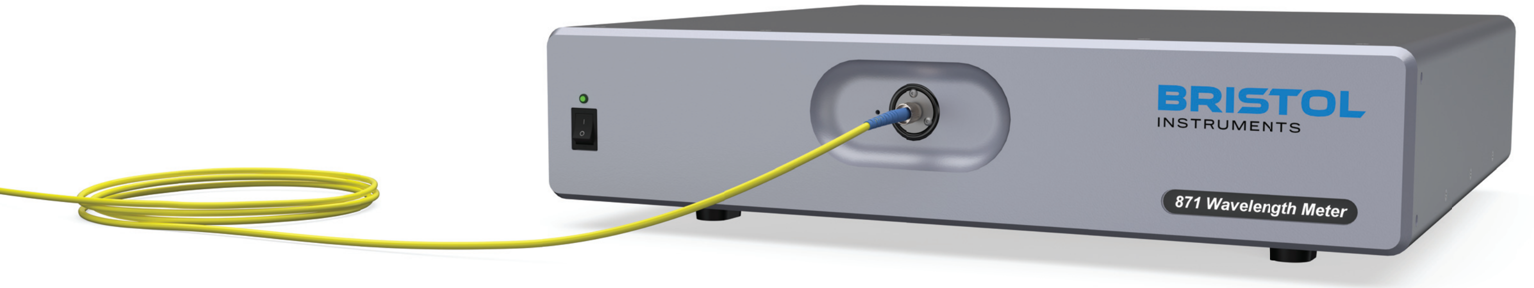

871 Series

LASER WAVELENGTH METER

Fast, accurate, and reliable wavelength measurement for pulsed and CW lasers.

BRISTOL
INSTRUMENTS

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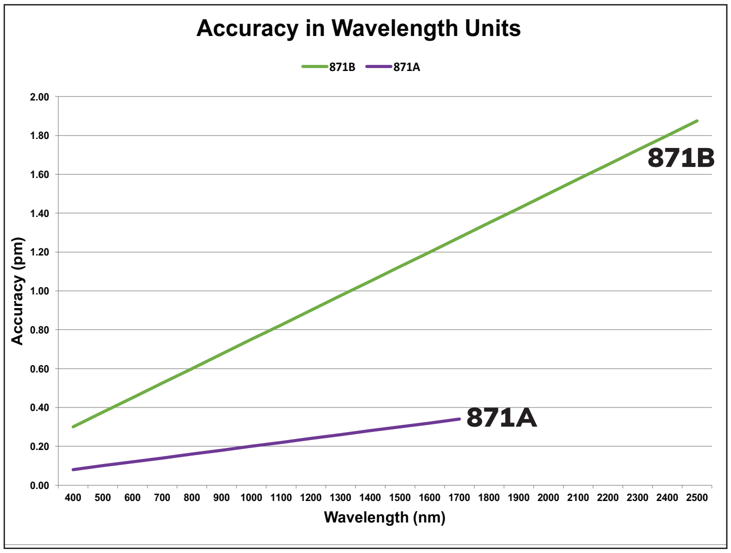
The 871 Series Laser Wavelength Meter is the best way for scientists and engineers to determine the exact wavelength of their pulsed and CW lasers. The 871 system uses proven Fizeau etalon technology to provide the fastest measurement of laser wavelength to an accuracy as high as ± 0.0001 nm. What's more, this is accomplished with an unprecedented level of reliability, versatility, and convenience.

LASER WAVELENGTH MEASUREMENT

Two versions of the 871 Laser Wavelength Meter are available. The model 871A is offered for the most demanding experiments, measuring laser wavelength to the highest accuracy of ± 0.2 parts per million (± 0.0002 nm at 1000 nm). For experiments that are less exacting, the model 871B is a lower-priced alternative with a wavelength accuracy of ± 0.75 parts per million (± 0.0008 nm at 1000 nm).



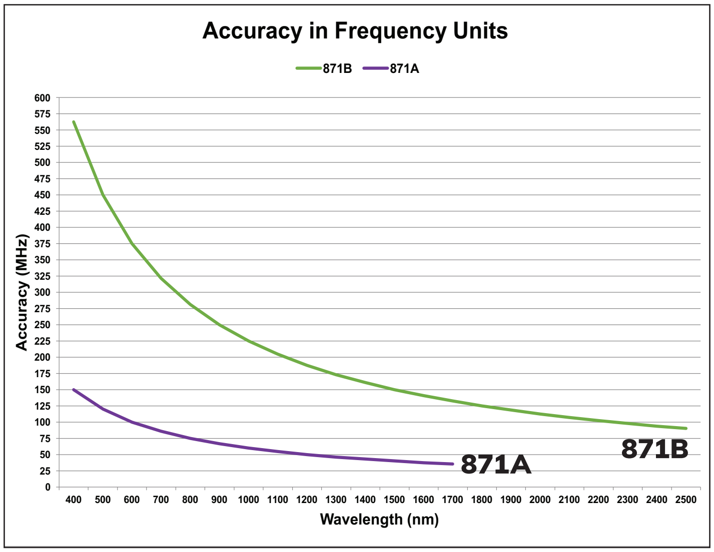


***Figure 1.** 871A and 871B Accuracy Performance in Wavelength Units (picometers).* ***Figure 2.** 871A and 871B Accuracy Performance in Frequency Units (MHz).*

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 the 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 871 Laser Wavelength Meter is designed to address both types of uncertainty. Automatic calibration with a built-in wavelength standard corrects for potential sources of systematic error. Random errors are minimized with a unique Fizeau etalon design.

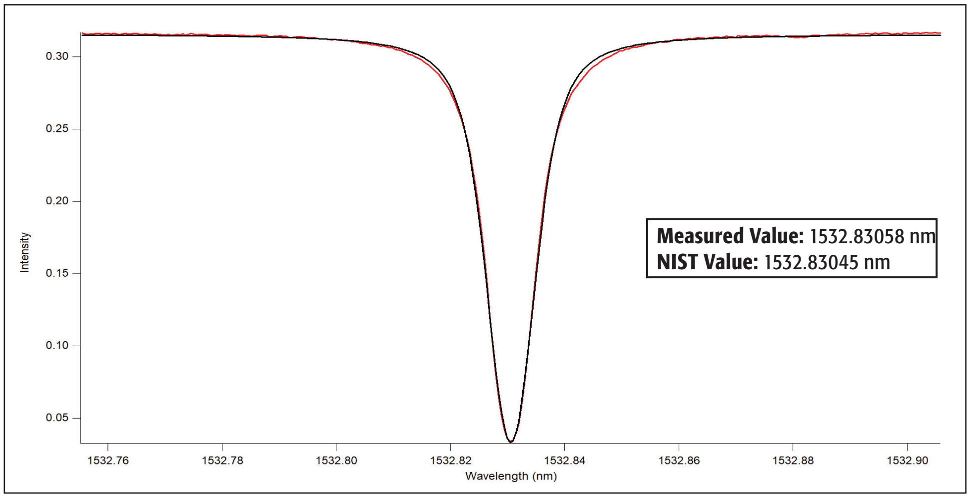


Figure 3. ***Wavelength data (red) measured with the model 871A-NIR as a laser tunes through an absorption of acetylene gas (NIST SRM 2517a). A Voigt curve fit of this data (black) gives a measured absorption wavelength of 1532.83058 nm. The published NIST value of 1532.83045 nm is well within the wavelength meter's accuracy of ± 0.3 pm.***

Automatic Calibration

To ensure the most meaningful experimental results, the wavelength accuracy specifications are guaranteed by automatic calibration with a built-in reference laser. The VIS models (375 – 1100 nm) use a 633 nm stabilized single-frequency HeNe laser with a wavelength that is fixed by fundamental atomic structure. The wavelength reference for the NIR models (630 – 1700 nm) and the NIR2 model (1-2.5 µm) is a 1532 nm laser diode that is locked to an absorption line of acetylene. According to NIST Special Publication 260-133, the wavelength of this absorption line is known to better than one part in 10^8.

The calibration process of the 871 Laser Wavelength Meter can be activated one of three ways: (1) manually, (2) automatically at a chosen time interval, or (3) based on the system's internal thermal conditions. A calibration request temporarily interrupts the wavelength measurement for less than one second.

Exceptional Repeatability

The Fizeau etalon design of the 871 Laser Wavelength Meter provides exceptional measurement repeatability to ensure that all wavelength measurements are well within the specified accuracy limits. A coverage factor of three is used resulting in a measurement confidence level of ≥ 99.7%.

The repeatability specification is defined as the standard deviation of all measurements over a one-minute period. Repeatability for the model 871A is 0.0075 parts per million (2.25 MHz at 1000 nm), and 0.0125 parts per million (3.75 MHz at 1000 nm) for the 871B system. The standard deviation for a 10-minute measurement period is about twice that of the one-minute period.

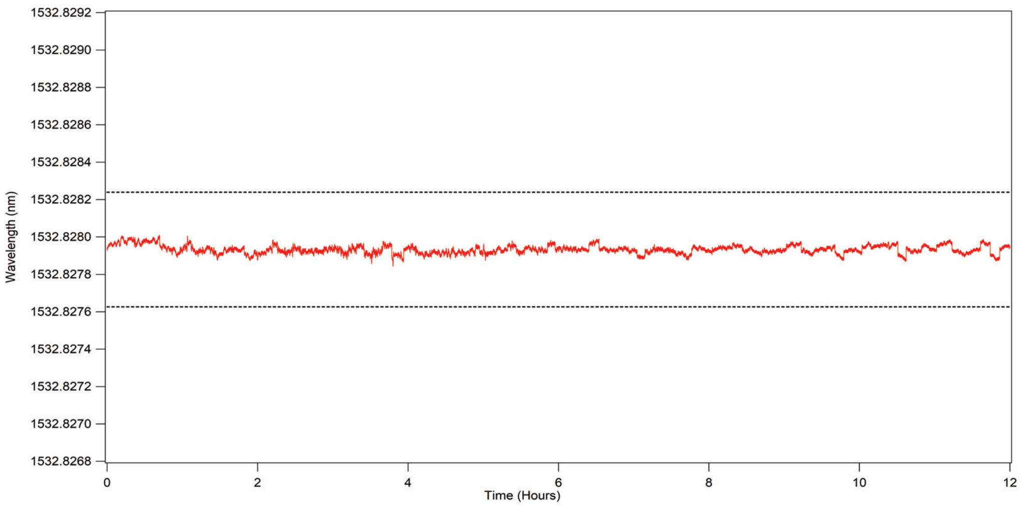


Figure 4. ***The repeatability of the model 871A-NIR is demonstrated with long-term wavelength measurement data of a DFB laser that is locked to an absorption line of acetylene. The accuracy specification of ± 0.2 ppm is shown by the dashed lines.***

The measurement repeatability specification of the 871 Laser Wavelength Meter also defines its ability to detect small changes in laser wavelength. This wavelength resolution is approximately two times the specified repeatability. Therefore, the model 871A can detect wavelength changes as small as 0.015 parts per million (5 MHz at 1000 nm). The 871B system can determine a wavelength deviation as small as 0.025 parts per million (8 MHz at 1000 nm).

Unsurpassed Measurement Rate

The 871 Laser Wavelength Meter provides the fastest wavelength measurement available. Interferometric data generated by the system's Fizeau etalons is collected by a photodetector array and quickly converted to an accurate wavelength value by an on-board digital signal processor. The result is a sustained measurement rate as high as 1 kHz that is not dependent on the connected computer.

The 871 system is able to measure the wavelength of every pulse of a laser operating at repetition rates of ≤ 1 kHz. At greater repetition rates, the system integrates all laser pulses arriving within the measurement window. In addition, the system's time resolution of 1 ms provides the most detailed wavelength characterization of tunable lasers and the fastest feedback for laser wavelength stabilization.

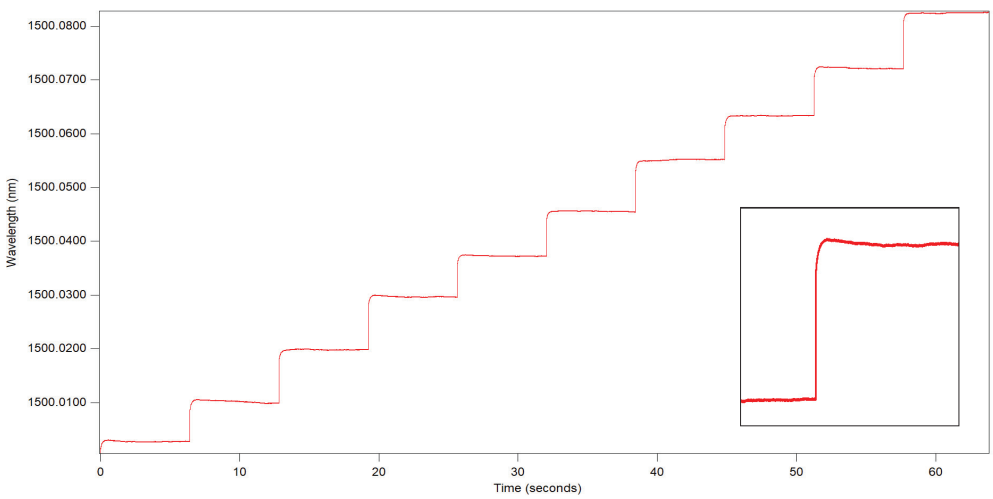


***Figure 5.** Laser wavelength vs. time of a tunable external cavity diode laser. With its speed, the 871 system has the capability of measuring the laser's tuning characteristics. Inset shows the laser overshoot and settling during the tuning process.*

OPERATION

The 871 Laser Wavelength Meter quickly measures the wavelength of pulsed and CW lasers with the reliable accuracy needed for the most meaningful experimental results. Three broad wavelength configurations and high sensitivity enable its use with a variety of laser sources. And, with versatile and convenient operation, it can be used either as a stand-alone instrument or completely integrated into an experiment.

Broad Wavelength Coverage

The 871 Laser Wavelength Meter is available in three broad wavelength configurations to satisfy many experimental requirements. These are designated as:

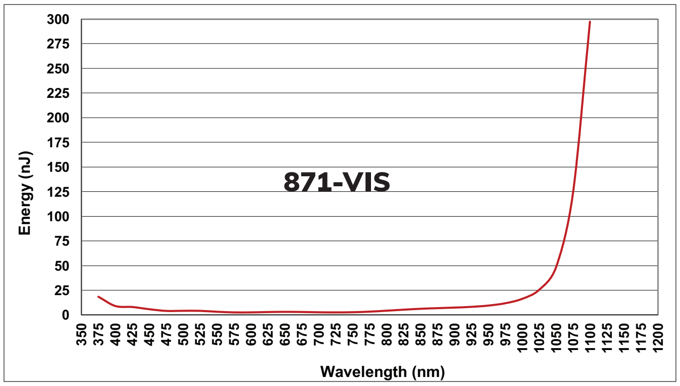
- **VIS with a detection range of 375 – 1100 nm**
- **NIR with a detection range of 630 – 1700 nm**
- **NIR2 with a detection range of 1 – 2.5 µm**

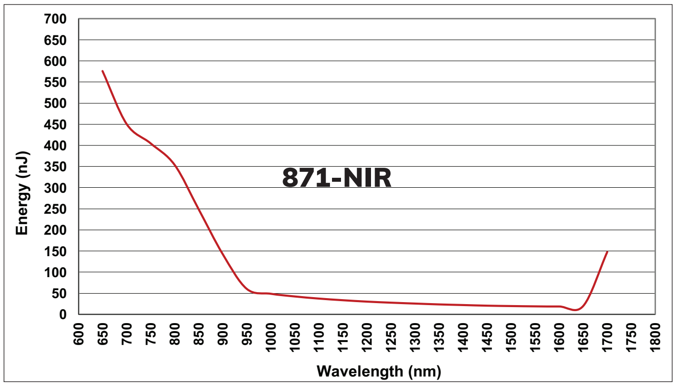
High Sensitivity

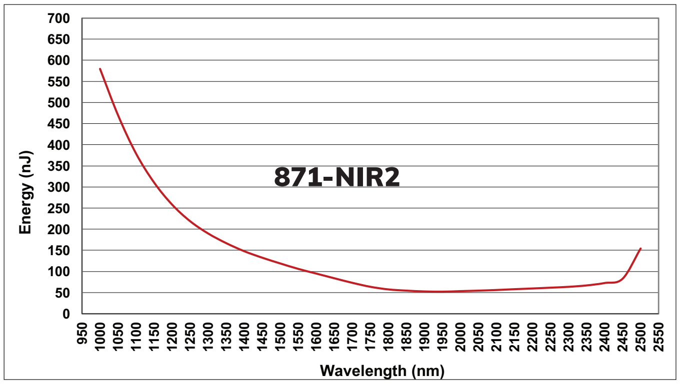
The minimum energy required by the 871 Laser Wavelength Meter from a single laser pulse is as low as 3 nJ. For CW lasers, the minimum power required can be approximated by multiplying the value for minimum energy by the frame rate of the photodetector array.

Therefore, the minimum power needed for CW lasers is as low as 3 µW when measuring at a rate of 1 kHz. For even greater sensitivity, the frame rate of the system's photodetector array can be reduced to increase the length of the measurement window thereby allowing for the integration of a greater number of laser pulses or a greater amount of CW laser power.

MINIMUM INPUT ENERGY FOR THE 871 SERIES







Broadband Laser Operation

The 871A Laser Wavelength Meter measures the wavelength of lasers with a bandwidth as large as 1 GHz to its specified accuracy of ± 0.2 parts per million. It also measures the wavelength of lasers with a bandwidth up to 10 GHz at the lower accuracy of ± 0.75 parts per million. The model 871B measures the wavelength of lasers with a bandwidth as large as 10 GHz to its specified accuracy of ± 0.75 parts per million.

Convenient Laser Input

A laser under test enters the 871 Laser Wavelength Meter through a pre-aligned FC/PC fiber-optic input connector. This ensures optimum alignment of the laser beam to the instrument's Fizeau etalons resulting in uncompromised accuracy. 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.

To achieve the specified accuracy (of ± 0.2 parts per million for the model 871A and ± 0.75 parts per million for the model 871B), a single-mode fiber for the wavelength of the laser under test must be used. Graded-index multi-mode fiber with core diameter up to 62.5 μm can be used with the 871B system for an accuracy of ± 1 part per million.

In either case, the 871 is very easy to set up, as there is no need to visually inspect, adjust, or optimize the interference pattern generated by the Fizeau etalons. All that is required to achieve the specified accuracy is to connect the input fiber to the system's FC/PC fiber-optic input connector.

Figure 6. ***Front panel of 871 Laser Wavelength Meter.***

Asynchronous Operation With Automatic Pulse Detection

When the 871 Laser Wavelength Meter is used with pulsed lasers, the wavelength measurement can be triggered automatically so that a wavelength measurement is made only when a laser pulse is detected by the system. The model 871 can also be triggered by a user-supplied signal for custom applications. For operation with CW lasers, wavelength measurements are made continuously at the chosen frame rate of the photodetector array.

Versatile Instrument Interface

The 871 Laser Wavelength Meter determines wavelength in real-time using an on-board digital signal processor. Therefore, the measured wavelength information can be reported or used in a variety of ways.

***Figure 7.** 871 Series rear panel showing connection layout.*

- Data can be transferred to a PC and displayed using a Windows-based software program provided by Bristol Instruments. The 871 system can connect directly to the PC using USB, or over a local area network using Ethernet.
- The 871 Laser Wavelength Meter can be integrated into an experiment for automatic wavelength reporting and control, eliminating the need for a dedicated PC. Wavelength information can be sent directly to an experiment's PC via USB or Ethernet using SCPI (Standard Commands for Programmable Instruments) programming. SCPI is more intuitive for custom programming with LabView and other languages and also enables operation with any PC operating system.
- An RS-422 serial interface is available for data streaming in order to realize the 871 system's measurement rate of 1 kHz. This data streaming can be triggered by the instrument itself, or with a user-supplied trigger signal.
- The 871 system will store as many as 1 million measurements to an internal data buffer for analysis at a later time.

Wavelength Measurement Display

The NuView™ software provided with the 871 Laser Wavelength Meter reports measurement data with an easy-to-read display. It offers many user customizable features to tailor measurements to a specific application.

Measurement units can be expressed in wavelength (nm or µm), wavenumber (cm^{-1}), or frequency (GHz or THz). Every measurement can be displayed, or a rolling average of as many as 100 measurements can be calculated automatically. Wavelength data can also be logged to a file using a *.csv format for analysis with other graphing programs.

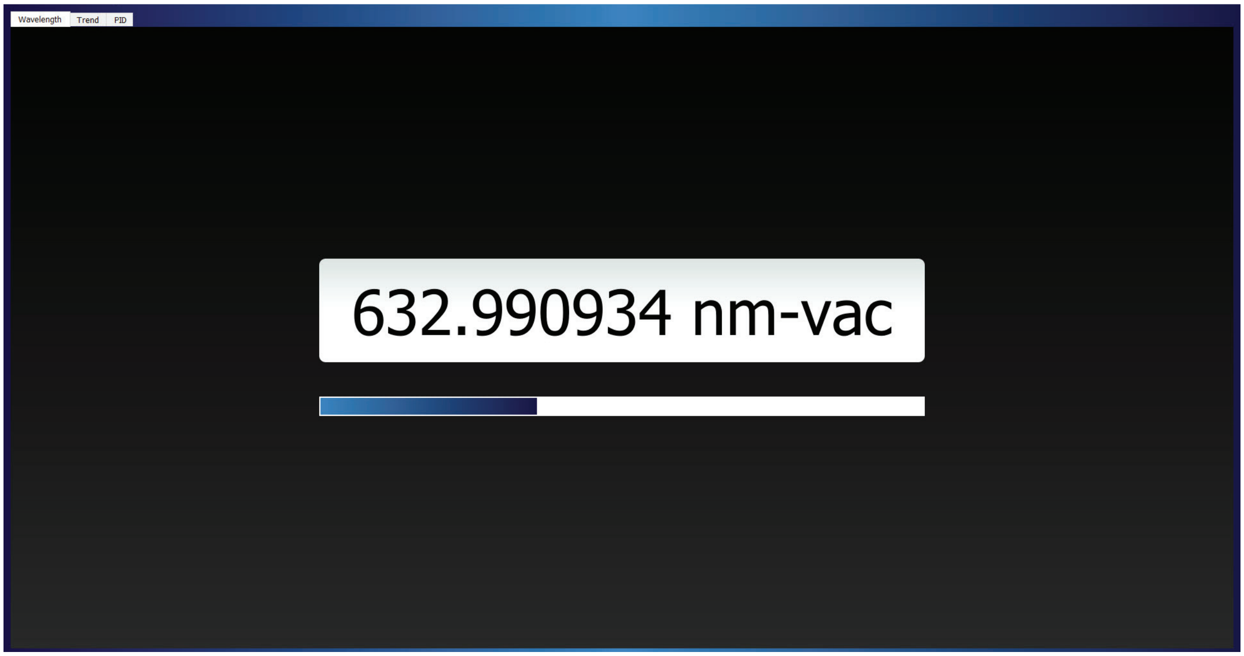


***Figure 8.** Sample NuView™ software display shown above of 871 wavelength measurement.*

Wavelength Measurement Trends

The 871 Laser Wavelength Meter display software offers an integrated wavelength trending feature that charts a laser's wavelength over time. A rolling graphical trace of up to 100,000 wavelength measurements can be 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.

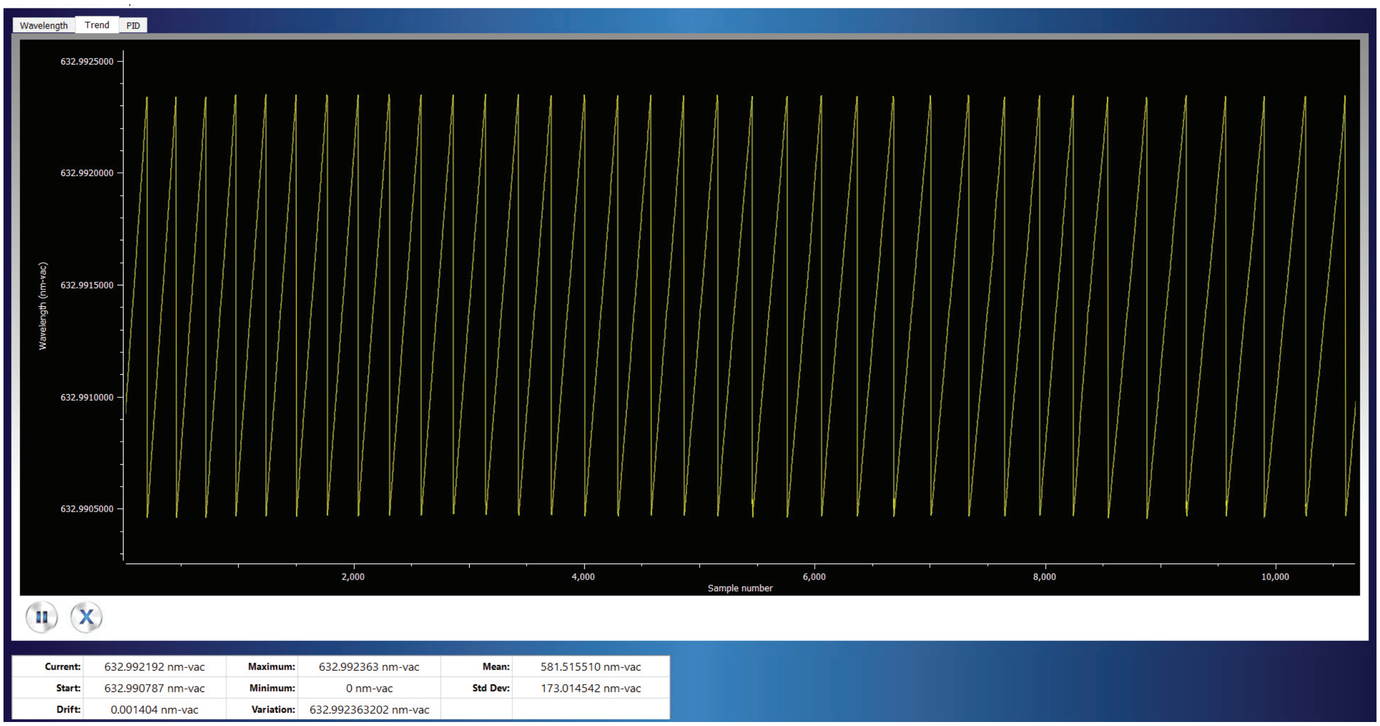


Figure 9. ***NuView™ software display of 871 wavelength measurement trend of a 633 nm laser with statistics table below.***

Built-In PID Controller

The 871 Laser Wavelength Meter includes a built-in Proportional-Integral-Derivative (PID) Controller that can be used to stabilize the wavelength of a laser. This is useful in experiments for which laser wavelength must be actively regulated (e.g. : atomic detection, laser cooling/trapping/manipulation, and Raman spectroscopy).

The PID Controller compares the current wavelength measurement to the user's set point and then generates a digital error signal. This error signal is converted to an analog output voltage that can be used to stabilize laser wavelength so that it is unaffected by changing experimental or environmental conditions. This voltage is delivered through a BNC connector on the back panel of the 871 system.

The PID calculation uses three user-defined error parameters. The first parameter, K_P, accounts for the current (Proportional) error magnitude and has the highest contribution to guiding the measured wavelength towards the desired wavelength. The second parameter, K_I, accounts for the sum of past errors (Integral) to minimize the effects of outlying data peaks or spikes on the correction voltage. The third parameter, K_D, factors in the current rate of change (Derivative) to avoid oscillation about the desired wavelength. These three components work together to ensure swift correction of the laser to the desired wavelength without overshooting or oscillating.

Operation of the PID controller is done using the PID Screen of the 871 system's display software. This screen allows entry of PID parameters and displays measured wavelength, wavelength error, and output voltage.

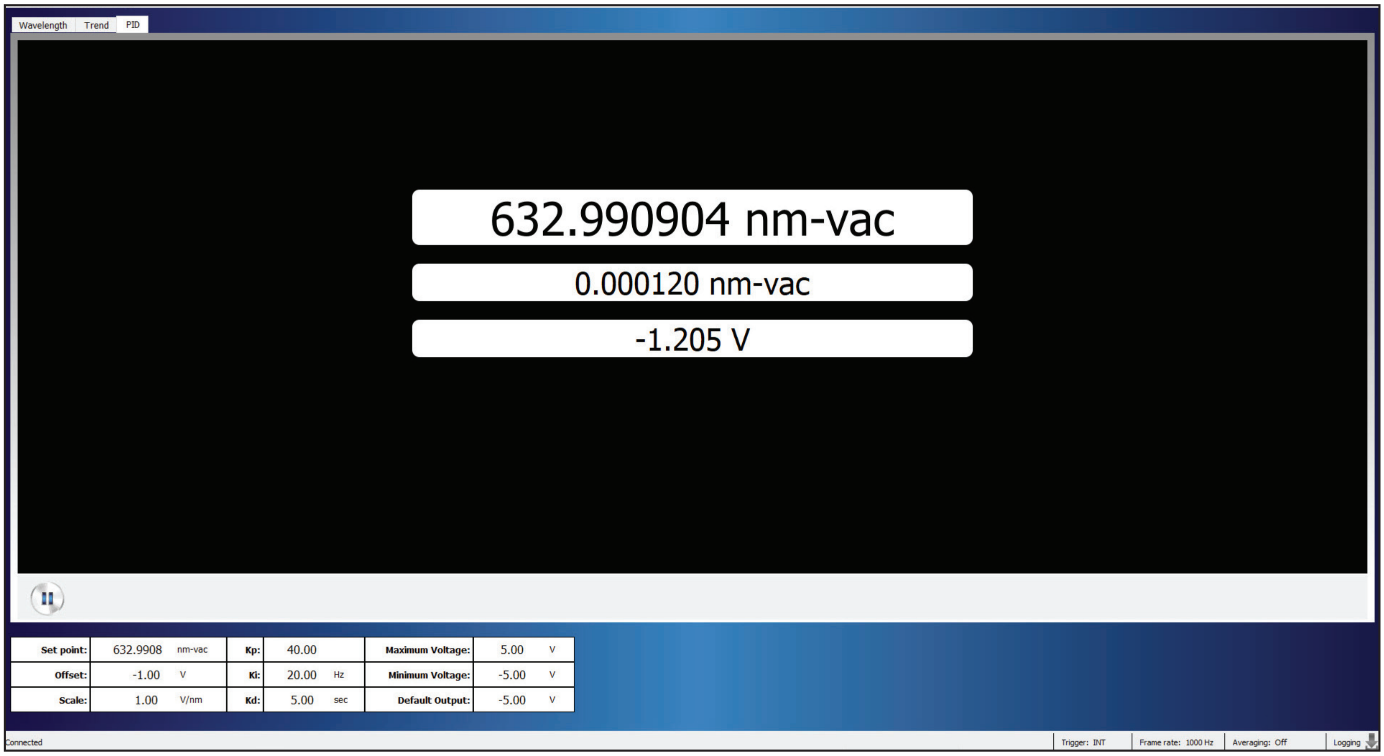


***Figure 10.** NuView™ software display showing wavelength, wavelength error, and PID output voltage.*

SPECIFICATIONS — 871 Series

MODEL	871A	871B
LASER TYPE	Pulsed and CW	
WAVELENGTH		
Range	VIS: 375 - 1100 nm NIR: 630 - 1700 nm	VIS: 375 - 1100 nm NIR: 630 - 1700 nm NIR2: 1000 - 2500 nm
Accuracy [1, 2, 3]	± 0.2 ppm (single-mode fiber) ± 0.0002 nm @ 1000 nm ± 60 MHz @ 300,000 GHz	± 0.75 ppm (single-mode fiber) ± 0.0008 nm @ 1000 nm ± 225 MHz @ 300,000 GHz ± 1 ppm (multi-mode graded-index fiber ≤ 62.5 µm diameter) ± 0.001 nm @ 1000 nm ± 300 MHz @ 300,000 GHz
Repeatability [3, 4, 5]	0.0075 ppm 0.0075 pm @ 1000 nm 2.25 MHz @ 300,000 GHz	0.0125 ppm 0.0125 pm @ 1000 nm 3.75 MHz @ 300,000 GHz
Calibration [6]	Automatic with built-in wavelength standard	
Display Resolution	9 digits	8 digits
Units [7]	nm, µm, cm^{-1}, GHz, THz	
OPTICAL INPUT SIGNAL		
Maximum Bandwidth (FWHM)	1 GHz	10 GHz
Minimum Input [8, 9, 10, 11]	VIS: 3 - 300 nJ NIR: 50 - 600 nJ	VIS: 3 - 300 nJ NIR: 30 - 600 nJ NIR2: 50 - 600 nJ
Maximum Input	CW: 10 mW Pulsed: 0.5 mJ (10 ns duration)	
MEASUREMENT RATE	1 kHz (VIS / NIR)	1 kHz (VIS / NIR) 1.5 kHz (NIR2)
INPUTS/OUTPUTS		
Optical Input [12, 13]	Pre-aligned FC/PC fiber connector (optional free beam-to-fiber coupler)	
Instrument Interface	USB and Ethernet interface with Windows-based display program Streaming via RS-422 (internal or external TTL trigger) Internal data storage for up to 1 million measurements Library of commands (SCPI) for custom and LabVIEW programming using any PC operating system PID controller (± 5 V output)	
COMPUTER REQUIREMENTS [14]	PC running Windows 10/11, 1 GB available RAM, USB 2.0 (or later) port, monitor, pointing device	
ENVIRONMENTAL[8]		
Warm-Up Time	< 15 minutes	
Temperature | Pressure | Humidity	+15°C to +30°C (-10°C to +70°C storage) | 500 – 900 mm Hg | ≤ 90% R.H. at + 40°C (no condensation)	
DIMENSIONS AND WEIGHT		
Dimensions (H x W x D)	3.5" x 17.0" x 15.0" (89 mm x 432 mm x 381 mm) Includes mounting hardware for 19-inch racks	
Weight	17 lbs (7.65 kg)	
POWER REQUIREMENTS	90 - 264 VAC, 47 - 63 Hz, 50 VA max	
WARRANTY	5 Years (parts and labor)	

(1) Defined as measurement uncertainty, or maximum wavelength error, with a confidence level of ≥ 99.7%.
(2) Traceable to accepted physical standards.
(3) Single-mode input fiber must have single-mode performance at the wavelength of the laser under test.
(4) Standard deviation for a 1 minute measurement period after the instrument has reached thermal equilibrium. Standard deviation for a 10 minute period is about twice the 1 minute specification.
(5) Wavelength resolution is approximately two times repeatability.
(6) For VIS version, stabilized single-frequency HeNe laser. For NIR and NIR2 versions, laser diode locked to acetylene absorption (NIST Special Publication 260-133).
(7) Data in units of nm, µm, and cm^{-1} are given as vacuum values.
(8) Characteristic performance, but non-warranted.
(9) Required minimum energy from a single laser pulse. Greater sensitivity is achieved by increasing the length of the measurement window to allow for the integration of a greater number of laser pulses.
(10) Required minimum power is approximated by multiplying the required minimum energy by the selected measurement rate.
(11) Sensitivity at specific wavelengths can be determined from graphs that are provided in the 871 Series Product Details brochure.
(12) Visual inspection and optimization of the interference fringe pattern is not required.
(13) An FC/PC terminated input fiber is required. System will not operate with FC/APC terminated fiber.
(14) For use with Windows-based display program. Interfacing via SCPI can be done using any PC operating system.

CLASS 1 LASER PRODUCT
IEC 60825-1 (2014)

CE

Bristol Instruments reserves the right to change the specifications as may be required to permit improvements in the design of its products.
Specifications are subject to change without notice.

REV 06-25