CAVILUX® HF

Operating Manual

CAVITAR

Contents

CAVILUX HF, Operating Manual, Version 4.4

1 Introduction

Thank you for choosing CAVILUX HF!

CAVILUX® HF is a Finnish quality product developed and manufactured by Cavitar Ltd. We hope that you will be satisfied with your product.

CAVILUX HF is a versatile, accurate, reliable and easy-to-use pulsed high power diode laser light source designed especially for the high-speed visualization of challenging processes in scientific and industrial R&D.

Please read this operating manual carefully before using CAVILUX HF.

Chapter 2 contains important safety information for the safe operation of CAVILUX HF.

Chapter 3 describes the properties of CAVILUX HF and Chapter 4 deals with the installation of the system. A quick start guide is attached to this manual as an appendix for convenience.

Chapter 5 describes the operation of CAVILUX HF. Please note that there is plenty of useful information related to the use of CAVILUX HF in Section 5.4. As an example, troubleshooting is covered in Section 5.4.7.

Chapters 6 to 8 cover issues related to maintenance, service, support, accessories and warranty.

The symbols below will be utilized throughout this operating manual:

NOTE!	indicates useful tips for easier operation
CAUTION!	indicates potential risk of serious damage to the device
WARNING!	indicates potential risk of serious injury to the user

2 Safety information

PLEASE CAREFULLY READ AND UNDERSTAND THE FOLLOWING SAFETY INSTRUCTIONS BEFORE USING CAVILUX HF. IT IS OF UTMOST IMPORTANCE TO STRICTLY OBEY THESE INSTRUCTIONS. OTHERWISE SERIOUS DAMAGE TO THE USER OR TO THE DEVICE MAY OCCUR.

ONLY A PERSON, WHO HAS CAREFULLY READ AND UNDERSTOOD ALL SAFETY INSTRUCTIONS BELOW AND THE REST OF THIS OPERATING MANUAL, IS QUALIFIED FOR USING CAVILUX HF. CAVITAR LTD. IS NOT LIABLE FOR ANY DAMAGE CAUSED BY THE IMPROPER USE OF CAVILUX HF.

CAUTION--USE OF CONTROLS OR ADJUSTMENTS OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS RADIATION EXPOSURE.

CAUTION--USE OF OPTICAL INSTRUMENTS WITH THIS PRODUCT WILL INCREASE EYE HAZARD.

WARNING!
CAUTION!

- CAVILUX HF is a class 4 laser product.
  - laser class is indicated by the yellow warning label on top of the laser unit
    - possible warning labels are shown above. Warning text depends on whether the laser unit is with (the warning label on the right) or without (the warning label on the left) optional green laser pointer
  - laser apertures on the laser unit and on illumination optics are indicated by yellow aperture labels (see the label above)
- Do not look into the direct, reflected or scattered laser beam!
  - CAVILUX HF emits invisible laser light at 810 ± 10 nm wavelength band
  - wear suitable laser safety goggles (always ensure that the goggles protect especially for the emission wavelength band of the laser!)
- The accidental exposure to direct/reflected/scattered laser beam has to be prevented:
  - utilize suitable casings, curtains, beam blockers/absorbers, closed doors, Remote Interlock (RIL) feature and warning plates/lights/sounds in such a way that no one can enter the region of potential laser exposure by accident
  - pay special attention to possible bystanders or persons passing by
  - ensure that the key is removed from the control unit after use

- Before turning the device on, make sure that (in addition to the instructions above):
  - everyone inside the region of potential laser exposure wears laser safety goggles that block laser radiation at 810 ± 10 nm
  - the laser output and laser light blockers/absorbers are aligned and positioned in such a way that the direct/reflected/scattered laser beam will not be dangerous to anyone
- If the laser is to be used at high duty cycle and if the beam is to be focused tightly, the possible risk of fire or explosion in the presence of flammable materials has to be taken into account
- Ensure that there is no risk of unintentional voltage signal/peak (e.g. static discharge) at the Set Mode I/O (SMIO) connector, since this may enable/disable laser output (see Chapter 3 for more information)
- Other instructions:
  - CAVILUX HF is not certified for medical use
  - Do not make ANY modifications to the device by yourself
  - Do not try to repair the device by yourself
  - It is strictly forbidden to open the cover of the laser unit or the control unit. Otherwise serious damage or injury to the user or to the device may occur. Laser unit contains gallium arsenide, which is a known human carcinogen
  - Before turning the device on, ensure that all connections are properly made
  - Do not expose the system to moisture, rain or condensing environment
  - Excessive vibration or strong mechanical impact may damage the equipment
  - The operating temperature of CAVILUX HF is +10…+40 °C. Do not expose CAVILUX HF to excessively low or high temperatures
  - If you are uncertain about any issue related to safety or proper operating conditions, please contact your vendor or Cavitar

CERTIFICATIONS:

- Cavitar Ltd. is an ISO 9001:2008 certified company
- EC-declaration of conformity
  - the device fulfils the requirements of the following directives/standards:
    - Low Voltage Directive (LVD) 2006/95/EC
    - Directive of Electromagnetic Compatibility (EMC) 2004/108/EC
    - Laser Safety Standard EN/IEC 60825-1
- Certifications for USA and Canada
  - Complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.
  - 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.

SAFETY FEATURES OF CAVILUX HF:

- Safety information in this manual
  - this safety information as well as the whole Operating Manual need to be fully read and understood before a person is qualified for using CAVILUX HF
- Key-operated master control for power on/off
  - only a person qualified for using CAVILUX HF has the right to possess the key for the key-operated master control for power on/off
  - the key has to be removed from the control unit when the device is not in use. This prevents the unauthorized use of CAVILUX HF
- Remote Interlock (RIL)
  - when used correctly, this safety feature ensures that the laser output will be switched off in case someone enters the region of potential laser exposure
- Mechanical shutter
  - a mechanical lever next to the laser output aperture for stopping the beam. Push the lever towards the laser aperture for stopping the beam. Pull the lever away from the laser aperture to let the beam propagate out of the laser unit
- Laser emission indicating devices
  - "POWER" led on the control unit front panel and the green light on the laser unit power supply indicate that the generation of laser light is possible
  - USA and Canada only: green power indicator led in the laser unit back panel indicates that the generation of laser light is possible
  - "PULSE" led on the control unit front panel is on when laser light is generated
  - Optional: blinking green laser pointer indicates that the generation of laser light is possible (frequency ~1 Hz) or that laser light is generated (frequency ~2.5 Hz). Laser pointer also indicates the location of the 810 nm laser beam
- Laser warning label and laser aperture labels
  - laser warning label states applicable warning texts as well as indicates the laser class and the related safety standards
  - laser aperture label indicates the location of the laser output beam
- Maximum continuous operation time of 10 s in High Speed Mode
  - the laser output will automatically stop after 10 s in High Speed Mode
- Laser safety goggles
  - the laser safety goggles delivered together with CAVILUX HF provide good protection at the laser wavelength band (810 ± 10 nm)

3 Properties

CAVILUX HF typically consists of the following components:

LASER UNIT

- class 4 laser product (see the yellow warning label on the laser unit)
- pulse power 500 W ± 10 % (see the device label on the bottom of the laser unit)
- pulse rise time <50 ns
- wavelength 810 ± 10 nm (see the device label on the bottom of the laser unit)
- four mounting holes on the bottom (M4 thread)
- physical dimensions approximately 75 mm x 78 mm x 288 mm (laser connector requires additional space behind the laser unit)
- mechanical shutter and laser aperture label
- optional green laser pointer (wavelength 532 ± 10 nm, max power < 5 mW, class 3R)

CONTROL UNIT

- 2…8 independently programmable outputs for laser units and cameras
- bursts of pulses with up to five pulses and five delays can be programmed to each output
- resolution 10 ns (all outputs)
- each laser pulse duration independently programmable between ~50 ns …10 µs
- max. laser output duty cycle (DC) 2 % (High Speed Mode)
- TRIG IN connectors for external synchronization
- USB connector for programming the control unit with a computer
- Remote Interlock (RIL) connector
- Set Mode I/O (SMIO) connector for start/stop commands using logic input
- key-operated master control for power on/off
- Start/Stop button

CAVILUX CONTROL SOFTWARE

- for controlling CAVILUX products, see Chapter 5

ADJUSTABLE ILLUMINATION OPTICS

- fiber optic light guide, length 2 m
- focusing optics for uniform illumination

CABLES & POWER SUPPLIES

- USB cable between computer and control unit
- laser cable between laser unit and control unit
- power supply (DC 12 V) for control unit
- power supply for laser unit and related cables

INSTALLATION CD INCLUDING OPERATING MANUAL

STORAGE CASE, LASER SAFETY GOGGLES AND TOOLS

Table 3.1. CAVILUX HF specifications.

Optical	
Wavelength	810 ± 10 nm
Pulse output power	500 W ± 10 %
Pulse duration	~50 ns – 10 μs (up to 200 μs with LP extension)
Pulse energy	~25 μJ – 5 mJ
Max duty cycle (DC)	2 % (for a duration of max 10 s)
Max average power	10 W ± 10 % (for a duration of max 10 s)
Laser class (according to EN/IEC 60825-1:2007)	4
Standard fiber core diameter	1,5 mm
Standard fiber numerical aperture	~0,4
Standard fiber minimum bend radius	20 cm
Optional green laser pointer wavelength	532 ± 10 nm
Optional green laser pointer output power	< 5 mW
Optional green laser pointer laser class	3R
Electrical	
Control unit power supply input voltage	AC 100-240 V, 47-63 Hz
Control unit power supply output voltage	DC 12 V
Control unit power supply power rating	25 VA
Laser unit power supply input voltage	AC 115 V/230 V, 50-60 Hz
Laser unit power supply output voltage	DC 70 V
Laser unit power supply power rating	300 VA
Mechanical	
Control unit dimensions	~100 mm x 123 mm x 190 mm (excl. connectors)
Control unit weight	~1,9 kg (depends on configuration)
Laser unit dimensions	~ 75 mm x 78 mm x 288 mm (excl. connectors)
Laser unit weight	~1,9 kg
Laser unit attachment	4 x M4 mounting holes, depth 5 mm
Laser unit power supply dimensions	~135 mm x 200 mm x 300 mm (excl. connectors)
Laser unit power supply weight	~3,5 kg
CAVILUX HF storage case dimensions	~303 mm x 497 mm x 627 mm
CAVILUX HF system weight (incl. storage case)	~20 kg (depends on configuration)
Environmental	
Storage temperature	0…+50 °C
Operation temperature	+10…+40 °C
Humidity	max 80 % RH non-condensing
Shock resistance	max 25 G (laser unit contains shock sensors)
Supply voltage fluctuations	±10 %
Overvoltage category	II

Table 3.2. Description of symbols.

	Danger: Refer to this manual (ISO 7000-0434)
	Direct current (IEC 60417-5031)
	Alternate current (IEC 60417-5032)
	Supply “ON” (IEC 60417–5007)
	Supply “OFF” (IEC 60417–5008)
	In-position of push-button switch (IEC 60417-5268)
	Out-position of push-button switch (IEC 60417-5269)
	Fuse (IEC 60417-5016)

Fig. 3.1. Front panel of CAVILUX Control unit.

Front panel controls:

OFF/ON	key-operated master control for power on/off
START/STOP	manual button for activating/disabling the outputs

Front panel indicators:

POWER	green led indicates that the device is ON
ACTIVE	yellow/orange led indicates that the device is initializing (blinking), cooling (blinking) or activated (on), i.e. generating pulses or waiting for external trigger
PULSE	red led indicates that the device is generating pulses
RIL	red led indicates that the terminals of the RIL connector are open-circuited (EN/IEC 60825-1)

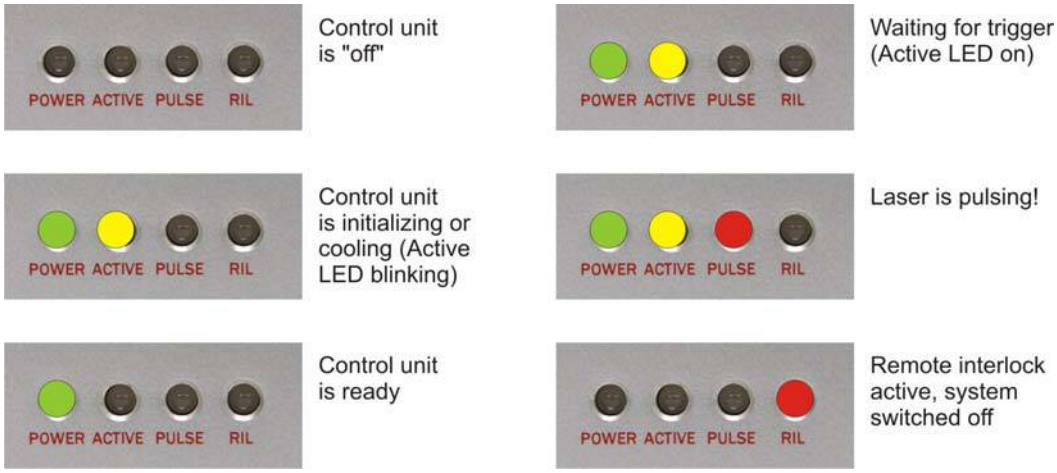

Fig. 3.2. Examples of front panel indicator operation.

Fig. 3.3. Rear panel of CAVILUX Control unit.

Rear panel connectors:

LASER1…4	D9 connector for connection between control unit and laser unit
CAM1…4	BNC connector for connection between control unit and camera
TRIG IN	BNC connector for external synchronization (TTL, allowed voltage range +0…5 V, input impedance approximately 34 kΩ) D9 connector for external synchronization (only to be used together with Cavitar optical triggers)
USB	USB connector for programming the control unit with a computer
RIL	Connector for remote interlock operation. The device will not emit laser radiation when the terminals of the RIL connector are open-circuited (EN/IEC 60825-1). Mating plug is LEMO FGG.0B.302.CLAD52Z
SMIO	Set Mode I/O for activating and disabling the outputs (optocoupler input; 0...+1 V → logic 0; +4…+24 V → logic 1). In harsh environment it is recommended to protect the unused input against unintentional switching with e.g. suitable termination resistance
DC 12V	5,5 / 2,1 mm dc connector for DC 12 V power supply. (Polarity: Positive pole in the center)

Fig. 3.4. Bottom view of CAVILUX Control unit (device label magnified on the right).

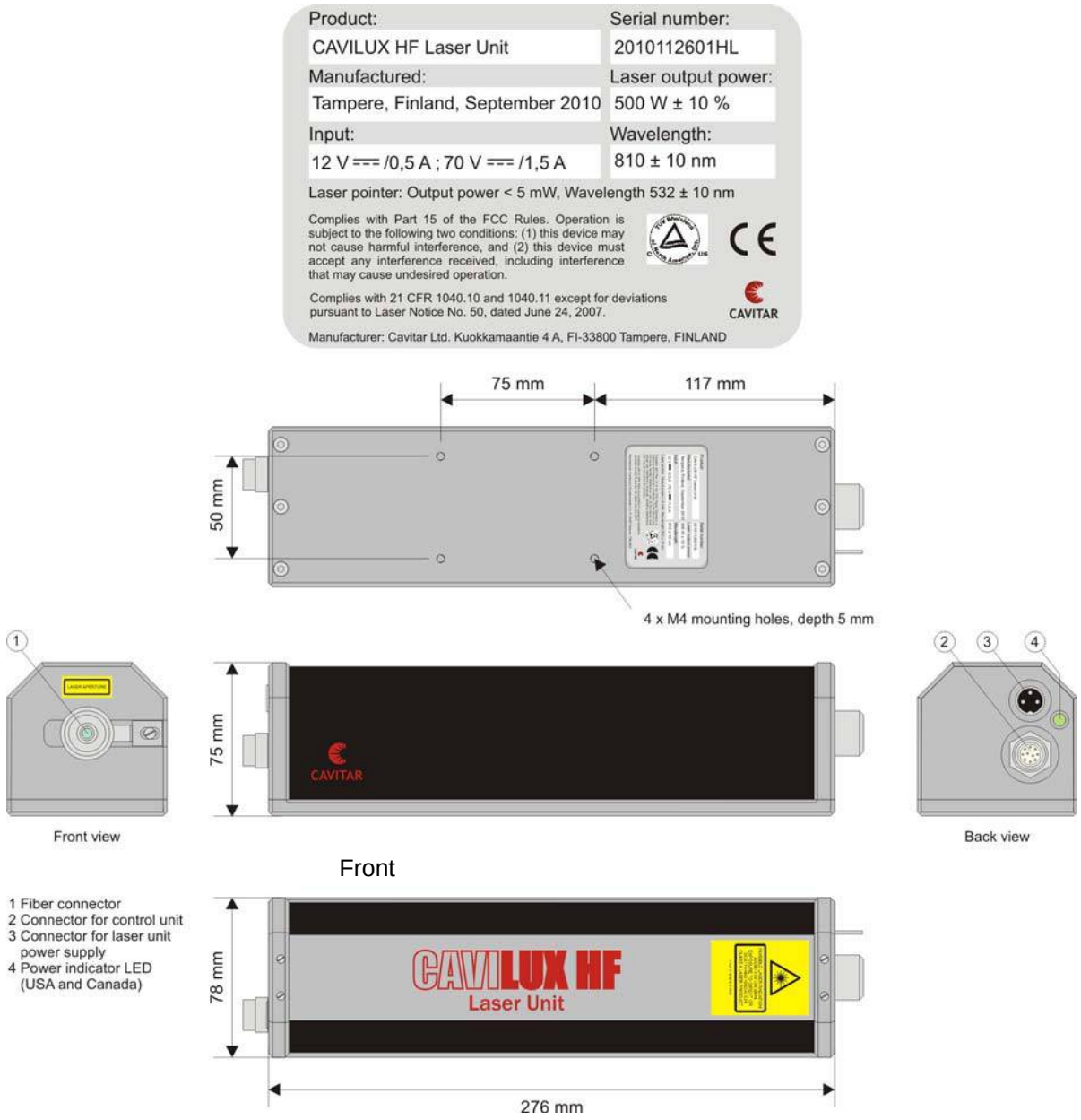

Fig. 3.5. CAVILUX HF laser unit (device label magnified on top).

Fig. 3.6. Adjustable illumination optics (laser aperture and warning labels shown).

Fig. 3.7. Bottom view of control unit power supply.

CAUTION!

- Do not connect other than the supplied control unit power supply to the control unit.
- Only connect the control unit power supply to a wall socket with protective grounding.
- If needed, control unit power supply can be disconnected from the mains supply by removing the control unit power supply plug from the wall socket.

Fig. 3.8. Top view of laser unit power supply (device label magnified on the right).

Fig. 3.9. Front view of laser unit power supply.

Fig. 3.10. Back view of laser unit power supply.

NOTE!

- One laser unit power supply can power two HF laser units. Both outputs are identical, so either one can be used in case only one HF laser unit is used.
- Selected voltage range (AC 115/230 V) is indicated in the label above mains connector (see Fig. 3.9).
- Voltage range selector is located under the plug in the back panel (see Fig. 3.10).
- Correct fuse: F10AH (Fast acting 10A High breaking capacity, see Fig. 3.9).

CAUTION!

- Before connecting the laser unit power supply to mains supply, ensure that the selected voltage range is correct.
- In case the voltage range selector is switched to another position, the label above mains connector (“SELECTED VOLTAGE”, see Fig. 3.9) must be updated.
- Do not connect other than the supplied laser unit power supply to the laser unit.
- Only connect the laser unit power supply to a wall socket with protective grounding.

4 Installation

4.1 Software installation

If applicable, please uninstall old software version before installing new software version!

Insert the CAVILUX Software CD into the CD drive and run the setup file. Follow the instructions on the screen. The screenshots below are valid for Windows XP. In case Windows logo test message box appears, please click "Continue Anyway" (see Fig. 4.1). After this software installation will be completed.

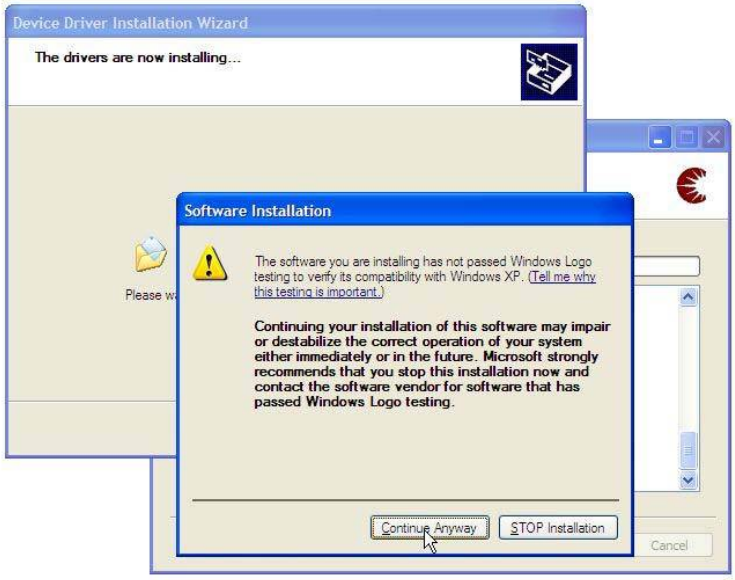

Fig. 4.1. Windows Logo test message box, click "Continue Anyway".

When the control unit is turned on and connected to the computer for the first time (or when connected to a new USB port for the first time), Windows starts to install CAVILUX drivers. Follow the driver installation instructions below (Figs. 4.2 – 4.4).

Fig. 4.2. Do not connect to Windows Update, choose “No, not this time” and click "Next".

Fig. 4.3. Choose "Install the software automatically" and click "Next".

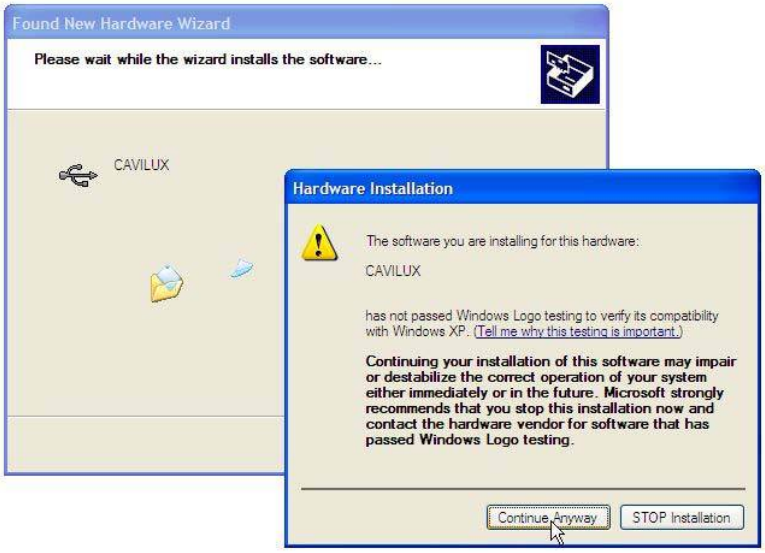

Fig. 4.4. Windows Logo test message box, click "Continue Anyway".

The installation of CAVILUX Control software and CAVILUX drivers is completed.

NOTE!

- The software has to be installed before connecting the control unit to computer.
- The software is designed for Windows XP/Vista/7 environment.
- The software requires Microsoft .NET Framework 2.0 and Microsoft Visual C++ 2008 Redistributable Package which are included in CAVILUX Control installer (starting from version 4.3).

4.2 Hardware installation

Installation of laser unit

The laser unit should be placed on a firm and stable surface so that the object can be properly illuminated with illumination optics. Also the safety instructions in Chapter 2 need to be taken into account. In the illumination of objects that may cause excessive radiation, heat, vibration or mechanical forces (e.g. explosions and materials processing) the laser unit (and illumination optics) need to be properly protected. If you feel uncertain about the correctness of the installation and/or about the suitability of the environment, please contact your vendor or Cavitar. Warranty does not cover damage caused by improper installation.

Installation of illumination optics to the laser unit

Illumination optics typically contains a fiber optic light guide. This provides versatility for different illumination requirements. A focusing lens can be installed to the end of the light guide for the generation of uniform illumination. Cavitar can also provide other illumination solutions such as back illumination or line illumination (see Chapter 6).

The installation of the fiber optic light guide includes the following steps:

- loosen the fiber optic light guide locking screw (on the laser unit fiber connector)
- install/change the fiber optic light guide
- gently tighten the locking screw

The focusing lens is installed as follows:

- thread the end of the fiber optic light guide inside the housing of the focusing lens
- gently tighten the locking screw(s) in the lens housing, do not use excessive force!

NOTE!

- In most cases the laser unit can be installed in a safe place by using a sufficiently long fiber optic light guide.
- The optical surfaces of illumination optics and fiber optic light guide need to be kept clean. Dirty optical surfaces reduce the amount of light reaching the object.
- The focusing lens produces a uniform illumination on a certain distance. This distance and the size of the illuminated area depend on the distance between the fiber optic light guide and the lens. A suitable illumination can be found by sliding the end of the fiber optic light guide back and forth with respect to the housing of the focusing lens. More information about this can be found from Section 5.4.1.
- Make sure that the laser unit end of the fiber optic light guide is pushed to the bottom of the connector on the laser unit. Otherwise a significant amount of light may not be coupled to the fiber optic light guide.

CAUTION!

- Do not use force while pushing the end of the fiber optic light guide to the connector in the laser unit. Handle the fiber optic light guide with special care.

- The fiber optic light guide will not tolerate excessive mechanical forces. The recommended minimum bending radius for 1,5 mm (2 mm) core diameter fiber is 300 mm (400 mm) (long term) or 150 mm (200 mm) (short term).

Installation of control unit

Control unit shall be placed on a firm surface. The safety instructions in Chapter 2 need to be taken into account.

Making the connections

The connections shall be made in the following order:

- check that the status of the control unit key-operated master control is ”OFF”
- connect your RIL circuit to the RIL connector (LEMO EPG.0B.302.HLN socket)
- connect the D9 connector of the laser cable to the LASER connector of the control unit and the M16 connector of the laser cable to the laser unit
- connect the control unit power supply (DC 12 V) between AC outlet and control unit
- ensure that the laser unit power supply voltage selector is in the right position!
- connect the laser unit power supply between AC outlet (AC 230 V or 115 V, 50-60 Hz) and laser unit (one cable between AC outlet and power supply, another cable between power supply and laser unit)
- in case that the control unit is used to control camera(s), connect a BNC cable between CAM connector of the control unit and camera
- in case that external synchronization is utilized, connect the external signal source to the TRIG IN connector of the control unit. Two TRIG IN connectors are available:
    - an optical trigger provided by Cavitar shall be connected to the D9 connector
    - other trigger signals shall be connected to the BNC connector, allowed signal: TTL, 0…+5 V (input impedance approx. 34 kΩ). For low impedance signal sources a termination resistance of corresponding value must used at input connector
- in case that an external logic signal is used for activating and disabling the outputs, connect the external logic signal source to the SMIO connector of the control unit (BNC connector)
- in case that the control unit is to be programmed or operated with a computer, connect the USB2 cable between the computer and the control unit. Make the connection only after the computer has fully started!

Useful images related to setting up the system can be found from the appendix at the end of this manual.

NOTE!

- To enable laser operation, the terminals of the Remote Interlock (RIL) connector (LEMO EPG.0B.302.HLN socket) need to be short-circuited together (do not connect to ground!). To disable operation, disconnect the terminals from each other. The device will not emit laser radiation when the terminals of the RIL connector are open-circuited (IEC/EN 60825-1).

CAUTION!

- **Only a TTL signal within the voltage range 0…+5 V can be delivered to the TRIG IN BNC connector.** E.g. negative voltage and/or excessively large voltage may damage the control unit.
- Ensure that the laser unit power supply voltage selector is in the right position (115 VAC or 230 VAC)! Otherwise the laser unit power supply will break.

WARNING!

- Ensure that there is no risk of unintentional voltage signal/peak (e.g. static discharge) at the Set Mode I/O (SMIO) connector, since this may enable/disable laser output (see e.g. Chapter 3 for more information).
- Ensure that the locations of all operation and adjustment controls as well as other system components are such that neither the operator nor anybody else can be exposed to laser radiation. Pay special attention to the placement of control unit and computer as these usually need to be accessed regularly during operation.
- Ensure that all system components are placed in such a way that the applicable mains plugs are always easily removable from the electrical network.

5 Operation

After successful installation CAVILUX HF is ready for operation. In the following the operation of the system is described in more detail.

5.1 Preliminary issues

Before operation the following preliminary issues need to be performed:

- check that laser unit, illumination optics and control unit are installed appropriately and that all optical surfaces are clean
- make sure that the key-operated master control of the control unit is ”OFF”
- make sure that the connections are as described in Section 4.2
- make sure that the safety instructions (Chapter 2) have been properly followed
- turn the control unit key-operated master control to ”ON”
    - Note1: if the USB cable is connected to a computer for the first time, driver installation will start, see Section 4.1
    - Note2: if the laser unit is equipped with green laser pointer, the pointer will start blinking at approximately 1 Hz frequency after turning the control unit on
- wait until the control unit has initialized (during initialization the “ACTIVE” led is blinking, see Chapter 3), this will take approximately 10 seconds
- switch the laser unit power supply on
- if the control unit is to be programmed or controlled with a computer, start CAVILUX Control software (this requires that the USB2 cable is connected between the computer and the control unit)

NOTE!

- After turning the key-operated master control to “ON”, the control unit will perform initialization routines. This can last max 10 s. During this time a yellow led indicator (ACTIVE) will blink in the front panel of the control unit and the control unit will not respond to commands from CAVILUX Control software.

5.2 CAVILUX Control software

The control unit can be programmed and controlled with CAVILUX Control software. The program is designed to be as versatile and easy-to-use as possible. The program also includes sophisticated safety check routines to protect the laser unit.

In the following the operation of the program is discussed in detail. Section 5.2.1 deals with general features, Section 5.2.2 with the selection of the operation mode and Section 5.2.3 with the programming of pulse patterns. Section 5.2.4 concentrates on triggering properties and Section 5.2.5 on power settings. Section 5.2.6 describes how to activate the outputs and Section 5.2.7 presents an example on how to use the program.

5.2.1 General

The front panel of the CAVILUX Control program is presented in Figs. 5.1 (Normal Mode) and 5.2 (High Speed Mode). The software version in the figures contains eight output channels, but the number of output channels can be e.g. two.

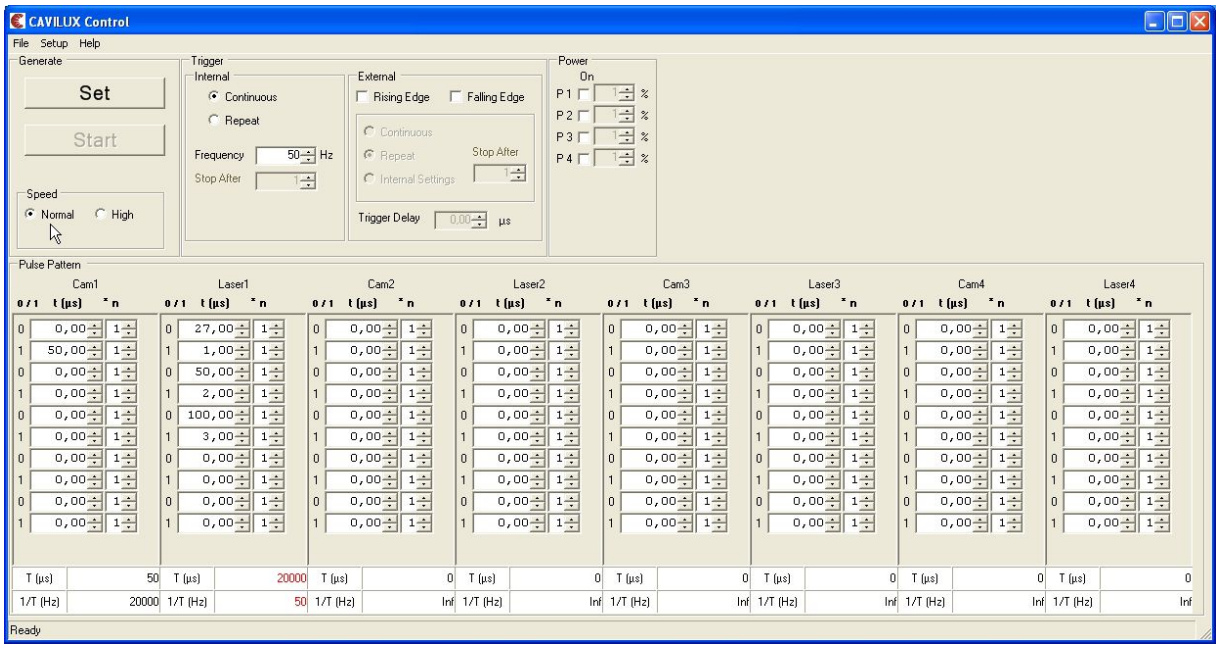

Fig. 5.1. The front panel of CAVILUX Control software (Normal Mode).

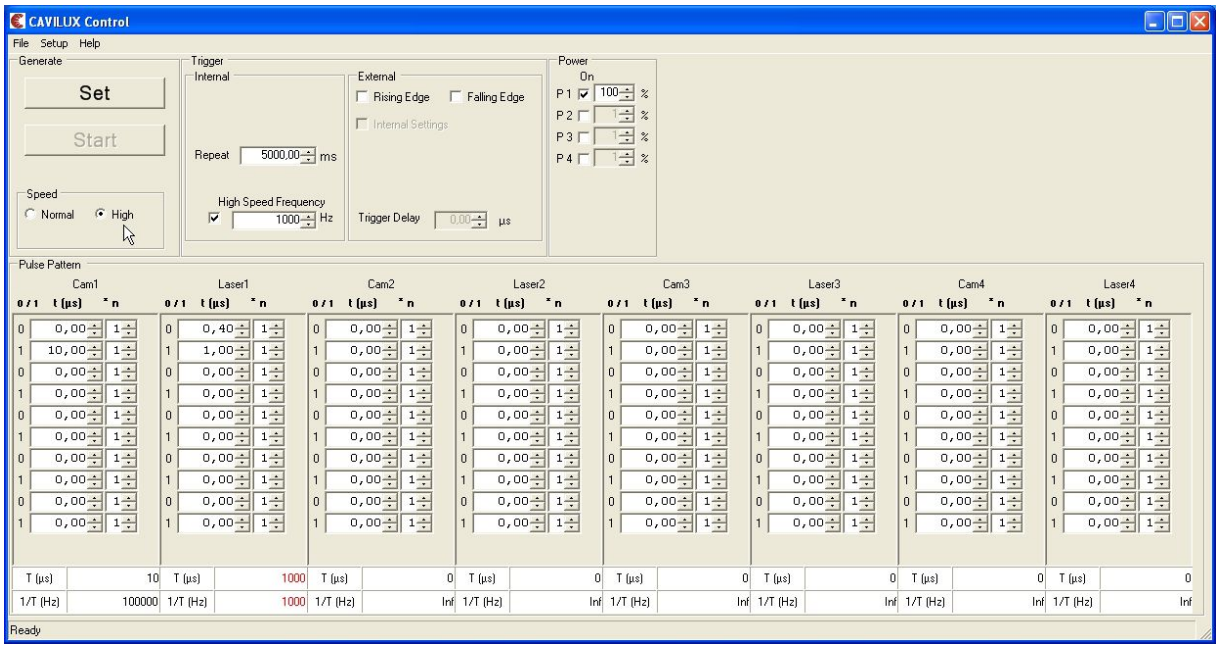

Fig. 5.2. The front panel of CAVILUX Control software (High Speed Mode).

CAVILUX Control contains three menus (File, Setup and Help) with the following functions:

File:

New	Open a new file for pulse pattern generation.
Open	Open a previously saved file for pulse pattern generation.
Save	Save the current pulse pattern settings with the existing file name.
Save As	Save the current pulse pattern settings with a new file name.
Exit	Exit the program.

Setup:

Settings — Default pattern file location: define a previously saved pulse pattern generation file that will be loaded when the program is started.
User log file location: define a log file for saving information about the operation of the program.

Show Messages — User can select whether info messages are shown on the screen or not.

Help:

CAVILUX Smart Manual — Launch the CAVILUX Smart Operating manual in pdf-format.

CAVILUX HF Manual — Launch the CAVILUX HF Operating manual in pdf-format.

About — Information about the program.

5.2.2 Choosing the operation mode

CAVILUX Control can be used in Normal Mode (“Normal”) or in High Speed Mode (“High”). The operation mode can be selected in the “Speed” block.

Normal mode is convenient e.g. while adjusting and aligning a high speed visualization system. In this mode the system can operate continuously at a max. duty cycle of 0,3 ‰. Duty cycle is the fraction of time that the laser is generating light. As an example, the generation of 1 μs pulses at 300 Hz corresponds to a duty cycle of 0,3 ‰.

High Speed Mode is convenient when higher repetition rates are required. Such needs may appear e.g. with high speed cameras. In this mode the system can operate at a max. duty cycle of 2 % for max. 10 s. After this the system will start a cooling period, during which the system will be inactive. After the cooling period the system will remain inactive.

The duration of the cooling period depends on the total laser active time during pulsing. With internal triggering (see Section 5.2.4) the cooling period is determined in such a way that the total laser active time divided by the cooling period results in a duty cycle of 3,3 ‰. For example, if the system operates at 2 % duty cycle for 10 s (total laser active time 200 ms), the cooling period will be approximately 60 s. This procedure is also valid for external triggering with internal settings. With other external triggering options the system will run for 10 s after which a 60 s cooling period will take place.

It is possible to operate CAVILUX HF at very high duty cycle (up to 90 %) for very short time (max. total laser active time 200 μs). Please see Section 5.4.5 for more details.

5.2.3 Programming pulse patterns

CAVILUX Control program can be used to create new pulse patterns and to load or modify existing pulse patterns. The programming of a new pulse pattern begins by selecting File → New.

The pulse patterns are programmed in the ”Pulse Pattern” block. Odd channels are for cameras (Cam) and even channels for laser units (Laser). In each channel there are three columns. The left column (0 / 1) determines the logic state of the signal (0 = signal off, 1 = signal on). The middle column (t (µs)) determines the temporal duration of the logic state in microseconds. The right column (* n) is a multiplier for the temporal duration. The values can be modified either by clicking the arrows or by typing the desired value from keyboard.

For example, in Fig. 5.1 the Cam1 channel output is ”on” for 50 µs, after which the signal goes ”off”. Accordingly, in the Laser1 channel the output is 27 µs ”off”, 1 µs ”on”, 50 µs ”off”, 2 µs ”on”, 100 µs ”off” and 3 µs “on”, after which the signal goes ”off”.

In Fig. 5.1 the rows T (µs) and 1/T (Hz) below each channel indicate the temporal durations and highest possible repetition rates of corresponding pulse patterns. In Fig. 5.1 the values in the Laser1 channel are red. This indicates that this channel restricts the highest possible repetition rate (in the case of Fig. 5.1 this repetition rate is 50 Hz).

When the pulse patterns in each channel are as desired, the settings can be saved (File → Save As). Saved pulse pattern settings can be loaded into the program by choosing File → Open. If it is convenient to open certain pulse pattern settings when the program is started, this can be accomplished by specifying the pulse pattern in Settings → Default pattern file location.

NOTE!

- The program contains safety features to protect the laser unit. This implies certain restrictions to the programming of pulse patterns. In laser channels the max. allowed duty cycle is 2 % (High Speed Mode) and the max. allowed temporal duration for a signal ”on” (signal “off”) state is 10 µs (1 ms). In camera channels the max. allowed temporal duration for each signal “on” and signal “off” state is 1 ms.

CAUTION!

- It is not allowed to try to override the above mentioned restrictions in the programming of pulse patterns. This may damage the device.

5.2.4 Trigger settings

After the pulse patterns have been programmed, it is time to choose trigger settings. CAVILUX HF contains versatile trigger properties, which are described in more detail below. Trigger settings are set in the ”Trigger” block (cf. Fig. 5.1).

CAVILUX HF can be used with Internal triggering or with External triggering.

Internal triggering:

Continuous — After activating the outputs (Section 5.2.6) the programmed pulse patterns are launched at the repetition rate indicated in the “Frequency” field until the outputs are disabled.

Repeat — After activating the outputs the programmed pulse patterns are launched the number of times indicated in the ”Stop After” field and at the repetition rate indicated in the ”Frequency” field. After this the outputs will be disabled.

NOTE!

- When using Repeat-mode at relatively high frequencies, the pulse patterns may be launched a few times more than what is specified in the “Stop After” field.

External triggering:

External triggering requires that a suitable synchronization signal is available at the TRIG IN connector of the control unit. **In case that the BNC connector is used, the external signal has to be a TTL signal within the voltage range 0…+5 V (input impedance approximately 34 kΩ)! Other signals are not allowed and may damage the control unit!** For more details, see Section 4.2. Triggering can be realized according to the rising (”Rising Edge” selected) or falling (”Falling Edge” selected) edge of the synchronization signal.

Continuous — After activating the outputs the programmed pulse patterns are launched once each time an external trigger signal is detected until the outputs are disabled.

Repeat — After activating the outputs the programmed pulse patterns are launched once each time an external trigger signal is detected until the pulse patterns have been repeated the number of times indicated in the ”Stop After” field. After this the outputs will be disabled.

Internal Settings — After activating the outputs and after an external trigger signal is detected, the programmed pulse patterns are launched according to internal trigger settings.

When using external triggering, it is possible to place an additional delay before launching the outputs. This can be done by setting a desired value to the “Trigger Delay” field. The maximum value of "Trigger Delay" is 1 s.

NOTE!

- Max. repetition rate depends on the laser active time. When using external triggering, the control unit will ignore those trigger signals that appear at higher frequencies than allowed. For example, if the maximum repetition rate is 1 kHz, there has to be at least 1 ms duration between successive trigger signals. In laser channels the highest allowed duty cycle is 2 % (High Speed Mode).

- When using external triggering in High Speed Mode, the device will stay active for 10 s (the time starts to run after the first trigger signal is received). After this the device will automatically be disabled due to the 60 s cooling time. This doesn't apply to external triggering with internal settings.

5.2.5 Power settings (not available for laser channels with CAVILUX HF laser units)

The power settings of each available laser channel can be controlled from the "Power" block. The power of each laser channel (P1 for Laser1, P2 for Laser2 etc.) can be turned on by selecting the corresponding "On" box. After this the power can be adjusted (1 % for min. power and 100 % for max. power).

5.2.6 Activating the outputs

After all settings are as desired, the "Set" button needs to be pressed. This will start the transfer of the current pulse pattern settings to the control unit. After the transfer is complete, the "Start" button will become enabled and the "Set" button is changed to "Change" button.

NOTE!

- After the "Start" button has been enabled, it is possible to remove the USB2 cable between the computer and the control unit, if desirable. The current settings will remain in the memory of the control unit until new settings are programmed. If the USB cable is reconnected between the computer and the control unit, CAVILUX Control software needs to be closed and restarted.

- If the "Change" button is pressed, the "Start" button will become disabled while the "Change" button changes back to "Set". This enables further modification of pulse patterns and trigger settings.

After the “Set” button has been pressed, the outputs can be activated by either:

- clicking the ”Start” button in CAVILUX Control software (requires USB2 connection!),
- pressing the Start/Stop button in the front panel of the control unit, or
- providing a rising edge (logic “0” → logic “1”) to the SMIO connector

After the activation of the outputs the operation of the system depends on trigger settings. The generation of programmed pulse patterns starts simultaneously in all channels and proceeds independently in each channel, row by row, until the whole pulse pattern has been produced.

If the laser unit is equipped with the optional green laser pointer, the blinking frequency of the green pointer beam will increase from approximately 1 Hz to approximately 2,5 Hz when the laser starts generating laser output at 810 nm. When the generation of laser output at 810 nm stops, the blinking frequency of the green pointer beam will decrease to approximately 1 Hz.

NOTE!

- The state of the outputs will be changed (from active to disabled or vice versa) each time a rising edge is detected at the SMIO connector.
- The blinking frequency of the optional green laser pointer depends on the state of the system. If the system is powered but not generating laser output at 810 nm, the blinking frequency of the green pointer beam is approximately 1 Hz. If the system generates laser output at 810 nm, the blinking frequency is approximately 2,5 Hz.

WARNING!

- The activation of the outputs means that the laser unit will generate laser light according to the programmed pulse pattern and trigger settings. Before activating the outputs ensure that the safety instructions in Chapter 2 have been properly followed!
- Ensure that there is no risk of unintentional voltage signal/peak (e.g. static discharge) at the Set Mode I/O (SMIO) connector, since this may enable/disable laser output (see e.g. control unit rear panel connector description in Chapter 3 for more details).

The outputs can be disabled by either:

- clicking the ”Stop” button in CAVILUX Control software (requires USB2 connection!),
- pressing the Start/Stop button in the front panel of the control unit, or
- providing a rising edge (logic “0” → logic “1”) to the SMIO connector

5.2.7 Example: using CAVILUX Control software

Let us program one 30 μs trigger pulse for the camera (sufficiently long pulse so that the camera will certainly react to it) and a double pulse with 50 μs delay between 1 μs pulses for the laser. Let us suppose that the camera delay is <20 μs. Triggering is set in such a way that the program will generate the pulse patterns 300 times at 20 Hz after detecting the rising edge of an external trigger signal.

a) programming the camera channel (”Pulse Pattern” block, ”Cam1” channel)
   - row 2: set duration to 30 (μs)
     - this is the trigger signal for the camera

b) programming the laser channel (”Pulse Pattern” block, ”Laser1” channel)
   - row 1: set duration to 20 (μs)
     - this ensures that the camera starts integrating before the first laser pulse is fired
   - row 2: set duration to 1 (μs)
   - row 3: set duration to 50 (μs)
   - row 4: set duration to 1 (μs)

c) adjusting trigger settings (”Trigger” block)
   - Internal:
     - select ”Repeat”
     - set ”Frequency” to 20 Hz
     - type 300 into the ”Stop After” field
   - External:
     - select ”Rising Edge”
     - select ”Internal Settings”

d) adjusting power settings (”Power” block) (not valid for CAVILUX HF laser units)
   - click the left mouse button over the white box to the right of “P1”
     - this will enable the percentage value on the right side of the white box
   - set the percentage value to “100” by clicking the up-arrow or by typing from keyboard

e) activating the outputs
   - press ”Set” button in the “Generate” block
   - activate the outputs by either clicking ”Start” button in the “Generate” block, by pressing the Start/Stop button in the Control unit front panel, or by providing a rising edge to the SMIO connector
     - after an external trigger signal is detected the system will launch the programmed pulse patterns 300 times at 20 Hz frequency

5.3 After operation

After the operation of CAVILUX HF the following issues should be carried out:
- make sure that the outputs are disabled (ACTIVE led is off)
- turn the key-operated master control “OFF” and remove the key from the control unit
- switch the laser unit power supply off
- exit CAVILUX Control program (if applicable)
- unplug cables
- carefully pack and store the whole system in the original storage case

5.4 Useful information

5.4.1 Spot sizes at different working distances

Table 5.1 presents the diameter of the illuminated spot with different fiber core diameters, different illumination optics and at different working distances. All spot sizes are approximate values.

Table 5.1. Spot sizes at different working distances.

Fiber core Ø (mm)	Illumination. optics Ø (mm)	Working distance (mm)	Spot size Ø (mm)
1,5	**50**	100	3
1,5	**50**	150	5
1,5	**50**	200	7
1,5	**50**	500	21
1,5	**50**	750	31
1,5	**50**	1000	41
1,5	25	100	4
1,5	25	150	8
1,5	25	200	11
1,5	25	500	29
1,5	25	750	44
1,5	25	1000	58
2	50	100	5
2	50	150	7
2	50	200	9
2	50	500	26
2	50	750	42
2	50	1000	55
2	25	100	7
2	25	150	10
2	25	200	15
2	25	500	39
2	25	750	57
2	25	1000	81

Standard components of CAVILUX HF system in bold.

5.4.2 Maximum repetition rates for different pulse durations

Table 5.2 shows maximum repetition rates for different pulse durations in Normal Mode and in High Speed Mode.

Table 5.2. Maximum repetition rates for different pulse durations.

	Maximum repetition rate (Hz)	
Pulse duration (ns)	Normal mode (DC 0,03 %)	High speed mode (DC 2 %)
100	3000	200000
200	1500	100000
400	750	50000
500	600	40000
1000	300	20000
2000	150	10000
4000	75	5000
5000	60	4000
10000	30	2000

5.4.3 Calculation of pulse energy

The pulse energy (E_{pulse}) is calculated by multiplying the pulse power (P_{pulse}) with the pulse duration (t_{pulse}):

$$E_{pulse} = P_{pulse} \times t_{pulse}$$

Table 5.3 presents pulse energies for different pulse durations (assuming P_{pulse} = 500 W).

Table 5.3. Pulse energies for different pulse durations.

t_{pulse} (µs)	0,1	0,5	1,0	2,0	5,0	10,0
E_{pulse} (mJ)	0,05	0,25	0,5	1,0	2,5	5,0

Note: With shortest pulse durations the actual pulse energy is lower due to rise and fall times.

5.4.4 Dependence of wavelength on temperature

The output wavelength of CAVILUX HF depends on temperature. Typically the output wavelength increases with increasing temperature by approximately 0,3 nm/°C. CAVILUX HF has been characterized in normal room temperature (~20 °C). If the operation temperature of CAVILUX HF deviates significantly from this, the output wavelength will be different from the wavelength indicated in the device label on the bottom of the laser unit.

If the laser is used together with a filter having a narrow transmission band, filter transmission can be significantly reduced due to the effect described above. The transmission band of such a filter can be shifted to lower wavelengths by tilting the filter with respect to camera lens. The optimal angle can be found by tilting the filter and viewing the resulting camera image. The angle is optimal when the image is as bright as possible.

5.4.5 Ultra high speed operation

In some applications there may be need for using the system at very high duty cycle for a short time. For this reason it is possible to use CAVILUX HF at max. 90 % duty cycle provided that the total laser active time is max. 200 μs. For example, one can generate 200 pulses of 1 μs duration at max 900 kHz or 2000 pulses of 100 ns duration at max 9 MHz.

CAVILUX HF has to be in High Speed Mode to enable this feature. Typical trigger settings are external triggering with internal settings. With these trigger settings the software can check the total laser active time beforehand and with a suitable external trigger signal the start of pulsing can be accurately determined.

5.4.6 Typical steps in using a complete visualization system

The visualization of a demanding object requires careful planning and preparation. Especially in many industrial processes one has to be very careful in order not to cause any danger to people, equipment or the process itself.

A visualization system based on CAVILUX laser illumination typically contains the following components:

- CAVILUX light source with appropriate illumination optics
- camera with an appropriate lens
- laser bandpass filter in front of the camera (only needed for hot/bright objects)
- external trigger source (if applicable)
- computer (if applicable)

Note that there are big differences in the compatibility of different cameras with CAVILUX light sources. For example, it is very important to use a monochrome camera. Please consult Cavitar for more information about suitable cameras for your specific application.

In the following some typical steps in using a visualization system are described. The steps are in no way comprehensive, but indicate some important issues to be considered.

Step 1: Find out the optimal synchronization arrangement between the camera and the laser

- the idea of this step is to operate the camera and the laser in such a way that the laser pulse is always fired immediately after the camera starts exposing
    - this enables the best possible overlapping of the laser pulse and the camera exposure time (especially important in the visualization of hot objects)
- if one uses the laser as the master, it is always possible to find out optimal synchronization between the camera and the laser, because a suitable delay can be generated to either laser or camera channel
- practical procedure (laser as the master, Normal Mode):
    - point the camera and the laser to a desired object (e.g. white paper)
    - verify that the camera and the laser are properly aligned (e.g. use the maximum camera exposure time and check that laser illumination is seen in the images)
    - set the camera exposure time to a minimum value and program the laser in such a way that the laser pulse is much shorter than the camera exposure time (e.g. 1 us camera exposure time and 100 ns laser pulse duration)

- find out the optimal laser/camera delay by adjusting the respective delays in CAVILUX Control software (first "0" row in laser/camera channel, see Sections 5.2.3 and 5.2.7)
- an optimal delay is found when:
  - the image is bright and stable AND
  - reducing the laser delay (or increasing the camera delay) by even a small amount makes the image darker and/or unstable (this ensures that the laser pulse is fired at the beginning of the camera exposure)
- note: the optimal delay values are camera-specific and need to be found out for each camera separately. The optimal delay settings for each camera can be saved in CAVILUX Control software (see Section 5.2.3)
- note: it is possible to study the operation of the camera shutter (delay, jitter, actual exposure time) by scanning a short laser pulse over the camera exposure time and looking at the images (dark, flickering, bright, flickering, dark …)

Step 2: Get familiarized with the process to be visualized

- ensure that the safety instructions can be properly followed (see Chapter 2 for laser safety issues related to CAVILUX)
- ensure that the visualization equipment can be used in the specific environment (see Chapter 2 for issues related to CAVILUX). Realize appropriate protection (e.g. cooling, protective windows, mechanical protection, vibration damping), if needed
- ensure that the equipment can be installed without danger to people, process or equipment
- determine the best installation location for each component of the visualization system

Step 3: Install the visualization system

- install the components of the visualization system and make all required connections
- after checking all connections, switch the system on

Step 4: Align and adjust the system

- align the camera to the object by using ambient light and long camera exposure time
  - for optimal focusing, fully open the iris of the camera lens and adjust the system in such a way that the desired region is in focus in the image. When closing down the iris the depth of view will increase, but the region of best focus will remain at the desired location
  - note: one can control the brightness of the images by adjusting the camera exposure time (e.g. if the image becomes too bright while opening the iris, simply reduce the camera exposure time appropriately)
  - note: there should be no bandpass filter in front of the camera at this stage!
- after the image looks OK, start using the laser
  - ensure that the safety instructions (Chapter 2) are followed properly
  - ensure that the laser operation is properly synchronized to the camera
  - note: use the laser at Normal mode at this stage (for continuous operation)
- point the laser to the object and once the laser spot is seen in the camera image:
  - reduce the camera exposure time to an appropriate value (best signal-to-noise ratio is achieved when the camera exposure time equals the laser pulse duration, provided that the synchronization between the camera and the laser is accurate, see Step 1)

        - in the visualization of hot objects it may be beneficial to use a somewhat longer laser pulse than the camera exposure time in order to ensure that the whole exposure period is covered by laser illumination
    - adjust the illumination so that the image looks optimal
    - add the bandpass filter, if applicable
    - verify that the focusing is optimal (by opening the iris and by adjusting the amount of light in the image), if needed
    - note: it is often beneficial to try different illumination geometries for different images and for different information (front illumination, side illumination, back illumination, mirror reflection, almost mirror reflection …)
    - note: the light output of CAVILUX HF is essentially plane-polarized. The effect of polarization in the images can be checked by rotating the laser unit around the optical fiber (rotating the fiber doesn't have any effect)

Step 5: Start visualization

- once more check all applicable safety issues, wirings etc.
- start the process and the visualization
- it is often beneficial to make notes during the visualization
    - what is the field of view of the image (e.g. take a calibration image)
    - what camera/laser parameters have been used in each image or set of images
    - what illumination geometry was applied
    - what were the relevant process parameters
    - also digital images of the visualization setup are often useful later

Step 6: After visualization

- preferably back up the image material on site
- for issues regarding CAVILUX HF, see Chapter 5.3
- remove and carefully pack all the components of the visualization system
    - be extremely careful not to leave/forget any components which might later cause damage to people, equipment or process
- store the equipment according to the instructions

5.4.7 Troubleshooting

The procedure below provides instructions for solving the situation if the system doesn't appear to generate light as expected. If these instructions don't help, please contact your vendor or Cavitar.

WARNING!

- At all stages ensure that accidental exposure to laser output can't occur. The realization of some of the following steps may result in immediate laser output!
- Only perform position j) in case you have proper knowledge and understanding of said voltage measurement.

a) check that all system components seem to be intact
   - pay special attention to cables and connectors
   - check the condition of the protective window of the illumination optics

b) check that the fiber-optic light guide is intact
   - if the fiber is broken or if the input or output end is dirty or damaged, the fiber will not transmit light properly. This can be checked by visual inspection and by removing the light guide from the laser and pointing e.g. a hand lamp to one end of the fiber and checking that light comes out from the other end of the fiber

c) check that all connections are properly made
   - refer to Chapter 4 of this manual and to the appendix at the end of this manual
   - pay special attention to the camera synchronization: if laser is the master, camera should be connected to "CAM" connector of the control unit and if laser is the slave, camera should be connected to "TRIG IN" connector of the control unit

d) check that the lens cap is not attached to the illumination optics

e) check that the mechanical shutter is open

f) check that the control unit is powered
   - POWER led in the control unit front panel should be on

g) check that CAVILUX Control is properly programmed
   - the duration of at least one of the "1" states (row 2, row 4, row 6, row 8 and/or row 10) in the laser channel under use has to be nonzero, refer to Section 5.2.3
   - ensure you have correct trigger settings (internal if laser is the master and external if laser is the slave), with both internal and external triggering the best mode for troubleshooting is "Continuous", refer to Section 5.2.4

h) check that the system is started
   - POWER, ACTIVE and PULSE leds in the control unit front panel should be on

i) check that the laser unit power supply is on
   - the green light in the power button of the power supply should be on

j) check that the laser unit power supply outputs correct voltage to the laser unit
   - turn off the power supply and remove the power cable from the laser unit end
   - turn on the power supply and measure the DC voltage from the pins of the cable with a suitable digital multimeter. A correct voltage value is ~70 VDC
   - if the specified voltage is not available on the cable end, repeat the measurement directly from the output of the power supply
   - turn off the power supply, attach the power cable back to the laser unit and turn on the power supply

k) check camera settings
   - ensure that the camera is set up correctly (refer to camera manual)
   - ensure you are in the correct triggering mode (internal or external)
   - try increasing the exposure time to 1/frame rate
   - go through Step 1 in Section 5.4.6
   - with some cameras a 50 ohm feed through terminator is required for proper signal transmission between the control unit and the camera

6 Maintenance and service information

CAVILUX HF is essentially maintenance and service free so normally there is no need for these operations. However, sometimes there may be need to clean optical surfaces or casings or to replace the protective window of illumination optics.

WARNING!

Ensure the system is turned off and all power supplies are detached from mains supply before performing any maintenance or service operations!

Cleaning optical surfaces

For optimal performance it is important to keep the following optical surfaces clean: laser output window in the laser unit, both fiber ends and protective window of illumination optics. Clean these sensitive optical surfaces primarily by using clean and dry pressurized air. If this is not sufficient, try dry optical wipes. If needed, the optical wipe can be moisted with ethanol. Be careful not to create any scratches on optical surfaces, as this will deteriorate the performance of the system.

Changing the protective window of illumination optics

Sometimes the protective window of illumination optics becomes so dirty that it must be replaced. Follow these steps to change the protective window:

- remove the lens cap
- detach the protective window holder from the body of illumination optics by rotating the holder counter clockwise (threads)
- replace the window
- attach the protective window holder to the body of illumination optics by rotating the holder clockwise (threads)
- attach the lens cap

Cleaning the system

Clean casings with slightly moist wipe. Avoid using strong solvents. Ensure the system is fully dry before connecting it to mains supply in order to avoid the risk of electrical shock (pay special attention to connectors).

Other maintenance or service needs

In case any other needs for maintenance or service appear, please contact your vendor or Cavitar (see Chapter 7 for more details).

7 Support, accessories and end of life

Support and contact information

It is of utmost importance to Cavitar that CAVILUX HF will work reliably and offers the greatest possible benefit to our customers. These objectives have guided the design and manufacturing of the product. However, if problems occur despite of our efforts, it will be our first priority to solve these problems as quickly and efficiently as possible.

In case of problems please contact your vendor or Cavitar by email or by telephone.

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Our current contact information is available at our website: www.cavitar.com.

Accessories

Several accessories are available for CAVILUX HF:

- expansion to a visualization system (camera + camera software)
- various objectives for the camera
- various filters for the camera
- tailored fiber optic light guides
    - various lengths
    - various illumination geometries (e.g. back and line illumination)
- optical triggers
- CAVILUX Control Software Development Kit
- remote control –feature enabling the remote control of CAVILUX Control software through Socket TCP/IP (e.g. C, Matlab, Labview)

Please contact your vendor or Cavitar for more information.

End of life

It is not allowed to dispose CAVILUX products as unsorted municipal waste. CAVILUX products must be returned to your vendor or to Cavitar for proper disposal at the end of their life. Alternatively one can consult local, state and federal regulations for proper disposal.

CAVILUX laser units contain Gallium Arsenide. Gallium Arsenide is toxic and must not be released to the environment.

8 Limited warranty

Cavitar warrants to the customer, that the product is free from defects in materials and workmanship and that the product is in good working order. Cavitar does not warrant error free or uninterrupted operation of the product.

The warranty is valid only if the serial number plate is on the product (i.e. not removed or defaced).

The warranty for the product is one year starting from the date of purchase or delivery (unless the applicable law establishes a longer period). Cavitar will provide warranty service and technical support free of charge during the warranty period.

In warranty service Cavitar will first diagnose the fault. Cavitar will repair or change the defective product either by delivering a new or refurbished product. Cavitar may give instructions regarding the return or replacement of defective products. Original packing materials should be retained for possible need during warranty period. All exchanged parts and products replaced under warranty period become the property of Cavitar. In the case that the product will be changed, the defective product has to be returned in its original packing materials to Cavitar without delay. Failure to return the defective product will result in an invoice at current or last published list price. A replacement product will be delivered without other parts, cables or options. Those parts need to be removed from the defective product and they have to be used with the replacement product.

Warranty service does not include repair or replacement caused by the following reasons:

1) negligence by the user of the product or overloading of the product or failure to observe the operating instructions or proper care,
2) transportation of the product,
3) unauthorized modifications or attachments have been made to the product,
4) the casing of the product has been opened,
5) circumstances outside the control of Cavitar such as freezing, fire or accident or it has been misused,
6) repairs or maintenance by maintenance people other than those authorized by Cavitar,
7) the use of other than original parts provided by Cavitar, and
8) normal wear and tear.

The warranty does not cover defects which are insignificant to the use of the product, such as repair of superficial scratches.

The statement of limited warranty is the exclusive warranty. All other expressed or implied warranties including merchantability and applicability for a certain purpose are excluded (except where the applicable law requires said implied warranties). Any warranty, either expressed or implied, will not apply after warranty period.

LIMITATION OF LIABILITY
To the extent of the applicable law, the sole remedy of the customer is the warranty service set forth above. Cavitar's liability for actual damages of any kind will be limited to the price paid for the product, its repair or replacement. This limitation of liability does not apply to bodily injury or property damage for which Cavitar is held legally liable. In no event will Cavitar be liable for lost profits nor for incidental, consequential or other damages even if advised of the possibility of said damages.

Appendix: CAVILUX HF quick start guide