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THORLABS

CAL-S200 - February 12, 2021

Item # CAL-S200 was discontinued on February 12, 2021. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

THERMAL POWER SENSORS (C-SERIES)

Hide Overview

OVERVIEW

Features

- Broad Spectral Ranges with Relatively Flat Spectral Responses (See Plots Below)
- Individually Calibrated with NIST- and PTB-Traceable Certificate of Calibration
- Free-Space and Fiber-Based Applications Supported
  - All Sensors Accept Free Space Input
  - Majority Accept Fiber Adapter (Available Below) for Fiber-Based Input
- C-Series Connector
  - Enables Quick Sensor Connection to Our Power Meter Consoles
  - Embedded EEPROM Contains Sensor and Calibration Data
- Ten Models Feature Over-Temperature-Alert Sensor (See *Specs* Tab for Details)

Click to Enlarge
S401C Connected to the PM100D Console


Click to Enlarge


Click to Enlarge

Internal SM05 (0.535"-40) threading on the S405C's aperture (left) accepts the included external SM05 to SM1 (1.035"-40) thread adapter (right). Most sensors include an SM1 externally threaded adapter that allows accessories like fiber adapters to be mounted.

Power Meter Selection Guide
Sensors
Photodiode Power Sensors
Thermal Power Sensors
Thermal Position & Power Sensors
Pyroelectric Energy Sensors
Power Meter Consoles

Thorlabs' C-Series Thermal Power Sensors are collectively able to detect power ranges from 10 µW to 200 W and wavelength ranges from 190 nm to 20 µm. These thermopile-based sensors are ideal choices for measuring broadband spectra from amplified spontaneous emission (ASE) sources, light emitting diodes (LEDs), filament lamps, swept-wavelength lasers, and other sources. In addition, thermal power sensors do not saturate, which makes them well suited to measuring pulsed sources with high pulse peak powers or long-duration pulses. These thermal power sensors also exhibit low dependency on the angle and position of the incident light beam. They are preferred for applications that cannot tolerate the strong wavelength dependencies and/or saturation thresholds of photodiode sensors. However, thermal power sensors generally have lower power resolutions and longer response times. We offer a wide range of thermal power sensors, with each including different design features.

Digital Handheld Console
Analog Handheld Console
Touchscreen Handheld Console
Dual-Channel Benchtop Console
Complete Power Meters
Power Meter Bundles
Wireless Power Meters with Sensors
Compact USB Power Meters
Field Power Meters for Terminated Fibers
USB Interfaces, External Readout

Mounting

The sensors sold here (except the S175C) can be mounted on our Ø1/2" Posts using an 8-32, M4, or M6 tap. A 60 mm or 75 mm tall post is included with select sensors. Additionally, many of our thermal sensors are compatible with 30 mm cage systems, Ø1" lens tube systems, and our fiber adapters (sold below). Please refer to the *Specs* tab for more information.

Calibration

Each sensor head is individually calibrated and is shipped with a NIST- and PTB-Traceable Calibration Certificate. The calibration and identification data is stored in the electrically erasable programmable read-only memory (EEPROM) built into the connector of the sensor and is downloaded automatically to the connected power meter console. The EEPROM also contains sensor model and serial numbers, wavelength range, information on the built-in thermistor (when present), and the calibration date. For more information on sensor calibration, please see the *Calibration* tab on our Power Meter and Sensor Tutorial.

Power Meter Compatibility

All sensors are connected to the power meter console via the C-Series connector, which offers quick sensor exchange. These sensors are compatible with our current power meter console offering but cannot be used with our previous generation of consoles. For our sensors with natural response times greater than 1 second, these power meters can use the data stored in the connector to predict the incident power after a single time constant of the sensor. Please see the *Operation* tab for more information.

Recalibration Services

Thorlabs offers recalibration services for our thermal power sensors. To ensure accurate measurements, we recommend recalibrating the sensors annually. This service can be ordered below (see Item # CAL-S200).

Sensor Upgrade and Service

All C-Series Sensors are incompatible with former generation power meter consoles with non-C-Series connectors. We offer a sensor upgrade service if you want to use your existing sensors with a new power meter console with a C-Series connector. Note: upgraded sensors will be incompatible with old power meter consoles with non-C-Series connectors. Please contact our Tech Support team for details.

Thermal Power Sensors Quick Links					
Type	**High Resolution**	**Max Power: 10 W**	**Max Power: 40 W to 200 W**	**High Max Power Density for Pulsed Lasers**	**Microscope Slide Thermal Sensor**
Wavelength Range[a]	190 nm - 20 µm	190 nm - 20 µm	190 nm - 20 µm	250 nm - 10.6 µm	300 nm - 10.6 µm
Optical Power Range[a]	10 µW - 5 W	2 mW - 10 W	10 mW - 200 W	100 µW - 10 W	100 µW - 2 W
Max Optical Power Density[a]	500 - 1500 W/cm² (Avg.)	1500 W/cm² (Avg.)	2 - 4 kW/cm² (Avg.)	35 W/cm² (Avg.); 100 GW/cm² (Peak, 1 ns Pulse)	200 W/cm²
Resolution[a]	1 µW - 5 µW	100 µW	100 µW - 5 mW	10 µW - 250 µW	10 µW

- Combined Range for All Sensors in the Respective Category

Hide Specs

SPECS

Thorlabs' Thermal Power Sensors (C-Series)

Click on the links in the following list or Selection Guide to move to the indicated specification tables.

- High Resolution
- Max Power: 10 W
- Max Power: 40 W to 200 W
- High Max Power Density for Pulsed Lasers
- Microscope Slide Thermal Sensor

High Resolution

Item #	S401C	S405C
Detection Specifications		
Detector Type	Thermal Surface Absorber with Background Compensation (Axial Thermopile)	Thermal Surface Absorber (Axial Thermopile)
Wavelength Range	190 nm - 20 µm	190 nm - 20 µm
Optical Power Range	10 µW - 1 W	100 µW - 5 W
Max Average Power Density[a]	500 W/cm²	1.5 kW/cm²
Max Pulse Energy Density	0.2 J/cm² (1 µs Pulse), 2 J/cm² (1 ms Pulse)	0.3 J/cm² (1 ns Pulse), 5 J/cm² (1 ms Pulse)
Max Intermittent Power[b]	3 W	-
Linearity	±0.5%	±0.5%
Resolution[c]	1 µW	5 µW
Measurement Uncertainty[d] **(Calibration Uncertainty)**	±3% @ 1064 nm ±5% @ 190 nm - 10.6 µm	±3% @ 1064 nm ±5% @ 250 nm - 17 µm
Response Time[e]	1.1 s	1.1 s
General Information		
Suggested Application	Low Power Lasers and LEDs	Low Power Lasers and LEDs
Absorber	High-Power Broadband Coating	High-Power Broadband Coating
Cooling	Convection (Passive)	
Temperature Sensor (In Sensor Head)	NTC Thermistor	NTC Thermistor
Console Compatibility	PM400, PM100D, PM100A, PM320E, and PM100USB	
Mechanical Specs		
Housing Dimensions (Without Adapter)	33.0 m x 43.0 mm x 15.0 mm (1.30" x 1.69" x 0.59")	40.6 mm x 40.6 mm x 16.0 mm (1.60" x 1.60" x 0.63")
Sensor Input Aperture	Ø10 mm	Ø10 mm
Active Detector Area	10 mm x 10 mm	10 mm x 10 mm
Distance to Detector[f]	3 mm	5 mm
Cable Length	1.5 m	
Connector	D-Sub 9 Pin Male	
Weight	0.05 kg (0.11 lb)	0.11 kg (0.24 lb)
Mounting and Accessories		
Post	Ø1/2" Post via Universal 8-32 & M4 Tap (Post Not Included)	Ø1/2" Post via Universal 8-32 & M4 Tap (Post Not Included)
Cage System Mounting	N/A	30 mm Cage Systems via Two 4-40 Tapped Holes; Two Ø6 mm Through Holes for ER Series Rods
Aperture Thread	Externally SM1-Threaded Adapter for Ø1" Lens Tubes and Fiber Adapters	Internally SM05-Threaded Aperture Externally SM1-Threaded Adapter for Ø1" Lens Tubes and Fiber Adapters
Fiber Adapters (Available Below)	S120 Series Fiber Adapters	

- For continuous wave (CW) sources, this value is equivalent to the peak power density, while for pulsed laser sources this value is calculated from the time-averaged power and beam profile.
- Twenty-minute maximum exposure time for the S401C. The S405C saturates for optical input powers >5 W.
- Measurement taken with the legacy PM200 console for the S401C and the PM400 console for the S405C. In both cases, the acceleration circuit was switched off. Resolution performance will be similar with our other power meter consoles.
- Measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.

Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s). See the *Operation* tab for additional information.
- Distance is measured from the detector to the front face of the housing.

Max Power: 10 W

Item #	S415C	S425C
Detection Specifications		
Detector Type	Thermal Surface Absorber (Axial Thermopile)	Thermal Surface Absorber (Axial Thermopile)
Wavelength Range	190 nm - 20 µm	190 nm - 20 µm
Optical Power Range	2 mW - 10 W	2 mW - 10 W
Max Average Power Density[a]	1.5 kW/cm²	1.5 kW/cm²
Max Pulse Energy Density	0.3 J/cm² (1 ns Pulse), 5 J/cm² (1 ms Pulse)	0.3 J/cm² (1 ns Pulse), 5 J/cm² (1 ms Pulse)
Max Intermittent Power[b]	20 W	20 W
Linearity	±0.5%	±0.5%
Resolution[c]	100 µW	100 µW
Measurement Uncertainty[d] (Calibration Uncertainty)	±3% @ 1064 nm ±5% @ 250 nm - 17 µm	±3% @ 1064 nm ±5% @ 250 nm - 17 µm
Response Time[e]	0.6 s	0.6 s
General Information		
Suggested Application	Low and Mid-Power Lasers & LEDs	Low and Mid-Power Lasers & LEDs
Absorber	High-Power Broadband Coating	High-Power Broadband Coating
Cooling	Convection (Passive)	
Temperature Sensor (In Sensor Head)	NTC Thermistor	
Console Compatibility	PM400, PM100D, PM100A, PM320E, and PM100USB	
Mechanical Specs		
Housing Dimensions (Without Adapter)	50.8 mm x 50.8 mm x 35.0 mm (2.00" x 2.00" x 1.38")	50.8 mm x 50.8 mm x 35.0 mm (2.00" x 2.00" x 1.38")
Sensor Input Aperture	Ø15 mm	Ø25.4 mm
Active Detector Area	Ø15 mm	Ø27 mm
Distance to Detector[f]	5 mm	4.6 mm
Cable Length	1.5 m	
Connector	D-Sub 9-Pin Male	
Weight	0.22 kg (0.49 lb)	0.22 kg (0.49 lb)
Mounting and Accessories		
Post	Ø1/2" Post via Universal 8-32 & M4 Tap (Post Not Included)	Ø1/2" Post via Universal 8-32 & M4 Tap (Post Not Included)
Cage System Mounting	N/A	N/A
Aperture Thread	Internally SM1-Threaded Aperture External SM1-Threaded Adapter for Ø1" Lens Tubes and Fiber Adapters	Internally SM1-Threaded (1.035"-40) with External SM1-Threaded Adapter for Ø1" Lens Tubes and Fiber Adapters
Fiber Adapters (Available Below)	S120 Series Fiber Adapters	

- For continuous wave (CW) sources, this value is equivalent to the peak power density, while for pulsed laser sources this value is calculated from the time-averaged power and beam profile.
- Two Minute Maximum Exposure Time
- Measurement taken with the PM400 with the acceleration circuit switched off. Resolution performance will be similar with our other power meter consoles.
- Measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser

calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s). As the natural response times of the S415C and S425C are fast, these do not benefit from accelerated measurements and this function cannot be enabled. See the *Operation* tab for additional information.
- Distance is measured from the detector to the front face of the housing.

Max Power: 40 W to 200 W

Item #	S350C	S425C-L	S322C
Detection Specifications			
Detector Type	Thermal Surface Absorber (Radial Thermopile)	Thermal Surface Absorber (Axial Thermopile)	Thermal Surface Absorber (Radial Thermopile)
Wavelength Range	190 nm - 1.1 µm, 10.6 µm	190 nm - 20 µm	250 nm - 11 µm
Optical Power Range	10 mW - 40 W	2 mW - 50 W	100 mW - 200 W
Max Average Power Density[a]	2 kW/cm²	1.5 kW/cm²	4 kW/cm²
Max Pulse Energy Density	0.7 J/cm² (1 ns Pulse), 10 J/cm² (1 ms Pulse)	0.3 J/cm² (1 ns Pulse), 5 J/cm² (1 ms Pulse)	0.5 J/cm² (1 ns Pulse), 10 J/cm² (1 ms Pulse)
Max Intermittent Power[b] **(2 Minute Max)**	60 W	75 W	250 W
Linearity	±1%	±0.5%	±1%
Resolution[c]	1 mW	100 µW	5 mW
Measurement Uncertainty[d] **(Calibration Uncertainty)**	±3% @ 351 nm ±5% @ 190 nm - 1100 nm	±3% @ 1064 nm ±5% @ 250 nm - 17 µm	±3% @ 1064 nm ±5% @ 266 nm - 1064 nm
Response Time[e]	9 s (1 s from 0 to 90%)	0.6 s	5 s (1 s from 0 to 90%)
General Information			
Suggested Application	High Power Excimer Lasers	Mid-Power Lasers	Mid-Power Lasers
Absorber	Excimer Coating	High-Power Broadband Coating	High-Power Broadband Coating
Cooling	Convection (Passive)		Forced Air with Fan[ef]
Temperature Sensor (In Sensor Head)	NTC Thermistor		
Console Compatibility	PM400, PM100D, PM100A, PM320E, and PM100USB		
Mechanical Specs			
Housing Dimensions (Without Adapter, if Applicable)	100 mm x 100 mm x 54.2 mm (3.94" x 3.94" x 2.13")	100.0 mm x 100.0 mm x 58.0 mm (3.94" x 3.94" x 2.28")	100 mm x 100 mm x 86.7 mm (3.94" x 3.94" x 3.41")
Sensor Input Aperture	Ø40 mm	Ø25.4 mm	Ø25 mm
Active Detector Area	Ø40 mm	Ø27 mm	Ø25 mm
Distance to Detector[g]	13 mm	4.6 mm	15 mm
Cable Length	1.5 m		
Connector	D-Sub 9-Pin Male		
Weight	1 kg (2.20 lb)	0.71 kg (1.57 lb)	0.75 kg (1.65 lb)
Mounting and Accessories			
Post	M6, 75 mm Long Ø1/2" Post Included	Ø1/2" Post via Universal 8-32 & M4 Tap (Post Not Included)	M6, 75 mm Long Ø1/2" Post Included
Cage System Mounting	N/A	N/A	30 mm Cage Systems via Four 4-40 Tapped Holes
Aperture Thread	Unthreaded	Internally SM1-Threaded Aperture with External SM1-Threaded Adapter for Ø1" Lens Tubes and Fiber Adapters	Externally SM1-Threaded Adapter for Ø1" Lens Tubes and Fiber Adapters
Fiber Adapters (Available			

Below)	S120 Series Fiber Adapters

- For continuous wave (CW) sources, this value is equivalent to the peak power density, while for pulsed laser sources this value is calculated from the time-averaged power and beam profile.
- Two Minute Maximum Exposure Time
- Measurement taken with the PM100D console, except for the S425C-L in which the PM400 was used. In all cases, the acceleration circuit was switched off. Resolution performance will be similar with our other power meter consoles.
- Measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s) for the S350C and S322C. As the natural response time of the S425C-L is fast, the S425C-L does not benefit from acceleration and this function cannot be enabled. See the *Operation* tab for additional information.
- 12 VDC power supply included.
- Distance is measured from the detector to the front face of the housing.

High Max Power Density for Pulsed Lasers

Item #	S370C	S470C
Detection Specifications		
Detector Type	Thermal Volume Absorber (Axial Thermopile)	Thermal Volume Absorber (Axial Thermopile)
Wavelength Range	0.4 - 5.2 µm	0.25 - 10.6 µm
Optical Power Range	10 mW - 10 W	100 µW - 5 W
Max Power Density	35 W/cm² (Avg); 100 GW/cm² (Peak, 1 ns Pulse)	35 W/cm² (Avg); 100 GW/cm² (Peak, 1 ns Pulse)
Max Pulse Energy Density	1 J/cm² (1 ns pulse) 10 J/cm² (1 ms pulse)	1 J/cm² (1 ns Pulse)
Max Intermittent Power[a]	15 W	-
Linearity	±1%	±0.5%
Resolution[b]	250 µW	10 µW
Measurement Uncertainty[c] (Calibration Uncertainty)	±3% @ 1064 nm ±5% @ 400 - 1064 nm	±3% @ 1064 nm ±5% @ 250 nm - 10.6 µm
Response Time[d]	45 s (3 s from 0 to 90%)	6.5 s (<2 s from 0 to 90%)
General Information		
Suggested Application	High Peak Power Lasers	High Peak Power, Low Average Power Lasers
Absorber	Broadband Volume Absorber (Schott NG1 Filter)	Broadband Volume Absorber (Schott NG1 Filter)
Cooling	Convection	Convection
Temperature Sensor (In Sensor Head)	N/A	N/A
Console Compatibility	PM400, PM100D, PM100A, PM320E, and PM100USB	PM400, PM100D, PM100A, PM320E, and PM100USB
Mechanical Specs		
Housing Dimensions (Without Adapter, if	75 mm x 75 mm x 51.2 mm (2.95" x 2.95" x 2.02")	45.0 mm x 45.0 mm x 18.0 mm (1.77" x 1.77" x 0.71")

Microscope Slide Thermal Sensor

Item #	S175C
Detection Specifications	
Detector Type	Thermal Absorber (Axial Thermopile)
Wavelength Range	0.3 - 10.6 µm
Optical Power Range	100 µW - 2 W
Max Power Density	200 W/cm²
Max Pulse Energy Density	0.1 J/cm² (1 µs pulse) 1 J/cm² (1 ms pulse)
Max Intermittent Power	-
Linearity	±0.5%
Resolution[a]	10 µW
Measurement Uncertainty[b] (Calibration Uncertainty)	±3% @ 1064 nm ±5% @ 300 nm - 10.6 µm
Response Time[c]	3 s (<2 s from 0 to 90%)
General Information	
Suggested Application	Light Measurement on the Microscope Objective Plane
Absorber	Broadband Coating
Cooling	Convection
Temperature Sensor (In Sensor Head)	N/A
Console Compatibility	PM400, PM100D, PM100A, PM320E, and PM100USB
Mechanical Specs	
Housing Dimensions	76 mm x 25.2 mm x 4.8 mm (2.99" x 0.99" x 0.19")
Input Aperture Size	18 mm x 18 mm
Active Detector	18 mm x 18 mm

Applicable)		
Input Aperture Size	Ø25 mm	Ø15 mm
Active Detector Area[e]	Ø25 mm	>Ø15 mm
Distance to Detector[f]	13 mm	5.1 mm
Cable Length	1.5 m	1.5 m
Connector	Sub-D 9-Pin Male	Sub-D 9-Pin Male
Weight	0.5 kg (1.10 lb)	0.1 kg (0.22 lb)
Mounting and Accessories		
Post	M6, 75 mm Long Post Included	Universal 8-32 / M4 Tap, Post Not Included
Cage System Mounting	4 x 4-40 Threads for 30 mm Cage Compatibility	N/A
Aperture Thread	Externally SM1-Threaded Adapter for Ø1" Lens Tubes and Fiber Adapters	External SM1-Threaded Aperture for Ø1" Lens Tubes and Fiber Adapters
Fiber Adapters (Available Below)	S120 Series Fiber Adapters	S120 Series Fiber Adapters

- Two Minute Maximum Exposure Time
- Measurement taken with the PM100D console for the S370C and with the legacy PM200 for the S470C. In all cases, the acceleration circuit was switched off. Resolution performance will be similar with our other power meter consoles.
- Measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <2 s). See the *Operation* tab for additional information.
- Input aperture size is the same as the active sensor area for the S370C. The S470C uses a Schott glass volume absorber that is designed to be slightly larger than the entrance aperture to make it easier to detect a beam that is entering the sensor at an angle.
- Distance is measured from the detector to the front face of the housing.

Area	
Distance to Detector[d]	1.1 mm
Cable Length	1.5 m
Connector	Sub-D 9-Pin Male
Weight	0.05 kg (0.11 lb)
Mounting and Accessories	
Post	N/A
Cage System Mounting	N/A
Aperture Thread	N/A
Fiber Adapters (Available Below)	N/A

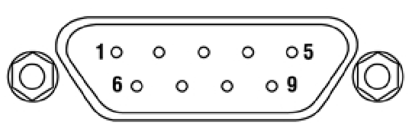
- Measurement taken with the legacy PM200 console with the acceleration circuit switched off. Resolution performance will be similar with our other power meter consoles.
- Measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s). See the *Operation* tab for additional information.
- Distance is measured from the detector to the front face of the housing.

Hide Pin Diagrams

PIN DIAGRAMS

C-Series Sensor Connector

D-Type Male



Pin	Connection
1	Not Used
2	EEPROM Data
3	Sensor and NTC Ground
4	Not Used

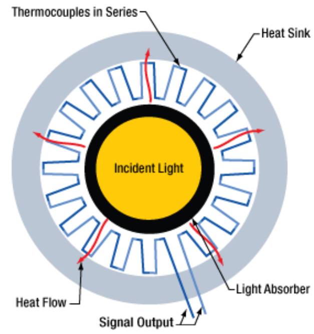
5	Not Used
6	EEPROM Ground
7	NTC
8	Sensor Signal
9	Not Used

Hide Operation

OPERATION

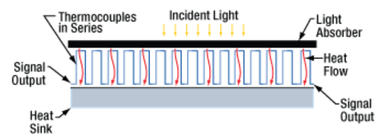
Operational Principle

Thorlabs' Thermal Power Sensors are based on thermopiles. The top layer of the sensor consists of a light-absorbing material. A region filled with multiple thermocouples, which are connected in series, is immediately adjacent to the absorber. Thermocouples are made by bringing two dissimilar metals into contact, and their point of contact is called a junction. On the other side of the thermocouples is a heat sink. The thermocouples are connected in series, and the placement of the junctions alternates from being in close proximity to the absorber to being in close proximity to the heat sink.



Click to Enlarge
Figure 1: A thermal sensor with radially configured thermocouples, which is depicted as seen from the top. Light is incident on the absorbing layer at the center, and heat flows through the thermocouples to the heat sink.

The absorber converts incident light energy into heat. The heat flows from the absorber, across the thermocouples, and to the heat sink, where it dissipates. The temperatures of the thermocouple junctions placed close to the absorber are higher than those the adjacent junctions placed close to the heat sink. This arrangement takes advantage of the thermoelectric (Seebeck) effect, in which a temperature difference between the adjacent junctions generates a proportional voltage difference. By connecting multiple thermocouples in series, the magnitude of the generated voltage is increased. The thermocouples are often arranged in a radial (also called a disk) configuration, as illustrated in Figure 1, or in an axial (also called a matrix) configuration, which is diagrammed in Figure 2. Thermal power sensors with both types of configurations are available from Thorlabs.



Click to Enlarge
Figure 2: A thermal sensor with axially configured thermocouples, which is depicted as seen from the side. Light is incident on the top, and heat flows down through the thermocouple layer and dissipates in the heat sink below.

Radial Configuration of Thermocouples

A diagram of a thermal power sensor with a radial thermopile is shown in Figure 1, viewed from the top. This construction places the light absorber at the center. It is surrounded by a concentric ring of thermocouples connected in series, which are surrounded by a concentric heat sink. Light incident on the absorber generates heat that flows in a radial direction through the thermocouples and towards the heat sink. The heat sink must be specially designed so that it is in good mechanical contact with the outer ring of thermocouple junctions, without being in thermal contact with the light absorber or the inner ring of thermocouple junctions. The area behind the absorber cannot be in thermal contact with anything that will divert the heat flow from its intended radial path of flow.

A benefit of the radial construction is that sensors can be designed to measure power levels as high as kilowatts. This high upper limit is made possible both by the thickness of the sensor disk and by displacing the thermocouples from the absorber, which protects them from the conditions in the laser impact area. Disadvantages of the radial thermopiles include the use of a heat sink with a special design, which adds complexity when customizing the sensor head, and a sensor head which is generally a least twice the diameter of the active detector area. Resolution for radial thermal power sensors is typically limited to around 10 mW.

Thorlabs' thermal power sensors featuring a radial configuration include the S350C and S322C, which are all designed for mid-power range applications.

Axial Configuration of Thermocouples

A diagram of a thermal power sensor with an axial configuration of thermocouples is shown in Figure 2. In this design, the thermocouples are arranged between two flat layers. One layer is the light absorber, and the other is the heat sink. As the heat flows directly from the front surface to the back side, the dimensions of these sensor packages can be made compact. The sensor housing can be approximately the same size as the active detector area.

The new generation of axially-designed sensors achieves high resolutions in the microwatt range while providing relatively fast response times. These sensors detect optical powers up to several Watts, which limited mostly by the thickness of the absorbing material. The performance of the newly designed sensors, which includes the S401C and S405C, contrasts with sensors of previous generations, which have slower response times.

Heat sink shapes and dimensions are much less constrained for axially, as compared with radially, configured thermopiles. Heat sinks for axial designs can be as simple as a block of aluminum attached with thermal glue, or as sophisticated as a metal-core PCB that is soldered to the sensor. Our S415C, S425C, and S425C-L thermal power sensors have heat sinks can be easily removed and replaced. This enables the user to upgrade the heat sink, potentially to one with fans or water cooling, or to integrate the sensor into a custom setup. Please note that the heat sink must provide heat dissipation adequate for the application.

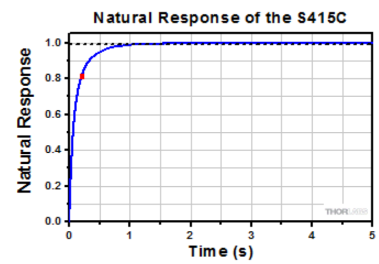
Volume Absorbers for Pulsed Lasers

Volume absorbers are alternatives to surface absorbers, which sustain damage when subjected to highly energetic and short pulses of nanosecond duration. Unlike surface absorbers, which suffer damage as a consequence of absorbing the pulse energy within a localized region, volume absorbers collect the heat from the light pulse and distribute it throughout a volume. Heat generated throughout the volume flows across the thermocouples and dissipates in the heat sink. Thorlabs offers two thermal power sensors with volume absorbers, S370C and S470C, which are both designed for the detection of Nd:YAG laser pulses, among other applications. In these axially-constructed sensors, the Schott glass volume absorber replaces the surface absorber of the other axial sensors. The response times of sensors with volume absorbers are slower than those with surface absorbers, as the thermal mass of the volume absorber is larger. The S470C is faster than the S370C, as its glass volume is smaller and other design changes have resulted in a faster response of the axial thermopile.

Natural Responses, the Sensor Time Constant, and Power Measurement Predictions

The typical **natural response** of the S415C thermal sensor to an instantaneous transition from darkness to being steadily illuminated is shown in Figure 3. This step function illumination stimulus produces a response that can be modeled using an exponential function and is similar to the function describing the rate at which a capacitor charges.

The **sensor time constant** is defined in terms of how long it takes for the sensor response to reach 99% of its maximum response. When the sensor has reached the 99% level, a time period equal to five sensor time constants has elapsed. In Figure 3, the dotted line corresponds to the 99% level and the red square to the response after a single sensor time constant has elapsed.



Click to Enlarge

Figure 3: Natural response of the S415C with the dotted line at 99% and the red square indicating the point on the curve corresponding to a single sensor time constant.

When the sensor's natural response characteristic function is known, it is possible to use it to model and **predict the final power reading** well before the sensor reading has stabilized. Thorlabs' power meter consoles calculate and display predictions of the stabilized power reading when Thorlabs sensors with sensor time constants ≥0.5 s (natural response times >1 s) are connected. Prediction is implemented using the sensor information stored in the EEPROM built into the C-Series connectors. The S415C, S425C, and S425C-L are fast enough, with sensor time constants <0.2 s (natural response times <0.6 s), that prediction is not necessary and is not enabled. Prediction is enabled for the other sensors.

When prediction is active, the first prediction is made after a time duration equal to a single sensor time constant, and this prediction is updated at time intervals of one sensor time constant until a total time duration of seven sensor time constants has elapsed. Prediction is then turned off; the power reading after seven time constants is 99.9% of the final reading. As there is uncertainty associated with the predicted measurements, they can exhibit some ripple. The faster the sensor, the less the uncertainty. After prediction is turned off, the gradient of the power reading is monitored, and prediction is re-enabled if an increase is detected which exceeds a defined threshold.

Protect Thermal Power Sensors from Thermal Disturbances

For the most accurate results, thermal power sensors should be protected from air flow and other thermal disturbances during operation. Otherwise, measurements will drift. This is of particular importance for low power sensors with high resolution. Handheld use is not recommended for any of the thermal power sensors, as body heat transferred to the sensor or heat sink can negatively impact the accuracy of the measurements.

Thermal power sensors operate by measuring a temperature differential, which is converted to a voltage signal. The sensor design assumes that heat generated in the absorber flows towards the heat sink. If the operator is in contact with the sensor housing during operation, body heat may transfer to the sensor and make spurious contributions to the power measurement. For example, if the sensor is held by the heat sink, heat transferred from the hand to the heat sink will flow towards the absorber. If no light is incident on the absorber, this will result in a negative power reading. If there is light incident on the absorber, it will result in an inaccurate power reading.

Hide Console Selection

CONSOLE SELECTION

Thorlabs offers a wide selection of power and energy meter consoles and interfaces for operating our power and energy sensors. Key specifications of all of our power meter consoles and interfaces are presented below to help you decide which device is best for your application. We also offer self-contained wireless power meters and compact USB power meters.

When used with our C-series sensors, Thorlabs' power meter consoles and interfaces recognize the type of connected sensor and measure the current or voltage as appropriate. Our C-series sensors have responsivity calibration data stored in their connectors. The console will read out the responsivity value for the user-entered wavelength and calculate a power or energy reading.

- Photodiode sensors deliver a current that depends on the input optical power and the wavelength. The current is fed into a transimpedance amplifier, which outputs a voltage proportional to the input current. The photodiode's responsivity is wavelength dependent, so the correct wavelength must be entered into the console for an accurate power reading. The console reads out the responsivity for this wavelength from the connected sensor and calculates the optical power from the measured photocurrent.
- Thermal sensors deliver a voltage proportional to the input optical power. Based on the measured sensor output voltage and the sensor's responsivity, the console will calculate the incident optical power.
- Energy sensors are based on the pyroelectric effect. They deliver a voltage peak proportional to the pulse energy. If an energy sensor is recognized, the console will use a peak voltage detector and the pulse energy will be calculated from the sensor's responsivity.

The consoles and interfaces are also capable of providing a readout of the current or voltage delivered by the sensor. Select models also feature an analog output.

Consoles

Item #	PM100A	PM100D	PM400	PM320E
(Click Photo to Enlarge)				
Key Features	Analog Power Measurements	Digital Power and Energy Measurements	Digital Power and Energy Measurements, Touchscreen Control	Dual Channel
Compatible Sensors	Photodiode and Thermal Power	Photodiode and Thermal Power; Pyroelectric		
Housing Dimensions (H x W x D)	7.24" x 4.29" x 1.61" (184 mm x 109 mm x 41 mm)	7.09" x 4.13" x 1.50" (180 mm x 105 mm x 38 mm)	5.35" x 3.78" x 1.16" (136.0 mm x 96.0 mm x 29.5 mm)	4.8" x 8.7" x 12.8" (122 mm x 220 mm x 325 mm)
Channels	1			2
External Temperature Sensor Input (Sensor not Included)	-	-	Instantaneous Readout and Record Temperature Over Time	-
External Humidity Sensor Input (Sensor not Included)	-	-	Instantaneous Readout and Record Humidity Over Time	-
GPIO Ports	-		4, Programmable	-
Source Spectral Correction	-	-	✔	-
Attenuation Correction	-	-	✔	-
External Trigger Input	-	-	-	✔
Display				
Type	Mechanical Needle and LCD Display with Digital Readout	320 x 240 Pixel Backlit Graphical LCD Display	Protected Capacitive Touchscreen with Color Display	240 x 128 Pixels Graphical LCD Display
Dimensions	Digital: 1.9" x 0.5" (48.2 mm x 13.2 mm) Analog: 3.54" x 1.65" (90.0 mm x 42.0 mm)	3.17" x 2.36" (81.4 mm x 61.0 mm)	3.7" x 2.1" (95 mm x 54 mm)	3.7" x 2.4" (94.0 mm x 61.0 mm)
Refresh Rate	20 Hz		10 Hz (Numerical) 25 Hz (Analog Simulation)	20 Hz
Measurement Views[a]				
Numerical	✔	✔	✔	✔
Mechanical Analog Needle	✔	-	-	-
Simulated Analog Needle	-	✔	✔	✔
Bar Graph	-	✔	✔	✔

Trend Graph	-	✔	✔	✔
Histogram	-	✔	-	✔
Statistics	✔	✔	✔	✔
Memory				
Type	-	SD Card	NAND Flash	-
Size	-	2 GB	4 GB	-
Power				
Battery	LiPo 3.7 V 1300 mAh		LiPo 3.7 V 2600 mAh	-
External	5 VDC via USB or Included AC Adapter		5 VDC via USB	Selectable Line Voltage: 100 V, 115 V, 230 V (±10%)

- These are the measurement views built into the unit. All of our power meter consoles except the PM320E can be controlled using the Optical Power Monitor software package. The PM320E has its own software package.

Interfaces

Item #	PM101	PM102	PM101A	PM102A	PM101R	PM101U	PM102U	PM100USB
(Click Photo to Enlarge)								
Key Features	USB, RS232, UART, and Analog Operation		USB and Analog SMA Operation		USB and RS232 Operation	USB Operation		USB Operation
Compatible Sensors	PM101 Series: Photodiode and Thermal Power PM102 Series: Thermal Power and Thermal Position & Power							Photodiode and Thermal Power; Pyroelectric
Housing Dimensions (H x W x D)	3.80" x 2.25" x 1.00" (96.5 x 57.2 x 25.4 mm)		3.94" x 2.25" x 1.00" (100.0 x 57.2 x 25.4 mm)		3.78" x 2.25" x 1.00" (95.9 x 57.2 x 25.4 mm)	3.68" x 2.25" x 1.00" (93.6 x 57.2 x 25.4 mm)		3.67" x 2.38 " x 1.13" (93.1 x 60.4 x 28.7 mm)
Channels	1							
External Temperature Sensor Input (Sensor Not Included)	NTC Thermistor		-					
External Humidity Sensor Input (Sensor not Included)	-							
GPIO Ports	-							
Source Spectral Correction	-							
Attenuation Correction	-							
External Trigger Input	-							
Display								
Type	No Built-In Display; Controlled via GUI for PC							
Refresh Rate	Up to 1000 Hz[a]							Up to 300 Hz[a]
Measurement Views[b]								
Numerical	Requires PC[b]							
Mechanical Analog Needle	-							
Simulated Analog Needle	Requires PC[b]							
Bar Graph	Requires PC[b]							
Trend Graph	Requires PC[b]							
	[b]							

Histogram	Requires PC		
Statistics	Requires PC[b]		
Memory			
Type	Internal Non-Volatile Memory for All Settings		-
Size	-		
Power			
Battery	-		
External	5 VDC via USB or 5 to 36 VDC via DA-15	5 VDC via USB	

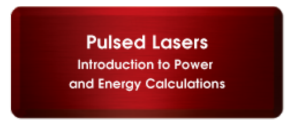
- Dependent on PC Settings
- These power meter interfaces do not have a built-in monitor, so all data must be displayed through a PC running the Optical Power Meter Software.

Hide Pulse Calculations

PULSE CALCULATIONS

Pulsed Laser Emission: Power and Energy Calculations

Determining whether emission from a pulsed laser is compatible with a device or application can require referencing parameters that are not supplied by the laser's manufacturer. When this is the case, the necessary parameters can typically be calculated from the available information. Calculating peak pulse power, average power, pulse energy, and related parameters can be necessary to achieve desired outcomes including:



Click above to download the full report.

- Protecting biological samples from harm.
- Measuring the pulsed laser emission without damaging photodetectors and other sensors.
- Exciting fluorescence and non-linear effects in materials.

Pulsed laser radiation parameters are illustrated in Figure 1 and described in the table. For quick reference, a list of equations are provided below. The document available for download provides this information, as well as an introduction to pulsed laser emission, an overview of relationships among the different parameters, and guidance for applying the calculations.

Equations:

***Period* and *repetition rate* are reciprocal:** $\Delta t = \frac{1}{f_{rep}}$ and $f_{rep} = \frac{1}{\Delta t}$

***Pulse energy* calculated from *average power*:** $E = \frac{P_{avg}}{f_{rep}} = P_{avg} \cdot \Delta t$

***Average power* calculated from *pulse energy*:** $P_{avg} = \frac{E}{\Delta t} = E \cdot f_{rep}$

***Peak pulse power* estimated from *pulse energy*:** $P_{peak} \approx \frac{E}{\tau}$

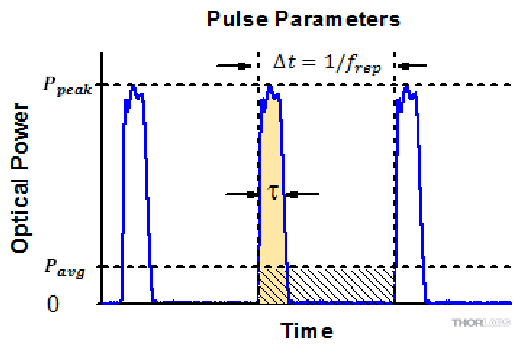
***Peak power* and *average power* calculated from each other:**

$$P_{peak} = \frac{P_{avg}}{f_{rep} \cdot \tau} = \frac{P_{avg} \cdot \Delta t}{\tau}$$ and $$P_{avg} = P_{peak} \cdot f_{rep} \cdot \tau = \frac{P_{peak} \cdot \tau}{\Delta t}$$

Peak power* calculated from *average power* and *duty cycle*:**

$$P_{peak} = \frac{P_{avg}}{\tau/\Delta t} = \frac{P_{avg}}{duty\ cycle}$$

*Duty cycle ($\tau/\ \Delta t$) is the fraction of time during which there is laser pulse emission.



Click to Enlarge

Figure 1: Parameters used to describe pulsed laser emission are indicated in the plot (above) and described in the table (below). **Pulse energy** (**E**) is the shaded area under the pulse curve. Pulse energy is, equivalently, the area of the diagonally hashed region.

Parameter	Symbol	Units	Description
Pulse Energy	**E**	Joules [J]	A measure of one pulse's total emission, which is the only light emitted by the laser over the entire period. The pulse energy equals the shaded area, which is equivalent to the area covered by diagonal hash marks.
Period	**Δt**	Seconds [s]	The amount of time between the start of one pulse and the start of the next.
Average Power	$\mathbf{P_{avg}}$	Watts [W]	The height on the optical power axis, if the energy emitted by the pulse were uniformly spread over the entire period.
Instantaneous Power	**P**	Watts [W]	The optical power at a single, specific point in time.
Peak Power	$\mathbf{P_{peak}}$	Watts [W]	The maximum instantaneous optical power output by the laser.
Pulse Width	τ	Seconds [s]	A measure of the time between the beginning and end of the pulse, typically based on the full width half maximum (FWHM) of the pulse shape. Also called **pulse duration**.
Repetition Rate	$\mathbf{f_{rep}}$	Hertz [Hz]	The frequency with which pulses are emitted. Equal to the reciprocal of the period.

Example Calculation:

Is it safe to use a detector with a specified maximum peak optical input power of **75 mW** to measure the following pulsed laser emission?

- Average Power: 1 mW
- Repetition Rate: 85 MHz
- Pulse Width: 10 fs

The energy per pulse:

$$E = \frac{P_{avg}}{f_{rep}} = \frac{1\ mW}{85\ MHz} = \frac{1\ x\ 10^{-3} W}{85\ x\ 10^{6} Hz} = 1.18\ x\ 10^{-11} J = 11.8\ pJ$$

seems low, but the peak pulse power is:

$$P_{peak} = \frac{P_{avg}}{f_{rep} \cdot \tau} = \frac{1\ mW}{85\ MHz\ \cdot 10\ fs} = 1.18\ x\ 10^3\ W = \mathbf{1.18}\ \boldsymbol{kW}$$

It is ***not safe*** to use the detector to measure this pulsed laser emission, since the peak power of the pulses is >5 orders of magnitude higher than the detector's maximum peak optical input power.

Hide Sensor Selection

SENSOR SELECTION

This tab outlines the full selection of Thorlabs' power and energy sensors. Refer to the lower right table for power meter console and interface compatibility information.

Click to Enlarge
The PM160 wireless power meter, shown here with an iPad mini (not included), can be remotely operated using Apple mobile devices.

In addition to the power and energy sensors listed below, Thorlabs also offers all-in-one, wireless, handheld power meters and compact USB power meter interfaces that contain either a photodiode or a thermal sensor, as well as power meter bundles that include a console, sensor head, and post mounting accessories.

Thorlabs offers four types of sensors:

- **Photodiode Sensors:** These sensors are designed for power measurements of monochromatic or near-monochromatic sources, as they have a wavelength dependent responsivity. These sensors deliver a current that depends on the input optical power and the wavelength. The current is fed into a transimpedance amplifier, which outputs a voltage proportional to the input current.
- **Thermal Sensors:** Constructed from material with a relatively flat response function across a wide range of wavelengths, these thermopile sensors are suitable for power measurements of broadband sources such as LEDs and SLDs. Thermal sensors deliver a voltage proportional to the input optical power.
- **Thermal Position & Power Sensors:** These sensors incorporate four thermopiles arranged as quadrants of a square. By comparing the voltage output from each quadrant, the unit calculates the beam's position.
- **Pyroelectric Energy Sensors:** Our pyroelectric sensors produce an output voltage through the pyroelectric effect and are suitable for measuring pulsed sources, with a repetition rate limited by the time constant of the detector. These sensors will output a peak voltage proportional to the incident pulse energy.

Power and Energy Sensor Selection Guide

There are two options for comparing the specifications of our Power and Energy Sensors. The expandable table below sorts our sensors by type (e.g., photodiode, thermal, or pyroelectric) and provides key specifications.

Alternatively, the selection guide graphic further below arranges our entire selection of photodiode and thermal power sensors by wavelength (left) or optical power range (right). Each box contains the item # and specified range of the sensor. These graphs allow for easy identification of the sensor heads available for a specific wavelength or power range.

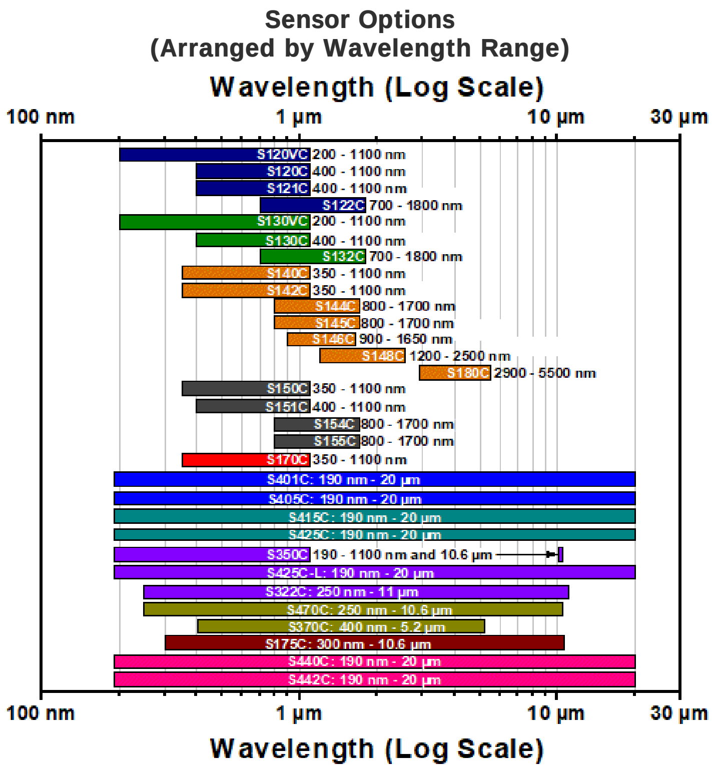
Console Compatibility							
Console Item #	PM100A	PM100D	PM400	PM320E	PM101 Series	PM102 Series	PM100USB
Photodiode Power	✓	✓	✓	✓	✓	-	✓
Thermal Power	✓	✓	✓	✓	✓	✓	✓
Thermal Position	-	-	✓	-	-	✓	-
Pyroelectric Energy	-	✓	✓	✓	-	-	✓

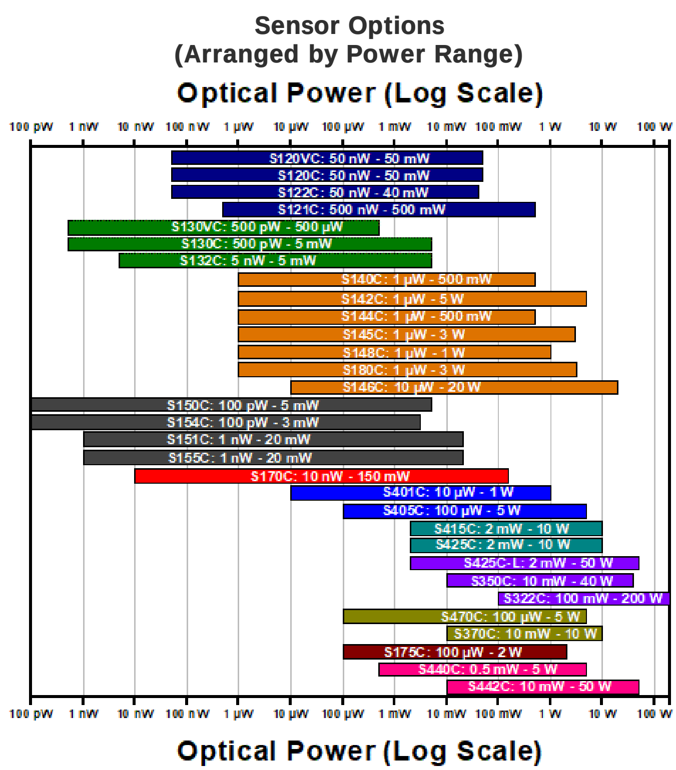
Photodiode Power Sensors	More [+]
Thermal Power Sensors	More [+]
Thermal Position & Power Sensors	More [+]
Pyroelectric Energy Sensors	More [+]

- The response time of the photodiode sensor. The actual response time of a power meter using these sensors will be limited by the update rate of your power meter console.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s) when the natual response time is approximately 1 s or greater. As the natural response times of the S415C, S425C, and S425C-L are fast, these do not benefit from accelerated measurements and this function cannot be enabled. For more information, see the *Operation* tab here.

With intermittent use: maximum exposure time of 20 minutes for the S401C, otherwise maximum exposure time is 2 minutes.

- All pyroelectric sensors have a 20 ms thermal time constant, τ. This value indicates how long it takes the sensor to recover from a single pulse. To detect the correct energy levels, pulses must be shorter than 0.1τ and the repetition rate of your source must be well below 1/τ.





Photodiode Sensors	Thermal Sensors
Standard	High Resolution
Slim	Max Power: 5 W to 10 W
Integrating Sphere	Max Power: 40 W to 200 W
Fiber Coupled	High Max Power Density
Microscope Slide	Microscope Slide
	Position Sensing

Hide High Resolution

High Resolution

Item #[a]	S401C	S405C
Sensor Image (Click the Image to Enlarge)		
Wavelength Range	190 nm - 20 µm	190 nm - 20 µm
Optical Power Range	10 µW - 1 W (3 W[b])	100 µW - 5 W
Input Aperture Size	Ø10 mm	Ø10 mm
Active Detector Area	10 mm x 10 mm	10 mm x 10 mm
Max Optical Power Density	500 W/cm² (Avg.)	1.5 kW/cm² (Avg.)
Detector Type	Thermal Surface Absorber (Thermopile) with Background Compensation	Thermal Surface Absorber (Thermopile)
Linearity	±0.5%	±0.5%
Resolution[c]	1 µW	5 µW
Measurement Uncertainty[d]	±3% @ 1064 nm ±5% @ 190 nm - 10.6 µm	±3% @ 1064 nm ±5% @ 250 nm - 17 µm
Response Time[e]	1.1 s	1.1 s
Cooling	Convection (Passive)	
Housing Dimensions (Without Adapter)	33.0 m x 43.0 mm x 15.0 mm (1.30" x 1.69" x 0.59")	40.6 mm x 40.6 mm x 16.0 mm (1.60" x 1.60" x 0.63")
Temperature Sensor (In Sensor Head)	NTC Thermistor	NTC Thermistor
Cable Length	1.5 m	
Post Mounting	Universal 8-32 / M4 Taps (Post Not Included)	Universal 8-32 / M4 Taps (Post Not Included)
30 mm Cage Mounting	-	Two 4-40 Tapped Holes & Two Ø6 mm Through Holes
Aperture Threads	-	Internal SM05
Accessories	Externally SM1-Threaded Adapter Light Shield with Internal SM05 Threading	Externally SM1-Threaded Adapter
Compatible Consoles	PM400, PM100D, PM100A, PM100USB, PM101A, and PM320E	

- High Resolution of 1 µW or 5 µW
- S401C and S405C Have Thermistors Used to Monitor Temperature of Sensor Head
- S401C: Background Compensation for Low-Drift Measurements
- S405C: Accommodates Average Optical Power Densities up to 1.5 kW/cm²

Click to Enlarge
S401C Thermal Sensor with Included Light Shield

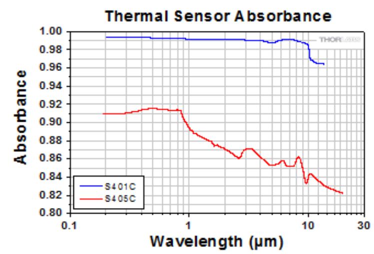
Thorlabs offers two broadband thermal power sensors designed to measure low optical power sources with high resolution. Both thermal sensor's broadband coating has a flat spectral response over a wide wavelength range, as shown in the plot below. The aperture size of Ø10 mm allows for easy alignment and measurement of large-spot-size laser sources. For easy integration with Thorlabs' lens tube systems and SM1-threaded (1.035"-40) fiber adapters (available below), both sensors include an externally SM1-threaded adapter.

The S401C uses active thermal background compensation to provide low-drift power measurements. This is implemented through the use of two sensor circuits to measure heat flow between the light absorber and heat sink in both directions. The measurements of the two sensor circuits are then subtracted, which minimizes the effect of thermal drift on the laser power measurement. (For information about how external thermal disturbances can affect thermal power sensor readings, please see the *Operation* tab.) The S401C's broadband coating offers high absorption at wavelengths between 0.19 and 20 µm (shown in the graph below), which makes it ideal for use with aligning and measuring Mid-IR Quantum Cascade Lasers (QCLs). The included, internally SM05-threaded (0.535"-40) light shield is shown in the photo above.

The S405C has internal SM05 (0.535"-40) threading that is directly compatible with our SM05 lens tubes, and it can also connect directly to Thorlabs' 30 mm Cage Systems.

Thorlabs offers a recalibration service for these sensors, which can be ordered below (see Item # CAL-S200).

- For complete specifications, please see the *Specs* tab.
- For conditions of intermittent use, with a maximum exposure time of 20 minutes for the S401C. The S405C saturates for optical input powers >5 W.
- Measurement taken with the legacy PM200 console for the S401C and the PM400 console for the S405C. In all cases, the acceleration circuit was switched off. Resolution performance will be similar with our other power meter consoles.
- Defined as the measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s). See the *Operation* tab for additional information.



Click to Enlarge
Raw Data: S401C, S405C
The S405 shares the same absorption curve with the S415C, S425C, and S245C-L. (All are sold below.)

Part Number	Description	Price	Availability
S401C	Thermal Power Sensor Head, Surface Absorber, 0.19 - 20 µm, 1 W, Ø10 mm	$785.62	Today
S405C	Thermal Power Sensor Head, Surface Absorber, 0.19 - 20 µm, 5 W, Ø10 mm	$746.87	Today

Hide Max Power: 10 W

Max Power: 10 W

Item #[a]	S415C	S425C
Sensor Image (Click Image to Enlarge)		
Wavelength Range	190 nm - 20 µm	190 nm - 20 µm
Optical Power Range	2 mW - 10 W (20 W[b])	2 mW - 10 W (20 W[b])
Input Aperture Size	Ø15 mm	Ø25.4 mm
Active Detector Area	Ø15 mm	Ø27 mm
Max Optical Power Density	1.5 kW/cm² (Avg.)	1.5 kW/cm² (Avg.)
Detector Type	Thermal Surface Absorber (Thermopile)	
Linearity	±0.5%	±0.5%
Resolution[c]	100 µW	100 µW
Measurement Uncertainty[d]	±3% @ 1064 nm ±5% @ 250 nm - 17 µm	±3% @ 1064 nm ±5% @ 250 nm - 17 µm
Response Time[e]	0.6 s	0.6 s

- 100 µW Optical Power Resolution
- Thermistors Used to Monitor Temperature of Sensor Head
- Removable Heat Sinks Included

These thermal power sensors are designed for general broadband power measurements of low and medium power light sources. All include an externally SM1-threaded (1.035"-40) adapter, with threading concentric with the input aperture. The adapters are useful for mounting Ø1" Lens Tubes and Fiber Adapters (available below). The apertures of the S415C and S425C have internal SM1 threading.

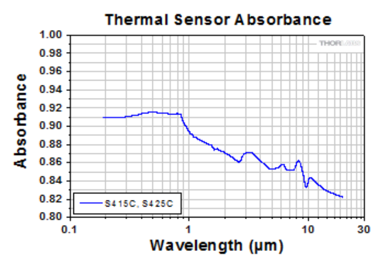
These sensors operate with fast (<0.6 s) natural response times, and their removable heat sinks provide a high degree of flexibility to those interested in integrating them into custom setups or replacing the included heat sink with one that is water or fan cooled. If replacing the heat sink, please note that the replacement must provide heat dissipation adequate for the application.

Thorlabs offers a recalibration service for these sensors, which can be ordered below (see Item #

Cooling	Convection (Passive)	
Housing Dimensions (Without Adapter)	50.8 mm x 50.8 mm x 35.0 mm (2.00" x 2.00" x 1.38")	50.8 mm x 50.8 mm x 35.0 mm (2.00" x 2.00" x 1.38")
Temperature Sensor (In Sensor Head)	NTC Thermistor	
Cable Length	1.5 m	
Post Mounting	Universal 8-32 / M4 Taps (Post Not Included)	Universal 8-32 / M4 Taps (Post Not Included)
30 mm Cage Mounting	-	-
Aperture Threads	Internal SM1	Internal SM1
Removable Heatsink	Yes	Yes
Accessories	Externally SM1-Threaded Adapter	Externally SM1-Threaded Adapter
Compatible Consoles	PM400, PM100D, PM100USB, PM100A, PM101A, and PM320E	

CAL-S200).

- For complete specifications, please see the *Specs* tab.
- Two Minute Maximum Exposure Time
- Measurement taken with the PM400 with the acceleration circuit switched off. Resolution performance will be similar with our other power meter consoles.
- Defined as the measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s). As the natural response times of the S415C and S425C are fast, these do not benefit from accelerated measurements and this function cannot be enabled. See the *Operation* tab for additional information.



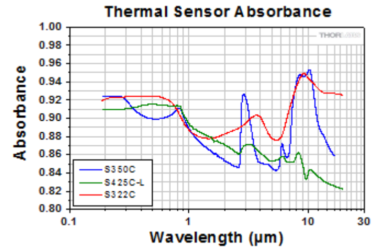
Click to Enlarge
Click Here for Raw Data
The absorption curves of each of the thermal power sensors designed for use with low and medium power optical sources.

Part Number	Description	Price	Availability
S415C	**Thermal Power Sensor Head, Surface Absorber, 0.19 - 20 µm, 10 W, Ø15 mm**	**$770.21**	**Today**
S425C	**Thermal Power Sensor Head, Surface Absorber, 0.19 - 20 µm, 10 W, Ø25.4 mm**	**$840.23**	**Today**

Hide Max Power: 40 W to 200 W

Max Power: 40 W to 200 W

- Thermistors Used to Monitor Temperature of Sensor Head
- S322C Has 4-40 Taps for Use with Our 30 mm Cage Systems
- S350C Has Ø40 mm Aperture Well Suited to Excimer and Other Lasers with Large Spot Sizes
- S425C-L Features Removable Heat Sink
- S322C is Fan Cooled with an Optical Power Range up to 200 W



Click to Enlarge
Raw Data: S350C, S425C-L, S322C
The absorption curves of each of the thermal power sensors designed for use with low and medium power optical sources.

These thermal power sensors are designed for general broadband power measurements of low and medium power light sources. With the exception of the S350C, all include an adapter with external SM1 (1.035"-40) threading concentric with the input aperture. This allows the sensors to be integrated into existing Ø1" lens tube systems in addition to being compatible with fiber adapters (available below). The aperture of the S425C-L has internal SM1 threading.

The S425C-L operates with a fast (<0.6 s) natural response time and has a removable heat sink, which provides a high degree of flexibility to those interested in integrating them into custom setups or replacing the included heat sink with one that is water or fan cooled. If replacing the heat sink, please note that the replacement must provide heat dissipation adequate for the application.

Thorlabs offers a recalibration service for these sensors, which can be ordered below (see Item # CAL-S200).

Item #[a]	S350C	S425C-L	S322C
Sensor Image (Click Image to Enlarge)			
Wavelength Range	190 nm- 1.1 µm, 10.6 µm	190 nm - 20 µm	250 nm - 11 µm
Optical Power Range	10 mW - 40 W (60 W[b])	2 mW - 50 W (75 W[b])	100 mW - 200 W (250 W[b])
Input Aperture Size	Ø40 mm	Ø25.4 mm	Ø25 mm
Active Detector Area	Ø40 mm	Ø27 mm	Ø25 mm
Max Optical Power Density	2 kW/cm² (Avg.)	1.5 kW/cm² (Avg.)	4 kW/cm² (Avg., CO_2)
Detector Type	Thermal Surface Absorber (Thermopile)		
Linearity	±1%	±0.5%	±1%
Resolution[c]	1 mW	100 µW	5 mW
Measurement Uncertainty[d]	±3% @ 351 nm ±5% @ 190 nm - 1100 nm	±3% @ 1064 nm ±5% @ 250 nm - 17 µm	±3% @ 1064 nm ±5% @ 266 nm - 1064 nm
Response Time[e]	9 s (1 s from 0 to 90%)	0.6 s	5 s (1 s from 0 to 90%)
Cooling	Convection (Passive)		Forced Air with Fan[f]
Housing Dimensions (Without Adapter, if Applicable)	100 mm x 100 mm x 54.2 mm (3.94" x 3.94" x 2.13")	100.0 mm x 100.0 mm x 58.0 mm (3.94" x 3.94" x 2.28")	100 mm x 100 mm x 86.7 mm (3.94" x 3.94" x 3.41")
Temperature Sensor (In Sensor Head)	NTC Thermistor		
Cable Length	1.5 m		
Post Mounting	M6 Threaded Taps, Includes Ø1/2" Post, 75 mm Long	Universal 8-32 / M4 Taps (Post Not Included)	M6 Threaded Taps, Includes Ø1/2" Post, 75 mm Long
30 mm Cage Mounting	-	-	Four 4-40 Tapped Holes
Aperture Threads	-	Internal SM1	-
Removable Heatsink	-	Yes	-
Accessories	-	Externally SM1-Threaded Adapter	Externally SM1-Threaded Adapter
Compatible Consoles	PM400, PM100D, PM100USB, PM100A, PM101A, and PM320E		

- For complete specifications, please see the *Specs* tab.
- Two Minute Maximum Exposure Time
- Measurement taken with the PM100D console, except for the S425C-L in which the PM400 was used. In all cases, the acceleration circuit was switched off. Resolution performance will be similar with our other power meter consoles.
- Defined as the measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s) for the S350C and S322C. As the natural response time of the S425C-L is fast, the S425C-L does not benefit from acceleration and this function cannot be enabled. See the *Operation* tab for additional information.
- 12 VDC power supply is included.

Part Number	Description	Price	Availability
S350C	**Thermal Power Sensor Head, Surface Absorber, 0.19 - 1.1 µm and 10.6 µm, 40 W, Ø40 mm**	**$1,162.19**	**Today**
S425C-L	**Thermal Power Sensor Head, Surface Absorber, 0.19 - 20 µm, 50 W, Ø25.4 mm**	**$910.25**	**5-8 Days**
S322C	**Thermal Power Sensor Head, Surface Absorber, 0.25 - 11 µm, 200 W, Ø25 mm, Fan Cooled**	**$1,439.22**	**5-8 Days**

Hide High Max Power Density for Pulsed Lasers

High Max Power Density for Pulsed Lasers

Item #[a]	S370C	S470C
Sensor Image (Click Image to Enlarge)		
Wavelength Range	400 nm - 5.2 µm	250 nm - 10.6 µm
Optical Power Range	10 mW - 10 W (15 W[b])	100 µW - 5 W (Pulsed and CW)
Input Aperture Size	Ø25 mm	Ø15 mm
Active Detector Area	Ø25 mm	Ø16 mm
Max Optical Power Density	35 W/cm² (Avg.); 100 GW/cm² (Peak)	
Detector Type	Thermal Volume Absorber (Thermopile)	
Linearity	±1%	±0.5%
Resolution[c]	250 µW	10 µW
Measurement Uncertainty[d]	±3% @ 1064 nm ±5% @ 400 nm - 1064 nm	±3% @ 1064 nm ±5% @ 250 nm - 10.6 µm
Response Time[e]	45 s (3 s from 0 to 90%)	6.5 s (<2 s from 0 to 90%)
Cooling	Convection (Passive)	
Housing Dimensions (Without Adapter, if Applicable)	75 mm x 75 mm x 51.2 mm (2.95" x 2.95" x 2.02")	45.0 mm x 45.0 mm x 18.0 mm (1.77" x 1.77" x 0.71")
Temperature Sensor (In Sensor Head)	N/A	N/A
Cable Length	1.5 m	
Post Mounting	M6 Threaded Taps, Includes Ø1/2" Post, 75 mm Long	Universal 8-32 / M4 Tap (Post Not Included)
30 mm Cage Mounting	Four 4-40 Tapped Holes	-
Aperture Threads	-	External SM1
Accessories	Externally SM1-Threaded Adapter	-

- Designed for Optical Power Measurements of Nd:YAG Lasers
- Ideal for Applications with High Peak Pulse Powers
- S370C: Ø25 mm Aperture for Large-Spot-Size Beams
- S470C: High-Sensitivity for High-Peak-Power Pulses with Low Average Power

The S370C and S470C Thermal Sensors are designed to measure short and highly energetic laser pulses. All of these units are post-mountable for free-space applications and feature NIST-traceable data stored in the sensor connector.

These thermal power sensors are unique in that they have thermal volume absorbers, where our other thermal power sensors have thermal surface absorbers. The volume absorber consists of a Schott glass filter. Incident pulses are absorbed and the heat is distributed throughout the volume. In this way, pulses that would have damaged the absorption coating of a thermal surface absorber are safely measured by these thermal volume absorbers.

The S370C features a large Ø25 mm aperture ideal for large-spot-size beams, and it is compatible with average powers from 10 mW to 10 W (CW).

In comparison, the S470C is faster, as the glass absorber volume is reduced and other design parameters have been optimized for speed. This results in a different optical power range, with the ability to measure powers down to 100 µW. The Ø15 mm aperture is of the S470C is smaller, and it has a lower max average power of 5 W. Its 10 µW resolution is better than the 250 µW resolution of

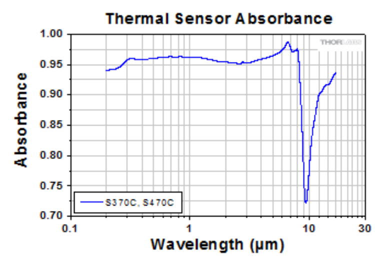
Compatible Consoles	PM400, PM100D, PM100USB, PM100A, PM101A, and PM320E

- For complete specifications, please see the *Specs* tab.
- Two Minute Maximum Exposure Time
- Measurement taken with the PM100D console for the S370C and with the legacy PM200 for the S470C. In all cases, the acceleration circuit was switched off. Resolution performance will be similar with our other power meter consoles.
- Defined as the measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <2 s). See the *Operation* tab for additional information.

the S370C.

For high-power, pulsed-lasers the S370C and S470C Thermal Sensors can withstand high average and peak power densities. However, for sensors with a broader spectral range or shorter response time, consider one of our Pyroelectric Energy Sensors.

Thorlabs offers a recalibration service for these sensors, which can be ordered below (see Item # CAL-S200).



Click to Enlarge
Click Here for Raw Data
This absorption curve is shown over a broader wavelength range than the sensors' operating ranges. See the table for the operating wavelength range of each sensor.

Part Number	Description	Price	Availability
S370C	Thermal Power Sensor Head, Volume Absorber, 0.4 - 5.2 µm, 10 W, Ø25 mm	$1,206.56	Today
S470C	Thermal Power Sensor Head, Volume Absorber, 0.25 - 10.6 µm, 0.1mW - 5W, Ø15 mm	$1,228.20	Today

Hide Microscope Slide Thermal Sensor

Microscope Slide Thermal Sensor

Item #[a]	S175C
Sensor Image (Click Image to Enlarge)	
Wavelength Range	0.3 - 10.6 µm
Power Range	100 µW - 2 W
Input Aperture Size	18 mm x 18 mm
Active Detector Area	18 mm x 18 mm
Max Optical Power Density	200 W/cm^2
Detector Type	Thermal Surface Absorber (Thermopile)
Linearity	±0.5%
Resolution[b]	10 µW
	±3% @ 1064 nm;

- Designed to Measure Optical Power at the Sample Plane of a Microscope
- 76.0 mm x 25.2 mm Footprint Matches Standard Microscope Slides
- Wavelength Range: 300 nm - 10.6 µm
- Sensitive to Optical Powers from 100 µW to 2 W
- Information Stored in Connector
  - Sensor Data
  - NIST- and PTB-Traceable Calibration Data


Click to Enlarge
The back of the S175C housing is engraved with the sensor specifications and a target for centering the beam on the sensor.

The S175C Microscope Slide Thermal Power Sensor Head is designed to measure the power at the sample in microscopy setups. The thermal sensor can detect wavelengths between 300 nm and 10.6 µm at optical powers between 100 µW and 2 W. The sensor head's 76.0 mm x 25.2 mm footprint matches that of a standard microscope slide and is compatible with most standard upright and inverted microscopes.

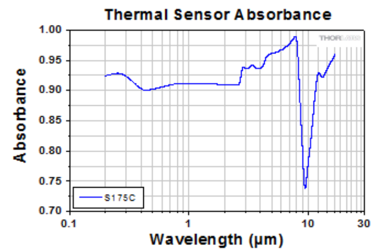
The thermal sensor has an 18 mm x 18 mm active area and is contained in a sealed housing behind a glass cover. An immersion medium (water, glycerol,

Measurement Uncertainty[c]	±5% @ 300 nm - 10.6 µm
Response Time[d]	3 s (<2 s from 0 to 90%)
Housing Dimensions	76 mm x 25.2 mm x 4.8 mm (2.99" x 0.99" x 0.19")
Temperature Sensor (In Sensor Head)	N/A
Cable Length	1.5 m
Housing Features	Integrated Glass Cover Engraved Laser Target on Back
Compatible Consoles	PM400, PM100D, PM100USB, PM100A, PM101A, and PM320E

- For complete specifications, please see the *Specs* tab.
- Measured with the legacy PM200 Touch Screen Console
- Defined as the measurement uncertainty during calibration at the specified wavelengths for a beam diameter > 1 mm. The ±3% specification was determined by laser calibration, and the ±5% specification was determined through spectral calibration, in which values were interpolated using the laser calibration data and the absorption curve for the absorber. Calibration can be performed at 10.6 µm upon request.
- Typical natural response time (0 - 95%). Our power consoles can provide estimated measurements of optical power on an accelerated time scale (typically <1 s). See the *Operation* tab for additional information.

oil) may be placed over the glass cover plate.

As seen in the image to the right, the bottom of the sensor housing features a laser-engraved target to aid in aligning and focusing the beam. In standard microscopes, the target can be used for beam alignment before flipping the sensor head to face the objective for power measurements. In inverted microscopes, turn on the trans-illumination lamp and align the target on the detector housing with the beam; this will center the sensor in front of the objective.



Click to Enlarge
Click Here for Raw Data
Typical absorption curve for the S175C (glass and absorber). Note that this curve is representative, and the actual absorption across the spectrum will vary from unit to unit.

Sensor specifications and the NIST- and PTB-traceable calibration data are stored in non-volatile memory in the sensor connector and can be read out by the latest generation of Thorlabs power meters. We recommend yearly recalibration to ensure accuracy and performance. Calibration may be ordered using the CAL-S200 recalibration service available below. Please contact Tech Support for more information.

The complete set of specifications are presented on the *Specs* tab above. Thorlabs also offers a Microscope Slide Sensor Head with a photodiode sensor for low-power, high-resolution measurements; the full presentation may be found here.

Part Number	Description	Price	Availability
S175C	Customer Inspired! Microscope Slide Thermal Power Sensor, 300 nm - 10.6 µm, 2 W	$1,206.56	Today

Hide Internally SM1-Threaded Fiber Adapters

Internally SM1-Threaded Fiber Adapters

These internally SM1-threaded (1.035"-40) adapters mate terminated fiber to any of our externally SM1-threaded components, including a selection of our photodiode power sensors, our thermal power sensors, and our photodetectors.

The APC adapters have two dimples in the front surface that allow them to be tightened with the SPW909 or SPW801 spanner wrench. The dimples do not go all the way through the disk so that the adapter can be used in light-tight applications when paired with SM1 lens tubes.

For details on narrow versus wide key connectors, please see our Intro to Fiber tutorial. Please contact Tech Support if you are unsure if the adapter is mechanically compatible.

Item #	S120-FC2	S120-FC	S120-APC2[a]	S120-APC[a]	S120-SMA	S120-ST	S120-SC	S120-LC
Adapter Image (Click the Image to Enlarge)								
Fiber Connector Type	FC/PC, 2.0 mm Narrow Key	FC/PC, 2.2 mm Wide Key	FC/APC, 2.0 mm Narrow Key	FC/APC 2.2 mm Wide Key	SMA	ST/PC	SC/PC[b]	LC/PC
Thread	Internal SM1 (1.035"-40)							

- The S120-APC and S120-APC2 are designed with a 4° mechanical angle to compensate for the refraction angle of the output beam.
- In certain angle-independent applications, this adapter may also be used with SC/APC connectors.

Part Number	Description	Price	Availability
S120-FC2	NEW! FC/PC Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads, Narrow Key (2.0 mm)	$42.20	Today
S120-FC	FC/PC Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads, Wide Key (2.2 mm)	$42.20	Today
S120-APC2	FC/APC Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads, Narrow Key (2.0 mm)	$32.96	Lead Time
S120-APC	Customer Inspired! FC/APC Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads, Wide Key (2.2 mm)	$32.96	Today
S120-SMA	SMA Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads	$42.20	Today
S120-ST	ST/PC Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads	$42.20	Today
S120-SC	SC/PC Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads	$53.02	Today
S120-LC	LC/PC Fiber Adapter Cap with Internal SM1 (1.035"-40) Threads	$53.02	Today

Hide Recalibration Service for Thermal Power and Pyroelectric Energy Sensors

Recalibration Service for Thermal Power and Pyroelectric Energy Sensors

Thorlabs offers recalibration services for our thermal power and pyroelectric energy sensors. To ensure accurate measurements, we recommend recalibrating the sensors annually. Recalibration of the console is included with the recalibration of a sensor at no additional cost. If you wish to recalibrate only your power meter console, please contact Tech Support for details.

The table to the right lists the sensors for which this calibration service is available. Please enter the Part # and Serial # of the sensor that requires recalibration prior to selecting Add to Cart.

Please Note:
To ensure your item being returned for calibration is routed appropriately once it arrives at our facility, please do not ship it prior to being provided an RMA Number and return instructions by a member of our team. Pyroelectric energy sensors returned for recalibration or servicing must include the separate BNC to DB9 adapter, which contains the sensor EEPROM.

Sensor Type	Sensor Item #s
Thermal Power	S175C, S302C[a], S305C[a], S310C[a], S314C[a], S322C, S350C, S370C, S401C, S405C, S415C, S425C, S425C-L, S470C
Pyroelectric Energy	ES111C, ES120C, ES145C, ES220C, ES245C

- This former catalog item is now offered as a special.

Part Number	Description	Price	Availability
CAL-S200	Recalibration Service for Thermal Power and Pyroelectric Energy Sensors	$193.70	Lead Time