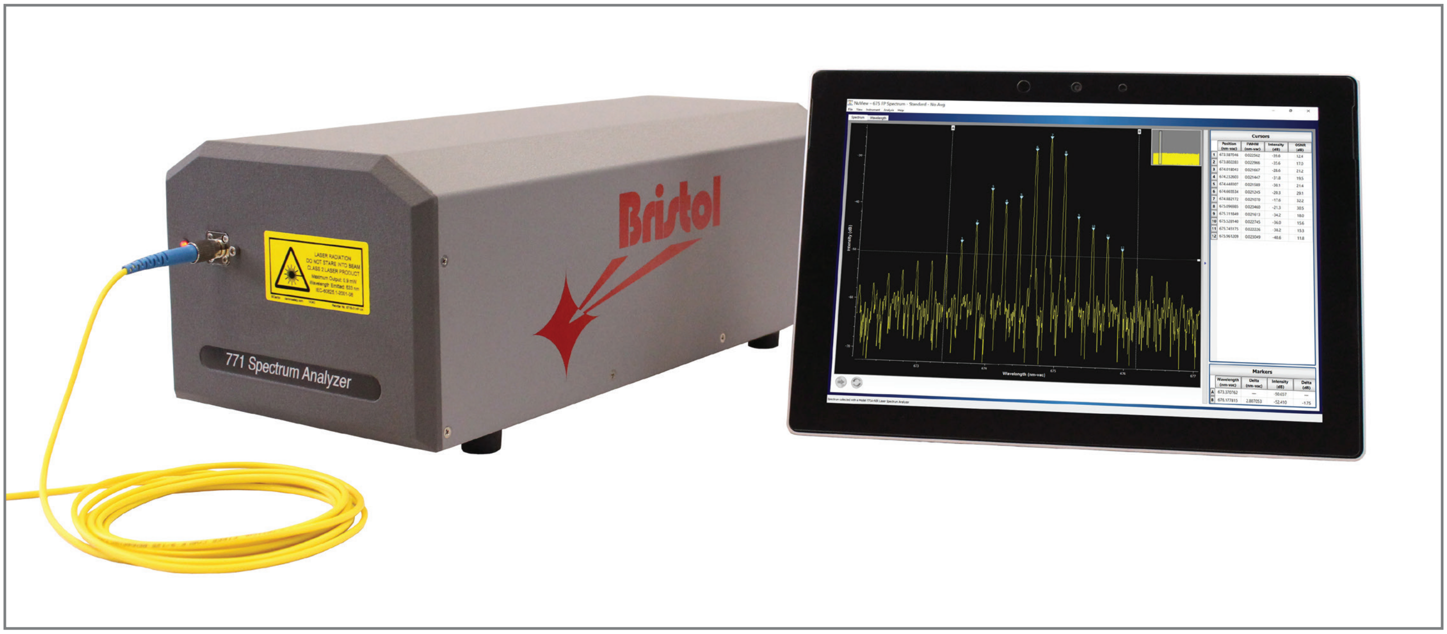
771 Series



LASER SPECTRUM ANALYZER

The Power of Precision in Spectral Analysis

Bristol Instruments

It's Our Business to be Exact!

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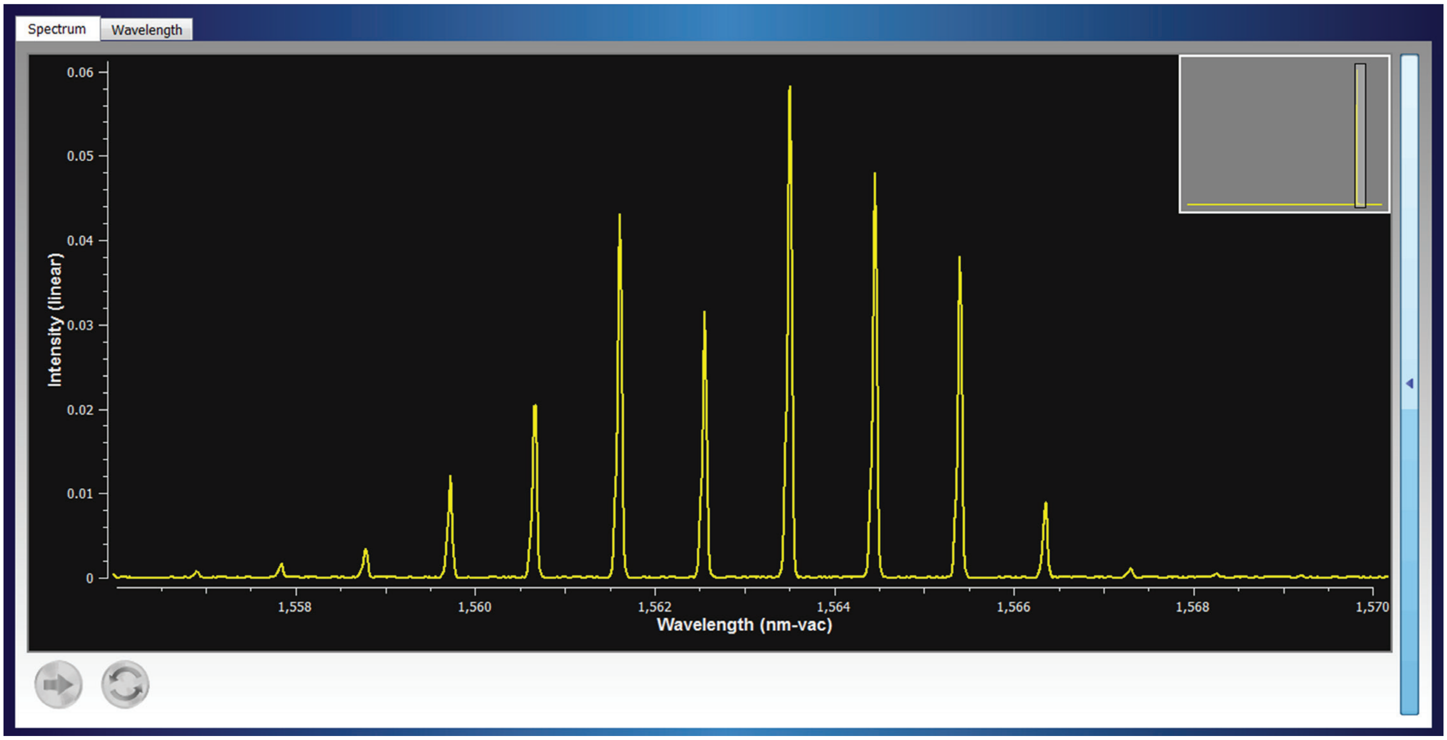
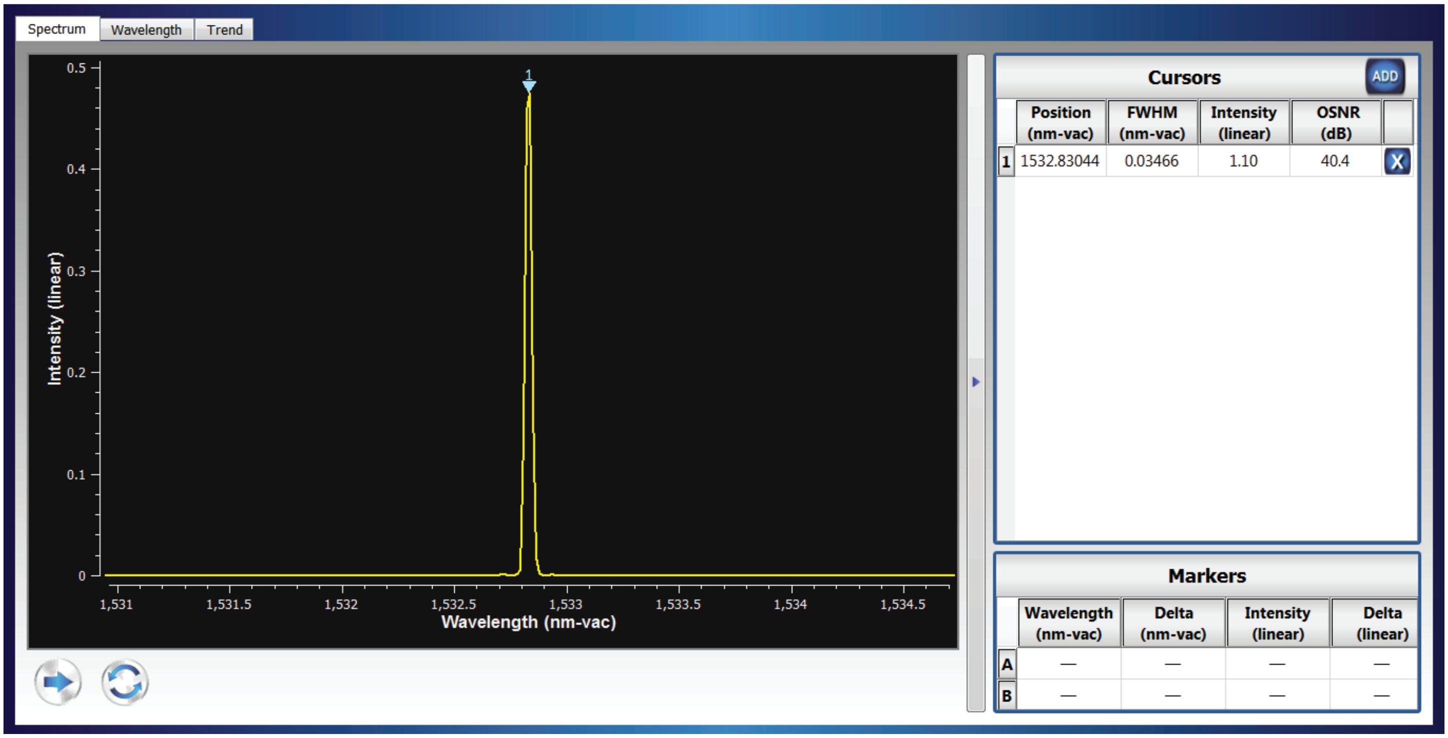
The 771 Series Laser Spectrum Analyzer combines proven Michelson interferometer technology with fast Fourier transform analysis resulting in a unique instrument that operates as both a high-resolution spectrum analyzer and a high-accuracy wavelength meter. With spectral resolution up to 2 GHz, wavelength accuracy as high as ± 0.2 parts per million (± 0.0002 nm at 1000 nm), and an optical rejection ratio of more than 40 dB, the model 771 provides the most detailed information about the spectral properties of lasers that operate from 375 nm to 12 µm.

LASER SPECTRAL ANALYSIS



The 771 Laser Spectrum Analyzer, when used as a high-resolution spectrum analyzer, measures and displays the spectral features of CW and high-repetition rate pulsed lasers. The spectrum is given as relative intensity versus wavelength (nm), wavenumber (cm^{-1}), or frequency (GHz). Relative intensity is displayed using a linear or log (dB) scale. Convenient zoom and scroll functions are available to optimize the displayed spectrum. In order to keep track of any changes, a thumbnail shows a small representation of the entire measured spectrum with an indication of the portion that is currently being displayed. The 771 system can generate a single spectrum, measure spectra continuously, or average a chosen number of spectra over time. For quantitative analysis, detailed information can be calculated automatically and reported in a data table.

Wavelength Accuracy



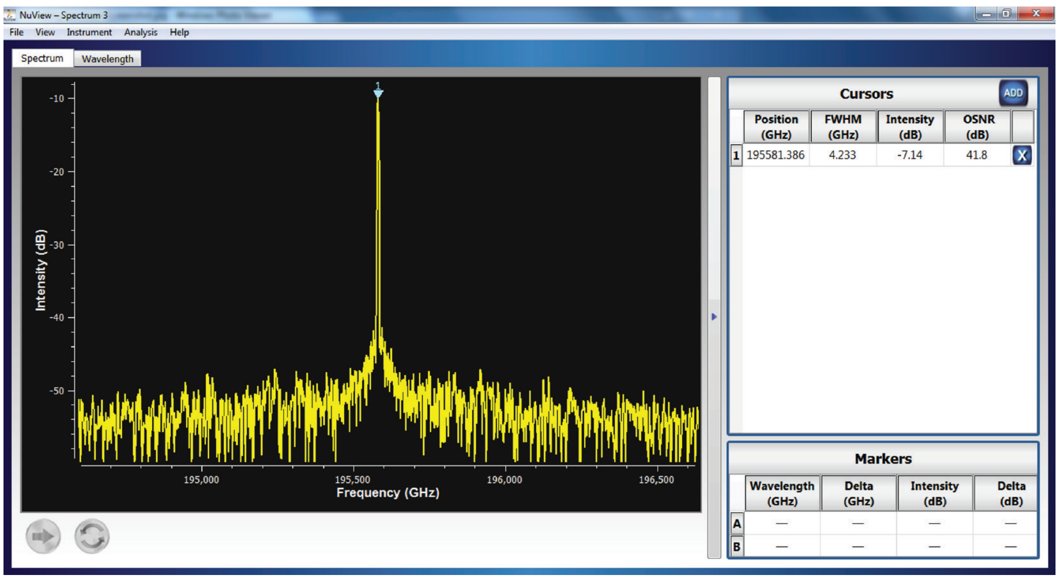
The spectrum's wavelength axis is calibrated to the specified accuracy of the instrument. The model 771A has a wavelength accuracy of ± 0.2 parts per million for the most precise measurements. For less demanding applications, the model 771B is available with an accuracy of ± 0.75 parts per million. For wavelengths greater than 5 µm, the accuracy is ± 1 part per million. To ensure the most meaningful experimental results, the wavelength accuracy specifications are guaranteed by continuous calibration with a built-in HeNe laser. This is an ideal reference source because its wavelength is well-known and fixed by fundamental atomic structure. To achieve the highest accuracy, the 771A system uses a single-frequency HeNe laser that is stabilized using a precise balanced longitudinal mode technique. A standard HeNe laser is used as the wavelength reference in the model 771B.

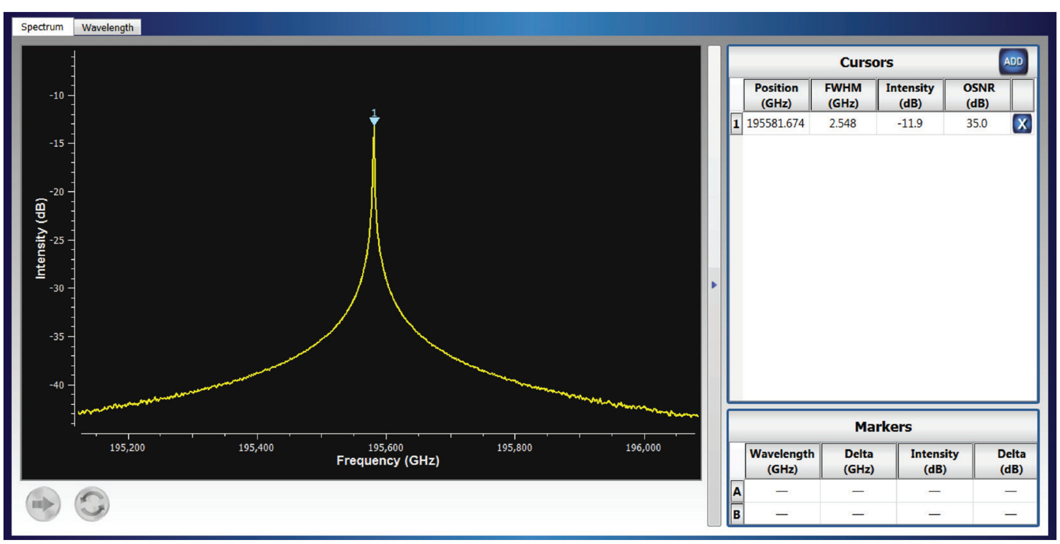
The figure above shows the spectrum generated by the 771A-NIR Laser Spectrum Analyzer of a laser diode locked to the P13 absorption of acetylene. The measured wavelength of the spectral peak is 1532.83044 nm. According to NIST Special Publication 260-133, the wavelength of the P13 acetylene transition is 1532.83045 nm. The difference between the measured and actual wavelengths is 0.00001 nm, which is well within the 771 system's accuracy limit of ± 0.2 parts per million (± 0.0003 nm).

Spectral Resolution

Spectral resolution is defined as the measured full width at half maximum intensity (FWHM) of an infinitely narrow optical signal. Three different measurement algorithms, Standard, High, and Low, are available to optimize the measured spectrum for a particular application.

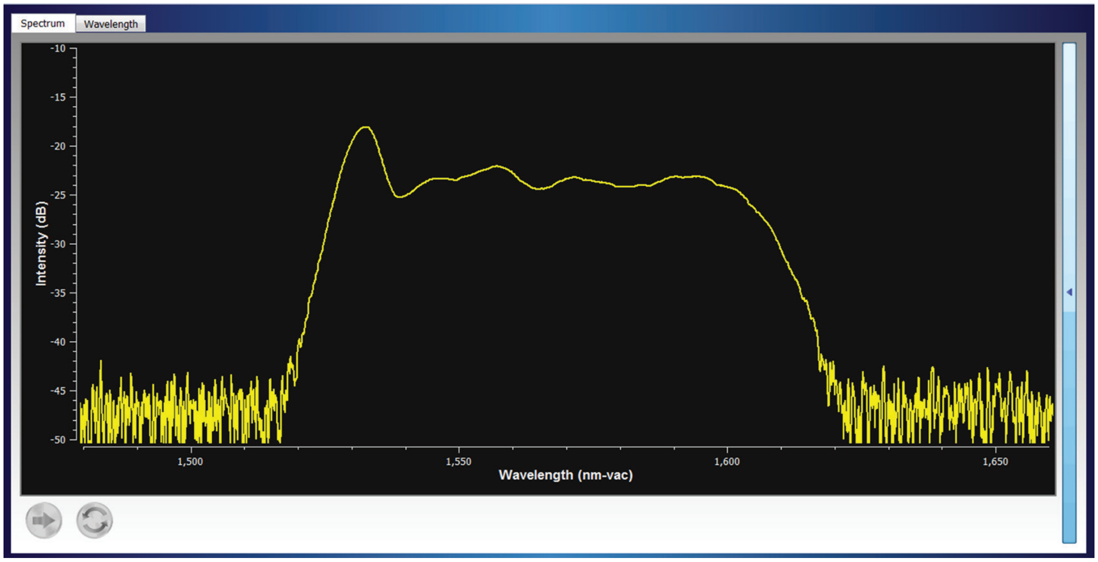
Standard Resolution combines a spectral resolution of 4 GHz (8 GHz with the IR version) with an optical rejection ratio of greater than 40 dB. A higher spectral resolution of 2 GHz (4 GHz with the IR version) can be achieved with the High Resolution algorithm. However, this results in a lower optical rejection ratio. This performance is demonstrated in the spectra shown below.



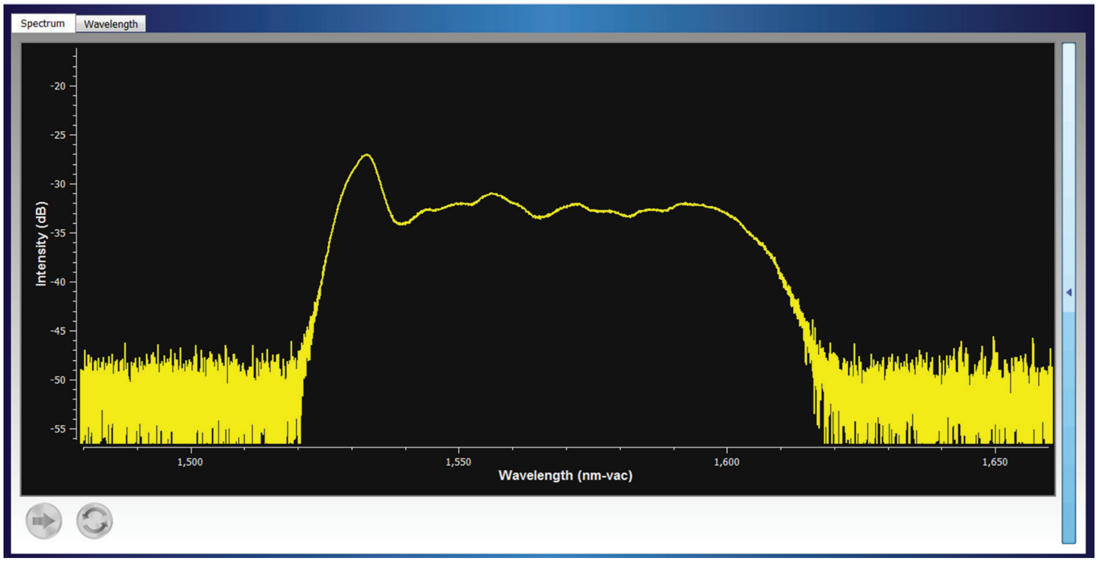


These two spectra are of the same narrow band laser. The first spectrum is generated using Standard resolution. The measured bandwidth is 4.233 GHz and the optical signal-to-noise ratio (OSNR) is greater than 40 dB at 1 nm away from the peak. The High resolution algorithm is used for the second spectrum. Higher spectral resolution is achieved as evidenced by the measured bandwidth of 2.548 GHz. However, the noise floor drops gradually near the peak thereby reducing the OSNR measurement.

The Low resolution option is available to better measure the spectral features of broadband lasers. The spectrum of a broadband SLED using Low resolution is shown below. Even with a bandwidth of 100 nm, the noise floor is about 30 dB below the spectrum's peak intensity.



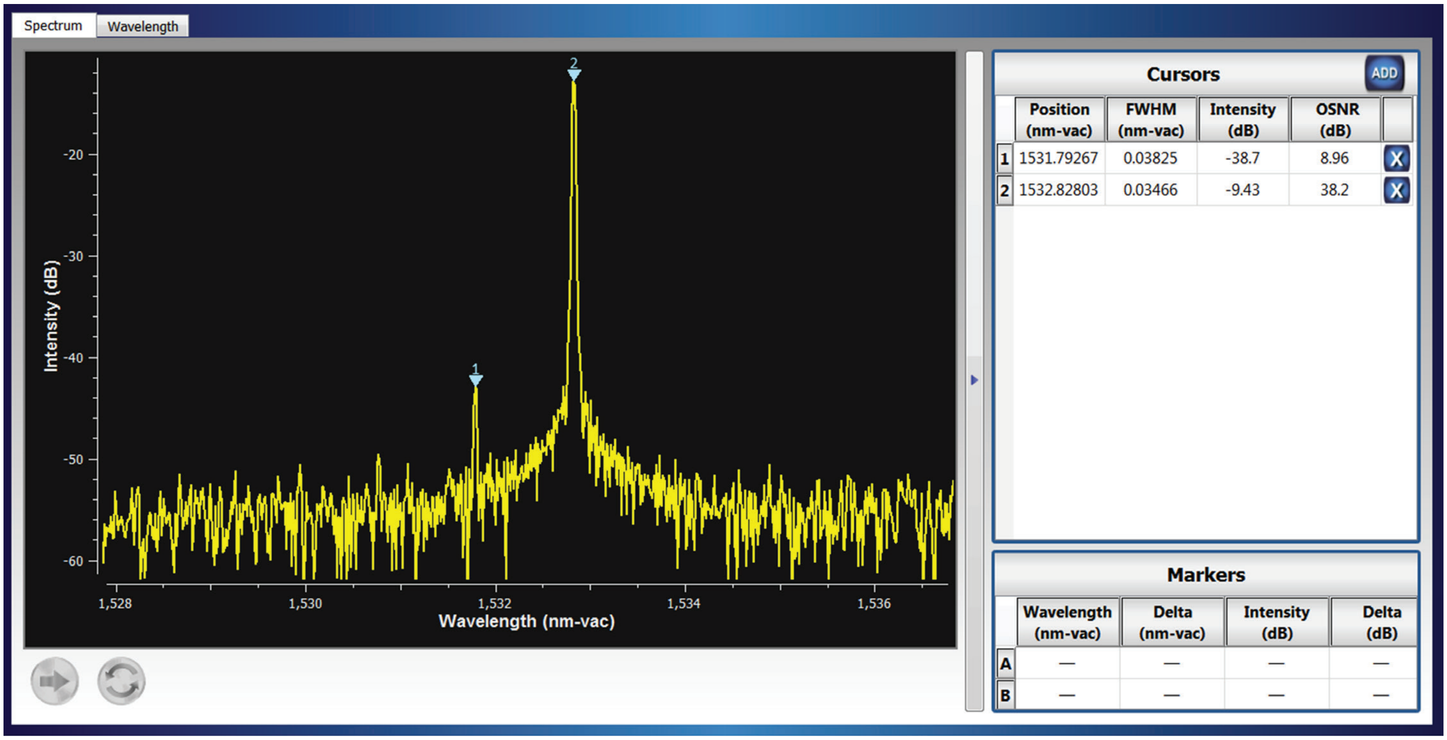
A spectrum of the same broadband SLED using standard resolution has a noise floor that is only about 25 dB below the spectrum's peak intensity.



Optical Rejection Ratio

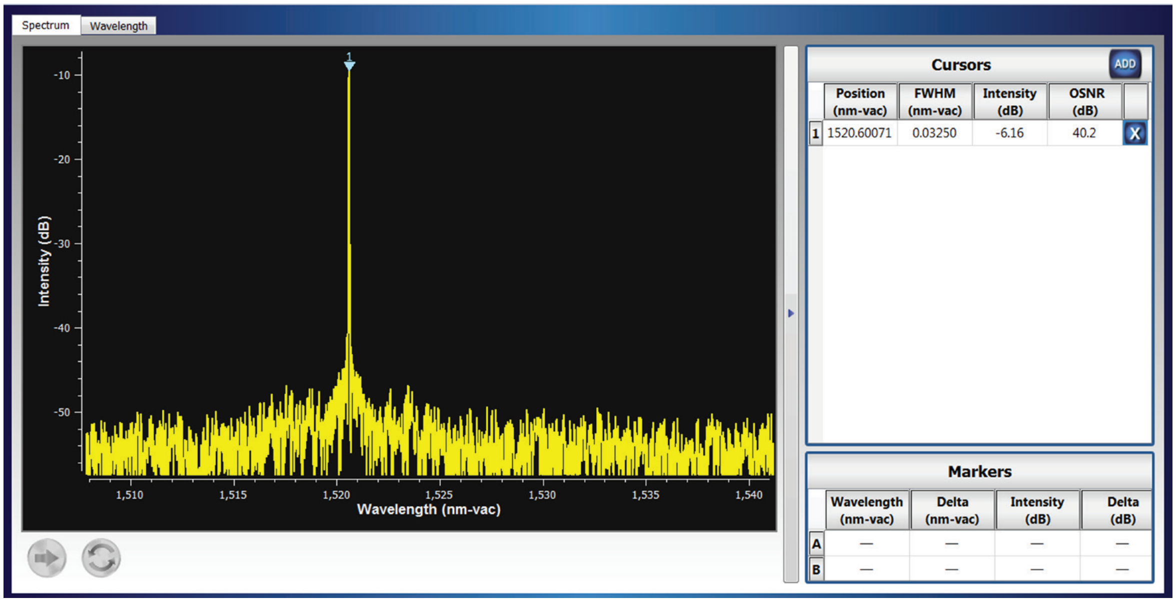
The Optical Rejection Ratio (ORR) of a laser spectrum analyzer defines its ability to measure a low intensity signal near a higher intensity peak. It is the ratio between the measured noise level at a given distance from the peak and the intensity of the peak. The ORR of the 771 Laser Spectrum Analyzer is greater than 40 dB (30 dB with the MIR version), the highest available for a Fourier transform-based laser spectrum analyzer. This is important because a laser spectrum analyzer with a higher ORR is able to provide a more detailed spectral response.

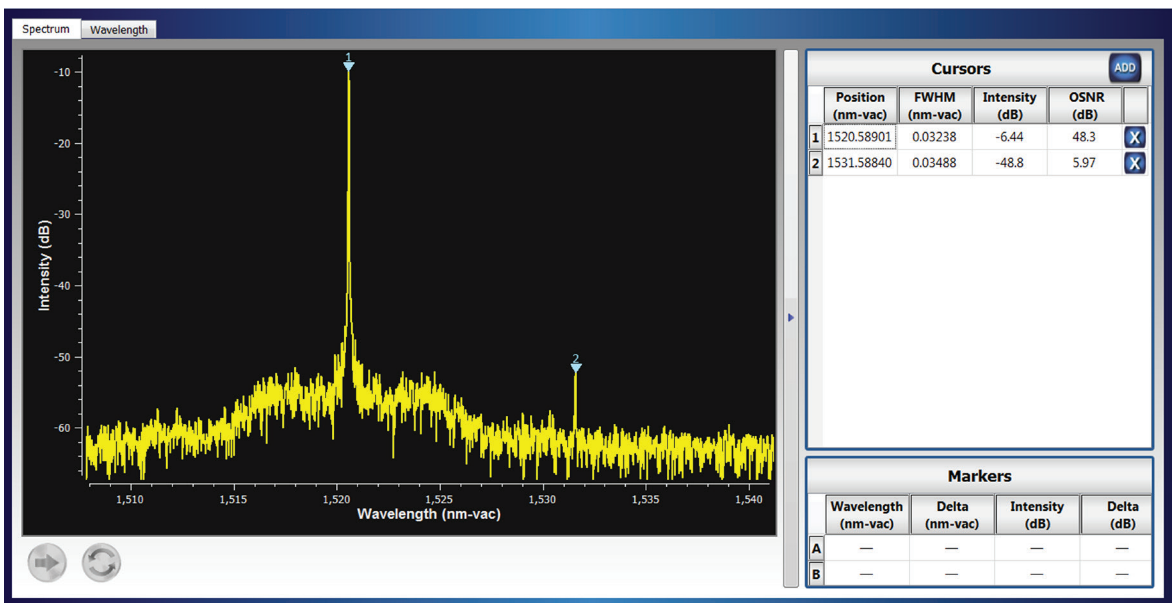
This performance is demonstrated with the following spectrum of an optical signal that includes two distinct lasers. The lasers have wavelengths that are 1 nm apart, and intensities that differ by about 30 dB. Because the 771 Laser Spectrum Analyzer has an ORR of 40 dB, the less intense laser signal is easily observed. An instrument with an ORR of only 30 dB would have a noise level that would obscure the second laser signal.



The fundamental limit of the 771 Laser Spectrum Analyzer's ORR is the electronic noise floor of the measurement. Because the specification of 40 dB is based on a single measurement, ORR can be improved by using averaging to lower the noise floor. The 771 system features a special co-addition algorithm that calculates a spectrum from an average of as many as 100 measured interferograms. This has the effect of lowering the noise floor, and therefore increasing the ORR, by a factor equal to the square root of the number of averaged interferograms. The result is an ORR improvement of 5 dB by averaging 25 scans or an improvement of 10 dB with an average of 100 scans.

The following spectra show the value of the co-addition averaging feature. The optical signal used to generate these spectra includes two distinct lasers with wavelengths that are about 10 nm apart. Their intensities differ by just over 40 dB. Without averaging, the second laser cannot be observed. It is only by averaging 100 interferograms that an ORR of about 50 dB is achieved to reveal this laser. In addition, this spectrum also shows that the more intense laser peak acutally sits on top of a “pedestal” about 45 dB below the peak.

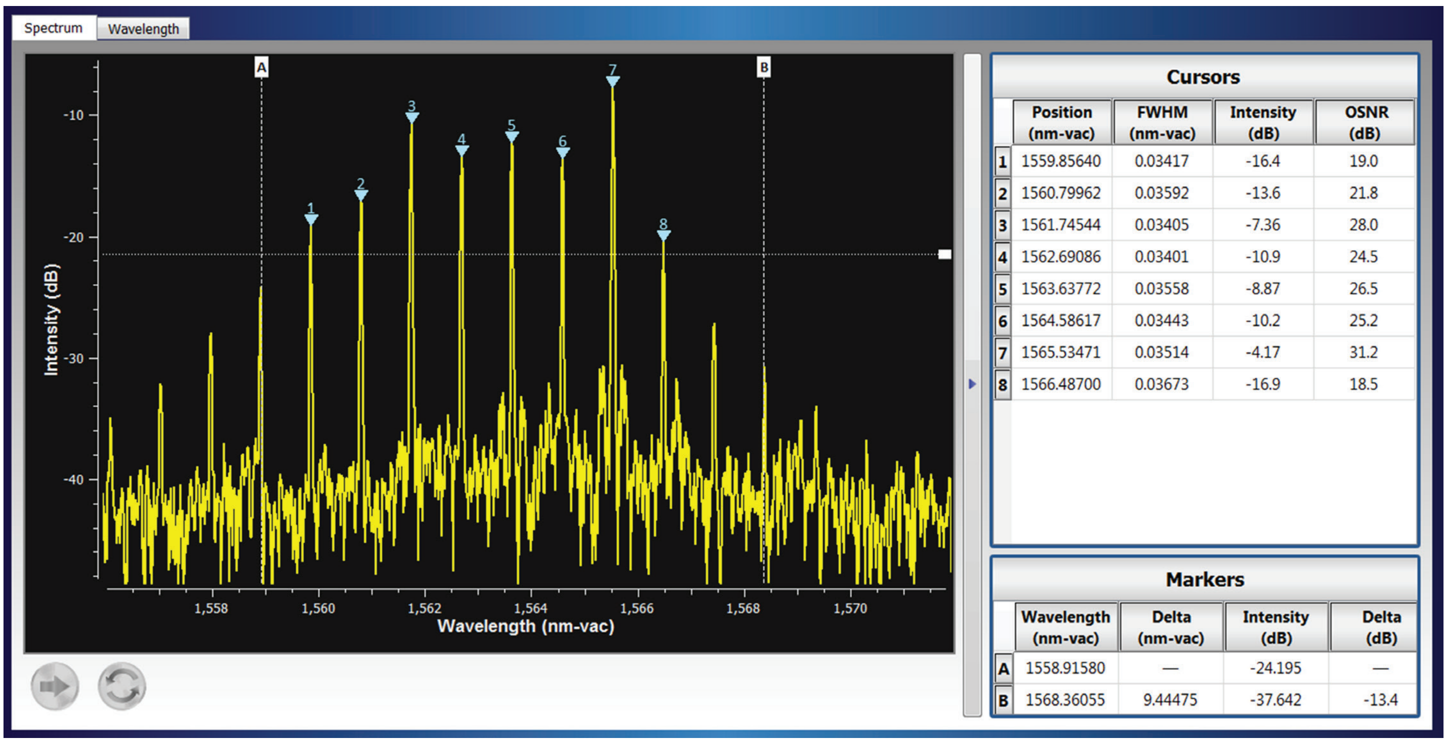




The ORR of the 771 Laser Spectrum Analyzer is also dependent on the intensity of the laser under test. The ORR rises as the input power increases from the minimum detectable power, and then levels off as the electronic noise floor begins to rise with the input signal.

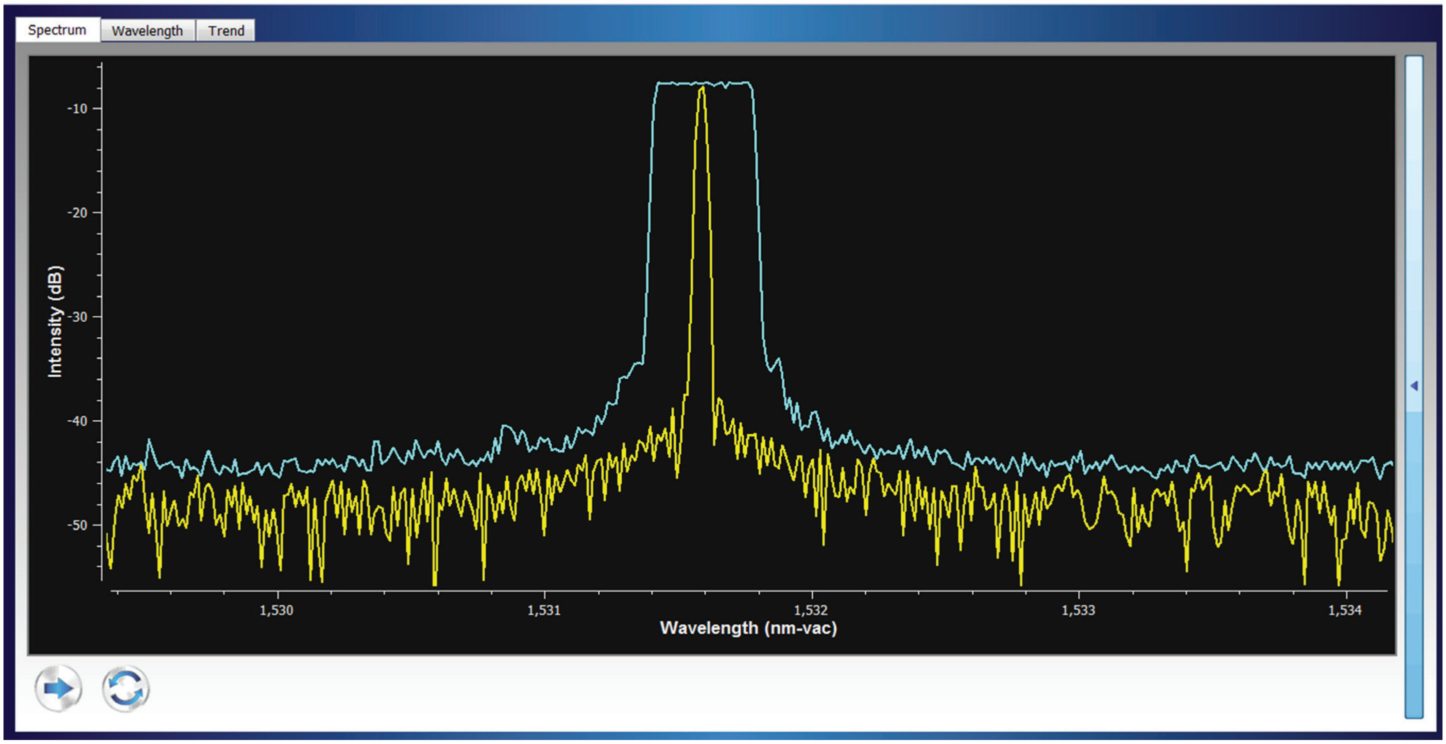
Detailed Quantitative Analysis

The 771 Laser Spectrum Analyzer has the ability to analyze a spectrum quantitatively using up to 100 cursors and a pair of markers. Each cursor is used to identify a specific spectral feature for which absolute wavelength, relative intensity, bandwidth (FWHM), and optical signal-to-noise ratio (OSNR) is calculated. Cursors can be placed manually by selecting any peak in the spectrum or using a threshold to automatically select all peaks above the desired intensity. The markers provide absolute wavelength and relative intensity information about any single point of the spectrum. A marker is manually positioned to the point of interest. The data generated by the cursors and markers are reported in a table beside the spectrum.



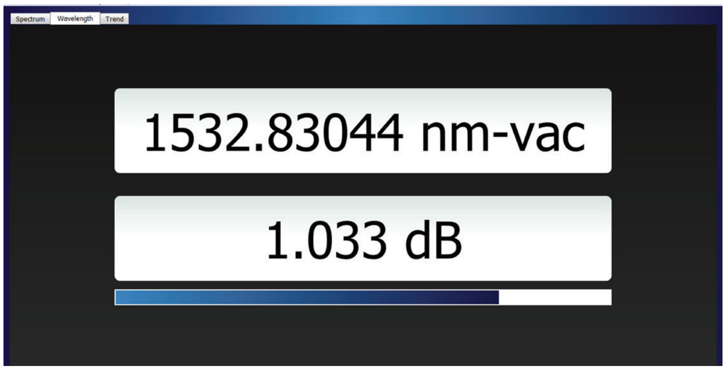
Spectral Stability Measurement

The 771 Laser Spectrum Analyzer has a unique feature that measures the frequency stability of the laser under test. The highest intensity for each point of the spectrum is recorded over time and displayed with the currently measured spectrum. This provides an indication of how the spectral features change with time. This is demonstrated in the following spectrum of a temperature-tuned DFB laser. The temperature is continuously cycled resulting in an "effective" laser bandwidth of about 0.25 nm shown in blue. The last measured spectrum is shown in yellow.



LASER WAVELENGTH MEASUREMENT

The 771 Laser Spectrum Analyzer also operates as a high-accuracy wavelength meter. It reports the wavelength (nm), wavenumber (cm^{-1}), or frequency (GHz) of a laser's most prominent spectral feature.

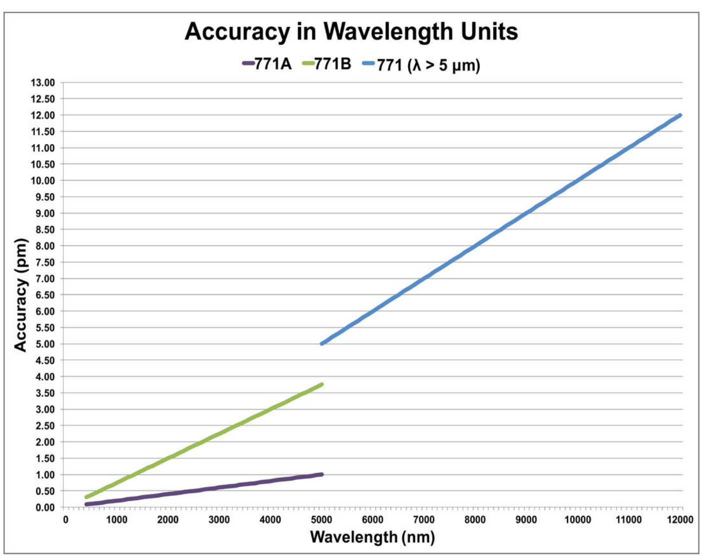


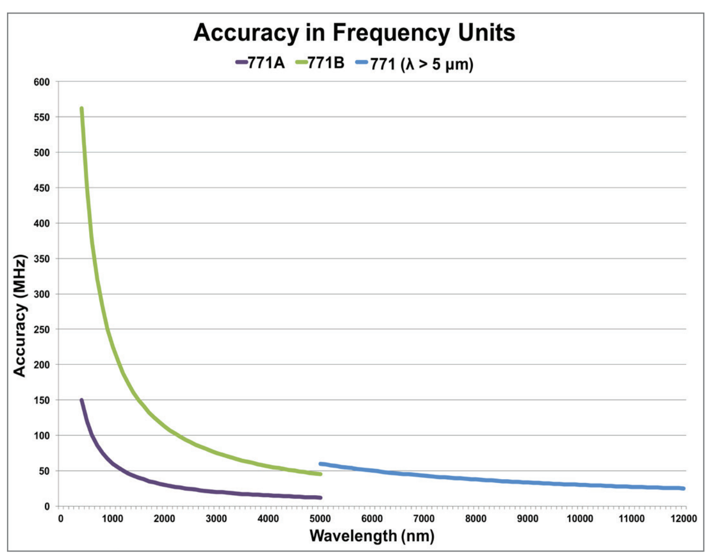
Guaranteed Accuracy

The most important aspect of a laser wavelength meter is its accuracy. Bristol Instruments guarantees this specification by taking into account all factors that can affect wavelength measurement.

Wavelength accuracy is quantified by Bristol Instruments using the NIST definition for expanded uncertainty. Components of error arising from both systematic and random effects are included. Systematic errors result in an offset between the measured value and the true value. Random errors result in measurements that have a statistical distribution associated with short-term measurement repeatability. The 771 Laser Spectrum Analyzer is designed to address both types of uncertainty. Continuous calibration with a built-in wavelength standard corrects for potential sources of systematic error. Random errors are minimized with a robust Michelson interferometer design.

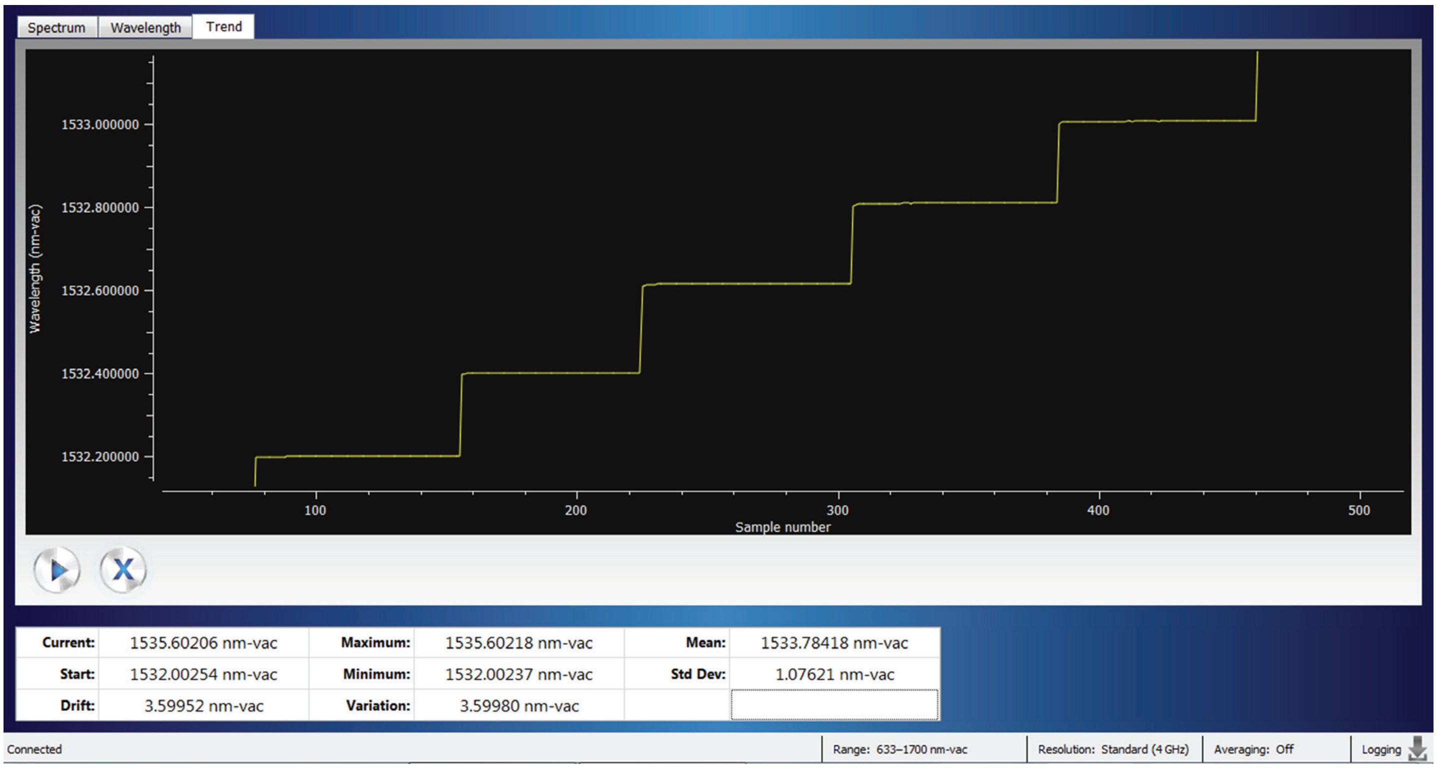
The result is an accuracy of ± 0.2 parts per million for the model 771A for lasers with a bandwidth less than 1 GHz. The 771B system, a lower-priced alternative, provides an accuracy of ± 0.75 parts per million for lasers with a bandwidth less than 10 GHz. The accuracy is ± 1 part per million for lasers with a wavelength greater than 5 μm.





Wavelength Measurement Trends

The software of the 771 Laser Spectrum Analyzer offers an integrated wavelength trending feature that automatically charts a laser's wavelength over time. A rolling graphical trace of up to 100,000 wavelength measurements is displayed. A variety of statistics over the measurement period are also computed. These include the maximum and minimum wavelength measurements, laser drift (current wavelength - start wavelength), standard deviation, and the mean. These values are reported in a table below the trend graph.

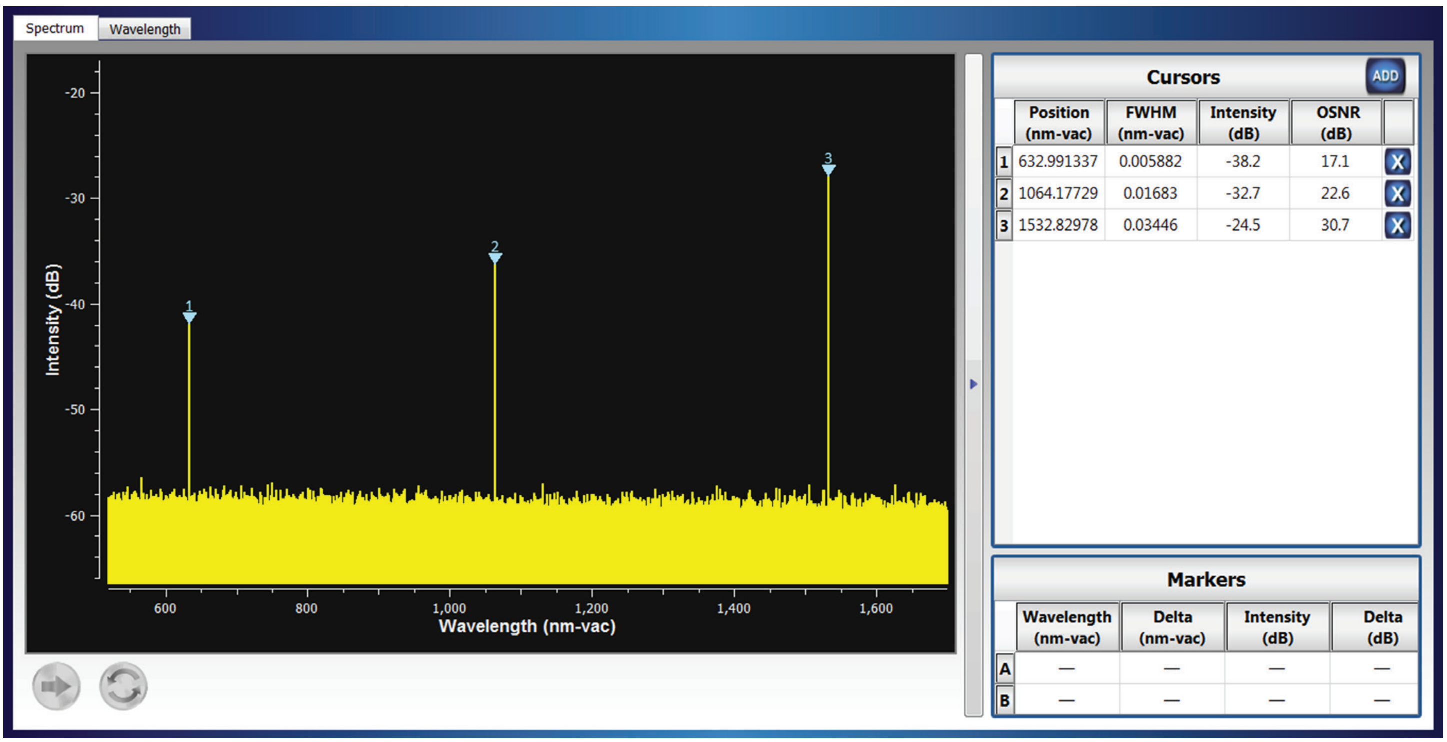


OPERATION

The 771 Laser Spectrum Analyzer makes it easy to determine the spectral characteristics of a laser. Operation is straightforward using a PC running under Windows. Using an on-board digital signal processor, the 771 system quickly generates a laser's spectrum, automatically calculates various quantitative data, and then transfers the information to the PC using a USB or Ethernet interface. Software is provided to control measurement parameters and to display the spectrum and report data in a variety of formats.

Broad Wavelength Coverage

The 771 Laser Spectrum Analyzer is available in four broad wavelength configurations to satisfy virtually any experimental requirement. These are designated as VIS (375 – 1100 nm), NIR (520 – 1700 nm), IR (1 – 5 µm), and MIR (1 – 12 µm). These ranges demonstrate the advantage of a Fourier transform-based laser spectrum analyzer. That is, the 771 system can quickly generate a spectrum over its entire operational wavelength range. For example, the following spectrum of an optical signal that consists of three distinct lasers (633 nm, 1064 nm, and 1533 nm) was generated in less than two seconds.



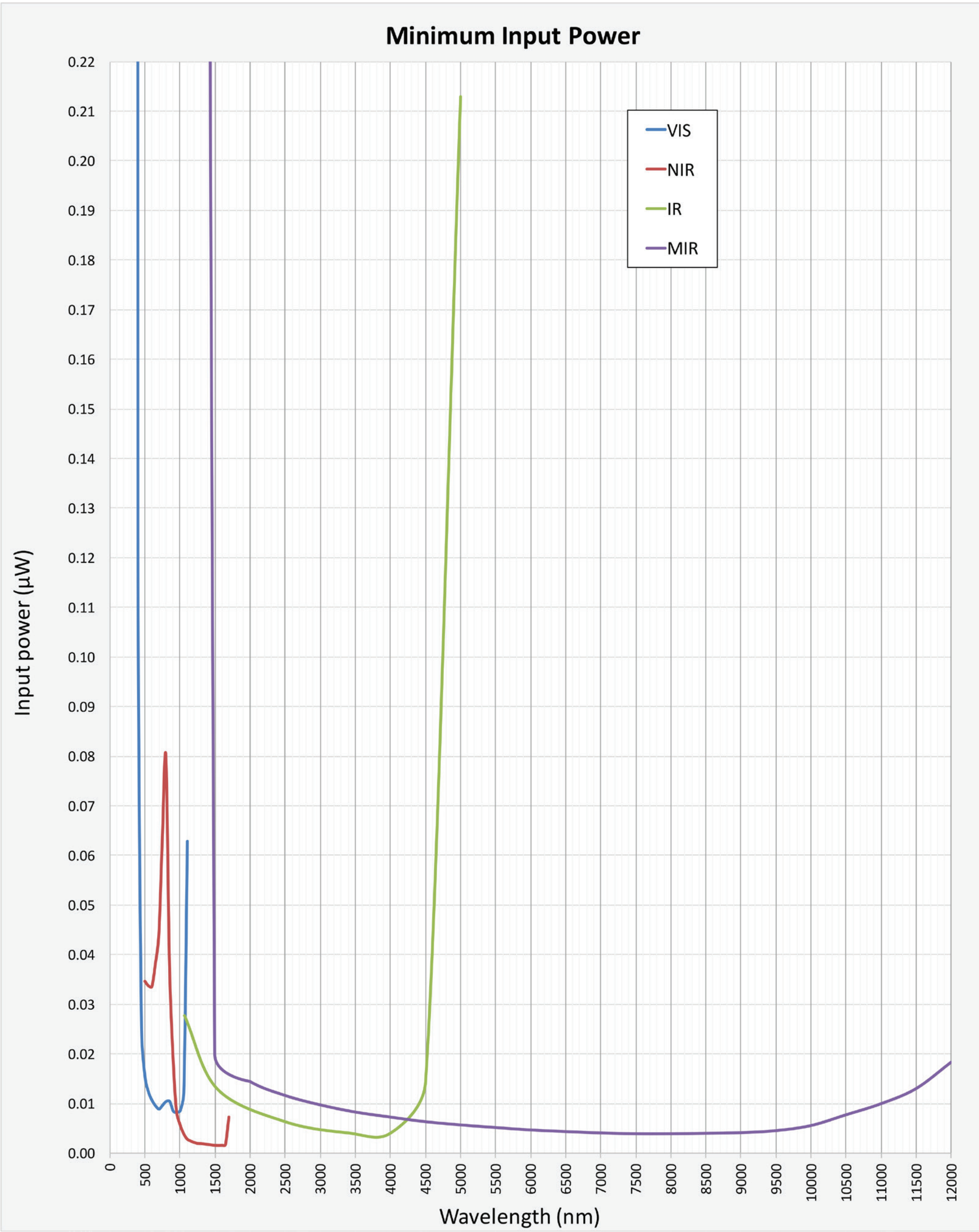
Convenient Laser Input

A laser under test enters the VIS and NIR versions of the model 771 through a pre-aligned FC/UPC or FC/APC fiber-optic input connector. This ensures optimum alignment of the laser beam to the instrument's interferometer resulting in uncompromised accuracy. With fiber-optic input, the 771 system can be placed in an out of the way location, thereby conserving valuable "optical real-estate." For free beam lasers, Bristol Instruments offers a variety of Fiber-Optic Input Couplers that provide a simple way to launch a laser beam into fiber.

Since fiber is not readily available for infrared wavelengths, the laser under test enters the IR and MIR versions of the model 771 through a 2-3 mm input aperture. To facilitate alignment to the instrument, the internal HeNe reference laser is emitted from the input aperture as a visible tracer beam. The laser under test is simply superimposed on the tracer beam to optimize alignment. This is accomplished by using the three adjustable-height legs (± 0.25") of the 771 system.

High Sensitivity

The minimum input signal required by the 771 Laser Spectrum Analyzer is as low as 3 nW. However, since this specification is defined as the power necessary to achieve a signal-to-noise ratio of 1 dB, a higher input power is preferred. Graph of minimum input power versus wavelength are given below.



Fast Spectral Measurements

The time required for the model 771 to generate a spectrum over its entire operational wavelength range is two seconds. In order to reduce the measurement time to one second, there is a software option that limits the spectral analysis to a smaller wavelength range resulting in more efficient calculations.

Operation with CW and Pulsed Lasers

The 771 Laser Spectrum Analyzer is ideal for measuring the spectral characteristics of CW lasers. The model 771 will also operate with pulsed lasers that have a repetition rate greater than 50 kHz and a pulse length greater than 50 ns. The analysis of pulsed lasers may result in modulation artifacts in the form of false spectral peaks. However, these artifacts can be minimized using the system's special co-add averaging algorithm.

Versatile Instrument Interface

The spectral information generated by the 771 Laser Spectrum Analyzer is transferred to a PC directly using a USB interface or via a local area network using Ethernet. Analysis is done with the system's Windows-based software, or relative intensity versus wavelength data can be collected and saved to a file using a *.csv format for analysis with other graphing programs. Data can also be transferred using a convenient library of commands for custom or LabVIEW programming.