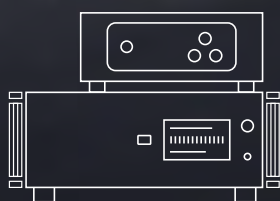
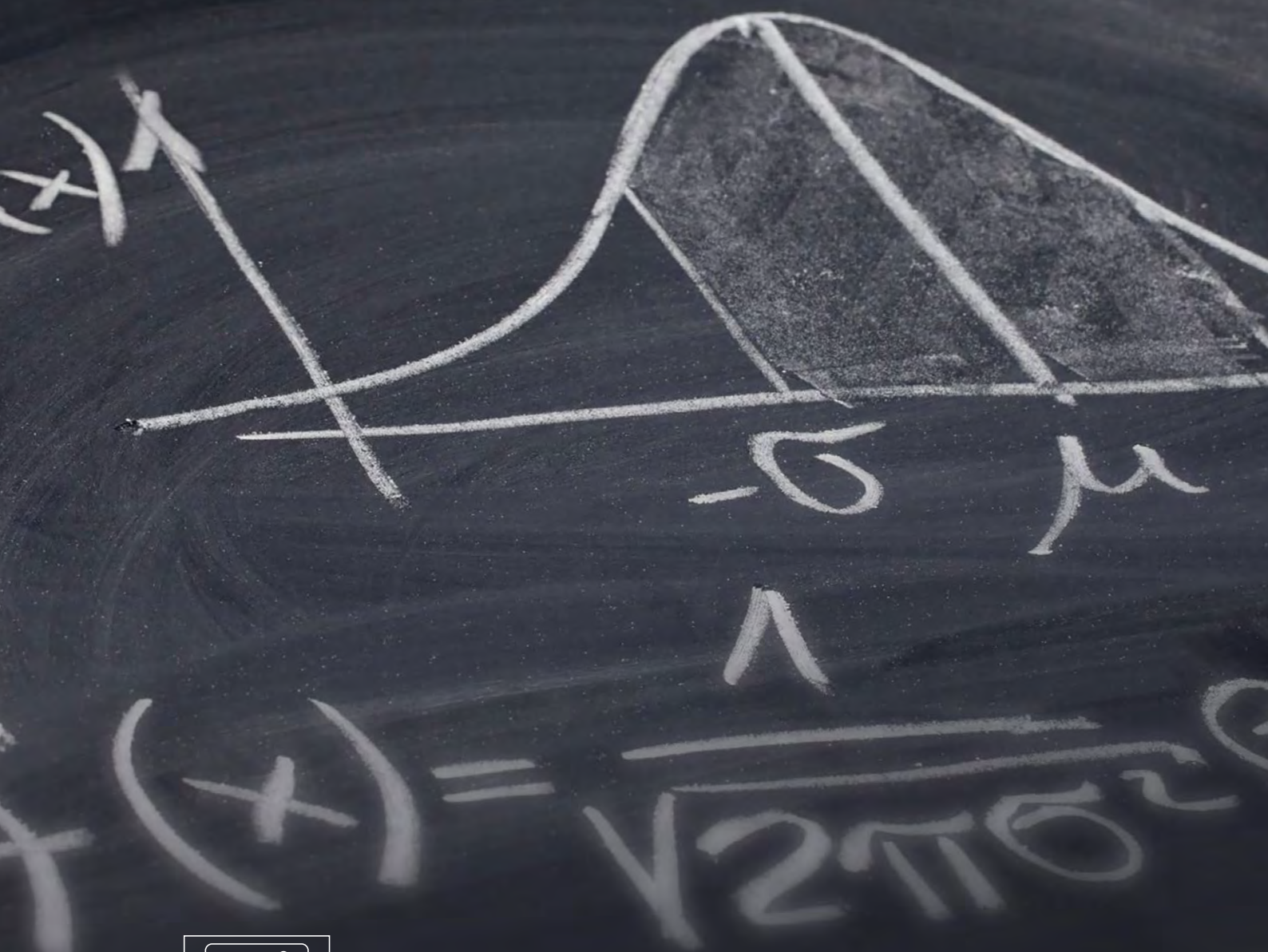




HighFinesse

The Standard of Accuracy



## Linewidth Analyzer

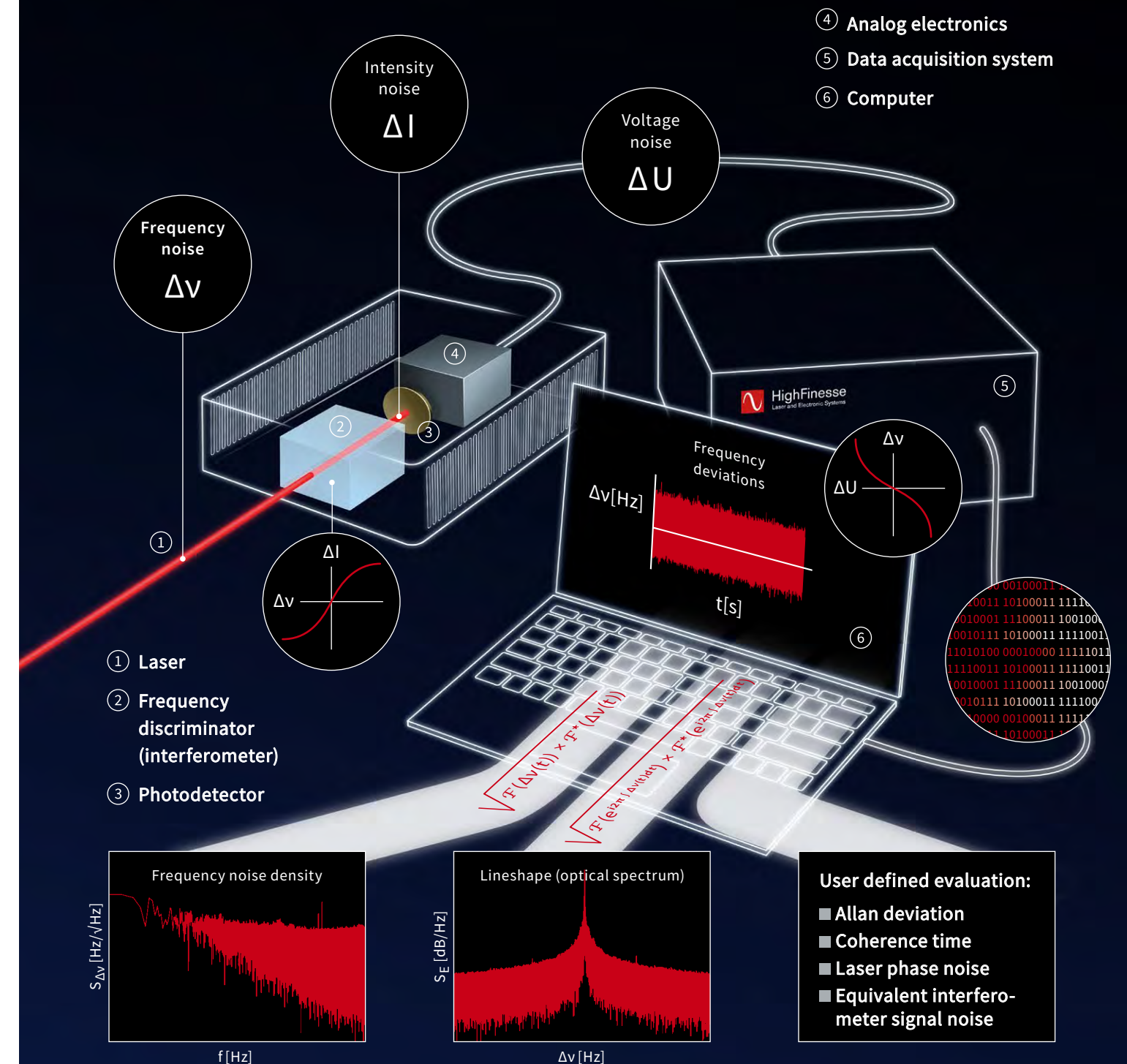
High resolution lineshape spectra  
and ultra sensitive noise analyzers  
for narrowband lasers



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

The main features are:

- Frequency noise density, optical lineshape and relative intensity noise (RIN) analysis with evaluation of intrinsic (Lorentzian) and effective (optical) linewidth
- Intrinsic (Lorentzian) linewidth measurements down to 350 Hz
- Effective (optical) linewidth measurement range down to 1 kHz
- Frequency noise density floor down to 5 Hz/ $\sqrt{\text{Hz}}$  with a dynamic range of 60 dB between 10 Hz and 10 MHz
- Laser phase noise density floor down to 3.2  $\mu\text{rad}/\sqrt{\text{Hz}}$
- RIN measurement down to -150 dB/Hz
- 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
- Extremely fast analysis: up to real time measurements and evaluation



The laser light ① is coupled to the input fiber and lead through an interferometer ② acting as a frequency discriminator. The transmitted intensity, which is directly proportional to the variations of the input frequency, is converted by a photodetector ③ and our analog electronics ④ into a voltage signal. This voltage is finally digitized by the Digitizer ⑤ to provide the data for evaluation on a computer ⑥.

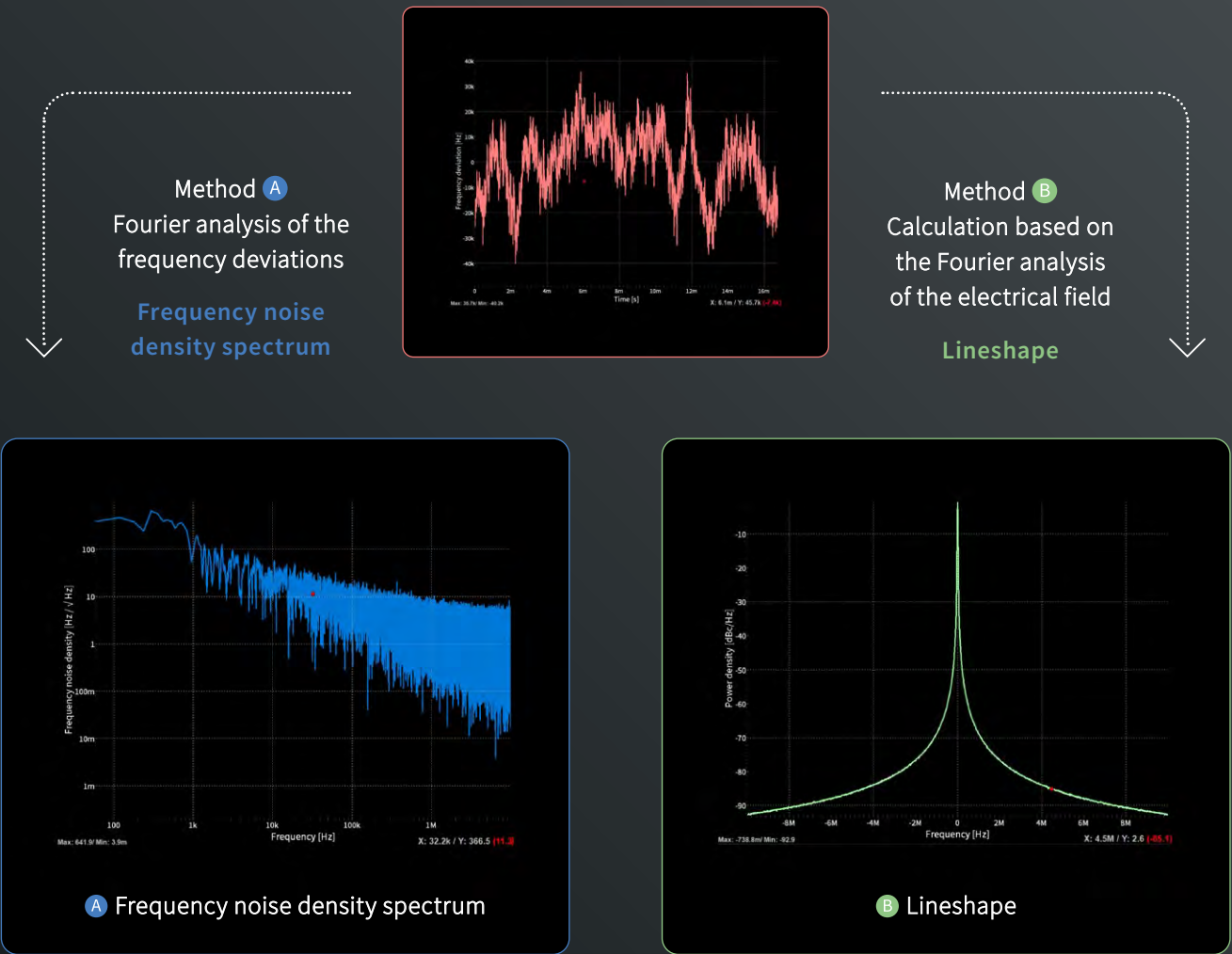
The included software recovers the original frequency noise using the precisely known interferometer function.

The recovered timeseries of the frequency deviations is now the basic dataset allowing to calculate easily the frequency noise density spectrum and the optical lineshape spectrum.

The user can also export the timeseries data in order to perform custom evaluation methods such as Allan deviation or coherence time analysis.



Let the Software Suite do the math for you. The LWA Software Suite is delivered with all LWA products.

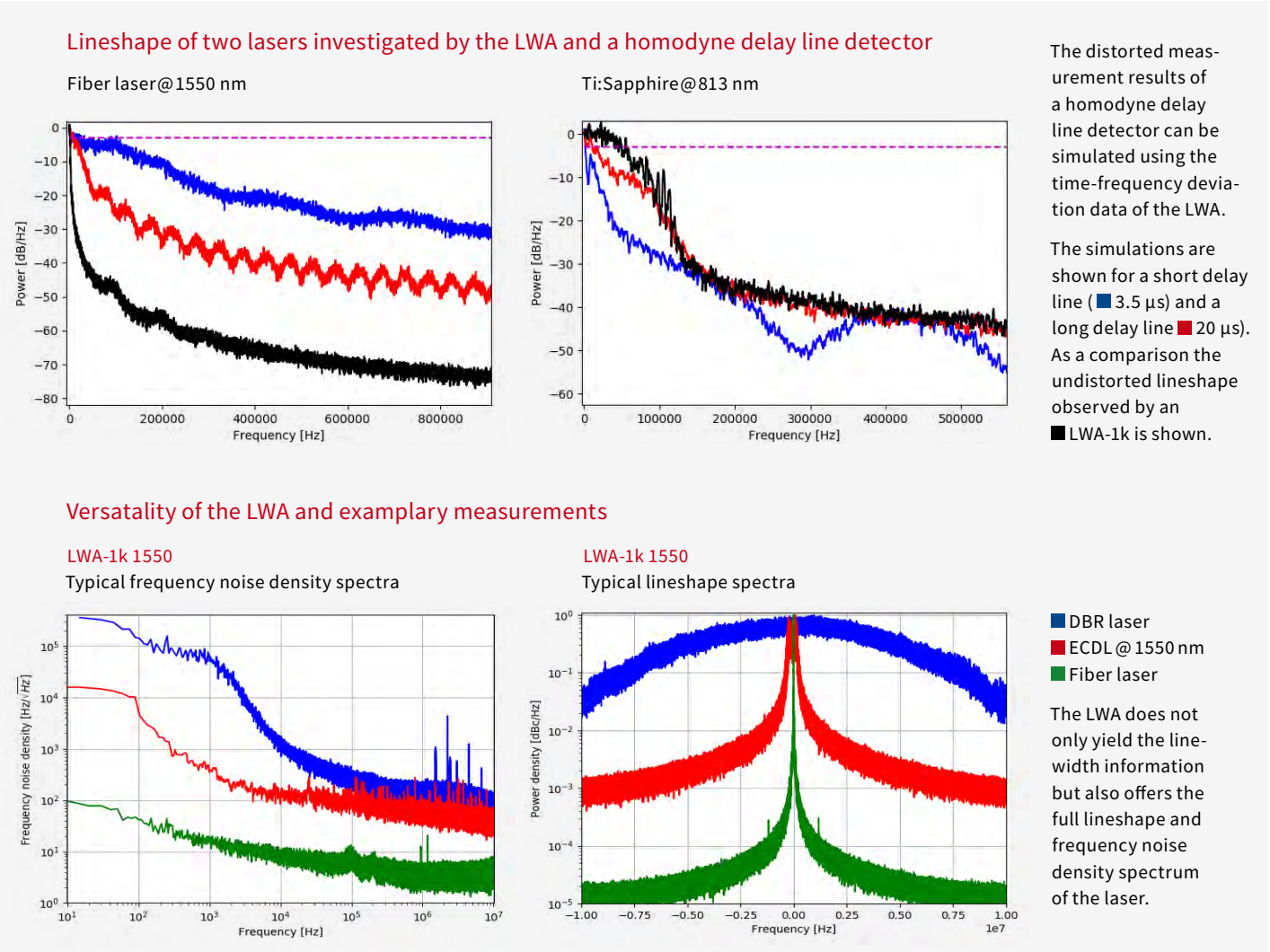


■ Real-Time Analysis

- Automatic calculation of:
  - frequency noise density.
  - intrinsic and effective laser linewidth based on the  $\beta$ -separation approach [DiDomenico Appl. Opt. 49 (2010)].
  - optical lineshape for various observation times.
  - linewidth parameters by fitting Voigt, Lorentzian or Gaussian models to the observed lineshape.
- Timeseries export allows for calculating many mode parameters like Allan deviation, coherence time, equivalent interferometer signal noise, etc.

Comparison: Discriminator- vs. Delay-line-technique

Beside the frequency discrimination approach, homo- and heterodyne delay-line techniques are commonly used for linewidth determination. However, using optical delay lines can lead to complex spectra with non-trivial evaluation needs due to the technique inherent loss of information.



	Discriminator (e.g. LWA-1k)	Delay-line approach
Principle	Direct frequency noise to intensity conversion	Optical delayed superposition by different path lengths
Limits	Steepness of discriminator-function	Length of delay path
Basic data	Frequency deviations in time	Spectrum of beat note (convolution of original spectrum)
Frequency noise density	By a Fourier analysis of the frequency deviations	Not possible without additional methods
Lineshape	By a Fourier analysis of the calculated electric fields	Lorentzian part (intrinsic linewidth) of the lineshape
Linewidth evaluation	Effective (optical) and intrinsic (Lorentzian) linewidths directly accessible via frequency noise density spectrum or lineshape spectrum	Only the Lorentzian part of the linewidth is accessible, because the frequency noise is high-passed by the delay line
Laser phase noise spectrum	By performing a Fourier analysis of the integrated frequency fluctuations	Not possible without additional methods
Interferometer signal noise spectrum	By performing a Fourier analysis of the calculated interferometer phase signal <sup>1)</sup>	Not possible without additional methods

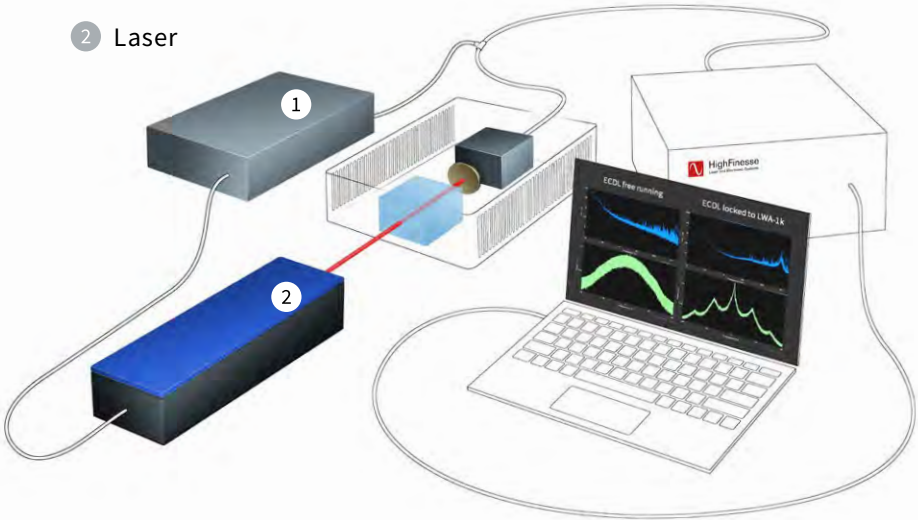
1) Assuming the interferometer working purely as a frequency discriminator and the interferometer phase signal being proportional to the frequency deviation signal.

Feedback Controller

Due to the design of the LWAs, the output voltage can be directly used as an error signal for a feedback controller allowing to reduce the frequency noise of the test laser.

Depending on the used feedback controller and the laser system the optical linewidth can be reduced by more than two orders of magnitude offering a vast amount of new opportunities.

- 1 Feedback controller
- 2 Laser



Active laser noise reduction

- Connect the Analyzer output signal **A** as input signal to a fast feedback controller.
- Connect the feedback controller to the laser’s fast DC modulation input (e.g. laser diode current). **B**
- Adjust the feedback to minimize the output signal of the Analyzer (e.g. PID parameters, gain)

Typical application

- Laser module quality control
- Laser design optimization
- Metrology and quantum technology
- Linewidth control for spectroscopy
- Modulation surveillance

Product Overview

Technical Data

Wavelength range
Input power range (@typical wavelength)
Required input power stability
Laser type
Input fiber type
Maximum frequency stroke (@ f > 10Hz)

Frequency Noise Specification

Noise floor $N_{\Delta\nu}$ @ typ. input power and wavelength <sup>6)</sup>
Laser phase noise floor @typ. input power and wavelength <sup>4) 9)</sup>
Equivalent interferometer signal noise @typ. input power and wavelength <sup>4) 6)</sup>
Frequency noise bandwidth <sup>5)</sup>
Minimum measurable intrinsic linewidth (lorentzian linewidth)
Effective linewidth range (optical linewidth) [β-separation method]
Relative intensity noise limit (lorentzian linewidth)
Dynamic range

Lineshape Specifications

Effective linewidth range (optical linewidth) [curve fitting method]
Dynamic range

Miscellaneous

Interface
Analog Output
Cutoff (highpass filter)
Dimensions
Weight

Digitizer Module

Sample rate
Resolution
Acquisition time (time series)
Evaluation time <sup>7)</sup>
Communication
Dimensions
Weight

2) Frequency noise and lineshape specifications are derived from measurements at 780 nm.

3) PM fiber recommended.

4) Not included in the software, can be calculated by the user from exported data.

5) According to a -3 dB criterion.

Unit	LWA-1k 780 <sup>2)</sup>						LWA-10k VIS <sup>2)</sup>						LWA-1k 1550						LWA-10k NIR						LWA-100k NIR					
	min	typ	max			min	typ	max			min	typ	max			min	typ	max			min	typ	max							
nm	760	780	1064			450	780	1064			1530	1550	1625			1064	1550	1625			1064	1550	1625							
mW	1	10	15			0.5	5	8			0.5	5	8			0.5	5	8			0.5	5	8							
%	± 5																													
	Laser type CW, single mode																													
	PM-FC/APC						SM or PM <sup>3)</sup> , FC/AP						PM-FC/APC						SM or PM <sup>3)</sup> , FC/AP						SM or PM <sup>3)</sup> , FC/AP					
MHz	30						40						30						40						100					
Hz	10	100	1k	10k	100k	>1M	10	100	1k	10k	100k	>1M	10	100	1k	10k	100k	>1M	10	100	1k	10k	100k	>1M	10	100	1k	10k	100k	>1M
Hz/√Hz	200	75	30	30	25	15	500	150	60	60	50	30	80	40	15	10	8	5	200	100	30	20	15	10	1k	200	60	50	40	25
rad/√Hz	20	750m	30m	3m	250μ	15μ	5	1.5	60m	6m	500μ	30μ	8	400m	15m	1m	80μ	5μ	20	1	30m	2m	150μ	10μ	100	2	60m	5m	400μ	25μ
dBrad/√Hz	26	-2.5	-30	-50	-72	-96	24	3.5	-24	-44	-66	-90	18	-8	-36	-60	-82	-106	26	0	-30	-54	-76	-100	40	6	-24	-46	-68	-92
rad/√Hz/m	6.2μ	2.3μ	920n	920n	770n	460n	16μ	4.6μ	1.8μ	1.8μ	1.6μ	920n	2.5μ	1.3μ	460n	310n	250n	160n	6.2μ	3.1μ	920n	620n	460n	310n	31μ	7μ	2μ	2μ	2μ	765n
dBrad/√Hz/m	-104	-112	-120	-120	-122	-126	-96	-106	-114	-114	-116	-120	-112	-118	-126	-130	-132	-136	-104	-110	-120	-124	-126	-130	-90	-104	-115	-116	-118	-122
Hz	10 – 10 M																													
Hz	<3 k						<12 k						<350						<2 k						<10 k					
Hz	<10 k – 20 M						<20 k – 30 M						<1 k – 20 M						<5 k – 30 M						<15 k – 100 M					
dB/Hz	–						–						–150						–						–					
dB													60																	
Hz	<10 k – 10 M						<20 k – 10 M						<1 k – 10 M						<5 k – 10 M						<15 k – 10 M					
dB													60																	
	USB 2.0 Type B						Ethernet						USB 2.0 Type B						Ethernet						Ethernet					
	BNC ± 7.5 (50Ω) ± 15 (high impedance) V, single ended																													
Hz	10, 1k, 10k, 100k						10						10, 1k, 10k, 100k						10						10					
mm	220 × 334 × 96						440 × 340 × 155 mm						220 × 334 × 96						440 × 340 × 155 mm						440 × 340 × 155 mm					
kg	8.0						12						8.0						12						12					
Sa/s	62.5 M (max.)																													
bits	16																													
s	1 m – 100 m																													
s	10 m – 1 (typ.)																													
	USB 3.0 Type B																													
mm	210 × 200 × 74																													
kg	2.0																													

6) This is the calculated noise of the interferometer phase of a two path interferometer with length imbalance L (in meters). The alculatation is performed for a given frequency noise density floor by  $2\pi nL/c \times N_{\Delta\nu}$ , with n being the refractive index of the reference fiber interferometer material and c being the speed of light in vacuum. Values in the table are given for an refractive index of n=1.46 and a reference length of 1 meter.

7) Windows 10 or newer, Intel i5 8600/AMD Ryzen 5 2600 or better, 16GB RAM or more.

8)  $N_{\Delta\nu}$  is the noise floor of the instrument in terms of the square root of the power spectral density of the frequency noise.

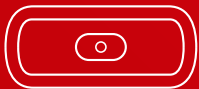
9) The phase noise floor corresponds to the noise floor of the square root of the power spectral density of the phase. It is calculated from  $N_{\Delta\nu}$  by the formula  $1/f \times N_{\Delta\nu}$ . Additionally, phase noise is often specified in terms of  $\mathcal{L}(f)$  which can be calculated with the formula  $\mathcal{L}(f) = 1/f^2 \times N_{\Delta\nu}^2/2$ .

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## Wavelength Meter

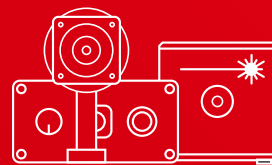
HighFinesse/Ångstrom offers sensitive and compact wavelength meters with a large spectral range for high speed measurement of lasers. The optical unit consists of temperature-controlled Fizeau-based interferometers that are read out by photodiode arrays. The high absolute accuracy is achieved by use 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

The grating based HighFinesse/Ångstrom Laser Spectrum Analyzers offer the capability for a very accurate simultaneous measurement of both the center wavelength and the linewidth of a laser source with a compact and versatile instrument.

The product series covers the ranges from 192 nm to 2250 nm. The grating based technology allows the analysis of laser sources over a large linewidth range. Utilizing the principle of non-moving parts just like the well-known HighFinesse WS-series wavemeters, the LSA offers the time-tested robustness and ability to measure both pulsed and cw lasers.



## Calibration Sources

HighFinesse offers a variety of frequency stabilized, narrow linewidth laser sources for the calibration of all wavelength meters and applications down to  $\pm 0.5$  MHz absolute accuracy. These are user friendly, plug and play devices that can be connected to the wavelength meter. Different technologies, accuracies and wavelengths are available to suit your application.

HighFinesse stabilized frequency references yield extremely accurate frequency stabilizations, ideal for calibration of our wavelength meters in the visible and infrared wavelength regimes.



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