Autocorrelator with *pulse*Link Driver

*pulse*Check Type II

User Manual

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IMPORTANT – READ CAREFULLY BEFORE USE – KEEP FOR FUTURE REFERENCE

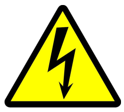
This user manual contains user information for the *pulse*Check USB. Read this manual carefully before operating the *pulse*Check USB, particularly Section 1 on safety instructions. The *pulse*Check USB is only to be used as described in this manual. Differing use may endanger safety and voids warranty.

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 and on the Measuring System

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

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



This symbol is intended to alert the operator to the presence of dangerous voltage within the product's enclosure that may be of sufficient magnitude to constitute a risk of electrical shock and to indicate possible risk of equipment damage.

Warranty

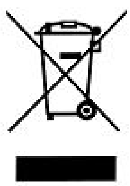
The warranty conditions are specified in the sales contract.

Any unauthorized modification (opening included) of the ***pulse*Check USB** system components or software will result in invalidity of the guarantee and service contract.

Disposal

The ***pulse*Check USB** fulfills the European Directive 2011/65/EU for reduction of hazardous substances in electrical and electronic equipment (RoHS).

All electrical and electronic products must 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 ***pulse*Check USB** system marked with the crossed out wheeled bin symbol are covered by the European Directive 2002/96/EC on waste of electrical and electronic equipment (WEEE) of the European Parliament and the Council of January 27, 2001. 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 A·P·E GmbH.

Contents

1. Safety Instructions

The European Community requirements for product safety are specified in the "Low Voltage Directive" (2006/95/EC). The "Low Voltage Directive" requires that electronic products comply with the standard EN 61010-1:2010 "Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use". Compliance of this product is certified by the CE mark.

1.1. Optical Safety

Since the *pulse*Check USB is intended to measure the duration of laser pulses all safety instructions relevant to the class of your laser have to be observed!

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

The greatest concern when using a laser 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 or beam splitters. Although weaker than the main beam, such beams may still be sufficiently intense to cause eye damage.

Direct eye contact with the output beam from the laser can cause serious damage and possible blindness.

Laser beams can be powerful enough to burn skin, clothing or paint. 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 some distance. The beam may also cause damage if contacted indirectly from reflective surfaces. For these reasons and others, the user is advised to follow the precautions below:

1. Observe all safety precautions given by the manufacturer of your laser.
2. All alignment procedures described herein shall only be done by qualified users who are familiar with laser safety practices and who are aware of the dangers involved.
3. 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.
4. Maintain experimental setups at low heights to prevent inadvertent beam-eye encounter at eye level.
5. As a precaution against accidental exposure to the laser beam or its reflection, those using the system have to wear laser 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 operator from seeing the beam. Therefore, use extreme caution even when using safety glasses.

6. Avoid direct exposure to the laser light. The intensity of the beam can possibly cause flesh burns or ignite clothing.
7. Extreme care must be taken during alignment procedures with the free laser beam. Always start alignment with a beam attenuated to a level that allows for save handling.

Caution! When opening the optical head top cover a laser beam might emerge in upward direction if the input beam to the unit is not properly blocked nor the laser switched OFF.

1.2. Electrical Safety

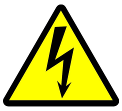
The ***pulse*Check USB** uses DC voltages in the controller and in the optical head. All units are designed to be operated with protective covers in place.
The device complies with protection Class III / EN 61140:2007, degree of ingress protection IP20, according to EN 60529:2010.

For the connection of the controller and the optical head only the delivered cable may be applied. It is only allowed to run the *pulse*Check USB with the delivered mains adapter.

Use only the *pulse*Link controller and the optical head that have been delivered together. The units are electronically fitted to one another. Connection of other units might cause damage of the delay drive and electronic components.

Users are not recommended to open the *pulse*Link controller 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 for the user to open the top cover of the optical head housing as described in the Paragraph 3.6.2 to exchange the detector unit. In this, the device has to be switched OFF and disconnected from the power supply.



Caution! High voltages can occur at the photomultiplier detector unit and its power supply.

1.3. **Electromagnetic Compatibility**

The European requirements for Electromagnetic Compliance (EMC) are specified in the EMC Directive (published in 2004/108/EC). Conformance (EMC) is achieved through compliance with the harmonized standards EN 61000. Compliance of the ***pulse*Check USB** autocorrelator system with the (EMC) requirements are certified by the CE mark.

2. Description and Specifications

2.1. Description and Intended Use

The ***pulse*Check USB** autocorrelator is a flexible device used to measure the pulse duration of a variety of laser systems emitting trains of femtosecond (fs) and picosecond (ps) pulses. It is designed for operation under laboratory conditions, that is, in closed, dry, and low-dust rooms at installation on an optical table or a similar stable vibration-free base.

The combination of the ***pulse*Check** optical head and the ***pulse*Link** USB Controller enables operation and measurement from a personal computer based on the comfortable and powerful ***pulse*Link** autocorrelator software.

The following main features are implemented with the ***pulse*Link** controller and its autocorrelator software:

- Fast USB 2.0 full speed interface to PC
- High resolution data acquisition (16 bit)
- High speed real time measurement

The autocorrelator ***pulse*Check USB** is based on the principle of scanning autocorrelation. It consists of three components:

1. ***pulse*Check USB** optical head
2. ***pulse*Link** controller unit
3. control software

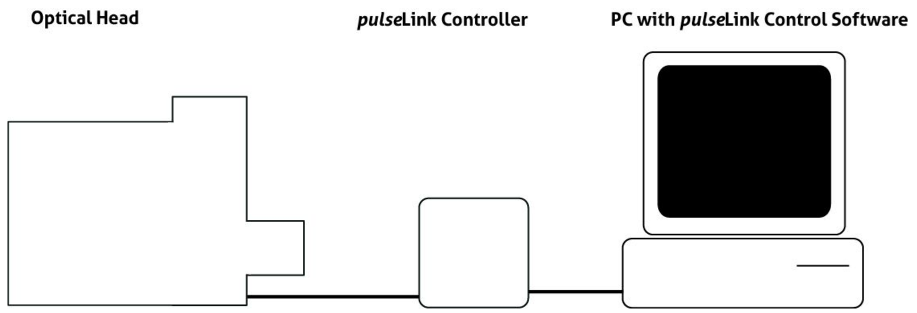


Figure 2.1.: ***pulse*Check USB** system

The control software runs on a computer with the Windows operating system (the computer is not included in the delivery).

The optical head comprises a Michelson interferometer, the delay unit, the interaction unit (SHG unit) and the detector module. The controller unit comprises the necessary drivers, amplifiers and the power supply. It acts as interlink between the optical head and a computer. Figure 2.2 shows the ***pulse*Check** optical head and the ***pulse*Link** controller unit. User interaction and control of the system is done on the computer with ***pulse*Link** Software.

Figure 2.2.: ***pulse*Check** optical head (left) and ***pulse*Link** controller (right)

2.2. Specifications

2.2.1. Optical Parameters

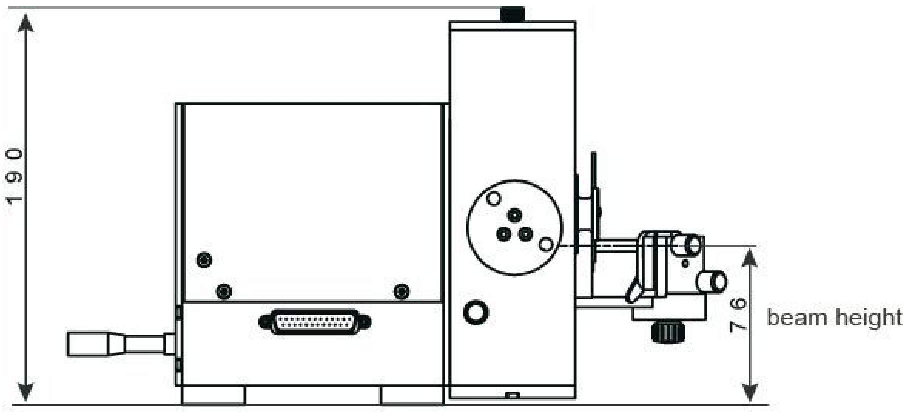
Laser repetition rate	> 100 kHz for high contrast measurement only
Dynamic range	> 10E4 or 80 dB (20 dB = Input laser power * 10)
Minimum pulse energy	0.2 μJ for max. contrast
Maximum input avg. power	1 W for oscillators with a rep. rate of approx. 70 MHz
Maximum input energy	10 μJ for amplied systems with rep. rates in the kHz range
Input polarization	linear, any orientaiotn
Standard wavelength range	700 … 1200 nm
Sensitivity (P_{AV} * P_{PEAK})	< 1 W^2 (PD)
Input beam height	75 mm

2.2.2. Electrical Parameters

Power adapter	input	100 … 240 VAC, 0.8 … 0.4 A, 47 … 63 Hz
	Output	12 VDC, 2.5 A
Trigger Input		TTL, 10 Hz … 50 kHz
Outputs (optional)	delay	0 … 10 V analog
	AC intensity	0 … 10 V analog
Communication interface		USB 2.0 full speed

2.2.3. Mechanical Parameters

Sizes (L x W x H)	optical head	see outline drawings
	***pulse*Link controller**	
	with feet	157 mm x 80 mm x 145 mm
	without feet	157 mm x 33 mm x 140 mm
Weights	optical head	5.4 kg (15 / 50 version)
		7.3 kg (150 version)
	***pulse*Link controller**	0.9 kg



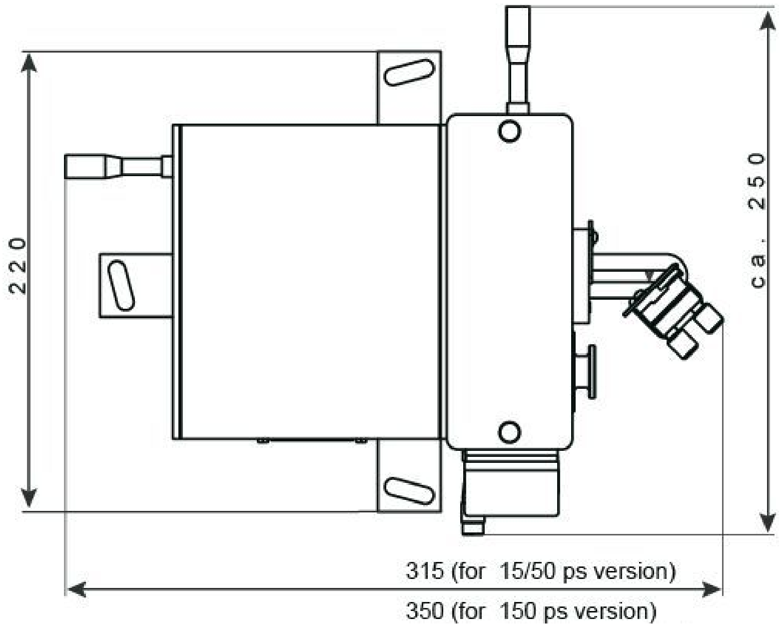


Figure 2.3.: Optical Head outline drawing (in mm)

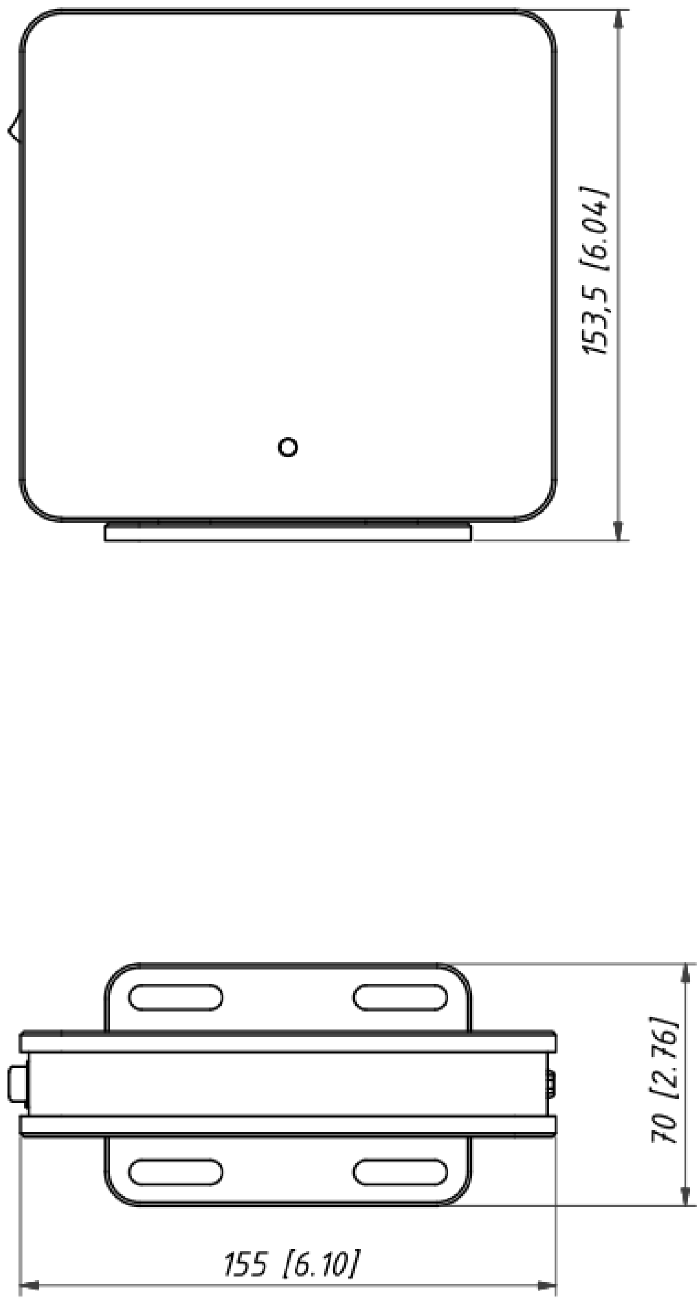


Figure 2.4.: ***pulse*Link** Controller outline drawing

2.3. System Requirements for *pulse*Link Control Software

The control computer should have at least the following configuration:

- Windows 7 / (Windows XP (SP2))[1] or higher
- 500 MB hard disc space
- Pentium IV or equivalent processor

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

- 2 GB of RAM
- Screen resolution of 1024 x 768 pixels

2.4. Environmental Requirements

The *pulse*Check USB 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 %, no condensation
Ambient temperature during operation:	+ 18 ... + 27 °C
Relative humidity during operation:	< 60 %, no condensation

3. Installation

3.1. Inspection of Delivery

On receipt of the ***pulse*Check USB** autocorrelator system:

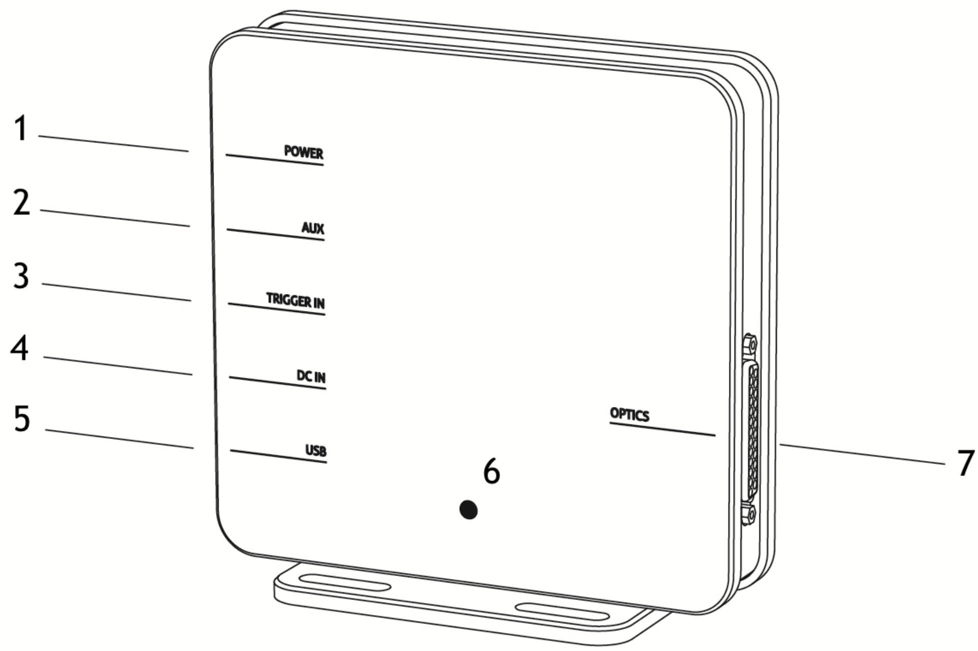
1. Inspect the packing crate for signs of rough handling or damage directly at arrival. If you discover any irregularities:
   - Take photographs of the condition of the package, the labels and the inside of the box, if necessary.
   - List all defects on the shipping documents and let the delivery company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

3.2. Contents of Delivery

Figure 3.1.: Contents of Delivery (detectors and crystals not pictured)

	Item	Amount
1	***pulse*Check** optical head	1
2	***pulse*Link** controller unit	1
3	PD detectors (high contrast, linear)	2
4	Optical post with half wave plate	1
5	USB drive with ***pulse*Link** control software	1
6	12-VDC power adapter	1
7	Box with SHG crystal module (may contain more than one crystal module depending on purchase)	1
	Cables:	
8	25-pin Sub-D connection cable ***pulse*Link** controller to ***pulse*Check** optical head	1
9	USB cable type A-B	1
10	Trigger input cable	1
	Other:	
11	Test report	1
12	Certificate of Calibration	1
13	This ***pulse*Check USB** user manual	1
14	Optics Set list (if appropriate)	1

3.3. System Controls and Indicators



1	POWER	power switch
2	AUX	auxiliary connector
3	TRIGGER IN	trigger input
4	DC IN	DC power connector (connect to 12-VDC power adapter)
5	USB	USB connector (connect to PC)
6	LED	multicolor status LED
7	OPTICS	25-pin Sub-D connector (connect to optics head)

The ***pulse*Link** has a status LED (6) that indicates its status as listed in the table below:

LED	status ***pulse*****Link** condition / status
OFF	***pulse*****Link** off
RED	Hardware selftest after powering on (approx. 1...2 sec)
RED	(blinking) Optical head not connected or wrong optical head
YELLOW	***pulse*****Link** is performing a selftest, connection with control software not (yet) established
GREEN	Optical head detected and connection with control software established
CYAN	Service only: Bootloader activated (approx. 1 sec)

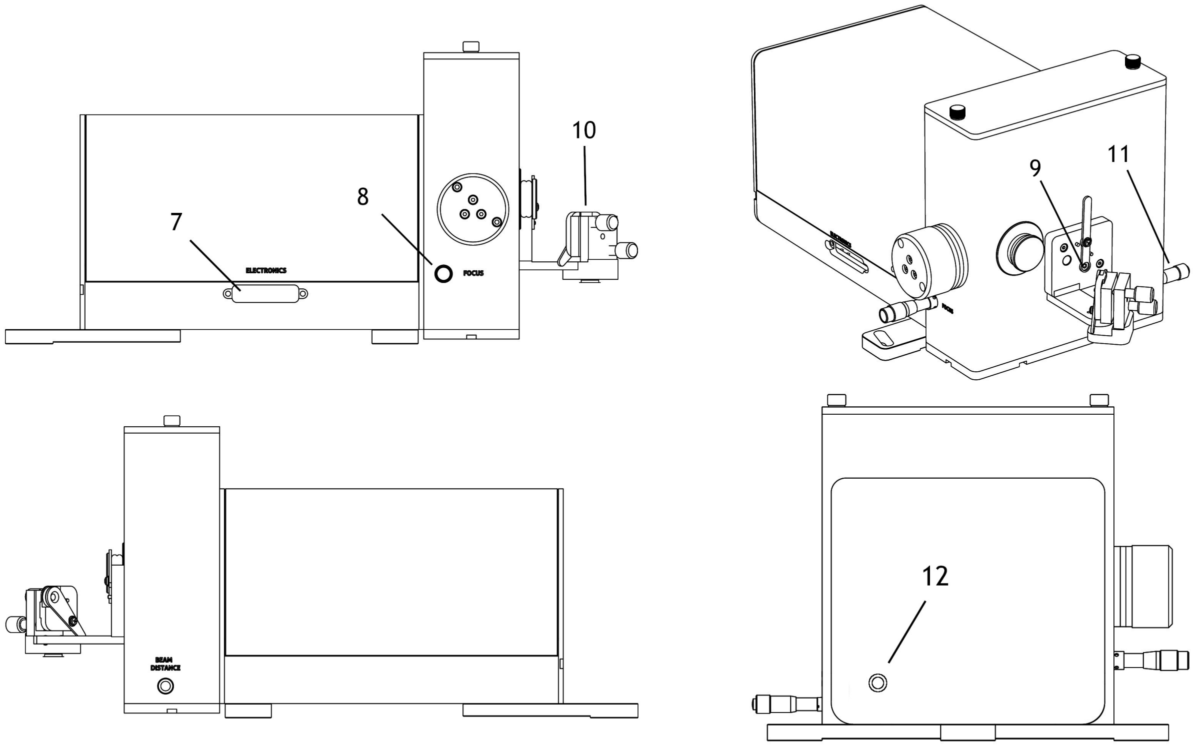


Figure 3.2.: ***pulse*****Check** Optical Head

7	25-pin Sub-D connector (connect to ***pulse*****Link controller**)
8	Focus alignment screw
9	Beam input with alignment aperture
10	Adjustable input mirror with alignment aperture
11	Beam distance adjustment screw
12	Manual delay adjustment screw (***pulse*****Check** 15 and 50 versions only)

3.4. Installation of the *pulse*Link Control Software

To control the ***pulse*Check USB** via the ***pulse*Link** controller it is necessary to use the delivered ***pulse*Link** control software. Before starting an autocorrelation measurement, please, install the ***pulse*Link** control software on your computer. For requirements to the computer refer to Section 2.3.
Proceed as follows:

1. Insert the delivered USB drive with the software and start "setup.exe".
2. Follow the instructions during installation of the software.

3.5. Cable Connection

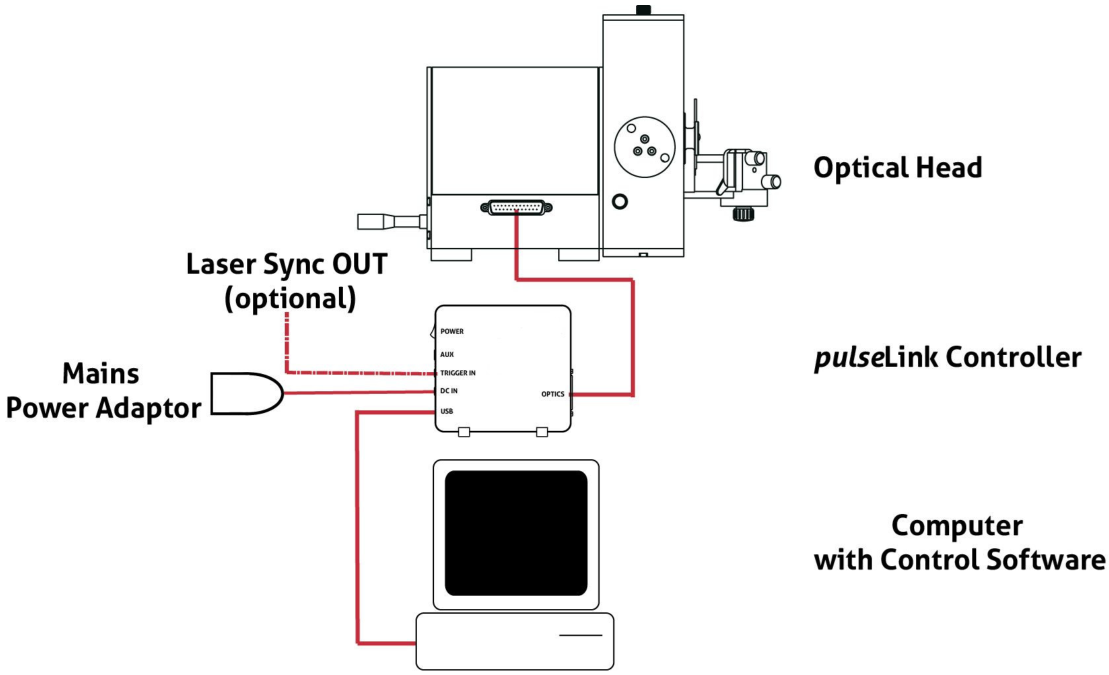


Figure 3.3.: Connection scheme

1. Connect the ***pulse*Check** optical head with the ***pulse*Link** controller ("OPTICS" port) using the delivered 25-pin Sub-D connection cable.
2. To avoid possible damage of the device:

Only connect an Optical Head to a *pulse*Link controller with the identical serial number!

3. Connect the ***pulse*Link** controller ("USB" port) with your computer using the delivered USB cable.
4. Connect the delivered AC/DC power adapter with the ***pulse*Link** controller ("DC IN" port) and the mains wall plug.
5. For measuring a low repetition rate laser system (> 10 Hz < 50 kHz) use the delivered trigger cable to connect the ***pulse*Link** controller ("TRIGGER IN" port) with the trigger source (usually the synchronization trigger output of your laser).

3.6. Installation of the Optical Head

If you have purchased more than one Optics Set make sure that the one fitting your laser wavelength range is mounted. If the suitable Optics Set is not already mounted, install the desired Optics Set as described below in the Paragraphs 3.6.1 "Mounting / Exchange of the SHG Crystal" and 3.6.2 "Exchange of the Detector Unit". The SHG crystal is packed separately and must be installed in any case before first measurement.

The optical head is secured by a transportation screw. After unpacking the ***pulse*Check** parts please remove screw (1) and replace with cover pin (2) (see Figure 3.4 and 3.5).

Attention! Before any further transportation the transportation screw has to be attached to the optical head again.

Attention! Autocorrelators with a 150 ps scan range do not have a transportation screw!

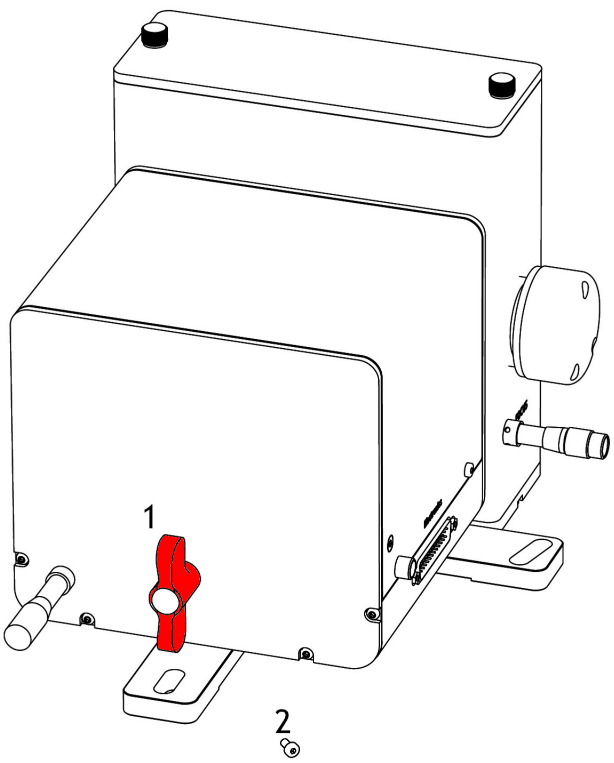


Figure 3.4.: Transportation screw (1) installed (for transportation), not included with ***pulse*Check USB** 150!

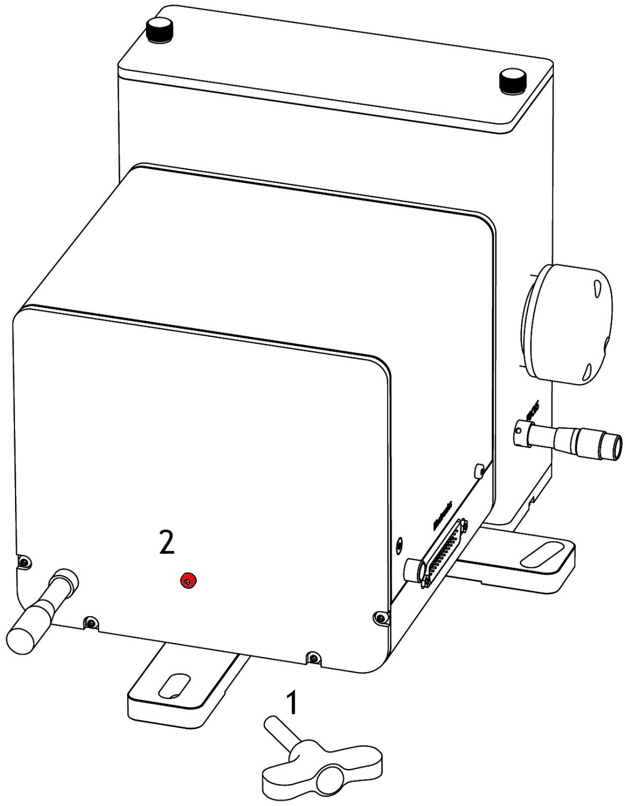


Figure 3.5.: Cover pin (2) installed (for operation), not included with ***pulse*Check USB** 150!

3.6.1. **Mounting / Exchange of the SHG Crystal**

At delivery of the ***pulse*Check** autocorrelator the crystal module (crystal and holder) is not installed in the optical head, but comes in a separate box to protect it from damage. It has to be installed before first operation. It may also be necessary to exchange the crystal module, if you need to work in a different wavelength range or with different pulse parameters if specified.

To install or exchange the crystal module proceed as follows:

1. Block or switch off the laser beam.
2. Switch off controller.
3. Open crystal lid (pull) (see Figure 3.6).
4. In order to exchange the crystal module, pull it out (as the crystal module is delivered separately, this is not necessary if the crystal module is mounted for the first time).
5. Insert new crystal module (ensure slot on crystal module fits into pin of container) (see Figure 3.7).
6. Close crystal lid.

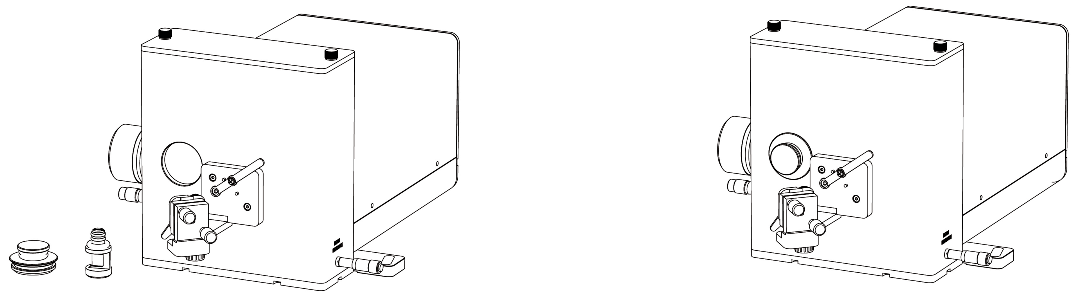


Figure 3.6.: Optical Head and crystal module (left - removed; right - installed)

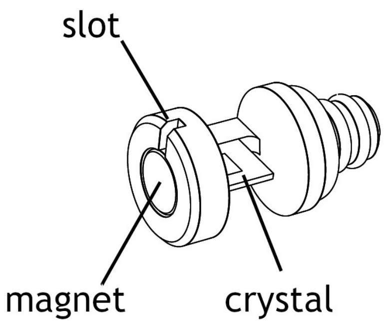


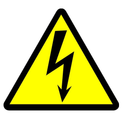
Figure 3.7.: Crystal module

3.6.2. Exchange of the Detector Unit

Make sure that the correct detector unit is installed according to wether pulse duration or high contrast is to be measured. Check with the Optics Set list. Change the detector unit, if necessary, according to the instructions in this Paragraph.

CAUTION! A laser will may emerge in an upward direction when opening the optical head top cover, if the unit is not properly blocked nor the laser switched off.

Caution! Do not expose the PMT of the detector module to intense light!



Caution! High voltages can occur at the PMT detector module and its power supply if electrical power is not properly switched OFF.

1. Switch OFF the laser or block the input laser beam.
2. Switch OFF the ***pulse*Link** controller and disconnect it from the power supply.
3. Remove top cover of the optical head (knurled screws).

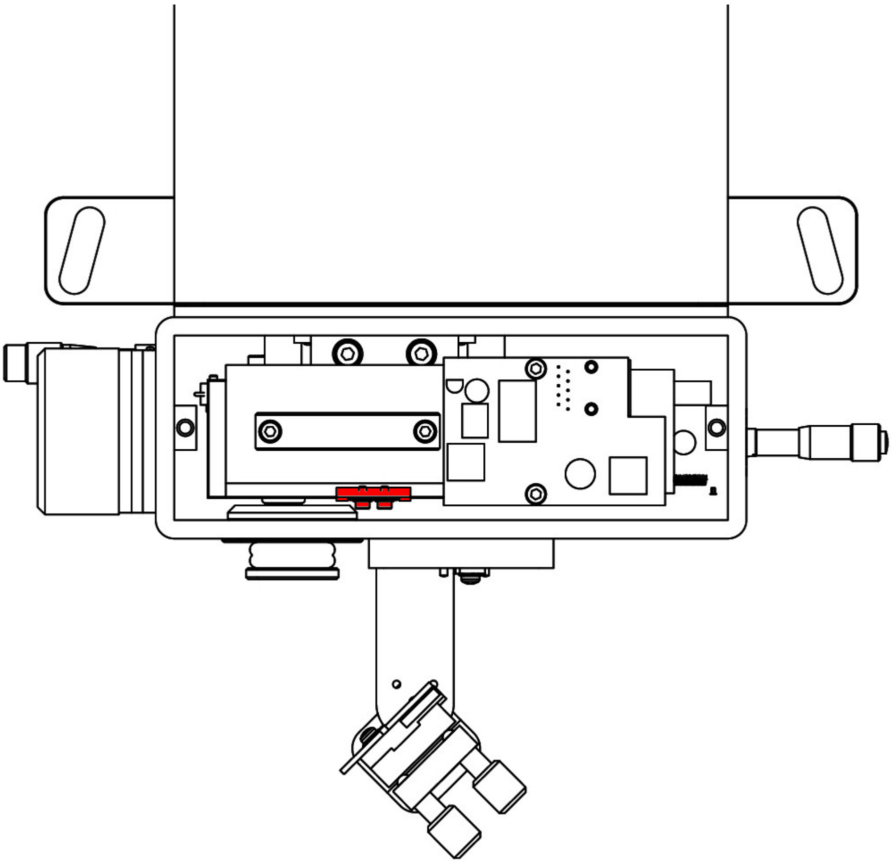


Figure 3.8.: Optical Head with removed top cover, detector module installed

4. To remove the detector module hook off bracket (red) and pull up detector.
5. Unplug the electrical connector.

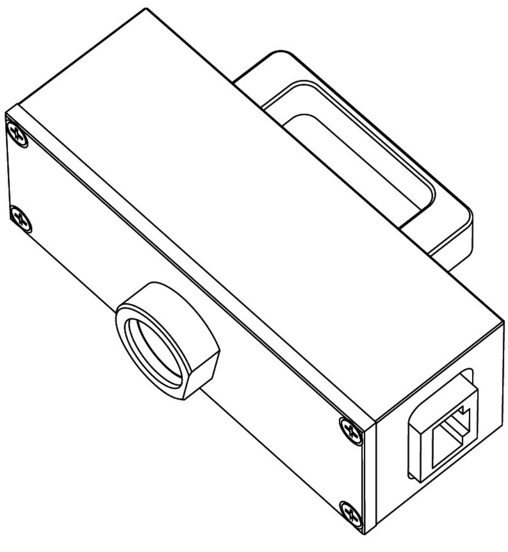


Figure 3.9.: Photodiode detector module

6. If using a PMT detector, disconnect the current PMT from power supply, and exchange with the PMT suitable for the respective wavelength range.

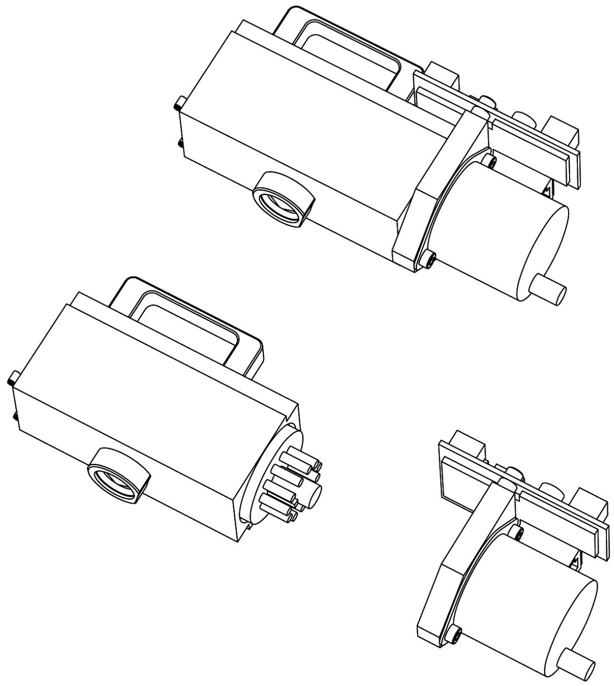


Figure 3.10.: PMT detector module consisting of PMT (with housing) and power supply

7. Plug in the connector of the new detector module and insert the module into the autocorrelator till the bracket snaps in.
8. Re-mount top cover.

4. High Contrast and Normal Autocorrelation Measurement - General Overview

The ***pulse*Check Type II** autocorrelator is able to measure the duration of laser pulses in terms of the full width at half maximum (FWHM) of the autocorrelation function (linear PD detector) as well as a high contrast autocorrelation function (logarithmic PD detector). In order to achieve a high contrast the autocorrelation must be nearly background-free and the detector must be able to process a signal dynamic range of several orders of magnitude. Therefore, changing between these two measuring modes requires to switch the detector and to change the data display to either linear scale or to logarithmic scale. Some functions and settings are also deactivated while the logarithmic mode is turned on. The user must use caution when operationg these two modes to avoid false readings.

The following chapter will provide information on aligning and setting up the ***pulse*Check Type II** in normal ACF mode. After that measuring a high contrast autocorrelation will be explained. Note that not all functions are accessible in high contrast mode. This will be pointed out where necessary.

5. Alignment and Measurement

After you have connected all components of the system and installed the ***pulse*Link** control software you are ready to start alignment and the first measurement. Proceed as follows:

1. Fasten the optical head on your optical table at a place where you can comfortably direct the laser beam to be measured onto the input mirror and handle the control elements. It should be possible to watch the display of your computer at the same time. The input mirror assembly can be mounted in two configurations allowing for different beam input directions (see Figure 5.1). To change the configuration loose the bottom thumb screw of the mirror assembly (see Figure 5.2).

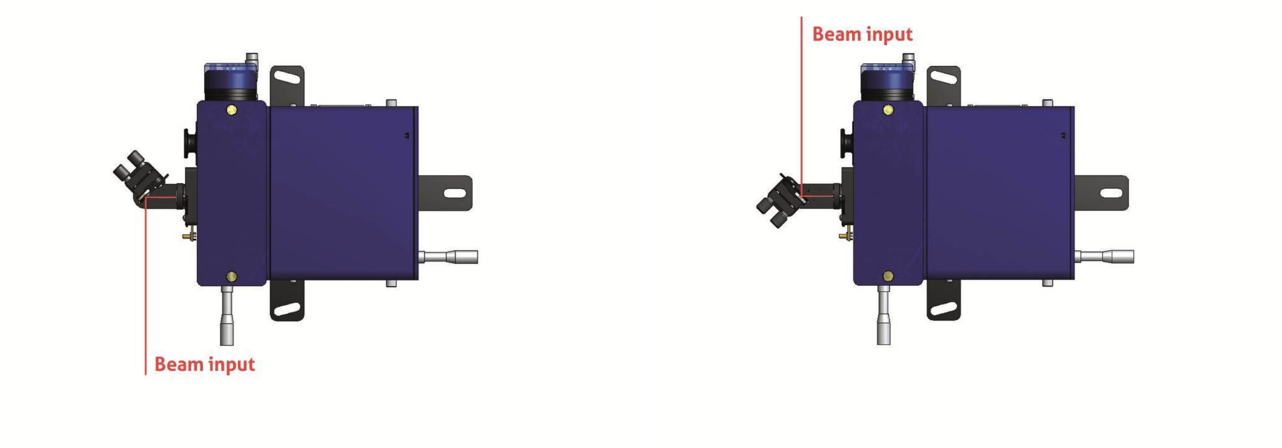


Figure 5.1.: Beam input: The input mirror assembly can be flipped to allow for beam input from either side.

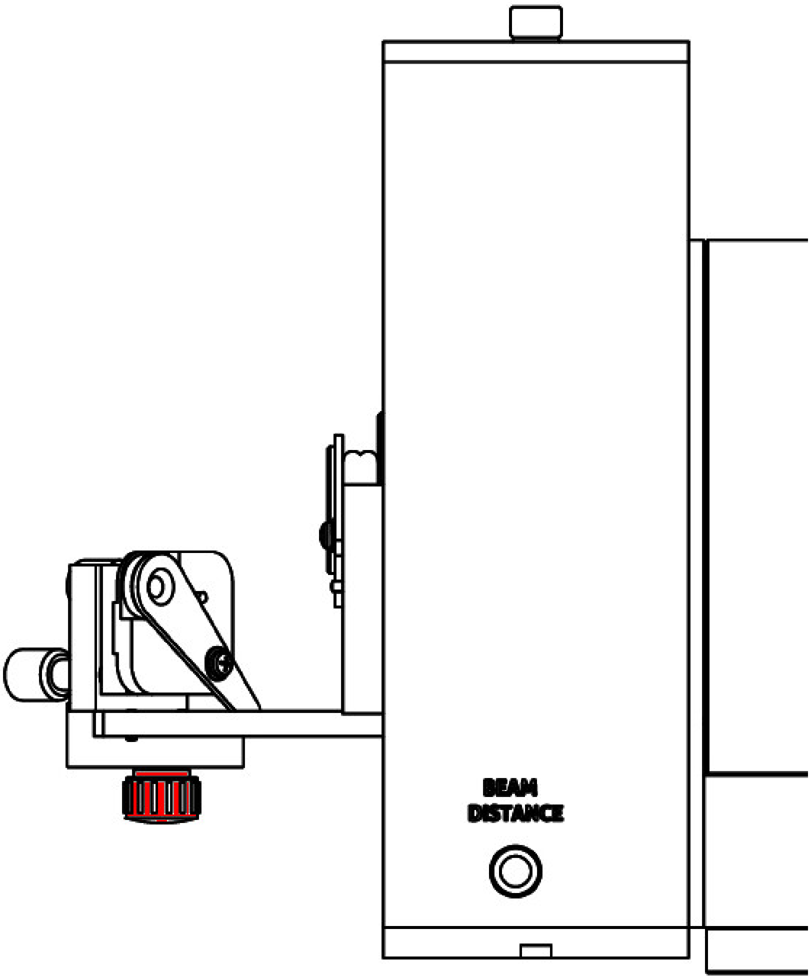


Figure 5.2.: Input mirror assembly: Loosen bottom screw to flip between configurations.

2. Turn the ***pulse*Link** ON.
3. Start the ***pulse*Link** control software. The measurement (main) window will open. For details of the controls and functional regions of the measurement window see Paragraph 5.4.1 "Measurement Window and its Controls".

5.1. Communication Setup

At start-up the A·P·E ***pulse*Link** control software automatically tries to initiate communication to the ***pulse*Link** controller. If communication is properly established the info window displays the status "Connected" (see Figure 5.3).
Additionally a green LED on the ***pulse*Link** indicates an established connection.

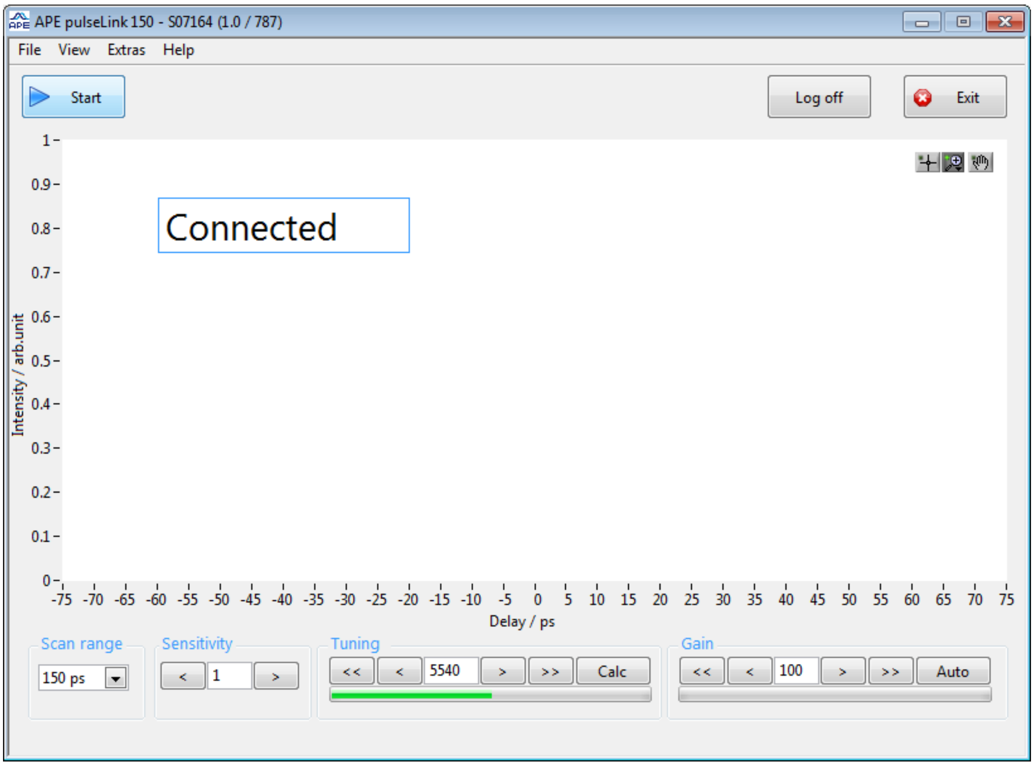


Figure 5.3.: ***pulse*****Link** control software is correctly connected

If the ***pulse*****Link** is not properly connected the info window shows the status "Not connected". In this case check the cable connections and make sure the ***pulse*****Link** is switched ON. After that, initiate communication to the ***pulse*****Link** controller by selecting "File/Connect..." from the menu bar (see Figure 5.4).

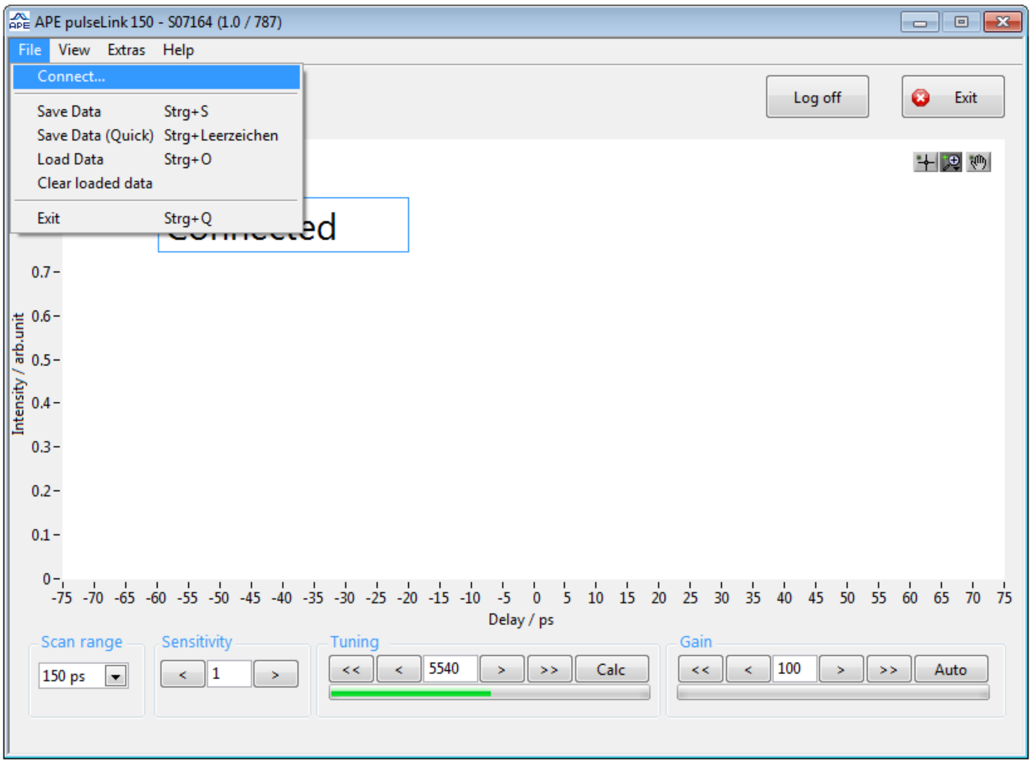


Figure 5.4.: Connect ***pulse*****Link** control software via the menu bar

Before you proceed with the next steps, the communication must be established and the status "Connected" must be displayed in the info window as shown in Figure 5.3.

5.2. Starting a Measurement

1. With established communication (see Section 5.1), press the "Start" button to get the scanner motor running (see Figure 5.5).

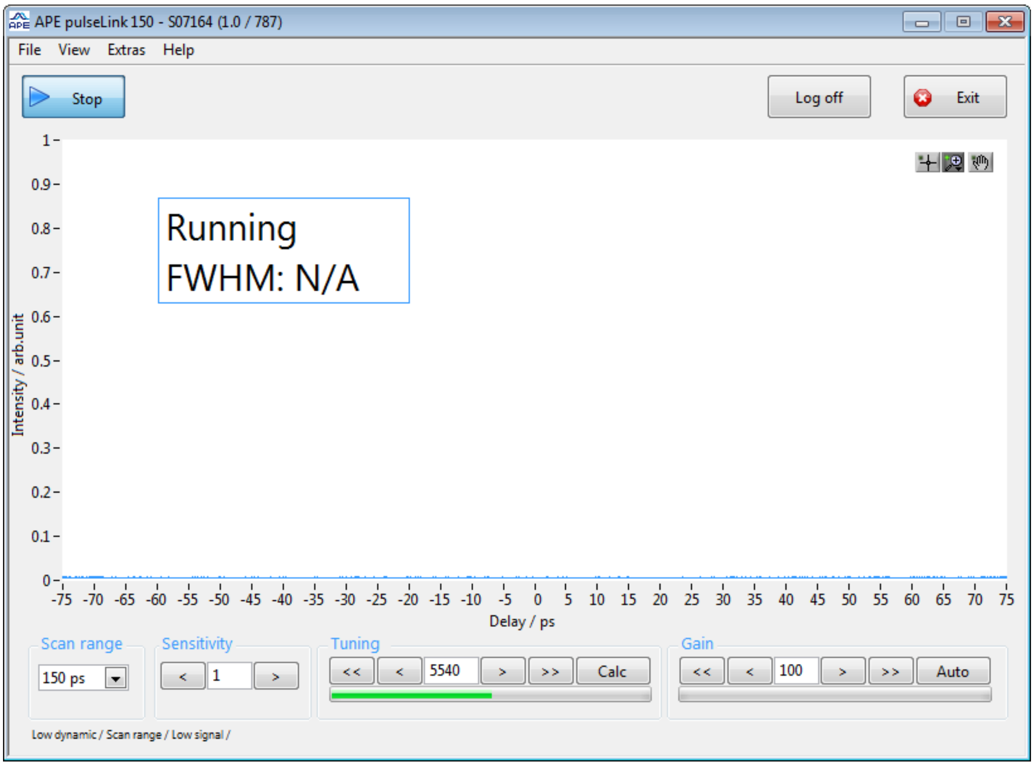


Figure 5.5.: By pressing the "Start" button the linear scanner motor starts running

2. Select the largest "Scan range" and the lowest gain, and the lowest sensitivity (***pulse*Link** control software: "Correlator settings").

5.2.1. Alignment of the Input Beam

3. Before aligning the beam to the ***pulse*Check Type II** place and fasten the provided optical post with the half wave plate in such a way that the laser beam passes the wave plate before hitting the input mirror of the ***pulse*Check Type II** . The laser beam must pass the wave plate in order to rotate its plane of polarization to 45°. Without the wave plate no or almost no signal can be genarated in the autocorrelator.
   Then use appropriate optics (e.g., glass plate, beam splitter) to direct a part of the laser beam to be measured to the center of the input mirror of the optical head (depending on the beam diameter you either close or open the beam aperture; see Figure 5.6). The beam diameter should be at least 1 ... 2 mm. Although the sensitivity is much higher and the signal will overload, for most configurations the average input power can be up to 1 W without danger of damaging the system. **However, if it**

is not stated explicitly for your device, the maximum power should not exceed 1 W for oscillators with a rep. rate of approx. 70 MHz or 10 μJ for amplied systems with rep. rates in the kHz range, whichever results in lower value! Once you have found an autocorrelation signal the input power usually must be reduced to avoid overload.

Figure 5.6.: Beam aperture: closed for 3 mm beam diameter, open for 6 mm beam diameter

4. Flip alignment aperture in front of the input aperture into alignment position (see Figure 5.7).

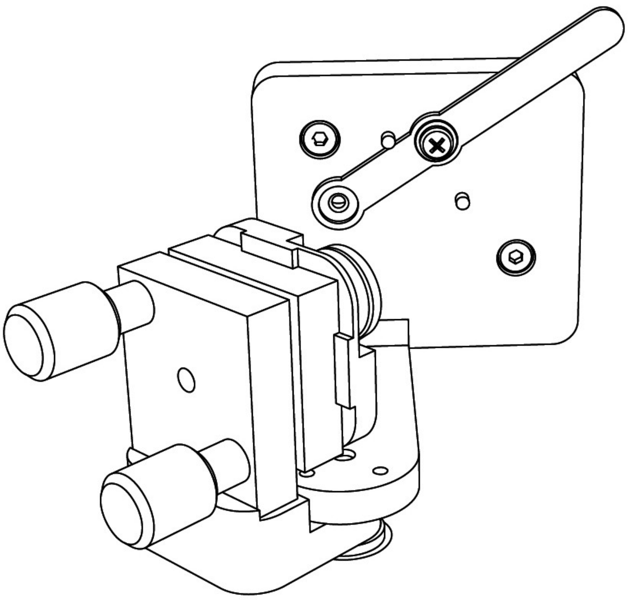


Figure 5.7.: Alignment aperture - alignment position

5. Align the input mirror to have the beam enter the device through the input aperture.
7. Use an IR-viewer to observe the alignment apertures if necessary.
8. Bring the alignment aperture back into the measurement position (see Figure 5.8)after the beam is centered on the aperture.

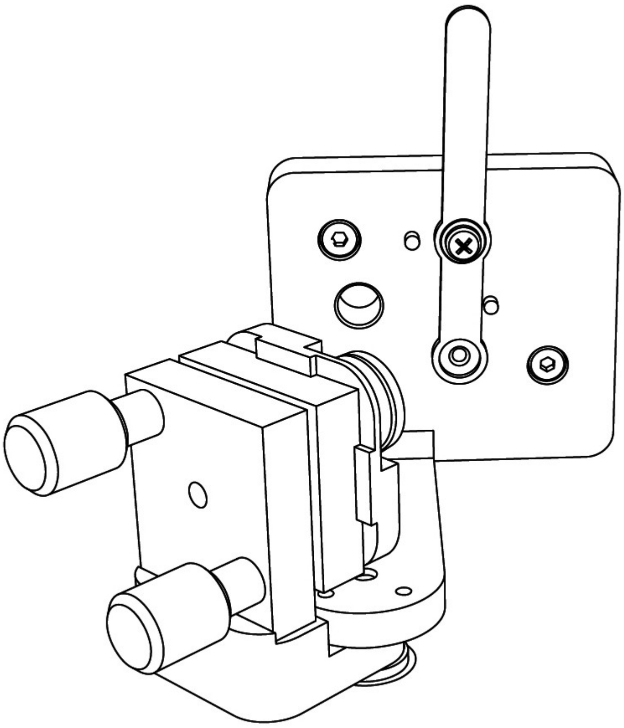


Figure 5.8.: Alignment aperture - measurement position

9. Check if the "FOCUS" screw at the optical head (see Figure 3.2, item 8) is at center position as given in the test report, and correct if necessary.
10. If applicable: Check if the "DELAY" screw at the optical head (see Figure 3.2, item 12) is at the "zero" position as given in the test report (this is usually not the micrometer position "0.00"), and correct if necessary.
11. Make sure that the correct tuning angle is set (see Section 5.2.2).
12. Slowly increase "gain" until a clear noise of the autocorrelation function (ACF) graph is shown, if necessary also increase "sensitivity".
13. If no signal is visible try to optimize the adjustment if the input mirror again.

5.2.2. **Crystal Tuning / Phase Matching**

"Tuning" is the procedure of adjusting the angle of the SHG crystal to achieve phase matching necessary for the detector to register a signal.

In case no autocorrelation signal is detected (i.e. with a new crystal or when the wavelength has changed) adjust the phase matching angle manually. Use the arrow buttons in the autocorrelator settings "tuning" section of the measurement window for manual tuning and maximize an appearing autocorrelation signal with these arrow buttons. Make sure that the crystal is not tuned to first, second or higher order phase matching (see Figure 5.9. To do this tune the crystal away from the maximum intensity and observe the display if a second or higher order maximum appears. If none or smaller maxima appear the previous crystal tuning setting with the highest intensity is the 0.th order.

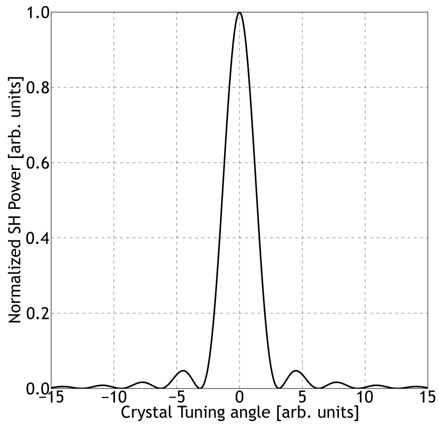


Figure 5.9.: Second harmonic intensity as function of the crystal tuning angle.

5.2.3. Searching for Signal Using "Zero" Scan Range

14. If so far you do not succeed in getting an ACF signal set "Scan range" to "Zero" and use the "tuning" arrow buttons until you observe a clear angle sensitive maximum of the noise background signal on the ACF graph.
15. Repeat input alignment.

5.2.4. Checking Alignment with the Beam Shutters

16. Check beam alignment using the internal beam shutters. To do so, open the "Settings" window (double click into the measurement window or select "Settings" from the "Extras" drop down menu of the menu bar) and locate the "shutter control" section on the "Main" tab. (see Figure 5.10).

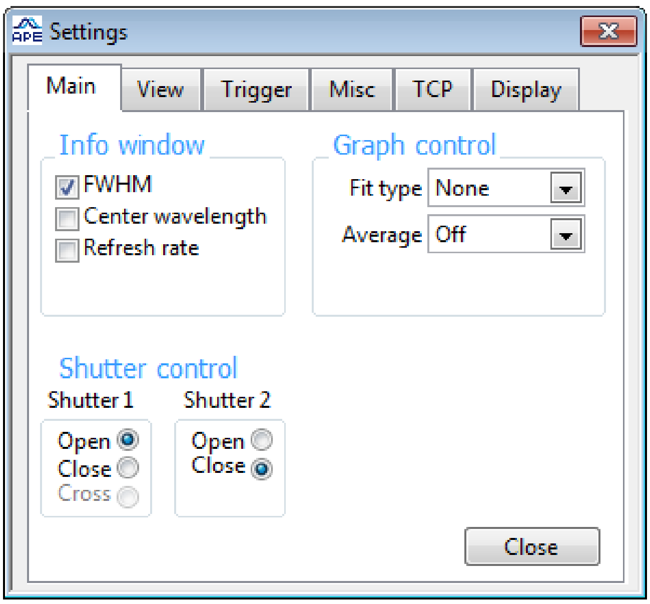


Figure 5.10.: "Main" tab of the "Settings" window with "shutter control"

17. First close either of the shutters. The background signal should go down to almost zero intensity. Repeat this step with the other shutter.
18. Close both shutters simultaneously. The signal should go down to zero (see Figure 5.11).

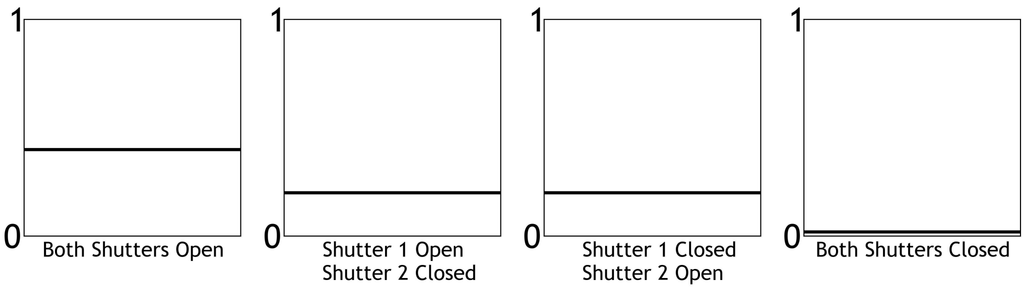


Figure 5.11.: Shutter related signal behavior in "Zero" scan mode

19. If the behavior of the signal is different, check beam alignment.
20. Select the largest "scan range" from the correlator settings section of the measurement window. You now should see an autocorrelation function (ACF).
21. Maximize the autocorrelation signal with the "sensitivity" and "gain" controls. For the latter an automated gain function can be used by pressing the "auto" button.
22. In case of overload (cut ACF peak) "Gain" and / or input power have to be reduced.
23. When you now operate the beam shutters the signal should behave as shown in Figure 5.13.

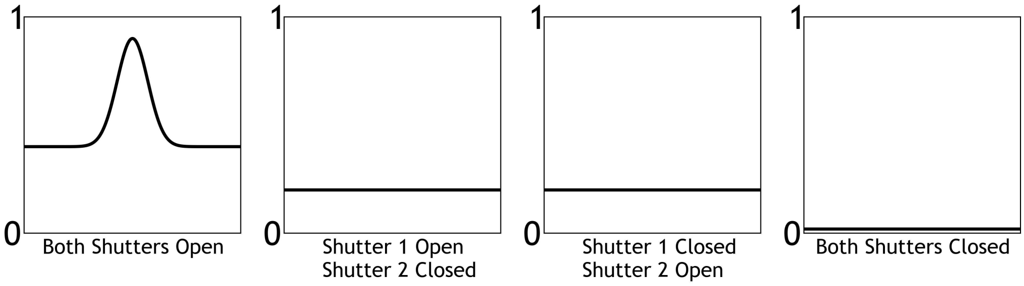


Figure 5.12.: Shutter related signal behavior in non-"Zero" scan mode

5.2.5. **Alignment Optimization**

24. Reduce "scan range" until it fits the pulses to be measured (one third to one fifth of scan range). See Section 5.7 "Error Sources of an Autocorrelation Measurement" for correct choice of scan range.
25. Maximize the autocorrelation signal by adjusting the input beam into the ***pulse*Check** optical unit.
26. Maximize ACF signal with the focus alignment micrometer at the optical head (adaption to beam divergence).

5.3. **High Contrast Measurement**

In order to measure in high contrast mode two things are necessary:

1. The logarithmic PD detector must be mounted in the optical head of the autocorrelator (see 3.6.2)
2. The data display in the software must be switched to "Log on".

If the signal was previously optimized already no further steps are necessary at this point. The control software will display the high contrast ACF with a logarithmic intensity axis. Figure 5.13 shows a example of a ACF in normal and in high contrast mode. Note that the two pictures display the same laser with the same pulse parameters in both pictures.

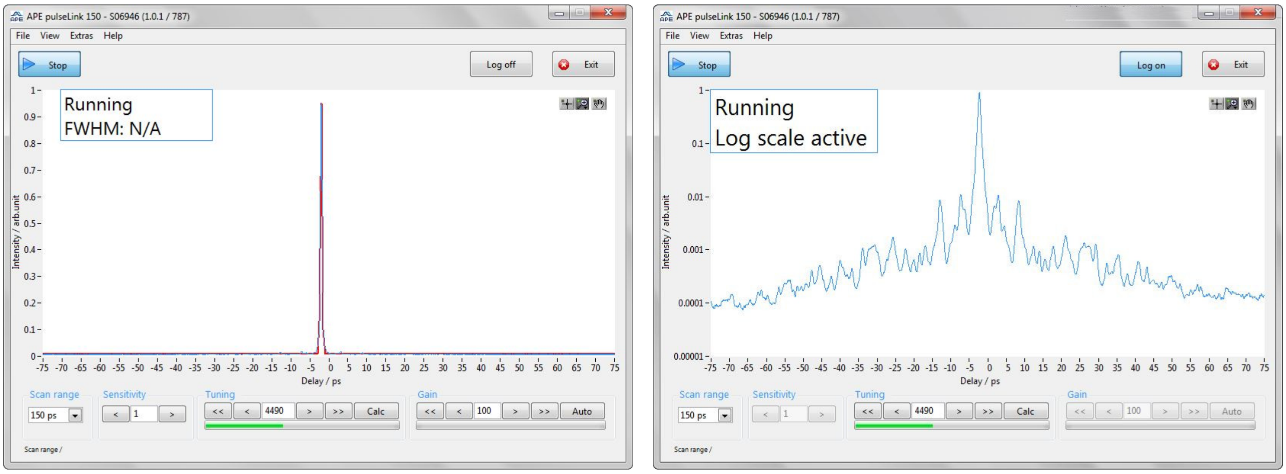


Figure 5.13.: Left: Normal ACF mode. Right: High contrast mode. Note that the time / delay axis is the same in both pictures.

It is important to keep in mind that although the lasers pulse parameters in the two pictures in Figure 5.13 are the same, the laser power is higher for the high contrast measurement. The reason is that the normal PD detector and the high contrast logatihmic detector have different properties. While the normal PD detector is linear the signal processing in the high contrast detector is logarithmic. In other words, while a relatively low laser power is necessary to saturate the normal detector (the signal peak is equal to 1 in the intensitiy scale of the control software) the high contrast detector needs multiple times more laser power to be saturated. Thus, the high contrast function of the logarithmic detector is that it is able to encompass relatively small signals (wings, pre or post pulses etc.) and the high peak intensity of laser pulses at the same time.

5.3.1. Optimizing High Contrast Measurement

A high contrast of the autocorrelation singal can only be achieved if background signal (from the individual beams in the interferometer) is minimized while the signal of the autocorrelation, i.e. when the beams of the interferometer arms overlap, is maximized. In order to achieve this high contrast typically it's necessary to optimize all adjustable manual settings such as:

1. The half wave plate
2. Input mirror
3. Focus screw
4. Beam distance
5. Crystal angle

If the beam diameter is of a similar width as the input apertures of the ***pulse*Check Type II** it may facilitate the optimization to close the input apertures (alignment position). This will reduce the laser beam diameter inside the ***pulse*Check Type II** and effects (asymmetric ACF) from spatial chirp of the beam will be minimized.

5.3.2. Options of High Contrast Measurement

While in high contrast mode ("Log on") the following functions are turned off:

1. The low pass filter. See section 6.2
2. The sensitivty adjustment buttons
3. The gain adjustment buttons

The software cursors can be activated in EXTRAS > SETTINGS > VIEW > GRAPH > CURSOR and positioned over the ACF by Drag and Drop. The vertical cursors measure the temporal distance while the horizontal cursors give the intensity contrast ratio as a fraction. Figure 5.14 showas a high contrast ACF measurement with cursors on.

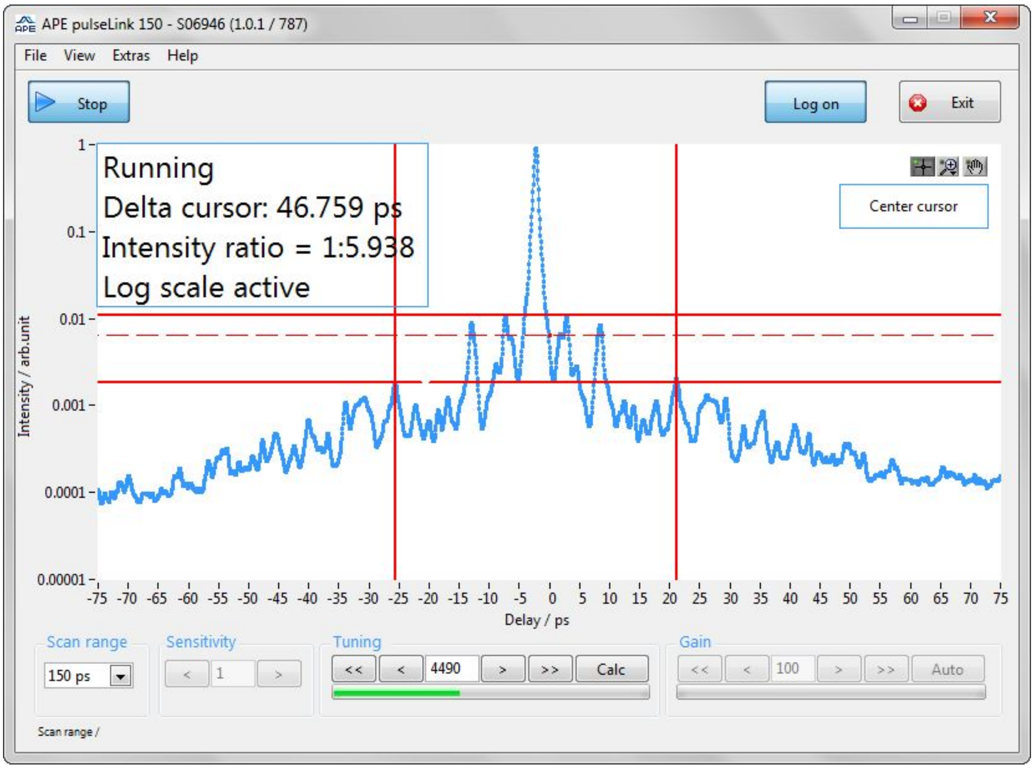


Figure 5.14.: High contrast ACF measurement with cursors on

5.4. Measurement and Display Configuration in Detail

The A·P·E ***pulse*Link** control software offers options and display configurations which are described in the following sections.

5.4.1. Measurement Window and its Controls

Figure 5.15 shows the measurement window of the A·P·E ***pulse*Link** control software that is displayed when you start the software (in this particular case with a autocorrelation function and the fit being on).

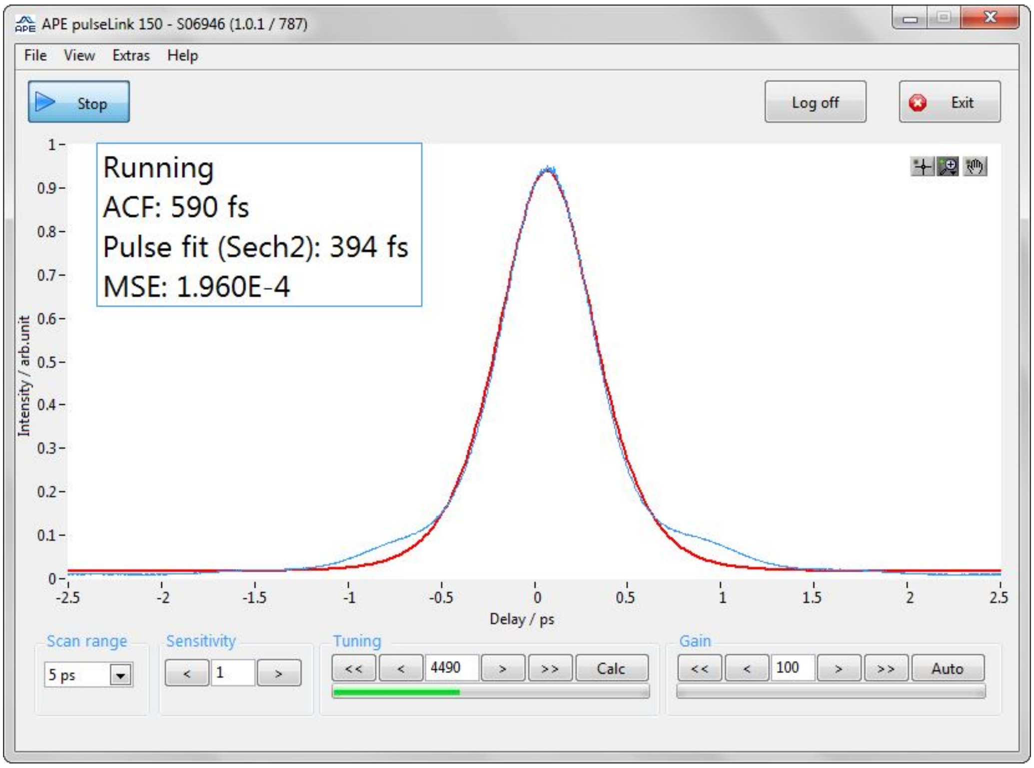


Figure 5.15.: Measurement window of the A·P·E ***pulse*Link** control coftware with ACF and fit

The following controls and functional regions are available in the measurement window:

Start / Stop Button: Starts or stops the scanner motor and the measurement

Log on / Log off Button: Switches between normal (linear detector) and high contrast (logarithmic detector) measurement display

Info window: Configurable, movable window that displays the status of the device and information about the current measurement.(Change the content and the size by a right mouse button click into the Info window. To move the window, drag and drop it with the left mouse button.)

Correlator settings: Software controlled change of autocorrelation measurement parameters:

- **"Scan range"**: Change of the time window of the autocorrelation measurement
- **"Sensitivity"**: Change the detector sensitivity for different signal power levels. If measuring high contrast ACF ("Log on") with the logarithmic view on the low-pass filter is **deactivated** by the software!
- **"Tuning"**: Turns the angle of the non-linear crystal to increase SHG signal by phase matching
- **"Gain"**: Change the detector gain to increase or decrease the measured autocorrelation amplitude. If measuring high contrast ACF ("Log on")with the logarithmic view on the low-pass filter is **deactivated** by the software!

5.4.2. The "View" Drop Down Menu

Open the "View" drop down menu in the menu bar to select the following options:

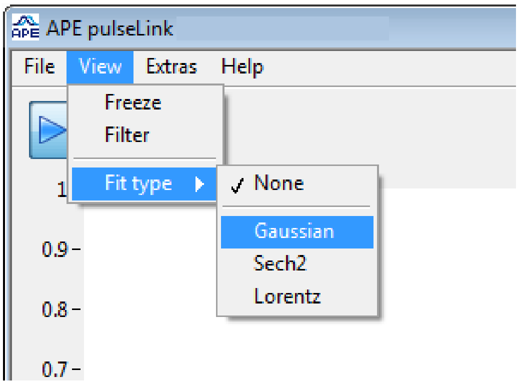


Figure 5.16.: "View" drop down menu

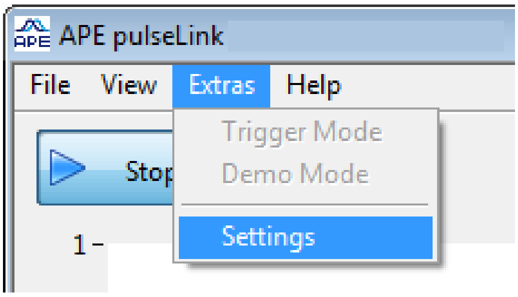
"Freeze": Stops the measurement update to show a snap-shot of an autocorrelation function

"Filter": Activate / de-activate a low-pass filter function to suppress noise substructure on the autocorrelation trace. If measuring high contrast ACF ("Log on") with the logarithmic view on the low-pass filter is **deactivated** by the software!

"Filter type": Set type of fit function (Gaussian, Sech^2 or Lorentzian) or turn fit off

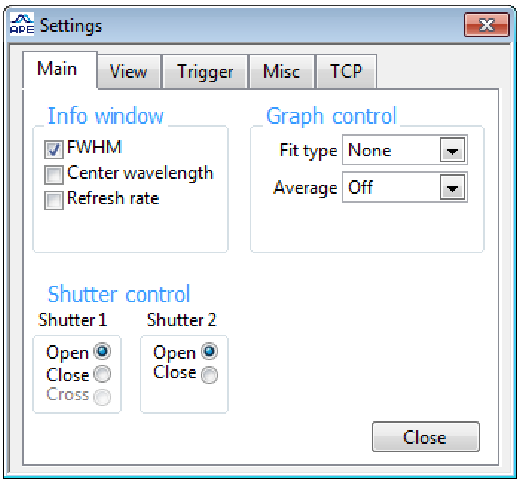
5.4.3. Setting Window

Most of the software and autocorrelator options can be chosen in the "Settings" menu. To activate the "Settings" menu, double click into the measurement window or select EXTRAS > SETTINGS from the menu bar.



"Main" Tab

The "Main" tab of the "Settings" menu is split in three subsections:



Info window The contents of the info window can be configured here.

- **FWHM:** Set a check mark to display the Full Width at Half Maximum of the function that is selected as "Fit Type" in the "graph control" subsection.
- **Center Wavelength:** **This function doesn't apply for high contrast autocorrelator configuration!**
- **Refresh rate:** Set a check mark to display the update rate of the measurement in Hz.

Graph control The graph displayed in the measurement window can be configured by the user.

- **Resolution:** The number of data points in averaged or triggered mode can be reduced to save acquisition time
- **Fit type:** The user can choose between displaying the autocorrelation measurement data (ACF) only, or additional curve fits of the measurement (e.g., Gaussian, Sech^2, Lorentzian)
- **Average:** The number of autocorrelation scans for measurement averaging can be changed.

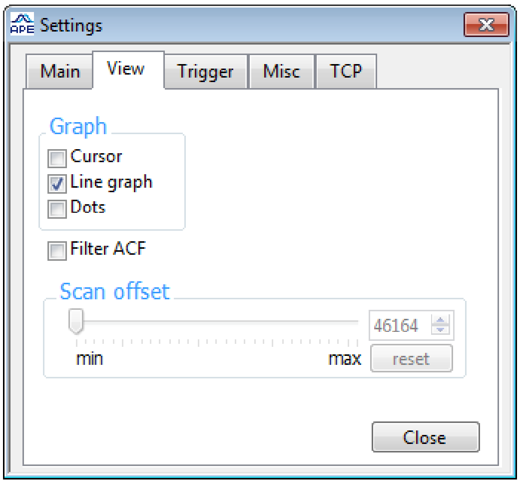
Shutter control The state/position of the two internal beam shutters in the ***pulse*Check** optical head can be switched from here. To check for the detection of a proper autocorrelation signal it is sometimes necessary to block the two interferometer arms in the ***pulse*Check** optics independently:

- to check if the autocorrelation signal exists only if both interferometer beams are unblocked, and vanishes if one of the beams is blocked
- to check if the contribution from both beams is approximately equal (i.e. approximately equal SHG background level from each interferometer beam in case of a collinear beam alignment).

Also refer to Paragraph 5.2.4 for the use of the beam shutters.

"View" Tab

Additional graphical options affecting the display of the measurement curve can be selected in the "View" tab:



Cursor: Set a check mark to show pairs of movable horizontal and vertical cursors. At half the distance between the two horizontal cursors an additional red horizontal line is displayed. The temporal separation between the two vertical cursors is displayed as a "Delta cursor" value in the info window.

Line graph: Set a check mark to connect the measurement points of the graph with lines.

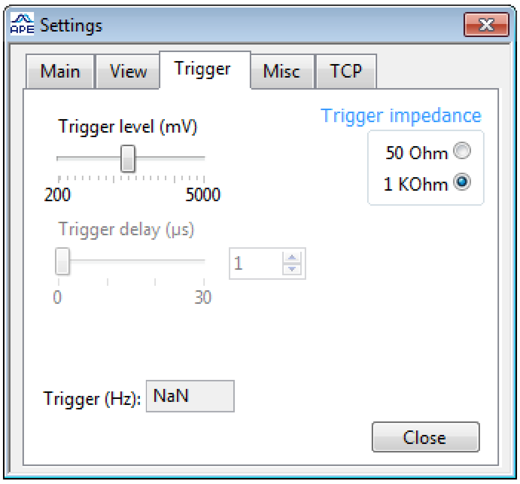
Dots: Set a check mark to highlight the measurement points of the graph as dots.

Filter ACF: Set a check mark to activate a filter function to suppress fringe or noise substructure on the autocorrelation function (refer to the "Filter" option in the "View" drop down menu of the menu bar). If measuring high contrast ACF ("Log on") with the logarithmic view on the low-pass filter is **deactivated** by the software!

Scan offset: This setting is active in combination with autocorrelators that have a 150 ps scan range. Instead of a delay screw the digital scan offset can be changed here to center the autocorrelation on the display if necessary.

"Trigger" Tab

In case the repetition rate of the laser to be measured is below 50 kHz the ***pulse*Link** has to be triggered with a synchronization signal with the same timing as the laser repetition rate in order to reconstruct a proper autocorrelation trace of the pulse train. The "Trigger" tab allows for setting electronic parameters to assure a proper application of the incoming trigger signal. **Note: Measuring with the logarithmic detector in triggered mode is not possible. High contrast measurements with the logarithmic detector can only be done with laser repetition rates higer than 100 kHz.**



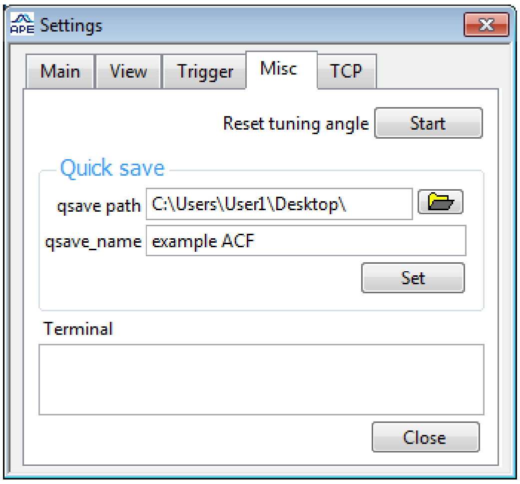
Trigger level (mV): The voltage level for the detection of an incoming trigger signal can be set. Change this value if a trigger signal is not recognized by the ***pulse*Link** . If possible the trigger level can be checked with an oscilloscope.

Trigger delay (μs): A temporal delay between the trigger pulse and the intensity measurement of the autocorrelator's detector can be set for proper synchronization. Changing this value may impare the strength of the signal dramatically if the trigger and pulse are not synchronized properly.

Trigger impedance (Ω): The appropriate input impedance for the trigger signal has to be set.

Frequency display: Display a frequency when a trigger input signal is recognized as valid. Use this to check for the expected trigger frequency. Adjust trigger level if necessary.

"Misc" Tab

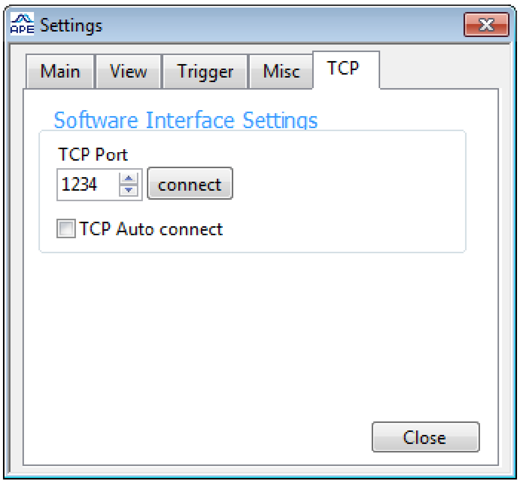


The "Reset tuning angle" option is only needed for a first setup of the ***pulse*Link** , after a system failure and if automatic tuning becomes imprecise.

Reset tuning angle: This procedure calibrates the crystal tuning motor position. During the calibration procedure the motor turns from its minimum position to its maximum position to recalibrate the position read out. Such a calibration becomes necessary if the memory of the motor position is lost, e.g., due to computer crash or at first installation of the system. It is also advisable to do this calibration procedure from time to time to ensure a proper wavelength calibrated crystal tuning. Press the "Start" button to start crystal calibration.

"TCP" Tab

For automatic or remote measurements via the A·P·E Software Interface the TCP/IP port has to be set in the TCP/IP tab:

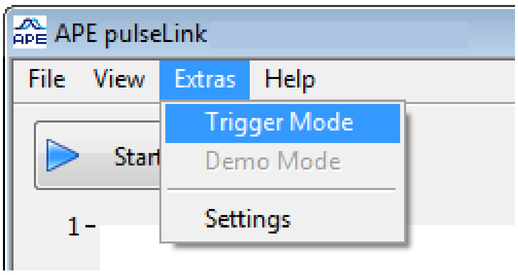


After setting a port number press “connect” for the ***pulse*Link** software to be ready to receive remote commands.
Important note: TCP/IP communication with the pulseLink is only possible via the software. The software must run on the local PC during remote communication. To avoid conflicts with standard TCP/IP ports (e.g. port 80 for HTTP) it is recommended to use port numbers between 50000 and 64000.

5.5. Triggered Measurement

Triggered measurement doesn’t apply to high contrast measurements with the logarithmic detector! For normal autocorrelation in trigerred mode using the linear detector please follow the steps below.

Apply a trigger signal to the ***pulse*Link** in case the repetition rate of the laser is between 10 Hz and 50 kHz . Use the delivered trigger cable to connect the ***pulse*Link** electronics ("TRIGGER IN" port) with the trigger source. The ***pulse*Link** software detects a trigger signal automatically and prompts the user to switch to trigger mode. If no trigger is detected try to change the trigger level to a lower value (see Section 5.4.3). For manually switching to trigger mode select EXTRAS > TRIGGER MODE from menu bar:



Open the "Trigger" tab in the settings menu and set the "Trigger level", the "Trigger delay", and the "Trigger impedance" to the appropriate values (refer to Paragraph 5.4.3). Use an oscilloscope to specify your trigger signal, if necessary. To optimize the ACF signal it may be necessary to adujst the trigger delay in the software. See Figure 5.17 for the correlation of the set trigger delay and the ACF intensity in the measurement window.

In trigger mode each trigger pulse initiates an SHG intensity measurement for the respective delay position. With increasing number of trigger pulses more and more data points are measured and form an autocorrelation trace.

In trigger mode the resolution can be changed (EXTRAS > SETTINGS > TRIGGER > RESOLUTION). A lower resolution gives a faster reconstruction of the autocorrelation trace, but is less accurate.

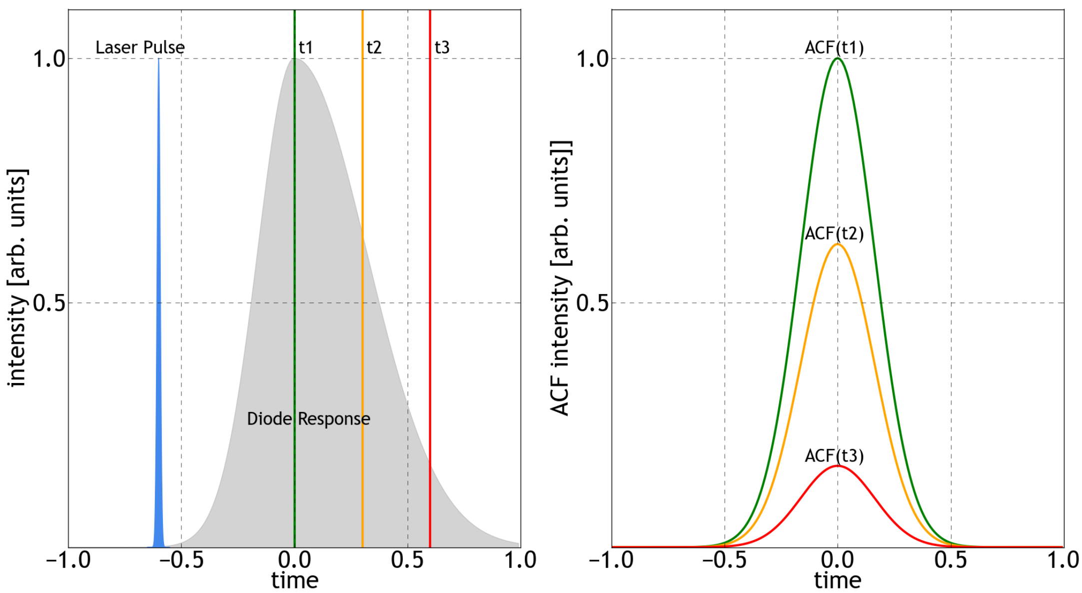


Figure 5.17.: Different trigger delays (t1-t3) will result in a different ACF intensitiy because of the point at which the detector is read out.

5.6. Changing the Trigger Frequency during Operation

If the trigger frequency of the laser (or other source) changes while in trigger mode a warning pops up to alert the user. The trigger mode automatically turns of. To measure with the changed trigger frequency one must switch trigger mode back on manually.

5.7. Error Sources of an Autocorrelation Measurement

The A·P·E ***pulse*Link** control software detects several error sources of the signal that could lead to imprecise evaluation of the laser pulse duration. If such a limitation of the measurement is detected the FWHM duration indicator in the info window is colored red and the critical parameter is displayed in the measurement details section in the lower left corner of the measurement window.
The following critical parameters are displayed if detected by the software:

- Scan range too small: If the chosen scan range is too small with respect to the detected width of the autocorrelation trace, a part of the measured autocorrelation might be clipped. The software needs to detect the whole ACF (i.e. maximum and minimum) to determine the FWHM of the SCF correctly. If the ACF is too broad for the scan range / measurement window the calculated FWHM value may be incorrect. Without a robust determination of the signal offset the evaluation of the half of maximum intensity to determine the FWHM value is not possible with the necessary precision (see Figure 5.18).

Action: Increase the scan range.

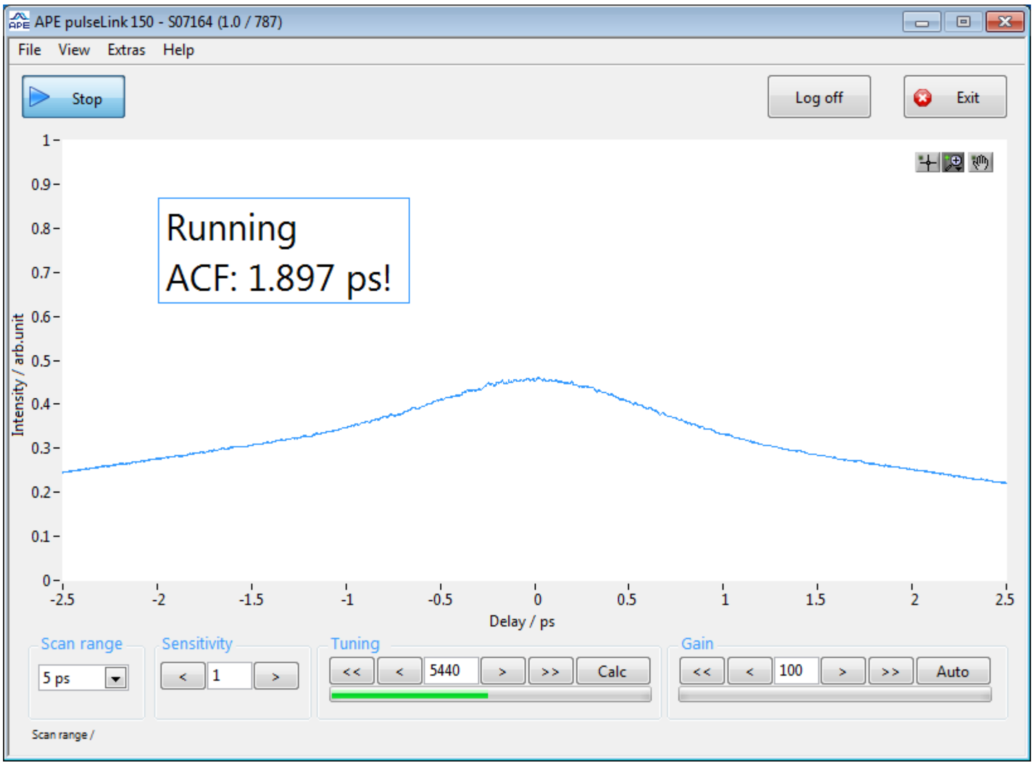


Figure 5.18.: The ACF indicator shows an exclamation mark and the info line shows a "Scan range/" error because the chosen scan range is too small for the detected width of the autocorrelation trace.

- Scan range too large: If the chosen scan range is too large with respect to the detected width of the autocorrelation trace, the data resolution is too low for a precise determination of the FWHM value (see Figure 5.19). Also this leads to an unnecessary high error of the FWHM value.

Action: Decrease the scan range.

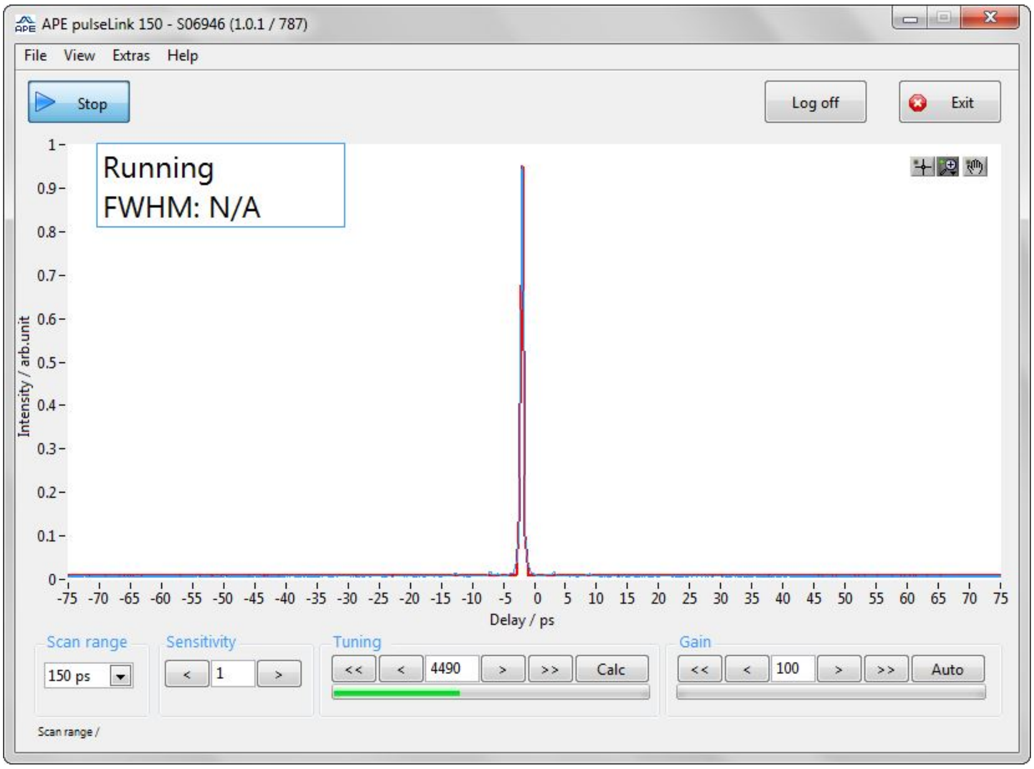


Figure 5.19.: The FWHM indicator shows N/A and the info line shows a "Scan range/" error to emphasize that the chosen scan range is too large for the detected width of the autocorrelation trace .

- Clipping: An intense autocorrelation signal can lead to detector overload which results in clipping of the measurement trace (see Figure 5.20).

Action: Decrease the gain, turn down the sensitivity or decrease the power of the input laser beam.

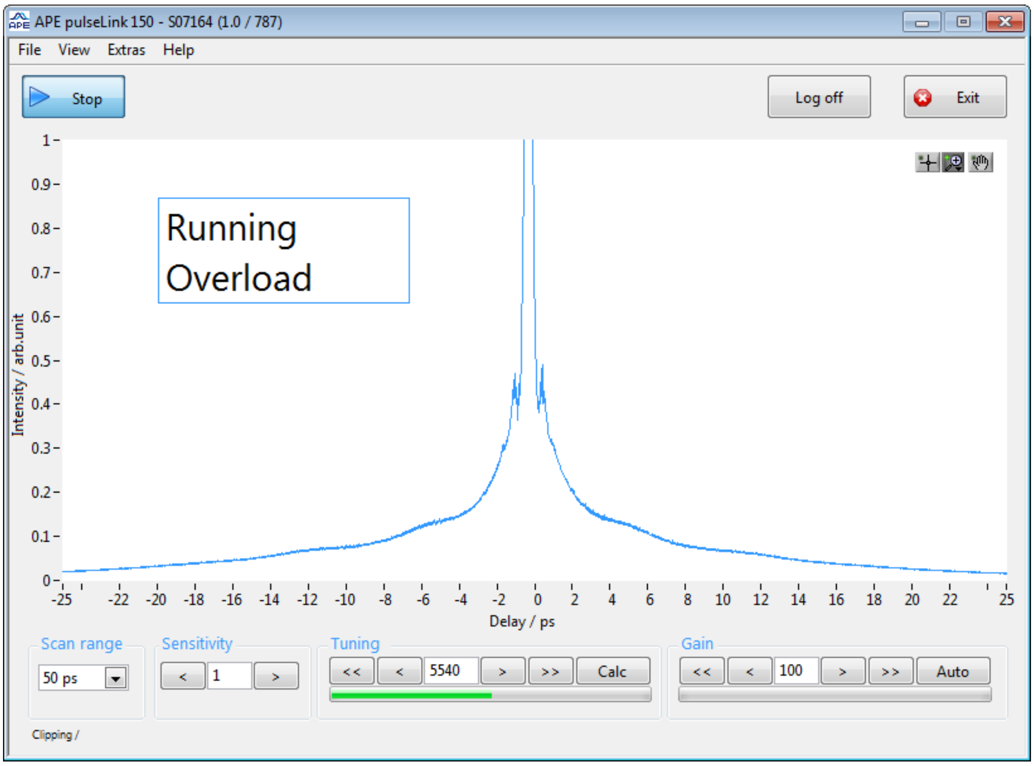


Figure 5.20.: The FWHM indicator is replaced by an "Overload" message and the info line shows a "Clipping/" error to emphasize that the intensity of the autocorrelation signal is too high.

- Low dynamic / low signal: A weak autocorrelation signal uses only a minor part of the given dynamic range. This can lead to an erroneous measurement of the FWHM value due to the low signal-noise ratio (see Figure 5.21).

Action: Increase the gain, the sensitivity, or the power of the input laser beam. Also check fo

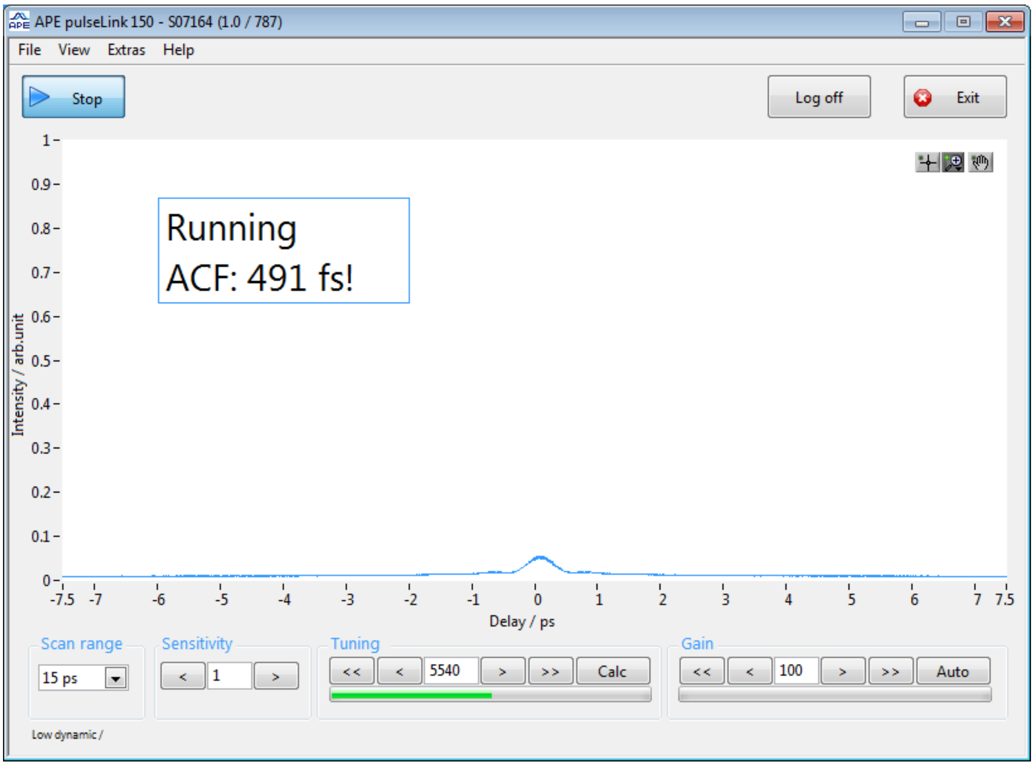


Figure 5.21.: The ACF indicator shows an exclamation mark and the info line shows a "Low dynamic/Low signal/" error to emphasize that the intensity of the autocorrelation signal is too weak.

- <u>Asymmetric signal:</u> An SHG autocorrelation function is always symmetric by definition. If the measured autocorrelation trace deviates too much from symmetry the info line shows an "asymmetric" error message (see Figure 5.22).

Action: Adjust the delay screw (*pulse*Check 15 and 50) or adjust EXTRAS > SETTINGS > VIEW > SCAN OFFSET (*pulse*Check 150) or optimize the beam alignment into the *pulse*Check optical head.

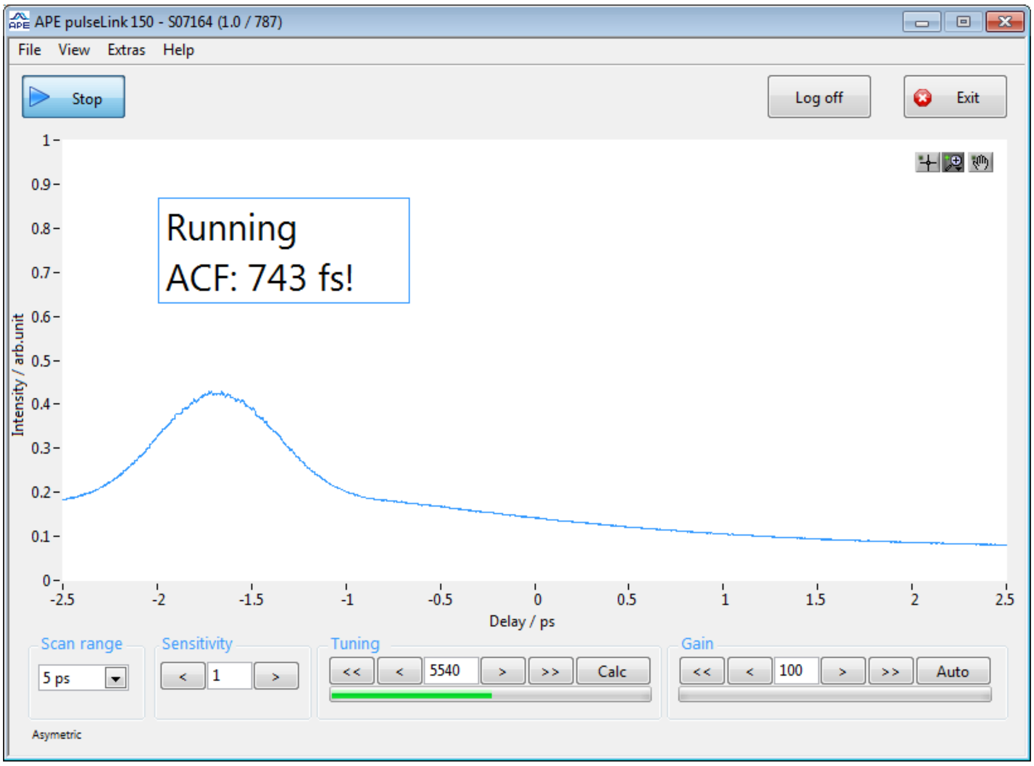


Figure 5.22.: Example of an asymmetric signal due to a large delay offset.

5.8. Troubleshooting

Error characteristics	Possible reason	Check and removal
No SHG Signal	wrong polarization direction	check with polarization rotator / wave plate; introduce a polarization rotator in the input beam
	wrong alignment	check beam position at input aperture; check "FOCUS" position; check phase matching
	no input pulses or pulses too long	check with an independent method (fast photodiode, spectral width etc.)
	input power too small	compare with sensitivity specifications
	delay zero position outside of scan range	check at wider scan ranges; check and correct for delay "zero" position (see test report)
No clear ACF	wrong scan range	check at wider scan ranges
	no input pulses or pulses too long	check with an independent method (fast photodiode, spectral width etc.)
SHG Signal w / o ACF peak	wrong alignment of beam on detector	check with shutters (i.e. if the signal level reacts to each of the shutters); realign input beam in horizontal direction only
	wrong "FOCUS" position	check and correct for "FOCUS" position
	Delay zero position outside of scan range	check at wider scan ranges; check and correct for delay "0" position (see test report)

6. Important Additional Hints

6.1. "Zero" Scan

In "Zero" scan the delay drive is stopped at the zero position. The zero position is the position of the retro reflectors where there is no delay between the pulses in the interferometer. Thus this is the position of the highest intensity of the ACF.

6.2. Low Pass Filter

This switchable filter suppresses high frequency noise from the detector. For the measurement in triggered mode or for high contrast measurements with the logarithmic detector ("Log on") the filter is automatically switched off.

6.3. Signal Level

The sensitivity range is very wide in order to adapt the autocorrelator to different power input levels. This might cause a high noise level at high gain and a loss of linearity at low gain because of the PMTs physics in particular. Therefore it is advisable to adapt the input level to an operation with moderate gain values for most exact measurements. The operation in triggered mode with very short pulses at low repetition rates is most critical. In this case, the detector can be overloaded at high input levels with low gain causing a suppression of the ACF peak. To prevent this it is strictly recommended to operate this regime with photodiode (PD) detectors only.

6.4. Rotation of the Plane of Polarization

The required laser input polarization of the ***pulse*Check** autocorrelator is 45°. Thus the ***pulse*Check** high contrast comes with a half wave plate that is factory set rotate a horizontally or vertically polarized beam to 45°.

6.4.1. Rotation with $\lambda/2$-Plate Polarization Rotator

The required laser input polarization of the ***pulse*Check** autocorrelator is 45°. Thus the ***pulse*Check** high contrast comes with a half wave plate that is factory set rotate a horizontally (0°) or vertically (90°) polarized beam to 45°. By positioning a $\lambda/2$ plate in the input beam and tilting the plate by an angle of α the polarization is rotated by 2α. The effect of polarization rotation can be very wavelength sensitive. Thus the provided half wave plate is designed to operate optimaly in the specified wavelength range of the ***pulse*Check** high contrast. Typically it is not necessary to adjust the tilt of the provided wave plate.

7. Maintenance

7.1. Cleaning

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

Use a soft lint-free dry or only slightly moist cloth to clean the covers of the ***pulse*Check USB** components.

Use dry methanol and lens cleaning tissue applying common optics cleaning techniques for cleaning the input mirror.

7.2. Storage of SHG Crystal

The SHG crystals are slightly hygroscopic. Store crystals that are not in use in an airtight box along with silica gel. If you do not use the autocorrelator for a long time it is recommended to remove the crystal (see Paragraph 3.6.1 for removal / mounting of the SHG crystal) from the ***pulse*Check** optical head and to store it in an airtight box along with silica gel.

7.3. Technical Support

For technical questions or problems within Germany, please contact:

A·P·E Angewandte Physik & Elektronik GmbH
Plauener Straße 163 - 165, Haus N
D - 13053 Berlin
tel +49 30 98601130
fax +49 30 986011333
service@ape-berlin.de
http://www.ape-berlin.com

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

http://www.ape-berlin.com

A. TCP/IP Command Set

This section provides a complete overview of the remote control commands of the ***pulse*****Check USB** . The command structure of the ***pulse*****Check USB** is mostly in agreement with the SCPI-standard. However, A·P·E does not state compliance nor conformance to the standard, since some standard commands are not yet implemented in the present version. Detailed information about the SCPI is found at: www.ivifoundation.org

For comprehensive usage and code examples in familiar programming languages such as C++, C#, LabVIEW, Python, Matlab, and Ruby, please go to our webpage:

http://www.ape-berlin.de/en/software-interface-tcpip/

IMPORTANT NOTE:
In order to remotly control the *pulse*Link the *pulse*Link sotware must run and a TCP/IP port must be set in the software. Do not attempt to send TCP/IP commands to the controller via USB!

The autocorrelator will execute the following commands:

***IDN?**

Get Device Identification

<idn> string
Device Information (APE GmbH, Devicename, Serialnumber, Software Version, Firmware Version)

Example:
```
*IDN?
```

***RST**

Perform Device Reset

Example:
```
*RST
```

***STB?**

Get Status Byte
<stb> integer
SCPI Status Byte (8 Bit unsigned as decimal) Bit0: reserved Bit1: reserved Bit2: Error Bit3: reserved Bit4: MAV Bit5: ESB Bit6: RSQ/MSS Bit7: OPE

Example:

```
*STB?
```

***CLS**

Clear Status Byte (STB)

Example:

```
*CLS
```

***ESE<value>**

Set Event Status Enable Register
<value> integer, range: 0 ... 255
ESE Register Value

Example:

```
*ESE=127
```

***ESE?**

Get Event Status Enable Register
<value> integer, range: 0 ... 255
ESE Register Value

Example:

```
*ESE?
```

***SRE<value>**

Set Service Request Enable Register
<value> integer, range: 0 ... 255
SRE Register Value

Example:

```
*SRE=127
```

***SRE?**

Get Service Request Enable Register
<value> integer, range: 0 ... 255
SRE Register Value

Example:

```
*SRE?
```

***ESR?**

Get Event Status Register
<value> integer, range: 0 ... 255
ESE Register Value

Example:

```
*ESR?
```

***OPC?**

Get Operation Complete Status
<status> integer, range: 0 ... 255
OPC Stats Value (always "1", since multi-command interface is not available)

Example:

```
*OPC?
```

***OPER?**

Get Operation Status
<oper> integer
SCPI Opertation Status (16 Bit unsigned as decimal) Bit0: Disconnected, Bit1: VISA Connected, Bit2: Device Initialized, Bit3: Device ready, Bit4: Device busy, Bit5: Standby (Delaymotor off), Bit6: Data Error (AFC not valid), Bit7: Software Error, Bit8: Firmware Error (see *FRMW?), Bit9: Shutdown, Bit10: Service Mode active, Bit11: unused, Bit12: unused, Bit13: unused, Bit14: unused, Bit15: unused

Example:

```
*OPER?
```

***INIT?**

Get Device Initialization Status
<init> integer
SCPI INIT Status (8 Bit unsigned as decimal, upper 4 Bits are always "1") Bit0: unused, forced to "0", Bit1: unused, forced to "0", Bit2: Link Initialization OK, Bit3: Optic Initialization OK, Bit4: unused, forced to "1", Bit5: unused, forced to "1", Bit6: unused, forced to "1", Bit7: unused, forced to "1"

Example:
```
*INIT?
```

***BUSY?**

Get Device Busy Status
<busy> integer
SCPI BUSY Status (8 Bit unsigned as decimal, upper 4 Bits are always "0") Bit0: IDLE, Bit1: New data available, Bit2: Measurement running, Bit3: Curvefit running, Bit4: unused, Bit5: unused, Bit6: unused, Bit7: unused

Example:
```
*BUSY?
```

***ERR?**

Get Data Error Status
<errs> integer
SCPI DATA ERROR Status (8 Bit unsigned as decimal, Bit 7 is always "0") Bit0: Signal too low, Bit1: Signal too high, Bit2: No Peak found, Bit3: ACF is asymmetric, Bit4: Dynamic range too low, Bit5: Scanrange too low, Bit6: Negative offset, Bit7: unused

Example:
```
*ERR?
```

***FRMW?**

Get Firmware Status
<frmw> integer
SCPI Firmware Error Status (16 Bit unsigned as decimal, Bit12..15 are always "0") Bit0: Parser Error, Bit1: Parameter Error, Bit2: FRAM Error, Bit3: I2C-0 Error, Bit4: I2C-0 Error, Bit5: I2C Locked, Bit6: Configuration Error, Bit7: Optics Error, Bit8: Buffer Overflow, Bit9: DMA Error, Bit10: USB Error, Bit11: Data Timeout, Bit12: unused, Bit13: unused, Bit14: unused, Bit15: unused

Example:
```
*FRMW?
```

SYSTEM:DEVICE?
SYS:DEVICE?

Get Device Name
<name> string
Device Name

Example:
```
:system:device?
```

SYSTEM:SNUMBER?
SYS:SNUMBER?

Get Device Serial number
<snr> string
Device Serial Number (S00000 - S99999)

Example:
```
:system:snumber?
```

SYSTEM:SOFTWARE?
SYS:SOFTWARE?

Get Software Version
<version> string
Software Version

Example:
```
:system:software?
```

SYSTEM:HARDWARE?
SYS:HARDWARE?

Get Hardware Version
<version> string
Hardware Version

Example:
```
:system:hardware?
```

SYSTEM:FIRMWARE?
SYS:FIRMWARE?

Get Firmware Version
<version> string
Firmware Version

Example:

```
:system:firmware?
```

SYSTEM:MOTOR?
SYS:MOTOR?

Get Motor Type
<version> string
Motor Type

Example:

```
:system:motor?
```

STATUS:AVERAGE<number>

Set numer of measurements used for averaging
<number> integer, range: 0 ... 4
Number of Measurements 0: Averaging OFF, 1: 2 Measurements, 2: 4 Measurements, 3: 8 Measurements, 4: 16 Measurements

Example:

```
:status:average=1
```

STATUS:AVERAGE?

Get numer of measurements used for averaging
<number> integer, range: 0 ... 4
Number of Measurements 0: Averaging OFF, 1: 2 Measurements, 2: 4 Measurements, 3: 8 Measurements, 4: 16 Measurements

Example:

```
:status:average?
```

STATUS:RESOLUTION<setting>

Set numer of data points used for averaging
<setting> string
Number of samples used 0/200/very low, 1/500/low, 2/1000/medium, 3/1500/high, 4/2000/very high

Example:

```
:status:resolution=1
```

STATUS:RESOLUTION?

Get numer of data point used for averaging

<setting> string

Number of samples used 0/200/very low, 1/500/low, 2/1000/medium, 3/1500/high, 4/2000/very high

Example:

```
:status:resolution?
```

STATUS:FITTYPE<type>

Set type of curve fit to apply to measured ACF

<type> integer, range: 0 ... 3

Fittype 0/OFF/NONE: No Curvefitting performed, 1/GAUSSIAN: Fit Gaussian Model, 2/SECH2: Fit Sech2 Model, 3/LORENTZ: Fit Lorentz Model

Example:

```
:status:fittype=1
```

STATUS:FITTYPE?

Get type of calculated curve-fit

<type> integer, range: 0 ... 3

Fittype 0: No Curvefit performed, 1: Gaussian Model, 2: Sech2 Model, 3: Lorentz Model

Example:

```
:status:fittype?
```

STATUS:START?

Status of Measurement

<status> string

Status of measurement (1 = Measurement running, 0 = Measurement paused)

Example:

```
:status:start?
```

STATUS:FILTER<status>

Set Status of ACF Filtering
<status> string

Example:
```
:status:filter=1
```

STATUS:FILTER?

Get Status of ACF Filtering
<status> string
Status of ACF filtering (1 = filter active, 0 = filter not active)

Example:
```
:status:filter?
```

MOTOR:SCANRANGE<scanrange>
MOTOR:SCR<scanrange>

Set ScanRange
<scanrange> integer, unit: fs
Scanrange (Device configuration dependent) 0: Zeroscan, 150: 150 fs, 500: 500 fs, 1500: 1.5 ps, 5000: 5 ps, 15000: 15 ps, 50000: 50 ps, 150000: 150 ps

Example:
```
:motor:scanrange=15000
```

MOTOR:SCANRANGE?
MOTOR:SCR?

Get ScanRange
<scanrange> integer, unit: fs
Scanrange (Device configuration dependent) 0: Zeroscan, 150: 150 fs, 500: 500 fs, 1500: 1.5 ps, 5000: 5 ps, 15000: 15 ps, 50000: 50 ps, 150000: 150 ps

Example:
```
:motor:scanrange?
```

DETECTOR:GAIN<value>

Set Gain value
<value> integer, range: 300 ... 1000
Gain Value

Example:

```
:detector:gain=450
```

DETECTOR:GAIN?

Get Gain value
<value> integer, range: 300 ... 1000
Gain Value

Example:

```
:detector:gain?
```

DETECTOR:AUTOGAIN<number>
DETECTOR:AUG<number>

Activate Autogain Feature
<number> integer
Status of autogain feature

Example:

```
:detector:autogain=1
```

DETECTOR:AUTOGAIN?
DETECTOR:AUG?

Get Autogain status (0=OFF, 1=ON)
<number> integer
Status of autogain feature

Example:

```
:detector:autogain?
```

DETECTOR:SENSITIVITY<number>
DETECTOR:SEN<number>

Set Sensitivity
<number> integer
Detector Sensitivity 1: Low Sensitivity, 10: High Sensitivity, 100: (optional "HighSen"-Feature)

Example:

```
:detector:sensitivity=10
```

DETECTOR:SENSITIVITY?
DETECTOR:SEN?

Get Sensitivity
<number> integer
Detector Sensitivity 1: Low Sensitivity, 10: High Sensitivity, 100: (optional "HighSen"-Feature)

Example:
```
:detector:sensitivity?
```

TRIGGER:LEVEL?
TRIGGER:LVL?

Get Trigger Level
<level> integer, unit: mV, range: 200 ... 5000
Trigger Level

Example:
```
:trigger:level?
```

TRIGGER:DELAY?
TRIGGER:DEL?

Get Trigger Delay
<level> integer, unit: us, range: 1 ... 50
Trigger Delay

Example:
```
:trigger:delay?
```

TRIGGER:FREQUENCY?
TRIGGER:FRQ?

Get Trigger Frequency
<level> integer, unit: Hz
Trigger Frequency

Example:
```
:trigger:frequency?
```

TRIGGER:IMPEDANCE?
TRIGGER:IMP?

Get Trigger Impedance
<level> integer, unit: Ohms
Trigger Impedance

Example:

```
:trigger:impedance?
```

ACF:DATA?

Get ACF Data (raw, unfiltered data)

<acf> array of s in block data format

ACF Data as binary Block (little-endian byte order); The returned data holds an interleaved array of Double (IEEE754) Values with the following scheme [y0,x0,y1,x1,...,yN,xN], x = Delay (ps), y = Intensity (a.u.) | Please note: the binary Data must be unpacked before it can be used. Please also see our example codes for more info about that.

Example:

```
:acf:data?
```

ACF:DISPLAYED_ACF?
ACF:DACF?

Get ACF Data as shown on the applications graph control (with applied filter, AVG, etc.)

<dacf> array of s in block data format

Displayed ACF Data as binary Block (little-endian byte order); The returned data holds an interleaved array of Double (IEEE754) Values with the following scheme [y0,x0,y1,x1,...,yN,xN], x = Delay (ps), y = Intensity (a.u.) | Please note: the binary Data must be unpacked before it can be used. Please also see our example codes for more info about that.

Example:

```
:acf:displayed_acf?
```

ACF:MEANDATA?

Get ACF Mean Data

<mean> string

Mean Values separated by semicolons: "[AVG];[Xmax];[Xmin];[Ymax];[Ymin]"

Example:

```
:acf:meandata?
```

ACF:FWHM?

Get FWHM Value
<fwhm> double
FWHM Value

Example:
```
:acf:fwhm?
```

ACF:FITFWHM?

Get fitted FWHM Value
<fwhm> integer
Fitted FWHM Value

Example:
```
:acf:fitfwhm?
```

SHUTTER:FIX<parameter>

Set fix-shutter position
<parameter> boolean
Shutter position, 1=open, 0=close

Example:
```
:shutter:fix=0
```

SHUTTER:FIX?

Get fix-shutter position
<parameter> boolean
Shutter position, 1=open, 0=close

Example:
```
:shutter:fix?
```

SHUTTER:SCAN<parameter>

Set scan-shutter position
<parameter> boolean
Shutter position, 1=open, 0=close

Example:
```
:shutter:scan=0
```

SHUTTER:SCAN?

Get scan-shutter position
<parameter> boolean
Shutter position, 1=open, 0=close

Example:

```
:shutter:scan?
```

XTAL:TUNING<parameter>
XTAL:TUN<parameter>

Set crystal tuning position
<parameter> integer, range: 500 ... 11000
Crystal position

Example:

```
:xtal:tuning=5000
```

XTAL:TUNING?
XTAL:TUN?

Get crystal tuning position
<parameter> integer, range: 500 ... 11000
Crystal position

Example:

```
:xtal:tuning?
```

XTAL:LAMBDATUNE<parameter>
XTAL:LTU<parameter>

Set crystal tuning in nm
<parameter> integer
Crystal target position in nm

Example:

```
:xtal:lambdatune=800
```

XTAL:LAMBDATUNE?
XTAL:LTU?

Get crystal tuning position
<parameter> integer
Crystal position in a.u.

Example:

```
:xtal:lambdatune?
```

XTAL:MOVE?
XTAL:MOV?

Get status of crystal motor

<number> integer

crystal motor status (1 - motor running, 0 - motor stopped)

Example:

```
:xtal:mov?
```

XTAL:SETXTAL?
XTAL:SEX?

Get crystal type

<parameter> string

XTAl Type

Example:

```
:xtal:setxtal?
```

B. Fitting Functions

B.1. Gaussian

The following functions are are only valid for the normal ACF measurement mode with the linear PD detector.
The mathematical description for a gaussian pulse is:

$$G(t) = e^{-t^2} \tag{B.1}$$

The autocorrelation of this pulse is given by the solution of the convolution integral

$$G_{ACF}(\tau) = \int_{-\infty}^{\infty} G(t)G(t-\tau)dt = \sqrt{\frac{\pi}{2}} e^{\frac{-\tau^2}{2}} \tag{B.2}$$

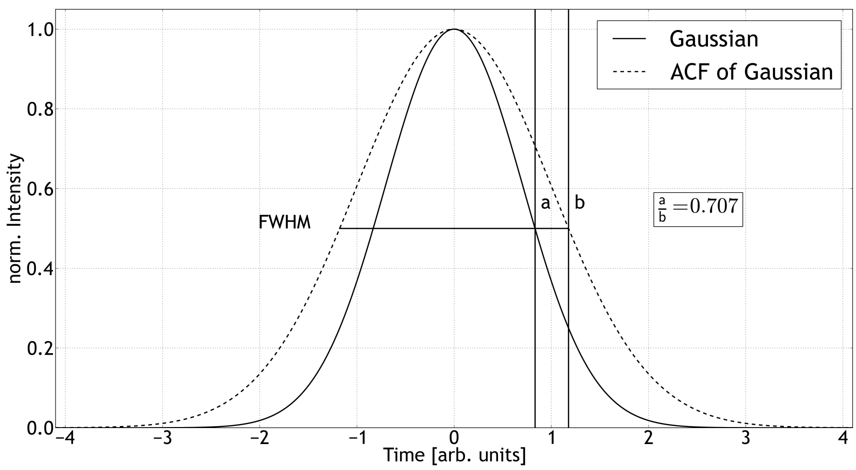


Figure B.1.: Gaussian function e^{-t^2} and its normalized autocorrelation $e^{\frac{-\tau^2}{2}}$ (dotted line)

Equating the normalized gaussian functions with $\frac{1}{2}$ gives the time value at half amplitude.

$$G(a) = \frac{1}{2} \qquad \Rightarrow a = \sqrt{\ln(2)} \tag{B.3}$$

$$G_{ACF}(b)\sqrt{\frac{2}{\pi}} = \frac{1}{2} \qquad \Rightarrow b = \sqrt{2\ln(2)} \tag{B.4}$$

The quotient of this time values supplies the transformation factor between the pulse width and the FWHM value of its autocorrelation function.

$$\frac{a}{b} = \frac{\sqrt{\ln(2)}}{\sqrt{2\ln(2)}} = 0.71 \tag{B.5}$$

B.2. Lorentzian

The mathematical description for a lorentzian pulse is:

$$L(t) = \frac{1}{1+t^2} \tag{B.6}$$

The autocorrelation of this pulse is given by the solution of the folding integral

$$L_{ACF}(\tau) = \int_{-\infty}^{\infty} L(t)L(t-\tau)dt = \frac{2\pi}{4+\tau^2} \tag{B.7}$$

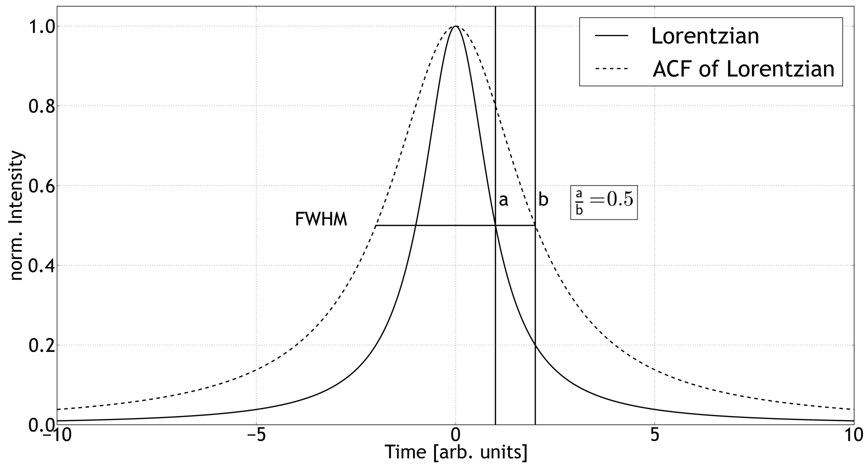


Figure B.2.: Lorentzian function $\frac{1}{1+t^2}$ and its normalized autocorrelation $\frac{4}{4+\tau^2}$ (dotted line)

Equating the normalized gaussian functions with $\frac{1}{2}$ gives the time value at half amplitude.

$$L(a) = \frac{1}{2} \qquad \Rightarrow a = 1 \tag{B.8}$$

$$L_{ACF}(b)\frac{2}{\pi} = \frac{1}{2} \qquad \Rightarrow b = 2 \tag{B.9}$$

The quotient of this time values supplies the transformation factor between the pulse width and the FWHM value of its autocorrelation function.

$$\frac{a}{b} = 0.5 \tag{B.10}$$

B.3. sech^2

The autocorrelation of the $S(t) = \text{sech}(t)^2$ pulse is given by the solution of its folding integral

$$S_{ACF}(\tau) = \int_{-\infty}^{\infty} S(t)S(t-\tau)dt = 4\text{csch}(\tau)^3(\tau\cosh(\tau) - \sinh(\tau)) \tag{B.11}$$

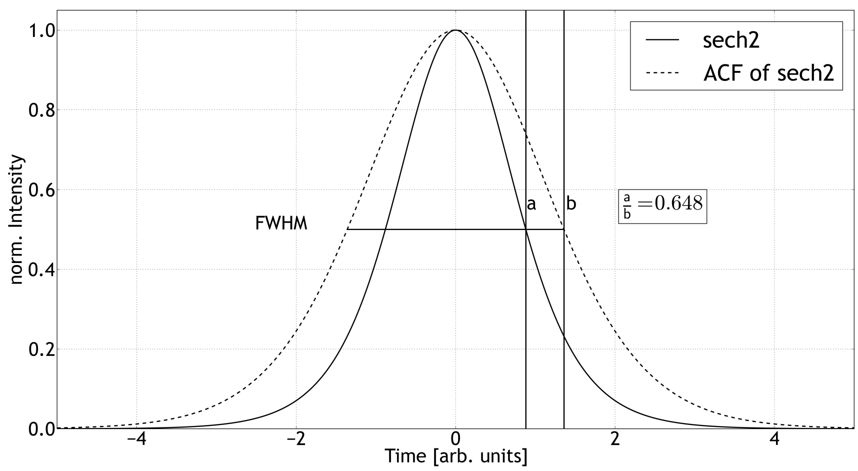


Figure B.3.: The function $\text{sech}(t)^2$ and its normalized autocorrelation $3\text{csch}(\tau)^3(\tau\cosh(\tau) - \sinh(\tau))$ (dotted line)

Equating the normalized functions with $\frac{1}{2}$ gives the time value at half amplitude.

$$S(a) = \frac{1}{2} \qquad \Rightarrow a = 0.881374 \tag{B.12}$$

$$L_{ACF}(b)\frac{3}{4} = \frac{1}{2} \qquad \Rightarrow b = 1.35979 \tag{B.13}$$

The quotient of this time values supplies the transformation factor between the pulse width and the FWHM value of its autocorrelation function.

$$\frac{a}{b} = 0.648 \tag{B.14}$$

C. Declaration of Conformity

We declare that the accompanying product, identified with the CE mark, complies with requirements of the Electromagnetic Compatibility Directive, 2004/108/EC dated December 15, 2004 and the Low Voltage Directive 2006/95/EC dated December 12, 2006.

Product name: ***pulse*Check Type II**
Product options: **all options**

CE mark affixed: Berlin, December 3, 2014

Type of Equipment: Electrical equipment for measurement, control and laboratory use in industrial locations.

Manufacturer: A·P·E Angewandte Physik & Elektronik GmbH Berlin
Plauener Straße 163-165
13053 Berlin, Germany

Standards Applied:
Compliance was demonstrated to the following standards to the extent applicable: BS EN 61010-1:2010, "Safety requirements for electrical equipment for measurement, control and laboratory use"
EN 55011 radio interference voltage class A
DIN EN 61000-4-2:2009
DIN EN 61000-4-3:2011
DIN EN 61000-4-4:2010
DIN EN 61000-4-5:2007
DIN EN 61000-4-6:2009
DIN EN 61000-4-8:2010
DIN EN 61000-4-11:2005

Name (printed): Dr. Bodo Richter
Title: CEO

Telephone: +49 30 98601130
Email: ape@ape-berlin.de

D. **Declaration of Conformity to EU RoHS**

A·P·E Angewandte Physik & Elektronik GmbH
Plauener Str. 163 – 165 | Haus N
13053 Berlin
Germany

Declaration of Conformity to EU RoHS

Products listed below that are manufactured by A·P·E Angewandte Physik & Elektronik GmbH are in compliance with Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 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 A·P·E 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	**Maximum Limit (ppm)**
Lead (Pb)	1000
Cadmium (Cd)	100
Mercury (Hg)	1000
Hexavalent Chromium (Cr6+)	1000
Poly Brominated Biphenyls (PBB)	1000
Poly Brominated Diphenyl ethers (PBDE)	1000

Product name: ***pulse*Check Type II**
Product options: **all options**

Signature:

Name (printed): Dr. Bodo Richter
Title: CEO Telephone: +49 30 98601130
Email: ape@ape-berlin.de