Enter a new world of accuracy with HighFinesse/Ångstrom sensitive, compact wavelength meters.

- **The most accurate instruments available**
  Absolute accuracy up to ± 2 MHz with a measurement resolution of 500 kHz
- **Extremely wide wavelength range**
  From hard UV to MID-IR (192 nm – 11 µm)
- **Extended range version: combined detectors**
  One instrument for all (330 – 1750 nm or 500 – 2250 nm)
- **Unrivaled technology without moving parts**
  Highspeed measurement (up to 600 Hz) and feedback control of up to 8 pulsed or cw lasers
- **Fizeau-interferometer technique**
  Insensitive to intensity fluctuations or sidemodes
- **Quick and easy to use due to ultra sensitive detectors**
  < 50 pJ @ 500 nm
- **Ultra wide optical spectrum analyzers for cw and pulsed lasers**
  330 – 1100 nm at once with 10 pm resolution

Ångstrom

HighFinesse
Laser and Electronic Systems

Technical Data		Unit	WS5	WS6		WS7	WSU			LSA	HDSA
				6-600	6-200		U-30	U-10	U-2		
Measurement range	Standard (330 – 1180 nm)		●	●	●	●	●	●	●	●	●
	UV-I (248 – 1180 nm)		●	●	●	●	●	○	○	●	●
	UV-II (192 – 800 nm)		●	●	●	●	○	○	○	●	●
	UV-II/VIS (192 – 1180 nm)		○	○	○	○	○	○	○	●	○
	VIS/IR (330 – 1750 nm)		●	●	●	○	○	○	○	●	○
	VIS/IR-II (500 – 2250 nm)		●	●	●	○	○	○	○	○	○
	IR-I (630 – 1750 nm)		●	●	●	●	●	●	○	●	●
	IR-II (1000 – 2250 nm)		●	●	●	●	●	○	○	●	○
	IR-III (2 – 11 µm)		●	○	●	○	○	○	○	●	○
Absolute accuracy [6]	192 – 330 nm [1]	pm	3	0.6	0.4	0.2	0.1	0.1	0.1	6	–
	330 – 420 nm	pm	2	0.3	0.2	0.04	0.02	0.01	0.01	3	3
	420 – 1100 nm	MHz	3000	600	200	60	30	10 [4]	2 [5]	6000	3000
	1100 – 2250 nm	MHz	2000	400	150	40	20	10 [4]	–	12000 [8]	3000
	2 – 11 µm	MHz	3000	–	200	–	–	–	–	1 – 5 nm [13]	–
Quick coupling accuracy (with multi mode fiber)		MHz	3000	600	600 [14]	150	100			20000	30000
Wavelength deviation sensitivity/Measurement resolution [2]		MHz	1000	100	50	10	5	2	0.5 [5]	3000 [8]	2000
Linewidth option [2]	Accuracy	MHz	2000 [3]	500 [3]	400 [3]	200 [3]	100 [3]			7000 [3]	15000
Measurement speed [7] (depending on PC hardware and settings)	Data acquisition	Hz	600		500					500	20
	Wavelength calculation	Hz	600		400					60	5
	Linewidth calculation	Hz	500		400					50	5
Required input energy and power	Standard	µJ (or µW) [11]	0.02 – 15							0.0001 – 0.04	0.05 – 10
	UV-I	µJ (or µW) [11]	0.02 – 10					–	–	0.0001 – 0.1	–
	UV-II	µJ (or µW) [11]	0.02 – 200			0.01 – 100	–	–	–	0.0001 – 0.1	–
	IR-I	µJ (or µW) [11]	2 – 200		1 – 100	2 – 200			–	0.02 – 2	0.05 – 10
	IR-II	µJ (or µW) [11]	2 – 80 [12]				–	–	–	–	–
	IR-III	mW	1	–	1	–	–	–	–	0.2	–
Calibration			Built-in calibration [16]			Built-in calibration [10]	Stabilized HeNe laser or any other well known laser source $\Delta\nu < 3$ MHz		SLR-780 or any well known laser source $\Delta\nu < 1$ MHz	Built-in calibration [16]	External calibration source (included)
Recommended calibration period			≤ 1 month			≤ 14 days	≤ 10 hours	≤ 1 hour	≤ 2 minutes	≤ 1 month	≤ 2 weeks
Warm-up time			No warm-up time under constant ambient conditions [15]				> 30 minutes			No warm-up time under constant ambient conditions [15]	
Dimensions L × W × H		mm	360×120×120		360 × 200 × 120					325×180×77	360×210×120
Weight		kg	2.8		5.3	6.1	6.4			2.8	4.8
Interface			High-speed USB 2.0 connection								1000BASE-T
Power supply			Power consumption < 2.3 W, power provided directly via USB cable IR-II, IR-III: external power supply included; IR-I and WSU via USB or external power supply possible								external power supply included

1) With multi mode fiber
2) Only for standard range
3) But not better than 5% (LSA: 10%) of the linewidth
4) ± 200 nm around calibration wavelength
5) ± 2 nm around calibration wavelength
6) According to 3σ criterion
7) Without switch and autocalibration usage
8) IR-ranges: please see LSA data sheet
9) HDSA ranges differ from WLM values. For further info please check HDSA data sheet.
10) Not IR-devices. External calibration source needed, e.g. SLR-1532
11) The cw power interpretation in [µW] compares to an exposure of 1s (generally the energy needs to be divided by the exposure time to obtain the required power)
12) µJ interpretation for pulsed lasers; cw signals need more power in [µW] since the exposure is limited at IR-II devices
13) depending on device type
14) 200 MHz for WS6-200 IR-III
15) IR-II: >30 min. warm-up, or until ambient equilibrium
16) IR-III: external reference required, e.g. SLR-1532

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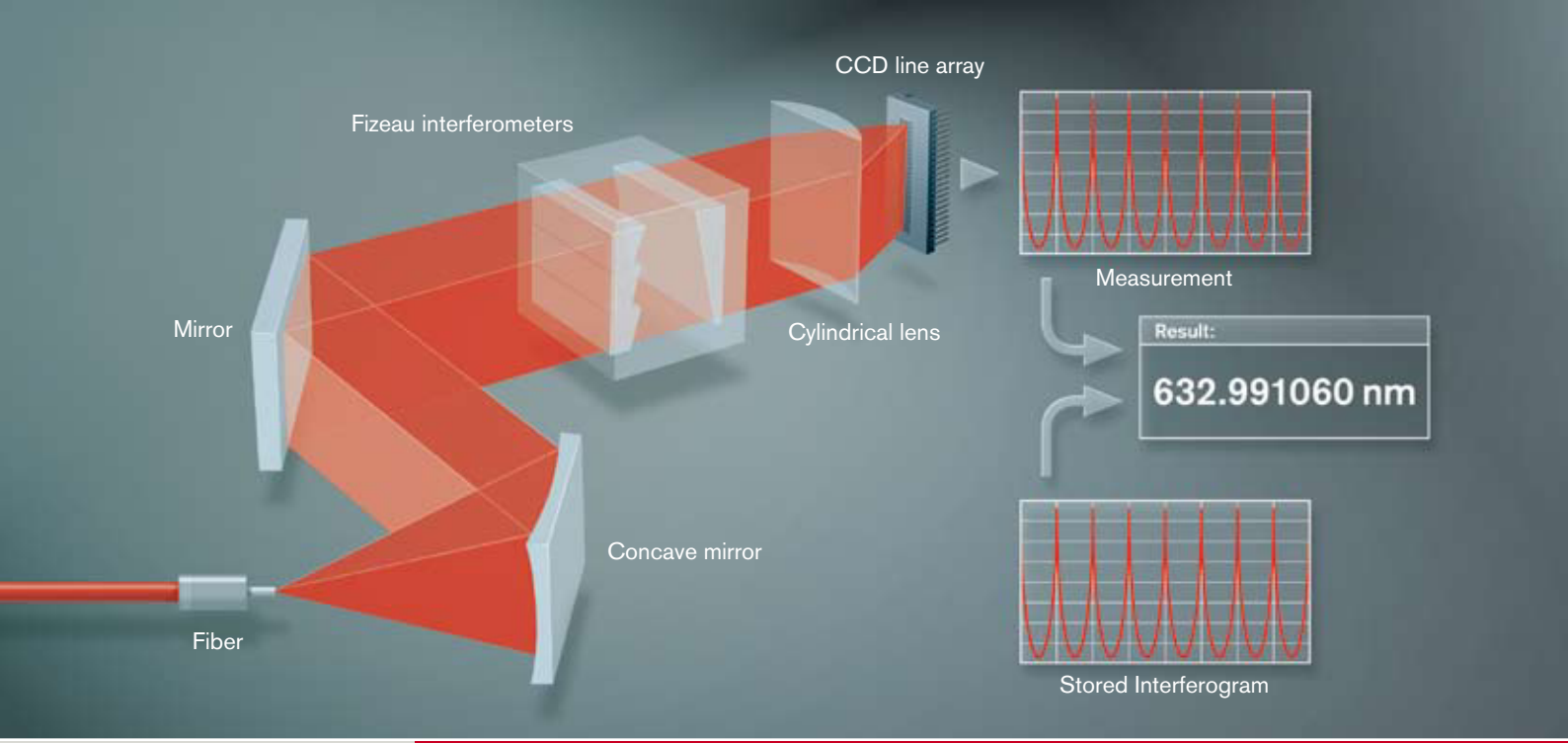


The optical unit consists of Fizeau-based interferometers which are read out by photodiode arrays. We achieve remarkable high accuracy and stability by using exclusive, solid-state, non-moving optics.

The light is coupled into the device via a fiber and then collimated by a mirror, before entering the solid-state Fizeau-interferometers. The interference pattern is projected by a cylindrical lens onto CCD photodiode arrays. This recorded pattern is transferred to your computer via a high-speed USB 2.0 connection which allows data acquisition rates of up to 600 Hz. The software fits and compares the pattern to the previously recorded calibration to calculate the wavelength.

One significant advantage of our Fizeau-based wavelength meters, compared with other available instruments, is the absence of mechanical moving parts. This ensures the high reliability of accuracies up to 2 MHz (absolute) and ensures the outstanding robustness HighFinesse wavelength meters are noted for. The sturdiness of this design has been proven even under extreme conditions such as freefall dropping experiments or in air-borne applications (LIDAR).

Another key benefit is the simplicity our wavelength meters offer. Simply connect the USB cable and run the program supplied. That's all it takes! An additional power supply is not necessary (except WSU and IR-Option), which makes handling especially safe and easy.

The optical unit and the associated electronics are packaged in a compact, thermally insulated housing. The device is connected to the computer via high-speed USB 2.0 port. The user-friendly graphical interface displays all interferometer information and is compatible with Windows. Additionally, all necessary controls and actions can be set, read and performed via external software access. An easy-to-use API can be accessed to completely integrate wavelength meter functionality into your own applications, with development environments such as C/C#/C++, Delphi, VB/VBA, LabVIEW, CVI, HP-Vee and other software.

Basic Features of the Standard Instruments:

■ Pressure consideration for enhanced measurement stability

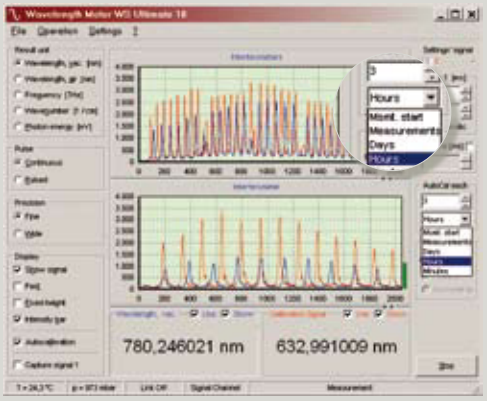
Measurements are temperature and (new) pressure compensated using ultra sensitive temperature and pressure sensors. That way it is possible to use the devices in aviatic measurement environments, high altitudes, LIDAR, ...

■ Thermal insulation for enhanced measurement stability

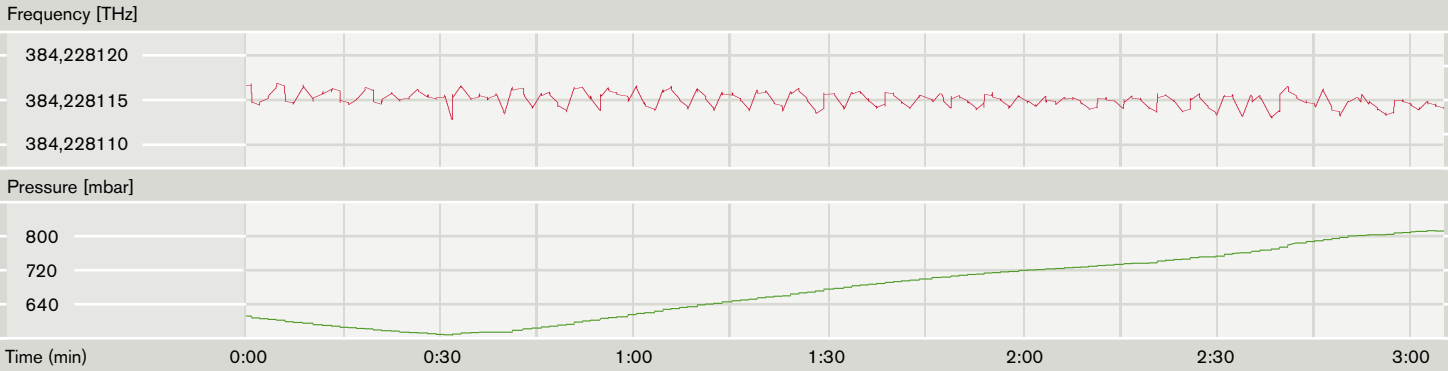
The following graph shows a measurement of a WS6-600 in a climate chamber. The thermally insulated casing contributes to the high stability of wavelength measurements. The internal temperature sensor compensates for thermal drifts.

■ Measurement of Wavelength & Frequency

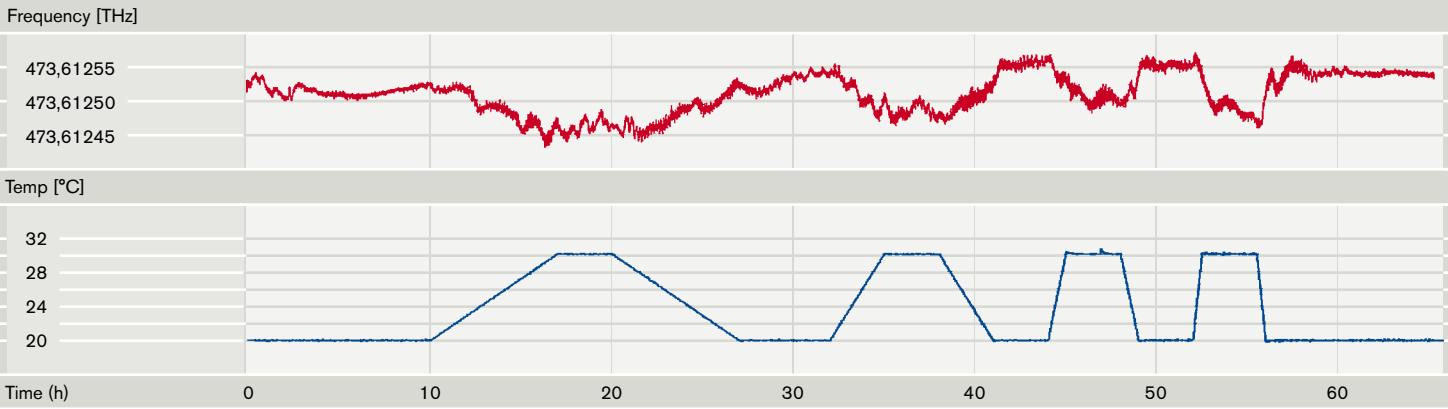
The measurement result is displayed on the computer via the supplied software and graphical user interface. Installation and set-up are fast and easy. The displayed results may be switched between wavelength, frequency, wavenumber or energy to suit your requirements. The interference pattern displayed provides information regarding the spectral profile of pulsed or continuous wave laser sources.



Stability of pressure (Ultimate 2, autocalibration with SLR 780)



Stability of temperature (WS-7, no calibration during whole 3 days measurement)



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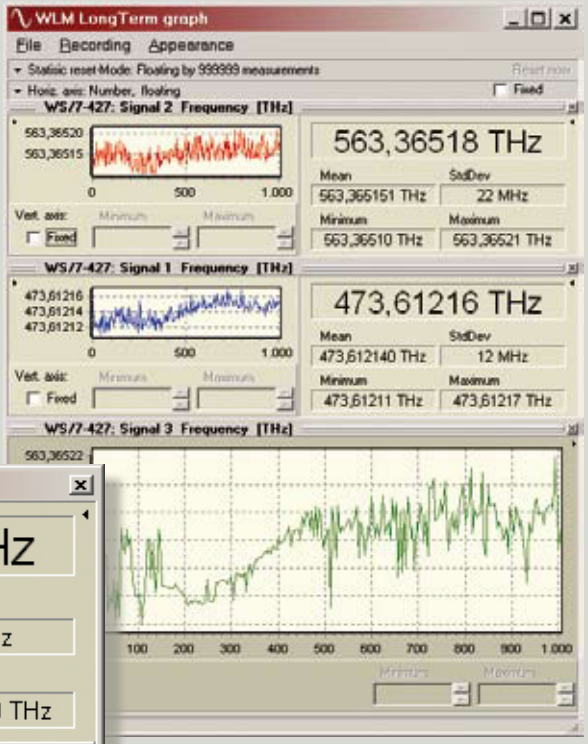
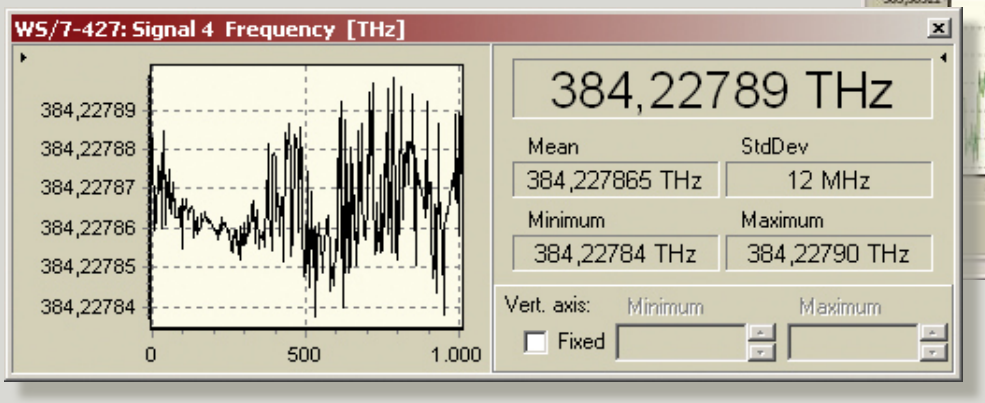
■ Record and Replay Mode

The recording operation mode records all interferometric and measurement-related data to a file and allows subsequent playback.

■ Long-term Measurement

This application acquires the measured wavelength and other values (temperature, analog output, etc.), displaying mean, max. and min. wavelengths as well as standard deviations. The software also allows the user to display the idler frequency, by measuring the pump and signal laser, or by showing the frequency distance between two lasers (THz generation). Any number of long-term windows may be opened simultaneously to monitor up to 8 laser sources (multi-channel option) per wavelength meter. No other product offers this flexibility.





■ Internal calibration

LSA, WS5, WS6, WS6-200 and WS7 have as a standard feature automatic internal calibration. The calibration period is selected either by measurement counts or time between calibrations.

■ Autocalibration

An external calibration source can be connected to a second FC/PC port for WSU-30 and WSU-10 calibration. With WSU-2 autocalibration can be performed via optical switch.

■ Quick coupling possibility

You can easily couple in using a 400 µm fiber by positioning the collimator in the beam by hand. If your laser runs between 370 – 900 nm a power output of approximately 10 µW is sufficient for free-hand coupling.

■ Built-in pulse detection

An integrated mechanism detects the optical peaks from a pulsed laser and allows synchronization with the measurement process.

■ Low power sensitivity

Highest sensitivity for exteme low power applications. This customized option offers special optical coatings that allow highest power sensitivities down to the pJ-range for our wavemeters (WS7) and spectrometers (LSA). Please contact us for further details!

Sensitivity of WS-series in the available measurement ranges as well as LSA and the new IS-series in standard range of 370 – 1100 nm.

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Calibration and Certification

To ensure the high quality and accuracy HighFinesse products are noted for, each wavelength meter is tested and calibrated individually. For this purpose, we use various high-precision laser systems:

Nd:YAG Laser

The diode pumped solid-state laser is frequency doubled and emits at 532 and 1064 nm. The laser frequency is locked to the iodine molecule absorption line R56, 32-0. The frequency of this line is 563.259 651 965 THz[Hol] corresponding to a vacuum wavelength of 532.245 576 181 nm. The uncertainty of this laser system is < 1 MHz.

HeNe Laser

The shown frequency stabilized HeNe-laser emits with a frequency of 473.612 467 THz corresponding to a vacuum wavelength of 632.991 060 nm. The laser has an uncertainty of ± 2×10^{-8}.

Frequency doubled Rubidium Spectroscopy Laser

A grating stabilized semiconductor laser diode is locked to a Rb-transition using saturated absorption spectroscopy. Its frequency is doubled with a PPLN crystal. The frequency of the $5S_{1/2}$ F=2 → $5P_{3/2}$ F'=3 transition[Mar] of ^{87}Rb is 384.228 115 147 THz corresponding to a vacuum wavelength of 780.246 021 nm . The respective wavelength after frequency doubling is 390.123 010 nm. The linewidth of this laser system is < 1 MHz.

The measurement uncertainties of the different types of wavelength meters are estimated in accordance with the NIST Guidelines[Tay] as follows:

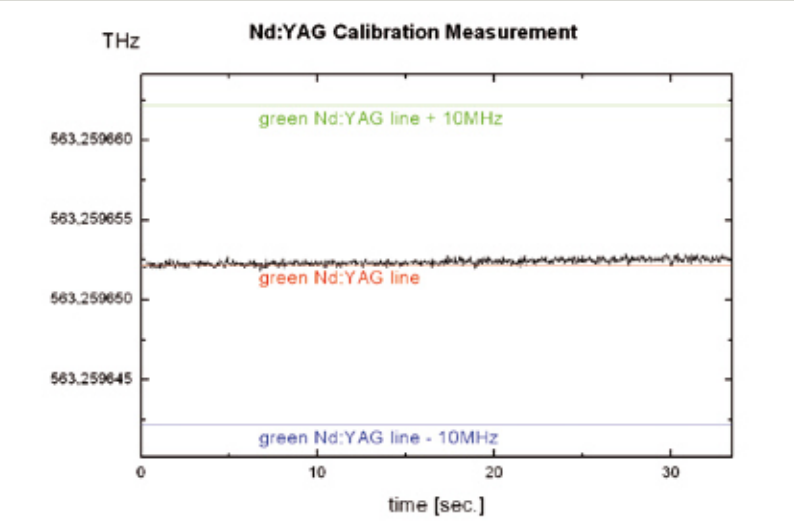
	Abs. accuracy[1]
LSA	6000 MHz
HDSA	3000 MHz
WS5	3000 MHz
WS6-600	600 MHz
WS6-200	200 MHz
WS7	60 MHz
WSU-30	30 MHz
WSU-10[2]	10 MHz
WSU-2[3]	2 MHz

1) in the range 370 – 1100 nm
2) ± 200 nm around calibration point
3) ± 2 nm around calibration point

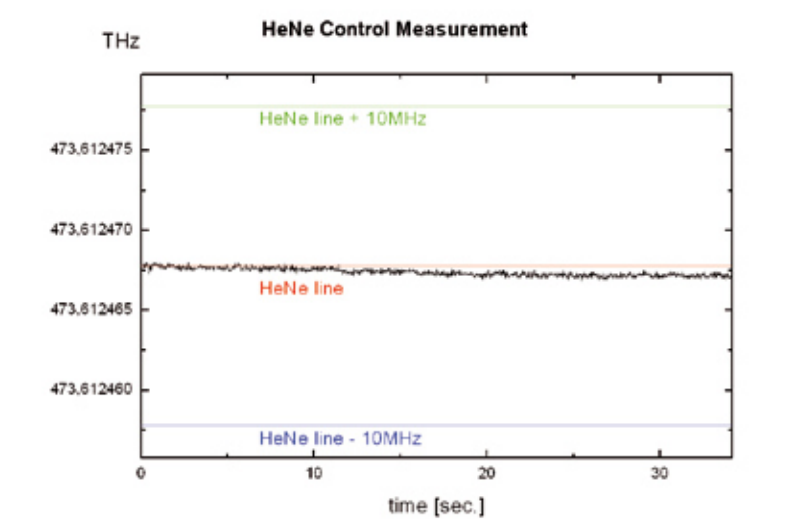
[Hol] R. Holzwarth et al., *Absolute frequency measurement of iodine lines with a femtosecond optical synthesizer*, Appl. Phys. **B 73**, 269-271 (2001).

[Mar] A. Marian et al., *Direct Frequency Comb Measurements of Absolute Optical Frequencies and Population Transfer Dynamics*, **PRL 95**, 023001 (2005).

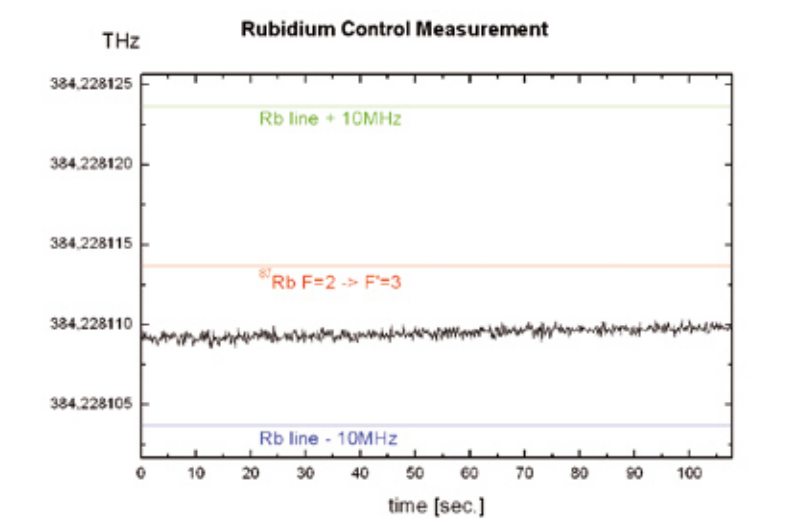
[Tay] B. Taylor and C. Kuyatt, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, NIST Technical Note **1297** (1994).



Typical measurement of an Ultimate-10 after calibration with this Nd:YAG line.



Typical measurement of a stabilized HeNe laser after calibration with the Nd:YAG laser system.



Typical measurement of the Rb-line after calibration with the Nd:YAG laser system.

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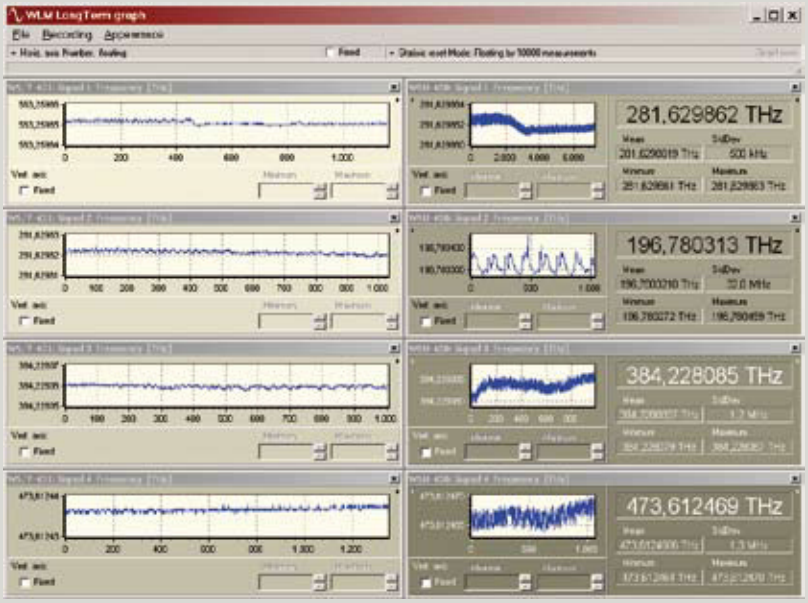
The flexible design of our wavelength meters allows the integration of additional optical components and software modules, enabling customization for your specific application requirements.

The following standard options are available:

Multi Channel Option (MC)
In order to measure the frequencies of more than just one laser at a time, an opto-mechanical switch (MEMS) is used. The combination of our high-speed wavelength meters with one of the quickest fiber switches (MEMS) available allows the measurement of up to 8 channels almost simultaneously. Exposure time and other parameters can be defined independently for each light source.

- Spectral range: 250 nm – 2200 nm
- Fiber: Multimode or Singlemode
- Lifetime: > 10^9 cycles
- Cycle time: 0.2 sec/8 channels



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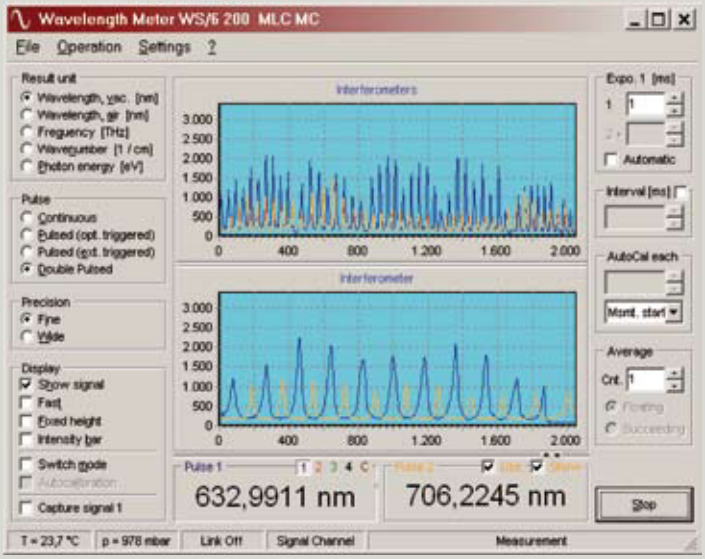
… Multi Channel Option (MC)

The multi-channel switch option provides the possibility for auto-calibration. Any well known laser source connected to the switch can be used for wavelength meter calibration as needed. For WSU we recommend singlemode switches. Multimode switches only allow quickcoupling accuracy.

■ Double-Pulse Trigger Option (DP)

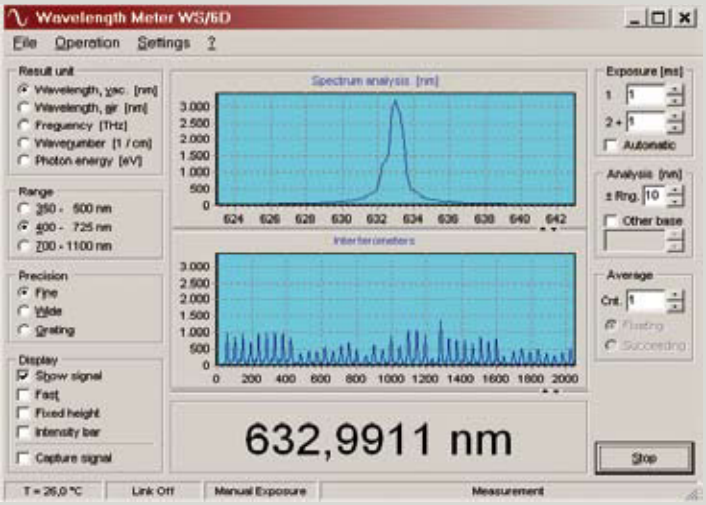
Detecting two different subsequent pulses supplied by one fiber and treating them as individual signals is possible using the double pulse option. In this mode the wavemeter is triggered externally. This allows additional applications as pump and probe measurements for instance.



This figure shows a measurement using the double-pulse option, where two readings are performed in very quick succession to allow pump and probe measurements.

■ Linewidth Option (L)

The linewidth estimation of a single-mode laser source is performed by a special algorithm which eliminates the interferometer's instrument response function. The algorithm enables the estimation of the linewidth several times better than the instrumental linewidth. The linewidth option can also be used for measuring the linewidth of multimode lasers or lasers with sidebands. In this case, the longitudinal mode splitting needs to be less than 300 MHz and the calculated result is the FWHM of the envelope function of the multi-line spectrum. Any instrument can be upgraded with the L-option, single mode fibers are required.



Graphical user interface of WS6D. The upper graph shows the grating broadened spectrum, the lower graph the Fizeau interferometer pattern of a HeNe.

■ Diffraction Grating Hybrid Option (D)

The diffraction grating option allows the analysis of the emission spectrum to an accuracy of 6 GHz, for laser sources with broad emission (but $^1/_5$ of the width in best case). The software automatically searches the spectral section where the laser emission line s located and displays it on the screen. In combination with the additional Fizeau interferometer array this allows wide range applications with a single device.

■ TTL-Trigger Option (TTL)

This option allows the user to trigger pulsed measurements externally. There are two different ways to trigger. In mode 1 the TTL-pulse starts the read out of the arrays. Afterwards the CCD-arrays are illuminated until the next TTL-pulse is detected. In mode 2, the TTL-pulse starts the measurement for a user-defined period of time. The TTL option guarantees synchronization between pulsed excitation and measurement. It provides low-noise, pollution-free signals when measuring pulsed signals with low duty cycles.

■ Low Power Option (LP)

For applications with extreme low powers we can heighten the sensitivity of our wavemeters (WS7) and spectrometers (LSA) by a factor of 1000 - down to required input energies of as low as 30 pJ! This customized option offers special optical coatings that allow highest power sensitivities in a narrow measurement range (~3nm) that can be customized to the customers requirements. Please contact us for further details!

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■ Laser Control Option (PID)

Make the laser do what you want it to do! As opposed to bulk error signal generation, the PID option provides full signal processing, accomplished by a software-based Proportional-Integral-Derivative (PID) controller. This option is very useful in experiments where the laser frequency has to fit changing experimental conditions, such as laser cooling, atomic detection, trapping and manipulation as well as Raman spectroscopy and other experiments where the laser frequency has to be actively regulated.

The regulation speed is generally the measurement speed of the Wavelength Meter. Regulations do not slow down the measurements. The regulation quality is the same as the Wavelength Meters' measurement deviation sensitivity and the absolute regulation accuracy is the same as the device's absolute measurement accuracy.

The PID option can do even more: it provides a function generator enabling the user to make the laser's frequency follow any arbitrary mathematical function, e.g. a sine, triangle, rectangle, stairs, trapezoid functions, etc. or any combination thereof.

The add-on program PID-SIM can be used to automatically detect the best regulation parameters and synchronize them with the main program. This method makes it easy to determine optimal regulation parameters. Additionally this program can be used as a regulation database, storing any number of named regulation sets.

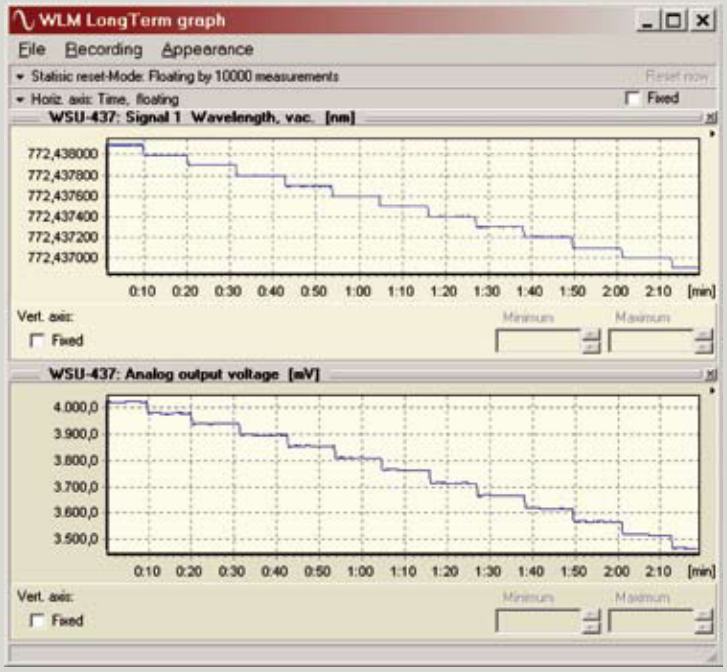
As an example, the figure on the right shows a step-modulation of a DFB laser diode running at 772 nm. The regulation of the emission frequency is done by the signal processing of the PID-controller option. The basic idea is to let the wavelength meter read the actual frequency and pass the result to the signal-processing part of the software, i.e. the PID option. By comparing the measurement result to the desired setpoint, an error signal is generated. The error signal is used by the software PID-controller to calculate the control signal which mainly consists of three contributing parts:

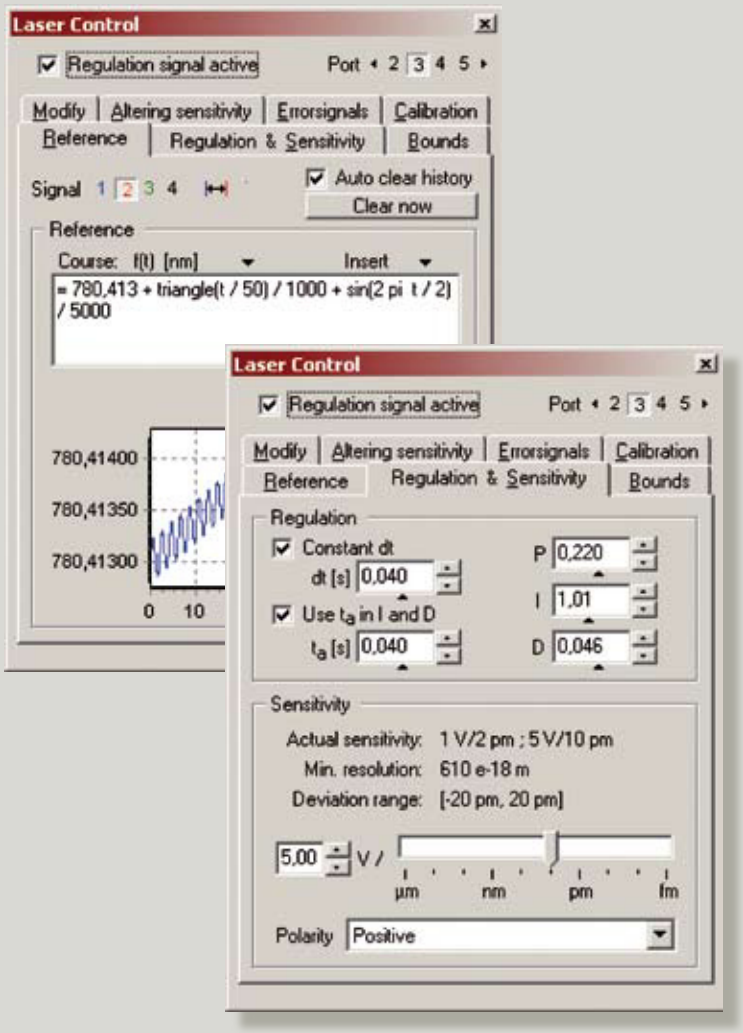
- To "handle the present", the error is multiplied by the proportional parameter P, to drive the output towards the setpoint. The proportional part cares for regulation speed.

- To "handle the past", the error is integrated over a period of time, and multiplied by the parameter I. The integral part is slow but can take setpoint errors into account.

- To "handle the future", the first derivative of the error is calculated with respect to time and multiplied by the derivative parameter D. This enables the controller to compensate over regulations and resident errors (drift).

The single parameters of the proportional (P), integral (I), and derivative (D) parts and the total output gain (V/nm) can be set independently or generated automatically (PID-Sim).





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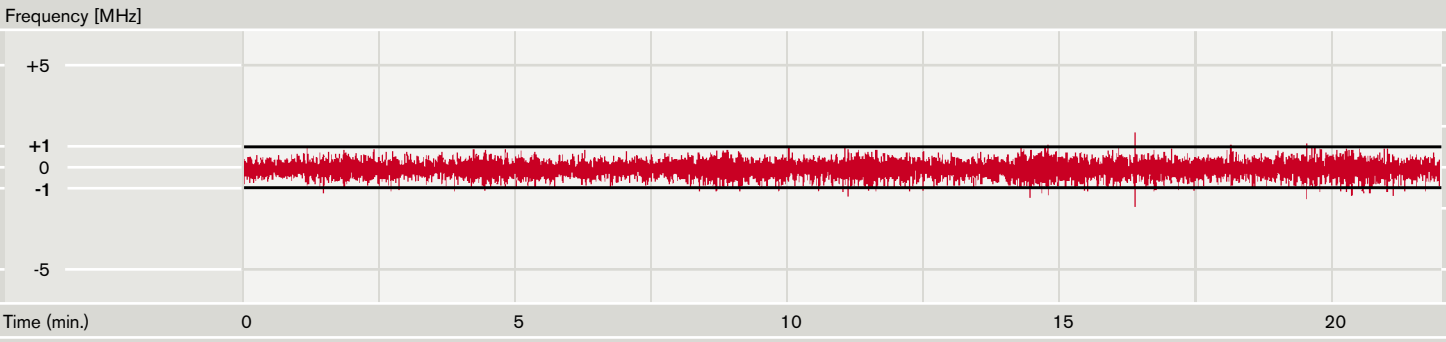
Measurement WS-Ultimate-PID

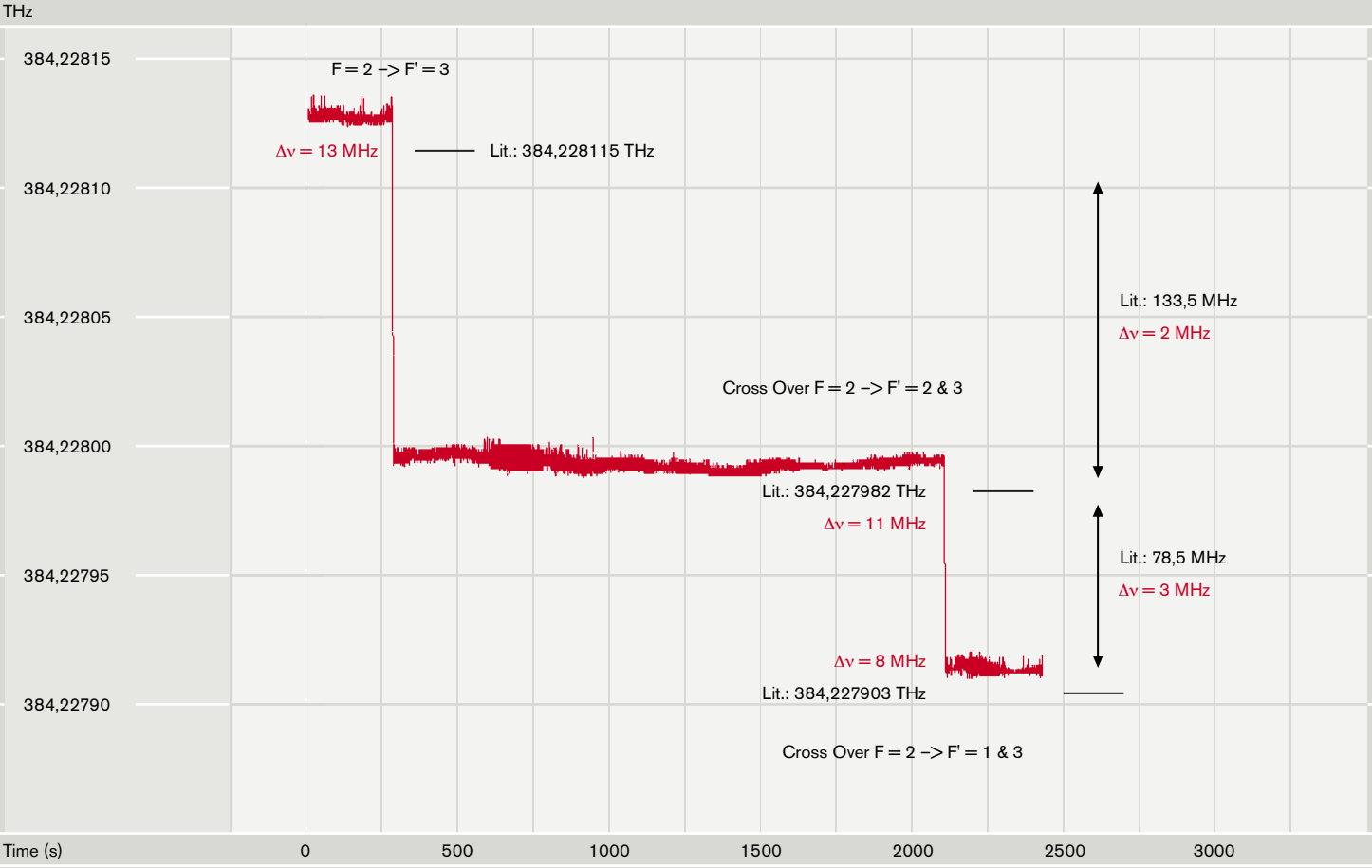


Measurement using the PID-controller

Recent measurements have demonstrated the outstanding accuracy of the WS Ultimate that goes even beyond the specifications. The diagram above shows the frequency stability, ± 2 MHz, of a semiconductor laser diode locked to a WS Ultimate using the PID-controller.

This laser was used for a magneto-optical trap (MOT); the number of atoms remained constant during the 20 minute measurement. The beat signal between the PID controlled laser and the Rb spectroscopy was monitored.

Saturation spectroscopy



Saturation spectroscopy measured by a WS7

The diagram shows a measurement with the WS Ultimate on a rubidium saturation spectrum (^{87}Rb D_2, $5S_{1/2} => 5P_{3/2}$)

Three lines are shown. **Black:** literature value
Red: measurement and mean deviation

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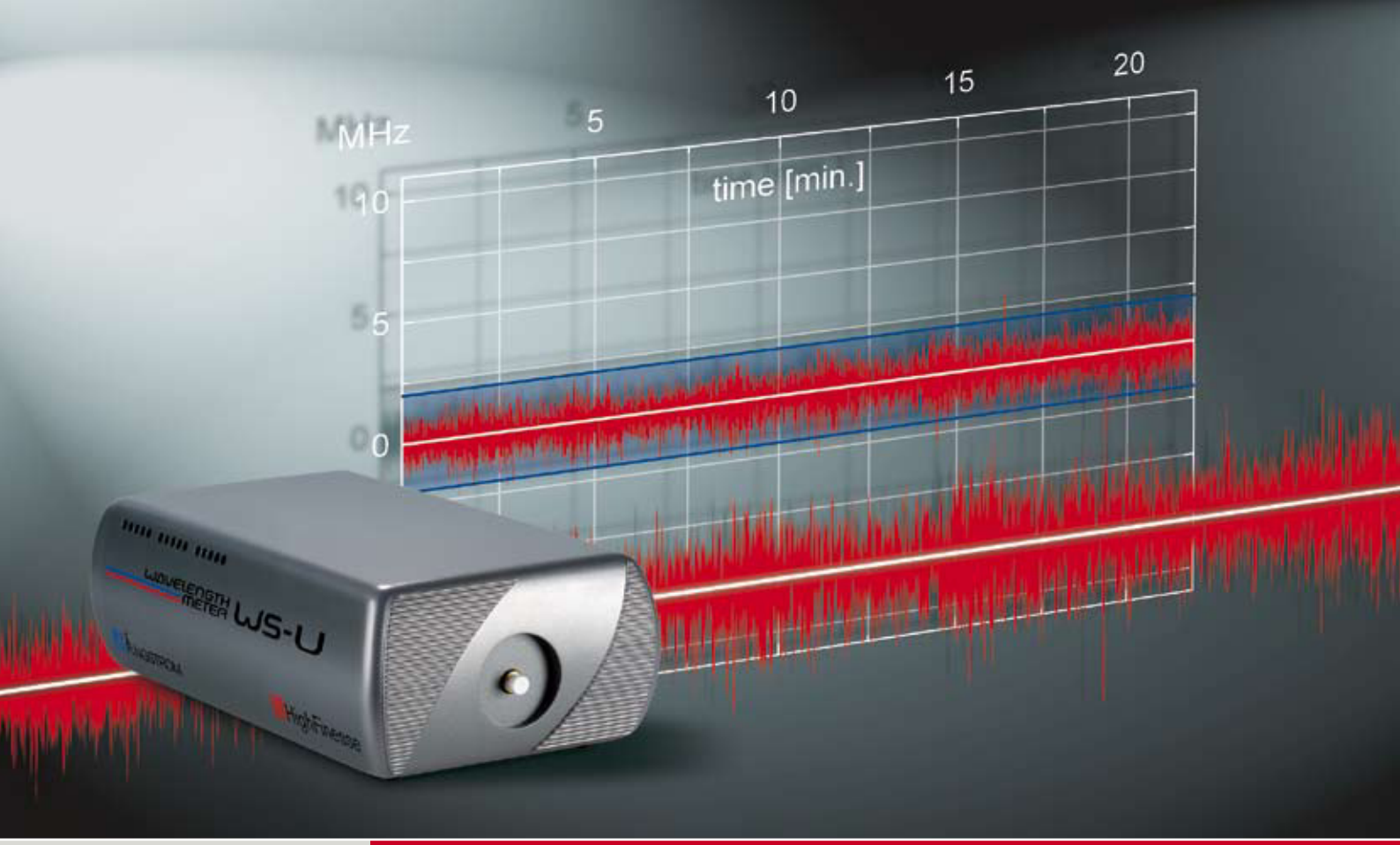

Laser Feedback Control: deviation down to ± 2 MHz

- **Continuous control of your lasers with our PID-Software**
- **Frequency deviation within ± 2 MHz (rms < 500 kHz) with our WS Ultimate-2**
- **Simultaneous control of up to 8 lasers**
- **Wavelength range: 192 – 11000 nm**
- **Repetition Rate: up to 600 Hz**

High resolution spectroscopy can be replaced by a HighFinesse/Ångstrom Wavelength Meter. Absolute measurement and regulation accuracy in MHz-range is reached in the spectral range of 330 – 1750 nm. In UV (192 – 350 nm) and MIR (2 – 11 µm) 100 MHz regulation accuracy is possible.

High measurement and feedback speed for in-situ frequency control of cw-laser-sources like singlemode diode lasers, DFB lasers, Dye lasers, TiSapph laser or any pulsed laser application (LIDAR) is reached.

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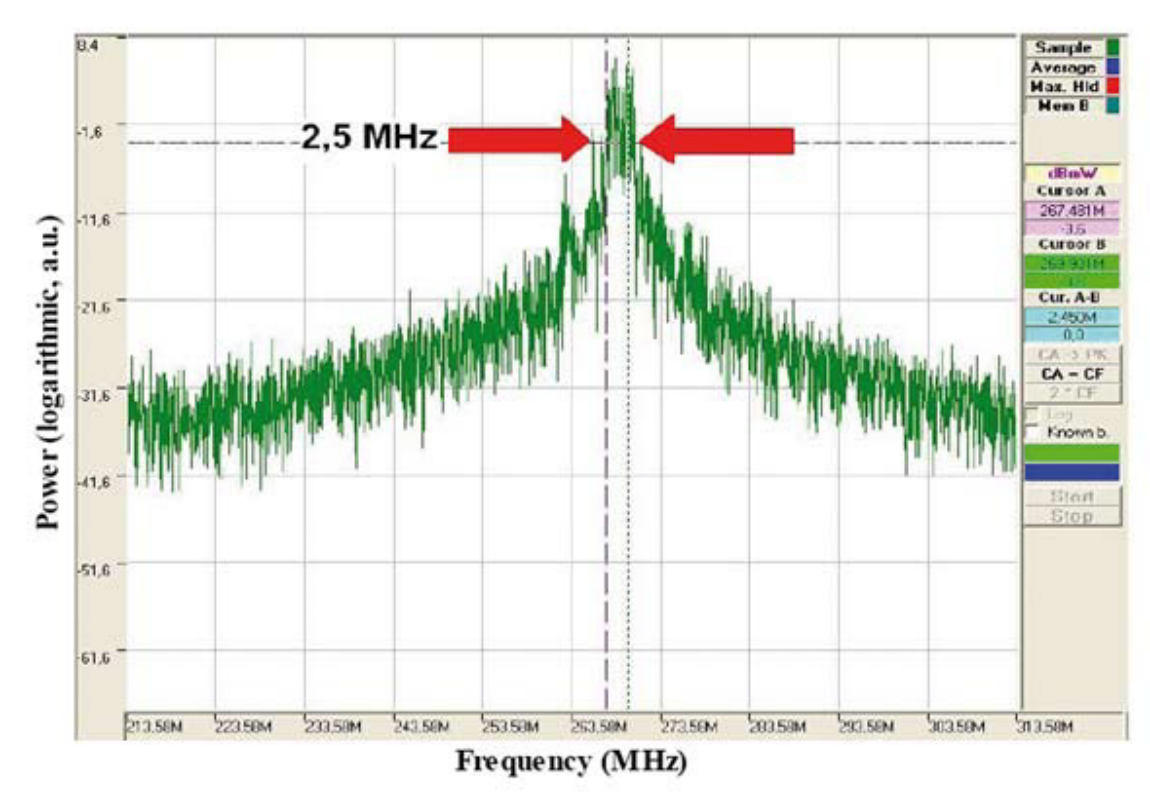
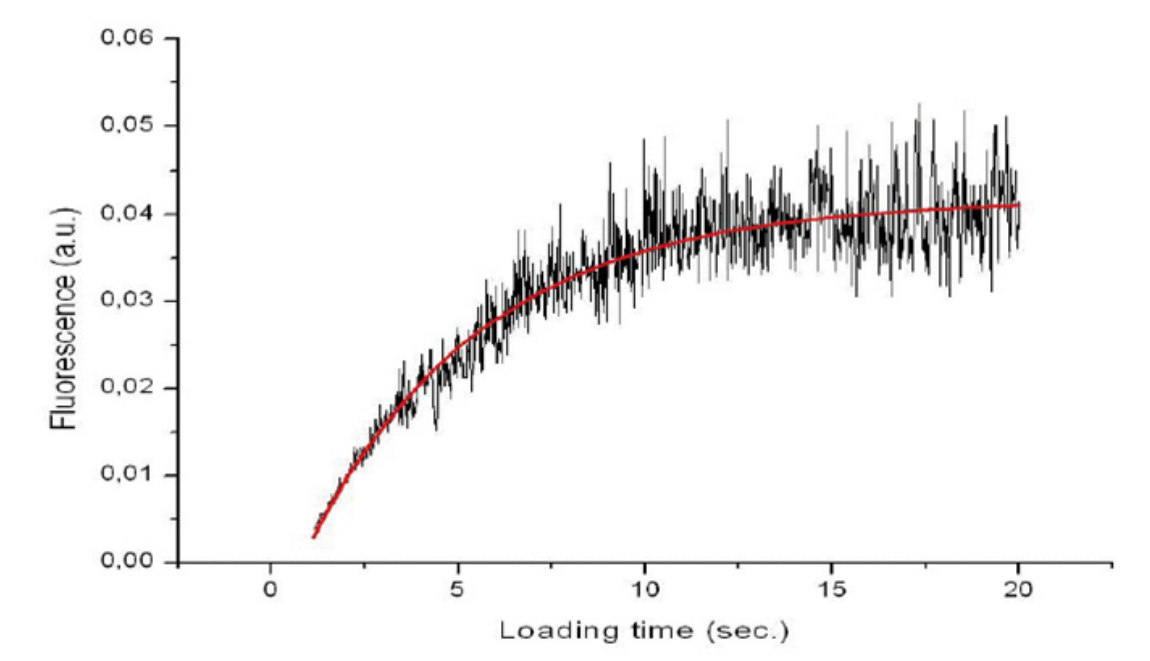
Application Example:



HighFinesse DFB laser diode controlled by WS Ultimate-10. Typical linewidth of the HighFinesse DFB laser < 2,5 MHz. High quality laser current and temperature controllers are available at HighFinesse.

Spectroscopic Application:



Loading a Magneto-Optical-Trap (MOT) with cold atoms. Laser frequencies of two DFB lasers are controlled by WS Ultimate-10. Fluorescence signal of cold Rb-atoms measured by a photodiode.

Further information: **www.highfinesse.com**

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Additional information
and distributors:
www.highfinesse.com

WS5 Precision Wavelength Meter

Absolute accuracy: 3000 MHz, resolution: 1000 MHz

NEW: VIS/IR-II measurement range (500 – 2250 nm)

Compact, reliable and versatile

The robust, compact HighFinesse/Ångstrom WS5 precision wavelength meter is designed for everyday control of pulsed and cw laser sources. It can be operated with very low light intensity coupled through an easy-to-use optical multi-mode fiber. Optical elements and electronics are housed in a compact, thermally insulated casing.

Power supply and data readout are accomplished with any PC via a USB interface. The wavelength meter is ready for use as soon as the software delivered with the device is installed. There is no warm-up time required under constant ambient conditions.

To enable customized applications, the WS5 design allows the integration of additional options – even years after purchase.

Enter a new world of accuracy!

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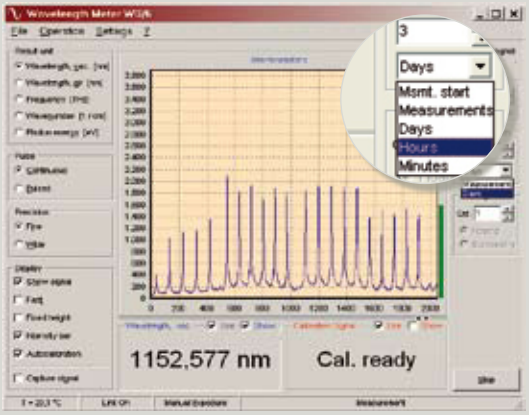
Technical Data		Unit	WS5
Measurement range	Standard (330 – 1180 nm)		●
	UV-I (248 – 1180 nm)		●
	UV-II (192 – 800 nm)		●
	VIS/IR (330 – 1750 nm)		●
	VIS/IR-II (500 – 2250 nm)		●
	IR-I (630 – 1750 nm)		●
	IR-II (1000 – 2250 nm)		●
	IR-III (2 – 11 µm)		●
Absolute accuracy [4]	192 – 330 nm [1]	pm	3
	330 – 420 nm	pm	2
	420 – 1100 nm	MHz	3000
	1100 – 2250 nm		2000
	2 – 11 µm		3000
Quick coupling accuracy (with multi mode fiber)		MHz	3000
Wavelength deviation sensitivity/Measurement resolution		MHz	1000
Linewidth option [2]	Accuracy	MHz	2000 [3]
Measurement speed [5] (depending on PC hardware and settings)	Max. bandwidth	GHz	50
	Data acquisition	Hz	600
	Wavelength calculation		600
	Linewidth calculation		500
Required input energy and power	Pattern display	µJ (or µW) [6]	300 (IR-III: 50 – 100)
	Standard		0.02 – 15
	UV-I		0.02 – 10
	UV-II		0.02 – 200
	IR-I		2 – 200
	IR-II		2– 80 [7]
	IR-III	mW	1 (pulsed: 20µJ) [8]
Fizeau interferometers	FSR	GHz	~100 (IR-III: 80 GHz)
Grating Option [2]	Spectral resolution	λ/Δλ	different designs possible: up to 20000 [9]
Coupling fiber diameter		µm	400
Calibration			Built-in calibration [10]
Calibration period			≤ 1 month (will be detected and done automatically [11])
Warm-up time			No warm-up time under constant ambient conditions (except IR-II and Vis/IR-II: > 30 minutes). Otherw. until thermal and air pressure equilibrium is reached.
Dimensions L × W × H		mm	360 × 120 × 120
Weight		kg	2.8 (IR-III: 5.8)
Interface			High-speed USB 2.0 connection
Power supply			Power consumption < 2.3 W, supply via USB cable; IR-II, VIS/IR-II, IR-III: external power supply included. IR-I via USB or external power supply possible

1) With multi mode fiber 2) Only for standard range 3) But not better than 5 % of the linewidth 4) According to 3σ criterion 5) Without autocalibration usage 6) The cw power interpretation in [µW] compares to an exposure of 1s (generally the energy needs to be divided by the exposure time to obtain the required power) 7) [µJ] interpretation for pulsed lasers; cw signals need more power in [µW] since the exposure is limited at IR-II devices 8) Signal/noise in this case will be 5:1, thus averaging is required 9) For IR-III λ/Δλ = 450 10) WS5 IR-III requires external calibration source with Δυ < 100 MHz, e.g. SLR-1532



Internal calibration

Automatic calibration with built-in wavelength standard, settable measurement counts or time period between calibrations.

Typical WS5 applications

The WS5 is a standard instrument for wavelength monitoring of tunable pulsed or cw laser sources such as Diode laser, Titanium Saphire Laser, Dye Laser, etc. It is well suited for spectroscopic applications with normal resolution.

Available WS5 options

■ Diffraction grating (D) ■ PID-controller (PID) ■ Multi-channel Switch (MC)
■ Double pulse (DP) ■ TTL-trigger (TTL)

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WS6 High-Precision Wavelength Meter

WS6-600, absolute accuracy: 600 MHz, resolution: 100 MHz
WS6-200, absolute accuracy: 200 MHz, resolution: 50 MHz

NEW: VIS/IR-II measurement range (500 – 2250 nm)

High performance and compact design

The HighFinesse/Ångstrom WS6 high-precision wavelength meter is a highly sensitive wavelength meter with integrated calibration for pulsed and continuous laser sources.

The WS6-600 combines both compact design and high resolution, achieved by a single set of multiple interferometers arranged in a unique geometric configuration. The WS6-200 uses 2 sets of multiple interferometers which triples the accuracy.

The WS6 design allows the integration of additional options, even years after purchase.

The WS6 is connected to the PC via a USB interface. The wavelength meter is ready for use as soon as the software delivered with the device is installed. There is no warm-up time required under constant ambient conditions.

Enter a new world of accuracy!

Ångstrom

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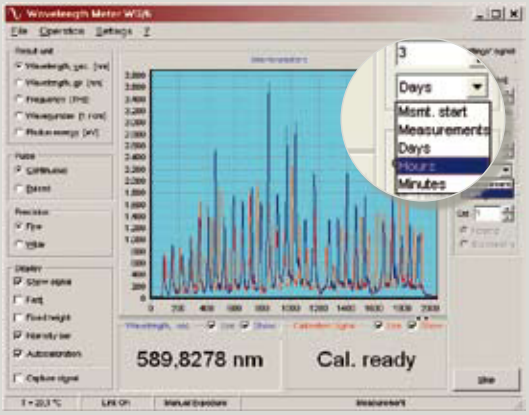
Technical Data		Unit	WS6-600	WS6-200
Measurement range	Standard (330 – 1180 nm)		●	●
	UV-I (248 – 1180 nm)		●	●
	UV-II (192 – 800 nm)		●	●
	VIS/IR (330 – 1750 nm)		●	●
	VIS/IR-II (500 – 2250 nm)		●	●
	IR-I (630 – 1750 nm)		●	●
	IR-II (1000 – 2250 nm)		●	●
	IR-III (2 – 11 µm)		○	●
Absolute accuracy [5]	192 – 330 nm [1]	pm	0.6	0.4
	330 – 420 nm	pm	0.3	0.2
	420 – 1100 nm	MHz	600	200
	1100 – 2250 nm	MHz	400	150
	2 – 11 µm	MHz	–	200
Quick coupling accuracy (with multi mode fiber)		MHz	600	600
Wavelength deviation sensitivity/Measurement resolution		MHz	100	50
Linewidth option [3]	Accuracy	MHz	500 [4]	400 [4]
	Max. bandwidth	GHz	50 (UV, IR: 10)	
Measurement speed [6] (depending on PC hardware and settings)	Data acquisition	Hz	600	500
	Wavelength calculation	Hz	600	400
	Linewidth calculation	Hz	500	400
Required input energy and power	Pattern display	µJ (or µW) [7]	300	150 (IR-III: 50 – 100)
	Standard	µJ (or µW) [7]	0.02 – 15	
	UV-I	µJ (or µW) [7]	0.02 – 10	
	UV-II	µJ (or µW) [7]	0.02 – 200	
	IR-I	µJ (or µW) [7]	2 – 200	1 – 100
	IR-II	µJ (or µW) [7]	2 – 80 [9]	
	IR-III	mW	–	1 (pulsed: 20 µJ) [10]
Fizeau interferometers [2]	FSR	GHz	~15/100 (UV, IR: ~20 – 30; IR-III: 8/80)	
Grating Option [3]	Spectral resolution	λ/Δλ	different designs: up to 20000	– [11]
Coupling fiber diameter		µm	400 µm	400 µm or single mode fiberset
Calibration			Built-in calibration [8]	
Calibration period			≤ 1 month (will be detected and done automatically [8])	
Warm-up time			No warm-up time under constant ambient conditions (except IR-II and Vis/IR-II: >30 minutes). Otherw. until thermal and air pressure equilibrium is reached.	
Dimensions L × W × H		mm	360 × 120 × 120	360 × 200 × 120
Weight		kg	2.8	5.3
Interface			High-speed USB 2.0 connection	
Power supply			Power consumption < 2.3 W, supply via USB cable; IR-II, VIS/IR-II, IR-III: external power supply included. IR-I via USB or external power supply possible	

1) With multi mode fiber 2) Values for fine/wide-mode 3) Only for standard range 4) But not better than 5% of the linewidth 5) According to 3σ criterion 6) Without autocalibration usage 7) The cw power interpretation in [µW] compares to an exposure of 1 s (generally the energy needs to be divided by the exposure time to obtain the required power) 8) WS6-200 IR-III requires external calibration source with $\Delta\upsilon < 100$ MHz, e.g. SLR-1532 9) [µJ] interpretation for pulsed lasers; cw signals need more power in [µW] since the exposure is limited at IR-II devices 10) Signal/noise in this case will be 5:1, thus averaging is required 11) For IR-III $\lambda/\Delta\lambda = 450$



Internal calibration

Automatic calibration with built-in wavelength standard, settable measurement counts or time period between calibrations.

Typical WS6 applications

The WS6 is well suited for scientific applications and spectroscopic applications with high resolution. Low-light intensity and fast readout make it ideal for monitoring diode lasers, frequency-doubled laser sources or optical parametric oscillators.

Available WS6 options

■ Diffraction grating (D) ■ Linewidth (L) ■ Multi-channel Switch (MC)
■ PID-controller (PID) ■ TTL-trigger (TTL) ■ Double pulse (DP)

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WS7 Super-Precision Wavelength Meter

Absolute accuracy: 60 MHz, resolution: 10 MHz

Superb precision for a wide range of applications

The HighFinesse/Ångstrom WS7 super-precision wavelength meter is a highly sensitive wavelength meter for pulsed and continuous laser sources.

The superb precision of the WS7 is achieved by using two sets of multiple interferometers in a special geometric configuration.

To enable customized applications even years after purchase, the WS7 design allows the integration of additional options.

The WS7 is connected to the PC via a USB interface. The wavelength meter is ready for use as soon as the software delivered with the device is installed. There is no warm-up time required under constant ambient conditions.

Enter a new world of accuracy!

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Technical Data		Unit	WS7
Measurement range	Standard (330 – 1180 nm)		●
	UV-I (248 – 1180 nm)		●
	UV-II (192 – 800 nm)		●
	IR-I (630 – 1750 nm)		●
	IR-II (1000 – 2250 nm)		●
Absolute accuracy [5]	192 – 330 nm [1]	pm	0.2
	330 – 420 nm	pm	0.04
	420 – 1100 nm	MHz	60
	1100 – 2250 nm	MHz	40
Quick coupling accuracy (with multi mode fiber)		MHz	150
Wavelength deviation sensitivity/Measurement resolution		MHz	10
Measurement resolution	Accuracy	MHz	200 [4]
Linewidth option [3]	Max. bandwidth	GHz	10
Measurement speed [6] (depending on PC hardware and settings)	Data acquisition	Hz	500
	Wavelength calculation	Hz	400
	Linewidth calculation	Hz	400
	Pattern display	Hz	150
Required input energy and power	Standard	µJ (or µW) [7]	0.02 – 15
	UV-I	µJ (or µW) [7]	0.02 – 10
	UV-II	µJ (or µW) [7]	0.01 – 100
	IR-I	µJ (or µW) [7]	2 – 200
	IR-II [8]	µJ (or µW) [7]	2 – 80
Fizeau interferometers [2]	FSR	GHz	4 / 20 – 30
Coupling fiber diameter		µm	400 µm or single mode fiberset
Calibration			Built-in calibration [9]
Calibration period			≤ 14 days [9]
Warm-up time			No warm-up time under constant ambient conditions (except IR-II: > 30 minutes warm-up time required) Otherw. until thermal and air pressure equilibrium is reached.
Dimensions L × W × H		mm	360 × 200 × 120
Weight		kg	6.1
Interface			High-speed USB 2.0 connection
Power supply			Power consumption < 2.3 W, supply via USB cable; IR-II: external power supply included. IR-I via USB or external power supply possible

1) With multi mode fiber 2) Values for fine/wide-mode 3) Only for standard range 4) But not better than 5 % of the linewidth 5) According to 3σ criterion 6) Without autocalibration usage 7) The cw power interpretation in [µW] compares to an exposure of 1 s (generally the energy needs to be divided by the exposure time to obtain the required power) 8) [µJ] interpretation for pulsed lasers; cw signals need more power in [µW] since the exposure is limited at IR-II devices 9) Not IR and UV-II devices. External calibration source needed, e.g. SLR-1532

Quick coupling with included multi mode fiber

Free-hand measurement with an accuracy of 150 MHz due to the high sensitivity and by default included multi mode fiber.

Typical WS7 applications

The WS7 is a high-resolution device for precision measurement in a wide variety of applications: molecular and atomic spectroscopy, gas detection with Raman scattering or laser-induced fluorescence, LIDAR systems, high-resolution spectroscopy, laser frequency stabilization and for calibration in combination with frequency combs.

Available WS7 options

- Linewidth (L)
- Multi-channel Switch (MC)
- PID-controller (PID)
- TTL-trigger (TTL)
- Double pulse (DP)

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WS Ultimate Wavelength Meter

Absolute accuracy: up to 2 MHz
Measurement Resolution: up to 500 kHz

For unrivaled precision!

The HighFinesse/Ångstrom WS Ultimate is the unsurpassed high-end instrument for wavelength measurement of pulsed or continuous laser sources. It delivers superb absolute and relative accuracy to address the highest application requirements.

The unmatched precision of the WS Ultimate is achieved by using two special multiple interferometer arrays in a unique geometric configuration.

The WSU is connected to the PC via a USB interface. The wavelength meter is ready for use as soon as the software delivered with the device is installed. Both optical elements and assigned electronics are packaged in a compact, thermally insulated housing.

The WSU design enables the integration of additional options, allowing customized solutions to specific applications even years after purchase.

Enter a new world of accuracy!

Ångstrom

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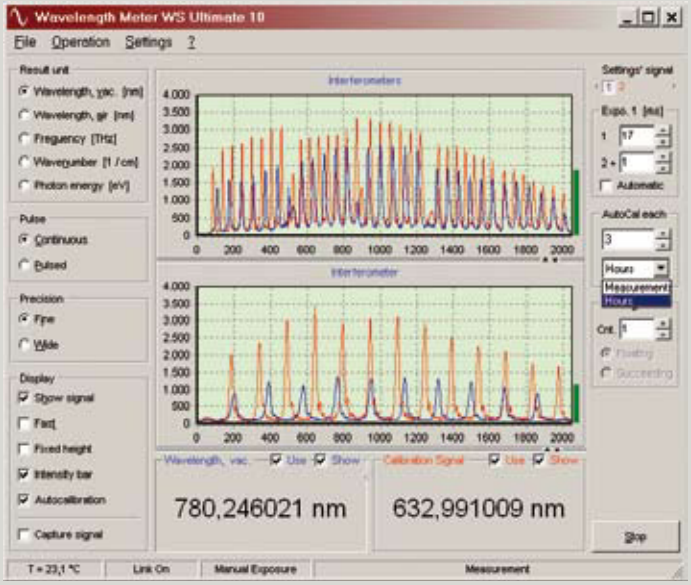
Laser and Electronic Systems

Technical Data		Unit	WSU-30	WSU-10	WSU-2
Measurement range	Standard (330 – 1180 nm)		●	●	●
	UV-I (248 – 1180 nm)		●	○	○
	IR-I (630 – 1750 nm)		●	●	○
	IR-II (1000 – 2250 nm)		●	○	○
Absolute accuracy [7]	192 – 330 nm [1]	pm	0.1	0.1	0.1
	330 – 420 nm	pm	0.02	0.01	0.01
	420 – 1100 nm	MHz	30	10 [5]	2 [6]
	1100 – 2250 nm	MHz	20	10 [5]	–
Quick coupling accuracy (with multi mode fiber)		MHz	100		
Wavelength deviation sensitivity/Measurement resolution		MHz	5	1 [5]	0.5 [6]
Linewidth option [3]	Accuracy	MHz	100 [4]		
	Max. bandwidth	GHz	0.8 (for high accuracy mode) – 8 (for low accuracy mode)		
Measurement speed [8] (depending on PC hardware and settings)	Data acquisition	Hz	500		
	Wavelength calculation	Hz	400		
	Linewidth calculation	Hz	400		
	Pattern display	Hz	150		
Required input energy and power	Standard	µJ (or µW) [9]	0.02 – 15		
	UV-I	µJ (or µW) [9]	0.02 – 10	–	–
	IR-I	µJ (or µW) [9]	2 – 200		–
	IR-II	µJ (or µW) [9]	2 – 200	–	–
Fizeau interferometers [2]	FSR	GHz	2 / 15 – 20		
Coupling fiber diameter		µm	400 µm or single mode fiberset		
Calibration			Stabilized HeNe laser or any other well known laser source $\Delta\nu < 3$ MHz		Any well known laser source $\Delta\nu < 1$ MHz
Calibration period			≤ 10 hours	≤ 1 hours	≤ 2 minutes
Warm-up time			> 30 minutes		
Dimensions L × W × H		mm	360 × 200 × 120		
Weight		kg	6.4		
Interface			High-speed USB 2.0 connection		
Power supply			Power consumption < 2.3 W, supply directly via USB cable, IR-II: external power supply included; IR-I and WSU via USB or external power supply possible		

1) With multi mode fiber 2) Values for fine/wide-mode 3) Only for standard range 4) But not better than 5 % of the linewidth 5) ± 200 nm around calibration wavelength 6) ± 2 nm around calibration wavelength 7) According to 3σ criterion 8) Without autocalibration usage
9) The cw power interpretation in [µW] compares to an exposure of 1s (generally the energy needs to be divided by the exposure time to obtain the required power)



Autocalibration Option

Automatic, continuous calibration with calibration wavelength standard, settable measurement counts or time period between calibrations.

Quick coupling with included multi mode fiber

Fast measurement with an accuracy of 100 MHz due to the high sensitivity multi mode fiber provided.

Typical WSU applications

The WSU high-end wavelength meter is mostly used in specialized applications, such as scientific measurement and frequency standards, laser frequency stabilization for laser cooling, high-precision spectroscopy and atomic optics. The device's unparalleled accuracy of up to 2 MHz allows for high-precision wavelength control for example in high-end LIDAR applications.

Available WSU options

■ Linewidth (L) ■ Multi-channel Switch (MC)
■ PID-controller (PID) ■ TTL-trigger (TTL) ■ Double pulse (DP)

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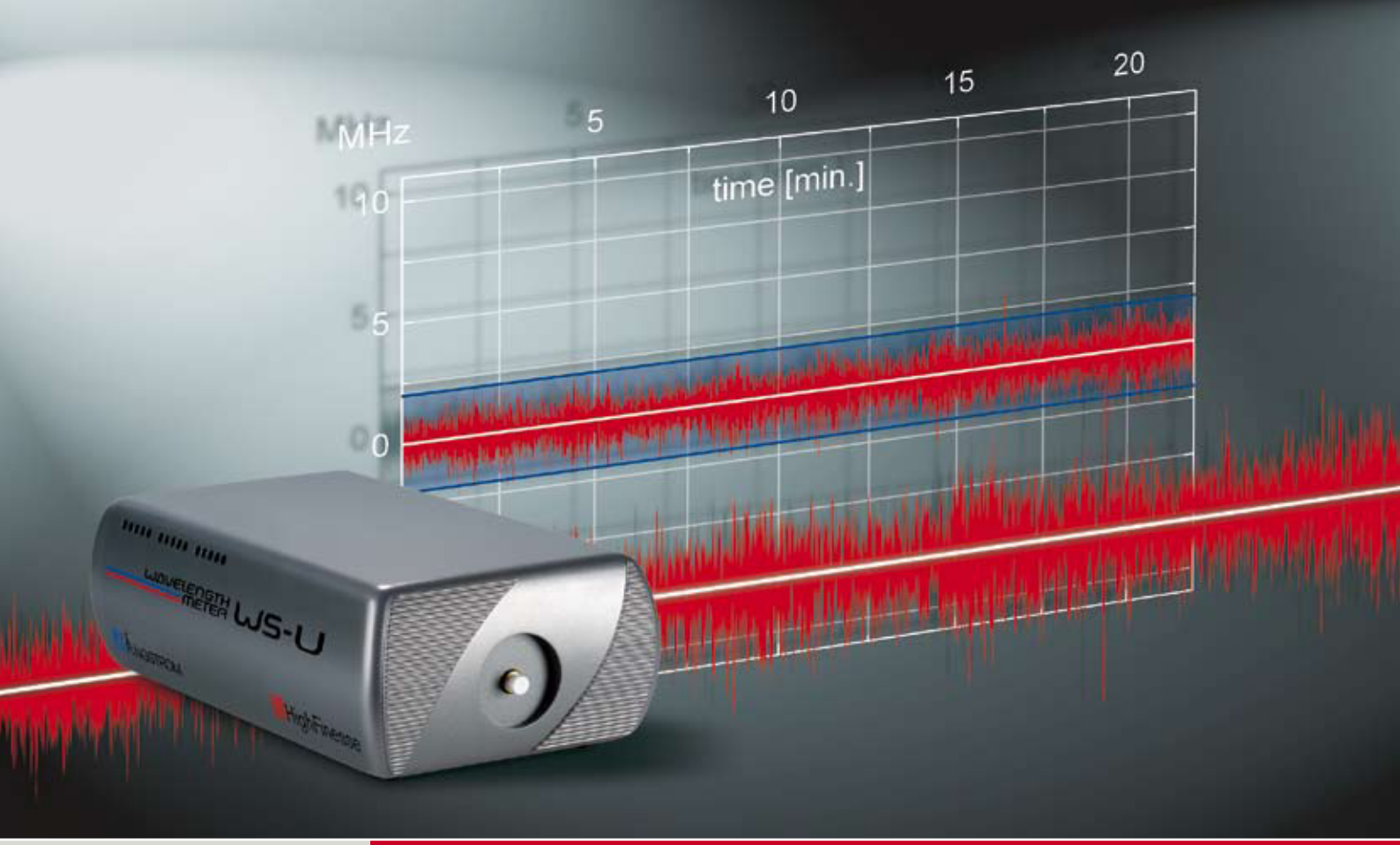

Autocalibration via external fiber input

for the Wavelength Meter WS-Ultimate

For ultimate accuracy and stability of measurements with our WS-Ultimates, it is possible to perform automatic recalibration of the wavelength meter at user defined intervals, from weeks to between every measurements. This automatic procedure takes less than one second before automatically returning to your laser. No user intervention is required. When used in conjunction with the PID option, no loss of control of the laser is experienced.

In order to use this option a calibration laser (normally a HeNe but other lasers can be used, too) is fiber coupled to an additional input on the wavelength meter. An internal switching module will then automatically switch between the laser being monitored and the calibration source. The software then updates the calibration data file.

You never need to stop your work or return your wavelength meter to ensure its accuracy!

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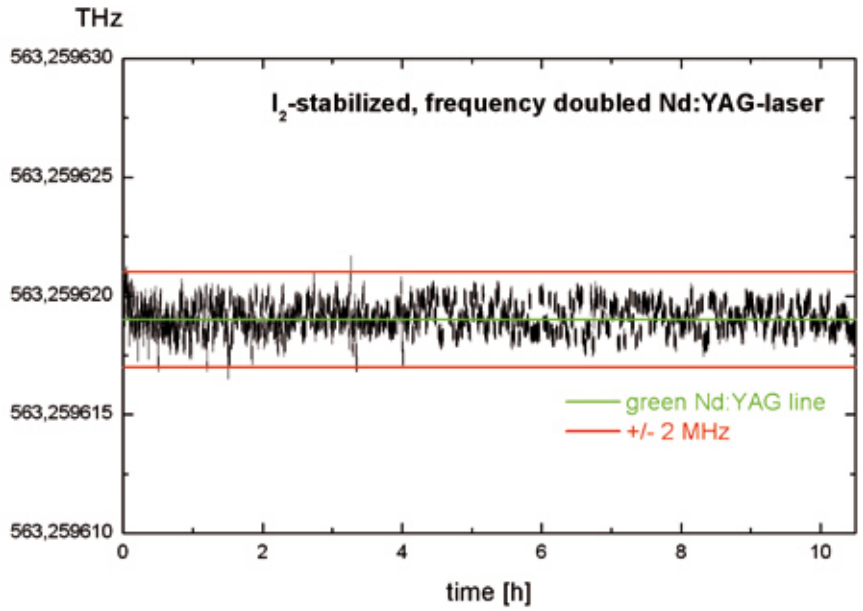
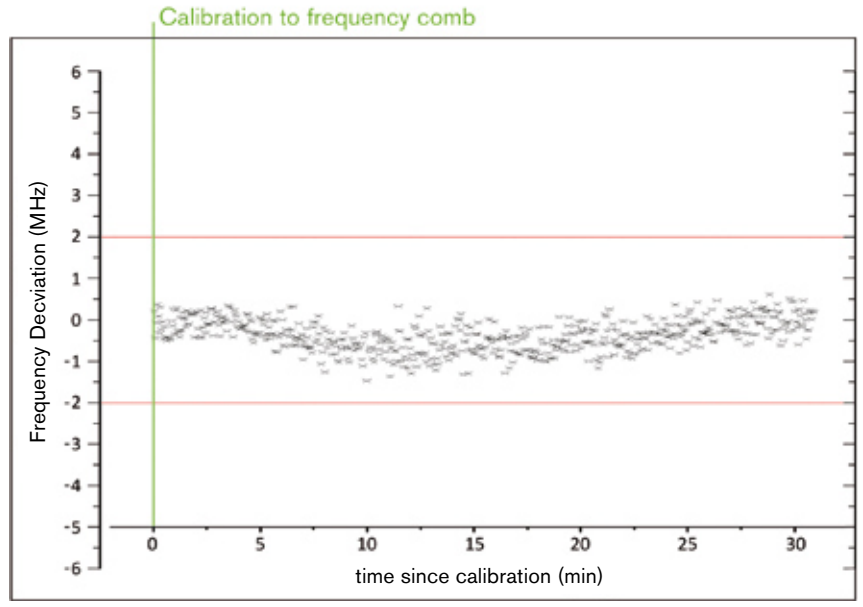


Note: The hardware supports a standard calibration range between 600 nm and 800 nm. Other calibration ranges are available on request.

■ Application Example:

Frequency measurement on a stabilized Nd:YAG-laser (532.245 576 nm) by WS Ultimate autocalibrated to a stabilized HeNe-laser (632.991 060 nm, 1 calibration per minute). The absolute accuracy of the measurement is within ± 2 MHz.



Constant lab conditions

Absolute accuracy within 3 min ± 500 kHz

■ Application Note:

The WS Ultimate-2 is calibrated to a frequency comb at t = 0. A diode laser at 960 nm is frequency controlled by the PID option of the WS Ultimate.

The diagram shows the frequency deviation between the diode laser and the reference comb mode.

If autocalibration is activated in a time sequence of a few minutes, the WS-U2 can be used as a reference that is comparable with high resolution atomic spectroscopy. The PID option enables direct laser frequency control just as locking to atomic spectra.

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Laser Spectrum Analyser – LSA

Absolute accuracy: 6000 MHz
Wavelength deviation sensitivity: 1 GHz

The LSA is designed to analyse the multi-line or broadband spectrum of light sources like cw and pulsed lasers, gas discharge lamps, super luminescence diodes, semiconductor laser diodes and LEDs.

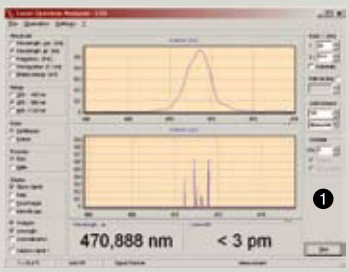
- **Sensitivity: 5 nJ @ 633 nm**
- **Low stage spectral resolution ($\lambda/\Delta\lambda_{FWHM}$): 500**
- **High stage spectral resolution ($\lambda/\Delta\lambda_{FWHM}$): 20000 (SM fiber), 10000 (50 µm fiber)**
- **Max. signal bandwidth: 2 THz**
- **Linewidth measurement accuracy: 10 %**
  Max. linewidth: 1.5 THz
- **Built-in light source for autocalibration**

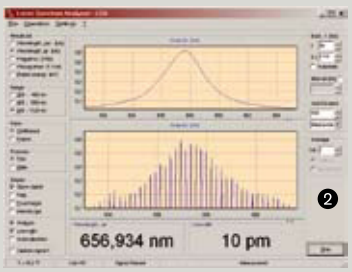
Ångstrom

HighFinesse
Laser and Electronic Systems

Technical Data		Unit	LSA
Measurement range	Standard (330 – 1180 nm)		●
	UV-I (248 – 1180 nm)		●
	UV-II (192 – 800 nm)		●
	UV-II-VIS (192 – 1180 nm)		●
	VIS-IR (330 – 1750 nm)		●
	IR-I (630 – 1750 nm)		●
	IR-II (1000 – 2250 nm)		●
	IR-III (2 – 11 µm)		● 7)
Absolute accuracy 4)	192 – 330 nm 1)	pm	6
	330 – 420 nm	pm	3
	420 – 1100 nm	MHz	6000
	IR-I		12000
	IR-II		25000
	IR-III		1 – 5 nm 7)
Quick coupling accuracy (with multi mode fiber)		MHz	20000 2)
Wavelength deviation sensitivity/ Measurement resolution	192 – 330 nm	pm	5
	330 – 420 nm	pm	2
	420 – 1100 nm	MHz	3000
	IR-I		6000
	IR-II		12000
	IR-III	nm	1
Spectral resolution	Standard, UV		20000 (single mode), 10000 (multi mode)
	IR-I		4000 (single mode), 2000 (multi mode)
	IR-II		2800 (single-mode), 2000 (multi mode)
	IR-III		15 – 30 nm 7)
Linewidth High stage 2)	Accuracy	MHz	Standard, UV-I: 7000, IR-I: 40 GHz 9), IR-II: 60 GHz, IR-III: 15 % (≥ 200 GHz)
	Max. linewidth	THz	1.5
Measurement speed 5) (depending on PC hardware and settings)	Data acquisition	Hz	500
	Wavelength calculation		60
	Linewidth calculation		50
	Pattern display		50
Required input energy and power	Standard	µJ (or µW) 6)	0.0001 – 0.04
	UV-I, UV-II		0.0001 – 0.1
	IR-I, IR-II		0.02 – 2
	IR-III	mW	1
Diffraction grating	FSR	GHz	~5400 7)
Coupling fiber diameter		µm	50 µm or single mode fiber set
Calibration			Built-in calibration 8)
Calibration period			≤ 1 month
Warm-up time			No warm-up time under constant ambient conditions Otherwise until thermal and air pressure equilibrium is reached.
Dimensions L × W × H		mm	325 × 180 × 77
Weight		kg	2.8
Interface			High-speed USB 2.0 connection
Power supply			Power consumption < 2.3 W, supply directly via USB cable; IR-III: external power supply included; IR-I and WSU via USB or external power supply possible

1) With multi mode fiber 2) Only for standard range 3) But not better than 5 % of the linewidth 4) According to 3σ criterion 5) Without autocalibration usage 6) The cw power interpretation in [µW] compares to an exposure of 1s (generally the energy needs to be divided by the exposure time to obtain the required power) 7) For further information on IR-III devices see separate sheet 8) IR-III: external calibration sources required, e.g. SLR-1532 9) But not better than 10 % of the linewidth





Sample measurements of the Laser Spectrum Analyser

1 Neon discharge lamp: The group of Ne-lines (spontaneous emission) filtered by interference filter. The upper graph represents the spectrum in the first diffraction order, the lower graph represents the 90th order after mathematic analysis.

2 Spectrum of a laser diode right below threshold. Mode spacing 200 pm.

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High Definition Spectrum Analyser – HDSA

NEW: HDSA-UV-I (330 – 800 nm)
HDSA-UV-II (192 – 400 nm)

The HDSA is designed to analyse emission spectra of any complexity, while processing the entire spectral range at once. The highly customizable HDSA design features the same fundamental principle of “no moving optics”, just like other HighFinesse products. This enables measurement of cw as well as pulsed light sources.

- **Entire spectral range at once:**
  Standard: 350 – 1050 nm
  IR-I: 940 – 1740 nm
  Telecom: 1500 – 1600 nm
  UV-I: 330 – 800 nm
  UV-II: 192 – 400 nm
  other ranges on request
- **Extreme sensitivity:**
  10 pJ @ 633 nm
- **Exposure time: 1 ms – 2 s**
- **Measurement and tracking of any selected line/area**
- **Record and replay mode**

Ångstrom

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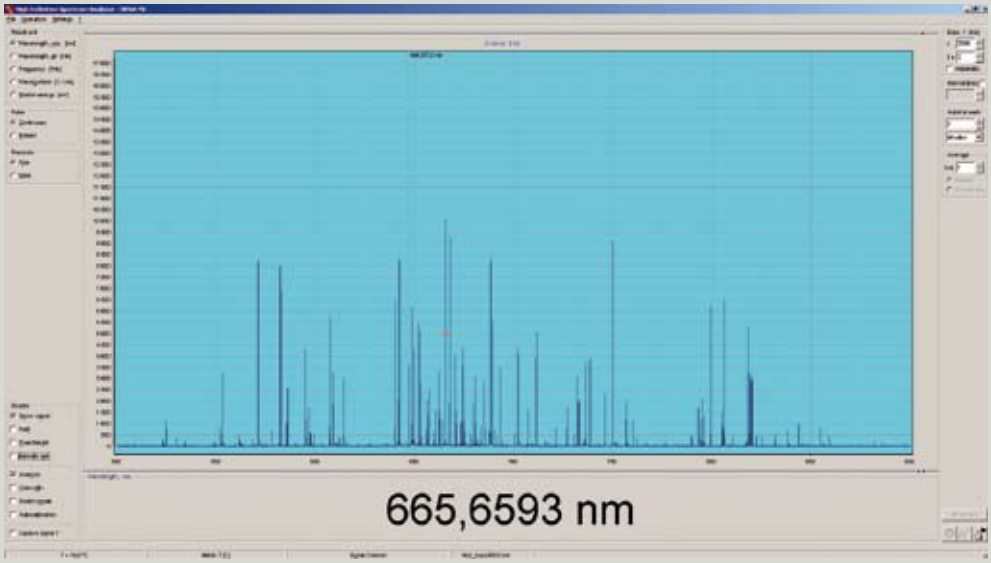
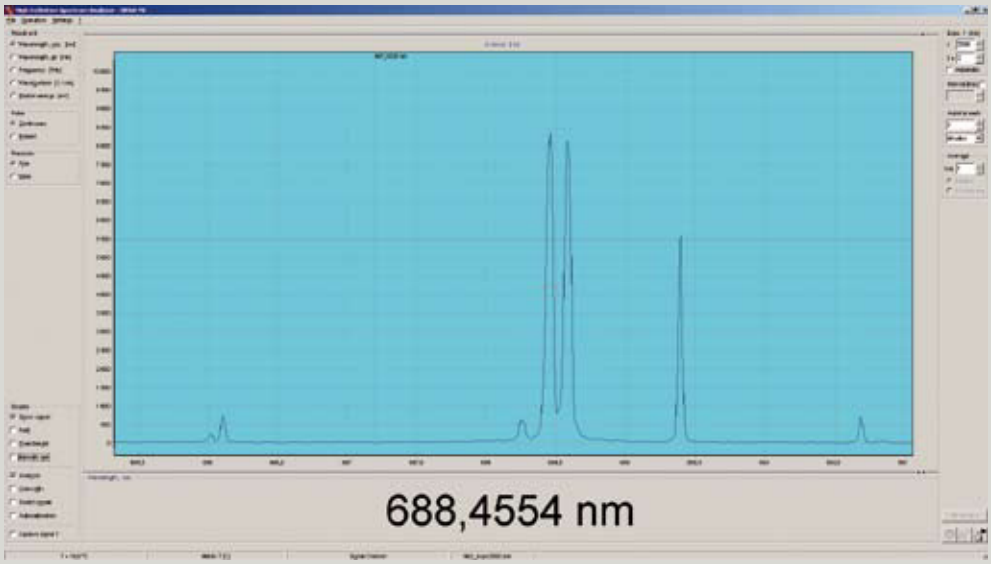
Technical Data	Unit	HDSA				
		UV-II	UV-I	Standard	IR-I	Telecom [1]
Measurement range	nm	192 – 400	330 – 800	350 – 1050	940 –1740	1500 – 1600
Absolute accuracy [2]	GHz	20	10	5	20	3
Wavelength deviation sensitivity/ Measurement resolution	GHz	5	3	2	2	0.6
Spectral resolution (λ/Δλ) (FWHM criteria)		5000 @ 325 nm	10000 @ 325 nm	15000 @ 633 nm	5000 @ 1500 nm	20000 @ 1500 nm
Measurement speed						
Data aquisition	Hz	1	15	15	60	60
Spectrum calculation		1	15	15	50	60
Required input energy and power	nJ	1 @ 325 nm	0.5 @ 325 nm	0.01 @ 633 nm	50 @ 1500 nm	100 @ 1500 nm
Calibration		External calibration source (included in delivery)				
Calibration period		≤ 7 days				
Warm-up time		No warm-up time under constant ambient conditions				
Dimensions L × W × H	mm	360 × 210 × 120				
Weight	kg	~4.5				
Interface		1000BASE-T Gigabit Ethernet			USB 2.0	
Power supply		External power supply included; Power consumption: 5 W			Directly via USB-cable	

1) Various modifications available: other spectral range, resolution, accuracy and measurement speed. Please contact us for further details! 2) According to 3σ criterion



Typical measurement of the spectrum of a gas discharge lamp.

The HDSA resolves lines over the entire spectral range.



The picture shows a high resolution zoom into two specific spectral lines of the measurement above.

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NEW: Mid-IR Laser Spectrum Analyser – LSA IR-III

Customized Mid-IR Spectrometer: choose any intervall in the range of 2 – 11 µm with maximal achievable accuracy!

Analyse single-line, multi-line or broadband spectra of any pulsed or cw Mid-IR light sources.

- **Typical combinations of range / accuracy / spectral resolution:**

LSA IR-III$_{2-3}$:	2 – 3 µm	/	1 nm	/	15 nm
LSA IR-III$_{2-6}$:	2 – 6 µm	/	2 nm	/	20 nm
LSA IR-III$_{2-11}$:	2 – 11 µm	/	5 nm	/	30 nm

- **Pulsed / cw laser measurements**
- **Sensitivity: 10 µJ / 0.2 mW**
- **Linewidth measurement accuracy: 15% (≥ 10 GHz)**

Ångstrom

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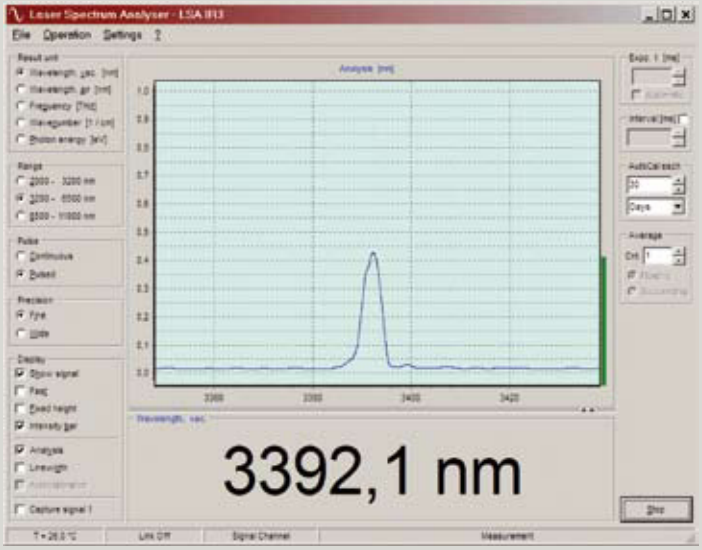
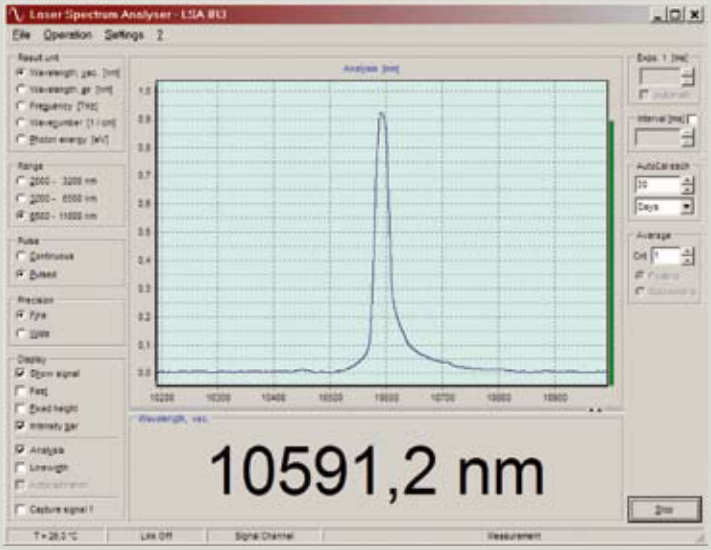
Technical Data LSA IR-III		Unit	Type 2 – 3	Type 2 – 6	Type 2 – 11
Measurement range		µm	2 – 3	2 – 6	2 – 11
Absolute accuracy [1]		nm	1	2	5
Relative accuracy			1.25×10^{-4}	3×10^{-4}	5×10^{-4}
Display resolution			0.7×10^{-4}	1.5×10^{-4}	2.5×10^{-4}
Spectral Resolution		nm	15	20	30
Linewidth measurement accuracy			15%		
Maximal linewidth		THz	1 (up to 15 [2])		
Measurement speed (depending on PC hardware and settings)	Wavelength & linewidth calculation	Hz	200		
	Analysis		15		
Required input power	Pulsed	µJ	10		
	cw	mW	0.2		
Diffraction Grating	FSR	THz	~ 2.7		
Coupling fiber			PIR-450/500 or CIR-450/500		
Calibration			SLR-1532 or 3.39 µm HeNe calibration laser (not included)		
Calibration period			15 days		
Warm-up time			No warm-up time needed		
Dimensions L x W x H		mm	325 × 180 × 77		
Weight		kg	3.0		
Interface			High-speed USB 2.0 connection		
Power supply			External power supply included		

1) According to 3σ criterion 2) Broad line versions. For further information please contact us

Sample measurements of the Laser Spectrum Analyser

Spectra of a non stabilized 3.4 µm HeNe and a CO_2 laser measured with the Laser Spectrum Analyser





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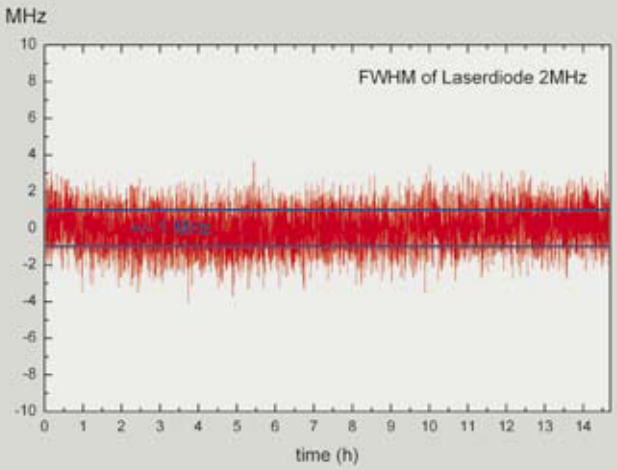
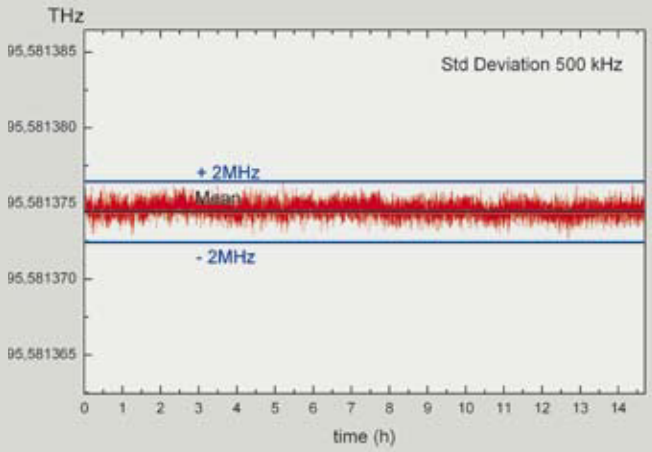
Highlight series: Stabilized Laser References

Calibration sources for all HighFinesse wavelength meters

- **Fiber coupled laser output**
- **Wavelengths: 780 nm, 850 nm, 895 nm, 1532 nm other wavelengths on request**
- **Output power (adjustable): 0 – 3 / 0 – 10 mW @ 1532 nm 0 – 5 mW @ 780, 850 & 895 nm**
- **Frequency stability and absolute accuracy: better than ± 2 MHz at constant temperature conditions**
- **Self (re-)calibration**
- **Compact design**
- **Easy to use – "Plug & Play"**



Measurement of the beat signal with a frequency comb over 14 hours



Longterm measurement by WSU IR-I wavelength meter

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HighFinesse calibration sources

- **Stabilized HeNe Laser @ 632 nm**
  SL-02
  Suitable for U30 (standard and UV-ranges)

- **Stabilized HeNe Laser @ 632 nm**
  SL03 + Isolator
  Suitable for U10 (standard and UV-ranges)

- **Stabilized Laser Reference @ 780, 850 & 895 nm**
  SLR-780, SLR-850 & SLR-895
  Suitable for U10 and U2 (standard and UV-ranges)

- **Stabilized Laser Reference @ 1532 nm**
  SLR-1532
  Suitable for WSU IR, WS7 IR, WS7 IR-II, WS6-200 IR-III & LSA IR-III

- **Infrared HeNe Laser @ 3.39 µm**
  MIR-HeNe
  Suitable for LSA IR-III

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