HighFinesse
Laser and Electronic Systems

Linewidth Analyzer

High resolution lineshape spectra and ultra sensitive noise analyzers for narrow and broadband lasers

The HighFinesse Linewidth Analyzers of the LWA-100k series are high-end devices for measuring and analyzing highly resolved lineshape and frequency noise spectra of narrow- and broadband lasers. A combination of two interferometric based measurement modes and specifically tailored optics and electronics enable the LWA-100k to quickly acquire various information about the laser source.

The main features are:

- Large wavelength intervals in the visible and near-infrared regime
- Spectral lineshape and frequency noise analysis
- Intrinsic linewidth measurement range from 1 kHz up to 1 MHz
- Effective linewidth measurement range from 100 kHz up to 300 MHz
- Frequency noise sensitivity below 100 Hz/√Hz for frequencies above 100 kHz
- High sample rate up to 30 MSa/s and fast acquisition rates up to real-time
- Linewidth accuracy down to 20 kHz
- No reference source required

The LWA-100k is perfectly suited for laser development and adjustment. In combination with a HighFinesse wavemeter high resolution classification of lasers and laser systems can be performed.

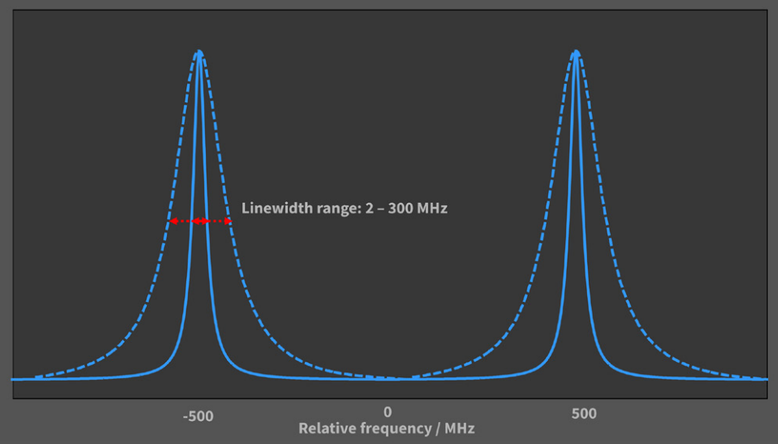
The HighFinesse instruments of the LWA-1k series are the ultimate high-end devices for measuring, analyzing and controlling frequency and intensity noise of lasers. The superb sensitivity of the LWA-1k series is achieved by combining an interferometric working principle with high-end optical and electronic components..

The main features are:

- Frequency noise, spectral lineshape and relative intensity noise (RIN) analysis with evaluation of intrinsic and combined intrinsic and effecitve linewidth
- Intrinsic linewidth measurement range down to 350 Hz
- Effective linewidth measurement range down to 2 kHz
- Frequency noise spectrum sensitivity down to 10 Hz/√ Hz with a dynamic range of 50 dB between 10 Hz and 10 MHz
- RIN down to −150 dB/Hz
- Extremely robust against acoustic noise
- Error signal generator for further linewidth, frequency noise or RIN reduction
- Powerful tool for a detailed analysis of noise sources like servo bumps, frequency drifts, power supply noise and acoustics.

The LWA-100k analyzes both, very narrow laser lines down to 100 kHz as well as broader bands up to 300 MHz. This is achieved by two distinct measurement modes. In the broadband-mode, a frequency-domain intensity spectrum is evaluated by determining the full width at half maximum (FWHM) of a curve fitted to the experimental data. In the narrowband-mode, time-domain recorded laser frequency deviations are analyzed yielding both a single-sided noise spectrum and a two-sided lineshape spectrum. Once connected to the PC via ethernet, the LWA-100k is controlled by an intuitively usable software interface that automatically evaluates and presents the data to the user. By monitoring the changes in the lineshape parameters over time, the stability of the light source can be determined. The LWA is ideal for optimizing the stability of laser setups by revealing mechanical, acoustic and electronic noise. Also, a high spectral resolution of 100 kHz in the broadband-mode allows supervising the single-mode operation of the laser and a free spectral range of 1 GHz enables the identification of sidebands.

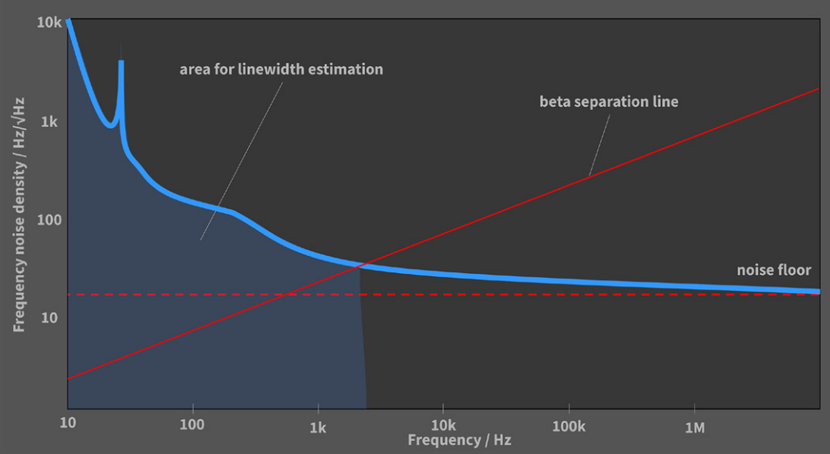
Demonstration of Broadband-Mode



The acquisition in the broadband mode yields an intensity spectrum in the frequency domain with evenly separated spectral bands.

The linewidth is then given by the full width at half maximum (FWHM) of the curve (Lorentzian or Gaussian) fitted to the data. The linewidth range in broadband-mode is between 2 (blue line) and 300 MHz (dashed line).

Demonstration of frequency noise spectrum evaluation

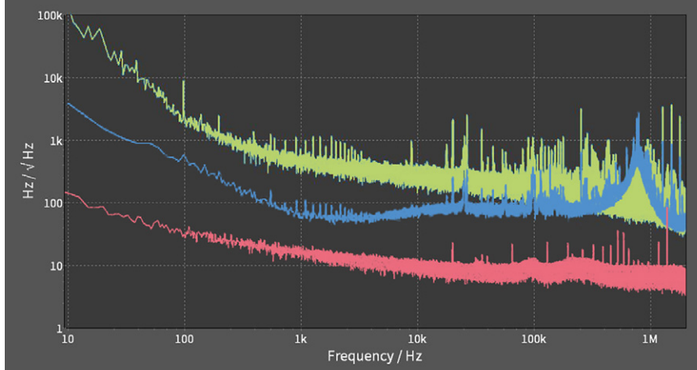


A Fourier analysis of recorded time-domain laser frequency deviation signals yields a frequency noise density plot in the frequency domain (blue line) with 1/f-noise, characteristic noise peaks and a white noise floor.

According to the β-separation method [1], the effective linewidth is proportional to the area of the frequency noise (blue) above the β-separation line (red line). The intrinsic linewidth is given by the noise floor level (in Hz²/Hz) times π (rule of thumb).

1) Di Domenico, et al., Applied Optics 49, issue 25, 4801 – 4807, 2010

Frequency noise spectrum

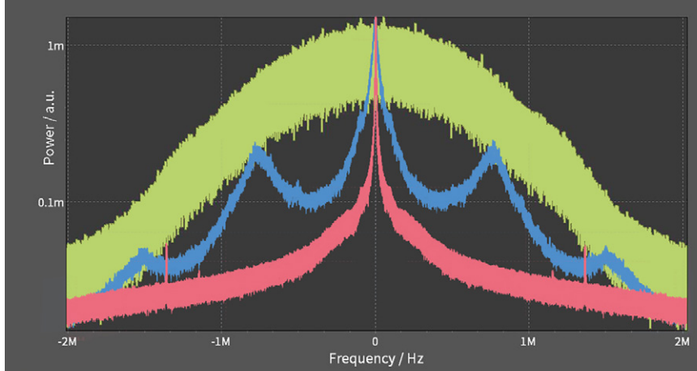


ECDL @1550 nm free running:
Effective (β-separation) 946.0 kHz; Intrinsic 53.2 kHz

ECDL @1550 nm locked to LWA-1k:
Effective (β-separation) 90.5 kHz; Intrinsic 110.6 kHz

Fiber laser @1550 nm: Effective (β-separation) 2.1 kHz; Intrinsic 0.3 kHz

Lineshape profile



ECDL @1550 nm free running: Linewidth 830.8 kHz

ECDL @1550 nm locked to LWA-1k: Linewidth 45.5 kHz

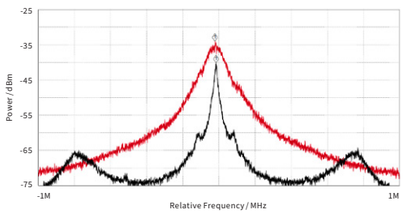
Fiber laser @1550 nm Linewidth 5.5 kHz

The LWA-1k featuring an improved resolution enables the analyzation of laser with very narrow linewidths down to 2 kHz. The analyzer unit automatically generates an output signal that is evaluated by the digitizer unit, connected to a PC via USB. An intuitively usable software interface performing the analysis provides the frequency noise related plots and values, such as the frequency noise spectrum and the lineshape spectrum together with the results of intrinsic and combined linewidth.

The frequency noise spectrum is a powerful tool for a detailed analysis of noise sources, servo bumps or frequency drifts enabling e.g. further laser locking improvements.

Additionally, the output signal provided by the analyzer unit of the LWA-1k series can be used as an error signal for further linewidth or RIN reduction in combination with an appropriate hardware such as a PID-controller.

As an example, the graphs on the lefts show frequency noise reduction of an ECDL with 1550 nm in the lab.



Spectrogram of beat between an ECDL and a fiber laser with (black) and without (red) external PID-lock of the ECDL to the LWA-1k confirming the lineshape spectrum in the graph to left.

Technical Data

Linewidth Analyzer

LWA-100k series

	Unit	400	500	750	980	1550
Wavelength range	nm	380 – 430	430 – 660	615 – 885	825 – 1200	1200 – 1700
Required input power [1]	mW	2 – 5				

Analyzer Unit

Laser type		CW and single-mode
Input type		FC/APC fiber
Broadband mode specification		
Optical frequency resolution	Hz	2 M
Free spectral range	Hz	1 G
Effective linewidth [2] range (FWHM)	Hz	2 M – 300 M
Spectral and frequency noise specifications		
Optical frequency resolution	Hz	1 k
Frequency noise bandwidth	Hz	100 – 1 M
Frequency noise sensitivity	Hz/√Hz	< 100 (@ > 100 kHz)
Intrinsic linewidth range [3]	Hz	1 k – 1 M
Effective linewidth range (β-separation) [2]	Hz	100 k – 1 M
Lineshape spectrum		
Effective linewidth [2] range (FWHM)	Hz	100 k – 1 M
Optical frequency resolution	Hz	100 k
Miscellaneous		
Dimensions	mm	150 × 280 × 79
Weight	kg	5

Digitizer module

Sample rate	Sa/s	31 M (max.)
Resolution	bits	16
Acquisition time	s	0.1 (typ.)
Evaluation time	s	< 1 (typ.)
Miscellaneous		
Communication		Ethernet
Dimensions	mm	357 × 112 × 145
Weight	kg	8

Software

Operating system		Microsoft® Windows® (7 – 10), 64 Bit
CPU (minimum)		Intel® Core™ i5 or equivalent
Memory (minimum)		8 GB
Ports		Ethernet
Graphical Evaluation options		Broadband spectrum, Frequency noise density graph, lineshape graph, frequency deviation distribution (histogram)

1) Best performance with maximum input power. Noise sensitivity scales inversly with input power.

2) Effective linewidth: Combination of intrinsic linewidth and additional broadening mechanisms (thermal, electronical and acoustic noise). Determination by β-separation method (noise density spectrum) or curvefitting procedure (lineshape spectrum).

3) Intrinsic linewidth: Limited by fundamental quantum processes and laser design. Determined by the noise floor (white noise) of the frequency noise spectrum and calculated by: noise density (in Hz^2/Hz) times π (rule of thumb). This value is most commonly denoted as “laser linewidth” by laser manufacturer.

Technical Data

Linewidth Analyzer

LWA-1k series

	Unit	LWA-1k 780	LWA-1k 1550
Wavelength range	nm	780 – 1020	1530 – 1565
Required input power [1]	mW	1– 10	0.5 – 5
Input power stability	%	± 5	

Analyzer Unit

Laser type		CW and single-mode	
Input type		PM-FC/APC fiber	
Spectral and frequency noise specifications			
Optical frequency resolution	Hz	8 k	1 k
Frequency noise bandwidth	Hz	10 – 10 M	
Frequency noise sensitivity	Hz/√Hz	< 50 – 10 M	< 10 – 10 M
Intrinsic linewidth range [3]	Hz	< 8 k	< 350
Effective linewidth range (β-separation) [2]	Hz	< 20 k – 10 M	< 2 k – 10 M
Relative intensity noise limit	dB/Hz	–150	
Lineshape specifications			
Effective linewidth [2] range (FWHM)	Hz	< 20 k – 4 M	< 2 k – 4 M
Optical frequency resolution	Hz	20 k	2 k
Dynamic range	dB	50	
Miscellaneous			
Interface		USB 2.0 Type B	
Analog Output / error signal [4]		BNC ± 7.5 (50 Ω) ± 15 (high impedance) V, single ended	
Cutoff (highpass filter)	Hz	10, 1 k, 10 k, 100 k	
Dimensions	mm	220 × 334 × 96	
Weight	kg	8	

Digitizer module

Sample rate	Sa/s	62.5 (max.)
Resolution	bits	16
Acquisition time	s	0.1 (typ.)
Evaluation time	s	< 1 (typ.)
Miscellaneous		
Communication		USB 3.0 Type B
Dimensions	mm	210 × 200 × 74
Weight	kg	2

Software

Operating system		Microsoft® Windows® (7 – 10), 64 Bit
CPU (minimum)		Intel® Core™ i5 or equivalent
Memory (minimum)		8 GB
Graphical Evaluation options		Frequency noise density graph, lineshape graph, frequency deviation distribution (histogram)

1) Best performance with maximum input power. Noise sensitivity scales inversly with input power.

2) Effective linewidth: Combination of intrinsic linewidth and additional broadening mechanisms (thermal, electronical and acoustic noise). Determination by β-separation method (noise density spectrum) or curvefitting procedure (lineshape spectrum).

3) Intrinsic linewidth: Limited by fundamental quantum processes and laser design. Determined by the noise floor (white noise) of the frequency noise spectrum and calculated by: noise density (in Hz^2/Hz) times π (rule of thumb). This value is most commonly denoted as “laser linewidth” by laser manufacturer.

4) Linewidth reduction/control: Analog output as error signal for use in combination with PID controller (not included) for frequency noise or RIN reduction.

Linewidth Analyzer · 07-2019
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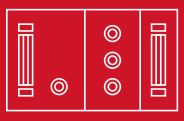
HighFinesse
Laser and Electronic Systems

Wavelength Meter

HighFinesse/Ångstrom offers sensitive and compact wavelength meters with a large spectral range for high speed measurement of lasers. The optical unit consists of temperature-controlled Fizeau-based interferometers that are read out by photodiode arrays. The high absolute accuracy is achieved by use of solid state, non-moving optics. The optical unit and associated electronics are housed in a compact, thermal casing. The connection to a computer or notebook is realized via a highspeed USB 2.0 port, which allows a high data read-out rate. The analyzing software displays all the interferometer information.

Spectrometer OSA

HighFinesse/Ångstrom optical spectrometers LSA and HDSA are designed to analyze 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. They are suitable to analyze the spectrum of telecom signals, resolve Fabry-Perot modes of a gain chip, and produce a spectral measurement of gas absorption.



Precision Current Sources

HighFinesse Precision Current Sources have been developed for experiments and quantum technologies in the areas of Cold atom physics and solid-state-physics. The linearly regulated BCS (Bipolar Current Source) and UCS (Unipolar Current Source) series deliver highly stable, low noise source currents for high precision magnetic field control. The current output is floating or is on a user defined potential. Ultrafast response to control signals and trigger functions, clear grounding, connection and signal isolation schemes make the integration of the current sources into complex experimental systems easy.

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