

# Optical Spectrum Analyzers



## Broadband Spectrometer and Wavelength Meter in One

Thorlabs' Optical Spectrum Analyzers obtain highly accurate measurements of the spectra of unknown light sources. They are continuously self-calibrated using a built-in, stabilized reference HeNe laser and internal temperature and pressure sensors, ensuring repeatable, reliable results across time and differing lab environments.

### Features

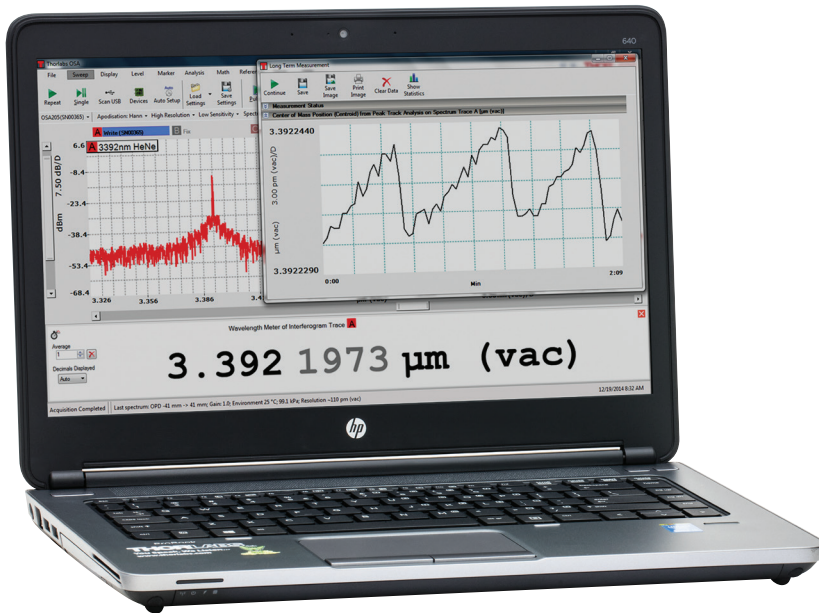
- ◆ Five Models Spanning Wavelengths from 350 nm to 12.0 μm
- ◆ 7.5 GHz (0.25 cm<sup>-1</sup>) Resolution in Spectrometer Mode
- ◆ 0.1 ppm Resolution in Wavelength Meter Mode
- ◆ Includes Laptop with Full Data Acquisition and Analysis Suite

**THORLABS**

# Visible, NIR, and MIR Spectral Analysis

The OSA product family consists of five models, each of which is designed to measure a different spectral range between 350 nm and 12.0  $\mu\text{m}$ . These optical spectrum analyzers are suitable for a wide range of applications, including 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.

The spectral ranges supported by the OSA product family include the majority of Thorlabs' light sources, including quantum cascade lasers, blackbody sources, and tunable external cavity lasers. These broad ranges make it possible to measure absorption signatures in the visible, NIR, C-band, L-band, and other transmission windows. Users can also measure molecular absorption lines for carbon monoxide and other atmospheric compounds.



## Available Models

Item #	Wavelength Range
OSA201C	350 - 1100 nm
OSA202C	600 - 1700 nm
OSA203C	1.0 - 2.6 $\mu\text{m}$ (10 000 - 3846 $\text{cm}^{-1}$ )
OSA205C	1.0 - 5.6 $\mu\text{m}$ (10 000 - 1786 $\text{cm}^{-1}$ )
OSA207C	1.0 - 12.0 $\mu\text{m}$ (10 000 - 833 $\text{cm}^{-1}$ )



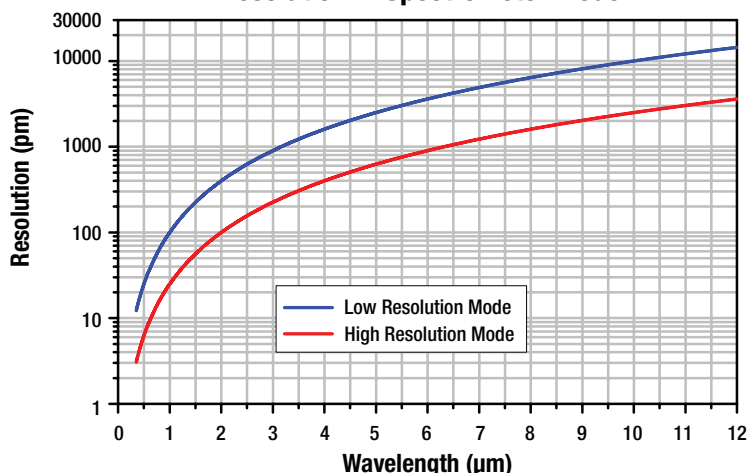
## Demo Units Available

To help ensure that our OSAs meet your application needs, we have designated several units for trial use. If you would like to try out an OSA in your lab, please contact us at [techsupport@thorlabs.com](mailto:techsupport@thorlabs.com) with your experimental requirements.

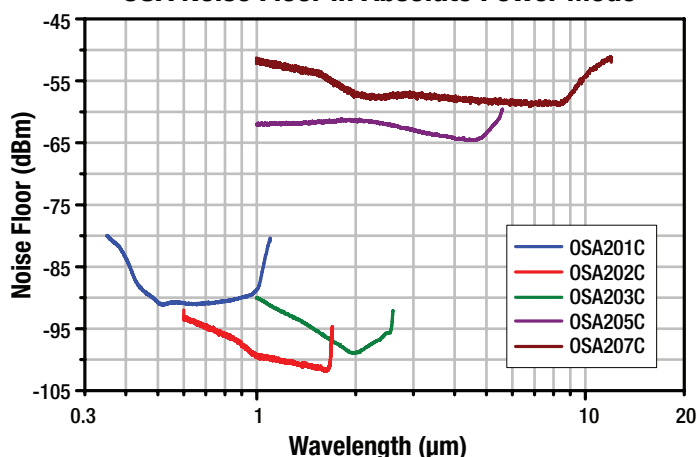
### Highly Accurate Spectral Measurements

The OSA product family is fully optimized for the characterization of broadband and narrowband light sources. For broadband sources, our OSAs provide  $\pm 2$  parts-per-million (ppm) spectral accuracy and 7.5 GHz ( $0.25 \text{ cm}^{-1}$ ) spectral resolution. For sources with linewidth  $< 10 \text{ GHz}$ , the Wavelength Meter mode provides center wavelength measurements with 0.1 ppm resolution and  $\pm 1$  ppm accuracy.

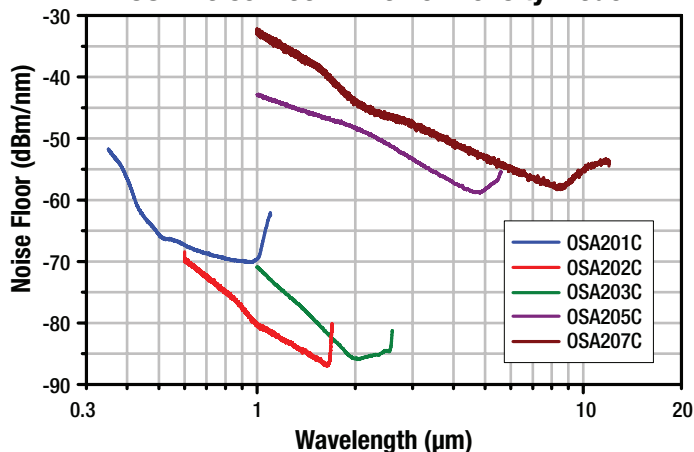
### Resolution in Spectrometer Mode



### OSA Noise Floor in Absolute Power Mode



### OSA Noise Floor in Power Density Mode



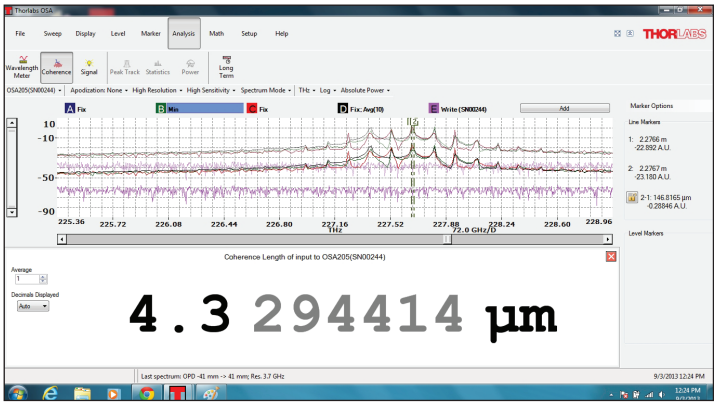
### Phase-Locked Loop with Stabilized HeNe Laser

Our high spectral accuracy and precision is retained across a wide range of environments by incorporating a stabilized 632.991 nm HeNe laser. The interferogram of this HeNe is measured simultaneously with the unknown source under test, and the result is used to continuously calibrate the instrument.

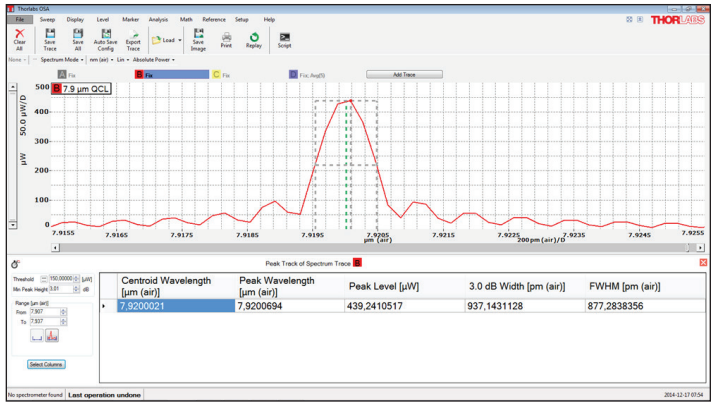
Small deviations in the HeNe wavelength can occur as a result of changing temperature and air pressure. Thorlabs' OSAs compensate for these in real time by using internal sensors to measure environmental variations. The sensor output is combined with the Edlén formula to calculate the refractive index and determine the HeNe wavelength on a shot-to-shot basis.

The HeNe interferogram is used to clock the 16-bit analog-to-digital converter, such that signals from the unknown source are measured at a fixed, equidistant optical path length interval. The HeNe reference fringe period is digitized, and its frequency is multiplied by a phase-locked loop. This phase-locked loop enables extremely high accuracy and precision over the entire operating range.

# Full Software Suite for Data Acquisition and Analysis



Coherence Length Module (Digits of Uncertainty are Displayed in Gray)



Peak Track Mode with 7.9 μm Quantum Cascade Laser

Each Optical Spectrum Analyzer includes a laptop with a Windows® operating system and the Thorlabs' OSA software suite. This software features an intuitive, responsive, straightforward interface that exposes all functions in one or two clicks.

We regularly update this software to add significant new features and make improvements suggested by our users. These software updates are available free of charge at [www.thorlabs.com](http://www.thorlabs.com).

## Built-In Tools for Narrowband and Broadband Signals

The OSA software displays either the raw interferogram or the Fourier-transformed spectrum obtained by the instrument. In the main window, it is possible to average multiple spectra; display the X axis in units of nm, cm<sup>-1</sup>, 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.

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 identify up to 2048 peaks or valleys within a user-defined wavelength range and follow them over a long period of time.

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.

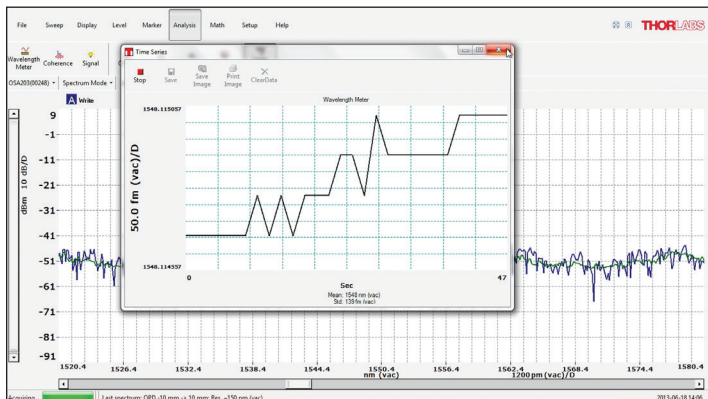
## Adjustable Sensitivity and Resolution Settings

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 below shows how the data acquisition rate depends upon the chosen settings.

Update Frequency		
	Low Resolution (1 cm <sup>-1</sup> )	High Resolution (0.25 cm <sup>-1</sup> )
Low Sensitivity	1.9 Hz (0.5 s)	0.6 Hz (1.8 s)
Medium Low Sensitivity	1.2 Hz (0.8 s)	0.3 Hz (2.9 s)
Medium High Sensitivity	0.7 Hz (1.5 s)	0.2 Hz (5.2 s)
High Sensitivity	0.4 Hz (2.7 s)	0.1 Hz (9.5 s)

The scan sensitivity and resolution are independent settings controlled from the software.



Output of Wavelength Meter Module over Time. One Division is Equal to 50.0 fm.

### Wavelength Meter Module for Narrowband Sources

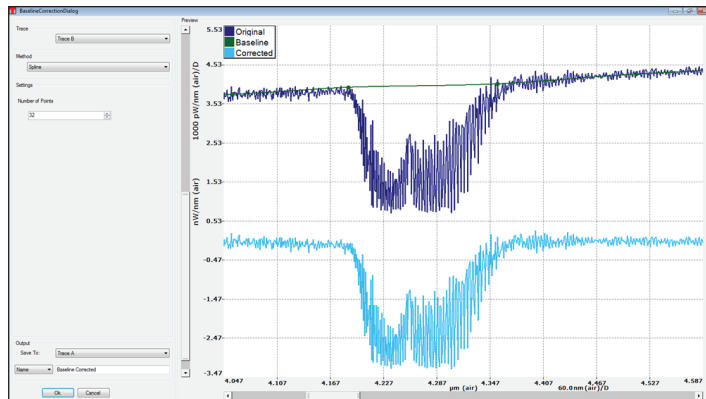
For sources with <10 GHz linewidth, the wavelength meter module enables extremely accurate determinations of the center wavelength ( $\pm 1$  ppm accuracy, 0.2 ppm precision, and 0.1 ppm resolution). This mode allows the system to resolve a fraction of a fringe in the interferogram, using the phase-locked loop that is generated by the internal stabilized reference HeNe laser. The uncertainty in the measurement is continuously determined and displayed as gray numbers.

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

Since 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. 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 OPD of  $\pm 4$  cm in high-resolution mode, making this module best suited for broadband sources.



Carbon Dioxide (CO<sub>2</sub>) Absorption Before and After Baseline Correction

### 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. The OSA software includes built-in support for HITRAN line-by-line references ([www.cfa.harvard.edu/hitrان](http://www.cfa.harvard.edu/hitrان)), 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.

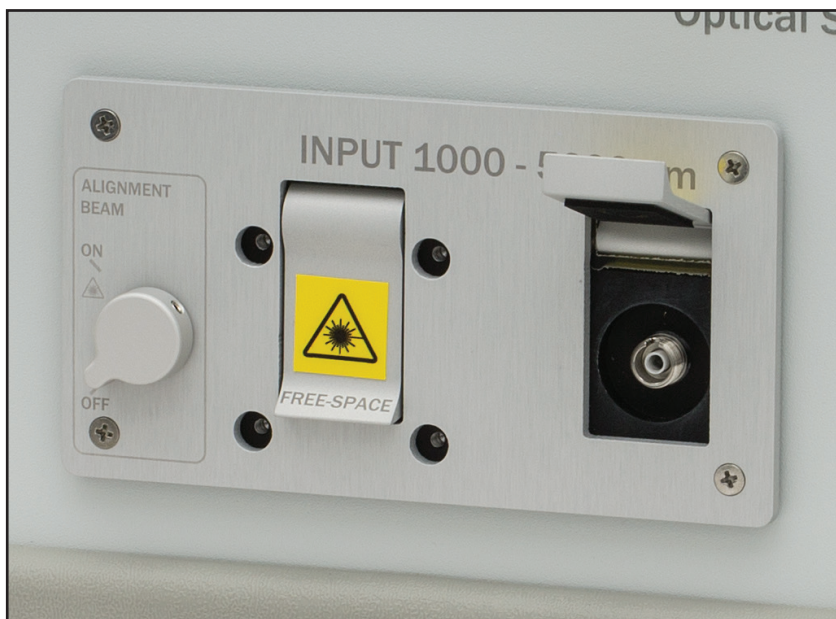
### Apodization and Interferogram Truncation

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. The effective optical path length can also be shortened to eliminate contributions from high-frequency spectral components.

# Fiber-Coupled and Free-Space Input Ports

All OSA models directly accept fiber-coupled input sources. The fiber-coupled input is compatible with single mode and step-index FC/PC multimode patch cables. Single mode patch cables provide the highest contrast. For measurements in the visible and NIR, we recommend core sizes up to  $\varnothing 50\text{ }\mu\text{m}$ . For measurements from  $2\text{ }\mu\text{m}$  to  $5.5\text{ }\mu\text{m}$ , we recommend our Indium Fluoride ( $\text{InF}_3$ ) patch cables with core sizes up to  $\varnothing 100\text{ }\mu\text{m}$ , which provide extremely low attenuation in the MIR region of the spectrum. Custom designs with other fiber input receptacles are available upon request.

In addition, all OSA models also accept free-space optical inputs up to  $\varnothing 6\text{ mm}$ . For alignment purposes, a red Class 1 beam is emitted from the aperture. The input beam will need to be collinear with the alignment beam for the best possible measurement accuracy. Four 4-40 taps around the free-space input provide compatibility with Thorlabs' 30 mm cage system, which reduces the mechanical degrees of freedom in a setup in order to simplify alignment.



OSAs are compatible with single mode and step-index multimode patch cables with cores up to  $\varnothing 50\text{ }\mu\text{m}$ , as well as fluoride multimode patch cables with cores up to  $\varnothing 100\text{ }\mu\text{m}$ . The fiber-coupled input on the OSA205C is shown here.



All OSAs accept free-space optical inputs up to  $\varnothing 6\text{ mm}$ . The free-space input on the OSA205C is shown here.



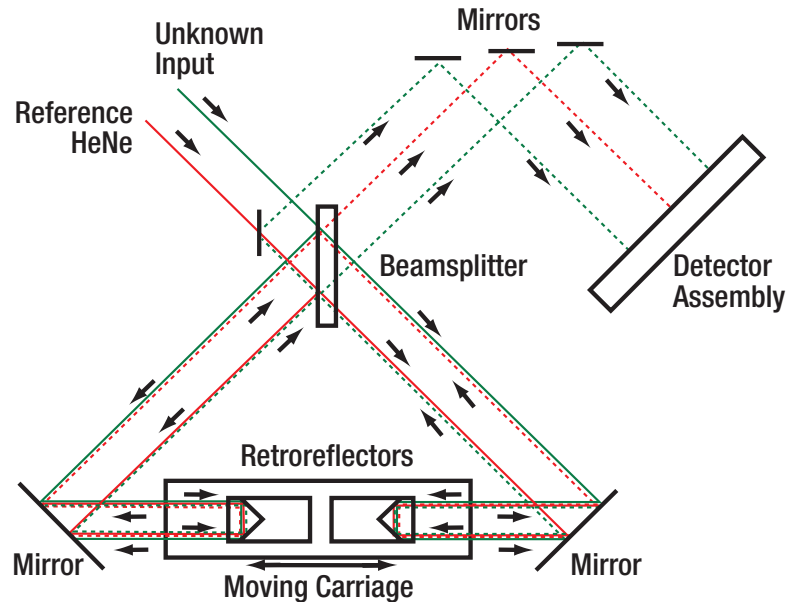
A  $\varnothing 1/2$ " off-axis parabolic mirror is mounted in a 30 mm cage system on the OSA205C. A rotational mount provides a rotational degree of freedom for alignment.

# Compact Interferometer with Precision Design

Thorlabs' Optical Spectrum Analyzers use a dual-retroreflector design, as shown in the figure to the right. These retroreflectors are mounted on a moving carriage that simultaneously adjusts the length of each arm of the interferometer in opposite directions. The advantage of this layout is that it changes the optical path difference (OPD) by four times the mechanical movement of the platform, reducing the physical package and decreasing the acquisition time.

The detector assembly is clocked by a phase-locked loop that is generated by the interferogram of the internal stabilized HeNe laser. The interferogram fringes trigger a 16-bit analog-to-digital converter, and the frequency of the reference fringes is multiplied by 16X, 32X, 64X, or 128X. At 128X, data points are acquired approximately every 1 nm of platform travel.

In high-resolution mode, the OPD is  $\pm 4$  cm, for a maximum spectral resolution of  $0.25 \text{ cm}^{-1}$  (7.5 GHz). Low-resolution mode, which improves the update rate by roughly a factor of three, reduces the OPD to  $\pm 1$  cm for a spectral resolution of  $1 \text{ cm}^{-1}$  (30 GHz). For narrowband sources (linewidth < 10 GHz), the Wavelength Meter module can be separately enabled to determine the center wavelength with 1 ppm accuracy. The Wavelength Meter takes advantage of the phase-locked loop to resolve data points to within a fraction of a fringe in the interferogram.

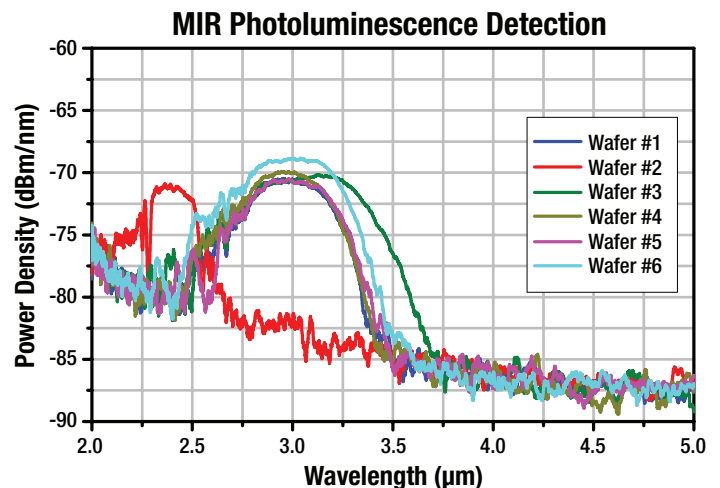


## Custom OSAs

We invite customers whose needs are not addressed by our standard OSA models to tailor an OSA to a specific application by working with our engineering and manufacturing team.

In the past, we have built OSAs with user-specified optical inputs, such as FC/APC and SMA905 fiber receptacles, and we have incorporated optical bandpass and notch filters directly into the optical path to reduce light source noise. In addition, 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. 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.



A user requested an OSA capable of detecting photoluminescence from wafers that emit in the 2 - 4  $\mu\text{m}$  spectral range. We provided a custom-built OSA which easily detected the predicted signal and had a greatly reduced noise floor compared to the OSA205C.

## Common Specifications

	Notes	Value
Spectral Resolution	Spectrometer Mode	7.5 GHz (0.25 cm <sup>-1</sup> )
Spectral Accuracy <sup>a</sup>		±2 ppm
Spectral Precision <sup>b</sup>		1 ppm
Wavelength Meter Resolution	Wavelength Meter Mode (Linewidth < 10 GHz)	0.1 ppm
Wavelength Meter Accuracy		±1 ppm
Wavelength Meter Precision <sup>c</sup>		0.2 ppm
Input Power (Max)	CW Source	10 mW (10 dBm)
Input Damage Threshold <sup>d</sup>	—	20 mW (13 dBm)
Power Level Accuracy <sup>e</sup>	—	±1 dB
Optical Rejection Ratio	—	30 dB
Input Fiber Compatibility	—	FC/PC Connectors All SM Fiber Patch Cables Step-Index MM Fiber Patch Cables with ≤Ø50 µm Core and ≤0.22 NA Step-Index Fluoride MM Fiber Patch Cables with ≤Ø100 µm Core and ≤0.26 NA
Free-Space Input	—	Accepts Collimated Beams up to Ø6 mm Red Alignment Laser Beam (Class 1)
Dimensions	—	320 mm x 149 mm x 475 mm (12.6" x 5.9" x 18.7")
Input Voltage <sup>f</sup>	—	100 - 240 VAC, 47 - 63 Hz 250 W (Max)
Storage Temperature	—	-10 °C to 60 °C
Relative Humidity	—	<80%, Non-Condensing

a After a 45 minute warm-up, for a single mode FC/PC-terminated patch cable at an operating temperature of 20 - 30 °C.

b Spectral Precision is the repeatability with which a spectral feature can be measured using the peak search tool.

c Using the same input single mode fiber for all measurements.

d Limited by the damage threshold of the internal components.

e 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 specified wavelength range is 400 - 1000 nm for OSA201C, 600 - 1600 nm for OSA202C, 1.0 - 2.4 µm for OSA203C, 1.3 - 5.0 µm for OSA205C, and 2.0 - 11.0 µm for OSA207C. Each specification is valid for a single mode FC/PC-terminated patch cable, as well as for a collimated free-space beam with diameter < 3 mm and divergence < 3 mrad, assuming the included protective window is installed in the free-space aperture.

f Each OSA and Windows® laptop comes with a region-specific power cord.

## Model-Specific Specifications

	OSA201C	OSA202C	OSA203C	OSA205C	OSA207C
Wavelength Range <sup>a</sup>	350 - 1100 nm	600 - 1700 nm	1.0 - 2.6 µm (10 000 - 3846 cm <sup>-1</sup> )	1.0 - 5.6 µm (10 000 - 1786 cm <sup>-1</sup> )	1.0 - 12.0 µm (10 000 - 833 cm <sup>-1</sup> )
Level Sensitivity <sup>b</sup>	-50 dBm/nm (350 - 500 nm) -60 dBm/nm (500 - 1100 nm)	-65 dBm/nm (600 - 700 nm) -70 dBm/nm (700 - 1700 nm)	-65 dB/nm <sup>c</sup>	-40 dB/nm	-30 dB/nm (1.0 - 2.0 µm) -40 dB/nm (2.0 - 12.0 µm)
Operating Temperature	10 °C to 40 °C				10 °C to 35 °C

a Limited by bandwidth of detectors and optics.

b Minimum detectable power per nanometer using Zero Fill = 0 and the highest resolution and sensitivity settings.

c Specified in high-temperature mode over 1.0 - 2.6 µm. In low-temperature mode, the level sensitivity is -70 dBm/nm over 1.0 - 2.5 µm.

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