Excellence in Ultrafast

Ultrafast Lasers

for Industrial and Scientific Applications

2018

LIGHT CONVERSION

Ultrafast Lasers

for Industrial and Scientific Applications

2018 Product Catalogue

Rev. 20180522

LIGHT CONVERSION

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What we do

We are the world leading manufacturer of wavelength tunable ultrafast light sources based on TOPAS and ORPHEUS series of optical parametric amplifiers (OPA) as well as DPSS femtosecond lasers PHAROS and CARBIDE. PHAROS, the most versatile femtosecond laser amplifier on the market, and the ultra-compact and cost-efficient CARBIDE feature market-leading output parameters along with robust design attracting both industrial and scientific customers.

PHAROS reliability is proven by hundreds of systems operating in 24/7 production environment since it was introduced. Main applications include drilling and cutting of different metals, ceramics, sapphire, glass, material ablation for mass-spectrometry, etc. Among the customers are major manufacturers in display, automotive, LED, medical device industries and others.

Our laser amplifiers are complemented by a strong portfolio of ultrafast products: harmonics modules (provide femtosecond pulses at 515, 343, 257 and 206 nm), OPAs (produce continuous tuning output from ~190 nm up to ~20 μm), HARPIA and CHIMERA spectrometers, TiPA and GECO autocorrelators. All devices can be modified and fine-tuned to meet the most demanding applications.

Who we are

Light Conversion (official name UAB MGF "Šviesos konversija") is a privately owned company with >190 employees. We are based in Vilnius, the capital of Lithuania. Design, R&D and production are done in our state-of-the-art facility opened in 2014. We are the largest manufacturer of femtosecond Optical Parametric Amplifiers (OPAs) and Non-Collinear OPAs (NOPAs). Apart from sales through our distributors, we also provide our production as OEM devices for other major laser manufacturing companies.

With more than 3000 systems installed worldwide, Light Conversion has established itself as a reliable and innovative producer of ultrafast optical devices.

Contents

Ultrafast Lasers

Scientific Instruments

PHAROS

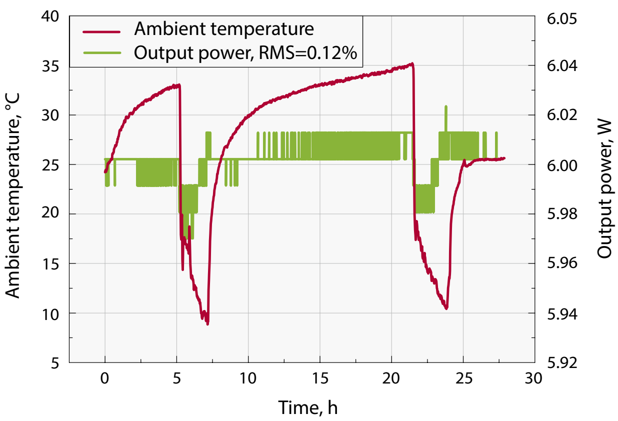
High Power and Energy Femtosecond Lasers

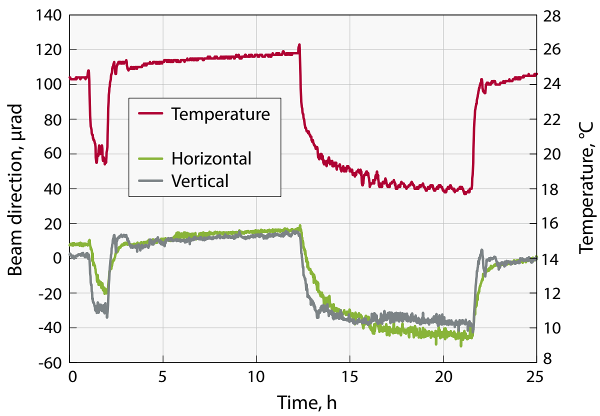
FEATURES

- 190 fs – 20 ps tunable pulse duration
- 2 mJ maximum pulse energy
- 20 W output power
- Single shot – 1 MHz tunable base repetition rate
- Pulse picker for pulse-on-demand operation
- Rugged, industrial grade mechanical design
- Automated harmonics generators (515 nm, 343 nm, 257 nm, 206 nm)

PHAROS is a single-unit integrated femtosecond laser system combining millijoule pulse energies and high average power. PHAROS features a mechanical and optical design optimized for industrial applications such as precise material processing. Compact size, integrated thermal stabilization system and sealed design allows PHAROS integration into machining work-stations. The use of solid state laser diodes for pumping of Yb medium significantly reduces maintenance cost and provides long laser lifetime.

Most of the PHAROS output parameters can be easily set via PC in seconds. Tunability of laser output parameters allows PHAROS system to cover applications normally requiring different classes of lasers. Tunable parameters include: pulse duration (190 fs – 20 ps), repetition rate (single pulse to 1 MHz), pulse energy (up to 2 mJ) and average power (up to 20 W). Its deliverable power is sufficient for most of material processing applications at high machining speeds. The built-in pulse picker allows convenient control of the laser output in pulse-on-demand mode. It comes along with an extensive external control interface dedicated for easy laser integration into larger setups and machining workstations. PHAROS compact and robust optomechanical design includes easy to replace modules with temperature stabilized and sealed housings ensuring stable laser operation across varying environments. PHAROS is equipped with an extensive software package, which ensures smooth hands-free operation.





PHAROS output power with power lock enabled under unstable environment

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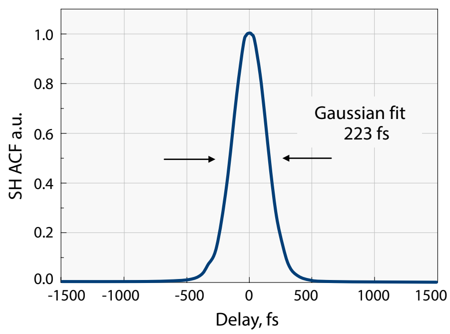
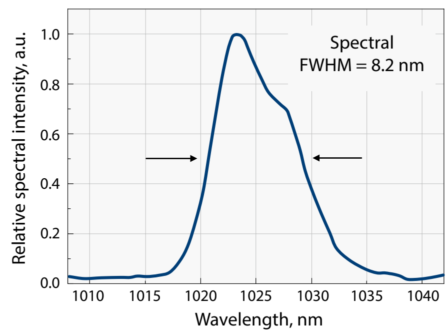
SPECIFICATIONS

Model	PHAROS-6W	PHAROS-10W	PHAROS-15W	PHAROS-20W	PHAROS SP	PHAROS SP 1.5	PHAROS 2mJ
Max. average power	6 W	10 W	15 W	20 W	6 W		6 W
Pulse duration (assuming Gaussian pulse shape)	< 290 fs				< 190 fs		< 300 fs
Pulse duration range	290 fs – 20 ps				190 fs – 10 ps		300 fs – 10 ps
Max. pulse energy	> 0.2 mJ or > 0.4 mJ				> 1.0 mJ	> 1.5 mJ	> 2 mJ
Beam quality	TEM_{00} ; M^2 < 1.2				TEM_{00} ; M^2 < 1.3		
Base repetition rate	1 kHz – 1 MHz [1]						
Pulse selection	Single-Shot, Pulse-on-Demand, any base repetition rate division						
Centre wavelength	1028 nm ± 5 nm						
Output pulse-to-pulse stability	< 0.5 % rms [2]						
Power stability	< 0.5 % rms over 100 h						
Pre-pulse contrast	< 1 : 1000						
Post-pulse contrast	< 1 : 200						
Polarization	Linear, horizontal						
Beam pointing stability	< 20 µrad/°C						
Oscillator output	Optional, please contact Light Conversion for specifications						
PHYSICAL DIMENSIONS							
Laser head	670 (L) × 360 (W) × 212 (H) mm						
Rack for power supply and chiller	640 (L) × 520 (W) × 660 (H) mm						
UTILITY REQUIREMENTS							
Electric	110 V AC, 50 – 60 Hz, 20 A or 220 V AC, 50 – 60 Hz, 10 A						
Operating temperature	15 – 30 °C (air conditioning recommended)						
Relative humidity	20 – 80 % (non condensing)						

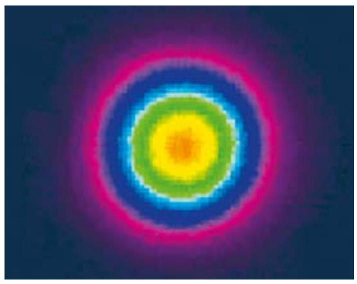
[1] Some particular repetition rates are software denied due to system design. *[2] Under stable environmental conditions.*



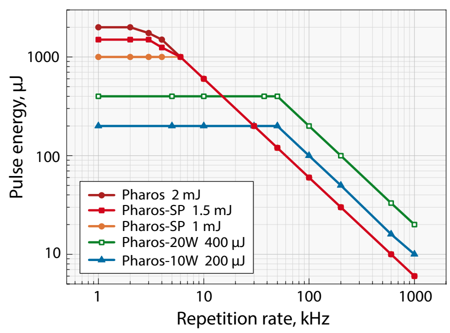
Pulse duration of PHAROS



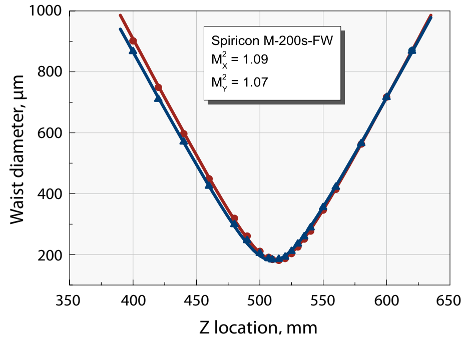
Spectrum of PHAROS



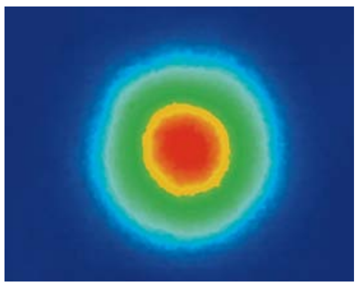
Typical PHAROS far field beam profile at 200 kHz



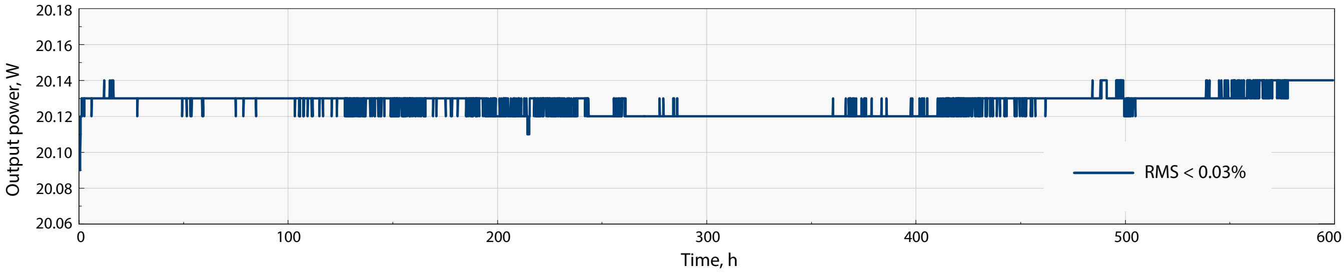
Pulse energy vs base repetition rate



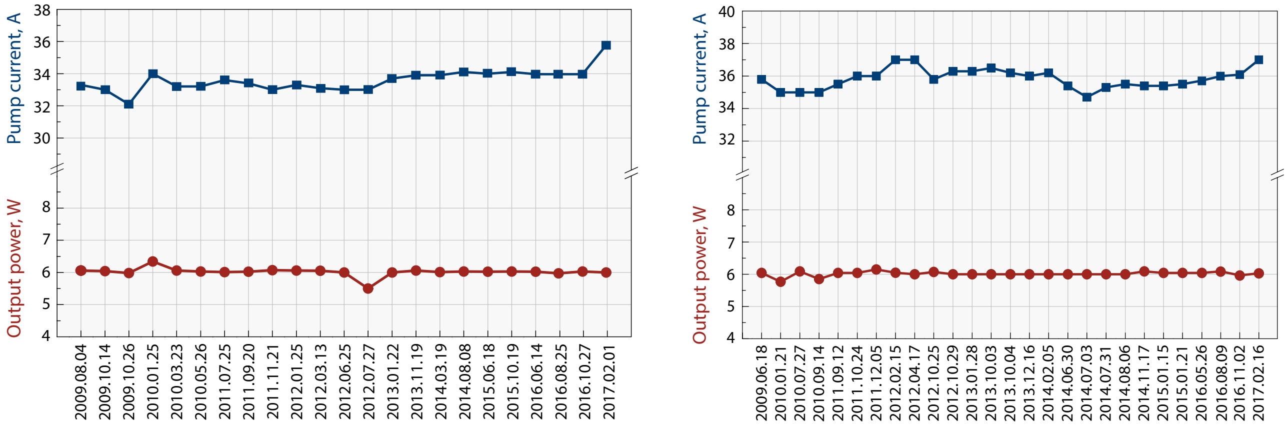
Typical PHAROS M^2 measurement data



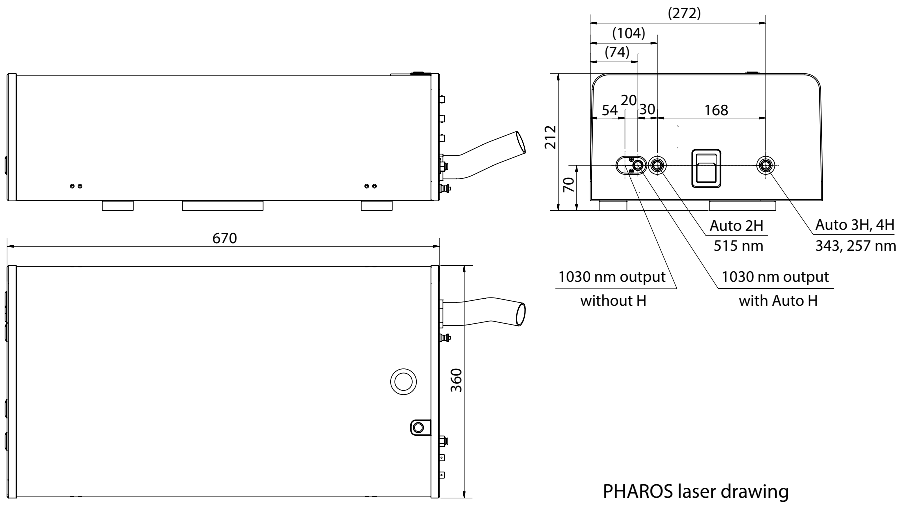
Typical PHAROS near field beam profile at 200 kHz



PHAROS long term stability graph



Output power of industrial PHAROS lasers operating 24/7 and current of pump diodes during the years



PHAROS laser drawing

Rev. 20180522

PHAROS

Automated Harmonics Generators

FEATURES

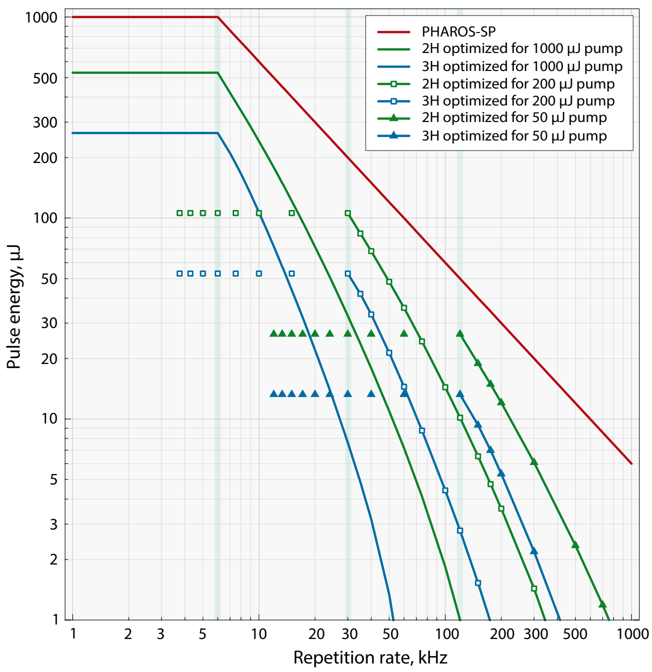
- 515 nm, 343 nm, 257 nm and 206 nm
- Output selection by software
- Mounts directly on laser head and integrated into the system
- Rugged, industrial grade mechanical design

PHAROS laser can be equipped with automated harmonics modules. Selection of fundamental (1030 nm), second (515 nm), third (343 nm), fourth (257 nm) or fifth (206 nm) harmonic output is available through software control. Harmonics generators are designed to be used in industrial applications where a single output wavelength is desired. Modules are mounted directly on the output of the laser and integrated into the system.

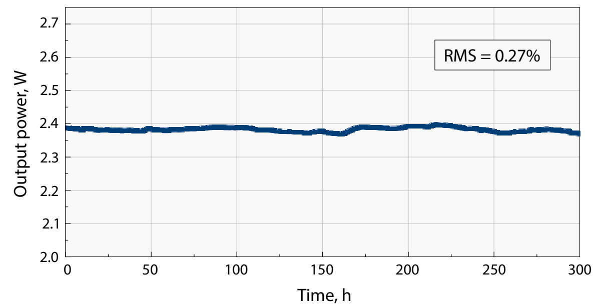
SPECIFICATIONS

Model	2H	2H-3H	2H-4H	4H-5H
Output wavelength (automated selection)	1030 nm 515 nm	1030 nm 515 nm 343 nm	1030 nm 515 nm 257 nm	1030 nm 257 nm 206 nm
Input pulse energy	20 – 2000 µJ	50 – 1000 µJ	20 – 1000 µJ	200 – 1000 µJ
Pump pulse duration	190 – 300 fs			
Conversion efficiency	> 50 % (2H)	> 50 % (2H) > 25 % (3H)	> 50 % (2H) > 10 % (4H) *	> 10 % (4H) * > 5 % (5H)
Pump laser beam quality (M^2)	< 1.2 / < 1.3 depends on a model			
Beam quality (M^2) ≤ 400 µJ pump	515 nm: M^2 (pump) + 0.1	515 nm: M^2 (pump) + 0.1 343 nm: M^2 (pump) + 0.2	515 nm: M^2 (pump) + 0.1 257 nm: n/a	n/a
Beam quality (M^2) > 400 µJ pump	515 nm: M^2 (pump) + 0.2	515 nm: M^2 (pump) + 0.2 343 nm: M^2 (pump) + 0.3	515 nm: M^2 (pump) + 0.2 257 nm: n/a	n/a

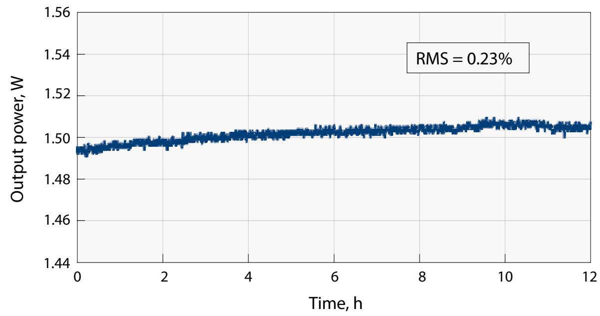
** Max 1 W output.*



Harmonics energy vs pulse repetition rate



3H output stability



4H output stability

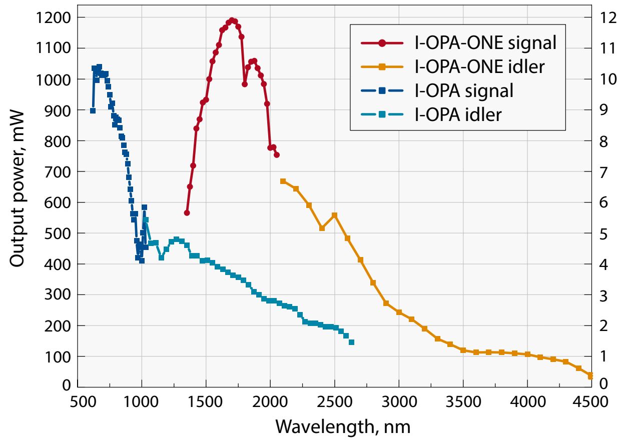
PHAROS

Industrial grade Optical Parametric Amplifier

FEATURES

- Based on experience with ORPHEUS line
- Manually tunable wavelength
- Industrial grade design provides excellent long-term stability
- Very small footprint
- Bandwidth limited or short-pulse configurations available
- CEP option

I-OPA is an optical parametric amplifier of white-light continuum pumped by the PHAROS laser. This OPA is focused on generating long-term stable output with reliable hands-free operation. Manually tunable output wavelength extends the application possibilities of a single laser source, instead of requiring multiple lasers based on different technologies.
In comparison to standard ORPHEUS line of devices, the I-OPA lacks only computer controlled wavelength selection. On the other hand, in-laser mounted design provides mechanical stability and eliminates the effects of air-turbulence, ensuring stable long-term performance and minimizing energy fluctuations.



I-OPA module energy conversion curves.
Pump: PHAROS-10W, 100 μJ, 100 kHz

PHAROS i-OPA MODEL COMPARISON TABLE

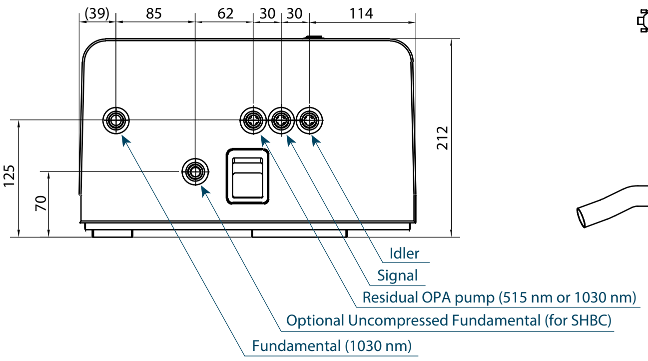
Model	I-OPA	I-OPA-F	I-OPA-ONE	I-OPA-CEP
Based on OPA	ORPHEUS	ORPHEUS-F	ORPHEUS-ONE	–
Pump pulse energy	10 – 500 μJ	10 – 400 μJ	20 – 500 μJ	150 – 500 μJ
Pulse repetition rate	Up to 1 MHz			Up to 100 kHz
Tuning range, signal	630 – 1030 nm	650 – 900 nm	1350 – 2060 nm	–
Tuning range, idler	1030 – 2600 nm	1200 – 2500 nm	2060 – 4500 nm	1400 – 2500 nm
Conversion efficiency signal+idler combined	> 12 %	> 10 %	> 14 %	> 10 %
Pulse energy stability < 2 % STD over 1 min. [1]	650 – 950 nm 1150 – 2000 nm	650 – 850 nm 1350 – 2000 nm	1500 – 3500 nm	1400 – 2000 nm
Pulse bandwidth [2]	100 – 150 cm^{-1}	200 – 600 cm^{-1}	80 – 200 cm^{-1}	~ 150 cm^{-1}
Pulse duration [3]	150 – 250 fs	30 – 80 fs	200 – 300 fs	< 200 fs
Applications	Micro-machining Microscopy Spectroscopy	Nonlinear microscopy Ultrafast spectroscopy	Micro-machining Mid-IR generation	OPCPA front-end

[1] *Better stability can be specified for a specific wavelength (e.g. < 1% STD at 800 nm).*
[2] *I-OPA-F outputs broad bandwidth pulses which are compressed externally.*
[3] *Output pulse duration depends on wavelength and pump laser pulse duration.*

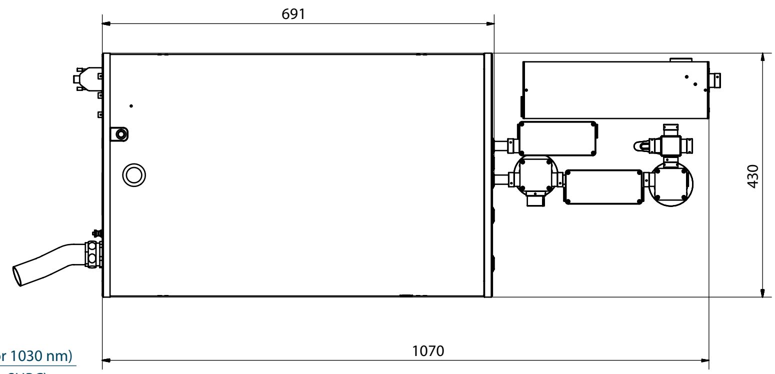
COMPARISON WITH OTHER FEMTOSECOND AND PICOSECOND LASERS

Laser technology	Our solution	HG or HIRO	I-OPA-F	I-OPA-ONE
		Pulse energy at 100 kHz, using PHAROS-10W laser		
Excimer laser (193 nm, 213 nm)	5H of PHAROS (205 nm)	5 µJ	–	–
TH of Ti:Sa (266 nm)	4H of PHAROS (257 nm)	10 µJ	–	–
TH of Nd:YAG (355 nm)	3H of PHAROS (343 nm)	25 µJ	–	–
SH of Nd:YAG (532 nm)	2H of PHAROS (515 nm)	50 µJ	35 µJ	–
Ti:Sapphire (800 nm)	OPA output (750 – 850 nm)	–	10 µJ	–
Nd:YAG (1064 nm)	PHAROS output (1030 nm)	100 µJ		
Cr:Forsterite (1240 nm)	OPA output (1200 – 1300 nm)	–	5 µJ	–
Erbium (1560 nm)	OPA output (1500 – 1600 nm)	–	3 µJ	15 µJ
Thulium / Holmium (1.95 – 2.15 µm)	OPA output (1900 – 2200 nm)	–	2 µJ	10 µJ
Other sources (2.5 – 4.0 µm)	OPA output	–	–	1 – 5 µJ

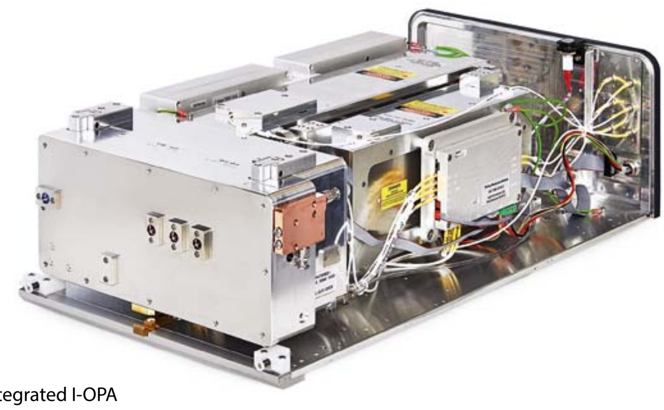
Note that the pulse energy scales linearly in a broad range of pump parameters. For example, a PHAROS-20W laser at 50 kHz (400 µJ energy) will increase the output power twice, and the pulse energy – 4 times compared to the reference table above. The pulse duration at the output is <300 fs in all cases. The OPA output is not limited to these particular ranges of operation, it is continuously tunable as shown in energy conversion curves.



Pharos with I-OPA output ports



PHAROS with I-OPA-F and compressors for signal and ilder



Pharos with integrated I-OPA

CARBIDE

new

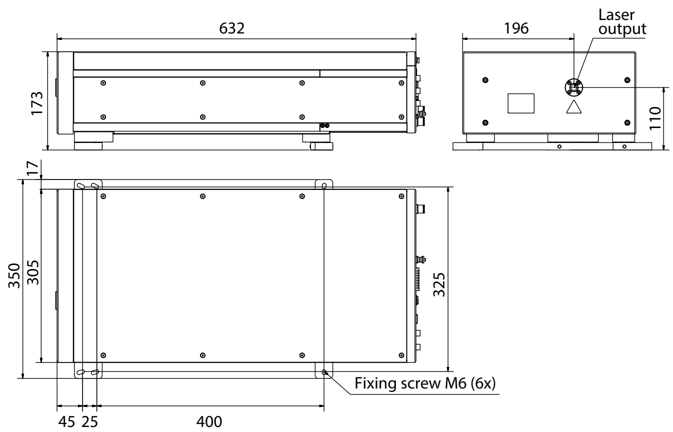
Femtosecond Lasers for Industrial and Medical Applications

FEATURES

- <290 fs – 10 ps tunable pulse duration
- >400 µJ pulse energies
- >40 W output power
- 60 – 1000 kHz tunable base repetition rate
- Includes pulse picker for pulse-on-demand operation
- Rugged, industrial grade mechanical design
- Air or water cooling
- Automated harmonics generators (515 nm, 343 nm, 257 nm)

CARBIDE industrial femtosecond lasers feature output power of >40 W at 1028 nm wavelength, with >400 µJ highest pulse energies, it maintains all the best features of its predecessor PHAROS: variable pulse repetition rate in the range of 60–1000 kHz (amplifier internal clock) with the built-in pulse picker feature for pulse-on-demand control, computer controllable pulse duration 290 fs – 10 ps. In addition to usual parameters CARBIDE brings in a few new technologies. One of the most important being a few times higher output average power to wall plug efficiency. It also features novel approach to a cavity design where oscillator, stretcher/compressor and amplifier are integrated into a single housing, this way optimized for volume production. It also allows fast warm-up (important for medical applications), easy access to pump LD modules for replacement. Intra-cavity pulse picker allows reduction of cost and power consumption. Highly integrated LD driver and control electronics, along with embedded control computer now provide less electromagnetic noise emission and allow faster assembly during production stage. However, one of the most impressive features of CARBIDE is its size of 631×324×167 mm air-cooled version and 632×305×173 mm water-cooled version including integrated power supply and air cooling unit. Water-cooled version has external chiller. This represents about 7 times reduction in system volume as compared to PHAROS, already one of the most compact ultrafast lasers on the market.

CARBIDE features number of optional components complementing different application requirements: certified safety shutter, beam conditioning unit (beam expander with optional spatial filter), automated attenuator, harmonics unit, additional pulse picker for enhanced contrast. CARBIDE is primarily targeted to the industrial market where relatively low average power cost effective solution with ultrafast pulses is needed. In largest part this is biomedical application with a direct biological tissue processing or biomedical device manufacturing. In addition output parameters of CARBIDE are sufficient to support different wavelength converters starting with harmonic generators to parametric amplifiers.



Outline drawing of water-cooled CARBIDE

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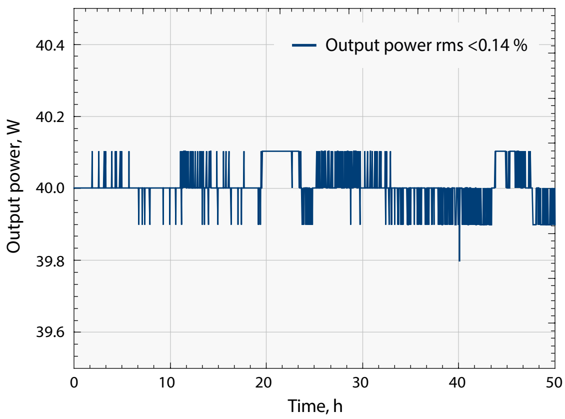
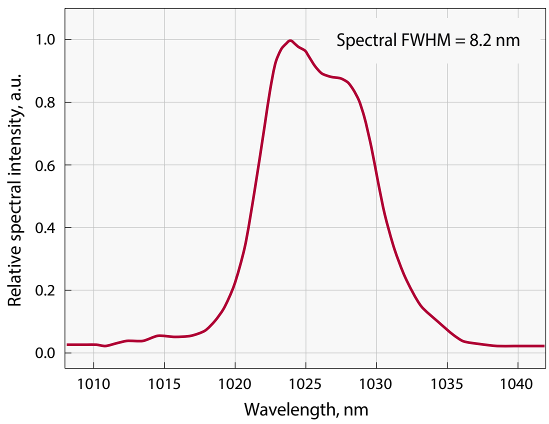
SPECIFICATIONS

Cooling method	Air-cooled [1]		Water-cooled	
Max. average power	>5 W	>4 W	>40 W	
Pulse duration (assuming Gaussian pulse shape)	<290 fs			
Pulse duration adjustment range	290 fs – 10 ps			
Max. pulse energy	>85 μJ	>65 μJ	>200 μJ	>400 μJ
Base repetition rate [2]	60 – 1000 kHz		200 – 1000 kHz	100 – 1000 kHz
Pulse selection	Single-Shot, Pulse-on-Demand, any base repetition rate division			
Centre wavelength [3]	1028±5 nm			
Beam quality	TEM_{00}; $M^2 < 1.2$			
Pulse picker	included	included, enhanced contrast AOM [4]	included	
Pulse picker leakage	<2 %	<0.1 %	<0.5 %	
Output power stability	<0.5% rms over 24 hours [5]			
PHYSICAL DIMENSIONS				
Laser head	631(L) × 324(W) × 167(H) mm		632(L) × 305(W) × 173(H) mm	
Power supply	220(L) × 95(W) × 45(H) mm			
UTILITY REQUIREMENTS				
Electric	110 – 220 V AC, 50 – 60 Hz, up to 300 W			
Operating temperature	17–27 °C (62–80 °F)			
Relative humidity	< 65 % (non-condensing)			

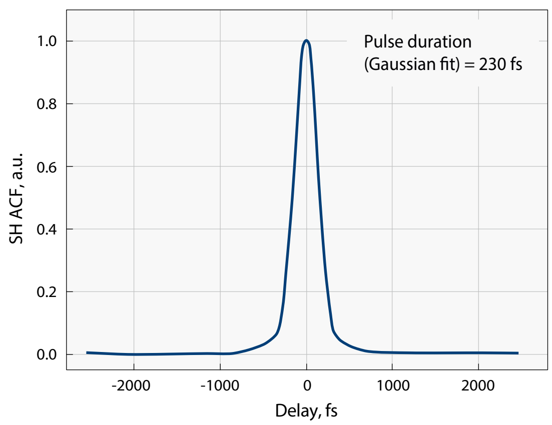
1) Water-cooled version available on request.
2) Lower repetition rates are available by controlling pulse picker.
3) 2nd (515 nm) and 3ed (343 nm) harmonic output also available.
4) Provides fast amplitude control of output pulse train.
5) Under stable environmental conditions.



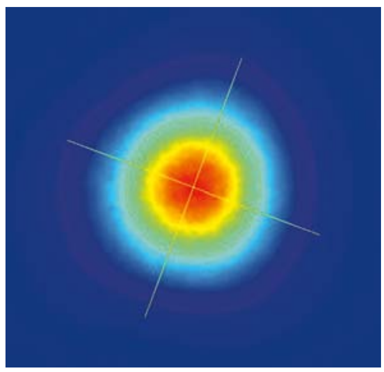
Long term power stability (water-cooled version)



Spectrum of CARBIDE (water-cooled version)



Pulse duration of CARBIDE (water-cooled version)



Typical CARBIDE beam profile (water-cooled version)

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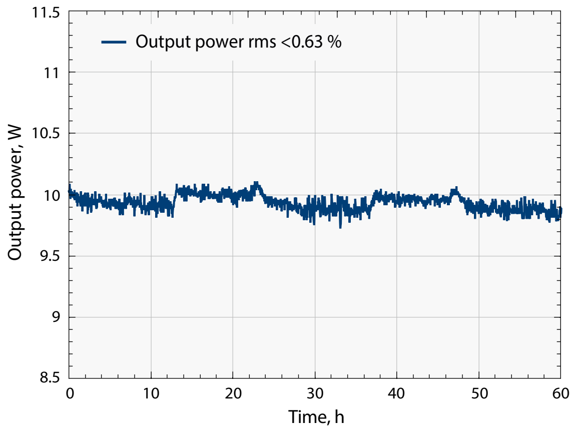
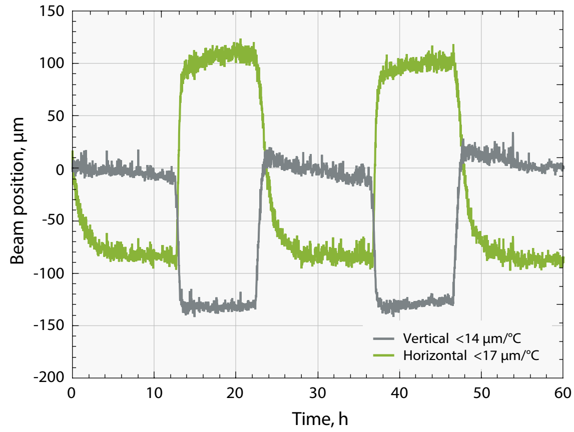
Air-cooled version of CARBIDE

FEATURES

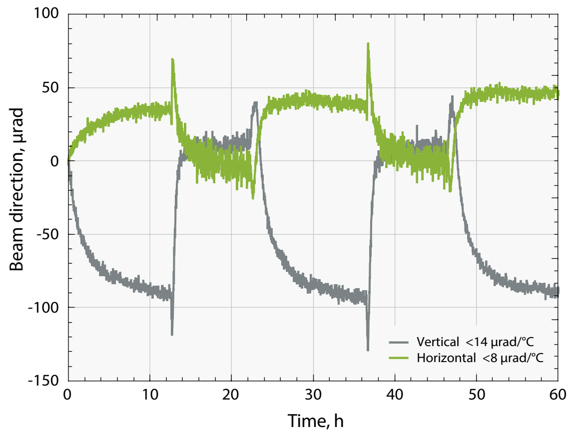
- <290 fs – 10 ps tunable pulse duration
- >85 µJ pulse energies
- >5 W output power
- Air or water cooling



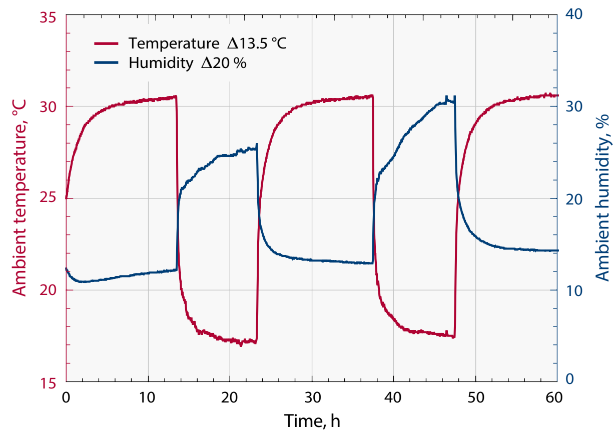
Output power under harsh environment conditions (air-cooled version)



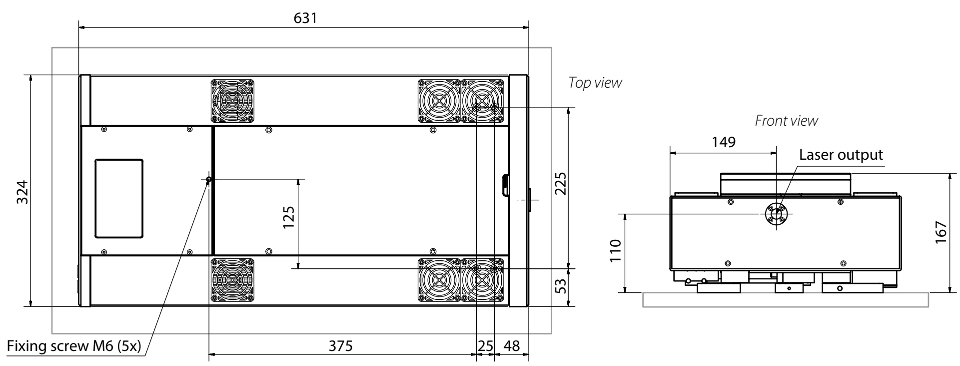
Beam position under harsh environment conditions (air-cooled version)



Beam direction under harsh environment conditions (air-cooled version)



Harsh environment conditions (air-cooled version)



Outline drawing of air-cooled CARBIDE

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CARBIDE

Automated Harmonics Generators

Air-cooled CARBIDE with harmonics generator module

FEATURES

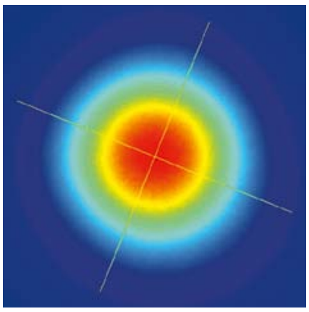
- 515 nm, 343 nm and 257 nm
- Output selection by software
- Mounts directly on laser head and integrated into the system
- Rugged, industrial grade mechanical design

CARBIDE laser can be equipped with automated harmonics module. Selection of fundamental (1030 nm), second (515 nm), third (343 nm) or fouth (257 nm) harmonic output is available by software control.

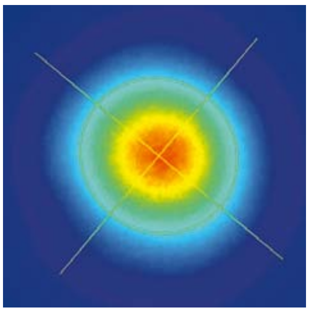
Harmonic generators are designed to be used in industrial applications where a single output wavelength is desired. Modules are mounted directly on the output of the laser and integrated into the system.

SPECIFICATIONS

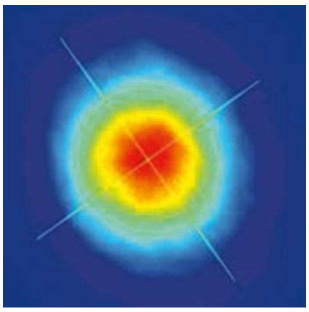
Model	CHM02-1H-2H	CHM01-1H-2H-3H	CHM01-1H-4H
Output wavelength (automated selection)	1030 nm 515 nm	1030 nm 515 nm 343 nm	1030 nm 257 nm
Input pulse energy	20 – 85 µJ		
Pump pulse duration	>300 fs		
Conversion efficiency	> 60 % (2H)	> 60 % (2H) > 30 % (3H)	>15% (4H)
Beam quality (M^2)	< 1.3 (2H)	< 1.3 (2H) < 1.4 (3H)	<1.4 (4H)
PHYSICAL DIMENSIONS			
Laser head with harmonics module	751 (L) × 324 (W) × 167 (H) mm		



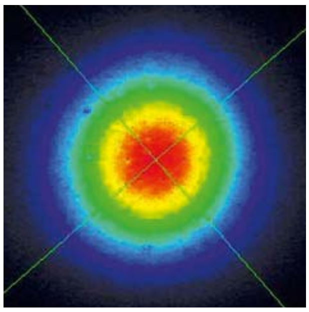
Typical CARBIDE 1H beam profile. 60 kHz, 5W



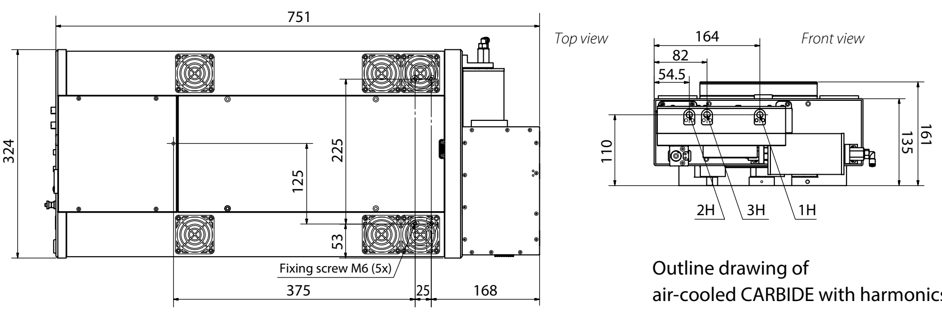
Typical CARBIDE 2H beam profile. 100 kHz, 3.4 W



Typical CARBIDE 3H beam profile. 100 kHz, 2.2 W



Typical CARBIDE 4H beam profile. 100 kHz, 100 mW



Outline drawing of air-cooled CARBIDE with harmonics generator module

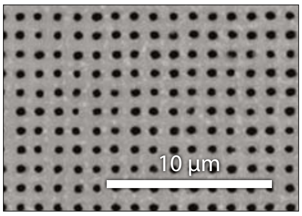
EXAMPLES OF INDUSTRIAL APPLICATIONS

STEEL FOIL M-DRILLING

- No melting
- Micron diameter

Applications:

- Filters
- Functional surfaces

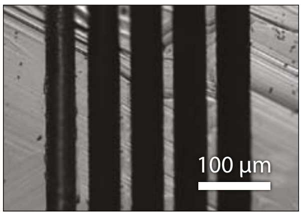


DIAMOND CUTTING

- Low carbonization
- No HAZ
- Low material loss

Applications:

- Diamond sheet cutting
- Chip breaker formation
- Diamond texturing/patterning

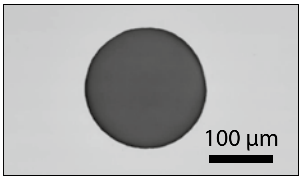


GLASS HOLES

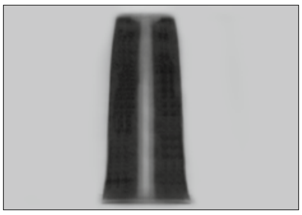
- Various hole sizes with routine tapper angle better than 5 deg
- Minimal debris around the edges of holes

Application:

- Microfluidics
- VIAs

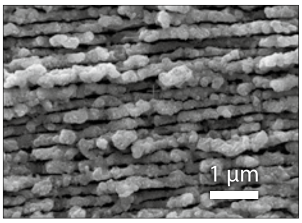


Top view


Cross-section

NANO RIPPLES

- Up to 200 nm ripple period fabricated using ultra-short laser pulses
- Individual nano-feature size on ripples: 10 – 50 nm
- Controlled period, duty cycle and aspect ratio of the ripples



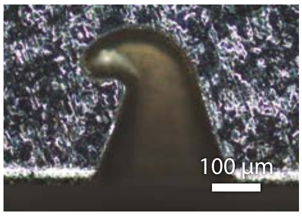
Developed in cooperation with Swinburne University, Australia

Application:

- Detection of materials with increased sensitivity using surface-enhanced Raman scattering (SERS)
- Bio-sensing, water contamination monitoring, explosive detection etc.

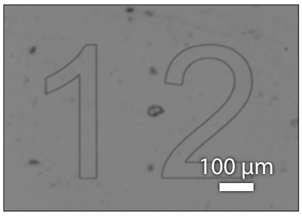
METAL MICROMACHINING

- 3D structures formed on steel surface
- High precision and surface smoothness achieved



MARKING OF CONTACT LENS

- Marking made inside the bulk of contact lens, preserving surface of lens and distortions
- Exact positioning of markings – 3D text format



Application:

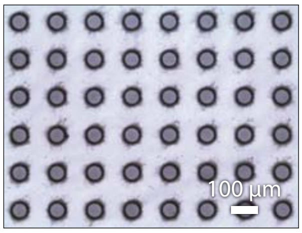
- Product counterfeit protection
- Serial number and customer identification

THIN GLASS DRILLING

- Taper angle control
- Low heat affect
- No cracking or chipping around holes

Applications:

- VIAs

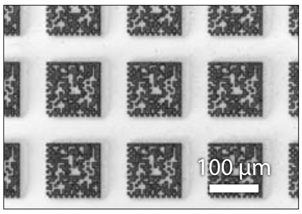


DATAMATRIX

- Data inscribed on a glass surface or inside bulk
- Extremely small elements, down to 5 µm in size

Application:

- Product marking

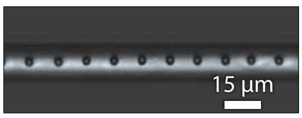


GLASS TUBE DRILLING

- Controlled damage and depth
- Hole diameter of few microns

Applications:

- Medical applications
- Biopsy equipment

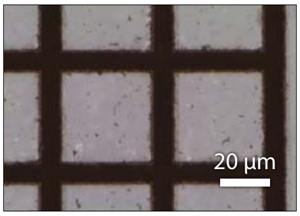


FERROELECTRIC CERAMICS ETCHING

- No or low melting and HAZ
- Easily removable debris
- Good structuring quality

Applications:

- Infrared sensors for cameras
- Memory chips

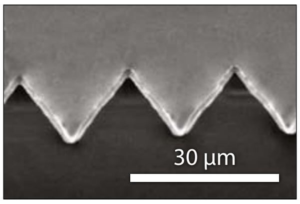


SILICON LASER ASSISTED ETCHING

- No HAZ
- No melting

Applications:

- Solar cell production
- Semiconductor industry

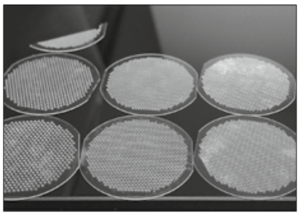


MASK FOR BEAM SPLITTER PATTERN DEPOSITION

- Borosillicate glass
- 150 um thickness
- ~900 holes per mask
- Mask diameter 25.4 mm

Appplication:

- Selective coating

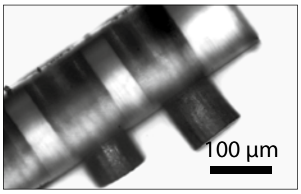


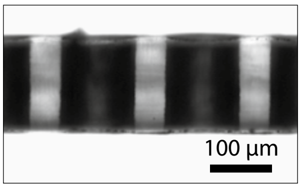
STENT CUTTING

- Holes in stent wall, cross-section view
- Polymer stent
- No heat effect, no debris
- Minimal taper effect

Application:

- Vascular surgery



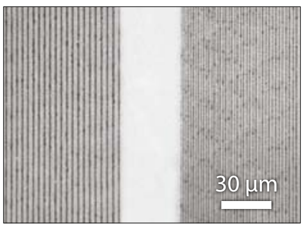


TEXTURIZED SAPPHIRE SURFACE

- Micron resolution
- Large area processing
- Single pulses used to form craters on the surface

Application:

- Better light extraction in LED
- Semiconductor structure growth



MARKING AND PATTERNING

- Smallest spots down to 3 µm in width
- Micron level positioning
- No heat effect

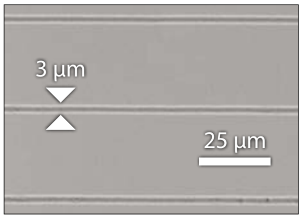
Metal

MICRO CHANNEL FORMATION

- Wide range of materials – from fused silica to polymers
- Controllable channel shape
- Low debris
- Smooth surface

Applications:

- Microfluidic sensors
- Waveguides

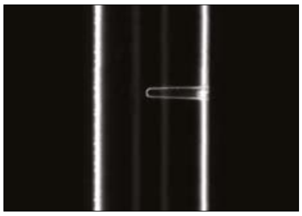


OPTICAL FIBER DRILLED TO THE CORE

- Diameter from <10 µm
- Various hole profiles possible
- Depth and angle control

Applications:

- Optical fiber sensors
- Material science

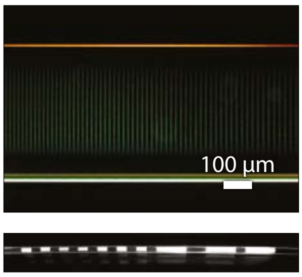


OPTICAL FIBER SCATTERING

- No impact on fiber strength
- No surface damage
- Even light dispersion

Applications:

- Medical fibers
- Oncology

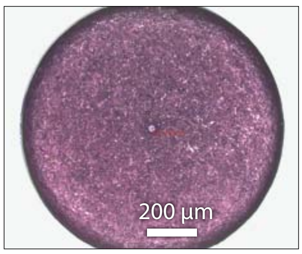


SYNTHETIC RUBY DRILLING

- No cracks after drilling
- Taper angle control

Application:

- High precision mechanical parts

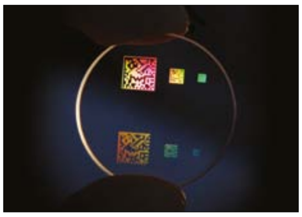


ULTRAFAST LASERS
OSCILLATORS
HARMONICS GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
TOPAS DEVICES
SPECTROMETERS
AUTOCORRELATORS

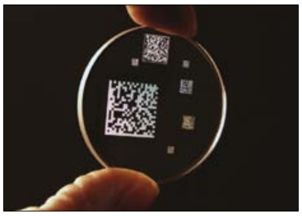
GLASS BULK PROCESSING

- Refractive index volume modification
- Bragg gratings with 99% diffraction efficiency
- Birefringent gratings/elements
- Low influence on strength of the substrate

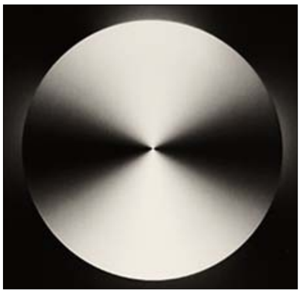
Birefringence modification inside fused silica. Photo in crossed polarized light



Sapphire



Glass

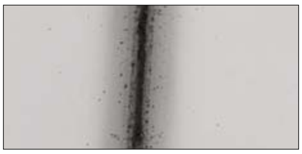


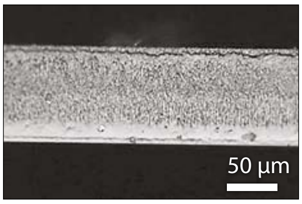
S-waveplate *

* M. Beresna, M. Gecevičius, P. G. Kazansky and T. Gertus, Radially polarized optical vortex converter created by femtosecond laser nanostructuring of glass, Appl. Phys. Lett. 98, 201101 (2011).

NON TEMPERED GLASS CUTTING

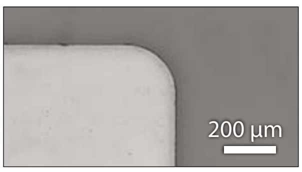
- Thickness: 0.03 – 0.3 mm
- Mechanical or heat assisted break after scribing
- Speed: up to 800 mm/s
- Any shape
- Round corners
- Surface quality: Ra ≤ 2µm





SAPPHIRE CUTTING

- Thickness: 100 – 900 µm
- Easy to break
- Circle shapes diameter: 3 – 15 mm
- Corner radius: from 0.5 mm
- Speed: up to 800 mm/s
- Cut quality: Ra ≤ 2 µm
- No surface cracks
- No or low chipping
- Non ablating process



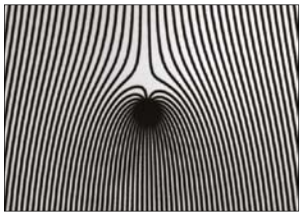
Thickness: 420 µm, clear sapphire

SELECTIVE METAL COATING ABLATION (REMOVAL)

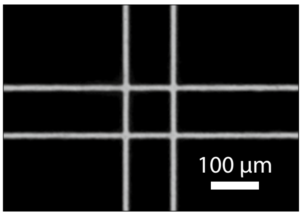
- Selective ablation of metal coatings from various surfaces
- Depth and geometry of ablation may vary

Application:

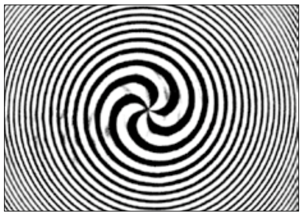
- Lithography mask production
- Beam shaping elements
- Optical apertures
- Other



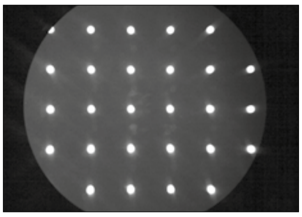
Amplitude grating formation



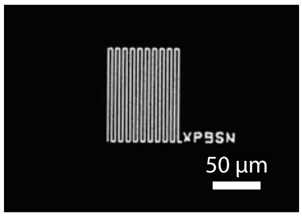
Titan coating selective ablation



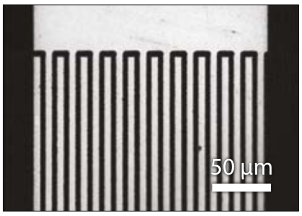
Chrome ablation for beam shaping



Apperture array fabrication



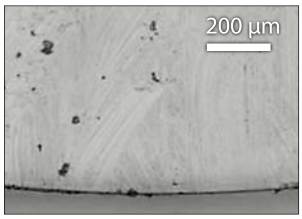
Gold layer removal without damage to MgO substrate – Au layer removal without damaging

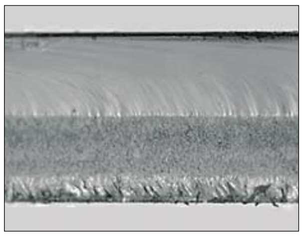


Chrome ablation from glass substrate

TEMPERED GLASS CUTTING

- Single pass process
- In bulk damage (closed cut), surface remains intact, practically no debris
- Homogeneous cut surface



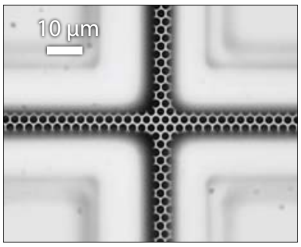


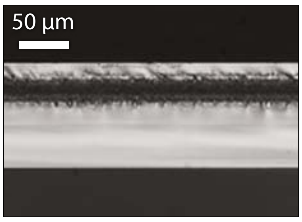
Samples provided by
Workshop of Photonics
www.wophotonics.com

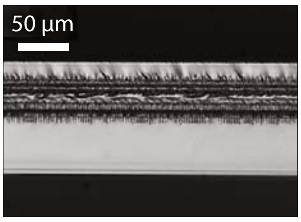
Rev. 20180522

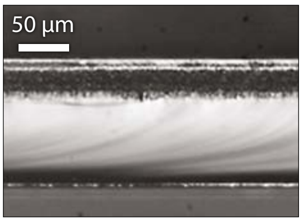
SAPPHIRE DICING FOR LED INDUSTRY

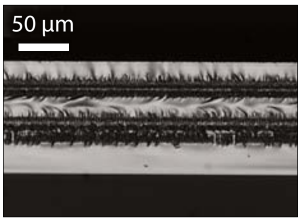
- Wafer thickness 50 to 330 µm
- Narrow street width up to ~10 µm
- Bending strength (650–900 MPa)
- High light extraction efficiency
- Controllable damage length
- Easy breaking
- Scribing with DBR coated backside of sapphire

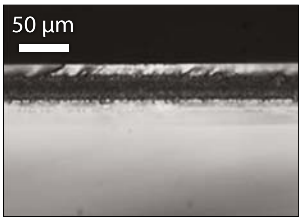


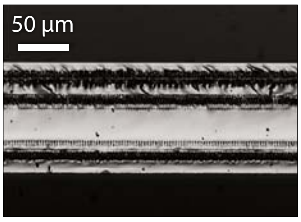










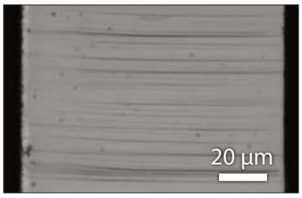


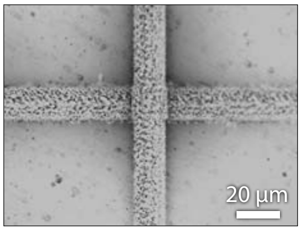
SILICON CARBIDE DICING

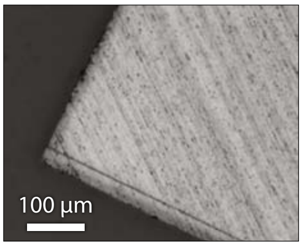
- No chipping on the edges
- Cleaved-surface roughness <1 µm
- Easy breaking

Applications:

- High power, high frequency electronics







EVANA TECHNOLOGIES

Samples provided by
Evana Technologies
www.evanatech.com

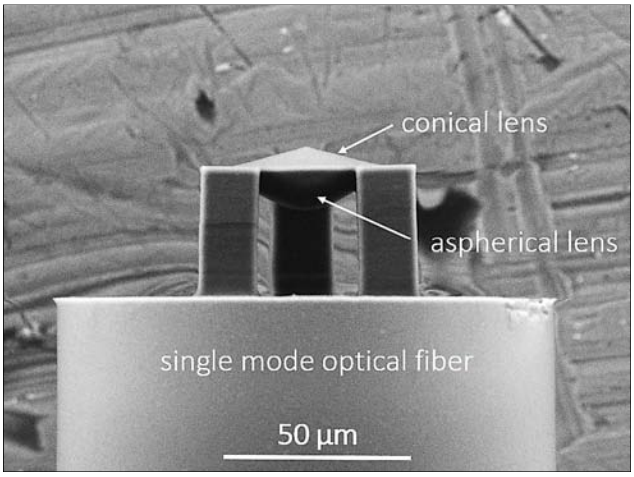
MULTI-PHOTON POLYMERIZATION

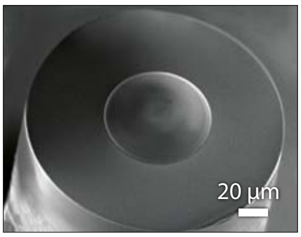
Multi-photon polymerization (MPP) is a unique method allowing the fabrication of 3D microstructures with a spatial resolution of the order of 100 nm. MPP technology is based on non-linear absorption at the focal spot of a tightly focused femtosecond laser beam, which induces well confined photopolymerization reactions. <290 fs pulses at >100 kHz repetition rates are advantageous for material modification via avalanche ionization – enabling fabrication of materials ranging from hybrid composites to pure proteins.

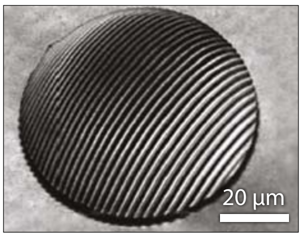
APPLICATION IN MICRO-OPTICS

Most of the photopolymers used in MPP technology are transparent in the visible range and could be directly applied in various micro-optical applications. Various mechanical as well as optical properties can be tuned.

Examples: prisms, aspherical lenses, lenses on the tip of an optical fiber, multi-lens arrays, vortex beam generators, diffractive optical elements, etc.







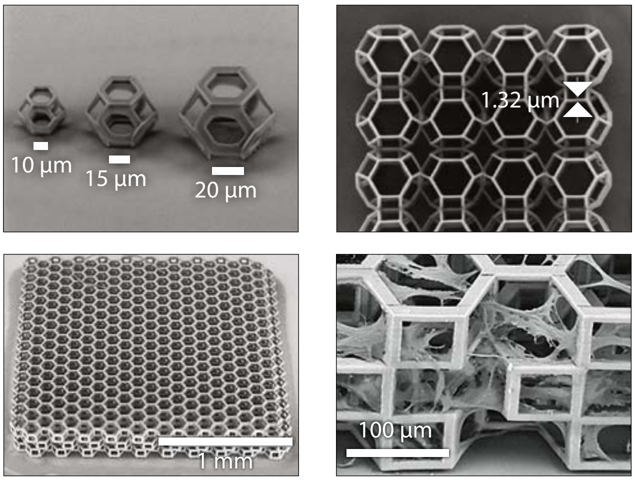
M. Malinauskas et al. Femtosecond laser polymerization of hybrid/integrated micro-optical elements and their characterization. J. Opt. 12, 124010 (2010).

M. Oubaha et al. Novel tantalum based photocurable hybrid sol-gel material employed inthe fabrication of channel optical waveguides and three-dimensionalstructures, Appl. Surf. Sci. 257(7), 2995–2999 (2011).

APPLICATION IN BIOTECHNOLOGY AND REGENERATIVE MEDICINE

MPP technique can be realized in biocompatible and even biodegradable materials, thus it is a perfect platform for regenerative medicine research and applications.

Examples: 3D polymeric scaffolds for cell growth and tissue engineering, drug delivery devices, micro-fluidic devices, cytotoxic elements.

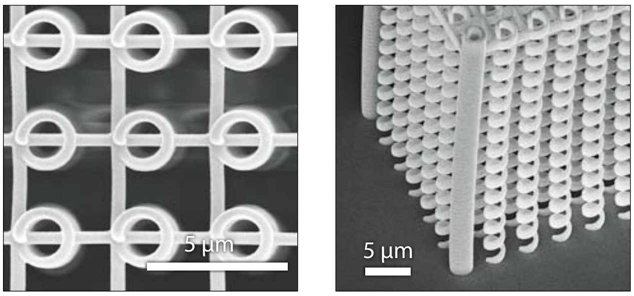


M. Malinauskas et al. 3D artificial polymeric scaffolds for stem cell growth fabricated by femtosecond laser. Lithuanian J. Phys., 50 (1), 75-82, (2010).

APPLICATION IN PHOTONICS

Highly repeatable and stable technological process enables the fabrication of various photonic crystal devices for controlling spatial and temporal properties of light at micrometer distances.

Examples: photonic crystal spatial filters, supercollimators, structural colours, etc.



L. Maigyte et al. Flat lensing in the visible frequency range by woodpile photonic crystals, Opt. Lett.38(14), 2376 (2013).

V. Purlys et al. Spatial filtering by chirped photonic crystals, Phys. Rev. A 87(3), 033805 (2013).

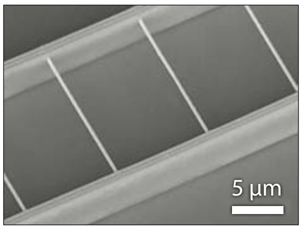
V. Purlys et al. Super-collimation by axisymmetric photonic crystals,Appl. Phys. Lett. 104(22), 221108 (2014).

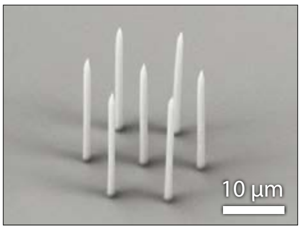
V. Mizeikis et al. Realization of Structural Colour by Direct Laser Write Technique in Photoresist, J. Laser Micro Nanoen. 9(1), 42 (2014).

APPLICATION IN MICROMECHANICS

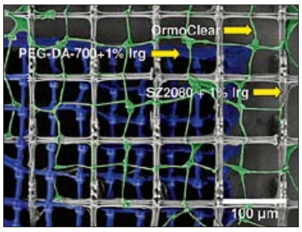
MPP technology gives the user ability to create multiscale and multimaterial 3D objects out of substances with various physical, chemical, and biological properties.

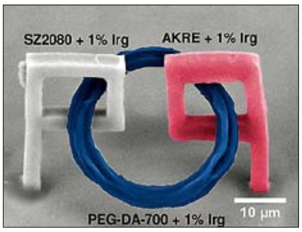
Examples: cantilevers, valves, micro-pore filters with controllable pore sizes, mechanical switches. [1)]





Examples of multicomponent structures. [2)]



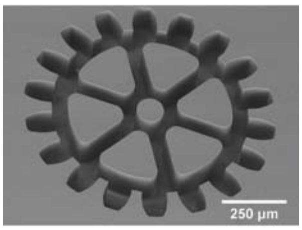


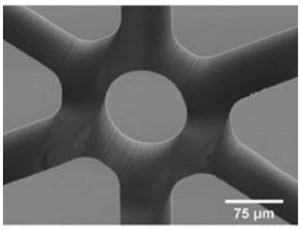
[1)] V. Purlys, Three-dimensional photonic crystals: fabrication and applications for controlof chromatic and spatial light properties, Ph.D. Thesis. Vilnius University: Lithuania (2015).

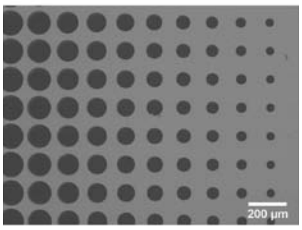
[2)] M. Malinauskas et al. Ultrafast laser processing of materials: from science to industry, Light: Sci. Appl., to be published, (2015).

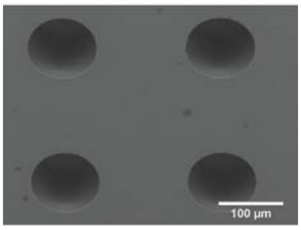
LASER ASSISTED SELECTIVE ETCHING

Can be applied in microoptics, micromechanics, medical engineering, etc.

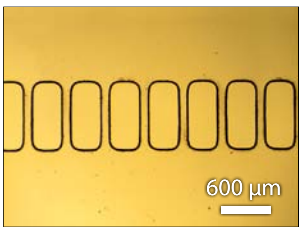


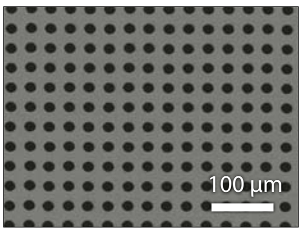






LASER ABLATION

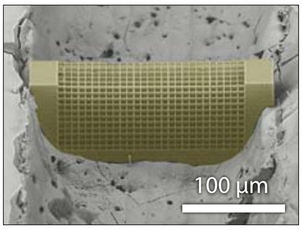


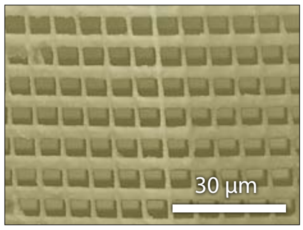


Hybrid microfabrication

ABLATION AND LITHOGRAPHY

Laser ablation allows a rapid production of glass channels while 3D laser lithography is used to integrate fine-mesh filters inside the channels. Then whole system is then sealed by laser welding.

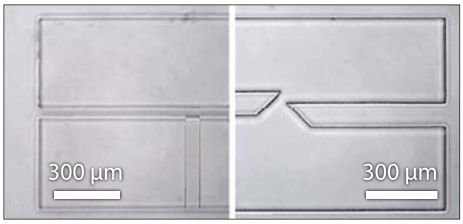


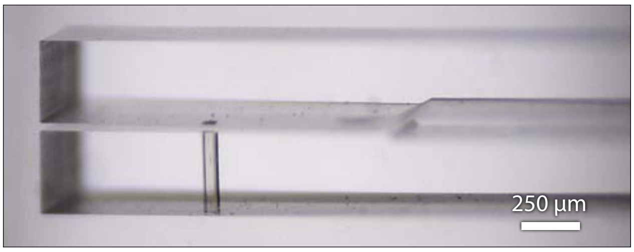


Jonušauskas et al., Opt. Eng. 56(9), 094108 (2017).

ETCHING AND POLYMERIZATION

Combining selective laser etching and photopolymerization allows manufacturing of cantilevers for sensing applications.





Tičkūnas et al., Opt. Express, 25(21), 26280-26288 (2017).

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For Scientific Inquiries
mangirdas.malinauskas@ff.vu.lt
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For Production Tool Inquiries
info@femtika.lt
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FLINT

Femtosecond Yb Oscillators

FEATURES

- Sub-80 fs without any additional pulse compressor
- 125 nJ pulse energy
- 10 W output power
- 76 MHz is standard
- Practically no amplified spontaneous emission
- Rugged, industrial grade mechanical design
- Automated harmonic generator (515 nm)
- Optional CEP stabilization
- Possibility to lock to external clock

The FLINT oscillator is based on Yb crystal end-pumping by high brightness laser diode module. Generation of femtosecond pulses is provided by Kerr lens mode-locking. Once started, mode-locking remains stable over a long period of time and is immune to minor mechanical impact. Piezo-actuator can be implemented in customized oscillators in order to control the cavity length. FLINT oscillator can also be equipped with Carrier Envelope Phase (CEP) stabilization system.

SPECIFICATIONS

Model	FLINT 1.0	FLINT 2.0	FLINT 4.0	FLINT 6.0	FLINT 10	FLINT SP
Max. average power	> 1 W	> 2 W	> 4 W	> 6 W	> 10 W [1]	> 600 mW
Pulse duration (assuming Gaussian pulse shape)	< 80 fs	< 100 fs			< 120 fs	< 40 fs
Pulse energy	> 12 nJ	> 25 nJ	> 50 nJ	> 75 nJ	> 125 nJ	> 7 nJ
Repetition rate	76 ± 0.5 MHz [2]					
Centre wavelength	1035 ± 10 nm [3]					
Output pulse-to-pulse stability	< 0.5 % rms over 24 hours [4]					
Polarization	Linear, horizontal					
Beam pointing stability	< 10 µrad/°C					
Beam quality	TEM_{00}; $M^2 < 1.2$					
Optional integrated 2H generator	Conversion efficiency > 30 % at 517 nm					
PHYSICAL DIMENSIONS						
Laser head	430 (L) × 195 (W) × 114 (H) mm					
Laser head with 2H	442 (L) × 270 (W) × 114 (H) mm					
Power supply and chiller rack (4HU, 19")	640 (L) × 520 (W) × 420 (H) mm					
Chiller (<100 W)	Different options					
UTILITY REQUIREMENTS						
Electric	110 V AC, 50 – 60 Hz, 2 A or 220 V AC, 50 – 60 Hz, 1 A					
Room temperature	15 – 30 °C (air conditioning recommended)					
Relative humidity	20 – 80 % (non-condensing)					

1) *Higher powers are available. Please contact Light Conversion for more information.*
2) *Other repetition rates are available in the range from 64 MHz to 84 MHz.*
3) *The center wavelength can be specified with tolerance ±2 nm for customized oscillators.*
4) *With enabled power-lock, under stable environment.*

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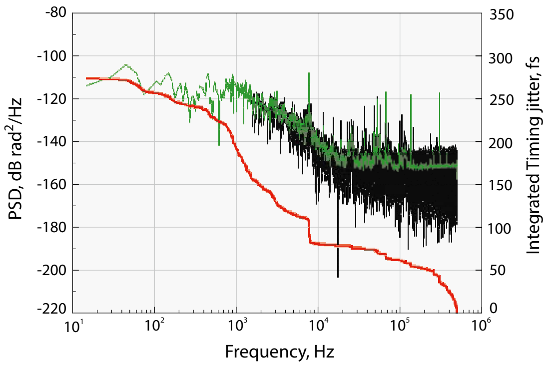
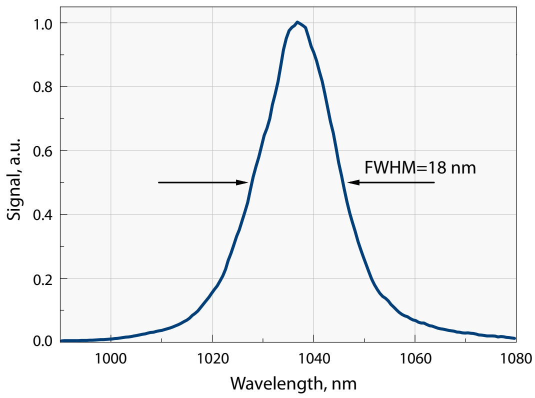
LOCKING OF THE OPTICAL PULSE TO AN EXTERNAL SIGNAL

PHAROS oscillator can be equipped with piezo actuators for precise control of the cavity length.



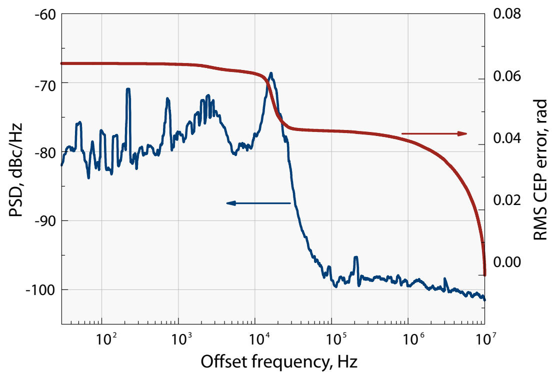
Timing jitter between oscillator pulse and external clock signal in 10 Hz – 500 kHz frequency range.



Optical Spectrum

CARRIER ENVELOPE PHASE (CEP) STABILIZATION

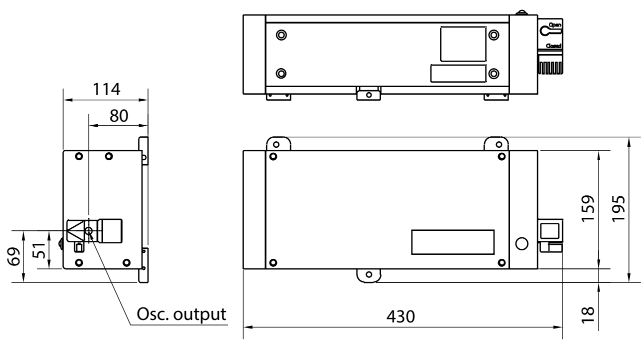
PHAROS oscillator can be equipped with nonlinear interferometer and feedback loop throughout the pump current of the laser diode bar for CEP stabilization. The figure on the right shows typical measurement of power spectrum density and integrated CEP phase error. The integrated phase error is in the frequency range from 50 Hz to 10 MHz is <70 mrad (in loop measurement).



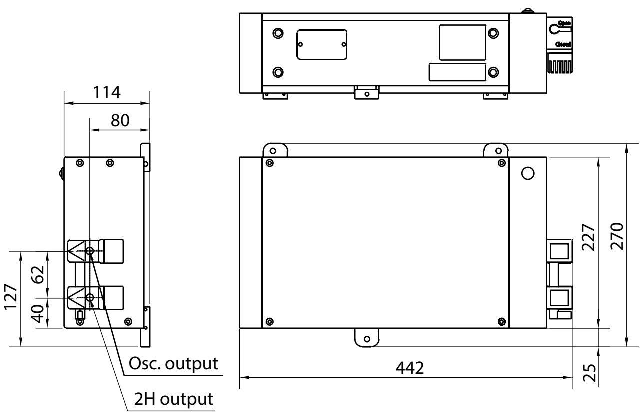
Single side power spectral density of f_{ceo} phase noise (in loop) and the integrated phase jitter.

OPTIONAL EQUIPMENT

Harmonics generator **HIRO**	*see p. 22*



FLINT dimensions



FLINT (with second harmonic generator) dimensions

HIRO

Harmonics Generator

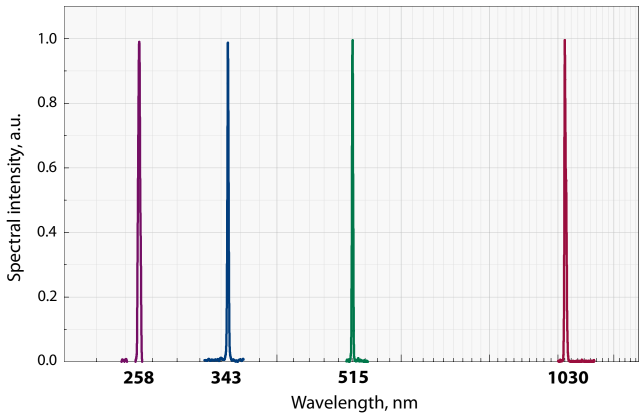
FEATURES

- 515 nm, 343 nm, 257 nm
- Easy switching between active harmonic
- Simultaneous outputs available
- Integrated separation of the harmonics
- Flexible in fixing and easily customized to include additional options (continuum generators, beam expanders down-collimators)

HIRO is a valuable option for PHAROS lasers and FLINT oscillators that provides high power harmonics radiation at 515 nm, 343 nm and 258 nm wavelengths. We offer several standard HIRO models (with open prospect of future upgrades) which meet most users' needs. The active harmonic is selected by manual rotation of the knob – changing the harmonics will never take longer than a few seconds thanks to its unique layout and housing construction.

HIRO is the most customizable and upgradable harmonics generator available on the market. It can be easily modified to provide white light continuum, beam splitting/expanding/down-collimating options integrated in the same housing as well as harmonics splitting that makes all three harmonics available at a time.

Please contact Light Conversion for customized version of HIRO.



HIRO output wavelengths

HIRO MODELS

Model	Generated harmonics	Output wavelengths
PH1F1	2H	515 nm
PH1F2	2H, 4H	515 nm, 258 nm
PH1F3	2H, 3H	515 nm, 343 nm
PH1F4	2H, 3H, 4H	515 nm, 343 nm, 258 nm
PH_W1	2H, 3H, 4H, WLG	any combination of harmonics and white-light continuum

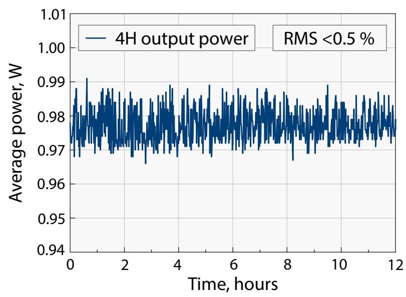
Residual fundamental radiation available upon request.

SPECIFICATIONS

Harmonics conversion efficiencies are given as percentage of the input pump power/energy when the repetition rate is up to 200 kHz.

Harmonic	Conversion efficiencies for different HIRO models		Output polarizations
	PH1F1, PH1F2	PH1F3, PH1F4	
2H	>50 %	>50 % [1]	H (V [2])
3H	–	>25 %	V (H [2])
4H	>10 %	>10 % [1] [3]	V (H [2])

[1] When the third harmonic is not in use.
[2] Optional, depending on request.
[3] Max 1 W.



Long term output stability

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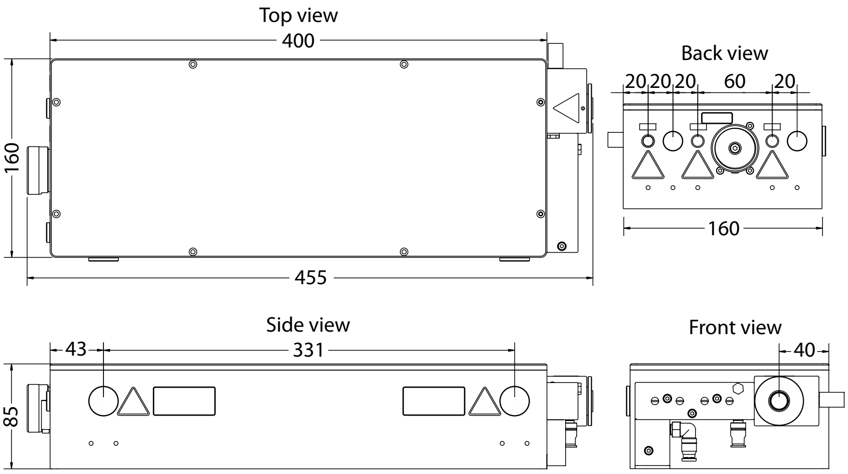
HARMONICS GENERATION

FLINT oscillator can be equipped with optional wavelength converter HIRO providing harmonics radiation at 517 nm, 345 nm and 258 nm wavelengths.

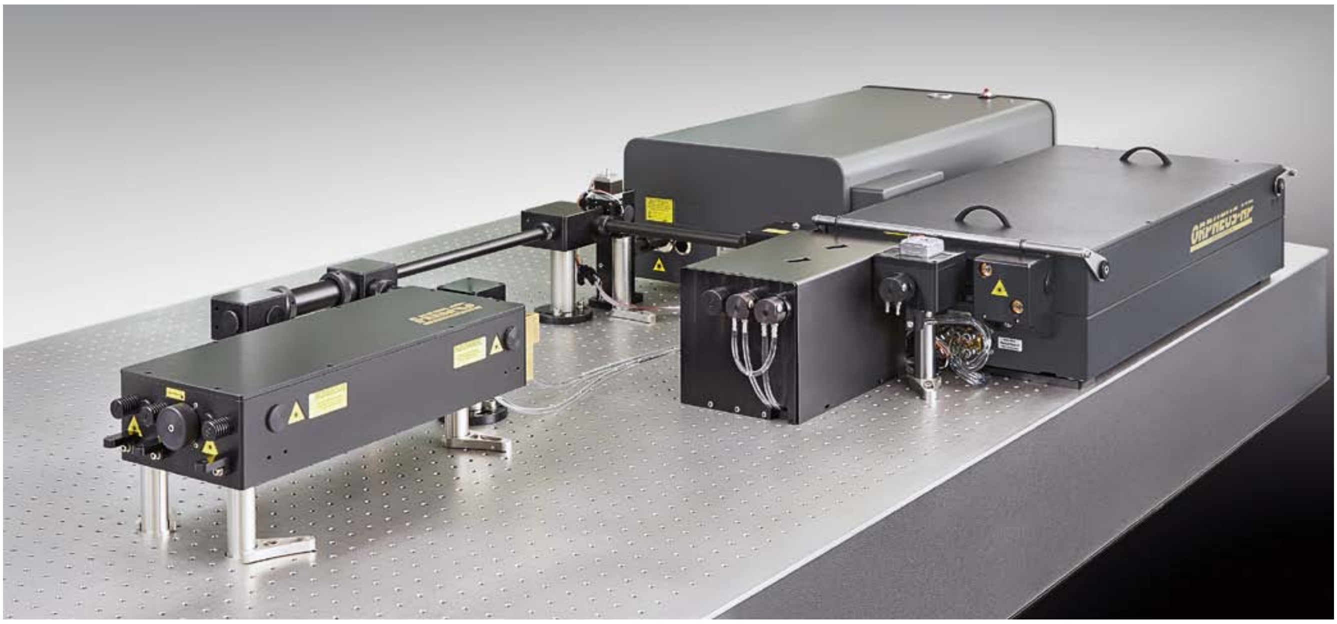
Generated harmonics	2H	3H	4H
Output wavelength	517 nm	345 nm	258 nm
Conversion efficiency	>35 %	>5 %	>1 %

DIMENSIONS (for HIRO all models)

	W × L × H
General dimension of the housing	160 × 455 × 85 mm
Recommended area for fixing	255 × 425 mm
Beam steering/intercepting	55 × 150 × 75 mm



HIRO housing with water cooling system dimensions and positions of input/output ports (mm)



HIRO, PHAROS and ORPHEUS-HP in the lab

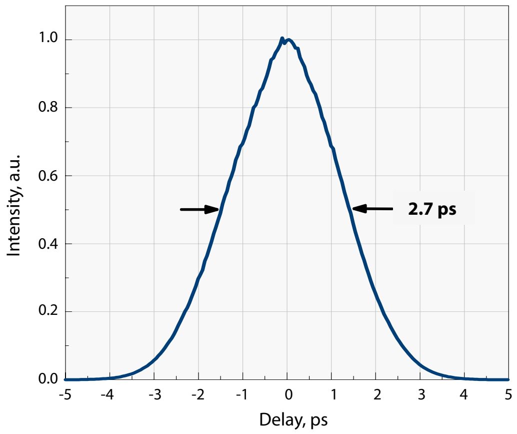
SHBC

Second Harmonic Bandwidth Compressor

FEATURES

- High conversion efficiency to the narrow bandwidth second harmonic
- Small footprint

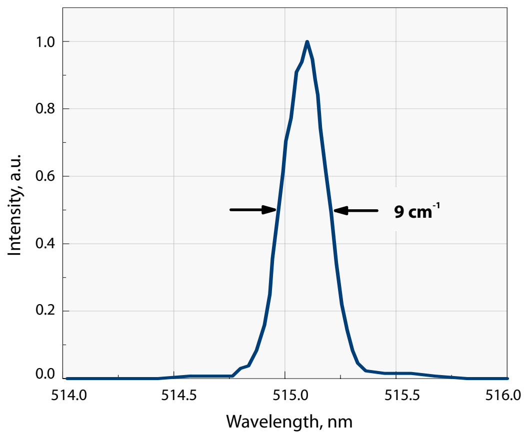
PHAROS harmonic generator product line features second harmonic bandwidth compressor abbreviated as SHBC. The device is dedicated for the formation of narrow bandwidth picosecond pulses from broadband output of ultrafast laser. In PHAROS platform SHBC is used to create flexible setups providing fixed wavelength or tunable narrow bandwidth ps pulses in combination with tunable wavelength broadband fs pulses. This feature is used in spectroscopy applications for mixing of wide and narrow bandwidth pulses such as sum frequency spectroscopy (SFG). This setup allows efficient SH generation and so provides high pulse energies.



Typical pulse duration SHBC output

SPECIFICATIONS

Parameter	Value
Pump source	PHAROS laser, 1030 nm, 70 – 120 cm^{-1}
Output wavelength	515 nm
Conversion ratio	> 30 %
Output pulse bandwidth	< 10 cm^{-1}



Typical spectrum of SHBC output

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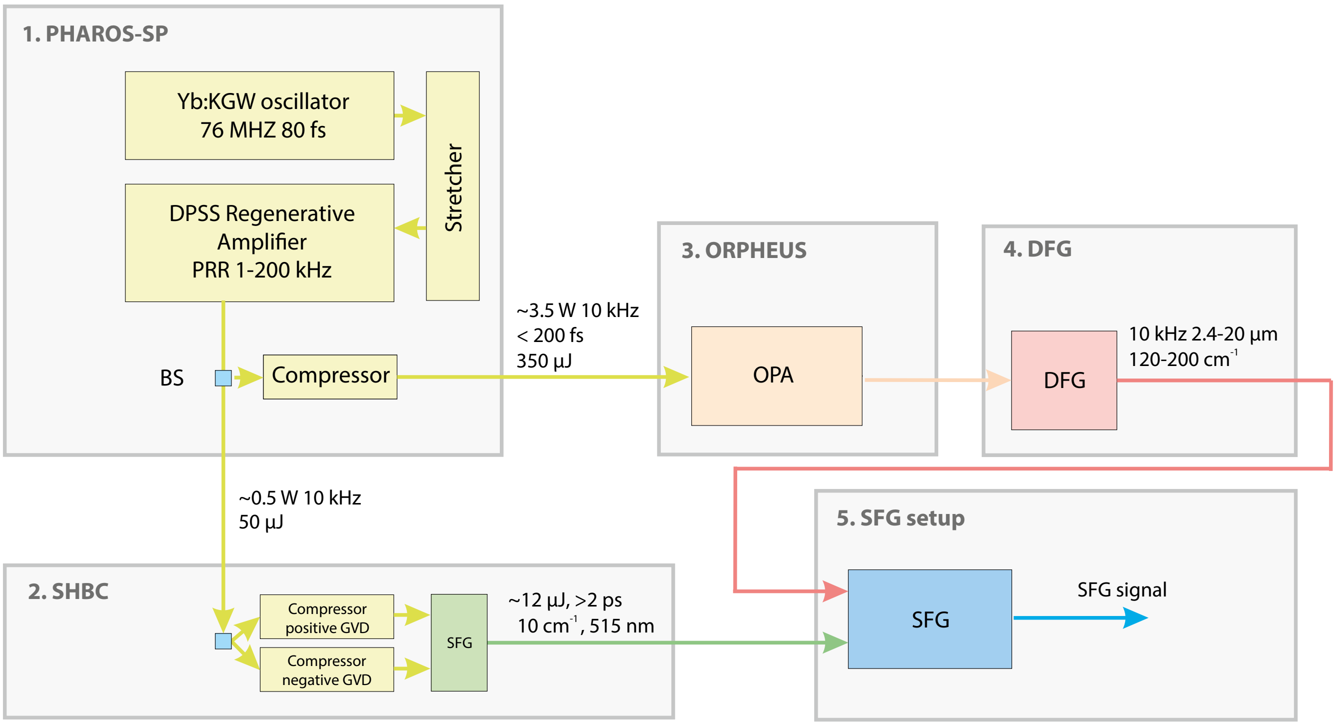
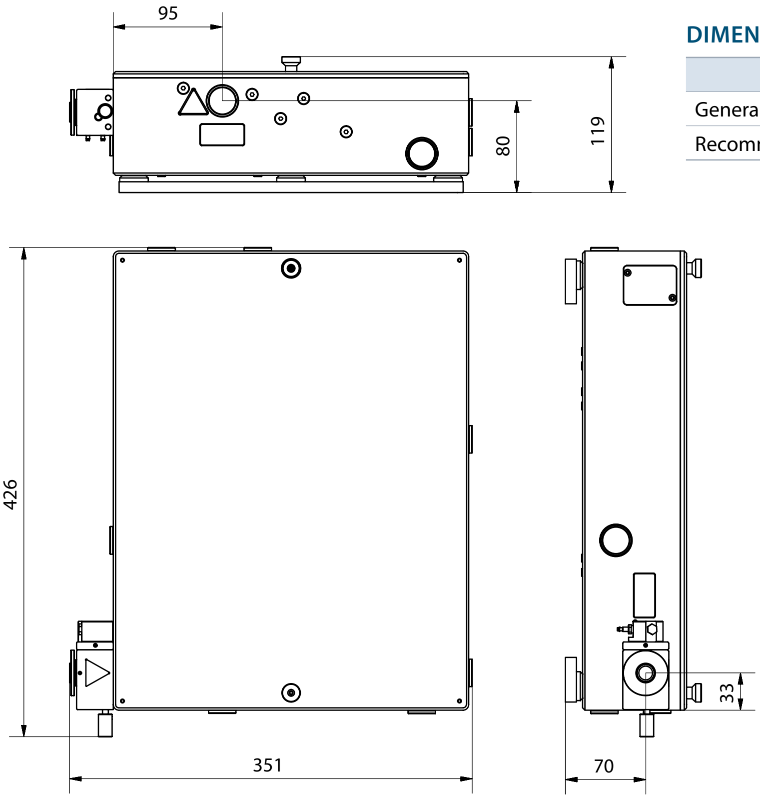


Principal layout of femtosecond sum frequency generation (SFG) spectroscopy system using SHBC to produce one of the probe beams



DIMENSIONS

	W × L × H
General dimension of the housing	351 × 426 × 119 mm
Recommended area for fixing	400 × 450 × 150 mm

ORPHEUS

Collinear Optical Parametric Amplifier

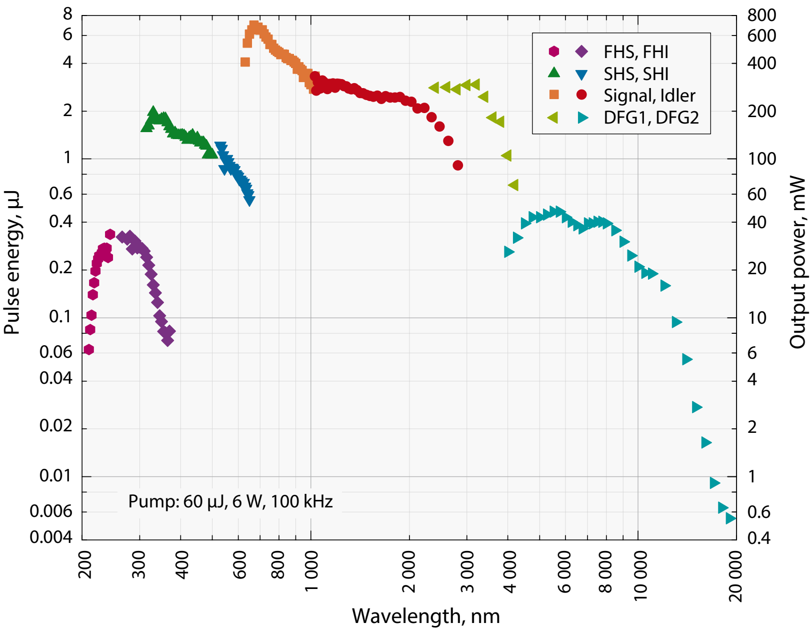
FEATURES

- 210 nm – 16000 nm tunable wavelength
- Single pulse – 1 MHz repetition rate
- Up to 8 W pump power
- Up to 0.4 mJ pump energy (2 mJ upon request)
- Computer controlled

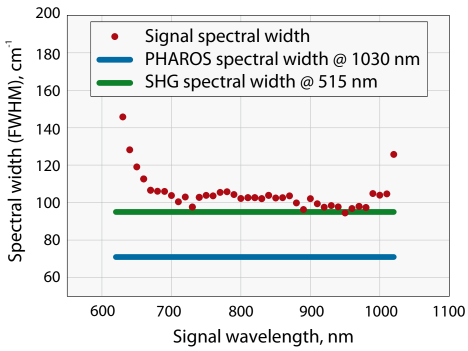
ORPHEUS is a collinear optical parametric amplifier of white-light continuum pumped by femtosecond Ytterbium based laser amplifiers. With the additional feature of being able to work at high repetition rates, ORPHEUS maintains the best properties of TOPAS series amplifiers: high output pulse stability throughout the entire tuning range, high output beam quality and full computer control via USB port as well as optional frequency mixers to extend the tuning range from UV up to mid-IR ranges.

ORPHEUS provides tunable OPA output (630 – 2600 nm) with residual second harmonic (515 nm) and fundamental radiation (1030 nm) beams at the same time.

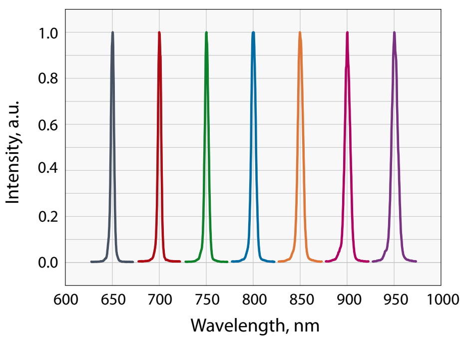
Femtosecond pulses, high power tunable output together with flexible multi-kilohertz repetition rate make the tandem of PHAROS and ORPHEUS an invaluable tool for multiphoton microscopy, micro-structuring and spectroscopy applications. Several ORPHEUS can be pumped by single PHAROS laser providing independent beam wavelength tuning.



Typical tuning curve of ORPHEUS



Typical output pulse spectral width



Typical spectra of signal wave

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SPECIFICATIONS [1]

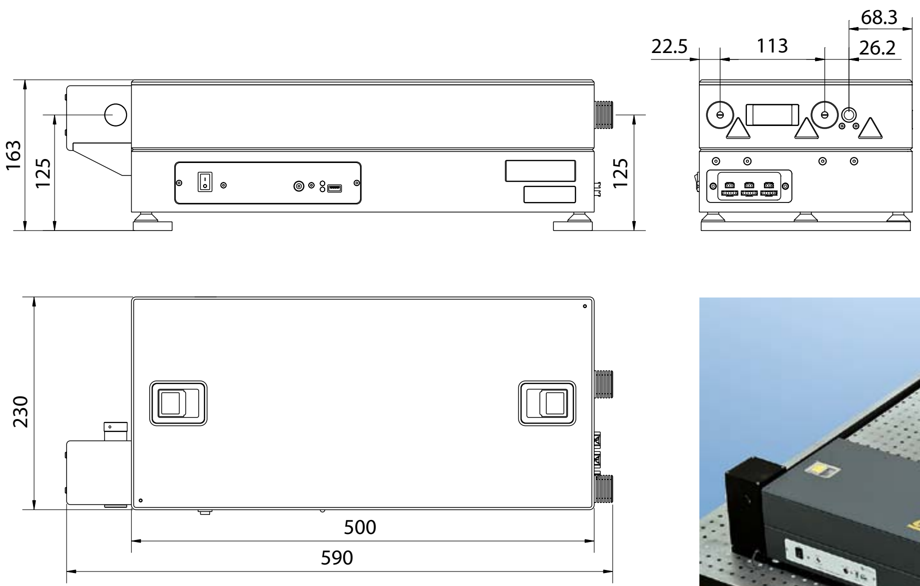
	ORPHEUS OPA
Required pump laser	PHAROS or CARBIDE laser
Tuning range	630 – 1020 nm (signal) and 1040 – 2600 nm (idler)
Integrated second harmonic (515 nm) generation efficiency	>40 %
Conversion efficiency at peak of tuning curve, signal and idler combined	>12 %, when pump energy is 20 – 400 µJ [2] >6 %, when pump energy is 8 – 20 µJ
Pulse energy stability	2 % rms @ 700 – 960 nm and 1100 – 2000 nm
Pulse bandwidth	80 – 120 cm^{-1} @ 700 – 960 nm, pumped by PHAROS 120 – 220 cm^{-1} @ 700 – 960 nm, pumped by PHAROS-SP
Pulse duration	150 – 230 fs, pumped by PHAROS 120 – 190 fs, pumped by PHAROS-SP
Time-bandwidth product	< 1.0
Integrated mini spectrometer [3]	Wavelength range: 650 – 1050 nm, resolution: ~1.5 nm

[1] Conversion efficiency specified as the percentage of input power to ORPHEUS.
[2] High energy version ORPHEUS-HE available for pump energies up to 2 mJ.
[3] ORPHEUS-HP only.

WAVELENGTH EXTENSIONS (210 – 630 nm and 2200 – 16000 nm)

Tuning range	Conversion efficiency at peak [1]
315 – 510 nm (SH of Signal) 520 – 630 nm (SH of Idler)	> 3 % at peak @ 20 – 400 µJ [2] > 1.2 % at peak @ 8 – 20 µJ
210 – 255 nm (FH of Signal) 260 – 315 nm (FH of Idler)	> 0.6 % at peak @ 20 – 400 µJ [2] > 0.3 % at peak @ 8 – 20 µJ
2200 – 4200 nm (DFG1)	> 3.0 % at 3000 nm @ 20 – 400 µJ [2] > 1.5 % at 3000 nm @ 8 – 20 µJ
4000 – 16000 nm (DFG2)	> 0.2 % at 10000 nm @ 20 – 400 µJ [2] > 0.1 % at 10000 nm @ 8 – 20 µJ

[1] Conversion efficiency specified as the percentage of input power to ORPHEUS.
[2] High energy version ORPHEUS-HE available for pump energies up to 2 mJ.



ORPHEUS drawings

Compact layout of PHAROS pump laser
in tandem with ORPHEUS on 0.5 square meter

Rev. 20180522

ORPHEUS-HP

High Power Optical Parametric Amplifier

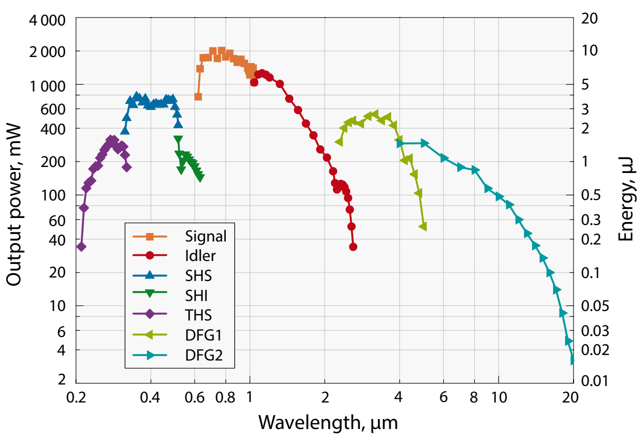
FEATURES

- 190 nm – 16000 nm tunable wavelenght
- Single pulse – 1 MHz repetition rate
- Up to 40 W pump power
- Up to 0.4 mJ pump energy (higher energy upon request)
- Automated wavelengths separation
- Integrated spectrometers for monitoring the output wavelength

ORPHEUS-HP is a collinear optical parametric amplifier of white-light continuum pumped by PHAROS laser. The device is a modified version of the ORPHEUS OPA, with UV-VIS and Mid-IR tuning range frequency mixers integrated into a thermally-stabilized monolithic housing. ORPHEUS-HP also provides the option of generating deep ultraviolet pulses (190 – 215 nm), in addition to 210 – 2600 nm.

The design of this OPA offers completely hands-free wavelength tuning and automatic wavelength separation, also ensuring the same position and direction for all wavelengths in UV-near-IR region. ORPHEUS-HP integrates a mini spectrometer for online monitoring of output wavelength and comes with specialized software that enables wavelength feedback.

ORPHEUS-HP is highly recommended over standard ORPHEUS if the input power is more that 8 W, or whenever the necessary tuning range requires both UV and mid-infrared generation (for example 315 – 5000 nm).

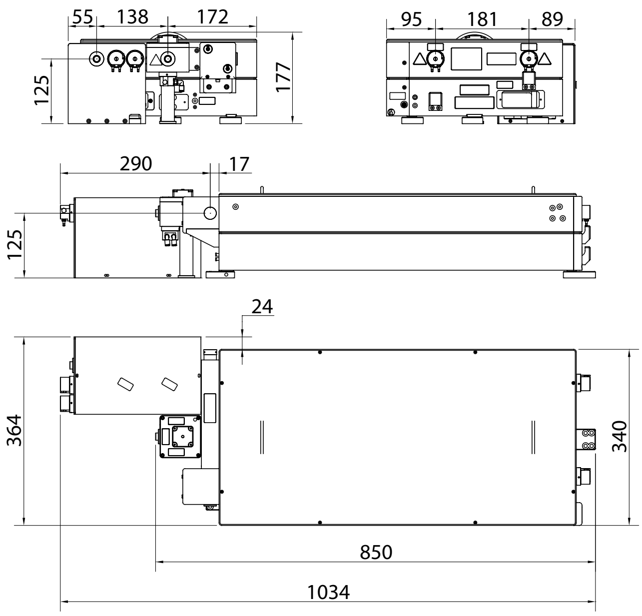


ORPHEUS-HP energy conversion curve.
Pump: 20 W, 200 kHz

Performance specifications are the same as of ORPHEUS except for UV and deep-UV ranges which are provided in the table below.

OUTPUT OF OPTIONAL UV AND DEEP-UV CONVERTER

	DUV	FHG	TH of Signal
Tuning range	190 – 215 nm	258 nm	210 – 315 nm
Pulse energy conversion efficiency at 20 – 1000 µJ	> 0.3 % @ 200 nm	> 5.0 %	> 0.8 % at peak
Pulse energy conversion efficiency at 8 – 20 µJ	Not available		> 0.4 % at peak



ORPHEUS-HP drawings

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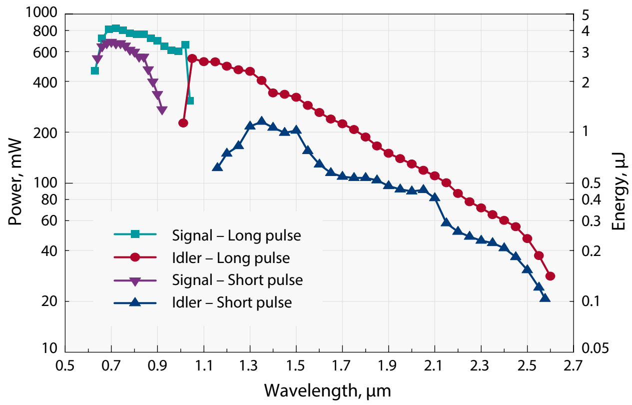
ORPHEUS-F

Broad Bandwidth Hybrid Optical Parametric Amplifier

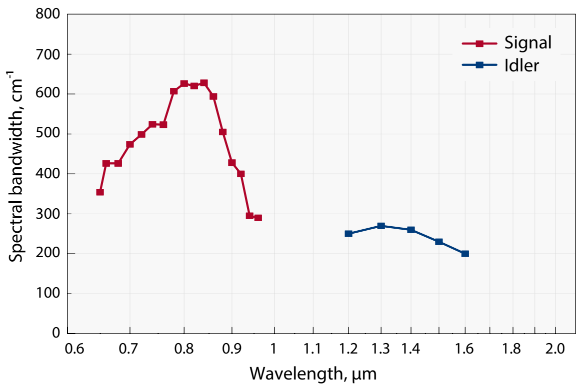
FEATURES

- Combines the best features of collinear and non-collinear OPA
- <100 fs pulse duration
- Variable bandwidth
- Single pulse – 1 MHz repetition rate
- Computer controlled
- Gap filling dual pulse length option

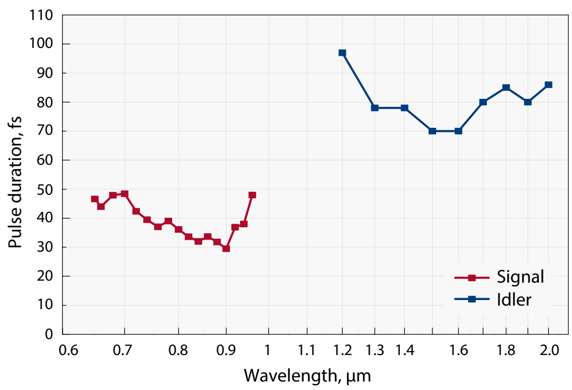
ORPHEUS-F is a hybrid optical parametric amplifier of white-light continuum pumped by femtosecond Ytterbium based laser amplifiers. This OPA combines the short pulse durations that are produced by a non-collinear OPA and wide wavelength tuning range offered by collinear version. The Signal beam can be easily compressed with a simple prism-based setup down to <60 fs in most of the tuning range, while Idler is compressed in bulk material down to 40 – 90 fs depending on wavelength. Switching to standard OPA configuration for tuning in 900 – 1200 nm range (250 fs) is optional. It possible to limit the output bandwidth to some extent (up to 2 – 3 times) without losing any output power. Standard ORPHEUS device uses spectral narrowing to produce bandwidth-limited 200 – 300 fs duration pulses directly at the output, with extended Signal/Idler tuning range and options to generate ultraviolet and mid-infrared light. Our non-collinear ORPHEUS-N-2H device produces even broader bandwidths, compressible down to <20 fs, but limits the tuning range to 650 – 900 nm. For most applications, the performance of ORPHEUS-F configuration is the optimal choice.



Typical performance of ORPHEUS-F



Typical spectral bandwidth of ORPHEUS-F



Pulse duration after external compression of ORPHEUS-F

SPECIFICATIONS [1)]

	ORPHEUS-F OPA
Required pump laser	PHAROS, PHAROS-SP or CARBIDE laser
Tuning range	650 – 900 nm (signal) and 1200 – 2500 nm (idler)
Conversion efficiency at peak of tuning curve, second stage signal and idler combined	>10 %, when pump energy is 10 – 500 μJ
Pulse energy stability	<2 % rms @ 700 – 900 nm and 1200 – 2000 nm
Pulse bandwidth	200 – 600 cm^{-1} @ 650 – 900 nm 150 – 500 cm^{-1} @ 1200 – 2000 nm
Pulse duration before compression	<250 fs
After compression [2)]	35 – 70 fs @ 650 – 900 nm 40 – 100 fs @ 1200 – 2000 nm
Compressor transmission [2)]	50 – 70 % @ 650 – 900 nm 70 – 80 % @ 1200 – 2000 nm

[1)] *Conversion efficiency specified as the percentage of input power to ORPHEUS-F.*
[2)] *Optional compressor includes two prism compressor for signal and bulk compressor for idler.*

ORPHEUS-N

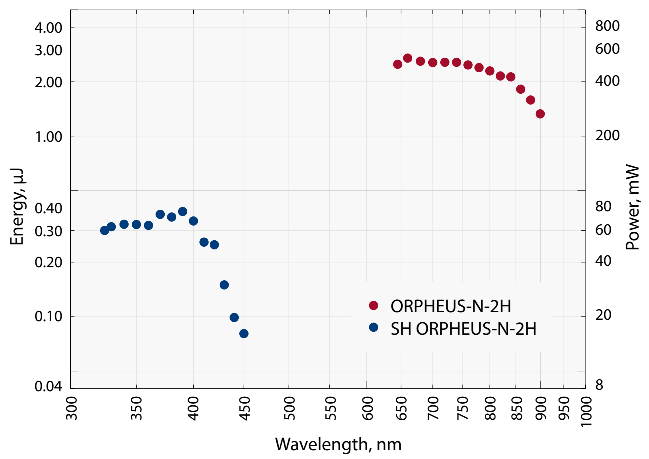
Non-Collinear Optical Parametric Amplifier

FEATURES

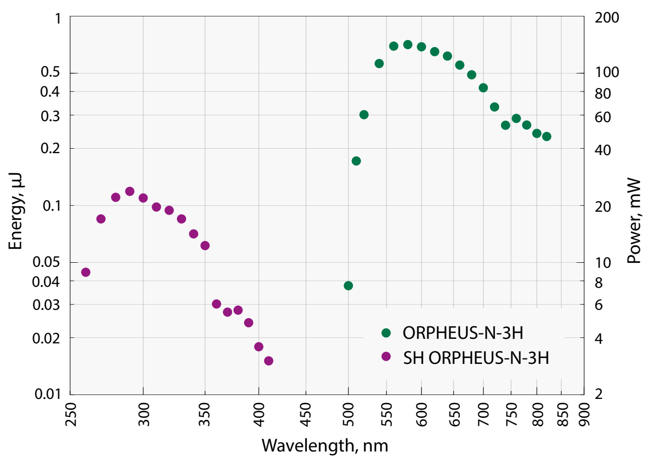
- < 30 fs pulse duration
- Integrated prism compressor
- Adjustable bandwidth and pulse duration
- Single pulse – 1 MHz repetition rate
- Computer controlled

ORPHEUS-N is a non-collinear optical parametric amplifier (NOPA) pumped by the PHAROS laser system. Depending on the ORPHEUS-N model, it has a built in second or third harmonic generator producing 515 nm or 343 nm pump. ORPHEUS-N with second harmonic pump (ORPHEUS-N-2H) delivers pulses of less than 30 fs in 700 – 850 nm range with average power of more than 0.5 W at 700 nm*. ORPHEUS-N with third harmonic pump (ORPHEUS-N-3H) delivers pulses of less than 30 fs in 530 – 670 nm range with average power of more than 0.2 W at 550 nm*. ORPHEUS-N works at repetition rates of up to 1 MHz. The device is equipped with computer controlled stepping motor stages, allowing automatic tuning of the output wavelength. An optional signal's second harmonic generator is also available, extending the tuning range down to 250 – 450 nm. Featuring a state of the art built in pulse compressor ORPHEUS-N is an invaluable instrument for time-resolved spectroscopy. More than two ORPHEUS-N systems can be pumped with a single PHAROS laser providing several pump and/or probe channels with independent wavelength tuning.

when pumped with 6 W @ 1030 nm, 200 kHz.



Typical tuning curve of ORPHEUS-N-2H
Pump: Pharos-6W, 200 kHz, 260 fs



Typical tuning curve of ORPHEUS-N-3H
Pump: Pharos-6W, 200 kHz, 260 fs

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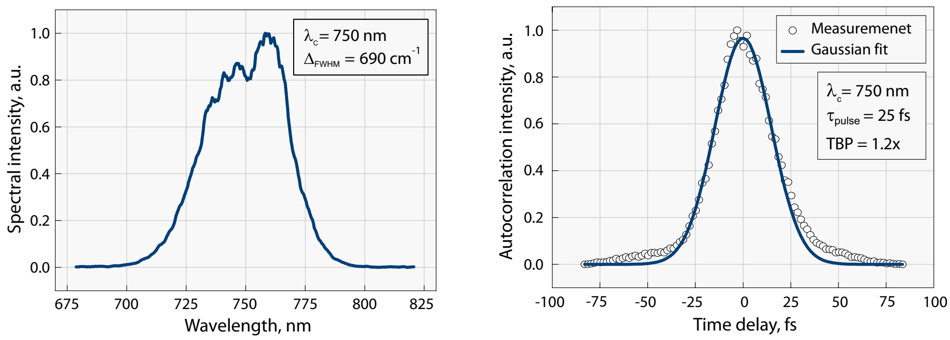
SPECIFICATIONS

	ORPHEUS-N-2H (pump: 30 µJ @1030 nm)	ORPHEUS-N-3H (pump: 30 µJ @1030 nm)
Tuning range	650 – 900 nm	500 – 800 nm
Built in harmonic generator	Second harmonic 515 nm wavelength >14 µJ pulse energy	Third harmonic 343 nm wavelength >8 µJ pulse energy
Output pulse energy (after prism compressor)	7 % at peak (700 nm) 3 % @ 850 nm Max. pump power is 8 W	1.3 % at peak (580 nm) 0.7 % @ 700 nm Max. pump power is 8 W
Pulse duration (Gaussian fit)	<30 fs at 700 – 850 nm	<30 fs at 530 – 670 nm <80 fs at 670 – 800 nm

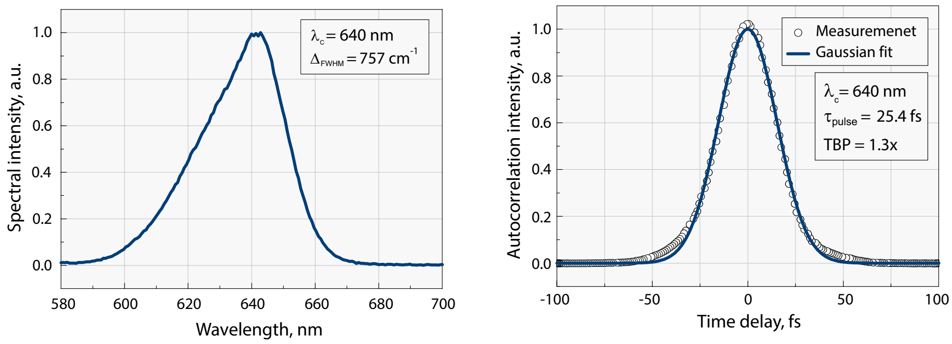
Requirements for the pump laser (typically PHAROS femtosecond laser):
wavelength 1030 nm, repetition rate 1 – 1000 kHz, pump pulse energy 8 – 200 µJ, pulse duration (FWHM) 180 – 290 fs.

OPTIONAL ACCESSORIES

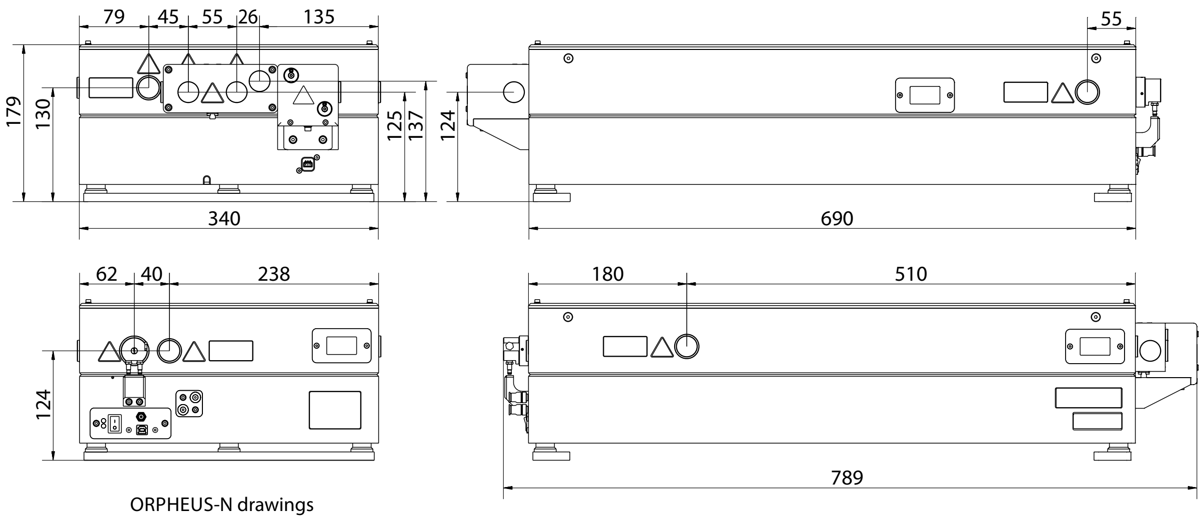
- Second harmonic generator of signal wave
- Computer controllable pulse duration



Typical output of ORPHEUS-N-2H



Typical output of ORPHEUS-N-3H



ORPHEUS-N drawings

ORPHEUS-ONE

Collinear Mid-IR Optical Parametric Amplifier

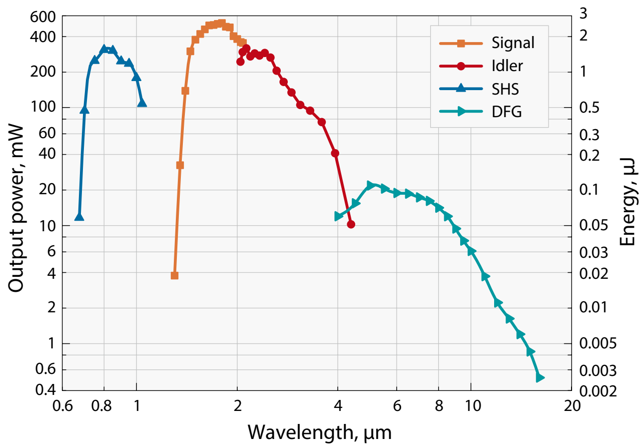
FEATURES

- Signal and idler tuning from 1350 nm to 4500 nm
- Tuning range extendable to 16000 nm
- Twice the output in mid-IR compared to standard ORPHEUS
- Built on well-known TOPAS OPA basis
- Repetition rate up to 1 MHz
- Adaptable to different pump pulse energy and pulse duration
- Full computer control via USB port and dedicated software

ORPHEUS-ONE is a collinear optical parametric amplifier of white-light continuum pumped by femtosecond Ytterbium based laser amplifiers and focused on mid infrared wavelengths generation in two stages.

In comparison to standard ORPHEUS + DFG configuration, the ORPHEUS-ONE provides higher conversion efficiency into the infrared range. Furthermore, ORPHEUS-ONE integrates the two stages into a single housing, which minimizes the footprint of the system and increases the long term stability.

The extended range 4500 – 16000 nm is accessed by mixing the signal and idler of the second stage in a mid-IR crystal. The scheme used in ORPHEUS-ONE can generate >150 cm^{-1} when OPA is configured for broad-bandwidth amplification.



Typical tuning curve of ORPHEUS-ONE.
Pump: Pharos-6W, 200 kHz, 260 fs

SPECIFICATIONS [1)]

	ORPHEUS-ONE OPA
Required pump laser	PHAROS, PHAROS-SP or CARBIDE laser
Tuning range	1350 nm – 2060 nm (signal) and 2060 nm – 4500 nm (idler)
Integrated second harmonic (515 nm) generation efficiency	~10 – 25 %, this beam is not accessible without special modification
Conversion efficiency at peak of tuning curve, second stage signal and idler combined	>14 %, when pump energy is 30 μJ – 400 μJ [2)]
Pulse energy stability	<2 % rms @ 1450 – 4000 nm
Pulse bandwidth	100 – 250 cm^{-1} @ 1450 – 2000 nm
Pulse duration	200 – 250 fs, pumped by PHAROS 120 – 190 fs, pumped by PHAROS-SP
Time-bandwidth product	< 1.0 @ 1450 – 2000 nm

[1)] Conversion efficiency specified as the percentage of input power to ORPHEUS-ONE .
[2)] High energy version ORPHEUS-ONE-HE available for pump energies up to 2 mJ.

OUTPUT OF OPTIONAL MID-IR CONVERTER

	DFG2
Tuning range	4500 – 16000 nm
Pulse energy conversion efficiency	>0.3 % @ 10000 nm
Pulse bandwidth	100 – 160 cm^{-1} @ 5000 – 10000 nm
Pulse energy stability	<3 % rms @ 5000 nm <4 % rms @ 10000 nm
Pulse duration	<300 fs @ 5000 – 10000 nm

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LIGHT CONVERSION

ORPHEUS-PS

Narrow Bandwidth Optical Parametric Amplifier

FEATURES

- Built on well known TOPAS-800 OPA basis
- Continuously tunable picosecond pulses in 315 – 5000 nm
- Near bandwidth limited output, <15 cm^{-1} spectral width
- High stability is possible by seeding with femtosecond white light continuum
- Repetition rate up to 100 kHz
- Full computer control via USB port and dedicated software

APPLICATIONS

- Stimulated Raman Spectroscopy
- Surface sum-frequency spectroscopy

SPECIFICATIONS

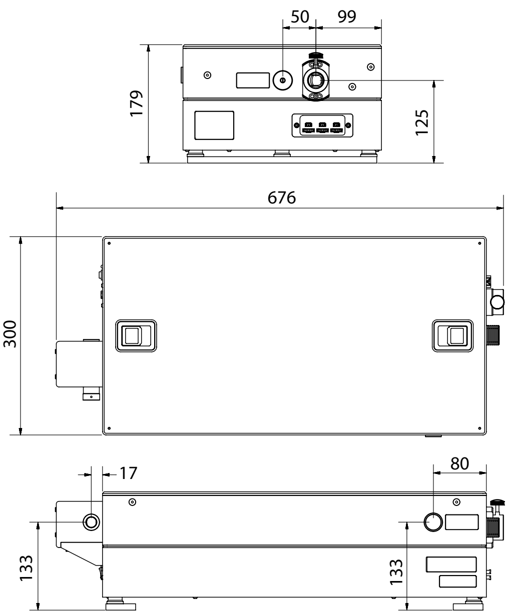
	ORPHEUS-PS OPA
Tuning range	630 – 1020 nm signal and 1040 – 2600 nm idler
Pulse energy conversion efficiency	>20 % (of pump from SHBC)
Pulse energy stability	<2.0 % rms @ 700 – 960 nm and 1100 – 2000 nm
Spectral width	<20 cm^{-1} @ 700 – 960 nm and 1100 – 2000 nm
Pulse duration	2 – 4 ps depending on pump pulse duration from SHBC-515
Time-bandwidth product	<1.0

Requirements for the input pulses:

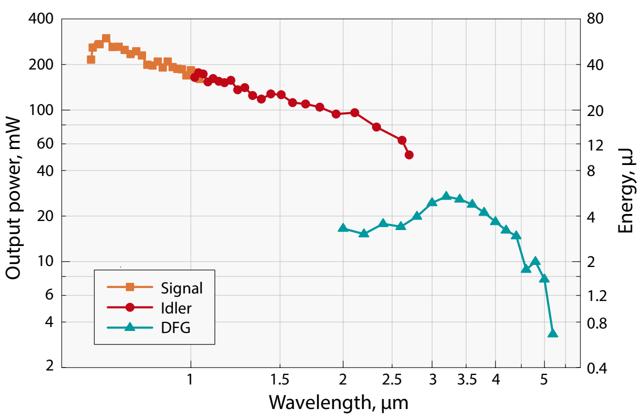
1) Picosecond 515 nm, produced by SHBC-515: energy 120 μJ – 1 mJ, pulse duration 2 – 5 ps, spectral width <10 cm^{-1};
2) Femtosecond 1030 nm: energy 2 – 3 μJ, pulse duration <300 fs.

ORPHEUS-PS is a narrow bandwidth optical parametric amplifier of white light continuum, designed for PHAROS pump laser. This device is pumped by the picosecond pulses produced in SHBC-515 narrow bandwidth second harmonic generator, and seeded by white light continuum generated by femtosecond pulses. This enables to achieve very high pulse to pulse stability compared to other methods of generating tunable picosecond pulses. The white light generation module is also integrated into the same housing as amplification modules, enabling even better long term stability and ease of use. The system features high conversion efficiency, nearly bandwidth and diffraction limited output, full computer control via USB port and LabVIEW drivers.

A part of the PHAROS laser radiation can be split to simultaneously pump a femtosecond OPA, providing broad bandwidth 630 nm – 16 μm tunable pulses, giving access to the complete set of beams necessary for versatile spectroscopy applications, for example narrow band Raman spectroscopy measurements, or surface sum-frequency spectroscopy.



ORPHEUS-PS drawings



ORPHEUS-PS performance.
Pumped by 2 W @ 5 kHz from SHBC 514.2 nm, Δλ=~8 cm^{-1}, τ=2.7 ps

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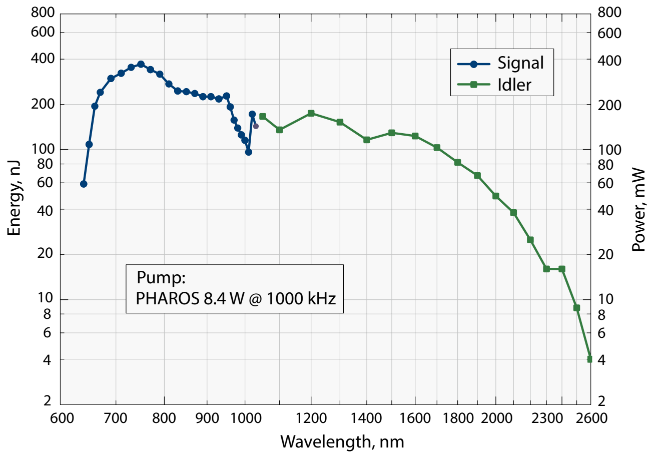
ORPHEUS twins

Two Independently Tunable Optical Parametric Amplifiers

FEATURES

- Two OPA units in a single compact housing
- 210 nm – 16 µm tunable wavelength
- Single pulse – 1 MHz repetition rate
- Up to 0.4 mJ pump energy (2 mJ upon request)
- Broadband and short-pulse (<100 fs) versions available
- Possibility of generating CEP stable mid-infrared output
- Integrated spectrometers for monitoring the output wavelength of OPA

ORPHEUS-Twins – two independently tunable optical parametric amplifiers designed for flexible pump parameters and OPA configuration. The two channels can be separately configured to be a version of either ORPHEUS, ORPHEUS-ONE, ORPHEUS-F or even ORPHEUS-N. Both OPA units are integrated into a single housing and share the same white light seed for amplification. The design of this OPA enables hands free wavelength tuning, optional automated wavelength separation and the possibility of generating broad band mid-infrared radiation, in the region of 4 µm – 16 µm, with a passively stable Carrier Envelope Phase (CEP).



SPECIFICATIONS

Required pump laser	PHAROS or CARBIDE
Accepted pump input pulse energy @ 1030 nm, 150 fs – 300 fs pulse duration	8 µJ – 2 mJ
Supported repetition rates	Single pulse – 1 MHz
Tuning range	Choice between ORPHEUS, ORPHEUS-F or ORPHEUS-ONE configurations
Output pulse energy	Depends on the configuration – check the specifications of the chosen models
Pulse bandwidth	Depends on configuration, up to 100 – 500 cm^{-1}
Pulse duration	Depends on configuration, down to 40 fs

Dimensions	**W × L × H**
Full dimension of the ORPHEUS Twins, including wavelength separation	810 × 430 × 164 mm
Full dimensions of the PHAROS+ORPHEUS Twins system with beam routing units	910 × 850 × 215 mm

TOPAS

Optical Parametric Amplifiers for Ti:Sapphire lasers

TOPAS is a range of white light seeded femtosecond Optical Parametric Amplifiers (OPA), which can deliver continuous wavelength tunability from 189 nm to 20 µm, high efficiency and full computer control. With more than 1700 units installed worldwide, TOPAS has become an OPA market leader and standard tool for numerous scientific applications. TOPAS can be pumped by Ti:Sapphire amplifiers with pulse duration ranging from 20 fs to 200 fs and pulse energies from10 µJ up to 60 mJ. Custom solutions beyond given specifications are also available.

FEATURES

- Typical energy conversion into the parametric radiation > 25 – 30% (signal and idler combined)
- Tuning range 1160 – 2600 nm out of a single box (extendable to 189 nm – 20 µm)
- High output stability throughout the entire tuning range
- Nearly bandwidth and diffraction limited output
- Passive carrier envelope phase (CEP) stabilization of the idler (1600 – 2600 nm)
- Computer controlled operation
- Custom solutions available

TOPAS-Prime

TOPAS-Prime is a two stage optical parametric amplifier of white-light continuum. TOPAS-Prime offers high energy conversion efficiency (>30% typically) without compromise in spatial, spectral and temporal qualities of the output. Two main versions of TOPAS-Prime are available: a standard version with input energy of up to 3.5 mJ @ 35 fs and TOPAS-Prime-Plus with increased input energy acceptance of up to 5 mJ @ 35 – 100 fs.

TOPAS-HR

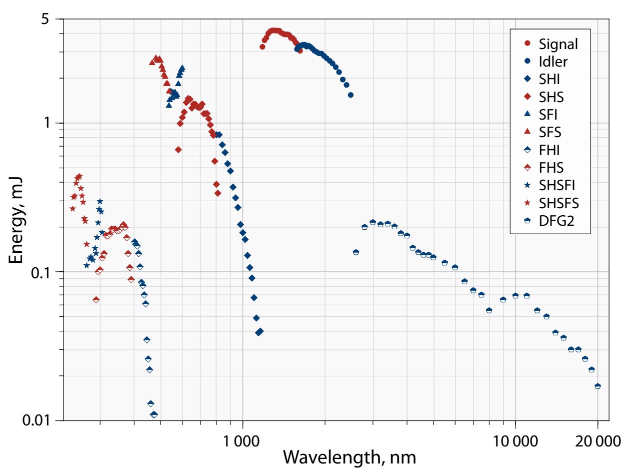
for High Repetition Rate Aplications

TOPAS-HR is an optical parametric amplifier designed for high repetition rate (10 kHz – 1 Mhz) applications. TOPAS-HR provides high pulse-to-pulse stability throughout the entire tuning range, high output pulse and beam quality, full automation via USB port as well as optional frequency mixing stages for tuning range extention. TOPAS-HR can be pumped by high repetition rate Ti:Sapphire femtosecond laser amplifiers and is an invaluable tool for spectroscopy, multiphoton microscopy, micro-structuring and other applications.

HE-TOPAS-Prime

for High Pump Energy

HE-TOPAS-Prime is a three stage optical parametric amplifier of white-light continuum designed for input energies higher than 5 mJ. Over 40% energy conversion efficiency to signal and idler is typically achieved. The system is compact, user-friendly and easily reconfigurable for different pump pulse parameters. Two main versions of HE-TOPAS-Prime are available: a standard version with input energy of up to 25 mJ @100 fs (8 mJ @ 35 fs) and HE-TOPAS-Prime-Plus with input energy of up to 60 mJ @ 100 fs (20 mJ @ 35 fs). Additional custom solutions are available, e.g. higher pump energy, temperature stabilized housing, slow loop idler-CEP stabilisation etc.



HE-TOPAS-Prime tuning curve. Pump: 22 mJ, 45 fs, 805 nm

NirUVis Frequency Mixer

NirUVis is an add-on frequency mixer unit for TOPAS-Prime and HE-TOPAS-Prime devices. It consists of three computer controlled nonlinear crystal stages in a monolithic housing. Output is generated by employing a combination of second and fourth harmonic generation as well as sum frequency generation. In comparison with separately standing wavelength mixing stages, NirUVis offers higher conversion efficiency in certain wavelength ranges, ease of operation, compact design, and low environmental sensitivity. In addition, wavelength separation is added after each nonlinear interaction ensuring high output pulse contrast.

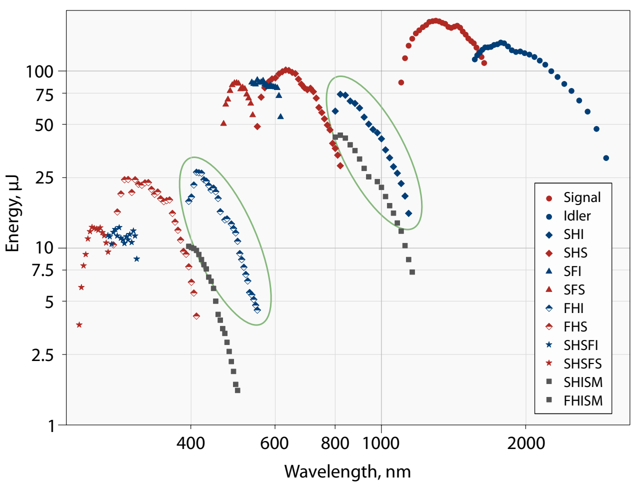
AUTOMATED NirUVis FEATURES

- Motorized wavelength tuning and separation – no manual operations
- Single output port for all wavelengths in 240 – 2600 nm range – same position and direction
- Automated polarization rotator for signal beam enables a more consistent output beam polarization for different interactions
- Automated signal dichroic mirror ensures good wavelength contrast ratio of SHI
- Increased conversion efficiency of idler related interactions
- Optical table layout can be U-shaped, L-shaped or in a straight line with respect to TOPAS-Prime

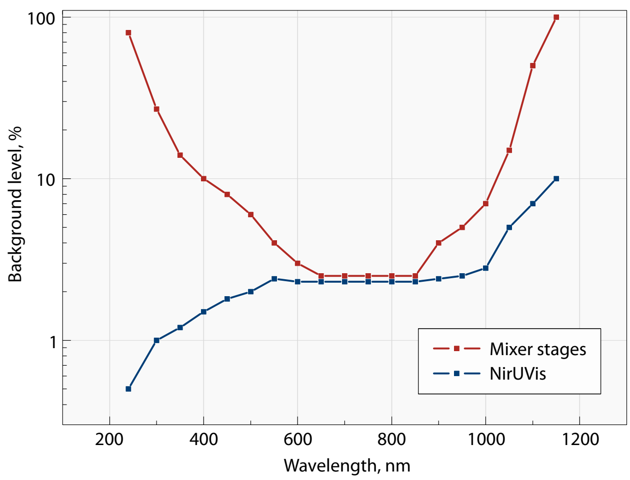
SPECIFICATIONS

	Automated NirUVis	Standard NirUVis	NirUVis-DUV
Maximum wavelength range	240 – 1160 nm	240 – 1160 nm	189 – 1160 nm
Wavelength tuning automated, except:	Fully automated	Manual change of wavelength separators	Manual change of wavelength separators
Number of output ports	Single output port for all the wavelengths	4 output ports (wavelength dependent)	4 output ports (wavelength dependent)
FRESH pump option *	Included	Optional	Included

** see next page for details*



Typical TOPAS-prime (Fresh Pump otion) + NirUVis output energies when pumped with 1 mJ, 100 fs, 800 nm pump.
(SHISM and FHISM energies achieved with separate mixing stages)



Background level comparison between NirUVis and separate mixing stages

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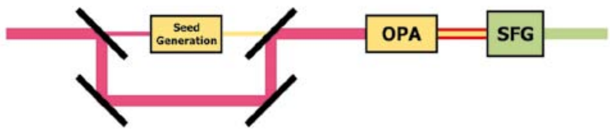
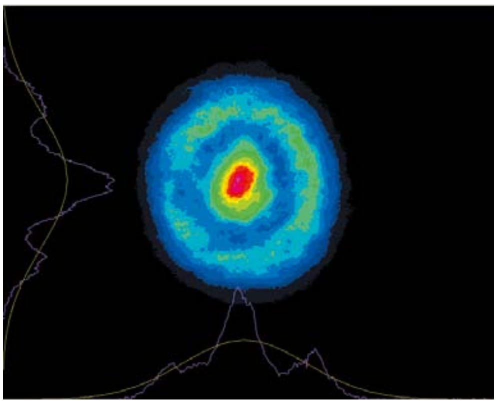
FRESH Pump Option

for Sum-Frequency Generation (SFG) in range 475 – 580 nm for TOPAS-Prime

DEPLETED pump option

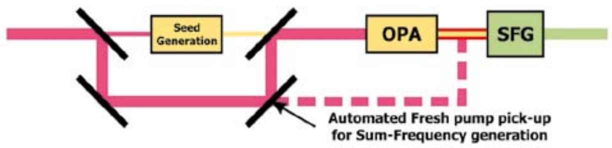


Option when DEPLETED pump is used for SFG

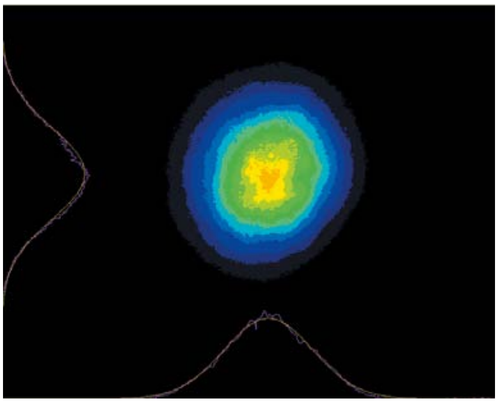


SF output profile for DEPLETED pump

FRESH pump option



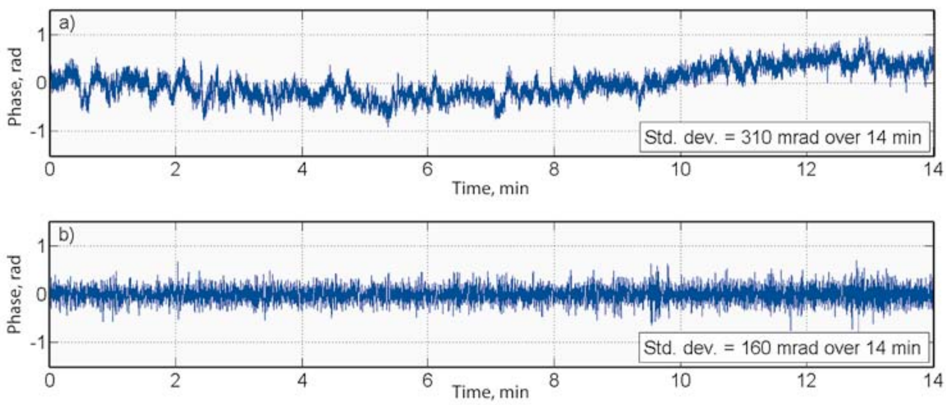
Option when FRESH pump is used for SFG



SF output profile for FRESH pump

Idler CEP Stabilization Kit

TOPAS idler wave (1600 – 2600 nm) is passively CEP locked due to a three-wave parametrical interaction, however a slow CEP drift caused by changes in pump beam pointing or environmental conditions still persist. Now we are offering a complete solution for CEP registration and slow drift compensation. Phase correction is performed by employing an f-2f interferometer and a feedback loop controlling temporal delay between seed and pump in power amplification stage of TOPAS-Prime or HE-TOPAS-Prime.



Retrieved value and computed standard deviation of the idler CEP over 14 min time range.
(a) without compensation of drift, (b) with compensation of drift with a slow loop. Integration time 4 ms (four pulses)

ULTRAFAST LASERS | OSCILLATORS | HARMONICS GENERATORS | OPTICAL PARAMETRIC AMPLIFIERS | TOPAS DEVICES | SPECTROMETERS | AUTOCORRELATORS

HARPIA-TA

new

Ultrafast Transient Absorption Spectrometer

APPLICATION FIELDS

- Photochemistry
- Photobiology
- Photophysics
- Material science
- Semiconductor physics
- Time-resolved spectroscopy

The popular transient absorption spectrometer HARPIA has been reimagined and redesigned to meet the needs and standards of today's scientific world. The new improved HARPIA offers a sleek and compact design and together with intuitive user experience and easy day-to-day maintenance. Adhering to the standards raised by the OPRHEUS line of devices, the entire spectroscopic system is now contained in a single monolithic aluminum casing that inherently ensures excellent optical stability and minimal optical path for the interacting beams. In contrast to its predecessor, the dimensions of the device are greatly reduced. The area was reduced roughly by 2.6×, whereas volume was reduced by nearly 4×. The new HARPIA can be easily integrated with both PHAROS / ORPHEUS and Ti:Sa / TOPAS laser systems. Just like its precursor, it features market leading characteristics such as 10^{-5} resolvable signals along with other unique properties such as the ability to work at high repetition rates (up to 1 MHz) when used with PHAROS/ORPHEUS system. High repetition rate allows measuring transient absorption dynamics while exciting the samples with extremely low pulse energies (thereby avoiding exciton annihilation effects in energy transferring systems or nonlinear carrier recombination in semiconductor/nanoparticle samples).

A number of probe configurations and detection options are available starting with simple and cost effective photodiodes for single wavelength detection and ending with spectrally-resolved broadband detection combined with white light continuum probing. Data acquisition and measurement control are now integrated within the device itself and offer such improved detection capabilities as:

- Single (sample-only) or multiple (sample and reference) integrated spectral detectors;
- Simple integration of any user-preferred external spectrograph;
- Beam monitoring and self-recalibration capabilities (both along the optical path of the pump/probe beams and at the sample plane) and an option for automated beam readjustment;
- Straightforward switching between transient absorption or transient reflection measurements;
- Capability to combine both transient absorption and Z-scan experiments on the same device;

Moreover, different delay line options can be selected to cover delay windows from 2 ns to 8 ns and HARPIA may house either standard linear leadscrew (20 mm/s) or fast ball-screw (300 mm/s) optical delay stages.

A number of optomechanical peripherals are now compactly enclosed in the HARPIA casing, including:

- An optical chopper that can either phase-lock itself to any multiple of the frequency of the laser system or operate in a free-running internally-referenced regime (standard);
- Motorized and calibrated Berek's polarization compensator that can automatically adjust the polarization of the pump beam (optional);
- Motorized transversely translatable supercontinuum generator (applicable for safe and stable supercontinuum generation in materials such as CaF_2 or MgF_2; optional);
- Automated sample raster scanner that translates the sample in the focal plane of the pump and probe beams, thus avoiding local sample overexposure (optional).

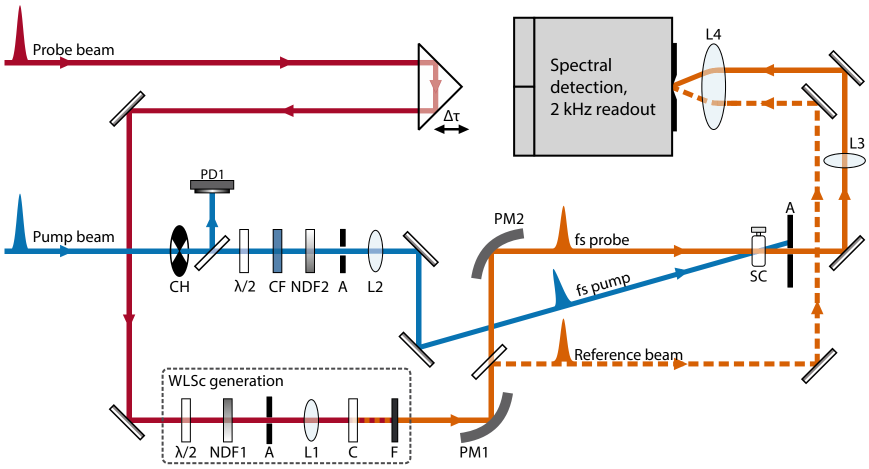
Moreover, the new HARPIA is designed to be compatible with any user-favored cryostat and/or peristaltic pump system (see mounting sheme). Capabilities of the new HARPIA can be further extended by introducing a third beam to the sample plane, thus allowing the user to perform multi-pulse transient absorption measurements.

In addition to experiment automation software, HARPIA includes data analysis package CarpetView for inspecting the acquired data and performing global and target analysis, probe dispersion compensation, exponential fitting etc. The software package features an intuitive and user friendly interface; it is delivered with a data analysis tutorial that offers seamless transition from the raw data to publication quality graphs and model based parameter estimation. All the software runs under MS Windows and it is easy to use. Even a novice will become an analysis expert in a matter of days!

SPECIFICATIONS

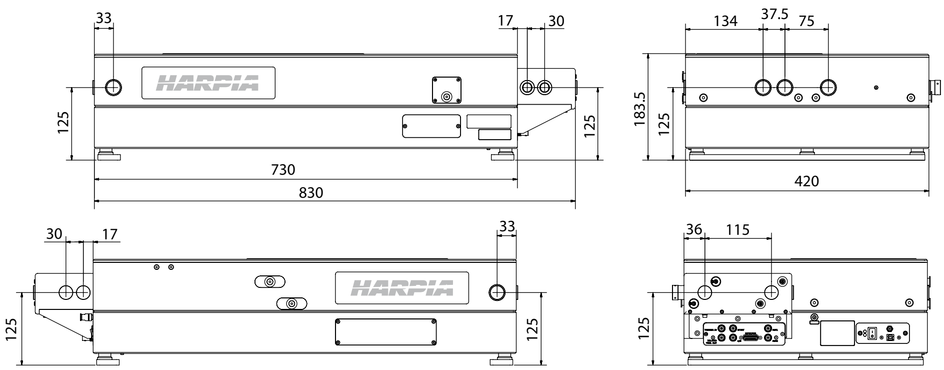
Probe wavelength range, supported by the optics	240 – 2600 nm
Probe wavelength range, white light supercontinuum generator, pumped by 1030 nm	350 – 750 nm, 480 – 1100 nm
Probe wavelength range, white light supercontinuum generator, pumped by 800 nm	350 – 1100 nm
Probe wavelength range of the detectors	200 nm – 1100 nm, 700 nm – 1800 nm, 1.2 µm – 2.6 µm
Spectral range of the spectral devices	180 nm – 24 µm, achievable with interchangeable gratings
Delay range	4 ns, 6 ns, 8 ns
Delay resolution	4.17 fs, 6.25 fs, 8.33 fs
Laser repetition rate	1 – 1000 kHz (digitizer frequency <2 kHz)
Time resolution	< 1.4 x the pump or probe pulse duration (whichever is longer)
Physical dimensions, L×W×H	730 × 420 × 160 mm [1]

[1] *Without external spectrograph.*



HARPIA-TA optical layout

Cryostat mounting scheme



HARPIA-TA outline drawings

HARPIA

new

Extended Spectroscopic Systems

Capabilities of HARPIA-TA spectrometer can be further expanded by HARPIA-TF and HARPIA-TB extensions. Fundamentally, the all-integrated HARPIA system can be viewed as a miniaturized lab facilitating all the most popular time-resolved spectroscopy experiments in a single package. The all-inclusive HARPIA system can provide an extensive comprehension of the intricate photophysical and photochemical properties of the investigated samples.

Switching between different experimental realizations is fully automated and requires very little user interference. The optical layout of HARPIA system is refined to offer both an incredibly small footprint (see the dimensions below) and an easy and intuitive user experience. Despite its small size, HARPIA is easily customizable and can be tailored for specific measurement needs. All the experiments that the HARPIA system provides are managed by a new and improved user application with experiment guiding wizards, measurement presets, and development kit for custom applications.

HARPIA setup unifies multiple time-resolved spectroscopy capabilities, including:

- Femtosecond transient absorption
- Femtosecond transient reflection
- Femtosecond multi-pulse transient absorption/reflection measurements
- Femtosecond fluorescence upconversion
- Hundred picoseconds-to-microsecond time-correlated single photon counting (TCSPC)
- Automated measurements of intensity dependence of transient absorption and time-resolved fluorescence signal
- Possibility to perform time resolved femtosecond stimulated Raman scattering (FSRS) experiments

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Available HARPIA configurations

HARPIA

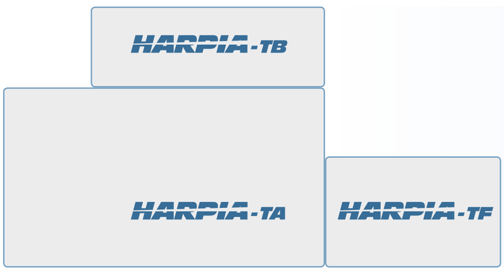
Ultrafast Transient Absorption, TCSPC and Fluorescence Upconversion Spectroscopic System

HARPIA

Ultrafast Multi-pulse Transient Absorption Spectroscopic System

HARPIA

Ultrafast Multi-pulse Transient Absorption, TCSCP and Fluorescence Upconversion Spectroscopic System



HARPIA-TF

new

Femtosecond Fluorescence Upconversion & TCSPC Extension

HARPIA-TF is a time-resolved fluorescence measurement extension to the HARPIA-TA mainframe that combines two time-resolved fluorescence techniques. For the highest time resolution, fluorescence is measured using the time-resolved fluorescence upconversion technique, where the fluorescence light emitted from the sample is sum-frequency mixed in a nonlinear crystal with a femtosecond gating pulse from the laser. The time resolution is then limited by the duration of the gate pulse and is in the range of 250 fs. For fluorescence decay times exceeding 150 ps, the instrument can be used in time-correlated single-photon counting (TCSPC) mode that allows for measuring high-accuracy kinetic traces in the 200 ps – 2 μs temporal domain. HARPIA-TF extension is designed around the industry leading Becker&Hickl® time-correlated single-photon counting system, with different detector options available.

The combination of two time-resolved fluorescence techniques enables recording the full decay of fluorescence kinetics at each wavelength; with full data available, spectral calibration of the intensity of kinetic traces taken at different wavelengths is possible, where the integral of time-resolved data is matched to a steady-state fluorescence spectrum.

High repetition rates of PHAROS laser system allows for measuring fluorescence dynamics while exciting the samples with extremely low pulse energies (thereby avoiding exciton annihilation effects in energy transferring systems, or nonlinear carrier recombination in semiconductor/nanoparticle samples).

Preset or custom delay times, number of averages per transient spectrum, automated upconversion signal search and optimization and other options are available at a click of the mouse.

FEATURES

- An unique first of its kind all-encompassing time-resolved spectroscopic system
- A small and compact design
- Straightforward operation and easy day-to-day maintenance
- Can be installed as an add-on to HARPIA-TA mainframe or it can be acquired as a standalone time-resolved fluorescence measurement system
- Easy switching between different spectroscopic measurement modes
- Compatible with PHAROS series lasers running at 50 – 1000 kHz
- Integrates industry-leading Becker&Hickl® time-correlated single-photon counter
- Automated spectral scanning and upconversion crystal/prism tuning – collect spectra or kinetic traces without major system adjustments
- Measure fluorescence dynamics from hundreds of femtoseconds to 2 microseconds in a single instrument
- Full control over the following parameters of pump beam:
  - Polarization (automated Berek variable waveplate in the pump beam);
  - Intensity (continuously variable neutral density filters in both beams with automated versions available);
  - Delay (gate/probe light is delayed in the optical delay line);
  - Wavelength (fluorescence is detected after the monochromator)
- Standard Andor Kymera 193i USB dual output monochromator. When combined with HARPIA-TA mainframe, a single monochromator can be used for both time-resolved absorption and fluorescence measurements with no detector swapping necessary. Other monochromator options are possible, such as double subtractive monochromator to ensure higher TCSPC time resolution, if necessary
- Standard 4 ns delay line with electronics and full software integration. Optional extension of probe times up to 8 ns is possible. Delay line is fully integrated in to HARPIA-TA mainframe housing
- Data analysis software for inspecting the acquired data and performing global and target analysis, dispersion compensation, exponential fitting etc. Includes user-friendly interfaces, runs under MS Windows and is supplied with a manual describing how to get started with target analysis of your data

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SPECIFICATIONS

TCSPC mode	
TCSPC module	Becker&Hickl SPC 130, fully integrated into the software [1]
Detector control	Becker&Hickl DCC 100
Photomultiplier	Becker&Hickl PMC 100 1 standard
Wavelength range	300 – 820 nm
Intrinsic time resolution	<200 ps
Time resolution with monochromator	<1.2 ns [2]
Signal-to-noise	< 100 : 1, assuming 5 s accumulation time per trace [3]
Upconversion mode	
Wavelength range	300 – 1600 nm [4]
Wavelength resolution	Limited by the bandwidth of gating pulse, typically around 100 cm^{-1}
Delay range	4 ns, 6 ns, 8 ns
Delay resolution	4.17 fs, 6.25 fs, 8.33 fs
Time resolution	< 1.4 × the pump or probe pulse duration (whichever is longer), 420 fs with standard PHAROS laser [5]
Signal-to-noise	100 : 1.5, assuming 0.5 s accumulation time per point [6]

1) See www.becker-hickl.de for specifications.

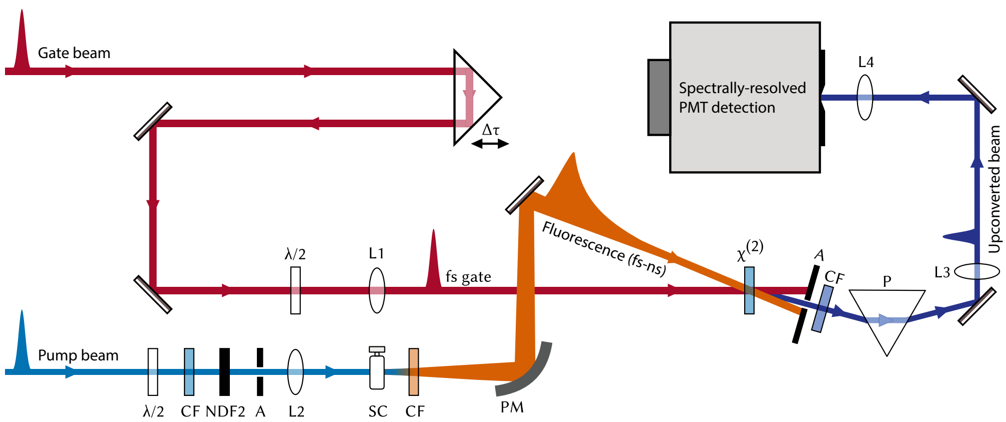
2) Estimated as the FWHM of the upconverted white-light supercontinuum generated in the sample or the derivative of the rise of the upconversion signal.

3) Estimated by fitting the kinetic trace measured in Rhodamine 6G solution at 580 nm with multiple exponentials, subtracting the fit from the data and taking the ratio between the STD of residuals and the 0.5 × maximum signal value. Laser repetition rate 250 kHz. Not applicable to all samples and configurations.

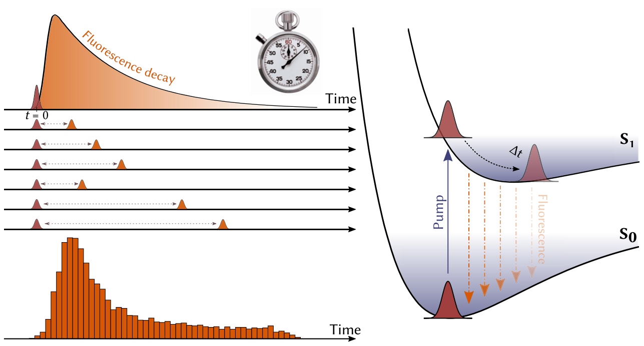
4) Depending on the gating source, may be achievable with different nonlinear crystals.

5) Estimated as the FWHM of the upconverted white-light supercontinuum generated in the sample or the derivative of the rise of the upconversion signal.

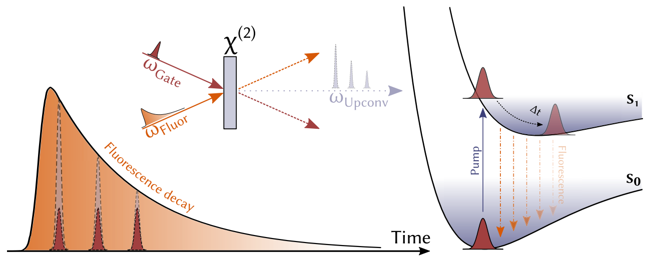
6) Estimated as standard deviation of 100 points at 50 ps measured in Rhodamine 6G dye at 360 nm upconverted wavelength with PHAROS laser running at 150 kHz repetition rate. Not applicable to all samples and configurations.



HARPIA optical layout for fluorescence upconversion experiments



Principle of time-correlated single photon counting (TCSPC)



Principle of time-resolved fluorescence upconversion

HARPIA-TB

Third Beam Delivery Extension

new

When standard spectroscopic techniques are not enough to unravel the intricate ultrafast dynamics of photoactive systems, multi-pulse time-resolved spectroscopic techniques can be utilized to shed additional insight. HARPIA-TB is a third beam delivery unit for the HARPIA-TA mainframe system that adds an additional dimension to typical time resolved absorption measurements. A temporally delayed auxiliary (third) laser pulse, as depicted below, can be applied to a typical pump-probe configuration in order to perturb the on-going pump-induced photodynamics.

An auxiliary pulse resonant to a stimulated emission transition band can deliberately depopulate the excited state species and thereby revert the excited system back to the ground state potential energy surface. This type of experiment is usually referred ad pump-dump-probe (PDP).

When the wavelength of the third pulse corresponds to an induced absorption resonance, the pulse is thus able to elevate the system to a higher excited state (that may or may not be detectable in the standard photoevolution) or return it to an earlier evolutionary transient. This type of measurement is typically referred as pump-repump-probe (PrPP).

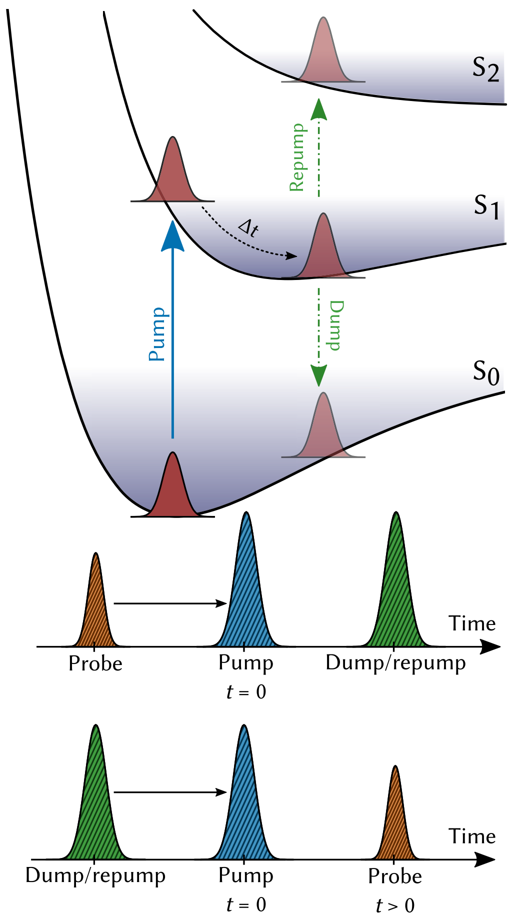
When the auxiliary pulse is resonant to an electronic ground-to-excited state transition, i.e., $S_0 \rightarrow S_n$, it makes it possible to either "replenish" the excited state population or to prepare a small portion of excited state population before the "main" pump pulse. This type of measurement is typically referred as prepump-pump-probe (pPPP).

Since both probe and the auxiliary pulse can be delayed in time in respect to one another, both kinetic trace and action trace experiments can be performed with a HARPIA-TB setup. In other words, we can obtain either the information on how a perturbation disturbs the standard photodynamic behavior of the investigated system (when the probe pulse is propagated in time), or we can monitor how the exact timing of perturbation influences the transient absorption spectrum at a fixed evolutionary phase system (when the auxiliary pulse is propagated in time).

Moreover, HARPIA-TB can be utilized to deliver frequency-narrowed (i.e., picosecond) pulses, thus providing the capability to perform time-resolved femtosecond stimulated Raman scattering (FSRS) spectroscopic measurements.

FEATURES

- Extends the capabilities of HARPIA-TA system
- Can be installed as an add-on to an already existing HARPIA-TA mainframe basis
- Provides an additional dimension to pump-probe measurements
- Provides additional insight to complex photodynamic systems
- Full control of the third beam:
  - Polarization (manual or automated Berek variable waveplate in the third beam path);
  - Intensity (continuously variable neutral density filters in the third beam path with automated version available);
  - Delay (the auxiliary laser pulse is delayed in an optical delay line with full delay ranging from 1.3 to 2.6 ns)
- Data analysis software for inspecting the acquired multi-pulse data and performing global and target analysis



Principle of multi-pulse time-resolved transient absorption spectroscopy

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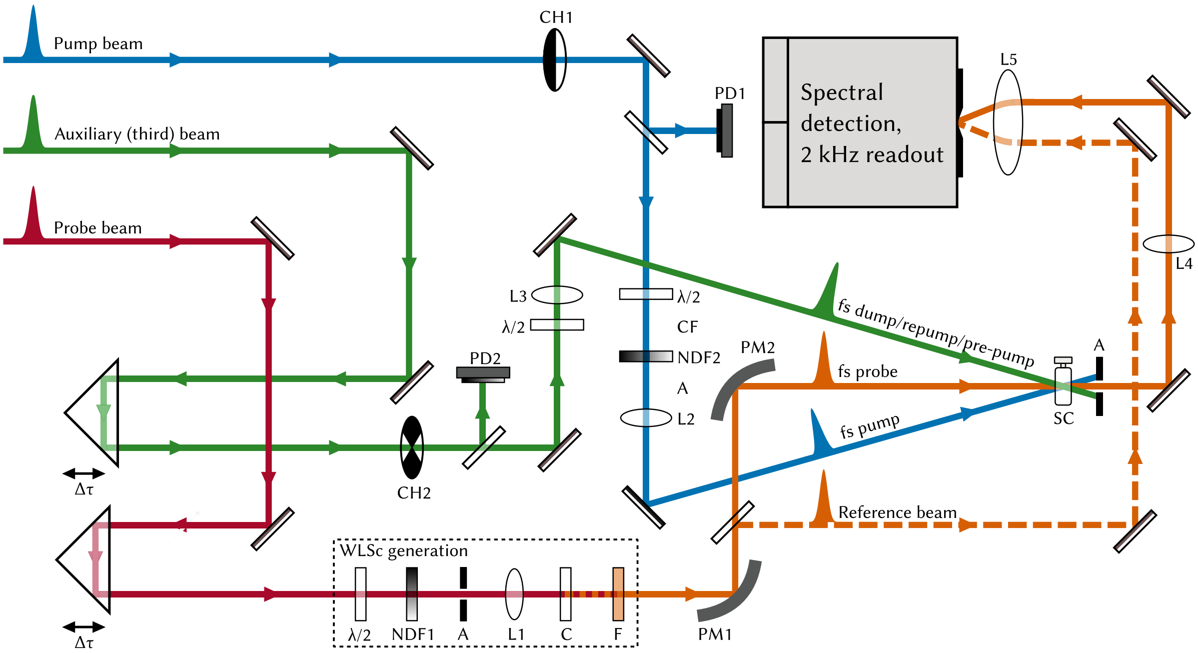
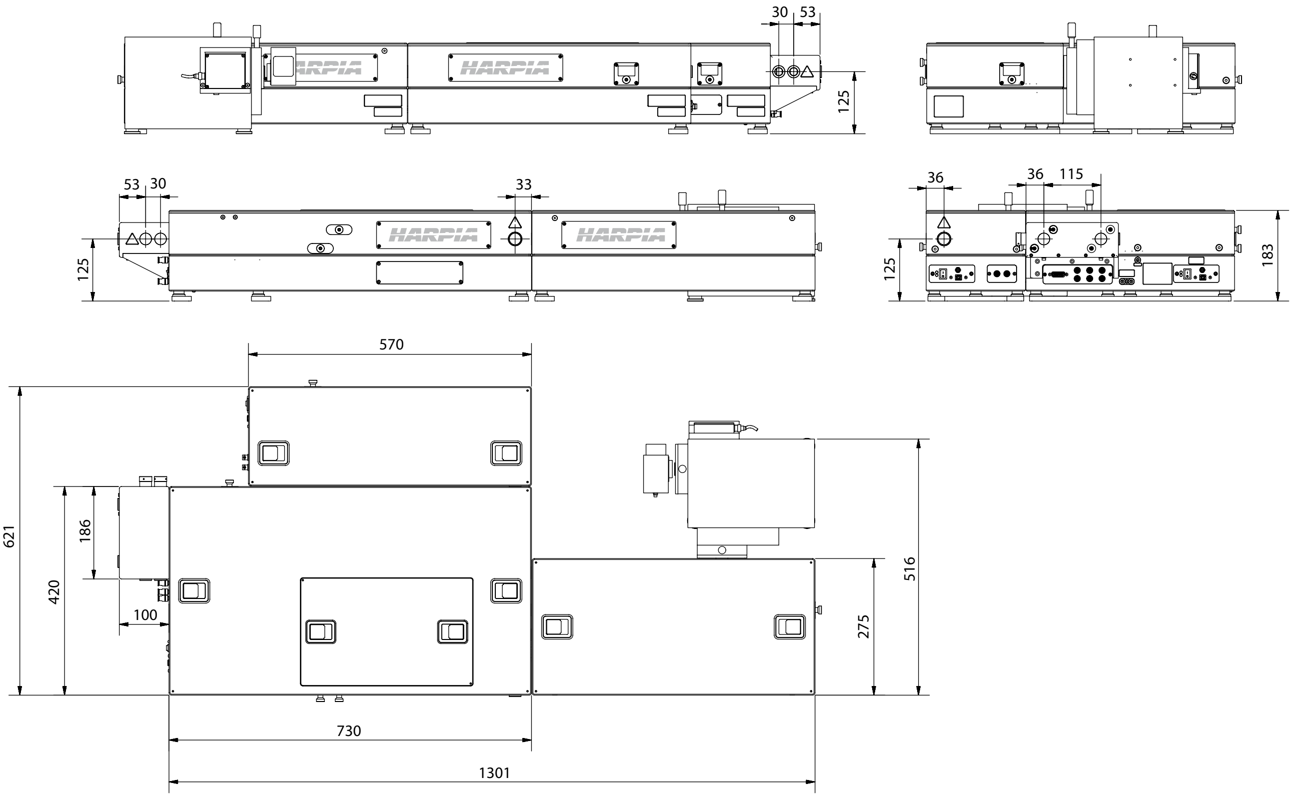


HARPIA optical layout for multi-pulse experiments



HARPIA drawings

CarpetView

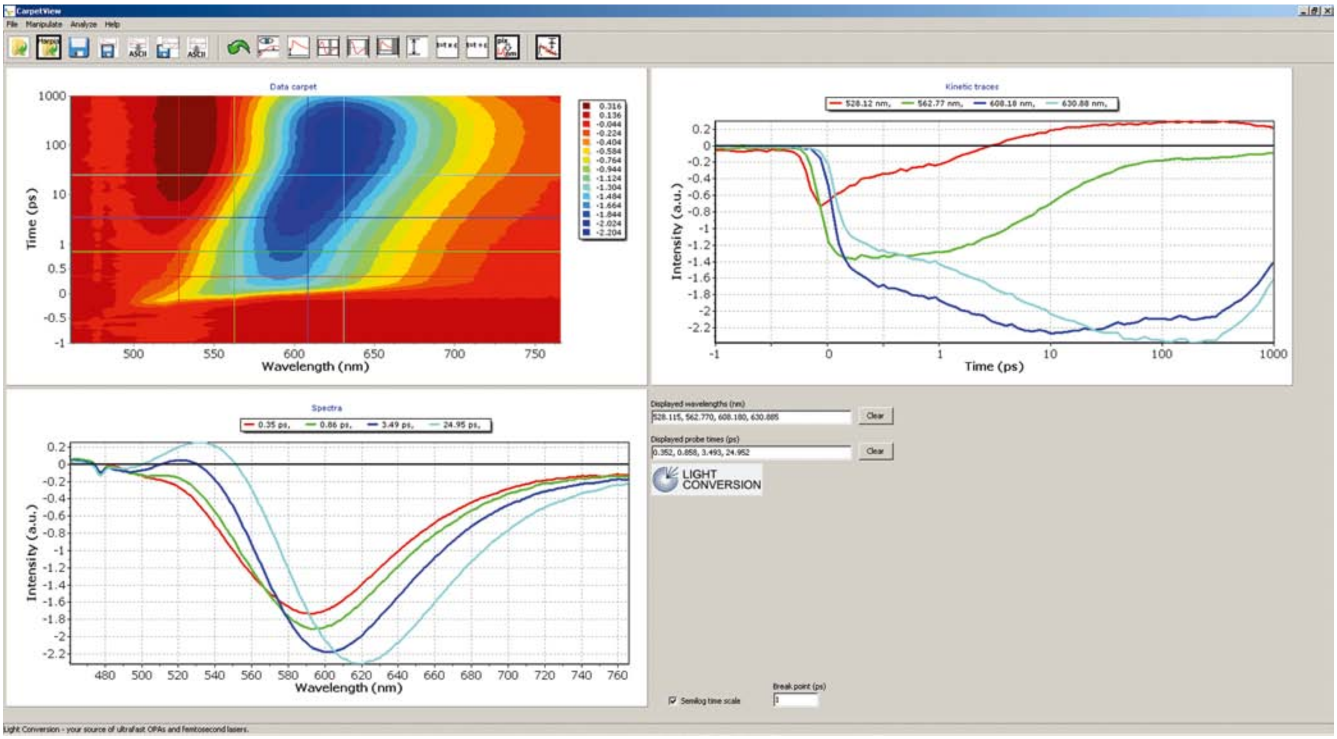
CarpetView is a software package dedicated for inspection, visualization and analysis of ultrafast spectroscopy data.

The program comes in two guises:

- ***Classical***, intended to be used with pump-probe and time-resolved fluorescence datasets,
- ***3D***, designed to be used with 2D electronic spectroscopy (2DES), and Fluorescence lifetime imaging (FLIM) datasets.

Visualization functions include:

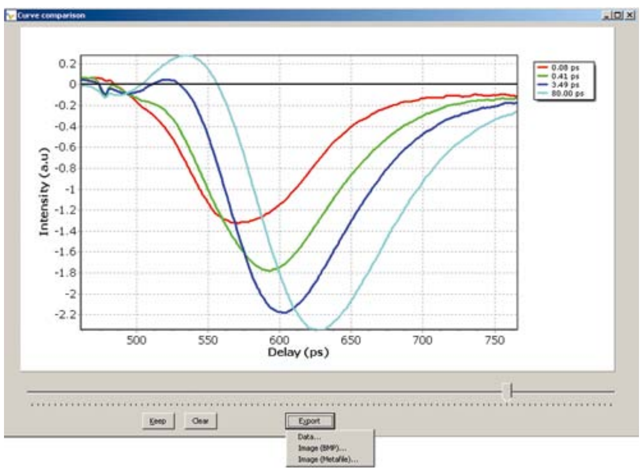
- Overview of your spectro-temporal transient absorption or fluorescence data as contour plot.
- Click-based selection of temporal and spectral slices.
- Comparison of several time-gated spectra or kinetic traces in a single graph.
- Export of produced graphs in bitmap or metafile formats.
- Export of the data of selected graphs in ASCII format.
- Linear and semi-logarithmic time axis in kinetic traces to aid visualizing spectral changes extending over many orders of magnitude in time.



Main window of *Classical* CarpetView displaying a pump-probe dataset

Besides viewing your data you can perform the trivial data manipulations, such as:

- Correct for the chirp in the probe light.
- Merge two datasets measured at different spectral windows.
- Limitation or removal of contaminated spectral or temporal region.
- Pre-time zero signal subtraction.
- Calibration of the spectrum using a reference absorption spectrum measured on your setup.
- Shift or rescale probe times.
- Change wavelength scales between wavenumbers, electron-volts and nanometers.
- Smooth spectra or traces to combat noise.



Spectra viewer window of CarpetView

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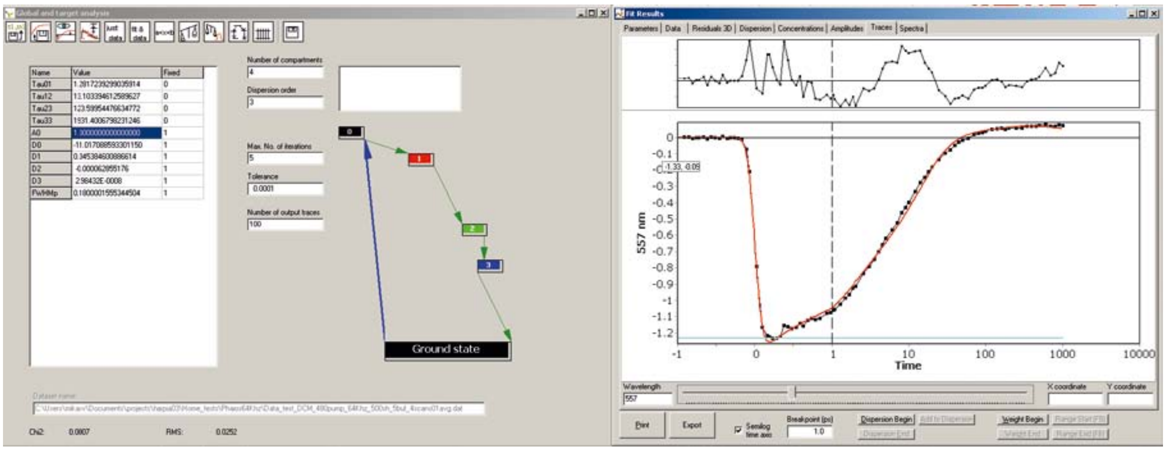
GLOBAL AND TARGET ANALYSIS OF ULTRAFAST DATA

A powerful analysis tool provides the fitting functionality for your spectro-temporal data. The data is analyzed using user-defined compartmental models, where different compartments are interconnected using sets of linear differential equations. The fitting procedure also allows including the chirp of the probe light in the data performs deconvolution with a Gaussian instrument response function.

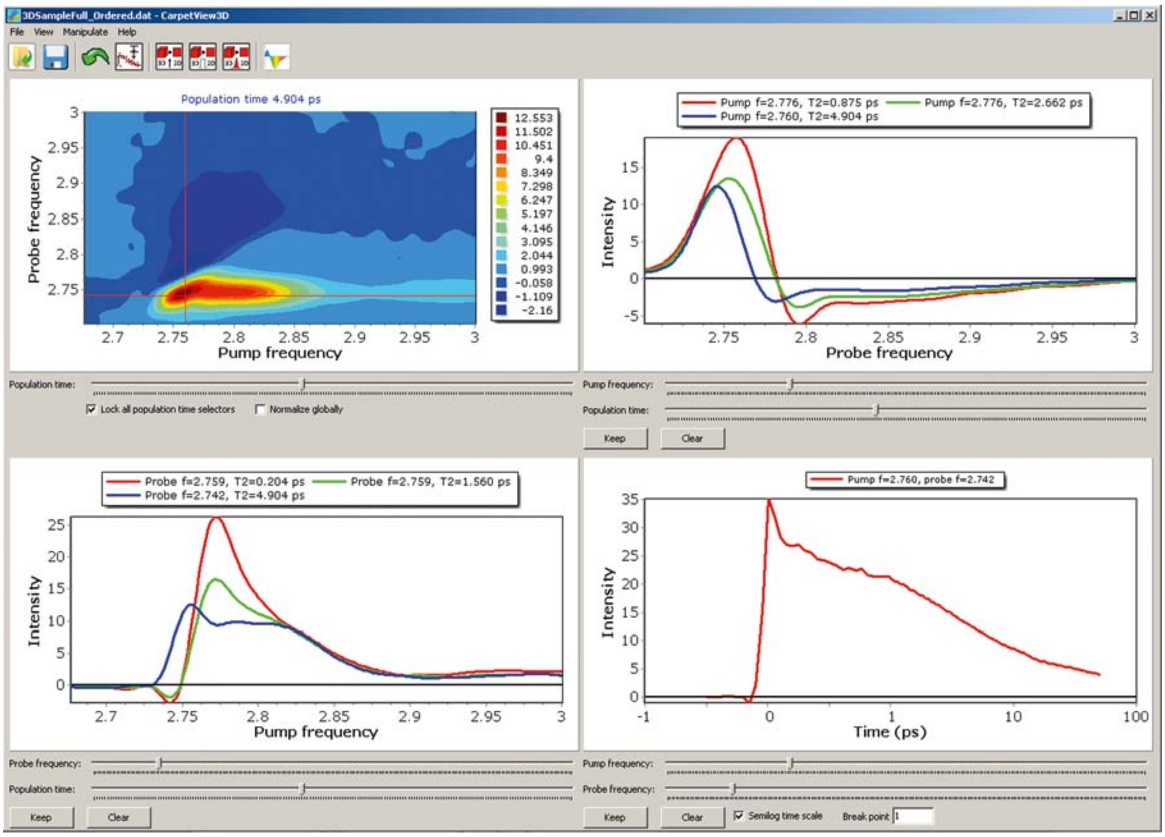
- Graphical construction of the model.
- Point-and-click based estimation of initial parameters of the dispersion curve.
- Advanced point weighting functions for physically sensible fitting.
- Comprehensive overview of the fitting results, including compartment populations, compartment-attributed spectra, fitting curves superimposed on the data and residuals.
- Report generation.
- Export of fitting data in ASCII format.
- Export of fitting graphs in metafile and bitmap formats.



Global and target analysis window of CarpetView

3D VERSION OF CARPETVIEW:

- Includes all the functionality of *Classical* version.
- Allows to visualize, inspect and manipulate data *cubes* obtained in 2DES or FLIM experiments.
- Performs global and target analysis either on the entire data cube, or its two-dimensional cuts.
- Performs trivial data manipulations:
  - Binning
  - Axis rescaling
  - Extraction of two-dimensional datasets from data cubes.



Main window of CarpetView-3D displaying a two-dimensional spectroscopy dataset

ULTRAFAST LASERS
OSCILLATORS
HARMONICS GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
TOPAS DEVICES
SPECTROMETERS
AUTOCORRELATORS

Geco

Scanning Autocorrelator

FEATURES

- Measures pulse duration in 10 fs – 20 ps range
- Single set of optics for 500 – 2000 nm range
- High resolution voice coil driven delay line
- Non-collinear intensity and collinear interferometric autocorrelation traces
- Onboard pulse-analysis software for pulse duration measurements
- Integrated controller and computer
- Non-dispersive polarization control
- FROG and FTIR ready

Operation of GECO autocorrelator is based on noncollinear second harmonic generation in a nonlinear crystal, producing intensity autocorrelation trace directly related to the input beam pulse duration. One arm of the fundamental pulse is delayed by means of a magnetic linear positioning stage, providing fast, reliable motion with < 0.15 fs resolution. GECO can acquire a full intensity autocorrelation trace of 10 fs to 20 ps pulses and covers the full 500 nm to 2000 nm wavelength range.

GECO features noncollinearity angle adjustment and can be simply transformed to a collinear setup, allowing to perform interferometric autocorrelation measurements which are useful for pulses in 10 fs range. Both arms of the autocorrelator have the same dispersion parameters for the most accurate results. It is also possible to switch GECO to Michelson interferometer configuration by simply replacing and removing a few elements, allowing the user to perform FTIR or other desired measurements. GECO comes with a convenient pulse-analysis software, providing straightforward pulse duration measurements. A computer is integrated inside the autocorrelator thus communications are handled via TCP/IP protocol which ensures a simple trouble-free installation. Software and hardware is also capable of generating FROG traces, provided that an external spectrometer is connected to the fiber coupler. Software API's are available for custom user adaptations.

SPECIFICATIONS

Input wavelength range	500 – 2000 nm
Temporal resolution	0.13 fs / step
Measurable pulse width	10 – 20000 fs
Minimum average power of radiation	2 – 200 mW @ 1 – 1000 kHz
Scan rate	5 scans/second @ 1 – 1000 kHz
Detector	Si photodiode

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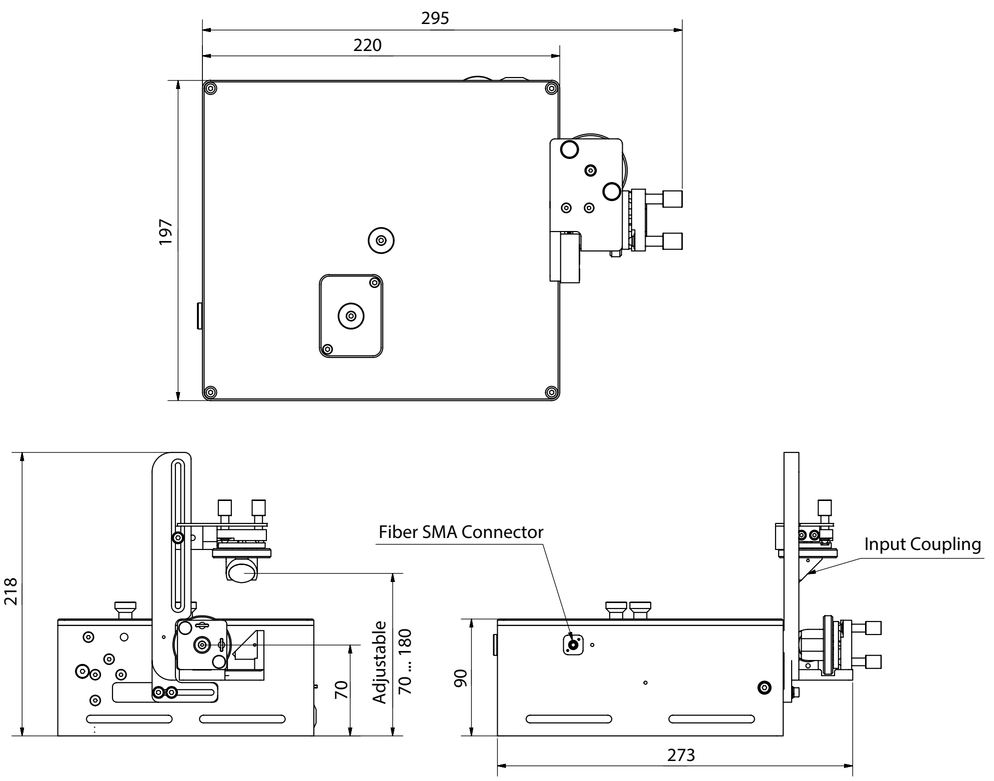


GECO drawings

TiPA

Single-Shot Autocorrelator for Pulse-Front Tilt and Pulse Duration Measurements

FEATURES

- 30 fs – 1 ps pulse duration range
- 500 nm – 2000 nm wavelenght range
- Measures pulse-front tilt
- Compact and portable design
- Hi-speed 12-bit CCD camera
- Pulse-analysis software for pulse duration measurements

TiPA is an invaluable tool for alignment of ultrashort pulse laser systems based on the chirped pulse amplification technique. Its unique design allows monitoring and measuring of the pulse duration as well as the pulse front tilt in both vertical and horizontal planes. TiPA is a straightforward and accurate direct pulse-front tilt measurement tool. Operation of TiPA is based on non-collinear second harmonic (SH) generation, where the spatial distribution of the SH beam contains information on the temporal shape of the fundamental pulse. This technique combines low background and single-shot measurement capability. The basic idea is that two replicas of a fundamental ultrashort pulse pass non-collinearly through a nonlinear crystal, in which SH generation takes place. SH beam's width and tilt in a plane perpendicular to propagation provide information about the pulse duration and pulse front tilt. The SH beam is sampled by the included CCD camera.

TiPA comes with a user friendly software package, which provides on-line monitoring of incoming pulse properties.

TiPA MODELS*

Model	Operation wavelength
AT1C1	700 – 900 nm
AT2C1	900 – 1100 nm
AT5C3	500 – 2000 nm

** Non-standard models available on request.*

PERFORMANCE SPECIFICATION

Wavelength range	500 – 530 nm	530 – 700 nm	700 – 2000 nm
Temporal resolution	~500 fs/mm		
Measurable pulse width	40 – 120 fs	40 – 1000 fs	30 – 1000 fs
Minimum average power of radiation	~5 mW	~5 mW	~1 mW
Detector	CCD		

CCD SPECIFICATIONS

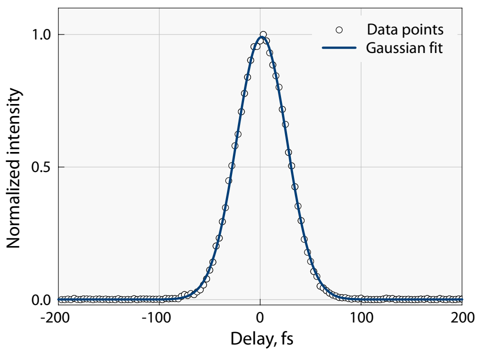
Maximum resolution	1296 (H) × 964 (V)
Pixel size	3.75 µm × 3.75 µm
Analog-to-Digital converter	12 bits
Spectral response*	0.35 – 1.06 µm
Power consumption from USB bus	2 W (max) at 5 V

** With glass window.*

DIMENSIONS

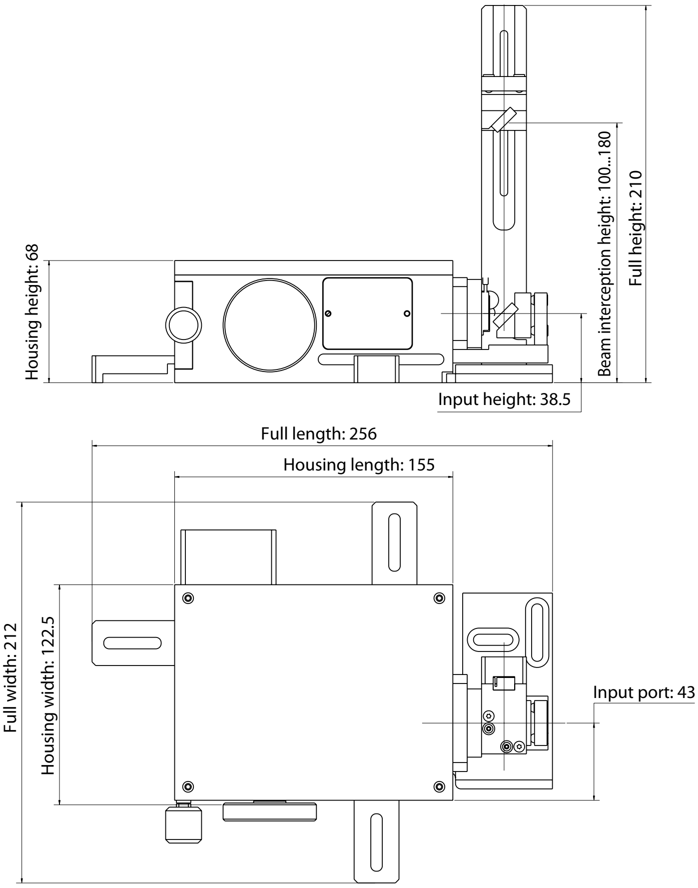
General dimensions of the housing	123 (W) × 155 (L) × 68 (H) mm
Recommended area for fixing	212 (W) × 256 (L) mm
Beam interception height	100 – 180 mm

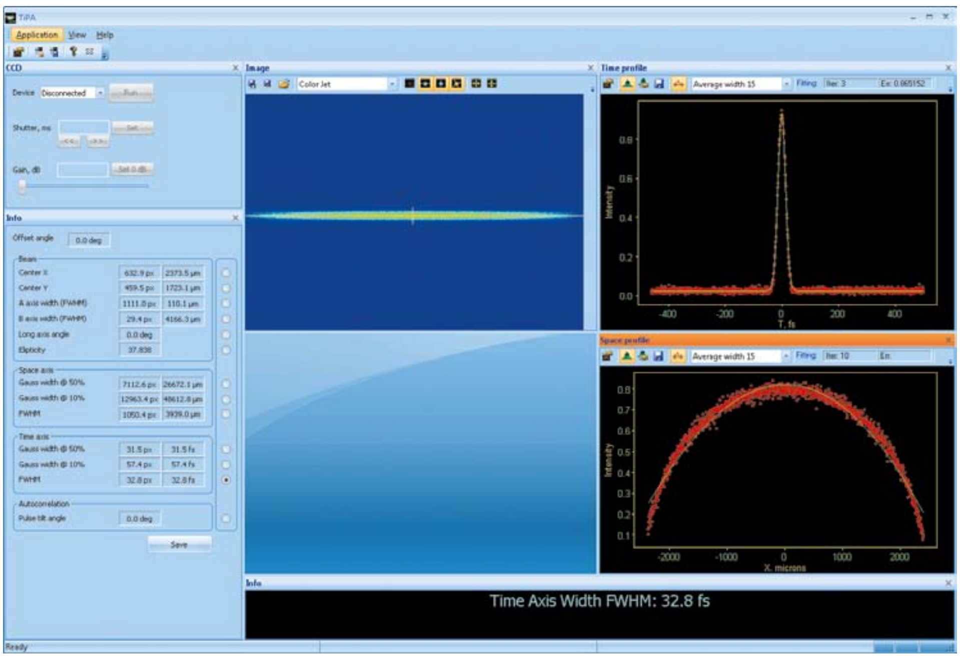
SAMPLE AUTOCORRELATION WITH DATA FITTING



TOPAS Idler Autocorrelation at 1700 nm (40 fs pump)

MEASUREMENT INFO	
Gaussian Width:	18.8 px – 58.8 fs
FWHM Width:	19.2 px – 59.8 fs
Gaussian Pulse Duration:	41.6 fs
$Sech^2$ Pulse Duration:	38.2 fs
Pulse Tilt:	-0.210 deg





View of the TiPA software window

CCD control and info panels on the left; image captured by CCD – middle; processed time profile of the image with Gaussian fit, and processed space profile of the image – right top and bottom respectively.

List of Local Distributors

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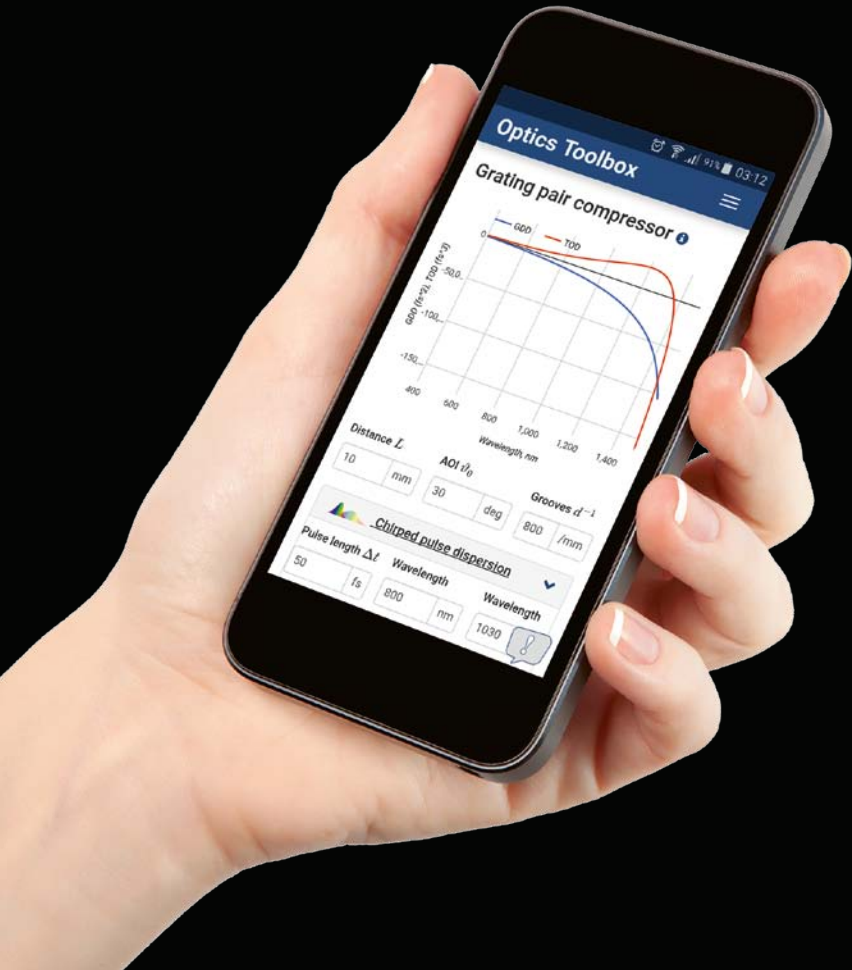

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LIGHT CONVERSION

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