

Femtowatt Photoreceiver

PDF10x Operation Manual





2018



Version: 1.3 Date: 05-Dec-2018

Copyright © 2018 Thorlabs

Contents

F	oreword
1	General Information
	1.1 Safety
2	Setting Up
	2.1 Parts List 2.2 Getting Started
3	Operating Instruction
	 3.1 General Principle of Operation
	3.4 Mounting the PDF10x Series
4	Maintenance and Service
5	4.1 Recommendations Appendix
	5.1 Technical Data 5.1.1 PDF10A 5.1.2 PDF10C 5.2 Dimensions
	5.3 Certifications and Compliances
	5.4 Warranty
	5.5 Exclusion of Reliability and Copyright
	5.6 Thorlabs 'End of Life' Policy (WEEE)
	5.7 Thorlabs Worldwide Contacts



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 constantly improve our products 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

The Thorlabs PDF10x series Femtowatt Photoreceivers combines a very low noise Silicon or InGaAs photodiode with a specially designed ultra low noise transimpedance amplifier with extremely high gain of up to 10^{12} V/A. This unique combination results in a Photoreceiver with femtowatt sensitivity due to its exceptional low NEP, making them ideal for low-light level detection applications, such as spectroscopy and fluorescence measurements. Direct detection of optical power down to ~10 fW is possible; in combination with an optional Lock-In Amplifier even sub-femtowatt sensitivity can be achieved.

Due to a very high sensitivity the PDF10x Femtowatt Photoreceivers can replace photomultiplier tubes (PMT's), avalanche photodiodes (APD's) and liquid nitrogen cooled germanium photodiodes in many applications. No expensive high voltage power supply or cooling is required.

The PDF10x cannot be damaged by unwanted ambient light, which is critical for many photomultiplier tubes.

The new slim line housing includes a removable threaded coupler that is compatible with a number of Thorlabs 1" and $\frac{1}{2}$ " threaded accessories. This allows convenient mounting of external optics, filters, apertures or fiber adapters, as well as providing an easy mounting mechanism using the Thorlabs cage assembly accessories. The PDF10x has three tapped mounting holes and includes an external power supply.

The "Getting Started 5" section below gives an overview of how to set up the PDF10x series Femtowatt Photoreceivers. Subsequent sections contain detailed information about principle of operation, operating suggestions and technical specifications.

1.1 Safety

Attention

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.

Before connecting the power supply to the mains make sure that the line voltage range marked on the power supply agrees with your local supply.

The unit must not be operated in explosion endangered environments!

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

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

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

Mobile telephones, handy 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 EN 50 082-1.

1.2 Ordering Codes and Accessories

The following models of PDF10x series are available:

PDF10A Femtowatt Photoreceiver, Silicon detector, 320 - 1100nm

PDF10C Femtowatt Photoreceiver, InGaAs detector, 800 - 1700nm

Accessories

S120-FC Fiber Adapter Cap with Internal SM1 (1.035"-40) Thread

S120-SMA SMA Fiber Adapter Cap with Internal SM1 (1.035"-40) Thread

In general, all Thorlabs internal SM1 (1.035"-40) and external SM05 (0.535"-40) threaded accessories are compatible with the PDF10x. Please refer to www.thorlabs.com for further information.

2 Setting Up

2.1 Parts List

Inspect the shipping container for damage.

If the shipping container seems to be damaged, keep it until you have inspected the contents and you have inspected the PDF10x mechanically and electrically.

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

- 1. PDF10x Femtowatt Photoreceiver
- 2. SM1T1 SM1 Coupler (internal thread)
- 3. Metal cover cap
- 4. LDS12B power supply (±12V, 250 mA), 100 V, 120 V, or 230 V line voltage
- 5. Operation manual

2.2 Getting Started

Note

Please check prior to operation, if the indicated line voltage range on the power supply matches with your local mains voltage! If you want to use your own power supply, you can ask Thorlabs for an appropriate power connector cable.

- If necessary, mount the unit on your optical table or application. The unit has three tapped mounting holes (see chapter Mounting the PDF10x Series a) for details).
- Make sure, the PDF10x is switched off (see Operating Elements 7)
- Switch the power supply to your local main voltage (100 VAC, 120 VAC, or 230 VAC):



Voltage Selector Switch

- Plug the power connector cable into the **POWER IN**.
- Plug the power supply into a 50-60 Hz, 100 VAC, 120 VAC, or 230 VAC outlet, turn power supply on.
- Connect the output with a coaxial cable to your data acquisition device. Please note, that a high impedance device (>10kOhm) should be used for best performance.

3 Operating Instruction

- Turn the power switch to on ("I") while the optical input is protected by the metal cover cap.
- Please check, that OUTPUT offset voltage is within the range listed in Technical Data. A small drift during warm up period (~5min) is typical.
- Please also check, that noise level is not higher than 5mVRMS. If noise level is significantly higher, please refer to recommendations and optimize your setup.
- Remove the metal cover cap to detect your optical signal.
- If necessary, mount external optics, filters, apertures or fiber adapters.
- The maximum OUTPUT voltage swing is +10V for high impedance loads (>10kOhm). The OUTPUT signal should be below this maximum output voltage to avoid amplifier saturation.
- Turn the power switch to O when you are finished the measurements.

Note

To prevent saturation of the amplifier keep the optical input powers less than the saturation power listed in Technical Data.

Attention

Refer to the Technical Data and pay attention to the optical damage threshold! Exceeding these values will permanently destroy the detectors!

3.1 General Principle of Operation

The Thorlabs PDF10x series Femtowatt Photoreceivers combines a very low noise Silicon or InGaAs photodiode with a specially designed ultra low noise transimpedance amplifier with extremely high gain of up to 10^{12} V/A. This unique combination results in a photoreceiver with femtowatt sensitivity due to its exceptional low NEP, making them ideal for low-light level detection applications, such as spectroscopy and fluorescence measurements. Direct detection of optical power down to ~10 fW is possible; in combination with an optional Lock-In Amplifier even sub-femtowatt sensitivity can be achieved.

An integrated ultra low noise high gain amplifier provides output signals in the range up to 10V, the output is short circuit proof.

The new slim line housing includes a removable threaded coupler that is compatible with a number of Thorlabs 1" and $\frac{1}{2}$ " threaded accessories. This allows to conveniently mount external optics, filters, apertures or fiber adapters, as well as providing an easy mounting mechanism using the Thorlabs cage assembly accessories. The PDF10x has three tapped mounting holes.

The PDF10x is powered by an LDS12B external linear power supply (±12V, 250mA) via a PICO M8 power connector.

In case of open beam, make sure that the beam is aligned properly to the detector input. If necessary, use a focusing lens in front of the detector.

If the PDF10x is used in fiber based applications we recommend a Thorlabs fiber connector adapter for coupling between fiber and PDF10x. Please see Ordering Codes and Accessories for details.

Please note, that coupling losses may occur due to small detector size, which will result in a reduced output signal. If angled connectors are used, the FC adapter can be rotated from its original position to check for an improved alignment. For this process apply an input signal with power below the saturation level while observing the output voltage using a digital voltmeter or other low-frequency measurement device. The maximum output voltage swing is +10V. Saturation of the output will occur at optical input power greater than CW Saturation Power listed in Technical Data 1. If necessary, use external neutral density filters or attenuators to reduce the input light level. Please note, that the Femtowatt Photoreceivers are extremely sensitive to unwanted stray light. It is essentail to carefully shield the PDF10x input aperture from any unwanted light sources. Common techniques are baffling or other opaque barriers like black cloths, beam tubes or the use of appropriate band pass filters in front of the detector to minimize the influence of stray light.

Warning

The optical damage threshold is 10mW. Exceeding this value will permanently destroy the Femtowatt Photoreceivers!



3.2 **Operating Elements**

- 1 BNC output connector
- 2 PICO M8 DC input power connector
- 3 ON-OFF switch
- 4 Photo detector
- 5 External SM1 (1.035"-40) thread
- 6 Internal SM05 (0.535"-40) thread

Note

Due to limitations in the IC, the high speed amplifier used in these devices may become unstable, exhibiting oscillations or negative output, if the power supply voltage is applied when the module is on. So, prior to connect the external power supply, please make sure the power-on switch on your PDF10x is in OFF position ("**O**").

3.3 **Properties and specifications**

Responsivity

The Thorlabs PDF10x delivers an output voltage, which is a function of incident light power P_{OPT} , detector responsivity $\Re(\lambda)$ and transimpedance gain G given by:

$$V_{OUT} = P_{OPT} \cdot \Re(\lambda) \cdot G$$

The responsivity $\Re(\lambda)$ for a given wavelength can be read from the diagrams (see technical PDF10A¹² or PDF10C¹⁴) to estimate the output voltage. Please note, that transimpedance gain tolerance is ±10% for an individual unit due to extremely high feedback resistors used for the transimpedance amplifier. Temperature changes or even humidity changes may affect transimpedance gain.

Output Voltage

The maximum output voltage swing of output is 10V for high impedance loads (>10kOhm). Depending on wavelength responsivity $\Re(\lambda)$ of the detector, the amplifier will reach saturation at optical input power greater than CW Saturation Power listed in Technical Data. The output signal should be below the maximum output voltage to avoid saturation.

Offset

The amplifier offset voltage is factory set to zero at 23°C ambient temperature. Due to the extremely high feedback resistors used in the transimpedance amplifiers small temperature changes or even humidity changes may affect offset voltage. Therefore it is recommended to use the PDF10x in a constant temperature environment after a short warm up period (~5min) for exact DC light level measurements.

Frequency Response

Typical frequency response curves of the output for model PDF10A and PDF10C can be found in the appendix (PDF10A12) and PDF10C14). For this measurement a test signal was fed through an optical chopper and fiber-coupled to the PDF10x input. The output voltage amplitude was measured with a oscilloscope.

Rise / Fall Time

Rise/Fall time measurement were carried out with the same setup described above. Typical measurement data for different modulation frequencies can be found as well in the appendix (see PDF10A¹³ resp. PDF10C¹⁵).

Noise

Noise is being characterized by different specifications. The spectral noise of PDF10X was measured using a 200kSample/s A/D converter. The power density spectrum was calculated from the sampled values with respect to transimpedance gain and detector responsivity. The optical Input of the PDF10x was blocked. Curves can be found in the appendix (see PDF10A 13 or PDF10C 15).

Other noise specifications are the NEP (Noise Equivalent Power) and the overall RMS output noise, specified for a defined bandwidth. These parameters are stated in Technical Data 1).

3.4 Mounting the PDF10x Series

The PDF10x series is housed in a rugged 53.4 x 43.2 x 21mm³ shielded aluminum enclosure. The new slim line housing includes a removable threaded coupler that is compatible with a number of Thorlabs 1" and $\frac{1}{2}$ " threaded accessories. This allows convenient mounting of external optics, filters, apertures or fiber adapters, as well as providing an easy mounting mechanism using the Thorlabs cage assembly accessories. The electrical connectors and the ON/OFF switch are conveniently located on the side walls of the housing for easy access and to mini-

mize the thickness of the PDF10x so it can fit into tight spaces. For maximum flexibility the PDF10x has three 8-32 (M4 for /M metric version) tapped mounting holes to mount the unit to a post or pedestal.





Possible mounting options for PDF10x



4 Maintenance and Service

Protect the PDF10x from adverse weather conditions. The PDF10x 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 a 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 20 for return instructions.

Do not remove covers!

Do not open the power supply unit!

Cleaning

To clean the PDF10x series housing, use a mild detergent and damp cloth. Do not soak the unit in water or use solvent based cleaners.

When cleaning the window of the photodetector, please remember that is a sensitive optical device. Gently blow off any debris using compressed air and wipe gently with an optic tissue wetted with propane.

4.1 Recommendations

Please always remember that the PDF10x are extremely sensitive devices. Careful shielding of the PDF10x from any unwanted light sources is essential. Common techniques are baffling or other opaque barriers like black cloths or beam tubes. Even a small power-on indicator LED far away from the PDF10x in a completely obscured lab can affect power measurements at femtowatt levels.

It is highly recommended to use appropriate band pass filters in front of the detector to minimize the influence of stray light.

Since stray light has its strongest frequencies at DC and line frequency or harmonics, optical chopping and Lock-In detection can further improve measurement sensitivity.

It is not necessary to switch off the PDF10x when it is exposed to ambient light. The amplifier will saturate but unlike Photomultiplier Tubes it will not be damaged or saturated for a long period of time.

Another critical point can be electrostatic coupling of electrical noise associated with ground loops. In most cases an electrically isolated post (see Thorlabs parts TRE or TRE/M) will suppress electrical noise coupling. You should always try to identify the electrical noise sources and increase the distance to the PDF10x. If possible, you can also rotate the PDF10x input away from the noise source. Different common ground points can also be tested.

The amplifier offset voltage is factory set to zero at 23°C ambient temperature. Due to the extremely high feedback resistors used in the transimpedance amplifiers small temperature changes or even humidity changes may affect offset voltage. Therefore it is recommended to use the PDF10x in a constant temperature environment after a short warm up period (~5min) for exact DC light level measurements.

Due to limitations in the IC, the high speed amplifier used in these devices may become unstable, exhibiting oscillations or negative output, if the power supply voltage is applied when the module is on. So, prior to connect the external power supply, please make sure the power-on switch on your PDF10x is in OFF position ("0") - see Operating elements 7° .

5 Appendix

5.1 Technical Data

Specification	PDF10A	PDF10C
Detector Material	Silicon	InGaAs / PIN
Detector Wavelength Range	320 - 1100nm	800 - 1700nm
Max. Responsivity	typ. 0.6A/W @ 960nm	typ. 1.0A/W @ 1550nm
Detector Active Area	1.1 x 1.1mm ²	Ø 0.5mm
Transimpedance Gain	1 x 10 ¹² V/A ±10%	1 x 10 ¹¹ V/A ±10%
Max. Conversion Gain	0.6 x 10 ¹² V/W ±10%	1 x 10 ¹¹ V/W ±10%
Output Bandwidth (-3dB)	DC - 20Hz	DC - 25Hz
Rise/Fall Time (10% -90%)	22ms	19ms
CW Saturation Power	16pW	100pW
Max. Input Power (photodiode damage threshold))	1	0mW
Minimum NEP (DC to 3dB bandwidth)	1.4fW/√Hz	7.5fW/√Hz
Integrated Noise (DC to 3dB bandwidth)	6.5 fW _{RMS}	35 fW _{RMS}
Overall output voltage noise, typ.	6.5 mV _{RMS}	3.5 mV _{RMS}
Electrical Output, Impedance	BNC, 200Ω 10V < ±150mV	
Maximum Output Voltage		
DC-Offset Electrical Output		
Size	Size 53.4 x 43.2 x 21 mm ³	
Power Supply	±12V	, 250 mA

All technical data are valid at $23 \pm 5^{\circ}$ C and $45 \pm 15^{\circ}$ rel. humidity (non condensing)

5.1.1 PDF10A



PDF10A Detector Responsivity



PDF10A output frequency response



PDF10A output time response



PDF10A spectral noise

5.1.2 PDF10C



PDF10C detector responsivity



PDF10C output frequency response



PDF10C output time response



PDF10C spectral noise

5.2 Dimensions



5.3 **Certifications and Compliances**

Category	Standards or description					
EC Declaration of Conformity - EMC	Meets intent of Directive 2004/108/EC ¹ for Electromagnetic Compatibility. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:					
	EN 61326-1:2006	Electrical equipment for measurement, control and laboratory use – EMC requirements: Immunity: complies with basic immunity test requirements ² . Emission: complies with EN 55011 Class B Limits ^{2,4} , IEC 610003-2 and IEC 61000-3-3.				
	IEC 61000-4-2	Electrostatic Discharge Immunity (Performance Criterion B)				
	IEC 61000-4-3	Radiated RF Electromagnetic Field Immunity (Performance Criterion A)				
	IEC 61000-4-4	Electrical Fast Transient / Burst Immunity (Performance Criterion B)				
	IEC 61000-4-6	Conducted RF Immunity (Performance Criterion A)				
FCC EMC Compli- ance	Emissions comply with the Class B Limits of FCC Code of Federal Regulations 47, Part 15, Subpart B ^{2,4} .					
EC Declaration of Conformity - Low Voltage	Compliance was demonstrated to the following specification as listed in the Official Journal of the European Communities: Low Voltage Directive 2006/95/EC ⁷					
	EN 61010-1:2001	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use - Part 1: General Requirements				
U.S. Nationally Re-	UL 61010-1 2 nd ed.					
Laboratory Listing	ISA-82:02.01 2 nd ed.					
Canadian Certifica- tion	CAN/CSA C22.2 No. 61010-1 2 nd ed.					
Additional Compli- ance	IEC 61010-1:2001					
Equipment Type	Test and Measuring					
Safety Class	defined in IEC 60950-1:2001)					
¹ Replaces 89/336/EEC.						
² Compliance demonstrated using high-quality shielded interface cables shorter than or equal to 3 meters.						
⁴ Emissions, which exceed	* Emissions, which exceed the levels required by these standards, may occur when this equipment is connected to a test object.					

7 Replaces 73/23/EEC, amended by 93/68/EEC

5.4 Warranty

Thorlabs warrants material and production of the PDF10x 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.

5.5 Exclusion of Reliability and Copyright

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.

All rights reserved. This document may not be reproduced, transmitted or translated to another language, either as a whole or in parts, without the prior written permission of *Thorlabs*.

Copyright © Thorlabs 2018. All rights reserved.

5.6 Thorlabs 'End of Life' Policy (WEEE)

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

This offer is valid for Thorlabs electrical and electronic equipment

- sold after August 13th 2005
- marked correspondingly with the crossed out "wheelie bin" logo (see figure below)
- sold to a company or institute within the EC
- currently owned by a company or institute within the EC
- still complete, not disassembled and not contaminated

As the WEEE directive applies to self contained operational electrical and electronic products, this "end of life" take back service does not refer to other Thorlabs products, such as

- pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- components
- mechanics and optics
- left over parts of units disassembled by the user (PCB's, housings etc.).

Waste treatment on your own responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

WEEE Number (Germany) : DE97581288

Ecological background

It is well known that waste treatment pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS Directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE Directive is to enforce the recycling of WEEE. A controlled recycling of end-of-life products will thereby avoid negative impacts on the environment.



Crossed out "Wheelie Bin" symbol

5.7 Thorlabs Worldwide Contacts

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



USA, Canada, and South America

Thorlabs, Inc. sales@thorlabs.com techsupport@thorlabs.com

Europe

Thorlabs GmbH europe@thorlabs.com

France

Thorlabs SAS sales.fr@thorlabs.com

Japan

Thorlabs Japan, Inc. sales@thorlabs.jp

UK and Ireland

Thorlabs Ltd. sales.uk@thorlabs.com techsupport.uk@thorlabs.com

Scandinavia

Thorlabs Sweden AB scandinavia@thorlabs.com

Brazil

Thorlabs Vendas de Fotônicos Ltda. brasil@thorlabs.com

China

Thorlabs China chinasales@thorlabs.com



