PRIMES

Original Instructions

HighPower-MSM-HighBrilliance

HP-MSM-HB, HP-MSM-HB 20 kW

LaserDiagnosticsSoftware LDS 2.98

Revision 00 EN - 01/2021

IMPORTANT!

READ CAREFULLY BEFORE USE.

KEEP FOR FUTURE USE.

Table of Contents

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 instructions

Intended Use

The HighPower-MSM-HighBrilliance 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 x, „Technical Data“, on page y 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.

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:

- 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.
- The numerical aperture of the laser beam must be smaller than 0.11. Otherwise, in the lower measuring positions Laser radiation from the edge of the measuring lens can be reflected into the room in an uncontrolled manner.
- Please wear **safety goggles** adapted to the power, power density, laser wave length and operating mode of the laser beam source in use.
- Depending on the laser source, it may be necessary to wear suitable **protective clothing** or **protective gloves**.
- Protect yourself from direct laser radiation, scattered radiation, and beams generated from laser radiation (by using appropriate shielding walls, for example, or by weakening the radiation to a harmless level).
- Use beam guidance or beam absorber elements that do not emit any hazardous substances when they come in to contact with laser radiation and that can withstand the beam sufficiently.
- Install safety switches and/or emergency safety mechanisms that enable immediate closure of the laser shutter.

Necessary safety measures due to magnetic spring with strong permanent magnet

The device contains a magnetic spring made of neodymium magnets (NdFeB magnets) with a very strong permanent magnet.

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 express consent of the manufacturer. The same applies to unauthorized 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 Symbol explanations

Warning messages

The following symbols and signal words indicate possible residual risks:

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 indicating requirements and possible dangers are used on the device:


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!

Further symbols in this manual:

Here you can find useful information and helpful tips.

CE With the CE designation, the manufacturer guarantees that its product meets the requirements of the relevant EC guidelines.

▶ Call for action

3 About this operating manual

This manual describes how to work with the HP-MSM-HB and operate it with the LaserDiagnosticsSoftware LDS 2.98 (referred to as “LDS” in the following).
The measuring device is operated via PC or via the system control.
The description of the software focuses on configuration and communication settings as well as measurement operation.

This operating manual describes the software version valid at the time of printing.
Since the user software is continuously being developed further, the supplied data medium may have a different version number. Correct functioning of the device is, however, still guaranteed with the software.

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***.

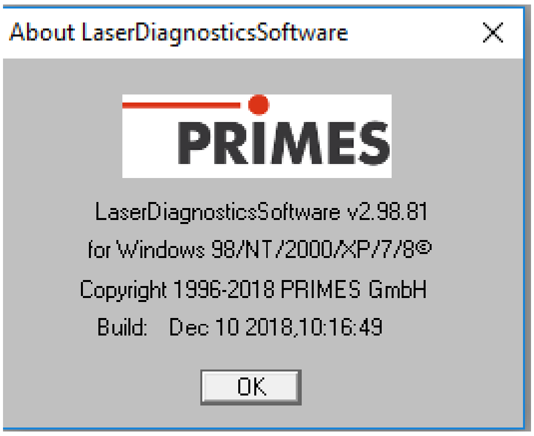

Fig. 3.1: Information regarding the current LDS software version

4 Device description

4.1 Device models and options

There are two models of HighPower-MSM-HighBrilliance:

- HP-MSM-HB and
- HP-MSM-HB 20 kW

The HP-MSM-HB is designed for a maximum beam power of 10 kW, the HP-MSM-HB 20 kW for a maximum of 20 kW.
The maximum travel distance z_{max} is 120 mm for the 10 kW model and 40 mm for the 20 kW model.
For the measurement of fiber lasers, the HP-MSM-HB can optionally be equipped with a measuring bridge with fiber adapter.
Another option is to measure the laser power with a PowerLossMonitor PLM (additional device).

4.2 Area of Application

The HP-MSM-HB is intended for the analysis of the focused beam in the diameter range between 20 µm up to 1000 µm. In the measuring range the power density distribution can be measured individually in up to 50 measuring planes. The beam caustic is then made up of these measuring planes.
The beam geometries (beam position, beam radius and semiaxes – lengths as well as the dumping of the semiaxes to the device axes) are determined for each plane according to the procedures described in the standard ISO 11146 (2. moment and 86 % power inclusion). By means of these beam geometries the beam propagation parameters (focus position, focus radius, Rayleigh length, divergence, M^2, K and beam parameter product) are determined. By means of the measuring data for the semiaxes of the beam, the ellipticity of the focus and the astigmatic difference are determined according to ISO 11146.

4.3 Device Assembly

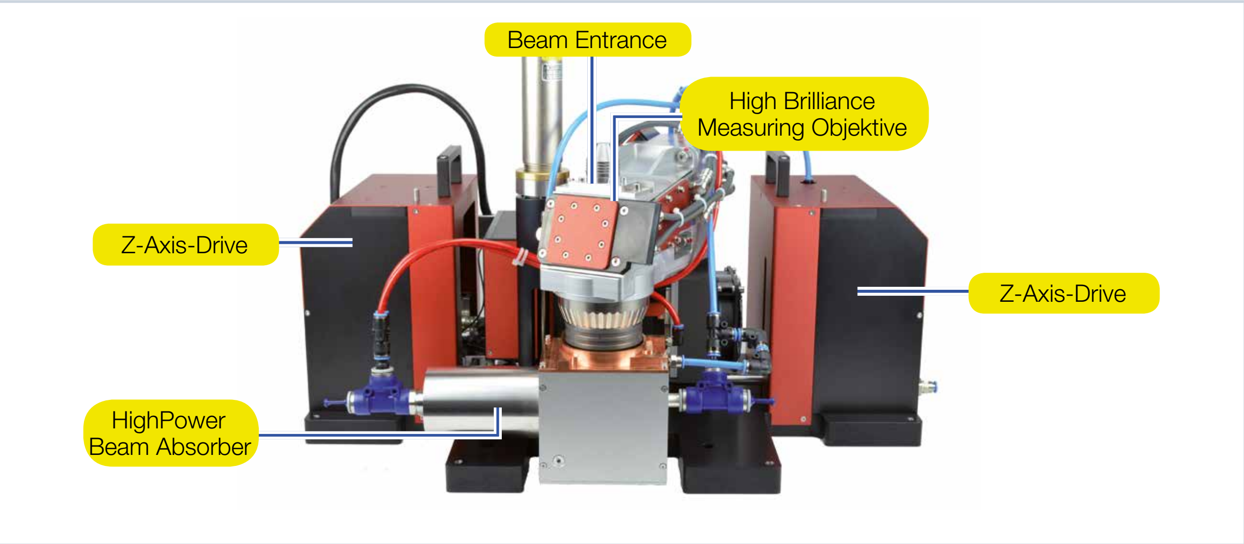

Fig. 4.1: Komponents of the HP-MSM-HB

4.4 Lever to adjust the magnification

There are two levers on the side of the device for adjusting the magnification. With the help of these two levers, either a magnification objective or an adjustment lens can be inserted into the beam path.
The magnification objective can be inserted into the beam path on the image side, directly behind a filter wheel, by moving both levers to the upper position.
The alignment objective simplifies the beam search, since it reduces the size of the image and the required positioning accuracy of the HP-MSM-HB is reduced by the reduction.
The alignment objective can also be inserted into the beam path on the image side by moving both levers to the lower position.

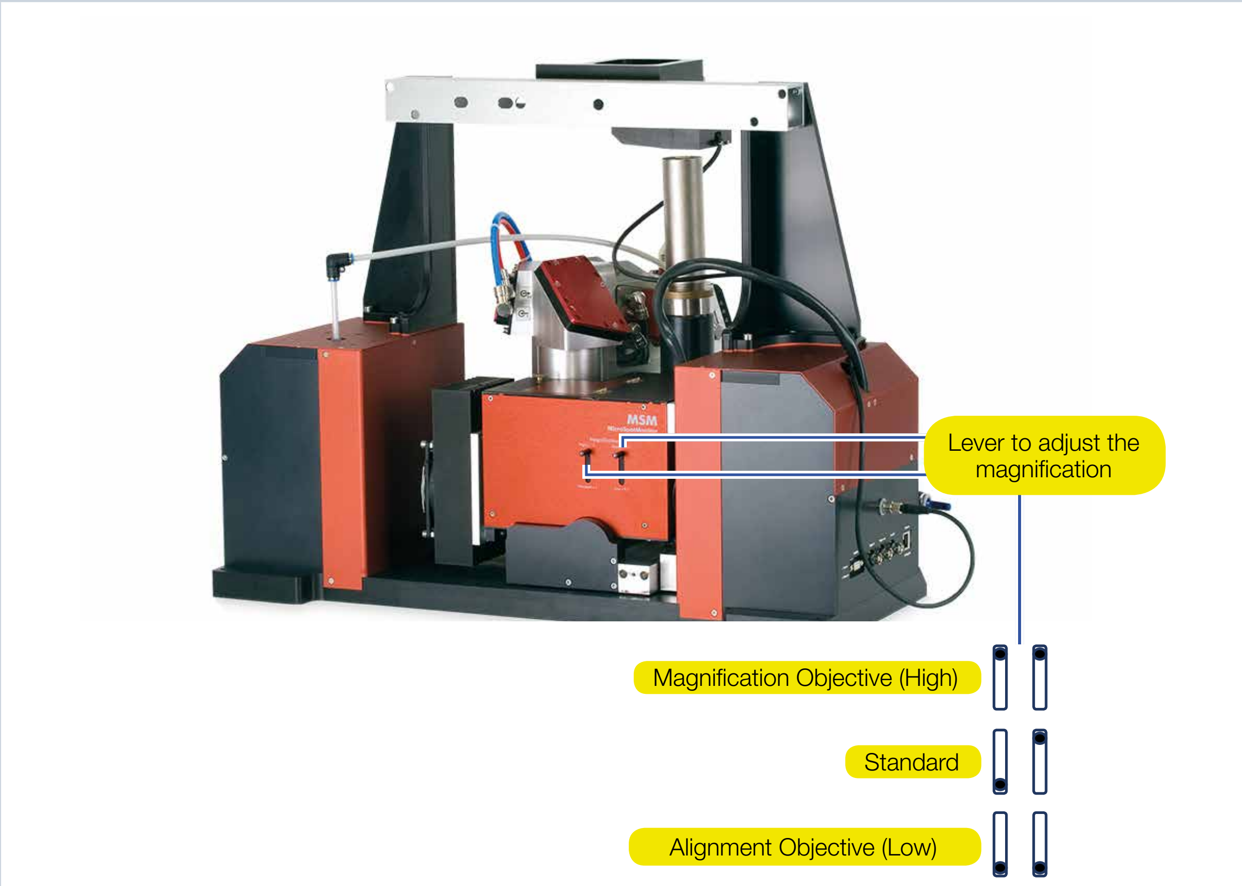

Fig. 4.2: Levers to adjust the magnification

4.5 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 via the beam splitter. The laser beam is attenuated by further optical elements in the device until it can be guided to a CCD sensor.

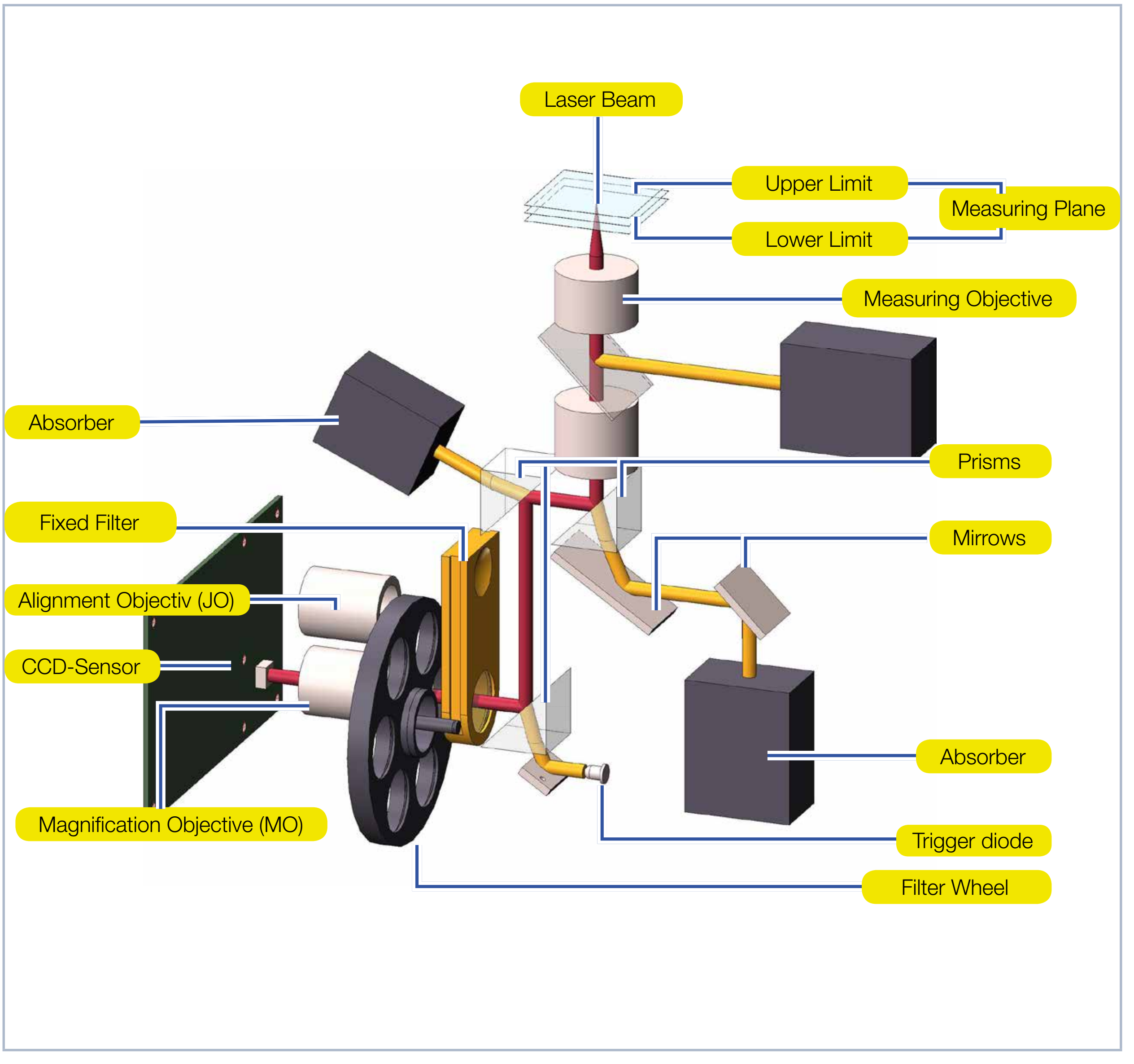

Fig. 4.3: Principle illustration of the optomechanical design

4.6 Measurement Range of the HP-MSM-HB

4.6.1 Measurement Range of the HP-MSM-HB 10 kW

Tab. 13.2 shows the correlation between power, diffraction index M² and the focus radius.

Focus radius ω₀ [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												
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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						
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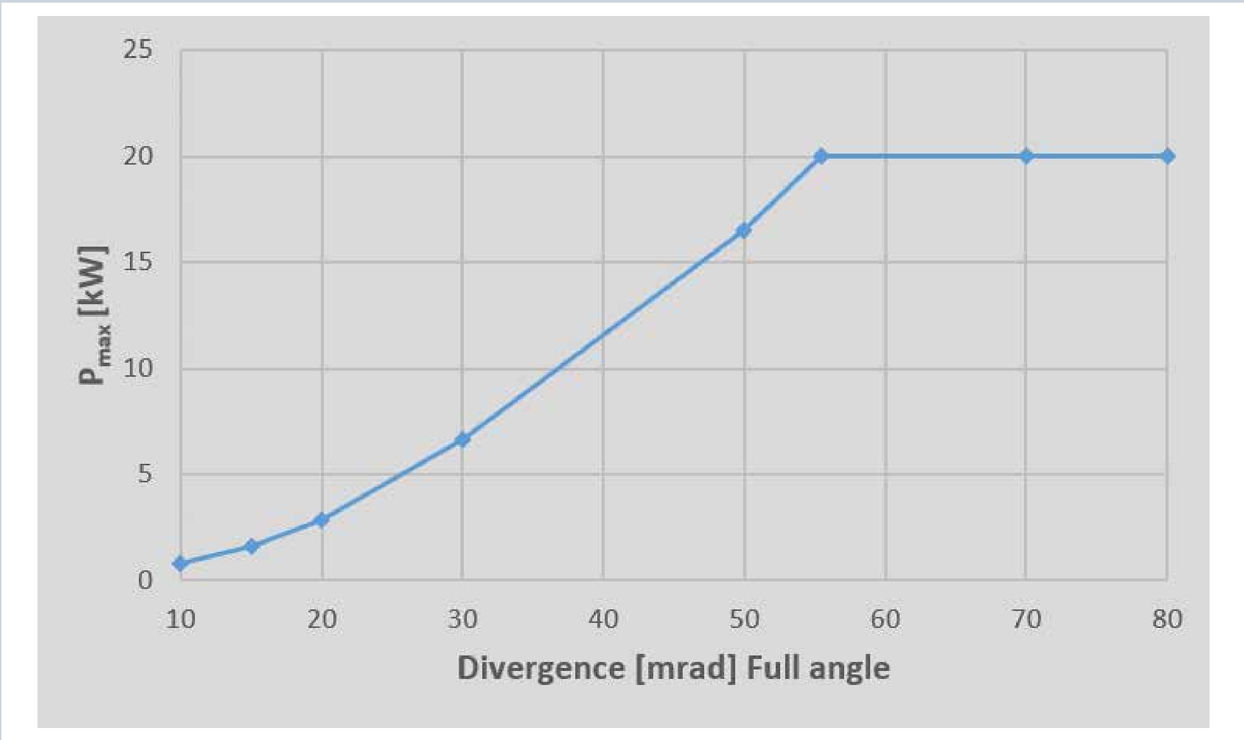
150	0,2	0,2	0,3	0,4	0,5	0,6	0,8	1,0	1,2	1,4	1,9	2,4	3,1	3,8	4,5	5,4	6,3	7,2	8,3	9,4	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
175	0,1	0,2	0,2	0,3	0,4	0,5	0,6	0,7	0,9	1,0	1,4	1,8	2,3	2,8	3,3	4,0	4,6	5,4	6,1	7,0	7,8	8,8	10,0	10,0	10,0	10,0	10,0	10,0	10,0	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: Power in kW as a function of the diffraction index M² and the focus radius

4.6.2 Measurement Range of the HP-MSM-HB 20 kW



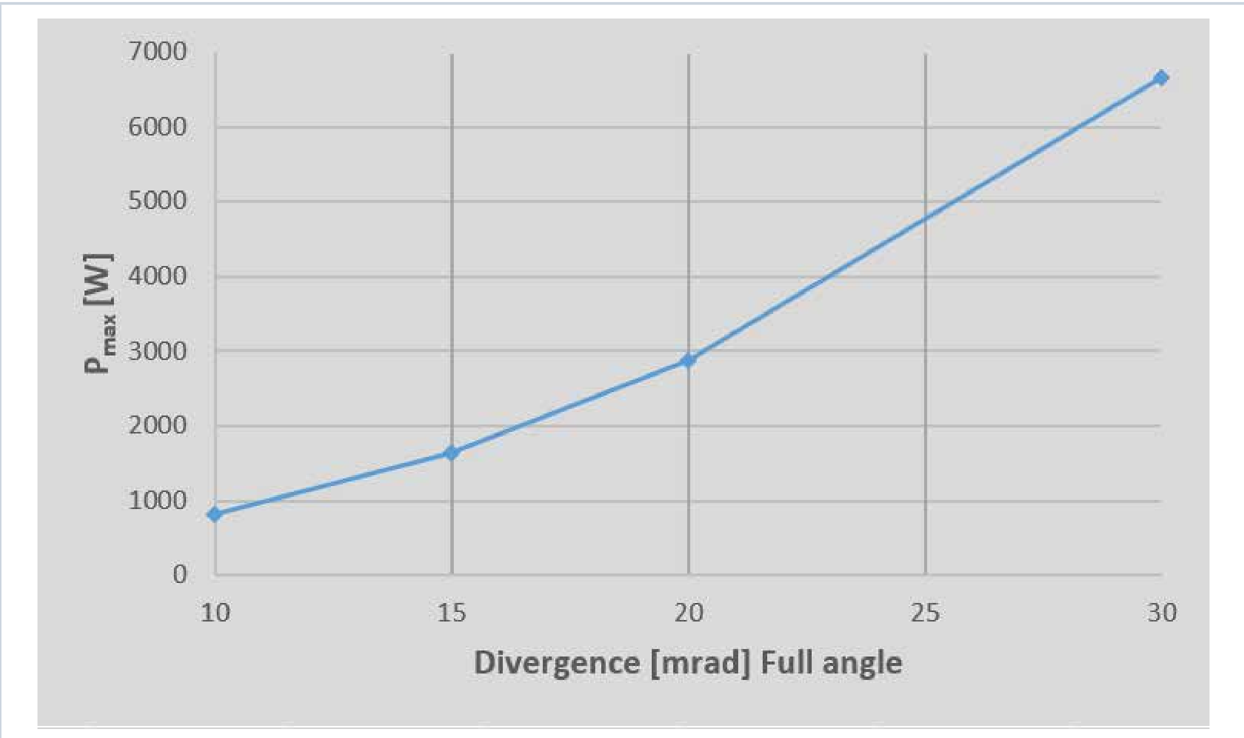


Fig. 4.4: Maximum power as a function of the laser divergence angle

4.7 Magnetic spring

With the HighBrilliance measuring objective, a magnetic spring is mounted, which counteracts to the weight of the measuring objective and thus relieves the traversing motors of the z-axis. Please note the warnings in this instructions when handling the magnetic spring.

5 Short overview installation

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

1. Taking 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. Disassemble the transport lock	Chapter 6 on page 19

3. Alignment to the laser beam and stable mounting • 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 20

4. Installing the water-cooling • Connection diameter 12 mm (16 mm for 20 kW-model) • Flow rate 7 l/min - 8 l/min (14 l/mi - 16 l/min for 20 kW-model)	Chapter 8.1 on page 27

5. Connecting the compressed air • Compressed air according to ISO 8573-1: 2010: 6:4:4. • 0,5 bar - 1 bar • Connection diameter 6 mm	Chapter 8.2 on page 30

6. Electrical connection • Establish voltage supply • External safety switch (interlock)	Chapter 9 on page 31

7. Connection with the PC • Connection via Ethernet	Chapter 11.3.2 on page 38

8. Installing the LaserDiagnosticsSoftware LDS on the PC • Software is part of the scope of delivery	Chapter 11 on page 36

6 Transport

WARNING

Risk of injury when lifting or dropping the device

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

- **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

Optical components may be damaged if the device is subjected to hard shocks or is allowed to fall.

- **Handle the measuring device carefully when transporting or installing it.**
- **To avoid contamination, close the measuring objective with the cover provided.**
- **Only transport the device in the original PRIMES transport box (option).**

NOTICE

Damaging/destroying the device

The device must only be transported with a mounted lock..

- **Keep the transport lock in a safe place for future reuse.**

After unpacking the device, the transport lock has to be removed first. The transport lock secures the linear actuator of the z-axis. It is located on the bottom plate and is fastened by means of 3 screws (see Fig. 6.1 on page 19).

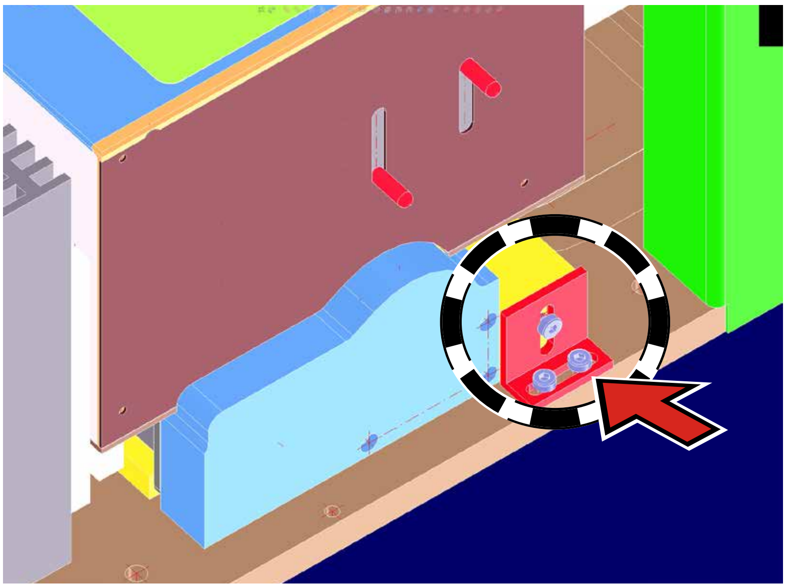


Fig. 6.1: Position of the transport lock

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

7 Installation

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 Preparation and mounting position

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.

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.**

Check the space available before mounting the device, especially the required space for the connection cables and the movement range of the z-axis (see chapter 21, „Dimensions“, on page 79). The device must be set up so that it is stable and fastened with screws (see chapter 7.3 on page 21).

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

NOTICE

Damaging/destroying the device

Obstacles in the movement range of the HP-MSM-HB can lead to collisions and damage the device.

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

7.3 Manually aligning the HP-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 be damage 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 measurement range is between an upper and a lower limit.

Upper limit

If the focus is located too high above the measuring objective, a focus on the image-sided beam path can develop. Together with too high beam intensities, the optics might be damaged. In addition, over-illumination of the aperture may occur, resulting in damage to the aperture.

Measuring plane

The power density distribution of the measuring plane is displayed 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.

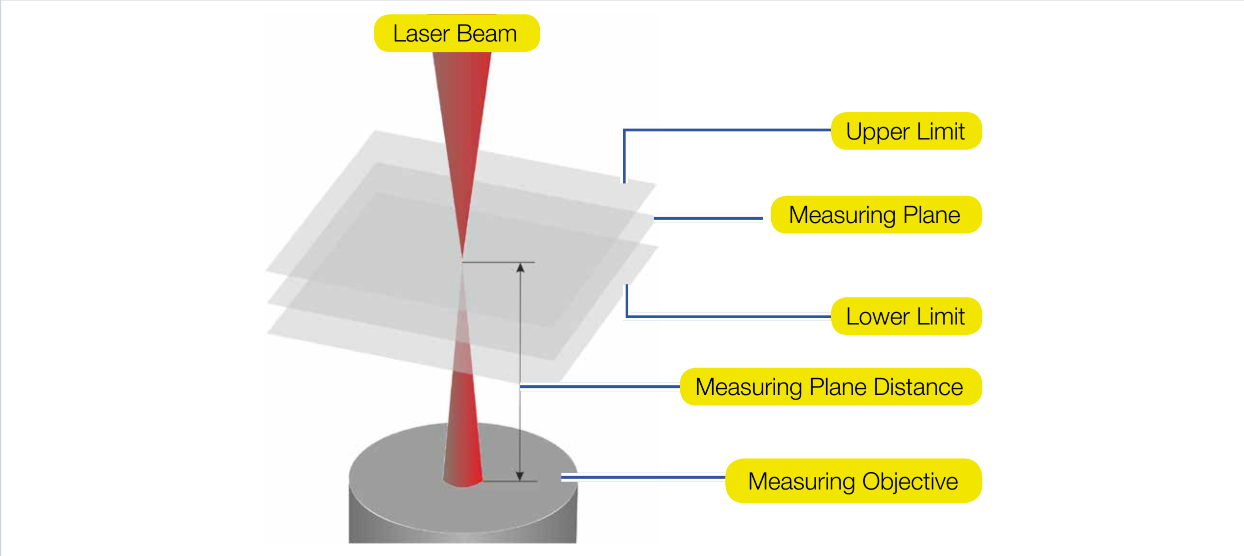


Fig. 7.1: Measuring range of the HP-MSM-HB

The measuring plane distance equals the distance of the measuring plane from the upper corner of the measuring objective.
In order to be able to align the HP-MSM-HB beneath the laser, an associated alignment tool is provided. By means of this alignment tool and a pilot laser beam, you can position the device with the necessary accuracy.

7.3.2 Mounting the cyclone

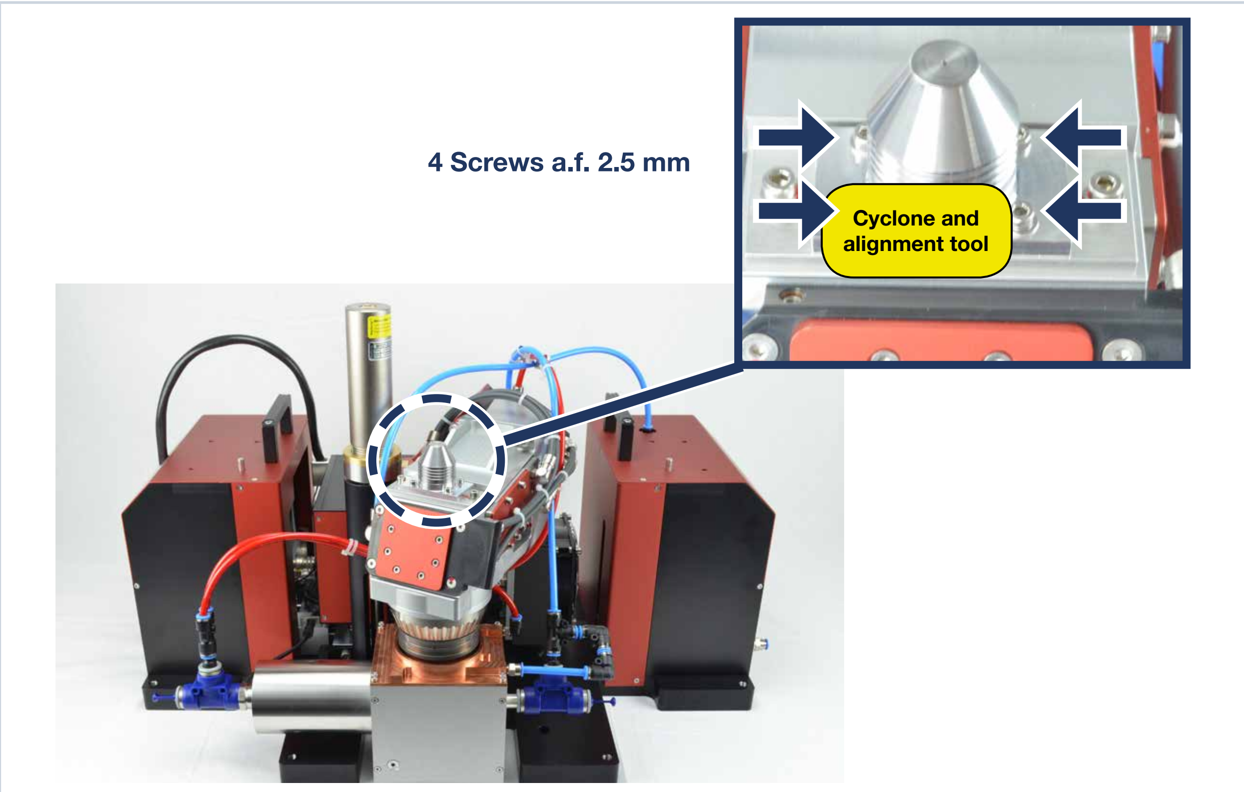


Fig. 7.2: Position of cyclone and alignment tool

The magnetically held alignment tool can fall down during shipping. Dirt may enter the objective. Therefore, the objective of the HP-MSM-HB is closed with a black transport lock.
Before removing the transport lock, the area around the aperture must be cleaned with clean compressed air and the purge air must be connected to the HP-MSM-HB.
If the purge air is not connected, dust can enter the objective directly when the cyclone is mounted.

- Turn on the purge air (see chapter 8.2 on page 30)
- Remove the transportation lock by loosening the four screws.

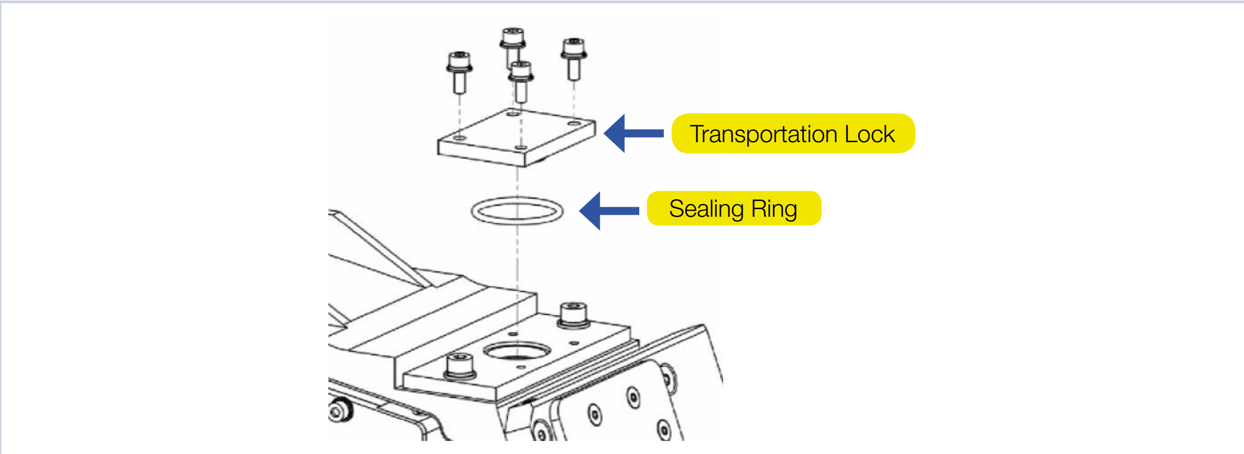


Fig. 7.3: Transportation lock at the beam entrance

- Store the transportation lock and the O-ring in a clean, sealable plastic bag. If you store or transport the device, you should remount the transport lock.
- Fasten the cyclone to the objevtive with the four screws.

7.3.3 Positioning the pilot laser beam above the cyclone

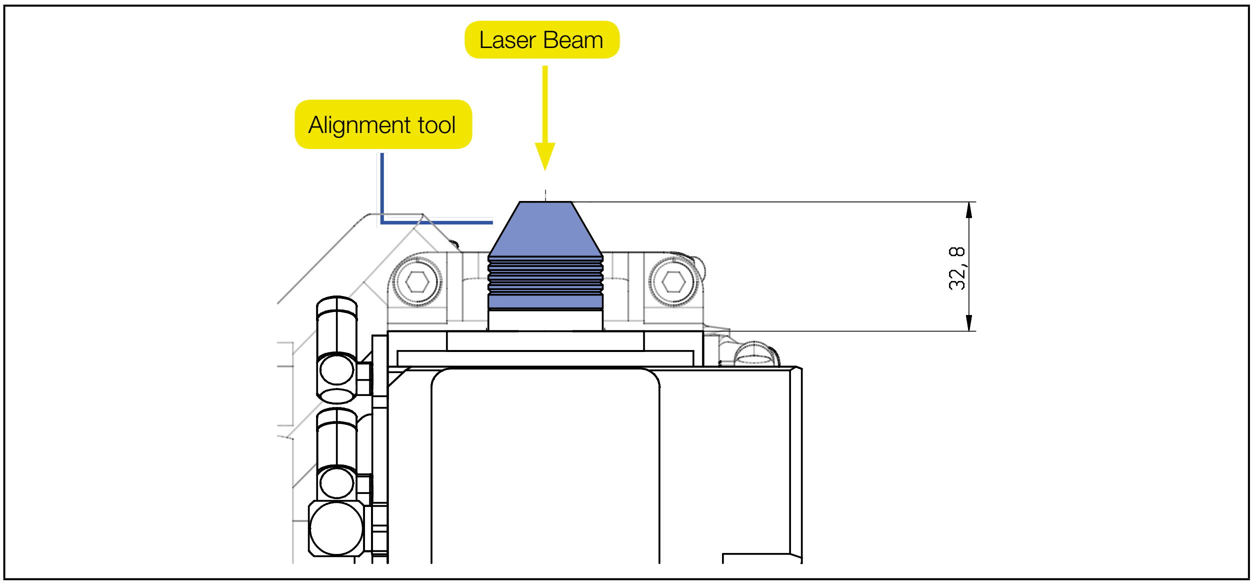


Fig. 7.4: Alignment tool for HP-MSM-HB

The measuring plane distance depends on the beam path (standard, magnification objective MO, alignment objective AO) (see Tab. 7.1 on page 24).

Measuring Objective	Wavelength in nm	Length of align-ment tool in mm	Measuring plane distance in mm		
			Standard	MO	AO
MOB HP-MSM-HB, 5-fold	1064	–	32,8	32,8	32,3

Tab. 7.1: Measuring plane distances

- ▶ Put the alignment tool on the cyclone. The upper corner equals the z-position of the measuring plane of the objective.
- ▶ Turn on the pilot laser. If the laser hits the little bore in the cover 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°).
- ▶ If the laser beam does not hit the bore vertically, you can align the HP-MSM-HB with the 6 screws in the threaded holes.
- ▶ Finally, fasten the device, so that it cannot be moved by accidental bumping or pulling on the cables.

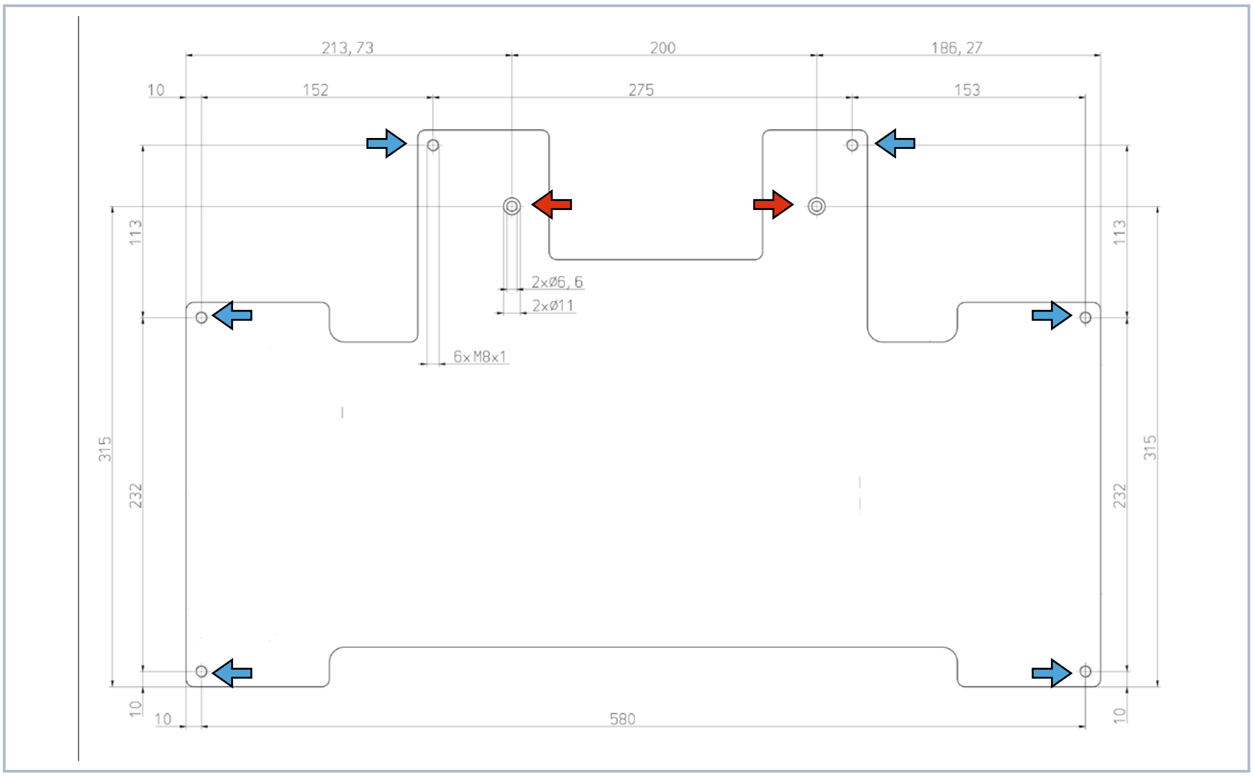


Fig. 7.5: Fastening bores HP-MSM-HB, view from above

2 Mounting holes Ø 6,6 mm

6 thread holes M8x1 for the alignment

7.4 Mounting the Fibre Bridge (option)

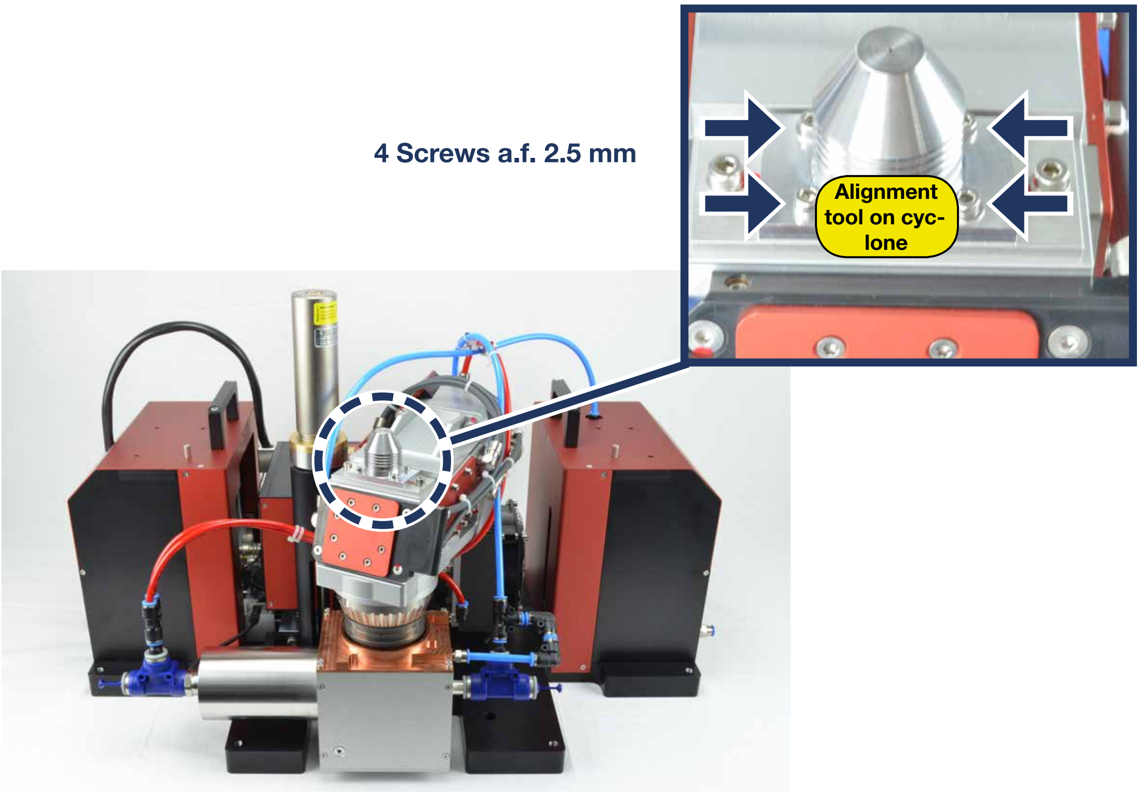
For mounting fiber lasers a fibre bridge with fiber holders can be mounted.

NOTICE

Damaging/destroying the device

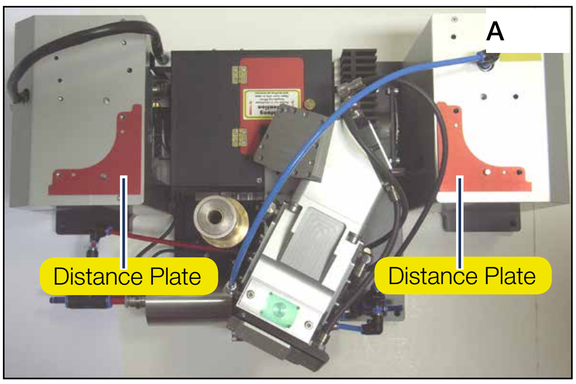
In the upper z-axis position the cyclone can collide with the fiber optic holder and damage it

▶ **Dismount the cyclone before the startup!**

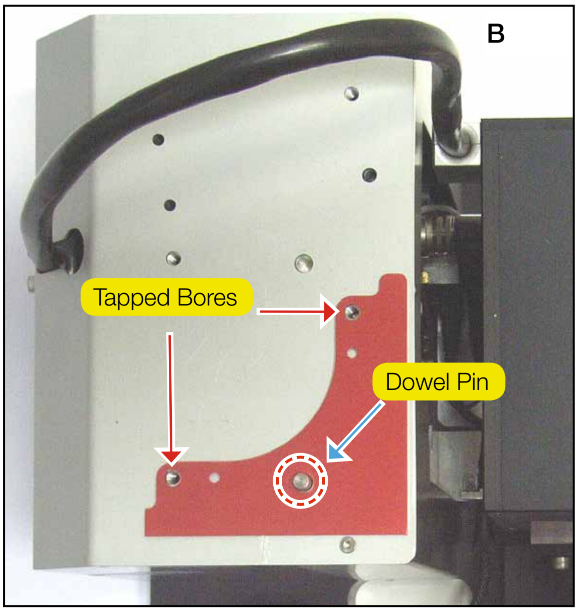


Mounting order

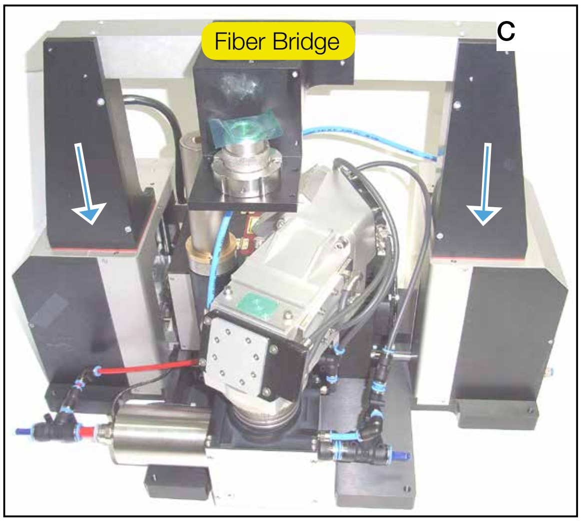
Distance plates are required to fix the fiber bridge. On newer models the plates are fixed under the feet of the fiber bridge, on older models they are enclosed separately. In the following, the installation with separate distance plates is described.



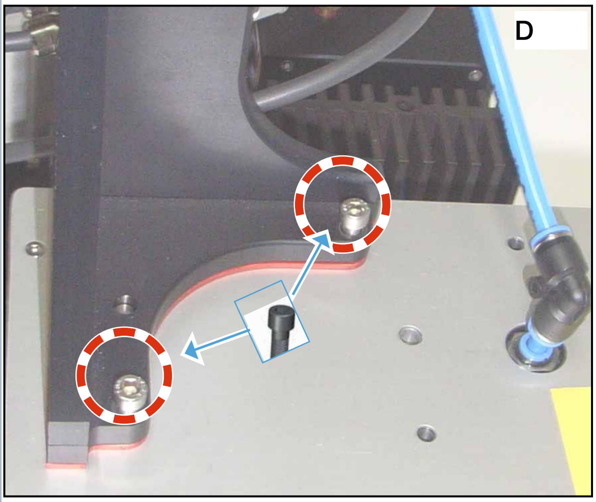
1. Put the distance plates on both sides of the housing (picture A) and fasten them by means of the dowel pins.



2. Align the plates with reference to the tapped bores (picture B).



3. Put the fiber bridge on the distance plates.



4. Fasten the fiber bridge by means of two screws on both sides M5 x 10 mm. Please note that longer screws (>10 mm) can block the Z-axis underneath.

8 Cooling water and compressed air connections

For the operation of the HP-MSM-HB both a cooling water and a compressed air supply is required. 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.

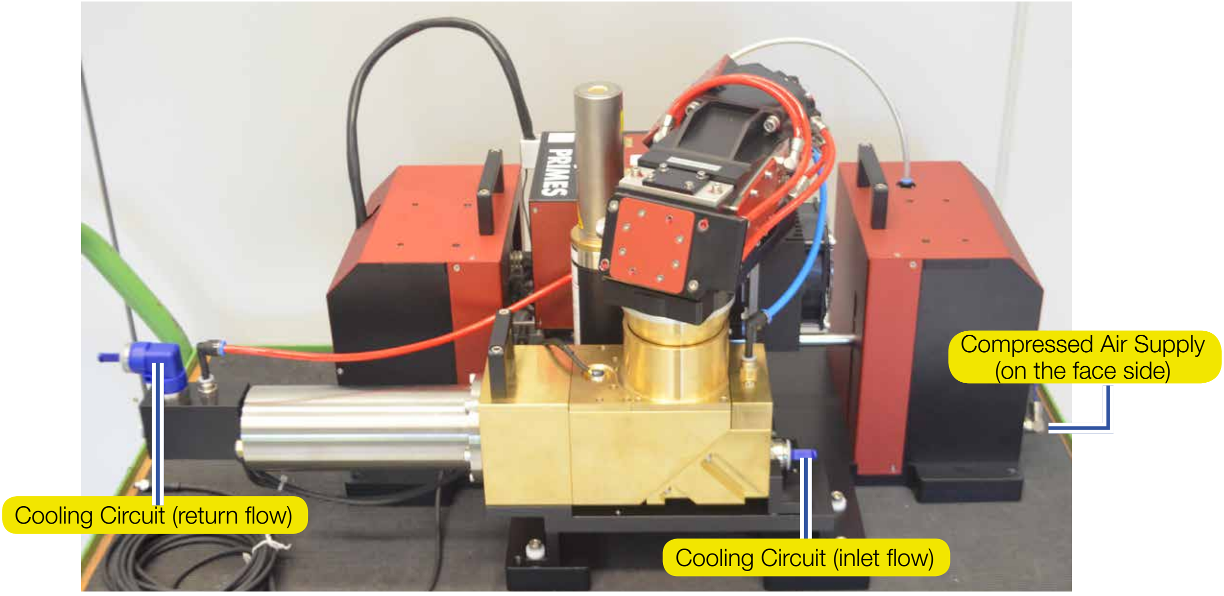


Fig. 8.1: Media Connections of the HP-MSM-HB (20 kW)

NOTICE

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

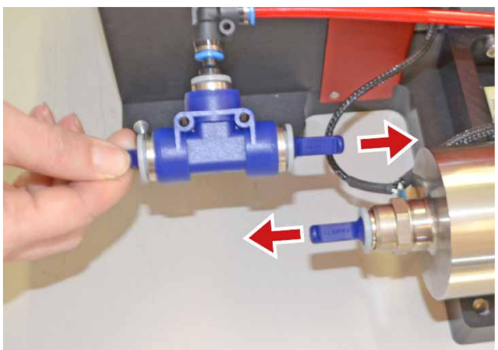
If there is no water cooling or a water flow rate which is insufficient, there is a danger of overheating, which can damage the device or set it on fire.

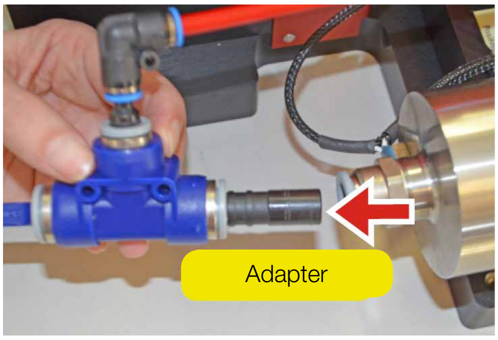
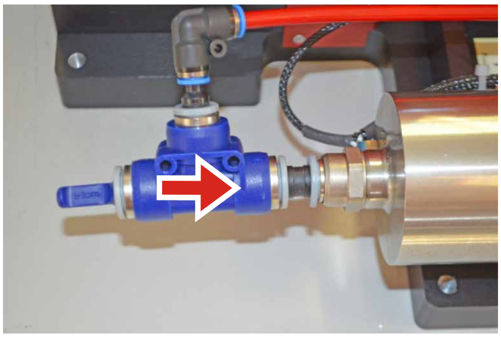
- ▶ **Operate the device with a connected water cooling and a sufficient water flow rate only.**

8.1 Cooling Circuit System

For packaging reasons the cooling water pipe of the absorber was removed. The device must not be operated without water cooling. The removed 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.	

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

8.1.1 Water quality

NOTICE

Damage/Destruction of the device due to different chemical potentials

The parts of the device which get in contact with cooling water consist of copper, brass or stainless steel. Connecting the unit to a cooling circuit containing aluminum components may cause corrosion of the aluminum due to the different chemical potentials.

▶ **Do not connect the device on a cooling circuit in which aluminum components are installed.**

- The device can be operated with tap water as well as demineralized water.
- Do not operate the device on a cooling circuit containing additives such as anti-freeze.
- Do not operate the device on a cooling circuit in which aluminum components are installed. Especially when it comes to the operation with high powers and power densities, it may otherwise lead to corrosion in the cooling circuit. In the long term, this reduces the efficiency of the cooling circuit.
- It is mandatory to use the installed interlock. Otherwise the device will be damaged in case of cooling fails.
- Large dirt particles or teflon tape may block internal cooling circuits. Therefore, please thoroughly rinse the system before connecting it.

8.1.2 Water pressure

For a reliable operation a water flow rate of

- 7 l/min to 8 l/min (at 10 kW)
- 14 l/min to 16 l/min (at 20 kW)

is required. Normally, 2 bar primary pressure at the entrance of the absorber are sufficient in case of an un-pressurized outflow.

NOTICE

Damage/Destruction of the device due to overpressure

▶ **The maximum permissible water inlet pressure must not exceed 4 bar.**

8.1.3 Humidity

- 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 (see Tab. 8.1 on page 29).

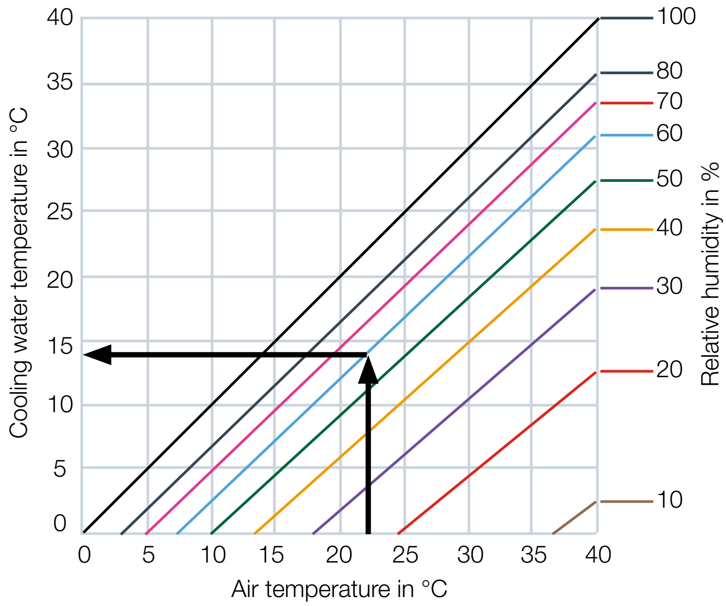
NOTICE

Damage/Destruction of the device due to condensing water

Condensation water inside of the objective will lead to damage.

▶ **Mind the dew-point in Tab. 8.1 on page 29.**

Do only cool the device during the measuring operation. We recommend starting the cooling approx. 2 minutes before the measurement and terminating it approx. 1 minute after the measurement.



Tab. 8.1: Dew point diagram: The temperature of the cooling water must not be lower than the dew point

Example

Air temperature: 22 °C
Relative humidity: 60 %

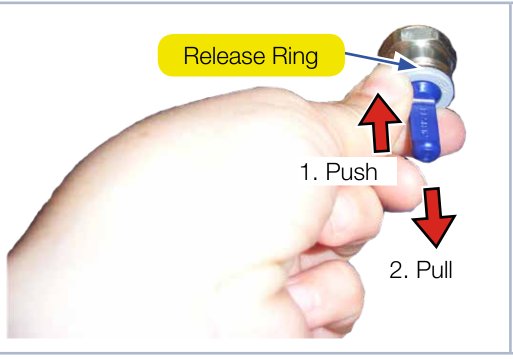
The cooling water temperature cannot fall below 14 °C.

8.1.4 Water connections and water flow rate

Connection diameter	Recommended flow rate	Minimum flow rate
PE hoses 12 mm	7-8 l/min (ca. 1 l/(min · kW)	not lower than 5 l/min
PE hoses 16 mm	14-16 l/min	not lower than 10 l/min

Tab. 8.2: Water connections and water flow rate

Remove the sealing plugs of the water connections



1. Please 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 and keep it in a save place.
3. Close the flow line (Water In) and the return flow (Water Out) of the device, by inserting the hose as far as possible (approx. 2 cm deep).

Fig. 8.2: Remove the sealing plugs of the water connections

8.2 Compressed Air

The compressed air is required in order to generate a rotating air flow in the cyclone which is directed outwards. This is supposed to prevent the penetration of dirt particles.
Connect the compressed air supply by means of a plastic hose with an outer diameter of 6 mm.

Please only connect compressed air with a pressure of 0,5 bar ... 1,0 bar.
Specification of compressed air according to ISO 8573-1: 2010: 6:4:4.

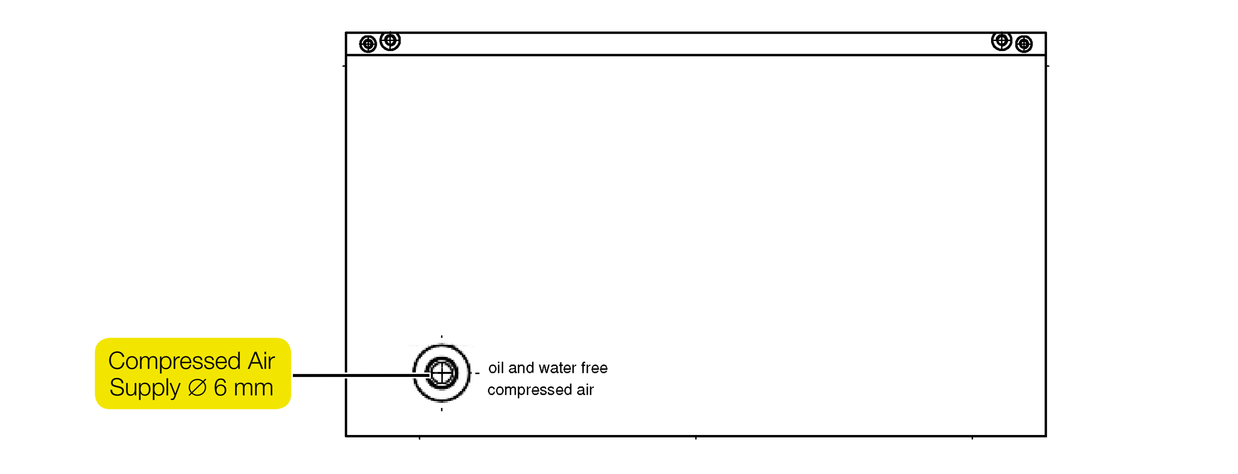


Fig. 8.3: Compressed air supply (on the face side)

9 Electrical connection

Please ensure that all electrical connections have been established and switch the device on before starting the LaserDiagnosticsSoftware LDS.

9.1 Connections

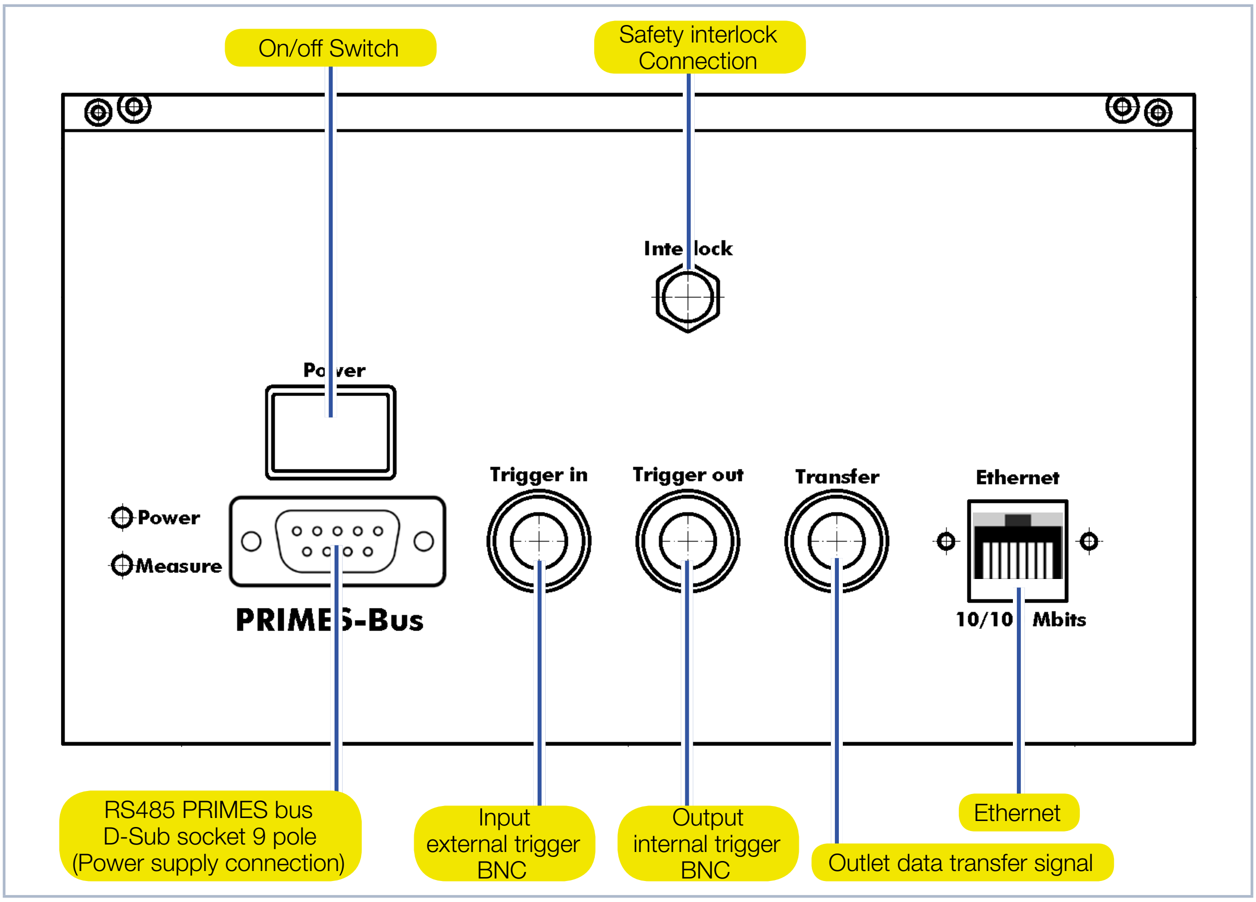
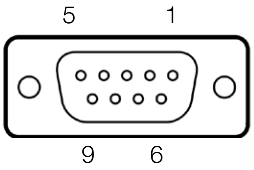


Fig. 9.1: Electrical connections

9.2 Pin assignment

9.2.1 Power supply

D-Sub socket, 9-pin (view: connector side)

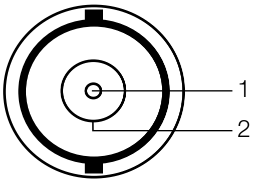


Pin	Function
1	GND
2	RS485 (+)
3	+24 V
4	Trigger RS485 (+)
5	Not assigned
6	GND
7	RS485 (–)
8	+24 V
9	Trigger RS485 (–)

Tab. 9.1: D-Sub socket RS485

9.2.2 Inlet external trigger

BNC connector (view: connector side)

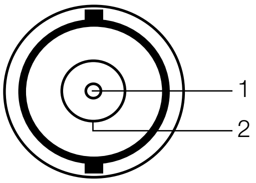


Pin	Function
1	+5 V (Trigger signal)
2	GND

Fig. 9.2: Connection socket inlet for an external trigger in the connection panel

9.2.3 Outlet internal trigger

BNC connector (view: connector side)

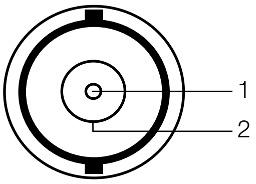


Pin	Function
1	+5 V (Trigger signal)
2	GND

Fig. 9.3: Connection socket outlet for the internal trigger in the connection panel

9.2.4 Outlet internal data-transfer signal

BNC connector (view: connector side)



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

Fig. 9.4: Connection socket outlet for the internal data-transfer signal in the connection panel

9.2.5 External Safety Circuit (Interlock)

An external safety circuit (interlock) is integrated in the HP-MSM-HB, which you must connect to the safety circuit of the laser. The safety circuit protects the measuring device from damage by switching off the laser beam in the event of a fault condition within the device.

NOTICE

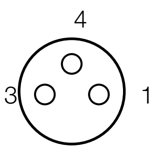
Danger of damage due to overheating

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

▶ **When connecting the laser control with the pins 1 and 4, please ensure that the laser is turned off in case of an interruption**

The following conditions open the safety circuit:

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

Pin diagram (view from plug-in side)	Pin	Core Color PRIMES Cable	Function
	1	Brown	Mutual Pin
	3	Blue	If ready for operation, bridged with pin 1
	4	Black	If not ready for operation (interlock mode), bridged with pin 1

Tab. 9.2: Interlock socket

9.3 Connection to the PC and connect power supply

The HP-MSM-HB requires a supply voltage of 24 V ±5 % (DC) for the operation. A suitable power supply is included in the scope of delivery.

▶ Use the adapter to connect the power supply to the 9-pin D-sub socket (RS485) of the device.
▶ Connect the device to the PC via a crossover cable or to the network via a patch cable.

NOTICE

Damage/Destruction of the device due to overvoltage

When the electrical cables are disconnected during operation (when the power supply is applied), voltage peaks occur which can destroy the communication components of the measuring device.

▶ **Connect/disconnect all plugs in a de-energized state only.**

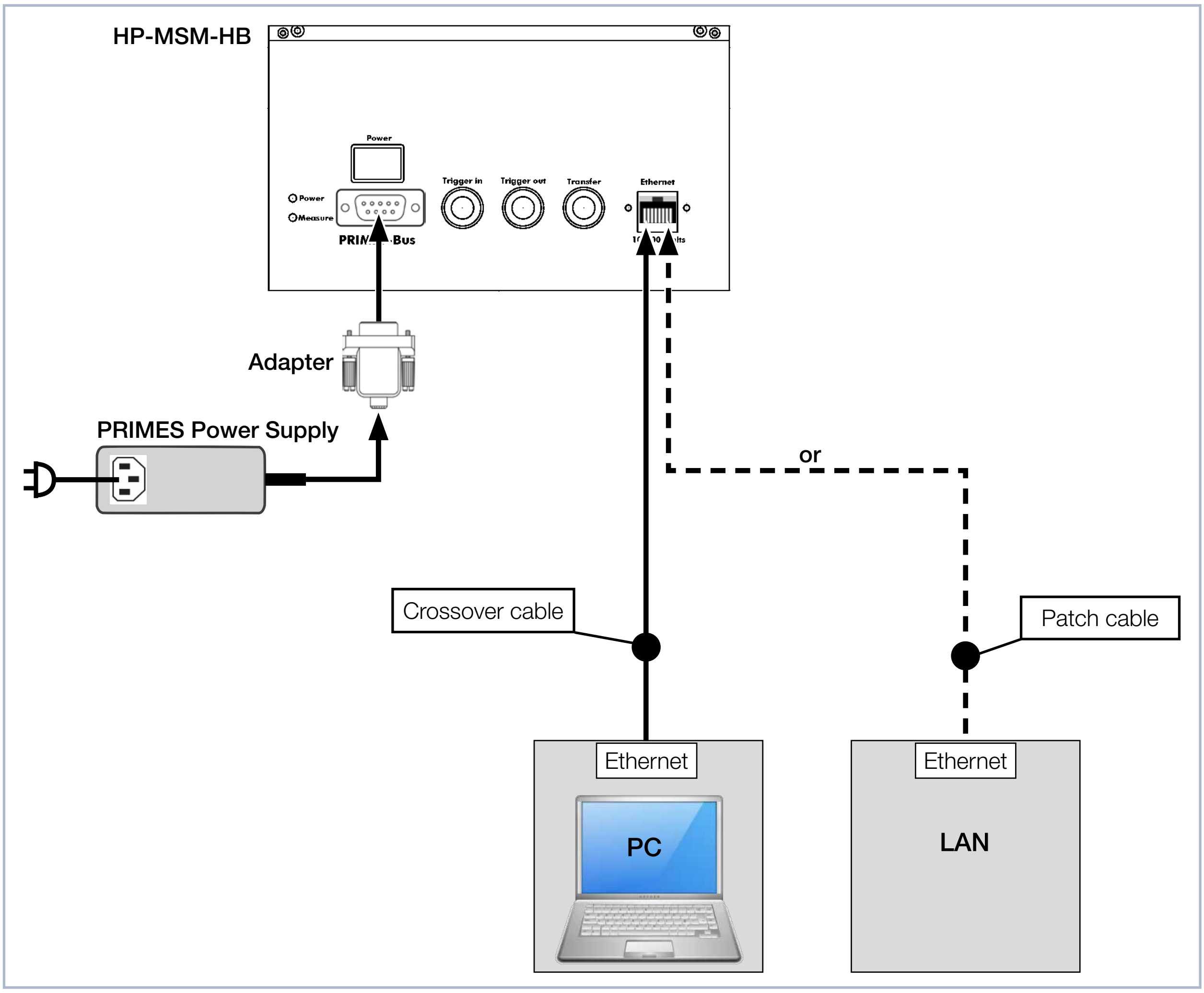


Fig. 9.5: Connection via Ethernet with a PC or a local network

10 Status LEDs

The device has got two status LEDs.

Name	Color	Meaning
Power	Green	The power supply is switched on
Measuring	Yellow	A measurement is running

Tab. 10.1: Description of the status LEDs on the HP-MSM-HB

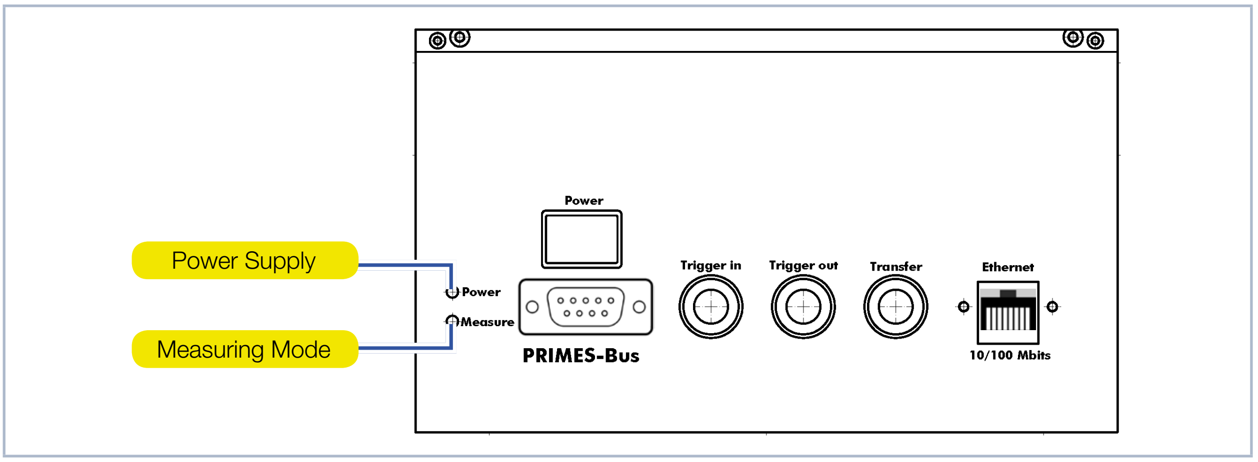


Fig. 10.1: Status LEDs at the HP-MSM-HB

11 Installation and configuration of the LaserDiagnosticsSoftware LDS

In order to operate the measuring device, the PRIMES LaserDiagnosticsSoftware LDS has to be installed on the computer. The program can be found on the enclosed medium.
You will find the latest version on the PRIMES website at: https://www.primes.de/en/support/downloads/software.html.

11.1 System requirements

Operating system:	Windows® 7/10
Processor:	Intel® Pentium® 1 GHz (or comparable processor)
Free disc space:	15 MB
Monitor:	19“ screen diagonal is recommended, resolution at least 1024x768
LDS-Version:	2.98 or higher

11.2 Installing the software

The installation of the software is menu driven and is effected by means of the enclosed medium. Please start the installation by double-clicking the file “Setup LDS v.X.X.exe” (X = placeholder for version number) and follow the instructions.

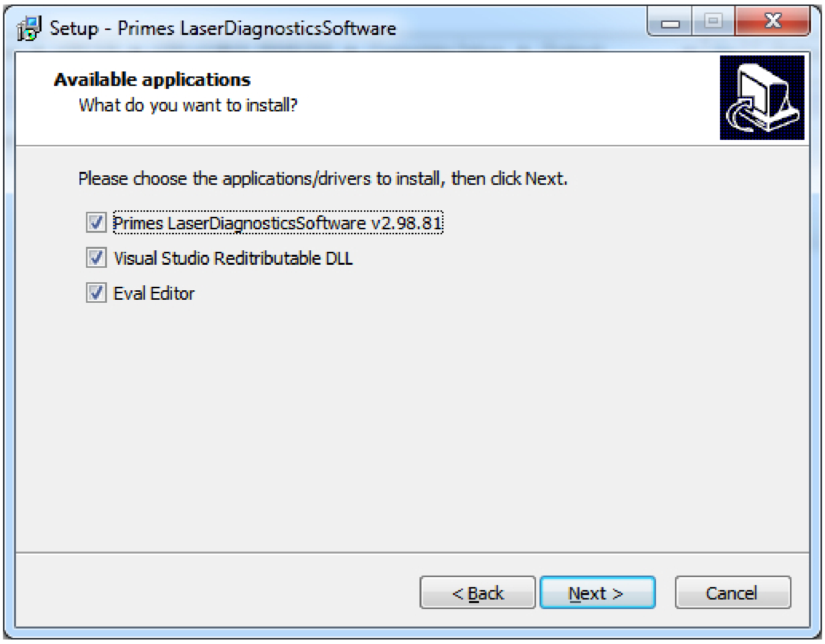


Fig. 11.1: Setup of the PRIMES LaserDiagnosticsSoftware LDS

If not stipulated differently, the installation software stores the main program “LaserDiagnosticsSoftware.exe” in the directory “Programs/PRIMES/LDS”. Moreover, the settings file “laserds.ini” is also copied into this directory. In the file “laserds.ini” the setting parameters for the PRIMES measuring devices are stored.

11.3 Ethernet configuration

11.3.1 Enter IP address

The HP-MSM-HB has a fixed IP address that is specified on the type plate:

- If the HP-MSM-HB is connected directly to the PC, enter the fixed IP address in the menu ***Communication > Free Communication*** (see chapter 11.3.2 on page 38).
- If the HP-MSM-HB is connected over a network, the HP-MSM-HB will spend about one minute pulling up a variable IP address in the network.
  You can enter this variable IP address in the menu Communication > Free communication (see chapter 11.3.2 on page 37).
- If you want to connect the HP-MSM-HB to the network using the fixed IP address, first turn on the HP-MSM-HB and then connect the network cable to the HP-MSM-HB. Then enter the fixed IP address in the menu ***Communication > Free Communication*** (see chapter 11.3.2 on page 38).

The standard IP address of the HP-MSM-HB is:

IP Address: 192.168.116.84
Subnet mask: 255.255.255.0

The PC must also have an IP address in the same subnet, for example:

IP Address: 192.168.116.XXX
Subnet mask: 255.255.255.0

The first three blocks of the IP address must match the IP of the HP-MSM-HB.

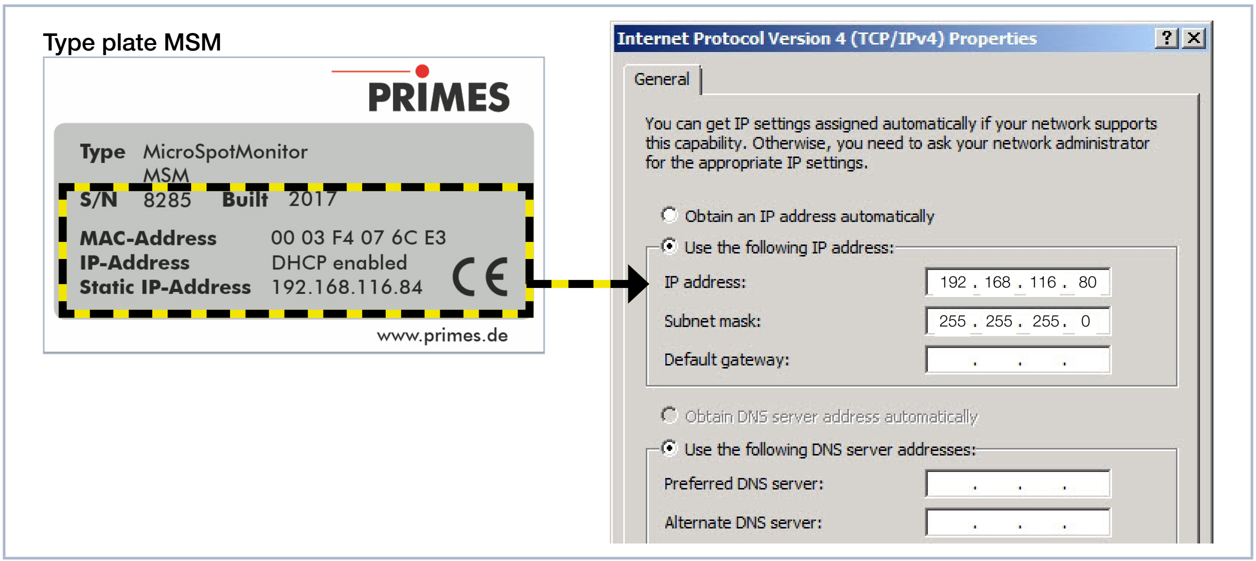


Fig. 11.2: Ethernet configuration in the dialogue window ***Ethernet***

11.3.2 Establishing a connection to PC)

1. Please start the LaserDiagnosticsSoftware LDS (see chapter 12 on page 42).
2. Open the dialogue window ***Communication > Free Communication***.
3. Choose in the field “Mode” ***TCP*** (the option “Second IP” must not be activated!).
4. Enter in the field “TCP” the IP Address.
5. Click on the ***Connect*** button (“connected” appears in the bus monitor).
6. Activate the Write bus protocol check box (the protocol can be very useful when problems occur):
- The protocol is saved in the installation directory of the LaserDiagnosticsSoftware LDS.
- The file name is buspro.log.YYYY.MM.DD (YYYY.MM.DD = date of file creation).
7. Click on the ***Safe Config*** button (the configuration is saved and does not need to be re-entered when starting the LaserDiagnosticsSoftware LDS again).
8. Click on the ***Find Primes Devices*** button.
- If a device is found, the dialog windows for the measurement settings are opened.

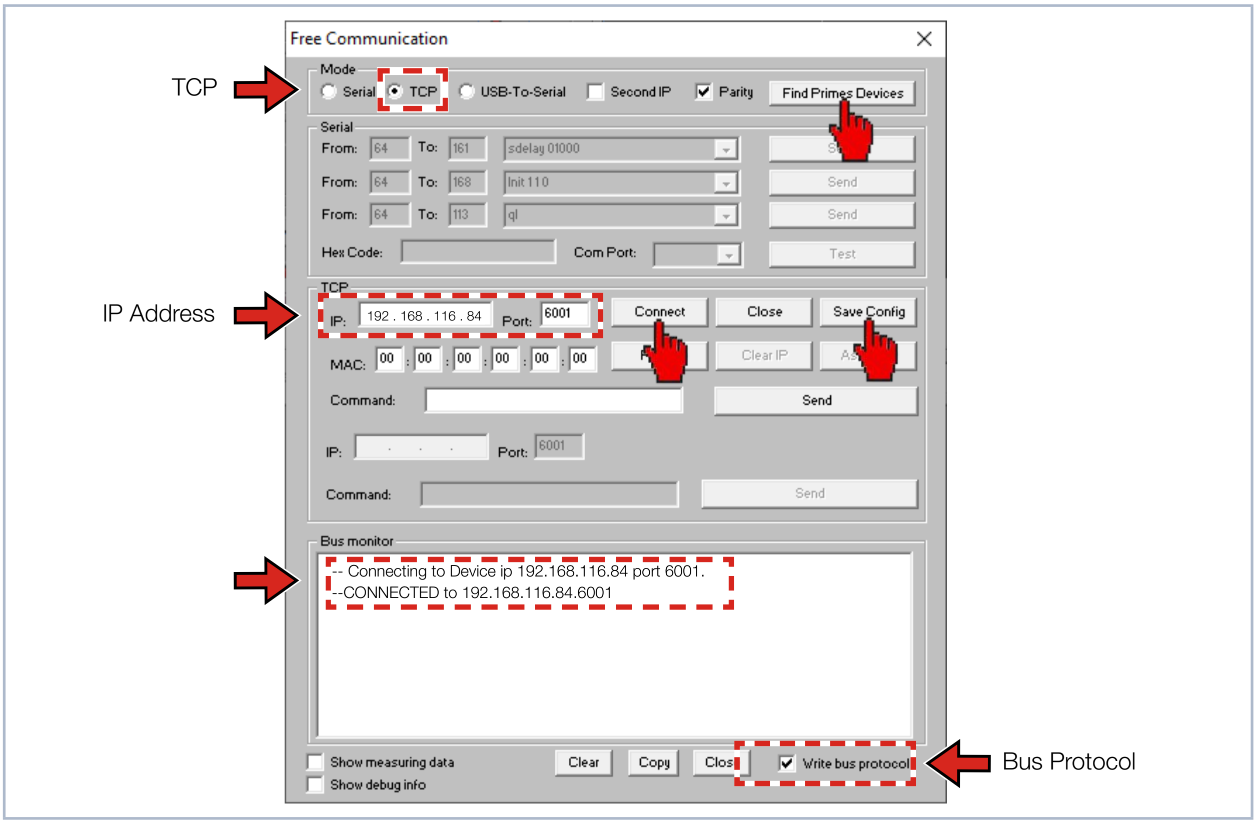


Fig. 11.3: Establishing a connection in the dialogue window ***Free Communication***

11.3.3 Changing the standard IP address of the device

If the fixed IP address of the HP-MSM-HB conflicts with another device bearing the same IP address on the network, the fixed IP address of the HP-MSM-HB can be changed.

NOTICE

Device malfunction due to incorrect entries

While changing the IP address, it is possible that another EE cell might be overwritten by a mistype, for example, and the HP-MSM-HB could thus be rendered unusable.

▶ **Only very skilled users should attempt to change the IP address.**

You can change the preset IP address in the menu ***Communication > Free communication*** by means of the following commands:

IP address (Sample address)	192.	168.	116.	85	DHCP
	↑	↑	↑	↑	↑
Commands	se0328 ✶ xyz	se0329 ✶ xyz	se0330 ✶ xyz	se0331 ✶ xyz	se0332 ✶ 001

Tab. 11.1: Changing the IP address

In this case **xyz** are place holders of the four IP-address bytes (values 1 - 254) which always have to be entered with three digits!
For example, the number 84 has to be entered like this: 084.
For reasons of clarity the symbol ✶ marks a space.

Example: You want to change the IP address from 192.168.116.**85** to 192.168.116.**86**.

1. Please start the LaserDiagnosticsSoftware LDS (see chapter 12 on page 42).
2. Open the dialogue window ***Communication > Free Communication***.
3. Choose in the field Mode ***TCP*** (the option “Second IP” must not be activated!).
4. Enter the current IP address in the ***TCP*** field.
5. Click on the ***Connect*** button (“connected” appears in the bus monitor).
6. Activate the check box ***Write bus protocol*** (the protocol can be helpful in case of problems):

- The protocol is saved in the installation directory of the LaserDiagnosticsSoftware LDS.
- The file name is buspro.log.YYYY/MM/DD (YYYY/MM/DD = date file was created).

7. Enter the following in the field ***Command***: **se0331 ✶ 086**
(please make sure that the blank character ✶ is entered correctly).
8. Click on the ***Send*** button and wait for the confirmation in the bus monitor
(see Fig. 11.4 on page 40 „-> Add:0331 value: 086“)
9. Please turn off the device and turn it on again:

- After the restart the IP-address is updated.

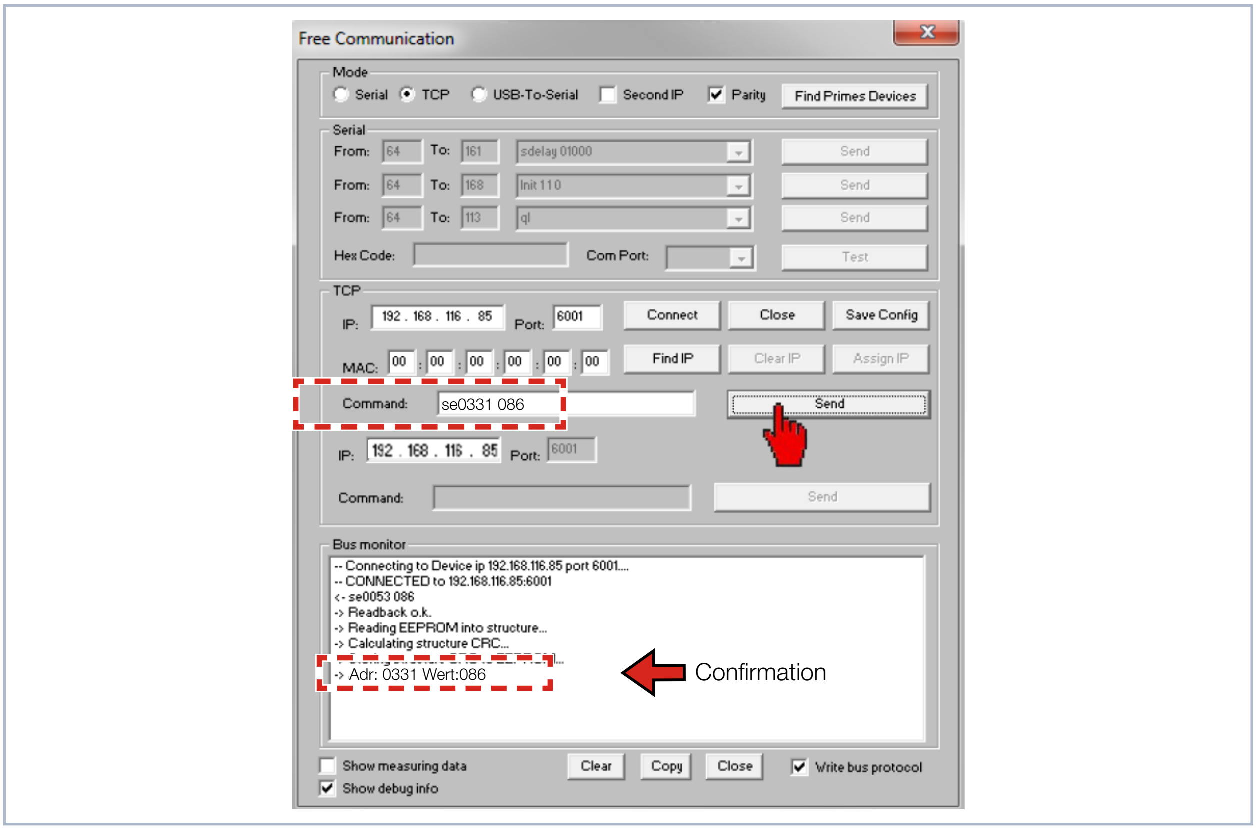


Fig. 11.4: Changing the IP address in the dialogue window ***Free Communication***

11.3.4 Retrieve IP address automatically with DHCP

DHCP (Dynamic Host Configuration Protocol) enables the automatic integration of a device into an existing network without its manual configuration.
You activate the DHCP function in the Laser Diagnostic Software with the command: se0331 ✶ 001.

1. Please start the LaserDiagnosticsSoftware LDS (see chapter 12 on page 42).
2. Open the dialogue window ***Communication > Free Communication***.
3. Choose in the field Mode ***TCP*** (the option “Second IP” must not be activated!).
4. Enter the current ***IP address*** in the ***TCP*** field.
5. Click on the ***Connect*** button (“connected” appears in the bus monitor).
6. Activate the check box ***Write bus protocol*** (the protocol can be helpful in case of problems):
   - The protocol is saved in the installation directory of the LaserDiagnosticsSoftware LDS.
   - The file name is buspro.log.YYYY/MM/DD (YYYY/MM/DD = date file was created).
7. Enter the following in the field ***Command***: ***se0331 ✶ 001***
   (please make sure that the blank character ✶ is entered correctly).
8. Click on the ***Send*** button and wait for the confirmation in the bus monitor
   (see Fig. 11.5 on page 41 „-> Add:0331 value: 001“)
9. Please turn off the device and turn it on again.

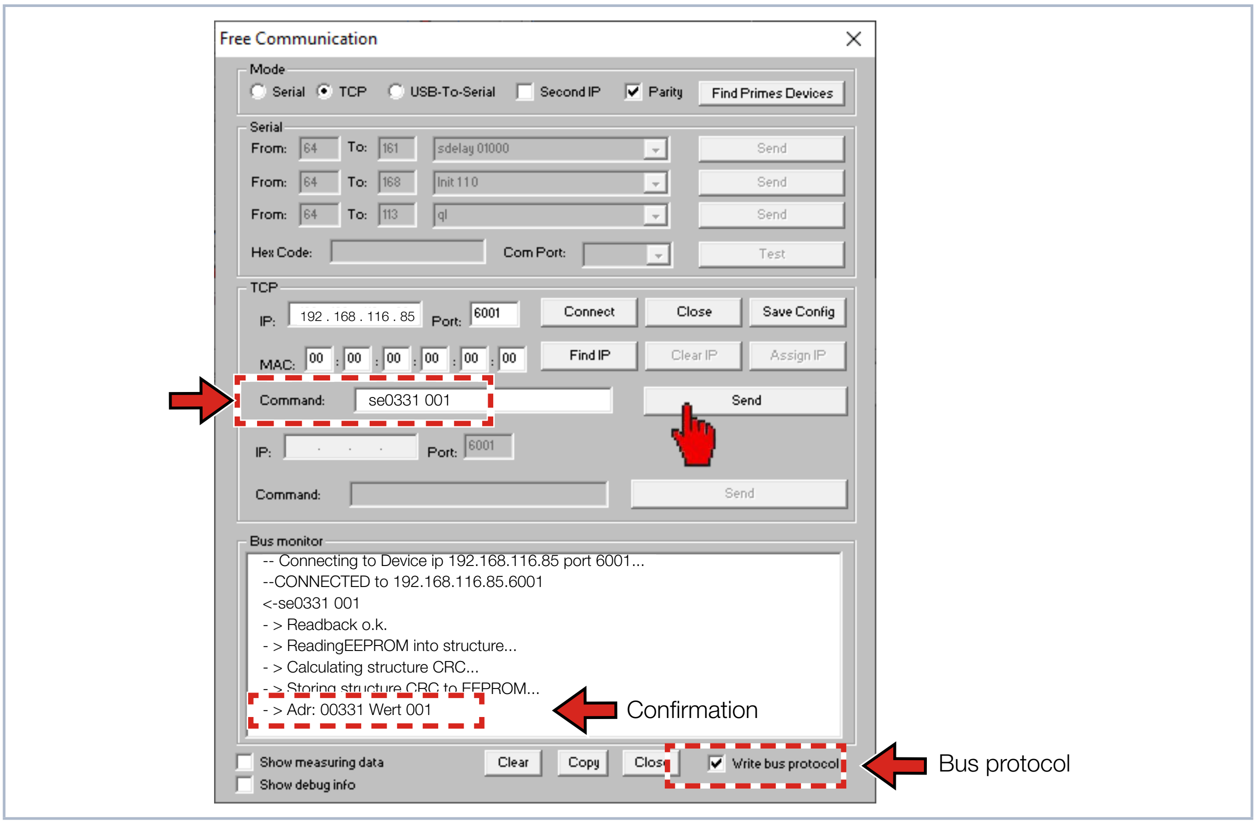


Fig. 11.5: Activating the DHCP function in the dialogue window ***Free Communication***

After restarting the device in the network, a new IP address is requested and automatically assigned by the server/router. The FindIP function using the MAC address is then not executable.
If there is no connection to the network (no response from the server), the static IP address (see identification plate) is activated in the BeamControl System BCS until the device is restarted.

You can deactivate the DHCP function with the command ***se0331*** ✶ ***000***.

12 Description of the LaserDiagnosticsSoftware LDS

The LaserDiagnosticsSoftware LDS is the control centre for all PRIMES measuring devices which measures the beam distribution as well as focus geometries by means of which the beam propagation characteristics can be determined.
The LaserDiagnosticsSoftware LDS includes all functions necessary for the control of measurements and displays the measuring results graphically.
Moreover, the systems uses the measured data to carry out an evaluation in order to give the operator of the beam diagnosis an information regarding the reliability of the measuring results.

Please do not start the LaserDiagnosticsSoftware LDS before all devices are connected and turned on.

Please start the program by double-clicking the LDS symbol in the new start menu group or the desktop link.

12.1 Graphical user interface

Firstly, a start window is opened in which you can choose, whether you would like to measure or whether you would just like to depict an existing measurement (factory setting "measurement").

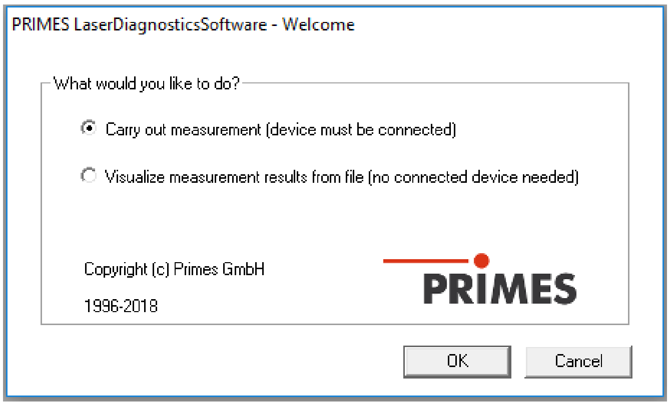


Fig. 12.1: Start window of the LaserDiagnosticsSoftware LDS

After the detection of the connected device, the graphical user interface and several important dialogue windows are opened.

In order to ensure that corresponding information can be assigned quickly, special markups for menu items, menu paths and texts of the user interface will be used in the following chapters.

Markup	Description
Text	Marks menu items. Example: Dialogue window ***Sensor parameters***
Text1 > Text2	Marks the navigation to certain menu items. The Order of the menus is depicted by means of the Sign "**>**" Example: ***Presentation > Caustic***
Text	Marks buttons, options and fields. Example: With the button ***Start***

Fig. 12.2: Special markups for menu items, menu paths and texts

The graphical user interface mainly consists of the menu as well as the toolbar by means of which different dialogue or display windows can be called up.

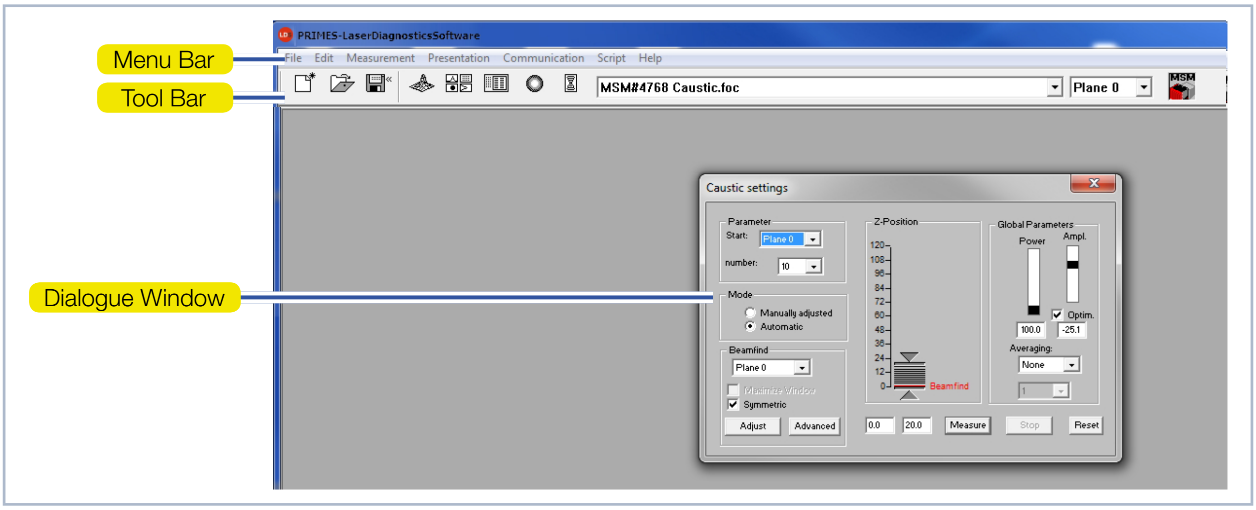


Fig. 12.3: The main elements of the user interface

It is possible to open several measuring and dialogue windows simultaneously. In this case, windows that are basically important (for the measurement or the communication) remain in the foreground. All other dialog windows fade into the background as soon as a new window opens.

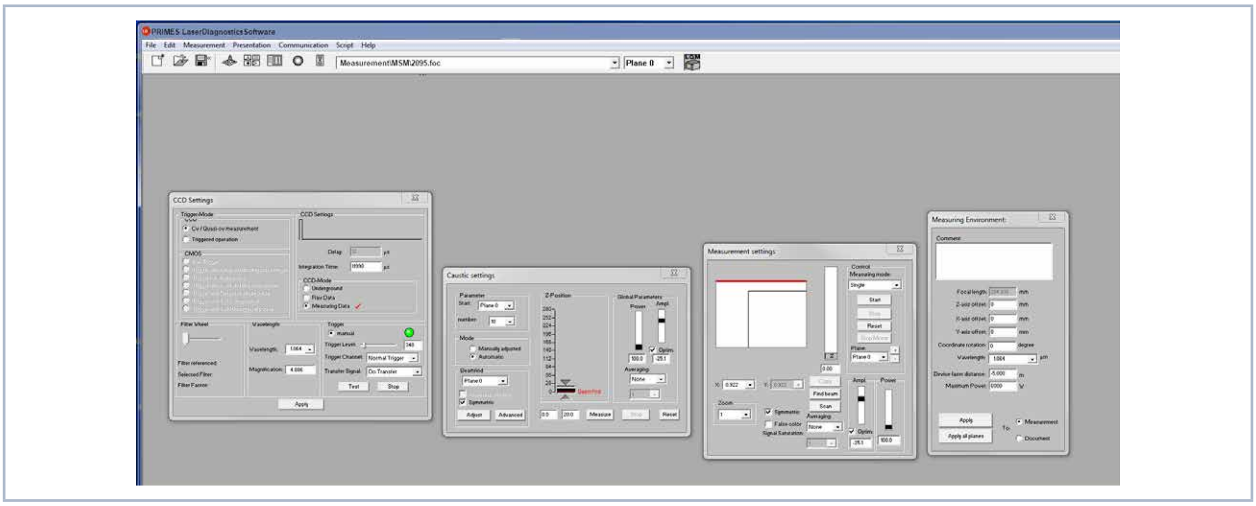


Fig. 12.4: The main dialogue windows

12.1.1 The menu bar

In the menu bar, all main and sub menus offered by the program can be opened.

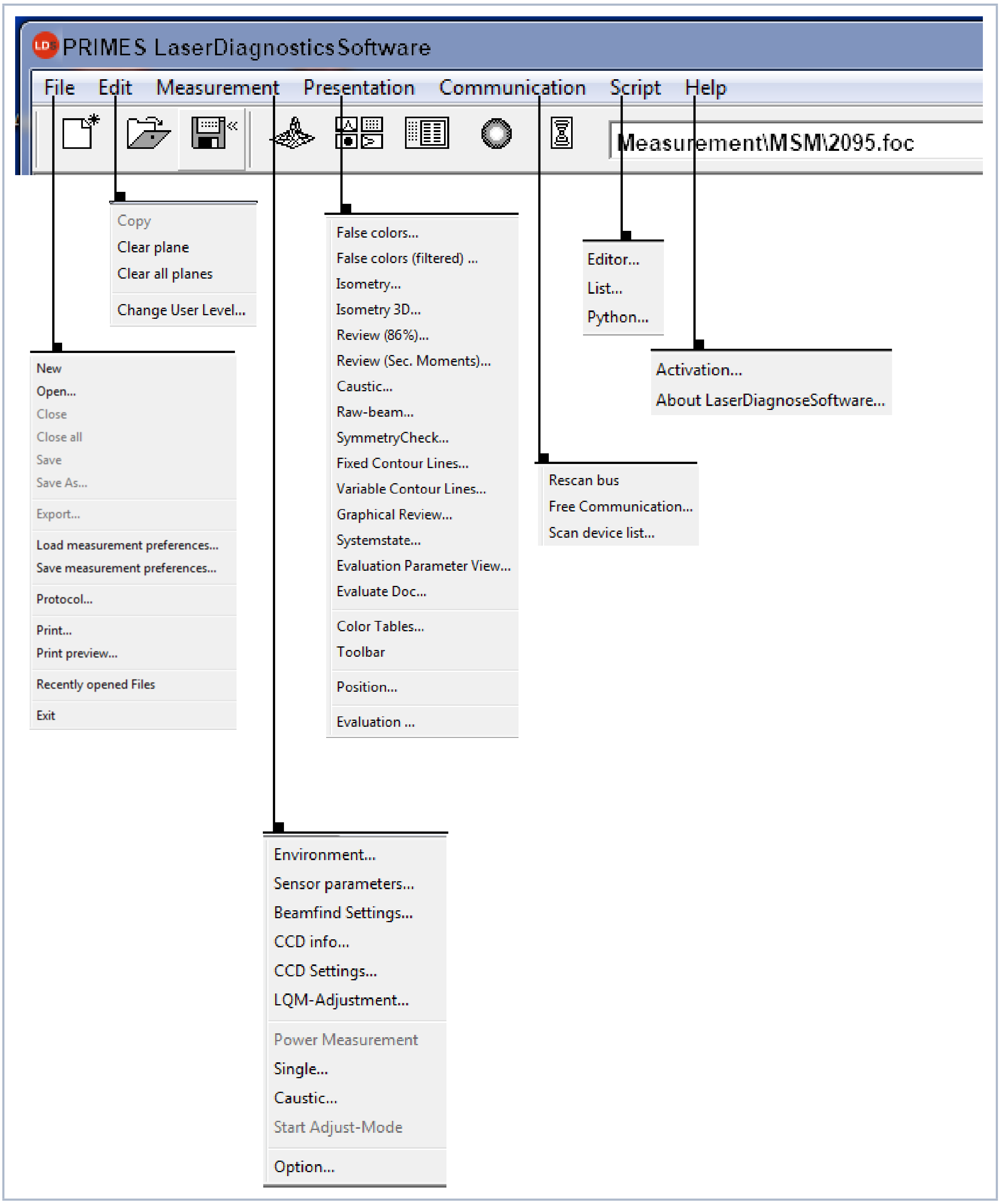


Fig. 12.5: Menu bar

12.1.2 The toolbar

By clicking the symbols in the toolbar, the following program menus can be opened.

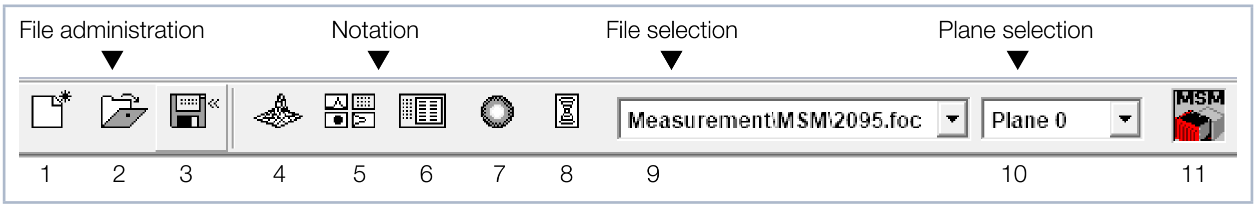


Fig. 12.6: Symbols in the toolbar

1. Create a new data record
2. Open an existing data record
3. Save the current data record
4. Open the isometric view of the selected data record
5. Open the variable contours line view
6. Open review (86%)
7. Open false color depiction
8. Caustic presentation 2D
9. List with all data records opened
10. Display of the selected measuring plane
11. Display of the measuring devices available for the bus by means of graphical symbols

All measuring results are always written into the document selected in the toolbar.
It is only possible to display documents chosen here. After opening, the data set has to be explicitly selected.

12.1.3 Menu overview

File	
New	Opens a new file for the measuring data
Open	Opens a measuring file with the extensions ".foc" or ".mdf"
Close	Closes the file selected in the toolbar
Close all	Closes all files opened
Save	Saves the current file in foc- or mdf format
Save as	Opens the menu for the storage of the files selected in the toolbar. Only files with the extensions ".foc" or ".mdf" can be imported safely
Export	Exports all current data in protocol format ".xls" and ".pkl"
Load measurement preferences	Opens a file with measurement settings with the extension ".ptx"
Save measurement preferences	Opens the menu to save the settings of the last program run. Only files with the extension ".ptx" can be opened
Protocol	Starts a protocol of the numeric results. They can either be written into a file or a data base
Print	Opens the standard print menu
Print preview	Shows the content of the printing order
Recently opened files	Shows the file opened before
Exit	Terminates the program
Edit	
Copy	Copies the current window to the clipboard
Clear plane	Deletes the data of the plane selected in the toolbar
Clear all planes	Deletes all data of the file selected in the toolbar
Change user level	By entering a password a different user level can be activated.
Measurement	
Environment	Different system parameters can be entered, e.g.: - Reference value for the laser power - Focal length - Wavelength - Comment - Device offset (Not relevant for HP-MSM-HB)
Sensor parameters	The following device parameters can be e.g. set here: - The mechanical locked area of the z-axis - The spatial resolution (32, 64, 128 or 256 Pixel) - The manual settings of the z-axis - Choosing the measuring devices connected to the bus - Deactivating the z-axis
Beamfind settings	Not relevant for HP-MSM-HB
CCD info	Provides information on device parameters
CCD settings	Special settings can be made, e.g.: - Trigger mode - Trigger level - Exposure time - Wave length

LQM-Adjustment	Not relevant for HP-MSM-HB
Power measurement	Not relevant for HP-MSM-HB
Single	This menu item enables the start of single measurements, of the monitor mode and the video mode
Caustic	Enables the start of a caustic measurement. Not only automatic measurements but also serial measurements of manually set parameters are possible. The automatic measurement starts with a beam search and then caries out the entire measuring procedure independently. Only the z-range that is to be examined as well as the desired measuring plane have to entered
Start adjustment mode	Not relevant for HP-MSM-HB
Options	Enables the setting of device parameters
Presentation	
False colors	False color display of the spatial power density distribution
False colors (filtered)	Usage of a spatial filtration (spline function) on the false color display of the power density distribution
Isometry	3-dimensional display of the spatial power density distribution
Isometry 3D	Allows a 3D display of caustic and power density distribution with spatial rotation as well as an optional isophote display
Review (86%)	Numerical overview of measuring results in the different layers basing on the 86% beam radius definition
Review (2. moment)	Numerical overview of the measuring results in the different layers basing on the 2. moment beam radius definition
Caustic	Results of the caustic measurement and the results of the caustic fit – such as beam quality factor M^2, focus position and focus radius
Raw beam	Not relevant for HP-MSM-HB
Symmetry check	Analysis tool to check the beam symmetry especially for the alignment of laser resonators. No standard feature of the device
Fixed contour lines	Display of the spatial laser density distribution with fixed intersection lines for 6 different power levels
Variable contour lines	Display of the spatial power density distribution with freely selectable intersection lines
Graphical review	Enables a selection of graphical displays – among them the radius, the x- and y- position above the z-position and the time
System state	Not relevant for HP-MSM-HB
Evaluation parameter	Loading stored evaluation parameters
Color tables	Different color charts are available in order to analyse e.g. diffraction phenomena in detail
Toolbar	In order to display or to hide the toolbar
Position	Moving the device into a defined position
Evaluation	Comparison of the measured values with defined limit values and evaluation (optionally)
Communication	
Rescan bus	The system searches the bus for the different device addresses. This is necessary whenever the device configuration at the PRIMES bus was changed after starting the software.
Free Communication	Display of the communication on the PRIMES bus
Scan device list	Lists the device addresses of the single PRIMES devices

Script	
Editor	Opens the script generator, a tool, by means of which complex measuring procedures are controlled automatically (with a script language developed by PRIMES).
List	Shows a list of the opened windows
Python	Opens the script generator in order to control complex measuring procedures automatically (scripting language Python)
Help	
Activation	Enables the activation of special functions
About LaserDiagnostics-Software LDS	Provides information regarding the software version

Tab. 12.1: Menu overview

Further information about the LDS you can find in the appendix..

13 Measurement

13.1 Safety instructions

DANGER

Serious eye or skin injury due to laser radiation

During the measurement the laser beam is guided on the device, which causes scattered or directed reflection of the laser beam (laser class 4). The reflected beam is usually not visible.

- **Please wear safety goggles adapted to the power, power density, laser wave length and operating mode of the laser beam source in use.**
- **Wear suitable protective clothing and protective gloves.**
- **Protect yourself from laser radiation by separating protective devices (e.g. by using appropriate shielding).**

DANGER

Serious eye or skin injury due to laser radiation

If the device is moved from its calibrated position, increased reflected radiation (laser class 4) may result during measuring operation.

- **When mounting the device, please ensure that it cannot be moved, neither due to an unintended push or a pull on the cables.**

NOTICE

Damaging/destroying the device

Obstacles in the movement range of the HP-MSM-HB can lead to collisions and damage the device.

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

NOTICE

Damaging/destroying the device

Contamination can damage or destroy the optical components.

- **Only open the device in a dust-free environment.**

13.2 HP-MSM-HB with 5-fold HP-objective and cyclone

1. Make sure that the connections of the water cooling are firmly mounted and tight.
2. Turn on the water-cooling.
3. Turn on the measuring device.
4. Wait until the measuring device has finished the referencing procedure (duration approx. 30 seconds).
5. Start the LaserDiagnosticsSoftware on your computer.
6. Change the z-position to 60 mm (center of the measuring range; 20 mm for HP-MSM-HB 20 kW)).
7. Open the compressed air supply.

8. Place the alignment tool on the cyclone. The upper edge corresponds to the z-position of the measuring plane of the objective. Turn on the pilot laser. If the laser hits the little bore in the cover vertically, it is displayed centrally on the sensor.
9. Remove the alignment tool.
10. 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).
11. Carry out a test measurement with the desired z-range and with small power.
12. During the measurement, check the surroundings of the measuring objective for scattered radiation (if necessary, reduce the misalignment angles in x and y direction to below 10 mrad).
13. Increase the power gradually until the measuring power is reached and carry out a caustic measurement (it might be necessary to adapt some parameters).
14. After finishing the last measurement, the objective should be covered with the alignment tool if it remains in place. If the instrument is to be transported, please use the transport lock of the objective lens.

13.3 HP-MSM-HB with Fiber Bridge

NOTICE

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

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

▶ **Please mind the limit values zmax given in table Tab. 16.1, measured from the surface of the aperture plate.**

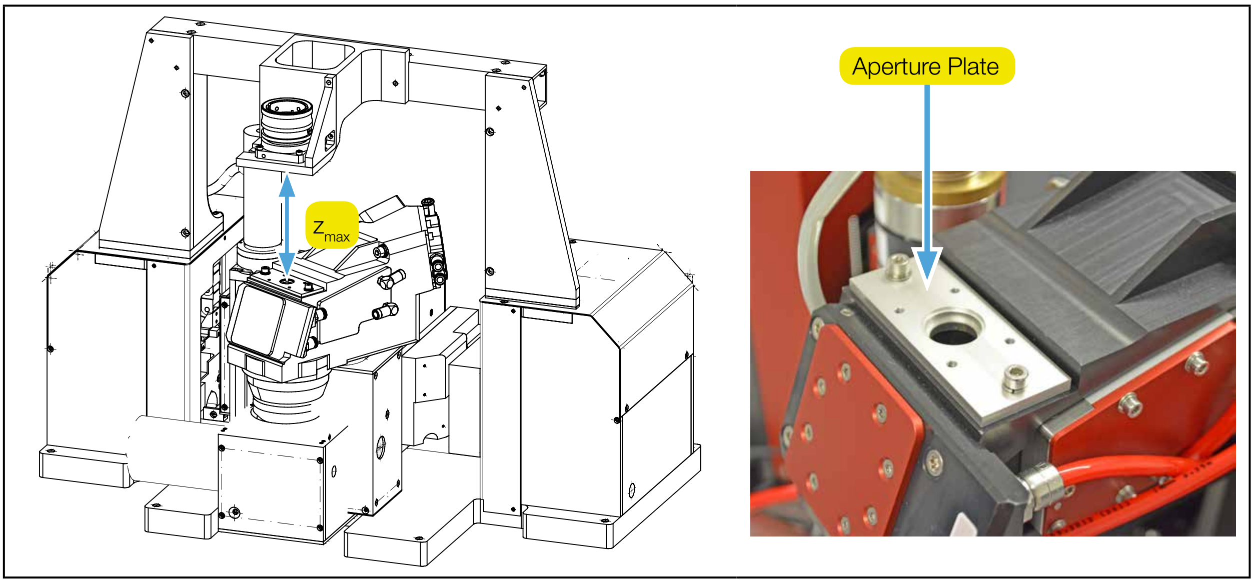


Fig. 13.1: Movement range of the HP-MSM-HB with fiber bridge

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

Tab. 13.1: Limit Values z_{max}

13.4 Prepare measurement

The following check lists should help you to realize the most important conditions for a measurement and to carry out all necessary settings of the LaserDiagnosticsSoftware LDS.

13.4.1 Check list measurement settings

❑	The device is stable and fixed.
❑	The movement range (z-axis) of the measuring device is free of obstacles.

Tab. 13.2: Check list safety precautions

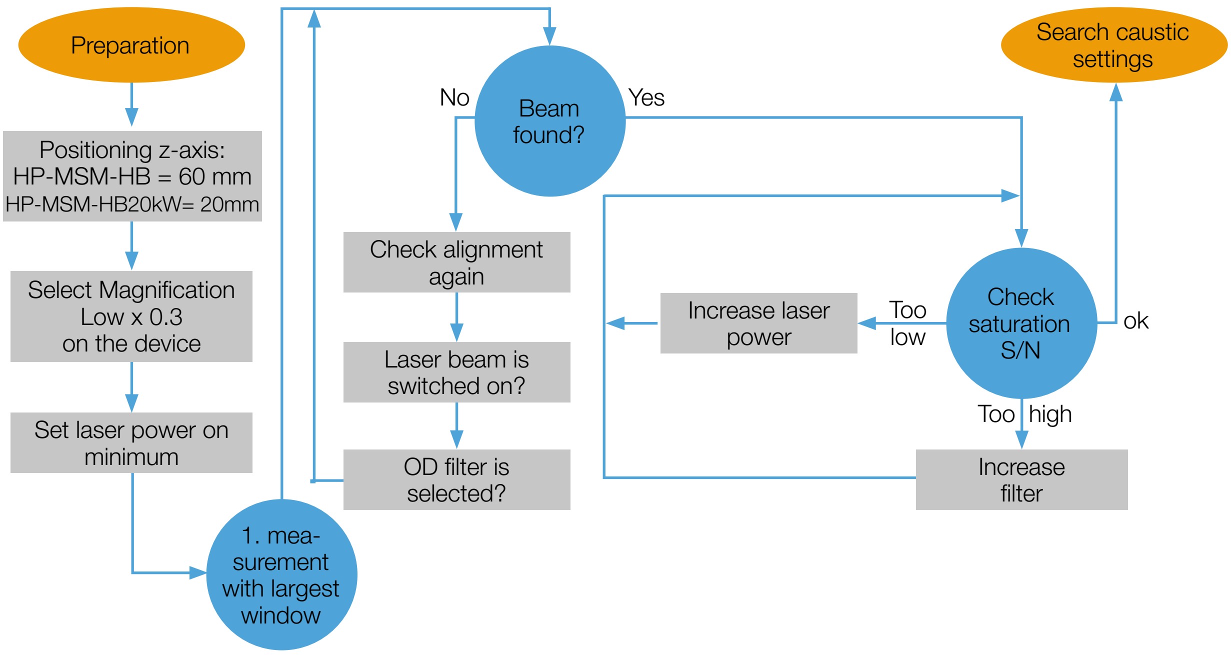
13.4.2 Check list measurement settings

LDS Menu Path	Action	
Measurement > Environment	❑	Enter the focal length
Measurement > Sensor parameters	❑ ❑	Preset 64 pixel for the resolution x Preset 64 pixel for the resolution y
Measurement > CCD Settings	❑ ❑ ❑	Select the trigger mode Cw/Quasi-cw Measurement Select the CCD mode Measuring data Select the correct wave length
Measurement > Single	❑	Activate the check box Optim.
Measurement > Caustic	❑ ❑	Activate the mode Automatic Activate the check box Optim.
Measurement > Option	❑ ❑	Preset the fillfactor Max: 0.7 Min: 0.5 Ref: 0.6 Analyse Settings: Activate the check box Enable adjust nullevel

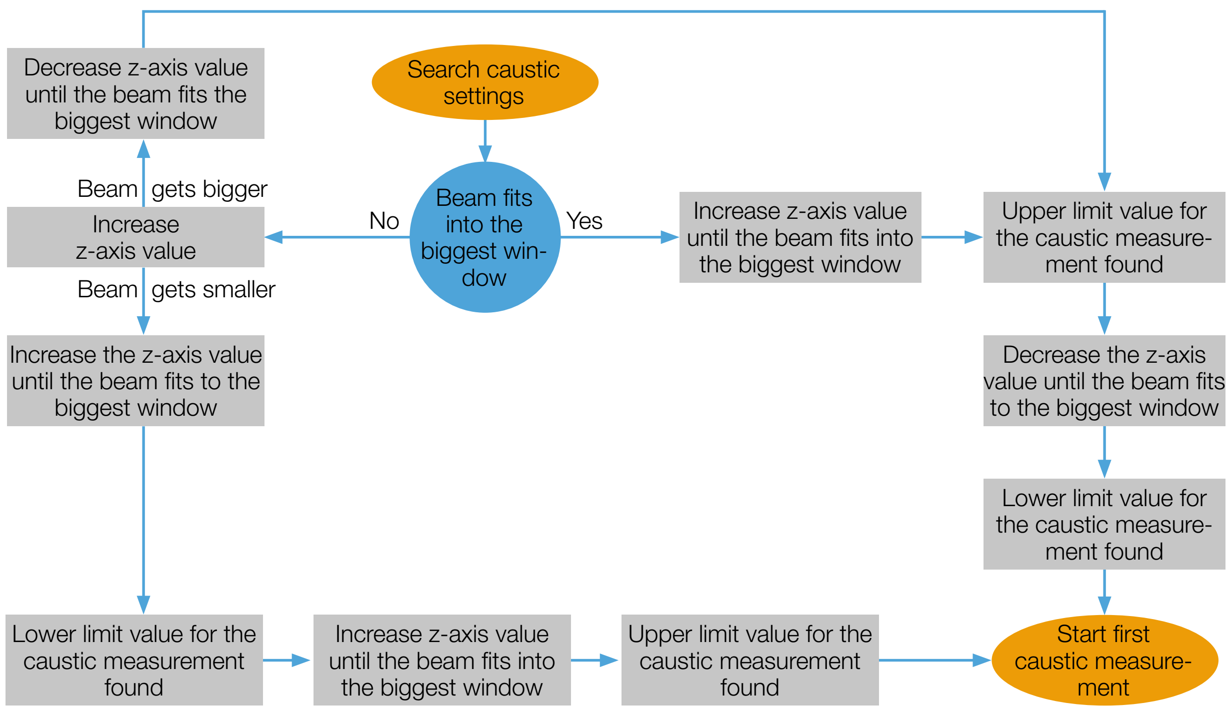
Tab. 13.3: Check list measurement settings

13.5 Flowchart of a measurement

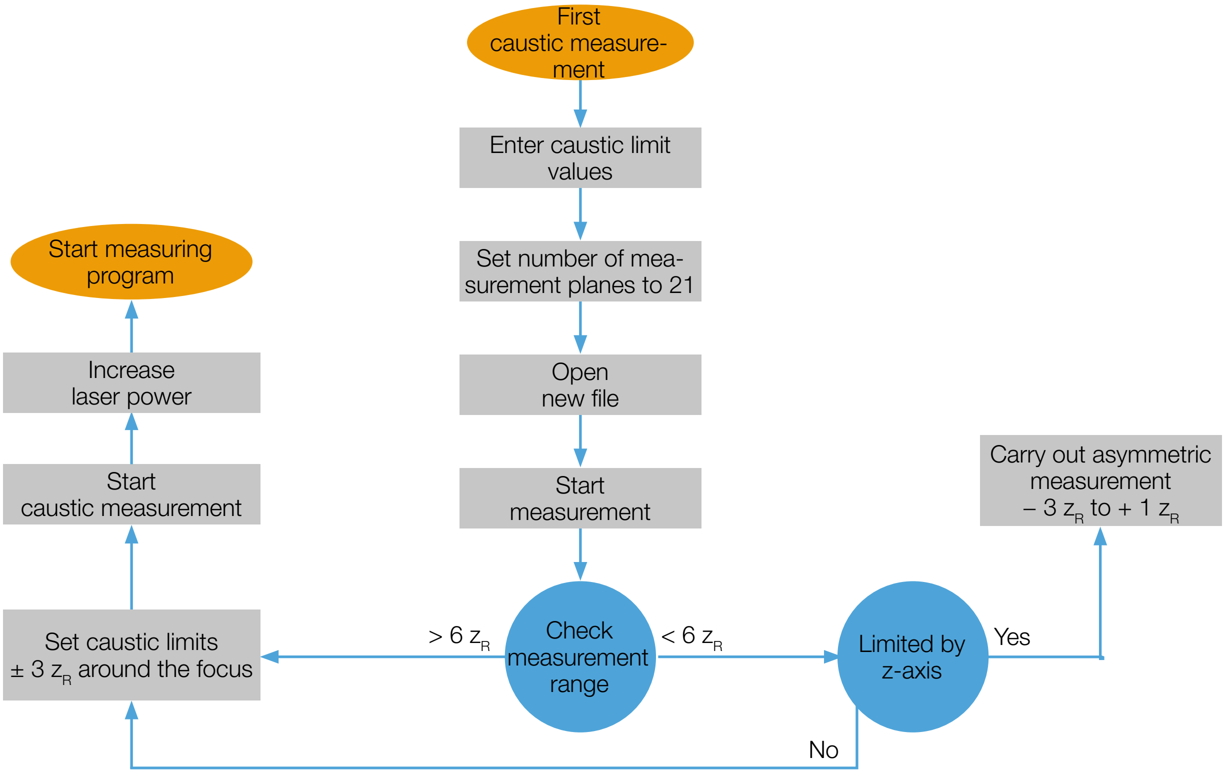
13.5.1 Prepare measurement



13.5.2 Set caustic limits



13.5.3 Perform caustic measurement



13.6 Perform measurement settings in the LaserDiagnosticsSoftware LDS

The following explanations of the configuration options should help you to make the right settings for the respective task.

The following chapters highlight important configuration options in color:

Color	Meaning
Red	This setting must always be set as shown.
Yellow	This setting is dependent from the desired operating mode (CW, pulse, single pulse, measurement series, etc.).
Green	This setting must be carried out before each measurement. The settings depend on the specific measurement task, such as the wavelength, the laser power or the geometry of the laser beam.

Tab. 13.4: Color meaning of the setting options

13.6.1 Sensor parameters (menu *Measurement* > *Sensor parameter*)

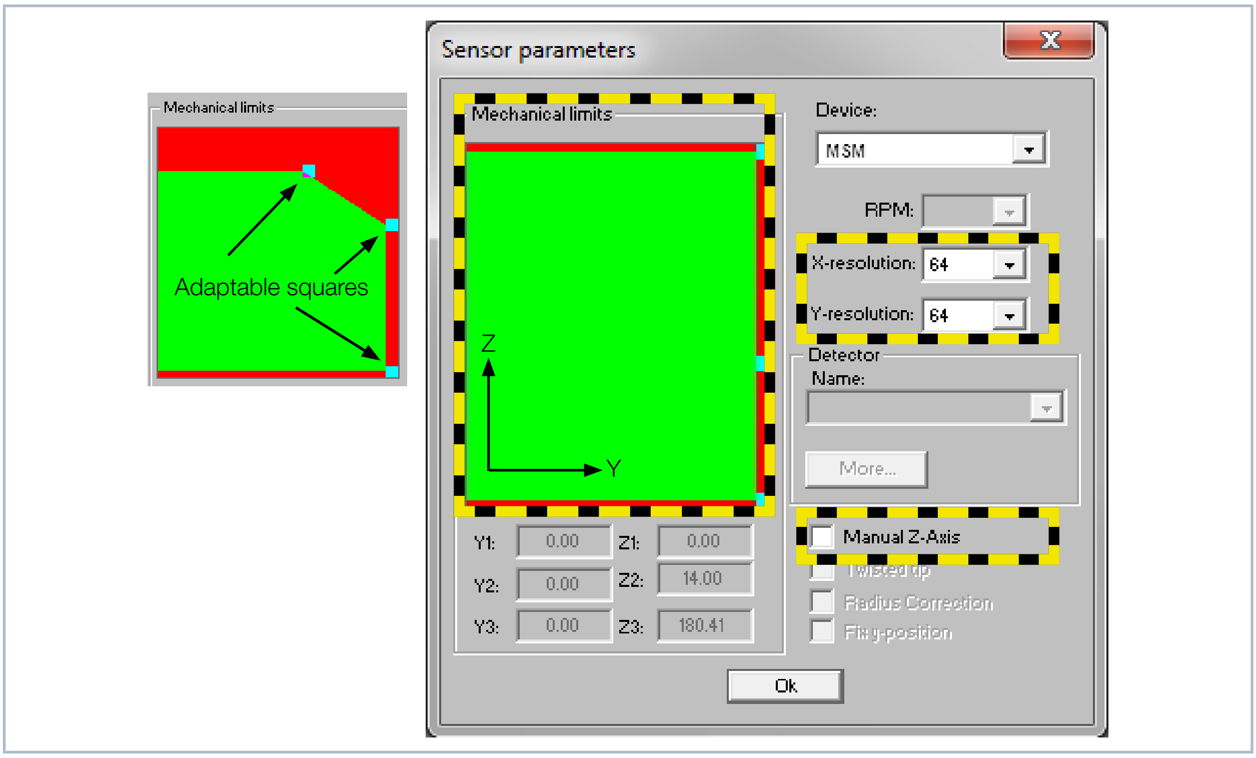


Fig. 13.2: Dialogue window ***Sensor parameters***

Mechanical limits

By pulling the turquoise square with the mouse pointer you can restrict the movement range of the y- and z-axis. Therewith you can prevent damages in case other components reach into the movement range of your device. The maximum value corresponds to the value Y3 and Z3.

Resolution

Here you can enter the number of pixels in the measuring window, ranging from 32 x 32 to 256 x 256 pixels. Generally, 64 x 64 pixels are sufficient. Please keep in mind that the more pixels there are, the longer the measurement will take.

Manual z-axis

With this function you can deactivate the z-axes of the measuring system. This is useful if you want to use external movement axes. In this case you can manually assign a z-value to every measurement plane in the dialogue window ***Single measurement***.

Please find further information on the menu Menu *Measurement* > *Sensor parameter* in chapter 24.3.2 on page 111.

13.6.2 Measuring environment (menu *Measurement* > *Environment*)

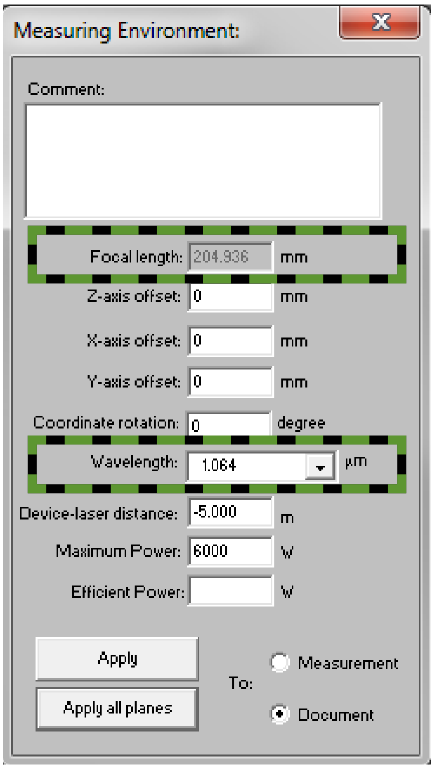


Fig. 13.3: Dialogue window ***Measuring Environment***

Focal length

Stating the focal length is relevant for the evaluation of the caustic measurements. From the caustic process and the entered focal length the raw beam diameter on the focussing optic can be calculated.

Wave length

The wave-length is the basis for a correct determination of the beam quality factor M². At the moment there is only one option:

- 1.064 µm for Nd:YAG laser

A wavelength can also be typed in numerically.

Please find further information on the menu *Measurement* > *Measuring environment* in chapter 24.3.1 on page 109.

13.6.3 Measurement settings (menu *Measurement* > *Single*)

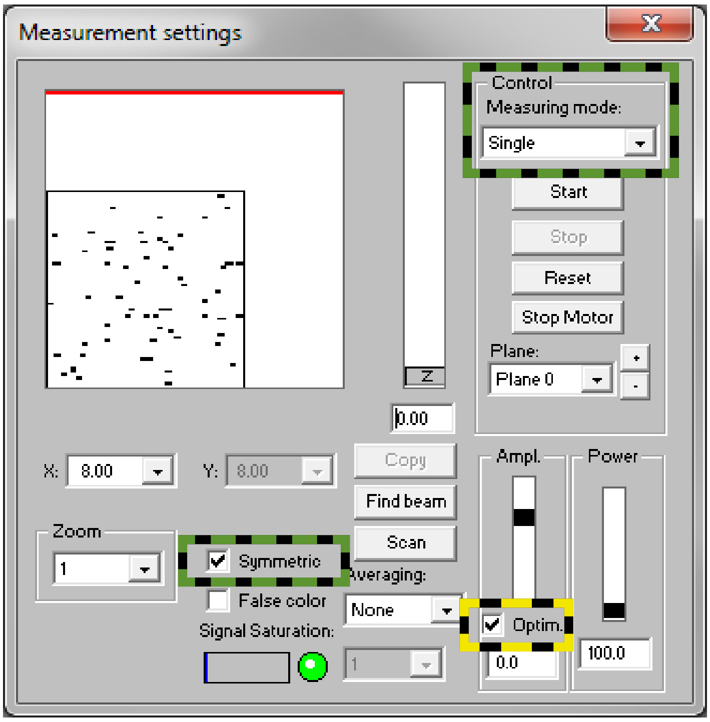


Fig. 13.4: Dialogue window ***Measurement settings***

Controlling measuring modes (individual measurement, monitor, and video mode)

There is a total of three different measuring modes that can be selected here. In the ***Individual Measurement*** and ***Monitor*** measuring mode, all necessary compensations (smear effect, diffusion) and exposure time adjustments are performed every time a new measurement is carried out. Valid measuring data is generated in this mode.

The measuring mode ***VideoMode*** does not produce valid measurement data. Here the exposure time is carried over from the last measurement and does not vary. Compensation measurements are not performed, making it unnecessary to consider or compensate for measuring artifacts such as smear effects.
Due to the “high” measuring frequency of about 5 Hz, this operating mode is particularly suited for use when aligning the device. The numeric results should not be interpreted absolutely, but rather always relative to each other.

Optical amplification (opt. ampl.)

This function activates the automatic adjustment of the exposure time of the CCD for every measurement. The function must be activated in order to keep the signal/noise ratio consistently high for a caustic measurement.
For special measuring applications, however, it might make sense to deactivate this function and set the exposure time to a fixed value between 12 µs and 200 ms. Here it is important to ensure sufficient attenuation of the laser beam with the help of the fixed ND filter or the filter wheel.

Symmetrical

Once this function is activated, only rectangular measuring windows will be allowed. In cases where an elliptical or even a square laser beam is being measured, this function should be deactivated so that the measuring window can be optimally adjusted.

Please find further information on the menu *Measurement* > *Single* in chapter 24.3.8 on page 115.

13.6.4 Caustic settings (menu *Measurement* > *Caustic)*

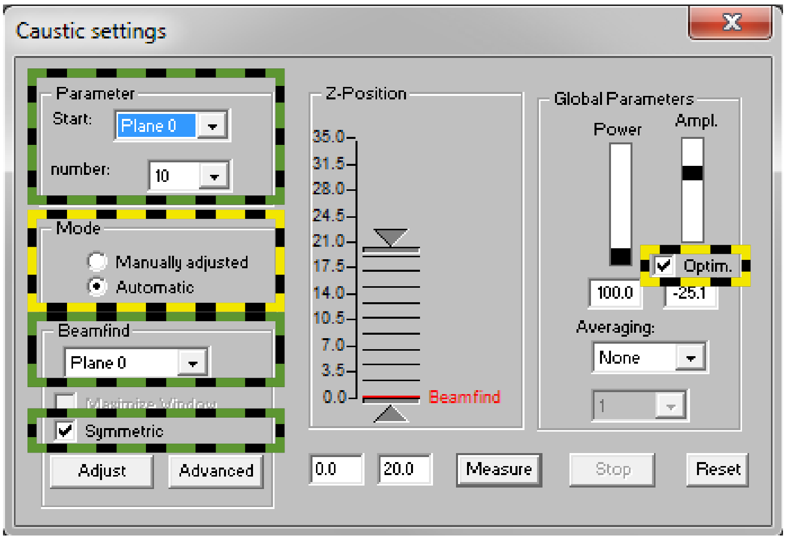


Fig. 13.5: Dialogue window ***Caustic settings***

Parameters (start number of the plane)

Under Start, the start number at which the measurement is initiated can be entered for the plane. By default, the start number is generally set to zero and should only be changed when you are measuring in an existing document and don't want the existing measurement data to be overwritten. If, for example, you have measured a caustic with 21 planes and want to magnify the measuring area to the smaller z-values, you can set the start plane to 21 and modify the measuring area appropriately. The new measuring values will then be written into the existing document starting with plane 21.

In the Quantity selection field, the number of planes to be measured in the specified z range is set. The following should be considered here:

- Since the LaserDiagnosticsSoftware LDS always sets the measuring plane distances so they are equidistant (equal spacing) and the measuring area is almost always situated symmetrically around the focal point, an odd number of measuring planes should be selected. The focus plane is calculated based on the measuring plane and displayed in the caustic illustration.
- Beam measurement norm DIN 11146 specifies that at least 10 measuring planes should be measured. Furthermore, five measurements should also be taken within a Rayleigh length and the other beyond 5 Rayleigh lengths. In order to meet all of the requirements with equidistant distribution, at least 17 measuring planes must be measured in a range of ± 3 Rayleigh lengths.

Mode (automatic and manual settings)

There are two different measuring modes for caustic measurement. In “Automatic” mode, the measuring system and the LDS determine the ideal measuring window position (x- and y-direction) for each measuring plane and the optimal measuring window size for the fill factor. Furthermore, the plane location in the z-direction is also calculated based on the specifications (number of measuring planes, measuring limits z-direction).

Especially when adjusting the measuring window size and the measuring window position in the x- and y-direction, the number of iterations (max. three per plane) can result in an extended measurement duration.

It is therefore possible to change the measuring mode to “Manual Settings” for recurring measuring tasks and for repeating measurements. In this case, the measuring system will take the measuring window positions and measuring window sizes from the previous measurement or from a .ptx file. This reduces the measurement duration considerably, but does require that the location and parameters of the laser beam change only minimally.

Beam search

This selection field specifies which plane the caustic measurement should be started in. If the optional ***Beam Find*** function is activated in the ***Options*** dialog window, that is also the plane in which this function will be performed. When the Beam Find function is deactivated, this plane must be manually measured ahead of time to make sure that the laser beam is found.

Please find further information on the menu *Measurement* > *Caustic* in chapter 24.3.9 on page 119.

13.6.5 CCD settings (menu *Measurement* > *CCD Settings*)

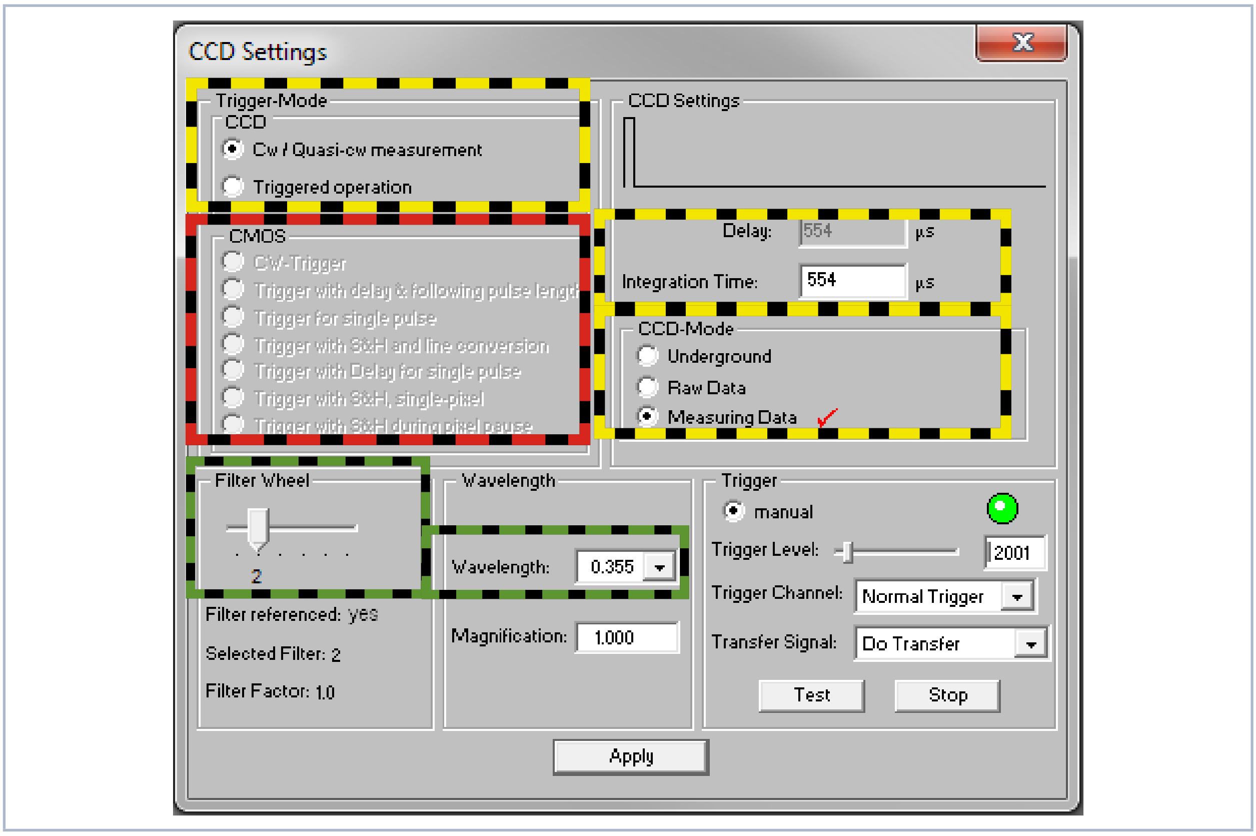


Fig. 13.6: Dialogue window ***CCD Settings***

The wavelength, attenuation, and operating mode are all set in the ***CCD Settings*** dialog window.

Trigger modes

The appropriate settings must be configured here in keeping with the operating mode of the laser to be measured. Here it is important to consider that pulsed lasers with a pulse frequency of more than 500 Hz can be measured in cw mode. If, however, the operating mode is set to pulsed and a cw laser system is involved, the measuring device will always display the error message “Error Black Pixel Measurement” or “Time Out During Measurement” in reaction to a measurement request.

Delay

This function can only be used with a “triggered operation” trigger mode. The time the measuring system should wait between when it detects the trigger pulse and the start of the measurement is set here. Together with the function “Integration Duration”, defined “Windows” from the plus cycles can be measured (e.g. exactly one pulse or parts of an ms pulse. The minimum delay is 12 µs.

CCD operating modes

Three different modes can be set here. If the ***Raw Data*** setting is activated, the measuring system will return the uncompensated data of the CCD when a measurement is requested. Especially with NIR irradiation, these can be riddled with measuring errors such as “smear effect” readout noise. Even the numeric beam data generated from this data will be affected by this.
If a ***Background*** is selected as the operating mode, only correction data will be returned while measuring. ***Measuring Data*** mode should always be the default setting here though. Only when this mode is turned on can the measuring system deliver reliable measuring values.

Integration duration

This function sets a defined integration duration. The optimizer must be deactivated before this can be accomplished, since otherwise the measuring device itself will optimize and thus change the integration duration. This function is also used mainly in measuring pulsed laser systems.

Filter wheel

Which filter is needed for measuring depends on the wavelength and the intensity of the laser beam being measured and the appropriate one must be chosen specifically for each measuring task.
A filter can be considered suitable when all measuring planes of a caustic measurement can be measured using an exposure time between 18 ms (-20 dB) and 0.18 ms (-60 dB). Outside of these limits, the S/N ratio of the CCD declines, thus reducing the accuracy.

Wavelength

Due to the wavelength-dependent overall magnification of the camera-based measuring system, it is important to check that the right selections have been made before each measurement. The wavelengths shown here represent the calibration points of the measuring objective. As a result of the achromatic properties of the measuring objective, a wavelength range between 1030 and 1100 can be achieved, for example, with a calibration point at 1064 nm without causing generating measuring errors.

General sequence control

- Empty the CCD register
- Aim for the holding point in line a (line in which photo transfer takes place); if the trigger is set off during sub-pulse, repeat line a (-> NLC = NoLineChange)
- Wait for the trigger if necessary and repeat line a (NLC)
- Wait out the delay if necessary and repeat line a (NLC)
- Aim for the holding point in line a through sub-pulse (-> delete the charge in the photo diodes)
- Integration – no cycles (sliding the charges through the register) of CCD
- Cycles start again, a few AD cycles later: Photo transfer
- Read out the CCD register; when the addresses match (= desired pixels), the measuring value is forwarded to the AD transformer.

The various signals going through the transfer output mark certain points in time during the sequence control:

Transfer signals	Meaning
Do transfer	Is high when the CCD is at the holding point in line a (referred to in this way, since photo transfer also takes place in this line – when it isn’t being suppressed by the NLC).
Do transfer & Xend	A short high-pulse, when we reach the end of line a.
Sub	Is high as long as a sub-pulse is running.
Start done	Is high when the CCD is ready for integration (or when waiting for the trigger) so when it is at the holding point in line a. Is low again when the CCD is read out. You could use the positive side to light the laser.

Transfer signals	Meaning
Wait for trigger	Is high when the CCD is at the holding point in line a and is waiting for the trigger signal. Is low as soon as the trigger is activated and the delay begins. Only a short high pulse occurs in untriggered operation. Could be used in addition to the trigger out connector to check triggering.
Integration done	Is high as soon as integration is complete. Is low again when the CCD is read out.
Photo cycle	Is high when the CCD is ready for integration. Is low as soon as integration is complete. During untriggered operation, the high phase returns exactly the integration time.

Tab. 13.5: Signals that can be sent through the transfer outlet

Please find further information on the menu *Measurement* > *CCD Settings* in chapter 24.3.5 on page 113.

13.6.6 Option (advanced user only) (menu *Measurement* > *Option*)

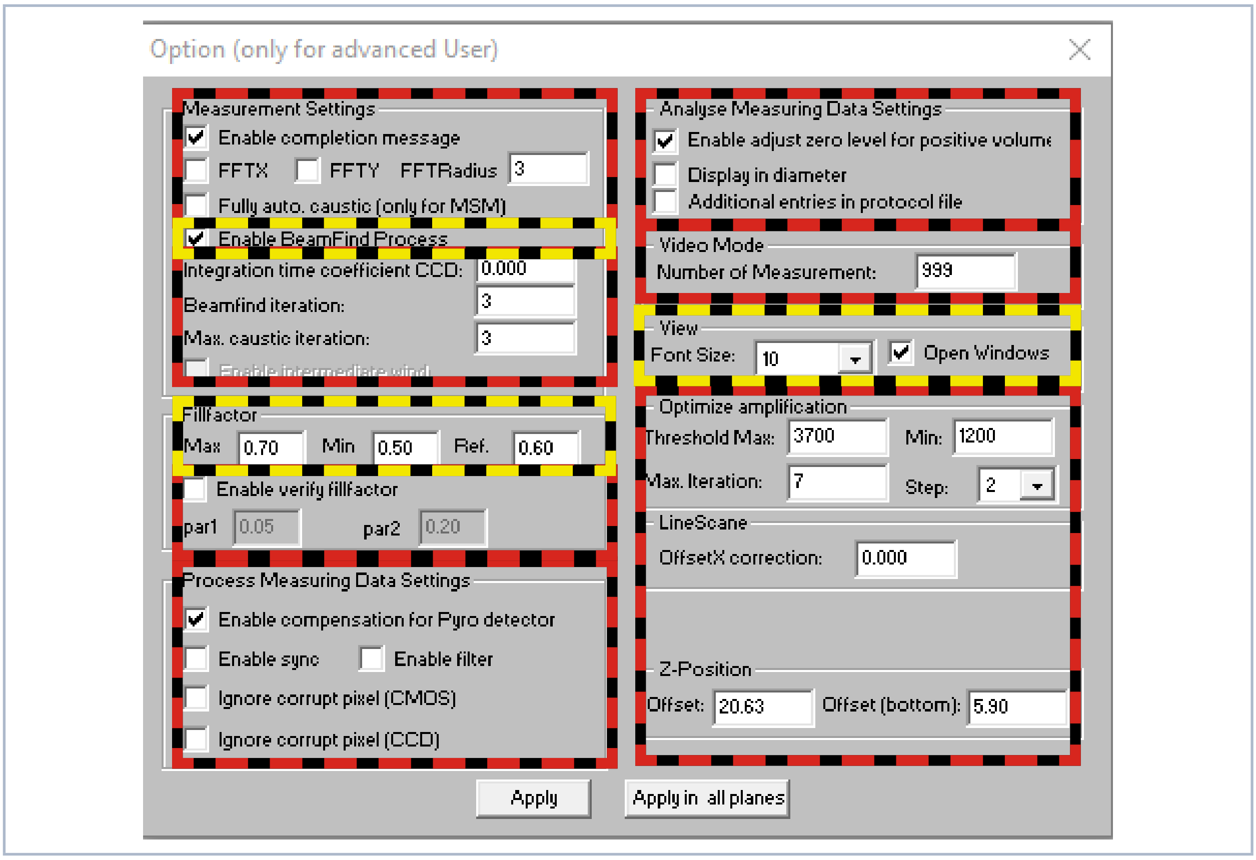


Fig. 13.7: Dialog window ***Option***

Enable beam find process

The Beam Find function must be used for caustic measurement. This involves an algorithm that separates the measuring signal from the measurement artifacts (e.g. noise) via an adjustable trigger threshold and adapts the size of the measuring window to this signal. This algorithm is only executed in the beam search plane (Dialog window ***Caustic***). On all other measuring planes, the measuring window size is determined using the fill factor.

If this function is deactivated, the beam search plane must be manually "premeasured" in the measuring system. Otherwise the measuring system might end up positioning the measuring window on the edge of the measuring area where there is no measuring signal. This makes it impossible to take a meaningful measurement.

If you turn the Beam Find function off and have the measuring measure the beam search plane system before each caustic measurement, you can save about 20 sec of measuring time per caustic measurement.

Summary: This function should be activated by default and only deactivated by experienced users. Turning off this function can shorten the time for caustic measurements by about 15 %.

Fill factor

The fill factor is the quotient of the beam diameter and the length of the sides of the measuring window. As long as the measuring signal is not cut off and there are no noise components in the measuring result and now errors in the offset determination, the fill factor won't influence the accuracy at all. But since every real measuring signal is tainted with noise and since the precision with which the zero level of a measuring signal can be determined is finite, very small fill factors can lead to a high level of accuracy. Depending on how substantial the RMS noise is and the errors in the zero level determination of a measuring plane, the optimal fill factor value to produce the best possible mathematical result will be different.
For TopHat and Gaussian beam shaped laser beams, the fill factor should range between 0.5 and 0.7. If the beam has diffraction rings, however, and if these are located completely within the measuring window, the optimal value for the fill factor can be between 0.5 and 0.6.

By default, the value should be set to: "Max 0.7 Min 0.5 Target 0.6". For extremely deformed beams, the value may be changed to "Max 0.6 Min 0.4 Target 0.5".

Font size

The font size for the most important display window can be changed here.
It is set to 10 points at the factory.

Open windows

When the window opening function is activated, some basic windows are opened when the LDS is started. If you don't want this to happen, the function can be deactivated.

13.6.7 CCD info (menu *Measurement* > *CCD Info*)

The most important device data is shown in the menu ***Measurement* > *CCD Info***. Here you can see the magnification information for the measuring objective and also check which beam path is turned on.
If obvious default values (1:1) are shown instead of the actual magnification, then please check the mounting of the measurement objective.

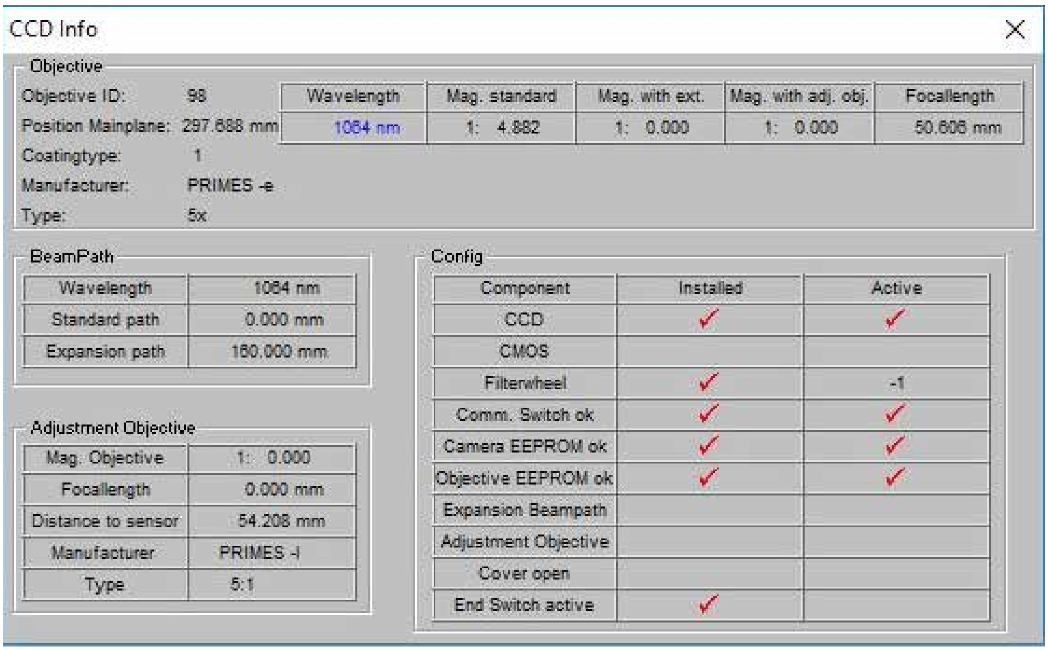


Fig. 13.8: Window ***CCD Info***

13.6.8 Single measurement (menu *Measurement* > *Single*)

This menu item is used for conducting single measurements. Settings for the measuring window position can be entered manually or automatically. The x- and y-axis measuring range of 2 mm x 2 mm at the device is much greater than the largest measuring window. It allows you to do a beam search manually or using the ***Scan*** function.

When a ***Scan*** is triggered, the HP-MSM-HB automatically tests the measuring range. When a point of maximum intensity is detected, the HP-MSM-HB automatically zooms to this point and adjusts the measuring window size. When the device has no x- or y-axis, the beam search function can be done automatically with item ***Find beam***.

The system only searches the area of the set-up window at the selected z-position. Afterwards, the ***Beam Search*** window appears. If the beam search is successful, a measurement window of appropriate size and position is displayed in the test panel of the "Single Measurement" window. The beam can then be recorded using the ***Measure*** button. The size of the measurement window depends on the magnification of the objective. Influencing factors are objective, wavelengths, and operating mode (standard, beam path extension, and calibration mode).

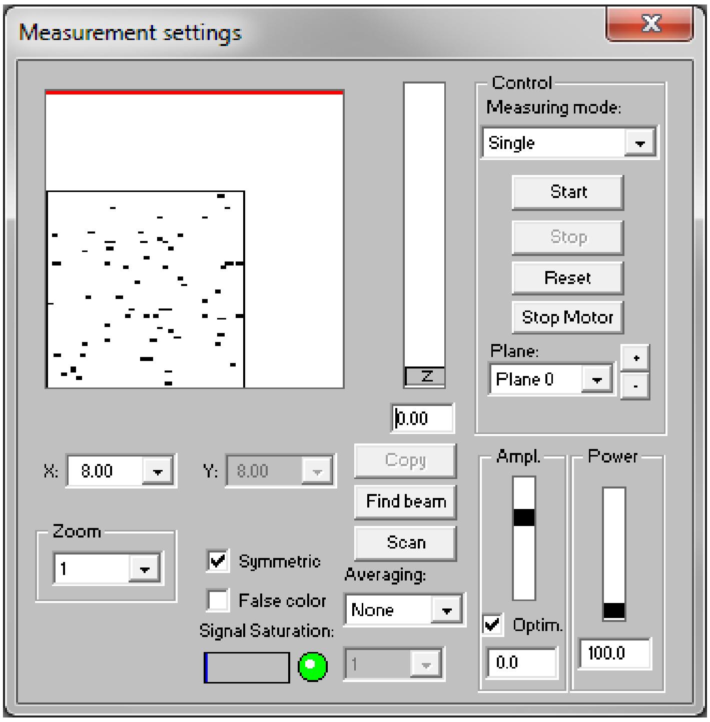


Fig. 13.9: Dialogue window ***Measurement settings***

During a manual beam search, the user can set the position and size of the measuring window within the mechanical limits himself. The selection is found in a pop-up menu, where you enter an x value for quadratic and/or x and y values for a rectangular measuring window. The position of the measuring window can be changed by clicking and dragging the frame using the mouse. The position of the window in the z-direction (height) can be changed using the z-sliding bar or by entering numerical values. The ***Zoom*** function allows a detail magnification of the measuring range.

A measurement is started with the ***Start*** button. The ***Monitor*** button starts periodic measurements based on current settings. The repetition rate depends on the spatial resolution and type of communications between the PC and the HP-MSM-HB.

The ***video mode*** only functions when using Ethernet communications. The HP-MSM-HB provides 4 frames per second in ***video mode***. Unlike the monitoring operation, only raw data is transmitted in ***video mode***.
If the detector is over driven during a measurement (the appearance of red in the representation and/or an A/D-Converter value of 4 095 in a clear section indicates ***signal saturation***), you should reduce the amplification using the Amplitude slider ***Ampl.*** and repeat the measurement. Amplification is automatically regulated when optimization is activated. If necessary, filtering must also be increased using a neutral glass density filter.

The radiated power can be configured using the ***Power*** scroll bar. The reference value for the scroll bar is entered in the ***Measurement > Environment*** menu. The power density is calculated in relation to the power values set here. Up to 50 individual measurements can be recorded in a measurement file. This is relevant when measuring the beam caustic and for time or power series. It is possible to switch back and forth between the individual measuring planes.

With the button ***Copy*** the measurement settings (window size and position, power and amplification) can be copied from the previous measuring plane.

By means of the option ***Averaging*** the average of the results of up to 50 single measurements per each plane is determined. There are different analysis algorithms available:

- ***Average*** determines the average value of the distributions measured
- ***Max. pixel*** determines the point wise maxima of the distributions measured
- ***Max. trace*** determines the maximum traces of the distributions measured

During a measurement, the status of the measurement system is constantly displayed. These are:

- the current measuring plane
- the run of the reference cycle
- positioning the measuring head
- the measurement
- the data transmission – the progress is shown by means of the bar display

Fig. 13.10: Display window ***Monitor***

By means of the button ***Stop*** you can cancel a running measurement (this does not disrupt movement along the z-axis). We recommend triggering a ***Reset*** cycle afterwards. Canceling will also end ***monitor*** operation. The ***Stop*** button can be used to stop the measurement. A ***Reset*** cycle should then be triggered before further measuring.

13.6.9 Caustic measurement (menu *Measurement* > *Caustic*)

The caustic measurement is a serial measurement where the z-position is varied. The goal is to examine propagation in the propagation direction. The results are stored in different planes. A different z-position is assigned to every measuring plane. As the beam radius as well as the power density change in every z-position, the position as well as the size of the window and the signal strength can vary from plane to plane. These parameters are therefore individually adjustable in every measuring plane.

The caustic measurement itself can be carried out either manually or automatically. For the automatic caustic measurement the following has to be entered:

- the minimum and maximum z-position
- the number of planes that are to be measured
- the starting plane for the beam search

After finding the beam, the system then measures the beam at equidistant intervals and determines the focus length, focus radius, and beam parameter product. During manual measurement, all parameters are configured by hand following individual measurements. The caustic can then be manually measured. The measuring parameters can be stored by means of the menu item ***File*** **>** ***Save measurement preferences*** and can be loaded again upon request.

Prepare a caustic measurement

When positioning the HP-MSM-HB, the beam focus should be in the middle of the z-axis working area. Depending on device model, this is approximately 60 mm above the null position for a standard device and 20 mm for a HP-MSM-HB 20 kW of the integrated z-axis. The following values can be set globally:

- power
- magnification
- the value and averaging mode

There should be a minimum of ten measuring planes within the range of ±2 Rayleigh lengths around focus point. There should be at least five with the range of ±1 Rayleigh length around the focus point.

To conform with ISO 11146 standards, one should measure, at a minimum, over four Rayleigh lengths. We recommend measuring over ± 3 Rayleigh lengths in 21 planes.

Automatic caustic measurement (menu *Measurement* > *Caustic* > *Automatic)*

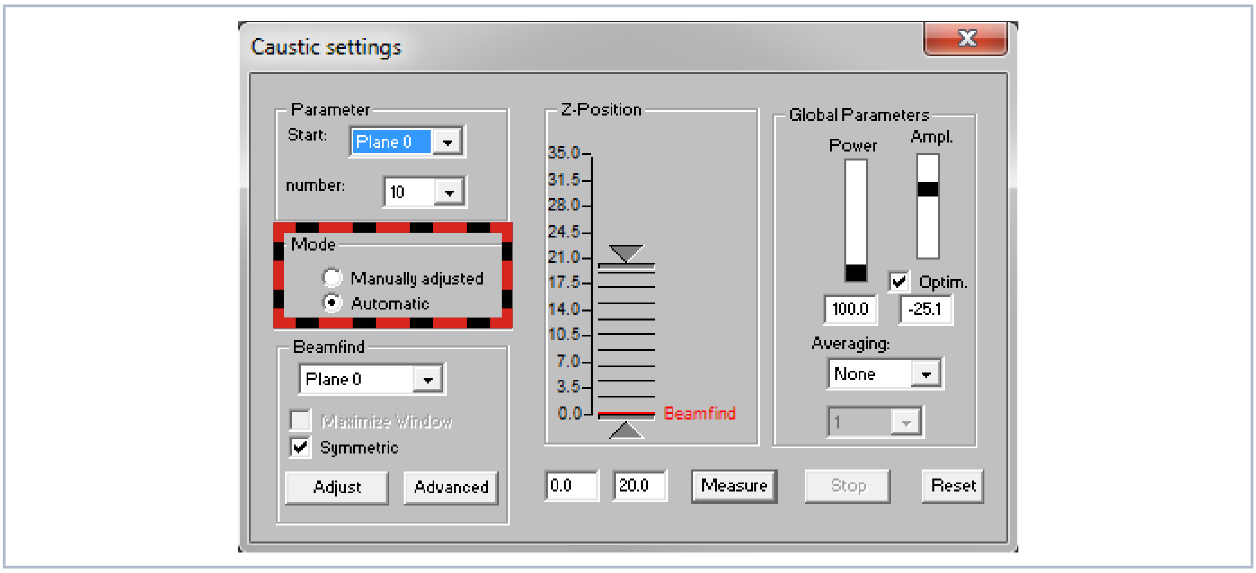


Fig. 13.11: Dialogue window ***Caustic settings***

During automatic caustic measurement, the minimum and maximum z-position is selected together with the number of measuring planes. The measurement cycle begins with an automatic beam search in the specified starting plane. The beam search only occurs within the area of the starting plane's measurement window.

If you don't want the search window size to take up the maximum space (depending on the lens), the window size can be adjusted, once the control box ***Maximize Window*** has been deactivated, by selecting ***Adjust*** in the menu. The ***Details*** menu point allows the user to configure the beam search parameters by changing the spacial resolution, threshold value, and minimum signal.

> If automatic find beam needs to be left out to save time, it can be deactivated in the ***Options*** dialog window (**Menu *Measurement* > *Option***) (activate check box ***Beamfind***).

Manual caustic measurement (menu *Measurement* > *Caustic) and* (menu *Measurement* > *Single*)

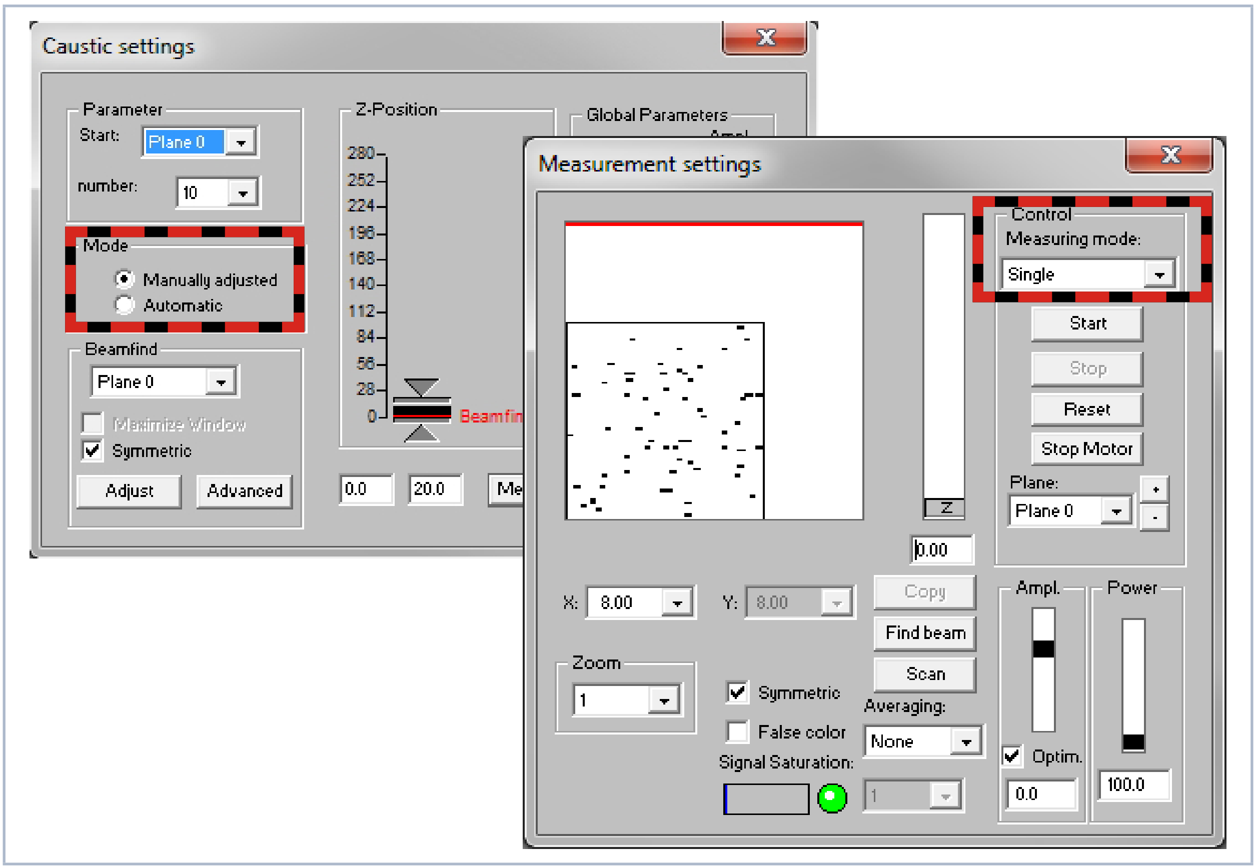


Fig. 13.12: Dialogue window ***Caustic settings*** and ***Measurement settings***

The manual caustic measurement consists of a series of individual measurements at various z-positions, with the results being stored in their own planes.

> The start plane and number of measuring planes must match the settings in the settings window- ***Measurement* > *Single* > *Measurement settings*** .

To conduct a manual caustic measurement, follow these steps:

1. Delete the old data in the ***Edit > Clear all planes***
   dialog window or create a new document ***File > New***.
2. In the ***Caustic settings*** dialog window, click on ***Manually adjusted (menu Measurement > Caustic)***.
3. Select the first plane in the ***Measurement settings dialog window (men Measurement > Single)***.
4. Configure the z-position in the ***Measurement settings*** dialog window.
5. Configure the measurement window size and position in the ***Measurement settings*** dialog window.
6. Perform a measurement in the configured pane.
7. Select the next plane and start again at Point 3.

Steps 3 through 6 can be repeated ten to fifteen times.

Record a time series (menu *Measurement > Single*)

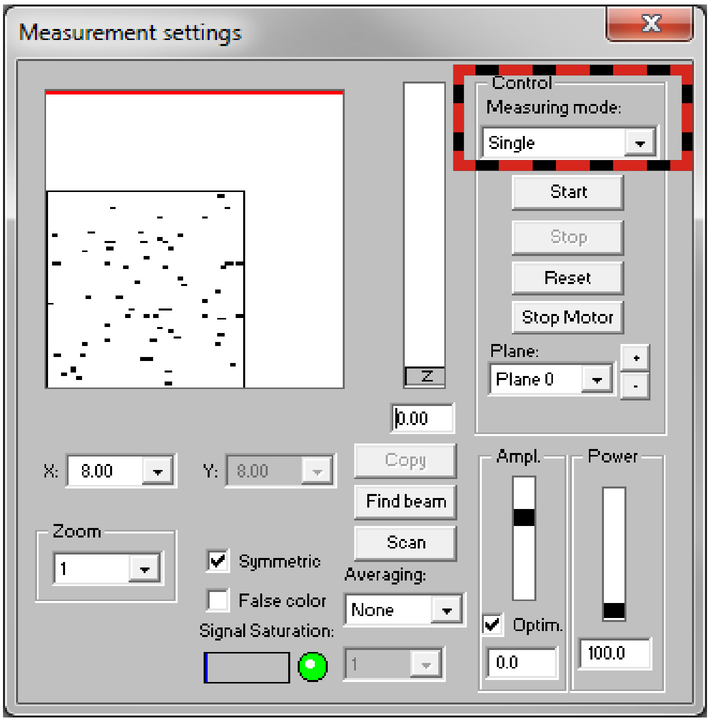


Fig. 13.13: Dialogue window ***Measurement settings***

Recording a time series corresponds to manual caustic measurement, but with the z-position staying the same on all planes.

1. Delete the old data in the ***Edit > Clear all planes***
   dialog window or create a new document ***File > New***.
2. Select the first plane in the ***Measurement settings dialog window (men Measurement > Single)***.
3. Configure the z-position in the ***Measurement settings*** dialog window.
4. Configure the measurement window size and position in the ***Measurement settings*** dialog window.
5. Perform a measurement in the configured pane.
6. Select the next plane and use the old settings by clicking the ***Copy*** button.

14 Troubleshooting

14.1 Error during a measurement

When there is an error during data transfer, a processor in the measuring system failed or there was an error during program execution. Attempt to restart the system with the ***Reset*** button in the LaserDiagnoseSoftware LDS. If this does not help, turn off and on the 24 V power supply for the bus system and start another "Reset Cycle". If necessary, restart the computer.

Notice

Damaging/destroying the device

If the power supply of the HB-MSM-HB is switched off and on again, the device readjusts itself. This may cause the laser to destroy the device.

▶ **Switch off the laser before each restart of the HP-MSM-HB.**

14.2 No measurement signal at the HP-MSM-HB

When there is no measurement signal detected, except for noise which is typically 270 - 300 counts at the HP-MSM-HB (the current number of counts can be found under the menu item ***Display > Variable Contour Lines***, recheck the device position. Besides wrong positioning a too high attenuation can cause the same problem.

15 Maintenance and service

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.

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

- Aperture at the beam entrance
- Protective glass in front of the power output opening and -
- Mirror or beam splitter in the measuring objective

The aperture at the beam inlet can be changed without further preparatory measures. To change the protective glass or mirror, the measuring objective must first be removed.

The measuring objective is a high-quality, very sensitive component which can be damaged easily. Consult PRIMES before disassembling the measuring lens.
Dismantling of the measuring lens may only be carried out by a qualified person. If possible, the disassembly should be carried out in a clean room.

Always observe the following warning messages

⚠ **DANGER**

Severe eye or skin injury due to laser radiation

If the protective window is not correctly positioned, reflections can cause directional laser radiation.

▶ **Make sure that the new protective window is settled flat in the groove of the protective window holder.**

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.**
- ▶ **Do not touch the protective window.**
- ▶ **When exchanging the protective window wear powder-free latex gloves.**

15.1 Demounting the Measuring Objective

1. Turn off the voltage supply.
2. Turn off the cooling water and the compressed air supply.
3. Mount the transport lock at the beam entrance aperture.
4. Disconnect the cooling water pipes at the quick connect couplings.
5. Remove compressed air hose from the connection for the housing flushing.
6. Remove the fastening screws(see chapter 3.3.4 on page 13).
7. Remove measuring objective
8. Drain cooling water and blow the cooling water pipes out with compressed air.
9. Dry and clean the measuring objective.

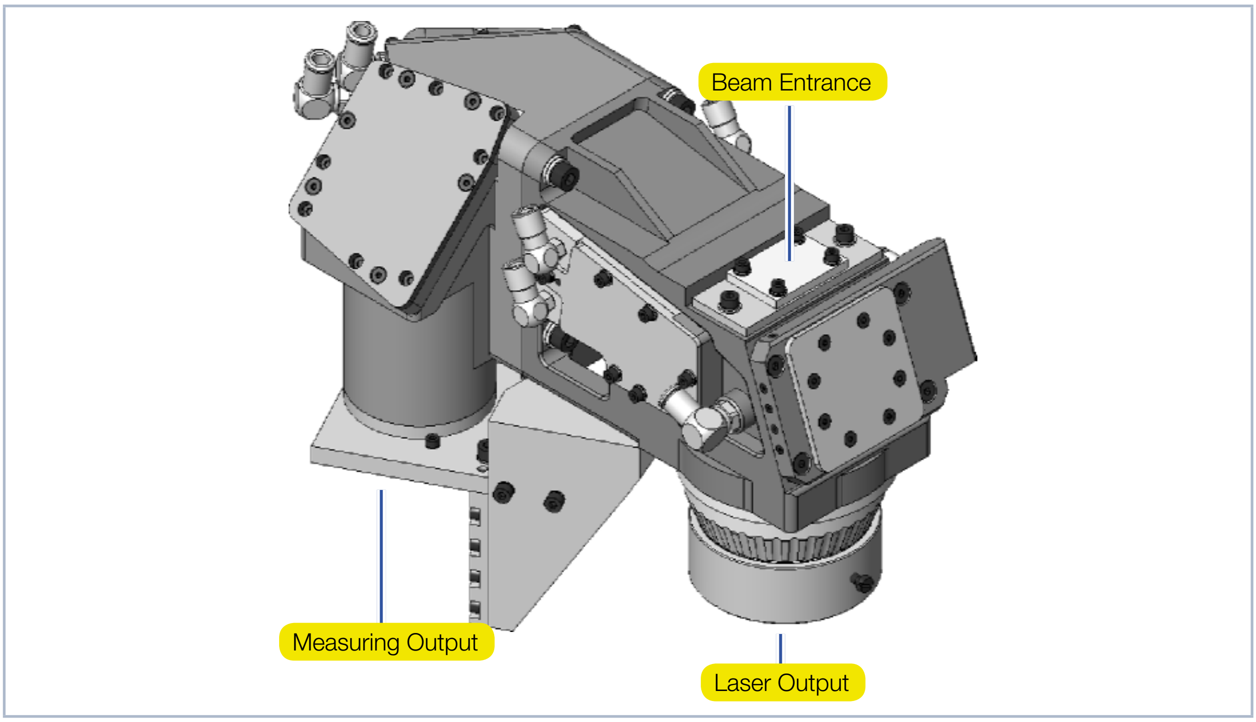


Fig. 15.1: Openings of the measuring objective

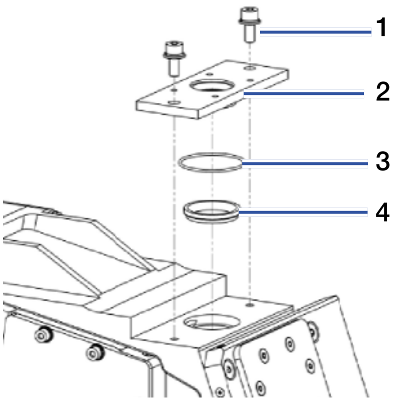
The objective is fastened at the device by means of three screws. The two screws of the transport lock S1 and S2 (M3x16, AF 2.5 mm) are required for the fastening of the objective on the device surface.

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

Fig. 15.2: Screws to fasten the objective

15.2 Changing the aperture at the Beam entrance

Observe the warning messages above



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.

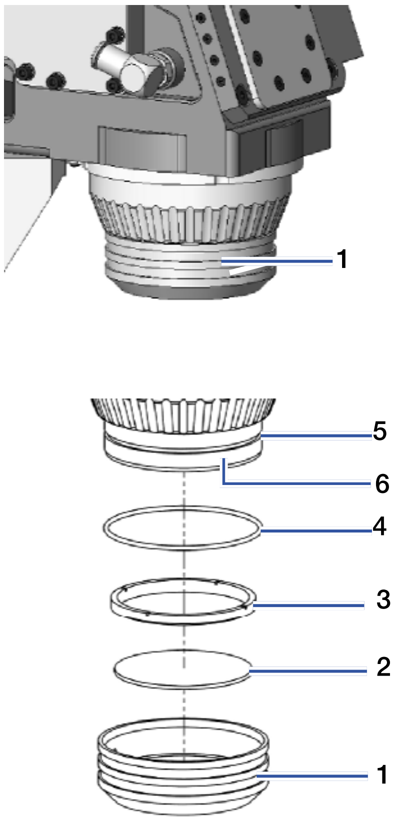
4. Put on the new aperture with O-ring and center it.
5. Fasten aperture with two cap screws (1)

Fig. 15.3: Changing the aperture at the Beam entrance

15.3 Exchanging the 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.



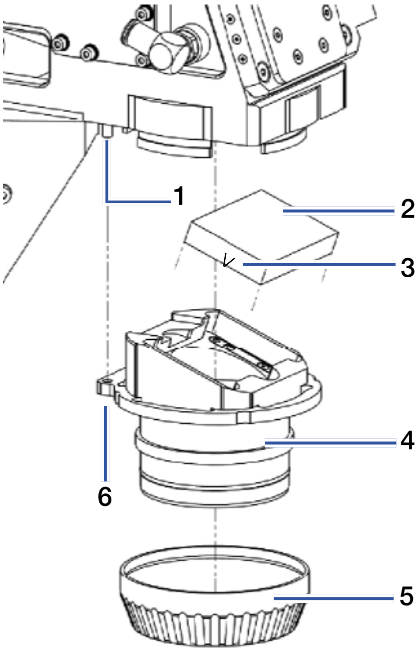
Components:
1. Protective Window Retainer
2. Protective Window
3. Ring Nut
4. O-Ring 60.08 x 1.78
5. Nut for O-Ring (4)
6. Optics Tube

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

15.4 Exchanging beam splitter

Observe the warning messages at the beginning of this chapter.



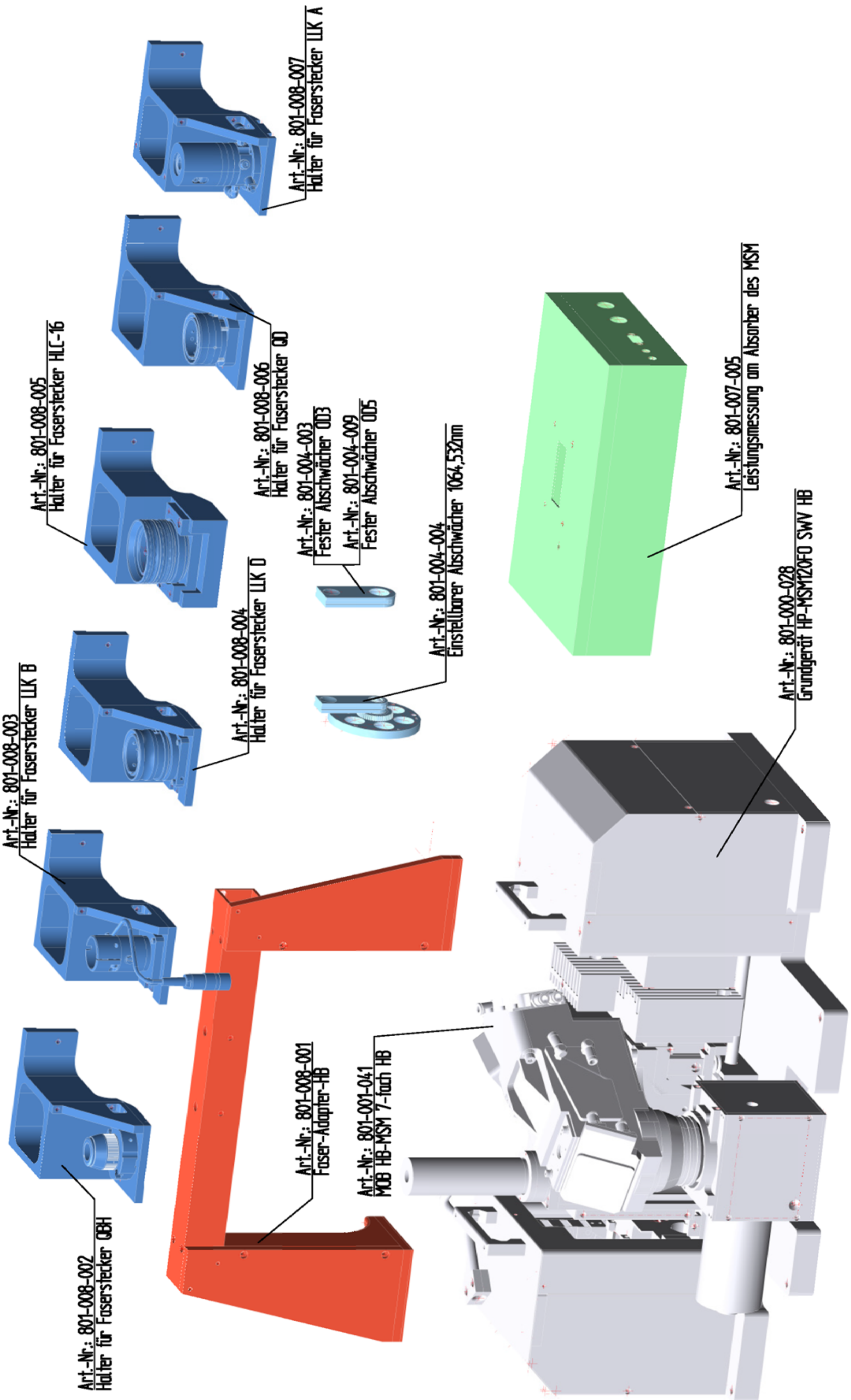
Components:

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 mirror (2).
5. Clean the mirror thoroughly. A new mirror has to be cleaned before it can be built in as well.
6. Turn the mirror until the arrow (3) on the side of the mirror points downwards (see fig.).
7. Put in the mirror 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 (please see the previous chapter).
11. Mount the protective window retainer.

Fig. 15.5: Exchanging beam splitter

16 Accessories



17 Transport or Storage

NOTICE

Damage/destruction of the optical components due to contamination or hard shocks

Contamination can damage or destroy the optical components. Hard knocks or dropping can damage the optical components.

- **The device must only be transported with a mounted transport lock.**
- **To avoid contamination, please cover the aperture with the provided lid or optical tape.**
- **Store the device in the original PRIMES transport box.**

Please note before storing devices:

NOTICE

Damage/destruction of the device caused by leaking or freezing cooling water

Leaking cooling water can damage the device. Storing the device at temperatures near or below freezing and without emptying the cooling circuit completely can damage the device.

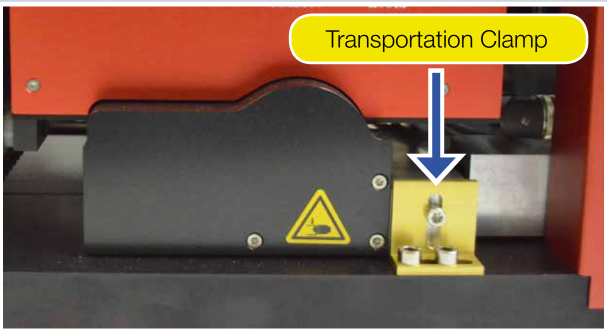
- **Empty the lines of the cooling circuit completely.**
- **Do not use compressed air to drain the cooling circuit of the PowerLossMonitor. However, you are welcome to use compressed air to drain the HP-MSM-HB.**
- **Even when the lines of the cooling circuit have been emptied, a small amount of residual water will remain in the device at all times. This may leak out and end up inside the device. Close the connector plug of the cooling circuit with the included sealing plug.**
- **Store the device in the original PRIMES transport box.**

17.1 Installing the transportation clamp

The transportation clamp 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 cassette has a direct influence on the adjustment of the fiber bridge.

▶ Installing the transportation clamp

1. Move the device into the parking position via software (LDS) (menu: Presentation-> Position-> Move to parking position).
2. Install the transportation clamp with three M4x10 cylinder head bolts.

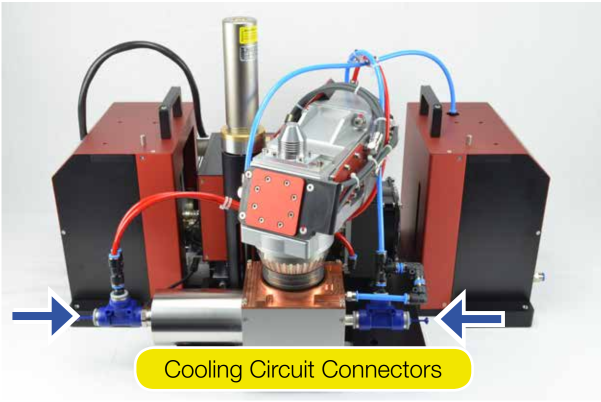


17.2 Draining the cooling circuit of the HP-MSM-HB

The cooling circuit of the HP-MSM-HB must be completely drained. Storage or transport at a temperature that is close to or below freezing 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 HP-MSM-HB.

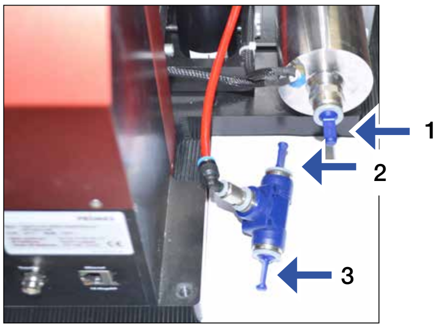


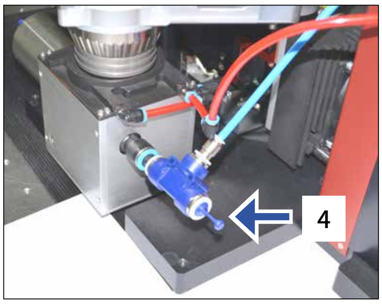
17.3 Sealing the cooling circuit of the HP-MSM-HB

Even if the cooling circuit has been drained completely, a small amount of residual water remains inside the device. This water could escape during transport and could 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 are required.





17.4 Draining the cooling circuit of the PowerLossMonitor

If you are also using a PLM for the purpose of power measurement and you also want to store or transport it, the cooling circuit of the PLM must also be completely drained. Storage or transport at a temperature that is close to or below freezing can lead to damages due to the formation of ice, if the cooling circuit is not completely drained.

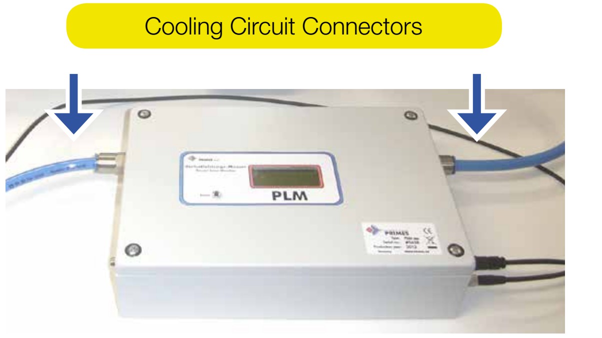
NOTICE

Danger of damage of the turbine

The turbine is not designated for high rotational speed.

- **Do not use compressed air to purge the cooling circuit.**

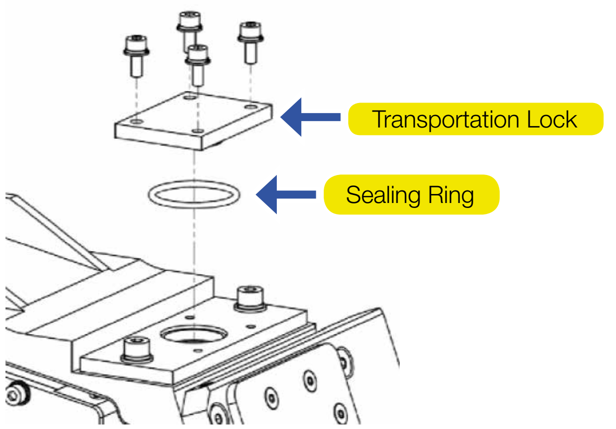
1. Remove cooling circuit hoses.
2. Drain the cooling circuit completely.
3. Seal the connectors of the cooling circuit using the enclosed plugs.



17.5 Sealing the aperture of the HB objective

The magnetically held alignment tool may fall off during shipping. This could allow dirt to enter the objective. The objective of the HP-MSM-HB must therefore be sealed for shipping with the enclosed black transportation lock.

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

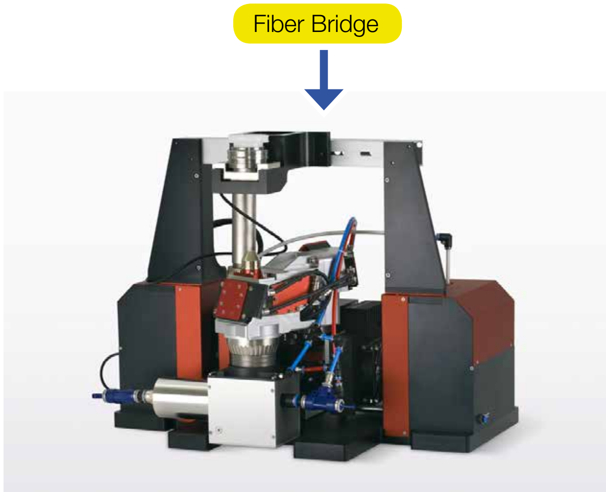


17.6 Packing the device

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 casps. All accessories must be completely enclosed.

The fiber bridge belonging to the device must be enclosed with each service shipment. During mechanical work on the HP-MSM-HB a correct alignment of the bridge to the device can not be guaranteed.

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



18 Measures for the product disposal

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). You can send PRIMES measuring devices to be disposed of within the EU (this service does not include shipping costs) 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) with the number WEEE-reg.-no. DE65549202.

19 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; HP-MSM; HP-MSM-HB

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 2004/22/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, May 2, 2018

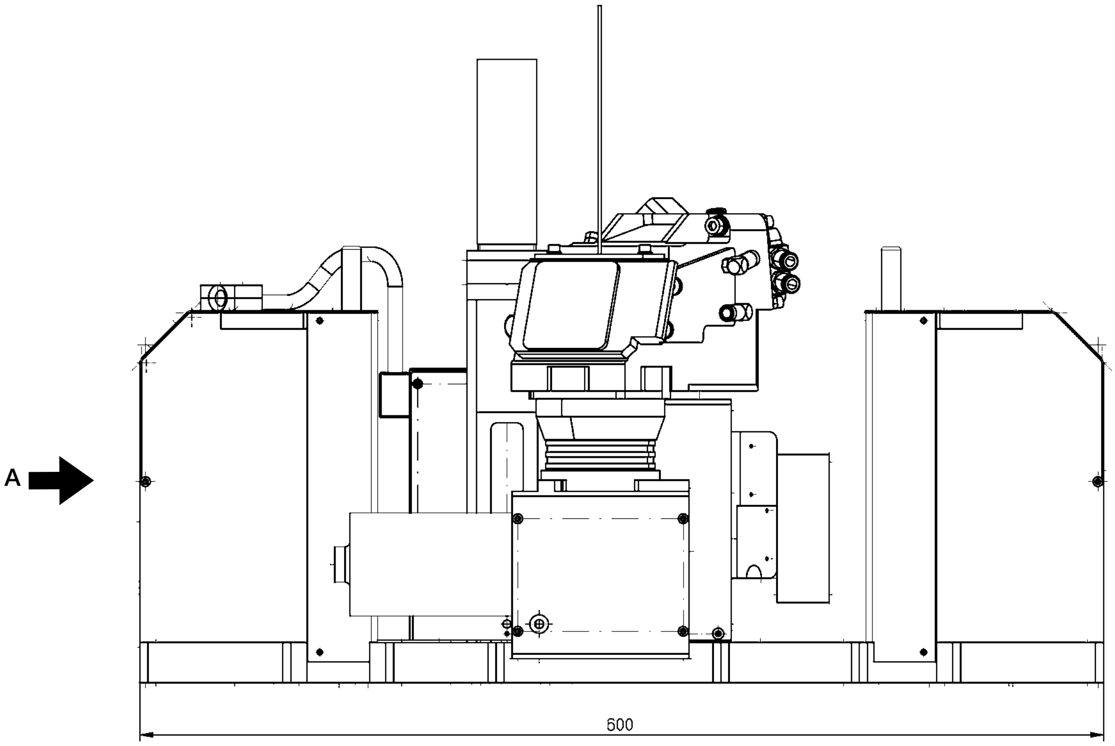
Dr. Reinhard Kramer, CEO

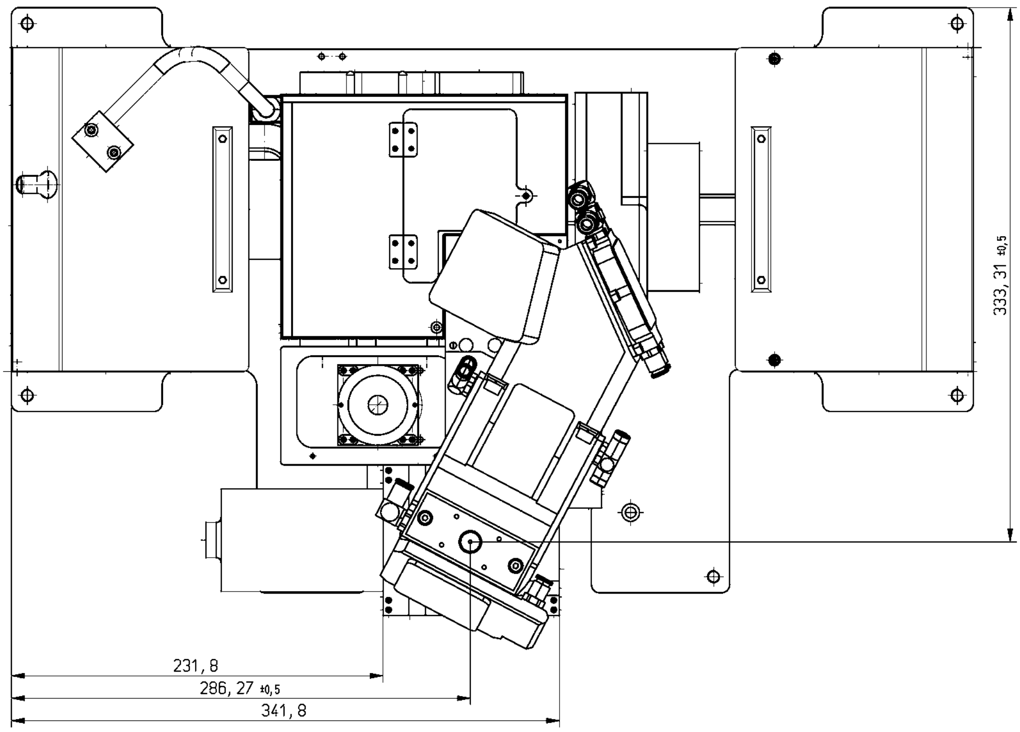
20 Technical data

	HP-MSM-HB	HP-MSM-HB 20 kW
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	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. movement range	120 mm	40 mm
Max. movement range with fiber bridge	see Tab. 13.1 on page 50	see Tab. 13.1 on page 50
Supply data		
Supply voltage, DC	24 V ± 5 %	
Max. current consuption	1,8 A	
in standby mode	0,4 A	
Min. Cooling water flow rate.	0,7 l/min/kW	
Cooling water temperature Tin	dew-point temperature < T_{in} < 30 °C	
Maximum water inlet pressure	< 5 bar	4 bar... 5 bar
Compressed Air Pressure	0,5 bar to 1,0 bar	
Maximum Pressure	2 bar	
Specification of compressed air according to ISO 8573-1: 2010	6:4:4	
Communication		
Ethernet	100 Mbit/s	
PRIMES-Bus (RS485)		
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
Ambient 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 %	

21 Dimensions

21.1 Dimensions of the HP-MSM-HB

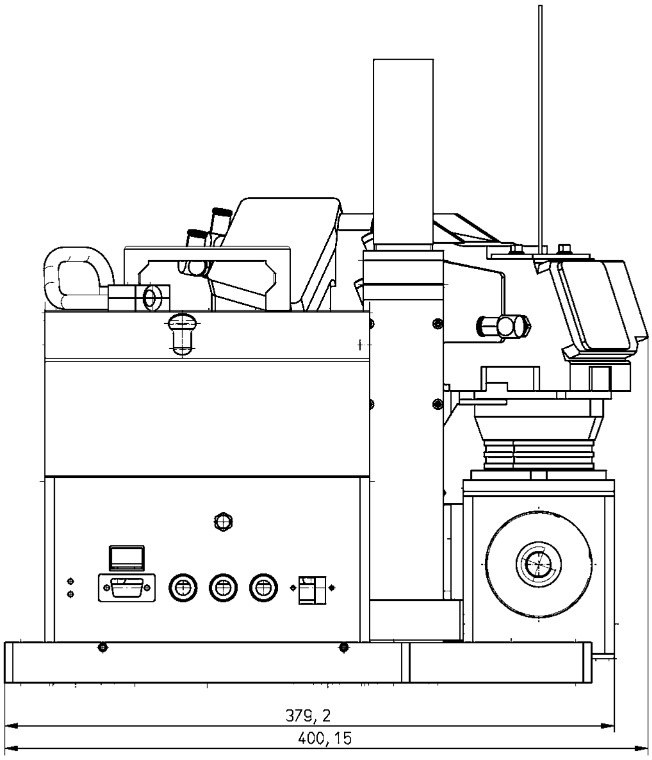




All dimensions in mm (general tolerance ISO 2768-v)

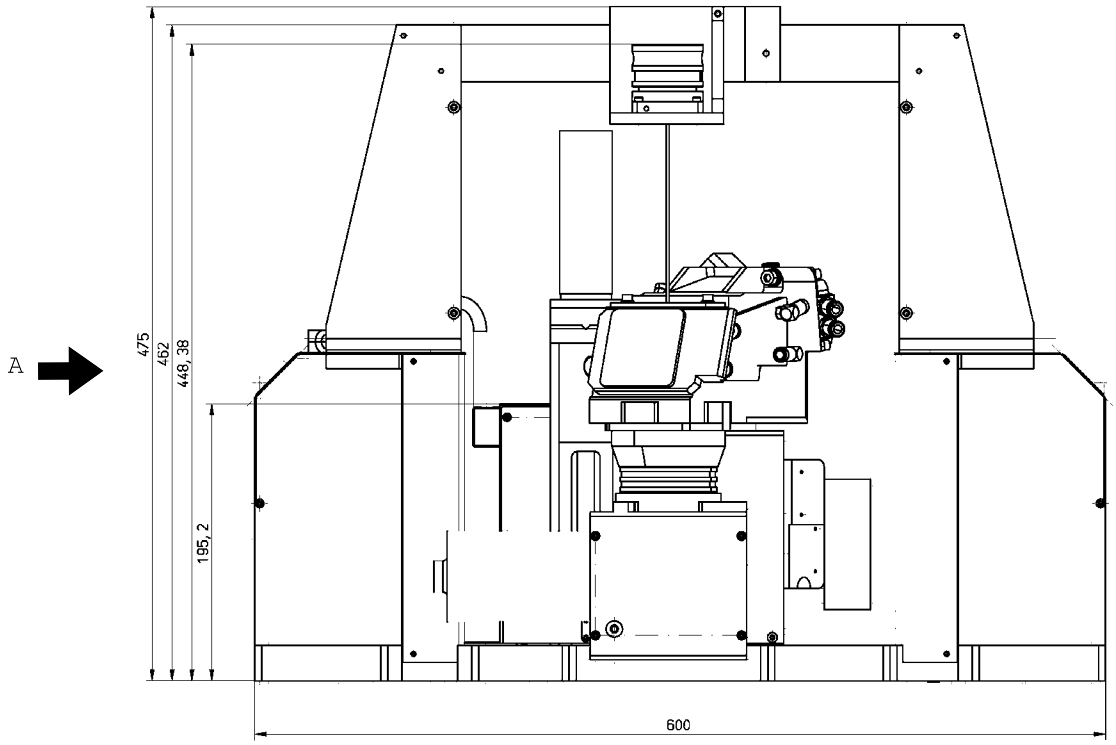
Dimensions of the HP-MSM-HB (continued)

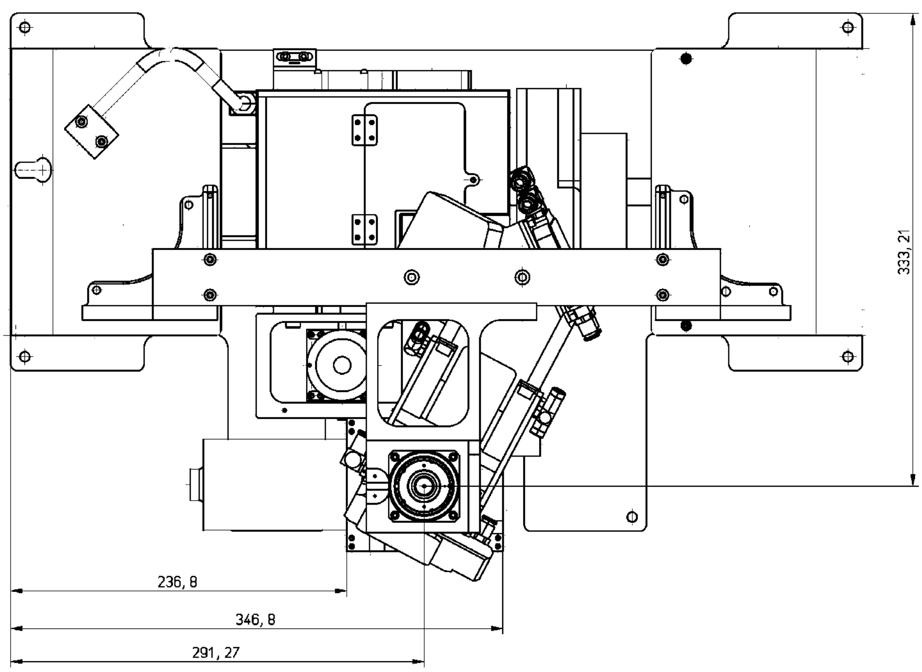
View A



All dimensions in mm (general tolerance ISO 2768-v)

21.2 Dimensions of the HP-MSM-HB with fibre bridge

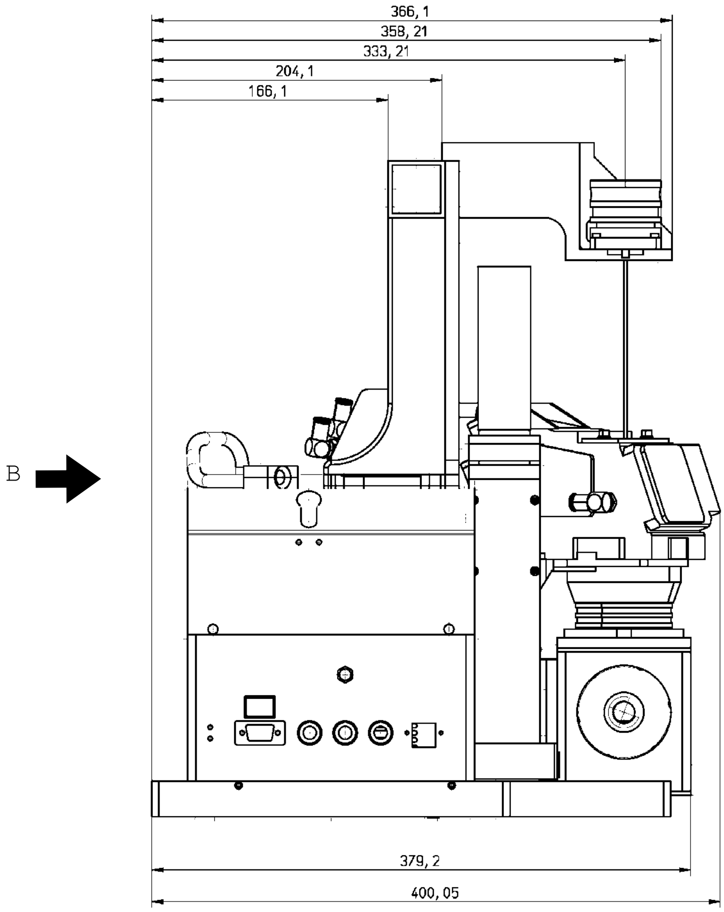




All dimensions in mm (general tolerance ISO 2768-v)

Dimensions of the HP-MSM-HB with fibre bridge (continued)

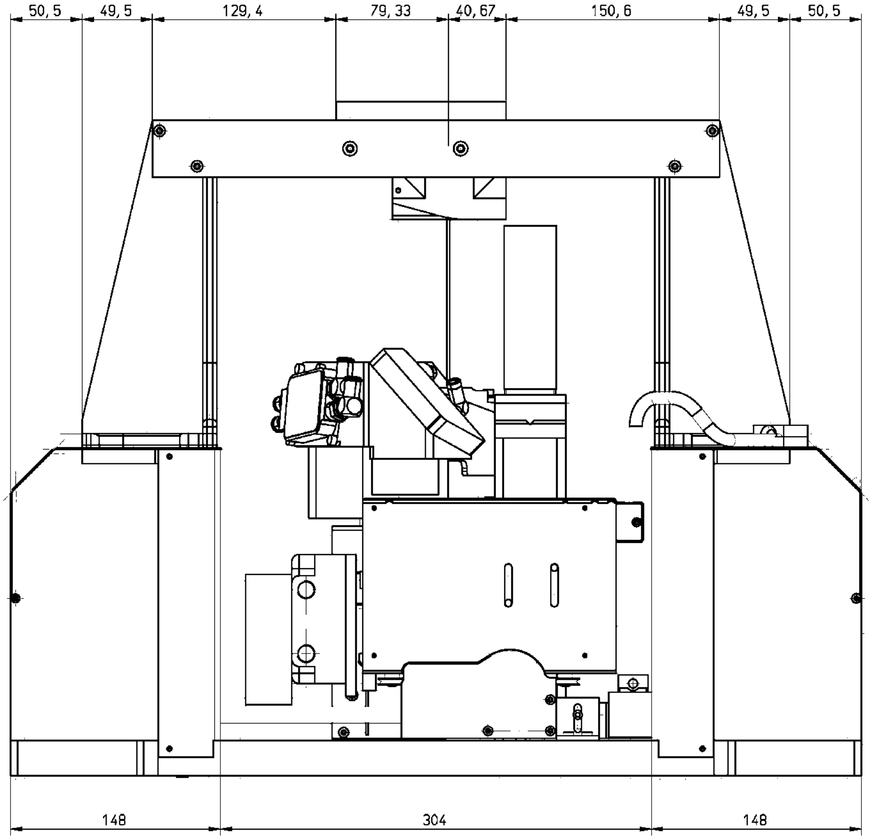
View A



All dimensions in mm (general tolerance ISO 2768-v)

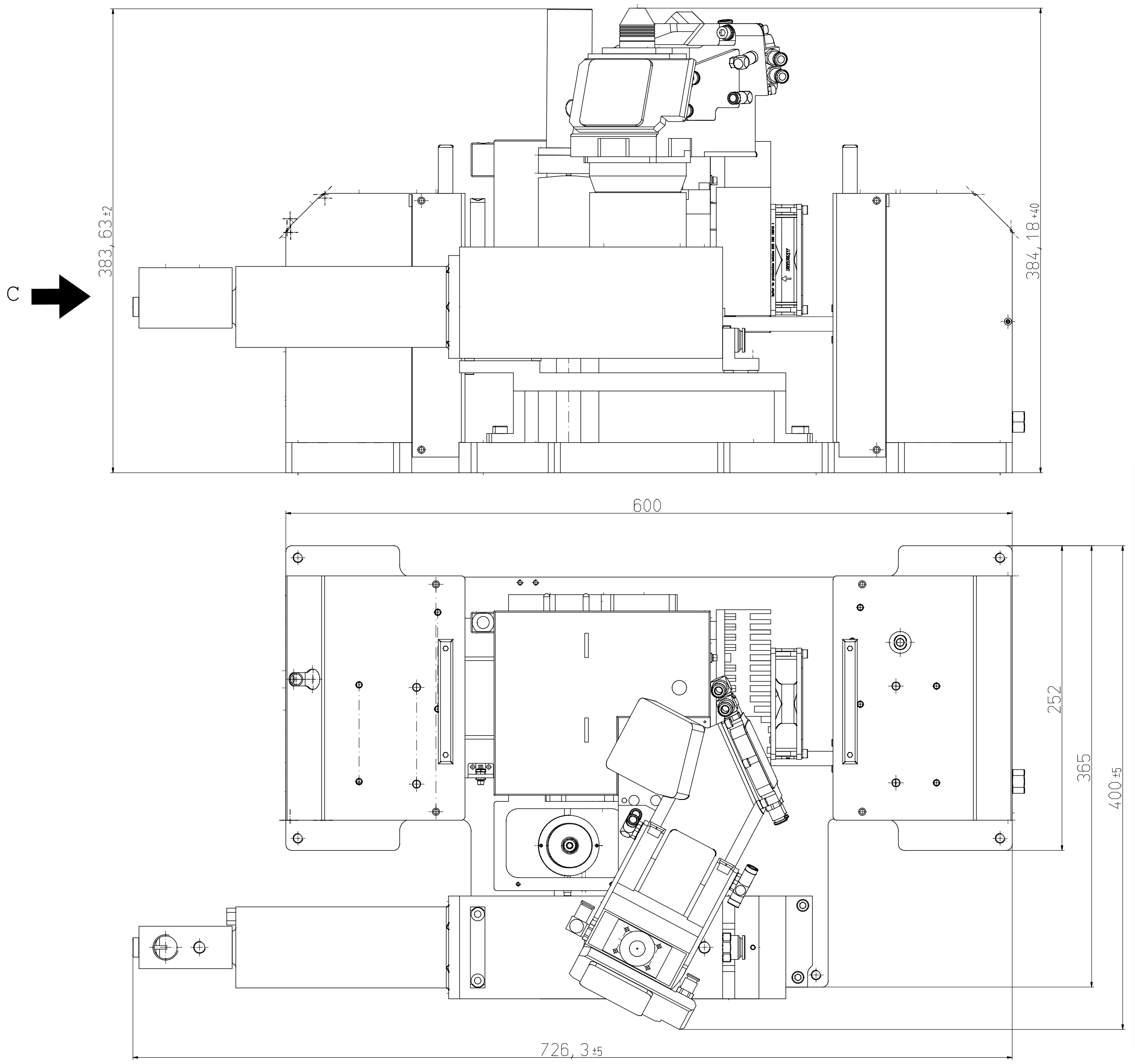
Dimensions of the HP-MSM-HB with fibre bridge (continued)

View B



All dimensions in mm (general tolerance ISO 2768-v)

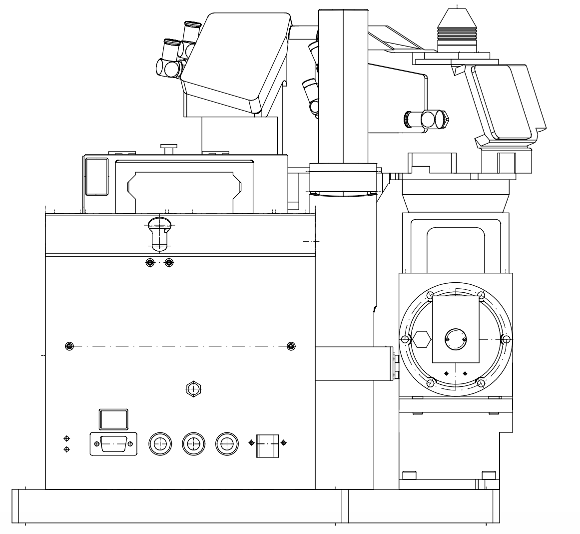
21.3 Dimensions of the HP-MSM-HB 20 kW



All dimensions in mm (general tolerance ISO 2768-v)

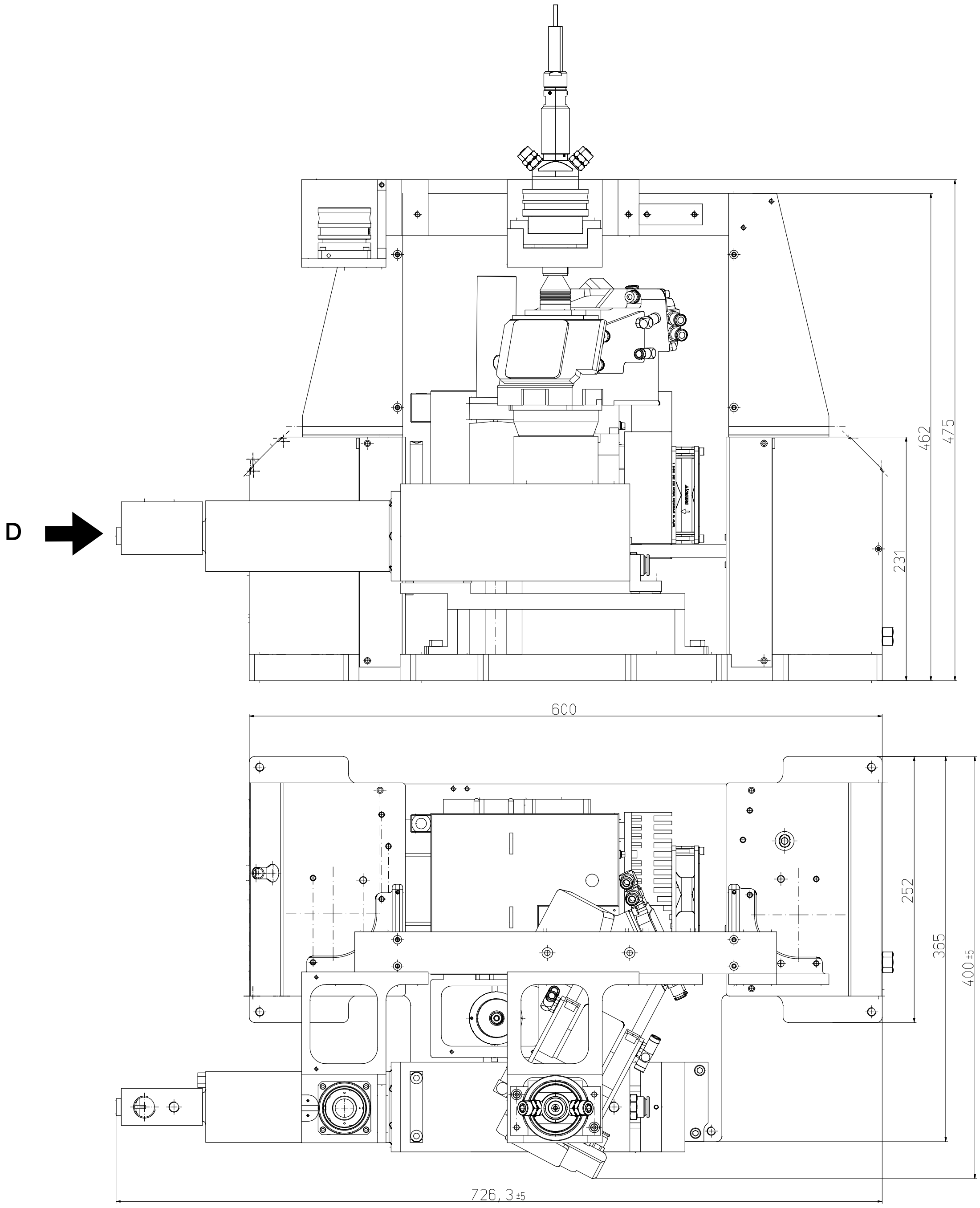
Dimensions of the HP-MSM-HB 20 kW, continued)

View C



All dimensions in mm (general tolerance ISO 2768-v)

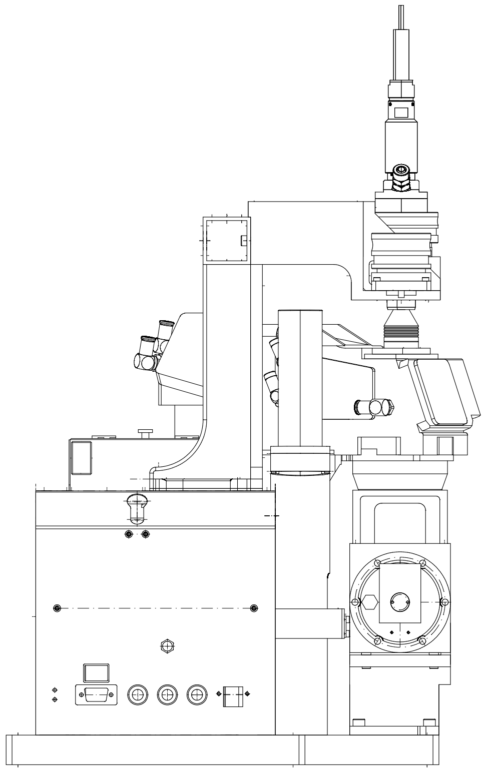
21.4 Dimensions of the HP-MSM-HB 20 kW with fibre bridge



All dimensions in mm (general tolerance ISO 2768-v)

Dimensions of the HP-MSM-HB 20 kW with fibre bridge (continued)

View D



All dimensions in mm (general tolerance ISO 2768-v)

22 Appendix A:

22.1 Power measurement with the PLM on the HP-MSM-HB

The PowerLossMonitor PLM is a system for the determination of power losses especially at water-cooled optical components. The system determines the flow rate as well as the temperature increase of the coolant between inlet and outlet. Based on this data the absorbed power is determined.

Water connections

For the HP-MSM-HB, the PLM is used to measure the power loss in the water-cooled absorber. To do this, connect the PLM into the water supply to the HP-MSM-HB: The cold water flows through the PLM and from there to the HP-MSM-HB. The hot water flows directly back to the cooling.

The lengths of these hoses have an influence on the time constants of the measuring device. Only use the hoses supplied!.

Temperature sensor

Attach the temperature sensor (black cable) to the second t-junction in the water return.

Interlock connection

The PLM has got two interlock connectors:

- One cable connects the PLM to the HP-MSM-HB
- The other cable is connected to the laser (either safety SPS or emergency off)

Both connectors are internally connected and can be swapped.

22.2 Measuring pulsed irradiation

The CCD sensor of the HP-MSM-HB has a dynamic of 55 dB. An integration time control has been implemented in order to expand this. The integration time can be freely chosen within the range of 12 µs to 186 ms.
If the ***Optm. (Optimize)*** function is activated in the ***Single*** or ***Caustic*** dialog window, then the LaserDiagnosticsSoftware LDS 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.

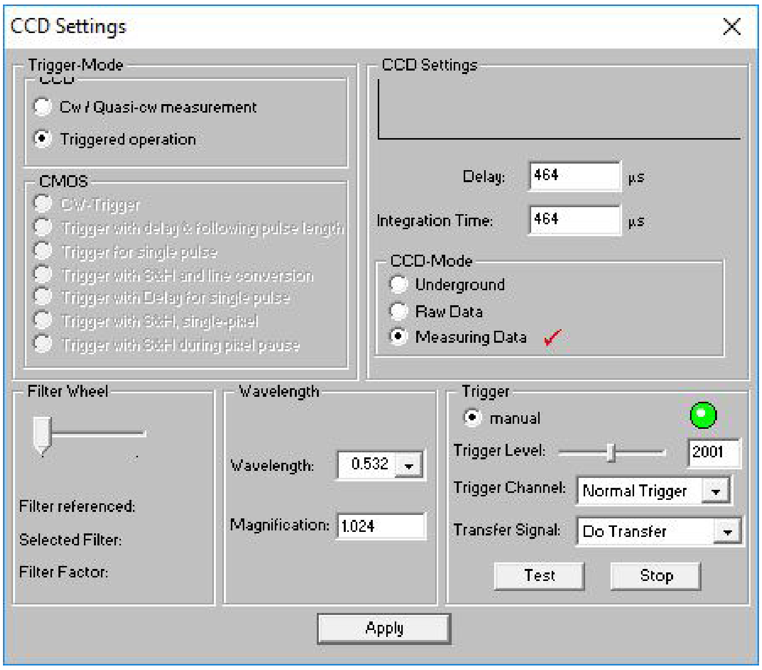


Fig. 22.1: CCD settings in the dialog window ***CCD Setting***

The integration time control magnifies the dynamics of the CCD sensor from 55 dB to over 130 dB. Once the ***Optim.*** Function is deactivated, a set integration time can be specified in the ***CCD Setting*** dialog window in the HP-MSM-HB (see Fig. 22.1 on page 89).

Integration time control alone isn't enough to be able to measure the full range of pulsed lasers. If, for example, it involves a pulsed laser with a very low pulse frequency (< 5 Hz), the maximum integration time of 186 ms will no longer be sufficient. This is why, in addition to the integration time control, a trigger option and delay time is also implemented.

In regards to triggering, there is an internal trigger and an external trigger.
A photo diode behind a prism functions as the internal trigger.
The user can determine the limit value of the trigger (0 ... 4 096).
The trigger is preset to the value 2001 This setting works well for the majority of all applications.

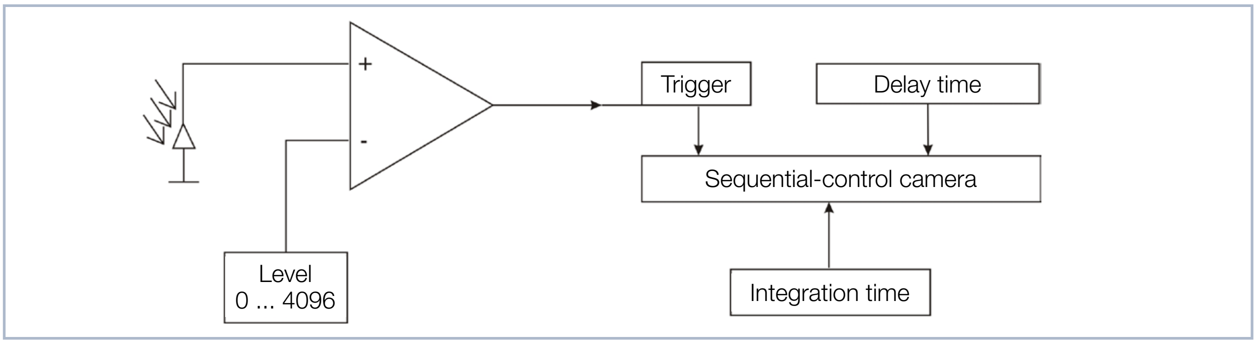


Fig. 22.2: Options for affecting the sequence control of the CCD sensor

Fig. 22.2 on page 90 Shows that the trigger, together with the adjustable delay and integration time, interferes with the sequence control of the CCD sensor. The user can now define discrete time frames in which the LQM is allowed to measure. The external trigger is connected via a BNC socket meant for this purpose. Similarly, it also interferes with the sequence control, meaning that it can be handled in the same way as the internal trigger.

The delay time and trigger type (external or internal trigger) settings are made in the ***CCD Settings*** dialog window of the LaserDiagnosticsSoftware LDS.
When you enter a delay or integration time, you must always be sure to confirm these entries with the ***Update*** button.

There are the following time constants:

Timeout:	20 sec (Standard)
Minimum integration time:	12 µs
Maximum integration time:	186 ms
Minimum delay:	12 µs
Maximum delay:	186 ms

The long timeout time (20 sec.) also helps to measure lasers with a pulse that is manually triggered. If this is the case, a measurement must first be taken. The HP-MSM-HB will move to the desired position and run through a certain routine internally. Once the HP-MSM-HB is ready for a trigger, notification of this will be displayed in the ***Free Communication*** dialog window. Right after the measurement is initiated, a communication flow will be visible.

If this stops with the indication ***Waiting for Trigger***, then the HP-MSM-HB is waiting for a trigger.
Every measurement of the HP-MSM-HB consists of a dark measurement and a measurement with photo transfer. This applies for triggered as well as untriggered operation. This means that each measurement requires at least two trigger signals or two laser pulses.

22.2.1 Measuring configuration selection

There are various measuring options to differentiate between:

- Measuring a single plane or a complete caustic
- Measuring a complete pulse or just a single section
- Measuring with a fixed integration time or with integration time control
- Measuring with triggered or untriggered operation
- Variations of optimal integration time caused by changing the attenuation

If you combine these measuring options with the pulse parameters:

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

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

22.2.2 Influence of the pulse parameters on the integration time control

The software-operated integration time control always assumes that there is a continual 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. 22.1 on page 91 And the diagram in Fig. 3.1 on page 12 makes this clear.

Pulse frequency	Number of pulses in	
in Hz	186 ms	1 ms
1	0	0 - 1
5	1	0 - 1
10	2	0 - 1
50	9	0 - 1
100	19	0 - 1
200	37	0 - 1
500	93	0 - 1
1 000	186	1 - 2
2 000	372	2 - 3
5 000	930	5,00
10 000	1860	10,00

Tab. 22.1: Number of detected pulses in correlation with the integration time and pulse frequency

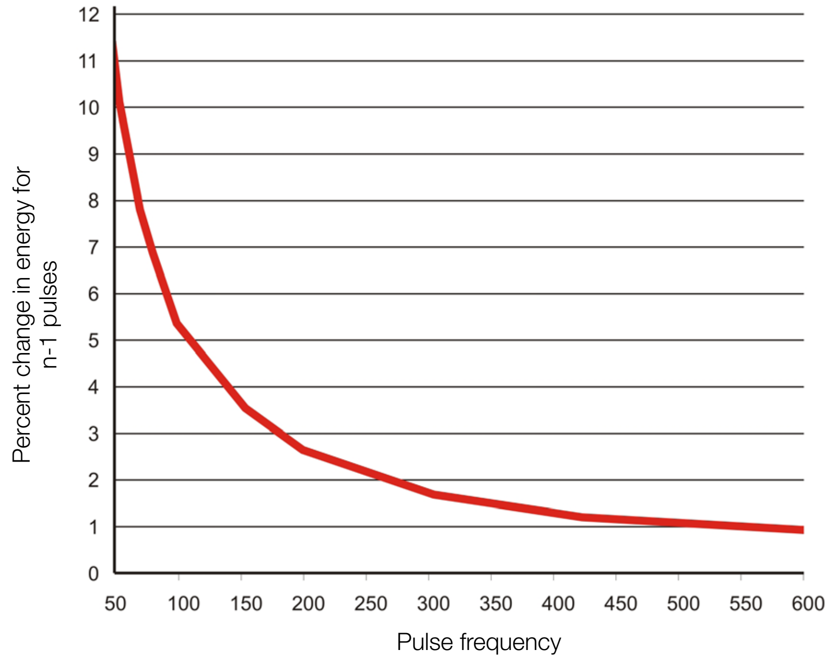


Fig. 22.3: Percentage of change in the detected energy when exactly one pulse is left out, in correlation with the pulse frequency

Tab. 22.1 on page 91 Shows the number of detected pulses during the maximum integration time (186 ms) and during an integration time of 1 ms for various pulse frequencies.
Quantization with low pulse frequencies is clearly illustrated in the column for the 186 ms integration time. While 1 860 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. 22.3 on page 92. It is important to recognize that, starting from a pulse frequency of 500 Hz, the minimum jump when the integration time is shortened amounts to 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. 22.1 on page 91, 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 pretty much 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 untriggered operation.

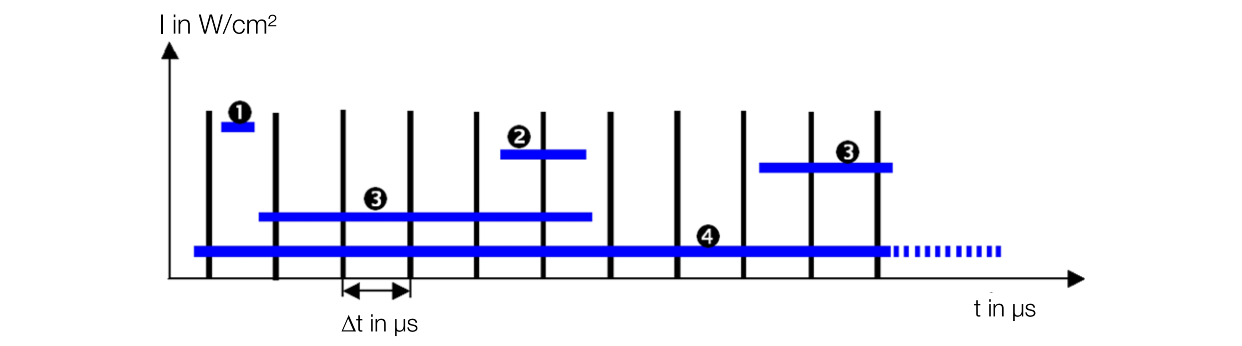


Fig. 22.4: Measuring with different integration times

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. 22.4 on page 93 shows pulsed irradiation. The pulse pauses amount to 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, no more than one pulse will be in the measurement statistically speaking. The probability of there being one pulse during each measurement of integration time control as well as during the actual measurement is slim.

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 1). This is the perfect state for measuring on one plane. The caustic can also be measured with this setup, since the dynamics of the CCD sensors is 55 dB for a single pulse, with the intensity only varying by a factor of 5 in the relevant caustic range. Here it is important to make sure that the signal saturation for the measurement in the beam waist 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 a situation where the integration time falls between the simple duration and the duration times ten 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 pretty much operates 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 - 4.

Furthermore, as was mentioned in the initial consideration, the HP-MSM-HB is equipped with quite a few options for triggering. Combined with integration time control and delay time control, it is possible to take good measurements even in Case 1.

These four cases can generally be sorted into two groups. Case 1 and 2 must be measured in the triggered measuring mode. Case 4, however, is best measured in untriggered measuring mode cw. Case 3 should be avoided altogether by choosing a suitable filter.
The below diagram in Fig. 3.1 on page 12 should help with case classification for the laser beams to be measured.

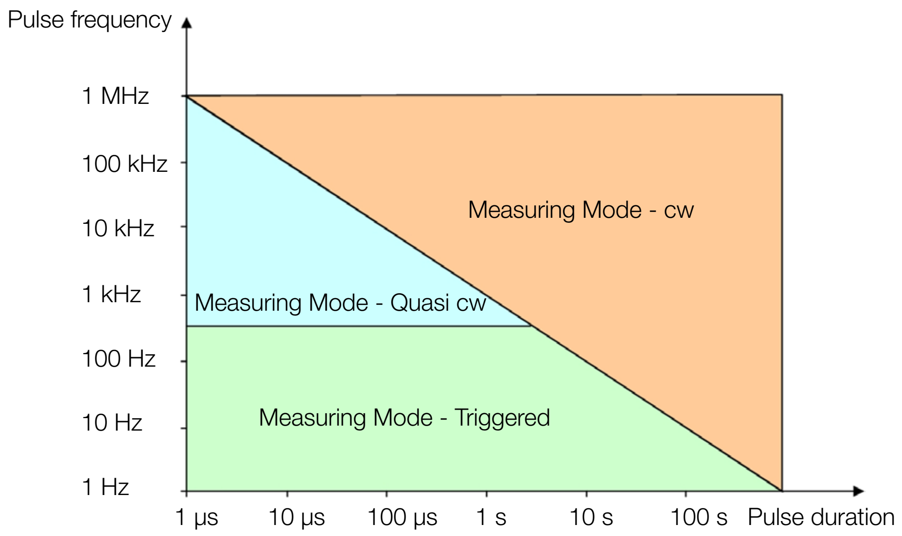


Fig. 22.5: Choosing the measuring mode through laser parameters

If the laser is in the blue range, it is best to choose measuring mode cw. It is, however, important to remember that the closer you get to the limit during triggered operation, the greater the integration time will be in order to achieve the virtual cw case. As a rule of thumb, the integration time within the focal point should amount roughly to the time for 35 pulses. If the laser being measured falls below the limit frequency of approx. 500 Hz, you should switch to triggered measuring mode.

While it is almost always possible to measure with the integration time control (optim. function) in the cw or virtual cw measuring mode, it only makes sense to use it for very long pulse durations (>1 ms) in triggered measuring mode. With the help of the attenuation filter, the integration time is thus set so that it only amounts to a fraction of the pulse duration. The trigger 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. 3.1 on page 12 or Example 2).

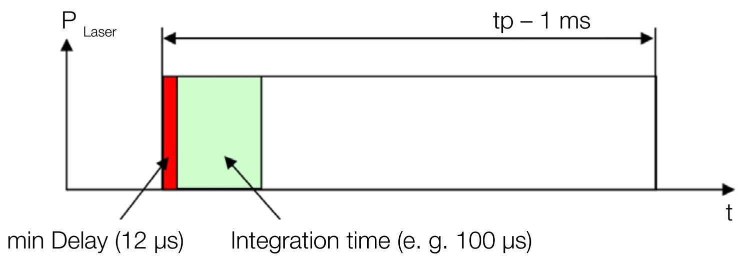


Fig. 22.6: Measuring parameters for pulsed laser systems with pulse duration greater than 1 ms

In all situations, it is advisable to specify a fixed integration time in order to, through the skilled selection of the filter as well as the delay and integration times, make sure that a fixed number of pulses is always measured (see Example 1).

22.2.3 Examples for triggered measuring mode

Example 1: Pulse duration 50 ns
Pulse frequency 1 kHz

HP-MSM-HB Settings:

Delay:	950 µs
Integration duration:	0.1 ms
Trigger channel:	External trigger

Depending on how precisely you are able to set off the trigger, you can also extend or shorten the integration time.

Measure:
Initiate a measurement. You now have 20 sec. to set off a trigger.
As a result of the delay value of 0.95 ms and the fixed integration time of 100 µs, the HP-MSM-HB detects the second laser pulse after setting off the trigger.

Example 2: Pulse duration 1 ms

HP-MSM-HB Settings:

Delay:	12 µs
Integration duration:	1 ms
Trigger channel:	Internal trigger

Measure:
Initiate a measurement. You now have 20 sec. to set off a laser pulse.
The HP-MSM-HB measures 12 µs after the trigger is set off.
In this example, the first 12 µs of the laser pulse are not measured:

Example 3: Measuring exactly one pulse
Trigger mode: Triggered operation

In the ***CCD Settings*** dialog window, there is a selection menu called ***CCD Operating Modes***. There you can choose between background, raw data, and measurement data.

When measuring in raw data mode, the CCD is read out quite normally. A second, dark measurement, is not performed though. Depending on the application case, wavelength, and integration time, there may be obvious errors in the background.

It makes sense to measure in this mode when exactly one pulse will be triggered. Since there won't be a second, dark, measurement, this single pulse is enough. Here the attenuation should be chosen so that the integration time is longer than the pulse duration. This makes it possible to avoid most background effects. If the integration time is too long though, more dark electrons will be generated.

If you would like to record the entire pulse, it must be triggered externally. In this case, the minimum delay between the trigger and start of the measurement should be 12 µs.

22.2.4 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 ***Optim.*** option. 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 come 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 smaller than the pulse pauses. If this is the case, it will no longer be possible to perform an untriggered measurement properly with the HP-MSM-HB.

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 (55 dB) is sufficient to measure the entire caustic with an acceptable S/N ratio.

23 Appendix B: Basis of laser beam diagnosis

23.1 Laser beam parameter

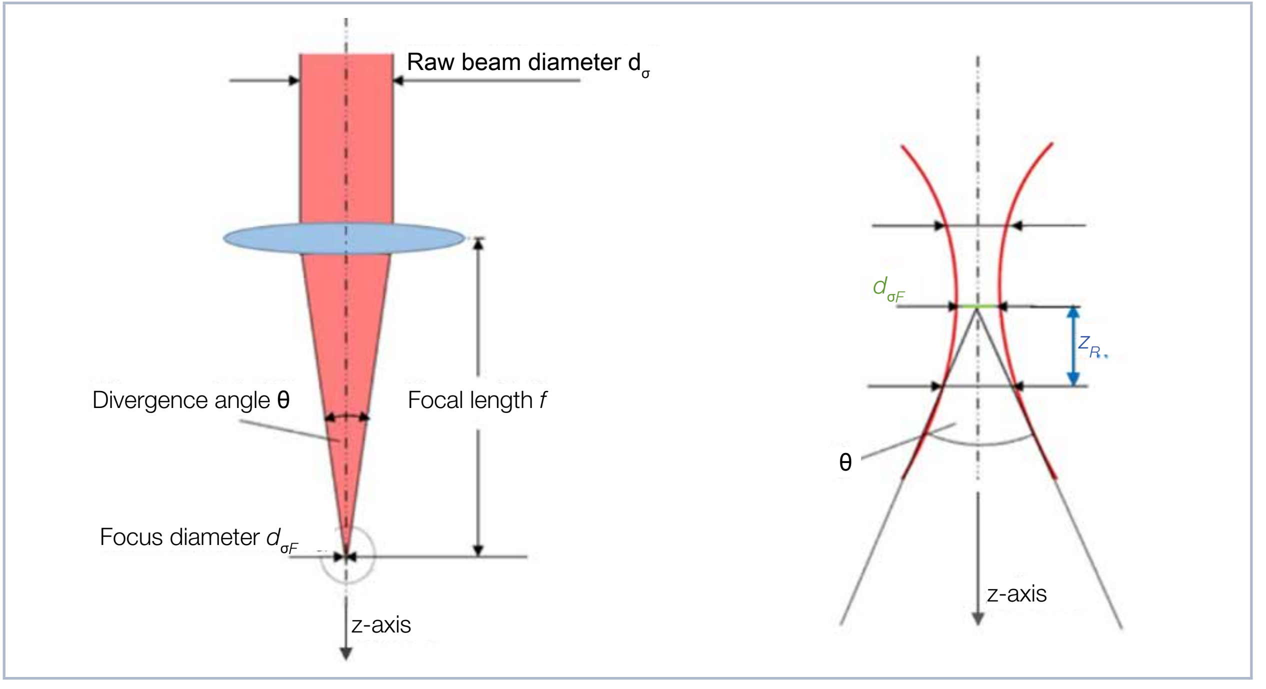


Fig. 23.1: Sketch for the definition of beam parameters

23.1.1 Rotationally symmetric beams

According to ISO 11145 as well as ISO 11146 three beam parameters are necessary for the characterization of a rotationally symmetric beam:

- the z-position of the beam waist (focus) z_0
- the diameter of the beam waist $d_{\sigma F}$
- the far field divergence angle Θ

By means of these three values it is possible to determine the beam diameter at every spot along the propagation direction. The following restriction is applicable: The divergence angle has to be smaller than 0.8 rad and the focus diameter and the divergence angle were determined with the 2. moment method.

$$d_\sigma(z)^2 = d_{\sigma 0}{}^2 + (z - z_0)^2 \cdot \Theta_\sigma^2 \qquad (1.1)$$

Furthermore, the beam propagation is described by means of the so called beam propagation ratio K.

$$K = \frac{1}{M^2} = \frac{4 \cdot \lambda}{\pi} \cdot \frac{1}{d_{\sigma 0} \cdot \Theta_\sigma} \qquad (1.2)$$

with:
K = beam propagation ratio
M^2 = beam propagation factor
λ = wavelength in a medium with the refractive index n
Θ_σ = divergence angle
$d_{\sigma 0}$ = beam waist diameter

The derived beam parameter product, is a constant size as long as image defect free and aperture free components are used.

$$SPP = \frac{d_{\sigma 0} \cdot \theta}{4} = \frac{\lambda}{\pi \cdot k} = \frac{M^2 \cdot \lambda}{\pi} \qquad (1.3)$$

An important beam parameter is the Rayleigh length:

The Rayleigh length is the distance towards the propagation in which the laser beam has increased by $\sqrt{2}$. It can be calculated by means of the following formula:

$$z_R = \frac{d_{\sigma 0}}{\Theta_\sigma} = \frac{\pi \cdot d_{\sigma 0}{}^2}{4 \cdot \lambda \cdot M^2} \qquad (1.4)$$

23.1.2 Non rotationally symmetric beams

In order to describe non rotationally symmetric beams, the following parameters are required:

- the z-position of the beam waist (focus) z_x and z_y
- the diameter of the beam waist $d_{\sigma 0x}$ and $d_{\sigma 0y}$
- the far field divergence angle $\Theta_{\sigma x}$ and $\Theta_{\sigma y}$
- the angle ϕ between the x´-axis of the measuring system and the x-axis of the beam (the x-axis of the beam is the one closest to the x-axis of the measuring system.)

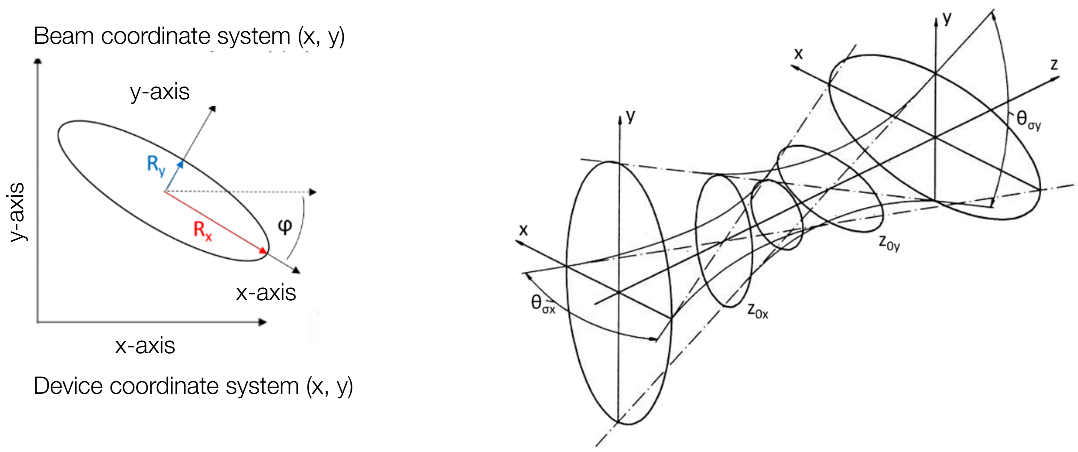


Fig. 23.2: Beam parameter of the not rotationally symmetric beam

All beams which can be characterized by two axes which are perpendicular to each other can be described by means of the above mentioned parameters.

Further beam parameter such as the K-figure or the beam propagation factor are calculated directionally by means of as the same equations as the rotationally symmetric beams. This always results in two parameters such as Kx and Ky.

23.2 Calculation of beam data

For the calculation of the beam data not only the algorithms for the 2. moment method are implemented as demanded by the ISO standard 11145 but also the 86 % method which is widely-spread within the industry. For the Gaussian TEM00-mode both methods offer similar results whereas in case of the majority of other laser beams the 2. moment method calculates bigger beam diameters than the 86 % method.
Laser radiation often is a mixture of different modes with different frequencies and coherent characteristics. All known measuring procedures only provide little information on the beam. Therefore the calculated beam parameters are always dependent on the measuring procedure. For the interpretation of the measuring results it is important to be aware of this fact.

The calculation of the beam radius requires the following to preparatory steps:

1. Measurement of the power density distribution
2. Determination of the zero level
3. Determination of the beam position

23.2.1 Determination of the zero level

The zero level can – for instance – be determined by means of a histogram by applying the frequency of the measured power density values (please see Fig. 23.3 on page 100).

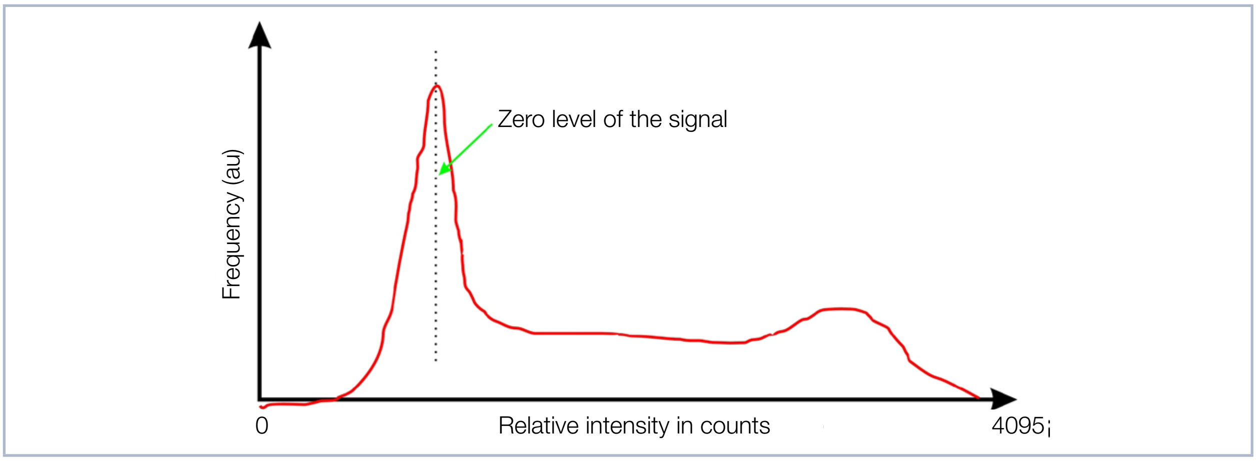


Fig. 23.3: Schematic histogram of the scanned measuring points

The histogram shows how frequently a certain power density was measured. The maximum of this curve indicates the power density of the zero level. The power density is deducted from all measured values of the power density distribution.

It is important to measure the zero level accurately because even the slightest error would lead to a drastic change as far as the volume is concerned. This in turn has a great impact on the measured beam radius.

23.2.2 Determination of the beam position

The beam position is determined by means of the 1. moment method. This means the moment of inertia of the power density distribution (E(x, y, z)) is determined.

$$\bar{x} = \frac{\int\int x \cdot E(x,y,z)dxdy}{\int\int E(x,y,z)dxdy} \qquad \bar{y} = \frac{\int\int y \cdot E(x,y,z)dxdy}{\int\int E(x,y,z)dxdy} \tag{1.5}$$

As mentioned at the beginning of the chapter, there are two possibilities how to determine the beam radius after the determination of the beam position.

23.2.3 Radius determination with the 2. moment method of the power density distribution

The calculation of the beam radius according to the 2. moment method of the power density distribution is effected as shown in equation ***(1.6)***.

$$\sigma_x^2(z) = \frac{\iint (x-\bar{x})^2 \cdot E(x,y,z)\,dxdy}{\iint E(x,y,z)\,dxdy} \qquad \sigma_y^2(z) = \frac{\iint (y-\bar{y})^2 \cdot E(x,y,z)\,dxdy}{\iint E(x,y,z)\,dxdy} \tag{1.6}$$

Based on equation ***(1.6)*** the beam diameter is determined as follows:

$$d_{\sigma x}(z) = 4 \cdot \sigma_x(z)$$

$$d_{\sigma y}(z) = 4 \cdot \sigma_y(z) \tag{1.7}$$

This algorithm contains the product derived from the power density and the squared distance to the moment of inertia. It is only reliable when the zero level is determined correctly. The fill factor, the ratio of the beam diameter divided by the integration range/measuring window size is a further important quantity. It should always have a value between 0.35 and 0.7.

23.2.4 Radius determination with the method of the 86 % power inclusion

The first step is the determination of the volume of the power density distribution. It is proportional to the total power. The addition of all power density values and their multiplication with the pixel dimensions result in the volume and therefore the total power. A reliable zero level subtraction is the fundamental basis.
Based on this total power, the focus lies on the range which includes the 86 % of the total beam power. This beam power must lie within the beam radius.
The integration typically starts with the values of the maximum power density. Then the integration range is enlarged until 86 % of the total power lie within the radius. As far as the integration is concerned, the number of pixels is counted. By means of this the 86 % range which means the beam diameter can be determined. For circular beams similar to the fundamental mode beams the procedure works well.

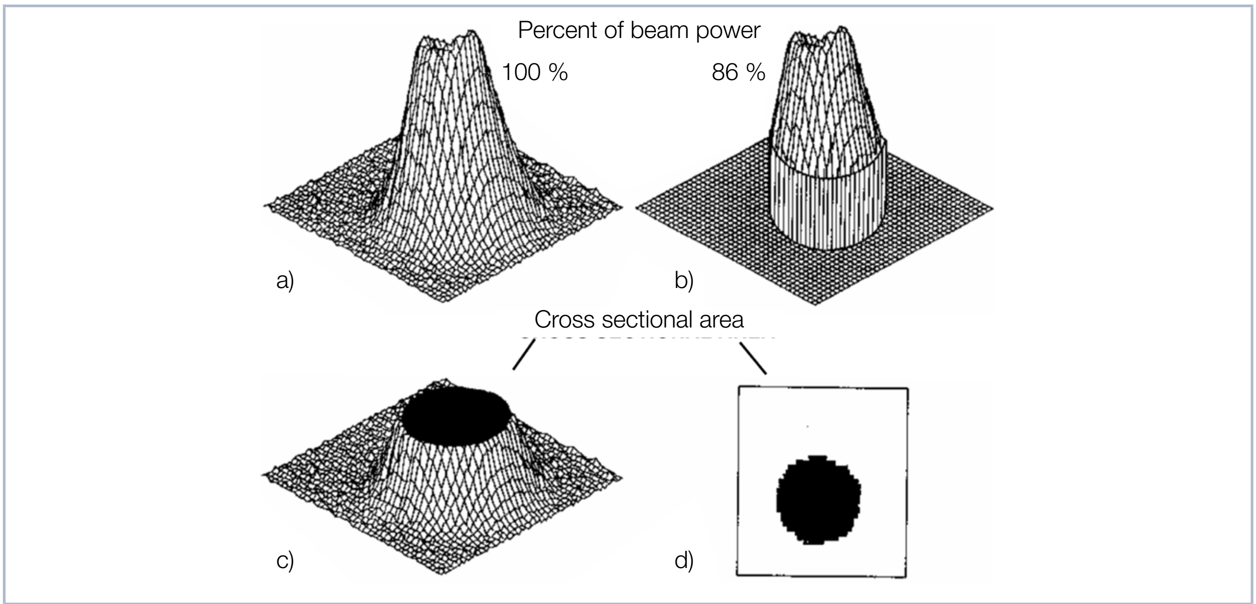


Fig. 23.4: Graphical presentation of the calculation of the 86% radius

a) Shows the power density distribution.
b) Shows the pixels which include 86 % of the power together.
As a clarification the pixels with a low power are set to zero.
c) Shows a section at the “86 % power density inclusion”.
The level lies at 14 % of the maximum power.
d) Shows the section through the distribution at 86 %.

23.2.5 Further radius definitions (option)

Not all measuring devices for the laser beam diagnosis come to the same measuring result when carrying out similar measurements with the same laser beam. Apart from a different validation of the measuring devices the measuring procedures and the used evaluation algorithms have an influence on the determined beam dimension.
Not all the processes used comply with the valid standards. However, they are the preferred choice for instance in the scientific area. For practical reasons, for instance for the design of the orifices or for the correlation with processing results, it can also be helpful to use alternative beam radius definitions.

As an option, we offer an extension to the following alternative radius definitions:

1. Knife edge method according to ISO 11146-3
2. Slit method according to ISO 11146-3
3. Gaussfit method
4. $1/e^2$ power density loss method
5. Power inclusion method with a freely definable 1st power value
6. Power inclusion method with a freely definable 2nd power value

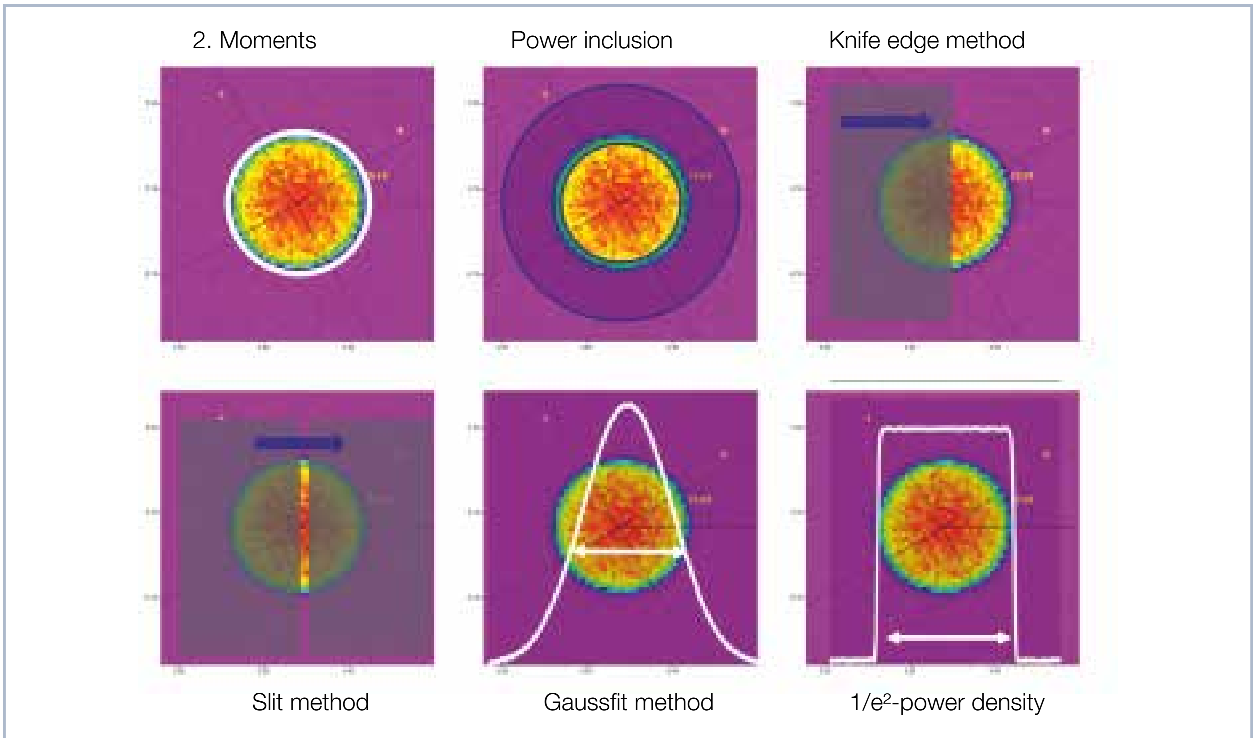


Fig. 23.5: Schematic illustration of the beam radius definitions that are offered optionally for the PRIMES LaserDiagnosticsSoftware LDS

23.3 Measurement errors

Regardless of the measuring principle, there are many sources of errors in determining beam radius.

- Determination of the zero level
- Finite size of the measurement window
- Resolution in x and y directions
- Intensity resolution

23.3.1 Error in determining zero level

Calculation of the beam waist radius is very strongly dependent on changes in the zero level. It doesn't matter if the 86% or 2. moment method is used.

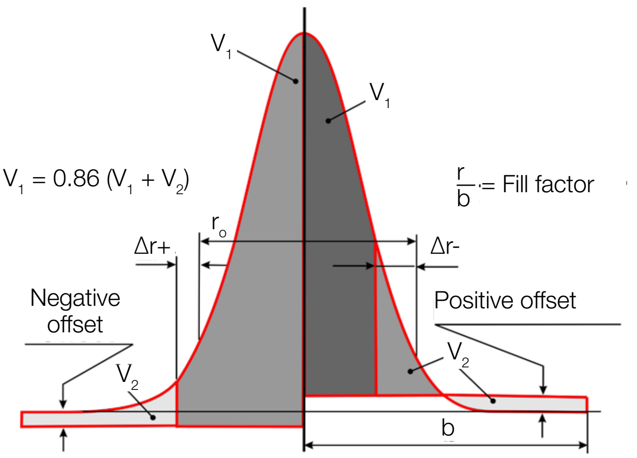


Fig. 23.6: Gaussian Intensity Distribution, zero level lowered (left) and raised (right)

Fig. 23.6 on page 104 illustrates this. When the zero level is lowered (left side), the total volume between the measurement values and the zero level increases. Because of this increase, a larger beam radius is calculated using the curve equation. Conversely, if the zero level is raised (right side), the volume decreases and the computed beam radius will be too small.

23.3.2 Saturating the signal

High signal amplitudes are clipped by the limited dynamics of the system. If the high power densities are missing from the calculation of beam geometry, the algorithm always computes a beam that is too large. This can be compensated for by increasing attenuation.

23.3.3 Errors from incorrect measurement window size

The entire laser beam must be within the measurement window for correct normalization of the volume of the measured distribution. Since the intensity distribution, in principle, extends infinitely, a fraction of the beam power is always outside the measuring range.
In the following, the normalization of beam radius is proportional by half to the window size. This size is defined as the Fill Factor (F).

$$F = \frac{2 \cdot r_s}{\textit{Width of the measuring window}} \qquad (1.8)$$

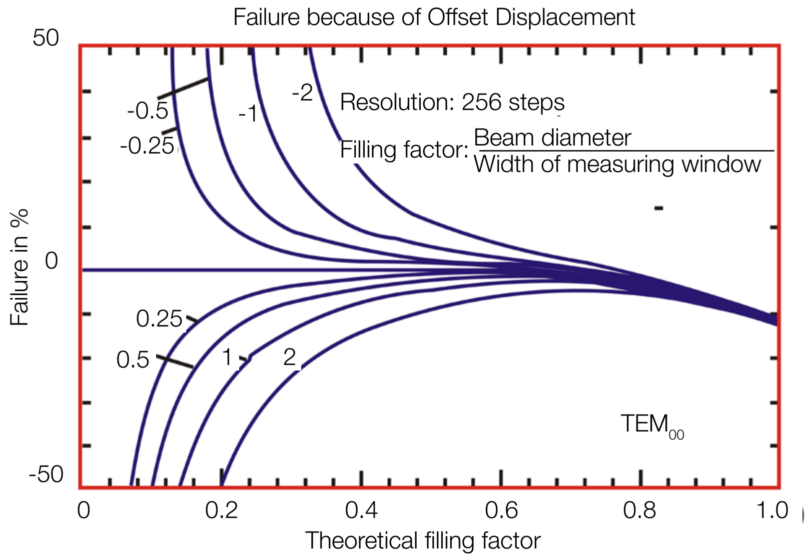


Fig. 23.7: Error During Beam Radius Calculation by Offset of the zero level Plane for Various Offset Values (Gaussian Intensity Distribution)

In Fig. 23.7 on page 105, the effect of a Fill Factor greater than 0.7 can clearly be seen. For Gaussian-like beams, the Fill Factor should be held between 0.4 and 0.6 to minimize errors. For Top-Hat distributions, the limit is around 0.9.

24 Appendix: LaserDIagnosticSoftware LDS

This chapter describes the functions of all main menus and submenus of the menu bar.

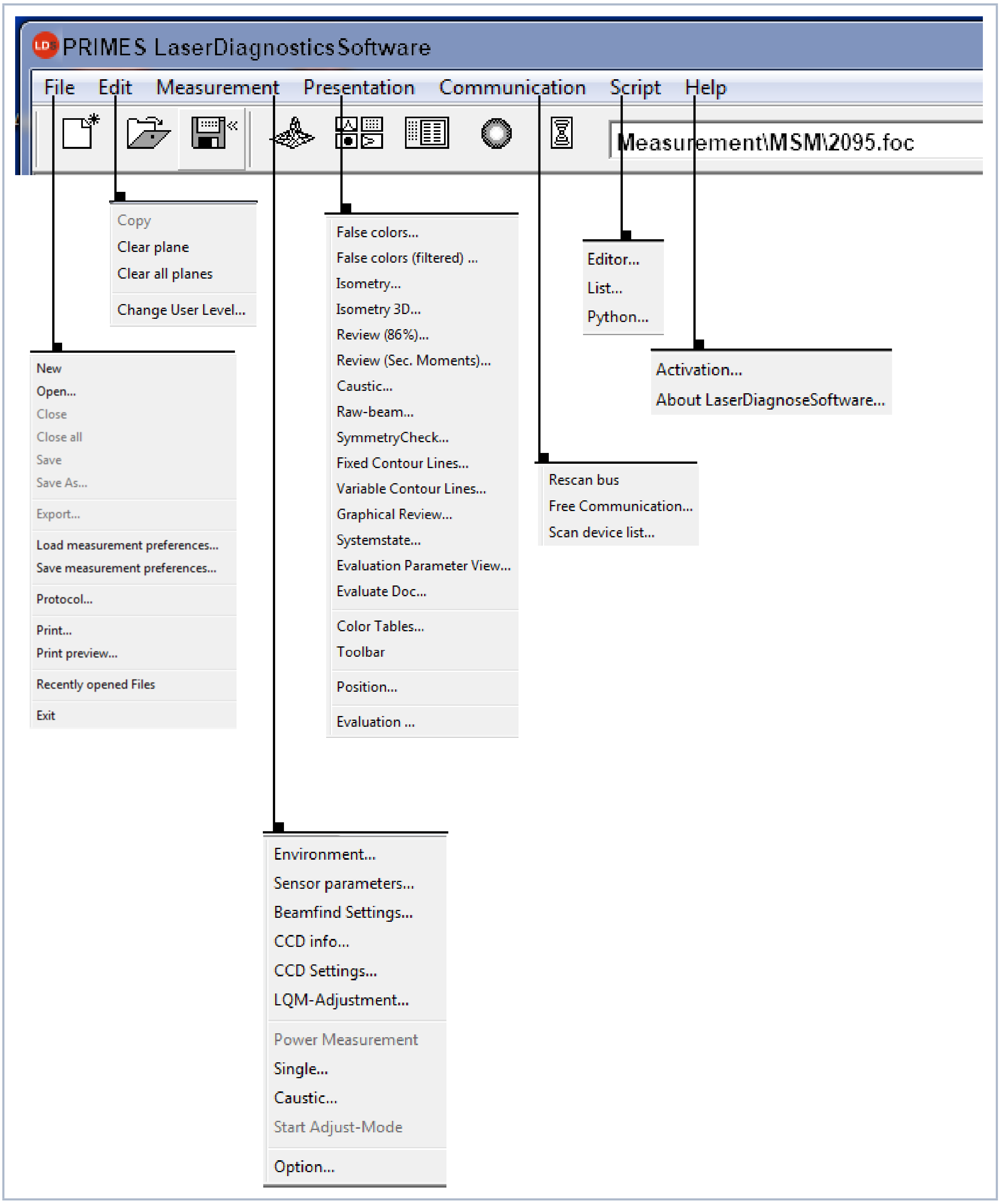


Fig. 24.1: Menu bar

24.1 File

This menu includes – among others – the administration of measurement and setting data.

24.1.1 New (menu *File* > *New*)

By means of New a new file is created.

24.1.2 Open (menu *File* > *Open*)

By means of ***Open*** a selected file is opened.

24.1.3 Close/Close all (menu *File* > *Close/Close all*)

Close will close the file that is currently open. ***Close all*** will close all files currently open.

24.1.4 Save (menu *File* > *Save*)

The file currently opened is stored. The standard type of file is a binary file format with a minimal memory requirements. The file ending for a measuring file of this type is ".foc". As an alternative, it is possible to store the data in a ASCII format with the extension ".mdf". Information regarding the file format ".mdf" can be found enclosed. Only files with this formats can be opened by the program.

24.1.5 Save as (menu *File* > *Save As*)

You have to assign a file name, choose the storage location and the file format.

Only save the measurement data with the extensions ".foc" or ".mdf". You can only view measurement data if the respective file was explicitly selected in the toolbar.

24.1.6 Export (menu *File* > *Export*)

Exports the pixel information of the power density distribution to a Excel table (*.xls). As an alternative, the numeric results from a ".foc" file can be stored in a tab-separated text file (*.pkl) which can be imported into Microsoft Excel. The pkl export function has a coordinate origin in the middle of the measuring area (yellow dot).

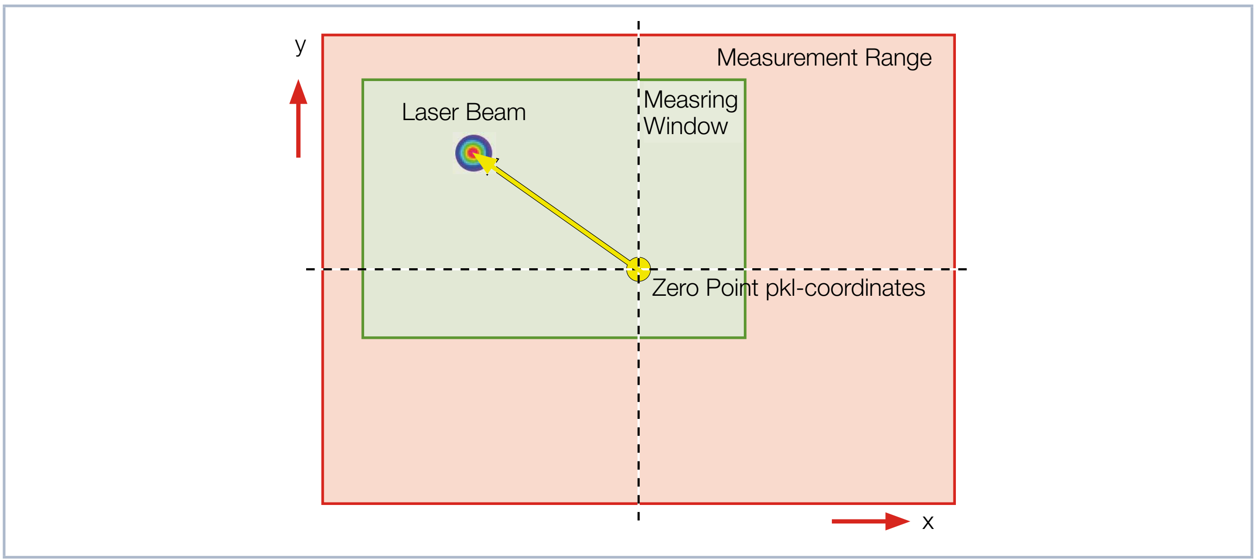


Fig. 24.2: Coordinates of the pkl-export function (the illustration is not to scale)

24.1.7 Load measurement preferences (menu *File* > *Load measurement preferences*)

Stored settings can be resorted to with ***Load measurement preferences***. The standardized extension for a setting file of the HP-MSM-HB is ".ptx".

24.1.8 Save measurement preferences (menu *File* > *Save measurement preferences*)

The current measurement settings are stored (.ptx-file).

24.1.9 Protocol (menu *File* > *Protocol*)

The calculated measurement results from a single plane can directly be written into a text file.
The following is stored:

- Date and time of the measurement
- Beam position and beam radius (according to 86 %- and 2. moment method definition)

Therefore please activate the check box ***Write***. Then you can directly enter the name in the field ***Filename*** or you can use the standard selection menu with the button ***Browse***.

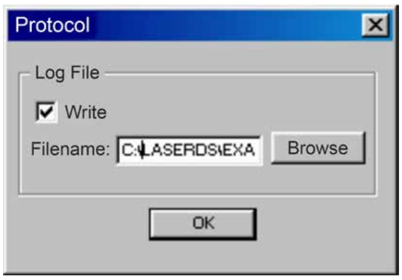


Fig. 24.3: Window ***Protocol***

24.1.10 Print (menu *File* > *Print*)

You can print directly from the program. The current window can be printed with the menu point ***Print*** in the menu ***File***. With the menu point ***Settings*** it is also possible to change the settings as far as the formats etc. are concerned.

24.1.11 Print preview (menu *File* > *Print preview*)

Shows a preview of your printing order.

24.1.12 Recently opened files (menu *File* > *Recently opened Files*)

Selection of the files processed before.

24.1.13 Exit (menu *File* > *Exit*)

Terminates the program.

24.2 Edit

24.2.1 Copy (menu *Edit* > *Copy*)

By means of the copy function a direct export of graphics to other programs is possible. In this case the content of the current window is transmitted to the Windows clipboard.

24.2.2 Clear plane (menu *Edit* > *Clear plane*)

The content of the actual displayed measurement plane of the measurement data set selected in the toolbar is deleted.

24.2.3 Clear all planes (menu *Edit* > *Clear all planes*)

The content of all measurement planes of the measurement data set selected in the toolbar is deleted.

24.2.4 Change user level (menu *Edit* > *Change User Level*)

By entering a password a different user level can be activated.

24.3 Measurement

24.3.1 Measuring environment (menu *Measurement* > *Environment*)

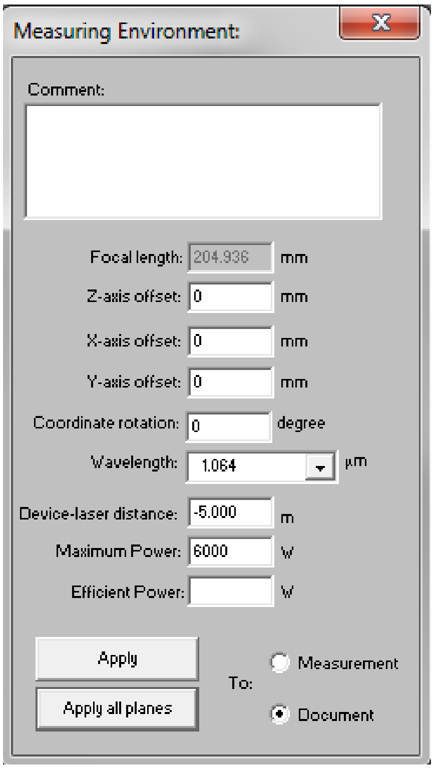


Fig. 24.4: Dialogue window ***Measuring Environment***

In the dialogue window ***Measuring Environment*** data such as the laser type, focal length etc. can be stored. These data can be read via ***Presentation*** > ***Review***.

Focal length

Stating the focal length is relevant for the evaluation of the caustic measurements. From the caustic process and the entered focal length the raw beam diameter on the focussing optic can be calculated.

Wave length

The wave-length is the basis for a correct determination of the beam quality factor M^2. It is 1.064 µm for Nd:YAG laser.

A wavelength can also be typed in numerically.

While only the calibration points of the measuring objective can be configured in the ***CCD Setting*** dialog window, the exact value of the laser's wavelength can be entered in this window. This value is used in all numeric evaluations, such as the calibration of the beam quality factor M^2.

Caution: If the wavelength is newly selected in the ***CCD Setting*** dialog window, the value in this window will be overwritten with the selected calibration point.

Application

By means of the button ***Apply*** the entries can also be changed after a measurement. With the button ***Apply all planes*** the entered values are inserted and settled, while the button ***Apply*** only refers to the value in the current plane.

Laser power

Entering the laser power is a reference value for the relative power position in the menu point ***Single measurement*** or ***Caustic measurement***. Furthermore, a z-axes offset as well as a coordinate rotation angle can be entered.

Comment

Please do not use the character # in the comment field "Comment". This character is used as a separator in the software. If it is entered in the field "Comment", problems could occur when it comes to storing or activating measuring data.
A line break can be enforced by means of the key combination: **<Ctrl> + <Enter>**.

24.3.2 Sensor parameters (menu *Measurement* > *Sensor parameter*)

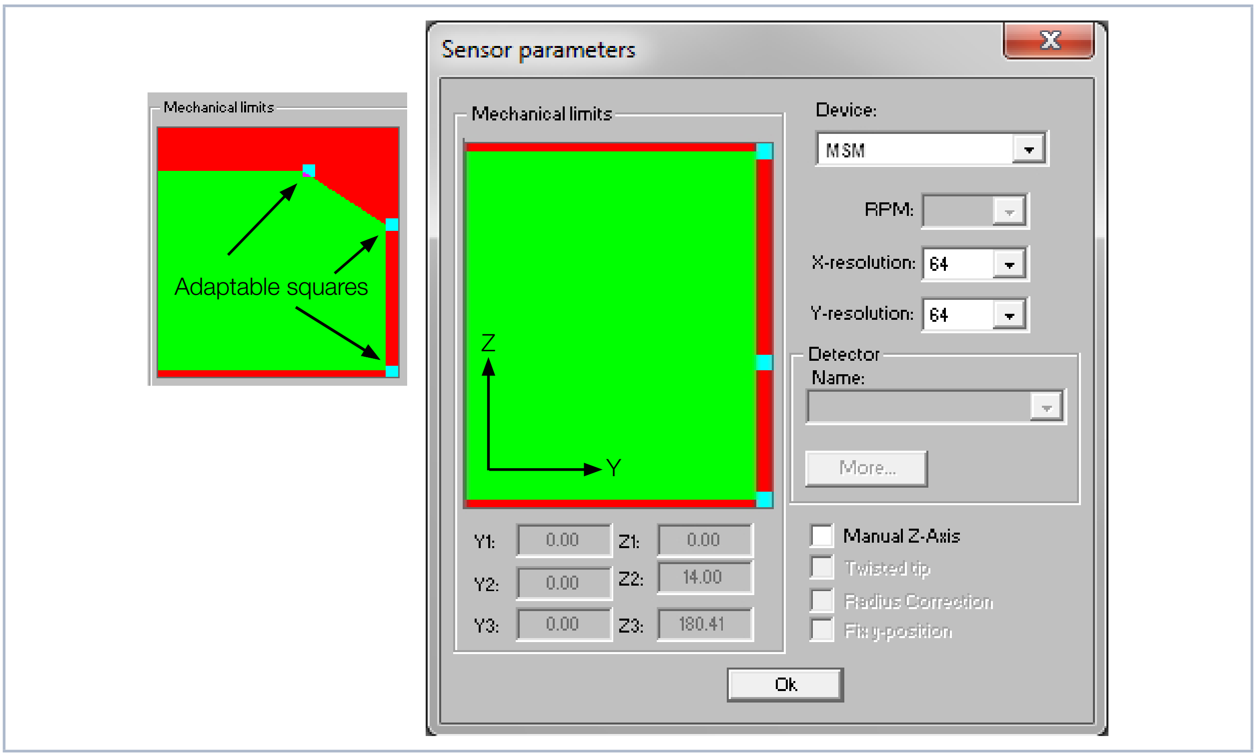


Fig. 24.5: Dialogue window ***Sensor parameters***

Mechanical limits

By pulling the turquoise square with the mouse pointer you can restrict the movement range of the y- and z-axis. Therewith you can prevent damages in case other components reach into the movement range of your device. The maximum value corresponds to the value Y3 and Z3.

Device

By means of this option, you can select the device which is supposed to be operated. Depending on the number of devices connected, additional device numbers are assigned.

RPM

Not relevant for HP-MSM-HB.

Resolution

Here you can enter the number of pixels in the measuring window, ranging from 32 x 32 to 256 x 256 pixels. Generally, 64 x 64 pixels are sufficient. Please keep in mind that the more pixels there are, the longer the measurement will take.

Detector

Not relevant for HP-MSM-HB.

Manual z-axis

With this function you can deactivate the z-axes of the measuring system. This is useful if you want to use external movement axes. In this case you can manually assign a z-value to every measurement plane in the dialogue window ***Single measurement***.

24.3.3 Beam find settings (menu *Measurement* > *BeamFind Settings: Beamfind*

Not relevant for HP-MSM-HB.

24.3.4 CCD info (menu *Measurement* > *CCD Info*)

The most important device data is shown in the menu ***Measurement* > *CCD Device Info***. Here you can see the magnification information for the measuring objective and also check which beam path is turned on.
If obvious default values (1:1) are shown instead of the actual magnification, then please check the mounting of the measurement objective.

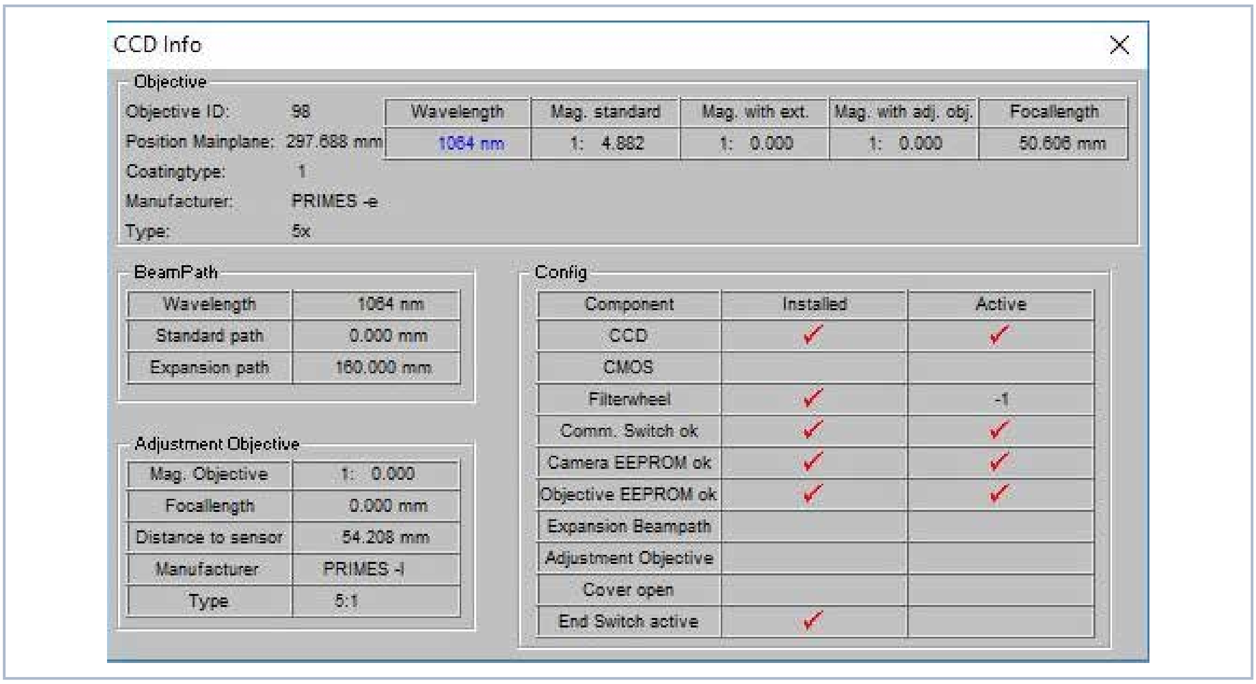


Fig. 24.6: Window ***CCD Info***

24.3.5 CCD settings (menu *Measurement* > *CCD Settings*)

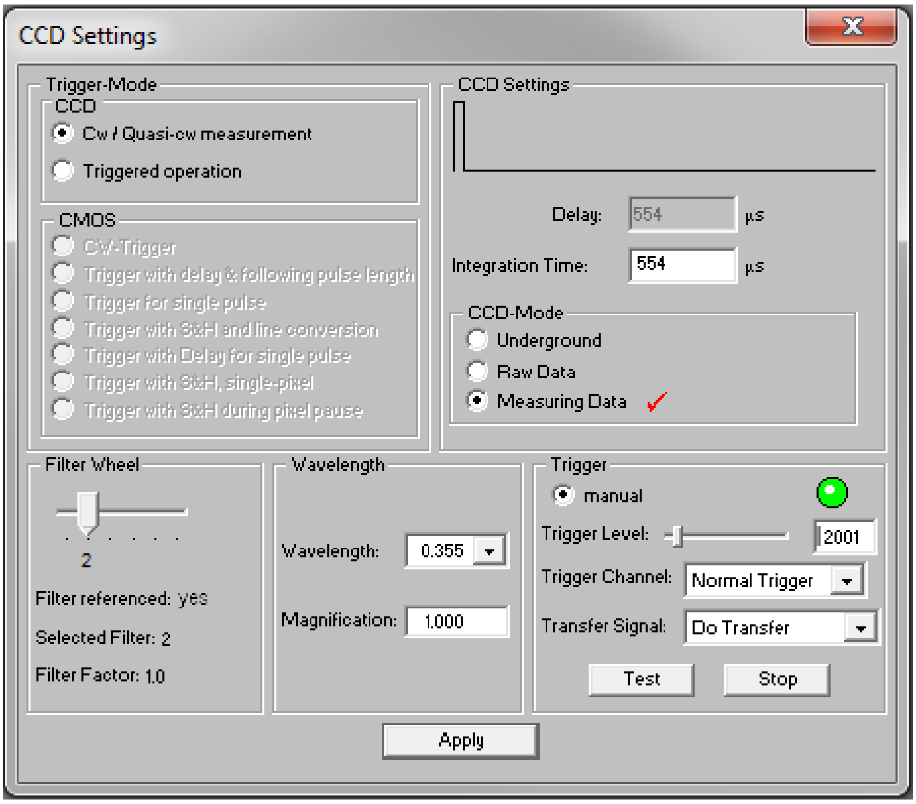


Fig. 24.7: Dialogue window ***CCD Settings***

The wavelength, attenuation, and operating mode are all set in the ***CCD Settings*** dialog window.

Trigger modes

The appropriate settings must be configured here in keeping with the operating mode of the laser to be measured. Here it is important to consider that pulsed lasers with a pulse frequency of more than 500 Hz can be measured in cw mode. If, however, the operating mode is set to pulsed and a cw laser system is involved, the measuring device will always display the error message "Error Black Pixel Measurement" or "Time Out During Measurement" in reaction to a measurement request.

Delay

This function can only be used with a "triggered operation" trigger mode. The time the measuring system should wait between when it detects the trigger pulse and the start of the measurement is set here. Together with the function "Integration Duration", defined "Windows" from the plus cycles can be measured (e.g. exactly one pulse or parts of an ms pulse. The minimum delay is 12 µs.

CCD operating modes

Three different modes can be set here. If the ***Raw Data*** setting is activated, the measuring system will return the uncompensated data of the CCD when a measurement is requested. Especially with NIR irradiation, these can be riddled with measuring errors such as "smear effect" readout noise. Even the numeric beam data generated from this data will be affected by this.
If a ***Background*** is selected as the operating mode, only correction data will be returned while measuring. ***Measuring Data*** mode should always be the default setting here though. Only when this mode is turned on can the measuring system deliver reliable measuring values.

Integration duration

This function sets a defined integration duration. The optimizer must be deactivated before this can be accomplished, since otherwise the measuring device itself will optimize and thus change the integration duration. This function is also used mainly in measuring pulsed laser systems.

Filter wheel

Which filter is needed for measuring depends on the wavelength and the intensity of the laser beam being measured and the appropriate one must be chosen specifically for each measuring task.
A filter can be considered suitable when all measuring planes of a caustic measurement can be measured using an exposure time between 18 ms (-20 dB) and 0.18 ms (-60 dB). Outside of these limits, the S/N ratio of the CCD declines, thus reducing the accuracy.

Wavelength

Due to the wavelength-dependent overall magnification of the camera-based measuring system, it is important to check that the right selections have been made before each measurement. The wavelengths shown here represent the calibration points of the measuring objective. As a result of the achromatic properties of the measuring objective, a wavelength range between 1 030 and 1 100 can be achieved, for example, with a calibration point at 1 064 nm without causing generating measuring errors.

Trigger

The trigger menu is only pertinent when measuring pulsed laser systems. A fixed value (2 001) is generally specified for the trigger diode by default. This value describes the threshold value at which a trigger signal is emitted. If you switch the trigger to automatic, the trigger level will first be set to the maximum value. The ***Test*** button is renamed in ***Optimize***. In the optimize routine (laser must be turned on), the trigger threshold is lowered gradually until the HP-MSM-HB starts receiving trigger signals (lower trigger level). The trigger level is then increased until the HP-MSM-HB stops receiving trigger signals (top trigger level). The final trigger level is determined by calculating the arithmetic mean of the two limit values. External trigger entry can be activated via the menu point ***Trigger Channel***. Transfer signal pertains to the transfer output of the MicroSpotMonitor. Here it is possible to define the CCD sensor state at which there should be a trigger signal (e.g. for turning on the laser).

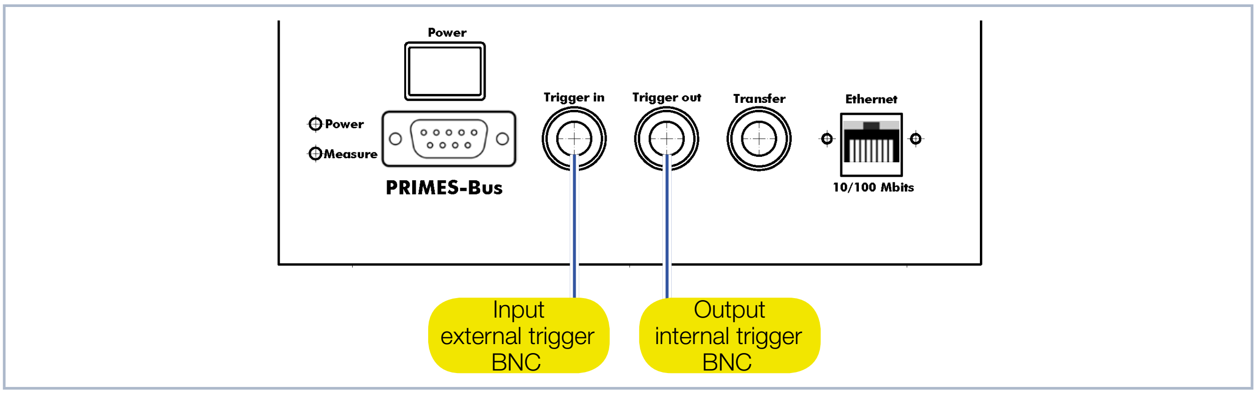


Fig. 24.8: Trigger connections

24.3.6 LQM adjustment (menu *Measurement* > *LQM Adjustment*)

Not relevant for HP-MSM-HB.

24.3.7 Power measurement (menu *Measurement* > *Power Measurement*)

Not relevant for HP-MSM-HB.

24.3.8 Single (menu *Measurement* > *Single*)

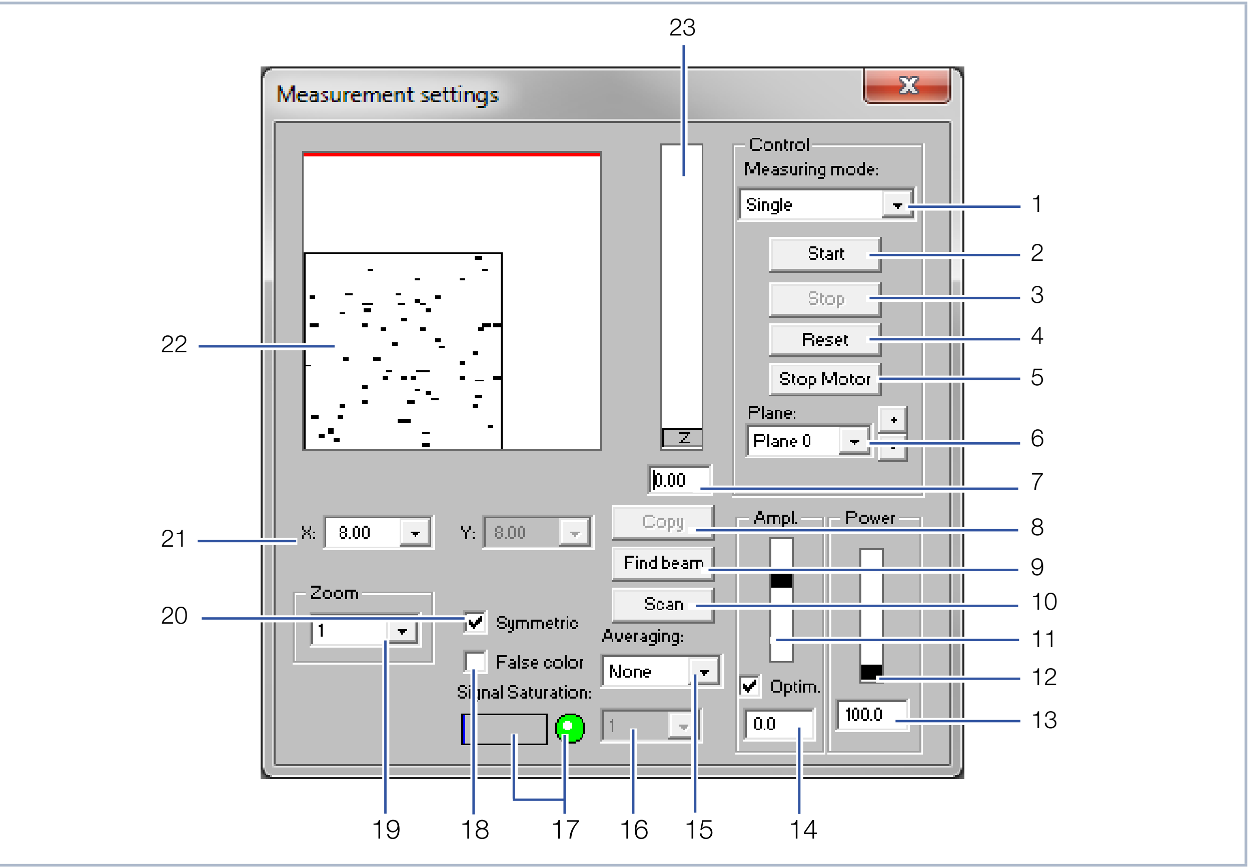


Fig. 24.9: Dialogue window ***Measurement settings***

1	Single Monitor Video Mode	Starts a measurement in the chosen plane Starts repeated measurements in the chosen plane automatically
2	Start	Starts a measurement in the currently chosen plane
3	Stop	Finishes the measurement in the currently chosen plane
4	Reset	The measuring device is reset
5	Stop Motor	Not relevant for HP-MSM-HB
6	Plane	Selection of the measuring plane (0-49) either explicit or by means of the buttons (+/-)
7	Entry field	Numerical entry of the z-position
8	Copy	Copies all settings (window size and window position; x, y, z; etc.) from the former plane to the current plane (e.g. 1>>2)
9	Find beam	Starts an automatic beam search in the current measuring plane
10	Scan	Starts an automatic beam search with the HP-MSM-HB. The algorithm works at a fixed z-position and searches only within the range of the specified measuring window.
11	Ampl.	Slide control in order to adjust the optical amplification (exposure time of the CCD)
12	Power	Slide control in order to adjust the laser power to save it in the software
13	Entry field Power	Numerical input of the laser power to save it in the software
14	Entry field Ampl.	Numerical input of the electrical amplification
15	Averaging	Analysis of the serial measurements. Averaging algorithms: average value, values of the maximum pixels and the value of the maximum trace
16	Averaging	Selectable number (1 – 50) of single measurements for the averaging
17	LED symbol and bar graph display	Display for the degree of the signal saturation (LED green ≙ ok, red ≙ not ok)
18	False color	Activates the option of the false color presentation
19	Zoom	Magnification settings for the measuring window
20	Symmetric	This option enforces the usage of square measurement windows, whose size is only adjustable via x.
21	X/Y	Set the measurement window size for non-square windows
22	Display	Measuring window shows the current measuring result
23	Z	Slide control in order to set the z-position

Tab. 24.1: Explanation of input and setting elements

With the dialogue window ***Measurement settings*** either single measurements or repeated measurements can be carried out. The measuring window position can be set either manually or automatically.

Controlling measuring modes (individual measurement, monitor, and video mode)

There is a total of three different measuring modes that can be selected here. In the ***Individual Measurement*** and ***Monitor*** measuring mode, all necessary compensations (smear effect, diffusion) and exposure time adjustments are performed every time a new measurement is carried out. Valid measuring data is generated in this mode.

The measuring mode ***VideoMode*** does not produce valid measurement data. Here the exposure time is carried over from the last measurement and does not vary. Compensation measurements are not performed, making it unnecessary to consider or compensate for measuring artifacts such as smear effects.
Due to the “high” measuring frequency of about 5 Hz, this operating mode is particularly suited for use when aligning the device. The numeric results should not be interpreted absolutely, but rather always relative to each other.

Power

The slider sets the actual laser power, so the software algorithm can calculate the spacial power density. It can be set to any power up to the maximum.
The maximum power is entered in the menu under ***Measurement > Environment***. The power density is calculated in relation to the power values set here. Up to 50 individual measurements can be recorded in a measurement file. The results can be easily compared and analyzed with the various presentation functions of the LaserDiagnosticsSoftware LDS.

Optical amplification (opt. ampl.)

This function activates the automatic adjustment of the exposure time of the CCD for every measurement. The function must be activated in order to keep the signal/noise ratio consistently high for a caustic measurement.
For special measuring applications, however, it might make sense to deactivate this function and set the exposure time to a fixed value between 12 µs and 200 ms. Here it is important to ensure sufficient attenuation of the laser beam with the help of the fixed ND filter or the filter wheel.

Copy

Using the ***Copy*** button, you can apply the measurement settings for window size, window position, power, and amplification from the previous measuring plane.

Beam search

The ***Beam Search*** will initiate an automatic beam search. When this happens, the system will only search the area of the currently set window for the set z-position.
If the beam search is completed successfully, a measuring window with the appropriate size and position will appear on the display screen. The beam can then be accepted using the ***Start*** button. The size of the measuring window depends on the magnification of the measuring objective. The measuring objective and the wavelength are the influencing variables here.

Scan

For devices such as the LaserQualityMonitor LQM, the measuring window is much smaller than the measuring area defined with the x- and y-axis (2 mm x 2 mm). The beam search is therefore supplemented with the ***Scan*** command. Once a scan is initiated, the HP-MSM-HB will automatically sense the measuring area. If a point of maximum intensity can be identified, the HP-MSM-HB will automatically zoom in on this area and adjust the measuring window size accordingly.

Size of the measuring window

During a manual beam search, you can define the location and size of the measuring window yourself in the dropdown menu within the mechanical limits. You can change the location of the measuring window by clicking on it and dragging the frame with the mouse.

Z-Slider

The location of the window in the z-direction (height) can be set by the z-slider or entering a numeric value.

Symmetrical

Once this function is activated, only rectangular measuring windows will be allowed. In cases where an elliptical or even a square laser beam is being measured, this function should be deactivated so that the measuring window can be optimally adjusted.

False color rendering

False color rendering is activated by clicking on the corresponding button. A measurement is initiated by clicking on the ***Start*** button. Selecting ***Monitor*** and pressing the ***Start*** button will initiate an ongoing, repeating measurement with the current settings. The repeat rate depends on the spacial resolution and the type of communication between the PC and the HP-MSM-HB.

Zoom function

The zoom function allows for detailed magnification of the measuring area.

24.3.9 Caustic measurement (menu *Measurement* > *Caustic*)

The caustic measurement is a serial measurement where the z position is varied. The results are stored in different planes. A different z-position is assigned to every measuring plane. As the beam radius as well as the power density change in every z-position, the position as well as the size of the window and the signal strength can vary from plane to plane. The parameters are automatically adjusted in the process and can also be configured separately for each measuring plane.

Parameters (start number of the plane)

Under Start, the start number at which the measurement is initiated can be entered for the plane. By default, the start number is generally set to zero and should only be changed when you are measuring in an existing document and don't want the existing measurement data to be overwritten. If, for example, you have measured a caustic with 21 planes and want to magnify the measuring area to the smaller z-values, you can set the start plane to 21 and modify the measuring area appropriately. The new measuring values will then be written into the existing document starting with plane 21.

In the Quantity selection field, the number of planes to be measured in the specified z-range is set. The following should be considered here:

- Since the LaserDiagnosticsSoftware LDS always sets the measuring plane distances so they are equidistant (equal spacing) and the measuring area is almost always situated symmetrically around the focal point, an odd number of measuring planes should be selected. This ensures that the focus plane is measured.
- Beam measurement norm DIN 11146 specifies that at least 10 measuring planes should be measured. Furthermore, five measurements should also be taken within a Rayleigh length and the other beyond 5 Rayleigh lengths. In order to meet all of the requirements with equidistant distribution, at least 17 measuring planes must be measured in a range of ± 3 Rayleigh lengths.

Mode (automatic and manual settings)

There are two different measuring modes for caustic measurement. In "Automatic" mode, the measuring system and the LDS determine the ideal measuring window position (x- and y-direction) for each measuring plane and the optimal measuring window size for the fill factor. Furthermore, the plane location in the z-direction is also calculated based on the specifications (number of measuring planes, measuring limits z-direction).

Especially when adjusting the measuring window size and the measuring window position in the x- and y-direction, the number of iterations (max. three per plane) can result in an extended measurement duration.

It is therefore possible to change the measuring mode to "Manual Settings" for recurring measuring tasks and for repeating measurements. In this case, the measuring system will take the measuring window positions and measuring window sizes from the previous measurement or from a .ptx file. This reduces the measurement duration considerably, but does require that the location and parameters of the laser beam change only minimally.

Beam search

This selection field specifies which plane the caustic measurement should be started in. If the optional ***Beam Find*** function is activated in the ***Options*** dialog window, that is also the plane in which this function will be performed. When the Beam Find function is deactivated, this plane must be manually measured ahead of time to make sure that the laser beam is found.

The window can be adjusted under the ***Adjust*** menu point. The settings for spacial resolution of the beam search, the threshold value, and the minimum signal strength can be entered under the ***Details*** menu point. Beam search can be turned off in the ***Measurement > Option (only for advanced users) menu*** by deactivating the checkbox ***Enable Beam Find Process***.

Automatic caustic measurement (menu *Measurement* > *Caustic* > *Automatic)*

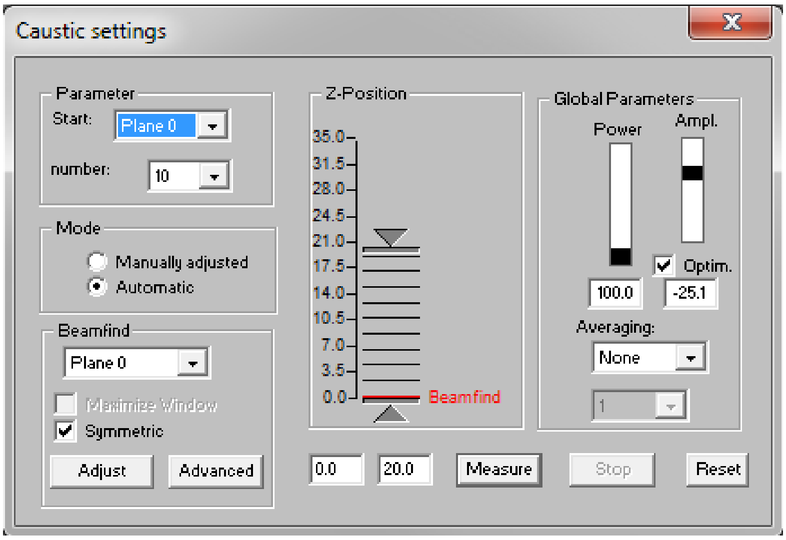


Fig. 24.10: Dialogue window ***Caustic settings***

During automatic caustic measurement, the minimum and maximum z-position is selected together with the number of measuring planes. The measurement cycle begins with an automatic beam search in the specified starting plane. The beam search only occurs within the area of the starting plane's measurement window.

Settings can be entered manually. After manually entering the settings for the measurement planes as described in the following section, the caustic measurement can be repeated automatically by choosing the ***Manually adjusted*** mode.

It is also possible to store measurement settings such as window size, position, etc. in a data file to be reloaded again if necessary (***File > Safe/Load measurement preferences***).

A measurement cycle is started by pressing the ***Measure*** button. All planes will be measured then one after the other during the measurement cycle.

Manual caustic measurement as time series (menu *Measurement* > *Caustic* > *Manually adjusted)*

The manual caustic measurement consists of a series of individual measurements at various z-positions, with the results being stored in their own planes.

24.3.10 Start adjust mode (menu *Measurement* > *Start Adjust mode*)

Not relevant for HP-MSM-HB.

24.3.11 Option (advanced user only) (menu *Measurement* > *Option*)

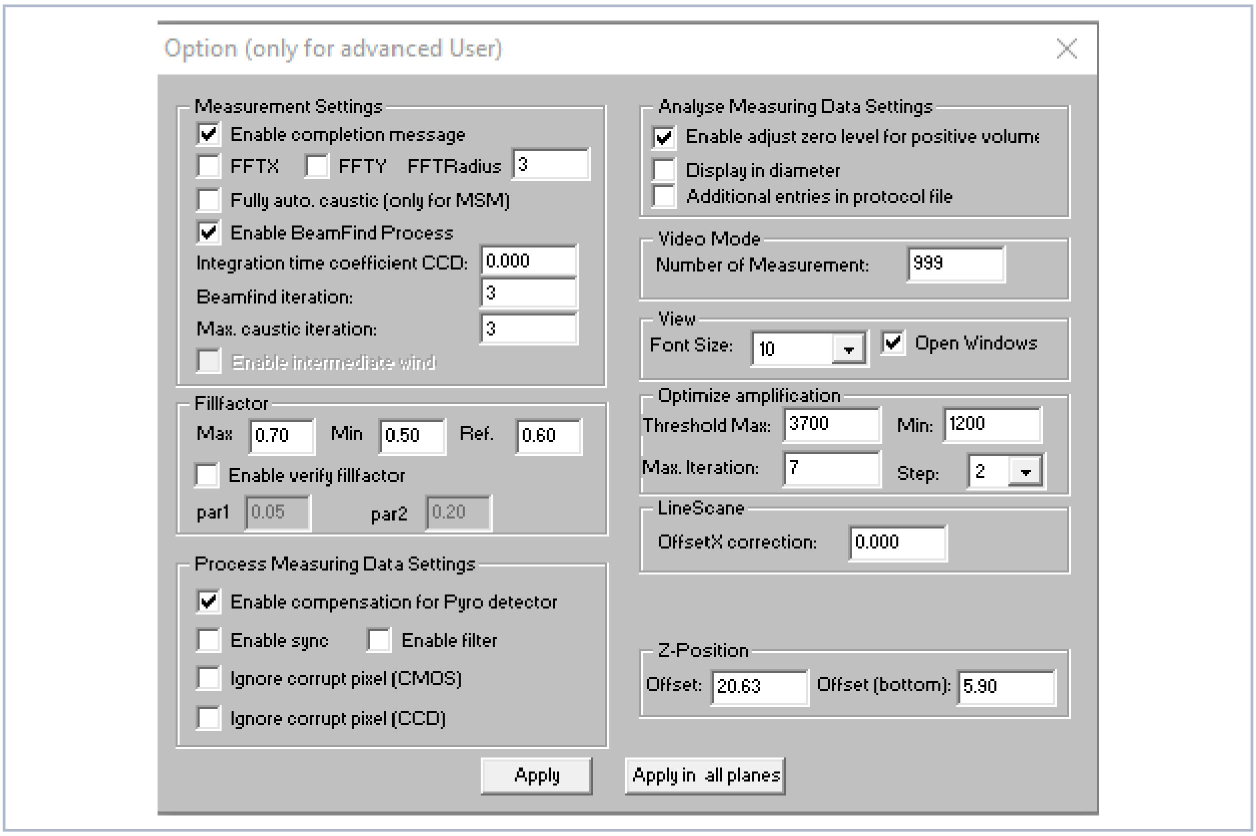


Fig. 24.11: Dialog window ***Option***

Enable beam find process

The Beam Find function must be used for caustic measurement. This involves an algorithm that separates the measuring signal from the measurement artifacts (e.g. noise) via an adjustable trigger threshold and adapts the size of the measuring window to this signal. This algorithm is only executed in the beam search plane (Dialog window ***Caustic***). On all other measuring planes, the measuring window size is determined using the fill factor.
If this function is deactivated, the beam search plane must be manually “premeasured” in the measuring system. Otherwise the measuring system might end up positioning the measuring window on the edge of the measuring area where there is no measuring signal. This makes it impossible to take a meaningful measurement.
If you turn the Beam Find function off and have the measuring measure the beam search plane system before each caustic measurement, you can save about 20 sec of measuring time per caustic measurement.

Summary: This function should be activated by default and only deactivated by experienced users. Turning off this function can shorten the time for caustic measurements by about 15 %.

Fill factor

The fill factor is the quotient of the beam diameter and the length of the sides of the measuring window. As long as the measuring signal is not cut off and there are no noise components in the measuring result and now errors in the offset determination, the fill factor won’t influence the accuracy at all. But since every real measuring signal is tainted with noise and since the precision with which the zero level of a measuring signal can be determined is finite, very small fill factors can lead to a high level of accuracy. Depending on how substantial the RMS noise is and the errors in the zero level determination of a measuring plane, the optimal fill factor value to produce the best possible mathematical result will be different.

For TopHat and Gaussian beam shaped laser beams, the fill factor should range between 0.5 and 0.7. If the beam has diffraction rings, however, and if these are located completely within the measuring window, the optimal value for the fill factor can be between 0.5 and 0.6.

By default, the value should be set to: “Max 0.7 Min 0.5 Target 0.6”. For extremely deformed beams, the value may be changed to “Max 0.6 Min 0.4 Target 0.5”.

Font size

The font size for the most important display window can be changed here.
It is set to 10 points at the factory.

Open windows

When the window opening function is activated, some basic windows are opened when the LDS is started. If you don’t want this to happen, the function can be deactivated.

24.4 Presentation

This chapter describes the presentation, analysis and storage of measuring results.

In order to carry out comparisons between different measurements, the program can manage several measuring data sets simultaneously. The opened data sets are shown in the toolbar. In order to open one presentation, the data which is to be examined is selected in the list of the data selection and afterwards the desired kind of presentation is chosen.

File management functions as well as various display types can be pulled up directly with the symbols in the menu bar.

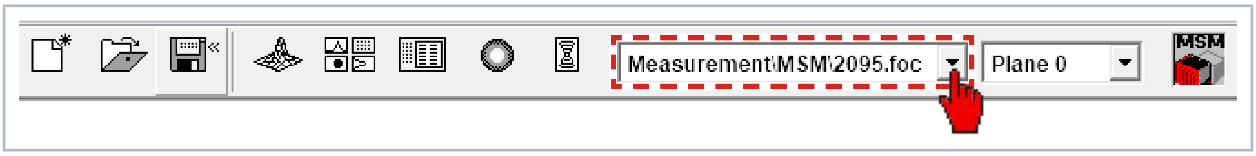


Fig. 24.12: Selection of a data set

On the selection plane, it is possible to switch back and forth between different image storages of the measuring series. When plane selection is activated, it is possible to move up or down by clicking the cursor. When plane selection is set to ***Global*** in the display menu, then it is also possible to move up/down with the cursor button.

In the menus for the notation of single measurements (***Presentation > Variable contour lines***, ***Presentation > Isometry*** and ***Presentation > False color presentation***) the option ***Autoscale*** effects the usage of the entire display range for the measuring values.

Moreover, you have the possibility of switching between different image memories of series of measurements by means of the ***Plane selection***. Switching is also possible by means of the cursor keys up/down if the plane selection is selected. If the plane selection in the display menus is set on ***Global***, switching simultaneously between the planes is possible via the selection in the toolbar.
The title of the dialogue window indicates the name of the data sets shown.

For the parallel evaluation of several measurements the program has 50 image memories which can record one measurement each. These image memories (measuring plane) can also be used in order to record changed measurement values in case of a parameter variation.

Due to the variation of the z-position in the different planes a caustic measurement is realized. Due to a change of the laser power it is possible to simulate, e.g. the thermal inflow-behavior of the system. Similarly, time series are possible. Respective displays are, for instance, possible by means of the menu item ***Presentation > Graphical review***.

24.4.1 False colors (menu *Presentation* > *False colors*)

Here, a false color presentation of the measured power density distribution is generated.

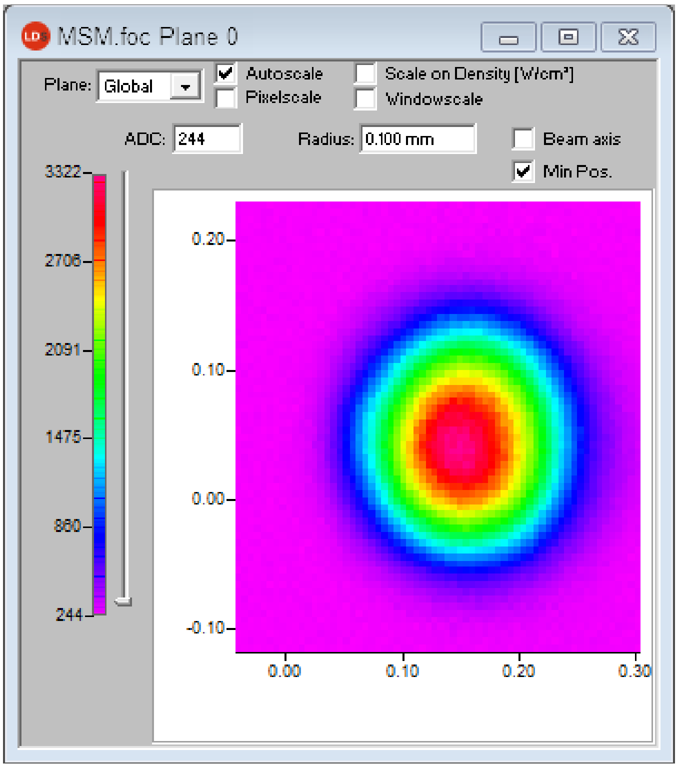


Fig. 24.13: Dialogue window ***False colors***

The used color scale is shown on the left. For a higher sensitivity, e.g. for the analysis of diffraction figures, it is possible to switch the used color scale in the menu ***Presentation > Color Tables***. By means of the slide control on the left hand side of the color scale you can display the sections of different ADC values with the corresponding radii.

Apart from the automatic scaling, there are three more types of scaling:

Scale on density

All planes of a caustic measurement are scaled on the maximum measured power density. This is supposed to help comparing the different planes more easily.

Pixel scale

This scaling is only interesting when it comes to the usage of asymmetric measuring windows. In this case the axis of the windows are no longer a function of the measuring window size but of the number of pixels measured.

Window scale

With regard to this function, all measuring windows of a caustic measurement are enlarged to the size of the maximum measuring window. This function, too, is supposed to help comparing the different measuring planes of a caustic measurement more easily.
The beam axes can be displayed in all types of scaling by activating the check box ***Beam axis***.

Rule function

The beam can be measured in any direction by left-clicking on the image.

24.4.2 False colors (filtered) (menu *Presentation* > *False colors (filtered)*)

The special function of the filter is called spline – function. It is characterized by the fact that the position of the maximum is maintained. The single pixels in the matrix are weighed by means of a 1-2-1 filter in order to reduce the noise.
This filter can also be used multiple times without the position of the maxima being moved.

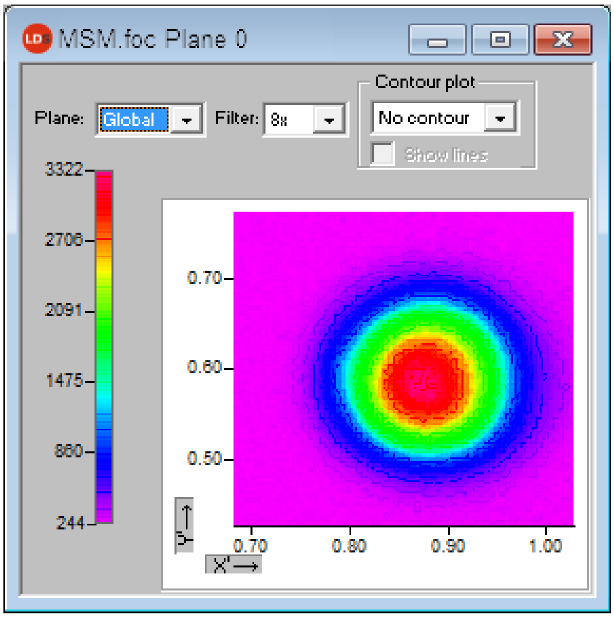
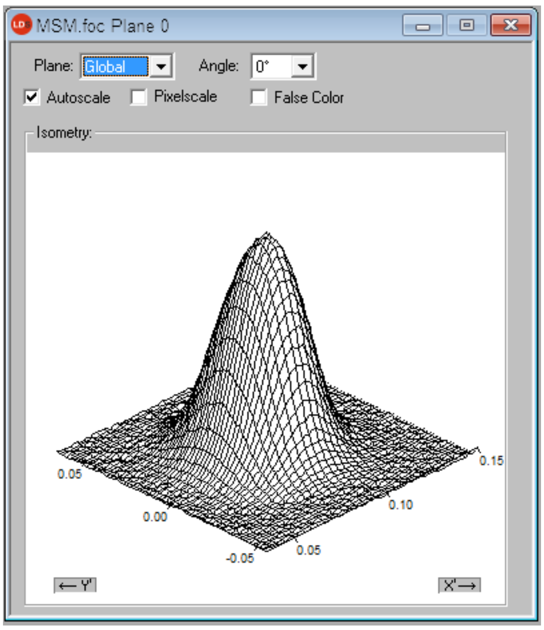


Fig. 24.14: Dialogue window ***False colors (filtered)***

24.4.3 Isometry (menu *Presentation* > *Isometry*)

This menu item generates a spatial display of the measured power density distribution of a plane. The false color display can be deactivated. A turn of the distribution by 90°, 180° and 270° each is possible.



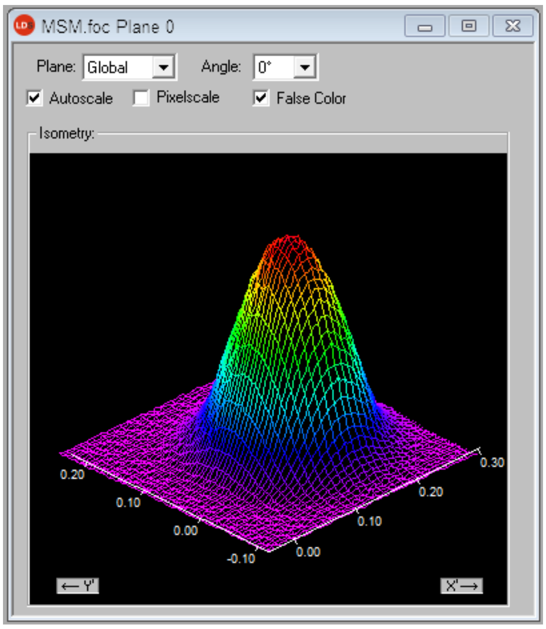


Fig. 24.15: Dialogue window ***Isometry*** (on the left with a deactivated color display)

24.4.4 Isometry 3D (menu *Presentation* > *Isometry 3D*)

This function generates three-dimensional displays of the power density distribution of a plane and all planes in false colors.
The presentation window is divided. On the left the caustic, on the right the power density distribution in a plane is displayed. The horizontal size of the single windows can be changed by drawing the separating bar by means of your mouse.
The graphics can be rotated along all three axis with the left mouse button and with the right mouse button they can be positioned in the window.

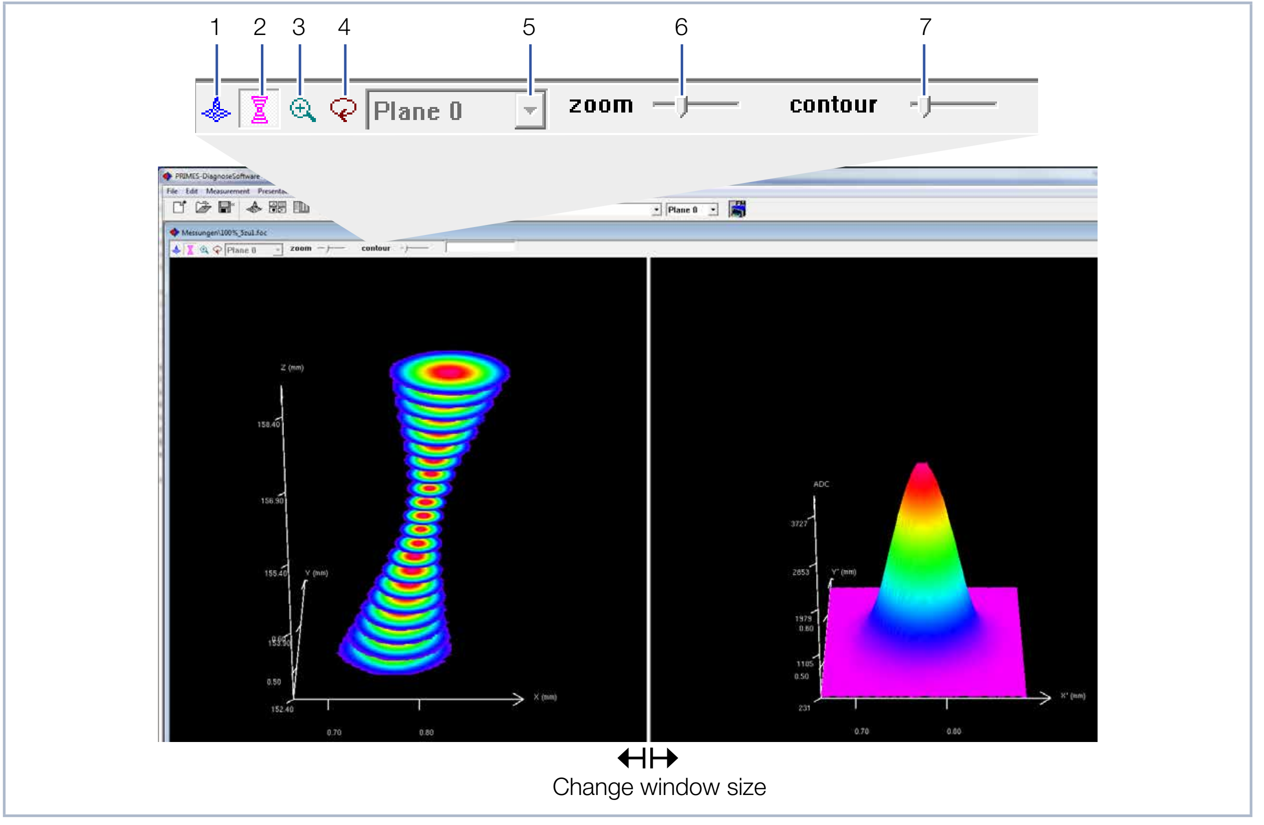


Fig. 24.16: Dialogue window ***Isometry 3D***

1	3D presentation of the plane	Inserts the 3D presentation of the power density distribution in the plane in the display window.
2	3D presentation of the caustic	Additionally inserts the 3D presentation of the caustic in the presentation window.
3	Magnification in the plane	In the left part of the presentation window a magnification of the plane displayed on the right is inserted (the desired area can be clicked by means of the left mouse button in the right window).
4	Rotation	Causes a rotation of both graphics along the z-axis.
5	Plane selection	Here the plane, which is to be displayed, can be chosen (you can also choose the desired plane in the 3D caustic by means of the left mouse button).
6	Zoom	Slide control for a continuous magnification of the presentation
7	Contour	Slide control for a contour trimming along the power density.

Tab. 24.2: Explanation of selection and setting elements

24.4.5 Review 86 % or 2. moment (menu *Presentation* > *Review (86%)/(2. moment)*)

For the radius definition there are two basic determination possibilities:

- Determination of the beam radii according to the 86% - power definition, (see chapter 23.2.4 on page 102).
- Determination of the beam radii according to the 2. moment method (ISO 11146), (see chapter 23.2.3 on page 101).

MSM.foc - 86% Review

Plane:	Plane 0	Plane 1	Plane 2	Plane 3	Plane 4	Plane 5	Plane 6	Plane 7	Plane 8	Plane 9	Plane 10
Radius [mm]	0.100	0.092	0.084	0.075	0.067	0.060	0.053	0.046	0.040	0.035	0.030
Position X [mm]	0.152	0.146	0.143	0.137	0.131	0.126	0.122	0.115	0.109	0.103	0.097
Position Y [mm]	0.043	0.040	0.033	0.032	0.028	0.023	0.021	0.017	0.012	0.010	0.006
Position Z [mm]	142.700	143.400	144.100	144.800	145.500	146.200	146.900	147.600	148.300	149.000	149.700
Zero level [A/D-Cnts]	261.750	260.000	265.000	264.750	264.750	264.500	258.750	262.000	258.750	259.000	261.000
Power [kW]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Radius inten. [kW/cm²]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Peak inten. [kW/cm²]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Date:	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014
Time:	10:26:56	10:26:59	10:28: 7	10:27: 9	10:27:11	10:27:13	10:27:17	10:27:19	10:27:22	10:27:25	10:27:28
Focal length [mm]	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000
Z-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Coord.rotation [deg.]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wavelength [µm]	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064
Fill Factor	0.577	0.528	0.483	0.645	0.582	0.516	0.604	0.534	0.686	0.601	0.519
Comment:											

Tab. 24.3: Result window ***86% Review***

MSM.foc - 2. Moments Review

Plane:	Plane 0	Plane 1	Plane 2	Plane 3	Plane 4	Plane 5	Plane 6	Plane 7	Plane 8	Plane 9	Plane 10
Radius [mm]	0.102	0.093	0.085	0.076	0.069	0.061	0.053	0.046	0.039	0.035	0.031
Radius X [mm]	0.101	0.094	0.085	0.075	0.068	0.060	0.052	0.045	0.038	0.034	0.030
Radius Y [mm]	0.102	0.093	0.086	0.076	0.069	0.062	0.054	0.047	0.040	0.036	0.032
Angle [°] (x/y-plane)	37.7	-44.5	40.2	24.3	16.8	10.5	5.5	1.1	2.7	-0.8	-3.6
Position X [mm]	0.153	0.147	0.144	0.137	0.131	0.125	0.121	0.115	0.108	0.103	0.097
Position Y [mm]	0.042	0.039	0.033	0.031	0.028	0.023	0.021	0.017	0.013	0.010	0.007
Position Z [mm]	142.700	143.400	144.100	144.800	145.500	146.200	146.900	147.600	148.300	149.000	149.700
Zero level [A/D-Cnts]	261.750	260.000	265.000	264.750	264.750	264.500	258.750	262.000	258.750	259.000	261.000
Power [kW]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Peak inten. [kW/cm²]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Date:	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014	24. 6.2014
Time:	10:26:56	10:26:59	10:28: 7	10:27: 9	10:27:11	10:27:13	10:27:17	10:27:19	10:27:22	10:27:25	10:27:28
Focal length [mm]	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000	205.000
Z-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Coord.rotation [deg.]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wavelength [µm]	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064	1.064
Radius X' [mm]	0.102	0.093	0.085	0.076	0.068	0.060	0.052	0.045	0.038	0.034	0.030
Radius Y' [mm]	0.102	0.093	0.085	0.076	0.069	0.062	0.054	0.047	0.040	0.036	0.032
Fill Factor	0.584	0.537	0.491	0.655	0.592	0.526	0.608	0.531	0.674	0.597	0.530
Ellipticity (Rmin/Rmax)	0.991	0.988	0.987	0.988	0.985	0.978	0.968	0.958	0.955	0.949	0.948
RadiusX/RadiusX'	0.997	1.006	0.994	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000
RadiusY/RadiusY'	1.003	0.994	1.006	1.002	1.001	1.001	1.000	1.000	1.000	1.000	1.000
3*RadiusX'/WindowsizeX	0.876	0.806	0.735	0.978	0.883	0.781	0.897	0.779	0.987	0.872	0.774
3*RadiusY'/WindowsizeY	0.878	0.806	0.737	0.986	0.894	0.797	0.927	0.813	1.033	0.919	0.816
Comment:											

Tab. 24.4: Result window ***2. Moment Review***

The parameters and results of the current selected plane are highlighted in blue. When the measuring signal only exceeds the zero level by a little bit, the measuring results are not shown in black, but rather in gray. In this case, check to see if the measuring values are reliable or need to be thrown out and the measurement repeated with different settings.

The entries for power, focal length, and wavelength as well as any comments can also be changed after the fact. For this purpose there is the button ***Apply*** in the menu item ***Measurement > Environment***.

24.4.6 Caustic (menu *Presentation* > *Caustic)*

The results of the caustic measurement can be displayed by means of the menu item ***Presentation* > *Caustic***. On the left Fig. 24.17 on page 128 shows the measured beam parameter either on the basis of the 86%-radii or the 2. moment method evaluation according to ISO 11146. In the middle of the picture the graphic shows the caustic profile. The beam radii are depicted on the beam spread direction. On the right is a false color presentation of the measurement plane selected with the mouse shown together with numerical results of this corresponding plane.

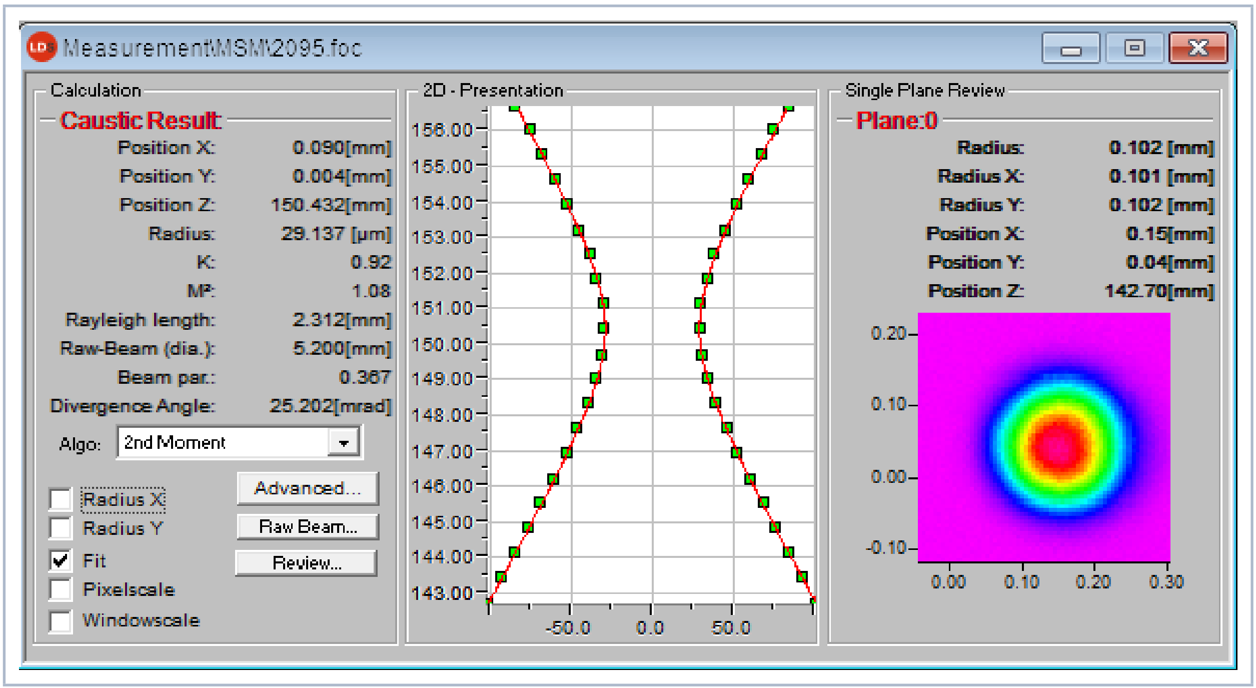


Fig. 24.17: Dialogue window ***Caustic***

The red line depicts a compensation curve according to the calculated fits which can be displayed via the check box ***Fit*** in the 2D presentation.

Compensating curve

In order to evaluate the caustic, a hyperbolic compensating curve (ISO 11146) is adapted to the measuring values. This compensating curve describes the propagation of an ideal laser beam mathematically. The development of the compensating curve is theoretically determined by means of the following parameters:

- Standardized beam quality factor M² or respectively beam propagation ratio K
- z-position
- focus radius
- Rayleigh length

Standardized beam quality factor M² (or respectively the beam propagation ratio $K=\frac{1}{M^2}$)

The normed beam quality factor describes how well the affected laser beam can be focused in relation to the dominant mode. The basic mode represents the theoretically best possible beam and has a beam quality factor M² of 1. All other beams have higher M² values.

Z-position

This value provides the position of the focus points in the z-position. As the compensation curve takes the measurement points into consideration, the calculated z-position is not necessarily located at the position, which has measured the smallest radius.

Focus radius

The focus radius is the smallest beam radius in the caustic. Generally, this value is similar to the smallest value measured, but not necessarily.
Due to different reasons it may occur that the adaptation to the measurement values was not carried out. This is the case if the compensation curve does not lie close to the measurement values. In this case the parameters of the adapted compensation curve are to be discarded.

Rayleigh length

The Rayleigh length is a derived parameter and describes the distance in z-direction with regard to which the beam radius has increased by the factor $\sqrt{2}$ (=1.41) and concerning which the beam area has increased by the factor 2. The Rayleigh length increases with the focal length of the focusing optics and the beam quality. The doubled Rayleigh length is an approximate point of reference, up to which material thickness (metal) a procession is possible with the optic employed.

In order to make sure that the adapted values have a high significance, the measurement is to be carried out in a z-range of at least ±2 Rayleigh lengths. As demanded in the ISO 11146 5 to 6 Rayleigh lengths would be ideal. However, this demand is often confronted with the problem of quickly sinking power densities of the laser beam which is to be measured. In case of a distance of 2 Rayleigh lengths from the focus the power density has sunk to just a quarter.

In this case the caustic measurement consists of a compromise between the desired measurement range in z-direction and the power density (signal-to-noise ratio) necessary for a perfect measurement.

Cyclic caustic measurements

When performing cyclic caustic measurements, it is useful to store settings for various display parameters in a data file. This data is available anytime and can be reloaded for a new measurement. For a quick check of the beam or when it is necessary to measure only part of the caustic.

Cyclic measurements are normally performed over a period of 2 to 3 minutes; by Ethernet communication much quicker. For measurements after laser or system servicing, you should use more planes to achieve greater accuracy in the results.

To start a measurement, saved caustic data is loaded from the settings file. This is done through the menu item ***File > Load Settings***. The data is loaded after entering the desired file name.

Advanced (menu *Presentation > Caustic > Advanced)*

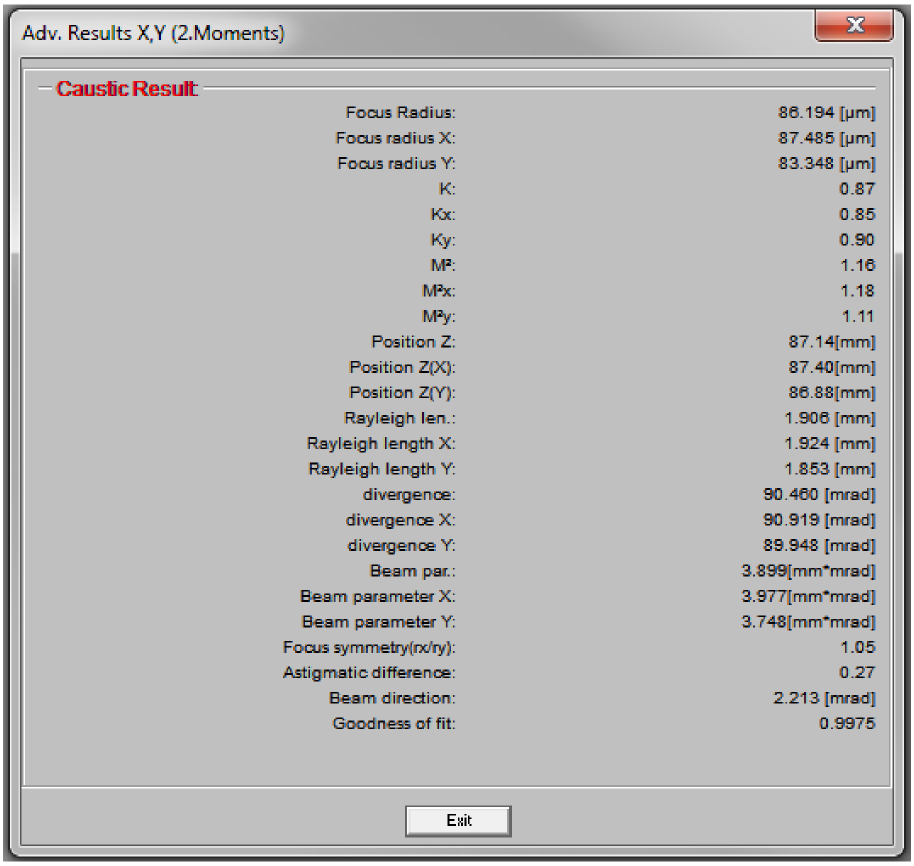


Fig. 24.18: Result window ***Results X,Y (2. moment)***

For the examination of asymmetric beams the dimensions of the main axes of the beam can be determined. On the basis of these values the program also calculates direction dependent beam propagation factors as well as beam position values. The related curves are shown via the two check boxes radius x, y while the numerical values are provided by the result window.

Raw beam (menu *Presentation > Caustic > Raw Beam)*

Not relevant for HP-MSM-HB.

Review (menu *Presentation* > *Caustic* > *Review)*

This function checks whether the results and settings of the caustic measurement are within the reliable range.

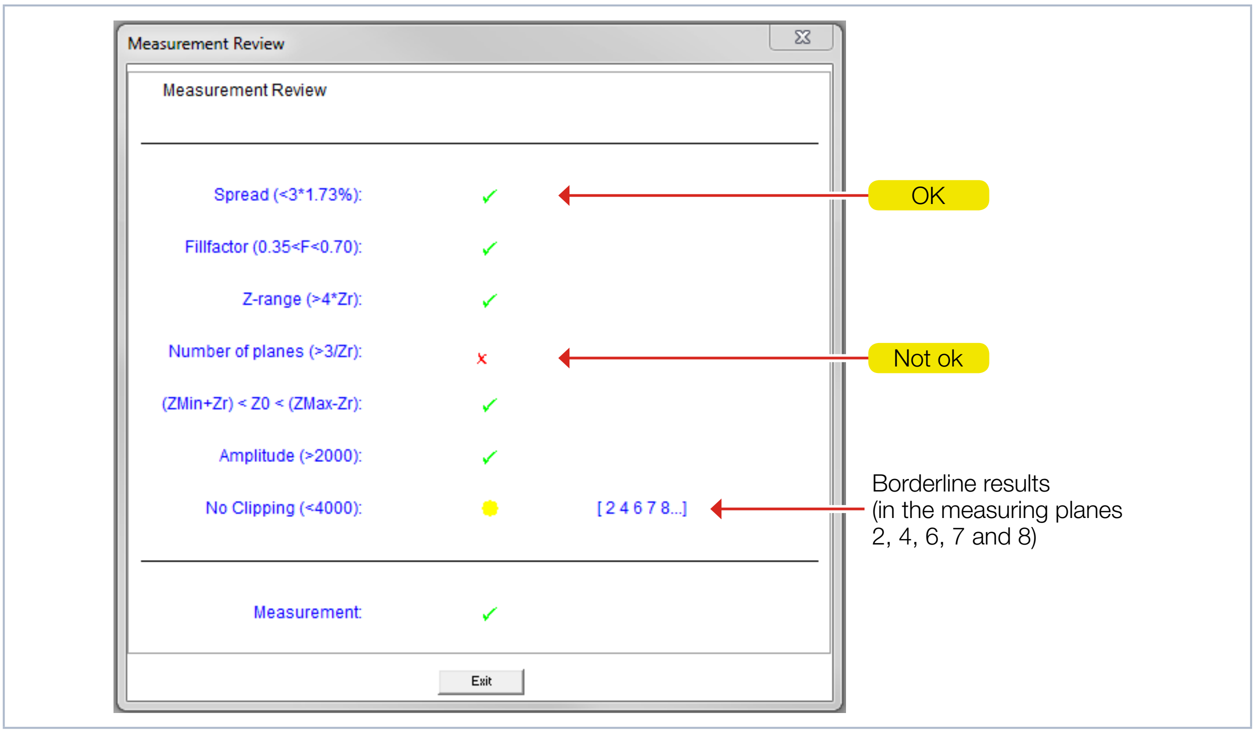


Fig. 24.19: Result window ***Measurement Review***

Under “spread” the average standard deviation of the caustic fit according to the 2. moment method radii is stated. A “tick” (✓) is set if the standard deviation is smaller than 3.5 % and if all of the measuring values lie within a range of ± 3 % standard deviation.
When the divergence receives a negative assessment (×) the affected measuring planes are also displayed. The displayed planes are arranged from left to right, starting with the greatest divergence and working its way down. This means that the plane with the greatest divergence (see Fig. 24.19 on page 131 Plane 2) will be the first one in front.

Valued functions	Test criterion	Positive evaluation ✓
Spread	Average relative standard deviation of the caustic fit according to the 2. moment method	Standard deviation < 3.5 %, all measurement values within a range of ± 3 % standard deviation
Fill factor	Describes the ratio of the beam diameter to the lengths of the sides of the measuring window	In the range 0.35 – 0.7
Z-range	Measuring range in z-direction	At least 4 Rayleigh lengths
Measurement planes	Number of measurement planes per Rayleigh length	At least 3 measurement planes per Rayleigh length
$(Z_{Min}+Z_r) < Z_0 < (Z_{Max}-Z_r)$	Minimum measurement range above and below the focusing plane	The focus lies within the minimum measurement range and this range accounts for at least one Rayleigh length in every z-direction
Amplitude (>2 000)	Signal control	Above 2 000 counts
No Clipping (<4 000)	Signal control	Below 4 000 counts

Tab. 24.5: Criteria for the evaluation

If all criteria are fulfilled, the measuring results have a high reliability. The absolute accuracy can not be stated from the standard deviation from the fits as all the systematic measuring errors as well as the accuracy of the calibration are additionally taken into account when it comes to the absolute error.

24.4.7 Raw beam (menu *Presentation* > *Raw-beam)*

Not relevant for HP-MSM-HB.

24.4.8 Symmetry check (menu *Presentation* > *SymmetryCheck*)

This display menu checks the rotational symmetry of the power density distribution of a laser beam. It can, for instance in connection with the monitoring operation (***Measurement*** > ***Single*** > ***Monitor***), be used for the alignment of laser resonators.
In the following, the figures Fig. 24.20 on page 132 and Fig. 24.21 on page 133 show two examples for the possible results of a symmetry check at an elliptic beam and a circular beam.

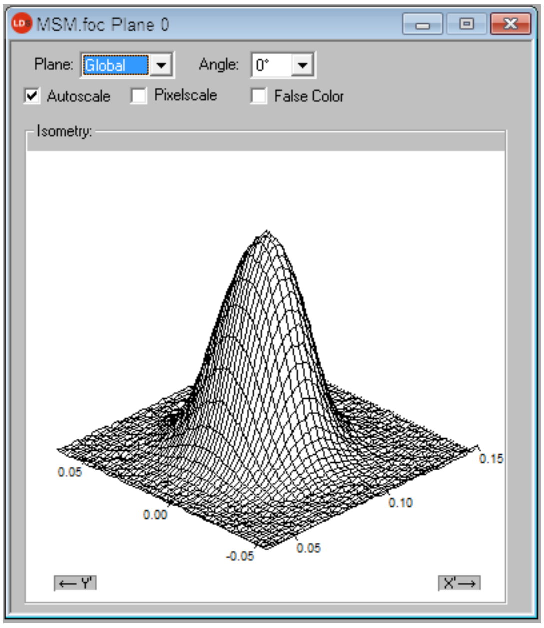


Fig. 24.20: Dialogue window (menu ***Presentation*** > ***Isometry***) power density distribution of an elliptic beam

The power density distribution of an elliptical beam as shown in Fig. 24.21 on page 133 together with the ***Symmetry check*** comes to the following results.

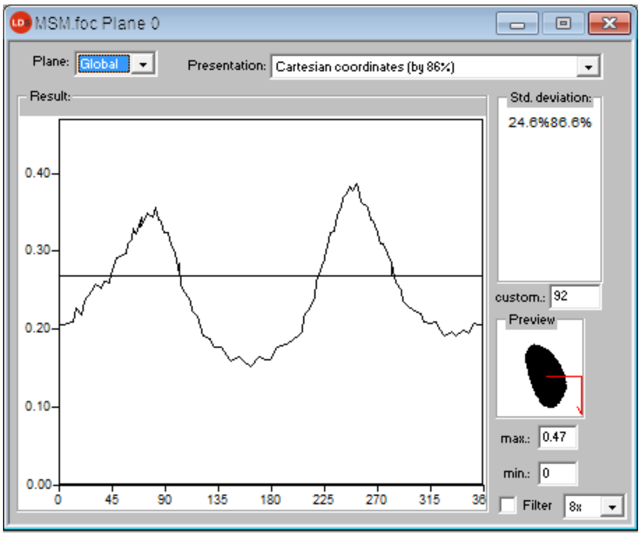


Fig. 24.21: Dialogue window ***Symmetry check*** in Cartesian coordinates of an elliptic beam

The abscissa in Fig. 24.21 on page 133 shows the angle and the ordinate shows the beam radius with the intersection line at 86 % of the total power.

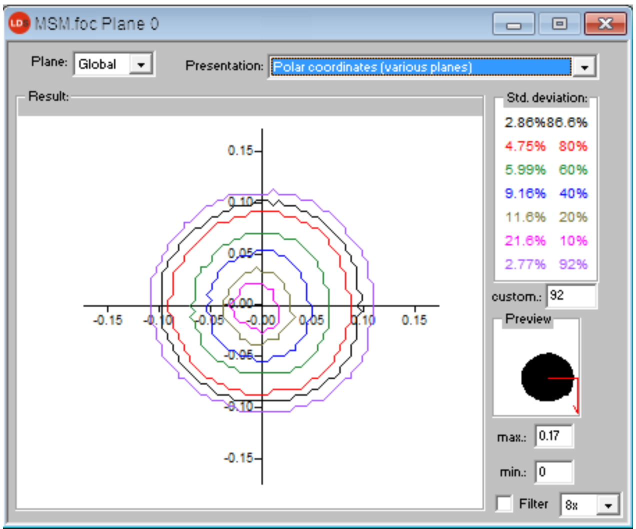


Fig. 24.22: Dialogue window ***Symmetry check*** in polar coordinates of an elliptic beam

On the screen the curves appear in different colors. The radius is indicated in pixel coordinates. The minimum as well as the maximum of the radius values can be chosen. On the right side the standard deviation of the different radius values are indicated. These values give detailed information on the symmetry of the beam distribution.

Well aligned resonators reach standard deviations in the range of 3 % to 5 %. Partially, values in a 1 % and 2 % range are possible.
A presentation in polar coordinates is also possible (Fig. 24.22 on page 133). The drawn in lines contain 86 % up to 10 % of the detected power. On the screen the graphs have different colors. X- and y-axis scale in pixel values.

24.4.9 Fixed contour lines (menu *Presentation* > *Fixed Contour Lines*)

The contour lines are displayed with different power levels. Intersection lines are selected with: 86 %, 80 %, 60 %, 40 %, 20 % and 10 % of the total power.
In this presentation it is also possible to measure distances by clicking the start and end points with the mouse.

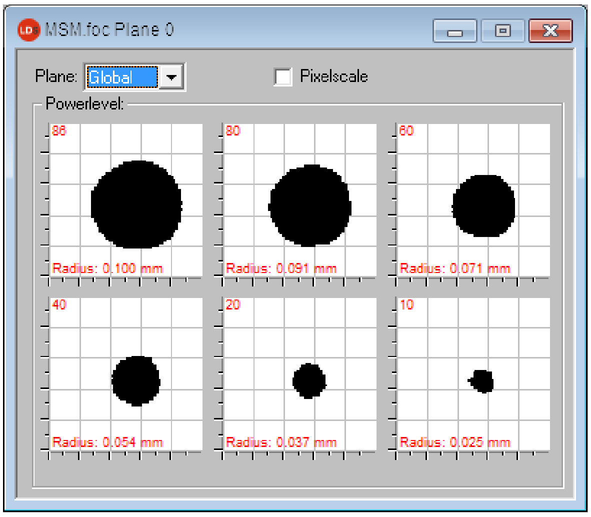


Fig. 24.23: Dialogue window ***Fixed contour lines***

24.4.10 Variable contour lines (menu *Presentation* > *Variable Contour Lines*)

Here the spatial power density distribution is displayed by means of freely selectable contour lines. Not only intersections in x- and y- direction but also in power density coordinates (A/D-converter-counts) can be carried out. The position of the intersections is settable by means of a slide control or the keyboard.

Setting by means of the keyboard:

- For the x-direction by means of the key ***x*** in order to increase the value and ***<shift> x*** in order to decrease it.
- For the y-direction by means of the key ***y*** in order to increase the value and ***<shift> y*** in order to decrease it.
- For the power density (intensity) by means of the key **i** in order to increase the value and ***<shift> i*** in order to decrease it.

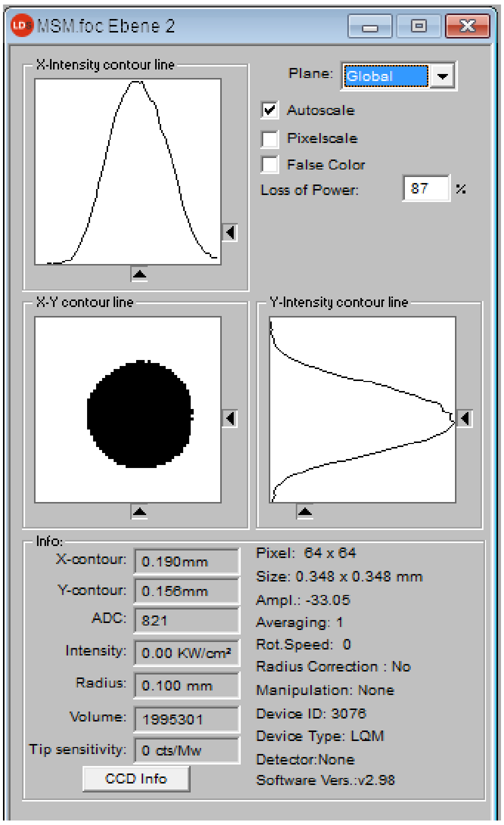


Fig. 24.24: Dialogue window ***Variable contour lines***

In the range of the left hand lower corner the current intersection coordinates, the power densities, the radius generated by the intersection as well as the relative volume are displayed. The values are calculated basing on the correctly entered laser power.

In the right hand upper corner it is possible to switch the scaling. Below it, there is an input field where the desired power loss (-inclusion) can be entered. This value correlates to the given power levels in the window.

In addition to these functions, this window also offers plenty of additional information on the conditions under which measurements are taken. The amplification, resolution number, and the software version used for measuring are all displayed while measuring as well.

One click on the ***CCD Info*** button will open a window with additional information on the device parameters such as trigger mode, trigger delay, integration time, magnification and focussing optic type.

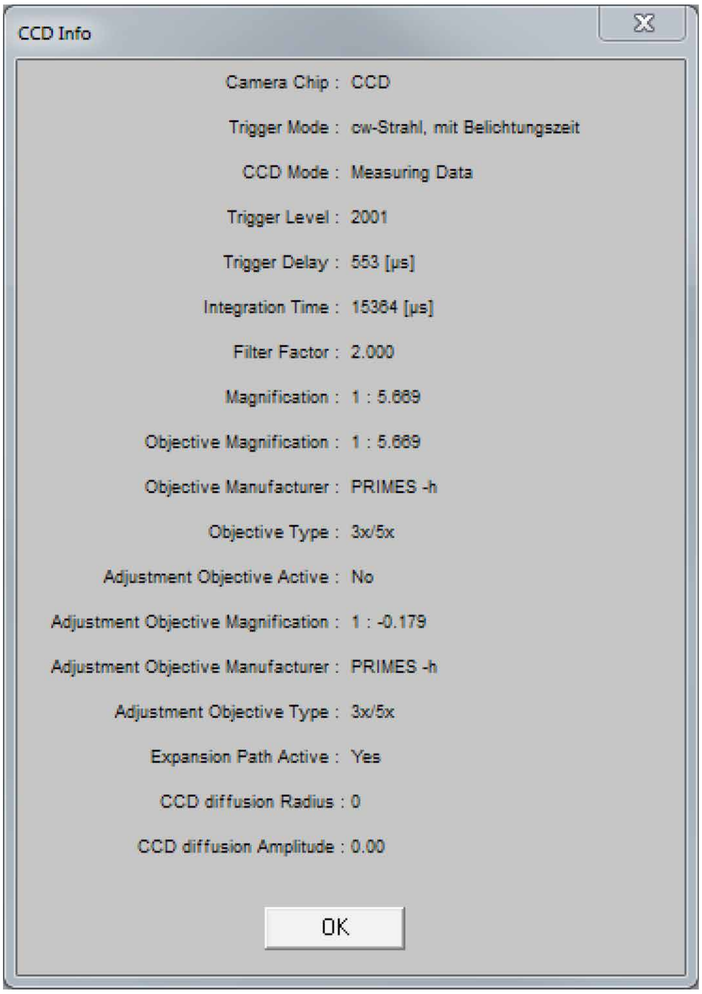


Fig. 24.25: Display window ***CCD Info***

24.4.11 Graphical review (menu *Presentation* > *Graphical Review*)

The display window ***Graphical review*** offers many possibilities to display the measurement values of the single measurement planes. In total this window can present 20 different graphs. The possible selections for the x- and y-coordinates are shown in the Tab. 24.6 on page 137.

y-axis	x-axis
Radius	Power
x-position	Time
y-position	Plane
Angle	Position
Ellipticity	

Tab. 24.6: Selections for the x/y coordinates

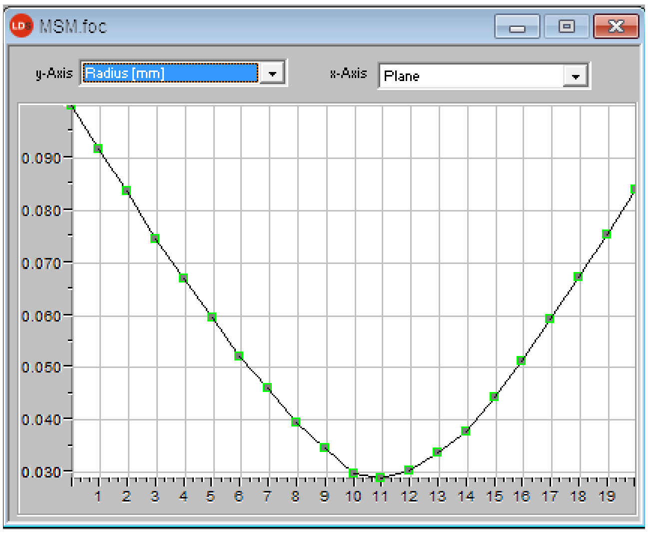


Fig. 24.26: Display window ***Graphical review*** – Example for assessment of a time series - radius/time

See chapter 24.3.9 on page 119, Section „Manual caustic measurement as time series (menu Measurement > Caustic > Manually adjusted)“.

24.4.12 Systemstate (menu *Presentation* > *Systemstate*)

Not relevant for HP-MSM-HB.

24.4.13 Evaluation parameter view (menu *Presentation* > *Evaluation Parameter View*)

In the directory “System“ in the LDS installation file (C:\Program\Primes\LDS2.98\System) you can find predefined parameter files for the raw beam retrograde calculation (RawBeamParams.eval) and the caustic evaluation (beamparams.eval). These can be pulled up under the menu point ***Presentation*** > ***Evaluation Parameter View***.

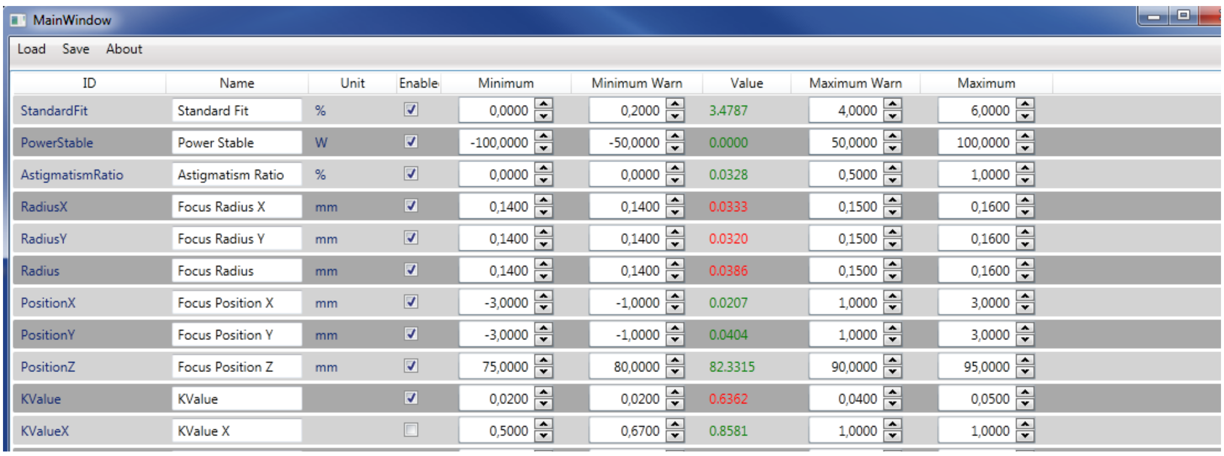

beamparams.eval
Beam parameter

	Min	Warn	Actual	Warn	Max
☑ Standard Fit [%]	0.00	0.50	3.48	3.00	5.00
☑ Power Stable [W]	-100	-50	0	50	100
☑ Astigmatism Ratio [%]	0.00	0.00	0.03	0.50	1.00
☑ Focus Radius X [mm]	0.0100	0.0300	0.0333	0.0500	0.1000
☑ Focus Radius Y [mm]	0.0100	0.0300	0.0320	0.0500	0.1000
☑ Focus Radius [mm]	0.0100	0.0300	0.0386	0.0500	0.1000
☑ Focus Position X [mm]	-0.200	-0.100	0.021	0.100	0.200
☑ Focus Position Y [mm]	-0.200	-0.100	0.040	0.100	0.200
☑ Focus Position Z [mm]	80.000	82.000	82.332	85.000	90.000
☑ KValue	0.50	0.67	0.64	1.00	1.00
☑ KValue X	0.50	0.67	0.86	1.00	1.00
☑ KValue Y	0.50	0.67	0.90	1.00	1.00
☑ Caustic Min Power [W]	50	100	0	10000	10000
☑ Caustic Max Power [W]	0	0	0	7500	8000
☑ Caustic Mean Power [W]	0	50	0	7500	8000
☑ BPP	0.200	0.250	0.532	0.750	1.000
☑ M²	1.00	1.00	1.57	1.50	2.00
☑ M² X	1.00	1.00	1.57	1.50	2.00
☑ M² Y	1.00	1.00	1.57	1.50	2.00
☑ BeamDirection [°]	0.00	0.00	0.36	2.00	3.00
☑ BeamDirection X [°]	0.00	0.00	0.36	2.00	3.00
☑ BeamDirection Y [°]	0.00	0.00	0.36	2.00	3.00
☑ Rayleigh Length [mm]	0.01	0.03	2.80	10.00	30.00
☑ Divergence [mrad]	0.05	0.10	10.00	0.35	0.40

Load settings

Fig. 24.27: Display window ***Evaluation Parameter View*** with opened parameter file

The desired parameters and their limit values can be stipulated by means of the program PRIMES-EvalEditor and can then be saved in the evaluation parameter file (*.eval). The program is automatically installed when the LDS-setup is carried out.


MainWindow
Load Save About

ID	Name	Unit	Enable	Minimum	Minimum Warn	Value	Maximum Warn	Maximum
StandardFit	Standard Fit	%	☑	0,0000	0,2000	3.4787	4,0000	6,0000
PowerStable	Power Stable	W	☑	-100,0000	-50,0000	0.0000	50,0000	100,0000
AstigmatismRatio	Astigmatism Ratio	%	☑	0,0000	0,0000	0.0328	0,5000	1,0000
RadiusX	Focus Radius X	mm	☑	0,1400	0,1400	0.0333	0,1500	0,1600
RadiusY	Focus Radius Y	mm	☑	0,1400	0,1400	0.0320	0,1500	0,1600
Radius	Focus Radius	mm	☑	0,1400	0,1400	0.0386	0,1500	0,1600
PositionX	Focus Position X	mm	☑	-3,0000	-1,0000	0.0207	1,0000	3,0000
PositionY	Focus Position Y	mm	☑	-3,0000	-1,0000	0.0404	1,0000	3,0000
PositionZ	Focus Position Z	mm	☑	75,0000	80,0000	82.3315	90,0000	95,0000
KValue	KValue		☑	0,0200	0,0200	0.6362	0,0400	0,0500
KValueX	KValue X		☐	0,5000	0,6700	0.8581	1,0000	1,0000

Fig. 24.28: Dialogue window EvalEditor with loaded *.eval-file

The evaluation parameter file can only be displayed if the file **BeamControls.xsd** is located in the same directory (C:\Program\Primes\LDS2.98\System)!

24.4.14 Evaluate document (menu *Presentation* > *Evaluate doc*)

The evaluation function compares selectable beam parameters and their adjustable limit values with the results of a current or a saved measurement.
Under the menu point ***Presentation > Evaluate doc*** of the LDS, the following dialog window is opened:

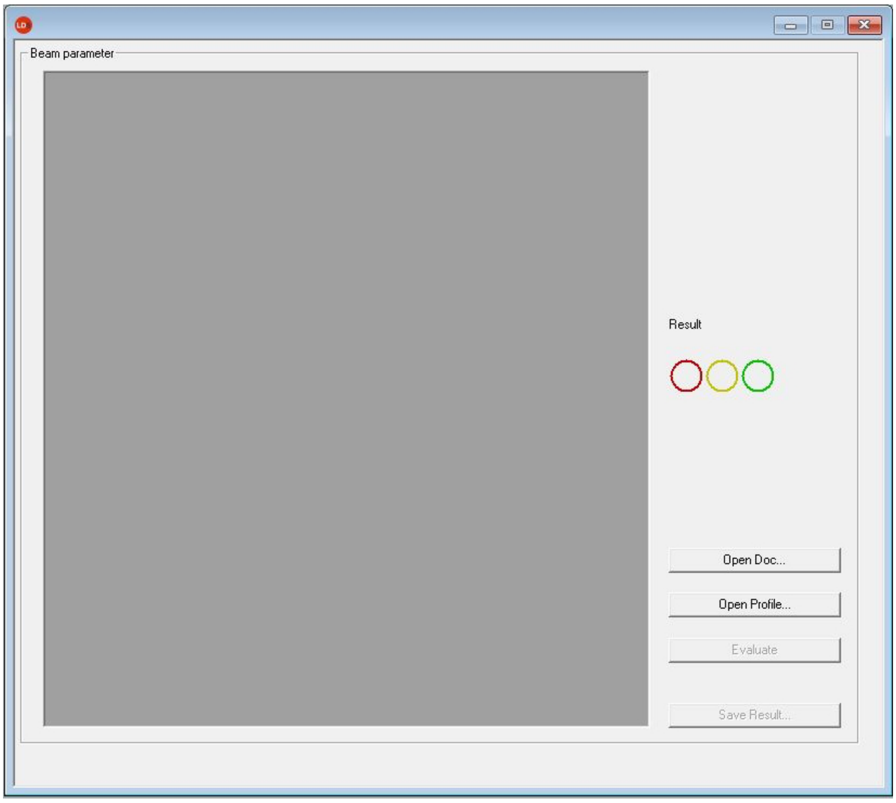


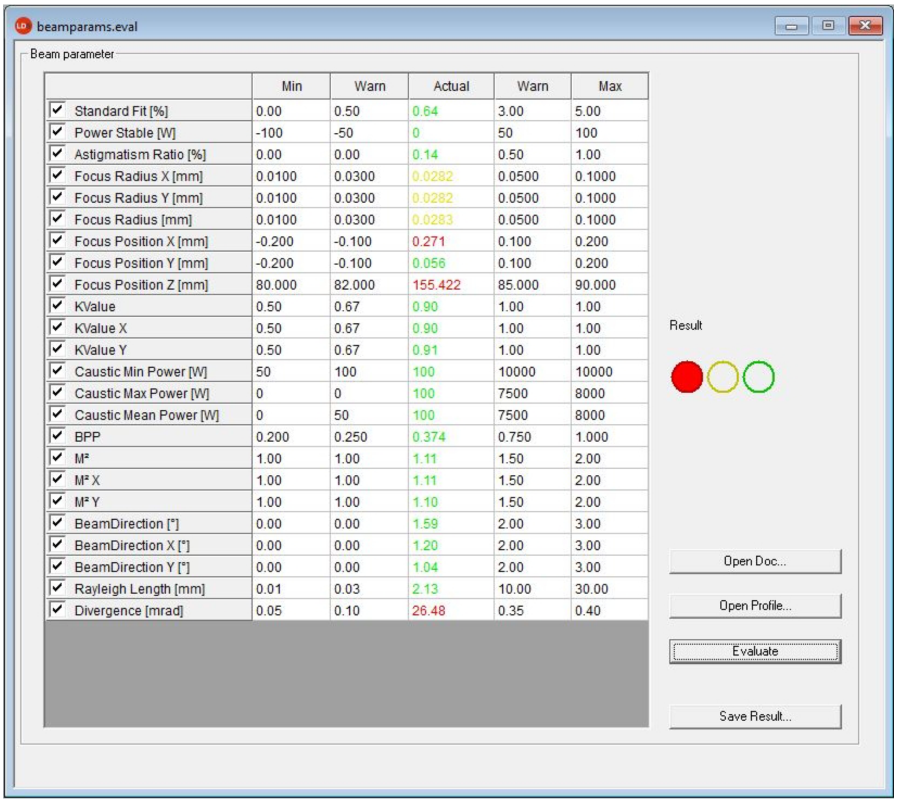
Fig. 24.29: Dialogue window ***Evaluate Document*** for loading an evaluation file

The button ***Open Doc*** opens a file selection window that allows to choose a saved measuring file (*.foc).

The button ***Open Profile*** opens a file selection window for choosing an evaluation parameter file (*.eval).

The button ***Evaluate*** triggers an evaluation (see Fig. 24.30 on page 140). The single evaluation parameters and the result of the evaluation are displayed. The overall evaluation (Result) of all results is displayed by means of a traffic light symbol.

Evaluation Criteria: Only if all single evaluations are ok, the overall evaluation is displayed in green in the traffic light symbol.



	Min	Warn	Actual	Warn	Max
Standard Fit [%]	0.00	0.50	0.64	3.00	5.00
Power Stable [W]	-100	-50	0	50	100
Astigmatism Ratio [%]	0.00	0.00	0.14	0.50	1.00
Focus Radius X [mm]	0.0100	0.0300	0.0282	0.0500	0.1000
Focus Radius Y [mm]	0.0100	0.0300	0.0282	0.0500	0.1000
Focus Radius [mm]	0.0100	0.0300	0.0283	0.0500	0.1000
Focus Position X [mm]	-0.200	-0.100	0.271	0.100	0.200
Focus Position Y [mm]	-0.200	-0.100	0.056	0.100	0.200
Focus Position Z [mm]	80.000	82.000	155.422	85.000	90.000
KValue	0.50	0.67	0.90	1.00	1.00
KValue X	0.50	0.67	0.90	1.00	1.00
KValue Y	0.50	0.67	0.91	1.00	1.00
Caustic Min Power [W]	50	100	100	10000	10000
Caustic Max Power [W]	0	0	100	7500	8000
Caustic Mean Power [W]	0	50	100	7500	8000
BPP	0.200	0.250	0.374	0.750	1.000
M²	1.00	1.00	1.11	1.50	2.00
M² X	1.00	1.00	1.11	1.50	2.00
M² Y	1.00	1.00	1.10	1.50	2.00
BeamDirection [°]	0.00	0.00	1.59	2.00	3.00
BeamDirection X [°]	0.00	0.00	1.20	2.00	3.00
BeamDirection Y [°]	0.00	0.00	1.04	2.00	3.00
Rayleigh Length [mm]	0.01	0.03	2.13	10.00	30.00
Divergence [mrad]	0.05	0.10	26.48	0.35	0.40

Fig. 24.30: Dialogue window ***Evaluate***

In case the warning or limit values are exceeded, this has an influence on the color display of the traffic light symbol. As soon as a warning value is exceeded or fallen short of, the yellow circle is filled. If the limit values (min/max) are exceeded or fallen short of, the red circle is filled. The actual values in the table of the evaluation window are marked in color as well.

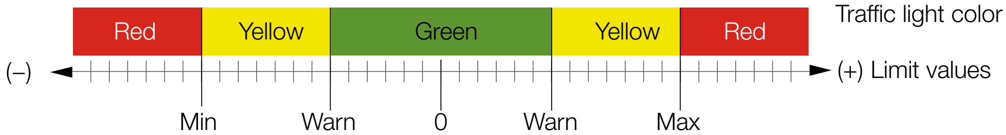


Fig. 24.31: Traffic light colors when warn- and limit values are exceeded

The overall result of the evaluation can be saved by means of the button ***Save***.

24.4.15 Color tables (menu *Presentation* > *Color Tables*)

Different color charts are available. It is possible to switch back and forth between the color charts. Thus the assignment of A/D converter values and different color scales can be varied. This is important for the false color presentation.

Three settings are possible:

- Linear color table (basic setting)
- Color table analogue to the root function
- Color table analogue to the fourth root function

These functions can especially be helpful as far as the analysis of slight variations near the zero level are concerned; e.g. the analysis of diffraction phenomena.

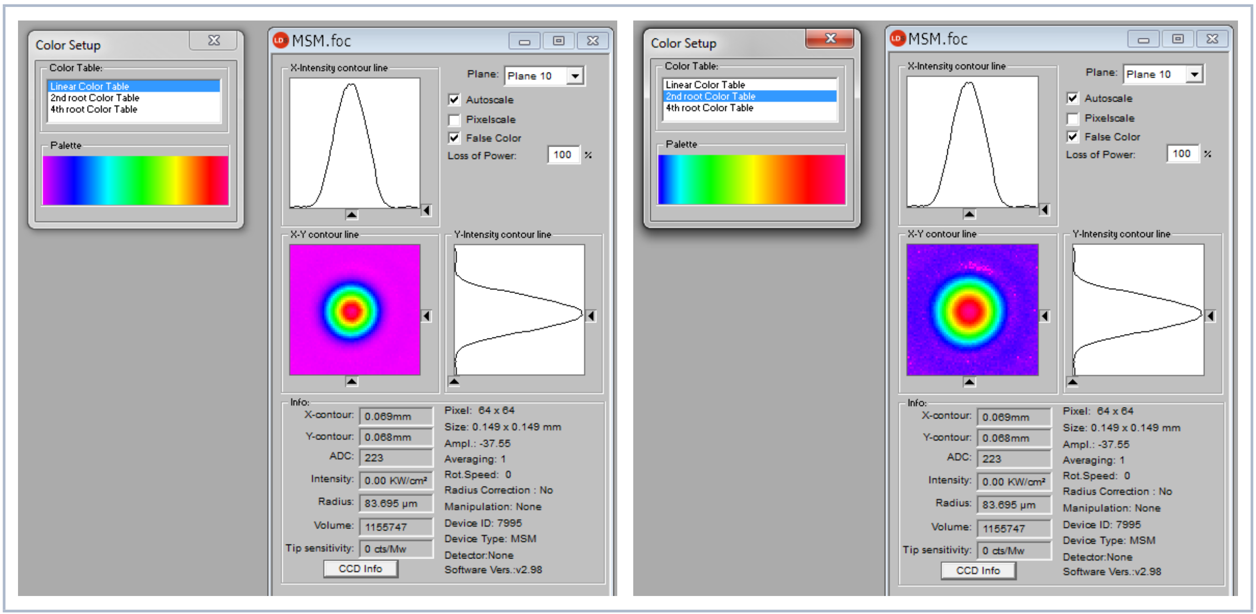


Fig. 24.32: Dialogue window ***Color Setup*** – Linear color table and 2nd root color table

24.4.16 Toolbar (Menu *Presentation* > *Toolbar*)

The toolbar can be shown or hidden by clicking ***Presentation*** > ***Toolbar*** in the menu.

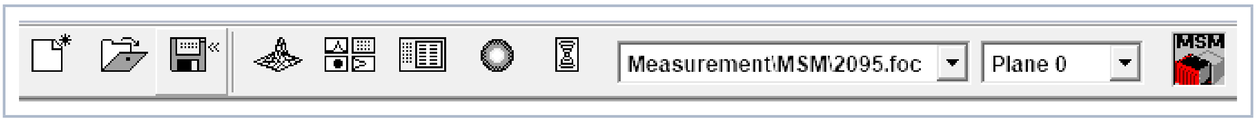


Fig. 24.33: Showing or hiding the toolbar

24.4.17 Position (menu *Presentation* > *Position*)

This menu can be used to move the device to its parked position.

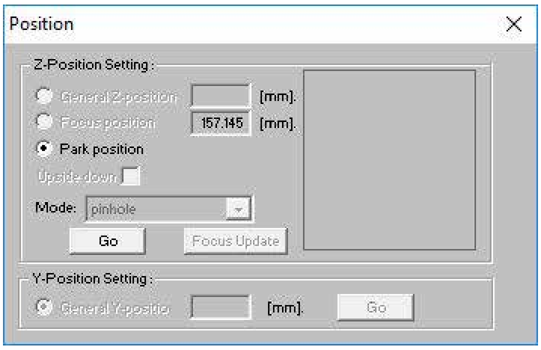


Fig. 24.34: Dialogue window ***Position***

24.4.18 Evaluation (option) (menu *Presentation* > *Evaluation*)

By means of this evaluation function, you can compare and evaluate different parameters of the measured caustic (.foc-file) with specified limit values (.pro-file). The evaluation result is displayed optically with an LED symbol (red=bad, green=good). The overall result (field Conclusion) is only considered as good provided that all results are within the critical parameters (☆).

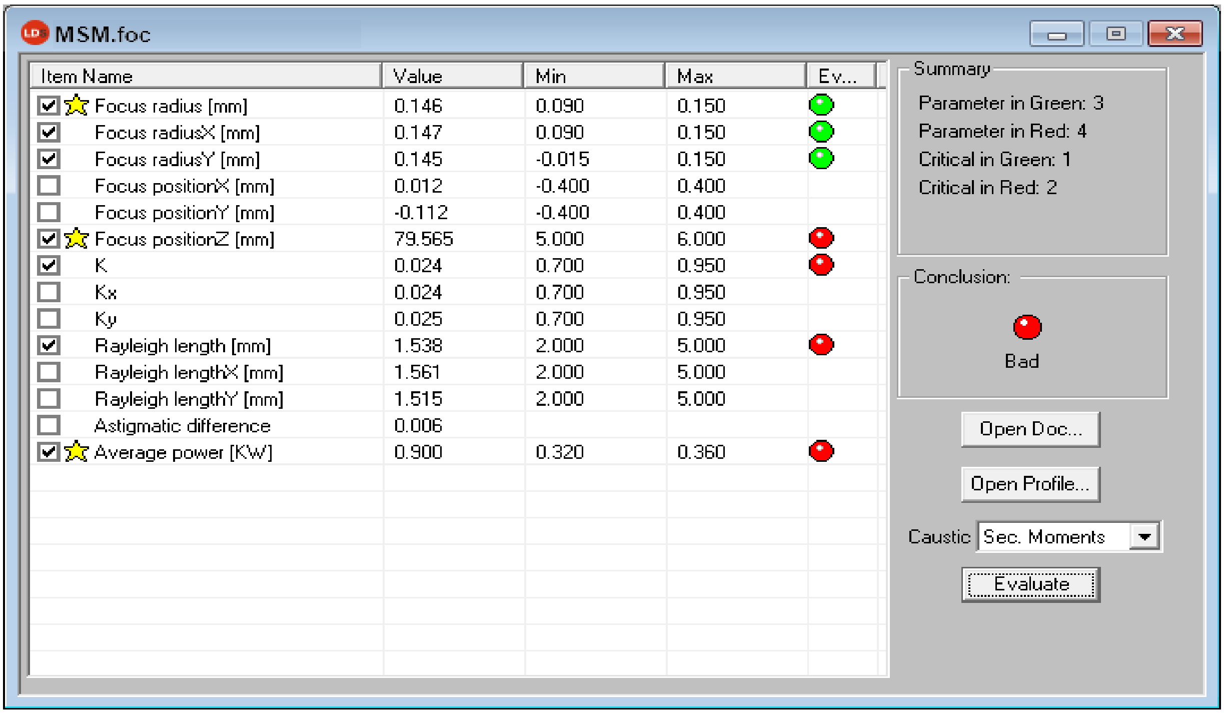
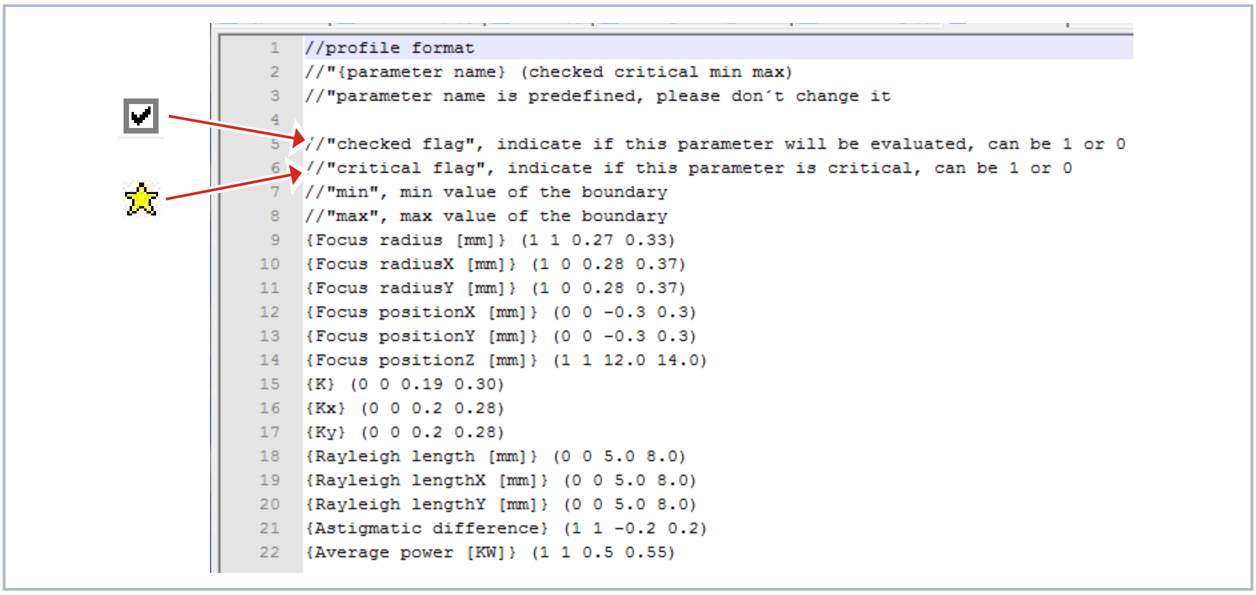


Fig. 24.35: Dialogue window ***Evaluation***

The parameters, the limit values and the identification of critical values are purported in a profile file (text file, please see the example file in Fig. 24.36 on page 143).



```
//profile format
//"{parameter name} (checked critical min max)
//"parameter name is predefined, please don´t change it

//"checked flag", indicate if this parameter will be evaluated, can be 1 or 0
//"critical flag", indicate if this parameter is critical, can be 1 or 0
//"min", min value of the boundary
//"max", max value of the boundary
{Focus radius [mm]} (1 1 0.27 0.33)
{Focus radiusX [mm]} (1 0 0.28 0.37)
{Focus radiusY [mm]} (1 0 0.28 0.37)
{Focus positionX [mm]} (0 0 -0.3 0.3)
{Focus positionY [mm]} (0 0 -0.3 0.3)
{Focus positionZ [mm]} (1 1 12.0 14.0)
{K} (0 0 0.19 0.30)
{Kx} (0 0 0.2 0.28)
{Ky} (0 0 0.2 0.28)
{Rayleigh length [mm]} (0 0 5.0 8.0)
{Rayleigh lengthX [mm]} (0 0 5.0 8.0)
{Rayleigh lengthY [mm]} (0 0 5.0 8.0)
{Astigmatic difference} (1 1 -0.2 0.2)
{Average power [KW]} (1 1 0.5 0.55)
```

Fig. 24.36: Example for a profile file

An evaluation is carried out as follows:

1. Click the button ***Open Doc*** and choose your measuring file (.foc-file).
2. Click the button ***Open Profile*** and choose your profile file (.pro-file).
3. Choose the desired radius definition in the selection ***Caustic***.
4. Click on the button ***Evaluate***.

24.5 Communication

24.5.1 Rescan bus (menu *Communication* > *Rescan bus*)

This menu can be used to reconnect a device that was connected previously.

24.5.2 Free communication (menu *Communication* > *Free Communication*)

By means of this menu you can control the communication via the PRIMES bus. Moreover, the settings for the communication are made here (see chapter 11.3.2 on page 38).

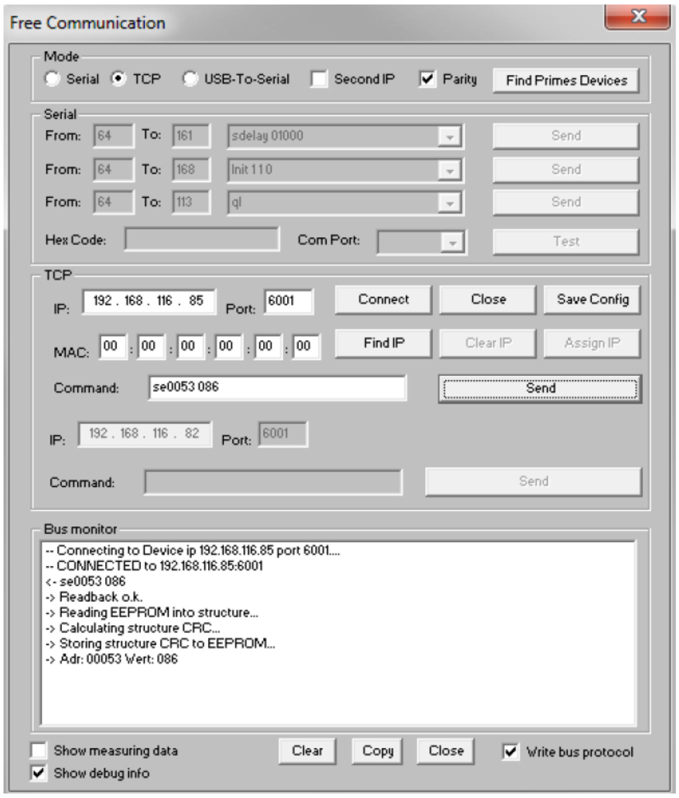


Fig. 24.37: Dialogue window ***Communication*** > ***Free Communication***

24.5.3 Scan device list (menu *Communication* > *Scan device list*)

Every PRIMES device has a certain bus address. If a device is supposed to be controlled by means of the LaserDiagnosticsSoftware LDS, the address has to be entered here. Moreover addresses can also be added or deleted in this menu.

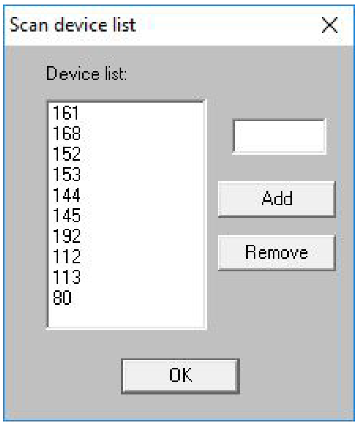


Fig. 24.38: Dialogue window ***Scan device list***

The following addresses for all PRIMES devices may be listed in the device list:
80, 92, 112, 113, 114, 144, 145, 152, 161, 168
For the HP-MSM-HB, the address 161 must be entered.

24.6 Script *(menu Script)*

By means of scripts complex measurement procedures can be controlled automatically. Scripts are programs which are written in several script languages. Scripts are almost exclusively provided as source files in order to enable an easy editing and adjustment of the program.

24.6.1 Editor (menu *Script > Editor)*

By means of the script editor you can draw up scripts which can control, for example, complex measuring procedures automatically. An example is given in Fig. 24.39 on page 146 – the beam find procedure with the HP-MSM-HB.
In order to open the script, the Open symbol has to be clicked, then a file can be chosen and played by using the button ▶. The button ⏸ stops and ■ ends the script.

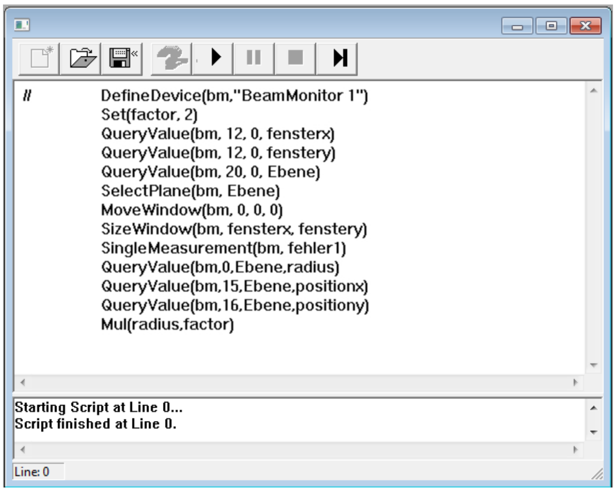


Fig. 24.39: Dialogue window ***Script*** – Script for the beam find procedure of the MicrosSpotMonitorMSM

24.6.2 List (menu *Script > List)*

Here all available scripts are listed.

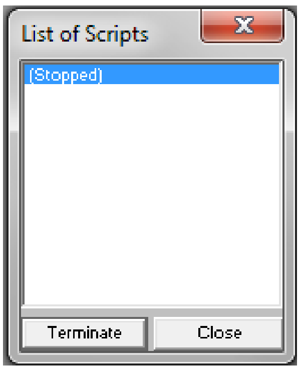


Fig. 24.40: Display window ***List of Scripts***

24.6.3 Python (menu *Script > Python)*

Starts the Python editor. The graphical user interface is identical to the one depicted in Fig. 24.39 on page 146. Python is a programming language with efficient abstract data structures and a simple but effective approach for an object-oriented programming. Python is not only suitable for scripts but also for a fast application development. For programming with Python a separate PRIMES documentation is available.

25 Appendix D: File formats

25.1 File “laserds.ini” – an Example

The contents of a laserds.ini file are shown below. Some information is gained regarding the startup settings for the system – such as:

- default serial interface.
- default settings for beam find, such as threshold and spatial resolution for the search.

The settings can be changed in a Windows® Editor. Close the LaserDiagnoseSoftware LDS before making changes in the laserds.ini file. Otherwise, the changes will not be activated and be reset when the program closes.

```
[Version]
No.=17

[Window]
left=10
top=10
right=1183
bottom=948

[Comm]
Data_Transfer_Mode=0
Port=
HighBaudrate=1
escan=161,168,152,144,145,
192,112,113,80

[Ethernet]
IP=0.0.0.0
Port=6001
MAC Address=00-00-00-00-00-00
[Device]
Type=
ID=-1

[Adresse]
Own=64

[Private]
Mode=0

Flag1=1111
Flag2=0
Flag3=0
[File]
Default=

[Laser]
Wellenlaenge=0.01060000
Drehzahlnr=0
Kamerachip=0
Laserleistung=6000.00000000
Brennweite=127.00000000
StrahlsucheTrigger=150
Strahlsuche Trigger für Pyro=150
Strahlsuche Trigger für Photo=50
StrahlsucheProzent=35
Funkvorhanden=1
Detektortyp=1
SperrbereichY0=8.00000000
...
...
Autoscaleon=1
Extern Z-Axis=0
Tip twisted=0

[Detectorparameter]
Detector 0 Tau1=10
Detector 0 Scale1=-0.1
Detector 0 Tau2=3500
Detector 0 Scale2=0.1
Detector 0 Tau3=0
Detector 0 Scale3=0
Detector 0 Name=Pyro-FM-1
Detector 1 Tau1=0
...
...

[TriggerModi]
TriggerMode 0=Dauer-Trigger
TriggerMode 1=Trigger mit Delay
und folgender Pulslänge
...
...
[Interface]
Startup=0
[Skript]
Startdatei=
[Output]
Out0=Port 0
Out1=Port 1
...
...

[Input]
In0=Port 0
In1=Port 1
In2=Port 2
...
...

[Multimon]
Rescan=32,33,128
Radius=1.

[Kaustik]
FuellMin=0.25
FuellMax=0.4
FuellSoll=0.35
[YAG-Kamera]
Trigger-Mode=0
Trigger-Level=0
Trigger-Delay=0
Pulslaenge=1
CCD-Mode=30
[Export]
Setting=0
[Service]
Firmenadresse=
Servicetechniker=

[BusProtokoll]
Befehl_Nr=0
Datei_Nr=1
Protokoll=0

[SchlittenKonstante]
Offset=1
OffsetFromBottom=5.9

[Process Data]
Mode=0

[View]
Font Size=10
Recent File1=
Recent File2=
Recent File3=
Single Window PositionX=0
Single Window PositionY=0
Caustic Window PositionX=0
Caustic Window PositionY=0
Sensor Window PositionX=0
Sensor Window PositionY=0
Envi Window PositionX=0
Envi Window PositionY=0
MSM Settings Window PositionX=0
MSM Settings Window PositionY=0
MSM Info Window PositionX=0
MSM Info Window PositionY=0
Free Window PositionX=0
Free Window PositionY=0
Power Window PositionX=0
Power Window PositionY=0
Show Measuring Windows=1
[Measurement]

Beamfind Iteration=3
```

25.2 Description of the MDF file format

The MDF file format is a simple ASCII-format which includes the main data of a beam measurement – the spatial power density distribution. MDF stands for “mailable data format”.
By means of this standardized format conversion problems between different evaluation programs are supposed to be reduced and a safe data transmission, e.g. per e-mail, is supposed to be ensured.

The files are arranged as follows:

1st line:	MDF 100 (file identifier)
2nd line:	Number of image points: in x-direction in y-direction
3rd line:	Size of the measurement range: length in x (mm) length in y (mm)
4th line:	Position along the beam axis: z-position (mm)
5th line:	Transversal position of the center of the measurement range: x-pos y-pos (mm)
6th line:	Amplification of the measuring signal: enhancement (dB)
7th line:	Number of averages: number
8th line:	Offset value displayed by the measuring device: offset-value
9th line:	Wavelength-value
10th line:	Power value
11th line:	Focal length value
12th line:	Date, time value

In the following lines the data can be found.
There is a maximum of 80 characters per line.

Comments

Comments are inserted as additional lines, into the lines after the file identifier.
The comment lines each start with a semicolon.

Example:

```
MDF100
;This is an example.
;These lines are a comment.
64    64
2    2
11
...
...
1
10
10 10 10 10 10 10 10 10 10 10
11 12 13 14 15 16 17 18 19 20
20 20 20 20 20 18 16 14 12 10
....
....
```