Autocorrelator with TPA Detector

User Manual

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IMPORTANT – READ CAREFULLY BEFORE USE – KEEP FOR FUTURE REFERENCE

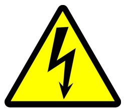
This user manual contains user information for the autocorrelator. Read this manual carefully before operating the autocorrelator, particularly Section 1 on safety instructions. The autocorrelator is only to be used as described in this manual. Differing use may endanger safety and voids warranty.

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

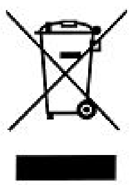
The warranty conditions are specified in the sales contract.

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

Disposal

The autocorrelator 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 autocorrelator 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 autocorrelator is intended to measure the width 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.
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 autocorrelator uses DC voltages in the control unit 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 control unit and the optical head only the delivered cable may be used. It is only allowed to run the autocorrelator with the delivered power supply.

Use only the autocorrelator control unit 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.

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.

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 autocorrelator system with the (EMC) requirements are certified by the CE mark.

2. Description and Specifications

2.1. Description and Intended Use

The autocorrelator is a flexible device used to measure the pulse width 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 is based on the principle of TPA (Two Photon Absorption). It consists of three components:

1. autocorrelator optical head
2. control unit
3. control software

Figure 2.1.: autocorrelator optical head (left) and control unit Unit (right)

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

The control unit comprises the necessary drivers, amplifiers and power supply for the optical head. The control 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 autocorrelator optical head and the control unit. User interaction and control of the system is performed at the computer through the control unit software.

2.2. Specifications

2.2.1. Optical Parameters

Wavelength range	700 - 1200 nm
Scan range	150 fs - 15 ps (150 fs, 500 fs, 1.5 ps, 5 ps, 15 ps)
Measureable pulse width	20 - 3500 fs
For all detector types	
Min. input power	> 2 mW
Max. input power	< 1 W or < 10 μJ (which ever results in the lower average power)
Repetition rate of input laser	300 Hz to 10 GHz (except TPA UV: 300 Hz to 2 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 Ω 0.1 ... 8 Vpp 1 kΩ impedance 50 Ω / 1 kΩ repetition rate 300 Hz ... 50 kHz width > 50 ns
Dimensions	see Figures 2.2 & 2.3

Table 2.1.: Specifications

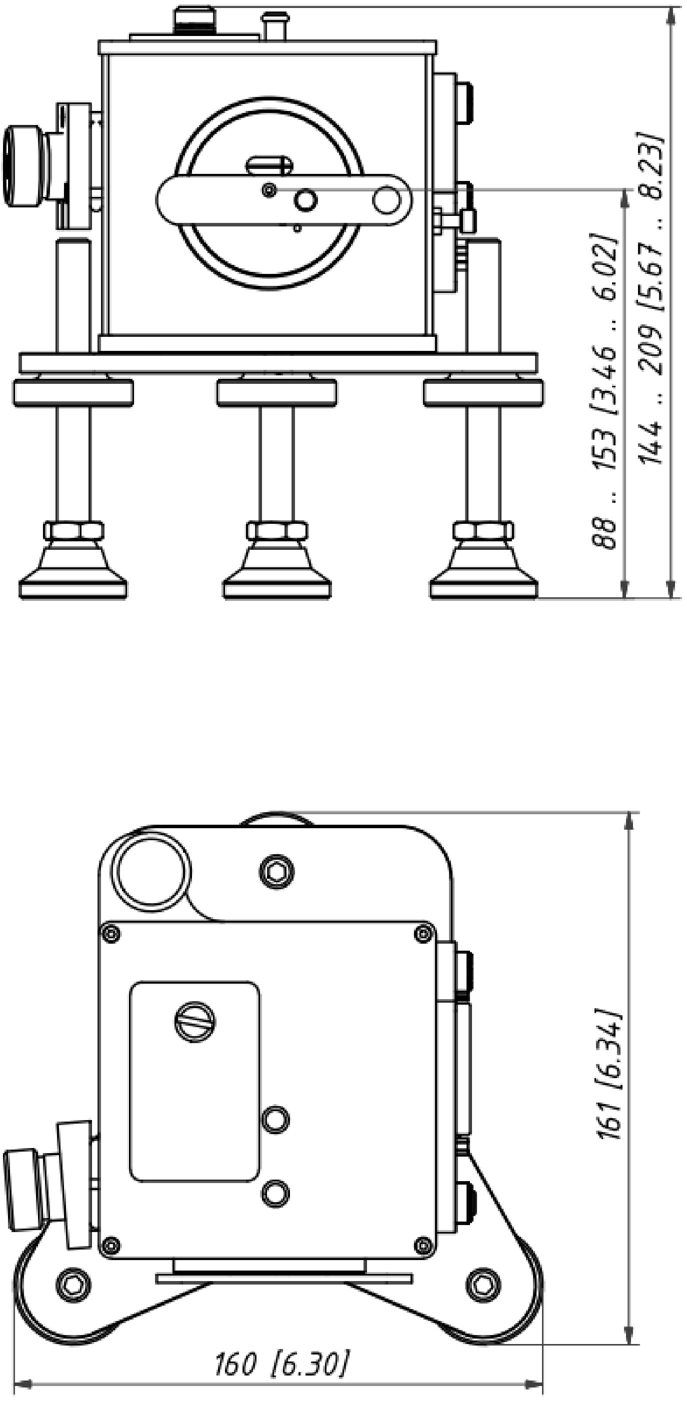


Figure 2.2.: Optical head outline drawing, front and top view in mm [inch]

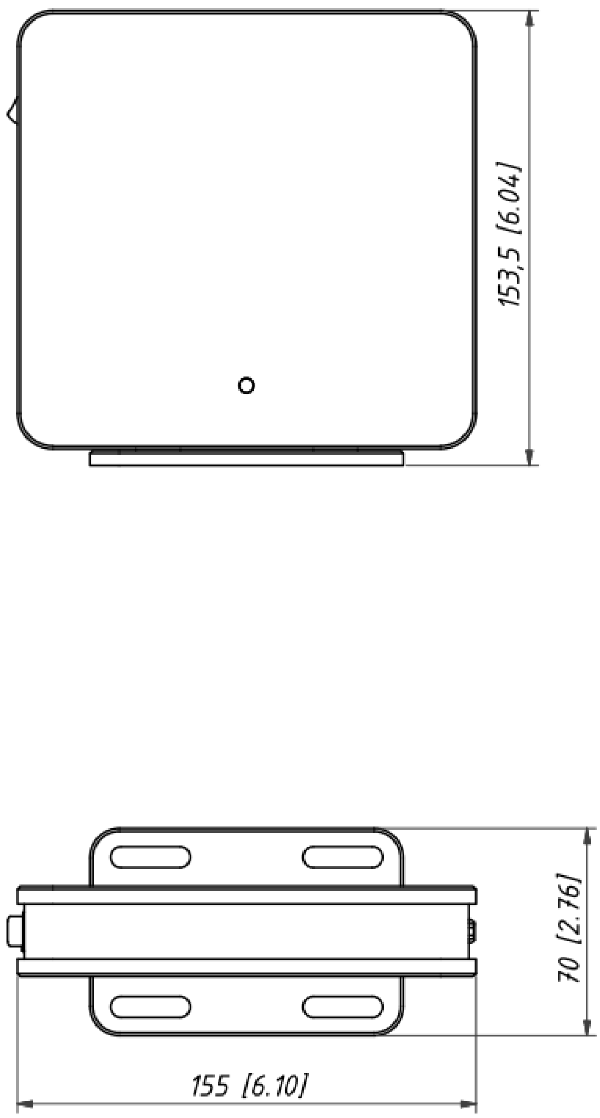


Figure 2.3.: control unit outline drawing, front and top view in mm [inch]

2.3. **Requirements to the Control Computer**

Minimum system requirements:

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

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

The autocorrelator 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

autocorrelator - consisting of:

- control unit
- autocorrelator optical head incl. detector
- 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
- autocorrelator user manual

3.2. Inspection on Receiving

On receipt of the 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 autocorrelator 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 autocorrelator system.
5. It is suggested to retain the packaging for future use.

3.3. System Controls and Indicators

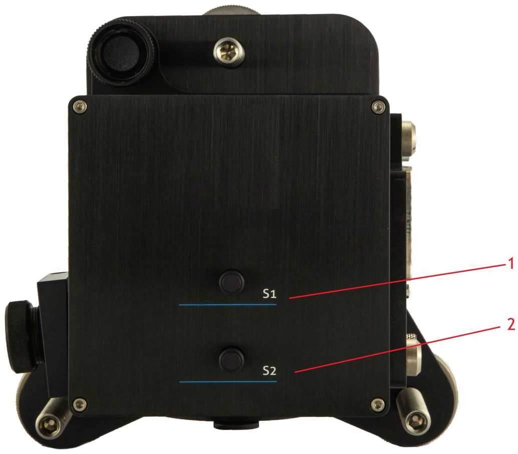
Figure 3.1.: autocorrelator optical head - data cable connection and detector (left), focus position screw (middle), shutter buttons S1, S2 (right)

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	see explanations below
7	OPTICS	25-pin D-Sub connector (connect to optical head)

Figure 3.2.: control unit controls and connectors

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

LED status	control unit condition / status
OFF	control unit off
RED	Hardware selftest after powering on (approx. 1...2 sec)
RED (blinking)	Optical head not connected or wrong optical head
YELLOW	control unit 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 Beam shutter S1

2 Beam shutter S2

Figure 3.3.: autocorrelator optical head with beam shutters

3.4. Installation of the control unit control software

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

The autocorrelator is controlled via the control unit. Hence the first step before using the autocorrelator is to install the included control software on your system. For requirements to the computer refer to Section 2.3 on page 12.

Proceed as follows:

1. Insert the USB Flash Drive that was included with your autocorrelator 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 it is automatically prompted to install the appropriate font.

3.5. **Cable Connection**

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

4. Alignment and Measurement

After having connected all components of the system and installed the 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 control software can be seen from the position of the alignment.
2. Turn the system on by operating the power switch on the control unit.

4.1. Communication Setup

After starting the control software it automatically tries to initiate a connection to the control unit. A communication between the software and the autocorrelator 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)).

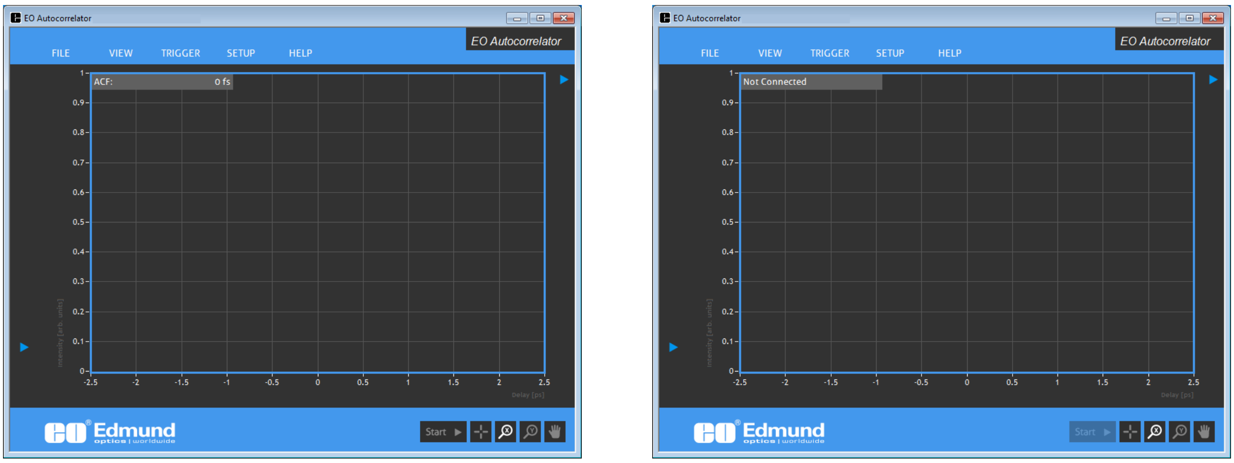


Figure 4.1.: control software start up window with established connection (left), and with failed connection (right)

If the control unit 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 control unit is switched ON. If this is the case, try again to initiate communication to the control unit 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 38 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 autocorrelator 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 autocorrelator 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 autocorrelator (see Table 2.1 on page 10 for specifications).

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 µJ 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 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.

Align the input beam through the alignment aperture to achieve a beam position similar to the one shown in Figure 4.3. The beam reflection should be aligned onto the cross-hair within the alignment window. Note that the autocorrelator is operated in collinear mode only.

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.

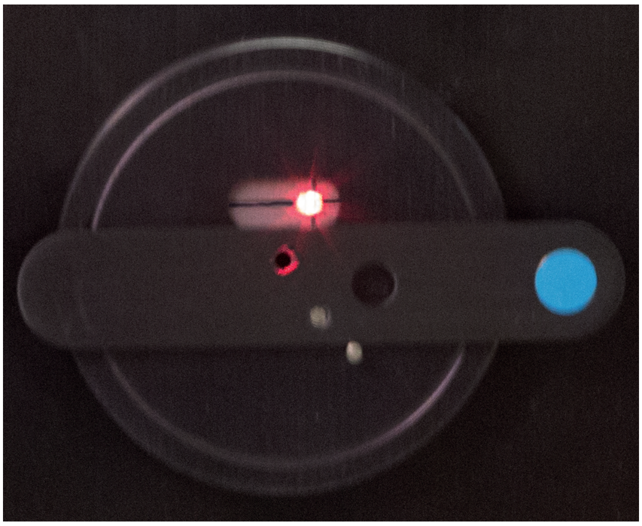


Figure 4.3.: View of alignment window (visible laser used for demonstration purpose).

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. Finally, the variable alignment aperture can now be moved into the measurement position (see Figure 4.2 on page 19).

4.2.2. **Finding the Autocorrelation Trace**

With the control unit 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. 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, dim the lights or block off the source of external light from the autocorrelator.

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 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.

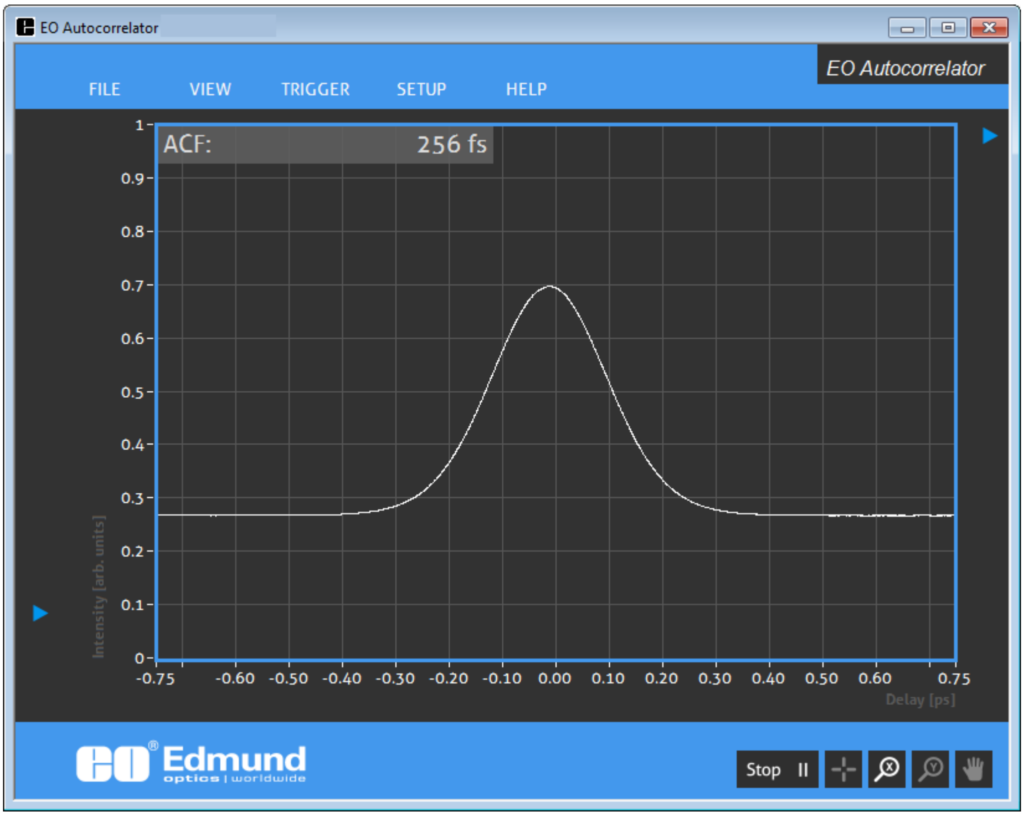


Figure 4.4.: Example of a good autocorrelation function (ACF)

To check the alignment, block one of the beams of the Michelson interferometer inside the autocorrelator by pushing the shutter knobs S1 and S2 on top of the autocorrelator (see Figure 3.3 on page 16). Blocking either beam individually will eliminate the signal originating from the interaction of the two beams (ACF) and decrease the baseline ideally by half.

Finally optimize the peak and the peak-to-background ratio of the autocorrelation signal through adjustment of the focus position (see Figure 3.1 on page 15).

- 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.
- Turn the focus screw in or out to maximize the ACF intensity.
- Sligthly optimize horizontal and vertical alignment of the optcal head to maximize the ACF intensity.
- Repeat the last two steps until no further improvement is possible.
- Finally, if the ACF signal is noisy turn on the low pass filter ("VIEW" → Filter) to clear the signal.

If after these above steps no 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 19) and make sure there is a back reflection at the cross hair (use a IR viewer or IR card for invisible wavelengths). Also make sure that the laser is mode-locked. For more help and tips refer to Section 6.1 Troubleshooting on page 38.

4.2.3. **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 displayed signal is similar to that of an oscilloscope. It is thereby possible to observe amplitude modulations due to alignment. Thus it is sometimes easier to adjust the autocorrelator to maximize the ACF in ZERO SCAN mode.

4.2.4. **Further Alignment Optimization: Beam Shutters**

A good beam alignment may be verified using the internal beam shutters. To do so the autocorrelator has two shutters activated by push buttons on top of the device (see Figure 3.3 on page 16). First close either of the shutters by pushing the corresponding button down. The background signal should ideally go down to approximately half the initial intensity. Repeat this step with the other shutter where the signal drop should be almost 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 4.5 on page 23. If the signal does not decrease by nearly the same amount check the horizontal and vertical beam alignment.

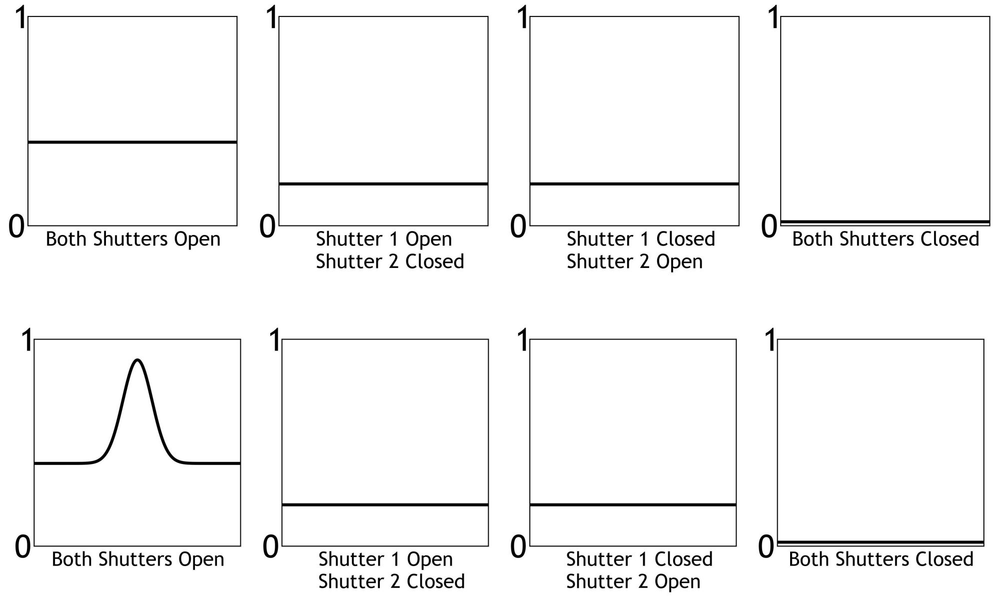


Figure 4.5.: Shutter functions with and without autocorrelation function

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 18 shows the measurement window of the control software that is displayed when you initially start the software (in this particular case with no autocorrelator optical head connected).

4.3.1. "FILE" Submenu

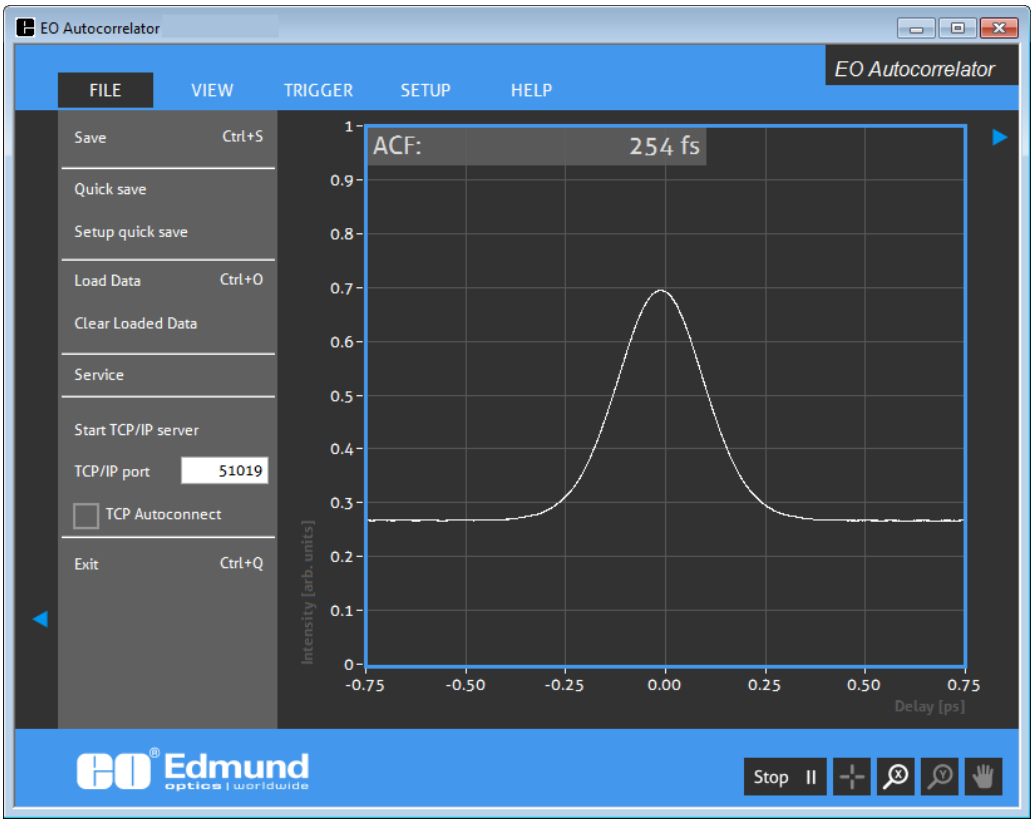


Figure 4.6.: File submenu

"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 control unit 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 control unit refer to Appendix B on page 44.

"TCP/IP port": Selects the TCP/IP port on which the control unit 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

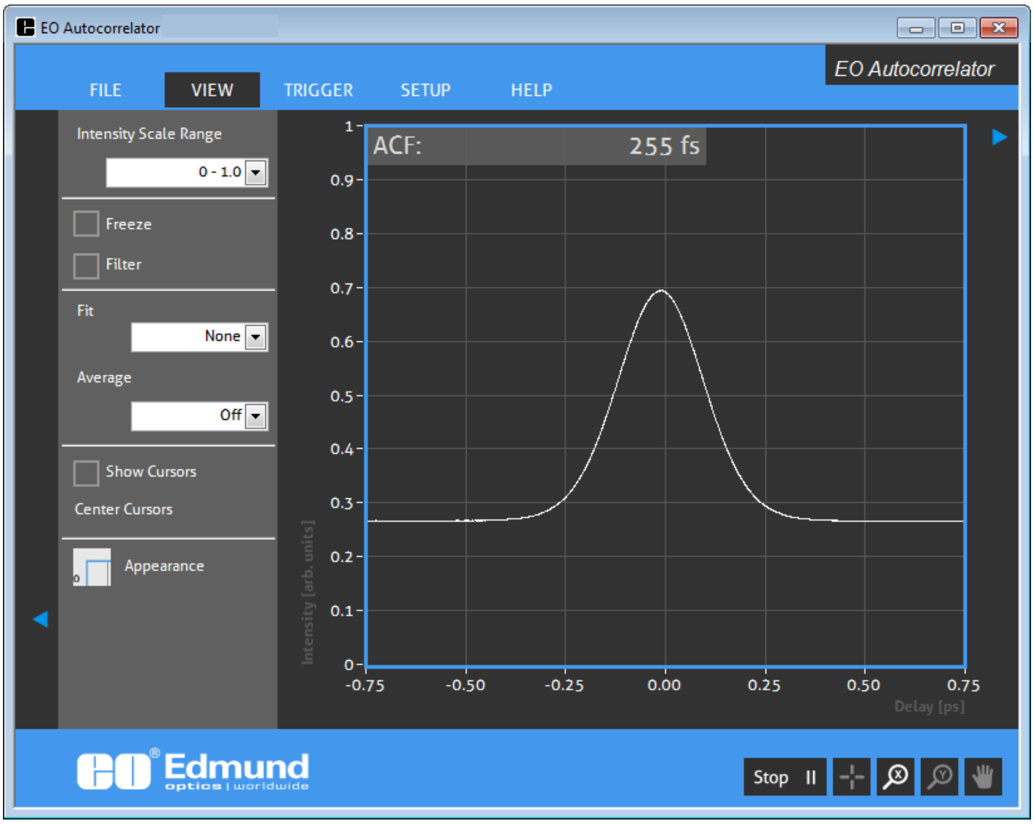


Figure 4.7.: View submenu

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

"Freeze" Checkbox: Check the box to freeze the currently displayed autocorrelation trace. Note: while the display is freezed 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 36.

"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 41.

"**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 control software.

4.3.3. "TRIGGER" Submenu

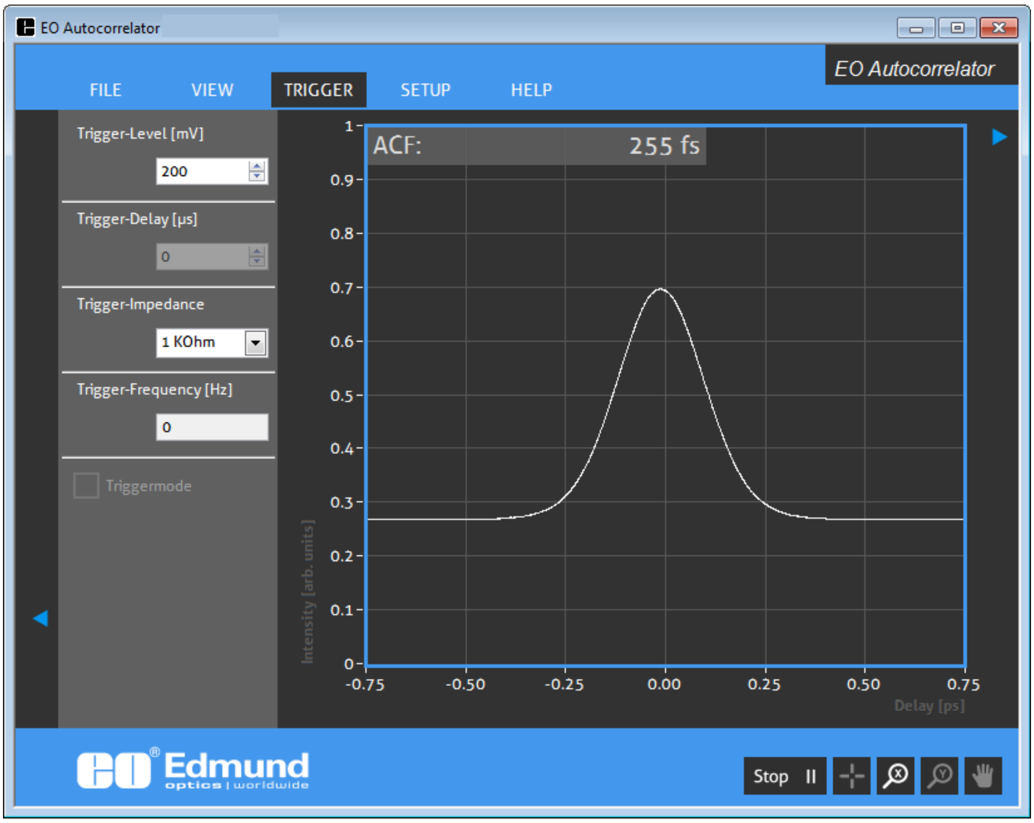


Figure 4.8.: Trigger submenu

In case the repetition rate of the laser under test is below 50 kHz the control unit 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 control unit optimally for the incoming trigger signal. For more details please refer to Section 4.4 on page 29. The following parameters are available:

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

"**Trigger-Delay (µs)**": 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 control unit.

4.3.4. "SETUP" Submenu

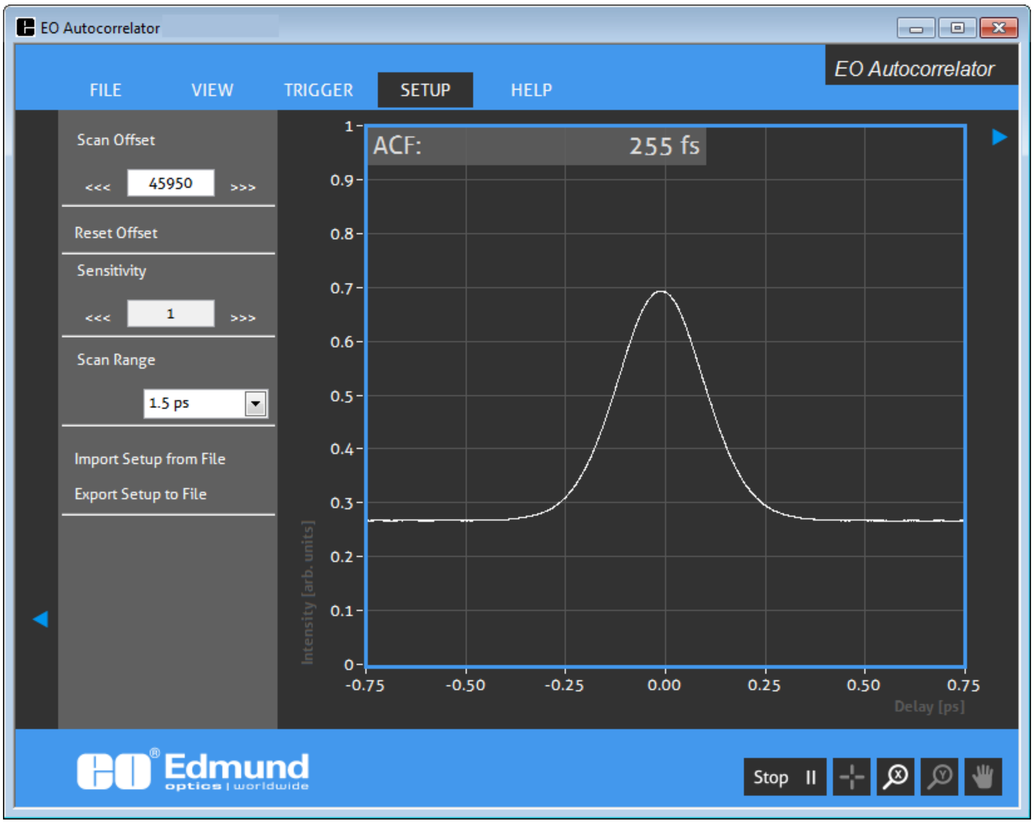


Figure 4.9.: Setup submenu

"**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.

"**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

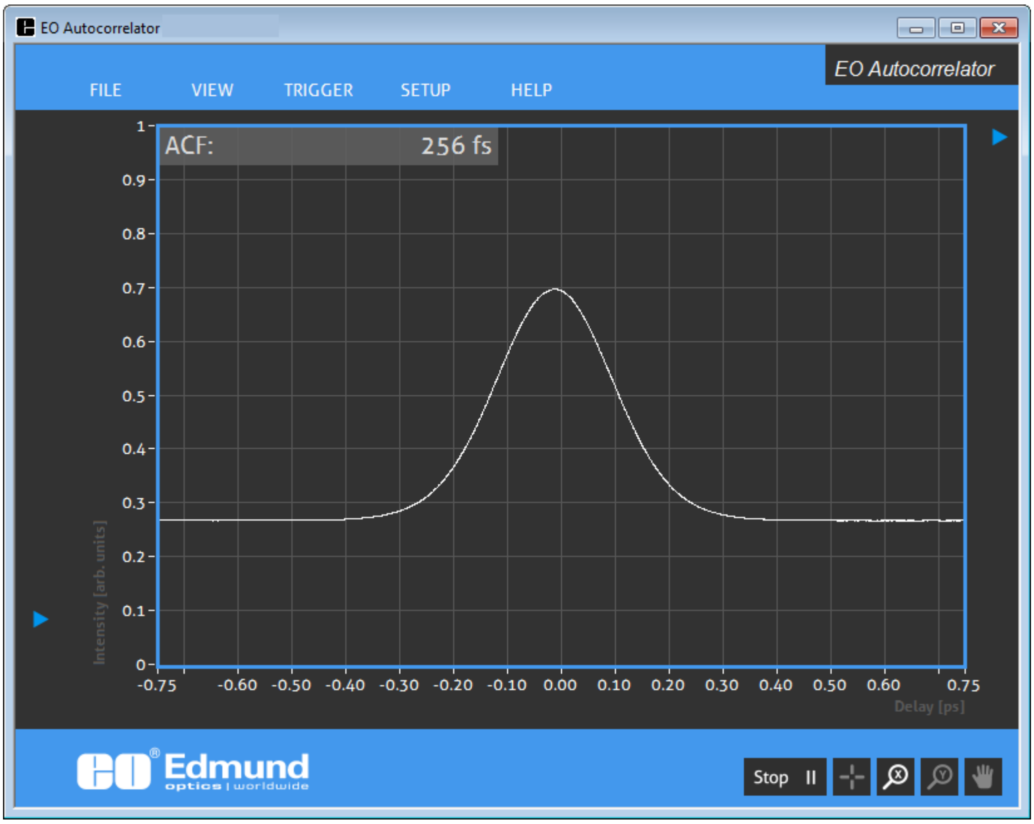


Figure 4.10.: Measurement window with additional display controls (lower right corner)

"**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 4.11).

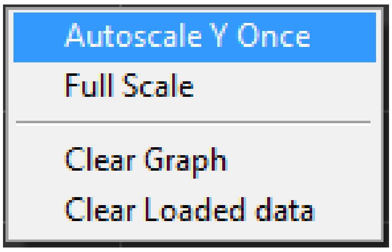


Figure 4.11.: Context menu available by right clicking on any free area within the measurement window.

"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 4.12)

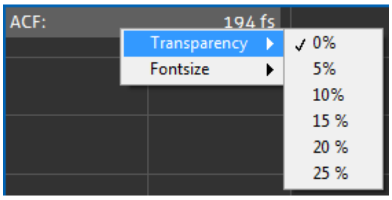


Figure 4.12.: Context menu available by right clicking on the Info box.

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 control unit in case the repetition rate of the laser is between 300 Hz and 50 kHz. Use the delivered trigger cable to connect the control unit electronics ("TRIGGER IN" port) with the trigger source. The 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 autocorrelator 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 4.13 demonstrates the connection between three exemplary trigger-delay values t1, t2, t3 and the respective ACF intensity. Here the blue peak on the left represents a laser pulse incident on the photodiode of the autocorrelator 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 t1-t3. 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.

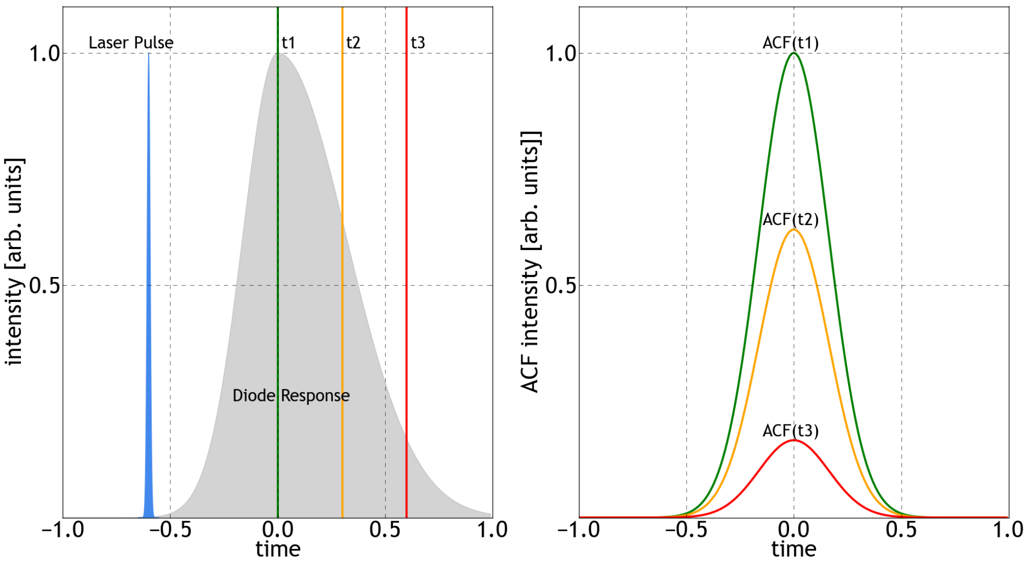


Figure 4.13.: Trigger delay versus ACF intensity

4.5. TCP/IP

The 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 autocorrelator accepts either the full command, e.g., "system", or the abbreviation marked by bold and capital LETTERS, e.g., "sys". The preface "ml" or "minilink" 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 44.

4.6. Error Sources of an Autocorrelation Measurement

4.6.1. Scan Range too small or too wide

The 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 4.14) the calculated FWHM value will be wrong.

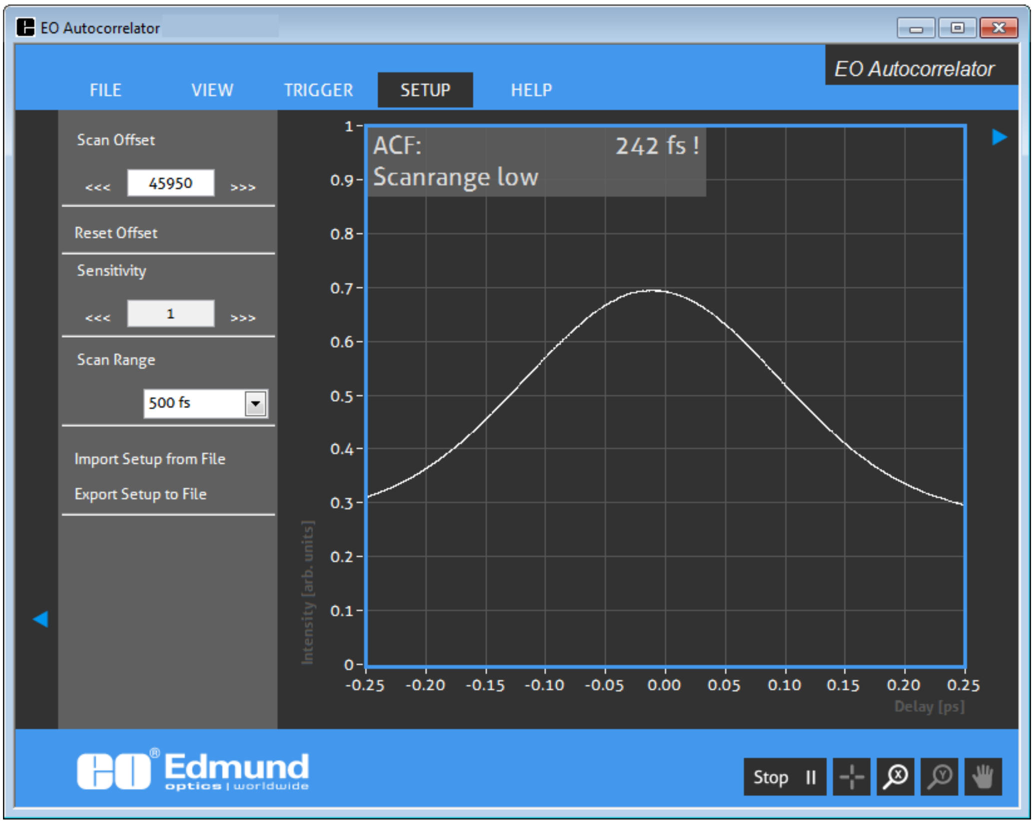


Figure 4.14.: If the Scan Range is too low a warning is displayed in the Info box

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 4.15). 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.

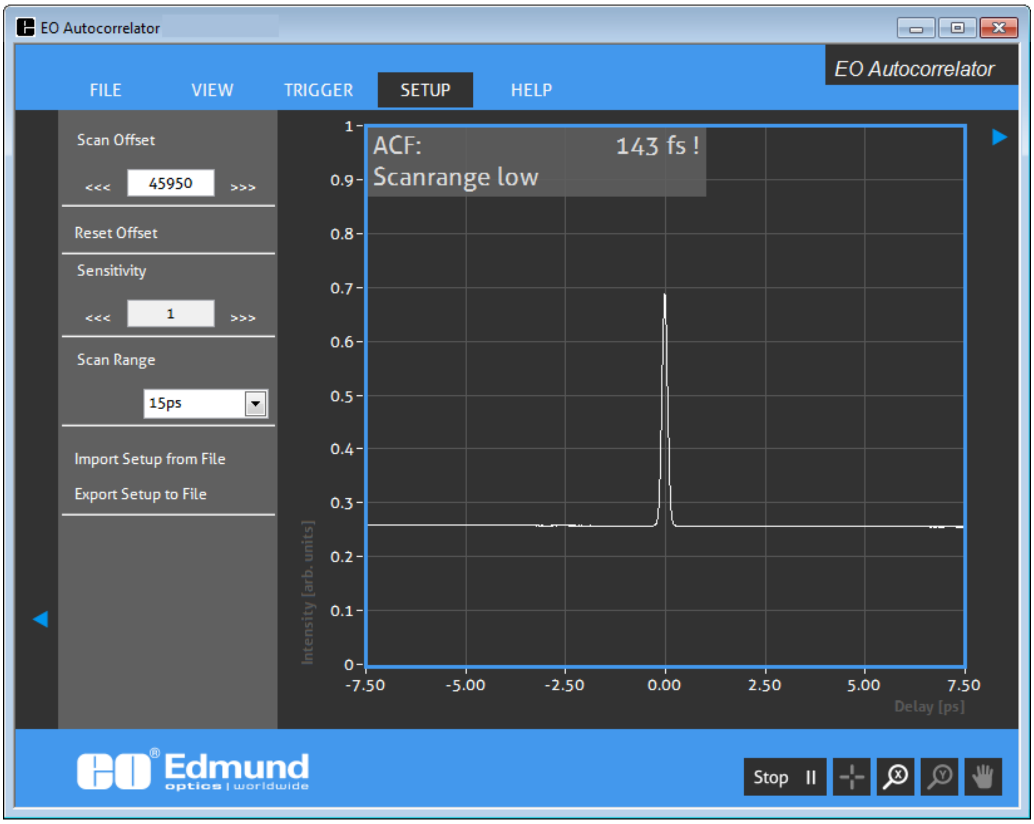


Figure 4.15.: The Scan Range is too large. The ACF is comprised by only few data points. This may lead to an unprecise measurement.

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 4.16). Clipping prevents the software from calculating the ACF value and must be avoided.

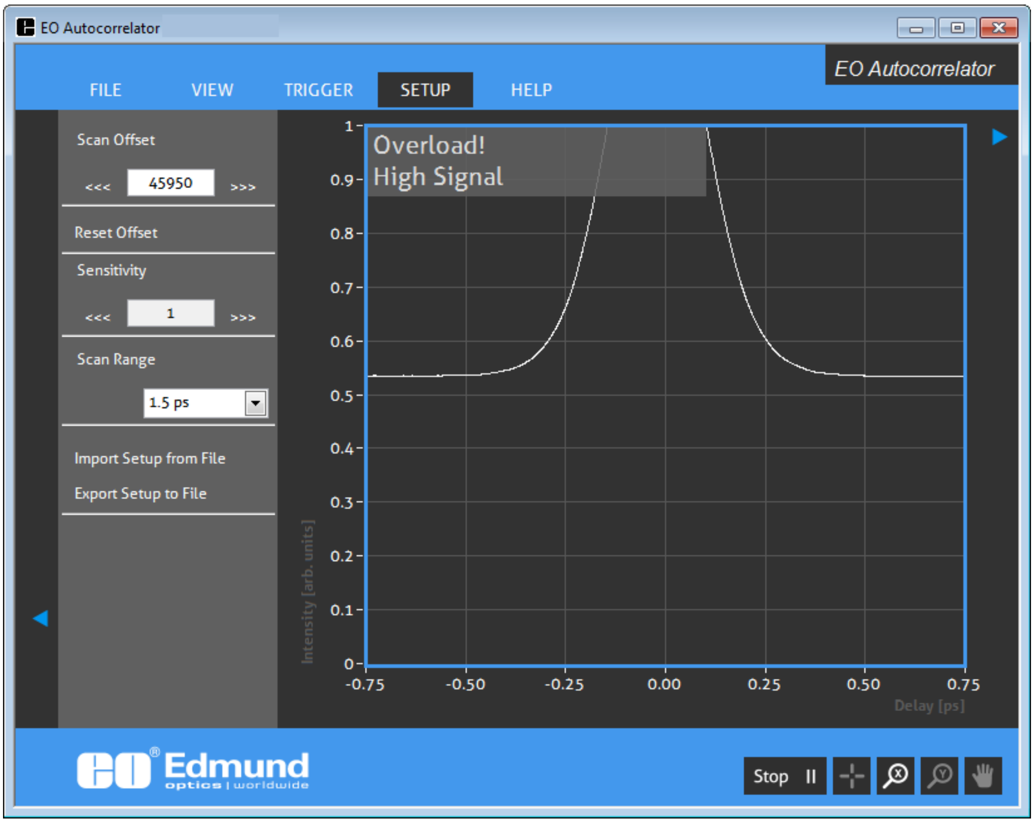


Figure 4.16.: A too high signal leading to ACF clipping is indicated by the info box.

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

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 4.17).

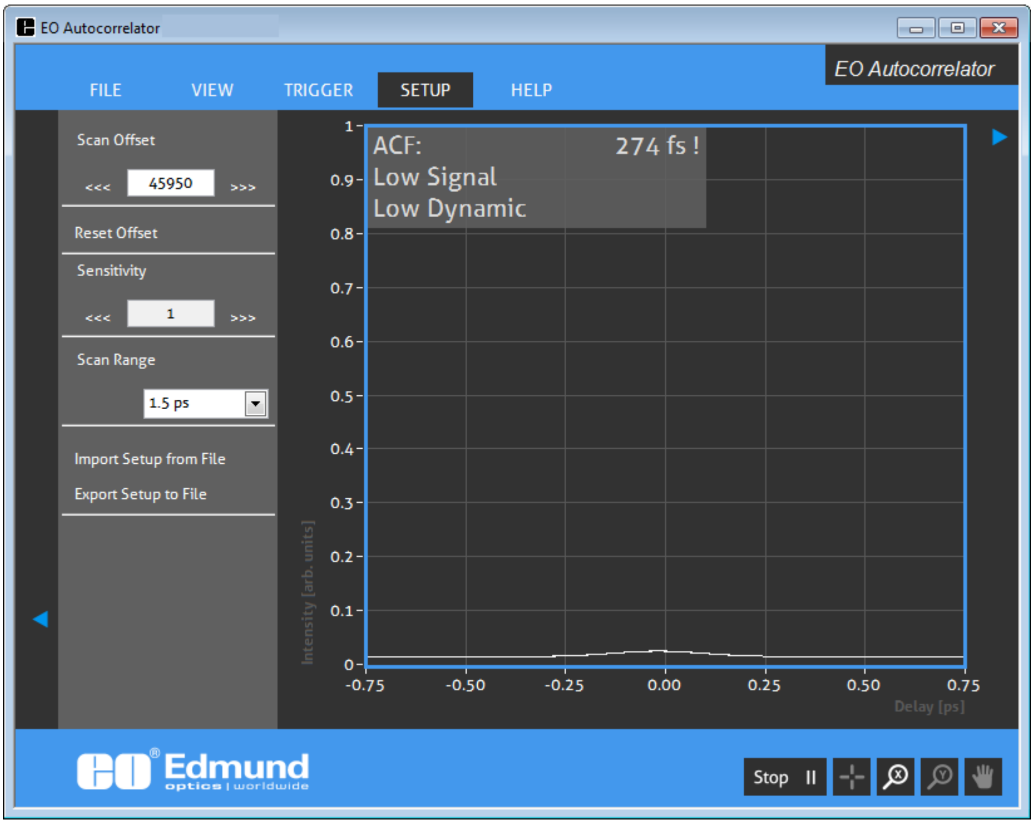


Figure 4.17.: A too weak signal leading to a low dynamic is indicated by the info box

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 4.18).

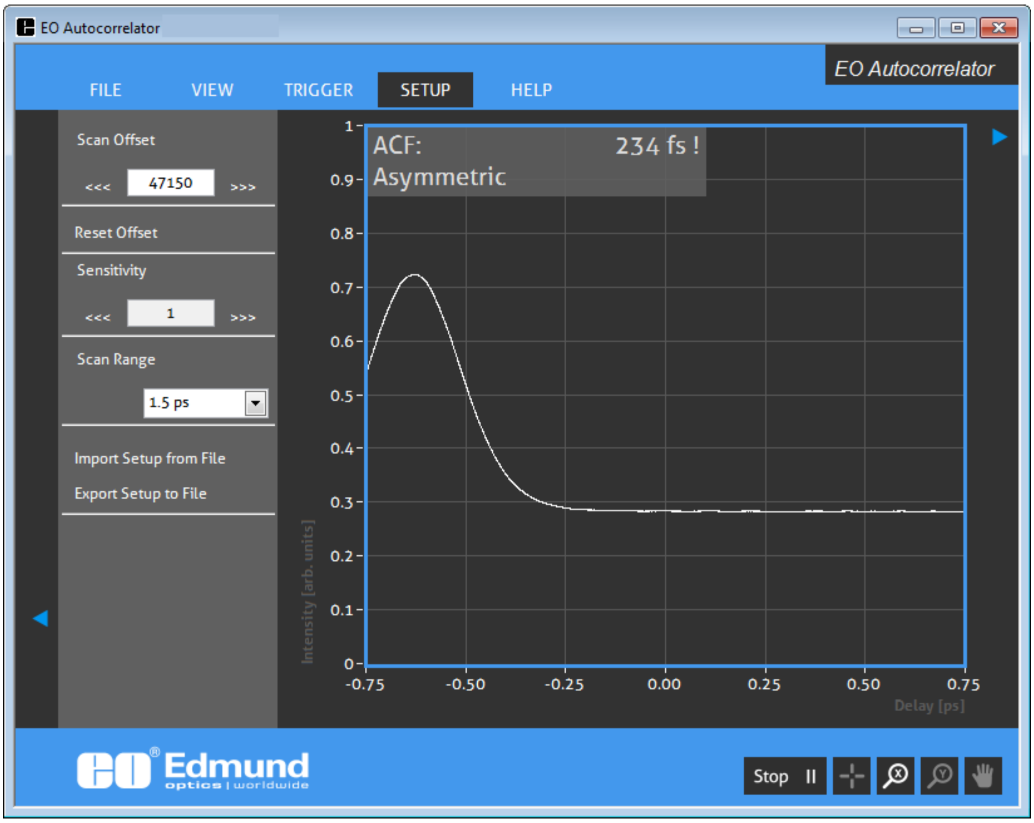


Figure 4.18.: ACF cut off to the left due to too large scan offset

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

5. Additional Hints

5.1. "Zero" Scan

In "Zero" scan range the delay drive is stopped at 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. During measurements mode the autocorrelation function is modulated with a fringe pattern. The filter suppresses this modulation. (This is not the case in triggered mode.) A comparison of an 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.

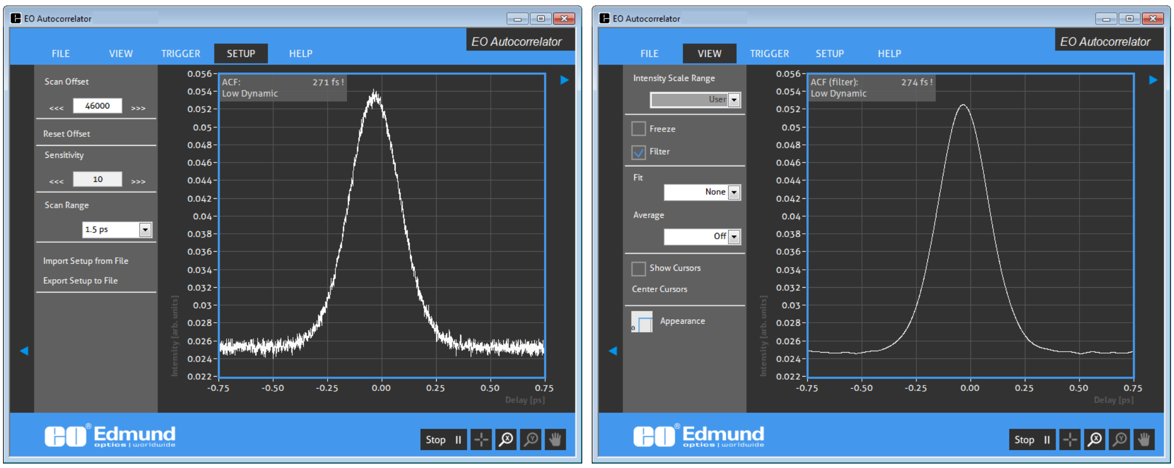


Figure 5.1.: ACF measurement with filter OFF (left) and filter ON (right)

5.3. 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. Therefore, for most exact measurements, it is advisable to adapt the power input level to an operation where only the lowest possible sensitivity is 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.

5.4. **Fundamental Overload**

At very extreme wavelengths (compared to the installed detector wavelength range) and input power levels the ACF can be superposed up to being completely covered by a background signal resulting from the fundamental wave. This can be avoided by using special filters and detectors. The latter can be ordered at your autocorrelator vendor.

6. Troubleshooting and Maintenance

6.1. Troubleshooting

Error characteristics	Possible reason	Check and removal
No TPA Signal	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.)
TPA Signal w / o ACF peak	wrong alignment of beam on detector	check with shutters (if it 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)

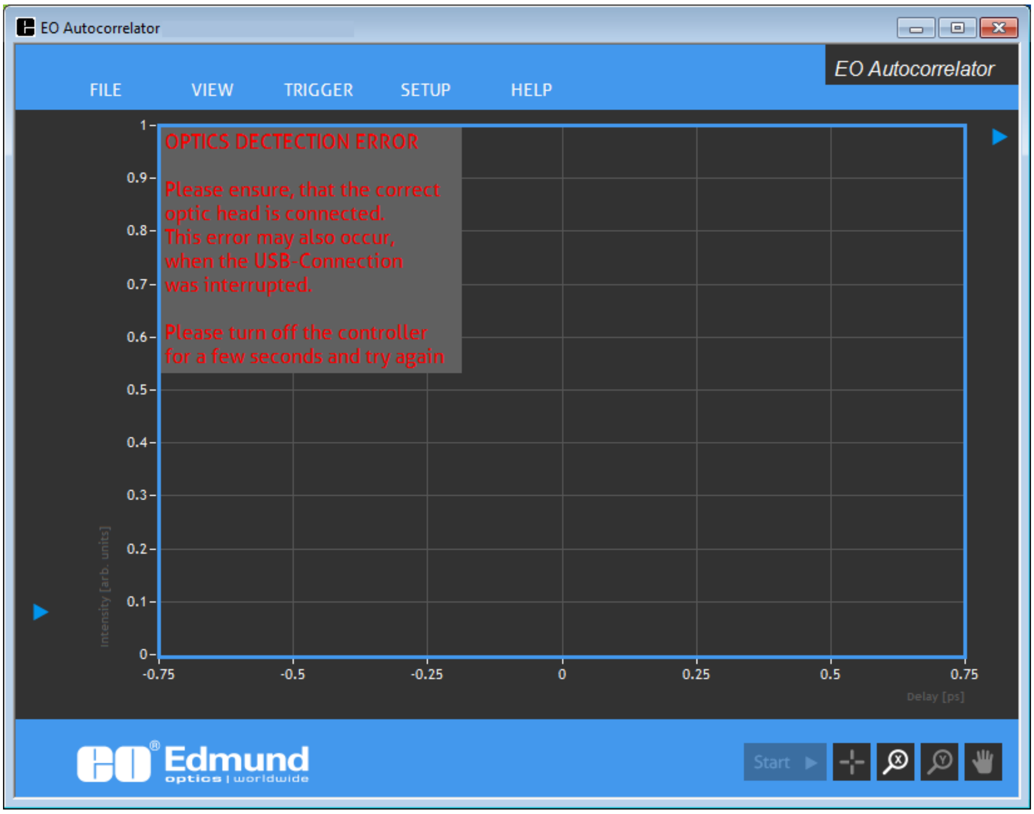


Figure 6.1.: "OPTICS DETECTION ERROR" Error Message

"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 autocorrelator system components or software by persons not authorized by A·P·E will result in invalidity of the guarantee and service contract.

6.2.1. Cleaning

Do not use any aggressive solvents to clean the autocorrelator components! Switch the laser OFF or block the input beam, switch the autocorrelator control unit 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 autocorrelator components.

6.3. 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
ape@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. Fitting Functions

A.1. Gaussian

The mathematical description for a Gaussian pulse is:

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

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

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

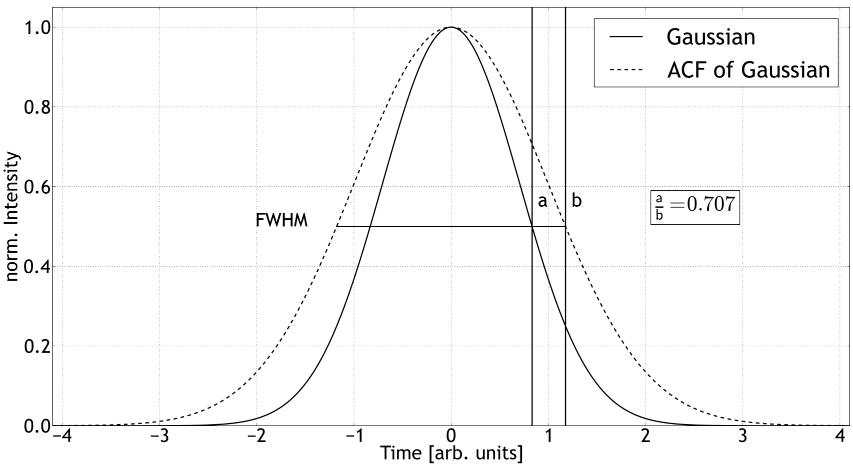


Figure A.1.: Gaussian function e^{-t^2} and its normalized autocorrelation $e^{\frac{-\tau^2}{2}}$ (dotted line)

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

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

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

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

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

A.2. Lorentzian

The mathematical description for a Lorentzian pulse is:

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

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

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

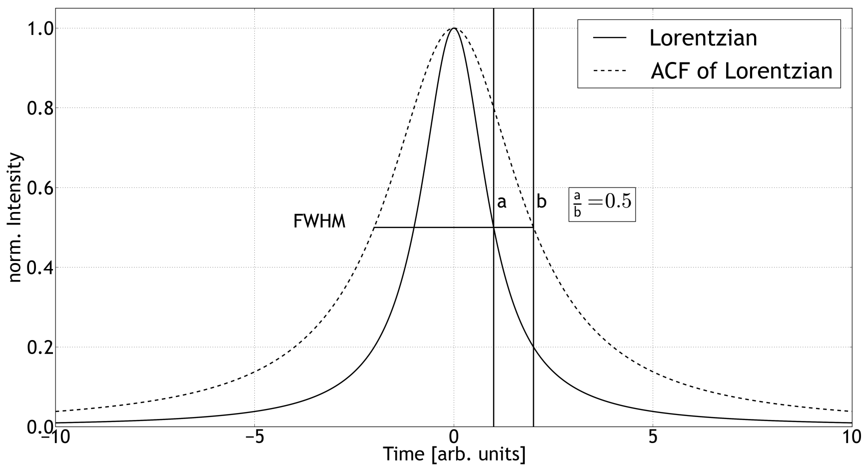


Figure A.2.: Lorentzian function $\frac{1}{1+t^2}$ and its normalized autocorrelation $\frac{4}{4+\tau^2}$ (dotted line)

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

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

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

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

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

A.3. sech^2

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

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

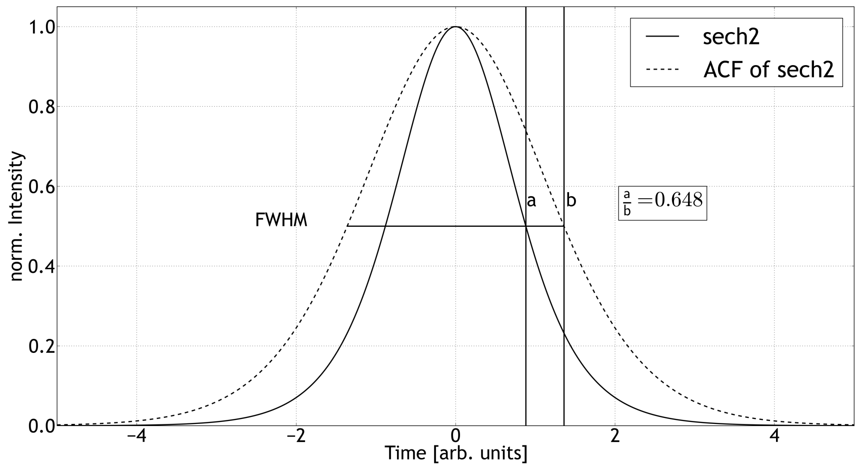


Figure A.3.: The function $\text{sech}(t)^2$ and its normalized autocorrelation $3\text{csch}(\tau)^3(\tau\cosh(\tau) - \sinh(\tau)$ (dotted line)

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

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

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

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

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

B. **TCP/IP Command Set**

This section provides a complete overview of the remote control commands of the autocorrelator. The command structure of the autocorrelator is mostly in agreement with the SCPI-standard. However, compliance nor conformance to the standard is stated here, 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 NOTICE:
In order to remotly control the control unit the software must run and a TCP/IP port must be set in the software. Do not attempt to send TCP/IP commands to the control unit 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 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

Example:

```
*OPER?
```

***INIT?**

Get Device Initialization Status

<init> integer

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"

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:

```
:sys:device?
```

SYSTEM:SNUMBER?
SYS:SNUMBER?

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

Example:

```
:sys:snumber?
```

SYSTEM:SOFTWARE?
SYS:SOFTWARE?

Get Software Version
<version> string
Software Version

Example:

```
:sys:software?
```

SYSTEM:HARDWARE?
SYS:HARDWARE?

Get Hardware Version
<version> string
Hardware Version

Example:

```
:sys:hardware?
```

SYSTEM:FIRMWARE?
SYS:FIRMWARE?

Get Firmware Version
<version> string
Firmware Version

Example:

```
:sys:firmware?
```

SYSTEM:MOTOR?
SYS:MOTOR?

Get Motor Type
<version> string
Motor Type

Example:

```
:sys:motor?
```

SYSTEM:HELP?
SYS:HELP?

Get List of all SCPI Commands
<command_list> array of s in block data format
Command List as block data

Example:

```
:sys:help?
```

STATUS:AVERAGE<number>
STA:AVERAGE<number>

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

Example:

```
:status:average 1
```

STATUS:AVERAGE?

STA:AVERAGE?

Get numer of measurements used for averaging

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

Example:

```
:status:average?
```

STATUS:FITTYPE<type>
STA:FITTYPE<type>

Set type of curve fit to apply to measured ACF

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

Example:

```
:status:fittype 1
```

STATUS:FITTYPE?
STA:FITTYPE?

Get type of calculated curve-fit

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

Example:

```
:status:fittype?
```

STATUS:START?
STA:START?

Status of Measurement

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

Example:

```
:status:start?
```

STATUS:FILTER<status>
STA:FILTER<status>

Set Status of ACF Filtering
<status> string

Example:

```
:status:filter 1
```

STATUS:FILTER?
STA:FILTER?

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

Example:

```
:status:filter?
```

STATUS:TRIGGER<status>
STA:TRIGGER<status>

Toggle Triggermode
<status> string

Example:

```
:status:trigger
```

STATUS:TRIGGER?
STA:TRIGGER?

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

Example:

```
:status:trigger?
```

STATUS:MEASUREMENT?
STA:MEA?

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

Example:

```
:status:trigger?
```

STATUS:DETECTOR?
STA:DETECTOR?

Get PMT Detection Status
<status> string
PMT detected (1 = PMT found, 0 = no PMT)

Example:

```
:status:detector?
```

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

Set Crystal Position
<number> integer
Crystal Position

Example:

```
:xtal:tuning 1234
```

CRYSTAL:TUNING?
XTAL:TUN?

Get Crystal Position
<number> integer
Crystal Position

Example:

```
:xtal:tuning?
```

CRYSTAL:MOVE?
XTAL:MOV?

Get Status of Optics Movement
<number> integer
Optics Servo Status (1 - Servo moving, 0 - Servo not moving)

Example:

```
:xtal:mov?
```

MOTOR:SCANFREQUENCYNOAMP?
MOT:SFRNA?

Get ScanFrquency
<number> integer
ScanFrequency in Hz

Example:

```
:motor:sfrna?
```

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

Set ScanRange
<scanrange> integer, unit: fs
Scanrange 0/ZREO: 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)

Example:

```
:motor:scr 15000
```

MOTOR:SCANRANGE?
MOT:SCR?

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

Example:

```
:motor:scr?
```

DETECTOR:GAIN<value>
DET:GAIN<value>

Set PMT Gain value (Function has no effect, if standard optics units (w/o a PMT) is connected)
<value> integer, range: 300 ... 1000
PMT Gain Value

Example:

```
:detector:gain 450
```

DETECTOR:GAIN?
DET:GAIN?

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

Example:

```
:detector:gain?
```

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

Activate Autogain Feature
<number> integer
Status of autogain feature

Example:

```
:detector:autogain 1
```

DETECTOR:AUTOGAIN?
DET:AUG?

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

Example:

```
:detector:autogain?
```

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

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

Example:

```
:detector:sensitivity 10
```

DETECTOR:SENSITIVITY?

DET:SEN?

Get Sensitivity

<number> integer

Detector Sensitivity | 1: Low Sensitivity | 10: High Sensitivity | 100: (optional "HighSen"-Feature)

Example:

```
:detector:sensitivity?
```

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

Set Trigger Level

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

Trigger Level

Example:

```
:trigger:level
```

TRIGGER:LEVEL?
TRI:LVL?

Get Trigger Level

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

Trigger Level

Example:

```
:trigger:level?
```

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

Set Trigger Delay

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

Trigger Delay

Example:

```
:trigger:delay
```

TRIGGER:DELAY?
TRI:DEL?

Get Trigger Delay

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

Trigger Delay

Example:

```
:trigger:delay?
```

TRIGGER:FREQUENCY?
TRI:FRQ?

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

Example:

```
:trigger:frequency?
```

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

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

Example:

```
:trigger:impedance
```

TRIGGER:IMPEDANCE?
TRI:IMP?

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

Example:

```
:trigger:impedance?
```

ACF:DATA?
ACF:RAW_DATA?

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

<acf> 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:FIT_DATA?
ACF:FIT?

Get ACF Fit Data as it is displayed

<acf> array of s in block data format

Fitted 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:fit?
```

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. (Note: Prior to V1.0.2.255 this value does not include the correction factor. Please multiply the value with 0.71 for gaussian, 0.5 for lorentz and 0.648 for sech2 fits to get the correct value)

Example:

```
:acf:fitfwhm?
```

ACF:FIT_COEFF?
ACF:FITC?

Get fit curve parameters
<fwhm> integer
Parameters calculated by the fitting algorithm, separated by semi-colons: [Amplitude];[X-Shift];[FWHM];[Y-Shift]

Example:

```
:acf:fit_coeff?
```

SERVICE:MODE?

Get current operation mode
<mode> integer
State of Service Mode (0 = Default mode, 1 = Service mode)

Example:

```
:serivce:mode?
```

SERVICE:CONFIG?

Get content of the local configuration/calibration file (Service Mode required)
<cfg> array of s in block data format
Content of the local configuration file

Example:

```
:serivce:config?
```

SERVICE:DEV_CONFIG?

Get content of the device configuration/calibration file (Service Mode required)

<cfg> array of s in block data format
Content of the device configuration file

Example:

```
:serivce:dev_config?
```

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:	autocorrelator
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 Identification:
Product

EO autocorrelator with TPA detector
A·P·E Id: 156525

Signature:

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

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