PHAROS

Modular-Design Femtosecond Lasers for Industry and Science

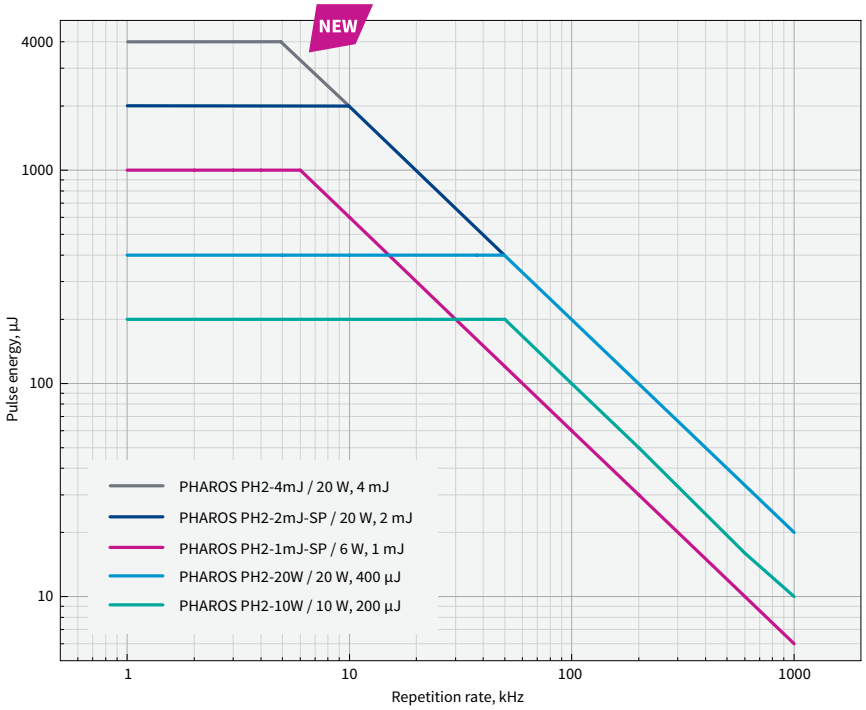
FEATURES

- Tunable pulse duration, 100 fs – 20 ps
- Maximum pulse energy of up to 4 mJ
- Down to < 100 fs right at the output
- Pulse-on-demand and BiBurst for pulse control
- Up to 5th harmonic or tunable extensions
- CEP stabilization or repetition rate locking
- Thermally-stabilized and sealed design

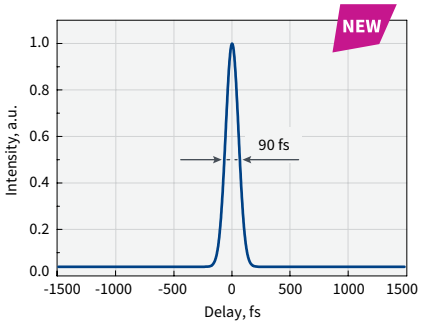
PHAROS is a series of femtosecond lasers combining multi-millijoule pulse energy and high average power. PHAROS features a mechanical and optical design optimized for both scientific and industrial applications. A compact, thermally-stabilized, and sealed design enables PHAROS integration into various optical setups and machining workstations. The robust optomechanical design provides an exceptional laser lifetime and 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 4 mJ), and average power (up to 20 W).

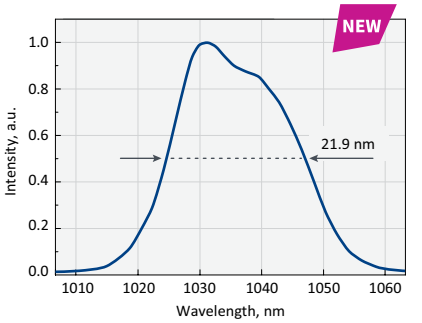
A pulse-on-demand mode is available using the built-in pulse picker. The versatility of PHAROS can be extended by a variety of options, including carrier-envelope phase (CEP) stabilization, repetition rate locking to an external source, automated harmonic modules and optical parametric amplifiers.



Pulse energy vs fundamental repetition rate of PHAROS



Typical pulse duration of PHAROS-PH2-UP



Typical spectrum of PHAROS-PH2-UP

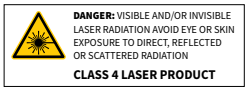
SPECIFICATIONS

NEW

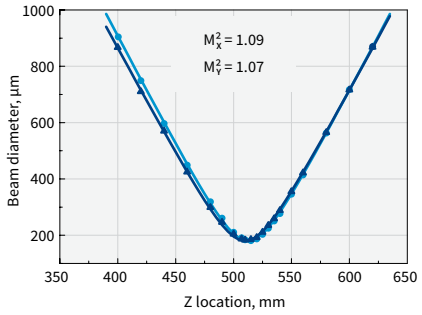
Model	PH2-10W	PH2-20W-SP			PH2-4mJ	PH2-UP
OUTPUT CHARACTERISTIC						
Center wavelength [1]	1030 ± 10 nm					
Maximum output power	10 W	20 W			20 W	
Pulse duration [2]	< 290 fs	< 190 fs			< 450 fs [3]	< 100 fs
Pulse duration tuning range	290 fs – 10 ps (20 ps on request)	190 fs – 10 ps (20 ps on request)			450 fs – 10 ps	100 fs – 10 ps
Maximum pulse energy	0.2 mJ	0.4 mJ	1 mJ	2 mJ	4 mJ	0.4 mJ
Repetition rate	Single-shot – 1 MHz					
Pulse selection	Single-shot, pulse-on-demand, any fundamental repetition rate division					
Polarization	Linear, horizontal					
Beam quality, M^2	< 1.2		< 1.3			< 1.2
Beam diameter [4]	3.3 ± 0.5 mm	4.0 ± 0.5 mm	4.5 ± 0.5 mm	6.6 ± 0.7 mm		4.5 ± 0.5 mm
Beam pointing stability	< 20 µrad/°C					
Pre-pulse contrast	< 1 : 1000					
Post-pulse contrast	< 1 : 200					
Pulse-to-pulse energy stability, 24 h [5]	< 0.5%					
Long-term power stability, 100 h [5]	< 0.5%					
MAIN OPTIONS						
Oscillator output [6]	1 – 6 W, 50 – 250 fs, ≈ 1035 nm, ≈ 76 MHz					
Harmonic generator [7]	515 nm, 343 nm, 257 nm, or 206 nm; *see page 22*					
Optical parametric amplifier [8]	320 – 10000 nm; *see page 30*					
BiBurst option	Tunable GHz and MHz burst with burst-in-burst capability; *see page 17*					
CEP stabilization	*See page 9*					
Repetition rate locking						
PHYSICAL DIMENSIONS						
Laser head (L × W × H) [9]	730 × 419 × 230 mm				827 × 492 × 250 mm	730 × 419 × 230 mm
Chiller (L × W × H)	590 × 484 × 267 mm					
24 V DC power supply (L × W × H) [9]	280 × 144 × 49 mm					

ENVIRONMENTAL & UTILITY REQUIREMENTS		
Operating temperature		15 – 30 °C (air conditioning recommended)
Relative humidity		< 80% (non-condensing)
Electrical requirements	Laser	100 V AC, 12 A – 240 V AC, 5 A, 50 – 60 Hz
	Chiller	100 – 230 V AC, 50 – 60 Hz
Rated power	Laser	1000 W
	Chiller	1400 W
Power consumption	Laser	600 W
	Chiller	1000 W

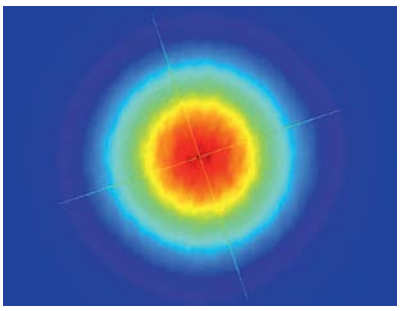
[1] *Precise wavelengths for specific models are available on request.*
[2] *Assuming Gaussian pulse shape.*
[3] *Pulse duration can be reduced to < 250 fs if pulse peak intensity of > 50 GW/cm² is tolerated by customer setup.*
[4] *FW 1/e², measured at laser output, using maximum pulse energy.*
[5] *Under stable environmental conditions. Expressed as normalized root mean squared deviation (NRMSD).*
[6] *Available simultaneously. Contact sales@lightcon.com for details or customized solutions.*
[7] *Integrated. For external harmonic generator, refer to HIRO.*
[8] *Integrated. For more options and OPAs for -4mJ and -UP models, refer to ORPHEUS series of OPAs.*
[9] *Dimensions depend on laser configuration and integrated options.*



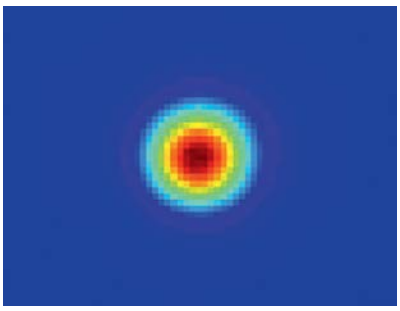
BEAM PROPERTIES



Typical M^2 measurement data of PHAROS

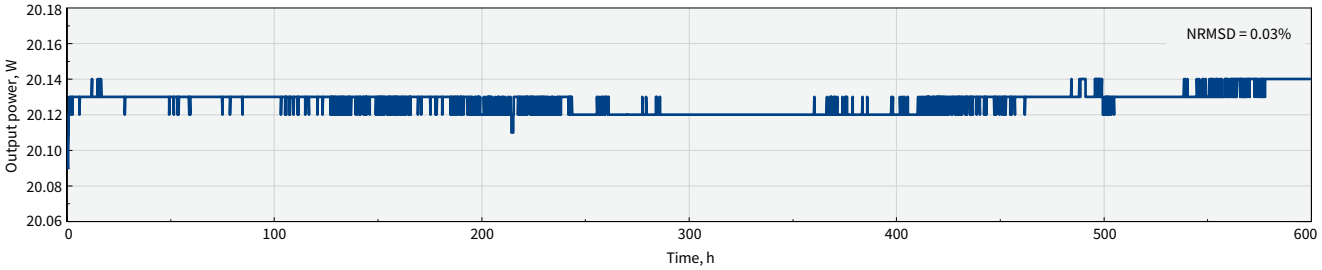


Typical near-field beam profile of PHAROS

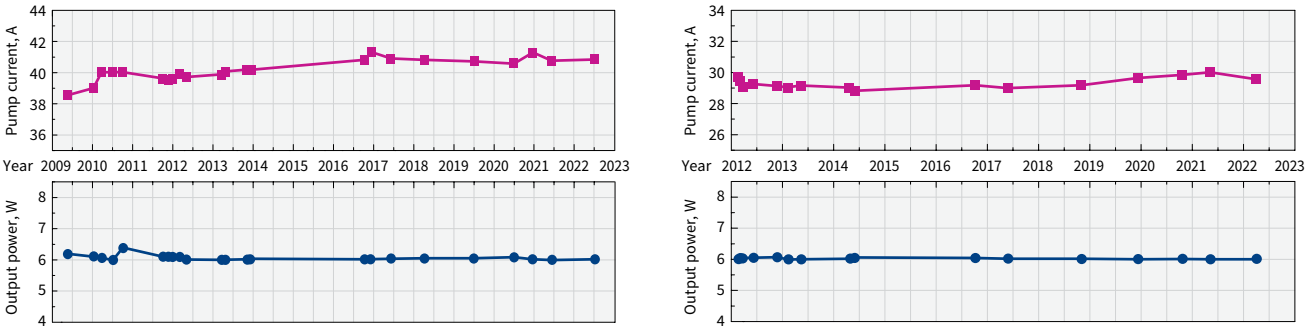


Typical far-field beam profile of PHAROS

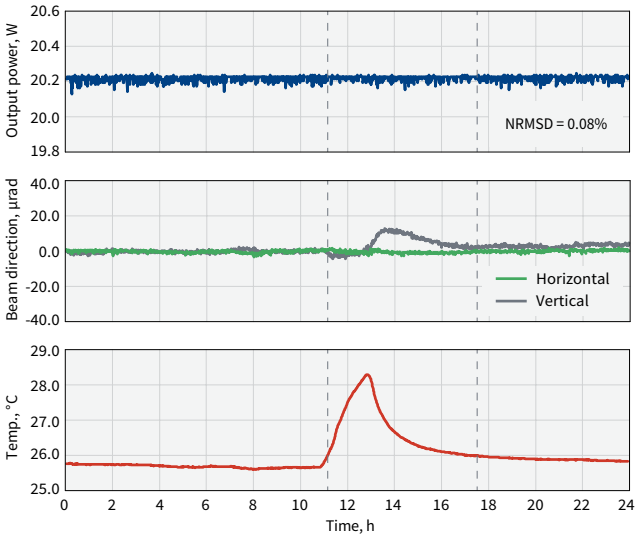
STABILITY MEASUREMENTS



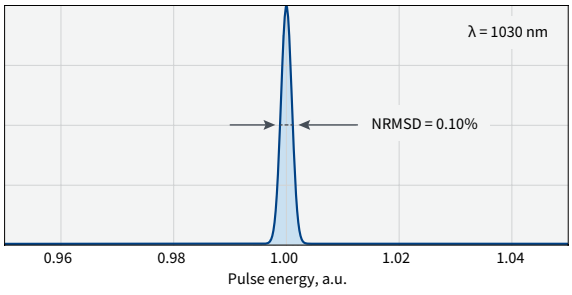
Long-term power stability of PHAROS



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



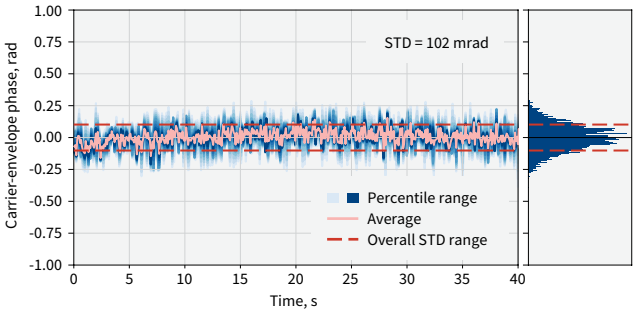
PHAROS output power and beam direction with power lock enabled, under varying environmental conditions



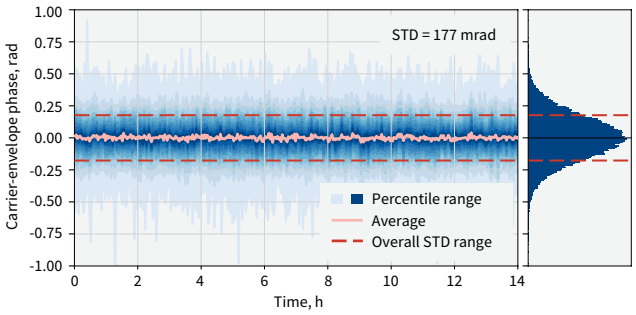
Typical pulse-to-pulse energy stability

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

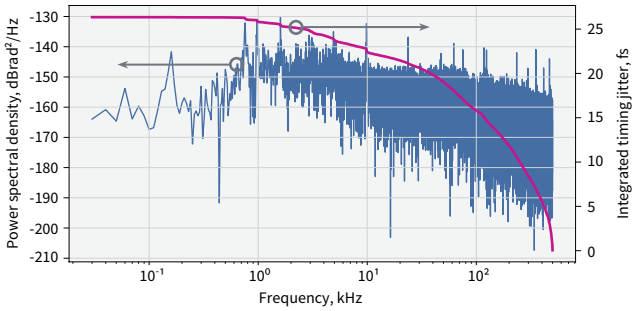


Long-term CEP stability of PHAROS operating at 200 kHz repetition rate

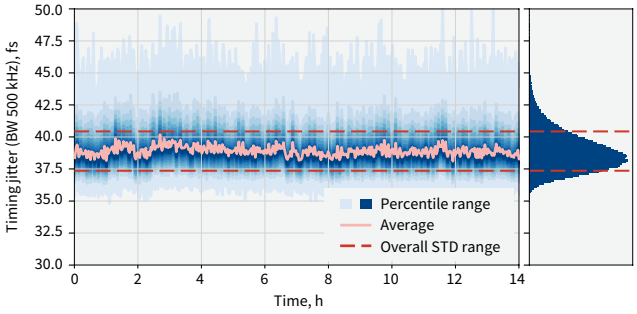
REPETITION RATE LOCKING

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.

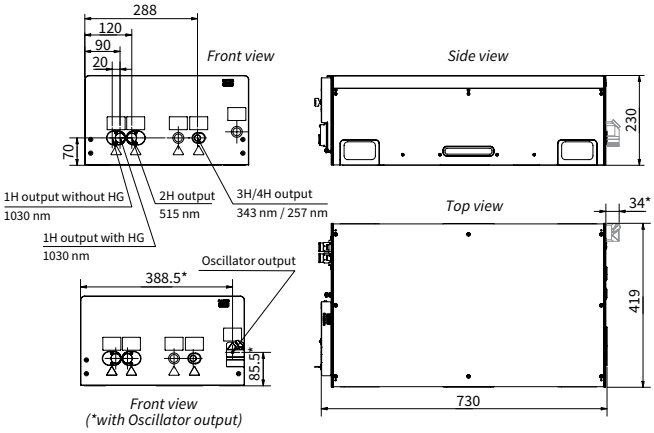


Phase noise data of PHAROS oscillator locked to a 2.8 GHz RF source

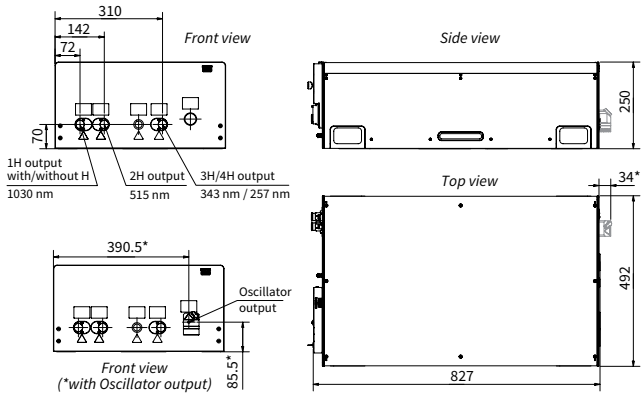


Timing jitter stability over 14 h; PHAROS oscillator locked to a 2.8 GHz RF source

DRAWINGS



PHAROS-PH2 / PH2-UP without harmonics



PHAROS-PH2-4mJ / PH2-UP with harmonics

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).

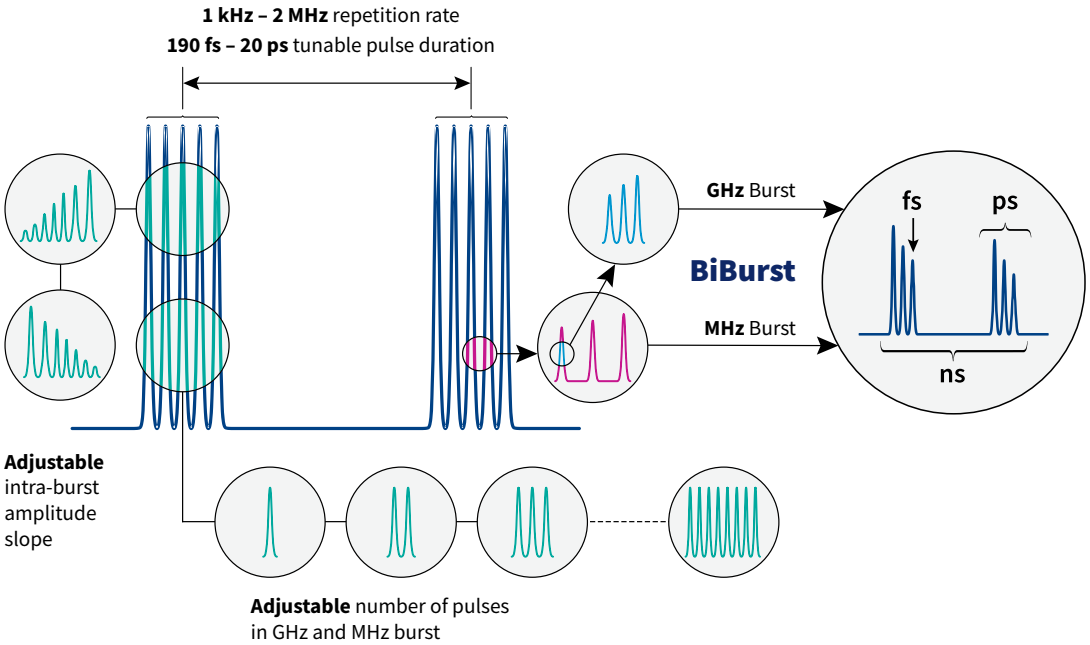
PHAROS and CARBIDE lasers with the BiBurst option bring new capabilities to high-tech manufacturing industries such as consumer electronics, integrated photonic chip manufacturing, future display manufacturing, and quantum technologies. The applications include:

- 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 [3])

[1] *Custom spacing is available on request.*
[2] *Maximum number of pulses in a burst depends on the laser repetition rate and the energy. Custom number of pulses is available on request.*
[3] *Fast energy control option. Enables formation of any pulse envelope at laser pulse repetition rate.*



HG | PHAROS

Automated Harmonic Generators

PHAROS with harmonic generator

FEATURES

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

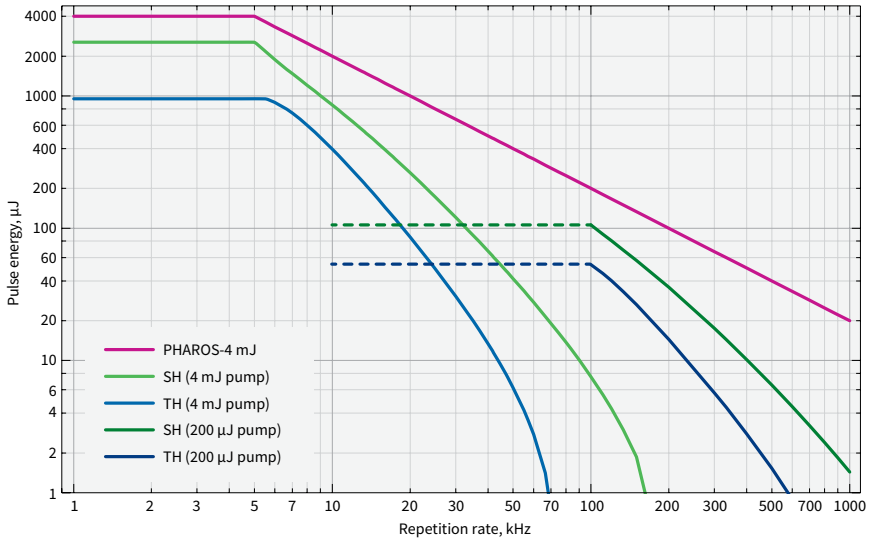
PHAROS lasers equipped with automated harmonic generators (HGs) provide a selection of fundamental (1030 nm), second (515 nm), third (343 nm), fourth (257 nm), or fifth (206 nm) harmonic outputs using software control.

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.

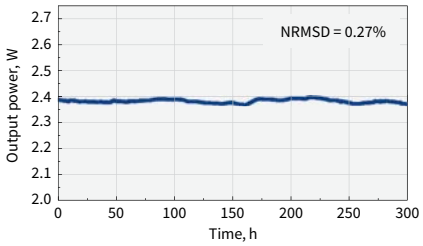
SPECIFICATIONS

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 – 4000 µJ	50 – 4000 µJ	20 – 4000 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)	

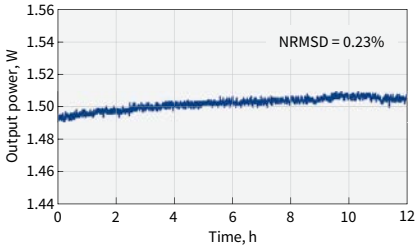
[1] Depends on pump laser model.
[2] Maximum output power of 2 W. Please contact sales@lightcon.com for higher power option.
[3] Maximum output power of 150 mW.



Pulse energy vs repetition rate of PHAROS with HG



3H output power stability



4H output power stability

LIGHT CONVERSION

I-OPA

Industrial-Grade Optical Parametric Amplifier

FEATURES

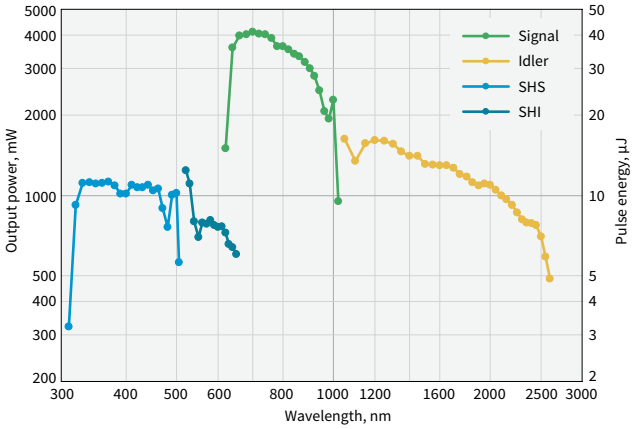
- Wavelength tunability in an industrial design
- Single-box solution
- Tunable or fixed-wavelength models
- Plug-and-play installation and robust performance
- The most compact OPA in the market

I-OPA-TW on air-cooled CARBIDE-CB5

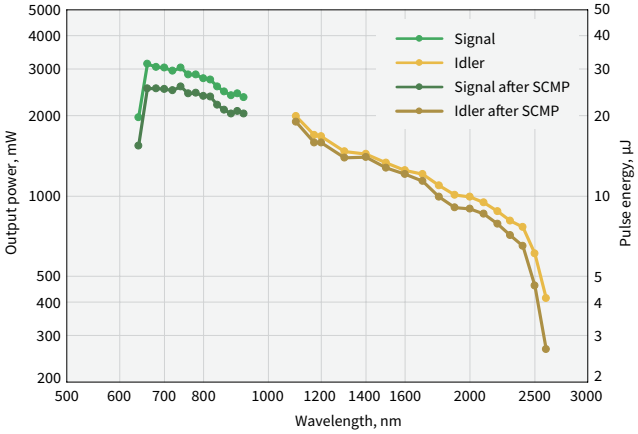
The industrial-grade optical parametric amplifier I-OPA series marks a new era of simplicity in the world of wavelength-tunable femtosecond sources. Based on decades of experience with optical parametric amplifiers, this solution combines wavelength tunability with robust industrial design.

The I-OPA is a rugged module integrated into our PHAROS or CARBIDE lasers, providing stability comparable to that of industrial harmonic generators. The sealed design provides mechanical stability and eliminates the effects of air turbulence, minimizing energy fluctuations and ensuring stable long-term performance.

The tunable I-OPA 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 models can also be used for micromachining and other industrial applications. The fixed-wavelength I-OPA is a cost-effective solution when a single wavelength is desired.



Typical I-OPA-TW-HP tuning curves.
Pump: 40 W, 400 µJ, 100 kHz

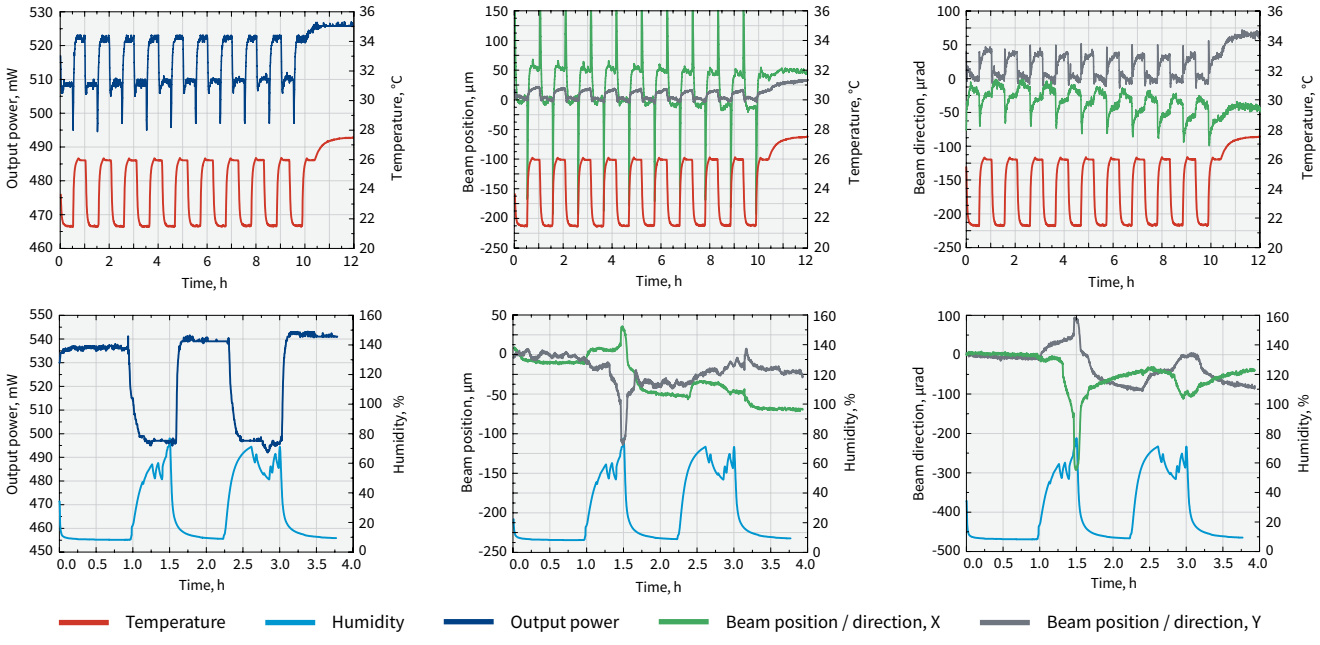


Typical I-OPA-TW-F tuning curves.
Pump: 40 W, 400 µJ, 100 kHz

SPECIFICATIONS

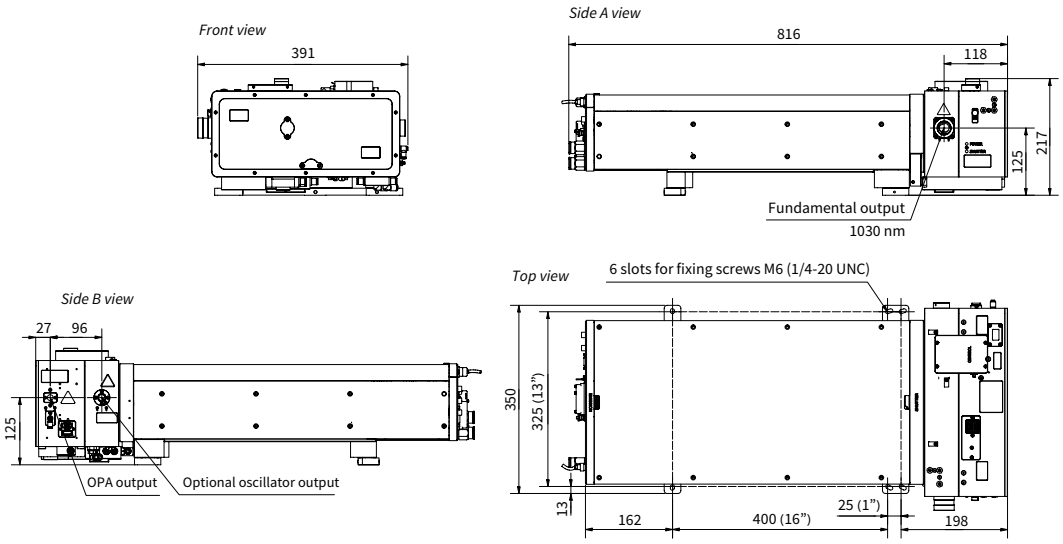
Model	I-OPA-HP	I-OPA-F	I-OPA-ONE
Configuration	ORPHEUS	ORPHEUS-F	ORPHEUS-ONE
Pump power	Up to 40 W		
Pump pulse energy	20 – 400 µJ		
Repetition rate	Up to 2 MHz		
Tuning range [1]	640 – 1010 nm (Signal) 1050 – 2600 nm (Idler)	650 – 920 nm (Signal) 1200 – 2500 nm (Idler)	1350 – 2000 nm (Signal) 2100 – 4500 nm (Idler)
Conversion efficiency	> 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 (20 – 40 µJ pump; up to 2 MHz)		> 6% @ 1550 nm (20 – 40 µJ pump; up to 2 MHz)
Spectral bandwidth [2]	80 – 220 cm^{-1} @ 700 – 960 nm	200 – 1000 cm^{-1} @ 650 – 920 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 – 920 nm < 70 fs @ 650 – 800 nm < 100 fs @ 1200 – 2000 nm	100 – 300 fs
Long-term power stability, 8 h [4]	< 1% @ 800 nm		< 1% @ 1550 nm
Pulse-to-pulse energy stability, 1 min [4]	< 1% @ 800 nm		< 1% @ 1550 nm
Wavelength extension options	320 – 505 nm (SHS) [5] 525 – 640 nm (SHI) [5]	Contact sales@lightcon.com	4500 – 10000 nm (DFG) [6]
Pulse compression options [2]	n/a	SCMP (Signal pulse compressor) ICMP (Idler pulse compressor) GDD-CMP (Compressor with GDD control)	n/a

[1] *In case of fixed wavelength (FW), a single wavelength can be selected from the Signal or Idler range. Signal may have accessible Idler pair, and vice versa.*
[2] *I-OPA-F broad-bandwidth pulses are compressed externally. Typical pulse duration before compression: 120 – 250 fs, after compression: 25 – 70 fs @ 650 – 920 nm, 40 – 100 fs @ 1200 – 2000 nm.*
[3] *Output pulse duration depends on the selected wavelength and pump laser pulse duration.*
[4] *Expressed as NRMSD (normalized root mean squared deviation).*
[5] *Conversion efficiency is 1.2% at peak; specified as the percentage of pump power.*
[6] *Up to 16 µm tuning range is accessible with an external difference frequency generator.*

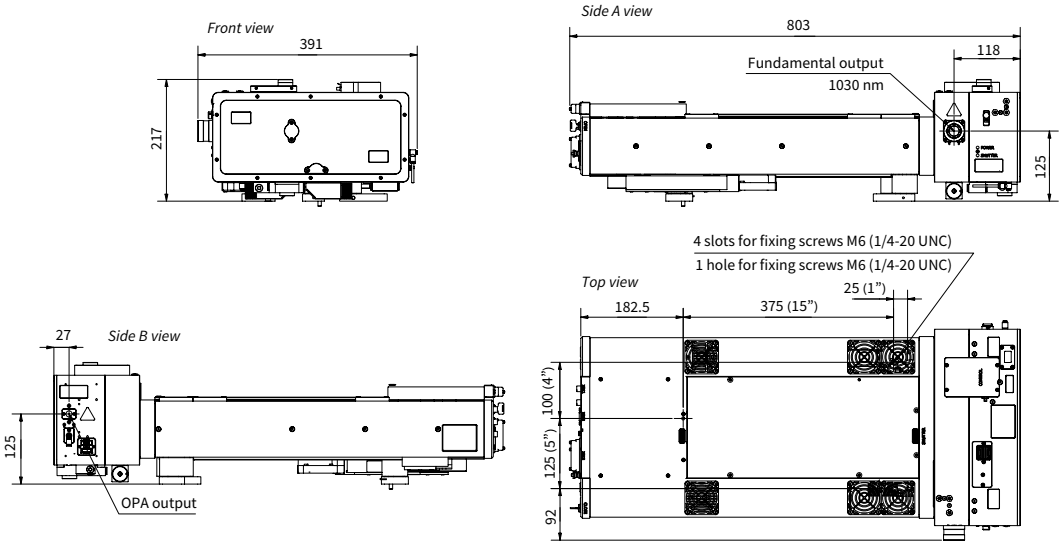


I-OPA output power, beam position, and beam direction under harsh environmental conditions

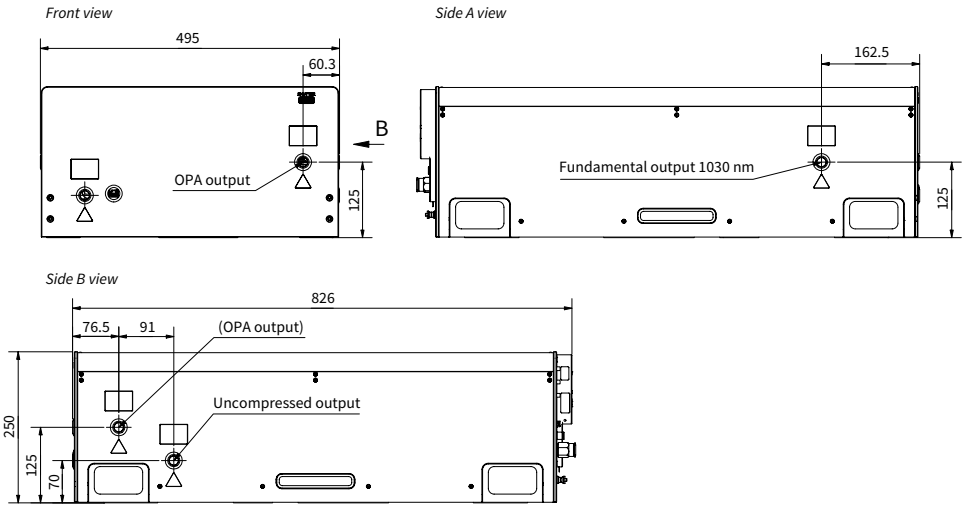
DRAWINGS



Drawing and output ports of CARBIDE-CB3 with wavelength-tunable/fixed I-OPA-HP



Drawing and output ports of CARBIDE-CB5 with wavelength-tunable/fixed I-OPA-HP



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