Wavelength Meter

Sensitive and compact, with a large spectral range for high speed measurements of pulsed and continuous lasers
The HighFinesse/Ångstrom wavelength meters are the unsurpassed high-end instruments for wave-
length measurement of pulsed and continuous laser sources. They deliver the superb absolute and
relative accuracy required by cutting edge scientific research, as well as industrial and medical appli-
cations. The unmatched precision of the WS8 series and all of our other wavelength meters is achieved
by using non-moving Fizeau interferometers in a unique geometric configuration.

The standard wavelength meters are connected to the PC via a USB interface and are ready for use as
soon as the software delivered with the instrument is installed. The wavelength meters are also available
as rack or standalone instruments with Ethernet connection facilitating the system integration.

A compact, thermally insulated housing holds the optical elements as well as the electronics. To allow
even higher stability and precision, temperature and pressure effects are compensated. The design
enables the integration of additional options, allowing customized solutions to specific applications even
years after purchase.

With an absolute accuracy of 2 MHz and a measurement resolution of 200 kHz the WS8-2 is
the ultimate solution for frequency monitoring and stabilization tasks. Together with the photonic
crystal switch technology only offered by HighFinesse it enables the quasi-simultaneous measure-
ment of up to 8 channels over a broad wavelength range. Despite its unmatched accuracy the
WS8-2 is a versatile, compact and reliable tool not only for quantum physics laboratories and appli-
cations such as quantum computing and atomic clocks.

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, non-moving optics.

The light is coupled into the instrument via a fiber and then collimated by a
mirror before entering the solid-state Fizeau-interferometers. The interfer-
ence pattern is imaged by a cylindrical lens onto CCD photodiode arrays.
This recorded pattern is transferred to your computer via a high-speed
USB con
nection (Standard Series) or a Camera link connection (Fast Series)
which allows data acquisition rates of up to 76 kHz.

The software fits and compares the pattern to a previously recorded calibration to calculate the wave-
length. One significant advantage of our Fizeau-based wavelength meters, compared with other available instru-
ments, is the absence of mechanical moving parts. This ensures the high
reliability of accuracies up to 2 MHz (absolute) and ensures the outstand-
ing robustness HighFinesse wave-
length meters are noted for. The de-
sign enables the precise measurement of not only continuous lasers, but also pulsed laser sources, which broadens the
application range even further.

Another key benefit is the simplicity of our wavelength meters. Simply connect the USB cable and run the
program supplied. That’s all it takes!
Applications

Astronomy

In astronomy artificial guide stars created by laser radiation are successfully used to correct atmospheric distortion of light drastically improving the image quality of telescopes. Not only the Very Large Telescope in Chile uses a customized HighFinesse Wavelength Meter in its guide star systems to stabilize the laser to keep the emission from sodium atoms at the maximum and in this way make the systems reliable and efficient.

The flexible design of our wavelength meters allows the integration of additional optical components and software modules. Please reach out to us if you need a customized solution for your specific application requirement.

The VLT in Chile with the guide star system.
Picture courtesy: ESO/Y. Beletsky

Quantum Computers

Researchers and companies working on quantum computing rely on the excellent accuracy of HighFinesse wavelength meters. In trapped ion quantum computers, the tasks laser cooling, state preparation, manipulation, and read out require wavelength meter for accurate laser wavelength measurements. Laser stabilization is a key task and can be carried out conveniently by using the PID option. HighFinesse is a partner in the following front-running research projects on quantum computers:

MUNIQC-atom\(^1\): This project aims on developing a quantum computer based on neutral atoms for solving problems in quantum chemistry and material sciences.

https://www.quantentechnologien.de/forschung/forderung/quantencomputer-demonstrations-aufbauten/muniqc-atoms.html

Rymax One\(^1\): The HighFinesse wavelength meter helps to fulfill the mission to build a quantum computer to solve the today’s real-world problems.

https://rymax.one/

Secure quantum communication

The QR.X project\(^1\) aims at developing quantum repeaters for secure quantum communication. Current fiber-based technology is limited to distances roughly below 100 km. HighFinesse wavelength meters assist partners from a strong team of different German universities in their research to overcome these limitations.

https://www.forschung-ikt-sicherheit-kommunikationssysteme.de/projekte/qr.x

HighFinesse is a project participant in the project founded by the German BMBF (Federal Ministry of Education and Research).

Demanding field applications

The robustness of the HighFinesse Fizeau-technology enables the use of wavelength meters in harsh environments: The German Aerospace Center (DLR) uses a HighFinesse wavelength meter in a plane.

Tolerating the demanding conditions (vibrations, pressure gradients) the wavemeter provides the researchers with accurate wavelength measurements for their research on the atmosphere.

Demanding field applications

Tools for high end laser diagnostics

Laser manufacturers use our wavelength meters as tools in R&D, production, quality control, and service as reliable and accurate instruments. Thanks to the HighFinesse non-moving part technology the wavelength meters are very robust and insensitive to shocks and vibrations. The compact size facilitates the use for field engineers. For seamless system integration the wavelength meters can be obtained as rack and standalone instruments. The well documented dynamic link library-based API enables full control of the instrument from external software and makes integration in software systems straightforward.

Atomic clocks

As effective laser cooling is a key technology in atomic clocks and relies on accurate laser wavelength diagnostic our high-end wavemeters are used in the frontrunning Opticlock project\(^6\). The aim of this project is to develop an easy-to-use optical clock for reliable operation in environments outside scientific laboratories. This project relies on the high accuracy and robustness of the HighFinesse WS8 wavemeter.

https://www.opticlock.de/en/info
Singlemode fiber switches are needed to provide homogeneous light input for measurements with our high-end instruments WS6-200, WS7 and WS8 to ensure the excellent accuracy.

The ranges of single mode fibers are limited to a few 100 nm which makes quasi-simultaneous measurements of lasers separated by more than that impossible. Our photonic-crystal-fiber (PCF) switches solve this problem. Using endlessly single mode PCF allows us to produce a switch that offers single mode operation for all wavelengths. The PCF switch enables to switch between light-sources at any wavelength within the instrument’s measurement range and maintain the full accuracy.

Combining the PCF switch with other options such as PID control opens new possibilities. Sold exclusively with all WS6-200, WS7 and WS8 instruments except for the UV-II and IR-III range the PCF switches are available in two-channel, four-channel, and eight-channel configurations.

### Product Overview WS Series

#### Photonic Crystal Fiber Switches

<table>
<thead>
<tr>
<th>Configuration</th>
<th>WS5</th>
<th>WS6-600</th>
<th>WS6-200</th>
<th>WS7-60</th>
<th>WS7-30</th>
<th>WS8-10</th>
<th>WS8-2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurement range</strong></td>
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<td>UV-II (192 – 800 nm)</td>
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<tr>
<td>UV-II (248 – 1180 nm)</td>
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<tr>
<td>Standard (330 – 1180 nm)</td>
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<tr>
<td>VIS / IR-I (330 – 2750 nm)</td>
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<tr>
<td>VIS / IR-II (500 – 2250 nm)</td>
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<td>IR-II (1000 – 2250 nm)</td>
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<td>IR-II (1400 – 11000 nm)</td>
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<td>0.6</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
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<tr>
<td>Hz</td>
<td>3000</td>
<td>900</td>
<td>300</td>
<td>100</td>
<td>50</td>
<td>20</td>
<td>10</td>
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<tr>
<td><strong>Minimum required input energy and power</strong></td>
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<tr>
<td>µJ (or µW)</td>
<td>0.02 – 15</td>
<td>0.02 – 15</td>
<td>0.02 – 15</td>
<td>0.02 – 15</td>
<td>0.02 – 8</td>
<td>0.08 – 60</td>
<td>0.08 – 60</td>
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<tr>
<td><strong>Linewidth option</strong></td>
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<td><strong>Recommended calibration period</strong></td>
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<tr>
<td>Warm-up time</td>
<td>≤ 1 month</td>
<td>≤ 14 days</td>
<td>≤ 10 hours</td>
<td>≤ 3 hour</td>
<td>≤ 24 hours</td>
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<tr>
<td>Dimensions L = W = H</td>
<td>360 × 120 × 120</td>
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<td>360 × 200 × 120</td>
<td>360 × 200 × 120</td>
<td>360 × 200 × 120</td>
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<tr>
<td>Weight</td>
<td>2.8</td>
<td>2.8</td>
<td>5.2</td>
<td>5.2</td>
<td>6.1</td>
<td>6.4</td>
<td>6.4</td>
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<tr>
<td>Power supply</td>
<td>High-speed USB 2.0 connection</td>
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</tbody>
</table>

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1) According to the criterion, but never better than 20% of the laser linewidth.
2) With multi-mode fiber.
3) ± 20 nm around calibration wavelength, outside of this range the accuracy as WS6-100 applies.
4) ± 20 pm around calibration wavelength, outside of this range the accuracy as WS6-100 applies.
5) Standard deviation. WS6-200 and higher models require singlemode or photonic crystal fibers to reach this resolution.
6) Not better than 2% of the linewidth.
7) Depending on PCB, hardware and settings, highpowered models up to 74 mW available.
8) The Coprue interpretation is [µW] compared to an exposure of 1 [µW] (generally the energy needs to be divided by the exposure time to obtain the required power).
9) µJ interpretation for pulsed lasers. CW signals need more power [µW] since the exposure is limited at IR-II instruments.

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<table>
<thead>
<tr>
<th>Specifications</th>
<th>WS5</th>
<th>WS6-600</th>
<th>WS6-200</th>
<th>WS7-60</th>
<th>WS7-30</th>
<th>WS8-10</th>
<th>WS8-2</th>
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</thead>
<tbody>
<tr>
<td>Product Overview WS Series</td>
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</table>

WWW.HIGHFINESE.COM/EXTRACTION/WS-SERIES Excel file to download more specs and brochures for our products.
Upgrade Options expand the capabilities of our wavelength meters to match individual requirements of cutting edge research and measurements. Among these powerful options are the HighFinesse multichannel fiber switches allowing for quasi-simultaneous measurement of up to 8 channels and the PID option for full wavelength control of up to 8 lasers.

Upgrade Option - Compatibility Overview

<table>
<thead>
<tr>
<th>Wavemeters</th>
<th>MC</th>
<th>Laser Control</th>
<th>External Trigger</th>
<th>Linewidth Estimation</th>
<th>Spectrometer</th>
<th>Calibration Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>WS8</td>
<td>✓</td>
<td>✓</td>
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<td>WS7-30</td>
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<td>WS7-60</td>
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<td>WS6-200</td>
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<td>WS6-600</td>
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<td>WS6-800</td>
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<td>WS7-30</td>
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<td>WS6-200</td>
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<td>WS6-600</td>
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</table>

The combination of our high-speed wavelength meters with one of the quickest fiber switches allows up to eight channels to be measured quasi-simultaneously. Exposure time and other parameters can be defined independently for each light source. The table below gives an overview of the HighFinesse multichannel switches which are available with 2, 4, and 8 input channels. Single mode fiber switches are needed to provide homogeneous light input for measurements with our high-end instruments WS6-200, WS7 and WS8 to ensure the excellent accuracy. The range of single mode fibers are limited to a few 100 nm which makes quasi-simultaneous measurements of lasers separated by more than that impossible. Our photonic-crystal-fiber switches solve this problem and offer single mode operation for all wavelengths.

For the WS5 and WS6-600 Multi mode fiber switches can be used which offer a broad wavelength range.

MC

The maximum linewidth that can be measured depends on the free spectral range (see specifications on page 8) of the interferometers used in the wavemeter. As a rule of thumb, the maximum linewidth is given by 30% FSR.

Example: For a WS6-200 in the fine mode the maximum linewidth is 30% × 16 GHz = 4.8 GHz. The use of single mode fiber is recommended for this option.

If you are interested in linewidth and noise characterization of narrow linewidth laser below 100 MHz you might be interested in our linewidth analyzers (LWA).


As soon as the laser current becomes stable the Wavemeter is triggered such that the wavelength measurement can be assigned to a certain stable current. In this way the laser wavelength dependence on laser current but also on other parameters can be screened efficiently.

Please note, if the option MC is ordered together with the TTL option, the TTL mode can only be used if the switch is set fixed to one input channel.
With the PID option it is possible to stabilize the frequency of a laser connected to the wavelength meter using a software based proportional-integral-derivative controller (PID controller). Unlike analog PID electronics, the PID option provides software based signal processing, allowing the laser to be stabilized to a specific user defined frequency or regulated with an arbitrary pattern.

This makes it extremely useful in experiments where the laser frequency has to be actively regulated or varied to fit changing experimental conditions, such as laser cooling, atomic detection, trapping and spectroscopy. Combined with the MC option the wavelength meter can be used to stabilize multiple lasers simultaneously.

The achievable resolution and loop capture range depends on the laser system that you would like to control. The table (page 11) gives a summary of the achievable loop capture range and resolution using a HighFinesse WS8 wavelength meter with PID option and a TOPTICA DL Pro with a typical sensitivity of 1 V/µm.

Watch how accurately the wavelength of multiple lasers can be controlled by a HighFinesse Wavelength Meter with PID option.

https://www.youtube.com/watch?v=3Tf1iwzCEP8
All standard HighFinesse wavelength meters are connected with USB to a computer running the easy-to-use and powerful HighFinesse wavelength meter software.

They can be controlled with external software via the dynamic link library-based API enabling easy integration in complex measurement processes. The HighFinesse network solution enables control of the wavemeters via the network from computers (with Windows, Linux or MAC operation system) in the same network as the computer running the wavelength meter software.

For even more convenient integration the HighFinesse WS wavelength meters can be ordered as Rack or Standalone systems with internal computer. Our standard configuration for Rack and Standalone wavelength meters is shown above. Both Rack and Standalone wavelength meter will come in 19” standard rack cases with 3 HU readily mountable in a standard rack system. The wavelength meter can be equipped with additional upgrade options such as Multichannel switches, PID Laser Control, or TTL external trigger. The Rack wavelength meter is connected via USB to an external computer.

Special preconfigured Standalone models for high measurement speed in the telecom range and beyond

The WS6-600 and WS6-200 IR-I Standalone offer a measurement rate of more than 1600 Hz over the range 630 – 1750 nm

- Turnkey Wavelength Measurement
- High Measurement Speed
- Ethernet control via dll-based API or SCPI commands
- Touchscreen
- Upgrade Options Linewidth estimation, PID laser control, External trigger available

Standalone wavemeters overcome the need for an external computer. They can be controlled locally by connecting screen, keyboard, mouse or via touchscreen (not available for all models) and using Ethernet connection via the dll-based API or SCPI commands.

Seamless Integration Rack & Standalone Instruments

OEM and customization

There are always cases when custom solutions are necessary for example if instruments are subject to extreme conditions. We are always happy to work with you on the perfect solution for instance improving the protection against environmental influences and increased shock resistance.
The HighFinesse WF6 Series features ultra high measurement rates – for monitoring ultrafast wavelength dynamics. Readout rates can be up to 24 kHz in the 380 – 1064 nm and even up to 76 kHz in the 980 – 1650 nm wavelength range. Fast swept laser sources can be precisely characterized with these wavelength meters.

The fastest commercially available wavelength meters.
HighFinesse 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.

HighFinesse Linewidth Analyzers (LWA) are specialized high-end instruments for measuring and analyzing the spectral shape of various laser sources. Through the use of two measurement modes, the LWA can analyze both very narrow laser lines down to 100kHz as well as broader spectra up to 1GHz. They feature an extremely high resolution and accuracy in determining the linewidth of the respective laser source and its spectral lineshape. The LWAs are ideal for optimizing the stability of laser setups.

Spectrometer OSA

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 110000 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.

HighFinesse GmbH
Wöhrdstraße 4
72072 Tübingen, Germany

T +49 (0) 7071 - 53 918 0
F +49 (0) 7071 - 53 918 99
M info@highfinesse.com

Additional information and distributors: www.highfinesse.com