Optical Power Meter

PM100USB
Operation Manual

2021

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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 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 PM100USB Optical Power and Energy Meter measures the optical power of laser light or other monochromatic or near monochromatic light, detected by an appropriate sensor and is compatible with all Thorlabs “C-Series” Photodiodes, Thermal Sensors, Pyroelectrics Energy Sensors, and respective custom sensors.

The PM100USB is run through the utility software Optical Power Monitor OPM 8 from a PC, tablet or laptop that is connected via a fast USB interface which makes it easy to integrate the instrument in test and measurement systems. The OPM software, including the instrument drivers, is available for download from the Thorlabs website. For previous TL software versions, please visit the Thorlabs software website.

These features, combined with its space saving design, enable a wide range of applications in Manufacturing, Quality Control, Quality Assurance, and R&D for stationary and field use.

Please refer to the user manual of the OPM software for detailed function description.

Attention

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

2 First Steps

Inspect the shipping container for damage.

If the shipping container seems to be damaged, keep it until you have inspected the contents for completeness and tested the PM100USB mechanically and electrically.

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

2.1 Parts List

1. PM100USB power/energy meter
2. USB cable, type ‘A’ to ‘mini-B’
3. Quick Reference
4. Certificate of Calibration

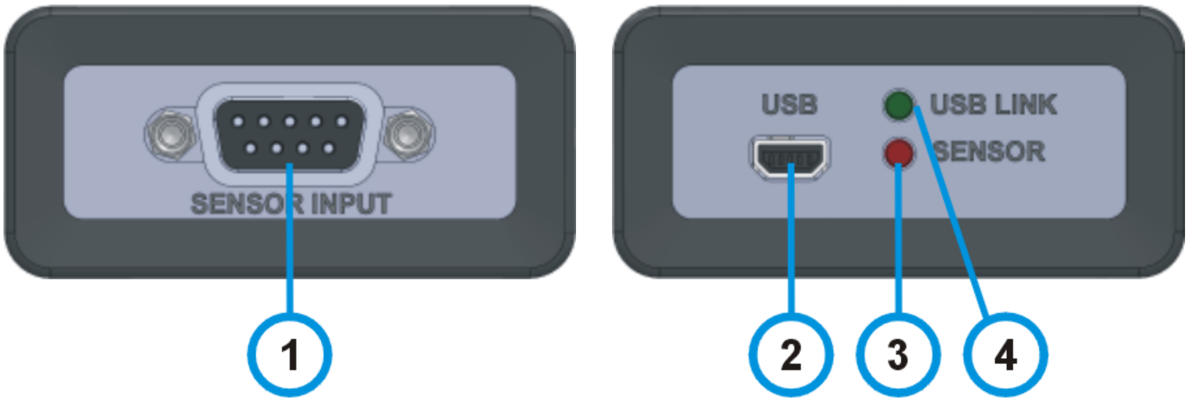
3 Operating Instruction

- Download and install the software Optical Power Monitor on the steering device (PC, laptop or tablet)

  Note

  Install the software prior to connecting the Power Meter to the PC.
- Connect a suitable sensor 6 to the PM100USB.
- Connect the PM100USB to the PC using the supplied USB cable.
- For detailed instructions on steering the PM100USB through the software, please download the manual for the application software OPM.

3.1 Operating Elements



1 DE-9 connector for power / energy sensors

2 USB connector to remote steering device (PC or tablet)

3 LED: sensor detected and PM100USB ready for operation

4 LED: USB connection to remote steering device (PC or tablet) established

3.2 Connecting a Power Sensor

The PM100USB supports all Thorlabs C-Series photodiode, energy, and thermal sensors, that can be easily identified by the red connector-housing of the DE-9 connector, compared to older versions of Thorlabs power sensors. Sensor type and calibration data are saved in the non-volatile memory of the DE-9 connector. Upon connection, this information is automatically sent to the PM100USB and to the steering device and software. The software will automatically recognize the sensor. For help to choose the most appropriate sensor, please refer to the chapter Choosing the Right Sensor 14.

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

DE-9 connector

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

Note

Although the power meter recognizes the sensor, this sensor information may not automatically be passed on to the utility software OPM. Please disconnect and reconnect the power meter to the PC to have the software recognize the power meter with the new sensor.

Note

Older Thorlabs Sensors without a DE-9 connector

The PM100USB will **NOT** automatically recognize sensors lacking a DE-9 connector, as for the case of the 'A' and 'B' series. Please contact Thorlabs 45 for an upgrade of old sensors with DE-9 connectors.

Note

Custom Sensors

To use sensors without a DE-9 connector, manufactured by Thorlabs or else, please provide an appropriate adapter. To build the adapter, refer to the pin-out of the DE-9 connector shown in the Appendix 35. The adapter will be automatically recognized by the application software Optical Power Monitor as "Photodiode adapter". For more information, please refer to the respective subsections in the manual chapter Sensor Dependent Functions 9 for Custom Photodiodes, Custom Thermal Sensors and Custom Pyroelectric Sensors 12.

4 Software

The utility software Optical Power Monitor (OPM) easily enables remote operation of the PM100USB from a PC, laptop or tablet. The software is available for download from the Thorlabs website and provides a Graphic User Interface to view, log, and analyze measurement data.

All information on device steering and data management software can be found in the software manual downloaded here.

Note

Do not connect the PM100USB prior to software installation!

Note

The PM100USB can also be run using custom made software. For this, please refer to the chapter Write-Your-Own-Application (WYOA) in the software manual.

Older software versions can still be used to run the PM100USB. Please refer to the software web page for more information.

Software Requirements

The software supplied for remote operation of the PM100USB requires a PC hardware and software environment as specified in the on the website and software manual.

4.1 Requirements

The software supplied for remote operation of the PM100USB requires a PC hardware and software environment as specified in the on the website and software manual.

5 Sensor Dependent Functions

5.1 Photodiode Sensors

The PM100USB is compatible with all Thorlabs S1xxC-Series photodiode power sensors, equipped with a DE-9 connector 6. The sensor is ready to operate only few seconds after plugging it to the DE-9 connector.

The S1xxC-Series includes photodiode sensors for various power levels that show advantages in sensitivity, stability and drift when compared to thermal sensors. To choose the appropriate sensor, refer to the section Choosing the Right Sensor 14, see the Thorlabs website or contact Thorlabs 45.

Attention

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

Sensor Calibration

Photodiodes, neutral density filters and integrating sphere materials show wavelength dependent behavior. Therefore each sensor is individually calibrated over its entire spectral operating range. The sensors spectral response data are stored in the non-volatile memory of the DE-9 connector and are automatically downloaded by the PM100USB and utility software upon plugging to the power meter.

Measurement Data

When using photodiodes in an experimental setup, it is critical to adjust the following settings in the utility software OPM.

5.1.1 Wavelength Setting

To perform an accurate measurement it is necessary to enter the operating wavelength of the measured light in the software so that the laser power can be calculated based on the measured photo current and the correct response value saved in the wavelength calibration table.

5.1.2 Bandwidth Setting (Signal Filtering)

The analogue bandwidth setting influences the power reading.

The bandwidth can be set in the utility software OPM either to **High** (range dependent bandwidth up to 100kHz) or to **Low** (15 Hz bandwidth).

For measuring CW or average power from pulsed sources, the bandwidth should be set to **Low**.

5.1.3 Custom Photodiodes

The following custom photodiodes can also be used with the PM100USB:

- Thorlabs photodiodes that are not part of the C-Series and do not have a DE-9 connector
- Photodiodes from other providers

Required Adaptations

1) Adapter Connector

To connect a custom sensor to the PM100USB, an adapter needs to be used. To build the adapter, please refer to the pin-out of the DE-9 connector shown in the Appendix 35. A photodiode and an interlock must be connected to the sensor input. Please ensure correct polarity - the photodiode cathode needs to be connected to ground.

The PM100USB and the utility software Optical Power Monitor will automatically recognize the presence of an adapter and show "Sensor Type: Photodiode Adapter" in the GUI.

2) Calibration Data

Be aware that spectral response calibration data of your custom photodiode are not sent to the OPM utility software. It is necessary to account for them in your analysis.

3) Measurement Data

In your experimental setup, it is critical to set the responsivity of the sensor at the measured operating wavelength in the utility software OPM under Devices-Settings, field: "Responsivity". Please refer to the specifications of your used sensor.

Note

If the adapter is not automatically recognized or the settings can not be adjusted in the software, please contact Thorlabs 45.

5.2 Thermal Power Sensors

The PM100USB is compatible with the Thorlabs C-Series of thermal power sensors (S3xxC, S4xxC, S175C), equipped with a DE-9 connector 6. The sensor is ready to operate only few seconds after plugging it to the DE-9 connector.

Thorlabs S3xxC and S4xxC Series of thermal sensors cover a wide range of applications and are available with different coatings. To choose the appropriate sensor, refer to the section Choosing the Right Sensor 14, see the Thorlabs website or contact Thorlabs 45.

Attention

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

Sensor Calibration

Thorlabs thermal sensors are calibrated for their spectral response and power at a specified wavelength. The sensors spectral response data are stored in the non-volatile memory of the DE-9 connector and are automatically downloaded by the PM100USB and utility software upon plugging to the power meter.

Measurement Data

In your experimental setup using thermal sensors, it is critical to adjust the following settings in the utility software OPM.

5.2.1 Wavelength Setting

To perform an accurate measurement it is necessary to enter the operating wavelength of the measured light in the software. This way, the laser power can be calculated based on the measured voltage and the correct response value from the wavelength calculation table.

5.2.2 Read-out Acceleration

Certain thermal sensors can show a fairly slow response. Please refer to the individual data sheet. When laser power hits the active area in these sensors, it takes up to 20 seconds until the system has settled and the power reading shows the correct value.

A slow sensor can be accelerated to up to 1-3 seconds by predicting the final power value based on the initial slope of the power reading.

This read-out acceleration can be set in the Devices - Settings panel of the utility software OPM. As this function has a disadvantage in that it induces noise to the measurement value, the acceleration circuit can be set to **Auto** or **Off**.

5.2.3 Custom Thermal Sensors

The following custom thermal sensors can also be used with the PM100USB:

- Thorlabs thermal sensors that are not part of the C-Series and do not have a DE-9 connector
- Thermal sensors from other providers

Required Adaptations

1) Adapter Connector

To connect a custom sensor to the PM100USB, an adapter needs to be used. To build the adapter, please refer to the pin-out of the DE-9 connector shown in the Appendix 35. A thermal sensor and an interlock must be connected to the sensor input.

The PM100USB and the utility software Optical Power Monitor will automatically recognize the presence of an adapter and show "Sensor Type: Photodiode Adapter" in the GUI.

2) Calibration Data

Be aware that spectral response or other calibration data of your custom thermal sensor are not automatically sent to the utility software. It is necessary to account for them in your analysis.

3) Measurement Data

In your experimental setup, it is critical to set the responsivity of the sensor at the measured operating wavelength in the utility software OPM under Devices-Settings, field: "Responsivity". Please refer to the specifications of your used custom sensor.

Note

If the adapter is not automatically recognized or the settings can not be adjusted in the software, please contact Thorlabs 45.

5.3 Pyroelectric Energy Sensors

The PM100USB is compatible with all Thorlabs ESxxxC Pyroelectric Energy Sensors (ES1xxC and ES2xxC series), equipped with a DE-9 connector 6. The sensor is ready to operate only few seconds after plugging it to the DE-9 connector.

Pyroelectric sensors allow to measure the pulse energy of single and repetitive pulses from coherent and incoherent sources. 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. To choose the appropriate sensor, refer to the section Choosing the Right Sensor 14, visit the Thorlabs website or contact Thorlabs 45.

Attention

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

Sensor Calibration

Thorlabs pyroelectric sensors are calibrated for their spectral response.The sensors spectral response data are stored in the non-volatile memory of the DE-9 connector and are automatically downloaded by the PM100USB and utility software upon plugging to the power meter.

Measurement Data

In your experimental setup, it is critical to adjust the following settings in the utility software OPM.

5.3.1 Auto Range

The PM100USB cannot be switched to auto range mode in the utility software OPM, 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 shown in the display.

5.3.2 Trigger Level

A trigger level can be set to exclude unwanted low-power pulses from the analysis. 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. Please see the manual of the OPM software for instructions on how to set the trigger level.

5.3.3 Average Power Measurement

The PM100USB calculates the average power of pulse trains from the single pulse energy and the repetition rate. Please see the manual of the utility software OPM for more details.

5.3.4 Density Calculation

When the correct beam diameter of the incident beam is entered, this function returns the energy density in J/cm^2.

5.3.5 Custom Pyroelectric Sensors

The following custom pyroelectric sensors can also be used with the PM100USB:

- Thorlabs pyroelectric sensors that are not part of the C-Series and do not have a DE-9 connector
- Pyroelectric sensors from other providers

Required Adaptations

1) Adapter Connector

To connect a custom sensor to the PM100USB, an adapter needs to be used. To build the adapter, please refer to the pin-out of the DE-9 connector shown in the Appendix 35. A pyroelectric sensor and an interlock must be connected to the sensor input.

The PM100USB and the utility software Optical Power Monitor will automatically recognize the presence of an adapter and show "Sensor Type: Photodiode Adapter" in the GUI.

2) Calibration Data

Be aware that spectral response of your custom pyroelectric sensor are not automatically sent to the utility software. It is necessary to account for them in your analysis.

3) Measurement Data

In your experimental setup, it is critical to set the responsivity, in V/J, of the sensor at the measured operating wavelength in the utility software OPM under Devices-Settings, field: "Responsivity". Please refer to the specifications of your used custom sensor.

6 Measurement Considerations

6.1 Choosing the Right Sensor

The optimal choice of sensor depends on several factors, starting with the type of light source to measure (wavelength and power) and the application. No single sensor can cover all applications. The table below provides guidance to find an optimal power sensor type depending on the light source. Be aware that within each sensor group there are special models best suitable for specific applications. For advice on selecting a sensor, please contact the engineers at Thorlabs 45.

Photodiode Sensors

Thorlabs offers photodiode sensors of the C-series for power levels from sub-nano watts up to 20 W that show advantages in sensitivity, stability and drift when compared to thermal sensors. The sensors are built as a combination of a photodiode with either a neutral density filter or a integrating sphere. They provide linearity over several orders of magnitude. For sensors which can handle small power levels down to the pW range, the sensor size can be reduced to a minimum. Further, the response time of such sensors is very fast down to the nanosecond range.

Thermal Sensors

Thermal sensors absorb incident laser power. This heats up the absorber and the heat flow through thermocouple elements between absorbing area and sensor heat sink generates a small voltage. Thorlabs C-Series thermal power sensors (S3xxC, S4xxC, S175C) cover a wide range of applications and are available with different coatings.

- **Black broad band coatings:** Depending on the sensor and operating wavelength, wavelength correction may not be required because the response is nearly flat from the UV to the mid-IR for some sensors. Please see the respective sensor manual.
- **Special hard coatings**: These high power broadband sensors withstand high power levels and show a good spectral flatness.
- Thorlabs offers **special heads** for power measurements with volume absorber coatings for high peak power levels (e.g. YAG Lasers).

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 100 mW up. Thorlabs offers also a special thermally isolated thermal head with flat response and on power levels starting in the µW range.

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	+	-	-	+++	+	-

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 (excessive energy causes mechanical damages on the layer). Here, the specified maximum temperature level must not be exceeded. It is important to pay attention to the maximum energy density, to the average power, and to the maximum power density during a pulse.

On the lower end, the detection is limited by the resolution and the minimum trigger level 12, as well as by the noise level.

Beam Diameter

The active area of the detector should be selected in such that it has a slightly larger diameter than the incident beam. The beam should not necessarily 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 of a power meter unit has an input impedance of 1 MΩ (similar to 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 maximum 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. A sensor specific correction curve is stored in the memory of the DE-9 connector for other wavelengths. The wavelength dependent response is nearly linear flat for black coating over a wavelength range from 185 nm to > 25µm; the ceramic coating is also suitable for this wavelength range, but is not flat over the entire wavelength range.

6.2 Reducing Noise for High Accuracy Measurements

Noise from grounding, cable capacitance, temperature effects, stray and ambient light, and detector noise are interfering with the measurement. The impact of noise is high for measurements of low optical power signal. Below are some recommendations on how to reduce interference to a minimum:

- The housing of power sensors is connected to the digital ground of the power meter and should be linked to earth ground (e.g. via post mounting).
- Energy sensors should be mounted as isolated devices, using the supplied isolation adapters, because the housing is connected to the power meter analog ground.
- The sensor cable conducts very small current or voltage signals. The cable capacitance induces disturbances when the cable is moved. Whenever very small power or energy levels are measured, the cable should be fixed in position.
- The bandwidth should be set to Low , when using photodiode sensors.
- The acceleration circuit should be switched off when using thermal sensors.
- Choose a suitable sensor: 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 to best shield the light path from external light sources.
- The temperature should be stable over the time of the measurement.

6.3 Power Measurement of Pulsed Signals

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

Photodiode Sensor

A photodiode sensor can follow short pulses in the nano second range. To achieve this, it is important that the pulse peak power is within the maximum power range of the sensor and that the power range in the software is set such that the peak power will not exceed this range. Otherwise, the reading will clip at the end of the range and lead to a wrong average 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.

Thermal Sensor

For a thermal sensor, pulse length, repetition rate and peak power are not critical as long as the peak power is lower than the damage threshold of the sensor. Some thermal sensors react very slowly and will integrate the power incident on the active area of the sensor. Therefore the time resolution of the thermal sensor is limited.

6.4 Line Width of Light Sources

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

Photodiode sensors show a strong dependency on the operating wavelength. For light sources with a line width greater than 10 nm (e.g. LED) there may be an influence on the displayed power. To achieve best results 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 show the optical power for a symmetrical spectral response shape.

6.5 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 affected by airflow disturbances or by heating of the heat sink, as for example during long-term exposure of the thermal disc to the laser beam.

To avoid disturbances it is recommended to shield the sensor 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).

6.6 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, install proper shielding of the sensor from ambient and stray light.

6.7 Back Reflection

The surfaces of photodiodes, ND filters and even the black coatings of thermal sensors show a small percentage 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. It is therefore recommended to slightly tilt the power meter sensor with respect to the laser beam. This way, the back reflection will not 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 is almost completely absorbed in the sensor.

6.8 Beam Diameter vs. Active Sensor Area

Most sensors are not completely uniform in their response over the active area. 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 values are given in the sensor specifications. The software displays the actual power or energy density for the beam diameter inserted in the software. 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. This means that the beam size in the plane of the sensors active area must not exceed the size of the active area.

6.9 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 as follows:

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

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

For typical single mode fibers the total angle 2*Θ 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 which causes 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 power meter. This minimizes measurement interference.

7 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 and vice versa. 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.

7.1 SCPI Commands

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

Note

The commands listed in this section are supported by a USBTMC protocol and can be used with the instrument driver PM100D (NI-VISA™), since here, NI-VISA™ provides USBTMC. The PM100D.dll is the instrument driver installed on you PC with software versions prior to May 2018.

Alternatively, the user can use the SCPI commands with the new TLPM.dll driver, as long as the user establishes an USBTMC protocol.

In any case, the user can switch to the former instrument driver PM100D (NI-VISA™) to use the SCPI-commands by using the Power Meter Driver Switcher that is installed with the Optical Power Monitor software package. Please ensure to also install NI-VISA™ to use the driver PM100D.dll.

7.1.1 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>
```

7.1.2 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?

7.1.2.1 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

7.1.2.2 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.

7.1.2.3 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).

7.1.2.3.1 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

7.1.2.3.2 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
:PTRansition?	Read the positive transition filter
:NTRansition <value>	Program the negative transition filter
:NTRansition?	Read the negative transition filter

Command	Description
: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.

7.1.2.3.3 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.

7.1.2.3.4 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
:THERmopile	

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

<table>
<tr><th>Command</th><th>Description</th></tr>
<tr><td>[UPPer]?</td><td>Queries the frequency range</td></tr>
<tr><td>LOWer?</td><td></td></tr>
<tr><td>POWer[: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>[W]}</td><td>Sets the power range in W</td></tr>
<tr><td>[:UPPer]? [{MINimum|MAXimum}]</td><td>Queries the power range</td></tr>
<tr><td>REFerence {MINimum|MAXimum|DEFault|<numeric_value>[W]}</td><td>Sets a delta reference value in W</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>UNIT {W|DBM}</td><td>Sets the power unit W or dBm</td></tr>
<tr><td>UNIT?</td><td>Queries the power unit</td></tr>
<tr><td>VOLTage[: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>[V]}</td><td>Sets the current range in V</td></tr>
<tr><td>[:UPPer]? [{MINimum|MAXimum}]</td><td>Queries the current range</td></tr>
<tr><td>REFerence {MINimum|MAXimum|DEFault|<numeric_value>[V]}</td><td>Sets a delta reference value in V</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>PEAKdetector *)</td><td></td></tr>
<tr><td>[:THReshold] {MINimum|MAXimum|DEFault|<numeric_value></td><td>Sets the trigger level in % for the energy mode</td></tr>
<tr><td>[:THReshold]? [{MINimum|MAXimum|DEFault}</td><td>Queries the trigger level setting</td></tr>
</table>

*) Commands for PM100D, PM100USB and PM200 only

7.1.2.3.5 INPut subsystem commands

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

7.1.2.3.6 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.

8 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 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 45 for return instructions.

Do not open the housing!

9 Appendix

9.1 Technical Data

General Data	
Detector Compatibility	Photodiode Sensors S1xxC Series Thermal Sensors S3xxC / S4xxC Series Pyroelectric Sensors EC1xxC/ES2xxC Series Photodiodes (max. 5 mA) Thermopiles (max. 1 V) Pyros (max. 100 V)
Display Type	External PC, Laptop, Tablet - Windows Application
Display Update Rate (max)	Up to 300 Hz, depending on PC and Settings
Display Format	Optical Power Monitor: Numerical, Tuning Needle, Bar Graph, Trend Graph, Statistics, Histogram
Current Input (Photodiode Sensors)	
Connector	DE-9 female, left side
Units	W, dBm, W/cm², A
Measurement Ranges	10^6 ; 50 nA - 5 mA Ranges selectable in W or A, Sensor Dependent
Display Resolution	1 pA / responsivity value (A/W)
AD Converter	16 bit
Measurement Uncertainty	± 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	DE-9 female, left side
Units	W, dBm, W/cm², V
Measurement Ranges	10^4 ; 1 mV - 1V Ranges selectable in W or V, Sensor Dependent
Display Resolution	1 µV / responsivity value (V/W)
AD Converter	16 bit
Measurement Uncertainty	± 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	DE-9 female, left side
Units	J, J/cm², W, W/cm², V
Measurement Ranges	10^4; 100 mV - 100V Ranges selectable in J or V, sensor dependent
Display Resolution	100 µV / responsivity value (V/J)
AD Converter	16 bit
Measurement Uncertainty	± 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	$1/e^2$
Sensor Temperature Measurement	
Supported Temperature Sensor	Thermistor
Temperature Measurement Range	-10°C ... +80°C

Interface	
Type	USB 2.0
Connector	Mini USB, left side
Power Supply	
External Power Supply	5V DC via USB
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	1 µA	± 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

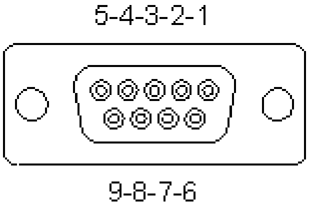
Voltage Range	Display Resolution	Measurement Accuracy
1 V	100 µV	± 0.5 % f.s.
100 mV	10 µV	
10 mV	1 µV	
1 mV	0.1 µV	± 1.0 % f.s.

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	

9.2 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.

9.3 Tutorial

Content

Definitions and explanations 36: This section gives an overview on specifications, their definitions and application to sensor families.

Calculations 39: Here common formulas are given - power, energy and densities can be calculated based on different given parameters.

9.3.1 Definitions and Explanations

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

9.3.1.1 Power Meter Specifications

- **Measurement Ranges**

  It is important to keep in mind that the optical power and energy measurement is based on a current measurement (photodiode sensors) or on a voltage measurement (thermal and pyroelectric sensors). That is why the measurement ranges are stated sensor dependent: For photodiode sensors, they are stated as the current ranges; For thermal and energy sensors, they are stated as 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 power meter 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 sensors responsivity.

  Current input (photodiode sensors): The resolution is specified as:

  1 pA / responsivity value [A/W]

  Therefore, the PM100USB has a resolution of 1 pA at the lowest measurement range (50 nA). The responsivity of a photo diode sensor is wavelength dependent and 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 δ at 930 nm is:

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

  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 clarify the difference between resolution and minimum power.

  Voltage input (thermopile sensors): The resolution is specified as

  1 µV / responsivity value [V/W]

Therefore, the PM100USB has a resolution of 1 µV at the lowest measurement range (1 mV). The power resolution depends on the used sensor.

Voltage input (pyroelectric sensors): The resolution is specified as:

100 µV / responsivity value [V/J]

Therefore, the PM100USB has a resolution of 100 µV at the lowest measurement range (200 mV . The energy resolution depends on the used sensor.

- **Measurement Uncertainty** of the PM100USB is the current (voltage) measurement accuracy. It is given in % f.s. (% of the full scale value). Please note that the accuracy of the power meter is different from the measurement uncertainty of the sensor.
- **Wavelength Correction** is the value that can be entered to the power meter in order to apply the correct responsivity and to receive a corrected measurement result.

  In case of a calibrated Thorlabs sensor, the actual wavelength is entered directly. The power meter retrieves the respective responsivity from the calibration table that was saved to the DE-9 connector memory and uses this value for power or energy calculation.

  In case of a custom sensor, the correct responsivity needs to be entered as a numerical value in the utility software OPM.

9.3.1.2 Sensor Specifications

a. 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 power meter 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.

b. 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 maximum measurable power in order to avoid saturation. Falling below the lower limit leads to increased measurement uncertainty due to the increasing impact of noise.
- **Max. Average Power Density** must not be exceeded to avoid damages to the sensor. For definition and calculation, please see section Calculations 40.
- **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 39.

c. 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 40.
- **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 41.
- **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.

d. Pyroelectric Energy Sensors (ESxxxC Series)

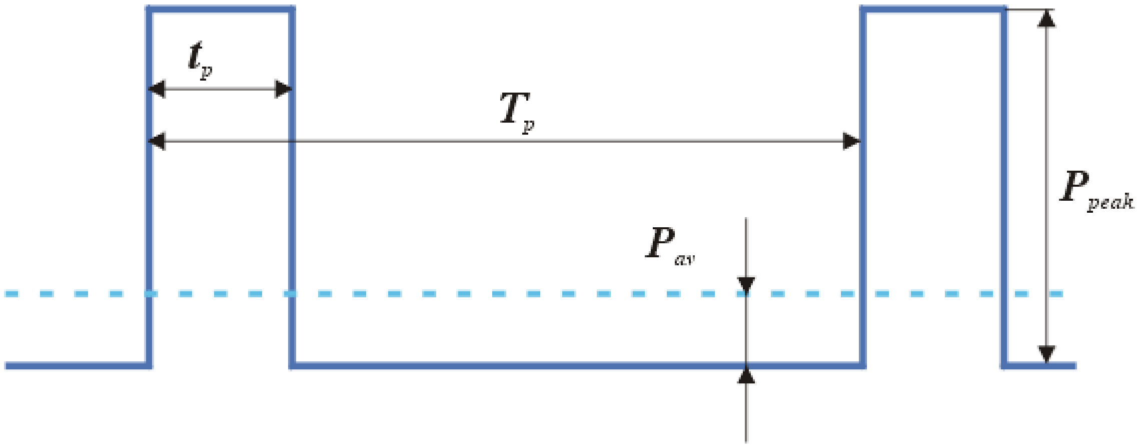
- **Optical Energy Range** specifies the minimum and maximum measurable energy. Take care about the correct trigger level setting, particularly if measure energy levels, close to the lower limit of the measurement range - sensor noise may interfere the correct triggering to the pulse edge, which leads 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 41.
- **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 41.
- **Max. Average Power** must not be exceeded to avoid damages to the sensor as a consequence of overheating.

9.3.2 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 during 1s. 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)	$\xi = 4\frac{P_{av}}{\pi \cdot d_B^2 \cdot f_P}$

9.4 Safety

Attention

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

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

The PM100USB must not be operated in explosion endangered environments!

Do not obstruct the air ventilation slots in the housing!

Do not remove covers!

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

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

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

All modules including control inputs / outputs and the sensor must be connected with duly shielded connection cables.

Attention

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

Note

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules and meets all requirements of the Canadian Interference-Causing Equipment Standard ICES-003 for digital apparatus. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

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.

Attention

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

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

9.5 Certifications and Compliances

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs GmbH

Of: Münchner Weg 1, 85232 Bergkirchen, Deutschland

in accordance with the following Directive(s):

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

hereby declare that:

Model: ***PM100USB***

Equipment: ***Optical Power and Energy Meter - USB Only Interface***

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

EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013
EN 61010-1	Safety requirements for electrical equipment for measurement, control, and laboratory use	2010

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

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

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

Signed:

On: 20 November 2019

Name: Bruno Gross

Position: General Manager

EDC - PM100USB -2019-11-20

9.6 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.

9.7 Copyright and Exclusion of Liability

Thorlabs has taken every possible care in preparing this document. We however assume no liability for the content, completeness or quality of the information contained therein. The content of this document is regularly updated and adapted to reflect the current status of the hardware and/or software. We furthermore do not guarantee that this product will function without errors, even if the stated specifications are adhered to.

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

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

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

9.8 Thorlabs Worldwide Contacts and WEEE policy

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

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

China
Thorlabs China
chinasales@thorlabs.com

Thorlabs 'End of Life' Policy (WEEE)

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

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