

# *PulseScout2* Autocorrelator



**PScout2 Series User's Manual**

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## 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:** *PulseScout2*

**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.

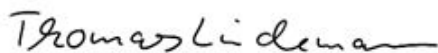
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Plauener Straße 163-165  
13053 Berlin, Germany

**Importer:** Newport Corporation  
1791 Deere Avenue  
Irvine, CA 92606  
United States of America

## 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



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## Declaration of Conformity to EU RoHS

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## Declaration of Conformity to EU RoHS

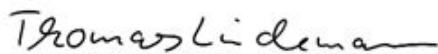
Products listed below that are manufactured by A·P·E Angewandte Physik & Elektronik GmbH are in compliance with Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (also 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 Identification:  
Product

Autocorrelator *PulseScout2* Base and detector modules

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**IMPORTANT - READ CAREFULLY BEFORE USE - KEEP FOR FUTURE REFERENCE** This user manual contains user information for the *PulseScout2* . Read this manual carefully before operating the *PulseScout2* , particularly Section 1 on safety instructions. The *PulseScout2* 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**

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## 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.

### Disposal

The *PulseScout2* 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.

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## 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 (see Appendix for CE Certificate).

### 1.1. Optical Safety



Since the *PulseScout2* 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. 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.



## 1. Safety Instructions

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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 safe 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 *PulseScout2* 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 used. It is only allowed to run the *PulseScout2* with the delivered power supply.



Use only the *PulseScout2* 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 *PulseScout2* controller housing. Opening the housing is only allowed for trained service personnel. 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 3.5.2 on page 20 to exchange the detector unit. In this case, 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 *PulseScout2* autocorrelator system with the (EMC) requirements are certified by the CE mark (see Appendix for CE Certificate).

## 2. Description and Specifications

### 2.1. Description and Intended Use

The **PulseScout2** 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 installed on an optical table or a similar stable vibration-free base.

The autocorrelator **PulseScout2** is based on the principle of intensity autocorrelation. It consists of three components:

1. **PulseScout2** optical head
2. **scoutLink** controller
3. Control Software

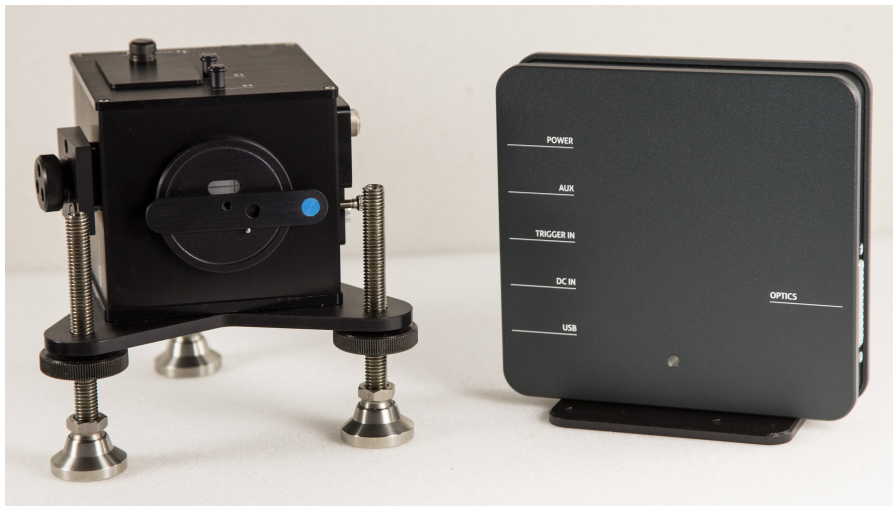


Figure 2.1.: **PulseScout2** optical head (left) and **scoutLink** Controller Unit (right)

The Control Software is operated on a computer with Microsoft Windows operating system (the computer is not included in the delivery).

The Controller Unit comprises the necessary drivers, amplifiers and power supply for the optical head. The Controller Unit itself is powered by an external power supply and acts as interlink between the optical head and a computer. Figure 2.1 shows the **PulseScout2** optical head and the **scoutLink** Unit. User interaction and control of the system is performed at the computer through the **scoutLink** Software.

2.2. Specifications

2.2.1. Optical Parameters

Base unit	<b>PSCOUT2-BASE</b>			
Wavelength range	420 - 1600 nm			
	<b>PSCOUT2-BLUE-PD</b>	<b>PSCOUT2-RED-PD</b>	<b>PSCOUT2-NIR-PD</b>	<b>PSCOUT2-IR-PD</b>
Wavelength range	420 - 550 nm	520 - 750 nm	700 - 1100 nm	1100 - 1600 nm
	<b>PSCOUT2-BLUE-PMT</b>	<b>PSCOUT2-RED-PMT</b>	<b>PSCOUT2-NIR-PMT</b>	<b>PSCOUT2-IR-PMT</b>
Wavelength range	420 - 550 nm	520 - 750 nm	700 - 1100 nm	1100 - 1600 nm
Suggested detector type	Depending on laser repetition rate: PD < 1 MHz and PMT > 1 MHz repetition rate			
Scan range	150 fs - 15 ps (150 fs, 500 fs, 1.5 ps, 5 ps, 15 ps)			
Measureable pulse width	20 - 3500 fs (selectable ranges)			
<b>For all detector types</b>				
Min. input power	> 2 mW			
Max. input power	< 250 mW or < 1 $\mu$ J (which ever results in the lower average power)			
Repetition rate of input laser	300 Hz to 10 GHz, PMT detector suggested above 1 MHz			
Linearity	1 % of actual scan range			
Polarization	Linear / horizontal			
Beam characteristics	diameter > 2 mm $1/e^2$			
PC interface	USB 2.0			
Remote control	TCP/IP (SCPI Standard) via Control Software			
Trigger Input	level 0.1 ... 5 Vrms 50 $\Omega$ 0.1 ... 8 Vpp 1 k $\Omega$ impedance 50 $\Omega$ / 1 k $\Omega$ repetition rate 300 Hz ... 50 kHz width > 50 ns			
Dimensions	see Figures 2.2 & 2.3			

Table 2.1.: Specifications

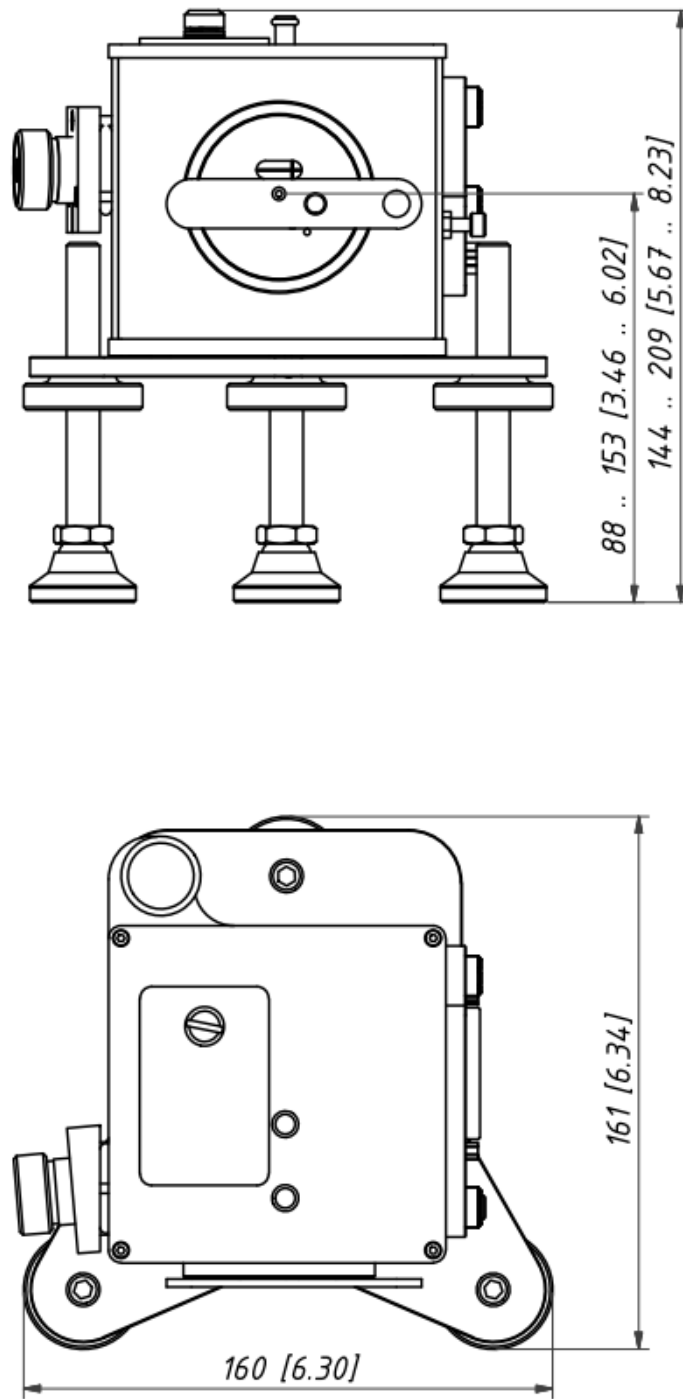


Figure 2.2.: Optical head outline drawing, front and top view in mm [inch]

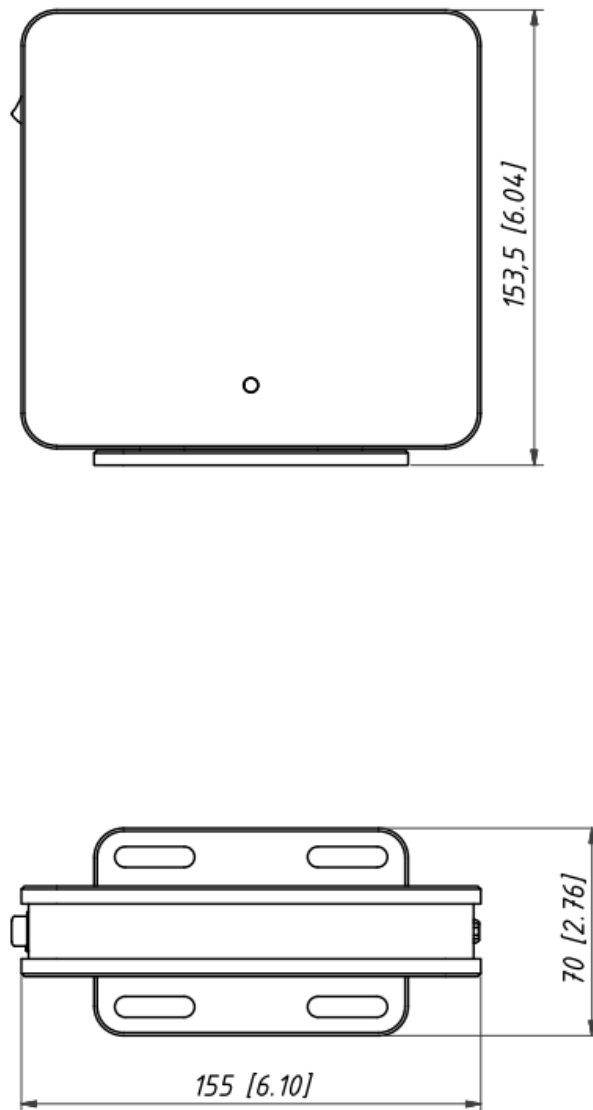


Figure 2.3.: Controller outline drawing, front and top view in mm [inch]

### 2.3. Requirements to the Control Computer

Minimum system requirements:

- Windows 7 <sup>1</sup>
- 500MB hard disc space
- Pentium IV or equivalent processor
- 2 GB of RAM
- USB port
- Screen resolution of 1024 x 768 pixels

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<sup>1</sup>Windows is a registered trademark of Microsoft Corporation in the United States and other countries.



The *PulseScout2* is intended for indoor operation, in dry and dust reduced rooms. It has to be firmly installed on an optical table or on a similar solid, vibration-free board.

Ambient conditions must be observed during transportation, storage, installation and operation. Ensure reasonable transport conditions, free of major shocks, jolt or fall; protect against frost. Use original packing material for relocation. Allow at least six hours for acclimatization of all components before operating the device.

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. Contents of Delivery

**PulseScout2** base unit - consisting of:

- **scoutLink** controller
- **PulseScout2** optical head
- 12-V DC power supply
- USB cable type "A-B"
- Trigger input cable
- 25-pin D-Sub connection cable for the optical head
- USB Flash Drive, including installation software
- Certificate of Calibration
- **PulseScout2** user manual

**PulseScout2** detector module incl. crystal (packed separately)

#### 3.2. Inspection on Receiving

On receipt of the **PulseScout2** autocorrelator system:

1. Inspect the packing material 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.
  - Inform your **PulseScout2** vendor immediately.
2. Use safe lifting practices.
3. Allow at least six hours for acclimatization of all components before unpacking and operating the device.
4. Unpack the **PulseScout2** system.
5. It is suggested to retain the packaging for future use.



3.3. System Controls and Indicators



Figure 3.1.: *PulseScout2* optical head - beam distance screw and detector module (left), focus position screw (middle), shutter buttons S1, S2 and crystal mount cover (right)

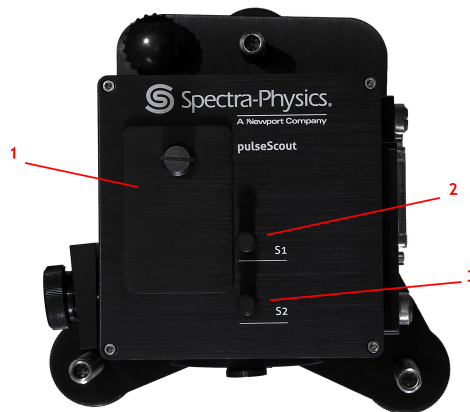


- |   |            |   |
|---|------------|---|
| 1 | POWER      | power switch  |
| 2 | AUX        | auxiliary connector (not used)                        |
| 3 | TRIGGER IN | trigger input   |
| 4 | DC IN      | DC power connector (connect to 12-V DC power adapter) |
| 5 | USB        | USB connector (connect to PC)                         |
| 6 | Status LED |   |
| 7 | OPTICS     | 25-pin D-Sub connector (connect to optical head)      |

Figure 3.2.: *scoutLink* controls and connectors

The *scoutLink* has a status LED that indicates its condition as listed in the table below:

LED status	<i>scoutLink</i> condition / status
OFF	<i>scoutLink</i> off
RED	Hardware selftest after powering on (approx. 1...2 sec)
RED (blinking)	Optical head not connected or wrong optical head
YELLOW	<i>scoutLink</i> 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)



- 1 Crystal mount cover
- 2 Beam shutter S1
- 3 Beam shutter S2

Figure 3.3.: *PulseScout2* optical head - beam shutters and crystal mount cover

#### 3.4. Installation of the *scoutLink* Control Software



**Important:** Before connecting and turning on the *scoutLink* please follow the instructions below to install the software first.

The *PulseScout2* is controlled via the *scoutLink* Controller Unit. Hence the first step before using the *PulseScout2* autocorrelator is to install the included *scoutLink* Control Software on your system. For requirements to the computer refer to Section 2.3 on page 14.

Proceed as follows:

1. Insert the USB Flash Drive that was included with your *PulseScout2* into the USB port of your computer.
2. Navigate to the Flash Drive and start the "setup.exe" via the Windows Explorer.
3. Follow the instructions during installation of the software. Note: After installation of the Control Software is automatically prompted to install the appropriate font.

#### 3.5. Installation of the Optical Head

You will need at least one detector module incl. crystal to use the *PulseScout2* for autocorrelation measurements. If you have purchased more than one detector module make sure that the one fitting your laser wavelength range is mounted. If the suitable detector module is not already mounted, install the desired detector module as described below in the Paragraphs 3.5.1 "Mounting / Exchange of the SHG Crystal" and 3.5.2 "Exchange of the Detector Unit". Upon delivery the SHG crystal is packed separately and must be installed in any case before starting the first measurement.

##### 3.5.1. Mounting / Exchange of the SHG Crystal

Upon delivery there is no crystal installed in the optical head of the *PulseScout2*. It comes in a separate box to protect it from damage and has to be installed before using the *PulseScout2* for the first time. Please note that you will need to order at least one detector module in addition to the base unit in order for the *PulseScout2* to work. As the measurable wavelength range depends on the choice of crystal it may also be necessary to exchange the crystal module at a later time in order to adapt the measurement range to your needs.

To install or exchange the crystal module proceed as follows:



**Caution!** A laser beam 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.

1. Block or switch off the laser beam.
2. Switch off controller.
3. Remove the thumb screw and pull open the lid (see Figure 3.4 on page 19).
4. In order to exchange the crystal module, pull it out (as the crystal module is delivered in a separate box, this is not necessary if the crystal module is mounted for the first time).
5. Insert new crystal module (see Figure 3.5 on page 20).
6. Close crystal lid.
7. Turn on controller.



Figure 3.4.: Base unit without top cover. With mounted crystal (left) and without crystal (right)



Figure 3.5.: Crystal module

#### 3.5.2. Exchange of the Detector Unit

Please note that you will need at least one detector module additionally to the *PulseScout2* base unit in order to make successful measurements. The detector module is not mounted upon delivery and must thus be installed before using the *PulseScout2* autocorrelator. In order to do so, please remove all packaging and follow the instructions below.

If you have purchased more than one detector module, make sure that the correct detector unit is installed. It must match the laser repetition rate. If in doubt, check with the list of available detector modules (See also Table 2.1 on page 12). Change the detector unit, if necessary, according to the instructions in this paragraph.



**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 incident laser beam.
2. Switch OFF the *scoutLink* controller and disconnect it from the power supply.
3. Detach the 25-pin D-Sub cable from the optical head
4. Remove the detector unit by loosening the two thumb screws (see Figure 3.6 on page 21).
5. Insert the new detector into the autocorrelator and fasten both thumb screws.
6. Reconnect the power supply and turn on the controller.

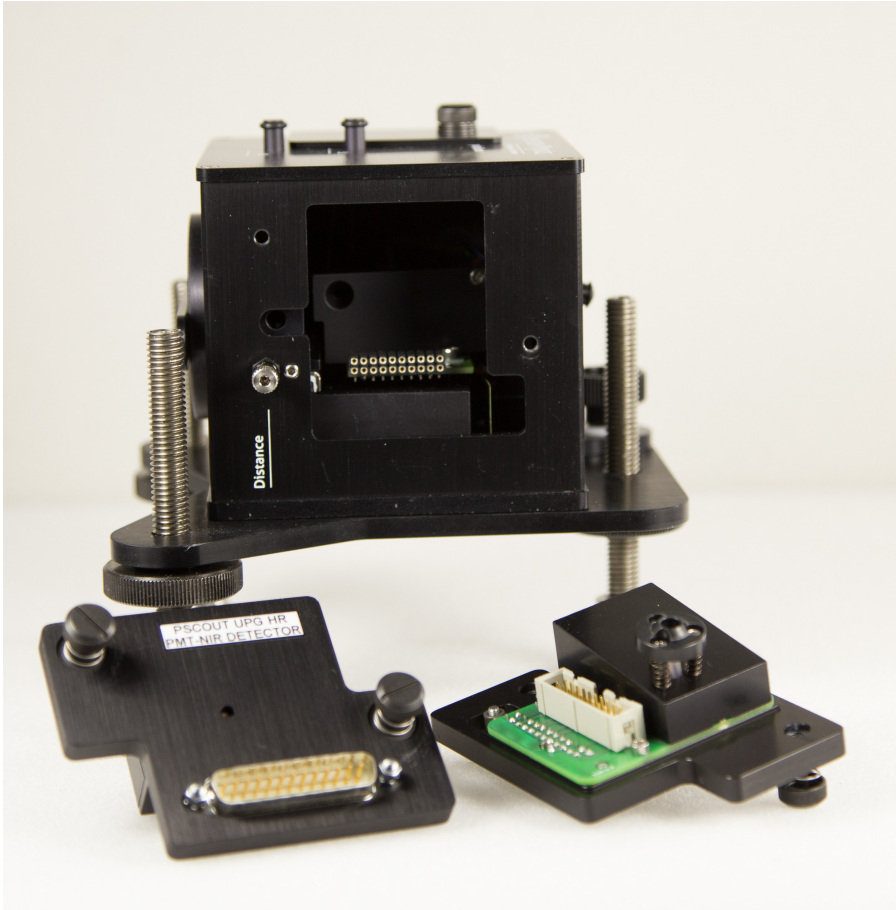


Figure 3.6.: *PulseScout2* Optical head with removed detector (front and back view)

#### 3.6. Cable Connection

1. Connect the *PulseScout2* optical head with the *scoutLink* controller ("OPTICS" port) using the supplied 25-pin D-Sub connection cable. **Always use the original cable!**
2. Connect the *scoutLink* controller ("USB" port) with your computer using the supplied USB cable.
3. Connect the supplied AC/DC power adapter with the *scoutLink* controller ("DC IN" port) and the power outlet.

## 4. Alignment and Measurement

After having connected all components of the system and installed the *scoutLink* 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 easily direct the laser beam nearly perpendicularly into the alignment aperture and handle the control elements. Ensure that the computer screen with the *scoutLink* Control Software can be seen from the position of the alignment.
2. Turn the system on by operating the power switch on the *scoutLink* controller.

### 4.1. Communication Setup

After starting the *scoutLink* Control Software it automatically tries to initiate a connection to the *scoutLink* controller. A communication between the software and the *PulseScout2* has been established when the serial number of the unit is shown in the window title.

If communication is established the info window displays the status "ACF: 0 fs" in the upper left corner of the measurement window (see Figure 4.1 (left)).

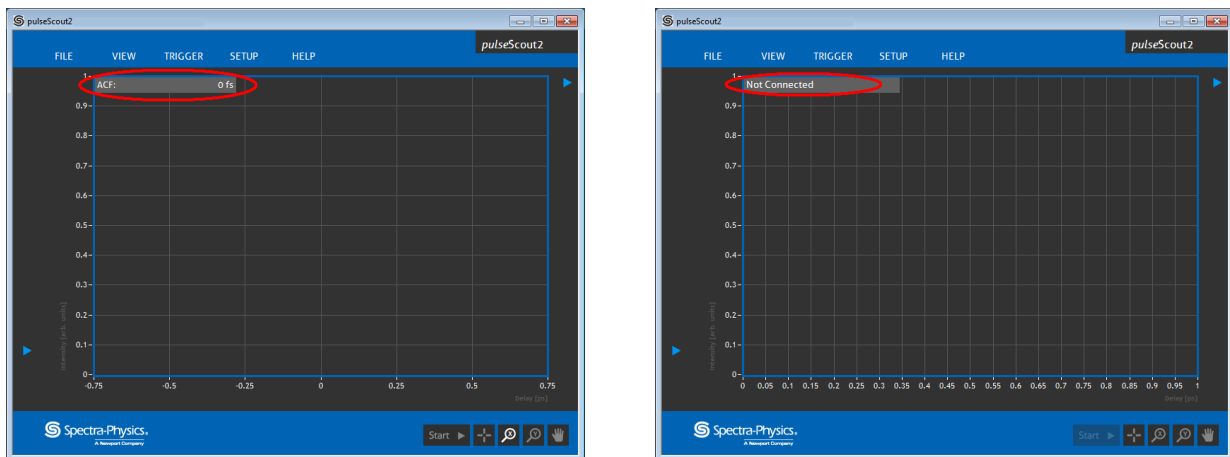


Figure 4.1.: Control Software start up window with established connection (left), and with failed connection (right)

If the *scoutLink* is not properly connected or the initialization has failed the info window shows the status "Not connected" (see Figure 4.1 (right)). In this case check the cable connections and make sure the *scoutLink* is switched ON. If this is the case, try again to initiate communication to the *scoutLink* controller by switching it off and back on again. Before you proceed with the next steps, the communication must be established and the status "ACF: 0 fs" must be displayed in the info window. If a connection cannot be established after following these steps repeatedly please refer to Section 6.1 on page 43 for troubleshooting.

## 4.2. Starting a Measurement

### 4.2.1. Alignment of the Input Beam

Set the variable alignment aperture to alignment position (see Figure 4.2). Align the input beam, using two optical elements (glass plate, mirror, etc.) through the aperture into the optical head while maintaining normal incident between the *PulseScout2* and the input beam. It is very important that the beam is parallel to the optical table and perpendicular to the input aperture of the *PulseScout2* optical head. The better these conditions are met the easier it is to adjust the optical head in the following steps. Ensure that the input beam power is below the maximum input power for the *PulseScout2* (see Table 2.1 on page 12 for specifications), and that the polarization of the input beam is horizontal and nearly collimated.

Although the sensitivity is much higher, for most configurations the average input power can be up to 250 mW without danger of damaging the system. However, if it is not stated explicitly for your device, be careful when using configurations for low repetition rates and high energy laser (amplifier) systems! For such configurations it is strongly recommended to keep the input pulse energy below 1  $\mu\text{J}$  to avoid damage of the autocorrelator. Once an autocorrelation signal is found the input power should always be lowered while maintaining a sufficient autocorrelation signal on the *scoutLink* Control Software.



Figure 4.2.: Alignment aperture (arrow) in alignment position and in normal measurement position.

The beam should enter through the input aperture of the autocorrelator nearly perpendicularly to the unit.

For ease of alignment, ensure that the beam distance is set to the non-collinear position and that the height of the optical head is adjusted parallel to the optical table.

Align the input beam through the alignment aperture to achieve a beam position similar to the one shown in Figure 4.3, non-collinear mode. Both beam reflections should be at the same height and the right reflection should be aligned onto the cross-hair within the alignment window.

Tweaking the optical assembly in the horizontal plane will move the back reflection in the horizontal plane and tilting the optical assembly up or down with the third leg will move the back reflection up or down.

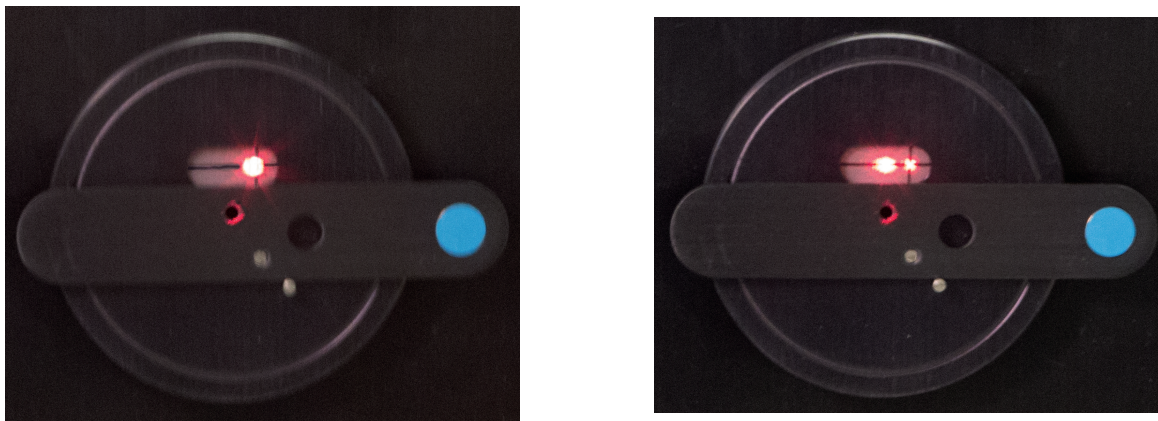


Figure 4.3.: View of alignment window in collinear and non-collinear mode (visible laser used for demonstration purpose).



Figure 4.4.: *PulseScout2* optical head right side view with beam distance screw

The beam distance, once the two reflections are aligned properly, can be changed to the collinear mode in order to maximize the autocorrelation signal on the Control Software. The autocorrelation signal will increase while changing from non-collinear to collinear mode.

If one has trouble finding the autocorrelation trace, turn the screw (see Figure 4.4) all the way in for collinear operation (see Figure 4.3). In collinear mode, a signal increase from the autocorrelator can be seen if the crystal is aligned at the proper angle, even if the two replica beams do not overlap temporally. Hence, due to the fewer variables involved, it is best to use the collinear configuration to begin with the optimization of the autocorrelation trace.

Once the optical assembly is coarsely aligned, it should be fixed to the table with the provided foot clamps.

Adjust the input beam in horizontal and vertical position in order to increase the autocorrelation signal in comparison to the background signal. The variable alignment aperture can now be moved into the measurement position (see Figure 4.2 on page 23).



### 4.2.2. Finding the Autocorrelation Trace

With the **scoutLink** turned on and the software connected press the "Start" button in the Control Software. A flat horizontal line over the whole screen should be displayed. It represents the signal detected by the detector module. If no signal is present the flat line is comprised only of background noise.

It is recommended to set the highest scan range ("SETUP" → Scan Range) to make sure to see even temporarily offset signals. Next, gradually increase "Sensitivity" ("SETUP" → Sensitivity) until either a clear signal or noise is observed. If the autocorrelator is responding to room or ambient light (this is especially true for devices with photomultiplier [PMT] detectors), dim the lights or block off the source of external light from the autocorrelator. Rotate the crystal using the "Tuning" arrows ("SETUP" → Tuning) to find the optimal phase-matching angle (refer to Section 4.2.3 on page 26 for more details on tuning and phase-matching). Note that the actual angular value of the crystal is shown between the tuning arrows in arbitrary units. If the maximum or minimum limit of the angle is reached such that the number displayed is no longer changing, reverse the tuning direction and turn the crystal to the opposite end in order to find the ACF signal. An optimal phase-matching is characterized by a clear, angle dependent signal maximum as depicted in Figure 4.6 on page 26.

At this point it is important to note that many laser sources (such as OPOs) may have a small portion of second harmonic light coincident with the fundamental laser pulse aligned to the **PulseScout2**, and this small amount of light may overlay the, in comparison weaker, second harmonic signal that is generated by the crystal inside the autocorrelator. To avoid this introduce a long pass filter into the laser beam such that the fundamental wavelength is transmitted and wavelengths close to the second harmonic are blocked.

If the autocorrelation signal extends beyond the intensity scale off the measurement screen ("Overload" appears on the screen), decrease "Sensitivity" and/or decrease the laser input power. Be aware that using neutral density (ND) filters to decrease laser power also temporally broadens the laser pulses (by dispersion) and thus may alter the measurement. The pulse broadening depends on the ND substrate material, the wavelength and the pulse width itself. Therefore a good practice is to take the reflection of a glass plate to reduce laser power without broadening the laser pulse.

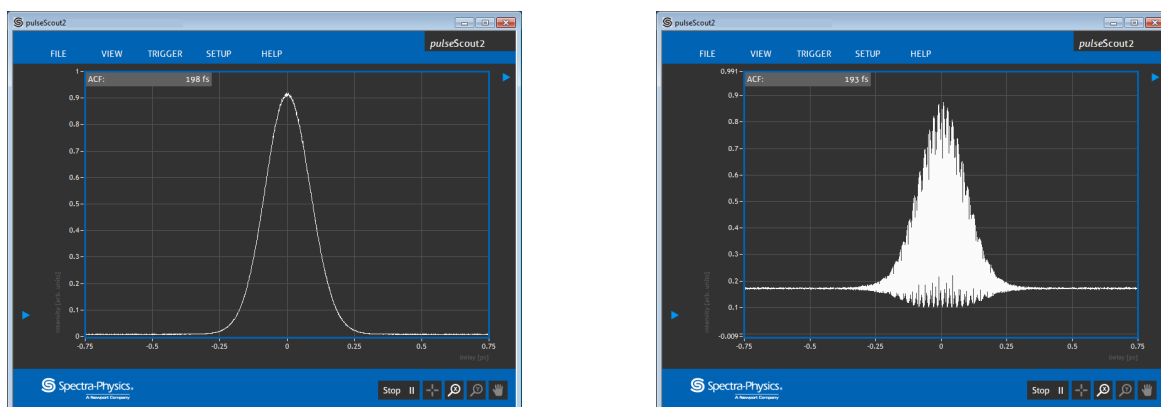


Figure 4.5.: Example of a good autocorrelation function (ACF) in the collinear mode (left) and non-collinear mode (right)

To check the autocorrelation signal, block one of the beams of the Michelson interferometer inside the autocorrelator by pushing the shutter knobs S1 and S2 on top of the **PulseScout2** (see Figure 3.3 on page 18). Blocking either beam individually will eliminate the signal originating from the interaction of the two beams (ACF) by half (collinear setting).

Finally optimize the peak and the peak-to-background ratio of the autocorrelation signal through adjustment of the crystal angle (see Section 4.2.3 on page 26 Crystal Angle Tuning and Phase-

matching), the focus position (see Figure 3.1 on page 17), the scan range ("SETUP" → Scan Range) and the low pass filter ("VIEW" → Filter):

- First set the Scan Range to a value approximately 3 to 5 times higher than the ACF width and make sure that the ACF drops to its minimum to the left and to the right of the maximum intensity.
- Next turn the focus screw in or out to maximize the ACF intensity. Change the crystal angle slightly to increase the intensity even more.
- Repeat the last two steps until no further improvement is possible.
- Finally, if the ACF signal is still noisy turn on the low pass filter ("VIEW" → Filter) to clear the signal.

If after the steps described above no angle dependent ACF signal is found, check that there are no other wavelengths (i.e. the second harmonic of the present beam) entering the autocorrelator by inserting a long pass filter into the beam. More importantly, recheck the alignment (see Section 4.2.1 on page 23) and make sure there is a back reflection at the cross hair. Also make sure that the input polarization is horizontal, and that the laser is mode-locked. For more help and tips refer to Section 6.1 Troubleshooting on page 43.

#### 4.2.3. Crystal Angle Tuning and Phase-matching

"Tuning" ("SETUP" → Tuning) refers to the process of adjusting the angle of the crystal with respect to the laser beam. The aim is to achieve phase-matching and hence to generate the second harmonic that is necessary for the detector to register a signal. If no autocorrelation signal is detected (i.e. because the crystal has been exchanged or the wavelength changed) the phase-matching angle must be readjusted manually.

In order to do this, use the arrow buttons in the "SETUP" menu next to "Tuning". Maximize the autocorrelation signal by tuning left or right.

**It is very important to only conduct measurements when the crystal is in the 0th order phase-matching angle.**

So that you can be sure that this is the case tune the crystal away from the point where the detector records the maximum intensity and observe the display. If none or smaller maxima appear on the display the previous crystal tune setting, which showed the highest intensity maximum, corresponds to the 0th order phase-matching angle.

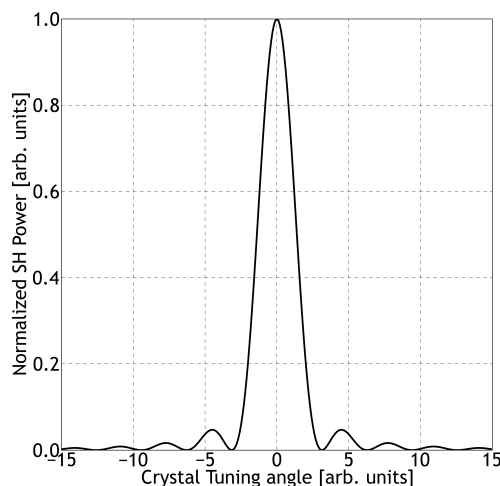


Figure 4.6.: Example ACF intensity behavior as a function of crystal angle. The highest intensity (0th order) occurs at 0 degrees deviation from the ideal phase-matching angle.

#### 4.2.4. Zero Scan Range

The ZERO SCAN function ("SETUP" → Scan Range → Zero) stops the delay at the zero position, i.e. the pulses in both interferometer arms travel the same, fixed, not periodically changing distance. On the measurement screen the signal becomes a flat line. Then SHG intensity is displayed as a function of time. Now the signal is similar to an oscilloscope. It is thereby possible to observe amplitude modulations and thus it is sometimes easier to adjust the autocorrelator to maximize the ACF.

#### 4.2.5. Further Alignment Optimization: Beam Shutters

A good beam alignment may be verified using the internal beam shutters. To do so the *PulseScout2* has two shutters activated by push buttons on top of the device (see Figure 3.3 on page 18). First close either of the shutters by pushing the corresponding button down. The background signal should go down to half intensity (provided you have set the "BEAM DISTANCE" screw to the collinear position). Repeat this step with the other shutter where the signal drop should be the same. If both shutters are closed simultaneously, the signal should go down to almost zero (only the background noise of the detector is visible). A sketch of the expected behavior is shown in Figure 4.7 on page 27. If the signal does not decrease by nearly the same amount check the horizontal beam alignment, the focusing and the crystal phase-matching angle.

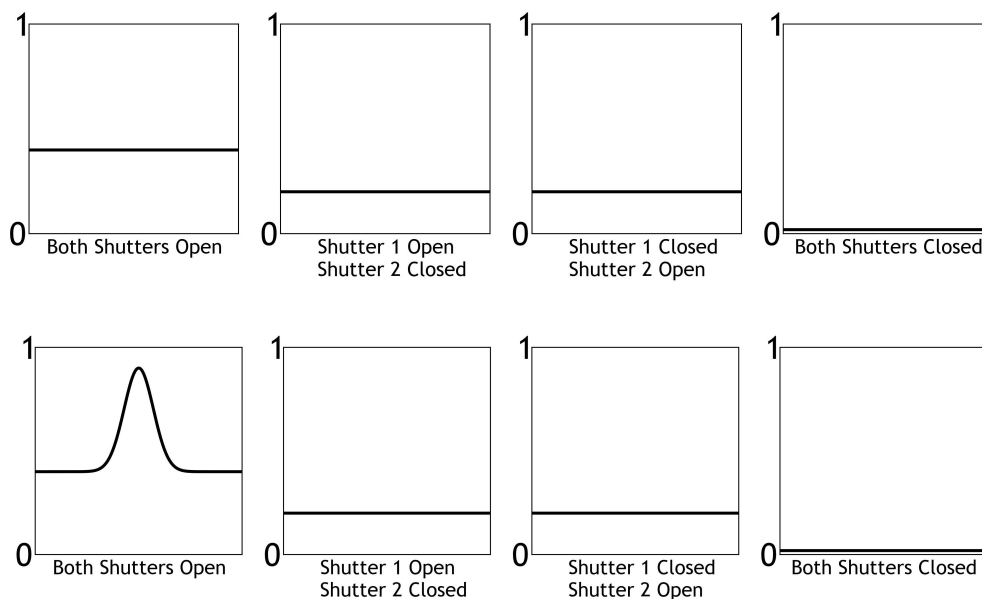


Figure 4.7.: Shutter functions with and without autocorrelation function

Also select the largest possible "scan range" (SETUP → Scan Range) in the Control Software to make sure that the ACF is not off the zero delay position and therefore not visible in a small scan range. The autocorrelation function should be visible. Maximize the autocorrelation signal with the "Sensitivity" arrows. Reduce either the sensitivity or gain settings in case of an overload condition, indicated by the software. Reduce the optical input power, in case the "overload" condition persists, until the error message disappears.

When you now operate the beam shutters the signal should behave as shown in Figure 4.7.

### 4.2.6. Background-Free (Non-Collinear) Autocorrelation

The interaction types collinear and background-free (non-collinear) can be selected by turning the "BEAM DISTANCE" screw at the optical head to the appropriate position. The beam distance of the interacting beams from the two interferometer arms can be changed between 0... 6 mm (observable at the alignment window next to the input aperture - the moving spot has to be at the left side of the fix spot). After changing the beam distance also the focusing, the sensitivity, and the phase-matching angle should be optimized again. For convenience, it is recommended to proceed in small steps, so that the ACF never disappears entirely. For a comparison between a collinear and non-collinear ACF refer to Figure 4.5 on page 25.

### 4.3. Measurement and Display Configuration in Detail

In this section the Control Software and its menus giving access to the control options are explained. Figure 4.1 on page 22 shows the measurement window of the A·P·E *scoutLink* Control Software that is displayed when you initially start the software (in this particular case with no *PulseScout2* optical head connected).

#### 4.3.1. "FILE" Submenu

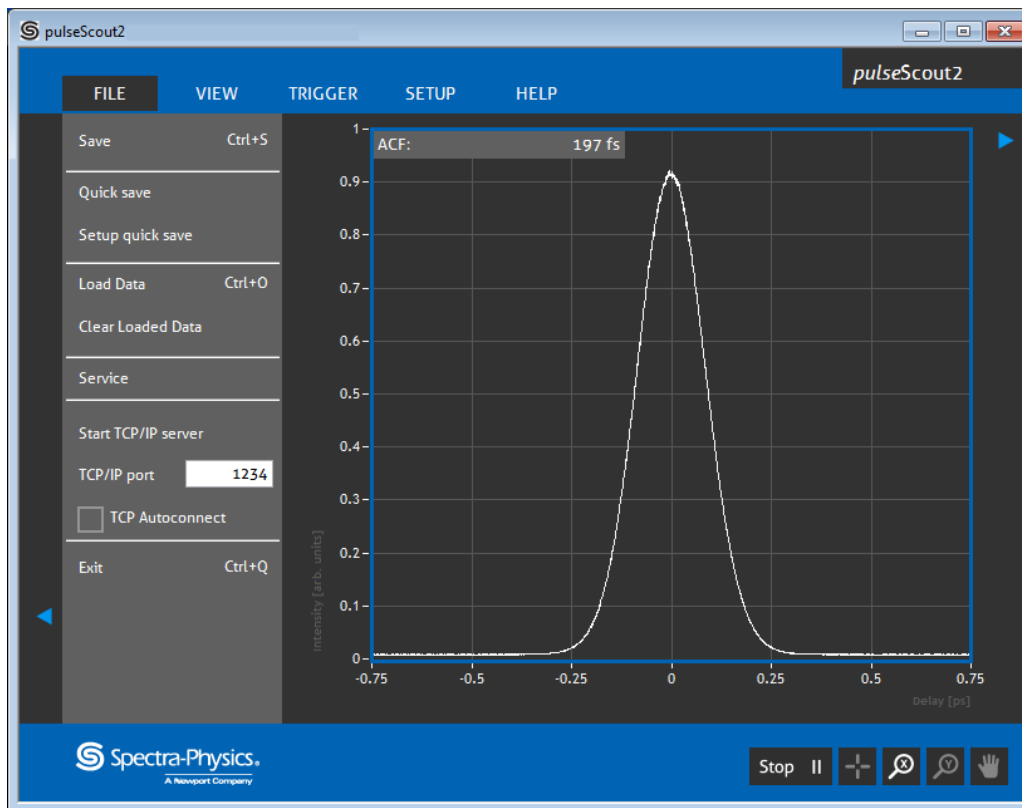


Figure 4.8.: File submenu

"Save": Opens a file dialog and allows to choose a file name and location to save the current autocorrelation trace displayed in the measurement window.

"Quick save": A file name is automatically generated (containing time and data) and the raw autocorrelation trace is saved to the user defined folder.

"Setup quick save": Chooses a default file name and location for the "Quick save" function.

"Load Data": Loads and displays previously made autocorrelation traces. The loaded trace is shown simultaneously with the current measurement for comparison and is highlighted in another color.

"Clear Loaded Data": Clears loaded data from the measurement window.

"Service" : The service menu contains advanced settings and is not available to the user.

"Start TCP/IP server": Starts the background server to control and read out the *scoutLink* remotely via TCP/IP. Note that TCP/IP communication may be restricted by your IT policy! Please contact your local administrator if necessary. For further information on commands and details to remote control the *scoutLink* refer to Appendix B on page 51.

"TCP/IP port": Selects the TCP/IP port on which the *scoutLink* server listens for commands.

"TCP Autoconnect" Checkbox: Check this box for an automatic server initialization at program start up.

"Exit": Closes the Control Software.

#### 4.3.2. "VIEW" Submenu

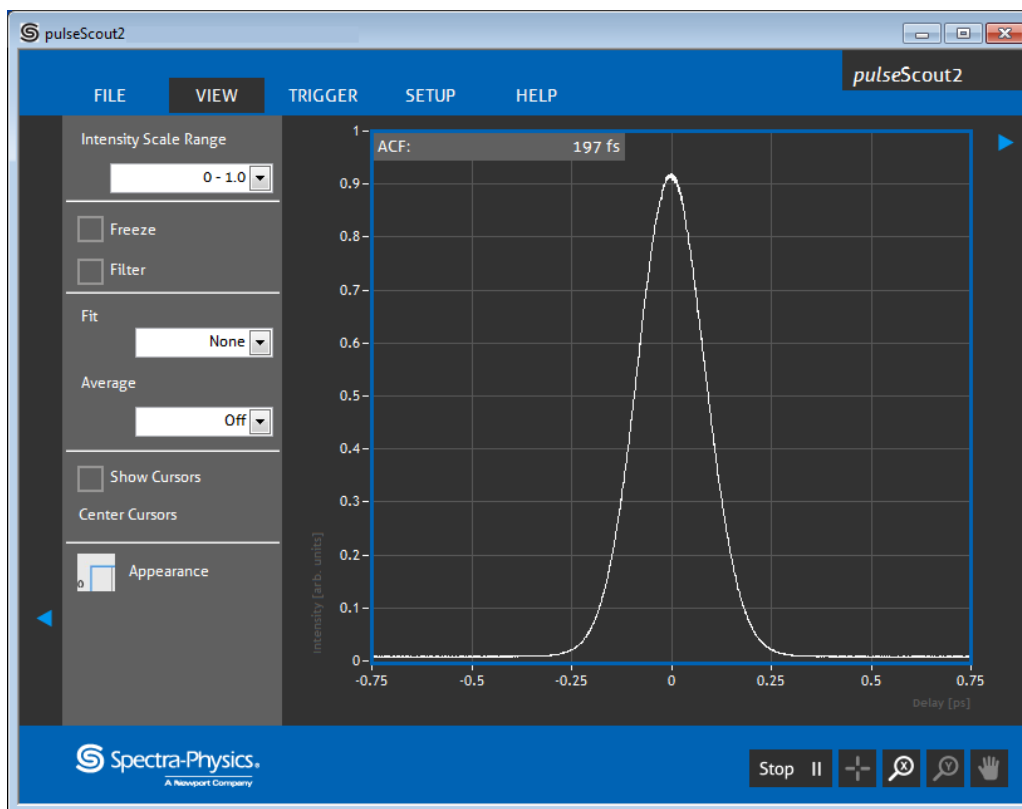


Figure 4.9.: View submenu

"Intensity Scale Range": Allows to choose the scaling of the y-axis ("Intensity") from a set of pre-defined ranges and to auto.

"Freeze" Checkbox: Check the box to freeze the currently displayed autocorrelation trace. Note: while the display is frozen the measurement is still running in the background.

"Filter" Checkbox: Check the box to activate the low pass filter to reduce noise on the autocorrelation trace. For more details refer to Section 5.2 on page 41.

"Fit": Choose between "None" or three different types of fit functions applied to the autocorrelation trace. In case of choosing a fitting function the Info box shows additional information such as the FWHM of the MSE (Mean Square Error) of the fit. For more details on fitting the ACF refer to Appendix A on page 48.

"Average": Choose between a 2, 4, 8, 16 manifold averaging of the autocorrelation trace. Note: After "Average" is selected another drop-down menu appears which allows choosing the data resolution. Choosing high resolution values may lead to the software slowing down on slow computers.

"Show Cursors" Checkbox: Check the box to display two pairs (vertical and horizontal) of cursors to manually take pulse width and intensity measurements. The temporal width of/between the vertical cursors is displayed in the measurement window. Additionally to the horizontal cursors half way in between there is a broken line indicating the half intensity to facilitate full width half maximum (FWHM) measurements. The cursors can also be activated by clicking

on the cross hair in the lower right corner, next to the "Start" button. To deactivate the cursor uncheck the box or right click the cross hair.

"Center Cursors": Click to center the cursors symmetrically on the measurement window.

"Appearance": Choose between a light or a dark theme for the **scoutLink** Control Software.

#### 4.3.3. "TRIGGER" Submenu

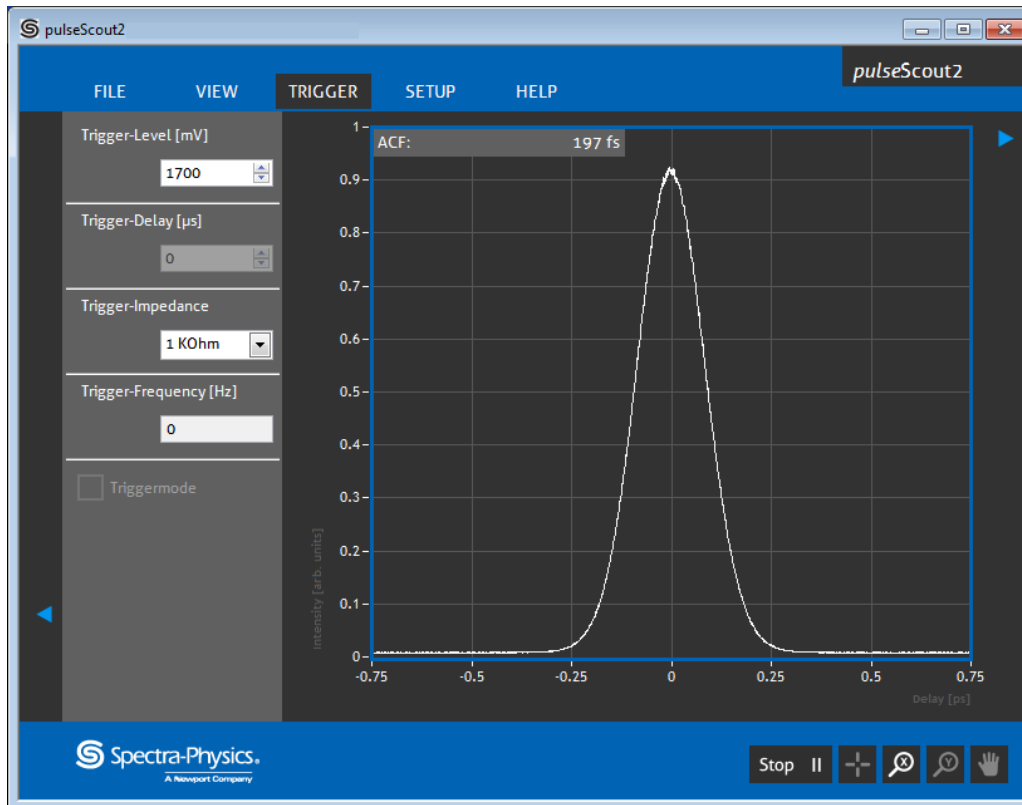


Figure 4.10.: Trigger submenu

In case the repetition rate of the laser under test is below 50 kHz the **scoutLink** has to be triggered with a synchronization signal. The trigger signal must have the same timing as the laser repetition rate in order to reconstruct a proper autocorrelation trace of the pulse train. The "TRIGGER" submenu contains settings of the electronic parameters to adapt the **scoutLink** optimally for the incoming trigger signal. For more details please refer to Section 4.4 on page 34. The following parameters are available:

"Trigger-Level (mV)": The voltage level at which the **scoutLink** registers an incoming trigger signal is set here in mV. Change this value if a trigger signal is not recognized by the **scoutLink**. If available the trigger level can be easily checked with an oscilloscope.

"Trigger-Delay ( $\mu$ s)": A temporal delay between a the trigger impulse and the intensity measurement of the detector of the autocorrelator can be set for proper synchronization. Changing this value may impair the strength of the signal dramatically if the trigger and pulse are not synchronized properly.

"Trigger-Impedance": Set the appropriate input impedance for the trigger signal. For the impedance value refer to specifications of the measured external trigger source.

"Trigger-Frequency (Hz)": Display of frequency if a trigger input signal is recognized.

"Triggermode": Check this box to choose between triggered and untriggered measurement. Note that the checkbox is only active if a trigger signal is already detected by the **scoutLink**.

## 4.3.4. "SETUP" Submenu

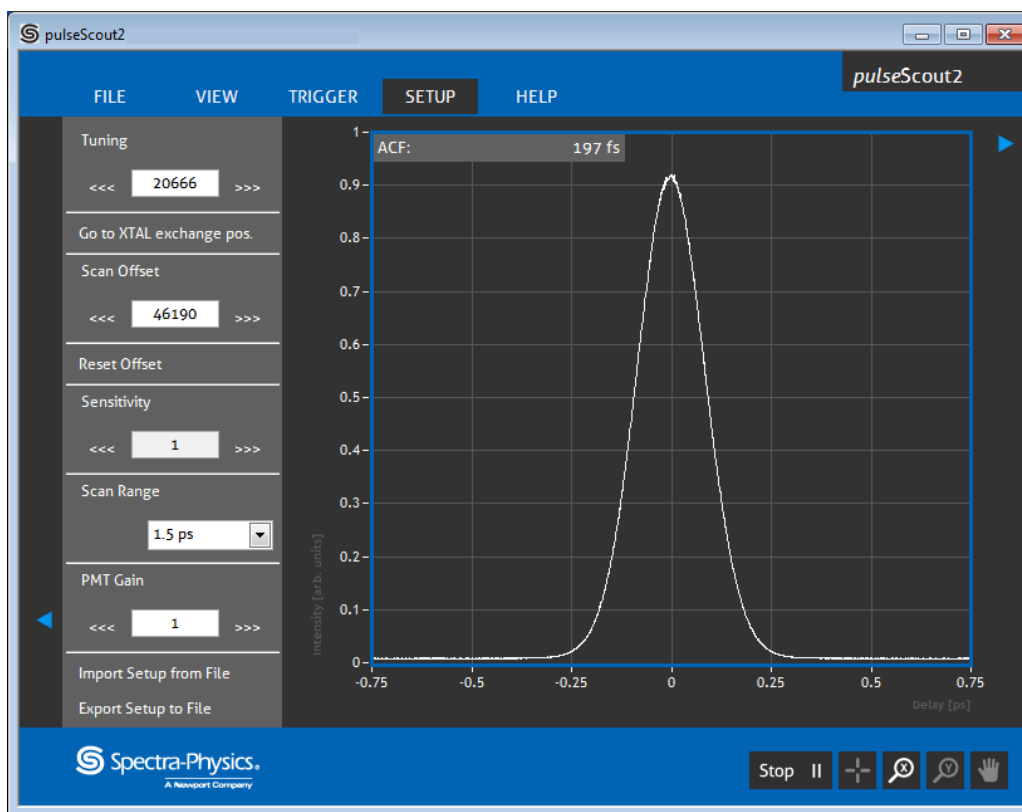


Figure 4.11.: Setup submenu

"Tuning" (arrows): Turns the angle of the non-linear crystal to optimize phase-matching for the actual laser wavelength. Single clicks change the angle in small steps. To sweep through a wide angle range click and hold an arrow.

"Go to XTAL exchange pos.": Before changing the crystal for another wavelength range click here. This will turn the crystal module to a position that facilitates the exchange.

"Scan Offset": This setting allows to adjust the delay zero position of the interferometer, i.e. the point where the pulses overlap temporarily and where the maximum of the ACF is located. Use this setting to center the ACF. Note: Click with the mouse between the digits of the (arb.) number displayed here to set the step width.

"Reset Offset": Resets changes made by the user to factory settings.

"Sensitivity" (arrows): Increase or decrease the sensitivity of the SHG detector to optimize the display of the autocorrelation function.

"Scan Range": Choose between 150 fs, 500 fs, 1.5 ps, 5 ps, and 15 ps scan range (delay of interferometer) according to the measured pulse width. Note: ideally the scan range should be chosen so that  $1/3$  scan range  $>$  FWHM  $>$   $1/10$  scan range.

"PMT Gain": This option appears only if a PMT detector is mounted. It allows to fine tune the PMT gain to adjust the ACF intensity.

"Import Setup" and "Export Setup": Save/export user made options and settings to a file. Import/open and apply options set from a file.



## 4.3.5. Additional Software Controls and Options

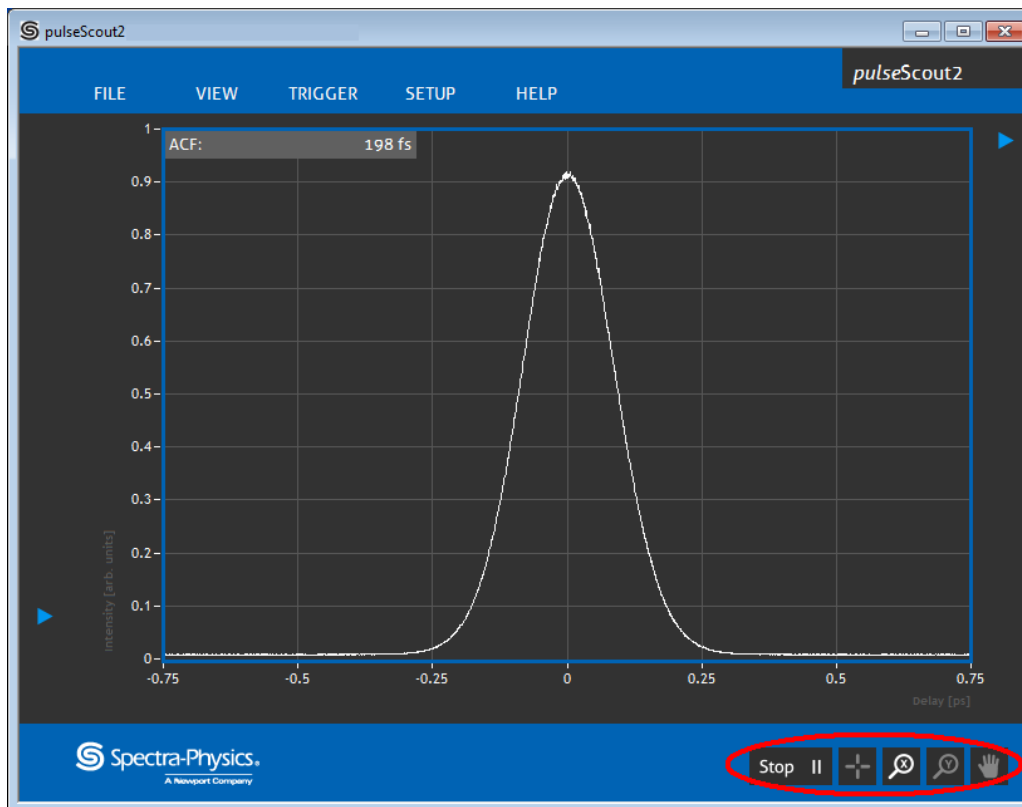


Figure 4.12.: Measurement window with additional display controls (lower right corner)

"Info Box": The Info box displays relevant measurement data and error messages. For convenience it can be placed with the mouse at any position of the measurement window. Additionally a right click opens the context menu where fontsize and transparency can be adjusted. The Info box can be switched ON and OFF by clicking the triangle symbol in the upper right corner of the Control Software

"Zooming and Panning": In the lower right corner of the Control Software there are four additional buttons that allow to activate the cursors, to zoom intensity and delay axis as well as to pan the whole display area. To reset changes right click on the respective button.

"Autoscale Intensity" / "Full Scale" / "Clear Graph" / "Clear Loaded Data": By right clicking on any free area within the measurement window a context menu is activated where the options "Autoscale", "Full Scale", "Clear Graph" and "Clear Loaded Data" are available (see Figure 4.13).

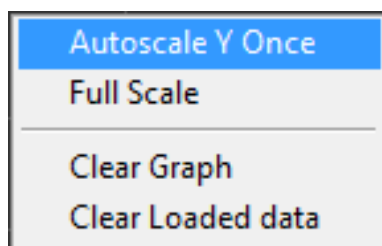


Figure 4.13.: Context menu available by right clicking on any free area within the measurement window.

"Transparency" / "Fontsize": By right clicking on the Info box a context menu is activated where the transparency and fontsize of the Info box can be set (see Figure 4.14)

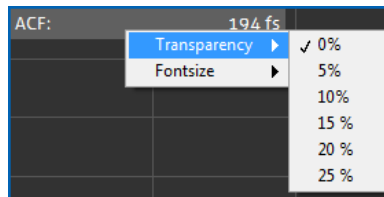


Figure 4.14.: Context menu available by right clicking on the Info box.

### 4.3.6. "Help" Submenu

The "HELP" submenu contains additional device specific information such as serial number, the firmware and software version. For service purposes only there is also the option to save the current system status and options to a file that can be analyzed by our technical experts.

## 4.4. Triggered Measurement

Apply a trigger signal to the **scoutLink** in case the repetition rate of the laser is between 300 Hz and 50 kHz. Use the delivered trigger cable to connect the **scoutLink** electronics ("TRIGGER IN" port) with the trigger source. The **scoutLink** Control Software detects a trigger signal automatically and prompts the user to switch to trigger mode provided the level (voltage) of the trigger signal is high enough. If no trigger is detected try to change the trigger level to a lower value (see Section 4.3.3). Be aware that setting the trigger level too low may cause the **PulseScout2** to recognize electronic noise as trigger signal and thus lead to false measuring behavior. To manually switch to trigger mode select the TRIGGER submenu and check the box "Triggermode". Use an oscilloscope to specify your trigger signal, if necessary.

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. It may be necessary to adjust the trigger-delay if the ACF intensity is too low. Figure 4.15 demonstrates the connection between three exemplary trigger-delay values  $t_1$ ,  $t_2$ ,  $t_3$  and the respective ACF intensity. Here the blue peak on the left represents a laser pulse incident on the photodiode of the **PulseScout2** detector. The electronic reaction of the detector is represented by the gray filled curve. The green, yellow and red lines represent a trigger impulse with a different delay  $t_1$ - $t_3$ . On the right are the ACF curves that correspond to each delay value. Ideally the trigger delay should be set to a value that is corresponding to the green line.

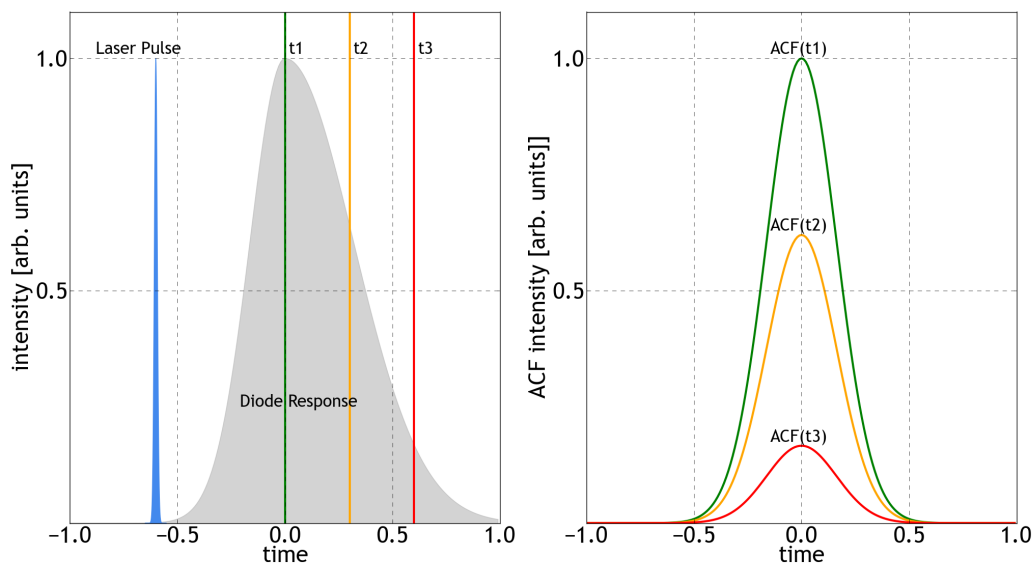


Figure 4.15.: Trigger delay versus ACF intensity

#### 4.5. TCP/IP

The *scoutLink* Control Software has the ability to run its own TCP/IP server allowing the user to remotely make measurements and to control the autocorrelator. Almost all options and operational modes of the autocorrelator can be changed or data can be read out via LAN or WI-FI connection using the standard TCP/IP protocol which is implemented by almost any operating system. This allows the user to implement automatic measurement routines with any programming language (C++, Python, LabView, Octave, MatLab, Excel). It is recommended to use a command line terminal to test the connectivity to the device and to get a better understanding of the TCP/IP command functionality. The *PulseScout2* accepts either the full command, e.g., "system", or the abbreviation marked by bold and capital LETTERS, e.g., "sys". The preface "sl" or "scoutlink" is also optional. To read the current status add a question mark "?" after the command with no space between. To set a value add an equal sign "=" or leave a space and then add the value that is to be set. A complete list of all available commands with short examples can be found in the Appendix B on page 51.

## 4.6. Error Sources of an Autocorrelation Measurement

### 4.6.1. Scan Range too small or too wide

The *scoutLink* Control Software detects several error sources of the signal that could lead to imprecise measurement of the laser pulse width. If such a limitation of the measurement is detected the critical parameter or relevant error message is displayed in the info box of the measurement window.

The following critical parameters are detected by the software:

#### Scan range too low:

If the chosen scan range is too low with respect to the detected width of the autocorrelation trace, a part of the measured autocorrelation might be clipped. Without a robust determination of the signal offset the evaluation of the total height of the maximum intensity is not possible. In order to determine the FWHM value precisely the maximum as well as the minimum of the ACF must be within the measurement window. If the minimum of the ACF is cut (see Figure 4.16) the calculated FWHM value will be wrong.

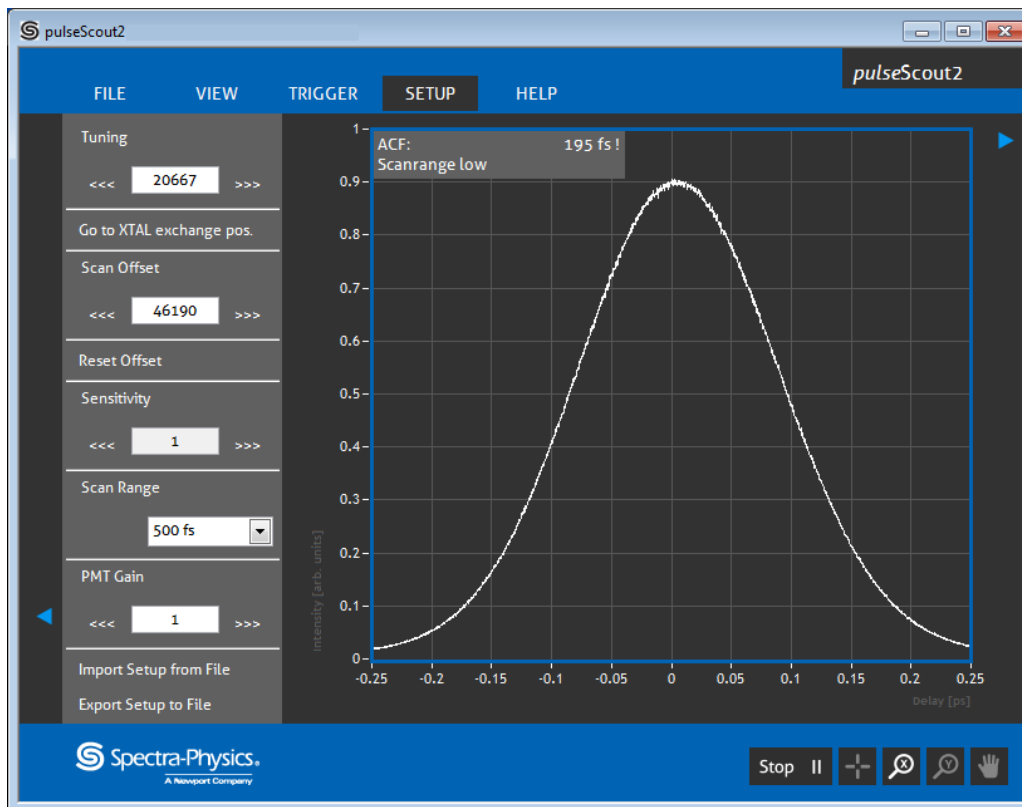


Figure 4.16.: If the Scan Range is too low a warning is displayed in the Info box

**Action:** Increase the scan range!

**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 may be too low for a precise determination of the ACF value (see Figure 4.17). Note that an error message indicating a too large scan range will appear in the Info box. This is not the case in the Figure below.

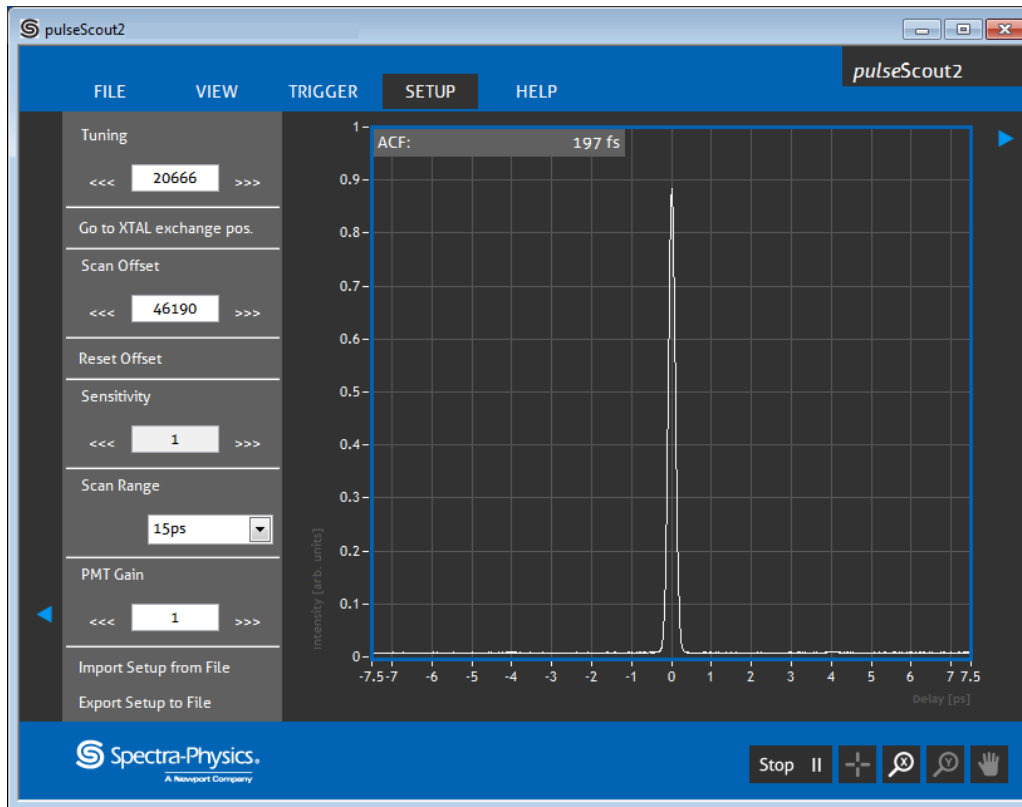


Figure 4.17.: The Scan Range is too large. The ACF is comprised by only few data points. This may lead to an unprecise measurement.

**Action: Decrease the scan range!**

### 4.6.2. Clipping of the ACF or Overload

#### Intensity too high:

An intense autocorrelation signal due to too high laser power can lead to an overload of the detector. The consequence is clipping of the measurement trace (see Figure 4.18). Clipping prevents the software from calculating the ACF value and must be avoided.

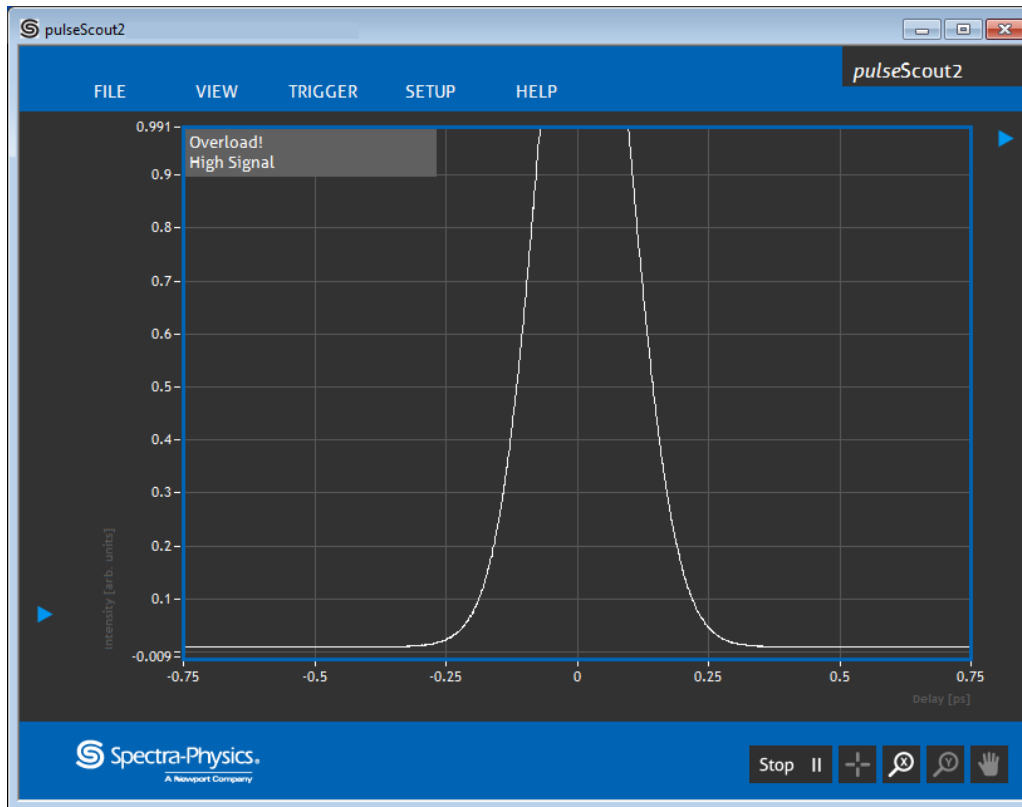


Figure 4.18.: A too high signal leading to ACF clipping is indicated by the info box.

**Action:** Decrease sensitivity in the SETUP menu or decrease laser power incident into the *PulseScout2* !

**Intensity too low:**

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-to-noise ratio (see Figure 4.19).

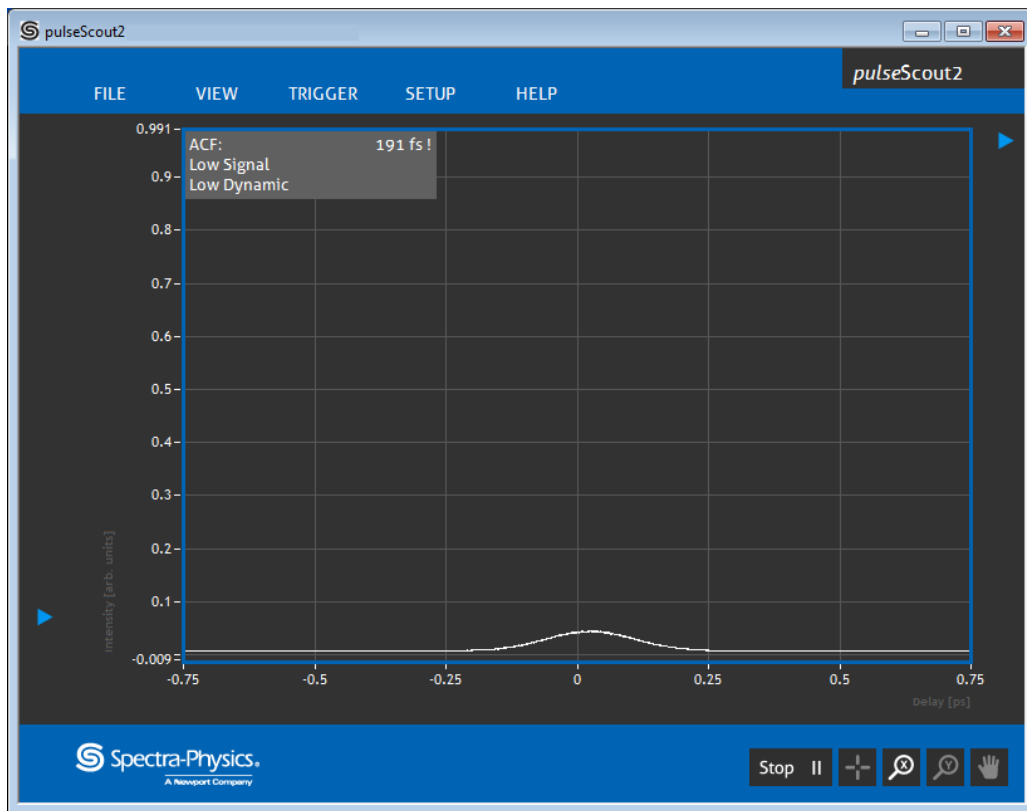


Figure 4.19.: A too weak signal leading to a low dynamic is indicated by the info box

**Action: Increase "Sensitivity" or laser power!**

## 4.6.3. Non-centered ACF

The autocorrelation function should ideally be centered in the measurement window. In case of a large scan offset the ACF may be cut off to the left or right of the scan range. If the measured autocorrelation trace deviates too much from symmetry the info box shows an "Asymmetric" error message (see Figure 4.20).

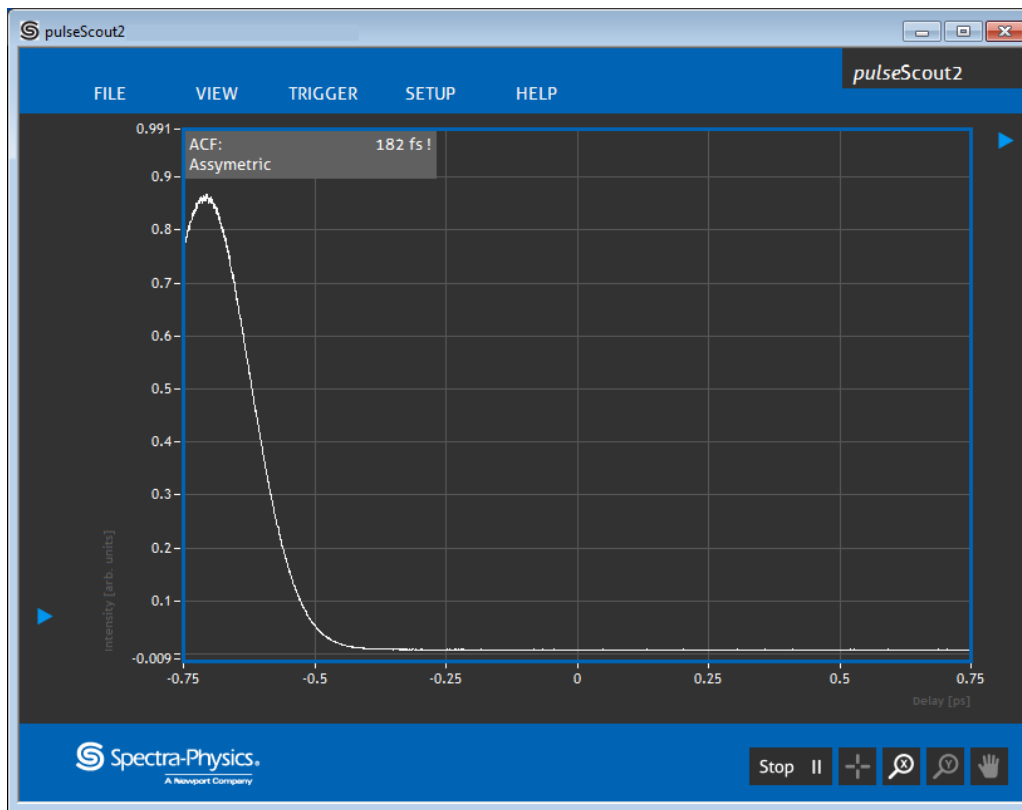


Figure 4.20.: ACF cut off to the left due to too large scan offset

**Action:** Adjust **SETUP** → Offset or optimize the beam alignment into the *PulseScout2* optical head.



## 5. Additional Hints

### 5.1. "Zero" Scan

In "Zero" scan range the delay drive is stopped at the zero position. The measurement window displays the measured intensity at the zero position as a function of time and behaves similar to an oscilloscope.

### 5.2. Low Pass Filter

The switchable filter suppresses high frequency signal components. This is useful in two cases:

1. If the autocorrelation signal is noisy the filter cleans up the signal and increases the Signal-to-noise ratio.
2. If measuring in collinear mode the autocorrelation function is modulated with a fringe pattern. The filter suppresses this modulation. (This is not the case in triggered mode. In triggered mode go to slightly non-collinear configuration.) A comparison of collinear ACF with the filter switched on and off is pictured in Figure 5.1. Also note that the filter is automatically switched off in triggered measurement mode.

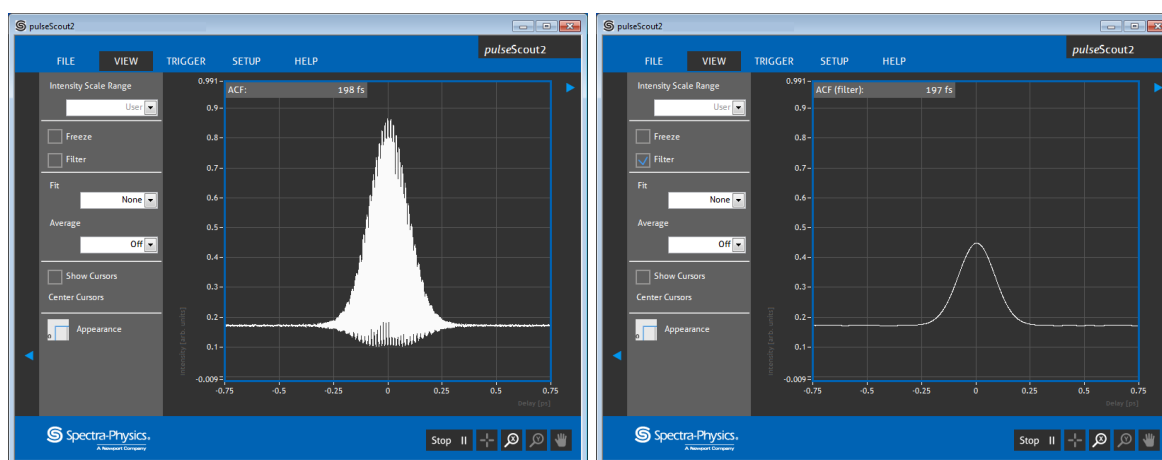


Figure 5.1.: Collinear ACF measurement with filter OFF (left) and filter ON (right)

### 5.3. Change of Wavelength Range (Crystal and Detector Exchange)

The wavelength range that the autocorrelator can be used for depends on the phase-matching angle of the crystal (crystal type and cut angle), and on the wavelength range of the detector. The detector has to be insensitive to the fundamental wavelength of the laser and highly sensitive to the SHG signal. Therefore the useful range for the detector is necessarily smaller than one octave and is determined by the detector itself and a block filter. Accordingly, the detector unit including a filter as well as the crystal (which together constitute a detector module) has to be exchanged when another wavelength range is required. Refer to Paragraphs 3.5.1 on page 19 and 3.5.2 on page 20, respectively, for directions on exchange of these components.

#### 5.4. Signal Level

To cover a wide input power range and/or pulse width range the sensitivity can be varied over a large scale. This may lead to high noise levels, especially when measuring with PMT detector modules. Therefore, for most exact measurements, it is advisable to adapt the power input level to an operation where only the lowest possible sensitivity (PD and PMT detectors) and gain (PMT detectors only) values are required. The operation in triggered mode with very short pulses at low repetition rates is most critical. In this case, the detector can become overloaded at high input levels with a low sensitivity setting thus causing a suppression of the ACF peak without cutting it off. The ACF may look similar to an ideal ACF but will be artificially broadened. **To prevent this it is strictly recommended to operate triggered mode with photodiode (PD) detectors only.**

#### 5.5. Rotation of Plane of Polarization

The *PulseScout2* autocorrelator requires a horizontal input polarization (E-field; for specifications see Table 2.1 on page 12). In consequence, if the laser beam that is to be measured is vertically polarized, the plane of polarization has to be rotated.

A  $\lambda/2$  plate can be used for rotating the beam's polarization: by placing the plate in the input beam and tilting it by an angle  $\alpha$  the polarization is rotated by  $2\alpha$ . However, this effect is usually very wavelength sensitive. Therefore this solution might not be applicable to your specific experimental setup.

## 6. Troubleshooting and Maintenance

### 6.1. Troubleshooting

Error characteristics		Possible reason	Check and removal
No SHG Signal		wrong polarization direction	check for horizontal polarization; introduce a polarization rotator into the input beam, if necessary
		wrong alignment	check beam position at input aperture; check back reflection at control window; 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	non-collinear case	wrong alignment of beam on detector	check with shutters (if it reacts to each of the shutters); realign input beam in horizontal direction only
	collinear case	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)

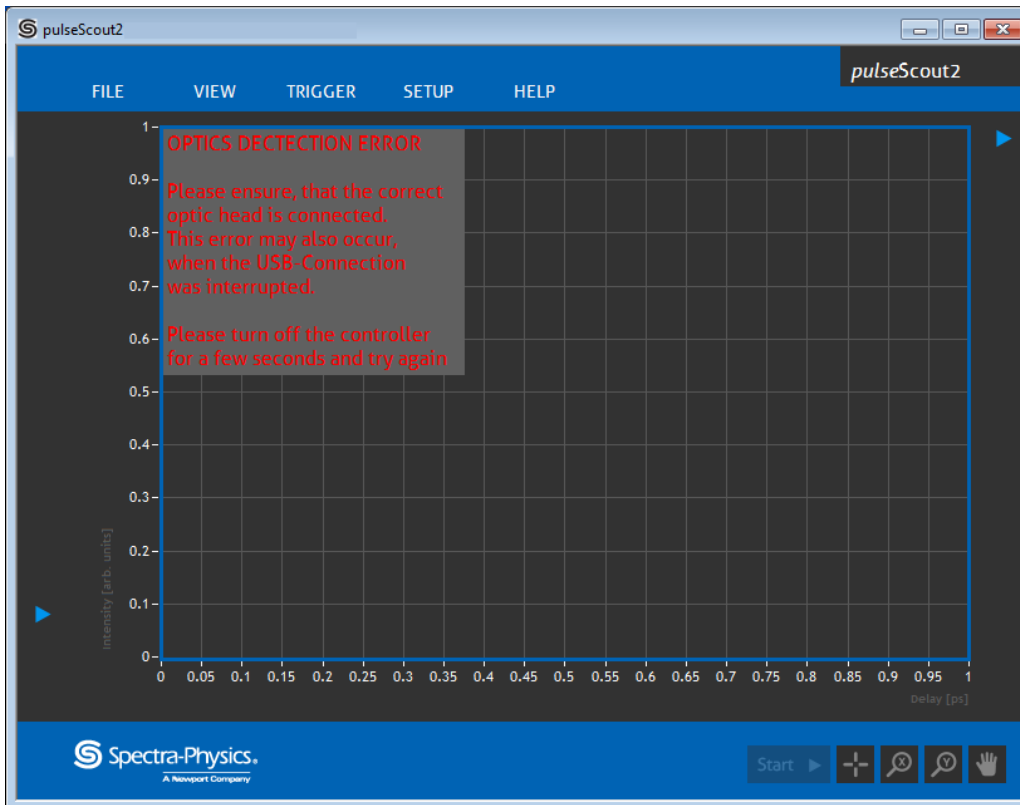


Figure 6.1.: "OPTICS DETECTION ERROR" Error Message

"OPTICS DETECTION ERROR": If this error message is displayed (see Figure 6.1) please check the Sub-D 25 pin cable connection with the optical head and follow on-screen instructions.

### 6.1.1. Known Issues

- **Trigger Mode:** If the trigger frequency changes during triggered measurement to a value higher than 100 kHz the ACF may become distorted or the software may prompt the user to restart it.
- **ACF Fit:** Sometimes the software may find wrong parameters for the fit function. The displayed fit thus is not on the ACF. Even the fit amplitude may become negative. Block and unblock the laser beam for a second to allow the software to find the correct fit parameters.

## 6.2. Maintenance

### Warranty

Work performed on the *PulseScout2* system components or software by persons not authorized by Newport will result in invalidity of the guarantee and service contract.

#### 6.2.1. Cleaning



Do not use any aggressive solvents to clean the *PulseScout2* auto-correlator components! Switch the laser OFF or block the input beam, switch the *PulseScout2* controller OFF and disconnect the power cord from the wall socket for cleaning!

Use a soft lint-free dry or only slightly moist cloth to clean the covers of the *PulseScout2* components.

#### 6.2.2. Storage of SHG Crystal

The SHG crystals provided with the *PulseScout2* 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 3.5.1 on page 19 for removal / mounting of the SHG crystal) from the *PulseScout2* optical head and to store it in an airtight box along with silica gel.

## 6.3. Technical Support

For technical questions or problems, please contact:  
for North America

**Newport Corporation Service Dept.**  
1791 Deere Ave. Irvine, CA 92606  
tel (949) 253-1694  
tel (800) 222-6440 x31694

for Asia

**Newport Opto-Electronics Technologies**  
253 Aidu Road, Bld #3, Flr 3, Sec C  
Shanghai 200131, China  
tel +86-21-5046 2300  
fax +86-21-5046 2323

for Europe

**Newport/MICRO-CONTROLE S.A.**  
Zone Industrielle  
45340 Beaune la Rolande, FRANCE  
tel +33 (0)2 38 40 51 56

Information and advice about the operation of any Newport product is available from our technical support engineers. For quickest response, ask for “Technical Support” and know the model and serial number for your product.

We typically respond to faxes and email within one business day.

### 6.3.1. Service

Your **PulseScout2** autocorrelator has been designed to provide years of trouble-free operation. Virtually no maintenance is required except for ensuring that the unit is not damaged, contaminated, or used in an unsafe manner.

### 6.3.2. Obtaining Service

If there are any defects in material or workmanship or a failure to meet specifications, promptly notify your local Newport office (see Section 6.3) within the warranty period to obtain a Return Material Authorization Number (RMA#). Return the product to Newport Corporation, freight prepaid, clearly marked with the RMA# and we will either repair or replace it at our discretion. Newport is not responsible for damage occurring in transit and is not obligated to accept products returned without an RMA#.

E-mail: [rma.service@newport.com](mailto:rma.service@newport.com)

When calling Newport Corporation, please provide the customer care representative with the following information:

- Your Contact Information
- Serial number or original order number
- Description of problem (i.e., hardware or software)

To help our Technical Support Representatives diagnose your problem, please note the following conditions:

- Is the system used for manufacturing or research and development?
- What was the state of the system right before the problem?
- Have you seen this problem before? If so, how often?
- Can the system continue to operate with this problem? Or is the system non-operational?
- Can you identify anything that was different before this problem occurred?

Please fill out a copy of the service form, located on the following page, and have the information ready when contacting Newport. Return the completed service form with the instrument.

### 6.3.3. Warranty

The warranty conditions are specified in the sales contract. This is in lieu of all other guarantees, expressed or implied, and does not cover incidental or consequential loss.

6.3.4. Service Form

Your local Newport office  
For contact information see section 6.3

Name \_\_\_\_\_

Return Authorization # \_\_\_\_\_

**(Please obtain RA# prior to return of item)**

Company \_\_\_\_\_

Address \_\_\_\_\_

\_\_\_\_\_

Date \_\_\_\_\_

Country \_\_\_\_\_ Phone Number \_\_\_\_\_

P.O. Number \_\_\_\_\_ Fax Number \_\_\_\_\_

**Item(s) Being Returned:**

Model # \_\_\_\_\_ Serial # \_\_\_\_\_

Description \_\_\_\_\_

**Reason for return of goods (please list any specific problems):**

## A. Fitting Functions

### A.1. Gaussian

The mathematical description for a Gaussian pulse is:

$$G(t) = e^{-t^2} \quad (\text{A.1})$$

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

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

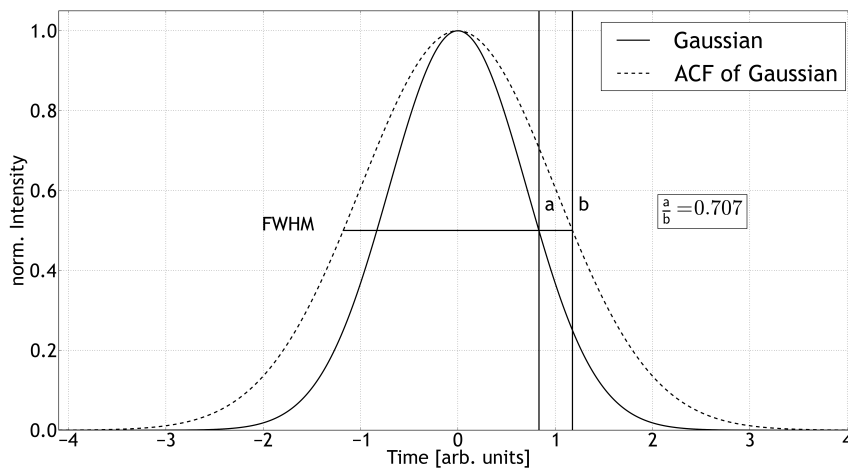


Figure A.1.: Gaussian function  $e^{-t^2}$  and its normalized autocorrelation  $e^{-\frac{\tau^2}{2}}$  (dotted line)

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

$$G(a) = \frac{1}{2} \quad \Rightarrow a = \sqrt{\ln(2)} \quad (\text{A.3})$$

$$G_{\text{ACF}}(b) \sqrt{\frac{2}{\pi}} = \frac{1}{2} \quad \Rightarrow b = \sqrt{2\ln(2)} \quad (\text{A.4})$$

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

$$\frac{a}{b} = \frac{\sqrt{\ln(2)}}{\sqrt{2\ln(2)}} = 0.71 \quad (\text{A.5})$$



### A.2. Lorentzian

The mathematical description for a Lorentzian pulse is:

$$L(t) = \frac{1}{1 + t^2} \quad (\text{A.6})$$

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

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

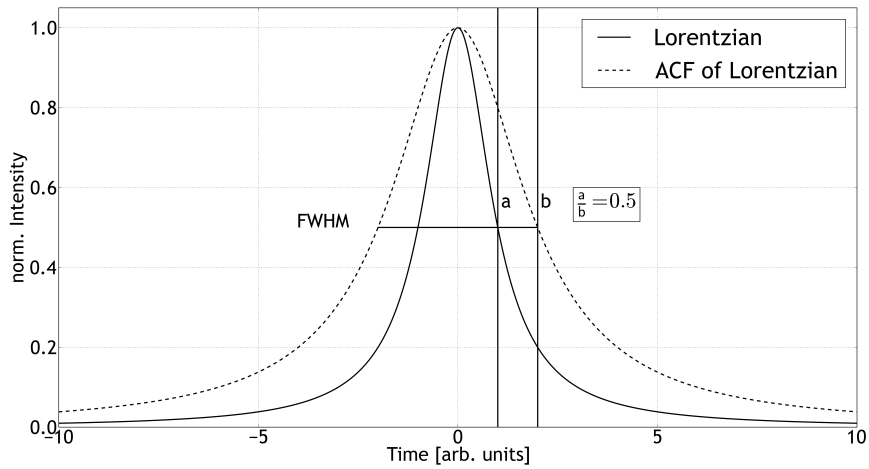


Figure A.2.: Lorentzian function  $\frac{1}{1 + t^2}$  and its normalized autocorrelation  $\frac{4}{4 + \tau^2}$  (dotted line)

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

$$L(a) = \frac{1}{2} \quad \Rightarrow a = 1 \quad (\text{A.8})$$

$$L_{ACF}(b) \frac{2}{\pi} = \frac{1}{2} \quad \Rightarrow b = 2 \quad (\text{A.9})$$

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

$$\frac{a}{b} = 0.5 \quad (\text{A.10})$$

### A.3. $\text{sech}^2$

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

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

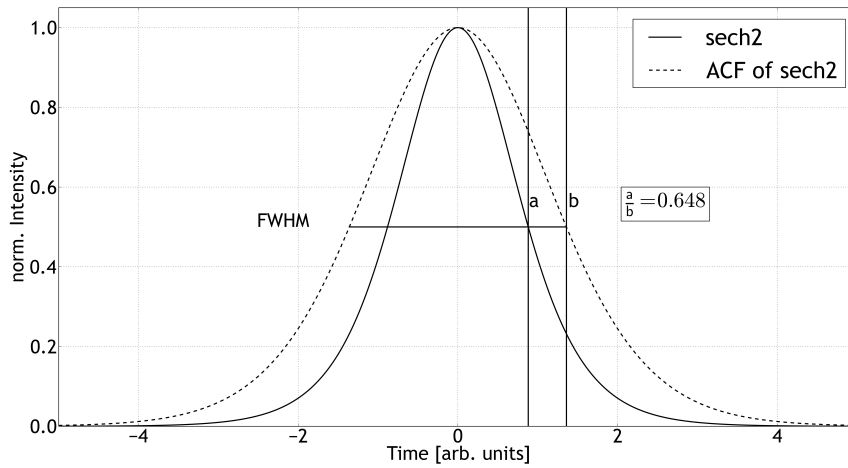


Figure A.3.: The function  $\text{sech}(t)^2$  and its normalized autocorrelation  $3\text{csch}(\tau)^3(\tau\cosh(\tau) - \sinh(\tau))$  (dotted line)

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

$$S(a) = \frac{1}{2} \quad \Rightarrow a = 0.881374 \quad (\text{A.12})$$

$$L_{\text{ACF}}(b) \frac{3}{4} = \frac{1}{2} \quad \Rightarrow b = 1.35979 \quad (\text{A.13})$$

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

$$\frac{a}{b} = 0.648 \quad (\text{A.14})$$

## B. TCP/IP Command Set

This section provides a complete overview of the remote control commands of the *PulseScout2*. The command structure of the *PulseScout2* 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](http://www.ivifoundation.org)

The autocorrelator will execute the following commands:

### \*IDN?

Get Device Identification

<idn> Device Information (Vendor, Devicename, Serialnumber, Software Version, Firmware Version) as string,

Example:

\*IDN?

### \*RST

Perform Device Reset

Example:

\*RST

### \*STB?

Get Status Byte

<stb> 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 as integer,

Example:

\*STB?

### \*CLS

Clear Status Byte (STB)

Example:

\*CLS

**\*ESE<value>**

Set Event Status Enable Register

<value> ESE Register Value as integer, range: 0 ... 255,

Example:

\*ESE=127

**\*ESE?**

Get Event Status Enable Register

<value> ESE Register Value as integer, range: 0 ... 255,

Example:

\*ESE?

**\*SRE<value>**

Set Service Request Enable Register

<value> SRE Register Value as integer, range: 0 ... 255,

Example:

\*SRE=127

**\*SRE?**

Get Service Request Enable Register

<value> SRE Register Value as integer, range: 0 ... 255,

Example:

\*SRE?

**\*ESR?**

Get Event Status Register

<value> ESE Register Value as integer, range: 0 ... 255,

Example:

\*ESR?

**\*OPC?**

Get Operation Complete Status

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

Example:

\*OPC?

**\*OPER?**

## Get Operation Status

<oper> SCPI Operation 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 as integer,

Example:

**\*INIT?**

## Get Device Initialization Status

<init> SCPI INIT Status (8 Bit unsigned as decimal, upper 4 Bits are always "1") Bit0: Config read OK, Bit1: Config parsing OK, 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" as integer,

Example:

**\*BUSY?**

## Get Device Busy Status

<busy> 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 as integer,

Example:

**\*ERR?**

## Get Data Error Status

<errs> 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 as integer,

Example:

**\*FRMW?**

## Get Firmware Status

<frmw> 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 as integer,

Example:

\*OPER?

**scoutlink:SYSTEM:DEVICE?**

**scoutlink:SYS:DEVICE?**

Get Device Name

<name> Device Name as string,

Example:

scoutlink:sys:device?

**scoutlink:SYSTEM:SNUMBER?**

**scoutlink:SYS:SNUMBER?**

Get Device Serialnumber

<snr> Device Serial Number (S00000 - S99999) as string,

Example:

scoutlink:sys:snumber?

**scoutlink:SYSTEM:SOFTWARE?**

**scoutlink:SYS:SOFTWARE?**

Get Software Version

<version> Software Version as string,

Example:

scoutlink:sys:software?

**scoutlink:SYSTEM:HARDWARE?**

**scoutlink:SYS:HARDWARE?**

Get Hardware Version

<version> Hardware Version as string,

Example:

scoutlink:sys:hardware?

**scoutlink:SYSTEM:FIRMWARE?**

**scoutlink:SYS:FIRMWARE?**

Get Firmware Version

<version> Firmware Version as string,

Example:

scoutlink:sys:firmware?

**scoutlink:SYSTEM:MOTOR?**  
**scoutlink:SYS:MOTOR?**

Get Motor Type

<version> Motor Type as string,

Example:

```
scoutlink:sys:motor?
```

**scoutlink:SYSTEM:HELP?**  
**scoutlink:SYS:HELP?**

Get List of all SCPI Commands

<command\_list> Command List as array of s in block data format,

Example:

```
scoutlink:sys:help?
```

**scoutlink:STATUS:AVERAGE<number>**  
**scoutlink:STA:AVERAGE<number>**

Set number of measurements used for averaging

<number> Number of Measurements 0: Averaging OFF, 1: 2 Measurements, 2: 4 Measurements, 3: 8 Measurements, 4: 16 Measurements as integer, range: 0 ... 4,

Example:

```
scoutlink:sta:average 1
```

**scoutlink:STATUS:AVERAGE?**  
**scoutlink:STA:AVERAGE?**

Get number of measurements used for averaging

<number> Number of Measurements 0: Averaging OFF, 1: 2 Measurements, 2: 4 Measurements, 3: 8 Measurements, 4: 16 Measurements as integer, range: 0 ... 4,

Example:

```
scoutlink:sta:average?
```

**scoutlink:STATUS:CLEAR\_DISPLAY**  
**scoutlink:STA:CLRD**

Reset the Averaging function and clear the current Fit

**scoutlink:STATUS:FITTYPE<type>**  
**scoutlink:STA:FITTYPE<type>**

Set type of curve fit to apply to measured ACF

<type> Fittype 0/OFF/NONE: No Curvefitting performed, 1/GAUSSIAN: Fit Gaussian Model, 2/SECH2: Fit Sech2 Model, 3/LORENTZ: Fit Lorentz Model as integer, range: 0 ... 3,

Example:

```
scoutlink:sta:fittype 1
```

**scoutlink:STATUS:FITTYPE?**  
**scoutlink:STA:FITTYPE?**

Get type of calculated curve-fit

<type> Fittype 0: No Curvefit performed, 1: Gaussian Model, 2: Sech2 Model, 3: Lorentz Model as integer, range: 0 ... 3,

Example:

```
scoutlink:sta:fittype?
```

**scoutlink:STATUS:START?**  
**scoutlink:STA:START?**

Status of Measurement

<status> Status of measurement (1 = Measurement running, 0 = Measurement paused) as string,

Example:

```
scoutlink:sta:start?
```

**scoutlink:STATUS:FILTER<status>**  
**scoutlink:STA:FILTER<status>**

Set Status of ACF Filtering

<status> as string,

Example:

```
scoutlink:sta:filter 1
```

**scoutlink:STATUS:FILTER?**  
**scoutlink:STA:FILTER?**

Get Status of ACF Filtering

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

Example:

```
scoutlink:sta:filter?
```

**scoutlink:STATUS:TRIGGER<status>**  
**scoutlink:STA:TRIGGER<status>**

Toggle Triggermode

<status> as string,

Example:

```
scoutlink:sta:trigger
```



**scoutlink:STATUS:TRIGGER?**  
**scoutlink:STA:TRIGGER?**

Get current Triggermode

<status> Triggermode (1 = active, 0 = inactive) as string,

Example:

```
scoutlink:sta:trigger?
```

**scoutlink:STATUS:DETECTOR?**  
**scoutlink:STA:DETECTOR?**

Get PMT Detection Status

<status> PMT detected (1 = PMT found, 0 = no PMT) as string,

Example:

```
scoutlink:sta:detector?
```

**scoutlink:CRYSTAL:TUNING<number>**  
**scoutlink:XTAL:TUN<number>**

Set Crystal Position

<number> Crystal Position as integer,

Example:

```
scoutlink:xtal:tuning 1234
```

**scoutlink:CRYSTAL:TUNING?**  
**scoutlink:XTAL:TUN?**

Get Crystal Position

<number> Crystal Position as integer,

Example:

```
scoutlink:xtal:tuning?
```

**scoutlink:CRYSTAL:MOVE?**  
**scoutlink:XTAL:MOV?**

Get Status of Optics Movement

<number> Optics Servo Status (1 - Servo moving, 0 - Servo not moving) as integer,

Example:

```
scoutlink:xtal:mov?
```

**scoutlink:MOTOR:SCANFREQUENCYNOAMP?**  
**scoutlink:MOT:SFRNA?**

Get ScanFrequency

<number> ScanFrequency in Hz as integer,

Example:

```
scoutlink:mot:sfrna?
```

**scoutlink:MOTOR:SCANRANGE<scanrange>**

**scoutlink:MOT:SCR<scanrange>**

Set ScanRange

<scanrange> Scanrange 0/ZERO: Zeroscan, 1/150: 150 fs, 2/500: 500 fs, 3/1500: 1.5 ps, 4/5000: 5 ps, 5/15000: 15 ps, 6/30000: 30 ps (optional) as integer, unit: fs

Example:

```
scoutlink:mot:scr 15000
```

**scoutlink:MOTOR:SCANRANGE?**

**scoutlink:MOT:SCR?**

Get ScanRange

<scanrange> Scanrange 0: Zeroscan, 150: 150 fs, 500: 500 fs, 1500: 1.5 ps, 5000: 5 ps, 15000: 15 ps, 30000: 30 ps (optional), as integer, unit: fs

Example:

```
scoutlink:mot:scr?
```

**scoutlink:DETECTOR:GAIN<value>**

**scoutlink:DET:GAIN<value>**

Set PMT Gain value (Function has no effect, if standard optics units (w/o a PMT) is connected)

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

Example:

```
scoutlink:det:gain 450
```

**scoutlink:DETECTOR:GAIN?**

**scoutlink:DET:GAIN?**

Get PMT Gain value

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

Example:

```
scoutlink:det:gain?
```

**scoutlink:DETECTOR:SENSITIVITY<number>**

**scoutlink:DET:SEN<number>**

Set Sensitivity

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

Example:

```
scoutlink:det:sen 10
```

**scoutlink:DETECTOR:SENSITIVITY?**  
**scoutlink:DET:SEN?**

Get Sensitivity

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

Example:

```
scoutlink:det:sen?
```

**scoutlink:TRIGGER:LEVEL<level>**  
**scoutlink:TRI:LVL<level>**

Set Trigger Level

<level> Trigger Level as integer, range: 100 ... 5000, unit: mV

Example:

```
scoutlink:tri:lvl
```

**scoutlink:TRIGGER:LEVEL?**  
**scoutlink:TRI:LVL?**

Get Trigger Level

<level> Trigger Level as integer, range: 100 ... 5000, unit: mV

Example:

```
scoutlink:tri:lvl?
```

**scoutlink:TRIGGER:DELAY<level>**  
**scoutlink:TRI:DEL<level>**

Set Trigger Delay

<level> Trigger Delay as integer, range: 1 ... 50, unit:  $\mu$ s

Example:

```
scoutlink:tri:del
```

**scoutlink:TRIGGER:DELAY?**  
**scoutlink:TRI:DEL?**

Get Trigger Delay

<level> Trigger Delay as integer, range: 1 ... 50, unit:  $\mu$ s

Example:

```
scoutlink:tri:del?
```

**scoutlink:TRIGGER:FREQUENCY?**  
**scoutlink:TRI:FRQ?**

Get Trigger Frequency

<level> Trigger Frequency as integer, unit: Hz

Example:

```
scoutlink:tri:del?
```

**scoutlink:TRIGGER:IMPEDANCE<level>**  
**scoutlink:TRI:IMP<level>**

Set Trigger Impedance

<level> Trigger Impedance as integer, unit: Ohms

Example:

```
scoutlink:tri:imp
```

**scoutlink:TRIGGER:IMPEDANCE?**  
**scoutlink:TRI:IMP?**

Get Trigger Impedance

<level> Trigger Impedance as integer, unit: Ohms

Example:

```
scoutlink:tri:imp?
```

**scoutlink:ACF:DATA?**  
**scoutlink:ACF:RAW\_DATA?**

Get ACF Data

<acf> ACF Data as SCPI Block; Interleaved Array of Double Values [y1,x1,y2,x2,...,yN,xN],  
x = Delay (ps), y = Intensity (a.u.) as array of s in block data format,

Example:

```
scoutlink:acf:data?
```

**scoutlink:ACF:DISPLAYED\_ACF?**  
**scoutlink:ACF:DACF?**

Get ACF Data as it is displayed (averaged/filtered/..)

<acf> Displayed ACF Data as SCPI Block; Interleaved Array of Double Values [y1,x1,y2,x2,...,yN,xN],  
x = Delay (ps), y = Intensity (a.u.) as array of s in block data format,

Example:

```
scoutlink:acf:displayed_acf?
```

**scoutlink:ACF:MEANDATA?**

Get ACF Mean Data

<mean> Mean Values separated by semicolons: "[AVG];[Xmax];[Xmin];[Ymax];[Ymin]"  
as string,

Example:

```
scoutlink:acf:meandata?
```

**scoutlink:ACF:FWMH?**

Get FWHM Value

<fwhm> FWHM Value as double,

Example:

```
scoutlink:acf:fwhm?
```

**scoutlink:ACF:FITFWMH?**

Get fitted FWHM Value

<fwhm> Fitted FWHM Value as integer,

Example:

```
scoutlink:acf:fitfwhm?
```