ORPHEUS-HP

High power optical parametric amplifier of white light continuum

User's Manual

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PREFACE

This manual contains user information for the optical parametric amplifier ORPHEUS-HP.

Please read this manual first before attempting to connect and/or operate ORPHEUS-HP. Special attention should be paid to the "Safety precautions" chapter, which describes the safety measures that should be taken while using the device. Always use the instrument only for its intended purpose and as described in the manual. Failing to do so may void the instruments warranty and compromise user's safety.

This manual is intended to give the user thorough description of the operation of ORPHEUS-HP, guidance on daily usage of the device and troubleshooting advice. The manual assumes that the device has been installed by a qualified service engineer. The user is strongly advised not to attempt to perform a new installation or re-installation of ORPHEUS-HP by following this manual without proper training.

Information in this manual is believed to be accurate and reliable. All information in this document is subject to change without notice. In no event will Light Conversion be liable for any direct or indirect damages resulting from any defects in this documentation. Always consult Light Conversion Support Team or your local service engineer, if you have doubts about any instructions written in the manual before taking action.

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Download the latest WinTOPAS software version from Light Conversion website www.lightcon.com:

Go to "Support" → "OPA Software Update" for the download link. No login required.

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SAFETY SIGNAL WORDS AND SIGNS

The following safety signal words and safety signs are used throughout this manual:

Table 1. Safety signal words and safety signs used in this manual

Safety sign	Signal word	Description
	DANGER	Indicates a hazardous situation that, if not avoided, will result in death or serious injury.
	WARNING	Indicates a hazardous situation that, if not avoided, could result in death or serious injury.
	CAUTION	Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury.
	**NOTICE**	Indicates information considered important, but not hazard-related (e.g. relating to property damage).
		Indicates danger of electrical hazard to personal safety.
		Indicates danger of exposure to hazardous laser radiation.

1. SAFETY PRECAUTIONS

This section should be carefully reviewed prior to operating the ORPHEUS-HP optical parametric amplifier (OPA). Safety precautions contained herein and throughout the manual must be carefully followed to ensure that all personnel who operate the laser and the OPA are protected from accidental exposure to laser radiation.

WARNING

ORPHEUS-HP, when coupled with an appropriate pump laser, comprises a* Class 4 *laser product. Avoid eye or skin exposure to direct or scattered radiation. It may cause skin injuries, eye damage with possible blindness, and could also constitute a fire hazard.

ORPHEUS-HP, when coupled with an appropriate pump laser, comprises a Class 4 laser product that poses safety hazards if not used properly. Produced direct or scattered radiation can cause permanent eye damage and possible blindness, skin injuries. Beams can be powerful enough to burn skin, clothes, or ignite fire and can also damage light sensitive optical equipment such as video cameras, photodiodes, etc. It is imperative that users learn all safety information, which is provided in this manual as well as the pump laser's manuals.

1.1 Optical Safety

Maximum accessible radiation level from the ORPHEUS-HP. The used and emitted power/pulse energy by ORPHEUS-HP may vary upon the type and model of the pump laser used. The maximum average input power can be up to 40 W, pulse energy up to 2 mJ with pulse duration ranging from 100 to 300 fs. Emitted radiation can be over 20 W of average power, over 1 mJ of pulse energy with 100-300 fs pulse duration. The wavelengths emitted by/present in ORPHEUS-HP are: 1030 nm, 515 nm, 630-3000 nm. Additional frequency mixers may also emit wavelengths ranging from 189 nm to 20000 nm. Be very careful when aligning and working with ORPHEUS-HP.

WARNING

Avoid viewing the beam and specular reflections. Always wear protective eyewear when aligning and operating the ORPHEUS-HP. Ensure your protective glasses cover all wavelengths emitted by the laser system.

Operators of the system and all other personnel present in the laboratory are advised to follow the precautions below:

1. Always wear protective eyewear. Choose protective eyewear appropriate to wavelength and intensity of the radiation, conditions of use, and visual function required. Remember that the ORPHEUS-HP output wavelength can be automatically and continuously tuned in broad wavelength range.
2. Never look directly into the laser beam or scattered laser light from any reflective surface or partially reflective surface. Remember that paper cards maybe reflective enough to cause eye injury.
3. Avoid wearing watches, jewelry and other objects that may reflect or scatter the laser beam.
4. Set up the laser system so that laser beam paths are located well below eye level. Keep the beams enclosed where possible.

5. Use energy absorbing targets and shields for beam blocking and preventing unnecessary reflections or scatter.
6. Avoid blocking the laser beam or its reflection with any part of your body.
7. Limit access to the laser system to qualified personnel only, who have received appropriate safety laser training and are aware of dangers involved.
8. Use the laser system in a closed room. Laser light remains collimated over long distances and therefore presents a potential hazard if not confined.
9. Do not work with ORPHEUS-HP cover opened unless necessary. Intense light beams, their specular and scattered reflections can be emitted from various parts of ORPHEUS-HP when the cover is opened.
10. Always keep the ORPHEUS-HP powered for the safety beam shutter to operate correctly.
11. Post appropriate warning signs near the laser system’s operation area.

1.2 Electrical Safety

1. Disconnect the power supply when working on any electrical equipment when it is not necessary for the equipment to be operational.
2. Do not connect or disconnect any cables with the power supply connected to the mains electricity.
3. Never work on electrical equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who is competent to administer first aid.
4. The equipment must only be connected to a mains electricity with protective earth to avoid risk of electrical shock.

WARNING ***To avoid the risk of electrical shock, this equipment must only be connected to a mains electricity with protective earth.***

1.3 Warning and Information Labels

Description of ORPHEUS-HP labels is presented in Figure 1 and Table 2.

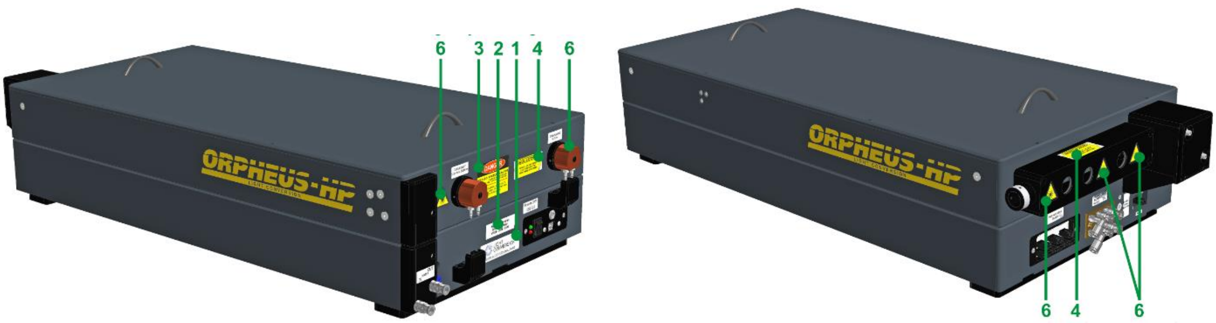
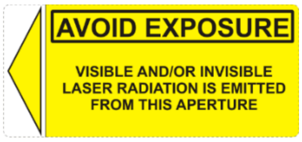
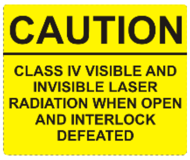


Figure 1. Location of the labels on the ORPHEUS-HP body

Table 2. Location and description of ORPHEUS-HP labels

No.	Label	Location and description
1	LIGHT CONVERSION Keramiku 2B, LT-10233 Vilnius, Lithuania	**Manufacturer identification** label is located on the side of the ORPHEUS-HP housing.
2	MODEL: 80C1 SERIAL NO: 06001 PROD. DATE: 01/06	**Device identification label** is located on the side of the ORPHEUS-HP base above Manufacturer label.
3		**Warning logotype** is located on the back side of the ORPHEUS-HP housing.
4		**Aperture label** is located next to the output aperture of the ORPHEUS-HP and points to it.
5		**Label for defeatably interlocked housing** is located on the interlock switch inside OPA.
6		**Laser radiation warning** logo is located at every input and output port of the housing.

2. ELECTRICAL AND PHYSICAL SPECIFICATIONS

For indoor use only!

ORPHEUS-HP is powered by external power supply provided by the manufacturer. Contact "Light Conversion" support team before using a power supply from other manufacturers.

Table 3. Electrical and utility requirements

Power requirements (external power supply)	Voltage: 100–240 VAC Frequency: 50/60 Hz Max. current: 1.6 A
Power requirements (control board)	Voltage: 24 VDC Max. current: 5 A
Altitude	Up to 2500 m
Operating temperature	15-40 °C
Relative humidity	10-70 % (non-condensing)

Table 4. Physical specifications

	Only ORPHEUS-HP	*With wheel box*
Length	787 mm	1023 mm
Width	340 mm	364 mm
Height	176 mm	176 mm
Weight	30 kg – 40 kg, depending on optional components	
Input/output port height	125 mm	
*Optical beam path length (ORPHEUS-HP)**	~2.00 m for signal/idler, ~2.34 m for DFG	

* From the input to the output port.

2.1 Dimensions

Recommended area on the optical table: 420 x 1250 x 200 (W x L x H, mm)

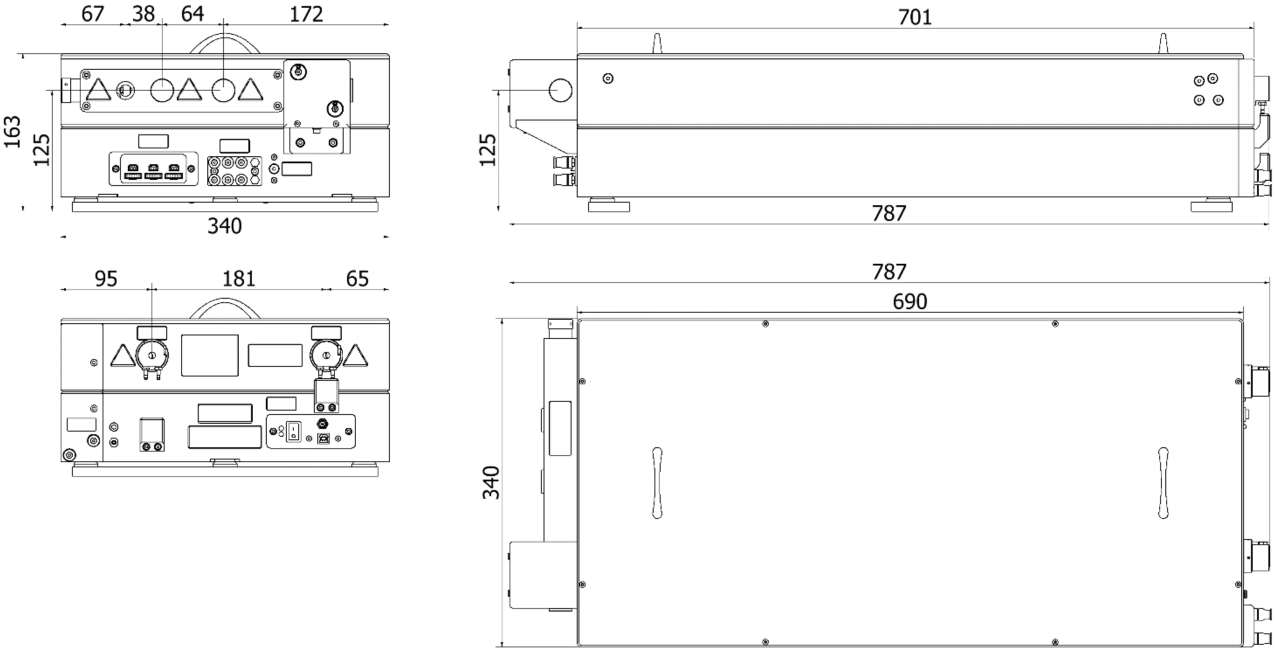


Figure 2. Physical dimensions (mm) of ORPHEUS-HP housing

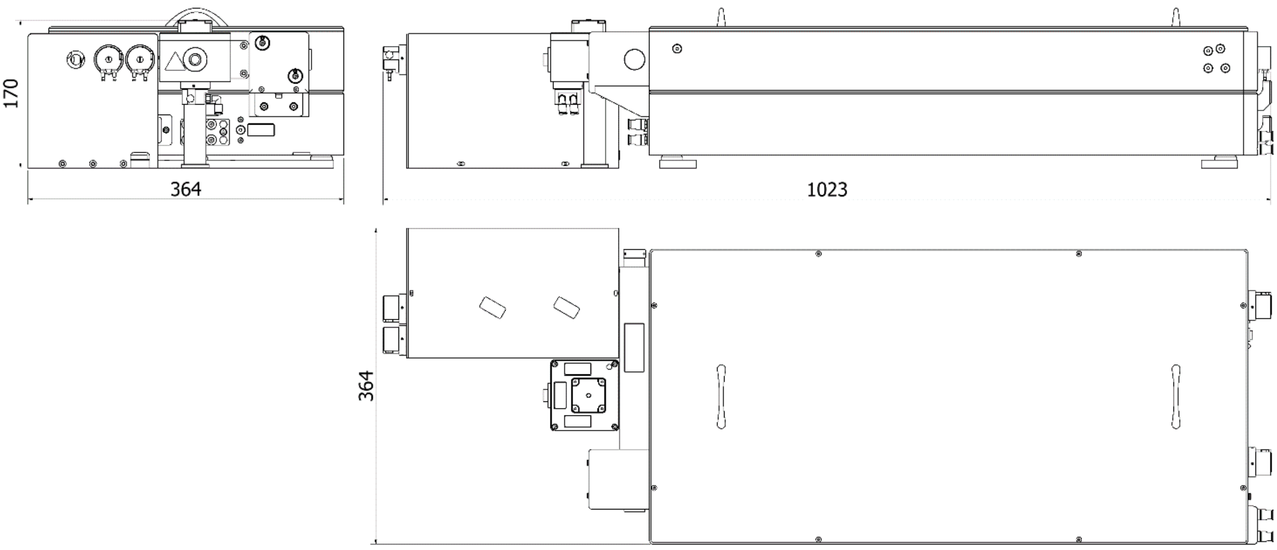


Figure 3. Physical dimensions (mm) of ORPHEUS-HP housing with separator wheel box

2.2 Description of Input and Output Ports

Figure 4. Location of input and output ports on ORPHEUS-HP housing

Figure 4 shows the layout of ORPHEUS-HP input and output ports. Parametric radiation is emitted from the main output ports B, C and D. Depending on the system configuration, some of the input and output ports may not be used, but there may still be some radiation emitted from those apertures. Full description of input and output ports is presented in Table 5.

There are also many smaller holes on ORPHEUS-HP body, which are used during alignment of the device. They are not specially identified; however, it is possible that some radiation may leak through these apertures. Therefore, make sure that every alignment aperture is closed during normal operation.

Table 5. Description of ORPHEUS-HP input/output ports

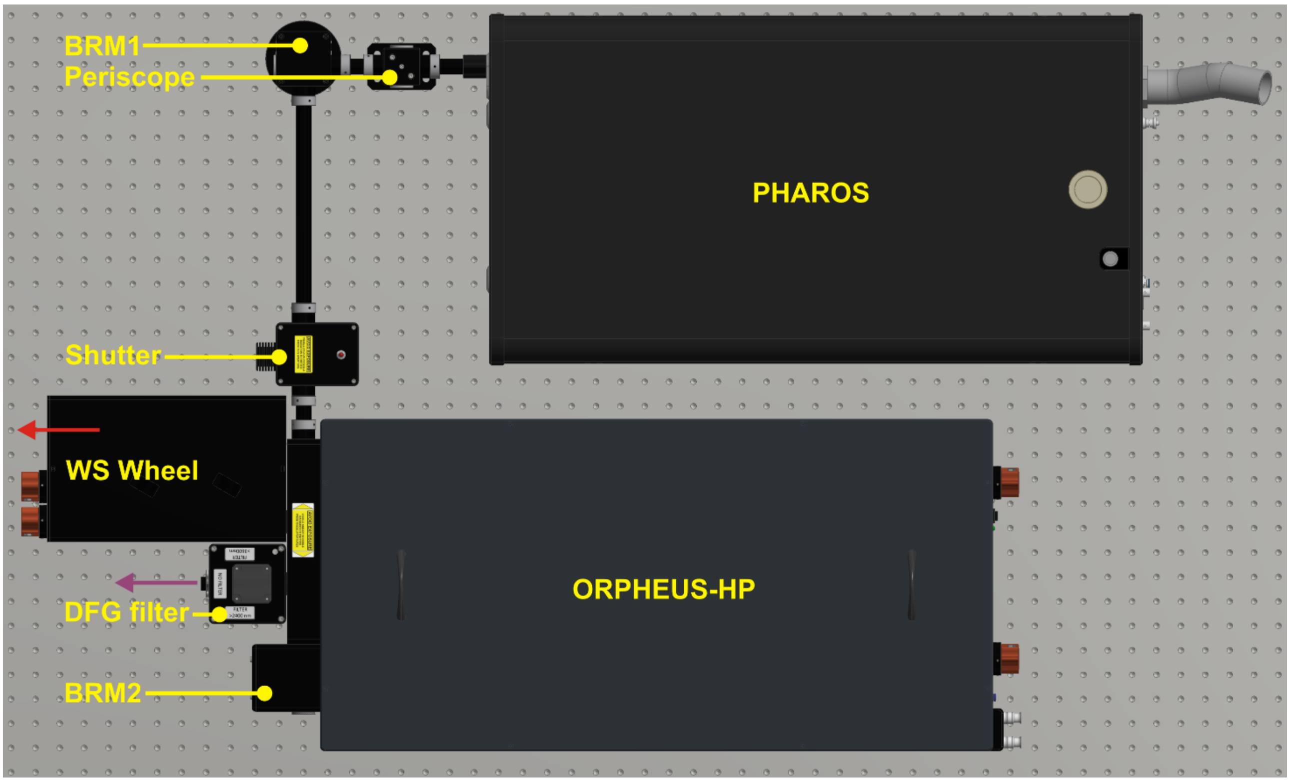
No.	Input/Output wavelength	Description
A	**Input, 1030 nm**	Pump laser input into ORPHEUS-HP
B	**Output, 189 – 3000 nm**	UV-VIS-NIR output port of ORPHEUS-HP Without SH/TH options: 620–3000 nm With SH option: 310–3000 nm With TH option: 210–3000 nm With DeepUV option: 189–3000 nm
C	**Output, 1030 nm or 620–3000 nm**	With DFG option: residual fundamental radiation (1030 nm) Without DFG option: residual signal or idler beam (630–3000 nm)
D	**Output 620–20000 nm**	Without DFG option: unused. With DFG1 option: 620–5000 nm With DFG2 option: 620–20000 nm
E	**Input, 1030 nm**	Pump laser input into ORPHEUS-HP
F	**Output, 515+1030 nm**	Residual second harmonic from the pre-amplifier and fundamental
G	**Output, 515 nm**	Residual second harmonic from the power-amplification stage

3. POSITIONING AND CONNECTING ORPHEUS

3.1 System Layout on Optical Table

Figure shows the recommended optical layout of ORPHEUS-HP and pump laser. It is recommended to position the OPA along the side of an optical table, about 5-20 cm from the table edge. Such a positioning allows convenient access while aligning and troubleshooting the device.

It is strongly recommended to fix all the system components on the same optical table and as close as possible to each other. Fixing the housings on a junction of the optical tables or letting the beam propagate several meters until it enters ORPHEUS-HP might increase the sensitivity of the system and/or lower the performance especially in terms of long time scale instabilities.



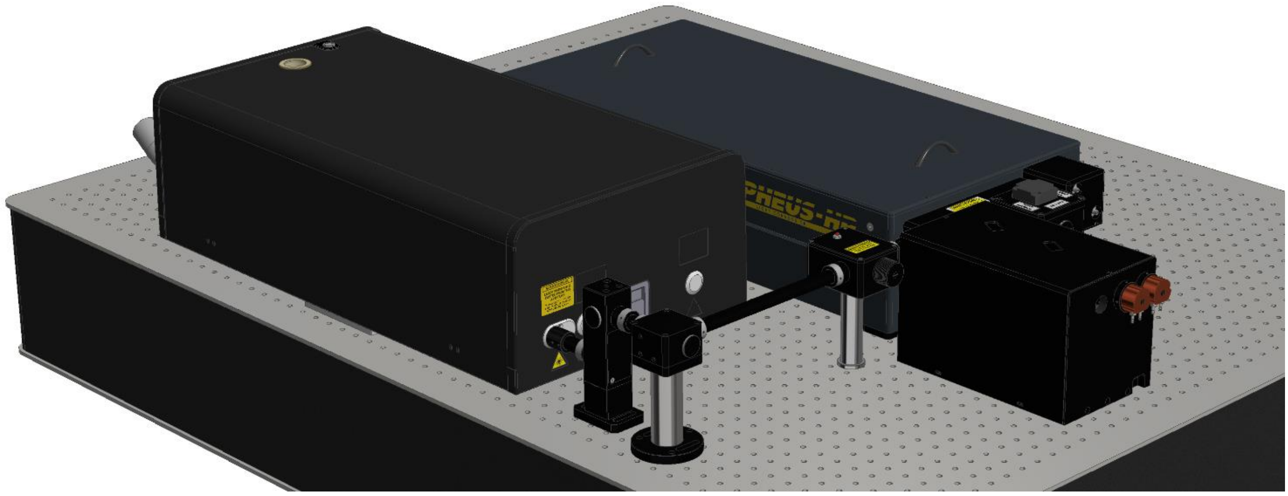


Figure 4. Recommended optical table layout of PHAROS pump laser and ORPHEUS-HP

The beam from the laser amplifier is lifted to the input beam height level using a periscope. Depending on the system layout, the periscope may direct the beam straight forward or at a 90 degree angle. Mirrors BRM1 and BRM2 direct the beam to the OPA. The output beams exit the housing at the same height as the input beam. Signal and Idler, or their harmonic beams are separated in an internal and external wavelength separation module, which translates the beam sideways by about 35 mm, but maintains the same height and direction for all beams. DFG beams have a dedicated output where they are separated from residual radiation by one or two Germanium filters, which translate the mid-IR beam by ~0.58 mm vertically.

3.2 Placing ORPHEUS-HP on the Optical Table (Ball-Groove Type Setup)

ORPHEUS-HP housing is fixed onto the optical table using special feet. The device freely rests on these feet via three balls located on the ORPHEUS-HP body. The feet are assembled into pads prepared for the width and length of the ORPHEUS-HP. They are fitted to the height of the pump beam and are not height adjustable.

The pads have 8 mounting holes each. Only two of them should be used for fixing to the optical table. Figure 5 shows correct positioning of the feet on an optical table with 25 mm hole spacing.

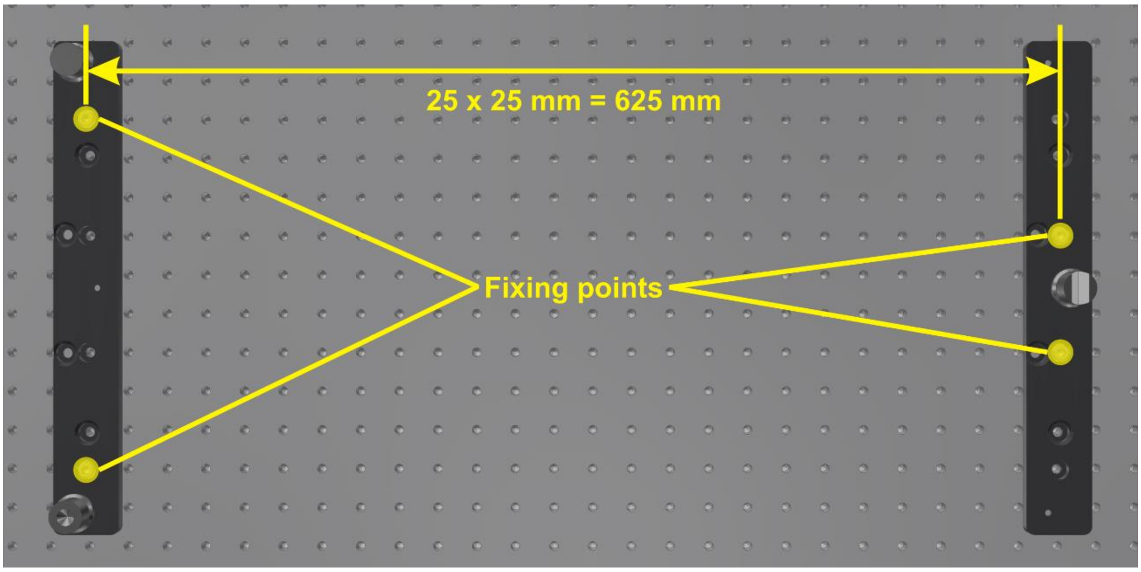


Figure 5. Positioning the feet of ORPHEUS-HP on the optical table (SI system)

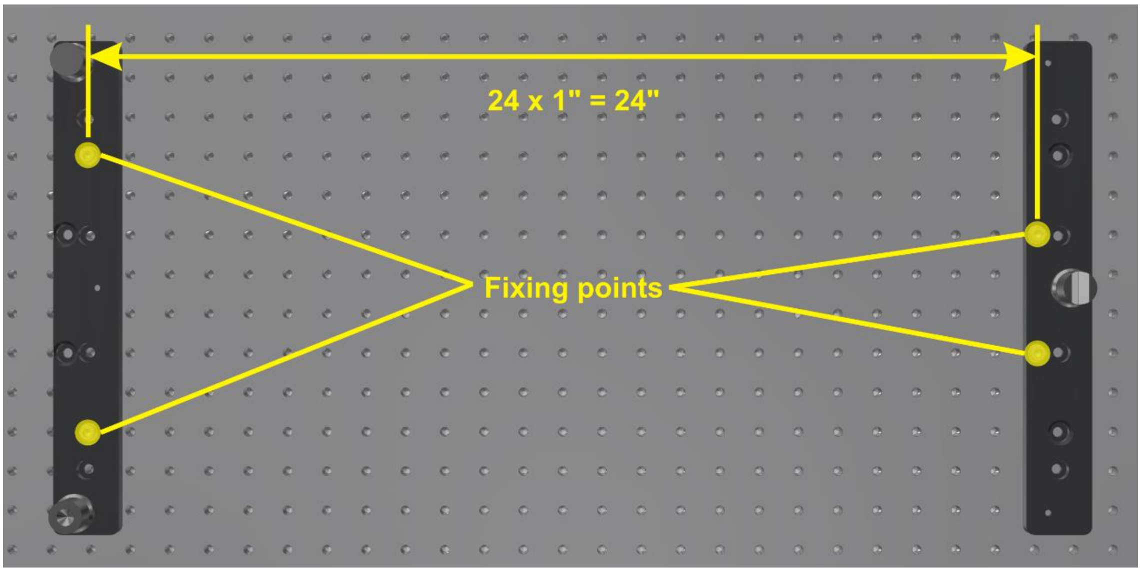


Figure 6. Positioning the feet of ORPHEUS-HP on the optical table (Imperial system)

Figure 6 shows the correct positioning of the feet on an optical table with 25.4 mm (1 inch) hole spacing. Notice that in this case, the other two mounting holes should be used.

Do not operate the system if either ORPHEUS-HP or the pump laser is not fixed to the optical table. This could lead to dangerous misalignment of ORPHEUS-HP and damage of internal components.

3.3 External Wavelengdth Separator Unit

Depending on the ORPHEUS-HP model and configuration, it can have an external wavelength separator unit, consisting of a box with one or two so called mirror wheels. This unit is directly fixed onto the optical table after the output of the ORPHEUS-HP. This can be done in two ways (see Figure 7):

1. Using screw holes on the bottom of the housing. It can be fixed both on the metric and imperial hole spacing tables. Using these fixing holes allows easy alignment of the ORPHEUS-HP output port and wavelength separator unit input port to be in line.
2. Using special adjustable pads, which gives more freedom to adjust the wavelength separator unit position on the optical table.

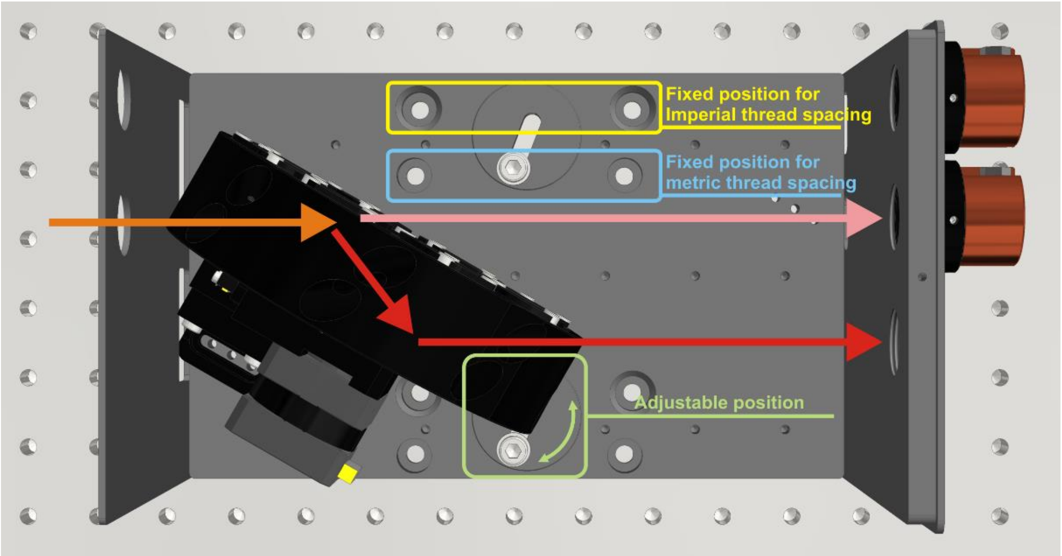


Figure 7. Fixing external wavelength separator unit on the optical table

3.4 Beam Routing Units

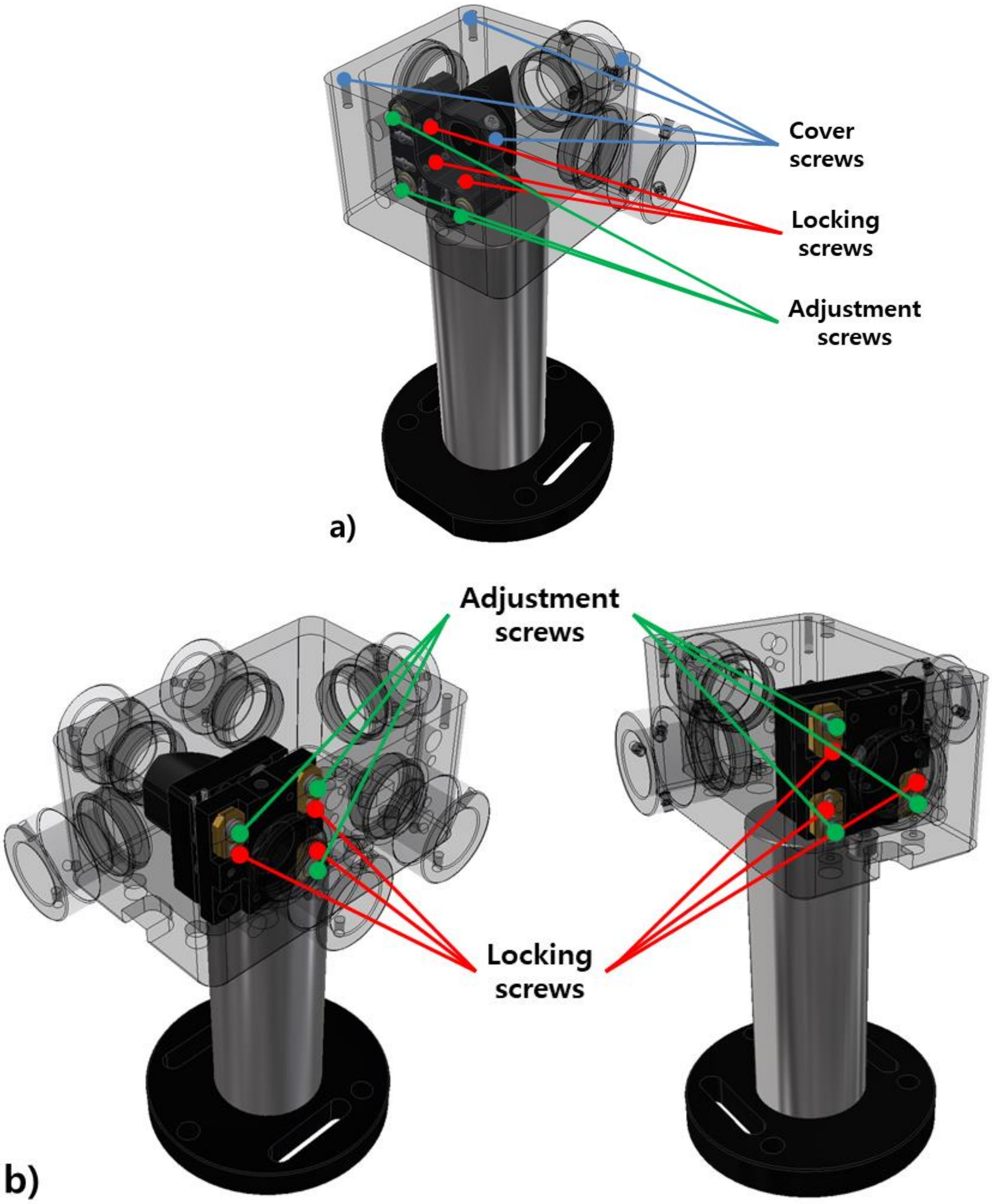


Figure 8. Location of the adjustment screws on: a) beam routing unit, b) magnetic beam routing mirrors-flippers

Depending on the model of the pump laser and system layout, it may be necessary to use periscopes, beam splitters (BS), beam routing mirrors (BRM), different types of magnetic beam routing mirrors-flippers (BRFL) to deliver the pump beam into ORPHEUS-HP. Optical components of these items are installed into metal enclosures designed for safety and stability. These enclosures are prepared for specific beam heights but are flexible in terms of system layout.

Tuning the angle of the mirrors is done by micrometer screws accessible with a 2 mm hex key, location of the screws is shown in Figure 8. It is recommended to use only **vertical** and **horizontal** screws for alignment (**not diagonal**). Depending on the model of the units, the position can be locked by tightening the locking screws.

Magnetic beam routing mirrors-flippers (BRFL) are used for a variety of purposes – to reflect the Signal beam to a compressor, to temporarily split-off a part of the beam or a full beam. Safety precautions should be taken when working with BRFL mounts.

WARNING ***Always make sure there is no laser emission before opening the BRFL top cover.***

Always block the beam before installing/removing the magnetic mirror mount (Figure 9). Install/remove the magnetic mirror mount only when you are sure that there is no emission and it is safe to open BRFL top cover. Do not install/remove magnetic mirror mount with bare fingers, use rubber gloves. Do not touch the optical surface of the mirror. Start laser emission only when BRFL top cover is closed. Adjust BRFL horizontal/vertical screws if needed.

Note: When a magnetic mirror mount is not used, place it in the designated area (parking place) under the BRFL housing. The optical coating surface should face the metal post. See picture below (Figure 9).

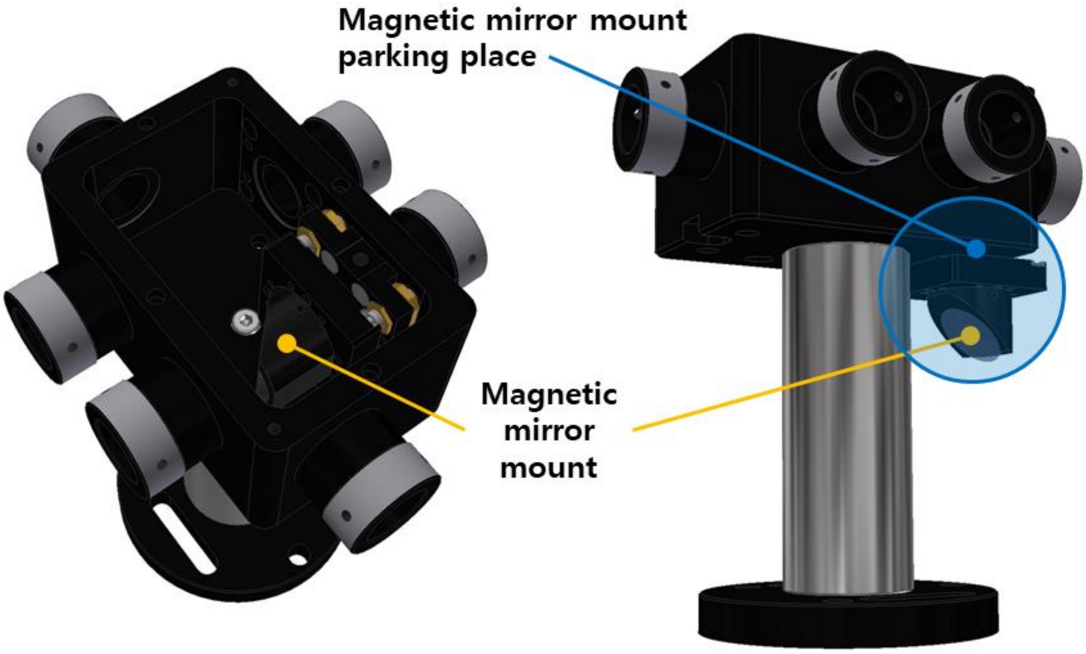


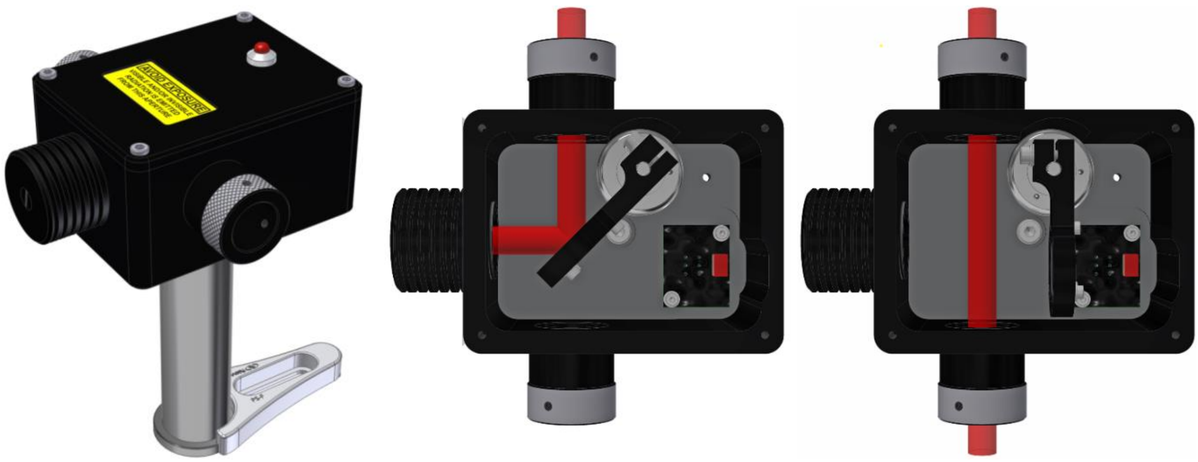
Figure 9. Location of the magnetic mirror mount parking place

The periscope consists of two mirrors and only the top mirror is coarsely adjustable. This mirror should be only adjusted once during the installation to keep the beam parallel to the optical table.

All enclosed beam routing units, the periscope, and the shutter are interconnected with hollow tubes to fully enclose the beam path. This is necessary to ensure user safety and stability of the OPA output.

3.5 Input Beam Shutter

ORPHEUS-HP is equipped with a stand-alone external shutter for enhanced heat management. Shutter is in "off" position when a mirror intercepts the beam and directs it towards a cooling unit.



a) b) c)

Figure 10. Shutter external view and principle of operation

Principle of operation relies on HR1030 mirror placed on a rotary solenoid. When the solenoid is not powered (turned off), the mirror is left at position Figure 10b, directing the input beam sideward into the air-cooled or water-cooled beam dump. When power is supplied to the solenoid, the mirror is displaced out of the beam path, into position Figure 10c, and the beam is passed through. When power is supplied to the shutter, the LED lights up.

The WinTOPAS4 software displays the current state of the shutter and provides the control for opening and closing it.

3.6 Connecting ORPHEUS-HP

ORPHEUS-HP needs to be connected to the power supply and to a computer to operate. ORPHEUS-HP has two electrical connection panels. The main panel for the power supply and USB connection is located on the back end of ORPHEUS-HP body. The connectors for external motors and shutter are located on the front side, below the output ports.

The system is supplied with water cooled beam dumps; water supply must be connected to the device. If water is not available, beam dumps must be replaced with air-cooled alternatives. Water inlet and outlet are located on the back side. On the front side there are water connectors to external beam dumps (shutter, wavelength separator wheels box, etc.). None of these available connectors should be left open before turning on water supply. Only steam-distilled or deionized water (Type II and lower grade (resistivity less than 18 MΩ·cm)) should be used for cooling the system.

All ORPHEUS-HP external connections have labels.

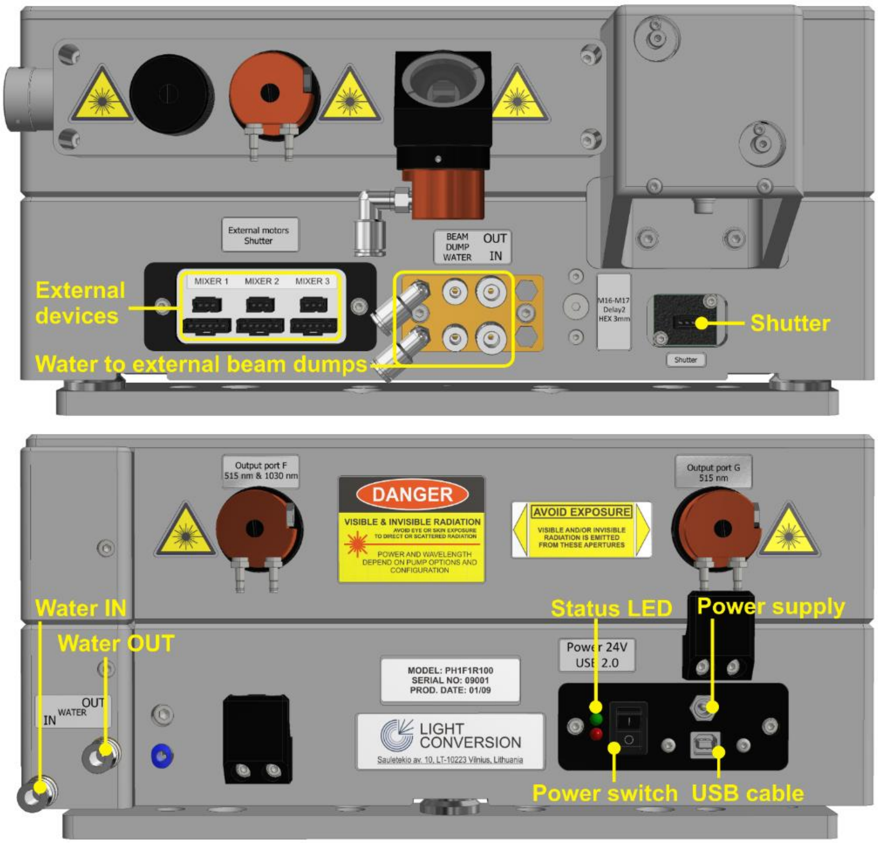


Figure 11. Electrical and water connectors of ORPHEUS-HP

The sequence of connecting the ORPHEUS-HP should be as follows:

1. Water cooling to the back of the ORPHEUS-HP.
2. Shutter water circuit to the front of the ORPHEUS-HP.
3. Water circuit to any other external beam dumps. None of available water connectors on the ORPHEUS-HP should be left open.
4. Shutter cable to the dedicated shutter connector.
5. External motors (separator wheels, DFG filter, etc.) to the extension plate (front electrical connection panel).
6. USB cable between the control board and computer.
7. Power supply cable.
8. Turn on the power switch. Make sure that the red LED is on and the green LED is flashing with ~1 sec interval.

NOTICE ***Always make sure the USB control board is powered off before connecting the extension cables.***

Use only power supplies from Light Conversion or contact our Support Team before connecting power supply from other manufacturer. Power supply from Light Conversion is suitable to both 110 V and 220 V outlets. Make sure that the main circuit board's switch is in "OFF" position before connecting the supply.

WARNING ***Always check that the supply and its cables are in proper condition and do not show any damage to any part of the insulation, before connecting.***

It is recommended to install the WinTopas4 software before connecting ORPHEUS-HP to a computer. Follow the instructions in the software start guide. Connect ORPHEUS-HP to a computer using the supplied USB cable.

Power LED (Red) should be always on and Status LED (Green) should blink with intervals of ~1 second during normal operation of the USB control board. The software needs to be configured for a device; hardware settings file must be linked in the software. Consult the WinTopas4 start guide and online help on software configuration.

A single computer can control up to 5 of the USB control boards. A USB-hub can be used if the computer does not have enough USB ports. Light Conversion does not guarantee proper operation of ORPHEUS-HP with non-branded USB-hubs.

3.7 Interlock

ORPHEUS-HP is equipped with an interlock mechanism. It is impossible to open the shutter when the interlock is active. The interlock is activated when an electrical circuit is broken, which happens when device cover is opened. This releases the button thus breaking the circuit.

CAUTION

Never work with ORPHEUS-HP cover removed unless aligning the device. Always pay close attention to safety precautions detailed in this manual, documentation of the laser and regulations in your laboratory.

Should it be necessary to open the shutter with the cover opened, the interlock can be defeated by pulling up the detection button.

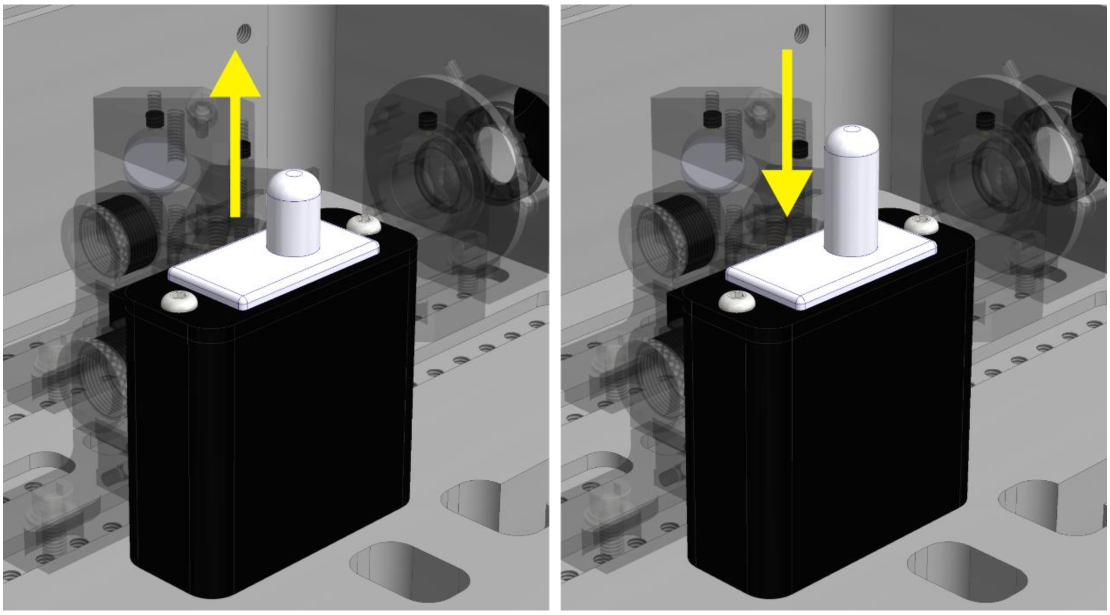


Figure 12. Interlock defeat procedure (push-pull button version)

4. DESCRIPTION OF OPERATION

4.1 Overview

ORPHEUS-HP is a two-stage optical parametric amplifier of white-light continuum. The device employs computer controlled translation and rotation stages for several key optical components, providing fast automated wavelength tuning. The basic configuration consists of several subunits:

1. Second harmonic generator of the pump beam.
2. White-light continuum generator.
3. First amplification stage (the pre-amplifier).
4. Second amplification stage (the power amplifier).
5. Wavelength separator after the amplification stage.
6. Second harmonic generation of Signal and Idler waves (optional).
7. Third harmonic generation of Signal waves (optional).
8. Sum frequency (Deep-UV) generation (optional).
9. Wavelength separator after the frequency mixing units (external, optional).
10. Difference frequency generator including filters unit (optional).

Layout of the subunits (except Deep-UV option) is shown in Figure 13 and the full optical layout of ORPHEUS-HP (without difference frequency generation and Deep-UV options) is presented in Figure 14.

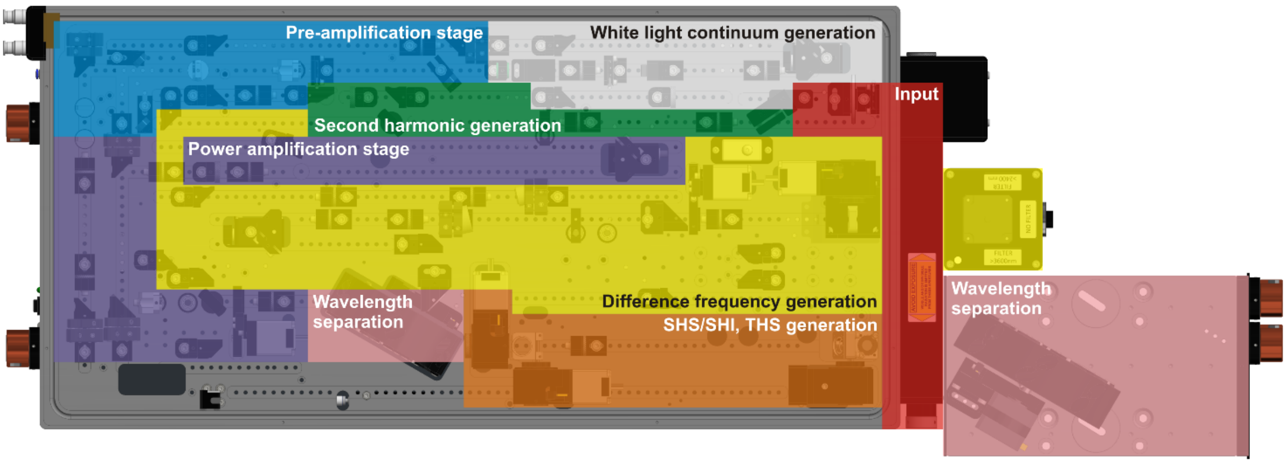


Figure 13. Layout of the subunits of ORPHEUS-HP device

ORPHEUS-HP can accept a variety of input pulse energies, repetition rates and beam sizes. However during installation, it is set and optimized for fixed pump parameters, which should not change by more than ±10 % for ORPHEUS-HP to operate correctly. A decrease of pump pulse intensity might lead to lower efficiency or even no output if white light generation cannot be obtained. An increase of pump pulse intensity poses a risk of damaging several optical components and non-linear crystals in particular. If it is needed to operate ORPHEUS-HP at different pump pulse parameters – replacement of several optical components and realignment should be performed to match new pump conditions, and it is usually done by a trained service engineer. This manual does not cover the possibility of operating ORPHEUS-HP with variable pump pulse parameters.

The beams present inside ORPHEUS-HP are dangerous not only to the human eye and skin, they can also heat and cause damage to the internal mechanical and optical components if the device is not aligned properly. Reflection shields and protective covers are used inside the device to catch most of the unwanted reflections and residual radiation before it reaches the sensitive components.

It is highly recommended to block the pump beam (close the shutter) whenever the OPA output is not used.

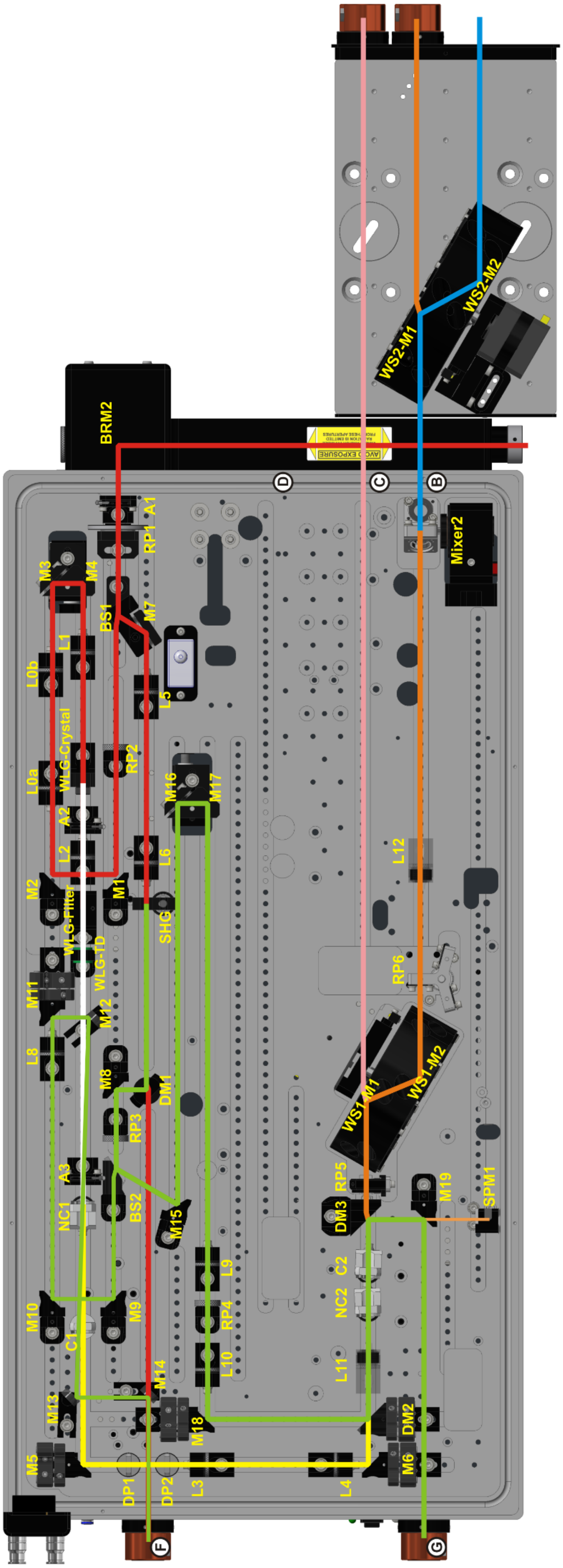


Figure 14. Optical layout of ORPHEUS-HP with optical elements labeled (SHS and SHI configuration)

A	*– iris aperture*
BS	*– beam splitter or polarizer*
C	*– compensator*
DM	*– dichroic mirror*
DP	*– delay plate*
L	*– lens*
M	*– mirror*
NC	*– nonlinear crystal*
RP	*– half-wave plate*
SHG	*– second harmonic of pump generation crystal*
SPM	*– spectrometer mirror*
WLG-Crystal	*– white light generation substrate*
WLG-Filter	*– pump blocking mirror*
WLG-TD	*– temporal dispersion medium*
WS	*– wavelength separator*

4.2 Pump Beam Delivery and Splitting

Pump beam from the laser is directed into ORPHEUS-HP using external mirrors and mirror BRM2 which is attached to OPA housing. The beam then passes an iris aperture A1 and a polarization rotator RP1 (λ/2 waveplate). A1 should always be fully open, unless aligning the input beam at very low pump intensities only. Beam height from the base of ORPHEUS-HP upper compartment is 25 mm at the input. A polarizer or beam splitter BS1 reflects most of the pump beam energy for the second harmonic of pump generation and transmits roughly 0.5 µJ – 1.5 µJ for white light continuum generation.

4.3 White Light Continuum Generation

After passing the polarizer BS1, pump beam polarization is rotated to vertical by RP2. The beam then travels to folding mirrors M1 and M2, and a retro-reflector M3-M4, placed on a computer controlled translation stage (“Delay 1” in the software). Computer controlled adjustment of the optical path length of pump beam ensures the temporal overlap of white light and pump pulses in the first amplification stage. The beam then passes through a lens L1, set to focus the beam into WLG-Crystal – white light continuum (WLC) generation substrate. The white light should be just at the threshold of generation, yet stable and single filament. The best way to check the shape of the WLC is to place a paper card right before the iris A2. If the WLC is not visible, its shape is asymmetric or has an interference pattern – proceed to the troubleshooting section of this manual.

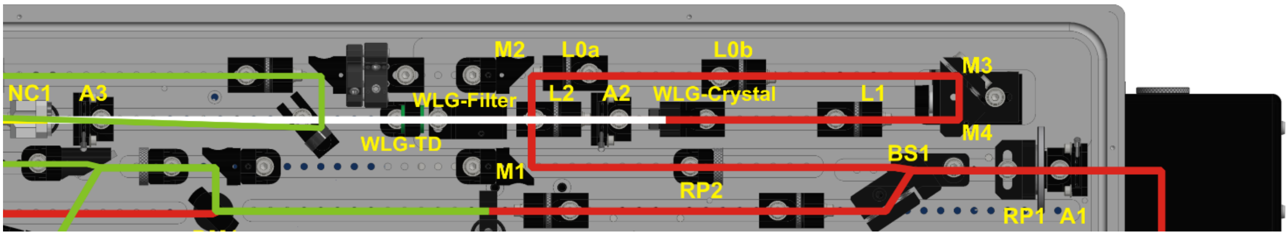


Figure 15. White light supercontinuum generation layout

The beam then passes through the L2 lens which focuses or collimates WLC (depends on the system configuration) at the non-linear crystal NC1 “Crystal 1” position in the first amplification stage. Iris aperture A2 blocks the outer rings of the WLC beam, normally the center of the aperture is open to roughly 1-2 mm diameter. A special mirror WLG-Filter reflects residual pump down and transmits the white light continuum. WLG-Filter mount is enclosed to block any residual pump reflections.

After WLG-Filter, the white light travels through WLG-TD plate into Crystal NC1. The white light will be overlapped with a pump pulse at the nonlinear crystal NC1. By tuning the “Delay 1” translation stage a different spectral region of white light is overlapped temporally with the pump pulse, which allows selective seeding of the amplification process.

4.4 Generation of Second Harmonic

Major part of the pump beam, which is reflected by the polarizer or beam splitter BS1, is used for generating the second harmonic of laser radiation. Lenses L5 and L6 constitute a telescope which decreases the beam size. The reduction factor and focusing condition is chosen depending on the pump pulse parameters during the device assembly/installation.

The second harmonic generation crystal "SHG-Crystal" is placed on a computer controlled rotation stage ("SHG Crystal" in the software). By changing the angle of the crystal it is possible to some extent to attenuate the power of the second harmonic radiation, and in turn – signal and idler radiation, however it can also change the wavelength, pulse duration, beam size of the output pulses. The crystal can also be rotated completely out of the beam path, giving access to the full first harmonic trough output port F of ORPHEUS-HP.

CAUTION

Never block the pump or second harmonic of pump beam with a paper card. The card will start burning; the fumes may gather onto the optical components and cause permanent damage. When necessary, use metal beam blockers only.

Dichroic mirror DM1 reflects only the second harmonic beam and transmits the fundamental. The transmitted beam then travels to the output port F or is directed towards the difference frequency generation unit.

After mirror DM1 the second harmonic beam is reflected from the mirror M8, passes through a rotator of polarization RP3 and goes to the polarizer or beam splitter BS2. The beam transmitted through BS2 (usually a smaller fraction) is used for the first (pre-) amplification stage, while the reflected part is for the second amplification stage. The splitting ratio depends on the system configuration.

Beam path in SHG unit:

- RP1 – BS1 – M7 – L5 – L6 – SHG-Crystal – DM1 – M8 – RP3 – BS2.
- The fundamental radiation (1030 nm) is transmitted through a DM1.

4.4.1 The First Amplification Stage

The pre-amplifier is used to produce stable and sufficiently bright seed pulses for the second amplification stage. M9-M12 mirrors direct the second harmonic pump beam (further pump beam) into the crystal NC1 while the lens L8 ensures proper intensity of it in the crystal. Wavelength tuning is performed by changing the delay of the WLC – adjusting the position of mirrors M3 and M4 with computer-controlled translation stage ("Delay 1" in the software). The phase matching angle adjustment is performed by computer-controlled rotation stage for crystal NC1 ("Crystal 1" in the software).

Several conditions must be met to ensure successful operation of the first amplification stage:

- proper pump intensity;
- bright and stable white light continuum;
- good temporal and spatial overlap of the pump and white light pulses;
- optimal phase matching angle of Crystal 1.

The residual pump from the first amplification stage is directed towards the output port F using mirrors M13 and M14.

4.4.2 The Second Amplification Stage

The amplified portion of the white light continuum (seed) after exiting the first amplification stage first travels through two delay plates DP1 and DP2. They are positioned on a computer controlled rotation stage ("Delay 2" in the software) and are used to fine-tune the temporal overlap of seed and pump pulses at the NC2 crystal ("Crystal 2" in the software). Lenses L3 and L4 re-collimate the beam and adjust the pre-amplified signal diameter to match the pump beam diameter at NC2 crystal. Dichroic mirror DM2 transmits the seed and reflects the pump beam. After amplification at the nonlinear crystal, parametric radiation is separated from the pump beam by the mirror DM3.

The pump beam reflected by polarizer BS2 and mirror M15 propagates to a retro-reflector M16-M17, positioned on a manual translation stage. Position of this manual stage needs to be adjusted only after alignment or replacement of some optical components has been performed. Adjusting the position of these mirrors is required to ensure proper temporal overlap of pump and seed beams at the NC2 crystal. To adjust this translation stage first remove the protective screw at the front side of ORPHEUS-HP (see Figure 16), then use a 3 mm hex key to turn the micrometer screw. The adjustment screw is located ~2 cm inside the OPA.

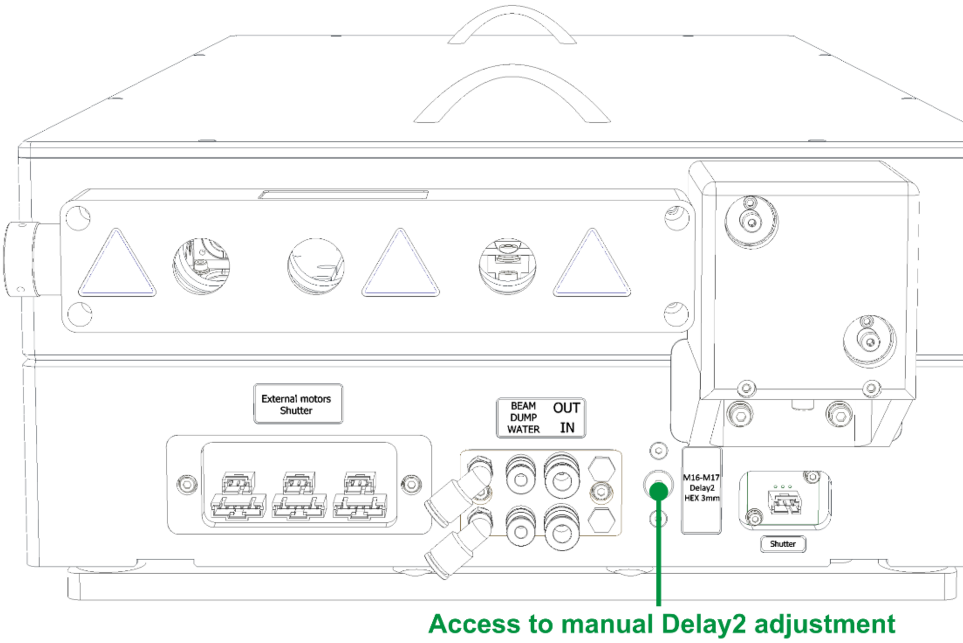


Figure 16. Location of the manual Delay2 adjustment screw

Half wave plate RP4 rotates the polarization back to horizontal, which is necessary for pumping nonlinear crystal NC2. A lens telescope L9-L10 sets the correct pump intensity for the pre-set pump parameters of the OPA. Mirrors M18 and DM2 direct the pump beam into nonlinear crystal NC2.

The phase matching angle adjustment is performed by computer controlled rotation stage for crystal NC2 ("Crystal 2" in the software).

The beam path of the pump beam (515 nm) in the power amplifier:

- BS2 – M15 – M16 – M17 – RP4 – L9 – L10 – M18 – DM2 – NC2 – C2 (optional) – DM3 – M19 – Output G

The beam path of the seed:

- M5 – DP1 – DP2 – L3 – L4 – M6 – DM2 – NC2 – C2 (optional) – DM3 (transmitted)

4.5 Beam Sampling for the Spectrometer

The ORPHEUS-HP is delivered with an integrated spectrometer. A small percentage of parametric light is reflected by the DM3 mirror, while mirror M19 transmits most of it. The residual light goes to mirror SPM1, directed downwards to mirror SPM2 and toward the spectrometer in the bottom compartment of the housing. The spectrometer is sensitive in the 350-1100 nm wavelength range. It connects to the control computer and uses software called "SpectraLight" to monitor the output wavelength of the parametric amplifier (Signal wave only, 630–1030 nm range). You can find the software installation package in the USB flash disk provided with the system.

4.6 Wavelength Separators and Polarization Rotators

Due to the collinear nature of amplification used in the power amplifier of ORPHEUS-HP, Signal and Idler waves both travel at the same position and direction. When the second harmonic of either Signal or Idler (SHS/SHI) is generated, it is also collinear to the initial beam. The resulting combination of SHS/SHI, Signal and Idler waves are separated by using specially coated dielectric mirrors, called wavelength separators (WS). Each WS consists of two dielectric mirrors with high reflectivity (HR) coatings for a specific Signal/Idler or SHS/SHI wavelength region, and high transmission coating for a corresponding Idler and/or Signal wavelength. The mirrors are also polarization sensitive, optimized for reflection of s-polarized light. This polarization requirement is managed by achromatic half-wave plates inside OPA (RP5 and RP6).

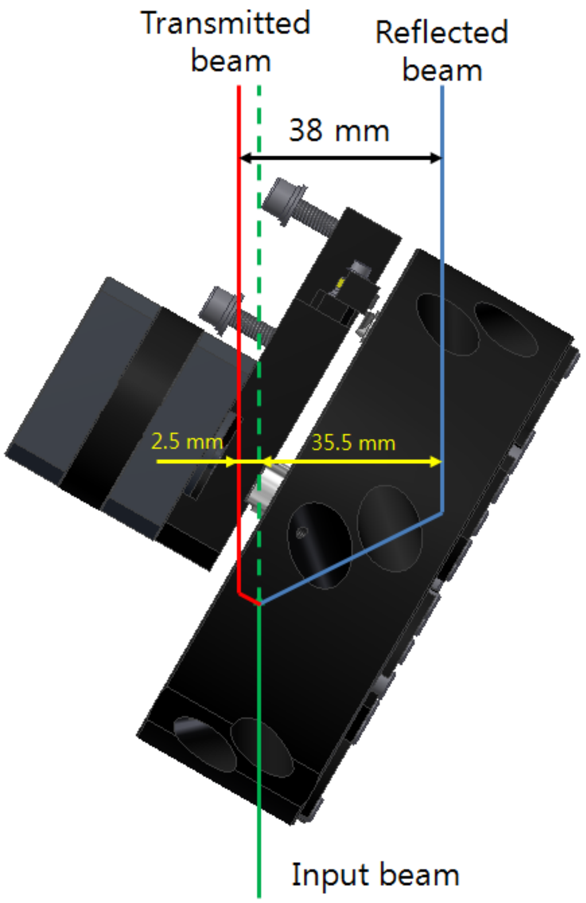


Figure 17. Beam paths going through the motorized wavelength separator wheel

A wavelength separator wheel (WS Wheel) consists of 6 or 8 pairs of mirrors. In ORPHEUS-HP, one wheel is integrated inside the housing, which reflects the beam sideward (630–2600 nm wavelength range). Depending on number of frequency converters in ORPHEUS-HP, there may be several different configurations of separators positioned externally inside a separate enclosure. For the simple case of no additional frequency converters (Signal/Idler only) – there are no additional external separators. For the case of the second harmonic option (SH of Signal, SH of Idler) there is one additional WS wheel with appropriate separators for 315–630 nm wavelength range and mirrors for reflecting signal/idler to maintain the same beam position. For the case of the third harmonic generation (TH of signal, 210–315 nm), the number of additional mirrors requires the use of a third WS wheel.

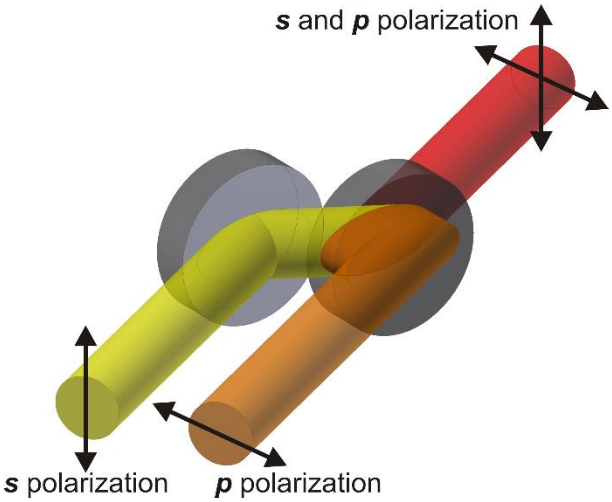


Figure 18. Principle of wavelength separation using a pair of dichroic mirrors

The residual p-polarized beams are transmitted through the first mirror of the pair, while requested s-polarized wavelength is reflected to the second mirror and then emitted through the aperture. The separator module (Wheel) is aligned such that the reflected beam maintains its original direction, but the position is translated by roughly 35 mm. The beam transmitted through the first mirror experiences a displacement of ~3 mm due to refraction. At the output of the separator module, there are two beams, separated by 38 mm.

The use of Polarization rotators and Wavelength Separators is automated in the WinTOPAS software package.

4.6.1 Polarization Rotator RP5

RP5 is used to rotate the polarization of Idler beam from horizontal to vertical, before it enters the separator mirrors. This rotator is a pre-aligned half-wave plate for 1100–2500 nm spectral region, fixed to the axis of a stepper motor. As the motor is rotated, the half-wave plate is either introduced or removed from the beam path of Signal+Idler.

4.6.2 Polarization Rotator RP6

RP6 is used to rotate the polarization of Signal or Idler before the Second or Third harmonic generation units. SH unit requires to rotate the polarization to horizontal, while for TH option – polarizations are adjusted to have 2:1 ratio (vertical/horizontal). RP6 rotation stage allows continuous adjustment of waveplate angle, and consequently any polarization at the output. This adjustment may be used to attenuate the output of the SH (TH) beam, but it also results in higher content of background in the beam (as Signal/Idler polarization is rotated – it is more difficult to separate in the WS mirror).

4.6.3 The First Wavelength Separator Wheel

The first wheel is used to separate Signal from Idler (or Idler from Signal). If Idler wave is requested as the active wavelength – half wave plate RP5 is inserted to make the correct polarization.

When a DFG wavelength is requested, the Signal wave is separated in Wheel1, and the Idler (transmitted through the first mirror of the WS) is used as seed in the DFG Mixer.

Table 6. Reflection ranges of wavelength separators used in WS Wheel 1

WS Wheel 1			
WS name	**Reflected range, nm**	**Interaction**	**Transmitted range**
WSO-1	1970 – 2600	Idler	Signal
WSO-2	1550 – 1970	Idler	Signal
WSO-3	1385 – 1550	Idler	Signal
WSO-4	1030 – 1385	Idler	Signal
WSO-5	755 – 1030	Signal, DFG	Idler
WSO-6	610 – 765	Signal, DFG	Idler

4.6.4 The Second Wavelength Separator Wheel (SH version)

The second wheel is used to separate Second harmonic of Signal/Idler from the residual Signal/Idler. Additional dielectric or metallic mirrors are used reflect the beam even when it does not need to be separated – in order to maintain the same beam position for all wavelengths.

Table 7. Reflection ranges of wavelength separators used in WS Wheel 2

WS Wheel 2			
WS name	**Range, nm**	**Interaction**	**Transmitted range**
WSO-7	465 – 620	SHS/SHI	Signal/Idler
WSO-8	365 – 460	SHS	Signal
WSO-9	300 – 365	SHS	Signal
Au	1385 – 2600	Idler	-
WSO-4	1030 – 1385	Idler	Residuals
WSO-5	755 – 1030	Signal	Residuals
WSO-6	610 – 765	Signal	Residuals

4.7 Mixer 1 – THS (SH generator)

Mixer 1 is reserved for the Third Harmonic option of ORPHEUS-HP. This version of the manual does not cover this option. See appendix of this manual if applicable.

4.8 Mixer 2 – Second Harmonic Generation of Signal and Idler

The second harmonic of parametric radiation is generated in a crystal (or set of crystals), installed in a motorized rotation stage "Mixer 2**."** Crystal angle tuning is done according to the calibration tables/curves by the software. When SHS/SHI is not required for the output wavelength, the crystal goes into its neutral position, out of the beam path.

In order to maintain vertical polarization for all outputs, Mixer2 crystals are rotated around horizontal axis, and the Signal/Idler beam polarization needs to be horizontal before the crystal. This is achieved by polarization rotator RP6, which rotates Idler polarization from horizontal to vertical.

4.9 Difference Frequency Generation (DFG)

See appendix of this manual if applicable.

4.10 Computer Controllable Motorized Stages

ORPHEUS-HP device uses computer controllable motorized stages for the quick wavelength tuning and beam separation of the output radiation. Up to 18 motors can be controlled at the same time. There are many possible configurations of internal and external motors, this portion of the manual covers only the typical setup. In addition to the motors, there is one control output for the beam shutter (solenoid).

Table 8. Description of the typical motorized stages in the ORPHEUS-HP

No.	Name	Optical element	Description
1.	Delay 1	M3 + M4	Pre-amplifier temporal overlap
2.	Crystal 1	NC1 + C1	Pre-amplifier crystal phase matching angle
3.	Delay 2	DP1 + DP2	Power amplifier temporal overlap
4.	Crystal 2	NC2 + C2	Power amplifier crystal phase matching angle
5.	SHG Crystal	SHG-Crystal	Second harmonic of pump (515 nm) crystal angle
6.	RP5 Idler Waveplate	RP5	Achromatic waveplate control for Idler polarization
7.	Wheel 1	WS1*	First wavelength separator wheel
8.	RP6 Signal Waveplate	RP6	Achromatic waveplate control for Signal and Idler polarization
9.	Crystal Stage 1		
10.	Mixer 2	MX2*	Second harmonic generation crystal angle
11.	Wheel 2	WS2*	Second wavelength separator wheel

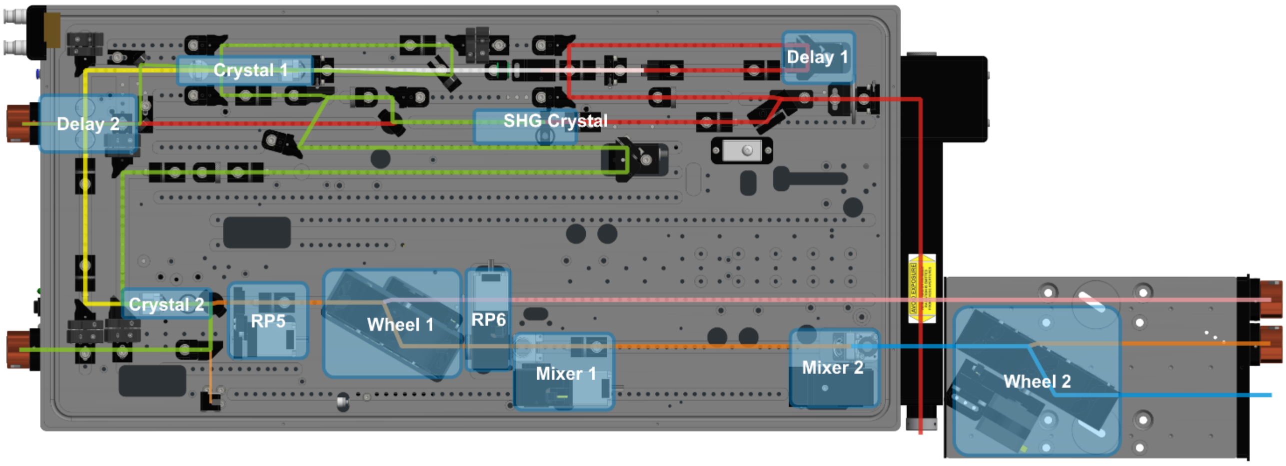


Figure 19. Location and names of the motorized stages inside the ORPHEUS-HP

The illustration above identifies the computer controllable elements of the ORPHEUS-HP.

4.11 Computer Control of ORPHEUS-HP

ORPHEUS-HP will be delivered with two main software packages: WinTOPAS4 application for OPA control and "SpectraLight" application for the spectrometer option. WinTOPAS is the framework on which most of the wavelength tuning, motor and shutter control is based. WinTopas4 should be installed by a field service engineer during the set-up of the system. You can find the last configuration backup in a USB memory stick, provided with the system user's manual:

- **19001_Configuration.zip** – device configuration files (where "19001" is serial number of the device). Download the latest version of WinTopas4 installer from "Light Conversion" website.

- **WinTopas4-preconf(19001)-setup.exe** (optional) – preconfigured installer, consisting of all system devices configuration files and WinTopas4 software. No separate WinTopas4 installation is required.

For more information, downloads, tutorial videos and instructions please visit WinTopas4 info page:

topas4info.lightcon.com

Control of the ORPHEUS-HP can also be integrated into the user's software. For more information please visit Topas4 Public API help page:

topas4api.lightcon.com/current

If you experience problems with the software, please contact:

support@lightcon.com

5. DAILY OPERATION

ORPHEUS-HP is installed and calibrated by the service engineer from Light Conversion or a service engineer from our local Representative. In most cases the operation of ORPHEUS-HP is possible without checking the beams inside. Computer controlled access of the translation and rotation stages ensures fully automated tuning of the output wavelength.

The main control board of ORPHEUS-HP should always be powered on – every time it is switched off the motors lose their position by a few steps. In that case it may be necessary to reset their positions using the software.

5.1 Start-up

1. Start the WinTopas4 software and make sure that the ORPHEUS-HP shutter is closed (the pump beam is blocked from entering ORPHEUS-HP).
2. Switch on and warm-up the PHAROS/CARBIDE laser and do day by day checking/testing procedures recommended by the user's manual of the laser.
3. Check the pump laser pulse energy).

NOTICE Never operate ORPHEUS-HP with higher than nominal input pulse energy. Too high pulse energy may result in damage to the optical components.

4.
5. Open the shutter using WinTopas4 and check if output beam is present after ORPHEUS-HP. Check the ORPHEUS-HP alignment and pump laser performance if ORPHEUS-HP gives no output. Avoid random adjustment of the intense pump beam into ORPHEUS-HP.
6. Position a power meter into the ORPHEUS-HP output beam and check the output power. Consult the installation report for expected power at the selected wavelength. Optimize the pump laser pulse compressor and delay generator timings for Pockels cells for maximum ORPHEUS-HP output if needed. Double check your pump laser performance and reset ORPHEUS-HP motors if the output power is low.
7. Check ORPHEUS-HP output spectrum.

ORPHEUS-HP is now ready to be used.

5.2 Setting the Wavelength

1. Start the WinTopas4 application.
2. Select the device to be operated (only applicable if more than one OPA/NOPA is controlled by the same computer).
3. Type in the wavelength of interest and press Enter.
4. Open the shutter by pressing the button in the software.
5. Check if the spectrometer can detect the correct wavelength.

   Please refer to the manual of WinTopas4 for more information on software operation and other ways to control the output of ORPHEUS-HP.

5.3 Optimizing the Output

To optimize the output power, you should first try to optimize the angle of "SHG crystal" stage while monitoring the output with a power meter. Tuning is performed via the "Motors" section of WinTopas4application.

If the OPA is producing insufficient output, input beam alignment should be checked. It is possible to gently push the BRM2 module in various directions while monitoring the output power – this provides a non-destructive way to check if the input beam direction needs optimization. If you see that doing so increases the output, you can adjust the fine screws of the BRM2 kinematic mount with a 2 mm hex key to maximize the power.

5.4 Shutdown

Close the shutter and exit the WinTopas4 software (including server application). Shutdown/standby pump laser. Always keep the ORPHEUS-HP powered.

5.5 Access to Residual or Fresh Pump Beams

Access to the residual input pump beam (1030 nm) is provided through output port F (with no DFG option). Access to fresh pump beam is also possible through this port, by rotating the SHG Crystal motor to 90 degrees, which turns the crystal completely out of the beam path.

Access to the residual second harmonic beam (515 nm) is provided through output ports F and G, for the residual pump of the first and the second amplification stages, respectively.

To remove water cooled beam dumps it is necessary to take off the cover below it, which is fixed to the housing by two screws. Use 2.5 mm key to remove them. The beam dump itself is fixed to the adapter with three pins. Use 1.5 mm key to loosen them then take out the beam dump. Do not disconnect the water from the beam dump.

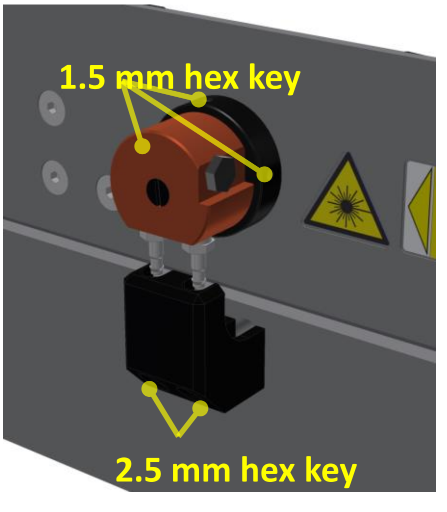


Figure 20. Location of the screws holding the water-cooled beam dump to the housing

6. TROUBLESHOOTING

6.1 Checking Pump Laser Parameters

The output performance of ORPHEUS-HP is very sensitive to the input beam/pulse parameters. If the output from ORPHEUS-HP changes significantly – the parameters of the pump laser would be the first thing to check.

The most important pump laser characteristics are the following:

1. Pump pulse energy.
2. Pump beam profile, diameter and collimation.
3. Pump pulse duration and compression.
4. Wavelength and spectral width.
5. Contrast ratio (pre- and post- pulses).
6. Stability of output energy (pulse-to-pulse).

Pump pulse energy is supposed to be kept the same or at least ±10% from the energy that was used during the installation. If the pump pulse energy will be significantly lower – there might be no output from ORPHEUS-HP or the output might be significantly lower, unstable. If pulse energy is higher – there is a risk of damaging optical components of ORPHEUS-HP, non-linear crystals. Pulse energy might change because of the following:

- Different pump current of laser diodes in the laser.
- Changes of internal repetition rate of the laser.
- Clipping of the beam on the beam steering optics, damage of the beam steering optics.
- Additional pump beam splitting or attenuation before ORPHEUS-HP.
- Degradation of the elements of the amplifier or misalignment of the cavity (lower output).

Pump pulse energy can be calculated from the total power of the pump laser and the repetition rate. Please check the installation documentation for a particular pump pulse energy for each device.

The profile of the beam should be at least visually inspected from time to time. Hot spots in the beam profile, diffraction patterns because of clipping might create small scale non-linear effects or even damage of the optical components inside the OPA. The change of the diameter and/or collimation will change the focusing conditions of the beams inside the OPA leading to lower/no output from the system.

Different pulse duration and compression affect the output of ORPHEUS-HP similar as different pulse energy. The compression/duration however does not change the energy of the pulse, but it changes the peak intensity. Usual indicator of problems with pulse duration is white light generator of ORPHEUS-HP: if pulse duration is unstable or higher than usual – WLC intensity will also be unstable or it may even not possible to obtain white light generation. This appears in some of the cases because of CW presence in the output from oscillator. Different pulse duration can originate from:

- Misalignment of the compressor length – can be checked/adjusted from the remote control.
- CW spectral modulation of the oscillator output – can be monitored with a spectrometer.
- Nanosecond operation if the oscillator is off / not mode locked / in CW regime / seed is blocked.
- Misalignment of the stretcher / amplifier / compressor.
- Different wavelength and spectral width from the oscillator.

If the oscillator is off/not-mode-locked/CW – the amplifier might deliver the same output power at slightly higher pump currents for laser diode bars. The output of unseeded regenerative amplifier is of nanosecond pulse duration and the intensity is too low to pump ORPHEUS-HP. In such a case it is not possible to have white light generation in ORPHEUS-HP, generation of the second harmonic is inefficient.

Wavelength and spectral width of the pump pulse affect calibration of ORPHEUS-HP. Phase matching angle of the crystals is a function of pump wavelength. If the change is even within 1 nm range – the angle might no longer be optimal. If the central wavelength of the pump cannot be recovered – the alignment of harmonic crystals and offsets (or even recalibration) for the tuning curves of ORPHEUS-HP might be necessary.

Pulse contrast ratio affects the pulse energy of "real" pulse. Only the most intense pulse takes part in amplification. Pre-pulses and post-pulses reduce the efficiency of harmonic generation and more energy is needed for white light generation. The contrast ratio can be checked with fast photodiode and an oscilloscope. Please refer to the manual of the pump laser on optimization of pulse contrast.

6.2 Resetting Motor Positions

Reset of the motor positions may be necessary after an electrical failure or software issues. There is no feedback from the rotation/translation stage to control card to monitor the exact position. The feedback – reset switch – is only at the very beginning of the moving range of the stage. Reset procedure of the motor double checks the absolute position of the stage with respect to the reset switch: the software rotates the motor until the stage hits a microswitch button and then moves the stage the exact number of steps as reported in the software.

This procedure is performed by pressing a "Reset" button in the "Motors" section of WinTOPAS software.

6.3 Input Beam Alignment

In case of pump laser re-alignment or a change in system layout, it may be necessary to re-introduce the pump beam to ORPHEUS-HP. This is performed by using iris apertures and special beam alignment targets (BAT) inside the housing. The beam should travel through the center of these apertures. The positions where to place the BAT when aligning the pump beam are shown in figures below.

NOTICE ***Consult Support Team first before performing input beam alignment procedure!***

Firstly, the beam should be centered on the iris A1 and then centered on the beam alignment target placed in the pump + SHG beam path. The correct procedure is to center the beam on the iris by adjusting the BRM1 mirror and then to center the beam on the target (BAT1) by adjusting mirror BRM2. It may take several iterations to get the beam centered on both apertures.

WARNING ***Never use the full pump power to align the beam. Use only enough power (10-50 mW) to visualize the pump beam on the IR card. Even less power is required to detect the SH of the pump beam.***

NOTICE

Always leave the A1 iris fully open after the alignment is done. Diffraction from partially closed A1 may damage the downstream optics.

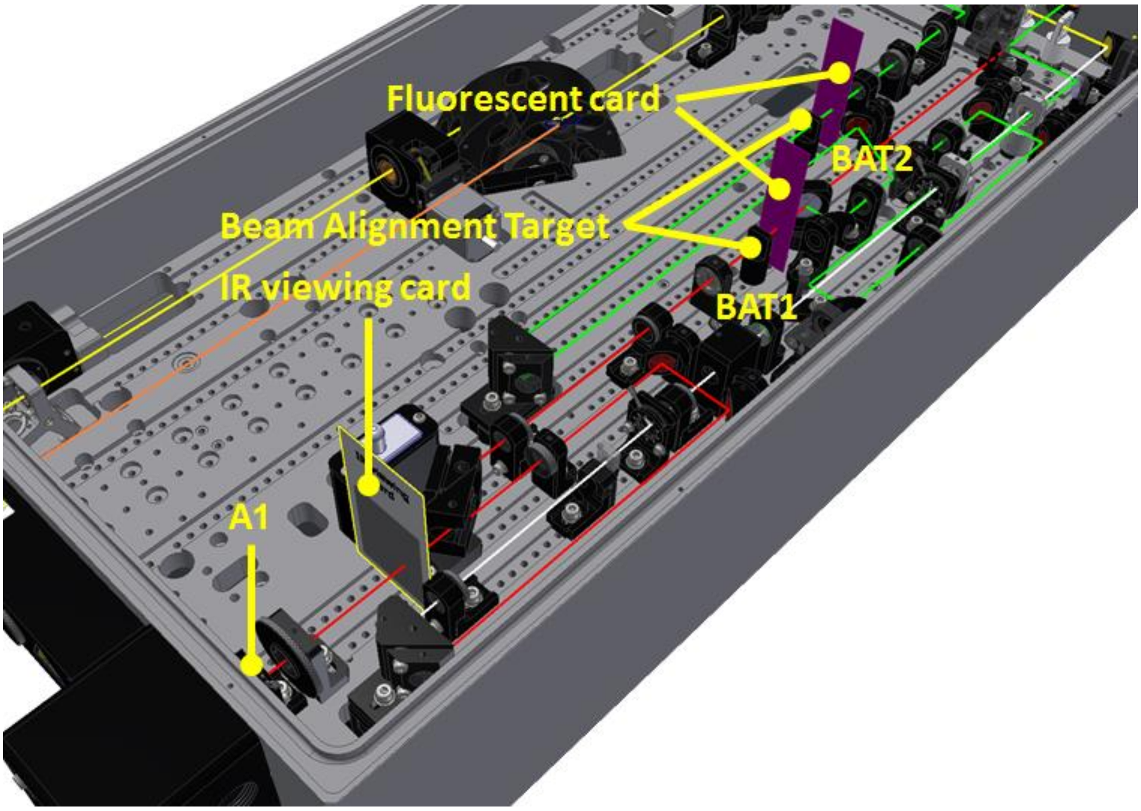


Figure 21. Input beam alignment, check point positions

Once the beam is centered on the first two apertures, proceed to place the BAT further in the beam path, as illustrated in Figure 21 – position BAT2. Adjust BRM2 mirror to center the beam on this aperture. When it is done, remove the BAT and start to increase the pump power. Final BRM2 mirror alignment should be performed while monitoring the output power of ORPHEUS-HP, attempting to achieve the installation value.

In case proper output power cannot be achieved with beam routing mirrors, make sure that all motors have been reset and input pump pulse parameters are the same as during installation. Only then you should proceed to optimization of ORPHEUS-HP internal alignment. Contact your local service engineer for more specific instructions.

6.4 Damage of White Light Generation Crystal

Depending on the intensity and repetition rate of the pump used for white light generation, the substrate itself can be damaged. The damage might occur on the first or second surface of the substrate.

If it is not possible to generate white light at all having the same parameters from the pump laser – that might also indicate the damage of the surface or bulk of the substrate.

In both cases the damage spot can be avoided rotating the WLG substrate around the axis. Please note that the crystal is glued on the pin which is fixed in the holder with a nylon tipped set screw. Do not release this screw while rotating the WLG crystal! Axial shift of the crystal might affect the stability/strength of white light signal as well as the focusing conditions of the beam into the nonlinear crystal.

To rotate the crystal:

1. Block the Second Harmonic Generation beam path of ORPHEUS-HP.
2. Insert HEX 1.5-2 mm key in the hole on the opposite end of pin of the WLG crystal.
3. Rotate the pin around the axis slightly.
4. Check if there is no scattering on the surfaces of WLG crystal while generating white light.

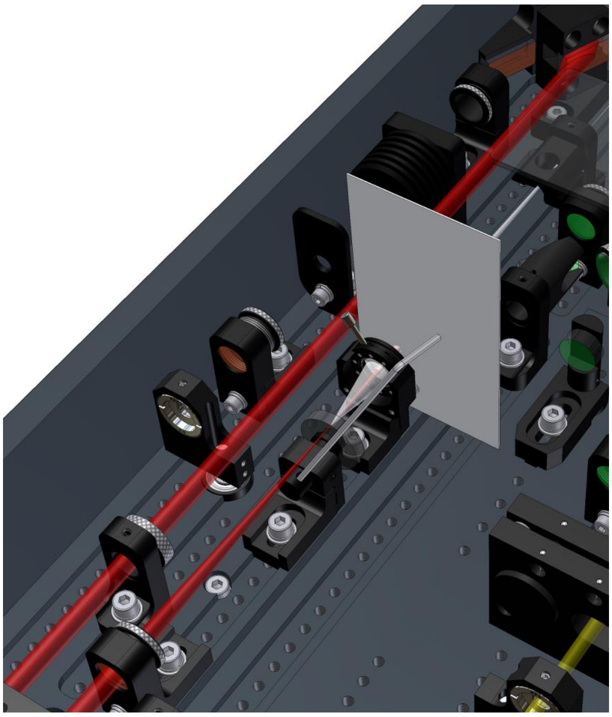


Figure 22. Illustration showing a key inserted into the axial adjustment hole in the WLG adapter

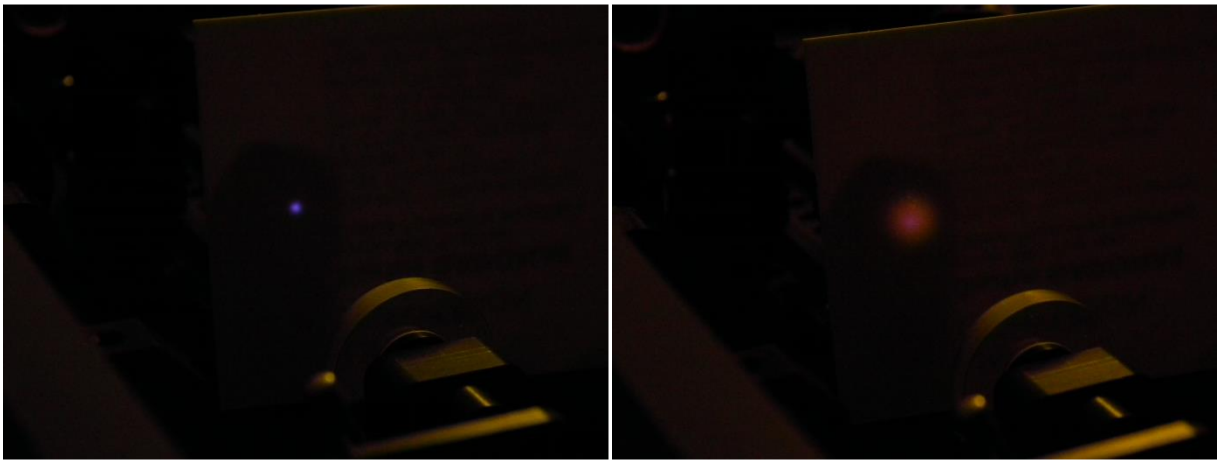
If it is not possible to generate white light in a fresh spot of the substrate – proceed to the section “Checking Pump Laser Parameters”. Probably, absence of white light is caused by change ofthe pump parameters.

6.5 Adjusting the Pump Intensity for White Light Generation

The intensity of pump for white light generation can be adjusted by rotating the half wave plate RP1:

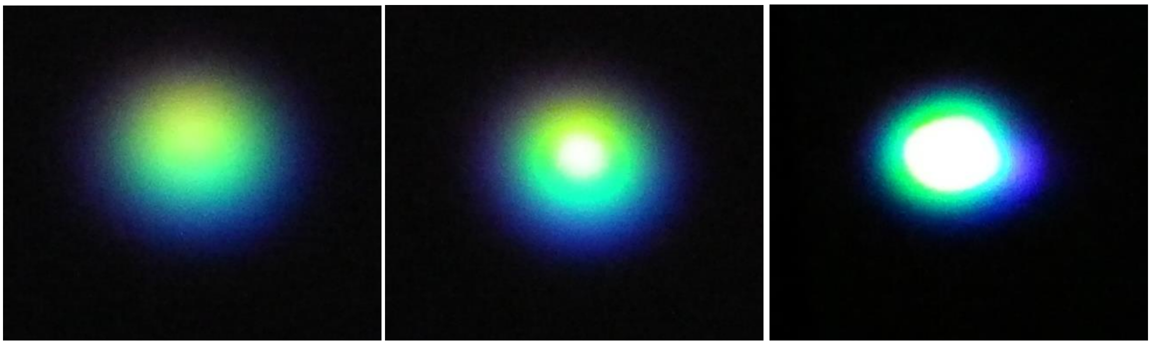
1. Block the SHG beam path of ORPHEUS-HP.
2. Set a paper card after the A2 iris to monitor white light
3. Rotate the RP1 adapter monitoring the WLC intensity, stability and shape.

White light should be stable and single filament – there should be no interference patterns seen in the beam profile (some rings can be seen around the central part – they can be ignored). If the intensity is too high – white light might have “boiling” structure or interference fringes across the beam. If the intensity is too low – white light might be unstable, appearing/disappearing.



(a) **(b)**

Figure 23. No white light generation (a) and very low intensity of white light (b) are indications that there is too little energy in the pulse, or the beam is focused improperly onto the crystal



(a) **(b)** **(c)**

Figure 24. Low (a), medium (b) and high (c) intensity of white light generated in the WLG substrate by 1030 nm radiation.

Note that all of the above illustrations are images taken at 100 kHz rep. rate. Images taken at lower rep. rates, or beam profile viewed by eye may appear slightly different (a more reddish hue can be expected). Low to medium intensity of white light is suitable for seeding the nonlinear crystal.

6.6 Applying Offsets for the Calibration Curve

After minor alignment of ORPHEUS-HP or small change in the pump parameters the calibration curve might be corrected applying an offset for the motors involved. This would especially be the case if different pump energy was needed for generation of white light. In such a case, the only parameter that would be wrong in calibration file is the temporal overlap of white light pulse and the first pump pulse. If the difference is not big and constant – it can be corrected applying offset for motor "Delay 1" of the calibration curve. An offset for "Crystal 1" or "Crystal Stage 2" and "Delay 2" stages would most likely be necessary after nonlinear crystal replacement.

To apply an offset:

1. Reset motor positions.
2. Switch to "Advanced user level" in WinTopas4 application using the menu "Tools" → "Access level". The password for advanced user level is "1600".
3. Set 680 nm as an output from the ORPHEUS-HP.
4. Select "Calibration" → "Optical" → "OPA" → "SIG" and select the motor (for which you want to apply an offset) on the left side of the window to gain access to the calibration curve.
5. For the same motor, select the motor control section on the right side of the window.
6. Adjust the position of the selected motor monitoring OPRHEUS-HP output: spectrum and/or pulse width.
7. Press "Set Offset" button.
8. Repeat steps 4-6 for other motors you want to apply an offset.

The offsets for each motor are stored in a calibration file. The settings of each calibration point remain unchanged. The logic of setting the wavelength with an offset is the following:

1. Lookup for the motor position from the calibration curve.
2. Interpolate the position if in-between wavelength is entered.
3. Add/subtract each motor position by the offset.

If the offset is re-zeroed – the position of each motor will be the same as the original calibration unless "Shift curve to make offset zero" was pressed after setting the offset. This function adds or subtracts offset value from the current tuning curve and makes the offset permanent. Visit WinTopas4 info page for more information.

7. MAINTENANCE

7.1 General Maintenance

Standard ORPHEUS-HP does not have any consumable parts. The lifetime of the device is mostly limited by the environment it is operated or stored in. Dust and humidity are the key factors affecting the long-term performance. Additionally, high repetition rate or extreme average power systems may suffer from degradation of the non-linear crystals.

Cleaning:

- Exterior of the ORPHEUS-HP housing can be cleaned with soft cloth moistened with ethanol. Do not use Acetone! While cleaning, take care that the dust does not contaminate the external or internal optics!

- Never clean inside of the housing due to risk of optics and crystal contamination.

NOTICE ***Never touch the optics with bare hands. Clean surfaces immediately, if touched.***

- Clean optics only when necessary. When cleaning, use acetone (methanol, ethyl acetate) of >99.5% purity.
- Do not attempt to clean surfaces of **gold/silver/aluminium** mirrors due to risk of damage.

7.2 Handling of Nonlinear Crystals

Nonlinear crystals used in ORPHEUS-HP for generation of Signal and Idler pulses as well as crystals for second harmonic or sum frequency generation are fabricated of beta-barium borate (BBO) or lithium triborate (LBO). These crystals are known to be hygroscopic. Crystals used in ORPHEUS-HP have protective coatings, however, the humidity level in the laboratory should be nevertheless kept to less than 70%.

When cleaning the faces of crystals use methanol or ethyl acetate of >99.5% purity.

NOTICE ***Never touch the crystals with bare hands. Clean surfaces immediately, if touched.***

NOTICE ***Do not attempt to clean surfaces of crystals thinner than 0.5 mm due to risk of damage.***

8. TROUBLESHOOTING GUIDE

This section lists the possible problems that might occur while operating ORPHEUS-HP. With each symptom possible causes and their solutions are presented.

8.1 White Light Generation Does Not Occur/Is Unstable

Cause	Corrective action
Wrong pump pulse energy/timing/compression settings.	Check the current status of laser operation, compare it with data measured during installation/service
Pump pulse intensity at WLG-Crystal is too low / too high	Adjust RP1 to minimize the transmitted energy, so that white light generation does not occur. Then rotate RP1 to achieve WLG just above the threshold.
WLG substrate is damaged	Refer to paragraph 6.4

8.2 Low Parametric Output or No Output at All

Cause	Corrective action
White light generation is unstable/no generation	Refer to the previous paragraph.
Second harmonic generation is inefficient	Refer to paragraph 4.4
Motors are not at their intended positions	Reset all OPA motors by clicking "Reset All" in the "Motors" window in WinTOPAS software.
Input beam misalignment	Refer to paragraph 6.3

8.3 Low Second Harmonic Generation Efficiency

Cause	Corrective action
Wrong input pulse energy/timing/compression settings.	Check the current status of laser operation, compare it with data measured during installation/service
Nonlinear crystal SHG-Crystal is not at optimal angle	Optimize the angle through "Motors" section in the WinTOPAS software
Pump pulse compression is not optimal	Optimize the pulse compression of the pump laser while monitoring the output power of second harmonic or Signal.
Low pump pulse contrast	Adjust the timing of Pockels Cells while monitoring the second harmonic power.

8.4 Signal and Idler beams are not collinear

Cause	Corrective action
Pump beam direction is off	Adjust the input Beam Routing Mirrors.
Internal misalignment of OPA	Contact support@lightcon.com

9. DISPOSAL

Dispose optical parametric amplifier system properly or return to the manufacturer.

i	**NOTICE**	***The laser-system may only be dismantled by authorized technicians who must be aware of the dangers involved.***
i	**NOTICE**	***Make sure that any government, district or local authority regulations regarding the disposal of environmentally dangerous substances are observed.***

Technical personnel must comply with the following:

- The safety instructions provided in the operating manual.
- Suitable protective clothing must be worn (protective gloves, safety shoes, goggles, etc.).
- The electrical energy supplies must be disconnected and secured against being switched on again in accordance with relevant accident prevention regulations.

9.1 Dismantling the System

Dismantle the optical parametric amplifier in the following order:

1. Switch off the device.
2. Unplug the power supply cable.
3. Remove all water from cooling system if applicable.
4. Dismantle the device into modules using the appropriate tools.
5. Disassemble the dismantled modules into their component parts.

9.2 Disposal

Dispose of the components in a suitable manner, observing any legal and company regulations for:

- Metals;
- Glass;
- Plastics;
- Cables;
- Packaging;
- Packaging materials;
- Batteries;
- Electric appliances;
- Electronic components;
- Transport media (pallets, etc.).

10. APPENDIX: DIFFERENCE FREQUENCY GENERATOR (DFG)

10.1 Overview

Difference frequency radiation (DFG) is generated by using the residual pump beam (leftover from second harmonic of pump generation) and Idler beam from the ORPHEUS-HP. The nonlinear crystals used depend on the configuration: standard configuration includes the DFG1 crystal for tuning from 2200 nm up to 4200 nm (DFG1 or DFP interaction), or/and DFG2 crystal for tuning from 4 to 16 µm (DFG2 or DFM interaction).

10.2 Pump Beam Path

As mentioned in the section 4.4, after second harmonic of pump generation beams travel towards DM1, which reflects only the second harmonic beam and transmits the residual fundamental. The transmitted beam then is directed towards the difference frequency generation unit using mirror DFG-M1. This pump beam has already passed through a second harmonic generation (SHG) crystal. For efficient DFG process the SHG crystal might be detuned from its optimal position to reduce the efficiency of the second harmonic generation and improve the energy and beam quality of the leftover pump. This pump beam is then reflected by several folding mirrors (DFG-M2 – DFG-M6) to compensate the beam path difference between the pump and Idler beams. After DFG-M6 the beam passes through a lens telescope LDFG-1 – DFG-L2 to reduce the beam diameter and increase the pump intensity for an efficient nonlinear process. DFG-M8 and DFG-M9 then directs the beam to mirror towards the DFG crystal "DFP-Crystal".

After difference frequency generation, pump is separated using a dichroic mirror DFG-M9, which reflects 1030 nm and transmits difference frequency and amplified Idler beams. Mirror DFG-M10 then directs residual pump towards output port C. Depending on the system configuration, this residual beam is blocked directly at the output port C or at the wavelength separator unit.

10.3 Seed (Idler) Beam Path

For difference frequency generation, the idler beam of the OPA is used as the seed of another amplification process. After the first wavelength separator wheel, Idler hits mirrors DFG-M11 and DFG-M12 which reflects it towards the retro-reflector DFG-M14 – DFG-M15. This retroreflector is placed on a motorized translation stage ("DFG delay" in the software) which is used for fine temporal overlap of the pump and seed pulses in the nonlinear crystal. The seed beam may also go through one or two lenses (DFG-L3 and DFG-L4) to either increase or decrease the beam diameter in the nonlinear crystal. The seed beam then travels through dichroic mirror DFG-M8 and overlaps with the pump in the difference frequency generation crystal "DFP-Crystal".

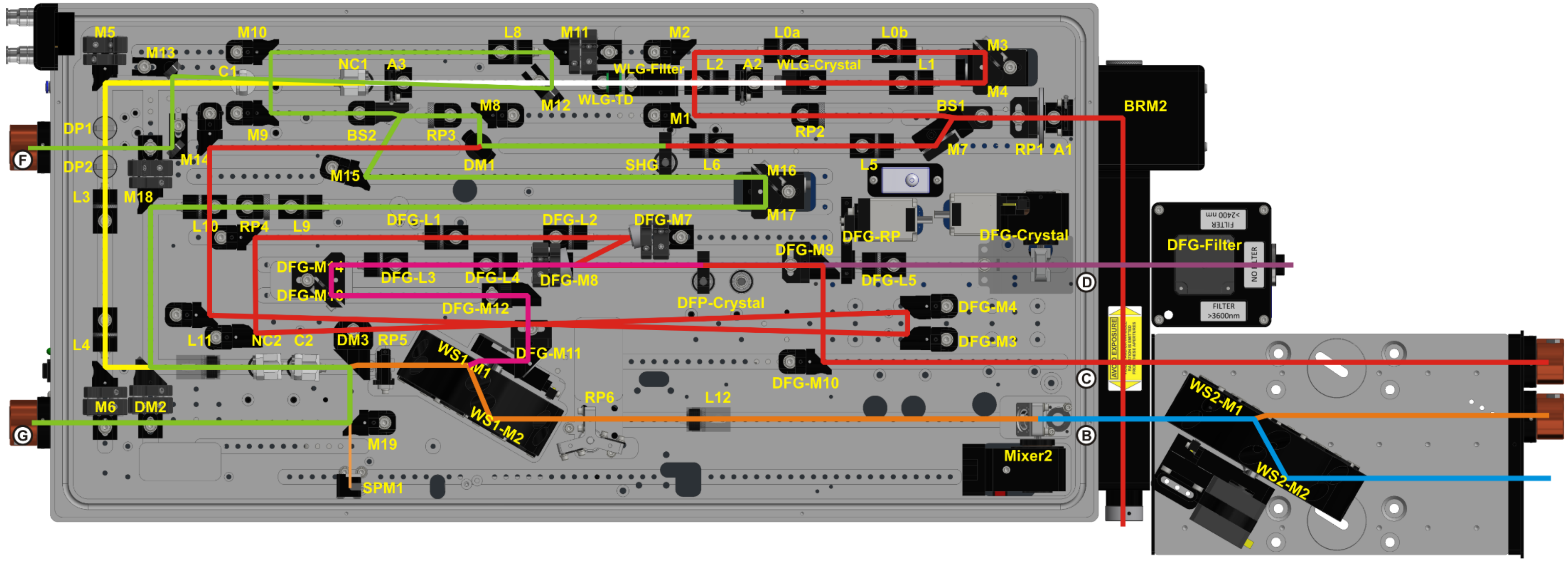


Figure 25. Optical layout of ORPHEUS-HP with optical elements labeled (SHS, SHI and DFG configuration)

A	– *iris aperture*	L	– *lens*	SPM	– *spectrometer mirror*
BS	– *beam splitter or polarizer*	M	– *mirror*	WLG-Crystal	– *white light generation substrate*
C	– *compensator*	NC	– *nonlinear crystal*	WLG-Filter	– *pump blocking mirror*
DM	– *dichroic mirror*	RP	– *half-wave plate*	WLG-TD	– *temporal dispersion medium*
DP	– *delay plate*	SHG	– *second harmonic of pump generation crystal*	WS	– *wavelength separator*

10.4 Difference Frequency Generation 1 (DFG1 or DFP)

As mentioned before, difference frequency generation is a similar process as optical parametric amplification. As a pump we are using 1030 nm to amplify the seed which comes from the ORPHEUS-HP as an Idler wave. During the process of this amplification, another wave is created, which we call DFG wave.

Interaction between the pump and the seed is collinear. As a result, the created DFG beam also travels in the same direction and position as the seed and pump.

Abbreviation DFP stands for difference frequency generation with pump, where pump is a fundamental wavelength from the laser source. It is used to distinguish it from other difference frequency generation types.

DFG1 (or DFP from now on) interaction is performed in DFG1 crystal, which is placed in the position DFP-Crystal. DFP polarization – vertical, tuning range – from 2200 nm to 4.2 µm. Residual pump is then reflected by mirror DFG-M9, which transmits difference frequency and amplified idler beams. Both beams exit ORPHEUS-HP at the output port D, where a filter ("DFG-Filter" in the software) is placed to separate DFP signal from the idler.. It reflects idler downwards and transmits the DFP. This filter has antireflective coating for wavelengths >2400 nm.

10.5 Difference Frequency Generation 2 (DFG2 or DFM)

To extend ORPHEUS-HP tuning further into infrared, DFG2 (also called DFM) stage is used. It consists of an achromatic half-wave plate "DFG-RP" and mixer "DFG-Crystal".

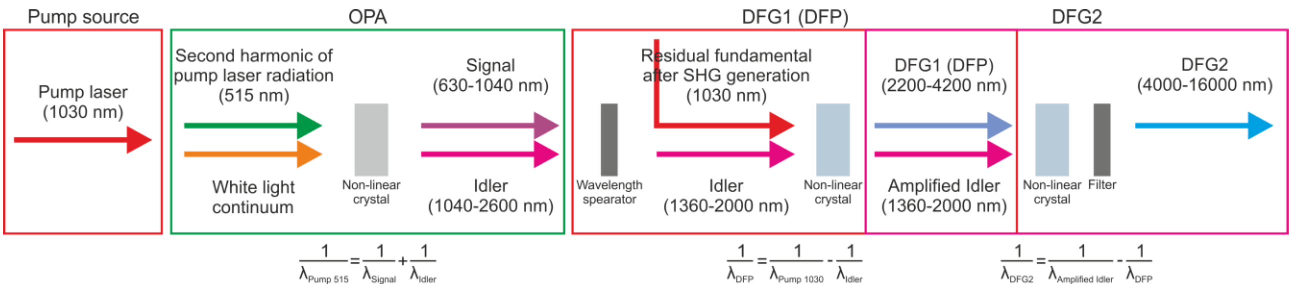


Figure 26. Difference frequency generation principle inside ORPHEUS-HP

In the case of DFG2, DFP from the DFG1 stage is used as a seed and corresponding amplified Idler – as a pump. For example, in order to generate DFG2 output at 10000 nm, it requires DFP seed at around 2298 nm. The corresponding Idler (seed for DFP generation itself) is about 1875 nm. Combining amplified Idler (1875 nm) and Seed (2298 nm) from the DFP stage (both travel at same angle and direction due to collinear interaction) in DFG-Crystal results in a DFG2 wave generation at 10000 nm.

In order to generate vertically polarized DFG2 (as DFP), seed must be of horizontal polarization and pump – vertical. The polarizations are rotated by a half-wave plate "DFG-RP".

DFG2 interaction is performed in DFG2 crystal, position-DFG-Crystal. Output polarization – vertical, tuning range is from 4 to 16 µm. All beams exit ORPHEUS-HP at the output port D where a filter is placed to separate beams. In case of DFG2, a filter is used, which transmits wavelengths >3600 nm and reflects downwards all the residuals.

10.6 Wavelength reference table

The table below provides a reference for the DFG1 and DFG2 wavelength, assuming the fundamental pump is centered at exactly 1030 nm (second harmonic of pump – 515 nm). A shift of the central wavelength will affect the calibration of the device.

Table 9. Signal and Idler wavelength reference, in nanometers

OPA Signal	OPA Idler / Idler, amplified in DFG1	DFG1 (DFP) signal	DFG2 (DFM) signal
650	2480	-	Limited by crystal transparency
660	2344	-	
670	2226	-	
680	2122	-	
690	2031	2090	
700	1949	2185	18025
710	1875	2285	10447
720	1809	2392	7416
730	1749	2506	5784
740	1694	2628	4764
750	1644	2759	4066
760	1598	2899	3558
770	1555	3050	Limited by crystal phase matching angle
780	1516	3214	
790	1479	3390	
800	1446	3583	
810	1414	3792	
820	1385	4022	
830	1357	4275	
840	1331	4554	
850	1307	4864	
860	1284	Limited by crystal transparency	
870	1262		
880	1242		