NKT Photonics
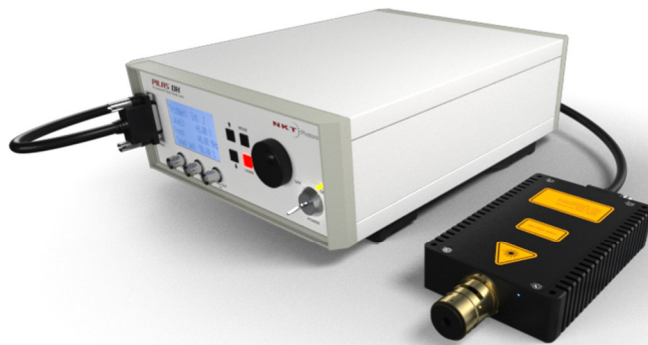
PILAS picosecond pulsed diode laser

Product Guide

sample manual only – not to be delivered with systems

Figures

1 General

The information given in this document is subject to change without notice.

1.1 Warranty and Assistance

This instrument manufactured by Advanced Laser Diode Systems is warranted against defects in material and workmanship for a period of 12 months from date of shipment to the customer. During the warranty period, Advanced Laser Diode Systems will, at its option, either repair or replace products which prove to be defective.

The warranty does not apply to defects resulting from improper use or maintenance by the buyer, from unauthorized modifications or operation outside the environmental specifications and from electrostatic discharge (ESD).

For warranty service or repair, please contact NKT Photonics A/S service and support. The instrument should be sent in appropriate packing, only after confirmation from service and support department. Please enclose a detailed fault report including instrument type and serial number.

1.2 Maintenance

The instrument does not require special maintenance if it is used correctly.

1.3 General Safety Considerations

Before switching on the instrument, make sure it has been properly grounded through the supplied AC power cable to a socket outlet with a protective earth contact. Any interruption of the grounding can result in personal injury.

This instrument must be used under normal conditions and as specified, otherwise the protection provided by the instrument could be impaired.

Always replace blown fuses with the same rating and acting speed.

ESD: Electrostatic discharge (ESD) on or near the connectors can damage electronic devices inside the instrument. Personnel should touch the metal frame of the instrument for a second before touching any connector.

Caution – use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

There is no scheduled maintenance necessary to keep the product in compliance although we recommend a calibration on a regular interval of five years.

There is no service allowed by the customer.

The driver or laser head must never be opened by the customer. Opening of laser head will damage the warranty label and internal sealing and can be detected by A.L.S. GmbH. If one these protections are damaged the warranty is lost.

1.4 Laser Safety

1.4.1 General Remarks

The radiation of the laser diode used in this instrument may be visible or invisible. The laser diode emits radiation in the 365 nm to 2000 nm spectral region.

Use caution to avoid hazardous exposure to the beam. Take precautions to eliminate exposure to a direct or reflected beam. Do not view the laser beam directly or indirectly with optical instruments or human eye. We point out, that collimated laser beams are especially dangerous, not losing their damage potential for eyes and skin with distance.

1.4.2 Laser Class

This PILAS laser system is classified as **class 3B laser product** according to IEC 60825-1:2014 during all procedures of operation.

Class 3B laser systems require wearing certified laser safety glasses.

The laser radiation is emitted through the optics at the front side of the optical head or by an attached optical fiber guiding the laser light.

1.4.3 Laser Warning Label – no CW option

According to laser safety regulations the following class 3B laser product *explanatory labels* are used. For the detailed laser parameter please see the test report. For laser heads with wavelengths outside 400 to 700 nm the label with "WARNING INVISIBLE RADIATION" is used.
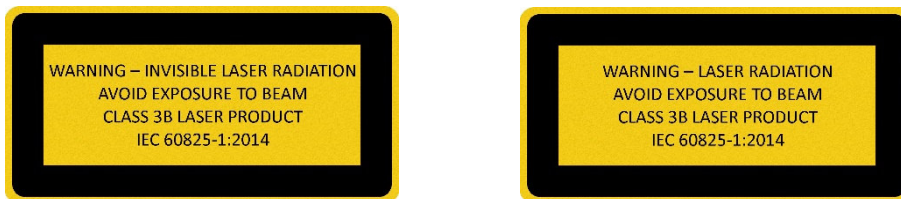
Figure 1 Explanatory label laser class

According to laser safety regulations the following class 3B laser product *explanatory (data) label* and *aperture label* are used:
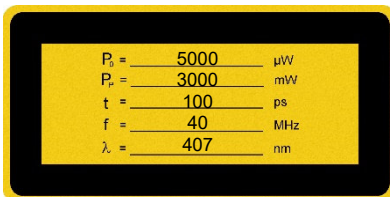
Figure 3 Explanatory data label   *Figure 2 Aperture label*
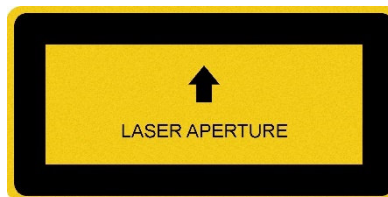
- Average radiant power at max. rep. rate: P_0
- Peak radiant power: P_p
- Pulse duration: t
- Max. pulse repetition rate: f
- Emitted Wavelength: λ

According to laser safety regulations the following *warning label* is used:

Figure 4 Warning label

1.4.4 Laser Warning Label – with CW option

According to laser safety regulations the following class 3B laser product **explanatory labels** are used. For the detailed laser parameter please see the test report. For laser heads with wavelengths outside 400 to 700 nm the label with "WARNING INVISIBLE RADIATION" is used.
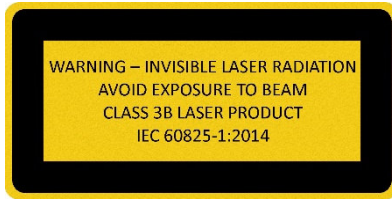
Figure 5 Explanatory label laser class
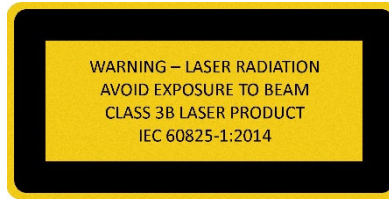
According to laser safety regulations the following class 3B laser product **explanatory (data) label** and **aperture label** are used:
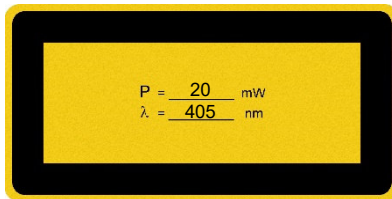
Figure 7 Explanatory data label   *Figure 6 Aperture label*
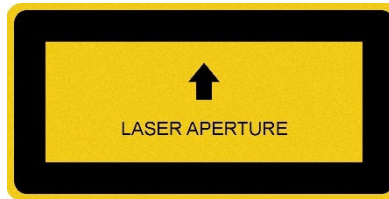
- Maximum CW power   P
- Emitted Wavelength: λ

According to laser safety regulations the following **warning label** is used:

Figure 8 Warning label

1.4.5 Label Location
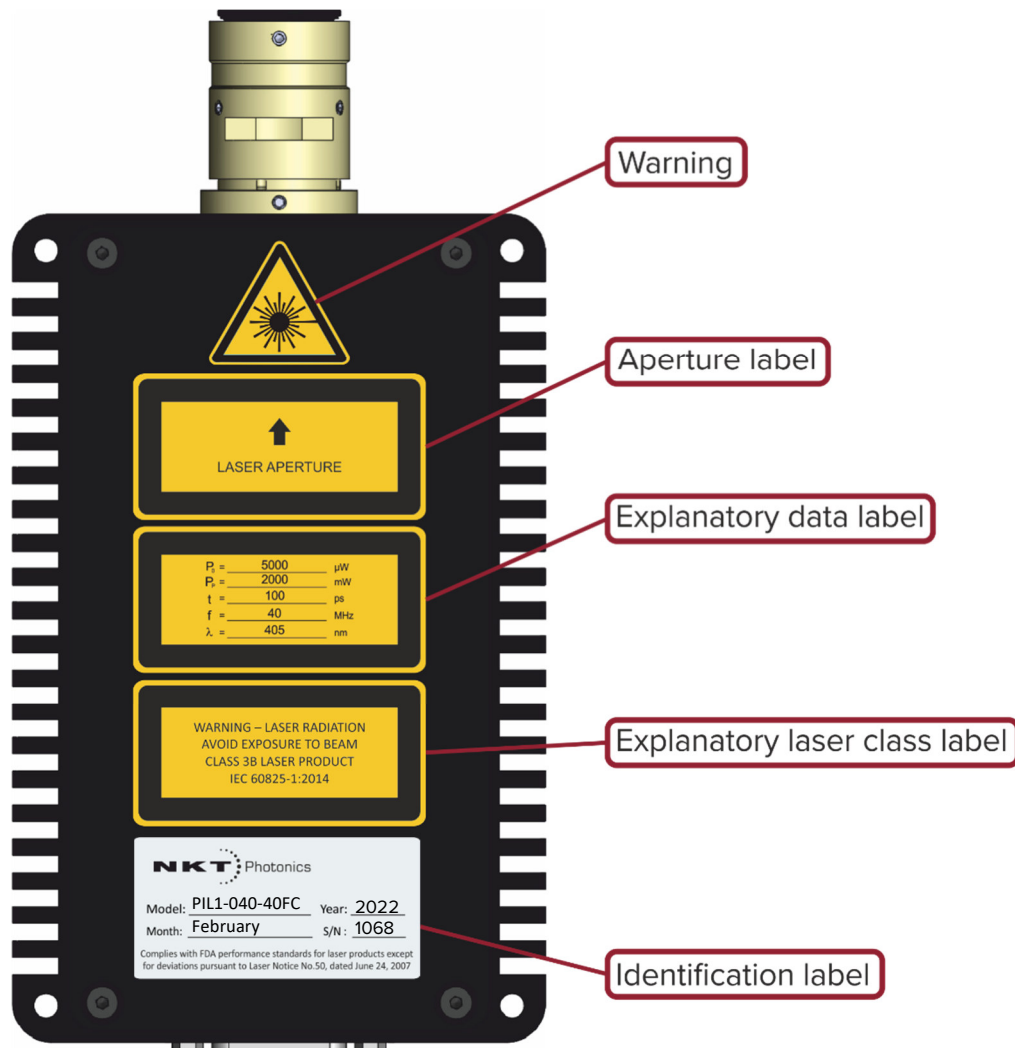
Figure 9 Laser warning and model/part number label location (shown labels are samples)

The shown laser head and labels are samples:

- **Warning label** for laser radiation is attached on top of the laser head near the laser emission aperture as shown in the diagram.

- **Laser aperture** label is attached on top of the laser head with the arrow pointing towards the laser emission aperture as shown in the diagram.

- **Explanatory laser data label** is attached on top of the laser head as shown in the diagram.

- **Explanatory laser class label** is attached on top of the laser head as shown in the diagram.

- **Laser head identification (model/part number) label** is attached on top of the laser head as shown in the diagram.

1.4.6 Laser Emission Warning

Figure 10 Laser head front side, laser emission LED position ("FS" free space version shown)

The Laser emission LED is a bright white light LED which should be visible also with most Laser safety goggles. Do not look into the laser beam while observing or checking the LED status. The controller "ON" button can be used as laser emission LED too. The controller "ON" button will light up red when laser is switched on.

1.5 Delivery Volume

- Control unit: EGI-D2-40

- Optical head: PiLxxx-FS (FS free space version, FC for fiber coupled version. "xxx" wavelength code)

- Connection cable: PIL1-MH-03 (for connection head with controller. For CE conformity please plug the two ferrites onto the DVI cable. One on every end near the DVI connector)

- Tools in blue box: key switch, hexagon socket screwdriver 1.5mm, 1.2mm slot screwdriver 1.2mm slot screw (only for fiber coupler, fiber collimator or microfocus option), eccentric key (only for fiber coupler or fiber collimator option)

- AC Power Cable: EU, US, China, Japan

- Manual   including Test Report at the end or separately

2 Introduction

The PILAS is a compact system generating ultra-short optical pulses using diode lasers. The system consists of a control unit and an optical head with the electrical driver and the laser diode. The optical head is configured to emit short light pulses within one wavelength in the spectral region between 365 nm and 2000 nm. Each head is individually adjusted to the laser diode to achieve optimal pulses emission performance down to pulse widths of 20 to 70 ps and optical peak powers between 20 and 1500mW. Several optical output options are available, including free space collimating optics, fiber coupled versions for multi- or single mode fibers and different micro foci.

Repetition rates of up to 40 MHz, very low jitter and different triggering possibilities make the PILAS a flexible and reliable system suitable for a wide range of applications.

The PILAS system uses the technique of gain-switching of laser diodes.

The laser diode represents a low impedance load, which is driven by special electronic circuit that generates an electrical pulse of high amplitude, variable pulse widths and a jitter of less than 3-4ps.

The following diagram illustrates the behavior and the relationship of electrical pumping current i, carrier density n and photon density N.
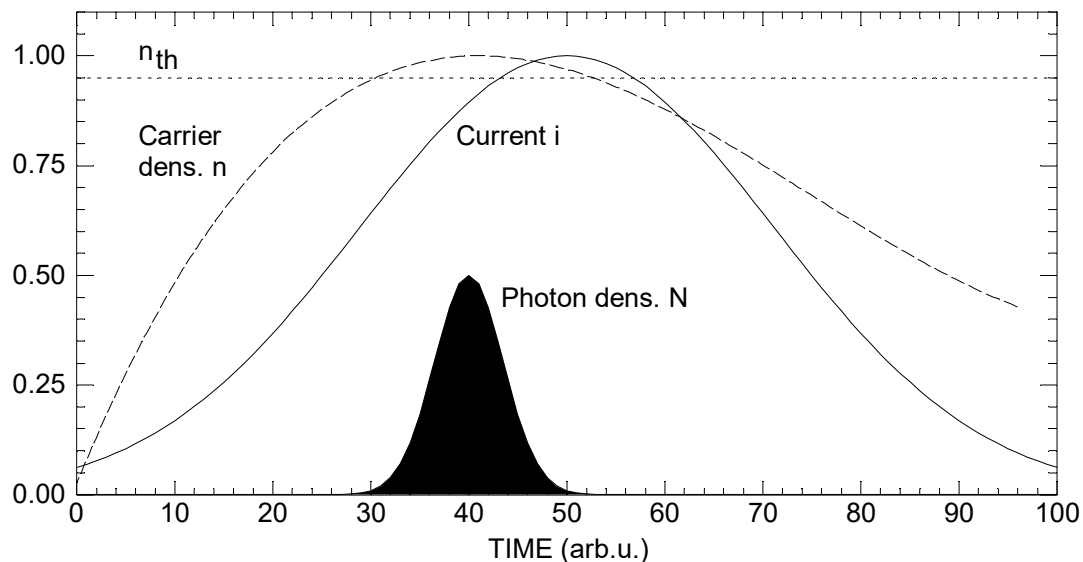
Figure 11 Gain switch, carrier and photon density development

The diagram shows that an increasing pumping current increases the carrier density n. At the carrier density threshold n_{th} a population inversion results in lasing emission from the laser diode. If the pumping current i is switched off shortly after this event, the carrier density n drops below the threshold again. This results in the emission of a single optical pulse. Applying the pumping current i for a longer period would lead to the emission of multiple pulses. These so-called relaxation oscillations continue for a short time (0.5 to 2ns depending on the diode laser technology and electronic circuit settings).

The pumping current i *is connected to* our TUNE value, which can be changed at the controller LCD menu (see chapter "Operation" and following). The controller, the laser head and the cables introduce a nonlinear frequency response, leading to different TUNE values for the repetition rates.

The required TUNE value for the black filled nominal or standard pulse at figure 7 can be found in our Test Report attached to this manual.

Although we specify the TUNE value for nominal pulse only, it is possible to use lower and higher TUNE values. This will lead to non-calibrated pulses deviating from the standard gain-switched pulses (see chapter "Tune Setup" how to adjust TUNE). For one selected frequency (typically the maximum of 40MHz) we show such sample measurement of three pulses: below nominal pulse amplitude, nominal pulse, above nominal pulse amplitude. This "Tune scan" can be found in the Test Report attached to this manual.

3 Operation

The following chapters describe controller settings. Nothing needs to be adjusted on the laser head to start operation.

3.1 Installation

Set up controller and laser head in stable position. Connect the power supply cable to the controller (100V - 240V, 50Hz - 60Hz). Connect the laser cable PIL1-MH-03 between controller and laser head. The key switch can be found in the laser head transport box. If the primary fuses are blown, they can easily be replaced by the user. Before switching on the controller, the rear panel power switch must be set to "1".

3.1.1 Rear Elements Control Unit
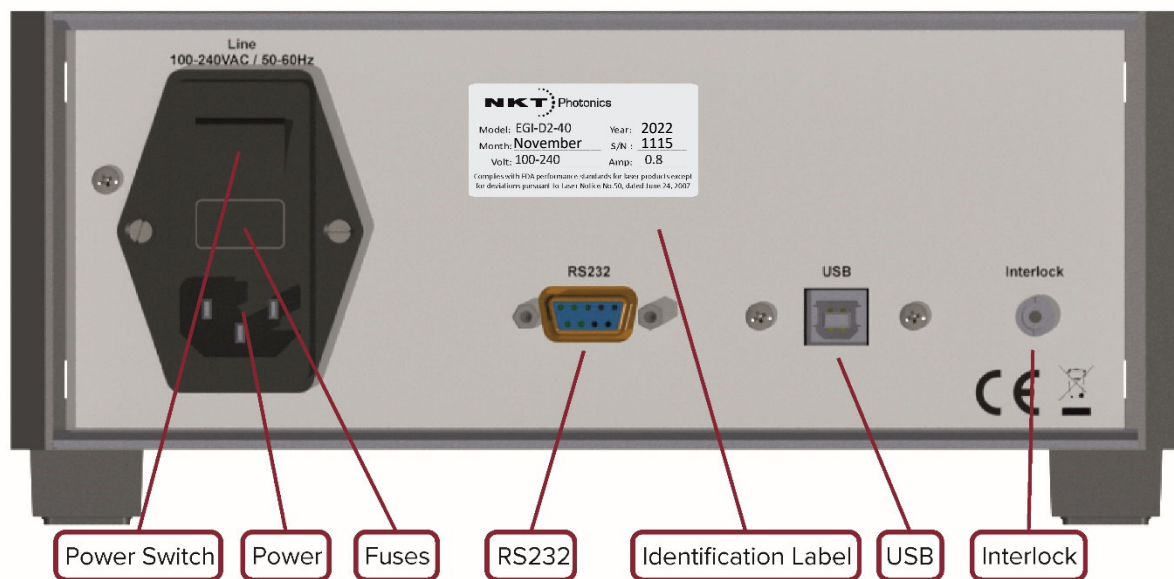
Figure 12 EGI-D2-40 rear panel with identification label (shown label is a sample)

3.1.2 Interlock

Laser emission is possible with activated interlock only (otherwise LCD error message appears). Activated means that a +5V control voltage is pulled down to ground (GND). For operation the interlock cable/connector must be connected to the rear panel 2.5mm plug. A two-pole 2.5mm interlock connector with short circuited cables is shipped with the system. The base contact is GND and the tip is +5V. You can cut off the cables and connect them with your interlock switch or use your own 2.5mm plug.

Figure 13 Interlock connector polarity

![NKT Photonics logo]

3.1.4 Front Elements Control Unit
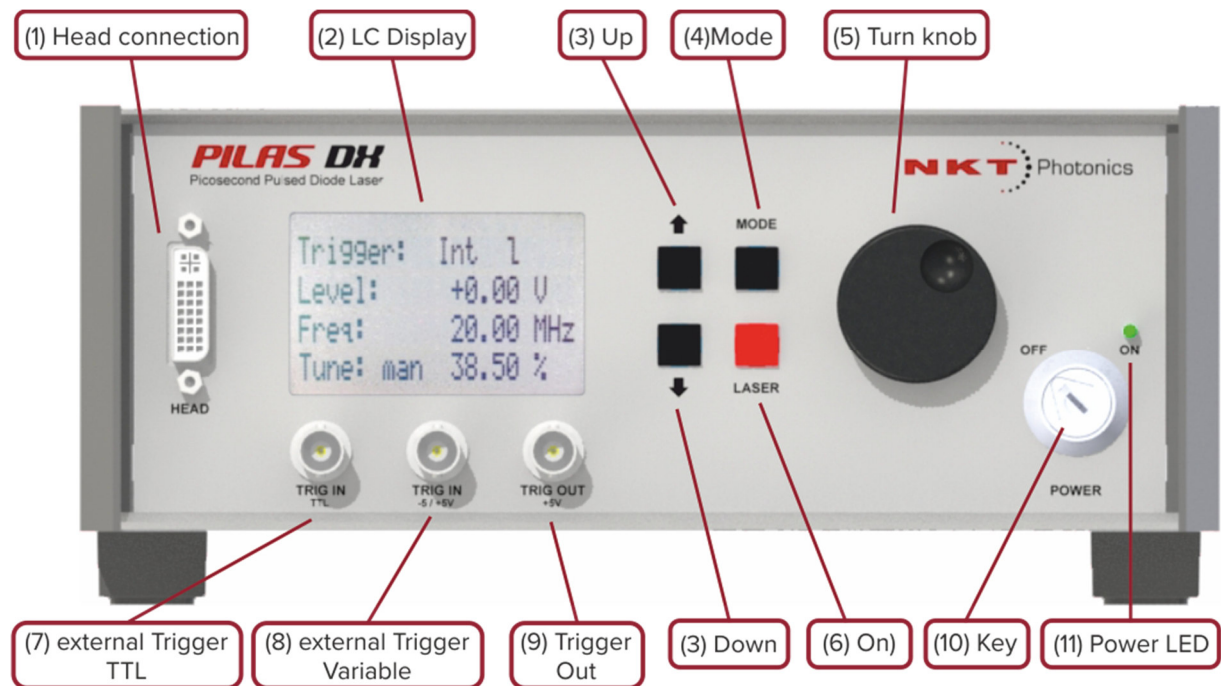
Figure 14 EGI-D2-40 front panel

1. Laser connection (to optical head)

2. illuminated Liquid crystal display (LCD)

3. UP, DOWN navigation buttons

4. MODE key, selection, confirmation and return

5. Rotary knob, value setting

6. ON laser button with red laser emission LED (there is also a 2nd laser emission LED on front side of laser head)

7. Trigger input, TTL, BNC plug

8. Trigger input, variable, BNC plug

9. Trigger output, BNC plug

10. Power key switch

11. Power LED, green

3.2 Controller button/rotary knob

The digital control unit of the PILAS is operated by four keys UP, DOWN, MODE, ON and rotary knob (see image).

You can select the different menus by pressing MODE keys. The UP and DOWN keys are for selections within the menus. The rotary knob will change the selected value. With the MODE button you confirm and leave the selected menu level automatically.

The ON button with red light emitting diode (LED) is for switching the laser emission on/off. A red glowing indicates laser emission. A white light LED on the laser head front side will also indicate laser emission.

3.3 Remote Control

Only one of the USB or the RS232 interfaces should be connected and used. Connecting via computer RS232 COM Port will not require any drivers. Connecting via USB will require the installation of a virtual com port chip set driver (VCP) from FTDI. The controller will appear as virtual COM port afterwards.

Properties	Connection
UART interface support 8 data bits, 1 stop-bit	null modem cable /cross over cable (2 on 3, 3 on 2)
data transfer rate 19200 baud	
carriage return (\r, CR-0xd) string for termination	

3.3.1 Start Operation (Examples)

A complete list of remote commands can be found in the in chapter "RS232 Commands...".

Before starting you must ensure that all laser safety measures are set.

Start your computer terminal program for transmitting remote commands between computer and laser controller. Check for correct settings and for termination char.

Connect RS232 or USB cable and power up the system with a 12V DC external power supply. System will boot up and require some seconds before accepting remote commands. At the connected COM port, it will send a multiline status message.

In the following examples the termination CR is shown with "\r".

Controller will reply with "done" message when command was accepted and executed. Invalid commands sent to controller will return the following error messages:

"invalid command!"
"data format error!"

3.3.2 Start laser with internal triggering

Sent	Description	Return Message
ts=0\r	Enable internal triggering	done\r\n
f=1250000\r	Set repetition rate to 1.25MHz	done\r\n
ld=1\r	Switch on laser emission	done\r\n
ld=0\r	Switch off laser emission	done\r\n

Above commands will enable laser emission at 1.25MHz until ld=0 shuts down emission finally.

3.3.3 Start laser with external triggering (TTL input)

Sent	Description	Return Message
ts=2\r	Enable external triggering (TTL plug)	done\r\n
ld=1\r	Switch on laser emission	done\r\n
ld=0\r	Switch off laser emission	done\r\n

Above commands will enable laser emission at external repetition rate until ld=0 shuts down emission finally. The external clock must be supplied via the TTL plug.

3.3.4 Start laser with external triggering (Adjustable input)

Sent	Description	Return Message
ts=1\r	Enable external triggering (Adj. plug)	done\r\n
te=1\r	Set rising trigger edge	done\r\n
tl=-500\r	Set trigger level to -500mV	done\r\n
ld=1\r	Switch on laser emission	done\r\n
ld=0\r	Switch off laser emission	done\r\n

Above commands will enable laser emission at external repetition rate until ld=0 shuts down emission finally. The external clock must be supplied via the Adj. plug.

3.3.5 Start with remote software PILAS Serial Console

You can download a simple serial console for sending commands and receiving the output on the NKTP support website (description or look can change):

This software is available for Windows in a 64 and 32 bit version. It uses preset serial settings of 19200 baud, bytes 8, stopbit one and time out 1s. It can send single remote commands to the controller and display the received message.

PiLAS software interface

Use this USB driver to communicate with any PiLAS laser.

DOWNLOAD >

Figure 15 NKTP support website
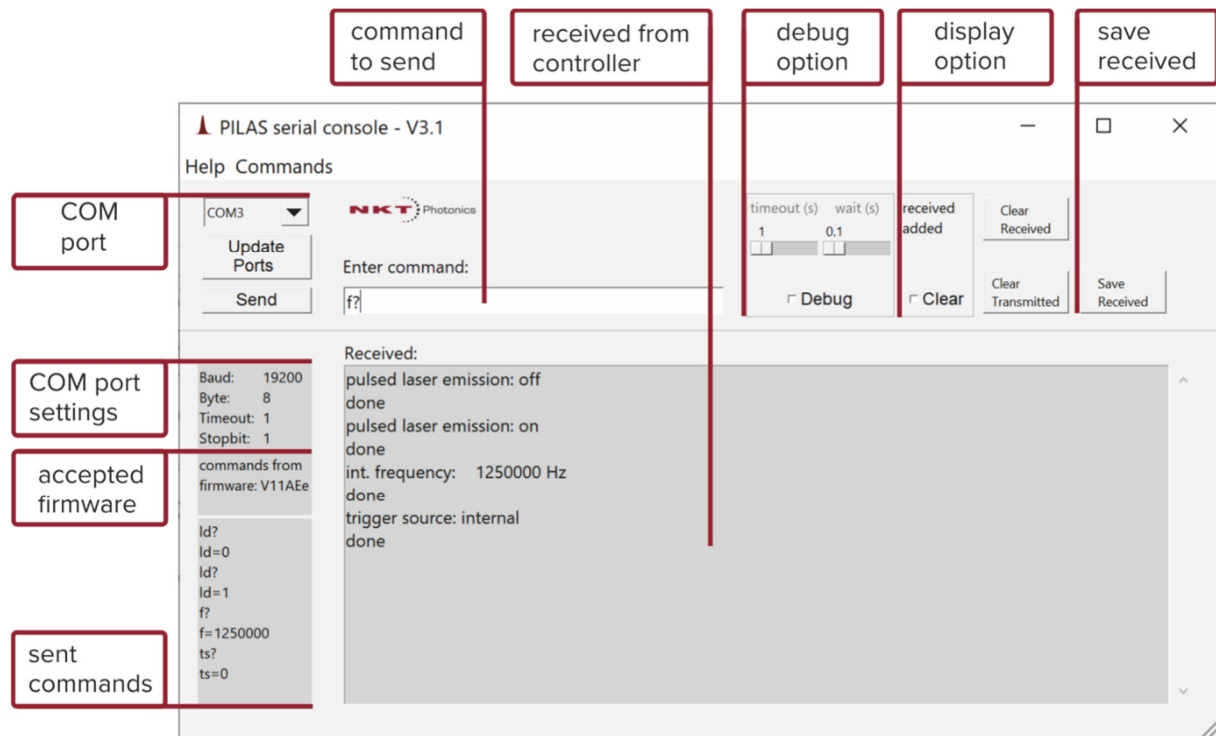
Figure 16 PILAS serial console screenshot

1. For the USB connection to work, install the VCP driver before launching the software.
2. Select COM port from Combobox. Wrong port will raise error messages. You can power on/off controller and check with "Update Ports" which port appears/disappears to find correct port.
3. Commands from the accepted firmware (V11AEe) can be entered in the entry widget. For command list see "Commands" menu.
4. Confirm command to be sent with "Send" button or RETURN on keyboard.

- "Help" menu show help text.
- Controller and program messages (errors for instance) will be displayed in the "Received:" window.
- "Debug" checkbox enables timeout (seconds) change (required for certain time-consuming commands) and wait (seconds) increase. Increasing wait between send and received can help to avoid serial errors.
- With "Debug" checkbox enabled, any input can be send to controller. Please note, that certain commands can lead to a non-functioning system!
- "Clear Received" will clear "Received:" window.
- "Clear Transmitted" will clear window for sent commands (history list).
- "Save Received" will save text in "Received:" window to a file.
- Last sent command can be recalled with ↑ on keyboard. Arrows Up, Down cycle through sent command list.
- Longer text will generate scrollbar in "Received:" window and you can you resize window bottom right.

3.4 Controller LCD Menu

The following adjustable laser parameters will be set by software menu:

- pulse repetition rate / frequency
- TUNE (pulse amplitude and width)
- Temperatures (only in debug mode)
- CW mode (only if ordered)
- Trigger methods a) internal 25Hz to 40 MHz b) external single shot to 40 MHz
- Input trigger TTL or variable
- trigger threshold and edge if trigger supplied by BNC plug (8) (variable)

3.4.1 Start Screen

After switching on the control unit, you get the text message:
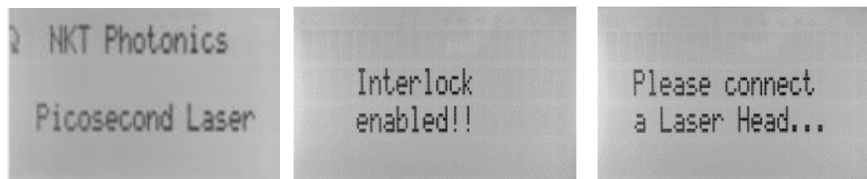
Figure 17 Start screen and two possible start error messages

For operation the interlock cable/connector must be connected to the rear panel 2.5mm plug. If the laser head is not connected an error message will be displayed too.

3.4.2 Main Menu

With interlock and laser head connected the controller shows the main menu after start up:

Figure 18 Main menu (left with internal trigger, right with eternal TTL trigger)

By pressing **ON** button, the laser would start operating with displayed parameter.

The TUNE value can be changed in the main menu by turning the rotary knob (but only if "manual" mode is selected in menu "TUNE Setup").

Pressing the MODE button switches to Setup menu.

Note: For internal triggering the current set frequency is displayed. For external triggering with f>150Hz, the measured frequency of the trigger source is shown. For lower frequencies, the value will be less exactly. This value should be seen as an indicator of the trigger clock and not an (exact) measurement.

3.4.3 Setup Menu
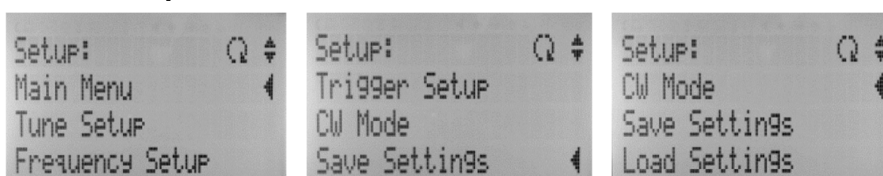
Figure 19 Setup menu

With the UP and DOWN keys, you can navigate within the setup menu. The selected menu is marked by "<" sign on right side. This is valid also for the next menus.

For switching to desired menu press MODE button.

The following menus are accessible from here:

- **Main Menu**   < screen switches back to main menu
- **Tune Setup**   < Tune value menu
- **Frequency Setup** < Selection of frequency parameter
- **Trigger Setup**   < Selection for external trigger parameter
- **CW Mode**   < CW options (out of function when CW option is not ordered)
- **Save Settings**   < save set up (saving TUNE, Frequency and Tune MODE)
- **Load Settings**   < load stored setup (saving TUNE, Frequency and Tune MODE)

3.4.4 Tune Setup
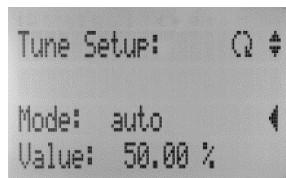
Figure 20 Tune menu

Mode: By turning the rotary knob you can select between "manual" and "automatic" TUNE mode. In "automatic" mode the default TUNE values from the manufacturer are used and locked. In "manual" mode the TUNE values can be changed by the user. To alter them press the UP or DOWN key until the "<" mark is in the row for "Value". Now the TUNE value can be adjusted by rotary knob.

Value: The TUNE value can be adjusted between 100 and 0% (in manual mode only).

TUNE 100%   low laser pulse amplitude

TUNE 0%   high laser pulse amplitude

The recommended TUNE value for the optimum pulse shape can be found in the delivered test report. In some cases, we recommend adjusting the TUNE value by +/- 5% to find optimum pulse parameter.

Please note that the TUNE value can be adjusted in the main menu by turning the rotary knob too (but only if "manual" mode is selected).

For external and internal (fine mode) frequencies values not given in the test report, the TUNE values will be interpolated in "automatic" TUNE mode linearly. They can be changed manually if mode is set to "manual" in TUNE menu.

Please note: Confirming with the MODE key will jump back to the setup menu also.

Note: The controller can store one TUNE set only in EPROM. In case you have ordered multiple heads, you have the following options:

First: Switch Tune Mode to "manual" and apply the correct TUNE for the laser head at the specific frequency manually with the rotary knob.

Second: the programmed tune values can be re-programmed by a remote command (via RS232 serial interface). Please contact us for documentation.

Third: We can provide a GUI program for remote controller reprogramming (via RS232 serial interface). Prior to operating the system, you can select a laser head and program the corresponding TUNE value into the controller EPROM. Please contact us.

3.4.5 Frequency Setup

Figure 21 Frequency menu

The maximum adjustable frequency can be found in the test report or purchase information (40MHz standard).

In the second row you can select between "coarse" and "fine" frequency resolution for internal triggering. Selection is done with the rotary knob.
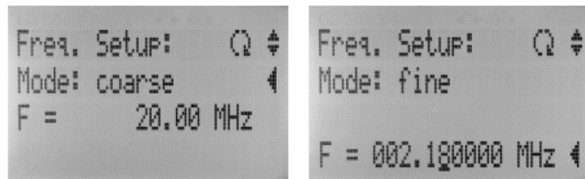
Mode coarse: With this option the frequency is adjusted in the third row in predefined steps. For the 40MHz version: 1kHz, 100kHz, 1MHz, 10MHz, 20MHz, 22MHz, 23MHz...41MHz.

Mode: fine: With this option the frequency is adjusted in the fourth row in fine steps. For most applications "coarse" is the better option. Lowest internal frequency is 25Hz.

By pressing the UP and DOWN key you can navigate to the frequency rows.

F: If "coarse" is selected the frequency is adjusted in this third row by rotary knob.

F: If "fine" is selected the frequency is adjusted in this fourth row. Continue pressing UP and DOWN for switching between the digits of the frequency value in fourth row. The digit value is adjusted by rotary knob.

Confirm selected frequency value with MODE key.

Please note: Confirming with the MODE key will jump back to the setup menu also.

3.4.6 Trigger Setup
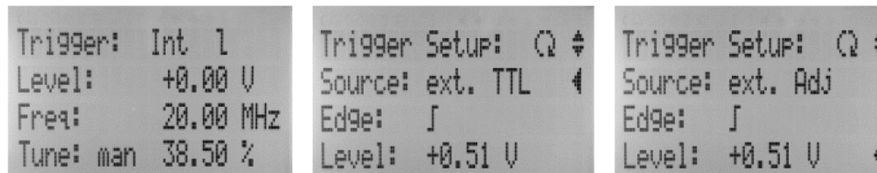
Figure 22 Trigger menu

Source: With the rotary knob you can switch between: "internal", "ext. TTL" (external TTL) and "ext. Adj" (external adjustable or variable) mode.

At "internal" setting the oscillator of the controller is used for generating the frequency. The "Edge" and "Level" is only used for external triggering.

For "ext. TTL" a trigger signal to the TTL BNC plug must be provided. An external oscillator will give the clock. Minimum required trigger voltage is 1.5V.

For "ext. Adj" a trigger signal up to +5/-5V BNC plug must be provided. An external oscillator will give the clock.

Lowest jitter is provided by "internal" clock.
"ext. TTL" provides the lowest jitter for external clock.
For variable and low clock signal amplitudes use "ext. Adj" input resulting in slightly increased jitter.

Please note that external oscillators may have worse frequency stability than controller internal clock. This can lead to increased jitter of subsequent pulses. Low external clock signal amplitude can also lead to increased jitter or bad laser pulse signal quality.

We recommend checking the controller trigger output signal because the trigger output is linear to the signal the laser diode is seeded with. Optimize the trigger threshold and (if possible) amplitude until the trigger output is clean and stable (no double or multiple pulses within a period).

The impedance for all BNC plugs is 50Ω. The external trigger sources must provide an impedance of 50Ω. Other values can lead to impedance mismatch and failure in external triggering.
The applied external clock frequency must not be higher than the device maximum allowed frequency (see purchase information).

Edge: Select leading or trailing edge for external and internal triggering.

The following settings are only used for "ext. Adj" triggering.

Level: Select trigger threshold level in Volt for "ext. Adj" triggering.
The applied external clock is measured, and the frequency is displayed in the main menu. If external triggering does not work the laser cannot be switched on and frequency shows 0Hz.

For external and internal (fine mode) frequencies values not given in the test report, the TUNE values will be interpolated linearly when TUNE mode "auto" is selected. TUNE values can be adjusted manually if TUNE mode is set to "manual" in the TUNE menu.

Please note: Confirming with the MODE key will jump back to the setup menu also.

3.4.7 CW Mode
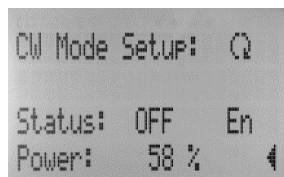
Figure 23 CW menu

Operation: The CW option can be switched on or off if available.

Power: The optical CW power in % can be adjusted if available.

A laser head can operate in one of the following two CW modes:
First for some laser heads the CW power can be adjusted by rotary knob between 0% and 100%. 0% means low power (but not 0 mW!), 100% maximum CW power. Please reduce the power by rotary knob to 0%, before switching on CW by changing OPERATION to ON This ensures that CW operation starts with low power. CW power depends nonlinear with % value.
Secondly some laser heads emit their maximum CW power right away if OPERATION is switched ON independent on % value. Turning the rotary knob will change the displayed % value but has no influence on CW power.
Whether the laser head belongs to first or second type you can see in the test report.
Please note: Confirming with the MODE key will jump back to the setup menu also.

3.4.8 Save / Load Menu

Figure 24 Save Load menu

Within this menu you have the option storing some working parameters like TUNE and frequency.
There are three memory slots.
Please note: Confirming with the MODE key will jump back to the setup menu also.

4 Optical Head

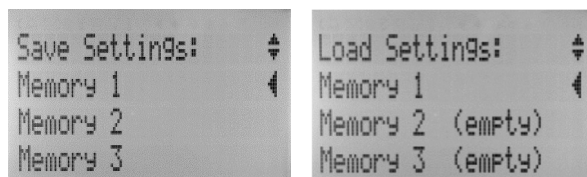The optical head is connected to the Laser connector of the control unit with the cable PIL1-MH-03 electrically. Please attach the screws of the cable to the control unit and the optical head gently. To fix the head mechanically, please use the five M4 threads (please check thread length) in the base plane of the optical head or the four corner through holes.

For detailed parameters please see the test report as a reference. Three main versions are offered:

- "FS" version - collimating optics, free space laser beam

- "FC" version – fiber coupling with fiber output FC/APC (removable)

- "FC" version - internal fiber coupling with fiber output FC/APC (fixed coupling)
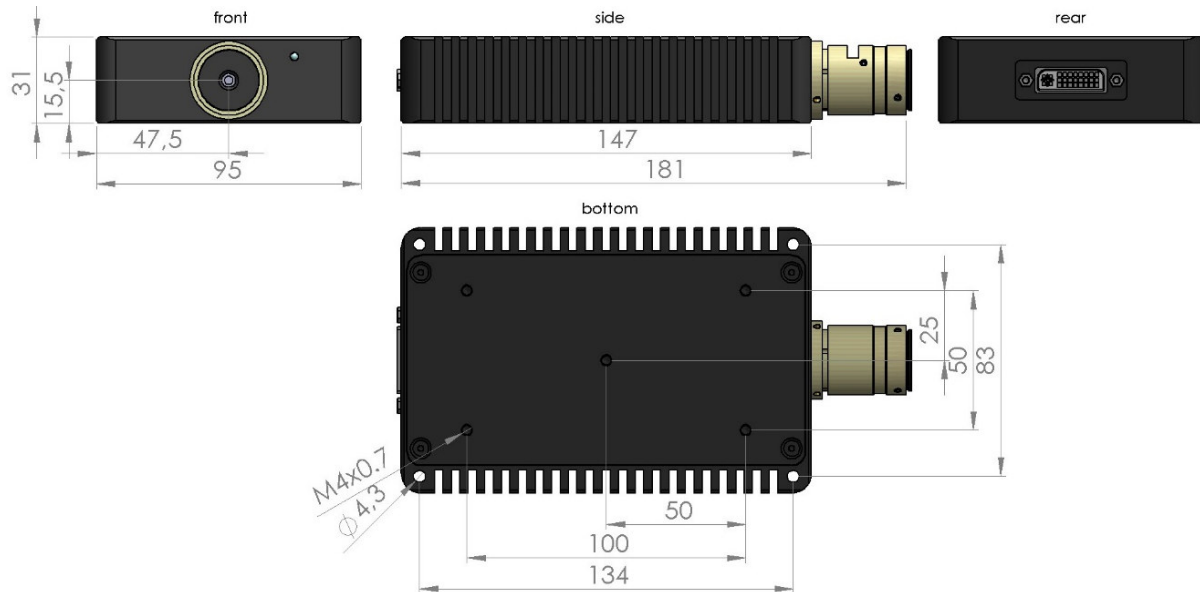
Figure 25 Laser head dimension and mounting scheme ("FS" free space version shown)

4.1 Handling and Adjustment

The following chapters describe the main optics shown in the picture above that can be used in conjunction with PILAS-systems. You will find the optics used for your system in the PILAS-test report attached to the manual.

4.2 Optics

A.L.S. GmbH uses high quality laser optics from ©Copyright Schäfter + Kirchhoff GmbH Germany. For details please see shipped test report.

4.2.1 Collimating Optics

The collimating optics delivers an elliptical collimated beam. For details please see shipped test report.

Our AR coated Bi-asphere lenses used for collimating the laser diode show the same correction and imaging quality compared to microscope lenses with three or four elements. The high NA lenses capture most of the emitted light. But caused by their specific manufacturing process, these lenses have microstructures on their surfaces, which also appear in the collimated beam, but not in the focused spot (see figure 24). For superior collimated beam profiles, we always recommend the fiber coupling option and a fiber collimator.

The inner tube, which holds the lens, is fixed to the main optics housing with two hexagon socket set screws on top. For re-focusing, first loosen these screws, and then use the delivered hexagon socket screwdriver to turn the optics. By slowly rotating the tool, the inner tube is slightly moved longitudinal in the main housing. After re-focusing, tighten the two screws again. Due to the mechanic tolerances changing the collimation may also change the beam axis.

4.2.2 Fiber Coupler (removable)

The "FC" option is delivered with a fiber coupling unit and a single or multimode mode fiber attached to it as standard. The single mode fiber can be PM fiber (polarization maintaining) or standard single mode fiber. The fiber coupling unit is plugged into to the main optics housing following the collimating tube. The laser beam coupler is fixed to the main housing with three hexagon socket set screws at the end of the main housing.

In case of removing the fiber coupler, using another fiber or misalignment, the coupler needs be optimized by customer. For a detailed fiber coupling description please contact us.

For most cases where the coupling is misaligned only slightly, it is sufficient to optimize the tilt adjustment only with the three counter hexagon socket set screws parallel to optical axis and no to touch the lens position.

The inner tube of the fiber coupler, which holds the focusing lens, is fixed to the housing with two small slotted set screws in the middle. For re-focusing to the fiber connector end surface, first loosen these screws and insert the delivered adjusting tool with an eccentric aligning plug in the right position into the hole of the housing of the laser beam coupler. By slowly rotating the tool, the inner tube is slightly moved longitudinal in the main housing. After re-focusing, tighten the two screws again.

The optical axis of the laser beam coupler is aligned to the optical axis of the collimated laser beam (paraxial fiber coupling). This is done by slightly adjusting the three hexagon head cap screws clockwise. Near optimum power coupling the three counter hexagon socket set screws are for locking and fine adjustment. All six screws are located parallel to the optical axis.

Please note, that the fiber connector of single mode fibers attached to the coupler is tightened with a small slotted set screw. Before screwing off the fiber connector this small screw must be loosen and after connecting again it must be tightened again with less pressure.

In case of polarization maintaining fiber, the laser diode polarization is aligned to the slow axis. The slow axis is aligned to the connector key as shown in the picture. Most common PM fiber type is PANDA.
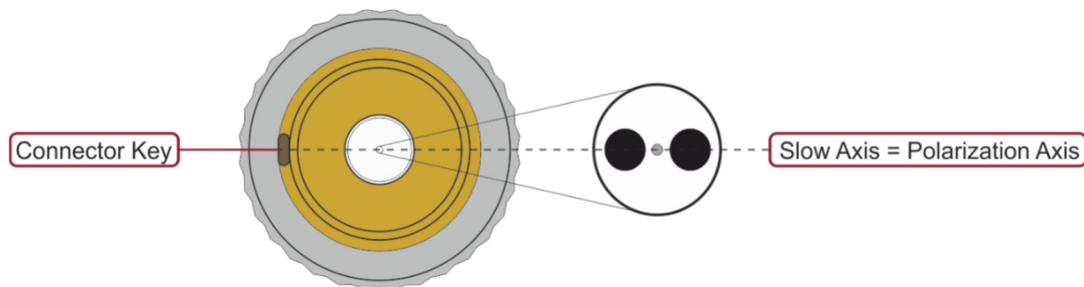
Figure 26 Polarization maintaining fiber, orientation

4.2.3 Fiber Coupler (fixed)

Optional the laser head is shipped with an internal fixed fiber coupler.

4.3 Cleaning

The need for cleaning of any precision optics should be reduced to a minimum by covering the optics and by use of a protective enclosure or similar to avoid contamination. We recommend that dust is blown off only. The laser must be switched off while checking and cleaning!

For the fiber coupled version "FC" keep the fiber connector end face clean. Connecting our output fiber to other fibers may exchange dust particles among them. We recommend a fiber inspection and clearing on regular base. The laser must be switched off while checking the fiber connector!

4.4 PILAS Optical Specifications

The optical specifications are given in the test report attached to this manual. A short description of these specifications is given here:

Specification	Unit	Description
Beam diameter	mm	Beam diameter for intensity drop to $1/e^2$ * maximum (100% to 13.5%)
Beam divergence	mm	Half beam divergence for intensity drop to $1/e^2$ * maximum (100% to 13.5%)
Wavelength	nm	Center wavelength pulsed operation
Spectral width	nm	Width of optical spectrum at 50% amplitude points
Frequency	Hz	rate at which the pulses are emitted (pulse repetition rate)
TUNE value	%	correspond to laser diode current inversely for pulsed operation, low TUNE = high diode current
FWHM	ps	pulse width, time between 50% amplitude of rising and falling flank
RMS-Jitter	ps	Timing jitter for an edge-reference measurement also phase jitter or time interval Error (TIE)
Av.power	µW	Optical average power
Energy	pJ	Optical pulse energy
Peak power	mW	Optical peak power

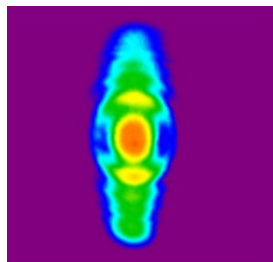### 4.4.1 Beam Profile and Spectrum

Figure 28 Standard elliptical beam Profile ("FS" versions)
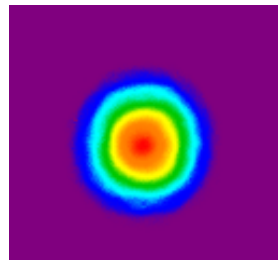

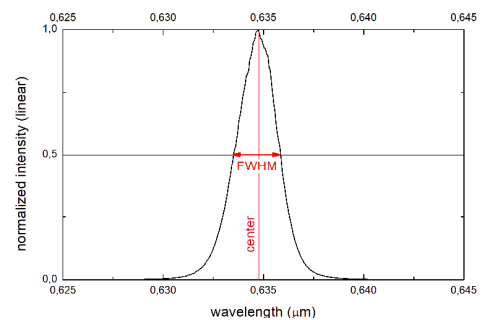*Figure 29 Beam profile out of SMF ("FC" version)*

Figure 27 Spectrum, center an FWHM

The collimation with a one lens system results in an elliptical beam profile with modulations from the lens manufacturer process (see chapter "Collimating Optics"). The best beam profile is emitted out of single mode fiber (SMF). The better quality comes at expense of lower output power (typical SMF coupling efficiency is 40 to 60%).

The optical spectrum of a picosecond pulsed gain switched diode laser is broadened (chirp) and has a different center wavelength compared to the CW spectrum (for Fabry-Perot type lasers). It also shifts with higher frequency to longer wavelengths. This depends on laser diode type, wavelength and pulse settings. Typically, the shift from 1kHz to 40MHz is about 0.2nm only.

4.4.2 Polarization Free Space Version

The laser beam is linear polarized with a ratio of 100:1 or 20dB. The direction of polarization is parallel to the bottom/table plane and perpendicular to propagation axis (red arrow).

The figure shows the collimated elliptical output beam of PILAS (blue ray) and the direction of polarization (red arrow).

Figure 30 Polarization

4.4.3 Peak Power Calculation

A useful relation between optical average power P_{av}, pulse energy E and frequency f is:

$$P_{av} = E\,f$$

With equation above peak power P_{pk} can be calculated approximately when the pulse width τ is measured (0.85 is a pulse shape factor):

$$P_{pk} \approx \frac{E}{\tau}\,0.85 = \frac{P_{av}}{f\tau}\,0.85$$

4.4.4 Timing Jitter

The measured timing jitter reflects fluctuations of the optical pulse arrival time t_i (at 50% amplitude) in reference to the controller electrical trigger out signal (from which also the optical signal is generated inside the laser head).

Let TIE_i be the measured time deviation from the ideal optical pulse rising flank position T_0 for measurement i (sampling oscilloscopes measure many edges): $TIE_i = t_i - T_0$

The oscilloscope calculates the standard deviation of TIE_i which is same as RMS value here because TIE_i average value is zero for random jitter distribution (Gaussian):

$$std\ dev_{TIE_i} = \sqrt{\frac{1}{N}\sum TIE_i{}^2} = RMS_{TIE_i}$$

Reported timing jitter TIE is also called time interval error or phase jitter and is an upper limit because it includes oscilloscope jitter.
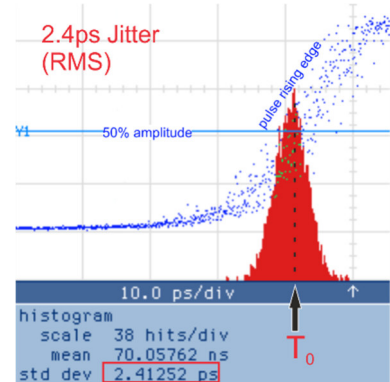
Figure 31Jitter measurement

4.5 Delay Times - Timings

The signal timings are shown in the sketch below. Please note: they vary depending on laser head model and factory settings. You need to add/subtract delays corresponding to your installed cables/fibers/optical path lengths for signal arrival time. A standard delay of 11.4ns between laser seed and BNC trigger out is activated by internal jumper.

Figure 32 Timings, delays

For certain custom systems the internal standard delay is set to 0ns. This would modify +19ns to 8ns, +32ns to 21ns and +37ns to 26ns (see sketch).

5 General Specifications

5.1 Control Unit EGI-D2-40

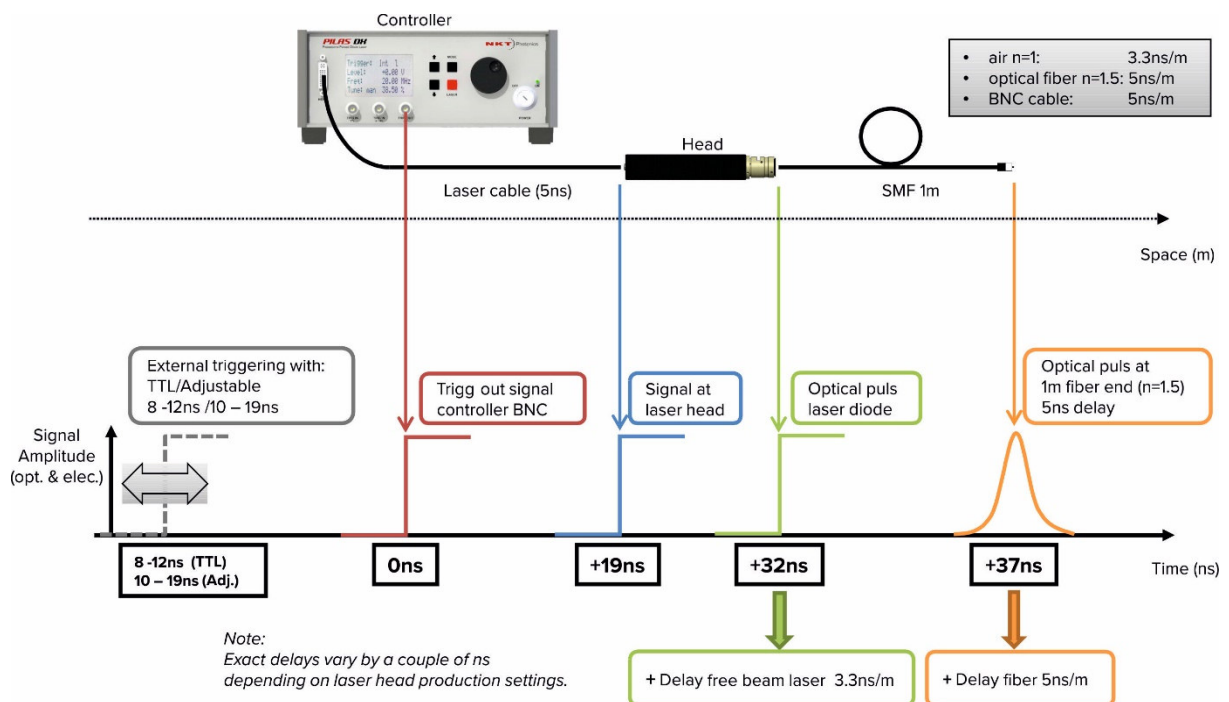|	
Internal trigger:	
Repetition rate	25 Hz to 40 MHz
Frequency resolution	1Hz to 2kHz (depends on frequency)
Frequency stability	max 200ppm @40MHz (depends on frequency)
External trigger input (TTL):	
Amplitude	+5 V max.
Trigger level states	TTL
Input impedance	50 Ω
Pulse width	>3.5 ns
Connector type	BNC
Frequency range	Single shot to 40 MHz
Delay (1,3)	42ns±5ns (for "FS" free space version)
External trigger input (variable):	
Amplitude	±10 V max.
Trigger level states	-4.8 V ... +4.8V
Input impedance	50 Ω
Pulse width	>3.5 ns
Connector type	BNC
Frequency range	Single shot to 40 MHz
Delay (1)	45ns±5ns (for "FS" free space version)
Synchronization (trigger) output:	
Amplitude	+2.5 V @ 50 Ω load
Output impedance	50 Ω
Pulse width	50 % duty cycle for internal oscillator >3.5 ns for external trigger
Connector type	BNC
Delay (2,3)	32ns±5ns (for "FS" free space version)
Remote Interlock	
Voltage	+5 V
Loop resistance	<1 Ω
Connector type	2.5mm mono TS (jack connector)
Remote control:	
Connector type	USB 2.0
Connector type	RS232 (null modem, cross over)
Temperature:	
Temperature drift trigger delay	10 ps/K
Warm up time (operating)	15 min
Power:	
Line voltage	100 V ... 240VAC
Line frequency	50 Hz ... 60 Hz
Power consumption	Typical 20 W, max 50W
Fuses rating for 230V AC	500 mA slow acting (5mmx20mm)
Connector type	standard IEC C13/C14 Power Plug
Environment (operating), also for the Optical Head:	
Temperature	25 °C ± 10 °C
Relative humidity	30 % to 70 %
Size of Control Unit:	236 x 89 x 316 (width x height x depth, mm^3)
Size of Optical Head (w/o optics):	95 x 31 x 147 (width x height x depth, mm^3)
Weight:	
Control unit and head	5 kg

Notes:

(1) Delay between electrical signal at trigger input BNC plug and optical pulse at last optical surface for "FS version. May vary depending on laser head configuration.

(2) Delay between electrical signal at trigger out BNC plug and optical pulse at last optical surface for "FS" version. May vary depending on laser head configuration.

(3) Delay depends also on the pulse repetition rate.

6 RS232 Commands v1.1.AEe

version?	-> return device information (software, hardware version, serial numbers, wavelength, options)
EIGserial?	-> return controller serial number
LHserial?	-> return laser head serial number
state?	-> return system state information (sent at controller boot up to listening COM port)
mState?	-> return system state information in string format using space delimiter
help?	-> return list of available commands
ld=	-> set pulsed laser emission (enable 1, disable 0)
ld?	-> return pulsed laser emission state
te=	-> set trigger edge (rising 1, falling 0)
te?	-> return trigger edge state
ts=	-> set trigger source (internal 0, ext. adj. 1, ext. TTL 2)
ts?	-> return trigger source state
tl=	-> set trigger level (-4800...+4800, where ±4800=±4.8V)
tlm?	-> return trigger level measured value
tl?	-> return trigger level
tm=	-> set tune mode (auto 1, manual 0)
tm?	-> return tune mode state
tune=	-> set tune value (0000 to 1000, where 1000=100%, 0500=50.0% and 0000=0%)
tune?	-> return tune value
f=	-> set internal oscillator frequency (from "f=25" for 25Hz up to maximum frequency)
f?	-> return internal oscillator frequency
ldtec?	-> return laser diode TEC controller state (on, off)
ldtemp?	-> return laser diode temperature indicator (good, bad)
lht?	-> return laser head temperature in °C
store	-> store settings boot memory location
saveX	-> save settings to memory position X=1,2,3
loadX	-> loads stored settings from memory position X=1,2,3
cw=	-> set CW laser emission (enable 1, disable 0, only if CW ordered)
cw?	-> return CW laser emission state
cwl=	-> set CW laser output power (0...100, where 100=100%, 050=50% and 0=0%)
cwl?	-> return CW output power (in %)

system state information in string format using space delimiter:
mState? -> 0 0 0 0 1 1 0 1 1 0 2393 0 50000 5000 2200

output string decoding (example):

Pos.	Value	Description
1	0	interlock state (1 on, 0 off)
2	0	laser emission pulsed (on 1, off 0)
3	0	laser emission CW (on 1, off 0)
4	0	trigger mode (internal 0, ext. adjustable 1, ext. TTL 2)
5	1	trigger edge (rising 1, falling 0)
6	1	tune mode (auto 1, manual 0)
7	0	internal frequency (fine 1, coarse 0)
8	1	laser diode TEC (on 1, off 0)
9	1	laser diode temperature state (temp ok 1, temp bad 0)
10	0	measured trigger level (+/- 0000V)
11	2393	measured laser head temperature (23.93°C)
12	0	measured ext. frequency (Hz)
13	50000	internal frequency (Hz)
14	5000	tune value (50.00%)
15	2200	CW power (22.00%)

7 Test Reports (attached to manual)