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THORLABS

Item # OSA202 - October 3, 2016

Item # OSA202 was discontinued on October 3, 2016. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

OPTICAL SPECTRUM ANALYZERS

- **Dual-Function Broadband Spectrometer and Wavelength Meter**
- **Six Models Support Wavelengths from 350 nm to 12.0 µm**
- **Includes Windows® Laptop with Pre-Installed Software**

All OSAs Include Laptop with Our Data Collection and Analysis Software

OSA202
600 - 1700 nm
FC/PC Input

OSA207
1.0 - 12.0 µm
FC/PC and Free-Space Inputs

OVERVIEW

Features

- Six Models Optimized for Different Spectral Ranges
  - OSA201: 350 - 1100 nm
  - OSA202: 600 - 1700 nm
  - OSA203B: 1.0 - 2.6 µm (10 000 - 3846 cm^{-1})
  - OSA205: 1.0 - 5.6 µm (10 000 - 1786 cm^{-1})
  - OSA206: 3.3 - 8.0 µm (3030 - 1250 cm^{-1})
  - OSA207: 1.0 - 12.0 µm (10 000 - 833 cm^{-1})
- 7.5 GHz Resolution (0.25 cm^{-1}) in Spectrometer Mode (Click for Graph)
- 0.1 ppm Resolution in Wavelength Meter Mode (Sources with <10 GHz Linewidth)
- Michelson Interferometer Acquires Spectrum via Fourier Transform
- Includes Windows® Laptop with Pre-Installed Software
  - Intuitive, Responsive, Flat Interface
  - Real-Time Math Operations, Unit Conversions, and Statistical Analysis
  - Libraries for LabVIEW™ and Common Programming Languages

Pre-Purchase Support

Contact Us

To help ensure that our OSAs will meet your needs, we can provide the following:

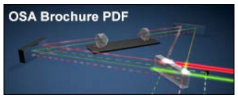
- Demo Units for Trial in Your Lab
- Example Measurements
- Evaluation of Suitability for Your Application
- "Virtual Device" Software Demo (See *Software* Tab)

If you would like any of these services, please contact us with your experimental requirements.

Thorlabs' Optical Spectrum Analyzers (OSAs) perform highly accurate measurements of the spectra of unknown light sources. These compact instruments suit a wide range of applications, such as analyzing the spectrum of a telecom signal, resolving the Fabry-Perot modes of a gain chip, and identifying gas absorption lines in a spectral measurement.

Many commonly available OSAs use grating-based monochromators, which have slow acquisition times due to the need to mechanically scan the grating and average out noise at each wavelength. Thorlabs' OSAs acquire the spectrum via a Fourier transform using a scanning Michelson interferometer in a push/pull configuration. This approach dramatically improves the acquisition time, enables a high-precision wavelength meter mode with ±1 part-per-million accuracy (i.e., 7 significant figures), and allows the included software to provide robust statistical analysis of the acquired spectra. See the *Design* tab and the video to the right for more information.

All of Thorlabs' OSAs are compatible with FC/PC-terminated fiber patch cables. Custom designs for other fiber input receptacles are available by contacting Tech Support. In addition, except for the OSA201 and OSA202, Thorlabs' OSAs can directly accept a collimated free-space optical input with a Ø6 mm maximum beam size, as detailed in the *Free-Space Coupling* tab. For wavelengths above 2 µm, we recommend single mode or multimode fluoride patch cables with cores up to Ø100 µm.



The instruments are designed to measure CW light sources, and also work in some applications where a pulsed light source is used; details may be found on the *Pulsed Sources* tab. Please contact Tech Support to discuss pulsed light source applications.

To reduce the presence of water absorption lines in the mid-IR region of the spectrum, the OSA203B, OSA205, OSA206, and OSA207 feature two 1/4" ID quick-connect hose connections on the back panel, through which the interferometer can be purged with dry air or nitrogen. Thorlabs' Pure Air Circulator Unit is ideal for this task. Since none of the optics in our OSAs are made from hygroscopic materials, purging is not necessary to prevent water-induced degradation of the cavity. An example spectroscopy setup is described in the *Gas Spectroscopy* tab above.

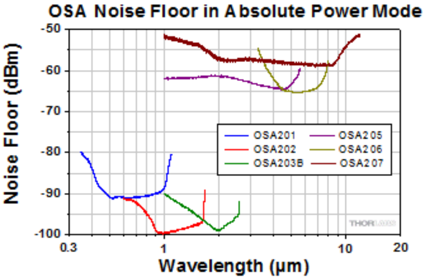
Our stock instruments are not designed for applications where it is necessary to recover small signals, including Raman spectroscopy and many fluorescence experiments. If your application would benefit from increased detection sensitivity, please see the *Custom OSAs* tab for some of our capabilities.

Key Specifications

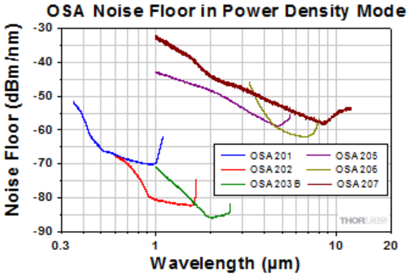
Please refer to the *Specs* tab for detailed specifications.

Quick Links		
Item #	**Wavelength Range**	**Optical Inputs**
OSA201	350 - 1100 nm	FC/PC Connector[a]
OSA202	600 - 1700 nm	
OSA203B	1.0 - 2.6 µm[b] (10 000 - 3846 cm^{-1})	FC/PC Connector[a] Free-Space Input
OSA205	1.0 - 5.6 µm (10 000 - 1786 cm^{-1})	
OSA206	3.3 - 8.0 µm (3030 - 1250 cm^{-1})	
OSA207	1.0 - 12.0 µm (10 000 - 833 cm^{-1})	

- Other Fiber Input Receptacles Available Upon Request (See *Custom OSAs* Tab)
- Specified in High-Temperature Mode



Absolute Power mode is recommended for narrowband sources. The OSA203B noise floor was measured in low-temperature mode.



Power Density mode is recommended for broadband sources. The OSA203B noise floor was measured in low-temperature mode.

Hide Specs

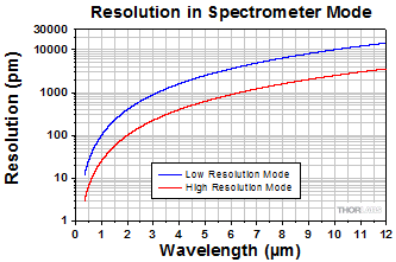
SPECS

Item #	Notes	OSA201	OSA202	OSA203B	OSA205	OSA206	OSA207
Wavelength Range	Limited by Bandwidth of Detectors and Optics	350 - 1100 nm	600 - 1700 nm	1.0 - 2.6 µm[a] (10 000 - 3846 cm^{-1})	1.0 - 5.6 µm (10 000 - 1786 cm^{-1})	3.3 - 8.0 µm (3030 - 1250 cm^{-1})	1.0 - 12.0 µm (10 000 - 833 cm^{-1})
Level Sensitivity[b]	See Graphs Below	-60 dBm/nm	-70 dBm/nm	-70 dBm/nm[c]	-40 dBm/nm	-45 dBm/nm	-30 dBm/nm for 1.0 - 2.0 µm -40 dBm/nm for 2.0 - 12.0 µm
Spectral Resolution[d]	Spectrometer Mode	7.5 GHz (0.25 cm^{-1}) See Graph Below					
Spectral Accuracy[e]		±2 ppm[f]					
Spectral Precision[g]		1 ppm[f]					
Wavelength Meter Resolution	Wavelength Meter Mode (Linewidth < 10 GHz)	0.1 ppm[f]					
Wavelength Meter Display Resolution[h]		9 Decimals					
Wavelength Meter Accuracy[e]		±1 ppm[f]					
Wavelength Meter Precision[i]		0.2 ppm[f]					
Input Power (Max)	CW Source	10 mW (10 dBm)					
Input Damage Threshold[j]	-	20 mW (13 dBm)					
Power Level Accuracy[k]	-	±1 dB					
Optical Rejection Ratio	See the *Design* Tab	30 dB					

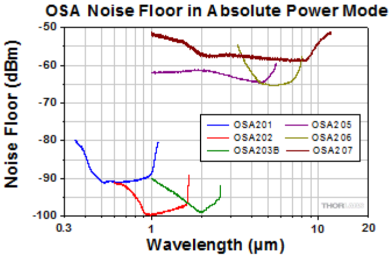
	for Details		
Input Fiber Compatibility	-	FC/PC Connectors[l] All Single Mode Fiber Patch Cables, Including Fluoride SM Fiber Patch Cables Standard and Hybrid Step-Index Multimode Fiber Patch Cables with ≤Ø50 µm Core and NA ≤ 0.22 Step-Index Fluoride Multimode Fiber Patch Cables with ≤Ø100 µm Core and NA ≤ 0.26 (Single Mode Patch Cables Provide the Highest Contrast)	
Free-Space Input	-	None	Accepts Collimated Beams up to Ø6 mm Red Alignment Laser Beam Four 4-40 Taps for 30 mm Cage Systems
Dimensions	-	320 mm x 149 mm x 475 mm (12.6" x 5.9" x 18.7")	
Input Voltage[m]	-	100 - 240 VAC, 47 - 63 Hz, 250 W (Max)	
Operating Temperature	-	10 °C to 40 °C	10 °C to 35 °C
Storage Temperature	-	-10 °C to 60 °C	
Relative Humidity	-	<80%, Non-Condensing	

a. Specified in high-temperature mode. In low-temperature mode, the wavelength range is 1.0 - 2.5 µm.
b. Minimum detectable power per nanometer using Zero Fill = 0 and the highest resolution and sensitivity settings.
c. Specified in low-temperature mode over 1.0 - 2.5 µm. In high-temperature mode, the level sensitivity is -65 dBm/nm over 1.0 - 2.6 µm.
d. Defined according to the Rayleigh criterion.
e. After a 45-minute warm-up, for a single mode FC/PC-terminated patch cable at an operating temperature of 20 - 30 ºC.
f. Specified in parts per million, which corresponds to nearly seven significant figures (depending on the specification). For instance, if the wavelength being measured is 1 µm, the wavelength meter precision will be 200 fm.
g. Spectral Precision is the repeatability with which a spectral feature can be measured using the peak search tool.
h. Can be set from 0 - 9 decimals and has a feature that automatically estimates the relevant number of decimals.
i. Using the same input single mode fiber for all measurements.
j. Limited by the damage threshold of the internal components.
k. Specified using Absolute Power Mode, Zero Fill = 2, and Hann apodization, after a 45-minute warm-up, for an operating temperature of 20 - 30 °C. (The different apodization modes available in the OSA software are described in section 16.2 of the manual.) The specified wavelength range is 400 - 1000 nm for OSA201, 600 - 1600 nm for OSA202, 1.0 - 2.4 µm for OSA203B, and 1.3 - 5.0 µm for OSA205, and the specification is valid for a single mode FC/PC-terminated patch cable. For OSA206 and OSA207, the specified wavelength ranges are 3.3 - 8.0 µm and 2.0 - 11.0 µm, respectively, and the specification is valid for collimated free-space beams with diameter < 3 mm and divergence < 3 mrad, assuming the included protective window is installed in the free-space aperture.
l. Custom connectors for other fiber input receptacles are available upon request. Please contact Tech Support or see the *Custom OSAs* tab for details.
m. The OSA and the Windows® laptop each come with a region-specific power cord.

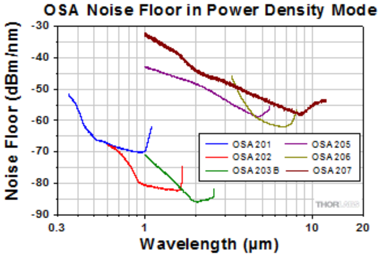
Resolution and Sensitivity Specifications



The resolution shown here was calculated using the formula explained in the *Design* tab. Although the formula is valid for all OSA models, the usable wavelength range of each model is limited by the bandwidth of the detectors and optical coatings.



Absolute Power mode is recommended for narrowband sources. Please note that the OSA203B noise floor was measured in low-temperature mode.



Power Density mode is recommended for broadband sources. Please note that the OSA203B noise floor was measured in low-temperature mode.

Data Acquisition Specifications

Time Between Updates		
Sensitivity	**Low Resolution**	**High Resolution**
Low	0.5 s (1.9 Hz)	1.8 s (0.6 Hz)
Medium Low	0.8 s (1.2 Hz)	2.9 s (0.3 Hz)
Medium High	1.5 s (0.7 Hz)	5.2 s (0.2 Hz)
High	2.7 s (0.4 Hz)	9.5 s (0.1 Hz)m.

The scan sensitivity and resolution are two independent settings controlled from the software. The sensitivity setting modifies the range of detector gain levels, while the resolution setting changes the optical path difference (OPD). For more details, see the *Design* tab.

Hide Design

DESIGN

Design

This tab describes the key concepts and implementation of the design used in Thorlabs' Optical Spectrum Analyzers.

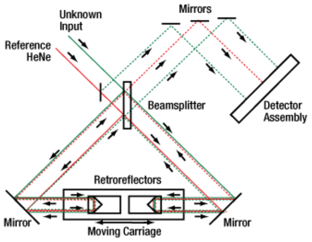
Contents

- Absolute Power and Power Density
- Interferogram Data Acquisition
- Interferogram Data Processing
- Wavelength Meter Mode
- Wavelength Calibration and Accuracy
- Optical Rejection Ratio

Interferometer Design

Thorlabs' Fourier Transform Optical Spectrum Analyzer (FT-OSA) utilizes two retroreflectors, as shown in the figure to the right. These retroreflectors are mounted on a voice-coil-driven platform, which dynamically changes the optical path length of the two arms of the interferometer simultaneously and in opposite directions. The advantage of this layout is that it changes the optical path difference (OPD) of the interferometer by four times the mechanical movement of the platform. The longer the change in OPD, the finer the spectral detail the FT-OSA can resolve.

After collimating the unknown input, a beamsplitter divides the optical signal into two separate paths. The path length difference between the two paths is varied from 0 to ±40 mm. The collimated light fields then optically interfere as they recombine at the beamsplitter.



Click to Enlarge
Schematic of the optical path in Thorlabs' OSA, detailing the dual retroreflector design. We will refer to this schematic throughout this tutorial.

The detector assembly shown in the figure to the right records the interference pattern, commonly referred to as an interferogram. This interferogram is the autocorrelation waveform of the input optical spectrum. By applying a Fourier transform to the waveform, the optical spectrum is recovered. The resulting spectrum offers both high resolution and very broad wavelength coverage with a spectral resolution that is related to the optical path difference. The wavelength range is limited by the bandwidth of the detectors and optical coatings. The accuracy of our system is ensured by including a frequency-stabilized (632.991 nm) HeNe reference laser, which acts to provide highly accurate measurements of beam path length changes, allowing the system to continuously self-calibrate. This process ensures accurate optical analysis well beyond what is possible with a grating-based OSA.

Each OSA model has a spectral resolution of 7.5 GHz, or 0.25 cm^{-1}. The resolution in units of wavelength is dependent on the wavelength of light being measured. For more details, see the *Resolution and Sensitivity* section below. In this context, the spectral resolution is defined according to the Rayleigh criterion and is the minimum separation required between two spectral features in order to resolve them as two separate lines. These spectral resolution numbers should not be confused with the resolution when operating in the Wavelength Meter mode, which is considerably better.

The Thorlabs FT-OSA utilizes a built-in, actively stabilized reference HeNe laser to interferometrically record the variation of the optical path length. This reference laser is inserted into the interferometer and closely follows the same path traversed by the unknown input light field. To reduce the presence of water absorption lines in the mid-IR region of the spectrum, the OSA203B, OSA205, OSA206, and OSA207 feature two quick-connect hose connections (1/4" ID) on the back panel, through which the interferometer can be purged with dry air or nitrogen. Thorlabs' Pure Air Circulator Unit, which uses hosing that can be directly inserted into these connectors, is ideal for this task.

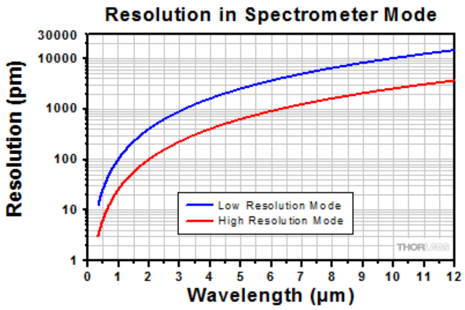
Resolution and Sensitivity

The resolution of this type of instrument depends on the optical path difference (OPD) between the two paths in the interferometer. It is easiest to understand the resolution in terms of wavenumbers (inverse centimeters), as opposed to wavelength (nanometers) or frequency (terahertz).

Assume we have two narrowband sources, such as lasers, with a 1 cm^{-1} energy difference, 6500 cm^{-1} and 6501 cm^{-1}. To distinguish between these signals in the interferogram, we would need to move away 1 cm from the point of zero path difference (ZPD). The OSA can move ±4 cm in OPD, and so it can resolve spectral features 0.25 cm^{-1} apart. The resolution of the instrument can be calculated as:

$$\Delta\lambda = \Delta k \times 100 \times \lambda^2$$

where $\Delta\lambda$ is the resolution in pm, Δk is the resolution in cm^{-1} (maximum of 0.25 cm^{-1} for this instrument) and λ is the wavelength in µm. The resolution in pm as a function of wavelength, converted using this formula, is shown in the graph to the right.

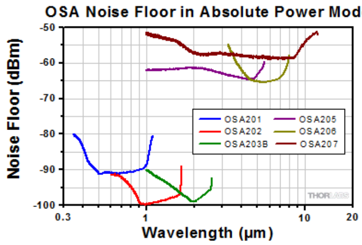


Click to Enlarge
OSA Resolution vs. Wavelength of the Unknown Input
The resolution shown here was calculated using the formula to the left, using Δk = 1 cm^{-1} for Low Resolution Mode and Δk = 0.25 cm^{-1} for High Resolution Mode. Although the formula is valid for all OSA models, the usable wavelength range of each model is limited by the bandwidth of the detectors and optical coatings.

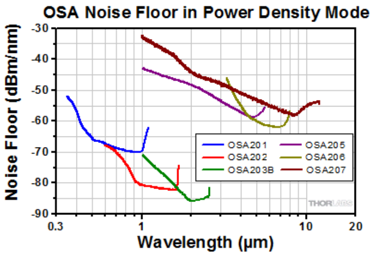
The resolution of the OSA can be set to High or Low in the main window of the software. In high resolution mode, the retroreflectors translate by the maximum of ±1 cm (±4 cm in OPD), while in low resolution mode, the retroreflectors translate by ±0.25 cm (±1 cm in OPD). The OSA software can cut the length of the interferogram that is used in the calculation of the spectrum in order to remove spectral contributions from high-frequency components.

The sensitivity of the instrument depends on the electronic gain used in the sensor electronics. Since an increased gain setting reduces the bandwidth of the detectors, the instrument will run slower when higher gain settings are used. The figures below show the dependency of the noise floor on the wavelength and OSA model.

The OSA is also designed so that it samples more points/OPD when the translation of the retroreflector assembly is slower. The data sampling is triggered by the reference signal from the internal stabilized HeNe laser. A phase-locked loop multiplies the HeNe period up to 128X for the highest sensitivity mode. This mode can be very useful when the measured light is weak and broadband, causing only a very short interval in the interferogram at the ZPD to contain all the spectral information. This portion of the interferogram is normally referred to as the zero burst.



Noise Floor in Absolute Power Mode
Absolute Power mode is recommended for narrowband sources. Note that the OSA203B noise floor was measured in low-temperature mode.



Noise Floor in Power Density Mode
Power Density mode is recommended for broadband sources. Note that the OSA203B noise floor was measured in low-temperature mode.

Absolute Power and Power Density

The vertical axis of the spectrum can be displayed as Absolute Power or Power Density, both of which can be displayed in either a linear or logarithmic scale. In Absolute Power mode, the total power displayed is based on the actual instrument resolution for that specific wavelength; this setting is recommended to be used only with narrow spectrum input light. For broadband devices, it is recommended that the Power Density mode is used. Here the vertical axis is displayed in units of power per unit wavelength, where the unit wavelength is based upon a fixed wavelength band and is independent of the resolution setting of the instrument.

Interferogram Data Acquisition

The interference pattern of the reference laser is used to clock a 16-bit analog-to-digital converter (ADC) such that samples are taken at a fixed, equidistant optical path length interval. The HeNe reference fringe period is digitized and its frequency multiplied by a phase-locked loop (PLL), leading to an extremely fine sampling resolution. Multiple PLL filters enable frequency multiplication settings of 16X, 32X, 64X, or 128X. At the 128X multiplier setting, data points are acquired approximately every 1 nm of carriage travel. The multiple PLL filters enable the user to balance the system parameters of resolution and sensitivity against the acquisition time and refresh rate.

A high-speed USB 2.0 link transfers the interferogram for the device under test at 6 MB/s with a ping-pong transfer scheme, enabling the streaming of very large data sets. Once the data is captured, the OSA software, which is highly optimized to take full advantage of modern multi-core processors, performs a number of calculations to analyze and condition the input waveform in order to obtain the highest possible resolution and signal-to-noise ratio (SNR) at the output of the Fast Fourier Transform (FFT).

A very low noise and low distortion detector amplifier with automatic gain control provides a large dynamic range, allows optimal use of the ADC, and ensures excellent signal-to-noise (SNR) for up to 10 mW of input power. For low-power signals, the system can typically detect less than 100 pW from narrowband sources. The balanced detection architecture enhances the SNR of the system by enabling the Thorlabs FT-OSA to use all of the light that enters the interferometer, while also rejecting common mode noise.

Interferogram Data Processing

The interferograms generated by the instrument vary from 0.5 million to 16 million data points depending on the resolution and sensitivity mode settings employed. The FT-OSA software analyzes the input data and intelligently selects the optimal FFT algorithm from our internal library.

Additional software performance is realized by utilizing an asynchronous, multi-threaded approach to collecting and handling interferogram data through the multitude of processing stages required to yield spectrum information. The software's multi-threaded architecture manages several operational tasks in parallel by actively adapting to the PC's capabilities, thus ensuring maximum processor bandwidth utilization. Each of our FT-OSA instruments ships complete with a laptop computer that has been carefully selected to ensure that both the data processing and user interface operate optimally.

Wavelength Meter Mode

When narrowband optical signals are analyzed, the FT-OSA automatically calculates the center wavelength of the input, which can be displayed in a window just below the main display that presents the overall spectrum. The central wavelength, λ, is calculated by counting interference fringes (periods in the interferogram) from both the input and reference lasers according to the following formula:

$$\lambda = \frac{m_0}{m} \times \frac{n_\lambda}{n_0} \times \lambda_0$$

Here, m_o is the number of fringes for the reference HeNe laser, m is the number of fringes from the unknown input, n_o is the index of refraction of air at the reference laser wavelength, n_λ is the index of refraction of air at the wavelength λ, and λ_o is the vacuum wavelength of the HeNe reference laser (632.991 nm).

The resolution of the FT-OSA operating as a Wavelength Meter is substantially higher than the system when it operates as a broadband spectrometer because the system can resolve a fraction of a fringe up to the limit set by the phase-locked loop multiplier (see the *Interferogram Data Acquisition* section above). In practice, the resolution of the system is limited by the bandwidth and structure of the unknown input, noise in the detectors, drift in the reference HeNe, interferometer alignment, and other systematic errors. The system has been found to offer reliable results as low as ±0.1 pm in the visible spectrum and ±0.2 pm in the NIR/IR (see the *Specs* tab for details).

The software evaluates the spectrum of the unknown input in order to determine an appropriate display resolution. If the data is unreliable, as would be the case for a multiple peak spectrum, the software disables the Wavelength Meter mode so it does not provide misleading results.

Wavelength Calibration and Accuracy

The FT-OSA instruments incorporate a stabilized HeNe reference laser with a vacuum wavelength of 632.991 nm. The use of a stabilized HeNe ensures long-term wavelength accuracy as the dynamics of the stabilized HeNe are well-known and controlled. The instrument is factory-aligned so that the reference HeNe and unknown input beams experience the same optical path length change as the interferometer is scanned. The effect of any residual alignment error on wavelength measurements is less than 0.5 ppm; the input beam pointing accuracy is ensured by a high-precision ceramic receptacle and a robust interferometer cavity design. No optical fibers are used within the scanning interferometer. The wavelength of the reference HeNe in air is actively calculated for each measurement using the Eldén formula with temperature and pressure data collected by sensors internal to the instrument.

For customers operating in the visible spectrum, the influence of relative humidity (RH) on the refractive index of air can affect the accuracy of the measurements. To compensate for this, the software allows the assumed RH value to be set manually. The effect of the humidity is negligible in the infrared.

Optical Rejection Ratio

The ability to measure low-level signals close to a peak is determined by the optical rejection ratio (ORR) of the instrument. It can be seen as the filter response of the OSA, and can be defined as the ratio between the power at a given distance from the peak and the power at the peak.

If the ORR is not higher than the optical signal-to-noise ratio of the source to be tested, the measurement will be limited by the OSA's response, rather than reflecting a true property of the tested source. The table to the right provides an example.

Distance from 1550 nm Peak	Optical Rejection Ratio
0.2 nm (25 GHz)	30 dB
0.4 nm (50 GHz)	30 dB
0.8 nm (100 GHz)	30 dB
4 nm (500 GHz)	39 dB
8 nm (1000 GHz)	43 dB

This table provides the Optical Rejection Ratio at 1550 nm for the OSA203B with the following settings: High Resolution, Low Sensitivity, Average = 4, Hann apodization. All OSA models show similar behavior if the distance from the peak is measured in GHz (units of frequency).

Hide Free-Space Coupling

FREE-SPACE COUPLING

Free-Space Coupling

Thorlabs' OSA203B, OSA205, OSA206, and OSA207 directly support free-space optical inputs. For the OSA201 and OSA202, we recommend using a reflective collimator to collect the output from a fiber end. For details on both of these options, please read below.

OSA203B, OSA205, OSA206, and OSA207: Directly Compatible with Free-Space Beams

The OSA203B, OSA205, OSA206, and OSA207 feature a built-in free-space optical input, allowing them to directly accept collimated light beams. The maximum beam size is Ø6 mm, and the input aperture includes four 4-40 taps for compatibility with our 30 mm cage systems. When the free-space door is open, a red alignment beam is emitted that should be made collinear and antiparallel to the unknown input for optimal measurement accuracy. For a demonstration, please refer to the video in the *Overview* tab at 2:54.

Free-Space Optical Input Behind Door


Cage-Mounted Polarizers in Front of Free-Space Input

Since the interferometer assembly normally "floats" on gel bushings inside the case when using the fiber input, it is necessary to lock the interferometer to an optical table surface when using the free space input. This can be accomplished by using the specially designed Ø1" pedestal posts included with the unit. By securing these pedestal posts with a CF175 clamping fork, the interferometer is locked to the optical table, allowing for stable free-space measurements.

We recommend only using the posts supplied with the OSA to secure it to the optical table. Other posts, including our Ø1/2" optical posts, should not be used to secure the OSA. Because the OSA weighs ~20 lbs (~10 kg), Ø1/2" posts will not provide adequate support. We also do not recommend using long optical posts to raise the OSA off of the optical table surface.

Beam Height Adjustment

When the interferometer is locked to an optical table, the beam height is 61 mm (2.4") from the table surface. We recommend using a periscope assembly, such as Thorlabs RS99 or one constructed with our DP14A damped post, to adjust the input beam height to that of the OSA's input.

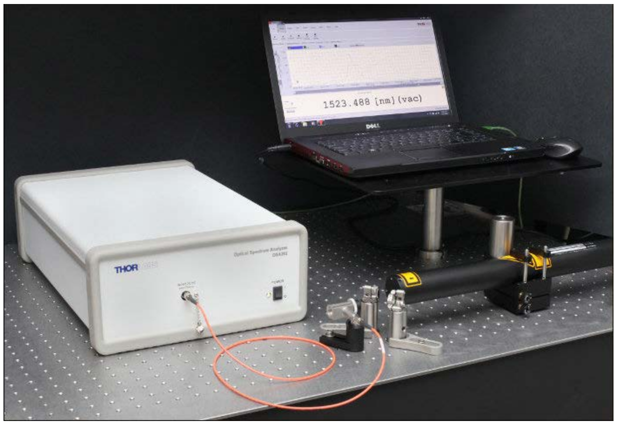

Click to Enlarge
The underside of the OSA203B, OSA205, OSA206, and OSA207 has M4-tapped holes that accept special optical posts included with the unit. These posts can be secured to an optical table using two CF175 clamping forks, which locks the OSA's interferometer to the table surface, allowing for stable free-space measurements.


Click to Enlarge
OSA203B secured to an optical table and used to measure the free-space beam of a laser diode. The laser diode is mounted in an LDM9T mount, and the beam is redirected by mirrors mounted in POLARIS-K1 and KCB1 kinematic mounts.

OSA201 and OSA202: Use a Reflective Collimator

To send a free-space input into the OSA201 or OSA202, we recommend using a reflective collimator and a Ø50 µm core, 0.22 NA multimode fiber to collect light and transport it to the instrument, as shown below. A single mode patch cable can also be employed to collect the light. This may provide more precise results, but the alignment procedure is far more difficult (see *Data Acquisition with a Single Mode Fiber Patch Cable*, below, for details).

A list of parts used in this setup is available in the tables below. Mouse over the photo to see the corresponding part highlighted in the tables.

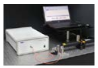


Item #	Description	Qty.
OSA202	Optical Spectrum Analyzer	1
M42L01	Ø50 µm Core FC/PC Multimode Patch Cable	1
RC08FC-P01	Reflective Collimator	1
LMR05	Ø1/2" Fixed Optic Mount	1
TR2	Ø1/2" Optical Post	1

Item #	Description	Qty.
UPH1.5	Ø1/2" Post Holder	1
PF05-03-P01	Ø1/2" Protected Silver Mirror	2
POLARIS-K05	Ø1/2" Ultra-Stable Mirror Mount	2
RS3P8E	Ø1" Optical Post	2
CF125	Clamping Fork	2

Item #	Description	Qty
P6	Ø1/5" Optical Post	1
C1513	Kinematic V-Clamp Mount	1
PM4	Large Adjustable Clamping Arm	1

Basic Setup


Click to Enlarge

Thorlabs' OSA can be used to study free-space light sources using a folding mirror pair and the RC08FC-P01 reflective collimator. In this example, a 1532 nm HeNe laser is coupled into the OSA202 Optical Spectrum Analyzer.

Coupling Equipment


Click to Enlarge

The 1523 nm HeNe laser can be attached to the optical table using a P6 Ø1.5" post and a C1513 Kinematic V-Clamp Mount. The folding mirror pair consists of two Ø1/2" PF05-03-P01 silver mirrors mounted in POLARIS-K05 mirror mounts. The Polaris mounts should be mounted on RS3P8E Ø1", 3" long posts held to the table with CF125 clamping forks. Mount the RC08FC-P01 reflective collimator using an LMR05 fixed mount, a TR2 Ø1/2" post, and a UPH1.5 post holder. The beam height should be kept as low as possible in order to provide the best alignment stability.

In this example, two output fibers were used: an M42L01 Ø50 µm core multimode FC/PC-to-FC/PC patch cable and a P1-SMF28E-FC-1 single mode FC/PC-to-FC/PC patch cable. Initial coupling alignment should be conducted using the multimode fiber. Once the system is aligned for good coupling efficiency using the multimode fiber, the MM patch cable can be replaced by an SM patch cable, if desired. The system will then need to be retweaked for optimal coupling efficiency.

Alignment Procedure

Our HLS635 635 nm, 1 mW portable alignment laser, which is a battery-powered 635 nm laser source, can be used to roughly align the system. At the start of the alignment, place both the HeNe laser and the reflective collimator at the same optical height as the folding mirror pair; this will minimize the amount of vertical adjustment of the beam path needed.

Click to Enlarge

Mount the collimator and laser parallel to the hole pattern in the table. Plug the laser into the output fiber to run the light backwards through the system. Place the first mirror onto the table so that the laser beam exiting the reflective collimator is incident on it at 45°, with the beam exiting the mirror parallel to the optical table's holes. Then, place the second mirror similarly, so that the beam is indicent on the output aperture of the laser. At this point, the clamping forks can be used to secure the post of each mirror mount to the table, and the system should be close to proper alignment.

Next, turn on the HeNe laser and view the two laser beams along the optical path using a VRC4 IR viewing card. Adjust the mirrors so that the beams are incident on the same spot on the card at each point along the optical path. In the photo to the right, the small bright beam is from the HeNe laser, while the large red beam is from the alignment laser, incident on the back side of the card.

Click to Enlarge

Next, measure the power of the free-space beam using the PM200 touch screen power meter and S122C sensor head. In this example, the free-space power of the laser was measured to be 1.55 mW.

Click to Enlarge

Next, set up the PM200 power meter with the S155C fiber-coupled sensor to measure the output power in the fiber while the alignment of the system is fine tuned.

Click to Enlarge

First, use the tip/tilt controls on one of the folding mirrors to find a maximum signal level. Next, turn the vertical adjustment screw on that mirror mount a quarter-turn, and then use the other folding mirror to find the new maximum. If this power level is higher than the original maximum, then continue this process until an absolute maximum is reached. If the power level was lower than the original level, repeat the same process, but turn the adjustment screw on the first mirror mount in the opposite direction.

Repeat this process for the horizontal adjustment, and then iterate between horizontal and vertical adjustments until an absolute maximum power level is reached. As shown by the final power measurement to the right, in this setup, a maximum coupling efficiency of ~80% was reached.

Data Acquisition

Finally, plug the M42L01 patch cable into the OSA to acquire data.

Click to Enlarge

Data Acquisition with a Single Mode Fiber Patch Cable

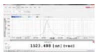
In some circumstances, using a single mode fiber patch cable may increase the accuracy of the OSA wavelength meter, due to reduced variations in the optical path length inside the fiber. The alignment procedure is similar with single mode fiber, except that single mode fiber is much more sensitive to errors in alignment. The system should be fully aligned using multimode fiber before switching to single mode fiber. Much smaller adjustments should be made with the folding mirror pair during single mode alignment, and a lower coupling efficiency should be expected.

Click to Enlarge

Here, a P1-SMF28E-FC-1 patch cable is being used to take data.

Results

Here is a screenshot of the OSA software taking data for this experiment. It shows the spectrum of the laser (top), as well as the OSA's wavelength meter.



Click to Enlarge

The 1523 nm HeNe laser line corresponds to the $2s^2 \rightarrow 2p^1$ transition in Ne I, which has an energy corresponding to a vacuum wavelength of 1523.48765 nm*. In this example, the OSA202 measured a center vacuum wavelength of 1523.488 nm, which is within the specified ±1.5 pm accuracy of the OSA wavelength meter.

* Information from the NIST Atomic Spectra Database.

Hide Software

SOFTWARE

Software for the Optical Spectrum Analyzer and CCD Spectrometers

Each Optical Spectrum Analyzer includes a Windows® laptop with our OSA software suite pre-installed. This software features an intuitive, responsive, flat interface that exposes all functions in 1 or 2 clicks. We regularly update this software to add significant new features and make improvements suggested by our users.

The software download page also offers programming reference notes for interfacing with our Optical Spectrum Analyzers using LabVIEW™, Visual C++, Visual C#, and Visual Basic. Please see the *Programming Reference* tab on the software download page for more information and download links.

This software package is also compatible with Thorlabs' Compact CCD Spectrometers.

Software

Version 2.70

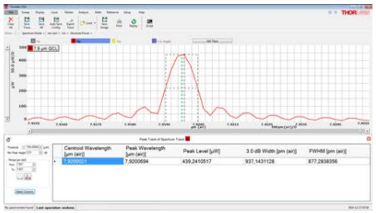
Includes a GUI for controlling the OSA, as well as a "virtual device" mode ideal for evaluating the software prior to purchase.

Software

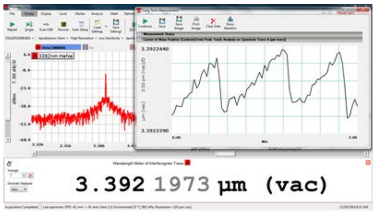
Software Highlights

The text below summarizes several key features of the OSA software suite. Complete details on the software are available from the manual (5 MB PDF).

Built-In Tools for Simple and Complex Analysis
The OSA software displays either the fast-Fourier-transformed spectrum or the raw interferogram obtained by the instrument. In the main window, it is possible to average multiple spectra; display the X axis in units of nm, cm^{-1}, THz, or eV; compare the live spectrum to previously saved traces; perform algebraic manipulations on data; and calculate common quantities such as transmittance and absorbance.


Click to Enlarge
Peak Track Mode Used with 7.9 µm Quantum Cascade Laser

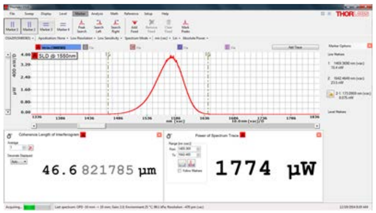
Robust graph manipulation tools include automatic and manual scaling of the displayed portion of the trace and markers for determining exact data values and visualizing data boundaries. Automated peak and valley tracking modules (see the screenshot to the right) identify up to 2048 peaks or valleys within a user-defined wavelength range and follow them over a long period of time. Statistical parameters of traces such as standard deviations, RMS values, and weighted averages are available, and a curve fit module fits polynomials, Gaussians, and Lorentzians to the spectrum or interferogram.



Click to Enlarge
Wavelength Meter Observes Mode Hopping of 3.392 µm HeNe

Acquired data can be saved as a spectrum file that can be loaded quickly into the main window. Data can also be exported into Matlab, Galactic SPC, CSV, and text formats.

Adjustable Sensitivity and Resolution Settings
The scan sensitivity and resolution can be adjusted by the user to balance the needs of the experiment against the data acquisition rate. These settings vary the number of data points per interferogram from 0.5 million to 16 million. The sensitivity setting modifies the range of detector gain levels, while the resolution setting controls the optical path difference (OPD). The table in the *Specs* tab shows how the data acquisition rate depends upon the chosen settings.



Click to Enlarge
Coherence Length and Power of 1550 nm Superluminescent Diode (SLD)

Wavelength Meter Module for Narrowband Sources
For sources with <10 GHz linewidth, the Wavelength Meter module enables extremely accurate determinations of the center wavelength (±1 ppm accuracy, 0.2 ppm precision, and 0.1 ppm resolution). This mode allows the system to resolve a fraction of a fringe in the interferogram, using the phase-locked loop that is generated by the internal stabilized reference HeNe laser (see Interferogram Data Acquisition in the *Design* tab for details). The uncertainty in the measurement is continuously determined and displayed as gray numbers.

As shown in the image to the right, a built-in module plots the output of the wavelength meter measurement as a function of time. If the software determines that the wavelength meter will give inaccurate results (as it would for broadband sources), it is automatically disabled.

Coherence Length Module for Broadband Sources
Because Thorlabs' OSAs obtain the raw interferogram of the unknown source (as opposed to grating-based spectrum analyzers, which cannot offer this capability), the software is able to calculate the coherence length of the input signal, as shown by the screenshot to the right. The Coherence Length module considers the envelope of the interferogram and reports the optical path length over which the envelope's amplitude decays to 1/*e* of its maximum value on both sides.

The ability to view the raw interferogram in real time allows the user to confirm the coherence length reported by the software and adjust the signal amplitude to avoid saturation. The maximum coherence length measurable by the OSA is limited by the maximum optical path difference of ±4 cm in high-resolution mode, making this module best suited for broadband sources.

Apodization and Interferogram Truncation

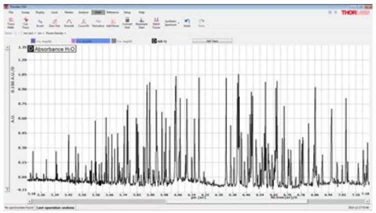
Since the resolution of any Fourier-transformed spectrum is intrinsically constrained by the finite path length over which the interferogram is measured, the software implements several functions to account for the effect of the finite path length on the spectrum that is obtained. The user may select from a number of apodization methods (dampening functions), including cosine, triangular, Blackman-Harris, Gaussian, Hamming, Hann, and Norton-Beer functions, and the effective optical path length can also be shortened to eliminate contributions from high-frequency spectral components.

Libraries for LabVIEW, C, C++, C#, and Java

Device interface libraries containing a multitude of routines for data acquisition, instrument control, and spectral processing and manipulation are also provided with the instrument. These libraries can be used to develop customized software using LabVIEW, C, C++, C#, Java, or other programming languages. We also provide a set of LabVIEW routines to assist with writing your own applications.

Spectroscopic Analysis from HITRAN Reference Database

In environmental sensing and telecom applications, it is often useful to identify atmospheric compounds (such as water vapor, carbon dioxide, and acetylene) whose absorption lines overlap with that of the unknown source being measured. Some example measurements are shown below. The OSA software includes built-in support for HITRAN line-by-line references, which can be used to calculate absorption cross sections as a function of vapor pressure and temperature. The predictions can be fit to the measured trace for comparison, and fits using mixtures of gases are supported. See the *Gas Spectroscopy* tab for an example setup.



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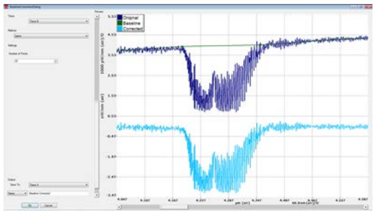
Experimentally Measured Water Absorbance in Mid-IR



Click to Enlarge

Carbon Dioxide (CO_2) Absorption Before and After Baseline Correction

Hide Pulsed Sources

PULSED SOURCES

Analyzing Pulsed Sources Using the OSA

Introduction and Summary of Results

While Thorlabs' Optical Spectrum Analyzers (OSAs) have been designed for analysis of CW signals, it is possible to measure pulsed spectra under certain situations. Measurement of pulsed spectra suffers from several issues that must be overcome for accurate measurements; for instance, "spectral ghosts" arise due to the pulsed nature of the source as well as the varying optical path difference (OPD) of the OSA. In addition, the noise floor for pulsed sources is much higher than that for CW sources. One method for measuring pulsed sources with the OSA involves taking several successive measurements at the four different sensitivity levels; the minimum at each wavelength of these four traces is used to form a combined spectrum, which suppresses the spectral ghosts. This technique is implemented in the OSA software by choosing "Pulsed" under the "Sweep" tab. The following tutorial explains the rationale of this technique and the pulsed sources for which it is useful.

In summary, for pulse rates over 30 kHz, standard mode can be used because the repetition rate is greater than the detectors' bandwidth. For broadband signals with low repetition rates, care must be taken to ensure that the "zero burst" of the interferogram coincides with one of the pulses. Also, when using a pulsed source "Automatic Gain" does not work properly, so the user must monitor the interferogram and manually set the gain so that a strong, but not saturated, signal is obtained.

Impact of a Pulsed Source on the Interferogram and Spectrum

As the Optical Path Difference (OPD) continuously changes during an interferogram measurement, a pulsed light source effectively modulates the interferogram. In the case of 100% modulation (i.e. on-off pulsation), the resulting interferogram will contain repetitive regions (slots) with no information. These slots correspond to OPDs when no light can be measured by the detector assembly. The resulting interferogram in this case is the true interferogram masked with the pulsed signal. Figure 1 shows measured interferograms and the corresponding spectra for a light source in CW and pulsed operation. Although the spectrum of the light source is expected to be the same for CW and pulsed operation (ignoring small changes in the peak shape and position due to, for example, a decreased LD chip temperature resulting from the pulsed drive), additional frequency artifacts appear symmetrically about the expected peak due to the modulation in the pulsed interferogram. These "spectral ghosts" are a result of the temporal, rather than the spectral, behavior of the source. To measure the true spectrum of the light source, it is crucial to make the spectral ghosts sufficiently small or force the spectral ghosts to fall outside the frequency / wavelength range of interest.

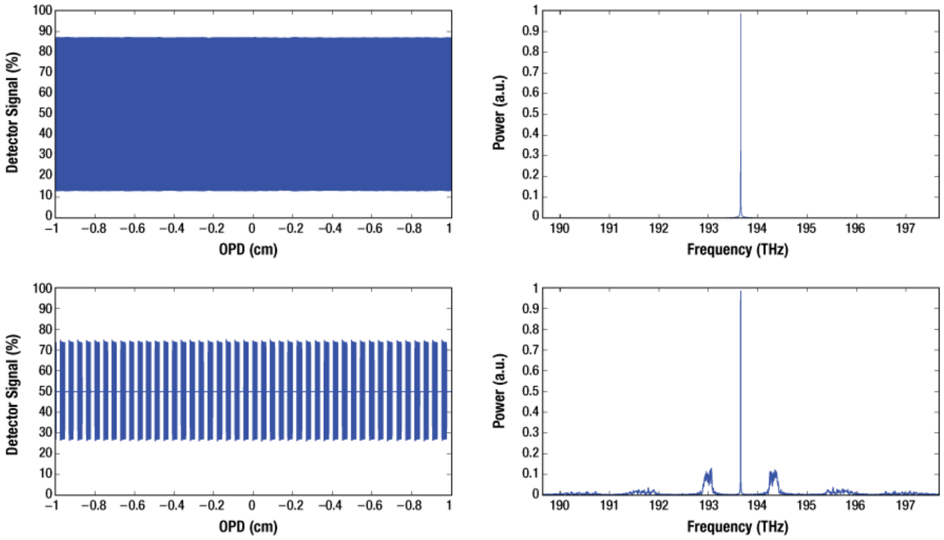
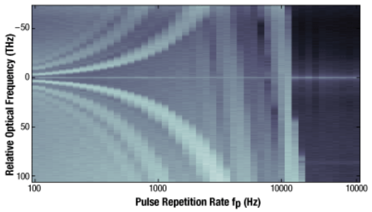


Figure 1: Measured interferograms and spectra for a narrowband light source in CW (Top) and pulsed at 20 kHz (Bottom) operation. The square wave modulation of the interferogram induces the spectral ghosts shown in the bottom left plot.

Mathematically, the resultant spectrum of a pulsed source can be described by a convolution between the spectrum of the light source and the spectrum corresponding to the pulses. As a result, the impact of these artifacts will vary with the pulse repetition rate and the modulation depth of the light source as well as the OPD sample rate (cm/s) of the OSA. The modulation depth of the light source determines the amplitude of the spectral ghosts; a weak modulation yields weak spectral ghosts while a modulation of 100% (on-off pulsation) yields the strongest spectral ghosts.



Click to Enlarge

Figure 2: Stacked spectra for 55 pulse repetition rates between 100 Hz and 100 kHz for a 1550 nm DFB laser diode. The intensity is mapped in a logarithmic scale. OSA settings: High Resolution, High Sensitivity, No Apodization, 5 averages.

Figure 2 shows how the behavior of the spectral ghosts as a function of the pulse repetition rate for a narrowband source. In the figure, the spectra were measured for 55 pulse repetition rates between 100 Hz and 100 kHz for a 1550 nm DFB laser diode. We have offset the y-axis such that the true peak (the light gray horizontal line) has been centered at a relative frequency of 0 THz. The figure can be divided into three regions: $f_p \leq 3$ kHz, 3 kHz < $f_p \leq 30$ kHz and f_p >30 kHz. For $f_p \leq 3$ kHz, the spectral ghosts are clearly observed symmetrically about the true peak within the resultant spectrum, and move farther and farther away from the true peak as the repetition rate increases. The second region starts above 3 kHz, when the first spectral ghosts have moved beyond the spectral range of the OSA. However, aliasing / folding create higher order spectral ghosts that appear within the spectral range of the OSA. In the third region, f_p > 30 kHz, the resulting spectrum agrees very well with the CW spectrum because the repetition rate of the source has extended beyond the bandwidth limit of the detectors. As a result, the pulsed source appears like a CW source to the OSA electronics.

"Pulsed Mode" Operation

To help remove some of these frequency artifacts, the OSA software contains a "Pulsed Mode" measurement (Figure 3). The "slot period" of the interferogram, determined by the pulse repetition rate of the light source and the OPD rate of the OSA, affects the positions of the spectral ghosts. A shorter slot period yields a larger spectral distance between the true peak and the first order ghost peaks. In Thorlabs' OSAs, the OPD sample rate is given by the speed of the moving carriage which can be controlled by the user indirectly through the sensitivity setting. The higher the sensitivity setting is, the speed of the moving carriage will be slower. Thus, the use of the "High" sensitivity mode of the OSA will provide the shortest slot period (i.e. the largest spacing between the feature of interest and the frequency artifacts). In pulsed mode, the software acquires four spectra with different sensitivity settings (or OPD sample rates) and filters out the changing spectral features. The sensitivity is first set to low, followed by Medium-Low, Medium-High, and High before it again is set to Low yielding a periodically changing sensitivity. The captured spectra are then combined using the minimum hold function. The spectral ghosts (Figure 4), whose positions depend on the sensitivity setting (the OPD rate), can then be reduced in the measurement as shown in Figure 4. It is important to note that the Pulse Mode button is found under the "Sweep" menu and can be started only after the current sweep has been completely stopped.

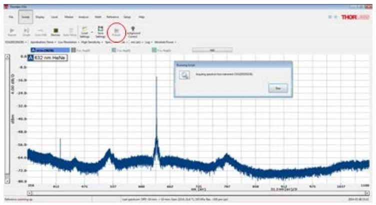


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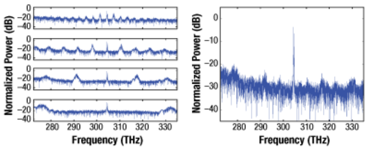
Figure 3: Screenshot of the OSA software in the Pulsed Mode; the icon is indicated with a red circle.



Click to Enlarge

Figure 4: (Left) Measured Spectra for a narrowband light source pulsed at 1 kHz with (from top to bottom) Low, Medium-Low, Medium-High, and High sensitivity settings (i.e. a decreasing OPD sample rate from top to bottom). (Right) Measured spectrum using the Pulsed Mode, i.e., a minimum hold combination of spectra similar to those shown in the bottom left plots.

Narrowband Light Source

A DFB laser diode emitting at 1550 nm (193.7 THz) was used as a narrowband light source and measured with an OSA203 in both CW and pulsed operation. The laser diode was modulated (using Thorlabs' ITC4001) with repetition rates between f_p = 20 Hz and 100 kHz. Five averaged spectra were captured for each light source setting; the CW spectra were acquired in high sensitivity mode, and the pulsed spectra were recorded in both high sensitivity and pulsed mode. It is important to note that the pulsed mode does not allow averaging. Instead the minimum hold function was used for 5 sets of spectra from the four different sensitivity settings.

Figure 5 shows the resultant spectra for the source in CW mode as well as four different pulse repetition rates between 100 Hz and 100 kHz. As the pulse rate increases, the spectral ghosts (as recorded in the high sensitivity mode) move further and further away from the true laser peak until nearly identical spectra are obtained at 100 kHz.

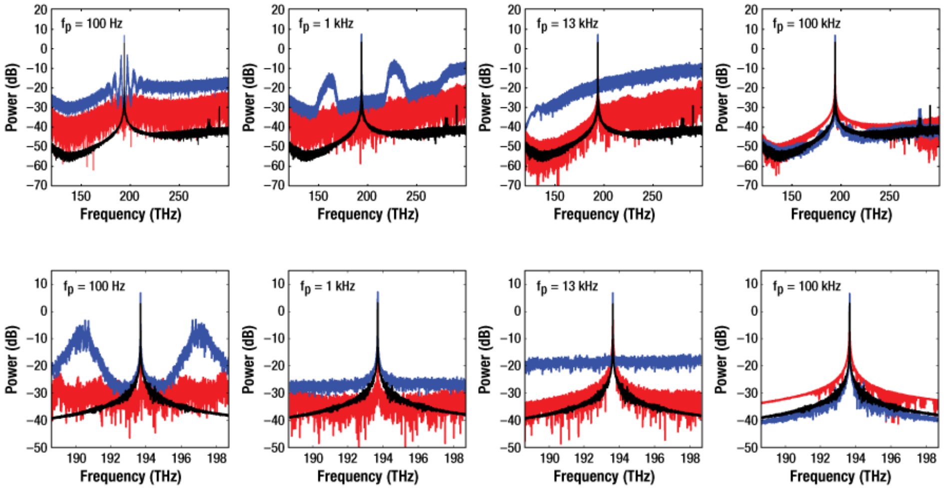


Figure 5: Spectra from measurements of a 1550 nm (193.7 THz) pulsed narrowband source. Pulse repetition rates shown (left to right): 100 Hz, 1 kHz, 13 kHz, and 100 kHz. Black line: CW measurement, blue line: pulsed source measured with high sensitivity, red line: pulsed source measured using the pulsed mode. The lower plots are the same data set as the upper plots only on a shorter frequency scale.

Broadband Light Source

A gain chip was driven in amplified spontaneous emission (ASE) mode to create a broadband light source centered at 850 nm (352.9 THz) with a FWHM of 36.4 nm (15.2 THz). An OSA201 was used to measure the spectrum for CW and pulsed operation with pulse repetition rates from f_p = 100 Hz to 100 kHz. The ASE diode was modulated (using Thorlabs' ITC4001) with a 50% duty cycle square wave. A total of 10 averaged spectra were acquired using high sensitivity (CW and pulsed sources) and the pulsed mode (pulsed source). Because pulsed mode does not allow averaging, the minimum hold function was used to acquire five sets of the four different sensitivity settings.

In general, the spectral ghosts are less visible for the broadband peak compared to a narrowband peak. However, the noise floor is higher and the spectral ghosts are clearly seen for a repetition rate of 1 kHz and 13 kHz in Figure 6. Similar to the narrowband source, the spectral ghosts move farther and farther away from the true peak with increasing repetition rate. For a repetition rate of 100 kHz both the measurement using high sensitivity and pulsed mode agree well with the CW measurement. As seen, the shape of the peak is slightly different for the CW spectrum compared to the pulsed spectrum. This is not related to the behavior of the OSA but due to a true change in the peak during pulsed operation, e.g., a lower chip temperature.

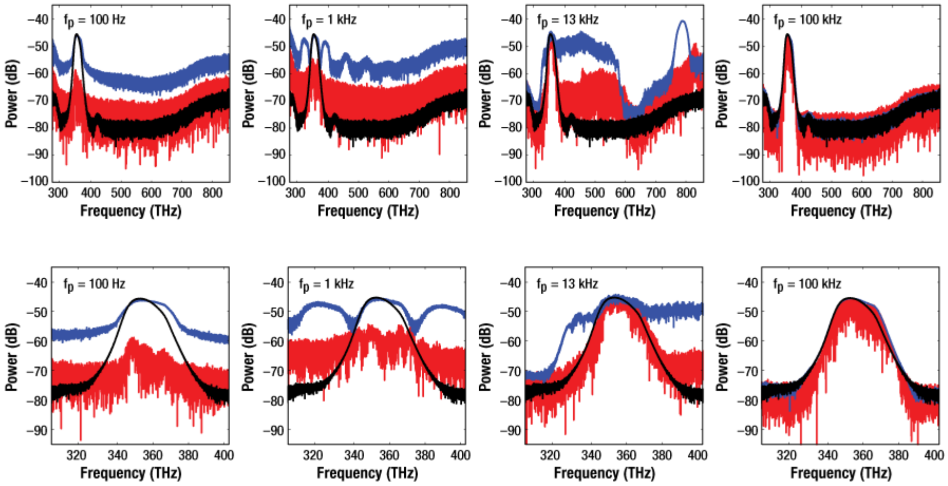


Figure 6: Measured spectra from a pulsed broadband source with a center wavelength (frequency) of 850 nm (352.9 THz). The pulse repetition rates shown are 100 Hz, 1 kHz, 13 kHz, and 100 kHz. Top and bottom rows show the full spectrum and the ±50 THz range surrounding the peak, respectively. Black Line: CW; Blue Line: Pulsed source measured using high sensitivity; Red Line: Pulsed Mode.

It is extremely important to note that in general, one has to be careful when measuring broadband peaks at low repetition rates. Since most of the information in the interferogram is located about the zero burst, the peak can be completely missed if the zero burst coincides with no light falling on the detector as shown in Figure 7.

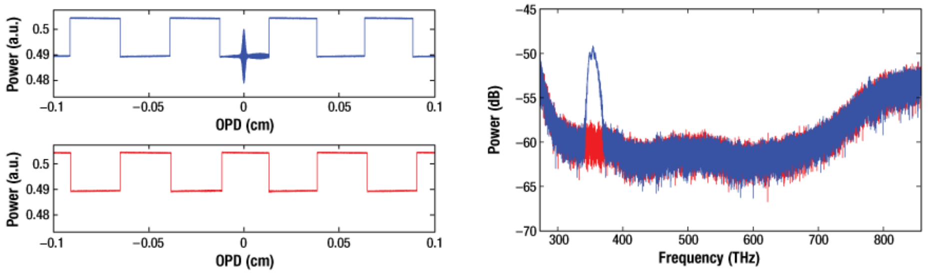


Figure 7: Measured interferograms (left) and spectra (right) obtained when the zero burst resulting from a broadband source coincides with a pulse (blue curves) and is missed if no light reaches the detector at OBD ~ 0 (red curves).

Femtosecond Pulsed Laser

We measured the spectrum of a broadband femtosecond laser (Thorlabs' OCTAVIUS-85M-HP) using an OSA201. This laser has a repetition rate of 85 MHz, a pulse width of 10 fs, and an average power of about 300 μW into the fiber. The OSA was set to Low Resolution, High Sensitivity, 5 spectral averages, and no apodization. Light output from the laser was collected with an SM600 (0.12 NA, 4.6 µm mode field diameter at 680 nm) patch cable connected to the OSA.

Figure 8 shows the interferogram collected during acquisition, which does not contain any empty slots. This was expected as the 85 MHz repetition rate of the laser is well beyond the 40 kHz bandwidth of the OSA's detectors. Furthermore, the spectrum measured by the OSA agrees very well with the reference spectrum captured using a grating-based OSA that is scanned slowly enough to provide adequate signal for each wavelength measured.

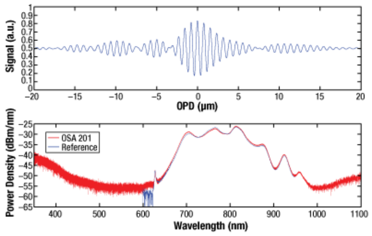


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Figure 8: (Top) Central portion of a captured interferogram from a broadband femtosecond laser. (Bottom) Measured spectrum captured using an OSA201 (red line) and a measured reference spectrum captured using a scanning grating-based OSA (blue line).

Hide Gas Spectroscopy

GAS SPECTROSCOPY

Gas Detection and Identification Using an Optical Spectrum Analyzer

Click to Enlarge
Hose Connections for Purging OSA Cavity

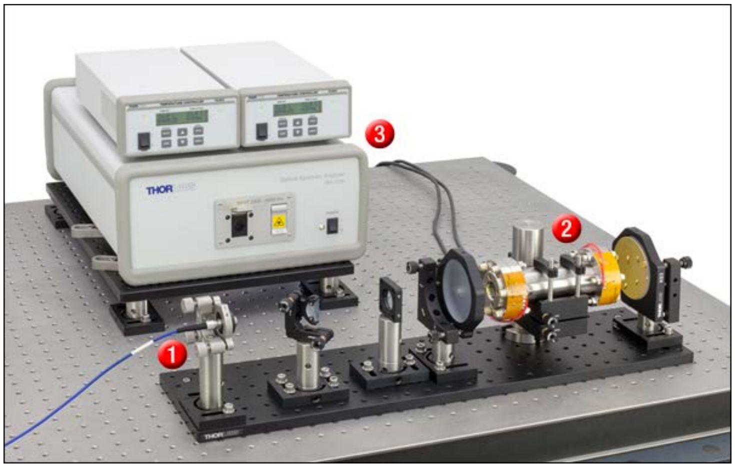
As shown in the table to the right, many of Thorlabs' Optical Spectrum Analyzers (OSAs) offer detection extending into the mid-infrared (MIR) region of the spectrum, where many gaseous species characteristically absorb. Moreover, the software included with all OSA models supports files from the HITRAN database, a spectroscopic reference standard. These files can be fit to measured traces to identify unknown gases. With the ability to fit multiple analytes simultaneously and built-in hose connections (compatible with Thorlabs' Pure Air Circulator Unit) for purging the interferometer's cavity of trace gases, these OSAs are ideal for use in home-built gas detection setups.

Item #	Frequency Range	Level Sensitivity (Click for Graph)[a]
OSA207	833 - 10 000 cm^{-1} (12.0 - 1.0 µm)	Absolute Power Power Density
OSA206	1250 - 3030 cm^{-1} (8.0 - 3.3 µm)	
OSA205	1786 - 10 000 cm^{-1} (5.6 - 1.0 µm)	
OSA203B	3846 - 10 000 cm^{-1} (2.6 - 1.0 µm)	

- Lower values of Level Sensitivity correspond to improved detection sensitivity. We therefore recommend selecting the OSA which provides the lowest level sensitivity for the analytes you intend to study.

Experimental Setup

A sample detection setup is shown below. Broadband MIR light generated by a Stabilized Light Source is emitted from a zirconium fluoride fiber (①), collimated, then sent into a multipass cell (②) containing the gas analyte in a sample chamber. Each end of the chamber is sealed by an airtight, transparent window. Gold mirrors on each side of the chamber provide multiple reflections that increase the sensitivity of the measurement; the mirror closer to the light source has a center hole to allow the optical path to enter and exit the chamber. Light exiting the detection setup is collimated by a long-focal-length lens and reflected by a D-shaped mirror into the free-space port of the OSA203B (③). The temperature inside the chamber is elevated and held constant in order to prevent the gas's absorption lines from shifting during the measurement.



Click to Enlarge

A gas detection setup using the OSA203B. A multipass cell is constructed around the sample chamber (②) in order to provide high detection sensitivity for the gaseous species sealed inside.

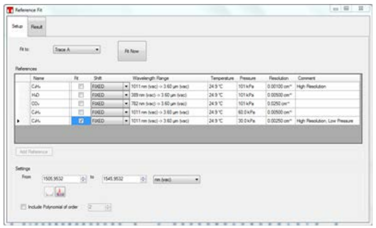
Parts Used in Sample Setup (Click Here for a Metric Item List)		
Item #	**Qty.**	**Description**
Light Source ①		
SLS202L	1	Stabilized Fiber-Coupled Light Source, 450 nm - 5.5 µm (Not Shown)
FB2000-500	1	Ø1" Bandpass Filter, 2.0 µm CWL, 0.5 µm FWHM (Not Shown)
MZ21L1	1	ZrF_4 Multimode Fiber Patch Cable, SMA905 Connectors
F021SMA-2000	1	SMA905 Fiber Collimator, AR Coated: 1.8 - 3.0 µm
POLARIS-K1	1	Polaris™ Ø1" Kinematic Mirror Mount
AD11NT	1	Unthreaded Adapter for Ø11 mm Cylindrical Components
Detection ③		
OSA203B	1	Optical Spectrum Analyzer, 1.0 - 2.6 µm
TC200	2	Temperature Controller
MB1218	1	12" x 18" Aluminum Breadboard
CF125C	3	Clamping Fork with Captive Screw
Other Optomechanics		
RS2	6	Ø1" Pillar Post, Length = 2"
RS3	1	Ø1" Pillar Post, Length = 3"
RS4	2	Ø1" Pillar Post, Length = 4"
BA2F	9	Flexure Clamping Base

Parts Used in Sample Setup (Continued) (Click Here for a Metric Item List)		
Item #	**Qty.**	**Description**
Beam Path Into and Out of Multipass Cell ②		
LB4374	1	Uncoated, Ø1", f = 1000 mm Bi-Convex UV Fused Silica Lens
CP02	1	Post-Mountable, SM1-Threaded Cage Plate for Ø1" Optics
CM750-200-M01	2	Ø75 mm, f = 200 mm Protected Gold Concave Mirror (One Mirror Contains a Center Hole, Similar to Our Herriott Cell Mirrors)
KS3	2	Kinematic Mount for Ø3" Mirrors
VPCH512	2	Ø2.75" ConFlat Flange with CaF_2 Window, 180 nm - 8.0 µm
N/A	1	Sample Chamber
C1513	1	Kinematic V-Clamp Mount
PM4	2	Clamping Arm (One Clamping Arm is Included with Each C1513 Mount)
P6	1	Ø1.5" Mounting Post, Length = 6"
PB2	1	Base for Ø1.5" Mounting Posts
PFD10-03-M01	1	1" Protected Gold D-Shaped Pickoff Mirror
KM100D	1	Kinematic Mount for 1" D-Shaped Pickoff Mirrors
MB624	1	6" x 24" Aluminum Breadboard

Assigning Peaks in an Unknown Spectrum

Once the experimental spectrum is obtained, the user chooses a gas or gas mixture that is believed to be present inside the sample chamber, as shown in the figure below to the left. There is no limit to how many species can be considered in the fit, but the fit is more likely to converge when fewer species are chosen. The OSA software ships with HITRAN line-by-line references for acetylene (C_2H_2), water vapor (H_2O), and carbon dioxide (CO_2), and can import additional references downloaded from the HITRAN database. Previously saved spectra in the OSA file format can also be used as references. See the References section of the OSA manual for details.

The user may optionally allow the software to shift the reference spectrum in wavelength in order to account for measurement effects related to the sample environment. In the case of gas mixtures (i.e., fits performed using more than one reference spectrum), the software scales the intensity of each reference as needed to reproduce the measured spectrum. As shown in the figure below to the right, the output of the fit operation is a graph comparing the measured spectrum, each scaled (and possibly also shifted) reference spectrum, and the sum of the scaled reference spectra.



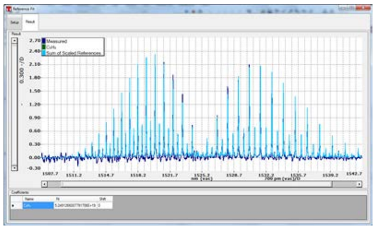
	Name	Fit	Shift	Wavelength Range	Temperature	Pressure	Resolution	Comment
	C_2H_2	☐	FIXED	1011 nm (vac) -> 3.60 µm (vac)	24.9 °C	101 kPa	0.00100 cm⁻¹	High Resolution
	H_2O	☐	FIXED	389 nm (vac) -> 3.60 µm (vac)	24.9 °C	101 kPa	0.00500 cm⁻¹	
	CO_2	☐	FIXED	782 nm (vac) -> 3.60 µm (vac)	24.9 °C	101 kPa	0.0250 cm⁻¹	
	C_2H_2	☐	FIXED	1011 nm (vac) -> 3.60 µm (vac)	24.9 °C	60.0 kPa	0.00500 cm⁻¹	
▸	C_2H_2	☑	FIXED	1011 nm (vac) -> 3.60 µm (vac)	24.9 °C	30.0 kPa	0.00250 cm⁻¹	High Resolution, Low Pressure

From 1505.9532 to 1545.9532 nm (vac)

☐ Include Polynomial of order 2

Click to Enlarge

In the Reference Fit Setup tab, checkboxes are used to indicate which gaseous species to consider in the fit. The absorption lines can be either "fixed" or "free"; the latter allows the software to shift the reference spectrum in wavelength. The measurement conditions for the HITRAN references are also displayed.



Click to Enlarge

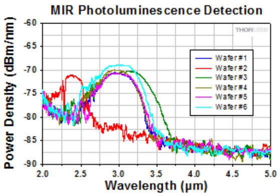
In the Reference Fit Result tab, the fitted spectrum is displayed simultaneously with the measured spectrum. The fitted spectrum is the sum of the scaled reference spectra included in the fit. The scaled spectrum for each individual gaseous species is also shown.

[Hide Custom OSAs](#)

CUSTOM OSAS

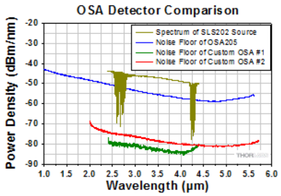
Custom OSA Options

- Optical Input
    - FC/PC, FC/APC, or SMA905 Fiber Receptacles
    - Free-Space Input for Collimated Beams
    - Permanently Installed Optical Bandpass and Notch Filters Before Interferometer
- Application-Optimized Detectors
    - High Sensitivity for Low-Level Signal Detection, Such as in Fluorescence or Raman Measurements
    - Wavelength Range and Noise Floor Chosen to Match a Specific Light Source
- Custom Software Modules for Data Analysis



Click to Enlarge

A user requested an OSA capable of detecting photoluminescence from wafers that emit in the 2 - 4 µm spectral range. We provided a custom-built OSA with a greatly reduced noise floor as compared to the OSA205, which easily detected the predicted signal.



Click to Enlarge

At typical humidities, water absorption peaks in the spectrum of Thorlabs' SLS202 light source drop well below the noise floor of the OSA205. For MIR applications that require such peaks to be resolved, we have qualified two MCT (HgCdTe) detector elements which achieve significantly lower noise floors, in exchange for a narrower wavelength range and lower maximum input power.

Thorlabs' in-stock OSA models offer a number of detection options for various experimental situations. For customers whose needs are not addressed by these models, we invite you to work with our engineering and manufacturing team to tailor an OSA to your specific application.

In the past, we have built OSAs with user-specified optical inputs, such as FC/APC fiber receptacles, SMA905 fiber receptacles, and free-space ports, and we have incorporated optical bandpass and notch filters directly into the optical path to reduce light source noise. For customers who use these instruments for sample characterization, our software team has implemented user-designed data analysis modules within the standard OSA software suite.

We have also worked with our customers to choose detector elements targeted at specific light sources and analytes. The graphs to the right were obtained from custom-built OSAs that were designed for especially high detection sensitivity. Our engineers are well-versed in the tradeoffs between detection bandwidth, sensitivity, and linearity, and can make recommendations based upon the needs of the application and prior customers' experiences. By constraining the OSA's design for a particular use case, additional performance enhancements for that application can be realized.

If you would like to discuss a custom OSA, please contact us with your experimental requirements.

[Hide Optical Spectrum Analyzer for 350 - 1100 nm](#)

Optical Spectrum Analyzer for 350 - 1100 nm

- 350 - 1100 nm Wavelength Range Ideal for Visible and NIR Detection
- FC/PC Fiber-Coupled Input
- Noise Floor: -60 dBm/nm (Power Density Mode; See *Design* Tab for Details)
- Includes Windows® Laptop with Thorlabs' OSA Software Pre-Installed
- Demo Units Available by Contacting Tech Support

Click to Enlarge
FC/PC Optical Fiber Input

Optimized for use in the 350 - 1100 nm spectral range, the OSA201 measures the optical power of both narrowband and broadband sources as a function of wavelength. This spectral range is frequently used for absorption spectroscopy, material identification, and quality control. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, as explained in the *Design* tab, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.

Fiber-Coupled Input
The OSA201's input port is compatible with single mode and step-index multimode FC/PC patch cables with cores up to Ø50 µm. Custom designs with other fiber input receptacles are available upon request; please contact Tech Support for details. For the highest contrast, single mode patch cables are recommended. To adapt a free-space input to the OSA201, please consider the procedures illustrated in the *Free-Space Coupling* tab above.

Part Number	Description	Price	Availability
OSA201	**Fourier Transform Optical Spectrum Analyzer, 350 - 1100 nm**	**$24,250.00**	**Today**

Hide Optical Spectrum Analyzer for 600 - 1700 nm

Optical Spectrum Analyzer for 600 - 1700 nm

- 600 - 1700 nm Wavelength Range Ideal for C-Band and L-Band Windows
- FC/PC Fiber-Coupled Input
- Noise Floor: -70 dBm/nm (Power Density Mode; See *Design* Tab for Details)
- Includes Windows® Laptop with Thorlabs' OSA Software Pre-Installed
- Demo Units Available by Contacting Tech Support


Click to Enlarge
FC/PC Optical Fiber Input

Optimized for use in the 600 - 1700 nm spectral range, the OSA202 measures the optical power of both narrowband and broadband sources as a function of wavelength. This spectral range includes the C-band (1530 - 1565 nm), L-band (1565 - 1625 nm), and other important telecom transmission windows. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, as explained in the *Design* tab, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.

Fiber-Coupled Input
The OSA202's input port is compatible with single mode and step-index multimode FC/PC patch cables with cores up to Ø50 µm. Custom designs with other fiber input receptacles are available upon request; please contact Tech Support for details. For the highest contrast, single mode patch cables are recommended. To adapt a free-space input to the OSA202, please consider the procedures illustrated in the *Free-Space Coupling* tab above.

Part Number	Description	Price	Availability
OSA202	**Fourier Transform Optical Spectrum Analyzer, 600 - 1700 nm**	**$24,250.00**	**Lead Time**

Hide Optical Spectrum Analyzer for 1.0 - 2.6 µm

Optical Spectrum Analyzer for 1.0 - 2.6 µm

- Wavelength Range Ideal for Molecular Absorption Bands and Telecom Windows:
  - 1.0 - 2.5 µm (10 000 - 4000 cm^{-1}) in Low-Temperature Mode
  - 1.0 - 2.6 µm (10 000 - 3846 cm^{-1}) in High-Temperature Mode
- Two Optical Input Ports:
  - FC/PC Fiber-Coupled Input
  - Free-Space Input with Red Alignment Beam and 4-40 Taps for 30 mm Cage Compatibility
- TEC-Cooled Detector for Reduced Noise and Enhanced Level Sensitivity
- Noise Floor (Power Density Mode; See *Design* Tab for Details):
  - -70 dBm/nm in Low-Temperature Mode
  - -65 dBm/nm in High-Temperature Mode
- Includes Windows® Laptop with Thorlabs' OSA Software Pre-Installed
- Built-In Hose Connections for Optional Purging
- Demo Units Available by Contacting Tech Support


Click to Enlarge
Free-Space Optical Input Behind Door


Click to Enlarge
FC/PC Optical Fiber Input Behind Door


Click for Details
Cage-Mounted Turning Mirror Mounted on the Free-Space Input


Click to Enlarge
Rear-Mounted Hose Connections Around Power Connector

Optimized for use in the 1.0 - 2.6 µm spectral range, the OSA203B measures the optical power of both narrowband and broadband sources as a function of wavelength. This spectral range includes molecular absorption bands for carbon monoxide, ammonia, and other compounds, as well as important telecom transmission windows. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, as explained in the *Design* tab, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.

Cooled Detector with Temperature Control
The OSA203B has a thermoelectrically cooled (TEC) detector for reduced noise compared to our other OSA models. The detector's temperature can be toggled between low-temperature and high-temperature (room-temperature) modes. In low-temperature mode, this optical spectrum analyzer achieves a very low noise floor of -70 dBm/nm, with a wavelength range of 1.0 - 2.5 µm. In high-temperature mode, the sensitivity is -65 dBm/nm and the wavelength range is extended to 2.6 µm.

Fiber-Coupled and Free-Space Inputs
The OSA203B directly accepts fiber-coupled or free-space optical inputs. The fiber-coupled input is compatible with single mode and step-index multimode FC/PC patch cables. For multimode patch cables made from standard silica glass, cores up to Ø50 µm are recommended; for multimode patch cables made from fluoride glass, cores up to Ø100 µm are recommended. Single mode patch cables provide the highest contrast. The free-space input (illustrated at 2:54 in the video above) accepts collimated input beams and has a Ø6 mm maximum beam size. When the free-space door is open, a red alignment beam is emitted that should be made collinear and antiparallel to the unknown input. Four 4-40 taps around the free-space input provide compatibility with our 30 mm cage systems; use cage rods no shorter than 1.5" to prevent attached cage components from clashing with the door.

If your application would benefit from detection extending out to 5.6 µm (1786 cm^{-1}) or 12.0 µm (833 cm^{-1}), please consider the OSA205 or OSA207 sold below.

Part Number	Description	Price	Availability
OSA203B	Fourier Transform Optical Spectrum Analyzer, 1.0 - 2.6 µm	$26,550.00	Today

Hide Optical Spectrum Analyzer for 1.0 - 5.6 µm

Optical Spectrum Analyzer for 1.0 - 5.6 µm

- 1.0 - 5.6 µm (10 000 - 1786 cm^{-1}) Wavelength Range Ideal for Fluoride Fiber Patch Cables
- Two Optical Input Ports:
  - FC/PC Fiber-Coupled Input
  - Free-Space Input with Red Alignment Beam and 4-40 Taps for 30 mm Cage Compatibility
- Noise Floor: -40 dBm/nm (Power Density Mode; See *Design* Tab for Details)
- Includes Windows® Laptop with Thorlabs' OSA Software Pre-Installed
- Built-In Hose Connections for Optional Purging
- Demo Units Available by Contacting Tech Support


Click to Enlarge
Free-Space Optical Input Behind Door


Click to Enlarge
FC/PC Optical Fiber Input Behind Door


Click to Enlarge
Cage-Mounted Polarizers in Front of Free-Space Input


Click to Enlarge
Rear-Mounted Hose Connections Around Power Connector

Optimized for use in the 1.0 - 5.6 µm spectral range, the OSA205 measures the optical power of both narrowband and broadband sources as a function of wavelength. This OSA is compatible with many of Thorlabs' quantum cascade and interband cascade lasers, as well as single mode and multimode fluoride patch cables with cores up to Ø100 µm. Moreover, its broad wavelength range overlaps with that of many FTIR spectrometers. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, as explained in the *Design* tab, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.

Fiber-Coupled and Free-Space Inputs
The OSA205 directly accepts fiber-coupled or free-space optical inputs. The fiber-coupled input is compatible with single mode and step-index multimode FC/PC patch cables. For multimode patch cables made from standard silica glass, cores up to Ø50 µm are recommended; for multimode patch cables made from fluoride glass, cores up to Ø100 µm are recommended. Single mode patch cables provide the highest contrast. The free-space input (illustrated at 2:54 in the video above) accepts collimated input beams and has a Ø6 mm maximum beam size. When the free-space door is open, a red alignment beam is emitted that should be made collinear and antiparallel to the unknown input. Four 4-40 taps around the free-space input provide compatibility with our 30 mm cage systems; use cage rods no shorter than 1.5" to prevent attached cage components from clashing with the door.

If your application does not require detection in the 2.5 - 5.6 µm range (4000 - 1786 cm^{-1}), please consider the OSA203B, sold above, which features a lower minimum detectable power.

Part Number	Description	Price	Availability
OSA205	Fourier Transform Optical Spectrum Analyzer, 1.0 - 5.6 µm	$28,750.00	Today

Hide Optical Spectrum Analyzer for 3.3 - 8.0 µm

Optical Spectrum Analyzer for 3.3 - 8.0 µm

- 3.3 - 8.0 µm (3030 - 1250 cm^{-1}) Wavelength Range Ideal for IR Spectroscopy and Many QCLs
- Two Optical Input Ports:
  - FC/PC Fiber-Coupled Input
  - Free-Space Input with Red Alignment Beam and 4-40 Taps for 30 mm Cage Compatibility
- Noise Floor: -45 dBm/nm (Power Density Mode; See *Design* Tab for Details)
- Includes Windows® Laptop with Thorlabs' OSA Software Pre-


Click to Enlarge
Free-Space Optical Input Behind Door


Click to Enlarge
FC/PC Optical Fiber Input Behind Door

Installed
- Built-In Hose Connections for Optional Purging
- Demo Units Available by Contacting Tech Support


Click to Enlarge
Cage-Mounted Polarizers in Front of Free-Space Input


Click to Enlarge
Rear-Mounted Hose Connections Around Power Connector

Optimized for use in the 3.3 - 8.0 µm spectral range, the OSA206 measures the optical power of both narrowband and broadband sources as a function of wavelength. This OSA is compatible with the majority of our quantum cascade and interband cascade lasers, as well as single mode and multimode fluoride patch cables with cores up to Ø100 µm. Moreover, its broad wavelength range overlaps with that of many FTIR spectrometers, extending into the fingerprint region of the spectrum. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, as explained in the *Design* tab, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.

Fiber-Coupled and Free-Space Inputs
The OSA206 directly accepts fiber-coupled or free-space optical inputs. The fiber-coupled input is compatible with single mode and step-index multimode FC/PC fluoride patch cables with cores up to Ø100 µm. Single mode patch cables provide the highest contrast. The free-space input (illustrated at 2:54 in the video above) accepts collimated input beams and has a Ø6 mm maximum beam size. When the free-space door is open, a red alignment beam is emitted that should be made collinear and antiparallel to the unknown input. Four 4-40 taps around the free-space input provide compatibility with our 30 mm cage systems; use cage rods no shorter than 1.5" to prevent attached cage components from clashing with the door.

If your application would benefit from a wider wavelength range and does not use broadband light sources, please consider the OSA207 sold above.

Part Number	Description	Price	Availability
OSA206	**Fourier Transform Optical Spectrum Analyzer, 3.3 - 8.0 µm**	**$29,800.00**	**Lead Time**

Hide Optical Spectrum Analyzer for 1.0 - 12.0 µm

Optical Spectrum Analyzer for 1.0 - 12.0 µm

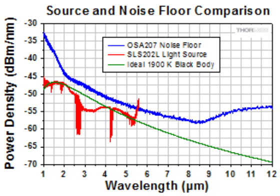
- 1.0 - 12.0 µm (10 000 - 833 cm^{-1}) Wavelength Range Ideal for Quantum Cascade Lasers (QCLs)
- Two Optical Input Ports:
  - FC/PC Fiber-Coupled Input
  - Free-Space Input with Red Alignment Beam and 4-40 Taps for 30 mm Cage Compatibility
- Noise Floor (Power Density Mode; See *Design* Tab for Details):
  - -30 dBm/nm for 1.0 - 2.0 µm
  - -40 dBm/nm for 2.0 - 12.0 µm
- Includes Windows® Laptop with Thorlabs' OSA Software Pre-Installed
- Built-In Hose Connections for Optional Purging
- Demo Units Available by Contacting Tech Support


Click to Enlarge
Free-Space Optical Input Behind Door


Click to Enlarge
FC/PC Optical Fiber Input Behind Door


Click for Details
Ø1/2" Off-Axis Parabolic Mirror in CRM1P Rotation Mount in Front of Free-Space Input


Click to Enlarge
Rear-Mounted Hose Connections Around Power Connector



Click to Enlarge
The OSA207's noise floor is too high to detect broadband light sources like Thorlabs' SLS202L (which was measured here with an OSA205). We therefore primarily recommend the OSA207 for narrowband light sources.

Optimized for use in the 1.0 - 12.0 µm spectral range, the OSA207 measures optical power as a function of wavelength. This OSA is compatible with all of Thorlabs' quantum cascade and interband cascade lasers, as well as single mode and multimode fluoride patch cables with cores up to Ø100 µm. Moreover, its broad wavelength range overlaps with that of many FTIR spectrometers, extending into the fingerprint region of the spectrum. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, as explained in the *Design* tab, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.

Designed for Narrowband Sources
Due to its broad wavelength responsivity, the OSA207's noise floor is higher than that of our other OSAs, which achieve lower noise floors at the expense of having narrower wavelength ranges. Please see the *Specs* tab for comparison graphs. This OSA will easily detect lasers and other narrowband sources, but many broadband sources will not have sufficient power spectral density to be detected. Therefore, we recommend using Thorlabs' other OSAs if compatibility with broadband sources is required. The plot to the left compares the OSA207's noise floor in Power Density mode to an ideal 1900 K black body and Thorlabs' SLS202L Stabilized Broadband Light Source.

Fiber-Coupled and Free-Space Inputs
The OSA207 directly accepts fiber-coupled or free-space optical inputs. The fiber-coupled input is compatible with single mode and step-index multimode FC/PC fluoride patch cables with cores up to Ø100 µm. Single mode patch cables provide the highest contrast. The free-space input (illustrated at 2:54 in the video above) accepts collimated input beams and has a Ø6 mm maximum beam size. When the free-space door is open, a red alignment beam is emitted that should be made collinear and antiparallel to the unknown input. Four 4-40 taps around the free-space input provide compatibility with our 30 mm cage systems; use cage rods no shorter than 1.5" to prevent attached cage components from clashing with the door.

Part Number	Description	Price	Availability
OSA207	**Fourier Transform Optical Spectrum Analyzer, 1.0 - 12.0 µm**	**$33,000.00**	**Lead Time**

Visit the *Optical Spectrum Analyzers* page for pricing and availability information:
https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=5276