LIGHT CONVERSION

FEMTOSECOND LASERS FOR INDUSTRY

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

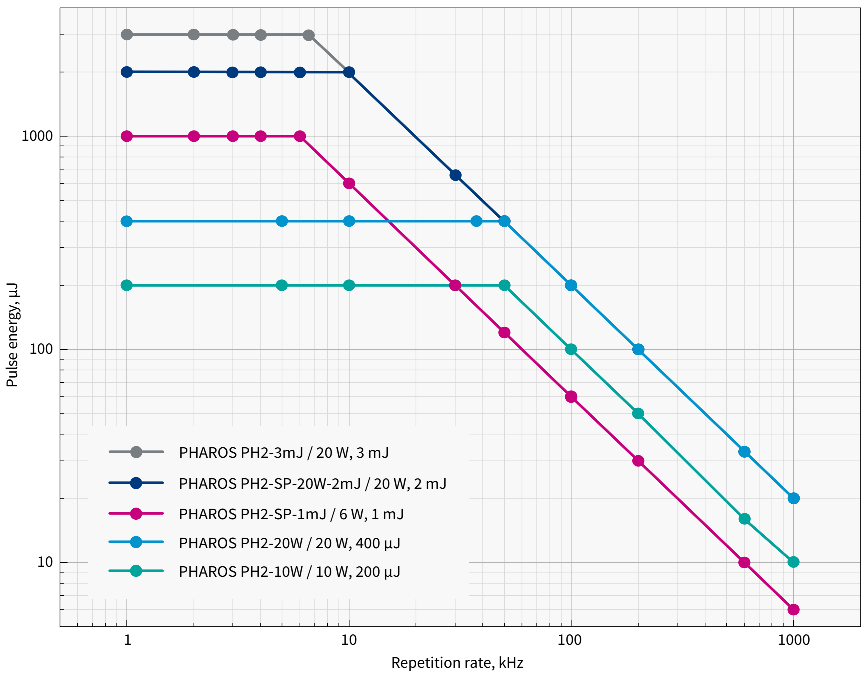
Modular-Design Femtosecond Lasers for Industry and Science

FEATURES

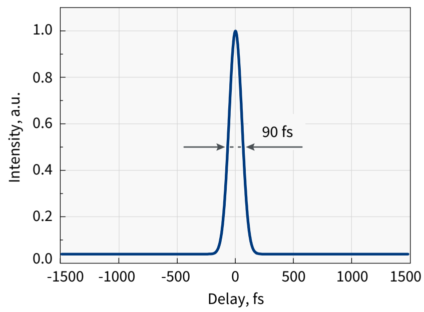
- 100 fs – 20 ps tunable pulse duration
- 3 mJ maximum pulse energy
- 20 W maximum output power
- Single-shot – 1 MHz repetition rate
- Pulse picker for pulse-on-demand mode
- BiBurst
- Automated harmonic generators (up to 5th harmonic)
- CEP stabilization option
- Repetition rate locking to an external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

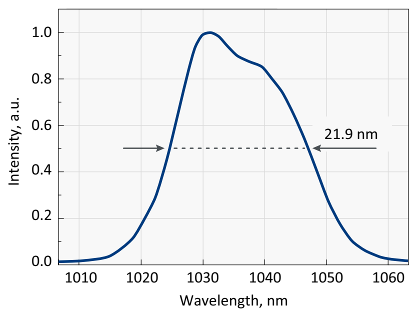
The tunability of PHAROS allows the system to cover applications normally requiring multiple different laser systems. Tunable parameters include pulse duration (100 fs – 20 ps), repetition rate (single-shot – 1 MHz), pulse energy (up to 3 mJ), and average power (up to 20 W). A pulse-on-demand mode is 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



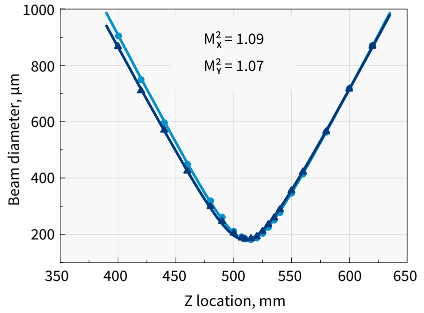
Typical spectrum of PHAROS-PH2-UP

SPECIFICATIONS

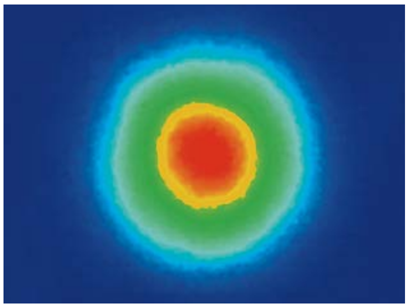
Model [1]	PH2-10W	PH2-20W	PH2-3mJ (NEW)	PH2-1mJ-SP	PH2-2mJ-SP	PH2-UP (NEW)
OUTPUT CHARACTERISTIC						
Maximum output power	10 W	20 W		10 W	20 W	10 W / 20 W
Pulse duration [2]	< 290 fs		< 350 fs [3]	< 190 fs		< 100 fs
Pulse duration tuning range	290 fs – 10 ps (20 ps on request)		350 fs – 10 ps (20 ps 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 14)*					
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.*

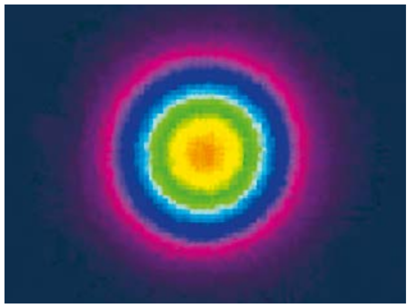
DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT



Typical M² measurement data of PHAROS

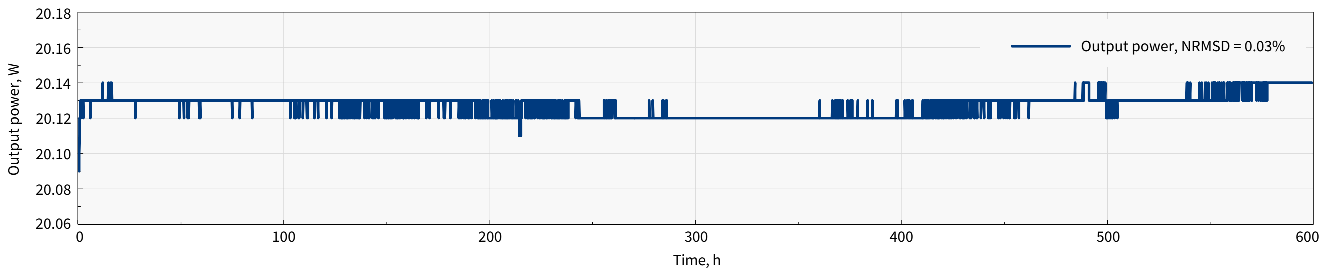


Typical near-field beam profile of PHAROS

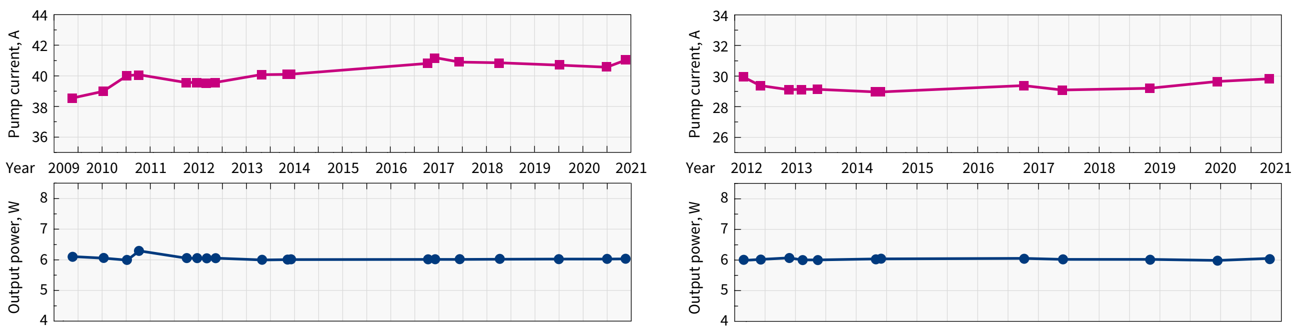


Typical far-field beam profile of PHAROS

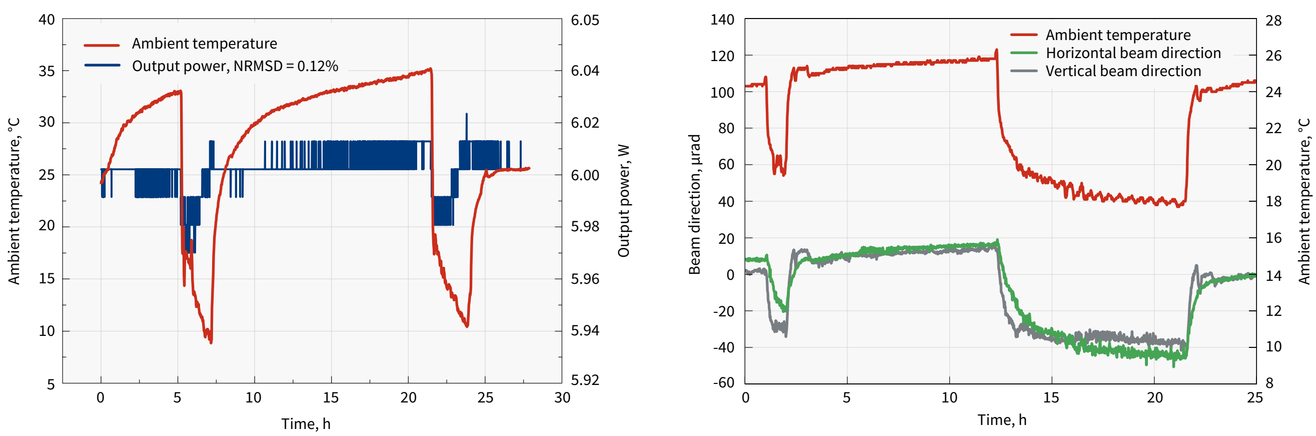
STABILITY MEASUREMENTS



Long-term power stability of PHAROS

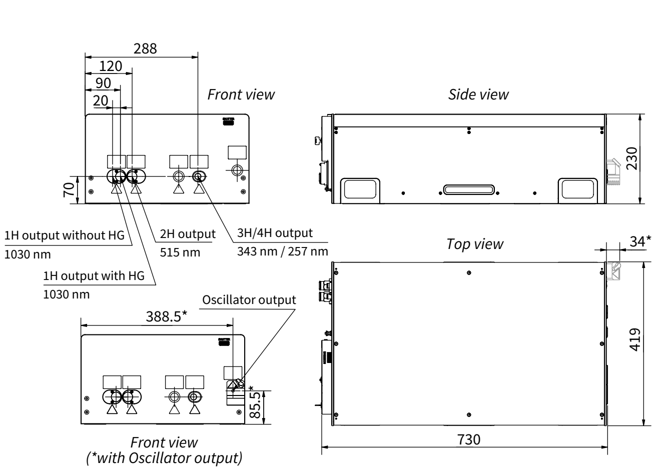


Output power of industrial-grade PHAROS lasers operating 24/7 and current of pump diodes during the years

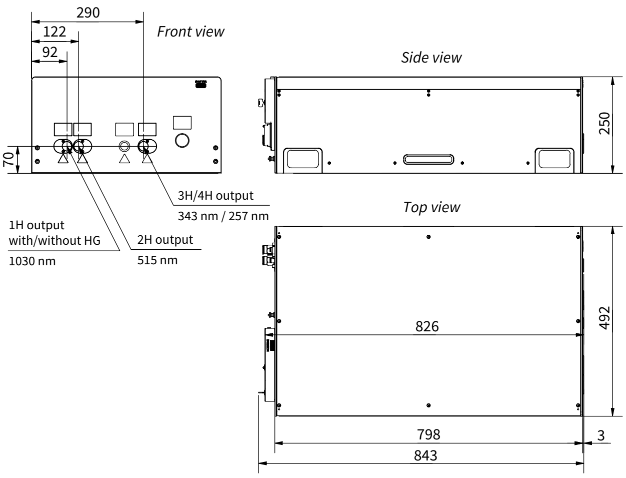


PHAROS output power and beam direction with power lock enabled, under harsh environmental conditions

DRAWINGS



PHAROS-PH2 drawing



PHAROS-PH2-3mJ drawing

HG | PHAROS

Automated Harmonic Generators

FEATURES

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

Harmonic generator attached to PHAROS

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.

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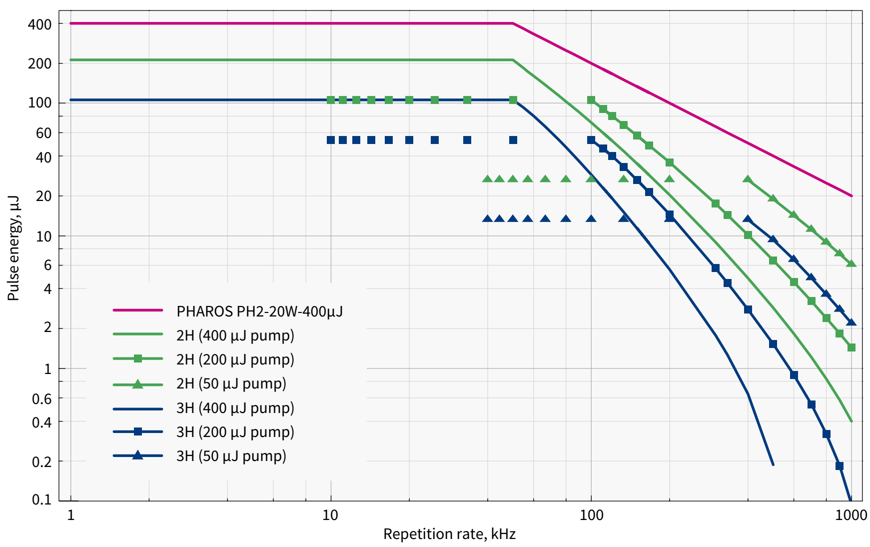
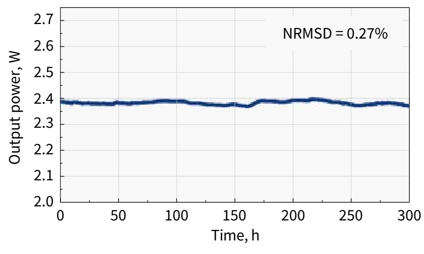
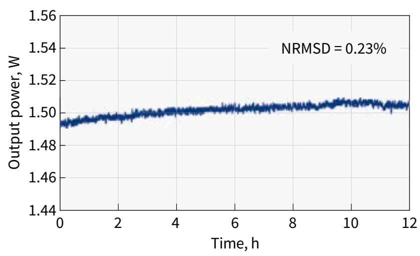


Pulse energy vs repetition rate of PHAROS with HG



3H output power stability



4H output power stability

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).

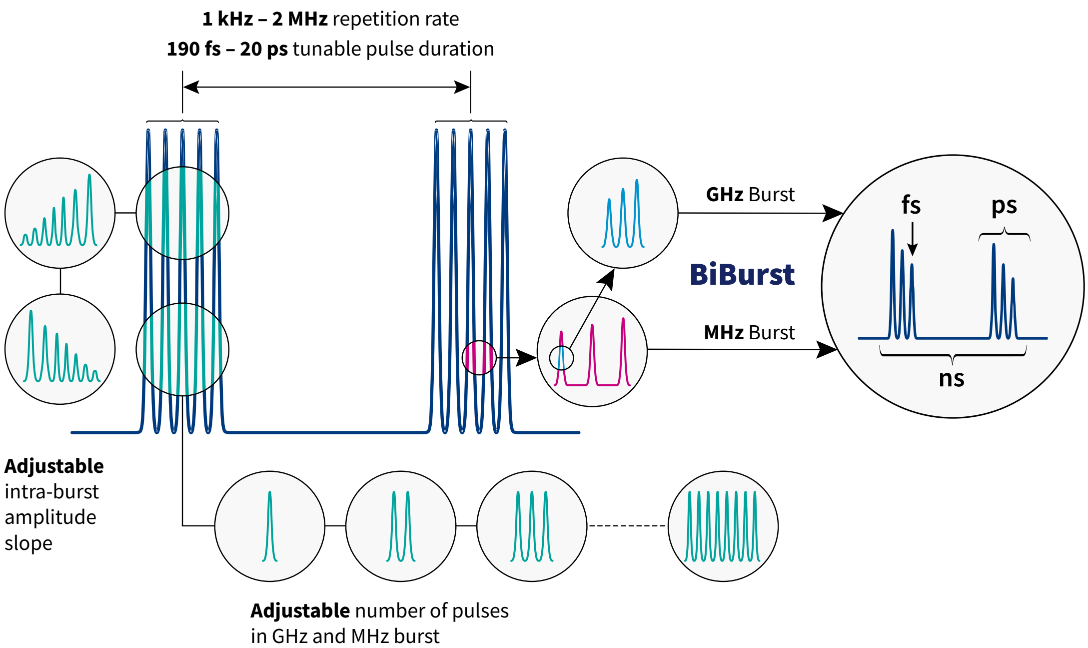
PHAROS and CARBIDE lasers with the BiBurst option bring new capabilities to high-tech manufacturing industries such as consumer electronics, integrated photonic chip manufacturing, future display manufacturing, and quantum technologies. The applications include:

- 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

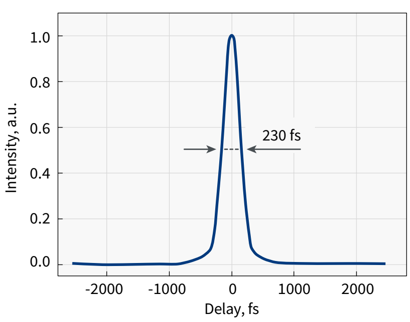
FEATURES

- 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

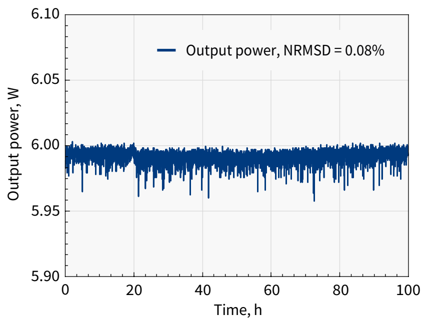
CARBIDE-CB3

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.

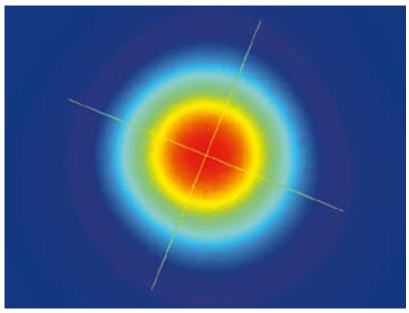
The tunability of CARBIDE lasers enables our customers to discover the most efficient manufacturing processes. Tunable parameters include pulse duration (190 fs – 20 ps), repetition rate (single-shot – 2 MHz), pulse energy (up to 2 mJ), and average power (up to 80 W). A pulse-on-demand mode is available 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.



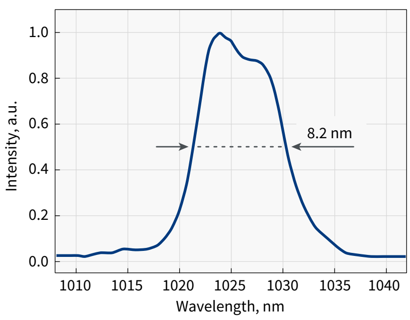
Typical pulse duration of CARBIDE laser



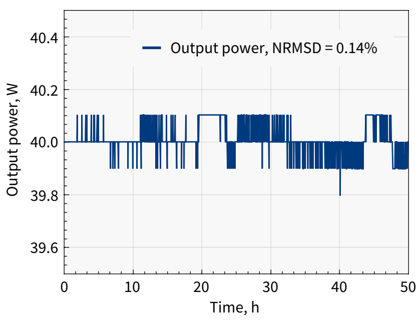
Long-term power stability of CARBIDE-CB5



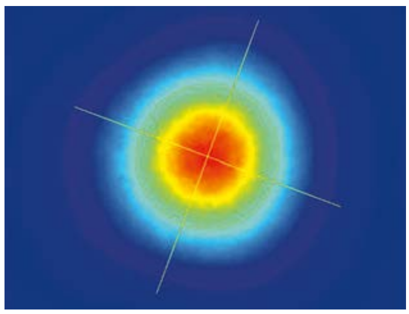
Typical beam profile of CARBIDE-CB5



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 13)*			
Output wavelength	515 nm, 343 nm, or 257 nm			
Optical parametric amplifier	Integrated, optional *(see page 14)*			
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

	CB3-20W	CB3-40W	CB3-80W	CB5 / CB5-SP
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

	CB3-20W	CB3-40W	CB3-80W	CB5 / CB5-SP
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	

DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION
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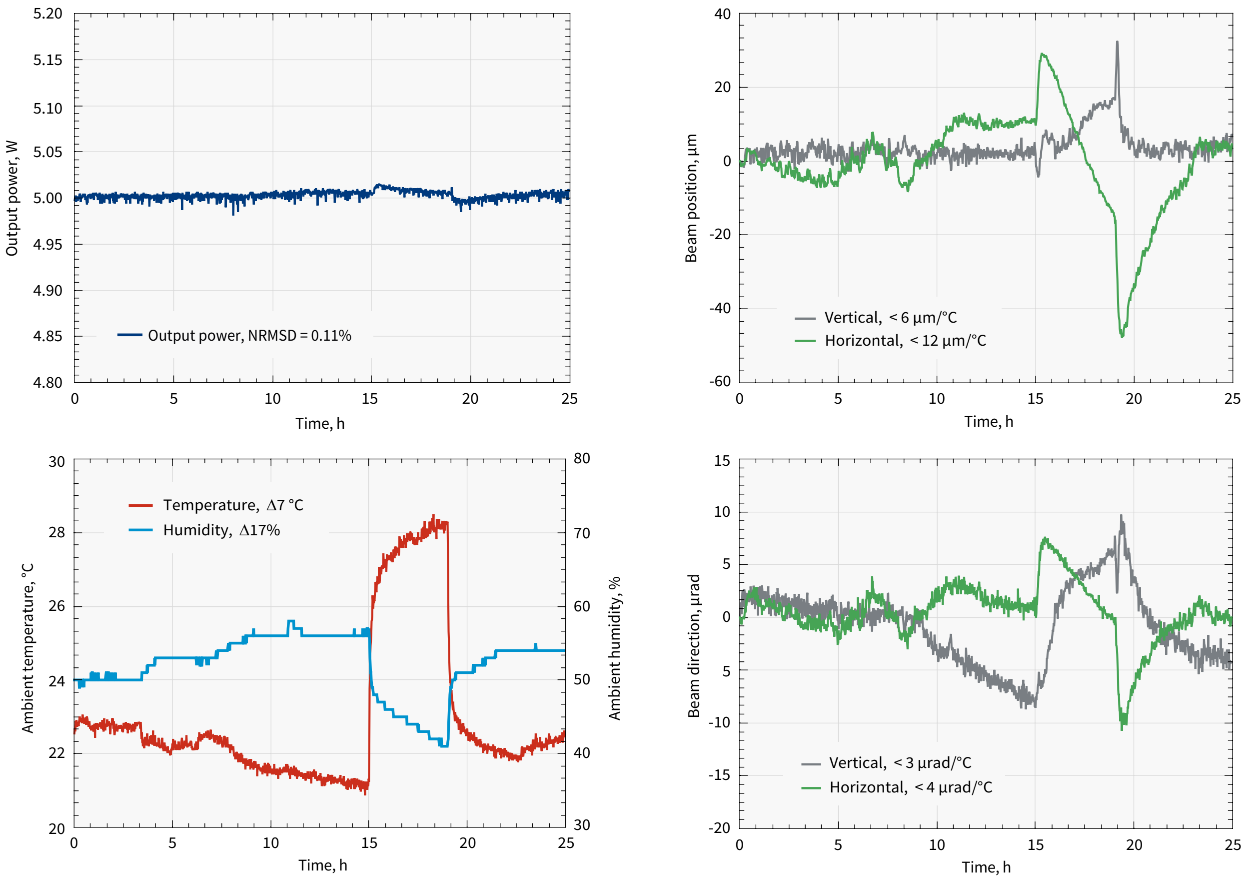
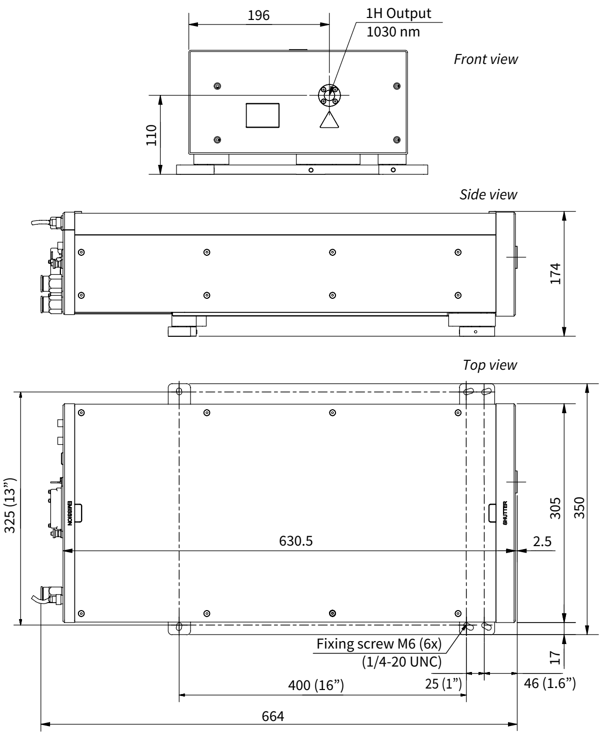
1) *Water-cooled version available on request.*
2) *Assuming Gaussian pulse shape.*
3) *Pulse duration can be reduced to < 250 fs if pulse peak intensity of > 50 GW/cm² is tolerated by customer setup.*
4) *Precise center wavelength for specific models available upon request.*
5) *FW 1/e², using maximum 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

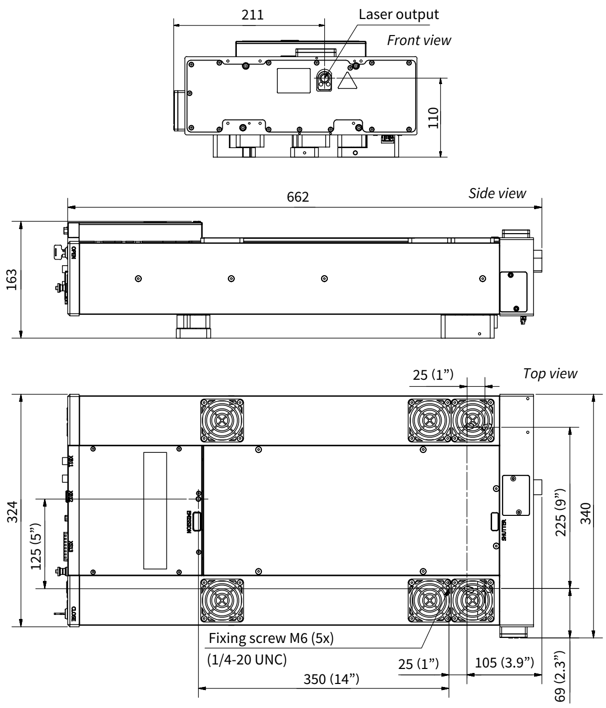


Output power, beam direction, and beam position of CARBIDE-CB5 under harsh environmental conditions

DRAWINGS



Drawing of CARBIDE-CB3



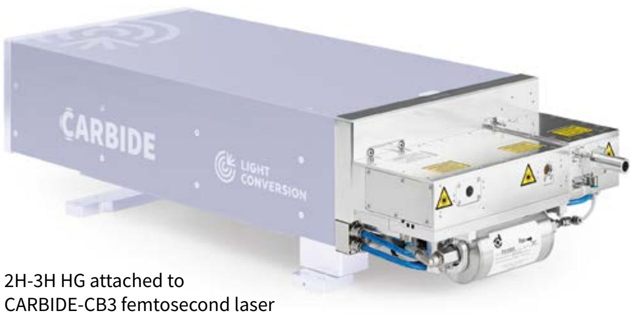
Drawing of air-cooled CARBIDE-CB5 with attenuator

HG | CARBIDE

Automated Harmonic Generators

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



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

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.

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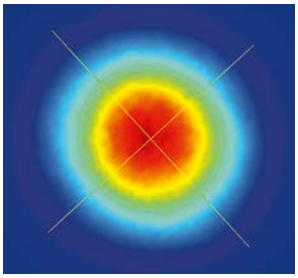
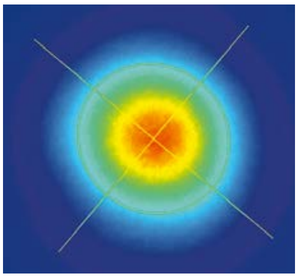
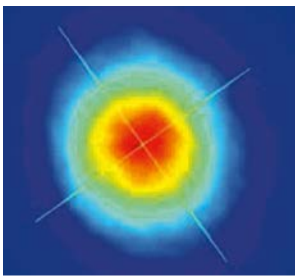
CLASS 4 LASER PRODUCT



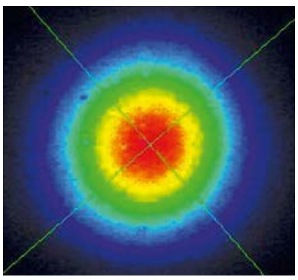
Typical 1H beam profile
of CARBIDE-CB5 (100 kHz, 6 W)



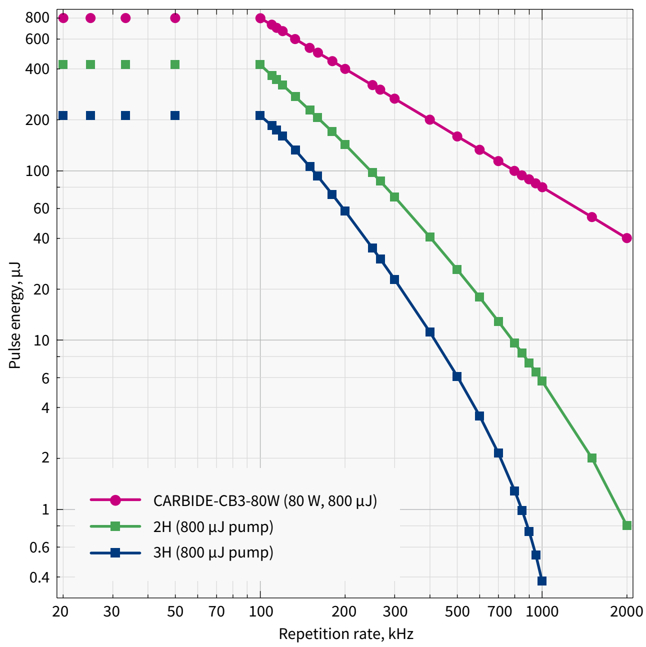
Typical 2H beam profile
of CARBIDE-CB5 (100 kHz, 3.4 W)



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

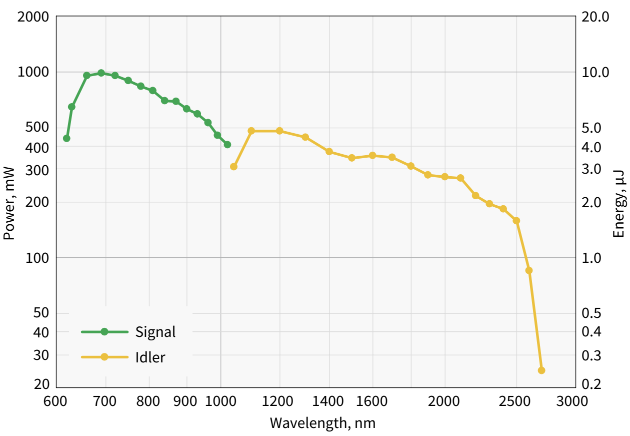
I-OPA-TW attached to air-cooled CARBIDE-CB5

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.

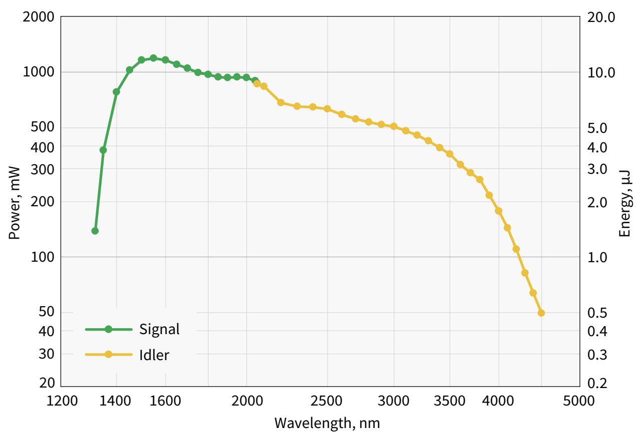
The tunable-wavelength I-OPA (I-OPA-TW) provides a wide tuning range and is primarily intended for spectroscopy and microscopy applications. In particular, the -HP model is targeted to be coupled with our HARPIA spectroscopy system as a pump beam source for ultrafast pump-probe spectroscopy. The -F model 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

LIGHT CONVERSION

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.*

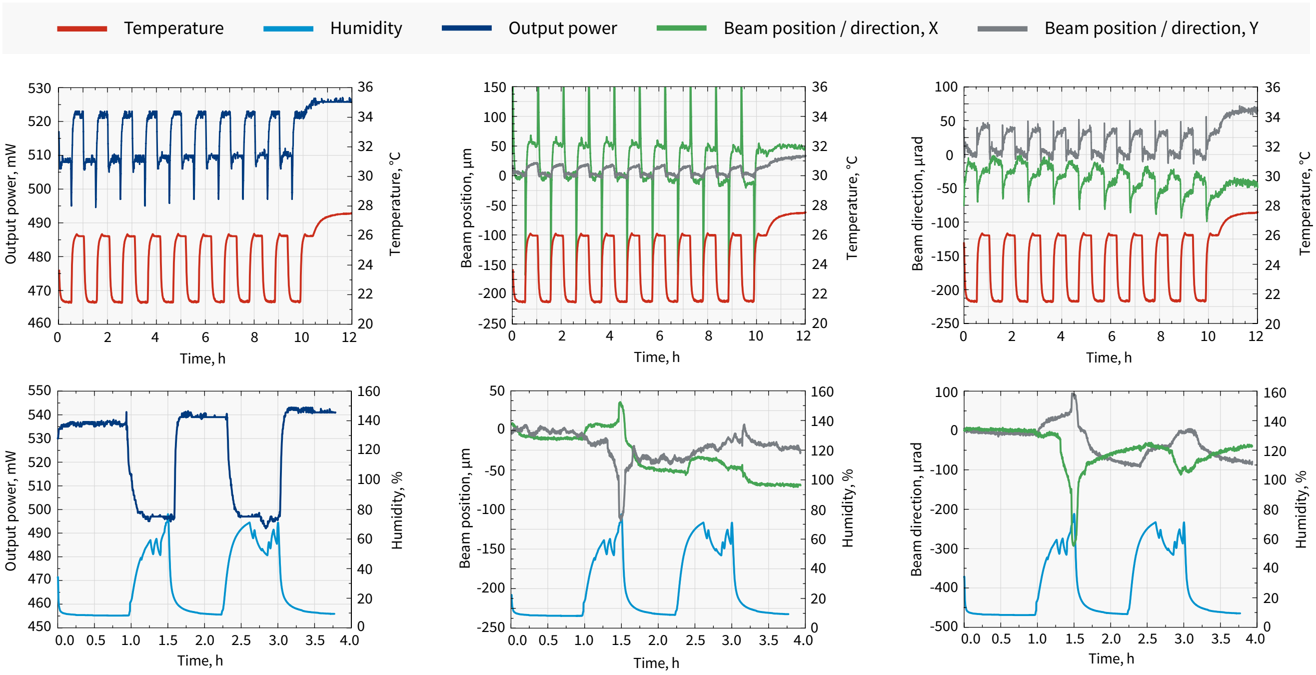
DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT

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.*

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



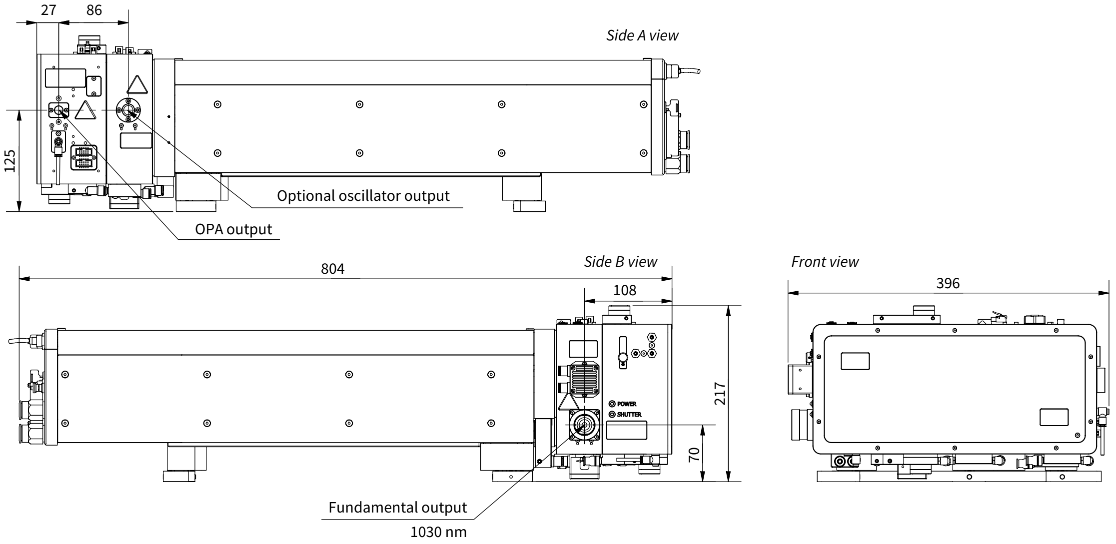
I-OPA-FW output power, beam position, and beam direction under harsh environmental conditions

COMPARISON WITH OTHER FEMTOSECOND AND PICOSECOND LASERS

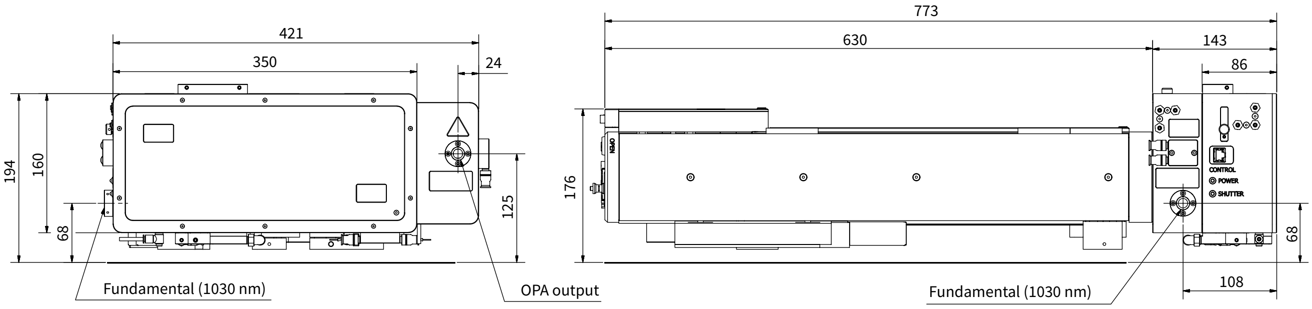
<table>
<tr><th rowspan="2">Laser technology</th><th rowspan="2">Our solution [1]</th><th colspan="4">Typical performance [2]</th></tr>
<tr><th>HG or HIRO</th><th>I-OPA-FW-HP</th><th>I-OPA-FW-F [3]</th><th>I-OPA-FW-ONE</th></tr>
<tr><td>Excimer (193 nm, 213 nm)</td><td>5H of laser (205 nm)</td><td>>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

[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.*

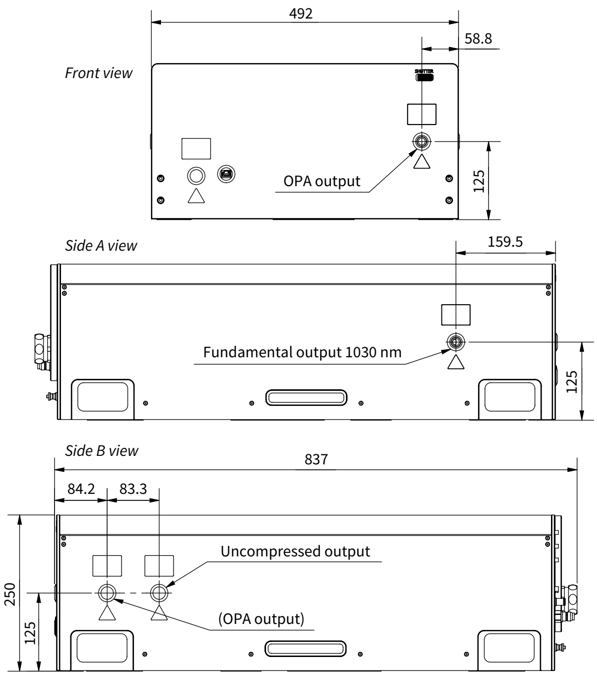
DRAWINGS



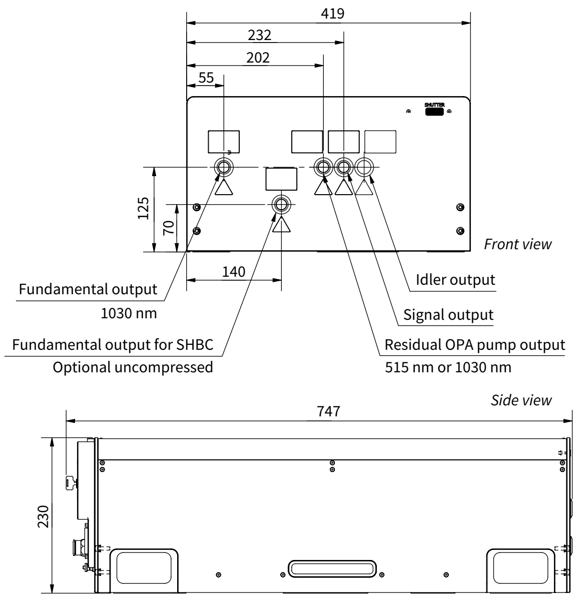
Drawing and output ports of CARBIDE-CB3 with tunable I-OPA-TW-HP



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

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.

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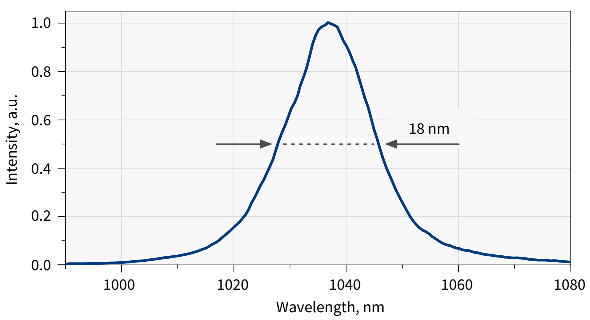
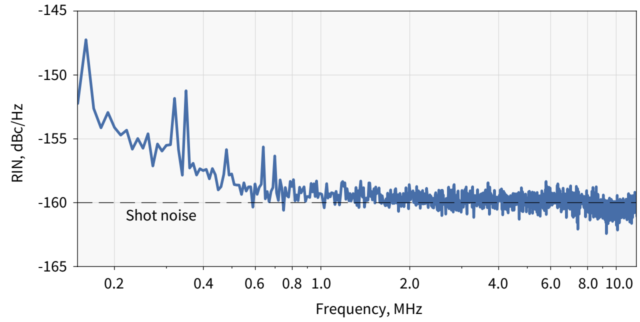
PERFORMANCE

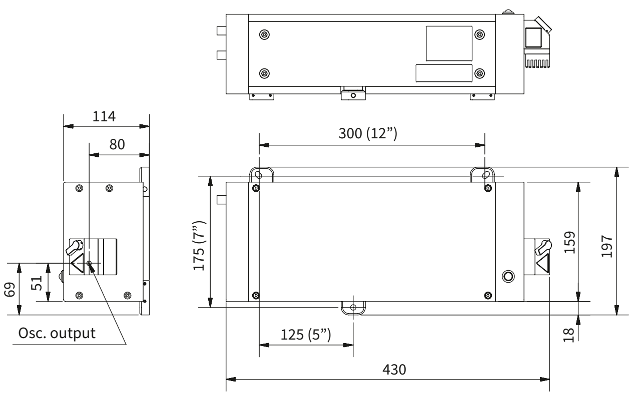


Typical FLINT optical spectrum

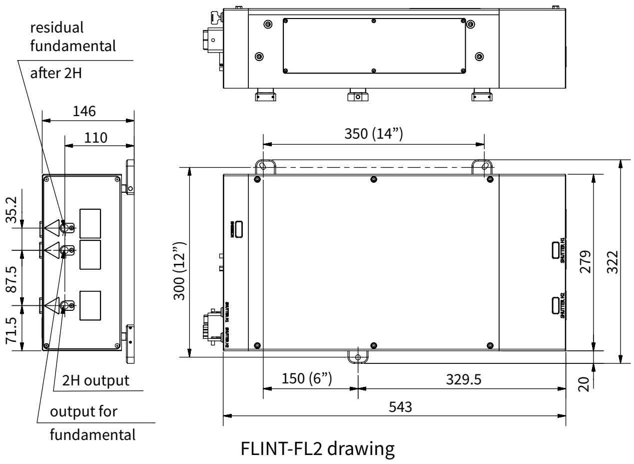


Relative intensity noise (RIN) of FLINT oscillator, shot-noise limited at -160 dBc/Hz above 1 MHz

DRAWINGS



FLINT-FL1 drawing



FLINT-FL2 drawing

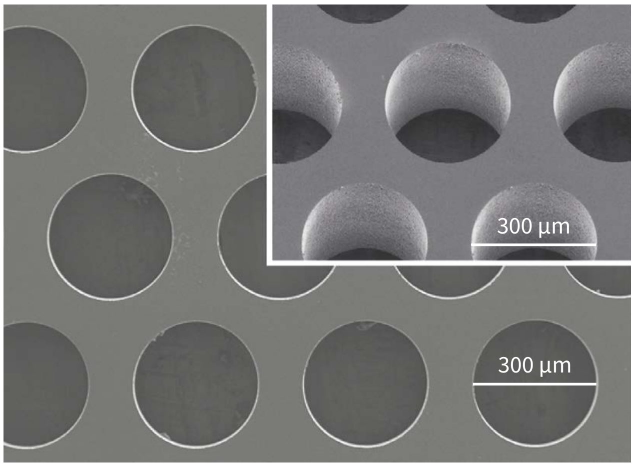
Examples of Industrial Applications

Birefringent volume modifications in glass

Form induced birefringence-retardance variation results in different colors in parallel polarized light.

Source: Workshop of Photonics.

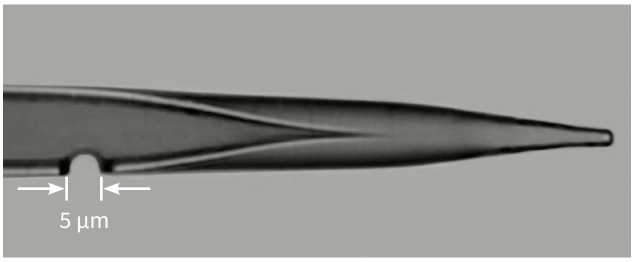
High precision glass drilling



Various glass drilling.

Source: Workshop of Photonics.

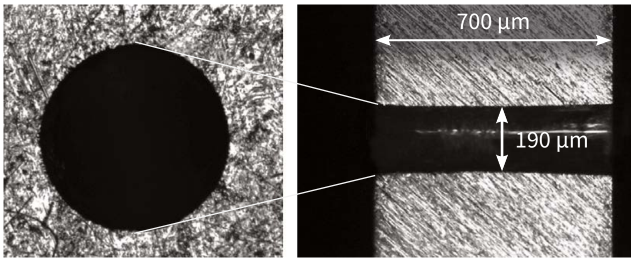
Glass needle microdrilling



Glass needle microdrilling.

Source: Workshop of Photonics.

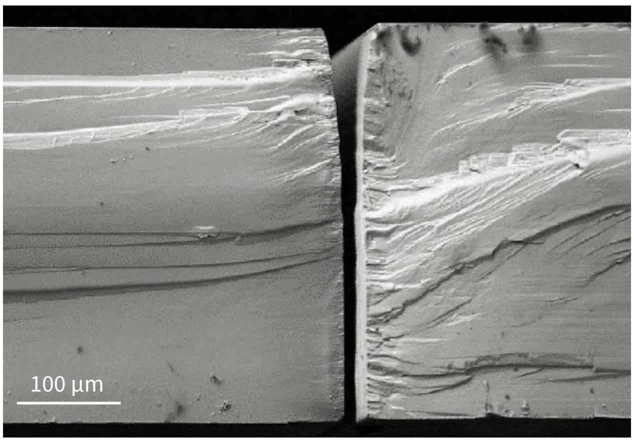
Steel drilling



Taperless hole microdrilling in stainless steel alloys.

Source: Workshop of Photonics.

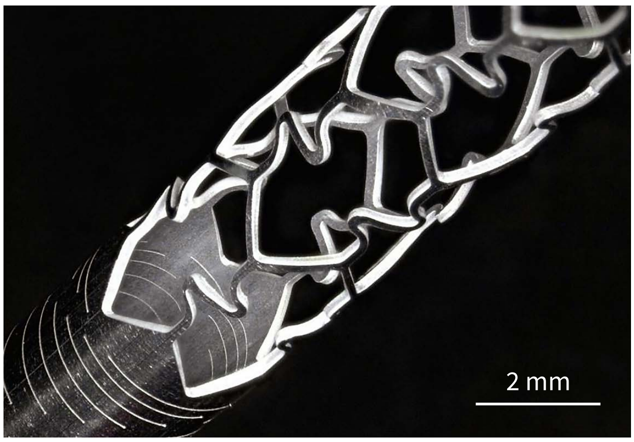
Brittle & highly thermal-sensitive material cutting



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.

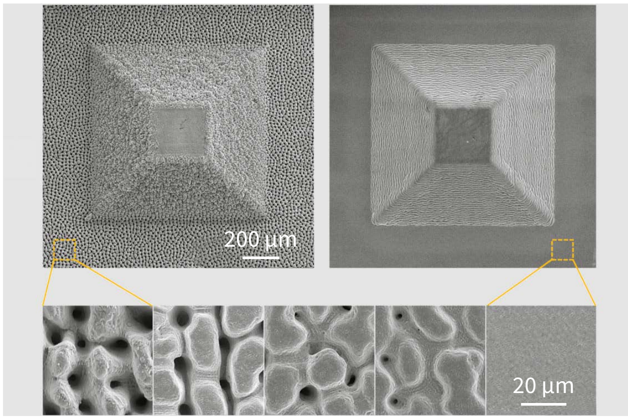
Source: Amada Miyachi America.

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).

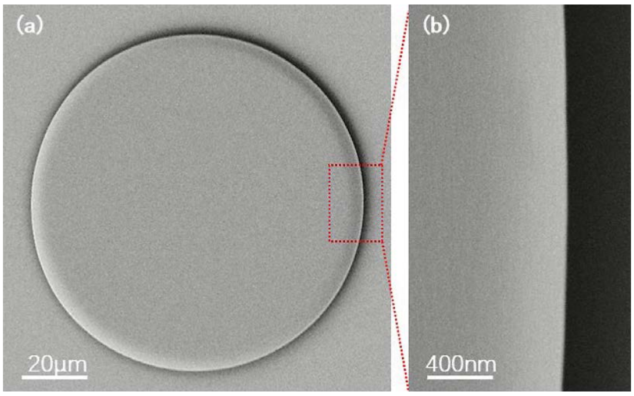
Stainless steel polishing



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).

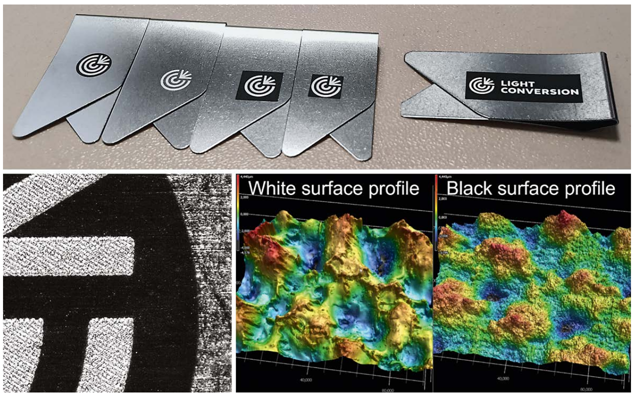
Selective ablation



Lithium niobate microdisks fabricated using selective ablation.

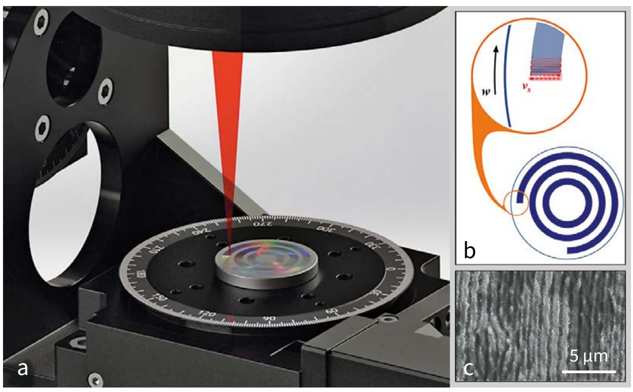
Source: "Fabrication of crystalline microresonators of high quality factors with a controllable wedge angle on lithium niobate on insulator", J.Zhang, Z.Fang, J.Lin, J.Zhou, M.Wang, R.Wu, R.Gao, Y.Cheng. Nanomaterials (2019).

High-contrast marking



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

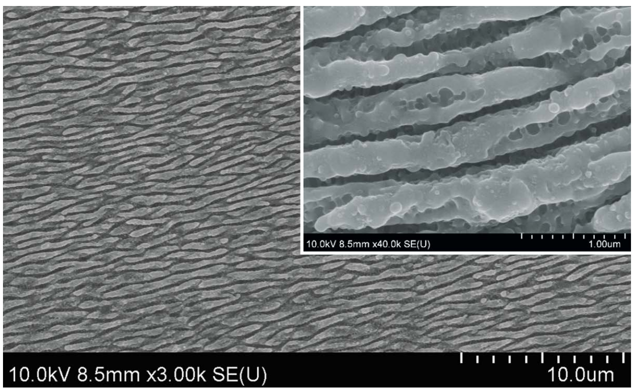
Friction and wear reduction



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).

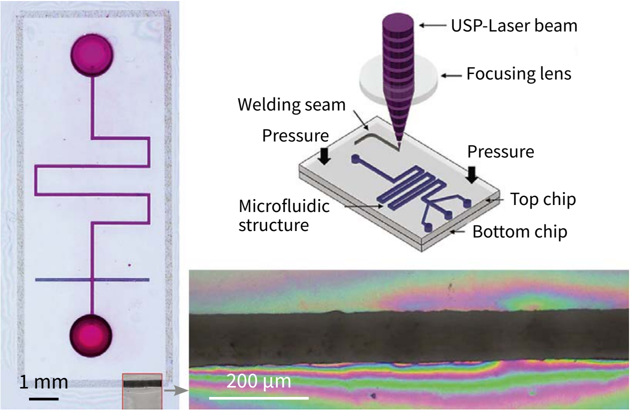
SERS sensor fabrication



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).

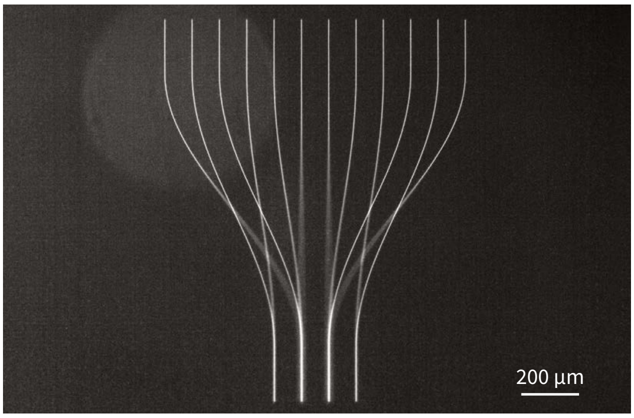
Lab-on-chip channel ablation and welding



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).

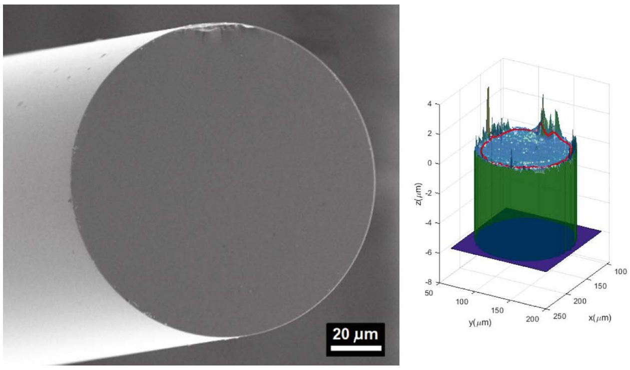
3D waveguides



3D waveguides fabricated in fused silica glass.

Source: Workshop of Photonics.

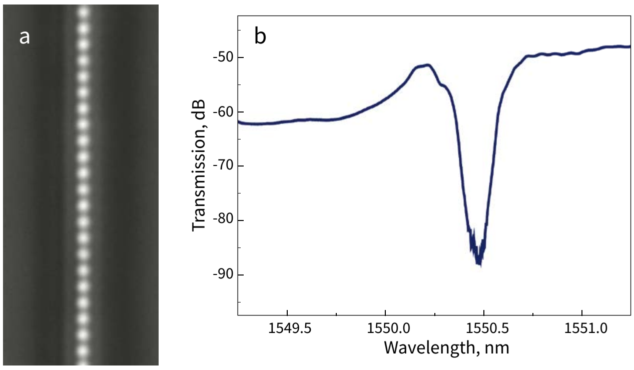
Fiber cleaving



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

Source: RMIT University, Melbourne.

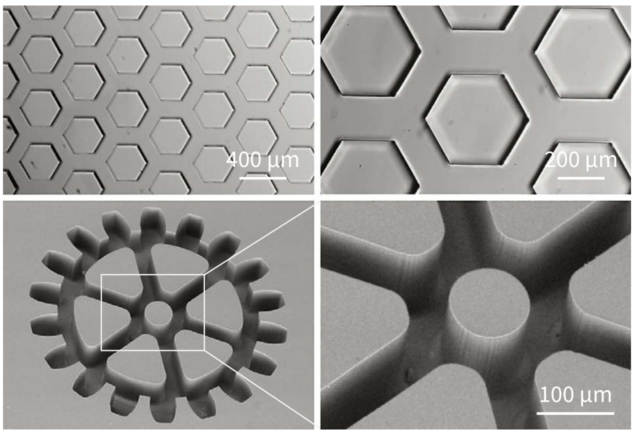
Bragg grating waveguide (BGW) writing



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).

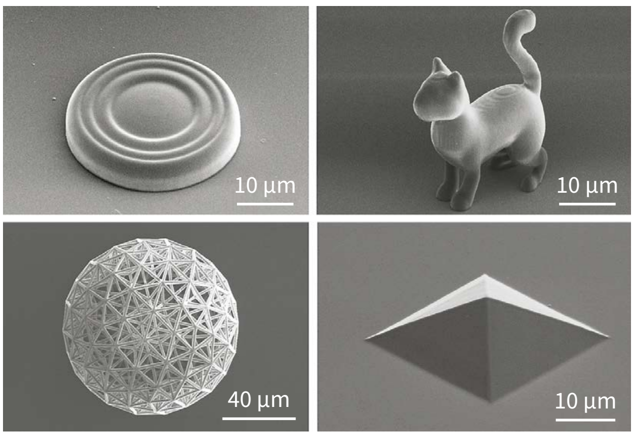
3D glass etching



Various structures fabricated in fused silica glass.

Source: Femtika.

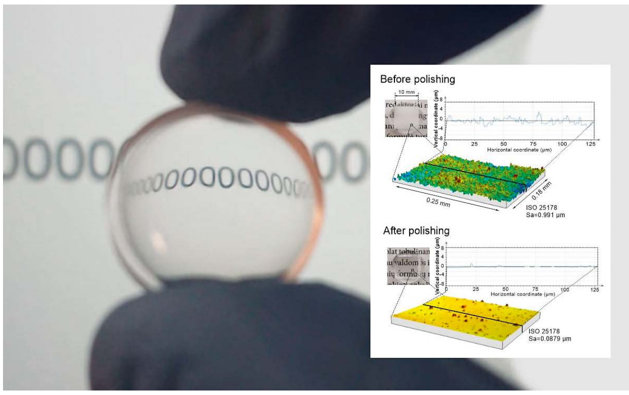
3D multiphoton polymerization



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

Source: Workshop of Photonics.

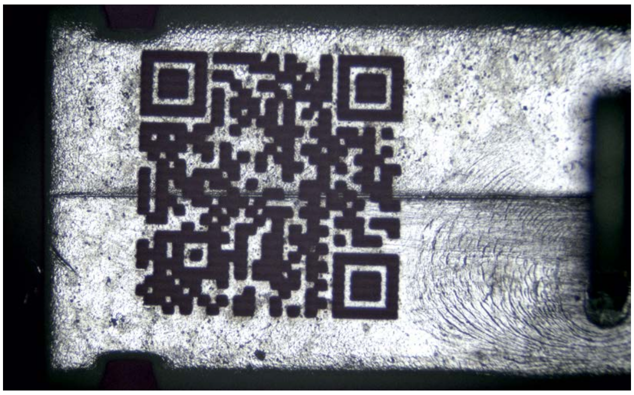
Polymer polishing



Polished curved surface and surface roughness measurements before and after polishing with GHz BiBurst.

Source: "Micromachining of Transparent Biocompatible Polymers Applied in Medicine Using Bursts of Femtosecond Laser Pulses", E. Kažukauskas, S. Butkus, P. Tokarski, V. Jukna, M. Barkauskas, V. Sirutkaitis. Micromachines (2020).

QR code marking



High contrast QR codes markings on various samples. Size 3 × 3 mm. Sky-writing mode enabled.

Source: Light Conversion apps lab.

Color center formation

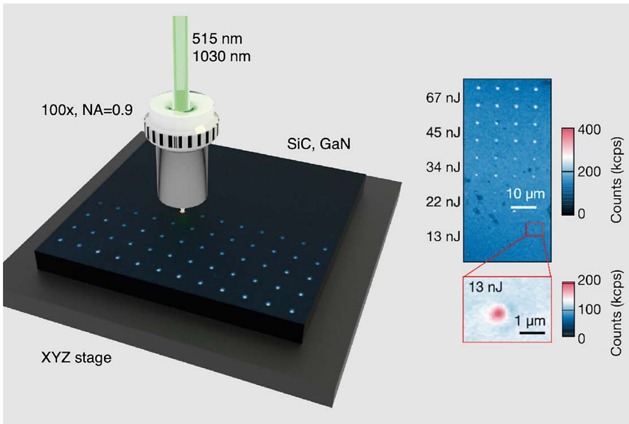
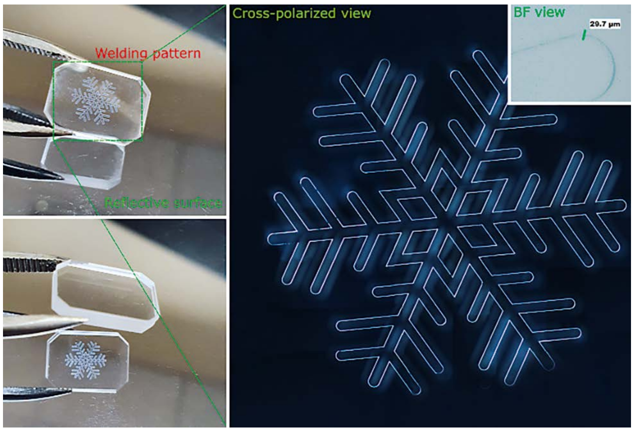


Illustration of the laser writing of color centers (left), silicon carbide containing arrays of laser-written color centers (right).

Source: "Color Centers Enabled by Direct Femto-Second Laser Writing in Wide Bandgap Semiconductors", S. Castelletto, J. Maksimovic, T. Katkus, T. Ohshima, B.C. Johnson, S. Juodkazis. Nanomaterials (2020).

Glass welding

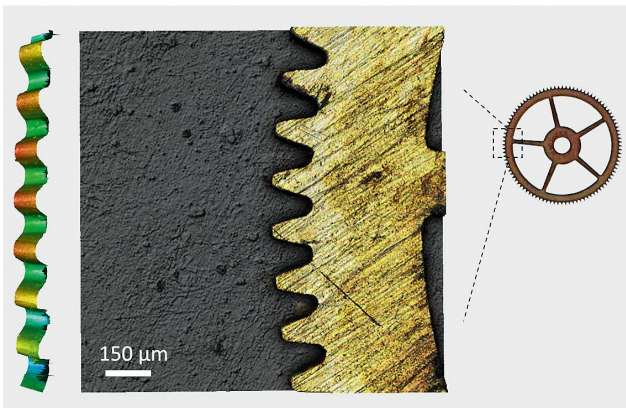


Example of 1 mm thick fused silica glass welding.

Glass cutting

Example of glass cutting. Source: Citrogene.

Precision parts cutting from brass



Example of gear cut from brass. Source: Lasea.

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