THORLABS

Adjustable Gain Avalanche Photodetectors

APD450C Operation Manual

2020

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Contents

We aim to develop and produce the best solution for your application in the field of optical measurement technique. To help us to live up to your expectations and improve our products permanently we need your ideas and suggestions. Therefore, please let us know about possible criticism or ideas. 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

Avalanche Photodetectors (APDs) have an exceptionally low noise-equivalent power (NEP), making them ideal for fast low-level light detection applications, such as spectroscopy, fluorescence measurements, laser radar and optical rangefinders. Due to their very high sensitivity, Avalanche Photodetectors can replace Photomultiplier Tubes (PMT) in many applications.

The Thorlabs APD450C temperature-compensated Avalanche Photodetector combines a high-sensitivity Avalanche Photodiode for detection of light from 1260 nm to 1620 nm with a specially designed ultra-low-noise transimpedance amplifier for detection of optical signals from 0.3 MHz to 1600 MHz.

The continuously adjustable gain is based on the adjustment of the APDs multiplication factor (M-factor). Each detector also features a special electronic circuit to compensate for the temperature dependency of the M-factor.

The detector housing can be integrated in optical setups using convenient 8-32 and M4 combi-thread mounting holes that are compatible with both imperial and metric threading.

The housing accommodates Thorlabs' SM05 (0.535"-40) and SM1 (1.035"-40) threaded adapters and accessories. This allows convenient mounting of external optics, light filters, and apertures. The product includes a 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. For accessories, please visit our website or contact Thorlabs 18.

The APD450C Avalanche Photodetectors are powered by the included external power supply LDS12B (±12 VDC, 250 mA) via a PICO M8 power connector. The appropriate input voltage (100 VAC, 120 VAC, 230 VAC) can be selected with a switch on the power supply 2.

Attention

Please find all safety information and warnings concerning this product in the chapter Safety 14 in the Appendix.

WARNING

Do not remove covers! Dangerous deadly high voltage!

1.1 Ordering Codes and Accessories

APD450C	Temperature Compensated Avalanche Photodetector, InGaAs APD, 1260 - 1620 nm, Bandwidth Range 0.3 MHz - 1600 MHz, Active Area Diameter: 75 µm (with ball lens 1.5 mm), Combi-Thread Mounting Holes Compatible with 8-32 and M4 Threads

2 Getting Started

2.1 Parts List

Inspect the shipping container for damage. Please do not cut through the cardboard. You might need the box for storage or for returns.

If the shipping container seems to be damaged, keep it until you have inspected the contents and you have inspected the APD450C mechanically and electrically.

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

1. APD450C Temperature-Compensated Variable Gain Avalanche Photodetector
2. Plastic Cover Cap (SM1EC2B) on a Coupler (SM1T1 SM1 Coupler) with a Retaining Ring (SM1RR SM1 Retaining Ring)
3. LDS12B Power Supply (±12V, 250 mA), 100 VAC, 120 VAC or 230 VAC line voltage
4. Quick Reference

2.2 Preparation

Carefully unpack the unit and accessories. If any damage is noticed, do not use the unit. Contact Thorlabs 18 and have us replace the defective unit.

Prior to operation, please check if the indicated line voltage range on the power supply matches with your local mains voltage! Adjust the power supply accordingly to 100 VAC, 120 VAC or 230 VAC.

Attention

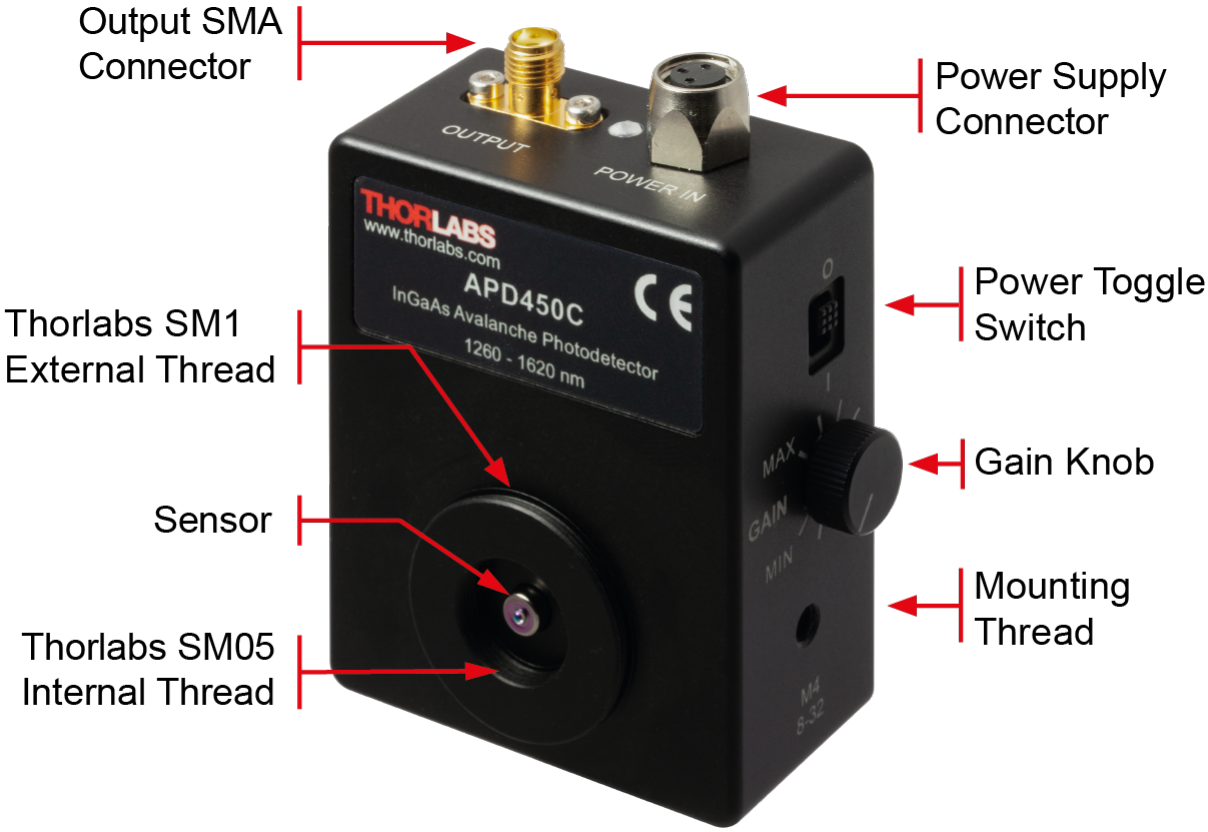
Wrong settings for the mains voltage may damage the power supply.

Note

If you prefer to use your own power supply, please ask Thorlabs 18 for an appropriate power connector cable.

3 Operating Instruction

3.1 Operating Elements



3.2 Mounting

Housing

The APD450C is housed in a rugged, shielded, 72.0 mm x 56.3 mm x 27.4 mm aluminum enclosure.

Mounting APD450C on an Optical Table

Mount the APD450C on an optical post by using either of the three tapped mounting holes on the sides and bottom. The combi-thread tapped holes accept both 8-32 and M4 threads, such that using either imperial or metric TR posts is possible.

Note

Please see the chapter Drawings 12 for precise dimensions.

Mounting External Optics

The APD450C housing allows to mount external optics, filters, apertures or fiber adapters. For this, it features Thorlabs' SM05 (0.535"-40) threads and SM1 (1.035"-40) threads that are compatible with any number of Thorlabs 1" and ½" threaded accessories. This also allows convenient mounting of lens tubes or cage systems. For accessories, please visit our website or contact Thorlabs 18.

The APD450C is delivered with an SM1 coupler (SM1T1) which adapts the external thread to an internal SM1 thread and holds the SM1RR retaining ring and a reusable protective plasic cover cap. Please unscrew the coupler if needed.

3.3 Operation

Attention

Prior to connecting the power supply to the mains power, ensure that the correct mains voltage is selected on the power supply 2. Wrong settings for the mains voltage may damage the power supply. The ±12 V, 250 mA power supply is included, no high voltage power supply is required for operation.

Attention

Exceeding the optical damage threshold input power will permanently destroy the detector! Please see the Technical Data 9 for the maximum input power.

Electrical Setup

- Mount 3 the detector using the combi-thread mounting holes on either side or on the bottom of the device.
- Plug the power connector cable into the POWER IN.
- Plug the power supply into an outlet.
- Connect the OUTPUT connector jack (SMA) to your data acquisition device with a coaxial cable. Please note that a 50 Ω impedance device should be used for best RF performance.
- Switch on the power supply.
- Move the power slider to I to turn on the APD450C. The green LED on the APD450C indicates the correct power supply.

Gain Adjustment

The Gain can be adjusted to achieve an optimal signal to noise ratio (SNR).

The photo-current generated by signal light is amplified by the gain. Because APDs generate noise due to the multiplication process, the noise also increases as the gain is increased. This means that the best SNR for a specific optical input signal exists at a specific gain that can be adjusted.

How to adjust the gain:

- Turn the GAIN knob to minimum before applying the optical signal to the APD450C. This is the condition when the APD450C is least sensitive, can tolerate its highest optical input level and has the lowest noise level.
- Align the light source with the optical input. To avoid electrical saturation, keep the output voltage below this maximum listed in the Technical Data 9. External neutral density filters or attenuators are recommended to reduce the input light level in critical cases.
- Increase the gain to achieve the optimal signal.

Turning off the APD450C

- Move the power slider to O after finishing the measurements.

Note

Avoid saturating the amplifier! Therefore, make sure that the optical input power does not exceed the CW saturation power level listed in Technical Data 9.

3.4 Recommendations

- **Ambient or stray light**
  - o Avalanche Photodetectors are extremely sensitive devices. To achieve precise results, shield the Avalanche Photodetectors from light sources during measurements to reduce the background. Use opaque light barriers like light boxes, cloth or lens tubes.
  - o It is highly recommended to use appropriate band pass filters in front of the detector to minimize the influence of stray light.
  - o It is not necessary to switch off the Avalanche Photodetector when it is exposed to ambient light. The amplifier might saturate but, unlike Photomultiplier Tubes, it will not be damaged or saturated for a long period of time.
- **High Optical Input Power**

  Upon excessive optical input power or at excessive power density (i.e. very focused light and very small beam diameter), a non-linearity caused by intrinsic effects of the APD may appear. Please keep the input power below the maximum input power stated in the Technical Data 9.
- **Electrostatic Coupling**

  Electrostatic coupling of electrical noise associated with ground loops can be critical. In most cases an electrically isolated post (see Thorlabs parts TRE or TRE/M) will suppress electrical noise coupling. Electrical noise sources should always be identified and the distance to the Avalanche Photodetector should be increased. If possible, rotate the Avalanche Photodetector input away from the noise source.
- **Impact of Temperature**
  - o The M-factor is factory set at 23°C ambient temperature. The APD450C is operated at an internal reverse bias voltage that is temperature-compensated. Therefore, the actual M factor will remain nearly constant within the specified ambient temperature range of (23±5)°C. Please see the Appendix for the Typical M factor Temperatur Dependency 11.

3.5 Operating Principle

In general, Avalanche Photodiodes use an internal gain mechanism to increase the sensitivity. Incident photons generate electron-hole pairs, as in normal photo diodes. By applying a high reverse voltage, a strong electric field is generated that accelerates these electrons and produces secondary electrons by impact ionization. This leads to an electron avalanche producing gain factors of up to several hundreds. The amplification depends on the reverse bias voltage and is described by the M-factor.

The reverse bias voltage can be adjusted with the rotary gain knob on the side of the APD450C, resulting in a variation of the M-factor that is equivalent to a gain variation.

3.5.1 Optical Input

The APD450C uses a InGaAs Avalanche Photodiode with a detector active area diameter of 75 µm, expanded with a ball lens to detect light of ∅ 1.5 mm, operating from 1260 to 1620 nm. The typical responsivity curves can be found in the appendix 10.

An open beam should be carefully aligned with the detector. External optics, filters or apertures can be easily attached to the Avalanche Photodetectors because the housing is compatible with any number of Thorlabs 1" and ½" threaded accessories.

For detectors with smaller active areas, as it is the case for APD450C, it is recommended to focus the optical signal out of the fiber onto the detector.

For this and other fiber coupled applications, fiber adapters like Thorlabs S120-xx series can be mounted on the optical input. The fiber adapter will accommodate a multi-mode as well as single-mode fiber. For detailed information on fiber coupling, please see the appendix 13.

Note

Coupling loss may occur due to small detector size, which will result in a reduced output signal. If angled connectors are used, the fiber adapter can be rotated from its original position to check for an improved alignment. For this process use an optical input power below the saturation power while observing OUTPUT voltage.

Saturation of the OUTPUT will occur at optical input power greater than CW Saturation Power listed in specifications 9. If necessary, use external neutral density filters or attenuators to reduce the input light level. Please note that Avalanche Photodetectors are extremely sensitive to unwanted stray light. Careful shielding of the Avalanche Photodetectors from any unwanted light sources is essential. Common techniques to minimize the influence of stray light include baffling or other opaque barriers like black cloths, beam tubes or using appropriate band pass filters in front of the detector.

Note

For the APD450C the output signal must not exceed the Output Power at 1 dB Compression, which is the point at which the amplified signal at 1 GHz is compressed by 1 dB. Above this value, the amplified signal will become non-linear and begin to saturate. The output voltage at this saturation point can be calculated using the following formula:

$$V = \sqrt{RP_0 10^{L(dBm)/10}}$$

where R is the load impedance (50 Ω), P_0 is defined as 1 mW, and L(dBm) is the power level in dBm.

Attention

The optical damage threshold is 1 mW. Exceeding this value will permanently destroy the Avalanche Photodetector!

3.5.2 Electrical Output

Thorlabs APD450C Avalanche Photodetectors deliver an output voltage. The ouput voltage V_{out} is a function of the incident light power P_{opt}, the detector's responsivity $\Re_M(\lambda)$ at a given wavelength and M-factor, and the transimpedance gain G:

$$V_{out} = P_{opt} \times \Re_M(\lambda) \times G$$

- $\Re_M(\lambda)$ for a given wavelength can be read from the typical spectral responsivity curves (see Appendix 10).
- The M-factor (gain) adjustment range for APD450C is 2 to 10 at 23°C ambient temperature.
- The amplifier's transimpedance gain G is 5 kV/A at 50 Ω.

The maximum output voltage of the APD450C is 2.0 V into 50 Ω. Depending on the wavelength, the responsivity $\Re(\lambda)$ of the detector and the M factor, the amplifier will reach saturation at optical input power greater than CW Saturation Power listed in specifications. To avoid saturation, keep the output signal below the specified maximum output voltage.

The ultra-low noise design includes an active low-pass filter to effectively suppress out-of-band noise.

Please find typical curves for Responsivity 10, Output Frequency Response 10 and Spectral Noise Distribution 11 and M Factor Temperature Dependency 11 in the chapter Appendix.

3.5.3 Temperature Compensation

Due to internal processes, the M-factor is temperature dependent. At a fixed reverse bias voltage the M-factor will change with temperature: with lower temperatures the M-factor will increase, with higher temperatures, it will decrease.

To compensate for this effect, the Thorlabs APD450C Avalanche Photodetectors carry a thermistor that senses the temperature inside the APD450C enclosure. A special electronic circuit controls the reverse voltage applied to the APD in accordance with the temperature change. Since the M-factor depends on the applied reverse voltage, this reduces the temperature dependency of the M factor. Please see the technical data for the M-factor Temperature Stability 9 specifications and the section M Factor Temperature Dependency 11 for typical curves.

4 Maintenance and Service

Protect the APD450C from adverse weather conditions. The APD450C 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 himself. If a malfunction occurs, please contact Thorlabs 18 for return instructions.

WARNING

Do not remove covers! Dangerous deadly high voltage!

5 Appendix

5.1 Technical Data

	APD450C
Parameter	
Detector Material/Type	InGaAs APD
Wavelength Range	1260 to 1620 nm
Typical Maximum APD Responsivity	9 A/W @ 1550 nm (M = 10)
Detector Active Area Diameter	75 µm, with ∅1.5 mm Ball Lens
M Factor Adjustment Range	2 - 10 (Continuous)
M Factor Temperature Stability[1]	± 2% (Typical); ± 3% (Max)
Transimpedance Gain	5 kV/A (50 Ω Termination)
Maximum Conversion Gain[2]	45 x 10^3 V/W (50 Ω)
Output Bandwidth (3 dB)[3]	0.3 MHz to 1600 MHz
CW Saturation Power	0.1 mW @ 1550 nm, M=10 0.5 mW @ 1550 nm, M=2
Maximum Input Power (Photodiode Damage Threshold)	1 mW
Minimum NEP[4]	1.1 pW/√ Hz (0.3 - 1600 MHz)
Integrated Noise (RMS)[3]	35 nW (0.3 - 1600 MHz)
Electrical Output, Impedance	SMA, 50 Ω
Maximum Output Voltage	2.0 V (50 Ω)
Power Supply	±12 V, 250 mA (100 V , 120 V , 230 V switchable)
General	
Operating Temperature Range [5]	0 to 40 °C
Storage Temperature Range	-40 to 70 °C
Dimensions (W x H x D)	2.22" x 2.83" x 1.08" (56.3 mm x 72.0 mm x 27.4 mm)
Weight	0.12 kg

[1] Ambient temperature within (23 ± 5)°C.

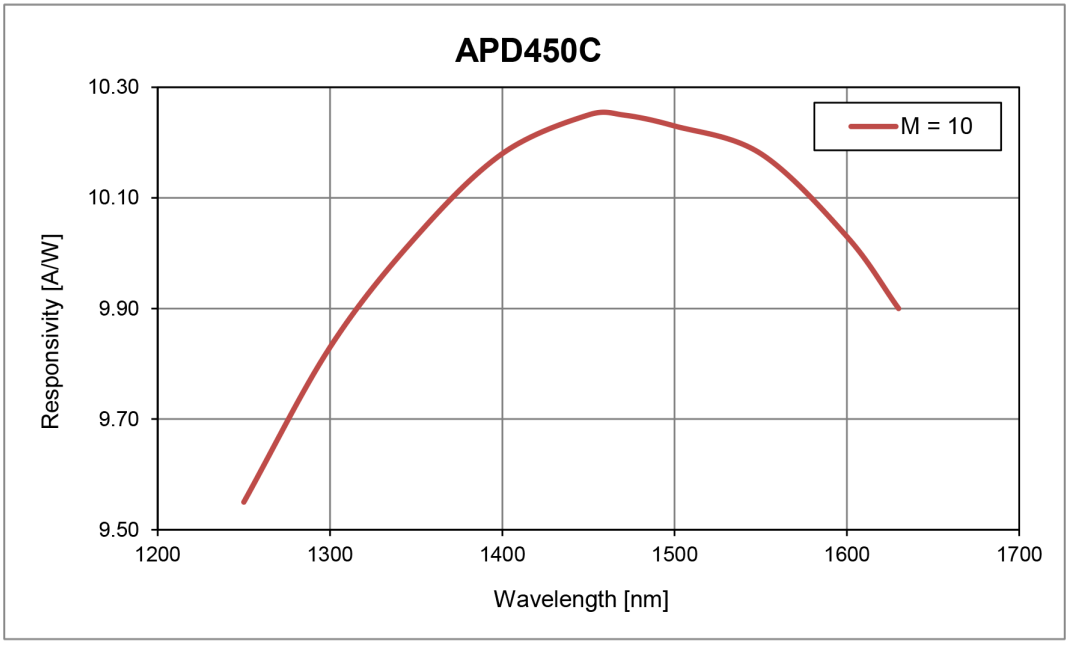
[2] The Conversion Gain is product of the Transimpedance Gain and the Responsivity for a given M factor and wavelength.

[3] At Maximum Gain Setting.

[4] For more information on how NEP is calculated, please see Thorlabs' Noise Equivalent Power White Paper.

[5] Non-condensing

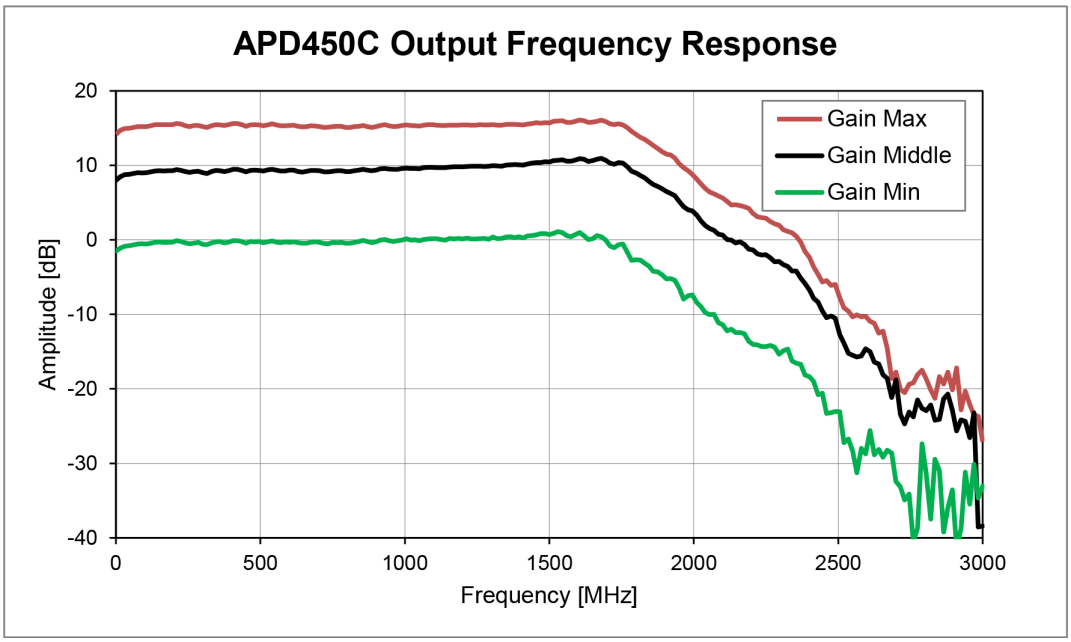
5.2 Typical Responsivity Curves



Typical Detector Responsivity APD450C; M = 10

5.3 Typical Output Frequency Response

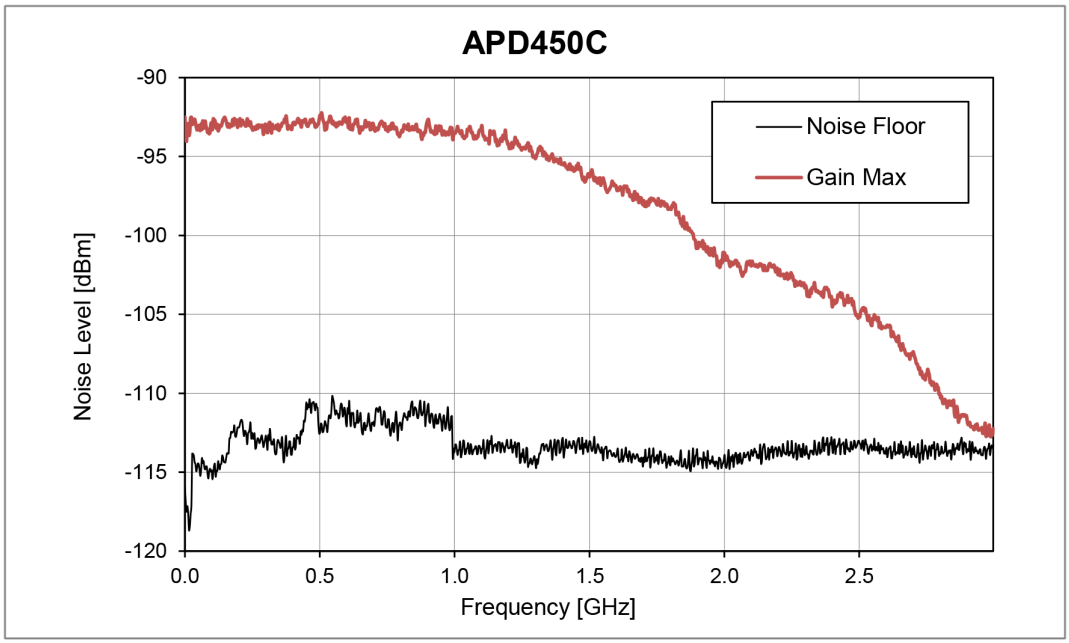
Effect of the gain settings on the respective Typical Output Frequency Response.
For this measurement a test signal, generated by an optical transmitter, was fiber-coupled to the Avalanche Photodetector. The Output Frequency Response was measured using an optical network analyzer.



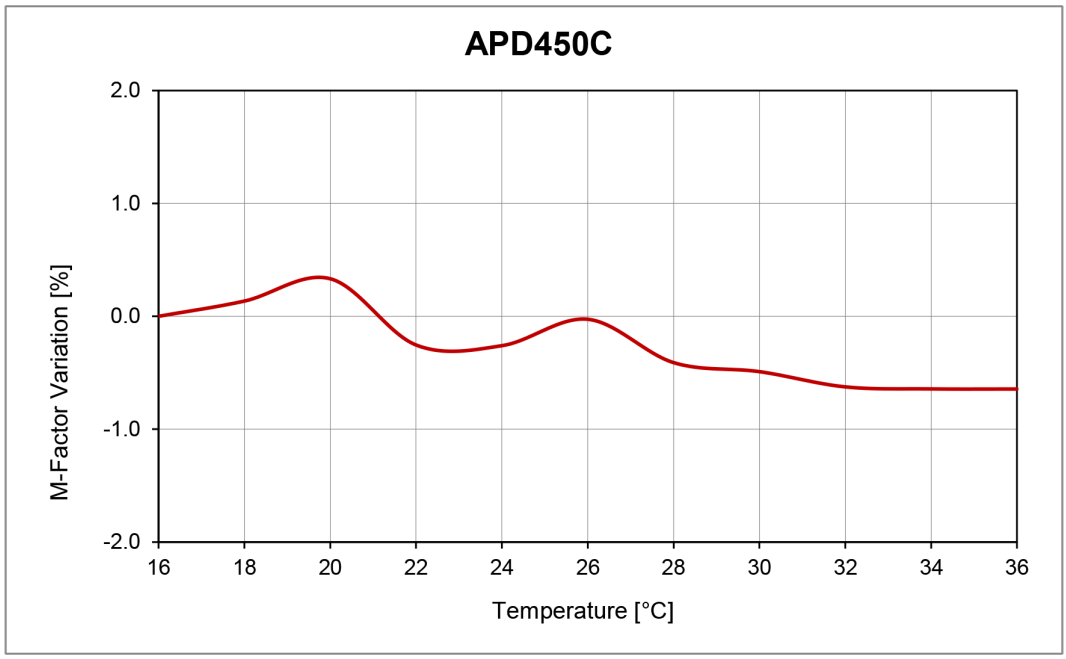
Typical Output Frequency Response APD450C

5.4 Typical Spectral Noise

The typical noise spectrum was measured using an electrical spectrum analyzer (resolution bandwidth 1 kHz, video bandwidth 1 kHz). The optical input of the detector was blocked. The black curve ("Reference") was measured with the same setup and the detector switched off, i.e., it represents the measurement system's noise floor.

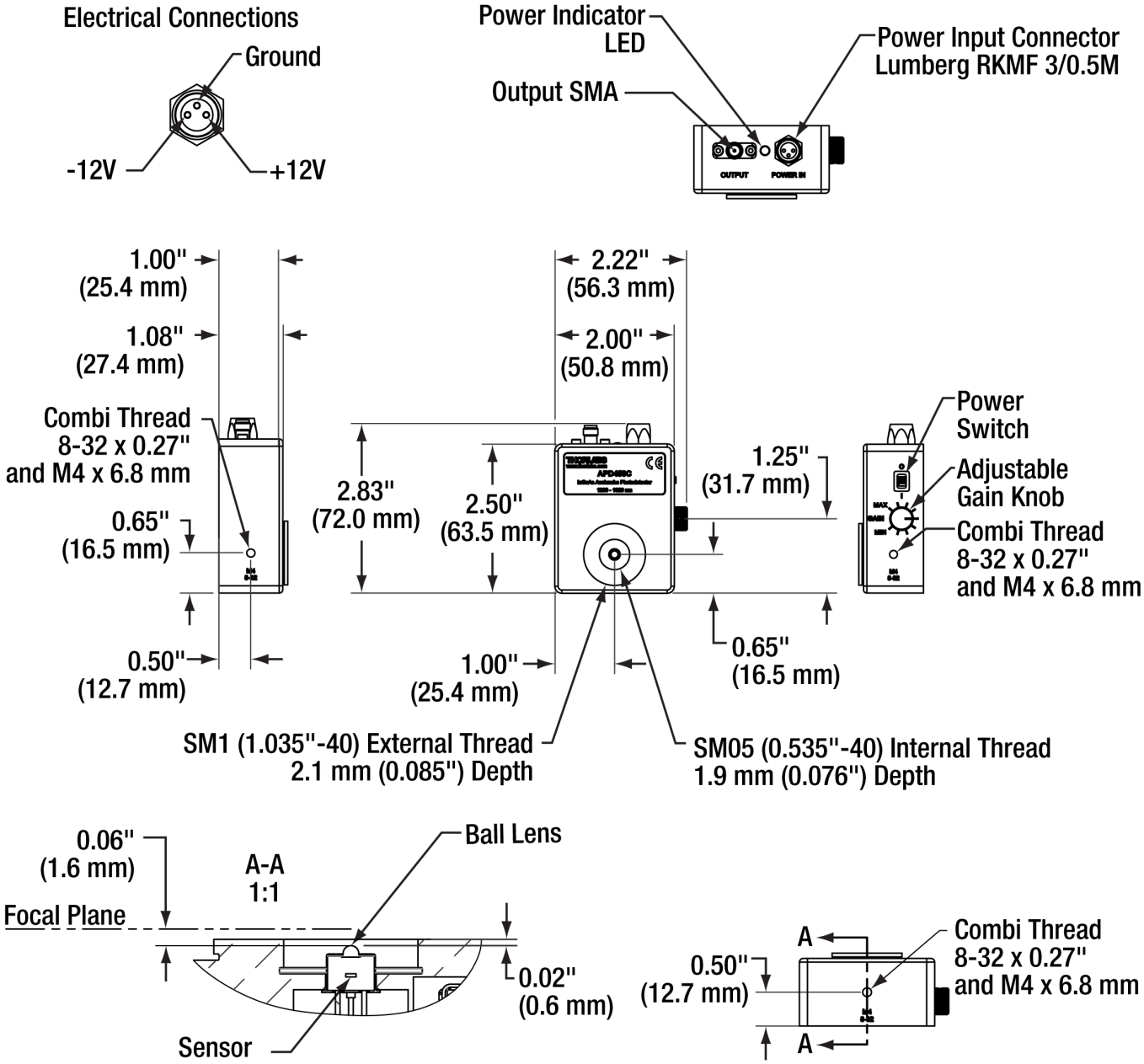


5.5 Typical M Factor Temperature Dependency



5.6 Drawings

The below drawings show the APD450C without the SM1 coupler.



5.7 Fiber Coupling onto Small Detector Area

When coupling an optical fiber into the APD450C, please consider the beam divergence out of the fiber tip and the active detector area.

For APD450C we recommend to compensate for possible beam divergence out of the fiber by using a collimator and a focusing lens. Below is a possible arrangement, shown on the example of the APD430A2/M. The arrangement is identical for all Thorlabs Avalance Photodiodes.

The assembly in front of the detector comprises of a fiber collimator (dependent on fiber), a lens tube collimator adapter (AD11F or AD12F, dependent on collimator), a SM1L1 lens tube with aspheric lens inside (not visible above) and a LM1XY X-Y translation mount.

The beam out of the fiber is collimated (transferred into a nearly parallel beam) and afterwards focused by the aspheric lens. In the case of the APD450C, the beam should be focused onto the focal plane of the integrated ball lens. The X-Y translation mount allows the focused beam to be aligned with the center of the sensor.

5.8 Safety

Attention

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 for.

The APD450C must not be operated in explosion endangered environments!

Do not obstruct the air ventilation slots in the housing!

Do not remove covers!

Do not open the cabinet.There are no parts serviceable by the operator inside!

This precision device is only serviceable if properly packed into the complete original packaging including the plastic foam sleeves. If necessary, ask for replacement packaging.

Refer servicing to qualified personnel!

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

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

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).

5.9 Manufacturer Address

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

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

5.10 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.

5.11 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: ***APD450C***

Equipment: ***Avalanche Photodetector***

is 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	2013

and which, issued under the sole responsibility of Thorlabs, is 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:

does not contain 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:* 15 November 2019

Name: Bruno Gross

Position: General Manager

EDC - APDxxxx -2019-11-15

CE

5.12 Warranty

Thorlabs warrants material and production of the APD450C for a period of 24 months starting with the date of shipment. During this warranty period Thorlabs will see to defaults by repair or by exchange if these are entitled to warranty.

For warranty repairs or service the unit must be sent back to Thorlabs. The customer will carry the shipping costs to Thorlabs, in case of warranty repairs Thorlabs will carry the shipping costs back to the customer.

If no warranty repair is applicable the customer also has to carry the costs for back shipment.

In case of shipment from outside EU duties, taxes etc. which should arise have to be carried by the customer.

Thorlabs warrants the hard- and/or software determined by Thorlabs for this unit to operate fault-free provided that they are handled according to our requirements. However, Thorlabs does not warrant a fault free and uninterrupted operation of the unit, of the software or firmware for special applications nor this instruction manual to be error free. Thorlabs is not liable for consequential damages.

Restriction of Warranty

The warranty mentioned before does not cover errors and defects being the result of improper treatment, software or interface not supplied by us, modification, misuse or operation outside the defined ambient stated by us or unauthorized maintenance.

Further claims will not be consented to and will not be acknowledged. Thorlabs does explicitly not warrant the usability or the economical use for certain cases of application.

Thorlabs reserves the right to change this instruction manual or the technical data of the described unit at any time.

5.13 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 hardware and/or software. We furthermore do not guarantee that this product will function without errors, even if the stated specifications are adhered to.

Under no circumstances can we guarantee that a particular objective can be achieved with the purchase of this product.

Insofar as permitted under statutory regulations, we assume no liability for direct damage, indirect damage or damages suffered by third parties resulting from the purchase of this product. In no event shall any liability exceed the purchase price of the product.

Please note that the content of this document is neither part of any previous or existing agreement, promise, representation or legal relationship, nor an alteration or amendment thereof. All obligations of *Thorlabs* result from the respective contract of sale, which also includes the complete and exclusively applicable warranty regulations. These contractual warranty regulations are neither extended nor limited by the information contained in this document. Should you require further information on this product, or encounter specific problems that are not discussed in sufficient detail in the document, please contact your local *Thorlabs* dealer or system installer.

5.14 List of Acronyms

Acronyms

AC	Alternating Current
APD	Avalanche Photo Diode
CW	Continuous Wave
DC	Direct Current
LED	Light Emitting Diode
NEP	Noise Equivalent Power
RF	Radio Frequencies
InGaAs	Indiumgalliumarsenide
SNR	Signal-to-Noise Ratio
UV	Ultraviolet

5.15 Thorlabs Worldwide Contacts and WEEE policy

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

USA, Canada, and South America
Thorlabs, Inc.
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Japan
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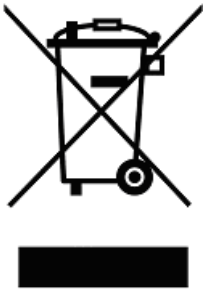
sales@thorlabs.jp

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.



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