LIGHT CONVERSION

GMP
GENERAL MICROTECHNOLOGY & PHOTONICS

FEMTOSECOND LASER SYSTEMS FOR SCIENCE

PRODUCT CATALOG

2022

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LIGHT CONVERSION

Founded in 1994 as a Vilnius University spin-off, LIGHT CONVERSION is now a major ultrafast laser technology company with over 350 employees, 10% of which hold PhD degrees, and more than 6000 installed systems worldwide. LIGHT CONVERSION designs and manufactures ultrafast lasers, oscillators, optical parametric amplifiers (OPAs), optical parametric chirped pulse amplifiers (OPCPAs), and spectroscopy systems for industrial and scientific applications.

LIGHT CONVERSION TOPAS and ORPHEUS series of OPAs constitute around 80% of the global continuously wavelength-tunable ultrafast light source market. Ultrafast laser applications are covered by the PHAROS and CARBIDE lasers. PHAROS is designed for basic research as well as material processing applications with a focus on customizability, reliability and process-tailored laser output parameters. CARBIDE is a compact industrial-grade femtosecond laser with air- and water-cooled models reaching average powers of up to 80 W. LIGHT CONVERSION also produces HARPIA – a comprehensive femtosecond pump-probe spectroscopy system.

LIGHT CONVERSION has decades of experience in managing international R&D projects. LIGHT CONVERSION is one of the key technology providers for the SYLOS laser at the ELI-ALPS facility delivering CEP-stabilized few-cycle multi-TW output at 1 kHz.

With a proven competence in the design and manufacture of lasers, OPAs and spectroscopy systems combined with close ties to research programs at Vilnius University and state-of-the-art R&D facilities, LIGHT CONVERSION offers unique solutions for today's most challenging ultrafast laser technology and application problems.

Contents

PHAROS

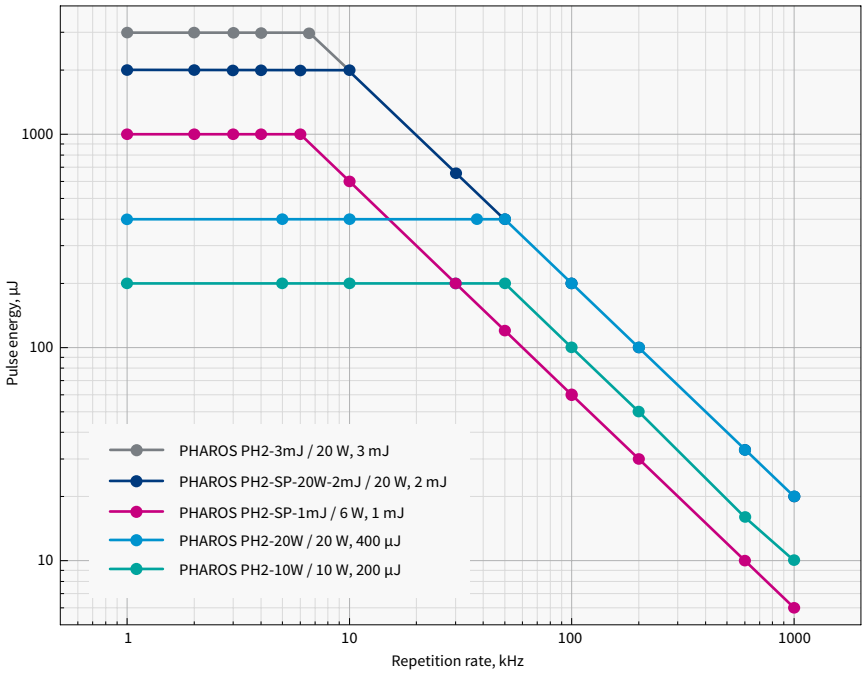
Modular-Design Femtosecond Lasers for Industry and Science

FEATURES

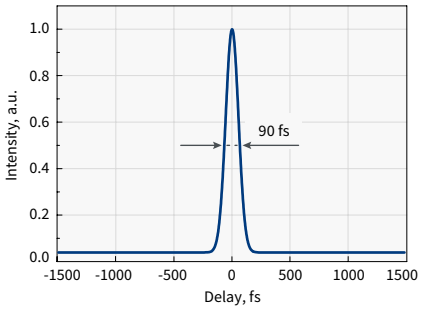
- 100 fs – 20 ps tunable pulse duration
- 3 mJ maximum pulse energy
- 20 W maximum output power
- Single-shot – 1 MHz repetition rate
- Pulse picker for pulse-on-demand mode
- BiBurst
- Automated harmonic generators (up to 5th harmonic)
- CEP stabilization option
- Repetition rate locking to an external source

PHAROS is a series of femtosecond lasers combining millijoule pulse energy and high average power. PHAROS features a mechanical and optical design optimized for both scientific and industrial applications. A compact, thermally-stabilized, and sealed design enables PHAROS integration into various optical setups and machining workstations. Diode-pumped Yb medium significantly reduces maintenance costs and provides a long laser lifetime, while the robust optomechanical design enables stable operation in varying environments.

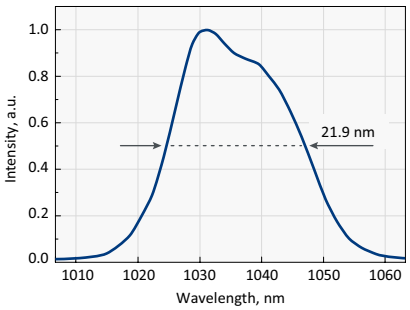
The tunability of PHAROS allows the system to cover applications normally requiring multiple different laser systems. Tunable parameters include pulse duration (100 fs – 20 ps), repetition rate (single-shot – 1 MHz), pulse energy (up to 3 mJ), and average power (up to 20 W). A pulse-on-demand mode is available using the built-in pulse picker. The versatility of PHAROS can be extended by a variety of options, including carrier-envelope phase (CEP) stabilization, repetition rate locking to an external source, and automated harmonic modules.



Pulse energy vs fundamental repetition rate of PHAROS



Typical pulse duration of PHAROS-PH2-UP

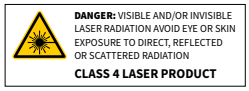


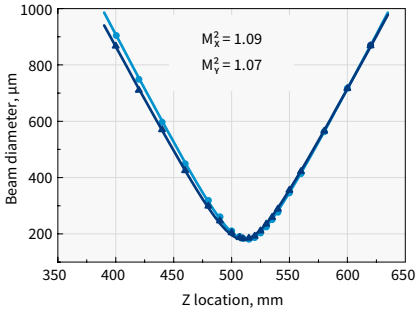
Typical spectrum of PHAROS-PH2-UP

SPECIFICATIONS

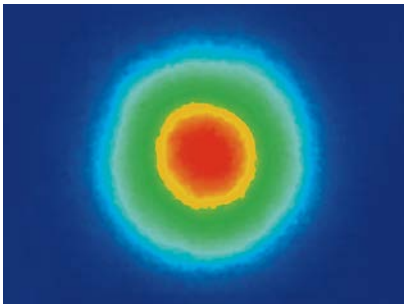
Model [1]	PH2-10W	PH2-20W	PH2-3mJ NEW	PH2-1mJ-SP	PH2-2mJ-SP	PH2-UP NEW
OUTPUT CHARACTERISTIC						
Maximum output power	10 W	20 W		10 W	20 W	10 W / 20 W
Pulse duration [2]	< 290 fs		< 350 fs [3]	< 190 fs		< 100 fs
Pulse duration tuning range	290 fs – 10 ps (20 ps on request)		350 fs – 10 ps (20 ps on request)	190 fs – 10 ps (20 ps on request)		100 fs – 10 ps
Maximum pulse energy	0.2 mJ / 0.4 mJ		3 mJ	1 mJ	2 mJ	0.2 mJ / 0.4 mJ
Repetition rate	Single-shot – 1 MHz					
Pulse selection	Single-shot, pulse-on-demand, any fundamental repetition rate division					
Center wavelength [4]	1030 ± 10 nm					
Polarization	Linear, horizontal					
Beam quality, M^2	< 1.2					
Beam diameter [5]	3.6 mm / 4.3 mm		7.3 mm	5 mm	7.3 mm	5.2 mm
Beam pointing stability	< 20 µrad/°C					
Pre-pulse contrast	< 1 : 1000					
Post-pulse contrast	< 1 : 200					
Pulse-to-pulse energy stability [6]	RMS deviation [7] < 0.5% over 24 h					
Long-term power stability [6]	RMS deviation [7] < 0.5% over 100 h					
OPTIONAL EXTENSIONS						
Oscillator output	Optional. Contact *sales@lightcon.com* for more details					
Typical output	1 – 6 W, 50 – 250 fs, ≈ 1035 nm, ≈ 76 MHz; available simultaneously					
Harmonic generator	Integrated, optional *(see page 8)*					
Output wavelength	515 nm, 343 nm, 257 nm, or 206 nm					
Optical parametric amplifier	Integrated, optional *(see page 15)*					
Tuning range	320 – 10000 nm					
BiBurst option	Tunable GHz and MHz burst with burst-in-burst capability, optional *(see page 9)*					
GHz-Burst						
Intra burst pulse period [8]	200 ± 40 ps					
Number of pulses, P [9]	1 – 25					
MHz-Burst						
Intra burst pulse period	≈ 15 ns					
Number of pulses, N	1 – 9 (7 with FEC)					
PHYSICAL DIMENSIONS						
Laser head (L × W × H) [10]	730 × 419 × 230 mm		843 × 492 × 250 mm	730 × 419 × 230 mm		
Chiller (L × W × H)	590 × 484 × 267 mm					
24 V DC power supply (L × W × H) [10]	280 × 144 × 49 mm					
ENVIRONMENTAL & UTILITY REQUIREMENTS						
Operating temperature	15 – 30 °C (air conditioning recommended)					
Relative humidity	< 80% (non-condensing)					
Electrical requirements	100 V AC, 12 A – 240 V AC, 5 A; 50 – 60 Hz					
Rated power	1000 W					
Power consumption	600 W					
Electrical requirements (chiller)	100 – 230 V AC; 50 – 60 Hz					
Rated power (chiller)	1400 W					
Power consumption (chiller)	1000 W					

[1] *More models are available on request.*
[2] *Assuming Gaussian pulse shape.*
[3] *Pulse duration can be reduced to < 250 fs if pulse peak intensity of > 50 GW/cm² is tolerated by customer setup.*
[4] *Precise wavelength for specific models are available on request.*
[5] *FW 1/e², measured at laser output, using maximum pulse energy.*
[6] *Under stable environmental conditions.*
[7] *Normalized to average pulse energy, NRMSD.*
[8] *Custom spacing is available on request.*
[9] *Maximum number of pulses in a burst depends on the laser repetition rate. Custom number of pulses are available on request.*
[10] *Dimensions depend on laser configuration and integrated options.*

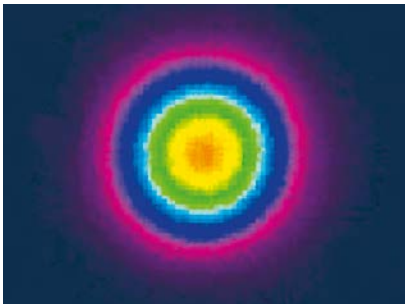




Typical M^2 measurement data of PHAROS

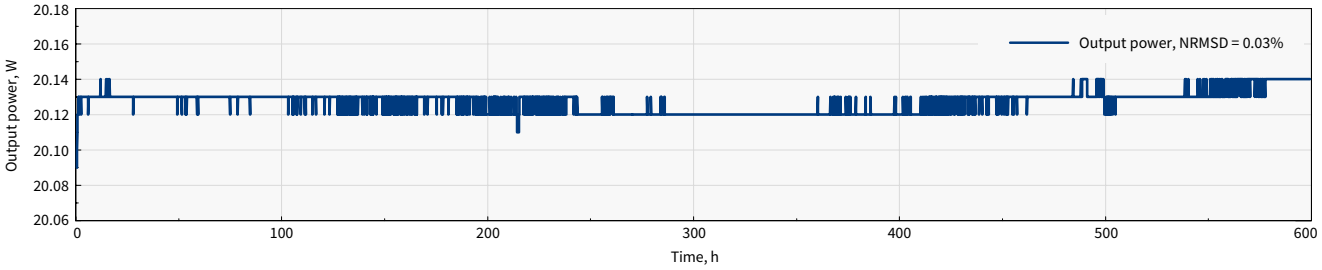


Typical near-field beam profile of PHAROS

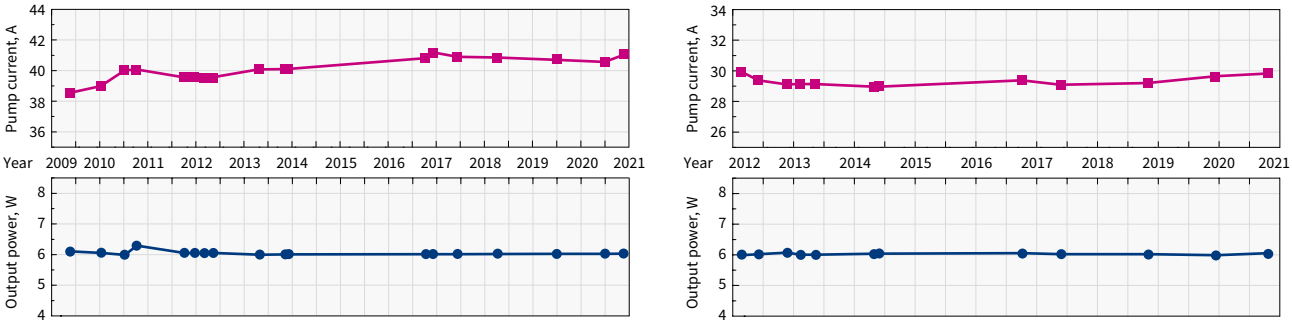


Typical far-field beam profile of PHAROS

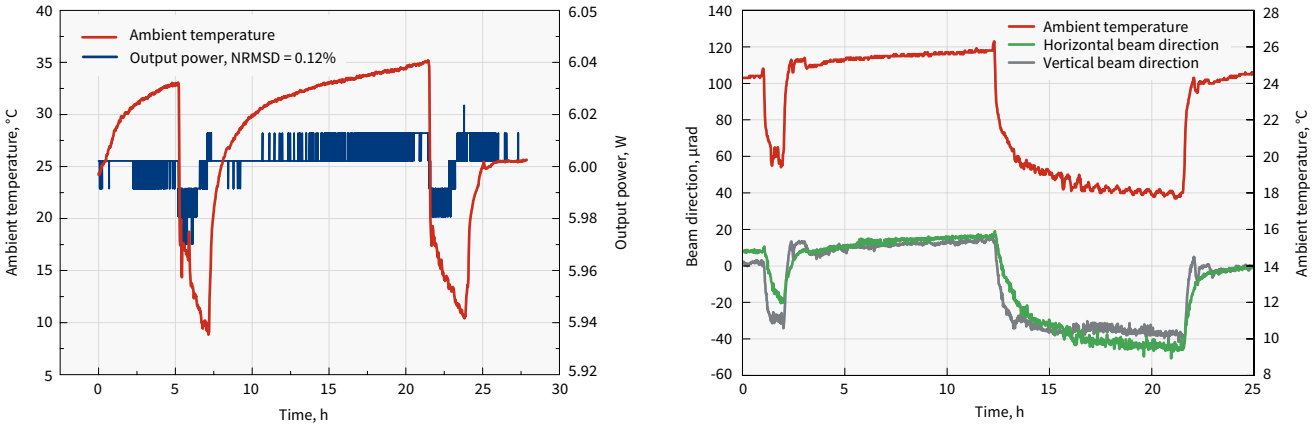
STABILITY MEASUREMENTS



Long-term power stability of PHAROS



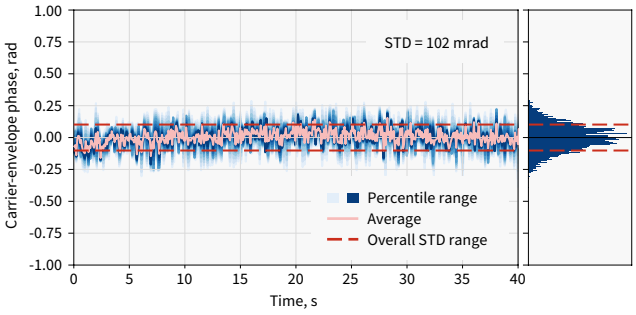
Output power of industrial-grade PHAROS lasers operating 24/7 and current of pump diodes during the years



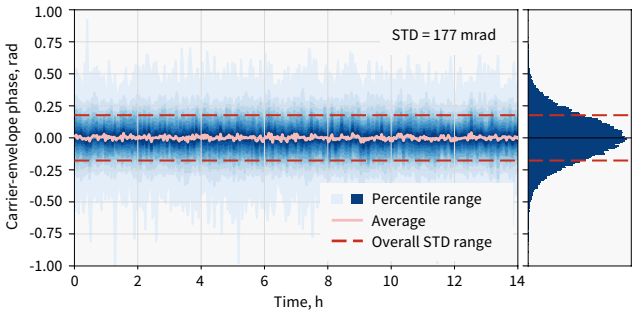
PHAROS output power and beam direction with power lock enabled, under harsh environmental conditions

CEP STABILIZATION

PHAROS lasers can be equipped with feedback electronics for carrier-envelope phase (CEP) stabilization of the output pulses. The carrier-envelope offset (CEO) of the PHAROS oscillator is actively locked to 1/4th of the repetition rate with a < 100 mrad standard deviation. The CEP stable pulses from the synchronized amplifier have a < 350 mrad standard deviation. The CEP drift occurring inside the amplifier and the user's setup can be compensated with an out of loop f-2f interferometer, which is a part of the complete PHAROS active CEP stabilization package.



Short-term CEP stability of PHAROS operating at 200 kHz repetition rate

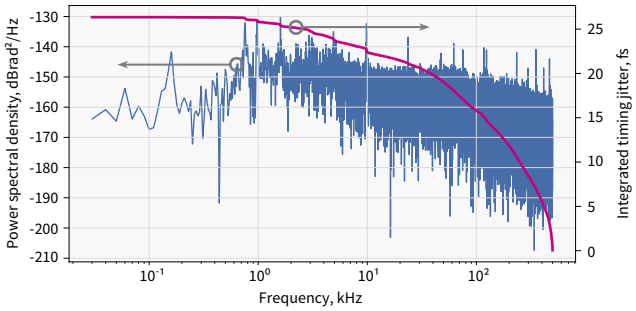


Long-term CEP stability of PHAROS operating at 200 kHz repetition rate

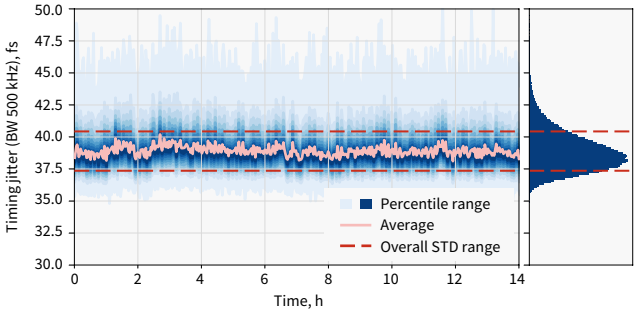
REPETITION RATE LOCKING

The oscillator of PHAROS laser can be customized for repetition rate locking applications. Coupled with the necessary feedback electronics, the repetition rate is synchronized to an external RF source using the two piezo stages installed inside the cavity.

The repetition rate locking system can assure an integrated timing jitter of less than 200 fs for RF reference frequencies larger than 500 MHz. Continuous phase shifting is available on request.

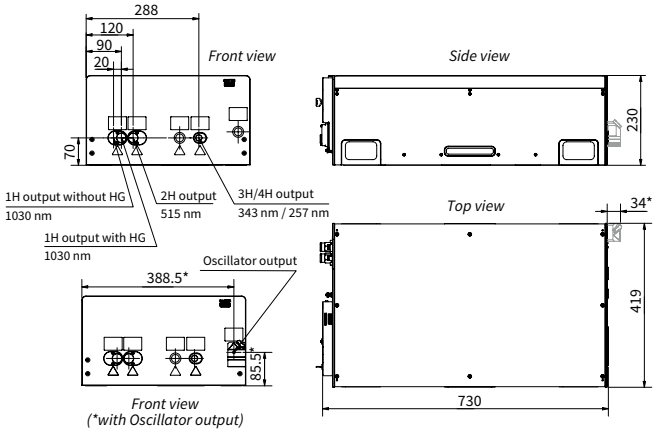


Phase noise data of PHAROS oscillator locked to a 2.8 GHz RF source

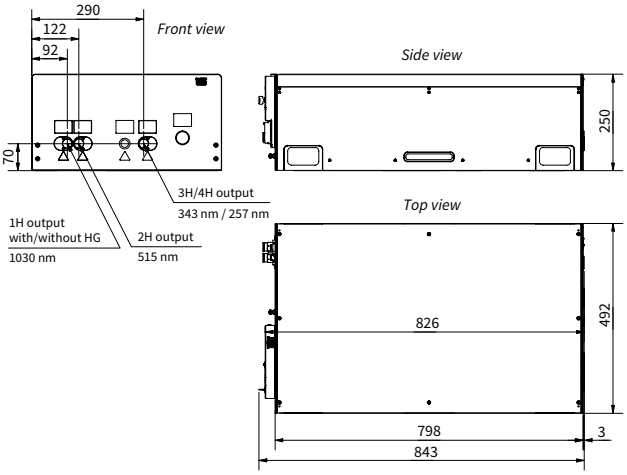


Timing jitter stability over 14 h; PHAROS oscillator locked to a 2.8 GHz RF source

DRAWINGS



PHAROS-PH2 drawing



PHAROS-PH2-3mJ drawing

HG | PHAROS

Automated Harmonic Generators

Harmonic generator attached to PHAROS

FEATURES

- 515 nm, 343 nm, 257 nm, or 206 nm output
- Automated harmonic selection
- Industrial-grade design

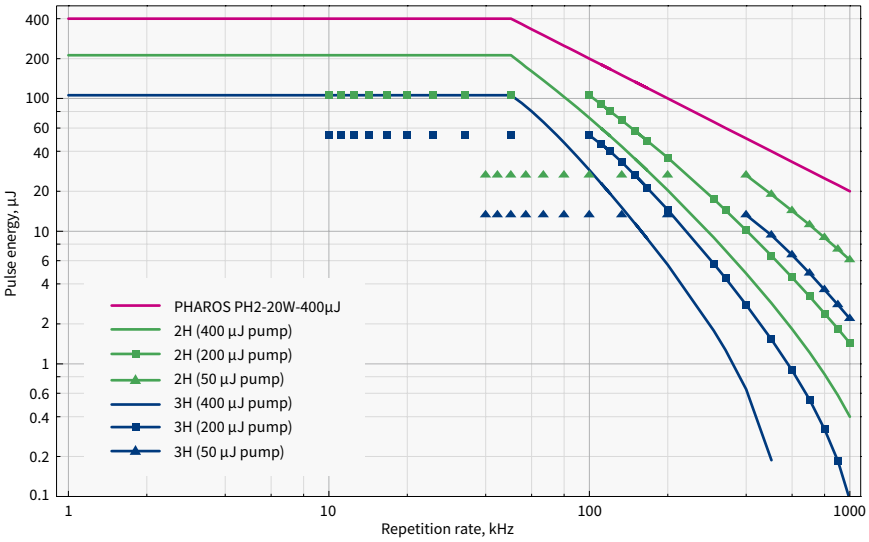
PHAROS lasers equipped with automated harmonic generators (HGs) provide a selection of fundamental (1030 nm), second (515 nm), third (343 nm), fourth (257 nm), or fifth (206 nm) harmonic outputs using software control.

HGs are perfect for industrial applications that require a single-wavelength output. Modules, mounted directly at the output of the laser, are fully integrated into the system.

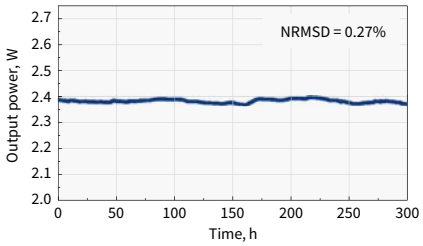
SPECIFICATIONS

Model		2H (-HE)	2H-3H (-HE)	2H-4H (-HE)	4H-5H
Output wavelength [1] **(automated selection)**		1030 nm 515 nm	1030 nm 515 nm 343 nm	1030 nm 515 nm 257 nm	1030 nm 257 nm 206 nm
Pump pulse energy		20 – 3000 µJ	50 – 3000 µJ	20 – 3000 µJ	200 – 1000 µJ
Pump pulse duration		100 – 500 fs			
Conversion efficiency		> 50% (2H)	> 50% (2H) > 25% (3H)	> 50% (2H) > 10% (4H) [2]	> 10% (4H) [2] > 5% (5H) [3]
Beam quality (M^2) typical values	≤ 400 µJ pump	< 1.15 (2H)	< 1.15 (2H) < 1.2 (3H)	< 1.15 (2H) n/a (4H)	n/a
	> 400 µJ pump	< 1.2 (2H)	< 1.2 (2H) < 1.3 (3H)	< 1.2 (2H) n/a (4H)	

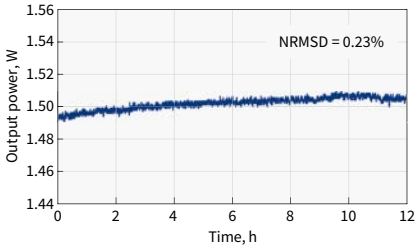
[1] Depends on pump laser model.
[2] Maximum output power of 1 W. Please contact sales@lightcon.com for higher power option.
[3] Maximum output power of 150 mW.



Pulse energy vs repetition rate of PHAROS with HG



3H output power stability



4H output power stability

LIGHT CONVERSION

BiBurst option

Tunable GHz and MHz Burst with Burst-in-Burst Capability

PHAROS and CARBIDE-CB3 lasers have an option for tunable GHz and MHz burst with burst-in-burst capability – called BiBurst.

In standard mode, a single pulse is emitted at some fixed frequency. In burst mode, the output consists of pulse packets instead of single pulses. Each packet consists of a certain number of equally separated pulses. MHz-Burst contains N pulses with a nanosecond period, GHz-Burst contains P pulses with a picosecond period. If both bursts are used, the equally separated pulse packets contain sub-packets of pulses (burst-in-burst, BiBurst).

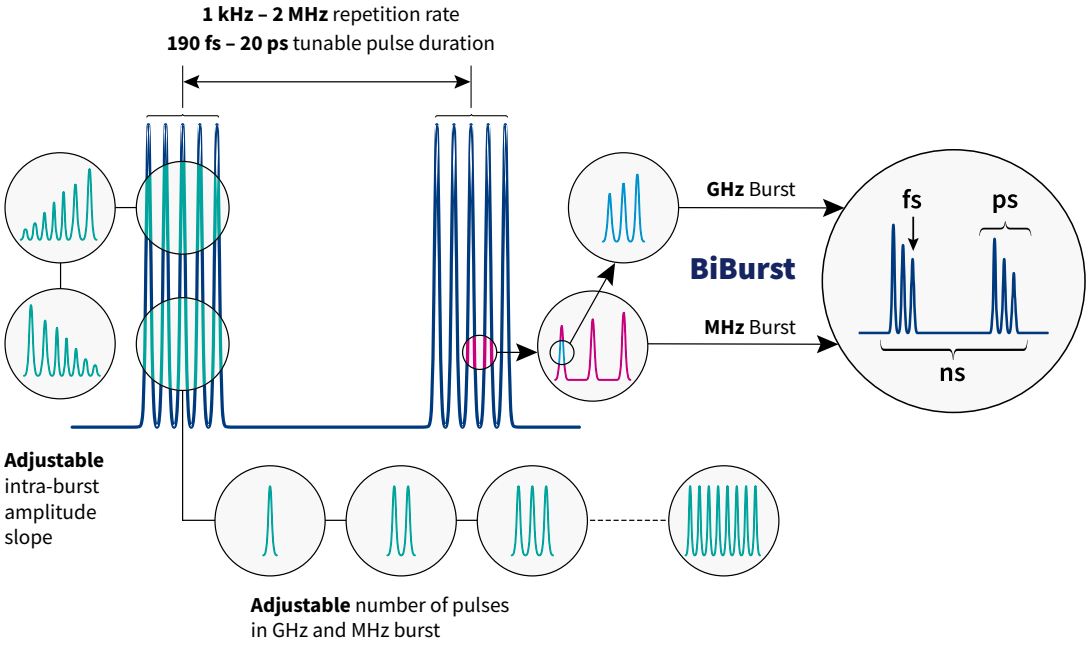
PHAROS and CARBIDE lasers with the BiBurst option bring new capabilities to high-tech manufacturing industries such as consumer electronics, integrated photonic chip manufacturing, future display manufacturing, and quantum technologies. The applications include:

- brittle material drilling and cutting
- deep engraving
- selective ablation
- volume modification of transparent materials
- hidden marking
- surface polishing
- surface functionalization

SPECIFICATIONS

Model		CARBIDE-CB3	PHAROS
GHz Burst	Intra burst pulse period [1]	440 ± 40 ps	200 ± 40 ps
	Number of pulses, P [2]	1 – 10	1 – 25
MHz Burst	Intra burst pulse period	≈ 15 ns	
	Number of pulses, N	1 – 10	1 – 9 (7 with FEC)

[1] *Custom spacing is available on request.*
[2] *Maximum number of pulses in a burst depends on the laser repetition rate. Custom number of pulses is available on request.*



CARBIDE

Unibody-Design Femtosecond Lasers for Industry and Science

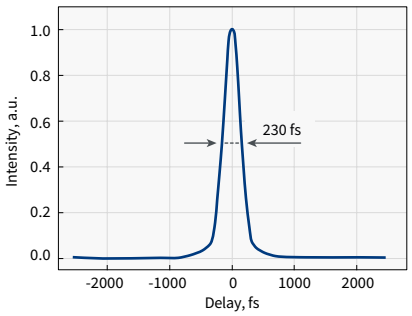
FEATURES

- 190 fs – 20 ps tunable pulse duration
- 2 mJ maximum pulse energy
- 80 W maximum output power
- Single-shot – 2 MHz repetition rate
- Pulse picker for pulse-on-demand mode
- Air-cooled version
- Automated harmonic generators
- Scientific interface module

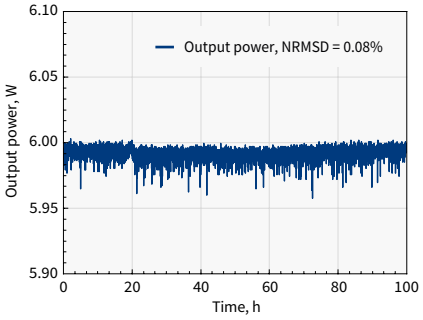
CARBIDE-CB3

CARBIDE is a series of femtosecond lasers combining high average power and excellent power stability. CARBIDE features market-leading output parameters without compromises to beam quality and stability. A compact and robust optomechanical CARBIDE design allows a variety of applications in top-class research centers, as well as display, automotive, LED, medical, and other industries. The reliability of CARBIDE has been proven by hundreds of systems operating 24/7 in the industrial environment.

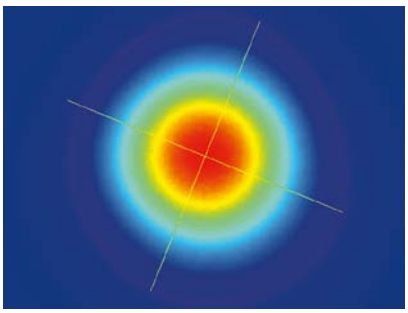
The tunability of CARBIDE lasers enables our customers to discover the most efficient manufacturing processes. Tunable parameters include pulse duration (190 fs – 20 ps), repetition rate (single-shot – 2 MHz), pulse energy (up to 2 mJ), and average power (up to 80 W). A pulse-on-demand mode is available using the built-in pulse picker. The CARBIDE lasers can be equipped with industrial-grade modules, including but not limited to high-power harmonic generators.

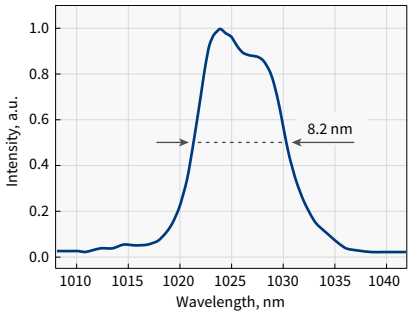


Typical pulse duration of CARBIDE laser

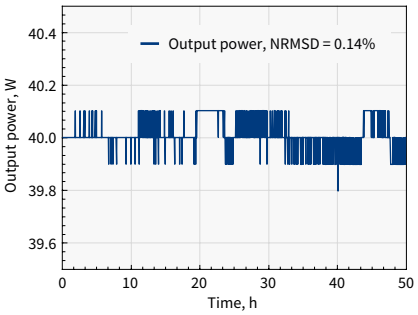


Long-term power stability of CARBIDE-CB5

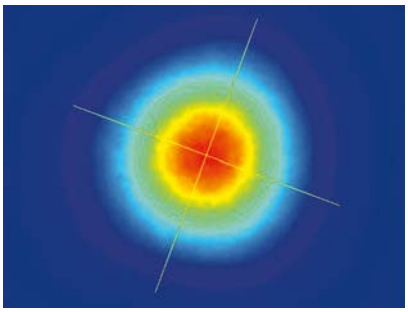

Typical beam profile of CARBIDE-CB5



Typical spectrum of CARBIDE laser



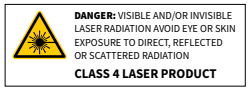
Long-term power stability of CARBIDE-CB3


Typical beam profile of CARBIDE-CB3

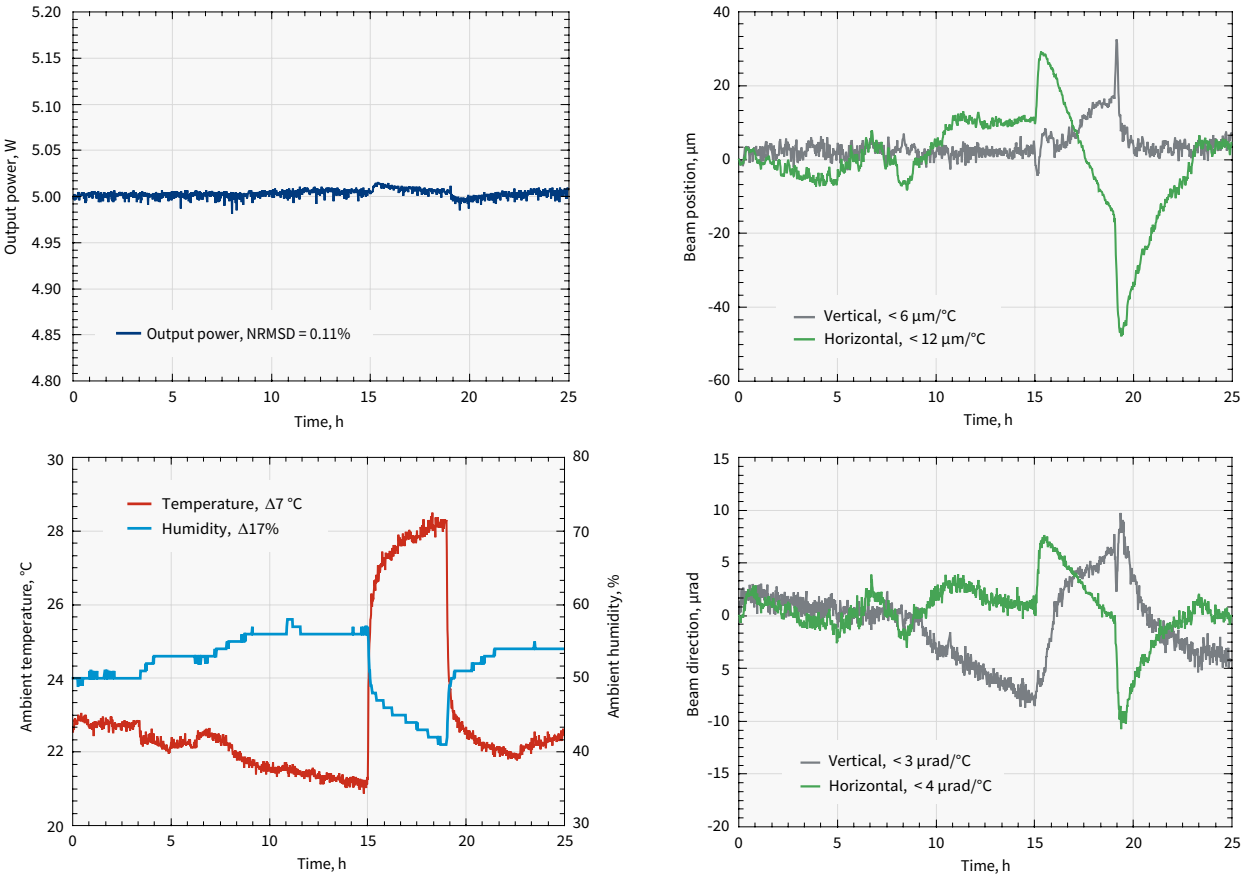
SPECIFICATIONS

Model	CB3-20W	CB3-40W	CB3-80W NEW		CB5		CB5-SP
OUTPUT CHARACTERISTICS							
Cooling method	Water-cooled				Air-cooled [1]		
Maximum output power	20 W	40 W	80 W		6 W	5 W	
Pulse duration [2]	< 250 fs			< 350 fs [3]	< 290 fs		< 190 fs
Pulse duration tuning range	250 fs – 10 ps			350 fs – 10 ps	290 fs – 20 ps		190 fs – 20 ps
Maximum pulse energy	0.4 mJ		0.8 mJ	2 mJ	100 µJ	83 µJ	100 µJ
Repetition rate	Single-shot – 1 MHz	Single-shot – 1 MHz (2 MHz on request)	Single-shot – 2 MHz		Single-shot – 1 MHz		
Pulse selection	Single-shot, pulse-on-demand, any fundamental repetition rate division						
Center wavelength [4]	1030 ± 10 nm						
Polarization	Linear, vertical; 1 : 1000						
Beam quality, M^2	< 1.2						
Beam diameter [5]	4.3 mm		4.6 mm	5.6 mm	2.3 mm		
Beam pointing stability	< 20 µrad/°C						
Pulse picker	FEC [6]				included	included [7]	included
Pulse picker leakage	< 0.5%				< 2%	< 0.1%	< 2%
Pulse-to-pulse energy stability [8]	RMS deviation [9] < 0.5% over 24 h						
Long-term power stability [8]	RMS deviation [9] < 0.5% over 100 h						
OPTIONAL EXTENSIONS							
Harmonic generators	Integrated, optional *(see page 14)*						
Output wavelength	515 nm, 343 nm, or 257 nm						
Optical parametric amplifier	Integrated, optional *(see page 15)*						
Tuning range	320 – 10 000 nm						
BiBurst option	Tunable GHz and MHz burst with burst-in-burst capability, optional *(see page 9)*				n/a		
GHz-Burst							
Intra burst pulse period [10]	440 ± 40 ps						
Number of pulses, P [11]	1 – 10						
MHz-Burst							
Intra burst pulse period	≈ 15 ns						
Number of pulses, N	1 – 10						
PHYSICAL DIMENSIONS							
Laser head (L × W × H)	632 × 305 × 173 mm				631 × 324 × 167 mm		
Chiller (L × W × H)	680 × 484 × 307 mm				Not required		
24 V DC power supply (L × W × H)	280 × 144 × 49 mm		320 × 200 × 75 mm		220 × 95 × 46 mm		
ENVIRONMENTAL & UTILITY REQUIREMENTS							
Operating temperature	15 – 30 °C (59 – 86 °F)				17 – 27 °C (62 – 80 °F)		
Relative humidity	< 80% (non-condensing)						
Electrical requirements	100 V AC, 7 A – 240 V AC, 3 A; 50 – 60 Hz		100 V AC, 12 A – 240 V AC, 5 A; 50 – 60 Hz		100 V AC, 3 A – 240 V AC, 1.3 A; 50 – 60 Hz		
Rated power	600 W		1000 W		300 W		
Power consumption	500 W		700 W		150 W		
Electrical requirements (chiller)	100 – 230 V AC; 50 – 60 Hz		200 – 230 V AC; 50 – 60 Hz		Not required		
Rated power (chiller)	1400 W		2000 W				
Power consumption (chiller)	1000 W		1300 W				

[1] *Water-cooled version available on request.*
[2] *Assuming Gaussian pulse shape.*
[3] *Pulse duration can be reduced to < 250 fs if pulse peak intensity of > 50 GW/cm² is tolerated by customer setup.*
[4] *Precise center wavelength for specific models available upon request.*
[5] *FW 1/e², using maximum pulse energy.*
[6] *Provides fast energy control; external analog control input available. Response time – next available RA pulse.*
[7] *Enhanced contrast AOM. Provides fast amplitude control of output pulse train.*
[8] *Under stable environmental conditions.*
[9] *Normalized to average pulse energy, NRMSD.*
[10] *Custom spacing is available on request.*
[11] *Maximum number of pulses in a burst depends on the laser repetition rate. Custom number of pulses is available on request.*

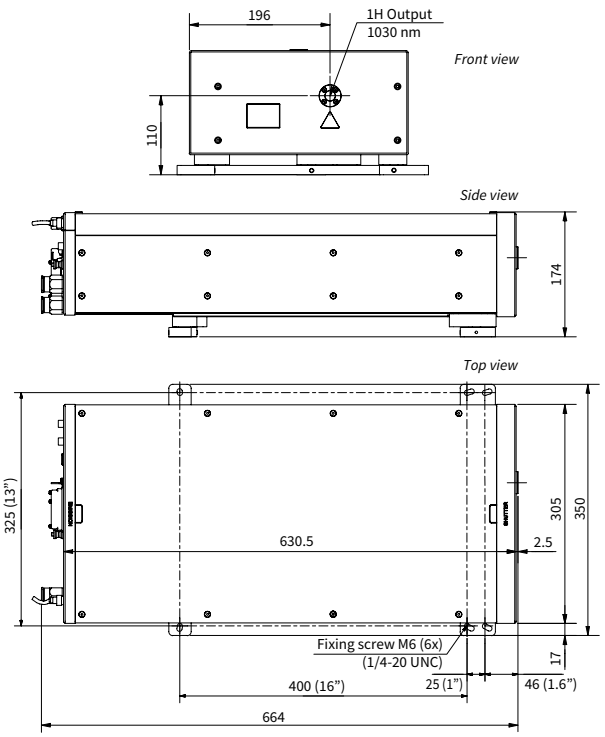


STABILITY MEASUREMENTS

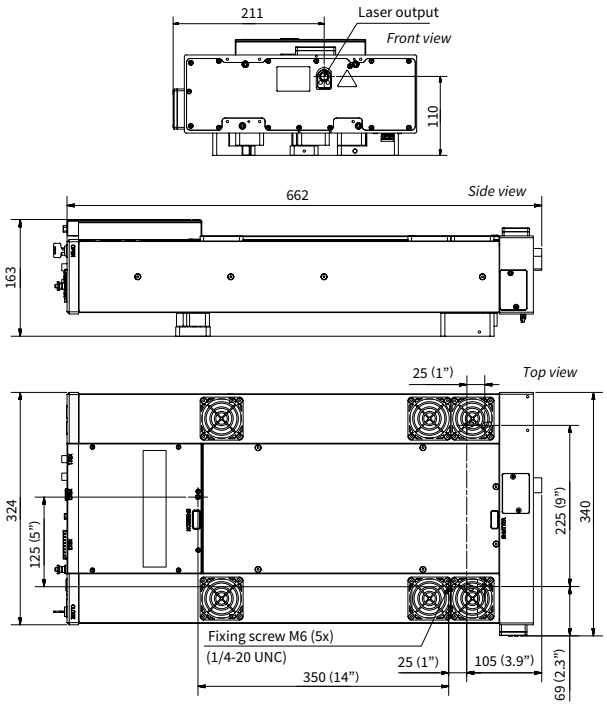


Output power, beam direction, and beam position of CARBIDE-CB5 under harsh environmental conditions

DRAWINGS



Drawing of CARBIDE-CB3



Drawing of air-cooled CARBIDE-CB5 with attenuator

SCI-M | CARBIDE

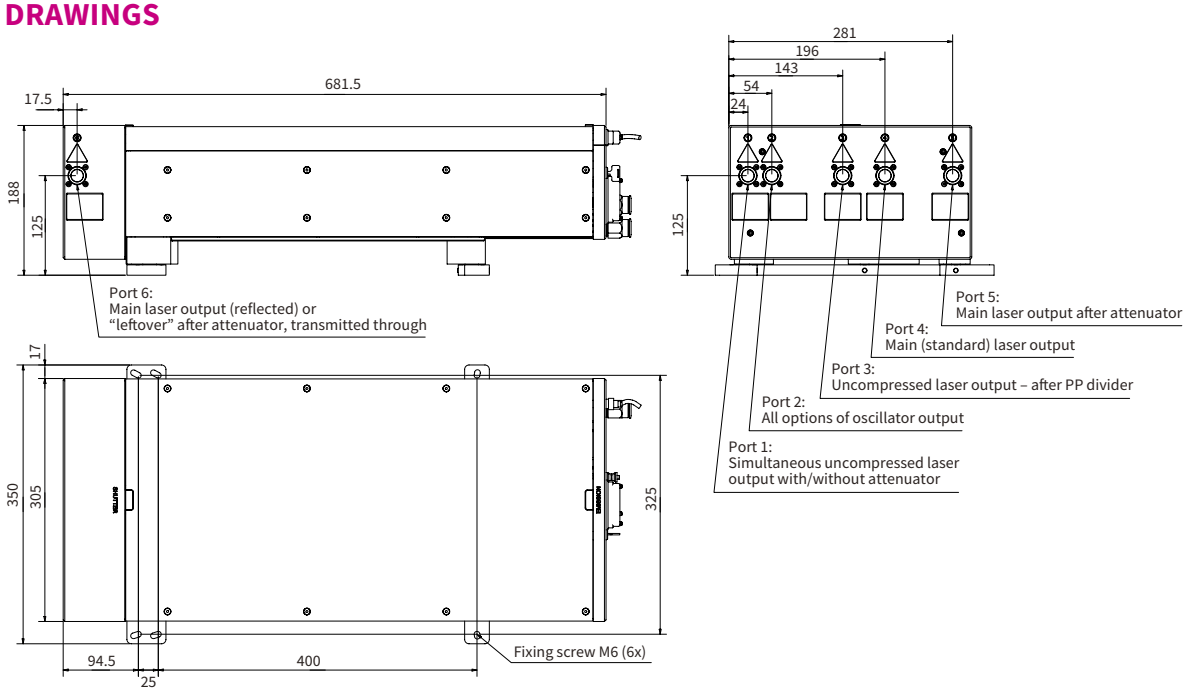
Scientific Interface Module for CARBIDE

FEATURES

- Simultaneous or separate oscillator output
- Uncompressed laser output
- Seeding by an external oscillator
- Beam-splitting options

The CARBIDE scientific interface module extends the versatility of the industrial-grade laser and makes it particularly attractive to scientific applications. This module incorporates multiple options such as a simultaneous or separate oscillator output, a second compressed or uncompressed laser output, and seeding by an external oscillator. For example, using it, the CARBIDE laser can be seeded by an oscillator from another CARBIDE laser, thus ensuring a precise optical synchronization between the two lasers. All the aforementioned outputs can be equipped with automated power attenuators. All options are compatible in between.

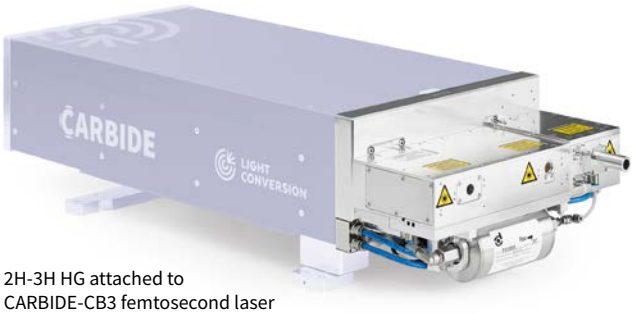
DRAWINGS



Drawing of CARBIDE-CB3-40-200 with scientific interface module

HG | CARBIDE

Automated Harmonic Generators



2H-3H HG attached to
CARBIDE-CB3 femtosecond laser

FEATURES

- 515 nm, 343 nm, or 257 nm output
- Automated harmonic selection
- Mounted directly on the laser head
- Industrial-grade design
- 30 W UV model

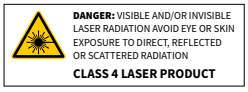
CARBIDE lasers equipped with automated harmonic generators (HGs) provide a selection of fundamental (1030 nm), second (515 nm), third (343 nm), or fourth (257 nm) harmonic outputs using software control.

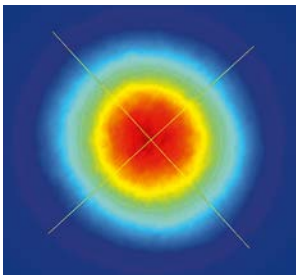
HGs are perfect for industrial applications that require a single-wavelength output. Modules, mounted directly at the output of the laser, are fully integrated into the system.

SPECIFICATIONS

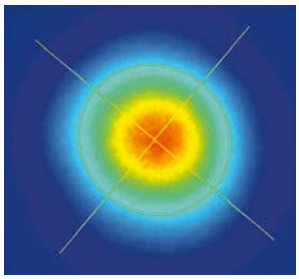
Model		2H	2H-3H	2H-4H	2H-3H (30W UV) [1]
Output wavelength [2] (automated selection)		1030 nm 515 nm	1030 nm 515 nm 343 nm	1030 nm 515 nm 257 nm	1030 nm 515 nm 343 nm
Pump pulse energy		20 – 2000 µJ	50 – 2000 µJ	20 – 2000 µJ	80 – 400 µJ
Pump pulse duration		< 300 fs			≈ 500 fs
Conversion efficiency / Output power		> 50% (2H)	> 50% (2H) > 25% (3H)	> 50% (2H) > 10% (4H) [3]	40 W (2H) 30 W (3H)
Beam quality (M^2) typical values	≤ 400 µJ pump	< 1.15 (2H)	< 1.15 (2H) < 1.2 (3H)	< 1.15 (2H) < n/a (4H)	< 1.2 (2H) < 1.3 (3H)
	> 400 µJ pump	< 1.2 (2H)	< 1.2 (2H) < 1.3 (3H)	< 1.2 (2H) < n/a (4H)	n/a

[1] Available only for CARBIDE-CB3-80W with maximum output power; 1 year lifetime.
[2] Depends on pump laser model. Up to 5th harmonic available; contact sales@lightcon.com for details.
[3] Maximum output power of 1 W.

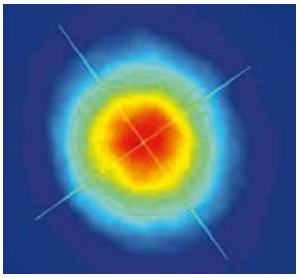




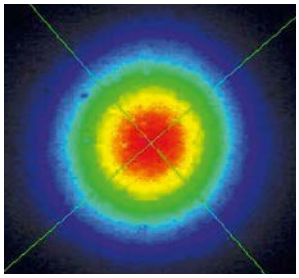
Typical 1H beam profile
of CARBIDE-CB5 (100 kHz, 6 W)



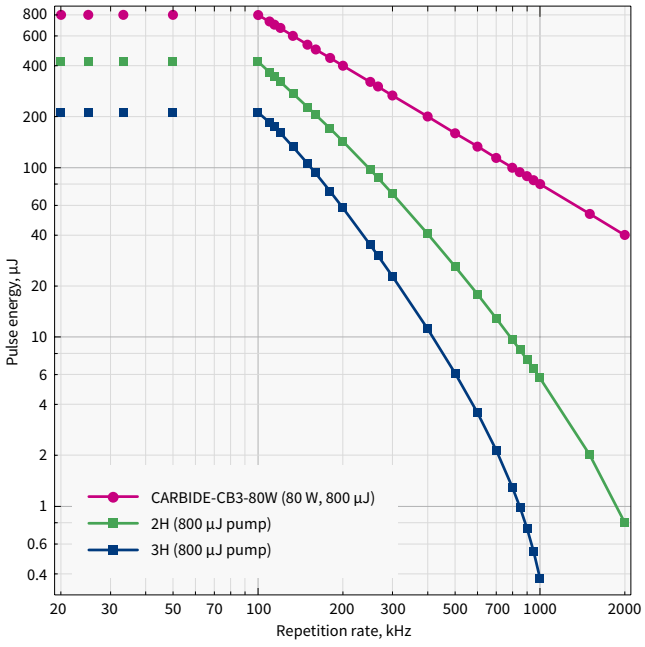
Typical 2H beam profile
of CARBIDE-CB5 (100 kHz, 3.4 W)



Typical 3H beam profile
of CARBIDE-CB5 (100 kHz, 2.2 W)



Typical 4H beam profile
of CARBIDE-CB5 (100 kHz, 100 mW)



Pulse energy vs repetition rate of CARBIDE-CB3-80W with HG

I-OPA

Industrial-Grade Optical Parametric Amplifier

FEATURES

- Tunable or fixed-wavelength models
- Industrial-grade design
- Plug-and-play installation and user-friendly operation
- Single-shot – 2 MHz repetition rate
- Up to 40 W pump power
- < 100 fs pulse duration

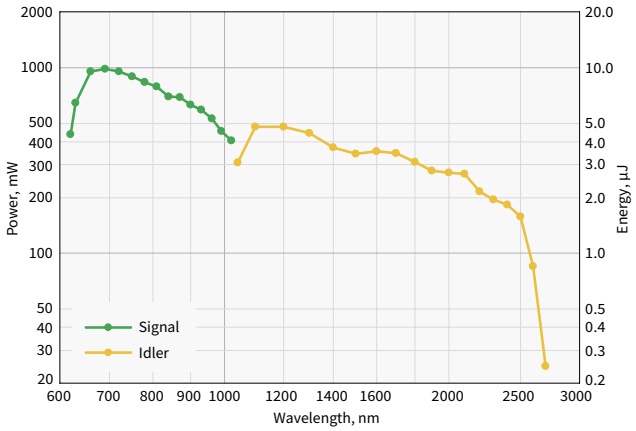
I-OPA-TW attached to air-cooled CARBIDE-CB5

The industrial-grade optical parametric amplifier I-OPA series marks a new era of simplicity in the world of wavelength-tunable femtosecond light sources. Based on over 10 years of experience producing the ORPHEUS series of optical parametric amplifiers, this solution brings together the tunability of wavelength with the robust industrial-grade design. The I-OPA is a rugged module attachable to our PHAROS and CARBIDE lasers, providing long-term stability comparable to that of the industrial-grade harmonic generators.

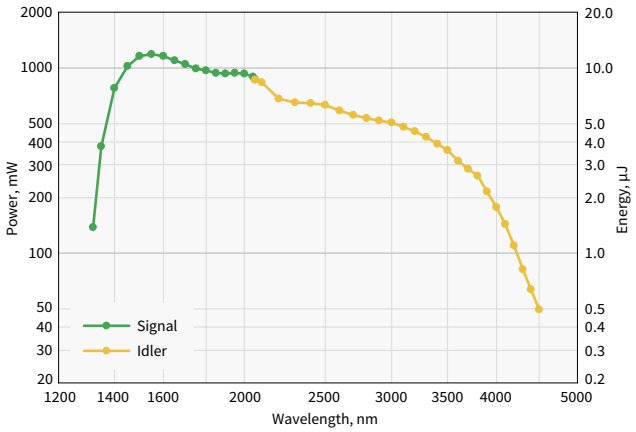
The tunable-wavelength I-OPA (I-OPA-TW) provides a wide tuning range and is primarily intended for spectroscopy and microscopy applications. In particular, the -HP model is targeted to be coupled with our HARPIA spectroscopy system as a pump beam source for ultrafast pump-probe spectroscopy. The -F model is primarily designed as a light source for multiphoton microscopy, the -ONE model – for IR spectroscopy and other applications where high energy MIR pulses are desired. All of the models can also be used for micromachining and other industrial applications.

The fixed-wavelength I-OPA (I-OPA-FW) is primarily intended for applications that desire a single-wavelength output. The industrial-grade design provides mechanical stability and eliminates the effects of air-turbulence, minimizing energy fluctuations and ensuring stable long-term performance.

The I-OPA-TW is best suited for R&D systems, while the I-OPA-FW is a cost-effective solution for large-scale production.



Typical I-OPA-TW-HP tuning curves.
Pump: 10 W, 100 µJ, 100 kHz

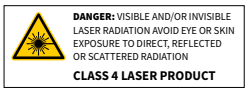


Typical I-OPA-TW-ONE tuning curves.
Pump: 10 W, 100 µJ, 100 kHz

SPECIFICATIONS OF TUNABLE I-OPA

Model	I-OPA-TW-HP	I-OPA-TW-F	I-OPA-TW-ONE
Configuration	ORPHEUS	ORPHEUS-F	ORPHEUS-ONE
Pump power	Up to 40 W		
Pump pulse energy	10 – 400 µJ		20 – 400 µJ
Repetition rate	Up to 2 MHz		
Tuning range	640 – 1010 nm (Signal) 1050 – 2600 nm (Idler)	650 – 900 nm (Signal) 1200 – 2500 nm (Idler)	1350 – 2000 nm (Signal) 2100 – 4500 nm (Idler)
Conversion efficiency at peak	> 7% @ 700 nm (40 – 400 µJ pump; up to 1 MHz)		> 9% @ 1550 nm (40 – 400 µJ pump; up to 1 MHz)
	> 3.5% @ 700 nm (10 – 40 µJ pump; up to 2 MHz)		> 6% @ 1550 nm (20 – 40 µJ pump; up to 2 MHz)
Spectral bandwidth [1]	80 – 220 cm^{-1} @ 700 – 960 nm	200 – 1000 cm^{-1} @ 650 – 900 nm 150 – 1000 cm^{-1} @ 1200 – 2000 nm	60 – 150 cm^{-1} @ 1450 – 2000 nm
Pulse duration [1] [2]	120 – 250 fs	< 55 fs @ 800 – 900 nm < 70 fs @ 650 – 800 nm < 100 fs @ 1200 – 2000 nm	100 – 300 fs
Long-term power stability, 8 h	< 1% @ 800 nm		< 1% @ 1550 nm
Pulse-to-pulse energy stability, 1 min	< 1% @ 800 nm		< 1% @ 1550 nm
Wavelength extension options	320 – 505 nm (SHS) [3] 525 – 640 nm (SHI) [3]	Contact sales@lightcon.com	4500 – 10000 nm (DFG) [4]
Pulse compression options [1]	–	SCMP (Signal pulse compressor) ICMP (Idler pulse compressor) GDD-CMP (Compressor with GDD control)	–

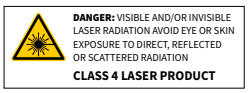
[1] I-OPA-TW-F broad-bandwidth pulses are compressed externally. Typical pulse duration before compression: 120 – 250 fs, after compression: 25 – 70 fs @ 650 – 900 nm, 40 – 100 fs @ 1200 – 2000 nm.
[2] Output pulse duration depends on the selected wavelength and pump laser pulse duration.
[3] Conversion efficiency is 1.2% at peak; specified as the percentage of pump power.
[4] Up to 16 µm tuning range is accessible with an external difference frequency generator.

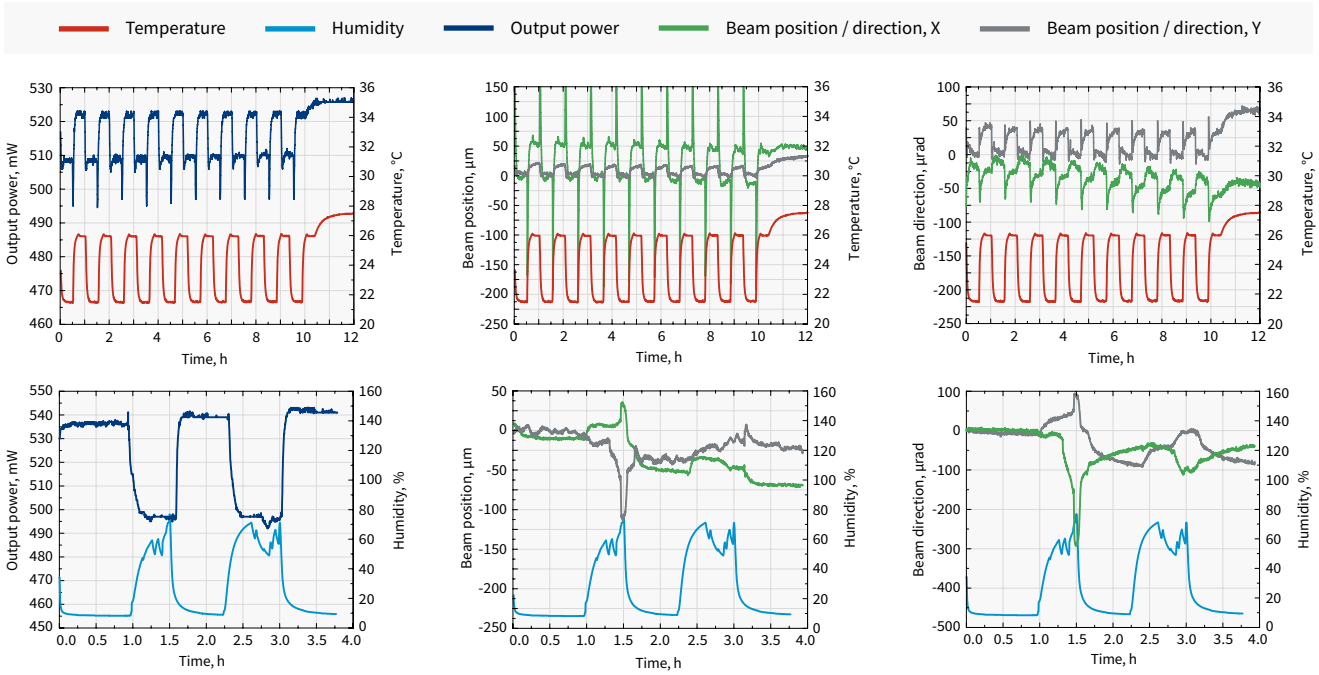


SPECIFICATIONS OF FIXED WAVELENGTH I-OPA

Model	I-OPA-FW-HP	I-OPA-FW-F	I-OPA-FW-ONE
Configuration	ORPHEUS	ORPHEUS-F	ORPHEUS-ONE
Pump power	Up to 40 W		
Pump pulse energy	10 – 500 µJ		20 – 1000 µJ
Repetition rate	Up to 2 MHz		
Wavelength selection range [1]	640 – 1010 nm (Signal) 1050 – 2600 nm (Idler)	650 – 900 nm (Signal) 1200 – 2500 nm (Idler)	1350 – 2000 nm (Signal) 2100 – 4500 nm (Idler)
Conversion efficiency at peak	> 7% @ 700 nm (40 – 500 µJ pump; up to 1 MHz)		> 9% @ 1550 nm (40 – 1000 µJ pump; up to 1 MHz)
	> 3.5% @ 700 nm (10 – 40 µJ pump; up to 2 MHz)		> 6% @ 1550 nm (10 – 40 µJ pump; up to 2 MHz)
Spectral bandwidth [2]	80 – 220 cm^{-1} @ 700 – 960 nm	200 – 1000 cm^{-1} @ 650 – 900 nm 150 – 1000 cm^{-1} @ 1200 – 2000 nm	60 – 150 cm^{-1} @ 1450 – 2000 nm
Pulse duration [2] [3]	120 – 250 fs	< 55 fs @ 800 – 900 nm < 70 fs @ 650 – 800 nm < 100 fs @ 1200 – 2000 nm	150 – 300 fs
Long-term power stability, 8 h	< 1% @ 800 nm		< 1% @ 1550 nm
Pulse-to-pulse energy stability, 1 min	< 1% @ 800 nm		< 1% @ 1550 nm

[1] A fixed wavelength can be selected from the Signal or Idler range. Signal may have accessible Idler pair, and vice versa.
[2] I-OPA-FW-F outputs broad-bandwidth pulses which are compressed externally. Typical pulse duration before compression: 120 – 250 fs, after compression: 25 – 70 fs @ 650 – 900 nm, 40 – 100 fs @ 1200 – 2000 nm.
[3] Output pulse duration depends on the selected wavelength and pump laser pulse duration.





I-OPA-FW output power, beam position, and beam direction under harsh environmental conditions

COMPARISON WITH OTHER FEMTOSECOND AND PICOSECOND LASERS

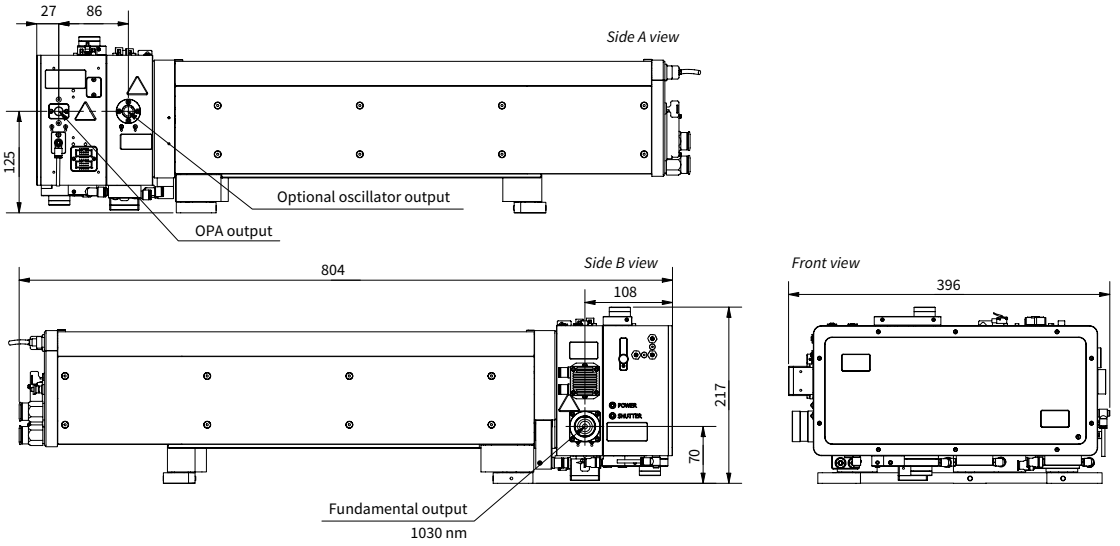
Laser technology	Our solution [1]	Typical performance [2]			
		HG or **HIRO**	**I-OPA-FW-HP**	**I-OPA-FW-F** [3]	**I-OPA-FW-ONE**
Excimer (193 nm, 213 nm)	5H of laser (205 nm)	> 20 µJ	–	–	–
3H of Ti:Sapphire (266 nm)	4H of laser (257 nm)	> 40 µJ			
3H of Nd:YAG (355 nm)	3H of laser (343 nm)	> 100 µJ	> 10 µJ		
2H of Nd:YAG (532 nm)	2H of laser (515 nm)	> 200 µJ	> 140 µJ		
Ti:Sapphire (800 nm)	OPA (750 – 850 nm)	–	> 25 µJ		
Nd:YAG (1064 nm)	Laser (1030 nm)	400 µJ			
Cr:Forsterite (1240 nm)	OPA (1200 – 1300 nm)	–	> 14 µJ		–
Erbium (1560 nm)	OPA (1500 – 1600 nm)		> 10 µJ		> 40 µJ
Thulium / Holmium (1950 – 2150 nm)	OPA (1900 – 2200 nm)		> 7 µJ		> 25 µJ
MIR sources (2500 – 4000 nm)	OPA (2500 – 4000 nm)		–		> 5 µJ

[1] OPA output is not limited to the given spectral ranges; see the full ranges in the specifications above.

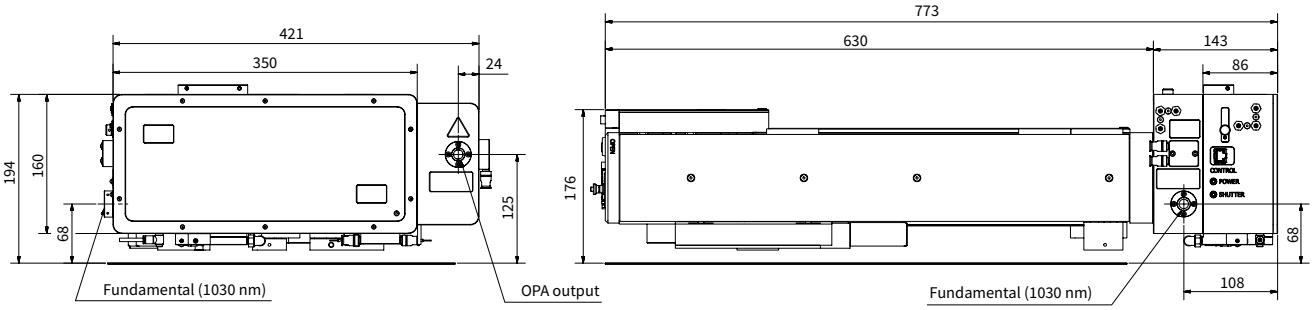
[2] Typical pulse energy when using 400 µJ pump from CARBIDE/PHAROS laser. Output scales linearly in a broad range of pump parameters. For exact specifications, contact sales@lightcon.com.

[3] I-OPA-FW-F broad-bandwidth pulses are compressed externally. For compression options, see specifications above.

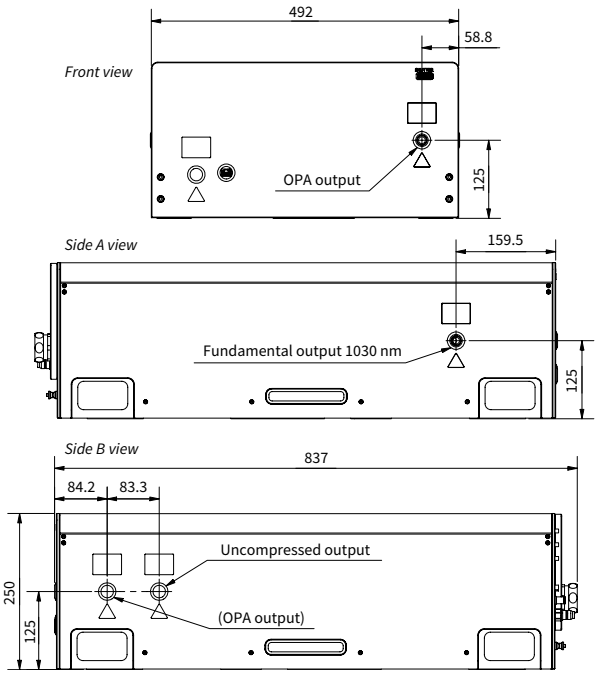
DRAWINGS



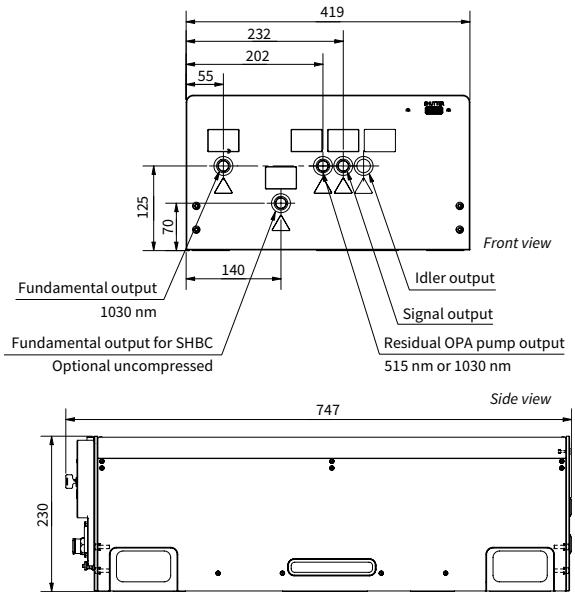
Drawing and output ports of CARBIDE-CB3 with tunable I-OPA-TW-HP



Drawing and output ports of CARBIDE-CB5 with tunable I-OPA-TW-HP



Drawing and output ports of PHAROS-PH2
with tunable I-OPA-TW-HP



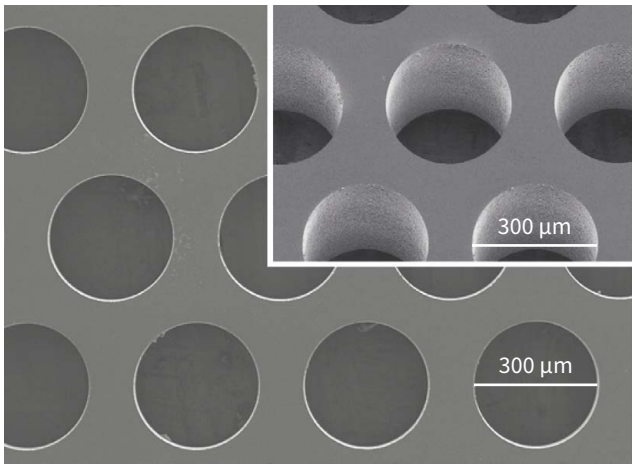
Drawing and output ports of PHAROS-PH2
with fixed-wavelength I-OPA-FW-HP

Examples of Industrial Applications

Birefringent volume modifications in glass

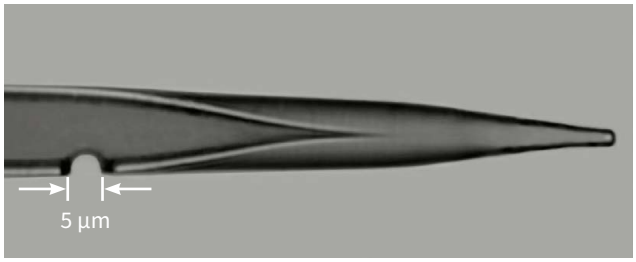
Form induced birefringence-retardance variation results in different colors in parallel polarized light.
Source: Workshop of Photonics.

High precision glass drilling



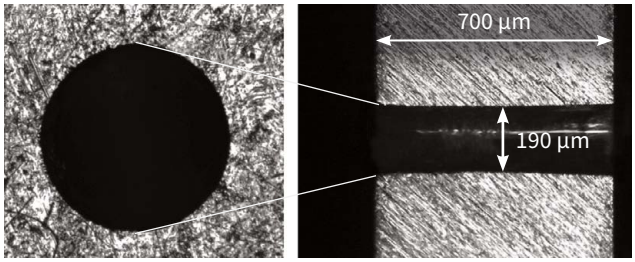
Various glass drilling.
Source: Workshop of Photonics.

Glass needle microdrilling



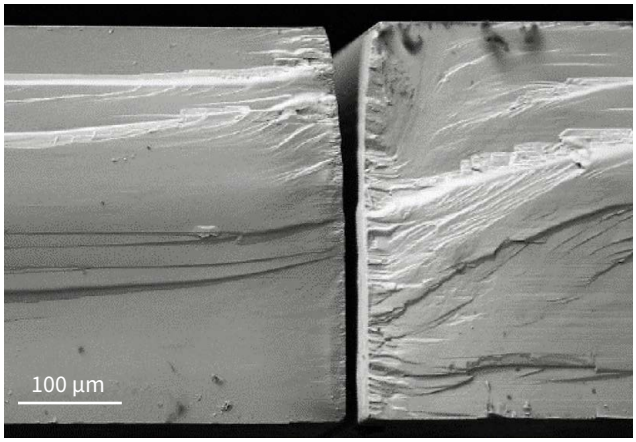
Glass needle microdrilling.
Source: Workshop of Photonics.

Steel drilling



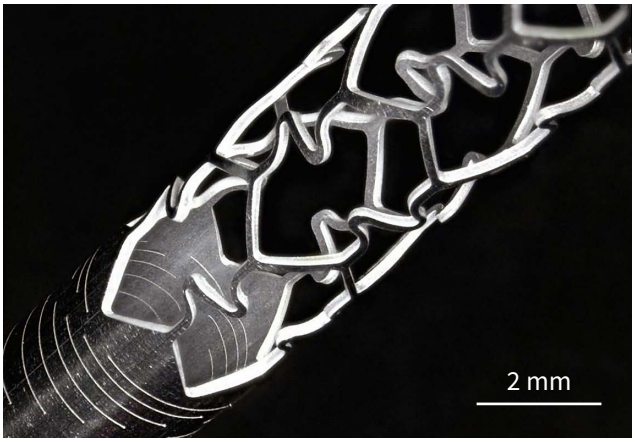
Taperless hole microdrilling in stainless steel alloys.
Source: Workshop of Photonics.

Brittle & highly thermal-sensitive material cutting



Multi-pass cadmium tungstate cutting.
No cracks. All thermal trace effects eliminated.
Source: Micronanics Laser Solutions Centre.

Stainless steel stent cutting



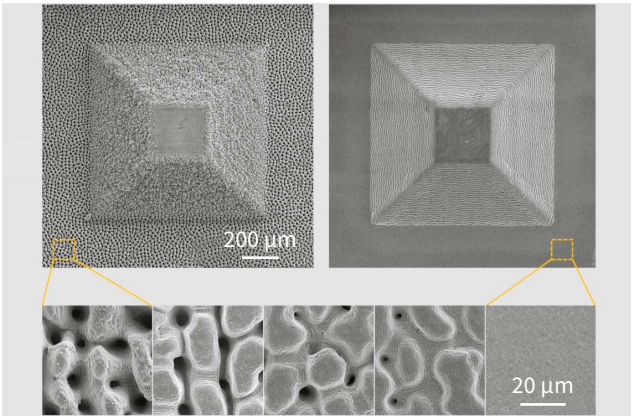
Stent cut using CARBIDE laser.
Source: Amada Miyachi America.

Milling of complex 3D surfaces

3D milled sample in copper. Zoom in SEM image.

Source: “Highly-efficient laser ablation of copper by bursts of ultrashort tuneable (fs-ps) pulses”, A.Žemaitis, P.Gečys, M.Barkauskas, G.Račiukaitis, M.Gedvilas. Scientific Reports (2019).

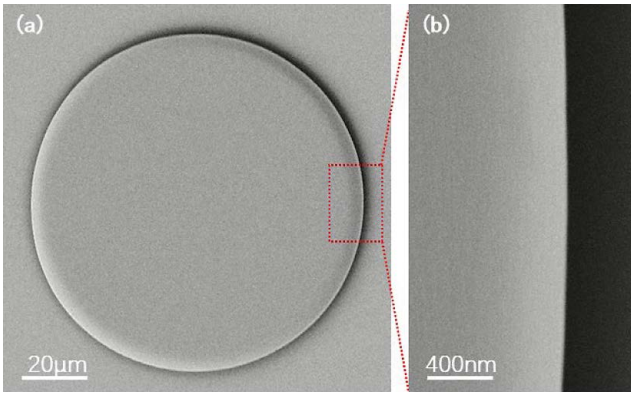
Stainless steel polishing



SEM image collage of structures ablated in stainless steel, before and after laser polishing using GHz burst (from left to right).

Source: “High quality surface treatment using GHz burst mode with tunable ultrashort pulses”, D.Metzner , P.Lickschat and S.Weißmantel. Applied Surface Science (2020).

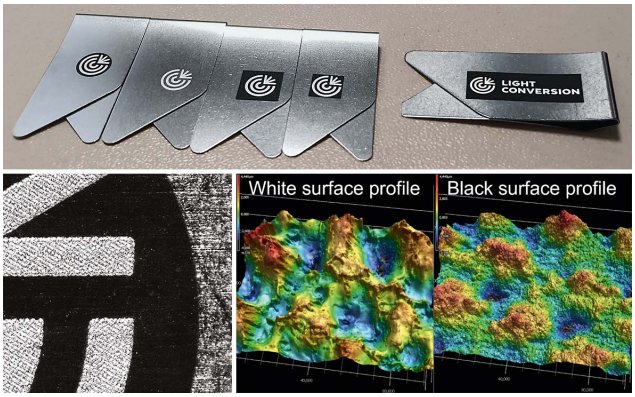
Selective ablation



Lithium niobate microdisks fabricated using selective ablation.

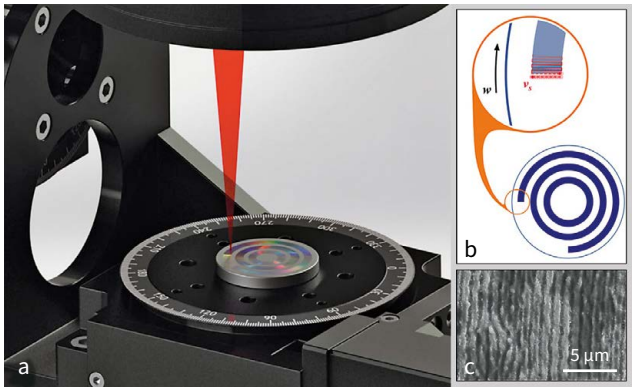
Source: “Fabrication of crystalline microresonators of high quality factors with a controllable wedge angle on lithium niobate on insulator”, J.Zhang, Z.Fang, J.Lin, J.Zhou, M.Wang, R.Wu, R.Gao, Y.Cheng. Nanomaterials (2019).

High-contrast marking



High-contrast black-and-white marking on stainless steel clips using the BiBurst option.

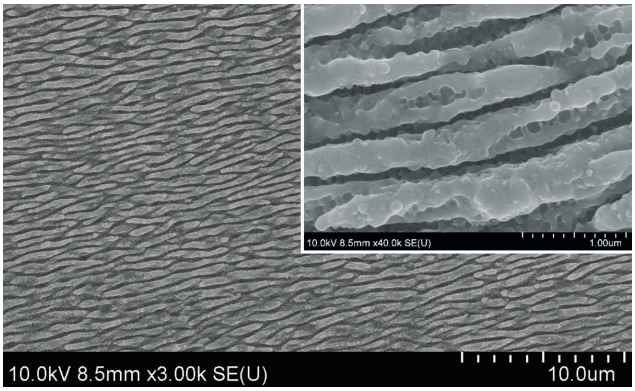
Friction and wear reduction



Schematic of the laser treatment (a), laser patterning strategy (b), SEM image of induced LIPSS (c).

Source: “Tribological properties of high-speed uniform femtosecond laser patterning on stainless steel”, I.Gnilitskyi, A.Rota, E.Gualtieri, S.Valeri, L.Orazi. Lubricants (2019).

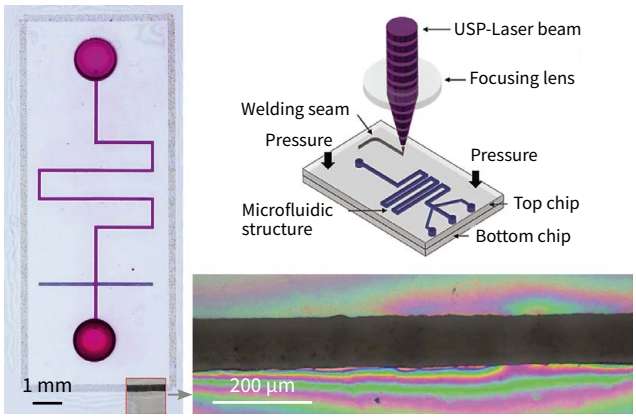
SERS sensor fabrication



SEM image of the Ti-6Al-4V (TC4) surface after irradiation with progressive laser scan.

Source: “Large-scale fabrication of nanostructure on bio-metallic substrate for surface enhanced Raman and fluorescence scattering”, L.Lu, J.Zhang, L.Jiao, Y.Guan. Nanomaterials (2019).

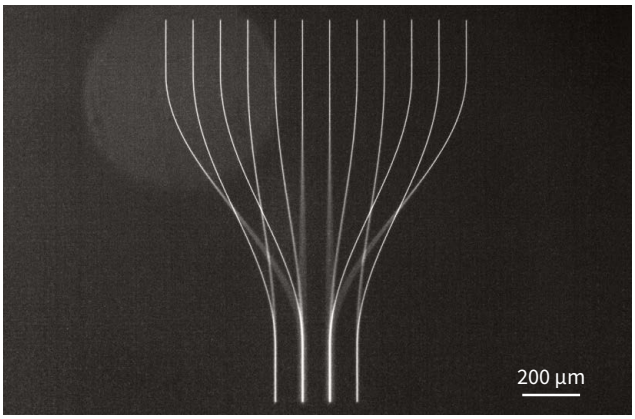
Lab-on-chip channel ablation and welding



Welding of transparent polymers for sealing of microfluidic devices. Top view on a sealed microfluidic device (left), welding seam (bottom right).

Source: "A new approach to seal polymer microfluidic devices using ultrashort laser pulses", G. Roth, C. Esen and R. Hellmann. JLMN-Journal of Laser Micro/Nanoengineering (2019).

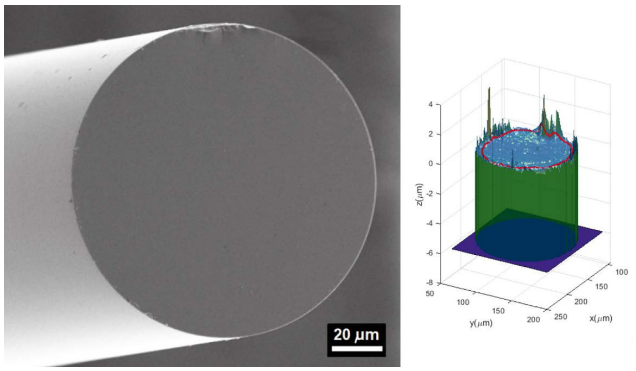
3D waveguides



3D waveguides fabricated in fused silica glass.

Source: Workshop of Photonics.

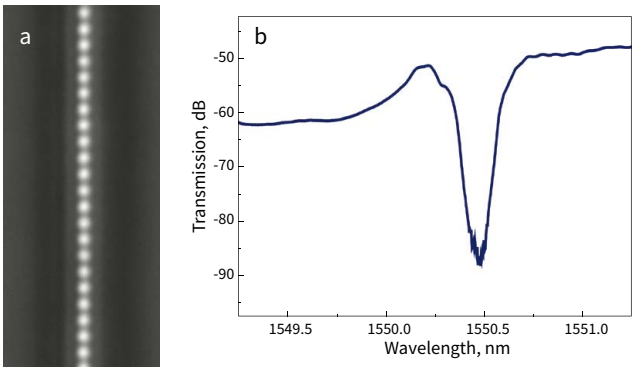
Fiber cleaving



Fiber end face after laser-based scribing (left) and its surface profile (right).

Source: RMIT University, Melbourne.

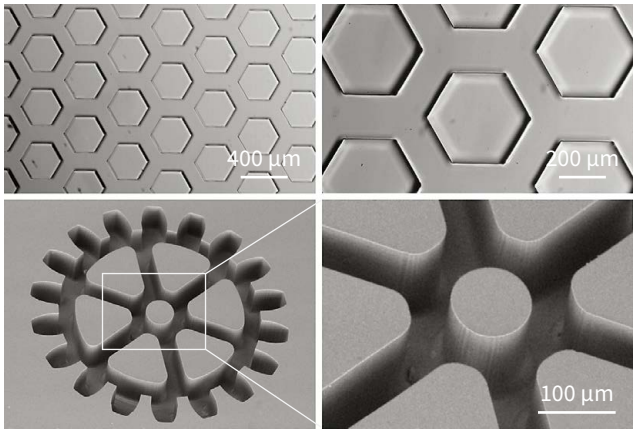
Bragg grating waveguide (BGW) writing



First-order Bragg gratings inscribed in waveguide (a). Resonant spectral transmission of inscribed BGW (b).

Source: "Ultrashort Bessel beam photoinscription of Bragg grating waveguides and their application as temperature sensors", G.Zhang, G. heng, M.Bhuyan, C.D'Amico, Y.Wang, R.Stoian. Photon. Res. (2019).

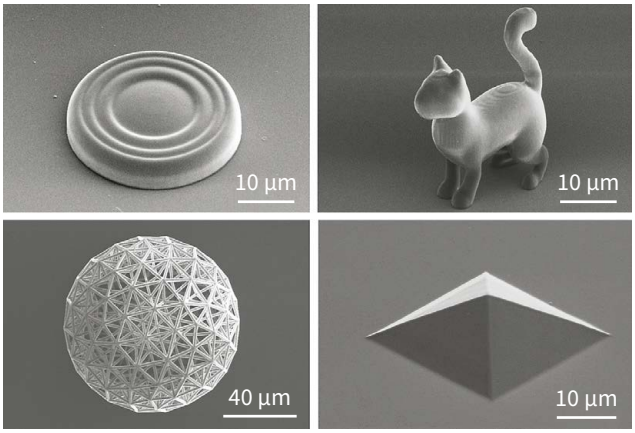
3D glass etching



Various structures fabricated in fused silica glass.

Source: Femtika.

3D multiphoton polymerization



Various 3D structures fabricated in SZ2080 polymer using multi-photon polymerization.

Source: Workshop of Photonics.

FLINT

Femtosecond Oscillators

FEATURES

- < 40 fs pulse duration
- Up to 260 nJ pulse energy
- Up to 20 W output power
- 76 MHz repetition rate
- Industrial-grade design
- Automated second harmonic generator
- CEP stabilization option
- Repetition rate locking to an external source

FLINT-FL2

FLINT is a series of femtosecond Yb oscillators providing industrial-grade design and state-of-the-art output parameters such as 20 W output power at 76 MHz repetition rate and sub-40 fs pulse duration. FLINT oscillators are based on Kerr-lens mode-locking. Once started, the mode-locking remains stable over a long time. Furthermore, oscillator cavity length can be adjusted with an optional piezo actuator. FLINT oscillators support carrier-envelope phase (CEP) stabilization and repetition rate locking to an external source.

SPECIFICATIONS

Model	FL1-02	FL1-08	FL2-12	FL2-20	FL2-SP	
Maximum output power	2 W	8 W	12 W	20 W	0.5 W	2 W
Pulse duration [1]	< 100 fs	< 120 fs	< 120 fs	< 170 fs	< 40 fs	< 50 fs
Maximum pulse energy [2]	25 nJ	105 nJ	157 nJ	260 nJ	6 nJ	25 nJ
Repetition rate	≈ 76 MHz [3]		≈ 76 MHz		≈ 76 MHz [4]	
Center wavelength	1035 [5] ± 10 nm	1030 ± 3 nm	1029 ± 3 nm	1026 ± 2 nm	1040 ± 10 nm	
Polarization	Linear, horizontal					
Beam quality	TEM_{00}; M^2 < 1.2					
Beam pointing stability	< 10 µrad/°C					
Pulse-to-pulse energy stability [6]	RMS deviation [7] < 0.5% over 24 h					
Long-term power stability	RMS deviation [7] < 0.5% over 100 h					
Internal 2H generator [8]	n/a		Optional; conversion efficiency > 30%			
Internal attenuator	n/a		Yes			

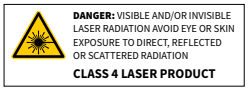
PHYSICAL DIMENSIONS

Laser head (L × W × H)	430 × 195 × 114 mm	542 × 322 × 146 mm
Power supply and chiller rack (L × W × H)	642 × 553 × 540 mm	642 × 553 × 673 mm
Chiller	Different options available. Contact sales@lightcon.com	

ENVIRONMENTAL & UTILITY REQUIREMENTS

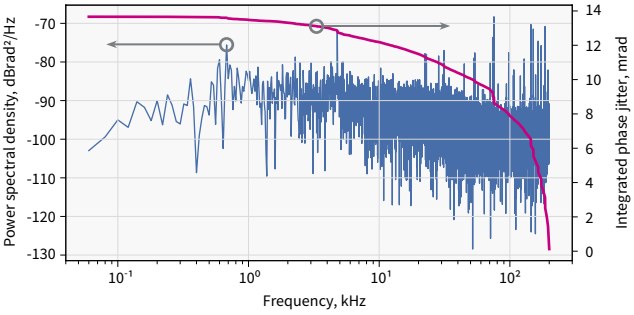
Operating temperature	15 – 30 °C (air conditioning recommended)		
Relative humidity	< 80% (non-condensing)		
Electrical requirements	100 V AC, 7 A – 240 V AC, 3 A; 50 – 60 Hz	100 V AC, 12 A – 240 V AC, 5 A; 50 – 60 Hz	
Rated power	200 W		
Power consumption	100 W	150 W	
Power consumption (chiller)	200 W	800 W	200 W

[1] Assuming Gaussian pulse shape.
[2] Depends on repetition rate. Approximate values are given for 76 MHz.
[3] Other repetition rates are available in the range from 60 to 100 MHz.
[4] Other repetition rates are available in the range from 70 to 80 MHz.
[5] Choice of a particular central wavelength with ±1 nm tolerance is available upon request.
[6] With enabled power-lock, under stable environment.
[7] Normalized to average pulse energy, NRMSD.
[8] For 3H or 4H generation, refer to HIRO for FLINT.



CEP STABILIZATION

FLINT oscillators can be equipped with feedback electronics for carrier-envelope phase (CEP) stabilization of the output pulses. The carrier-envelope offset (CEO) of the oscillator is actively locked to 1/4th of the repetition rate with a <100 mrad standard deviation.

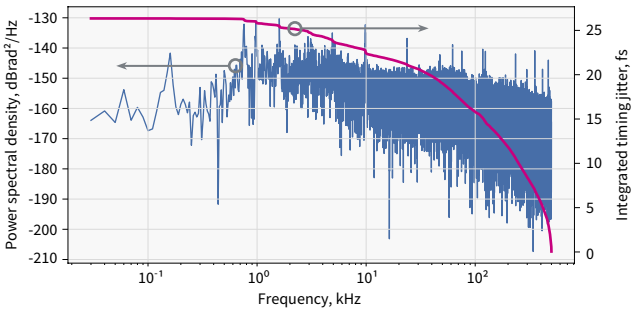


Phase noise data of CEP locked FLINT oscillator

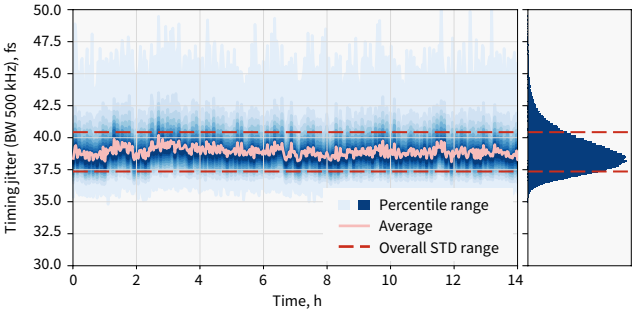
REPETITION RATE LOCKING

FLINT oscillators are customizable for repetition rate locking applications. Coupled with the necessary feedback electronics, the repetition rate can be synchronized to an external RF source using the two piezo stages installed inside the cavity.

The repetition rate locking system can assure an integrated timing jitter of less than 200 fs for RF reference frequencies larger than 500 MHz. Continuous phase shifting is available on request.

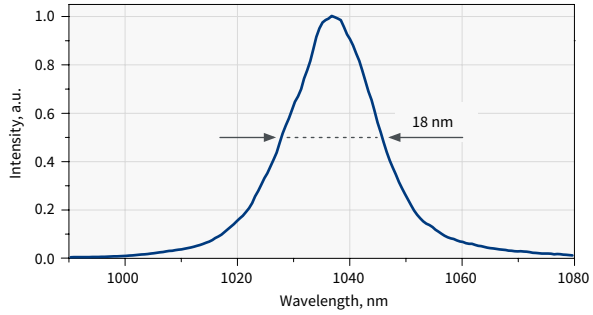


Phase noise data of FLINT oscillator
locked to a 2.8 GHz RF source

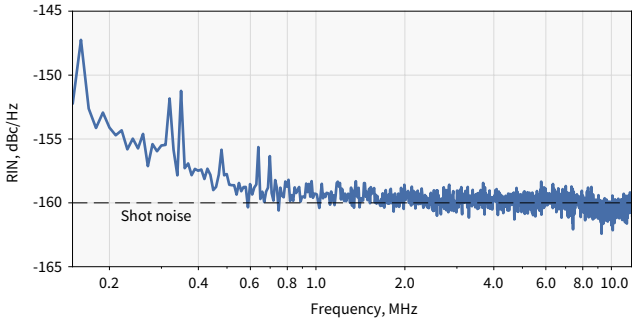


Timing jitter stability over 14 h;
FLINT oscillator locked to a 2.8 GHz RF source

PERFORMANCE

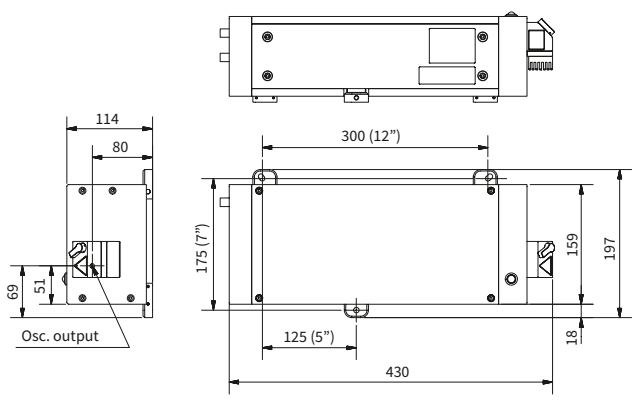


Typical FLINT optical spectrum

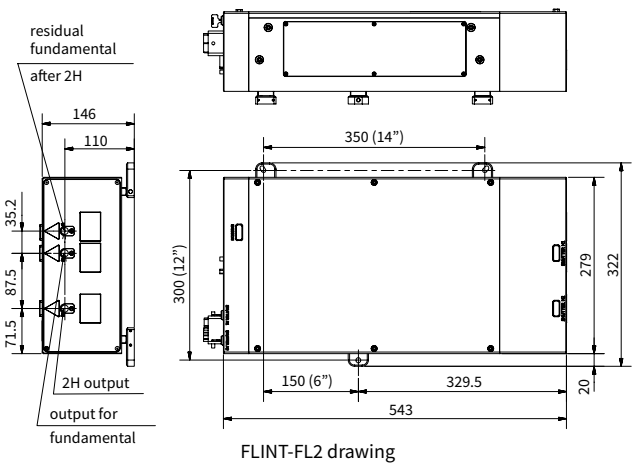


Relative intensity noise (RIN) of FLINT oscillator,
shot-noise limited at -160 dBc/Hz above 1 MHz

DRAWINGS



FLINT-FL1 drawing



FLINT-FL2 drawing

HIRO

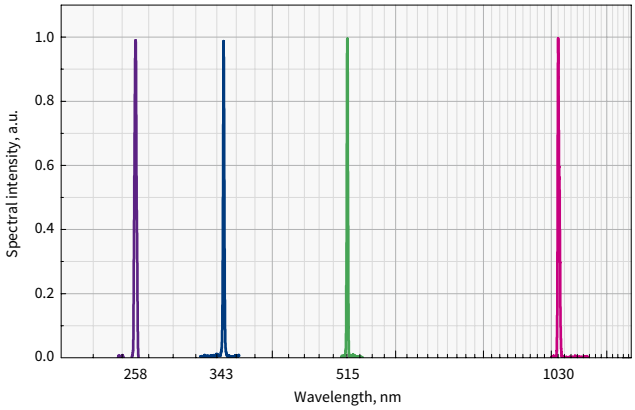
Customizable Harmonic Generator

FEATURES

- 1030 nm, 515 nm, 343 nm, and 257 nm outputs
- Simple selection of active harmonic
- Simultaneous or switchable outputs
- Customizable for additional options

HIRO is a customizable free-standing harmonic generator for PHAROS and CARBIDE lasers, and FLINT oscillators. It provides a high power harmonic radiation at 515, 343, and 258 nm wavelengths. The selection of an active harmonic is manual but requires less than a few seconds thanks to unique optomechanical design.

HIRO can be customized for additional options such as beam size and collimation adjustment, white light continuum generation, as well as beam division and harmonics splitting, which makes all harmonics available at the same time.



HIRO outputs

SPECIFICATIONS (for PHAROS and CARBIDE lasers)

Model	PH1F1	PH1F2	PH1F3	PH1F4	PH_W1
Available outputs [1) 2)]	515 nm (2H)	515 nm (2H) 258 nm (4H)	515 nm (2H) 343 nm (3H)	515 nm (2H) 343 nm (3H) 258 nm (4H)	any combination and white light continuum
Maximum pump power [3)]	20 W				
Pump pulse energy [3)]	8 – 1000 µJ				
Conversion efficiency [4)]	> 50% (2H) > 10% (4H) [6)]		> 50% (2H) [5)] > 25% (3H) > 10% (4H) [5) 6)]		
Polarization [7)]	Linear, horizontal (2H) Linear, vertical (3H, 4H)				

PHYSICAL DIMENSIONS

Housing (L × W × H)	455 × 160 × 85 mm
Recommended area for fixing (L × W)	425 × 255 mm
Beam steering/intercepting (L × W × H)	150 × 55 × 75 mm

1) Depends on pump laser model.
2) Residual fundamental radiation available on request.
3) Models for up to 80 W and 3 mJ are available upon request, contact sales@lightcon.com.
4) Percentage of pump power; for repetition rate of up to 200 kHz.
5) When the third harmonic is not in use.
6) Maximum output power of 1 W.
7) Different polarization is available on request.

DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT

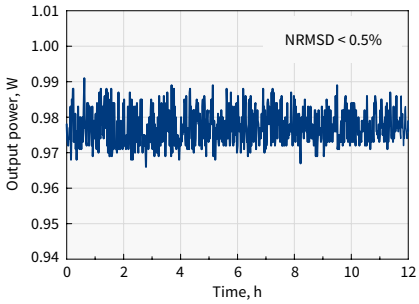
SPECIFICATIONS (for FLINT oscillators)

Generated harmonics	2H	3H	4H
Output wavelength [1]	515 nm	343 nm	258 nm
Maximum pump power [2]	4 W		
Conversion efficiency [3]	> 35%	> 5%	> 1%

PHYSICAL DIMENSIONS

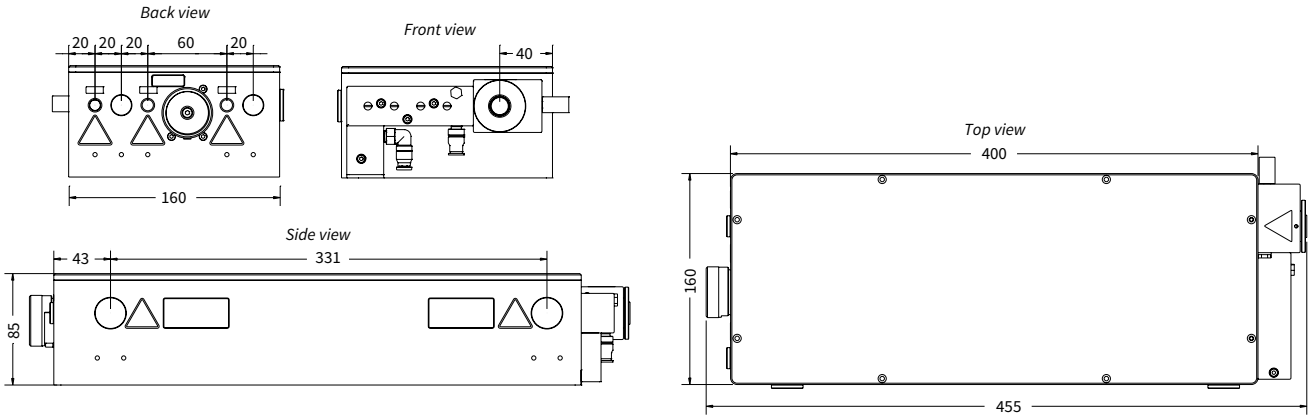
Housing (L × W × H)	455 × 160 × 85 mm
Recommended area for fixing (L × W)	425 × 255 mm
Beam steering/intercepting (L × W × H)	150 × 55 × 75 mm

[1] Depends on pump laser model.
[2] For high power 2H, refer to HG for FLINT.
[3] For pump power of > 500 mW.



4H output power stability

DRAWINGS



Drawings of HIRO with water-cooling

SHBC

Second Harmonic Bandwidth Compressor

FEATURES

- 515 nm output
- < 10 cm^{-1} spectral bandwidth
- 2 – 4 ps pulse duration
- > 30% conversion efficiency
- Used to pump ORPHEUS-PS
- Compact footprint

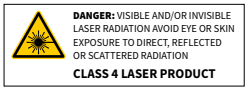
SHBC is a second harmonic bandwidth compressor dedicated to the generation of narrow-bandwidth picosecond pulses from a broad-bandwidth output of PHAROS and CARBIDE femtosecond lasers.

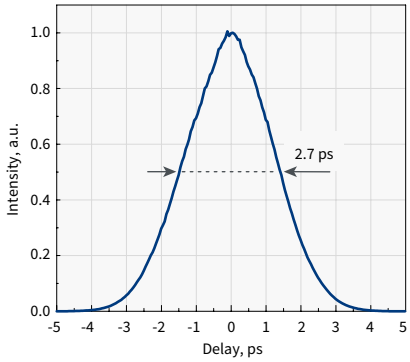
SHBC enables the creation of versatile optical setups which use fixed-wavelength or tunable narrow-bandwidth picosecond pulses in combination with tunable-wavelength broadband femtosecond pulses. In particular, such setups are of interest in sum-frequency generation (SFG) spectroscopy and femtosecond stimulated Raman spectroscopy (FSRS).

SPECIFICATIONS

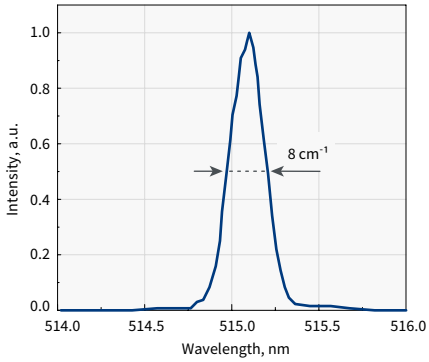
Model	**SHBC**
OUTPUT CHARACTERISTICS	
Output wavelength [1]	515 nm ± 5 nm
Conversion efficiency	> 30%
Spectral bandwidth [2]	< 10 cm^{-1}
Pulse duration [3]	2 – 4 ps
PUMP LASER REQUIREMENTS	
Pump source	PHAROS or CARBIDE with uncompressed output option
Pump pulse energy	40 µJ – 4 mJ
Maximum pump power	40 W
DIMENSIONS	
Housing (L × W × H)	426 × 351 × 119 mm
Recommended area for fixing (L × W × H)	450 × 400 × 150 mm

[1] *Depends on pump laser model.*
[2] *< 2 cm^{-1} model available; contact sales@lightcon.com.*
[3] *SHBC can be adjusted to shorter pulse durations at the expense of narrow spectral bandwidth.*



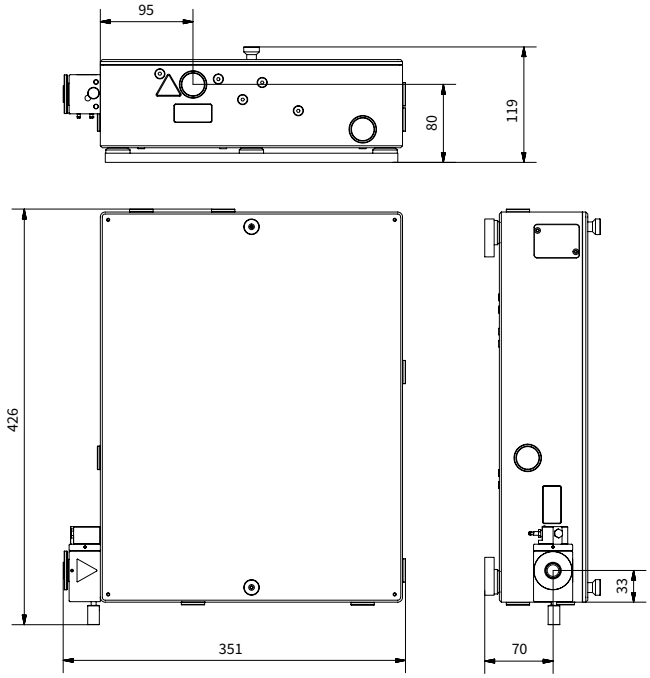


Typical pulse duration of SHBC output



Typical spectrum of SHBC output

DRAWINGS



ORPHEUS

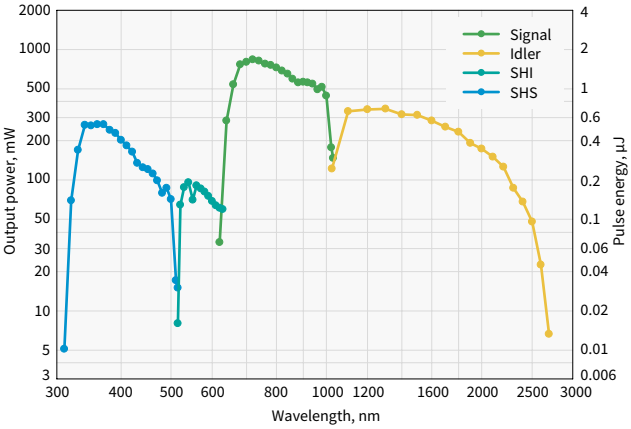
Collinear Optical Parametric Amplifier

FEATURES

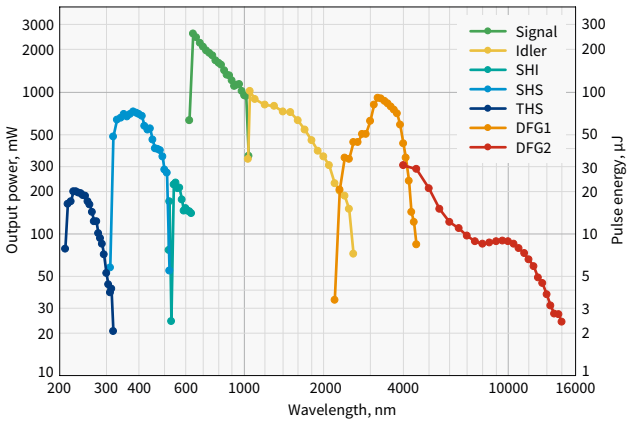
- 190 – 16000 nm tuning range
- Single-shot – 2 MHz repetition rate
- Up to 80 W pump power
- Up to 2 mJ pump pulse energy
- Completely automated

ORPHEUS is a collinear optical parametric amplifier (OPA). Coupled with a PHAROS or CARBIDE femtosecond laser, ORPHEUS emits femtosecond pulses tunable from ultraviolet (UV) to mid-infrared (MIR) at a repetition rate of up to 2 MHz. Thus, it is an invaluable tool for ultrafast spectroscopy, nonlinear microscopy, and microstructuring applications.

The ORPHEUS collinear OPA comes in three different configurations to perfectly match the customer needs. The basic ORPHEUS configuration is a cost-effective choice providing a wide and gapless tuning range from 630 to 2600 nm, which is extendable down to 210 nm with an external harmonic generator. If higher pump power and a higher-level of automation are desired, the ORPHEUS-HP configuration is your choice. It offers complete automation and integrates all of the wavelength extension options into a single thermally-stabilized housing. Its wavelength tuning is completely hands-free and uses automated wavelength separation to ensure the same position and direction for the 190 – 2600 nm output. The spectral range is extendable up to 16 µm; thus, covering the entire spectrum from UV to MIR. Similar to ORPHEUS-HP, the ORPHEUS-HE configuration brings the aforementioned automation but also accepts high pump pulse energy.



Typical tuning curves of **ORPHEUS**.
Pump: 8 W, 16 µJ, 500 kHz



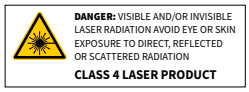
Typical tuning curves of **ORPHEUS-HE**.
Pump: 20 W, 2 mJ, 10 kHz

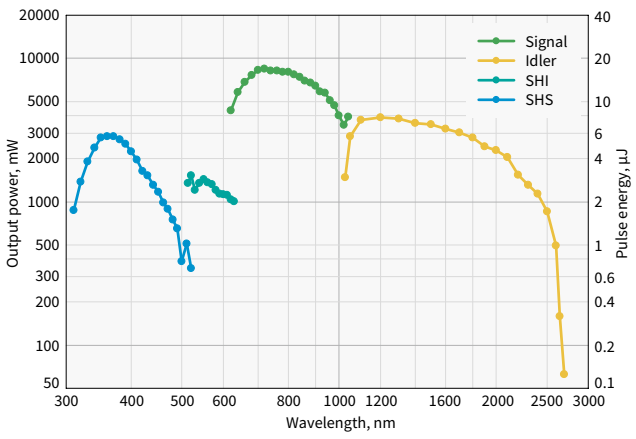
For custom tuning curves visit *http://toolbox.lightcon.com/tools/tuningcurves/*

SPECIFICATIONS

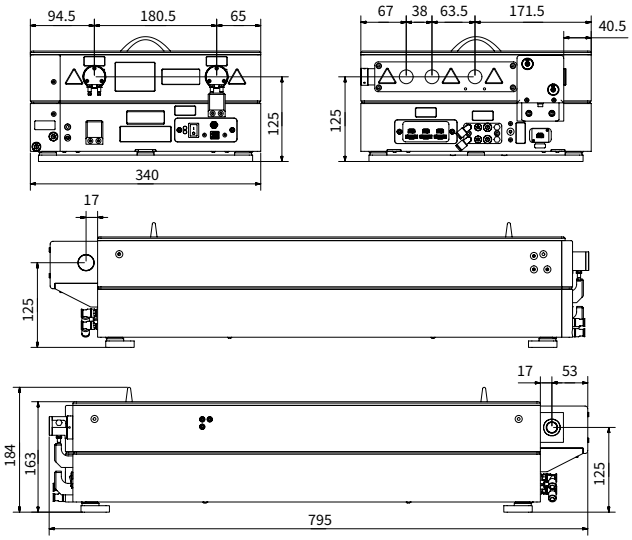
Model	ORPHEUS		ORPHEUS-HP		ORPHEUS-HE
MAIN OUTPUT (630 – 2600 nm)					
Tuning range	630 –1030 nm (Signal) 1030 – 2600 nm (Idler)				
Maximum pump power	8 W		80 W		
Pump pulse energy	8 – 20 µJ	20 – 400 µJ	8 – 20 µJ	20 – 400 µJ	400 – 2000 µJ [1]
Conversion efficiency at peak	> 6% (Signal and Idler combined)	> 12% (Signal and Idler combined)	> 4.5% (Signal) > 2% (Idler)	> 9% (Signal) > 4% (Idler)	
Integrated 2H (515 nm) generation efficiency	> 35% [2]		not specified		
Pulse duration	120 – 250 fs				
Spectral bandwidth @ 700 – 960 nm	75 – 220 cm^{-1}				
Long-term power stability, 8 h [3]	< 2% @ 800 nm				
Pulse-to-pulse energy stability, 1 min [3]	< 2% @ 800 nm				
WAVELENGTH EXTENSIONS (190 – 16000 nm)					
Pump pulse energy	8 – 20 µJ	20 – 400 µJ	8 – 20 µJ	20 – 400 µJ	400 – 2000 µJ [1]
SH package at peak **315 – 515 nm (SHS)** **515 – 630 nm (SHI)**	> 1.2%	> 3%	> 1.2%	> 2.4%	
210 – 315 nm (THS)	n/a		> 0.4% [4]	> 0.8% [4]	
FH package at peak **210 – 258 nm (FHS)** **258 – 315 nm (FHI)**	Contact sales@lightcon.com		n/a		
190 – 215 nm (DUV)	n/a		> 0.3% [5]	Contact sales@lightcon.com	
2200 – 4200 nm (DFG1)	Contact sales@lightcon.com		> 1.5% @ 3000 nm	> 3% @ 3000 nm	
4000 – 16 000 nm (DFG2)			> 0.1% @ 10000 nm	> 0.2% @ 10000 nm	

[1] Pump energy of up to 5 mJ available; contact sales@lightcon.com for details.
[2] At designated output port B; not simultaneous to OPA output.
[3] Expressed as NRMSD (normalized root mean squared deviation).
[4] Maximum output power of 400 mW.
[5] For pump power of < 10 W. Maximum output power of 40 mW @ 200 nm.





Typical tuning curves of **ORPHEUS-HP**.
Pump: 80 W, 160 µJ, 500 kHz



ORPHEUS-HP drawings

ORPHEUS | ONE

Mid-Infrared Collinear Optical Parametric Amplifier

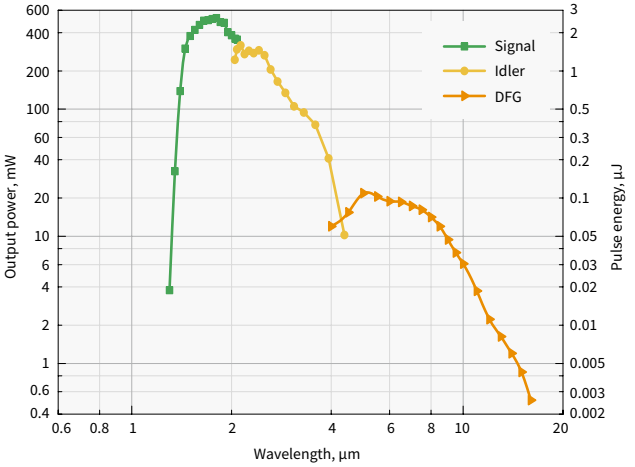
FEATURES

- High conversion efficiency in mid-IR
- 1350 – 16000 nm tuning range
- Single-shot – 2 MHz repetition rate
- Up to 80 W pump power
- Up to 2 mJ pump pulse energy

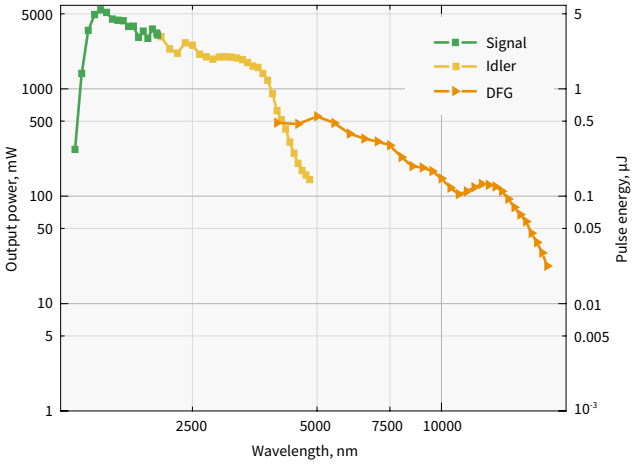
ORPHEUS-ONE is an optical parametric amplifier (OPA) designed for the mid-infrared (MIR) spectral range from 1350 to 16000 nm. Compared to ORPHEUS-HP, it has fewer wavelength extension options but provides higher pump laser conversion efficiency into MIR.

Three models of ORPHEUS-ONE offer the same tuning range, are reliable and easy to use, but vary based on the design automation and pump parameters. The basic ORPHEUS-ONE model is a cost-effective choice but is limited to 8 W pump power. The ORPHEUS-ONE-HP enables up to 80 W pump power, while the ORPHEUS-ONE-HE accepts the same pump power but also pulse energy of up to 2 mJ.

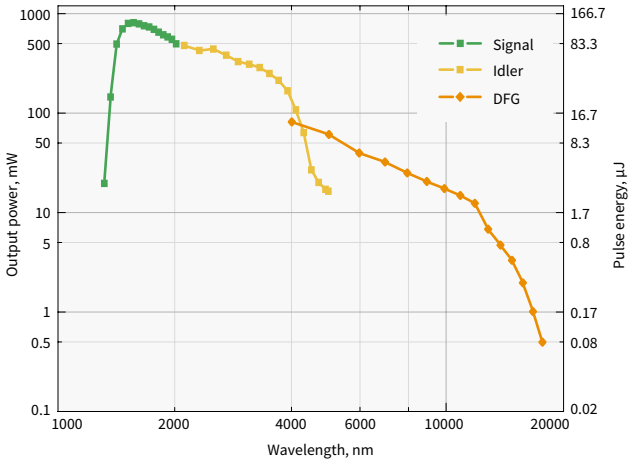
The spectral bandwidth of ORPHEUS-ONE output is defined by the pump laser pulses; thus, for sum-frequency generation (SFG) spectroscopy and other applications requiring broad-bandwidth infrared pulses – refer to ORPHEUS-MIR.



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



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



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

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

SPECIFICATIONS

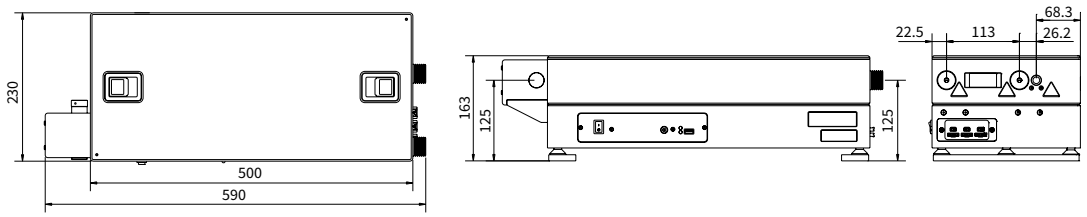
Model	ORPHEUS-ONE	ORPHEUS-ONE-HP	ORPHEUS-ONE-HE
MAIN OUTPUT (1350 – 4500 nm)			
Tuning range	1350 – 2000 nm (Signal) 2100 – 4500 nm (Idler)		
Maximum pump power	8 W	80 W	
Pump pulse energy	12 – 400 µJ	12 – 400 µJ	400 – 2000 µJ
Conversion efficiency at peak [1] **(Signal @ 1550 nm)**	> 9%, 30 – 2000 µJ pump > 6%, 12 – 30 µJ pump		
Spectral bandwidth	60 – 150 cm^{-1} @ 1450 – 2000 nm		
Long-term power stability, 8 h [2]	< 2% @ 1550 nm		
Pulse-to-pulse energy stability, 1 min [2]	< 2% @ 1550 nm		
WAVELENGTH EXTENSION (4500 – 16000 nm)			
4500 – 16000 nm (DFG)	Conversion efficiency [1]	> 0.3% @ 10000 nm, 30 – 2000 µJ pump > 0.2% @ 10000 nm, 12 – 30 µJ pump	
	Spectral bandwidth	60 – 150 cm^{-1} @ 5000 – 8000 nm	60 – 120 cm^{-1} @ 5000 – 8000 nm

[1] *Specified as percentage of pump power.*

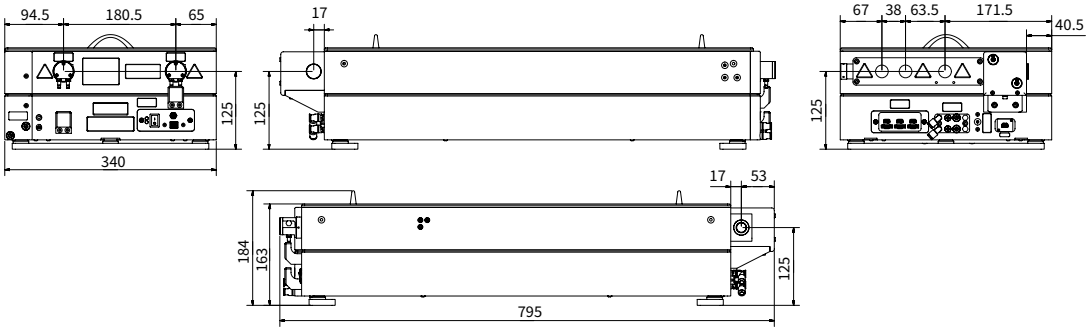
[2] *Expressed as NRMSD (normalized root mean squared deviation).*

DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT

DRAWINGS



ORPHEUS-ONE drawings



ORPHEUS-ONE-HP drawings

ORPHEUS | F

Broad-Bandwidth Hybrid Optical Parametric Amplifier

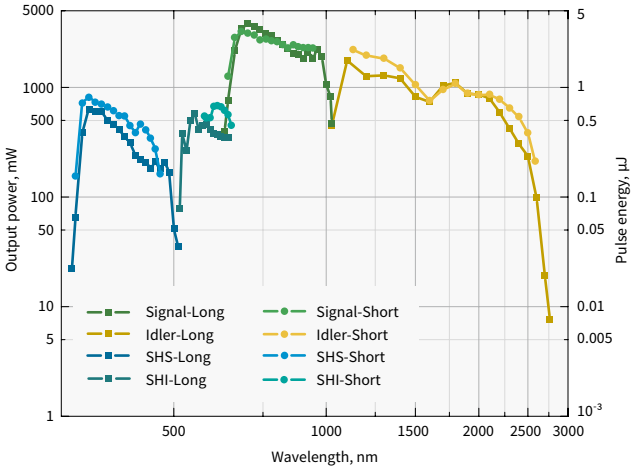
FEATURES

- Combination of best OPA and NOPA features
- 650 – 900 nm and 1200 – 2500 nm tuning range
- Single-shot – 2 MHz repetition rate
- < 100 fs pulse duration
- Adjustable spectral bandwidth
- Long pulse mode for gap-free tunability

ORPHEUS-F is a hybrid optical parametric amplifier (OPA), combining the short pulse duration produced by a non-collinear OPA (NOPA) and the wide tuning range offered by a collinear OPA.

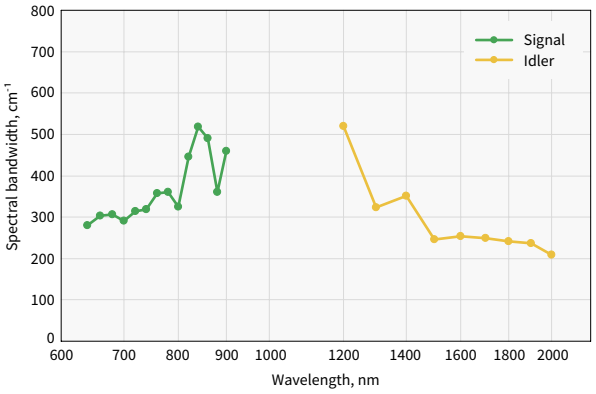
The Signal pulses of ORPHEUS-F are tunable in a 650 – 900 nm range and can be compressed with a simple prism-based compressor down to 25 – 70 fs pulse duration. The Idler pulses are tunable in a 1200 – 2500 nm range and reach pulse duration of 40 – 100 fs. In addition, a long-pulse mode is available for accessing the 900 – 1200 nm tuning range; thus, enabling a gap-free tunability.

ORPHEUS-F provides significantly shorter pulses compared to the standard ORPHEUS model and a wider tuning range compared to the non-collinear ORPHEUS-N. Thus, for many scientific applications, ORPHEUS-F is the optimal choice.

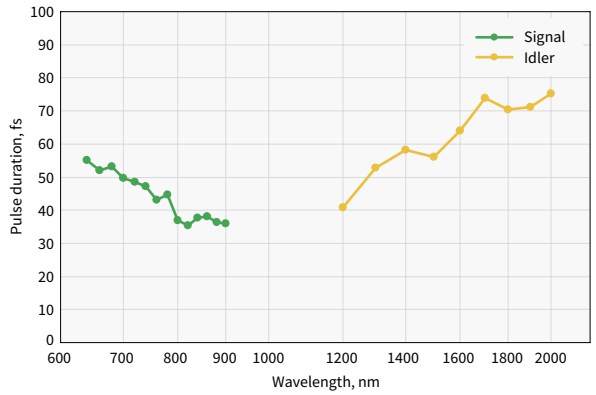


Typical tuning curves of **ORPHEUS-F**.
Pump: 40 W, 40 µJ, 1000 kHz

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



Typical spectral bandwidth of ORPHEUS-F



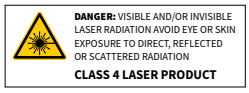
Pulse duration after compression of ORPHEUS-F

SPECIFICATIONS

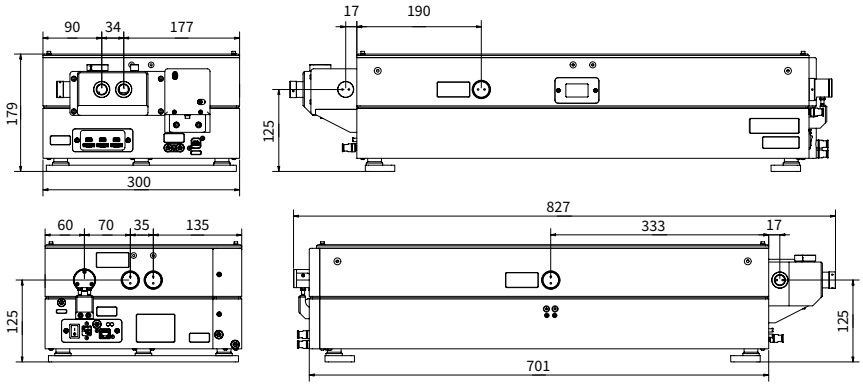
Model	ORPHEUS-F	
MAIN OUTPUT (650 – 900 nm and 1200 – 2500 nm)		
Mode of operation	Short pulse mode [1]	Long pulse mode
Tuning range	650 – 900 nm (Signal) 1200 – 2500 nm (Idler)	650 – 1010 nm (Signal) 1050 – 2500 nm (Idler)
Maximum pump power	80 W	
Pump pulse energy	10 – 500 µJ	
Conversion efficiency at peak [2]	> 10% (Signal and Idler combined)	
Integrated 2H (515 nm) generation efficiency [3]	> 35%	
Pulse duration before compression [1]	< 290 fs	
Spectral bandwidth	200 – 750 cm^{-1} @ 650 – 900 nm	75 – 220 cm^{-1} @ 650 – 900 nm
Pulse duration after compressor [1]	< 55 fs @ 800 – 900 nm < 70 fs @ 650 – 800 nm < 100 fs @ 1200 – 2000 nm	n/a
Compressor transmission	> 65% @ 650 – 900 nm > 80% @ 1200 – 2000 nm	
Long-term power stability, 8h [4]	< 2% @ 800 nm	
Pulse-to-pulse energy stability, 1 min [4]	< 2% @ 800 nm	

WAVELENGTH EXTENSION OPTIONS (325 – 15000 nm) [5]		
325 – 450 nm (SHS)	> 1%	n/a
325 – 505 nm (SHS)	n/a	> 1%
525 – 650 nm (SHI)		> 0.5%
600 – 650 nm (SHI)	> 0.5%	n/a
210 – 252 nm (FHS)	n/a	> 0.1%
263 – 325 nm (FHI)		> 0.1%
2500 – 15000 nm	See ORPHEUS-MIR *(page 34)*	

[1] In short pulse mode, broadband pulses are compressed externally. Typical pulse duration before compression: 120 – 250 fs, after compression: 25 – 70 fs @ 650 – 900 nm, 40 – 100 fs @ 1200 – 2000 nm.
[2] Specified as percentage of pump power.
[3] At designated output port; not simultaneous to OPA output.
[4] Expressed as NRMSD (normalized root mean squared deviation).
[5] For > 15 µJ pump pulse energy.



DRAWINGS



ORPHEUS-F drawings

ORPHEUS | MIR

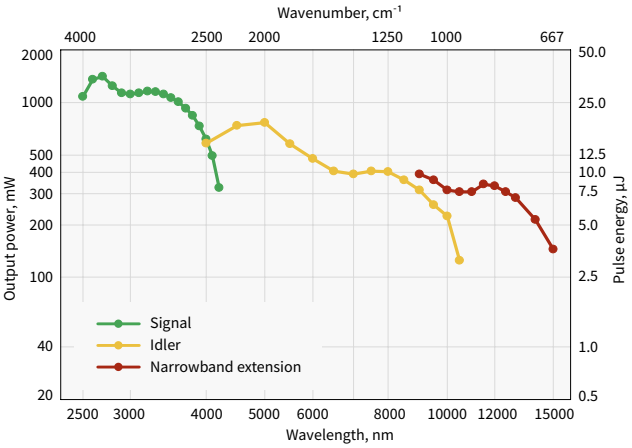
Broad-Bandwidth Mid-Infrared Optical Parametric Amplifier

FEATURES

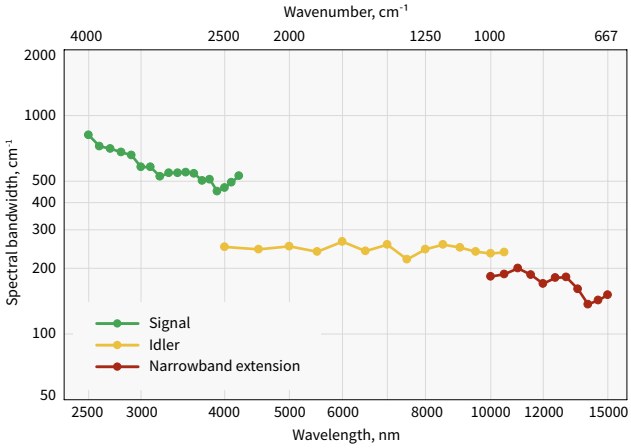
- Up to 800 cm^{-1} spectral bandwidth
- 2500 – 15 000 nm tuning range
- < 100 fs pulse duration
- Up to 400 kHz repetition rate
- Up to 80 W, 2 mJ pump
- Short-pulse high-energy output at 2000 nm
- Optimization for bandwidth
- CEP-stable option

ORPHEUS-MIR is an optical parametric amplifier (OPA) optimized for the efficient generation of broad-bandwidth MIR pulses. The laser system provides broadband pulses in the tuning range of 2.5 – 10 µm and reaches up to 15 µm with a narrow-bandwidth extension. Due to the novel system design, ORPHEUS-MIR provides < 100 fs pulses directly at the output. Signal and Idler outputs are available simultaneously. The system architecture is well-suited for high-energy and high-power PHAROS and CARBIDE femtosecond pump lasers.

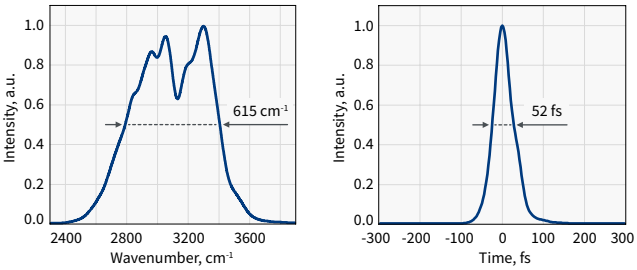
ORPHEUS-MIR serves as an excellent high-repetition-rate source for infrared spectroscopy such as broadband vibrational sum-frequency generation (SFG) spectroscopy. Combined with a narrow-bandwidth output of SHBC, it forms a compact laser system for SFG measurements, covering most of the MIR spectrum while also providing high spectral resolution. Furthermore, its high output stability is the key to fast and high-quality SFG imaging.



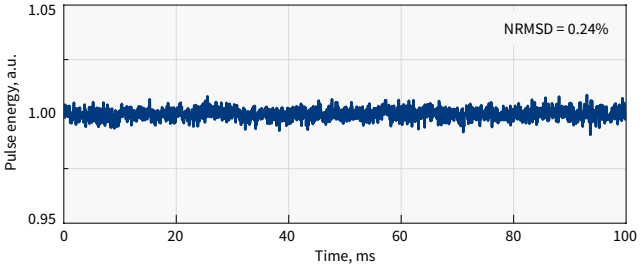
Typical tuning curves of **ORPHEUS-MIR**.
Pump: 80 W, 2 mJ, 40 kHz



Typical spectral bandwidth of **ORPHEUS-MIR**



Typical output spectrum (left) and pulse duration (right).
Measured at ≈ 3000 nm



Pulse-to-pulse energy stability of **ORPHEUS-MIR**.
Measured at ≈ 3000 nm

SPECIFICATIONS

Model	ORPHEUS-MIR	
MAIN OUTPUT (2 500 – 10 000 nm)		
Mode of operation	Standard	Optimized for bandwidth [1]
Tuning range	2 500 – 4 000 nm (Signal) 4 000 – 10 000 nm (Idler)	
Maximum pump power	80 W	
Pump pulse energy	200 µJ – 2 mJ	
Pulse duration	< 100 fs	
Conversion efficiency [2]	> 1.2% @ 3 000 nm > 1.0% @ 3 500 nm > 0.6% @ 5 000 nm	
	> 0.3% @ 9 000 nm	> 0.2% @ 9 000 nm
Spectral bandwidth [3]	> 300 cm^{-1} @ 2 500 – 4 000 nm > 200 cm^{-1} @ 4 000 – 8 000 nm	
	> 200 cm^{-1} @ 8 000 – 10 000 nm	> 350 cm^{-1} @ 8 000 – 10 000 nm
Long-term power stability, 8 h [4]	< 2% @ 5 000 nm	
Pulse-to-pulse energy stability, 1 min [4]	< 2% @ 5 000 nm	
AUXILIARY OUTPUT 1 (2 000 nm)		
Output wavelength [5]	2000 ± 100 nm	
Pulse duration	< 50 fs	
Conversion efficiency [2]	> 8%	
Spectral bandwidth	> 350 cm^{-1}	
AUXILIARY OUTPUT 2 (1 350 – 2 000 nm)		
Tuning range [6]	1 350 – 2 000 nm	
Pulse duration	< 300 fs	
Conversion efficiency [2]	Contact sales@lightcon.com	
Spectral bandwidth	60 – 150 cm^{-1}	
WAVELENGTH EXTENSION (10 000 – 15 000 nm)		
Tuning range	10 000 – 15 000 nm	
Pulse duration	< 300 fs	
Conversion efficiency [2]	> 0.2% @ 12 000 nm	
Spectral bandwidth	100 – 150 cm^{-1}	

[1] Optional mode of operation. Optimized for maximum spectral bandwidth at expense of conversion efficiency.

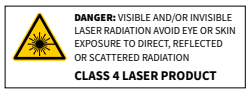
[2] Specified as a percentage of pump power.

[3] FWHM (full width at half maximum).

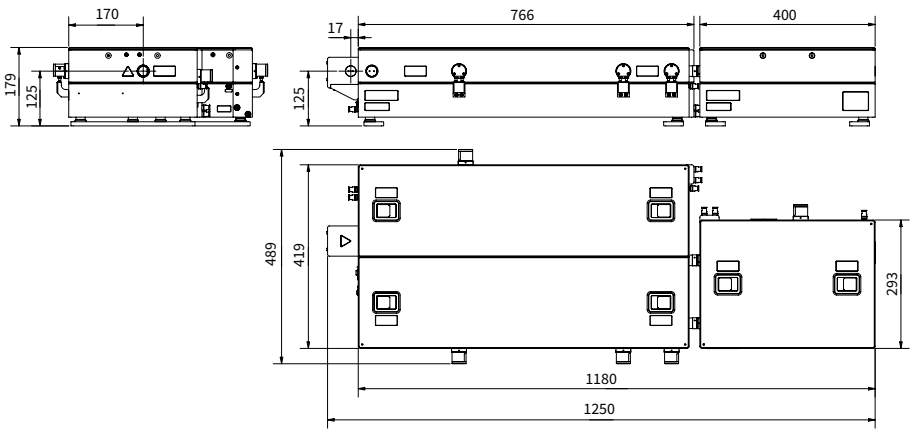
[4] Expressed as NRMSD (normalized root mean squared deviation).

[5] Not tunable, optimized for best overall performance. Not simultaneous to OPA output.

[6] Simultaneous to OPA output. Available on request.



DRAWINGS



ORPHEUS-MIR drawings

ORPHEUS | N

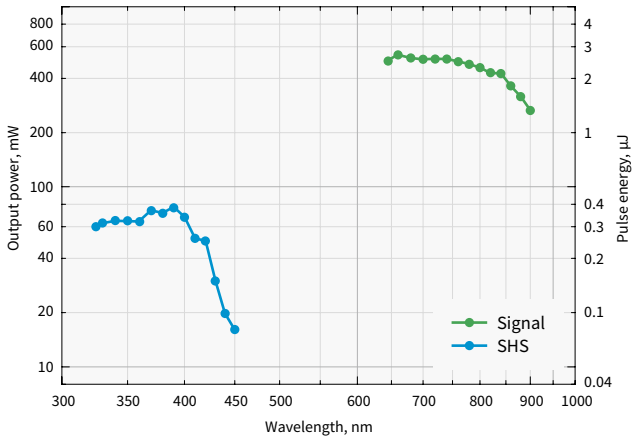
Non-Collinear Optical Parametric Amplifier

FEATURES

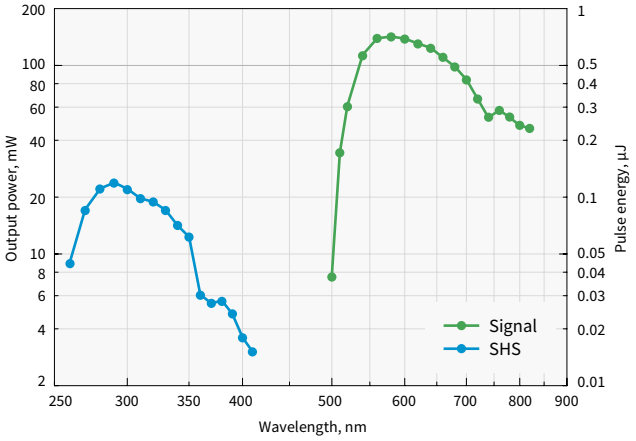
- < 30 fs pulse duration
- Integrated pulse compressor
- Adjustable spectral bandwidth and pulse duration
- Wavelength feedback with internal spectrometer

ORPHEUS-N is a non-collinear optical parametric amplifier (NOPA). Depending on the model, ORPHEUS-N has an integrated second- or third-harmonic generator producing a 515 nm or 343 nm pump, respectively. ORPHEUS-N with a second-harmonic pump (ORPHEUS-N-2H) delivers < 30 fs pulses in the 700 – 850 nm range. ORPHEUS-N with a third harmonic pump (ORPHEUS-N-3H) delivers < 30 fs pulses in the 530 – 670 nm range. An optional second harmonic generator is available, extending the tuning range down to ultraviolet (UV) spectral range.

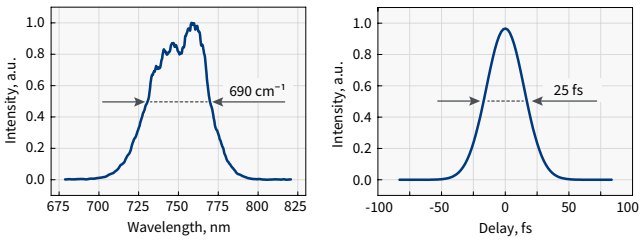
Featuring a built-in prism-based pulse compressor, ORPHEUS-N is an invaluable instrument for ultrafast spectroscopy and nonlinear microscopy. A single PHAROS or CARBIDE femtosecond laser can pump multiple NOPAs providing pump and/or probe channels with independent wavelength tuning for your state-of-the-art experiments.



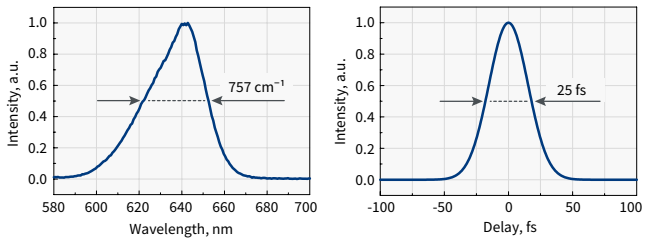
Typical tuning curves of **ORPHEUS-N-2H**
Pump: 6 W, 30 µJ, 200 kHz



Typical tuning curves 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 curves visit *http://toolbox.lightcon.com/tools/tuningcurves/*

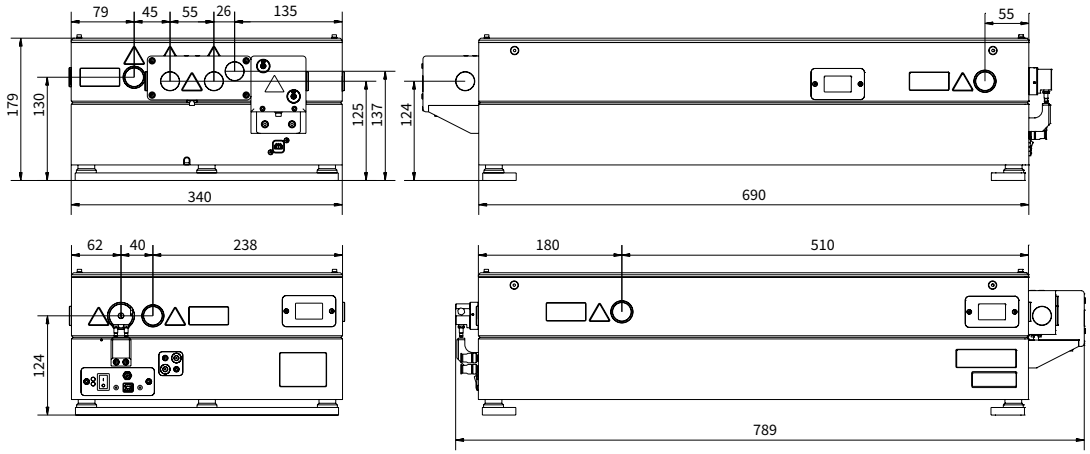
SPECIFICATIONS

Model	ORPHEUS-N-2H	ORPHEUS-N-3H
OUTPUT FROM ORPHEUS-N		
Tuning range	650 – 900 nm (Signal)	520 – 900 nm (Signal)
Maximum pump power	8 W	
Pump pulse energy	10 – 200 µJ	12 – 200 µJ
Conversion efficiency	< 7% @ 700 nm < 5% @ 800 nm	< 1.3% @ 580 nm < 0.7% @ 700 nm < 0.3% @ 800 nm
Integrated 2H / 3H generation efficiency [1]	> 35% (515 nm)	> 25% (343 nm)
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]	< 2% @ 800 nm	< 2% @ 580 nm
Pulse-to-pulse energy stability, 1 min [2]	< 2% @ 800 nm	< 2% @ 580 nm
WAVELENGTH EXTENSIONS		
Tuning range (SHS)	325 – 450 nm	260 – 450 nm
Conversion efficiency at peak	> 10% of Signal	

[1] *Not simultaneous to NOPA output.*
[2] *Expressed as NRMSD (normalized root mean squared deviation).*

DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT

DRAWINGS



ORPHEUS-N drawings

ORPHEUS | TWINS

Dual Optical Parametric Amplifier

FEATURES

- Two simultaneous and independent outputs
- 210 – 16000 nm tuning range
- Single-shot – 2 MHz repetition rate
- Up to 60 W pump power
- Up to 0.5 mJ pump pulse energy
- CEP-stable option

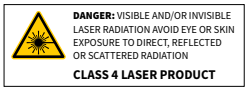
ORPHEUS-TWINS consists of two independently tunable optical parametric amplifiers (OPAs); thus, providing two simultaneous outputs. Integrated into a single housing, both OPAs share the same white-light seed enabling the generation of broadband mid-infrared (MIR) radiation with a passively stable carrier-envelope phase (CEP).

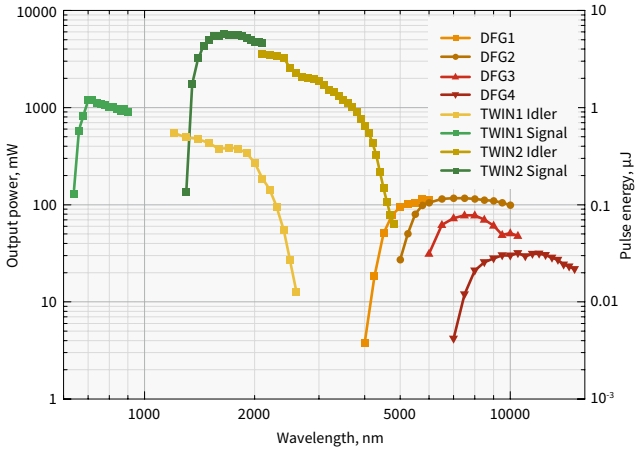
Each of the OPA can be separately configured to be a version of ORPHEUS, ORPHEUS-F, or ORPHEUS-ONE. Check the respective models for more information and detailed specifications.

SPECIFICATIONS

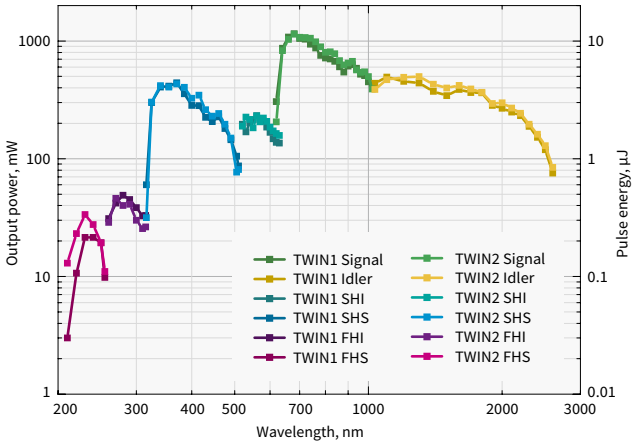
Model	**ORPHEUS-TWINS**
OUTPUT FROM ORPHEUS-TWINS	
Tuning range	Choice between ORPHEUS, ORPHEUS-F, and ORPHEUS-ONE configurations
Output pulse energy	Depends on the configuration, see the specifications of the chosen models
Spectral bandwidth	Depends on configuration, 100 – 750 cm^{-1}
Pulse duration	Depends on configuration, down to 40 fs
Supported repetition rates	Single-shot – 2 MHz
PUMP LASER REQUIREMENTS	
Required pump laser	PHAROS or CARBIDE
Center wavelength	1030 ± 10 nm
Maximum pump power	60 W
Repetition rate	Single-shot – 2 MHz
Pump pulse energy [1)]	16 – 500 µJ
Pulse duration [2)]	180 – 300 fs

[1)] Up to 2 mJ on request.
[2)] FWHM, assuming Gaussian pulse shape.





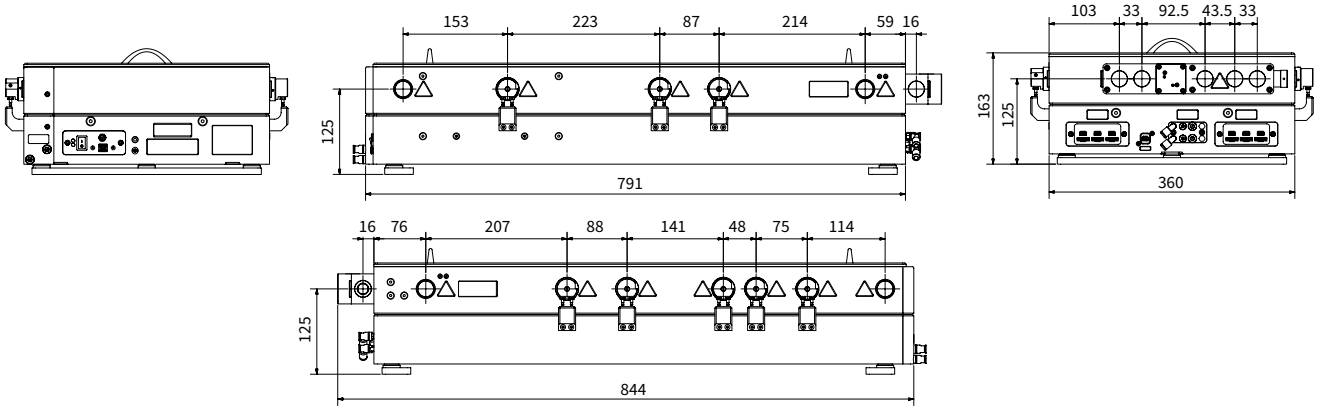
ORPHEUS-TWINS (ONE / F configuration)
tuning curves. Pump: 40 W, 40 µJ, 1 000 kHz



ORPHEUS-TWINS (ORPHEUS / ORPHEUS configuration)
tuning curves. Pump: 20 W, 20 µJ, 100 kHz

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

DRAWINGS



ORPHEUS-TWINS drawings

ORPHEUS | PS

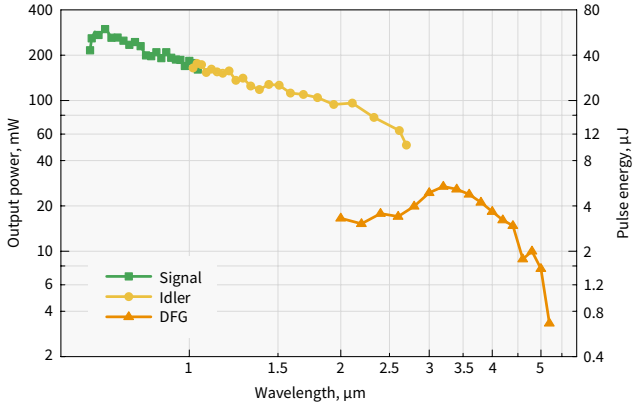
Narrow-Bandwidth Optical Parametric Amplifier

FEATURES

- 210 – 4800 nm tuning range
- 1 – 4 ps pulse duration
- < 20 cm^{-1} spectral bandwidth
- Nearly bandwidth-limited output
- Up to 100 kHz repetition rate
- High output stability

ORPHEUS-PS is a narrow-bandwidth optical parametric amplifier, designed for PHAROS and CARBIDE lasers. ORPHEUS-PS is pumped by the picosecond pulses produced in a second harmonic bandwidth compressor SHBC and is seeded by a white-light continuum generated by femtosecond pulses. This enables very high pulse-to-pulse stability compared to other methods of generating tunable picosecond pulses. The white-light generation module is integrated into the same housing as the amplification, enabling high long-term stability and ease of use. The system also features high conversion efficiency, bandwidth- and diffraction-limited output, and complete computer control.

Part of the laser radiation can be split to simultaneously pump a femtosecond OPA, providing broad-bandwidth 630 nm – 16 µm tunable pulses, giving access to the set of beams necessary for versatile spectroscopy applications such as femtosecond stimulated Raman spectroscopy (FSRS) and sum-frequency generation (SFG) spectroscopy.

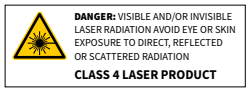


Orpheus-PS tuning curves.
Pump: 5 W, 1000 µJ, 5 kHz from PHAROS-SP.

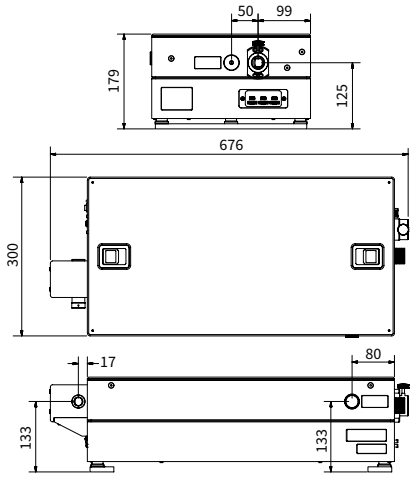
SPECIFICATIONS

Model	ORPHEUS-PS
MAIN OUTPUT	
Tuning range	640 – 1000 nm (Signal) 1060 – 2600 nm (Idler)
Conversion efficiency at peak	> 8% (Signal and Idler combined)
Pulse duration	800 fs – 3 ps
Spectral bandwidth	< 20 cm^{-1} @ 700 – 2000 nm
Pulse-to-pulse energy stability [1]	< 2% @ 700 – 960 nm, 1100 – 1500 nm
AUXILIARY OUTPUT 1 (515 nm)	
Wavelength [2]	515 nm ± 5 nm
Generation efficiency [3]	> 15%
AUXILIARY OUTPUT 2 (1030 nm)	
Wavelength [4]	1030 ± 10 nm
Pulse duration	< 300 fs
Pulse energy	> 5 µJ
WAVELENGTH EXTENSION	
SH package at peak (320 – 500 nm (SHS), 530 – 640 nm (SHI))	> 3%
FH package at peak (210 – 250 nm (FHS), 265 – 320 nm (FHI))	> 0.3% [5]
2400 – 4800 nm (DFG)	> 0.25% @ 3200 nm [5]
PUMP LASER REQUIREMENTS	
Pump source	PHAROS or CARBIDE with uncompressed output option
Wavelength	1030 nm
Repetition rate	Single-shot – 100 kHz
Maximum pump power	20 W
Pump pulse energy	100 µJ – 3.2 mJ

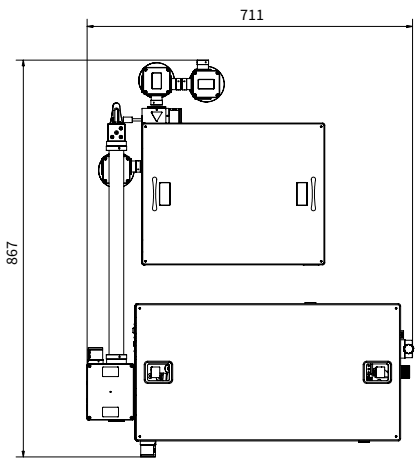
[1] Expressed as NRMSD (normalized root mean squared deviation).
[2] Direct SHBC output, not simultaneous to OPA; see details in SHBC specifications.
[3] Specified as percentage of pump pulse energy.
[4] Compressed pump output.
[5] For > 200 µJ pump pulse energy.



DRAWINGS



ORPHEUS-PS drawings



ORPHEUS-PS with SHBC drawing

TOPAS

Optical Parametric Amplifiers for Ti:Sapphire Lasers

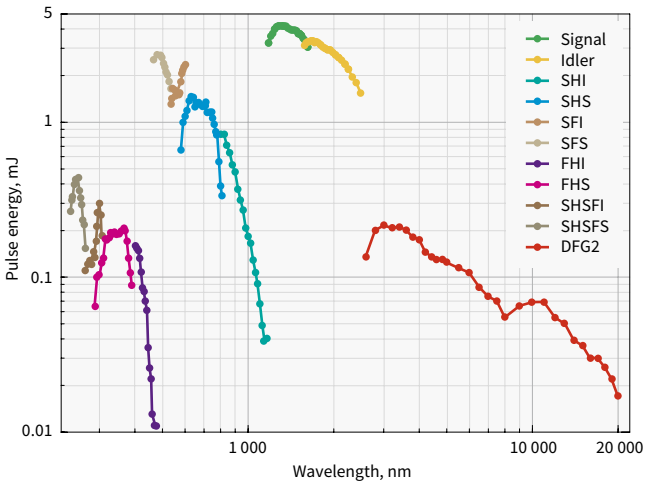
TOPAS is a series of femtosecond optical parametric amplifiers (OPAs) for Ti:Sapphire lasers which delivers continuous wavelength tunability from 189 nm to 20 µm, high conversion efficiency, high output stability, and full computer control. With more than 2000 units installed worldwide, TOPAS has become an OPA market leader for numerous scientific applications. TOPAS can be pumped by Ti:Sapphire lasers with pulse duration from 20 fs to 200 fs and pulse energy from 15 µJ to 60 mJ. Custom solutions beyond the given specifications are available; contact sales@lightcon.com for more details.

TOPAS | PRIME-HE

High Energy Optical Parametric Amplifier

FEATURES

- 189 nm – 20 µm tuning range
- Up to 60 mJ pump pulse energy
- Up to 50% conversion efficiency
- High output stability
- CEP stabilization of Idler
- Fresh pump channel for improved temporal and spatial properties of sum-frequency options



TOPAS-PRIME-HE tuning curves. Pump: 22 mJ, 45 fs, 805 nm

TOPAS-PRIME-HE is a high-energy femtosecond optical parametric amplifier based on TOPAS-PRIME with an additional high energy and low dispersion amplification stage which allows using pump pulse energy of up to 60 mJ while maintaining the shortest possible pulses at the output.

The standard TOPAS-PRIME-HE model accepts pump pulse energy of up to 8 mJ @ 35 fs (up to 20 mJ @ 100 fs), while TOPAS-PRIME-HE-PLUS accepts higher pump pulse energy, up to 18 mJ @ 35 fs (up to 47 mJ @ 100 fs). The pump pulse energy of 60 mJ is possible with longer pulses, ca. 150 fs. Both models come with wavelength extension options, covering the wavelength range from 189 nm to 20 µm for TOPAS-PRIME-HE and 240 nm to 20 µm for TOPAS-PRIME-HE-PLUS.

TOPAS | PRIME

Collinear Optical Parametric Amplifier

FEATURES

- 189 nm – 20 µm tuning range
- Up to 5 mJ pump pulse energy
- > 25% conversion efficiency
- High output stability
- CEP stabilization of Idler
- Fresh pump channel for improved temporal and spatial properties of sum-frequency options

TOPAS-PRIME is a collinear femtosecond optical parametric amplifier designed for Ti:sapphire lasers. The standard TOPAS-PRIME model accepts pump pulse energy of up to 3.5 mJ @ 35 fs (up to 4 mJ @ 100 fs), while TOPAS-PRIME-PLUS accepts higher pump pulse energy, up to 5 mJ @ 35 – 100 fs. Both models come with wavelength extension options, covering a wavelength range from 189 nm to 20 µm.

TOPAS | SHBC-400

Narrow-Bandwidth Optical Parametric Amplifier

FEATURES

- Femtosecond pulse conversion to < 20 cm^{-1} spectral bandwidth
- 240 nm – 10 µm tuning range
- Up to 4 mJ pump pulse energy
- High output stability

TOPAS-SHBC-400 combines a second harmonic bandwidth compressor (SHBC) and an optical parametric amplifier (OPA) for the generation of tunable pulses with a spectral bandwidth of 3 – 20 cm^{-1} when pumped by femtosecond pulses with a spectral bandwidth of 150 – 500 cm^{-1}. The device is designed to be pumped by a fundamental harmonic of a femtosecond Ti:Sapphire laser and covers a wavelength range from 480 to 2400 nm.

Optional frequency mixers extend the tuning range down to 240 nm and up to 10 µm.

TOPAS | TWINS

Dual Optical Parametric Amplifier

FEATURES

- Two independently tunable outputs
- 240 nm – 20 µm tuning range, in each channel
- > 25% conversion efficiency
- High output stability

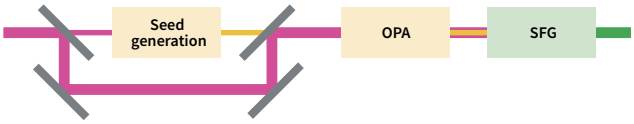
TOPAS-TWINS consists of two independently tunable optical parametric amplifiers (OPAs) integrated into a single housing. Both OPAs share the same white light source to provide excellent stability of both outputs, and CEP stabilized MIR pulses in a tuning range of 4.5 – 15 µm.

Both OPAs come with wavelength extension options, covering the wavelength range from 240 nm to 20 µm. Output specifications for each OPA are the same as those of TOPAS-PRIME. The maximum pump pulse energy depends on the pulse duration; see the specifications for more details.

FRESH PUMP OPTION

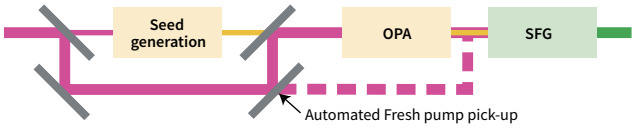
TOPAS-PRIME option for sum-frequency generation (SFG) in 475 – 580 nm range.

DEPLETED PUMP OPTION

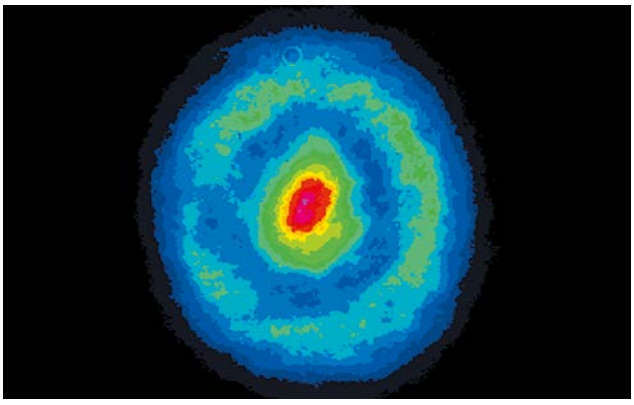


Optical scheme with depleted pump for SFG

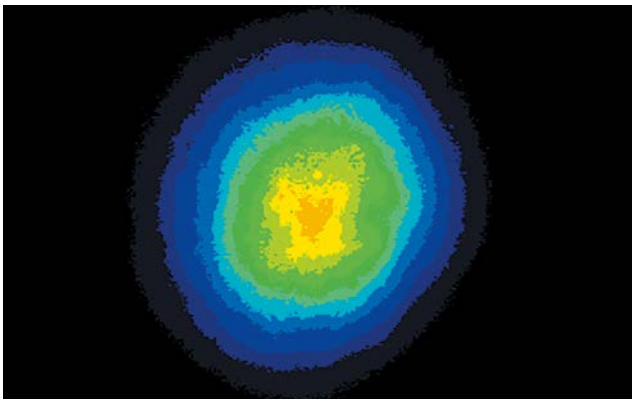
FRESH PUMP OPTION



Optical scheme with fresh pump for SFG



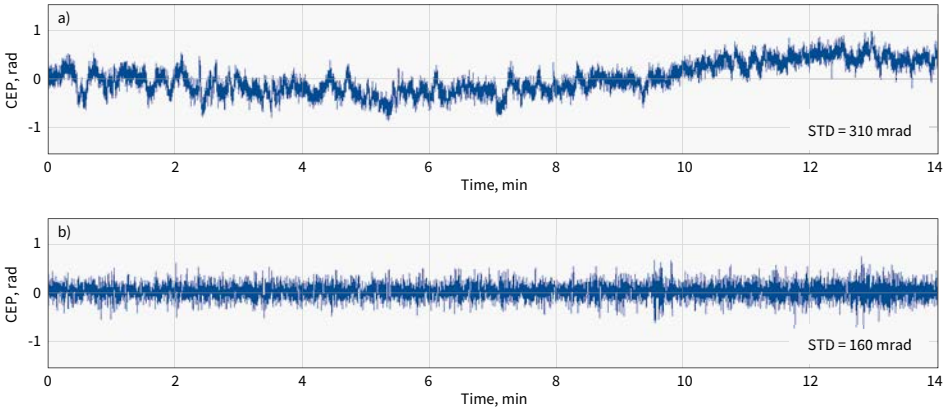
SFG output beam profile using depleted pump



SFG output beam profile using fresh pump

CEP STABILIZATION OF IDLER

TOPAS Idler (1600 – 2600 nm) is passively CEP locked due to a three-wave interaction. However, a slow CEP drift may persist because of changes in pump beam pointing or environmental conditions. Such a drift can be compensated by employing an f-2f interferometer and a feedback loop controlling the temporal delay between seed and pump in the power amplification stage of TOPAS-PRIME and TOPAS-PRIME-HE.



CEP stability of Idler over 14 min.
(a) without compensation of drift, (b) with compensation of drift with a slow loop

NIRUVIS

Frequency Mixer for TOPAS

FEATURES

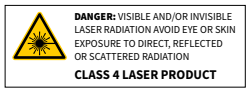
- Automated wavelength tuning and separation
- Wavelength extension down to 189 nm
- Controlled output beam polarization
- High output pulse contrast
- High conversion efficiency

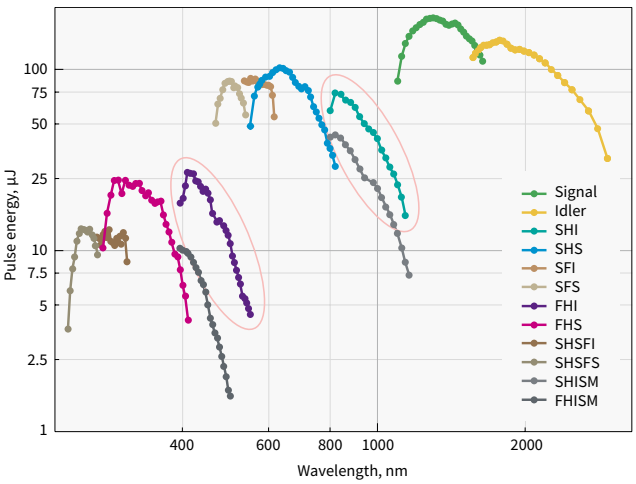
NIRUVIS is a frequency mixer for TOPAS-PRIME and TOPAS-PRIME-HE. It consists of three automated nonlinear crystal stages in a monolithic housing. The output is generated by a second and fourth harmonic generation as well as sum-frequency generation. In contrast to free-standing frequency mixers, NIRUVIS offers high conversion efficiency, simple operation, compact design, and low environmental sensitivity. Furthermore, wavelength separation after each nonlinear interaction ensures high output pulse contrast.

SPECIFICATIONS

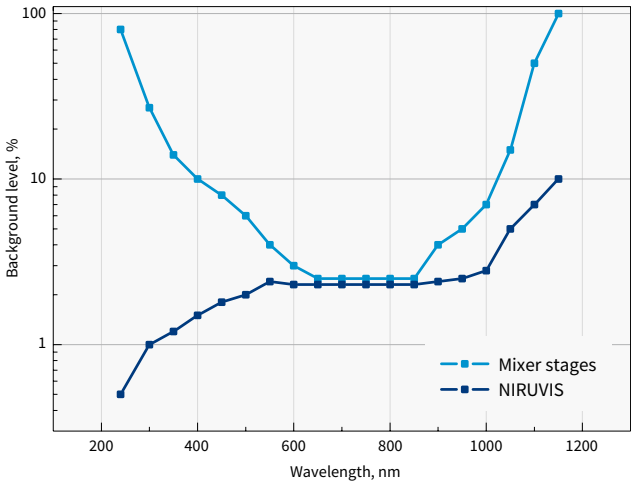
Model	Automated NIRUVIS	Standard NIRUVIS	NIRUVIS-DUV
Maximum tuning range	240 – 1160 nm		189 – 1160 nm
Type of tuning	Fully automated	Manual, using wavelength separators	
Number of output ports	Single output port for all wavelengths	4 output ports (wavelength-dependent)	
Fresh pump option [1]	Included	Optional	Included

[1] *See page 44 for details.*





Tuning curves of TOPAS-PRIME with fresh pump option and NIRUVIS (SHISM and FHISM achieved with separate mixing stages). Pump: 1 mJ, 100 fs, 800 nm.



Background level comparison between NIRUVIS and separate mixing stages

OPCPA

Optical Parametric Chirped-Pulse Amplification Systems

FEATURES OVERVIEW

- Shortest pulses, extreme peak and average powers
- 800 nm – 3 µm wavelengths
- TW-level peak power
- Down to 6 fs pulse duration
- 10 Hz – 1 MHz repetition rate
- < 250 mrad CEP stability

Optical parametric chirped-pulse amplification (OPCPA) 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. Our answer to these demands is a portfolio of cutting-edge OPCPA products based on years of experience in developing and manufacturing optical parametric amplifiers and femtosecond lasers.

OPCPA system delivering 5.5 TW peak power (6.6 fs, 36 mJ) pulses.
Built for ELI-ALPS in collaboration with Ekspla.

ORPHEUS | OPCPA

Compact, Few-cycle, CEP-stable OPCPA Systems

FEATURES

- < 6 fs transform-limited pulse duration
- Up to 1 MHz repetition rate
- Up to 320 W pump power
- Up to 8 mJ pump pulse energy
- CEP stabilization option
- Compact footprint

Benefiting from the industrial-grade stability and reliability of the PHAROS and CARBIDE lasers, ORPHEUS-OPCPA delivers few-cycle, CEP-stable pulses in a package as compact as our standard parametric amplifiers. All of the ORPHEUS-OPCPA models use the same base architecture to produce CEP-stable, few-cycle pulses in one of the four center wavelengths: 800 nm, 1600 nm, 2000 nm, and 3000 nm. ORPHEUS-OPCPA is available in versions with pulse compressors for direct use in applications or in versions intended as seed sources, delivering background-free pulses with near-single-cycle bandwidths, excellent spectral phase coherence, and CEP stability.

By using bundled CARBIDE or PHAROS lasers, pump power of up to 320 W and pump pulse energy of up to 8 mJ is accessible. The use of other pump sources for higher power, such as thin-disk or innoslab lasers, is available upon request.

SPECIFICATIONS

Model	ORPHEUS-OPCPA			
Center wavelength	800 nm	1600 nm	2000 nm	3000 nm
Pump source [1]	PHAROS / CARBIDE			
Pump power [1]	20 – 320 W			
Pump pulse energy [1]	0.2 – 8 mJ			
Repetition rate	1 kHz – 1 MHz			
Conversion efficiency [2]	> 7%	> 10%	> 9%	> 6%
Pulse duration [2]	< 10 fs	< 40 fs	< 25 fs	< 45 fs
Transform-limited pulse duration [2] [3]	< 6 fs	< 30 fs	< 15 fs	< 35 fs
CEP stability, 1h [2] [4]	< 250 mrad			
Long-term power stability, 8 h [2] [5]	< 1.5%			
Pulse-to-pulse energy stability, 1 min [2] [5]	< 1.5%			

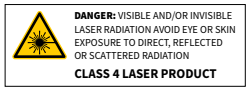
[1] *For using other pump sources, such as thin-disk or innoslab lasers, contact sales@lightcon.com.*

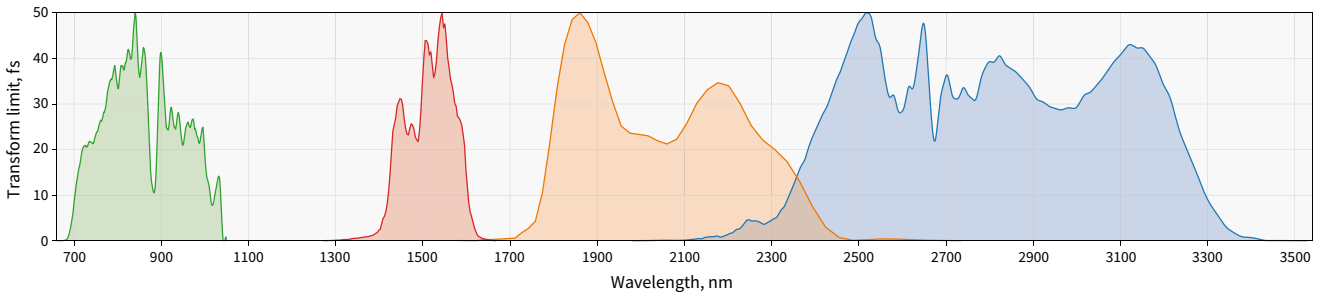
[2] *Typical values. For custom inquiries, contact sales@lightcon.com.*

[3] *Uncompressed, for seeding larger amplifiers.*

[4] *CEP values calculated from unaveraged, single-shot measurements.*

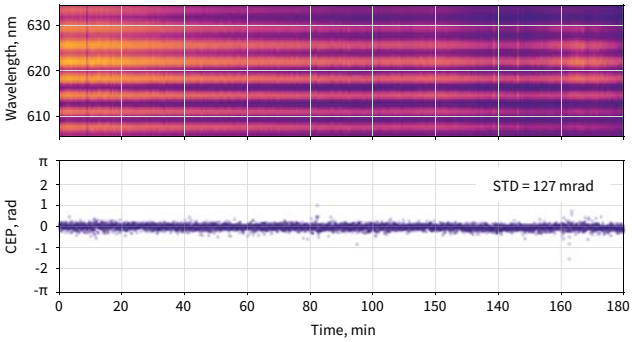
[5] *Expressed as normalized root mean squared deviation (NRMSD).*





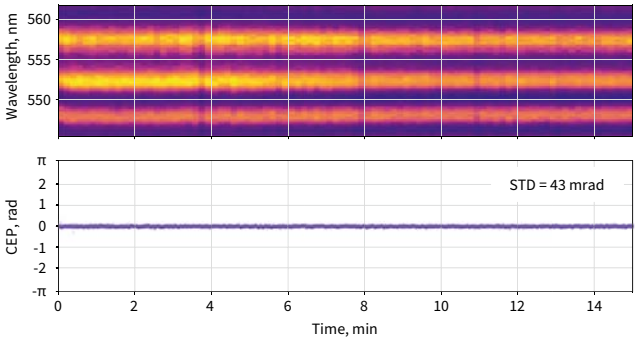
Example spectra of four models of ORPHEUS-OPCPA

STABILITY



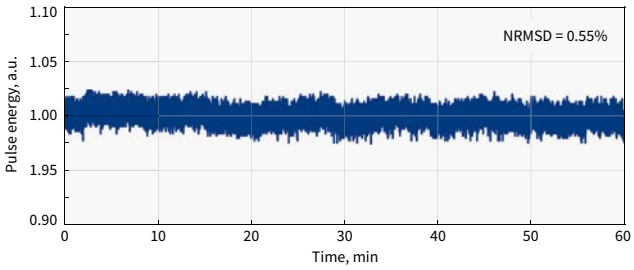
CEP stability of ORPHEUS-OPCPA (800 nm, 100 kHz)

All CEP values calculated from unaveraged, single-shot measurements!

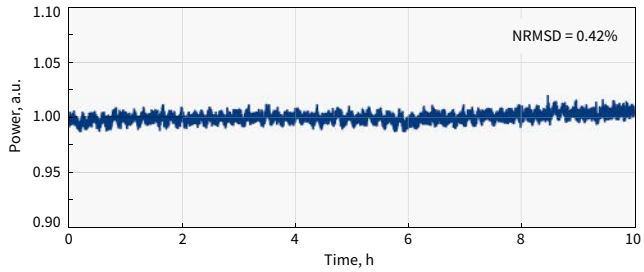


CEP stability of ORPHEUS-OPCPA (3 µm, 1 kHz)

All CEP values calculated from unaveraged, single-shot measurements!



Pulse-to-pulse energy stability of ORPHEUS-OPCPA at 800 nm



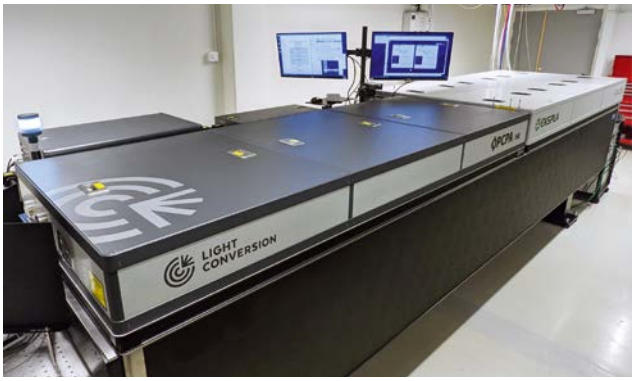
Long-term output stability of ORPHEUS-OPCPA at 800 nm

OPCPA | HE

High-Energy OPCPA Systems

FEATURES

- Multi-TW peak-power pulses at up to 1 kHz
- > 10^{12} pre-pulse contrast
- < 250 mrad CEP stability
- < 1.5% pulse energy stability
- < 9 fs pulse duration
- < 1-hour warm-up time
- Spectral–temporal output pulse shaping options



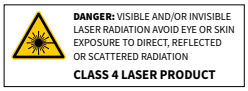
Applications like high-energy attosecond pulse generation, generation of high harmonics from solid targets, and laser electron acceleration all benefit from few-cycle pulse durations and excellent pulse contrast while requiring multi-millijoule pulse energy. Our most powerful high energy OPCPA systems are scalable to multi-TW peak powers at kHz repetition rates while maintaining few-cycle pulse durations. Thus, they fit the most demanding requirements while providing stability and reliability unprecedented for systems of this scale.

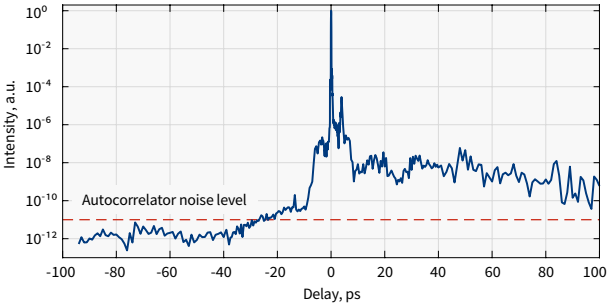
Furthermore, > 10^{12} pre-pulse contrast is obtained without complex and lossy nonlinear pulse cleaning techniques, while < 250 mrad CEP stability and < 1.5% pulse energy stability are maintained throughout a full day of operation, making it a robust and reliable multi-TW system.

SPECIFICATIONS

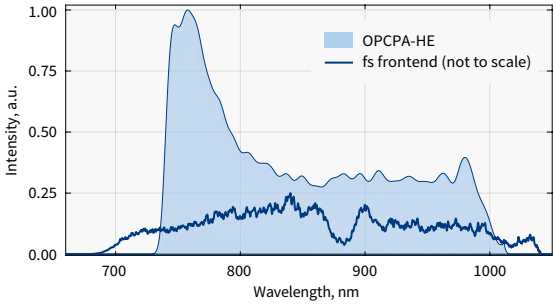
Model	OPCPA-HE		
Center wavelength	800 nm	1600 nm	2000 nm
Pump source	Picosecond Nd:YAG lasers, seeded by ORPHEUS-OPCPA		
Repetition rate	10 Hz – 1 kHz		
Maximum output pulse energy [1]	120 mJ	100 mJ	50 mJ
Pulse duration [1]	< 9 fs	< 50 fs	< 30 fs
CEP stability, 1h [1] [2]	< 250 mrad		
Long-term power stability, 8 h [1] [3]	< 1.5%		
Pulse-to-pulse energy stability, 1 min [1] [3]	< 1.5%		

[1] *Typical values. For custom inquiries, contact sales@lightcon.com.*
[2] *CEP values calculated from unaveraged, single-shot measurements.*
[3] *Expressed as as normalized root mean squared deviation (NRMSD).*

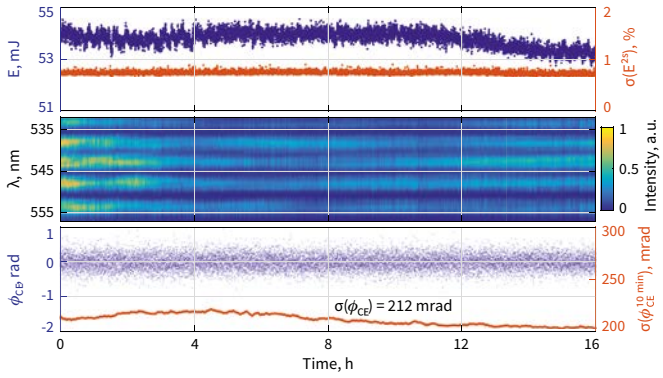




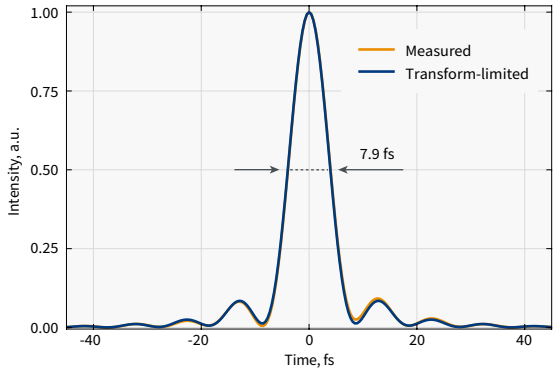
High-dynamic-range third order autocorrelation measurement of an OPCPA-HE system



OPCPA-HE output spectrum



OPCPA-HE pulse energy, f-2f interferogram and CEP stability measured over 16 h



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

HARPIA

Comprehensive Spectroscopy System

The HARPIA comprehensive spectroscopy system performs a variety of sophisticated time-resolved spectroscopic measurements in a compact footprint. It offers an intuitive user experience and easy day-to-day maintenance meeting the needs of today's scientific applications. Extension modules and customization options tailor the HARPIA system to specific measurement needs.

The system is built around the HARPIA-TA transient absorption spectrometer and can be expanded using time-correlated single-photon counting and fluorescence upconversion (HARPIA-TF), third beam delivery (HARPIA-TB), and microscopy (HARPIA-MM) modules. HARPIA is designed for easy switching between measurement modes and comes with dedicated data acquisition and analysis software. Each module is contained in a monolithic aluminum body ensuring excellent optical stability and minimal optical path lengths.

For a single-supplier solution, the HARPIA spectroscopy system is combined with a PHAROS or a CARBIDE laser together with ORPHEUS series OPAs. HARPIA also supports Ti:sapphire lasers with TOPAS series OPAs.

APPLICATIONS

- Transient absorption and reflection in bulk and microscopy modes
- Multi-pulse transient absorption and reflection
- Femtosecond fluorescence upconversion
- Picosecond-to-microsecond fluorescence TCSPC
- Femtosecond stimulated Raman scattering (FSRS)
- Intensity-dependent transient absorption and reflection
- Flash photolysis
- Z-scan

HARPIA | TA

Ultrafast Transient Absorption Spectrometer

FEATURES

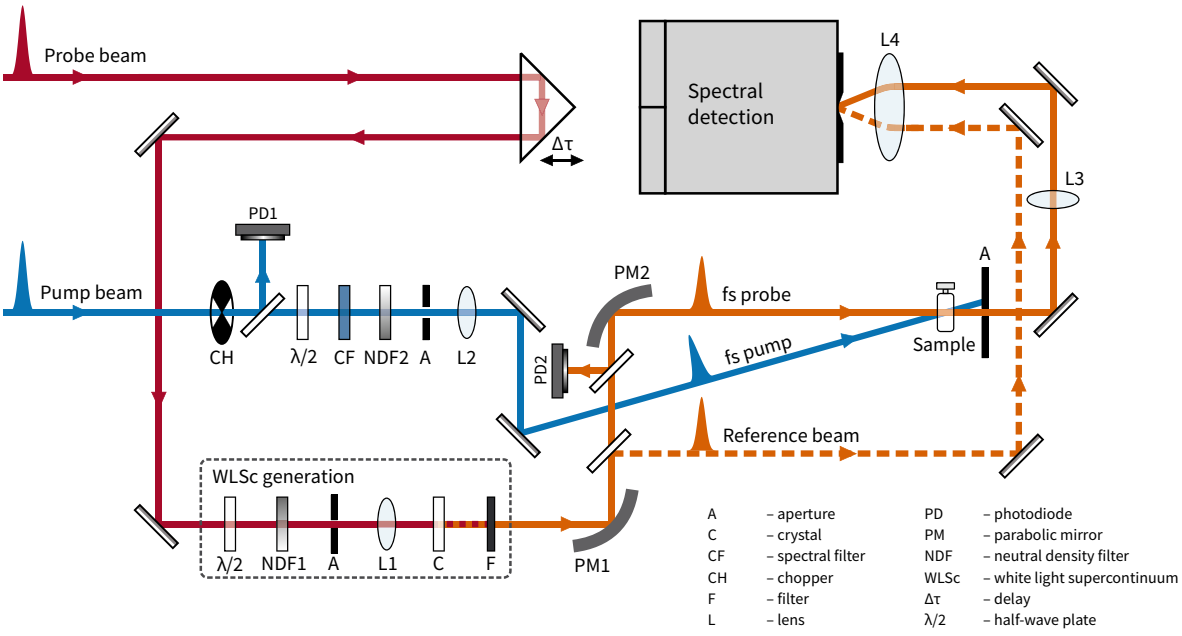
- Market-leading sensitivity
- 330 nm – 24 µm spectral range
- Probe delay ranges from 2 ns to 8 ns
- Pump pulse energies down to nJ
- Cryostat and peristaltic pump support

The HARPIA-TA ultrafast transient absorption spectrometer provides pump-probe measurement functionality in a HARPIA system. Several probe light configurations and detection options are available: from a photodiode for single-wavelength detection to white-light supercontinuum probing combined with spectrally-resolved broadband detection. HARPIA-TA features extensive automation options providing pump and probe beam position tracking and alignment, pump polarization control, supercontinuum generator switching, sample positioning, as well as switching between transient absorption and transient reflection measurements.

Broadband probe options cover a 330 – 1600 nm range, while a monochromatic probe can be used up to 24 µm. The probe delay stage is configurable from 2 ns to 8 ns.

HARPIA-TA features market-leading sensitivity of 0.05 mOD (10^{-4} ΔT/T) and can be operated at high repetition rates of up to 1 MHz when used with a PHAROS or CARBIDE laser and an ORPHEUS series OPA, which allows the study of transient absorption dynamics with excitation pulse energies down to several nanojoules.

HARPIA-TA is compatible with cryostats and peristaltic pumps, and the capabilities of the spectrometer are extendable using expansion modules.



HARPIA-TA optical layout for pump-probe experiments

SPECIFICATIONS

Model	HARPIA-TA			
PUMP–PROBE SPECIFICATIONS				
Configuration	UV / VIS / NIR / SWIR			MIR
Probe excitation wavelength	1030 nm	515 nm	800 nm	n/a [1]
Probe spectral range	460 – 1600 nm	350 – 750 nm	330 – 1400 nm	190 nm – 16000 nm [2]
Detection spectral range	200 – 1100 nm / 900 – 1700 nm / 900 – 2600 nm			2 – 13 µm [3]
Delay range	2 ns / 4 ns / 8 ns			
Delay resolution	2.1 fs / 4.2 fs / 8.3 fs			
Laser repetition rate	1 – 1000 kHz			
Temporal resolution	< 1.4× pump or probe pulse duration, whichever is longer			
Maximum data acquisition rate	4000 spectra/s			–
SNR [4]	250 : 1			–
OPTIONAL FLASH PHOTOLYSIS EXTENSION				
Delay resolution	100 ps			
Temporal resolution	2 ns			
SNR [5]	40 : 1			
DIMENSIONS				
Physical dimensions (L × W × H) [6]	730 × 420 × 160 mm			
Internal sample chamber area (L x W) [7]	205 × 216 mm			

[1] *A wavelength-tunable source such as ORPHEUS-HP is used instead of a laser-excited white-light continuum.*

[2] *An extended tuning range of ORPHEUS-HP. Also applicable to UV / VIS / NIR / SWIR configuration.*

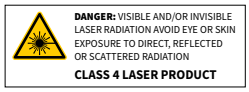
[3] *Up to 24 µm available upon request; contact sales@lighton.com for more details.*

[4] *Estimated as the standard deviation of a set of 2500 spectra measured in SCHOTT OG530 glass with 54 nJ, 370 nm pump and > 4.5 mOD at a maximum of the spectrum. Not applicable to all samples and configurations.*

[5] *Estimated as the standard deviation of a set of 2000 spectra measured in SCHOTT OG530 glass with 515 nm pump and > 10 mOD at a maximum of the spectrum. Not applicable to all samples and configurations.*

[6] *Without external spectrograph.*

[7] *External sample placement option is available.*

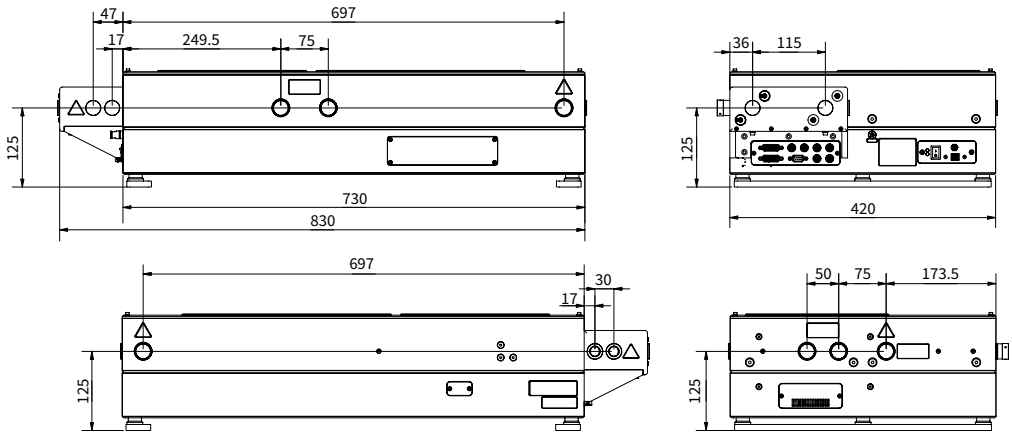


CRYOSTAT MOUNTING OPTION

HARPIA-TA supports cryostats that can be mounted externally or internally. For more details, contact sales@lightcon.com.

Internal cryostat mounting option

DRAWINGS



HARPIA-TA drawings

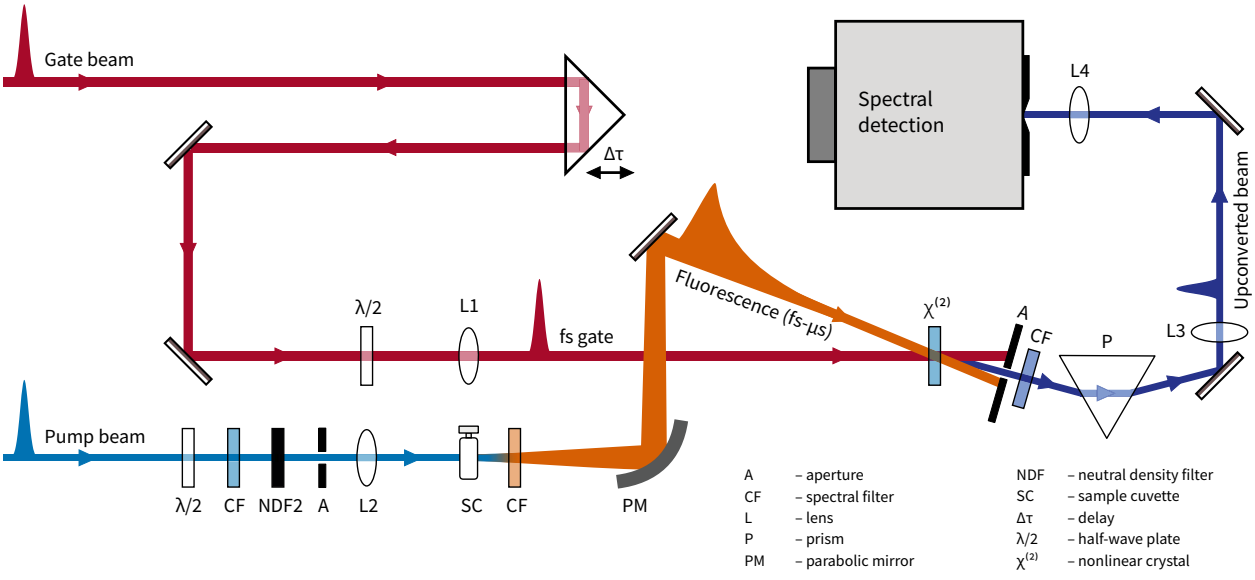
HARPIA | TF

Femtosecond Fluorescence Upconversion and TCSPC Module

FEATURES

- Femtosecond-to-microsecond measurements
- Automated switching between fluorescence upconversion and TCSPC
- Automated spectral scanning and calibration
- Optional operation as a stand-alone unit

The HARPIA-TF is a time-resolved fluorescence measurement module that combines fluorescence upconversion and TCSPC techniques. In fluorescence upconversion, the signal from the sample is mixed in a nonlinear crystal with a gating femtosecond pulse to achieve high temporal resolution, which is limited by the duration of the gate and pump pulses. For fluorescence decay times in the nanosecond to microsecond range, the instrument can be used in time-correlated single-photon counting (TCSPC) mode to measure kinetic traces up to 5 µs. The combination of the two methods enables the measurement of spectrally-resolved fluorescence decay in the femtosecond to microsecond range. Using a high repetition rate PHAROS or CARBIDE laser, the fluorescence dynamics can be measured while exciting the samples with pulse energies down to several nanojoules.

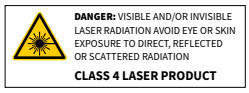


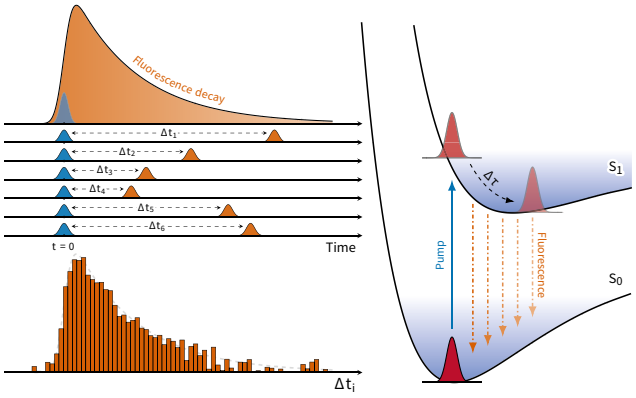
HARPIA optical layout for fluorescence upconversion measurements

SPECIFICATIONS

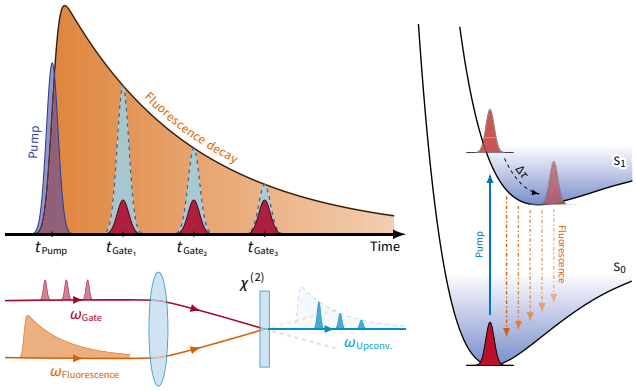
Model	HARPIA-TF	
UPCONVERSION MODE		
Spectral range [1]	300 – 1600 nm	
Spectral resolution [2]	≈ 100 cm^{-1}	
Delay range	2 ns / 4 ns / 8 ns	
Delay resolution	2.1 fs / 4.2 fs / 8.3 fs	
Temporal resolution	< 1.4× pump or gate pulse duration, whichever is longer	
SNR [3]	65 : 1	
TCSPC MODE		
Spectral range [4]	320 – 820 nm	
TCSPC detector [5]	Standard	High-speed
Temporal resolution	< 180 ps	< 50 ps
Maximum measurement range [6]	5 µs	
SNR [7]	100 : 1	
DIMENSIONS		
Physical dimensions (L × W × H) [8]	571 × 275 × 183 mm	

1) *Depends on the gating source, full range covered with different nonlinear crystals.*
2) *Limited by the spectral bandwidth of the gating pulse.*
3) *Estimated as the standard deviation of a set of 100 points at 50 ps intervals measured in Rhodamine 6G dye at an upconverted wavelength of 360 nm using a PHAROS laser running at 150 kHz repetition rate; assuming 0.5 s averaging per point. Not applicable to all samples and configurations.*
4) *Different models available; contact sales@lightcon.com for details.*
5) *Spectral range is extendable to NIR; contact sales@lightcon.com for details.*
6) *Maximum measurement range can be extended with a phosphorescence upgrade.*
7) *Estimated by fitting a kinetic trace measured in Rhodamine 6G solution at 580 nm with multiple exponents, subtracting the fit from the data and taking the ratio between the standard deviation of the residuals and the 0.5× maximum signal value, at 250 kHz repetition rate; assuming 5 s averaging per trace. Not applicable to all samples and configurations.*
8) *Without external spectrograph.*





Principle of time-correlated single-photon counting (TCSPC)



Principle of time-resolved fluorescence upconversion

HARPIA | TB

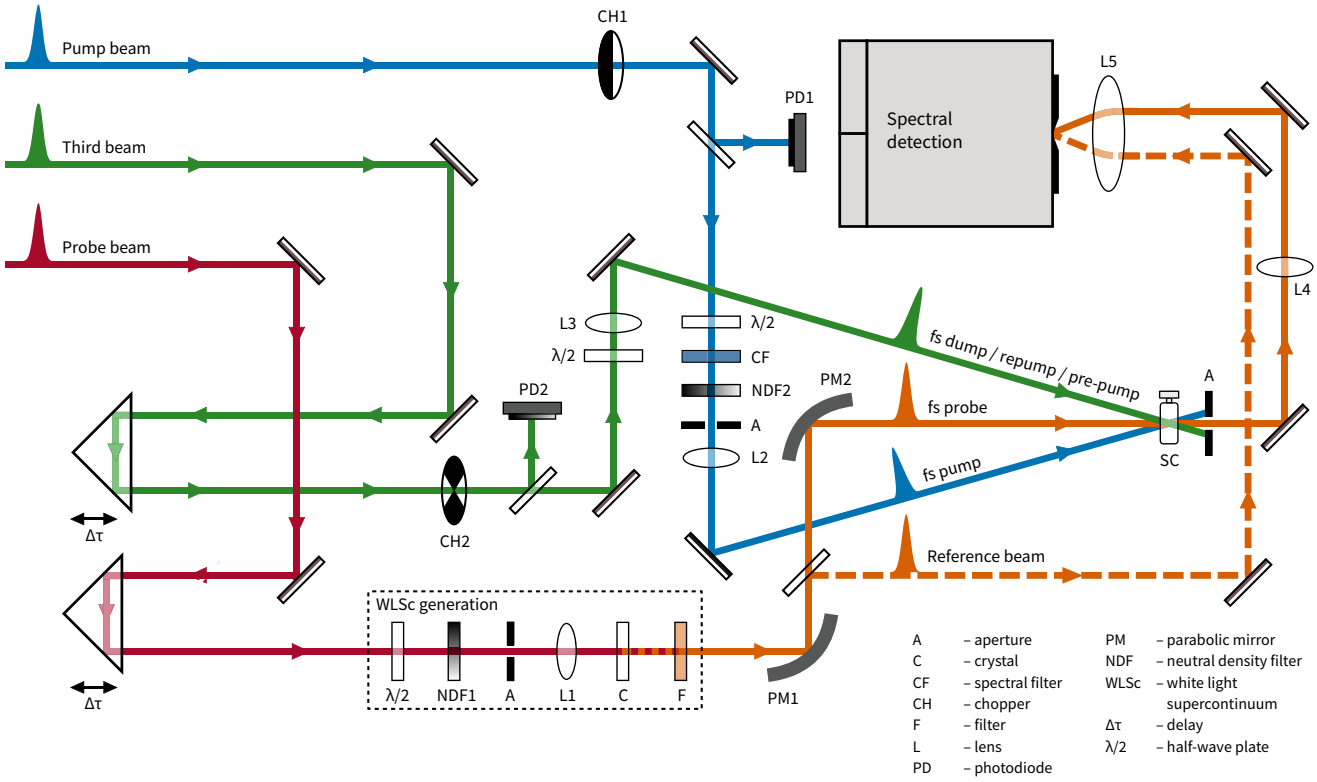
Third Beam Delivery Module

FEATURES

- Delivery of an additional femtosecond or picosecond beam
- Polarization, intensity, and delay control
- Femtosecond stimulated Raman scattering (FSRS) support
- Z-scan support

The HARPIA-TB is a third beam delivery module for the HARPIA-TA unit for an additional dimension to time-resolved absorption measurements. It allows multi-pulse time-resolved spectroscopic techniques, in which the ongoing pump-probe photodynamics are perturbed by a delayed third pulse.

In conjunction with a narrow-bandwidth picosecond pulse source, HARPIA-TB can be used to perform femtosecond stimulated Raman scattering (FSRS) measurements. Furthermore, HARPIA-TB supports Z-scan measurements.



HARPIA optical layout for multi-pulse experiments

SPECIFICATIONS

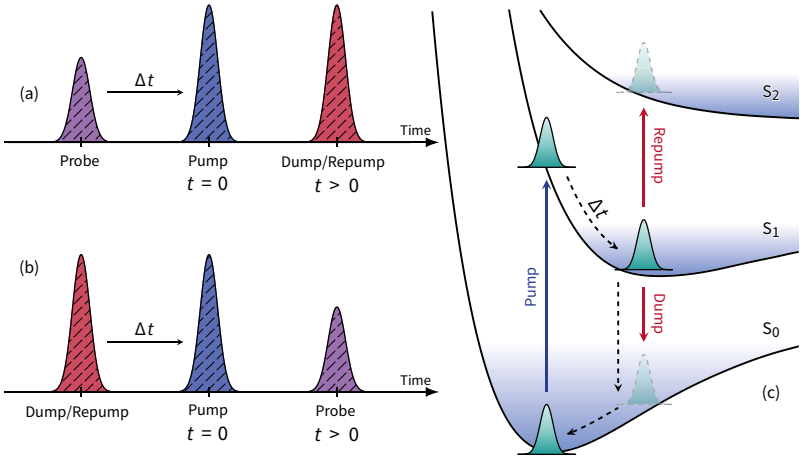
Model	HARPIA-TB
Delay range [1]	2 ns / 4 ns
Delay resolution	2.1 fs / 4.2 fs

DIMENSIONS

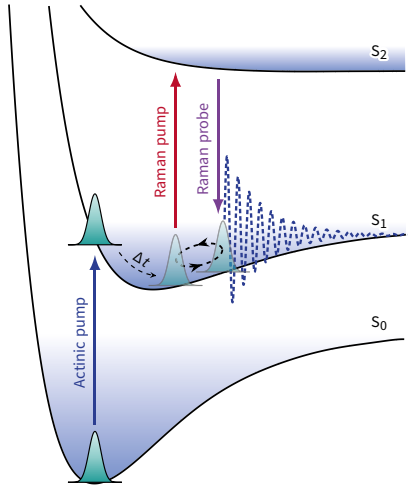
Physical dimensions (L × W × H)	670 × 252 × 183 mm

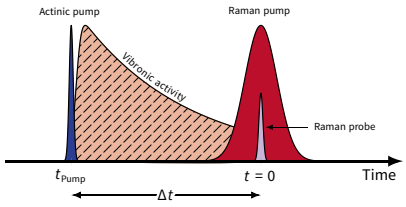
[1] *8 ns delay range is available on request; contact sales@lightcon.com for details.*

DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT



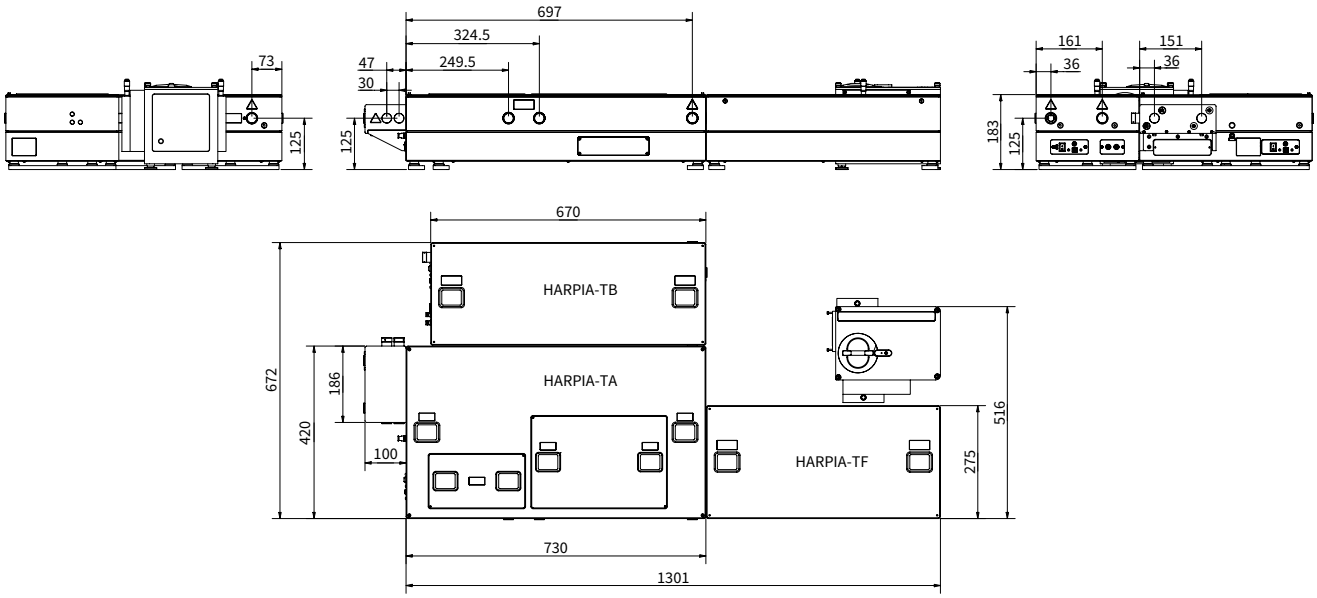
State transitions and pulse timing in multi-pulse time-resolved transient absorption spectroscopy





Femtosecond stimulated Raman scattering (FSRS)

DRAWINGS



Drawings of HARPIA system with HARPIA-TB and HARPIA-TF modules

HARPIA | MM

Microscopy Module

FEATURES

- Down to 2 µm spatial resolution
- Broadband and monochromatic probe options
- Motorized XYZ sample stage
- Transmission, specular and diffuse reflection geometry

SPECIFICATIONS

Model	HARPIA-MM	
Spatial resolution [1]	monochromatic	polychromatic
	< 2 µm	< 10 µm
Full spectral range	460 – 900 nm	
Temporal resolution	500 fs	
Maximum working distance [2]	13 mm	
Sample motion range	13 × 13 × 13 mm	

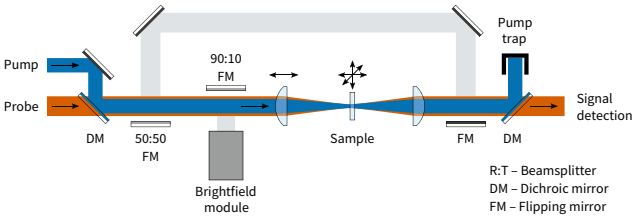
[1] *Depends on the spectral range and the objective used; provided values represent best-effort cases.*
[2] *Depends on the objective used; contact sales@lightcon.com for details.*

HARPIA with bulk (top) and microscopy (bottom) modules installed

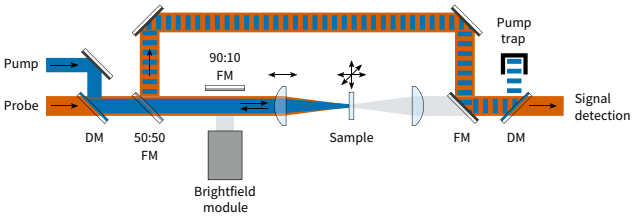
HARPIA-MM is a microscopy module add-on to the HARPIA spectrometer, which enables spatially-resolved pump-probe measurements with a spatial resolution down to 2 µm. The sample can be positioned and scanned in a 13 mm range along XYZ axes using a motorized stage. Microscopic transient transmission and reflection signals can be measured using a broadband or a monochromatic probe.

HARPIA-MM allows the acquisition of time-resolved spectra at a fixed position, difference absorption images at a fixed probe delay, and other types of data. Switching between bulk and microscopic pump-probe modes is implemented using self-contained modules, allowing experiment reconfiguration without disturbing the sample. The microscopy module features a brightfield mode to observe the sample and to determine the pump-probe spot location.

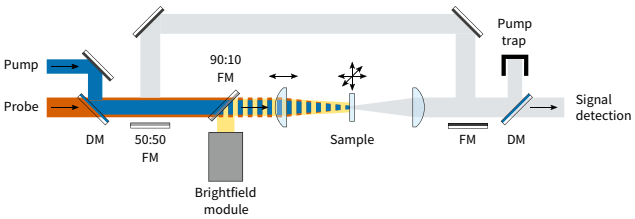
TRANSMISSION MODE



REFLECTION MODE



BRIGHTFIELD MODE



HARPIA Service App

System control and data acquisition software

A single software solution for all measurement modes, featuring:

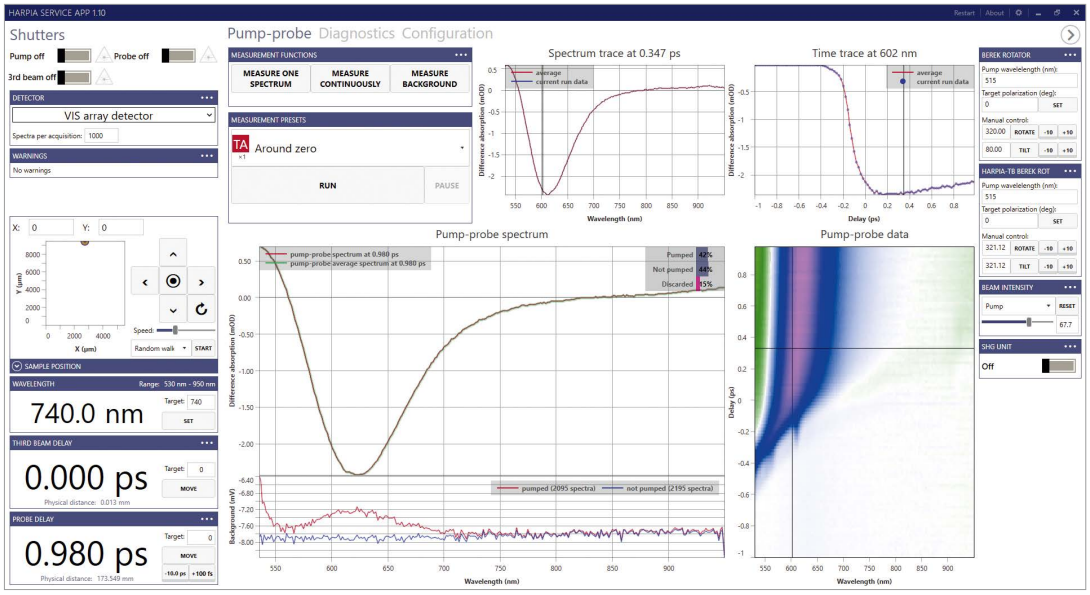
- User-friendly interface
- Measurement presets
- Measurement noise suppression
- Diagnostics and data export
- Continuous support and updates
- API for remote experiment control using third-party software (LabVIEW, Python, MATLAB)

CarpetView

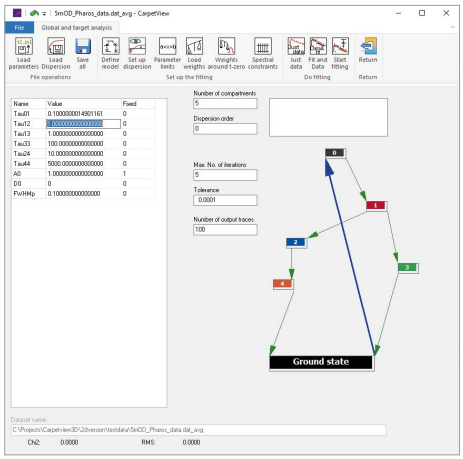
Data analysis software

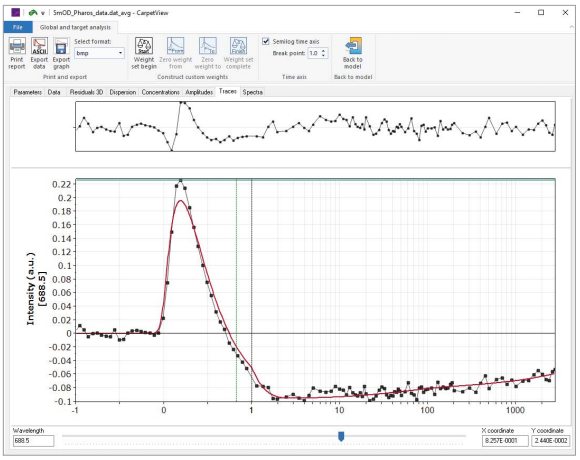
An ultrafast spectroscopy data analysis software, featuring:

- Advanced data wrangling: slicing, merging, cropping, smoothing, fitting, etc.
- Advanced global and target analysis
- Probe spectral chirp correction, calibration and deconvolution
- Support for 3D data sets (2D electronic spectroscopy, fluorescence lifetime imaging)
- Publication-ready figure preparation and data export



HARPIA Service App main window

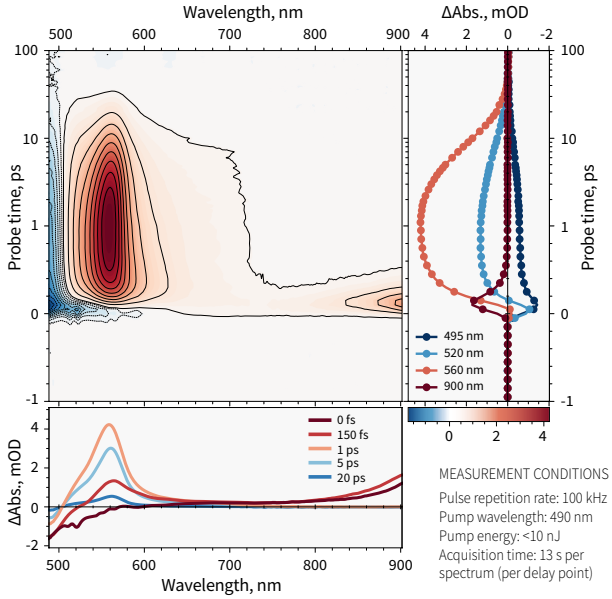




Global and target analysis windows of CarpetView

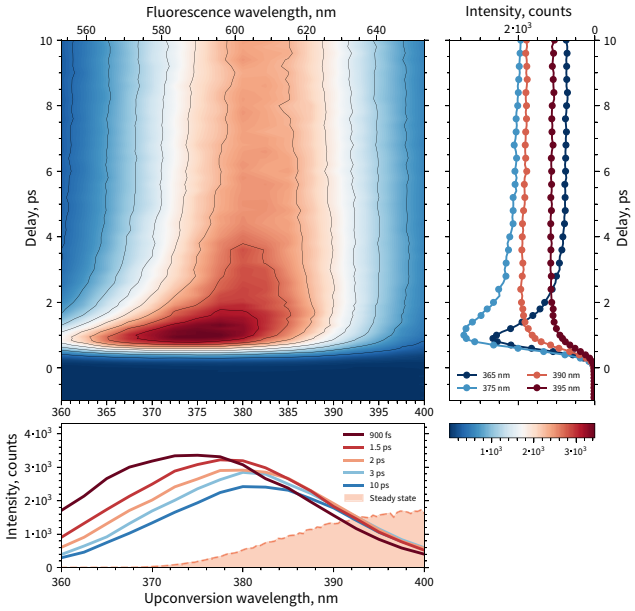
Examples of Spectroscopy Applications

FEMTOSECOND PUMP-PROBE



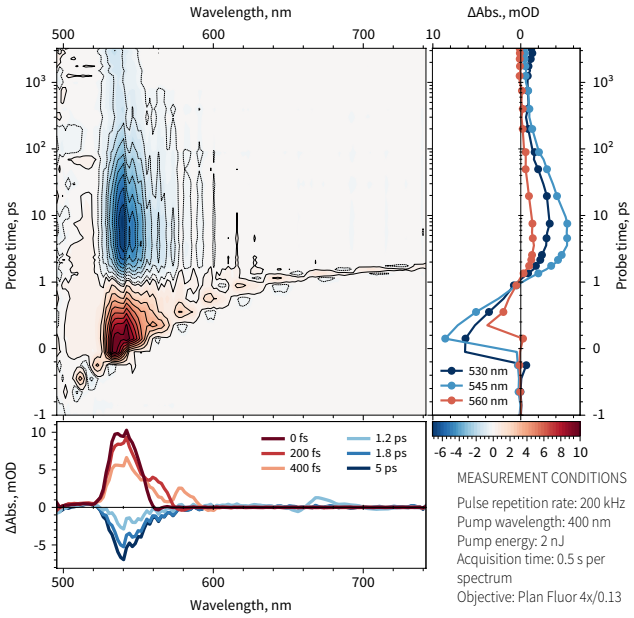
Spectral dynamics of beta-carotene in solution acquired using HARPIA-TA

FLUORESCENCE UPCONVERSION

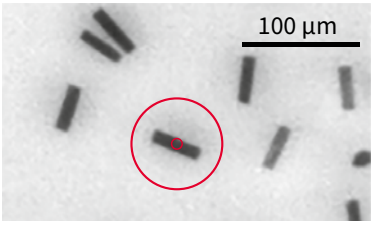


Fluorescence dynamics of DCM laser dye in solution acquired using HARPIA-TF in fluorescence upconversion mode

FEMTOSECOND PUMP-PROBE MICROSPECTROSCOPY



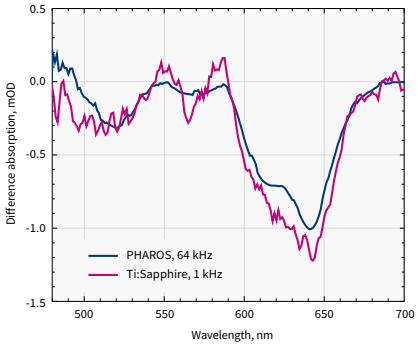
Single perovskite crystallite pump-probe spectral kinetics, pump at 400 nm



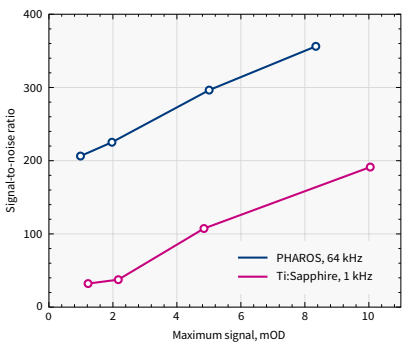
Pump-probe spot marked by the small circle

PERFORMANCE AT HIGH REPETITION RATES

The HARPIA spectroscopy system achieves an excellent signal-to-noise ratio at high repetition rate and low energy excitation conditions. The graphs below compare the signal-to-noise ratio (SNR) of difference absorption spectra obtained with a Ti:Sapphire laser operating at 1 kHz and a PHAROS laser operating at 64 kHz with the same acquisition time.



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



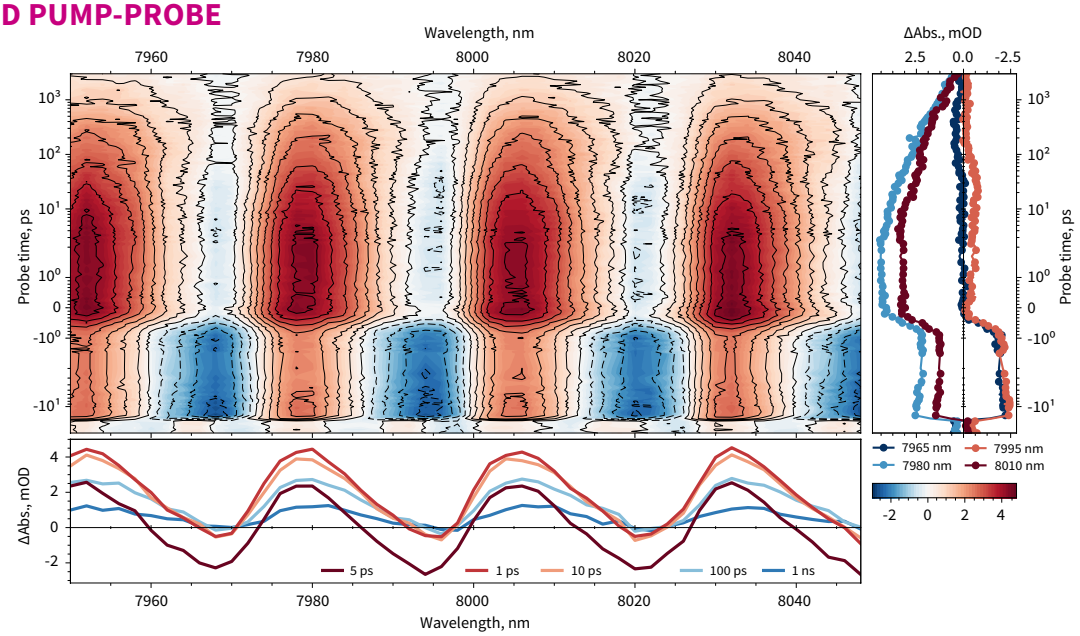
Best-effort SNRs, achieved with HARPIA-TA spectrometer driven by a Ti:Sapphire laser at 1 kHz (magenta) and a PHAROS laser at 64 kHz (blue)

IR FEMTOSECOND PUMP-PROBE

Pump-probe dynamics of GaAs wafer in IR measured using signal and reference single-channel detectors

MEASUREMENT CONDITIONS

Pulse repetition rate: 75 kHz
Pump wavelength: 700 nm
Acquisition time: 1 s per point

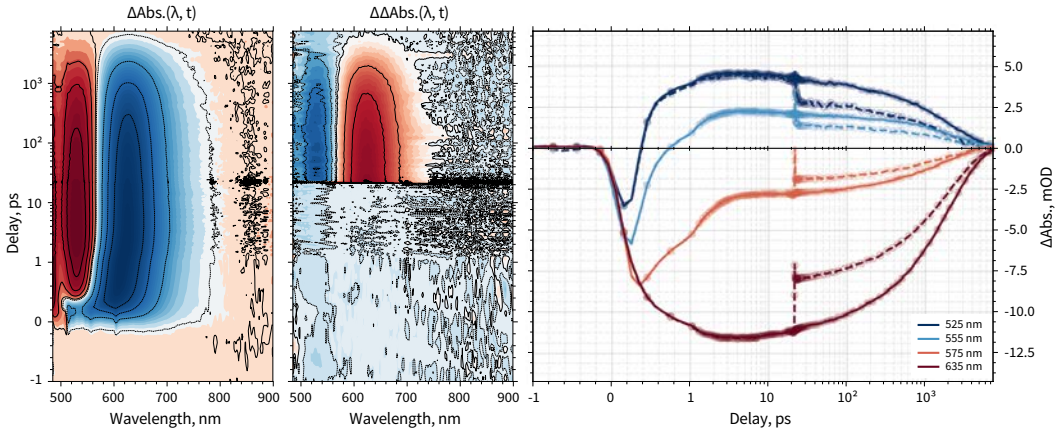


FEMTOSECOND PUMP-DUMP-PROBE

Pump-dump-probe dynamics of DCM laser dye with dump pulse resonant to the emission band of DCM

MEASUREMENT CONDITIONS

Pulse repetition rate: 50 kHz
Pump wavelength: 515 nm
Dump wavelength: 700 nm
Dump delay: 21 ps
Pump energy: 90 nJ
Dump energy: 190 nJ

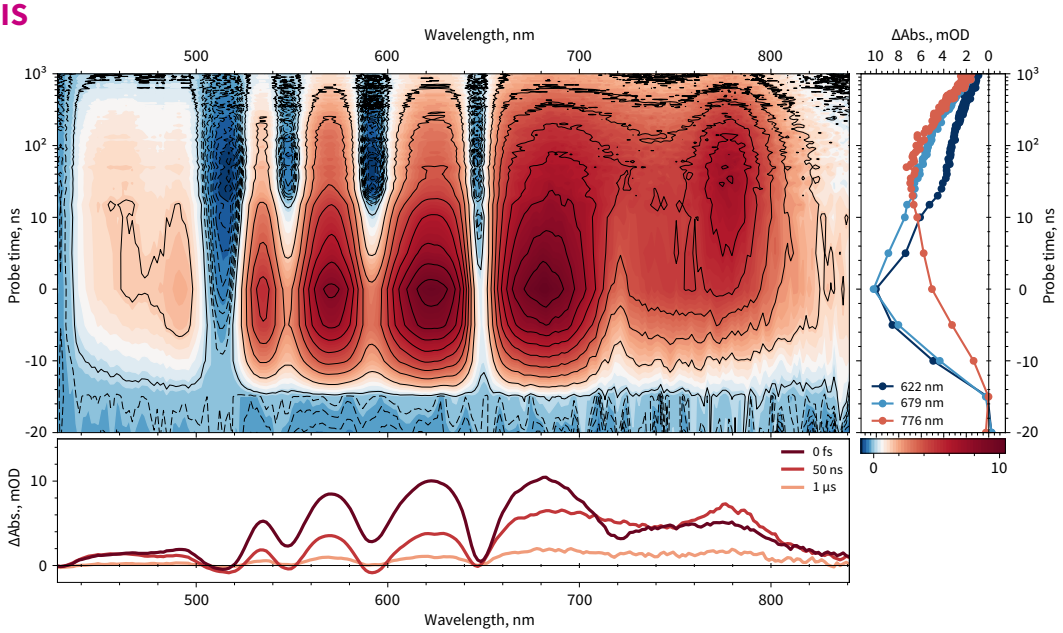


FLASH PHOTOLYSIS

Nanosecond spectral dynamics of meso-Tetraphenylporphine in solution acquired using HARPIA in flash photolysis mode

MEASUREMENT CONDITIONS

Pulse repetition rate: 1.8 kHz
Pump wavelength: 343 nm
Pump energy: 5.4 µJ



CRONUS | 3P

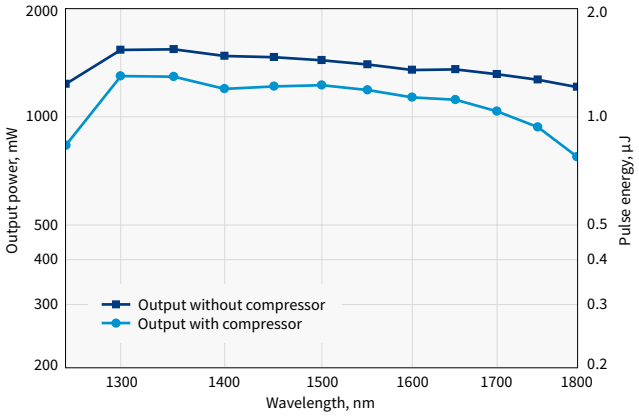
Laser Source for Advanced Nonlinear Microscopy

FEATURES

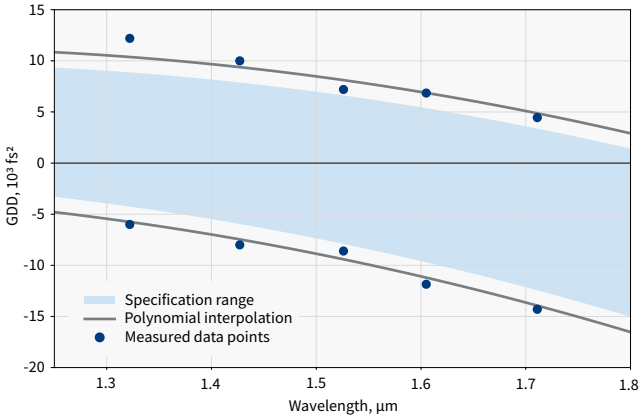
- High pulse energy, high repetition rate, and high average power
- 1250 – 1800 nm tuning range
- Down to 50 fs pulse duration
- Automated GDD control
- Industrial-grade design
- High output stability

CRONUS-3P is a laser source developed specifically for advanced nonlinear microscopy. It provides µJ-level pulses down to 50 fs at repetition rates of up to 2 MHz and tunable in the short-wavelength infrared (SWIR) range from 1.25 to 1.8 µm, thus covering the biological transparency windows at 1.3 µm and 1.7 µm for three-photon microscopy.

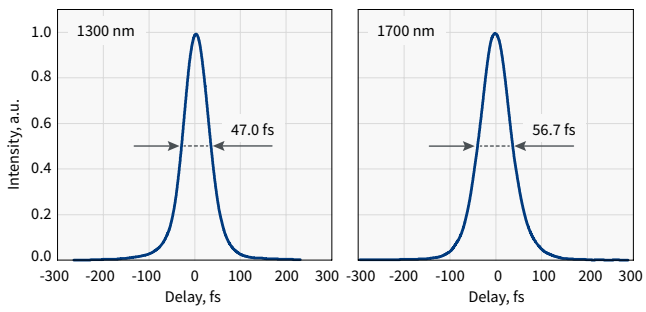
Typically, multiphoton imaging in the SWIR range requires a complex multi-device laser system and, usually, a good portion of an optical table and skilled staff – this reality encumbers neuroscience and other biomedical applications – the CRONUS-3P system is a next-generation, industrial-grade, single-supplier solution that is more compact, more reliable, and more versatile, and achieves tunable femtosecond excitation with an integrated group delay dispersion (GDD) control, ensuring optimal pulse duration at the sample, and industrial-grade design to guarantee high short- and long-term output stability.



Output power and pulse energy vs wavelength.
Pump: 40 W, 1 MHz.



GDD control range



Typical pulse duration at 1300 nm and 1700 nm

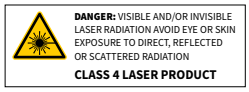
SPECIFICATIONS

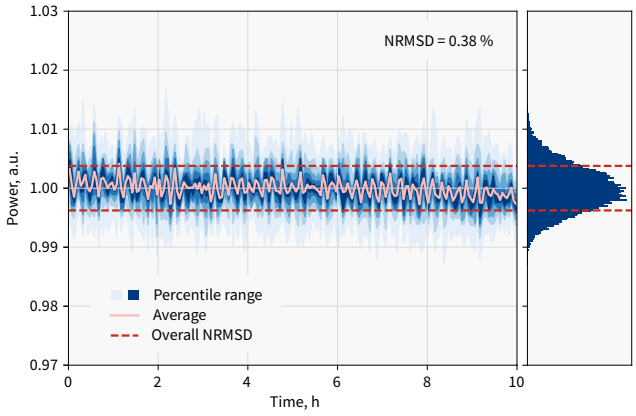
Model	CRONUS-3P	
Tuning range	1250 – 1800 nm	
Repetition rate [1]	Single-shot to 2 MHz	
	1300 nm	**1700 nm**
Pulse duration	< 50 fs	< 65 fs
Output power	> 1200 mW @ 1 MHz > 800 mW @ 2 MHz	> 750 mW @ 1 MHz > 500 mW @ 2 MHz
GDD control range [2]	−4000 to +9000 fs²	−12000 to +3500 fs²
Beam diameter [3]	2 – 3 mm	
Beam quality (M^2)	< 1.4	
Beam ellipticity	> 0.8	
Beam divergence	< 1 mrad	
Long-term power stability, 24 h [4]	< 1%	
Pulse-to-pulse energy stability, 1 min [4]	< 1%	

OUTPUT WITHOUT COMPRESSOR

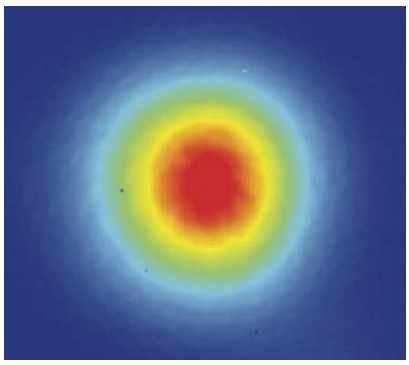
Output power	> 1500 mW @ 1 MHz > 1000 mW @ 2 MHz	> 1050 mW @ 1 MHz > 700 mW @ 2 MHz

[1] *Lower repetition rate and higher pulse energy options available.*
[2] *Continuously controlled dispersion that can be added before the microscope, i.e., −3000 fs² compensates a microscope with +3000 fs².*
[3] *FWHM, measured at compressor output.*
[4] *Expressed as NRMSD (normalized root mean squared deviation).*



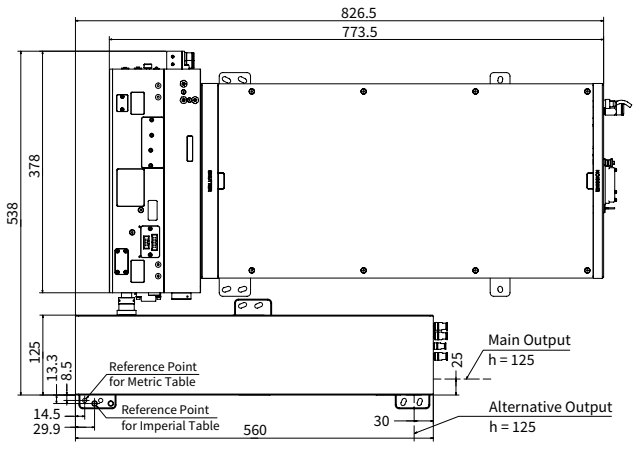


Long-term power stability, measured at 1700 nm over 10 h



Beam profile at 1300 nm, 2.5 mm diameter (FWHM)

DRAWINGS



CRONUS-3P drawing

CRONUS | 2P

Three-Channel Wavelength-Tunable Femtosecond Laser

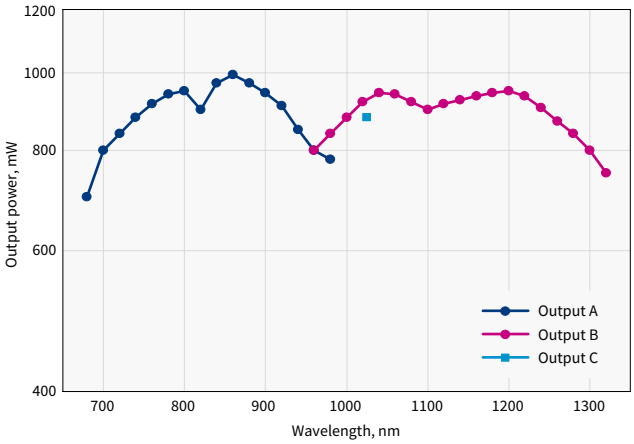
FEATURES

- Three simultaneous and synchronized outputs
- Automated GDD control
- High repetition rate and high output power
- Industrial-grade design
- High output stability

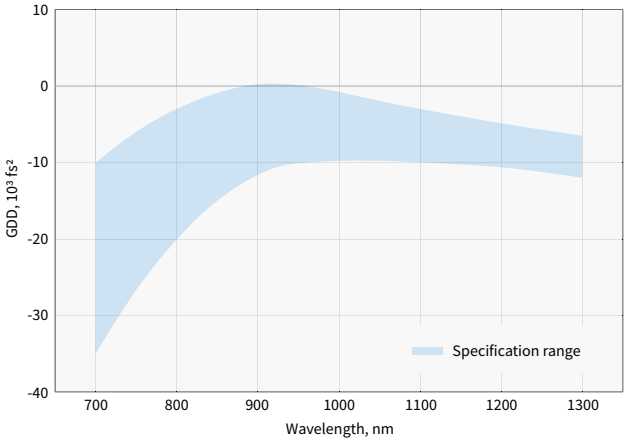
CRONUS-2P is a femtosecond laser providing three simultaneous and synchronized outputs with high repetition rate, high output power, short pulse duration, and GDD control, making it the ultimate source for nonlinear microscopy. Two outputs are independently tunable in the 680 – 960 nm and 960 – 1300 nm ranges, while the third is fixed at 1025 nm. The CRONUS-2P can be used for simultaneous excitation of multiple fluorescent probes, calcium indicators, or opsins at their absorption maxima, whereas second- and third-harmonic emission (SHG and THG) can be spectrally shifted for ease of detection or resonant enhancement.

The three simultaneous outputs also enable advanced coherent anti-Stokes and stimulated Raman scattering (CARS and SRS) applications with dual-band imaging, a broader selection of vibrational resonance frequencies, constant-difference dual-beam tuning, resonant enhancement, and more.

CRONUS-2P is a fully automated and robust next-generation laser system built on over 25 years of experience in designing and manufacturing femtosecond lasers and wavelength-tunable sources.



CRONUS-2P tuning curve



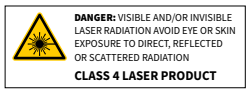
GDD control range

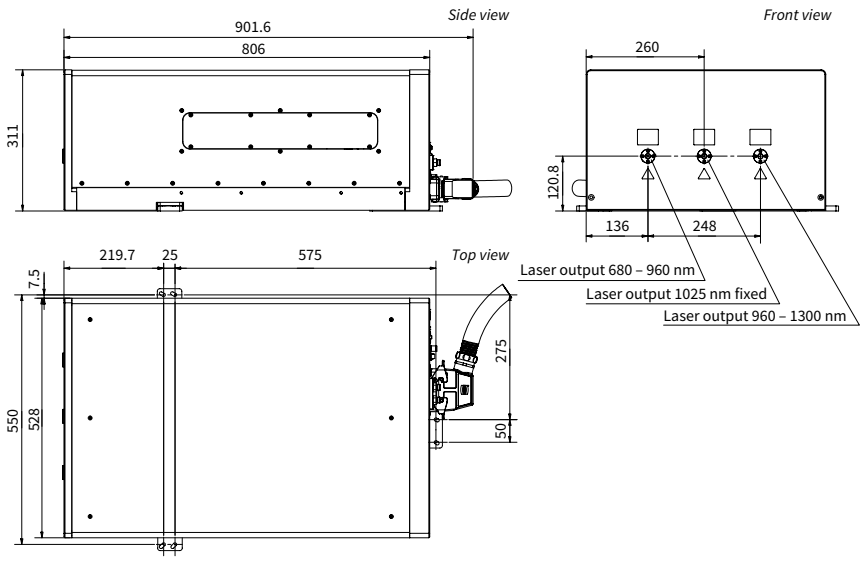
* Distributed by LaVision BioTec GmbH – a Miltenyi Biotec Company. Contact contact@miltenyi.com for inquiries.

SPECIFICATIONS

Model	CRONUS-2P		
MAIN OUTPUT			
	Output A	**Output B**	**Output C**
Tuning range	680 – 960 nm	960 – 1300 nm	1025 nm (fixed)
Output power	> 700 mW @ 700 nm **> 900 mW @ 850 nm** **> 700 mW @ 960 nm**	> 700 mW @ 960 nm **> 800 mW @ 1100 nm** **> 700 mW @ 1300 nm**	> 800 mW
Pulse duration [1) 2)]	< 160 fs		
Repetition rate	76.8 ± 1 MHz		
Beam quality [2)]	TEM_{00}; M2 < 1.2		
Polarization	Linear, horizontal		
Beam divergence, full angle	< 1 mrad		< 1.5 mrad
Beam diameter [2)] **($1/e^2$)**	3.0 ± 0.4 mm	3.2 ± 0.4 mm	2.8 ± 0.4 mm
Beam ellipticity [2)]	> 0.8		
Beam astigmatism [2)]	< 20%		
Beam pointing stability [3)]	< 200 µrad		–
Long-term power stability [2) 4)]	< 1%		
GDD control range	-10000 to -35000 fs^2 @ 700 nm -3000 to -20 000 fs^2 @ 800 nm 0 to -10 000 fs^2 @ 960 nm	0 to -10 000 fs^2 @ 960 nm -3000 to -10 000 fs^2 @ 1100 nm -6 000 to -12 000 fs^2 @ 1300 nm	–
ENVIRONMENTAL REQUIREMENTS			
Altitude	< 2000 m		
Temperature, operating	18 – 30 °C		
Temperature, storage	10 – 35 °C		
Relative humidity, operating	< 80% (non-condensing)		
DIMENSIONS			
Laser head (L × W × H)	806 × 528 × 311 mm		
Rack for power supply and chiller (L × W × H)	642 × 553 × 673 mm		

1) IR pulse duration determined assuming sech2 shape.
2) At 850 nm, 1050 nm, and 1025 nm respectively.
3) Beam pointing deviation over the entire tuning and GDD control range.
4) Expressed as NRMSD (normalized root mean squared deviation) over 2 h with less than ±1 °C temperature change after 1 h warm up.



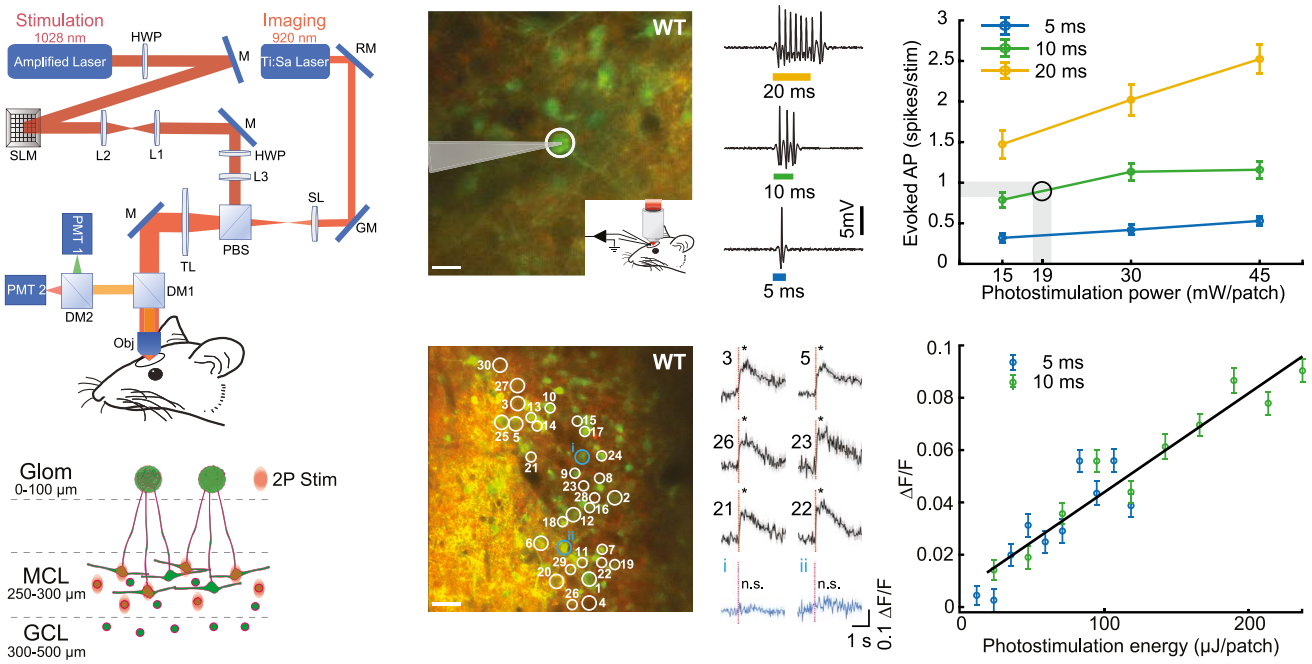


CRONUS drawing

Examples of Microscopy Applications

HOLOGRAPHIC 2P OPTOGENETICS

Traditional full-brain neurostimulation using CW light lacks specificity, whereas point-by-point laser-scanning, despite being highly specific, can be slow and is not simultaneous. Holographic multiphoton neurostimulation, on the other hand, is capable of random-access-style volumetric neuron activation and is therefore used for advanced behavioral neuroscience studies. Holographic stimulation is exceptionally demanding on the laser source, requiring very high average power, combined with complex on-demand pulse train control – features that are well supported by the CARBIDE and PHAROS laser families.

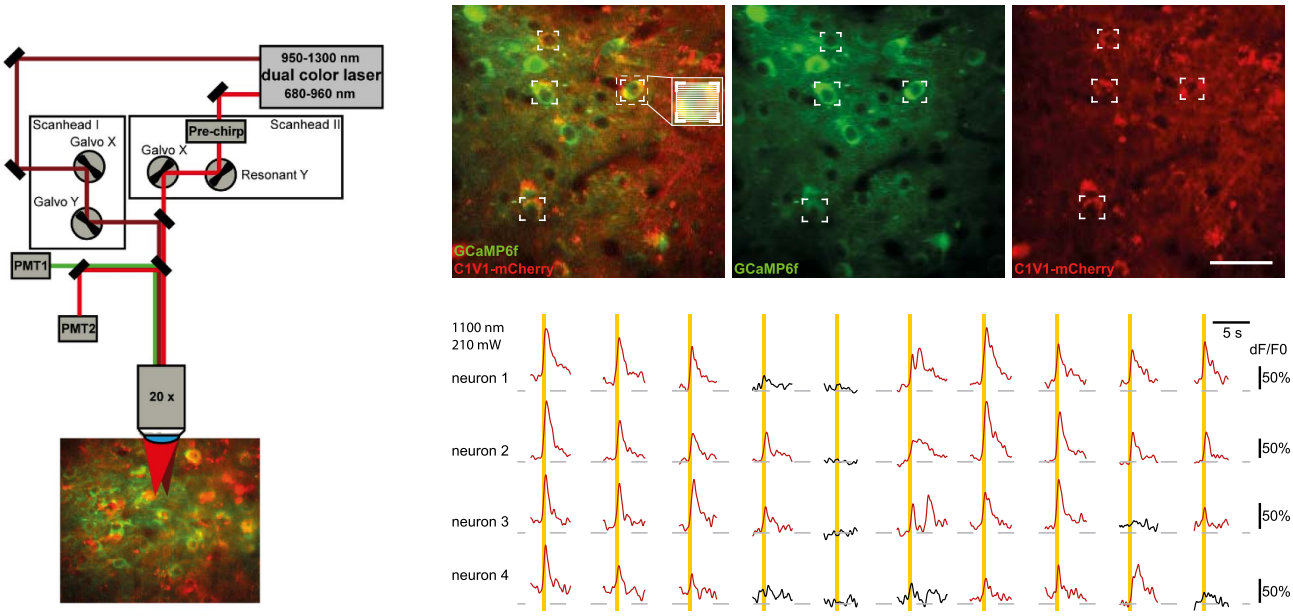


Holographic 2P optogenetic stimulation of mouse olfactory bulb neurons using laser system with PHAROS femtosecond laser.

Courtesy of Shy Shoham and Dmitry Rinberg groups, New York University. Source: J. V. Gill *et al.*, Precise holographic manipulation of olfactory circuits reveals coding features determining perceptual detection, Neuron 108 (2020).

2P OPTOGENETICS

Despite the advances in 3-photon excitation sources providing longer wavelengths and higher pulse energies, certain imaging challenges are still better addressed by tunable high-repetition-rate oscillator-based lasers. This is especially true when imaging speed is the primary factor. For these applications, the CRONUS-2P laser offers the ultimate solution with its optically synchronized three-outputs, two of which are independently tunable. A three-beam source enables a variety of multiphoton excitation pathways, many of which are inaccessible using traditional single- and two-beam solutions. Furthermore, independent tunability of the two beams enables new coherent Raman scattering modalities.

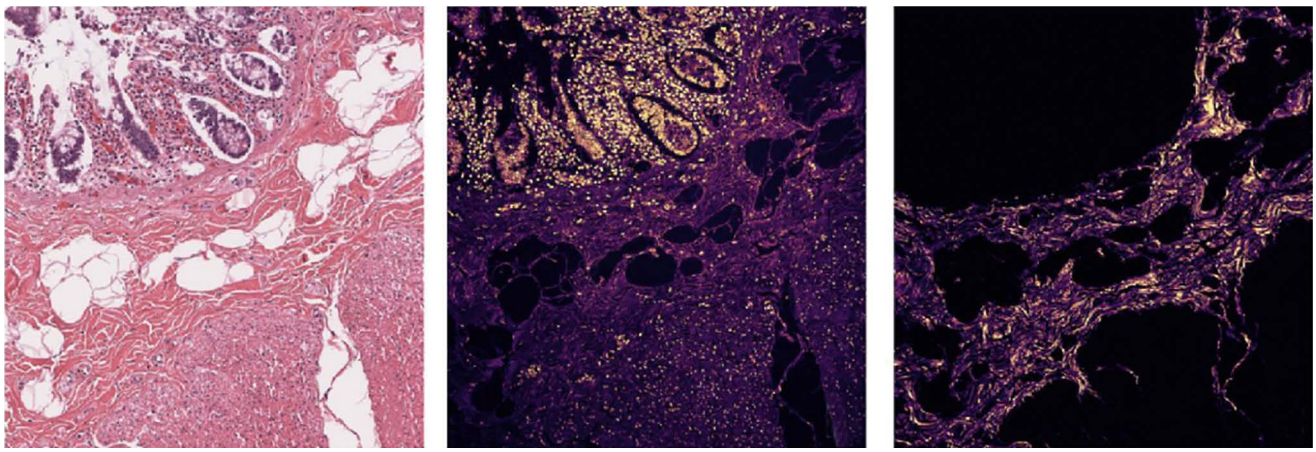


2P optogenetic stimulation of individual neurons using CRONUS-2P.

Courtesy of Albert Stroh group, University Medical Center Mainz and Leibniz Institute for Resilience Research. Source: T. Fu *et al.*, Exploring two-photon optogenetics beyond 1100 nm for specific and effective all-optical physiology, iScience 24 (2021).

RASTER-SCANNING 2P/3P MICROSCOPY

For applications requiring a fixed-wavelength femtosecond laser, such as multiphoton-driven fluorescence (MPEF), excited at 1 µm, and harmonic-generation (SHG, THG) microscopy, the FLINT oscillator is a high-performance solid-state source in a proven, industrial-grade package and a compact footprint. In particular, the FLINT oscillator provides stable 24/7 operation with excellent noise performance, characterized by a RIN that is <140 dBc/Hz above 200 kHz and shot-noise-limited at -160 dBc/Hz above 1 MHz.

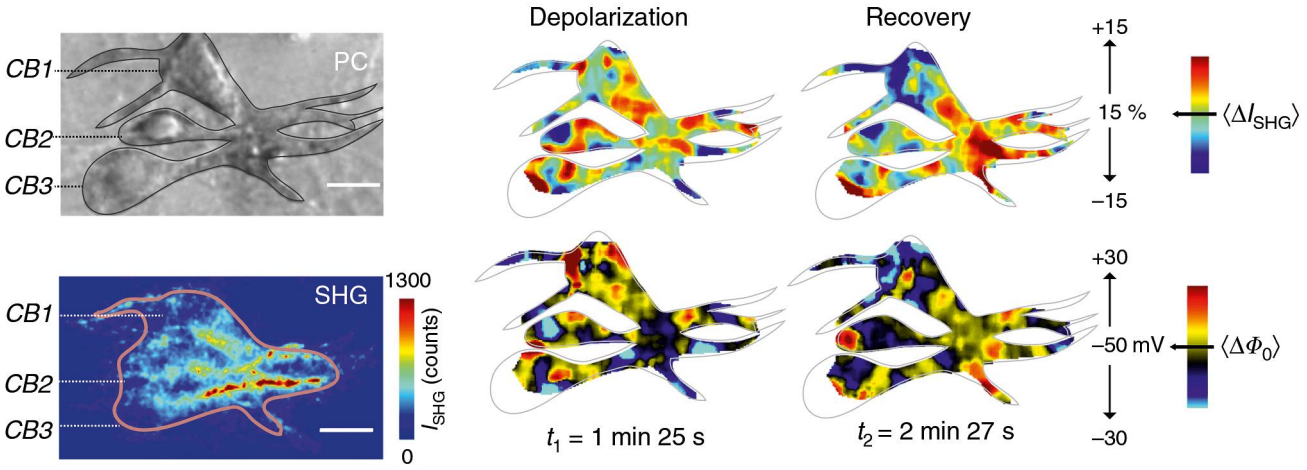


SHG and THG images of H&E-stained colon using FLINT femtosecond oscillator.

Courtesy of Virgis Barzda group, Vilnius University.

WIDEFIELD SHG NEUROIMAGING

Nonlinear widefield excitation, and in particular second-harmonic generation (SHG) imaging, has a distinct advantage in neuronal voltage potential imaging. This is due to the fact that membrane potential affects the organization of SHG-active molecules and thus SHG imaging enables unprecedented, contactless, real-time voltage imaging at the individual neuron level. Here too, the configuration versatility as well as the low-noise excitation performance of the PHAROS and CARBIDE lasers are very useful.

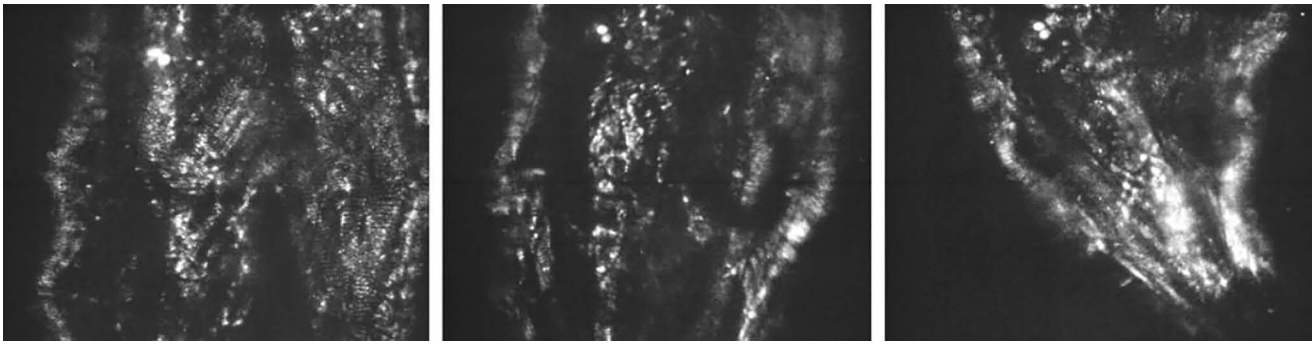


Widefield SHG neuroimaging of neuronal membrane potentials and ion efflux by means of water using PHAROS femtosecond laser.

Courtesy of Sylvie Roke group, École Polytechnique Fédérale de Lausanne. Source: M. E. P. Didier *et al.*, Membrane water for probing neuronal membrane potentials and ionic fluxes at the single cell level, Nature Communications 9 (2018).

LABEL-FREE *IN VIVO* WIDEFIELD SHG IMAGING

Nonlinear excitation requires very high peak intensities and thus has been traditionally limited to laser-scanning microscopy using tightly focused beams. For some *in vivo* and high-throughput applications, however, laser scanning is too slow. With improved femtosecond laser technology delivering ever-increasing average power, it is now possible to excite nonlinear signals over a large area using widefield nonlinear microscopy. Since optimal excitation conditions are application dependent, the tunable repetition rate and pulse energy of the PHAROS and CARBIDE lasers as well their industrial reliability and low-noise performance are key parameters when building widefield setups.

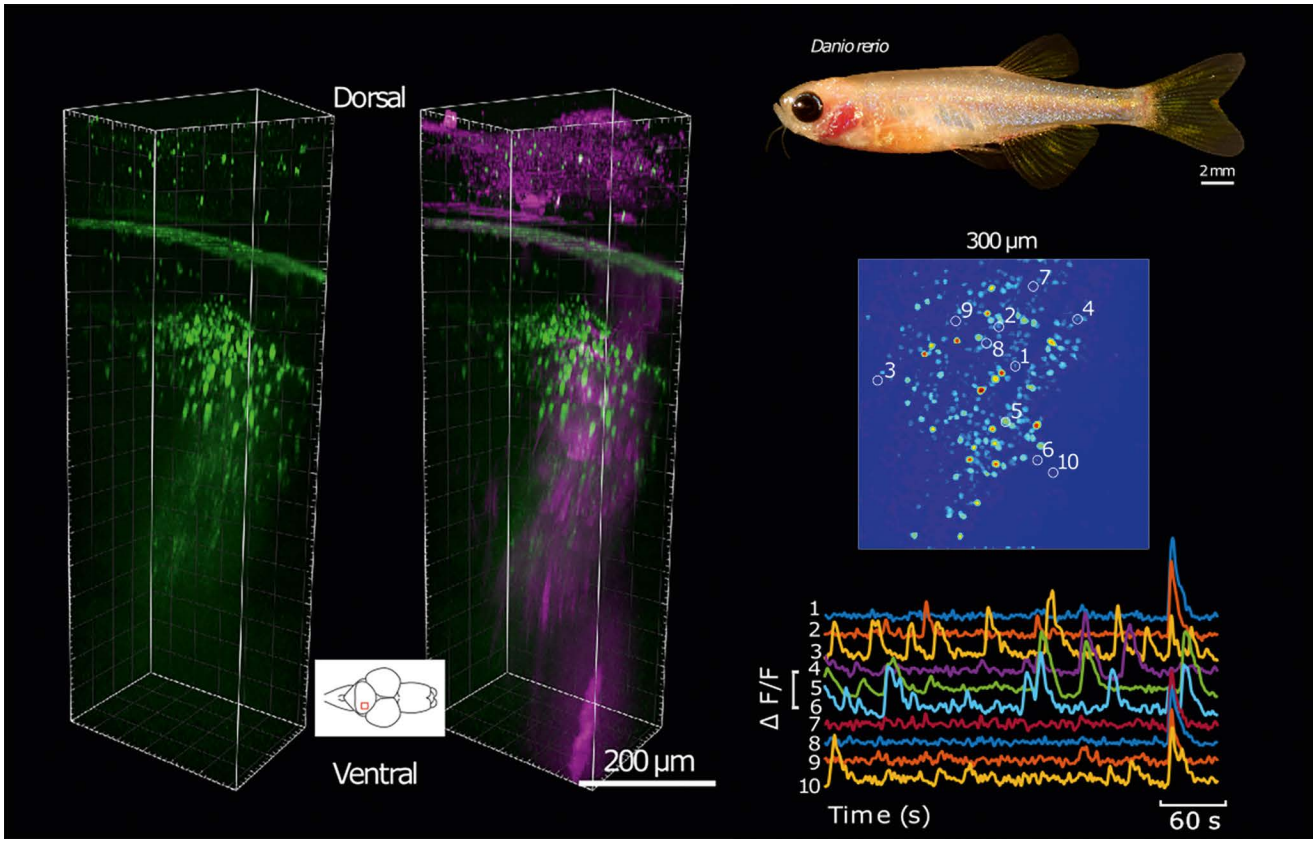


Label-free *in vivo* widefield SHG imaging of fruit fly larva using PHAROS femtosecond laser.

Courtesy of Virgis Barzda group, University of Toronto.

FUNCTIONAL 3P NEUROIMAGING

Recording of real-time single-neuron activity in the deep brain layers of awake animals is crucial for understanding behavior as well as brain connectivity and function. These applications have been advanced by neuron imaging and stimulation using high-power, high-pulse-energy, medium-repetition-rate lasers tunable in the SWIR range, which spans the biological transparency windows at 1.3 µm and 1.7 µm. For two- and three-photon-excited fluorescence (2PEF, 3PEF) and harmonic-generation (SHG, THG) imaging in deep tissues, dispersion-controlled femtosecond pulses from ORPHEUS line OPAs and microscopy-dedicated CRONUS-2P and CRONUS-3P lasers are truly a state-of-the-art choice.



Functional three-photon neuroimaging of zebrafish using OEM OPA in ORPHEUS-F configuration.

Courtesy of Chris Xu and Joe Fetcho groups, Cornell University. Source: D. M. Chow *et al.*, Deep three-photon imaging of the brain in intact adult zebrafish, Nature Methods 17 (2020).

GECO

Scanning Autocorrelator

FEATURES

- 10 fs – 20 ps pulse duration range
- 500 – 2000 nm wavelength range
- High-resolution voice coil driven delay line
- Integrated controller
- Compact and portable design
- Pulse-analysis software
- FROG-ready

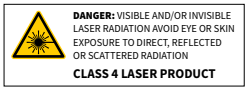
GECO is a scanning autocorrelator designed for pulse duration measurements. It is based on noncollinear second-harmonic generation, producing intensity autocorrelation trace related to the fundamental pulse duration. GECO features a noncollinearity angle adjustment and can be transformed into a collinear setup for measurements down to 10 fs. High resolution is ensured by a delay line with a 0.13 fs/step.

GECO comes with an integrated controller and pulse analysis software. It is capable of generating FROG traces, if an external spectrometer is connected. Software APIs are available for user adaptation.

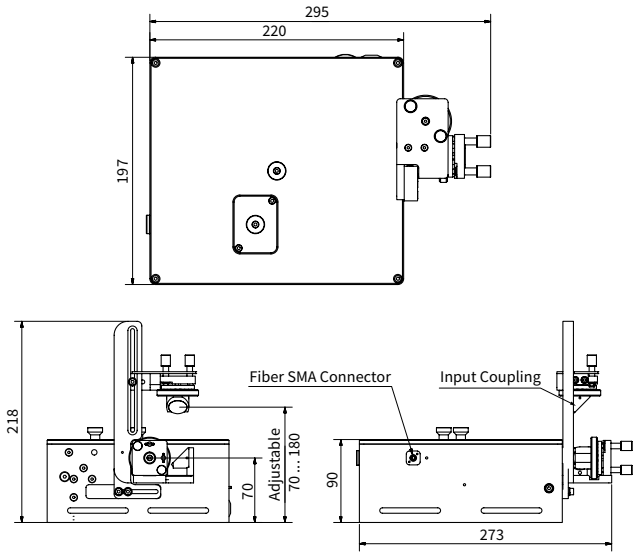
SPECIFICATIONS

Input wavelength range		500 – 2000 nm
Input pulse duration		10 fs – 20 ps
Minimum repetition rate		1 kHz
Minimum input power [1)]	from amplifiers	2 mW @ 1 kHz 200 mW @ 1000 kHz
	from oscillators	400 mW @ 800 nm, 76 MHz, 100 fs 250 mW @ 1030 nm, 76 MHz, 100 fs
Temporal resolution		0.13 fs/step
Scan rate		5 scans/s @ 1 – 1000 kHz
Detector		Si photodiode

[1)] *For specific input requirements, contact sales@lightcon.com.*



DRAWINGS



GECO drawings

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