PHAROS

Single-unit Integrated Femtosecond Laser System

User's Manual

Document publishing date: January 14, 2020
Document code: MAN-PH-FM-001

Light Conversion, UAB
Address: Keramikų 2B, LT-10233 Vilnius, Lithuania
Tel: +370 5 2491830
E-mail: company@lightcon.com
www.lightcon.com

PREFACE

This manual contains user information for safe installation, operation and maintenance of the PHAROS laser system.

NOTICE ***The latest version of all product manuals is always available online at www.lightcon.com. User registration is required to access the download section.***

Read this manual carefully before operating the laser for the first time. Special attention must be paid to the "SAFETY PRECAUTIONS" chapter, which describes hazards associated with the system and precautions that must be taken to operate the laser safely.

CAUTION ***Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.***

Thank you for using Light Conversion products.

Support Needs

If you have any technical questions or problems, please contact our authorized representatives or Light Conversion directly:

Light Conversion, UAB
Keramikų str. 2B,
LT-10233 Vilnius, Lithuania
Email: lasers@lightcon.com
Web: www.lightcon.com
Phone: +370 5 249 18 30 (work hours 9:00 – 18:00 UTC+2)

Legal information

TABLE OF CONTENTS

List of Figures

List of Tables

Abbreviations

- CPA - Chirped pulse amplification
- CW - Continuous wave
- HV - High voltage
- LD - Laser diode
- LDD - Pump laser diodes driver
- ML - Mode-locking
- OSC - Oscillator
- SC - Stretcher compressor
- PD - Photodiode
- PP - Pulse picker
- PSU - Power supply unit
- RA - Regenerative amplifier
- TEM - Timing electronics module
- SELV - Safety Extra Low voltage

WARRANTY STATEMENT

Light Conversion warrants that the supplied laser system is free from defects in parts and workmanship. Light Conversion will make any necessary repairs or replacement of parts to remedy any defect according to the conditions drawn in this statement.

The warranty period for the delivered system is agreed upon prior to purchase due to the possibility of additional modifications to the standard system or purchase of an extended warranty. Warranty terms may differ for some internal components from the entire laser system. The warranty period starts after the final acceptance report is approved or one month after delivery, whichever occurs first.

Due to the sealed design, most of the Light Conversion products have limited on-field engineer access to the internal components. Repair works requiring access to the internal laser components shall be carried in a clean room at the Light Conversion facility. If such repairs become necessary, the laser system or its components shall be sent to Light Conversion for repairs. Shipping expenses from customer's facility to Light Conversion shall be covered by the customer. Repairs and return shipment expenses shall be covered by Light Conversion.

This warranty does not cover equipment or parts damaged by accident, improper use (including, without limitation, incorrect voltages, power surges, fires, operation in an improper environment, natural disasters or other situations out of the control of Light Conversion), failure to operate in accordance with instructions provided in the User's Manuals, including specific safety and operational warnings contained therein, cosmetic damage sustained in use, and damage caused by unauthorized modifications of any equipment which impair or alter its normal functioning. The limited warranty and remedy contained in this paragraph are the only warranty and remedy pertaining to the equipment.

Light Conversion disclaims all other warranties, expressed or implied, including any warranty of merchantability or fitness for a particular purpose. No oral or written information or advice given by Light Conversion, its dealers, its distributors, agents, officers, or employees shall create a warranty or in any way increase the scope of this warranty. Light Conversion in no event will be liable for any accidental, consequential, or other damages or costs, lost profits or inconvenience caused by equipment downtime or labor expended by persons not so authorized by Light Conversion. Shall the system require minimal repair or maintenance which can be performed by the customer himself, customer is entitled to perform such a repair only after explicit Light Conversion approval.

In the event of return shipping of the laser product to Light Conversion for maintenance, repairs or any other reason, it is the customers responsibility to properly pack the laser product. Responsibility for any damages or cosmetic wear caused by improper packaging of the laser product will fall upon the customer. Contact Light Conversion for laser product packaging requirements.

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 with Light Conversion representatives if you have any doubts regarding any information written in this manual prior to taking action.

INTRODUCTION

This document is directed towards anyone who works with the PHAROS laser system or performs maintenance tasks. The structure of this document is linear in such a way, how the user should be introduced to the laser system. The document begins with essential safety precautions and warnings, followed with a general laser system overview, system installation and ends with instructions on daily device operation with both the User App and the Service App. At the end of this document you will also find an appendix containing various additional but non-essential information.

Throughout this document there are reference to various type of personnel, definition and requirements for each type of personnel are listed below:

- **Qualified personnel** are considered individuals, who on account of their professional training, knowledge and experience, as well as their knowledge of the relevant statutory provisions, can make a correct assessment of work assigned to them and identify possible dangers. They must be familiar with the PHAROS laser structure, principles of operation, laser and electrical safety precautions.
- **Instructed personnel** are considered individuals, who have been instructed and educated (if necessary) on the work assigned to them, as well as on the potential dangers arising from inappropriate conduct. Individuals with knowledge about required protective devices and protective measures.
- **Service personnel** are considered individuals from Light Conversion or its authorized representatives, who are specifically trained on this type of laser, with specialist knowledge and experience with the structure of the device and its optical and electrical layouts.

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 exposure to hazardous laser radiation.
		Indicates danger of electrical hazard to personal safety.
		Indicates fire hazard.
		Indicates toxic materials released because of laser material processing or as by-product of the laser process.

1 SAFETY PRECAUTIONS

This section should be carefully reviewed prior to operating the PHAROS laser. Safety precautions contained herein and throughout the manual must be carefully followed to ensure that all personnel who operate the laser are protected from accidental exposure to laser radiation and high voltage.

	**WARNING**	***The laser system was designed for indoor use only. Usage of the laser system outdoors poses potential optical, electrical, chemical and fire hazards.***

1.1 Safety Hazards

Optical Hazards

PHAROS is a Class 4 laser product that poses safety hazards if not used properly. Produced direct or scattered laser 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.

PHAROS emits invisible and visible femtosecond pulses with an average power up to several watts. Direct viewing of the laser output beam or even specular reflection from polished or diffuse surfaces can cause instantaneous and permanent eye damage and/or possible blindness.

	**WARNING**	***Avoid viewing the laser beam and specular reflections. Always wear protective eyewear when aligning and operating the PHAROS laser. Ensure your protective glasses cover all wavelengths emitted by the laser.***
	**WARNING**	***Ensure that the emission status indicator is clearly visible both to the naked eye and through the filters of your protective eyewear. If necessary install additional emission indicators in accordance with IEC 60825-1.***
	**WARNING**	***Areas in which the maximum permissible ocular exposure is exceeded must be protected by screens. All access panels and doors must be secured by means of interlock switches connected to the power supply unit.***

All PHAROS Laser users are advised to follow the precautions below:

1. Always wear protective eyewear. Choose protective eyewear appropriate to the intensity and wavelength of the radiation, as well as environmental conditions of use and required visual functions.
2. Never look directly into the laser beam or at any scattered laser light from any reflective (or partially reflective) surface.
3. Avoid wearing watches, jewellery and other objects that may reflect or scatter the laser beam.
4. Set up the laser system in such a way, that the laser beam paths are located well below eye level.
5. Use energy absorbing targets and shields to block the beam and/or prevent unnecessary beam reflections or scatter.
6. Avoid blocking the output beam or its reflection with any part of your body. The intensity of the beam can cause skin burns or ignite clothing.

7. Maintain a high ambient light level in the laser operating area. This keeps the eye's pupils constricted and can reduce the possibility of eye damage in case of an accident.
8. Extreme caution must be exercised when using volatile solvents near laser.
9. Limit laser access to qualified personnel only, who have received appropriate safety laser trainings and are aware of the dangers involved.
10. Use the laser in a closed room. Laser light remains collimated over long distances and therefore presents a potential hazard if not confined.
11. Post warning signs near the laser operation area.

Electrical Hazards

Hazardous voltages are present in the PSU. Do not disassemble or otherwise modify the PSU.

1. Never remove the access covers of the power supply or the laser electro-optical units unless the power supply is switched off and disconnected from the mains. Voltages present on these components present a safety hazard, which could result in personal injury or death.
2. Do not connect or disconnect any cables while the power supply is turned on.
3. Never work on electrical equipment unless there is another person present who is familiar with the operation and hazards of the equipment and is competent to administer first aid.
4. After disconnecting the main power, wait at least one minute for the capacitors to discharge before touching any electrical equipment.

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

CAUTION ***If laser is plugged to the wall socket, clearances must be kept allowing easy and fast access to the plug-in case of emergency.***

Chemical Hazards

Exposure to dust and gases released during laser material processing.

WARNING ***A suitable extraction system must be connected if laser is used to processed materials.***

Explosion and Fire Hazards

The laser beam can ignite substances in its path even at some distance.

DANGER ***Risk of fire and explosion! Due to the energy and power density of the laser beam there is risk of fire and explosion. Never install the laser-system in locations exposed to fire and explosion hazards.***

Mechanical hazards

The PHAROS laser head is up to 53 kg in weight. It must be transported, unpacked and dismantled respectively. Some parts and boxes may have sharp edges while dissembling them.

NOTICE

The laser system may be installed and dismantled by authorized technicians who must be aware of the dangers involved. Use safety shoes while handling heavy pieces of equipment. Use safety gloves where indicated by the signs.

1.2 Safety Related Controls

Several engineering controls have been implemented to ensure the safe use of the laser and are listed in the table below and shown in the figure after the table.

Table 2. PHAROS laser safety related controls

Safety related controls	Description
Main switch	The main switch connects or disconnects the PSU from the mains. It also performs the function of a thermal 16 A circuit breaker. The switch is located on the back of PSU.
Shutter key	The shutter key is used to enable/disable the Safety Shutter. If the key is turned to a position where the Safety Shutter is enabled, the Safety Shutter can be controlled by software and/or external inputs signals. Refer to electrical safety section at the end of this document for information on controlling shutter externally.
Laser emission indicator	Two laser emission indicators are installed on the laser system. One indicator is located on the power supply front panel and the other indicator is placed on the PHAROS laser head top. Laser emission indicators are red colored LEDs, which are active when the shutter is open.
Remote interlock	The Safety Shutter has an integrated remote interlock function in compliance with IEC 60825-1. The interlock circuit can be installed by the user to prevent access to areas where ocular exposure exceeds the maximum permissible levels, specified in the International Laser Safety Standard IEC 60825-1. Interlock switches must be installed on all access panels and doors. Once the interlock circuit is open the Safety-Shutter is closed. No laser radiation is emitted! After closing the interlock circuit, the Interlock Reset button must be pressed to open the Safety Shutter again.
Emergency Stop	The Safety Shutter has an integrated Emergency Stop function. Emergency Stop hardware is not an integral part of the power supply itself, but the power supply provides the necessary outputs for an emergency function activation, in case of a shutter failure.

WARNING

Even when the Safety-Shutter is closed there is hazardous laser radiation present inside the laser enclosure. Removal of the laser enclosure or any works inside the laser enclosure must only be carried out by Qualified or Service Personnel.

	**WARNING**	Any modification or use of the <Laser Model Variable> laser which changes, disables or overrides the function of these safety related controls invalidates the Class 4 certification of the laser described in this manual.

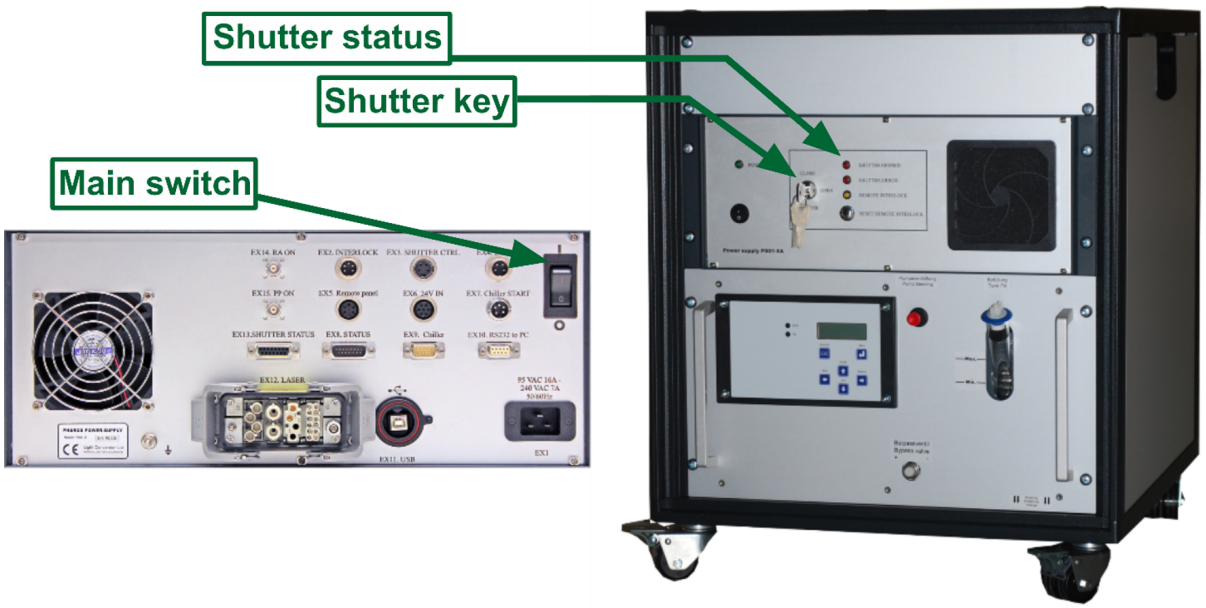


Figure 1. Location of the PHAROS laser main switch, shutter key and shutter status indication

1.3 Warning and Informational Labels

System areas with potential risks are marked with the prescribed warning and information labels on the relevant spots. Description and location of these labels is presented in the table and figures below.

Table 3. Description of PHAROS labels

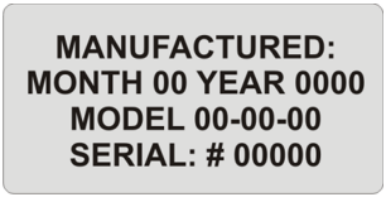
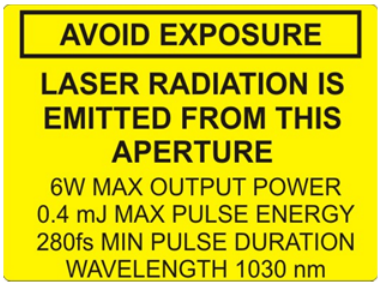
No.	Label	Location and description
1		**Warning label** is located on the side of the PHAROS housing. Depending on the model, the label shows max pulse energy, max average output power, pulse duration and wavelength.
2		**Product identification label** is located on the back of the PHAROS housing.
3		**Manufacturer identification label** is located on the back of the PHAROS housing.
4		**Grounding contact label** is located on the back of the CARBIDE housing, near the grounding contact.

Table 3. Description of PHAROS labels

No.	Label	Location and description
5		**Warning label** is located on the side of the <Laser Model Variable> housing. Depending on the model, the label shows max pulse energy, max average output power, pulse duration and wavelength.
6		**Aperture label** is located next to the beam output aperture of <Laser Model Variable> laser system. Depending on the device model actual emitted pulse energy and duration are stated on this label.
7		**Aperture label** is located next to the beam output aperture.
8		**High voltage warning label** is located on the housings of devices in which high voltage is used (not displayed in present figures).
9		**Warning label** is located on the top cover of the PSU.
10		**Power supply product identification label** is located on the rear panel of the PSU.
11		**Warning label** is located on the side covers of the PSU.

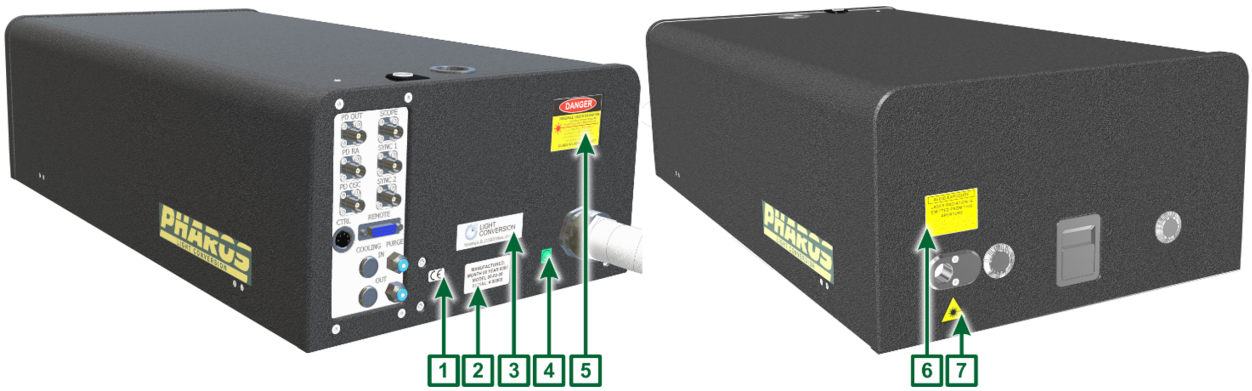


Figure 2. Label locations on the PHAROS laser head

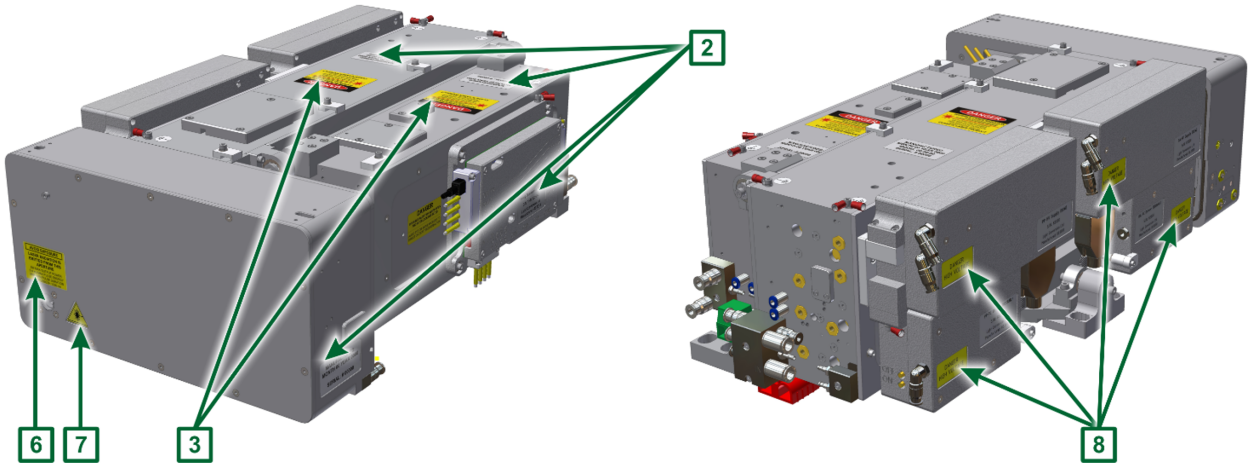


Figure 3. Label locations on the PHAROS laser head

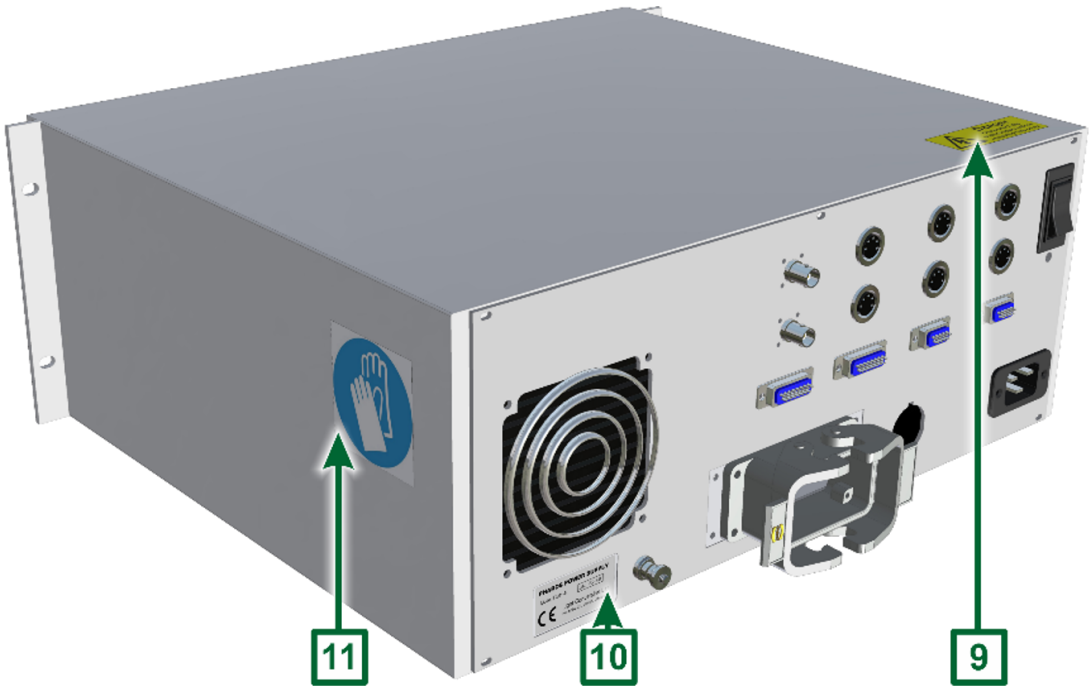


Figure 4. Label locations on the PHAROS power supply

1.4 Integration of the Laser

The laser system is designed and constructed in accordance with essential health and safety requirements. Additional external safety controls can be installed, such as the external interlock switches or the emergency stop switch. **It is the integrators responsibility to install these additional safety controls.**

If the laser system is integrated in to another system, it must not begin operations within the European Community until the finalized system has been declared in conformity with all the applicable EC Directives.

The manufacturer shall not be responsible or liable, directly or indirectly, for any damage or loss, caused or alleged to be caused systems, containing the laser system as one of the components of a different system.

WARNING

When integrating the laser system, keep in mind the possibility of laser beam reflections from external components. Avoid collimated and especially diverging reflections from external optics or surfaces towards the laser head as this may damage internal optics comprising the laser. For example, reflections from negative lenses (often used in beam expanders) with non-optimized coating. Back-reflections of even 1% of the laser beam may cause irreplaceable damage to the optics.

1.5 Disposal

NOTICE

The laser system may only be dismantled by authorized technicians who must be aware of the dangers involved.

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.

1.5.1 Dismantling the System

Dismantle the laser-system in the following order:

1. Switch off the laser-system.
2. Switch off the power supply.
3. Unplug the power cable.
4. If a chiller is used in the laser system, remove all the water from laser head cooling system and chiller.
5. Dismantle the laser-system into modules using the appropriate tools.
6. Disassemble the dismantled modules into their component parts.

1.5.2 Disposal

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

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

WARNING

Pockels cell drivers contains BeO ceramics (see "LIST OF HAZARDOUS MATERIALS USED IN PRODUCT" attached at the end of this document). It is prohibited to perform grinding, sanding, polishing, crushing, abrading or any other form of machining without adequate safety precautions. This information must be passed to any personnel or organization responsible for recycling of the Pockels cell drivers.

2 ELECTRICAL AND PHYSCIAL SPECIFICATIONS

Table 4. Electrical characteristics

PHAROS Laser	Voltage: Frequency: Max. current: Max. power: Electric protection class: IP classification:	95-240VAC 50/60 Hz 16 A (at 95VAC), 7A (at 240VAC) 1500W I IP30

Table 5. Environmental characteristics

*Operating temperature**	15-30°C (air conditioning highly recommended)
*Relative humidity**	2-80% (non-condensing)
Altitude	Up to 2000 m

NOTICE

Both the temperature and relative humidity should be kept at optimal levels to prevent condensation on the laser parts. The ranges provided display only the maximum and minimum allowed conditions, but not the optimal conditions. Optimal temperature and humidity should be calculated based on your environment and considering that the laser is cooled by internal fans to an approximate setpoint of 23°C.

NOTICE

Some chiller models have an internal transformer set for an input voltage of 230 V prior to delivery. Please check the voltage used in your environment and reconnect an appropriate internal transformer plug. See accompanying chiller documentation for more information.

Table 6. Physical characteristics

<table>
<tr><td>Weight of OEM Laser head</td><td colspan="3">34 kg*</td></tr>
<tr><td>Weight of Laser head with external enclosure</td><td colspan="3">42 kg*</td></tr>
<tr><td>Weight of the power supply unit</td><td colspan="3">13 kg</td></tr>
<tr><td>Dimensions of the Laser Head</td><td colspan="3">Dimensions of the laser head vary depending on its modification and included components,
please refer to your purchase order for laser head dimensions.</td></tr>
<tr><td rowspan="4">Dimensions of the power supply and chiller cabinet (rack)</td><td colspan="3">Length: 640 mm
Width: 520 mm</td></tr>
<tr><td>Height:</td><td>With casters:</td><td>Without casters:</td></tr>
<tr><td>9U</td><td>530 mm</td><td>460 mm</td></tr>
<tr><td>12U</td><td>660 mm</td><td>590 mm</td></tr>
</table>

*Weight of laser may vary depending on its modification.

2.1 Output specifications

Table 7. Output specifications for PHAROS laser

Output	Parameter	Specification
Fundamental output	**Central wavelength**	1030 nm ± 10 nm
	Average output power	Depends on laser specifications*
	Maximum pulse energy	Depends on laser specifications*
	Typical pulse duration	Depends on laser specifications*
	Spatial mode	Depends on laser specifications*
	Polarization	Horizontal
	Stability of pulse energy, STD	< 0.5%

*Refer to the factory test certificate of the supplied laser.

2.2 Data Interface Specifications

Table 8. Default data interface specifications

RS-232 interface	*Baud rate*	57600
	Data bits	8
	Stop bits	1
	Parity	None
	Flow control	None

3 LASER SYSTEM DESCRIPTION

The PHAROS laser is an electronically controlled device, used to generate ultra-short pulses of coherent electromagnetic radiation. It can be used for micro-machining, cutting and removing various materials, it can also be used for scientific applications such as ultra-fast spectroscopy, non-linear optics, etc. The PHAROS laser is a technical tool that is intended only for professional or scientific use.

PHAROS may not be used for any purpose other than those described above (for example, it cannot be used in laser light shows or any outdoor application, etc.).

NOTICE ***The operator shall assume all liability for use of the PHAROS for anything other than its intended purpose.***

Depending on the system configuration certain components may not match the figures and descriptions.

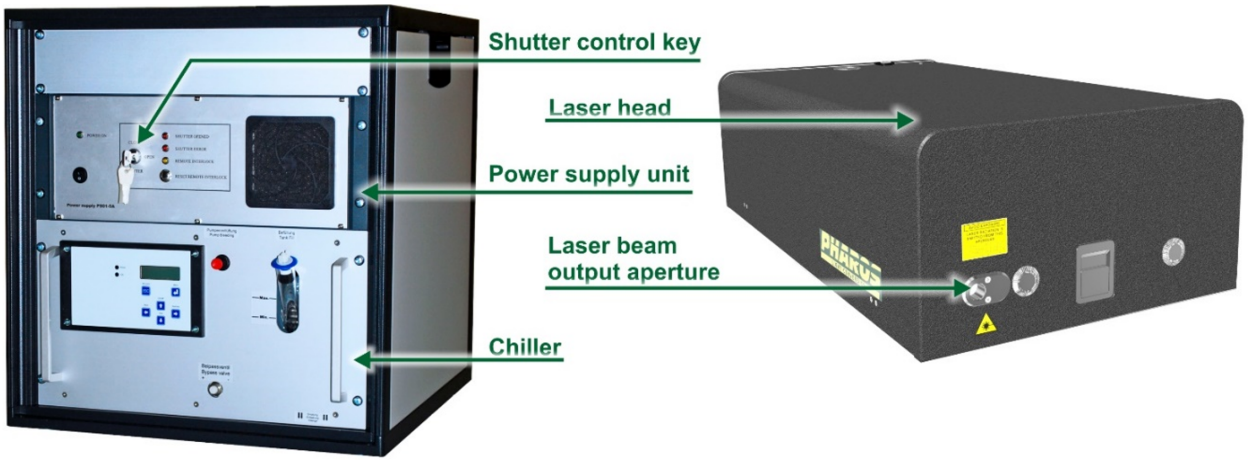


Figure 5. PHAROS laser system components

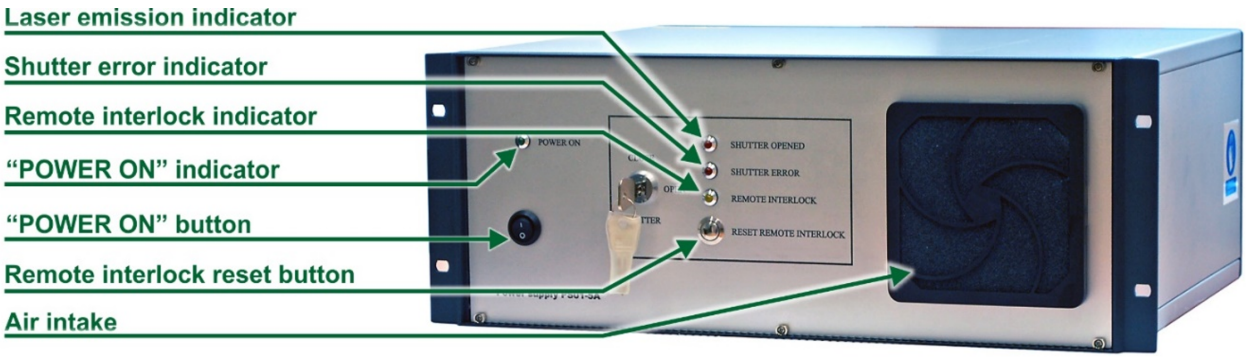


Figure 6. PHAROS power supply unit

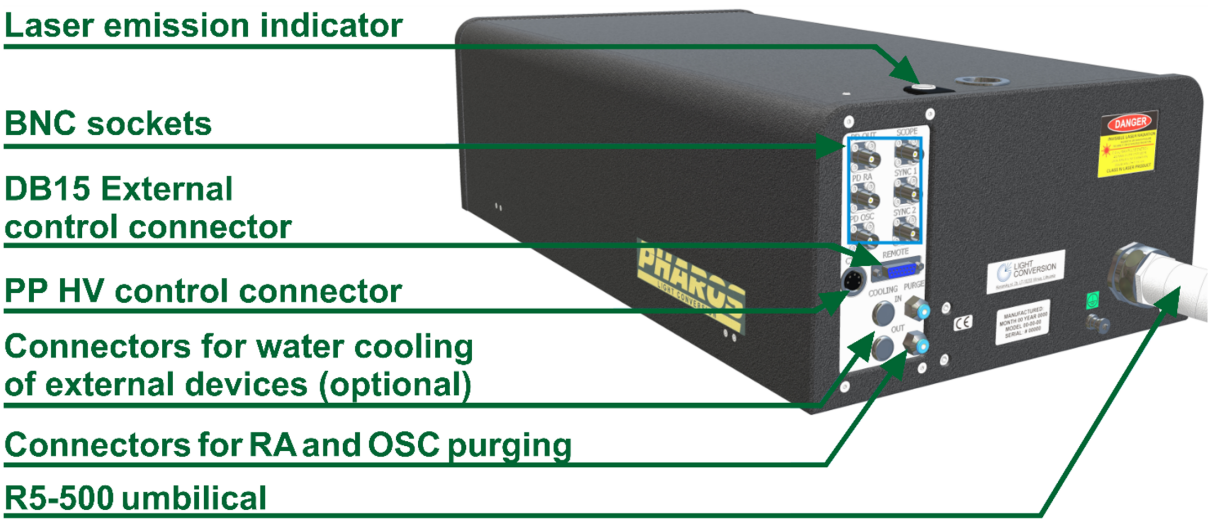


Figure 7. PHAROS rear panel main components

3.1 Laser system internal components

PHAROS is a compact high repetition rate femtosecond laser system based on the chirped pulse amplification (CPA) technique, which employs directly diode-pumped Yb:KGW as an active medium.

The PHAROS laser system consists of an Oscillator (OSC), Regenerative Amplifier (RA), Stretcher-Compressor (S-C), Chiller, and Power Supply Unit (PSU), supplying electrical current for Laser Diodes (LD), which are used for pumping the active medium and other parts mentioned above. The system also includes an electro-optical Pulse-Picker (PP) for output pulse control and contrast enhancement. System operation is automatically controlled by the Timing Electronics Module (TEM).

The PHAROS system can be operated via the PHAROS control software installed on a personal computer. The computer must be connected to the PSU via a USB connection.

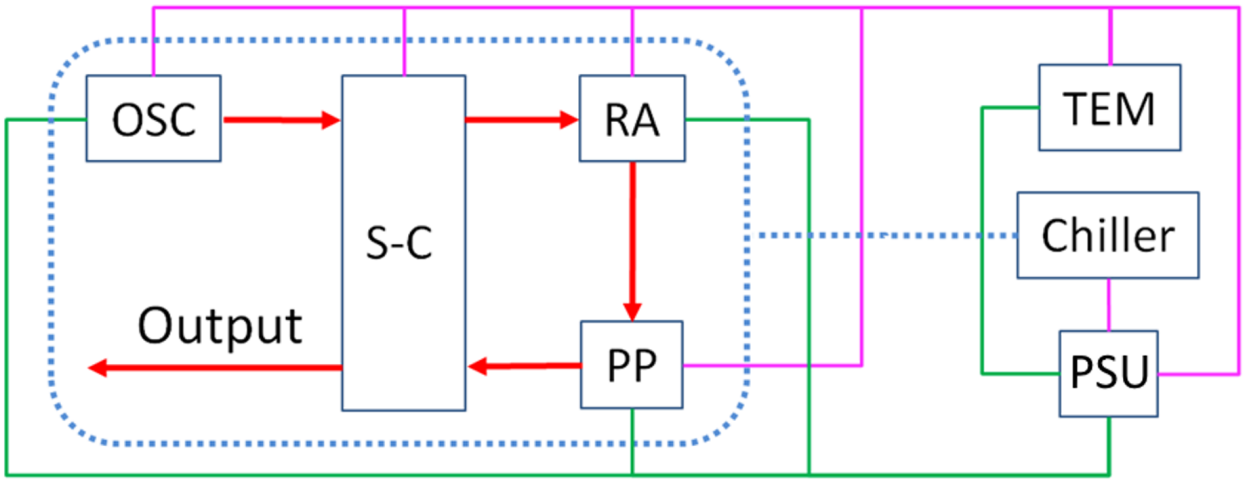


Figure 8. PHAROS system design

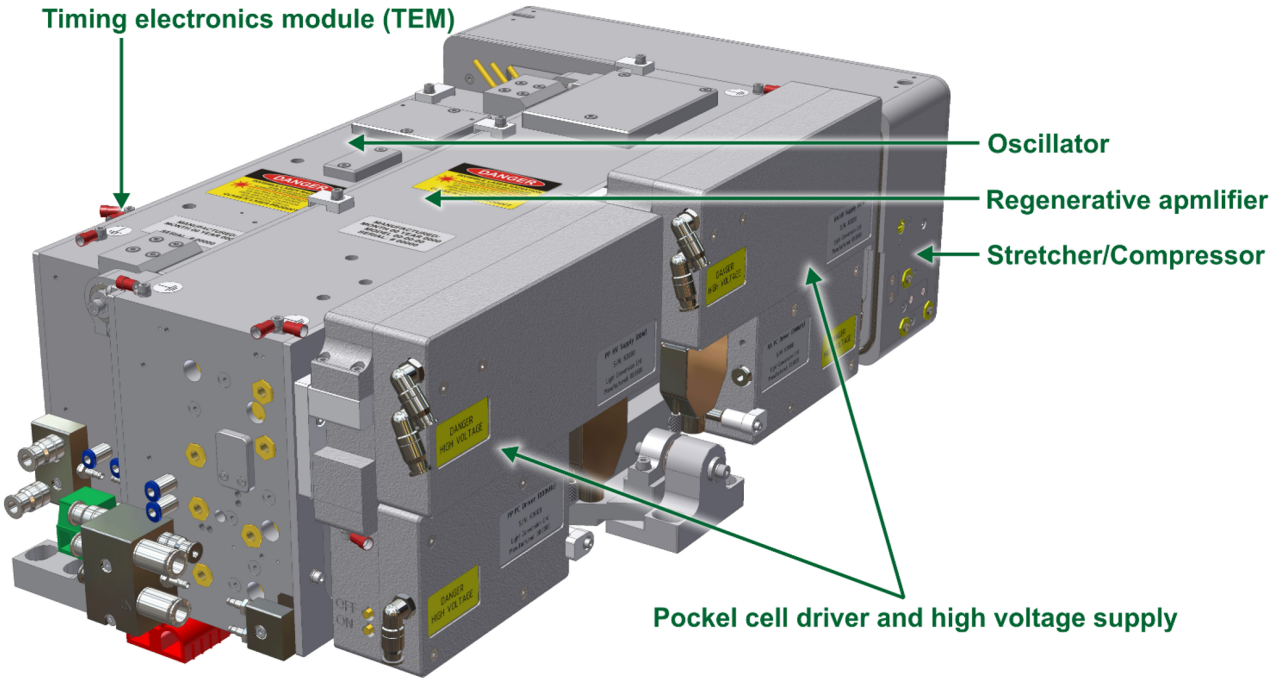


Figure 9. Design of the PHAROS laser head (without external cover)

The PHAROS laser head has a multi module structure (see figure above), which includes:

- Oscillator;
- Regenerative Amplifier;
- Stretcher/Compressor;
- Timing Electronics Module;
- High voltage supplies and drivers for Pockels cells.

All modules are water cooled, resulting in effective heat management and ensuring mechanical stability independent of environmental conditions.

3.1.1 Oscillator (OSC)

The oscillator (OSC) employs a cavity with active medium directly pumped by high brightness LD modules. Generation of a high repetition rate femtosecond pulse train is ensured by the Kerr lens mode-locking. Oscillator operation is controlled automatically by the internal firmware of the laser. The repetition rate of the oscillator pulses is typically 76 MHz. The OSC output power is actively stabilized by the power lock function.

3.1.2 Regenerative Amplifier (RA)

The regenerative amplifier (RA) incorporates an active medium pumped by continuous wave (CW) LD modules. A Pockels cell is arranged inside the amplifier cavity to control injection of the seed pulses and extraction of amplified pulses. The Pulse picker (PP), which consists of a second Pockels cell, can be used to control every pulse from the RA output and is mainly used to reduce repetition rate without changing the operation of the RA

3.1.3 Stretcher/Compressor (SC)

PHAROS laser system employs a chirped pulse amplification technique. It is based on stretching the seed pulses, amplification and compression to achieve the highest pulse peak power with an ultra-short pulse duration. Both the stretcher and the compressor are enclosed in the same housing.

The resulting pulse width can be tuned by changing the compressor length. Tuning the pulse duration is accomplished by inducing positive or negative chirp from a model-specific shortest value to a maximum of approximately 10 ps. This tuning can be performed with a motorized translation stage, controlled with the PHAROS software.

3.1.4 Timing Electronics Module (TEM)

The PHAROS RA and PP operation is controlled by the Timing Electronics Module (TEM). The TEM is responsible for these functions:

- Synchronization of RA operation to OSC optical pulses.
- Control of RA and PP optical gates (Pockels cells).
- Protection of RA components from optical damage.

3.1.4.1 Timing of Laser Control Signals

Table 9. TEM timing parameters

Parameter		Min	Min	Max	Jitter	
Oscillator period	τ_{OSC}		13-14			ns
SYNC period	τ_{SYNC}	1-5*		1000	1 τ_{OSC}	µs
SCOPE to SYNC delay	τ_{S1}		6 τ_{OSC}		1 τ_{OSC}	ns
RA on delay	τ_{ON}	0		45		ns
RA off delay	τ_{OFF}	145		500	0.5 (typical)	ns
Cavity Dumping Time	τ_{CD}	145		500	0.5 (typical)	ns
HV driver delay	τ_{DR}		60			ns
Pulse picker offset	$\tau_{PP\ offset}$	-30		30		ns
PP OFF delay to PP ON	$\tau_{PP\ OFF}$				10	ns
SCOPE, SYNC1, SYNC2 delay to PHAROS output	τ_{OUT}				0.5 (peak to peak at 10^7 pulses)	ns
"Soft Start" time			5			s
Time between RA STOP and Run commands		3				s

*Depends on laser model

Overall thermal peak to peak stability 500 ps in 5-75 °C range.

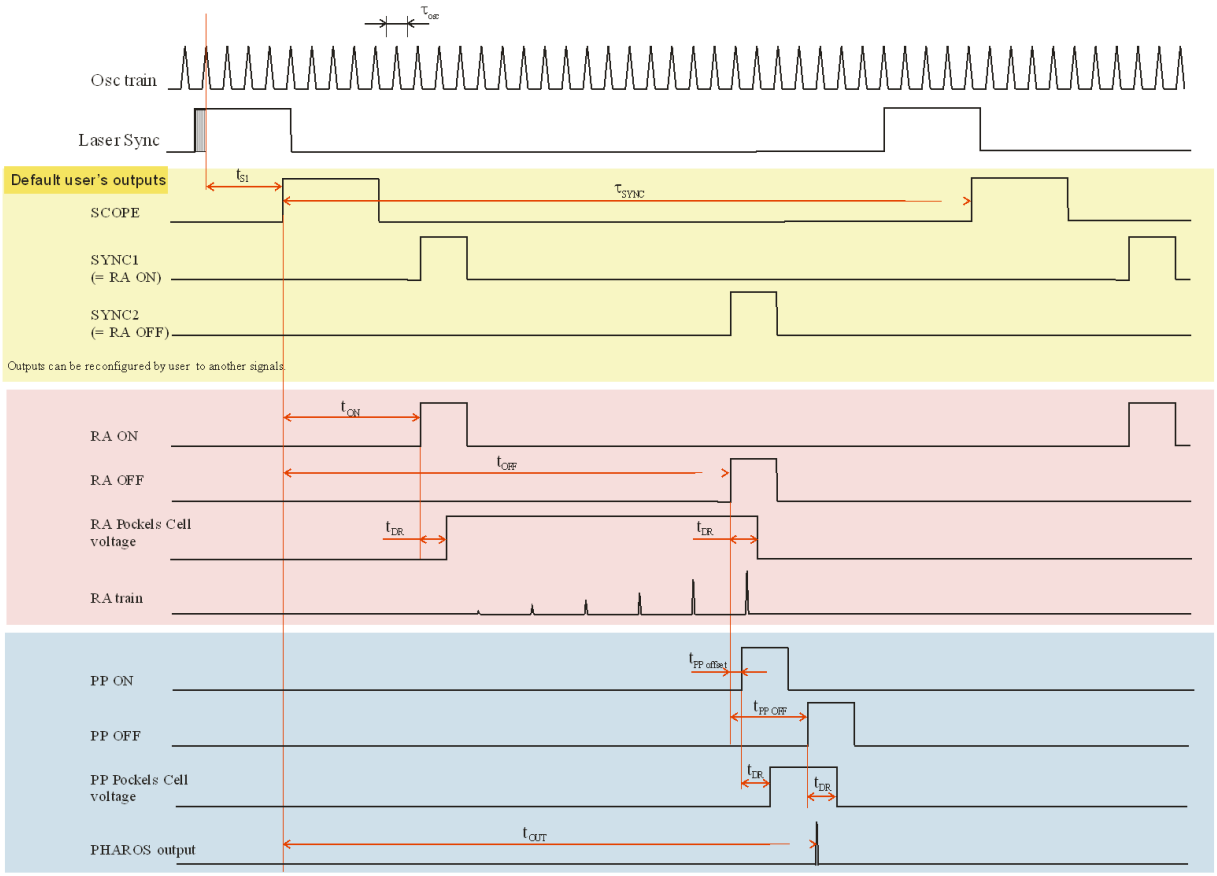


Figure 10. Laser timing diagram with reference to optical pulses of OSC and RA

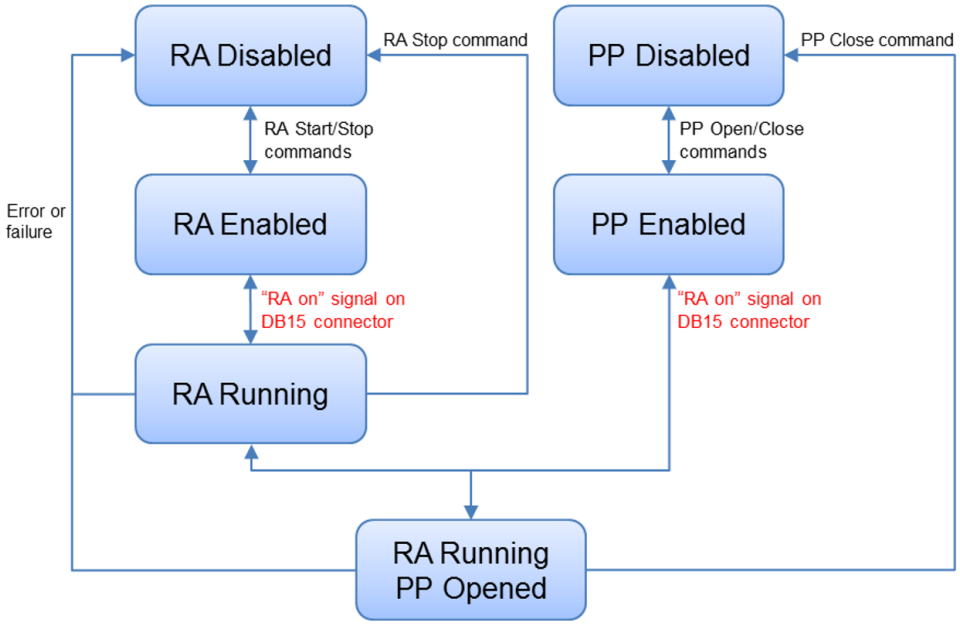


Figure 11. TEM states diagram with external RA and PP control enabled

Three main PHAROS control operations: synchronization of laser pulses, starting/stopping of RA and opening/closing of PP can be performed with electric signals using the external laser control interface. The external control interface must be enabled and configured using a computer and the PHAROS Service App software.

If external RA and/or PP control sources are selected, the "*RA Start*" and/or "*PP Open*" commands must be issued to allow laser control from the external control interface. Figure above shows the TEM states when

external RA and PP control sources are selected. "*RA Start*" and "*PP Open*" commands are transmitted over the CAN bus from the PHAROS control application or user's software.

The PHAROS laser also support external control. The remote control connector is described further below in the Electrical connections section.

The diagram of remote laser control signals and laser output pulse timing is shown in the figures below, they also display the waveforms for the laser remote control signals.

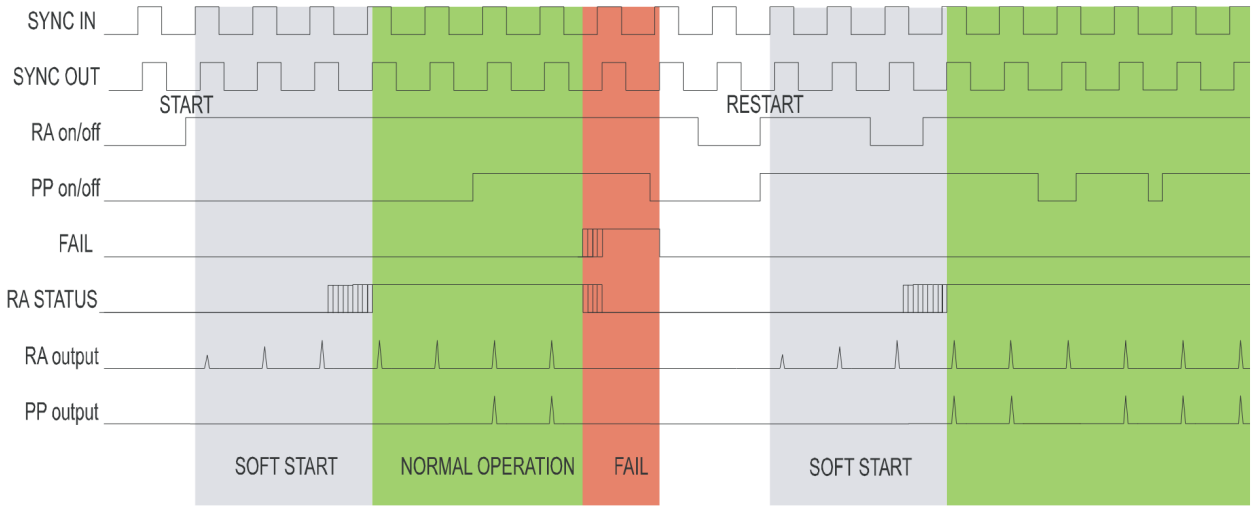


Figure 12. Waveforms for remote control signals and laser output

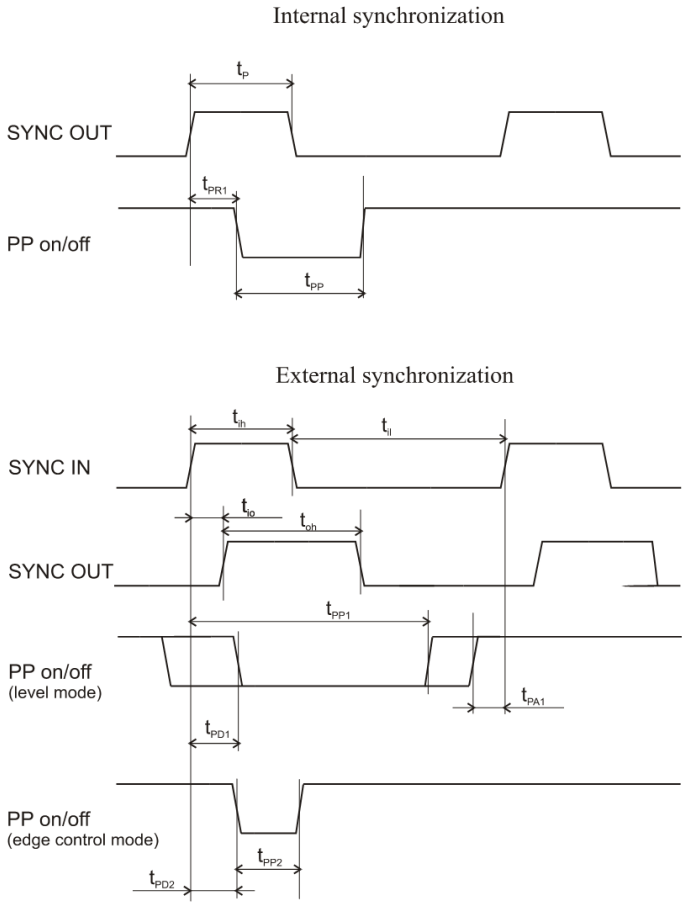


Figure 13. Laser remote control timing reference

The table below shows the required signal parameters.

Table 10. Signal parameters for laser synchronization from the external device

Parameter		Min	Typical	Max	
Internal synchronization					
SYNC OUT high	τ_p		500		ns
PP on/off signal delay	τ_{pr1}	0		130	ns
PP on/off signal hold	τ_{PP}	50		70	ns
External synchronization					
SYNC IN high	τ_{ih}	100		500	ns
SYNC IN period	$\tau_{il} + \tau_{ih}$	1-5*		1000	µs
SYNC IN to SYNC OUT delay	τ_{io}		100		ns
SYNC OUT high	τ_{oh}	500		τ_{ih} if>500	ns
PP on/off signal delay in level control mode	τ_{PD1}			150	ns
PP on/off signal hold starting from SYNC IN in level control mode	τ_{PP1}	560			ns
PP on/off signal delay in edge control mode	τ_{PD2}	50		100	ns
PP on/off signal hold in edge control mode	τ_{PP2}	50		700	ns

*Depends on laser model

Note: Exact timing parameters can vary depending from TEM firmware version.

3.1.5 Laser "REMOTE" control connector DB15

The PHAROS external control interface is realized as DB15 connector with three logical inputs and three outputs. Figure below shows the electrical circuit of the external control interface inputs and outputs.

Table 11. Laser "REMOTE" control connector DB15

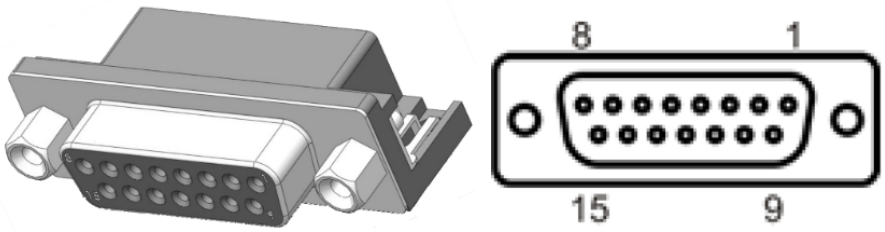
PIN	Name	Dir	Description
			
Type: D-SUB 15 female			
1-7	GND	-	-
8	N.C.	-	Not connected
9	SYNC IN	IN	Input of the external clock for the laser synchronization – initiates *sync** of the laser. Input must be stable continuous frequency f=1-200kHz (or 1 MHz depending on laser configuration). Duration of the high level must be between 100 ns and 500 ns

Table 11. Laser "REMOTE" control connector DB15

PIN	Name	Dir	Description
10	RA on/off	IN	Starts (low level) and stops (high level) RA operation. Stops RA operation starting from the first valid *sync** of the laser. Start – initiates "*Soft Start*" of RA (RA STATUS output can be used to monitor when RA is leaving "*Soft Start*" and starts operating in a defined regime)
11	PP on/off	IN	The signal controls the PP (low level – opened, high level - closed). The status is loaded with valid *laser sync** transition
12	RA STATUS	OUT	High level indicates that RA is operating in a defined regime (soft start has finished and there are no fails in the system)
13	SYNC OUT	OUT	Output of laser *sync** signal triggered by the internal laser oscillator or SYNC IN. In the case of an external clock the pulse duration is the same as the input pulse duration. If SYNC IN is < 500ns then SYNC OUT is extended to ~500 ns. In the case of internal clock SYNC OUT is ~500 ns
14	FAIL	OUT	Indicates fail of the laser (OSC or RA). When Fail is high RA is stopped. When fail returns to low RA on/off rising transition will start RA operation
15	N.C.	-	Not connected

**Laser sync* is an internal synchronization signal in the laser. It can be produced by the internal clock of the laser or external SYNC IN signal.

3.2 Power Supply Unit

The PHAROS PSU provides electrical power to the laser head and its electronics. It is also used to communicate with the laser controller. Most of the safety precaution circuits and controllers, as well as the Safety Shutter controller are also part of the PSU.

3.2.1 Power Supply Unit Connectors

The PHAROS is shipped with all necessary cables and connectors to start the system. Some optional safety features, which are not installed by default, but are supported by the system, can be integrated by the user:

- *Interlock circuit (socket EX2).* The interlock circuit plug is supplied with the laser. It can be used to bypass the interlock circuit, or it can be used to connect the user's interlock system to the laser.
- *Emergency stop circuit (socket EX4).*

The table and figure below contain a description of all sockets and plugs.

Table 12. Description of the PS01-5A PSU connectors

Name	Plug type (part number)	Description
EX1	IEC C19	Mains input (95-240 VAC, <16A, 50/60 HZ)
EX2	Amphenol C091 31D005 1002	Shutter remote interlock input
EX3	Amphenol C091 31H004 1002	Shutter control input
EX4	Amphenol C091 31D004 1002	E-STOP circuit output
EX5	Amphenol C091 31H005 1002	Remote panel connection output

Table 12. Description of the PS01-5A PSU connectors

Name	Plug type (part number)	Description
EX6	Amphenol C091 31H007 1002	Shutter controller power input
EX7	Microphone 5 plug	Chiller remote start output
EX8	DB15 female	Power supply status outputs
EX9	DB9 female	RS-485 or RS-232 output to chiller
EX10	DB9 male	RS-232 output to computer
EX11	USB type B	USB output to computer
EX12	Harting modular plug	Connection to laser head
EX13	DB15 male	Shutter status outputs
EX14	BNC plug	RA start signal: if external RA start is configured on laser, grounding of central line starts the laser
EX15	BNC plug	PP open signal: if external PP control is configured on laser, grounding of central line opens the Pulse Picker

WARNING ***When connecting or disconnecting the EX12 Harting modular plug to the laser, the power supply must be unplugged from the mains.***

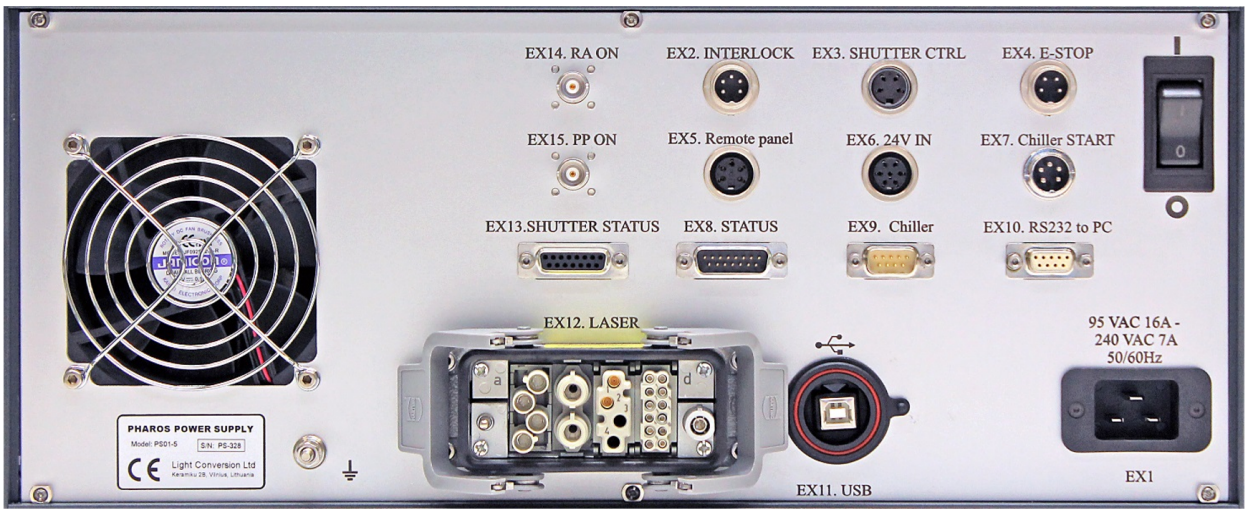


Figure 14. PHAROS power supply unit PS01-5A rear panel connectors

3.3 Shutter Controller

To reduce the risk of direct or scattered laser radiation from femtosecond laser systems, the PS01-5A PSU is equipped with a safety shutter controller. This safety shutter controller meets performance requirements "level d" as defined by EN 13489-1:2008.

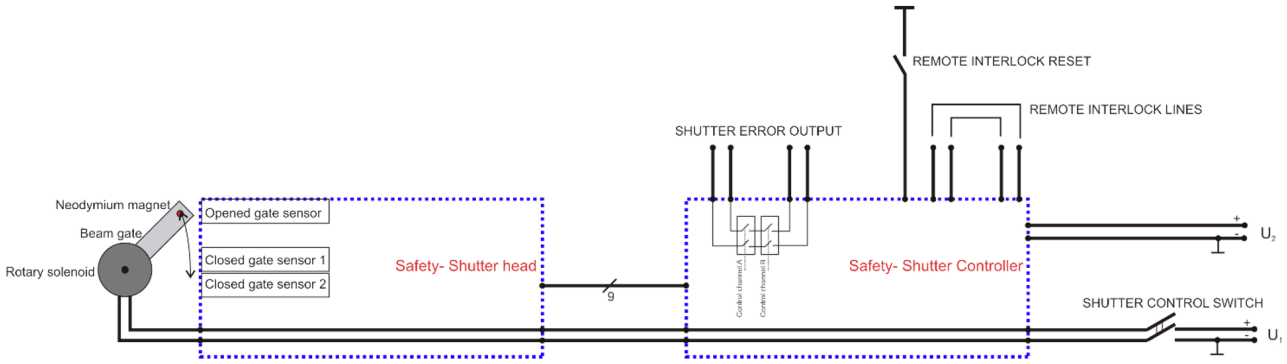


Figure 15. Functional schematics of the PHAROS shutter

The shutter is designed to perform 2 functions:

1. To allow the operator to ensure safe laser system operation by opening and closing the laser beam aperture. The operator must connect the shutter control lines to a 24V DC power source to open the shutter or disconnect the power source to close the shutter and block the beam.
2. To detect failures in the shutter control system and break the E-STOP circuitry if failures are detected. Two independent E-STOP lines are present in the laser system, each is in the closed state if the shutter operates normally or in the open state if failure is detected.

	**CAUTION**	***The PSU is not designed to stop the laser system in the event of shutter failure. The laser system must be equipped with additional systems responsible for monitoring the state of the interlock lines and de-powering the laser system in the event of shutter failure.***
	**WARNING**	***The shutter controller is not repairable and must be replaced in the case of failure.***

3.3.0.1 Shutter Mechanical Design

The safety shutter is installed in the PHAROS stretcher/compressor and acts as a beam blocker. It is used to block the laser beam and prevent accidental or uncontrolled emission of laser radiation.

The safety shutter consists of control electronics and a rotational solenoid used to move the aluminium gate. Application of 24V DC to the rotational solenoid causes it to rotate and lift the aluminium gate. After the 24V DC power source is disconnected, the internal solenoid spring returns the gate back to the closed position, preventing emission of laser radiation.

3.3.0.2 Shutter Operation Principle

The shutter is designed using designated architecture of 3 safety related devices. Two independent logic units A and B each receive signals from 5 input sensors. Each logic unit has a separate pair of shutter line sensors. Shutter gate position sensors are shared because of space requirements. The logic units have separate power supplies. Each logic unit controls one actuator-relay used to break the interlock circuit. Actuators are connected sequentially.

The logic units are programmed to perform diagnostic checks on the input sensors. If diagnostic coverage fails, actuators are activated, the shutter electronics break the interlocking circuit. Diagnostic checks of the actuators (relays) are performed on system start up Start up diagnostics can detect stuck relay contact.

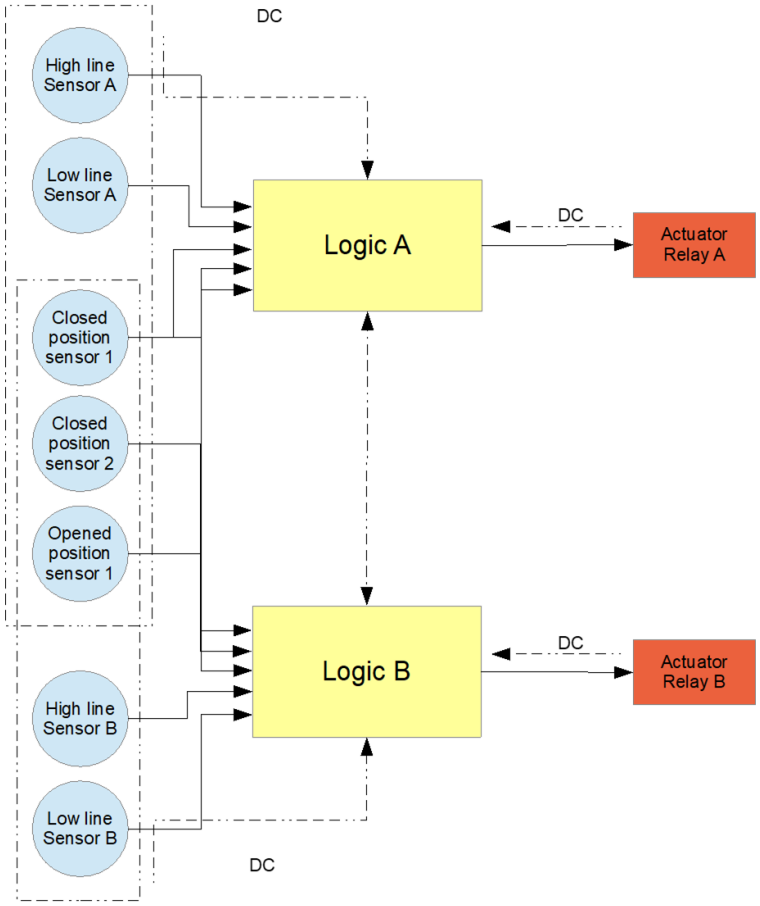


Figure 16. Shutter control structure

While operating without failures the shutter can be in one of three states: closed, opened and transitional. The transition state is initiated when a change of state is detected on any of Low Line and High Line input sensors. Transition state lasts for 210 ms. In this state the shutter gate is moved and any information from all sensors is ignored. After the transition state finishes, the sensor check is enabled, and the shutter control logic enters one of two normal states or the failure state.

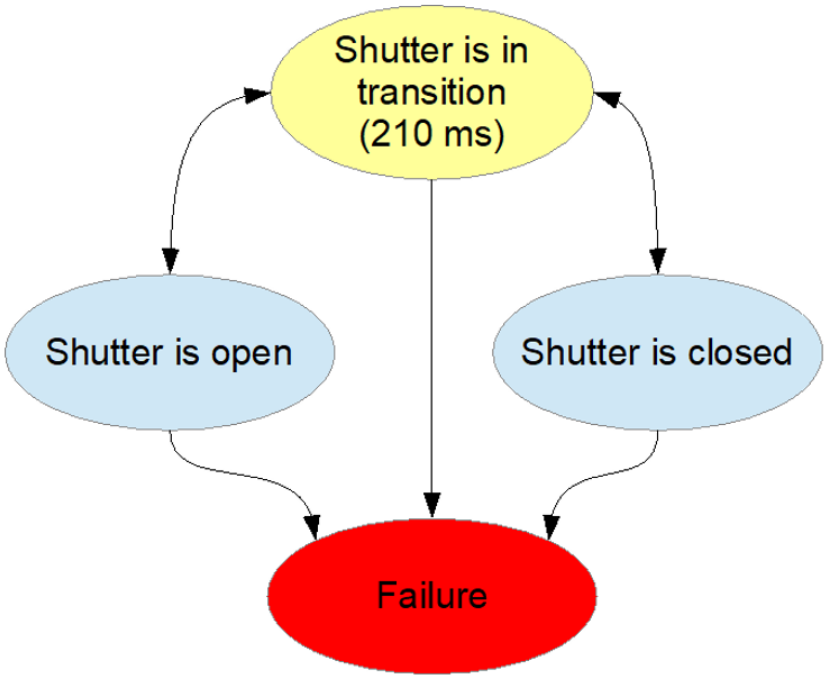


Figure 17. Shutter controller logic states

3.3.0.3 Shutter Timing Specifications

If the voltage level change on the shutter high and/or low control lines is longer than 13.1 ms, then the shutter enters the transient state and the status of the proximity sensors is ignored. The shutter leaves this state automatically after 210 ms.

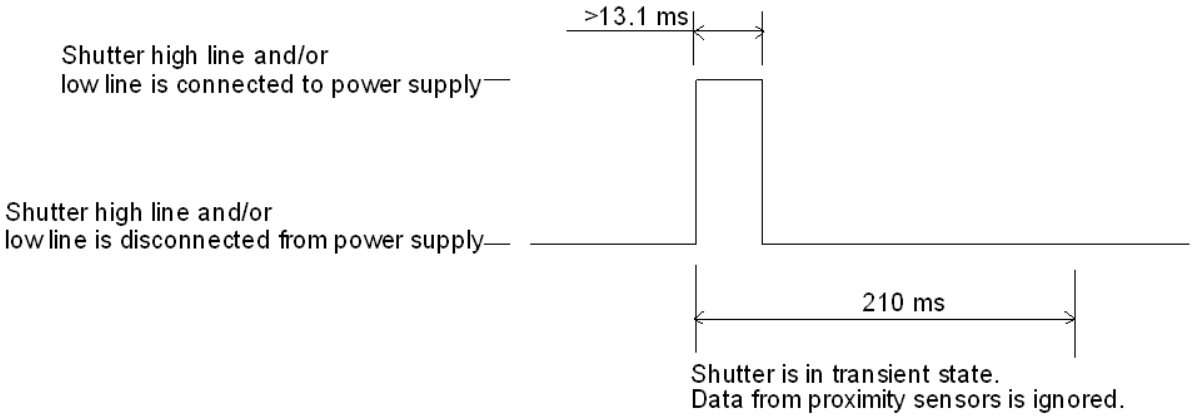


Figure 18. Shutter transient state

To protect the shutter from staying in the transitional state permanently, the maximum shutter operating frequency is limited to 3 Hz. If 3 pulses (7 state changes) longer than 13.1 ms are generated on the shutter high and/or low control lines in a 1000 ms period, the shutter generates a FAILURE signal.

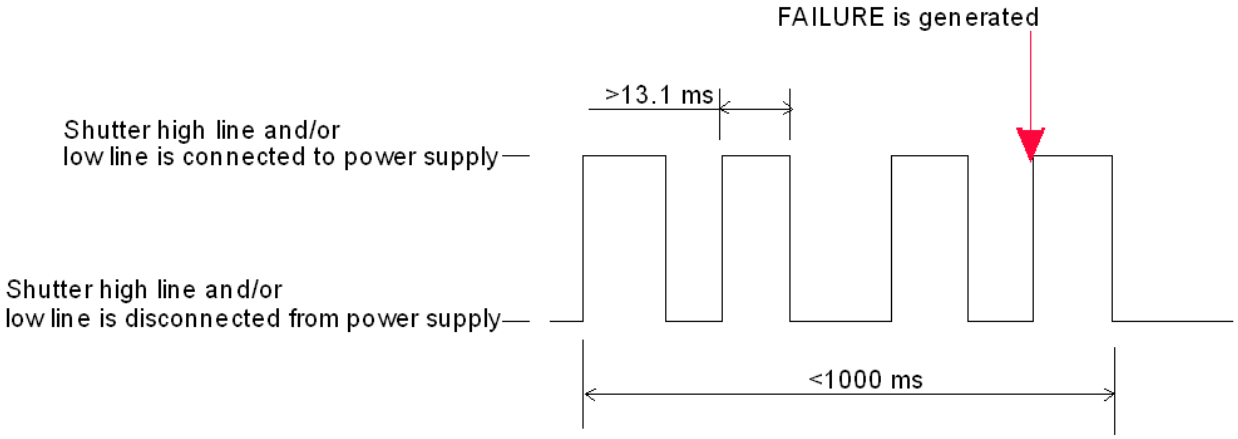


Figure 19. Protection from frequent shutter state changes

To protect the shutter from staying permanently in the transitional state because of oscillating high and/or low control lines (or shutter control switch bounce) the number of control line state changes is limited to 512.

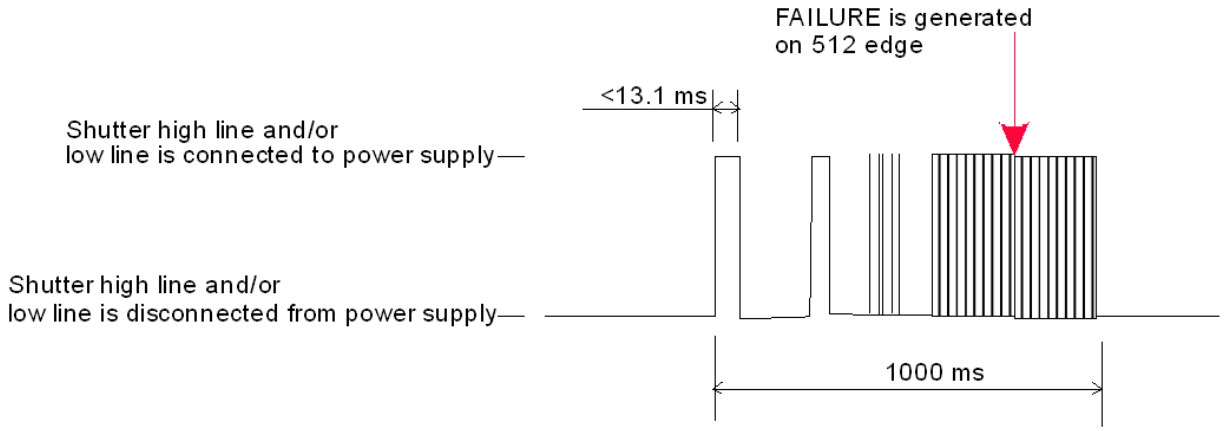


Figure 20. Protection from oscillating shutter lines

Table 13. Summary of shutter timing parameters

Duration of transitional state	210 ms
Shutter gate move time	~100 ms
Shutter operating frequency	<3 Hz
Max. count of shutter control line changes (state change last longer than 13.1 ms)	7 in 1000 ms period
Max. count of shutter control line changes (state change last less than 13.1 ms)	512 in 1000 ms period

Table 14. Shutter electrical specifications

0V input line	0V
24V input line	0-26V, 500 mA max.

Table 14. Shutter electrical specifications

Requirements for power supply used to feed shutter controller logic and shutter solenoid	Class II electrical power supply meeting SELV requirements ☐	
Shutter solenoid 0V control line	0-26V, 500 mA max.	
Shutter control 24V logic supply voltage	0-26V, 500 mA max.	
Shutter control logic supply voltage	Min Nominal Max	8V 24V 26V
Remote interlock lines	5V DC, 100 mA max.	
Emergency STOP lines	0-60V DC, 500 mA max.	

3.3.0.4 Shutter Control

NOTICE ***A two-channel switch must be used to open and close both shutter control lines simultaneously***

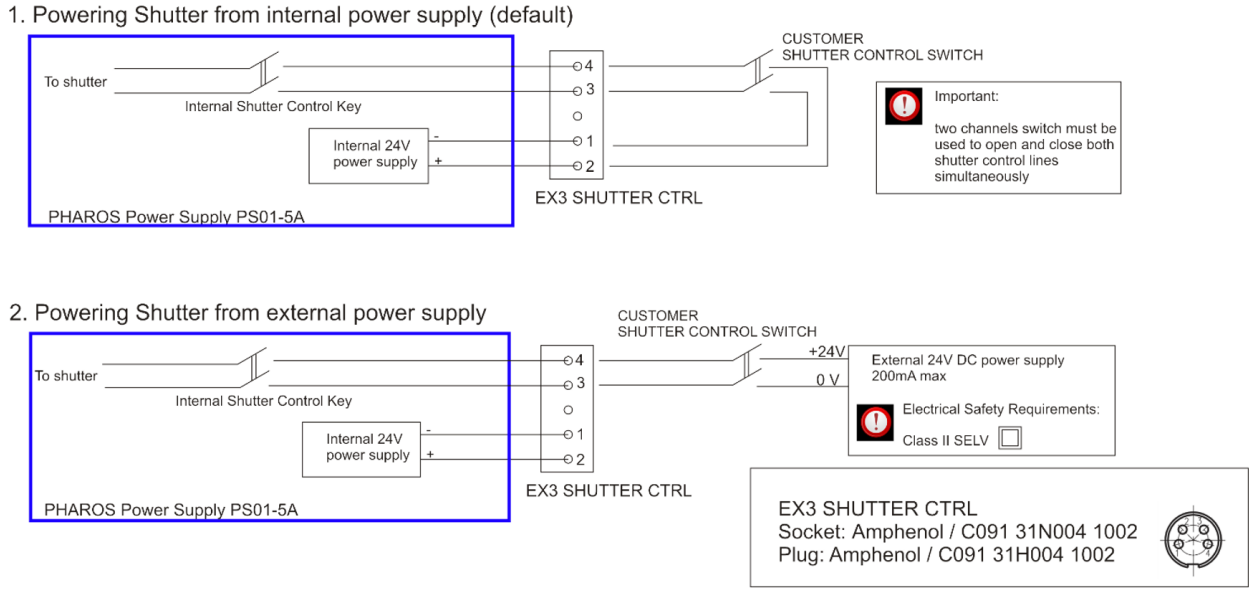


Figure 21. Shutter control options

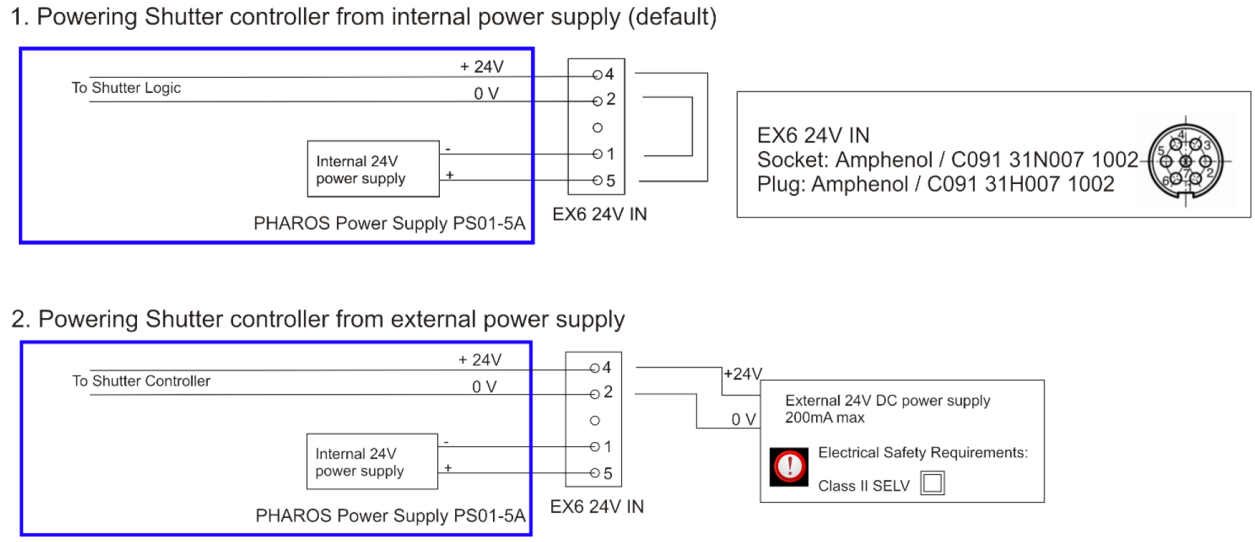


Figure 22. Powering shutter controller options

3.3.1 Remote Interlock

The PS01-5A PSU provides remote interlock functionality as required by IEC 60825-1. This function is realized by the shutter controller. Initially a bypass plug is provided, deactivating the remote interlock.

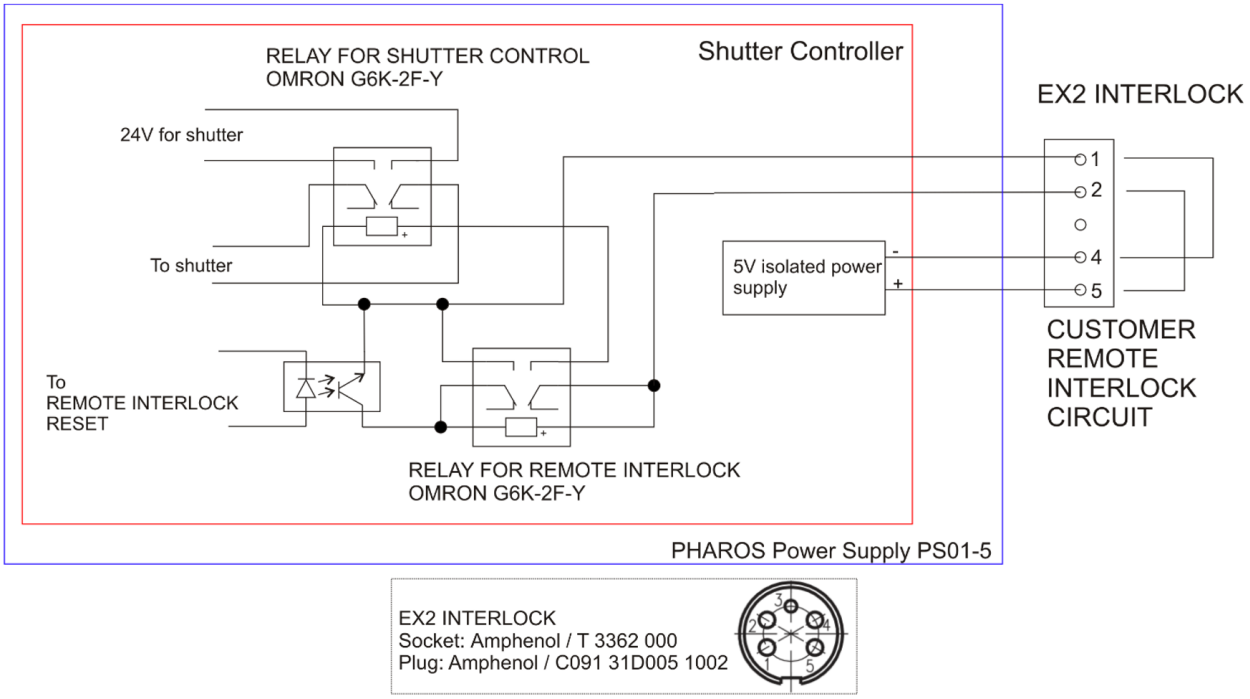


Figure 23. Interlock circuit

To use the remote interlock, the user must provide two closed lines to socket EX2. If one or both lines are opened, then shutter is closed automatically. Check the figure above for information how to implement the remote interlock.

The remote interlock active state is displayed by an indicator led on the power supply front panel. Resetting the remote interlock is possible only by pressing *Reset Remote Interlock* button on the front panel of the power supply.

3.3.2 Emergency Stop (E-STOP)

The emergency stop function must be implemented by the user. The PS01-5A PSU provides two emergency stop (E-STOP) lines. These lines are controlled by the shutter controller and are in the closed state when the shutter is operating normally. The state is changed to open when shutter failure is detected. Shutter failure and activation of E-STOP lines are shown by an indicator on the front panel of the PSU. Check figure below for recommendations on emergency stop circuit implementation.

Socket EX6. 24V IN can be used to provide a separate 24 V voltage for the shutter and USB channel controllers in case of emergency shut-down of the laser system. This allows to keep shutter controller alive in case of emergency stop of the laser and be able to read the shutter state and the cause of the shutter failure.

Initially the PS01-5A PSU is provided with a bypass switch powering the shutter controller from the internal 24V power supply.

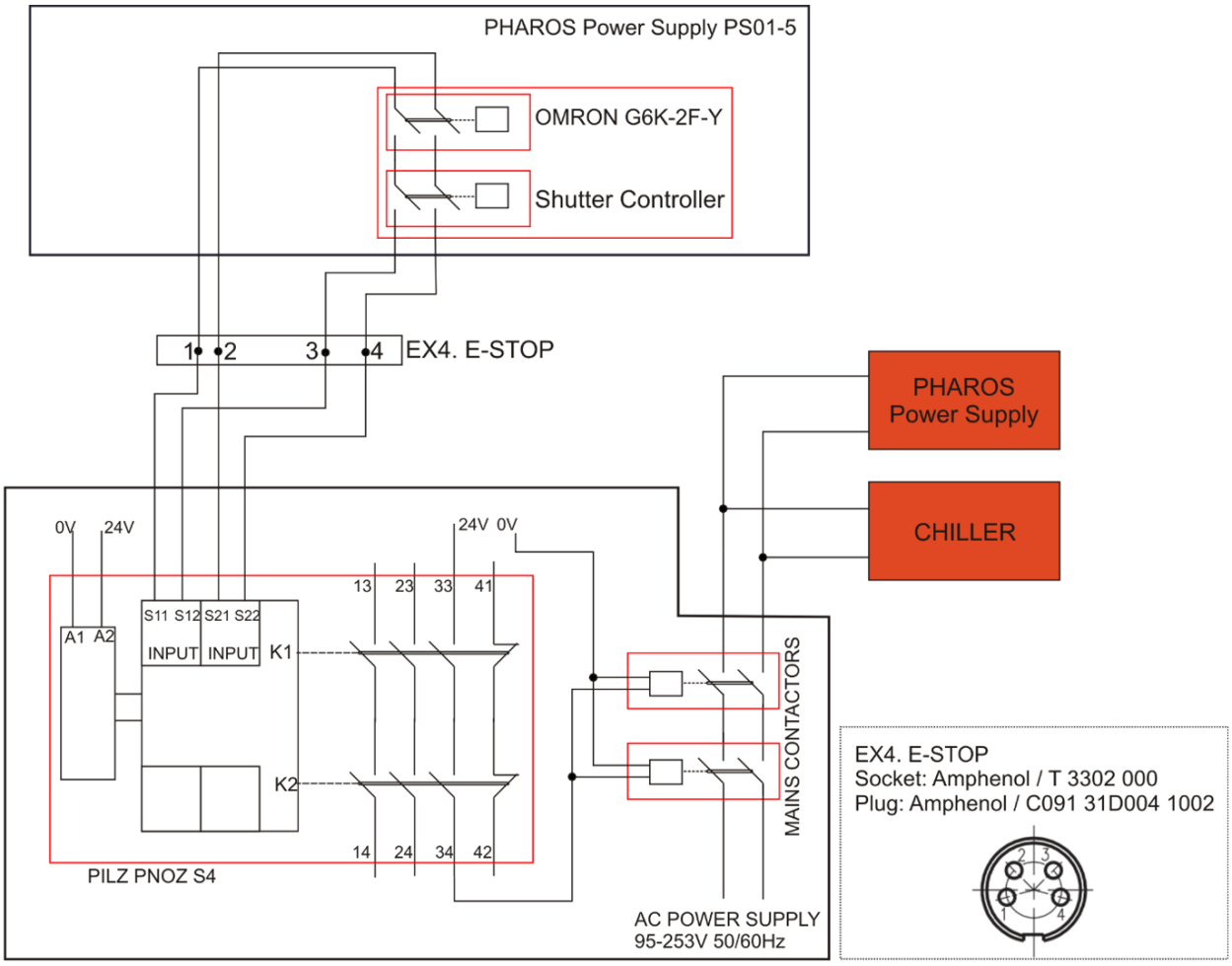


Figure 24. Recommended user emergency stop circuit

3.3.3 Shutter Status Connector EX13 Pinout

Table 15. Shutter status connector EX13 pinout

Pin	Description		Pin	Description
1	GND		9	Active on shutter error (active state 24V, inactive state 0V)
2	Active if shutter is closed (active state 24V, inactive state 0V)		10	Active on shutter error (active state 24V, inactive state 0V)
3-7	Not in use		11-14	Not in use
8	Remote Interlock Reset input (4kOhm pull up to 3.3V). Must be connected to pin 15 to reset active remote interlock state		15	GND for Remote Interlock Reset

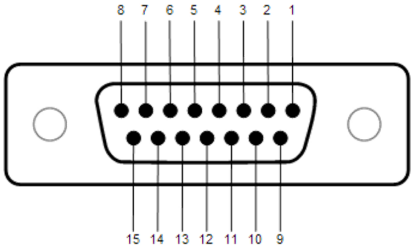


Figure 25. Shutter status connector EX13

3.3.4 Power Supply Status Connector EX8 pinout

The active state corresponds to 24 V and the inactive state corresponds to 0 V output.

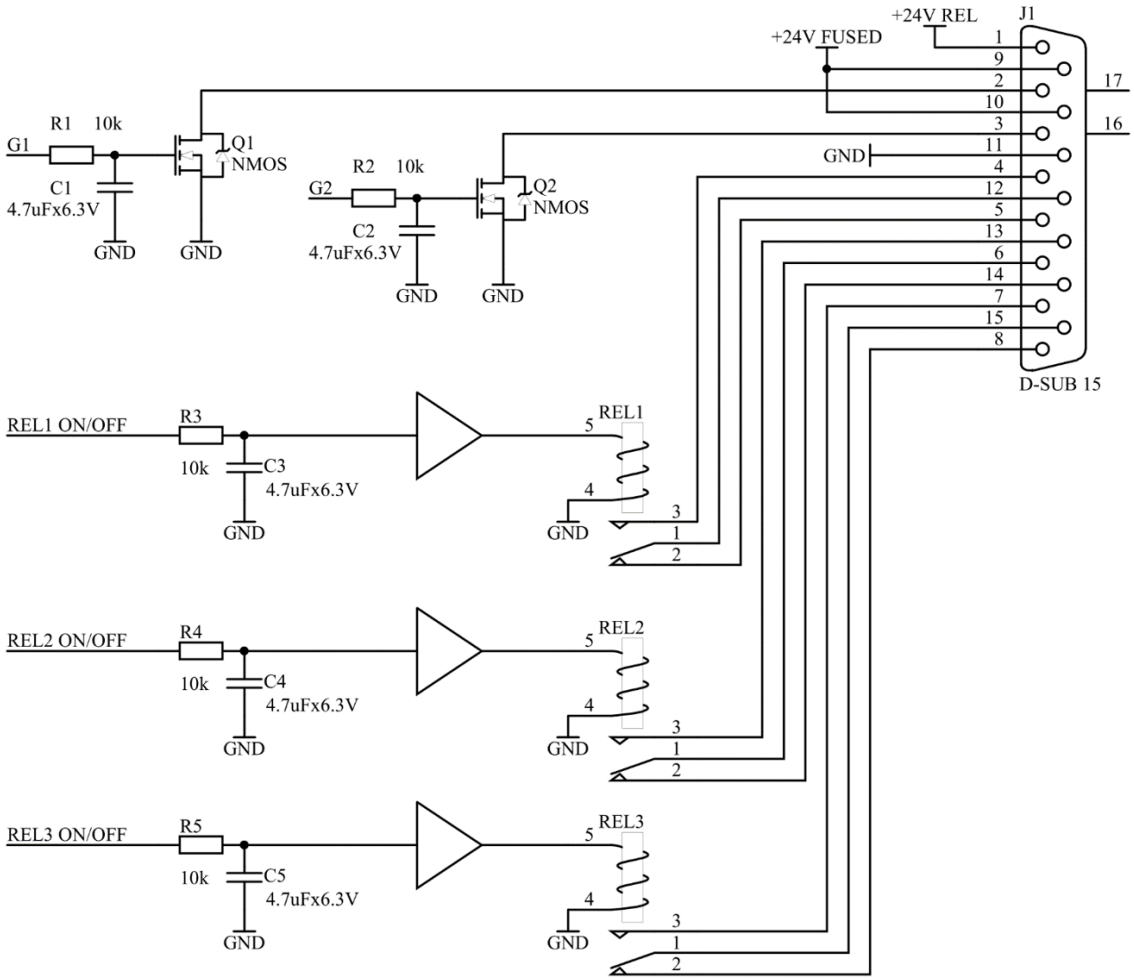


Figure 26. Power supply status connector EX8 circuit diagram

Table 16. Power supply status connector EX8 pin out

Pin	Description		Pin	Description
1	24V output if power supply PS01-5A is switched on		9	24V output if power supply is connected to AC line
2	Open drain output. Active (connected to the ground) if shutter error is detected		10	24V output if power supply is connected to AC line
3	Open drain output. Active (connected to the ground) if shutter is opened		11	GND
4	Galvanically isolated output connected to pin 12 when power supply is turned on		12	Common pin for relay connected to pin 4 or 5
5	Galvanically isolated output connected to pin 12 when power supply is turned off		13	Galvanically isolated output connected to pin 6 when shutter is opened
6	Common pin for relay connected to pin 13 or 14		14	Galvanically isolated output connected to pin 6 when shutter is closed
7	Galvanically isolated output connected to pin 15 when remote interlock is active		15	Common pin for relay connected to pin 7 or 8
8	Galvanically isolated output connected to pin 15 when remote interlock is not active			

3.4 User Output Panels

Outputs from the TEM and some additional photodiodes are located on the panel fitted on the rear of the PHAROS head (see figure below). See table below for a description of user TEM outputs.

Figure 27. PHAROS user output panels (standard and OEM versions)

Table 17. Description of user TEM inputs and outputs

Name	Direction	Description	Connector type
PD OUT	Output	50 Ohm coaxial output from PHAROS output photodiode	BNC socket
PD RA	Output	50 Ohm coaxial output from RA photodiode. This sensor is used to monitor laser pulses inside RA cavity	BNC socket
PD OSC	Output	50 Ohm 2.4V coaxial user's output. This output can be programmed to monitor different signals. Output is source terminated and can be used on high resistance load as 5V output	BNC socket
SCOPE	Output	50 Ohm 2.4V coaxial user's output. This output can be programmed to monitor different signals. Output is source terminated and can be used on high resistance load as 5V output	BNC socket
SYNC1	Output	50 Ohm 2.4V coaxial user's output. This output can be programmed to monitor different signals. Output is source terminated and can be used on high resistance load as 5V output	BNC socket
SYNC2	Output	50 Ohm 2.4V coaxial user's output. This output can be programmed to monitor different signals. Output is source terminated and can be used on high resistance load as 5V output	BNC socket

Table 17. Description of user TEM inputs and outputs

Name	Direction	Description	Connector type
HV CTRL	Input	10 kOhm Coaxial input for PP HV control. This input can be used to control the laser output power. Analogue mode must be enabled for this mode to work. Input signal voltage range: 0-10V	BNC socket
REMOTE	Output/Input	PHAROS external control interface connector	DB15 socket

4 INSTALLATION

4.1 Unpacking

NOTICE	***The PHAROS laser was packed with great care and its container was inspected prior to shipment. If any major damage was noticed at the time of receipt (holes in the container, water leak, crushing, etc.), please, notify the carrier and manufacturer.***
NOTICE	**If laser was transported in cold weather conditions, keep it in transportation boxes for at least 6 hours at room temperature to prevent possible water condensation on sensitive components of the laser after opening. Laser head is hermetically sealed.**
NOTICE	**It is recommended that you wait for Light Conversion representative to unpack your system. In no event you should attempt to install the laser by yourself without prior agreement from Light Conversion. Any unauthorized action may result in warranty void charge for the repair of any damage.**
NOTICE	***PHAROS laser head weights 53 kg. To avoid any mechanical or personal damage, unpacking and installation of the laser system should be done by at least two people!***
NOTICE	**The Power Supply may only be connected/disconnected to/from the laser only while it is disconnected from the mains! Disconnecting or connecting the power supply while it is connected to the mains may damage the laser control boards.**

1. Carefully open the transportation boxes without damaging them. Transportation boxes might be necessary for future transportation. The latest example of the laser head transportation box is equipped with holding mechanisms that tightly close the lid of the transportation box without the need of any screws. Raise the collapsible handle of each lock and loosen the grip, until the gripping claw can be moved away from the lid. Once all gripping claws are removed, lift the lid to uncover the laser (see Figure below). Transportation boxes may vary depending on the equipment (some will be closed with simple screws or Allen (hex socket) screws).

Figure 28. Handling of a transportation box

2. Unpack the transportation boxes, remove all external components, such as the humidity absorbers, cables, manuals, factory test certificates. Take all contents out of the top layer and remove packing material.

Figure 29. Transportation box contents

NOTICE

The contents of the transportation boxes may vary depending on the laser model, modification or any other special-order alterations. The contents and their placement provided earlier are intended as an example only and does not guarantee the presence of these items in your shipment. Please check the "Assembly List", which is normally packed with the laser head for a full list of all contents of your shipment (see figure below), if some components are missing based on your "Assembly list", please contact Light Conversion.

LIGHT CONVERSION
UAB MGF Šviesos Konversija

ASSEMBLY LIST	L18925
	P4-F2 v.1
Product: PHAROS	Page 1 of 1
Assembled by: Remigijus Sirutis	2018-06-20

Box #1

ITEM	DESCRIPTION		QUANTITY	NOTES
1.	PHAROS laser head PH1-10-0200-02-10 S/N: L18925		1	
2.	PHAROS factory test certificate		1	
3.	Fixing screws for laser head M6x25 (metric)		7	

Box #2

ITEM	DESCRIPTION		QUANTITY	NOTES
1.	Power supply PS01-5A, S/N: PS-1026		1	
2.	Power cable for power supply C19<-> EU (Schuko), 250V 16A	MC10-300	1	
3.	Power cable for chiller C19<-> EU (Schuko), 250V 16A	MC10-300	1	
4.	Chiller data cable	P59-100	1	
5.	Chiller start cable	P55-100	1	
6.	USB cable for power supply/computer connection	P58-200	1	

Box #3

ITEM	DESCRIPTION		QUANTITY	NOTES
1.	Chiller Termotek, Type P307-22305, water-to-air S/N: 91237		1	
2.	Spare filter for chiller		1	
3.	Test protocol of chiller		1	

Figure 30. Assembly list example

3. Remove the laser head, PSU and chiller from the transportation box.
4. Place the laser head on the optical table (or onto other machinery in which it will reside) and fix it using appropriate screws (screws are normally provided along with the laser). Fixing of the laser

head with an external enclosure is shown in figure below. Note that you will need to remove the cover of the PHAROS external enclosure and disconnect the grounding cables (see figures below).

	NOTICE	***Avoid harsh mechanical impacts when placing the laser head on the optical table. Be careful while positioning the laser head in to the correct position.***
	NOTICE	***Cylindrical bearings in the mounting legs have some backlash in the axial direction. When fixing the laser head to a base-plate it is necessary to check that the position of the bearing is not up to the edge. This may cause mechanical deformations in the housing of the RA.***

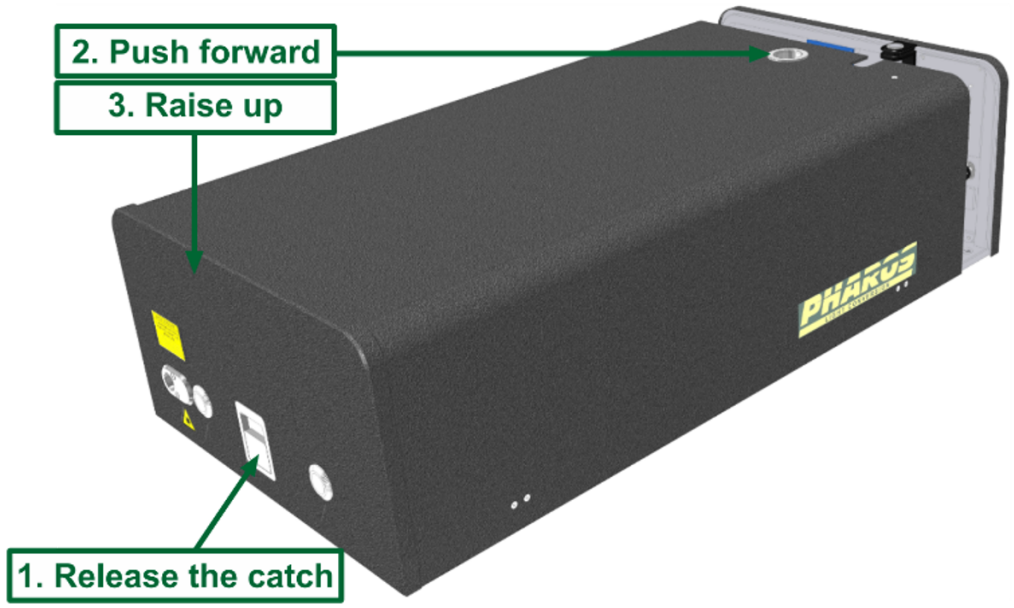


Figure 31. Cover removal of a laser with an external enclosure

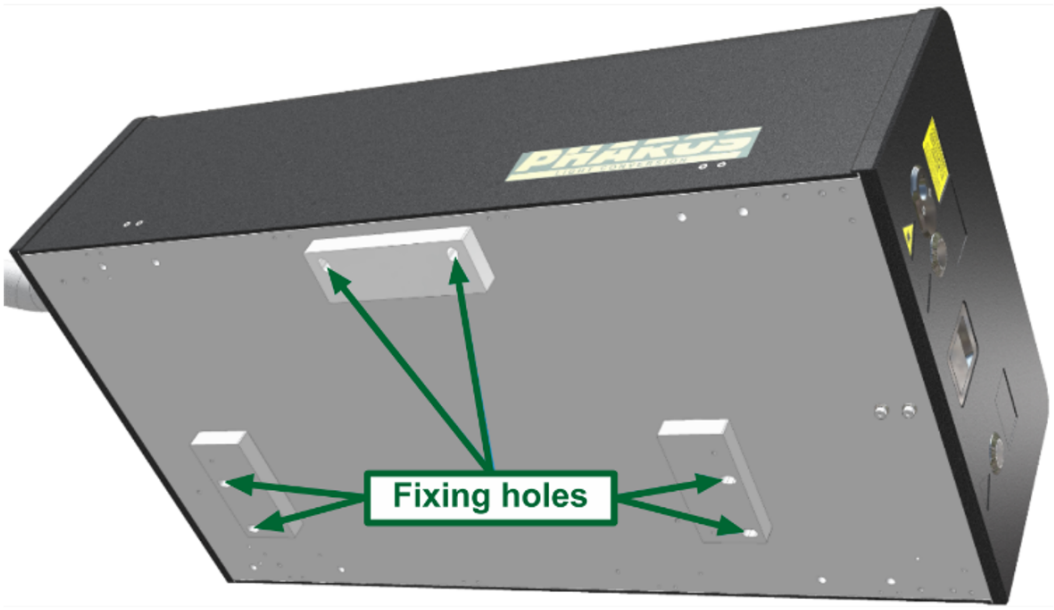


Figure 32. Bottom view of the PHAROS laser head. The six fixing holes are marked with arrows

5. Mount the Chiller and the PSU into the rack enclosure (see figure below), **if it is supplied with the laser system.** It is recommended to mount the Chiller on the lower rack, while the PSU should be

mounted on the top rack. This reduces potential damage in the event of a water leakage from the chiller.

Figure 33. Rack enclosure with recommended equipment placement

WARNING ***When connecting or disconnecting the EX12 Harting modular plug (R5-500) to the laser, the power supply must be unplugged from the mains.***

6. Connect the cables:

   a. Prepare to connect the "R5-500" umbilical from laser head to the PSU socket EX12. The "R5-500" is supplied already affixed to the laser head, it is covered in a metallic mesh to reduce EM radiation (see figure below). **The power supply must be turned off when connecting the umbilical!**

Figure 34. R5-500 umbilical

   b. To properly connect the "R5-500" umbilical, make sure that the connector is properly aligned with the PSU socket, and the connector patterns match on both sides. Once the umbilical is placed, pull on two fixators from the PSU towards the "R5-500" umbilical connector to firmly fix it in place (see figure below).

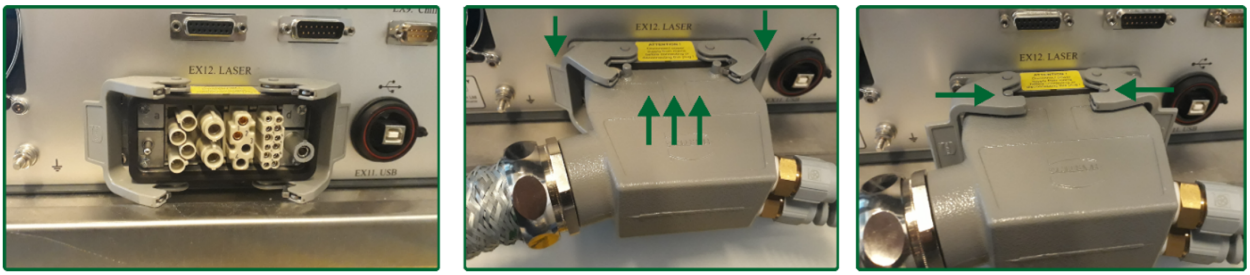


Figure 35. R5-500 umbilical connection

c. Connect the serial communication cable from the chiller (**Termotek or SMC**) to the PSU:

- Socket "RS232" on the chiller to socket EX9 on the PSU (**Termotek chiller**) (for examples, see figures below).
- RS 232 type socket (unmarked) on the chiller to socket EX9 on the PSU (**SMC chiller**) (for examples, see figures below). Please note that the SMC chiller must be connected by using a special adapter, which removes the 9th pin from the RS 232 connector.

d. Connect the Termotek remote Start cable to the PSU. Socket "INTERLOCKS" on the chiller to PSU socket EX8 (**Termotek chiller**).

Figure 36. Termotek chiller to laser power supply connection

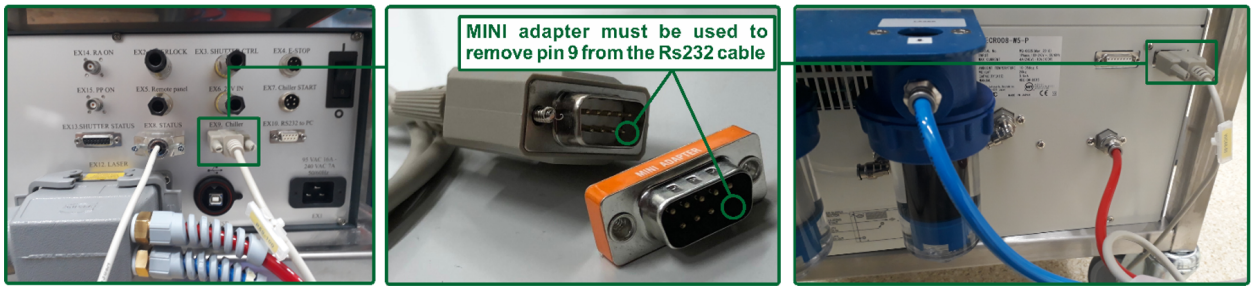


Figure 37. SMC chiller to laser power supply connection

e. Connect the mains power cables to the Chiller and the PSU.

f. If an emergency stop circuit is used, connect the Emergency STOP lines to the PSU socket EX4.

g. If interlocks are installed, remove the bypass connector ad connect the interlock lines to the PSU socket EX2.

7. Locate the shutter key, packed with the PSU wires in the PSU transportation box. Put it into the shutter control keyhole on the front panel of the PSU:

8. Connect the water tubes from the laser head (from the R5-500 connector) to the chiller. Check the colour coding on the tubes and water connectors.

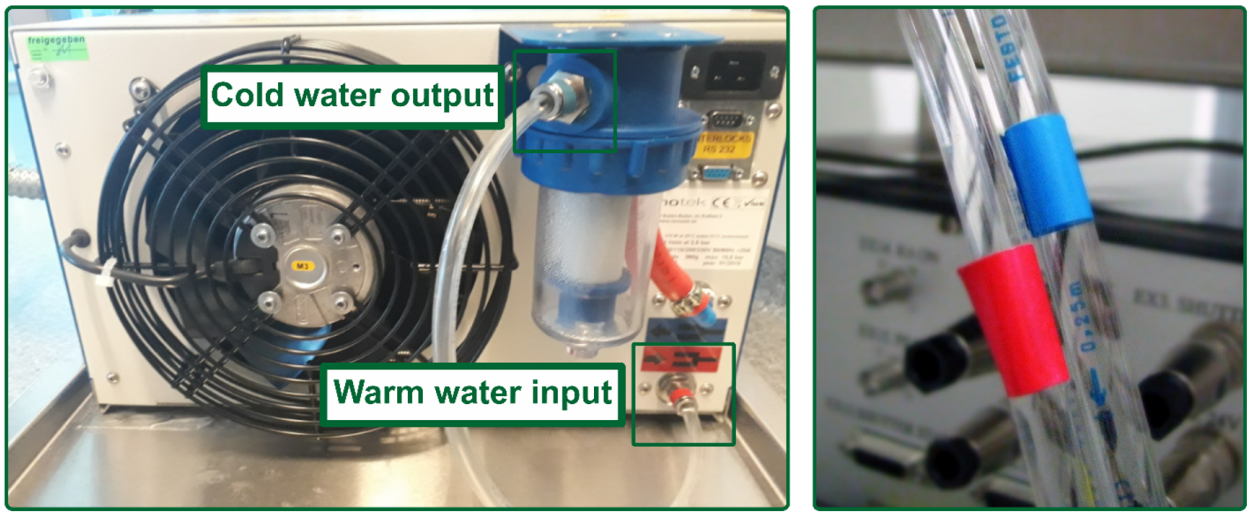


Figure 38. Color coding on chiller water fittings and tubes

	NOTICE	***The direction of cooling water flow is important for correct system operation. Connect the hoses carefully with proper flow direction. Incorrect flow may cause unstable operation.***
	NOTICE	***Chiller should be placed in such a way, so that the warm air exhaust at the rear panel does not vent into the PSU and vice versa.***

9. Fill the chiller with purified water (distilled (preferred) or deionized). Note that the manufacturer does not recommend using any special water additives to prevent corrosion and/or growth of algae. Consult the manufacturer before using any water additive. Make sure the coolant level is somewhere in between the minimum and maximum mark. There is a possibility of some air remaining trapped inside. Once the system is running it is mandatory to check the coolant level, as it may decline. Check the chiller manufacturer user manual for more information.

Figure 39. Coolant filling and coolant level location for Termotek and SMC chillers

NOTICE

The user must not operate the chiller without coolant. The coolant level must be checked regularly and maintained to an appropriate level.
Use only steam-distilled or Type II and lower grade (resistivity less than 18 MΩ·cm) deionized water.

10. Turn the PSU main switch (located on the back of the unit) on and a front-located power button to position *"*Power ON*"*. Then turn the shutter key to position "Open". As a safety precautionary measure, when the laser is not in use, the shutter key position should be turned to position "Closed".

Figure 40. Power supply switches

11. Check the chiller for water leakage. Add water if necessary. The temperature of the cooling water must be set to the operating temperature defined in the *"Factory test certificate"* (**typical value: 23^{o}C**). Adjust the bypass valve of the chiller to reach the water flow value given in the *"Factory test certificate"* (typical flow rate is 3.0 l/min). **Consult the chiller manual for adjustment of the flow rate. To set operating temperature follow these steps described for each chiller:**

    a. For the **Termotek chiller**, once it is on, locate the display on the front panel. Click the "ESC / Set point" button to display the operating temperature, afterwards adjust it with the arrow keys. Once the necessary temperature is set, click the "Enter Arrow / Menu" button to save the set temperature.

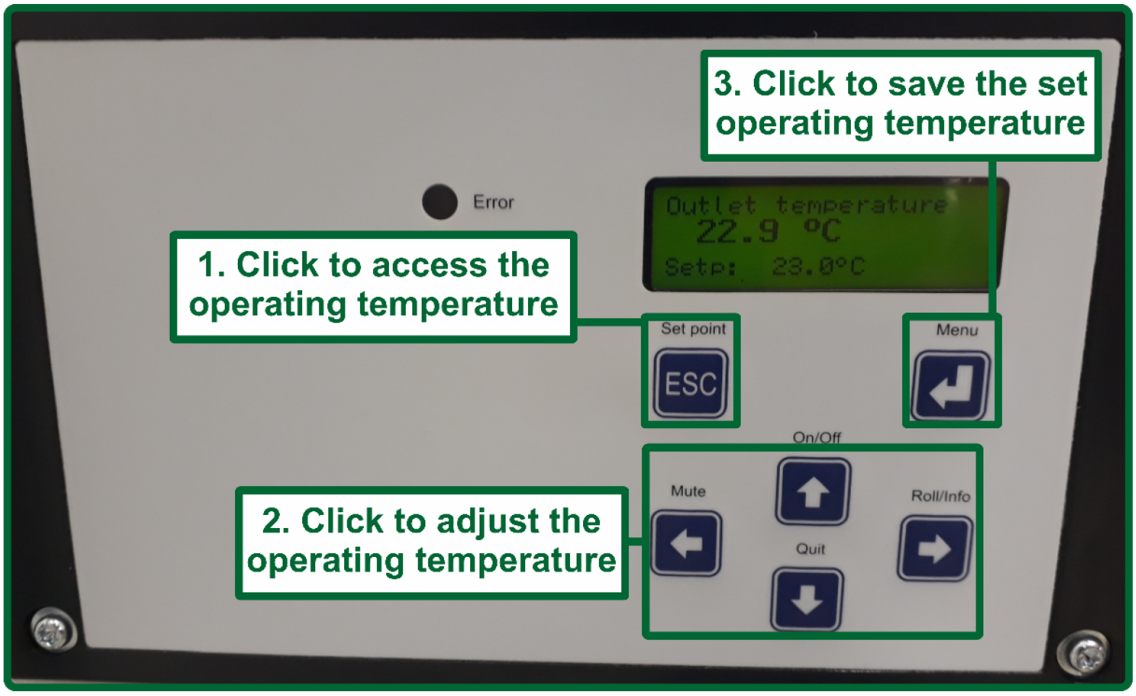


Figure 41. Termotek chiller operating temperature adjustment

b. For the **SMC chiller**, once it is on, locate the display on the front panel. Click the "SEL" button until you see the window show in Figure. Once there, click the up and down arrows to adjust the operating temperature. The setting is saved automatically. **PV** – is the current temperature, **SV** – the set operating temperature.

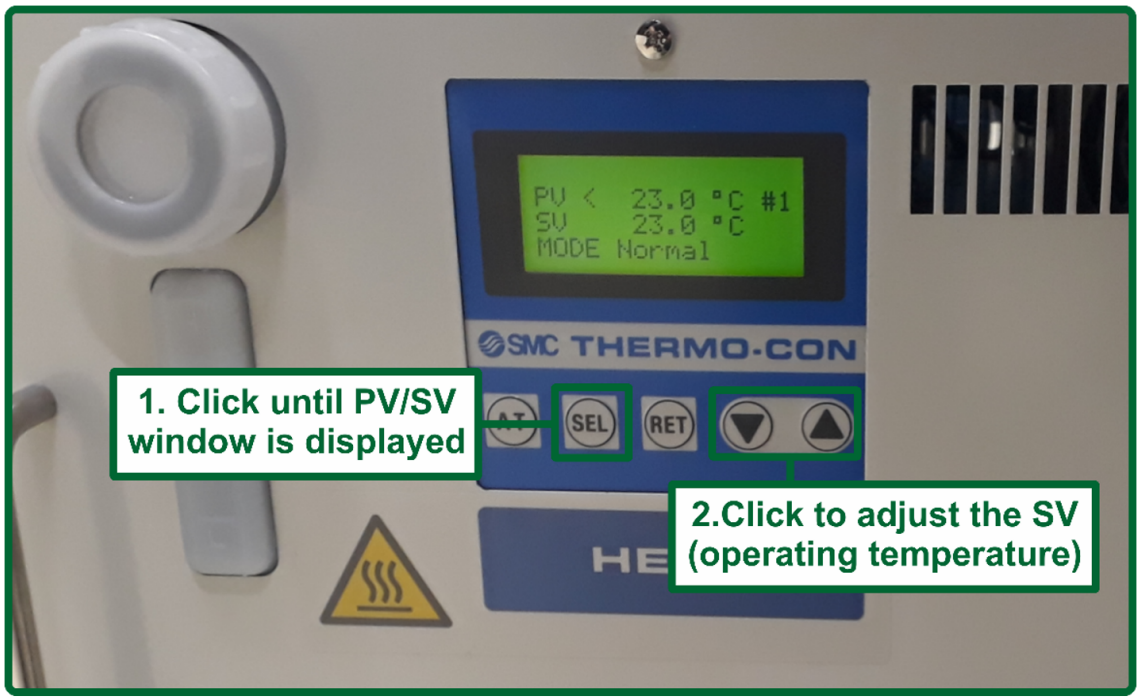


Figure 42. Termotek chiller operating temperature adjustment

12. Wait until the chiller temperature reaches the setpoint.
13. Install the PHAROS software. The PHAROS software can be found on the USB memory card shipped with this manual or attached to the factory test certificate. Software along with the

manual can also be downloaded from the Light Conversion website (www.lightcon.com; registration is required to access the downloads section).

Figure 43. Termotek chiller operating temperature adjustment

14. Connect the computer to the PSU via provided USB cable. The USB cable is constructed with a screw-on fixator on the laser side. Once the cable is connected, it is important to screw on the cap for a firm connection and to avoid accidental damages.
15. Start up the PHAROS User App and press the "Connect" button, located in the top right corner of the application window.
16. Press "Go to standby" when prompted. This procedure initiates the start of the laser OSC.
17. Choose a laser setting pre-set from the list and press execute. After the preset is executed, the laser is ready for use (an information message "Operational" will appear in the top left corner of the app).

5 DAILY OPERATION

	**NOTICE**	***PHAROS control software can be installed on any PC with a Window 7 or newer operating system. If required, .NET framework will be installed automatically.***
	**NOTICE**	***The control software is updated often. Therefore, screenshots herein may not exactly model the current version, and should be used for illustration purposes only.***
	**NOTICE**	***The Power Supply may only be connected/disconnected to/from the laser only while it is disconnected from the mains! Disconnecting or connecting the power supply while it is connected to the mains may damage the laser control boards.***

The newest versions of PHAROS User and Service Apps can be downloaded from Light Conversion web site (www.lightcon.com). User registration is required to access the downloads section.

5.1 Installing the PHAROS User App

	**NOTICE**	***Section is based on the PHAROS User App version 3.14.0***

The PHAROS Service application installation package is supplied on a USB memory stick stored in the system manual. The latest version of the software can be downloaded from the Light Conversion website, PHAROS support section (registration required). If PHAROS laser is delivered with the control computer, PHAROS control software is already installed.

The PHAROS Service application supports 32 and 64-bit operating systems from Microsoft Windows 7 and onwards. To install the software run the installation file and follow the installation instructions. After the software is installed, connect the PHAROS power supply to the mains, plug the USB cable into the computer and PHAROS PSU. Windows will detect new hardware and install the drivers.

5.2 Start-Up

1. Check if the power supply is turned on (button of the front panel of the PSU). If previously the laser was switched off using the control app, chiller will not be running.
2. Start the PHAROS User App and press "*Connect*" in the top right corner of the menu bar.
3. Wait for the system to detect the laser state.
4. If asked, press "*Go to standby*". This will initiate OSC start.
   NOTE. If the PSU was turned by the button on its front panel, after turning on the PSU, the chiller will start as well. In this case, the software will detect system state as "*Failure*". This is a normal occurrence and you can proceed to the next step.
5. After the previous step is finished, choose a preset from the presets lits and press "*Execute*".

6. Wait for the preset to start. Once the laser is ready to use, press "*Enable*" to open the shutter and release the laser beam.

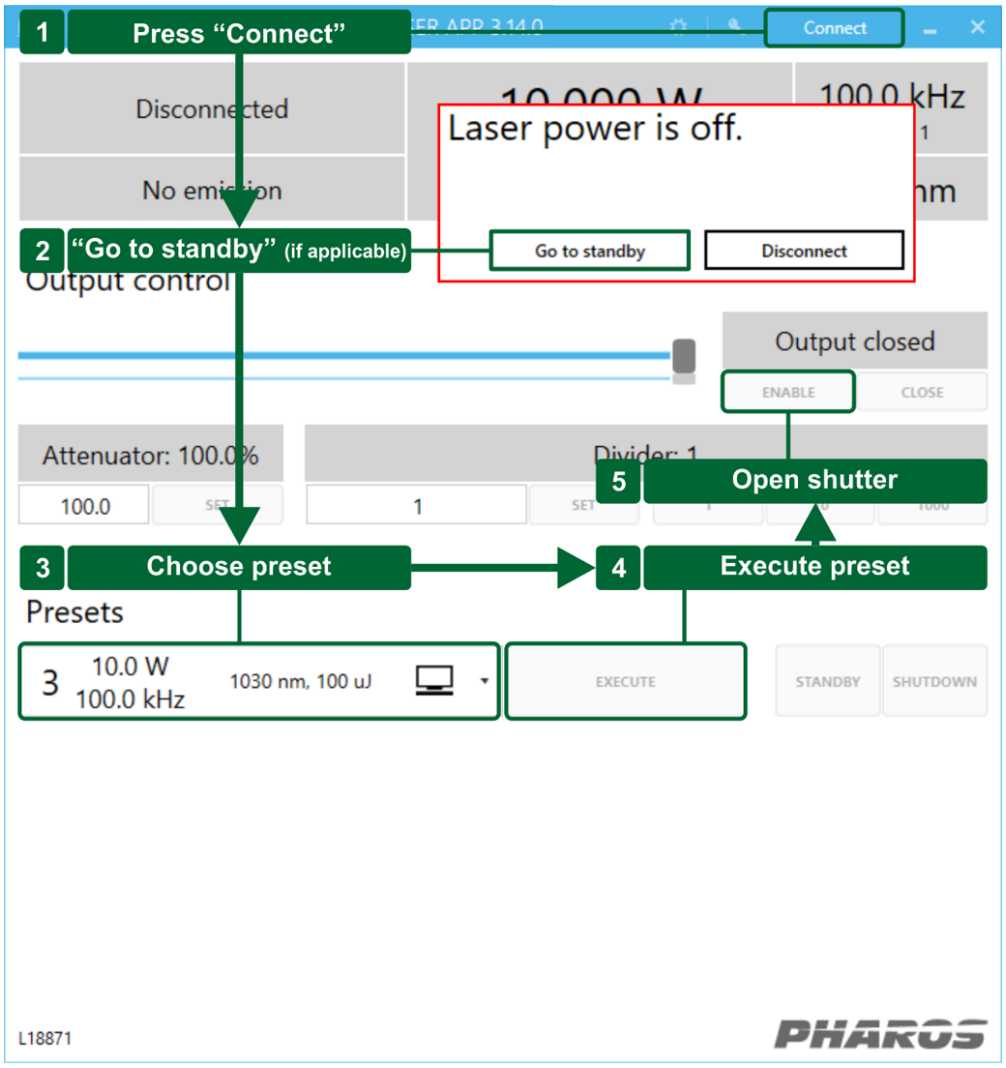


Figure 44. Start-Up procedure in the PHAROS User App

NOTE. Starting the laser in user access mode will execute a preset with single pulse mode (no pulse packets).

5.3 Shut-Down

1. Press "Shutdown".
2. Press "Shutdown laser" when prompted "What do you want the system to do?".
3. Wait until the laser is shut-down press "Disconnect" when message "Laser power is off" appears. If "Go to standby" is selected in the last step, software start the OSC and leaves it running.

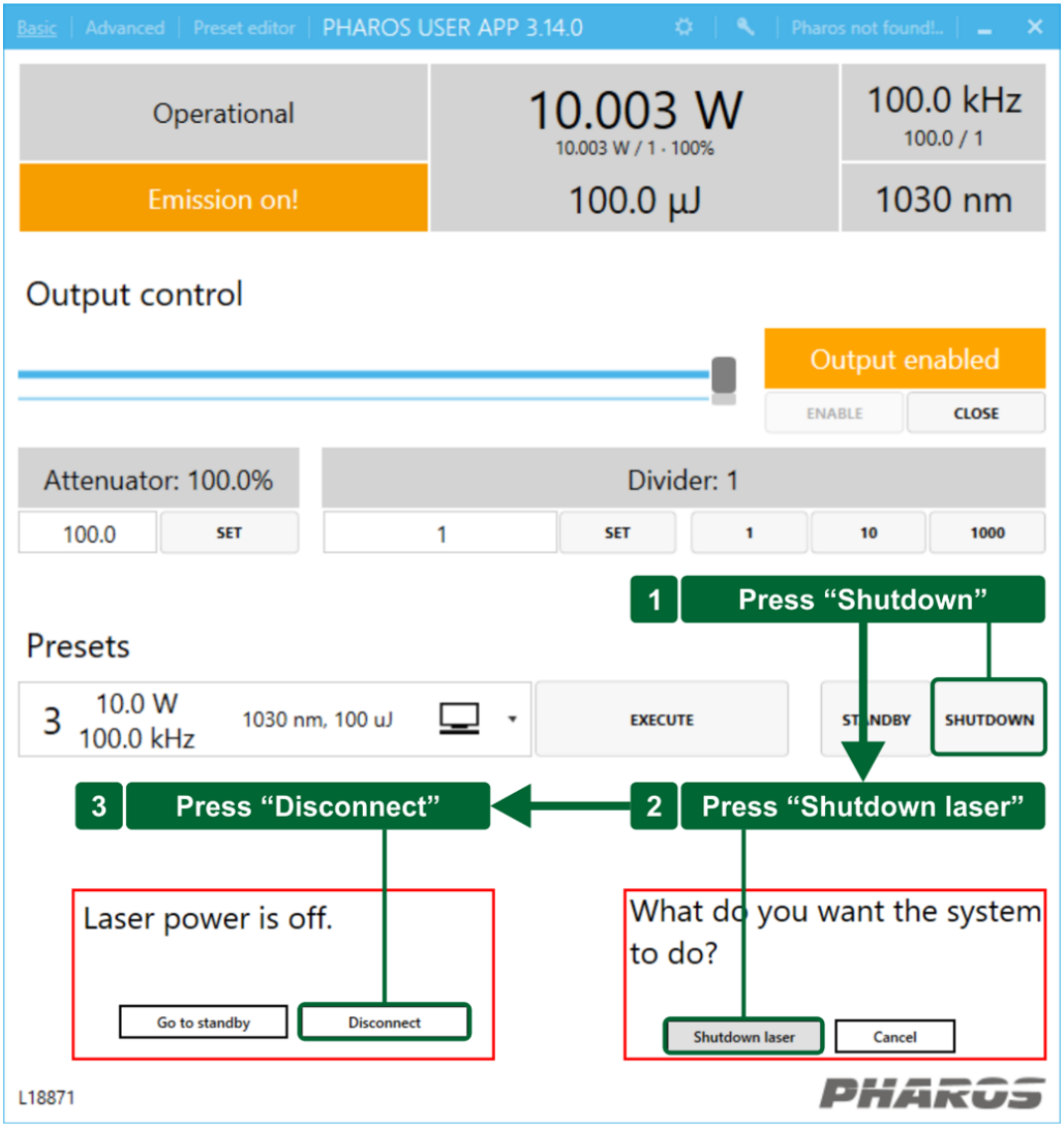


Figure 45. Shut-down procedure in the PHAROS User App

5.4 Pulse Picker Control

The PHAROS laser system has a pulse picker installed. The PP is an electrically controlled optical switch, which extracts pulses from a pulse train. PP divider reduces the repetition rate by emitting every n^{th} pulse and it does not change the internal amplifier frequency. The pulse energy remains the same, but the average power reduces by the same amount the repetition rate was reduced. I.e. if laser is running at 100 kHz repetition rate, entering a divider 10 (ten) reduces laser output frequency to 10 kHz by letting out only every 10^{th} pulse.

To control the PP:

- *Method 1*. Enter a desired value in the "Divider" window and press "Set".
- *Method 2*. Press one the three pre-defined buttons (default "1", "10", "1000").

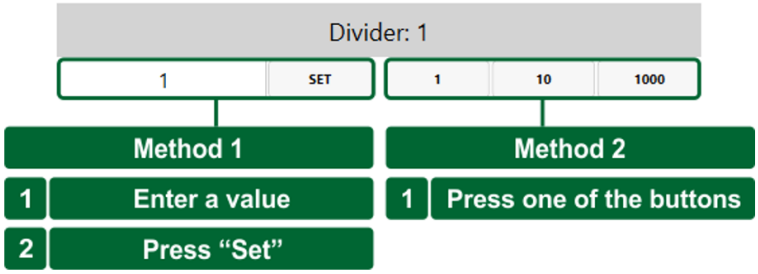


Figure 46. Pulse picker control in the PHAROS User App

When using the 2nd method, user can change the values of these three pre-defined PP divider buttons:

1. Enter PP value.
2. Press "*Set*" to set a divider.
3. Right mouse click on one of the buttons.
4. Press "*Set to actual*".

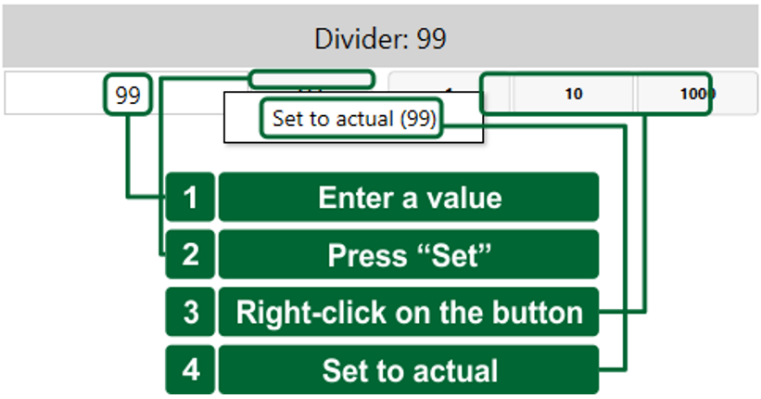


Figure 47. Change pulse picker value for the pre-defined button

5.5 Reduce Output Pulse Energy for the Current Preset

Output pulse energy can be reduced without changing the operation of the RA by the means of controlling the PP. This can be performed by adjusting the "Attenuator":

- To reduce output pulse energy (resulting in lower average output power), adjust the attenuator slider with a mouse, or enter a numeric value and press "Set". **NOTE:** Attenuator value "100.0%" corresponds to a full transmission.

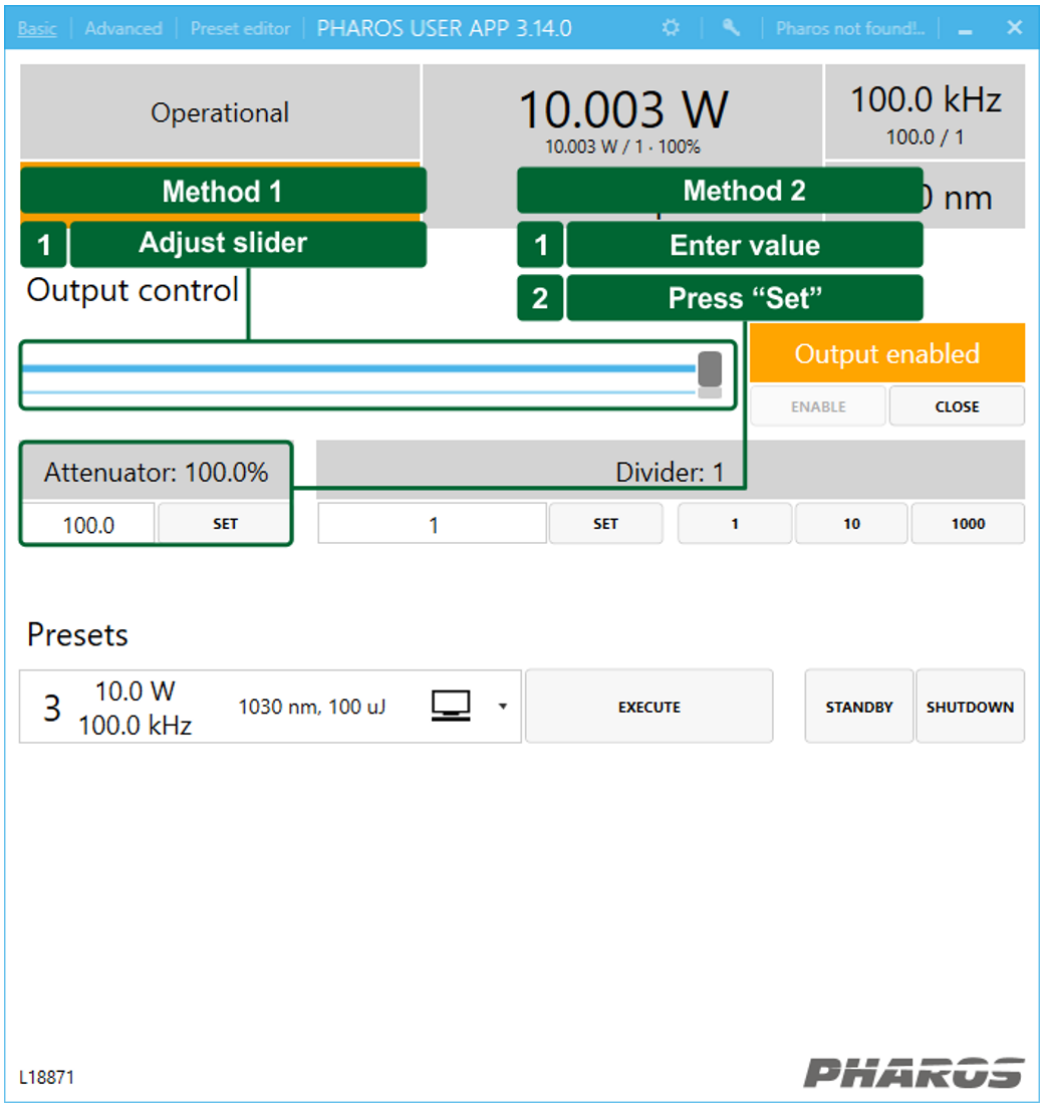


Figure 48. Attenuator adjustment to reduce output pulse energy

5.6 Adjust Compressor Position

If laser application requires pulse and/or post-pulse duration adjustment, i.e., increasing pulse duration to several picoseconds, or ensuring optimal compression, compressor adjustment can be performed:

1. Go to "*Advanced*" window.
2. Adjust the compressor by entering a value and pressing *"Set"*. Alternately it can be adjusted by pressing buttons ±10, ±100 or placing the mouse cursor on the digit and using the keyboard arrow keys "Up" and "Down".

Note that this compressor adjustment will not update an existing value in currently running preset and it will reset to a default position during the next laser start or preset re-execution. Refer to next section on how to save a new compressor value to the current preset.

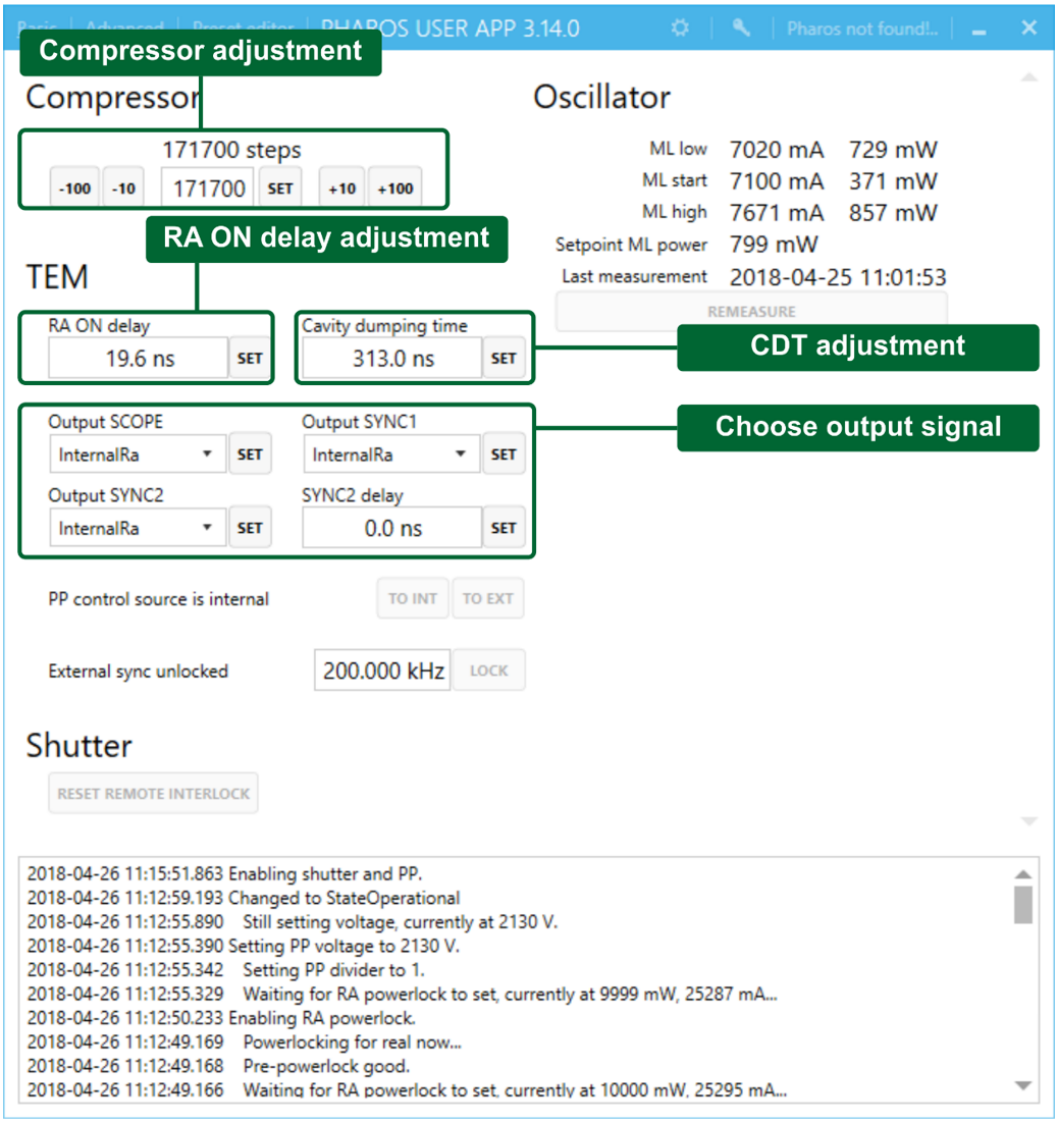


Figure 49. Adjusting the Compressor, RA ON delay and Cavity dumping time; Selecting BNC output signals

5.7 Adjust RA ON Delay and Cavity dumping time

If laser application requires pre-pulse and/or post-pulse contrast optimization:

1. Go to "*Advanced*" window.
2. Adjust RA ON delay and/or Cavity dumping time by entering e new value and pressing "Set" or placing a mouse cursor on the digit and using keyboard arrow keys Up and Down.

Note that this adjustment will not update existing values in currently running and it will reset to a default during next laser start or preset re-execution. Refer to section 6.7 on how to save new RA ON delay and Cavity dumping time values to a current preset.

5.8 Save New Compressor, RA ON Delay and/or Cavity Dumping Time Values to a Preset

If user requires new Compressor or timing values (RA ON delay, Cavity dumping time) updated in currently running preset, it can be performed in two ways:

- By directly editing a preset in the "Preset editor" window (see section 6.10).
- Updating the current preset from the "Advanced" window.

To update a preset from the advance window:

1. Gain technician access level (see section 6.12).
2. Go to the "Advanced" window.
3. Adjust the compressor.
4. After adjusting the compressor, a floppy disc icon will appear near the title "Compressor". Right-click on this icon and press "Update Preset".
5. Adjust RA ON delay and/or Cavity dumping time.
6. After RA ON delay and Cavity dumping time adjustment, the floppy disc icon will appear near the title "TEM". Right click on this icon and press "Update preset"

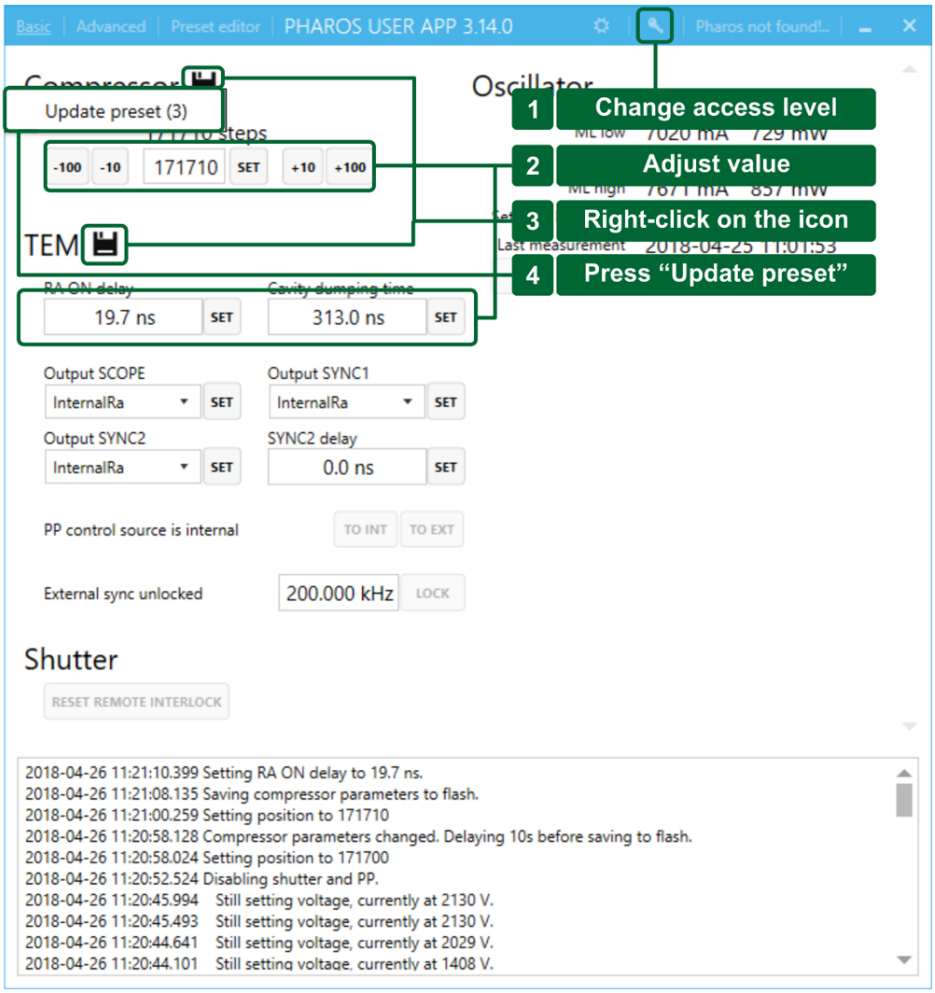


Figure 50. Quick update of the current preset

5.9 Select BNC Output Signals

Several signals types can be selected from the three programmable BNC output ports on the back of the laser head (called "SCOPE", "SYNC1", "SYNC2"). This can be done through the "Advanced" window:

1. Go to the "Advanced" window.
2. Choose a BNC output port that you prefer (SCOPE, SYNC1 or SYNC2).
3. Select a signal type from the frop-down list.
4. Press "Set".
   List of available output signals is presented in the table below.

Table 18. List of available signals for "SCOPE", "SYNC1" and "SYNC2" outputs

Signal	Description
InternalRA	Signal from internal RA frequency generator
OscSync	TTL version of OSC_SYNC input of TEM
RaOn	Copy of "RA ON" signal used to trigger RA Pockels cell
RaOff	Copy of "RA OFF" signal used to trigger RA Pockels cell
PpOn	Copy of "PP ON" signal used to trigger PP Pockels cell
PpOff	Copy of "PP OFF" signal used to trigger PP Pockels cell
Sync2	Signal with user-controlled delay, locked to "RA OFF" signal
SyncOut	Copy of "SYNC OUT" output on DB15 connector
Running	"RA STATUS" output on DB15 connector
PowerOk	"5V supply failure" output
RaFail	"RA common failure" output
PpEnable	A modified copy of "PP ON" signal
Db15SyncIn	Copy of "SYNC IN" input on DB15 connector
Db15PpIn	Copy of "PP on/off" input on DB15 connector
Db15RaIn	Copy of "RA on/off" input on DB15 connector
RaOpen	Output active from "RA ON" until "RA OFF" signal
PpOpen	Output active from "PP ON" until "PP OFF" signal

5.10 Enable external Pulse-Picker Control

If the laser is running, changing the PP control source (to external or back to internal) requires the laser to go into standby mode. To switch between PP control sources:

1. Switch the laser to standby mode.
2. Gain Technician access level (see section 6.11).
3. Go to the "Advanced window".
4. Change the PP control source either to "TO EXT" (to external) or "TO INT" (to internal).

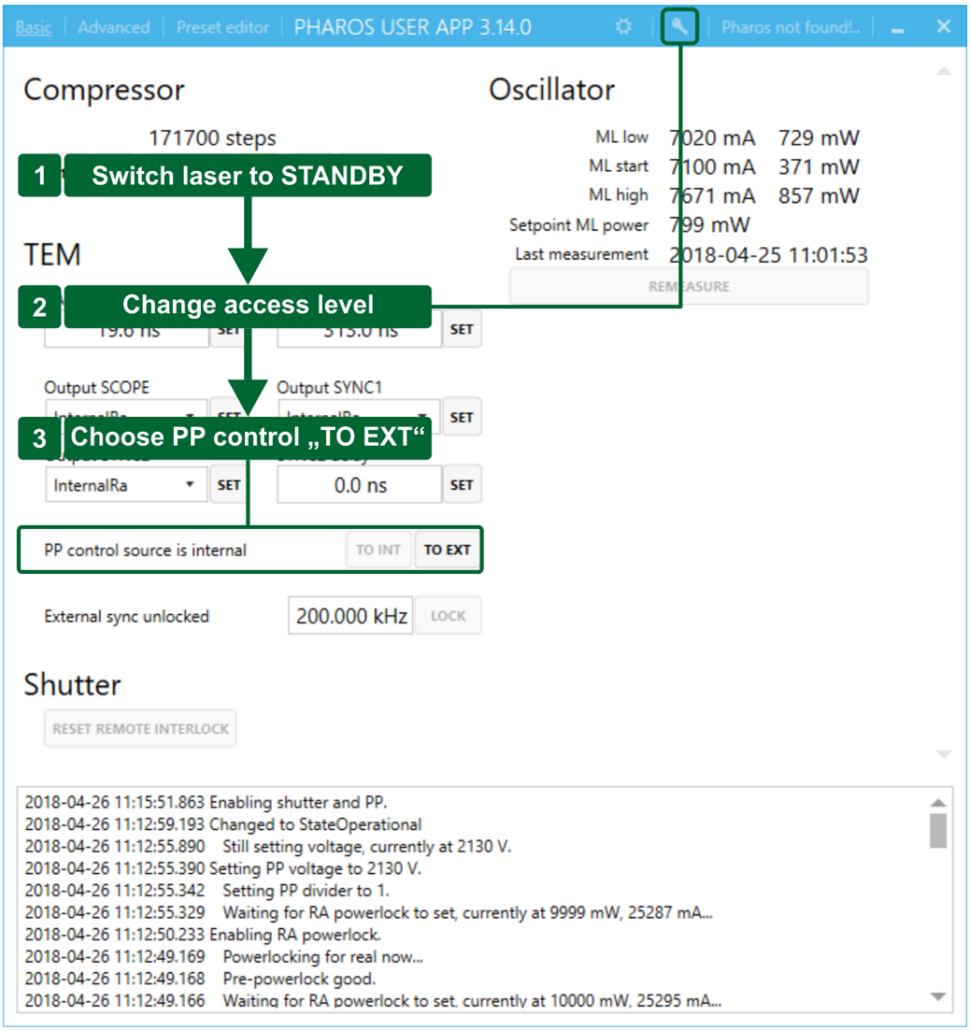


Figure 51. Selecting external pulse picker control source

5.11 Application Logs

The PHAROS User app constantly records application logs. These logs contain various operational information, errors and laser system information. Logs are stored a folder where the User app was installed. These logs are necessary for diagnostic purposes and will be requested by Light Conversion in case of a system malfunction. To quickly access the logs folder, follow these steps:

1. Go to the settings window of the PHAROS User App,
2. Click the OPEN LOGS FOLDER button.

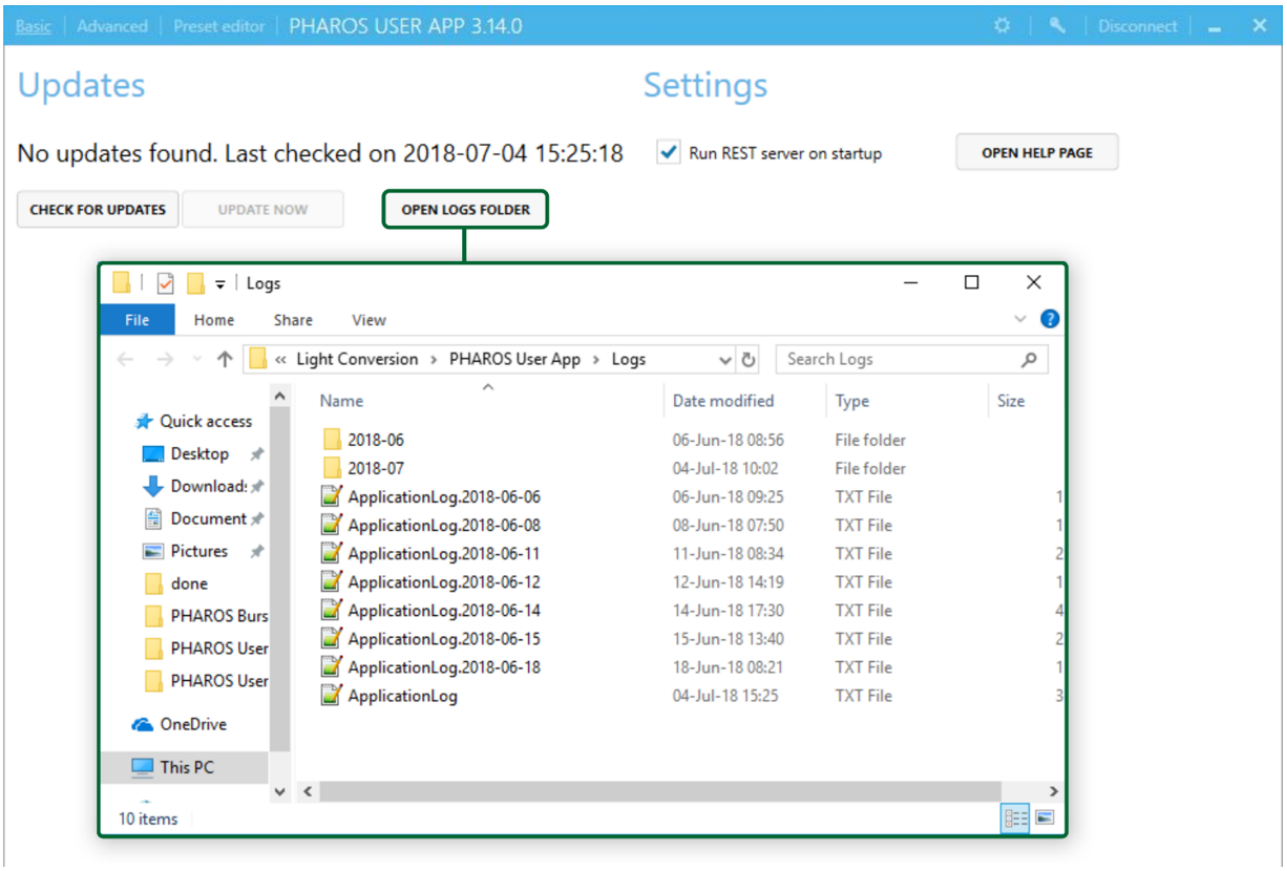


Figure 52. Accessing the logs folder

5.12 Edit/Add/Remove Presets

Adding, removing and editing the presets requires technician access level (see last section of this chapter).

Presets are managed in the "Preset Editor" tab. Preset creation procedure can be divided into two separate procedures:

1. Basic preset creation which involves only the PHAROS User App and the factory test certificate. With this method you take factory tested parameters from the factory test certificate (Output pulse measurement section) and create a preset based on them. This can also be done based on existing presets. Slightly different parameters can be calculated based on the provided data, but this should be done only if the new values differ no more than 10% than the factory tested values.
2. The second method is intended for those who wish to create a highly specific preset, which cannot be based off of the factory test certificate. This method involves the use of the PHAROS Service App and is for experienced users only.

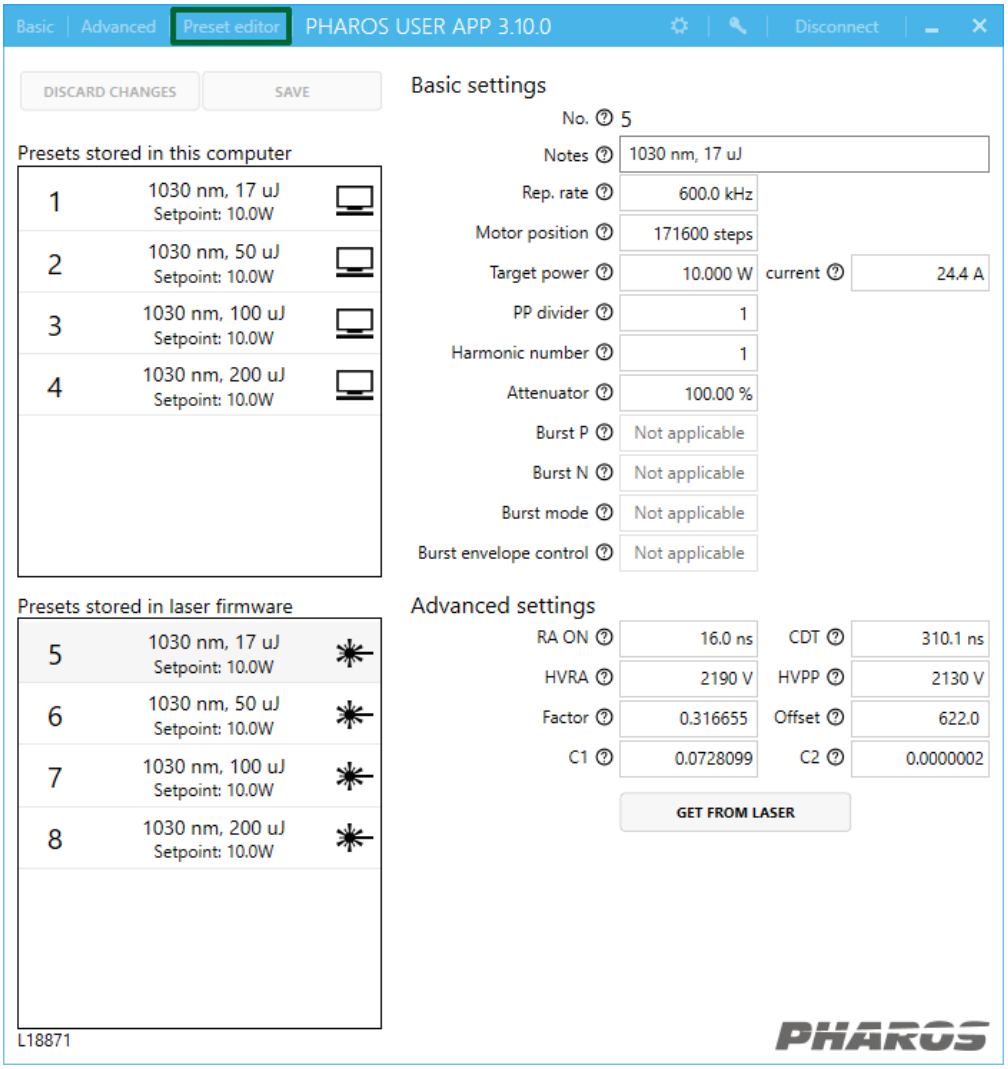


Figure 53. Preset editor window

5.13 Basic Preset Creation Method

Basic preset creation should start by first analyzing the existing output pulse measurements in the factory test certificate.

2. Output pulse measurement

Repetition rate, kHz	Pump current, A	Output power, W	Pulse energy, μJ	Pulse duration, fs	RA On Delay / Cavity Dumping Time, ns	Compressor position, (No. of a step)
1	19.00	0.215	215	233	19.4/297.4	34400
15	21.10	3.05	203	229	19.4/297.4	34500
30	23.40	6.12	204	226	19.5/297.1	34700
60	23.10	6.07	101	208	19.3/296.6	33700
200	22.40	6.01	30	199	19.2/296.9	33400
1000	21.30	6.05	6	193	17.3/294.9	33600

Fig. 7 Output power and pulse energy vs pump current

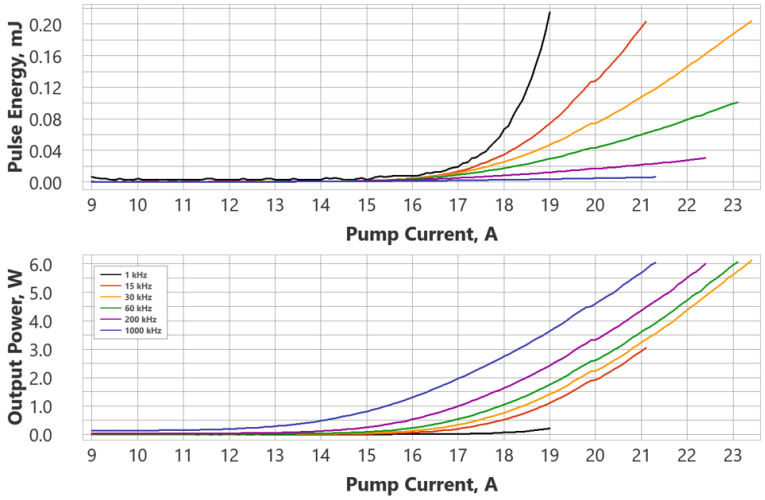


Figure 54. Output pulse measurement excerpt from the factory test certificate (For example purposes only! Do not base the preset creation on these values!

Next it is recommended to also analyze existing preset via the PHAROS User App, pay most attention to the preset stored in the laser firmware.

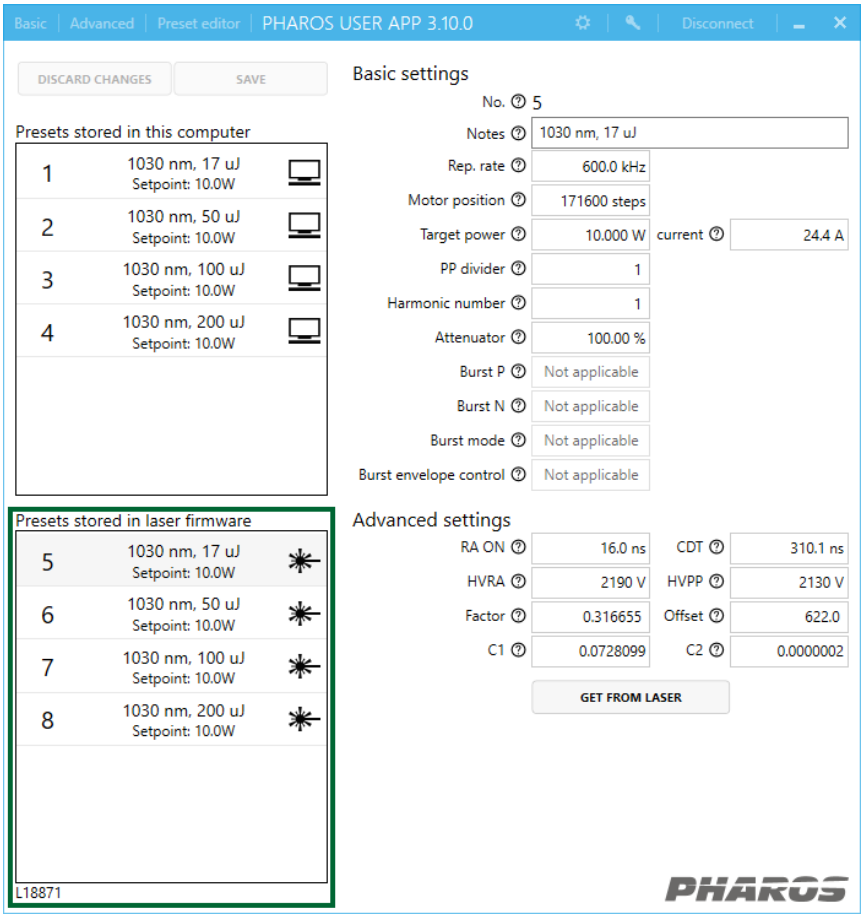


Figure 55. PHAROS User App - Preset editor - analyzing the laser stored presets

See if any of the existing presets or the measured parameters are within the 10% parameter difference of the preset that you wish to create. Now you can start creating a preset:

1. Start by loading a preset with parameters closest to the parameters of the preset that you wish to create.
2. Input the basic settings of the preset. Motor position and Pump current can be approximately calculated proportionally by comparing adjacent presets with higher power and lower power settings.
3. The Advanced settings remains as is, no changes are made to them.
4. Save the preset.

5.13.1 Advanced Preset Creation Method

Advanced preset creation is more complex but allows creating preset which differ completely from the factory standard preset. This method involves using the PHAROS Service App.

Basically the laser is turned on and tuned in the Service App to the settings of a preset that you wish to create, after which all the parameters are written down and transfered to the PHAROS User App. This method requires in-depth understanding of the PHAROS Service App, because of this, there is no easy step by step description of the process. Refer to APPENDIX 1, for instructions on how to use the PHAROS Service App.

5.14 Enabling the REST server

The REST server is a virtually emulated server that enables the control of the PHAROS laser via REST requests. If enabled, it starts automatically each time the PHAROS User App starts. TO enable the REST server on startup:

1. Press the gear button in the top right corner of the PHAROS User App.
2. Tick the check box "Run REST server on startup".
3. Restart the PHAROS User App.

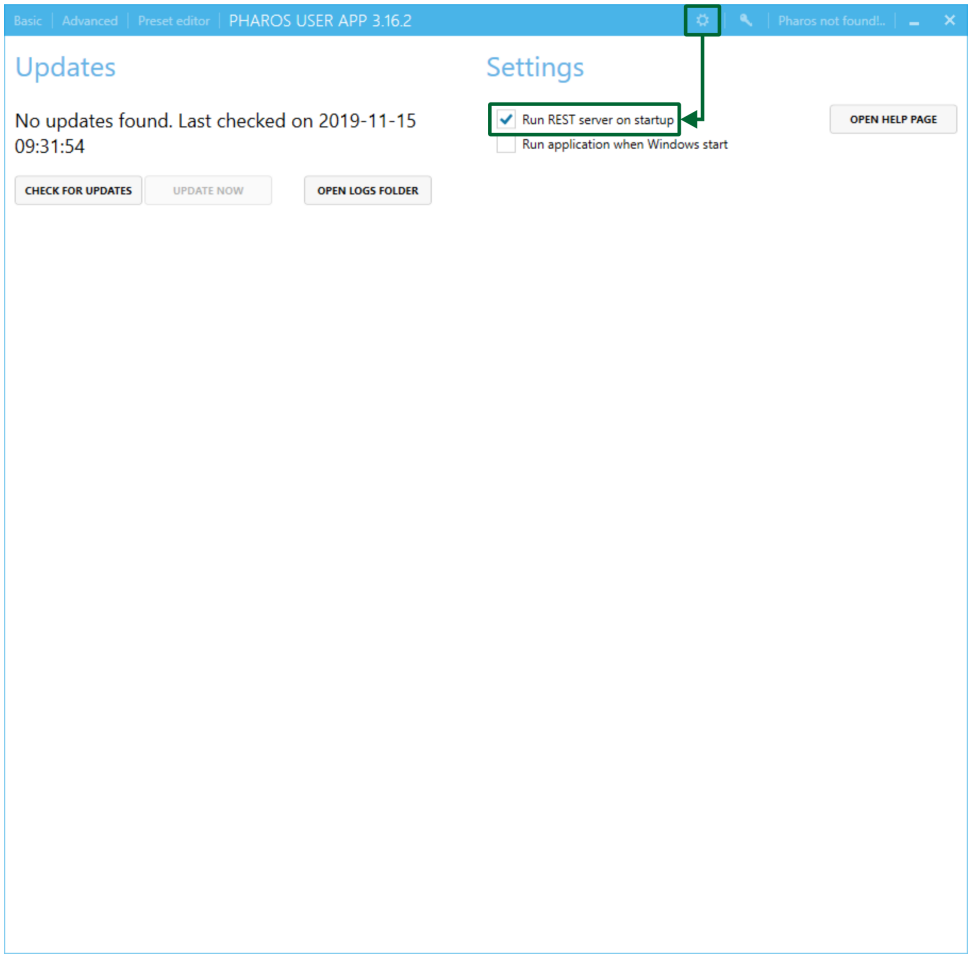


Figure 56. PHAROS User App - enabling the REST Server

	NOTICE	***The "OPEN HELP PAGE" will not work until the "Run REST server on startup" check-box is enabled and the PHAROS User App was restarted.***
	NOTICE	***The "OPEN HELP PAGE" Contains general REST control documentation, standard endpoints, request and response examples.***
	NOTICE	***Advanced developers information is available at www.lightcon.com . Registration and login is required.***

5.15 Change Access Level

To change the software access level to Technician level (which would allow additional actions and modifications of some parameters):

1. Press the key button in the top right corner of the app (or press the F12 key).
2. Enter the Technician access level password. **Technician access level password is 5172.**
3. Press "Enter" or the "Login" button.

To switch back to regular user access level, repeat step 1 and press "Enter" or "Login" without entering any password.

6 MAINTENANCE

6.1 Chiller Maintenance

Each PHAROS laser system is aligned and optimized for a defined cooling water temperature, usually 23 °C (the actual number is given in the *"Factory test certificate"* provided with each laser). Operation at a different water temperature can cause misalignment or poor performance of the system.

NOTICE

It is important to prevent water condensation on cooled laser components in a high humidity and high temperature environment. Use a psychometric chart to calculate a dew point in your environment. Do not use laser if there is a risk of water condensation. Consult manufacturer for optimal regime of laser operation at high humidity conditions.

It is important to prevent formation of algae in the cooling system water. The presence of algae in the cooling system can lead to the formation of blockages in critical places, causing overheating of the laser crystal, softening of water tubes and possibly flooding and damaging the laser. To prevent algae formation, it is important to change the cooling water periodically.

NOTICE

The user must not operate the chiller without coolant. The coolant level must be checked regularly and maintained at an appropriate level

NOTICE

Use only steam-distilled or Type II and lower grade (resistivity less than 18 MΩ·cm) deionized water.

The coolant filter must be replaced along with every coolant change. The water filter of the cooling system is situated on the rear panel of the chiller (depending on the chiller model). The laser cooling system must be rinsed with clean water twice during the coolant replacement. Remove the filter and wash it carefully when changing the coolant.

NOTICE

Coolant and filter change periods may vary, depending on the chiller manufacturer. For accurate and additional maintenance (not listed in this document) please refer to the chiller manufacturer manual supplied with the chiller.

6.2 Power Supply Unit Maintenance

The PSU of the PHAROS laser system is equipped with an air filter, located on the front panel. The air filter must be visually inspected at least every three months and replaced if necessary. More frequent inspection should be performed if the operating environment is not clean.

WARNING

The user must ensure that the power supply and the laser system is turned off and disconnected from the mains while performing maintenance.

To properly inspect and replace the air filter, the user should follow the steps below:

1. Remove the plastic lid covering the filter. This is achieved by pressing the lid with fingers on two opposite sides and pulling it away from the PSU.
2. Inspect the filter visually. If the filter is dirty, it should be replaced. Dust accumulation on the filter may disrupt the cooling of the PSU, leading to overheating.
3. Close the plastic lid by pushing it towards the panel.

6.3 Maintenance Schedule and Spare Parts List

Table 19. Maintenance schedule

Component	Action	Periodicity
Oscillator mode-locking range	Measure	2 weeks (OR after the oscillator current to have the same ML power drifts >0.4)
Chiller coolant water level	Check; refill if necessary	1 day
Chiller coolant water	Replace	6 months**
Chiller coolant water filter	Replace	6 months**
Power supply unit air filter	Check; replace if necessary	3 months
Power supply unit air filter	Replace	12 months

Table 20. Maintenance spare parts list

Component	Part description	Part no.
Chiller coolant water	Distilled (preferred) or deionized (Type II and lower grade)* water, 4-8 l	
Chiller water filter	Primary circuit (coolant water): 25 µm	S-PG10325
	Secondary circuit (industrial water)***: 50 µm	S-PG10414
Power supply unit air filter	Filter foam	S-PE-CM-PS01-5-001

* Do not use Type I (resistivity higher than 18 MΩ·cm) deionized water.
** Actual periods may vary depending on the chiller model, refer to the chiller manual for accurate maintenance information.
*** For water-to-water chiller models

NOTICE

Actual maintenance periods may vary depending on the chiller manufacturer and model. Maintenance periods and part numbers provided are generalize. For more accurate information please refer to the supplied chiller user's manual.

7 TROUBLESHOOTING

7.1 Errors and Warnings

Both warnings and errors are numbered incrementally and grouped into functional groups. Location of warnings and error messages is shown below.

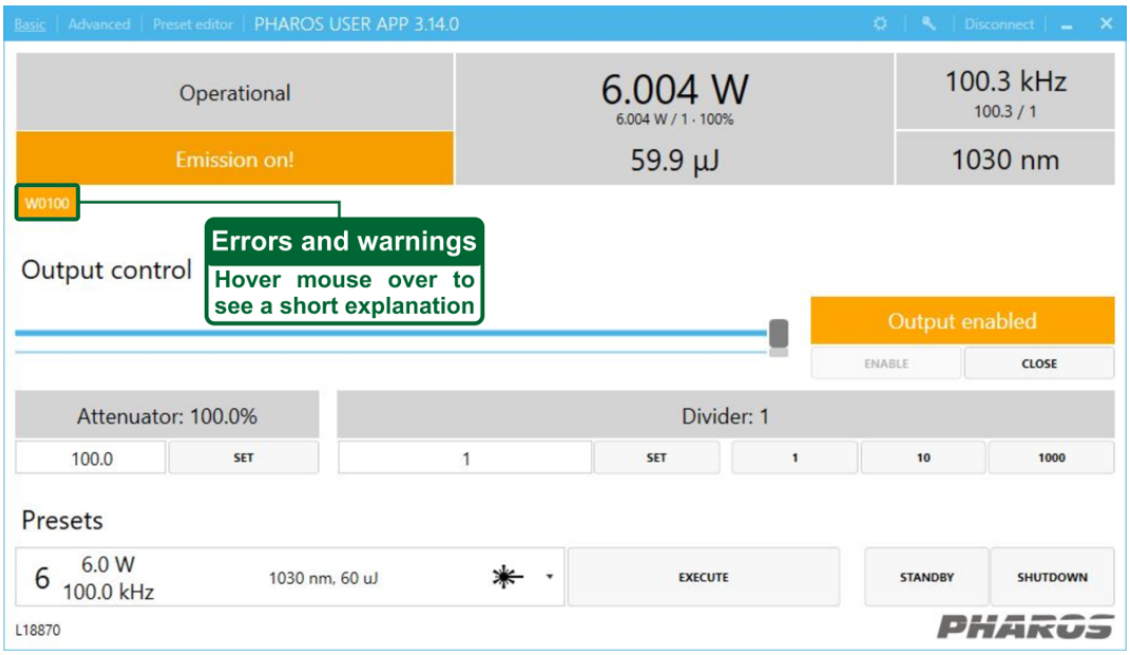


Figure 57. Location of errors and warnings in the PHAROS User App

List of all functioning groups is provided below, afterwards error codes for each functioning group are described in separate sub sections.

Table 21. PHAROS error and warning groups

Functional group	Range
Software	0100-0199
Safety	0200-0299
Hardware	0300-0399
Power supply	0400-0499
Pumping	0500-0599
Cooling	0600-0699
Timing	0700-0799
Not applicable	0800-0899
Stretcher / compressor	0900-0999
Operational	1000-1099

7.1.1 Software errors and warnings

Table 22. Software errors and warnings

Code	Type	Description
0100	Warning	PHAROS User App is connected to the PHAROS Service App instead of a direct USB connection. This approach is experimental and not recommended.

7.1.2 Safety errors and warnings

Currently there are no error or warning codes in this category

7.1.3 Hardware errors and warnings

Table 23. Hardware errors and warnings

Code	Type	Description
0300	Error	Timing electronics module 1 is missing or is not communicating
0301	Error	Timing electronics module 2 is missing or is not communicating
0302	Error	HVC3 controller is missing or is not communicating
0303	Error	HVC4 controller is missing or is not communicating
0304	Error	HVC3 does not start
0305	Error	HVC4 doest not start
0306	Error	RA HV controller is missing or is not communicating
0307	Error	PP HV controller is missing or is not communicating
0308	Error	RA HV controller does not start
0309	Error	RA HV controller can't reach voltage setpoint
0310	Error	PP HV does not start

7.1.4 Power supply errors and warnings

Table 24. Power supply errors and warnings

Code	Type	Description
0400	Error	Power supply does not start

7.1.5 Pumping errors and warnings

Currently there are no error or warning codes in this category

7.1.6 Cooling errors and warnings

Table 25. Cooling errors and warnings

Code	Type	Description
0600	Error	OSC humidity is too high
0601	Error	RA humidity is too high
0602	Error	Incorrect body temperature

7.1.7 Timing errors and warnings

Table 26. Timing errors and warnings

Code	Type	Description
0700	Error	Delay cannot be set
0701	Error	RA OFF time (master) cannot be set
0702	Error	PP offset cannot be set
0703	Error	RA ON delay cannot be set (TEM1)
0704	Error	RA ON delay cannot be set (TEM2)
0705	Error	RA OFF cannot be set (TEM2)

7.1.8 Stretcher-Compressor errors and warning

Table 27. Stretcher-Compressor errors and warnings

Code	Type	Description
0900	Warning	Compressor motor homing procedure failed

7.1.9 Operational errors and warnings

Table 28. Operational errors and warnings

Code	Type	Description
1000	Error	Oscillator does not start
1001	Error	CW detector error
1002	Error	OSC LDD is not stopping
1003	Error	RA LDD cannot reach setpoint
1004	Error	RA LDD cannot be enabled
1005	Error	RA (TEM1) stopped unexpectedly
1006	Error	RA (TEM1) does not start
1007	Error	RA (TEM2) stopped unexpectedly
1008	Error	RA (TEM2) does not start
1009	Error	RA (TEM1) power-lock failure
1010	Error	Can't execute preset because it is not valid
1011	Error	Oscillator stopped unexpectedly
1012	Error	Can't go to Stand-By state because oscillator is not running
1013	Error	Can't go to Stand-By state because oscillator is running
1014	Error	HVC3 stopped unexpectedly
1015	Error	HVC4 stopped unexpectedly
1016	Error	RA HV stopped unexpectedly

8 APPENDIX 1. PHAROS SERVICE APP

NOTICE ***This section is based on the PHAROS Service application version 1.6.124***

Full control of PHAROS parameters is accessible from the PHAROS Service App (PSA) software. This application can also be used for PHAROS state monitoring, visualization and logging. This software is used when the computer is connected to the PHAROS PSU via USB cable.

8.1 Installing the PHAROS Service App

The PHAROS Service application installation package is supplied on a USB memory stick. The latest version of the software can be downloaded from the Light Conversion website, PHAROS support section (registration is required to access the section).

To install the software run the `Setup.exe` file and follow the installation instructions. After the software is installed, connect the PHAROS PSU to the mains, then connect the computer to the PHAROS PSU via USB cable. Windows will detect new hardware and install the drivers. Start the PHAROS Service application, once running, it will automatically connect to the laser. If the laser was not connected when the application was started, press the "*Connect*" button in toolbar menu

8.2 Description of the PHAROS Service App

Figure 58. Possible PHAROS Service application window layout

The PHAROS Service application is designed as a set of module windows. Every window contains controls and indicators grouped by function or PHAROS system subunits. Windows can be shown or hidden

using the *"View"* menu option. If the resolution of the PC monitor is low, the user can choose to hide unnecessary windows. All windows can be docked inside the main application window or docked and tabbed inside each other to save display space and design an ergonomic control environment. To dock or tab a window, move the mouse to the caption area, press the left mouse button and drag the window to the required position. A graphical menu with docking and tabbing options will appear near the mouse cursor.

A possible window layout is shown in (excluding Graph windows). This default layout can be found in the application installation folder under the name *"*`default.UI_state`*"*. Use *"Load windows state from file"* from the *"Windows"* menu to load this layout

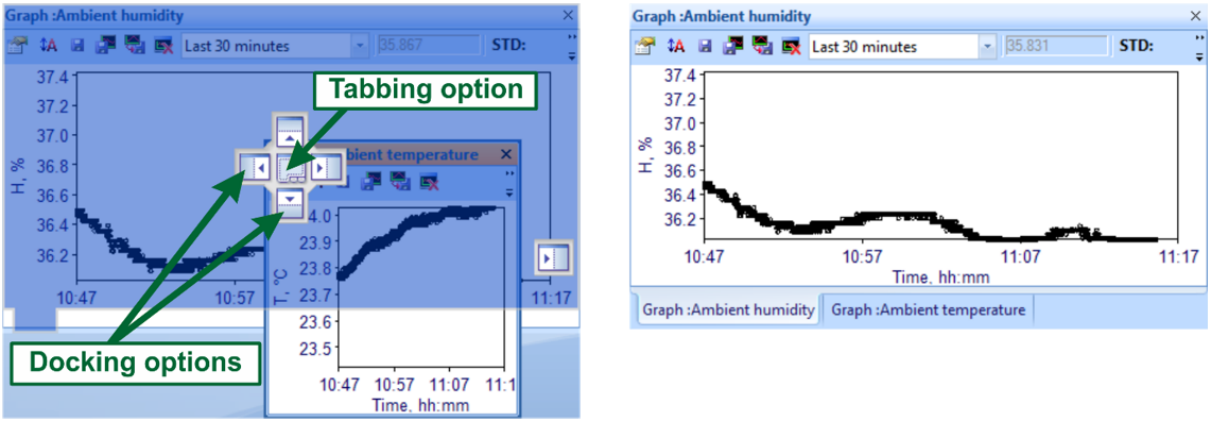


Figure 59. Left image - windows docking and tabbing options, Right image - tabbed windows

8.3 Control windows

This chapter briefly describes the main functions of the PHAROS Service application components and control windows. A list of all windows can be displayed after expanding the menu option *"View"*.

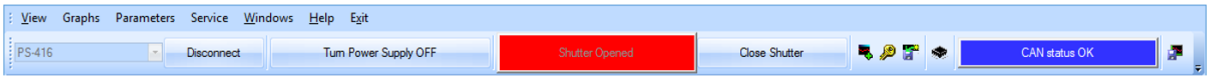


Figure 60. PHAROS Service application menu and toolbar

The section of the PHAROS Service application under the menu is used to select a PHAROS device (if more than one laser is connected to the same computer), connect/disconnect to the laser, turn the power supply ON/OFF, close/open the shutter, etc. If only one laser is connected to the computer, the PSU is connected to the mains and connected to the computer via a USB cable, the application will connect to the laser automatically. There is no need to disconnect the application while shutting-down.

Menu and toolbar items are described below:

View	List of application control windows to be displayed or hidden
Graphs	List of certain parameters monitoring graph windows
Parameters	Controlling some technical parameters of the laser and its parts
Service	Access to some servicing tasks of the laser
Windows	Save/Load application windows state (layout)
Help	Application help section
Exit	To exit software. **NOTE: Exiting does not stop the laser**

Toolbar items are described below:

Connect/Disconnect	Connect/Disconnect laser. If more than one laser is connected to the same computer, select device by the power supply serial number from the drop-down list on the left
Turn Power Supply ON/OFF	Turns power supply ON or OFF
Shutter Opened	Shutter status display
Open shutter/ Close shutter	If the shutter is powered by means of the shutter key switch, opens/closes the shutter
	Select parameter graphs to display
	Select application access level (User, Technician and Manufacturer)
	San and save PHAROS parameters
	**PHAROS** system information
	Saves all open graphs to files

The behaviour of the "*Turn Power Supply ON/OFF*" button is equivalent to manual switching of the power button on the PHAROS PSU. The laser can only be switched on by the software when the button on the PSU is in the "POWER ON" position.

NOTICE

PHAROS electronics prevent immediate laser shutdown if current on LD bars is not switched off. Current on LD bars is decreased to 0 and only then the power supply and the laser are switched off. Shutdown procedure can take up to 1 minute.

8.3.1 OSCILLATOR LDD and RA LDD windows

Two separate windows allow control of the laser diode bar currents, monitoring of actual current and voltage values.

Start	When turning on, status label changes colour to orange while current is setting and then to green when current is set
Off	When turning off, status label changes colour to grey while current is decreasing
Set	Sets a new current value, entered in the yellow window to the left of the button. Inactive when power-lock is enabled

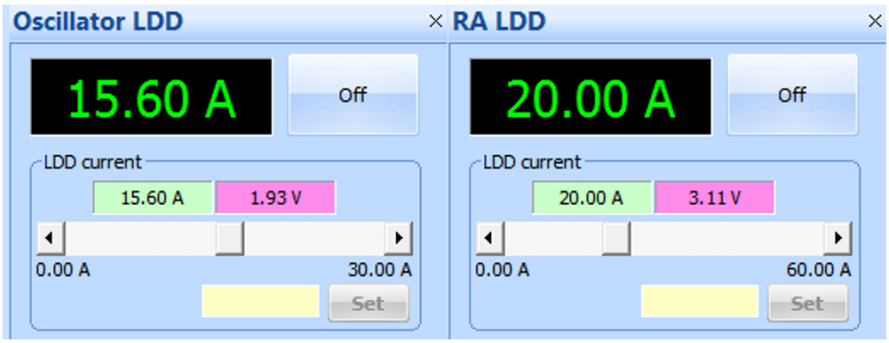


Figure 61. Oscillator and RA bar driver windows

8.3.2 OSCILLATOR window

"Oscillator" window displays actual OSC output power, state of mode-locking and Power-lock.

Start Oscillator	Starts OSC automatically. If modes in OSC are locked, "*ML active*" is highlighted green
Run Starter	Introduces optical noise in the OSC cavity to initiate mode-locking. The "*Starter runs*" flag will be highlighted until the starter stops. If modes in OSC are locked, "*ML active*" is highlighted green
Set new Power Traget	Enter new value in milliwatts and press button to set new power target for OSC power-lock
Lock/Unlock	Activates power-lock function and maintains the power set in *"Power Target"* window. Alternatively, you can lock the current value by pressing "Lock Actual Power" (expand menu by clicking the arrow at the right side of the button). The "*Power-Lock Active"* label turns yellow when power is locked
Switch OSC beam to RA	If OSC output option is installed, this button is used to switch OSC beam from the output aperture to the RA and back

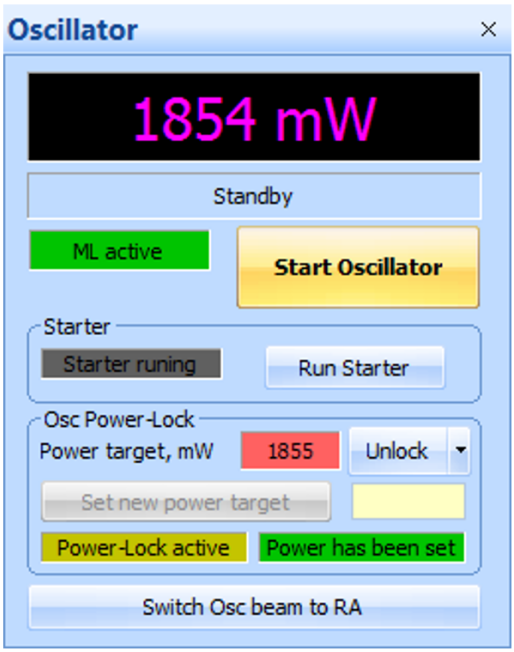


Figure 62. "Oscillator" window

8.3.3 RA and TEM FAILURES windows

The *"RA"* and *"TEM Failures"* windows are important while controlling the RA. The *"Failures"* window displays the contents of the Timing Electronics Module (TEM) failures register. Check boxes on the left side of the window allow masking some failures. The RA won't stop on a failure that is masked. Boxes on the right-side display accumulated failures. Accumulated values can be important when determining the reasons for a RA malfunction. In cases when the APP is connected to a PHAROS laser system.

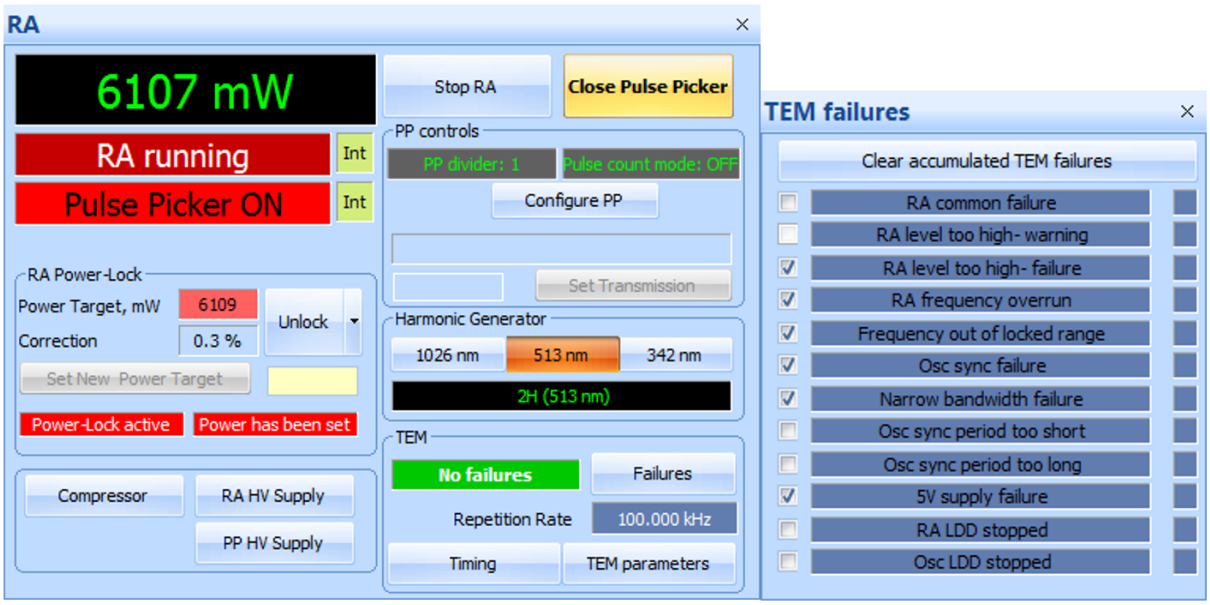


Figure 63. "RA" and "TEM Failures" windows

Start RA/Stop RA	Starts/Stops the TA
Open/Close Pulse Picker	Opens/Closes the PP
Configure PP	Opens the pulse-picker configuration window
Failures	Opens/Closes the "TEM Failures" window
Timing	Changes the RA repetition rate, cavity dumping time and other timing parameters
TEM Parameters	Opens the "TEM Parameters" window
RA HV Supply	Opens the RA Pockels cell high voltage controller window
PP HV Supply	Opens the pulse picker Pockels cell high voltage controller window
Compressor	Opens the pulse duration optimization (compressor length adjustment) window
Set New Power target	Enter a new value in milliwatts and press the button to set new power target for the RA power-lock
Lock/Unlock	Activates the power-lock function and maintains the power set in the *"Power Target"* window. Alternatively, you can lock the current value by pressing "Lock Actual Power" (expand menu by clicking the arrow at the right side of the button). The "*Power-Lock Active"* and *"Power has been set"* labels turns red when the power is locked

8.3.4 POWER SUPPLY window

The "*Power supply Controller*" window is used to monitor the PHAROS PSU.

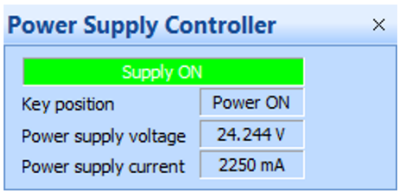


Figure 64. "Power Supply" window

8.3.5 ENVIRONMENT window

The "*Environment*" window is used to monitor PHAROS environmental parameters like the temperature of the LD bars, humidity inside the OSC and the RA, etc. Chiller parameters and controls are supported only for Termotek and HIB chillers.

Set New Water Temp.	Changes the chiller water temperature set point to the value entered in the window on the left. <u>This function is supported only Termotek and HIB chillers</u>

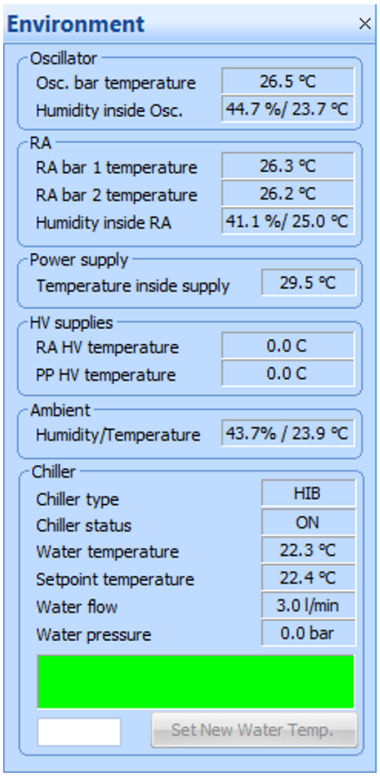


Figure 65. "Envionment" window

8.4 Graph Windows

Additional graph windows can be added if long term monitoring of certain parameters is required. To add graph windows, press the *"Select parameter graphs to display"* button, located at the top select menu *Graphs → Add New Graph*. A dialog with a selection of graphs will appear.

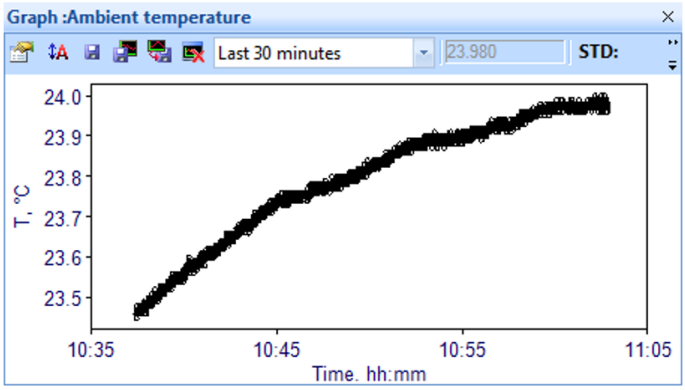
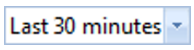


Figure 66. Graph window example

Parameters and position of the graph windows are saved when the PHAROS Service application shuts down and are restored on the next start-up of the software. The toolbar at the top of the graph window provides buttons for these operations:

	Access to the graph properties. Allows customization of graph colours and fonts, type and size of data points and lines, vertical axis range, enable/disable auto scaling and logarithmic vertical scale
	Auto scale graph
	Save data points to ASCII file
	Save graph as image
	Enable real-time backup of graph data to a file
	Clear all collected data
	Change the time scale of a graph from 1 minute to 64 hours
STD:	Standard normalized deviation of data displayed on graph

8.5 Protection of Laser Configuration Parameters

PHAROS system parameters are stored in the internal flash memory of various controllers. All parameters can be scanned and saved to a computer disk using the menu command *Service → Save settings to file*.

8.6 Access Levels

Some laser parameters can be changed without disturbing the laser functionality. Other parameters are defined by the laser design and modification of these parameters can cause serious damage to the

PHAROS system. To prevent intentional or unintentional modification of critical system parameters, access levels are defined for each laser parameter. There are three different access levels used in the PHAROS system:

- **User Access Level.** This level is turned on by default when the PHAROS system is powered on. It allows changing only the basic set of parameters needed for day-to-day laser operation.
- **Technician Access Level.** This level allows modification of all important laser parameters, which are not predefined by the device design.
- **Manufacturer Access Level.** For service engineers only.

Actual access level is displayed in the main PHAROS Service application window caption.

For instructions on changing the access level see Section "Daily Operation of the PHAROS Service App".

8.7 Daily Operation of the PHAROS Service App

Once the laser is started, it is recommended to always keep the PHAROS control software running. The software constantly logs PHAROS status and parameters. These logs are useful in event of a laser system malfunction.

8.7.1 Start-Up

To start-up the laser system, follow these steps:

1. Turn the PSU power button to position ON, this will power up the chiller and the HV sup-ply for the Pockels cells.
2. Start the PHAROS service App.
3. Turn on the OSC and RA PD current.
4. Wait 10 minutes for the pump module to heat up and set the correct pump wavelength.
5. Press "Start Oscillator".
6. Set the required RA parameters: Pump current, Cavity dump time and Pulse repetition rate.
7. Press "*Start RA*" in the RA window.
8. Press "*Open Pulse Picker*" in the RA window. This will activate the PP and direct the RA output light to the output aperture of the laser.

To start the OSC, two buttons can be used: "*Run Starter*" or "*Start Oscillator*". It is important to distinguish between these buttons, as each button has a different function associated to it. For normal daily operation, only the "*Start Oscillator*" button should be used.

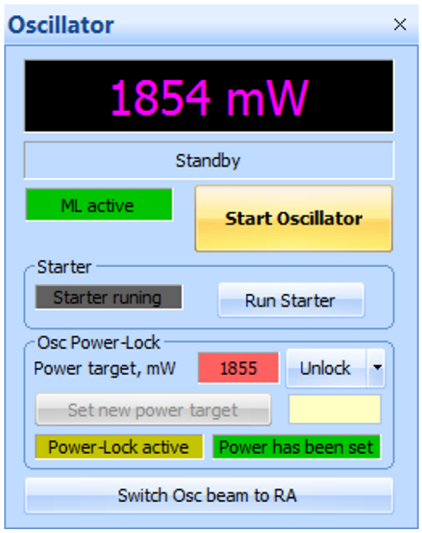


Figure 67. Oscillator window in the PHAROS Service application

8.7.2 Shut-Down

To properly shutdown the laser system:

1. *Press the "Stop RA" button* - This action stops the RA
2. *Turn the power button on the PSU to position OFF* - This action slowly reduces pump currents for OSC and amplifier diodes and switches-off the system

NOTICE

Laser shut-down takes ~1 minute due to gradual decrease of pump currents. The power supply only switches off after the RA and OSC currents are reduced to zero.

8.7.3 Pulse-Picker Control

The PHAROS laser system has a PP installed. The PP is an electrically controlled optical switch, which extracts pulses from a pulse train. The PP can be used in three regimes:

- **Regenerative amplifier division** reduces the repetition rate by emitting every n^{th} pulse. It does not change the internal amplifier frequency. The pulse energy remains the same, but the average power reduces by the same amount the repetition rate was reduced.
- **Pulse packet** extracts a an exact number of pulses. The user can choose the packet size.
- RA beam attenuation attenuates the RA beam by reducing the voltage of the PP Pockels cell. As a result, pulses of lower energy are released from the laser, while maintaining the same pulse repetition rate. The beam profile, divergence and pointing stability change is smaller in comparison to

output power reduction via RA pump current reduction, as this method does not cause any fluctuations to the cooling system of the laser.

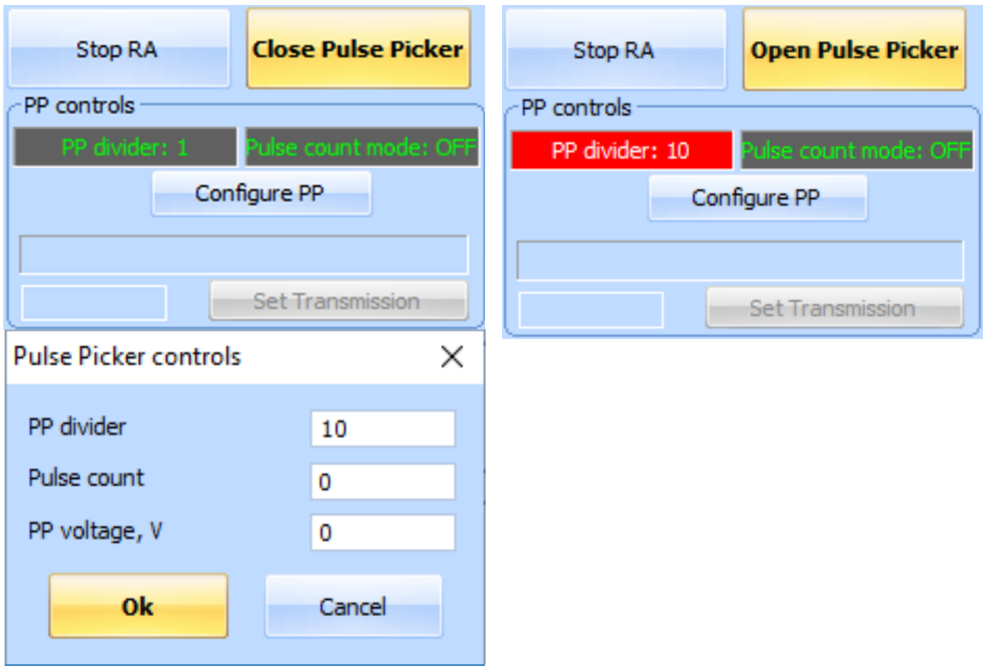


Figure 68. Left image - pulse picker control window, Right image - pulse picker indicator when pulse divider is used

To use the PP in division regime:

1. Press "*Configure PP*" in RA control window.
2. Enter how many times you want to reduce repetition rate in "PP divider", press "OK".

For example: if the laser is running at 100 kHz repetition rate, entering a divider 10 (ten) reduces laser output frequency to 10 kHz by letting out only every 10-th pulse. Using the PP repetition rate can be reduced to 1 Hz. NOTE: reducing the repetition rate this way to very low output powers can lead to possible beam distortion, as the beam intensity becomes of comparable amplitude to the PP leak.

After configuration of the PP attenuation, the attenuation slider appears below the "*Configure PP*" button.

To configure the PP attenuation slider:

1. Determine the optional PP HV value of your laser (It can be found in the *"Factory test certificate"* or after pressing the "*PP HV Supply"* button in the RA section.
2. Fill in the *"PP Voltage, V"* field with the appropriate PP HV value.
3. Change the PP slider position to obtain a desired PP attenuation. **NOTE**: reduction of the PP HV supply value is limited to 300 V, further reduction will not have any effect.

8.7.4 Setting Laser Output Power

Changing PHAROS average output power is achieved by controlling the RA pump laser diodes (LDD) current. ***NOTE!*** It is not possible to change LDD current if the power-lock setting is active. Fist stop the power-lock.

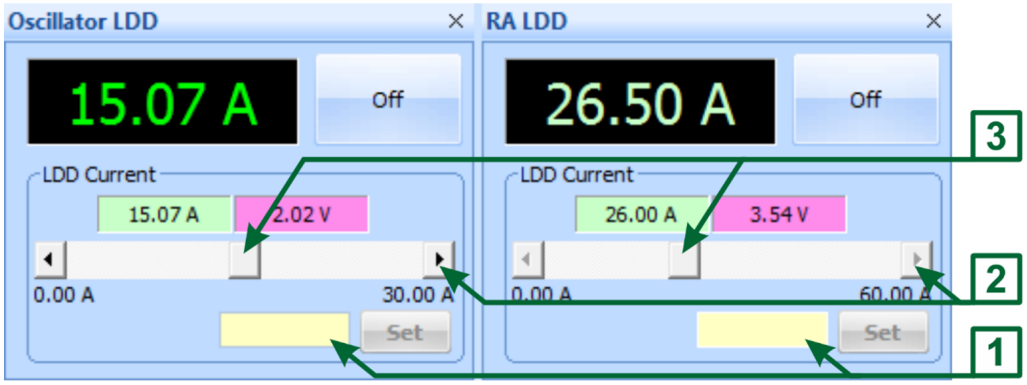


Figure 69. Changing OSC or RA LDD current: 1) type in desired value or 2) press arrows or 3) move slider

To set the output power:

1. When setting the maximum output power, use the "*Factory test certificate"* to find the maximum allowed output power for the pulse repetition rate and pre-determine the required pump current of the RA LD bars. The pump current may slightly vary after some time.
2. Place an external power meter at the output of the PHAROS laser system, to measure the actual output power.
3. Locate "RA LDD" window.
4. Type the desired pump current in the yellow field and click the "*Set"* button. Alternatively, you can change the pump current by clicking the arrow buttons of the slider (each click changes the pump current by 0.01 A). Monitor the output power with the external power meter.

The PHAROS has a two-level protection system against high optical pulse energy which can damage optical components of the cavity. The Timing Electronics Module continuously measures the amplitude of the optical pulse. The two-level protection against high pulse energy is implemented as follows:

- **RA level WARNING** - pulse reaches the maximum allowed energy, system doesn't stop the RA.
- **RA level FAIL** - pulse energy is too high, system stops the amplifier.

	**NOTICE**	***The "RA level" protection system is not fast enough to stop amplification of a pulse during a single amplification cycle. Do not start the RA at a high pump current and long cavity dumping time at low repetition rates.***

8.7.5 Power Stabilization (Power-Lock Function)

The PHAROS laser system provides an option for users to stabilize the OSC and the RA output powers – minimizing instabilities and fluctuations in order to ensure a as stable operation as possible. Stabilization of the RA/OSC output power means that the RA/OSC LDD current is changed automatically to keep the fixed power value.

Follow these steps to enable RA power-lock:

1. Locate the "*RA*" window in the application.
2. Select the drop-down menu on the right of "*Lock*" button and choose "*Lock actual power*" if you want to lock the current output power or enter a new value in the yellow window below and press "*Set New Power Target*".
3. Press "Lock".

RA power lock can change the RA LDD current by ±2 A in order to avoid damaging the active medium. It is monitored in the *"Correction"* field. It shows the percentage of the 2 A current range, that was used. If the power lock is functioning properly, the "Power-Lock Active" and "Power has been set" indicators should turn to red.

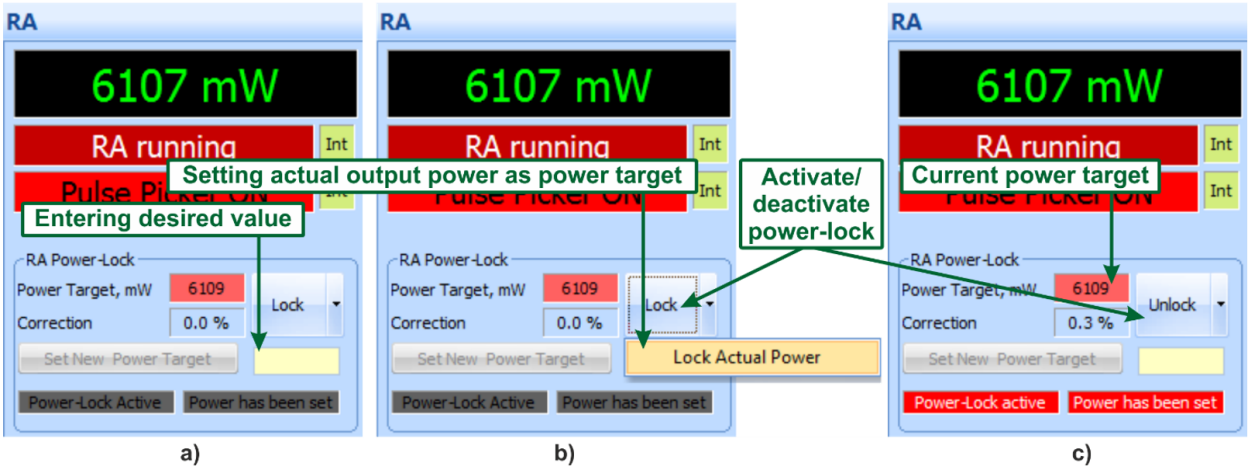


Figure 70. Images "a" and "b" show how to enable RA power-lock in the Service applications; Image "c" depicts the active power-lock

Usually the OSC is power-locked if automatic start-up was used. If the OSC was operated manually, the power-lock procedures are described below.

Follow these steps to enable OSC power-lock:

1. Locate the "*Oscillator*" window in the Service application.
2. Select drop-down menu on the right of the "*Lock"* button and choose "*Lock actual power"* if you want to lock current output power or enter a new value in the yellow window below and press "*Set new Power Target".*

3. Press "*Lock*".

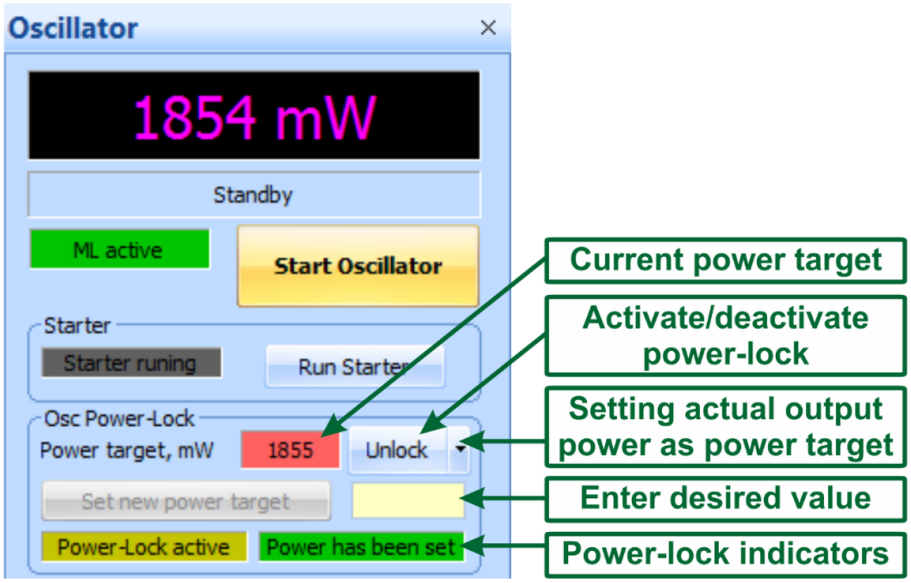


Figure 71. Enabling OSC power-lock

If power lock is functioning properly, the "*Power-Lock Active*" indicator should turn to yellow and the "*Power has been set*" indicator to green.

8.7.6 Changing Pulse Repetition Rate

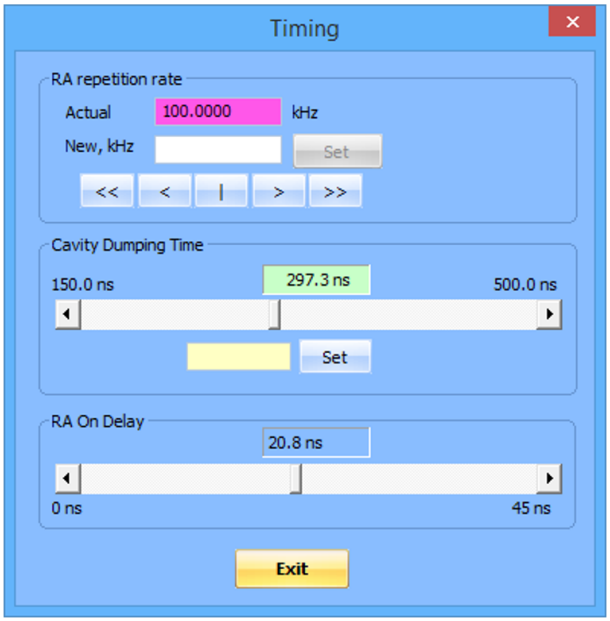


Figure 72. "Timing" window

Typically, several narrow frequency ranges cannot be selected due to their coincidence to the internal resonant frequencies of the Pockels cells used in the laser head. The specific forbidden laser frequency table can be found in the "Factory Test Certificate" of the laser.

To change the RA frequency, follow these steps:

1. Locate the "*RA*" window in the application.
2. Click the "Timing" button. The "Timing" window should pop up.

3. Actual frequency is displayed in *"RA repetition rate"* frame field *"Actual"*. To change the frequency, type the new value in the field *"New, kHz"*.
4. To confirm the selection. click the "Set" button.
5. Set Cavity Dumping Time.

8.7.7 Setting Cavity Dumping Time and RA ON Delay

Follow these steps to set the Cavity Dumping Time (optimize post-pulse contrast ratio) on standard PHAROS laser system.

1. Locate the "*RA*" window in the application.
2. Click the "Timing" button. The "Timing" window should pop up.
3. Locate Cavity Dumping Time section. Move the slider with the mouse, click the slider arrows or enter the desired value in the yellow box under the slider and press "*Set"* to change the cavity dumping time. Check the *"Factory test certificate"* to determine the required cavity dumping time for the particular pulse repetition rate.
4. Set RA On Delay - move the slider with the mouse or click the slider arrows. Check the *"Factory test certificate"* to determine the required RA On Delay value for the particular pulse repetition rate.
5. Click the "*Exit*" button to close the *"Timing"* window.
6. Optimize pulse compression (see section below).

	**NOTICE**	**Do not try to saturate the optical pulse train in the RA cavity by increasing the cavity delay time. This may lead to self-modulation of the optical pulse and damage of optical components in the RA cavity.**
	**NOTICE**	**The duration of a single round-trip of the OSC pulse in the RA cavity is ~12 ns, therefore do not change the Cavity Dumping Time >±6 ns, as this would add or subtract an additional round-trip of the pulse in the cavity.**

8.7.8 Optimizing Pulse Duration (Adjusting Compressor Length)

Pulse duration optimization can be performed by adjusting the compressor length (optimizing pulse compression).

To change the compressor length with the PHAROS Service application, follow these steps:

1. Locate the "*RA*" window in the application.
2. Click the "*Compressor"* button, the *"Pulse Duration Optimization"* window should pop up.
3. Move the slider with the mouse or click arrows to change the compressor delay line position. Check the *"Factory test certificate"* to determine the required compressor position for the particular pulse repetition rate. Enter the desired value in the yellow box under the slider and press "*Move"*. Alternatively optimal compression can be determined by performing a non-linear experiment (i.e., second harmonic generation from the PHAROS output) and adjusting the compression until maximum efficiency of this experiment is achieved.
4. Set RA On Delay - move the slider with the mouse or click the slider arrows. Check the *"Factory test certificate"* to determine the required RA On Delay value for the particular pulse repetition rate.

5. Click the "*Exit*" when done.

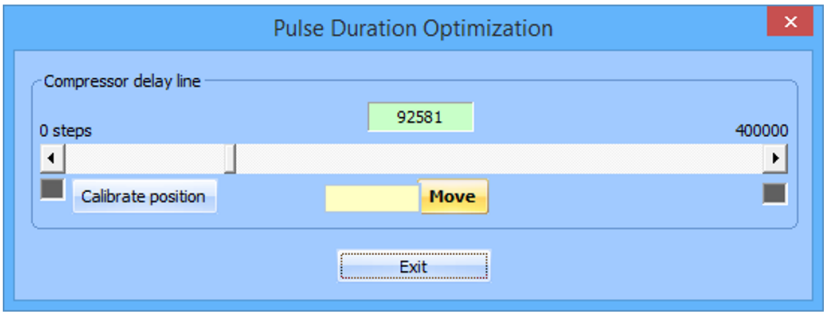


Figure 73. Compressor control in the Service application

8.7.9 Controlling TEM Parameters

When connected to a standard PHAROS laser system, TEM parameters are controlled from the RA window by pressing the *"TEM parameters"* button. It opens the *"TEM Parameters"* window. Some of the parameters are not user adjustable and will be excluded from the description.

Table 29. "TEM Parameters" section description

Section	Description
External Control Interface	Used to control PHAROS external control interface modes. Parameters can be accessed in *"Technician"* and *"Manufacturer"* system access levels
Enable external RA start source	DB15 input "RA on/off" is used to start/stop RA. Additionally the "Enable" button in the RA window is used to allow DB15 operation
Enable external Pulse Picker control source	DB15 input "PP on/off" is used to open/close PP. Additionally the "Enable PP" button in RA window is used to allow DB15 operation
Enable external sync source	DB15 input "SYNC IN" is used to trigger RA shots
Invert RA and PP control levels	Not for user control
Synchronous RA mode	If checked and external RA sync source is not selected, OSC output pulses are used as RA sync source. Changing RA frequency means changing OSC's output pulses divisor factor in this regime
PP mode	PP operation mode
External RA frequency source control	Displays actual "SYNC IN" input frequency and value of "Locked external frequency". If "SYNC IN" frequency differs from "Locked external frequency" more than 10% RA is stopped and failure "Frequency out of locked range" is activated
SCOPE SYNC source	Controls multiplexer of user's outputs (TTL levels). List of available outputs is shown in the next table
SYNC1 source	
SYNC2 source	
Timing adjustments	Not for user control
Pulse Picker OPEN mode	Not for user control
RA Off start, PP Offset	Not for user control
Oscillator Sync adjustments	Not for user control
Osc Sync Level	Not for user control
Osc too short/too long failure	Not for user control

Table 29. "TEM Parameters" section description

Section	Description
Tune to Osc	Not for user control
Narrow bandwidth failure	Not for user control
RA level too high failure	Not for user control
Advanced	Not for user control

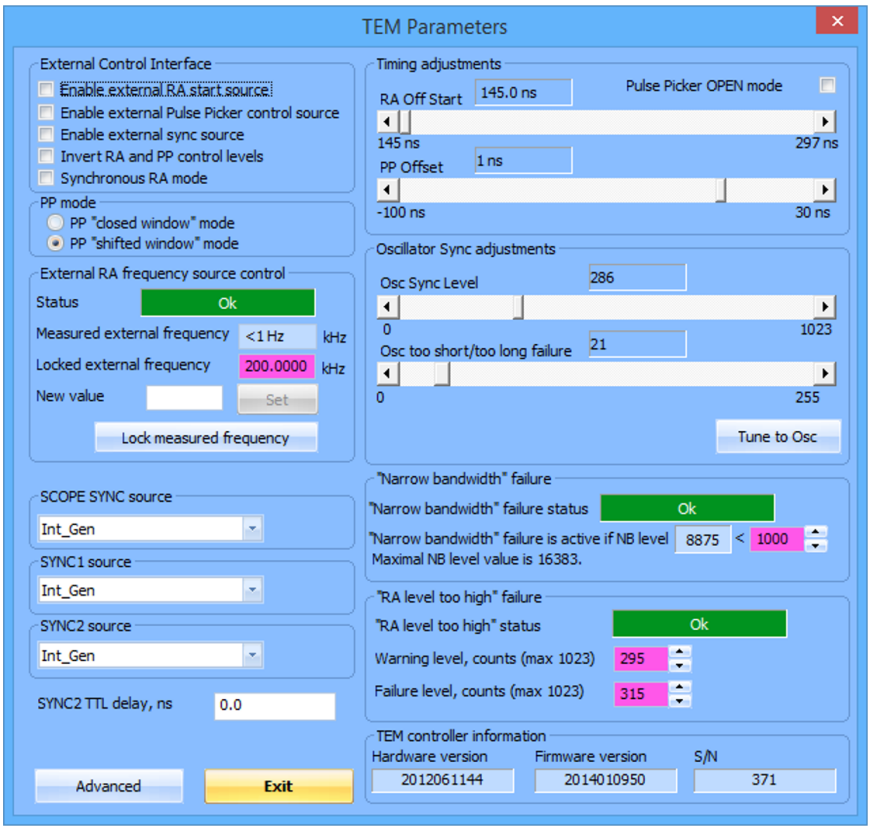


Figure 74. TEM parameters window

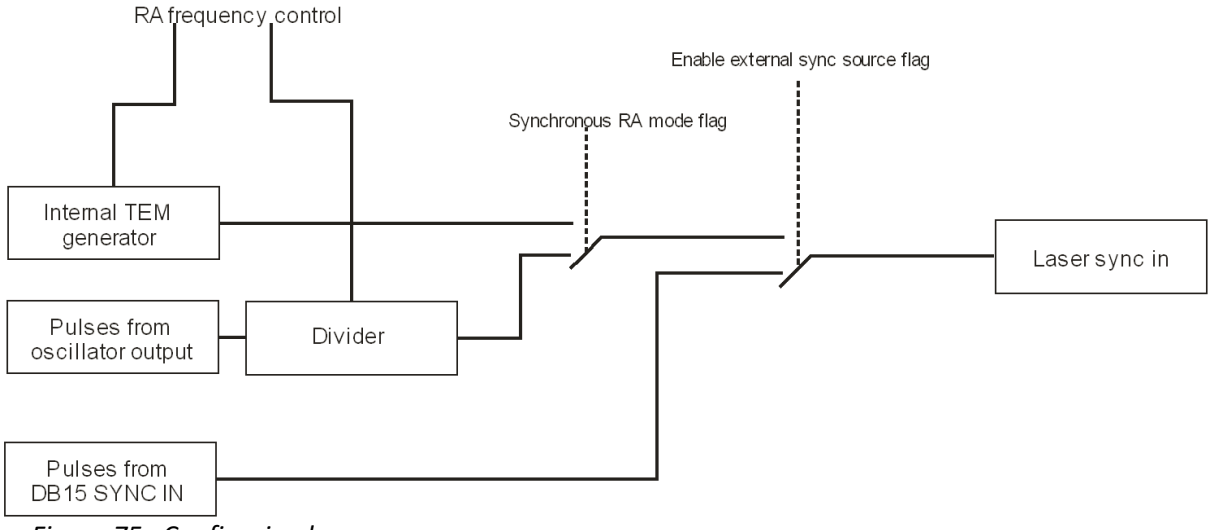


Figure 75. Configuring laser sync sources

8.7.10 Select BNC Output Signals

Several signal types can be selected from the three programmable BNC output ports on the back of the laser head (called "SCOPE", "SYNC1", "SYNC2"). The description of available signals is presented in the table below.

Table 30. Signals for "SCOPE SYNC", "SYNC1" and "SYNC2" outputs

Signal	Description
Int_Gen	Signal from internal RA frequency generator
OSC_SYNC	TTL version of OSC_SYNC input of TEM
RA_ON	Copy of "RA ON" signal used to trigger RA Pockels cell
RA_OFF	Copy of "RA OFF" signal used to trigger RA Pockels cell
PP_ON	Copy of "PP ON" signal used to trigger PP Pockels cell
PP_OFF	Copy of "PP OFF" signal used to trigger PP Pockels cell
SYNC2 TTL	Signal with user-controlled delay, locked to "RA OFF" signal
RA_rdy	Internal TEM signal
RA_delay_rdy	Internal TEM signal
SYNC_OUT	Copy of "SYNC_OUT" output on DB15 connector
RUNNING	"RA STATUS" output on DB15 connector
RA_Overrun	"RA frequency overrun" failure output
Power_OK	"5V supply failure" output
RA_Fail	"RA common failure" output
OUTPUT_PD_CMP0	Internal TEM signal
OUTPUT_PD_CMP1	Internal TEM signal
RA_LEVEL_CMP0	Internal TEM signal
RA_LEVEL_CMP1	Internal TEM signal
Narrow_Spectrum_Level_OK	"Narrow bandwidth" failure output
oclk	Internal TEM signal
osclk_b	Internal TEM signal
oclk_c	Internal TEM signal
prd_invalid	Internal TEM signal
prd_valid_gate	Internal TEM signal
Osc_period_short	"Osc sync period too short" failure active signal
Osc_period_long	"Osc sync period too long" failure active signal
oclk_bad	Internal TEM signal
oclk_active	Internal TEM signal
oclk_rdy	Internal TEM signal
DB15_SYNC_IN	Copy of "SYNC IN" input on DB15 connector
DB15_PP_IN	Copy of "PP on/off" input on DB15 connector
DB15_RA_IN	Copy of "RA on/off" input on DB15 connector
RA_OPEN	Output active from "RA ON" until "RA OFF" signal
PP_OPEN	Output active from "PP ON" until "PP OFF" signal
PP_ENABLE	Internal TEM signal

8.7.11 Setting Oscillator Pump Current

Use the *"Factory test certificate"* to determine the required OSC pump current. Due to different environmental conditions, the required pump current may be slightly different from the one indicated in the *"Factory test certificate"*. During daily operation, PHAROS Service App will inform a user to remeasure OSC mode-lock range once in two weeks. This only happens if PHAROS Service App is closed completely after turning off the laser and opened again. Please note that it is advised to perform the automatic mode locking range measurement only after the OSC has warmed up (>10 min of operation assuming water cooling temperature is constant).

To initiate the automatic mode-lock range measurement, follow these steps:

1. Go to menu *Parameters → CW detector parameters*. The CW detector parameters window should appear.
2. Press the "*Measure Oscillator's operational range"* button to start the measurement.
3. The message "Finished: Standby" will appear the below measure button after the measurement is complete. The measured parameters are displayed in the field *"CW detector info"*.

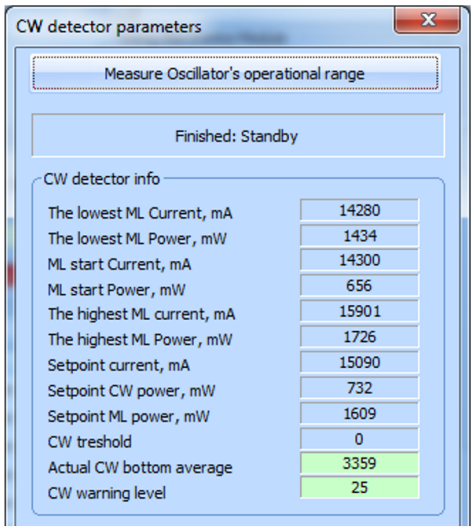


Figure 76. Part of the CW detector parameters window

8.7.12 Analogue mode for External PP Control

The PP can be controlled externally via analogue signal. The analogue signal must be connected to the "HV CTRL" BNC connector. For external PP control, analogue mode must be enabled in the PHAROS service App.

To enable analogue mode, follow these steps:

1. Locate the *RA* window and press the "*PP HV Supply"* button. The *PP HV Supply* window will appear.
2. Click the "Turn Off" button, to power down the PP HV power supply, if it is on, you will not be able to enable analogue HV control.
3. Click the "*Parameters"* button. The *PP HV Supply parameters* will appear.

4. Check the *Enable analogue HV control* checkbox. No elevated access level is necessary to check this checkbox.

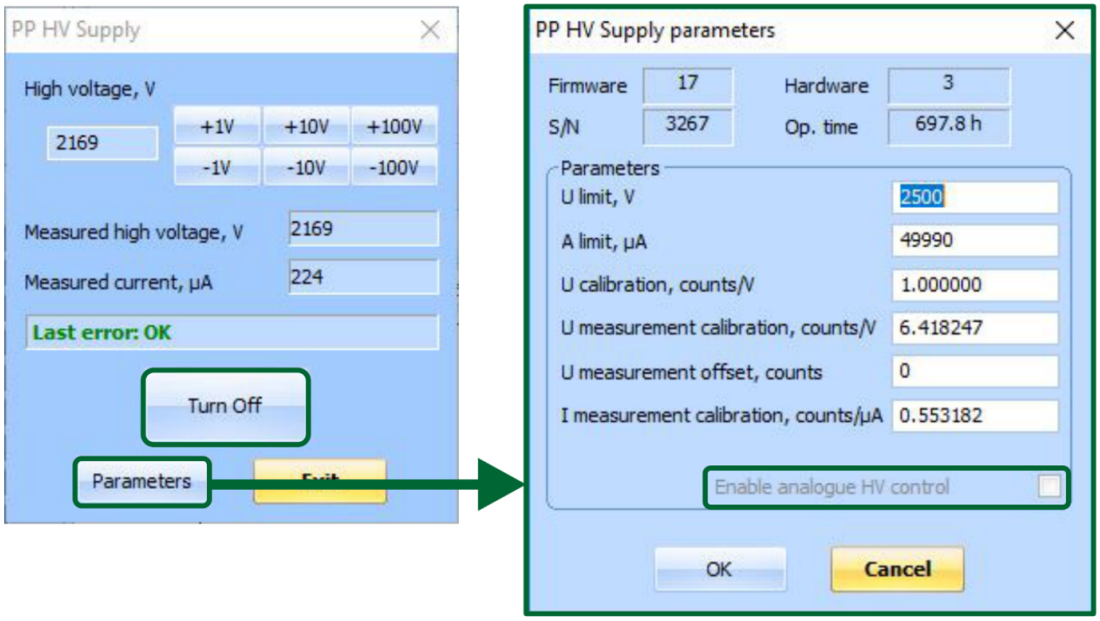


Figure 77. Enabling analogue mode for external PP control

8.7.13 Change System Control Access Level

To prevent intentional or unintentional modification of critical system parameters, access levels are defined for every laser parameter.

To change system control access level, follow these steps:

1. Press the "key" toolbar button or select *Service* → *Access Level* menu option.
2. Choose access level.
3. Enter the 4-digit security code and press *"Enter"*. If the code is correct the required access level will be set. If not, the access level will reset to "User".

NOTE. Code for a Technician Access Level is: **5172**.

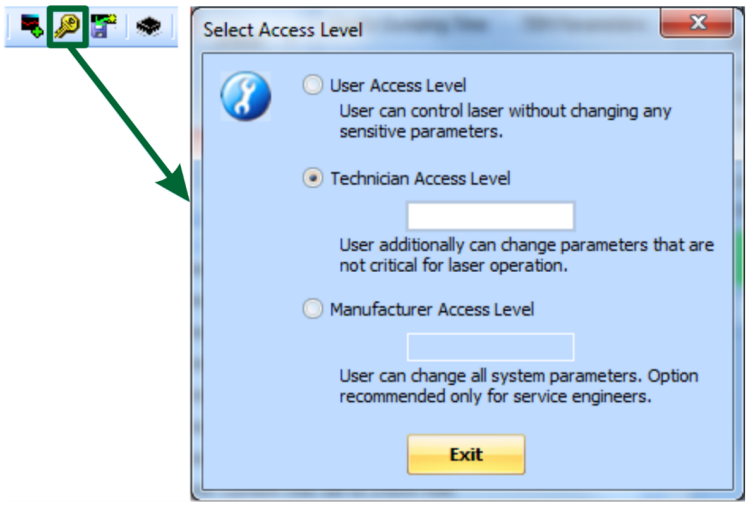


Figure 78. Setting PHAROS Service application access level

8.7.14 TEM Warning/Failure Flags - Troubleshooting

Failures and warnings of the PHAROS laser system can be divided into two categories:

- Timing Electronics Module (TEM) warnings/failures.
- OSC and RA laser diode driver and other failures.

The TEM state is displayed as a set of 12 different warnings/failures flags, shown in and can be observed in the PHAROS Service App.

Table 31. Description of TEM failures/warnings

TEM warning/failures	Description	Action required
RA common failure	General failure activated when at least one RA failure is detected, and the RA was stopped	Check other failures below
RA level too high-warning	Warning indicating that the RA output pulse energy is approaching the maximum allowed value for the specific laser model. Active warning doesn't stop the laser	No action required. It is an indication that the laser has reached the specified pulse energy
RA level too high-failure	Failure indicates that the RA output pulse energy has reached the maximum allowed value. In this case, RA is immediately stopped	Reduce the RA LDD current or increase RA repetition rate and start regenerative amplifier
RA frequency overrun	Failure indicates that RA cavity dumping time is too long for the actual frequency. If enabled, this failure stops the RA. If disabled – some laser pulses are missed	Reduce RA frequency
Frequency out of locked range	Failure indicates that the RA Sync signal is routed from the external interface (DB15 connector) and its frequency differs from the previously locked value by more than 10%. If enabled, this failure stops the RA	Check the external synchronization device. Check if the locked frequency in the TEM parameter window is entered correctly. Check all necessary cables
Osc sync failure	General failure indicates that the Osc. Sync signal from the oscillator is missing, has too low/too high amplitude, irregular period or the oscillator is in double pulse mode. If enabled, this failure stops the RA	Check all cables are connected and functioning properly. Check that the oscillator is operating in the purely mode-locked regime
Narrow bandwidth failure	Failure indicates that narrow spectrum detector inside the stretcher/compressor has reached critical value. If enabled, this failure stops the RA	Check that the oscillator is operating in the mode-locked regime. Check that the light from oscillator is not blocked at the entrance to the stretcher (direct osc output not enabled).
Osc sync period too short	The oscillator pulse train period detected by the TEM is shorter than a typical value	"Osc. Sync level" and "Osc. Sync Period too long/too short" parameters must be adjusted
Osc sync period too long	The oscillator pulse train period detected by the TEM is longer than a typical value	"Osc. Sync level" and "Osc. Sync Period too long/too short" parameters must be adjusted

Table 31. Description of TEM failures/warnings

TEM warning/failures	Description	Action required
5V supply failure	Failure indicates that there is a problem with the TEM electronics power supply circuits. This failure always stops the RA	The 5 V supply from the TEM should be checked. Check cabling. Contact Light Conversion if necessary
RA LDD stopped	Failure indicates that the RA laser diodes driver malfunctioned and stopped. Can occur when the user turns off the RA LDD while the RA is operating	Turn on the regenerative amplifier LDD
Osc LDD stopped	Failure indicates that the oscillator laser diodes driver malfunctioned and stopped. Can occur when the user turns off the Osc LDD while the oscillator is operating. This failure stops the RA	Turn on the oscillator LDD. Start mode-locking

TEM failures can be observed in the PHAROS control software window. If a failure is detected, the failure name turns red. There is a feature to select and mark the names of failures, which are treated as critical (NOTE: disabling the NB failure as critical is possible with "Technician" access level; other critical errors can be disabled only in "Manufacturer" access level). A critical failure immediately shuts down the laser system whenever it is detected. In the first column of the figure below there is a list of TEM warning/failure indicators. Whenever a failure occurs, the corresponding indicator turns red (in the case of a warning it turns yellow). A second column of squares is used to track failure history. To clear this history, press the "*Clear Acc. Failures"* button.

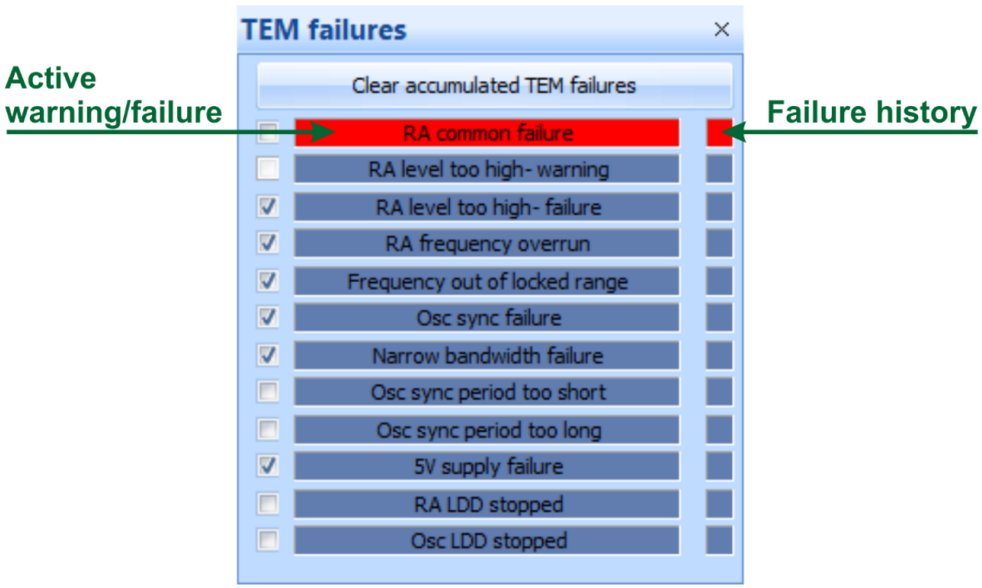


Figure 79. "TEM Failures" window

OSC and RA laser diode driver failures are indicated in the PHAROS Service application interface. Whenever a failure occurs, a failure notification replaces the numbers showing the exact OSC and RA LDD currents (see figure below). Failure descriptions are shown in the table below.

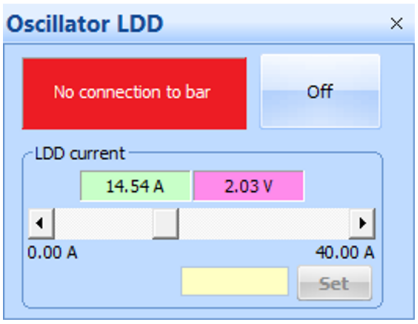


Figure 80. Oscillator LDD window when an error of the oscillator driver is present

Table 32. LDD failures

Failure	Description	Action required
Short connection	Activates when the laser diode driver electrical circuit experiences short connection or the laser diode is over driven	Contact Light Conversion representatives
Bar not connected	Activates when the laser diode driver LDD is not connected properly or experiences malfunction	Check that the LDD cables are connected properly. Check if they are hot. If correctly connected LDD cables remain hot, immediately shut down the laser system and contact Light Conversion
No connection to bar	Activates when the electronics cannot detect the information about the laser diode temperature. May be caused by incorrect connection of the laser head	Check that the laser head is connected properly. Contact Light Conversion if the head is connected, but the failure is still active
Bar overheat	Activates when the laser diode overheats. This may be caused by a chiller malfunction	Check that the chiller is functioning properly. Contact Light Conversion if chiller is operating correctly, but the failure is still active
Power supply overheat	Activates when the power supply over-heats. This may be caused by malfunction of the power supply fan or the temperature of the operating environment is too high, or the air filter of the power supply needs replacement	Check that the power supply fan is functioning. Check the operating environment temperature. Check the air filter for contamination
Communication error	CAN bus communication error. Low possibility of occurrence	Check that the laser system is grounded. Check that all cables are connected properly. Contact Light Conversion
Mains failure	Activates when the mains voltage is too low or too high	Check the mains voltage

Declaration of Conformity

Manufacturer	Light Conversion, UAB Telephone: +370 5 2491830 FAX: +370 5 2698723 Email: company@lightcon.com Internet: http://www.lightcon.com Address: Keramikų str. 2B, LT-10233 Vilnius, Lithuania
Product	Femtosecond laser system “PHAROS All models, manufacture after May 1, 2011

The manufacturer declares that the above products and manufacturing environment satisfy the requirements of following applicable directives and regulations:

- 2004/108/EC Electromagnetic compatibility Directive
- 2006/95/EC Low voltage Directive
- 21907/2006 REACH Regulation
- 2011/65/EU RoHS 2 Directive
- 2006/42/EC Machinery Directive
- 89/391/EEC Workplace Health and Safety Framework Directive
- 2009/104/EC Directive concerning the minimum safety and health requirements for the use of work equipment by workers at work

Compliance was demonstrated for the following specifications:

EN 55011:2009	Industrial, scientific and medical equipment - Radio-frequency disturbances characteristics: Conducted disturbance at the mains terminals.
EN 61000-3-2:2006 +A1 +A2	Harmonic current emission
EN 61000-3-3:2008	Voltage changes, fluctuations and flicker
EN 61000-6-1:2007	Electrostatic discharge immunity test
EN 61000-6-1:2007	Radiated RF electromagnetic field immunity test
EN 61000-6-1:2007	Electrical fast transient/burst immunity test
EN 61000-6-1:2007	Surges immunity test
EN 61000-6-1:2007	Immunity to conducted radio frequency electromagnetic disturbances
EN 61000-6-1:2007	Power frequency magnetic field immunity test
EN 61000-6-1:2007	Voltage dips, short interruptions and voltage variations immunity test
EN 61010-1:2001	Safety requirements for electrical equipment for measurement, control and laboratory use. Part 1: General requirements
IEC 60825-1+A1+A2:2001	Safety of laser products-Part1: Equipment classification and requirements

Vilnius, 2019-02-11

Darius Mikalauskas, Quality Manager

List of Hazardous Materials Used in Product

Manufacturer

Light Conversion, UAB
Telephone: +370 5 2491830
FAX: +370 5 2698723
Email: company@lightcon.com
Internet: http://www.lightcon.com
Address: Keramikų str. 2B, LT-10233 Vilnius, Lithuania

The manufacturer declares under sole responsibility that the products

Femto-second laser systems "***PHAROS" (all models),***

to the best of our knowledge, contain these hazardous materials:

Material	Quantity	Area in use
BeO ceramics	< 3 grams	Pockels Cell drivers

Vilnius, 2019-02-11

Darius Mikalauskas, Quality Manager

Declaration of Conformity to EU RoHS

Manufacturer

Light Conversion, UAB
Telephone: +370 5 2491830
FAX: +370 5 2698723
Email: company@lightcon.com
Internet: http://www.lightcon.com
Address: Keramikų str. 2B, LT-10233 Vilnius, Lithuania

The manufacturer declares under sole responsibility that the products

Femto-second laser systems "*PHAROS" (all models),*

PHAROS Harmonics modules (all models)

Are in compliance with Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (also known as "RoHS Recast"). Products listed in this declaration do not contain the substances listed in the table below in concentrations greater than the listed maximum value.

Substance	Maximum limit (ppm)
Lead (Pb)	1000
Cadmium (Cd)	100
Mercury (Hg)	1000
Hexavalent Chromium (Cr^{6+})	1000
Poly Brominated Biphenyls (PBB)	1000
Poly Brominated Diphenyl ethers (PBDE)	1000

Vilnius, 2019-02-11

Darius Mikalauskas, Quality Manager

Declaration of Conformity

Manufacturer Light Conversion, UAB
Telephone: +370 5 2491830
FAX: +370 5 2698723
Email: company@lightcon.com
Internet: http://www.lightcon.com
Address: Keramikų str. 2B, LT-10233 Vilnius, Lithuania

The manufacturer declares that Safety- Shutter controllers used in femtosecond laser systems ***PHAROS***, ***CARBIDE***, ***CARBIDE-alpha*** meet requirements for performance level **d** as defined by EN 13849-1:2008 (reference "Technical report of the Type testing of the Laser System Interlock Safety Shutter", Report no.LV86359T", 2014-12-23, TÜV SÜD Rail GmbH, Embedded Systems, Barthstraße 16, D-80339 München).

Safety function	Safety-related stop function		
Type of safety function	Monitoring of safety-related parameters		
Reliability parameters			
	Safety Shutter version		
PHAROS	E01-300-10/ E01-310-05	E01-300-11/ E01-310-05	E01-300-12/ E01-310-05
CARBIDE	E01-300-10/ E01-310-05	E01-300-11/ E01-310-05	E01-300-12/ E01-310-05
$MTTF_d$ (Mean time to failure dangerous):	141 years	141 years	141 years
MTTF (Mean time to failure):	69 years	65 years	65 years
DC_{avg} (Diagnostic Coverage)	91%		
CCF (Common Cause Failure)	65		
Performance level in accordance with EN 13849-1: 2008	**d**		

Vilnius, 2019-02-11

Darius Mikalauskas, Quality Manager