FEMTOSECOND LASERS FOR INDUSTRY

PRODUCT CATALOGUE

2020
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Femtosecond Solutions for Industry and Science

The key drivers at LIGHT CONVERSION are consistency, the persistent quest for corporate goals, close attention to clients’ needs, and an assurance of the exclusive quality of the products developed by the company. We have been developing technologies that alter the worlds of science and industry. Using our knowledge, experience, and leading position, we strive for perfection and continued growth. On the day our company was founded, we chose the path of research and have been following it ever since. Investments into this field have opened up a doorway to global markets for us. For more than two decades, we have been searching for and discovering new ways to apply femtosecond laser technology. The clients of LIGHT CONVERSION range from research centers and labs and industrial corporations to medical companies.

What We Do

We are the world-leading manufacturer of wavelength-tunable femtosecond optical parametric amplifiers (OPA) based on our TOPAS and ORPHEUS series as well as diode pumped solid state femtosecond lasers PHAROS and CARBIDE. Both PHAROS, the most versatile femtosecond laser amplifier on the market, and the ultra-compact and cost-efficient CARBIDE, feature market-leading output parameters along with a robust design attractive to both industrial and scientific customers. With major industrial customers operating in display, automotive, LED, medical device, and other industries, the reliability of PHAROS and CARBIDE has been proven by hundreds of systems operating in 24/7 production environments. The lasers are mainly used for drilling and cutting of various metals, ceramics, sapphire, glass, and material ablation for mass-spectrometry. However, customers are always finding new ways for PHAROS and CARBIDE to make existing manufacturing processes more efficient.

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

Who We Are

Founded in 1994 in Vilnius, LIGHT CONVERSION is a privately-owned company with >300 employees. Our >6500 m² facility accommodates design, R&D, and production teams so that all key manufacturing processes are managed in-house. With more than 4500 systems installed worldwide, LIGHT CONVERSION has established itself as an innovative producer of ultrafast optical devices and the largest manufacturer of femtosecond optical parametric amplifiers (OPAs) and non-collinear OPAs. In addition to selling our products via a wide range of distributors, we also provide our OEM devices for other major laser manufacturing companies.
PHAROS
High Power and Energy Femtosecond Lasers

FEATURES
- 190 fs – 20 ps tunable pulse duration
- 2 mJ maximum pulse energy
- 20 W output power
- 1 kHz – 1 MHz tunable base repetition rate
- Pulse picker for pulse-on-demand operation
- Rugged industrial grade mechanical design
- Automated harmonics generators
  (515 nm, 343 nm, 257 nm, 206 nm)
- Optional CEP stabilization
- Possibility to lock oscillator to external clock

PHAROS is a femtosecond laser system combining millijoule pulse energies and high average powers. PHAROS features a mechanical and optical design optimized for industrial applications such as precise material processing. Compact size, an integrated thermal stabilization system, and sealed design allow PHAROS integration into machining workstations. Laser diodes pumping Yb medium significantly reduces maintenance costs and provides a long laser lifetime. Software tunability of PHAROS allows the system to cover applications normally requiring different classes of laser. Tunable parameters include pulse duration (190 fs – 20 ps), repetition rate (single pulse to 1 MHz), pulse energy (up to 2 mJ) and average power (up to 20 W). Its power level is sufficient for most material processing applications at high machining speeds. The built-in pulse picker allows convenient control of the laser output in pulse-on-demand mode. PHAROS compact and robust optomechanical design features stable laser operation across varying environments.
## SPECIFICATIONS

<table>
<thead>
<tr>
<th>Model</th>
<th>PH1-10W</th>
<th>PH1-15W</th>
<th>PH1-20W</th>
<th>PH1-SP-1mJ</th>
<th>PH2-SP-20W-2mJ</th>
</tr>
</thead>
</table>

### OUTPUT CHARACTERISTIC

<table>
<thead>
<tr>
<th></th>
<th>PH1-10W</th>
<th>PH1-15W</th>
<th>PH1-20W</th>
<th>PH1-SP-1mJ</th>
<th>PH2-SP-20W-2mJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. average power</td>
<td>10 W</td>
<td>15 W</td>
<td>20 W</td>
<td>6 W</td>
<td>20 W</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>&lt; 290 fs</td>
<td>&lt; 190 fs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(assuming Gaussian pulse shape)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse duration adjustment range</td>
<td>290 fs – 10 ps (20 ps on request)</td>
<td>190 fs – 10 ps (20 ps on request)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. pulse energy</td>
<td>&gt; 0.4 mJ</td>
<td>1 mJ</td>
<td>&gt; 2 mJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fundamental repetition rate</td>
<td>1 kHz – 1 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse selection</td>
<td>Single-shot, Pulse-on-Demand, any base repetition rate division</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centre 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></td>
<td></td>
<td>TEM₀₀ ; M² &lt; 1.3</td>
<td></td>
</tr>
<tr>
<td>Pulse-to-pulse energy stability</td>
<td>RMS deviation &lt; 0.5 % over 24 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output power stability</td>
<td>RMS deviation &lt; 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

<table>
<thead>
<tr>
<th></th>
<th>PH1-10W</th>
<th>PH1-15W</th>
<th>PH1-20W</th>
<th>PH1-SP-1mJ</th>
<th>PH2-SP-20W-2mJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oscillator output</td>
<td>Optional. Please contact <a href="mailto:sales@lightcon.com">sales@lightcon.com</a> for more details or customized solutions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical output</td>
<td>1 – 6 W, 50 – 250 fs, ~1035 nm, ~76 MHz, simultaneously available</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harmonics generator</td>
<td>Integrated, optional</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output wavelength</td>
<td>515 nm, 343 nm, 257 nm, 206 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical parametric amplifier</td>
<td>Integrated, optional</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuning range</td>
<td>640 – 4500 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BiBurst mode</td>
<td>Tunable GHz and MHz burst with burst-in-burst capability, optional</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHz-mode (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra burst pulse separation</td>
<td>~ 200 ± 40 ps</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. no. of pulses</td>
<td>1 . . . 25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MHz-mode (N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra burst pulse separation</td>
<td>~ 16 ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. no. of pulses</td>
<td>1 . . . 9, (7 with FEC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PHYSICAL DIMENSIONS

<table>
<thead>
<tr>
<th></th>
<th>PH1-10W</th>
<th>PH1-15W</th>
<th>PH1-20W</th>
<th>PH1-SP-1mJ</th>
<th>PH2-SP-20W-2mJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser head</td>
<td>670 (L) × 360 (W) × 212 (H) mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rack for power supply &amp; chiller</td>
<td>642 (L) × 553 (W) × 673 (H) mm</td>
<td></td>
<td></td>
<td>PS integrated in the laser head</td>
<td></td>
</tr>
</tbody>
</table>

### ENVIRONMENTAL & UTILITY REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>PH1-10W</th>
<th>PH1-15W</th>
<th>PH1-20W</th>
<th>PH1-SP-1mJ</th>
<th>PH2-SP-20W-2mJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td>15 – 30 °C (air conditioning recommended)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative humidity</td>
<td>&lt; 80 % (non condensing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric</td>
<td>110 V AC, 50 – 60 Hz, 20 A or 220 V AC, 50 – 60 Hz, 10 A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated power</td>
<td>2000 W</td>
<td></td>
<td></td>
<td>1000 W</td>
<td></td>
</tr>
<tr>
<td>Power consumption</td>
<td>600 W</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹⁾ More models are available on request.
²⁾ Some particular repetition rates are software-restricted due to system design.
³⁾ Precise wavelengths for specific models available upon request.
⁴⁾ Under stable environmental conditions.
⁵⁾ Normalized to average pulse energy.
⁶⁾ Custom spacing on request.
⁷⁾ Maximum number of pulses in a burst is dependent on the laser repetition rate. Custom number of pulses on request.
⁸⁾ Dimensions might increase for non-standard laser specifications.
EXAMPLES OF INDUSTRIAL APPLICATIONS | FLINT OSCILLATORS | I-OPA OPTICAL PARAMETRIC AMPLIFIERS | CARBIDE LASERS | PHAROS LASERS

STABILITY MEASUREMENTS

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

PHAROS output power with power lock enabled under unstable environment
Short term pulse-to-pulse energy stability of PHAROS lasers. $1.2 \times 10^7$ pulses (1 min at 200 kHz), STD < 0.11%, peak-to-peak < 1%.

OUTLINE DRAWINGS

PHAROS-PH1 laser outline drawing

PHAROS-PH2 laser outline drawing
PHAROS Laser can be equipped with automated harmonics modules. A selection of fundamental (1030 nm), second (515 nm), third (343 nm), fourth (257 nm) or fifth (206 nm) harmonic outputs are available through software control.

Harmonics generators are designed to be used in industrial applications where a single output wavelength is desired. Modules are mounted directly on the output of the laser and integrated into the system.

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

### SPECIFICATIONS

<table>
<thead>
<tr>
<th>Model</th>
<th>2H</th>
<th>2H-3H</th>
<th>2H-4H</th>
<th>4H-5H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output wavelength</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(automated selection)</td>
<td>1030 nm</td>
<td>515 nm</td>
<td>343 nm</td>
<td>1030 nm</td>
</tr>
<tr>
<td>515 nm</td>
<td></td>
<td></td>
<td></td>
<td>257 nm</td>
</tr>
<tr>
<td>343 nm</td>
<td></td>
<td></td>
<td></td>
<td>206 nm</td>
</tr>
<tr>
<td>Pump pulse duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></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)</td>
</tr>
<tr>
<td></td>
<td>&gt; 25 % (3H)</td>
<td>&gt; 10 % (4H)</td>
<td>&gt; 10 % (4H)</td>
<td>&gt; 5 % (5H)</td>
</tr>
<tr>
<td>Beam quality (M²)</td>
<td>&lt;1.3 (2H), typical &lt;1.15</td>
<td>&lt;1.3 (2H), typical &lt;1.15</td>
<td>&lt;1.3 (2H), typical &lt;1.15</td>
<td>n/a (4H)</td>
</tr>
<tr>
<td>≤ 400 μJ pump</td>
<td>&lt;1.3 (2H), typical &lt;1.15</td>
<td>&lt;1.3 (2H), typical &lt;1.15</td>
<td>&lt;1.3 (2H), typical &lt;1.15</td>
<td>n/a (4H)</td>
</tr>
<tr>
<td></td>
<td>&lt;1.4 (2H)</td>
<td>&lt;1.4 (2H)</td>
<td>&lt;1.4 (2H)</td>
<td>n/a (4H)</td>
</tr>
<tr>
<td>Beam quality (M²)</td>
<td>&lt;1.4 (2H)</td>
<td></td>
<td>&lt;1.5 (3H)</td>
<td></td>
</tr>
<tr>
<td>&gt; 400 μJ pump</td>
<td>&lt;1.4 (2H)</td>
<td></td>
<td>&lt;1.5 (3H)</td>
<td></td>
</tr>
</tbody>
</table>

³⁾ Depends on pump laser model.
²⁾ High energy versions are available, please contact Light Conversion for specifications.
³) Max 1 W output.
⁴) Max 0.15 W output.

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PHAROS harmonics energy vs pulse repetition rate

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3H output stability

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4H output stability
PHAROS and CARBIDE 40W (CB3) have an option for tunable GHz and MHz burst with burst-in-burst capability – called BiBurst. The distance between burst packet groups is called nanosecond burst, \( N \) (MHz-Burst). The distance between sub-pulses in the group is called picosecond burst, \( P \) (GHz-Burst).

In single pulse mode, one pulse is emitted at a time at some fixed frequency. In burst mode, the output consists of several picosecond burst packets each separated by an equal time period between each packet. Each packet can contain a number of sub-pulses which are also separated by an equal time period between each pulse.

High pulse energy femtosecond lasers PHAROS and CARBIDE with flexible BiBurst functionality bring new production capabilities to high-tech manufacturing industries such as consumer electronics, integrated photonic chip manufacturing, stent cutting, surface functionalization, future displays manufacturing and quantum computing.

BiBurst material fabrication areas cover:
- brittle material drilling and cutting
- deep engraving
- selective ablation
- transparent materials volume modification
- hidden marking
- surface functional structuring.

### SPECIFICATIONS

<table>
<thead>
<tr>
<th>Model</th>
<th>CARBIDE-CB3 (40 W)</th>
<th>PHAROS</th>
<th>PHAROS-SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P ), GHz-mode</td>
<td>Intra burst pulse separation ¹⁾</td>
<td>~440 ± 40 ps</td>
<td>~200 ± 40 ps</td>
</tr>
<tr>
<td>Max no. of pulses (^2)</td>
<td>1 . . 10</td>
<td>1 . . 25</td>
<td>1 . . 10</td>
</tr>
<tr>
<td>( N ), MHz-mode</td>
<td>Intra burst pulse separation</td>
<td>~16 ns</td>
<td></td>
</tr>
<tr>
<td>Max no. of pulses</td>
<td>1 . . 10</td>
<td>1 . . 9, (7 with FEC)</td>
<td>1 . . 9, (7 with FEC)</td>
</tr>
</tbody>
</table>

¹⁾ Custom spacing on request.
²⁾ Maximum number of pulses in a burst is dependent on the laser repetition rate. Custom number of pulses on request.
CARBIDE
Femtosecond Lasers for Industry and Science

FEATURES
- < 290 fs – 10 ps tunable pulse duration
- > 800 μJ pulse energies
- > 80 W output power
- 60 – 2000 kHz tunable base repetition rate
- Includes pulse picker for pulse-on-demand operation
- Rugged, industrial-grade mechanical design
- Air or water cooling
- Automated harmonics generators (515 nm, 343 nm, 257 nm)
- Scientific interface enhancing system flexibility

CARBIDE femtosecond lasers feature an output power of >80 W at 1030 nm wavelength. The laser emits pure pulses with ASE background of <10⁻⁹ and recently updated maximum energy specifications without compromises to the beam quality, industrial grade reliability and beam stability regardless of environmental conditions. Continuously tunable repetition rate in a range of 60 kHz to 2 MHz is combined with an in-built Pulse Picker for output pulse timing and full-scale energy control with <10 microsecond response time, enabling arbitrary shaping of the emission. Pulse duration can be tuned in a range of 290 fs – 10 ps. Excellent power stability of <0.5 % RMS is standard. The laser output can be split into a burst of several pulses of pico- and nano- separation while having the ability to modify the burst envelope. Harmonic generator options permit femtosecond applications at different wavelengths. The parameters are entirely software adjustable.
## SPECIFICATIONS

### Model
<table>
<thead>
<tr>
<th></th>
<th>CB3-40W</th>
<th>CB3-80W</th>
<th>CBS</th>
</tr>
</thead>
</table>

### OUTPUT CHARACTERISTICS

#### Cooling method
- Water-cooled
- Air-cooled<br>¹)

#### Max. average power
- > 40 W<br>>< 80 W<br>>< 6 W<br>>< 5 W

#### Pulse duration (assuming Gaussian pulse shape)
- < 290 fs

#### Pulse duration adjustment range
- 290 fs - 10 ps

#### Max. pulse energy
- > 0.4 mJ<br>>< 0.8 mJ<br>>< 100 μJ<br>>< 83 μJ

#### Fundamental repetition rate ²)
- 100 – 2000 kHz<br>>< 60 – 1000 kHz

#### Pulse selection
- Single-shot, Pulse-on-Demand, any base repetition rate division

#### Centre wavelength ³)
- 1030 ± 10 nm

#### Pulse-to-pulse energy stability ⁴)
- RMS deviation ⁵) < 0.5 % over 24 hours

#### Output power stability
- RMS deviation ⁵) < 0.5 % over 100 h

#### Beam pointing stability
- < 20 μrad/°C

#### Pulse picker
- FEC ⁶) included<br>>< included, enhanced contrast AOM ⁷)

#### Pulse picker leakage
- < 0.5 %<br>>< 2 %<br>>< 0.1 %

### OPTIONAL EXTENSIONS

#### Harmonics generator
- Integrated, optional (see page 14)

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

#### Tuning range
- 640 – 4500 nm

### PHYSICAL DIMENSIONS

#### Laser head
- 632 (L) × 305 (W) × 173 (H) mm<br>>< 631 (L) × 324 (W) × 167 (H) mm

#### Power supply
- 280 (L) × 144 (W) × 49 (H) mm<br>>< 220 (L) × 95 (W) × 45 (H) mm

#### Chiller
- 590 (L) × 484 (W) × 267 (H) mm<br>>< Not required

### ENVIRONMENTAL & UTILITY REQUIREMENTS

#### Operating temperature

#### Relative humidity
- < 80 % (non condensing)

#### Electric
- 110 – 220 VAC, 50 – 60 Hz

#### Rated power
- 600 W<br>>< 1000 W<br>>< 300 W

#### Power consumption
- 500 W<br>>< 700 W<br>>< 150 W

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¹) Water-cooled version available on request.
²) Lower repetition rates are available by controlling pulse picker.
³) Precise wavelengths for specific models available upon request. 2nd (515 nm) and 3rd (343 nm) harmonic output also available.
⁴) Under stable environmental conditions.
⁵) Normalized to average pulse energy.
⁶) Provides fast energy control; external analog control input available. Response time = next available RA pulse.
⁷) Provides fast amplitude control of output pulse train.
⁸) Custom spacing on request.
⁹) Maximum number of pulses in a burst is dependent on the laser repetition rate. Custom number of pulses on request.
STABILITY MEASUREMENTS

Output power under harsh environment conditions of CARBIDE-CB5

Beam direction under harsh environment conditions of CARBIDE-CB5

Harsh environment conditions of CARBIDE-CB5

OUTLINE DRAWINGS

Outline drawing of air-cooled CARBIDE-CB5 with attenuator

Outline drawing of CARBIDE-CB3
The CARBIDE scientific interface module is an optional laser add-on which extends the flexibility of industrial-grade laser configurations and makes it particularly attractive to scientific applications. This module incorporates multiple options which include a simultaneous or separate oscillator output, a second compressed or uncompressed main amplifier output and seeding by an external oscillator. For example, it can be seeded by another CARBIDE laser with its own oscillator, thus ensuring precise optical synchronization between two lasers. All the mentioned amplifier outputs can be equipped with motorized power attenuators and all options are compatible in-between.
**EXAMPLES OF INDUSTRIAL APPLICATIONS**

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

**FEATURES**

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

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

**SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Model</th>
<th>2H</th>
<th>2H-3H</th>
<th>2H-4H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output wavelength</strong> (automated selection)</td>
<td>1030 nm</td>
<td>1030 nm</td>
<td>1030 nm</td>
</tr>
<tr>
<td></td>
<td>515 nm</td>
<td>515 nm</td>
<td>515 nm</td>
</tr>
<tr>
<td></td>
<td>343 nm</td>
<td>343 nm</td>
<td>257 nm</td>
</tr>
<tr>
<td><strong>Input pulse energy</strong></td>
<td>20 – 800 µJ</td>
<td>50 – 800 µJ</td>
<td>20 – 800 µJ</td>
</tr>
<tr>
<td><strong>Pump pulse duration</strong></td>
<td>&lt; 300 fs</td>
<td>&gt; 50% (2H)</td>
<td>&gt; 50% (2H)</td>
</tr>
<tr>
<td><strong>Conversion efficiency</strong></td>
<td>&gt; 50% (2H)</td>
<td>&gt; 25% (3H)</td>
<td>&gt; 50% (2H)</td>
</tr>
<tr>
<td><strong>Beam quality (M²) ≤ 400 µJ pump</strong></td>
<td>&lt; 1.3 (2H), typical &lt; 1.15</td>
<td>&lt; 1.3 (2H), typical &lt; 1.15</td>
<td>&lt; 1.3 (2H), typical &lt; 1.15</td>
</tr>
<tr>
<td><strong>Beam quality (M²) &gt; 400 µJ pump</strong></td>
<td>&lt; 1.4 (2H)</td>
<td>&lt; 1.4 (2H)</td>
<td>&lt; 1.4 (2H)</td>
</tr>
</tbody>
</table>

¹⁾ Depends on pump laser model.
²⁾ Maximum output power 1 W.

**DANGER:**

Visible and/or invisible laser radiation. Avoid eye or skin exposure to direct, reflected or scattered radiation. Class 4 laser product.

**Typical beam profiles**

- Typical 1H beam profile of CARBIDE-CB5, 60 kHz, 5 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

**Harmonics energy vs pulse repetition rate** for CARBIDE-CB3-80W

---

**Notes:**

- CARBIDE-CB3-80W (80 W, 800 µJ)
- SH (800 µJ pump)
- TH (800 µJ pump)
I-OPA

Industrial-grade Optical Parametric Amplifier

FEATURES

- Automatically tunable or fixed wavelength options
- Robust, integrated mechanical design
- Plug and play installation
- User friendly operation
- Up to 2 MHz repetition rate, down to single shot operation
- Up to 40 W pump power
- Short pulse duration option (< 100 fs)
- Integrated tunable beam splitter for pump laser beam

I-OPA series of optical parametric amplifiers marks a new era of simplicity in the world of tunable wavelength femtosecond light sources. Based on 10 years of experience producing the ORPHEUS series of optical parametric amplifiers, this solution brings together the flexibility of tunable wavelength with robust industrial-grade design. The original I-OPA is a rugged module attached to our PHAROS laser, providing long term stability comparable to that of the industrial harmonics modules. The new and improved tunable version is designed to be coupled with our PHAROS and CARBIDE series femtosecond lasers and primarily intended to be used with spectroscopy or microscopy applications that demand high stability. The -HP model is targeted to be coupled with our HARPIA series as a pump beam source for ultrafast pump-probe spectroscopy. The -F model is primarily designed to be used as a light source in multiphoton microscopy devices. The -ONE model will be useful in the field of mid-IR spectroscopy, as well as other applications where higher pulse energy is required in the infrared part of the spectrum. All of these models can be used for micromachining and other industrial applications; the tunable version suited to be the ideal R&D system, while the fixed wavelength I-OPA would be the cost-effective solution for large scale production.

Typical I-OPA module energy conversion curves. Pump: PHAROS-10W, 100 µJ, 100 kHz

Fixed wavelength I-OPA-FW beam pointing and output power measurements under harsh environment conditions (humidity and temperature cycling)
## 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>Based on ORPHEUS model</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>Pulse repetition rate</td>
<td>Up to 2 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuning range, signal</td>
<td>640 – 1010 nm</td>
<td>650 – 900 nm</td>
<td>1350 – 2060 nm</td>
</tr>
<tr>
<td>Tuning range, idler</td>
<td>1050 – 2600 nm</td>
<td>1200 – 2500 nm</td>
<td>2060 – 4500 nm</td>
</tr>
<tr>
<td>Conversion efficiency at peak, signal wavelength</td>
<td>&gt; 7 % @ 700 nm</td>
<td>&gt; 9 % @ 1550 nm</td>
<td></td>
</tr>
<tr>
<td>Additional options</td>
<td>n/a</td>
<td>SCMP: Signal pulse compressor</td>
<td>PCMP: pre-chirp dispersion compensator</td>
</tr>
<tr>
<td>Pulse bandwidth</td>
<td>80 – 220 cm⁻¹ @ 700 – 960 nm</td>
<td>200 – 750 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>Wavelength extension options</td>
<td>SHS: 320 – 505 nm</td>
<td>Conversion efficiency 1.2% at peak</td>
<td>DFG: 4500 – 10000 nm</td>
</tr>
<tr>
<td>Applications</td>
<td>Micro-machining, Microscopy, Spectroscopy</td>
<td>Nonlinear microscopy, Ultrafast spectroscopy</td>
<td>Mid-IR spectroscopy, AFM microscopy</td>
</tr>
</tbody>
</table>

¹⁾ I-OPA-F outputs broad bandwidth pulses which are compressed externally.
²⁾ Output pulse duration depends on wavelength and pump laser pulse duration. I-OPA-F requires pulse compressors to achieve short pulse duration.
³⁾ Up to 16 μm tuning range is accessible with external Difference Frequency Generator.
Fixed wavelength I-OPA in comparison to tunable version or standard ORPHEUS line devices lacks only computer-controlled wavelength selection. On the other hand, in-laser mounted design provides mechanical stability and eliminates the effects of air-turbulence ensuring stable long-term performance and minimizing energy fluctuations.

**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>Pump power</td>
<td>Up to 40 W</td>
<td>Up to 2 MHz</td>
<td></td>
</tr>
<tr>
<td>Pump pulse energy</td>
<td>10 – 500 μJ</td>
<td>10 – 500 μJ</td>
<td>20 – 1000 μJ</td>
</tr>
<tr>
<td>Pulse repetition rate</td>
<td></td>
<td>Up to 2 MHz</td>
<td></td>
</tr>
<tr>
<td>Wavelength range, signal</td>
<td>640 – 1010 nm</td>
<td>650 – 900 nm</td>
<td>1350 – 2060 nm</td>
</tr>
<tr>
<td>Wavelength range, idler</td>
<td>1050 – 2600 nm</td>
<td>1200 – 2500 nm</td>
<td>2060 – 4500 nm</td>
</tr>
<tr>
<td>Conversion efficiency at peak, signal wavelength</td>
<td>&gt;7 % @ 700 nm</td>
<td>&gt;7 % @ 700 nm</td>
<td>&gt; 9 % @ 1550 nm</td>
</tr>
<tr>
<td>Pulse bandwidth</td>
<td>80 – 220 cm⁻¹ @ 700 – 960 nm</td>
<td>200 – 750 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>Applications</td>
<td>Micro-machining</td>
<td>Nonlinear microscopy</td>
<td>Micro-machining</td>
</tr>
<tr>
<td></td>
<td>Microscopy</td>
<td>Ultrafast spectroscopy</td>
<td>Mid-IR generation</td>
</tr>
</tbody>
</table>

¹⁾ I-OPA-F outputs broad bandwidth pulses which are compressed externally.  
²⁾ Output pulse duration depends on wavelength and pump laser pulse duration.  
I-OPA-F requires external pulse compressors to achieve short pulse duration.

**COMPARISON WITH OTHER FEMTOSECOND AND PICOSECOND LASERS**

<table>
<thead>
<tr>
<th>Laser technology</th>
<th>Our solution</th>
<th>HG or HIRO</th>
<th>I-OPA-FW-F</th>
<th>I-OPA-FW-ONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excimer laser (193 nm, 213 nm)</td>
<td>5H of PHAROS (205 nm)</td>
<td>5 μJ</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Th of Ti:S (266 nm)</td>
<td>4H of PHAROS (257 nm)</td>
<td>10 μJ</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Th of Nd:YAG (355 nm)</td>
<td>3H of PHAROS (343 nm)</td>
<td>25 μJ</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>SH of Nd:YAG (532 nm)</td>
<td>2H of PHAROS (515 nm)</td>
<td>50 μJ</td>
<td>35 μJ</td>
<td>n/a</td>
</tr>
<tr>
<td>Ti:Sapphire (800 nm)</td>
<td>OPA output (750 – 850 nm)</td>
<td>n/a</td>
<td>10 μJ</td>
<td>n/a</td>
</tr>
<tr>
<td>Nd:YAG (1064 nm)</td>
<td>PHAROS output (1030 nm)</td>
<td>n/a</td>
<td>100 μJ</td>
<td>n/a</td>
</tr>
<tr>
<td>Cr:Forsterite (1240 nm)</td>
<td>OPA output (1200 – 1300 nm)</td>
<td>n/a</td>
<td>5 μJ</td>
<td>n/a</td>
</tr>
<tr>
<td>Erbium (1560 nm)</td>
<td>OPA output (1500 – 1600 nm)</td>
<td>3 μJ</td>
<td>15 μJ</td>
<td>n/a</td>
</tr>
<tr>
<td>Thulium / Holmium (1.95 – 2.15 μm)</td>
<td>OPA output (1900 – 2200 nm)</td>
<td>2 μJ</td>
<td>10 μJ</td>
<td>n/a</td>
</tr>
<tr>
<td>Other sources (2.5 – 4.0 μm)</td>
<td>OPA output</td>
<td>n/a</td>
<td>1 – 5 μJ</td>
<td>n/a</td>
</tr>
</tbody>
</table>

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

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

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

Output ports of PHAROS with fixed wavelength I-OPA-FW

PHAROS with fixed wavelength I-OPA-FW-F and compressors for signal and idler
FLINT
Femtosecond Yb Oscillators

FEATURES
- Sub-40 fs without any additional pulse compressor
- 250 nJ pulse energy
- 20 W output power
- 76 MHz is standard
- No amplified spontaneous emission
- Rugged, industrial-grade mechanical design
- Automated second harmonic generator
- Optional CEP stabilization
- Possibility to lock to external clock

The FLINT oscillator is based on Yb crystal pumped by a high brightness laser diode module. Generation of femtosecond pulses is provided by Kerr lens mode-locking. Once started, mode-locking remains stable over a long period of time and is immune to minor mechanical impact. Piezo-actuator can be implemented in customized oscillators in order to control the cavity length. FLINT oscillator can also be equipped with a Carrier Envelope Phase (CEP) stabilization system.

SPECIFICATIONS

<table>
<thead>
<tr>
<th>Model</th>
<th>FL1-02</th>
<th>FL1-08</th>
<th>FL1-SP</th>
<th>FL2-12</th>
<th>FL2-20</th>
<th>FL2-SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. average power</td>
<td>2 W</td>
<td>8 W</td>
<td>up to 2 W</td>
<td>&gt; 12 W</td>
<td>&gt; 20 W</td>
<td>up to 2 W</td>
</tr>
<tr>
<td>Pulse duration (assuming Gaussian pulse shape)</td>
<td>&lt; 100 fs</td>
<td>&lt; 120 fs</td>
<td>30 ... 50 fs</td>
<td>&lt; 120 fs</td>
<td>&lt; 170 fs</td>
<td>30 ... 50 fs</td>
</tr>
<tr>
<td>Max. pulse energy</td>
<td>&gt; 25 nJ</td>
<td>&gt; 100 nJ</td>
<td>up to 25 nJ</td>
<td>&gt; 150 nJ</td>
<td>&gt; 250 nJ</td>
<td>up to 25 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></td>
<td></td>
</tr>
<tr>
<td>Centre wavelength</td>
<td>1035 ± 10 nm</td>
<td>1030 ± 3 nm</td>
<td>1040 ± 10 nm</td>
<td>1029 ± 3 nm</td>
<td>1026 ± 2 nm</td>
<td>1040 ± 10 nm</td>
</tr>
<tr>
<td>Output pulse-to-pulse stability</td>
<td>&lt; 0.5 % rms over 24 hours</td>
<td></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>
<td></td>
</tr>
<tr>
<td>Beam quality</td>
<td>TEM₀₀; M² &lt; 1.2</td>
<td></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>
<td></td>
</tr>
<tr>
<td>Optional 2H section</td>
<td>n/a</td>
<td>Yes, conversion efficiency &gt; 30 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal attenuator</td>
<td>n/a</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PHYSICAL DIMENSIONS

| Laser head | 430 (L) × 195 (W) × 114 (H) mm |
| Power supply and chiller rack | 642 (L) × 553 (W) × 540 (H) mm |
| Chiller | Included. Different options are available |

ENVIRONMENTAL & UTILITY REQUIREMENTS

| Operating temperature | 15 – 30 °C (air conditioning recommended) |
| Relative humidity | <80 % (non-condensing) |
| Electric | 110 V AC, 50 – 60 Hz, 2 A or 220 V AC, 50 – 60 Hz, 1 A |
| Rated power | 200 W |
| Power consumption | 100 W | 150 W |

¹⁾ Depends on output power ~600 mW <40 fs; up to 2 W <50 fs.
²⁾ Other repetition rates are available in the range from 60 to 100 MHz.
³⁾ Other repetition rates are available in the range from 70 to 80 MHz.
⁴⁾ Choice of a particular central wavelength with ±1 nm tolerance is available upon request.
⁵⁾ With enabled power-lock, under stable environment.

DANGER: VISIBLE AND/OR INVISIBLE LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT, REFLECTED OR SCATTERED RADIATION. CLASS 4 LASER PRODUCT.
LOCKING OF THE OPTICAL PULSE TO AN EXTERNAL SIGNAL

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

LONG TERM HARMONIC LOCK STABILITY TEST (40 hours)

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

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

CARRIER ENVELOPE PHASE (CEP) STABILIZATION

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

OPTIONAL EQUIPMENT

Harmonics generator HIRO see p. 24

OUTLINE DRAWINGS

FLINT-FL1 outline drawing

FLINT-FL2 outline drawing

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

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

Glass needle microdrilling

Glass needle microdrilling.
Source: Workshop of Photonics.

Steel drilling

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

Various type glass drilling

Various glass drilling.
Source: Workshop of Photonics.

Nanodrilling in fused silica

Longitudinal section of the single void.
**Milling of complex 3D surfaces**

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


**Selective Cr thin film ablation**

(a) SEM image of a fabricated LiNbO₃ micro-disk resonator, (b) close up view, (c) atomic force microscopy (AFM) image of micro-disk wedge, (d) optical microscope image of micro-disk resonator with different diameters.


**Terahertz broadband anti-reflection structures**

Fabricated moth-eye 3-D profile image, 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.


**3D waveguides**

3D waveguide 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 progressively laser scan.

Lab-on-chip channel ablation and welding

(a) Welding of transparent polymers for sealing of microfluidic devices, (b) COC welding seam (c) top view on a sealed microfluidic device.


3D micro printing using multi-photon polymerization

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

Source: Femtika.

Bragg grating waveguide (BGW) writing

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


3D glass etching

Various structures fabricated in fused silica glass.

Source: Femtika.

Birefringent glass volume modifications

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

Source: Workshop of Photonics.

3D free shape multi-photon polymerization

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

Source: Workshop of Photonics.
List of Local Distributors

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