LIGHT CONVERSION

Ultrafast Lasers and Instruments

2013 Product Catalogue

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Revision IM2013.05.22

LIGHT CONVERSION

INTRODUCTION

UAB MGF "Šviesos konversija" (doing business as Light Conversion on the international market) is the world-leading manufacturer of continuously wavelength tunable ultrafast light sources based on TOPAS series of optical parametric amplifiers, frequency mixers and PHAROS femtosecond laser system. From the very start in production and many years ahead of its competitors, Light Conversion TOPAS series of parametric amplifiers has offered numerous pioneering solutions.

Applications of PHAROS lasers are concentrated in the fields of precise machining where femtosecond pulses offer advantages over nanosecond and picosecond pulses. Light Conversion is proud to know that some modern items improving life are made using PHAROS laser, such as LED lighting devices, fuel injectors in car engines, blood vessel stents and many others. PHAROS lasers are used worldwide in production lines by the microelectronics, automotive and medical industries. As the number of applications for short pulse lasers is expanding, the number of manufactured PHAROS lasers rapidly increases establishing femtosecond lasers in novel technologies not available before.

Light Conversion offers a wide range of optical equipment. Collinear and non-collinear parametric amplifiers from ORPHEUS series were developed on the well known TOPAS platform and integrated with PHAROS lasers to provide complete ultrafast, tunable, compact systems which can even be wheeled from lab-to-lab. Other output options include white light generators, manually or computer controlled sealed harmonic generators up to the 5th harmonic (206 nm) and narrow bandwidth generator SHBC.

Two spectrometers have been developed by Light Conversion based on PHAROS systems' remarkable stability: femtosecond transient absorption spectrometer HARPIA and ultrafast fluorescence upconversion spectrometer CHIMERA. HARPIA also can be used with 1 kHz Ti:Sapphire lasers. The full potential of CHIMERA spectrometer is revealed with the ability of PHAROS-based laser systems to operate at high pulse energies and high repetition rates.

Exciting recent developments include carrier envelope phase (CEP) stabilized PHAROS systems. As laser science heads toward attosecond physics, which should reveal a lot of new opportunities and a deeper understanding in the extreme nonlinear optical physics, proper femtosecond driving lasers are needed, providing high intensity and stable CEP. The first CEP stabilized lasers were based on Ti:Sapphire active media, but recently CEP stabilization was also demonstrated on Yb:KGW doped oscillators and regenerative amplifiers [1]. Femtosecond diode pumped ytterbium laser amplifiers present an interesting opportunity in this field as compared to Ti:Sapphire because of the average power and repetition rate scalability.

[1] *T.Balčiūnas, O.D. Mücke, P.Mišeikis, G. Andriukaitis, A. Pugžlys, L.Giniūnas, R.Danielius, R.Holzwarth and A. Baltuška, Carrier envelope phase stabilization of a Yb:KGW laser amplifier, Optics Letters, 36 (2011), 16; S. 3242-3244*

Contents

FLINT

Ultrafast Yb Oscillator

FEATURES

- First choice for seeding of Yb based ultrashort pulse amplifiers
- Excellent pulse contrast due to the high nonlinearity inherent for optical Kerr effect
- High output power up to 10 W (pulse energy up to 130 nJ at 76 MHz)
- Ideal source for broadband THz generation
- Spectrum bandwidth is broad enough for seeding simultaneously Yb and Nd based laser sources in OPCPA systems
- Optional CEP stabilization
- Possibility to lock output pulse phase to external clock
- Sub-80 fs pulses directly from the cavity of the laser without any additional external pulse compressors

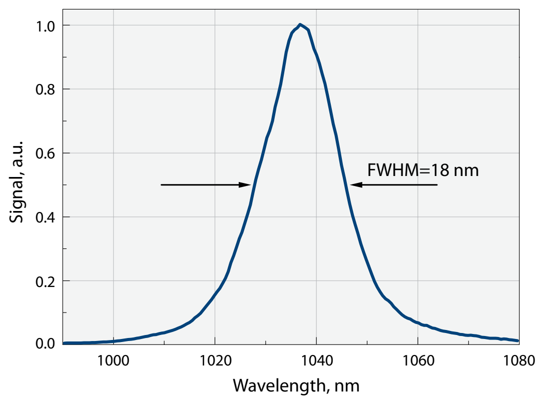
The FLINT oscillator is based on Yb:KGW crystal end-pumping by high brightness laser diode module. Generation of femtosecond pulses is provided by Kerr lens mode-locking, which is induced by perturbation of the cavity length. Once started, mode-locking remains stable over a long period of time and is immune to minor mechanical impact. Chirped mirrors are used in the laser cavity to adjust precisely the group velocity dispersion and cavity length. The oscillator can be equipped with external electrooptical Pulse Picker and appropriate timing electronics allowing selection of a single pulse at repetition rates up to 100 kHz. Piezo-actuator can be implemented in customized oscillators in order to control the cavity length. FLINT oscillator can also be equipped with Carrier Envelope Phase (CEP) stabilization system.

The oscillator module is machined from a single monolithic aluminium block which is cooled by water to ensure stable and robust operation. The oscillator housing has two seperate sections: cavity section and pump module section on the opposite side. Detector module, which includes a photodiode for oscillator power monitoring, is attached to the front side. The oscillator is contained in an external casing in order to reduce the performance impact of enviromental temperature changes. The special design of the external casing includes three point kinematic mounts which are used to support the oscillator preventing any mechanical stress caused by differences of thermal expansion between the optical table and the laser housing.

SPECIFICATIONS

Model	FLINT 1.0	FLINT 2.0	FLINT 4.0	FLINT 6.0
Max. average power	>1 W	>2 W	>4 W	>6 W
Pulse duration (assuming Gaussian pulse shape)	<80 fs	<100 fs	<100 fs	<100 fs
Pulse energy	>12 nJ	>25 nJ	>50 nJ	>75 nJ
Repetition rate	76 ± 0.5 MHz [1]			
Centre wavelength	1035 ± 10 nm [2]			
Output pulse stability	< 0.5 % rms over 24 hours [3]			
Polarization	Linear, horizontal			
Beam pointing stability	<10 µrad/°C			
Beam quality	TEM_{00}; $M^2 < 1.2$			
Optional 2H generator	Conversion efficiency >30% at 517 nm			

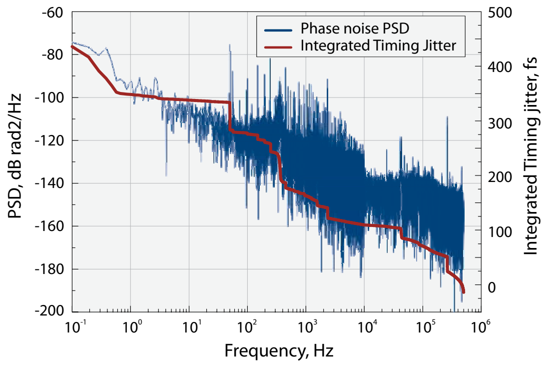
[1] *Other repetition rates are available in the range from 64 MHz to 84 MHz.*
[2] *The center wavelength can be specified with tolerance ±2 nm for customized oscillators.*
[3] *With power lock on under stable environment.*



Optical Spectrum

LOCKING OF THE OPTICAL PULSE TO AN EXTERNAL SIGNAL

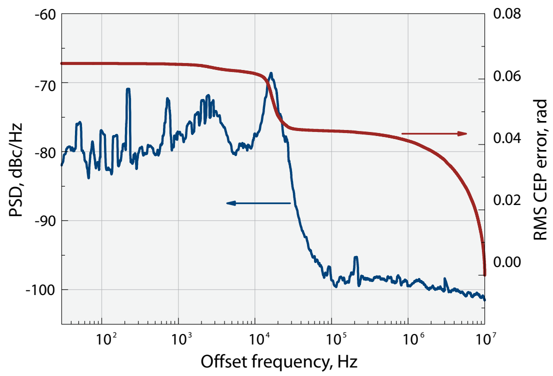
PHAROS oscillator can be equipped with piezo actuators for precise control of the cavity length. This feature allows one to lock the optical pulse of the laser to an external signal with timing jitter <450 fsec in the 0.1 Hz – 500 kHz frequency range.



Timing jitter between oscillator pulse and external clock signal in 0.1 Hz – 500 kHz frequency range.

CARRIER ENVELOPE PHASE (CEP) STABILIZATION

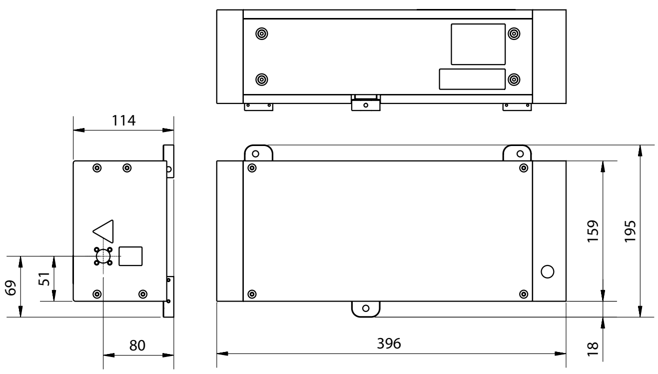
PHAROS oscillator can be equipped with nonlinear interferometer and feedback loop throughout the pump current of the laser diode bar for CEP stabilization. The figure on the right shows typical measurement of power spectrum density and integrated CEP phase error. The integrated phase error is in the frequency range from 50 Hz to 10 MHz is <70 mrad (in loop measurement).



Single side power spectral density of f_{ceo} phase noise (in loop) and the integrated phase jitter.

PHYSICAL DIMENSIONS

Laser head (L × W × H)	396 × 195 × 114 mm
Laser head with 2H (L × W × H)	408 × 270 × 114 mm
Power supply and chiller rack (4HU, 19") (L × W × H)	640 × 520 × 420 mm
Chiller (<100 W)	Different options



Outline drawing

OPTIONAL EQUIPMENT

Harmonic generator **HIRO**	*see p. 12*

UTILITY REQUIREMENTS

Electric	110 VAC, 50-60 Hz, 2 A or 220 VAC, 50-60 Hz, 1 A
Room temperature	15-30 °C (air conditioning recommended)
Relative humidity	20-80 % (non-condensing)

PHAROS

High-Power Femtosecond Lasers

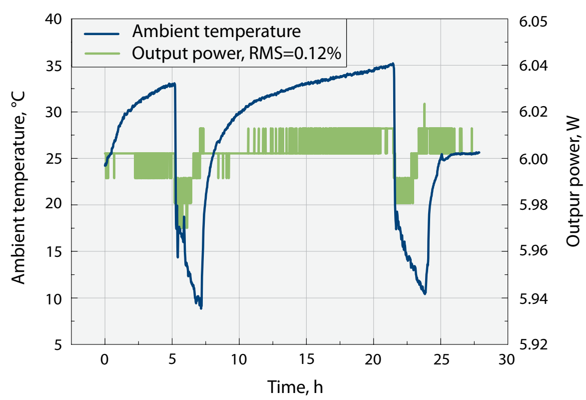
FEATURES

- <190 fs pulse duration
- Tunable pulse duration 190 fs – 10 ps
- Up to 2 mJ pulse energy
- Up to 15 W average power
- 1 kHz – 1 MHz tunable repetition rate
- Includes pulse picker for pulse-on-demand operation
- Rugged, industrial grade mechanical design
- Automatic harmonic generators (2H, 3H, 4H , 5H)

PHAROS is a single-unit integrated femtosecond laser system combining millijoule pulse energies and high average power. PHAROS features a mechanical and optical design optimized for industrial applications such as precise material processing. Market-leading compact size, integrated thermal stabilization system and sealed design allows PHAROS integration into machining workstations. The use of solid state laser diodes for pumping of Yb medium significantly reduces maintenance cost and provides long laser lifetime.

Most of the PHAROS output parameters can be easily set via control pad or PC tuning the laser for a particular application in seconds. Tunability of laser output parameters allows PHAROS system to cover applications normally requiring different classes of lasers. Tunable parameters include: pulse duration (190 fs – 10 ps), repetition rate (1 kHz to 1 MHz), pulse energy (up to 1.5 mJ) and average power (up to 15 W). Its deliverable power is abundant for most of material processing applications at high machining speeds. The built-in pulse picker allows convenient control of the laser output in pulse-on-demand and burst modes. It comes along with an extensive external control interface dedicated for easy laser integration into larger setups and machining workstations. PHAROS compact and robust optomechanical design includes easy to replace modules (oscillator, amplifier and stretcher/compressor) with temperature stabilized and sealed housings ensuring stable laser operation across varying environments. PHAROS is equipped with an extensive software package, which ensures smooth hands-free operation as well as allows fast and easy integration into various processing devices.

PHAROS is built upon the conventional chirped pulse amplification technique, employing the seed oscillator, regenerative amplifier and pulse stretcher/compressor modules. A Kerr lens mode-locked oscillator delivers >700 mW output with sub-80 fs pulse duration. The regenerative amplifier is based on Yb:KGW lasing medium. Both oscillator and amplifier are non-collinearly pumped by one or two (respectively 4 W or 6–15 W PHAROS) Light Conversion proprietary design high brightness, solid state laser diode pump modules. Low loss BBO Pockels cells support operation of the amplifier and pulse picker at repetition rates up to 200 kHz (extendable to 1 MHz). The stretcher/compressor module is based on a single transmission grating exhibiting high efficiency and excellent power handling capability. Operating parameters are adjustable from the remote control module or external PC connected via USB interface.



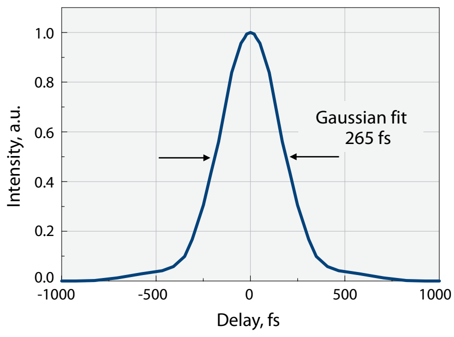
PHAROS output power with power lock on under unstable environment

SPECIFICATIONS

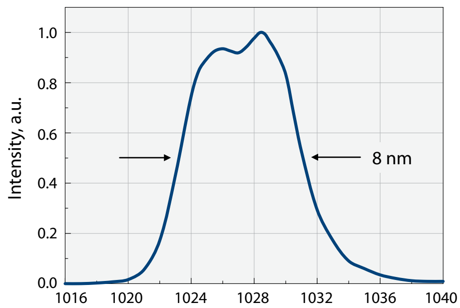
Model	PHAROS-4W	PHAROS-6W	PHAROS-10W	PHAROS-15W	PHAROS SP	PHAROS SP 1.5	PHAROS 2mJ	PHAROS LP
Max. average power	4 W	6 W	10 W	15 W	6 W		6 W	18 W
Pulse duration (assuming Gaussian pulse shape)	290 fs				190 fs		300 fs	10 ps
Pulse duration range	290 fs – 10 ps				190 fs – 10 ps		300 fs – 10 ps	10 ps
Max. pulse energy	> 0.2 mJ				> 1.0 mJ	> 1.5 mJ	> 2 mJ	> 30 µJ
Beam quality	TEM_{00}; $M^2 < 1.2$			TEM_{00}; $M^2 < 1.3$				TEM_{00}; $M^2 < 1.2$
Repetition rate	Single pulse – 200 kHz (extendable to 1 MHz)							600 kHz
Centre wavelength	1028 nm ± 5 nm							
Output pulse stability	< 0.5 % rms over 24 hours *							
Pre-pulse contrast	< 1 : 1000 **							
Post-pulse contrast	< 1 : 200							
Polarization	Linear, horizontal							
Beam pointing stability	< 20 µrad/°C							
Beam divergence	1.1x diffraction limited (of $M^2 < 1.2$ or $M^2 < 1.3$ beam)							
Burst output	Pulse burst output on trigger signal. Every n^{th} pulse continuous or trigger controlled output (pulse temporal spacing in burst corresponds to amplifier repetition rate)							
Oscillator output	Optional, typical output 0.5–1 W, 76 MHz, < 100 fs							

** Under stable environmental conditions*

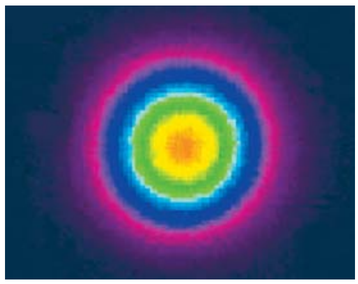
*** With the pulse picker installed*



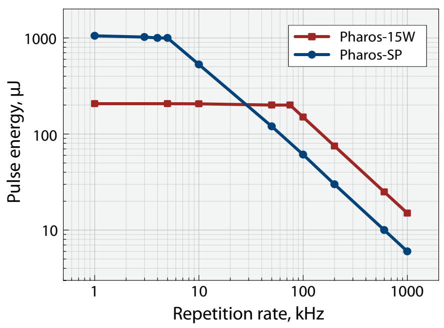
Pulse duration of PHAROS



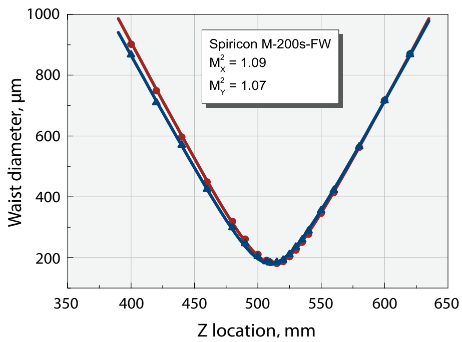
Spectrum of PHAROS



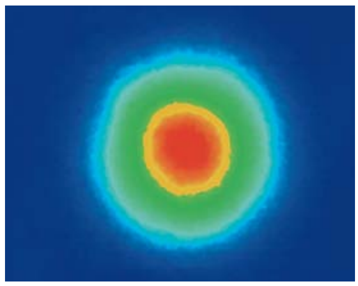
Typical PHAROS far field beam profile at 200 kHz



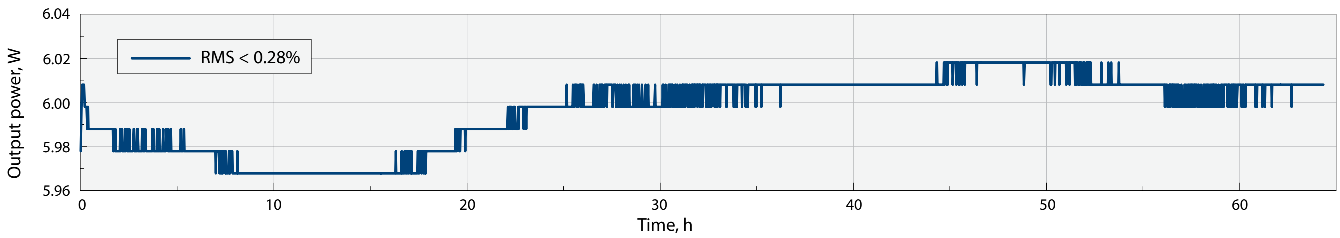
Pulse energy vs PRR



Typical PHAROS M^2 measurement data

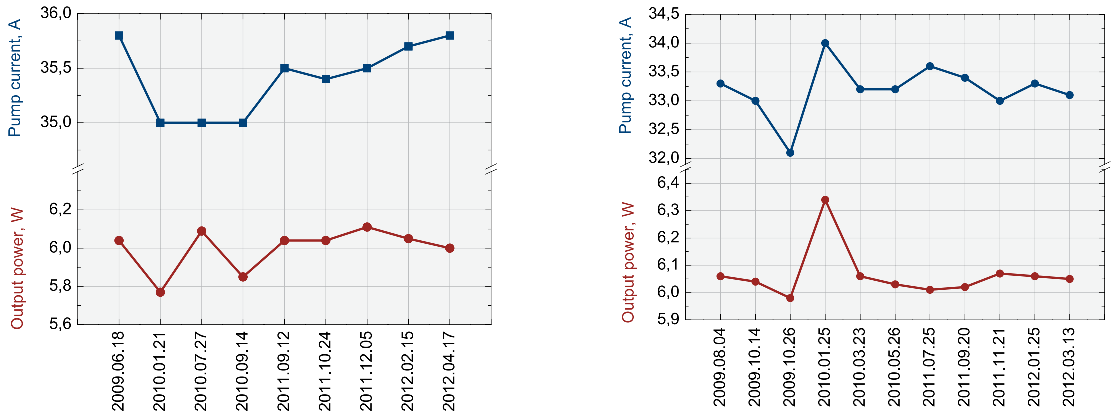


Typical PHAROS near field beam profile at 200 kHz

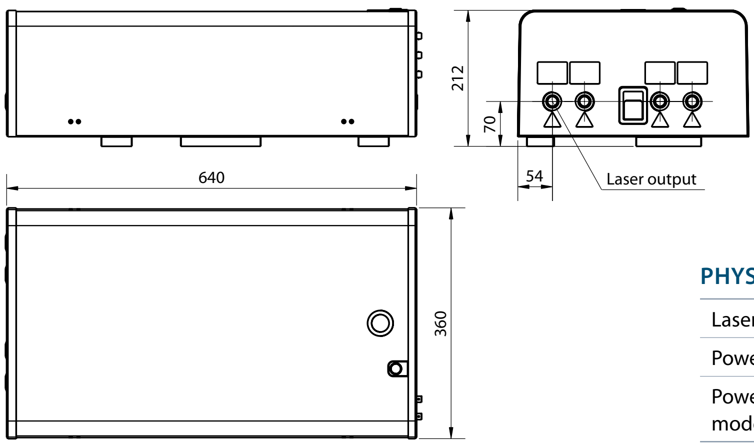


PHAROS long term stability graph

OSCILLATORS
LASER SYSTEMS
HARMONIC GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
SPECTROMETERS
AUTOCORRELATORS
APPLICATIONS



Output power of industrial PHAROS lasers and current of pump diodes during the years



PHAROS laser drawing

PHYSICAL DIMENSIONS (mm)

Laser head	640 L x 360 W x 212 H
Power supply rack for PHAROS-4W	640 L x 520 W x 420 H
Power supply rack for other PHAROS models	640 L x 520 W x 553 H

UTILITY REQUIREMENTS

Electric	110 VAC, 50-60 Hz, 20 A or 220 VAC, 50-60 Hz, 10 A
Room temperature	15-30 °C (air conditioning recommended)
Relative humidity	20-80 % (non condensing)

CARBIDE

Femtosecond Laser for Industrial and Medical Applications

FEATURES

- <300 fs pulse duration
- Tunable pulse duration 300 fs – 10 ps
- >50 μJ pulse energies
- > 4 W output power
- 50 – 1000 kHz flexible repetition rate
- Includes pulse picker for pulse-on-demand operation
- Rugged, industrial grade mechanical design

APPLICATIONS

- Biomedical applications
- Micromachining
- Micro- and nano-structuring
- Multi-photon polymerization
- Nonlinear optics
- Time-resolved spectroscopy
- Microscopy

Pico- and femtosecond lasers are now at the cutting edge of material micro processing in fields ranging from optoelectronics devices to eye surgery. Advantage of the ultrafast lasers lies in highly nonlinear interaction of short and intense light pulses with matter when ablation occurs without significant thermal impact. Minimization of thermally affected zone in the laser ablation process dramatically increases the machining precision and produces less damage to the surrounding material as compared to long pulse laser processing. Over the past years Light Conversion has established itself as a manufacturer of reliable high performance femtosecond industrial grade lasers of PHAROS product line. Owing to their flexibility, a number of PHAROS systems are being used in processing units as well as in basic research laboratories.

As a step forward from the existing technology we now offer CARBIDE industrial femtosecond laser. Featuring output power of >4 W at 1028 nm wavelength, with highest pulse energies of >50 μJ, it maintains all the best features of its predecessor PHAROS: variable pulse repetition rate in the range of 50–1000 kHz (amplifier internal clock) with the built-in pulse picker feature for pulse output control, computer controllable pulse duration 300 fs – 10 ps. In addition to usual parameters CARBIDE brings in a few new technologies. One of the most important being a few times higher output average power to wall plug efficiency. It also features novel approach to a cavity design where oscillator, stretcher/compressor and amplifier are integrated into a single housing, this way optimized for volume production. It also allows fast warm-up (important for medical applications), easy access to pump LD modules for replacement. Intra-cavity pulse picker allows reduction of cost and power consumption. Highly integrated LD driver and control electronics, along with embedded control computer now provide less electromagnetic noise emission and allow faster assembly during production stage. However, one of the most impressive feature of CARBIDE is its size of 631×324×150 mm including integrated power supply and air cooling unit. This represents about 7 times reduction in system volume as compared to PHAROS, already one of the most compact ultrafast lasers on the market.

CARBIDE features number of optional components complementing different application requirements: certified safety shutter, beam conditioning unit (beam expander with optional spatial filter), automated attenuator, harmonics unit, additional pulse picker for enhanced contrast CARBIDE is primarily targeted to the industrial market where relatively low average power cost effective solution with ultrafast pulses is needed. In largest part this is biomedical application with a direct biological tissue processing or biomedical device manufacturing. In addition output parameters of CARBIDE are sufficient to support different wavelength converters starting with harmonic generators to parametric amplifier. Please refer to product catalog to find more information on available devices.

PRELIMINARY SPECIFICATIONS

Max. average power	>4 W
Pulse duration (assuming Gaussian pulse shape)	<300 fs
Pulse duration range	300 fs – 10 ps
Max. pulse energy	>50 µJ
Repetition rate	50 – 1000 kHz *
Centre wavelength	1028±5 nm
Beam quality	TEM_{00}; $M^2 < 1.2$
Pulse contrast	<1:200
Output pulse stability	<0.5% rms over 24 hours **

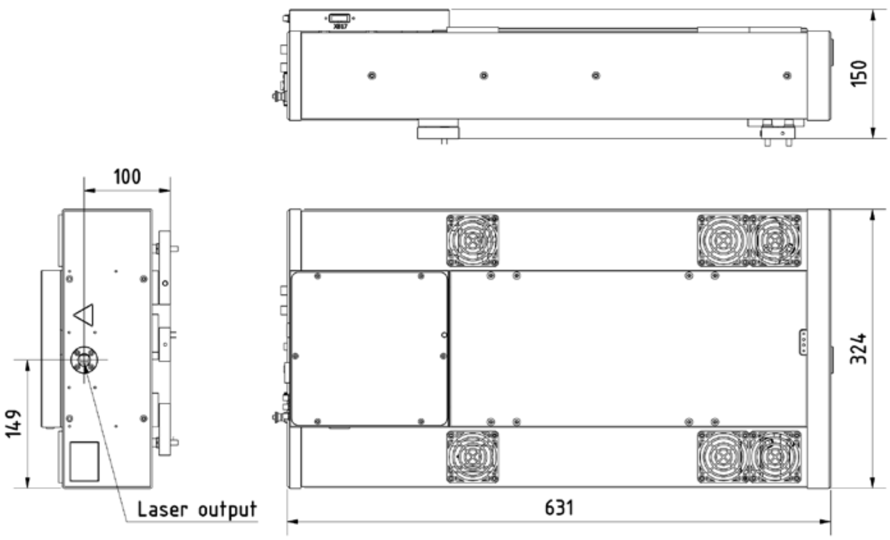
PHYSICAL DIMENSIONS

Laser head including cooling and power supply	615(L) × 324(W) × 150(H) mm

UTILITY REQUIREMENTS

Electric	110 – 220 V AC, 50 – 60 Hz, up to 300 W
Operating temperature	18–26 °C (64–78 °F)
Humidity	<65%, non-condensing

* *Lower repetition rates are available by controlling pulse picker*
** *Under stable environmental conditions*



Outline drawing

LIGHT CONVERSION

PHAROS

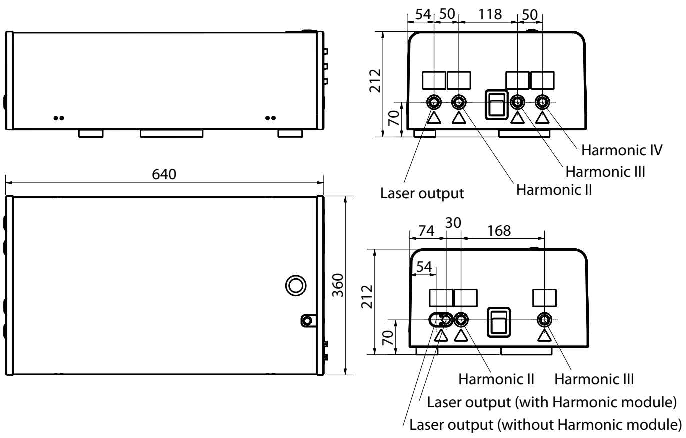
Automated Harmonic Generators

PHAROS laser can be equipped with optional wavelength converters providing high power harmonics radiation at 515 nm, 343 nm and 257 nm wavelengths. Harmonic 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.

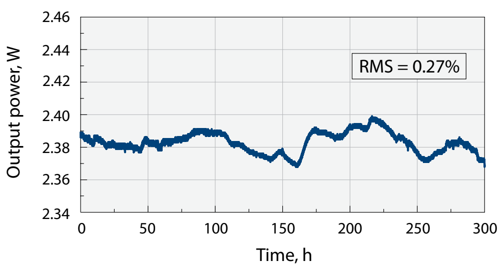
The principal of OEM harmonic generators operation is based on collinear generation of higher laser radiation harmonics in angle-phase-matched nonlinear crystals. The optical layout of OEM harmonic generator also includes beam reduction and collimation optics that ensures highest harmonics conversion efficiencies. In a standard setup the particular harmonic is produced in a single OEM harmonic generator module, different modules are required for different order harmonics generation. Automatic harmonic modules are also available allowing selection of fundamental, second, third, fourth or fifth harmonic output by software control. All the accessible harmonics exiting OEM harmonic generators are separated from the pump radiation by dichroic mirrors.

SPECIFICATIONS

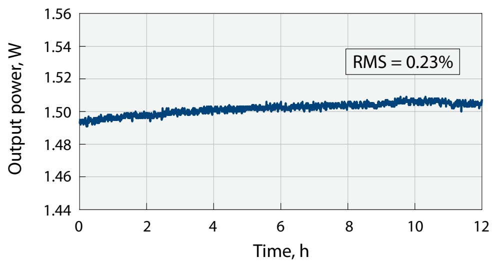
Model	G2	G3	G4	GA
Generated harmonics	2H	3H	4H	Fundamental, 2H, 3H, 4H, 5H (automated harmonic selection)
Output wavelength	515 nm	343 nm	257 nm	1030 nm, 515 nm, 343 nm, 257 nm, 206 nm
Recommended minimum pump energy at 1030 nm	> 20 μJ	> 50 μJ	> 50 μJ	>20 μJ 2H, >50 μJ 3H, >50 μJ 4H
Supported pump pulse durations	190 fs – 10 ps	190 – 300 fs	190 – 300 fs	190 – 300 fs
Conversion efficiency	>50 %	>25 %	>10 %	>50 % 2H, >25 % 3H, >10 % 4H, >5 % 5H
Beam quality	$M^2 < 1.4$	$M^2 < 1.7$	–	M^2 <1.4 2H, <1.7 3H



Drawing of PHAROS laser with harmonic generators



Long term output stability of the third harmonic



Long term output stability of the fourth harmonic

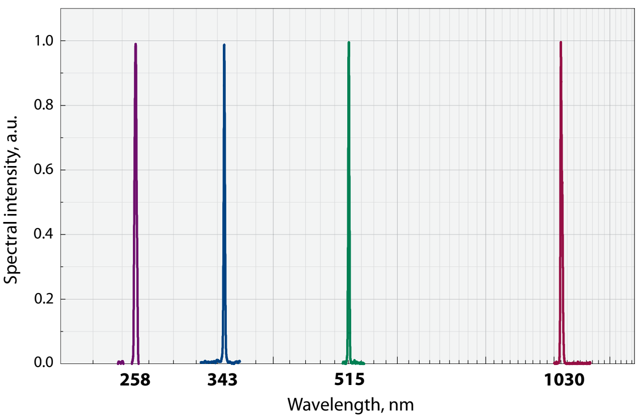
HIRO

Harmonic Generator

FEATURES

- High conversion rate to the second/third/fourth harmonic
- Easy switching between active harmonic
- Small footprint
- Integrated separation of the harmonics
- Flexible in fixing and easily customized to include additional options (continuum generators, beam expanders down-collimators)

HIRO is a valuable option for PHAROS lasers and FLINT oscillators that provides high power harmonics radiation at 515 nm, 343 nm and 258 nm wavelengths. We offer several standard HIRO models (with open prospect of future upgrades) which meet most users' needs. The active harmonic is selected by manual rotation of the knob – changing the harmonics will never take longer than a few seconds thanks to its unique layout and housing construction.



HIRO output wavelengths

HIRO is the most customizable and upgradable harmonics generator available on the market. It can be easily modified to provide white light continuum, beam splitting/expanding/down-collimating options integrated in the same housing as well as harmonics splitting that makes all three harmonics available at a time.

The principal of HIRO operation is based on collinear generation of higher laser radiation harmonics in angle-phase-matched nonlinear crystals. The optical layout of HIRO also includes beam reduction and collimation optics that ensures highest harmonics conversion efficiencies. Usually one active harmonic can be selected from HIRO, however the residual lower harmonics can be also accessed through the output ports. All the accessible harmonics exiting HIRO are already separated from the lower ones by dichroic mirrors.

Please contact Light Conversion for customized version of HIRO.

HIRO MODELS

Model	Generated harmonics	Output wavelengths
PH1F1	2H	1030 nm*, 515 nm
PH1F2	2H, 4H	1030 nm*, 515 nm, 258 nm
PH1F3	2H, 3H	1030 nm*, 515 nm, 343 nm
PH1F4	2H, 3H, 4H	1030 nm*, 515 nm, 343 nm, 258 nm
PH_W1	2H, 3H, 4H, WLG	any combination of harmonics and white-light continuum

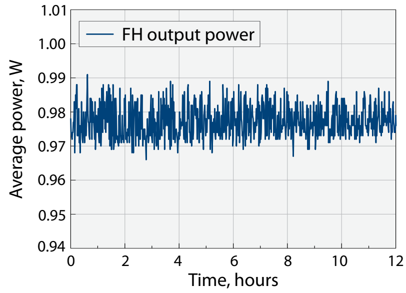
**residual fundamental radiation*

SPECIFICATIONS

Harmonic conversion efficiencies are given as percentage of the input pump power/energy when the repetition rate is up to 200 kHz.

Harmonic	Conversion efficiencies for different HIRO models		Output polarizations
	PH1F1, PH1F2	PH1F3, PH1F4	
2H	>50 %	>30 % (>50 %*)	H (V**)
3H	–	>30 %	V (H**)
4H	>10 %	>8 % (>10 %*)	V (H**)

** when the third harmonic is not in use*
*** optional, depending on request*



Long term output stability

HARMONICS GENERATION

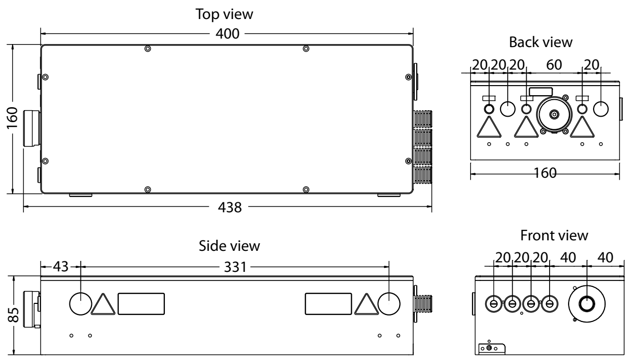
FLINT oscillator can be equipped with optional, wavelength converter HIRO providing harmonics radiation at 517 nm, 345 nm and 258 nm wavelengths.

Generated harmonics	2H	3H	4H
Output wavelength	517 nm	345 nm	258 nm
Conversion efficiency	>35%	>5%	>1%

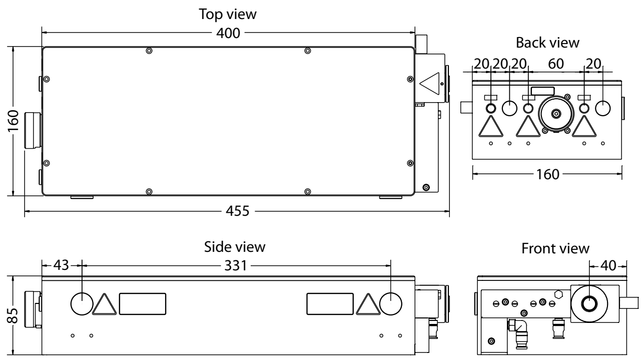
DIMENSIONS (for HIRO all models)

	W × L × H (mm)
General dimension of the housing	155 × 355 × 125*
Recommended area for fixing	255 × 425
Beam steering/intercepting	55 × 150 × 75

** Optional hight is from 70 mm up to 200 mm.*



HIRO housing dimensions and positions of input/output ports (mm)



HIRO housing with water cooling system dimensions and positions of input/output ports (mm)

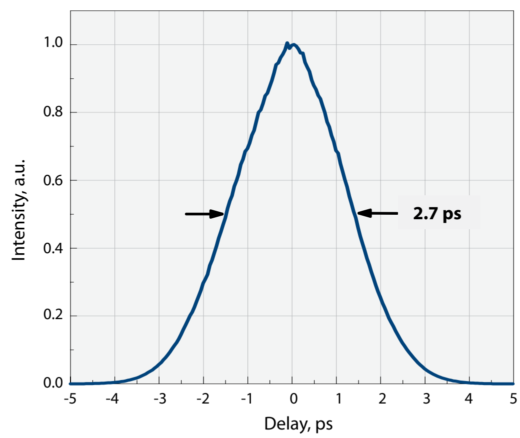
SHBC

Second Harmonic Bandwidth Compressor

FEATURES

- High conversion efficiency to the narrow bandwidth second harmonic
- Small footprint
- Integrated separation of residual pump radiation

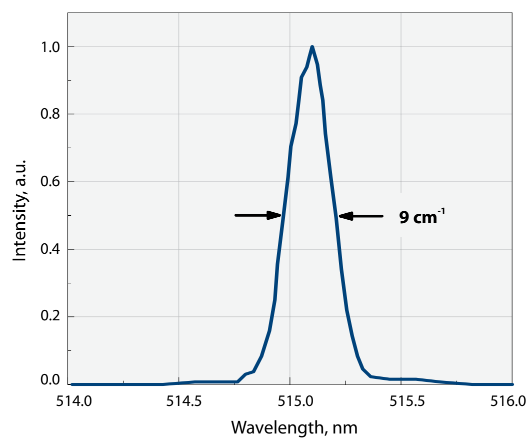
PHAROS harmonic generator product line features second harmonic bandwidth compressor abbreviated as SHBC. The device is dedicated for the formation of narrow bandwidth picosecond pulses from broadband output of ultrafast laser. In PHAROS platform SHBC is used to create flexible setups providing fixed wavelength or tunable narrow bandwidth ps pulses in combination with tunable wavelength broadband fs pulses. This feature is used in spectroscopy applications for mixing of wide and narrow bandwidth pulses such as sum frequency spectroscopy (SFG). SHBC is based on two compressors producing inversely chirped pulses which are non-collinearly mixed in a BBO crystal producing narrow-band second-harmonic. This setup allows efficient SH generation and so provides high pulse energies.



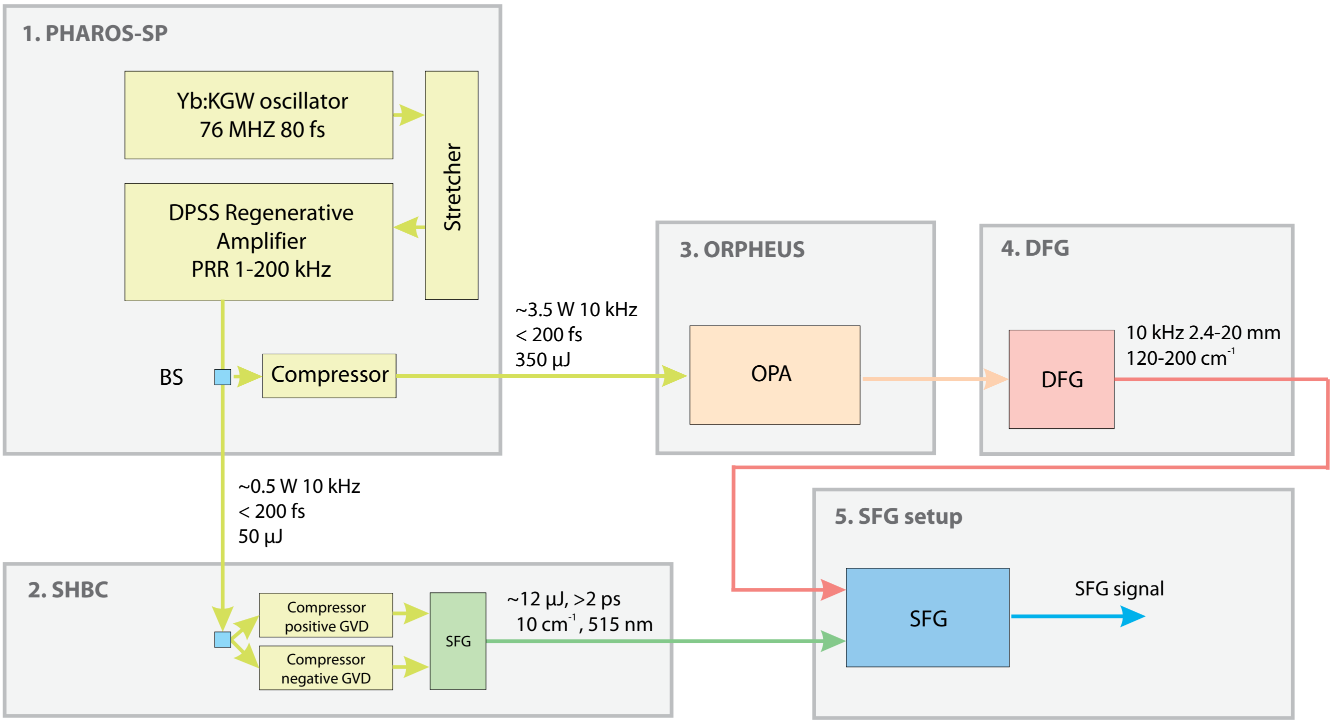
Typical pulse duration SHBC output

SPECIFICATIONS

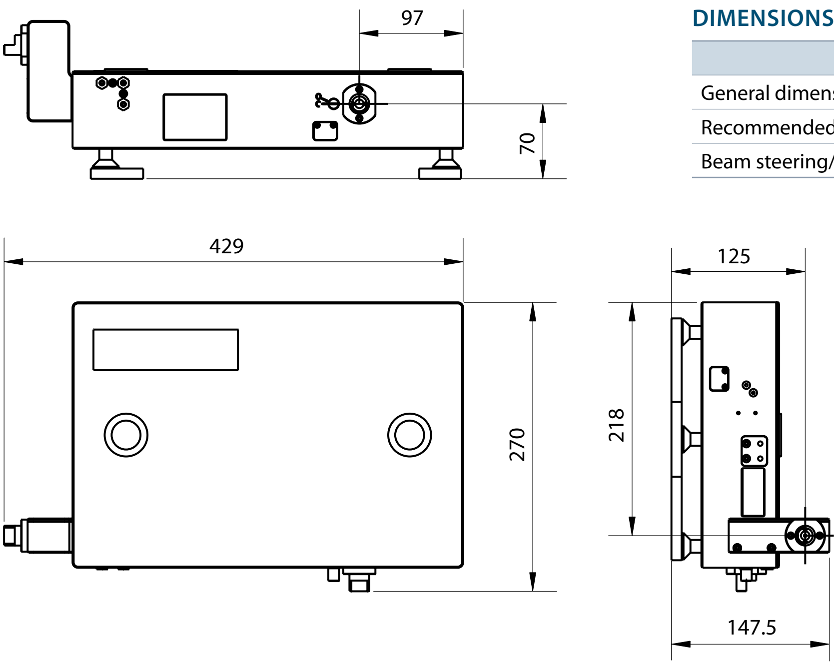
Parameter	Value
Pump source	PHAROS laser, 1030 nm, 70-120 cm^{-1}
Output wavelength	515 nm
Conversion ratio	> 30 %
Output pulse bandwidth	< 10 cm^{-1}



Typical spectrum of SHBC output



Principal layout of femtosecond sum frequency generation (SFG) spectroscopy system using SHBC to produce one of the probe beams



DIMENSIONS

	W × L × H (mm)
General dimension of the housing	155 × 355 × 75
Recommended area for fixing	255 × 425
Beam steering/intercepting	55 × 150 × 75

ORPHEUS

Collinear Optical Parametric Amplifier

FEATURES

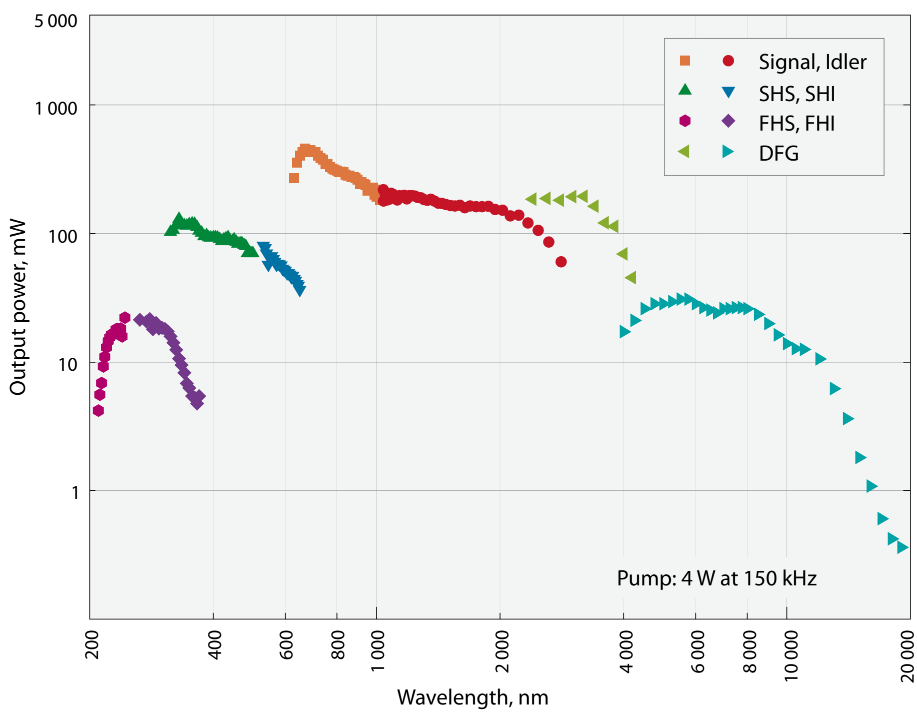
- Built on well known TOPAS OPA basis
- Repetition rate up to 1 MHz
- High energy conversion into parametric radiation
- Near bandwidth and diffraction limited output
- Adaptable to different pump pulse energy, repetition rate and pulse duration
- Full computer control via USB port and dedicated software
- Fundamental and second harmonic of pump laser available from the same enclosure
- Compact footprint when combined with PHAROS pump laser <0.5 square meter

ORPHEUS is a collinear optical parametric amplifier of white-light continuum pumped by PHAROS laser. ORPHEUS maintains the best features of TOPAS series amplifiers: high output stability throughout the entire tuning range, high output pulse and beam quality, full computer control via USB port as well as optional frequency mixers to extend the tuning range from UV up to mid-IR ranges. It can also operate at a wide range of repetition rates from 1 kHz up to 1 MHz.

Parametric amplification is performed with the second harmonic of pump laser (515 nm). The pump beam is generated inside of OPA unit with computer controlled angle adjustment. Fresh or residual fundamental and second harmonic radiation (1030 nm and 515 nm respectively) are accessible from dedicated output ports. ORPHEUS provides tunable OPA output (630-2600 nm) with residual second harmonic and fundamental radiation beams at the same time.

Femtosecond pulses, high power tunable output together with flexible multi-kilohertz repetition rate make the tandem of PHAROS and ORPHEUS an invaluable tool for multiphoton microscopy, micro-structuring and spectroscopy applications.

Several ORPHEUS can be pumped by a single PHAROS laser providing independent beam wavelength tuning.



Typical tuning curve of ORPHEUS

OSCILLATORS
LASER SYSTEMS
HARMONIC GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
SPECTROMETERS
AUTOCORRELATORS
APPLICATIONS

SPECIFICATIONS

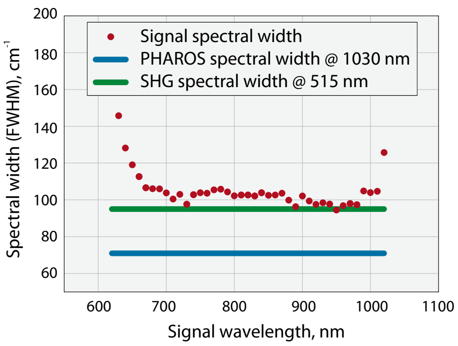
	ORPHEUS OPA
Tuning range	630-1020 nm signal and 1040-2600 nm idler
Pulse energy conversion efficiency	>14 % at peak, signal with idler combined, at 1-200 kHz >8 % at peak, signal with idler combined, at 500 kHz >5 % at peak, signal with idler combined, at 1 MHz
Pulse energy stability	<2 % rms @ 700-960 and 1100-2000 nm
Pulse bandwidth	80-120 cm^{-1} @ 700-960 nm, pumped by PHAROS 4-15W 120-220 cm^{-1} @ 700-960 nm, pumped by PHAROS SP
Pulse duration	120-300 fs depending on the wavelength and pump pulse width
Time-bandwidth product	< 1.0
Integrated SHG	515 nm, conversion efficiency >40 %

Requirements for the pump laser (typically PHAROS femtosecond laser):
wavelength 1030 nm, Repetition rate 1 kHz – 1 MHz, Pump pulse energy 6 µJ – 1 mJ, Pulse duration (FWHM) 180-290 fs.

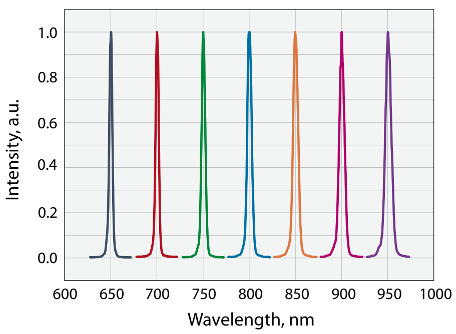
OUTPUT OF LYRA – OPTIONAL TUNING RANGE EXTENSION UNIT

	SH of signal	SH of idler	FH of signal	FH of idler	DFG1	DFG2
Tuning range	315-510 nm	520-630 nm	210-255 nm	260-315 nm	2200-4200 nm	4000-16000 nm
Pulse energy conversion efficiency	>4 %* at peak @ 100 kHz		>0.8 %* at peak @ 100 kHz		>3 %* @ 3000 nm	>0.2 %* @ 10000 nm

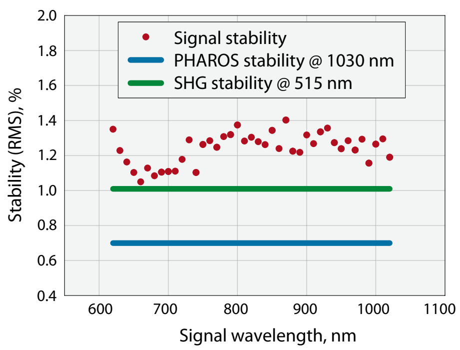
** calculated as percentage of input power to ORPHEUS.*



Typical output pulse spectral width

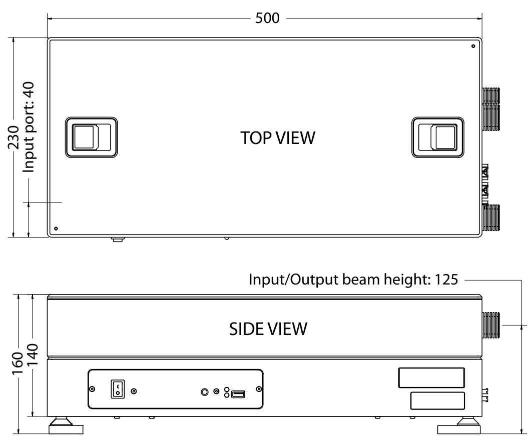


Typical spectra of signal wave



Stability of ORPHEUS output pulse

Compact layout of PHAROS pump laser in tandem with ORPHEUS on 0.5 square meter



ORPHEUS drawings

ORPHEUS-N

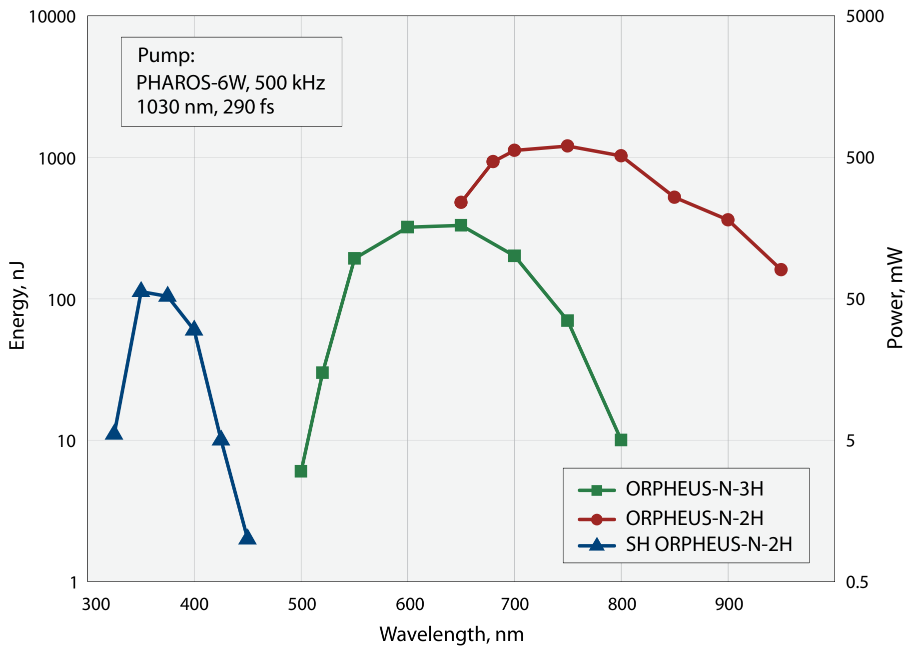
Non-Collinear Optical Parametric Amplifier

FEATURES

- Pulse duration down to 15 fs
- High repetition rates (up to 1 MHz)
- Computer controlled wavelength tuning
- Compact and flexible design

ORPHEUS-N is a non-collinear optical parametric amplifier (NOPA) pumped by the PHAROS laser system. Depending on the ORPHEUS-N model, it has a built in second or third harmonic generator producing 515 nm or 343 nm pump. ORPHEUS-N with second harmonic pump (ORPHEUS-N-2H) delivers pulses of less than 25 fs in 650-850 nm range with average power of more than 0.5 W at 700 nm*. ORPHEUS-N with third harmonic pump (ORPHEUS-N-3H) delivers pulses of less than 20 fs in 530-700 nm range with average power of more than 0.2 W at 550 nm*. ORPHEUS-N works at repetition rates of up to 1 MHz. The device is equipped with computer controlled stepping motor stages, allowing automatic tuning of the output wavelength. An optional signal's second harmonic generator is also available, extending the tuning range down to 250-450 nm. Featuring a state of the art built in pulse compressor ORPHEUS-N is an invaluable instrument for time-resolved spectroscopy. More than two ORPHEUS-N systems can be pumped with a single PHAROS laser providing several pump and/or probe channels with independent wavelength tuning.

**when pumped with 6 W @1030 nm, 200 kHz.*

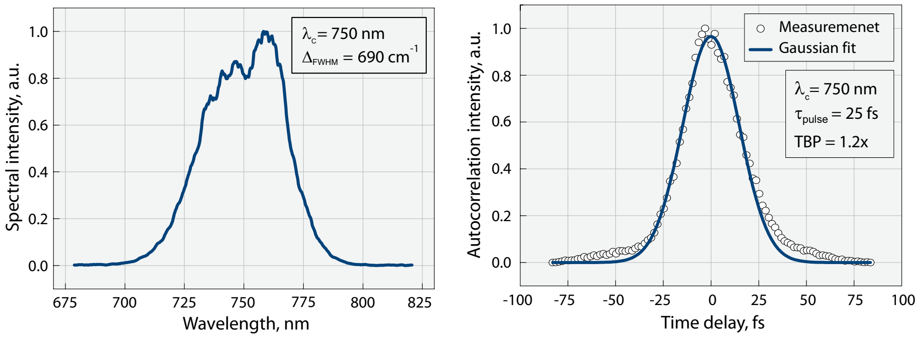


Typical tuning curve of ORPHEUS-N

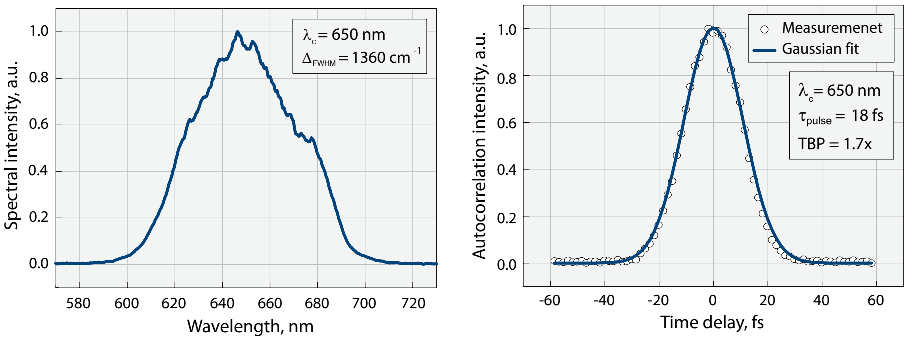
SPECIFICATIONS

	ORPHEUS-N-2H (pump: 30 µJ @1030 nm)	ORPHEUS-N-3H (pump: 30 µJ @1030 nm)
Tuning range	650-900 nm	500-900 nm
Built in harmonic generator	Second harmonic 515 nm wavelength >14 µJ pulse energy	Third harmonic 343 nm wavelength >8 µJ pulse energy
Output pulse energy (after prism compressor)	>2.2 µJ at 700 nm >0.9 µJ at 850 nm	>0.4 µJ at 550 nm >0.3 µJ at 700 nm
Pulse duration (Gaussian fit)	<30 fs at 700-850 nm	<30 fs at 530-700 nm <80 fs at 650-900 nm

Requirements for the pump laser (typically PHAROS femtosecond laser):
Wavelength 1030 nm, Repetition rate 1-1000 kHz, Pump pulse energy 8- 60 µJ, Pulse duration (FWHM) 180-290 fs.



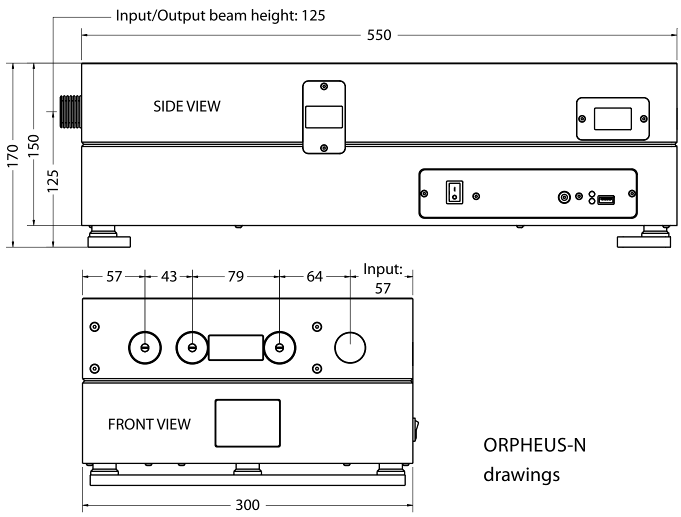
Typical output of ORPHEUS-N-2H



Typical output of ORPHEUS-N-3H

OPTIONAL ACCESSORIES

- Second harmonic generator of signal wave
- Computer controllable pulse duration



ORPHEUS-N drawings

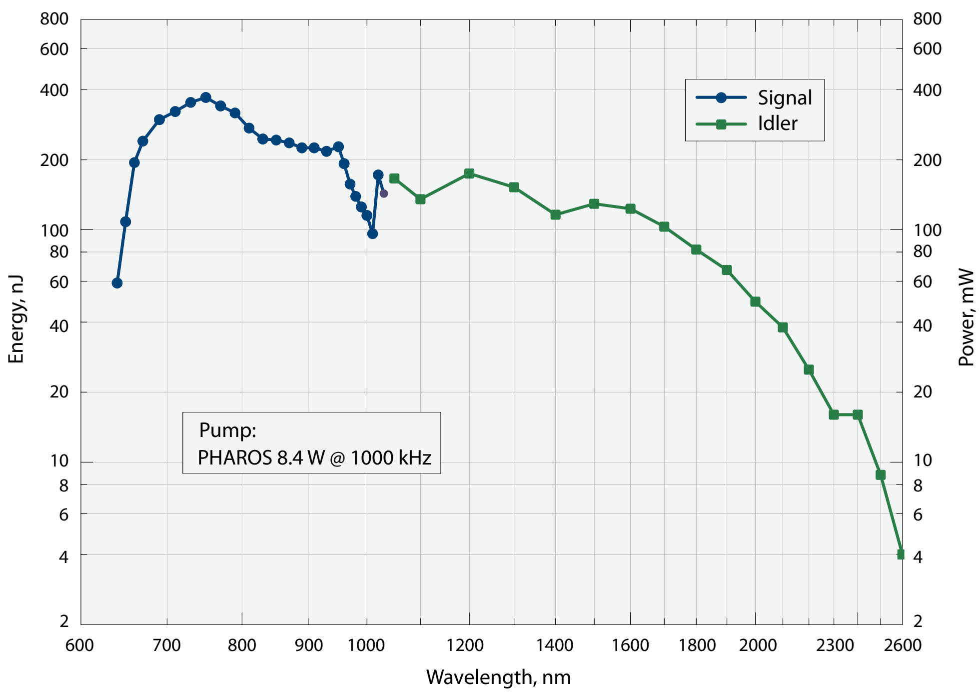
ORPHEUS twins

Two Independently Tunable Optical Parametric Amplifiers

ORPHEUS Twins – two independently tunable optical parametric amplifiers designed for high repetition rate operation. Both OPAs are integrated into a single monolithic housing and share the same white light continuum source as seed for amplification. ORPHEUS Twins provides two outputs, independently tunable in the 630 nm – 2600 nm range and pulse durations below 200 femtoseconds. The design of this OPA offers completely hands-free wavelength tuning and automatic Signal/Idler separation, also ensuring the same position and direction for all wavelengths. ORPHEUS Twins integrates two mini spectrometers for online monitoring of output wavelength, with self-calibration and capabilities for laser diagnostic functions.

FEATURES

- Designed for high-power and high repetition rates (up to 1 MHz)
- Single output beam position and direction through the whole tuning range
- Automated wavelength separators for hands-free operation
- Compact design leaves more table space for your experiments
- Integrated spectrometers monitor the output wavelength of OPAs in 650 nm – 1050 nm wavelength range
- The pulse picker integrated into our lasers enables single pulse and pulse-on-demand operation for your application
- Residual fundamental (1030 nm) and second harmonic (515 nm) beams available through dedicated output ports
- Optional fresh second harmonic is accessible when one of the OPAs is not being used
- Pulse durations of <200 fs out of the box, no additional pulse compressors required
- The package includes a MS Windows™ laptop computer with standard WinTOPAS OPA software + additional LabView™ based software for OPA control and wavelength monitoring



SPECIFICATIONS

Required pump laser	PHAROS or PHAROS-SP
Accepted pump input pulse energy @ 1030 nm, 150 fs – 300 fs pulse duration	9 μJ – 25 μJ
Supported repetition rates	Single pulse – 1 MHz
Integrated second harmonic generation efficiency (515 nm)	>45%
Tuning range	650 – 1020 nm signal and 1040 – 2600 nm idler
Output pulse energy at 9 μJ pump, each OPA *Output energy scales linearly with input energy	>100 nJ @ 700 – 950 nm >75 nJ @ 650 – 700 nm, 1050 – 1500 nm
Output polarization	Horizontal @ active OPA wavelength. Note that Signal and Idler wavelength are always orthogonal at the output. If Idler (1030 – 2600 nm) is selected as "active"– idler polarization is horizontal, signal – vertical. If Signal is selected as "active" – signal polarization will be horizontal, Idler polarization – vertical
Pulse energy stability	<2% rms @ 700 – 1000 nm and 1050 – 2000 nm
Pulse Bandwidth	80 – 120 cm^{-1} @ 700 – 960 nm, pumped by PHAROS 120 – 220 cm^{-1} @ 700 – 960 nm, pumped by PHAROS-SP
Pulse duration	150 – 230 fs, pumped by PHAROS 120 – 190 fs, pumped by PHAROS-SP
Time-bandwidth product	<1.5x bandwidth limited TBP
Integrated mini spectrometers	Wavelength range: 650 – 1050 nm, resolution: ~1.5 nm

Dimensions	**W × L × H (mm)**
Full dimension of the ORPHEUS Twins, including wavelength separation	810 × 430 × 164
Full dimensions of the PHAROS+ORPHEUS Twins system with beam routing units	910 × 850 × 215
Input/ Output beam height out of the housing from the optical table	125 mm
Output beam heights after the wavelength separator	90 mm for "active" wavelength, 128 mm for "passive"

HARPIA

Off-the-Shelf Pump-Probe Spectrometer

PHAROS, ORPHEUS, ORPHEUS-N, HARPIA and CHIMERA in the lab

Transient absorption spectrometer HARPIA is the first of the series of ultrafast spectrometers developed by Light Conversion to be used together with PHAROS/ORPHEUS or Ti:Saph/TOPAS laser systems. It features market-leading characteristics such as 10^{-5} resolvable signals, along with other unique properties such as the ability to work at high repetition rates of PHAROS lasers, up to 1 MHz. High repetition rate allows measuring transient absorption dynamics while exciting the samples with extremely low pulse energies (thereby avoiding exciton annihilation effects in energy transferring systems, or nonlinear carrier recombination in semiconductor/nanoparticle samples).

A number of probe configurations and detection options are available, starting with simple and cost-effective photodiodes for single-wavelength detection, and ending with spectrally-resolved broadband detection combined with white-light continuum probing. Similarly, different delay line options can be selected to cover delay windows from 1.7 ns (standard) to 7.5 ns.

HARPIA includes a PC with pre-installed National Instruments LabView® – based measurement automation software providing fully controllable, customizable and automatic performance of pump-probe measurements. Flexibility of NI LabView allows easy customization of software by the user to tailor it to the needs of specific measurements. Preset or custom delay times, number of averages per transient spectrum and other options are available at a click of the mouse.

In addition to experiment automation software, HARPIA includes data analysis package CarpetView for inspecting the acquired data and performing global and target analysis, probe dispersion compensation, exponential fitting etc. The software package features an intuitive and user-friendly interface; it is delivered with a data analysis tutorial that offers seamless transition from the raw data to publication-quality graphs and model-based parameter estimation. All the software runs under MS Windows and is easy to use. Even a novice will become an analysis expert in a matter of days!

FEATURES

- Compatible with laser systems running at 0.01-1000 kHz repetition rate
- When backed-up by PHAROS laser system, capable of measuring pump probe signals at extremely low pump pulse energies (<1 nJ), compared to 1 kHz Ti:Sapphire laser systems
- In combination with PHAROS/ORPHEUS laser system, easily resolves kinetic traces with maximum amplitude of 0.0001 OD
- Temporal resolution – 1.4 times laser pulse duration.
- Probe spectral range: 200 nm – 2600 µm, depends on the probe source and detection options
- Full control over the following parameters of pump and probe beams:
  - Polarization (Berek variable waveplate in the pump beam, half waveplate in the probe)
  - Intensity (continuously variable neutral density filters in both beams)
  - Delay (probe light is delayed in the optical delay line)
  - Wavelength (pump delivered 'as is'), probe can be dispersed by the spectral device
- Single wavelength and multichannel detector options available
- Spectral device: user-selected spectrograph or monochromator, depends on the selected options (see table below)
  - Detection by single detector (typically Thorlabs DET10A - Si Detector, 200 - 1100 nm)
  - Multichannel detector (range 200 - 1100 nm, up to 2000 spectra per second), probe spectral range 480 - 1100 nm, temporal resolution 1.4 times laser pulse duration
- LabView based measurement automation software provides full control and automatic execution of pump-probe measurements. The flexibility of LabView allows for easy customization of the software by the user, including preset or custom delay times, number of averages per transient spectrum, number of scans, etc.
- Standard 1.7 ns delay line with electronics and full software integration. Optional extension of probe times up to 7.8 ns is possible. Delay line is fully integrated in HARPIA's housing
- Ample sample space to fit a cryostat or flow system. Standard Sample holder with precision xy translation stage is included
- Includes beam delivery optics kit
- Data analysis software for inspecting the acquired data and performing global and target analysis, probe dispersion compensation, exponential fitting etc. Includes user-friendly interfaces, runs under MS Windows and is supplied with a manual describing how to get started with target analysis of your data
- There is a wide range of user selectable components

PERFORMANCE SPECIFICATIONS

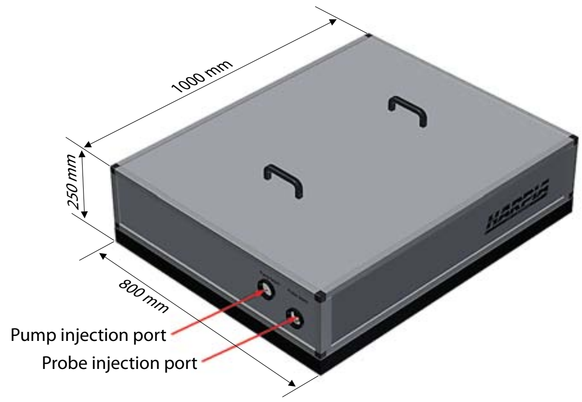
Probe wavelength range supported by the optics:	240 – 2600 nm
Probe wavelength range, white light supercontinuum generator, pumped by 1030 nm	480 – 1100 nm
Probe wavelength range white light supercontinuum generator pumped by 800 nm	350 – 1100 nm
Probe wavelength range of the detectors:	200 nm – 1100 nm, 700 nm – 1800 nm, 1.2 µm – 2.6 µm
Spectral range of the spectral devices	180 nm – 24 µm, achievable with interchangeable gratings
Delay range	1.7 ns, 3.8 ns, 7.8 ns
Delay resolution	16.67 fs, 33.3 fs, 66.7 fs
Noise level – single wavelength *	$<10^{-5}$ (assuming 2 s averaging per point)
Noise level – multichannel detection **	$< 2\times10^{-5}$ (assuming 5 s averaging per spectrum)
Laser repetition rate	1-200 kHz (digitizer frequency <2 kHz)
Time resolution	< 1.4 x the the pump or probe pulse duration (whichever is longer)

* *Test conditions: PHAROS laser running at 80 kHz, pump source: ORPHEUS @ 480 nm; probe source 1b, spectral device 3d, detector 2a-a. The value is standard deviation of 100 measurement points taken at the fixed delay. Not applicable for any laser system or any sample.*

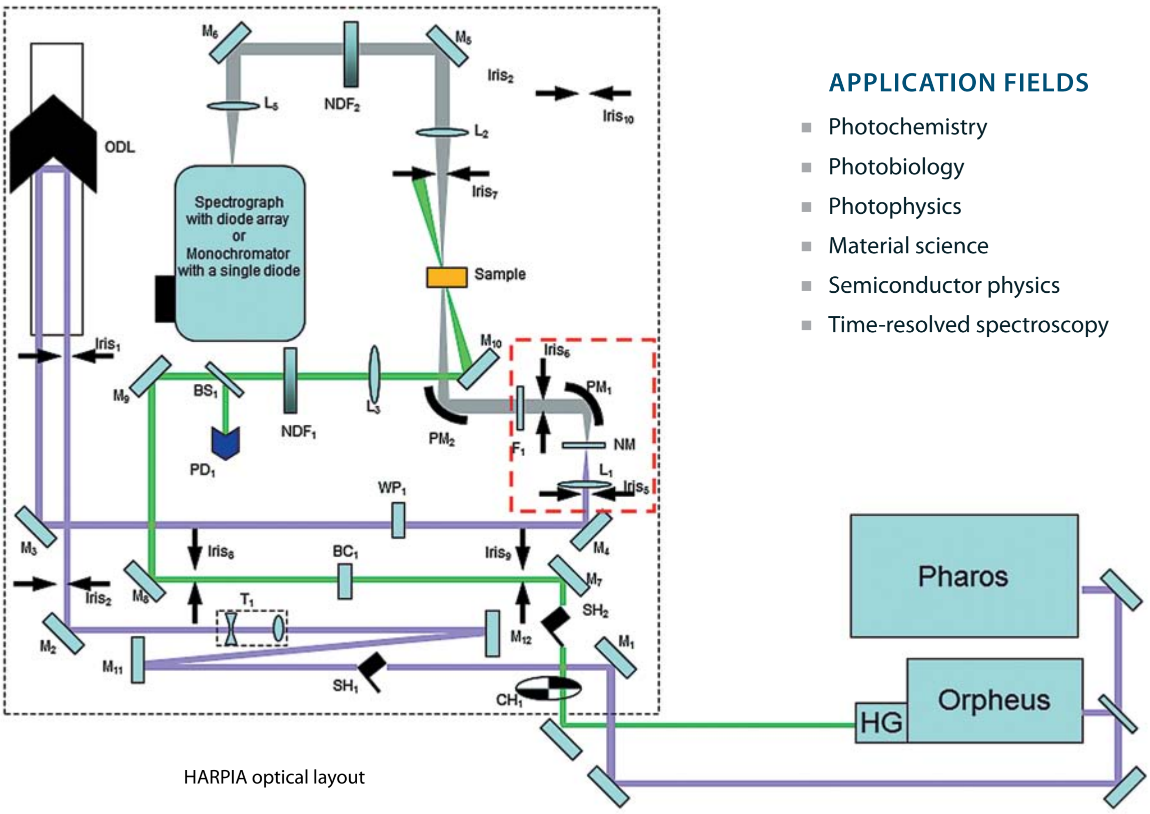
** *Test conditions: PHAROS laser running at 64 kHz, pump source: ORPHEUS @480 nm; probe source 1b, spectral device 3d, detector 2b. The value is standard deviation of 100 measurement points taken at the fixed delay, calculated using the signal at ca. 550 nm. a wavelength. Not applicable for any laser system or any sample or any spectral range covered by white light supercontinuum generator.*

PHYSICAL CHARACTERISTICS

Physical dimensions L×W×H	1000×800×300 mm
Weight	Optical head: ca 100 kg (depends on selected options) Electronics unit, including PC: ca 50 kg



HARPIA optical bench housing, dimensions and positions of input ports



HARPIA optical layout

APPLICATION FIELDS

- Photochemistry
- Photobiology
- Photophysics
- Material science
- Semiconductor physics
- Time-resolved spectroscopy

OSCILLATORS
LASER SYSTEMS
HARMONIC GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
SPECTROMETERS
AUTOCORRELATORS
APPLICATIONS

CHIMERA

Fluorescence Upconversion/Time-Correlated Single Photon Counting Spectrometer

CHIMERA is a time-resolved fluorescence spectrometer combining two time-resolved fluorescence techniques. For highest time resolution, fluorescence is measured using upconversion technique, where the fluorescence light emitted from the sample is mixed in a nonlinear crystal with a femtosecond gating pulse from the laser. The time resolution is then limited by the duration of the gate pulse and is in the range of 250 fs. For fluorescence decay times exceeding 150 ps, the instrument can be used in time-correlated single-photon counting mode that allows for measuring high-accuracy kinetic traces in the 200 ps – 5 µs domain.

CHIMERA is designed around the industry leading Becker& Hickl® time-correlated single-photon counting system, with different detector options available.

The combination of two time-resolved fluorescence techniques enables recording the full decay of fluorescence kinetics at each wavelength; with full data available, spectral calibration of the intensity of kinetic traces taken at different wavelengths is possible, where the integral of time-resolved data is matched to a steady-state fluorescence spectrum.

High repetition rates of PHAROS laser system allows for measuring fluorescence dynamics while exciting the samples with extremely low pulse energies (thereby avoiding exciton annihilation effects in energy transferring systems, or nonlinear carrier recombination in semiconductor/nanoparticle samples).

CHIMERA includes a PC with pre-installed National Instruments LabView® – based measurement automation software that provides the fully controllable, customizable and automatic performance of time resolved fluorescence measurements. Flexibility of NI LabView allows easy customization of software by the user to tailor it to the needs of specific measurements. Preset or custom delay times, number of averages per transient spectrum and other options are available at a click of the mouse. In addition to experiment automation software CHIMERA includes the data analysis package CarpetView for inspecting the acquired data and performing global and target analysis, probe dispersion compensation, exponential fitting etc. The software package features an intuitive and user-friendly interface; it is delivered with a data analysis tutorial that offers seamless transition from the raw data to publication-quality graphs and model-based parameter estimation. All the software runs under MS Windows and is easy to use. Even a novice will become an analysis expert in a matter of days!

FEATURES

- Straightforward operation
- Modular, customizable design
- Compatible with PHAROS series lasers running at 1-1000 kHz
- Integrates industry-leading Becker&Hickl® time-correlated single-photon counter
- Automated spectral scanning and upconversion crystal tuning – collect spectra or kinetic traces without system adjustments
- Measure fluorescence dynamics from hundreds of femtoseconds to 5 microseconds in a single instrument
- When backed-up by PHAROS laser system, capable of measuring pump probe signals at extremely low pump pulse energies (<1 nJ), compared to 1 kHz Ti:Sapphire laser systems
- Full control over the following parameters of pump beam:
  - Polarization (Berek variable waveplate in the pump beam)
  - Intensity (continuously variable neutral density filters in both beams),
  - Delay (probe light is delayed in the optical delay line)
  - Wavelength (pump delivered 'as is'), probe can be dispersed by a spectral device
- Standard Newport/Oriel CornerstoneTM – 130 USB monochromator. Other monochromator options are possible, such as double subtractive monochromator to ensure high TCSPC time resolution
- Standard 1.7 ns delay line with electronics and full software integration. Optional extension of probe times up to 7.8 ns is possible. Delay line fully integrated in CHIMERA's housing
- Ample sample space to fit a cryostat or flow system. Standard Sample holder with precision xy translation stage is included
- Includes beam delivery optics kit
- Data analysis software for inspecting the acquired data and performing global and target analysis, dispersion compensation, exponential fitting etc. Includes user-friendly interfaces, runs under MS Windows and is supplied with a manual describing how to get started with target analysis of your data

APPLICATION FIELDS

- Photochemistry
- Photobiology
- Photophysics
- Material science
- Semiconductor physics
- Time-resolved spectroscopy

SPECIFICATIONS – upconversion mode

Wavelength range	400-1600 nm*
Wavelength resolution	Limited by the bandwidth of the gating pulse, typically around 100 cm^{-1}
Delay range	1.8 ns (3.7 ns, 7.8 ns optional)
Delay step	16.7 fs (33 fs)
Time resolution	1.5 × laser pulse duration (420 fs with standard PHAROS laser) **
Signal-to-noise	100:1.5, assuming 0.5 s accumulation time per point ***
Monochromator	Newport/Oriel Cornerstone™ 130 USB standard **** (See www.newport.com for detailed specifications)
Crystal rotator	XY plane: manual; YZ plane: motorized, 0.01° degree resolution (phase matching angle automatically adjusted by the software while changing wavlengths)
Measurement software	LabView® – based ChimeraSoft for data collection and experiment automation; Global and target analysis package for data analysis and presentation. Includes a PC for experiment automation/data analysis

* *Depending on the gating source, may be achievable with different nonlinear crystals*
** *Estimated as the FWHM of the upconverted white-light supercontinuum generated in the sample, or the derivative of the rise of the upconversion signal.*
*** *Estimated as standard deviation of 100 points at 50 ps measured in Rhodamine-6G dye at 360 nm upconverted wavelength with PHAROS laser running at 150 kHz repetition rate. Not applicable to all samples and configurations.*
**** *Other monochromator options possible, such as double subtractive monochromator to ensure high TCSPC time resolution.*

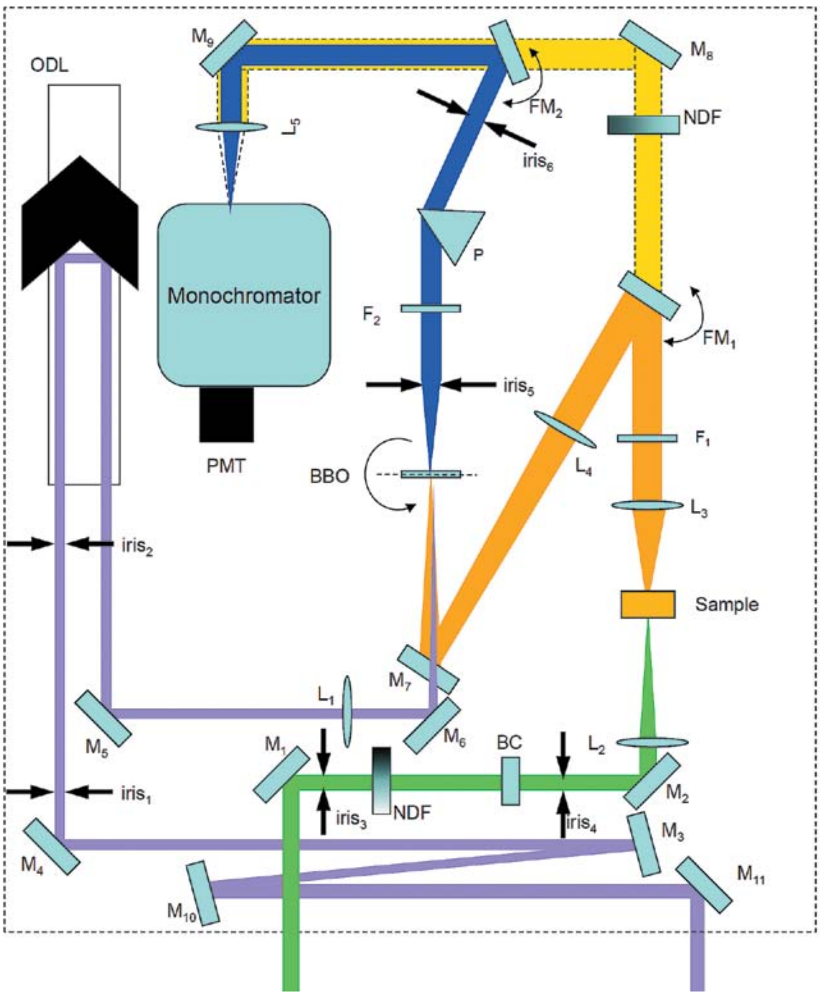
SPECIFICATIONS – TCSPC mode

TCSPC module	Becker&Hickl SPC-130, fully integrated into ChimeraSoft*
Detector control	Becker&Hickl DCC-100
Photomultiplier	Becker&Hickl PMC-100-1 standard
Wavelength range	300 - 820 nm
Intrinsic time resolution	< 200 ps
Time resolution with monochromator	< 1.2 ns**
Signal-to-noise	< 100:1 assuming 5 s accumulation time per trace***

* *See http://www.becker-hickl.de/ for spec sheets.*
** *Estimated as the FWHM of the upconverted white-light supercontinuum generated in the sample, or the derivative of the rise of the upconversion signal.*
*** *Estimated by fitting the kinetic trace measured in Rhodamine 6G solution at 580 nm with multiple exponentials, subtracting the fit from the data and taking the ratio between the STD of residuals and the 0.5 x maximum signal value. Laser repetition rate 250 kHz Not applicable to all samples and configurations.*

PHYSICAL DIMENSIONS

L × W × H	1000×800×300 mm



CHIMERA optical layout

OSCILLATORS
LASER SYSTEMS
HARMONIC GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
SPECTROMETERS
AUTOCORRELATORS
APPLICATIONS

TiPA

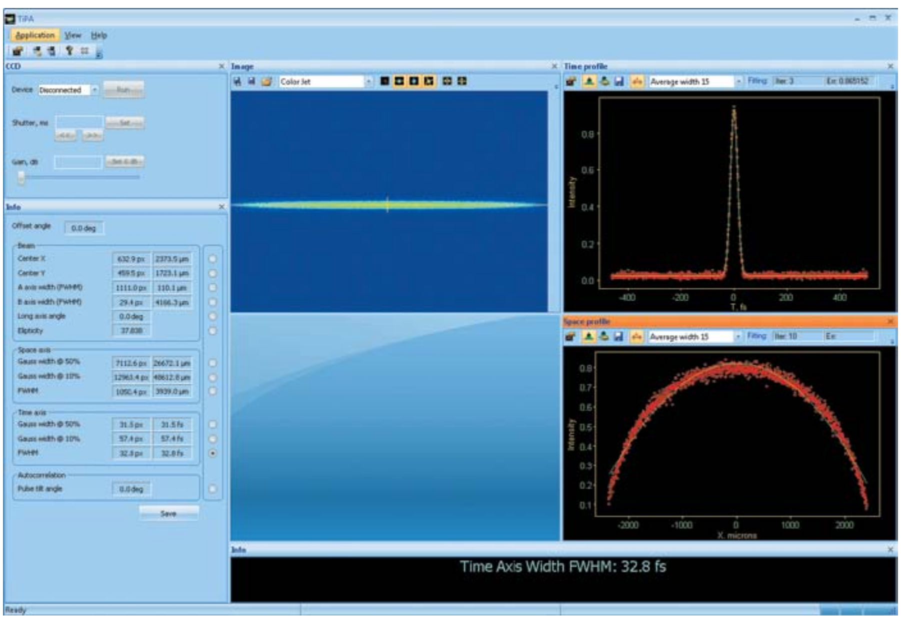
Single-Shot Autocorrelator for Pulse-Front Tilt and Pulse Duration Measurements

FEATURES

- Measures pulse duration in 30–1000 fs range
- Measures pulse-front tilt
- Working range – from 500 nm up to 2000 nm
- Easy to align and operate
- Compact design
- Hi-speed 12-bit CCD camera
- User friendly pulse-analysis software

TiPA is an invaluable tool for alignment of ultrashort pulse laser systems based on the chirped pulse amplification technique. Its unique design allows monitoring and measuring of the pulse duration as well as the pulse front tilt in both vertical and horizontal planes. TiPA is a straightforward and accurate direct pulse-front tilt measurement tool. Operation of TiPA is based on non-collinear second harmonic (SH) generation, where the spatial distribution of the SH beam contains information on the temporal shape of the fundamental pulse. This technique combines low background and single-shot measurement capability. The basic idea is that two replicas of a fundamental ultrashort pulse pass non-collinearly through a nonlinear crystal, in which SH generation takes place. SH beam's width and tilt in a plane perpendicular to propagation provide information about the pulse duration and pulse front tilt. The SH beam is sampled by the included CCD camera.

TiPA comes with a user friendly software package, which provides on-line monitoring of incoming pulse properties.



View of the TiPA software window

CCD control and info panels on the left; image captured by CCD – middle; processed time profile of the image with Gaussian fit, and processed space profile of the image – right top and bottom respectively.

TiPA MODELS*

Model	Operation wavelength
AT1C1	700 – 900 nm
AT2C1	900 – 1100 nm
AT5C3	500 – 2000 nm

**Non-standard models available on request.*

PERFORMANCE SPECIFICATION

Wavelength range	500 – 530 nm	530 – 700 nm	700 – 2000 nm
Temporal resolution	~500 fs/mm		
Measurable pulse width	40 – 120 fs	40 – 1000 fs	30 – 1000 fs
Minimum average power of radiation	~5 mW	~5 mW	~1 mW
Detector	CCD		

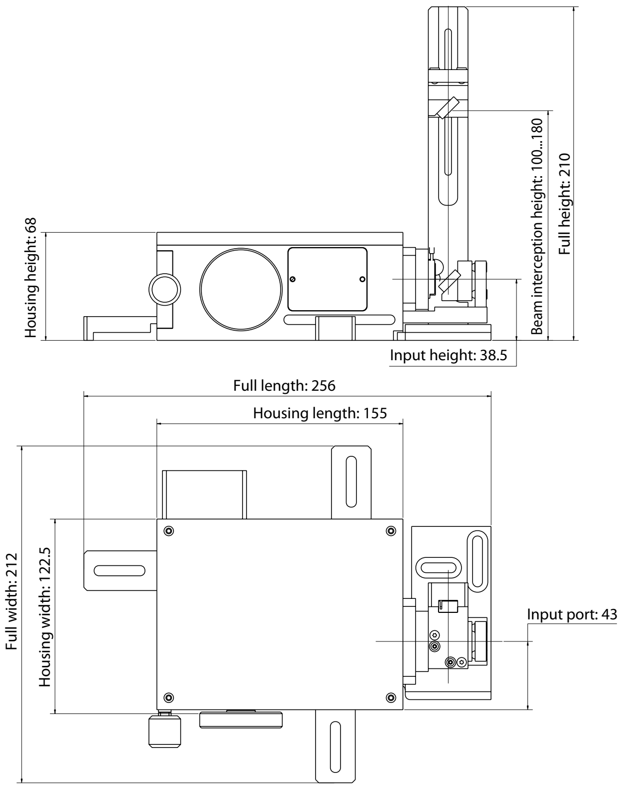
CCD SPECIFICATIONS

Maximum resolution	1296 (H) × 964 (V)
Pixel size	3.75 µm × 3.75 µm
Analog-to-Digital converter	12 bits
Spectral response*	0.35 – 1.06 µm
Power consumption from USB bus	2 W (max) at 5 V

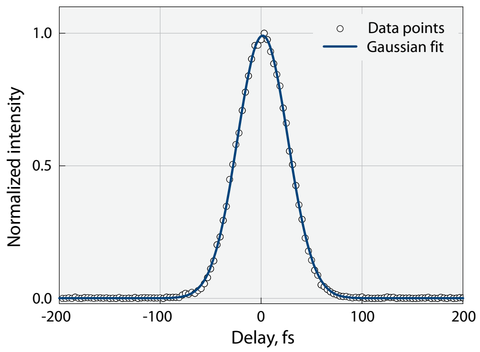
** With glass window.*

DIMENSIONS

General dimensions of the housing	123 (W) × 155 (L) × 68 (H) mm
Recommended area for fixing	212 (W) × 256 (L) mm
Beam interception height	100 – 180 mm



SAMPLE AUTOCORRELATION WITH DATA FITTING



TOPAS Idler Autocorrelation at 1700 nm (40 fs pump)

MEASUREMENT INFO

Gaussian Width:	18.8 px – 58.8 fs
FWHM Width:	19.2 px – 59.8 fs
Gaussian Pulse Duration:	41.6 fs
$Sech^2$ Pulse Duration:	38.2 fs
Pulse Tilt:	-0.210 deg

Geco

Scanning Autocorrelator

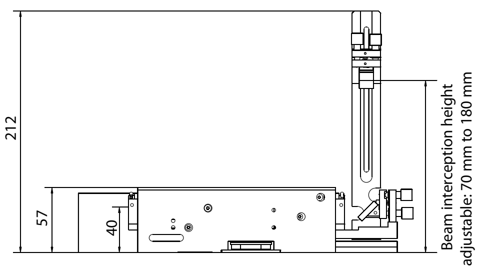
FEATURES

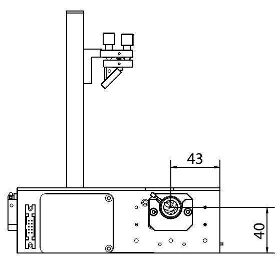
- Measures pulse duration in 10 fs – 3000 fs range
- Measures wavelengths down to 500 nm and up to 2000 nm
- Compact and portable design
- Pulse-analysis software for pulse duration measurements

Operation of Autocorrelator is based on noncollinear second harmonic generation in a nonlinear crystal, producing an intensity autocorrelation trace directly related to the input beam pulse duration. One arm of the fundamental pulse is delayed by means of a high-resolution 5-phase stepping motor, at 3 fs for full step this resolution can be further enhanced up to ten times by means of step division integrated into our electronics and software.

The beam to Autocorrelator is directed with the periscope which can be arranged in either polarization-maintaining or polarization-rotating setup, allowing easy measurement of vertically or horizontally polarized pulses. The beam is then split by a broadband metallic beamsplitter, and both beams are directed to a concave mirror, which focuses and combines the beams into a nonlinear crystal, producing a sum-frequency signal of the two beams. The intensity of the generated sum-frequency is directly related to the temporal overlap between the two fundamental pulses. By varying the timing difference with a stepping motor, we can acquire a full intensity autocorrelation trace of 10 fs to 3 ps pulse duration.

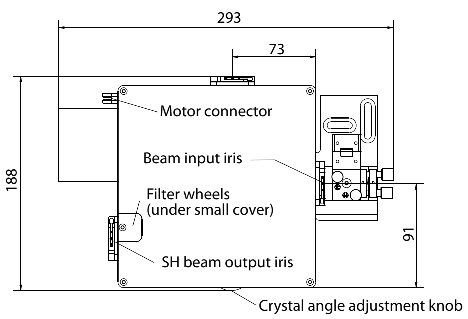
There are four filters and two nonlinear crystals available to cover the full 500 nm to 2000 nm range. Filters are placed on an easily changeable wheel with magnetic fixing.





REQUIREMENTS

- Minimum required input beam radiation (DC photodiode):
  20 mW at 500-550 nm, 10 mW
  at 550-2000 nm, for 100 fs pulse duration
- PC for data acquisition software



SPECIFICATIONS

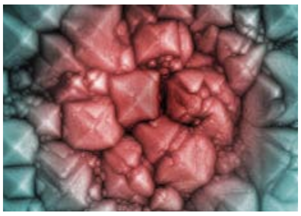
Input wavelength range, nm	500 – 2000
Temporal resolution	3.33 fs / step, down to 0.3 fs per microstep
Measurable pulse width, fs	10 – 3000
Minimum average power of radiation for ~100 fs pulse	>20 mW @ 1 MHz @ <550 nm, >10 mW @ 1 MHz @ >550nm
Detector	Si photodiode

MICROMACHINING

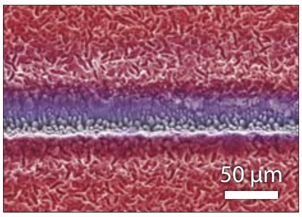
PROCESSING OF SOLAR CELLS

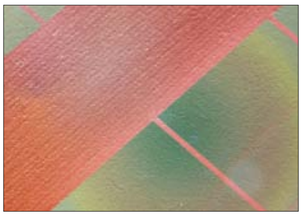
Applications:

- Front contact formation
- Back contact formation

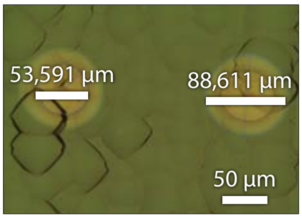


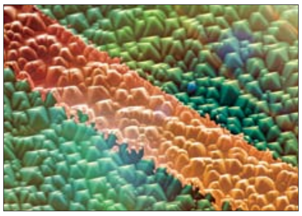
EDGE ISOLATION FOR SOLAR CELLS



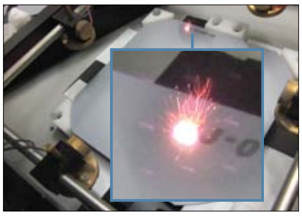


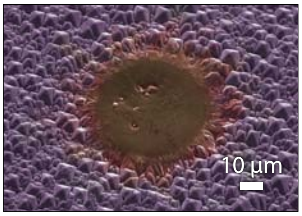
SELECTIVE DIELECTRIC LAYERS REMOVAL FOR SOLAR CELLS





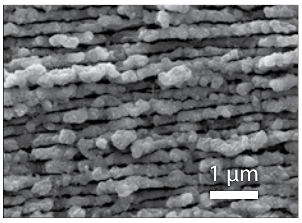
LASER MARKING OF SOLAR CELLS





NANO RIPPLES

- Up to 200 nm ripple period fabricated using ultra-short laser pulses
- Individual nano-feature size on ripples: 10 – 50 nm
- Controlled period, duty cycle and aspect ratio of the ripples



SWINBURNE UNIVERSITY OF TECHNOLOGY

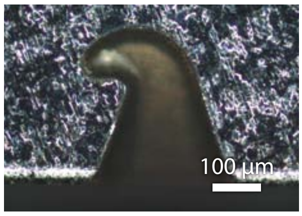
Developed in cooperation with Swinburne University, Australia

Application:

- Detection of materials with increased sensitivity using surface-enhanced Raman scattering (SERS)
- Bio-sensing, water contamination monitoring, explosive detection etc.

METAL MICROMACHINING

- 3D structures formed on steel surface
- High precision and surface smoothness achieved



MARKING OF CONTACT LENS

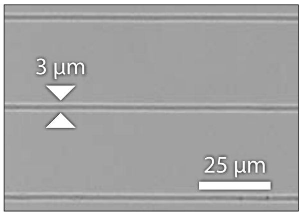
- Marking made inside the bulk of contact lens, preserving surface of lens and distortions
- Exact positioning of markings – 3D text format

Application:

- Product counterfeit protection
- Development of novel products

MICRO CHANNEL FORMATION

- Wide range of materials – from glass to polymers

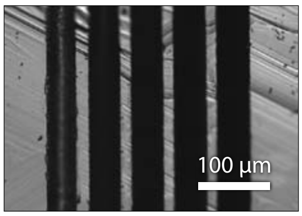


Applications:

- Microfluidic sensors
- Waveguides

DIAMOND CUTTING

- Low carbonization
- No HAZ
- Low material loss

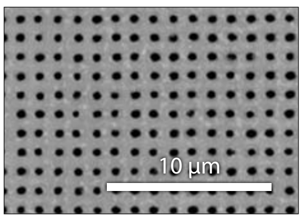


Applications:

- Diamond sheet cutting
- Diamond texturing/patterning

STEEL FOIL M-DRILLING

- No melting
- Micron diameter



Applications:

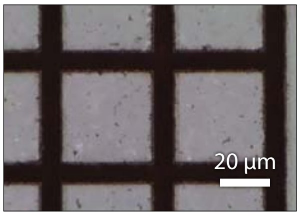
- Filters
- Functional surfaces

FERROELECTRIC CERAMICS ETCHING

- No or low melting
- Easily removable debris
- Good structuring quality

Applications:

- Infrared sensors for cameras
- Memory chips

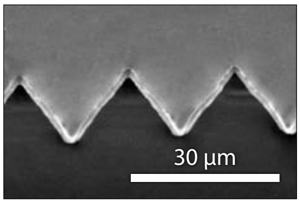


SILICON LASER ASSISTED ETCHING

- No HAZ
- No melting

Applications:

- Solar cell production
- Semiconductor industry

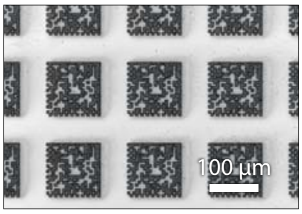


DATAMATRIX

- Data inscribed on a glass surface
- Extremely small individual elements, up to 5 µm in size

Application:

- Product marking



HOLOGRAM PRODUCTION

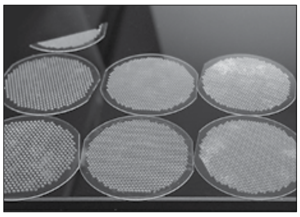
- Example: hologram view generated using glass sample

MASK FOR BEAM SPLITTER PATTERN DEPOSITION

- Borosillicate glass
- 150 um thickness
- ~900 holes per mask
- Mask diameter 25.4 mm

Appplication:

- Selective coating

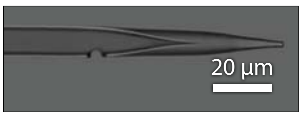


GLASS TUBE DRILLING

- Controlled damage and depth

Applications:

- Tissue biopsy equipment

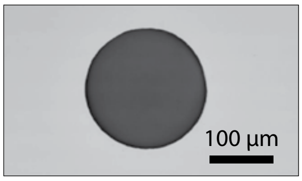


GLASS HOLES

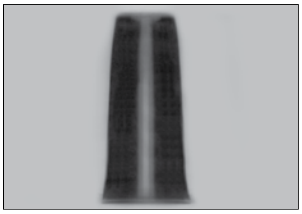
- Various hole sizes with routine tapper angle better than 5 deg
- Minimal debris around the edges of holes

Application:

- Microfluidics



Top view



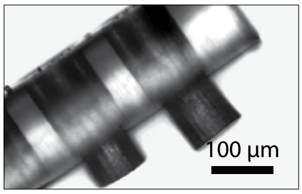
Cross-section

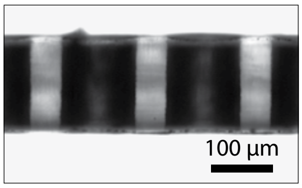
STENT CUTTING

- Holes in stent wall, cross-section view
- Polymer stent
- No heat effect, no debris
- Minimal taper effect

Application:

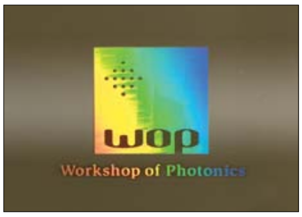
- Vascular surgery





MARKING AND PATTERNING

- Smallest spots up to 3 µm in width
- Micron level positioning
- No heat effect



Metal

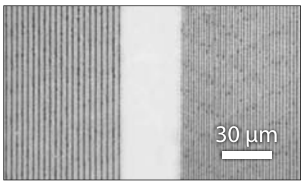
Hair

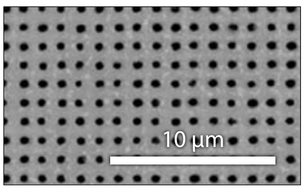
TEXTURIZED SAPPHIRE SURFACE

- Micron resolution
- Large area processing
- Single pulses used to form craters on the surface

Application:

- Better light extraction in LED
- Semiconductor structure growth

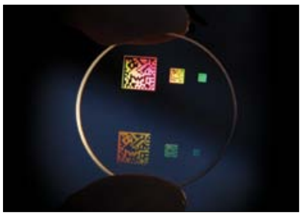




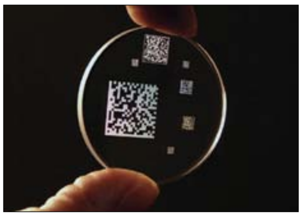
MARKING INSIDE A BULK OF TRANSPARENT MATERIAL

- Colorful structures due to small pixel size
- Surface not affected
- Very small or no cracks near markings
- Low influence on strength of the substrate

Optical fiber



Sapphire



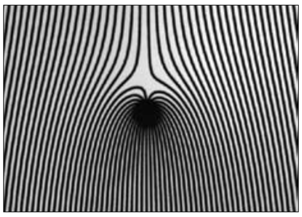
Glass

SELECTIVE METAL COATING ABLATION (REMOVAL)

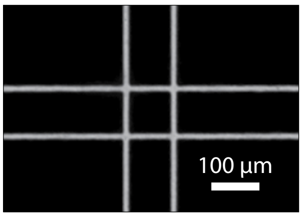
- Selective ablation of metal coatings from various surfaces
- Depth and geometry of ablation may vary

Application:

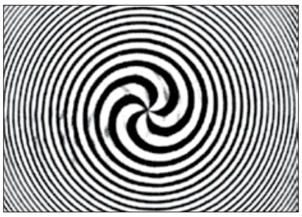
- Lithography mask production
- Beam shaping elements
- Optical apertures
- Other



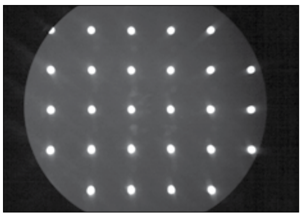
Amplitude grating formation



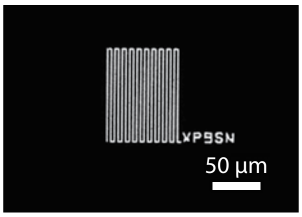
Titan coating selective ablation



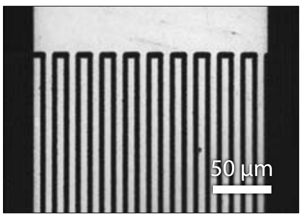
Chrome ablation for beam shaping



Apperture array fabrication



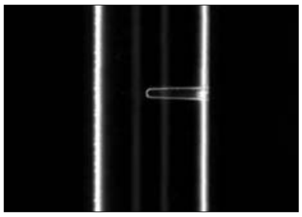
Gold layer removal without damage to MgO substrate – Au layer removal without damaging



Chrome ablation from glass substrate

OPTICAL FIBER DRILLED TO THE MIDDLE

- Diameter from <10 µm
- Various hole profiles possible
- Depth and angle control

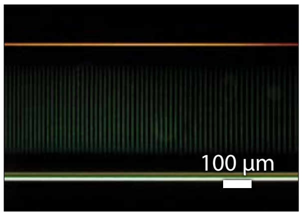


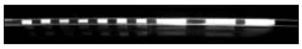
Applications:

- Optical fiber sensors
- Material science

OPTICAL FIBER SCATTERING

- No impact on fiber strength
- No surface damage
- Even light dispersion



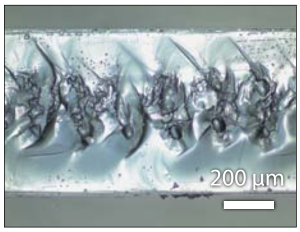


Applications:

- Medical fibers
- Oncology

TEMPERED GLASS CUTTING, 700 µm thick

- Only bulk is damaged (closed cut), surface remains intact, practically no debris



Side view after breaking

Workshop of Photonics

Samples provided by **Workshop of Photonics**

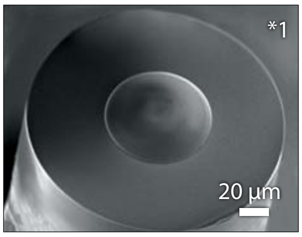
www.wophotonics.com

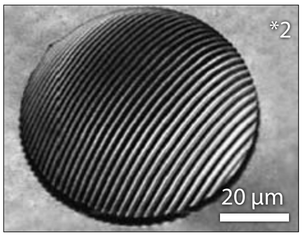
OSCILLATORS
LASER SYSTEMS
HARMONIC GENERATORS
OPTICAL PARAMETRIC AMPLIFIERS
SPECTROMETERS
AUTOCORRELATORS
APPLICATIONS

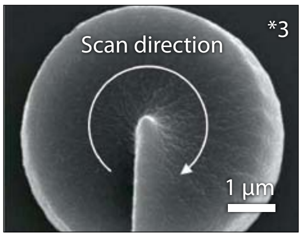
MULTI-PHOTON POLYMERIZATION

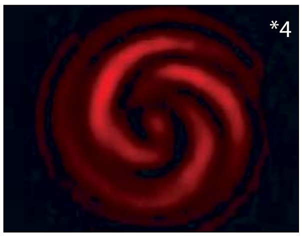
APPLICATION IN MICRO-OPTICS

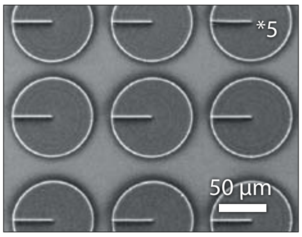
Many polymers are transparent to visible light and can be combined with other materials like Zr or Ge. The ability to control light flow can be used in micro optical devices, such as micro lenses, hybrid micro lenses with phase gratings, micro lens arrays, vortex beam generators, vortex generator arrays etcetera. The MPP* technology allows integrating of such micro optical devices on limited surfaces like the tip of an optical fiber.





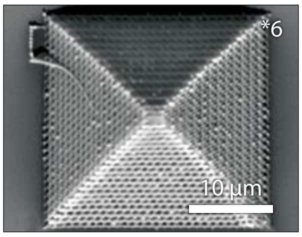


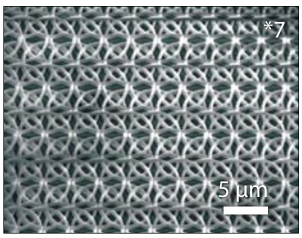




APPLICATION IN PHOTONICS

Highly repeatable and stable technological process aims at fabrication of phase/diffractive gratings and photonic crystals.

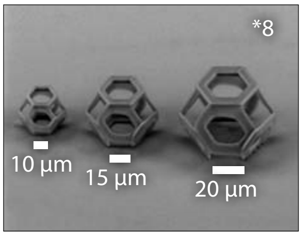


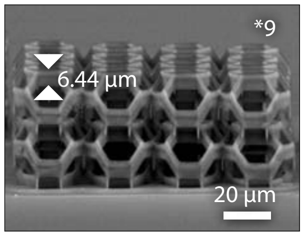


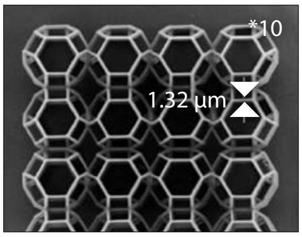
APPLICATION IN REGENERATIVE MEDICINE

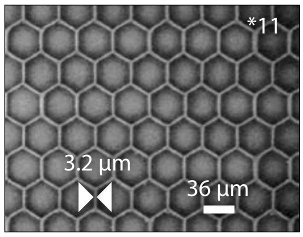
Regenerative medicine is the most promising application field for MPP technology, because polymerization can offer a variety of custom elements which need controllable precision, biocompatibility or biodegradability. Polymeric scaffolds for stem cells growth can be fabricated in any 3D shape for applications in tissue engineering.

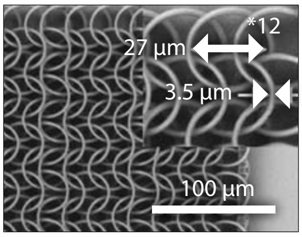
- Scaffolds for tissue engineering.The last picture shows that artificial scaffold is suitable for cell proliferation, because there is a cell growing in mitosis stage.

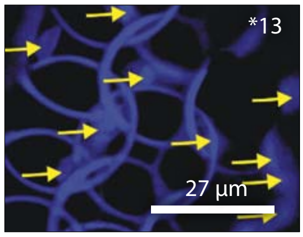


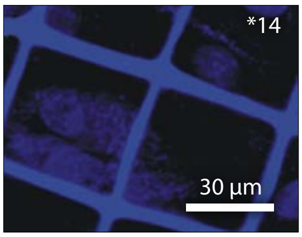


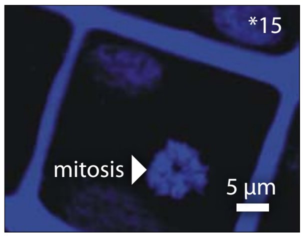




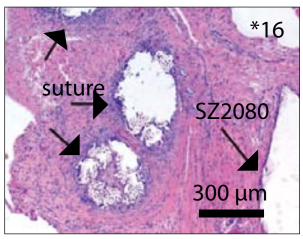








- Biocompatibility and biodegradability have been tested in vivo and in vitro. Histological tests show that sol-gel material is more biocompatible than a surgical suture or surgical clip.



* MPP – multi-photon polymerization.

LIGHT CONVERSION

* Illustration Reference

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