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User Manual of Ultra-Short Pulse Laser

Model: PX400-3-GH
SN:620
Date: 2014.03.04

******* Important! *******

It is absolutely mandatory, that the safety instructions in section 3 have to be studied before operation of the laser!

The mechanical laser blockers, screwed to the laser apertures (section 2.2) have to be removed before switching the laser on!

Table of content

1 About this manual

1.1 General remarks

This manual is an important part of the laser. It has to be stored with the laser and has to be supplied to the laser operators at the place of the operation of the laser.

The laser has been manufactured according to the technical state of the art and fulfills the current safety regulations. Because of the residual risks it is indispensable, that every person, working with the laser has to be informed about possible dangers and has to be instructed on how to safely operate the system.

In this context it is especially important to strictly keep to the safety rules given in section 3 of this manual. Missing compliance with these instructions may lead to the lost of liability and guaranty claims against the laser manufacturer.

Do not start to operate the laser if you did not read and fully understand the safety information in section 3 of this manual.

1.2 Classification of Laser safety

Lasers are categorized according to their safety hazards into different classes. In Germany these classification is described in the VBG 93, in the United States of America the classification is given by the American National Standards for the safe use of Lasers ANSI Z 136.1 – 1986. FDA 21CFR 1040.10 and 1040.11 and IEC-825. According to these standards, the INNOSLAB-laser is a class 4 (high-power) laser and therefore has to be seen as a potential hazard to the operator and a potential fire hazard. The safety rules given in section 3 of this manual have to be strictly followed.

1.3 Safety symbols used

In order to mark possible safety hazards signs are attached to the lasers as specified below. These signs are used in the text as well to indicate the specific safety hazards.

Danger, laser beam

The INNOSLAB-laser is a class 4 laser, emitting visible or invisible radiation, depending on the model. This radiation may cause hazards, especially danger to the eye of the operator, if the laser is improperly used. When using or integrating the laser into a laser device or assembly (cf. section 1.4) the existing safety regulations explained in section 3 have to be strictly followed. This means for instance:

- laser radiation always has to be shielded properly, so that no hazard of the operator can occur,
- when it is unavoidable to work with unshielded laser systems, protective eyewear is mandatory,
- it has to be made sure, that only authorized and trained personnel will work with the laser.

Attention High Voltage

In the laser head life-threatening high-voltage is generated. In normal operation, with all covers properly closed, this high-voltage is safely shielded from the user. If the covers are opened or if the laser head is not properly grounded and internal cables are damaged, parts with high voltage may be open or may become in contact with the operator. In order to avoid such hazards, the safety regulations explained in section 3 have to be strictly followed. This includes in particular:

- installation and modifications of the laser are restricted to trained personnel, who are aware of high-voltage hazards and who have a training on how to avoid these hazards,
- during installation and modifications of the laser, the laser has to be fully disconnected from the electrical power supply network,
- the laser head and the power supply must only be opened by persons of EdgeWave or persons, who have been put in charge for this by EdgeWave,
- the laser head has to be properly electrically grounded.

General Hazard Warning

This sign indicates a general hazard beyond the ones discussed above. The laser may for instance cause a fire, if the beam is directed to inflammable material.

1.4 Laser terminology

According to the terminology, defined in ISO 11145 the INNOSLAB-laser is regarded as a so-called »laser-device«, consisting of the components laser-head, power-supply and cooling unit, as shown in Fig. 1. The determined use of the laser device is the integration into a »laser-assembly« or »laser-unit« , as shown in Fig. 1.

As the INNOSLAB laser is solely distributed as a laser-device, the manual in hand can only describe the properties, operation and safety aspects of a system, which is not yet integrated into a »laser-assembly« or »laser-unit«. The legal entity (“laser integrator”), which integrates the laser-device into a »laser-assembly« or »laser-unit« is fully responsible for any safety issues and extensions of the manual, being additionally necessary due to the integration procedure.

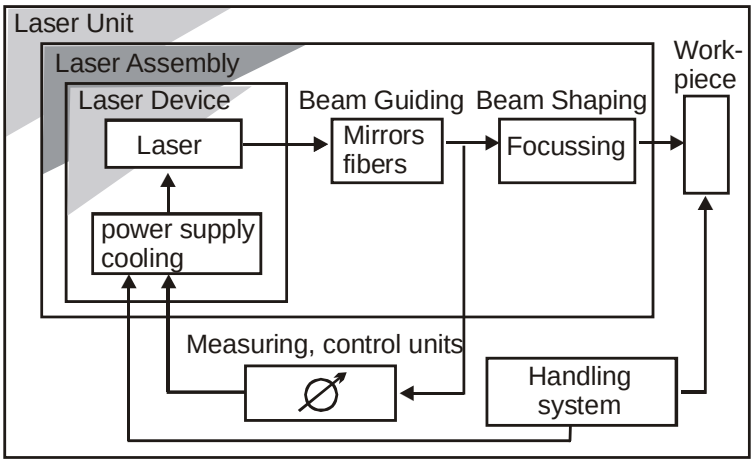


Fig. 1: Components of a laser-unit according to ISO 111 45

Definitions

Laser (or laser head)	The laser (laser head) consists of an active medium, which is excited by diode laser radiation and generates a coherent beam due to stimulated emission.
Laser Device	A laser together with the necessary supply units such as electrical power supply and cooling unit.
Laser Assembly	A laser device together with all necessary additional components for beam delivery and beam shaping
Laser Unit	One or several laser assemblies, together with systems for work piece handling, control and measurement systems

2 Survey on the Laser

The section hereunder gives a short survey on the laser with the components and supply units.

2.1 Total system

The photograph in Fig. 2 shows the complete laser device, consisting of the laser head and the electrical power supply.

Additionally a cooling system (water/water OR water/air heat exchanger) is needed to remove the waste heat and a control unit (e.g. PC) is needed and to control the laser via the power supply; these systems are not shown in the picture. The control unit is not included in the scope of delivery.

Before starting the laser the components shown in Fig. 2 have to be properly connected with cables and tubes, as detailed in section 4.1. In order to integrate the laser device into a laser assembly or laser unit, additional connections and means are necessary, being in the scope of responsibility of the laser integrator. The necessary interfaces for this integration, provided by the power supply are described in section 5.3.

Fig. 2: Photograph of the INNOSLAB-laser device, consisting of the laser head and Power Supply

Attention: This is a SAMPLE figure. Please refer the real laser device.

2.2 Laser Head

Fig. 3 shows schematically the principal setup of an ultra-short pulse laser head which consists of a seeder, a pulse picker, an amplifier, a modulator and eventually frequency converter (optional).

Fig. 3: Scheme of ultra short pulse oscillator and amplifier system

Seeder

The seeder is a diode pumped and passively mode locked oscillator. The standard repetition rate is $f_s = 1/T_s = 20MHz$. It can be adapted if required. Please refer Fig. 4a).

Pulse picker

To reduce the pulse repetition rate a pulse picker is used. In this ps laser an acousto optical modulator is used for pulse picking. There are two parameters which customers can set according to application requirements:

- The Seeder Frequency Divider SFD. The burst frequency after SFD $f_b = 1/T_b$. The value can be from a min f_b to $f_b = f_s$ (refer Fig. 4b));
- and the Pulses Per Burst PPB. In the example shown $PPB = 3$ (refer Fig. 4c)).

Amplifier

The typical pulse energy after pulse picking is about 100nJ which is too low for most material processing process. In order to get application relevant pulse energy of several µJ to several 10µJ the pulse burst one or multistage amplifier will be used (refer Fig. 4d)). The amplifier in this ps laser is based on the INNOSLAB technology, where slab shaped crystal(s) is (are) longitudinally pumped by diode laser stacks.

Modulator

The most stable operation will be achieved when the seeder and the amplifier is pumped constantly and the extracted average power from the seeder and the amplifier is kept constantly. To change the pulse

energy/average power (power level) and to switch the pulses on/off (gating) an electroptical modulator (EOM) is used. The two functions of the EOM are:

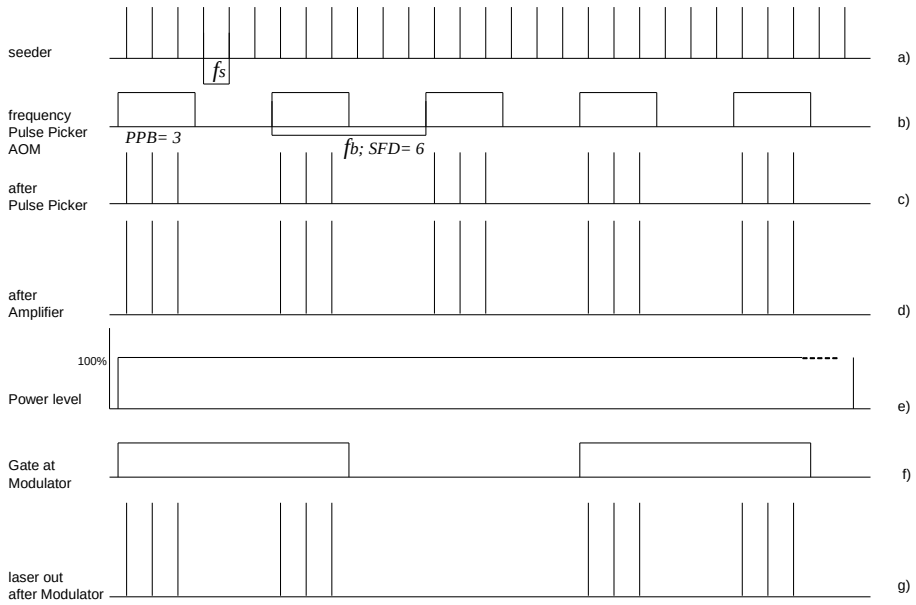
- Adaption of the power level (refer Fig. 4e));
- Gating the pulses (refer Fig. 4f) and g)).

Frequency converter (OPTION)

The emitting wavelength of Nd:YVO4 is 1064nm. For getting 532nm, 355nm, 266nm, etc. frequency converter with nonlinear crystals will be used (optional).

Fig. 4 shows the operation principle of an ultra-short pulse laser.

Fig. 4: Operation principle of an ultra-short pulse laser



The laser head is supplied from the rear (cf. Fig. 2) with electrical power, signals and cooling water, the laser is emitted from the aperture at the front of the laser head, indicated with the sign shown at the left.

Warning: Never look into the laser beam!

Always make sure, that no laser radiation will get into your eyes. This not only applies to laser radiation, coming directly from the laser head but as well for laser radiation, which might be reflected by obstructions in the beam path or by the work piece itself! Please comply strictly to the safety instructions in section 3.

The mechanical beam blocker is included for protection of the laser aperture while transportation and provides an additional safety feature in order to avoid accidental emission of a laser beam, for instance during maintenance and service. The aperture of the laser head, where the laser beam is leaving the head, can be safely screwed down with the provided massive knob. **Please pay attention to remove the knob before putting the laser in operation!** If the laser beam is turned on with the knob screwed to the aperture the laser head may be seriously damaged.

If the cover of the laser head is opened, hazardous laser radiation may escape and harm the operator. The label shown on the left side is sticked on the rear part of the laser warning about this situation.

The laser head was assembled in a clean-room and was hermetically sealed before leaving the clean-room. If the laser head is opened in a non-appropriate environment, laser components or even the whole laser can be impaired or damaged. The laser head must only be opened by EdgeWave personnel.

In order to keep a dry atmosphere inside the laser, the different laser areas are supplied with a drying cartridge, which is screwed into the housings. If the humidity of the air inside the laser increases above the accepted level, this is indicated by a color change at the outside of the cartridge. In this case the cartridge has to be replaced. In case of replacing the cartridges the laser must be turned off.

The control of the laser is solely handled by PC or a numerical controller, the RS232 or CAN-bus interface of which has to be linked to the power supply by a serial 1:1 cable. The control commands and messages are described in section 6.2.

Warning:
If the laser head is opened, the user may get in contact with extremely dangerous high voltage. Maintenance and repair is therefore strictly restricted to personnel with appropriate qualification. When working on electrical components with high voltage all relevant safety regulations have to be observed (cf. section 3).

2.3 Electrical power supply

The power supply provides the following voltages and signals for the laser head:

- current sources for driving of diode lasers,
- auxiliary voltages and signals for the supply of electronic circuits in the laser head,

- electrically redundant safety loops with built-in self-monitoring (EN 954-1 category 4).
- Power supply control unit
- Interfaces

Operation and interface ports of the power supply are explained in detail in section 5.3.

Warning:
If the power supply is opened, the user may get in contact with dangerous voltage. Maintenance and repair is therefore strictly restricted to personnel with appropriate qualification. When working on electrical components with high voltage all relevant safety regulations have to be observed (cf. section 3).

2.4 Cooling system

The cooling system provides clean water with the appropriate temperature and flowing rate. The water supply and return hoses are conducted from the cooling unit to the laser head. The safety loop signals of the cooling unit (for instance “low water flow”) have to be connected to the corresponding interlock interfaces of the power supply (connector “chiller”, cf. section 5.3) in order to avoid damage of the diode lasers and laser head due to overheating. For a trouble-free operation of the laser it is particularly important to regularly control the water filter in the cooling system.

The cooling system may only be filled with deionized and filtered water; tap water may cause the damage of the laser! Improper filling of the water reservoir may lead to lost of guaranty.

Additional information on the use, the maintenance and on safety issues of the cooling system are given in the attached manual of the chiller manufacture.

3 Safety information

3.1 General directions

Intended Use

This laser device is intended to be integrated into a laser assembly or laser unit for industrial manufacturing, in particular for the industrial processing of materials. If the laser device is used in any other area, this is solely to the risk and the responsibility of the user.

When integrating the laser device into a laser assembly or laser unit the laser integrator is responsible for the consideration and application of all relevant safety regulations for this laser assembly or laser unit. This concerns especially the local laser safety regulations.

The laser beam must never be directed to human beings and animals.

Modifications

The laser may only be operated with the delivered components (laser head, power supply, cooling system, hoses and cables). The use of for instance other power supplies or cooling units or modifications of the laser device may seriously affect safety and operational reliability and are not permitted.

Operation and troubleshooting

The laser may only be operated by properly instructed, skilled and assigned persons, who are in particular familiar with all relevant aspects of laser safety (section 3.2) and electrical safety (section 3.3).

Troubleshooting may only be carried out by properly instructed, qualified and authorized persons.

When carrying out dangerous work it has to be considered, that never such work should be carried out alone! A second person should be present, being informed about the safety issues and in case of an accident being able to switch out the laser and to provide first aid.

Safety of Use

The laser device has to secure adequately against misuse and inadvertent use. It is not permitted to bridge or circumvent protection circuits! Before putting the laser into operation it has to be made sure, that all necessary safety labels, safety directions and protection circuits are still in place and in proper operation.

Adherence to Safety Directions

The user of the laser device is obliged to adhere to the safety directions given in this manual, to general safety rules and to the other information in this manual. He is obliged to stick to the recommended inspection and maintenance procedures. If the given directions are disregarded, this may result in a loss of liability and loss of warranty claims against the laser manufacturer.

3.2 Laser Safety

The INNOSLAB laser is a class 4 laser product, emitting pulsed or continuous infrared, green or UV laser radiation with high power.

Warning:
The INNOSLAB laser emits high power laser radiation which may cause considerable damage of the eyes and skin!

Due to the high output power of several 10 Watt (averaged or cw, respectively) the laser may cause damages by harming the eye, by burning of the skin or by burning of inflammable materials. Laser radiation, which falls directly or indirectly into the eye, is focused by the eye lens to the retina, thus leading to burning of retina tissue and subsequent reduction or lost of sight.

This hazard is not restricted to the case when the user looks directly into the beam path, it may as well be caused by laser radiation, which is directly or diffusely reflected into the eye by obstacles in the beam path or by the work piece.

Safety Directives

- The area, in which the laser beam is propagating open, which means without hermetically sealed radiation-safe covers, is called the “laser area”. This laser area has to be clearly marked and delimited in a way, that it is impossible, that direct or reflected laser radiation may leave this laser area and hit the user or other persons. Technical means includes for instance, but are not restricted to: radiation sealed fire-proof covers and tubes, cabins or movable walls.

- With appropriate safety circuits and contacts it has to be assured, that the laser is switched off, if delimiting elements such as covers and doors are opened. The personnel safety interlocks, integrated into the power supply (cf. section 5.3), should be used for this purpose.

- The bridging of protection circuits is not permitted! If this should be inevitable, for instance in case of service or maintenance, the work may only be carried out by qualified and authorized experts.

- If the laser is operating, this has to be signalized by appropriate signs and/or signal lamps. The power supply provides appropriate interfaces for this (cf. section 5.3).

- If it is inevitable to work with an open laser beam without covers or shielding, for instance during service or maintenance, appropriate protection eye ware is mandatory. This holds for every person, who might be hit by direct or reflected laser radiation.

- Before using the protection eye ware it has to be made sure by the user, that the glasses do not have apparent defects. The spectral protection range of protection glasses is quite narrow. The user therefore has to check in advance, that the used glasses are approved for the laser wavelength and power level.

- The customer, using the laser, has to adhere to all national and local laser safety rules and regulations.

Measures if accidents happen

In case of accidents, the following rules apply:

- switch off the laser immediately,

- inform the supervisor in charge, the company medical officer and the safety officer,

- provide first aid until professional aid has arrived.

3.3 Electrical Safety

If the laser head, the power supply or the cooling system is opened, the user may come into contact with high-voltage. The operation of the laser therefore is only permitted with properly closed covers and duly installed and shielded connection lines between laser head and supply units.

When working on electrical components of the laser and the supply units all national and local electrical safety rules and regulations have to be adhered, in particular:

- Installation, modifications and repairs may only be performed by qualified and instructed personnel.

- All contacts of the laser device, which are connected to high voltage, are properly shielded by covers. Before opening or removing these covers, the laser and the supply units have to be completely disconnected from the electrical supply net. Furthermore it has to be made sure by protection devices and/or appropriate labels, that the power supply can not be reconnected accidentally or deliberately with the electrical supply net.

- As high-power capacitors are discharging relatively slowly, the respective contacts have to be grounded and one has to wait some minutes, before the contact may be touched.

- Before starting to work at open electrical contacts, it has to be made sure with appropriate measuring devices, that the contacts are voltage-free.

- If it is inevitable, that measurements or maintenance work has to be carried out at the power supply in operation, it has to be made sure, that appropriate safety distance to parts with high voltages are adhered.

3.4 Further Safety Directions

Fire Prevention

Due to the high output power of a class 4 laser, materials being hit by laser radiation may be inflamed and may cause a fire. Therefore appropriate fire prevention measures have to be taken, in particular:

- in the vicinity of the laser beam or at places, which may be hit by reflected laser radiation, easily inflammable materials such as paper, tissue or thin wood sheets must not be used,

- in the working area of the laser beam it is not permitted to store bins with highly inflammable gases or liquids like solvents or cleaning fluids.

Pollutants caused by laser materials processing

During the processing of materials with laser radiation pollutants may be created, being dangerous to health. These pollutants may be either solid (smoke) or gaseous and can be absorbed by the user via skin or breathing. In order to protect the user from such pollutants, appropriate measures have to be taken, for instance by suction cleaning and subsequent filtering of the exhaust. The integrator and user of the INNOSLAB laser device is responsible for the determination and the adherence of all safety rules and regulations in this context.

4 Laser Installation

4.1 Interconnecting the laser components

The following picture shows schematically how the components laser head, power supply, cooling system and PC are connected to each other with the provided cables and hoses. The cables and hoses are labeled as shown in the Fig. 5.

In the laser head a flowing rate meter was integrated (only PX400-Laser). Please make sure that the chiller is correctly connected to the laser head (ref. signs of inlet and outlet in laser head and in chiller). Otherwise the laser head can be damaged!

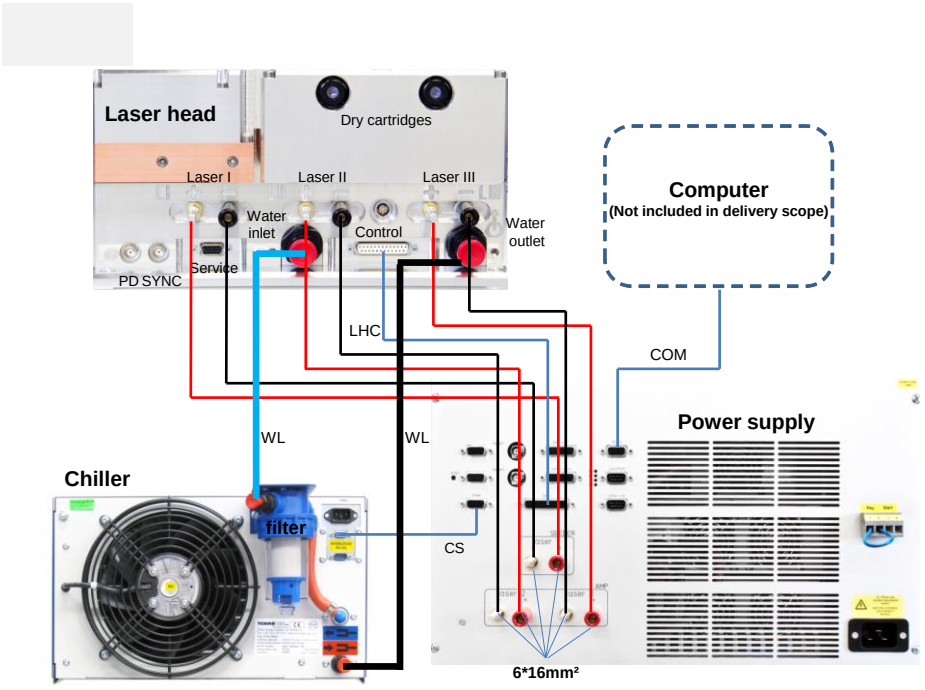
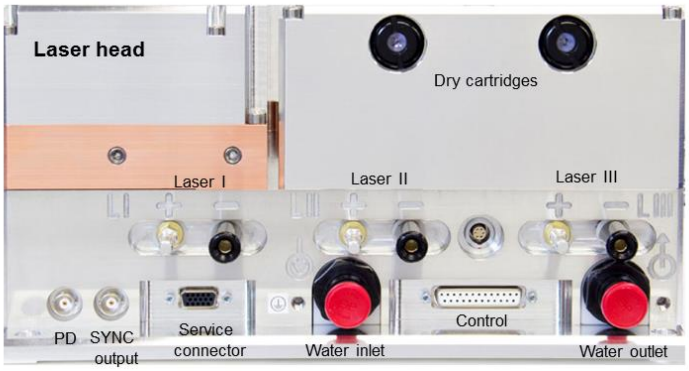


Fig. 5: Schematics for the connection of the laser head with power supply, cooling unit and a PC for the control of the power supply

The following two figures show the connection sides of the laser head and the power supply and indicate the different ports to be connected with the cables and hoses as it will be detailed later in this section.

Fig. 6: Rear side of the laser head with the connection ports.



“Dry cartridges”

Dry cartridges are used for keeping the laser chambers at low humidity and need be checked each month. They shall be blue. Otherwise, they shall be replaced with new ones.

“Water inlet and Water outlet”

They are the connectors for cooling water and shall be connected to chiller with the delivered hoses.

“Laser I, Laser II and Laser III”, + and – (high current connectors)

These high current connectors shall be connected to the corresponding high current connectors on the back side of the power supply, for getting the driving current for the diode lasers installed inside the laser head.

“Control” (SubD 25)

The SubD-connector labeled “Control” shall be connected to the SubD 25 connector labeled by “Laser” on the back side of the power supply for getting auxiliary voltages, safety loops and control signals for the laser head.

“SYNC out” (BNC connector)

The SYNC output provides signal for the laser handling synchronization. A description of SYNC output could be found in section 6.5.

“monitor/PD” (BNC connector) – Photo Diode

The PD provides photodiode signal of laser after pulse picker. An Oscilloscope with 50Ohm termination can be used for visualizing (pulse width is a few ns).

“Service connector” (VGA connector)

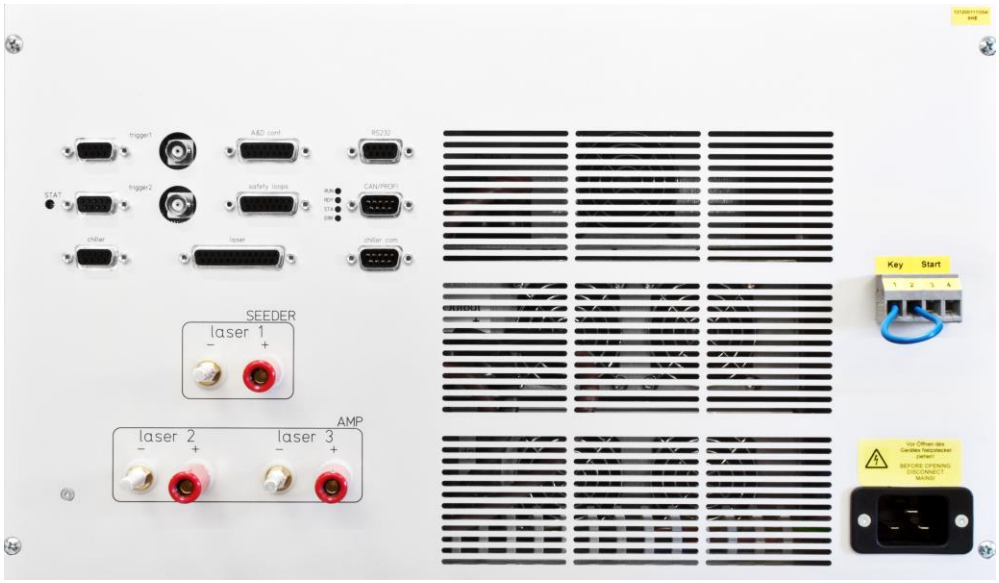
This connector is used only when the laser control software inside laser head shall be upgraded. (Do not connect! Usage by EdgeWave employees only.)

“PE”

The laser head has to be probably connected to protected earth via the hole indicated by PE.

In Fig. 7 the rear of the power supply is shown with the ports for the connection to the laser head, the cooling system and the PC.

Fig. 7: Rear of the power supply with the connectors for the supply cables



Basic installation requires the connection of several ports using the provided cables and hoses as listed in the table hereunder (NA – not available or not specified):

Unit – from	**Port labeling**	**Cable/hose**	**Unit – to**	**Port labeling**
power supply	Laser	LHC	laser head	control
power supply	Laser 1 +	Red 16mm²	laser head	Laser 1 +
power supply	Laser 1 -	Black 16mm²	laser head	Laser 1 –
power supply	Laser 2 +	Red 16mm²	laser head	Laser 2 +
power supply	Laser 2 -	Black 16mm²	laser head	Laser 2 –
power supply	Laser 3 +	Red 16mm²	laser head	Laser 3 +
power supply	Laser 3 -	Black 16mm²	laser head	Laser 3 –
power supply	Chiller	9 pin SubD 1:1	cooling unit	Interlocks
power supply	RS232 or CAN	use standard 1to1 cable **(Not included)** for CAN: a 120Ohm termination is required	PC, PLC, control unit	NA
main supply	PE (Protected Earth) / ground	not included	laser head	PE symbol
cooling system	blue (filter)	WL (water hoses)	laser head	IN
cooling system	red	WL (water hoses)	laser head	OUT

The further connectors of the power supply, their functions and interfaces connections are described in the next section.

5 Power supply functions and interfaces

5.1 General description

The power supply incorporates current drivers for the diode laser in the laser head. The drivers are providing continuous currents of up to 70 Ampere at a driving voltage of up to 22 Volt. In addition the following functions are supplied by the power supply:

- safety loops,
- auxiliary voltages for the electronic modules in the laser head,
- numerical controller and interface to the PC or the control unit.

5.2 Front-Side

Fig. 8 shows the front panel of the power supply with all control elements. In section 6.1 it is described how the different switches, keys and button have to be actuated in order to put the laser in operation.

Fig. 8: Front-side view of the power supply with the control elements.

Main Power Switch

The red switch in the upper left part of the panel is the main power switch. With this switch the power supply is switched on and when turning off this switch the power supply is completely disconnected from the electrical supply net. When the switch is on, it is back-lighted.

Key-switch

With this key-switch the laser can be secured against unauthorized use. The laser can only be started if the key-switch is in “on” position (key orientation horizontal). The key can not be pulled out when the key-switch is in the “on” position. Operation of the laser is not possible without the key.

OPTION (Chiller remote start): The water pump of the cooling system starts when the main power and Key-switch are switched on. Be sure that the tubes are connected between cooling system and laser head.

Emergency Stop Switch

This self locking switch is redundantly implemented with two independent circuits. If the red knob is pressed, the driver for the diode laser current is immediately switched off. Before switching the laser on again, the emergency stop switch has to be unlocked by turning and pulling out the red knob. After this procedure the laser can be restarted by pressing the “Start”-Button.

If the laser device is integrated into a laser assembly or laser unit, it is required, that additional emergency stop switches have to be installed by the integrator. These additional switches have to be installed in the direct vicinity of the user, so that in case of emergency the switch can be activated without delay. In order to install these additional emergency switches, the power supply provides interfaces at the rear side (port “safety loops”), which are described in section 5.3.

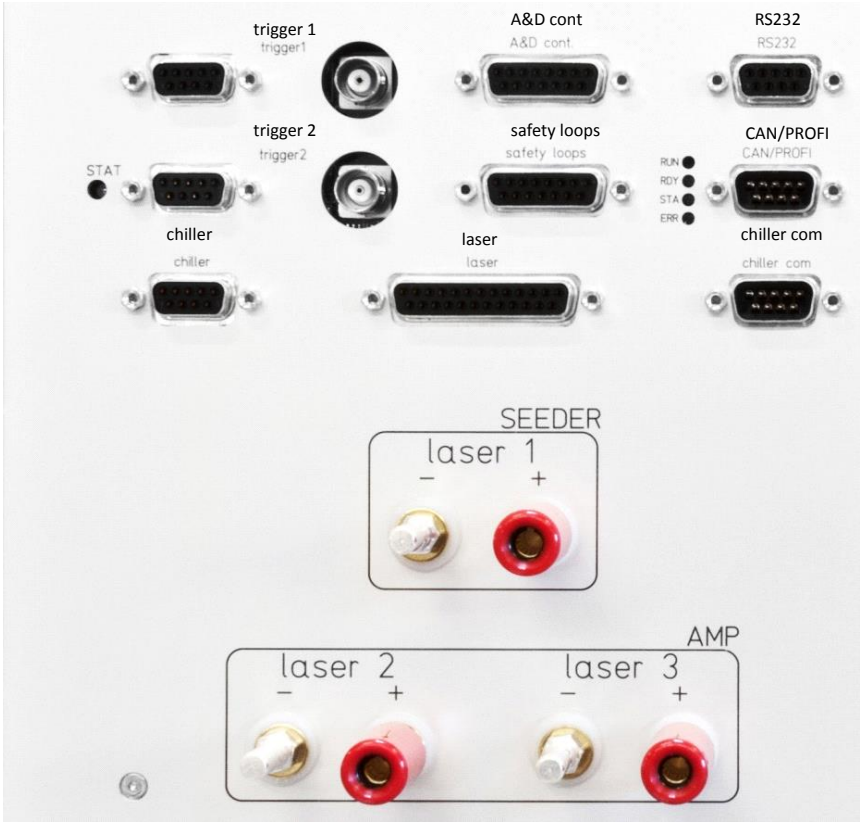
Pushbutton “Start”

With this button the laser is released and subsequently the laser beams can be switched on with one of the software commands described in section 6.2.

5.3 Description of the connection ports

In Fig. 7 of the foregoing section 4 all connector ports on the rear side of the power supply are shown. Function and technical specifications of the ports are described hereunder. The following picture shows the control ports and high current connectors in detail.

Fig. 9: Rear of the power supply with the connectors



“laser”, + and – (high current connectors)

With these high current connectors the laser is supplied with the driving current for the diode laser.

“laser” (SubD 25)

The SubD-connector labeled “laser” provides auxiliary voltages, safety loops and control signals for the laser head.

“safety loops” (SubD 15)

With this SubD-connector a couple of safety loops are provided. The pin assignment of the connector is given in the table hereunder.

As the status “Emergency Stop” and “Door Open” are essential for the safety of persons, they are implemented with a twofold redundancy, which means, that the laser can only be put in operation, if **both** of the connector pairs given in the table are closed. If even one of the pairs is not closed, the laser is switched off. This behavior has to be considered by the integrator when designing the safety circuits and the actuation switches. In case of not using one of these safety loops, both contact pairs have to be bridged; otherwise the laser cannot be started. The circuits are redundant with built-in self-monitoring (EN 945-1 category 4).

The “Interlock” interface may only be used for the protection of the laser device, **not** for personnel safety circuits, as it is implemented in hardware and not redundantly, as the two safety interfaces described before.

Emergency stop (for personnel safety)	PIN1 to PIN2 **AND** PIN3 to PIN4
Door open (for personnel safety)	PIN5 to PIN6 **AND** PIN7 to PIN8
“Laser On”–Lamp	PIN9 to PIN10
Interlock (only for device protection)	PIN11 to PIN12

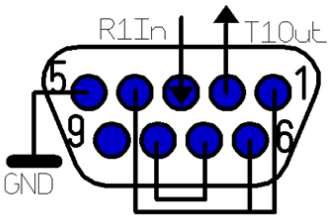
The contact pair PIN9 and PIN10 provides a potential-free relay contact for an external signal lamp. The contacts can be loaded with at maximum 24 V and 0,5 A. The contact closed after laser diode current is released by “laser ON”. The contact is open after “laser off” or during ERROR state.

“RS232” (SubD) and “CAN” (SubD) – “Profi”-Bus (option)

The power supply is controlled by either a Personal Computer (PC) or a CAN-bus controller which have to be connected to the power supply interfaces “RS232” or “CAN” respectively, by standard 1:1 9-pin SubD cables. Via these interfaces a couple of read and write commands can be send with which the power supply is controlled and status information on the power supply are retrieved by the PC or Controller.

The pin assignment of the RS232 interface is as follows (NC-not connected):

Pin Number	Assignment
1	Connected to Pin4 and Pin6
2	T1Out
3	R1In
4	Connected to Pin1 and Pin6
5	GND
6	Connected to Pin1 and Pin4
7	Connected to Pin8
8	Connected to Pin7
9	NC



The pin assignment of the CAN-bus interface is as follows (NC-not connected):

Pin-number	Assignment
1	NC
2	CANL
3	GND
4	NC
5	NC

Pin-number	Assignment
6	GND
7	CANH
8	NC
9	NC

A 120 Ohm termination is required between CANH and CANL on the first and the last CAN device.

“Trigger 1” (SubD) “Trigger 1” (BNC)

This is the TTL trigger interface for controlling the modulator.

SubD-connector	BNC-connector	Assignment
PIN 1	Center	Trigger_in TTL (≥4V;≥7mA)
PIN 6	Shield	Ground

“Trigger 2” (SubD) “Trigger 2” (BNC)

This is the TTL trigger interface for the laser 2. **It is NOT used!**

SubD-connector	BNC-connector	Assignment
PIN 1	Center	Trigger_in TTL (≥4V;≥7mA)
PIN 6	Shield	Ground

“A & D Cont.” (SubD 15 -- OPTION)

This 15-pin SubD connector provides inputs and outputs to control laser operation via a digital and analog controller (e.g. PLC). The pin assignment is as follows:

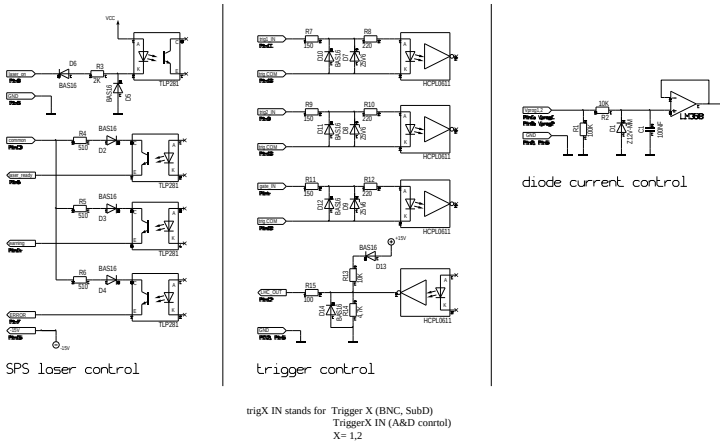
Pin-number	Assignment
1	Vprog 1 IN
2	GND
3	Trigger 2 IN
4	Gate IN
5	GND
6	Laser Ready OUT
7	Laser Error OUT
8	Laser on/off IN

Pin-number	Assignment
9	Vprog 2 IN
10	Trigger return (COM)
11	Trigger 1 IN
12	LHC Status OUT
13	COMMON (to 6,7,14)
14	Laser Warn. OUT
15	-15V OUT

- Vprog: the voltages to programme the current drivers which are delivered for seeder (1) and amplifier (2). 0 … 10V is linear to 0 … 70A (PX400 amplifier 3 not supported!)
- Laser Ready/Error/Warn: Indicator for the actual laser state referring section 6.1
- Laser on/off: a switch to enable/disable the current dirvers of laser diodes
- Gate/LHC Status: reserved, NOT used.

The electronics scheme could be found in Fig. 10.

Fig. 10: Schematics of the port A & D Control



“Chiller” (SubD 9)

Via this connector the power supply is connected to the cooling system. The cooling system transmits status and error messages via this connector to the power supply. In case of a malfunction of the cooling system, signalized via this interface, the laser is switched off in order to avoid damage of the diode lasers due to overheating. Via this connector the power supply signalizes the cooling unit to start the water pump. Connect to chiller port “INTERLOCK”.

“chiller com” (SubD 9 -- OPTION)

RS232 Interface for chiller control. Connect to chiller port “RS232”.

“STAT” LED

This RGB led signalizes the actual laser status with different colors.

- White: wait status
(5 sec after power supply on, reset and clear error AND if door is open)

- Blue: laser ready for operation
(no error, laser diode current not on)

- Green: laser diode current on

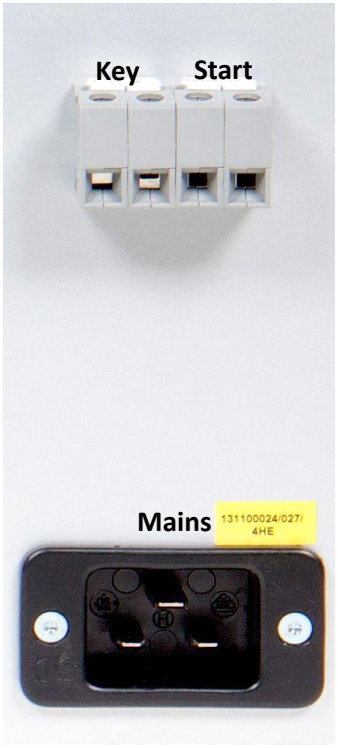
- Red: ERROR !
(always flashing – when any error occurs and laser is switched off)

- Blinking lights: WARNING !
(e.g. flow rate close to the limit, humidity close to limit, …)

Blinking lights can show WARNINGS during every laser status (white, blue and green).

The following picture shows the screw-type champing unit and mains connection port of the laser power supply.

Fig. 11: Rear of the power supply with connectors



Mains

AC supply for the laser power supply. Specs for mains see type plate on power supply.

“Key” screw terminals

This contact pair is for connecting an external key switch e.g. inside a laser system or machine. Its function is comparable to the key switch on the front of the laser power supply. For laser operation the contact pair must be connected.

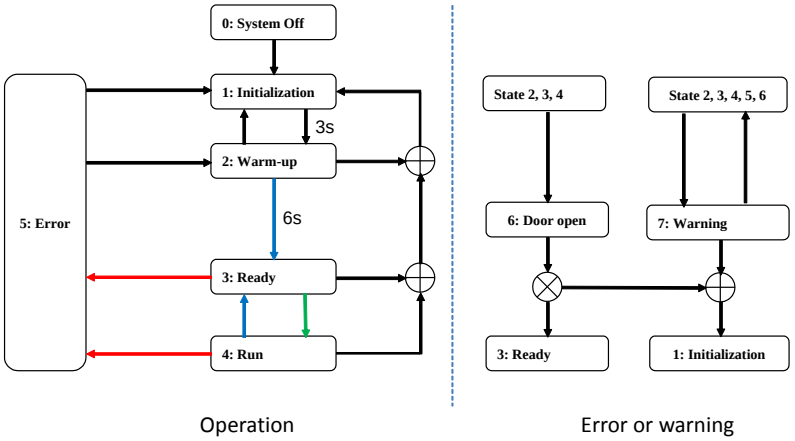
“Start” screw terminals

This contact pair is for connecting an external start switch e.g. inside a laser system or machine. Its function is comparable to the start button on the front of the laser power supply. Close this loop to release laser power supply.

6 Laser Operation

Fig. 12 shows the state machine of laser state interaction process in the software. There are totally 7 states with numbering to specify the whole laser system.

Fig. 12: Laser state interaction process



- There are 4 laser states that could be read out by command „r99“

laser state	return	comment
Error	0 / 8000	no warning / with warning
Warm-up	1 / 8001	no warning / with warning
Ready	2 / 8002	no warning / with warning
Run	3 / 8003	no warning / with warning

The definitions of these states could be found in the following table. Section 6.1 describes which action(s) could cause these laser state interaction processes.

State	Definition
0: System Off	The whole system is power off
1: Initialization	System power on, initialization of power supply and laser head
2: Warm-up	Power supply checks datas with laser head and chiller
3: Ready	System ready. Laser could be released to emit
4: Run	Current drivers for laser diodes are on. Laser is emitting
5: Error	There is any error in system.
6: Door open	Door is open.
7: Warning	There is any warning in system.

6.1 Basic operation directions

To understand the laser operation it is helpful to use the states in following table defined by the status of the each laser components:

State	Main	Chiller	Seeder	Pulspicker	Amp	MOD	LED
0: System Off	off	off	off	off	off	off	off
1: Initialization	on	on	off	off	off	off	white
2: Warm-up	on	on	off	off	off	off	white
3: Ready	on	on	ready	ready	ready	ready	blue
4: Run	on	on	on	on	on	on	green
5: Error	on	on	off	off	off	off	red&blinking
6: Door open	on	on	off	off	off	off	white
7: Warning	on	on	stay	stay	stay	stay	blinking

Part I: Laser power on process

State 0 to State 1:

1. Turn main power and chiller on. If the remote start is used, chiller will start automatically by main power on.
2. Turn the key-switch into the “On”-position (horizontally), regarding connection on screw terminal “key”.
3. Press the green “Start” button. Be sure that the emergency stop button is not pressed!

Attention: if the start button is not pressed or the emergency stop is pressed then the laser will stay at Initialization until the start button is pressed or emergency stop is released!

State 1 “Initialization” is reached. LED is white.

State 1 to State 2:

4. This state change takes approx. 3s. The internal communication and control modules will be initialized. 3s later the laser will go from “Initialization” to “Warm-up” automatically.

State 2 “Warm-up” is reached if there is no error (see section 6.3 for more info about error codes). LED is white.

State 2 to State 3:

5. This state change takes approx. 6s. If it is a power on process, the parameters of laser head will be checked with the parameters of power supply to ensure the matching of them. If it is an error releasing process it is just an internal software delay.
   6s later the laser will go from “Warm-up” to “Ready” automatically.

State 3 “Ready” is reached if there is no error. LED is blue.

State 3 to State 4:

6. Set the currents of Laser 1 (Seeder) and Laser 2 (Amp) to allowable values. For QX-Laser,the current of Laser 3 (Amp) should also be set.
7. Activate the Pulspicker and modulator (cf. section 6.2 to section 6.8).
8. Input the laser start command to turn the laser on. Laser will be emitted.

State 4 “Run” is reached if there is no error. LED is green.
Please keep in mind that laser could only go from “Ready” state to “Run” state. There is no other way to set laser to “Run” state.

Part II: The other laser state interaction processes

State 4 to State 3:

To switch off the laser, you can input the laser stop command to turn laser off. If there is no error, the laser will go from “Run” to “Ready”.

State 3 is reached. LED is blue.

State x (x=3 or 4) to State 5:

If there is any error and these errors could not be released by the software itself, the laser will go from actual state x to state 5 (“Error”) automatically.

State 5 is reached. LED is red and blinking. What an error or errors could make the actual state change to “**Error**” state, please refer section 6.3.

State 5 to State 2:

To release the errors you can input the command for releasing. If there are no errors any more the laser will go from “Error” to “Warm-up” and otherwise it will stay in the “Error” state.

State 2 is reached if there is no error any more. LED is white.
And now the laser will go from “Warm-up” to “Ready” automatically (see step 5 of part I).

State x (x=2, 3 or 4) to State 6:

If the door is open the laser will go from actual state x to state 6 (“Door open”) automatically. This error could be released by software itself if the error exists not any more. State 6 is the same as “Warm-up” State.

State 6 is reached. LED is white.

State 6 to State 3:

If the door is back closed, the error could be released in 1.5s and the laser will go from “Door open” to “Ready” automatically.

State 3 is reached if no any error exists. LED is blue.

State x (x=2, 3, 4, 5 or 6) to State 7:

If there is any warning in the laser, it will add state 7 (“Warning”) to the actual state x. State 7 (“Warning”) is not a separate state; it is always added to the actual state. The statuses of components stay as before.

State x with State 7 is reached. LED blinks with the color before.
Warnings could be released by software itself or by user when there is no warning any more. After releasing of warnings the laser will go back to the old state.

State x (x=2, 3, 4, 5, 6 or 7) to State 1:

By inputting reset command the laser could be reset from actual state x. The laser will go from actual state to State 1 (“Initialization”) automatically. Reset is the same with power on process. Refer part I to get more information.

We recommend that if laser power is not needed for a relative short while, please keep the laser at the state 4 – Run. This will increase the reliability of the total laser system. Start/stop laser emission by the modulator signal.

Please be aware that beginning from the state 4 – Run there is laser output, which may cause considerable damage of the eyes and skin! Please comply strictly to the safety instructions in section 3.

6.2 Software commands for laser control

“RS232-Interface”

The RS232 interface is working with the following parameters:
57,6 KBauds, 1 start bit, 8 data bits, no parity, 1 stop bit.
A free laser control software can be downloaded from Edge Wave Homepage. The Microsoft Windows Hyper Terminal program can for instance also be used.

Use an one to one connection to connect to the control unit.

The control commands consist of elements as described in the following:

<command>[number][space][value]<return>

Only three commands (element “<command>”) are available:

w	„write“: sends a value to the power supply
r	„read“: reads a value from the power supply
h	“help”: display the command list

The element “[number]” defines the action to be taken, for instance “laser on” or “read current”.

In case of w-commands the action-number is followed by a value, for instance for the specification of the diode laser current. r-commands need no value. The only valid value for the h-command is 01.

The elements “[number]” and “[value]” have to be separated by a space. With <carriage return> (ASCII Code 13; ‘\r’) the transfer of the command is terminated.

Examples:

w60 1\r switch Laser on

w60 0\r swtich Laser off

w61 30\r set current of Laser 1 to 30 A

“CAN-Bus Interface”

With the CAN-bus interface it is possible to control up to 15 lasers or power supplies resp. by only one PC.

Each end of the CAN-bus has to be terminated with a 120Ohm load resistor, which has to be connected CANH and CANL. One terminating resistor has to be installed at the PC and one at the “last” CAN-Device.

Each CAN-device is identified by an individual and unique identifier (ID), which ranges from 1 to 16. With the software command “w11 xx” (xx is the ID of the device) the ID of a device can be set and modified.

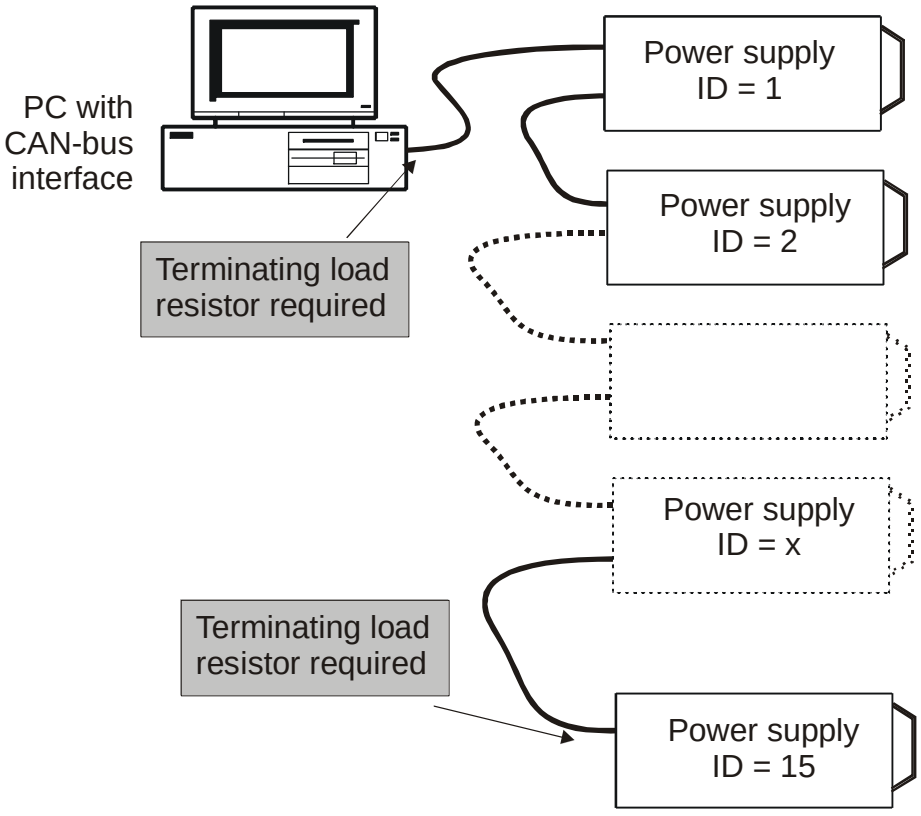


Fig. 13: Principle for cascading and terminating EdgeWave laser devices in a CAN-bus chain

The transfer rate is 1Mbit/s. Standard-CAN-Identifier (11 bit) are used. Every device is identified with an explicit CAN-Bus-ID, the standard setting is 15 (0x0F). The CAN-Identifiers are:

transmit (to device): 0x780 + ID (0x78F for CAN-ID=15)
receive (from device): 0x740 + ID (0x74F for CAN-ID=15)

All frames include 8 Byte Data, for this data the following protocol is used:

Byte 0	Command : „r“ , „w“, see RS232 except „h“
Byte 1	0
Byte 2	Number of parameter according to the table “commands overview” given below
Byte 3	0
Byte 4-7	value as 4-byte float value

Examples

Read value (e.g. driving current for laser 1):

Frame to device (Identifier 0x78F)

‚r‘	00	61	00	00	00	00	00

Device answer (Identifier 0x74F)

‚r‘	00	61	00	WB1	WB2	WB3	WB4

WB1-WB4: 4-byte float value

Write value (e.g. driving current for laser 1):

Frame to device (Identifier 0x78F)

‚w‘	00	61	00	WB1	WB2	WB3	WB4

WB1-WB4: 4-byte float value

Device answer (Identifier 0x74F)

‚w‘	00	61	00	WB1	WB2	WB3	WB4

WB1-WB4: 4-byte float value

In case of incorrect input (for instance value to high) the former value will be submitted to PC, this value is valid, until a new correct value is set.

Commands overview (for RS232 and CAN-bus interfaces)

para-meter no.	w/r	value	Min	Max	Unit	comment
1	r	Serial Number Power-Supply				
2	r	Serial-Number Laser-Head				
5	w/r	Temperature Setpoint oven 1	20	85	°C	Set working-temperature of oven 1; OPTION
6	r	Actual temperature oven1			°C	OPTION
7	r	Deviation oven 1			°C	in the range -2.5 to 2.5; 0 means no deviation; OPTION
9	w	Continuous data output oven 1	0	1		0/1: disable/enable continuous data output
11	w/r	Var. CAN-ID	0	15		Valid after saving to NVRAM and restart
15	w/r	Temperature Setpoint oven 2	20	85	°C	OPTION
16	r	Actual temperature oven2			°C	OPTION
17	r	Deviation oven 2			°C	OPTION
19	w	Continuous data output oven 2	0	1		0/1: disable/enable continuous data output
20	r	Actual temperature of power supply			°C	
21	r	Humidity Laser 1			% r.h.	NOT used, return -1%
22	r	Temperature Laser 1			°C	Seeder Temperature
23	r	Humidity Laser 2			% r.h.	NOT used, return -1%
24	r	Temperature Laser 2			°C	NOT used, return -1%
25	w/r	Temerature Setpoint oven 3	20	85	°C	OPTION
26	r	Actual temperature oven 3			°C	OPTION
27	r	Deviation oven 3			°C	OPTION
29	w	Continuous data output oven 3	0	1		0/1: disable/enable continuous data output
30	w/r	Water temperature setpoint	(r 36)	(r 37)	°C	No effect without serial chiller commumication
31	r	Water flow rate setpoint			l/min	
32	r	Actual water flow rate			l/min	
33	r	Water flow minimum			l/min	
34	r	Water flow maximum			l/min	
35	r	Actual water temperature			°C	
36	r	Water temperature minimum			°C	
37	r	Water temperature maximum			°C	
38	r	Minimum cooling power			kW	
39	r	Number of stacked laser-diodes				
51	r	Total power-on hours			hh.mm	Total operation hours of power supply and laser head
52	r	Output Voltage Laser Diode Driver LDD 1			V	Actual output voltage of current driver LDD1
53	r	Output Current Laser Diode Driver LDD 1			A	Actual output current of current driver LDD1
54	r	Programmed Current Laser Diode Driver LDD 1			A	Actual programmed current of current driver LDD1
55	r	Output Voltage Laser Diode Driver LDD 2			V	Actual output voltage of current driver LDD2
56	r	Output Current Laser Diode Driver LDD 2			A	Actual output current of current driver LDD2
57	r	Programmed Current Laser Diode Driver LDD 2			A	Actual programmed current of current driver LDD2
58	r	Operating hours diode(-stack) 1			hh.mm	
59	r	Operating hours diode(-stack) 2&3			hh.mm	
60	w/r	switch Laser on/off	0	1		0/1: disable/enable current driver LDD1&2&3

para-meter no.	w/r	value	Min	Max	Unit	comment
61	w/r	Current Setpoint Iout LDD 1	r186	r67	A	
62	w/r	Current Setpoint Iout LDD 2	0	r69	A	
63	w/r	Laser1 on/off	0	1		RESERVED
64	w/r	Laser2 on/off	0	1		RESERVED
65	w/r	External Current Driver control	0	1		0/1: disable/enable analogue current setpoint programmimg (Ext. Voltage Source required) OPTION
66	r	I-MAX-1			A	Absolut maximum current Laser 1 (Seeder)
67	w/r	I-limit1	0	I-MAX-1	A	User defined current limit for Laser1 (limited by Pulsepicker-setting (r172)
68	r	I-MAX-2			A	Absolut maximum current Laser 2 (Amplifier)
69	w/r	I-limit2	0	I-MAX-2	A	User defined current limit Laser2 (limited by Pulsepicker-setting (r172)
71	w/r	Trigger mode 1	0	7		cf. section 6.6
72	w/r	Trigger mode 2	0	7		NOT used.
73	w/r	Trigger Freqency 1	300	r76	Hz	
74	w/r	T Charge 1	0.3	Tperiod	µs	Tperiod= 1000000/(r73) [us]; Tperiode>= T Charge 1
75	w/r	T Charge 2	0.3	r79	µs	NOT used
76	r	Trigger Freq Max 1			kHz	
77	r	Trigger Freq Max 2			kHz	NOT used
78	r	T Charge 1 max.			µs	
79	r	T Charge 2 max.			µs	NOT used
80	r	Humidity Laser 1			% r.h.	NOT used, return -1%
81	r	Humidity Laser 2			% r.h.	NOT used, return -1%
82	r	Humidity Resonator 1 (Laser 3)			% r.h.	Resonator Humidity
83	r	Humidity Resonator 2 (Laser 4)			% r.h.	NOT used, return -1%
84	r	Humidity Aux 1 (Laser 5)			% r.h.	NOT used, return -1%
85	r	Humidity Aux 2 (Laser 6)			% r.h.	NOT used, return -1%
86	r	Temperature Laser 1			°C	Seeder Temperature, If no monitoring, return (100+actual temerature)%
87	r	Temperature Laser 2			°C	NOT used, return -1%
88	r	Temperature Resonator 1 (Laser 3)			°C	Resonator Temperature
89	r	Temperature Resonator 2 (Laser 4)			°C	NOT used, return -1%
90	r	Read Errors				cf. section 6.3 for error codes
91	w/r	w: clear, r: read warnings	101	101		w91 101: clear warnings
92	w/r	Pointer on/off	0	1		0/1: disable/enable pointer
96	r	Firmware-Versions				Versions of laser head (LHC) and power supply (PSC)
97	w	Clear errors	101	101		w97 101: clear errors
98	w	Save settings to NVRAM	101	101		w98 101: save settings
99	w/r	Reset	101	101		r99: read actual laser state 0: Error; 1: Warm-up; 2: Ready; 3: Run Answer: with warning 800X or without warning X (X=0,1,2,3)
110	w/r	SYNC mode	0	1		0:seeder clock; 1: envelope; (cf. section 6.5)
152	r	Output Voltage Laser Diode Driver LDD 3			V	Actual output voltage of current driver LDD3
153	r	Output Current Laser Diode Driver LDD 3			A	Actual output current of current driver LDD3
154	r	Programmed Current Laser Diode Driver LDD 3			A	Actual programmed current of current driver LDD3
161	w/r	Current Setpoint Iout LDD 3	0	r167	A	
163	w/r	Laser3 on/off	0	1		RESERVED
166	r	I-MAX-3			A	Absolut maximum current Laser 3 (Amplifier)

para-meter no.	w/r	value	Min	Max	Unit	comment
167	w/r	I-limit3	0	I-MAX-3	A	User defined current limit for Laser3
170	r	Nominal seeder frequency			kHz	
171	r	Actual seeder frequency			kHz	
172	w/r	Seeder Frequency Devider (SFD)	>= PPB (r173)	r 180		turn laser off before changing, cf. section 6.4
173	w/r	Pulse(s) Per Burst (PPB)	0	SFD (r172)		turn laser off before changing, cf. section 6.4
175	w/r	Adjustable HV -level Setpoint	30	100	%	Levels >=95%- will be set to 100%
176	r	Actual HV- level			%	
178	w/r	Activiate HV Regulator	0	1		0: HV off; 1: HV regulated to setpoint (r175)
180	r	MAX SFD3				The highest period after pulse picking (min. frequency)
181	r	Maximum Amplifier 2 Current for SFD >SFD2 && SFD <=SFD3			A	
182	r	MAX SFD2				The mediumest period after pulse picking (med. frequency)
183	r	Maximum Amplifier 2 Current for SFD >SFD1 && SFD <=SFD2			A	
184	r	MAX SFD1				The lowest period after pulse picking (max. frequency)
185	r	Maximum Amplifier 2 Current for SFD <= SFD1			A	
186	r	Minimum Seeder Current			A	I1_min
188	r	Start delay			s	delay: turn laser on until laser is emitted
191	r	Maximum Seeder Current for SFD >SFD2 && SFD <=SFD3			A	
192	r	Maximum Seeder Current for SFD >SFD1 && SFD <=SFD2			A	
193	r	Maximum Seeder Current for SFD <= SFD1			A	
194	r	Maximum Amplifier 3 Current for SFD >SFD2 && SFD <=SFD3			A	
195	r	Maximum Amplifier 3 Current for SFD >SFD1 && SFD <=SFD2			A	
196	r	Maximum Amplifier 3 Current for SFD <= SFD1			A	
203	r	avg. power			mW	avg.power; OPTION

Notes:

1) The user defined current limit for the diode laser (r67/r69/r167) can be set by the user, for instance in order to avoid accidental setting of a current and therefore a laser power, which is too high for the desired processing result.

2) The absolute maximum current for the diode laser (r66/r68/r166) can not be set by the user, it is hard-coded by the laser manufacture. The driving current for the diode laser must never exceed this absolute maximum current, as the diode laser are damaged at currents above.

3) With this command “w98 101” the current settings are saved in the non-volatile RAM of the power supply controller. If the power supply is restarted these values are automatically loaded.

6.3 Error Codes

If an error occurs during operation, the diode laser driver current will be switched to zero and the external signal laser lamp blinks (cf. section 5.3).

The table below shows what and when an error or errors could make the actual laser state go to "**Error**" state:

3: Ready	Chiller error; Safety Loop error; Laser head error (e.g. temperature, humidity etc.); Intern error
4: Run	Chiller error; Safety Loop error; Laser head error (e.g. temperature, humidity etc.); Current/Voltage error; Intern error

With the command "r90" the occurred error and the command "r91" the occurred warning can be read out. The following error codes are provided:

Laser errors and warnings:

Code	Meaning	ERR	WAR	WAR limit	ERR limit
73	flow rate out of limit	x			
80	temperature Laser 1 too high	x	x	33/1*, 2*	35/1*, 5*
81	temperature Laser 1 too low	x	x	17/1*,3*	15/1*, 6*
82	temperature Laser 2 too high	x	x	33	35
83	temperature Laser 2 too low	x	x	17	15
84	LBO temperature too high (oven 1 and oven 2)	x	x	82	85
85	LBO temperature too high (oven 3 and oven 4)	x	x	82	85
86	LBO temperature unstable (warm up)		x	4*	
87	LBO temperature too low (oven 1 and oven 2)	x	x	16	15
88	LBO temperature too low (oven 3 and oven 4)	x	x	16	15
91	Shutter is blocked	x			
92	door open	x			
93	Ext. Interlock open	x			
94	Chiller common error	x			
95	Laser diode current too high/low	x			
96	Laser diode voltage too high	x			
98	Humidity in Laser 1 too high	x	x	40	50
99	Humidity in Laser 2 too high	x	x	40	50
100	Emergency Stop is pressed	x			
101	Laser diode driver no communication/not ready	x			
102	no communication with laser head	x			
103	Start button not pressed or emergency stop pressed	x			
110	Humidity in Laser 3 too high	x	x	40	50
111	Humidity in Laser 4 too high	x	x	40	50
112	Humidity in Laser 5 too high	x	x	40	50

113	Humidity in Laser 6 too high	x	x	40	50
120	temperature Laser 3 too high	x	x	35	40
121	temperature Laser 3 too low	x	x	16	15
122	temperature Laser 4 too high	x	x	35	40
123	temperature Laser 4 too low	x	x	16	15
124	Temperature of power supply too high	x	x	65	70
170	Seeder pulse missing		x		
201	Laser head and power supply not compatible	x			
202	Firmware Version laser head and power supply different		x		
203	serial number of power supply not equal to laser head		x		

x this code is an error or a warning (ERR = error; WAR = warning)
1* this limit is adjustable for px-Laser (s. below) / fixed for ns-Laser (the fixed values are before "/")
2* Seeder temperature warning: chiller temperature Setpoint (r30) + 5 °C
3* Seeder temperature warning: chiller temperature Setpoint (r30) - 1.5 °C
5* Seeder temperature error: chiller temperature Setpoint (r30) + 6 °C
6* Seeder temperature error: chiller temperature Setpoint (r30) – 3 °C

4* +/- 2.5°C from setpoint
ERROR: LED blinking in red
WARNING: LED blinking (not red)

For ps-Laser, an overview of the sensors could be found in following table:

name	possible sensors	commands for Hum. / Temp.	comments
Laser 1	Humidity; Temeperature	r21 or r80 / r22 or r86	• Laser 1 is corresponded to seeder • Only temperature sensor is installed; no humidity sensor
Laser 2	Humidity; Temeperature	r23 or r81 / r24 or r87	• Laser 2 is corresponded to Pump Module • Sensors may be installed . • For humidity sensor if it is not enabled to be monitored: r81 will return actual value + 100% and r23 is actual
Laser 3	Humidity; Temeperature	r82 / r88	• Laser 3 is corresponded to main laser chamber (resonator) • Both sensors are installed • For humidity sensor if it is not enabled to be monitored: r82 will return actual value + 100%
Laser 4	Humidity; Temeperature	r83 / r89	Not used
Laser 5	Only Humidity	r84	Not used
Laser 6	Only Humidity	r85	Not used

Attention: the "Laser x" (x=1…6) in the table above are corresponded to sensor's locations. Do not mistake with laser diode drivers (LDD).

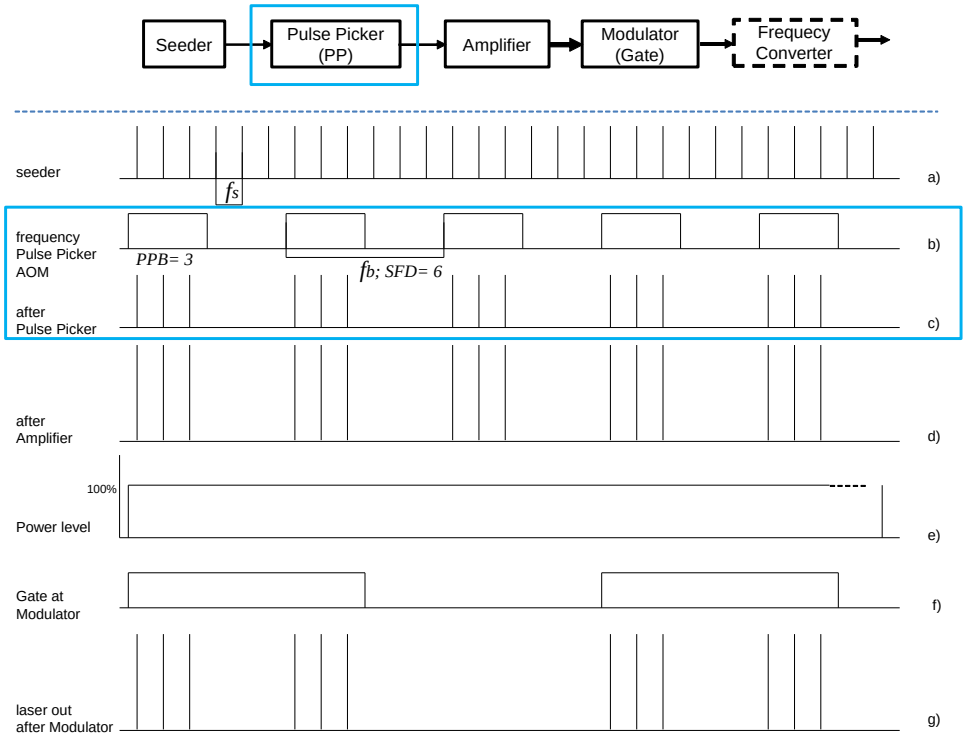
After removal of the cause of error the error status has to be cleared with the command „w97 101". This command automatically initiates a complete system checking, referring section 6.1 for more information.

If the error has been removed, the external signal lamp is extinguished and the laser can be started again.

6.4 Pulse picking

In PX-Laser laser output could be picked by using pulse picker. According to Fig. 3 it is the second step of the ultra short pulse oscillator and amplifier system, see Fig. 14

Fig. 14 pulse picking



Command “w172 x” can define the seeder frequency devider (SFD). “r172” can read out the actual setting of the SFD. Command “w173 x” can define the pulse(s) per burst (PPB). “r173” can read out the actual setting of the PPB. SFD and PPB setting must be intergers. In the example:

$$SFD = 6$$
$$PPB = 3$$

The burst frequency (after pulse picker) can be calculated by the followed formula:

$$f_b = f_s / SFD$$

f_s is the seeder frequency, typical 20 MHz.

To set SFD and PPB, there is always a range condition which must be filled out:

	Min	**Max**
SFD	actual PPB (“r173”)	SFD3 (“r180”)
PPB	0	actual SFD (“r172”)

Attention: Before setting SFD, make sure that the actual current of seeder (“r61”) and amplifier (“r62”) cannot exceed the max. current of this SFD. See section 0 for detail. Otherwise an “Error” will be returned.

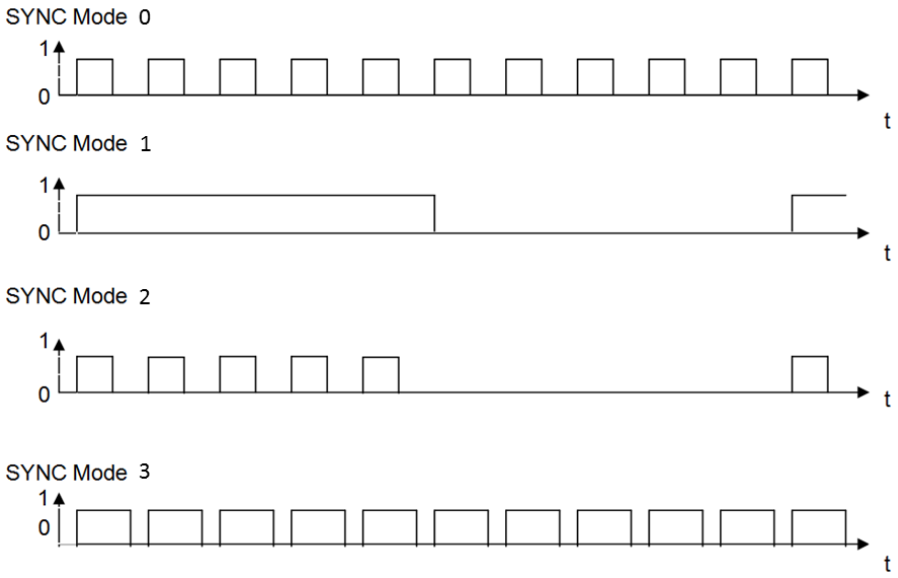
6.5 SYNC output

To synchronize the laser with a machine or handling, a SYNC output is provided. It is a TTL signal and has 4 modes:

1. Clock signal with the same frequency of seeder (typ. 20MHz)
2. Envelope signal specified by the pulse picker setting (SFD and PPB depending)
3. Clock signal under the envelope specified by the pulse picker setting
4. For EdgeWave Service only

Example: pulse picker is set as “w172 10; w173 5”, which SFD=10, PPB=5. For a 20MHz seeder the laser output frequency is 2MHz.

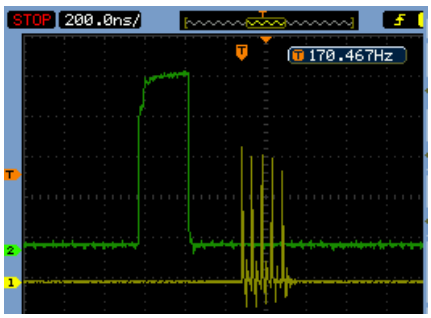
Fig. 15 SYNC output modes



The mode could be set by commands (w/r 110), please refer section 6.2 for more information.

There is a delay between SYNC and laser output as showed in the following picture.

Fig. 16
Envelope SYNC vs. laser output

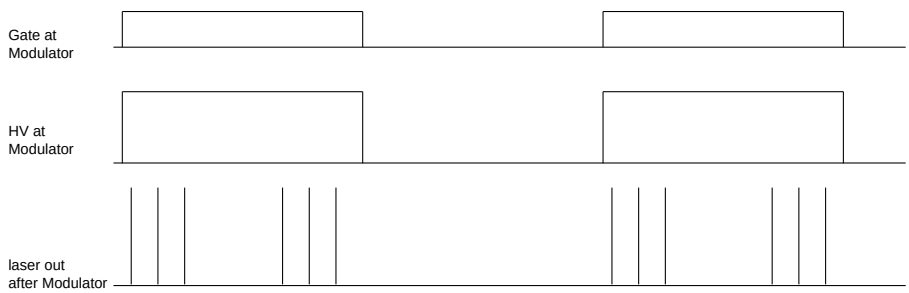


Channel 2 is SYNC output in SYNC mode 2 “envelope” (PPB= 5). Channel 1 is laser output. The time delay is according to Fig. 16 appx. 500ns.

6.6 Modulator control

After amplifier the laser pulses will be transferred to a HV controlled modulator. This HV controlled modulator will control the real laser output pulses.

Fig. 17
HV of modulator



Part I: Gating

The HV is controlled by a gate signal. Referring Fig. 17 an overview of gate signal and HV of modulator is illustrated. The table below shows which trigger mode for gating could be set (RESERVED is not allowed to use):

Modi	Description	Comment
0	trigger intern	
1	trigger extern BNC	
2	CW	
3	trigger extern LVDS	RESERVED
4	Gated BNC	RESERVED
5	Gated LVDS	RESERVED
6	nop	RESERVED
7	HV always on	

Command “w71 x” (x= 0, 1, 2 or 7) is used to set trigger mode. For ps-Laser there are 4 modes possible to set:

- **Trigger mode 0**: intern trigger. Use command “w71 0” to set trigger as intern (cf. command overview).
- **Trigger mode 1**: extern trigger (BNC or SubD connector). At this mode the clock of the extern pulse generator should be the clock of SYNC output. Otherwise there will be synchronous problem.
- **Trigger mode 2**: CW (continuous wave), no laser pulse out
- **Trigger mode 7**: all laser pulses out.

Command “r71” can read out the actual trigger mode.
To specify the intern trigger frequency, the command “w73 x” (x in “Hz”) could be used. With the command “r73” the actual trigger frequency could be read out. Please be aware that the frequency (intern and extern) cannot exceed the max. frequency (r76).

Part II: Output power control

The laser output power is dependent on the HV level, which could be changed by the software:

1. Use command “r178” to read if the HV regulator active or not. If not active, use command “w178 1” to activiate it.
2. Use command “w175 x” to set the HV level in %. x is in the range between 30 and 100. “r175” can read out the HV level setpoint.
3. Use command “r176” to read out the actual HV level in %. It is possible there is any deviation to the setpoint.

See laser datasheet to get more information about power level. After HV of modulator the laser pulses is like Fig. 17

6.7 Power level control

Power level is dependent on the pulse picking, HV modulator, and currents of seeder and amplifier. This section describes how to set the currents of seeder and amplifier to achieve max. laser output power:

1. Put a Laser Power Meter in front of the laser aperture to measure laser power.
2. Use communication Software (e.g. EdgeWave Laser Control in advanced mode OR MS HyperTerminal) for the following steps:
3. Type “h01”, you get the help list for the commands
4. Set the pulse frequency to the nominal pulse repetition rate f_{nom}, e. g. 1 MHz by typing “w172 xx”. (cf. section 6.4)
5. Set the pulse(s) per burst by typing “w173 xx” (cf. section 6.4)
6. Set trigger mode to HV always on: “w71 7”.
7. Type “r67“, “r69” and “r167“ to read Maximum currents I_{max1}, I_{max2}, I_{max3}
8. Type “w60 1” to turn laser on. According to the manufacture setting it will take some seconds (typ. 10s, ‘r188’) till the laser could be emitted. This time delay exists only in the laser turn switching on process
9. Type “w61 xx”, “w62 xx” and “w161 xx” to set the currents of seeder and amplifier to be I_{max1}, I_{max2}, I_{max3}
10. Type “r61“, “r62“ and “r161“ to read and verify the current settings
11. Type “w175 xx” to set HV-level at maximum output power (see laser datasheet, normally the factory setting is at max. output power)
12. Type “r176” to read and verify the HV level. Using command “w98 101” to save actual settings.

Check the value of the power meter if it is the max. power according to the datasheet. Some words need to be stated about the max. current I_{max2} (“r69”)of amplifier 2, the max. current I_{max2} (“r167”) of amplifier 3 and the max. current I_{max1} (“r67”) of seeder. There are 3 current tables for the amplifier and seeder which specifiy the max. currents at a certain SFD:

	SFD<= SFD1	SFD1<SFD<=SFD2	SFD2<SFD<=SFD3
Max.Current of Amplifier 2	“r185”	“r183”	“r181”
Max.Current of Amplifier 3	“r196”	“r195”	“r93”
Max.Current of Seeder	“r193”	“r192”	“191”

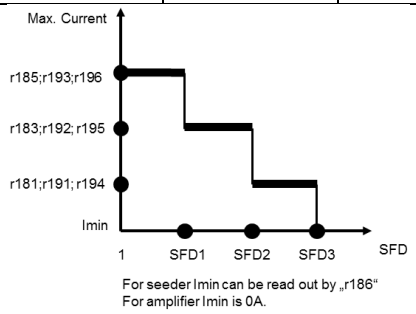


Fig. 18
Max. Current vs. SFD

Fig. 18 illustrates the relationship between max. currents of seeder and amplifier related to SFD sepoint. The max. currents, SFD limits (SFD1, SFD2, SFD3) are hard coded by the manufacturer.
Command “r67”/“r69”/”r167” returns always the max. current of seeder/amplifier regarding the actual SFD setting. When changing the current of the seeder or amplifier, be aware of the actual SFD setting. The currents could not exceed the max. current of the SFD set point. Otherwise there may be an error message.

6.8 Optimize wavelength conversion (OPTION)

For frequency doubling/tripling/quadling a LBO crystal is used. The LBO is mounted inside an oven. To get maximum output in green the temperature is stabilized within 0.1°C with a micro controller. For optimization of the green output power do as in the following (continue from section 0):

13. Type “r05” to read the factory setting for the oven temperature T_0 and note it.
14. Make a temperature curve of the laser power in the range between -4°C+T_0 and T_0+4°C with a step of 0,5°C with the command “w05 xx.x” (xx.x means the new nominal Temperature).
15. Find the temperature with the highest power T_{max1} and make a temperature curve of the laser power in the range between -0,6°C+T_{max1} and T_{max1}+0,6°C with a step of 0,1°C
16. Find the temperature with the highest power T_{max} and set the working temperature by “w05 T_{max}”
17. Save the temperature setting by “w98 101”

Attention: Oven temperature changes very slowly. Change them step by step with small steps. Wait until laser power is changing (ca. 0.5min after change).

After setting the oven temperature laser could emitt at a max. power. To control the power level, we recommend that:

- **Set the currents of seeder and amplifier max. values at the certain SFD in respection of Fig. 18**
- **To control the power level, change the HV-level, referring section 6.6**

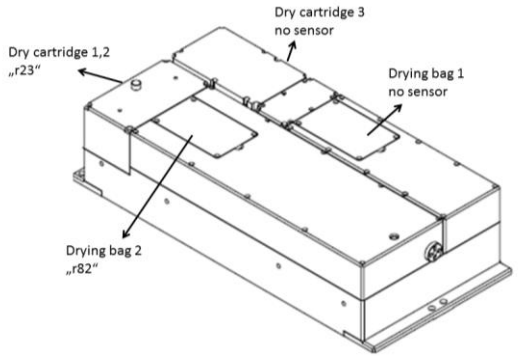
7 Service and Maintenance

In case of service or maintenance remove the key from the power supply (except during control of the safety loops).

With the air dryer cartridges, which are screwed into the diode laser compartment of the laser head, the humidity of the air is absorbed and controlled. The cartridge has to be routinely controlled, at best once in a month. If the color indicated in the cartridge cover turns from dark blue to light blue, the cartridge is depleted and has to be replaced. This may be carried out only by properly trained persons! As during the replacement of the cartridge the laser head is open and dust may intrude into the head, the replacement has to be carried out quickly and under appropriate conditions.

Besides, there are two drying bags mounted in the top side of laser head, referring Fig. 19. Commands “r23” and “r82” are used to read the humidity of the speicified dry cartridges and bag.If this value exceeds the error limits (cf.section 0), they must be replaced with a new one.

Fig. 19 drying bag in the top side



Never let the laser head stand open with the drying cartridge screwed out!

The water gauge in the cooling system has to be checked regularly. If the gauge is below the marked minimum, water has to be refilled. Only use filtered, distilled and deionized water for refill!

The water particle filter has to be controlled regularly, approx. once a week. If the color of the filter changes from white to brown, the filter has to be replaced. This has to be carried out by properly trained persons!

Regularly, approx. once in a month, the operativeness of all installed safety loops have to be controlled.

8 Transport and Storage

The laser includes sensitive optical elements. During transportation the laser therefore has to be appropriately packed and shielded against shock and humidity.

In order to avoid electrostatic damage of the diode lasers the provided short-circuit clips have to be put on the connectors labeled “Laser” on the rear side of the laser head, if the laser head is disconnected from the power supply.

Do not transport or store the laser head with a screwed-out drying cartridge!

Before transport or storage all cooling water has to be completely taken out of the laser head and the cooling unit. It is recommended to remove the water by blowing the units out with compressed air with pressure below 3bars. This is particularly important, if the laser is transported or stored at temperatures below the freezing point 0° C. Freezing of residual water in the cooling system, but in particular in the diode lasers may lead to serious damaged in the cooling system or may even completely destroy the diode lasers!

If the laser head or the supply unit are transported or stored at temperatures below 15° C all laser units have to be stored an appropriate period of time at room temperature, until all components have reached room temperature. Otherwise conpensation water may cause damage to components.

9 Specifications and Drawings

The following picture shows the outer dimensions of the laser head.

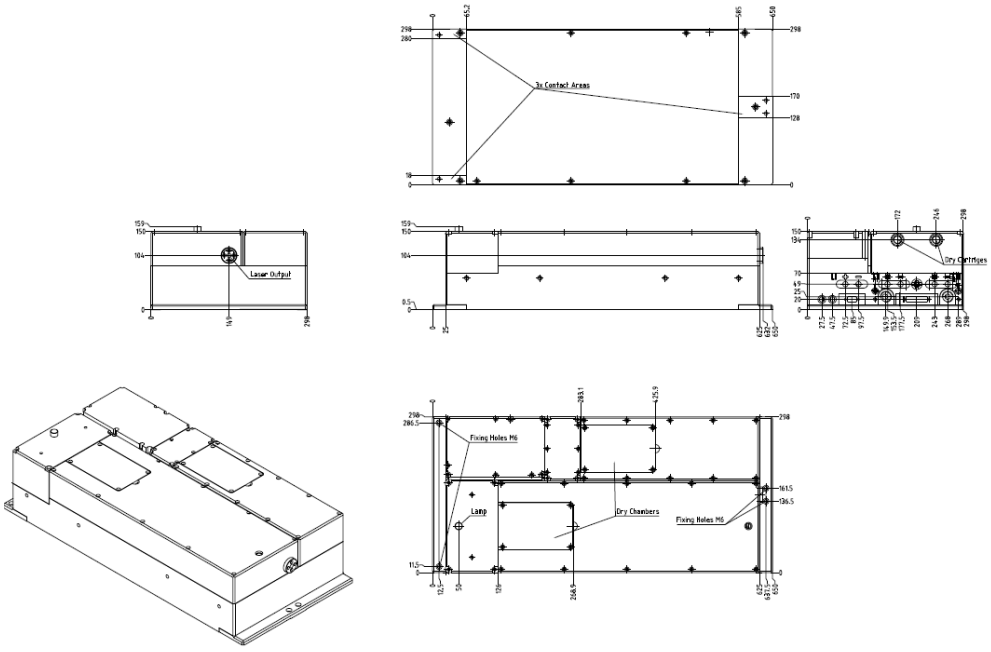


Fig. 20: Outer dimensions of the laser, all units in mm