LASER SPECTROMETER

waveScan

User Manual

Manual of **waveScan**

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10/2021 | Manual Revision: 1304

IMPORTANT – READ CAREFULLY BEFORE USE – KEEP FOR FUTURE REFERENCE

This user manual contains user information for the waveScan. Read this manual carefully before operating the waveScan. The waveScan has only to be used as described in this manual. Differing use may endanger safety and voids warranty.

CAUTION - USE OF CONTROLS OR ADJUSTMENTS OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS RADIATION EXPOSURE

Symbols Used in This Manual

This symbol is intended to alert the operator to the danger of exposure to hazardous visible and invisible laser radiation.

This symbol is intended to emphasize the presence of important operating instructions.

This symbol is intended to alert the operator of potential electrical hazard to personal safety.

This symbol is intended to inform the operator about important or useful but not hazard-related information.

Warranty

The warranty conditions are specified in the sales contract. Any unauthorized modification of the **waveScan** system components or software will void the guarantee and service contract.

Disposal Hints

All electrical and electronic products should be disposed separately from the standard municipal waste system. Proper disposal of your old appliance prevents potential negative consequences for the environment and human health.

Some components of your **waveScan** system are marked with the crossed-out wheeled bin symbol covered by the European Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) of the European Parliament. These items must be disposed via designated collection facilities appointed by government or local authorities.

For more information about disposal of your old product, please contact APE GmbH.

Contents

1 Safety Instructions

1.1 Safety Features and Compliance to Government Requirements

US government requirements are contained in 21 CFR, Subchapter J, Part II administered by the Center for Devices and Radiological Health (CDRH).
The European Community requirements for product safety are specified in the “Low Voltage Directive” (2014/35/EU). The “Low Voltage Directive” requires that electronic products comply with the standard EN61010-1:2020 “Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use”.
Compliance of this product is certified by the CE mark accordingly.

1.2 Optical Safety

Because of its special properties, laser light poses safety hazards not associated with light from conventional sources. The safe use of lasers requires that all laser users – and everyone else near the laser system - are aware of the dangers involved. The safe use of the laser depends upon the user becoming familiar with the instrument and the properties of intense and coherent beams of light.

Direct eye contact with the output beam of a laser or the reflection of the laser beam can cause serious damage to the eye and possible blindness.

Since the waveScan is intended to measure the spectrum of a laser all safety instructions relevant to the class of your laser have to be observed!

The greatest concern when using laser equipment is eye safety. In addition to the main beam there are often many smaller beams present at various angles near the laser system.
These beams are formed by specular reflections of the main beam at polished surfaces such as lenses and beam splitters or any metallic objects. Although weaker than the main beam, such beams may still be sufficiently intense to cause eye damage. Laser beams are powerful enough to burn skin, clothing, or other materials. They can ignite volatile substances such as alcohol, gasoline, ether, and other solvents, and can damage light-sensitive elements in video cameras, photomultipliers, and photodiodes.

The laser beam can ignite substances in its path, even at a distance. The beam may also cause damage if contacted indirectly from reflective surfaces. For these and other reasons, the user is advised to follow the precautions below:

1. Observe all safety precautions in the user manual.
2. Extreme caution should be exercised when using solvents in the area of the laser.
3. Limit access to the laser to qualified users who are familiar with laser safety practices and who are aware of the dangers involved.
4. Never look directly into the laser light source or at scattered laser light from any reflective surface. Never sight down the beam into the source.
5. Maintain experimental setups at low heights to prevent inadvertent beam-eye contact at eye level.
6. As a precaution against accidental exposure to the output beam or its reflection, those using the system should wear safety glasses as required by the wavelength being generated.

Laser safety glasses can present a hazard as well as a benefit; while they protect the eye from potentially damaging exposure, they block light at the laser wavelengths, which prevents the user from seeing the beam. The user should therefore use extreme caution even when using safety glasses.

7. Avoid direct exposure to the laser light. The intensity of the beam can easily cause flesh burns or ignite clothing.
8. Use the laser in an enclosed room. Laser light will remain collimated over long distances and therefore presents a potential hazard if not confined.
9. Post warning signs in the area of the laser beam to alert those present.
10. Advise all those using the laser of these precautions. It is good practice to operate the laser in a room with controlled and restricted access.

1.3 Electrical Safety

The **waveScan** uses DC voltages. All units are designed to be operated with protective covers in place. The device complies with protection Class I / EN 61140:2016, degree of protection IP20, according to EN 60529:2014. Certain procedures in this manual require removal of the protective covers. These procedures are normally used by a qualified trained service personnel. Safety information contained in the procedures must be strictly observed by anyone using the procedures.

Users are not recommended to open the **waveScan** housing. Opening the housing is only allowed for trained service personal. In case it is necessary to open the housing for service purposes the device has to be disconnected from the power supply.

It is only allowed to run the **waveScan** with the delivered mains adapter.

1.4 Electromagnetic Compatibility

The European requirements for electromagnetic compatibility are specified in the directive to electromagnetic compatibility 2014/30/EU. Conformance to this directive is achieved through compliance with the harmonized standards EN 61000. The **waveScan** meets the emission requirements for Class A, Group 1 as specified in EN 55011:2018-05. Compliance of this product with the directives requirements is certified by the CE mark accordingly.

2 Device Description and Specifications

2.1 Description and Intended Use

The **waveScan** is an easy to use, high resolution device for spectral analysis of cw and mode-locked laser systems. It is based on the spinning grating spectrometer technology. With its resolution down to 0.1 nm (depending on the wavelength range), it offers greater precision over a larger wavelength range compared to standard compact CCD based spectrometers. Especially in the spectral region longer than 1.1 μm which is beyond the capability of silicon based CCDs the **waveScan** offers an easy way for high resolution measurement. The **waveScan** is also an ideal alignment tool because of its high scan rates.
The **waveScan** is available in different versions covering scan ranges from 250 ... 6300 nm. The **waveScan** comes with integrated entrance slit and focusing optics for use with free laser beams. The **waveScan** can optionally be equipped with a SMA, FC/PC, or FC/APC type connector for fiber input.

Figure 2.1: **waveScan** spectrometer

The **waveScan** consists of the optical head, the power adapter, and the control software that runs on your personal computer under Microsoft Windows[1] operating system. The Control Software manages the data transfer between the optical head and the PC via USB connection and allows for a comfortable graphical display of the spectra as well as data storage and processing.

[1]Windows is a registered trademark of Microsoft Corporation in the United States and other countries.

2.2 Technical Background

The **waveScan** is a grating spectrometer in Littrow configuration. The grating rotates with a rate of about six rounds per second. A spectrum is measured each round trip. With this design a fast refresh rate is made possible. The optical signal is taken by a photodiode placed behind the exit slit. Different spectral versions of the **waveScan** are available which use different photodetectors: Si, InGaAs, or combined Si / InGaAs, depending on the version. At a distinct angle position of the grating a high precision trigger starts the measurement. From that trigger on a fixed number of data points is sampled with 1 MHz sampling rate. Measurement data is pre-processed in the optical head's micro controller and a subset of the data is transferred to the control PC. The **waveScan** control software is the user interface that allows for control of the measurement as well as graphical display and data processing and storage.

2.3 Specifications

2.3.1 Optical Parameters

	Wavelength range	Resolution
waveScan version	200 ... 1100 nm	0.2 nm
	220 ... 540 nm	0.05 nm
	500 ... 1600 nm	0.2 nm
	800 ... 2600 nm	0.5 nm
	1500 ... 6300 nm	2 nm

Scan rate	6 scans per second
Laser repetition rate	> 4 MHz or cw real time measurement > 100 kHz accumulation mode > 100 Hz triggered mode
Input polarization	optimized for horizontal polarization
Sensitivity	50 μW per nm bandwidth @ 633 nm cw
Dynamic range	16 bit A/D converter
Fiber input (optional)	SMA, FC/PC, or FC/APC connector (Fiber is not included. Recomended: Single Mode)

2.3.2 Electrical Parameters

Power Adapter	Input: 100 ... 240 VAC, 0.8 ... 0.4 A, 47 ... 63 Hz Output: 12 VDC, 2.5 A
Connectivity	USB 2.0 Full Speed

2.3.3 Mechanical Parameters

Dimensions (mm): see outline drawings in Fig. 3.3.

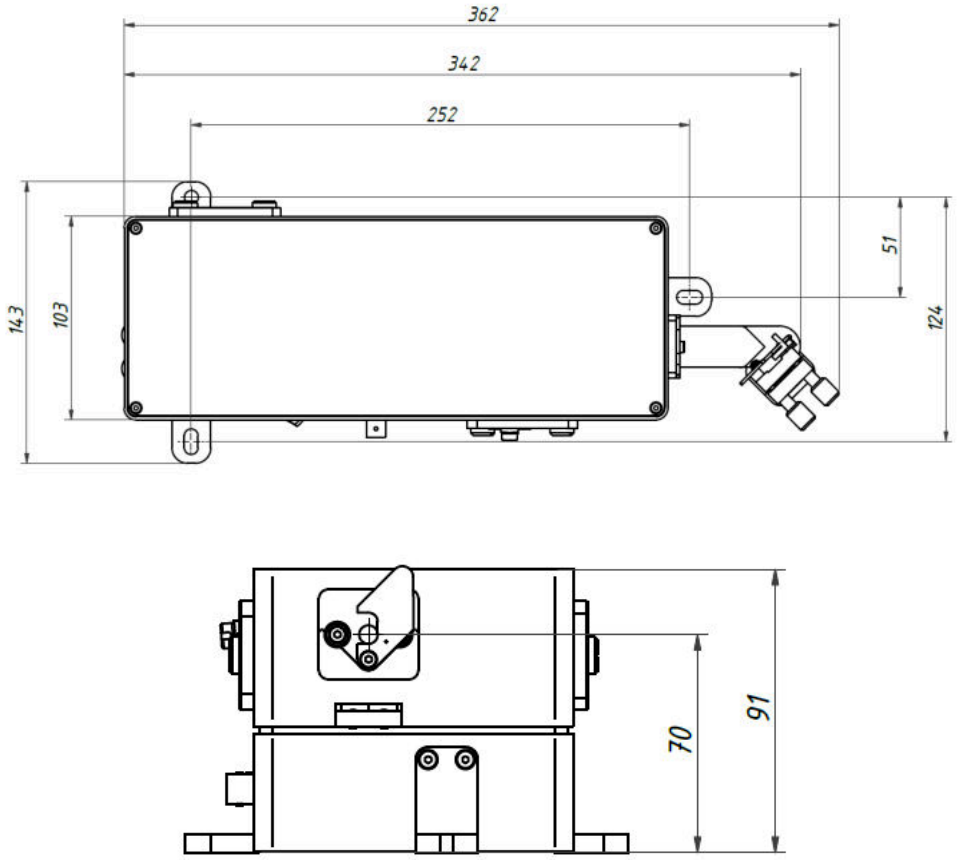

Figure 2.2: Mechanical dimensions (mm) of the waveScan.

Input beam height	70 mm (free beam)
Weight	4.2 kg

2.3.4 Electrical Connections and Indicators

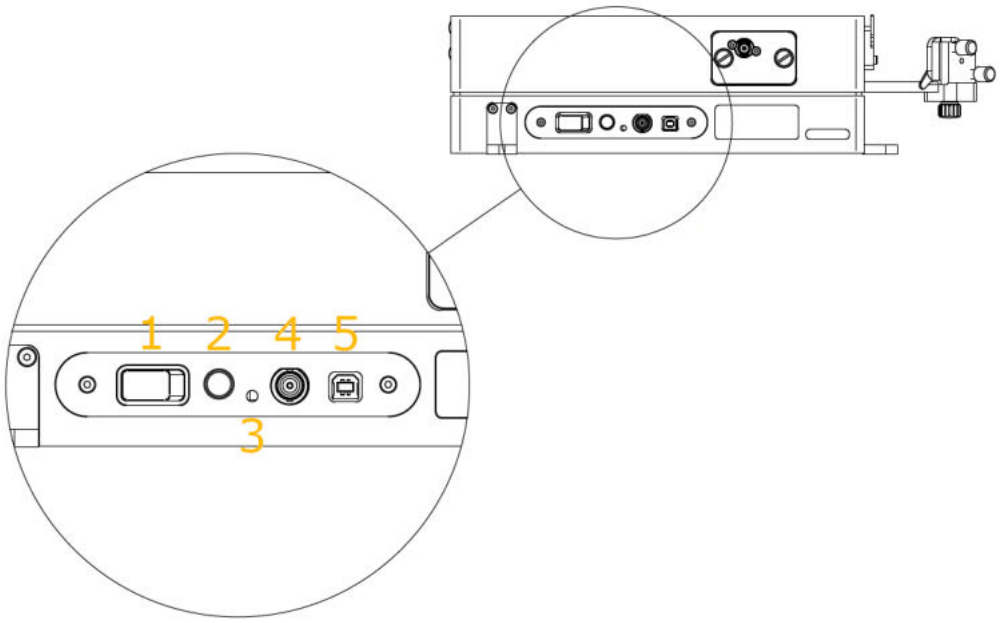

Figure 2.3: Side of **waveScan** with electrical connectors and indicators.

1. Power - Power switch

2. DC In - Power supply input

3. Status - Power status LED

4. Trigger - BNC trigger input for external trigger source

5. USB - USB connector

2.3.5 Mechanical Controls

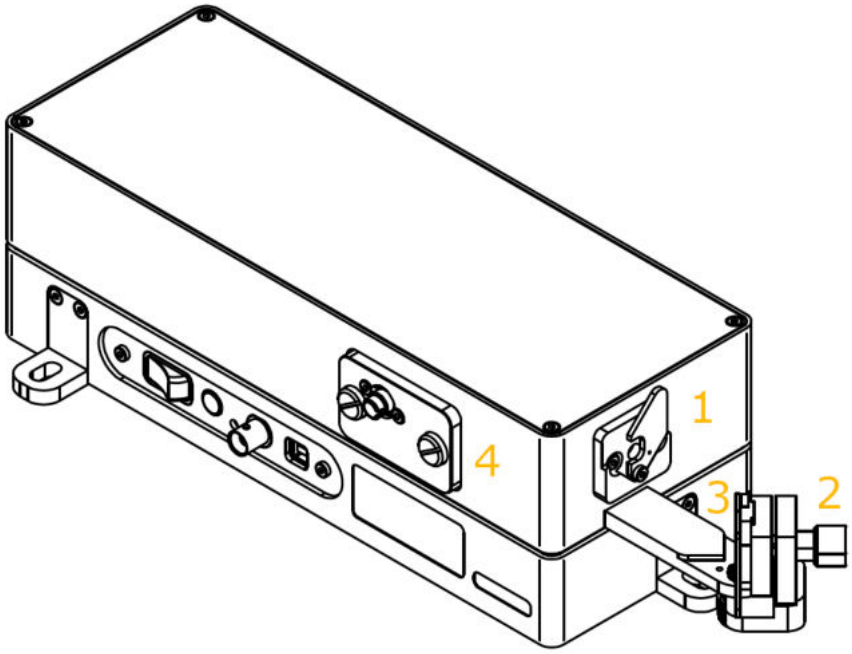

Figure 2.4: Mechanical controls at the front side.

1. Entrance alignment aperture
2. Alignment mirror
3. Mirror alignment aperture
4. Optional: Exchangeable fiber input - see 3.6

2.3.6 System Requirements for User Software

The control computer should have at least the following configuration to run the user software:

- Windows[2] 7 or higher operating system
- 500 MB hard disc space
- Intel® Core™ i3 or equivalent processor
- 1 GB of RAM

[2]Windows is a registered trademark of Microsoft Corporation in the United States and other countries.

2.3.7 Environmental Requirements

The **waveScan** is intended for operation in indoor, dry and dust reduced rooms. It has to be firmly installed on an optical table or on a similar solid, vibration-free board.

During storage, transport, for the installation and during operation, the ambient conditions must be observed. Ensure reasonable transport conditions, free of major shocks, jolt or fall; protect against frost. Use original packing material for relocation. Before unpacking the device wait for at least six hours to allow for acclimatization of all components.

Ambient temperature during transportation:	- 30 ... + 50 °C
Relative humidity during transportation:	10 % ... 80 %, non-condensing
Ambient temperature during operation:	+ 18 ... + 27 °C
Relative humidity during operation:	< 60 %, non-condensing

3 Installation

3.1 Inspection of Delivery

Please inspect the delivered package very carefully for potential damage. Take photos of potential damage or document it otherwise. If you find damage please inform the carrier and APE or our authorized distributor.

On receipt of the **waveScan**:

1. Inspect the packing crate for signs of rough handling or damage directly at arrival. If you discover any irregularities:
   - Take photographs of the condition of the package, the labels and the inside of the box, if necessary.
   - List all defects on the shipping documents and let the delivery company countersign.
   - Inform APE and your **waveScan** vendor immediately.
2. Use safe lifting practices.
3. Before unpacking the **waveScan** wait at least six hours to allow for acclimatization of all components.
4. Retain the packaging for future use.

3.2 Scope of Delivery

waveScan comes with a variety of additional components. Therefore, please refer to the ”Packing List” for the actual contents of your delivery. The ”Packing List” is typically located on top of the packaging.

Typical contents of **waveScan** package are:

- **waveScan** unit
- Connecting cables and power supply

- Packing List and Manual
- USB drive with software
- Fastening screws
- Optional: fiber input module (installed in **waveScan**)

Figure 3.1: Package contents of **waveScan**

3.3 Unpacking

Before unpacking the device wait for at least six hours (the actual time depends on the temperature difference between device and room temperature) to allow for acclimatization of all components to avoid condensation outside and inside of **waveScan**.

1. Open the cardboard box carefully by cutting the tape at the upper side.
2. Remove the first layer of the foam material and find this manual ;)

Figure 3.2: Opening the carboard box.

3. Take out the additional components and small packages.
4. Remove the next layer of the foam material and take the **waveScan** out.

Figure 3.3: Additional components in the box.

3.4 Software Instalation

waveScan was deliverd with a USB drive containing the software. To install the software please run ”setup.exe” and follow the instructions of the installer. During the installation process you are prompted to select an installation directory for the software as well as for the components of the National Instruments runtime engine. We recommend to keep the default entries. After successful installation a program group ”APE/waveScan”

will be created in the start menu of your Windows and a desktop icon. From there you can start the software.

3.5 Laser Alignment

This section applies only to free space beam input. If you have obtained **waveScan** with a exchangeable fiber input module beam alignment is not necessary. Please refer to 3.6 to learn how to switch between fiber and free space beam input.

Place the **waveScan** on your optical table in a position where you can comfortably direct the laser beam to be measured onto the input mirror. It should be possible to watch the display of your computer with the software at the same time. The input mirror assembly can be mounted in two configurations allowing for different beam input directions (see Fig.3.4). To change the configuration loosen the knurled fixing screw at the bottom of the mirror assembly.

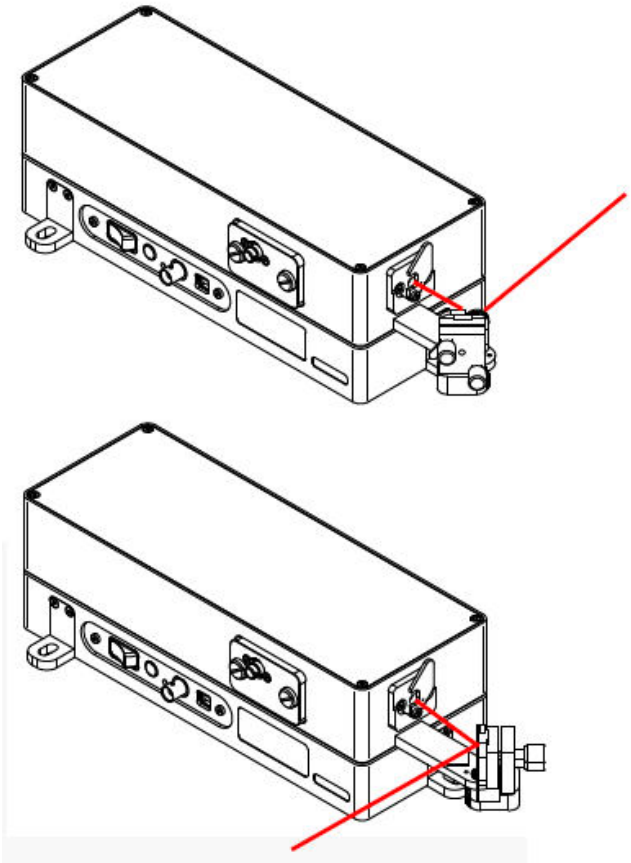

Figure 3.4: Change mirror orientation by loosening the knurled screw below it.

Fasten the **waveScan** with the provided screws on the optical table or make otherwise sure that it doesn't move during beam alignment. Make sure that the USB cable is

connected to the PC running the software and turn on the **waveScan** and start the software.

Alignment apertures: On the input mirror and before the input aperture are two flip apertures to facilitate alignment by reducing the beam diameter. Use the apertures for a faster alignment procedure. After alignment open the apertures again to pass the whole beam.

Note: Clipping of the beam my result in an distorted spectrum if the laser has a frequency shift across the beam diameter (”Spatial Chirp”).

After having connected the power cable to the mains and the USB cable to your PC start the software to begin with the actual alignment procedure. If the software can’t connect with the **waveScan** it will display this message as pictured in Fig. 3.5. In this case check power status (LED is green) and USB connection. Eventually, make sure that you use the original USB cable.

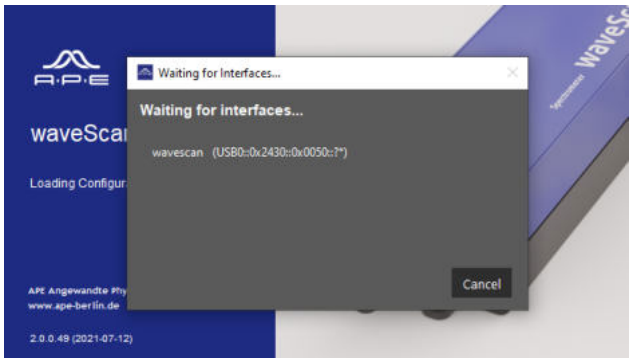

Figure 3.5: Software waiting for a **waveScan** to be connected.

Make sure that the input polarization is horizontal. The beam diameter should be < 6 mm to avoid clipping.

Note: With vertical polarization the sensitivity is strongly reduced due to the orientation of the grating.

Avoid inputting high laser power into the **waveScan**, especially during alignment, to avoid damaging of the entrance slit inside the device. Do not exceed 5 mW/nm for laser oscillators (MHz range) or 0.5 µJ/nm for laser amplifiers (kHz range). After alignment and optimization of the signal intensity the input power may be increased to maximize the signal.

Align the laser beam and center it on the first aperture on the input mirror. Then, adjust the input mirror to have the beam enter the device through the input aperture using the horizontal and vertical adjustment screws (Fig. 3.6). While aligning the input mirror observe the the signal in the software until a spectrum appears.

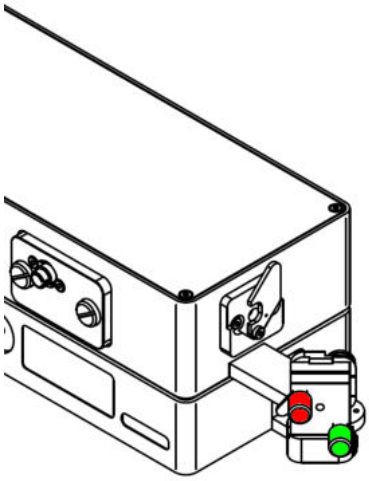

Figure 3.6: Use top screw (red) for horizontal and bottom screw (green) for vertical alignment.

After initial alignment open the alignment apertures again to allow the whole beam to pass into the spectrometer.

3.6 Fiber Input Module - Exchange

If you have obtained the exchangeable fiber input option with your **waveScan** you can either use this fiber input or the free space beam input. If the fiber input is already pre-installed an appropriate fiber connector (depending on your purchase FC/PC, FC/APC or SMA) can be connected and the measurement can be started.

In order to use the free space input the fiber module has to be mounted in the storage bay first.

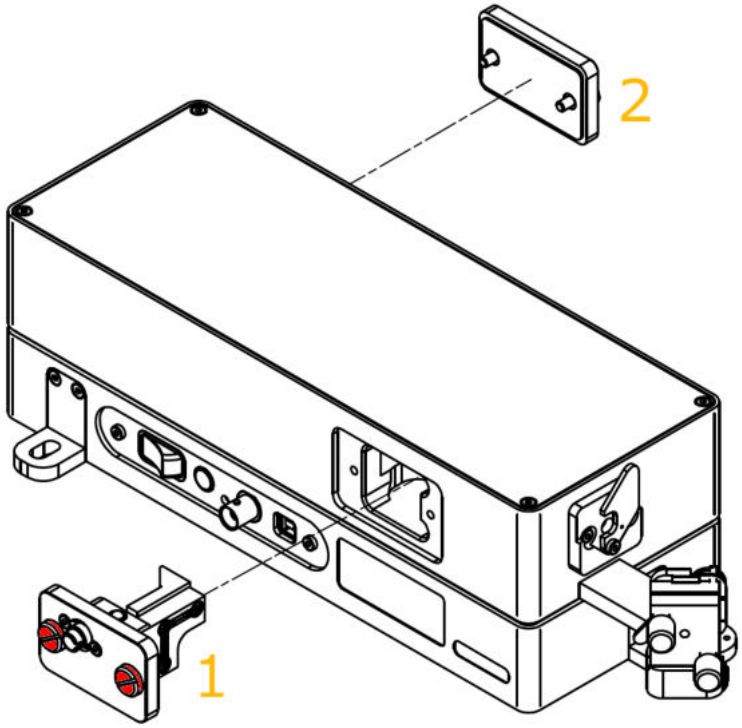

Figure 3.7: Fiber module (1) with fastening screws (red) and lid of the storage bay (2).

Proceed as follows to exchange the fiber input:

1. Unscrew the two screws holding the storage bay lid.
2. Unscrew the two screws holding the fiber input.
3. Switch the fiber input with the storage bay lid and fasten the screws again.

Caution! Be careful when you put the fiber input in place. There is a mirror at its head. Make sure you insert it evenly either into the fiber adapter socket or the storage bay!

Do not turn the screws at the inside of the fiber adapter (marked with red paint) since this can compromise the factory alignment and calibration!

4 Control Software Interface and Functions

4.1 Overview of WaveScan Control Software

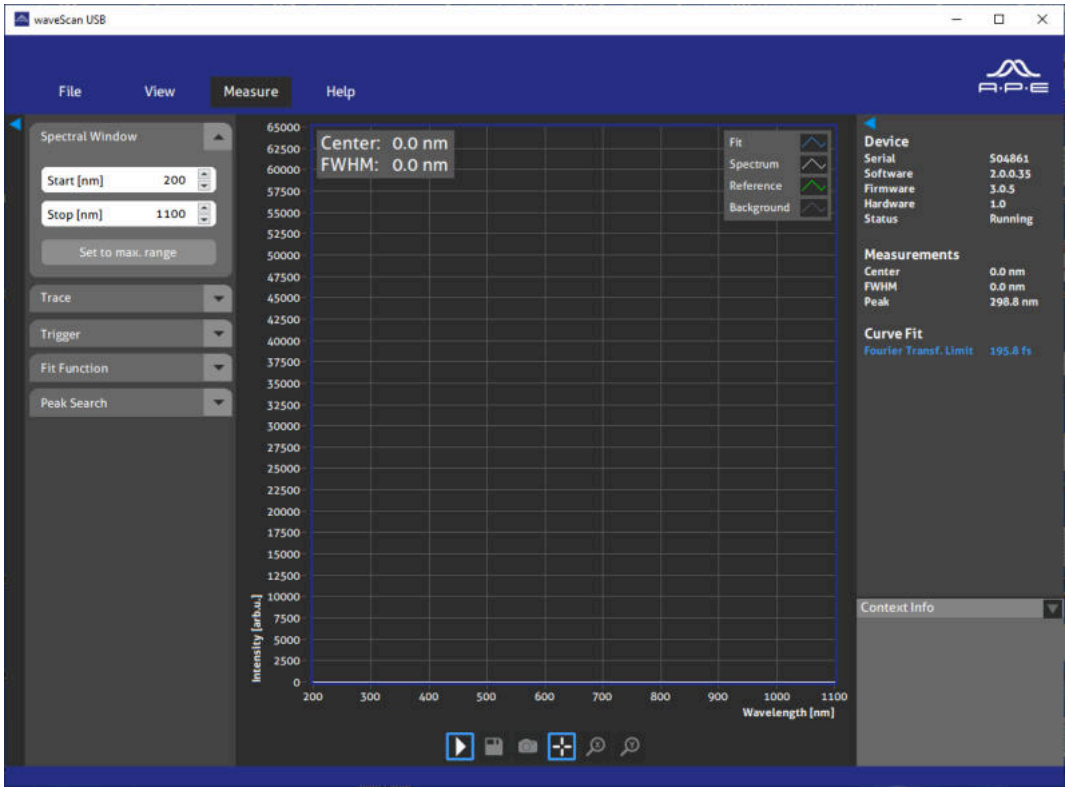

Figure 4.1: User interface of **waveScan** control software.

The user interface of the **waveScan** control software (see figure 4.1) is devided in:

- Menu bar (top left, see section 4.3 for further details)
- Controls of chosen menu (center left)
- Measurement window (center). Shows graph of measured spectra.
- Quick control buttons (below graph, see section 4.2 for further information)
- Calculated parameters of measured spectra (center right). Detailed information on each parameter is given in the Context info box.

- Context info box (bottom right)

4.2 Quick Control Buttons

Figure 4.2: Quick control buttons of the **waveScan** control software.

The quick control buttons (see figure 4.2) allow an easy and fast access to the most common features of the **waveScan** control software. The buttons are located below the center measurement window. From left to right the buttons are ”Start” button, ”Save Spectrum” button, ”Save Screenshot” button, ”Cursor” button, ”Zoom-X-Axis” button and ”Zoom-Y-Axis” button. The functions of all buttons are discribed below.

4.2.1 ”Start” Button

Click the button to start the continuous spectral measurement (blue button border appears). The display will be refreshed at the spectral scanning rate of the **waveScan** device (typically 6 Hz).

The continuous measurement can by stopped by pressing again the ”Start” button (blue button border disappears). The last measured spectrum will remain on the display and can be saved, zoomed, and so on.

4.2.2 ”Save Spectrum” Button

Button saves the currently shown spectrum. Upon each button click, the user is asked to specify the file name and file storage location.

Note, that the spectrum is only saved within the displayed wavelength range (x-axis), whereas the saved intensity range (y-axis) is not limited by the currently shown area.

4.2.3 ”Save Screenshot” Button

Click the button to save a screenshot of the **waveScan** control software in the ”Desktop” folder of the Microsoft Windows operation system. The storage location is fixed and cannot be changed by the user.

4.2.4 ”Cursor” Button

The ”Cursor” button is a tool-button with three different functions:

Single left-click on this button to enable the cursors. If the cursors are enabled but not visible in the graph, do a double left-click on this button. This will center the cursors in the currently visible graph area. If you want to hide the cursors again right-click on this button. This will disable the cursors.

All these functions are also available in the “VIEW → Cursors” submenu, which is in detail discribed in section 4.3.2.6.

4.2.5 ”Zoom-X-Axis” Button

This button enables the zoom tool along the wavelengths axis for the graph. You can use it to magnify a wavelength section of the graph window. A right-click on this button will adjust the wavelength axis again to the maximum range of the **waveScan** device.

Important: Using the ”Zoom-X-Axis” feature influences the spectral resolution of the measurement. On the center right of the user interface is given the parameter ”Resolution”, which indicates the current spectral measurement resolution. A save command will only save the spectrum inside the displayed wavelength range. For further information see section 4.3.3.1.

4.2.6 ”Zoom-Y-Axis” Button

This button enables the zoom tool along the spectral intensity axis for the graph. You can use it to magnify an spectral intensity range of the graph window. A right-click on this button will adjust the spectral intensity axis again to the maximum range of the **waveScan** device.

Using the ”Zoom-Y-Axis” button does not influence the saved intensity range. A save command always saves the entire intensity range, independent of the currently magnified intensity area.

4.3 Menu Bar

4.3.1 ”File” Menu

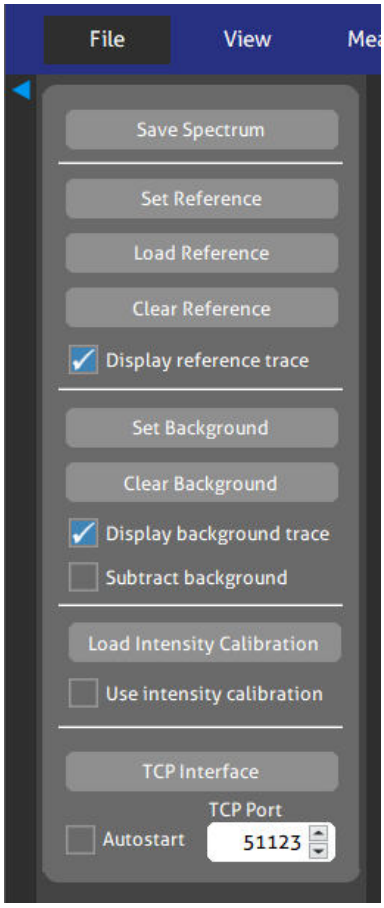

Figure 4.3: Control panel of the file menu.

In the ”File” menu (see figure 4.3) the following control items are available:

- ”Save Spectrum” button (see 4.3.1.1)
- Set, load, clear and display the reference spectrum (see 4.3.1.2)
- Set, clear, display and substract the backround spectrum (see 4.3.1.3)
- Load and use intensity calibration (see 4.3.1.4)
- ”TCP Autostart Server” control (see 4.3.1.5)

4.3.1.1 ”Save Spectrum” Button

Button saves the currently shown spectrum. Upon each button click, the user is asked to specify the file name and file storage location. In case the spectral fit is activated

(see section 4.3.3.4), the fit function will be saved in the same file.

Note, that the spectrum is only saved within the displayed wavelength range (x-axis), whereas the saved intensity range (y-axis) is not limited by the currently shown area.

4.3.1.2 Set, load, clear and display the reference spectrum

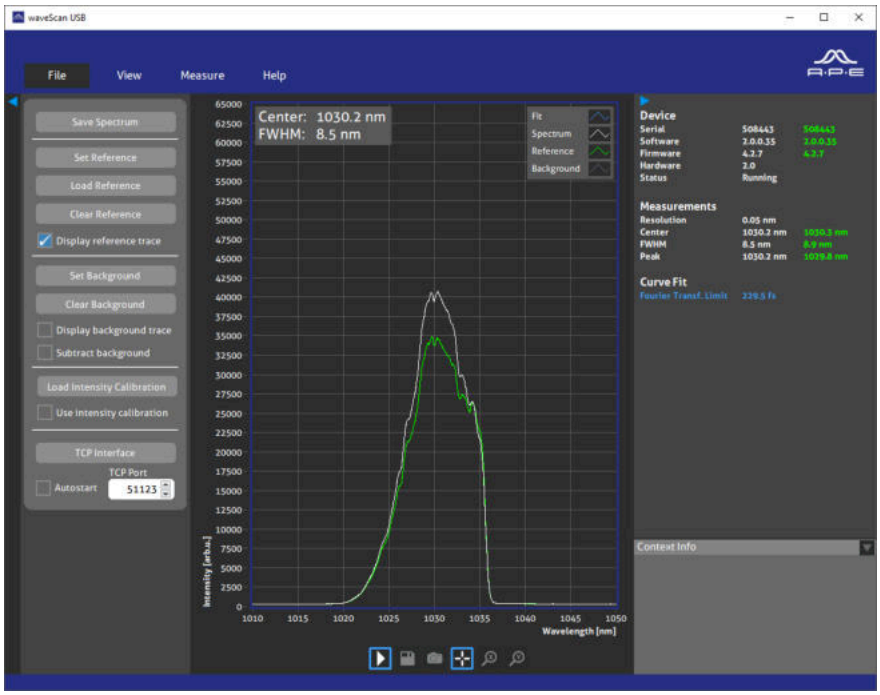

Figure 4.4: Reference spectrum displayed as additional green curve. On the right side are given the calculated spectral parameters of the reference spectrum in green letters.

The **waveScan** software allows the user to display a second spectrum as reference beside the currently measured one. The ”Set as Reference” button loads the current spectrum into the reference memory and displays it as additional green curve in the center graph (see figure 4.4). The calculated parameters of the reference spectrum are shown in green letters on the right side of the GUI.

One can also load a previously saved spectrum as reference spectrum by using the ”Load Reference” button. The reference spectrum is kept in memory until the user presses the ”Clear Reference” button. The saved reference button is displayed or hiden according to the ”Display reference trace” checkbox status.

Note, that the reference spectrum is only saved within the displayed wavelength range (x-axis).

4.3.1.3 Set, clear, display and substract the backround spectrum

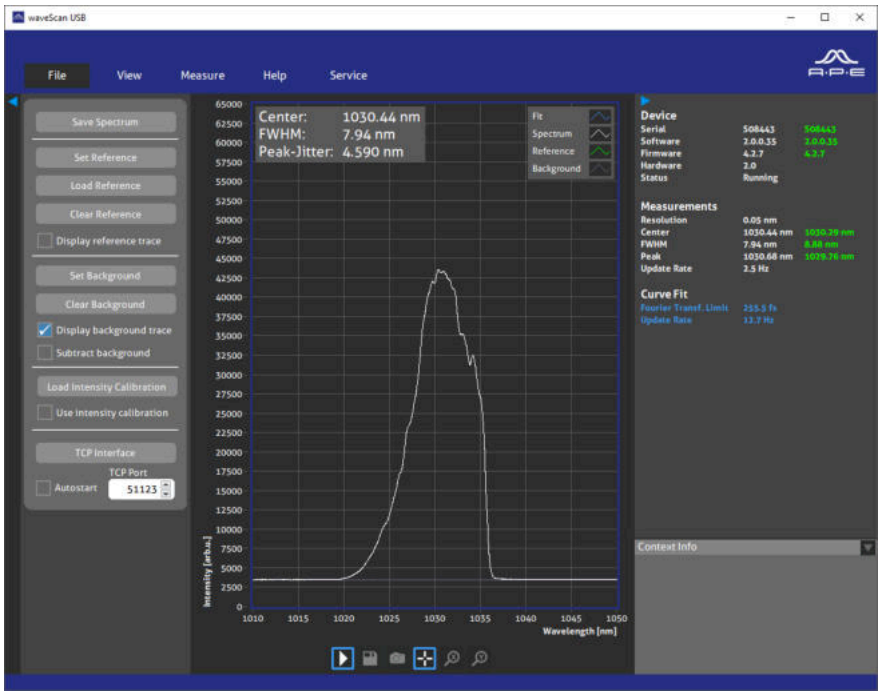

Figure 4.5: Background spectrum displayed as additional grey curve. By enabling the ”Substract background” checkbox, the background is automatically substracted.

The **waveScan** software allows to substract automatically a background signal from the measured spectrum. To prepare this function, the user has to take a background spectrum by pressing the ”Set Background” button. **Important:** Block the input beam before taking the background spectrum.

The background spectrum is kept in memory until the user either presses the ”Clear Background” button or if the displayed wavelength range is changed. The background spectrum can be shown as grey line in the center graph by activating the ”Display background trace” checkbox.

The background substraction is activated by enabling the ”Substract background” checkbox. This function only works if previously a background spectrum was measured.

Important note: In case the wavelength window (X-axis) is changed, the background memory is reset to zero and a new background spectrum has to be taken. The reason is, that performing a background subtraction is done on a point-by-point basis assuming the same abscissa for each data point. Due to the fact, that changing the wavelength measurement window also influences the measured abscissa wavelength positions, the background trace is cleared everytime the x-axis is rescaled (see section 4.3.3.1 for more details on the wavelength data resolution).

4.3.1.4 Load and use spectral intensity calibration

The **waveScan** spectrometer allows the application of a spectral intensity calibration. In this case, the measured spectrum of the device is automatically multiplied with a spectral intensity calibration curve and only the obtained result is shown in the **waveScan** user software. Also all obtained spectrum parameters (FWHM, center wavelength, FFT limit, ..) will be calculated from the calibrated spectrum.

To use this function, the user has to load a calibration file into the software memory via using the ”Load Intensity Calibration” button. The spectral intensity calibration can be enabled and disabled via the ”Use intensity calibration” checkbox.

Note: After a restart of the **waveScan** user software, the calibration data memory is automatically cleared. In case the user likes to apply permanently a wavelength calibration, the loading of the calibration file has to be performed after each restart of the software.

The loaded spectral calibration file has to meet certain requirements. Aside from a device-specific file header, the calibration data array has to satisfy this specifications:

- The calibration data have to be given in a [wavelength in nm, calibrationfactor]-pair in a tab-/or space-seperated two-column array
- The calibrationfactors have to be numbers between 0.0 and 1.0
- Each number pair has to constist of exact two values (wavelength and calibrationfactor)
- The calibration file can only contain a maximum of 100 [wavelength in nm, calibrationfactor]-pairs.
- The smallest and biggest wavelengths of all [wavelength in nm, calibrationfactor]-pairs cannot lye outside of the **waveScan**-specific measurement-range.
- In case the calibrated wavelength range is smaller than the wavelength range of the **waveScan** spectrometer, measurement points inside the non-covered spectral area will be multiplied with 1.0.

Note: A calibration file can only be loaded, if the device serialnumber and software serialnumber in the file header matched the respective numbers of your **waveScan** spectrometer.

The user can create a device-specific template calibration file with the ”sss” button in the ”Help” menu (see section 4.3.4.4). In the created file, only the spectral calibration data have to be added. The file header information is allready customized for the specific **waveScan** spectrometer.

4.3.1.5 ”TCP Interface” Button, ”TCP Autostart” Checkbox and ”TCP Port” Input Box

The **waveScan** software includes a TCP/IP software interface for interaction and data exchange with other applications. Enter a TCP port address (number between 0 and 65535) and press the ”TCP Interface” button for activating the TCP/IP server (button turns black when activated). The server will now listen for clients and establish a connection if possible. The TCP/IP commands are described in chapter 5.

Selecting the TCP autostart checkbox will start the TCP server automatically at the next program start.

4.3.2 ”View” Menu

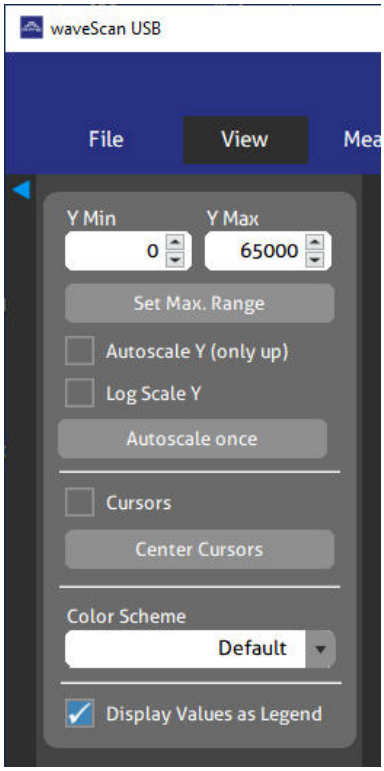

Figure 4.6: Control panel of the view menu.

In the ”View” menu (see figure 4.6) the following control items are available:

- ”Y Min” and ”Y Max” input fields (see 4.3.2.1)
- ”Set Max. Range” button (see 4.3.2.2)
- ”Autoscale Y (only up)” checkbox (see 4.3.2.3)
- ”Log scale Y” checkbox (see 4.3.2.4)
- ”Autoscale once” button (see 4.3.2.5)
- ”Cursors” checkbox and ”Center Cursors” button (see 4.3.2.6)
- ”Color Scheme” dropbox (see 4.3.2.7)
- ”Display Values as Legend” checkbox (see 4.3.2.8)

4.3.2.1 ”Y Min” and ”Y Max” input fields

With this input fields the user can select the minimum-to-maximum range of the intensity (Y-) scale which should be displayed in the center graph of the **waveScan** control software.

4.3.2.2 ”Set to max. int.-range” button

“Set to max. int.-range” sets the intensity (Y-) axis of the graph to the full available range (0 … 65000). This function is also available via a right-click on the graph and a selection of ”Full Scale Y” (see section 4.4.2).

4.3.2.3 ”Autoscale Y (only up)” checkbox

The ”Autoscale Y (only up)” option fits the scale of the intensity (Y-) axis of the graph continuously to the data range of the currently measured spectrum. This function is also available via a right-click on the graph (see section 4.4.2).

4.3.2.4 ”Log scale Y” checkbox

”Log scale Y” sets the intensity (Y-) axis of the graph to a logarithmic display mode. Uncheck the checkbox to return to the linear display mode. This function is also available via a right-click on the graph (see section 4.4.2).

4.3.2.5 ”Autoscale once” button

”Autoscale once” fits the scale of the intensity (Y-) axis of the graph once to the data range of the current spectrum. This function is also available via a right-click on the graph (see section 4.4.2).

4.3.2.6 ”Cursors” checkbox and ”Center Cursors” button

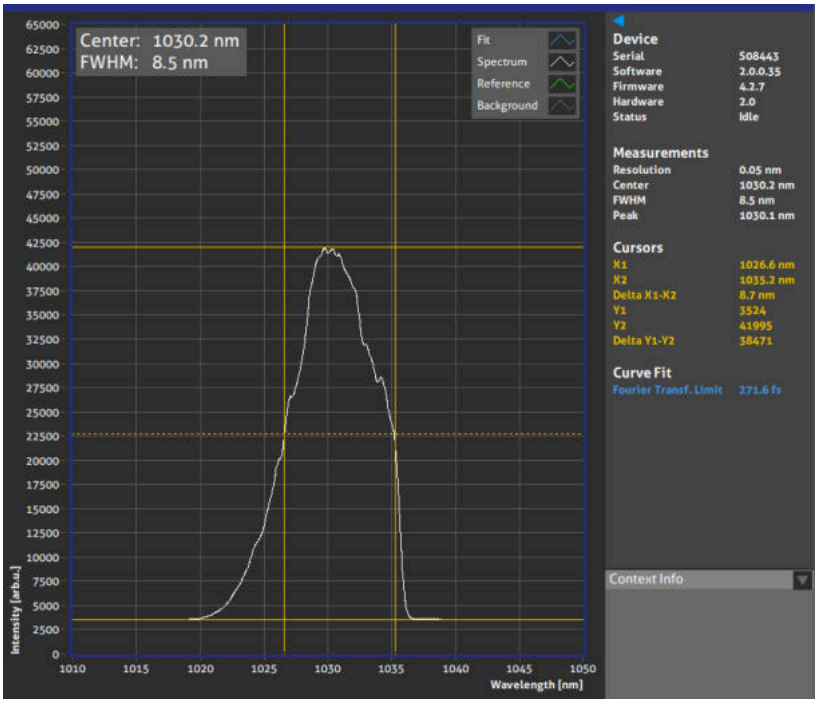

Figure 4.7: Laser spectrum with applied cursors (yellow lines). In the example, the cursor positions are manually chosen, such that the curser positions (yellow text on right side) gives information about the spectral FWHM bandwidth.

Cursors can be used for example to estimate the FWHM of a shown spectrum or to determine the wavelength seperation of two peaks or features of a spectrum.

Activating the ”Cursors” checkbox shows yellow cursors in the graph window (see figure 4.7). With activated cursor tool (cross button below the graph, see 4.2.4) the cursors can be moved by left-clicking the corresponding cursor line and moving the mouse while holding the left mouse button pressed. If the cursors are outside the visible range of the graph window they can be centered by clicking the “Center Cursors” button.

On the right side of the **waveScan** user interface the cursor x-positions (vertical cursors), y-positions (horizontal cursors) and their respective differences are displayed in yellow text (see figure 4.7).

4.3.2.7 ”Color Scheme” dropbox

With this dropbox the user can choose between the ”default” standard color scheme and a brighter, color-neutral scheme called ”White-Black”. The second color scheme is especially useful, when the customer wears laser goggles which block certain colors of the **waveScan** software user interface.

4.3.2.8 ”Display Values as Legend” checkbox

Activating this checkbox will display an info box in the upper left corner of the graph window with information of the measured spectra. Shown are the parameters center wavelength and full width at half maximum (FWHM) of the spectum. Note that in case of multiple peaks only the parameters of the highest peak is shown.

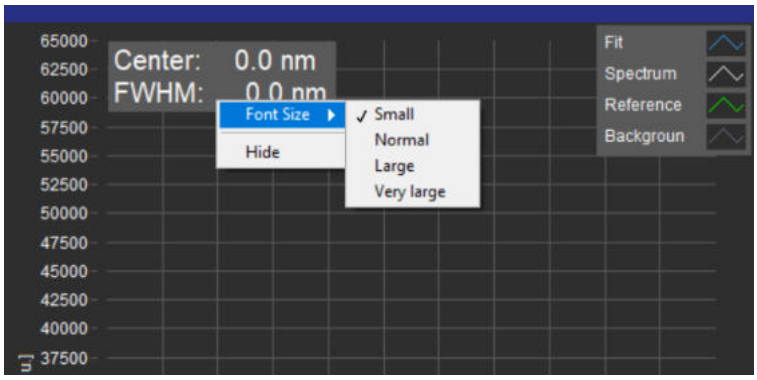

Figure 4.8: Right click on the box to change font size or hide the info box.

A right click on the info box allows to change the font size of this info box (see figure 4.8). To hide the info box, right click on it and select ”Hide”, or undo the ”Display Values as Legend” Checkbox in the ”View” menu. Activate the checkbox again in order to show the info box again.

4.3.3 ”Measure” Menu

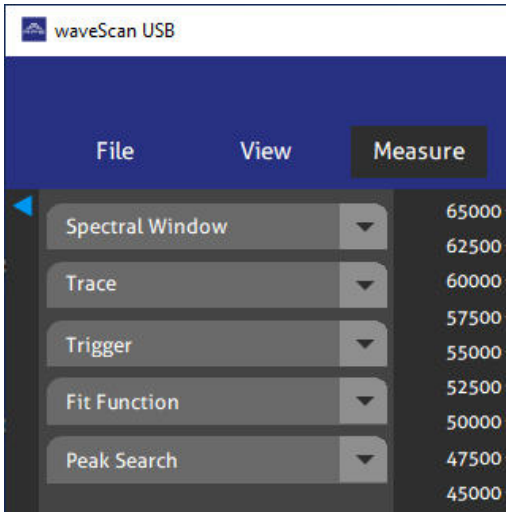

Figure 4.9: Submenus of the ”Measure” menu.

The ”Measure” menu (see figure 4.9) contains the following submenus which are subsequently explained in detail:

- ”Spectral Window” submenu (see 4.3.3.1)
- ”Trace” submenu (see 4.3.3.2)
- ”Trigger” submenu (see 4.3.3.3)
- ”Fit Function” submenu (see 4.3.3.4)
- ”Peak Search” submenu (see 4.3.3.5)

4.3.3.1 ”Spectral Window” Submenu

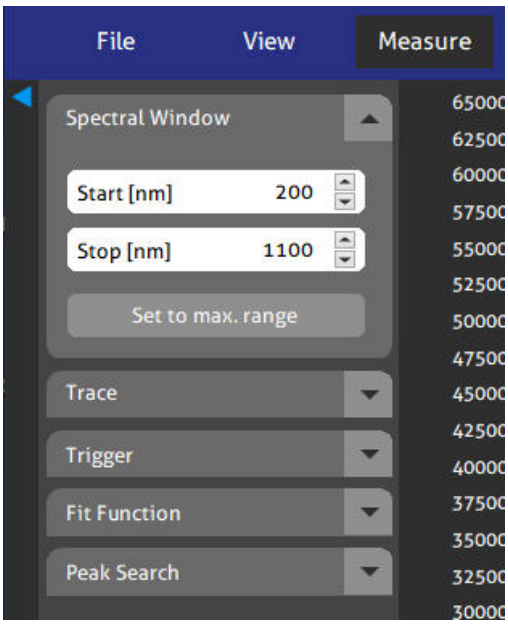

Figure 4.10: Control panel of the ”Spectral Window” submenu.

In the ”Spectral Window” submenu the user can adjust the wavelength measurement range of the **waveScan** spectrometer. The user can freely choose the range by typing the desired start and/or stop wavelengths in the respective input fields. Click on the “Set to max. range” button to adjust the measured wavelength range to the maximum possible range your **waveScan** device is built for.

The wavelength measurement range can also be changes by using the ”Zoom-X-Axis” button located below the center graph of the **waveScan** user software (see section 4.2.5).

Important note: The **waveScan** will only measure and save spectral information inside the chosen wavelength range with a spectral resolution of fixed 2048 points (wavelength equidistant). As result, the spectral resolution of the **waveScan** spectrometer is directly dependent on the chosen wavelength measurement window. The current spectral resolution is shown via the ”Resolution” parameter on the right side of the user interface of the **waveScan** software. The smallest spectral resolution is physically limitted by the physical properties of your particular instrument (grating, slit size e.g.) and cannot be changed by the user.

4.3.3.2 ”Trace” submenu

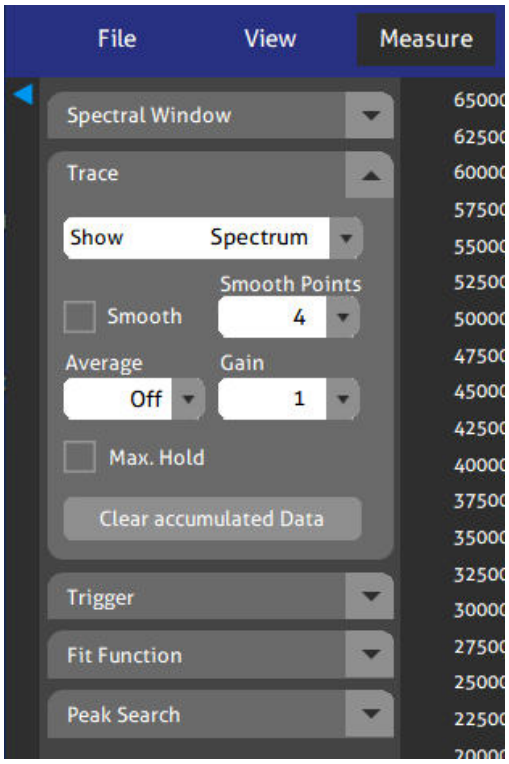

Figure 4.11: Control panel of the ”Trace” submenu.

The functions of the ”Trace” submenu are subsequentially explained in section 4.3.3.2.1 to 4.3.3.2.6

4.3.3.2.1 ”Show” dropbox

With the “Show” drop-down menu the displayed data can be switched between the default ”spectrum”, the ”0-Order” and ”Spectrum (Raw)”.

In contrast to the default spectrum obtaining 2048 wavelength equidistant data points, the raw spectrum obtains up to 20000 data points with the downside of no applied calibrations, missing background substraction, a non-equidistantly spaced wavelength scale and a potentially slower refresh speed. The ”0-Order” shows the relative position of the reflected 0-order from the internal spinning grating and is used to re-calibrate in the service mode the wavelength calibration of the **waveScan** spectrometer (see section 4.3.4.1 for information on the service mode).

4.3.3.2.2 ”Smooth” function

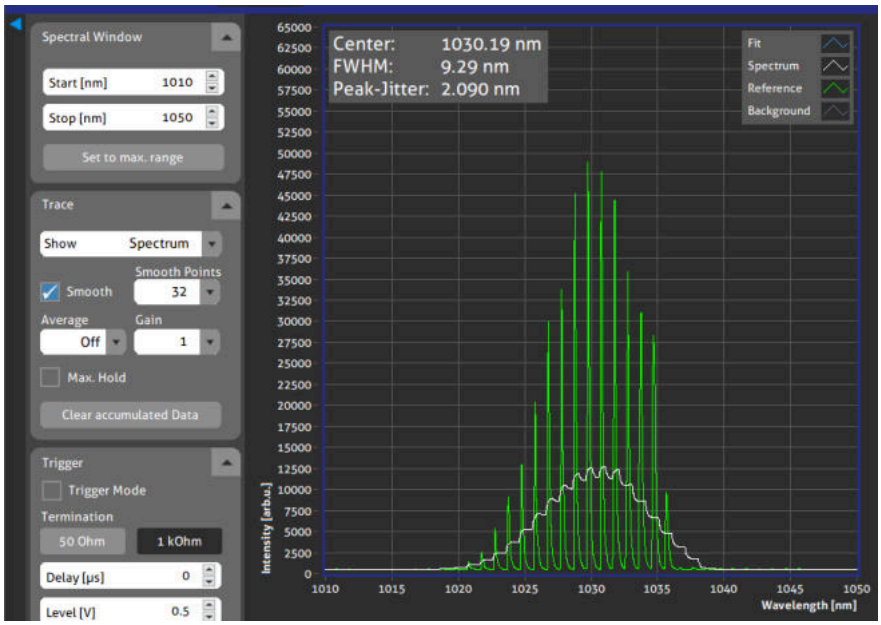

Figure 4.12: Select ”Smooth” to apply a smoothing function to the displayed spectrum. In green is shown an example of a strongly modulated, comb-like spectrum without smoothing. By applying the smoothing function, the white spectrum is obtained.

Very noisy or modulated signals can be smoothed with a mathematical smooth function where for each data point the mean over its neighboring points is calculated. The number of used neighboring points is controlled with the “Smooth Points” value.

4.3.3.2.3 ”Average” dropbox

The **waveScan** control software allows the user to average over a certain number of measurements. The number of averaged spectra can be chosen by changing the ”Average” dropbox. ”Off” means that there is no averaging applied. When the average number is increased, the display directly shows the rolling average over the chosen number of measured spectra.

4.3.3.2.4 ”Gain” dropbox

The detected signal of the spectrometer detector can be electrically amplified. The amplification is controlled by the ”Gain” dropbox in the ”Trace” submenu. This function can be espacially useful for very weak spectrometer input powers.

The ”Gain” functionality is not available for mid-range infrared **waveScan** devices (wavelength range 1500 - 6300 nm).

4.3.3.2.5 ”Max. Hold” (= ”accumulation mode”)

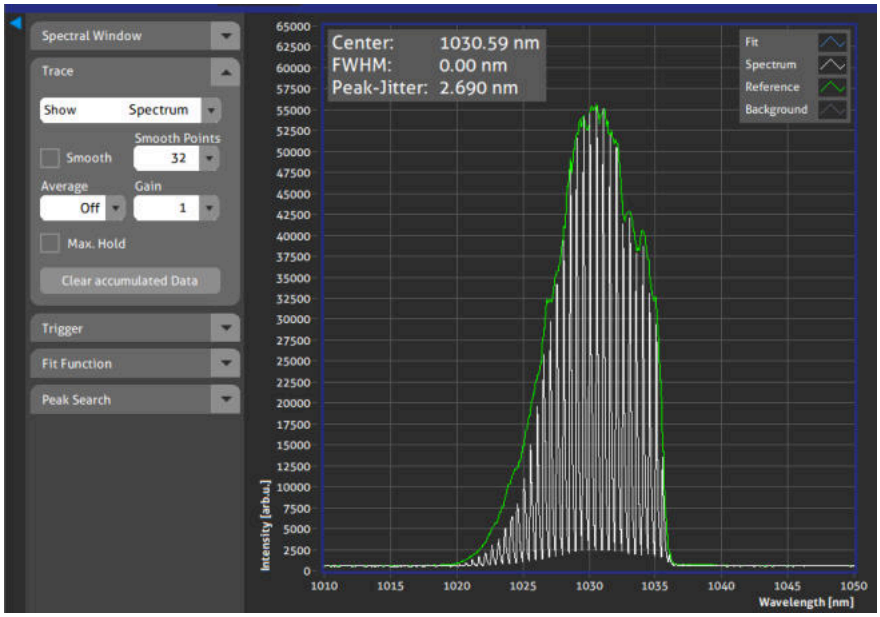

Figure 4.13: Select ”Max. Hold” to accumulate an envelope of fast changing, modulated spectra. The white graph shows a spectrum measured in continous mode, which is comb-like modulated due to the low repetition rate (100 kHz) of the laser. The green curve gives the real laser spectrum by using the ”Max. Hold” function over 10 seconds.

The ”Max. Hold” function is very important for low repetition rate lasers! Please consider the following paragraph.

The **waveScan** spectrometer is a scanning device, which samples the full spectrum with a 1 MHz sampling rate. Due to the scanning nature of the measurement process, the spectra of low repetition rate lasers (below 1 MHz) cannot be measures in the default continous measurement mode. In this case a comb like structure will be measured instead (see white spectrum in figure 4.13).

With activated ”Max. Hold” function, the **waveScan** device collects and displays the maximum intensities that occur for each data channel (each of the 2048 wavelength points) over an unlimited time, until the user deactivates this function or stops the measurement (”Play” button below the graph). The ”Max. Hold” function is perfectly suited to measure the spectrum of lasers with pulse repetition rates between 1 MHz and around 100 kHz. Below 100 kHz repetition rate it is recommented to use the triggered measurement mode instead (see section 4.3.3.3).

4.3.3.2.6 ”Clear accumulated Data” button

The ”Clear accumulated Data” button deletes the current spectrum in the user software memory. This button is most important in the ”Max. Hold” mode (= ”accumulation mode”) or ”Trigger Mode” to reset the accumulated spectral information to zero.

4.3.3.3 ”Trigger” submenu

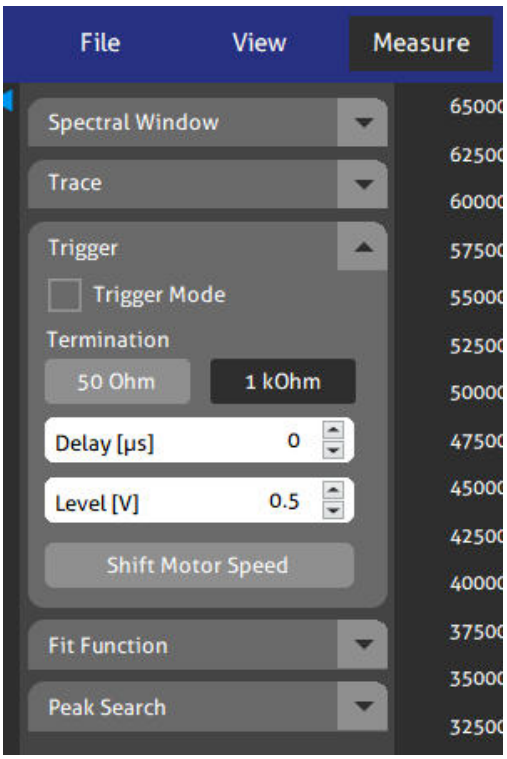

Figure 4.14: Control panel of the ”Trigger” submenu.

The **waveScan** spectrometer allows a triggered spectrum measurement of pulsed light sources. This feature is usable for pulse repetition rates below 100 kHz and requires an input trigger signal which has to be connected to the ”Trigger input” BNC port (see section 2.3.4 for the location of this port). A trigger signal can be obtained for example from a photo diode in a reflection of the input laser beam or by directly connecting to a trigger output connection of the driving laser system.

To start the triggered measurement activate the ”Trigger Mode” checkbox. The impedance of the trigger input BNC termination can be changed between 50 Ohm and 1 kHz Ohm by pressing the respective control button in the trigger submenu. Also set the trigger signal level (”Level” input box) below the provided trigger signal height in Volts. If you are not sure about the signal height and quality of your trigger signal, use an oscilloscope to check.

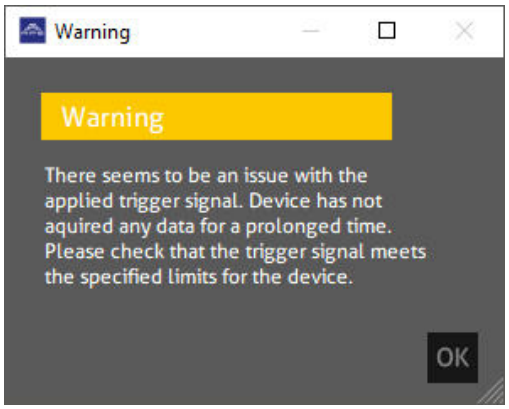

Figure 4.15: Shown error measage in case no valid trigger signal is detected.

In case the triggered measurement mode is started (by activating the ”Trigger Mode” checkbox), but the **waveScan** spectrometer doesn’t detect a valid trigger signal, an error message will appear (see figure 4.15). In this case, check if you connected a valid trigger signal to the trigger input port of the **waveScan** device or refere to the troubleshooting section of the manual (see section 6.2).

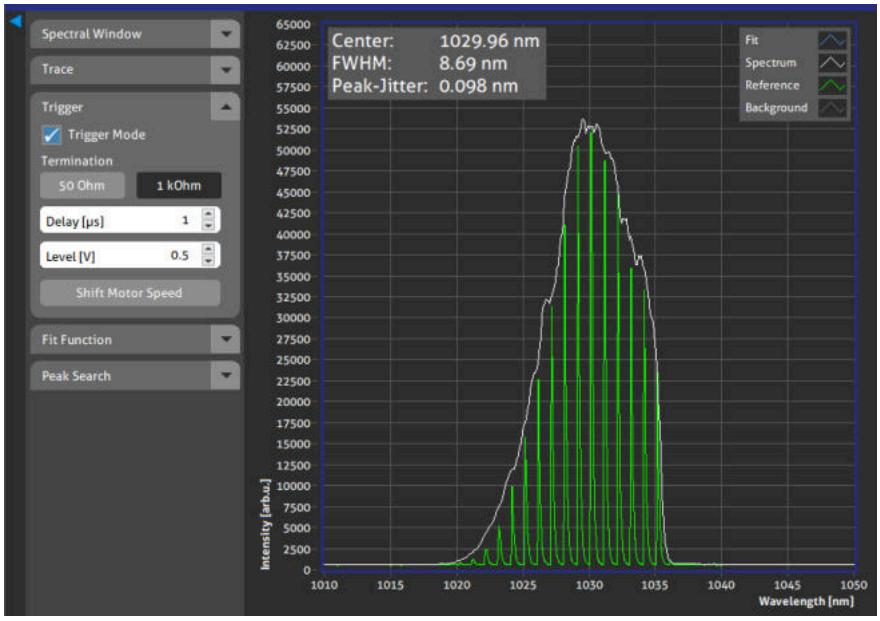

Figure 4.16: Example triggered measurement. Green is shown the spectrum in continuous measurement mode of a 100 kHz laser. In white is shown the obtained, real spectral shape after 5 seconds of accumulation in the triggered measurement mode.

In case a correct trigger signal is detected, the **waveScan** spectrometer will start the triggeres measurement and the accumulated triggered spectral data are shown in the center graph (see figure 4.16). In triggered operation the ”Status” parameter on the

right side of the **waveScan** user software shows ”triggered”. In case a trigger error occures, this parameter shows ”trigger error”.

In order to optimize the spectral measurement in the trigger mode, the user has to adjust the trigger delay value (”Delay µs” input box value). This trigger delay value influences the temporal delay between the detection of the trigger signal and the performed triggered measurement of the detector inside the **waveScan** device. This number is typically somewhere between 0 and 5 µs, but can be strongly influences by the way the trigger signal is generated, by the trigger input cable length or by any additional electronics placed between trigger generation and the **waveScan** trigger input port. A change of the trigger delay value therefore directly influences the height of the detected spectrum. The trigger delay value is optimized, when the measured spectrum in the triggered mode has the same height as the envelope of the spectral comb measured in continuous mode (see figure 4.16).

In order to pause the triggered spectral measurement the user can press the ”Start” button (arrow-shaped button below center graph of user interface, see section 4.2.1). When pressing the ”Start” button again to continue with the measurement, the accumulated spectrum will be reset to zero.

The accumulated spectrum in the trigger mode can be also cleared by pressing the ”Clear accumulated Data” button in the ”Trace” submenu of the ”Measure” menu.

The button ”Shift Motor Speed” changes slightly the spinning frequency of the internal optical grating inside the **waveScan** spectrometer. The **waveScan** spectrometer is a scanning measurement device, where a rotating optical grating scans the diferent laser frequencies over the detector position. For laser pulse repetition rates below 1 MHz it is possible, that the sampling speed are similar to the pulse repetion rate, therefor resulting in a low beat frequency. As result, in trigger mode the device will measure spectral points at every scan cycle at the same frequency positions and the spectral resolution would be heavily reduced. By changing the grating rotation speed via the ”Shift motor frequency” button, the beat frequency is changed and the problem would be solved.

4.3.3.4 ”Fit Function” submenu

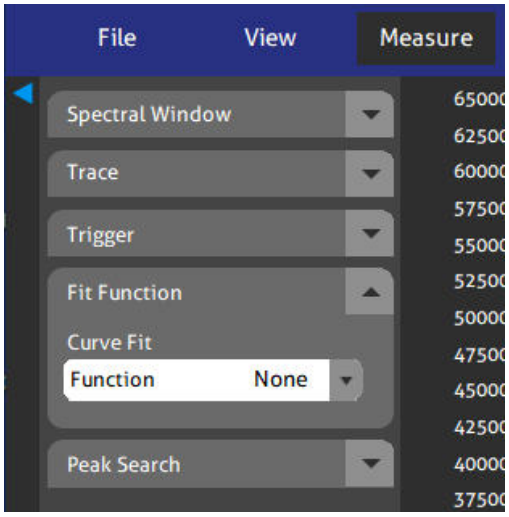

Figure 4.17: Control panel of the ”Fit Function” submenu.

The drop down menu ”Curve Fit” activates a curve fit of the measured spectrum. There are three fit types available (Gauss, Lorentz and Sech^2). Choose ”None” if you want to deactivate the fit routing.

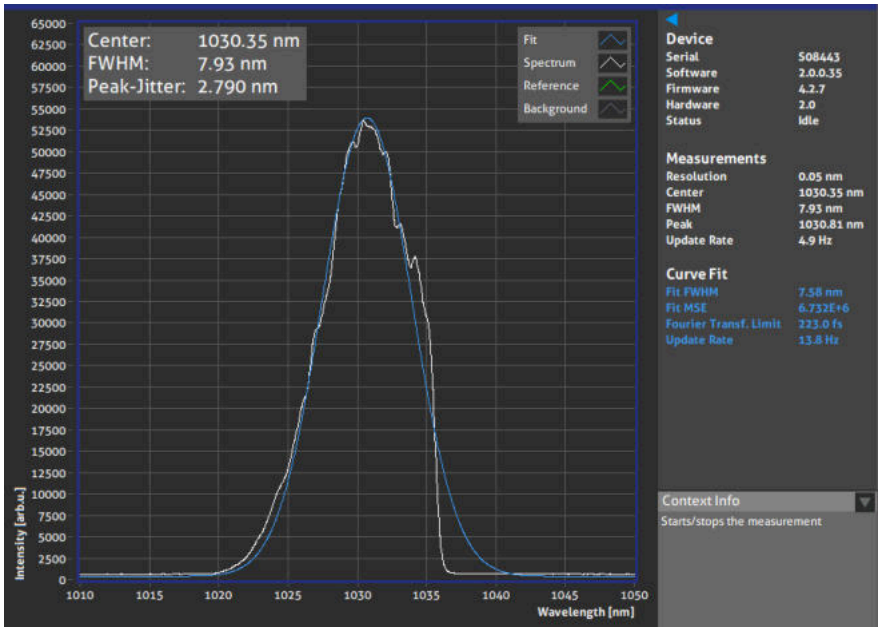

Figure 4.18: Measured spectrum (white line) with overlayed fit curve (blue line). Fit parameters are given on the right side in blue color.

The fit curve is shown as a blue line in the center graph of the **waveScan** user software while the calculated fit parameters (fit FWHM, MSE) are given in blue text on the right

side of the user software. The fit curve and fit parameters are saved together with the measured spectral data, in case a save command is executed (see section 4.3.1.1 for information on the save function).

4.3.3.5 ”Peak Search” submenu

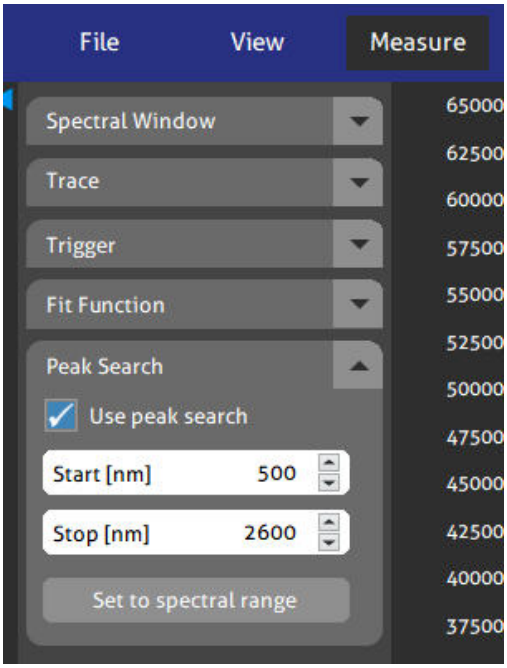

Figure 4.19: Control panel of the ”Peak Search” submenu.

The ”Peak Search” submenu gives the user the ability to calculate automatically the peak wavelength, centroid wavelength (center of gravity), and full width at half maximum (FWHM) inside a specified ”Peak search” wavelength range. When activated, these values are shown in purple text on the right side of the **waveScan** user software.

To start the peak search function, the user has to activate the ”Use peak search” checkbox. Afterwards the ”Start” and ”Stop” wavelength can be specified in the respective input boxes. The current peak search wavelength range limits are optically shown as purple, dotted vertical lines in the center graph of the **waveScan** software (see figure 4.20). The ”Start”and ”Stop” values can be also changed, by left-click on one of the purple lines and drag-drop it to a new wavelength position. This drag-drop functionality is only available, when the ”Cursor” button is activated (cross-like button below the center graph; see section 4.2.4 for more details on the ”Cursor” button).

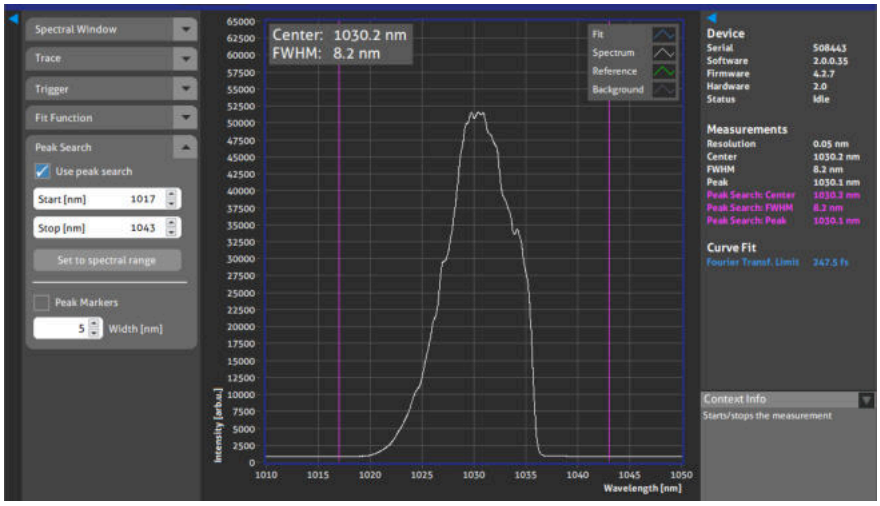

Figure 4.20: Activated peak search function with shown peak search area (purple dotted lines) and calculated parameters inside the peak search window (purple text on right side).

The peak search range can lie outside of the shown wavelength range of the center graph and is only limited by the maximum wavelength range of the specific **waveScan** spectrometer. The button ”Set to spectrum range” adjusts the peak search range to the current wavelength range of center graph in the **waveScan** user software.

Independent of the user peak search function, the **waveScan** software always automatically calculates the peak wavelength, center of gravity wavelength (COG), and full width at half maximum (FWHM) over the current wavelength range of the center graph. These values are shown in the text field inside the top left corner of the graph and on the right side of the **waveScan** software interface.

4.3.4 ”Help” Menu

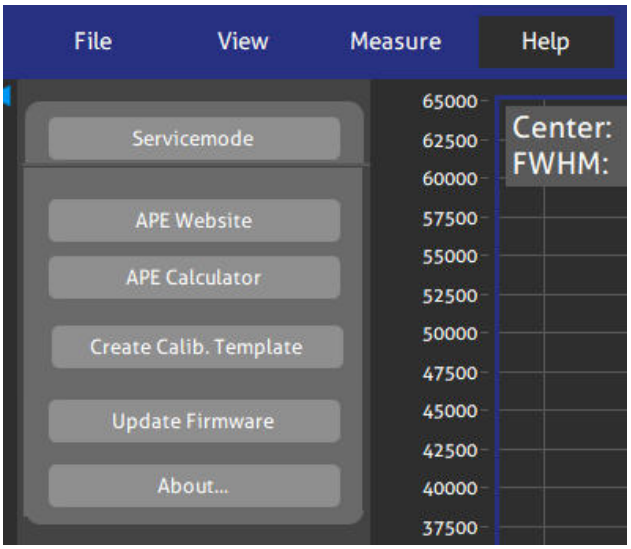

Figure 4.21: Control panel of the help menu.

The ”Help” menu (see figure 4.21) provides the following control items:

- ”Servicemode” button (see 4.3.4.1)
- ”APE Website” button (see 4.3.4.2)
- ”APE Calculator” button (see 4.3.4.3)
- ”Create Calib. Template” button (see 4.3.4.4)
- ”Update Firmware” button (see 4.3.4.5)
- ”About...” button (see 4.3.4.6)

4.3.4.1 ”Servicemode” button

Selecting the ”Servicemode” button opens a dialog to enter the service password.

The servicemode is used for service functions like remote support or recalibration. Use this function only after consultation with APE GmbH or your local service provider. They will tell you the service password if required.

4.3.4.2 ”APE Website” button

Opens the APE GmbH website on the system web browser. On the website can be found for more information on the **waveScan** device as well as support contact information.

4.3.4.3 ”APE Calculator” button

Opens the website of the APE calculator on the system web browser. The APE calulcator can there also be downloaded as application for various mobil devices.

The APE Calculator is a software which helps to easily solve often needed (non)linear equations in optics. Some examples are the photon energy relations in Sum Frequency Generation (SFG), Difference Frequency Generation (DFG), the wavelength relations in an Optical Parametric Oscillator (OPO) as well as in coherent anti-Stokes Raman scattering (CARS) spectroscopy. Also the conversion between wavelength, wavenumber, and frequency as well as different characterizations of pulses can be calculated.

4.3.4.4 ”Create Calib. Template” button

The button creates a template file for the spectral Intensity calibration. See section 4.3.1.4 for further information of this function.

4.3.4.5 ”Update Firmware” button

In case you want to update the firmware of the **waveScan** spectrometer, follow these instructions:

1. Press the ”Update Firmware” button. A dialog box appears (see figure 4.22).

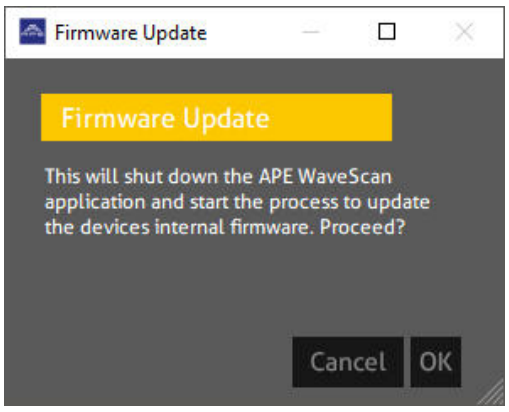

Figure 4.22: Firmware update dialog box.

2. Press ”OK”. The **waveScan** software will shut down and the firmware updater software will start (see figure 4.23).

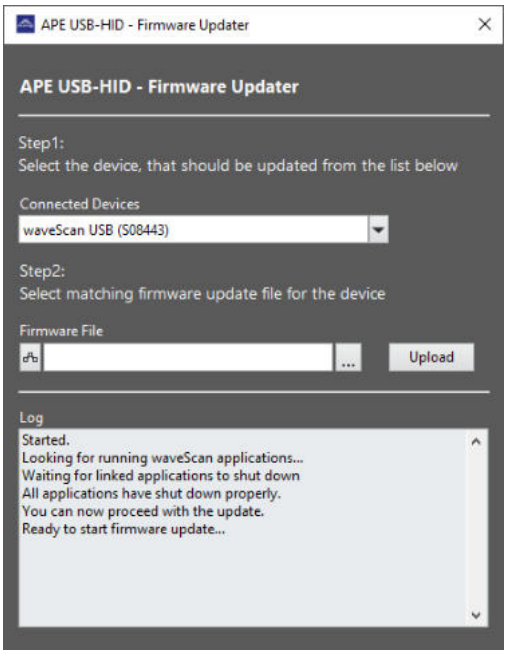

Figure 4.23: Firmware updater software.

3. Choose in the drop box ”Connected Devices” your **waveScan** spectrometer. Select the firmware file (typically a ”.hex.dfuae”-file), which was provided by APE or your local APE product distributor.

4. Press the ”Upload” button. The log text ”Writing Firmware to device ...” will appear.

5. Important: Wait until the log text ”Device firmware was successfully updated” appears (see figure 4.24).

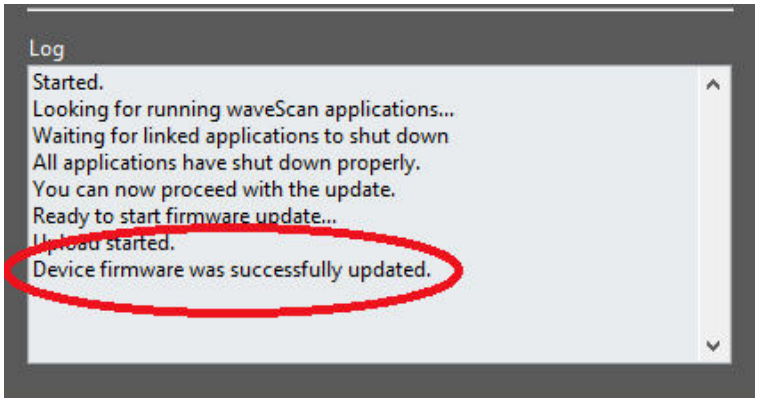

Figure 4.24: Log text confirming succesful firmware update.

6. Switch the power of the **waveScan** spectrometer off and after a few second on.

7. Start the **waveScan** spectrometer software. Your should see the new firmware revision number on the right side of the control software (see figure 4.25).

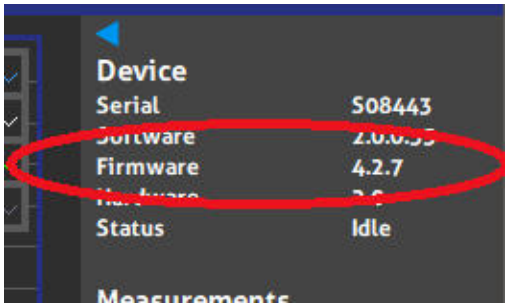

Figure 4.25: Location of current firmware revision number.

4.3.4.6 ”About...” button

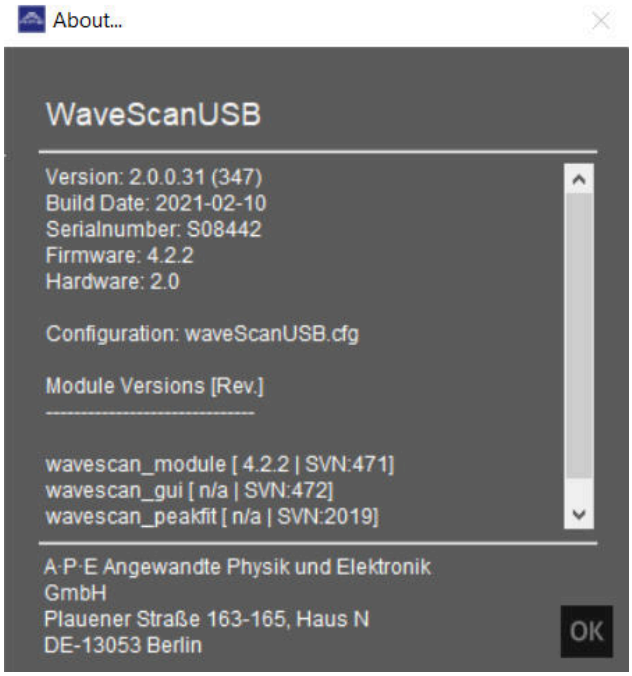

Figure 4.26: About **waveScan** info box.

After pressing the ”About ..” button a popup window is shown, displaying all relevant serial number, firmware and software information of the **waveScan** device (see figure 4.26). Please refer to this information (especially the serial number) when you contact APE GmbH with questions regarding your **waveScan**.

4.4 Context Menus

Some of the functions that have already been discussed in the respective paragraphs are also accessible through context menus. Context menus are available for the info string and for the measurement graph. Right-click into the respective area to open the context menus.

4.4.1 Info String Context Menu

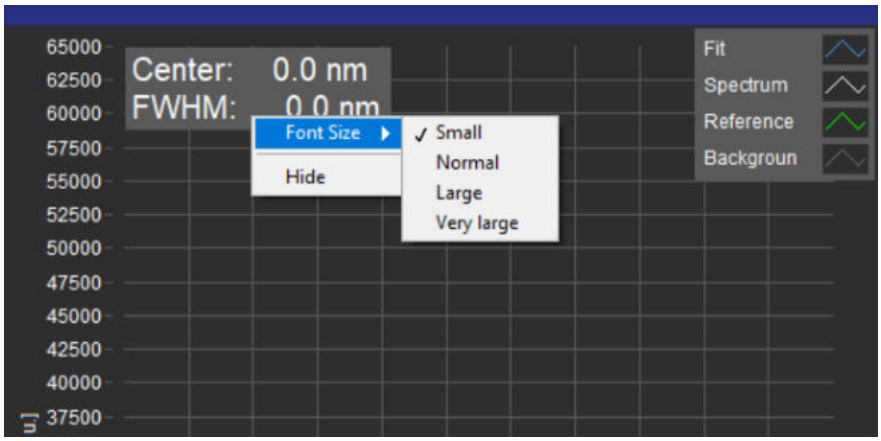

Figure 4.27: Context menu of the info string.

Available function	Explaination
”Font Size”	Changes the font size of the info box text.
”Hide”	Hides the info box. For re-appearance click the ”Large Area Value” checkbox (see section 4.3.2.8).

4.4.2 Graph Context Menu

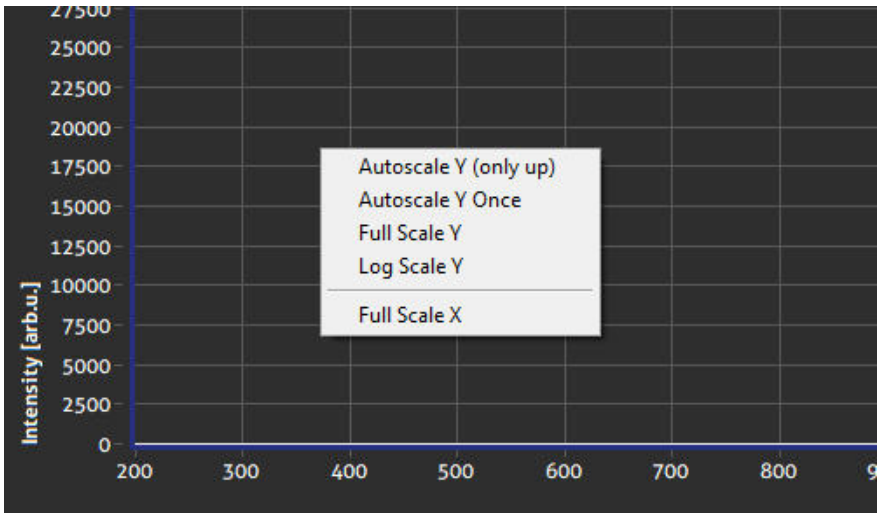

Figure 4.28: Context menu of the measurement graph.

Available function	Explained in paragraph
”Full Scale X”	4.3.3.1
”Autoscale Y (only up)”	4.3.2.3
”Autoscale Y Once”	4.3.2.5
”Log Scale Y”	4.3.2.4
”Full Scale Y”	4.3.2.2

5 Remote Communication and Automatization by USB or TCP/IP commands

You can remote control or automate the **waveScan** by two means:

1. Direct USB communication and control with USB commands.
2. Indirect communication via TCP/IP commands and the **waveScan** software.

The second means of communication requires **waveScan** software to run on a PC and to have a USB connection with the **waveScan** established. the software acts as a server and provides a TCP/IP port to connect with. This option makes remote or Ethernet communication possible where the controlling PC can connect to the software on another PC. The TCP/IP communication and measurement control allows for a wider range of commands and options since the software itself is processing high level calculations.

The direct USB communication in contrast, doesn't require the software to run but at the same time to alternative allows for less complex functions and commands.

For a complete list of USB and TCP/IP commands and examples please refer to a separate PDF file ("USB and TCP/IP Command Set") on the provided USB drive. If this file is missing or got lost, please contact APE or your local distributor (see 6.3).

6 Maintenance and Troubleshooting

6.1 Cleaning

Do not use any aggressive solvents to clean the **waveScan** spectrometer components! Switch the laser OFF or block the input beam, switch the **waveScan** OFF and unplug the mains power adapter from the wall power socket for cleaning!

Use a soft lint-free dry or only slightly moistened cloth to clean the covers of the **waveScan** components.
Use dry methanol (toxic!) or isopropanol and lens cleaning tissue applying common optics cleaning techniques to clean the input mirror.

6.2 Troubleshooting

Problem	Possible reason	Action
Message ”Not connected” in the info string	**waveScan** not properly connected to the PC	check USB cable connection between **waveScan** and computer
	power not switched on	make sure the power adapter is plugged into the wall outlet and into the **waveScan**, respectively, make sure power is switched on
	software driver not properly installed	re-install **waveScan** Control Software on your computer
No noise signal on the graph, message ”Connected” in the info string	measurement not started	press ”Start” button (see 4.2.1)
	wavelength or intensity ranges not properly set	set wavelength window to ”Full scale” (see 4.3.3.1), set X-axis to ”Full scale X” (see 4.3.2.2), set Y-axis to ”Autoscale Y” (see 4.3.2.3)
No laser spectrum to be found	wavelength or intensity ranges not properly set	set wavelength window to ”Full scale” (see 4.3.3.1), set X-axis to ”Full scale X” (see 4.3.2.2), set Y-axis to ”Autoscale Y” (see 4.3.2.3)
	alignment of the input beam not correct	use the alignment apertures of the input mirror and the beam entrance, follow the steps in 3.5
	laser outside the **waveScan** specifications	make sure the laser beam to be measured is inside the wavelength and power specifications of your **waveScan** model

Problem	Possible reason	Action
Warning missing trigger signal appears, when the trigger mode is activated.	No trigger signal cable connected to trigger input port of **waveScan** device.	Check that the BNC cable with the trigger signal is properly connected to the trigger input port (see section 2.3.4 for location of the port).
	Connected trigger signal is not detected correctly.	Check with an oscilloscope the signal height of the trigger signal. The trigger signal should be a pulse with a height between +0.5 V and +5 V. Adjust the parameter trigger level to roughly half the height of the trigger signal. See section 4.3.3.3 for more information on the trigger feature.
Triggered **waveScan** operation starts correctly, but only a flat noisefloor without the expected spectrum is measured.	Alignment of the laser beam is not correct or spectral range of expected spectrum lies outside the current wavelength scale.	See solutions above at problem ”No laser spectrum to be found”. At pulse repetition rates above 10 kHz it can be useful to use the continuous measurement mode for beam alignment instead of the triggered mode.
	Trigger delay is not set correctly.	Adjust the parameter ”delay” in the trigger-submenu (see section 4.3.3.3) until the spectrum appears in the measurement and the spectral height is optimized.
Measured spectrum obtains comb-like shape with moving peak positions.	The pulse repetition rate of the light source is too small to be measured in the continuous measurement mode (continuous mode for rep. rates beyond 1 MHz).	Use the ”Max. Hold” measurement mode in case the pulse repetition rate is roughly between 100 kHz and 1 MHz (see 4.3.3.2.5). Use the triggered measurement mode for pulse repetition rates below 100 kHz (see 4.3.3.3).

6.3 Technical Support

For technical questions or problems within Germany, please contact:

APE Angewandte Physik & Elektronik GmbH
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D - 13053 Berlin
tel +49 30 98601130
fax +49 30 986011333
service@ape-berlin.de
http://www.ape-berlin.de

To contact our international distributors, please have a look at our website:

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https://www.ape-berlin.de/en/contact/

For technical support in all other countries, please contact your local **waveScan** vendor.

Declaration of Conformity to EU RoHS

Products listed below that are manufactured by APE Angewandte Physik & Elektronik GmbH are in compliance with EU Directive 2015/863 of the European Parliament and of the Council of July 22, 2019 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (also known as **RoHS Recast**). In addition, this declaration of conformity is issued under the sole responsibility of APE Angewandte Physik & Elektronik GmbH. Specifically, products manufactured do not contain the substances listed in the table below in concentrations greater than the listed maximum value.

Substance	Limit (ppm)
Cadmium (Cd)	< 100
Lead (Pb)	< 1000
Mercury (Hg)	< 1000
Hexavalent Chromium (Cr VI)	< 1000
Poly Brominated Biphenyls (PBB)	< 1000
Poly Brominated Diphenyl ethers (PBDE)	< 1000
Bis(2-Ethylhexyl) phthalate (DEHP)	< 1000
Benzyl butyl phthalate (BBP)	< 1000
Dibutyl phthalate (DBP)	< 1000
Diisobutyl phthalate (DIBP)	< 1000

Signature:

Name (printed): Dr. Konrad von Volkmann
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