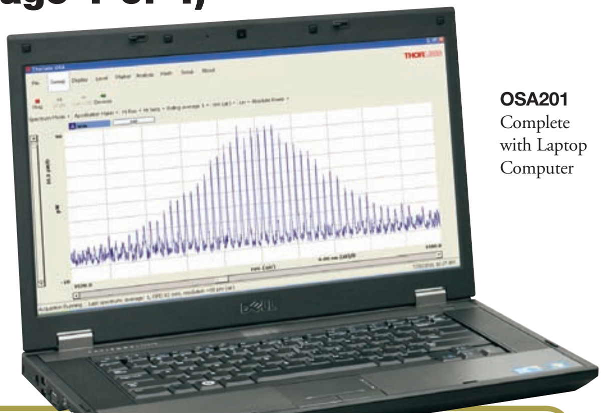
Optical Spectrum Analyzers (Page 1 of 4)



OSA201
Complete with Laptop Computer

Features

- Dual Function Broadband Spectrometer and Wavelength Meter
- Wavelength Ranges Available
  - OSA201: 350 - 1100 nm
  - OSA203: 1000 - 2500 nm*
- Resolution
  - Optical Spectrum Analyzer: 10 pm @ 633 nm
  - Wavelength Meter Mode: 0.1 ppm
- Update Rate as Fast as 2 Hz
- Includes Laptop with Pre-Installed Software

*Extended Wavelength ranges available, contact Thorlabs for details.

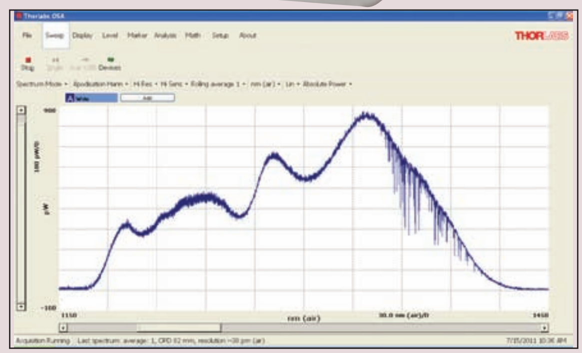


Figure 1a: Thorlabs' LS2000B broadband optical source, approximately 270 nm edge to edge, with approximately 5 µW of power delivered to the input of the FT-OSA. The fine structure visible across the spectrum is due to Fabry Perot modes of the semiconductor element, and the structure on the right are the expected water absorption lines that occur in the 1350 to 1400 nm range.

Introduction

Thorlabs' Optical Spectrum Analyzers (OSA201 and OSA203) are general-purpose instruments that measure optical power as a function of wavelength. These OSA instruments are versatile enough to analyze broadband optical signals as shown in Figures 1a and 1b, the Fabry Perot modes of a gain chip as shown in Figure 2, or a long-coherent-length, single mode external cavity laser as shown in Figure 4c.

SPECIFICATIONS	NOTES	OSA201	OSA203
Wavelength Range(1)	Detector Limited	350 - 1100 nm	1000 - 2500 nm
Spectral Resolution(2)	Broadband FT-OSA Mode	10 pm (0.25 cm^{-1}, 7.5 GHz)	60 pm (0.25 cm^{-1}, 7.5 GHz
Wavelength Meter Resolution(3) (6)	Wavelength Meter Mode Linewidth < 4 GHz	0.1pm	0.2 pm
Display Resolution(4)	Wavelength Meter Display Window	System Controlled with User Override, max 0.01 ppm	System with User Override, max 0.01 ppm
Spectral Accuracy(6)	Broadband FT-OSA Mode	±2 pm	±4 pm
Wavelength Meter Accuracy(6)	Wavelength Meter Mode	±1 pm	±2 pm
Spectral Precision(5) (6)	Broadband FT-OSA Mode	±1 pm	±1 pm
Wavelength Meter Precision(5) (6)	Wavelength Meter Mode	0.1 pm	0.2 pm
Measurement Rate	2 Hz		
Signal-to-Noise Ratio	>40 dB		
Level Sensitivity	-70 dB		
Input Power (Max)	10 dBm		
Dimensions	320 mm x 149 mm x 475 mm (12.6" x 5.9" x 18.7")		

1. Other detector options are available, please contact us for details.
2. Spectral Resolution is defined according to the Rayleigh Criterion as the wavelength separation required resolve two spectral lines.
3. Wavelength Meter Resolution is defined here as the smallest change the system can measure for an input with a FWHM linewidth of less than 4 GHz.
4. The Display Resolution is the number of digits shown on the Wavelength Meter Mode window, see Figure 4C.
5. Precision (Repeatability) is defined as the degree to which repeated measurements under unchanged conditions show the same results. The Spectral Precision was determined using an Acetylene cell absorption lines as shown in Figure 4D. Wavelength Meter Precision was determined using a 543 nm HeNe laser as well as an external cavity laser operating at 1550 nm.
6. Measurements for the OSA201 are made at 633 nm, and for the OSA203 are made at 1550 nm.

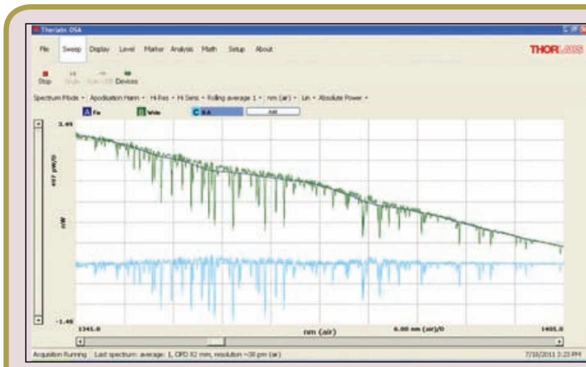


Figure 1b: Using the analysis features of the Optical Spectrum Analyzer, the absorption lines can be viewed by subtracting off the overall envelope of the source. As shown on page 1603 in Figure 4D, the absorption lines can be individually labeled and identified. Another function will automatically label any valley (or peak) that crosses a user-defined threshold.

Commonly available Optical Spectrum Analyzers are typically grating-based monochromators. While these devices offer broad wavelength coverage and good dynamic range, their resolution is usually limited to approximately 0.1 - 0.05 nm. The Thorlabs OSA is a Fourier Transform Optical Spectrum Analyzer (FT-OSA), which utilizes a scanning Michelson Interferometer in a push/pull configuration as shown in Figure 3. This approach allows for the design of a full-featured OSA with the additional benefit of a high precision Wavelength Meter (details are provided on page 1602).

Optical Spectrum Analyzers (Page 2 of 4)

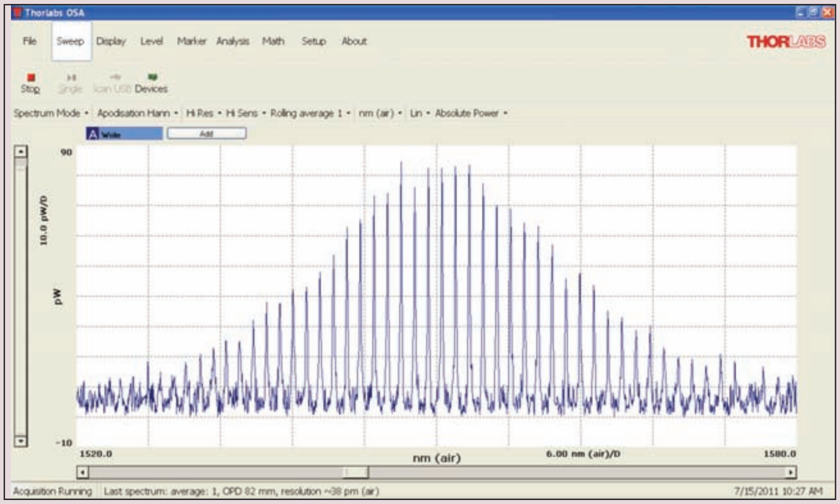


Figure 2: A 1550 nm laser diode operating below threshold, the overall gain curve of the device is evident, as well as the individual Fabry Perot modes of the semiconductor chip.

The Thorlabs FT-OSA has an FC-style optical fiber input (both single mode or multimode fibers up to Ø50 µm can be used), and after collimating the input, a beamsplitter divides the optical signal into two separate paths. The path length difference between the two paths is varied from zero to ± 40 mm. The collimated light fields then optically interfere as they recombine at the beamsplitter. The Detector Assembly shown in Figure 3 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 delay range. The wavelength range is limited by the bandwidth of the detectors and optical coatings. Furthermore, the accuracy of our system is ensured by including a frequency-stabilized 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's possible with a grating-based OSA. More on these points will be presented below.

Interferometer Design

As mentioned, the instrument uses an arrangement with two retro-reflectors as shown in Figure 3. These retro-reflectors 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 that the FT-OSA can resolve. The OSA201 has a Spectral Resolution of 10 pm at 633 nm, while the OSA203 has a spectral resolution of 60 pm at 1550 nm. In this context, the Spectral Resolution is defined according to the Rayleigh Criterion (please see the manual for these systems available online at www.thorlabs.com; search on OSA201) 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 HeNe Reference 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. The interferometer utilizes a dispersion compensation plate to nullify the wavelength-dependent optical path length differences for the two arms of the interferometer, which is mainly attributed to the beamsplitter.

Interferogram Data Acquisition

The interference pattern of the Reference Laser is used to clock a 16-bit 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 16, 32, 64, or 128. At the128 multiplier setting, the data points are acquired approximately every 5 nm. The multiple PLL filters enable the user to choose system parameters optimized for measurements that range from high speed, reduced sensitivity, reduced resolution to lower speed, high sensitivity, high resolution.

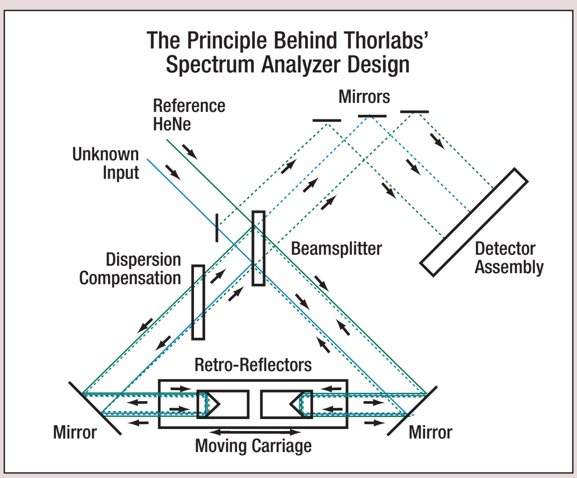


Figure 3: The optical schematic of the Thorlabs FT-OSA detailing the dual retro-reflector design. Note both retro-reflectors are attached to a common carriage that is moved via a voice coil motor. This configuration provides an optical delay that is four times the displacement of the carriage.

Optical Spectrum Analyzers (Page 3 of 4)

Interferogram Data Acquisition Continued…

A high-speed USB link transfers the interferogram for the device under test at 6 MBytes/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 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 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 l is calculated by counting interference fringes (periods in the interferogram) from both the Input and Reference Lasers according to the following formula:

$$\lambda = \frac{m_o}{m} \cdot \frac{n_\lambda}{n_o} \cdot \lambda_o$$

Here, m_o is the number of fringes for the HeNe Reference Laser, m is the number of fringes from the Unknown Input, no is the index of refraction of air at the Reference Laser wavelength, nl is the index of refraction for air at the wavelength λ, and λ_o is the vacuum wavelength of the HeNe Reference Laser.

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 section on Interferogram Data Acquisition). 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 Laser, 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 Specification Table 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 as to not provide misleading results.

Wavelength Calibration and Accuracy

These FT-OSA Instruments incorporate a stabilized HeNe Reference Laser with a vacuum wavelength of 632.9913 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 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 Laser 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 RH to be set manually. The effect of the humidity is negligible in the infrared.

Dynamic Range

The Dynamic Range of an OSA can be defined as the noise floor, which is 500 GHz from the peak when measuring a narrowband laser source. Table 2 provides some example values for the Dynamic Range of the OSA203.

FROM PEAK	DYNAMIC RANGE
0.2 nm (25 GHz)	28 dB
0.4 nm (50 GHz)	30 dB
0.8 nm (100 GHz)	30 dB
4 nm (500 GHz)	40 dB
8 nm (1000 GHz)	45 dB

Table 2: Dynamic Range Measurement for an OSA203 at 1550 nm with the following settings: High Resolution, Low Sensitivity, Average 4, Apodization Hann.

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 represented in either linear or logarithmic scale. In Absolute Power mode, the total power displayed is based on the actual instrument resolution for that specific wavelength; we recommend this setting only be used with narrow spectrum input light. For broadband devices, we recommend use of the Power Density mode. 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.

Optical Spectrum Analyzers (Page 4 of 4)

Operation

A GUI allows easy operation from a PC connected via USB port to the FT-OSA. The PC records the interferometric signal from the FT-OSA, which is then fast Fourier transformed (FFT) to yield the resulting spectra.

Monochromatic light may be viewed with sub-picometer resolution by utilizing the Wavelength Meter Mode of the FT-OSA. Broadband emission can also be viewed through the OSA's software, which has built-in zoom and peak analysis features. A peak discriminator can select bands that exceed a user-defined intensity and display them according to their wavelength (nm), wavenumber (cm^{-1}), or frequency (GHz). The instrument has a spectral resolution of 10 pm at 633 nm and 60 pm at 1550 nm and a wavelength accuracy better than 1 pm. In the Wavelength Meter Modes the resolution is 0.1 pm.

Software

The FT-OSA is shipped with the software package pre-installed on the laptop computer that is included with the purchase of this instrument.

The software has a customizable graphical user interface for acquiring, inspecting, manipulating, and analyzing spectra and interferograms. The software makes it easy to locate and track spectral peaks or valleys, measure the optical input power over any wavelength range, calculate an absorption spectrum in real-time, or track a large number of parameters over time.

A device interface library, containing a multitude of routines for data acquisition, instrument control, and spectral processing and manipulation, is also provided with the instrument. The library can be used to develop customized software for your own application using LabVIEW, C, C++, C#, Java, or another programming language. Each OSA ships with a set of LabVIEW routines to assist with writing your own applications.

The screen shots below were taken using the included software. Each trace utilized a 1550 nm laser diode and demonstrates some of the various measurements that are possible with the optical spectrum analyzer.

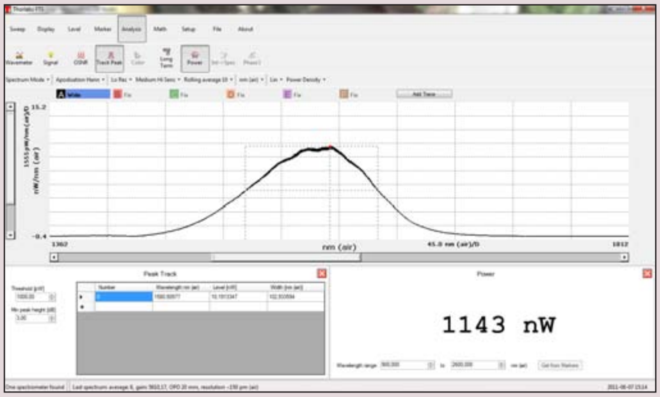


Figure 4a: The peak and total optical power of a 1550 nm gain chip operating well below threshold.

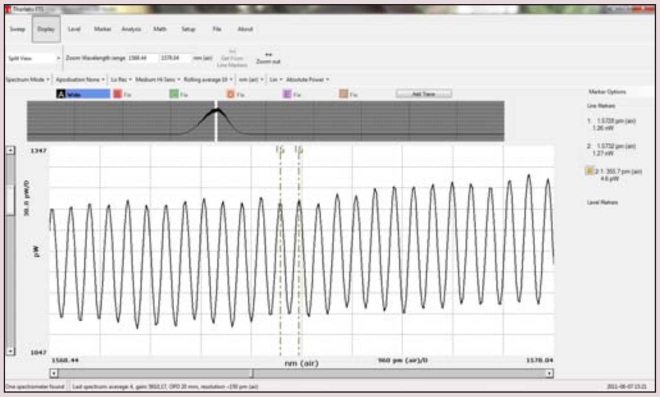


Figure 4b: The ASE spectrum of the same 1550 nm gain chip as in Figure 4a. The ripple is caused by Fabry Perot modes in the chip.

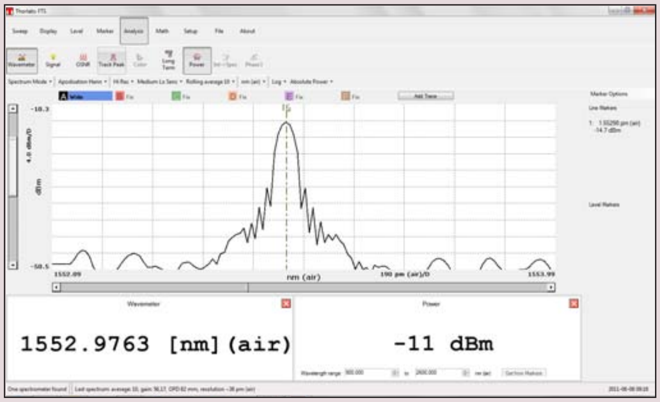


Figure 4c: 1550 nm gain chip in an external cavity laser. The software is set up to display the spectrum and the optical power. The Wavelength Meter Mode window is also activated.

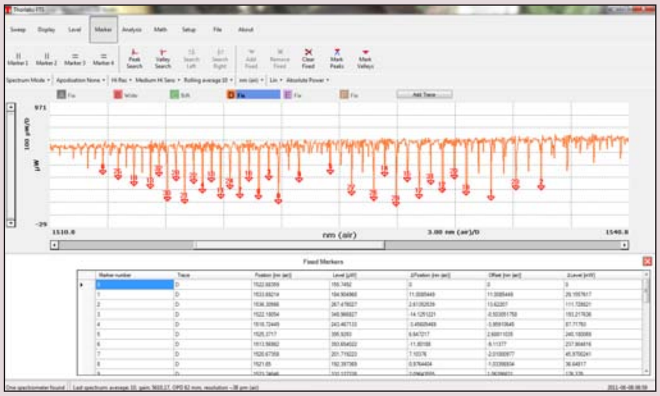


Figure 4d: A trace of the Acetylene absorption spectrum. The 1550 nm gain chip was used in ASE mode as the source, with the valley search function activated.

ITEM #	$	£	€	RMB	DESCRIPTION
OSA201	$ 23,000.00	£ 16,560.00	€ 20.010,00	¥ 183,310.00	Optical Spectrum Analyzer, 350 - 1100 nm
OSA203	$ 23,500.00	£ 16,920.00	€ 20.445,00	¥ 187,295.00	Optical Spectrum Analyzer, 1000 - 2500 nm