THORLABS

Single Photon Detector

SPDMA
Operation Manual

2021

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Contents

We aim to develop and produce the best solutions for your applications in the field of optical measurement techniques. To help us to live up to your expectations and constantly improve our products, we need your ideas and suggestions. We and our international partners are looking forward to hearing from you.

Thorlabs GmbH

Warning

Sections marked by this symbol explain dangers that might result in personal injury or death. Always read the associated information carefully before performing the indicated procedure.

Attention

Paragraphs preceded by this symbol explain hazards that could damage the instrument and the connected equipment or may cause loss of data.

Note

This manual also contains "NOTES" and "HINTS" written in this form.

Please read this advice carefully!

1 General Information

The Thorlabs' SPDMA Single Photon Detector uses a cooled silicon avalanche photodiode, specialized for a wavelength range from 350 to 1100 nm with a maximum sensitivity at 600 nm. Incoming photons are converted into a TTL pulse in the detector. The SMA connection offers a direct output pulse signal from the module that can be viewed on an oscilloscope or connected to an external counter.

An integrated Thermo Electric Cooler (TEC) element stabilizes the diode's temperature to reduce the dark count rate. The low dark count rate and high photon detection efficiency allow detection of power levels down to fW. The active quenching circuit integrated into the diode of the SPDMA enables high count rates. The output signal can further be optimized by continuous adjustment using the Gain Adjustment Screw.

Using a TTL Trigger IN signal, the SPDMA can be externally triggered to select the time frame for the detection of single photons.

Optical alignment is simplified by the relatively large active area of the diode with a diameter of 500 µm. The diode is actively aligned at the factory to be concentric with the input aperture, which adds to the high quality of this device.

For flexible integration into optical systems, the SPDMA accommodates any Thorlabs 1" lens tubes as well as the Thorlabs 30 mm Cage System. The SPDMA can be mounted in metric or imperial systems due to 8-32 and M4 combi-thread mounting holes.

The product includes an SM1T1 SM1 Coupler which adapts the external thread to an internal thread and holds the SM1RR Retaining Ring and a reusable protective plastic cover cap.

Another advantage is that the SPDMA cannot be damaged by unwanted ambient light, which is critical for many photomultiplier tubes.

Attention

Please find all safety information and warnings concerning this product in the chapter Safety in the Appendix.

1.1 Ordering Codes and Accessories

SPDMA	Single Photon Detector, 350 nm - 1100 nm, Active Area Diameter 0.5 mm, Combi-Thread Mounting Holes Compatible with 8-32 and M4 Threads

Included Accessories

- Power Supply (±12 V, 0.3 A / 5 V, 2.5 A)
- Plastic Cover Cap (Item # SM1EC2B) on an included SM1T1 SM1 Coupler with an SM1RR SM1 Retaining Ring.

Optional Accessories

- All Thorlabs internal or external SM1 (1.035"-40) threaded accessories are compatible with the SPDMA.
- The 30 mm Cage System can be mounted on the SPDMA.

Please visit our homepage http://www.thorlabs.com for various accessories like fiber adapters, posts and post holders, data sheets and further information.

2 Getting Started

2.1 Parts List

Please inspect the shipping container for damage. Please do not cut through the cardboard, as the box might be needed for storage or returns.

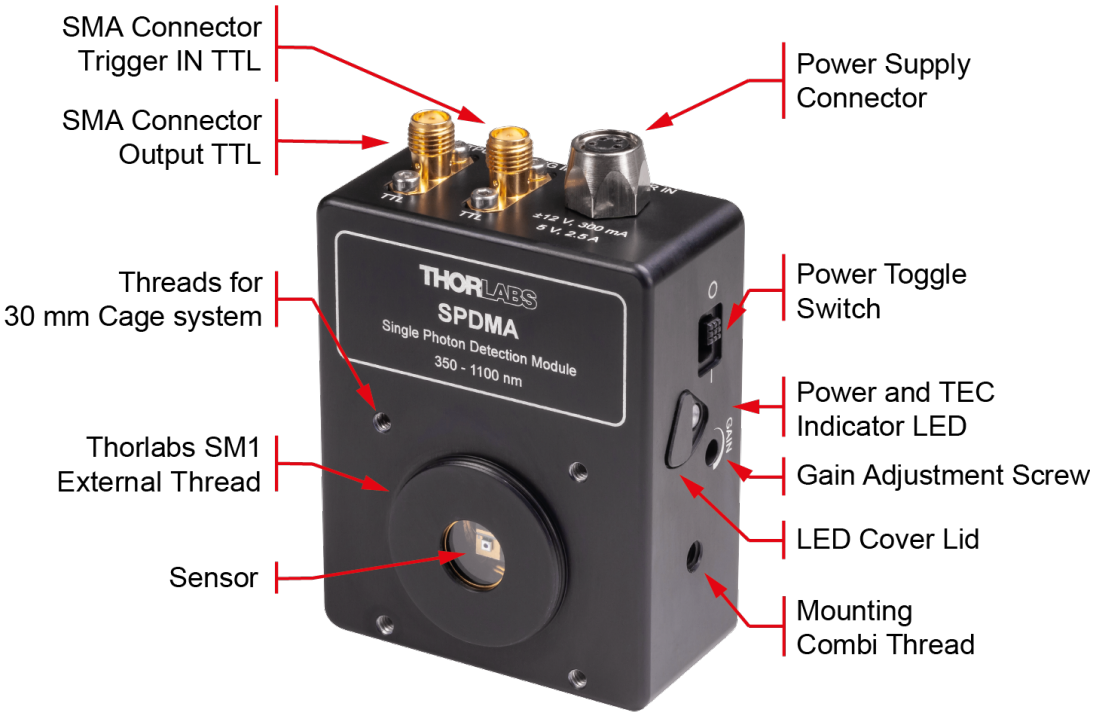
If the shipping container appears to be damaged, keep it until you have inspected the contents for completeness and tested the SPDMA mechanically and electrically.

Verify that you have received the following items within the package:

1. SPDMA Single Photon Detector
2. Plastic Cover Cap (Item # SM1EC2B) on SM1T1-SM1 Coupler with an SM1RR-SM1 Retaining Ring
3. Power Supply (±12V, 0.3 A / 5 V, 2.5 A) with Power Cord, Connector According to Ordering Country
4. Quick Reference

3 Operating Instructions

3.1 Operating Elements



3.2 Mounting

Mounting SPDMA on an Optical Table

Mount the SPDMA on an optical post by using either of the three tapped mounting holes on the left and right side, and bottom of the device. The combi-thread tapped holes accept both 8-32 and M4 threads, such that using either imperial or metric TR posts is possible.

Mounting External Optics

The customer system can be attached and aligned using either the external SM1 thread or the 4-40 mounting holes for a 30 mm Cage System. The positions are indicated in the Operating Elements section. The external SM1 thread accommodates Thorlabs' SM1-threaded (1.035"-40) adapters that are compatible with any number of Thorlabs 1" threaded accessories, like external optics, filters, apertures, fiber adapters, or lens tubes. The SPDMA is shipped with an SM1T1 SM1 coupler that adapts the external thread to an SM1 internal thread. A retaining ring in the coupler holds the protective cover cap. Please unscrew the coupler if needed.

For accessories, please visit our website or contact Thorlabs.

3.3 Setup

After mounting the SPDMA, set up the detector as follows:

1. Power up the SPDMA using the included power supply.
2. Switch on the SPDMA, using the toggle button on the side of the instrument.
3. Push the cover from the status LED to see the status:
   a. Red: The LED will initially be red upon connection to the power supply to indicate this connection and the need to wait until the detector has reached the operating temperature. Within a few seconds, the diode is cooled down and the status LED will turn to green. The

status LED will return to red when the diode temperature is too high. If the LED is red, no signal is sent to pulse output.

b. Green: Detector is ready for operation. The diode is at operating temperature and signal arrives at the pulse output.

Note

The Status LED will turn red whenever the operating temperature is too high. Please ensure sufficient air ventilation.

4. Push the cover back in front of the status LED to prevent LED light from disturbing the measurement.
5. To increase the photon detection efficiency, turn the Gain Adjustment Screw with a slotted screw driver (1.8 to 2.4 mm, 0.07" to 3/32"). For more information on the gain, please refer to the chapter Operating Principle.
   a. Use Minimum Gain when a low dark count rate is critical. This comes at the cost of low photon detection efficiency.
   b. Use Maximum Gain when it is desirable to collect a maximum number of photons. This comes at the cost of a higher dark count rate.
   c. Because the time between photon detection and signal output changes with the gain setting, please reevaluate this parameter after changing the gain setting.

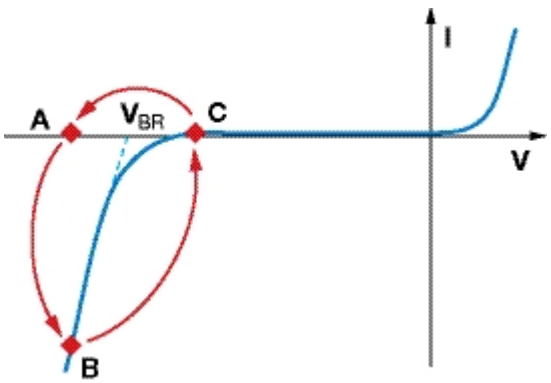
Note

"Trigger In" and "Pulse Out" are of a 50 Ω impedance. Make sure that the trigger pulse source is capable to work on a 50 Ω load and that the device connected to "Pulse Out" operates at a 50 Ω input impedance.

3.4 Operating Principle

The Thorlabs SPDMA uses a silicon avalanche photo diode (Si APD), operated in reverse direction and biased slightly beyond the breakdown threshold voltage $\mathbf{V_{BR}}$ (see diagram below, point **A**), also known as the avalanche voltage.

This operating mode is also known as "Geiger mode". An APD in Geiger mode will remain in a metastable state until a photon arrives and generates free charge carriers in the PD's junction. These free charge carriers trigger an avalanche (point **B**), leading to a significant current. An active ***quenching circuit*** integrated into the APD limits the current through the APD in order to avoid destruction and lowers the bias voltage below the breakdown voltage $\mathbf{V_{BR}}$ (point **C**) immediately after a photon released an avalanche. This enables high count rates with dead time between counts down to the specified dead time at max gain. Afterwards the bias voltage is restored.



During the quenching time, which is known as the dead time of the diode, the APD is insensitive to any other incoming photons.

Spontaneously triggered avalanches are possible while the diode is in a metastable state. If these spontaneous avalanches occur randomly, they are called **dark counts**. An integrated TEC element stabilizes the diode's temperature below the ambient temperature to reduce the dark count rate. This eliminates the need for a fan and avoids mechanical vibrations.

In case the spontaneously triggered avalanches are correlated in time with a pulse caused by a photon, it is called an **afterpulse**.

Note

Due to APD properties, not all single photons may be detected. Reasons are the APD's intrinsic dead time during quenching and the APD's nonlinearity.

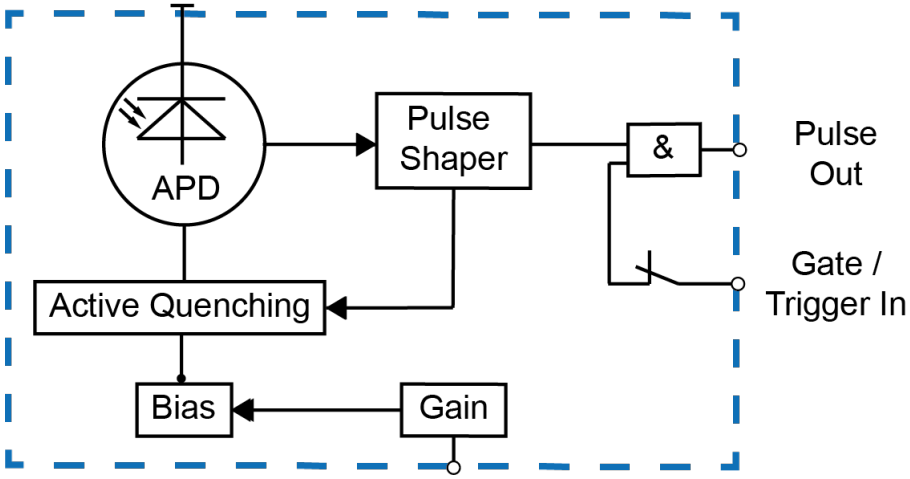
Gain Adjustment

Using the gain adjustment screw, an overvoltage beyond the breakdown voltage can be adjusted to the SPDMA. This increases the photon detection efficiency but also the dark count rate.

Please be aware that the probability of afterpulsing slightly rises with higher gain settings and that adjusting the gain also affects the time between photon detection and signal output.

The dead time increases with decreasing gain.

3.5 Block Diagram and Trigger IN



The current pulse generated by an incoming photon passes a pulse shaping circuit, which is shortening the APD's output TTL pulse duration. On the "Pulse Out" terminal the signal from the pulse shaper is applied so that counts can be viewed on an oscilloscope or registered by an external counter. In the absence of a Trigger, the gate is closed and allows signal out.

The Gain changes the Bias (overvoltage) on the APD. The Bias is physically guided through the active quenching element but does not impact the active quenching.

TTL Trigger:

The TTL Trigger allows for selective activation of the pulse output: At high Trigger Input (specified in the Technical Data) the signal arrives at Pulse Out. This is the default whenever no external TTL signal is applied as a trigger.

Whenever a TTL trigger input signal is used, the default TTL input needs to be "Low". Signal from photon detection is sent to Pulse Out as the Trigger Input voltage switches to "High". High and Low signal are specified in the section Technical Data.

Note

"Trigger In" and "Pulse Out" are of a 50 Ω impedance. Make sure that the trigger pulse source is capable to work on a 50 Ω load and that the device connected to "Pulse Out" operates at a 50 Ω input impedance.

4 Maintenance and Service

Protect the SPDMA from adverse weather conditions. The SPDMA is not water resistant.

Attention

To avoid damage to the instrument, do not expose it to spray, liquids or solvents!

The unit does not need regular maintenance by the user. It does not contain any modules and/or components that could be repaired by the user. If a malfunction occurs, please contact Thorlabs for return instructions.

Do not remove covers!

4.1 Troubleshooting

APD over temperature indicated

The temperature control circuit recognized that the actual temperature of the APD exceeded the set point. Under normal operation conditions this should not happen, even after long term operation. However, increase beyond the limits of the specified operating temperature range or excessive thermal radiation on the detector can cause an overtemperature alert. The Status LED will turn to red to indicate overheating.

- Ensure enough air flow around the device or provide external passive cooling.

5 Appendix

5.1 Technical Data

All technical data are valid at 45 ± 15% rel. humidity (non condensing).

Item #	SPDMA
Detector	
Detector Type	Si APD
Wavelength Range	350 nm - 1100 nm
Diameter of Active Detector Area	500 µm
Typical Photon Detection Efficiency (PDE) at Gain Max	58% (@ 500 nm) 66% (@ 650 nm) 43% (@ 820 nm)
Gain Adjustment Factor (Typ)	4
Count Rate @ Gain Max. Min Typ	 >10 MHz 20 MHz
Dark Count Rate @ Gain Min @ Gain Max	 < 75 Hz (Typ); < 400 Hz (Max) < 300 Hz (Typ); < 1500 Hz (Max)
Dead Time @ Maximum Gain	< 35 ns
Output Pulse Width @ 50 Ω load	10 ns (Min); 15 ns (Typ); 20 ns (Max)
Output Pulse Amplitude @ 50 Ω load TTL High TTL Low	 3.5 V 0 V
Trigger Input TTL Signal [1] Low (closed) High (open)	 < 0.8 V > 2 V
Afterpulsing Probability @ Gain Min.	1% (Typ)
General	
Power Supply	±12 V, 0.3 A / 5 V, 2.5 A
Operating Temperature Range [2]	0 to 35 °C
APD Operating Temperature	-20 °C
APD Temperature Stability	< 0.01 K
Storage Temperature Range	-40 °C to 70 °C
Dimensions (W x H x D)	72.0 mm x 51.3 mm x 27.4 mm (2.83 " x 2.02 " x 1.08 ")
Weight	150 g

[1]) Default in the absence of a TTL signal is > 2 V, allowing signal to the pulse output. The detector behavior is not defined between 0.8 V and 2 V.

[2]) Non-condensing

5.2 Definitions

Active Quenching occurs when a fast discriminator senses the steep onset of the avalanche current, released by a photon, and quickly reduces the bias voltage so that it is below breakdown momentarily. The bias is then returned to a value above the breakdown voltage in preparation for detection of the next photon.

Afterpulsing: During an avalanche, some charges can be trapped inside the high field region. When these charges are released, they can trigger an avalanche. These spurious events are called afterpulses. The life of those trapped charges is on the order of 0.1 µs to 1 µs. Hence, it is likely that an afterpulse occurs directly after a signal pulse.

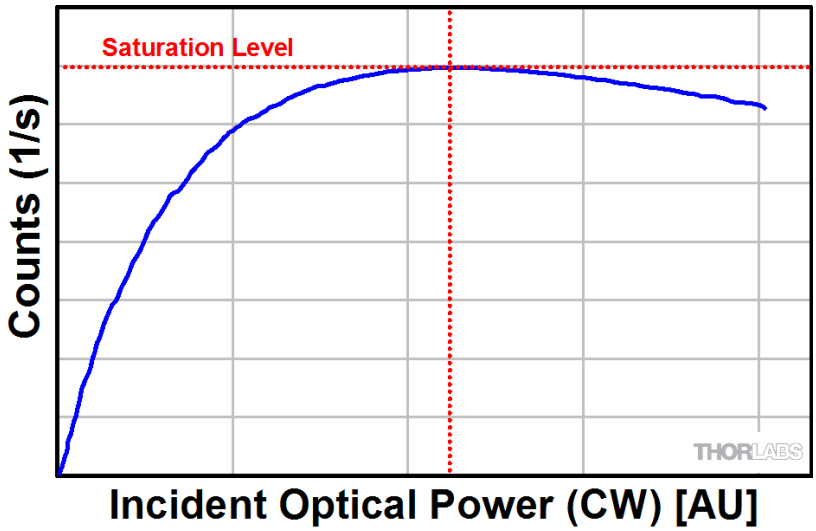
Dead Time is the time interval the detector spends in its recovery state. During this time, it is effectively blind to incoming photons.

Dark Count Rate: This is the average rate of registered counts in the absence of any incident light and determines the minimum count rate at which the signal is dominantly caused by real photons. The false detection events are mostly of thermal origin and can therefore be strongly suppressed by using a cooled detector.

Geiger Mode: In this mode, the diode is operated slightly above the breakdown threshold voltage. Hence, a single electron-hole pair (generated by absorption of a photon or by a thermal fluctuation) can trigger a strong avalanche.

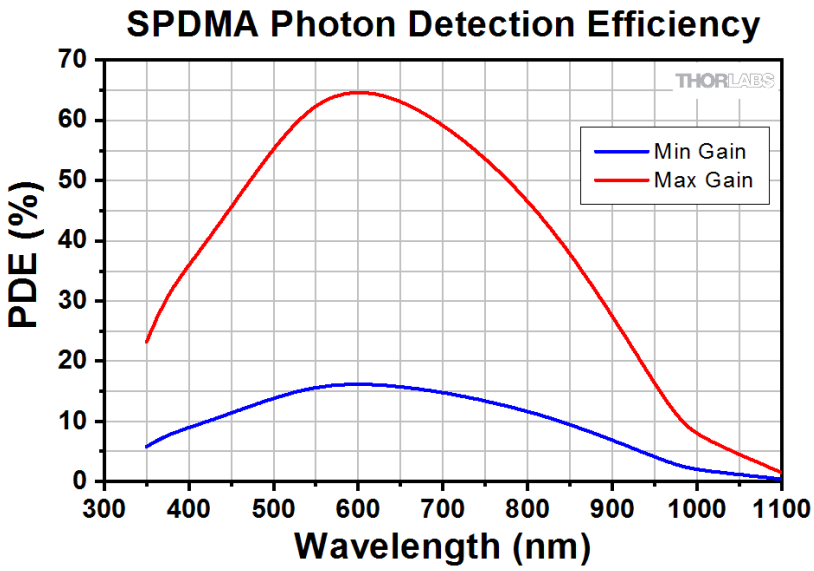
Gain Adjustment Factor: This is the factor by which the gain can be increased.

Saturation of the APD: The photon count by an APD is not exactly linearly proportional to the incident optical CW power; the deviation increases smoothly with increasing optical power. This non-linearity leads to the wrong photon count at high input power levels. At a certain input power level, the photon count begins even to decrease with further increase in optical power. Each delivered SPDMA is tested for appropriate Saturation behavior to resemble this example.

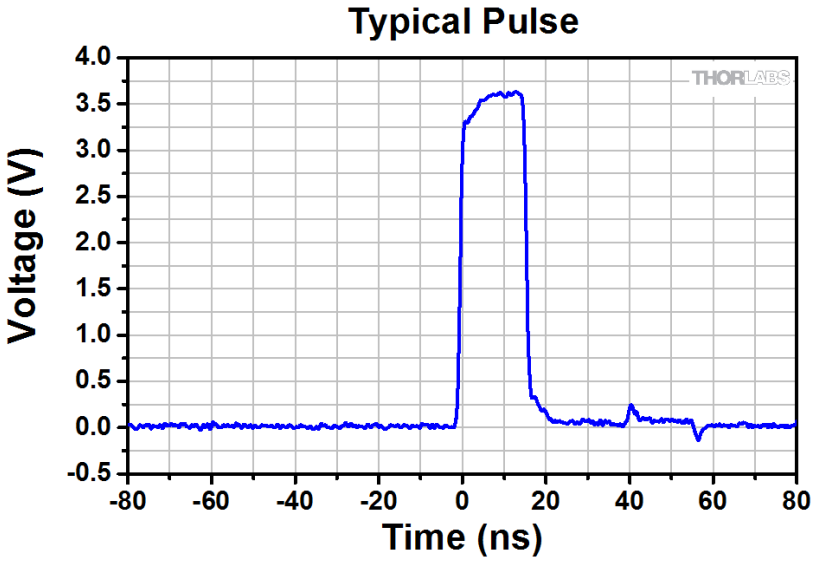


5.3 Performance Plots

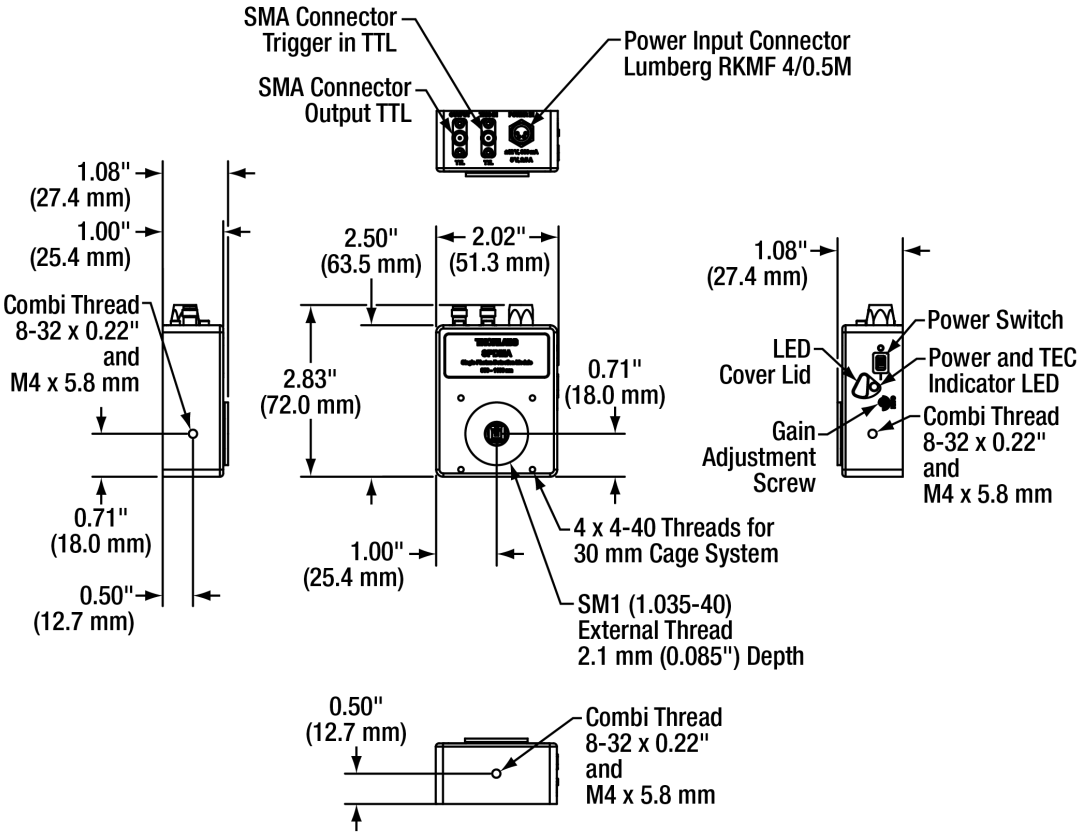
5.3.1 Typical Photon Detection Efficiency



5.3.2 Pulse Out Signal



5.4 Dimensions



5.5 Safety

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

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly as it was designed.

The SPDMA must not be operated in explosion endangered environments!

Do not obstruct any air ventilation slots in the housing!

Do not remove covers or open the cabinet. There are no user-serviceable parts inside!

This precision device is only serviceable if returned and properly packed into the complete original packaging including the cardboard inserts. If necessary, ask for replacement packaging.

Refer servicing to qualified personnel!

Changes to this device cannot be made nor may components not supplied by Thorlabs be used without written consent from Thorlabs.

Attention

Prior to applying power to the SPDMA, make sure that the protective conductor of the 3 conductor mains power cord is correctly connected to the protective earth ground contact of the socket outlet! Improper grounding can cause electric shock resulting in damage to your health or even death!

All modules must only be operated with duly shielded connection cables.

Attention

The following statement applies to the products covered in this manual, unless otherwise specified herein. The statement for other products will appear in the respective accompanying documentation.

Note

This equipment has been tested and found to comply with the limits for a Class B 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 a residential 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. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Users that change or modify the product described in this manual in a way not expressly approved by Thorlabs (party responsible for compliance) could void the user's authority to operate the equipment.

Thorlabs GmbH 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.

Attention

Mobile telephones, cellular phones or other radio transmitters are not to be used within the range of three meters of this unit since the electromagnetic field intensity may then exceed the maximum allowed disturbance values according to IEC 61326-1.

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).

5.6 Certifications and Compliances

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs GmbH

Of: Münchner Weg 1, 85232 Bergkirchen, Deutschland

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: ***SPDMA***

Equipment: ***Single Photon Detection Module***

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
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2021

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:* 26 July 2021

Name: Dr. Bruno Gross

Position: General Manager

EDC - SPDMA -2021-07-26

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5.7 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.

5.8 Manufacturer Address

Manufacturer Address Europe
Thorlabs GmbH
Münchner Weg 1
D-85232 Bergkirchen
Germany
Tel: +49-8131-5956-0
Fax: +49-8131-5956-99
www.thorlabs.de
Email: europe@thorlabs.com

EU-Importer Address
Thorlabs GmbH
Münchner Weg 1
D-85232 Bergkirchen
Germany
Tel: +49-8131-5956-0
Fax: +49-8131-5956-99
www.thorlabs.de
Email: europe@thorlabs.com

5.9 Warranty

Thorlabs warrants material and production of the SPDMA for a period of 24 months starting with the date of shipment in accordance with and subject to the terms and conditions set forth in Thorlabs' General Terms and Conditions of Sale which can be found at:

General Terms and Conditions:

https://www.thorlabs.com/Images/PDF/LG-PO-001_Thorlabs_terms_and_%20agreements.pdf

and

https://www.thorlabs.com/images/PDF/Terms%20and%20Conditions%20of%20Sales_Thorlabs-GmbH_English.pdf

5.10 Copyright and Exclusion of Liability

Thorlabs has taken every possible care in preparing this document. We however assume no liability for the content, completeness or quality of the information contained therein. The content of this document is regularly updated and adapted to reflect the current status of the product.

Please refer to the general terms and conditions linked under Warranty.

5.11 Thorlabs Worldwide Contacts - WEEE Policy

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

USA, Canada, and South America
Thorlabs, Inc.
sales@thorlabs.com
techsupport@thorlabs.com

UK and Ireland
Thorlabs Ltd.
sales.uk@thorlabs.com
techsupport.uk@thorlabs.com

Europe
Thorlabs GmbH
europe@thorlabs.com

Scandinavia
Thorlabs Sweden AB
scandinavia@thorlabs.com

France
Thorlabs SAS
sales.fr@thorlabs.com

Brazil
Thorlabs Vendas de Fotônicos Ltda.
brasil@thorlabs.com

Japan
Thorlabs Japan, Inc.
sales@thorlabs.jp

China
Thorlabs China
chinasales@thorlabs.com

Thorlabs 'End of Life' Policy (WEEE)

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 users responsibility to delete all private data stored on the device prior to disposal.

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