LIGHT CONVERSION

Ultrafast Lasers

for Industrial and Scientific Applications

2019

25 YEARS OF FEMTOSECOND SOLUTIONS

Ultrafast Lasers
for Industrial and Scientific Applications

2019 Product Catalogue

Rev. 20190416

LIGHT CONVERSION

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What we do

We are the world leading manufacturer of wavelength tunable femtosecond optical parametric amplifiers (OPA) based on TOPAS and ORPHEUS series as well as diode pumped solid state femtosecond lasers PHAROS and CARBIDE.

Both 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 a robust design attractive both to industrial and scientific customers.

With major industrial customers operating in display, automotive, LED, medical device, and other industries, PHAROS and CARBIDE reliability has been proven by hundreds of systems operating in 24/7 production environment. The lasers are mainly used for drilling and cutting of various metals, ceramics, sapphire, glass, and material ablation for mass-spectrometry. However, customers are always finding new ways for PHAROS and CARBIDE to make existing manufacturing processes more efficient.

To complement our laser amplifiers we offer a strong portfolio of femtosecond products: harmonic modules (provide pulses at 515, 343, 257 and 206 nm), OPAs (produce continuous tuning output from ~190 nm up to ~20 µm), HARPIA spectrometers, TiPA and GECO autocorrelators. All our products can be customized and fine-tuned to meet the most demanding applications.

Who we are

Founded in 1994 in Vilnius, Light Conversion is a privately-owned company with >200 employees. Our >6500 m^2 facility accommodates design, R&D, and production teams so that all key manufacturing processes are managed in-house. With more than 3000 systems installed worldwide, Light Conversion has established itself as an innovative producer of ultrafast optical devices and the largest manufacturer of femtosecond optical parametric amplifiers (OPAs) and non-collinear OPAs. In addition to selling our products via a wide range of distributors, we also provide our OEM devices for other major laser manufacturing companies.

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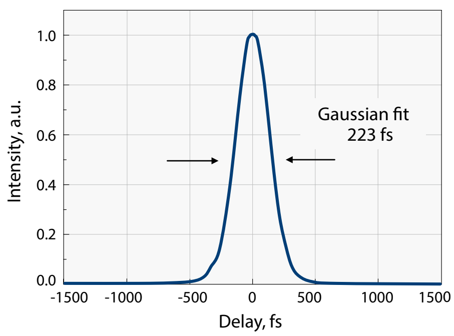
PHAROS

High Power and Energy Femtosecond Lasers

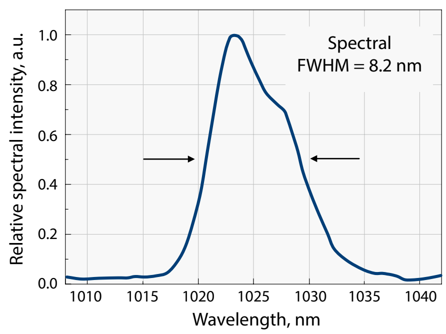
FEATURES

- 190 fs – 20 ps tunable pulse duration
- 2 mJ maximum pulse energy
- 20 W output power
- 1 kHz – 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)
- Optional CEP stabilization
- Possibility to lock oscillator to external clock

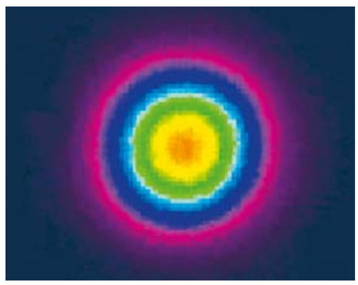
PHAROS is a single-unit integrated femtosecond laser system combining millijoule pulse energies and high average powers. PHAROS features a mechanical and optical design optimized for industrial applications such as precise material processing. Compact size, integrated thermal stabilization system and sealed design allow PHAROS integration into machining workstations. 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. PHAROS compact and robust optomechanical design features stable laser operation across varying environments. PHAROS is equipped with an extensive software package which ensures smooth hands-free operation.



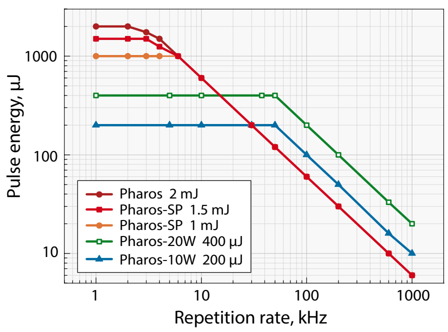
Pulse duration of PHAROS



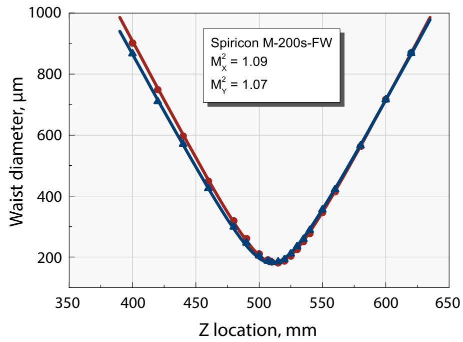
Spectrum of PHAROS



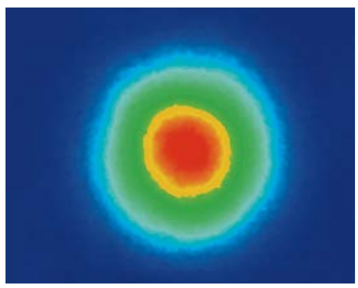
Typical PHAROS far field beam profile at 200 kHz



Pulse energy vs base repetition rate



Typical PHAROS M^2 measurement data



Typical PHAROS near field beam profile at 200 kHz

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SPECIFICATIONS

Product name	PH1-10	PH1-15	PH1-20	PH1-SP-1mJ	PH1-SP-1.5mJ	PH1-SP-10W	PH1-2mJ
Max. average power	10 W	15 W	20 W	6 W		10 W	6 W
Pulse duration (assuming Gaussian pulse shape)	< 290 fs			< 190 fs			< 300 fs
Pulse duration range	290 fs – 10 ps (20 ps on request)			190 fs – 10 ps (20 ps on request)			300 fs – 10 ps
Max. pulse energy	> 0.2 mJ or > 0.4 mJ			> 1 mJ	> 1.5 mJ	> 1 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 over 24 hours [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 sales@lightcon.com for specifications						
Burst mode							

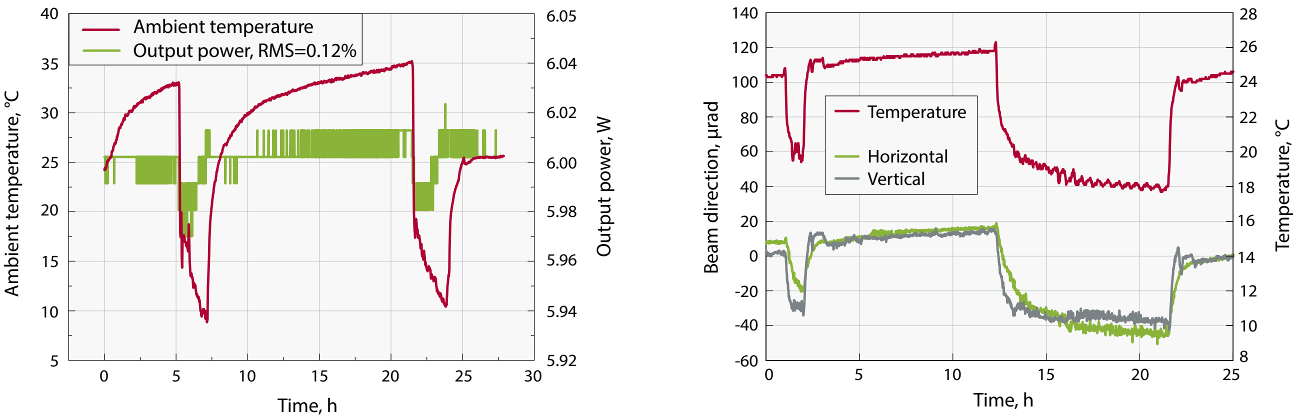
PHYSICAL DIMENSIONS

Laser head	670 (L) × 360 (W) × 212 (H) mm [3]
Rack for power supply and chiller	642 (L) × 553 (W) × 673 (H) mm

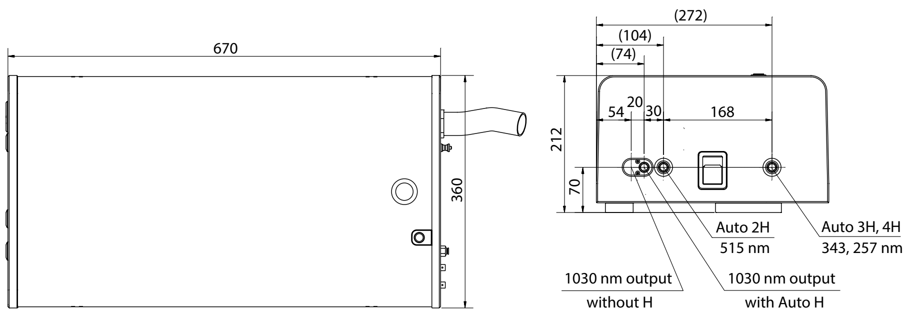
UTILITY REQUIREMENTS

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	< 80 % (non condensing)

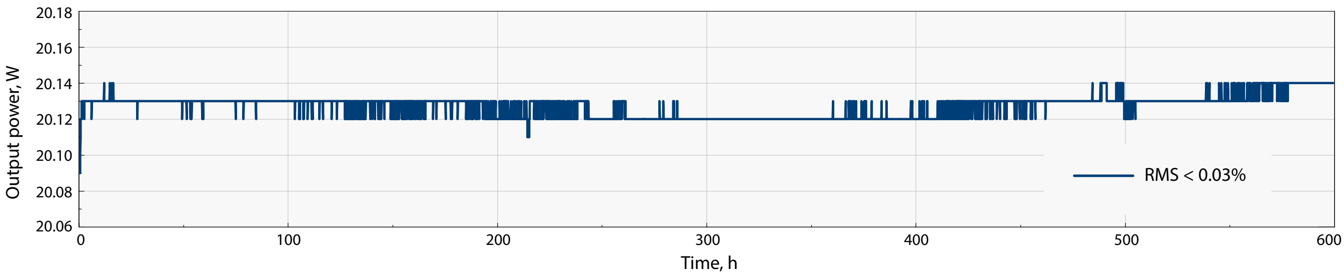
[1] Some particular repetition rates are software denied due to system design.
[2] Under stable environmental conditions.
[3] Dimensions might increase for non-standard laser specifications



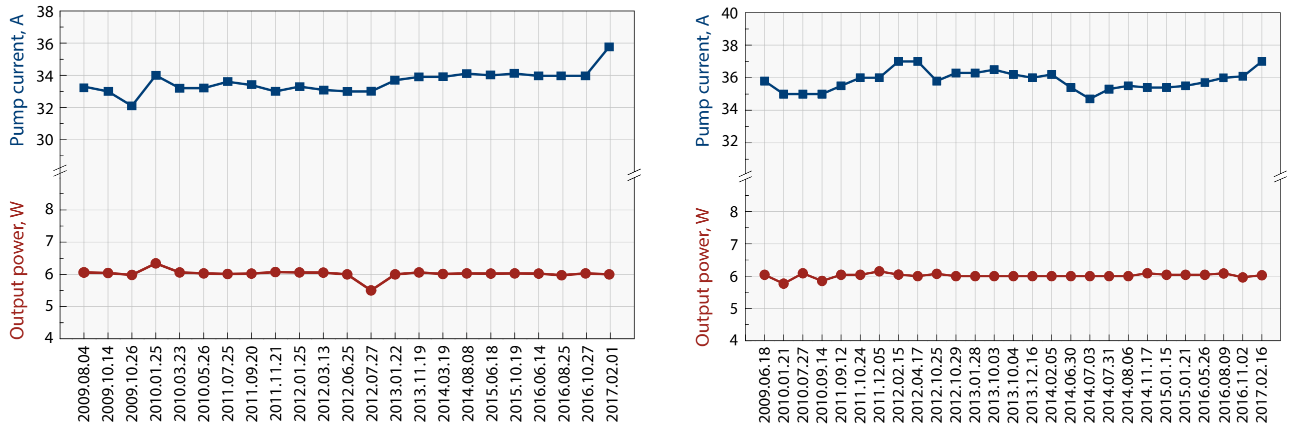
PHAROS output power with power lock enabled under unstable environment



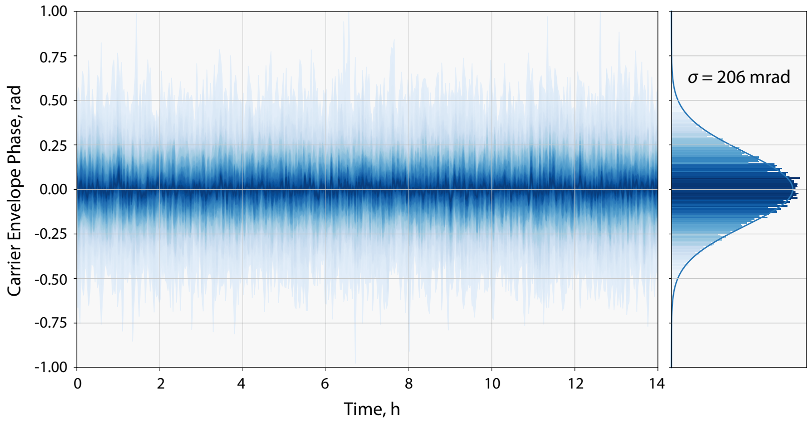
PHAROS laser outline drawing



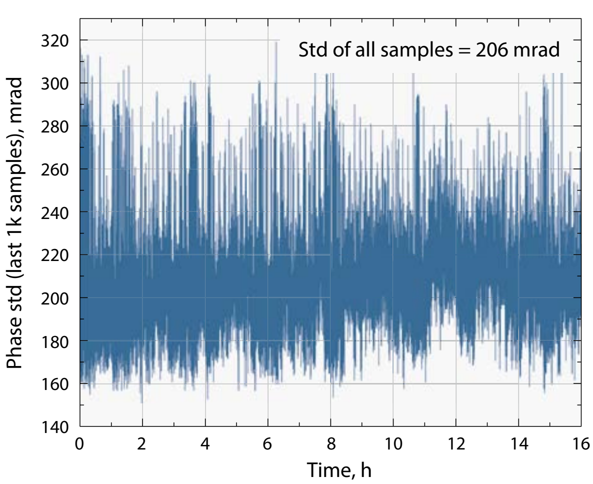
PHAROS long term stability graph



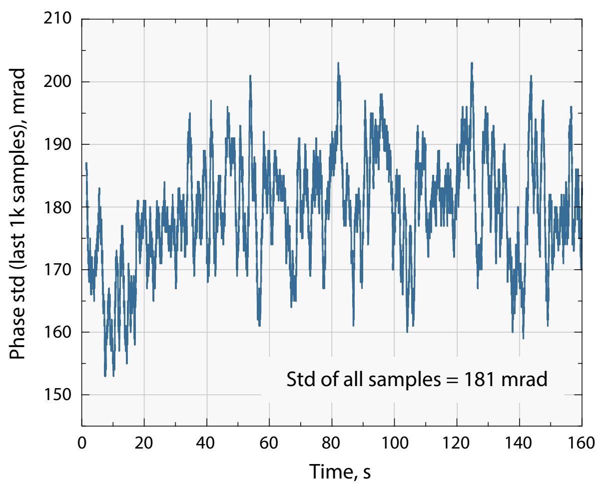
Output power of industrial PHAROS lasers operating 24/7 and current of pump diodes during the years



Carrier envelope phase (CEP) over the long period with active phase stabilization system



CEP stability over a long time scale



CEP stability over a short time scale

Pharos CEP stability when laser is isolated from all noticeable noise sources – vibrations, acoustics, air circulation and electrical noise. System can achieve < 300 mrad std of CEP stability over a long time scale (> 8 hours) and < 200 mrad over a short time scale (< 5 min)

PHAROS

Automated Harmonics Generators

FEATURES

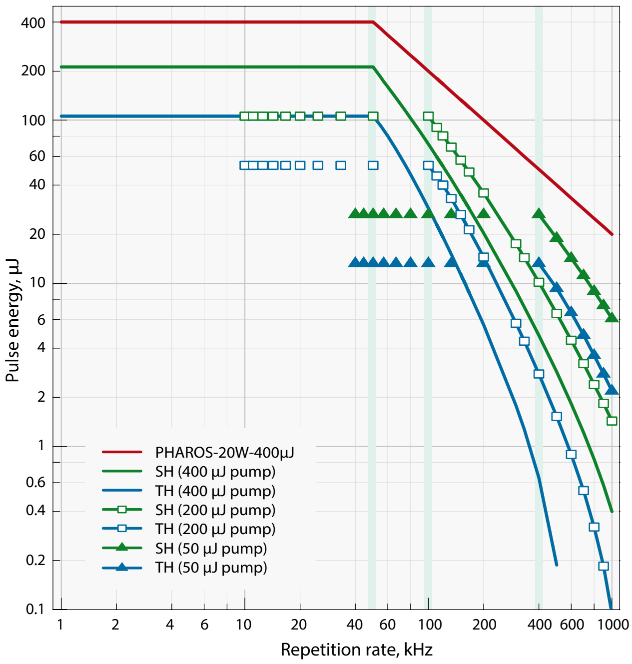
- 515 nm, 343 nm, 257 nm and 206 nm
- Output selection by software
- Mounts directly on a laser head and integrated into the system
- Rugged industrial grade mechanical design

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.

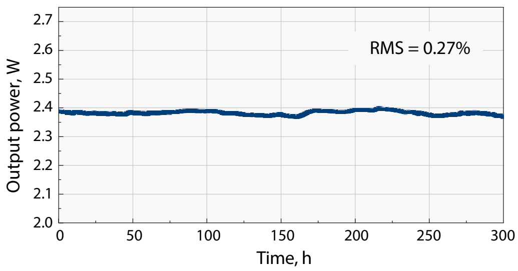
SPECIFICATIONS

Product name	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) [1]	> 10 % (4H) [1] > 5 % (5H) [2]
Beam quality (M^2) ≤ 400 µJ pump	< 1.3 (2H), typical < 1.15	< 1.3 (2H), typical < 1.15 < 1.4 (3H), typical < 1.2	< 1.3 (2H), typical < 1.15 n/a (4H)	n/a
Beam quality (M^2) > 400 µJ pump	< 1.4 (2H)	< 1.4 (2H) < 1.5 (3H)	< 1.4 (2H) n/a (4H)	n/a

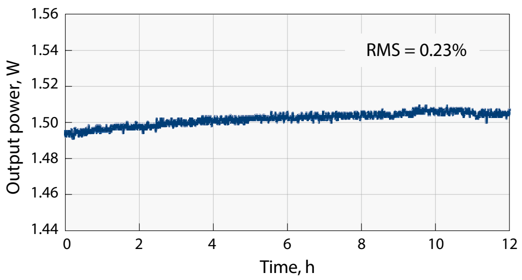
1) Max 1 W output. *2) Max 0.15 W output.*



PHAROS harmonics energy vs pulse repetition rate



3H output stability



4H output stability

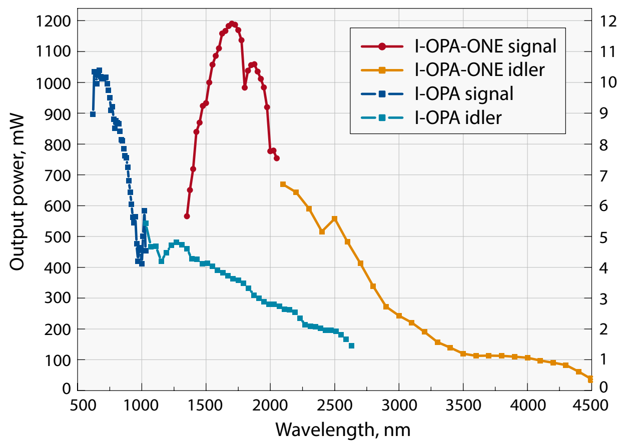
PHAROS

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 available

I-OPA is the first industrial grade optical parametric amplifier which features long-term stable output with a reliable hands-free operation. Manually tunable output wavelength extends application possibilities of a single laser source instead of requiring multiple lasers based on different technologies.
In comparison to standard ORPHEUS line devices, the I-OPA lacks only a 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

Product name	I-OPA	I-OPA-F	I-OPA-ONE
Based on ORPHEUS model	ORPHEUS	ORPHEUS-F	ORPHEUS-ONE
Pump pulse energy	10 – 500 µJ	10 – 500 µJ	20 – 1000 µJ
Pulse repetition rate		Up to 1 MHz	
Tuning range of signal	630 – 1030 nm	650 – 900 nm	1350 – 2060 nm
Tuning range of idler	1030 – 2600 nm	1200 – 2500 nm	2060 – 4500 nm
Conversion efficiency at peak, signal+idler combined	> 12 % when pump energy 20 – 500 µJ > 6 % when pump energy 10 – 20 µJ	> 10 %	> 14 % when pump energy 30 – 1000 µJ > 10 % when pump energy 20 – 30 µJ
Pulse bandwidth [1)]	80 – 150 cm^{-1} @ 700 – 960 nm when pumped by Pharos 100 – 220 cm^{-1} @700 – 960 nm when pumped by Pharos-SP	200 – 750 cm^{-1} @ 650 – 900 nm 150 – 500 cm^{-1} @ 1200 – 2000 nm	60 – 150 cm^{-1} @ 1450 – 2000 nm
Pulse duration [2)]	130 – 290 fs when pumped by Pharos 120 – 190 fs when pumped by Pharos-SP	< 55 f @ 800 – 900 nm < 70 fs @ 650 – 800 nm < 100 fs @ 1200 – 2000 nm	200 – 300 fs
Applications	Micro-machining Microscopy Spectroscopy	Nonlinear microscopy Ultrafast spectroscopy	Micro-machining Mid-IR generation

[1)] *I-OPA-F outputs broad bandwidth pulses which are compressed externally.*
[2)] *Output pulse duration depends on wavelength and pump laser pulse duration.*

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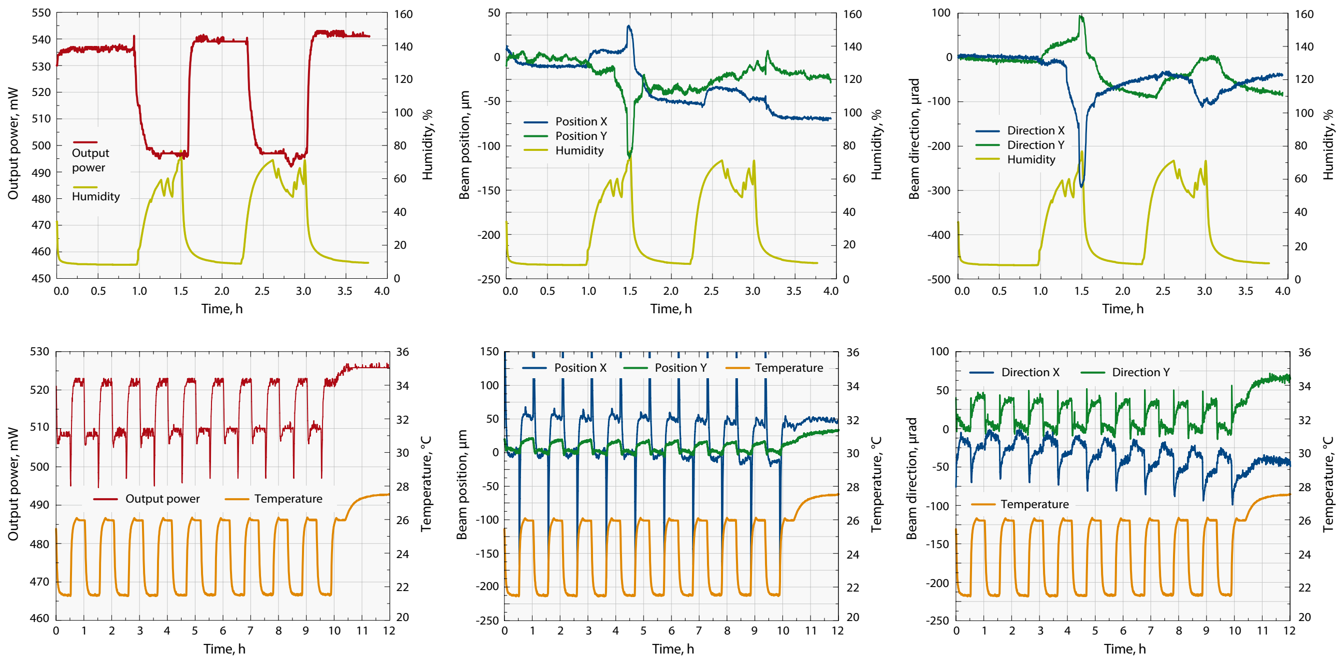
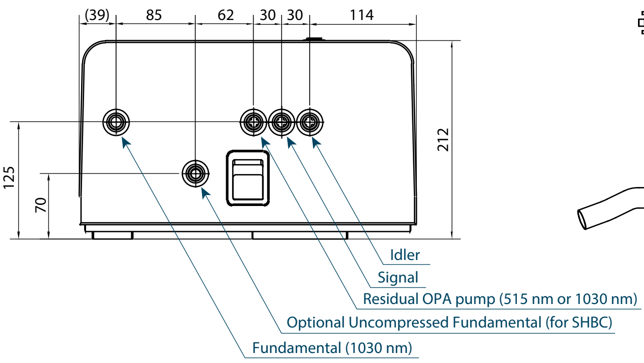
COMPARISON WITH OTHER FEMTOSECOND AND PICOSECOND LASERS

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

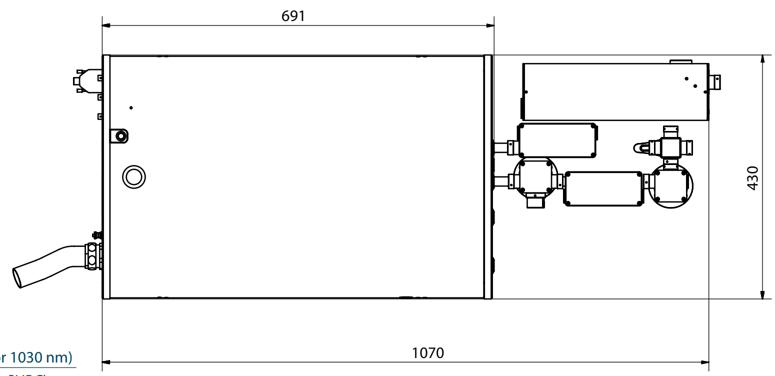
Note that the pulse energy scales linearly in a broad range of pump parameters. For example, a PHAROS PH1-20 laser at 50 kHz (400 µJ energy) will increase the output power twice, and the pulse energy – 4 times compared to the reference table above. The pulse duration at the output is <300 fs in all cases. The OPA output is not limited to these particular ranges of operation, it is continuously tunable as shown in energy conversion curves.



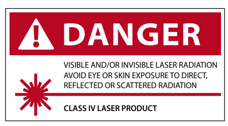
I-OPA beam pointing and output power measurements under harsh environment conditions (humidity and temperature cycling)



Pharos with I-OPA output ports



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



CARBIDE

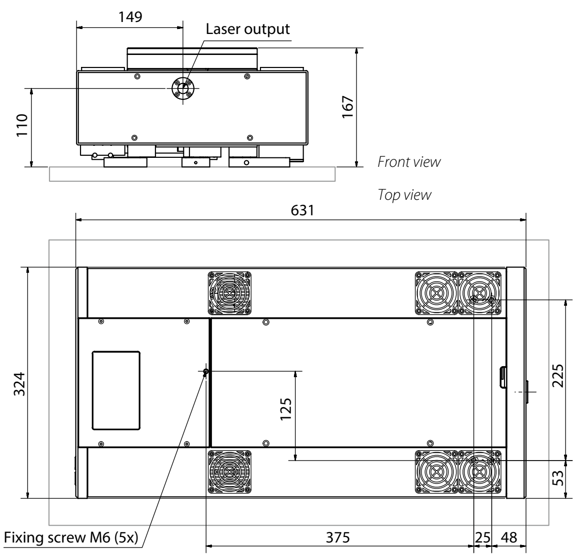
Femtosecond Lasers for Industry and Science

FEATURES

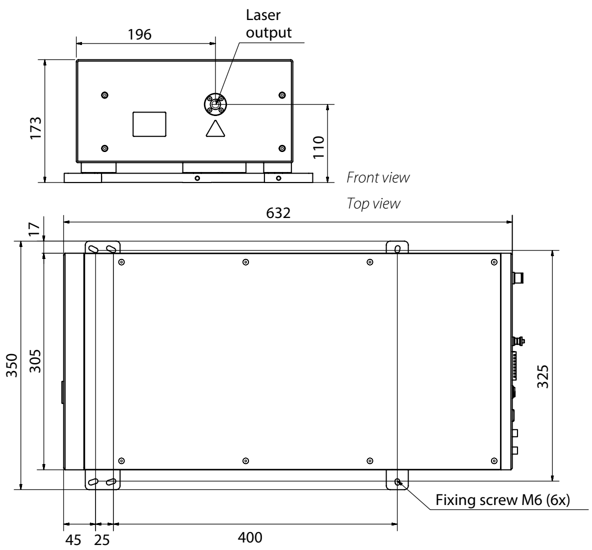
- < 290 fs – 10 ps tunable pulse duration
- > 400 μJ pulse energies
- > 40 W output power
- 60 – 1000 kHz tunable base repetition rate
- Includes pulse picker for pulse-on-demand operation
- Rugged, industrial grade mechanical design
- Air or water cooling
- Automated harmonics generators (515 nm, 343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

CARBIDE industrial femtosecond laser features an output power of > 40 W at 1028 nm wavelength. The laser emits single pure temporal contrast (>1:200) and up to 400 μJ energy pulses without any compromises to the beam quality, industrial grade reliability and beam stability regardless of the environment it is put in. Continuously tunable base repetition rate in a range of 60 – 1000 kHz is combined with an in-built pulse picker for convenient output pulse control. Software adjustable pulse duration can be easily set in a range of 290 fs – 10 ps in seconds. Excellent power stability of < 0.5 % RMS is standard.

Single monolithic housing allows fast warm-up times. Laser is maintenance free. Electronical and most optical components in the laser are field accessible and upgradeable.
Carbide ships with an integrated shutter fulfilling performance level d requirements according to EN 13849-1 by default. Due to an in-built computer laser control is smooth via the provided extensive software package. Multiple custom laser control options are also available; they are convenient when lasers are being integrated in medical or industrial processing applications. CARBIDE can be equipped with a growing number of optional features: a beam expansion unit, an automated attenuator, harmonics or can be used as a seed source for parametric amplifiers and OPCPA systems.



Outline drawing of air-cooled CARBIDE



Outline drawing of water-cooled CARBIDE

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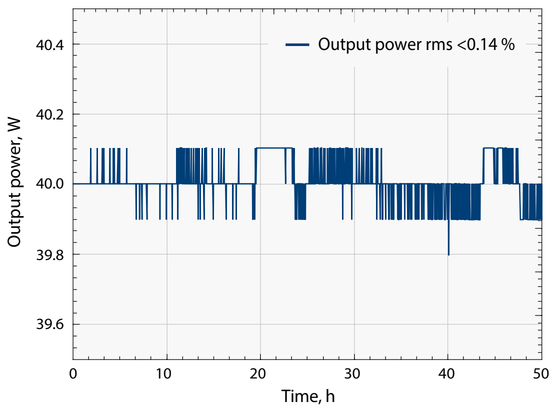
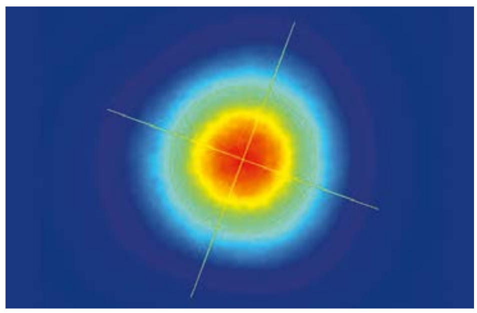
SPECIFICATIONS

Product name	**CB5-05**	**CB5-04**	**CB3-40-200**	**CB3-40-400**
OUTPUT CHARACTERISTICS				
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, any base repetition rate division			
Centre wavelength [3]	1028 ± 5 nm			
Output pulse-to-pulse stability	< 0.5 % rms over 24 hours [4]			
Output power stability	< 0.5 % rms over 100 hours			
Beam quality	TEM_{00}; $M^2 < 1.2$			
Pulse picker	included	included, enhanced contrast AOM [5]	included	
Pulse picker leakage	< 2 %	< 0.1 %	< 0.5 %	
Beam pointing stability	< 20 µrad/°C			
ENVIRONMENTAL & UTILITY REQUIREMENTS				
Operating temperature	17 – 27 °C (62 – 80 °F)		15 – 30 °C (59 – 86 °F)	
Relative humidity	< 65 % (non condensing)		< 80 % (non condensing)	
Electric	110 – 220 VAC, 50 – 60 Hz			
Power consumption	100 W		1.5 kW	
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		280 (L) × 144 (W) × 49 (H) mm	
Chiller	–		590 (L) × 484 (W) × 267 (H) mm	

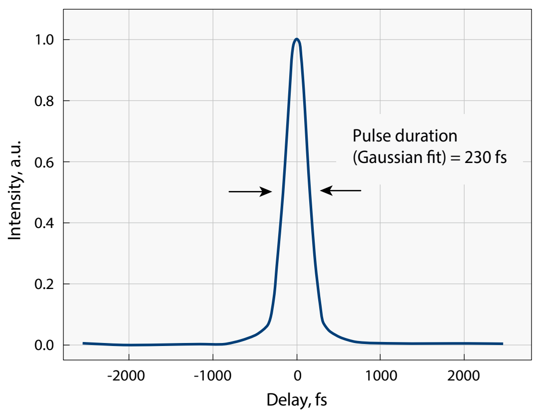
[1] *Water-cooled version available on request.*
[2] *Lower repetition rates are available by controlling pulse picker.*
[3] *2nd (515 nm) and 3rd (343 nm) harmonic output also available.*
[4] *Under stable environmental conditions.*
[5] *Provides fast amplitude control of output pulse train.*



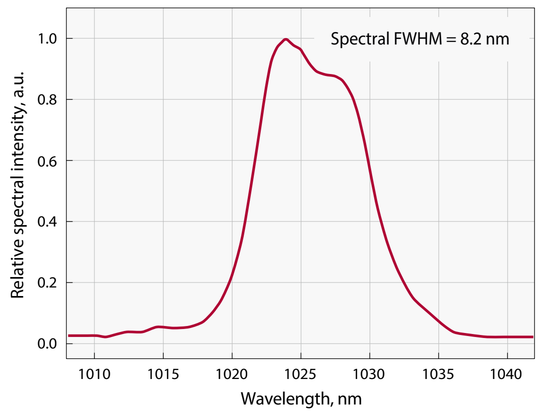
Long term power stability (water-cooled version)



Typical CARBIDE beam profile (water-cooled version)

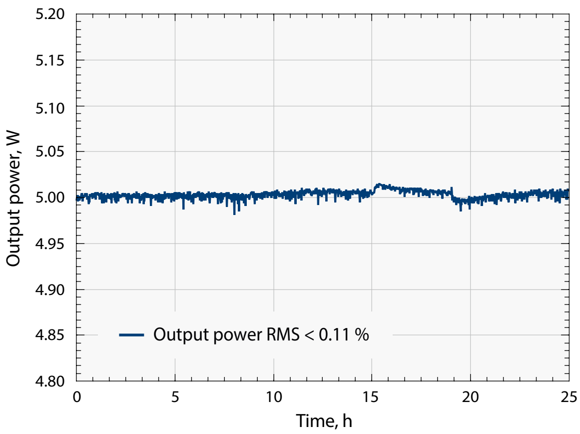


Pulse duration of CARBIDE (water-cooled version)

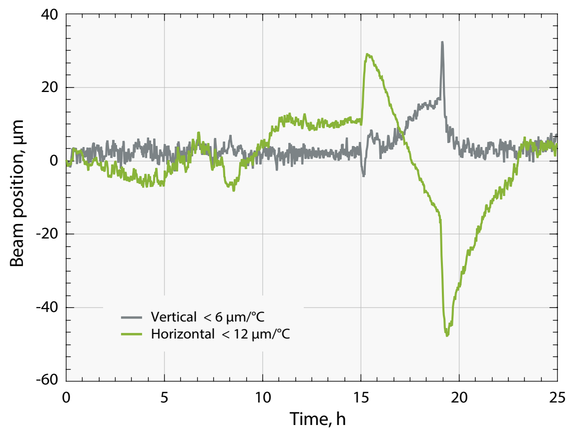


Spectrum of CARBIDE (water-cooled version)

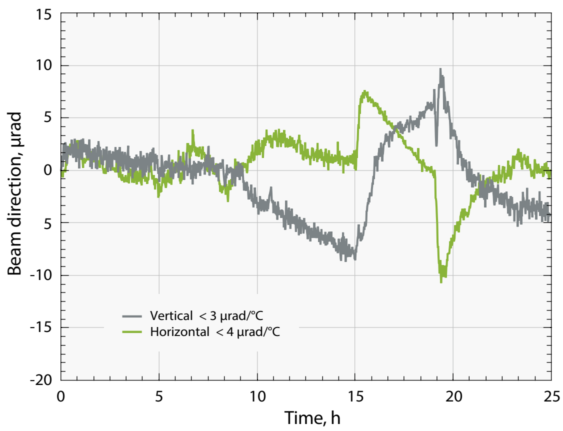
AIR-COOLED CARBIDE STABILITY MEASUREMENTS



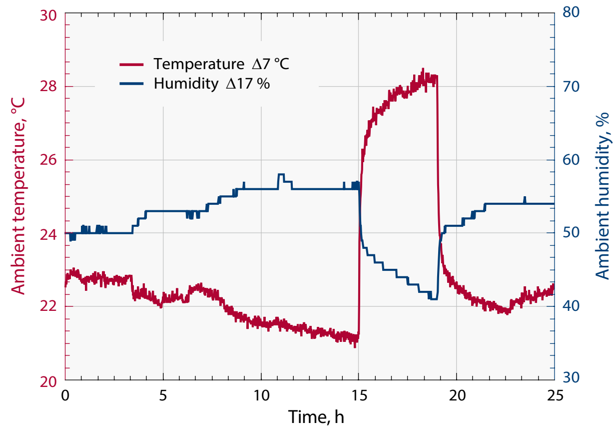
Output power under harsh environment conditions (air-cooled version)



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

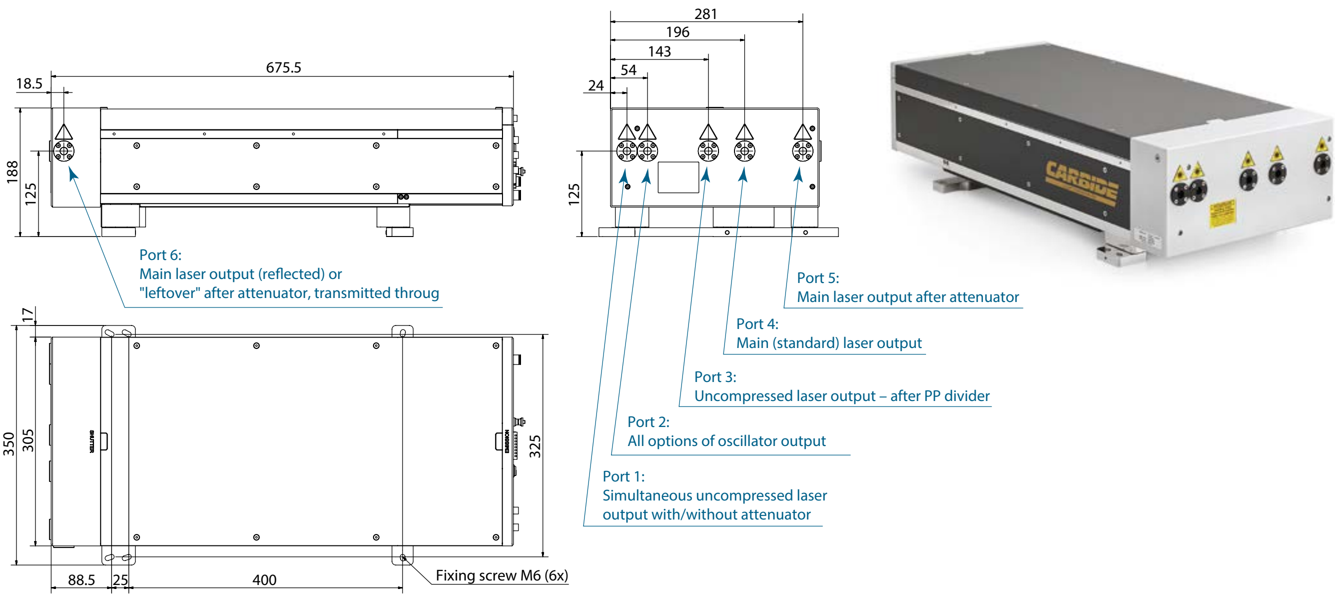


Beam direction under harsh environment conditions (air-cooled version)



Harsh environment conditions (air-cooled version)

WATER-COOLED CARBIDE WITH A SCIENTIFIC INTERFACE



Drawings of CARBIDE with scientific interface

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CARBIDE

Automated Harmonics Generators

Air-cooled CARBIDE with harmonics generator module

FEATURES

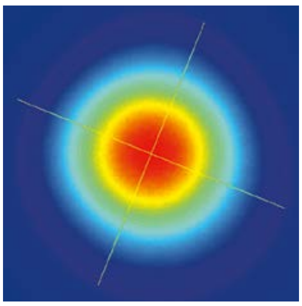
- 515 nm, 343 nm and 257 nm
- Output selection by software
- Mounted directly on a laser head and integrated into the system
- Rugged, industrial grade mechanical design

CARBIDE laser can be equipped with automated harmonics modules. Selection of fundamental (1030 nm), second (515 nm), third (343 nm) or fourth (257 nm) harmonics outputs are available by software control. Harmonics generators are designed to be used in industrial applications where a single output wavelength is desired.

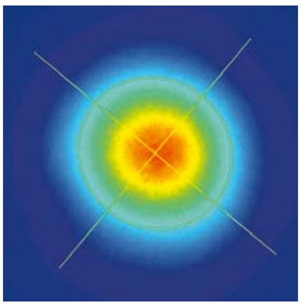
SPECIFICATIONS

Product name	2H	2H-3H	2H-4H
Output wavelength (automated selection)	1030 nm 515 nm	1030 nm 515 nm 343 nm	1030 nm 515 nm 257 nm
Input pulse energy	20 – 400 µJ		
Pump pulse duration	< 300 fs		
Conversion efficiency	> 50 % (2H)	> 50 % (2H) > 25 % (3H)	> 50 % (2H) > 10% (4H) [1)]
Beam quality (M^2)	< 1.3 (2H), typical < 1.15	< 1.3 (2H), typical < 1.15 < 1.4 (3H), typical < 1.2	< 1.3 (2H), typical < 1.15 n/a (4H)

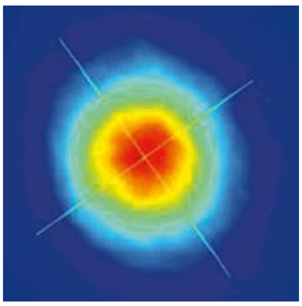
[1)] *Maximum output power 1 W.*



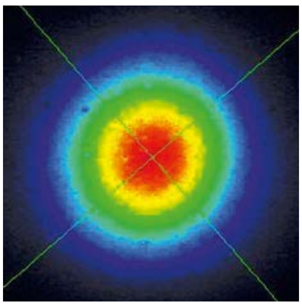
Typical CARBIDE 1H beam profile.
60 kHz, 5W



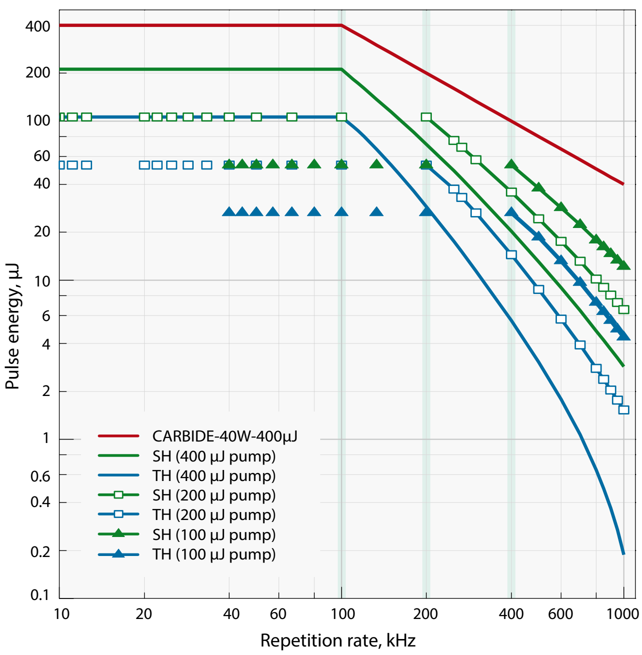
Typical CARBIDE 2H beam profile.
100 kHz, 3.4 W



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



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



CARBIDE harmonics energy vs pulse repetition rate

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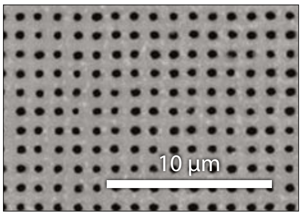
EXAMPLES OF INDUSTRIAL APPLICATIONS

STEEL FOIL M-DRILLING

- No melting
- Micron diameter

Applications:

- Filters
- Functional surfaces

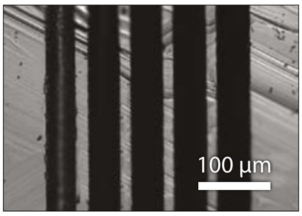


DIAMOND CUTTING

- Low carbonization
- No HAZ
- Low material loss

Applications:

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

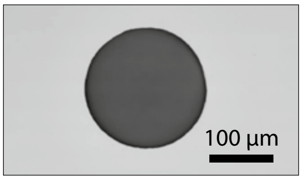


GLASS HOLES

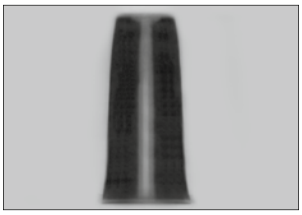
- Various hole sizes with routine tapper angle better than 5 deg
- Minimal debris around the edges of holes

Application:

- Microfluidics
- VIAs

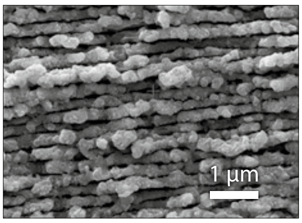


Top view


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



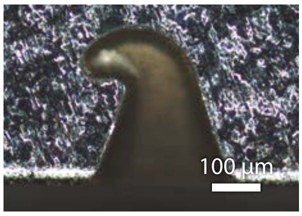
Developed in cooperation with Swinburne University, Australia

Application:

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

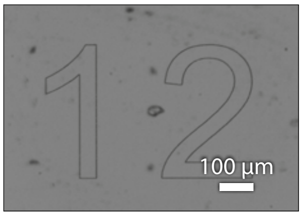
METAL MICROMACHINING

- 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:

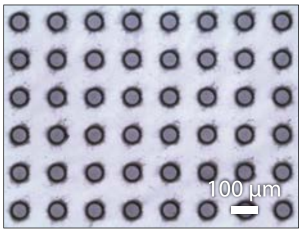
- Product counterfeit protection
- Serial number and customer identification

THIN GLASS DRILLING

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

Applications:

- VIAs

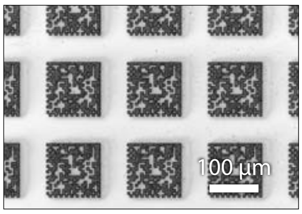


DATAMATRIX

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

Application:

- Product marking

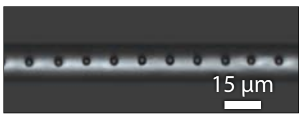


GLASS TUBE DRILLING

- Controlled damage and depth
- Hole diameter of few microns

Applications:

- Medical applications
- Biopsy equipment



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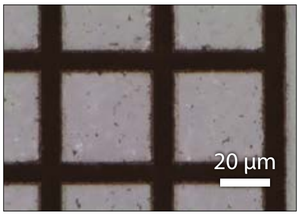
FERROELECTRIC CERAMICS ETCHING

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

Applications:

- Infrared sensors for cameras
- Memory chips

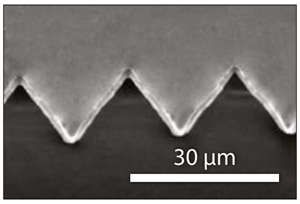


SILICON LASER ASSISTED ETCHING

- No HAZ
- No melting

Applications:

- Solar cell production
- Semiconductor industry

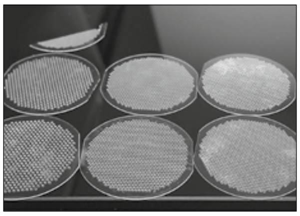


MASK FOR BEAM SPLITTER PATTERN DEPOSITION

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

Appplication:

- Selective coating

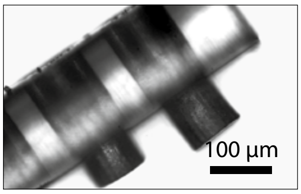


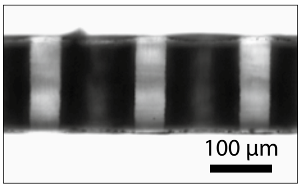
STENT CUTTING

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

Application:

- Vascular surgery



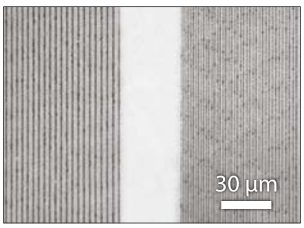


TEXTURIZED SAPPHIRE SURFACE

- 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

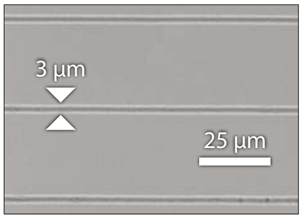
Metal

MICRO CHANNEL FORMATION

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

Applications:

- Microfluidic sensors
- Waveguides

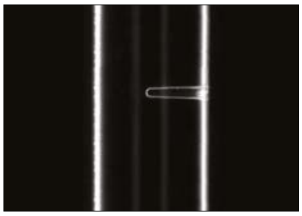


OPTICAL FIBER DRILLED TO THE CORE

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

Applications:

- Optical fiber sensors
- Material science

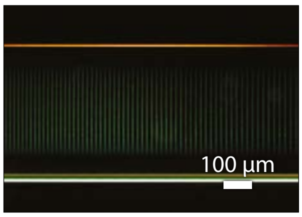


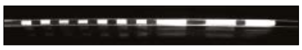
OPTICAL FIBER SCATTERING

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

Applications:

- Medical fibers
- Oncology



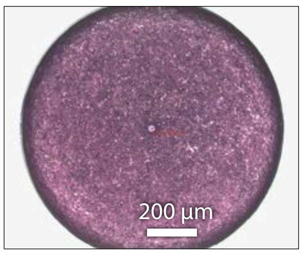


SYNTHETIC RUBY DRILLING

- No cracks after drilling
- Taper angle control

Application:

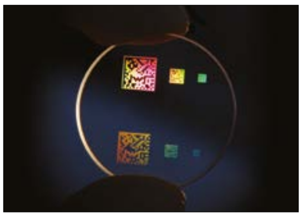
- High precision mechanical parts



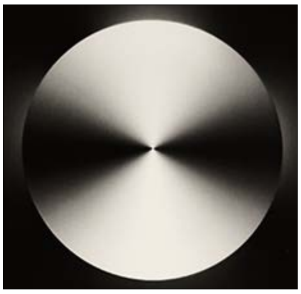
GLASS BULK PROCESSING

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

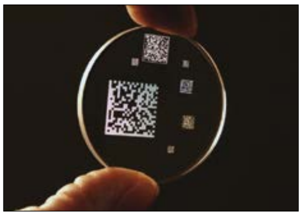
Birefringence modification inside fused silica. Photo in crossed polarized light



Sapphire



S-waveplate *

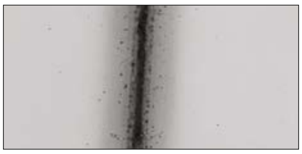


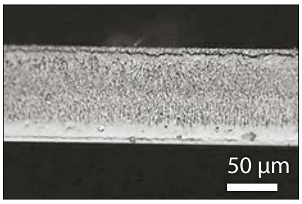
Glass

* 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

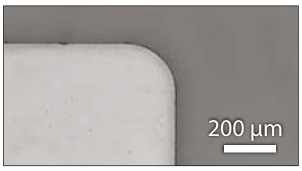
- Thickness: 0.03 – 0.3 mm
- Mechanical or heat assisted break after scribing
- Speed: up to 800 mm/s
- Any shape
- Round corners
- Surface quality: Ra ≤ 2µm





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



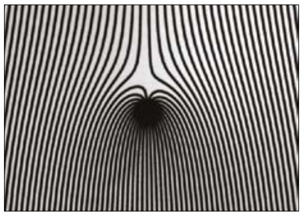
Thickness: 420 µm, clear sapphire

SELECTIVE METAL COATING ABLATION (REMOVAL)

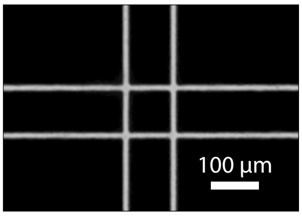
- Selective ablation of metal coatings from various surfaces
- Depth and geometry of ablation may vary

Application:

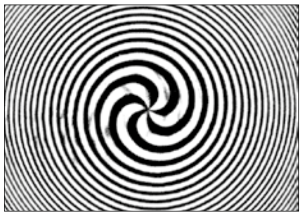
- Lithography mask production
- Beam shaping elements
- Optical apertures
- Other



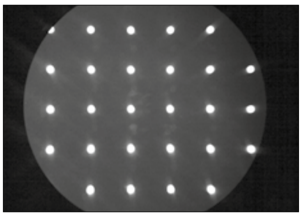
Amplitude grating formation



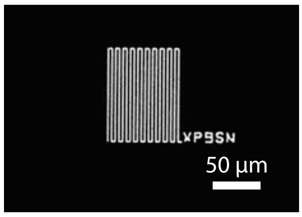
Titan coating selective ablation



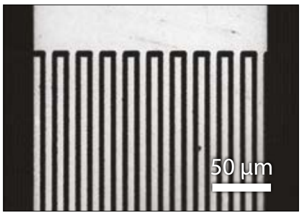
Chrome ablation for beam shaping



Apperture array fabrication



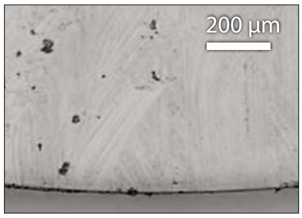
Gold layer removal without damage to MgO substrate – Au layer removal without damaging

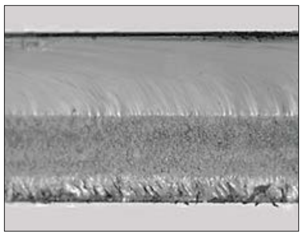


Chrome ablation from glass substrate

TEMPERED GLASS CUTTING

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





Workshop of Photonics

Samples provided by **Workshop of Photonics** *www.wophotonics.com*

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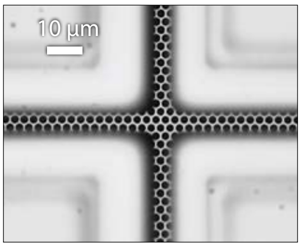
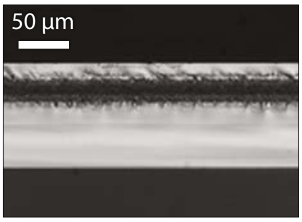
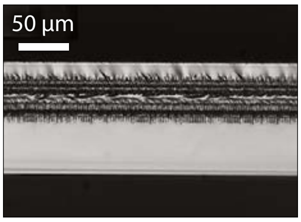
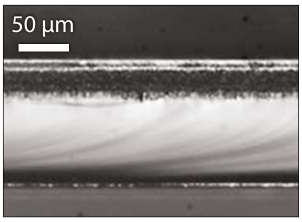
SAPPHIRE DICING FOR LED INDUSTRY

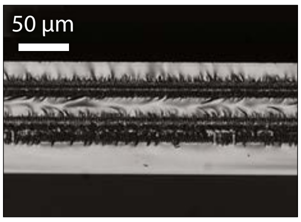
- Wafer thickness 50 to 330 µm
- Narrow street width up to ~10 µm
- Bending strength (650–900 MPa)
- High light extraction efficiency
- Controllable damage length
- Easy breaking
- Scribing with DBR coated backside of sapphire

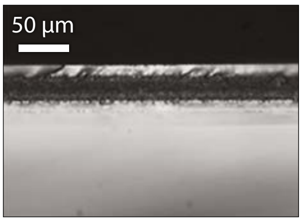


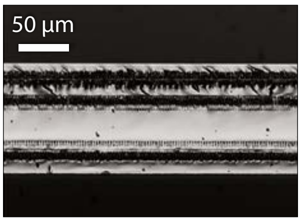










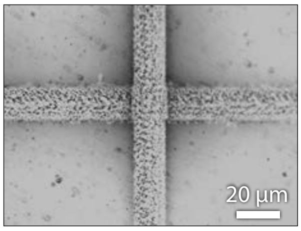


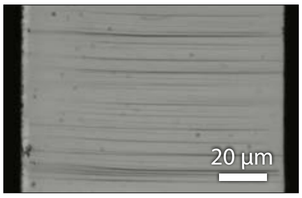
SILICON CARBIDE DICING

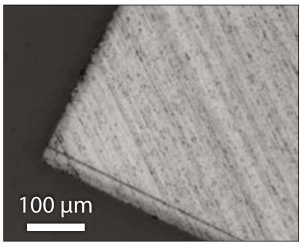
- No chipping on the edges
- Cleaved-surface roughness <1 µm
- Easy breaking

Applications:

- High power, high frequency electronics







Samples provided by
Evana Technologies
www.evanatech.com

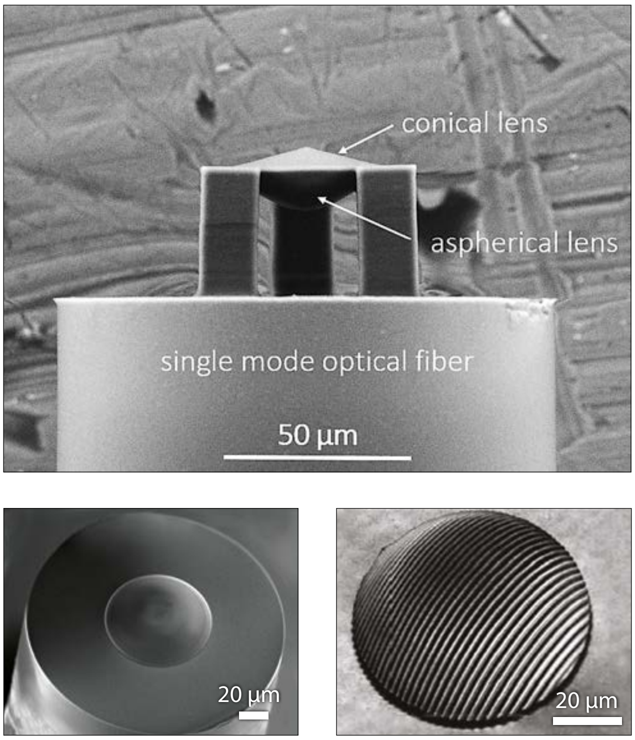
MULTI-PHOTON POLYMERIZATION

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.



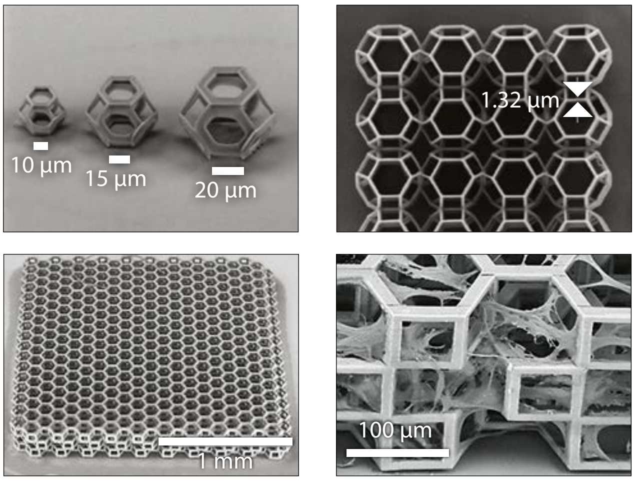
M. Malinauskas et al. Femtosecond laser polymerization of hybrid/integrated micro-optical elements and their characterization. J. Opt. 12, 124010 (2010).

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.

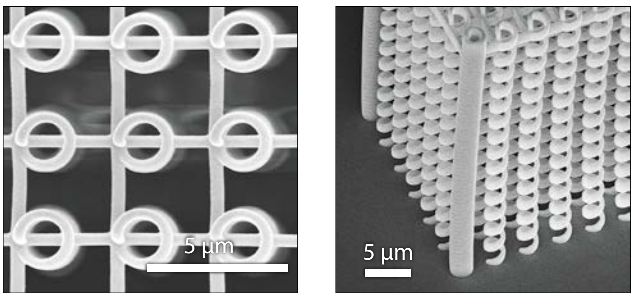


M. Malinauskas et al. 3D artificial polymeric scaffolds for stem cell growth fabricated by femtosecond laser. Lithuanian J. Phys., 50 (1), 75-82, (2010).

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).

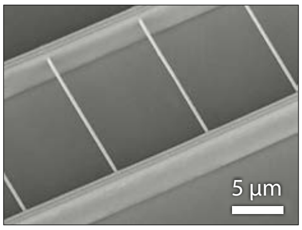
V. Purlys et al. Super-collimation by axisymmetric photonic crystals,Appl. Phys. Lett. 104(22), 221108 (2014).

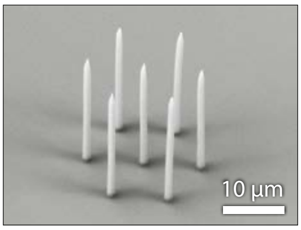
V. Mizeikis et al. Realization of Structural Colour by Direct Laser Write Technique in Photoresist, J. Laser Micro Nanoen. 9(1), 42 (2014).

APPLICATION IN MICROMECHANICS

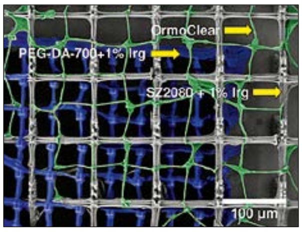
MPP technology gives the user ability to create multiscale and multimaterial 3D objects out of substances with various physical, chemical, and biological properties.

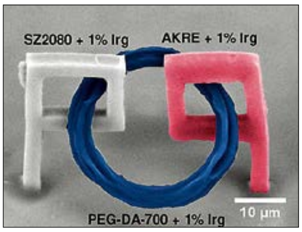
Examples: cantilevers, valves, micro-pore filters with controllable pore sizes, mechanical switches. [1)]





Examples of multicomponent structures. [2)]



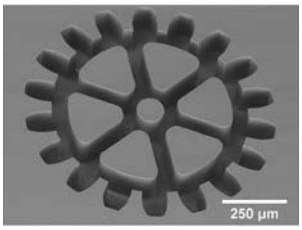


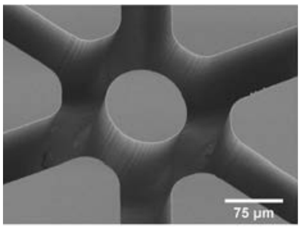
1) V. Purlys, Three-dimensional photonic crystals: fabrication and applications for controlof chromatic and spatial light properties, Ph.D. Thesis. Vilnius University: Lithuania (2015).

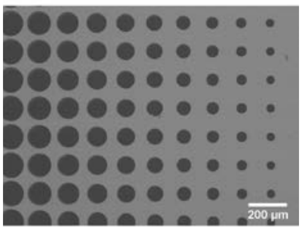
2) M. Malinauskas et al. Ultrafast laser processing of materials: from science to industry, Light: Sci. Appl., to be published, (2015).

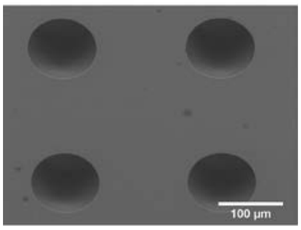
LASER ASSISTED SELECTIVE ETCHING

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

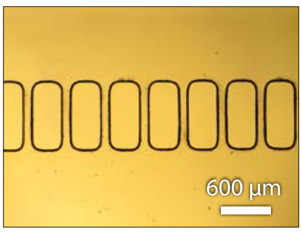


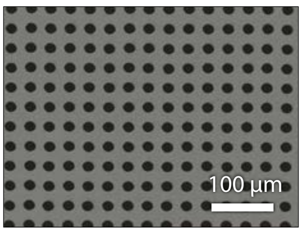






LASER ABLATION

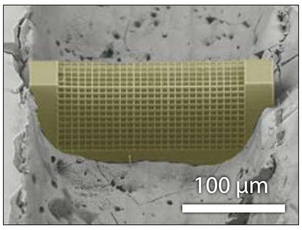


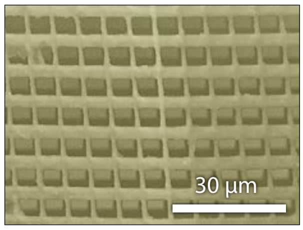


Hybrid microfabrication

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.

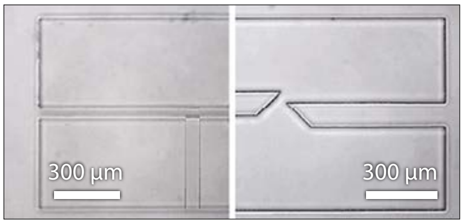


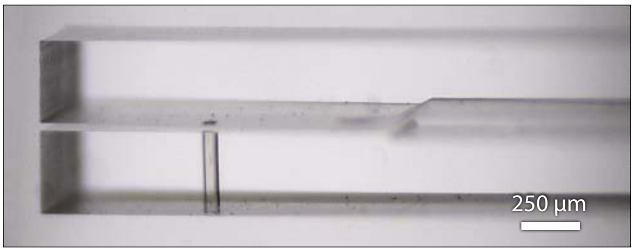


Jonušauskas et al., Opt. Eng. 56(9), 094108 (2017).

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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femtika

For Production Tool Inquiries
info@femtika.lt
www.femtika.lt

Rev. 20190416

FLINT

Femtosecond Yb Oscillators

Typical view of FLINT model FL2

FEATURES

- Sub-40 fs without any additional pulse compressor
- 250 nJ pulse energy
- 20 W output power
- 76 MHz is standard
- 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 pumped 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

Product name	FL1-02	FL1-08	FL2-12	FL2-20	FL1-SP
Max. average power	2 W	8 W	> 12 W	> 20 W	up to 2 W
Pulse duration (assuming Gaussian pulse shape)	< 100 fs	< 120 fs	< 120 fs	< 160 fs	< 40 fs
Pulse energy	> 25 nJ	> 100 nJ	> 150 nJ	> 250 nJ	up to 25 nJ
Repetition rate	~ 76 MHz [1]		~ 76 MHz		~ 76 MHz [2]
Centre wavelength	1035 ± 10 nm				
Output pulse-to-pulse stability	< 0.5 % rms over 24 hours [3]				
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		542 (L) × 322 (W) × 146 (H) mm		430 (L) × 195 (W) × 114 (H) mm
Laser head with 2H	442 (L) × 270 (W) × 114 (H) mm		542 (L) × 322 (W) × 146 (H) mm		
Power supply and chiller rack	642 (L) × 553 (W) × 540 (H) mm		642 (L) × 553 (W) × 673 (H) mm		642 (L) × 553 (W) × 540 (H) mm
Chiller	Included. Different options are available				
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	< 80 % (non-condensing)				

1) *Other repetition rates are available in the range from 60 to 100 MHz.*
2) *Other repetition rates are available in the range from 70 to 80 MHz.*
3) *With enabled power-lock, under stable environment.*

OPTIONAL EQUIPMENT

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

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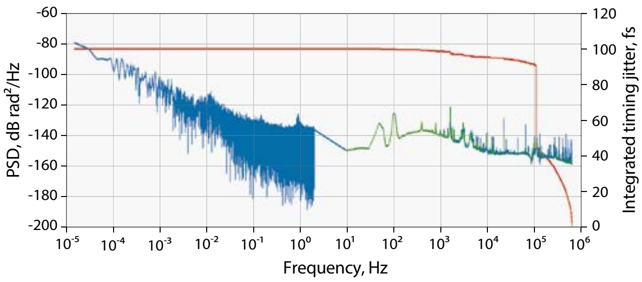
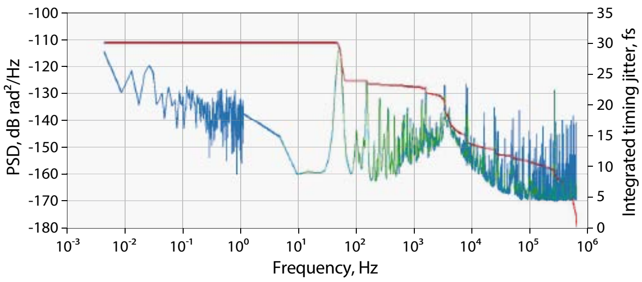
LOCKING OF THE OPTICAL PULSE TO AN EXTERNAL SIGNAL

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

LONG TERM HARMONIC LOCK STABILITY TEST (40 hours)

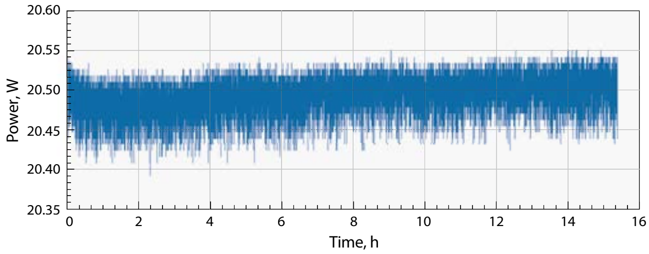


Laser oscillator (62.513 MHz) is locked to RF reference R&S SMB 100A (500.104 MHz). Measured integrated timing jitter* at 0.01 mHz – 600 kHz bandwidth is 110 fs

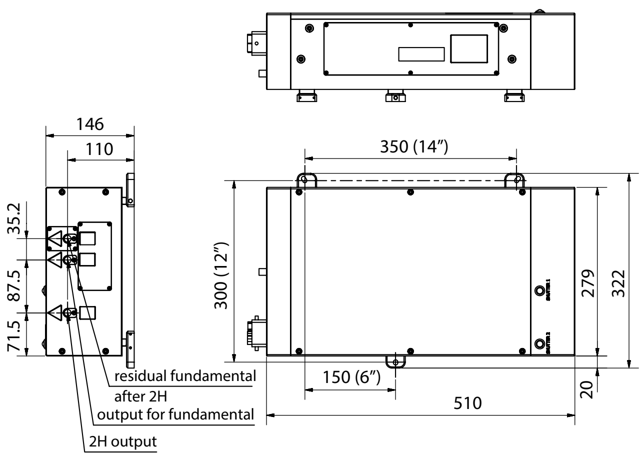


Laser oscillator (72.656 MHz) is locked to reference laser oscillator (72.656 MHz). Measured integrated timing jitter* at 0.01 Hz – 600 kHz bandwidth is 30 fs

* *Integrated timing jitter up to 100 – 300 fs depending on RF source frequency, noise, environment conditions etc. For actual jitter specification please contact Light Conversion.*



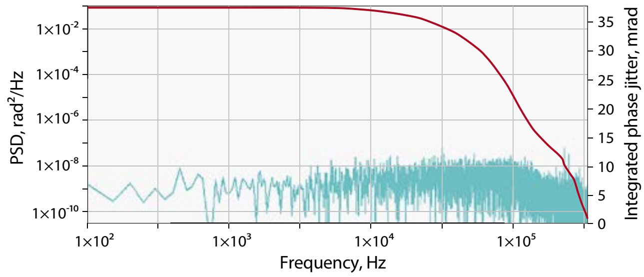
FLINT FL2-20 (20 W) output power stability



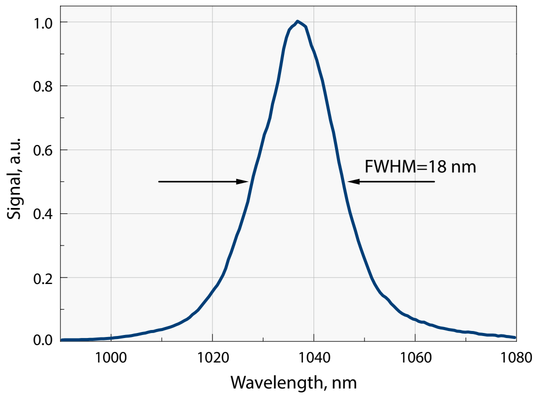
FLINT FL2 outline drawing

CARRIER ENVELOPE PHASE (CEP) STABILIZATION

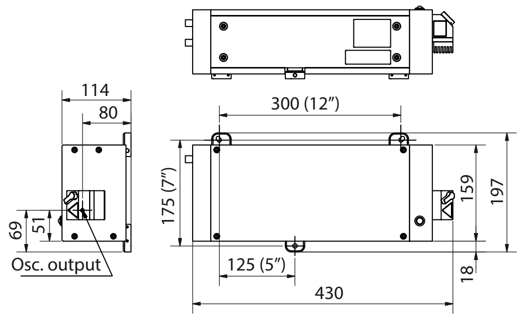
PHAROS oscillator can be equipped with nonlinear interferometer and feedback loop throughout the pump current of the laser diode bar for CEP stabilization.



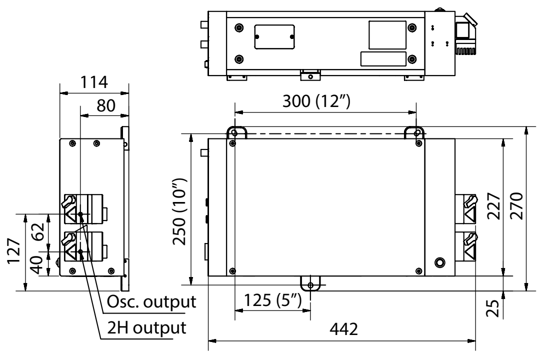
Single side power spectral density of f_{ceo} phase noise (in loop) and the integrated phase jitter.



Typical FLINT optical spectrum



FLINT FL1 dimensions



FLINT FL1 dimensions with second harmonic generator

HIRO

Harmonics Generator

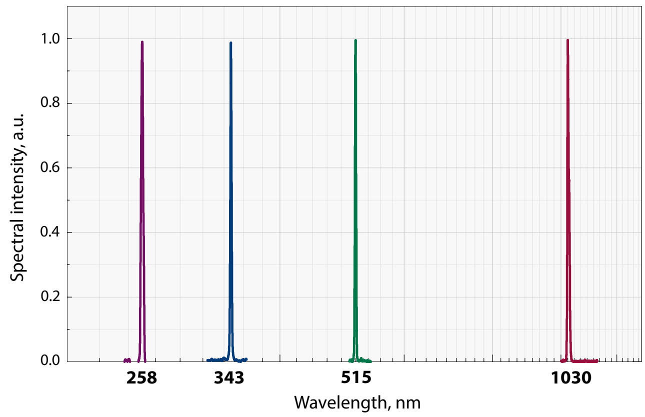
FEATURES

- 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 / CARBIDE 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

Product name	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

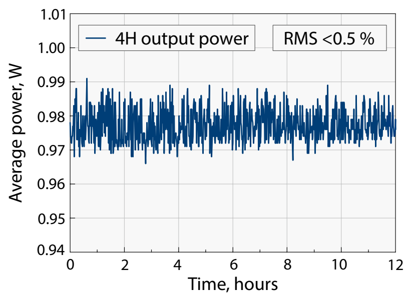
Residual fundamental radiation available upon request.
HIRO pumped with ps pulses available on request.

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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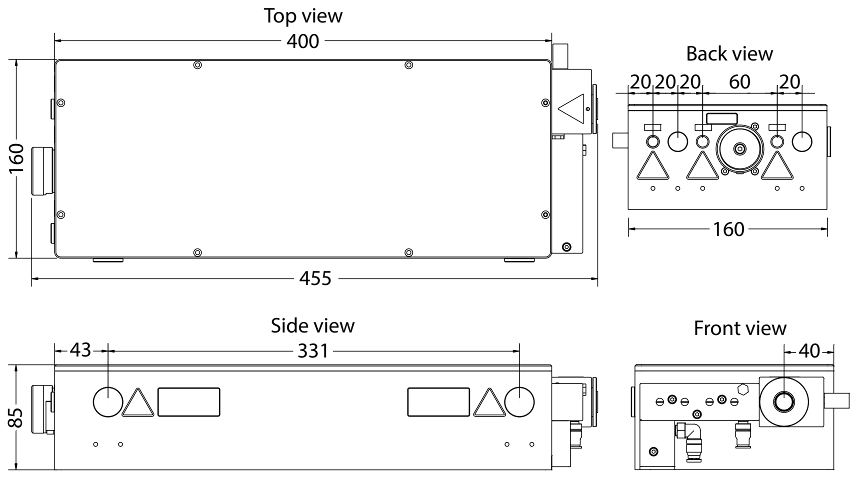
HARMONICS GENERATION

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

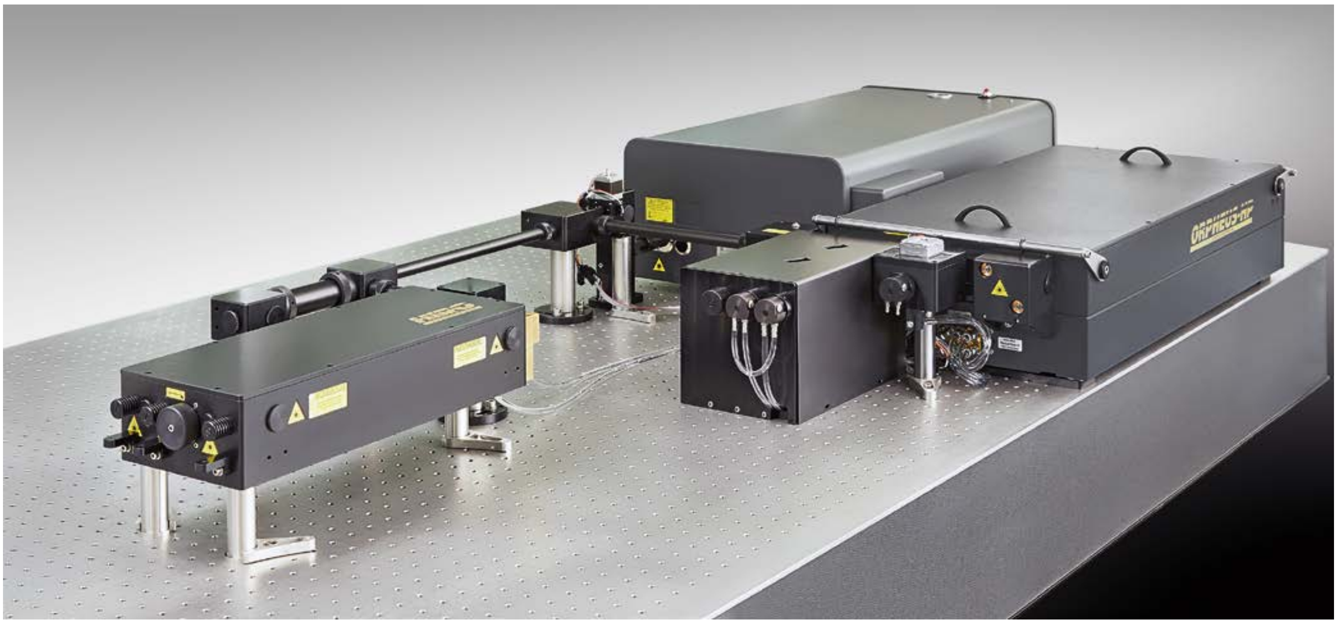
Generated harmonics	2H	3H	4H
Output wavelength	517 nm	345 nm	258 nm
Conversion efficiency	> 35 %	> 5 %	> 1 %

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

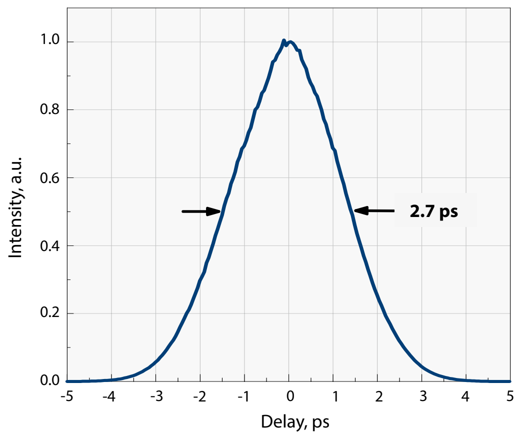
FEATURES

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

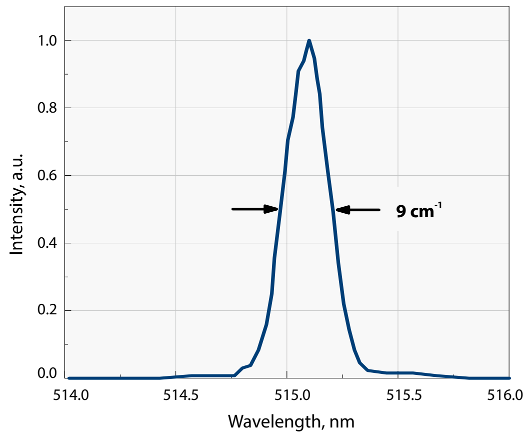
PHAROS / CARBIDE harmonic generator product line features second harmonic bandwidth compressor abbreviated as SHBC. The device is dedicated for the formation of narrow bandwidth picosecond pulses from broadband output of ultrafast laser. In PHAROS / CARBIDE platform SHBC is used to create flexible setups 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.

SPECIFICATIONS

Parameter	Value
Pump source	PHAROS / CARBIDE laser, 1030 nm, 70 – 120 cm^{-1}, 10 – 2000 μJ input pulse energy
Output wavelength	515 nm
Conversion ratio	> 30 %
Output pulse bandwidth	< 10 cm^{-1}



Typical pulse duration SHBC output



Typical spectrum of SHBC output

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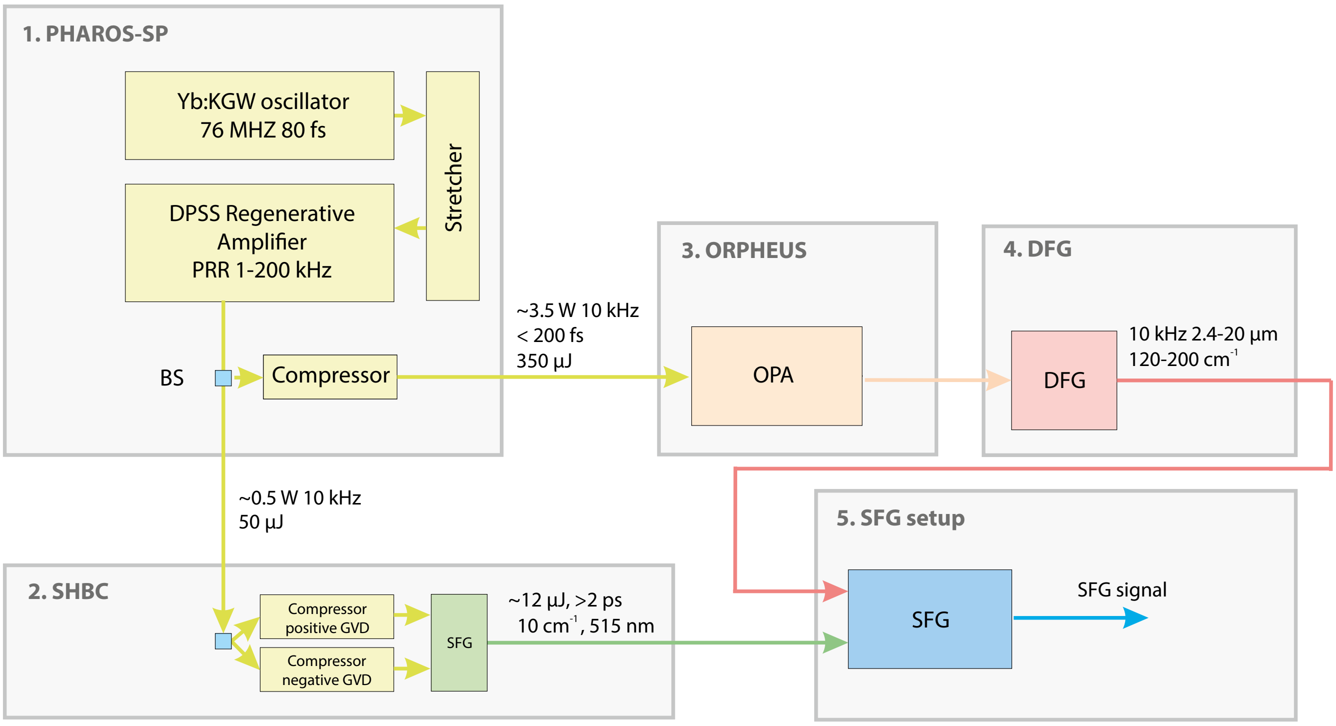
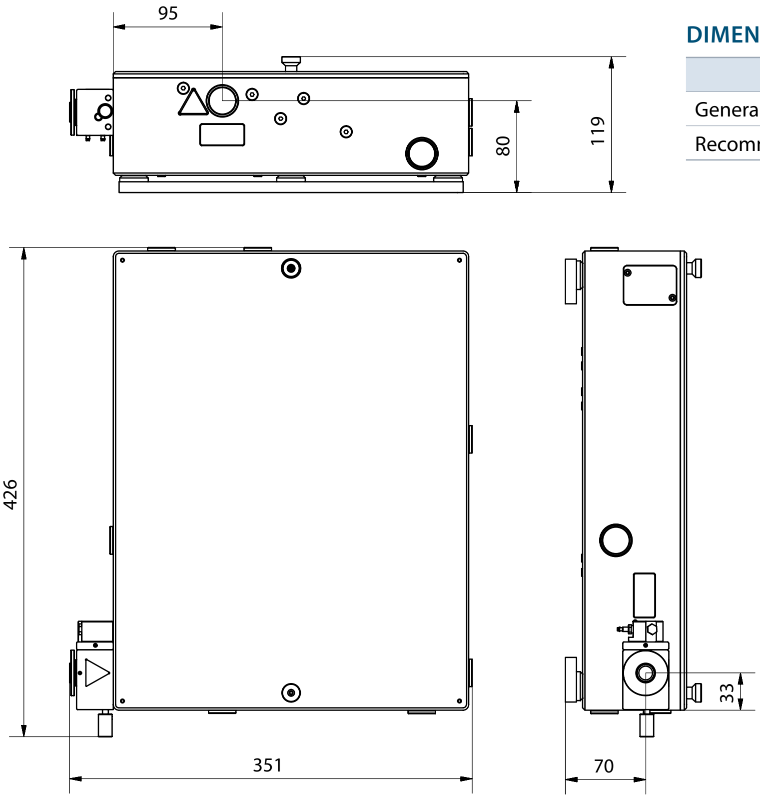


Principal layout of femtosecond sum frequency generation (SFG) spectroscopy system using SHBC to produce one of the probe beams



DIMENSIONS

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

ORPHEUS

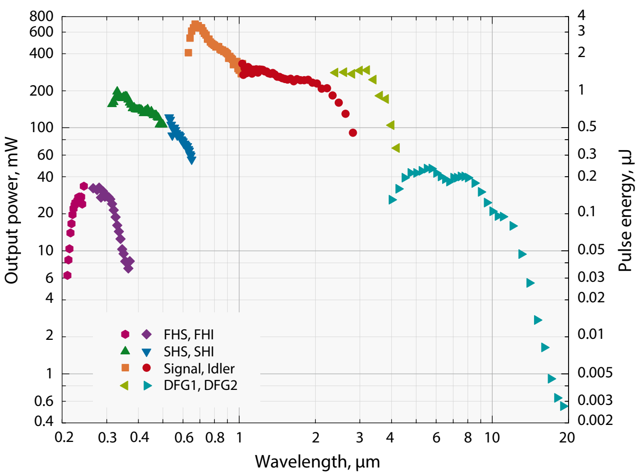
Collinear Optical Parametric Amplifier

FEATURES

- 190 nm – 16000 nm tunable wavelength
- Single pulse – 1 MHz repetition rate
- Up to 40 W pump power
- Up to 2 mJ pump energy
- Completely automated
- Integrated spectrometers
  for monitoring the output wavelength

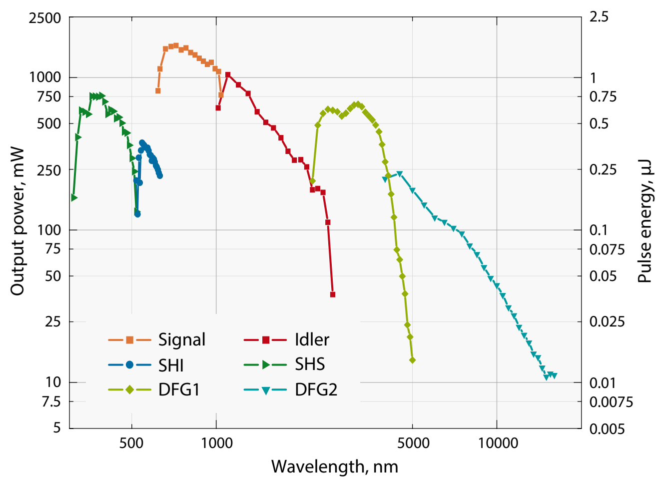
ORPHEUS is collinear optical parametric amplifier of white light continuum pumped by femtosecond Ytterbium based laser amplifiers. With the additional feature of being able to work at high repetition rates, ORPHEUS maintains the best properties of TOPAS series OPA's: high output pulse stability throughout 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. Femtosecond pulses, high power tunable output together with flexible multi kilohertz repetition rate make the tandem of ORPHEUS and PHAROS or CARBIDE laser an invaluable tool for multiphoton microscopy, micro structuring and spectroscopy applications. Several ORPHEUS can be pumped by a single PHAROS or CARBIDE laser providing independent beam wavelength tuning.

ORPHEUS-HP and ORPHEUS-HE devices are modified versions of the ORPHEUS. ORPHEUS-HP is available with UV-VIS tuning range frequency mixers integrated into a thermally stabilized monolithic housing. Also, it provides the option of generating deep ultraviolet pulses (190 – 215 nm) and DFG (2200 – 16000 nm). The design offers completely hands free wavelength tuning and automated wavelength separation, ensuring the same position and direction for all wavelengths in UV, VIS and near IR regions. A mini spectrometer is integrated for online monitoring of output wavelength and comes with specialized software that enables wavelength feedback and automatic calibration. ORPHEUS-HE is available with UV-VIS tuning range extension and is dedicated for high energy pump lasers (1 – 2 mJ).



ORPHEUS

Typical tuning curve of ORPHEUS.
Pump: 6 W, 30 μJ, 200 kHz



ORPHEUS-HP

Typical tuning curve of ORPHEUS-HP.
Pump: 40 W, 40 μJ, 1000 kHz

For custom tuning curve value visit *http://toolbox.lightcon.com/tools/tuningcurves/*

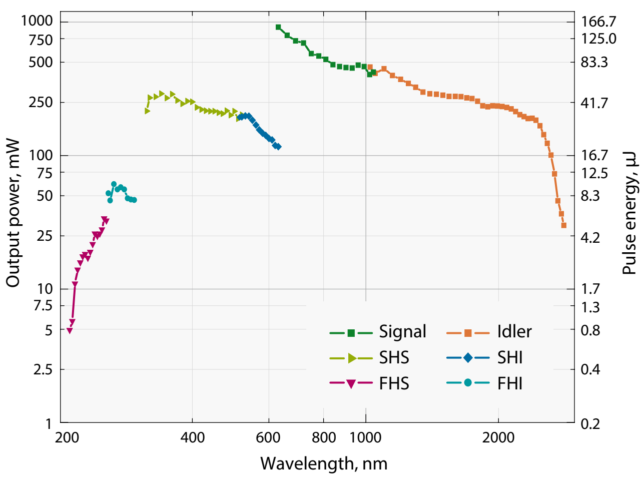
Rev. 20190416

SPECIFICATIONS

Product name	ORPHEUS		ORPHEUS-HP		ORPHEUS-HE
OUTPUT FROM ORPHEUS					
Tuning range	630 –1030 nm (Signal) 1030 – 2600 nm (Idler)				
Integrated second harmonic generation efficiency	> 35 % (515 nm) port B		not specified		
Pump power (max)	8 W		40 W		10 W
Pump energy	8 – 20 µJ	20 – 400 µJ	8 – 20 µJ	20 – 1000 µJ	1000 – 2000 µJ [1]
Conversion efficiency at peak	> 6 % (Signal + Idler combined)	> 12 % (Signal + Idler combined)	> 4.5 % (Signal) > 2.8 % (Idler)	> 9 % (Signal) > 4 % (Idler)	
Pulse duration	130 – 290 fs (PHAROS / CARBIDE) 120 – 190 fs (PHAROS-SP)				
Pulse bandwidth @ 700 – 960 nm	80 – 150 cm^{-1} (PHAROS / CARBIDE) 100 – 220 cm^{-1} (PHAROS-SP)				
Long term power stability (8 h)	< 2 % @ 800 nm				
Pulse energy stability (1 min)	< 2 % @ 800 nm				
Features	Cost effective		Completely automated		High energy
WAVELENGTH EXTENSIONS					
When pump energy	8 – 20 µJ	20 – 400 µJ	8 – 20 µJ	20 – 1000 µJ	1000 – 2000 µJ [1]
315 – 515 nm (SH of Signal) 515 – 630 nm (SH of Idler)	> 1.2 %	> 3 %	> 1.2 %	> 2.4 %	
210 – 315 nm (TH of Signal)	—		> 0.4 %	> 0.8 %	—
210 – 255 nm (FH of Signal) 255 – 315 nm (FH of Idler)	> 0.3 %	> 0.6 %	—		> 0.6 %
190 – 215 nm (DeepUV)	—			> 0.3 % [2]	Contact Light Conversion
2200 – 4200 nm (DFG1)	> 1.5 % @ 3000 nm	> 3 % @ 3000 nm	> 1.5 % @ 3000 nm	> 3 % @ 3000 nm	
4000 – 16 000 nm (DFG2)	> 0.1 % @ 10000 nm	> 0.2 % @ 10000 nm	> 0.1 % @ 10000 nm	> 0.2 % @ 10000 nm	

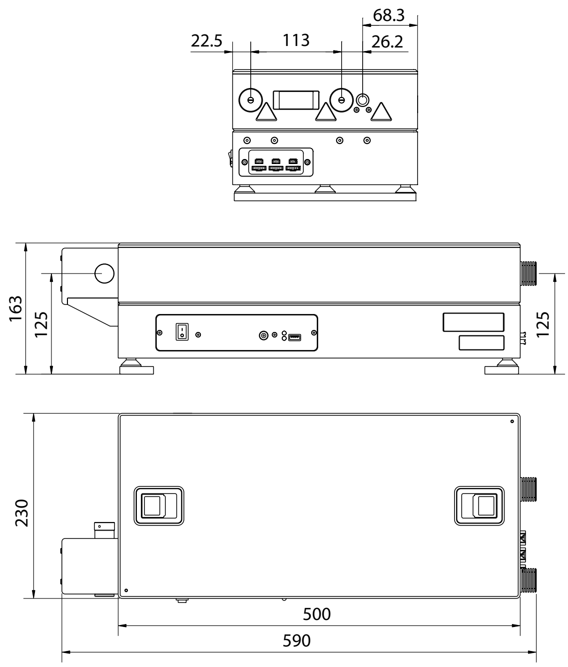
[1] *Pump energy up to 5 mJ available, please contact sales@lightcon.com for specifications.*

[2] *DeepUV conversion efficiency is speficied only when pump input to OPA is <10 W. In case of higher pump power, DeepUV efficiency decreases, the maximum output power is limited to ~40 mW @ 200 nm.*



ORPHEUS-HE

Typical tuning curve of ORPHEUS-HE.
Pump: 6 W, 1 mJ, 6 kHz



ORPHEUS drawings

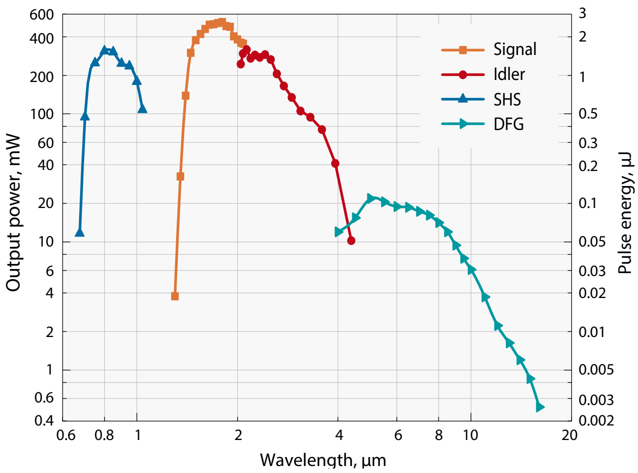
ORPHEUS-ONE

Mid-IR Collinear Optical Parametric Amplifier

FEATURES

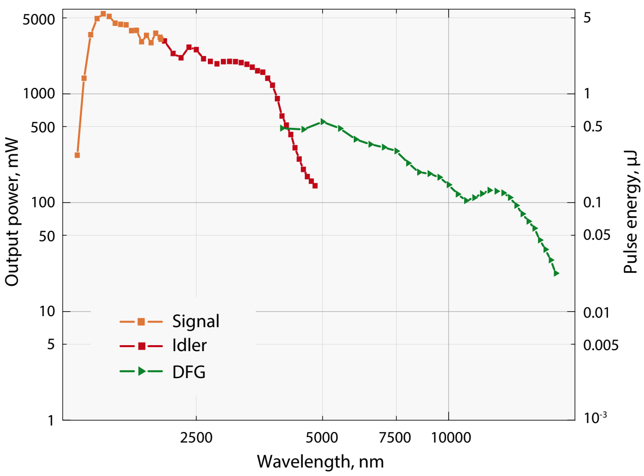
- Twice the output in mid-IR
- Broad-bandwidth > 200 cm^{-1} configuration available
- 1350 nm – 16000 nm tunable wavelength
- Single pulse – 1 MHz repetition rate
- Up to 40 W pump power
- Up to 2 mJ pump energy
- Computer controlled

ORPHEUS-ONE is a collinear optical parametric amplifier (OPA) of white-light continuum pumped by femtosecond Ytterbium based laser amplifiers and focused on mid-infrared wavelengths generation.
In comparison to standard ORPHEUS + DFG configuration, the ORPHEUS-ONE provides higher conversion efficiency into the infrared range. The scheme used in ORPHEUS-ONE can generate >150 cm^{-1} bandwidth pulse when OPA is configured for broad-bandwidth amplification.



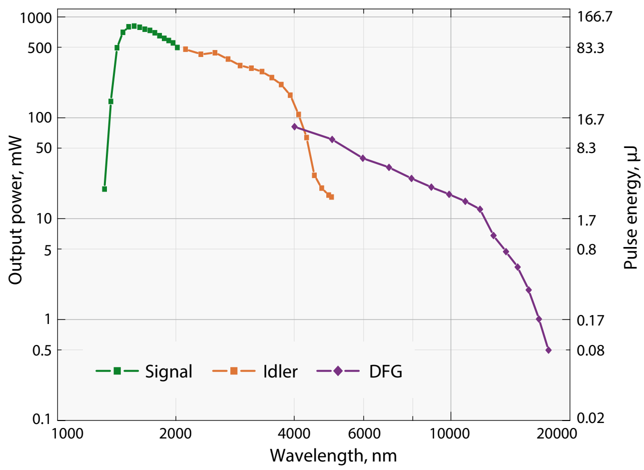
ORPHEUS-ONE

Typical tuning curve of ORPHEUS-ONE.
Pump: 6 W, 30 μJ, 200 kHz



ORPHEUS-ONE-HP

Typical tuning curve of ORPHEUS-ONE-HP.
Pump: 40 W, 40 μJ, 1000 kHz



ORPHEUS-ONE-HE

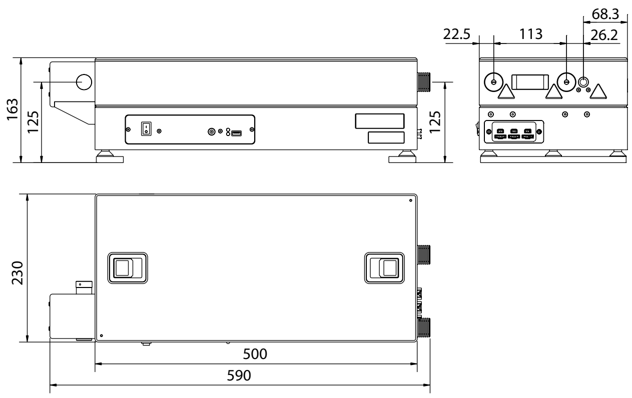
Typical tuning curve of ORPHEUS-ONE-HE.
Pump: 6 W, 1 mJ, 6 kHz

For custom tuning curve value visit *http://toolbox.lightcon.com/tools/tuningcurves/*

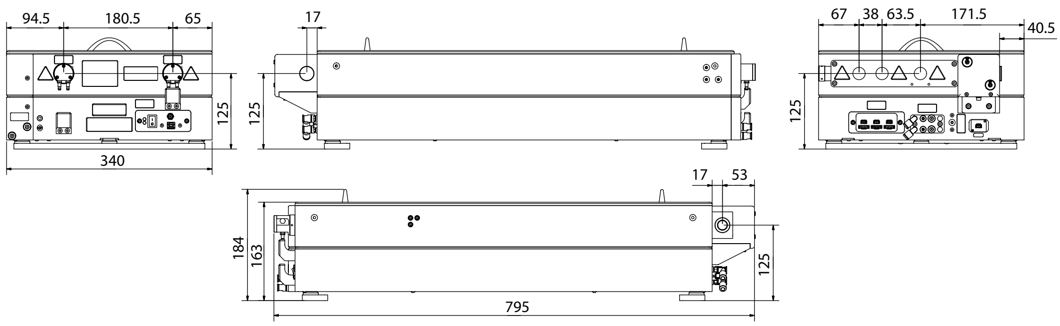
SPECIFICATIONS

Product name	ORPHEUS-ONE	ORPHEUS-ONE-HP	ORPHEUS-ONE-HP (BB)	ORPHEUS-ONE-HE
OUTPUT FROM ORPHEUS-ONE (1350 – 4500 nm)				
Tuning range	1350 – 2060 nm (Signal) 2060 – 4500 nm (Idler)			
Maximum pump power	8 W	40 W		10 W
Pump energy	12 – 400 µJ	12 – 1000 µJ		1000 – 2000 µJ
Conversion efficiency at peak of tuning curve, signal and idler combined [1]	> 14 %, pump 30 – 1000 µJ > 10 %, pump 12 – 30 µJ			> 14 %
Pulse bandwidth	60 – 120 cm^{-1} @ 1450 – 2000 nm	60 – 150 cm^{-1} @ 1450 – 2000 nm	> 300 cm^{-1} @ 1400 nm 60 – 140 cm^{-1} @ 1550 – 2000 nm	60 – 150 cm^{-1} @ 1450 – 2000 nm
Long term power stability (8 h)	< 2 % @ 1550 nm			
Pulse energy stability (1 min)	< 2 % @ 1550 nm			
Features	Cost effective	High power		High energy
WAVELENGTH EXTENSIONS				
Tuning range (SHS)	720 – 970 nm			
Pulse energy conversion efficiency [1]	> 2 % at peak			
Pulse bandwidth	70 – 150 cm^{-1} @ 800 – 970 nm			
Tuning range (DFG2)	4500 – 16000 nm (based on signal and idler calibration)			
Pulse energy conversion efficiency [1]	> 0.3 % @ 10000 nm, when pump energy 30 – 2000 µJ > 0.2 % @ 10000 nm, when pump energy 12 – 30 µJ			
Pulse bandwidth	60 – 150 cm^{-1} @ 5000 – 8000 nm	60 – 120 cm^{-1} @ 5000 – 8000 nm		

[1] *Conversion efficiency specified as the percentage of input power to ORPHEUS-ONE.*



ORPHEUS-ONE outline drawings



ORPHEUS-ONE-HP and ORPHEUS-HP outline drawings

ULTRAFAST LASERS
OSCILLATORS
HARMONICS GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
SPECTROMETERS
AUTOCORRELATORS

ORPHEUS-F

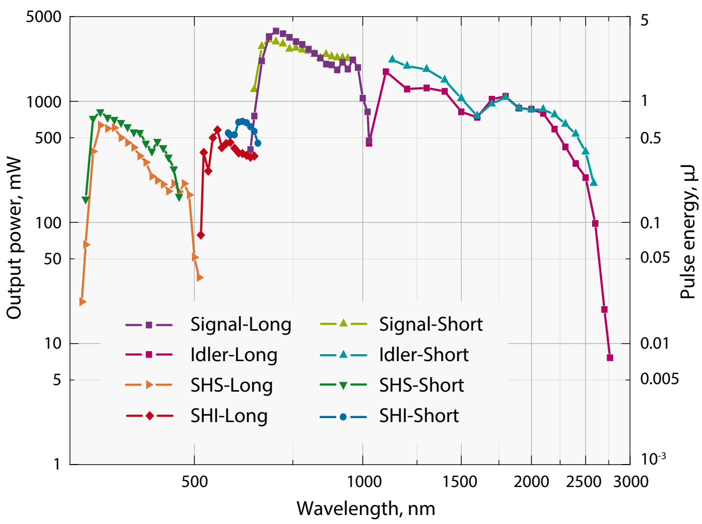
Broad Bandwidth Hybrid Optical Parametric Amplifier

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
- Dual pulse width option provides gap free tunability (650 – 2500 nm)

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 (620 – 900 nm) offered by collinear OPA. 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.

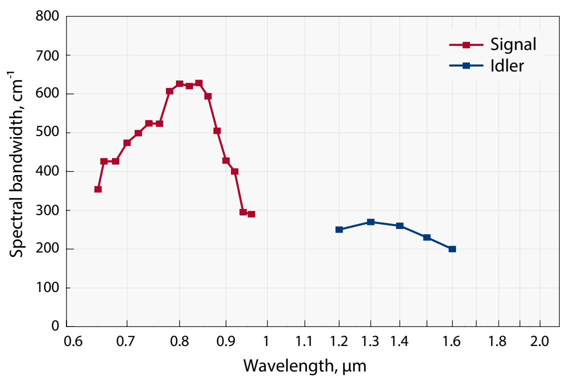
Standard ORPHEUS device uses spectral narrowing to produce bandwidth-limited 200 – 300 fs duration pulses directly at the output, with extended Signal/Idler tuning range and options to generate ultraviolet and mid-infrared light. Our non-collinear ORPHEUS-N-2H device produces even broader bandwidths, 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.



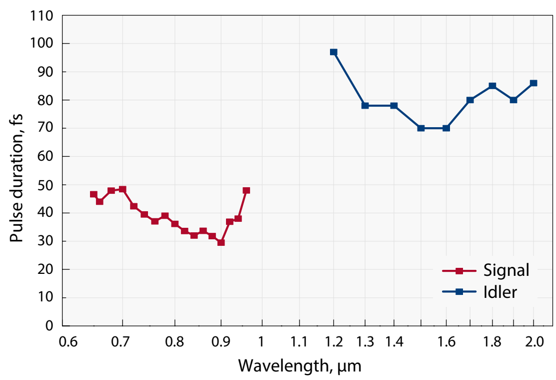
ORPHEUS-F

ORPHEUS-F energy conversion curve.
Pump: 40 W, 40 μJ, 1000 kHz

For custom tuning curve value visit
http://toolbox.lightcon.com/tools/tuningcurves/



Typical spectral bandwidth of ORPHEUS-F



Pulse duration after compression of ORPHEUS-F

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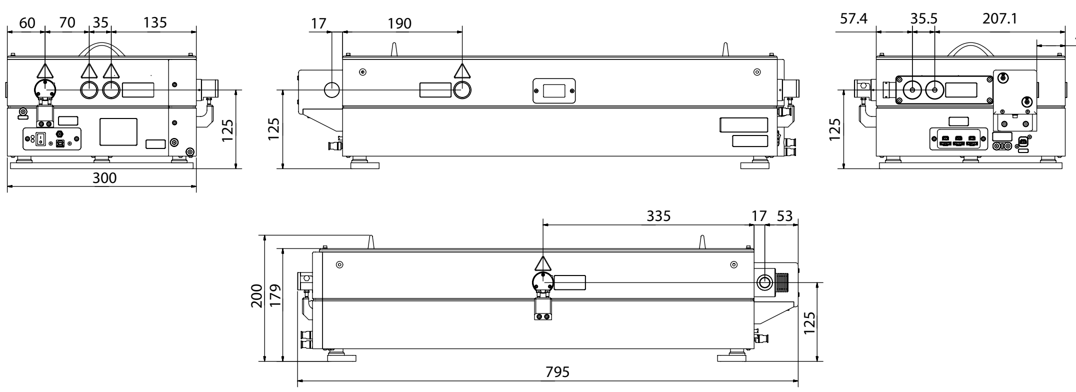
SPECIFICATIONS

Product name		ORPHEUS-F [short pulse mode]	ORPHEUS-F [long pulse mode]
OUTPUT FROM ORPHEUS-F			
Tuning range	Signal	650 – 900 nm	650 – 1010 nm
	Idler	1 200 – 2 500 nm	1050 – 2500 nm
Integrated second harmonic generation efficiency		> 35 % (515 nm) [1]	
Pump power (maximum)		Up to 40 W	
Pump energy		10 – 500 µJ	
Conversion efficiency at peak, Signal + Idler combined		> 10 %	
Pulse duration before compression		< 290 fs	
Pulse bandwidth	650 – 900 nm	200 – 750 cm^{-1}	80 – 150 cm^{-1} (PHAROS / CARBIDE) 100 – 220 cm^{-1} (PHAROS-SP)
Pulse duration after compressor	800 – 900 nm	< 55 fs	—
	650 – 800 nm	< 70 fs	
	1200 – 2000 nm	< 100 fs	
	Typical: 650 – 900 nm	25 – 70 fs	
	Typical: 1200 – 2000 nm	40 – 100 fs	
Compressor transmission	650 – 900 nm	> 65 %	
	1200 – 2000 nm	> 80 %	
Long term power stability (8 h)		< 2 % @ 800 nm	
Pulse energy stability (1 min)		< 2 % @ 800 nm	
WAVELENGTH EXTENSIONS			
At peak	325 – 450 nm (SH of Signal)	> 1 %	—
	325 – 505 nm (SH of Signal)	—	> 1 %
	525 – 650 nm (SH of Idler)		> 0.5 %
	600 – 700 nm (SH of Idler)	> 0.5 %	—
	210 – 252 nm (FH of Signal)	—	> 0.1 %
	263 – 325 nm (FH of Idler)		> 0.2 %
	2200 – 4200 nm (DFG1)	Contact Light Conversion	
	4000 – 16 000 nm (DFG2)		

[1] *At designated output port.*



ORPHEUS-F outline drawings

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ORPHEUS-N

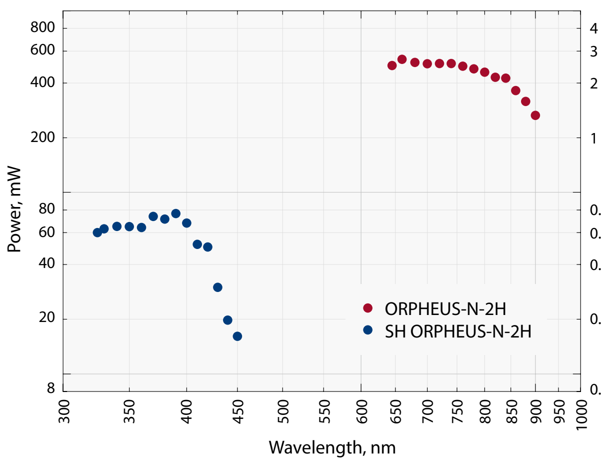
Non-Collinear Optical Parametric Amplifier

FEATURES

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

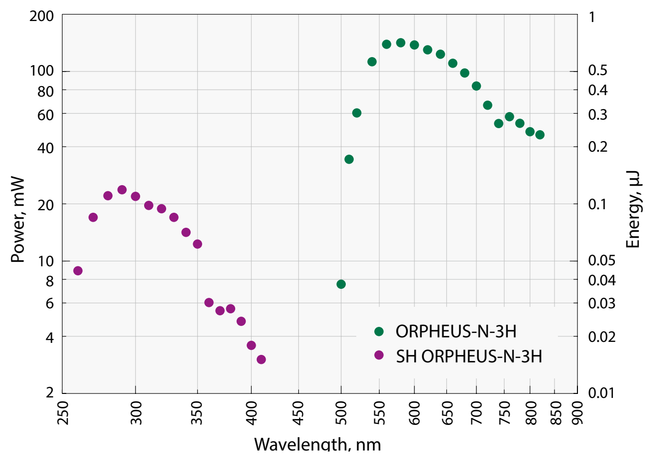
ORPHEUS-N is a non-collinear optical parametric amplifier (NOPA) pumped by Ytterbium based femtosecond laser amplifier. Depending on the ORPHEUS-N model, it has a built in second or third harmonic generator producing 515 nm or 343 nm pump. ORPHEUS-N with second harmonic pump (ORPHEUS-N-2H) delivers pulses of less than 30 fs in the 700 – 850 nm range with average power of more than 0.5 W at 700 nm [1]. ORPHEUS-N with third harmonic pump (ORPHEUS-N-3H) delivers pulses of less than 30 fs in the 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 one ORPHEUS-N systems can be operated simultaneously with a single amplifier providing several pump and/or probe channels with independent wavelength tuning.

[1] *When pumped with 6 W @ 1030 nm, 200 kHz.*



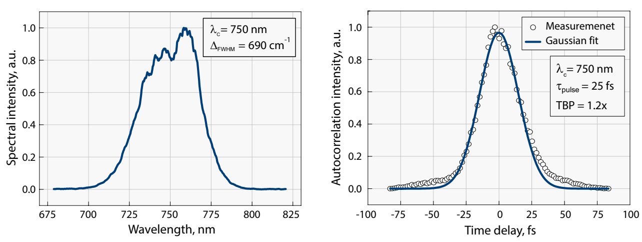
ORPHEUS-N-2H

Typical tuning curve of ORPHEUS-N-2H
Pump: 6 W, 30 µJ, 200 kHz

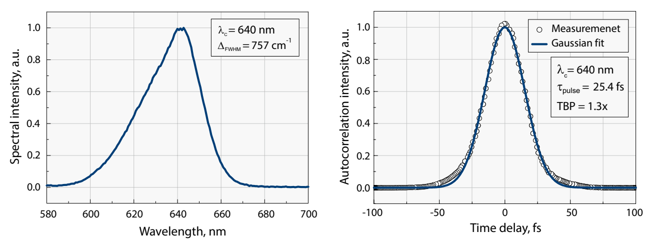


ORPHEUS-N-3H

Typical tuning curve of ORPHEUS-N-3H
Pump: 6 W, 30 µJ, 200 kHz



Typical output of ORPHEUS-N-2H



Typical output of ORPHEUS-N-3H

For custom tuning curve value visit *http://toolbox.lightcon.com/tools/tuningcurves/*

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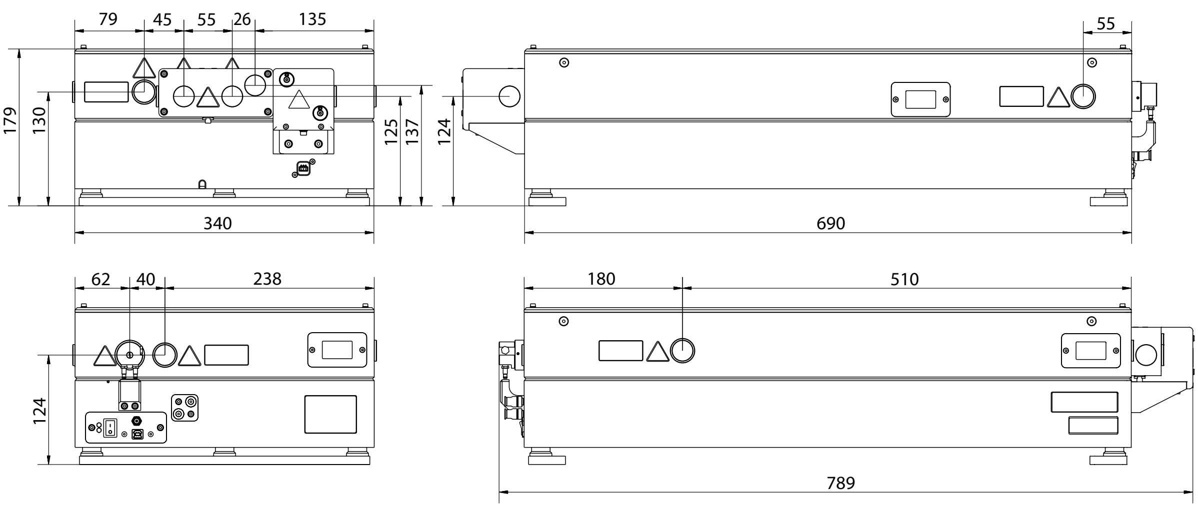
SPECIFICATIONS

Product name	ORPHEUS-N-2H		ORPHEUS-N-3H		
OUTPUT FROM ORPHEUS-N					
Tuning range	650 – 900 nm (Signal)		520 – 900 nm (Signal)		
Integrated second (third) harmonic generation efficiency	> 35 % (515 nm)		> 25 % (343 nm)		
Pump power (maximum)	8 W				
Pump pulse energy	10 – 200 µJ		12 – 200 µJ		
Conversion efficiency at peak	700 nm	800 nm	580 nm	700 nm	800 nm
	> 7 %	> 5 %	> 1.3 %	> 0.7 %	> 0.3 %
Pulse duration after compressor	< 30 fs (700 – 850 nm)		< 30 fs (530 – 670 nm) < 80 fs (670 – 900 nm)		
Long term power stability (8 h)	< 2 % @ 800 nm				
Pulse energy stability (1 min)	< 2 % @ 800 nm				
WAVELENGTH EXTENSIONS					
Tuning range (SH of Signal)	325 – 450 nm		260 – 450 nm		
Conversion efficiency at peak	> 10 % of Signal				



ORPHEUS-N outline drawings

ORPHEUS-N setup example

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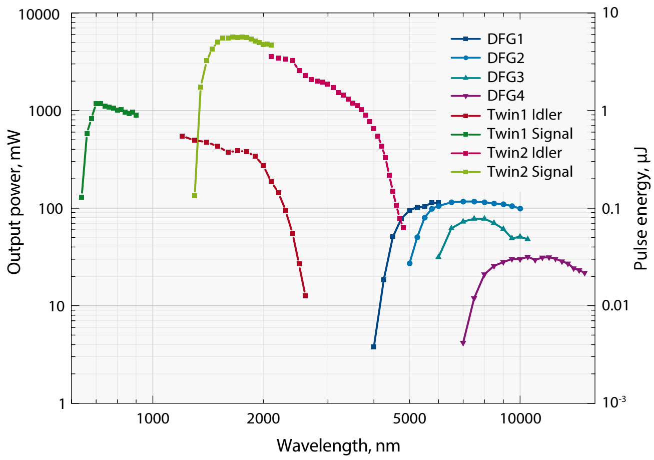
ORPHEUS-TWINS

Two Independently Tunable Optical Parametric Amplifiers

FEATURES

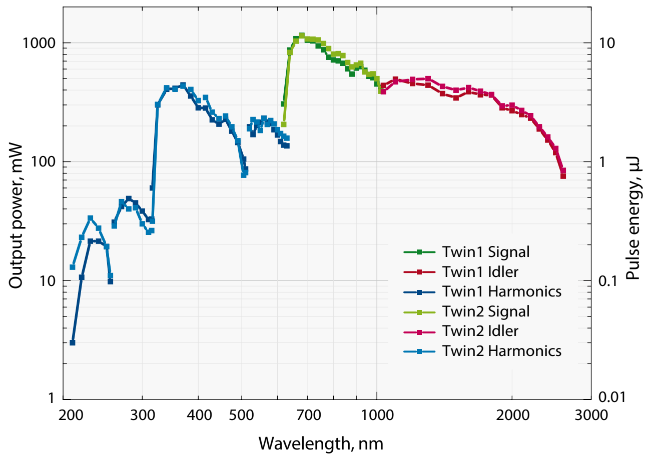
- Two OPA units in a single compact housing
- 210 nm – 16 µm tunable wavelength
- Single pulse – 1 MHz repetition rate
- Standard pump energy up to 0.5 mJ (2 mJ upon request)
- Broadband and short-pulse (<100 fs) versions available
- CEP stable mid-infrared output available
- Integrated spectrometers for monitoring OPA output wavelength

ORPHEUS-TWINS consists of 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 broadband mid-infrared radiation, in the region of 4 µm – 16 µm, with a passively stable Carrier Envelope Phase (CEP).



ORPHEUS-TWINS

ORPHEUS-TWINS (ONE / F configuration)
output power conversion curve.
Pump: 40 W, 40 µJ, 1 000 kHz



ORPHEUS-TWINS

ORPHEUS-TWINS (ORPHEUS / ORPHEUS configuration)
output power conversion curve.
Pump: 20 W, 20 µJ, 100 kHz

For custom tuning curve value visit *http://toolbox.lightcon.com/tools/tuningcurves/*

SPECIFICATIONS

Required pump laser	PHAROS or CARBIDE
Accepted pump input pulse energy @ 1 030 nm, 180 – 300 fs pulse duration	8 µJ – 2 mJ
Supported repetition rates	Single pulse – 1 MHz
Tuning range	Choice between ORPHEUS, ORPHEUS-F, ORPHEUS-N-2H 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 – 750 cm^{-1}
Pulse duration	Depends on configuration, down to 40 fs

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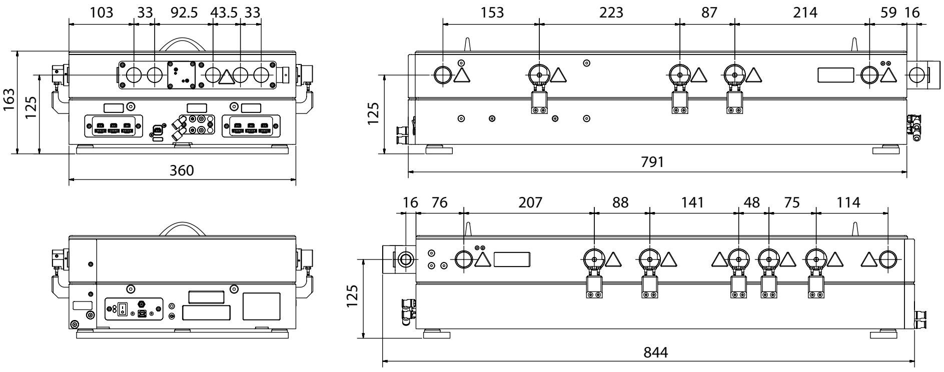
Dimensions	W × L × H
Full dimension of the ORPHEUS-TWINS, including wavelength separation	810 × 430 × 164 mm
Full dimensions of the PHAROS+ORPHEUS-TWINS system with beam routing units	910 × 850 × 215 mm



ORPHEUS-TWINS outline drawings

ORPHEUS-TWINS setup example

ORPHEUS-PS

Narrow Bandwidth Optical Parametric Amplifier

FEATURES

- Built on well known TOPAS-800 OPA basis
- Continuously tunable picosecond pulses in 320 – 5000 nm
- Near bandwidth limited output, <15 cm^{-1} spectral width (typical)
- High stability is possible by seeding with femtosecond white light continuum
- Repetition rate up to 100 kHz
- Computer controlled

APPLICATIONS

- Stimulated Raman Spectroscopy
- Surface sum-frequency spectroscopy

SPECIFICATIONS

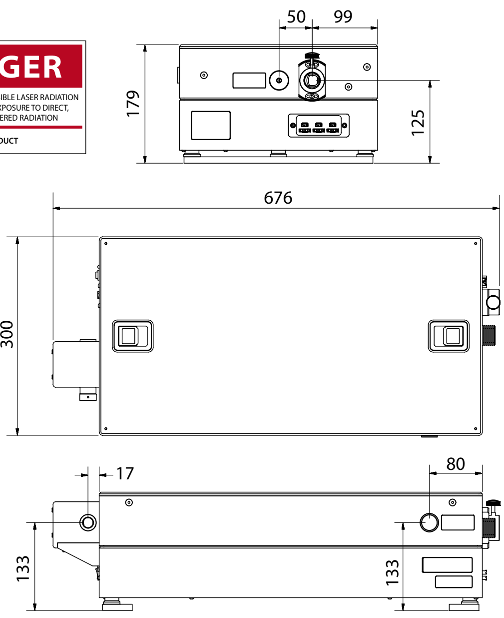
Product name	ORPHEUS-PS
Tuning range	640 – 1010 nm signal and 1050 – 2600 nm idler
Pulse energy conversion efficiency	>20 % (of pump from SHBC)
Pulse energy stability	<2.0 % rms @ 700 – 960 nm and 1100 – 1500 nm
Spectral width	<20 cm^{-1} @ 700 – 2000 nm if pump bandwidth <10 cm^{-1}
Pulse duration	1 – 4 ps depending on pump pulse duration from SHBC-515
SH option	Tuning range: 320 – 505 nm; 525 – 640 nm. Conversion efficiency: >3 % at peak
DFG option	Available, contact Light Conversion for details

Requirements for the input pulses:

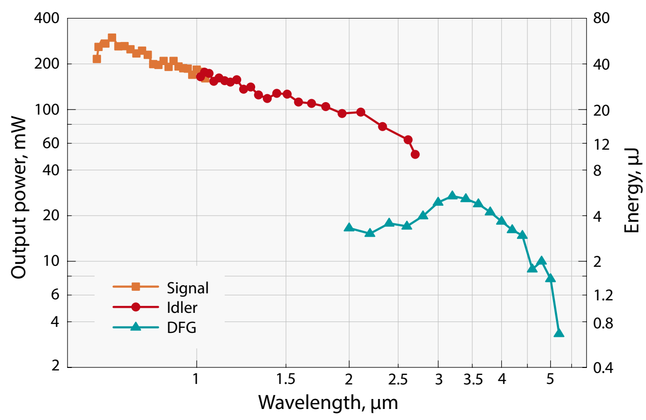
1) Picosecond 515 nm, produced by SHBC-515: energy 120 µJ – 1 mJ, pulse duration 1 – 3 ps, spectral width <20 cm^{-1};
2) Uncompressed input from SHBC is required.
3) Max pump power limitation:
   6 W @ 40 – 100 kHz; 8 W @ 20 – 40 kHz; 10 W @ 1 – 20 kHz.

ORPHEUS-PS is a narrow bandwidth optical parametric amplifier of white light continuum, designed for PHAROS / CARBIDE 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 / CARBIDE 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

ORPHEUS-PS performance.
Pump: 2 W, 400 µJ, 5 kHz from SHBC 514.2 nm, Δλ=~8 cm^{-1}, τ=2.7 ps

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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

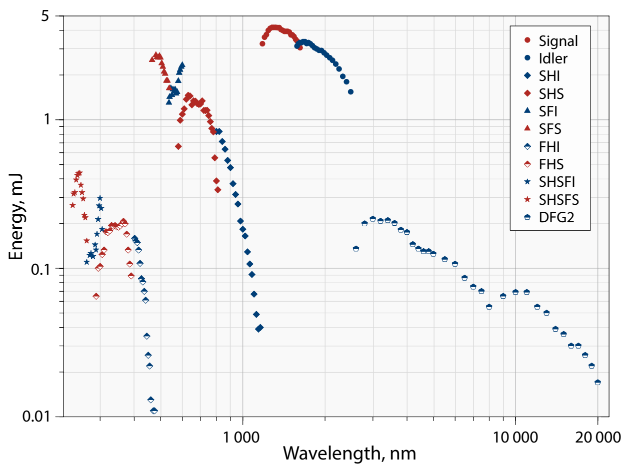
for High Repetition Rate Aplications

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.

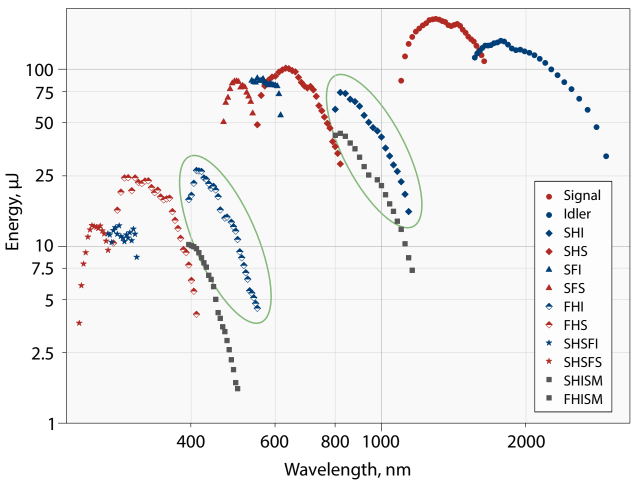
AUTOMATED **NirUVis** FEATURES

- 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

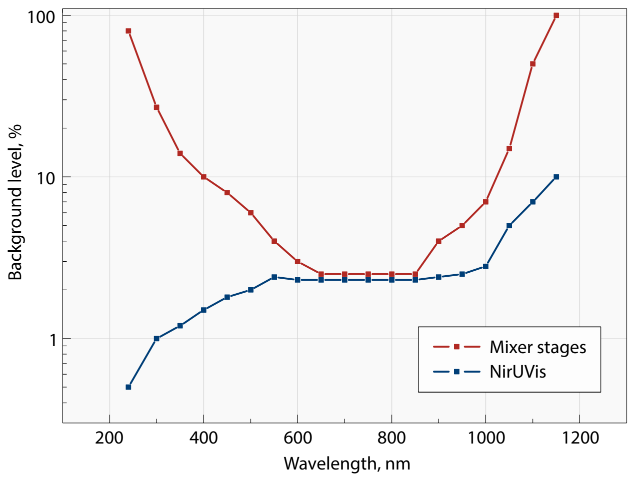
SPECIFICATIONS

Product name	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)

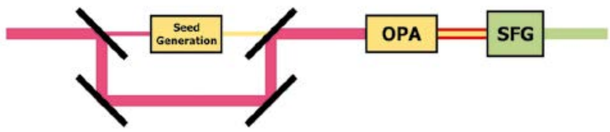


Background level comparison between NirUVis and separate mixing stages

FRESH Pump Option

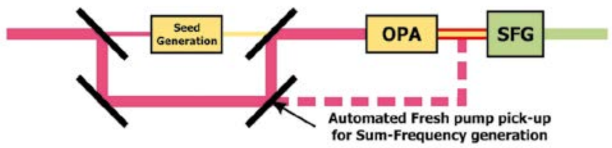
for Sum-Frequency Generation (SFG) in range 475 – 580 nm for TOPAS-Prime

DEPLETED pump option

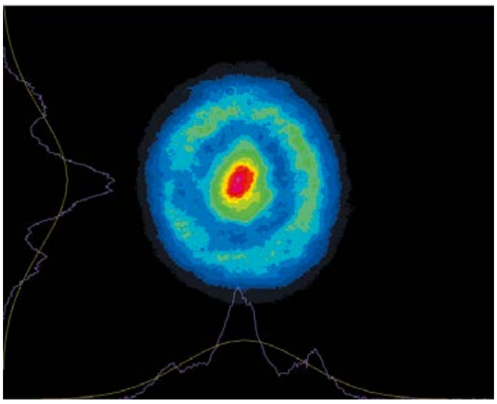


Option when DEPLETED pump is used for SFG

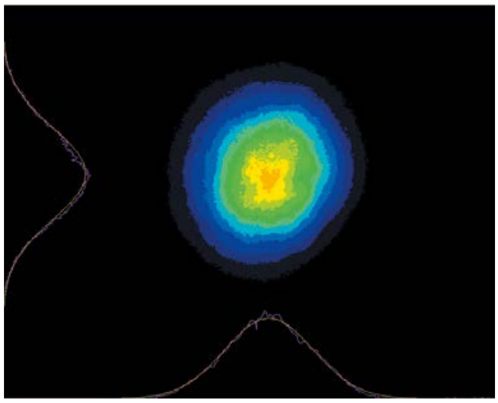
FRESH pump option



Option when FRESH pump is used for SFG



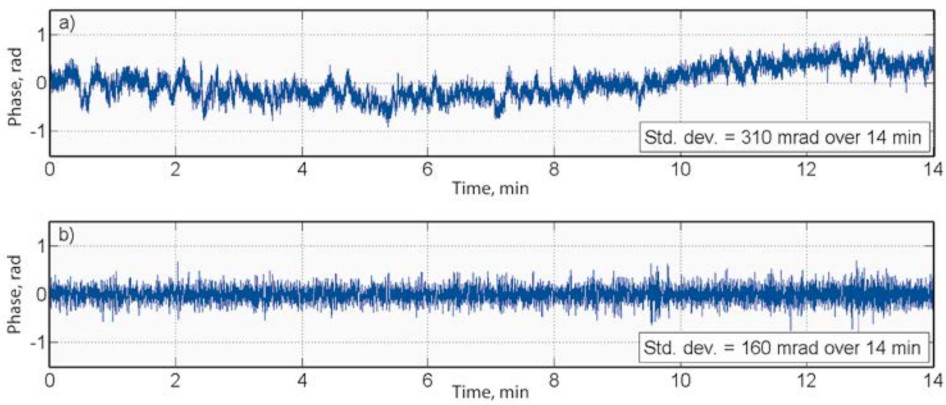
SF output profile for DEPLETED pump



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)

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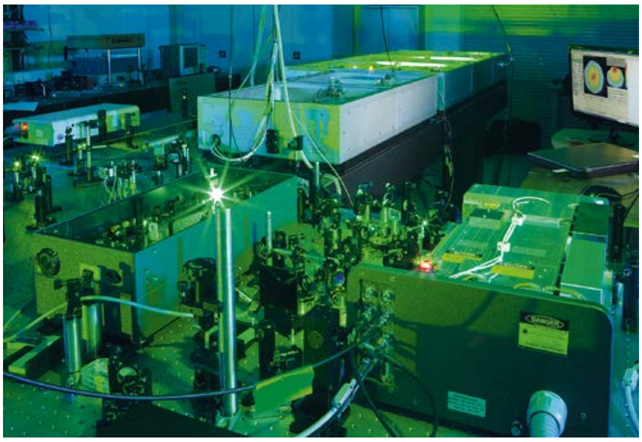
OPCPA

Custom Optical Parametric Chirped Pulse Amplification Systems



FEATURES

- Front end is based on field-proven PHAROS laser
- Passive CEP stabilization is done employing a temperature controlled Optical Parametric Amplifier (OPA)
- White light continuum (WLC) generation provides background free broadband seed, ensuring excellent temporal pulse contrast
- Reliable direct optical synchronization: the PHAROS laser provides options for directly seeding a variety of Yb- or Nd- based high energy picosecond lasers, allowing to combine our frontend and OPCPA technologies with all common types of high energy and/or high power picosecond pump lasers

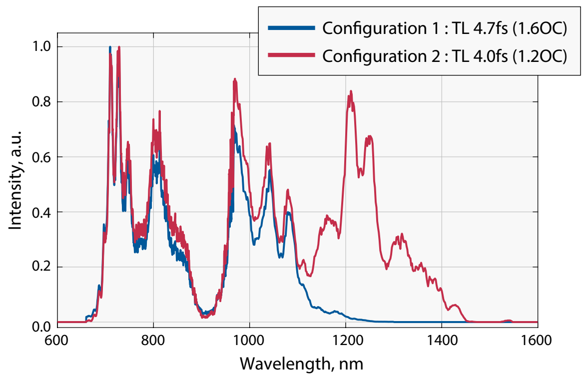
Optical parametric chirped pulse amplification is the only currently available laser technology simultaneously providing high peak and average power, as well as few cycle pulse duration required by the most demanding scientific applications. Light Conversion's answer to these demands is a portfolio of cutting-edge OPCPA products that are based on years of experience in developing and manufacturing of Optical Parametric Amplifiers and Femtosecond Lasers.

OPCPA frontends

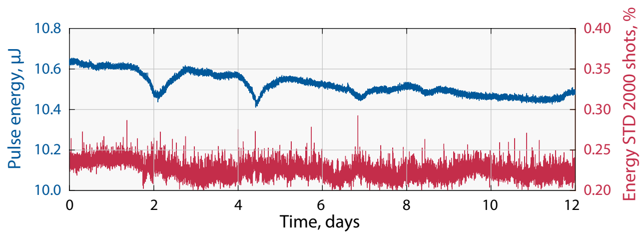
FEATURES

- Scalable in repetition rate from < 1 to 100 kHz and above
- High pulse energy (up to 100 µJ pulse energy at 1 – 10 kHz) improves contrast of OPCPA output
- Intrinsically free from ASE background; postpulse-free versions available
- Passive CEP stabilization eliminates complex electronics
- Sub-200 mrad CEP noise
- Bandwidths down to the near-single-cycle regime in the NIR
- Output spectra can be engineered to maximize energy in a desired spectral range
- Can also be used as reliable high energy, high contrast seed source for Ti:Sa amplifiers
- Central wavelength up to 2.2 µm is available on request

Our OPCPA frontend technology marks a solid step up from seeding an OPCPA directly from a Ti:Sapphire oscillator. The OPCPA frontend setups are based on the industrial-grade PHAROS laser and femtosecond optical parametric amplification technology. We use passive CEP stabilization and take advantage of the femtosecond pulse duration of the PHAROS laser to produce extremely clean broadband OPCPA seed pulses.



Spectra of pulses produced by OPCPA frontends, two configurations are available



Energy and energy stability of the passively CEP stabilized pulses generated in an OPCPA frontend measured over 12 days

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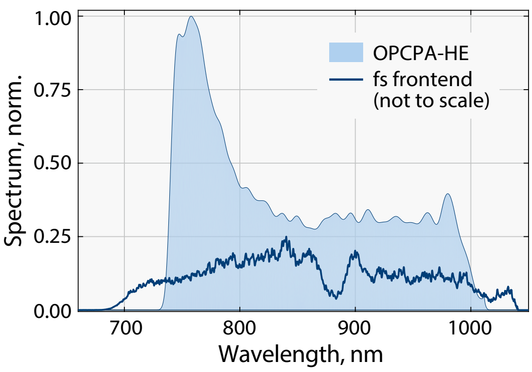
OPCPA-HE

Driving low efficiency nonlinear processes, such as high harmonic generation laser-driven THz generation, requires high pump energies. For applications of this type, Light Conversion produces OPCPA systems delivering up to 50 mJ pulse energy, combined with exceptional energy and CEP stability, as well as temporal contrast, owing to the advanced front-end technology and favourable properties of the OPCPA process.

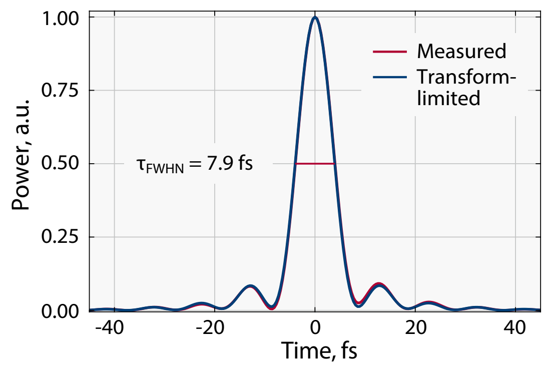
Light Conversion and Ekspla consortium has recently set a new standard in the field by delivering a 5.5 TW, 1 kHz few cycle OPCPA system to ELI-ALPS. Besides the record-setting output parameters, the system also exhibits excellent short-and-long-term stability and reliability. More information about this system can be found in: *https://doi.org/10.1364/OE.25.005797*.

FEATURES

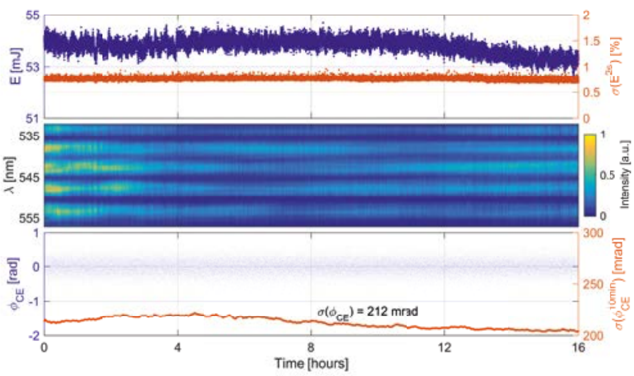
- Multi-TW peak power pulses produced at up to 1 kHz repetition rate
- Pre-pulse contrast exceeding 10^{12} achievable without complex and lossy nonlinear pulse cleaning techniques
- Sub-220 mrad CEP noise and < 1 % energy stability maintained throughout full day of operation
- Pulse duration down to < 9 fs
- Safe and simple spectral-temporal shaping of output pulses possible
- Integrated control and diagnostics system
- Less than 1 hour warm-up time



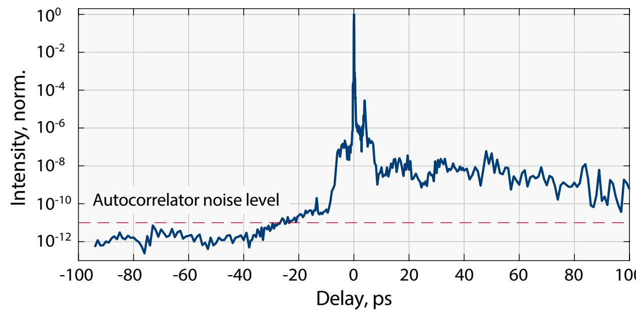
OPCPA-HE output spectrum



Temporal profile of OPCPA-HE output pulses measured with a self-referenced spectral interferometry device



OPCPA-HE pulse energy, f-2f interferogram and CEP stability measured during a 16-hour test run

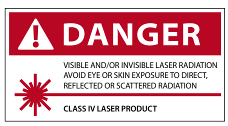


High dynamic range third order autocorrelation measurement of an OPCPA-HE system

SPECIFICATIONS

Product name	Output Energy	Output power	Output pulse duration	Max. Peak Power	Repetition rates
OPCPA-HE	1 – 50 mJ	up to 50 W	< 10 fs	up to 5 TW	up to 1 kHz
OPCPA-HR	10 µJ – 1 mJ	up to 100 W	< 10 fs	up to 100 GW	up to 200 kHz

Different pulse repetition rates, output energies, pulse durations and wavelengths are also available – please contact Light Conversion for more information.

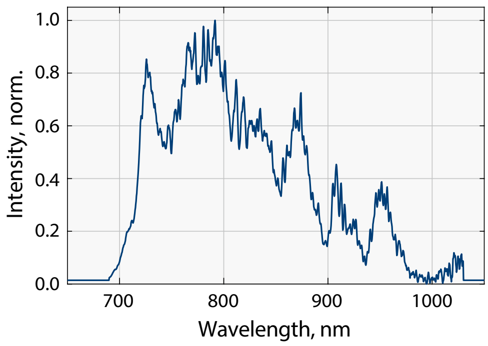


OPCPA-HR

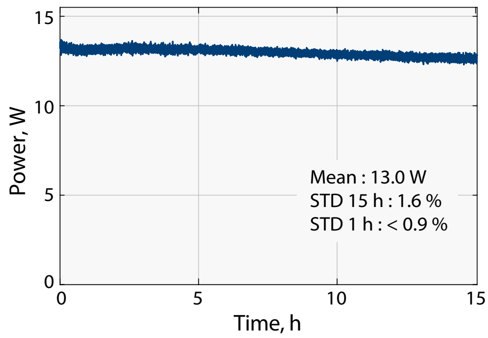
The technology developed by Light Conversion can be readily integrated with high repetition rate pump lasers to create high average power OPCPA systems. In this regime, few cycle pulses can be produced at repetition rates up to 200 kHz. A special dual pulse picker system in the Pharos laser can be used to adjust the repetition rate of the frontend independently of the pump laser. This allows to conveniently reduce the output power for alignment of experimental setups without affecting pulse energy or beam direction. Furthermore, residual pump beams can readily be used, for example, to generate photoelectron bunches synchronized with OPCPA output for advanced experiments.

FEATURES

- Pulse repetition rates up to 200 kHz
- Average power > 15 W at 100 kHz
- Passive CEP stabilization available
- Pulse duration down to < 8 fs
- Arbitrary division of OPCPA pulse repetition rate possible
- Convenient integrated control and monitoring software
- Compact footprint



OPCPA-HR pulse spectrum

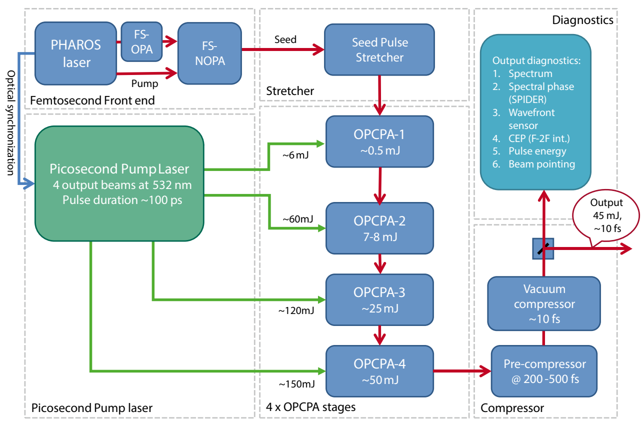


Output power of OPCPA-HR measured over 15 hours

INSTALATIONS

Light Conversion and EKSPLA Consortium have won the public procurement tender of the ELI-ALPS facility for the design and construction work for the SYLOS laser system. To our knowledge, the SYLOS laser system will be able to generate four times higher peak power pulses than the current state of the art at 1 kHz rep rate. The system is based on Light Conversion's Optical Parametric Chirped Pulse Amplifiers driven by Light Conversion's femtosecond (fs) laser PHAROS and EKSPLA's picosecond laser.

PHAROS pumps two fs OPAs: the first (FS-OPA) produces passively CEP stabilized pulse at 1.3 µm used for generation of CEP stable WLC, while the second (FS-NOPA) amplifies WLC in 700 – 1000 nm range providing high contrast seed pulse for the subsequent OPCPA stages. The pulse amplified to 50 mJ of energy at an 850 nm central wavelength is compressed in a sequence of glass blocks and chirped mirrors down to 10 fs pulse duration.



ELI-ALPS OPCPA laser system SYLOS block diagram

Laser system SYLOS ready for delivery

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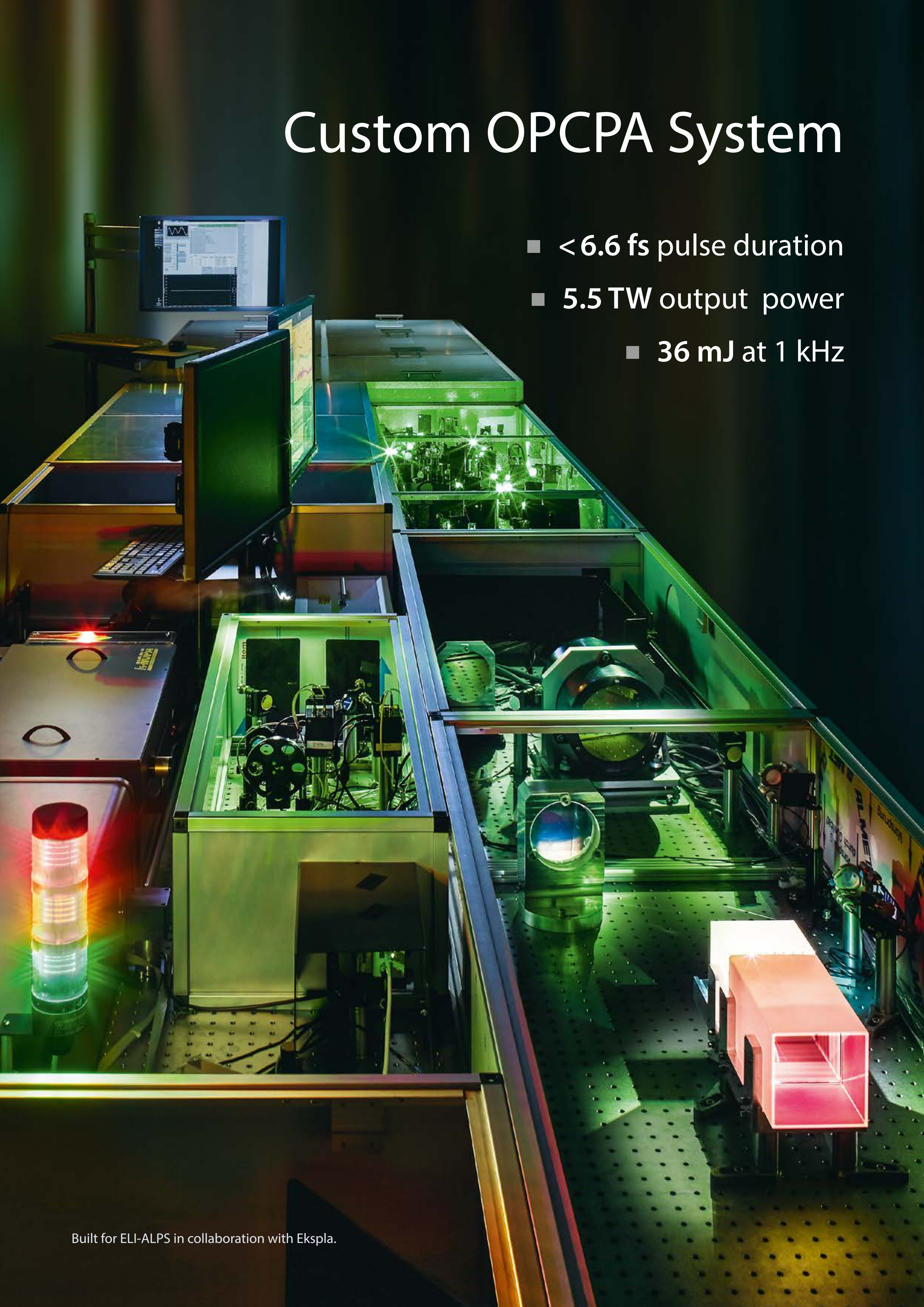
Custom OPCPA System

- < **6.6 fs** pulse duration
- **5.5 TW** output power
- **36 mJ** at 1 kHz



Built for ELI-ALPS in collaboration with Ekspla.

HARPIA-TA

new

Ultrafast Transient Absorption Spectrometer

APPLICATION FIELDS

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

The transient absorption spectrometer HARPIA offers a sleek and compact design together with intuitive user experience and easy day-to-day maintenance meeting the needs of today's scientific world. Adhering to the standards raised by the OPRHEUS line of devices, the entire spectroscopic system is contained in a single monolithic aluminum casing that inherently ensures excellent optical stability and minimal optical path for the interacting beams. HARPIA can be easily integrated with both PHAROS / ORPHEUS and Ti:Sa / TOPAS laser systems. HARPIA 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 up to several nanojoules.

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 supercontinuum 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
- Point detectors (photodiodes)
- 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 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
- 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 moving unit that translates the sample in the focal plane of the pump and probe beams, thus avoiding local sample overexposure (optional)
- Integrated PC (optional)
- Sample stirrer.

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.

For simple systems – all-in-one package (no external electronics rack).

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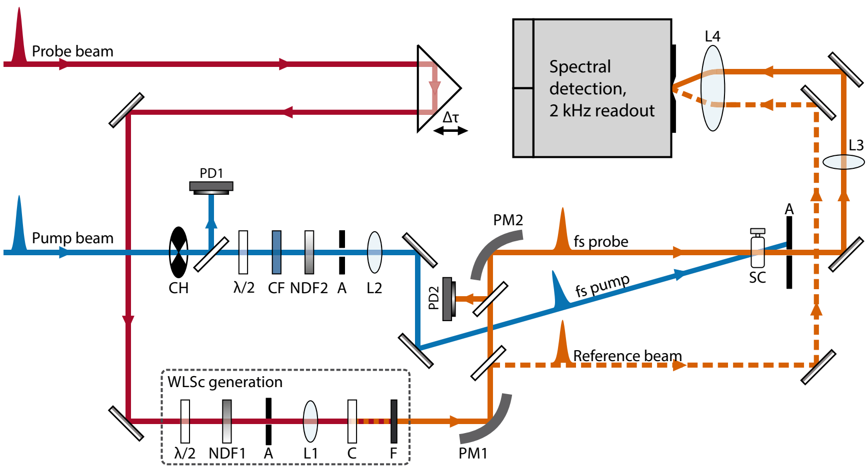
SPECIFICATIONS

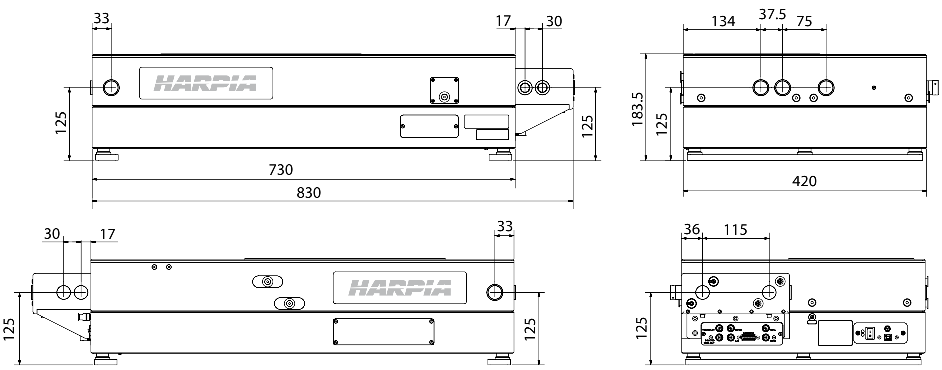
Probe wavelength range, supported by the optics	240 – 2600 nm
Probe wavelength range, white light supercontinuum generator, pumped by 1030 nm	350 – 750 nm, 480 – 1100 nm
Probe wavelength range, white light supercontinuum generator, pumped by 800 nm	350 – 1100 nm
Probe wavelength range of the detectors	200 – 1100 nm, 700 – 1800 nm, 1.2 – 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]
Sample area	205 × 215 mm

[1] *Without external spectrograph.*



HARPIA-TA optical layout for pump-probe experiments

Cryostat mounting scheme



HARPIA-TA outline drawings

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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.

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

- Femtosecond transient absorption / 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
- Time resolved femtosecond stimulated Raman scattering (FSRS) experiments
- Flash photolysis

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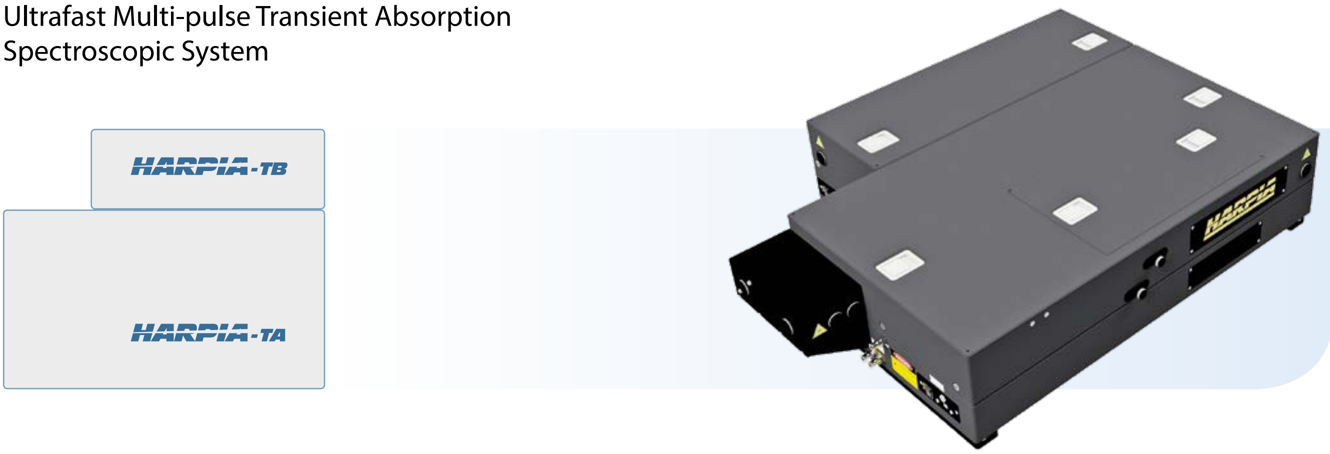
Available HARPIA configurations

HARPIA

Ultrafast Transient Absorption, TCSPC and
Fluorescence Upconversion Spectroscopic System

HARPIA

Ultrafast Multi-pulse Transient Absorption
Spectroscopic System



HARPIA

Ultrafast Multi-pulse Transient Absorption, TCSPC 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 up to several nanojoules.

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
- Option with analog PMT detector (fluorescence upconversion only)
- 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 (Berek polarization compensator 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 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 8 ns delay line with electronics and full software integration. Delay line is fully integrated in to HARPIA-TA mainframe housing

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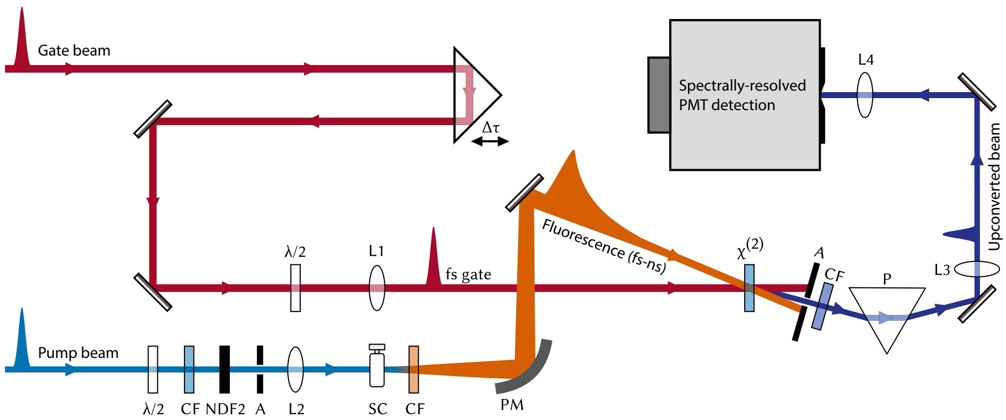
SPECIFICATIONS

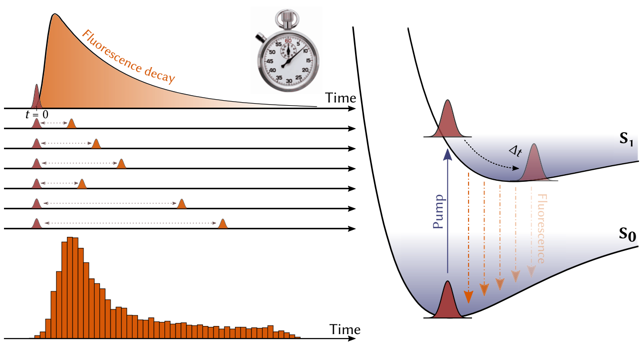
TCSPC mode	
TCSPC module	Becker&Hickl SPC 130, fully integrated into the software [1]
Detector control	Becker&Hickl DCC 100
Photomultiplier	Becker&Hickl PMC 100 1 standard
Wavelength range	300 – 820 nm
Intrinsic time resolution	<200 ps
Time resolution with monochromator	<1.2 ns [2]
Signal-to-noise	< 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]

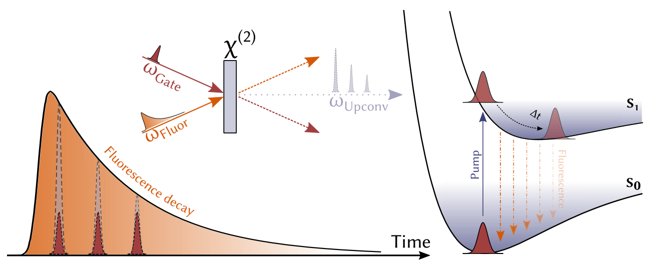
1) *See www.becker-hickl.de for specifications.*
2) *Estimated as the FWHM of the upconverted white-light supercontinuum generated in the sample or the derivative of the rise of the upconversion signal.*
3) *Estimated by fitting the kinetic trace measured in Rhodamine 6G solution at 580 nm with multiple 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

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HARPIA-TB

new

Third Beam Delivery Extension

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).

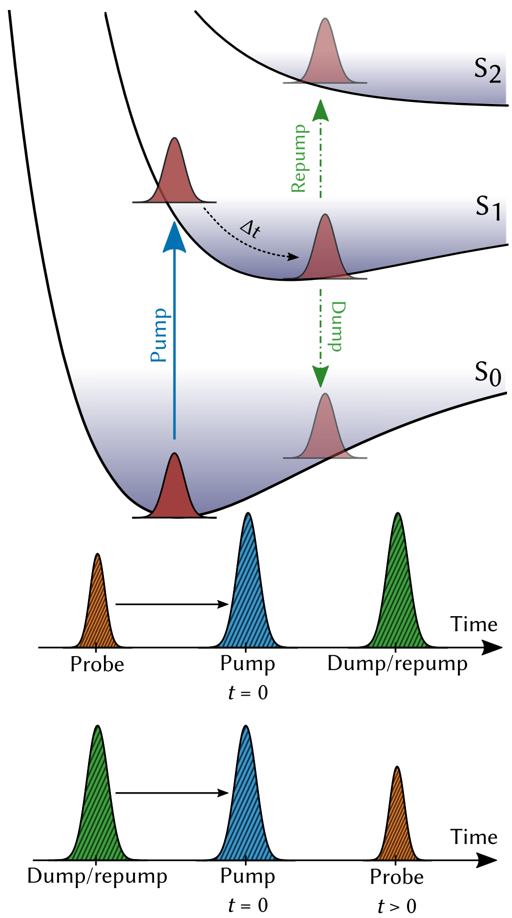
When the auxiliary pulse is resonant to an electronic ground-to-excited state transition, i.e., $S_0 \rightarrow S_n$, it makes it possible to either “replenish” the excited state population or to prepare a small portion of excited state population before the “main” pump pulse. This type of measurement 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 polarization compensator 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)



Principle of multi-pulse time-resolved transient absorption spectroscopy

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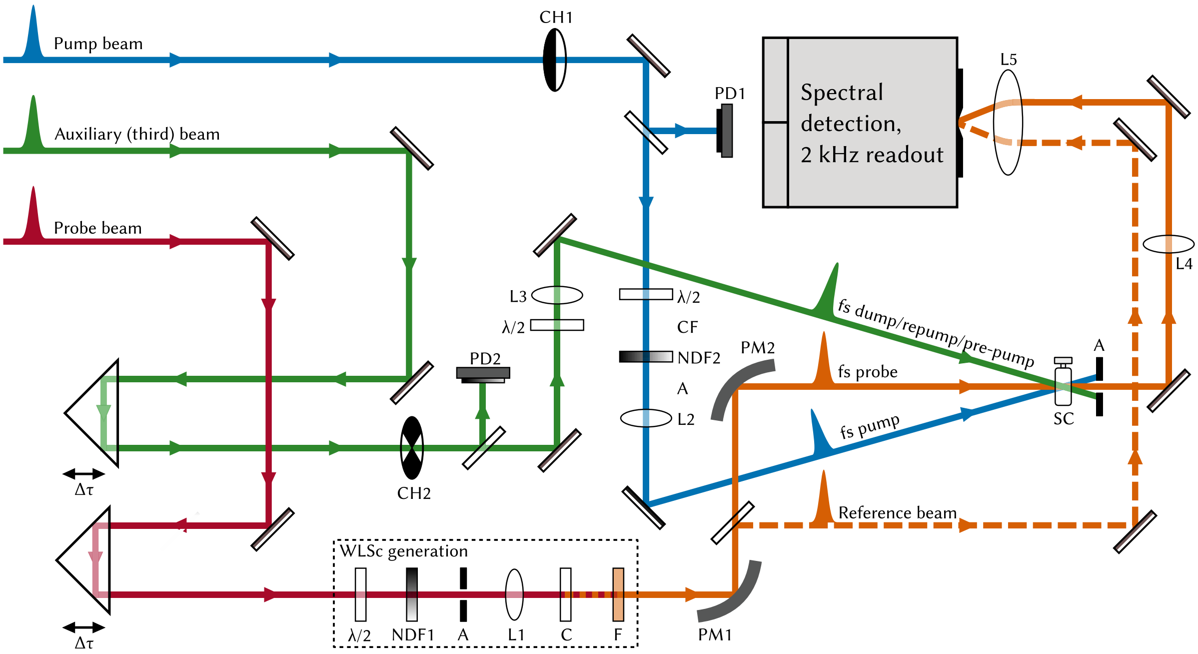
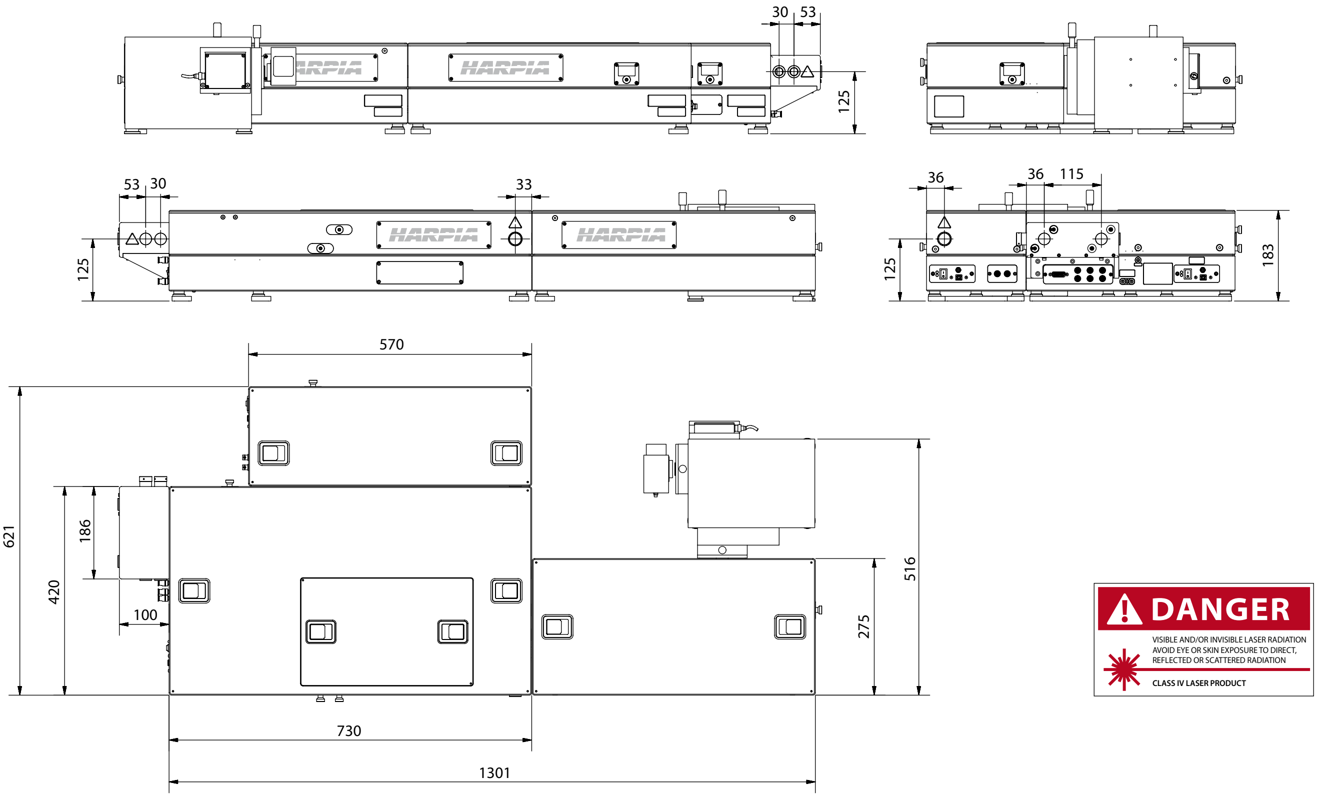


HARPIA optical layout for multi-pulse experiments



Outline drawings of HARPIA system with extensions

HARPIA Software

HARPIA Service App

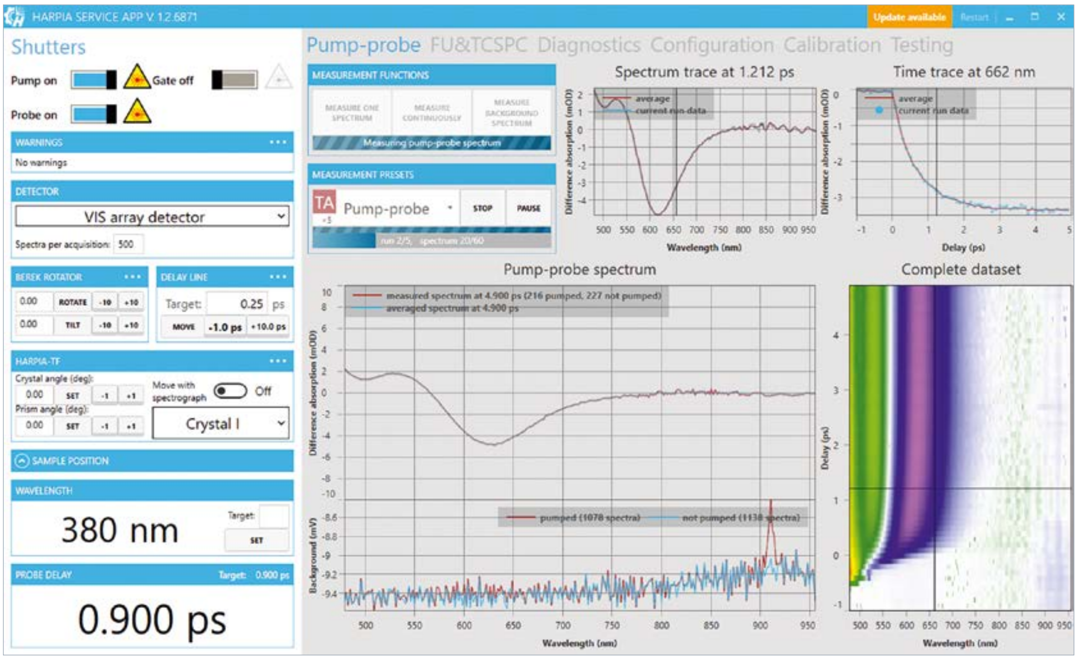
Single application for transient absorption, fluorescence upconversion and TCSPC measurements, featuring:

- Intuitive and user friendly interface
- Experiment guiding and calibration wizards, and measurement presets
- Optional advanced measurement post-processing (data balancing for noise suppression, signal saturation detection, outlier detection, etc.)
- Diagnostics and data export tools
- REST API, allowing for experiment management over network using third-party software and/or other operating system
- API examples using LabView, Python and Matlab
- Online software updates
- Support and feature request handling

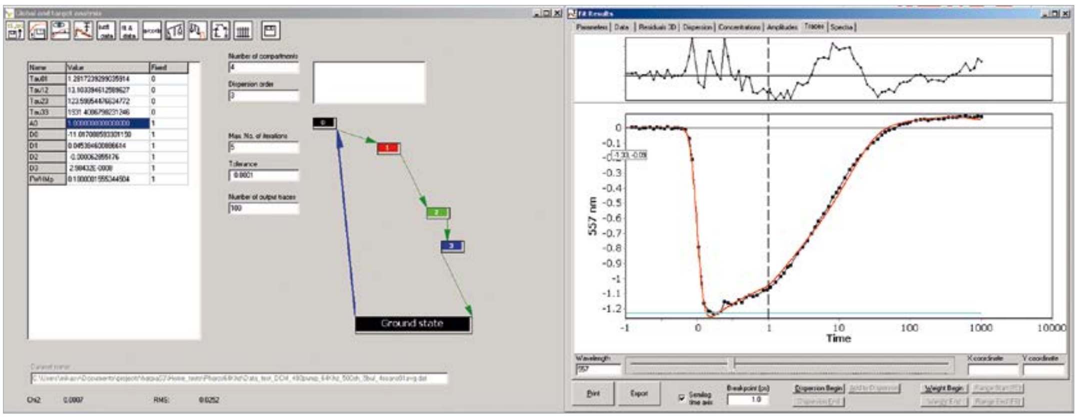
CarpetView data analysis application

Advanced ultrafast spectroscopy data data analysis application, featuring:

- Advanced visualization and data export tools
- Publication-quality graph preparation
- Advanced data wrangling: slicing, merging, cropping, shifting, smoothing, fitting, subtracting, etc.
- Chirp correction and calibration using a reference absorption spectrum
- Advanced global and target analysis:
  - Fitting to user-defined physical compartment model;
  - Probe light chirp correction and deconvolution with an instrument response function;
  - Advanced point weighting
- Version, designated for three-dimensional data sets (2D electronic spectroscopy, fluorescence lifetime imaging)



HARPIA Service App



Global and target analysis window of CarpetView

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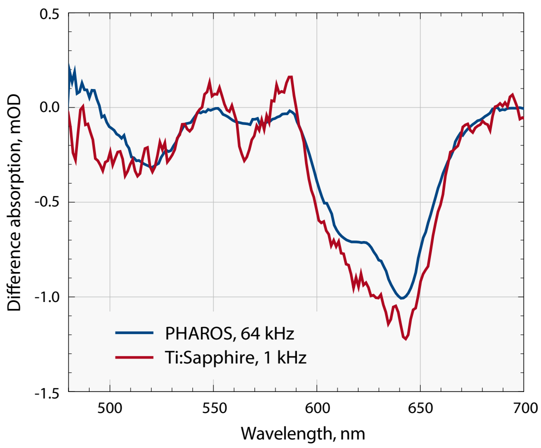
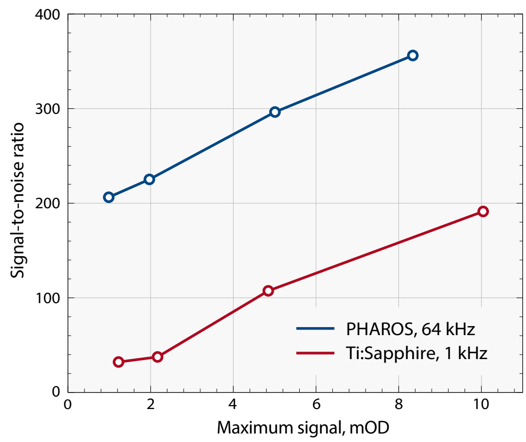
HARPIA Data Samples

HARPIA performance at high repetition rate

HARPIA system offers excellent signal-to-noise ratio at low energy excitation conditions, when used with high repetition rate laser systems. Below are the results of measured difference absorption spectra with Ti:Sapphire laser operated at 1 kHz and Pharos laser operated at 64 kHz, both adjusted to operate at best available performance.

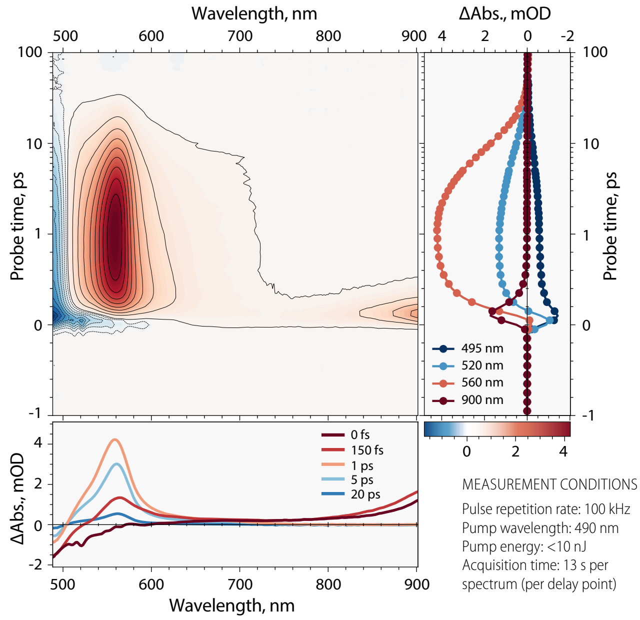


Measured difference absorption spectra of CdSe/ZnS quantum dots using low- and high-repetition rate lasers with 5 s acquisition time



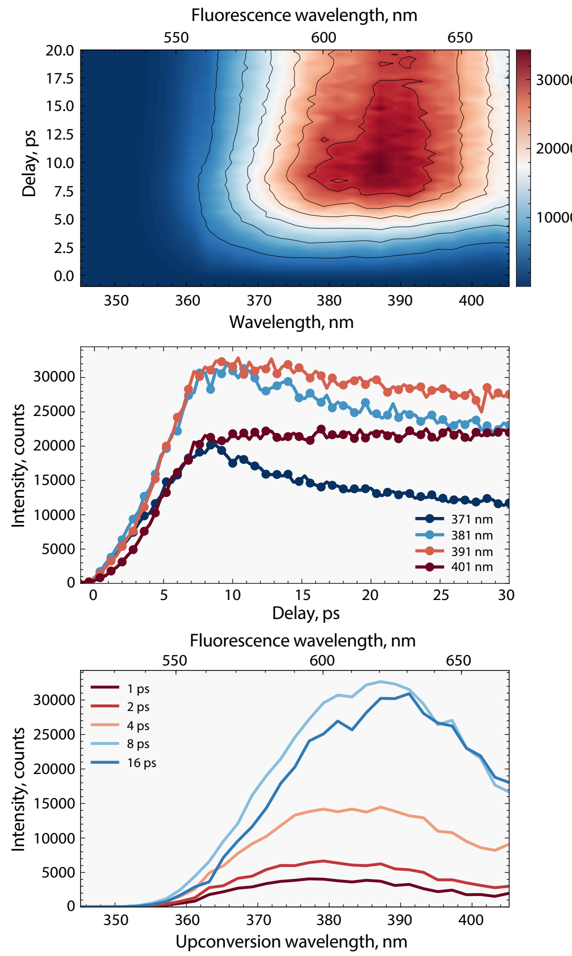
Best-effort signal-to-noise ratios, achieved with HARPIA-TA spectrometer driven by Ti:Sapphire laser operating at 1 kHz (red) and Pharos laser operating at 64 kHz (blue)

HARPIA-TA pump-probe measurement



Spectral dynamics of beta-carotene in solution

HARPIA-TF fluorescence upconversion



Fluorescence dynamics of DCM laser dye in solution

Rev. 20190416

Geco

Scanning Autocorrelator

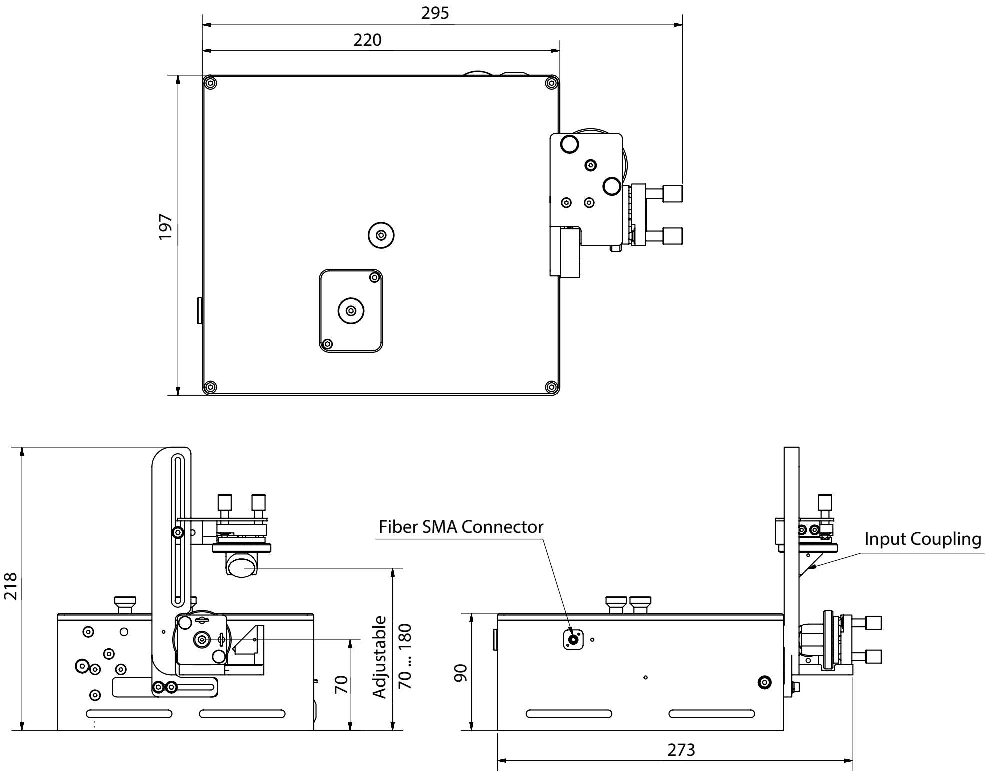
FEATURES

- 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 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.
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



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*

Product name	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 pulse energy	single-shot mode: ~30 – 100 μJ @ 1 – 10000 Hz integration mode: ~1 – 5 nJ @ 1 – 1000 kHz		
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

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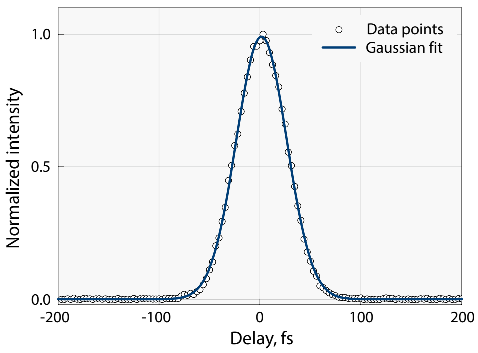
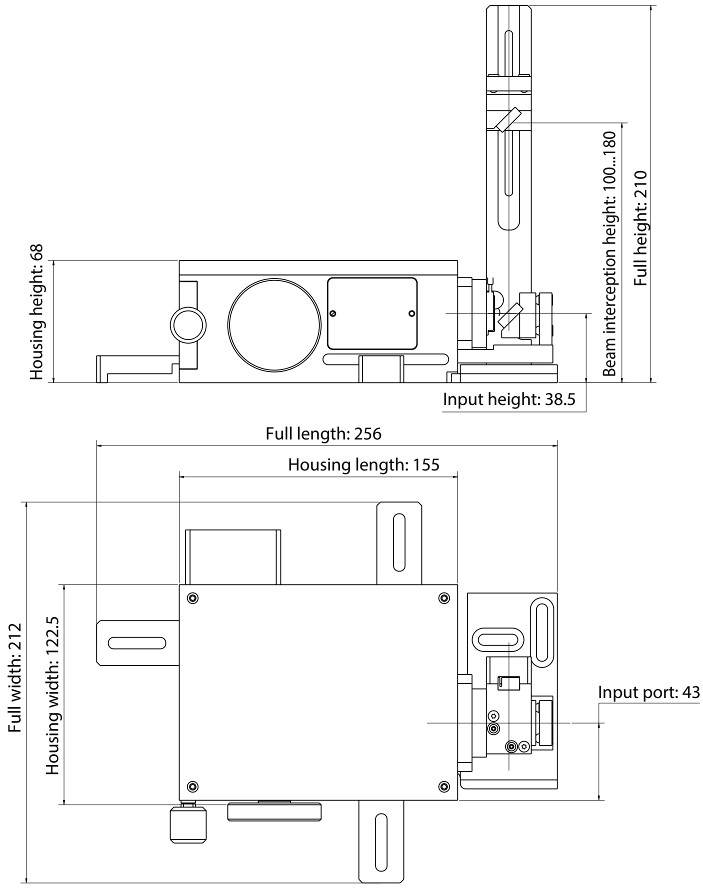
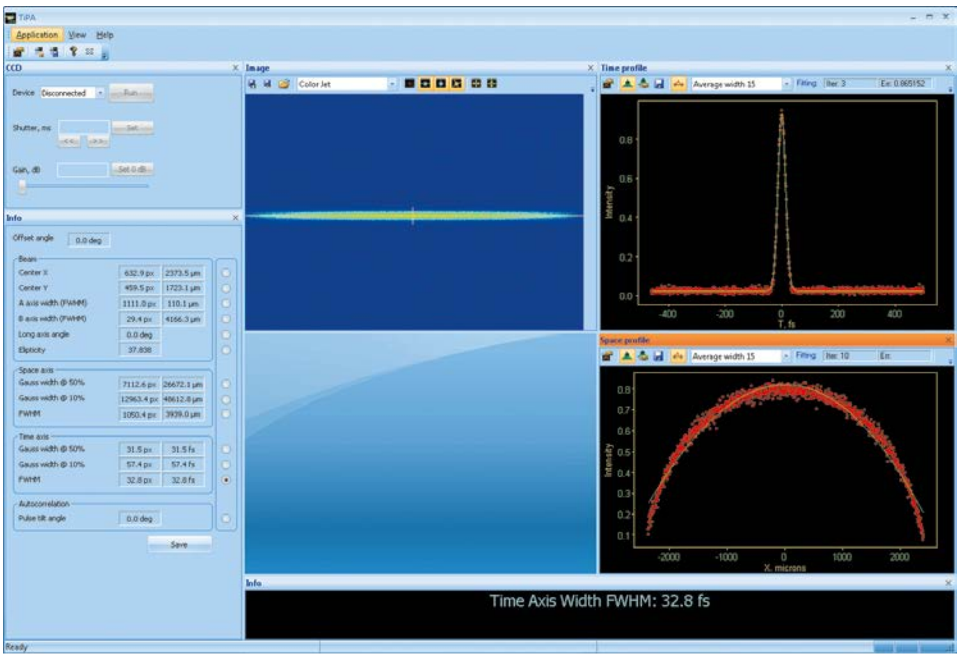
SAMPLE AUTOCORRELATION WITH DATA FITTING



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.

ULTRAFAST LASERS
OSCILLATORS
HARMONICS GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
SPECTROMETERS
AUTOCORRELATORS

List of Local Distributors

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Notes