PRIMES

Original Instructions

FocusMonitor FM+ HPD

LaserDiagnosticsSoftware LDS

Revision 02 EN - 02/2021

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

Use for any other purpose is considered as not intended and is strictly prohibited. Furthermore, intended use requires that you observe all information, instructions, safety notes and warning messages in this operating manual. The specifications given in “17 Technical data” on page 45 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.

DANGER

Serious eye or skin injury due to laser radiation

The device measures direct laser radiation, but does not emit any radiation itself. However, during the measurement the laser beam is reflected at the rotating FS³. This produces scattered or directed reflection of the laser beam (laser class 4). The reflected beam is usually not visible.

- ▶ **In measurement mode, a safety distance of one meter to the device must be maintained even when wearing safety goggles and safety clothing.**
- ▶ **Protect yourself from direct and reflected laser radiation while working with the device by taking the following measures:**

- Never leave the device unattended when taking measurements.
- If the device is moved from its aligned position, increased scattered or directed reflection of the laser beam occurs during measuring operation. Fix the device in such a way that it cannot be moved by unintentional bumping or pulling on the cables.
- Install safety switches or emergency safety mechanisms that allow the laser to be switched off immediately.
- Use suitable beam guidance and beam absorber elements which do not emit any hazardous substances when irradiated.
- Wear **safety goggles (OD 6)** adapted to the power, power density, laser wave length and operating mode of the laser beam source in use.
- Wear suitable **protective clothing** or **protective gloves** if necessary.
- If possible, also protect yourself from direct laser radiation and scattered radiation by using separating protective devices that block or attenuate the radiation.

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 unauthorised opening, dismantling and repair. The removal of covers is only permitted within the scope of the intended use.

Liability disclaimer

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

2 Symbol explanations

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.

The following symbols indicating requirements and possible dangers are used on the device:

Laser radiation warning

Hand injuries warning

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

Further symbols that are not safety-related:

Here you can find useful information and helpful tips.

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 documentation describes the installation and configuration of the FocusMonitor FM+ HPD and the execution of measurements with the LaserDiagnosticsSoftware LDS.

The LaserDiagnosticsSoftware LDS, Version 1.042 or higher must be installed on the PC for measuring operation of the FocusMonitor FM+ HPD. The basic version of the LaserDiagnosticsSoftware LDS is included in the scope of delivery for the device.

For a detailed description of the software installation, file management and evaluation of the measured data, please refer to the separate operating manual LaserDiagnosticsSoftware LDS.

4 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.

DANGER

Serious eye or skin injury due to glass splinters

A mechanical damage to the FS³ can destroy it during measurement operation. Due to the high speed of the FS³, ejected glass splinters can lead to severe injuries of the skin, the eyes or even to a loss of vision.

- ▶ **Do not operate the device without the curved touch protection in front of the FS³.**
- ▶ **Protect yourself by placing an appropriate shielding wall between the device and the area where people are present.**

DANGER

Fire and explosion hazards due to scattered or directed laser radiation

When the FocusMonitor FM+ HPD is being operated, the irradiation must be fully absorbed behind the measurement zone. Fire bricks or other partly-absorbing surfaces are not suitable.

- ▶ **Use a suitable absorber. PRIMES offers, depending on the application, suitable laser power meters for permanent absorption, e.g. the PowerMonitor PM 48/100.**
- ▶ **Don’t store any flammable materials or highly flammable substances at the measuring location.**

5 Device description

5.1 Functional description

The FocusMonitor FM+ HPD is an opto-mechanical scanning measurement system for the analysis of continuous laser radiation in the NIR (1 000 – 1 100 nm). The laser beam is scanned with a rotating FS³ on the x-axis.
Using the horizontal and vertical carriers, the FS³ is moved along the y- and z-axes so that the characteristics of the focused laser beam can be spacially measured.

The FS³ is equipped with a touch protection to prevent damage to the FS³ and to slow down glass splinters flying around if the rotating FS³ is destroyed. Therefore, do not operate the device without the touch protection.

The FocusMonitor FM+ HPD has an Ethernet interface for fast and secure data exchange with the PC.

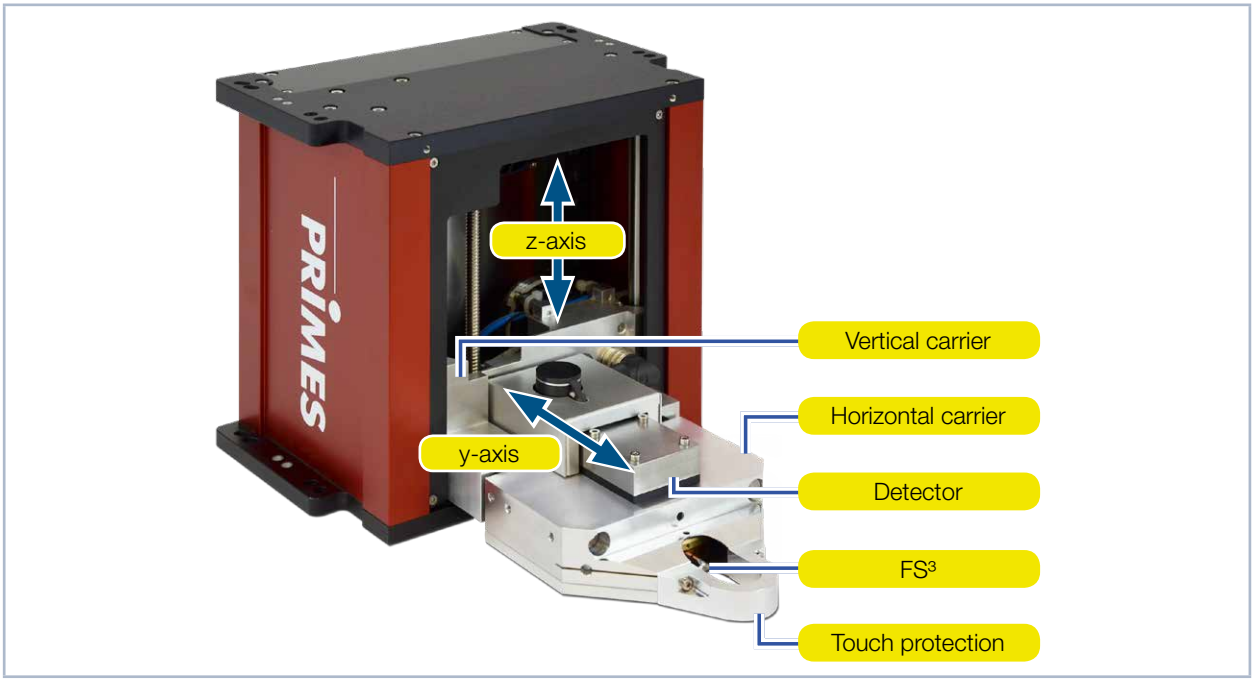


Fig. 5.1: Components of the FocusMonitor FM+ HPD

5.2 Measuring principle

The FocusMonitor FM+ HPD (High Power Density) is used to analyze focused laser beams in the NIR. The device measures the spatial power density distribution in the focus range of the processing optics. From the measured power density distributions, the LaserDiagnosticsSoftware LDS calculates the beam diameters and derives beam parameters such as the focus diameter, the spatial focus position and the beam quality factor M².

The FocusMonitor FM+ HPD with the new fused silica sensor system FS³ is designed for particularly high power densities up to 50 MW/cm². The power density distribution in the focus is measured with the FocusMonitor FM+ HPD using a rotating FS³, which rotates in the x-direction and scans the beam cross section line by line in the y-direction.

The tiny diffuser in the FS³ separates out a small part of the laser beam. A mirror then guides the measuring signal to a detector. The FS³ is automatically moved in z direction by a vertical carrier. This ensures that the propagation parameters can be determined in full by moving along the beam caustic.

6 Quick overview installation

1. Installing the LaserDiagnosticsSoftware LDS, Version 1.042 or higher on the PC • Software is part of the scope of delivery	See separate Operating Manual of the LaserDiagnosticsSoftware LDS
2. Taking safety precautions	Chapter 1 on page 7
3. Prepare Installation • Observe safety instructions • Make preparations • Set installation position	Chapter 8.1 on page 14 to chapter 8.3 on page 17
4. Electrical connection • Establish voltage supply	Chapter 9 on page 21
5. Connect with the PC • Via Ethernet or LAN	Chapter 9.3 on page 23
6. Connect with the PowerMonitor PM 48/100 • Via RS485	Chapter 9.4 on page 24
7. Inert gas connection • To protect the FS³ against contamination	Chapter 10 on page 25
8. Complete installation • Align the device • Mount the device firmly	Chapter 8.5 on page 18 and chapter 8.6 on page 20
9. Perform the measurement • Observe safety instructions • Perform a sample measurement	Chapter 12 on page 26

7 Transport

NOTICE

Damage/Destruction of the device

The device's axes and carriers may be damaged if the device is subjected to hard shocks or is allowed to fall.

- ▶ Handle the device carefully when transporting or installing it.
- ▶ Transport the device only with inserted dust protection (see chapter 8.4 on page 17).

NOTICE

Damage/Destruction of the FS³

Touching the FS³ can lead to burn-in by the laser radiation at the points of contact. Burn-in lead to damage or bursting of the FS³.

- ▶ Do not touch the FS³.

8 Installation

8.1 Safety instructions

Areas on the device that could be particularly hazardous for hand injuries are marked with the following pictogram:

Hand injuries warning

CAUTION

Risk of injury caused by rotating parts

The FS³ of the FocusMonitor FM+ HPD rotates at high rotational speed during the measuring operation. Even after the motor has been turned off, the FS³ will continue to rotate for a certain amount of time.

- **Do not reach into or hold any objects into the inlet aperture of the device (see Fig. 8.1 on page 15).**
- **After the motor has been turned off, wait until the FS³ comes to a complete stop.**

CAUTION

Risk of crushing

Unlike the housing, the horizontal and vertical carrier of the FocusMonitor FM+ HPD can move along the y- and z-axis.

- **Do not reach into the movement range of the horizontal and vertical carrier (see Fig. 8.2 on page 15).**

Fig. 8.1: Danger posed by rotating parts

Fig. 8.2: Crushing hazard at the FocusMonitor FM+ HPD

8.2 Preparation

Before installation, check the available space, especially to ensure that there is enough room for the movement range of the FocusMonitor FM+ HPD.
The device must be firmly assembled and must be mounted with screws (see chapter 8.6 on page 20).

NOTICE

Damage/Destruction of the device

Obstacles in the movement range of the horizontal and vertical carrier can lead to collisions and damage the device.

- **Keep the movement range free of obstacles (cutting nozzle, pressure rolls, etc.). Please note that the horizontal and vertical carrier automatically moves into its resting position after the power supply has been turned off and on again or following a reset. Keep this area clear.**

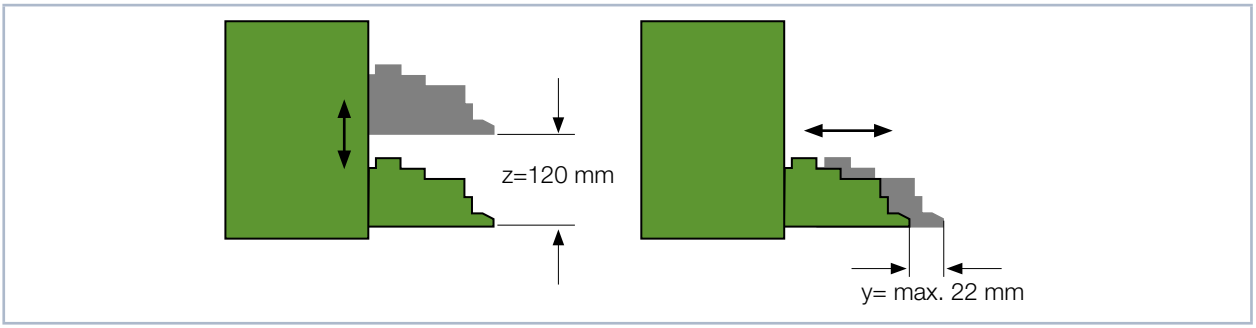


Fig. 8.3: Movement range of the horizontal and vertical carrier

In the LaserDiagnosticsSoftware LDS you have the option to restrict the movement range of the FocusMonitor FM+ HPD (locked area, for further information see chapter 12.5.4 on page 34).

DANGER

Fire and explosion hazards due to scattered or directed laser radiation

When the FocusMonitor FM+ HPD is being operated, the irradiation must be fully absorbed behind the measurement zone. Fire bricks or other partly-absorbing surfaces are not suitable.

- **Use a suitable absorber. PRIMES offers, depending on the application, suitable laser power meters for permanent absorption, e.g. the PowerMonitor PM 48/100.**
- **Don't store any flammable materials or highly flammable substances at the measuring location.**

NOTICE

Damage/Destruction of the absorber (e.g. PowerMonitor PM 48/100)

If the focused laser hits the absorber, it may be destroyed.

- **Ensure there is enough distance between the FocusMonitor FM+ HPD and the absorber (the maximum permissible power density of the absorber must not be exceeded).**

8.3 Installation position

The device is designed exclusively for beam incidence from above. Install the device according to the installation position shown in Fig. 8.4 on page 17.

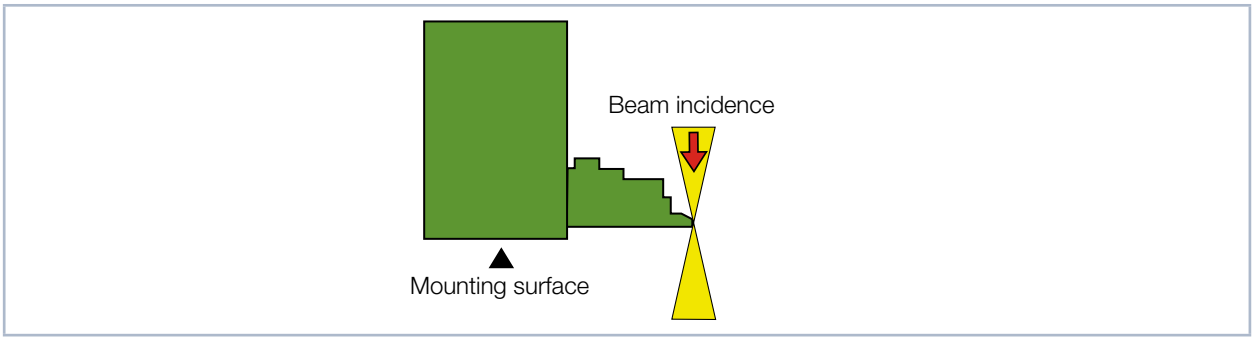


Fig. 8.4: Installation position

8.4 Remove/insert the dust protection of the FS³

The dust protection protects the FS³ from mechanical damage and from contamination (see Fig. 8.5 on page 17).
The dust protection must be removed before each measurement and reinstalled after the measurement has been completed.

The dust protection consists of an upper part with the identification TOP and a lower part. The two parts are connected with inserted magnets. If the dust protection is in the correct position, it is in contact with the touch protection without gaps.

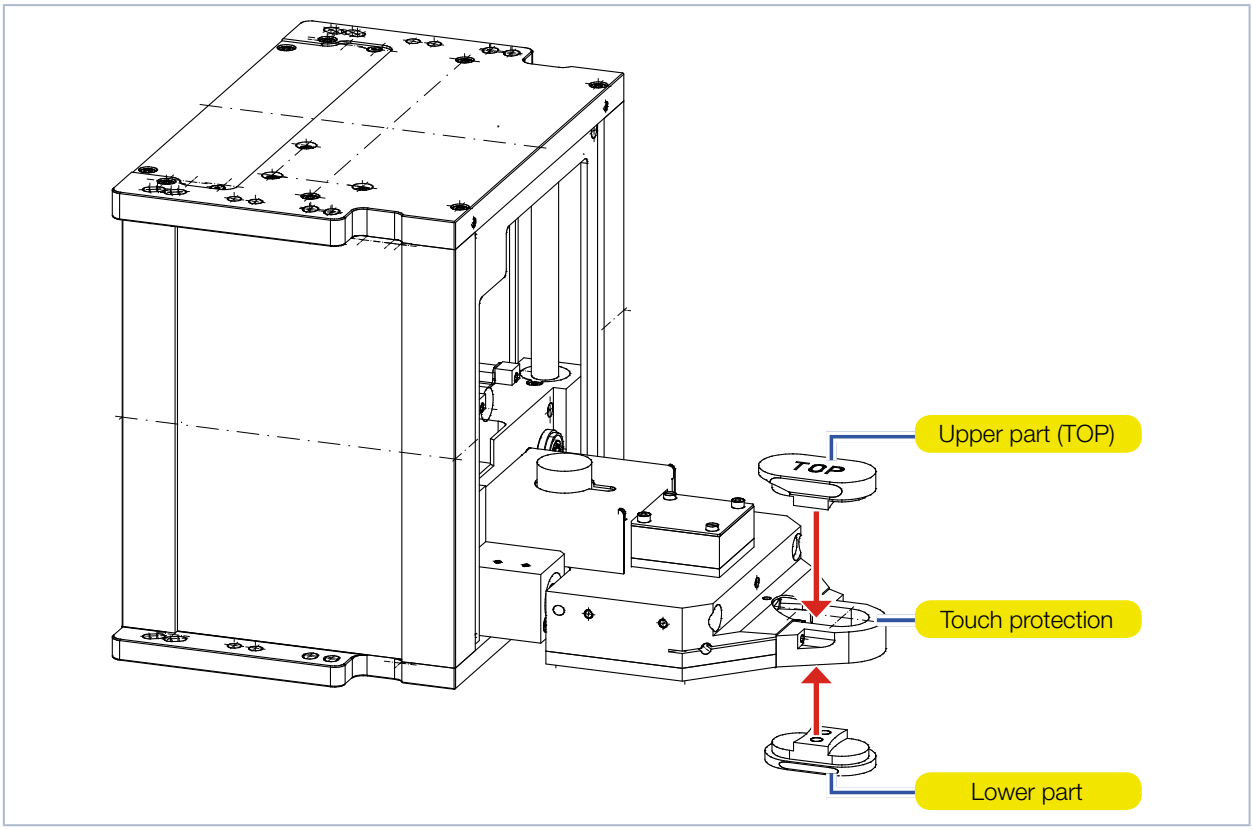


Fig. 8.5: Remove/insert the dust protection

8.5 Align the FocusMonitor FM+ HPD

8.5.1 Device's position in relation to the laser beam

For the FocusMonitor FM+ HPD, the beam must enter vertically to the x-y-plane (see Fig. 8.6 on page 18).

The vertical alignment (z-axis) is primarily dependent on the expected focal length. The maximum vertical stroke of the measuring device is 120 mm.

The focus plane should be centered to the measuring range of the FocusMonitor FM+ HPD (see Fig. 8.6 on page 18).

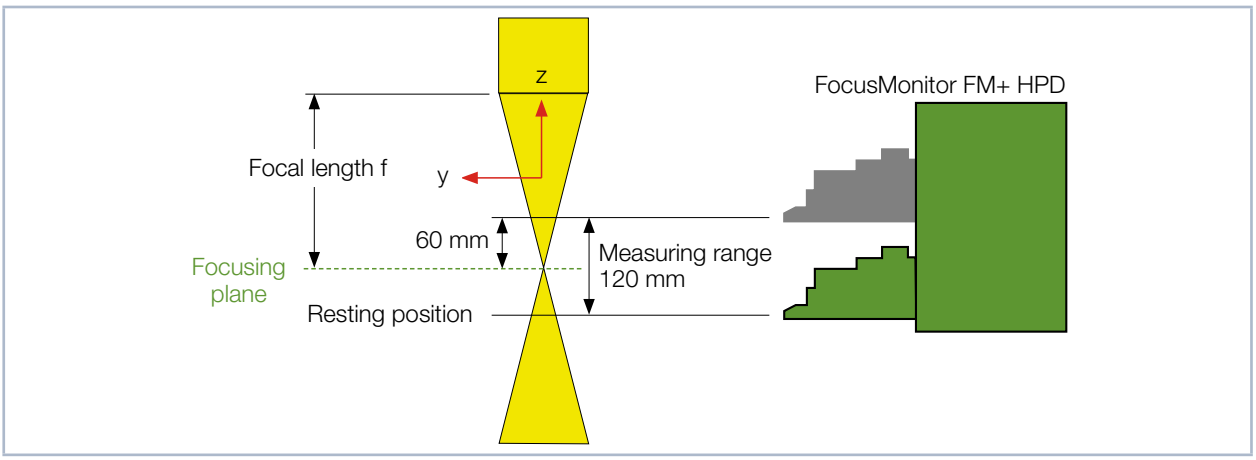


Fig. 8.6: Measuring range of FocusMonitor FM+ HPD

8.5.2 Align the FocusMonitor FM+ HPD with the Adjustment tool

An Adjustment tool (see Fig. 8.7 on page 19) is included with the device for easy alignment (x-y-plane) to the laser beam.

⚠ CAUTION

Risk of injury caused by rotating or moving parts

The linear movement of the horizontal and vertical carrier and the rotating FS³ pose an injury hazard.

- ▶ **Do not reach into the movement range of the horizontal and vertical carrier.**
- ▶ **Only align the FocusMonitor FM+ HPD while the FS³ is stationary.**

1. Connect the FocusMonitor FM+ HPD with the LaserDiagnosticsSoftware LDS as described in chapter 12.4 on page 29.

2. Choose the function scanner of the FocusMonitor FM+ HPD as described in chapter 12.5.1 on page 31.

3. In accordance with chapter 12.5.3 on page 33, enter the value of 60 mm in the ***Device Control > Advanced > Move axes*** menu:

- The horizontal carrier will move to the position 60 mm above its resting position (see Fig. 8.6 on page 18) without a rotated FS³.

4. Remove the dust protection according to chapter 8.4 on page 17.

5. Place the Adjustment tool on the horizontal carrier (see Fig. 8.7 on page 19).

6. Turn on the pilot laser and align the device:
- If the pilot laser beam hits perpendicular to and in the middle of the small marking in the Adjustment tool, the device is properly aligned.

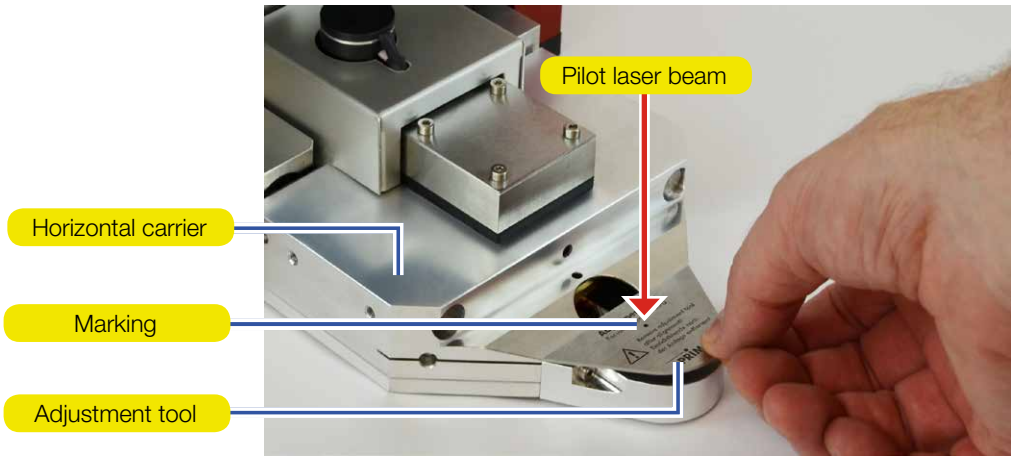


Fig. 8.7: Adjustment tool at the horizontal carrier of FocusMonitor FM+ HPD

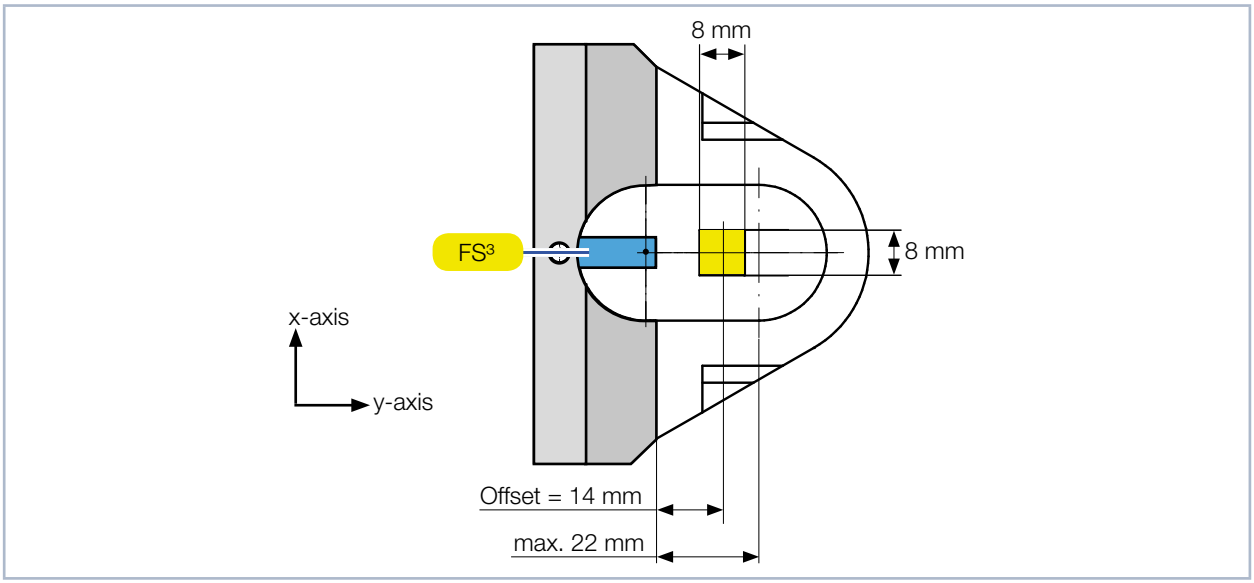


Fig. 8.8: Offset of a measurement window size of 8 x 8 mm

NOTICE

Damage/destruction of the adjustment tool and the FS³

If the adjustment tool is irradiated with the laser, the adjustment tool and the underlying FS³ will be destroyed.

▶ **Remove the adjustment tool before turning on the laser.**

Five to twelve seconds after the supply voltage is switched on, the FocusMonitor FM+ HPD moves into the resting position (lowest z-position).

8.6 Install the FocusMonitor FM+ HPD

DANGER

Serious eye or skin injury due to laser radiation

If the device is moved from its aligned position, increased scattered or directed reflection of the laser beam occurs during measuring operation (laser class 4).

- **Mount the device so that it cannot be moved by an unintentional knock or cables being pulled accidentally.**

The mounting surface of the housing has six slotted holes Ø 6.4 mm and four alignment holes Ø 6^{H7} mm for assembly on a support bracket provided by the customer or the PowerMonitor PM (see Fig. 8.9 on page 20).

Use at least four M6 screws to fasten the housing. The total length of the screws depends on the dimensions of the customer's support bracket.

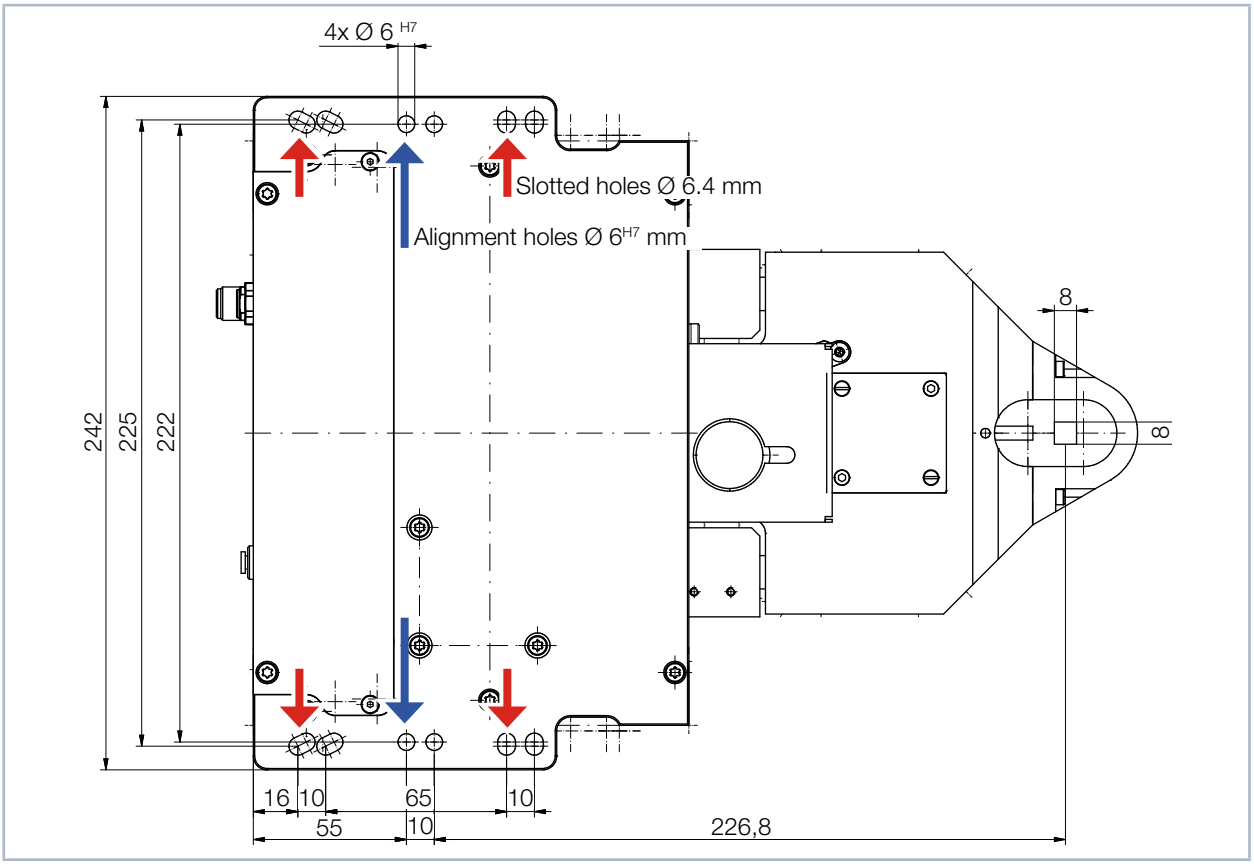


Fig. 8.9: Mounting holes, view from above (same hole pattern below)

DANGER

Serious eye or skin injury due to laser radiation

If the laser beam hits the FS³ located in the inlet aperture, scattered or directed reflection of the laser beam occurs (laser class 4).

- **Wear powder-free latex gloves and move the FS³ out of the inlet aperture.**

9 Electrical connections

The FocusMonitor FM+ HPD requires a voltage supply of 24 V ±5 % (DC) for the operation. A suitable power supply is included in the scope of delivery.

Data is transmitted between the FocusMonitor FM+ HPD and PC via the Ethernet connection.

Another device, such as a PowerMonitor PM 48/100, can be connected to the FocusMonitor FM+ HPD via the RS485 interface (PRIMES bus). The signal from the PowerMonitor PM 48/100 is transmitted through the FocusMonitor FM+ HPD to the PC via the Ethernet interface. The additional measuring device is powered by the power supply of the FocusMonitor FM+ HPD.

Please use only the provided original PRIMES power supply and the connection lines.

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

9.1 Connections

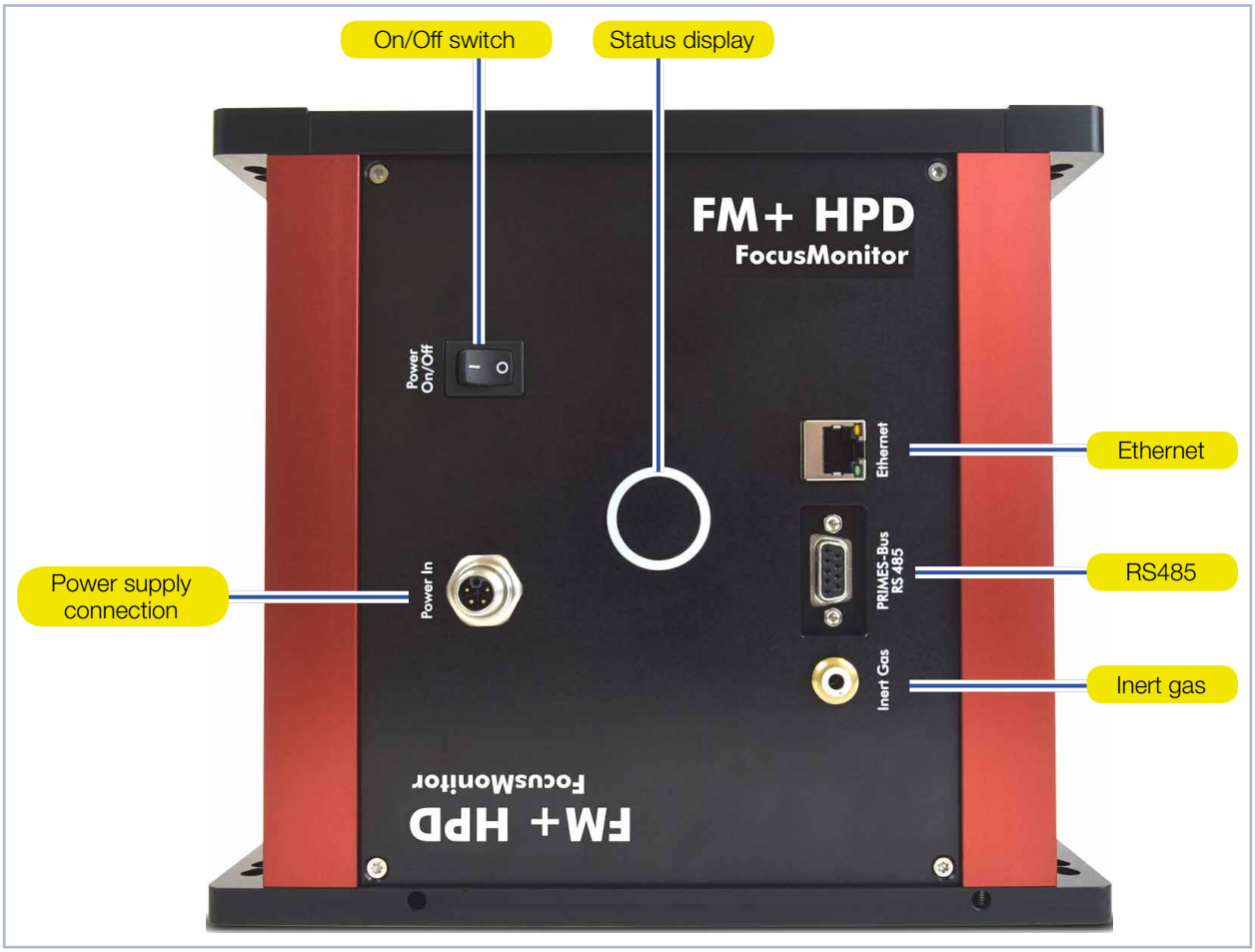
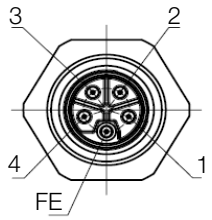


Fig. 9.1: FocusMonitor FM+ HPD connections

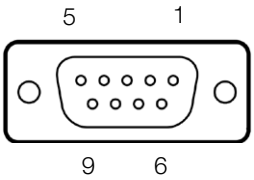
9.2 Pin assignment

9.2.1 Power supply

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

Tab. 9.1: Connection socket for the power supply

9.2.2 PRIMES bus RS485

Pin arrangement D-sub socket, 9-pin (view of plug-in side)		
	Pin	Function
	1	GND
	2	RS485 (+)
	3	+24 V
	4	Not assigned
	5	Not assigned
	6	GND
	7	RS485 (–)
	8	+24 V
	9	Not assigned

Tab. 9.2: D-sub socket, PRIMES bus

9.3 Connection to the PC and establishing the power supply

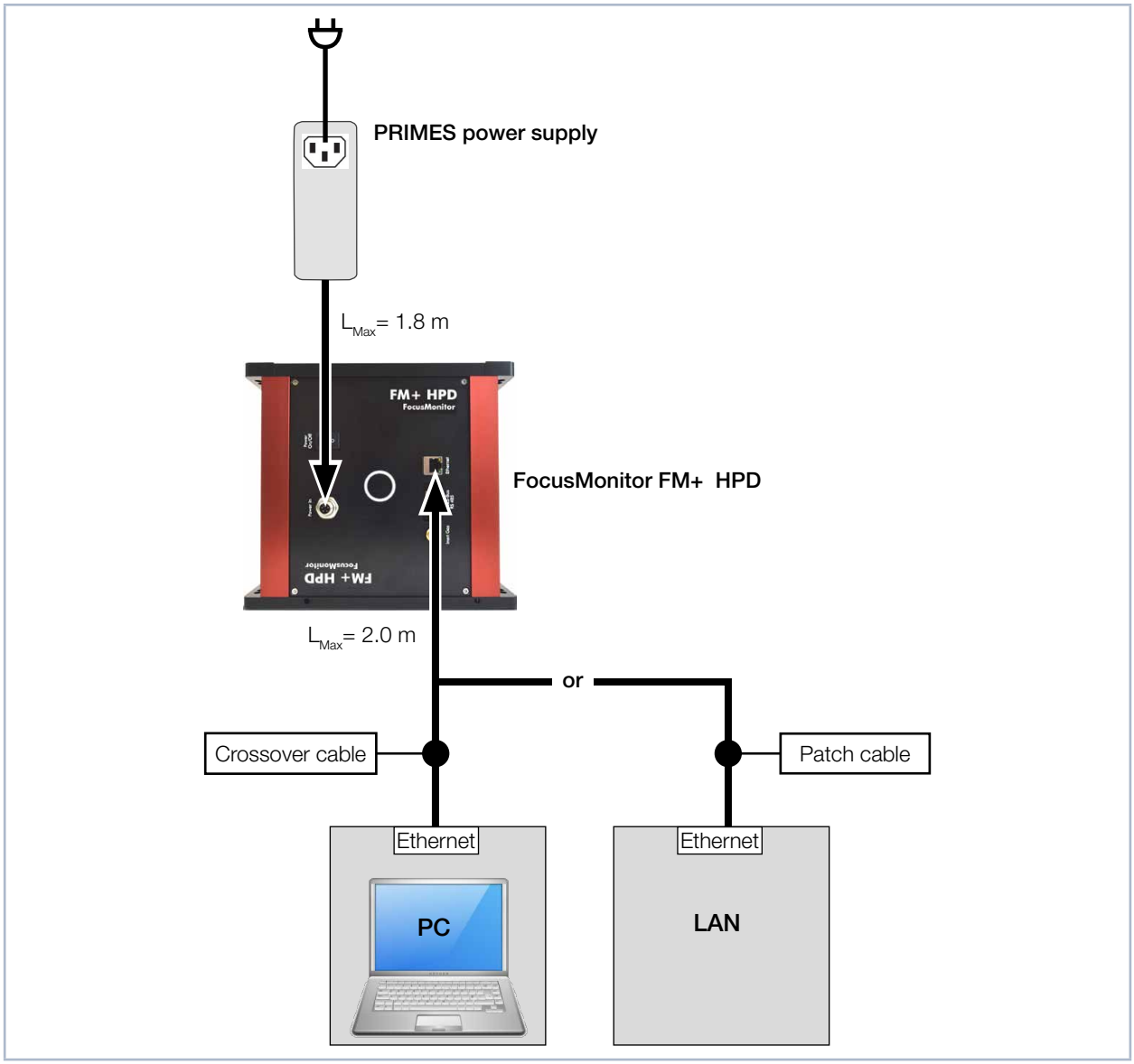


Fig. 9.2: Connection of FocusMonitor FM+ HPD

Connect the FocusMonitor FM+ HPD to the PC via a crossover cable or to the network via a patch cable.

9.4 Connection of the FocusMonitor FM+ HPD and PowerMonitor PM 48/100 to the PC

For full absorption of the radiation behind the measurement zone, you can use the PRIMES PowerMonitor PM 48/100. The water-cooled PowerMonitor PM 48/100 measures the laser power and provides additional information on cooling water flow and temperature.

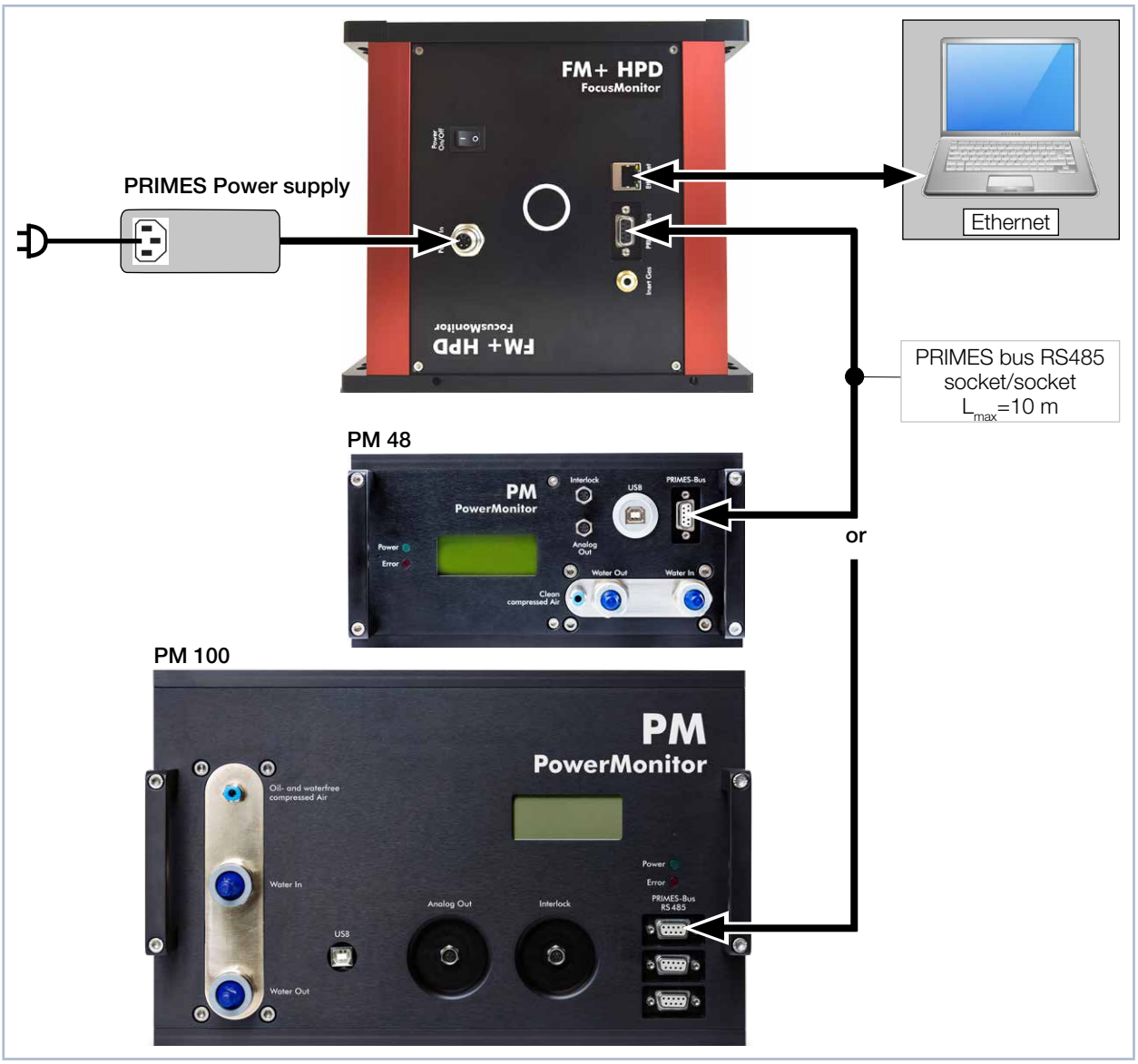


Fig. 9.3: Connection of the FocusMonitor FM+ HPD and PowerMonitor PM 48/100 to the PC

NOTICE

Damage/Destruction of the device due to overvoltage

When disconnecting the electric cables during operation (when the supply voltage is connected), voltage peaks can be generated that could destroy the communication modules of the measuring devices.

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

When connecting several devices, always use only one PRIMES power supply unit on the FocusMonitor FM+ HPD for powering the devices.

10 Inert gas connection

To protect the FS³ from dust particles and contamination, the FS³ can be flushed with inert gas or cleaned compressed air via the inert gas connection.

NOTICE

Damage/Destruction of the device

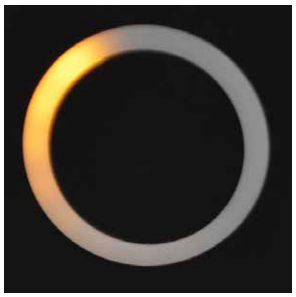
The effects of uncontrolled gas flow (e.g. process gas) could distort the measurement or even damage the device.

- ▶ **Only use helium, nitrogen or argon as the inert gas at the intended connection. The pressure may not exceed a maximum of 0.5 bar.**

Fig. 10.1: Inert gas connection on the FocusMonitor FM+ HPD

11 Status display

The status display consists of a light ring that indicates different states of the FocusMonitor FM+ HPD with different colors and static or rotating lights.



Color	Lighting state	Meaning
White	The entire ring illuminates	The supply voltage is connected
Yellow	Rotating light	The FS³ rotates and the different rotational speeds are indicated.
Red	Rotating light	The FS³ rotates and the y-axis is moved. The measurement is in progress, the different rotational speeds are indicated.

Tab. 11.1: States of the status display

12 Measuring

12.1 Safety instructions

DANGER

Serious eye or skin injury due to laser radiation

The device measures direct laser radiation, but does not emit any radiation itself. However, during the measurement the laser beam is reflected at the rotating FS³. This produces scattered or directed reflection of the laser beam (laser class 4). The reflected beam is usually not visible.

- ▶ Please wear safety goggles (OD 6) 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).
- ▶ In measurement mode, a safety distance of one meter to the FocusMonitor FM+ HPD must be maintained even when wearing safety goggles and safety clothing.

DANGER

Serious eye or skin injury due to glass splinters

A mechanical damage to the FS³ can destroy it during measurement operation. Due to the high speed of the FS³, ejected glass splinters can lead to severe injuries of the skin, the eyes or even to a loss of vision.

- ▶ Do not operate the device without the curved touch protection in front of the FS³.
- ▶ Protect yourself by placing an appropriate shielding wall between the device and the area where people are present.

DANGER

Serious eye or skin injury due to laser radiation

If the device is moved from its aligned position, increased scattered or directed reflection of the laser beam occurs during measuring operation (laser class 4).

- ▶ Mount the device so that it cannot be moved by an unintentional knock or cables being pulled accidentally.

DANGER

Fire and explosion hazards due to scattered or directed laser radiation

When the FocusMonitor FM+ HPD is being operated, the irradiation must be fully absorbed behind the measurement zone. Fire bricks or other partly-absorbing surfaces are not suitable.

- ▶ Use a suitable absorber. PRIMES offers, depending on the application, suitable laser power meters for permanent absorption, e.g. the PowerMonitor PM 48/100.
- ▶ Don’t store any flammable materials or highly flammable substances at the measuring location.

CAUTION

Risk of injury caused by rotating parts

The FS³ of the FocusMonitor FM+ HPD rotates at high rotational speed during the measuring operation. Even after the motor has been turned off, the FS³ will continue to rotate for a certain amount of time.

- **Do not reach into or hold any objects into the inlet aperture of the device.**
- **After the motor has been turned off, wait until the FS³ comes to a complete stop.**

CAUTION

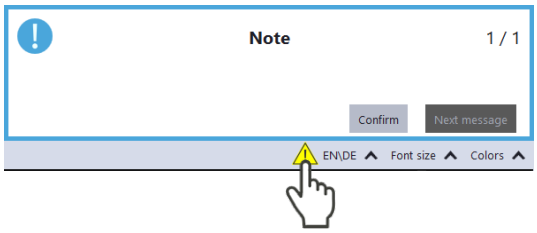
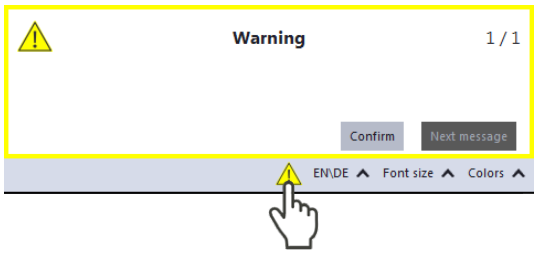
Risk of crushing

Unlike the housing, the horizontal and vertical carrier of the FocusMonitor FM+ HPD can move along the y- and z-axis.

- **Do not reach into the movement range of the horizontal and vertical carrier.**

12.2 Notes of the LaserDiagnosticsSoftware LDS during measurement

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

Notes Notes provide assistance in interpreting the measurement results and are displayed in a blue window. By clicking on the warning triangle in the footer, further information about the problem is displayed.	
Warnings Non-safety-critical problems that influence the quality of the measurement results, for example, are displayed in a yellow window. By clicking on the warning triangle in the footer, further information about the problem is displayed.	
Safety critical device errors Safety-critical problems that can result in damage/destruction of the device are displayed in a red window. Safety-critical problems must be resolved immediately. The safety-critical message must be confirmed to continue the measurement.	

12.3 Clean FS³ before each measurement (tutorial video link)

The FS³ must be cleaned before each measurement.

Do you need help?

You can find a tutorial video under the following link:
www.primes.de/en/support/downloads/tutorialvideos/fmplus-hpd.html

NEED HELP?
www.primes.de/de/support/downloads/tutorialvideos/fmplus-hpd.html

⚠ CAUTION

Burns due to hot components

Parts near the FS³ can be hot due to scattered radiation.

- **Do not clean the FS³ directly after a measurement.**
- **Let the device cool down for an adequate period of time. The cooling time varies depending on the laser power and the irradiation time.**

NOTICE

Damage/destruction of the dust protection and the FS³

If the dust protection is irradiated with the laser, the dust protection and the underlying FS³ will be destroyed.

- **Remove the dust protection before measuring.**

1. Remove the dust protection according to chapter 8.4 on page 17.

NOTICE

Damage/Destruction of the FS³

Touching the FS³ can lead to burn-in by the laser radiation at the points of contact. Burn-in lead to damage or cracking of the FS³.

- **Do not touch the FS³.**
- **When cleaning the FS³ wear powder-free latex gloves.**

2. Put on powder-free latex gloves.
3. Carefully clean the FS³ with isopropanol when cooled down (observe the safety instructions of the manufacturer) and lens cleaning cloth.

12.4 Connect the FocusMonitor FM+ HPD with the LaserDiagnosticsSoftware LDS

12.4.1 Connect device

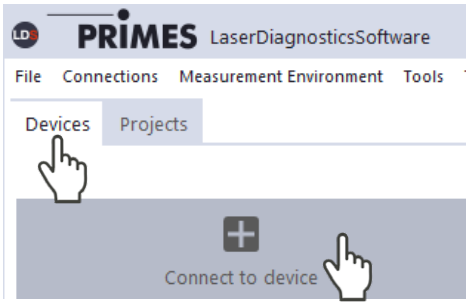
1. Switch on the FocusMonitor FM+ HPD.

👁 The operating mode is shown in the status display (see chapter 11 on page 25).

2. Start the LaserDiagnosticsSoftware LDS.

3. Click on the ***Devices*** tab.

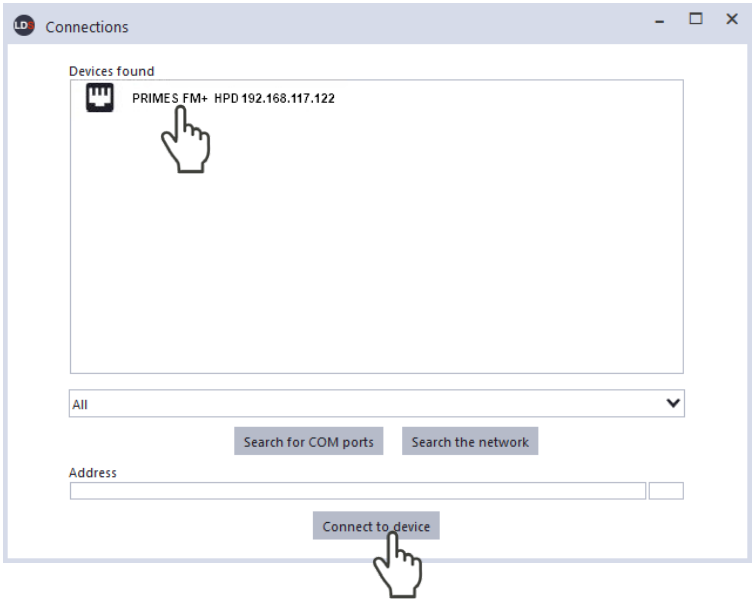
4. Click on the ***+ Connect to device*** button under the tab.



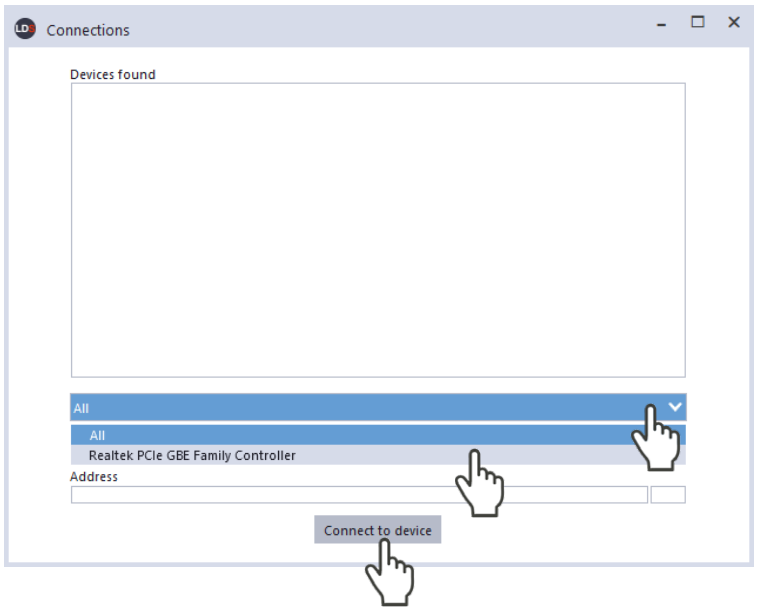
👁 The ***Connections*** window appears.

5. Click on the desired device.
- If the device does not appear in the ***Connections*** window, see chapter 12.4.2 on page 30.

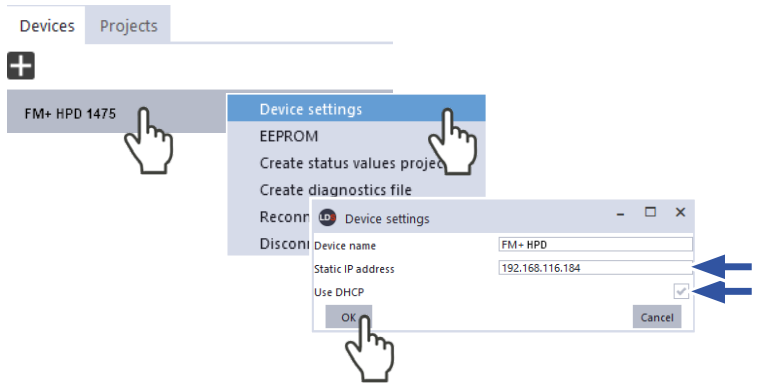
6. Click on the ***Connect to device*** button.



12.4.2 If the device does not appear in the connections window

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

12.4.3 Change the network address of a connected device

Proceed as follows in order to assign a different IP address to a connected device: 1. Right-click on the device and select the ***Device settings*** menu point. 2. Enter in the desired IP address or use the ***Use DHCP*** option and confirm the entry with ***OK***. 3. Turn the FocusMonitor FM+ HPD off and on again.	

12.5 Performing an automatic caustic measurement

This chapter aims to provide some basic information as you get to know the FocusMonitor FM+ HPD, discussing the example of an automatic caustic measurement with the LaserDiagnosticsSoftware LDS.
For a detailed description of the software installation, file management and evaluation of the measured data, please refer to the separate operating manual LaserDiagnosticsSoftware LDS.

12.5.1 Selecting the measuring mode automatic caustic

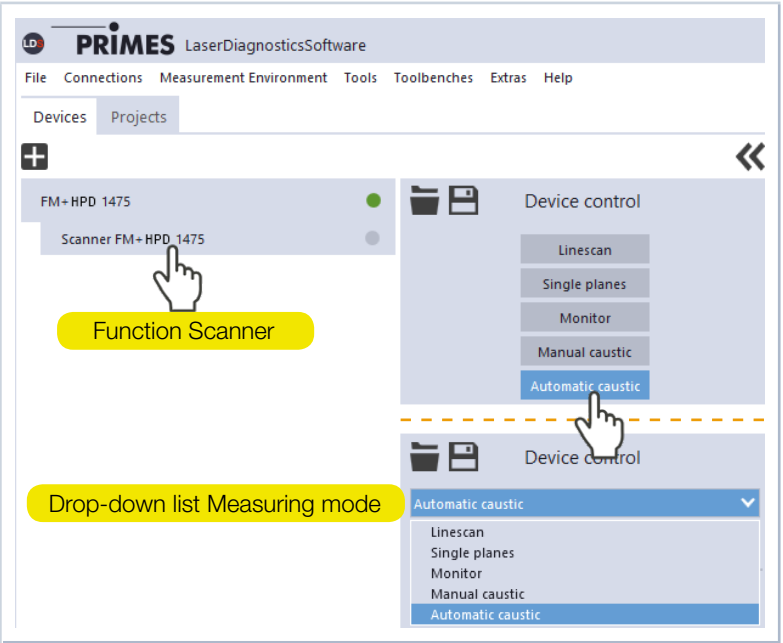
1. Connect the device according to chapter 12.4 on page 29 with the LaserDiagnosticsSoftware LDS.

👁 The FocusMonitor FM+ HPD is established as a connected device.

2. Click on the ***Scanner*** function.

👁 The ***Device control*** menu opens.

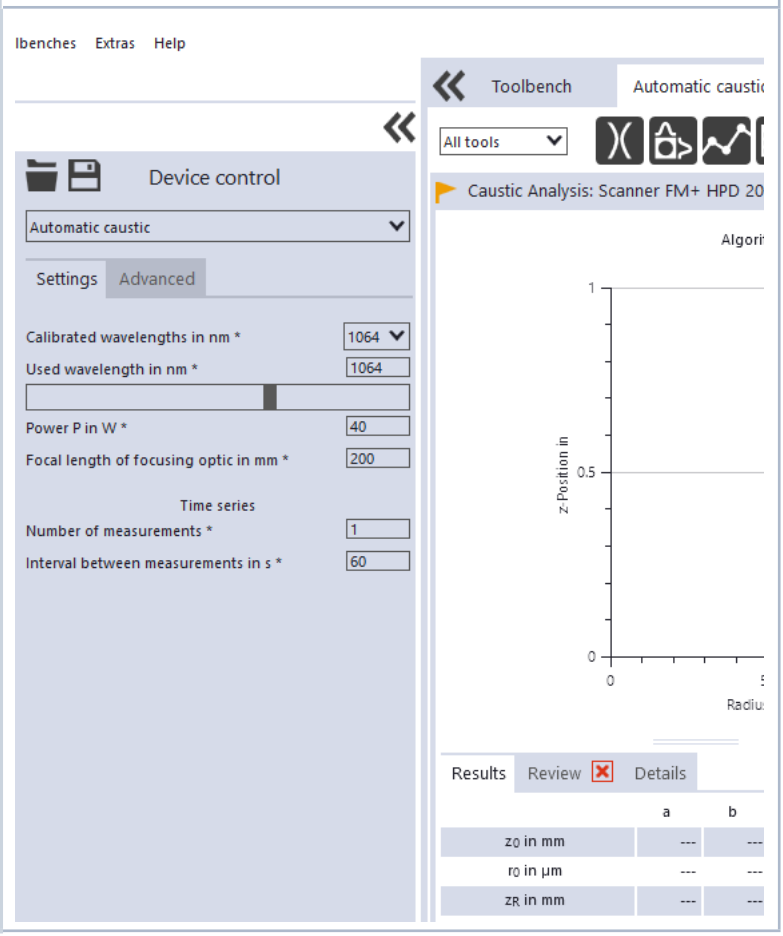
3. Click on the ***Automatic caustic*** button or on the drop-down list measurement mode and ***Automatic caustic***.



👁 The corresponding ***Device control*** opens.

👁 The ***Automatic caustic*** tool bench opens with the following tools:

- ***Caustic analysis***
- ***Plane analysis***



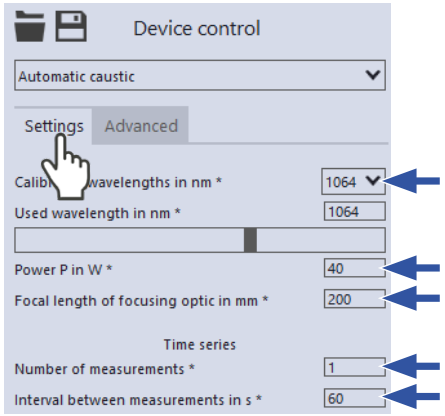
12.5.2 Configuring the settings (*Device control* > *Settings*)

1. Click on the ***Settings*** tab.

2. Enter the ***Used laser wavelength in nm***.
3. Enter the ***Power in W***.
4. Enter the ***Focal length of the focusing lens in mm***.

Only when measuring a Time series
A time series consists of multiple measurements with the same settings, taken over a longer period of time.
Here the measurement interval is the time between the end of a complete caustic measurement and the triggering of the subsequent measurement in seconds.
The actual measurement duration depends on the selected speed, measuring window size, and resolution and can vary for this reason

1. Enter the ***Number of measurements***.
2. Enter the ***Interval between measurements in s***.



12.5.3 Configuring advanced settings (*Device control > Advanced*)

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

2. Enter the number of ***Pixel in x/y***-direction in order to configure the resolution.

3. Enter the ***Number of planes***.
- For a standard-compliant measurement according to ISO 11146 we recommend to measure 21 planes over 6 Rayleigh lengths.

Precaustic
By entering the upper and lower limits of the precaustic, the range in which the precaustic is measured is determined. This function is particularly useful for measuring beams with high divergence. The settings can be used to limit the range of the FocusMonitor FM+ HPD for focus search.

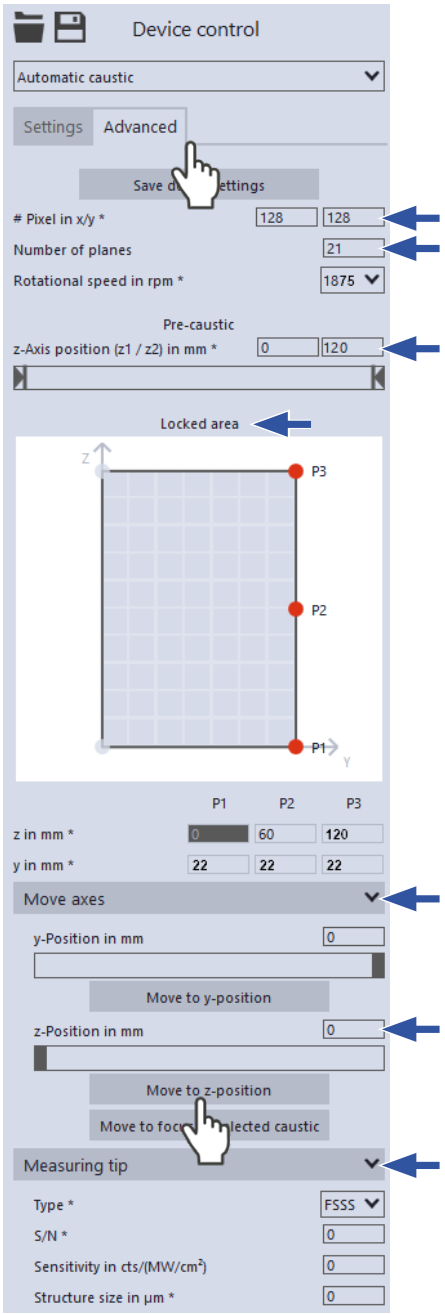
1. Enter the range of the ***z-axis position (z1 / z2) in mm***.

Locked area
1. Define a locked area when there are obstacles in the measuring area.
- More detailed information on locked areas can be found in chapter 12.5.4 on page 34.

Move axes
To align the device (see Fig. 8.6 on page 18) or to start a measurement at this position, you can move the FS³ to the desired position.

1. Enter 60 for the ***z-position in mm***.
2. Click on the ***Move to z-Position*** button.
- The vertical carrier moves to the specified position.
- For detailed information on moving the axes, please refer to chapter 12.5.5 on page 35.

Measuring tip
Here you will find information about the FS³, such as the serial number ***S/N***.



Saving/loading settings in the menu *Device control > Advanced*
The entries marked with an asterisk can be saved as default settings by clicking on the symbol .
To load a preset, click on the icon .

12.5.4 Defining the locked area (*Device control* > *Advanced* > *Locked area*)

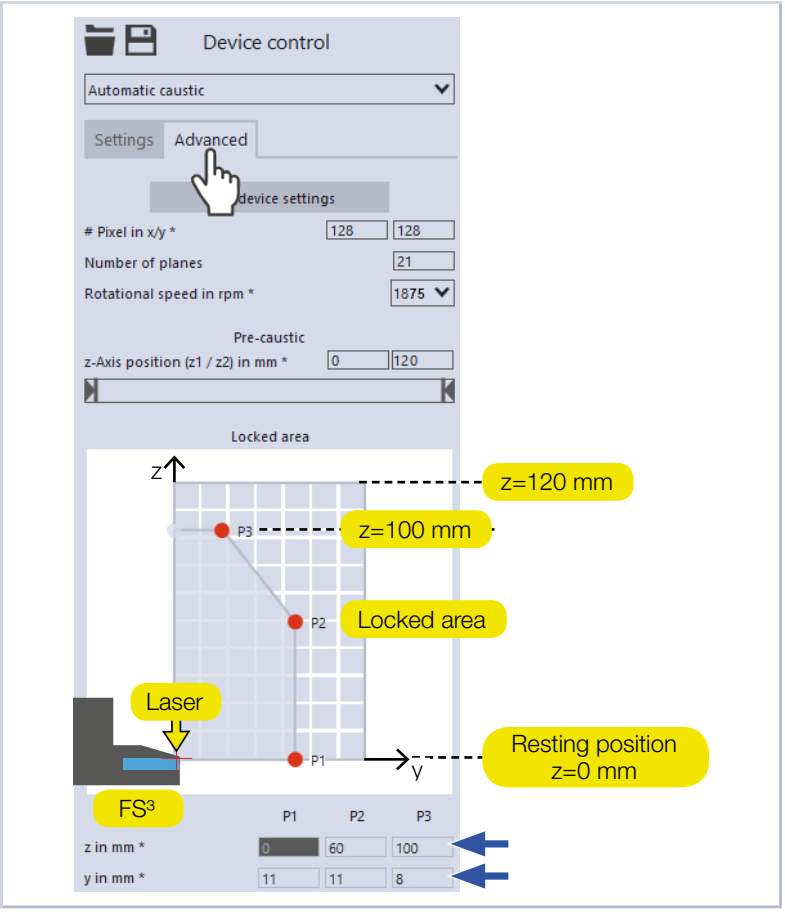
Obstacles in the movement range of the horizontal and vertical carrier can lead to collisions and damage the device. With the settings in the locked area field, a spatial limitation of the measuring range in y and z direction is defined to avoid collisions with possible obstacles.

The origin of the locked area is defined by the diffuser in the FS³.
The position z=0 and y=0 defines the lower left corner of the locked area.

1. Define the locked area by dragging the three points P1, P2, P3 using your mouse.
- As an alternative, you can numerically enter the locked area in the entry fields below.

Example
In the figure, the locked area is set to z=100 mm for the z-axis in Point P3.
- This causes the device's vertical carrier to move in the z-direction from z=0 mm to z=100 mm.

The z-coordinate of the point P1 is already defined by the resting position of the FS³ and cannot be changed.



12.5.5 Moving the axes (*Device control* > *Advanced* > *Move axes*)

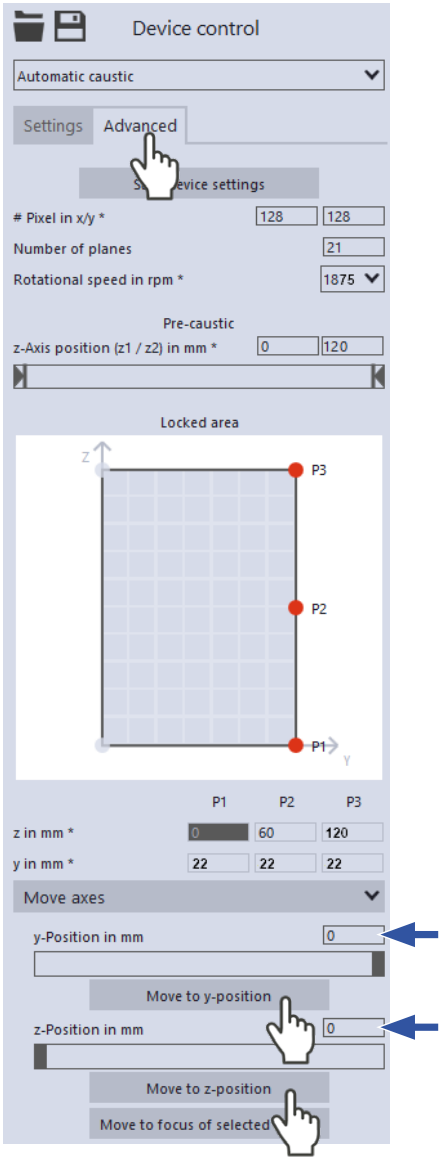
1. Enter the desired y- and z-position of the horizontal and vertical carrier into the entry field numerically.
- As an alternative, you can set the y- and z-position on the slide control.

2. Click on the ***Move to y-position*** button.
- The horizontal carrier tip is positioned at the selected y-position.

3. Click on the ***Move to z-position*** button.
- The vertical carrier is positioned at the selected z-position.

Move to the determined focus
You can also move to the determined focus of a caustic that has already been recorded if, for example, you want to measure a similar beam. During this process, the z_0 value of the ***Invariant moments*** algorithm is used:

1. Select a caustic within your project tree (see separate operating manual of the LaserDiagnosticsSoftware LDS).
2. Click on the button ***Move to focus of selected caustic***.
- The reference plane on the horizontal carrier is approached (see chapter 12.6.1, „Distance of the diffuser in the FS³ to the horizontal carrier“, on page 41).



12.5.6 Starting an automatic caustic measurement

1. Follow the safety instructions in chapter 12.1 on page 26.
2. Turn on the laser.
3. Click on the ***Start*** button.

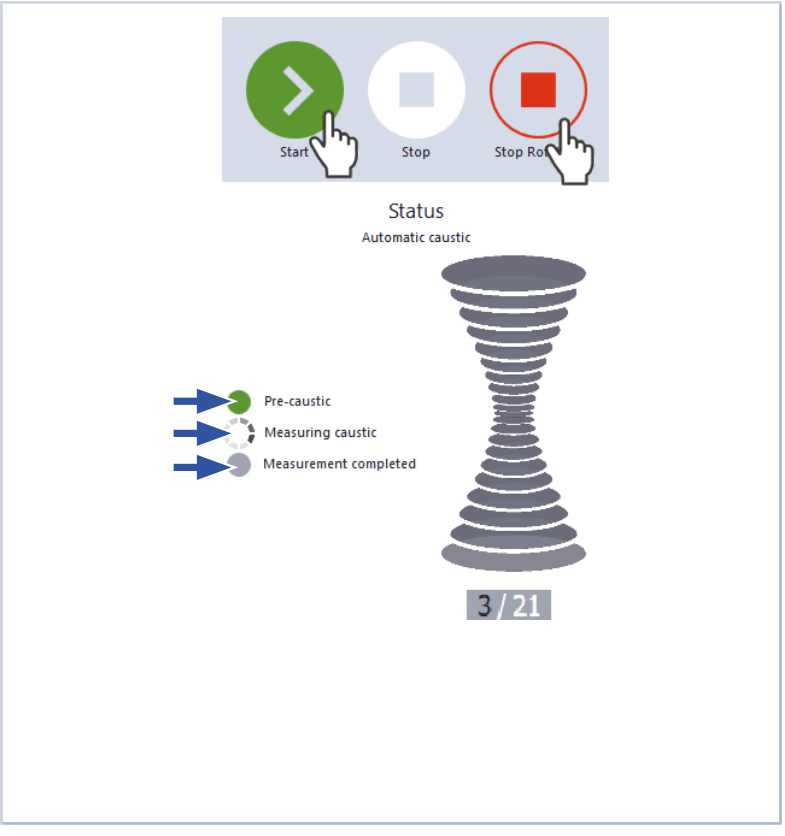
The progress of the measurement is indicated when ***Pre-caustic***, ***Measuring caustic*** and then ***Measuring completed*** are displayed:

Pre-caustic
During the display, the optimum measurement parameters such as the z-range along the beam propagation, measurement window position and measurement window size are determined automatically.

Measuring caustic
The actual measurement is carried out during the indication.

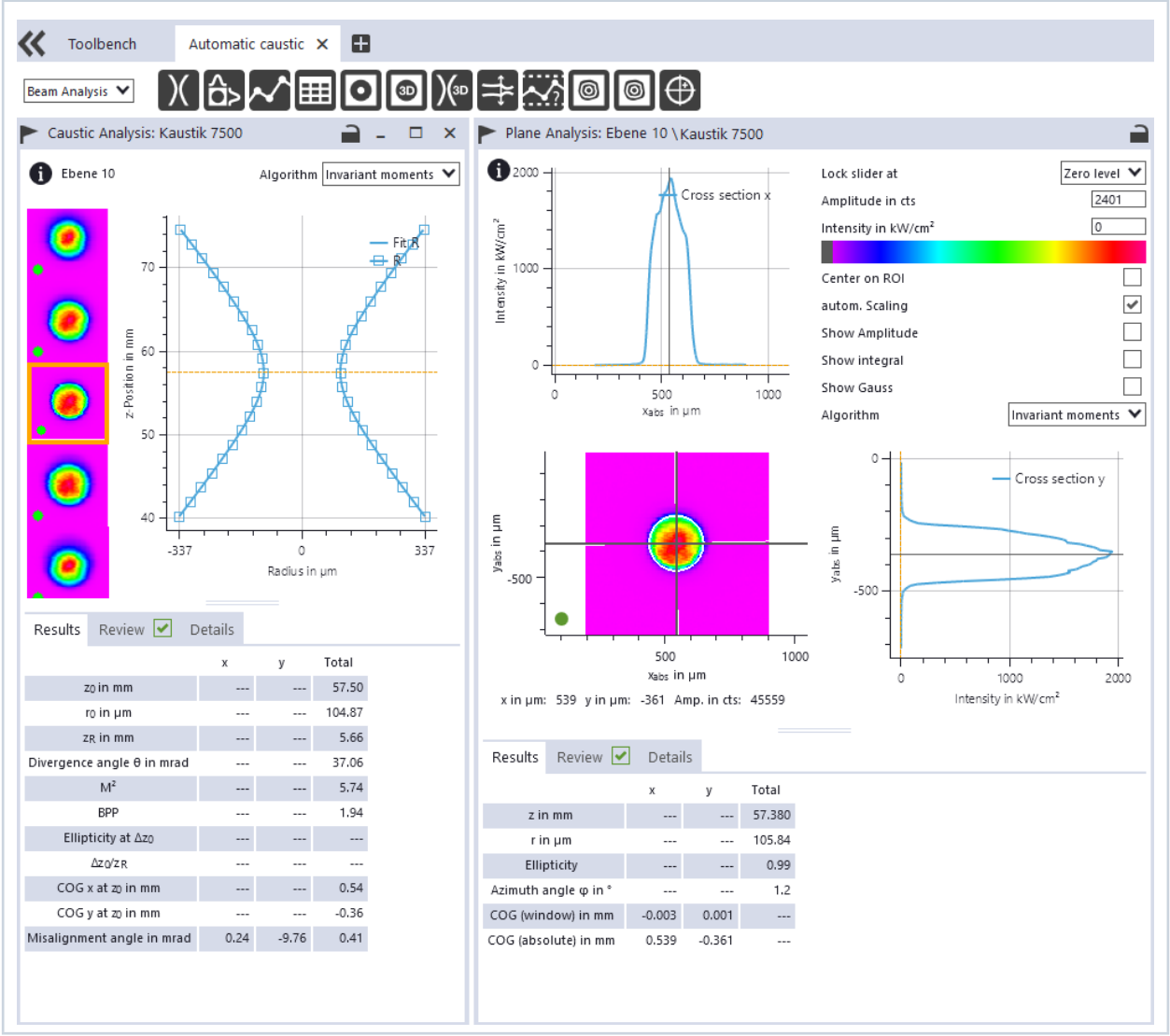
Measuring completed
The measurement has been completed.

4. Turn off the laser.
5. Press the ***Stop Rotation*** button to stop the rotation of the FS³.



12.5.7 Displaying the measurement results

The measuring results are displayed in the opened tools once the measurement has been completed (see below). A detailed description of the tools and the assessment of the measuring results can be found in the separate operating manual for the LaserDiagnosticsSoftware LDS.



	x	y	Total
z_0 in mm	---	---	57.50
r_0 in µm	---	---	104.87
z_R in mm	---	---	5.66
Divergence angle θ in mrad	---	---	37.06
M^2	---	---	5.74
BPP	---	---	1.94
Ellipticity at Δz_0	---	---	---
$\Delta z_0/z_R$	---	---	---
COG x at z_0 in mm	---	---	0.54
COG y at z_0 in mm	---	---	-0.36
Misalignment angle in mrad	0.24	-9.76	0.41

	x	y	Total
z in mm	---	---	57.380
r in µm	---	---	105.84
Ellipticity	---	---	0.99
Azimuth angle φ in °	---	---	1.2
COG (window) in mm	-0.003	0.001	---
COG (absolute) in mm	0.539	-0.361	---

12.5.8 Display of measurement deviation in the LaserDiagnosticsSoftware LDS

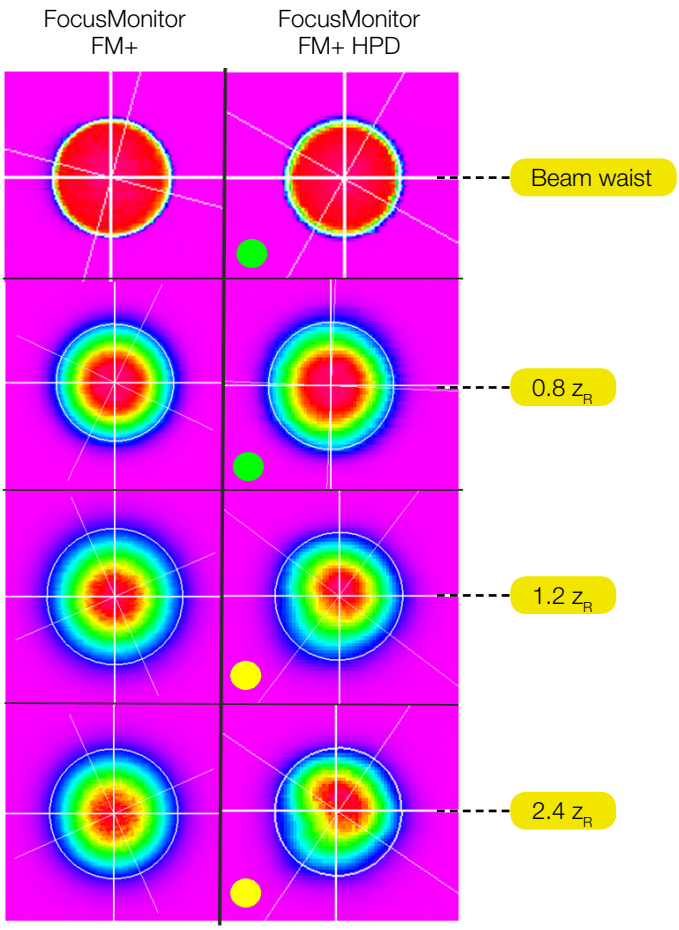
Measurements with the FocusMonitor FM+ HPD may show deviations in the power density distribution in the far field of a caustic (> 1 Rayleigh length z_R).
The deviation near the beam waist are very small and the focal plane itself is displayed correctly.

For easier classification, planes are highlighted by a colored dot (green/yellow) in the Laser Diagnostics Software LDS:

- A green dot marks planes close to the focus where the deviation of the power density distribution are very small.
- A yellow dot marks planes located in the far field where the power density distribution may be distorted.
  As these efects differ from measuring tip to measuring tip a plane marked by a yellow dot is not necesseraly effected.

Planes can only be evaluated by the LaserDiagnosticsSoftware LDS if they are available in the project tree as part of a valid caustic measurement.
If no dot is displayed, automatic evaluation by the LaserDiagnosticsSoftware LDS is not possible:

- The caustic is indicated by the LaserDiagnosticsSoftware LDS as not valid.



12.5.9 Uncertainties in the determination of the beam parameters

Due to possible distortions of the power density distribution in the far field of a caustic, certain beam parameters, may show increased uncertainties. This is taken into account by an increased tolerance range ($\Delta r/r < 10$ %). The specified measurement uncertainties are given in Tab. 12.1 on page 39.

Limit values of the beam parameters for safe determination of the beam parameters	
min. beam radius	50 µm
max. beam radius	600 µm
max. power density	50 MW/cm²
Max. beam divergence	120 mrad
Wavelength range	1 000 – 1 100 nm

Measurement uncertainties	
Focus radius r_0	5 %
Beam radius r ($\|z\| < 1\ z_R$)	5 %
Beam radius r ($\|z\| > 1\ z_R$)	10 %
Focus position z_0	3 % z_R
Rayleigh length z_R	15 %
Beam quality factor M²	15 %
Beam divergence	10 %

Tab. 12.1: Limit values and measurement uncertainties

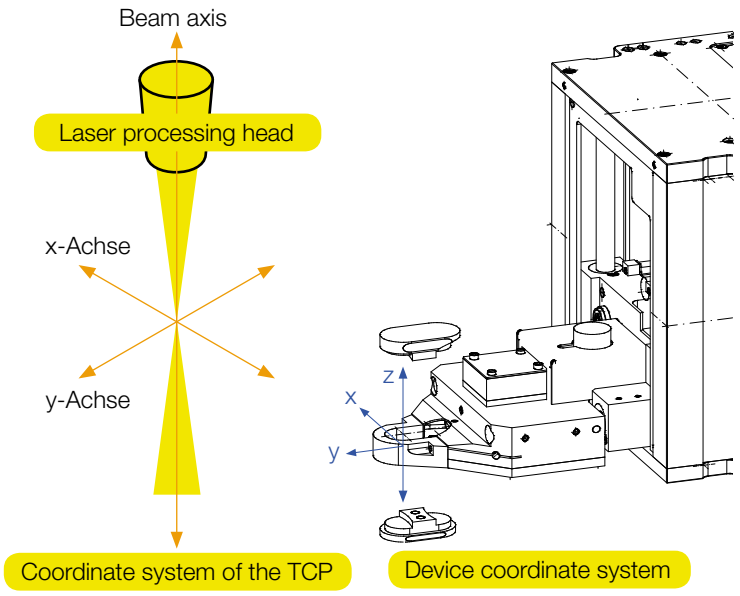
The measurement uncertainties refer to the use of rotationally symmetric algorithms: Invariant moments or 86 %. Other evaluation algorithms may lead to increased uncertainties.

12.6 Determining the tool center point (TCP) using the FocusMonitor FM+ HPD

The tool center point (TCP) is usually located on the beam axis on the focus plane.

1. Align the FocusMonitor FM+ HPD as described in chapter 8.5 on page 18.
2. Install the FocusMonitor FM+ HPD as described in chapter 8.6 on page 20.
3. Perform an automatic caustic measurement as described in chapter 12.5 on page 31.
4. Move the measuring carrier of the FocusMonitor FM+ HPD to the determined focus plane as described in chapter 12.5.5 on page 35.

- The FocusMonitor FM+ HPD moves the reference plane to the focus position (see figures in chapter 12.6.1 on page 41).



5. Measure the Distance z between the reference plane of the horizontal carrier (see figure in chapter 12.6.1 on page 41) and the reference plane on the laser processing head.

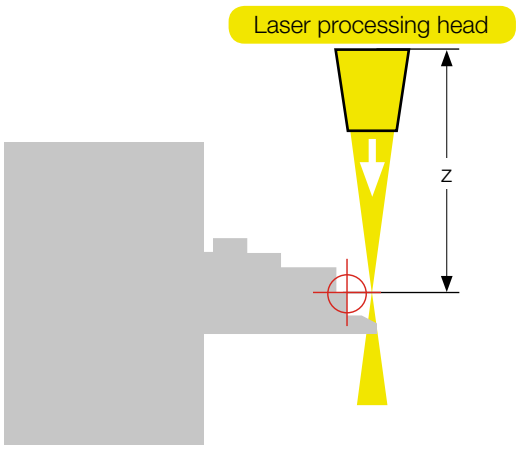
The following description is an example for the further determination of the TCP using a coaxial vision system.

6. Position the laser processing head at distance z above the workpiece.

- Here z is the distance from the reference plane at the laser processing head to the workpiece surface.

7. Specify a short laser pulse with low output on the workpiece.
8. Align the reticle of the coaxial observation camera with the penetration (x, y-position).
9. Use the reticle to align the laser processing head with a known fixed point in the machine coordinate system.
10. Set the correct working distances between the laser processing head and the previously selected fixed point.
11. Apply the axis values for this position.

- The tool center point (TCP) has been determined.



12.6.1 Distance of the diffuser in the FS³ to the horizontal carrier

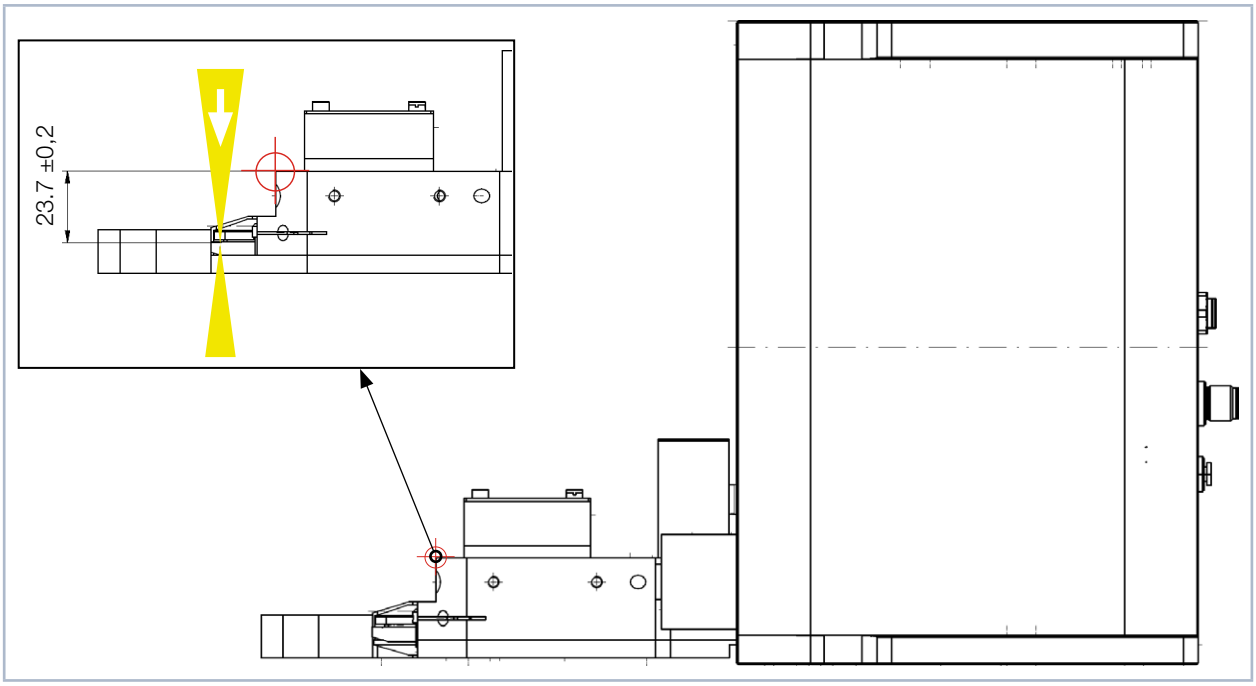


Fig. 12.1: Distance of the diffuser in the FS³ to the horizontal carrier

13 Troubleshooting

Error	Possible cause	Remedy
There is no connection between the FocusMonitor FM+ HPD and the PC.	Network address of the PC is not within the range of the FocusMonitor FM+ HPD.	In Windows > Control panel > Network and Sharing Center, assign an IP address to your PC that is in the same address range as the FocusMonitor FM+ HPD.
	The connection may be blocked by the firewall.	Enable the UDP port 20034 according to chapter 12.4.2 on page 30.
	An incorrect Ethernet card is selected.	Select the appropriate Ethernet card according to chapter 12.4.2 on page 30.
Error during a measurement	• Data transmission error • Processor crash in the measuring system • Program execution error	1. Restart the LaserDiagnosticsSoftware LDS. 2. Turn the supply voltage off and on again to start a reset cycle. 3. Restart the PC.
Apart from the ambient noise and zero offset, no measuring signal is available.	The device is not aligned correctly.	Check the device alignment to the laser beam.
	The power density in the focus is too low.	Increase the laser power. The absolute power density in the focus typically has to be several hundred kW/cm² to achieve a significant measuring signal.
	The selected resolution is too low for smaller focus spots (e.g. r_f= 80 µm) and a maximum measuring window.	First measure outside the direct focus area. If this does not lead to a result, increase the resolution (e.g. 256 x 256).
	The signal enhancement is too low.	Set the maximum enhancement and select the maximum measuring range.
The FS³ is destroyed during the measurement.	• The power density is too high. • Mechanical damage has occurred.	A damaged FS³ must be replaced to ensure safe operation.
When measuring small beams, an offset of the recorded measuring tracks to each other is observed.	Variations in the synchronism of the rotary disk as well as delays in triggering the trigger signal.	Position the beam as close to the left edge of the window as possible. The time interval between the trigger signal and start of the measurement is then smaller and errors can thus be reduced. Averaging is also often helpful in this case.
The representation of the measured beam deviates clearly from the expectations.	Internal defect of the FS³	Please contact PRIMES technical support. E-mail address: support@primes.de We recommend to include some sample measurements when contacting PRIMES.

14 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.

15 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.

16 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:

FocusMonitor (FM)

Types: FM 35; FM 120; FM+; FM+ HPD; FMW; FMW+

is in conformity with the following relevant EC Directives:

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

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

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

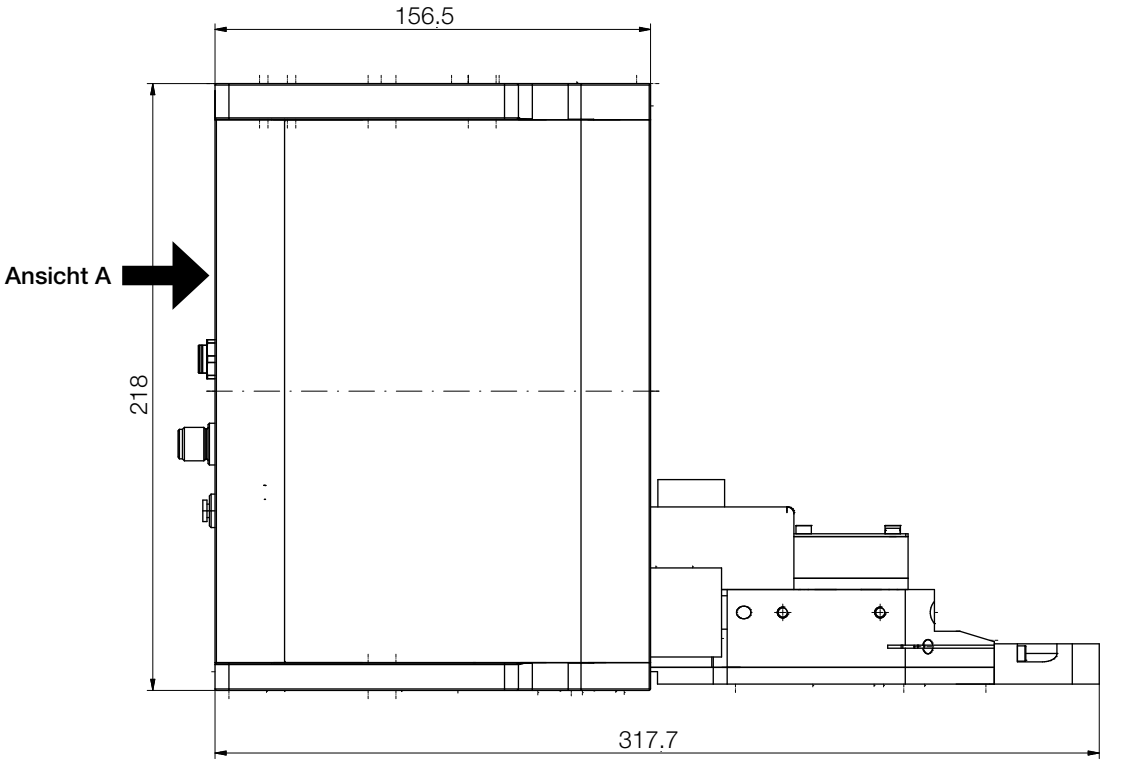
Pfungstadt, November 7, 2019

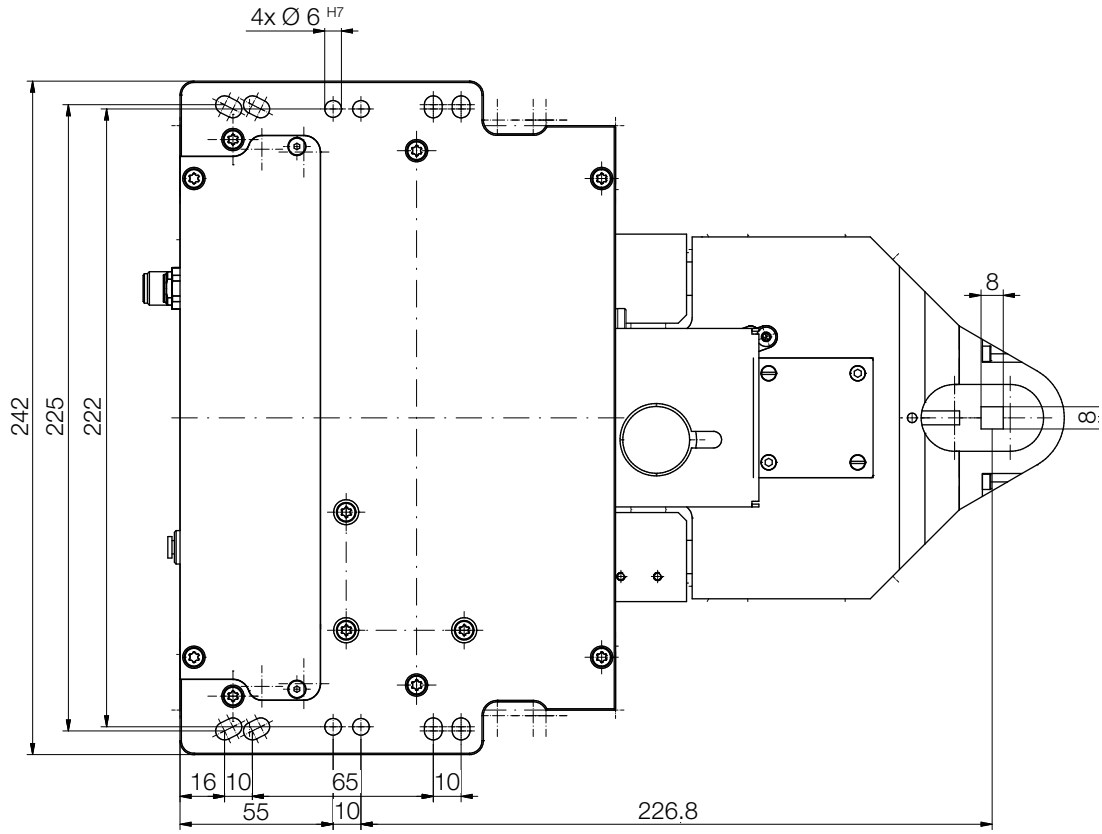
Dr. Reinhard Kramer, CEO

17 Technical data

Measurement parameters	
Power range	30 – 25 000 W
Wavelength range	1 000 – 1 100 nm
Beam diameter	100 – 1 200 µm*
Max. power density	50 MW/cm²
Max. beam divergence	120 mrad
* The size of the beam distribution to be measured must not exceed 1 200 µm in the 86 % power inclusion. Within this range, measurement of multispots is also possible.	
Determined parameters	
Focus position x, y, z	yes
Focus radius x, y	yes
Beam quality factor M²	yes
Raw beam diameter with focussing element	yes
Beam parameter product BPP	yes
Divergence angle	yes
Power density distribution	2D, 3D
Device parameters	
Working range x-y	8 x 8 mm
Working range z	120 mm
Mechanical aperture	8 x 8 mm
Resolution	32 x 32 – 1 024 x 1 024 pixel
Rotation speed of the FS³	1 875 rpm
Supply data	
Power supply	24 V DC ± 5 %, max. 3.5 A
Inert gas (water and oil free)	Helium, Nitrogen, Argon, compressed air
Specification of compressed air according to ISO 8573-1: 2010	1:4:2
Pressure protective gas	typ. 0.5 bar
Communication	
Interfaces	RS485/Ethernet
Dimensions and weight	
Dimensions (L x W x H)	318 x 242 x 218 mm
Weight (approx.)	8.5 kg
Environmental conditions	
Operating temperature range	10 – 40 °C
Storage temperature range	5 – 50 °C
Reference temperature	22 °C
Permissible relative humidity (non-condensing)	10 – 80 %

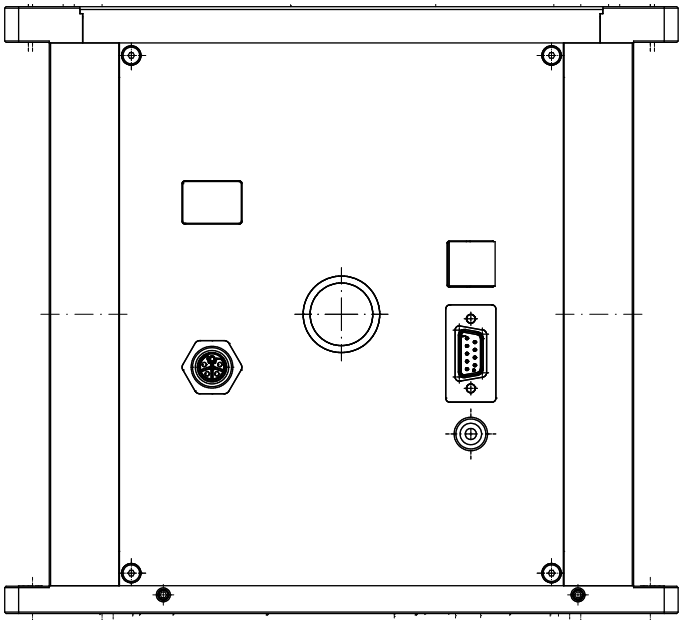
18 Dimensions





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

View A



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

19 Appendix

19.1 Change the rotational disk (tutorial video link)

Do you need help?

You can find a tutorial video under the following link:
www.primes.de/en/support/downloads/tutorialvideos/fmplus-hpd.html

NEED HELP?
www.primes.de/de/support/downloads/tutorialvideos/fmplus-hpd.html