PRIMES

Original Instructions

MicroSpotMonitor MSM+ HB10

MicroSpotMonitor+ HighBrilliance

MSM+ HB10, MSM+ HB20

LaserDiagnosticsSoftware LDS

Revision 01 EN - 01/2023

IMPORTANT!

READ CAREFULLY BEFORE USE.

KEEP FOR FUTURE USE.

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PRIMES - The Company

PRIMES manufactures measuring devices used to analyze laser beams. These devices are employed for the diagnostics of high-power lasers ranging from CO_2 lasers and solid-state lasers to diode lasers. A wavelength range from infrared through to near UV is covered, offering a wide variety of measuring devices to determine the following beam parameters:

- Laser power
- Beam dimensions and position of an unfocused beam
- Beam dimensions and position of a focused beam
- Beam quality factor M^2

Development, production and calibration of the measuring devices is performed at PRIMES. This guarantees optimum quality, excellent service, and a short reaction time, providing the basis for us to meet all of our customers' requirements quickly and reliably.

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1 Basic safety notes

Intended use

The device has been designed exclusively for measurements in the beam of high-power lasers.

Use for any other purpose is considered as not intended and is strictly prohibited. Furthermore, intended use requires that you observe all information, instructions, safety notes and warning messages in this operating manual. The specifications given in chapter “14 Technical data” on page 97 apply. Any given limit values must be complied with.

If not used as intended, the device or the system in which the device is installed can be damaged or destroyed. In addition, there is an increased risk to health and life. Only use the device in such a way that there is no risk of injury.

This operating manual is an integral part of the device and must be kept in the immediate vicinity of the place of use, accessible to personnel at all times.
Every person who is responsible for the installation, start-up or operation of the device must have read and understood the operating manual and, in particular, the safety instructions.
If you still have questions after reading this operating manual, please contact PRIMES or your supplier for your own safety.

Observing applicable safety regulations

Observe the safety-relevant laws, guidelines, standards and regulations in the current editions published by the state, standardization organizations, professional associations, etc. In particular, observe the regulations on laser safety and comply with their requirements.

Necessary safety measures

The device measures direct laser radiation, but does not emit any radiation itself. However, during the measurement the laser beam is directed at the device. This produces scattered or directed reflection of the laser beam (laser class 4). The reflected beam is usually not visible.

Protect yourself from direct and reflected laser radiation while working with the device by taking the following measures:

- Never leave the device unattended when taking measurements.
- If the device is moved from its aligned position, increased scattered or directed reflection of the laser beam occurs during measuring operation. Fix the device in such a way that it cannot be moved by unintentional bumping or pulling on the cables.
- Connect the laser control’s safety interlock to the device. Check that the safety interlock will switch off the laser properly in case of error.
- Install safety switches or emergency safety mechanisms that allow the laser to be switched off immediately.
- Use suitable beam guidance and beam absorber elements which do not emit any hazardous substances when irradiated.
- Wear **safety goggles** adapted to the power, power density, laser wavelength and operating mode of the laser beam source in use.
- Wear suitable **protective clothing** or **protective gloves** if necessary.
- If possible, also protect yourself from direct laser radiation and scattered radiation by using separating protective devices that block or attenuate the radiation.

Necessary safety measures due to magnetic spring with strong permanent magnet

The device contains a magnetic spring made of neodymium magnets with a very strong magnetic field.

DANGER

Danger to life for persons with pacemaker or implanted defibrillator

Magnetic spring rotors consist mainly of neodymium magnets (NdFeB magnets). These can impair the correct functioning of pacemakers.

▶ **If you have a cardiac pacemaker or implanted defibrillator, keep a minimum distance of 1 m from the device.**

- Do not bring magnetic parts near the measuring device. Careless handling can lead to serious injuries (bruises, broken fingers, etc.).
- Please note that magnetic springs can act like tensioned springs. The sliders spring back to their original position as soon as they are let loose, even if he machine is disconnected from the power supply.
- Keep a safe distance to the magnetic spring with objects that can be damaged by magnetism. These include, for example, televisions and monitors, credit cards, computers, data carriers, video tapes, mechanical watches, hearing aids and loudspeakers.

Employing qualified personnel

The device may only be operated by qualified personnel. The qualified personnel must have been instructed in the installation and operation of the device and must have a basic understanding of working with high-power lasers, beam guiding systems and focusing units.

Conversions and modifications

The device may not be modified in terms of design or safety without the explicit consent of the manufacturer. The same applies to unauthorised opening, dismantling and repair. The removal of covers is only permitted within the scope of the intended use.

Liability disclaimer

Manufacturer and distributor exclude any liability for damages and injuries which are direct or indirect consequences of using the device not as intended or modifying the device or the associated software without authorization.

2 Symbols and conventions

Warning messages

The following symbols and signal words indicate possible residual risks in the form of warnings:

DANGER

Means that death or serious physical injuries **will** occur if necessary safety precautions are not taken.

WARNING

Means that death or serious physical injuries **may** occur if necessary safety precautions are not taken.

CAUTION

Means that minor physical injury **may** occur if necessary safety precautions are not taken.

NOTICE

Means that property damage **may** occur if necessary safety precautions are not taken.

Product safety labels

The following symbols are used on the device itself to indicate imperatives and possible dangers:

No access for people with pacemakers or implanted defibrillators

General warning sign

Hand injuries warning

Magnetic field warning

Read and observe the operating instructions and safety guidelines before startup!

Do not lift the device by the objective

Labeling according to WEEE directive:
The device must not be disposed of with household waste, but in a separate WEEE collection in an environmentally friendly way.

Further symbols and conventions in this operating manual

Here you can find useful information and helpful tips.

▶ Indicates a simple instruction.
If several such instructions appear one below the other, then the order of their execution is irrelevant or they are alternative procedures.

1.
2.
...
A numbered list identifies a sequence of instructions that must be executed in the specified order.

➜ Indicates the result of an action to explain processes that take place in the background.

Indicates an observation prompt to draw attention to visible feedback from the device or the software.
Observation prompts make it easier to check whether an instruction was executed successfully. Often they also guide to the next instruction.

Points to a control element that is to be pressed / clicked.

Points to an element described in the text (for example an input field).

3 About this operating manual

This manual describes the installation and operation of the MSM+ HB and how to perform measurements with the LaserDiagnosticsSoftware LDS 1.1.2.
For measurement operation with a PC, the LaserDiagnosticsSoftware LDS must be installed on the PC. The LDS is included in the scope of delivery.

The software description includes a brief introduction on using the device for measurements.
For a detailed description of the software installation, file management and evaluation of the measurement data, please refer to the separate instructions for the LaserDiagnosticsSoftware LDS.

This operating manual describes the software version valid at the time of printing. Since the operating software is subject to continuous further development, it is possible that the the supplied data carrier may contain a higher version.

If you have any questions, please let us know the software version you are using. The software version can be found under the following menu item: ***Help > About LaserDiagnosticsSoftware***.

4 Device description

4.1 Device types

There are two types of MSM+ HighBrilliance:

- MSM+ HB10
- MSM+ HB20

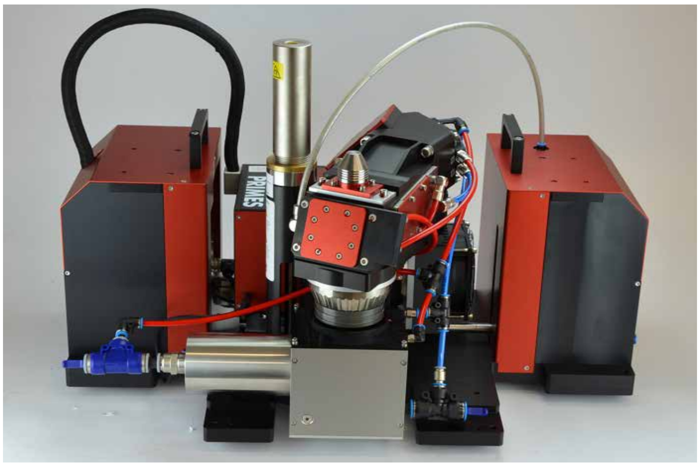


Fig. 4.1: MSM+ HB10

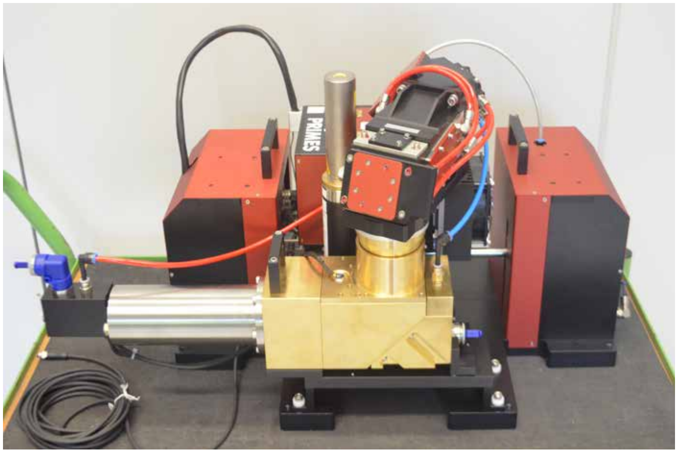


Fig. 4.2: MSM+ HB20

The main distinguishing feature between the two devices is the absorber, which is dimensioned for different beam powers. The MSM+ HB10 is designed for a maximum beam power of 10 kW. The MSM+ HB20 is designed for a maximum power of 20 kW and is therefore equipped with a larger absorber.
Due to the special absorber design of the MSM + HB20, the possible maximum travel in z-direction is limited: it is 120 mm for the 10 kW type and 40 mm for the 20 kW type (not with the fiber bridge installed!).
The x- and y-axes of the 20 kW type are fixed. The device cannot be moved in x- or y-direction.

4.2 Functional description

The MSM+ HB is used to analyze the focused laser beam in the range from 20 µm to 1000 µm. For this purpose, the device records the power density distribution in the area around the focus in form of a caustic. A caustic comprises several measurement planes (according to ISO 11146-1 at least 10). A measurement plane maps the true power density distribution at an associated z coordinate along the optical axis of the laser beam.

The beam geometries (beam position, beam radius and azimuth angle) are determined for each plane according to the procedures described in the standard ISO 11146 (2. moment and 86 % power inclusion). The beam propagation parameters (focus position, focus radius, Rayleigh length, divergence, M^2, K and beam parameter product) are determined with the beam geometry data. From the measurement data for the semi-axes of the beam, the ellipticity of the focus and the astigmatic difference are determined according to ISO11146.
An automatic function supports the user when measuring a caustic.

Device Assembly

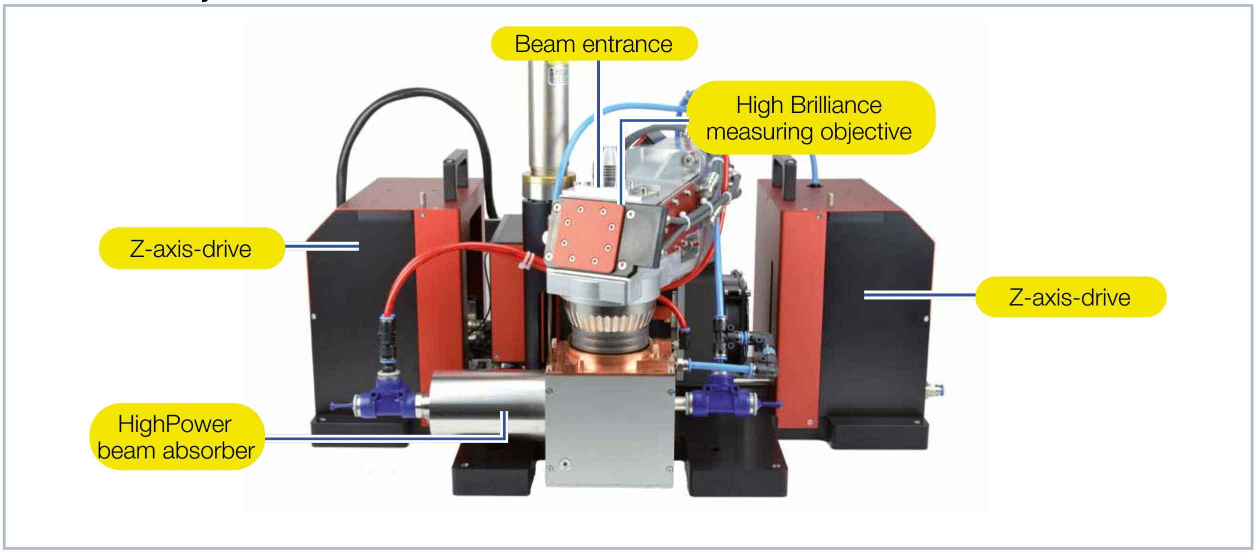


Fig. 4.3: Components of the MSM+ HB

Lever to adjust the magnification

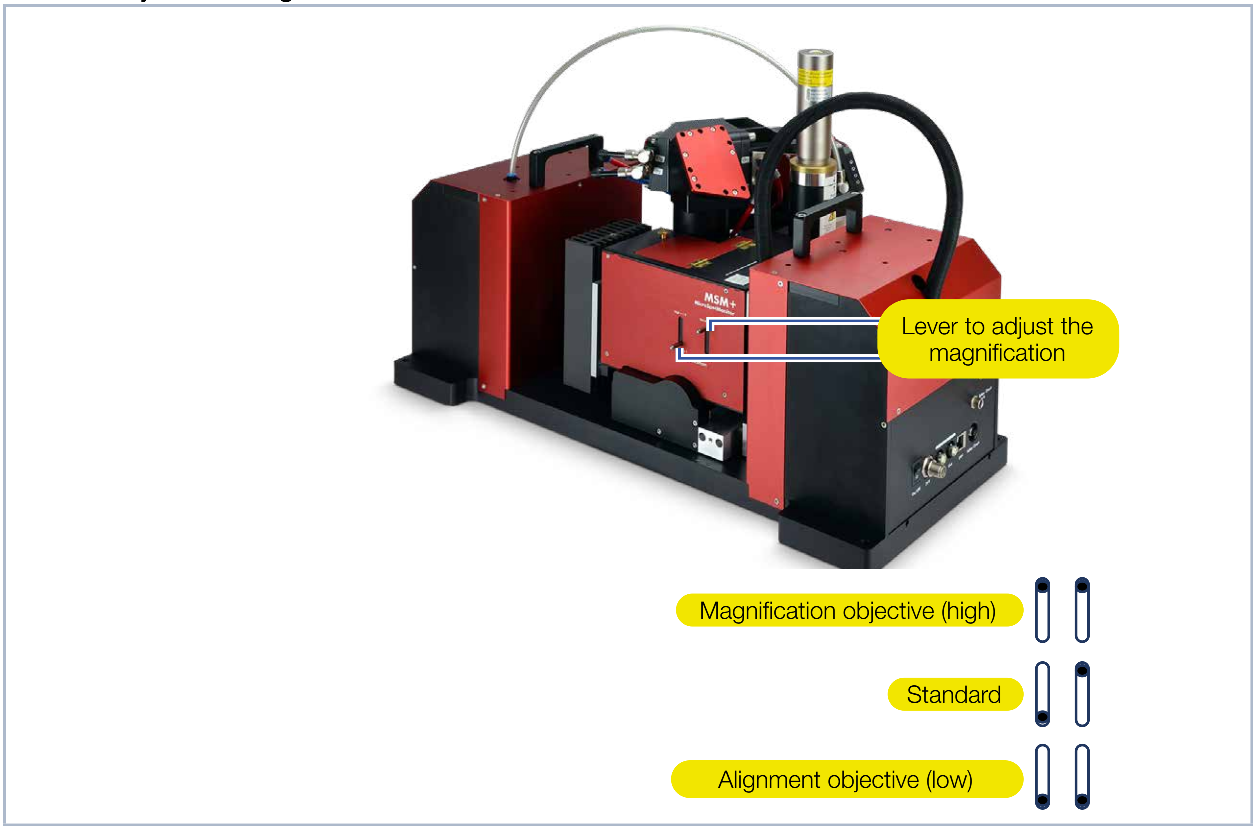


Fig. 4.4: Levers to adjust the magnification

There are two levers on the side of the device for adjusting the magnification. With these two levers, either a magnification objective or an adjustment lens can be inserted into the beam path.
The magnification objective can be inserted on the image side by moving both levers to the upper position.
The alignment objective can be inserted into the beam path by moving both levers to the lower position.
The alignment objective simplifys the beam search, since the measuring range (in x, y) is increased. For the measurement, the best suited objective should be chosen.

4.3 Measuring principle

There are several beam splitters integrated in the measuring objective so that 99.9 % of the laser power is guided to appropriately dimensioned absorbers. The laser beam is attenuated by further optical elements in the device until it can be guided to a CCD sensor.

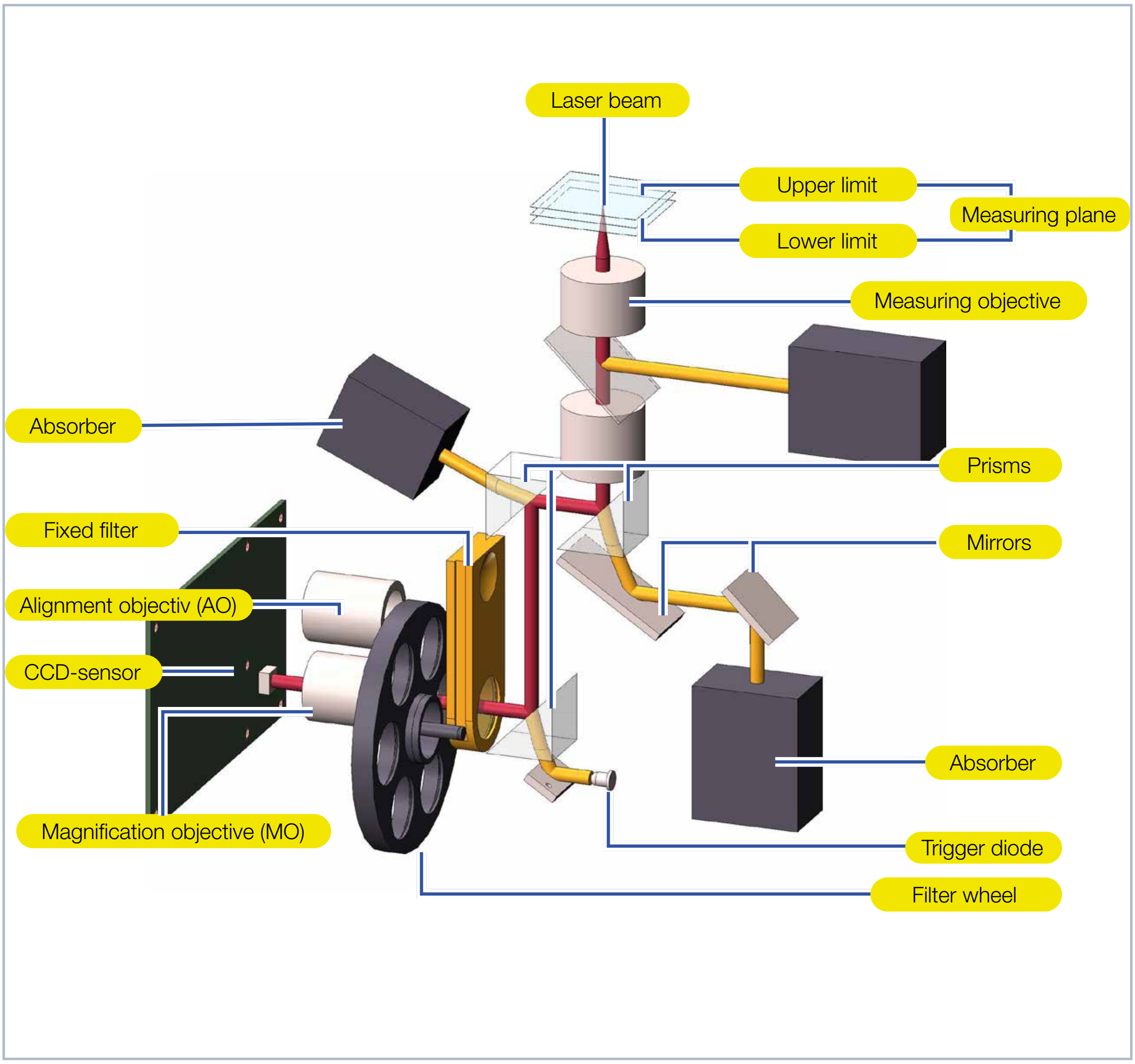


Fig. 4.5: Schematic illustration of the optomechanical design

4.4 Measurement Range of the MSM+ HB

4.4.1 Measurement Range of the MSM+ HB10

For a measurement, the divergence should be at least 20 mrad (full angle).
Tab. 4.1 shows the correlation between power, diffraction index M² and the focus radius.

Focus radius ω_0 [µm] \ Diffraction index M²	1	1,2	1,4	1,6	1,8	2,0	2,3	2,5	2,8	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	10	11	12	13	14	15	18	20	23	25	28	30	33	35	38	40
8	10,0	10,0	10,0	10,0	10,0	10,0	10,0																															
10	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																													
12	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																											
14	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																										
16	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																									
18	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																								
20	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																							
22	6,9	9,8	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																						
24	5,8	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																				
26	5,0	7,1	9,6	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																			
30	3,8	5,4	7,2	9,4	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0																	
35	2,8	4,0	5,4	7,0	8,8	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0															
40	2,1	3,1	4,1	5,4	6,7	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0														
45	1,7	2,4	3,3	4,3	5,4	6,6	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0												
50	1,4	2,0	2,7	3,5	4,4	5,4	6,7	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0											
55	1,1	1,6	2,2	2,9	3,6	4,4	5,6	6,9	8,3	9,8	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0										
60	1,0	1,4	1,9	2,4	3,1	3,8	4,7	5,8	7,0	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0									
65	0,8	1,2	1,6	2,1	2,6	3,2	4,0	5,0	6,0	7,1	9,6	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0									
70	0,7	1,0	1,4	1,8	2,3	2,8	3,5	4,3	5,2	6,1	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0								
80	0,6	0,8	1,1	1,4	1,7	2,1	2,7	3,3	4,0	4,7	6,4	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0							
90	0,4	0,6	0,8	1,1	1,4	1,7	2,1	2,6	3,2	3,8	5,1	6,6	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0						
100	0,4	0,5	0,7	0,9	1,1	1,4	1,7	2,1	2,6	3,1	4,1	5,4	6,7	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0					
125	0,2	0,3	0,4	0,6	0,7	0,9	1,1	1,4	1,7	2,0	2,7	3,5	4,4	5,4	6,5	7,7	8,9	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0		
150	0,2	0,2	0,3	0,4	0,5	0,6	0,8	1,0	1,2	1,4	1,9	2,4	3,1	3,8	4,5	5,4	6,3	7,2	8,3	9,4	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
175	0,1	0,2	0,2	0,3	0,4	0,5	0,6	0,7	0,9	1,0	1,4	1,8	2,3	2,8	3,3	4,0	4,6	5,4	6,1	7,0	7,8	8,8	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
200	0,1	0,1	0,2	0,2	0,3	0,4	0,4	0,6	0,7	0,8	1,1	1,4	1,7	2,1	2,6	3,1	3,6	4,1	4,7	5,4	6,0	6,7	8,3	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
225	0,1	0,1	0,1	0,2	0,2	0,3	0,4	0,4	0,5	0,6	0,8	1,1	1,4	1,7	2,0	2,4	2,8	3,3	3,8	4,3	4,8	5,4	6,6	7,9	9,4	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
250	0,1	0,1	0,1	0,1	0,2	0,2	0,3	0,4	0,4	0,5	0,7	0,9	1,1	1,4	1,7	2,0	2,3	2,7	3,1	3,5	3,9	4,4	5,4	6,5	7,7	8,9	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
275	0,0	0,1	0,1	0,1	0,2	0,2	0,2	0,3	0,4	0,4	0,6	0,7	0,9	1,1	1,4	1,6	1,9	2,2	2,5	2,9	3,2	3,6	4,4	5,4	6,4	7,4	8,6	9,8	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0

Tab. 4.1: Maximum power in kW as a function of the diffraction index M² and the focus radius

4.4.2 Measurement Range of the MSM+ HB20

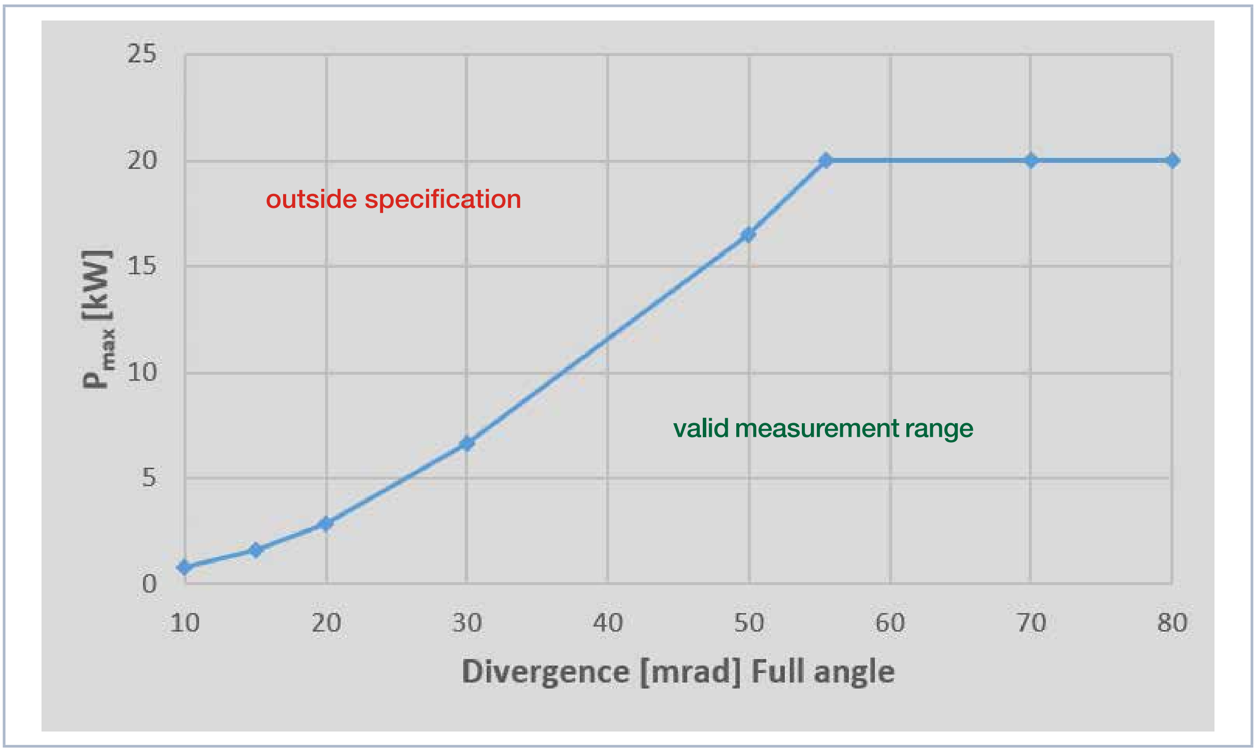


Fig. 4.6: Maximum power as a function of the laser divergence angle

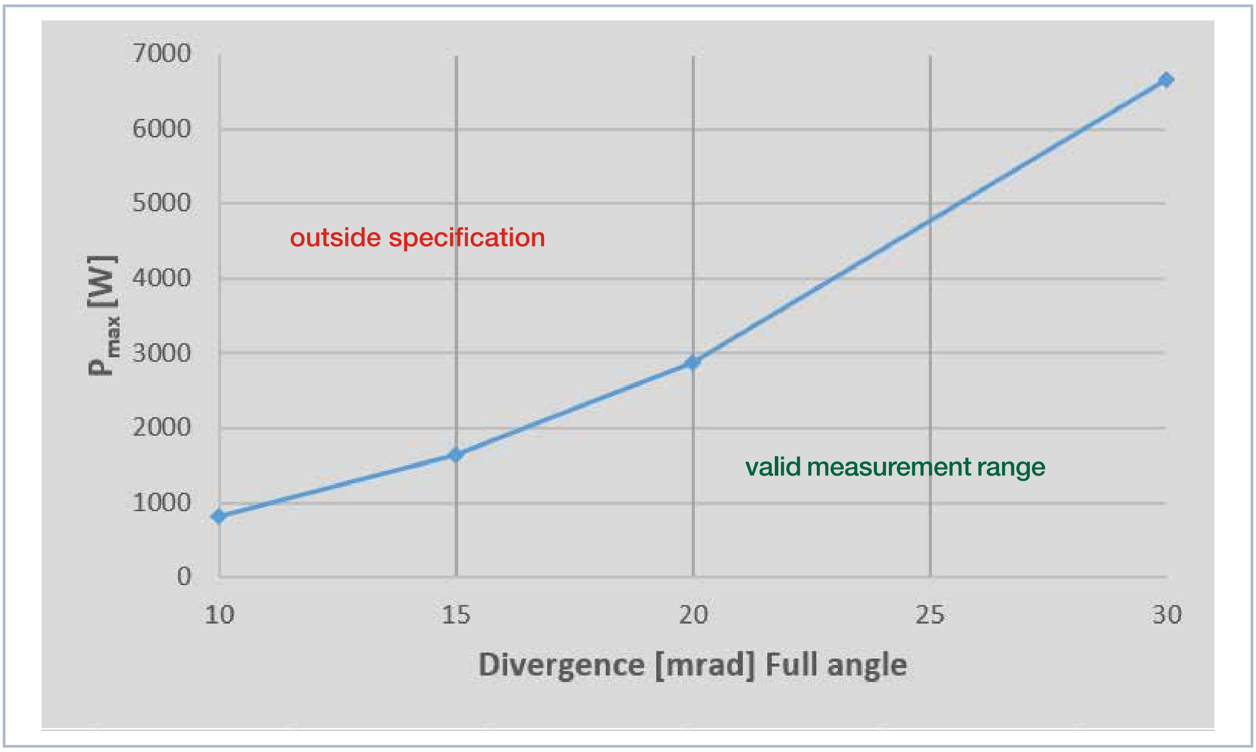
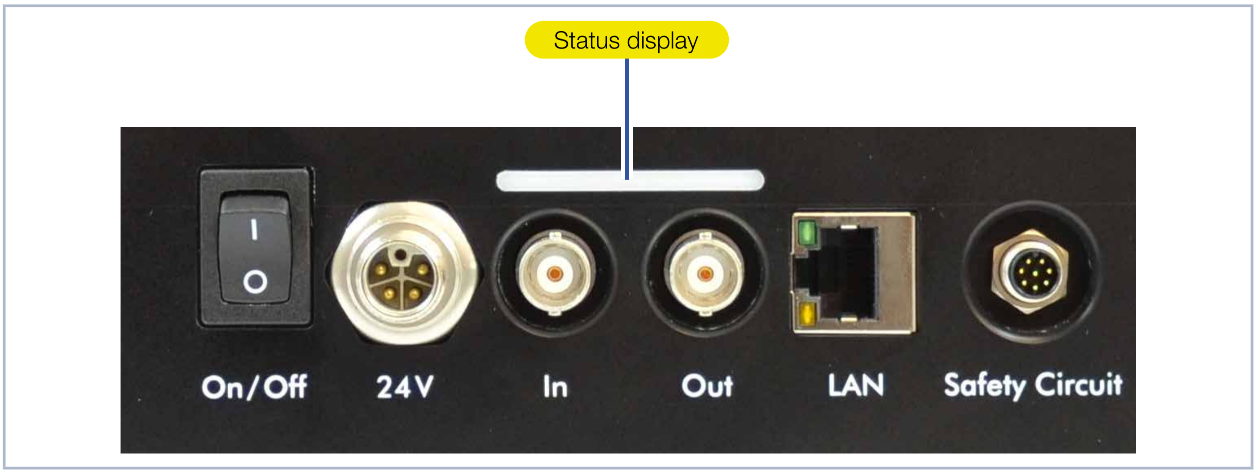


Fig. 4.7: Maximum power as a function of the laser divergence angle (excerpt)

4.5 Optical displays

The various measuring states are indicated by different colors and light signals within the status display.



Tab. 4.2: Status display

Color	Meaning
White	The device is switched on and is operational.
Yellow	A measurement is running.
Red	Lights up briefly: a measuring plane is being recorded. Staying lit: a device error has occurred. The device error is shown in the LaserDiagnosticsSoftware LDS.

Tab. 4.3: Description of the colors and light states of the status display

4.6 Explanation of the product safety labels

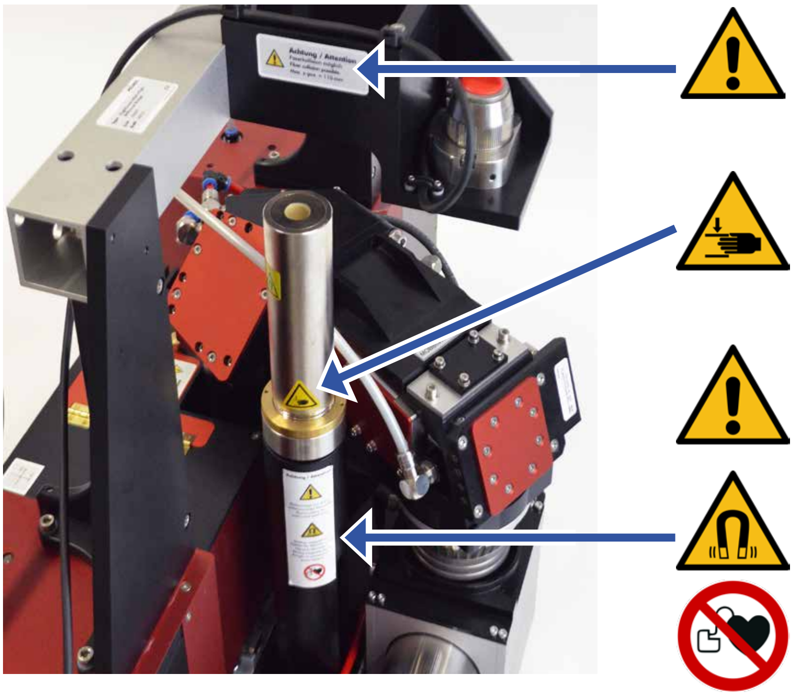


Fig. 4.8: Position of the product safety label I

There is a magnetic spring in the MSM+ HB which counteracts the weight of the measuring objective and thus relieves the traverse motors of the z-axis.
The device contains a magnetic spring made of neodymium magnets (NdFeB magnets) with a very strong magnetic field

No access for people with pacemakers or implanted defibrillators

A possible hazard area for persons with pacemakers or implanted defibrillators is marked with a symbol on the device.
The magnetic spring may affect the correct functioning of pacemakers or implanted defibrillators. If you have a pacemaker or implanted defibrillator, keep a minimum distance of 1 m from the device.

Hand injuries warning due to magnetic spring

A possible hazard area for hand injuries is marked with a symbol on the device.
Note that magnetic springs can behave like tensioned springs. The sliders snap into their rest position as soon as they are released, even if, for example, the machine is disconnected from the power supply. Do not bring any magnetic parts near the measuring device. Careless handling can result in serious injuries (crushing, broken fingers, etc.).

Magnetic field warning

A possible hazard area, originating from a magnetic field, is marked with a symbol on the device.
Keep a safe distance from the magnetic spring with objects that can be damaged by magnetism. These include, for example, televisions and monitors, credit cards, computers, data carriers, video tapes, mechanical watches, hearing aids and loudspeakers.

Hand injuries warning due to movement of camera housing

Another possible hazard area for hand injuries is marked with a symbol on the device.
The camera housing of the device can be moved along the z axis. Do not reach into the operating range of the camera housing. Careless handling may result in crushing.

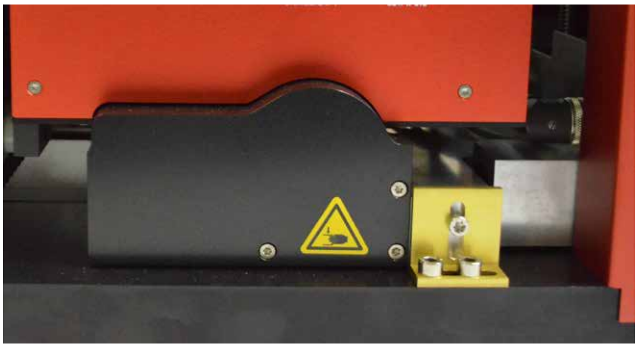


Fig. 4.9: Position of the product safety label II

Do not lift the device by the objective

A possible hazard area for damage to the device due to incorrect lifting is marked with a symbol on the device.
Do not lift or transport the device by the objective.

Fig. 4.10: Position of the product safety label III

General warning sign (Option, devices with fiber bridge only)

A possible hazard area for device damage is marked with a symbol on the fiber adapter.
Depending on the type of fiber adapter, a collision may occur at this point when moving the device along the z axis.

4.7 Scope of delivery and accessories

The scope of delivery of the MSM+ HB includes:

- USB stick with, USB-driver, LaserDiagnosticSoftware LDS, PDF operating manual
- Operating manual
- Power supply unit
- Power cable
- Cable patch Cat. 5e
- Interlock cable
- sealing plugs for water connections (mounted)
- Transport lock (mounted)
- Inlet and outlet aperture covers (mounted)
- Cyclone with alignment tool

For the MSM+ HB the following accessories are available:

- Safety, transport and storage case
- Fiber bridge
- Fiber adapter: LLK-D, HLC16, QBH

For the measurement of fiber lasers, a fiber bridge with fiber adapter can be mounted optionally on the MSM+ HB.
Another option is to measure the laser power with a PowerLossMonitor PLM (additional device).
See chapter “16.2 Appendix B: Using a PLM for power measurement” on page 107.

The accessories are provided with the appropriate connection cables and hoses.

5 Quick overview installation

This quick overview informs you in advance about necessary protective measures, mediums necessary for operation and required connecting elements.

1. Take safety precautions	Chapter 1 on page 9

DANGER

Danger to life for persons with pacemaker or implanted defibrillator

Magnetic spring rotors consist mainly of neodymium magnets (NdFeB magnets). These can impair the correct functioning of pacemakers.

▶ **If you have a cardiac pacemaker or implanted defibrillator, keep a minimum distance of 1 m from the device.**

2. Aligne the device to the laser beam and mount stable • An alignment tool is included in the scope of delivery • You need 6 screws M8x1 and 2 screws for the mounting holes Ø 6.6 mm	Chapter 7 on page 27

3. Install the water-cooling • Connection diameter 12 mm (16 mm for 20 kW-model) • Flow rate 7 l/min - 8 l/min (14 l/min - 16 l/min for 20 kW-model)	Chapter 8.9 on page 39

4. Connect the compressed air • Compressed air according to ISO 8573-1:2010 [6:4:4]. • 0.5 bar - 1 bar • Connection diameter 6 mm	Chapter 8.10 on page 43

5. Disassemble the inlet aperture cover	Chapter 6 on page 23

6. Electrical connection • Establish voltage supply • External safety switch (interlock)	Chapter 8.2 on page 36

7. Connect with the PC • Connection via Ethernet	Chapter 8.3 on page 36

8. Install the LaserDiagnosticsSoftware LDS on the PC • Software is part of the scope of delivery	Chapter 9 on page 44

6 Transport and storage

6.1 Warning messages

WARNING

Risk of injury when lifting the device

Lifting and positioning heavy devices can, for example, stress intervertebral disks and cause chronic changes to the lumbar or cervical spine.

- **Use a lifting device to lift and position the device.**
- **Without a lifting device, several people must lift and position the device.**

NOTICE

Damaging / destroying the device due to improper handling

Contamination can damage or destroy the optical components. Components may be damaged if the device is subjected to hard shocks or is allowed to fall.

- **Move the camera housing to home position before transporting / storing the device.**
- **The device must only be transported / stored with a mounted lock.**
- **Handle the device with care when transporting it.**
- **To avoid contamination, close the measuring objective with the supplied cover before transporting / storing the device.**
- **If possible, transport / store the device in the original PRIMES transport case (optional).**

The device only fits into the original PRIMES transport case (optional) when the camera housing is in home position.

NOTICE

Damaging / destroying the device due to leaking or freezing cooling water

The device can be damaged by leaking cooling water.
Even if the pipe system of the cooling circuit has been drained, a small amount of water always remains in the device. This can leak out and enter the interior of the device.

- **Drain the pipe system of the cooling circuit thoroughly before transporting / storing the device. You can use compressed air for draining.**
  Attention: Do not use compressed air to drain the PowerLossMonitor PLM cooling circuit.
- **Before transporting / storing the device, close the water connections of the cooling circuit with the sealing plugs provided.**

NOTICE

Damaging / destroying the device due to incorrect storage conditions

Incorrect storage conditions can damage / destroy the device.

- **Only store the device within the permissible environmental conditions specified in chapter “14 Technical data” on page 97.**

6.2 Removing transport lock

After unpacking the device, the transport lock has to be removed first. The transport lock secures the linear carrier of the z-axis. It is located on the base plate and is fastened with three screws (see Fig. 6.1 on page 24).

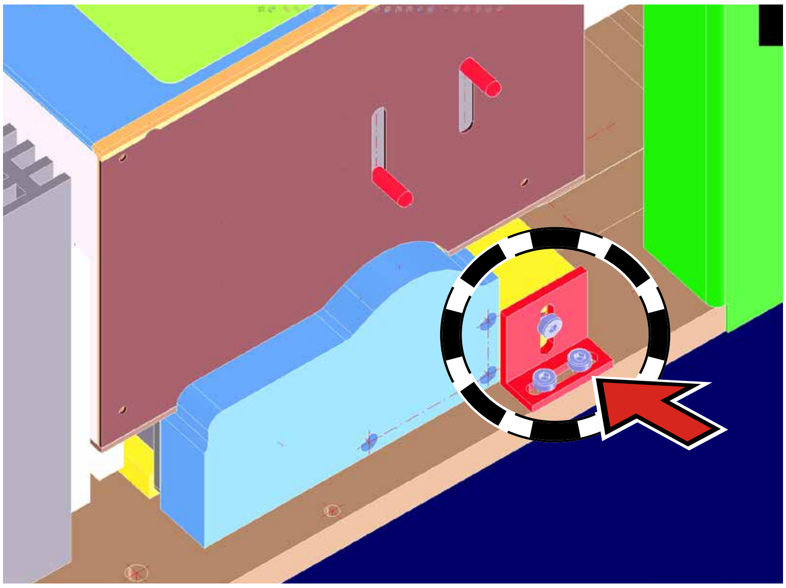


Fig. 6.1: Position of the transport lock at MSM+ HB10

The transport lock of the MSM+ HB20 is longer than the one shown here.

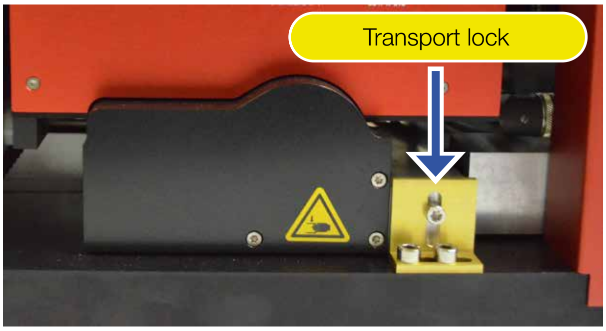
Keep this transport lock in a safe place, as it should be reassembled before each transport of the device.

6.3 Installing transport lock

Install the transport lock before storing or transporting the device. The transport lock secures the camera cassette to the base plate of the device and prevents misalignment of the axes due to mechanical influences. The misalignment of the camera housing has a direct influence on the adjustment of the fiber bridge.

▶ Installing the transport lock

1. Disconnect the device from the LaserDiagnostics software LDS and switch it off as described in chapter 9.3 on page 47. Make sure that the camera housing is in the zero position before switching off.
2. Install the transport lock with three M4x10 cylinder head screws. (The transport lock of the MSM+ HB20 is longer than shown here.)

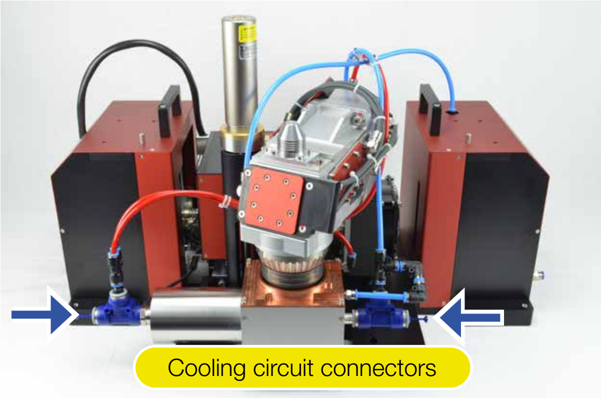


6.4 Draining the cooling circuit of the MSM+ HB

The cooling circuit of the MSM+ HB must be completely drained. Storage or transport at a temperature that is close to or below freezing point can lead to damages due to the formation of ice, if the cooling circuit is not completely empty.

- ▶ Drain the cooling circuit completely.

You may use compressed air to purge the cooling circuit of the MSM+ HB.



The photo shows the situation at the MSM+ HB10

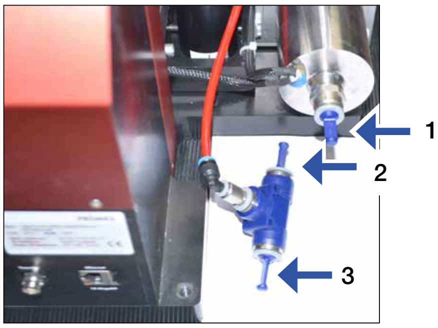
6.5 Sealing the cooling circuit of the MSM+ HB

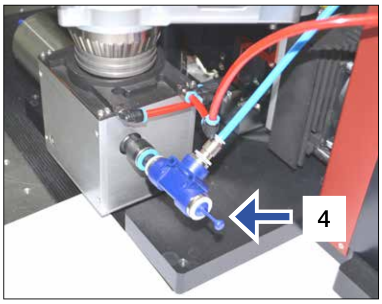
Even if the cooling circuit has been drained completely, a small amount of residual water remains inside the device. This may leak during transport and damage the electronics of the device.

- ▶ Seal the connecting plugs of the cooling circuit by using of the enclosed plugs.

A total of 4 plugs with 12 mm outer diameter is required for the MSM+ HB10.

A total of 2 plugs with 16 mm is required for the MSM+ HB20



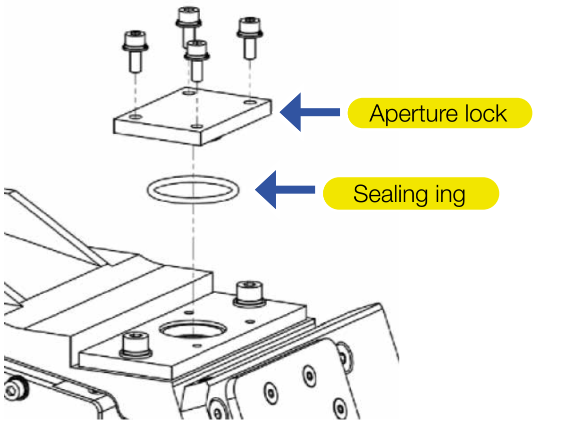


The photos show the situation at the MSM+ HB10

6.6 Sealing the aperture of the HB objective

The magnetically held alignment tool may fall off during shipping. This can lead to contaminations within the objective. The objective of the MSM+ HB must therefore be sealed for shipping with the enclosed black aperture lock.

1. Turn on the compressed air.
2. Remove the alignment tool.
3. Disassemble the cyclone.
4. Install the aperture lock and the sealing ring with 4 cylinder head bolts M3x8.
5. Turn off the compressed air.

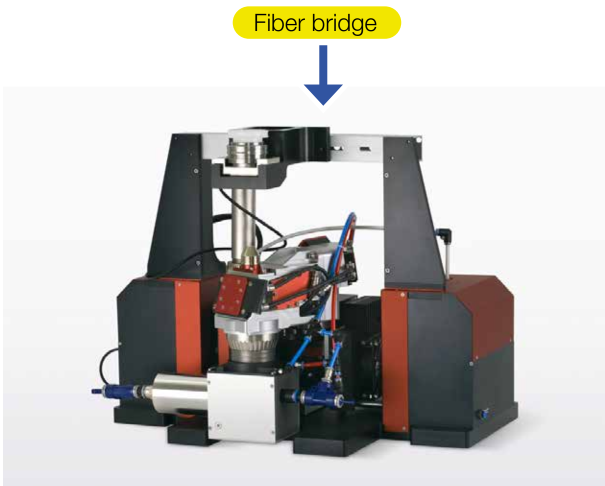


6.7 Packing the device

1. Pack the device completely in a plastic wrap to avoid contamination with particles from the case padding foam.
2. Place the packaged unit in the PRIMES transport case and close the cover with all tension locks. All accessories must be completely enclosed.

The fiber bridge belonging to the device (option) must be enclosed with each service shipment. Else a correct alignment of the bridge to the device cannot be guaranteed performing mechanical work on the MSM+ HB.

1. Uninstall the fiber bridge.
2. Pack the fiber bridge separately.



7 Mounting

DANGER

Danger to life for persons with pacemaker or implanted defibrillator

Magnetic spring rotors consist mainly of neodymium magnets (NdFeB magnets). These can impair the correct functioning of pacemakers.

- ▶ **DO NOT install the device if you have a cardiac pacemaker or implanted defibrillator. Keep a minimum distance of 1 m from the device.**

DANGER

Serious eye or skin injury due to scattered radiation

- ▶ **The numerical aperture (NA) of the laser beam has to be smaller than 0.11 in order to ensure that no scattered radiation occurs on the corner of the objective.**
- ▶ **Wear safety goggles which are adapted to the used laser wavelength.**
- ▶ **When mounting the device, please ensure that it cannot be moved by unintentional pushes or pulling the cables or hoses.**
- ▶ **Shield the device from scattered radiation.**

WARNING

Danger of injuries due to a strong magnetic attraction

The magnet spring sliders can exert considerable forces as soon as they are close enough to other sliders or iron. If they are not handled with the utmost care, this can lead to serious injuries (contusions, broken fingers, etc.).

- ▶ **The magnet spring must only be mounted or demounted by trained personnel. Handle the magnet spring with the utmost care when modifying the objective.**

NOTICE

Danger of damage due to a strong magnetic field of magnet spring.

Magnet spring sliders mainly consist of very strong magnets.

- ▶ **Keep a safety distance to all devices and parts which could be damaged by magnetism, e.g. TVs and screens, credit cards, computers, data mediums, video tapes, mechanical clocks, hearing aids and loud speakers.**

7.1 Conditions at the installation site

- The device must not be operated in a condensing atmosphere.
- The ambient air must be free of organic gases.
- Protect the device from splashes of water and dust.
- Operate the device in closed rooms only.

7.2 Mounting position

The MSM+ HB is designed to operate in a horizontal position with a beam incidence from above.

Check the space conditions before mounting. Especially check the required space for the connecting cables and the traverse range of the z-axis (see chapter 15, „Dimensions“, on page 98). The device must be set up in a stable manner and fastened with screws (see chapter 7.3 on page 28).

NOTICE

Damaging/destroying the device

The camera housing of the device can be moved along the z-axis. Obstacles in the traverse range of the MSM+ HB can lead to collisions and damage the device.

- ▶ **Keep the traverse range free of obstacles (cutting nozzle, pressure rolls, etc.).**

7.3 Aligning the MSM+ HB

7.3.1 Important conditions for the position of the focused laser beam

Due to the imaging characteristics of the measuring objective it is necessary for the laser beam focus to be positioned in a certain range above the measuring objective.

NOTICE

Damaging/destroying the device

The focus has to be in a defined range with reference to the measuring objective. In case it is too close or too distant, the optics might get damaged in case of high beam intensities.

- ▶ **Use the enclosed alignment tool for the alignment.**

The size of the range in which the focus is to be positioned before the first measurement depends on the divergence of the focused laser beam and the power used. The z-measurement range is between an upper and a lower limit.

Upper limit

If the focus is too far above the measuring objective, a focus can occur on the image-side beam path. Together with high beam intensities, this can cause damage to the optics. In addition, the aperture of the objective can get damaged due to absorbed laser light.

Measuring plane

The power density distribution of the measuring plane is imaged on the CCD sensor.

Lower limit

If the focus is too close to the measuring objective, the beam splitter may be damaged, depending on the type of focusing and the power used.

Measuring plane distance

The measuring plane distance corresponds to the distance of the measuring plane from the upper edge of the objective.
With the included alignment aid and a pilot laser beam, you can position the measuring device with the necessary accuracy.

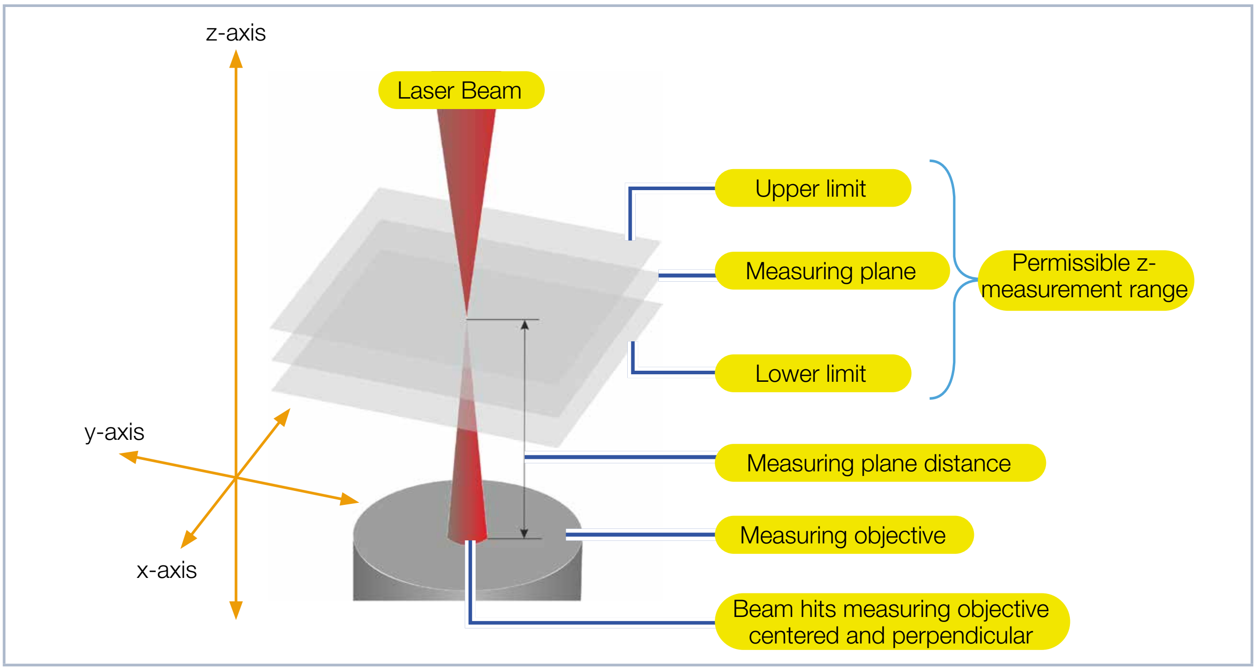


Fig. 7.1: z-measurement range of the MSM+ HB

7.3.2 Mounting the cyclone

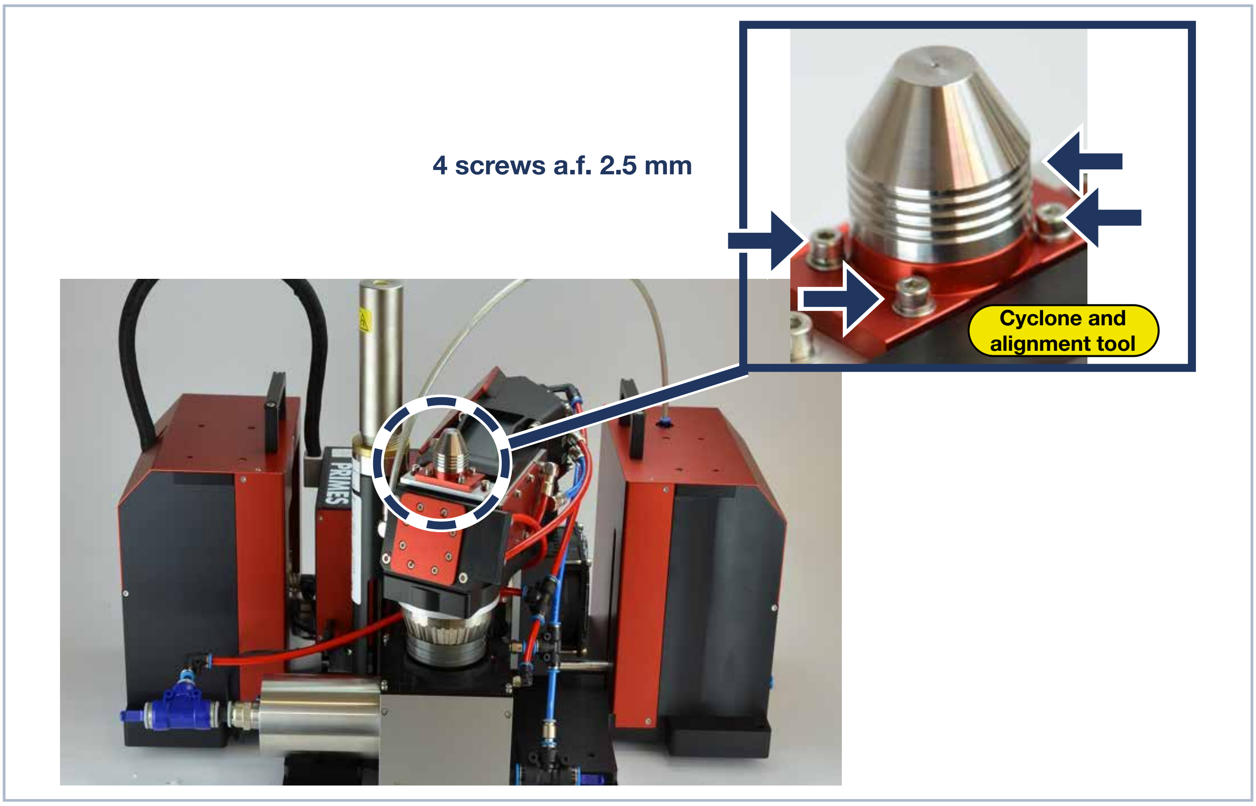


Fig. 7.2: Position of cyclone and alignment tool

The magnetically held alignment tool can fall down during shipping. Dirt may enter the objective. Therefore, the objective of the MSM+ HB is closed with a black aperture lock.
You must remove the aperture lock on the objective first, then you can mount the cyclone.
Before removing the aperture lock, the area around the aperture must be cleaned with clean compressed air and the purge air must be connected to the MSM+ HB.

If the purge air is not connected, dust can enter the objective directly when the cyclone is mounted.

1. Turn on the purge air (see chapter 8.10 on page 43)
2. Remove the aperture lock by loosening the four screws.

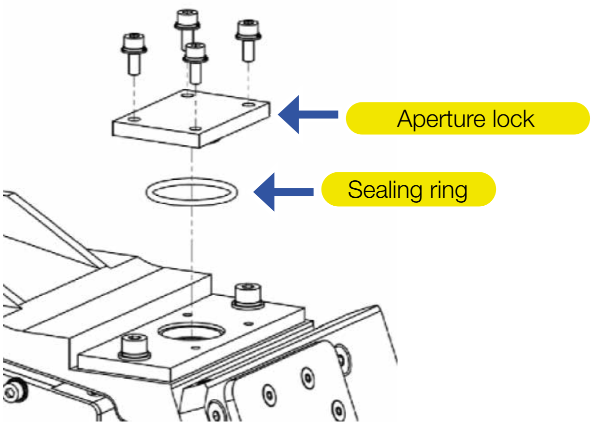


Fig. 7.3: Aperture lock at the beam entrance

3. Store the aperture lock and the O-ring in a clean, sealable plastic bag. If you store or transport the device, you should remount the aperture lock.
4. Fasten the cyclone to the objevtive with the four screws.
5. Cover the cyclone with the alignment tool.

7.3.3 Moving camera housing to axis center position

▶ Before aligning and mounting the device, check the approximate z-position of the camera housing.

If the camera housing is in home position, it cannot be moved further down on the z-axis during measurement. We recommend moving the camera housing to the center position of the z-axis before alignment. If a caustic measurement is to be performed, the same amount of travel is available on both sides of the expected beam focus.

⚠ CAUTION

Crushing hazard

The camera housing of the device can be moved along the z-axis.

▶ **Never reach into the traversing range of the camera housing.**

NOTICE

Damaging / destroying the device

The camera housing of the device can be moved along the z-axis. Obstacles in the traversing range of the device can lead to collisions and damage the device.

▶ **Always keep the traversing range of the camera housing free of obstacles.**

Proceed as follows to move the camera housing to the axis center position:

1. Establish the electrical connections according to chapter 8 on page 35.
2. Switch on the device and connect it to the LaserDiagnosticsSoftware LDS according to chapter 9.3 on page 47.
3. Open the ***Device control*** menu according to chapter 9.4.1 on page 51.
4. Move the camera housing to the axis center position according to chapter 9.4.2 on page 51.

7.3.4 Positioning the pilot laser beam above the cyclone

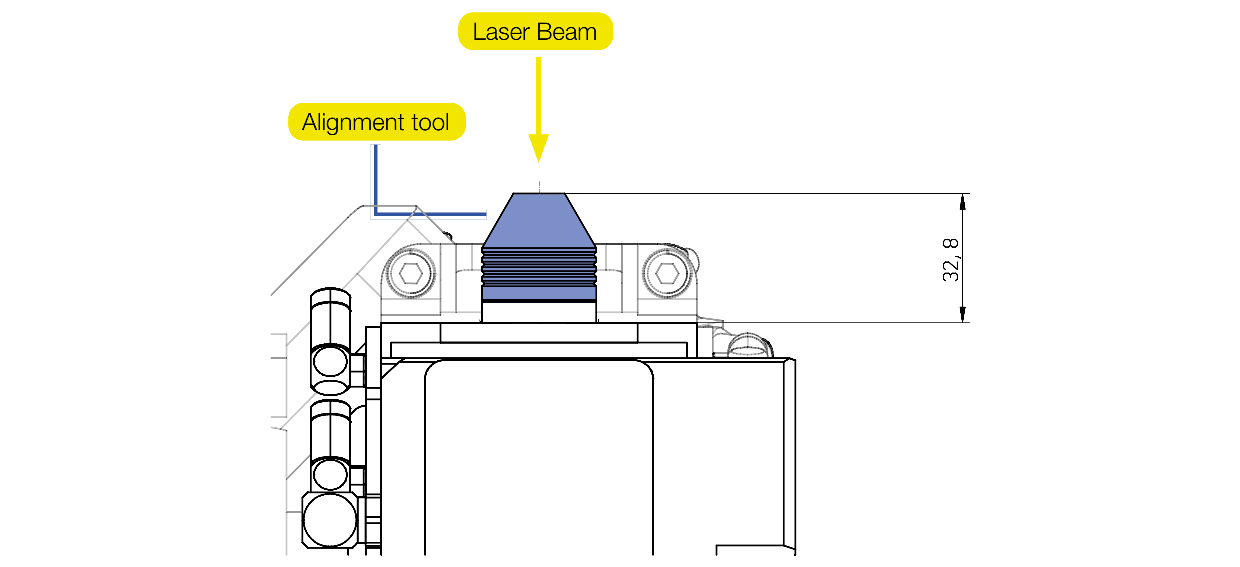


Fig. 7.4: Alignment tool for MSM+ HB

Due to the imaging features of the measuring objective, it is necessary to position the laser beam focus in a certain area above the cyclone. The device must be aligned to the laser beam along the z-axis as well as on the x-y plane.
The measuring objective is imaging a measuring plane onto the CCD sensor. The measuring plane is outside the measuring device. The beam must be aligned along the z-axis (centrically and perpendicular) into the measuring plane.
Ideally, the beam focus should be exactly on the measuring plane after alignment. In practice, it is sufficient if the beam focus is within the limits of a permissible z measuring range. Otherwise, the measuring objective can be damaged if the beam intensities are too high.
The measuring plane distance depends on the beam path (standard, magnification objective MO, alignment objective AO) (see Tab. 7.1 on page 31).

Measuring Objective	Wavelength in nm	Length of alignment tool in mm	Measuring plane distance in mm		
			Standard	MO	AO
MOB MSM+ HB	1064	32,8	32,8	32,8	32,3

Tab. 7.1: Measuring plane distances

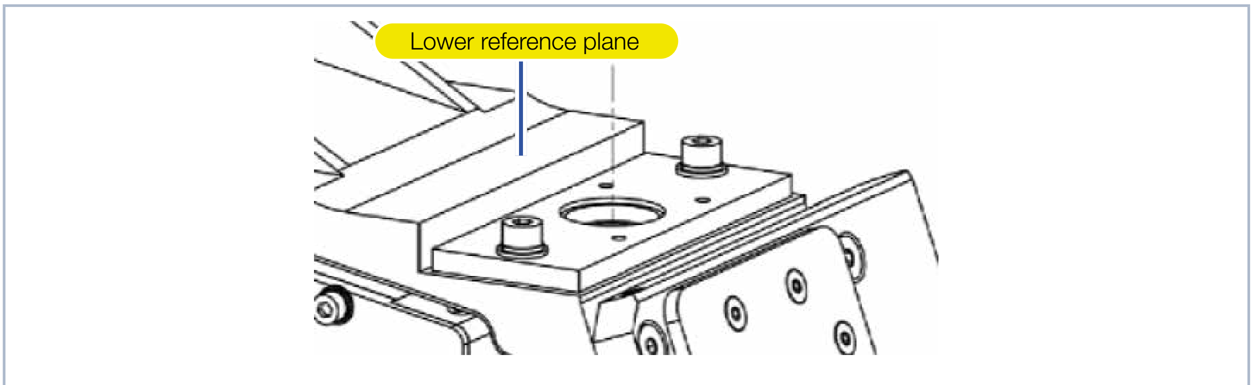


Fig. 7.5: Lower reference plane

1. Put the alignment tool on the cyclone. The upper surface corresponds to the z-position of the measuring plane of the objective. The distance between lower reference plane and upper surface of alignment tool is z.
2. Turn on the pilot laser. If the laser hits the small hole in the alignment tool vertically, it is displayed centrally on the sensor. Typically, the misalignment angle between the beam and the instrument axis should not exceed a divergence of 10 mrad (0.5°).
3. If the laser beam does not hit the small hole vertically, you can align the MSM+ HB with the 6 screws in the threaded holes.
4. Finally, fasten the device, so that it cannot be moved by accidental bumping or pulling on the cables.

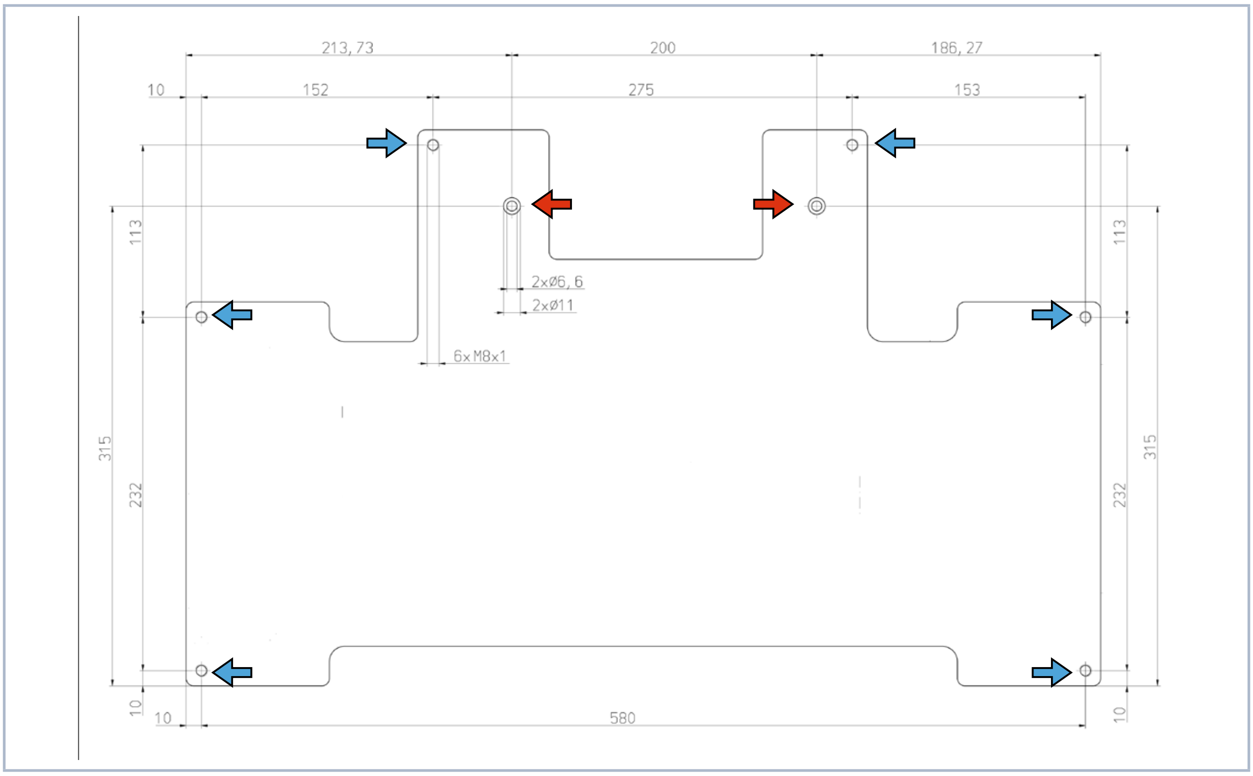


Fig. 7.6: Fastening bores MSM+ HB, view from above

2 mounting holes Ø 6,6 mm

6 thread holes M8x1 for the alignment

7.4 Mounting the Fibre Bridge (option)

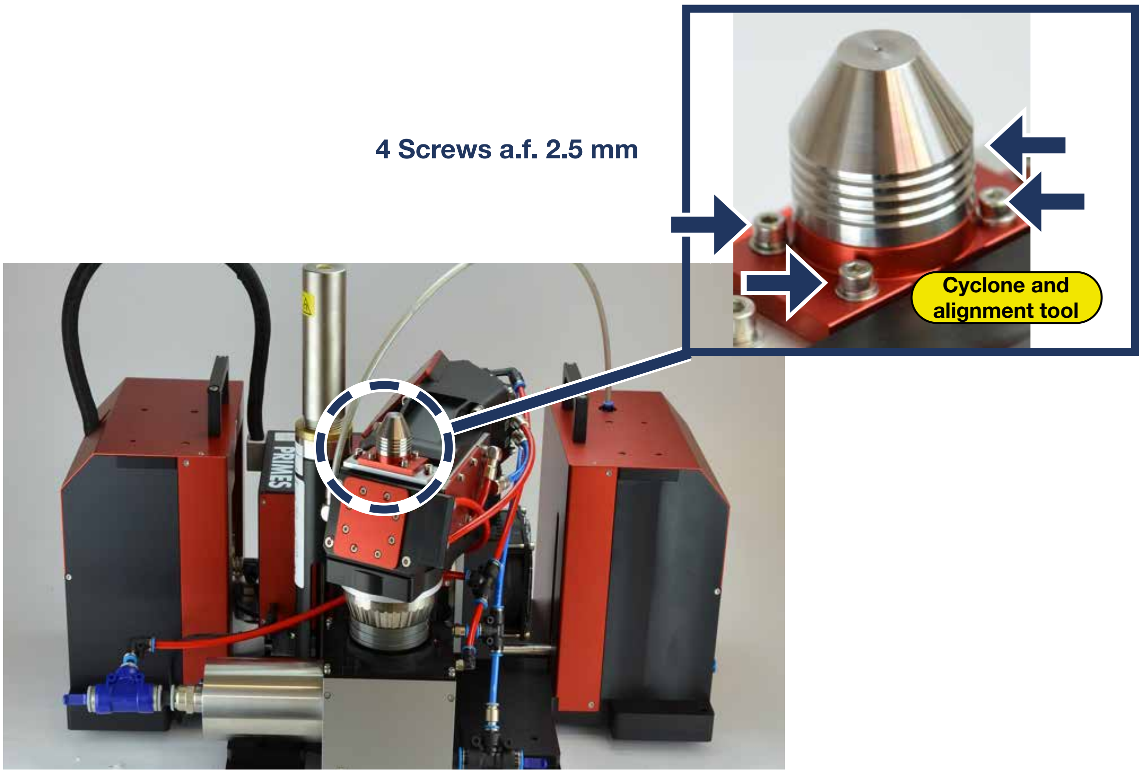
To fix fibres - for example when using fibre lasers - a fibre bridge with fibre adapter can be mounted.

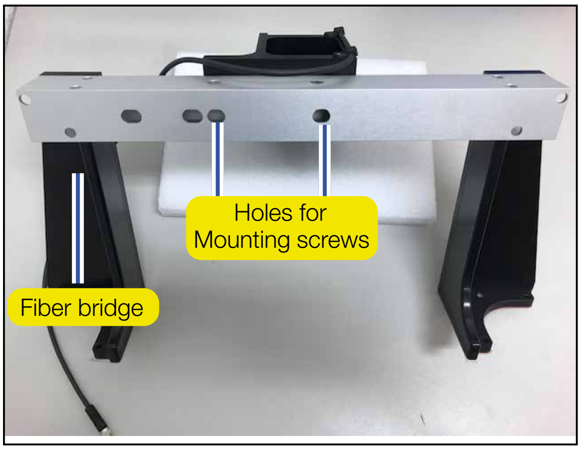
NOTICE

Damaging/destroying the fiber

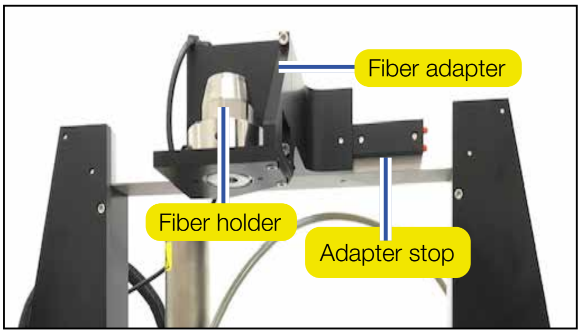
In the upper z-axis position the device can collide with the plugged fiber and damage it

- **Note the maximum travel range (chap. “14 Technical data” on page 97)**
- **Dismount the cyclone before the startup!**

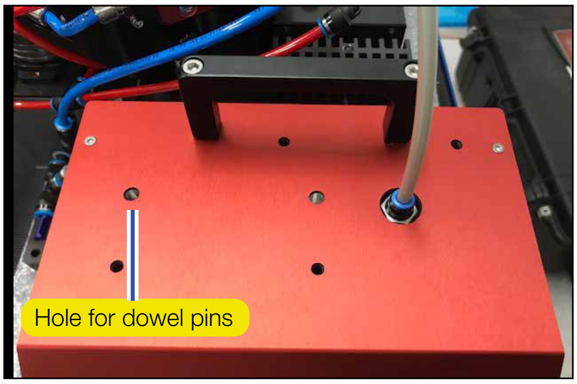
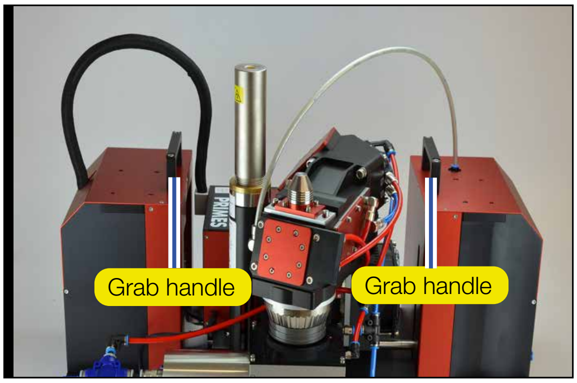
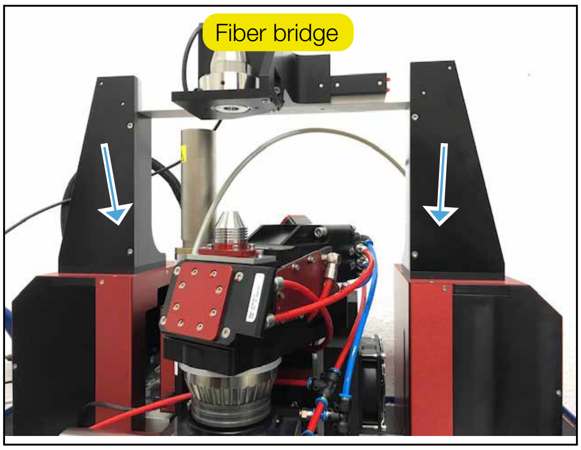
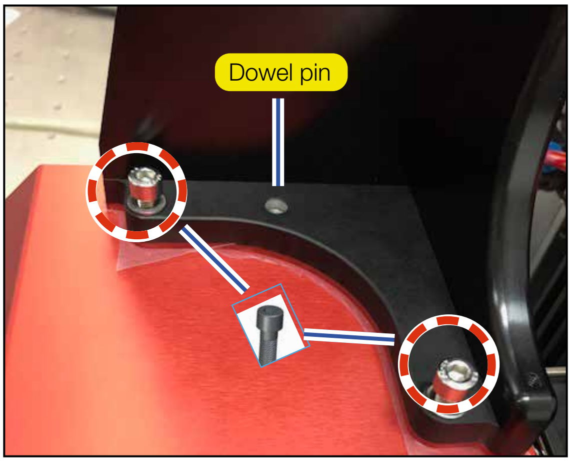




1. Disassemble the cyclone.
2. Mount the fiber adapter on the fiber bridge. To do this, attach the fiber adapter to the fiber bridge with two screws. Do not fully tighten the screws yet.



3. The position of the fiber adapter is fixed with the adapter stop. Press the fiber adapter against the adapter stop and tighten the screws.

	4. Insert the enclosed dowel pins on both sides into the hole provided.
	5. Disassemble the two grab handles on the MSM+ HB. To do this, loosen the visible screws in the grab handle.
	6. Put the fiber bridge on the MSM+ HB.
	7. Fasten the fiber bridge by means of two screws (M5 x 10 mm) on both sides. Please note that longer screws (>10 mm) can block the Z-axis underneath.

8 Connections

Only the supplied PRIMES power supply unit and the supplied connection cables and hoses may be used to establish the connections.

8.1 Overview of the connections

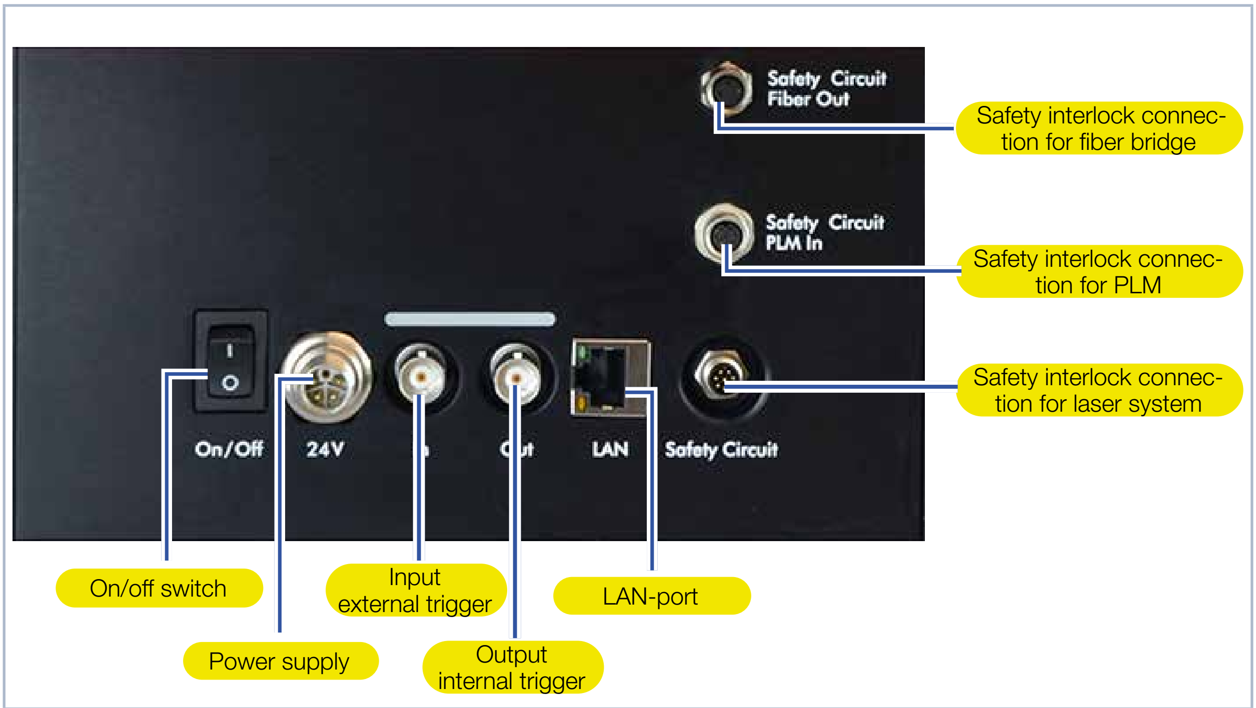


Fig. 8.1: Electrical connections at the device

Both a cooling water supply and a compressed air supply are required to operate the MSM+ HB.
The device is equipped with a HighBrilliance measuring objective, which has to be cooled with water and flushed with compressed air. The required hoses are already preassembled.

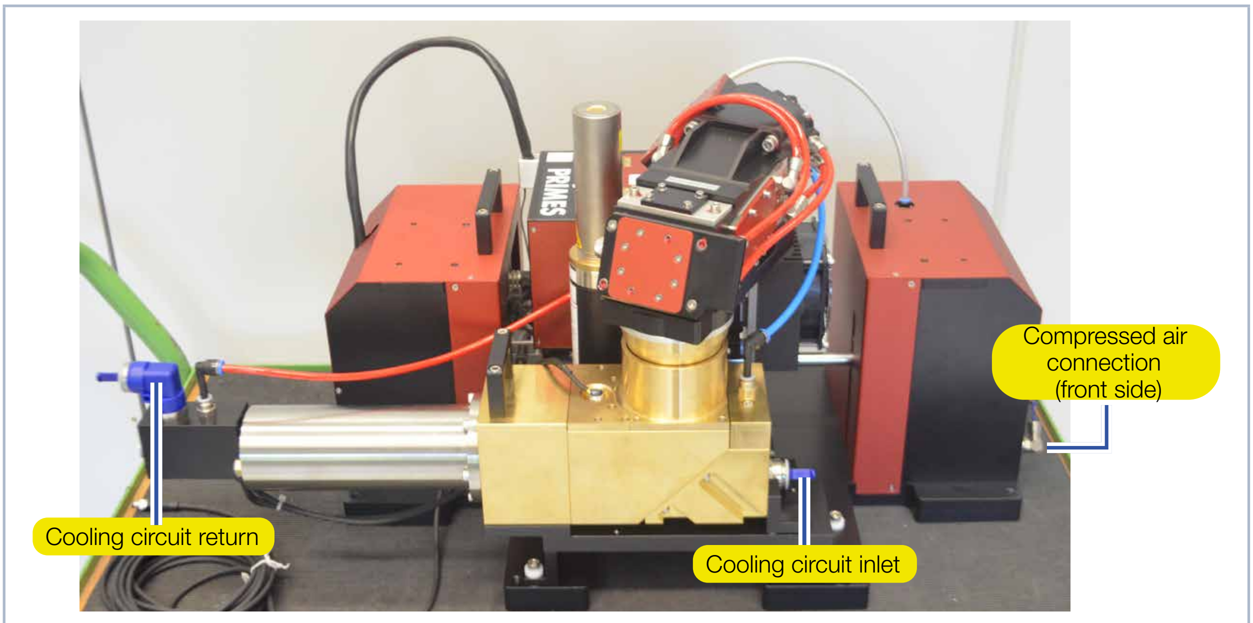
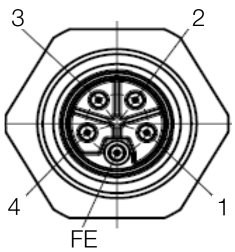


Fig. 8.2: Water and compressed air connections at the MSM+ HB20

8.2 Power supply (24V)

The device requires a supply voltage of 24 V ± 5% (DC) for operation. A suitable power supply unit with cable is included.
The connection socket for power supply is a 5-pin, L-coded M12 connector.

Harting M12-P-PCB-THR-2PC-5P-LCOD-M-STR	Pole	Function
	1	+24 V
	2	Not connected
	3	GND
	4	Not connected
	5	FE (functional earth)

Tab. 8.1: Connection socket for the power supply

8.3 Ethernet (LAN)

NOTICE

Damage / destruction of the device due to voltage peaks

Disconnecting the connecting cables during operation causes voltage peaks. This could destroy the communication modules of the device.

▶ **Connect / disconnect all plugs only when the power is off.**

1. Connect the device with the PC or with the network.
2. Plug the power supply into the connector socket for the power supply.

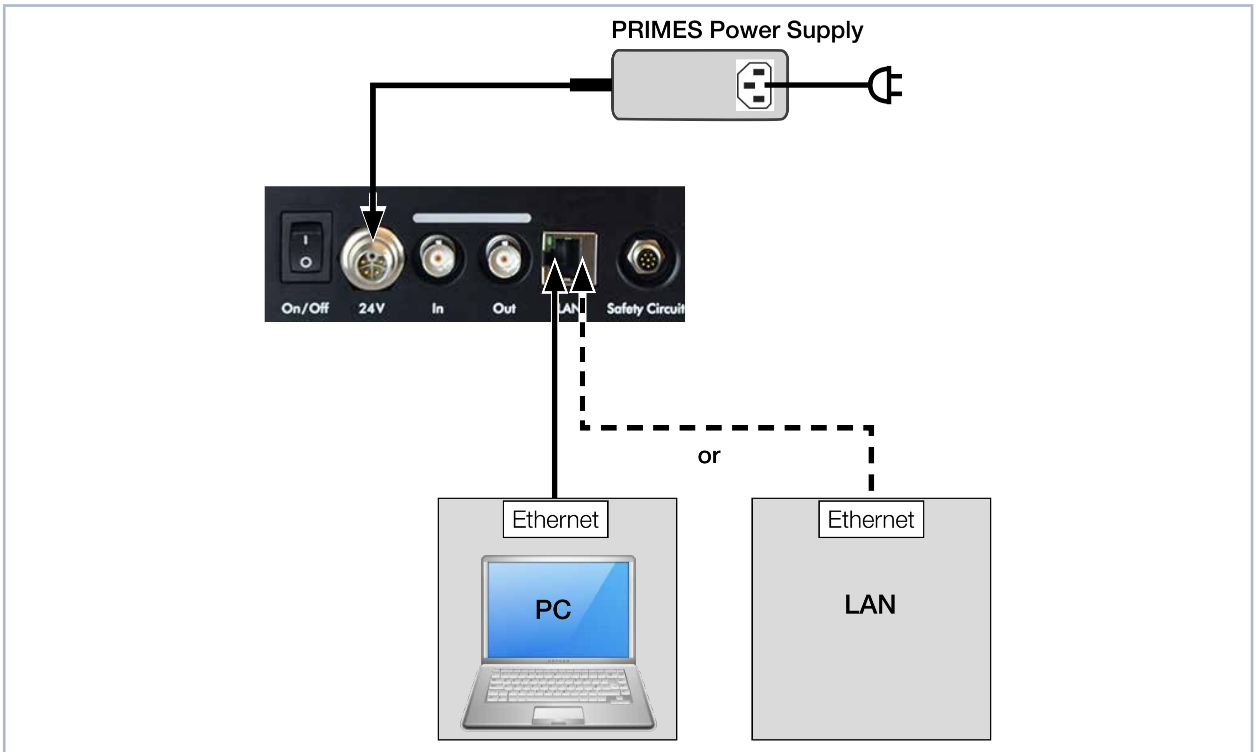


Fig. 8.3: Connection via Ethernet with a PC or a local network

8.4 Safety Circuit

Connect this port to your laser system (Safety PLC or Emergency off).
The Safety Interlock protects the MSM+ HB from damage by switching off the laser in the following cases:

- The voltage supply at the MSM+ HB is not connected or interrupted
- There is an overtemperature at the absorber
- A referencing procedure is triggered during the measurement

DANGER

Fire hazard; Damage / Destruction of the device

If the safety circuit is not connected, the operating conditions of the device are not monitored.

- ▶ **Connect the safety interlock of the laser control in such a way that the laser is switched off in the event of a fault.**
- ▶ **Check that the safety interlock will switch off the laser properly in case of error.**

The interlock connection provides two redundant safety circuits.

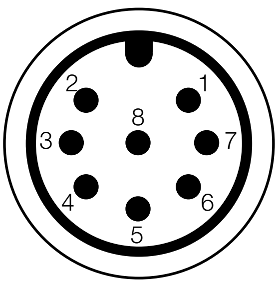
NOTICE

Damage/destruction of the device due to overvoltage.

The MSM+ HB provides + 24 V via pin 7 and 8. If 24 V are applied externally, the device may be damaged.

- ▶ **Do not apply any external voltage to pin 7 and 8.**

M8 connector 8-pin (Pin: view connector on device; Color: color of cable core)



Pin	Color	Function
1	White	COM 1: Connected with pin 2 when not ready for operation Connected with pin 3 when ready for operation
2	Brown	NoClosed 1: Connected with pin 1 when not ready for operation
3	Green	NoOpen 1: Connected with pin 1 when ready for operation
4	Yellow	COM 2: Connected with pin 5 when not ready for operation Connected with pin 6 when ready for operation
5	Grey	NoClosed 2: Connected with pin 4 when not ready for operation
6	Pink	NoOpen 2: Connected with pin 4 when ready for operation
7	Blue	Connection for switch or bridge
8	Red	+ 24 V applied by the device, connection for switch or bridge

Matching ready-made cable: Binder 79-3808-52-08

Tab. 8.2: Pin assignment of the safety interlock connector

If the safety interlock is triggered, pin 1 and pin 2 (pin 4 and pin 5) are connected. If the values correspond to the operating conditions, pin 1 and pin 3 (pin 4 and pin 6) are connected.

Pin 7 must be connected to pin 8 via an external switch or a bridge.

8.5 Safety Circuit PLM In (option)

This connection is only used if you are using a PowerLossMonitor PLM for power measurement.

NOTICE

Danger of damage due to overheating

If the safety circuit is not connected, the device can be damaged due to overheating.

- ▶ **Connect the Safety Interlock of the PowerLossMonitor PLM to the MSM+ HB.**
- ▶ **Check that the laser is switched off properly by the external safety circuit in the event of a fault.**

The Safety Interlock protects from damage by switching off the laser in the following cases:

- The water flow is too low.

Make sure that the Safety Interlock MSM connector on the PowerLossMonitor PLM is connected to the Safety Circuit PLM-In connector on the MSM+ HB. Use the enclosed 8-pin cable, which is pre-assembled on both sides.

The interlock connection provides two redundant safety circuits.

8.6 Safety Circuit Fiber Out (option)

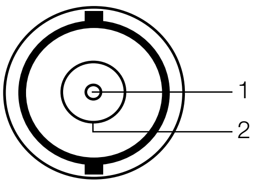
This connection is only used if you are using a fiber bridge to connect a laser.
The Safety Interlock protects against damage by switching off the laser in the following cases:

- The fiber is not mounted correctly.

Make sure that the safety interlock connection on the fiber holder is connected to the Safety Circuit Fiber Out connector at the MSM+ HB. Use the enclosed 3-pin cable.

8.7 Inlet external trigger (In)

BNC connector (view: connector side)

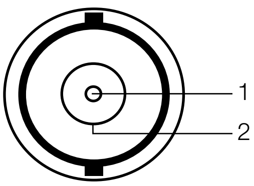


Pin	Function
1	+5 V (Trigger signal)
2	GND

Tab. 8.3: Connection socket inlet for an external trigger in the connection panel

8.8 Outlet internal trigger (Out)

BNC connector (view: connector side)



Pin	Function
1	+5 V (Trigger signal)
2	GND

Tab. 8.4: Connection socket outlet for the internal trigger in the connection panel

8.9 Cooling water

NOTICE

Fire hazard; Damage/Destruction of the device due to overheating

If there is no water cooling or a water flow rate which is insufficient, there is a danger of overheating, which can damage the device or set it on fire.

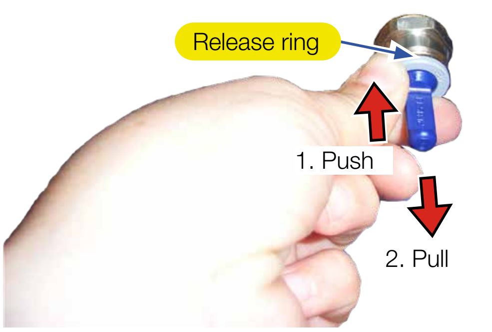
▶ **Only operate the device with a connected water cooling and a sufficient water flow rate.**

The connections at the MSM+ HB are intended for PE-hoses with a diameter of 12 mm (respectively 16 mm at MSM+ HB 20 kW). Connect the cooling circuit (inlet and return flow) to the water supply and check if the hose connections are tight.

If you use a PowerLossMonitor PLM start the cooling approx. 2 minutes before the start of the measurement and stop it approx. 1 minute after the end of the measurement. Only cool the device during measurement, the number of operating hours influences the service life of the turbine in the PowerLossMonitor PLM.

8.9.1 Connecting water supply

The plug-in connectors are sealed with plugs on delivery so that no residual water can leak out. Remove the sealing plugs and keep them for later transport or shipment.



1. Push down the release ring of the connection and pull out the plug with your free hand.
2. Remove the sealing plugs of the water connections
3. Keep them in a save place.

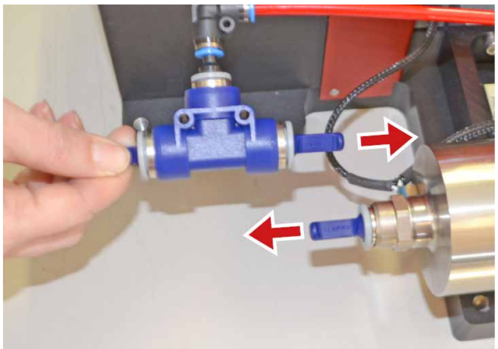
Fig. 8.4: Remove the sealing plugs of the water connections

4. Connect the flow line (Water In) and the return line (Water Out) of the device, by inserting the hose as far as possible (approx. 20 mm deep).
5. Check whether the hose connections are tight.

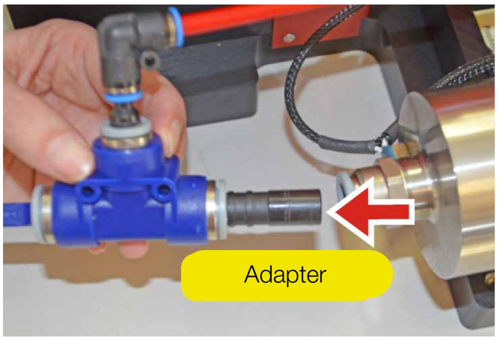
Connecting cooling circuit at MSM+ HB10

For packaging reasons the cooling water pipe of the absorber has been removed. The cooling water pipe has to be reconnected with the absorber.

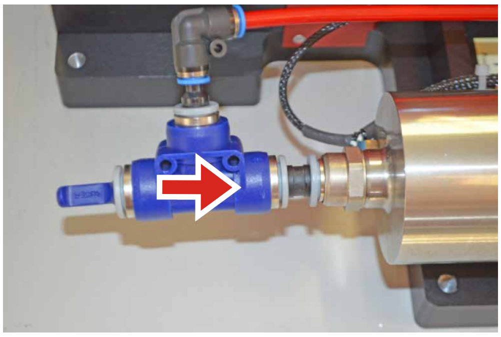
- ▶ Remove the sealing plug from both the water pipe and the absorber.



- ▶ Insert the adapter into the connector of the water pipe.



- ▶ Insert the adapter into the absorber.



- ▶ Connect cooling circuit.

You can use compressed air to drain the cooling circuit of the MSM+ HB.

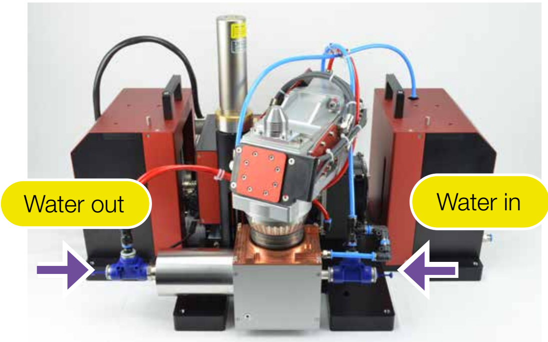
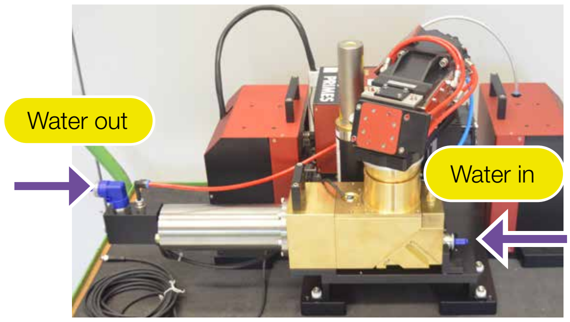


Fig. 8.5: Cooling circuit connection at MSM+ HB10

Connecting cooling circuit at MSM+ HB20

There is no adapter required for the MSM+ HB20.

- ▶ Connect the cooling water directly to the device.



8.9.2 Danger to the device

NOTICE

Damage/Destruction of the device

If the following requirements for the cooling circuit are not observed, the measuring device may be damaged.

- ▶ **Observe the following requirements.**

Water quality

The device can be operated with tap water as well as demineralized water.
An operation with strongly deionized water (DI-water, conductivity < 30 µS/cm) is only possible with the respective connection parts (stainless steel) – we would be glad to advise you if necessary.

Large dirt particles or teflon tape may block internal cooling circuits. Therefore, please thoroughly rinse the system before connecting it.

Aluminum components

Do not operate the device on a cooling circuit in which aluminum components are installed. Otherwise, corrosion in the cooling circuit can occur, particularly when operating at high powers and power densities. In the long term, this will reduce the efficiency of the cooling circuit.

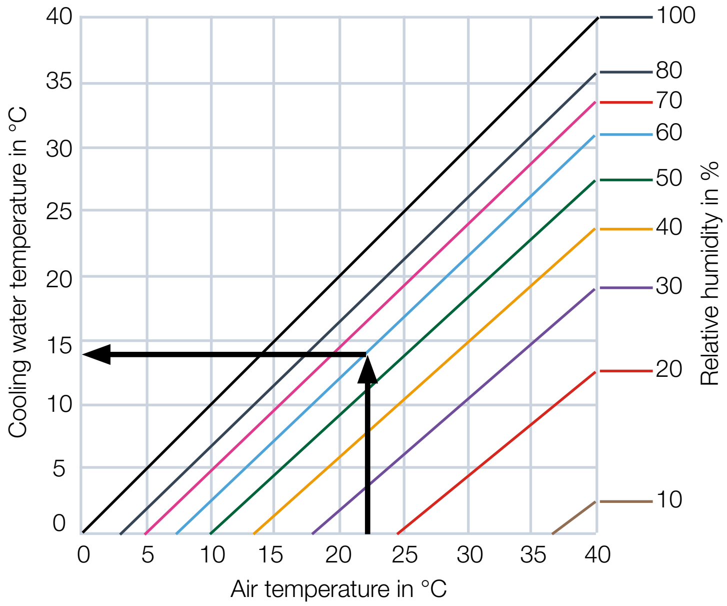
8.9.3 Parameters of cooling water connection

Data	MSM+ HB10	MSM+ HB20
PE hose diameter	12 mm	16 mm
Recommended flow rate	7 - 8 l/min	14 - 16 l/min
Minimum flow rate	5 l/min	10 l/min
Recommended water pressure	2 bar	2 bar
Maximum water pressure	4 bar	4 bar

Condensates within the device

The device must not be operated in a condensing atmosphere. The humidity has to be considered in order to prevent condensates within and outside the device.

The temperature of the cooling water must not be lower than the dew point.



Tab. 8.5: Dew point Diagram

Example

Air temperature: 22 °C
Relative humidity: 60 %

The cooling water temperature must not fall below 14 °C.

Flow rate

The value for the flow rate should not be below 0.7 l/min per kW laser power.

The following rule of thumb can be used to determine the flow rate - depending on the laser power used:
For each kW of laser power, a flow rate of approx. 1 l/min of cooling water is required.
Example: With a laser power of 7 kW, this corresponds to a flow rate of 7 l/min.

8.10 Compressed Air

The compressed air is required in order to generate an air flow in the cyclone which is directed outwards. This is supposed to prevent the penetration of dirt particles.

NOTICE

Damage to the optical components

Contaminated compressed air can permanently damage the optical components of the measuring device.

▶ **The compressed air must be according to specification ISO 8573-1: 2010 [6: 4: 4].**

Connect the compressed air supply by means of a plastic hose.

Data	Value
Hose diameter	6 mm
Typical air pressure	0.5 - 1.0 bar
Maximum permissible air pressure	2 bar
Specification according to	ISO 8573-1: 2010 [6: 4: 4].

The compressed air connector is located opposite the connection side of the device.

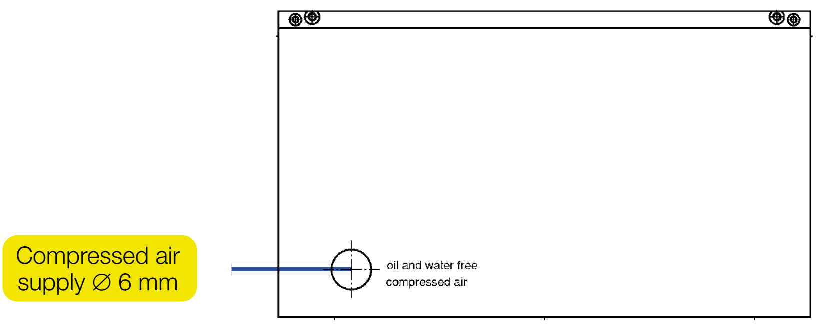


Fig. 8.6: Compressed air supply

CAUTION

Hearing damage

If the compressed air hose is loosened when pressure is still applied to the hose, this generates noise. This can cause hearing damage.

▶ **Only loosen the compressed air hose when there is no longer any pressure.**

Connecting the compressed air hose

▶ Push the hose into the plug-in connection as far as it will go.

Disconnecting the compressed air hose (Only when the measuring objective is closed)

▶ Press down the blue release ring of the connector with one hand and pull out the hose with the other hand.

9 Measurement

This chapter describes measurements with the LaserDiagnosticsSoftware LDS. For a detailed description of the software installation, file management and evaluation of the measured data, refer to the separate operating manual LaserDiagnosticsSoftware LDS.

9.1 Warning messages

DANGER

Serious eye or skin injury due to laser radiation

During the measurement the laser beam is directed at the device. This produces scattered or directed reflection of the laser beam (laser class 4). The reflected beam is usually not visible.

- ▶ **Wear safety goggles adapted to the power, power density, laser wavelength and operating mode of the laser beam source in use.**
- ▶ **Wear suitable protective clothing or protective gloves if necessary.**
- ▶ **Protect yourself against laser radiation by means of separating devices (e.g. suitable shielding walls).**

CAUTION

Crushing hazard

The camera housing of the device can be moved along the z-axis.

- ▶ Never reach into the traversing range of the camera housing.

NOTICE

Damaging / destroying the device

Obstacles in the traversing range of the device can lead to collisions and damage the device.

- ▶ Always keep the traversing range of the device free of obstacles (cutting nozzles, pressure rollers, etc.).

NOTICE

Damaging / destroying the device

Contamination and fingerprints on the protective window can lead to damage or shattering or splintering of the protective window during measurement.

- ▶ Do not touch the protective window.
- ▶ Regularly check the condition of the protective window and exchange it in case of pollution (see chapter 11.4, „Exchange wear parts“, on page 90).
- ▶ Only operate the device with a clean protective window.

9.2 Preparing measurement

9.2.1 Measurement process

The described measurement process is an example. Adapt the procedure to the conditions on site.

1. Follow the basic safety notes and the warning messages.
2. Observe the technical data in Chapter (“14 Technical data” on page 97
3. Make sure that the cyclone is mounted and covered with the alignment tool.
4. Make sure that the connections of the water cooling are firmly mounted and tight.
5. Turn on the water-cooling.
6. Turn on the measuring device.
7. Wait until the measuring device has finished the referencing procedure (duration approx. 30 seconds).
8. Start the LaserDiagnosticsSoftware LDS on your computer.
9. Change the z-position to 60 mm (center of the measuring range; 20 mm for MSM+ HB20).
10. Open the compressed air supply.
11. Turn on the pilot laser. The laser must hit the small hole in the alignment tool vertically, only then it is displayed centrally on the sensor.
12. Remove the alignment tool.
13. At the beginning measure the laser at low power and define the measuring range for the caustic measurement. The measuring range typically comprises 2 to 3 Rayleigh lengths above and below the focus-plane.
14. Carry out a test measurement with the desired z-range and at small power.
15. Increase the power gradually until the measuring power is reached and carry out a caustic measurement (it might be necessary to adapt some parameters).
16. After finishing the last measurement, the objective should be covered with the alignment tool if it remains in place. If the device is to be transported, use the aperture lock of the objective.

9.2.2 MSM+ HB with Fiber Bridge (option)

For a device with fiber bridge, pay attention to the traverse range in z-direction because it is limited by the fiber adapter.
For an MSM+ HB10, select the “Fiber mode” measuring mode in the LaserDiagnosticsSoftware LDS. In this mode, the travel path in x and y direction is blocked (see chapter “9.4.3 Open a measuring mode with adapted toolbench” on page 52 and “9.10 Fiber mode measurement” on page 88).

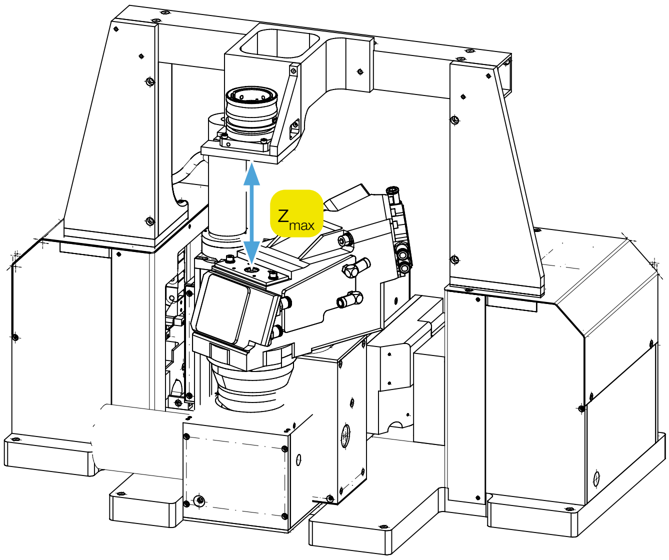
With the MSM+ HB20, the movement in the x and y directions is blocked at the factory.

NOTICE

Danger of damage due to a collision of the objective with the fiber adapter.

The traverse range of the MSM+ HB in z-direction is limited by the fiber adapter. The maximum traverse range depends on the used type of fiber adapter.

▶ **Please mind the limit values z_{max} given in Tab. 9.1 on page 46, measured from the surface of the aperture plate.**



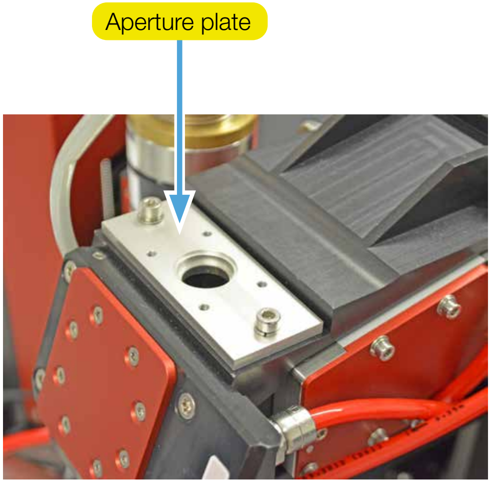


Fig. 9.1: Traverse range of the MSM+ HB with fiber bridge

Type of Fiber Adapter	Maximum Traverse range z_{max} in mm	
	MSM+ HB	MSM+ HB 20 kW
QBH	106	26
HLC-16	118	38
LLK-D	120	40

Tab. 9.1: Limit Values for z_{max}

9.3 Connect / disconnect the device with the LaserDiagnosticsSoftware LDS

9.3.1 Switch on the device and connect it to the LDS

⚠ CAUTION

Crushing hazard

The camera housing of the device can be moved along the z-axis.

▶ **Never reach into the traversing range of the camera housing.**

NOTICE

Damaging / destroying the device

The camera housing of the device can be moved along the z-axis. Obstacles in the traversing range of the device can lead to collisions and damage the device.

▶ **Always keep the traversing range of the camera housing free of obstacles.**

If the camera housing was not in the home position when the device was switched off / disconnected from power source, then it moves to the home position after it is switched on / connected to power source. This happens even before the device is connected to the LaserDiagnosticsSoftware LDS. The axes are referenced to the home position.

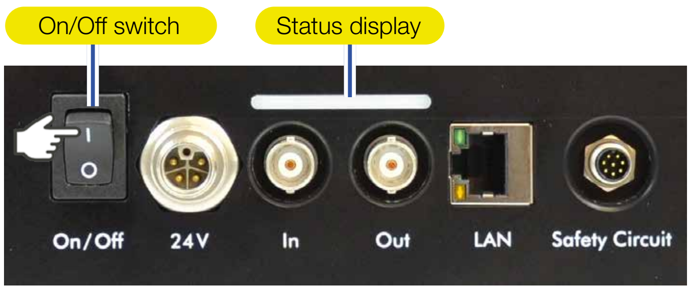
Observe the correct sequence:

- All electrical connections must be established before the device is switched on (see Kapitel “8 Connections” on page 35).
- The device must be switched on before the LaserDiagnosticsSoftware LDS is started.

1. Switch on the device.

👁 The operating status is shown in the status display. If the device is ready for operation, the display lights up white.

👁 If necessary, the camera housing moves to the home position.



2. Use one the following options to start the LaserDiagnosticsSoftware LDS:

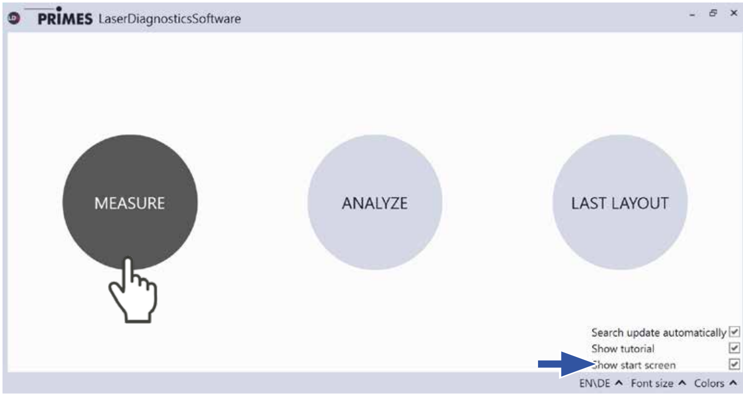
▶ Double-click on the program icon in the start menu group.

▶ Double-click on the desktop shortcut.

👁 The start logo appears for a short time.

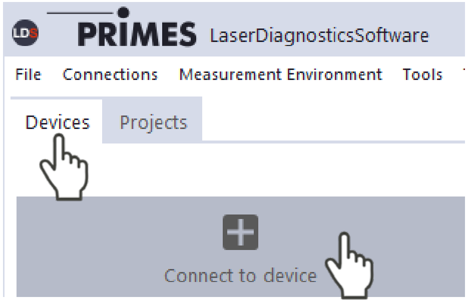
The start screen appears.

3. Select the ***Measure*** operating mode.



Only if the *Show start screen* option is disabled:

- Click on the ***Devices*** tab and then on the ***+Connect to device*** button.



The ***Connections*** window appears.

If you have connected a power meter (e.g. PowerLossMonitor PLM):

4. First click on the power meter.

5. Click on the button ***Connect to device.***

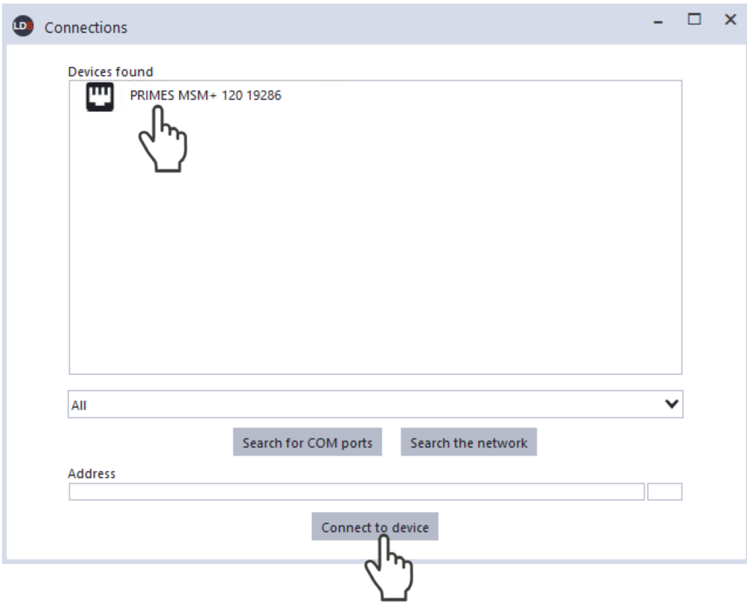
6. Then click on the MSM+.

7. Click on the button ***Connect to device*** again.

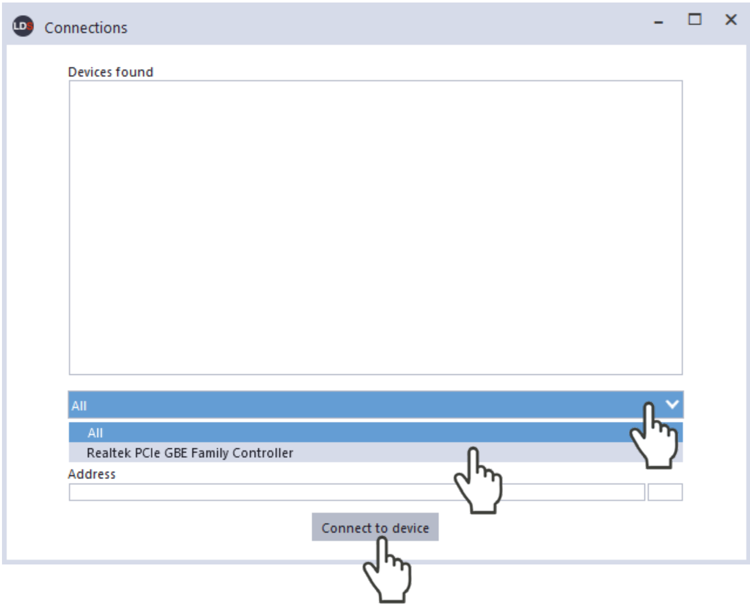
If you do not use a power meter, follow instructions 6. and 7. only.

If the device does not appear:

8. Click on the ***Search the network*** button
9. If the device still does not appear in the Connections window, see chapter 9.3.2 on page 49.

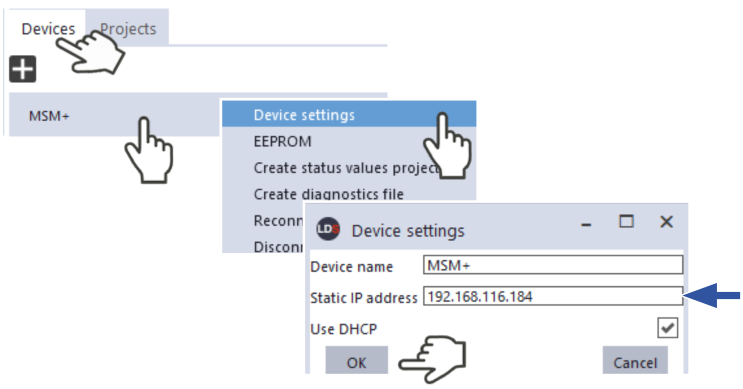


9.3.2 If the device does not appear in the connections window

The connection of the device to the LaserDiagnosticsSoftware LDS may be blocked by the firewall: ▶ In ***Windows > Control panel > Firewall***, enable the UDP port 20034	The UDP port should be enabled by a system administrator.
The network address of the PC is not within the range of the device. ▶ In ***Windows > Control panel > Network and Sharing Center***, assign an IP address to your PC that is in the same address range as the device. The IP address of your device can be found on the identification plate.	The IP address should be set by a system administrator.
If several network interface cards or a USB3-to-Ethernet card are installed in the PC, the connection of the device to the LaserDiagnosticsSoftware LDS may be blocked by the selection of the wrong network interface card. 1. Select the appropriate network card in the ***Connections > All*** window. 👁 The device is displayed in the ***Connections*** window. 2. Click on the device. 3. Click on the ***Connect to device*** button.	

9.3.3 Change the network address of a connected device

For communication in a network, a ***Static IP address*** is stored for the device in the LDS and the function ***Use DHCP*** is activated. When establishing a connection, the device will first wait to be assigned a suitable IP address via DHCP. If this proofs unsuccessful, it will revert to the static IP address.
If ***Use DHCP*** is disabled, the device will directly use the static IP address. As a result, the connection can be established faster.
For a connected device, both the IP address and the activation of DHCP can be changed.

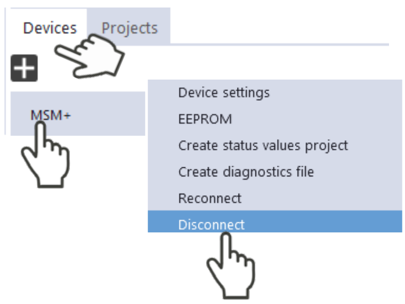
Change the IP address of a device as follows: 1. Click on the ***Devices*** tab. 2. Right-click on the device and select the ***Device settings*** menu point. 3. Enter in the desired IP address or use the ***Use DHCP*** function 4. Confirm the entry with ***OK***. 5. Switch the device off and on again.	

9.3.4 Disconnect and switch off the device

When measurements are completed, the device must be disconnected from the LaserDiagnosticsSoftware LDS and switched off.

> The camera housing must be in the home position before the device is transported or stored.
> If the camera body was not in the home position when the device was switched off, it will move back to home position when it is switched on again (see chapter 9.3 on page 47).

1. Click on the ***Devices*** tab.
2. Right-click on the device and select the ***Disconnect*** menu point.

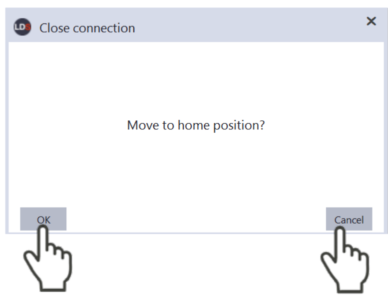


The ***Close connection*** window appears.

3. Select one of the options offered:

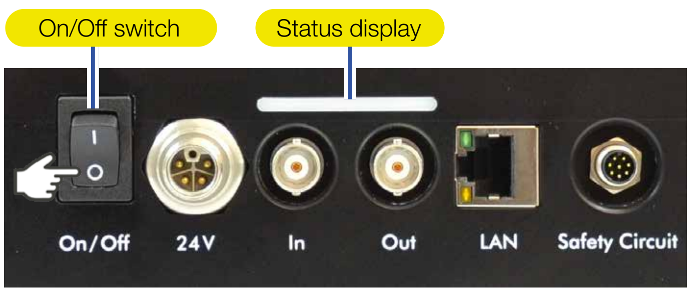
▶ Confirm by clicking the ***OK*** button.
Select this option to prepare the device for transport or storage.
The device is disconnected from the LaserDiagnosticsSoftware LDS. The camera housing moves to home position.

▶ Click on the ***Cancel*** button.
The device is disconnected from the LaserDiagnosticsSoftware LDS. The camera housing remains in the current axis position.



4. Switch off the device.
The status display turns off.

5. Disconnect the electrical connections if necessary.



9.4 General procedure for measuring

This chapter contains general information about the LaserDiagnosticsSoftware LDS. Read this general information before turning to the following chapters on the different measuring tasks.

9.4.1 Open the „Device control“ menu

After connecting the device, the ***Device control*** menu must be opened:

1. Click on the ***Devices*** tab.
2. Select the device and click on the device function ***CCD*** below the device name.

The ***Device control*** menu with the ***Adjustment*** and ***Measuring modes*** sections opens.

9.4.2 Move camera housing to desired z-position

The ***Adjustment*** area of the ***Device control*** menu offers various options for moving the camera housing.

Option	Explanation
z-Position in mm	▶ Enter the desired z-position in the input field or use the slider.
Move to axis position	▶ Click this button to move the camera housing to the z position specified in the ***z-Position in mm*** field.
Move to axis center position	▶ Click this button to move the camera housing to the center position of the (unlocked) z-axis traversing range. Note that this does not have to be the maximum traversing range of your device. If a locked area of the z-axis was stored in the EEPROM during a previous use of the device, then this locked area is active. The camera housing then moves to the center position of the unblocked area.

Tab. 9.2: Options in the ***Adjustment*** area of the ***Device control*** menu

9.4.3 Open a measuring mode with adapted toolbench

In the ***Device control*** menu, a measuring mode can be selected. Here, all relevant settings for a measuring task are clearly arranged in a menu. For example, to measure individual planes, the ***Single planes*** mode provides all the options necessary.

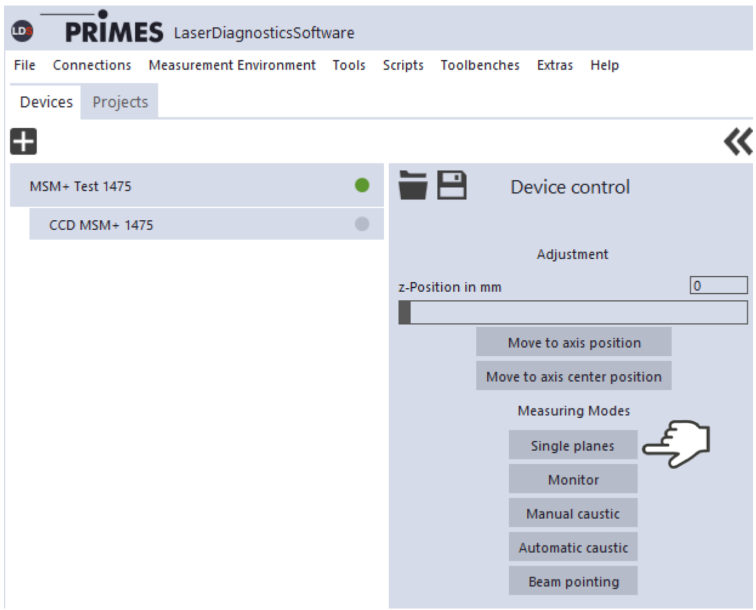
The following measuring modes can be selected:

- ***Single planes*** (see chapter 9.5, „Single planes measurement“, on page 57)
- ***Monitor*** (see chapter 9.6, „Continuous plane measurement (Monitor)“, on page 66)
- ***Manual caustic*** (see chapter 9.7, „Manual caustic measurement“, on page 73)
- ***Automatic caustic*** (see chapter 9.8, „Automatic caustic measurement“, on page 79)
- ***Beam pointing*** (see chapter 9.9, „Beam pointing“, on page 84)
- ***Fiber mode*** (see chapter 9.10, „Fiber mode measurement“, on page 88)

Opening a measuring mode and the adapted toolbench

1. Open the ***Device control*** menu according to chapter 9.4.1 on page 51 .

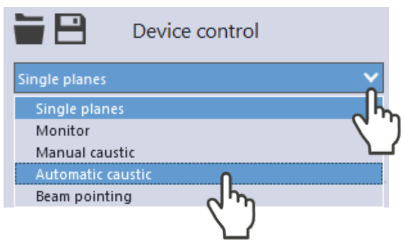
2. After opening the ***Device control*** menu, click the button of the desired measuring mode, for example ***Single planes***.



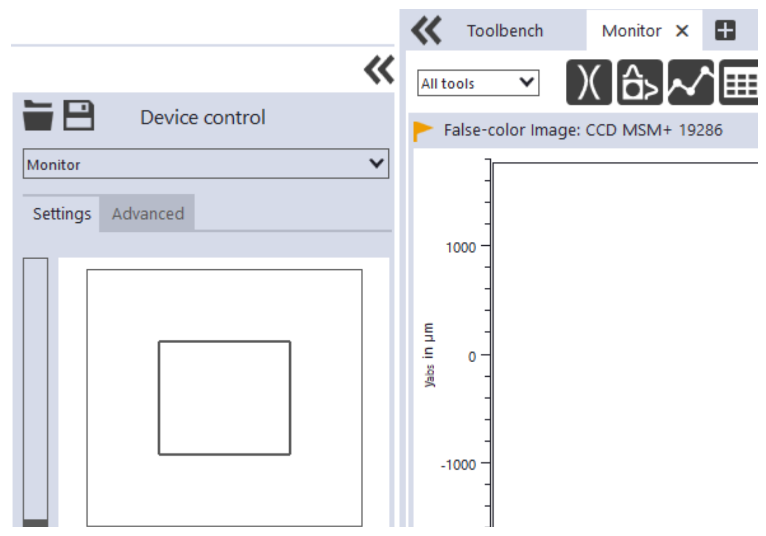
A drop-down list for changing the measuring mode appears in the upper area of the ***Device control*** menu.

Optional:

3. Click on the arrow to open the drop-down list.
4. Click on the measuring mode to which you want to switch.



The toolbench adapted to the selected measuring mode is automatically opened in the main area of the user interface.

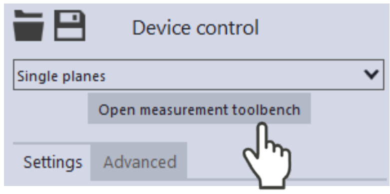


Only if the *Open measurement toolbenches* option is disabled in the *Extras > Options* menu:

The ***Open measurement toolbench*** button appears in the upper area of the ***Device control*** menu.

This button also appears for the selected measuring mode whenever the customized toolbench had been closed.

5. Click this button to open the adapted toolbench in the main area of the user interface.



9.4.4 Configure and save measurement settings

After selecting a measuring mode, numerous measurement and device settings in the ***Settings*** and ***Advanced*** tabs of the ***Device control*** menu can be configured. Which options exactly and what you need to know about them is described in the following chapters on the different measuring tasks. However, some operating steps in the ***Device control*** menu apply equally to all measuring modes. They are described in the following overview.

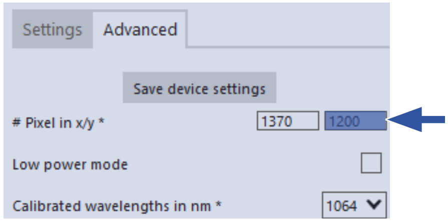
When configuring settings in one mode, note that some options may also be offered in other modes. For example, if a parameter is entered in the ***Single planes*** mode, it will automatically be applied to all other modes that have that same parameter field.

When saving / loading a configuration, note that although the command is made in a specific measuring mode, the saved / loaded data set also includes the settings of the other measuring modes.

Entering and activating parameters

To transfer a parameter value entered in the ***Device control*** menu to the active configuration, it must be confirmed with the Enter key.

1. Enter the desired value in the parameter field.
   - The background color of the parameter field changes to blue.
2. Confirm the entry by pressing the Enter key.
   - The field returns to its original background color.



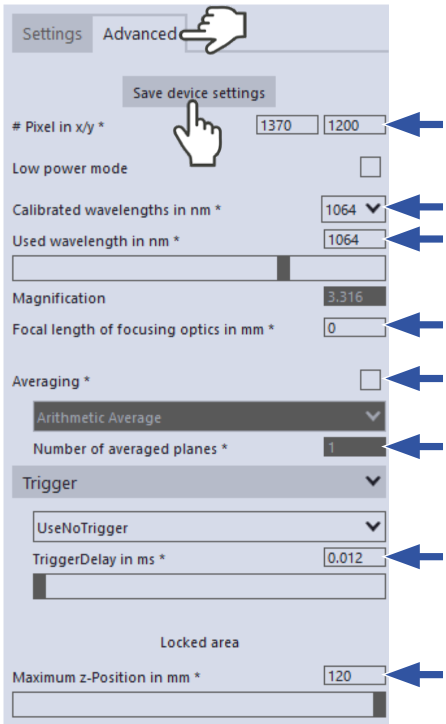
Saving a configuration in the device

All options marked with an asterisk in the ***Device control*** menu can be saved in the EEPROM in the device.
In this case, the settings are retained even if the device is switched off or disconnected from the power source.

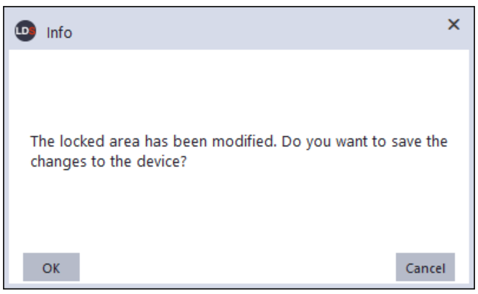
1. Click on the ***Advanced*** tab.
2. Click on the ***Save device settings*** button.

Saving a safety-relevant locked area

We recommend saving a configuration in the device especially if a safety-relevant locked area is configured in the ***Advanced*** tab.



- If the locked area was configured but not saved via ***Save device settings***, then a dialog box appears after clicking the ***Start*** button (to start a measurement).



▶ If you now want to save the locked area (and the other options marked with an asterisk) in the device, click the ***OK*** button.

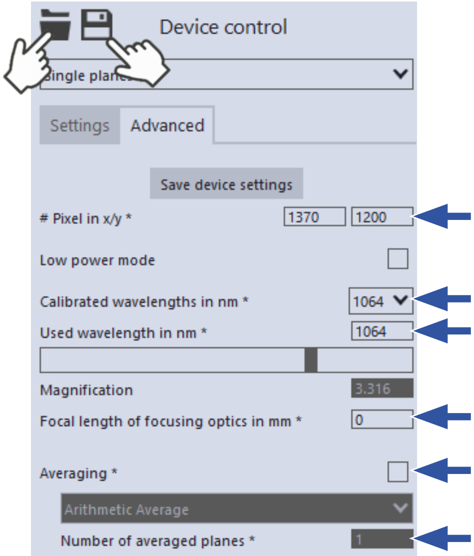
▶ Otherwise, click on the ***Cancel*** button.

➜ The settings are active during the measurement, but must be configured again when the device is switched off or disconnected from the power source.

Saving a configuration to a file / loading from a file

All options marked with an asterisk in the ***Device control*** menu can be saved to a preset file with the ***.pre*** extension.

- ▶ To save a configuration, click the 💾 icon.
- ▶ To load a configuration, click the 📂 icon.



9.4.5 Messages in the LaserDiagnosticsSoftware LDS during measurement

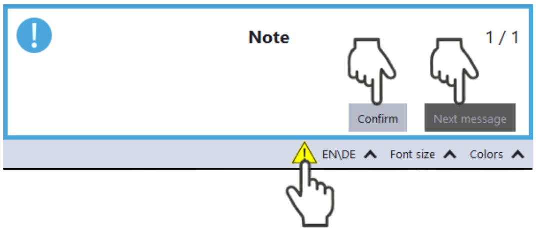
If problems occur during a measurement, the LDS displays them in different categories and different colors.

Notes

Notes provide assistance in interpreting the measurement results and are displayed in a blue window.

Use one of the following options:

- ▶ Click on the warning triangle in the footer to display / hide the window.
- ▶ If applicable, click the ***Next message*** button to display more messages of the same category.
- ▶ Click the ***Confirm*** button to remove the displayed message.

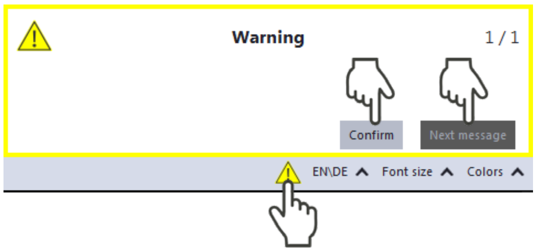


Warnings

Non-safety-critical problems that influence the quality of the measurement results, for example, are displayed in a yellow window.

Use one of the following options:

- ▶ Click on the warning triangle in the footer to display / hide the window.
- ▶ If applicable, click the ***Next message*** button to display more messages of the same category.
- ▶ Click the ***Confirm*** button to remove the displayed message.



Safety critical device errors

Safety-critical problems that can result in damage / destruction of the device are displayed in a red window.

In this case, proceed as follows:

1. Fix the problem immediately.
2. Click the ***Confirm*** button to remove the message.

   👁 The message disappears. If the problem is not fixed, then the message appears again shortly afterwards.
3. Do not proceed with the measurement until the problem is solved.

9.5 Single planes measurement

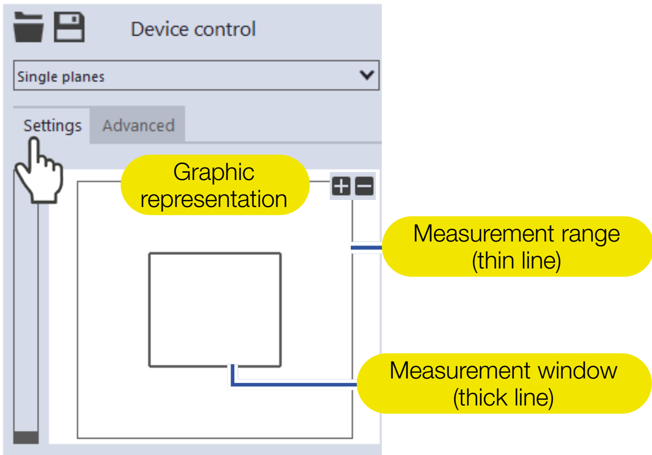
In the ***Single planes*** measuring mode, single planes are measured at selected z-positions. Measurement window size and exposure can be set automatically or determined freely. You can also have the software search the laser beam automatically in the entire measurement range.

To measure a custom caustic, several planes can be measured — either individually or by means of a series measurement. To define the caustic measurement, an increment along the z-axis can be configured. According to ISO 11146-1, at least 10 planes shall be measured. Approximately half of the measurements shall be distributed within one Rayleigh length on either side of the focus, and approximately half of them shall be distributed beyond two Rayleigh lengths from the focus.

By means of the variable integration time control, a large number of pulsed beams can be measured in quasi-cw operation in addition to cw laser beams. An exception are, for example, laser beams with a very low pulse frequency. Trigger operation is available for measuring such beams. If this is enabled, the device only measures within defined time periods. The laser pulse or the corresponding trigger signal marks the beginning of such a period and the (freely adjustable) integration time marks its end. A measurement can be triggered internally or externally. Internal signals are triggered by the photodiode integrated in the device. Externally triggered signals enter the device via a BNC socket. For detailed information on the measurement of pulsed laser beams and the trigger operation, please refer to chapter 16.3 on page 110.

9.5.1 Configure settings

1. Click on the ***Settings*** tab.
2. Maintain the options according to the explanations in the following table.



Option	Explanation
Graphic representation	In a window in the upper area of the ***Settings*** tab, the measurement plane is displayed graphically. Here you can see: • the entire measurable area (measurement range, thin lines) • the area to be recorded (measurement window, thick lines) • after a measurement a false-color image of the recorded area You can make changes in the graphic representation as follows: ▶ To create a new measurement window, position the mouse pointer anywhere within the measurement range. Drag while holding down the left mouse button. Keep the mouse button pressed until the measurement window meets your requirements. The maximum size of the window depends, among other things, on the magnification of the measuring objective. ▶ To move the measurement window to another location, position the mouse pointer inside the measurement window. Drag while holding down the right mouse button. ▶ To zoom to the center of the graphic representation, first move the mouse pointer over the graphic representation until the plus / minus buttons appear. Then press the buttons. ▶ To zoom in on the position of the mouse pointer, position the mouse pointer anywhere within the graphic representation. Then turn the mouse wheel. ▶ To set the zoom section to the size of the measurement window, position the mouse pointer inside the measurement window. Then double-click left. ▶ To set the zoom section to the size of the measurement range, position the mouse pointer outside the measurement window. Then double-click left.
z-Position in mm	Use one of the following options to set the desired z-position of the plane to be measured: ▶ Enter a value in the input field. ▶ Use the slider on the left side of the graphic representation.
Reset measurement window	▶ Click this button to maximize the measurement window and simultaneously center it in the measurement range.
z-Increment in mm	▶ If you want to measure multiple planes with fixed spacing, enter the desired z-increment (see chapter 9.5.4, „Measure further planes“, on page 65).
Power P in W *	To calculate the power density, the laser power used must be entered. Otherwise, the measured amplitudes are given directly in counts. ▶ Enter the laser power used during measurement.
autom. Measurement window	If this option is enabled, then the measurement window size will be set automatically. ▶ Set the check mark to enable the option.
Window size in mm	The maximum size of the measurement window depends, among other things, on the magnification of the measuring objective. If the ***autom. Measurement window*** option is disabled, the size of the measurement window can be adjusted manually. Use one of the following options: ▶ Enter the length of a horizontal / vertical side in the input field on the left / right. ▶ Position the mouse pointer anywhere within the measurement range and drag while holding down the left mouse button. Keep the mouse button pressed until the measurement window meets your requirements.

Tab. 9.3: Options in the ***Device control > Settings*** tab of the ***Single planes*** measuring mode

Option	Explanation
Position in mm	Use one of the following options to adjust the position of the measurement window: ▶ Enter the x-position / y-position of the center of the measurement window in the input field on the left / right. ▶ Position the mouse pointer within the measurement window. Then drag while holding down the right mouse button.
Find beam	This option enables a measurement in which the laser beam is automatically searched for in the entire measurement range. The plane at the defined z-position is then displayed in the graphic representation. Measurement window size, integration time, and filter level of the filter wheel are set automatically. ▶ Click on the button to start the beam search. Note that the determined measurement data will not be saved in the project tree of the ***Projects*** tab.
autom. Exposure	If this option is enabled, the integration time is set automatically. ▶ Set the check mark to enable the option.
Integration time in ms	If the ***autom. Exposure*** option is disabled, the integration time can be set manually. Use one of the following options: ▶ Enter a value in the input field (0.006 ms to 225 ms). ▶ Use the slider below the input field.
Filter level	The selected setting will only be active if the ***autom. filter adjustment*** option is disabled. The filter required for measurement depends on the wavelength and intensity of the laser beam to be measured. We recommend selecting a filter level that achieves a detector modulation of between 60 % and 80%. ▶ Select a filter level in the drop-down list.
autom. filter adjustment	If this option is enabled, then the filter levels are set automatically. ▶ Set the check mark to enable the option.
Time series	A time series consists of several single plane measurements with the same settings.
Number of measurements *	▶ Enter the desired number of single plane measurements of the time series.
Interval between measurements in s *	▶ Enter the pause between the single plane measurements of the time series. This is the time gap between the end of one measurement and the start of the next.
Parameter settings	All settings in the ***Device control*** menu can be individually saved for each device. The saving location is the local installation of the LaserDiagnosticsSoftware LDS.
Save current parameters	▶ Click this button to save all current settings of the connected device.
Load last parameters	▶ Click this button to load the last saved device configuration.

Tab. 9.3: Options in the ***Device control > Settings*** tab of the ***Single planes*** measuring mode

9.5.2 Configure advanced settings

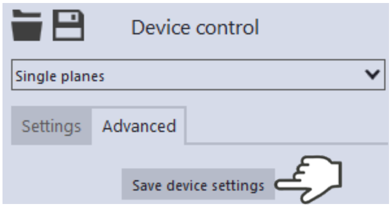
1. Click on the ***Advanced*** tab.
2. Maintain the options according to the explanations in in the following table:.

Option	Explanation
Save device settings	All options marked with an asterisk in the ***Device control*** menu can be saved in the EEPROM of the device. These and other options for saving / loading configurations are described in chapter 9.4.4 on page 53.
# Pixel in x/y *	This option enables setting the resolution of the CCD sensor: ▶ Enter the number of pixels in the x-direction / y-direction in the input field on the left / right.
Low power mode	This option is only relevant when performing a beam search (***Find beam*** option, see chapter 9.5.1 on page 57). We recommend activating it for low power laser beams (< 1 W). If this option is enabled, the following initial values are selected during beam search • Filter level of the filter wheel: 0 (instead of 1 otherwise) • Integration time: 10 ms (instead of 1 ms otherwise). ▶ Set the check mark to enable the option.
Calibrated wavelength(s) in nm *	▶ Select the calibrated wavelength in the drop-down list. The values displayed correspond to the calibration points of the measuring objective. The correct value should be selected before each measurement to enable high measurement accuracy.
Used wavelength in nm *	Use one of the following options to set the used wavelength of the laser: ▶ Enter a value in the input field. ▶ Use the slider below the input field. This parameter must be distinguished from the factory calibrated wavelength of the measuring objective. The exact value should be entered, because it is used for calculating the significant beam quality factor M^2. The wavelength used should approximately match the calibrated wavelength. To enable high measurement accuracy, a preconfigured acceptance range must be observed. For example, if the calibration point 1 064 nm is selected, measurements can be taken in a range between 1 030 and 1 100 nm with high measurement accuracy. Hence the value from the ***Calibrated wavelength in nm*** option is automatically adopted in the input field if a new selection was made there. If this value is replaced by an impermissible high / low value, the impermissible value is automatically overwritten with the maximum / minimum permissible value.
Magnification	This field displays the magnification of the measuring objective.
Focal length of focusing optics in mm *	▶ Enter the focal length used by the focusing optics of the laser system. If several planes of a caustic have been measured, the caustic fit and the entered focal length are used to calculate the raw beam diameter on the focusing optics.

Tab. 9.4: Options in the ***Device control*** > ***Advanced*** tab of the ***Single planes*** measuring mode

Option	Explanation
Averaging *	If this option is enabled, different algorithms for averaging a plane measurement can be selected in the drop-down list below. Averaging over several measurements can be useful, for example, when measuring a laser with significant power fluctuations. 1. Set the check mark to enable the option 2. Select an algorithm from the drop-down list: • ***Arithmetic mean***: The measured values for each pixel are added together and divided by the number of planes. • ***Max. intensity per pixel***: The values from all the measurements are compared for each pixel and only the maximum value for each one is displayed. • ***Max. lines***: The values from all the measurements are compared for each line (meaning the line issuing from the measuring device in the x-direction for example) and only the maximum value for each one is displayed.
Number of averaged planes *	▶ With the ***Averaging*** option enabled, enter the number of plane measurements for averaging.
Trigger	Drop-down area for displaying the options of the trigger operation. The trigger operation is suitable for measuring special pulsed beams. Detailed information on this topic can be found in the chapter 16.3 on page 110.
Drop-down list for trigger selection	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. You can select from the following options: • ***UseNoTrigger***: Switches to the default cw / quasi-cw operation. • ***UsePhotoTrigger***: Switches to a trigger operation in which the measurement is triggered internally. The signals come from the photodiode built into the device. • ***UseExternalTrigger***: Switches to a trigger operation in which the measurement is triggered externally. The trigger signals enter the device via the BNC socket.
TriggerDelay in ms *	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. The trigger delay specifies the period between the trigger signal and the beginning of the integration time. Use one of the following options to set the trigger delay time: ▶ Enter a value in the input field (0.012 ms to 400 ms). ▶ Use the slider below the input field.
TriggerLevel *	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. The trigger level is the threshold value for triggering a signal via the internal photodiode. Use one of the following options to set the trigger level: ▶ Enter a value in the input field. ▶ Use the slider below the input field. You can determine the threshold value suitable for a measurement task as follows: 1. Set the trigger level to the maximum value. 2. Decrease the value step by step until the device receives some trigger signals (lower trigger level). 3. Increase the value until the device does not receive any trigger signals (upper trigger level). 4. Calculate the trigger level as the arithmetic mean of the two limit values.

Tab. 9.4: Options in the ***Device control > Advanced*** tab of the ***Single planes*** measuring mode

Option	Explanation
Locked area	Locked area means a restriction of the traversing range in the z-direction. The lower limit of the enabled traversing range is always home position. The upper limit can be set freely.
Maximum z-Position in mm *	1. Use one of the following options to set the locked area: ▶ Enter the upper limit of the permitted z-traversing range in the input field. ▶ Use the slider below the input field. We recommend saving a locked area in the device, if it is safety-relevant: 2. If you want to save the locked area (and the other options marked with an asterisk) in the device, click the ***Save device settings*** button. ➜ The settings are retained even if the device is switched off or disconnected from the power source. 

Tab. 9.4: Options in the ***Device control*** > ***Advanced*** tab of the ***Single planes*** measuring mode

9.5.3 Measure a plane

DANGER

Serious eye or skin injury due to laser radiation

- **Observe the warning messages in chapter 9.1 on page 44.**

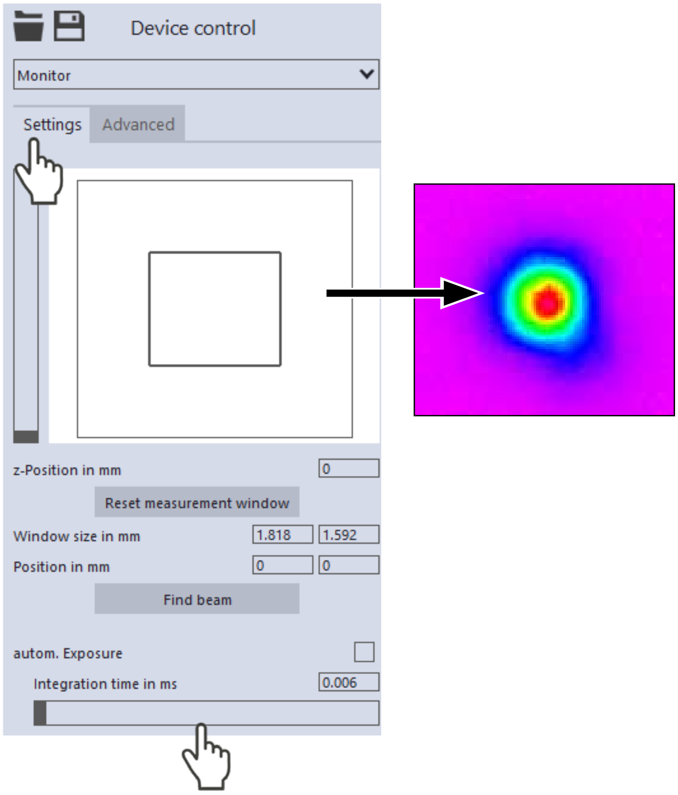
1. Switch on the laser.
2. Click on the ***Settings*** tab.
3. Click on the ***Find beam*** button.

➜ The laser beam is automatically searched for in the entire measurement range. Measurement window size, integration time and filter level of the filter wheel are set automatically.

👁 If the search is successful, the beam is displayed in the graphic representation.

If the beam is not displayed:

4. Select the ***Low power mode*** option or increase the integration time or select a weaker filter of the filter wheel.
5. Select a different z-position.
6. Check again the correct alignment of the device on the x-y plane.
7. Increase the laser power (step by step).

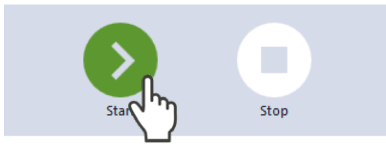


As soon as the beam is displayed:

8. Click the ***Start*** button.

➜ The measurement begins.

9. Optional:
   If necessary, click the ***Stop*** button to end the measurement prematurely.



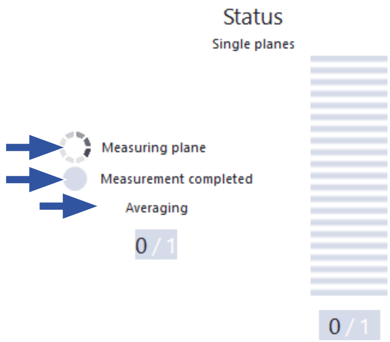
During the measurement, the progress is shown in the following indicators:

Measuring plane
While the indicator is rotating, the measurement is performed.

Measurement completed
After successful measurement, the indicator lights up green.

10. Switch off the laser after the measurement is completed, unless you want to perform further measurements.

Averaging (if enabled)
The indication shows the measured planes that are used to average a measured value.

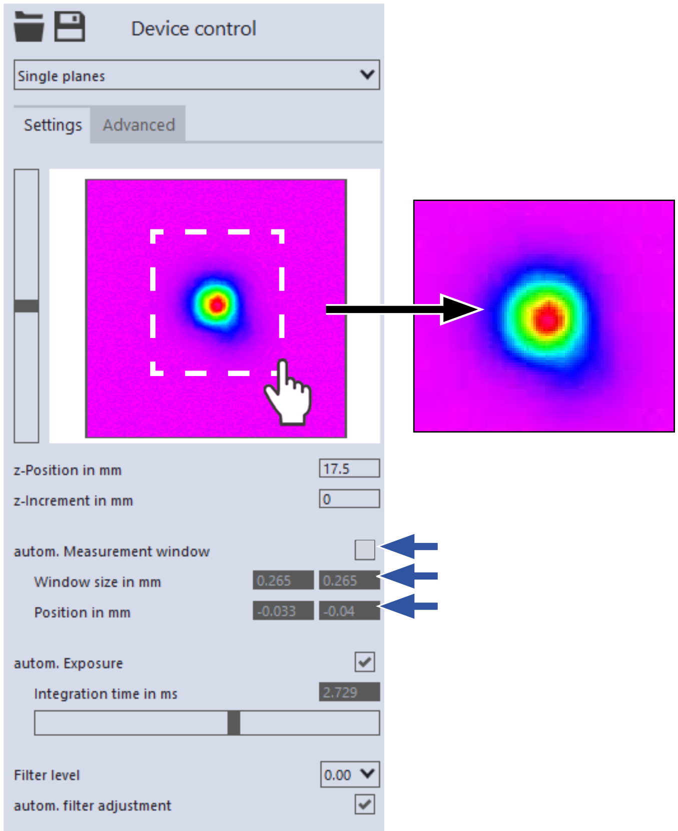


Adjusting size and position of the measurement window (optional)

11. Make sure that the ***autom. Measurement window*** option is not enabled. Otherwise, the manual setting may be overwritten when starting a measurement.

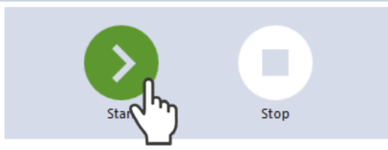
12. Use one of the following options to adjust the size of the measurement window:
   - ▶ Enter the length and width in the corresponding fields.
   - ▶ Position the mouse pointer anywhere within the measurement range and drag while holding down the left mouse button. Keep the mouse button pressed until the measurement window meets your requirements.

13. Use one of the following options to adjust the position of the measurement window:
   - ▶ Enter the x-position / y-position of the center of the measurement window in the corresponding fields.
   - ▶ Position the mouse pointer within the measurement window. Then drag while holding down the right mouse button.



14. Click the Start button to perform the measurement in the manually customized measurement window.

15. Switch off the laser after the measurement is completed, unless you want to perform further measurements.

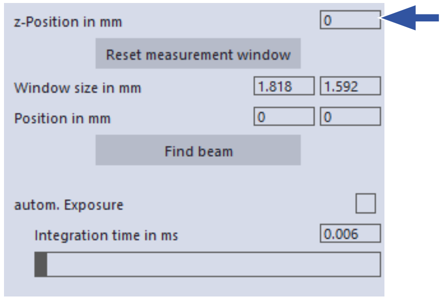


9.5.4 Measure further planes

Directly after a plane measurement, further measurements at other z-positions can be performed. Doing so a caustic with individual increments can be measured.

Single measurement at a specific z-position

1. Click on the ***Settings*** tab.
2. In the ***z-Position in mm*** field, enter the desired position of the next plane to be measured.
3. Start and stop the measurement according to chapter 9.5.3 on page 63.



Single measurements using z-increment spacing

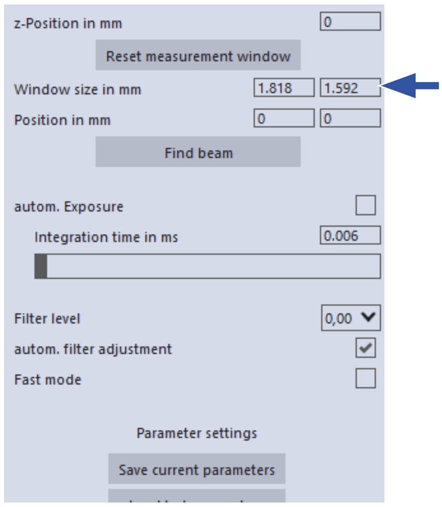
1. Click on the ***Settings*** tab.
2. Enter the spacing for the further measurements in the ***z-Increment in mm*** field.
3. Start a measurement by clicking on the ***Start*** button and wait until the measurement is completed (see chapter 9.5.3 on page 63).

➔ The measured plane is one z-increment away from the previously measured plane.

4. Click the ***start*** button again and wait until the measurement is completed (see chapter 9.5.3 on page 63).

➔ The measured plane is one z-increment away from the previously measured plane.

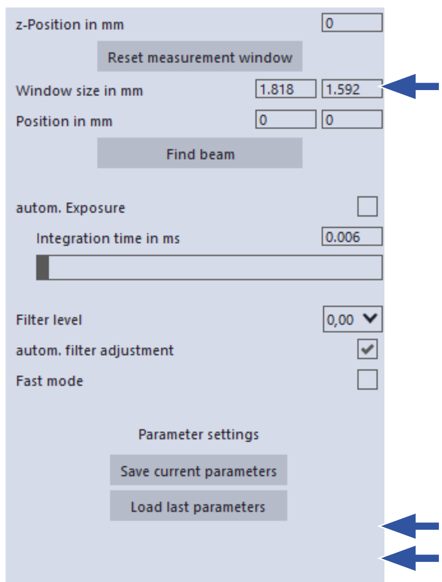
5. Repeat the last step as often as you like.



Series measurement using z-increment spacing

The combination of the ***Time series*** and ***z-Increment in mm*** options enables measuring a free caustic in one run.

1. Click on the ***Settings*** tab.
2. Enter the spacing for the planes to be measured in the ***z-Increment in mm*** field.
3. In the ***Number of measurements*** and ***Interval between measurements in s*** fields, enter the number of measurements and the interval. The interval is the time between the end of one measurement and the start of the next.
   Start and stop the series measurement according to chapter 9.5.3 on page 63.

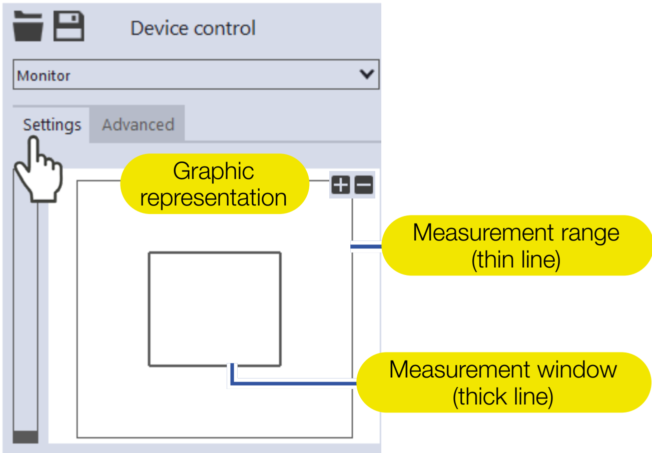


9.6 Continuous plane measurement (Monitor)

In the ***Monitor*** measuring mode, you can continuously view the beam profile at a selected z-position in a false color image. First of all, you can have the laser beam automatically searched for at the z position in the entire measurement range. After a successful search the measurement can be run as long as desired. During the measurement, data is continuously being read out and displayed with a high frame rate. The z-position of the camera housing can be changed during measurement. Measurement data is not saved in the project tree of the ***Projects*** tab.

9.6.1 Configure settings

1. Click on the ***Settings*** tab.
2. Maintain the options according to the explanations in in the following table..



Option	Explanation
Graphic representation	In a window in the upper area of the ***Settings*** tab, the measurement plane is displayed graphically. Here you can see: • the entire measurable area (measurement range, thin lines) • the area to be recorded (measurement window, thick lines) • after a measurement a false-color image of the recorded area You can make changes in the graphic representation as follows: ▶ To create a new measurement window, position the mouse pointer anywhere within the measurement range. Drag while holding down the left mouse button. Keep the mouse button pressed until the measurement window meets your requirements. The maximum size of the window depends, among other things, on the magnification of the measuring objective). ▶ To move the measurement window to another location, position the mouse pointer inside the measurement window. Drag while holding down the right mouse button. ▶ To zoom to the center of the graphic representation, first move the mouse pointer over the graphic representation until the plus / minus buttons appear. Then press the buttons. ▶ To zoom in on the position of the mouse pointer, position the mouse pointer anywhere within the graphic representation. Then turn the mouse wheel. ▶ To set the zoom section to the size of the measurement window, position the mouse pointer inside the measurement window. Then double-click left. ▶ To set the zoom section to the size of the measurement range, position the mouse pointer outside the measurement window. Then double-click left.

Tab. 9.5: Options in the ***Device control*** > ***Settings*** tab of the ***Monitor*** measuring mode

Option	Explanation
z-Position in mm	Use one of the following options to set the desired z-position of the plane to be measured: ▶ Enter a value in the input field. ▶ Use the slider on the left side of the graphic representation.
Reset measurement window	▶ Click this button to maximize the measurement window and simultaneously center it in the measurement range.
Window size in mm	The maximum size of the window depends, among other things, on the magnification of the measuring objective. Use one of the following options to adjust the size of the measurement window: ▶ Enter the length of a horizontal / vertical side in the input field on the left / right. ▶ Position the mouse pointer anywhere within the measurement range and drag while holding down the left mouse button. Keep the mouse button pressed until the measurement window meets your requirements.
Position in mm	Use one of the following options to adjust the position of the measurement window: ▶ Enter the x-position / y-position of the center of the measurement window in the input field on the left / right. ▶ Position the mouse pointer within the measurement window. Then drag while holding down the right mouse button.
Find beam	This option enables a measurement in which the laser beam is automatically searched for in the entire measurement range. The plane at the defined z-position is then displayed in the graphic representation. Measurement window size, integration time, and filter level of the filter wheel are set automatically. ▶ Click on the button to start the beam search. Note that the determined measurement data will not be saved in the project tree of the ***Projects*** tab.
autom. Exposure	If this option is enabled, then the integration time is set automatically. ▶ Set the check mark to enable the option.
Integration time in ms	If the ***autom. Exposure*** option is disabled, the integration time can be set manually. Use one of the following options: ▶ Enter a value in the input field (0.006 ms to 225 ms). ▶ Use the slider below the input field.
Filter level	The selected setting will only be active if the ***autom. filter adjustment*** option is disabled. The filter required for measurement depends on the wavelength and intensity of the laser beam to be measured. We recommend selecting a filter level that achieves a detector modulation of between 60 % and 80%. ▶ Select a filter level in the drop-down list.
autom. filter adjustment	If this option is enabled, then the filter levels are set automatically. ▶ Set the check mark to enable the option.

Tab. 9.5: Options in the ***Device control*** > ***Settings*** tab of the ***Monitor*** measuring mode

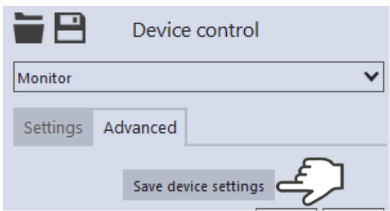
Option	Explanation
Fast Mode	If this option is enabled, the plane is displayed with a higher frame rate. Note, however, that no corrective measurements are then performed. The measurement data may therefore be affected by measurement artefacts such as the readout noise "smear effect". In addition, no radii are displayed in the ***False-color image*** tool. ▶ Set the check mark to enable the option.
Parameter settings	All settings in the ***Device control*** menu can be individually saved for each device. The saving location is the local installation of the LaserDiagnosticsSoftware LDS.
Save current parameters	▶ Click this button to save all current settings of the connected device.
Load last parameters	▶ Click this button to load the last saved device configuration.

Tab. 9.5: Options in the ***Device control*** > ***Settings*** tab of the ***Monitor*** measuring mode

9.6.2 Configure advanced settings

1. Click on the ***Advanced*** tab.

2. Maintain the options according to the explanations in in the following table..

Option	Explanation
Save device settings	All options marked with an asterisk in the ***Device control*** menu can be saved in the EEPROM of the device. These and other options for saving / loading configurations are described in chapter 9.4.4 on page 53.
# Pixel in x/y *	This option enables setting the resolution of the CCD sensor: ▶ Enter the number of pixels in the x-direction / y-direction in the input field on the left / right.
Magnification	This field displays the magnification of the measuring objective.
Low power mode	This option is only relevant when performing a beam search (***Find beam*** option, see chapter 9.6.1 on page 66). We recommend activating it for low power laser beams (< 1 W). If this option is enabled, the following initial values are selected during beam search • Filter level of the filter wheel: 0 (instead of 1 otherwise) • Integration time: 10 ms (instead of 1 ms otherwise). ▶ Set the check mark to enable the option.
Locked area	Locked area means a restriction of the traversing range in the z-direction. The lower limit of the enabled traversing range is always home position. The upper limit can be set freely.
Maximum z-Position in mm *	1. Use one of the following options to set the locked area: ▶ Enter the upper limit of the permitted z-traversing range in the input field. ▶ Use the slider below the input field. We recommend saving a locked area in the device, if it is safety-relevant: 2. If you want to save the locked area (and the other options marked with an asterisk) in the device, click the ***Save device settings*** button. ➜ The settings are retained even if the device is switched off or disconnected from the power source. 

Tab. 9.6: Options in the ***Device control*** > ***Advanced*** tab of the ***Monitor*** measuring mode

9.6.3 Aligne the MSM+ HB with the Monitor measuring mode

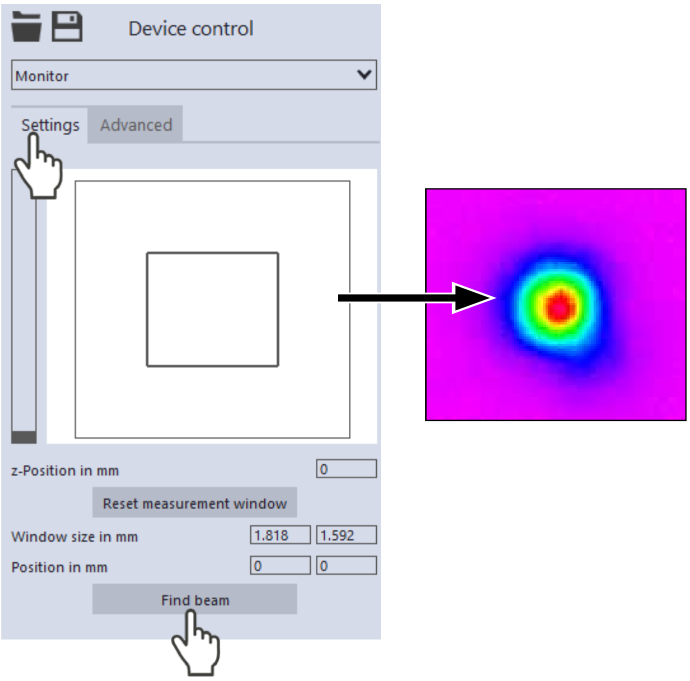
Using a pilot laser:

You can use the continuous plane measurement to align the MSM+ HB. Use the pilot laser for this purpose.

1. Switch on the pilot laser.
2. Click on the ***Advanced*** tab.
3. Activate ***Low power mode***
4. Click on the ***Settings*** tab.
5. Click on the ***Find beam*** button.

➜ The laser beam is automatically searched for in the entire measuring range.

👁 After a successful search, the beam is displayed in the graphical representation..



Using a laser of laser class 4:

⚠ DANGER

Serious eye or skin injury due to laser radiation

▶ **Only align the device using a laser (laser class 4) if the process is carried out remotely behind a separating protective equipment. The protective equipment must be suitable for blocking the radiation or attenuating it to a non-hazardous level. Use the laser‘s low power mode.**

Only align the device by means of a laser of laser class 4 if

- alignment with the pilot laser is not possible and
- the process is carried out remotely behind a separating protective equipment. The protective equipment must be suitable for blocking the radiation or attenuating it to a non-hazardous level. Use the lowest possible power on the laser.

9.6.4 Measure a plane continuously

1. Switch on the laser.

2. Click on the ***Settings*** tab.

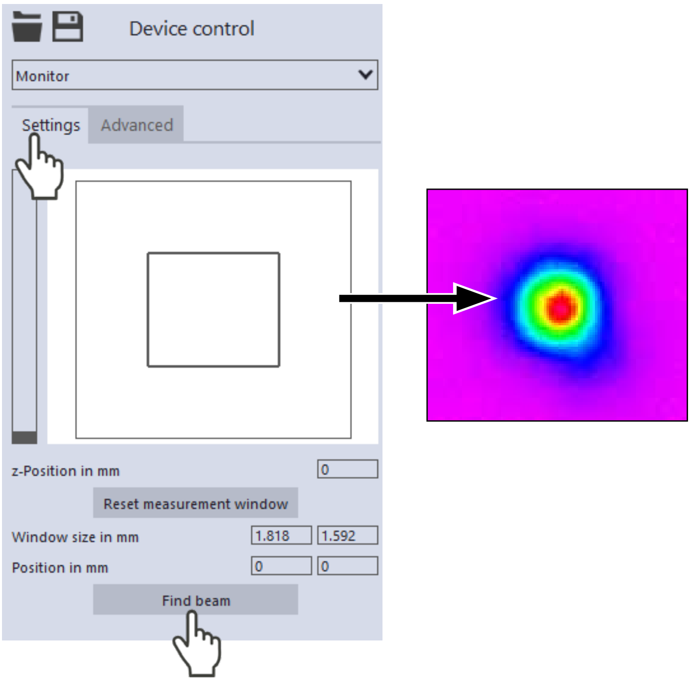
3. Click on the ***Find beam*** button.

➜ The laser beam is automatically searched for in the entire measurement range. Measurement window size, integration time and filter level of the filter wheel are set automatically.

👁 If the search is successful, the beam is displayed in the graphic representation.

If the beam is not displayed:

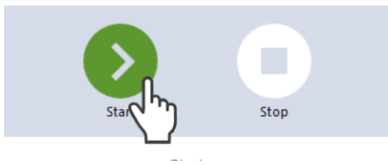
4. Select the ***Low power mode*** option or increase the integration time or select a weaker filter of the filter wheel.
5. Select a different z-position.
6. Check again the correct alignment of the device on the x-y plane.
7. Increase the laser power (step by step).



As soon as the beam is displayed:

8. Click the ***Start*** button.

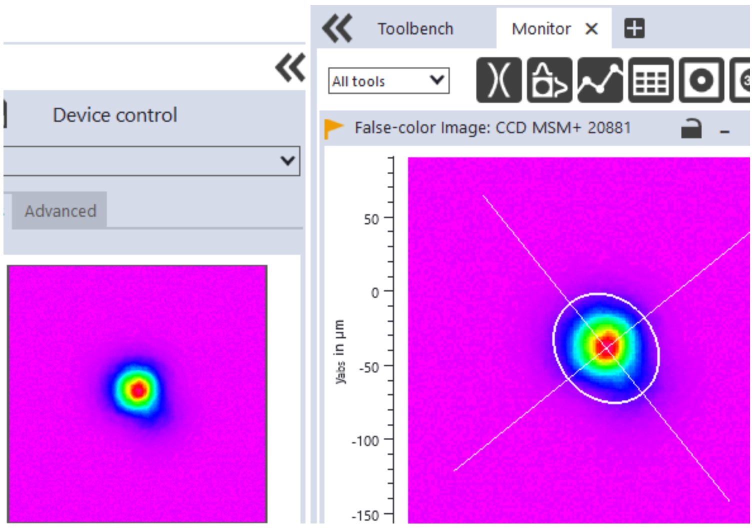
➜ The measurement begins.



👁 Data is continuously read out from the previously set measurement window and displayed with a high frame rate in the false-color image.

9. To stop the measurement, click on the ***Stop*** button.

10. Switch off the laser after the measurement is completed, unless you want to perform further measurements.

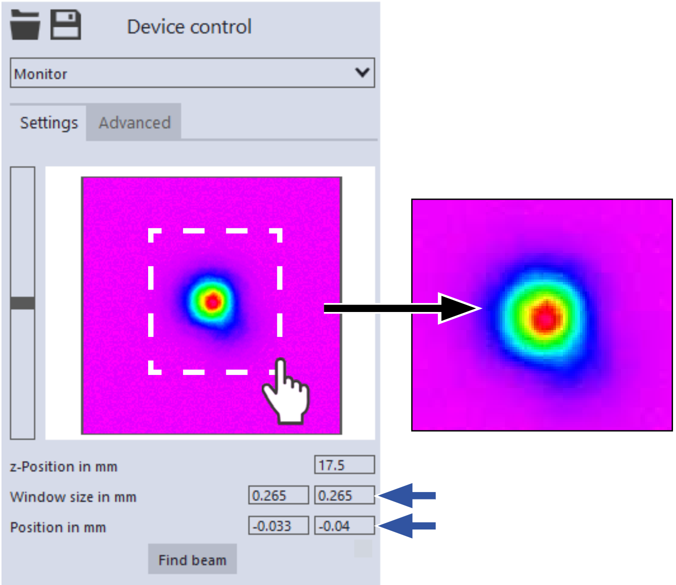


Adjusting size and position of the measurement window (optional)

11. Make sure that the ***autom. Measurement window*** option is not enabled. Otherwise, the manual setting may be overwritten when starting a measurement.

12. Use one of the following options to adjust the size of the measurement window:
▶ Enter the length of a horizontal / vertical side in the input field on the left / right.
▶ Position the mouse pointer anywhere within the measurement range and drag while holding down the left mouse button. Keep the mouse button pressed until the measurement window meets your requirements.

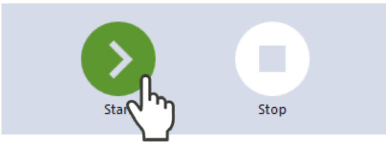
13. Use one of the following options to adjust the position of the measurement window:
▶ Enter the x-position / y-position of the center of the measurement window in the input field on the left / right.
▶ Position the mouse pointer within the measurement window. Then drag while holding down the right mouse button.



14. Click the ***Start*** button to perform the measurement in the manually customized measurement window.

15. To stop the measurement, click on the ***Stop*** button.

16. Switch off the laser after the measurement is completed, unless you want to perform further measurements.



9.7 Manual caustic measurement

In the ***Manual caustic*** measuring mode, only the z-range and the number of planes have to be specified. All other required settings are automatically determined and adjusted. In addition, advanced settings can be applied.

According to ISO 11146-1, at least 10 planes shall be measured. Approximately half of the measurements shall be distributed within one Rayleigh length on either side of the focus, and approximately half of them shall be distributed beyond two Rayleigh lengths from the focus.

For two reasons, an odd number of measuring planes makes it more likely that the focal plane will be measured. First, the LaserDiagnosticsSoftware LDS always sets the spacing between the measuring planes equal. Second, the measuring range along the z-axis is almost always symmetrical around the focus. We recommend measuring at least 21 planes within 6 Rayleigh lengths.

By means of the variable integration time control, not only cw lasers but also pulsed lasers can be measured in quasi-cw operation. An exception are, for example, laser beams with a very low pulse frequency. Trigger operation is available for measuring such beams. If this is enabled, the device only measures within defined time periods. The laser pulse or the corresponding trigger signal marks the beginning of such a period and the (freely adjustable) integration time marks its end. A measurement can be triggered internally or externally. Internal signals are triggered by the photodiode integrated in the device. Externally triggered signals enter the device via a BNC socket. For detailed information on the measurement of pulsed laser beams and the trigger operation, please refer to chapter 16.3 on page 110.

9.7.1 Configure settings

1. Click on the ***Settings*** tab.
2. Maintain the options according to the explanations in in the following table..

Option	Explanation
Optimized measurement settings	If this option is activated, the measurement takes shorter time. Fewer process steps are required, since the initial settings for a plane measurement are taken from the settings of the previous plane measurement. Please note, however, that beam artefacts may not be adequately detected in the single plane measurements due to the transfer of the settings. ▶ Set the check mark to activate the option.
Number of planes *	▶ Enter the number of planes to be measured.
z-Axis position (z1 / z2) in mm *	This option enables configuring the z-range in which the measurement is to be performed. ▶ Regarding the traversing range in which the measurement is to be performed, enter the lower limit z1 in the left field and the upper limit z2 in the right field. ▶ Alternatively, use the sliders.
Caustic suggestion	When a caustic measurement is completed, a z-range is displayed in these fields. The limits of the suggested z-range have a distance of ± 3 Rayleigh lengths to the determined beam focus. This z-range is optimized according to Primes quality criteria.

Tab. 9.7: Options in the ***Device control*** > ***Settings*** tab of the ***Manual caustic*** measuring mode

Option	Explanation
Use	▶ Click this button to transfer the z-values displayed in the ***Caustic suggestion*** fields to the ***z-Axis position (z1 / z2) in mm*** fields.
Reset z-Axis position	▶ Click this button to reset the z-axis position to the default values
Power P in W *	To calculate the power density, the laser power used must be entered. Otherwise, the measured amplitudes are given directly in counts. ▶ Enter the laser power used during measurement.
Filter level	The selected setting will only be active if the ***autom. filter adjustment*** option is disabled. The filter required for measurement depends on the wavelength and intensity of the laser beam to be measured. We recommend selecting a filter level that achieves a detector modulation of between 60 % and 80%. ▶ Select a filter level in the drop-down list.
autom. filter adjustment	If this option is enabled, then the filter levels are set automatically. ▶ Set the check mark to enable the option.
Time series	A time series consists of several caustic measurements with the same settings.
Number of measurements *	▶ Enter the desired number of caustic measurements of the time series.
Interval between measurements in s *	▶ Enter the pause between the caustic measurements of the time series. This is the time gap between the end of one measurement and the start of the next.

Tab. 9.7: Options in the ***Device control*** > ***Settings*** tab of the ***Manual caustic*** measuring mode

9.7.2 Configure advanced settings

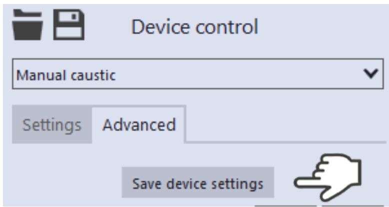
1. Click on the ***Advanced*** tab.
2. Maintain the options according to the explanations in in the following table..

Option	Explanation
Save device settings	All options marked with an asterisk in the ***Device control*** menu can be saved in the EEPROM of the device. These and other options for saving / loading configurations are described in chapter 9.4.4 on page 53.
# Pixel in x/y *	This option enables setting the resolution of the CCD sensor: ▶ Enter the number of pixels in the x-direction / y-direction in the input field on the left / right.
Averaging *	If this option is enabled, different algorithms for averaging a plane measurement can be selected in the drop-down list below. Averaging over several measurements can be useful, for example, when measuring a laser with significant power fluctuations. 1. Set the check mark to enable the option 2. Select an algorithm from the drop-down list: • ***Arithmetic mean***: The measured values for each pixel are added together and divided by the number of planes. • ***Max. intensity per pixel***: The values from all the measurements are compared for each pixel and only the maximum value for each one is displayed. • ***Max. lines***: The values from all the measurements are compared for each line (meaning the line issuing from the measuring device in the x-direction for example) and only the maximum value for each one is displayed.
Number of averaged planes *	▶ With the ***Averaging*** option enabled, enter the number of plane measurements for averaging.
Low power mode	We recommend enabling this option for relatively low power laser beams. If this option is enabled, the following initial values are selected during beam search • Filter level of the filter wheel: 0 (instead of 1 otherwise) • Integration time: 10 ms (instead of 1 ms otherwise). ▶ Set the check mark to enable the option.
Calibrated wavelength(s) in nm *	▶ Select the calibrated wavelength in the drop-down list. The values displayed correspond to the calibration points of the measuring objective. The correct value should be selected before each measurement to enable high measurement accuracy.

Tab. 9.8: Options in the ***Device control > Advanced*** tab of the ***Manual caustic*** measuring mode

Option	Explanation
Used wavelength in nm *	Use one of the following options to set the used wavelength of the laser: ▶ Enter a value in the input field. ▶ Use the slider below the input field. This parameter must be distinguished from the factory calibrated wavelength of the measuring objective. The exact value should be entered, because it is used for calculating the significant beam quality factor M^2. The wavelength used should approximately match the calibrated wavelength. To enable high measurement accuracy, a preconfigured acceptance range must be observed. For example, if the calibration point 1 064 nm is selected, measurements can be taken in a range between 1 030 and 1 100 nm with high measurement accuracy. Hence the value from the ***Calibrated wavelength in nm*** option is automatically adopted in the input field if a new selection was made there. If this value is replaced by an impermissible high / low value, the impermissible value is automatically overwritten with the maximum / minimum permissible value.
Magnification	This field displays the magnification of the measuring objective.
Focal length of focusing optics in mm *	▶ Enter the focal length used by the focusing optics of the laser system. The caustic fit and the entered focal length are used to calculate the raw beam diameter on the focusing optics.
Trigger	Drop-down area for displaying the options of the trigger operation. The trigger operation is suitable for measuring special pulsed beams. Detailed information on this topic can be found in the chapter 16.3 on page 110.
Drop-down list for trigger selection	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. You can select from the following options: • ***UseNoTrigger***: Switches to the default cw / quasi-cw operation. • ***UsePhotoTrigger***: Switches to a trigger operation in which the measurement is triggered internally. The signals come from the photodiode built into the device. • ***UseExternalTrigger***: Switches to a trigger operation in which the measurement is triggered externally. The trigger signals enter the device via the BNC socket.
TriggerDelay in ms *	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. The trigger delay specifies the period between the trigger signal and the beginning of the integration time. Use one of the following options to set the trigger delay time: ▶ Enter a value in the input field (0.012 ms to 400 ms). ▶ Use the slider below the input field.

Tab. 9.8: Options in the ***Device control > Advanced*** tab of the ***Manual caustic*** measuring mode

Option	Explanation
*TriggerLevel **	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. The trigger level is the threshold value for triggering a signal via the internal photodiode. Use one of the following options to set the trigger level: ▶ Enter a value in the input field. ▶ Use the slider below the input field. You can determine the threshold value suitable for a measurement task as follows: 1. Set the trigger level to the maximum value. 2. Decrease the value step by step until the device receives some trigger signals (lower trigger level). 3. Increase the value until the device does not receive any trigger signals (upper trigger level). 4. Calculate the trigger level as the arithmetic mean of the two limit values.
Locked area	Locked area means a restriction of the traversing range in the z-direction. The lower limit of the enabled traversing range is always home position. The upper limit can be set freely.
Maximum z-Position in mm *	1. Use one of the following options to set the locked area: ▶ Enter the upper limit of the permitted z-traversing range in the input field. ▶ Use the slider below the input field. We recommend saving a locked area in the device, if it is safety-relevant: 2. If you want to save the locked area (and the other options marked with an asterisk) in the device, click the ***Save device settings*** button. ➜ The settings are retained even if the device is switched off or disconnected from the power source. 

Tab. 9.8: Options in the ***Device control*** > ***Advanced*** tab of the ***Manual caustic*** measuring mode

9.7.3 Measure a caustic manually

DANGER

Serious eye or skin injury due to laser radiation

- **Observe the warning messages in chapter 9.1 on page 44.**

1. Switch on the laser.

2. Click the ***Start*** button.
   ➜ The measurement begins.

3. Optional:
   If necessary, click the ***Stop*** button to end the measurement prematurely.

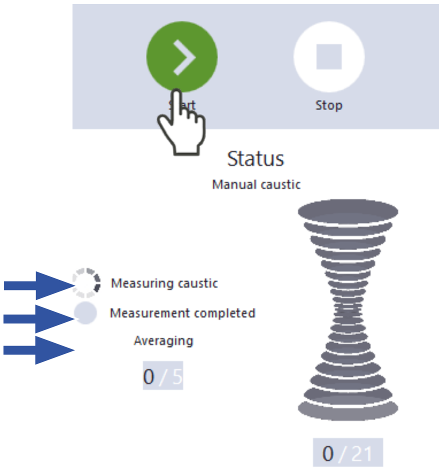
During the measurement, the progress is shown in the following indicators:

Measuring caustic
While the indicator is rotating, the measurement is performed. The measurement parameters are optimized according to Primes quality criteria.

Measurement completed
After successful measurement, the indicator lights up green.

4. Switch off the laser after the measurement is completed, unless you want to perform further measurements.

Averaging (if enabled)
The indication shows the measured planes that are used to average a measured value.



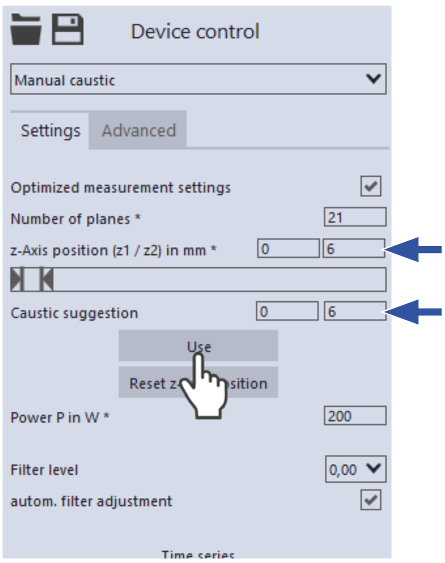
Applying a caustic suggestion (optional)

After the measurement is completed, a z-range is displayed in the ***Caustic suggestion*** fields. The limits of the suggested z-range have a distance of ± 3 Rayleigh lengths to the determined beam waist position.
This z-range is optimized according to Primes quality criteria.

5. If you want to apply this suggestion, click the ***Use*** button.
   The suggested limit values z1 / z2 are transfered to the ***z-Axis position (z1 / z2) in mm*** fields.

6. Click the ***Start*** button again to perform the measurement in the suggested z-range.

7. Switch off the laser after the measurement is completed, unless you want to perform further measurements.



9.8 Automatic caustic measurement

In the ***Automatic caustic*** measuring mode, only press the start button to automatically determine a caustic. The centre axis position is preset as the z position. The default setting for the number of measuring planes is 21. The z-range as well as all other required settings are determined and adjusted automatically. In addition, advanced settings can be applied.

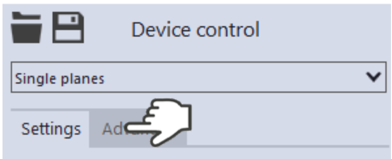
According to ISO 11146-1, at least 10 planes shall be measured. Approximately half of the measurements shall be distributed within one Rayleigh length on either side of the focus, and approximately half of them shall be distributed beyond two Rayleigh lengths from the focus.

For two reasons, an odd number of measuring planes makes it more likely that the focal plane will be measured. First, the LaserDiagnosticsSoftware LDS always sets the spacing between the measuring planes equal. Second, the measuring range along the z-axis is almost always symmetrical around the focus. We recommend measuring at least 21 planes within 6 Rayleigh lengths.

By means of the variable integration time control, not only cw lasers but also pulsed lasers can be measured in quasi-cw operation. An exception are, for example, laser beams with a very low pulse frequency. Trigger operation is available for measuring such beams. If this is enabled, the device only measures within defined time periods. The laser pulse or the corresponding trigger signal marks the beginning of such a period and the (freely adjustable) integration time marks its end. A measurement can be triggered internally or externally. Internal signals are triggered by the photodiode integrated in the device. Externally triggered signals enter the device via a BNC socket. For detailed information on the measurement of pulsed laser beams and the trigger operation, please refer to chapter 16.3 on page 110.

9.8.1 Configure settings

1. Click on the ***Settings*** tab.
2. Maintain the options according to the explanations in the following table.



Option	Explanation
z-Position in mm	The centre axis position is selected as the default setting. Use one of the following options to set the initial z-position for the pre-caustic measurement: ▶ Enter a value in the input field. ▶ Use the slider below the input field.
Parking position after caustic	▶ In the drop-down list, select the parking position to which the camera housing will be moved after the caustic measurement. You can select from the following options: • ***Focus***: The camera housing is moved back to the position of the determined beam focus. • ***Start position***: The camera housing is moved back to the start position. • ***Final position***: The camera housing remains in the final position. The selected position is also the start position for the pre-caustic measurement of the next measurement (unless you enter a different value in the ***z-Position in mm*** field).
Power P in W *	To calculate the power density, the laser power used must be entered. Otherwise, the measured amplitudes are given directly in counts. ▶ Enter the laser power used during measurement.

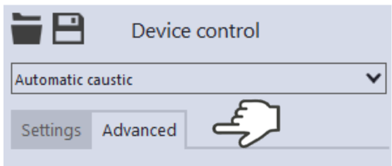
Tab. 9.9: Options in the ***Device control > Settings*** tab of the ***Automatic caustic*** measuring mode

Option	Explanation
Filter level	The selected setting will only be active if the ***autom. filter adjustment*** option is disabled. The filter required for measurement depends on the wavelength and intensity of the laser beam to be measured. We recommend selecting a filter level that achieves a detector modulation of between 60 % and 80%. ▶ Select a filter level in the drop-down list.
autom. filter adjustment	If this option is enabled, then the filter levels are set automatically. ▶ Set the check mark to enable the option.
Time series	A time series consists of several caustic measurements with the same settings.
Number of measurements *	▶ Enter the desired number of caustic measurements of the time series.
Interval between measurements in s *	▶ Enter the pause between the caustic measurements of the time series. This is the time gap between the end of one measurement and the start of the next.

Tab. 9.9: Options in the ***Device control*** > ***Settings*** tab of the ***Automatic caustic*** measuring mode

9.8.2 Configure advanced settings

1. Click on the ***Advanced*** tab.
2. Maintain the options according to the explanations in the following table..

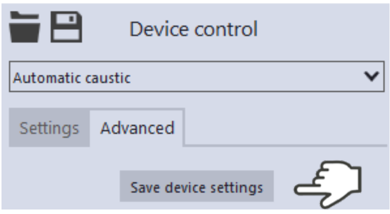


Option	Explanation
Save device settings	All options marked with an asterisk in the ***Device control*** menu can be saved in the EEPROM of the device. These and other options for saving / loading configurations are descri-bed in chapter 9.4.4 on page 53.
# Pixel in x/y *	This option enables setting the resolution of the CCD sensor: ▶ Enter the number of pixels in the x-direction / y-direction in the input field on the left / right.
Number of planes *	The default setting is 21 planes. ▶ Enter the number of planes to be measured.
Low power mode	We recommend enabling this option for relatively low power laser be-ams. If this option is enabled, the following initial values are selected during beam search • Filter level of the filter wheel: 0 (instead of 1 otherwise) • Integration time: 10 ms (instead of 1 ms otherwise). ▶ Set the check mark to enable the option.

Tab. 9.10: Options in the ***Device control*** > ***Advanced*** tab of the ***Automatic caustic*** measuring mode

Option	Explanation
Calibrated wavelength(s) in nm *	▶ Select the calibrated wavelength in the drop-down list. The values displayed correspond to the calibration points of the measuring objective. The correct value should be selected before each measurement to enable high measurement accuracy.
Used wavelength in nm *	Use one of the following options to set the used wavelength of the laser: ▶ Enter a value in the input field. ▶ Use the slider below the input field. This parameter must be distinguished from the factory calibrated wavelength of the measuring objective. The exact value should be entered, because it is used for calculating the significant beam quality factor M^2. The wavelength used should approximately match the calibrated wavelength. To enable high measurement accuracy, a preconfigured acceptance range must be observed. For example, if the calibration point 1 064 nm is selected, measurements can be taken in a range between 1 030 and 1 100 nm with high measurement accuracy. Hence the value from the ***Calibrated wavelength in nm*** option is automatically adopted in the input field if a new selection was made there. If this value is replaced by an impermissible high / low value, the impermissible value is automatically overwritten with the maximum / minimum permissible value.
Magnification	This field displays the magnification of the measuring objective.
Focal length of focusing optics in mm *	▶ Enter the focal length used by the focusing optics of the laser system. The caustic fit and the entered focal length are used to calculate the raw beam diameter on the focusing optics.
Trigger	Drop-down area for displaying the options of the trigger operation. The trigger operation is suitable for measuring special pulsed beams. Detailed information on this topic can be found in the chapter 16.3 on page 110.
Drop-down list for trigger selection	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. You can select from the following options: • ***UseNoTrigger***: Switches to the default cw / quasi-cw operation. • ***UsePhotoTrigger***: Switches to a trigger operation in which the measurement is triggered internally. The signals come from the photodiode built into the device. • ***UseExternalTrigger***: Switches to a trigger operation in which the measurement is triggered externally. The trigger signals enter the device via the BNC socket.
TriggerDelay in ms *	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. The trigger delay specifies the period between the trigger signal and the beginning of the integration time. Use one of the following options to set the trigger delay time: ▶ Enter a value in the input field (0.012 ms to 400 ms). ▶ Use the slider below the input field.

Tab. 9.10: Options in the ***Device control > Advanced*** tab of the ***Automatic caustic*** measuring mode

Option	Explanation
TriggerLevel*	This drop-down list is only visible if the drop-down area for displaying the options of the trigger operation is open. The trigger level is the threshold value for triggering a signal via the internal photodiode. Use one of the following options to set the trigger level: ▶ Enter a value in the input field. ▶ Use the slider below the input field. You can determine the threshold value suitable for a measurement task as follows: 1. Set the trigger level to the maximum value. 2. Decrease the value step by step until the device receives some trigger signals (lower trigger level). 3. Increase the value until the device does not receive any trigger signals (upper trigger level). 4. Calculate the trigger level as the arithmetic mean of the two limit values.
Locked area	Locked area means a restriction of the traversing range in the z-direction. The lower limit of the enabled traversing range is always home position. The upper limit can be set freely.
Maximum z-Position in mm*	1. Use one of the following options to set the locked area: ▶ Enter the upper limit of the permitted z-traversing range in the input field. ▶ Use the slider below the input field. We recommend saving a locked area in the device, if it is safety-relevant: 2. If you want to save the locked area (and the other options marked with an asterisk) in the device, click the ***Save device settings*** button. ➜ The settings are retained even if the device is switched off or disconnected from the power source. 

Tab. 9.10: Options in the ***Device control*** > ***Advanced*** tab of the ***Automatic caustic*** measuring mode

9.8.3 Measure a caustic automatically

DANGER

Serious eye or skin injury due to laser radiation

▶ **Observe the warning messages in chapter 9.1 on page 44.**

1. Switch on the laser.
2. Start the measurement by clicking on the Start button.
   The measurement can be ended prematurely by clicking on the red Stop button.

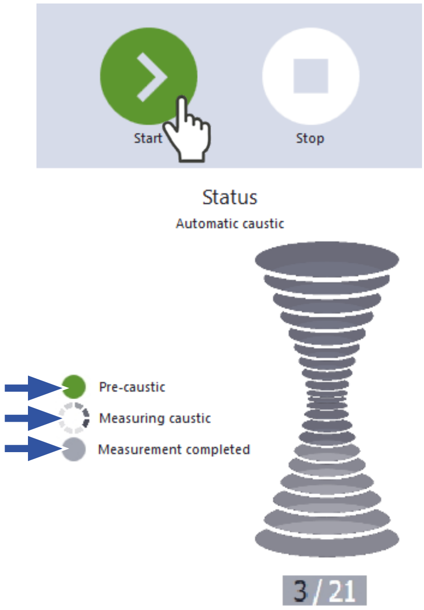
During the measurement, the progress is shown in the following indicators:

Pre-caustic
While the indicator is rotating, the measurement parameters are determined automatically (for example measurement window position, measurement window size, integration time, z-range). The measurement parameters are optimized according to Primes quality criteria.
After successful pre-caustic measurement, the indicator lights up green.

Measuring caustic
While the indicator is rotating, the actual measurement is performed.

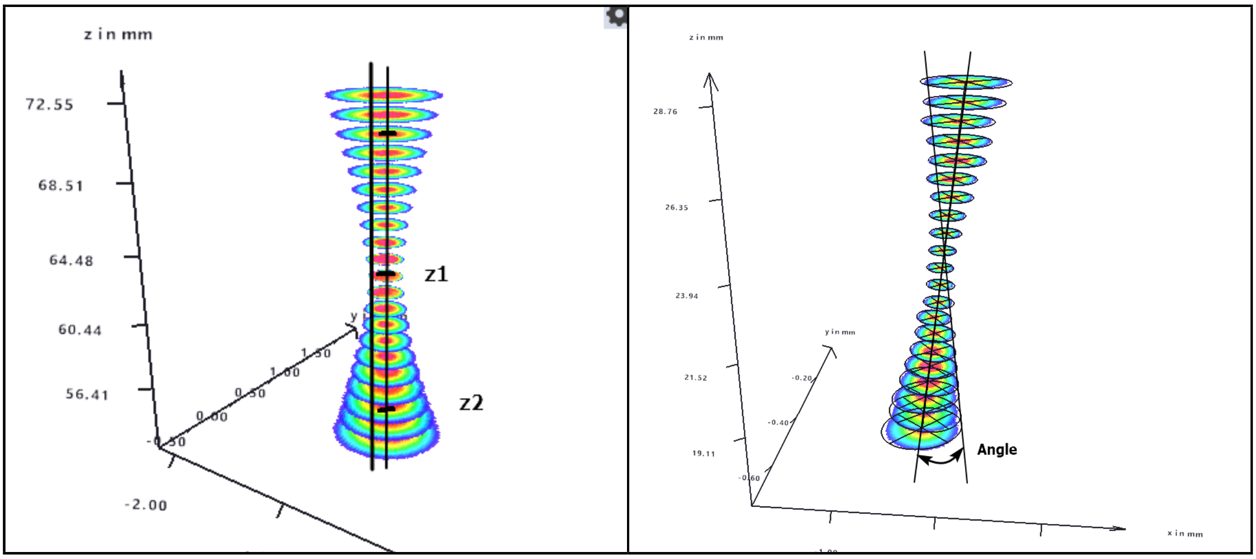
Measurement completed
The measurement, is completed.

3. Switch off the laser after the measurement is completed, unless you want to perform further measurements.



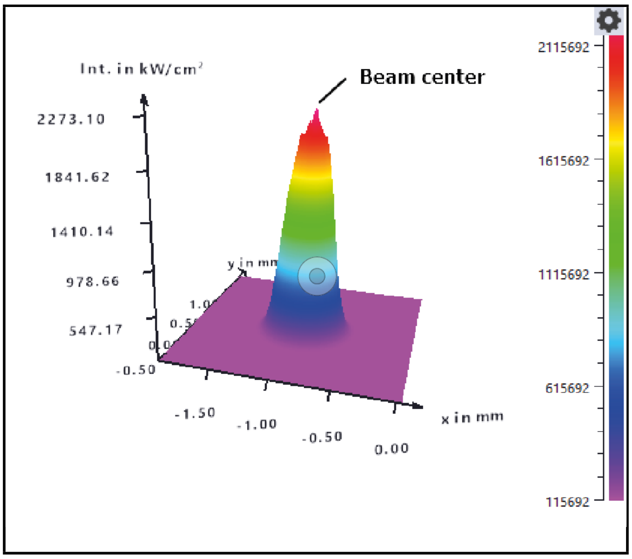
9.9 Beam pointing

In this measuring mode, the pointing stability of a laser beam is measured and evaluated. For this purpose the MSM+ HB alternately performs measurements at two different z-positions. As a result the position of the center of gravity towards the tool center point (TCP) as well as the tilting towards the optical axis of the device is determined.



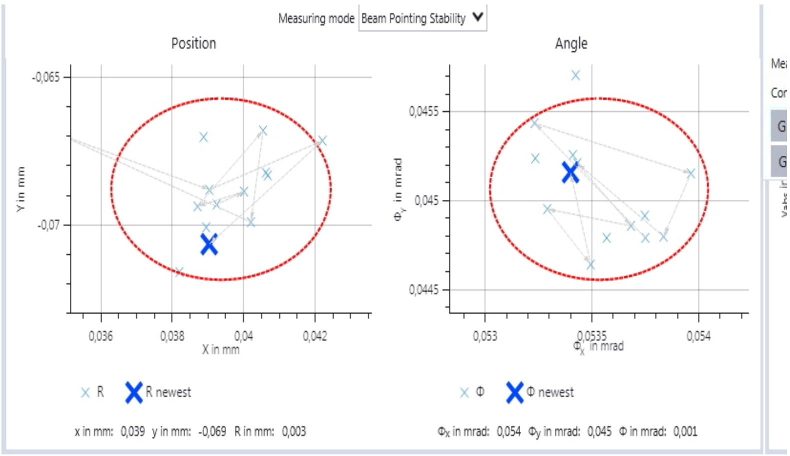
After running a fully automatic pre-caustic, that is ideally started slightly above focus, the MSM+ HB determines on the z-axis the focus position (z_0) and Rayleigh length (z_R) of the beam to be analyzed.

For the xy-planes at z1 (focus position) and z2 ($-2z_R$), the x/y coordinates of the center of gravity are determined.
The following figure shows an example for a center of gravity (beam center).



The coordinates are used to calculate the following values:
- x/y position and
- tilting (angle)

These two values are displayed in the two coordinate windows of the ***Beam Pointing*** tool



9.9.1 Configure settings

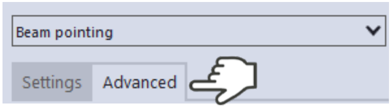
1. Click on the ***Settings*** tab. 2. Maintain the options according to the explanations in the following table.	

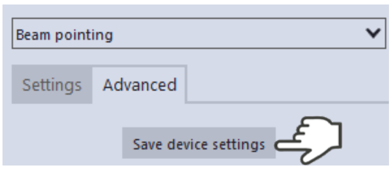
Option	Explanation
z-Position in mm	Use one of the following options to specify the desired initial z-position of the camera housing for the pre-caustic measurement: ▶ Enter a value in the input field. ▶ Use the slider below the input field. It is recommended to start the pre-caustic 1 or 2 Rayleighlength above focus.
Number of measurements	▶ Enter the number of measurements. The default setting is 15 measurements. With this input you determine the number of measuring points that are displayed in the coordinate windows of the ***Beam Pointing Stability*** tool. For an unlimitted and recorded measurement enter the value „0“.
z-Axis position (z1 / z2)	The measuring positions z1 and z2 determined during the pre-caustic measurement are displayed here.

Tab. 9.11: Options in the ***Device control*** > ***Settings*** tab of the ***Beam pointing*** measuring mode

9.9.2 Configure advanced settings

1. Click on the ***Advanced*** tab.
2. Maintain the options according to the explanations in the following table..



Option	Explanation
Save device settings	All options marked with an asterisk in the ***Device control*** menu can be saved in the EEPROM of the device. These and other options for saving / loading configurations are described in chapter 9.4.4 on page 53.
# Pixel in x/y *	This option enables setting the resolution of the CCD sensor: ▶ Enter the number of pixels in the x-direction / y-direction in the input field on the left / right.
Low power mode	We recommend enabling this option for relatively low power laser beams. If this option is enabled, the following initial values are selected during beam search • Filter level of the filter wheel: 0 (instead of 1 otherwise) • Integration time: 10 ms (instead of 1 ms otherwise). ▶ Set the check mark to enable the option.
Locked area	Locked area means a restriction of the traversing range in the z-direction. The lower limit of the enabled traversing range is always home position. The upper limit can be set freely.
Maximum z-Position in mm *	1. Use one of the following options to set the locked area: ▶ Enter the upper limit of the permitted z-traversing range in the input field. ▶ Use the slider below the input field. We recommend saving a locked area in the device, if it is safety-relevant: 2. If you want to save the locked area (and the other options marked with an asterisk) in the device, click the ***Save device settings*** button. ➜ The settings are retained even if the device is switched off or disconnected from the power source. 

Tab. 9.12: Options in the ***Device control*** > ***Advanced*** tab of the ***Beam pointing*** measuring mode

9.9.3 Measure beam pointing stability

DANGER

Serious eye or skin injury due to laser radiation

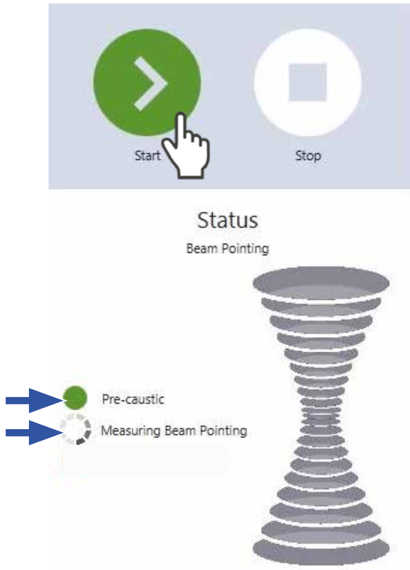
▶ **Observe the warning messages in chapter 9.1 on page 44.**

Starting measurement

1. Switch on the laser.
2. Enter z-position.
3. Click the ***Start*** button.

➔ The measurement begins.

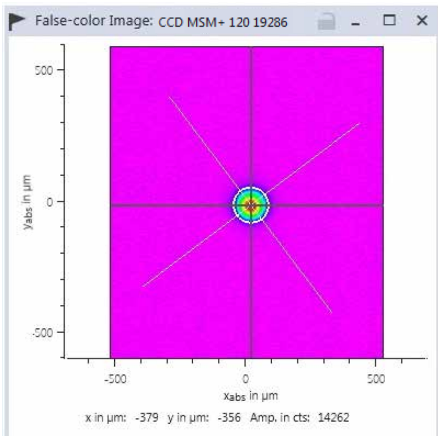
During the measurement, the progress is shown in the following indicators:



Pre-caustic

While the indicator is rotating, the z1 and z2 positions along the beam propagation are identified. The positions are optimized according to Primes quality criteria. After successful pre-caustic measurement, the indicator lights up green.

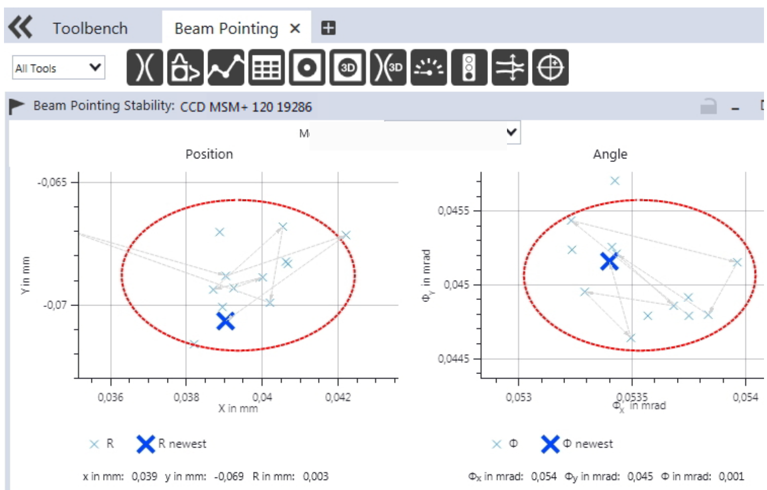
The process is visualized in the ***False-color Image*** tool.



Measuring beam pointing

While the indicator is rotating, the beam center and the angle are constantly determined.

The determined measuring points are displayed in the coordinates of the ***Beam Pointing Stability*** tool. The current position of the beam is marked with a large X, previous positions are marked with a small x.

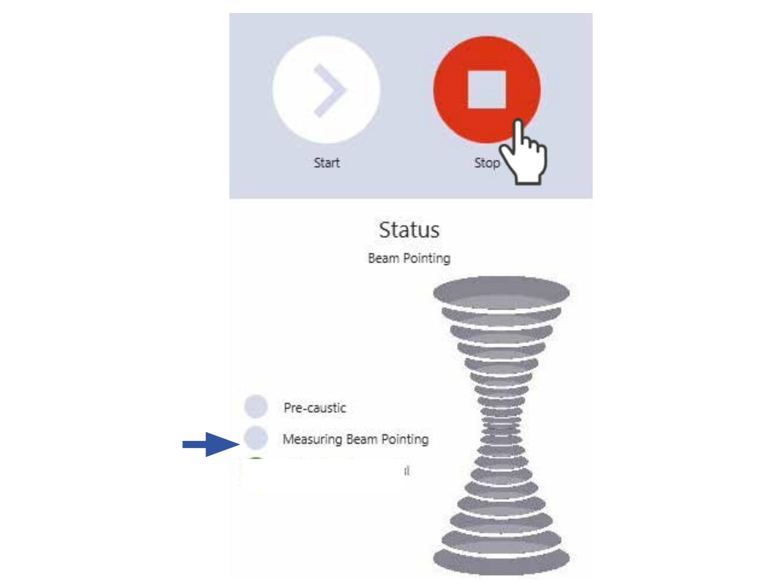


Completing measurement

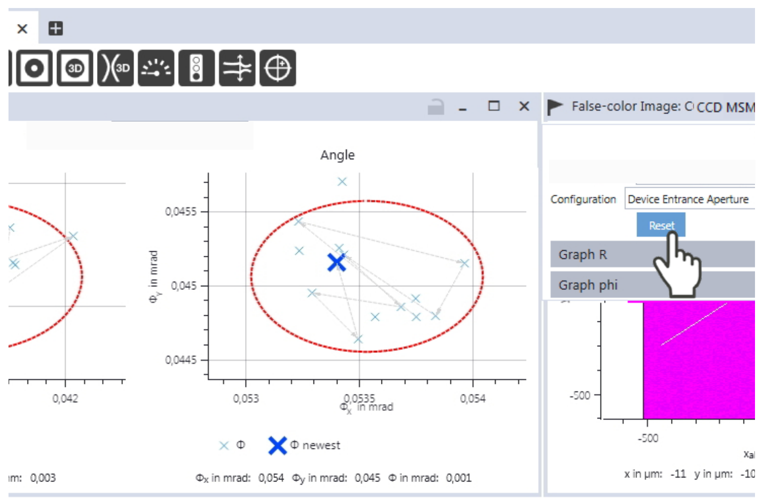
👁 When the beam pointing measurement is completed, the indicator ***Beam Pointing*** changes to green.

1. Click on the ***Stop*** button.

2. Switch off the laser.



You can reset the measured values in the ***Position*** and ***Angle*** windows by pressing the ***Reset*** button.



9.10 Fiber mode measurement

The measuring mode ***Fiber mode*** is - apart from one difference - identical to the measuring mode ***Manual caustic*** (see Chapter “9.7 Manual caustic measurement” on page 73).
The difference is that the axes are locked in the x and y direction, i.e. they cannot be moved.
In this mode, it is shown below the green start button that the axes are locked.
This measuring mode is available only for the MSM+ HB10. With the MSM + HB20, the movement in the x and y directions is always blocked.

Select this measuring mode instead of the ***Manual caustic*** measuring mode if you have installed a fiber bridge. Without locking the axes, damage to the fiber or the fiber holder can occur.

10 Troubleshooting

10.1 Error during a measurement

The following problems may occur during a measurement:
- an error during data transfer,
- a processor in the measuring system failed or
- there was an error during program execution.

Turn the device off and on.
If necessary, restart the computer.

Notice

Damaging/destroying the device

If the power supply of the MSM+ HB is disconnected and connected again, the device readjusts itself. This may cause the laser to destroy the device.

▶ **Always switch off the laser before restarting the MSM+ HB.**

10.2 No measurement signal at the MSM+ HB

If, apart from a noise level - with the MSM+ HB typically approx. 270 - 300 cts. - no measurement signal can be detected, check the device position. It may be helpful to use the alignment objective.
In addition to incorrect positioning, an attenuation that is selected too high can also lead to such a case.

11 Maintenance and service

11.1 Maintenance intervals

The operator is responsible for determining the maintenance intervals for the measuring device.
PRIMES recommends a maintenance interval of 12 months for inspection and validation.
If the device is used only sporadically, the maintenance interval can be extended up to 24 months.
Please note that the safety and warning functions of the device must be checked regularly.

11.2 Cleaning the device surface

You can remove light contamination with compressed air. Make sure that all device openings are closed.
For further cleaning, PRIMES recommends a mixture of distilled water and isopropanol in a ratio of approx. 5:1. Use lint-free cleaning cloths that do not scratch. This can be e.g. microfiber cloths or paper towels from the cosmetics sector.
If these steps are not sufficient, please contact PRIMES or your PRIMES distributor.

11.3 Spare parts

The following parts of the HighBrillance measuring objective can be cleaned or replaced during maintenance:

- Cyclone with alignment tool (order nr.: 801-007-008)
- Protective window in front of the power output opening (order nr.: 801-001-023)
- Beam splitter in the measuring objective (order nr.: 670-002-021)
- Optics tube (order nr.: 500-000-013)

Only use original PRIMES spare parts!

11.4 Exchange wear parts

Since the aperture at the beam inlet is directly accessible, it can be changed without any further preparatory measures.
To change the protective glass or the mirror, the measuring objective must be removed first.

The measuring objective is a high-quality, very sensitive component. Consult PRIMES before disassembling the measuring objective.
Dismantling of the measuring objective has to be carried out by a qualified person. The disassembly must be carried out in a clean room.
Always observe the following warning message

NOTICE

Damaging/destroying the device

Contamination and fingerprints on the protective window / mirror can lead to damage or shattering or splintering of the protective window during measuring operation.

- ▶ **Only replace the protective window in a dust-free environment.**
- ▶ **When exchanging the protective window wear powder-free latex gloves.**

11.4.1 Demount the measuring objective

1. Turn off the voltage supply.
2. Turn off the cooling water.
3. Mount the inlet aperture cover at the beam entrance aperture.
4. Turn off the compressed air supply.
5. Disconnect the cooling water pipes at the quick connect couplings.
6. Seal cooling water pipes.

7. Remove compressed air hose from the connection for the housing flushing.
8. Remove the fastening screws (see Fig. 11.2 on page 91).
9. Remove measuring objective
10. Dry and clean the measuring objective.

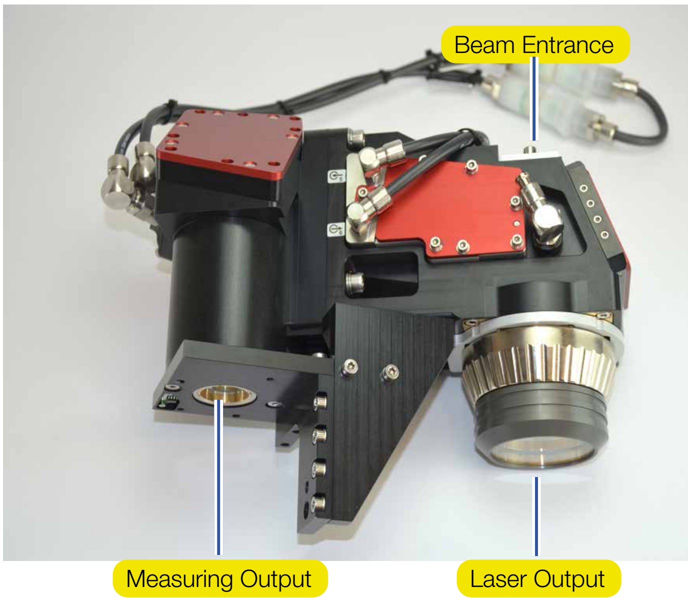
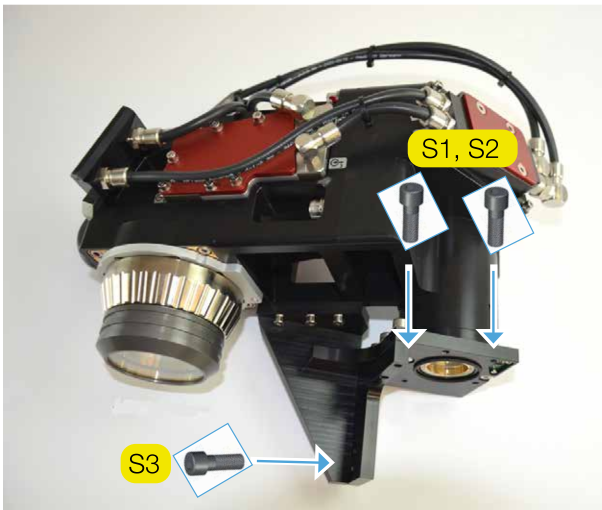


Fig. 11.1: Openings of the measuring objective (foto shows MSM+ HB10)



The objective is fastened at the device by means of three screws. The two screws S1 and S2 (M3x16, AF 2.5 mm) are required for the fastening of the objective on the device surface.

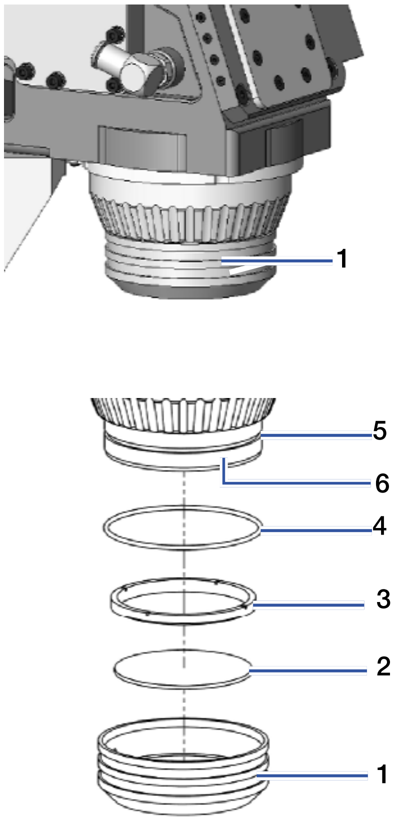
Another screw S3 (M5 x 15, AF 4 mm) fastens the upright of the device laterally.

Fig. 11.2: Screws to fasten the objective

11.4.2 Exchange protective window in front of the power output aperture

- Observe the warning messages above.
- Keep the protective window free from contaminations.
- Do not touch the plane surface of the protective window when putting it in!

The protective window protects the optical elements behind it from contaminations. A polluted protective window does not affect the function of the measuring objective. However, the increased scattering of the laser light leads to a heating up of the protective window and the housing which can finally result in the destruction of the protective window itself. This can damage sensitive optical components in the measuring objective. Therefore, a contaminated protective window has to be exchanged immediately.



Components:

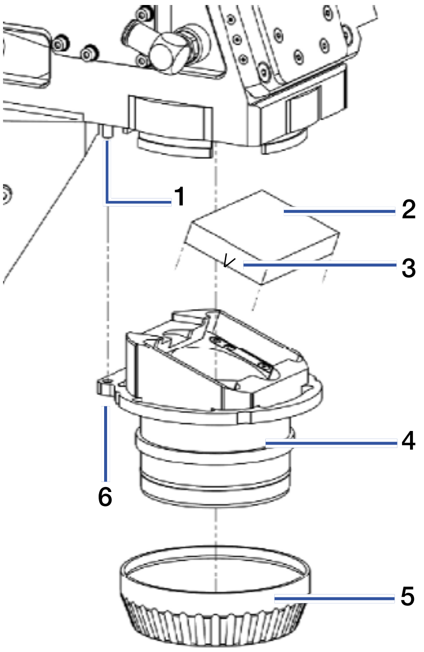
1. Protective window retainer
2. Protective window
3. Ring nut
4. O-ring 60.08 x 1.78
5. Nut for O-ring (4)
6. Optics tube

1. Carefully remove the protective window retainer (1).
2. Check O-ring (4) in the nut (5) for damages and a tight fit. If necessary, it has to be replaced.
3. Remove the ring nut (3) from the protective window retainer by means of the screw-in tools.
4. Take the protective window (2) out of the protective window retainer and replace it by a new protective window.
5. Screw the ring nut back in the protective window retainer.
6. Position the protective window retainer back on the optics tube.

Fig. 11.3: Change of the protective glass in front of the power output opening (on a 10 kW unit)

11.4.3 Exchange beam splitter

Observe the warning messages at the beginning of this chapter.



Components:

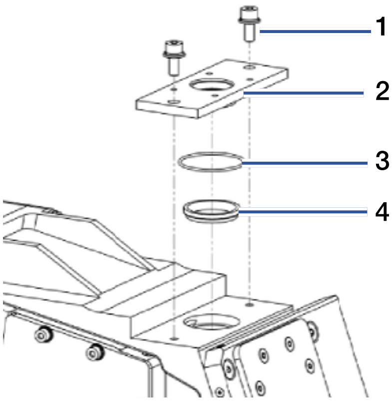
1. Cylinder pin ISO 2338 m6 4x12
2. Beam splitter
3. Labeling “Arrow” has to point downwards.
4. Optics tube
5. Coupling ring
6. Drilling

1. Remove protective window retainer, see previous chapter.
2. Remove coupling ring (5).
3. Pull optics tube (4) out of the housing.
4. Remove the beam splitter (2).
5. Clean the beam splitter thoroughly. A new beam splitter has to be cleaned before it can be built in as well.
6. Turn the beam splitter until the arrow (3) on its side points downwards, see figure.
7. Put in the beam splitter carefully.
8. Push the optics tube back into the housing. The pin (1) has to be pushed into the drilling (6).
9. Screw the coupling ring on manually.
10. Check the protective window in the protective window retainer for contaminations. If necessary, it has to be replaced (see the previous chapter).
11. Mount the protective window retainer.

Fig. 11.4: Exchanging beam splitter

11.4.4 Change aperture at the beam entrance

Observe the warning messages above

<table>
<tr>
<td>
</td>
<td>

Required tools:
Allen wrench, SW 3

Components:
1 Cylinder head screw ISO 4762 M4x10
2 Aperture
3 O-ring 21,95 x 1,78
4 Centering ring (option)

1. Unscrew two cylinder head screws (1) with spring lock washer and washer.
2. Remove the aperture (2) .
3. Check O-ring (3) for damage and replace if necessary.

Important!
The mounting holes in the aperture have a tolerance to center the aperture. A centering ring (4) can be used as a positioning aid.

4. Put on the new aperture with O-ring and center it.
5. Fasten aperture with two cylinder head screws (1)

</td>
</tr>
</table>

Fig. 11.5: Changing the aperture at the beam entrance

12 Measures for the product disposal

As a B2B device, this PRIMES measuring device is subject to the European Waste Electrical and Electronic Equipment (WEEE) Directive and the corresponding national laws. The WEEE directive obliges the operating company to dispose of the device in an environmentally sound manner, not with household waste, but in a separate WEEE collection.

PRIMES gives you the opportunity to return your PRIMES measuring device for free disposal within the scope of the Waste of Electrical and Electronic Equipment (WEEE Directive). This service does not include shipping costs. You can send PRIMES measuring devices to be disposed of within the EU to our address:

PRIMES GmbH
Max-Planck-Str. 2
64319 Pfungstadt
Germany

If you are located outside the EU, please contact your local PRIMES distributor to discuss the disposal procedure for your PRIMES measuring device.

PRIMES is a registered manufacturer in the German “Used Appliances Register“ stiftung elektro-altgeräte register (stiftung ear). Our number is: WEEE-reg.-no. DE65549202.

13 Declaration of conformity

Original EG Declaration of Conformity

The manufacturer: PRIMES GmbH, Max-Planck-Straße 2, 64319 Pfungstadt, Germany,

hereby declares that the device with the designation:

MicroSpotMonitor (MSM)

Types: MSM 35; MSM 120; MSM-HP
MSM+ 35; MSM+ 120; MSM+ HB10; MSM+ HB20

is in conformity with the following relevant EC Directives:

- Machinery Directive 2006/42/EC
- EMC Directive EMC 2014/30/EU
- Low voltage Directive 2014/35/EU
- Directive 2011/65/EC on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment
- Directive 2014/32/EC on measuring instruments

Authorized for the documentation:
PRIMES GmbH, Max-Planck-Straße 2, 64319 Pfungstadt, Germany

The manufacturer obligates himself to provide the national authority in charge with technical documents in response to a duly substantiated request within an adequate period of time.

Pfungstadt, August 5, 2020

Dr. Reinhard Kramer, CEO

UKCA Declaration of Conformity

The manufacturer: PRIMES GmbH, Max-Planck-Straße 2, 64319 Pfungstadt, Germany,

hereby declares that the device with the designation:

MicroSpotMonitor (MSM)

Types: MSM 35; MSM 120; MSM-HP
MSM+ 35; MSM+ 120; MSM+ HB10; MSM+ HB20

is in conformity with the following relevant UK Regulations:

- Supply of Machinery (Safety) Regulations 2008
- Electromagnetic Compatibility Regulations 2016
- Electrical Equipment (Safety) Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012
- Measuring Instruments Regulations 2016

Authorized for the documentation:
PRIMES GmbH, Max-Planck-Straße 2, 64319 Pfungstadt, Germany

The manufacturer obligates himself to provide the national authority in charge with technical documents in response to a duly substantiated request within an adequate period of time.

Pfungstadt, October 11, 2021

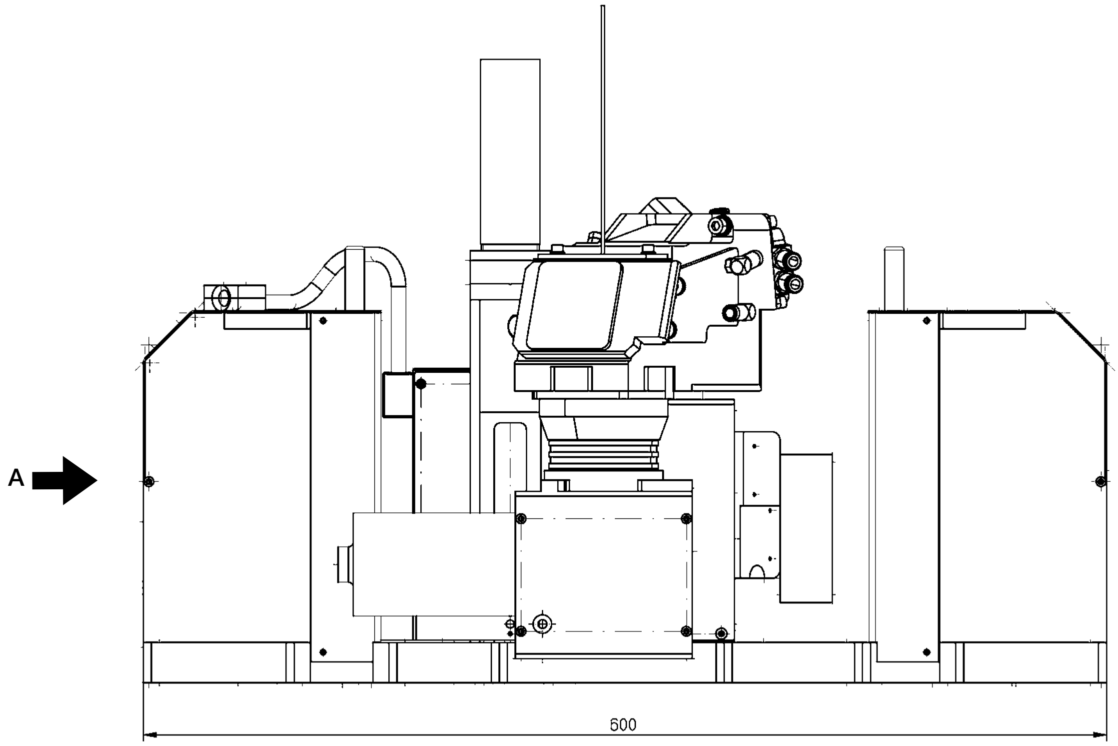
Dr. Reinhard Kramer, CEO

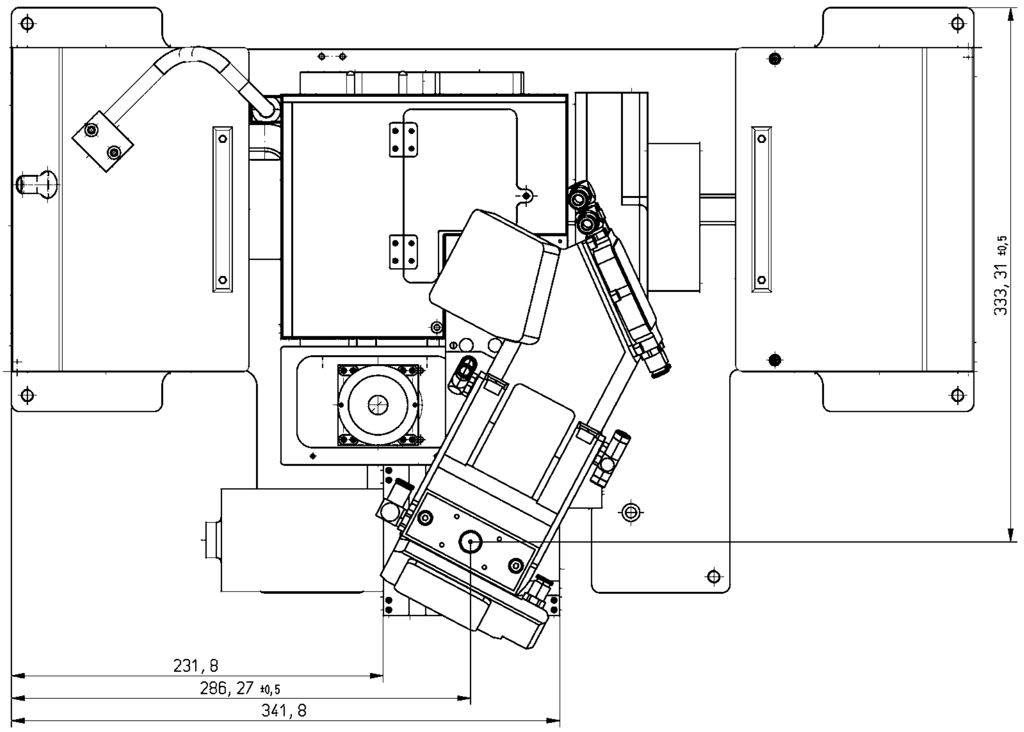
14 Technical data

	MSM+ HB10	MSM+ HB20
Characteristics Measurement		
Max. medium power Singlemode Multimode	 5 kW 10 kW	 10 kW 20 kW
Beam diameter	20 µm - 1000 µm	
Wavelength range	1000 nm - 1100 nm	
Admissible wavelength range of the laser light	1025 nm - 1080 nm	
Admissible measuring range	$\pm 3z_R$	
Design wavelength	1064 nm	
Magnification (using MO)	4,5	
Max. input-NA	0.11	
Max. energy density on the 1. optical surface at 10 ns	on request	
Max. energy density on the 1. optical surface (cw-mode)	on request	
Max. traverse range	120 mm	40 mm
Max. trav. range with fiber bridge/QBH	106 mm	26 mm
Max. trav. range with fiber bridge/HLC-16	118 mm	38 mm
Max. trav. range with fiber bridge/LLK-D	120 mm	40 mm
Supply data		
Supply voltage, DC	24 V ± 5 %	
Max. current consumption	1.8 A	
in standby mode	0.4 A	
Recommended cooling water flow rate	0.7 l/min/kW	
Min. cooling water flow rate	5 l/min	10 l/min
Cooling water temperature T_{in}	dew-point temperature < T_{in} < 30 °C	
Maximum water inlet pressure	4 bar	
Hose diameter	12 mm	16 mm
Compressed Air Pressure	0.5 bar - 1.0 bar	
Maximum Pressure	2 bar	
Specification of compressed air	ISO 8573-1: 2010 [6:4:4]	
Hose diameter	6 mm	
Communication		
Ethernet	100 Mbit/s	
Safety circuit (Interlock)		
Measures and weight		
L x W x H (without cables and plugs)	600 x 401 x 388	727 x 400 x 385
Weight, approx.	35 kg	42 kg
Environmental conditions		
Service temperature range	+15 °C ... +40 °C	
Storage temperature range	+5 °C ... +50 °C	
Reference temperature	+ 22 °C	
Admissible relative air humidity (non-condensing)	80 %	

15 Dimensions

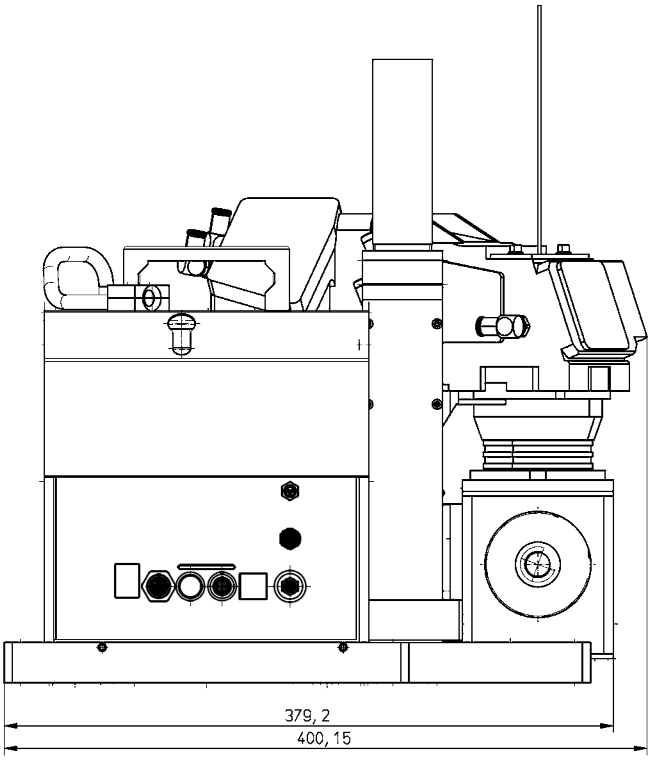
15.1 Dimensions of the MSM+ HB10



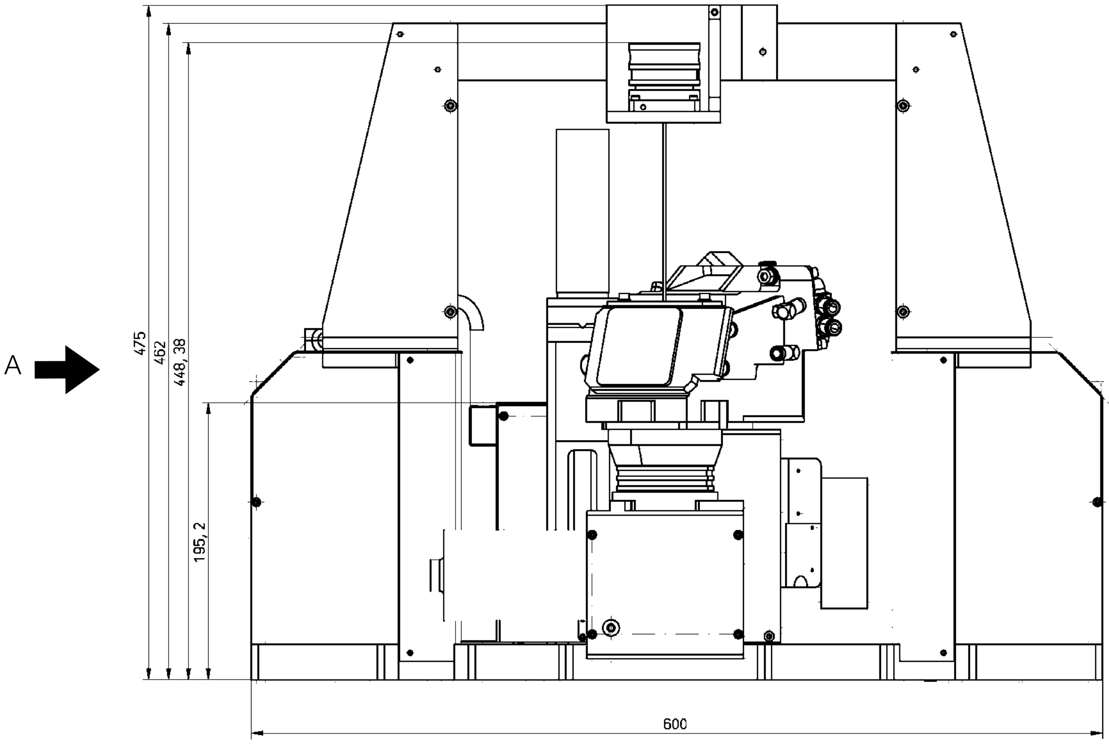


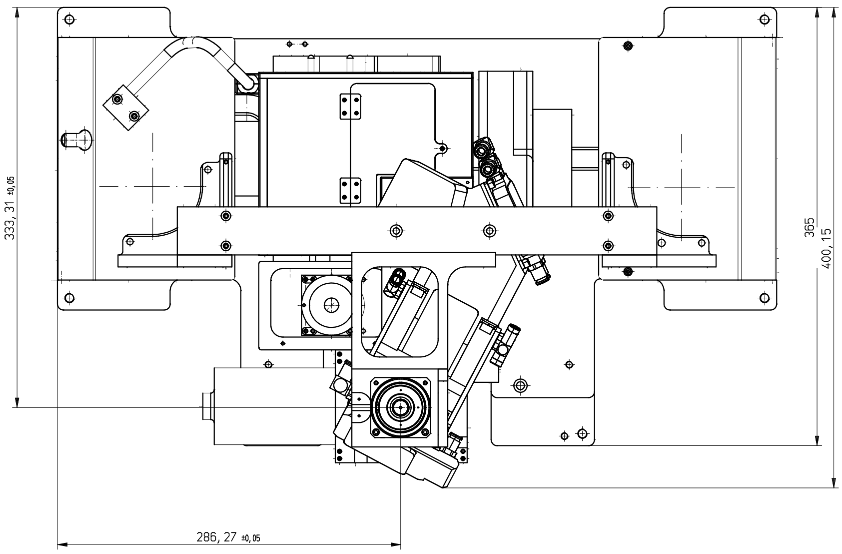
Dimensions of the MSM+ HB10 (continued)

View A



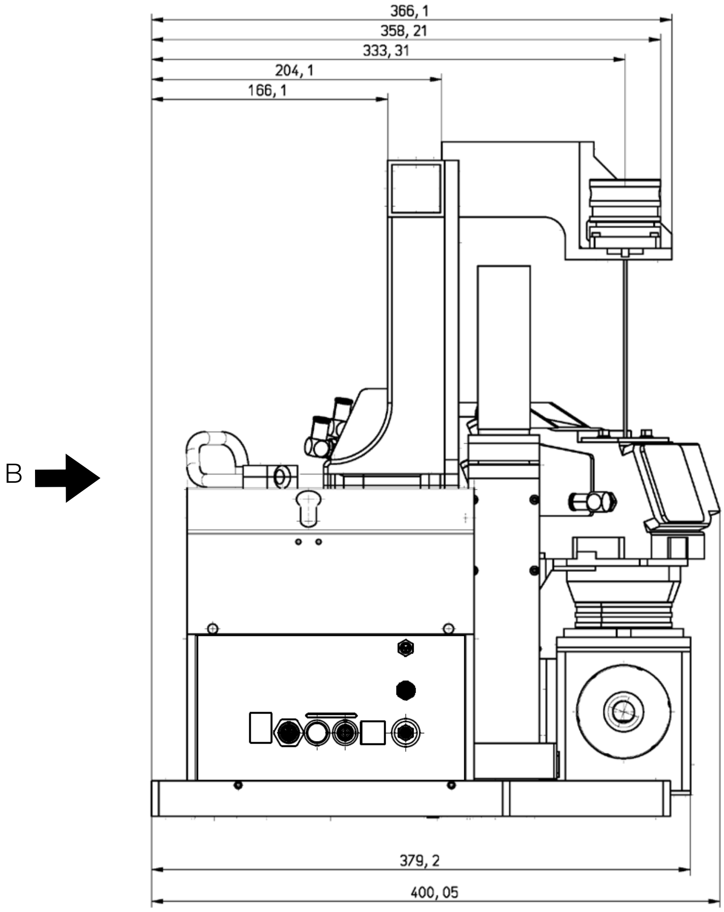
15.2 Dimensions of the MSM+ HB10 with fibre bridge





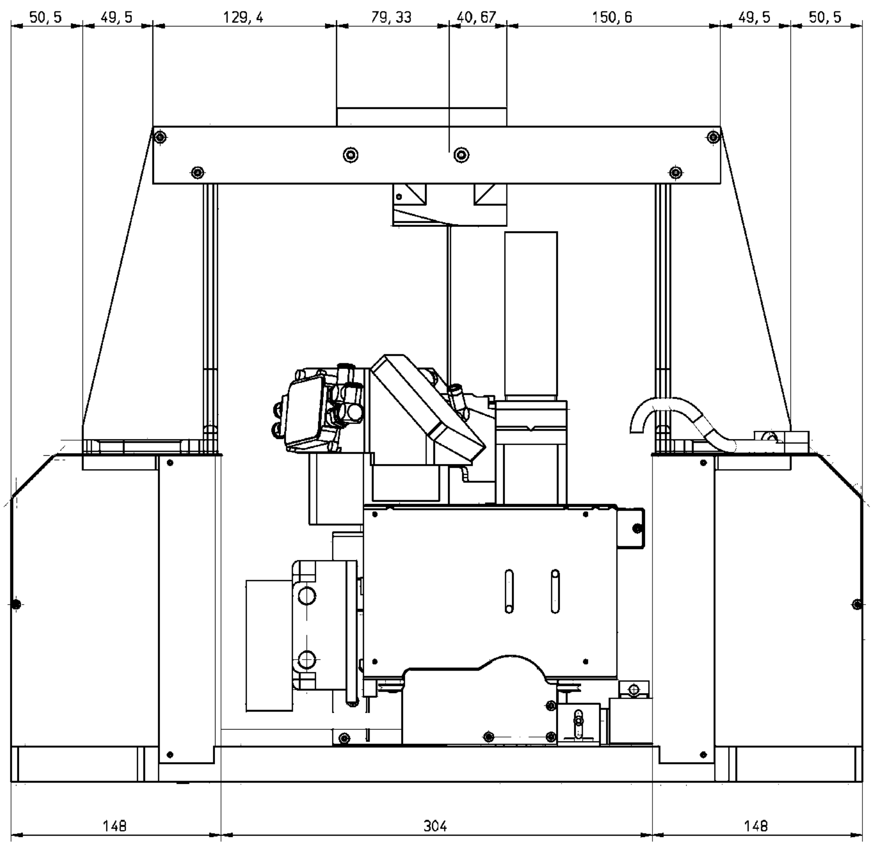
Dimensions of the MSM+ HB10 with fibre bridge (continued)

View A

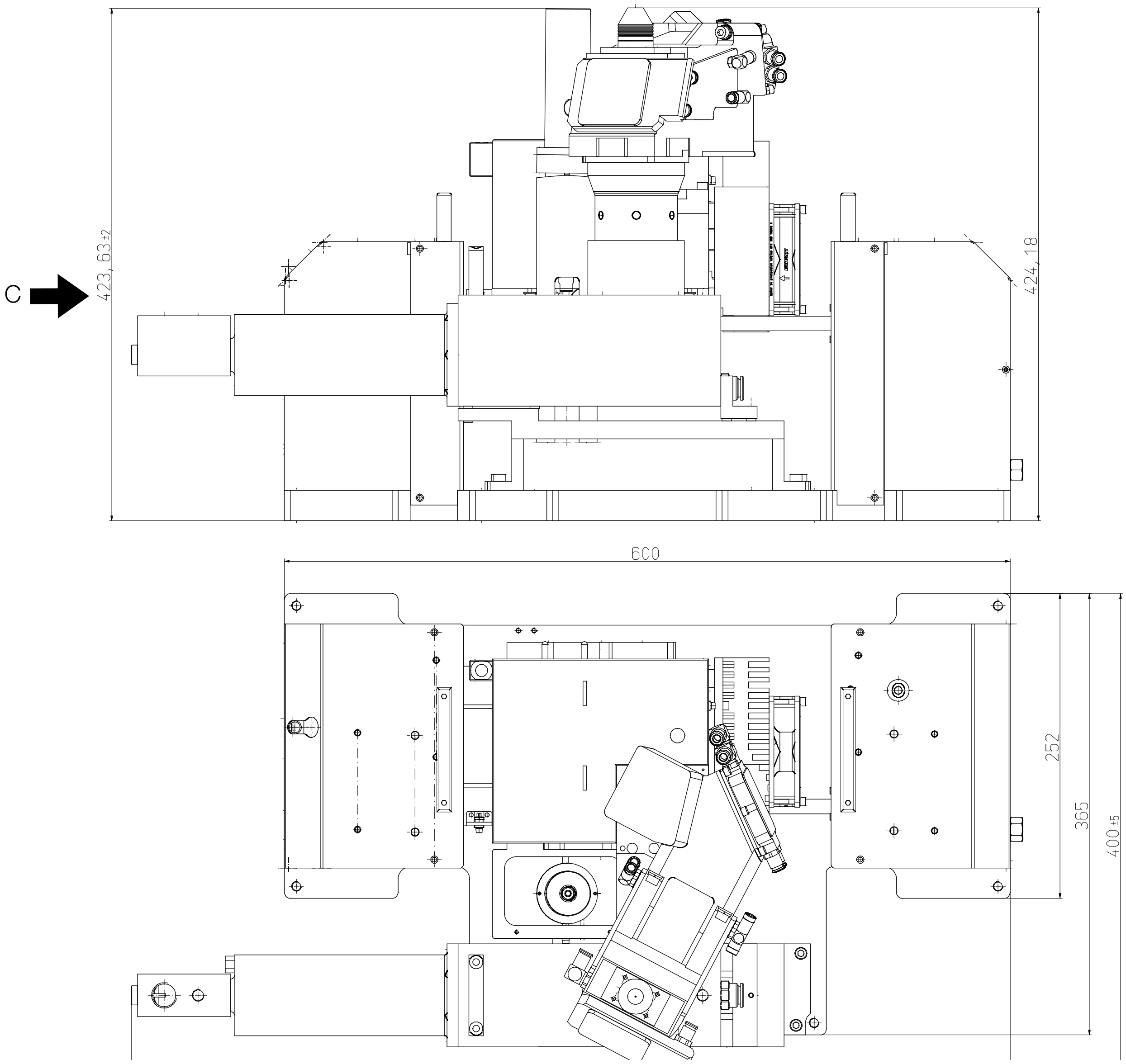


Dimensions of the MSM+ HB with fibre bridge (continued)

View B

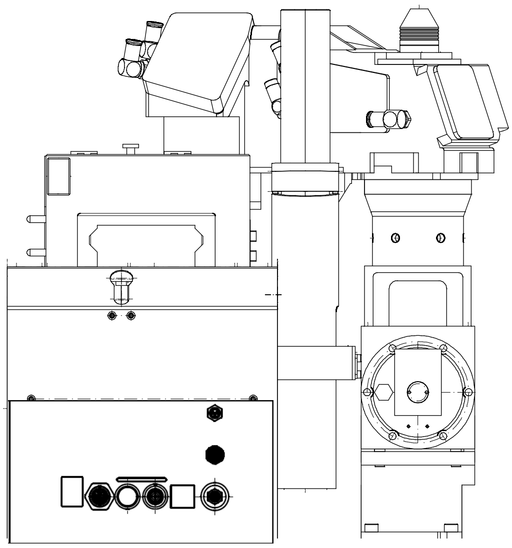


15.3 Dimensions of the MSM+ HB20 (at z_{max})

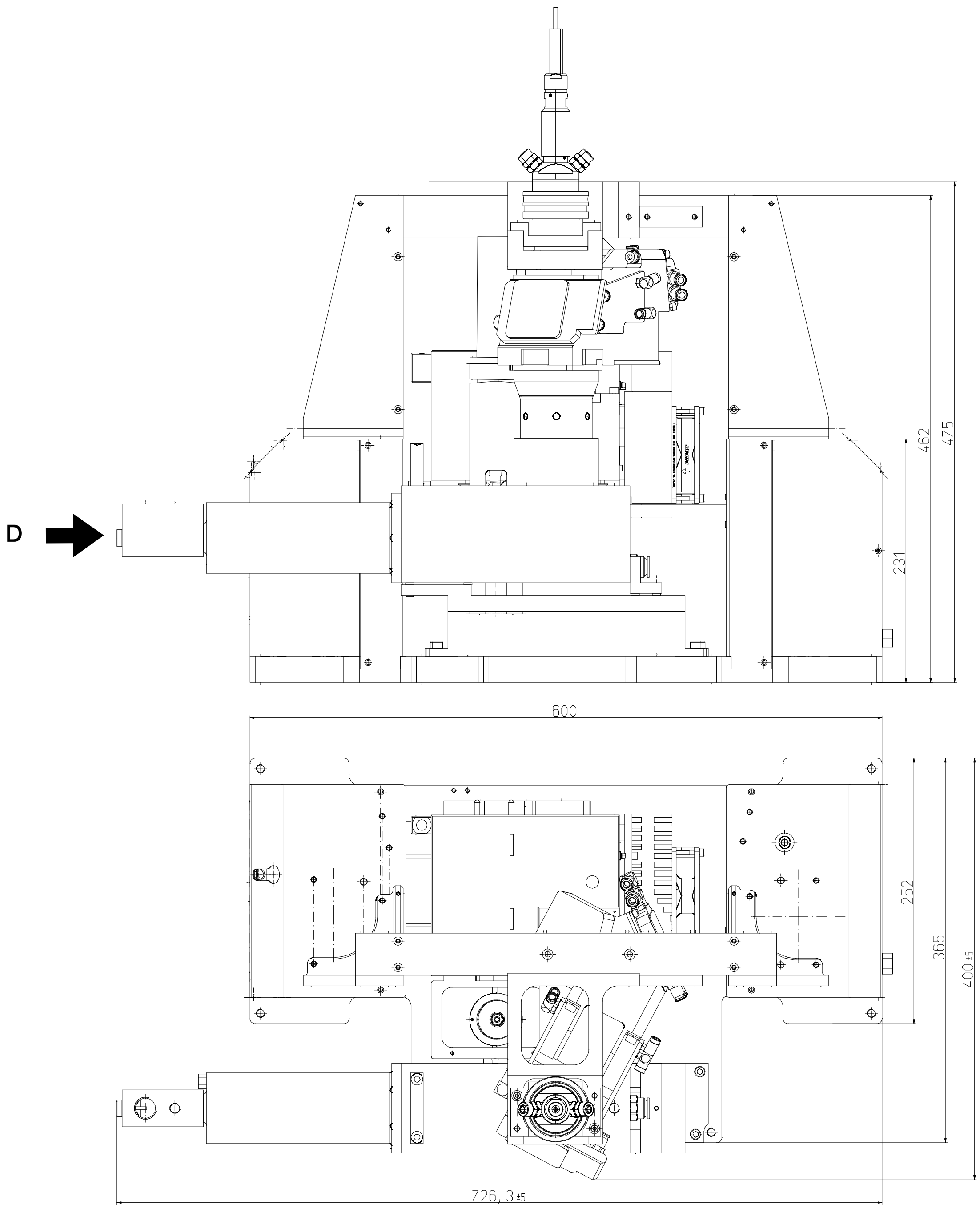


Dimensions of the MSM+ HB20, continued)

View C

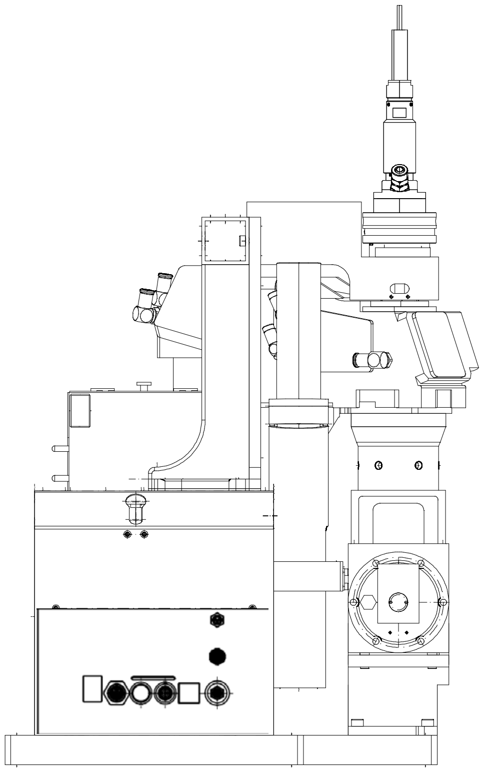


15.4 Dimensions of the MSM+ HB20 with fibre bridge (at z_{max})



Dimensions of the MSM+ HB20 with fibre bridge (continued)

View D



16 Appendix

16.1 Appendix A: GNU GPL license notice

The software of this product contains software code that is licensed subject to the GNU General Public License (GPL) Version 2 or later. The license terms of the GNU GPL Version 2 or later are available on the following websites:

- https://www.gnu.org/licenses/old-licenses/gpl-2.0.en.html
- https://www.gnu.org/licenses/licenses.en.html

16.2 Appendix B: Using a PLM for power measurement

The PowerLossMonitor PLM is a system that determines power losses within water-cooled optical systems. The PLM measures the flow rate as well as the temperature increase of the cooling water between inlet and outlet. Based on this data, the absorbed power is calculated.

16.2.1 Cooling water connection

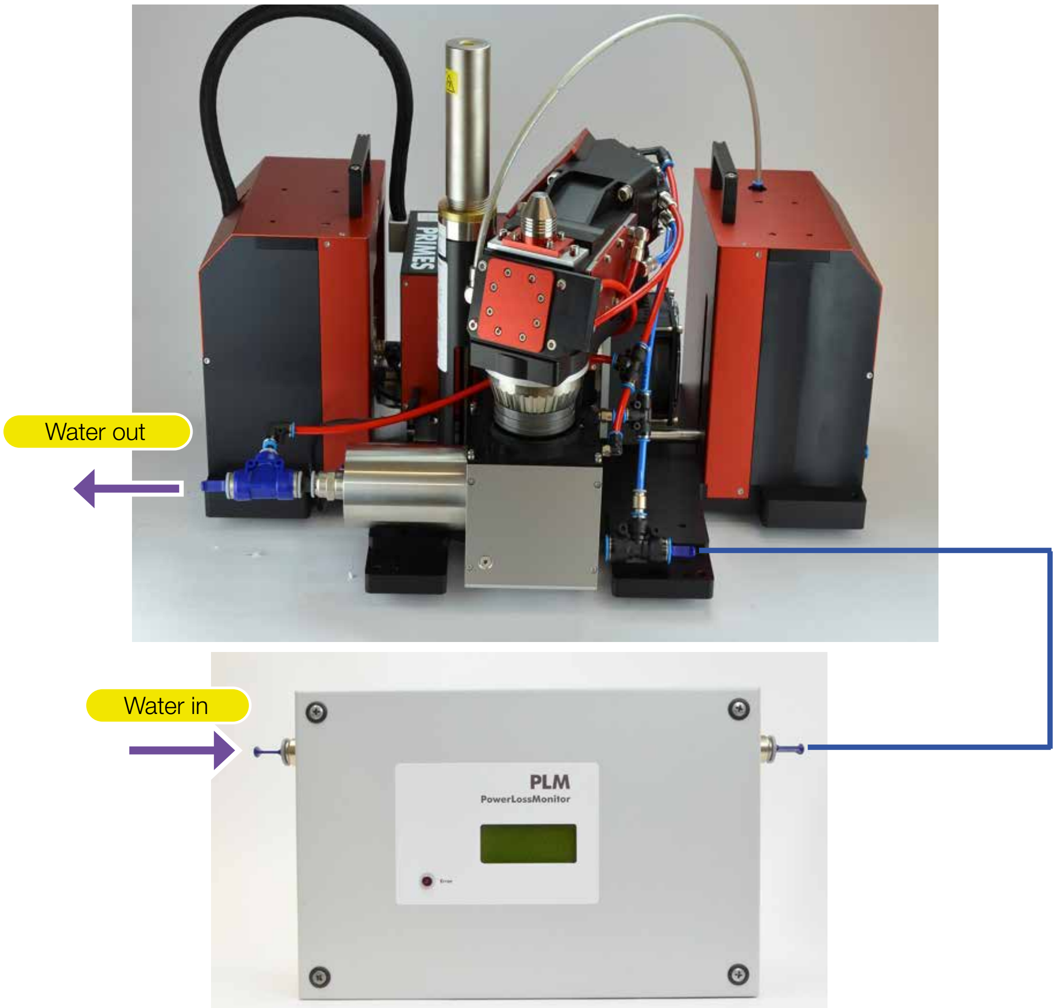


Fig. 16.1: Water connection (Figure shows PLM with MSM+ HB10)

The PowerLossMonitor PLM measures the laser power absorbed within the water-cooled absorbers of the MSM+ HB. As the PLM is calibrated along with the MSM+HB including all connecting hoses, using the provided hose during measurement is mendatory.

Connect the water supply acording to Fig. 16.1:

1. Connect water in to PLM.
2. Connect water out at PLM to water in at MSM+ HB, using the supplied hose.
3. Connect water out at MSM+ HB to cooling.
   In the case of an MSM+ HB10, the temperature sensor embedded in a T-adapter must be installed between the MSM+ output and the chiller.

The lengths of the hose has an influence on the time constants of the measuring device. Only use the hose supplied!

16.2.2 Electrical connections

Connect USB

Connect the USB port of the PLM to the PC or network using the supplied USB-cable.

Connect temperature sensor

- MSM+ HB10:
  Install the temperature sensor, which is integrated within a T-adapter, between the MSM+ output and the chiller
- MSM+ HB20:
  Connect the permanently mounted temperature sensor cable (black cable on the water return of the MSM+ HB20) to the PowerLossMonitor PLM

Connect interlock

Connect the interlock of the PowerLossMonitor PLM to the Safety-Circuit-PLM-In of the MSM+ HB. For this purpose, use the enclosed 8-pin cable which is pre-assembled on both sides.

16.2.3 Transport or storage of the PowerLossMonitor PLM

The cooling circuit of the PLM must be drained completely before transport or storage. Temperatures close to or below freezing point can lead to damages due to the formation of ice, if the cooling circuit is not completely drained.

NOTICE

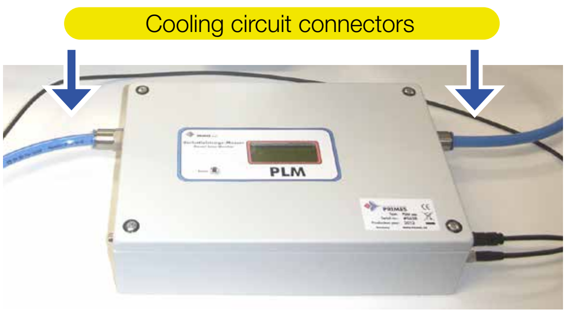
Damage of the turbine

The turbine is not designated for high rotational speed.

▶ **Do not use compressed air to drain the cooling circuit of PLM.**

Unlike the MSM+ HB, the cooling circuit of the PLM is not allowed to be drained with compressed air.

1. Remove cooling circuit hoses.
2. Drain the cooling circuit completely.
3. Seal the connectors of the cooling circuit using the enclosed plugs.



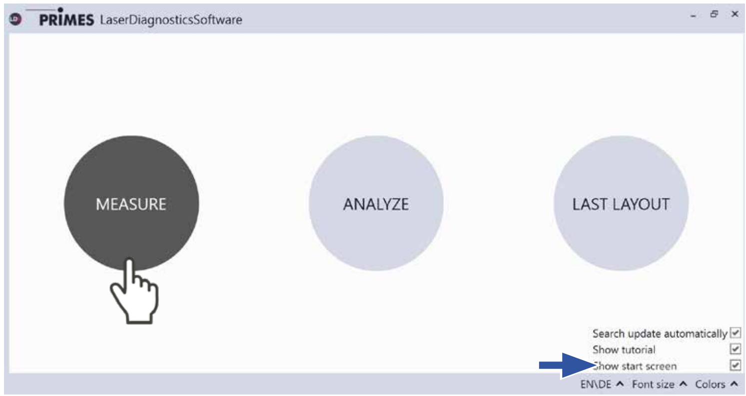
16.2.4 Measurement with PLM

Observe the sequence when setting up the connection with the LaserDiagnostics software LDS.
Only then the LDS integrates the results of the power measurement into the results of the MSM+ HB measurement. This means that the actual power is stored to every single plane.
Otherwise, the LDS considers the two devices as two completely independent devices.

1. Start the LDS

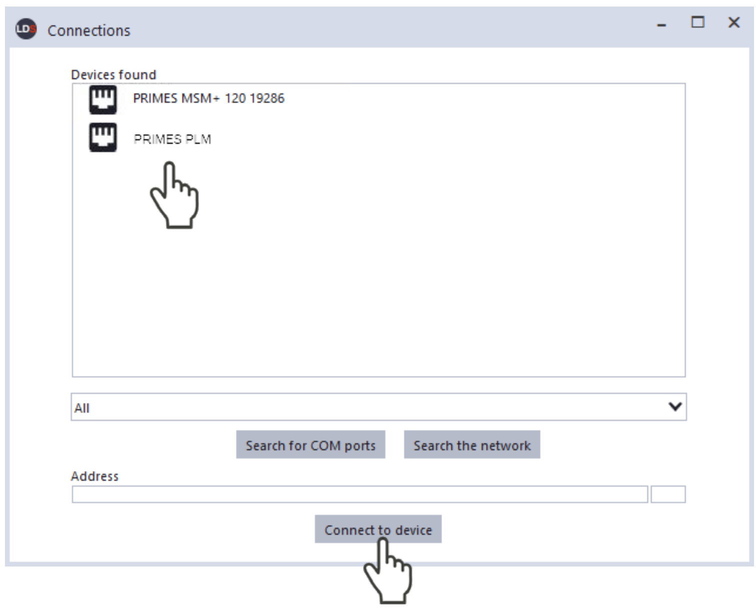
👁 The start screen appears.

2. Select the ***Measure*** operating mode.



👁 The ***Connections*** window appears.

3. First click on the power meter.
4. Click on the button ***Connect to device.***
5. Then click on the MSM+ HB.
6. Click on the button ***Connect to device*** again.



Start the cooling approx. 2 minutes before the start of the measurement and stop it approx. 1 minute after the end of the measurement operation.
Only cool the device during measurement operation. The number of operating hours has an impact on the service life of the turbine in the PowerLossMonitor PLM.

16.3 Appendix C: Measuring pulsed irradiation

16.3.1 Trigger operation

The dynamic range of the CCD sensor in the camera housing is extended by means of a variable integration time control. The integration time can be freely determined in the range between 6 µs and 225 ms, or it can be set automatically (for this purpose, activate the ***Autom. exposure*** option in the ***Settings*** tab of the ***Single planes*** measuring mode.

If the automatic exposure is enabled, then the software will automatically – using a series of pre-measurements – set the integration time at which the output signal of a pixel in the array is too high. The optimal integration time will then be a little below that.

By means of the variable integration time control, not only cw laser beams but also a multitude of pulsed beams can be measured in quasi-cw operation. An exception are, for example, laser beams with a very low pulse frequency. For measuring such beams, the trigger operation is available in the measuring modes ***Single planes*** / ***Manual caustic*** / ***Automatic caustic***. If this is enabled, the device only measures within defined time periods. The laser pulse or the corresponding trigger signal marks the beginning of such a period and the (freely adjustable) integration time marks its end.

Fig. 16.2 shows that in addition to the trigger signal and the integration time, a further variable intervenes in the sequential control of the CCD sensor: the trigger delay. It indicates the time period between the trigger signal and the start of the integration time.

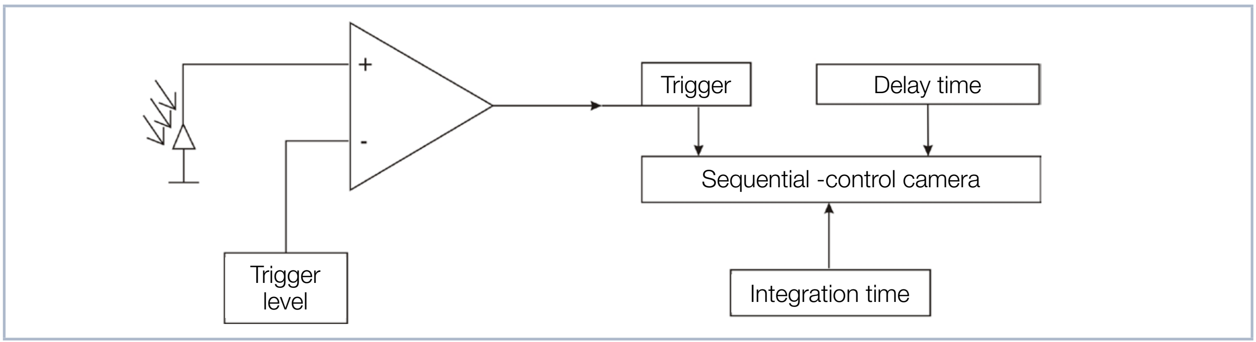


Fig. 16.2: Options for affecting the sequence control of the CCD sensor

A measurement can be triggered internally or externally. Internal signals are triggered by the photodiode integrated in the device. Externally triggered signals enter the device via a BNC socket. You can freely determine the threshold value of the internal trigger signal (trigger level).

Every measurement consists of a dark measurement and a measurement with photo transfer. This applies for trigger operation as well as cw / quasi-cw operation. This means that each measurement requires at least two trigger signals.

The following time constants apply:

Timeout:	2 sec (Standard)
Minimum integration time:	6 µs
Maximum integration time:	225 ms
Minimum delay:	12 µs
Maximum delay:	400 ms

16.3.2 Measuring configuration selection

There are various measuring options to differentiate between:

- Measuring a single plane or a caustic
- Measuring a complete pulse or just a single section
- Measuring with freely adjustable integration time or with automatic integration time control
- Measuring in trigger operation or quasi-cw operation
- Variations of optimal integration time caused by changing the attenuation

Combining these measurement options with the following pulse parameters provides numerous possibilities:

- Pulse duration: fs – ms
- Pulse frequency: 1 Hz – 1 kHz

The following merely describes a rough structure that is intended to help in choosing measuring settings.

16.3.3 Influence of the pulse parameters on the integration time control

The software-operated integration time control always assumes that there is a cw laser beam.
This may cause quantization of the integration time for slow pulse lasers (< 500 Hz) or lasers with high pulse energy (integration time very short). Tab. 16.1 And the diagram in Fig. 16.3 on page 112 illustrates this.

Pulse frequency	**Number of detected pulses**	
in Hz	at maximum integration time 225 ms	at integration time 1 ms
1	0	0 – 1
5	1	0 – 1
10	2	0 – 1
50	11	0 – 1
100	22	0 – 1
200	45	0 – 1
500	112	0 – 1
1 000	225	1 – 2
2 000	450	2 – 3
5 000	1 125	5.00
10 000	2 250	10.00

Tab. 16.1: Number of detected pulses in correlation with the integration time and pulse frequency

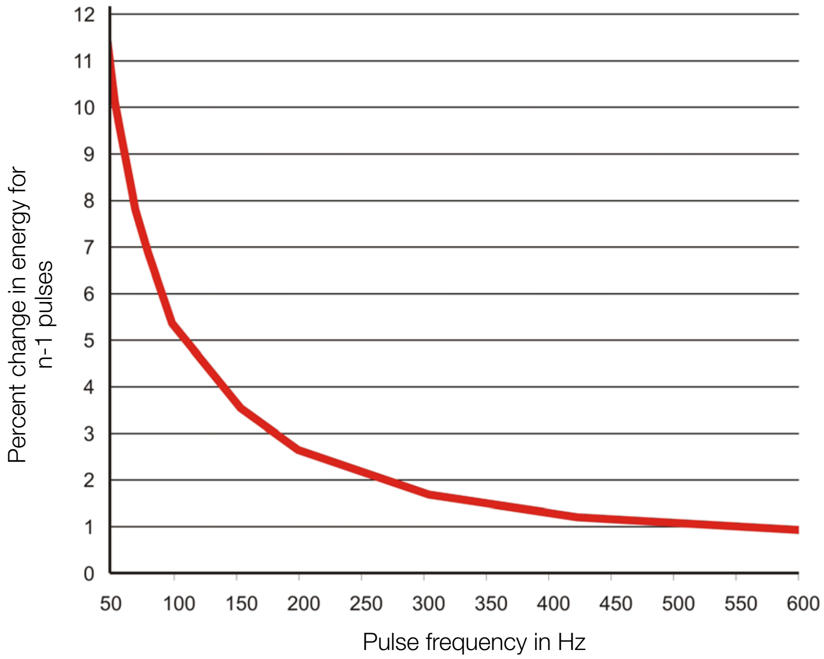


Fig. 16.3: Percentage of change in the detected energy when exactly one pulse is left out, in correlation with the pulse frequency

Tab. 16.1 shows the number of detected pulses during the maximum integration time and during an integration time of 1 ms for different pulse frequencies. Quantization with low pulse frequencies is clearly illustrated in the column for the maximum integration time. While 2 250 pulses are detected at a pulse frequency of 10 kHz, at 10 Hz there is only one or no more than two.

If the signal level is too high during a measurement at 10 Hz pulse frequency and the software tries to adjust the integration time, there are only three possible results. The energy application for a measurement remains the same, it decreases by 50 %, or it drops to zero. These increments are less significant at a pulse frequency of 10 kHz. This correlation is shown in general terms in Fig. 16.3 on page 112. It can be seen that from a pulse frequency of 500 Hz, the minimum jump with a reduction of the integration time is 1 %.

Small pulse frequencies aren't the only thing that will cause quantization though. If the pulse energy is very high and it isn't possible to further increase the attenuation, the integration times will be smaller. In Tab. 16.1, an integration time of 1 ms is added to the maximum integration time. In this case, a pulse frequency of 500 Hz is not sufficient in order to quasi continuously control the energy application for each measurement through integration time control.

A total of four states can always be differentiated on the way from low to high pulse frequencies or from short to long integration times. This is demonstrated by the following example for measuring pulsed irradiation during quasi-cw operation.

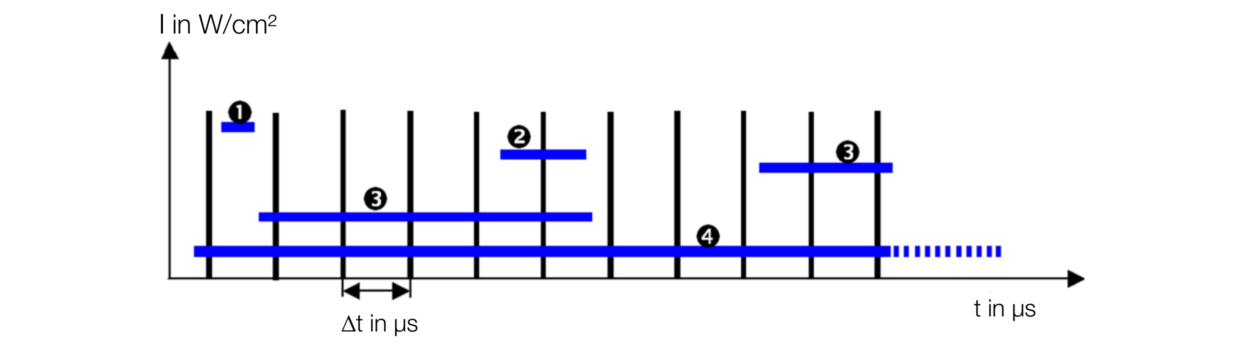


Fig. 16.4: Measuring with different integration times

❶	12 – 200 µs:	Sporadic measuring of pulses
❷	200 – 400 µs:	1 pulse
❸	200 – 2 ms:	Quantization noise cause by a varied number of pulses
❹	2 – 200 ms:	Virtually continual integration time control

Fig. 16.4 shows pulsed irradiation. The pulse pauses are 200 µs. The required integration time of the sensor correlates directly with the intensity of the laser beam.

If it is smaller than the pulse pause as in case 1, statistically there is a maximum of 1 pulse in the measurement. The probability that a pulse is present during each measurement for integration time control as well as during the actual measurement is low.

If the optimal integration time falls exactly between the simple and double duration of the pulse pause, there will always be just one pulse in each measurement (case 2). This is the perfect state for measuring on one plane. The caustic can also be measured with this setup. Here it is important to make sure that the signal saturation for the measurement in the focus is as high as possible. Only then is it possible to ensure that there is a sufficient S/N ratio when measuring a plane far outside of the focus.

Case 3 describes the case in which the integration time ranges between the single and tenfold duration of the pulse pause. Within this range, every pulse is more or less noticeable as a clear signal jump during the integration time. Integration time control is only possible with quantization. The measuring results often have a bad S/N ratio or the signal level is too high.

If the integration time increases even more, the signal jumps become flatter. Integration time control operates quasi continuously (case 4). The laser being measured can now be measured as a cw laser.

The neutral-density filters, which can be inserted into the optical path, make it possible to always work within the desired range 1 to 4.

In addition, trigger operation is available for the device. Together with the integration time control and a delay time control, measurements can also be made reliably in case 1.

These four cases can generally be sorted into two groups. Case 1 and 2 must be measured in trigger operation. Case 4, however, is best measured in quasi-cw operation. Case 3 should be avoided altogether by choosing a suitable filter.

The diagram in Fig. 16.5 shows a classification of laser beams to be measured with regard to the suitable operation mode.

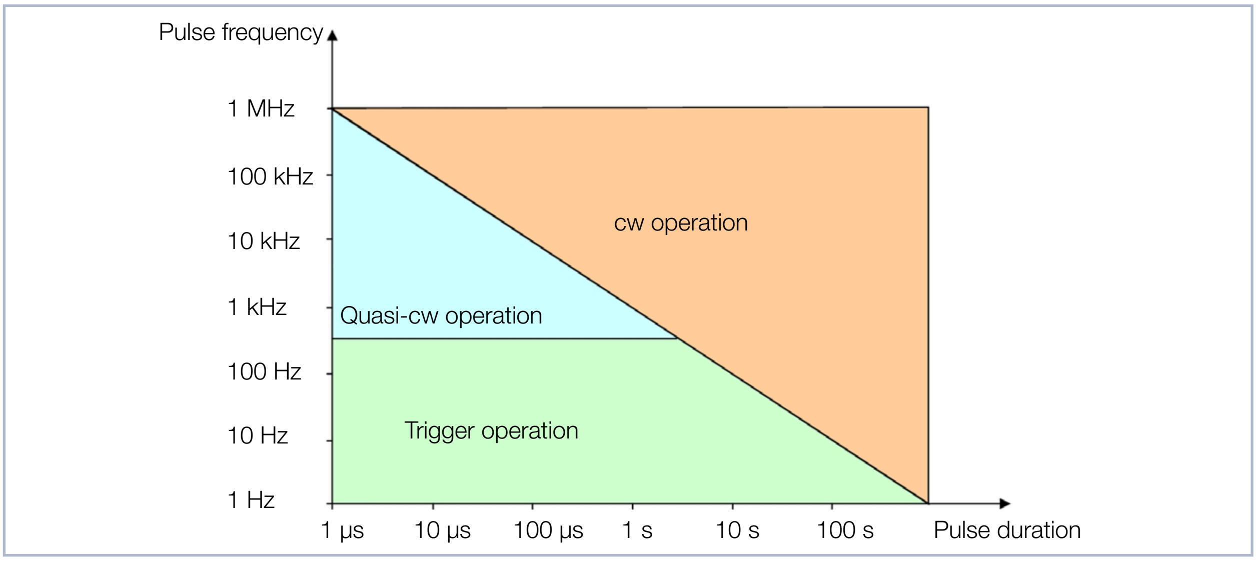


Fig. 16.5: Selection of the appropriate measurement mode based on laser parameters

For the blue field laser beams, the quasi-cw operation is most suitable. However, be aware that as the pulse frequency decreases, the required integration time increases to ensure the quasi-cw case. As a rule of thumb, the integration time of a focal plane measurement should be approximately the same as the time for 35 pulses. If the laser beam to be measured falls below a pulse frequency of approx. 500 Hz, you should switch to trigger operation.

While it is almost always possible to measure with the integration time control in the cw or quasi-cw operation, it only makes sense to use it for very long pulse durations (>1 ms) in trigger operation. With the help of the attenuation filters, the integration time is adjusted in such a way that it is only a fraction of the pulse duration. The trigger signal will then merely specify to the device the starting time for the measurement. The integration time may increase or decrease during the course of the caustic measurement without leaving the pulse path (see Fig. 16.6 and "Example 2: very long pulse duration" on page 115).

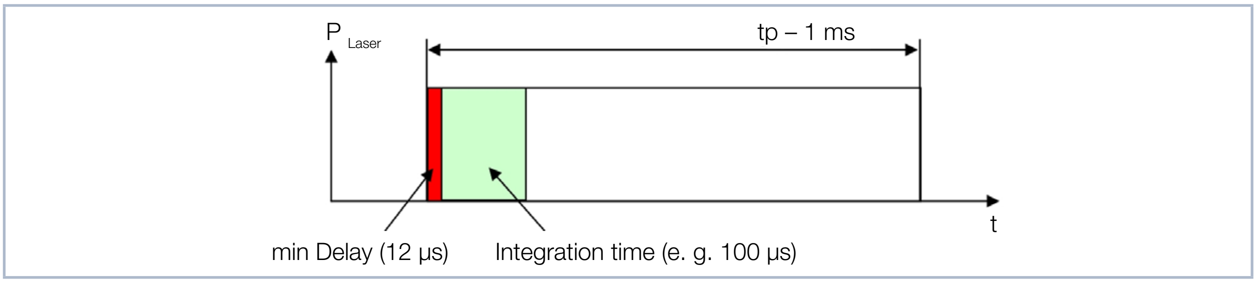


Fig. 16.6: Measuring parameters for pulsed laser systems with pulse duration greater than 1 ms

For all other cases, it is advisable to specify a fixed integration time in order to always measure a fixed number of pulses by cleverly selecting the filters and the delay and integration time ("Example 1: fixed integration time" on page 115).

16.3.4 Examples for trigger operation

Example 1: fixed integration time

With these settings, the device detects the second laser pulse after the trigger is released. Depending on how precisely it can be triggered, the integration time can also be varied.

Laser parameter		Device settings	
Pulse duration:	50 ns	Delay:	950 µs
Pulse frequency:	1 kHz	Integration time:	100 µs
		Trigger channel:	external trigger signal

Example 2: very long pulse duration

In this example, the first 12 µs of the laser pulse are not measured.

Laser parameter		Device settings	
Pulse duration:	1 ms	Delay:	12 µs
		Integration time:	1 ms
		Trigger channel:	internal trigger signal

16.3.5 Summary

If the laser is pulsing at a high frequency (> 500 Hz) or if the pulses last a long time (> 1ms), it is best to measure with the automatic integration time control. This makes it possible to vary or optimize the integration time during a caustic measurement.
For the long pulse duration, choose the attenuation so that the integration time is smaller than the pulse duration even outside of the focal point.
When the pulse frequency is very high, however, the attenuation must be chosen so that enough laser pulses are integrated during the measuring cycle. If too few pulses occur during an integration time, the number of photoelectrons will change too much with each pulse. The regulating routines of the LaserDiagnosticsSoftware LDS will then lead to measurements with signal levels that are statistically too high.

It is important to make sure that the integration time is never shorter than the pulse pauses. If this is the case, it will no longer be possible to perform an untriggered measurement properly with the device.

So it sometimes makes sense to set the attenuation so that exactly one pulse is enough to expose the sensor at the focal point. You can then measure a caustic with a fixed delay and an integration time set when the focus was measured. The dynamic of the CCD sensor is sufficient to measure the entire caustic with an acceptable S/N ratio.