

The 'Xbeam' logo consists of a stylized orange 'X' shape followed by the word 'beam' in a black, lowercase, sans-serif font.

Xbeam

User Manual

User Manual
For the Lambda beam with PowerBox Laser
Version: 1.4.6
Date: March 2023

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1 Laser Safety Precautions



CAUTION: This device emits visible and invisible **LASER** radiation. Avoid exposure to the beam!

Lasers emit visible and invisible radiation that may cause damages to material and person, mainly by thermal effect. Radiation entering the human eye can damage the retina, which leads to partial or total loss of vision. The damage can occur without particular perception or sensation of pain.

Please consider all protection and safety regulations while handling laser systems. Always use laser protection glasses for the specified wavelength range.

Never direct the laser towards people. Keep the laser beam away from reflective surfaces in order to avoid uncontrolled reflections. Do not mount the laser at eye level.

It is your responsibility to guarantee the laser safety as required by law. Please pay attention to safety regulations DIN EN 61010-1, DIN EN 60825-1:2003-10 and DIN EN 60950 when operating the laser.

The Lambda beam series is specified by the United States National [Center of Device and Radiological Health \(CDRH\)](#) as a class 3b laser product. Visible and invisible laser radiation is emitted.

Modifications that may affect any aspect of the product's performance or intended functions will require re-certification and re-identification of the product in accordance with the provisions of 21CFR 1040.10 and 1040.11.

Lambda beam laser modules are marked with a warning label as shown on the right.



2 Introduction

2.1 Product Overview

The Lambda beam series offers high performance, modulatable laser modules in a small design. The high quality product „Made in Germany“ guarantees universal capabilities in almost all fields of applications, with optical output powers up to 1000 mW. High durability, excellent beam quality and various options for system integration (for example into the Qioptiq rail system FLS 40) guarantee highest flexibility in industrial, scientific and medical applications.

Laser Head Features

- Small design
- Optical output powers up to 1000 mW
- Active Temperature Stabilization
- IP67 protected housing, optionally vacuum sealed
- Optional fiber coupler
- Horizontal, vertical and diagonal mounting options
- Produced in clean-room atmosphere
- Adjustable temperature
- Professional housing

Laser Controller Features

- Attaches directly to laser head
- Highly compact design
- Straightforward connection via screw-type terminal block
- Digital control via [Universal Serial Bus \(USB\)](#)
- Powered by 12 V to 36 V [direct current \(DC\)](#)
- Modulation input analog or digital 0 V to 5 V [DC - absolut maximum voltage rating =Vcc](#)
- Low speed and high speed modulation inputs

- Interlock on/off input

2.2 Package Contents

Laser head

In order to provide the best beam quality only high quality optical components are used within the laser head. A thermoelectric cooler is integrated for stabilizing the temperature.

Cable

A standard Mini [USB](#) cable is used for connecting the laser to a computer or power supply. The length of the cable is 1.5 m (5 ft).

Laser controller

The PowerBox laser controller attaches directly to the laser head through the [D-Subminiature 9 \(DSUB-9\)](#) connector with a locking mechanism. The back side holds a six-pin screw terminal block, a [USB](#) port and two coaxial modulation inputs (standard version). The terminal block can be pulled out and removed from the controller.

Download link

At our website you find the Windows application software Ltune for configuring and controlling the laser system as well as this manual as a [Portable Document Format \(PDF\)](#) file.



3 Installation and Operation

3.1 Precautions

- **Take care of all laser safety instructions** as described in [chapter 1](#). Always wear laser protection glasses for the specified wavelength range.
- Consider regulations for [electrostatic discharge \(ESD\)](#).
- Do not open the laser head. Opening the case voids the warranty and may cause uncontrolled laser radiation.
- Always mount the laser module securely and pay attention to sufficient heat dissipation.
- **Never disconnect the laser head from the controller** while connected to the power supply. This can damage the laser.
- **Do not reflect the laser beam back into the laser head.** The laser diode could be damaged if more than 2% of the emitted power is reflected back into it. Carefully check all mirroring surfaces of your optical setup for possible back reflections. If required, use a suitable optical insulator.
- Do not exceed the environment conditions specified in [chapter 5](#).

3.2 Device Setup

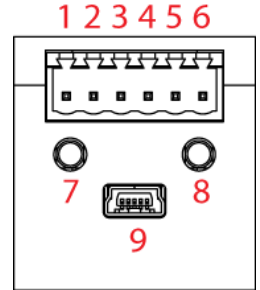
1. Attach the PowerBox controller to the Lambda beam laser head.
2. If you have several laser modules, please note that the controllers are not interchangeable. Make sure the serial numbers on the laser head and the laser controller match each other.
3. Move the locking slider on the connector to the locked position.
4. Connect the pins of the screw terminal block and the modulation inputs as required. Please see the following section for more details.
5. Turn on the supply voltage VCC.
6. After a quick self-test the green POWER LED should be lit continuously and the RDY output should be high (+5 V).

Connector and Pin Assignment

The connectors for the standard version are described in the table below (table 3.1):

Table 3.1: Connector and Pin Assignment

1	V_{CC}	Supply voltage
2	GND	Ground
3	INT	Interlock input
4	RGY	Ready output
5	TTL	Digital low-speed modulation input
6	AN	Analog low-speed modulation input
7		Digital coaxial modulation input (MMCX)
8		Analog coaxial modulation input (MMCX)
9		USB connector





The high speed modulation option does not include the coaxial modulation inputs (7 and 8) and the digital low-speed modulation input (5) on the controller. Instead, a high speed digital modulation input (Micro-miniature coaxial (MMCX)) is placed directly on the back of the laser head.

All pins are low if not connected. For modulation you can choose to use the low speed terminal block input or higher speed coaxial input, depending on your bandwidth requirements. The technical specifications for the inputs can be found in chapter 5. Please note that the input levels are different for low and high speed modulation inputs. You can also use both low speed and coaxial inputs at the same time. In this case, the digital inputs are logically-OR combined and the analog inputs added.

Status Indicators

The laser module includes two light emitting diodes (LEDs) to indicate the laser status:

LEDs	Status	Description
POWER 	On Off Flashing	Power supply connected, self-test successful Powersupply not connected Error
EMISSION 	On Off Flashing	Laser active, emission possible (depending on selected output power) Laser inactive 5 s delay before activating laser

3.3 Stand-alone laser operation

To operate the laser continuously at maximum output power, please connect the three Interlock, [transistor-transistor logic \(TTL\)](#) and analog modulation inputs to +5 V or V_{CC} . The laser starts operation with a five second delay, as required by [CDRH regulation](#)¹. Once the laser is active, the EMISSION indicator is lit continuously. Afterwards, you can turn the laser on and off instantly by using the [TTL](#) modulation input or adjust the output power using the analog modulation input. In stand-alone operation, the laser operated in “Combined Modulation Mode”, which means that the laser emission is determined by both analog and digital modulation inputs.

3.4 Computer-controlled laser operation

The Lambda beam series can be controlled via [USB](#). The operation is described in [chapter 4](#).

In order to turn the laser on, please:

1. Connect the system as described in [section 3.2](#).
2. For Digital or Analog Modulation Mode, please apply a voltage at the modulation input ([MMCX-Connector](#)). Note that even with an input voltage of 0 V, a small amount of luminescence may be emitted. For operation in Constant Power Mode, you don't need to connect anything to the modulation inputs.
3. Connect the interlock input 5 V or VCC.
4. Start the Ltune application software, set an output power and click on the Power On/Off button. The laser starts with a 5 s delay as described above.

¹Custom modification without delay is available for [OEM](#) integration.

Note for lasers at 532 nm: It is recommended to initially operate the laser at full maximum output power for 5 min. Afterwards the output power can be adjusted to any value. At low output powers these lasers often exhibit multi-mode emission.

3.5 Operation modes

You can select the operation mode using Ltune or your own custom software. In stand-alone operation, the laser system is always in Combined Modulation Mode. The technical specifications for the modulation inputs can be found in [chapter 5](#).

Constant Power Mode

The Lambda beam laser systems can be driven in [continuous wave \(CW\)](#) mode without an external control voltage. In this case, the laser emission is constant at the value which is defined by the Ltune Software.

Analog Modulation Mode

In this mode the optical output power can be controlled by an external voltage at the analog modulation input connector. The output power is modulated proportional to this signal.

Digital Modulation Mode

Here, the digital modulation input is used to switch the laser off and on between 0 % and 100 % maximum power. The nominal [TTL](#) input levels for the low-speed modulation input are 0 V (laser off) and 5 V (laser on)².

Combined Modulation Mode

In this mode, the laser emission is determined by both analog and digital modulation inputs. It can be turned on and off using the digital input and the output power can be adjusted using the analog input.

3.6 Disconnecting the system

Always disconnect the power supply before removing the controller from the laser head in order to prevent damage to the laser!

²However, all signals below 0.8 V are considered as off and above 2 V as on.

3.7 Troubleshooting

If the device is detected by Ltune, but there is no laser emission:

Please make sure that these conditions are met:

- The green LED is lit continuously (if not, please check the bottom of the Ltune window for error messages).
- The interlock pin is between +5 V and VCC.
- The power on/off button in Ltune is turned on and an output power larger than zero is selected.
- Either Constant Power Mode is selected or a proper signal is connected to the modulation inputs.

If the green LED is flashing, please run Ltune and check the bottom of the window for error messages.

If the device is not detected when Ltune is started

First of all, please disconnect the laser from the computer, restart the computer, connect the laser again and start the Ltune software.

If the laser is still not found: The Ltune software communicates with the laser using a "virtual serial port". If the driver is installed correctly, it should show up in the Windows Device Manager. You can open the device manager by clicking Start -> Control Panel (-> Performance and Maintenance) -> System -> Hardware -> Device Manager.

In the device manager, please open the "Ports (COM & LPT)" subtree. One of the COM ports listed there should belong to your laser. If you right-click on the correct item, choose "Properties" and then the "Driver" tab page, it should read: "Driver Provider: FTDI" and "Driver Version: 2.8.14.0" (or later). If this is the case, please start Ltune and try to select this COM port manually by unchecking "Auto-scan all serial ports" in "Device setup".

If your laser is not listed in the device manager or marked with an exclamation or question mark, please try the following:

1. Disconnect your laser from the computer and from power supply.
2. Download <http://www.ftdichip.com/Resources/Utilities/FTClean.zip> and run this tool to remove the FTDI driver from your computer.
3. Reinstall Ltune from [our website](#).
4. Reconnect the laser to the computer.
5. Start Ltune.

4 Computer Control

The Lambda beam uses a [USB](#) interface for remote control. The laser can be controlled with

- The Windows application software Ltune (included) or
- Custom user software via serial communication.

4.1 Ltune Laser Control Software

The Lambda beam can be configured and controlled using the Ltune software for Windows.

The software features:

- Modulation mode selection
- Output power adjustment
- Display of the laser status, configuration and operating hours
- Temperature display and adjustment

To install the software, simply run the setup file from our [website](#).

The setup package then installs the application software and the device driver. For the operating system to properly recognize the de software first before attaching the device.

The software is tested with 32 and 64 bit versions of Windows 11, 10, 7, Vista and XP. It requires the Microsoft .NET framework version 3.5 or 4.0, which is already installed on most [Personal Computers \(PCs\)](#). If this framework is not installed, the setup package asks you to install it first. You can find the setup file for the .NET framework on Microsoft's website. Please note that you need at least version 3.5 of the .NET framework. After the software is installed, please connect your Lambda beam to a [USB 2.0](#) port on the computer. You can use the provided [USB](#) cable or almost any other Mini-USB cable. If not already installed wait until the laser driver is completely installed. The laser should be detected automatically. If not you can click on device setup to start a new search.

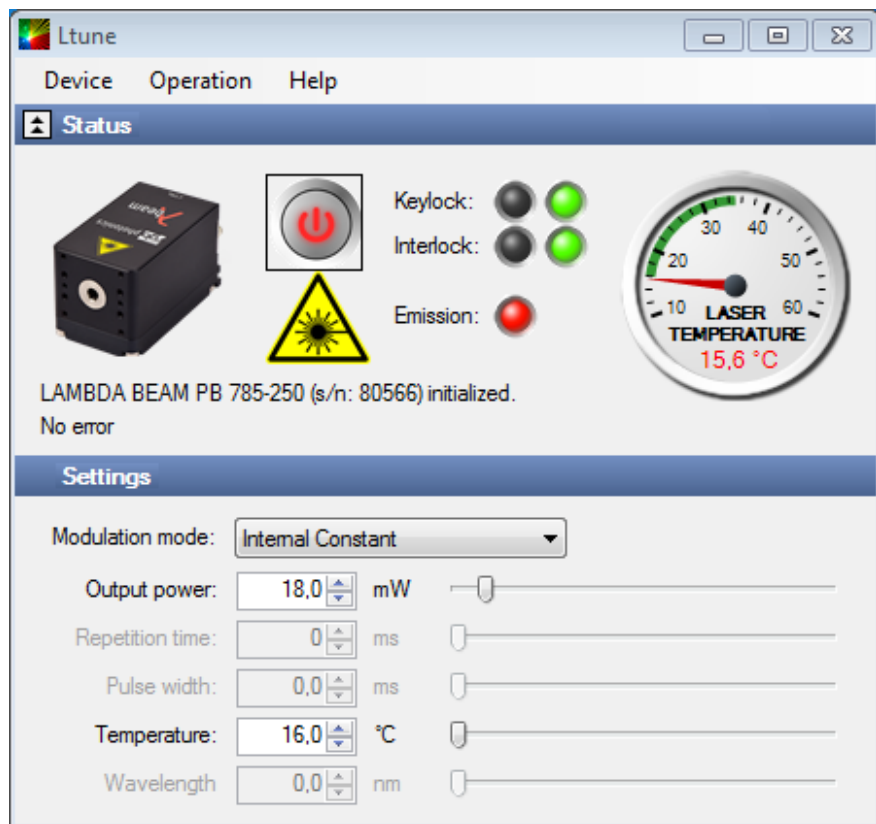


Figure 4.1: Ltunes GUI

Please note that you can change the user interface to a more compact view by clicking the small button next to "Device Properties".

Please also note that the Ltune software works with different laser modules and therefore provides support for some features that are not included in the Lambda beam .

4.2 Serial Communication

Overview

When the laser controller is connected to a PC and the device driver installed, it shows up as a virtual [communication port/serial port \(COM\)](#) port and can be accessed from almost any programming language. A detailed description of the commands and queries is given in the following section.

The command settings are not stored when the system is powered down.

Communication protocol

The commands and queries have the following syntax:

Commands: `command=<parameter value>`

A command changes an actual setting. The syntax is the command, followed by an equal sign and the parameter value. The parameter value is the value to be set. Commands have no return value.

Queries: `query?`

A query returns information about the device or the value of a setting. The syntax is the query, followed by a question mark. Queries have no parameter value. A query delivers a return value.

Return Code

A return code gives information about the processing of a command or query. There is always a space character between the return code and the result. The return codes are listed in [table 4.1](#).

Table 4.1: Return Codes

Code	Name	Description
0	COMMAND_SUCCESS	Command successful
1	COMMAND_INVALID	Command invalid
2	PARAMETER_ERROR	Wrong numbers of parameters
3	VALUE_INVALID	Parameter value is out of range
4	CODE_INVALID	Unlocking code is wrong
5	DEVICE_LOCKED	Device is locked for this command
6	FUNCTION_NOT_SUPPORTED	This function is not supported
7	COM_TIME_OUT	Timeout while reading command (60 s)
8	VALUE_NOT_AVAILABLE	This value is currently not available

All commands and queries and all responses from the device are followed by the line termination string "\r\n" (carriage return & line feed). All instructions have to be written in capital letters.

Initializing the serial communication

The Lambda beam uses the communication settings displayed in [table 4.2](#).

Table 4.2: Lambda beam communication settings

Baud rate	57600
Parity	None
Data bits	8
Stop bits	1

To initialize the controller, send "INIT". The controller responds with the return code 0 (Command successful).

Closing the communication

Send "BYE" to close the connection to the laser controller.

Turning the laser on and off

This command is used to set the and read the "Laser Enable" request. The laser can only be activated if the key switch is in the ON position and the interlock is closed.

Table 4.3: Laser Enable commands

Command/ Query	Parameter value	Return code	Return value
0=	0: Delete Enable Request 1: Set Enable Request	COMMAND_SUCCESS PARAMETER_ERROR	-
0?	-	COMMAND_SUCCESS	0: Enable Request not set 1: Enable Request set

Temperature settings³

The Lambda beam monitors the operating temperature. If it exceeds the permitted temperature range, the laser is turned off to prevent damage to the module. The commands for temperature settings are listed in [table 4.4](#)

³Not all laser systems support this function

Table 4.4: commands for temperature settings

Command/ Query	Parameter value	Return code	Return value
T?	-	COMMAND_SUCCESS VALUE_NOT_AVAILABLE	Current temperature in °C
TD?	-	COMMAND_SUCCESS	Default temperature in °C
T0=	Temperature offset in °C (value between LTN and LTP)	COMMAND_SUCCESS VALUE_INVALID FUNCTION_NOT_SUPPORTED	-
T0?	-	COMMAND_SUCCESS	Temperature offset in °C
LTN?	-	COMMAND_SUCCESS	Lowest operating temperature in °C
LTP?	-	COMMAND_SUCCESS	Highest operating temperature in °C

The command T0= expects a temperature offset for the default temperature (TD?) to be decreased or increased. The temperature can be adjusted with a resolution of 0.1 °C.

The highest and lowest possible temperature value can be queried with LTP? and LTN?, respectively.

Selection of modulation mode

The following commands are used to change the mode of modulation:

Table 4.5: commands for selection of modulation mode

Command/ Query	Parameter value	Return code	Return value
M=	A = external analog T = external TTL C = internal CW M = combined analog & TTL	COMMAND_SUCCESS VALUE_INVALID FUNCTION_NOT_SUPPORTED	-
M	-	COMMAND_SUCCESS	A = external analog T = external TTL C = internal CW M = combined analog & TTL

CW mode

The Lambda beam series can be operated in CW mode at constant power between 0 % and 100 % of the maximum output power. There is no need to supply an external control voltage.

Table 4.6: CW mode commands

Command/ Query	Parameter value	Return code	Return value
P?	-	COMMAND_SUCCESS	Output power in mW
P=	Output power in mW (value between 0 and LP)	COMMAND_SUCCESS VALUE_INVALID	-
LP?	-	COMMAND_SUCCESS	Maximum output power in mW

Status and device information

The query S? gets the actual status of the laser system including information about the Enable Request, the key switch, the interlock, active errors and the temperature control.

The query R? returns the operation hours of the laser system. The operation time is the accumulated time during which the laser was active (red LED on).

Table 4.7: Status and device information commands

Query	Parameter value	Return code	Returnvalue
S?	-	COMMAND_SUCCESS	Current device status (see table below)
R?	-	COMMAND_SUCCESS	Total operating hours [hhhh:mm]
DM?	-	COMMAND_SUCCESS	Manufacturer
DT?	-	COMMAND_SUCCESS	Device name
DS?	-	COMMAND_SUCCESS	Serial number
D0?	-	COMMAND_SUCCESS	Software version
DW?	-	COMMAND_SUCCESS	Emission wavelength in nm
DF?	-	COMMAND_SUCCESS	Available features: T = Temperature adjustable H = High speed TTL integrated D = Drive mode changeable (ACC/APC) C = Temperature is controlled M = External analog and digital modulation A = Modulation inputs can be combined R = Round beam L = Wavelength E = ECDL laser W = Water-cooled B = Multi-mode beam S = Customized
DC?	-	COMMAND_SUCCESS	ACC = active current control (ACC) APC = active Power control (APC)

The result of the status request S? is a bit-wise combination of the values listed in [table 4.8](#)

Table 4.8: status request commands

Code	Mnemonic	Description
0x01	LASER_ON	Laser system in active, radiation can be emitted
0x02		(reserved)
0x04	INTERLOCK_OPEN	The interlock is open
0x08	ERROR	Error is active (error can be read with E? query)
0x10	TEMPERATURE_OK	Temperature of laser head is ok

Error status of the laser system

The query *E?* reads the actual active errors of the laser system.

Table 4.9: Error status of the laser system

Query	Parameter value	Return code	Return value
E?	-	COMMAND_SUCCESS	Error code (see table below)

Possible error codes are shown in [table 4.10](#)

Table 4.10: error codes

Code	Mnemonic	Description
0x01	LASER_HEAD_OVERTEMP	Temperature of laser head is too high
0x02	LASER_HEAD_UNDERTEMP	Temperature of laser head is too low
0x04	TEMP_SENSOR_OPEN	Temperature-sensor connection is broken
0x08	TEMP_SENSOR_SHORTENED	Temperature sensor cable is shortened
0x40	LASER_OVERCURRENT	Current for laser head is too high
0x80	FATAL_INTERNAL_ERROR	Internal error (laser system cannot be activated)

5 Specifications

All specifications are based on stable environmental conditions.

5.1 General Specifications

Noise:	<2 % RMS
Power stability:	<1 % (10 h)
Warm-up time:	ready for use after 5 s, calibrated operation after 5 min
Drive mode:	532 nm : APC others: ACC
Modulation modes:	Constant power, analog and digital external modulation
Modulation frequency:	standard version: 1.5 MHz (with coaxial inputs) 532 nm : 15 kHz ⁴ high speed mod. option: digital 50 MHz, analog 500 Hz
Control mode:	Power, temperature and modulation controllable via USB
Temperature control:	active TEC
TEC accuracy:	<10 mK
glsCDRH Classification	Class 3b
Weight:	94.4 g (laser head)
ESD protection:	Level 4
Operating temperature:	0 °C to 45 °C (non-condensing)
Storage temperature:	-25 °C to 70 °C

⁴An optional [acousto-optical modulator \(AOM\)](#) may be used for faster modulation.

5.2 Beam Specifications

Beam diameter:	532 nm: 1.2 mm circular others: 1.1 mm × 2.2 mm to 1.2 mm × 4.3 mm
Divergence:	<0.9 mrad
Spatial beam mode:	TEM ₀₀
Polarization:	>100/1 linear
Polarization angle:	horizontal ±5° (other on request)
Beam alignment:	<5 mrad and <0.1 mm (compared to base mount)
Pointing stability (10 h):	5 μrad/K

5.3 Electrical Specifications

Power Supply and Control

Supply voltage VCC	12 V to 36 V
Supply current ICC:	≤2 A at V _{CC} = 12 V
Interlock input:	0 V to 5 V (<0.8 V: low, >2 V: high) - absolut max. voltage rating =Vcc
Ready output:	0 V and 5 V (active high)

Absolute Maximum Ratings

Supply voltage V _{CC} :	−40 V to +40 V	
Terminal block inputs:	−0.3 V to V _{CC} + 0.3 V	
Coaxial MMCX inputs:	Standard version:	0 V to 2 V
	High speed modulation:	0 V to 5.5 V

Low-speed Modulation Inputs

Connector type:	Screw terminal block	
Analog / digital input:	0 V to 5 V	
Digital input threshold:	< .8V: low, >2V: high	
Input polarity:	active high	
Modulation speed:	Standard version:	0 kHz to 200 kHz
	High speed modulation:	0 Hz to 500 Hz
Input impedance:	10 k Ω	

Coaxial Modulation Inputs

Standard version

Connector type:	MMCX coaxial connector
Analog / digital input:	0 V to 0.5 V
Digital input threshold:	<0.2 V: low, >0.3 V: high
Input polarity:	active high
Modulation speed:	0 kHz to 1500 kHz
Input impedance:	50 Ω

High speed modulation option

Connector type:	MMCX coaxial connector
Analog / digital input:	0 V to 0.5 V
Digital input threshold:	<0.8 V: low, >2 V: high
Input polarity:	active high
Modulation speed:	0 MHz to 200 MHz
Input impedance:	1 k Ω

Mechanical specifications

Lambda beam laser head

All dimensions in mm.

Length: 63.5 mm (2.5 in)
 Width: 31 mm (1.22 in)

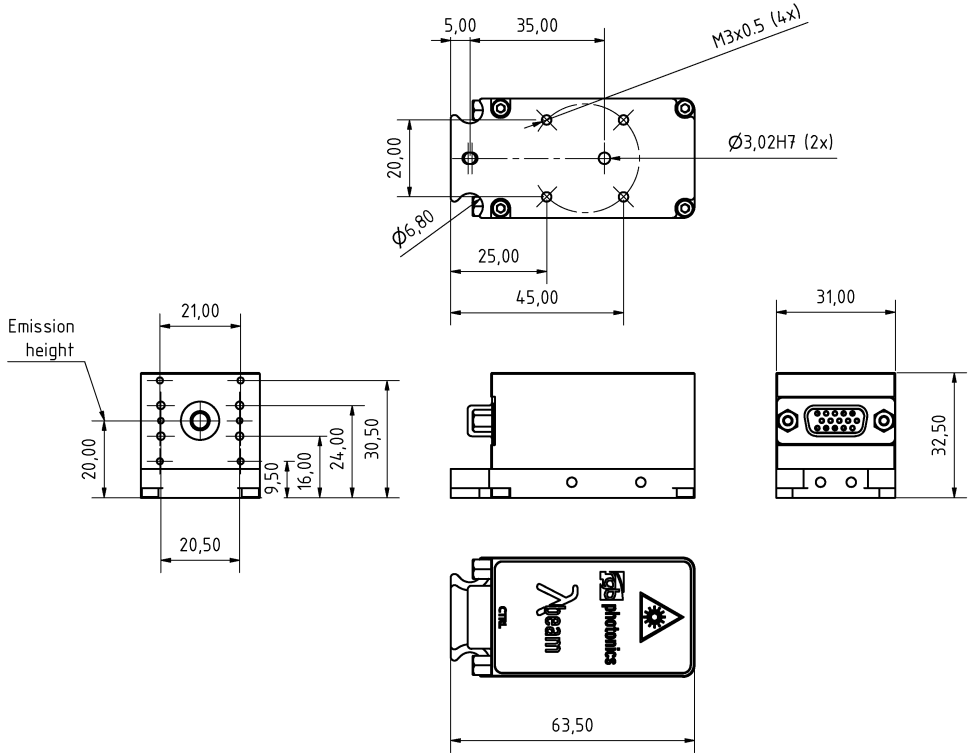


Figure 5.1: LambdaBeam technical drawing

3D computer-aided design (CAD) files are available for download on www.rgb-lasersystems.com.

PowerBox laser controller

Length: 39 mm (2.5 in)
 Width: 31 mm (1.22 in)
 Height: 32.5 mm (1.28 in)

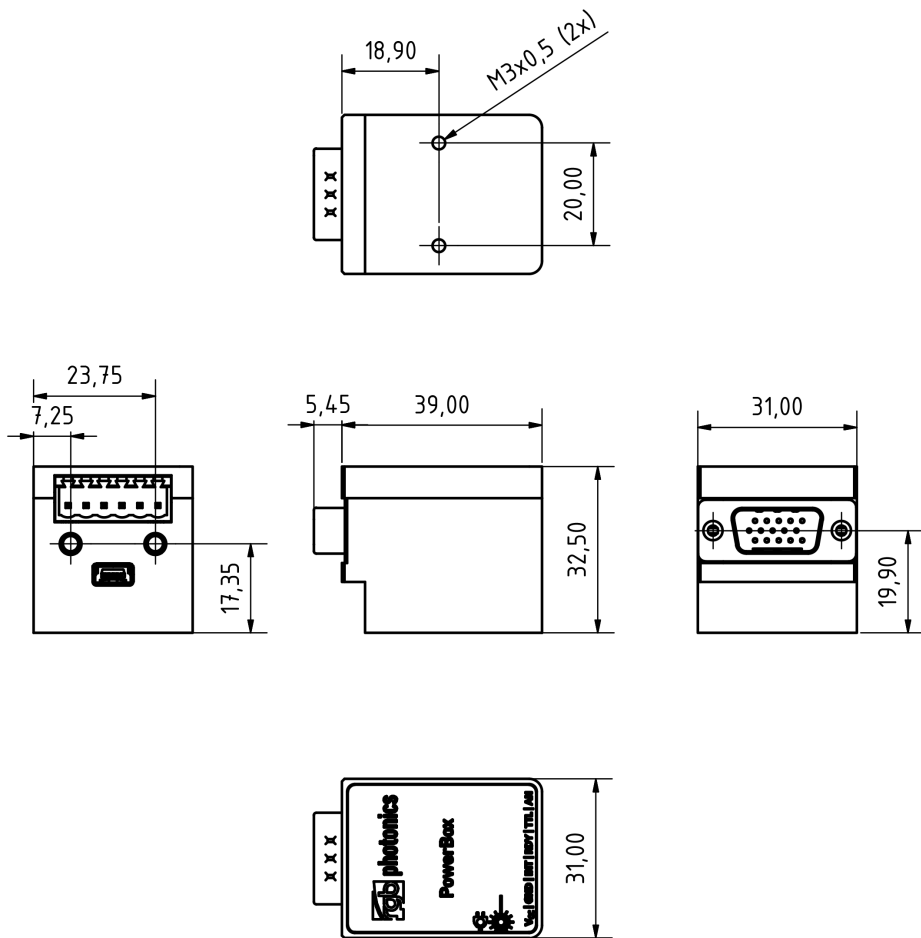


Figure 5.2: PowerBox laser controller technical drawing

All dimensions in mm.

3D CAD files are available for download on www.rgb-lasersystems.com.

PowerBox with Lambda beam attached

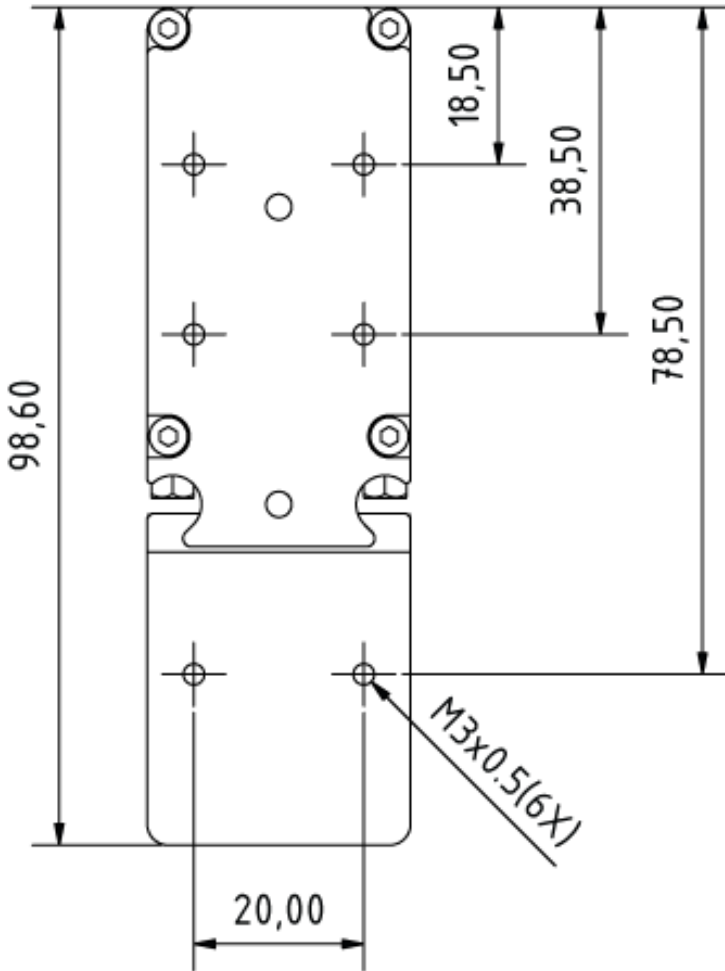


Figure 5.3: PowerBox with Lambda beam attached technical drawing

6 Optional system configurations

Fiber coupler

Each Lambda beam laser system can be equipped with a fiber coupler.

Water cooling system

For operation in extreme conditions, there is an optional water cooling system for the bottom plate. This ensures an optimal heat dissipation.

Wavelock

The Wavelock option provides an exceptionally stable single mode emission. Available for wavelengths of 405 nm, 633 nm, 638 nm, 640 nm, 658 nm, 685 nm, 785 nm, 808 nm and 852 nm.

7 Certifications and Compliance

CE Declaration of Conformity

The manufacturer

RGB Lasersystems GmbH
Donaupark 13
93309 Kelheim



declares that the following product

Lambda beam Version 1.0

complies with the following normative documents

EN6100-6-4: 2007 + A1:2011
EN6100-6-2: 2005

and therefore with the following EG requirements

Electromagnetic compability (2014/30/EU)

This declaration applies to all models of the above named product version, in case it will be used in the configuration of the tesst assembly.

A handwritten signature in blue ink, appearing to read 'Stefan Englbrecht', is written over a faint, illegible printed name.

Kelheim , November 19th, 2020

Stefan Englbrecht

FCC Compliance

This declaration applies to the following product:

Lambda beam Version 1.0



This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

A handwritten signature in blue ink, appearing to read 'Stefan Englbrecht', is positioned above the printed name.

Kelheim , November 14th , 2020

Stefan Englbrecht

RoHS Declaration of Conformity

The manufacturer

RGB Lasersystems GmbH
Donaupark 13
93309 Kelheim

declares that the following product

Lambda beam Version 1.0

contains no toxic substances which are specified in the

RoHS Directive 2011/65/EU.

The conformity to **RoHS** Directive 2011/65/EU is confirmed

This declaration applies to all models of the above named product version, in case it will be used in the configuration of the test assembly.



Kelheim, October 12th, 2020

Stefan Englbrecht

WEEE Directive

Please respect the **Waste Electrical and Electronic Equipment (WEEE)** directive 2012/19/EU and do not throw your RGB Lasersystems GmbH product into waste disposal but recycle it.



Acronyms

ACC	active current control. 16 , 19
AOM	acousto-optical modulator. 19
APC	active Power control. 16 , 19
CAD	computer-aided design. 21 , 23
CD-ROM	Compact Disc Read-Only Memory. 4 , 9 , 11
CDRH	Center of Device and Radiological Health. 1 , 7
CE	Conformité Européenne. 27
COM	communication port/serial port. 12
CW	continuous wave. 8 , 15
DC	direct current. 3
DSUB-9	D-Subminiature 9. 4
ESD	electrostatic discharge. 5 , 19
FCC	Federal Communications Commission. 28
LED	light emitting diode. 5 , 6 , 9
MMCX	Micro-miniature coaxial. 5 , 6 , 7 , 20 , 21
OEM	Original Equipment Manufacturer. 7
PC	Personal Computer. 11 , 12
PDF	Portable Document Format. 4
RMS	root mean square. 19
RoHS	Restriction of the use of certain hazardous substances. 29
TEC	thermo electric cooler. 19
TEM	transverse electromagnetic mode. 20
TTL	transistor-transistor logic. 5 , 7 , 8 , 15 , 16
USB	Universal Serial Bus. 3 , 4 , 5 , 7 , 11 , 19
WEEE	Waste Electrical and Electronic Equipment. 29

