THORLABS

Optical Power Meter

PM100USB
Operation Manual

2017

Version: 1.2
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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 preceeded 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 these advices carefully!

1 General Information

The PM100USB Hand-held Optical Power and Energy Meter is designed to measure the optical power of laser light or other monochromatic or near monochromatic light sources.

The space-saving, battery powered design and compatibility to all Thorlabs "C Series" Photodiode and Thermal sensors, and custom Photodiode and Thermal detectors, featured with a fast USB device interface open a wide range of applications in Manufacturing, Quality Control, Quality Assurance, and R&D for stationary and field use.

The provided software, including drivers and applications for LabVIEW and C makes it easy to integrate the instrument in test and measurement systems.

The unit can be recharged with the supplied AC adapter or via USB connection to a PC or laptop.

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.

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. If necessary, ask for a replacement package.

The power meter PM100USB must not be operated in explosion endangered environments!

Control inputs / outputs and the sensor must be connected with duly shielded connection cables.

Do not remove covers!

Refer servicing to qualified personal!

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).

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.

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/T.V. technician for help.

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 GmbH. 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.

1.2 Ordering Codes and Accessories

PM100USB

2 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 PM100USB mechanically and electrically.

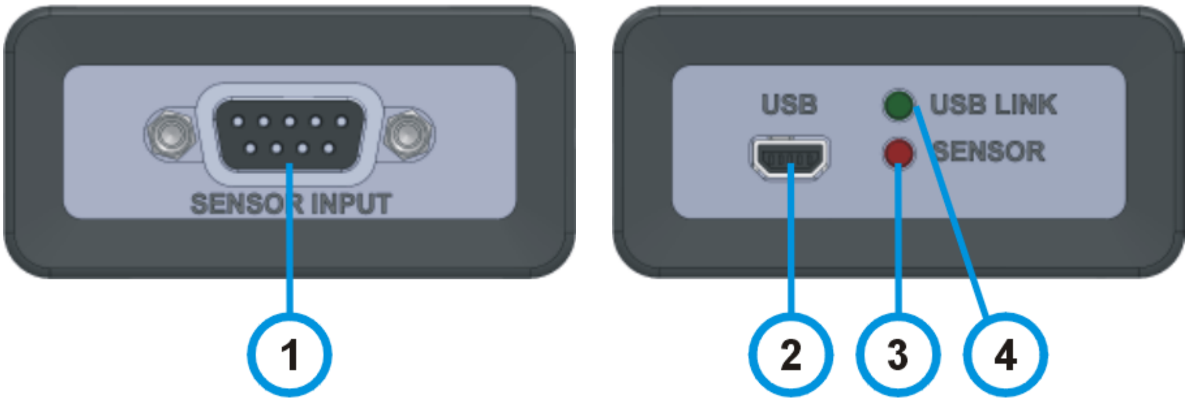
Verify that you have received the following items within the package:

1. PM100USB power/energy meter console
2. USB cable, type ‘A’ to ‘mini-B’
3. Quick-start guide
4. USB memory stick with instrument drivers, user application and operation manual
5. Certificate of Calibration

3 Operating Instruction

- Install software from the supplied data carrier (see section Software Installation).
- Connect a suitable sensor.
- Connect the PM100USB to the PC using the supplied USB cable.
- For detailed instructions, please see section Graphic User Interface.

3.1 Operating Elements



1 Connector for power / energy sensor
2 USB connector to PC
3 LED: Sensor detected and ready for operation
4 LED: USB device ready for operation

3.2 Connecting a Power Sensor

The PM100USB supports all Thorlabs 'C-Series photodiode, energy and thermal sensors, that can be easily identified by their red connector housing, compared to older versions of Thorlabs power sensors. The console will not recognize sensors from the 'A' and 'B' series. Please contact Thorlabs for the upgrade of old sensors with 'C-Series' connectors.

To plug or remove a sensor slightly press on the two bolts in the connector housing, that fix it by resilience.

Sensors can be 'hot-swapped' to the console, after recognizing a new valid sensor the type and calibration data will be downloaded to the console in approximately 2 seconds, and the unit is ready to operate with the new sensor.

The PM100USB also supports custom detectors, please refer to System Settings for the console measurement settings; the pin-out of the DB9 sensor connector can be found in Appendix.

4 Requirements

These are the requirements to the PC intended to be used for remote operation of the PM100USB.

4.1 Hardware Requirements

CPU: 1 GHz or higher

RAM: 256 MB

Graphic card with at least 32 MB memory

Hard disc with at least 100 MB free storage space

Free USB2.0 port

USB cable according the USB 2.0 specification

4.2 Software Requirements

The PM100USB software is compatible with the following operating systems:

- Windows® XP (32-bit) SP3
- Windows® Vista (32-bit, 64-bit)
- Windows® 7 (32-bit, 64-bit)
- Windows® 8 / 8.1 (32-bit, 64-bit)
- Windows® 10 (32-bit, 64-bit)

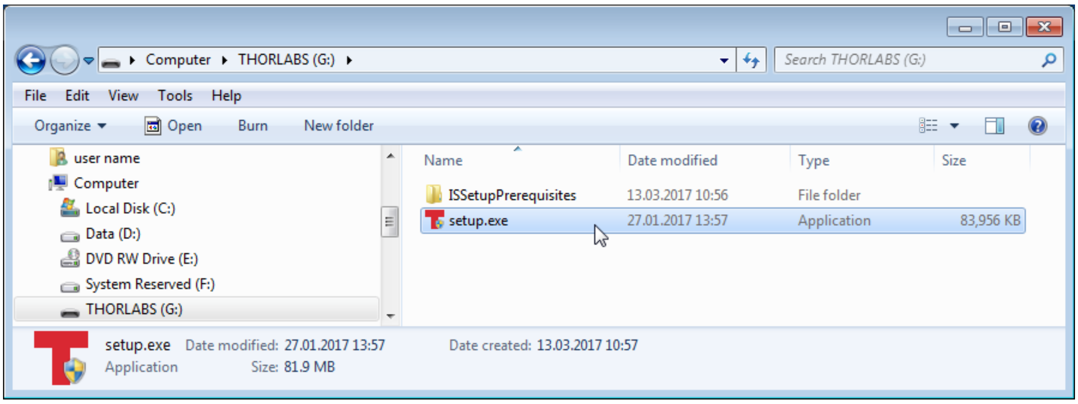
For proper operation of the PM100USB, a NI-VISA Runtime (version 5.4 or higher) is required. This software comes with the Thorlabs PM100USB installation package on the delivered USB stick or can be downloaded from National Instruments' website www.ni.com.

5 Software Installation

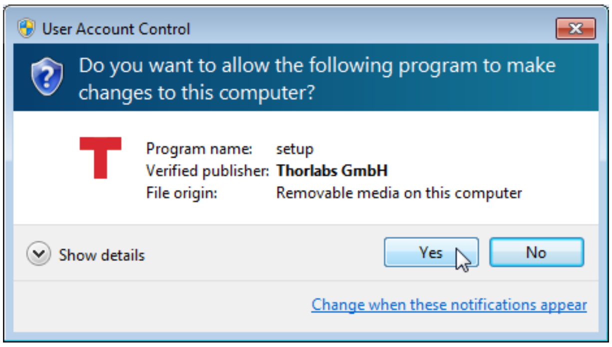
Note

Prior to install software, please close all running application, as the installation process may require one ore more restarts of the computer.

Insert the supplied with the PM100USB USB stick into a free USB terminal and select in the appearing dialog "Open folder to view files":



Double-click the file "setup.exe" (see above). The start screen comes up:



The setup file checks the target PC system and selects the software components that need to be installed.

- NI VISA Runtime V 5.4
- NI LabView Runtime 2015
- Microsoft Visual C++ 2010 SP1
- Thorlabs DFU Wizard
- Thorlabs Instrument Communicator
- PM100 VXIPnP Instrument Driver

Please follow the instructions to ensure a proper software installation. Do not remove the USB stick from your computer before the software has been installed completely.

6 Optical Power Meter Utility Software

The PM100USB comes with a utility software that easily enables remotely operating the PM100USB and visualizing and logging measurement data. The software is written in LabVIEW 2015 and can be installed either from the data carrier as executable (LabVIEW is not required to be installed on the PC) or can be run under LabVIEW 2015 or higher.

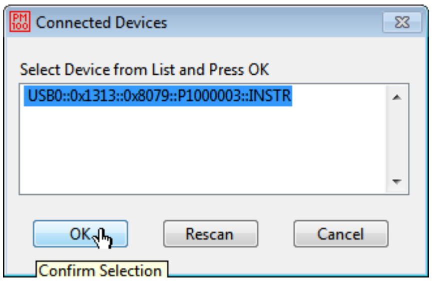
The source code of the application is included on the data carrier and can be used to build own applications or to modify the utility program to specific requirements.

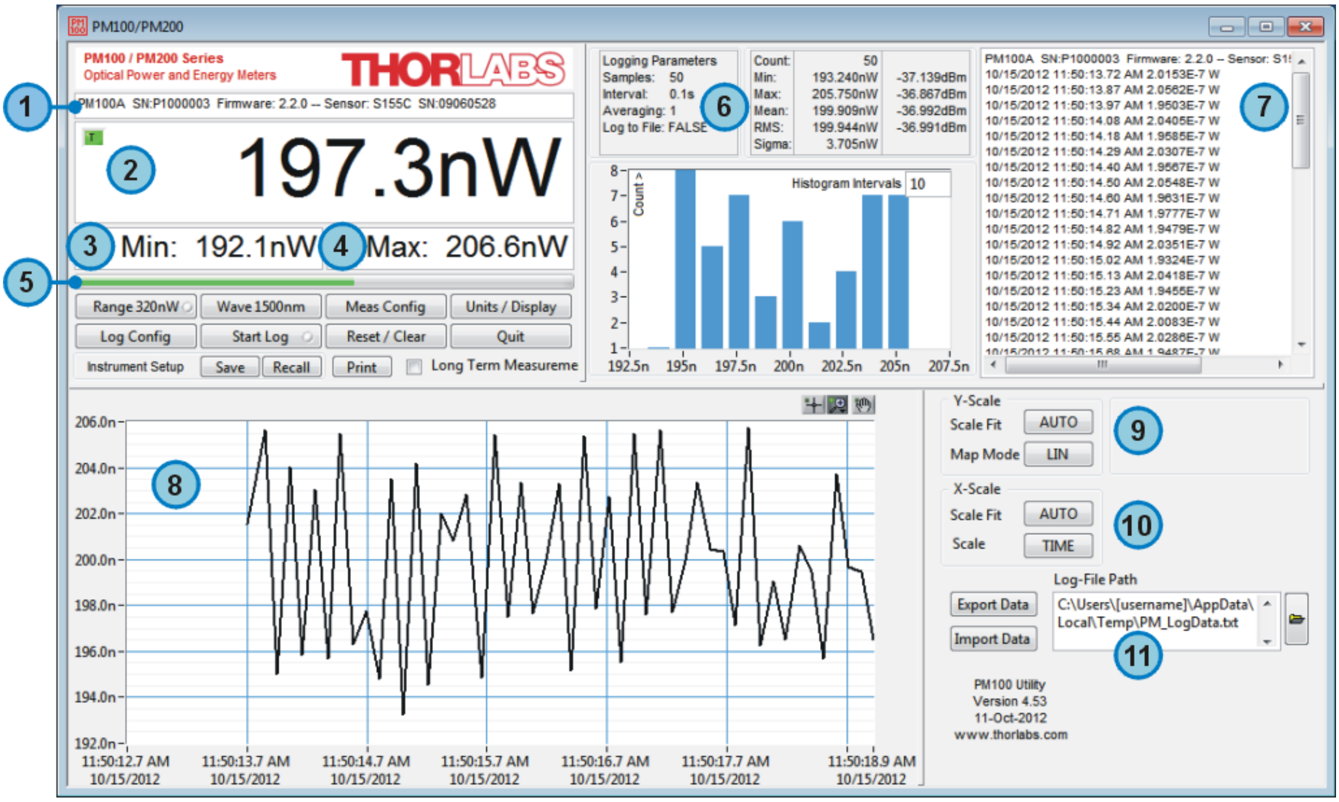
Note

Do not connect the PM100USB prior to install software!

6.1 Graphic User Interface

After launching the Optical Power Meter Utility program it will automatically screen for connected PM100A, PM100D or PM100USB devices. Select the desired device and press o.k. In case that the connected PM100USB is not yet recognized, press Rescan to perform a new search for connected PM100USB devices.





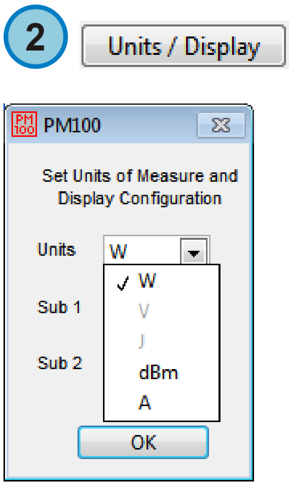
1

Header

This indicator shows the device setup:

- console type (PM200, PM100A, PM100D or PM100USB)
- serial number of the console
- sensor type
- sensor serial number

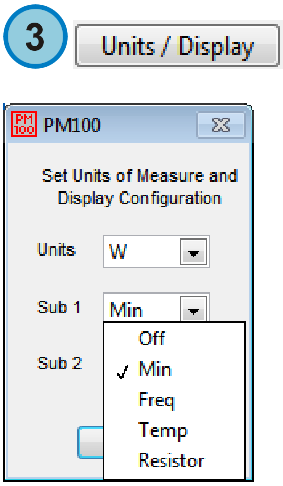
2



Main Display

The display has a configurable display resolution. Independent from the measurement range the display always has the full number of the selected digits.
To achieve best AD converter resolution it is necessary to set the measurement range according to the signal to measure.
A trigger indicator shows whether the unit is sampling data ‘A’ indicator or a new measurement value gets displayed ‘T’ indicator and green light.

3



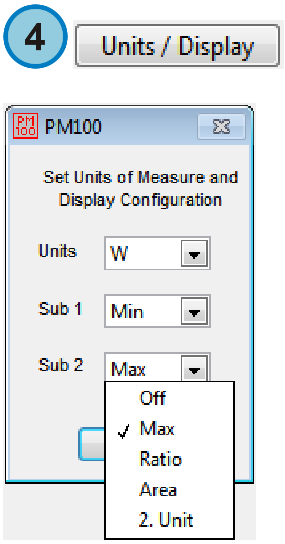
Left Sub Display

The display has the following configurable items:

- no display
- maximum value - sampling until reset
- ratio max/min value - sampling until reset
- power or energy density
- alternate unit depending on connected sensor

The possible choices depend on the connected sensor

4



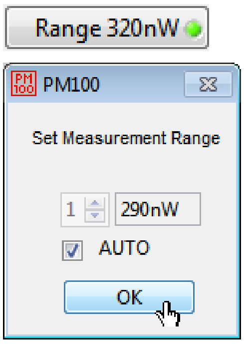
Right Sub Display

The display has the following configurable items, the possible choices depend on the connected sensor::

- no display
- minimum value - sampling until reset
- frequency or repetition rate
- temperature
- resistance of temperature sensor

5	**Bargraph indicator** The bargraph indicator shows the incidence or the used measurement range.
6	**Statistics screen** • Statistical values in linear and logarithmic representation
7	**Histogram** Power / Energy histogram • displays histogram data
8	**Chart display** • Power/Energy Chart with Y auto scale and a 1000 point history length
9	**Y scaling of the chart display** • Scale fit: AUTO / FIX • Map mode: LOG / LIN
10	**X scaling of the chart display** • Scale fit: AUTO / FIX • Scale: TIME / SAMPLES
11	**Dialog to export and import data**

Control buttons

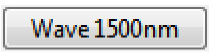


Range button

Press to open a dialog box for setting the measurement range

The indicator in the button shows the currently used measurement range in the chosen unit. A green light indicates 'auto-ranging'

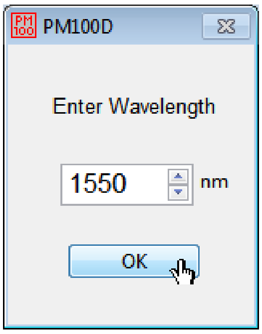
Shortcut: [Shift + F1]

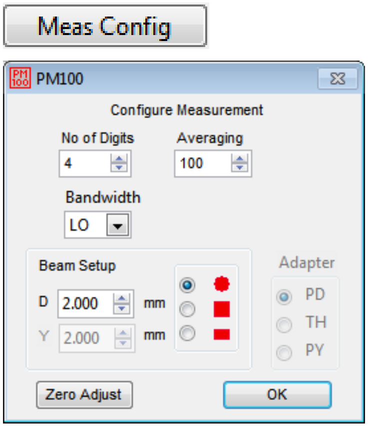


Wavelength / Response button

Press this button to open a dialog box for setting the correction wavelength, or in adapter mode to enter the responsivity value in A/W or V/W.
The currently used parameter is indicated in the button label.

Shortcut: [Shift + F2]





Measurement configuration button
Depending on the connected sensor the following parameters can be set in the dialog box:

- display resolution - set number of digits
- averaging rate, a rate of 3000 averages the incoming measurement values for approx. 1 second
- photodiode bandwidth HI and LO
- acceleration circuit for thermal sensors ON and OFF
- trigger level for pyroelectric sensors
- Zeroing for photodiode and thermal sensors

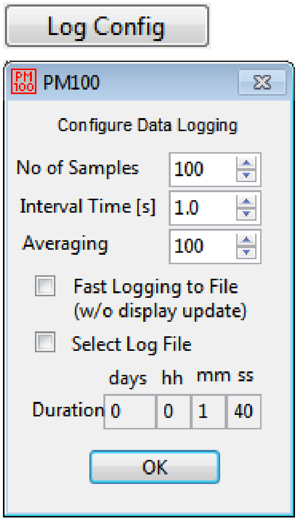
Shortcut: [Shift + F3]

Units / Display button

A dialog box with the following items appears:

- configure unit of measure, depending on the connected sensor in W, J, dBm, V and A
- configure the left sub display
- configure the right sub display

Shortcut: [Shift + F4]



Logging configuration button
Open dialog box to:

- set averaging rate for logging
- set interval between samples
- set number of samples
- configure logging into data file

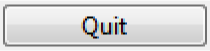
Shortcut: Shift + F5

Start/Stop log button - Shortcut: [Shift + F6]

- \- start and stop data logging

Reset / Clear button - Shortcut: [Shift + F7]

- reset min/max monitor
- clear power / energy graph
- clear power / energy histogram
- clear power / energy statistics
- clear log screen



Quit button - Shortcut: [Shift + F8]

- stops the PM100 application
- to restart press the white arrow in the tool bar

6.2 Zeroing

When measuring very low power levels, the dark current of photodiode sensors or the zero voltage of thermal sensors influence the measurement result and must be compensated by the zero adjustment. A negative power reading or a reading much greater than zero, with the sensor aperture covered, is an indicator that the sensor needs to be zeroed. At negative power readings, additionally a ‘ZERO!’ warning appears in the status display.

Note:

Do not hold the sensor in the hand, when performing a zero adjustment. Temperature effects will influence the quality of the zeroing result, especially in the case of a thermal sensor.

After performing the zero adjustment, the detected zero value will be included in all power readings. Basic unit (V; A) will still measure the absolute values, with no zero correction. The detected zero value may influence the wavelength corrected full scale power range calculated in the lower power ranges. In the bar graph display, a zero shift applies as well.

In logarithmic (dBm) representation the unit cannot display negative values. In this case the display will show ‘--‘.

Photodiode sensors deliver a small current ("dark current"), even when no photons hit the active area. The dark current is temperature dependent and reaches values of up to several nA for Si and InGaAs sensors and up to several µA for Ge sensors.

Thermopile sensors need to be zeroed if a thermal difference (gradient) appears between active area (thermal disk) and the sensor heat sink, with no light incident to the active area, or if the heat sink gets hot during light exposure. The zero value will be negative if the heat sink is hotter than the active area and positive, if the active area is hotter than the heat sink. With both heat sink and active area temperatures at room temperature, a zero voltage of some µV is normal.

6.3 Light Intensity Measurement

In order to display the power (energy) density or the light intensity value in W/cm^2 (J/cm^2), enter in the right sub display the diameter of the incident beam or, in case the beam overfills the active sensor area, the diameter of the sensor aperture. The utility software allows to configure the beam shape and automatically calculates the beam diameter value:

Beam shape	Used for calculation beam diameter
Round; Ø **a**	$1/e^2$ * **a**
Square; edge length **a**	1.128 * **a**
Rectangular; edge lengths **a** and **b**	1.128 *√(**a***b**)

7 Sensor Dependent Functions

7.1 Photo Diode Sensors

The PM100USB is compatible with all Thorlabs S1xxC series photodiode power sensors. The sensor is ready to operate few seconds after plugging to the DB9 connector.

Attention

Refer to the sensor data sheet and pay attention to the optical damage threshold! Exceeding these values will permanently destroy the sensor!

Thorlabs offers photodiode sensors for power levels from nano-watts up to 20 W that show big advantages in sensitivity, stability and drift against thermal sensors. The sensors are built up in a combination of a photodiode and a neutral density filter or a photodiode in combination with an integrating sphere. They provide linearity over several decades and show a very good sensitivity at smallest power levels down to the pW range. Handling fairly small power levels the sensor size can be held small, further the response time of such sensors is very fast down to the sub-microsecond range.

Photodiodes, neutral density filters and also integrating sphere materials show a wavelength dependent behavior and therefore each sensor is individually calibrated over it's entire spectral operating range in 5 or 10nm steps. Thereby the sensors spectral response data gets stored in a non-volatile memory inside the DB-9 sensor connector and downloaded to the PM100USB when plugged to the unit. To perform an accurate measurement it is necessary to enter the operating wavelength of the light to measure so that the PM100USB can calculate the laser power from the measured photo current and the correct response value from the wavelength calibration table.

7.1.1 Bandwidth Setting (Signal Filtering)

The analogue bandwidth setting influences the power reading. The bandwidth can be selected either to ‘HI’ (range dependent bandwidth up to 100kHz) or to ‘LO’ (15 Hz bandwidth).

For measuring CW or average power from pulsed sources the bandwidth should be set to ‘LO’.

7.1.2 Power Measurement with Photodiodes

Common photodiodes can be used for power measurements with the PM100USB. Therefore the PM100USB needs to be set to the ‘Photodiode’ custom sensor input adapter type. A photodiode and an interlock must be connected to the sensor input (see section Pin Assignment of the Sensor Connector).

Please make sure for correct polarity - the photodiode cathode needs to be connected to ground.

The operation is similar to photodiode power sensors with the exception that using the soft button of the wavelength menu, a response value in A/W for the actual wavelength must be set.

7.2 Thermal Power Sensors

The PM100USB is compatible to the Thorlabs S3xxC and S4xxC series thermal power sensors. The sensor is ready for operation a few seconds after plugging to the DB9 connector.

Attention

Refer to the sensor data sheet and pay attention to the optical damage threshold! Exceeding these values will permanently destroy the sensor!

Thermal sensors absorb the incident laser power. This power is heats up the absorber, and this heat generates a small voltage that is caused by the heat flow through thermocouple elements between absorbing area and sensor heat sink. Thorlabs S3xxC and S4xxC Series of thermal sensors cover a wide range of applications. The sensors are available with different coatings:

- Black broad band coatings. The absorber does not need a wavelength correction because the response is nearly flat from the UV to the mid-IR.
- Special hard coatings (high power broadband) that withstand high power levels and show also a good spectral flatness.
- Further Thorlabs offers special heads for Excimer lasers with large beam diameters and short pulse lasers with coatings for very high peak power levels.

The output voltage of a thermal sensor is linear proportional to the incident laser power, as long the thermal system is properly zeroed. The main application area for thermal sensors is the measurement of high power levels from 100mW up. Thorlabs offers also a special thermally isolated thermal head with flat response and on power levels starting in the µW range.

7.2.1 Read-out Acceleration

Thermal sensors show a fairly slow response. When laser power hits the active area it takes from some 1 up to 20 seconds, depending on the sensor type, until the system has settled and the power reading shows the right value.

Through special circuitry this time can be shortened to approximately 1-3 seconds by ‘predicting’ the final power value. The PM100USB automatically adjusts the electronics to the time constant of the thermal sensor.

Nevertheless, this circuitry has a disadvantage: It induces some noise to the measurement value. Therefore the acceleration circuit can be disabled / enabled in the measurement configuration.

7.2.2 Custom Thermal Sensors

Custom thermal elements can be used for power measurements with the PM100USB. Therefore the PM100USB needs to be set to the 'Thermopile' custom sensor input adapter type. A thermal element and an interlock must be connected to the sensor input (see section Pin Assignment of the Sensor Connector). The operation is similar to thermal power sensors with two exceptions:

- The wavelength setting is replaced by a button to enter a response value for one wavelength in V/W.
- In the measurement configuration menu a thermal time constant can be set. This time constant adjusts the acceleration circuit for the measurement prediction.

7.3 Pyroelectric Energy Sensors

The PM100USB is compatible with all Thorlabs ES1xxC and ES2xxC series pyroelectric energy sensors. The sensor is ready to operate few seconds after plugging to the DB9 connector.

Attention

Refer to the sensor data sheet and pay attention to the optical damage threshold! Exceeding these values will permanently destroy the sensor!

Pyroelectric sensors allow to measure the pulse energy of single and repetitive laser pulses. The incident pulse energy is converted to a voltage pulse. The peak pulse voltage is proportional to the pulse energy and almost independent of the laser wavelength.

The PM100USB cannot be switched to auto range mode, when a pyroelectric sensor is connected. The measurement value will be updated with each incoming pulse. When no pulses appear, the last measured value will be hold in display.

Trigger Level

In the measurement configuration, the trigger level can. When an incoming pulse exceeds the set trigger level, the peak detector circuit gets armed and is waiting until the pulse peak is reached. After finding the maximum voltage, this level is kept and the microprocessor reads the AD converted voltage for displaying the pulse energy. Finally the peak detector circuit gets a reset and is ready for the next pulse.

The trigger level can be adjusted between 1% and 100% of each selected energy range. Only pulses that are higher than the adjusted trigger level are recognized by the PM100USB. The trigger level should be set between the noise level and the expected pulse height.

Average Power Measurement

The PM100USB calculates the average power of pulse trains (continuously repetitive pulses) from the pulse energy and the repetition rate.

Repetition Rate

The pulse repetition rate in Hz can be displayed in the left sub display.

Density Calculation

When the correct beam diameter of the incident beam is entered, this function returns either the average power density in W/cm² or the energy density in J/cm².

7.3.1 Custom Pyroelectric Sensors

Custom pyro detectors can be used for energy measurements with the PM100USB. Therefore the PM100USB needs to be set to the ‘Pyro Electric’ custom sensor input adapter type. A pyro detector and an interlock must be connected to the sensor input (see section Pin Assignment of the Sensor Connector). The pyro detector must provide a positive signal. The operation is similar to pyro-electric energy sensors with exception that using the soft button of the wavelength menu, a response value in V/J for the actual wavelength must be set.

8 Measurement Considerations

8.1 Choosing the right sensor

The question of the right sensor depends on many factors starting with the light source to measure and the application. No sensor can cover all applications; the following table shows the main pros and cons of the different power sensor types. Of course this can only be a rough guide because within each sensor group there are special models best suitable for specific applications.

Power Sensors:

Light Source	Photo Diode Sensor			Thermal Sensors		
	Si	Ge	InGaAs	BB	HPB	Volume
Diode Lasers UV - NIR	+++	+	-	++	-	-
Diode Lasers NIR	-	+	+++	++	-	-
High Power Fiber Lasers	-	-	++	++	++	-
ASE Sources	-	-	++	++	-	-
Femtosecond Lasers	-	+	++	++	+	-
Gas Lasers	++	-	-	++	+	-
Excimer Lasers	-	-	-	-	+++	+
YAG Lasers	-	-	-	-	+	+++
LEDs	+	-	-	+++	+	-

8.2 Reducing Noise for high Accuracy Measurements

Noise from grounding, the cable capacitance, temperature effects, stray and ambient light and detector noise are interfering the measurement. This impact is the higher, the lower to measured optical power. Below are given some hints and recommendations how to reduce interferences to a minimum:

- The housing of power sensors is connected to the digital ground of the meter and should be linked to earth ground (e.g. via post mounting).
- Energy sensors should be mounted isolated, because the housing is connected to the meter analog ground.
- The sensor cable conducts very small current or voltage signals. The cable capacitance induces disturbances when the cable is moved. If very small power or energy levels are measured, the cable should be fixed in position.
- With photodiode sensors the bandwidth should be set to “Low” setting; with thermal sensors the acceleration circuit should be shut off.
- The detector noise is lowest with Si or InGaAs sensors.

- For long term measurements in free space applications it is necessary to provide constant ambient light conditions, or shielding the light path from external light sources.
- The temperature should be stable over the time of the measurement.

8.3 Power Measurement of Pulsed Signals

The PM100USB will read the average value of a pulsed signal if the following conditions apply:

Thermal Sensor

For a thermal sensor, pulse length, repetition rate and peak power are uncritical as long as the peak power is lower than the damage threshold of the sensor. A thermal sensor reacts very slow and will integrate the power incident on the active area of the sensor.

Photodiode Sensor

A photodiode sensor can follow short pulses in the ns range. Therefore, it is important that the pulse peak power is within the maximum power range of the sensor. It is also important that the power range is set in such a way, that the peak power won't exceed this range, otherwise the reading will clip at the end of the range, which leads to a wrong average value. Furthermore, it is important to use a power range that can measure the peak value. To find the appropriate power range, the Min-Max display function is very helpful. Depending on pulse length and repetition rate, the bandwidth setting will influence the power reading. It is recommended to use the 'LOW' bandwidth setting for a stable display. If the pulse should be monitored via the analog output, the bandwidth should be set to 'HIGH'.

8.4 Line Width of Light Sources

The line width of light sources can be neglected only when using a broadband thermal or pyro-electric sensor.

Photodiode sensors show a strong dependency on the operating wavelength so if the line width of the light source is greater than 10nm (e.g. LED) there may be an influence on the displayed power. To achieve the best result for broadband light sources with a photodiode sensor it is necessary that the response curve is nearly linear over the line width. When entering the center wavelength of the light source as operation wavelength, the PM100USB will nearly show the right optical power for a symmetrical spectral response shape.

8.5 Temperature Effects on Thermal Sensors

Thermal sensors respond to any temperature differences that occur between thermal disc and heat sink. The measurement result can be interfered by airflow disturbances or by heating up the heat sink, e.g., during long-term exposure of the thermal disc to the laser beam.

To avoid disturbances it is recommended to shield the sensor as good as possible from airflow and to zero it properly in the operating condition. That means for short term measurements zero the cold sensor, for long term measurements zero the sensor when it is in a state of thermal stability (e.g. after 10 minutes light exposure).

8.6 Ambient and Stray Light

Ambient or stray light can strongly affect the measurement accuracy in free-space applications. A permanent background light level can be subtracted by conducting a zero adjustment. In case of varying ambient light like daylight or turning on/off room light, the only solution is a proper shielding of the sensor from ambient and stray light.

8.7 Back Reflection

The surfaces of photodiodes, ND filters and even the black coatings of thermal sensors show a certain kind of back reflection of the incoming light. If this back reflection hits for example a laser diode or a HeNe laser, this may have an impact on the power stability of the laser, therefore it is recommended to slightly tilt the power meter sensor with respect to the laser beam. This way, the back reflection won't enter the laser.

If back reflections must be completely avoided it is advised to use a S14xC series integrating sphere sensor where the incoming light gets nearly completely absorbed in the sensor.

8.8 Beam Diameter vs. Active Sensor Area

Most sensors are not completely uniform in their response over the active area; except integrating sphere sensors. To overcome uniformity issues the incident beam should have a diameter larger than 10% of the active sensor area.

Another important point is the maximum allowed power and energy density of the sensor. The maximum ratings are given in the sensor specifications. The PM100USB can display the actual power or energy density for a known beam diameter. For high power or high energy beams a good efficiency can be reached by selecting a sensor with a detector size about 20% - 30% larger than the beam diameter.

It is also important not to overfill the sensor. That means, that the beam size in the plane of sensor's active area must not exceed the size of the active area.

8.9 Fiber Based Measurements

Laser light is emitted from an optical fiber tip in a conical shape, with an angle twice the acceptance angle of the fiber. The acceptance angle is calculated by:

$$\Theta = n^* \arcsin (NA)$$

where NA - numerical aperture of the fiber
n - refraction index; in air n = 1

Fore typical single mode fibers the total angle 2*Q of the emitted light is between 15° and 25°, for an angled connector (APC) the cone is tilted by approximately 4° from the fiber axis.

This expansion of the beam has to be considered to avoid overfilling the detector and getting wrong results. On the other hand for measurements with high power fiber lasers a certain gap between fiber tip and detector surface has to be kept to decrease the power density.

Thorlabs offers fiber adapters with the most common connectors that are verified with the S12xC series optical sensors and with most thermal sensors.

For large divergence angles or fiber measurements that are critical to back-reflections it is recommended to use an integrating sphere sensor of the S14xC series.

Another good choice for fiber based measurements are the fiber heads of the S15xC series. They plug directly to the meter and have no cable between sensor and console. This minimizes measurement interferences.

8.10 Energy Measurement using Pyroelectric Sensors

The selection of the best suitable pyroelectric energy sensor must be made with respect to the following parameters:

Energy to Measure

The maximum allowed energy is limited by the absorption layer (too high energy causes mechanical damages on the layer) and by the sensor material, that must not exceed a certain temperature level. It is also important to pay attention to the maximum energy density, to the average power and to the maximum power density during a pulse.

To the lower end, the detection is limited by the resolution and the minimum settable trigger level of the display unit, as well as by the noise level. To minimize the noise level and to avoid ground loops it is recommended to mount the detectors using the supplied isolation adapters.

Beam Diameter

The active area of the detector should be selected in such way, that it has a slightly larger diameter than the incident beam. Not necessarily the beam should cover most of the sensor area, but the maximum allowed energy density must not be exceeded.

Repetition Rate

The maximum pulse repetition rate depends on the combination of the internal capacitance of the detector and the load resistor. The display unit has an input resistor of 1MΩ (like the typical input resistor of an oscilloscope).

Pulse Length

Energy sensors can detect and measure pulses with a duration from sub-nanosecond range to approximately 2 ms. The max. pulse duration depends on

- the electrical time constant of the sensor, given by detector capacity and load resistance
- the thermal time constant of the sensor.

Usually the latter is the more significant.

Wavelength

The sensors are typically calibrated at one wavelength, for other wavelengths a sensor specific correction curve is stored in the memory in the sensor connector. The black coating is nearly linear flat over a wavelength range from 185nm to > 25µm; the ceramic coating is also suitable for this wavelength range, but is not linear over the entire wavelength range.

9 Computer Interface

The PM100USB optical power meter has a USB 2.0 interface that allows to send commands from a host computer to the instrument. The connection between PC and PM100USB is accomplished by a USB cable with a male type 'A' connector at the PC side and a type 'Mini-B' connector on the instrument side.

9.1 SCPI Commands

SCPI (*Standard Commands for Programmable Instruments*) is an ASCII-based instrument command language designed for test and measurement instruments.

9.1.1 Introduction to the SCPI Language

SCPI commands are based on a hierarchical structure, also known as a tree system. In this system, associated commands are grouped together under a common node or root, thus forming subsystems. A portion of the SENSE subsystem is shown below to illustrate the tree system.

```
[SENSe:]
  CORRection
       :COLLect
          :ZERO
             [:INITiate]
             :ABORt
             :STATe?
             :MAGNitude?
       :BEAMdiameter {MINimum|MAXimum|DEFault|<numeric_value>[mm]}
       :BEAMdiameter? [{MINimum|MAXimum|DEFault}]
       :WAVelength {MINimum|MAXimum|<numeric_value>[nm]}
       :WAVelength? [{MINimum|MAXimum}]
       :POWer
           [:PDIode]
              [:RESPonse] MINimum|MAXimum|DEFault|
<numeric_value>[A]}
              [:RESPonse]? [{MINimum|MAXimum|DEFault}]
           :THERmopile
              [:RESPonse] {MINimum|MAXimum|DEFault|
<numeric_value>[V]}
              [:RESPonse]? [{MINimum|MAXimum|DEFault}]
```

`SENSe` is the root keyword of the command, CORRection is the second-level keyword, and COLLect and BEAMdiameter are third-level keywords, and so on. A colon (:) separates a command keyword from a lower-level keyword.

Command Format

The format used to show commands in this manual is shown below:

```
CURRent[:DC]:RANGe {MINimum|MAXimum|<numeric_value>[A]}
CORRection:BEAMdiameter {MINimum|MAXimum|DEFault|
<numeric_value>[mm]}
```

The command syntax shows most commands (and some parameters) as a mixture of upper- and lower-case letters. The upper-case letters indicate the abbreviated spelling for the command. For shorter program lines, send the abbreviated form. For better program readability, send the long form.

For example, in the above syntax statement, `CURR` and `CURRENT` are both acceptable forms. You can use upper- or lower-case letters. Therefore, `CURRENT`, `current` and `Current` are all acceptable. Other forms, such as `CUR` and `CURREN`, will generate an error.

Braces (**{ }**) enclose the parameter choices for a given command string. The braces are not sent with the command string. A *vertical bar* (**|**) separates multiple parameter choices for a given command string.
Triangle brackets (**< >**) indicate that you must specify a value for the enclosed parameter. For example, the above syntax statement shows the *range* parameter enclosed in triangle brackets. The brackets are not sent with the command string. You must specify a value for the parameter (such as `"CURR:DC:RANG 50E-6"`).
Some parameters are enclosed in *square brackets* (**[ ]**). The brackets indicate that the parameter is optional and can be omitted. The brackets are not sent with the command string. In this example `[:DC]` can be omitted, so the command string can be shortened to `"CURR:RANG 50E-6"`. If you do not specify a value for an optional parameter, the power/energy meter chooses a default value.

Command Separators

A *colon* (**:**) is used to separate a command keyword from a lower-level keyword. You must insert a *blank space* to separate a parameter from a command keyword. If a command requires more than one parameter, you must separate adjacent parameters using a *comma* as shown below:

```
"SYST:TIME 10, 34, 48"
```

A *semicolon* (**;**) is used to separate commands within the *same* subsystem, and can also minimize typing. For example, sending the following command string:

```
"CORR:BEAM 1; WAVE 1310"
```

... is the same as sending the following two commands:

```
"CORR:BEAM 1"
"CORR:WAVE 1310"
```

Use a colon and a semicolon to link commands from different subsystems. For example, in the following command string, an error is generated if you do not use both the colon and semicolon:

`"CORR:BEAM 1;:AVER 300"`

Using the *MIN* and *MAX* Parameters

You can substitute `MINimum`=or `MAXimum`=in place of a parameter for many commands. For example, consider the following command:

`CURRent[:DC]:RANGe {MINimum|MAXimum|<numeric_value>[A]}`

Instead of selecting a specific current range, you can substitute MIN to set the range to its minimum value or MAX to set the range to its maximum value.

Querying Parameter Settings

You can query the current value of most parameters by adding a question mark (`?`) to the command. For example, the following command sets the operating wavelength to 1550 nm: `"CORR:WAVE 1550"`

You can query the operating wavelength by executing: `"CORR:WAVE?"`

You can also query the minimum or maximum operating wavelength allowed as follows:

```
"CORR:WAVE? MIN"
"CORR:WAVE? MAX"
```

Caution

If you send two query commands without reading the response from the first, and then attempt to read the second response, you may receive some data from the first response followed by the complete second response. To avoid this, do not send a query command without reading the response. When you cannot avoid this situation, send a device clear before sending the second query command.

SCPI Command Terminators

A command string sent to the power/energy meter must terminate with a <new line> character. The IEEE-488 EOI (end-or-identify) message is interpreted as a <new line> character and can be used to terminate a command string in place of a <new line> character. A <carriage return> followed by a <new line> is also accepted. Command string termination will always reset the current SCPI command path to the root level.

IEEE488.2 Common Commands

The IEEE-488.2 standard defines a set of common commands that perform functions like reset, self-test, and status operations. Common commands always begin with an asterisk (`*`), are four to five characters in length, and may include one or more parameters. The command keyword is separated from the first parameter by a blank space. Use a semicolon (`;`) to separate multiple commands as shown below:

`"*RST; *CLS; *ESE 32; *OPC?"`

SCPI Parameter Types

The SCPI language defines several different data formats to be used in program messages and response messages.

Numeric Parameters Commands that require numeric parameters will accept all commonly used decimal representations of numbers including optional signs, decimal points, and scientific notation.
Special values for numeric parameters like `MINimum`, `MAXimum` and `DEFault` are also accepted. You can also send engineering unit suffixes with numeric parameters (e.g., `M`, `K`, or `u`). If only specific numeric values are accepted, the power/energy meter will automatically round the input numeric parameters. The following command uses a numeric parameter:

```
POWer:REFerence {MINimum|MAXimum|DEFault|<numeric_value>[W]}
```

Discrete Parameters Discrete parameters are used to program settings that have a limited number of values (like `W`, `DBM`). They can have a short form and a long form just like command keywords. You can mix upper- and lower-case letters. Query responses will *always* return the short form in all upper-case letters. The following command uses discrete parameters:

```
POW:UNIT {W|DBM}
```

Boolean Parameters Boolean parameters represent a single binary condition that is either true or false. For a false condition, the power/energy meter will accept "`OFF`" or "`0`". For a true condition, the meter will accept "`ON`" or "`1`". When you query a boolean setting, the instrument will *always* return "`0`" or "`1`". The following command uses a boolean parameter:

```
CURRent:RANGe:AUTO {OFF|0|ON|1}
```

String Parameters String parameters can contain virtually any set of ASCII characters. A string *must* begin and end with matching quotes; either with a single quote or with a double quote. You can include the quote delimiter as part of the string by typing it twice without any characters in between. The following command uses a string parameter:

```
DIAG:CALString <quoted string>
```

9.1.2 IEEE488.2 Common Commands

Common commands are device commands that are common to all devices according to the IEEE488.2 standard. These commands are designed and defined by this standard. Most of the commands are described in detail in this section. The following common commands associated with the status structure are covered in the "Status Structure" section: *CLS, *ESE, *ESE?, *ESR?, *SRE, *SRE?, *STB?

9.1.2.1 Command Summary

Mnemonic	Name	Description
***CLS**	Clear status	Clears all event registers and Error Queue
***ESE <NRf>**	Event enable command	Program the Standard Event Enable Register
***ESE?**	Event enable query	Read the Standard Event Enable Register
***ESR?**	Event status register query	Read and clear the Standard Event Register
***IDN?**	Identification query	Read the unit's identification string
***OPC**	Operation complete command	Set the Operation Complete bit in the Standard Event Register
***OPC?**	Operation complete query	Places a "1" into the output queue when all device operations have been completed
***RST**	Reset command	Returns the unit to the *RST default condition
***SRE <NRf>**	Service request enable command	Programs the Service Request Enable Register
***SRE?**	Service request enable query	Reads the Service Request Enable Register
***STB?**	Status byte query	Reads the Status Byte Register
***TST?**	Self-test query	Performs the unit's self-test and returns the result.
***WAI**	Wait-to-continue command	Wait until all previous commands are executed

9.1.2.2 Command Reference

***IDN? – identification query - read identification code**

The identification code includes the manufacturer, model code, serial number, and firmware revision levels and is sent in the following format: THORLABS,MMM,SSS,X.X.X

Where: MMM is the model code
SSS is the serial number
X.X.X is the instrument firmware revision level

***OPC – operation complete - set OPC bit**

***OPC? – operation complete query – places a “1” in output queue**

When *OPC is sent, the OPC bit in the Standard Event Register will set after all pending command operations are complete. When *OPC? is sent, an ASCII “1” is placed in the Output Queue after all pending command operations are complete.
Typically, either one of these commands is sent after the INITiate command. The INITiate command is used to take the instrument out of idle in order to perform measurements. While operating within the trigger model layers, many sent commands will not execute. After all programmed operations are completed, the instrument returns to the idle state at which time all pending commands (including *OPC and/or *OPC?) are executed. After the last pending command is executed, the OPC bit and/or an ASCII “1” is placed in the Output Queue.
When *OPC is sent, the OPC bit in the Standard Event Register will set after all pending command operations are complete. When *OPC? is sent, an ASCII “1” is placed in the Output Queue after all pending command operations are complete.

***RST – reset – return instrument to defaults**

When the *RST command is sent, the instrument performs the following operations:

- Returns the instrument to the default conditions
- Cancels all pending commands.
- Cancels response to any previously received *OPC and *OPC? commands.

***TST? – self-test query – run self test and read result**

Use this query command to perform the instrument self-test routine. The command places the coded result in the Output Queue. A returned value of zero (0) indicates that the test passed, other values indicate that the test failed.

***WAI – wait-to-continue – wait until previous commands are completed**

The *WAI command is a no operation command for the instrument and thus, does not need to be used. It is there for conformance to IEEE488.2.

9.1.2.3 PM100USB specific SCPI Command Reference

See also SCPI Specification, Version 1999.0, May, 1999, http://www.scpiconsortium.org. All commands with a 'SCPI' checkmark are described in the SCPI specification.

All described commands work with the PM100D, PM100A, PM100USB and PM200 instruments (with some limitations due to the hardware capabilities).

9.1.2.3.1 SYSTem subsystem commands

Command	Description
SYSTem	Path to SYSTem subsystem. (SCPI Vol.2 §21)
:ERRor	
[:NEXT]?	Returns the latest <error code, "message">. (SCPI Vol.2 §21.8.8)
:VERSion?	Query level of SCPI standard (1999.0) . (SCPI Vol.2 §21.21)
:LFRequency <numeric value>	Sets the instrument's line frequency setting to 50 or 60Hz. (SCPI Vol.2 §21.13)
:LFRequency?	Query the instrument's line frequency setting. (SCPI Vol.2 §21.13)
:SENSor	
:IDN?	Query information about the connected sensor. This is a query only command. The response consists of the following fields: `<name>,<sn>,<cal_msg>,<type>,<subtype>,<flags>` `<name>` Sensor name in string response format `<sn>` Sensor serial number in string response format `<cal_msg>` Calibration message in string response format `<type>` Sensor type in NR1 format `<subtype>` Sensor subtype in NR1 format `<flags>` Sensor flags as bitmap in NR1 format. Flag: / Dec.value: Is power sensor 1 Is energy sensor 2 Response settable 16 Wavelength settable 32 Tau settable 64 Has temperature sensor 256

9.1.2.3.2 STATus subsystem commands

Command	Description
STATus	Path to STATus subsystem. (SCPI Vol.2 §20)
:MEASurement	Path to control measurement event registers
[:EVENt]?	Read the event register
:CONDition?	Read the condition register
:PTRansition <value>	Program the positive transition filter

Command	Description
:PTRansition?	Read the positive transition filter
:NTRansition <value>	Program the negative transition filter
:NTRansition?	Read the negative transition filter
:ENABle <value>	Program the enable register
:ENABle?	Read the enable register
:AUXillary	Path to control measurement event registers
[:EVENt]?	Read the event register
:CONDition?	Read the condition register
:PTRansition <value>	Program the positive transition filter
:PTRansition?	Read the positive transition filter
:NTRansition <value>	Program the negative transition filter
:NTRansition?	Read the negative transition filter
:ENABle <value>	Program the enable register
:ENABle?	Read the enable register
:OPERation	Path to control operation event registers
[:EVENt]?	Read the event register
:CONDition?	Read the condition register
:PTRansition <value>	Program the positive transition filter
:PTRansition?	Read the positive transition filter
:NTRansition <value>	Program the negative transition filter
:NTRansition?	Read the negative transition filter
:ENABle <value>	Program the enable register
:ENABle?	Read the enable register
:QUEStionable	Path to control questionable event registers
[:EVENt]?	Read the event register
:CONDition?	Read the condition register
:PTRansition <value>	Program the positive transition filter
:PTRansition?	Read the positive transition filter
:NTRansition <value>	Program the negative transition filter
:NTRansition?	Read the negative transition filter
:ENABle <value>	Program the enable register
:ENABle?	Read the enable register
:PRESet	Return status registers to default states.

9.1.2.3.3 CALibration subsystem commands

Command	Description
CALibration	Path to CALibration subsystem. (SCPI Vol.2 §5)
:STRing?	Returns a human readable calibration string. This is a query only command. The response is formatted as string response data.

9.1.2.3.4 SENSe subsystem commands

Command	Description
[SENSe]	Path to SENSe subsystem. (SCPI Vol.2 §18)
AVERage	
[:COUNt] <value	Sets the averaging rate (1 sample takes approx. 3ms)
[:COUNt]?	Queries the averaging rate
CORRection	
[:LOSS[:INPut[:MAGNitude]]] {MINimum|MAXimum|DEFault|<numeric_value>}	Sets a user attenuation factor in dB
[:LOSS[:INPut[:MAGNitude]]]? [{MINimum|MAXimum|DEFault}]	Queries the user attenuation factor
COLLect	
ZERO	
[:INITiate]	Performs zero adjustment routine
ABORt	Aborts zero adjustment routine
STATe?	Queries the zero adjustment routine state
MAGNitude?	Queries the zero value
BEAMdiameter {MINimum|MAXimum|DEFault|<numeric_value>[mm]}	Sets the beam diameter in mm
BEAMdiameter? [{MINimum|MAXimum|DEFault}]	Queries the beam diameter
WAVelength {MINimum|MAXimum|<numeric_value>[nm]}	Sets the operation wavelength in nm
WAVelength? [{MINimum|MAXimum}]	Queries the operation wavelength
POWer	
[:PDIOde]	Sets the photodiode response value in A/W
[:RESPonse] {MINimum|MAXimum|DEFault|<numeric_value>[A]}	
[:RESPonse]? [{MINimum|MAXimum|DEFault}]	Queries the photodiode response value

<table>
<tr><th>Command</th><th>Description</th></tr>
<tr><td>:THERmopile</td><td></td></tr>
<tr><td>[:RESPonse] {MINimum|MAXimum|DEFault|<numeric_value>[V]}</td><td>Sets the thermopile response value in V/W</td></tr>
<tr><td>[:RESPonse]? [{MINimum|MAXimum|DEFault}]</td><td>Queries the thermopile response value</td></tr>
<tr><td>ENERgy</td><td></td></tr>
<tr><td>[:PYRO]</td><td></td></tr>
<tr><td>[:RESPonse] {MINimum|MAXimum|DEFault|<numeric_value>[V]}</td><td>Sets the pyro-detector response value in V/J</td></tr>
<tr><td>[:RESPonse]? [{MINimum|MAXimum|DEFault}]</td><td>Queries the pyro-detectro response value</td></tr>
<tr><td>CURRent[:DC]</td><td></td></tr>
<tr><td>RANGe</td><td></td></tr>
<tr><td>AUTO {OFF|0|ON|1}</td><td>Switches the auto-ranging function on and off</td></tr>
<tr><td>AUTO?</td><td>Queries the auto-ranging function state</td></tr>
<tr><td>[:UPPer] {MINmum|MAXimum|<numeric_valuje>[A]}</td><td>Sets the current range in A</td></tr>
<tr><td>[:UPPer]? [{MINimum|MAXimum}]</td><td>Queries the current range</td></tr>
<tr><td>REFerence {MINimum|MAXimum|DEFault|<numeric_value>[A]}</td><td>Sets a delta reference value in A</td></tr>
<tr><td>REFerence? [{MINimum|MAXimum|DEFault}]</td><td>Queries the delta reference value</td></tr>
<tr><td>STATe {OFF|0|ON|1}</td><td>Switches to delta mode</td></tr>
<tr><td>STATe?</td><td>Queries the delta mode state</td></tr>
<tr><td>ENERgy *)</td><td></td></tr>
<tr><td>RANGe</td><td></td></tr>
<tr><td>[:UPPer] {MINmum|MAXimum|<numeric_valuje>[J]}</td><td>Sets the energy range in J</td></tr>
<tr><td>[:UPPer]? [{MINimum|MAXimum}]</td><td>Queries the energy range</td></tr>
<tr><td>REFerence {MINimum|MAXimum|DEFault|<numeric_value>[J]}</td><td>Sets a delta reference value in J</td></tr>
<tr><td>REFerence? [{MINimum|MAXimum|DEFault}]</td><td>Queries the delta reference value</td></tr>
<tr><td>STATe {OFF|0|ON|1}</td><td>Switches to delta mode</td></tr>
<tr><td>STATe?</td><td>Queries the delta mode state</td></tr>
<tr><td>FREQuency *)</td><td></td></tr>
</table>

Command	Description
Range	
[UPPer]?	Queries the frequency range
LOWer?	
POWer[:DC]	
RANGe	
AUTO {OFF|0|ON|1}	Switches the auto-ranging function on and off
AUTO?	Queries the auto-ranging function state
[:UPPer] {MINmum|MAXimum|<numeric_valuje>[W]}	Sets the power range in W
[:UPPer]? [{MINimum|MAXimum}]	Queries the power range
REFerence {MINimum|MAXimum|DEFault|<numeric_value>[W]}	Sets a delta reference value in W
REFerence? [{MINimum|MAXimum|DEFault}]	Queries the delta reference value
STATe {OFF|0|ON|1}	Switches to delta mode
STATe?	Queries the delta mode state
UNIT {W|DBM}	Sets the power unit W or dBm
UNIT?	Queries the power unit
VOLTage[:DC]	
RANGe	
AUTO {OFF|0|ON|1}	Switches the auto-ranging function on and off
AUTO?	Queries the auto-ranging function state
[:UPPer] {MINmum|MAXimum|<numeric_valuje>[V]}	Sets the current range in V
[:UPPer]? [{MINimum|MAXimum}]	Queries the current range
REFerence {MINimum|MAXimum|DEFault|<numeric_value>[V]}	Sets a delta reference value in V
REFerence? [{MINimum|MAXimum|DEFault}]	Queries the delta reference value
STATe {OFF|0|ON|1}	Switches to delta mode
STATe?	Queries the delta mode state
PEAKdetector *)	
[:THReshold] {MINimum|MAXimum|DEFault|<numeric_value>	Sets the trigger level in % for the energy mode
[:THReshold]? [{MINimum|MAXimum|DEFault}	Queries the trigger level setting

*) Commands for PM100D, PM100USB and PM200 only

9.1.2.3.5 INPut subsystem commands

Command	Description
INPut	
[:PDIode]	
:FILTer	
[:LPASs]	
[STATe] {OFF|0|ON|1}	Sets the bandwidth of the photodiode input stage
[STATe]?	Queries the bandwidth of the photodiode input stage
:THERmopile	
:ACCelerator	
[STATe] {OFF|0|ON|1}	Sets the thermopile accelerator state
[STATe]?	Queries the thermopile accelerator state
:AUTO {OFF|0|ON|1}?	Sets the thermopile accelerator to auto mode
:TAU {MINimum|MAXimum|DEFault|	Queries thermopile accelerator auto mode
<numeric_value>[s]}	Sets thermopile time constant 0-63% in s
:TAU? [{MINimum|MAXimum|DEFault}]	Queries the thermopile time constant in s
:ADAPter	
[:TYPE] {PHOTodiode|THERmal|PYRo}	Sets default sensor adapter type
[:TYPE]?	Queries default sensor adapter type

9.1.2.3.6 Measurement commands

Command	Description
INITiate[:IMMediate]	Start measurement
ABORt	Abort measurement
CONFigure[:SCALar]	
[:POWer]	Configure for power measurement
:CURRent[:DC]	Configure for current measurement
:VOLTage[:DC]	Configure for voltage measurement
:ENERgy	Configure for energy measurement
:FREQuency	Configure for frequency measurement
:PDENsity	Configure for power density measurement
:EDENsity	Configure for energy density measurement
:RESistance	Configure for sensor presence resistance measurement
:TEMPerature	Configure for sensor temperature measurement
MEASure[:SCALar]	
[:POWer]	Performs a power measurement
:CURRent[:DC]	Performs a current measurement
:VOLTage[:DC]	Performs a voltage measurement
:ENERgy	Performs a energy measurement
:FREQuency	Performs a frequency measurement
:PDENsity	Performs a power density measurement
:EDENsity	Performs a energy density measurement
:RESistance	Performs a sensor presence resistance measurement
:TEMPerature	Performs a sensor temperature measurement
FETCh?	Read last measurement data (SCPI Vol.2 §3.2)
READ?	Start new measurement and read data (SCPI Vol.2 §3.3)
CONFigure?	Query the current measurement configuration.

10 Maintenance and Service

Protect the PM100USB from adverse weather conditions. The PM100USB 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 for return instructions.

Do not remove covers!

11 Appendix

11.1 Technical Data

General Data	
Detector Compatibility	Photodiode Sensors S100C Series Thermal Sensors S3xxC / S4xxC Series Pyroelectric Sensors EC100C/ES200C Series Photodiodes (max. 5 mA) Thermopiles (max. 1 V) Pyros (max. 100 V)
Display Type	External PC - Windows Application
Display Update Rate (max)	Up to 300 Hz, depending on PC and settings
Display Format	Numerical, Bar Graph, Trend Graph, Statistics, Histogramm (Utility Software)
Current Input (Photodiode Sensors)	
Connector	DB9F, left side
Units	W, dBm, W/cm², A
Measurement Ranges	6 decades; 50 nA - 5 mA Ranges selectable in W or A, sensor depending
Display Resolution	1 pA / responsivity value (A/W)
AD Converter	16 bit
Accuracy	± 0.2 % f.s. (5µA - 5mA) ± 0.5 % f.s. (50nA)
Input Bandwidth (Analog)	DC - 100kHz, depending on sensor and settings
Wavelength Correction	nm (A/W)
Beam Diameter Setting	1/e²
Voltage Input (Thermopile Sensors)	
Connector	DB9F, left side
Units	W, dBm, W/cm², V
Measurement Ranges	4 decades; 1 mV - 1V Ranges selectable in W or V, sensor dependent
Display Resolution	1 µV / responsivity value (V/W)
AD Converter	16 bit
Accuracy	± 0.5 % f.s. (10 mV - 1 V range) ± 1.0 % f.s. (1 mV range)
Input Bandwidth (Analog)	DC - 10Hz, depending on sensor and settings
Wavelength Correction	Sensor depending; nm, (V/W)
Beam Diameter Setting	1/e²

Voltage Input (Pyroelectric Sensors)	
Connector	DB9F, left side
Units	J, J/cm², W, W/cm², V
Measurement Ranges	4 decades; 100 mV - 100V Ranges selectable in J or V, sensor dependent
Display Resolution	100 µV / responsivity value (V/J)
AD Converter	16 bit
Accuracy	± 0.5 % f.s.
Trigger Threshold	0.1 % to 99.9 % f.s.
Input Bandwidth (Analog)	3 kHz
Input Impedance	1 MΩ
Wavelength Correction	Sensor depending; nm, (V/J)
Beam Diameter Setting	1/e²
Sensor Temperature Control	
Supported temperature sensor	Thermistor
Temperature measurement range	-10°C ... +80°C

Interface	
Type	USB2.0
Connector	Mini USB, left side
Power Supply	
External power supply	5V DC via USB
Accessories	
USB cable A to Mini-B, 2 m	
USB Stick with - Application Software - Instrument Drivers - Thorlabs Instrument Communicator - Thorlabs DFU (Device Firmware Upgrade) Wizard	
General	
Operating Temperature Range [1])	0 to + 40 °C
Storage Temperature Range	-40 to +70 °C
Dimensions (W x H x D)	93.1 mm x 60.4 mm x 28.7 mm (3.67" x 2.38" x 1.13")
Weight	approx. 0.15 kg
Relative Humidity	max. 80 % up to 31° C, decreasing to 50 % at 40° C
Operation Altitude	< 3000 m

[1]) non-condensing
All technical data are valid at 23 ± 5°C and 45 ± 15% rel. humidity (non condensing)

Current Input Photo Diode Sensors

Current Range	Display Resolution	Measurement Accuracy
5 mA	1µA	± 0.2 % f.s.
500 µA	100 nA	
50 µA	10 nA	
5 µA	1 nA	
500 nA	100 pA	
50 nA	10 pA	± 0.5 % f.s.

Voltage Input Thermal Sensors

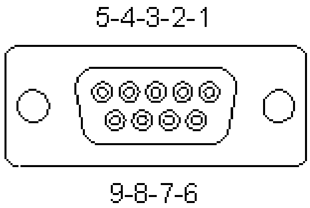
Voltage Range	Display Resolution	Measurement Accuracy
1 V	100 µV	± 0.5 % f.s.
100 mV	10 µV	
10 mV	1 µV	
1 mV	0.1 µV	± 1.0 % f.s.

Voltage Input Pyroelectrical Sensors

Voltage Range	Display Resolution	Measurement Accuracy
100 V	100 mV	± 0.5 % f.s.
10 V	10 mV	
1 V	1 mV	
0.1V	100 µV	

11.2 Pin Assignment of the Sensor Connector

The PM100USB is capable to support custom made detectors. Please read carefully the following instruction prior to connecting a self made sensor.



Pin-out of the 9pin DSUB sensor connector (female)

pin	connection
3	AGND (analog ground): photodiode ground (anode), thermal and pyro sensor ground
4	photodiode cathode
5	pyroelectric sensor +
8	thermal sensor +
7	PRESENT: Connect this pin via a 1kΩ – 10kΩ resistor to pin 3 (AGND) to enable a custom sensor
1	+5V (max. current 50mA from this pin)
6	DGND (digital ground)
9	n.c.

Warning

Pin 2 is uniquely used for the EEPROM Digital I/O (memory in Thorlabs sensor heads) and MUST NOT be used. Connecting this pin may cause malfunction of the PM100USB.

11.3 Tutorial

Content

Definitions and explanations: This section gives an overview on specifications, their definitions and application to sensor families.

Calculations: Here common formulas are given - power, energy and densities can be calculated based on different given parameters.

11.3.1 Definitions and explanations

In this section the key parameters of Thorlabs Power Meters and Sensors are commented.

11.3.1.1 Console Specifications

- **Measurement Ranges**

  It is important to keep in mind, that the optical power (energy) measurement is based on a current measurement (photodiode sensors) or on a voltage measurement (thermal and pyroelectric sensors). That's why the measurement ranges are stated sensor dependent - for photodiode sensors are stated the current ranges, for thermal and energy sensors - voltage ranges.

- **Display Resolution**

  Note:

  The resolution is the minimum detectable change of power (energy), it is **not** the minimum measurable power (energy)!

  As the console measures a current or a voltage, the display resolution can be stated only in A or V. In the specifications the resolution is stated for the most sensitive measurement range. The optical power resolution depends on the actual sensor's responsivity.

  Current input (photodiode sensors): The resolution is specified to "1 pA / responsivity value (A/W)". This means, that the PM100USB has in the lowest measurement range (50 nA) a resolution of 1 pA. The responsivity of a photo diode sensor is wavelength dependent, thus the power resolution is wavelength dependent as well.

  Example: A S120C sensor has a responsivity of 7.35 × 10^{-2} A/W at 930 nm, and 5.05 × 10^{-3} A/W at 455 nm. In the lowest measurement range the displayed power resolution is at 930 nm

$$\delta_{935nm} = \frac{1 \cdot 10^{-12}\,\mathrm{A}}{7.35 \cdot 10^{-2}\,\mathrm{A}/\mathrm{W}} = 1.36 \cdot 10^{-11}\,\mathrm{W} = 13.6\,\mathrm{pW}$$

  and at 455 nm

$$\delta_{455nm} = \frac{1 \cdot 10^{-12}\,\mathrm{A}}{5.05 \cdot 10^{-3}\,\mathrm{A}/\mathrm{W}} = 1.98 \cdot 10^{-10}\,\mathrm{W} = 198\,\mathrm{pW}$$

In contrast to above resolution values, the minimum measurable optical power for S120C is 50 nW. This should make clear the difference between resolution and minimum power.

Voltage input (thermopile sensors): The resolution is specified to "1 µV / responsivity value (V/W)". This means, that the PM100USB has in the lowest measurement range (1 mV) a resolution of 1 µV. The power resolution depends on the used sensor.

Voltage input (pyroelectric sensors): The resolution is specified to "100 µV / responsivity value (V/J)". This means, that the PM100USB has in the lowest measurement range (200 mV) a resolution of 100 µV. The energy resolution depends on the used sensor.

- **Accuracy** of the PM100USB is the current (voltage) measurement accuracy. It is given in % f.s. (% of the full scale value). Please note that the console's accuracy is different from the sensor's measurement uncertainty.
- **Wavelength Correction** is value that can be entered to the console in order to apply the correct responsivity and to get this way a correct measurement result.

  In case of a calibrated Thorlabs sensor, the actual wavelength is entered directly. The console retrieves the according responsivity from the calibration table, which is saved to the sensor's memory, and uses this value for power (energy) calculation.

  In case of a custom sensor, the console needs to be set to the correct sensor type (photodiode, thermal or pyroelectric sensor) and the responsivity needs to be entered as numerical value.

11.3.1.2 Sensor Specifications

1. Common parameters

- **Wavelength Range:** Within this range the sensor is calibrated and thus able to measure with the specified measurement uncertainty.
- **Resolution** is the minimum detectable change of the measured parameter. The resolution is always specified for a certain console type and bandwidth setting.
- **Measurement uncertainty** states the measurement accuracy and is specified for the entire wavelength range of the sensor. For some sensor types, an alternative value might be specified for a partial wavelength range.

2. Photo Diode Sensors (S12xC, S13xC and S15xC Series)

- **Optical Power Range** specifies the minimum and maximum measurable power. Exceeding the upper limit leads to sensor saturation and wrong measurement results. If pulsed signals are measured, the pulse peak power must not exceed the max. measurable power in order to avid saturation. Underrunning the lower limit leads to increased measurement uncertainty due to noise impact.

- **Max. Average Power Density** must not be exceeded to avoid damages to the sensor. For definition and calculation, please see section Calculations.
- **Max. Pulse Energy** is an alternative specification to max. average power density, which must not be exceeded. In case of the S15xC fiber sensors, the max. pulse energy density is given. The reason is that fibers may have a very small beam diameter at the fiber tip, leading to high energy densities. For definition and calculation, please see section Calculations.

3. **Integrating Sphere Sensors (S14xC Series) and Thermal Sensors (S3xxC / S4xxC Series)**

- **Optical Power Range** specifies the minimum and maximum measurable power. Exceeding the upper limit leads to sensor saturation and wrong measurement results. If pulsed signals are measured, the pulse peak power must not exceed the max. measurable power in order to avid saturation. Underrunning the lower limit leads to increased measurement uncertainty due to noise impact.
- **Max. Average Power Density** must not be exceeded to avoid damages to the sensor. For definition and calculation, please see section Calculations.
- **Max. Pulse Energy Density** is an alternative specification to max. average power density, which must not be exceeded. For definition and calculation, please see section Calculations.
- **Max. Intermittent Power (2 min. Max.)** can be applied to the sensor for max. 2 minutes without damages to the sensor. In case of pulsed signals, the average power of the pulse train is considered. Please note that this specification is higher than the max. measurable power, consequently the sensor will enter saturation and the measurement result will not be correct.

4. **Pyroelectric Energy Sensors (ESxxxC Series)**

- **Optical Energy Range** specifies the minimum and maximum measurable energy. Take care about the correct trigger level setting, particularly if measure energy levels, close to the lower limit of the measurement range - sensor noise may interfere the correct triggering to the pulse edge, which leads to wrong measurement results.
- **Max. Power Density** is related to the pulse peak power and must not be exceeded to avoid damages to the sensor. For definition and calculation, please see section Calculations.

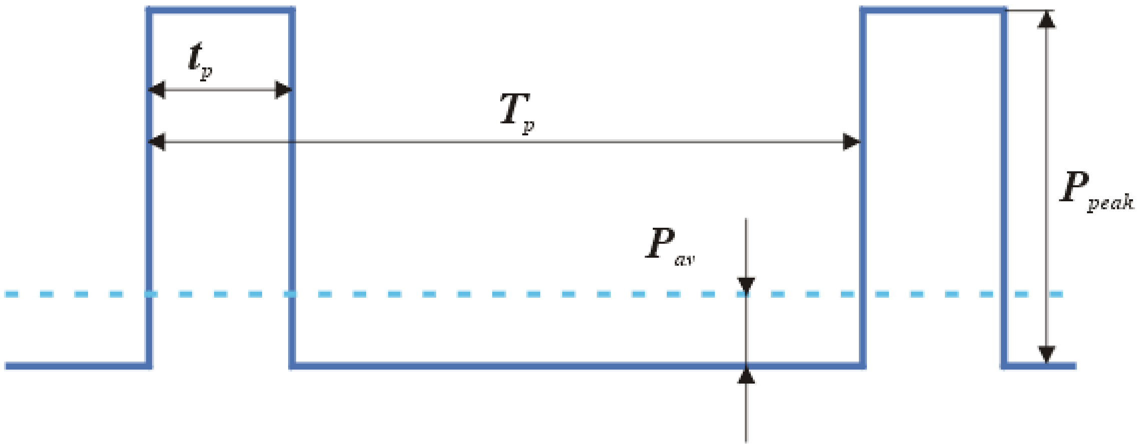
- **Max. Pulse Energy Density** is an alternative specification to max. average power density, which must not be exceeded. For definition and calculation, please see section Calculations.
- **Max. Average Power** must not be exceeded to avoid damages to the sensor as a consequence of overheating.

11.3.2 Calculations

In this section a collection of formulas is given to ease the conversion of pulse train parameters.

Note

All formulas below are given for rectangular pulses.



Pulse diagram

t_P pulse duration
T_P pulse period
P_{Peak} pulse peak power
P_{av} pulse average power

Repetition rate is related to pulse period:

$$f_p = \frac{1}{T_P} \quad [1]$$

Duty cycle is the ratio of pulse duration to pulse period:

$$D = \frac{t_P}{T_P} = t_P \cdot f_p$$

Pulse average power:

$$P_{av} = \frac{t_P}{T_P} P_{peak} = t_P \cdot f_p \cdot P_{peak} \quad [2]$$

Pulse peak power:

$$P_{peak} = \frac{T_P}{t_P} P_{av} = \frac{P_{peak}}{t_P \cdot f_p} \quad [3]$$

Energy: The measurement unit of energy is J (Joule) - 1J is the energy that is necessary to provide the power of 1 W(att) during 1s(ec). It can be calculated from the peak power of the pulse and the pulse duration:

$$W = P_{peak} \cdot t_P \quad [4]$$

By substitution of peak power by average power (formula [3]), the energy can be calculated from average power and repetition rate:

$$W = \frac{P_{av}}{f_P} \quad [5]$$

Power (Energy) Density

is the power (energy) per unit of beam area. The formulas below are based on a circular beam shape with the beam diameter d_B and an area of

$$A = \frac{\pi}{4} d_B^2$$

If the beam shape is not circular, the area must be calculated using the appropriate formula. For example, if the beam shape is elliptical with d_1 (long axis) and d_2 (short axis), the beam area is

$$A = \frac{\pi}{4} d_1 \cdot d_2$$

Average Power Density Ψ_{av}

The average power density is the ratio of the average power of the light beam to the area illuminated by this beam.

Given parameters	Formula
P_{av} (average power), d_B (beam diameter)	$\Psi_{av} = 4 \frac{P_{av}}{\pi \cdot d_B^2}$
P_{peak} (pulse peak power), f_P (repetition rate), t_P (pulse duration), d_B (beam diameter)	$\Psi_{av} = 4 \frac{P_{peak} \cdot t_P \cdot f_P}{\pi \cdot d_B^2}$
W (pulse energy), f_P (repetition rate) d_B (beam diameter)	$\Psi_{av} = 4 \frac{W \cdot t_P}{\pi \cdot d_B^2}$

Peak Power Density Ψ_{peak}

Given parameters	Formula
P_{peak} (pulse peak power), d_B (beam diameter)	$\Psi_{peak} = 4\frac{P_{peak}}{\pi \cdot d_B^2}$
W (pulse energy), t_P (pulse duration), d_B (beam diameter)	$\Psi_{peak} = 4\frac{W}{\pi \cdot d_B^2 \cdot t_P}$
P_{av} (average power), f_P (repetition rate), t_P (pulse duration), d_B (beam diameter)	$\Psi_{peak} = 4\frac{P_{av}}{\pi \cdot d_B^2 \cdot t_P \cdot f_P}$

Pulse Energy Density ξ

Given parameters	Formula
W (pulse energy), d_B (beam diameter)	$\xi = 4\frac{W}{\pi \cdot d_B^2}$
P_{peak} (pulse peak power), t_P (pulse duration), d_B (beam diameter)	$\xi = 4\frac{P_{peak} \cdot t_P}{\pi \cdot d_B^2}$
P_{av} (average power), f_P (repetition rate), d_B (beam diameter)	$\xi = 4\frac{P_{av}}{\pi \cdot d_B^2 \cdot f_P}$

11.4 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	EMC requirements for Class A electrical equipment for measurement, control and laboratory use, including Class A Radiated and Conducted Emissions [2,3,4]) and Immunity. [2,3,4])
	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 Compliance	Emissions comply with the Class A Limits of FCC Code of Federal Regulations 47, Part 15, Subpart B [2,3,4].	
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 [5]	
	EN 61010-1:2010	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use - Part 1: General Requirements
U.S. Nationally Recognized Testing Laboratory Listing	UL 61010-1 2nd ed.	
Canadian Certification	CAN/CSA C22.2 No. 61010-1 3rd ed.	
Additional Compliance	IEC 61010-1:2010	
Equipment Type	Test and Measuring	
Safety Class	Class I equipment (as 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.

[3] Emissions, which exceed the levels required by these standards, may occur when this equipment is connected to a test object.

[4] Minimum Immunity Test requirement

[5] Replaces 73/23/EEC, amended by 93/68/EEC

11.5 Warranty

Thorlabs warrants material and production of the PM100USB 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.

11.6 Copyright and Exclusion of Reliability

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.

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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.

11.7 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

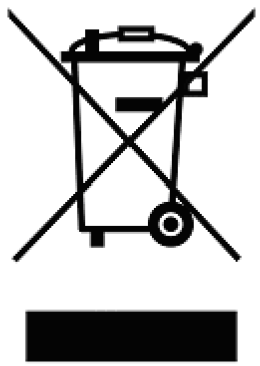
If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

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

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