FEMTOSECOND LASERS FOR INDUSTRY

PRODUCT CATALOG

2021
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Founded in 1994 as a Vilnius University spin-off, LIGHT CONVERSION is now a major ultrafast laser technology company with over 300 employees, 10% of which hold PhD degrees, and more than 5000 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 and nanosecond pump-probe spectroscopy and microscopy system.

LIGHT CONVERSION has over 15 years of experience in managing international R&D projects. LIGHT CONVERSION was one of the key technology providers for the single-cycle SYLOS laser at the ELI-ALPS facility delivering CEP-stabilized 6.6 fs pulses with a peak power of 4.9 TW 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.
PHAROS
Modular-Design Industrial-Grade Femtosecond Lasers

FEATURES
- 190 fs – 20 ps tunable pulse duration
- 2 mJ maximum pulse energy
- 20 W maximum output power
- Single-shot – 1 MHz repetition rate
- Pulse picker for pulse-on-demand mode
- Industrial-grade design
- Optional automated harmonic generator
- Optional CEP stabilization
- Optional 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 (190 fs – 20 ps), repetition rate (single-shot – 1 MHz), pulse energy (up to 2 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 optional modules.

![Typical spectrum of PHAROS](image)

![Typical pulse duration of PHAROS](image)

![Pulse energy vs fundamental repetition rate of PHAROS](image)
### SPECIFICATIONS

#### OUTPUT CHARACTERISTIC

<table>
<thead>
<tr>
<th>Model</th>
<th>PH2-10W</th>
<th>PH2-15W</th>
<th>PH2-20W</th>
<th>PH2-SP-1mJ</th>
<th>PH2-SP-20W-2mJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum output power</td>
<td>10 W</td>
<td>15 W</td>
<td>20 W</td>
<td>10 W</td>
<td>20 W</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>&lt; 290 fs</td>
<td></td>
<td></td>
<td>190 fs – 10 ps (20 ps on request)</td>
<td></td>
</tr>
<tr>
<td>Pulse duration tuning range</td>
<td>290 fs – 10 ps (20 ps on request)</td>
<td></td>
<td></td>
<td>190 fs – 10 ps (20 ps on request)</td>
<td></td>
</tr>
<tr>
<td>Maximum pulse energy</td>
<td>0.4 mJ</td>
<td>1 mJ</td>
<td>2 mJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetition rate</td>
<td>Single-shot – 1 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse selection</td>
<td>Single-shot, pulse-on-demand, any fundamental repetition rate division</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center wavelength</td>
<td>1030 ± 10 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear, horizontal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam quality</td>
<td>TEM₀₀ ; M² &lt; 1.2</td>
<td>TEM₀₀ ; M² &lt; 1.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam diameter</td>
<td>2.5 mm</td>
<td>2.9 mm</td>
<td>4.3 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse-to-pulse energy stability</td>
<td>RMS deviation ≤ 0.5% over 24 h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-term power stability</td>
<td>RMS deviation ≤ 0.5% over 100 h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam pointing stability</td>
<td>&lt; 20 μrad/°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-pulse contrast</td>
<td>&lt; 1 : 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-pulse contrast</td>
<td>&lt; 1 : 200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### OPTIONAL EXTENSIONS

- **Oscillator output**: Optional. Contact sales@lightcon.com for more details or customized solutions
- **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 = 200 ± 40 ps
  - **Number of pulses, P**: 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)**: 780 × 419 × 230 mm
- **Chiller (L × W × H)**: 590 × 484 × 267 mm
- **24 V DC power supply (L × W × H)**: 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

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1) More models are available on request.
2) Assuming Gaussian pulse shape.
3) Precise wavelengths for specific models are available on request.
4) FWHM, measured at laser output, using maximum pulse energy.
5) Under stable environmental conditions.
6) Normalized to average pulse energy, NRMSD.
7) Custom spacing is available on request.
8) Maximum number of pulses in a burst depends on the laser repetition rate. Custom number of pulses are available on request.
9) Dimensions might increase for the lasers with integrated optional modules.
EXAMPLES OF INDUSTRIAL APPLICATIONS

FLINT OSCILLATORS

I-OPA OPTICAL PARAMETRIC AMPLIFIERS

CARBIDE LASERS

PHAROS LASERS

STABILITY MEASUREMENTS

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
EXAMPLES OF INDUSTRIAL APPLICATIONS

- FLINT OSCILLATORS
- I-OPA OPTICAL PARAMETRIC AMPLIFIERS
- CARBIDE LASERS
- PHAROS LASERS

PHAROS-PH2 laser PH2-730 housing drawing

**Front view**

- Oscillator output
- Side view
- Top view

**Dimensional Details:**
- 1H output without H: 1030 nm
- 1H output with Auto H: 1030 nm
- 2H output: 515 nm
- 3H/4H output: 343 nm / 257 nm
- 1H output without H: 1030 nm
- 1H output with Auto H: 1030 nm

**Notes:**
- (*with Oscillator output)
HG | PHAROS

Automated Harmonic Generators

FEATURES
- 515 nm, 343 nm, 257 nm, or 206 nm output
- Automated harmonic selection
- Mounted directly on the laser head
- 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

<table>
<thead>
<tr>
<th>Model</th>
<th>2H (-HE)</th>
<th>2H-3H (-HE)</th>
<th>2H-4H (-HE)</th>
<th>4H-5H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output wavelength ³</td>
<td>1030 nm</td>
<td>1030 nm</td>
<td>1030 nm</td>
<td>1030 nm</td>
</tr>
<tr>
<td>(automated selection)</td>
<td>515 nm</td>
<td>515 nm</td>
<td>515 nm</td>
<td>257 nm</td>
</tr>
<tr>
<td>343 nm</td>
<td>257 nm</td>
<td>206 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump pulse duration</td>
<td>190 – 300 fs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversion efficiency</td>
<td>&gt; 50% (2H)</td>
<td>&gt; 50% (2H)</td>
<td>&gt; 50% (2H)</td>
<td>&gt; 10% (4H) ³</td>
</tr>
<tr>
<td></td>
<td>&gt; 25% (3H)</td>
<td></td>
<td>&gt; 10% (4H) ³</td>
<td>&gt; 5% (5H) ⁴</td>
</tr>
<tr>
<td>Beam quality (M²)</td>
<td>≤ 400 µJ pump</td>
<td>&lt;1.15 (2H)</td>
<td>&lt;1.15 (2H)</td>
<td>&lt;1.15 (2H)</td>
</tr>
<tr>
<td>typical values</td>
<td>&lt;1.2 (2H)</td>
<td>n/a (4H)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 400 µJ pump</td>
<td>&lt;1.2 (2H)</td>
<td>n/a (4H)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;1.3 (3H)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹⁾ Depends on pump laser model. ²⁾ High energy versions are available, contact sales@lightcon.com for specifications. ³⁾ Maximum output power of 1 W. Please contact sales@lightcon.com for higher power option. ⁴⁾ Maximum output power of 0.15 W.
**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**

<table>
<thead>
<tr>
<th>Model</th>
<th>CARBIDE-CB3</th>
<th>PHAROS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GHz-Burst</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra burst pulse period ¹</td>
<td>440 ± 40 ps</td>
<td>200 ± 40 ps</td>
</tr>
<tr>
<td>Number of pulses, P ²</td>
<td>1 ... 10</td>
<td>1 ... 25</td>
</tr>
<tr>
<td><strong>MHz-Burst</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra burst pulse period ¹</td>
<td>≈ 15 ns</td>
<td></td>
</tr>
<tr>
<td>Number of pulses, N</td>
<td>1 ... 10</td>
<td>1 ... 9 (7 with FEC)</td>
</tr>
</tbody>
</table>

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 Industrial-Grade Femtosecond Lasers

FEATURES
- 190 fs – 20 ps tunable pulse duration
- 800 µJ maximum pulse energy
- 80 W maximum output power
- Single-shot – 2 MHz repetition rate
- Pulse picker for pulse-on-demand mode
- Industrial-grade design
- Air- or water-cooled models
- Optional automated harmonic generator
- Optional scientific interface module

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 0.8 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.

![Typical pulse duration of CARBIDE laser](image1)

![Long-term power stability of CARBIDE-CB5](image2)

![Typical spectrum of CARBIDE laser](image3)

![Long term power stability of CARBIDE-CB3](image4)
## SPECIFICATIONS

### OUTPUT CHARACTERISTICS

<table>
<thead>
<tr>
<th>Model</th>
<th>CB3-20W</th>
<th>CB3-40W</th>
<th>CB3-80W</th>
<th>CB5</th>
<th>CBS</th>
<th>CBS-SP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooling method</strong></td>
<td>Water-cooled</td>
<td></td>
<td></td>
<td>Air-cooled ¹⁾</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maximum output power</strong></td>
<td>20 W</td>
<td>40 W</td>
<td>80 W</td>
<td>6 W</td>
<td>5 W</td>
<td></td>
</tr>
<tr>
<td><strong>Pulse duration</strong> ²⁾</td>
<td>&lt; 250 fs</td>
<td></td>
<td></td>
<td>&lt; 290 fs</td>
<td>&lt; 190 fs</td>
<td></td>
</tr>
<tr>
<td><strong>Pulse duration tuning range</strong></td>
<td>250 fs – 10 ps</td>
<td></td>
<td></td>
<td>290 fs – 20 ps</td>
<td>190 fs – 20 ps</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum pulse energy</strong></td>
<td>0.4 mJ</td>
<td></td>
<td></td>
<td>0.8 mJ</td>
<td>100 µJ</td>
<td>83 µJ</td>
</tr>
<tr>
<td><strong>Repetition rate</strong></td>
<td>Single-shot – 1 MHz (2 MHz on request)</td>
<td>Single-shot – 1 MHz</td>
<td>Single-shot – 2 MHz</td>
<td>Single-shot – 1 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pulse selection</strong></td>
<td>Single-shot, pulse-on-demand, any fundamental repetition rate division</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Center wavelength</strong> ³⁾</td>
<td>1030 ± 10 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Polarization</strong></td>
<td>Linear, vertical; 1 : 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beam quality</strong></td>
<td>TEM₀₀; M² &lt; 1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beam diameter</strong> ⁴⁾</td>
<td>2.5 mm</td>
<td>2.7 mm</td>
<td>1.4 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pulse-to-pulse energy stability</strong> ⁵⁾</td>
<td>RMS deviation⁶⁾ &lt; 0.5% over 24 h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Long-term power stability</strong></td>
<td>RMS deviation⁴⁾ &lt; 0.5% over 100 h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beam pointing stability</strong></td>
<td>&lt; 20 μrad/°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pulse picker</strong></td>
<td>FEC ⁷⁾</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pulse picker leakage</strong></td>
<td>&lt; 0.5%</td>
<td></td>
<td></td>
<td>&lt; 2%</td>
<td>&lt; 0.1%</td>
<td>&lt; 2%</td>
</tr>
</tbody>
</table>

### OPTIONAL EXTENSIONS

- **Harmonic generators**
  Integrated, optional (see page 14)

- **Optical parametric amplifier**
  Integrated, optional (see page 15)

### 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

### ENVIRONMENTAL & UTILITY REQUIREMENTS

|-----------------------|--------------------------|-------------------------|

- **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
- **Rated power (chiller)**
  1400 W
  2000 W
  Not required
- **Power consumption (chiller)**
  1000 W
  1300 W

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¹⁾ Water-cooled version available on request.

²⁾ Assuming Gaussian pulse shape.

³⁾ Precise wavelengths for specific models available upon request.

⁴⁾ FWHM, measured at laser output, using maximum pulse energy.

⁵⁾ Under stable environmental conditions.

⁶⁾ Normalized to average pulse energy, NRMSD.

⁷⁾ Provides fast energy control; external analog control input available. Response time – next available RA pulse.

⁸⁾ Enhanced contrast AOM. Provides fast amplitude control of output pulse train.

⁹⁾ Custom spacing is available on request.

¹⁰⁾ 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

DRAWS

Drawing of CARBIDE-CB3

Drawing of air-cooled CARBIDE-CB5 with attenuator
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.
I-OPA
Industrial-Grade Optical Parametric Amplifier

FEATURES
- Tunable or fixed wavelength options
- 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 option
- Integrated tunable beam splitter for pump laser beam

The industrial-grade optical parametric amplifier I-OPA series marks a new era of simplicity in the world of tunable wavelength 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 mid-IR 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.

![I-OPA-TW attached to air-cooled CARBIDE-CBS](image)

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

<table>
<thead>
<tr>
<th>Model</th>
<th>I-OPA-TW-HP</th>
<th>I-OPA-TW-F</th>
<th>I-OPA-TW-ONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration</td>
<td>ORPHEUS</td>
<td>ORPHEUS-F</td>
<td>ORPHEUS-ONE</td>
</tr>
<tr>
<td>Pump power</td>
<td>Up to 40 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump pulse energy</td>
<td>10 – 400 µJ</td>
<td>20 – 400 µJ</td>
<td></td>
</tr>
<tr>
<td>Repetition rate</td>
<td>Up to 2 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuning range</td>
<td>640 – 1010 nm (Signal)</td>
<td>650 – 900 nm (Signal)</td>
<td>1350 – 2000 nm (Signal)</td>
</tr>
<tr>
<td></td>
<td>1050 – 2600 nm (Idler)</td>
<td>1200 – 2500 nm (Idler)</td>
<td>2100 – 4500 nm (Idler)</td>
</tr>
<tr>
<td>Conversion efficiency at peak</td>
<td>&gt; 7% @ 700 nm (40 – 400 µJ pump; up to 1 MHz)</td>
<td>&gt; 9% @ 1550 nm (40 – 1000 µJ pump; up to 1 MHz)</td>
<td>&gt; 6% @ 700 nm (10 – 40 µJ pump; up to 2 MHz)</td>
</tr>
<tr>
<td>Spectral bandwidth</td>
<td>80 – 220 cm⁻¹ @ 700 – 960 nm</td>
<td>200 – 1000 cm⁻¹ @ 650 – 900 nm</td>
<td>60 – 150 cm⁻¹ @ 1450 – 2000 nm</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>120 – 250 fs</td>
<td>&lt; 55 fs @ 800 – 900 nm</td>
<td>100 – 300 fs</td>
</tr>
<tr>
<td>Long-term power stability, 8 h</td>
<td>&lt; 1% @ 800 nm</td>
<td>&lt; 1% @ 800 nm</td>
<td>&lt; 1% @ 1550 nm</td>
</tr>
<tr>
<td>Pulse-to-pulse energy stability, 1 min</td>
<td>&lt; 1% @ 800 nm</td>
<td>&lt; 1% @ 800 nm</td>
<td>&lt; 1% @ 1550 nm</td>
</tr>
<tr>
<td>Contact</td>
<td><a href="mailto:sales@lightcon.com">sales@lightcon.com</a></td>
<td></td>
<td>4500 – 10000 nm (DFG)</td>
</tr>
<tr>
<td>Pulse compression options</td>
<td>–</td>
<td>SCMP (Signal pulse compressor)</td>
<td>GDD-CMP (Compressor with GDD control)</td>
</tr>
</tbody>
</table>

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

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

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.
COMPARISON WITH OTHER FEMTOSECOND AND PICOSECOND LASERS

<table>
<thead>
<tr>
<th>Laser technology</th>
<th>Our solution</th>
<th>Typical performance</th>
<th>HG or HIRO</th>
<th>I-OPA-FW-HP</th>
<th>I-OPA-FW-F</th>
<th>I-OPA-FW-ONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excimer (193 nm, 213 nm)</td>
<td>5H of laser</td>
<td>&gt; 20 µJ</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3H of Ti:Sapphire (266 nm)</td>
<td>4H of laser</td>
<td>&gt; 40 µJ</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3H of Nd:YAG (355 nm)</td>
<td>3H of laser</td>
<td>&gt; 100 µJ</td>
<td>&gt; 10 µJ</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2H of Nd:YAG (532 nm)</td>
<td>2H of laser</td>
<td>&gt; 200 µJ</td>
<td>&gt; 14 µJ</td>
<td>&gt; 25 µJ</td>
<td>&gt; 40 µJ</td>
<td>&gt; 25 µJ</td>
</tr>
<tr>
<td>Ti:Sapphire (800 nm)</td>
<td>OPA (750 – 850 nm)</td>
<td>–</td>
<td>&gt; 25 µJ</td>
<td>&gt; 40 µJ</td>
<td>&gt; 25 µJ</td>
<td>&gt; 25 µJ</td>
</tr>
<tr>
<td>Nd:YAG (1064 nm)</td>
<td>Laser (1030 nm)</td>
<td>400 µJ</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cr:Forsterite (1240 nm)</td>
<td>OPA (1200 – 1300 nm)</td>
<td>–</td>
<td>&gt; 14 µJ</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Erbium (1560 nm)</td>
<td>OPA (1500 – 1600 nm)</td>
<td>–</td>
<td>&gt; 10 µJ</td>
<td>&gt; 40 µJ</td>
<td>&gt; 25 µJ</td>
<td>&gt; 25 µJ</td>
</tr>
<tr>
<td>MIR sources (2500 – 4000 nm)</td>
<td>OPA (2500 – 4000 nm)</td>
<td>–</td>
<td>–</td>
<td>&gt; 5 µJ</td>
<td>&gt; 5 µJ</td>
<td>&gt; 5 µJ</td>
</tr>
</tbody>
</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.
³⁾ TSO-P-F F broad-bandwidth pulses are compressed externally. For compression options, see specifications above.
Examples of industrial applications

Flint Oscillators

I-OPA Optical Parametric Amplifiers

Carbide Lasers

Pharos Lasers

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 Oscillators

Features
- < 40 fs pulse duration
- Up to 260 nJ pulse energy
- Up to 20 W output power
- 76 MHz repetition rate
- No amplified spontaneous emission
- Industrial-grade design
- Optional automated second harmonic generator
- Optional CEP stabilization
- Optional repetition rate locking to an external source

FLINT oscillators are based on an Yb crystal pumped by a high-brightness laser diodes. Generation of femtosecond pulses is provided by Kerr lens mode-locking. Once started, mode-locking remains stable over a long period and is immune to minor mechanical impact. Oscillator cavity length can be adjusted using an optional piezo actuator. FLINT oscillators can also be equipped with carrier-envelope phase (CEP) stabilization and repetition rate locking to an external source.

Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>FL1-02</th>
<th>FL1-08</th>
<th>FL2-12</th>
<th>FL2-20</th>
<th>FL2-SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum output power</td>
<td>2 W</td>
<td>8 W</td>
<td>12 W</td>
<td>20 W</td>
<td>2 W</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>&lt; 100 fs</td>
<td>&lt; 120 fs</td>
<td>&lt; 120 fs</td>
<td>&lt; 170 fs</td>
<td>30 ... 50 fs</td>
</tr>
<tr>
<td>Maximum pulse energy</td>
<td>26 nJ</td>
<td>105 nJ</td>
<td>157 nJ</td>
<td>260 nJ</td>
<td>26 nJ</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>≈ 76 MHz</td>
<td>≈ 76 MHz</td>
<td>≈ 76 MHz</td>
<td>≈ 76 MHz</td>
<td>≈ 76 MHz</td>
</tr>
<tr>
<td>Center wavelength</td>
<td>1035 ± 10 nm</td>
<td>1030 ± 3 nm</td>
<td>1029 ± 3 nm</td>
<td>1026 ± 2 nm</td>
<td>1040 ± 10 nm</td>
</tr>
<tr>
<td>Pulse-to-pulse energy stability</td>
<td>RMS deviation &lt; 0.5% over 24 h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear, horizontal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam quality</td>
<td>TEM₀₀₀; M² &lt; 1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam pointing stability</td>
<td>&lt; 10 μrad/°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal 2H generator</td>
<td>n/a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal attenuator</td>
<td>n/a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
- Rated power 200 W
- Power consumption 100 W, 150 W
- Power consumption (chiller) 200 W, 800 W, 200 W

1/ Maximum output power and pulse energy depends on the chosen pulse duration, e.g., < 50 fs – 2 W, 26 nJ, < 40 fs – 1 W, 13 nJ.
2/ Assuming Gaussian pulse shape.
3/ Depends on repetition rate. Approximate values are given for 76 MHz repetition rate.
4/ Other repetition rates are available in the range from 60 to 100 MHz.
5/ Other repetition rates are available in the range from 70 to 80 MHz.
6/ Choice of a particular central wavelength with ±1 nm tolerance is available upon request.
7/ With enabled power lock, under stable environment.
8/ Normalized to average pulse energy, NRMSD.
EXAMPLES OF INDUSTRIAL APPLICATIONS

- FLINT OSCILLATORS
- I-OPA OPTICAL PARAMETRIC AMPLIFIERS
- CARBIDE LASERS
- PHAROS LASERS

PERFORMANCE

- Typical FLINT optical spectrum
- FLINT-FL2-20 (20 W) output power stability under harsh environmental conditions

DRAWINGS

- FLINT-FL1 drawing
- FLINT-FL2 drawing

- Typical FLINT optical spectrum
- FLINT-FL2-20 (20 W) output power stability under harsh environmental conditions
EXAMPLES OF INDUSTRIAL APPLICATIONS

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


Glass needle microdrilling


Steel drilling


Various type glass drilling


Nanodrilling of fused silica

**EXAMPLES OF INDUSTRIAL APPLICATIONS**

Flint Oscillators

I-OPA Optical Parametric Amplifiers

Carbide Lasers

Pharos Lasers

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**Milling of complex 3D surfaces**

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


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**Selective Cr thin film ablation**

Cr thin film ablation for creation of LiNbO₃ micro-disk resonator. (a,b) SEM images, (c) AFM image of micro-disk wedge, (d) optical images of micro-disk resonators with different diameters.


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**Terahertz broadband anti-reflection structures**

Fabricated moth-eye 3D profile, taken by laser scanning microscope.


---

**Friction and wear reduction**

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


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**3D waveguides**

3D waveguides fabricated in fused silica glass.

Source: Workshop of Photonics.

---

**Surface-enhanced Raman scattering (SERS) sensors fabrication**

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

EXAMPLES OF INDUSTRIAL APPLICATIONS  

FLINT OSCILLATORS  

I-OPA OPTICAL PARAMETRIC AMPLIFIERS  

CARBIDE LASERS  

PHAROS LASERS  

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).


Bragg grating waveguide (BGW) writing  

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


Birefringent glass volume modifications  

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

Source: Workshop of Photonics.

3D micro printing using multi-photon polymerization  

Various 3D structures fabricated in SZ2080 polymer using multi-photon polymerization – nanophotonic devices, microoptics, micromechanics.

Source: Femtika.

3D glass etching  

Various structures fabricated in fused silica glass.

Source: Femtika.

3D multi-photon 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.

Color center creation

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

Glass cutting

Example of glass cutting. Source: Citrogene.

QR code marking

High contrast QR codes markings on various samples. Size 3 × 3 mm. Sky-writing mode enabled.
Source: Light Conversion apps lab.

Stainless steel surface polishing

SEM image collage of structures ablated in stainless steel, before and after laser polishing. Typical micro-cone structure (bottom, left) and smoothing with GHz burst mode (right).

Precision parts cutting from brass

Example of gear cut from brass. Source: Lasea.
List of Local Distributors

AUSTRALIA
Lastek Pty Ltd
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alex.stanco@lastek.com.au
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CARBIDE
Unibody-Design Industrial-Grade Femtosecond Lasers

FEATURES
- 190 fs – 20 ps tunable pulse duration
- 800 µJ maximum pulse energy
- 80 W maximum output power
- Single-shot – 2 MHz repetition rate
- Pulse picker for pulse-on-demand mode
- Industrial-grade design
- Air- or water-cooled models
- Optional automated harmonic generator

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