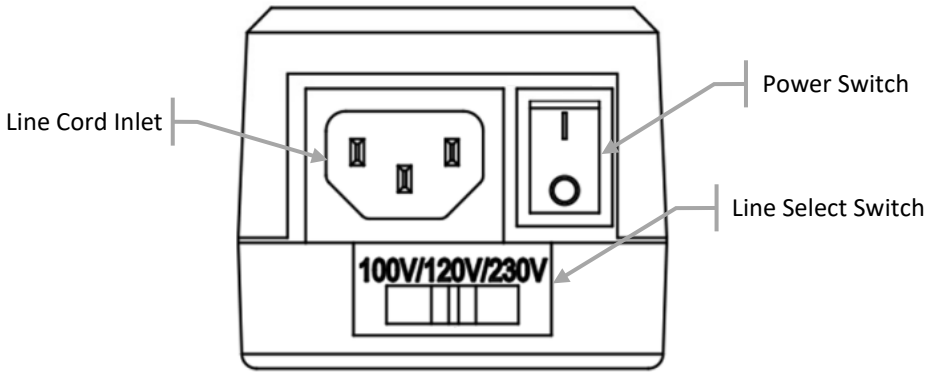


Figure 1 LDS12B Power Supply Features

Chapter 2 Description

2.1 Introduction

The PDA40 through PDA45 series of amplified silicon photomultiplier (SiPM) detectors consists of six versions offering varying detector sizes and responsivities. Refer to the **Specifications** section. SiPM detectors, also known as Multi-Pixel Photon Counters (MPPC) are extremely sensitive to light and are well suited for very low-light detection applications.

A ±12 VDC power supply is included with each amplified photodetector, and a slide switch on the power supply must be set to select the appropriate input line voltage (100, 120, or 230 VAC). The PDA housing includes a removable threaded coupler (SM1T1) and retaining ring (SM1RR) that are compatible with any of Thorlabs' SM1-threaded (1.035"-40) accessories. This allows convenient mounting of external optics, light filters, and apertures, as well as providing an easy mounting mechanism using Thorlabs' cage assembly accessories. 8-32 (M4) tapped mounting holes are provided in two locations for mounting to Thorlabs' mounting posts.

A buffered output drives 50 Ω load impedances up to +/- 2 V.



Figure 2 PDA Features and Accessories

2.2 Receiving and Unpacking

Your detector was thoroughly tested and carefully packed at the factory. Once the detector shipment is accepted for delivery, the carrier assumes full responsibility for its safe arrival. Should you receive your shipment with any damage—concealed or apparent—please contact the carrier at once. The carrier will instruct you on how to initiate a damage claim. If a visual inspection reveals damage upon receipt, it must be noted on the freight bill or express receipt and the notation signed by the carrier's agent. Failure to do so can result in the carrier refusing to honor the claim.

To return your detector to Thorlabs for service, you must first contact your local Thorlabs office or distributor and request a Return Material Authorization (RMA). Returns will not be accepted without an RMA. See the **Warranty and RMA Information** section for details.

2.3 Supplied Equipment

The following is a list of equipment that is supplied with your amplified detector unit:

- PDA4x SiPM Amplified Detector
- LDS12B AC-DC Power Supply
- SM1T1 Threaded Coupler
- SM1RR Retaining Ring
- SM1EC2B Lens Tube End Cap
- AC Line Cord specific to your region

2.3.1 Optional Items

- 2249-C-xx BNC Male to BNC Male cables for connecting the detector output (not included with the unit).

Chapter 3 Setup & Installation

3.1 Optical and Mechanical Mounting Considerations

3.1.1 Using an SM1 Lens Tube

All Thorlabs' PDA detector products are compatible with the Thorlabs line of SM1 1" lens tubes. Simply thread the tube onto the mating SM1 internal threads on the SM1T1 on the front of the unit or remove the SM1T1 and thread a compatible lens tube onto the external threads on the main housing.



Figure 3 PDA shown with SM1 Options

3.1.2 Mounting the Detector

Two 8-32 (M4) tapped holes are provided, one on the bottom and one on the side of the housing. These tapped holes are compatible with Thorlabs posts. For more information on Thorlabs posts, please visit www.thorlabs.com.

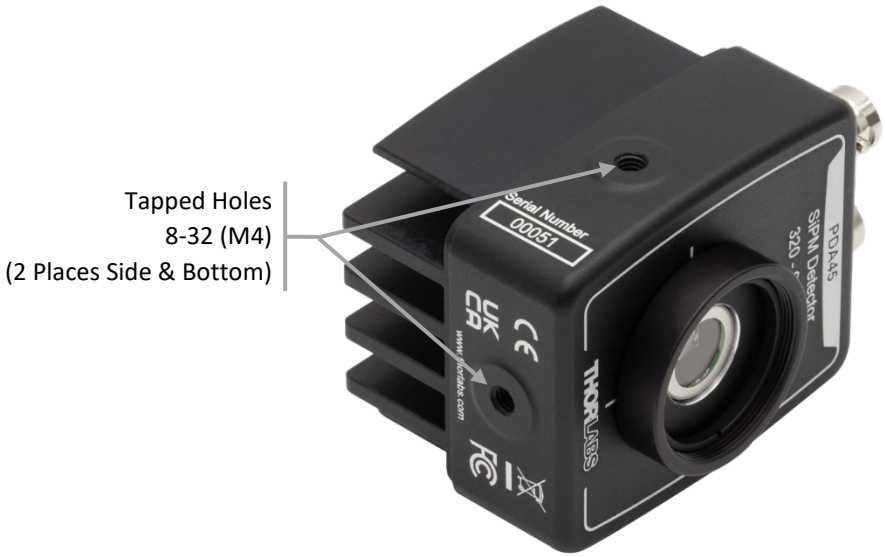


Figure 4 8-32 (M4) Tapped Mounting Holes on Detector

3.2 Electrical Connections



Figure 5 PDA Power and Output Connectors

1. Set the LDS12B power supply to the "O" off position. Set the voltage selector switch on the power supply to the appropriate input voltage (100, 120, or 230 VAC), **then** plug into a 50 – 60 Hz outlet.
2. Set the PDA's power switch to the "O" off position. Connect the power supply's 3-pin plug into the DC Input power receptacle on the PDA. Align the pins and then fully thread the power supply connector into the PDA connector.
3. Attach a 50 Ω BNC-type coaxial cable (i.e. RG-58U) to the output BNC connector of the PDA. For best performance, we recommend terminating the cable with a 50 Ω load at the measurement instrument. If the instrument has a high impedance input, then adding an external 50 Ω load resistor may be an option. Do not add an external 50 Ω resistor if the instrument has an internal 50 Ω termination, as the resulting 25 Ω load could damage the output of the PDA.

Chapter 4 Operation

4.1 Starting the Detector

When power is applied to the detector unit, the Status LED will light up solid yellow, turning to solid green several seconds to a minute after power is applied. The table below details the conditions represented by the status indicator.

LED	LED is Off	LED is On	LED is Toggling
Status	There is no power to the detector or there is a malfunction.	**Yellow**: Detector has power, but the internal cooling system has not reached its set point, or the unit cannot maintain -10 °C internally. (See **Chapter 7** Troubleshooting) **Green**: Detector has reached the proper cooling level and detector bias has switched on. The unit is now fully functional.	If the LED is changing from Green to Yellow repeatedly this indicates a saturated detector, which is causing the thermal system to cycle. Lower the light intensity that the detector is exposed to, lower the Bias level setting, or lower both. (See **Chapter 5.4** and **Chapter 7**)

1. Turn the PDA on by setting the LDS12B power switch to the "I" on position, then slide the power switch location on the side of the PDA unit to the "I" position. Wait for the Status LED to change to green.
2. Apply the light source to the detector. Be sure to not overfill the detector area, as this can affect the thermal performance as well as the overall output quality.
3. The maximum output of the PDA is ± 2 V for 50 Ω loads. The output signal should always be below the maximum output voltage. If necessary, use the external neutral density filters to reduce the input light level.
4. The output Signal will have a small DC offset component of up to ± 20 mV (into 50 Ohms).
5. Adjust the bias level as required by rotating the Bias Level knob on the side of the unit to achieve a Single Electron Pulse (SER) of approximately 100 mV. Bear in mind the DC offset mentioned above. The bias level has ten fixed bi-directional adjustment steps and will rotate through the min/max settings (step 1 into step 10 and vice versa). Increasing the bias level will increase the SER level, but will also increase noise, crosstalk, and afterpulses. See **Output Signal Information** for more information. **Table 1** represents the typical bias level for each setting; a device specific data sheet with recommended bias settings is included with each SiPM detector.

Bias Levels[a] (± 1.5 VDC)		
Setting	**PDA40, PDA41, PDA42, PDA43**	**PDA44, PDA45**
1	39.5	50.0
2	41.2	52.0
3	42.8	54.0
4	44.5	56.0
5	46.3	57.8
6	48.0	59.8
7	49.7	61.7
8	51.5	63.7
9	53.0	65.5
10	54.8	67.5

a. Bias levels are typical values for each setting; a device specific data sheet with recommended bias settings is included with each SiPM detector.

Table 1 Bias Level Settings

Chapter 5 Specifications

The following specifications are valid for PDA40, PDA41, PDA42, PDA43, PDA44, and PDA45 detectors.

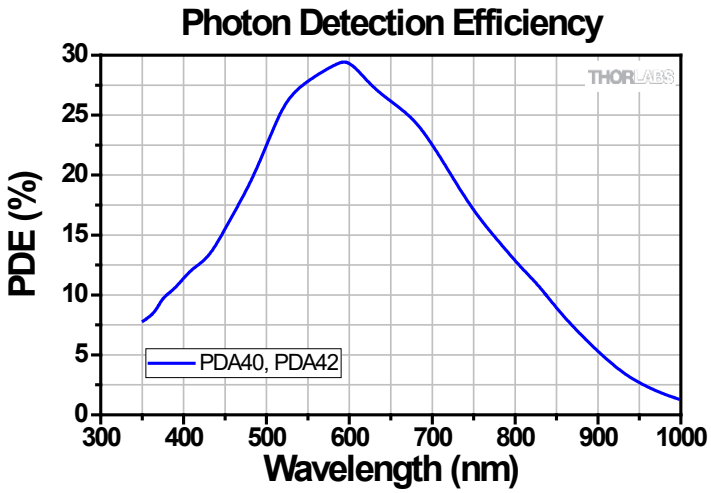
5.1 SiPM Detector Specifications

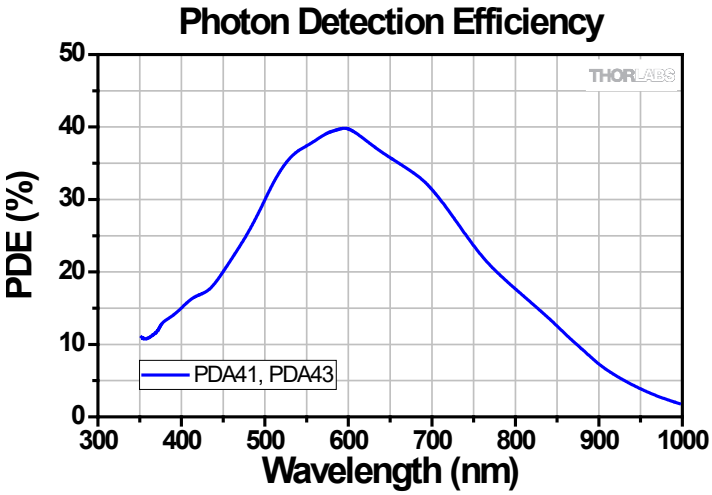
Specifications[a]						
Item #	**PDA40**	**PDA41**	**PDA42**	**PDA43**	**PDA44**	**PDA45**
Wavelength Range	350 - 1000 nm				320 - 900 nm	
Peak Sensitivity	600 nm				450 nm	
Active Area	Ø1.5 mm	Ø1.5 mm	Ø3.0 mm	Ø3.0 mm	1.3 x 1.3 mm	3 x 3 mm
Photon Detection Efficiency (PDE)	30%	40%	30%	40%	40%	
Pixel Pitch	25 µm	50 µm	25 µm	50 µm	50 µm	
Number of Pixels	2876	724	11344	2836	667	3600
Fill Factor	63%	81%	63%	81%	74%	
Dark Counts (Typ./Max.)	35 / 90 kcps		140 / 350 kcps		5 / 13 kcps	25 / 72 kcps
Breakdown Voltage (Vbr)	40.5 ± 5 V				51.1 ± 5 V	
Recommended Bias V	Vbr + 5 V				Vbr + 3 V	
Photon Pulse Height	~100 mV					
Photon Pulse Width[b]	4 ns					
Crosstalk Probability	1.5%	5%	1.5%	5%	3%	
Gain	0.9×10^6	3.6×10^6	0.9×10^6	3.6×10^6	1.7×10^6	
Window Material	Borosilicate Glass					
Window Refractive Index	1.52					
Cooling	Two-Stage TE-Cooled					
Cooling Set Point	-10 °C					
Power Consumption[c]	11 W					
Output Voltage	±2 V (into 50 Ohm load)					
Operating Voltage	100 / 120 / 230 VAC ± 10% 50 - 60 Hz					
Operating/Storage Temperatures	Operating: 10 to 35 °C (Non-condensing) / Storage: 0 to 55 °C					

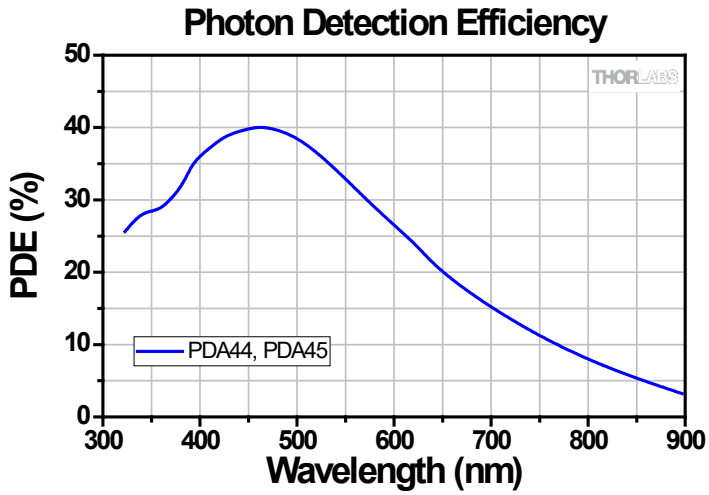
a. Typical values @ 25° C ambient and -10° C detector temperature, Bias Level = Vbr + 5 V, unless otherwise noted
b. Typical value at FWHM
c. Total maximum power consumption from AC mains with LDS12B power supply

5.2 Photon Detection Efficiency

(Typical at $T_{ambient}$ = 25 °C)

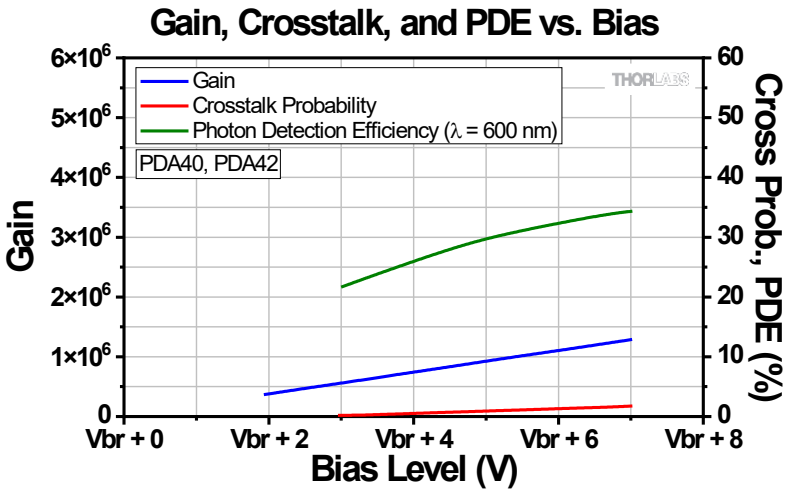


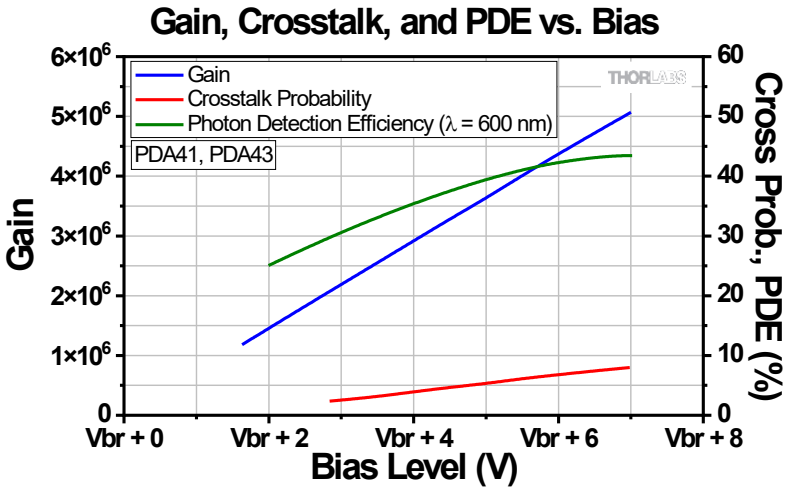


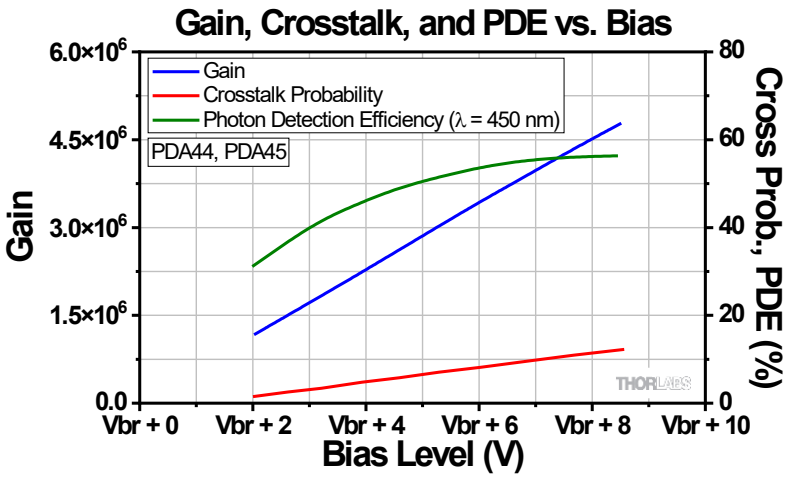


5.3 Gain, Crosstalk, and PDE vs. Bias Level

(Typical at $T_{ambient}$ = 25 °C, T_{chip} = -10 °C)







5.4 Output Signal Information

5.4.1 SiPM Signal Characterization

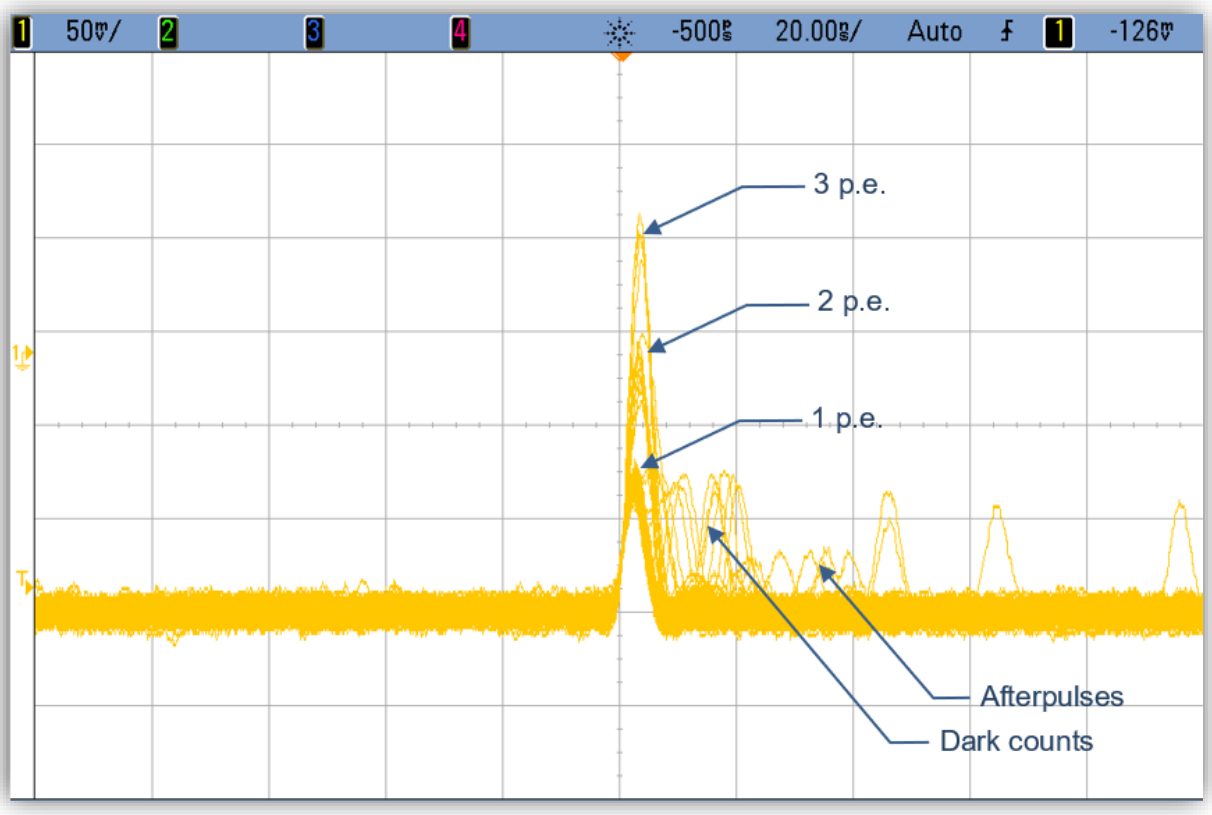


Figure 6 Cumulative Capture of Output Signal

The typical output waveform of the amplified SiPM PDA consists of a number of aspects worth noting:

- The output pulse is relative to the number of photons incident on any given pixel. Multiple photons on a pixel will result in pulses at multiples of the single photoelectron (1 p.e.) response.
- The output pulse may also be the result of dark current electrons entering a pixel. They exist with or without exposure to light. They are typically 1 p.e. in amplitude and are indistinguishable from pulses generated from photons. These are characterized in the "Dark Count" specification in Section **5.1**.
- Afterpulsing occurs, as the name implies, after a valid photon or dark count pulse. They are generally <1 p.e.
- Crosstalk occurs when an emitted photon reaches an adjacent pixel, resulting in a near simultaneous pulse response. This would present itself as a 2 p.e. output pulse and is indistinguishable from pulses generated from a two-photon event. Crosstalk is characterized as "Crosstalk Probability" in the Specifications table in Section **5.1**.
- The applied bias level influences dark count, afterpulsing, and crosstalk behavior, increasing all three with increasing bias levels.
- The applied bias level also increases/decreases the amplitude of the single electron response. Ideally aim for a level close to Vbr + 5 V (refer to **Table 1**) to achieve approximately 100 mV for 1 p.e.

The following two images show examples of an over-exposed SiPM MPPC. Both examples could be the result of too much incident light and/or a bias level setting that is too high. Setting the bias level higher than nominal results in an increase in dark counts, adding to the overall signal. In both cases it is only a matter of time before the thermal system saturates and shuts down the PDA – indicated by a yellow status light. **Figure 8** shows a fully saturated SiPM that is operating at the maximum capabilities of the output amplifier, resulting in clipping. Avoid both conditions by either installing an ND filter, lowering the bias level, or both.

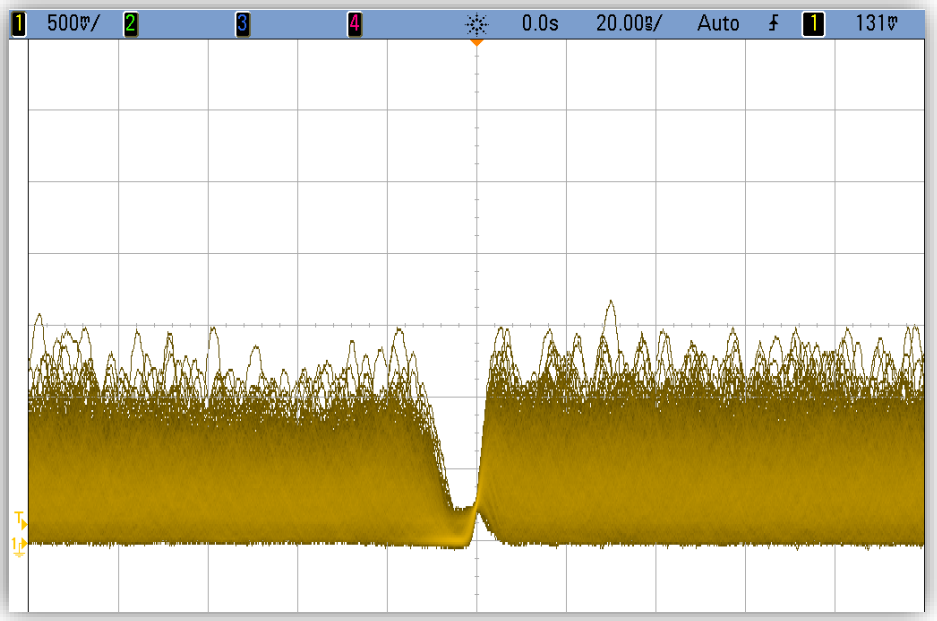


Figure 7 High Incident Light or Bias Level

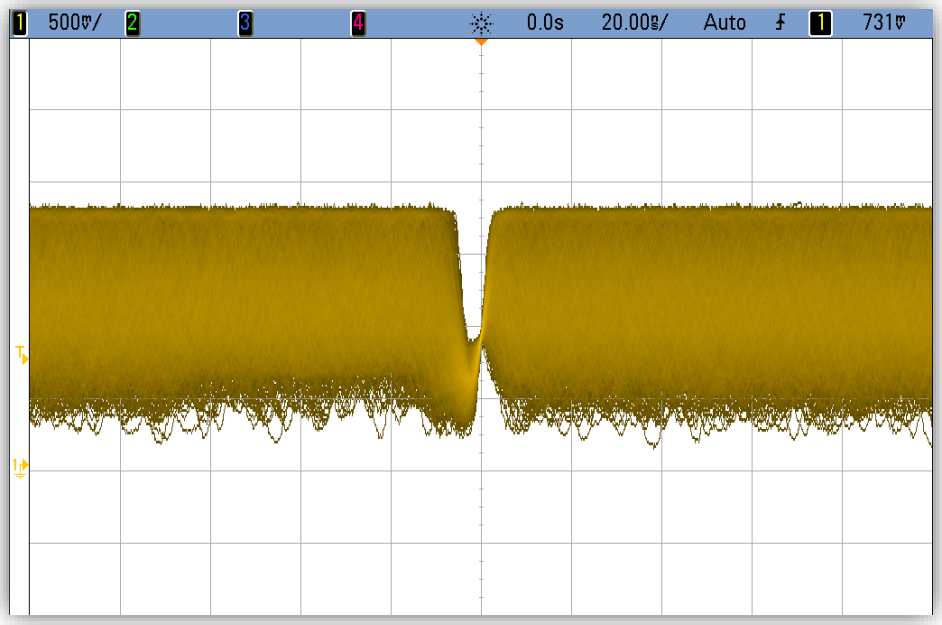


Figure 8 Excessive Light or Bias Level

5.4.2 Reflective Pulse Compression

A typical SiPM single electron response (SER) has a very fast rising leading edge followed by a relatively slowly decaying tail. The SiPM PDA family employs a proprietary integrated Reflective Pulse Compression (RPC) circuit that effectively removes the tail from the SER pulse, resulting in a cleaner and more distinguishable signal.

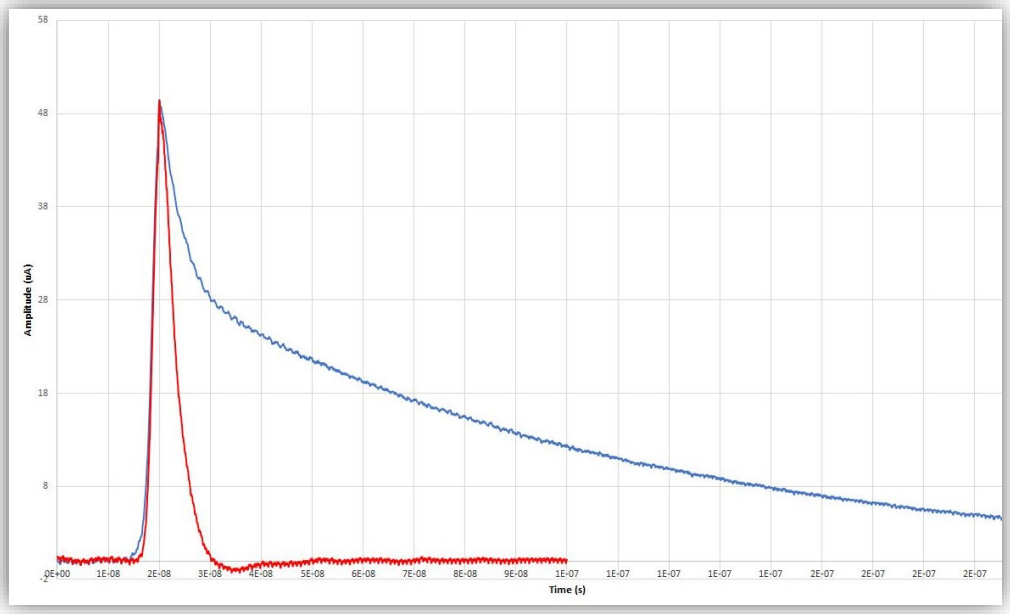


Figure 9 Simulated Uncompensated SER (Blue) and RPC SER (Red)

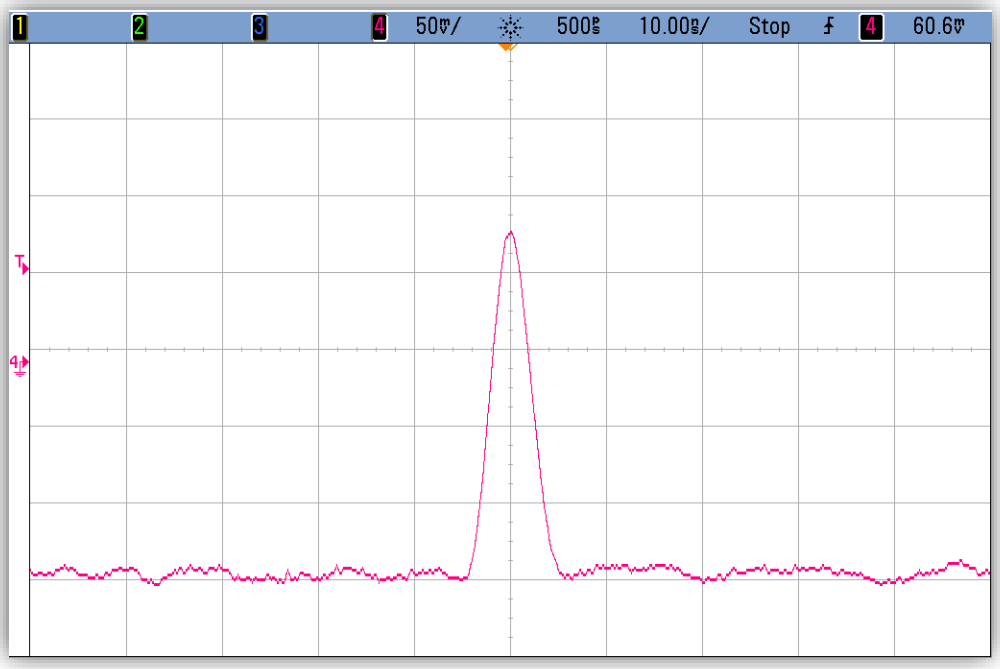


Figure 10 Actual RPC Output Signal (Approx. 2 p.e.)

Chapter 6 Mechanical Drawings

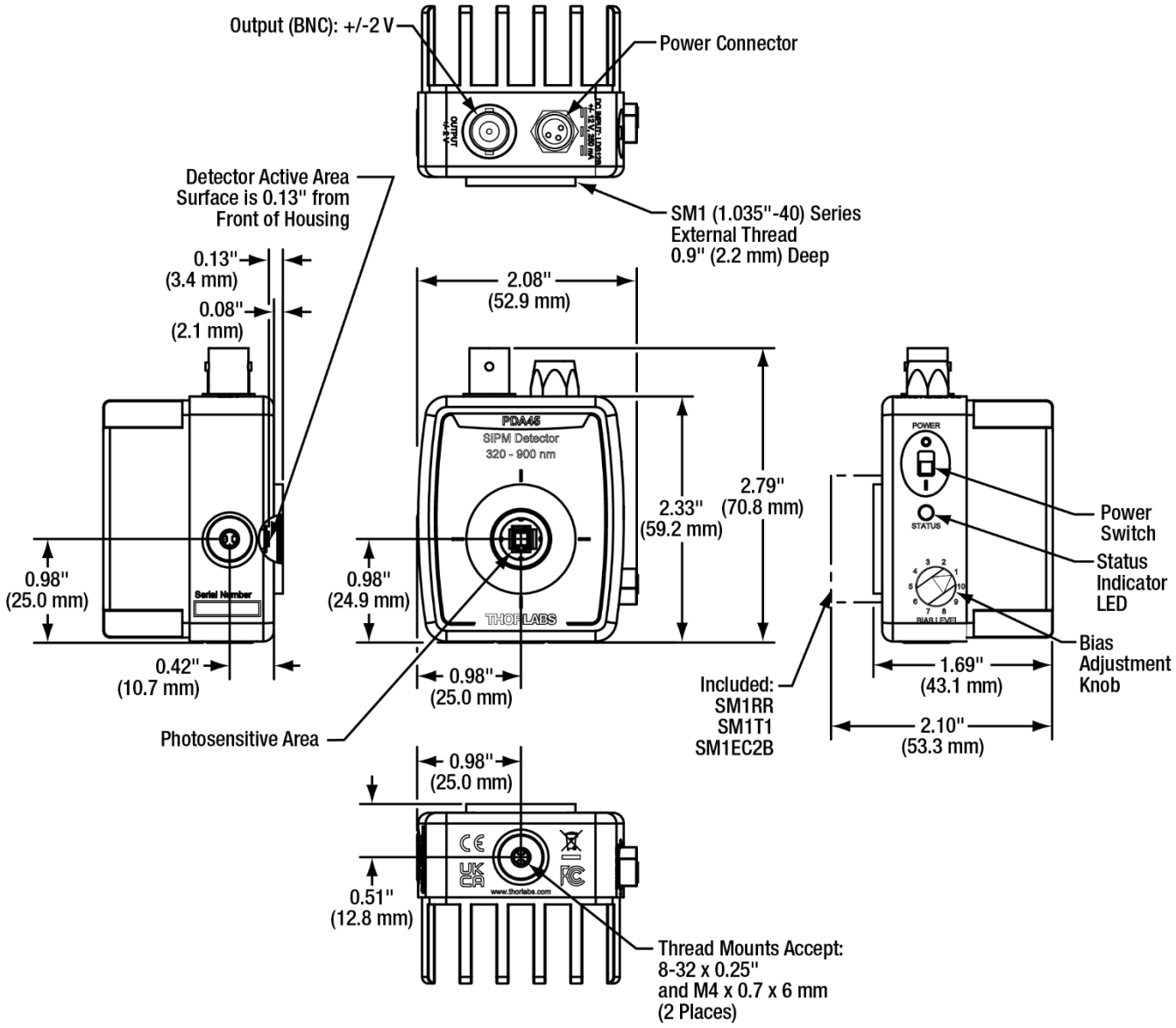


Figure 11 SiPM Amplified Detector Dimensions

Chapter 7 Troubleshooting

Problem	Symptoms	Possible Cause	Remedy
No Output	• No discernable signal from output connector • Status LED is Yellow	Detector is not powered. (Status LED will be Off)	Ensure the LDS12B power switch and the PDA power switch are both set to their ON positions.
		Detector is not at the internal temperature set point. (Yellow LED)	Output is turned off until temperature is at set point. Wait for Status LED to turn Green – typically less than 3 mins after turning on unit.
		Electronics failure	Disconnect detector power supply and contact customer service.
Low Output	SER is lower than expected	Lens cap is installed.	Remove lens cap.
		Bias level is set too low.	Increase the Bias level adjustment one step at a time until you reach the desired output level.
Detector is excessively warm	• Detector is too hot to safely hold with an ungloved hand • Status LED is Yellow	Detector is not properly ventilated or is in an environment greater than 40 °C.	Remove any obstructions or provide adequate ventilation around detector. Move to cooler environment.
		Electronics failure	Disconnect detector power supply and contact customer service.
Yellow Indicator	Status LED is Yellow	Detector is not at the internal temperature set point.	1. Wait for Status LED to turn Green – typically less than 3 mins after turning on unit. 2. Lower the Bias level setting. 3. Lower the light level the detector is exposed to. 4. Both #2 and #3 above.
		Electronics failure	Disconnect detector power supply and contact customer service.
No Status LED	Status LED is not On	Detector is not powered.	Ensure the LDS12B power switch and the PDA power switch are both set to their ON positions.
		Electronics failure	Disconnect detector power supply and contact customer service.
Status LED is constantly changing	Status LED changed from yellow to green repeatedly	Detector is saturated. (over exposed to light)	1. Reduce the level of light that is incident on the detector. 2. Reduce the Bias level.
		Thermal system is stressed.	1. Provide adequate ventilation around detector. Move to cooler environment. 2. Reduce light levels. 3. Reduce Bias level.

Chapter 8 Maintenance

There are no user-serviceable parts inside the detector. Removing the rear cover of the detector without expressed authorization from Thorlabs will void the detector warranty.

Thorlabs SiPM amplified detectors are manufactured and tested to assure they meet stringent specifications for performance, cleanliness, and quality.

Frequent optics changes, especially without careful attention to contaminants, can allow debris to accumulate on the detector window. Therefore, Thorlabs provides the following guidelines for cleaning those components.

To minimize the need to clean the optical surfaces, do not remove the protective lens cap shipped with the detector until you are ready to mount the detector to the optical system.

For an informative tutorial refer to the "Handling and Cleaning Procedures for Optical Components". The following guidelines, specific to Thorlabs detectors, are meant to be used in conjunction with the procedures described in the tutorial.

8.1 Cleaning the Detector Window

- ***What if the contamination is only a few dust particles?***

  Use a CLEAN, DRY (preferably brand-new), lens tissue to gently wipe the particles off of the window.

- ***What if the contamination includes a smudge?***

  1. Remove the detector from the optical assembly and bring the detector to a clean, dry location where it is safe to use flammable solvents (please see "Caution" below).
  2. Remove any SM1 adapters from detector to allow better access to the detector window.
  3. Use a CLEAN, DRY (preferably brand-new), lens tissue to wipe the particles off of the window.
  4. Re-examine the window after removing the dust. If a smudge is still visible, proceed by dipping a clean, lint-free cotton swab in ethyl or isopropyl alcohol. The swab should be saturated, but not dripping.
  5. Carefully draw the swab once across the surface, then rotate the swab 180 degrees to expose the fresh surface and draw it across the window surface again. Be careful not to pool alcohol on the glass surface.
  6. Re-examine once again and repeat the process once, if necessary.

If contamination continues to be a problem, please call Thorlabs for assistance.



Caution
Ethyl and isopropyl alcohols are highly flammable! Do not use near extreme heat, arcing electrical equipment (such as space heaters), or open flame! Use only with proper ventilation. Follow all safety instructions provided by the manufacturer of the alcohol product.

Chapter 9 Certifications and Compliance



in accordance with EN ISO 17050-1:2010

We: Thorlabs Inc.

Of: 56 Sparta Avenue, Newton, New Jersey, 07860, USA

in accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***PDA40, PDA41, PDA42, PDA43, PDA44, PDA45***

Equipment: ***SiPM Amplified Detector***

is/are in conformity with the applicable requirements of the following documents:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010 + A1:2019 + AC:2019.
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013
EN 63000	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances	2018

and which, issued under the sole responsibility of Thorlabs, is/are in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

contains no substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed:  *On:* 08 December 2022

Name: Danielle Strong

Position: Director of Quality and Compliance

EDC - PDA40, PDA41, PDA42, PD...

CE

9.1 FCC / ICES Statement

The following statement applies to the products covered in this manual, unless otherwise specified herein. The statement for other products will appear in the accompanying documentation. Inputs and outputs must only be connected with shielded connection cables.

This product has been tested and found to comply with the limits according to IEC 61326-1 for using connection cables shorter than 3 meters (9.8 feet).

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules, and meets all requirements of the Canadian Interference Causing Equipment Standard ICES-003 for digital apparatus. These limits are designed to provide reasonable protection against harmful interference in an industrial installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

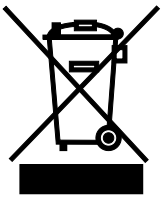
Thorlabs is not responsible for any radio television interference caused by modifications of this equipment or the substitution or attachment of connecting cables and equipment other than those specified by Thorlabs. The correction of interference caused by such unauthorized modification, substitution or attachment will be the responsibility of the user. The use of shielded I/O cables is required when connecting this equipment to any and all optional peripheral or host devices. Failure to do so may violate FCC and ICES rules.

9.2 General Compliance Statement

The products presented in this user guide comply with the following regulatory requirements for laboratory grade equipment:

CE UK CA FC **Canadian ICES-003**

Chapter 10 Warranty and RMA Information



Annex I

Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return "end of life" Annex I category electrical and electronic equipment sold after August 13, 2005 to Thorlabs, without incurring disposal charges. Eligible units are marked with the crossed out "wheelie bin" logo (see right), were sold to and are currently owned by a company or institute within the EC and are not dissembled or contaminated. Contact Thorlabs for more information. Waste treatment is your own responsibility. "End of life" units must be returned to Thorlabs or handed to a company specializing in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site. It is the user's responsibility to delete all private data stored on the device prior to disposal.

10.1 Return of Devices

This precision device is only serviceable if returned and properly packed into the complete original packaging including the complete shipment plus the cardboard insert that holds the enclosed devices. If necessary, ask for replacement packaging. Refer servicing to qualified personnel.

10.2 General Product Warranty

Thorlabs warrants that all products sold will be free from defects in material and workmanship and will conform to the published specifications under normal use, when correctly installed and maintained.

10.3 Specific Warranties and Repairs

All specific warranty and repair information can be found in the general terms and conditions located at **https://www.thorlabs.com/Images/PDF/LG-PO-001_Thorlabs_terms_and_%20agreements.pdf**

Chapter 11 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at **www.thorlabs.com/contact** for our most up-to-date contact information.



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