APE Autocorrelator Product Family

APE Autocorrelators

- The autocorrelator product family by APE includes a variety of impressive features and properties, designed to cater for a wide range of ultrafast laser applications. Market pioneer for almost 25 years, APE provides both standard and customized solutions for even the most sophisticated requirements.

- The technology behind APE products makes it possible to measure ultrashort pulses from femtoseconds to picoseconds, with either Second Harmonic Generation (SHG) detection or Two Photon Absorption (TPA) detection principle, to suit your individual measurement needs.

APE Autocorrelators at a Glance

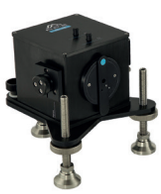
- Wide choice of optics and detector sets (PMT, PD, or TPA)
- Ready to use software and USB interface
- Wide wavelength range from 200 nm to 12 µm
- Wide range of pulse widths from < 10 fs to 400 ps
- Compact footprint with the Mini PD and Mini TPA line
- NIST traceable calibration
- TCP/IP remote control with standardized command set for easy programming

Autocorrelators Model Overview

pulseCheck

- Multitalent for any task

page 4



Mini TPA

- Compact and tuning-free

page 10

Mini PD

- Routine tasks with a fixed wavelength range

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Carpe

- First choice for multiphoton microscopy

page 16

... Benefits & Technology

Optics and Detector Technology

- The APE range of three different detector types and Optics Sets enables you to cover a wide diversity of professional applications. For example, photomultiplier (PMT) detectors are highly sensitive and are therefore ideal for pulse measurement at lowest pulse energies. Spectrally enhanced photodiodes, on the other hand, are perfect for measurements of higher power laser beams. In combination with highly efficient optics, these detectors pave the way for measurements across an extensive wavelength spectrum from 200 nm to 12 µm.

Collinear and Non-Collinear Measurements

- Both the pulseCheck and Mini PD products support fast switching between collinear and non-collinear measurement modes. Collinear, often referred to as interferometric or fringe-resolved mode, provides additional qualitative information about the chirp and central wavelength of the pulse. In contrast, non-collinear mode, also known as intensity autocorrelation, provides a background-free autocorrelation with a high dynamic range. A „hybrid“ of these two modes, collinear intensity autocorrelation, is realized with the Mini TPA and TPA Optics Sets for the pulseCheck.

Automatic Phase Matching

- Phase-sensitive, nonlinear processes, such as those used by the autocorrelator, require phase matching for highly efficient Second Harmonic Generation. The pulseCheck by APE achieves this fully automatically for any wavelength range, resulting in precise and fast operation with no manual adjustment needed. Because they perform the task of both detector and nonlinear optics, the TPA detectors provides tuning-free operation over a wide wavelength range.

NIST Traceable Calibration

- Laboratories and manufacturers are often faced with systematically establishing an unbroken chain of calibrations to specified references. All APE autocorrelator models are calibrated to a traceable standard in accordance with NIST (U.S. National Institute of Standards and Technology) measurement traceability specifications. A printed and signed calibration certificate is provided with each instrument.

Acquisition Software and TCP/IP Standard Software Interface

- All models come with an easy to use data acquisition software, allowing for real-time data display. Furthermore, the TCP/IP-based standard software interface by APE makes it straight forward to set up remote control. This allows you, for example, to design your own automated measurement routines. Simply use our protocol templates for rapid configuration with familiar programming languages, including C++, C#, LabVIEW, Python, Matlab, and Ruby.

pulseCheck The Modular Autocorrelator

Pulse Measurement Perfection with the Multitalent from APE

- It is good to have plenty of options at hand. Suitable for the characterization of virtually any ultrafast pulsed laser, the pulseCheck autocorrelator from APE covers the broadest possible range of wavelengths and pulse widths. This flexibility is achieved by using exchangeable Optics Sets, typically consisting of a nonlinear crystal and a dedicated detector module.

- Exchangeable Optics Sets for broadest spectrum coverage from 200 nm to 12 µm
- Pulse widths from as low as <10 fs all the way up to 400 ps
- Ultra-precise delay resolution
- Toggle between interferometric and intensity autocorrelation
- Wide range of sensitivity levels covered with PMT, PD, and TPA
- Automatic phase matching
- Gaussian, $Sech^2$, and Lorentzian fitting routines
- Ready to use software and USB interface
- TCP/IP remote control with standardized command set for easy programming
- NIST traceable calibration
- ☐ Option: FROG for complete pulse characterization (page 8)

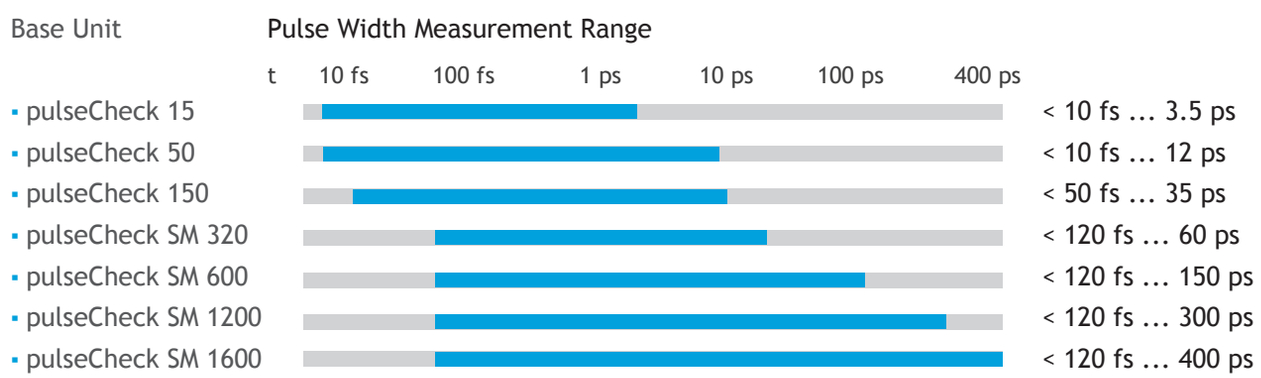
... Flexibility for your Experiments

Maximum Functionality through Modular Design

- APE fulfills a growing need for maximum functionality and flexibility with the modular concept on which its pulseCheck autocorrelator series is based.

1. From Ultrashort to Longer Pulses

- The various pulseCheck configurations can be optimized accordingly to suit your individual pulse width measurement needs. Extra-long pulse durations are accessible with pulseCheck SM, which utilizes fast and highly precise stepping motor technology to measure long pulses across a larger scan range.



2. High Sensitivity and Low Noise with Three Types of Detectors

- The three detector types address the need for low noise and enhanced sensitivity in different applications. For pulse measurement with extreme sensitivity and low pulse energy, we recommend our photomultiplier (PMT) detector. Spectrally enhanced photodiodes (PD, TPA), on the other hand, are the ideal choice for measurements requiring sensitivities of a few mW^2.

▪ Photodiode Detector (PD)	Standard sensitivity up to 1 W^2
▪ Photomultiplier (PMT)	Highest sensitivity up to 10^{-6} W^2
▪ Two Photon Absorption (TPA)	High sensitivity up to 10^{-2} W^2

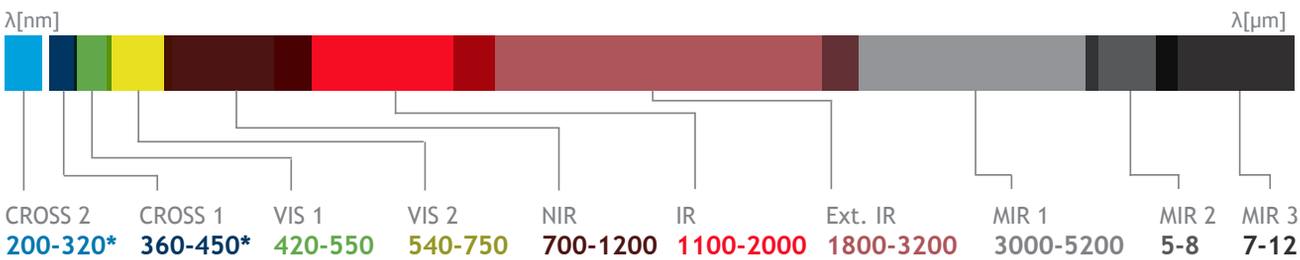
pulseCheck Unprecedented Wavelength Range

3. Ultimate Wavelength Range

- The detectors and Optics Sets available from APE cover a wide range of wavelengths, from UV at 200 nm to Mid-IR at 12 µm.

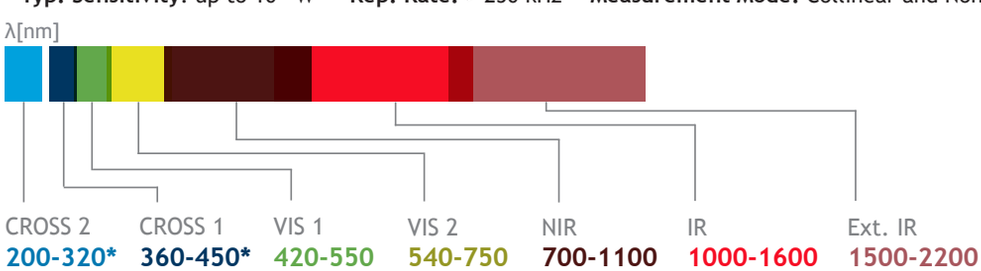
Photodiode (PD)

▪ **Typ. Sensitivity:** 1 W^2 ▪ Rep. Rate: > 10 Hz ▪ Measurement Mode: Collinear and Non-collinear



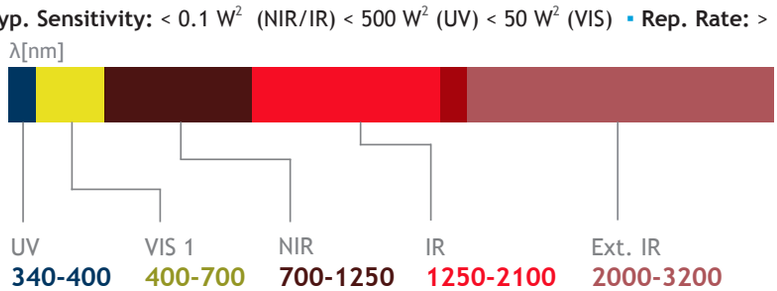
Photomultiplier (PMT)

▪ **Typ. Sensitivity:** up to 10^{-6} W^2 ▪ **Rep. Rate:** > 250 kHz ▪ **Measurement Mode:** Collinear and Non-collinear



Two Photon Absorption (TPA)

▪ **Typ. Sensitivity:** < 0.1 W^2 (NIR/IR) < 500 W^2 (UV) < 50 W^2 (VIS) ▪ **Rep. Rate:** > 10 Hz ▪ **Measurement Mode:** Collinear Intensity



* For cross-correlation, wavelength range depends on pump wavelength

pulseCheck Specifications

Specifications

Measurable Pulse Width Range	depending on Base Unit: < 10 fs ... 3.5 ps < 10 fs ... 12 ps < 50 fs ... 35 ps < 120 fs ... 60 ps < 120 fs ... 150 ps < 120 fs ... 300 ps < 120 fs ... 400 ps
Wavelength Range	200 nm - 12 µm, depends on Optics Set
Optics Sets	Exchangeable
Detector (Optics Sets)	PMT, PD, or TPA
Delay Resolution	< 0.001 % of scan range
Delay Linearity	< 1 %
Sensitivity	Typically 1 ... 10^{-6} W^2 depending on Optics Set*
Recommended Repetition Rate	PD, TPA: 10 Hz and above; PMT: 250 kHz and above
Type of Measurement Mode	PMT, PD : non-collinear intensity, collinear interferometric; TPA: hybrid collinear intensity
Mode Switching	Available for PMT, PD
SHG Tuning for Phase Matching	PMT/PD: automatic; TPA: not applicable
Trigger Mode	TTL, f < 50 kHz; pulseCheck SM < 1 kHz
Input Polarization	Linear horizontal, vertical available as option
Input Beam Coupling	Free-space; Option: fiber coupling FC/PC, FC/APC, SMA
Max Input Power	1 W (e.g. oscillator with a rep. rate of approx. 70 MHz) or 10 µJ (e.g. amplified system with rep. rates in the kHz range), whichever results in lower value
Input Aperture	6 mm (free-space)
Software	Included; Real-time display of pulse width and central wavelength, different fitting routines
Fitting Routine	Gaussian, $Sech^2$, Lorentz
Connection	USB
Remote Control	Possible via TCP/IP (SCPI command set)
Calibration	NIST traceable calibration certificate included

Options

- Various Optics Sets incl. detector
- Fiber coupling
- Polarization rotator
- FROG**

Dimensions and Power

Dimensions	250 x 190 x 315 mm (pulseCheck 15 / 50) Different dimensions for pulseCheck 150 and SM series (See appendix for details)
Power	95 ... 240 V, 50 ... 60 Hz, 60 W

* Measured sensitivity including Optics Set, defined as average power times peak power of the incident pulses P_{AV} * P_{peak}
** Except for pulseCheck SM models

Second Harmonic Generation FROG

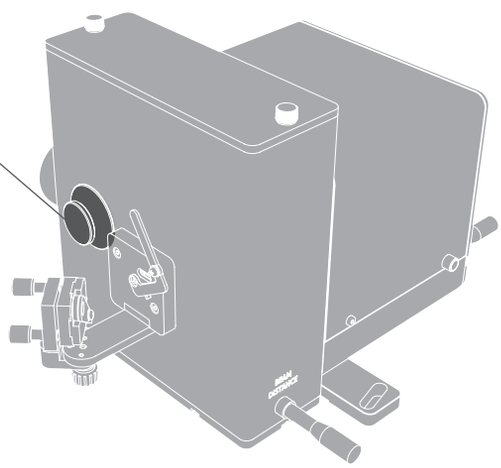
Complete Pulse Characterization with pulseCheck and FROG Option

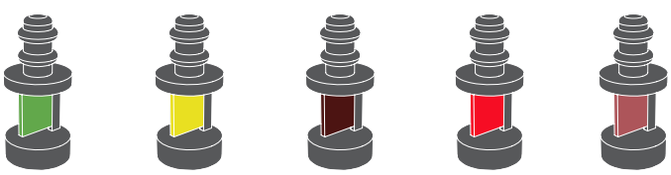
- Second Harmonic Generation FROG is the most popular spectrometer-less Frequency Resolved Optical Gating method. The pulseCheck autocorrelators by APE optionally integrate FROG, giving access to complete pulse characterization. The addition of a special nonlinear crystal module and dedicated software opens the door to complete spectral and temporal pulse characterization.

Crystal Module

FROG Setup:

1. Crystal Module within pulseCheck
2. Replacement Focus Mirror
3. FROG Software Upgrade





VIS I **420-550** | VIS II **550-700** | NIR **700-900** | IR I **900-1200** | IR II **1200-1600**

Different crystal modules for various wavelength ranges.*

- Complete pulse characterization with Second Harmonic Generation FROG
- Different crystal modules available to cover wavelengths from 420 – 1600 nm
- FROG trace data processing and visualization with included software
- Pulse width ranges from as low as 20 fs up to 6 ps
- High spectral resolution up to 0.1 nm
- Available for the pulseCheck autocorrelator series**

* See appendix for configuration details (page 20)
** Except for pulseCheck SM models; Required laser rep. rate >10 kHz

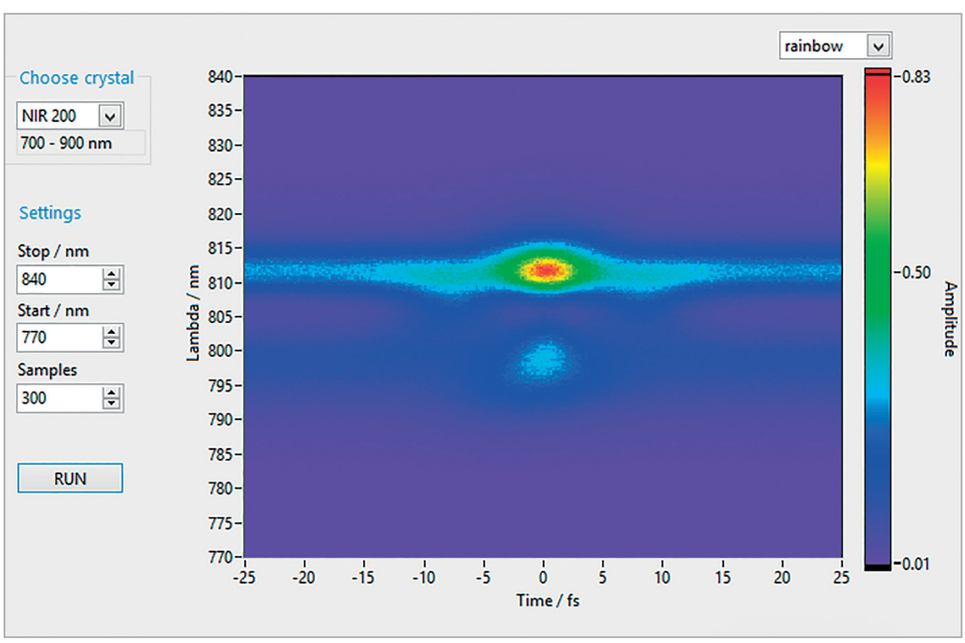
... FROG Pulse Characterization Software

FROG Trace

- The software provides the laser pulse intensity as a function of time and frequency (wavelength). This is visualized in form of the common FROG trace diagram.
- With the implemented phase matching routine from pulseCheck, it only is a matter of seconds to automatically find the required phase matching tuning angle.

Wavelength and Pulse Coverage

- The various crystals available guarantee coverage of wavelengths from 420 nm right up to 1600 nm, of pulse widths from 20 fs to 6 ps, and a spectral resolution starting as high as 0.1 nm.
- The FROG option is designed for laser repetition rates above 10 kHz and is available for the pulseCheck autocorrelator series (except for SM models).



Software interface FROG for pulseCheck

Mini TPA Compact and Tuning-free Autocorrelator

Compact and Tuning-free Autocorrelator

- The Mini TPA by APE is the perfect combination of tuning-free autocorrelation measurement, compact size and high sensitivity.

- Exchangeable Optics Sets for spectral coverage from 340 nm to 3200 nm
- Tuning-free TPA detection process
- UV measurement without cross-correlation
- Compact design for minimum space requirements and maximum portability
- Ultra-precise delay resolution
- Hybrid collinear intensity autocorrelation
- Gaussian, $Sech^2$, and Lorentzian fitting routines
- Including software and USB interface
- TCP/IP remote control with standardized command set for easy programming
- NIST traceable calibration
- Aluminium carrying case

... with Exchangeable Optics Sets

Tuning-Free Wavelength Matching

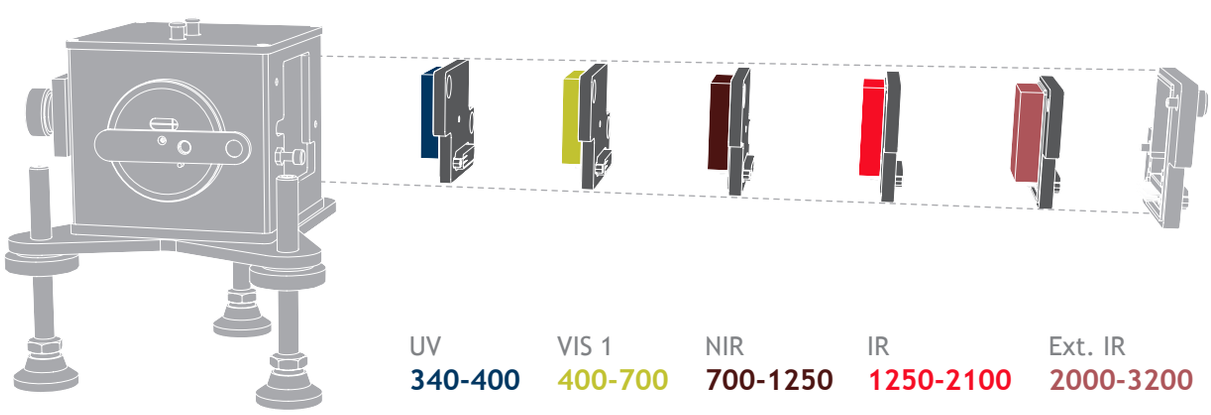
- Conventionally, autocorrelators used to split an optical pulse into two replicas and recombine them for the Second Harmonic Generation (SHG) in a nonlinear crystal. The APE Mini TPA instead benefits from the two photon absorption principle. This eliminates the need of SHG crystal angle tuning and makes the wavelength tuning process unnecessary.

UV Range without Cross-Correlation

- Together with an UV Optics Set, the Mini TPA provides simple pulse width measurement in the UV range, from 340 nm to 400 nm — without the need for cross-correlation. Elimination of the cross-correlation approach also makes the data evaluation easier, by cutting the conventional two-step process to a single-step solution.

Ultra-wide Wavelength Coverage in Compact Design

- APE provides a selection of exchangeable Optics Sets, ranging from UV at 340 nm to IR at 3200 nm, for sensitive measurements across an extremely broad wavelength region. Due to its compact footprint, the Mini TPA is also the perfect answer to your space-saving and easy portability requirements.



Mini TPA Specifications

Specifications

Measurable Pulse Width Range	50 fs ... 3.5 ps; Optional: down to 35 fs
Wavelength Range	340 nm - 3200 nm, depending on Optics Set
Optics Sets	Exchangeable
Delay Resolution	< 0.001 % of scan range
Delay Linearity	< 1 %
Sensitivity	Typically 0.1 W^{2*}, UV range < 500 W^{2*} (depending on Optics Set)
Recommended Repetition Rate	> 300 Hz; For UV only: upper limit 2 MHz
Type of Measurement Mode	Collinear intensity
Mode Switching	No
SHG Tuning for Phase Matching	Not required
Trigger Mode	300 Hz ... 50 kHz
Input Polarization	Linear horizontal, vertical available as option
Max. Input Power	300 mW or 5 µJ (whichever results in lower value)
Input Aperture	6 mm (free-space)
Input Beam Coupling	Free-space; Optional: fiber coupling FC/PC, FC/APC, SMA
Beam Input Height	86 … 150 mm; Optional 50 mm
Software	Included; Real-time display of pulse width and central wavelength, different fitting routines
Fitting Routine	Gaussian, $Sech^2$, Lorentz
Connection	USB
Remote Control	Possible via TCP/IP (SCPI command set)
Calibration	NIST traceable calibration certificate included

Options

- Various Optics Sets incl. detector
- Short pulse option
- Fiber coupling
- Input polarization rotator
- Reduced input beam height

Dimensions and Power

Dimensions	160 x 220 (or 140**) x 155 mm (W x H x D) (See appendix for details)
Power	95 ... 240 V, 50 ... 60 Hz, 60 W

* Measured sensitivity including Optics Set, defined as average power times peak power of the incident pulses $P_{AV} * P_{peak}$
** Optional for 50 mm input beam height

Mini PD Autocorrelator for Routine Tasks

Autocorrelator for Routine Tasks

- The Mini PD by APE is the perfect combination of compact size and a single wavelength range.

- Available in various models, each covering a different wavelength range
- Compact design for minimum space requirements and maximum portability
- Switching between interferometric and intensity autocorrelation
- Ultra-precise delay resolution
- Software-aided phase matching
- Gaussian, $Sech^2$, and Lorentzian fitting routines
- Including software and USB interface
- TCP/IP with standardized command set for easy programming
- NIST traceable calibration
- Aluminium carrying case

... Autocorrelator for Routine Tasks

Different Models for Different Wavelengths

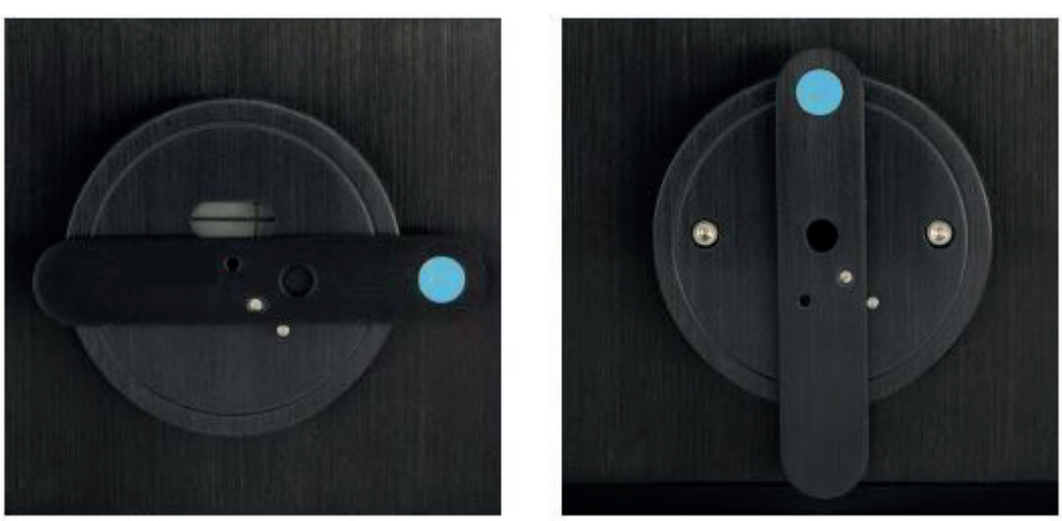
- The Mini PD is available in a selection of models, each of which covers a different wavelength range, and is ideal for routine tasks where a change in Optics Sets is not necessary.

Compact Design

- With its compact footprint of only 160 x 220 x 155 mm, the Mini PD is perfect for working environments where space is limited. When it is needed elsewhere, simply place this portable unit in the lightweight aluminum case provided, for easy and safe transportation to the next site.

Switching Between Collinear and Non-Collinear Mode

- The Mini PD supports quick and easy switching between collinear and non-collinear measurement modes. While collinear mode provides pulse width measurement with additional qualitative information about the chirp, non-collinear mode gives background-free autocorrelation with a high dynamic range.



View of alignment window in collinear and non-collinear mode.

Mini PD Specifications

Specifications

Measurable Pulse Width	50 fs ... 3.5 ps; Optional: down to 10 fs
Wavelength Versions	VIS 1 420 ... 550 nm; VIS 2 540 ... 750 nm; NIR 700 ... 1200 nm; IR 1100 ... 1800 nm
Optics Sets	Not exchangeable
Detector	PD
Delay Resolution	< 0.001 % of scan range
Delay Linearity	< 1 %
Sensitivity	Typically 1 W^{2}*
Recommended Repetition Rate	> 300 Hz
Type of Measurement Mode	Non-collinear intensity, collinear interferometric
Mode Switching	Yes
SHG Tuning for Phase Matching	Software aided
Trigger Mode	300 Hz ... 50 kHz
Input Polarization	Linear horizontal, vertical available as option
Max. Input Power	1 W (e.g. oscillator with a rep. rate of approx. 70 MHz) or 10 µJ (e.g. amplified system with rep. rates in the kHz range), whichever results in lower value
Input Aperture	6 mm (free-space)
Input Beam Coupling	Free-space; Optional: fiber coupling FC/PC, FC/APC, SMA
Beam Input Height	86 … 150 mm; Optional 50 mm
Software	Included; Real-time display of pulse width and central wavelength, different fitting routines
Fitting Routine	Gaussian, $Sech^{2}$, Lorentz
Connection	USB
Remote Control	Possible via TCP/IP (SCPI command set)
Calibration	NIST traceable calibration certificate included

Options

- Short pulse option
- Input polarization rotator
- Fiber coupling
- Reduced beam input height

Dimensions and Power

Dimensions	160 x 220 (or 140**) x 155 mm (W x H x D) (See appendix for details)
Power	95 ... 240 V, 50 ... 60 Hz, 60 W

* Measured sensitivity including Optics Set, defined as average power times peak power of the incident pulses P_{AV} * P_{peak}
** Optional for 50 mm input beam height

Carpe Microscopy Autocorrelator

Microscopy Autocorrelator

- APE's Carpe is a handy option for reviewing the management of short laser pulses in an optical microscope system.
- The Carpe autocorrelator measures the pulse duration at both the sample location and the input of the microscope. A comparison of the pulse widths obtained at these two spots enables you to calculate the pulse broadening effect. This effect is caused by dispersion of the microscope optics, but also depends to a large extent on the pulse width of the incoming laser beam.
- Furthermore, power detection at the sample location supports systematic and quantitative studies which explore how laser power affects samples or the fluorescence lifetime of probes.
- By examining the influence of the laser pulse duration, the power, and the dispersion of the microscope optics, you can fine-tune and optimize microscopy imaging at the relevant spot.
- These measurements can be also done using large NA (numerical aperture) or immersion lenses.

- Study the effect of pulse duration, power, and optics dispersion on microscopy imaging
- Measure pulse widths at the sample position and point of microscope input
- Measure average power at sample position
- Estimate the peak power in conjunction with the pulse width
- ☐ Option: Short working distance, e.g. for immersion objective lenses
- ☐ Option: femtoControl for optimizing the duration of femtosecond laser pulses

Carpe Specifications

Specifications

Measurable Pulse Width	50 fs ... 3.5 ps; Optional: 30 fs ... 3.5 ps
Wavelength Range (for pulse width measurement)	700 ... 1100 nm
Wavelength Range (for power detection)	700 ... 1000 nm
Power Measurement	0 ... 30 mW; 0 ... 300 mW
Recommended Repetition Rate	> 500 kHz
Working Distance	> 0.5 mm; Optional < 0.5 mm
Input Polarization	Linear horizontal

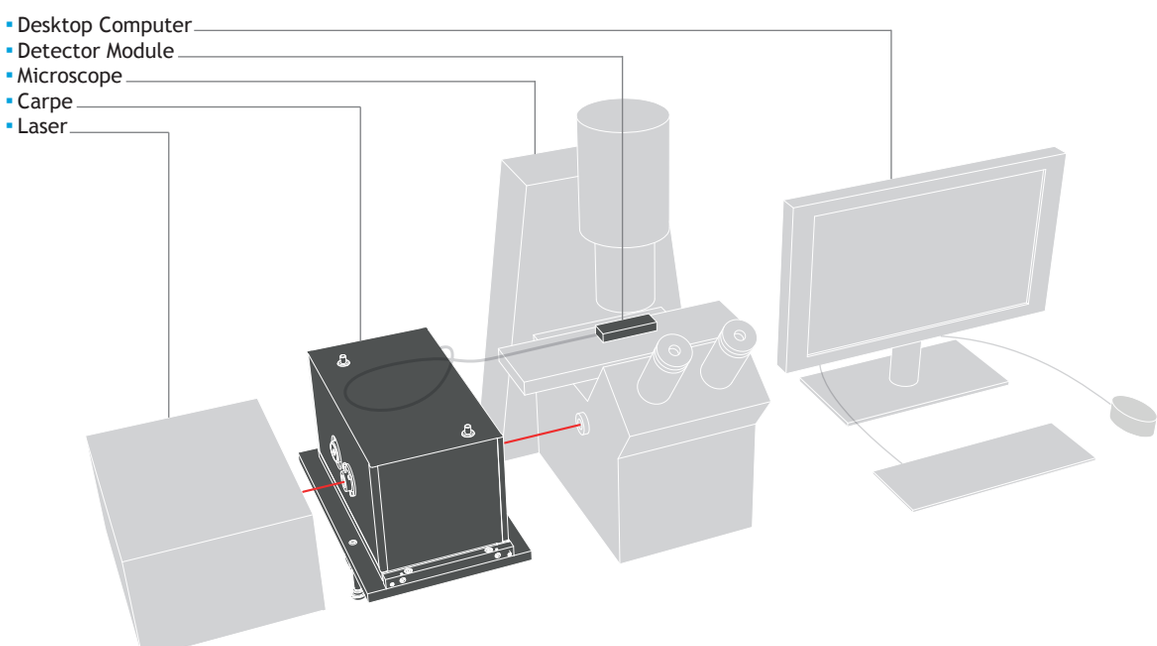
Options

- Short working distance < 0.5 mm (e.g. immersion lenses)
- APE pulse compressor femtoControl (Dispersion management)

Dimensions and Power

Dimensions	295 x 173 x 180 mm (See appendix for details)
Power	95 ... 240 V, 50 ... 60 Hz, 60 W

Example Setup



Example setup of how the Carpe can be used

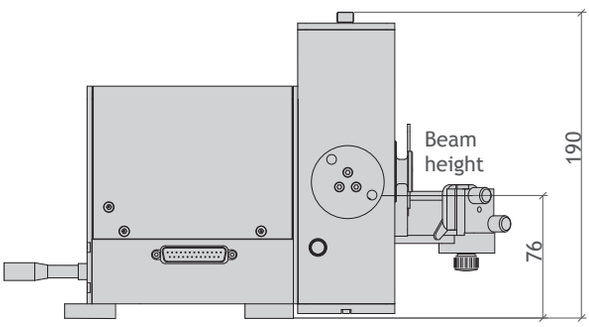
Appendix Technical Drawings

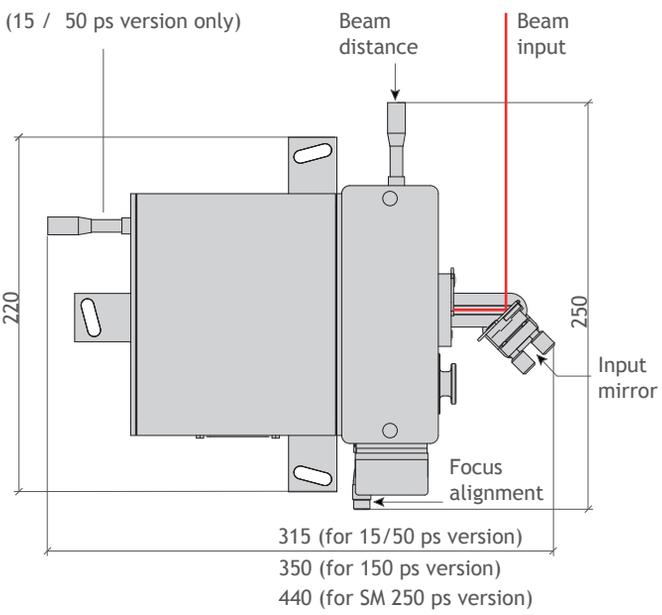
All Dimensions in mm

pulseCheck

- Multitalent for any task

page 4





Mini TPA

- Compact and tuning-free

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Mini PD

- Routine tasks with a fixed wavelength range

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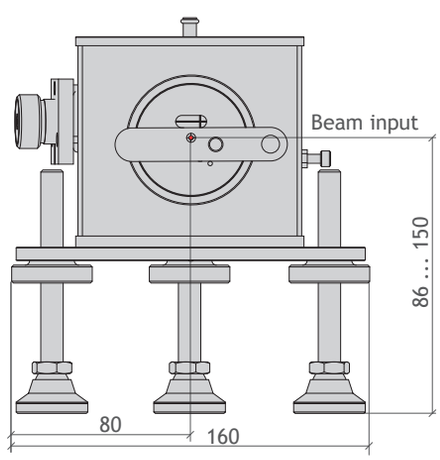
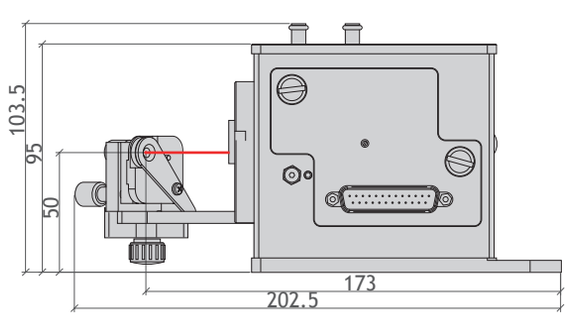
Standard Version



Optional Reduced Beam Input Height Version



Mini TPA and Mini PD have the same case

Appendix Technical Drawings

All Dimensions in mm

Carpe

- First choice for multiphoton microscopy

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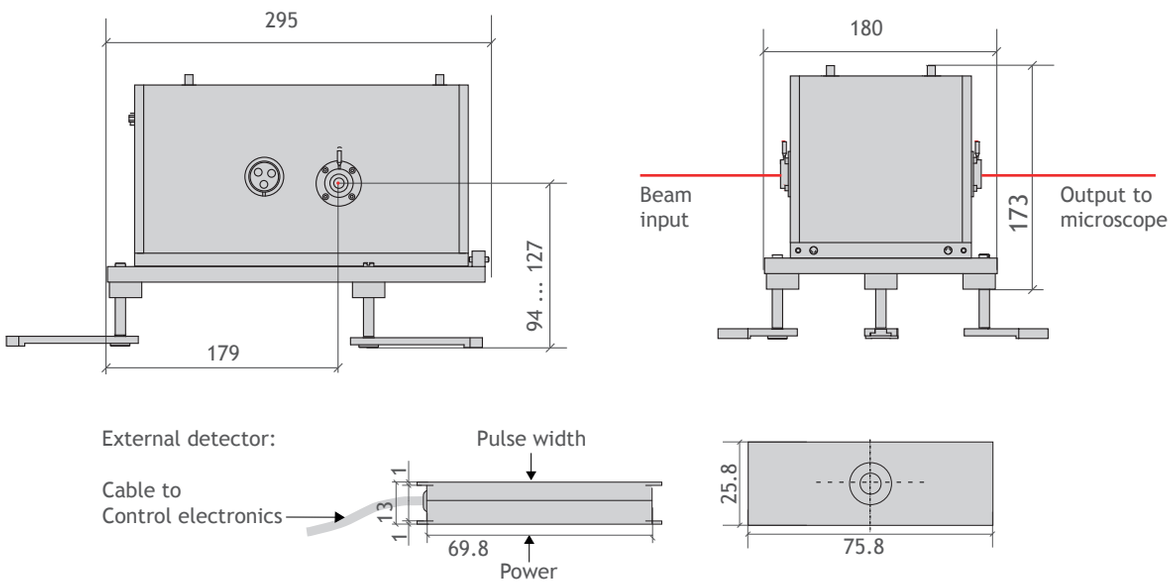

Appendix FROG Crystals

FROG Crystal	Wavelength Range	Pulse Width Range	Spectral Resolution
VIS-I-200	420 ... 550 nm	200 ... 6000 fs	0.1 nm
VIS-I-50	420 ... 550 nm	50 ... 200 fs	0.3 nm
VIS-I-20	420 ... 550 nm	20 ... 70 fs	1 nm
VIS-II-150	550 ... 700 nm	150 ... 2000 fs	0.1 nm
VIS-II-50	550 ... 700 nm	50 ... 200 fs	0.3 nm
VIS-II-20	550 ... 700 nm	20 ... 60 fs	2 nm
NIR-200	700 ... 900 nm	200 ... 5000 fs	0.1 nm
NIR-50	700 ... 900 nm	50 ... 500 fs	0.2 nm
NIR-20	700 ... 900 nm	20 ... 50 fs	3 nm
IR-I-150	900 ... 1200 nm	150 ... 900 fs	0.2 nm
IR-I-60	900 ... 1200 nm	60 ... 200 fs	1 nm
IR-I-30	900 ... 1200 nm	30 ... 60 fs	5 nm
IR-II-100	1200 ... 1600 nm	100 ... 700 fs	0.5 nm
IR-II-50	1200 ... 1600 nm	50 ... 100 fs	2 nm
IR-II-30	1200 ... 1600 nm	30 ... 50 fs	9 nm

Similar Products

Spider - Complete pulse characterization
waveScan - High resolution spectrometer
peakDetect - Pulse quality monitoring

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