Operating Manual

Translation of the Original Instructions

FocusParameterMonitor

PROFIBUS/PROFINET

Revision 05/2018 EN

IMPORTANT!

READ CAREFULLY BEFORE USE.

KEEP FOR FUTURE USE!

Contents

PRIMES - The Company

PRIMES is a manufacturer of measuring devices used for the characterization of laser beams. These devices are used for the diagnostics of high power lasers that range from CO_2-lasers to solid-state lasers or diode lasers. The wavelength-range is covered from infrared to near UV. A great variety of measuring devices for the determination of the following parameters is available:

- The laser power
- The beam dimensions and beam position of an unfocused beam
- The beam dimensions and beam position of a focused beam
- The diffraction index M^2
- The polarization of the laser beam

Both the development and the production of the measuring devices are effected by PRIMES. This is how we ensure an optimal quality, excellent service and a short reaction time which is the basis to meet our customers‘ requirements fast and reliably.

PRIMES Max-Planck-Str. 2 - 64319 Pfungstadt - Germany - info@primes.de - www.primes.de

1 Basic Safety Instructions

Intended Use

The FocusParameterMonitor (FPM) has been designed exclusively for measurements carried out in or near the optical path of high-power lasers. Please observe and adhere to the specifications and limit values given in Chapter „18 Technical Data“ on page 54. Other uses are considered to be improper. The information contained in this operating manual must be strictly observed to ensure proper use of the device.

Using the device for unspecified use is strictly prohibited by the manufacturer. By usage other than intended the device can be damaged or destroyed. This poses an increased health hazard up to fatal injuries. When operating the device, it must be ensured that there are no potential hazards to human health.

The device itself does not emit any laser radiation. During the measurement, however, the laser beam is guided onto the device which causes reflected radiation (laser class 4). That is why the applying safety regulations are to be observed and necessary protective measures need to be taken.

Observing applicable safety regulations

Please observe valid national and international safety regulations as stipulated in ISO/CEN/TR standards as well as in the IEC-60825-1 regulation, in ANSI Z 136 “Laser Safety Standards” and ANSI Z 136.1 “Safe Use of Lasers”, published by the American National Standards Institute, and additional publications, such as the “Laser Safety Basics”, the “LIA Laser Safety Guide”, the “Guide for the Selection of Laser Eye Protection” and the “Laser Safety Bulletin”, published by the Laser Institute of America, as well as the “Guide of Control of Laser Hazards” by ACGIH.

Necessary Safety Measures

If people are present within the danger zone of visible or invisible laser radiation, for example near laser systems that are only partly covered, open beam guidance systems, or laser processing areas, the following safety measures must be implemented:

- 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.
- Ensure that the device is mounted securely to prevent any movement of the device relative to the beam axis and thus reduce the risk of scattered radiation. This in the only way to ensure optimum performance during the measurement.

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 must not be modified, neither constructionally nor safety-related, without our explicit permission. The device must not be opened e.g. to carry out unauthorized repairs. Modifications of any kind will result in the exclusion of our liability for resulting damages.

Liability Disclaimer

The manufacturer and the distributor of the measuring devices do not claim liability for damages or injuries of any kind resulting from an improper use or handling of the devices or the associated software. Neither the manufacturer nor the distributor can be held liable by the buyer or the user for damages to people, material or financial losses due to a direct or indirect use of the measuring devices.

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 **can** occur if necessary safety precautions are not taken.

CAUTION

means that a slight physical injury **can** occur if necessary safety precautions are not taken.

NOTICE

means that property damages **can** occur if necessary safety precautions are not taken.

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

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

Further symbols that are not security relevant:

Here you can find useful information and helpful tips.

CE With the CE-marking the manufacturer guarantees that the product is in conformity with the EC-guidelines.

▶ Call for action

3 Conditions at the Installation Site

- The measuring device must not be operated in a condensing atmosphere.
- The ambient air must be free from organic gases.

4 Introduction

4.1 Laser Beam Measurement

Laser beams in industrial applications, whether they be CO_2, Nd:YAG- diode or fibre lasers, work with invisible beams in the infra-red or near infra-red spectral range (NIR). Hence changes in beam quality or power cannot be detected visually, and only become evident from the outcome of their application. Under some circumstances, this results in very expensive rejects being produced.
If the deterioration in quality is not recognised in the manufacturing process, this usually results in the subsequent failure of the product in use, with consequences for the manufacturer of rectification, replacement and loss of image.

This is where PRIMES beam diagnostics devices for measuring beam quality, focusability and laser power come in. Process monitoring in production with laser beam diagnostics devices by PRIMES enables consistent quality assurance and allows the timely detection and elimination of malfunctions of laser beams.

PRIMES measuring devices allow the reliable recording of current beam parameters, and enable ongoing documentation of beam properties for quality assurance purposes. This is a requirement that should not be underestimated in many industrial areas, such as automotive or medical technology.

With PRIMES devices for beam diagnostics, troubleshooting of laser applications is simplified considerably. The beam intensity profile, beam diameter, beam caustic before and after focusing, and laser power to be applied are directly measured and analysed. Based on the readings and their evaluation, maintenance and servicing personnel can work in a targeted way on repair. Loss of time and system downtimes due to “trying out” possible causes of the problem are effectively avoided.

The same applies to process optimisation and approval of process windows in laser material processing. Only if the focal position and focal dimension and also the intensity profile of the laser beam are known, can processes such as laser beam cutting, welding or drilling be adjusted to the particular component geometry, materials be selected and the breadth of process windows be determined reliably.

5 System Description

The FocusParameterMonitor (FPM) is designed for the laser beam measurement. The beam quality is controlled by means of periodic measurements which ensures the process quality. The following parameters are measured

- Laser power
- Beam position and beam dimensions
- Power density distribution

The FocusParameterMonitor consists of three main components: the power measuring unit, the beam analysis unit and the PROFIBUS/PROFIINET interface. These components are included in a stable aluminium housing. An electrically operated shutter protects the beam entrance from pollution. In addition, an exchangeable protective window is integrated. It is constantly surrounded by compressed air.

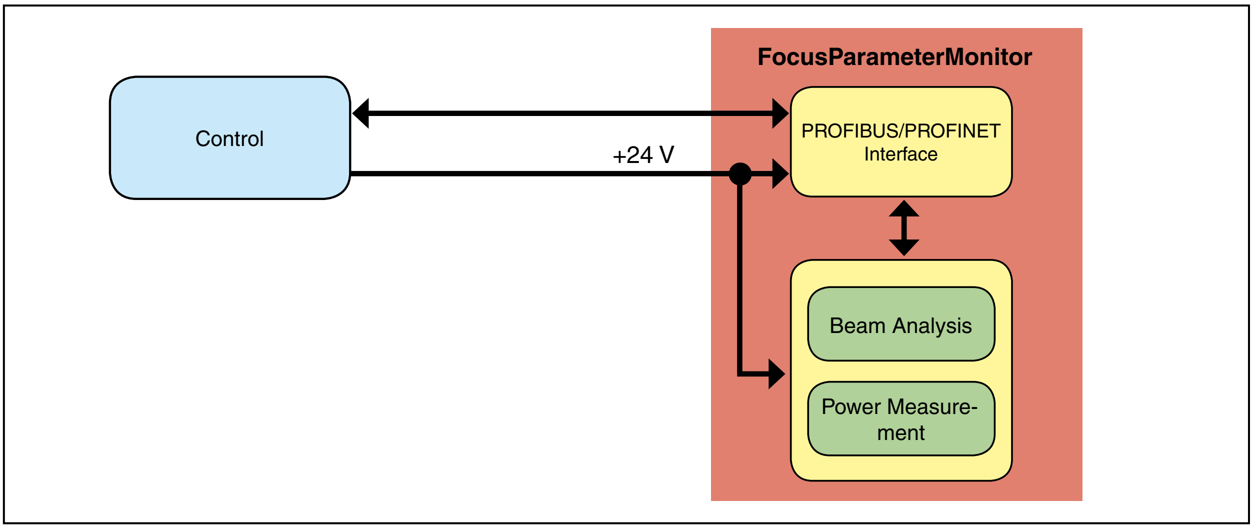


Fig. 5.1: Block diagram FocusParameterMonitor

5.1 Measuring Principle

The laser power is measured calorimetrically. Therefore, the test piece (absorber) of the power measuring unit is irradiated with the laser for a defined period of time. By means of the known heat capacity, the temperature rise of the test piece, and the measured or stipulated irradiation time, the power is measured. In the camera-based analysis system the beam geometry and the power density distribution are measured with a CCD-sensor.
The measuring data are transmitted to the system control via a Profibus interface.

5.2 Device Assembly

The beam is guided through the device via a deflection mirror. It is then guided to the PRIMES measuring components by means of a beam splitter and another deflection mirror. The power is determined by means of the power measuring unit while the beam analysis unit determines the beam geometry as well as the power density distribution.
The aperture is protected from contamination by means of an electrical shutter.

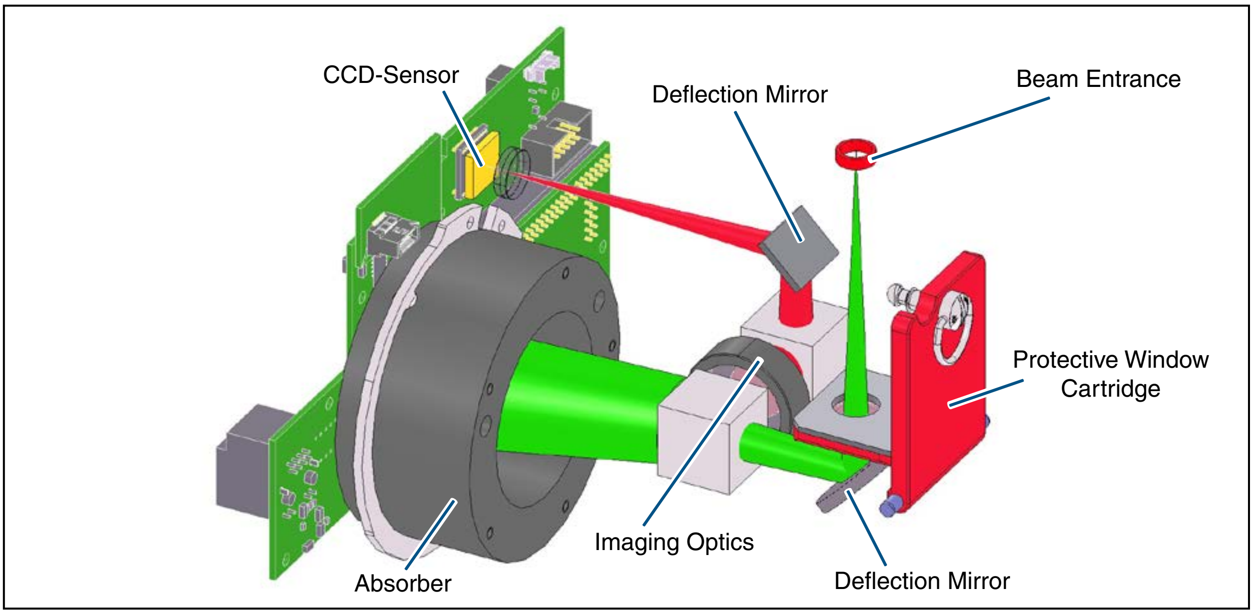


Fig. 5.2: Beam path in the FPM

Please note that the measuring plane of the FocusParameterMonitor is 2.5 mm below the entrance plane.

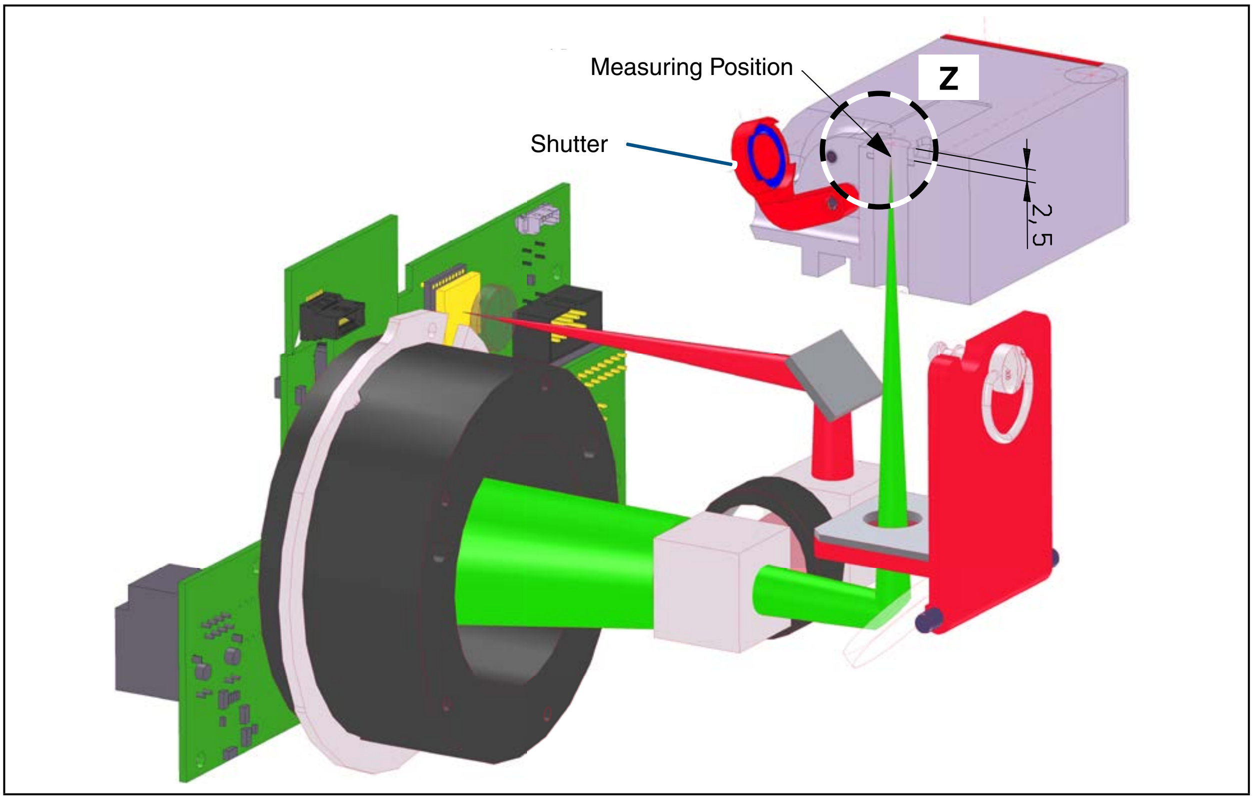


Fig. 5.3: Beam path in the FocusParameterMonitor

6 Transport

NOTICE

Danger of damage

Hard impacts or dropping can damage optical components.

- **Please be careful when transporting and installing the device!**

7 Assembly Instructions

WARNING

Injury hazard

An incorrect installation by unqualified personnel may lead to material damages or even personal injuries.

- **Read and observe the safety instructions in chapter „1 Basic Safety Instructions“ on page 7.**

7.1 Installation into the Laser System

The FPM is intended for the installation into a laser system. Therefore neither constructive nor safety related modifications may be made to the FPM unless we have given our explicit written consent. In case of any modifications, we do not accept any liability for resulting damages.

Please keep the following points in mind when installing the device.

1. First of all, the laser source has to be turned **off**.
2. Ensure that the moving parts, e.g. robot arms, etc. are at a standstill and that they cannot be set in motion unintentionally.
3. Mount the device securely in order to prevent a relative movement to the beam axis, reducing a danger posed by scattered radiation.

WARNING

Injury hazard

Moving the measuring device out of a set position can lead to scattered stray radiation during the measurement.

- **When mounting the device, please ensure that it cannot be moved, either by accidental contact or by tension on the cables.**

4. **Mounting space:** Please note that the shutter of the PMM is opened and closed during operation. A complete opening of the shutter has to be ensured (see chapter 19 on page 55). Please make sure that there is enough space to prevent a collision of the shutter with other parts of the machine as well as to exclude a hazard for the operating personnel by crushing.

7.2 Installation Position and Fastening

The FPM can be mounted both horizontally and vertically. Due to the danger of contamination we recommend a vertical mounting with a horizontal beam incidence. Align the device perpendicularly to the laser beam.

In order to avoid direct reflections into the laser system, the device can be installed offset at an angle of max. 10 mrad to the incoming beam.

In the base plate of the housing (A) as well as in the side wall (B) there are four fastening threads M6 for the fixture on a customer specific mounting (see Fig. 7.1). Please mount the housing with four screws M6. We recommend screws of the strength class 8.8 and a tightening torque of 35 N·m.

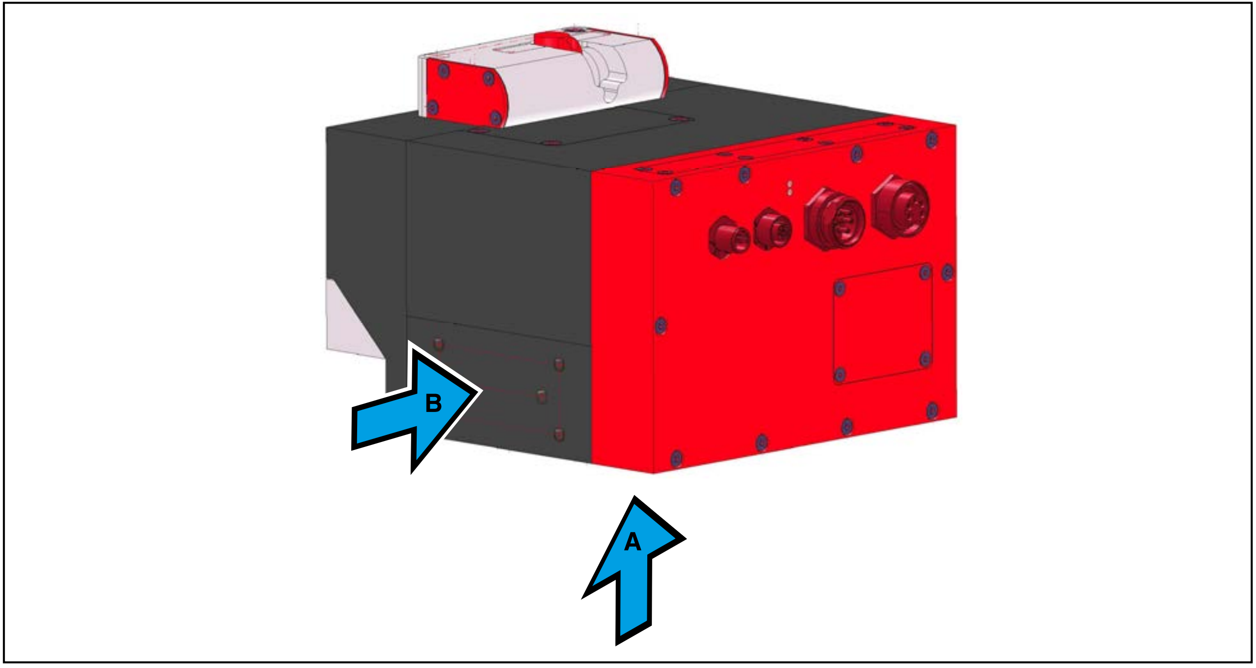


Fig. 7.1: Mounting possibilities of the FPM

NOTICE

Danger of damage

Screws which are too long can damage the screw-in thread.

- **When choosing the mounting screws, please ensure that the maximum extension into the device does not exceed 12 mm.**

7.3 Removal from the Laser System

1. First of all, the laser source has to be turned off.
2. Turn off the voltage supply.
3. Ensure that moving parts, e. g. robot arms, etc. are at a standstill and that they cannot be set in motion unintentionally.
4. Close the shutter
5. Remove all connection cables and remove the device.

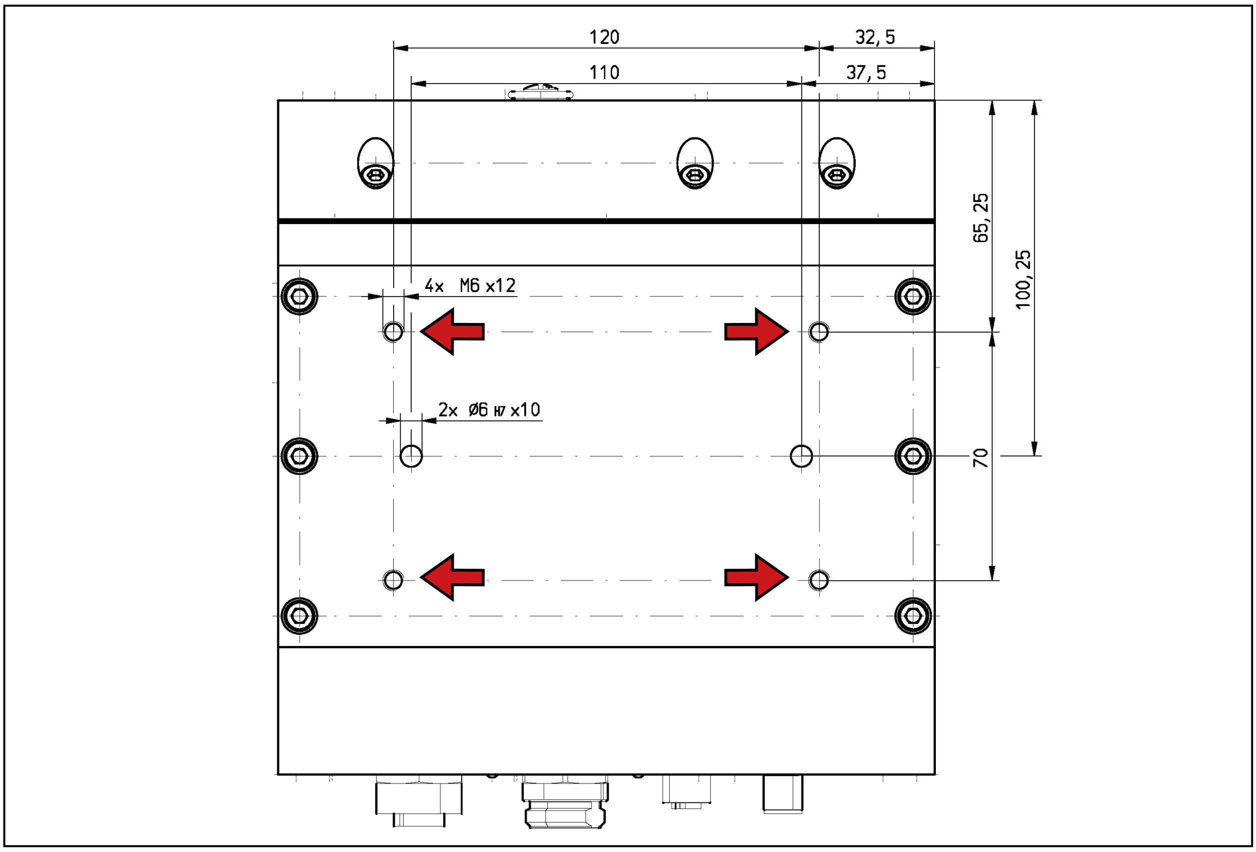


Fig. 7.2: Mounting hole in the base plate (view A)

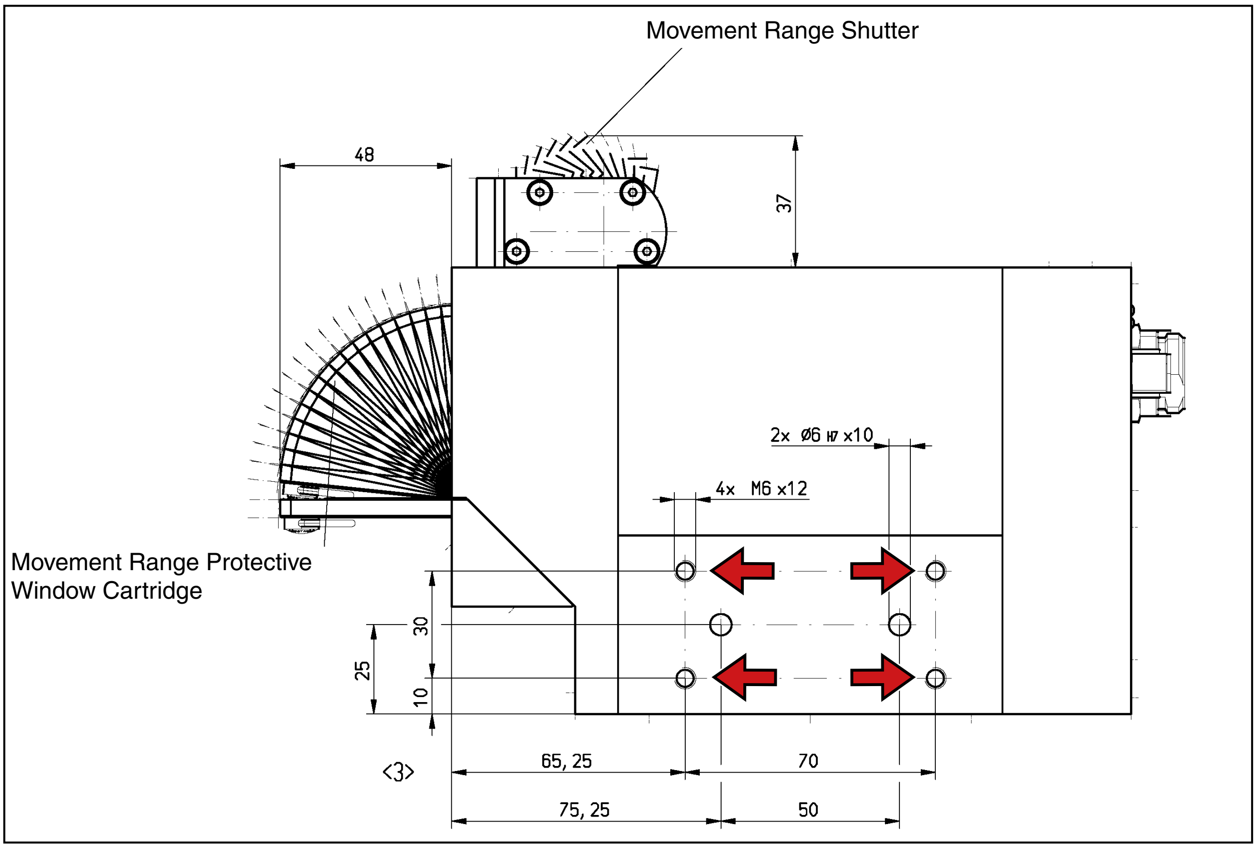


Fig. 7.3: Mounting holes in the side wall (view B)

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

8 Electrical Connection

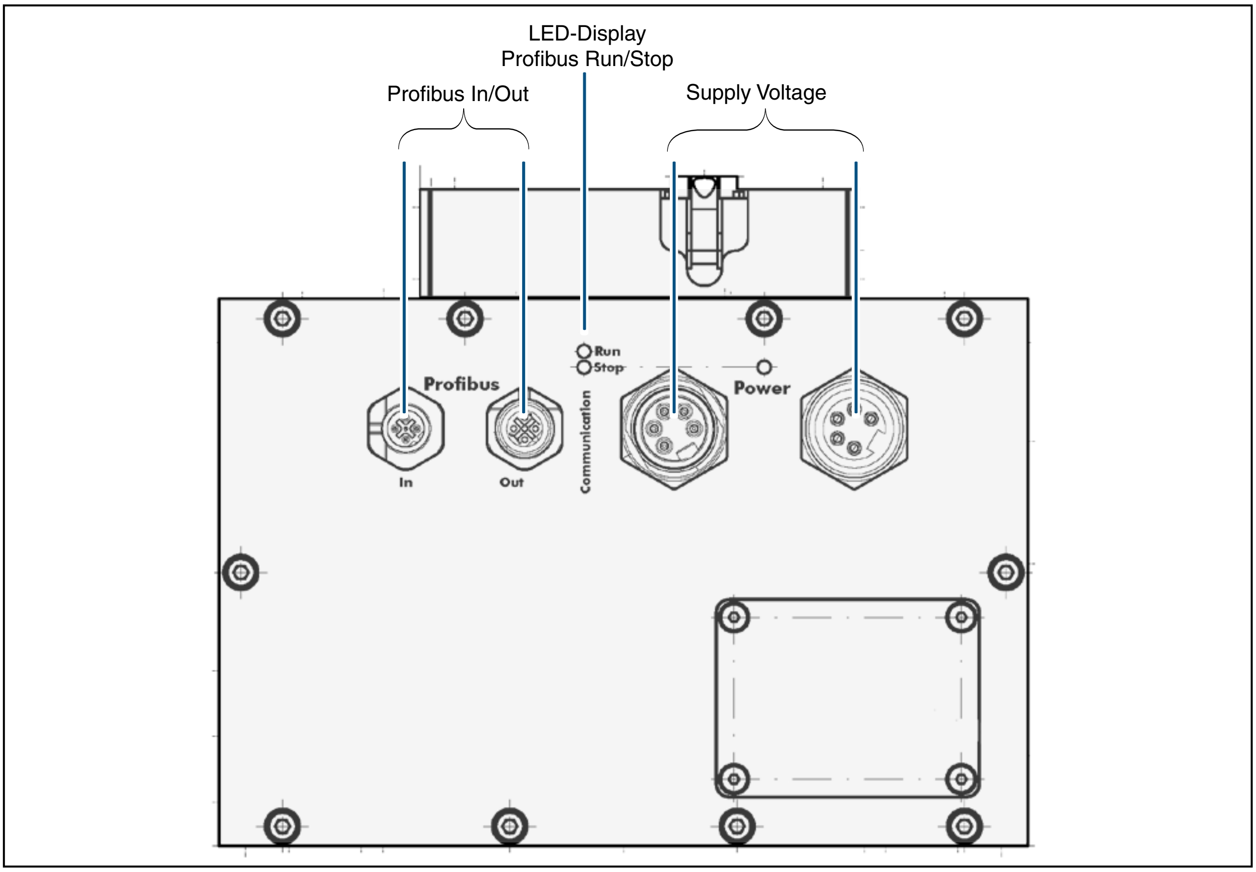


Fig. 8.1: FPM-PROFIBUS-connection side

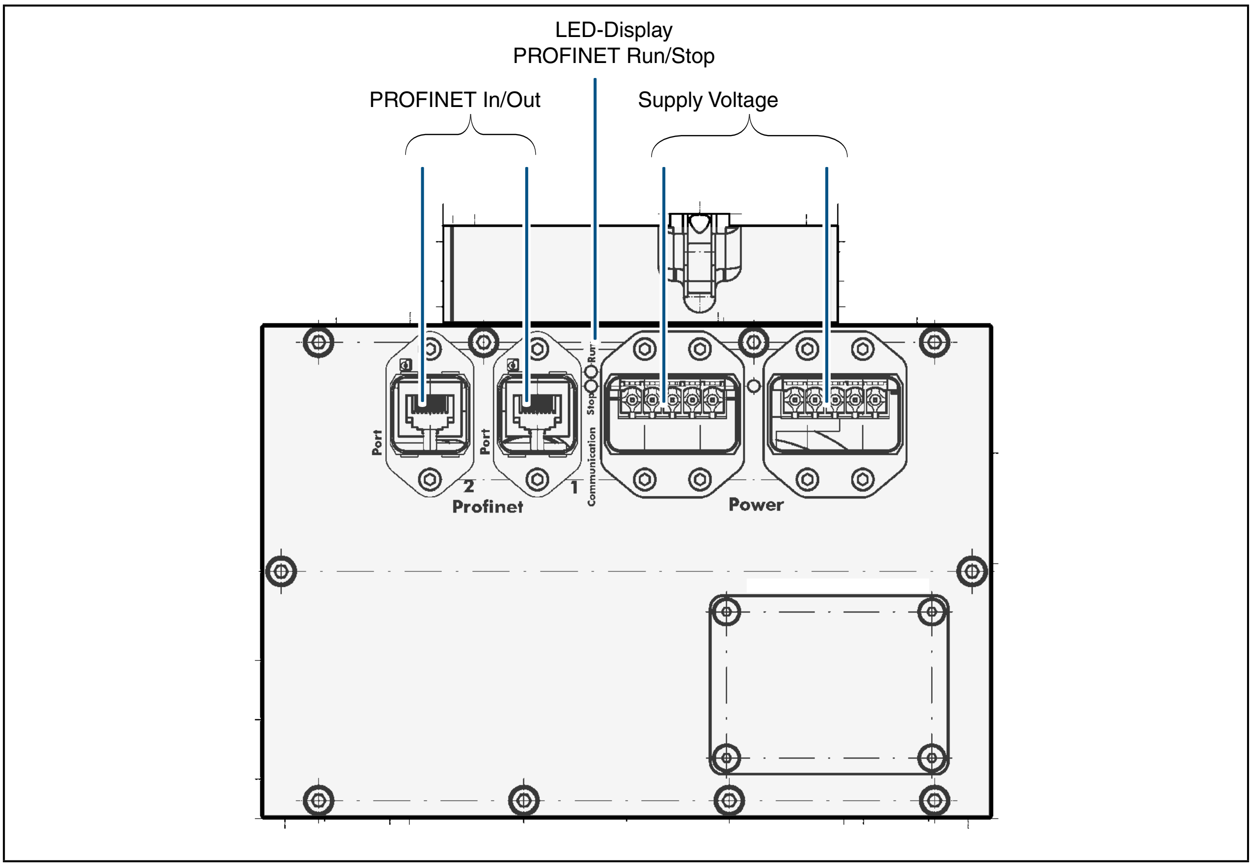
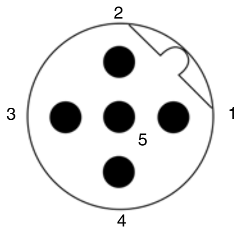
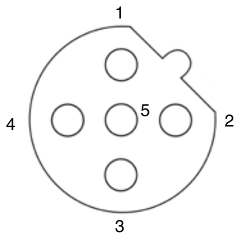


Fig. 8.2: FPM-PROFINET-connection side

8.1 PROFIBUS Data

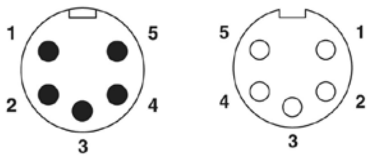
The plug or jack for PROFIBUS® is a 5-pole, B-coded M12 connector.

Plug assignment (top view plug-in side)	**Pin**	**Function**
	1	Not connected
	2	Signal A
	3	Not connected
	4	Signal B
	5	Not connected
Socket assignment (top view plug-in side)	**Pin**	**Function**
	1	+5 V
	2	Signal A
	3	ISOGND
	4	Signal B
	5	Not connected

Tab. 8.1: PROFIBUS® connector

8.2 PROFIBUS Power Supply

The power supply uses a 7/8“ connectors. Both connectors are internally connected 1:1.

Assignment (top view plug-in side)	**Pin**	**Function**
 Plug Socket	1	GND Actor
	2	GND Sensor
	3	FE
	4	Sensor supply 24 V
	5	Actuator supply 24 V

Tab. 8.2: Power supply connector

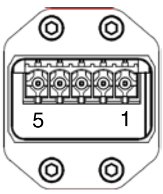
8.3 PROFINET Data Connector

The PROFINET® connectors are AIDA compatible RJ45 connectors. Both RJ45 connectors are connected internally via an integrated switch. There are two status LED's on the left side of the connector. The green LED (Tx/Rx) glows as soon as the physical connection has been established. The yellow LED glows during data transfer.

8.4 PROFINET Power Supply

The power supply is realized via the AIDA compatible connectors. Both connectors are connected internally 1:1. The power consumption of the FPM is below 500 mA, which is covered by the sensor supply.

Power-Device connector (top view plug-in side)



Pin	Function
1	+24 V Sensor power supply
2	GND Sensor power supply
3	+24 V Actor power supply
4	GND Actor power supply
5	FE

Tab. 8.3: Pin assignment power supply

9 Mechanical Connections

9.1 Compressed Air Connection

NOTICE

Danger of damage of optical components

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

▶ **Compressed air has to be clean, dry and oil-free. We recommend an additional pre-filter (typ. 0.01 µm).**

Compressed air is required to generate excess temperature in the housing, which prevents dirt particles from prenetrating. Allow for a flow rate of typ. 10 l/min ... 15 l/min.

Connect the compressed air supply by means of a plastic hose (Polyurethan) with an outer diameter of 4 mm. A pressure of 1 bar ... 2 bar should not be exceeded.

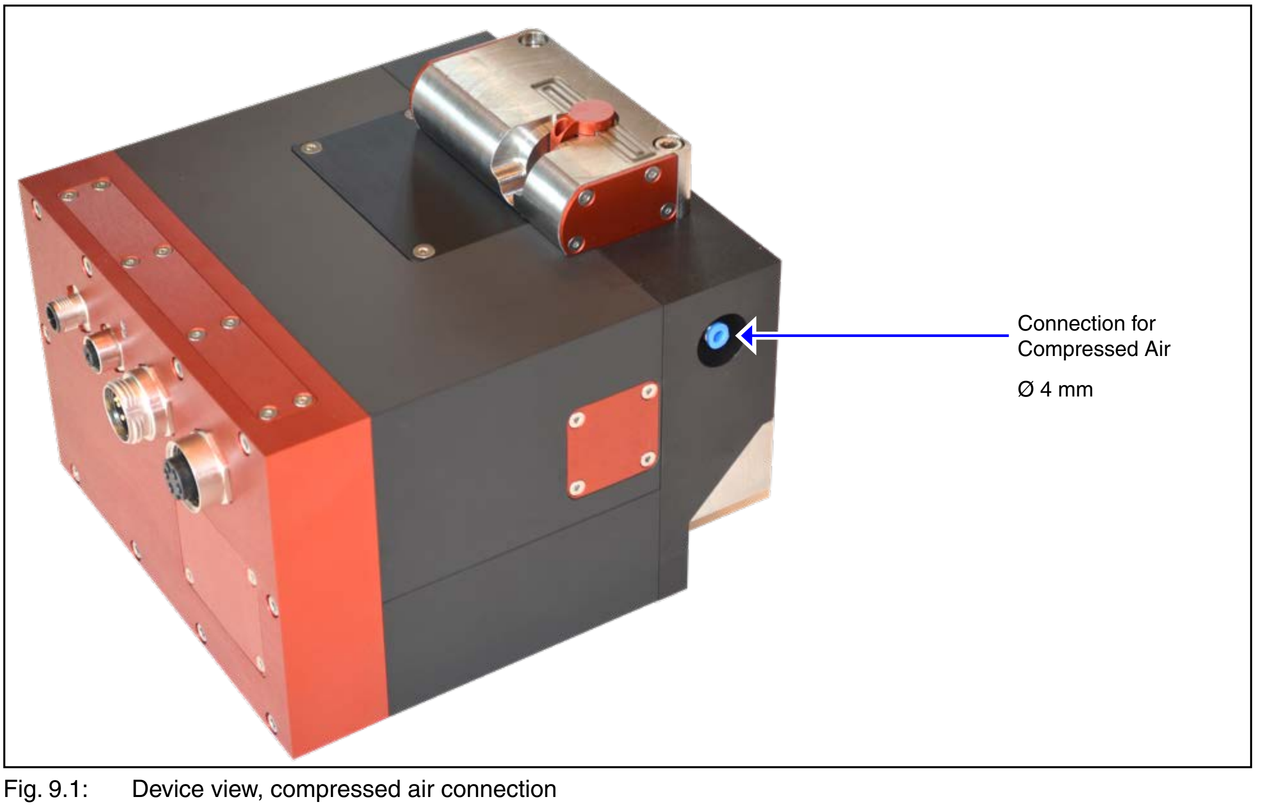


Fig. 9.1: Device view, compressed air connection

10 Setting the PROFIBUS Address

The PROFIBUS address can be set from 1 to 99. Address 17 is set ex works.

1. Remove the four screws as well as the cover of the inspection opening.
2. The desired bus address can be set by means of the rotary switches A and B. The arrowhead of the rotary switch has to point at the respective figure.

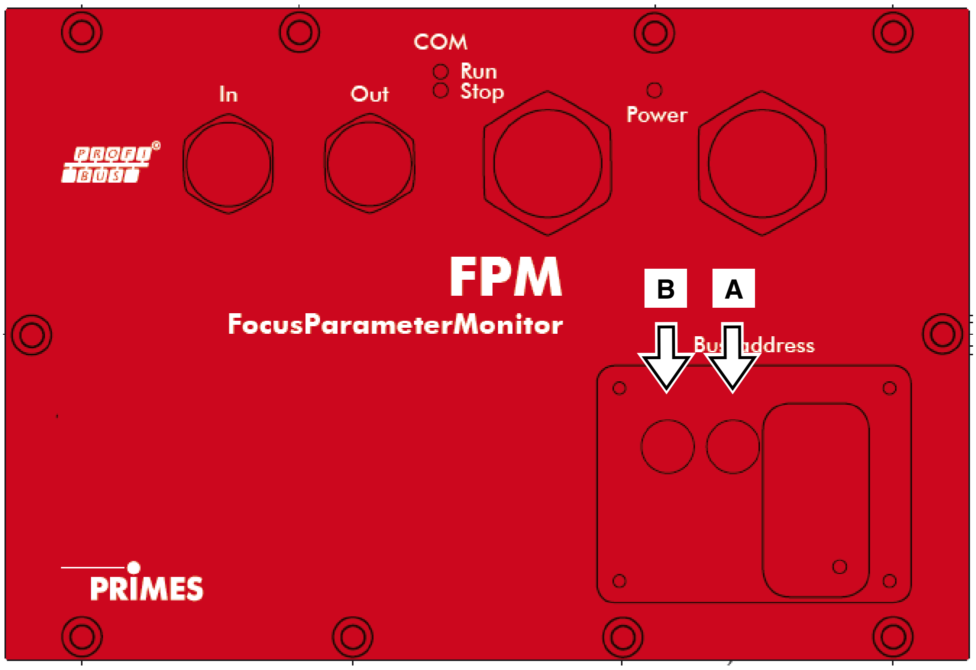


Fig. 10.1: Rotary switch in inspection opening

Please mind that it is a two-digit address. Switch A is used for the first digit (tens), switch B sets the second digit (ones).

3. Insert the cover into the inspection opening and screw it.

11 Measurement Settings

In case of subsequent measurements, the residual capacity of the absorber for another laser pulse has to be considered.

NOTICE

Risk of damage caused by overheating

If the residual application of energy before a measurement is not taken into account, the absorber can be damaged or destroyed.

- **Before triggering a measurement sequence (for caustic measurements before every single plane measurement), observe the remaining capacity (variable "PMM result: remaining_capacity") and the absorber temperature ("PMM result: absorber temperature").**
- **Also note any over-temperature warnings of the device ("PMM status: too hot" flag is set).**

Example:

With a laser power of 2 kW and an irradiation time of 200 ms, 400 J are absorbed.

$E = P \cdot t = 2000\ W \cdot 0.2\ s = 400\ J$

11.1 Store Setup

You can store four different measurement settings (setups) using bits 256.0 to 256.3. In order to carry out a measurement with the stored settings, the bit corresponding to the desired setup must be set to 1. If none of these bits are set to 1, the measurement will be carried out with the parameters stored in the controller (address 256.5 to 276, see chapter 14.2 on page 47).

The starting state of the system cannot be set as "SaveSetupParams", "Start Measurement", or "Calc Caustic". The FPM must be in the "idle" operating condition.

System	FocusParameterMonitor
Sets parameters for setup/measurement	
Sets "ReadSetupParams"	
	Reads parameters for setup
	Sets "SetupParamsRead"
	Deletes "Idle"
Deletes "ReadSetupParams"	
Sets "SaveSetupParams"	
	Deletes "SetupParamsRead"
	Sets "Idle"
Deletes "SaveSetupParams"	

11.2 Determine Exposure Time

The FPM is designed to measure single pulses and doesn't feature any automated adjustment of the exposure time. This makes it necessary to determine the appropriate exposure time for the various beam configurations. The combination of the parameters and measuring results delivered through the field bus offer a way to do this. The settings based on the transmitted results must be illustrated and explained here.

Other than preparing it for measuring, no settings are necessary for performance measurement. Only the parameters relevant for setting the exposure time are scrutinized. The remaining settings are not changed during the process and are configured as follows:

Address	Parameter	Value	Note
268	Trigger level	2000	Set value for pulse detection [cts]
264	Trigger delay	0	Delayed start of the measurement [µs]
270	Attenuation	0	[dB]; is not used here
276	Beam position Z	0	Only for documentation [µm]
260	BeamFindCounts	200	Settings for beam search
262	BeamFindPercent	30	
280	Resolution X	512	Maxmium resolution
282	Resolution Y	256	
284	Window size x	2240	Maximum asymmetrical measurement window **(caution: device-specific), values are noted on the device.**
286	Window size y	1493	
288	Window position x	0	Offset to centering of the measurement window on the camera chip
288	Window position y	0	
256.0	Setup 1	0	No setup use
256.1	Setup 2	0	
256.2	Setup 3	0	
256.3	Setup 4	0	
257.0	Measurement mode 0	FALSE	Normal measurement with measurement result transmission
257.1	Measurement mode 1	FALSE	
257.2	Evaluation 0	FALSE	Evaluation with 2 Moments
257.3	Evaluation 1	FALSE	
257.4	Integration time unit	TRUE	Exposure is controlled via the exposure time
257.5	Automatic exposure	FALSE	Deactivated, single pulse measurement
257.7	Simplified measurement	TRUE	Mode for single pulse measurement
258.0	External trigger	FALSE	Use of integrated pulse detection
258.1	Trigger mode 0	FALSE	Deactivation of the cw measurement
258.2	Trigger mode 1	TRUE	
258.3	Read setup parameter	FALSE	Handshake signals for storing a setup
258.4	Save setup parameter	FALSE	

The measurement procedure must be correctly integrated and implemented (e.g. the handshake for triggering a measurement).

Necessary control parameter (OUT):

272	Exposure time	20000	[µs]; 20ms as output value

Necessary result parameters (IN):

326	% overmodulation	Percentage of area of measured beam that is overmodulated
342	Exposure time used	[µs]; value as specified in output
346	Optimal exposure time	From the measurement of calculated optimal exposure time
282.5	Irradiation failure	General warning for measurement
292	WarnSingle	Warning code for the last measurement

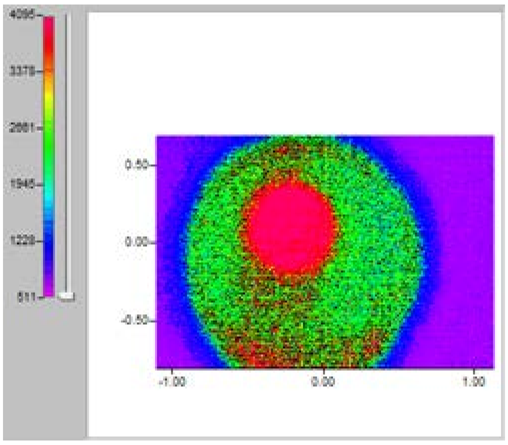
The internal evaluation uses the results of a measurement to calculate the idea exposure time. For this approximately 3300-3500 cts is achieved in the measurement in order to balance out minimal fluctuations in output.
When the exposure time is close to what is optimal, so there is only slight over or underexposure, this calculation provides reliable values.
If the exposure time is too long, several iterative steps are necessary in order to reach the optimal range.
If the exposure time is too short, there may not be enough of a signal to facilitate an evaluation. The resulting values will then be unrealistic and the optimal setting for the exposure time incalculable.

It is therefore best to start with specifications for an exposure time that may be too long and then take several steps to determine the optimal setting.

The following example starts off with an exposure time that is as along as possible, with the FPM already delivering good measurement results.
Exposure times of 200 µs and 35 ms are used as a reference point for usable measurements.

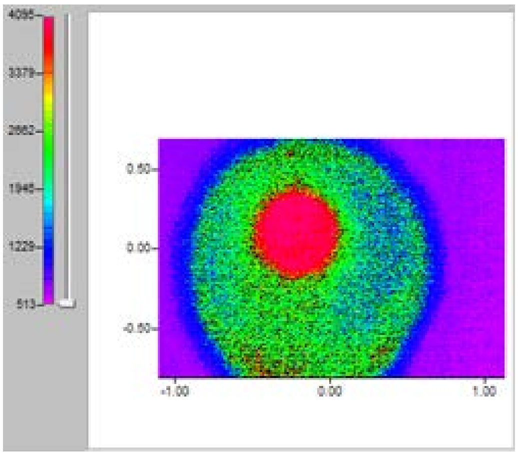
Measurement data for each iterative step is read and illustrated in order to visually show the optimization process.

EB	326	"% des Strahls überst."	DEZ	21
ED	342	"verw. Belichtungszeit"	DEZ	L#10035
ED	346	"optimale Belichtungszeit"	DEZ	L#7767
AD	272	"Belichtungszeit"	DEZ	L#10000
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#001F



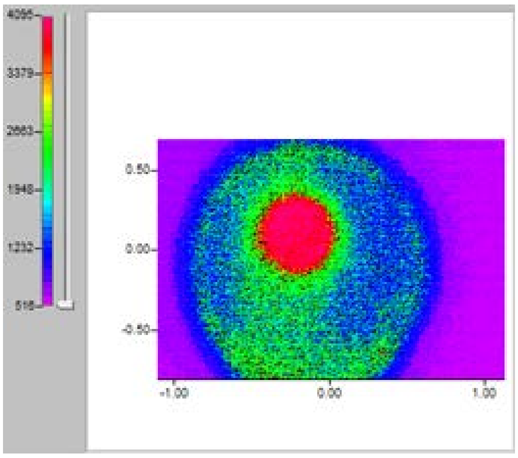
Here the measurement is overmodulated and the beam reaches out to the edge of the measurement window. A considerable part of the beam surface is overmodulated.

EB	326	"% des Strahls überst."	DEZ	13
ED	342	"verw. Belichtungszeit"	DEZ	L#7790
ED	346	"optimale Belichtungszeit"	DEZ	L#6029
AD	272	"Belichtungszeit"	DEZ	L#7767
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#001F

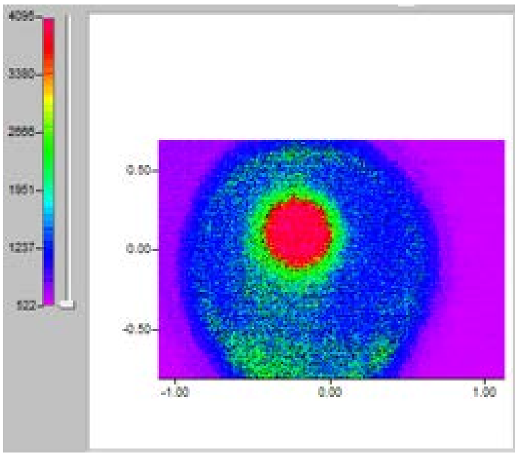


The overmodulated portion of the beam surface will decrease in the upcoming measurements...

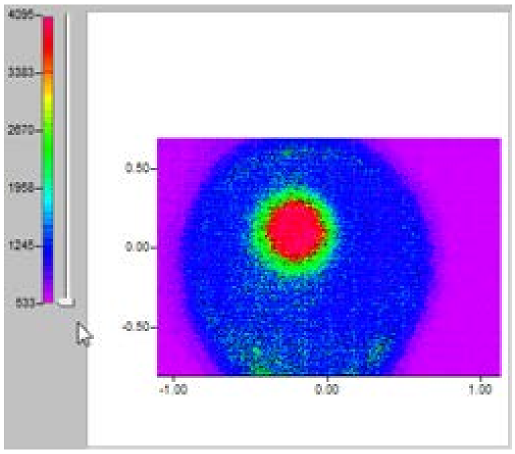
EB	326	"% des Strahls überst."	DEZ	9
ED	342	"verw. Belichtungszeit"	DEZ	L#6047
ED	346	"optimale Belichtungszeit"	DEZ	L#4680
AD	272	"Belichtungszeit"	DEZ	L#6029
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#001F



EB	326	"% des Strahls überst."	DEZ	7
ED	342	"verw. Belichtungszeit"	DEZ	L#4694
ED	346	"optimale Belichtungszeit"	DEZ	L#3633
AD	272	"Belichtungszeit"	DEZ	L#4680
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#001F

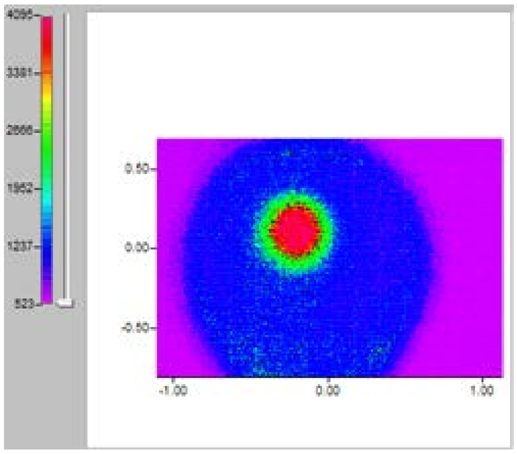


EB	326	"% des Strahls überst."	DEZ	5
ED	342	"verw. Belichtungszeit"	DEZ	L#3643
ED	346	"optimale Belichtungszeit"	DEZ	L#2820
AD	272	"Belichtungszeit"	DEZ	L#3633
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#000F

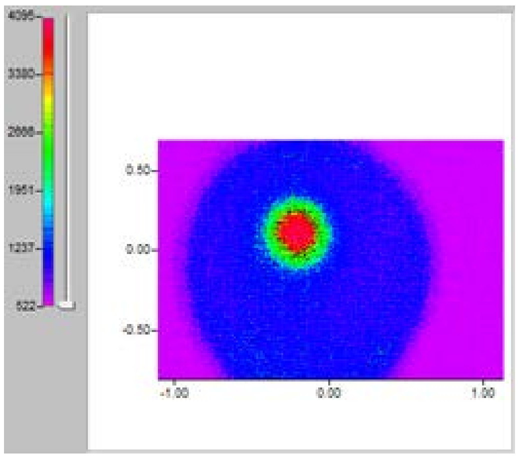


...ever more until the limit value for overmodulation of 5% of the exposure surface is exceeded. So the warning code for the entry for overmodulation goes away. The maximum modulation in the illustration of the measurement data is still at a maximum of 4096 cts.

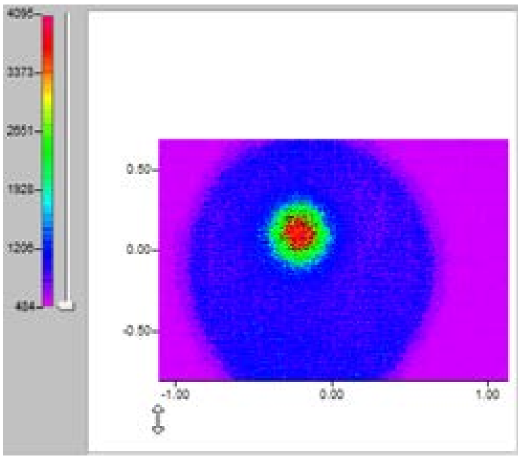
EB	326	"% des Strahls überst."	DEZ	3
ED	342	"verw. Belichtungszeit"	DEZ	L#2828
ED	346	"optimale Belichtungszeit"	DEZ	L#2190
AD	272	"Belichtungszeit"	DEZ	L#2820
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#000F



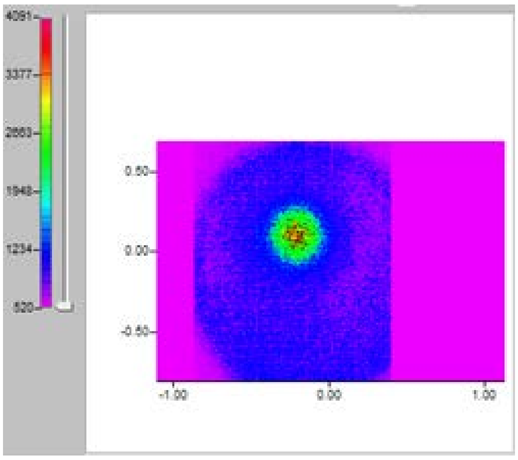
EB	326	"% des Strahls überst."	DEZ	1
ED	342	"verw. Belichtungszeit"	DEZ	L#2195
ED	346	"optimale Belichtungszeit"	DEZ	L#1700
AD	272	"Belichtungszeit"	DEZ	L#2190
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#000F



EB	326	"% des Strahls überst."	DEZ	0
ED	342	"verw. Belichtungszeit"	DEZ	L#1704
ED	346	"optimale Belichtungszeit"	DEZ	L#1320
AD	272	"Belichtungszeit"	DEZ	L#1700
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#000F

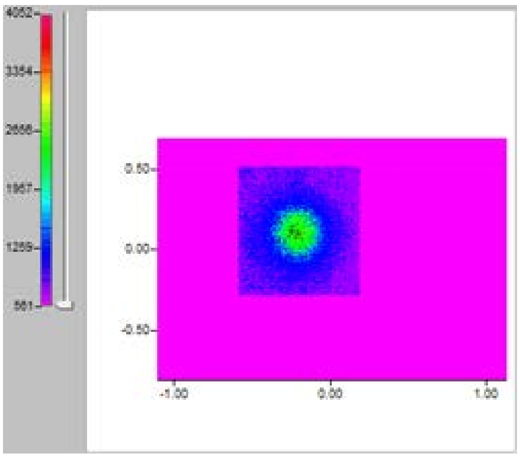


EB	326	"% des Strahls überst."	DEZ	0
ED	342	"verw. Belichtungszeit"	DEZ	L#1323
ED	346	"optimale Belichtungszeit"	DEZ	L#1026
AD	272	"Belichtungszeit"	DEZ	L#1320
E	282.5	"Irradiation failure"	BOOL	true
E	288.2	"GroupWarnSingle"	BOOL	true
EW	292	"WarnSingle"	HEX	W#16#000C



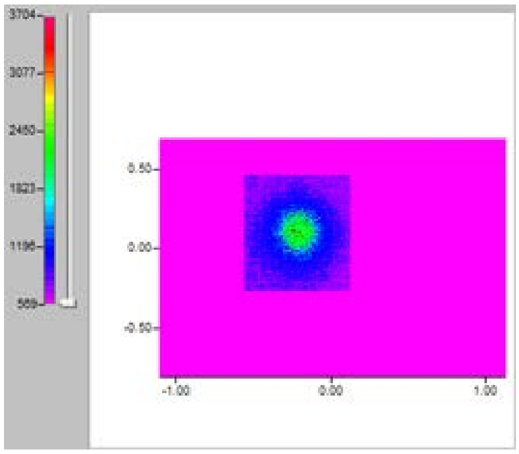
The maximum value of the measurement data is no longer at the edge of the value range. The automatic measuring window adjustment starts to cut the measuring area for better assessment.

EB	326	"% des Strahls überst."	DEZ	0
ED	342	"verw. Belichtungszeit"	DEZ	L#1027
ED	346	"optimale Belichtungszeit"	DEZ	L#805
AD	272	"Belichtungszeit"	DEZ	L#1026
E	282.5	"Irradiation failure"	BOOL	false
E	288.2	"GroupWarnSingle"	BOOL	false
EW	292	"WarnSingle"	HEX	W#16#0000

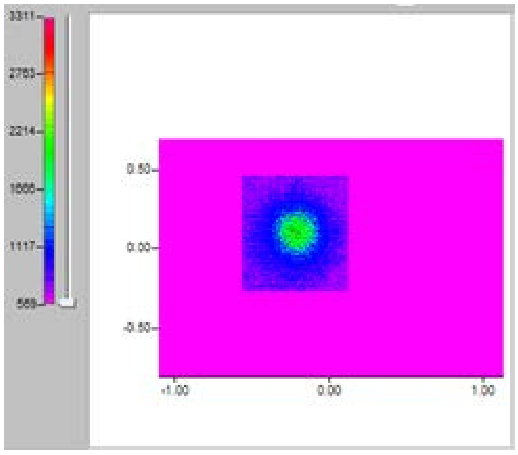


The ROI (region of interest) situated around the actual beam can now be correctly determined. The maximum value of the measurement data doesn't yet lie in the desired window.

EB	326	"% des Strahls überst."	DEZ	0
ED	342	"verw. Belichtungszeit"	DEZ	L#806
ED	346	"optimale Belichtungszeit"	DEZ	L#702
AD	272	"Belichtungszeit"	DEZ	L#805
E	282.5	"Irradiation failure"	BOOL	false
E	288.2	"GroupWarnSingle"	BOOL	false
EW	292	"WarnSingle"	HEX	W#16#0000



EB	326	"% des Strahls überst."	DEZ	0
ED	342	"verw. Belichtungszeit"	DEZ	L#702
ED	346	"optimale Belichtungszeit"	DEZ	L#699
AD	272	"Belichtungszeit"	DEZ	L#702
E	282.5	"Irradiation failure"	BOOL	false
E	288.2	"GroupWarnSingle"	BOOL	false
EW	292	"WarnSingle"	HEX	W#16#0000



The modulation of the measurement is now in the desired range. This way the optimal exposure time is very close to that used for the last measurement.
These steps complete the determination process for optimal exposure time for a laser power stage and beam geometry.

12 Measuring

12.1 Measuring Procedure Power Measurement

System	FocusParameterMonitor
Sets command.start	
	If Shutter is open:
	Deletes status.idle
	Sets status.acknowledge
Deletes command.start	
	Deletes status.acknowledge
	Ensures readiness for operation
	Deletes status.measurement_finished
	Sets status.ready
Turns on the laser	
Turns off the laser (after the necessary irradiation time)	
	The irradiation carried out is identified (by means of the temperature rise of the test piece)
	Deletes status.ready
	Sets status.measurement_running
	Waits for thermalization (11 s)
	Optionally: detects the irradiation time
	Carries out power measurement
	Enters results into the profibus register
	Deletes status.measurement_running
	Sets status.idle
	Sets status.measurement_finished
Reads out the results	

12.2 Measuring Procedure Focus Measurement (untriggered)

System	FocusParameterMonitor
Sets parameters for measurement	
Sets command.start	
	Deletes status.idle
	Deletes status.measurement_finished
	Deletes errorflags and -identification
	Reads parameters for the measurement (from the setup or the profibus)
	Sets status.ready_for_measurement
	Sets status.acknowledge
If status.ready_for_measurement ==1: turns on the laser	
If laser is on and status.acknowledge == 1: deletes command.start"	
	Deletes status.acknowledge
	Sets status.measurement_running
	Starts the measurement
	When the measurement is finished: deletes status.measurement_run-ning
	Deletes status.ready_for_measurement
Turns off the laser (after the necessary irradiation time)	
	Calculates parameters
	Enters parameters into Profibus register or error detections
	Sets status.measurement_finished
	Sets status.idle
Reads out results/error detections	

12.3 Measuring Procedure Focus Measurement (triggered)

System	FocusParameterMonitor
Sets parameters for the measurement	
Sets command.start	
	Deletes status.idle
	Deletes status.measurement_finished
	Deletes Errorflags and -identification
	Reads parameters for the measurement (from the setup or the profibus)
	Sets status.acknowledge
If status.acknowledge == 1: deletes command.start	
	Deletes status.acknowledge
	Sets status.measurement_running
	Sets status.ready_for_measurement
If status.ready_for_measurement==1: turns on the laser	
	Laser is detected (trigger)
	Starts the measurement
	When the measurement is finished: deletes status.measurement_running
	Deletes status.ready_for_measurement
Turns off the laser (after the necessary irradiation time)	
	Calculates parameters
	Enters parameters into Profibus register or error detections
	Sets status.measurement_finished
	Sets status.idle
Reads out results/error detections	

12.4 Measuring Procedure Combined Measurement

System	FocusParameterMonitor
Sets command.start for power module	
	If shutter is open:
	Power module deletes status.idle
	Power module sets status.acknowledge
Deletes command.start for power module	
	Power module deletes status.acknowledge
	Power module ensures readiness for operation
	Power module deletes status.measurement_finished
	Power module sets status.ready
Sets parameters for measurement with focus module	
Sets command.start for focus module	
	Focus module deletes status.idle and status.measurement_fin-ished
	Focus module deletes Errorflags and -identification
	Focus module reads parameters for the measurement (from the setup or from the Profibus)
	In case of a untriggered measurement: Focus module sets status. ready_for_measurement
	Focus module sets status.acknowledge
„In case of a untriggered measurement: if status.ready_for_measurement==1: turns on laser“	
If status.acknowledge == 1 (and the laser is on in case of a untriggered measurement): deletes command.start for focus module	
	Focus module deletes status.acknowledge
	Focus module sets status.measurement_running
	In case of a triggered measurement: Focus module sets status. ready_for_measurement
„In case of a triggered measurement: if status. ready_for_measurement==1: turns on the laser“	
	In case of a triggered measurement: Laser is detected by the Focus module (trigger)
	Focus module starts measurement
	When the measurement is finished: Focus module deletes status. measurement_running
	Focus module deletes status.ready
Turns off the laser (after the necessary irradia-tion time)	
	Focus module calculates parameters
	Focus module enters parameters into Profibus register or error detections
	Focus module sets status.measurement_finished
	Focus module sets status.idle

System	FocusParameterMonitor
Reads out focus module results	
	Irradiation carried out is detected by the power module (temperature rise)
	Power module deletes status.ready
	Power module sets status.measurement_running
	Power module waits for thermalization (11 s)
	Optionally: Power module detects irradiation time
	Power module carries out power measurement
	Power module enters results into Profibus register
	Power module deletes status.measurement_running
	Power module sets status.measurement_finished
	Power module sets status.idle
Reads out power module results	

12.5 Measuring Procedure Caustic Measurement

System	FocusParameterMonitor
Sets command.caustic_measurement	
Sets parameter for caustic and for measure-ment	
Sets command.start	
	Deletes status.idle
	Deletes status.measurement_finished
	Deletes errorflags and -identification
	Reads parameters for the measurement (from the setup or the profibus)
	Sets status.caustic_measurement_running
	Sets status.ready_for_measurement
	Sets status.acknowledge
"If status.acknowledge == 1: deletes command.start"	
	Deletes status.acknowledge
	Sets status.measurement_running
	Starts the measurement
	When the measurement is finished: deletes status.measurement_ running
	Deletes status.ready_for_measurement
	Calculates parameters
	Enters parameters into Profibus register or error detections
	Sets status.measurement_finished
	Sets status.idle
Repeat from "Sets parameter for caustic and for measurement", for all planes	
Sets command.calculate_caustic	
	Deletes status.caustic_measurement_running
	Carries out caustic fit, calculates beam parameter
	Enters parameters into Profibus register or error detections
	Sets status.caustic_measurement_finished
Reads out focus results/ error detections	
Deletes command.calculate_caustic	
NOTICE! Setting and deleting command. calculate_caustic must also be performed if the caustic measurement is to be aborted (for example, because plane results are invalid).	

12.6 Timing Diagram Power Measurement

As soon as the shutter is open, the device is ready for operation. In order to initialize the measuring device for the measurement, the bit „start" has to be set in the "Command"-byte by the external control (see Fig. 12.1).

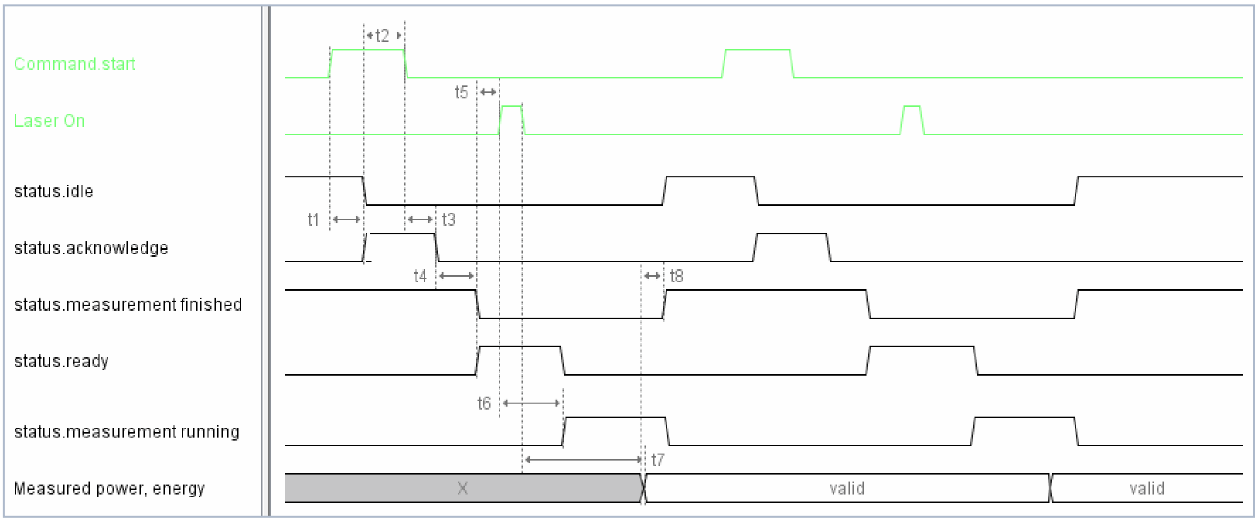


Fig. 12.1: Timing diagram power measurement

t1: To confirm that the start command has been received, the measuring device sets the "Acknowledge" flag and deactivates "Idle".

t2: Then the "Start" command must be deactivated.

t3: Once "Start" has been deactivated again, "Acknowledge" is deactivated.

t4: Once it is ready to measure, "Measurement Finished" is deactivated and"Ready" is set.

t5: The laser pulse can then be triggered (shoot at the test piece for the calculated period of time or optional pulse length measurement).

t6: After a short time, the measuring device will detect the laser pulse due to the increase in temperature of the test piece. The "Ready" is deactivated and the thermalization phase of the test piece is displayed in the status byte by the "Measurement Running" bit.
After about 1 s, the shutter can be closed again ("PMM_do_close_shutter" flag set).

t7: After the thermalization phase ends (approx. 11 seconds), the pulse length can be determined if applicable and the measuring results (power, energy) calculated.

t8: Once calculations are finished, the results log is populated; "Measurement Running" is deactivated, and it is set to "Measurement Finished" and "Idle". The results can now be read out.

12.7 Timing Diagram Focal Point Measurement (Untriggered)

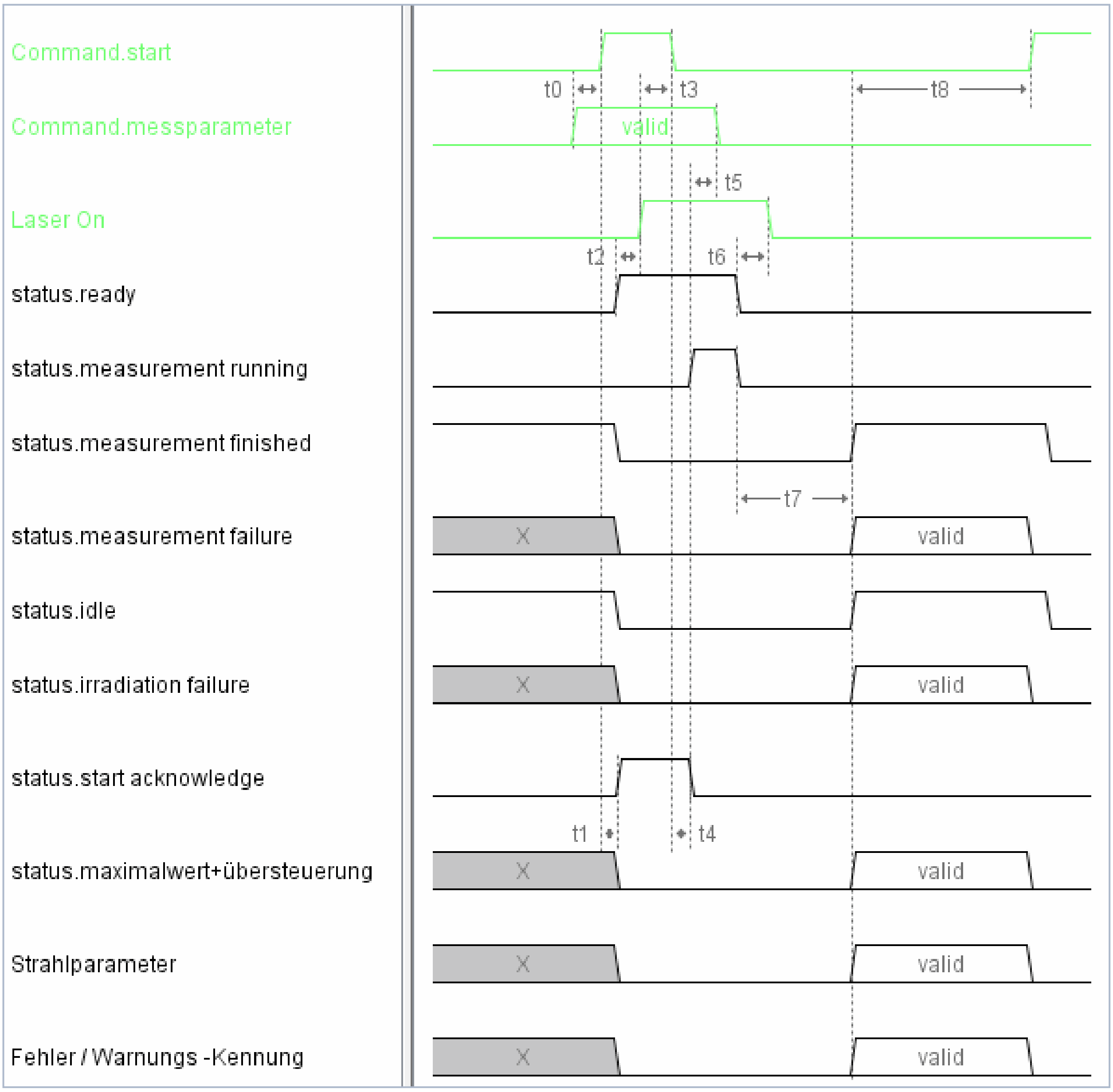


Fig. 12.2: Timing diagram for focal point measurement (untriggered)

t0: The measuring parameters (setup no. or detailed measuring parameters) must be set before the "Start" flag is set.

t1: To confirm that the start command and measuring parameters have been received, the "Start Acknowledge" flag is set and "Idle" and "Finished" deactivated. Likewise, the results log, the failure flags, and the failure identifiers are also deactivated.

For an untriggered measurement, the "Ready" flag is set at the same time to indicate that the laser can be switched on.

t2: Once "Ready" is set, the laser pulse should be triggered "Laser On".

t3: Only then can the “Start” flag be deactivated, since the measurement starts after that (this only applies to untriggered measurements; with triggered measurements, “Start Acknowledge” can be acknowledged directly by deactivating “Start”).

t4: Once “Start” has been deactivated again, “Start Acknowledge” is deactivated and “Measurement Running” set.

t5: Once “Start Acknowledge” has been deactivated again, this means that the measuring parameters have been imported; they can then be modified as desired (e.g. in preparation for the next measurement).

t6: Once the actual measurement has come to an end, “Measurement Running” and “Ready” are deactivated. From this point on, the laster pulse “Laser On” can be switched off, since it will not be needed for subsequent calculations.

t7: Once calculations have been completed (or a fatal failure has occurred), the flags are set to “Finished” and “Idle”.

If the “Measurement Failure” flag is activated, a fatal error has occurred and the measurement or calculation has been disrupted. The cause of the failure is coded in the “Error Identified” log.

If “Measurement Failure” is not set, the measurement and calculation has been successfully performed and the results can be found in the “Beam Parameter” results log. The maximum value of the raw data and an indication of how many pixels were overloaded is coded in the high byte of the status value.

It is possible that the “Irradiation Failure” flag has been set; in that case, a non-fatal failure has occurred (measurement overloaded or underloaded, beam on the edge of the measurement window). The cause is coded in the “Warning Identifier” log. Beam parameters have been determined, however, and these are available in the results registers.

t8: Results as well as failure flags and identifiers are maintained until the next measurement is initiated by “Start”.

t9: With a triggered measurement, the measuring process is initiated once “Start” is deactivated and continues until the point at which the device is ready to measure and is waiting to be triggered (laser detected).

t10: “Ready” is then set to show that the laser should now be switched on, “Laser On”. The laser pulse shouldn’t have been triggered in advance, since in that case it could be gone by the time the device is ready to measure!

t11: In this case as well, “Measurement” and “Ready” are deactivated after the end of the actual measurement. From that point on, the laser pulse “Laser On” can be switched off.

12.8 Timing Diagram Focal Point Measurement (Triggered)

The following timing diagram shows a triggered measurement. This is the standard case.

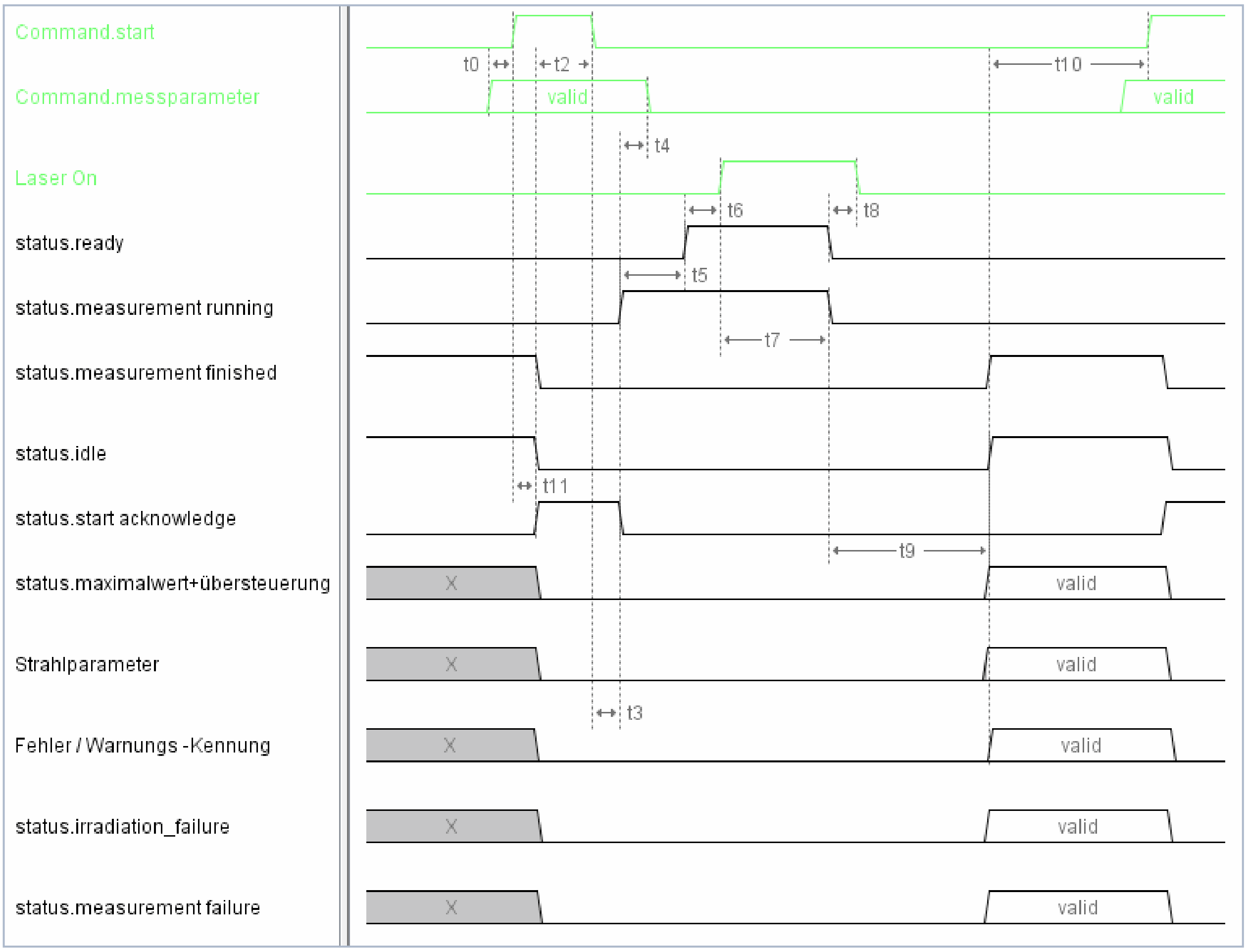


Fig. 12.3: Timing diagram for focal point measurement (triggered)

T0: The measuring parameters (setup no. or detailed measuring parameters) must be set before the “Start” flag is set.

t1: To confirm that the start command and measuring parameters have been received, the “Start Acknowledge” flag is set and “Idle” and “Finished” deactivated. Likewise, the results log, the failure flags, and the failure identifiers are also deactivated.

t2: Then the “Start” flag can be deactivated.

t3: Once “Start” has been deactivated again, “Start Acknowledge” is deactivated and “Measurement Running” set.

t4: Once “Start Acknowledge” has been deactivated again, this means that the measuring parameters have been imported; they can then be modified as desired (e.g. in preparation for the next measurement).

t5: Once it is ready to measure, it is set to “Ready”. “Laser On” indicates that the laser should now be switched on. The laser pulse shouldn’t have been triggered in advance, since in that case it could be gone by the time the device is ready to measure!

t6: The laser pulse triggers the actual measurement.

t7: Once this has come to an end, “Measurement Running” and “Ready” are deactivated.

t8: From this point on, the laster pulse “Laser On” can be switched off, since it will not be needed for subsequent calculations.

t9: Once calculations have been completed (or a fatal failure has occurred), the flags are set to “Finished” and “Idle”.

If the “Measurement Failure” flag is activated, a fatal error has occurred and the measurement or calculation has been disrupted. The cause of the failure is coded in the “Error Identified” log.

If “Measurement Failure” is not set, the measurement and calculation has been successfully performed and the results can be found in the “Beam Parameter” results log. The maximum value of the raw data and an indication of how many pixels were overloaded is coded in the high byte of the status value.

It is possible that the “Irradiation Failure” flag has been set; in that case, a non-fatal failure has occurred (measurement overloaded or underloaded, beam on the edge of the measurement window). The cause is coded in the “Warning Identifier” log. Beam parameters have been determined, however, and these are available in the results registers.

t10: Results as well as failure flags and identifiers are maintained until the next measurement is initiated by “Start”.

12.9 Timing diagram caustic measurement

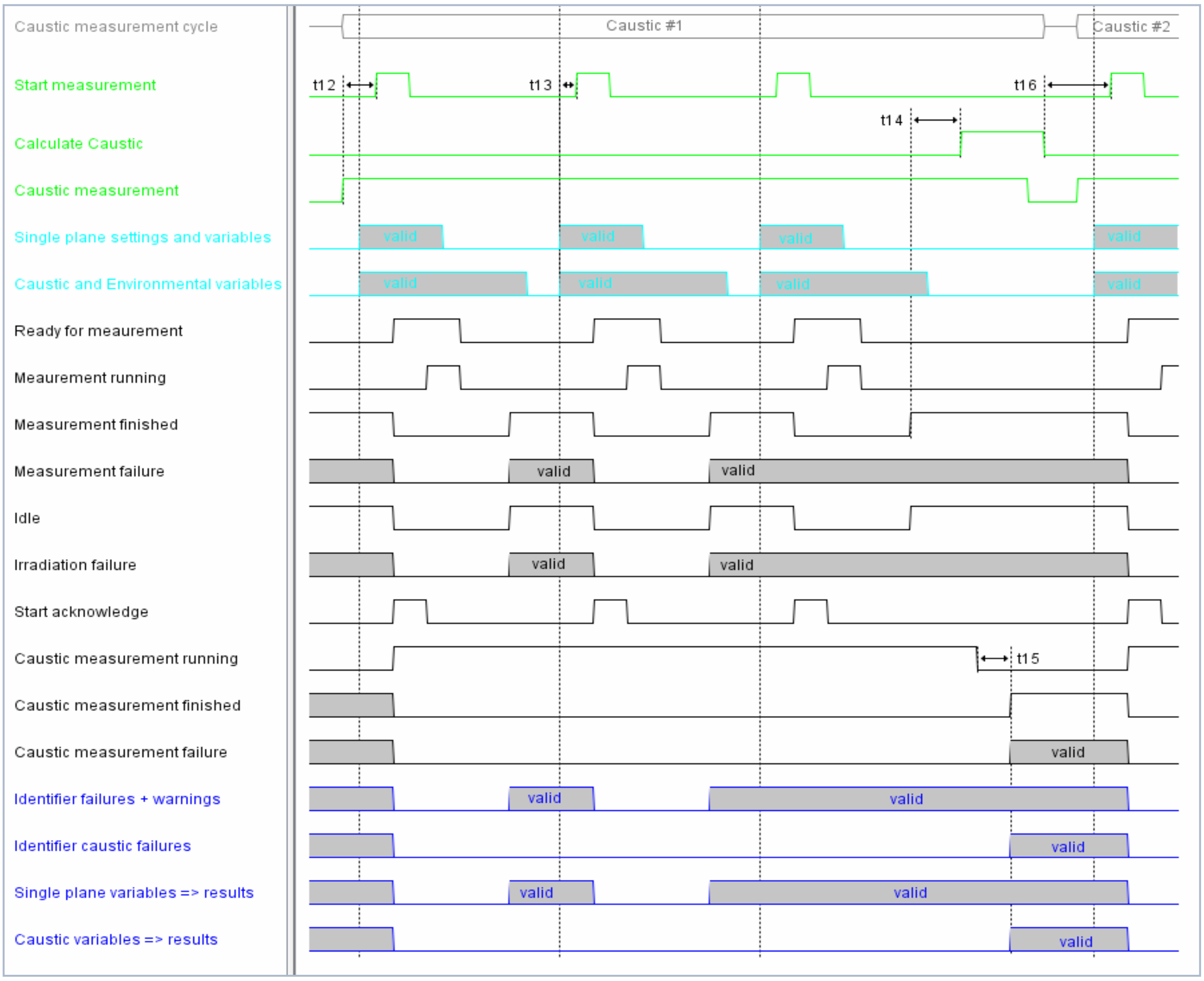


Fig. 12.4: Timing diagram for caustic measurement

t12: Before the start of the first single plane measurement, “Caustic Measurement” must be set and then only deactivated once “Caustic Measurement Finished” has been set. The flag can also stay activated the whole time if you want to measure multiple caustics one right after the other.

t13: The caustic variables (plane index and Z position) must be set just like the single plane variables before the “Start Measurement” flag is set. This applies to every single measurement plane. The parameters should be deleted only once “Start Acknowledge” has been deactivated again, and the Environmental variable should even be retained until “Measurement Finished” is set. As soon as the caustic variables have been imported, “Caustic Measurement Running” is set.

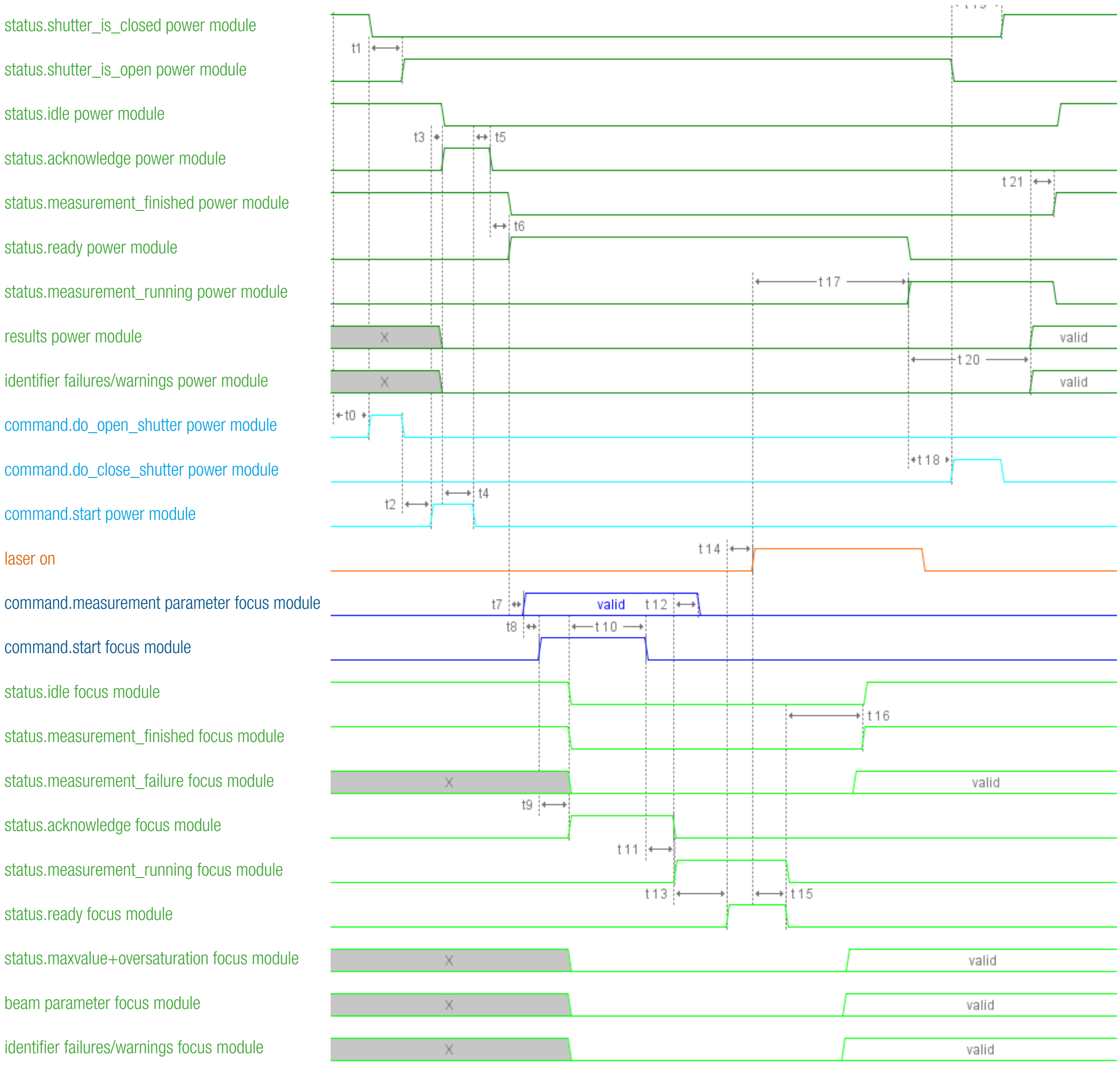
t14: Once the last single plane has been measured and the corresponding calculations performed (“Measurement Finished” set), then you can set “Calculate Caustic”. “Caustic Measurement Running” will then be deactivated.

t15: Once the caustic fit and calculation of the beam parameters have been performed, “Caustic Measurement Finished” is set. Then the results (“Caustic Variables”) will also be available. If errors occur, “Caustic Measurement Failure” is set, the cause of the failure is coded in the logs identifier for caustic measurement errors/warnings.

t16: “Calculate Caustic” **must** be deactivated before the next caustic measurement (meaning “Caustic Measurement” is set) can be initiated.

When completing a caustic measurement, “Calculate Caustic” must be set, even in case of error, and then deactivated again so that a new caustic measurement can be initiated.

12.10 Timing diagram combined measurement (triggered focal point measurement and power measurement)



t0: If the shutter is closed, opening must be triggered by setting the “do_open_shutter” bit in the PMM command byte.

t1: If the “shutter_is_open” flag is set in the PMM status word (status of the power module), this has happened and the device is ready for measurement. “Do_open_shutter” can then be deleted.

t2: To initialize the measurement, the “start” bit must be set in the PMM command byte.

t3: As confirmation that the start command has been received, the measuring device sets the flag in the PMM status word “acknowledge” and “idle” is deleted.

t4: The “start” command in the PMM command byte must then be deleted.

t5: When “start” has been deleted again, “acknowledge” is deleted.

t6: When the device is ready for measurement, “measurement finished” in the PMM status word is deleted and “ready” is set.

The focus module is now addressed. The command bits and status flags described below are those contained in the focus module part (not PMM).

t7: The measurement parameters (Setup No. or detailed measurement parameter) must be set before the “start” flag is set.

t8: By analogy with the handshake at the start of power measurement, the “start” bit is then set in the command field for initialization.

t9: As confirmation that the start command and the measurement parameters have been received, the “acknowledge” flag is set, “idle” and “finished” are deleted. The results registers, error flags and error identifiers are also deleted.

t10: The “start” flag may then be deleted.

t11: When “start” has been deleted again, “acknowledge” is deleted and “measurement running” is set.

t12: When “acknowledge” has been deleted again, this confirms that the measurement parameters have been read in; they can then be changed as required (e.g. In preparation for the next measurement).

t13: When the device is ready for measurement, “ready” is set as a signal that the laser should now be switched on.

t14: The laser pulse can then be triggered (“Laser on” - fire at the test specimen for the calculated time or pulse duration measurement option). The laser pulse triggers the actual measurement.

t15: When this has been completed, “measurement running” and “ready” are deleted.

t16: When the calculations have been completed (or a fatal error has occurred), the flags “finished” and “idle” are set.
If the “measurement failure” flag is set, a fatal error has occurred and the measurement or calculation was aborted. The cause of the error is encoded in the register “Error identifier”.
If “measurement failure” is not set, the measurement and calculation was carried out successfully and the results can be found in the “beam parameter” results registers. The maximum value of the raw data and an indication of how many pixels were overridden is encoded in the high byte of the status word.
The flag “irradiation failure” may be set; in this case, a non-fatal error has occurred (measurement signal level too high or too low, beam lies at the edge of the measurement window). The cause is encoded in the register “Warning identifier”. Beam parameters were nevertheless determined; these are then available in the results registers.

The power measurement is also carried out during the beam parameter measurement and calculation.

t17: After a short Laser ON time, the power module detects the laser pulse from the increase in temperature of the test specimen. The “ready” flag in the PMM status word is deleted and the thermalization phase of the test specimen is indicated by “measurement running”.

t18: After approx. 1 s, when the laser has been switched off again, the shutter can also be closed again (set flag “PMM_do_close_shutter”).

t19: When the “shutter_is_closed” flag is set in the PMM status word, this has happened. “PMM_do_close_shutter” can then be deleted.

t20: After the end of the thermalization phase (approx. 11 seconds), the pulse duration may be determined and the measurement results (power, energy) are calculated.

t21: When the calculations have been completed, the results are written to the results register of the power measurement. In the PMM status word, “measurement running” is deleted, “measurement finished” and “idle” are set. The results can now be read out.

Results, error flags and identifiers are retained until the next measurement is initiated.

13 Presentation of a measurement in the web browser

The FPM has a web interface. This can be used to display a measurement as an HTML page.
Proceed as follows to access the measuring values:

13.1 Standard FPM

The Ethernet connection jack is located under the cover for the inspection opening.

Remove the cover from the inspection opening on the port side of the device.
1. Connect the FPM to your network using an RJ45 cable.
2. Make sure that the FPM and your PC are on the same network. To do so, you may need to change the IP address of your PC. The IP address of the FPM is on its identification plate.
3. Open the web browser on your PC and enter the IP address of the FPM.

13.1 FPM with Ethernet Port (Option)

The Ethernet connection jack is fed outwards through the cover for the inspection opening.

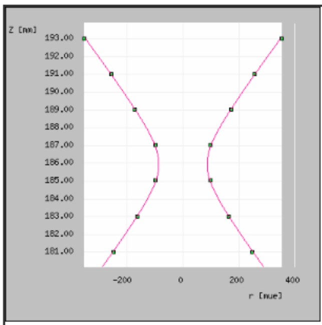
1. Connect the FPM to your network using an RJ45 cable.
2. Make sure that the FPM and your PC are on the same network. To do so, you may need to change the IP address of your PC. The IP address of the FPM is on its identification plate.
3. Open the web browser on your PC and enter the IP address of the FPM.

Fig. 13.1: FocusParameterMonitor with Ethernet connection

After a measurement, the single planes that have been measured are shown. It will display the power density distribution as a 2D display and the measuring values in tabular form.

If a caustic has been measured, this is also presented in 2D. The calculated values are shown in tabular form. The last single plane of the caustic to be measured is also shown with the corresponding measuring values (see Fig. 13.2 on page 43).

You can save the website with any of the most common browsers (except Edge) for documentation purposes.

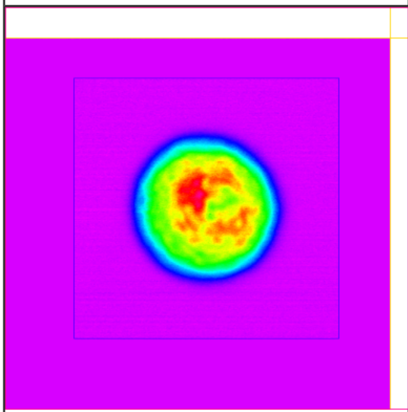


number of planes: 07	wavelength: 1064 nm		
Fit algorithm:	**combined**	**X**	**Y**
Focus Position [mm]:		0.117	0.043
Focus Position Z [mm]:	185.996	185.983	186.009
Focus Radius [mue]:	86.184	87.085	85.279
Focus plane index:	2	2	2
K:	0.082	0.082	0.083
M2:	12.129	12.165	12.090
Rayleigh length [mm]:	1.808	1.841	1.776
BPP [mm*mrad]:	4.108	4.120	4.095
Divergence [mrad]:	95.328	94.622	96.028
beam direction [mrad]:		1.353	5.547

image scaling		
image	resolution x = 400	resolution y = 400
caustic area	pixelpos x = 100	pixelpos y = 070
caustic area	pixelsize x = 250	pixelsize y = 310

gridlines r	number: 4	unit: mue
index	**pixelpositionX**	**value**
00	154	-200.00
01	225	0.00
02	296	200.00
03	367	400.00

gridlines Z	number: 13	unit: mm
index	**pixelpositionY**	**value**
00	089	181.00
01	111	182.00
02	134	183.00
03	156	184.00
04	179	185.00
05	202	186.00
06	224	187.00
07	247	188.00
08	269	189.00
09	292	190.00
10	315	191.00
11	337	192.00
12	360	193.00



Plane number: 06	
r [mue]:	351.4
rx [mue]:	349.0
ry [mue]:	353.7
posx [mm]:	0.129
posy [mm]:	0.114
posz [mm]:	193.100
angle X [°]:	36.41
volume:	19215608
peak intensity [kW/cm^2]:	786
raw data max:	1995
overexposed [%]:	0
fill factor [%]:	51.4
attenuation final [dB]:	-32.0
integration time final [muesec]:	5451
int. time recommended [muesec]:	11099
ROI position x [mm]:	1.075
ROI position y [mm]:	0.657
ROI size x [mm]:	1.378
ROI size y [mm]:	1.357
ROI resolution x:	337
ROI resolution y:	332

image scaling	
projection:	2.152
pixelzoom [img.pixel/meas.pixel]:	1
image scale x [mue/pixel]:	8.797
image scale y [mue/pixel]:	8.797
center of measurement area:	
x [mm]:	1.635
y [mm]:	1.226

	[mm]	**pixel**
image pos x:	-1.326	0
image size x:	4.495	512
image pos y:	-1.360	0
image size y:	4.504	512
window pos x:	-1.014	-24
window size x:	2.093	512
window pos y:	-1.100	-40
window size y:	2.093	512
ROI pos x:	-0.560	87
ROI size x:	1.378	337
ROI pos y:	-0.569	90
ROI size y:	1.357	332

Fig. 13.2: Example for presentation of a caustic measurement in the web browser

14 PROFIBUS/PROFINET-Parameter Set

14.1 Inputs

In	FPM	FPM with caustic option	FPM	FPM with caustic-option		Unit/Rep. rate	Length	Type	Sign	FPM	FPM with caustic option
	Address		Register address								
"Version (read only)"	256	256	0	0	Device / Software revision	fix	2 byte	word		32 Byte	32 Byte
"Constants (read only)"	258	258	1+2	1+2	PMM constant: maximal capacity		4 byte	lword			
	262	262	3+4	3+4	PMM constant: minimal energy		4 byte	lword			
	266	266	5	5	PMM constant: minimal irradiation time		2 byte	word			
	268	268	6	6	PMM constant: maximal irradiation time		2 byte	word			
	270	270	7	7	PMM constant: maximal power		2 byte	word			
	272	272	8	8	PMM constant: minimal absorber temperature		2 byte	word			
	274	274	9	9	PMM constant: maximal absorber temperature		2 byte	word			
	276	276	10	10	PMM constant: pulse duration measurement available		2 byte	word			
	278	278	11	11	PMM constant: device type		2 byte	word			
	280	280	12	12	PMM constant: release		2 byte	word			
Status (read only)	282.0	282.0	13 high	13 high	Ready for Measurement	> 1Hz	1 byte	bool			
	282.1	282.1			Measurement running	> 1Hz		bool			
	282.2	282.2			Measurement finished	> 1Hz		bool			
	282.3	282.3			Measurement failure	> 1Hz		bool			
	282.4	282.4			Idle	> 1Hz		bool			
	282.5	282.5			Irradiation failure	> 1Hz		bool			
	282.6	282.6			Start acknowledge	> 1Hz		bool			
	282.7	282.7			Setup Params read	> 1Hz		bool			
	283.0	283.0	13 low	13 low	Caustic measurement running	> 1Hz	1 byte	bool			
	283.1	283.1			Caustic measurement finished	> 1Hz		bool			
	283.2	283.2			Caustic measurement failure	> 1Hz		bool			
	283.3	283.3						bool			
	283.4	283.4						bool			
	283.5	283.5						bool			
	283.6	283.6						bool			
	283.7	283.7						bool			
"PMM StatusSystem"	284.0	284.0	14 high	14 high	PMM status: ready		1 byte	bool			
	284.1	284.1			PMM status: running			bool			
	284.2	284.2			PMM status: finished			bool			
	284.3	284.3			PMM status: too hot			bool			
	284.4	284.4			PMM status: idle			bool			
	284.5	284.5			PMM status: irradiation failure			bool			
	284.6	284.6			PMM status: start acknowledge			bool			
	284.7	284.7			PMM status: shutter acknowledge			bool			
"PMM StatusShutter"	285.0	285.0	14 low	14 low	PMM status: shutter is open		1 byte	bool			
	285.1	285.1			PMM status: shutter is closed			bool			
	285.2	285.2			PMM status: shutter is moving			bool			
	285.3	285.3			PMM status: shutter timeout			bool			
	285.4	285.4			PMM status: error shutter anglesensor			bool			
	285.5	285.5						bool			
	285.6	285.6						bool			
	285.7	285.7						bool			
StatusReserve	286	286	15	15			2 byte	word			

In	FPM	FPM with caustic option	FPM	FPM with caustic option		Unit/ Rep.rate	Length	Type	Sign	FPM	FPM with caustic option
	Address		Register address								
Warnings and errors (read only)	288.0	288.0	16 high	16 high	Group warning: general warning		1 byte	bool		64 byte	64 byte
	288.1	288.1						bool			
	288.2	288.2			Group warning: single measurement warning			bool			
	288.3	288.3			Group warning: caustic measurement warning			bool			
	288.4	288.4			Group error: hardware error			bool			
	288.5	288.5			Group error: parameter error			bool			
	288.6	288.6			Group error: single measurement error			bool			
	288.7	288.7			Group error: caustic measurement error			bool			
	289	289	16 low	16 low			1 byte	byte			
	290	290	17	17	Identifier for general warnings	per meas. cycle	2 byte	word			
	292	292	18	18	Identifier for single measurement warnings	per meas. cycle	2 byte	word			
	294	294	19	19	Identifier for caustic measurement warnings	per meas. cycle	2 byte	word			
	296	296	20	20	Identifier for hardware errors	per meas. cycle	2 byte	word			
	298	298	21	21	Identifier for parameter errors	per meas. cycle	2 byte	word			
	300	300	22	22	Identifier for single measurement errors	per meas. cycle	2 byte	word			
	302	302	23	23	Identifier for caustic measurement errors	per meas. cycle	2 byte	word			
Variable; single plane (read only)	304	304	24	24	Beam radius combined	m*E-7 /per meas. cycle	2 byte	word			
	306	306	25	25	Beam radius in x	m*E-7 /per meas. cycle	2 byte	word			
	308	308	26	26	Beam radius in y	m*E-7 /per meas. cycle	2 byte	word			
	310	310	27	27	Beam position in x	µm /per meas. cycle	2 byte	word			
	312	312	28	28	Beam position in y	µm /per meas. cycle	2 byte	word			
	314	314	29	29	Angle x	°*E-2 /per meas. cycle	2 byte	word	+/-		
	316	316	30+31	30+31	Beam volume	ADC-Counts	4 byte	lword			
	320	320	32+33	32+33	Peak Intensity	kW/cm² /per meas. cycle	4 byte	lword			
	324	324	34	34	Level indicator: maximum of raw data	per meas. cycle	2 byte	word			
	326	326	35 high	35 high	% of beam overdriven (i.e. raw data == 4095)	% /per meas. cycle	1 byte	byte			
	327	327	35 low	35 low	Fill factor	% / per meas. cycle	1 byte	byte			
	328	328	36	36	ROI window position x	µm per meas. cycle	2 byte	word			
	330	330	37	37	ROI window position y	µm /per meas. cycle	2 byte	word			
	332	332	38	38	ROI window size x	µm /per meas. cycle	2 byte	word			
	334	334	39	39	ROI window size y	µm /per meas. cycle	2 byte	word			
	336	336	40	40	ROI resolution x	Pixel	2 byte	word			
	338	338	41	41	ROI resolution y	Pixel	2 byte	word			

In	FPM	FPM with caustic option	FPM	FPM with caustic option		Unit/ Rep.rate	Length	Type	Sign	FPM	FPM with caustic option
	Address		Register address								
	340	340	42	42	Used attenuation	dB * (-10) / per meas. cycle	2 byte	word			
	342+344	342	43+44	43+44	Used integration time	µsec /per meas. cycle	4 byte	lword			
	346+348	346	45+46	45+46	Optimal integration time	µsec / per meas. cycle	4 byte	lword			
	350	350	47	47			18 byte				
"Variable; caustic (read only)"		352		48	Focus position x	µm / per meas. cycle	2 byte	word	+/-		"24 byte (12 words)"
		354		49	Focus position y	µm /per meas. cycle	2 byte	word	+/-		
		356+358		50+51	Focus position z	per meas. cycle	4 byte	lword	+/-		
		360		52	Focus radius combined	m*E-7 / per meas. cycle	2 byte	word			
		362		53	Focus radius in x	m*E-7 / per meas. cycle	2 byte	word			
		364		54	Fokus radius in y	m*E-7 / per meas. cycle	2 byte	word			
		366+368		55+56	Focus position zx	µm / per meas. cycle	4 byte	lword	+/-		
		370+372		57+58	Focus position zy	µm / per meas. cycle	4 byte	lword	+/-		
		374		59	Divergence angle (mrad)	rad *E-5 / per meas. cycle	2 byte	word			
"Variable; PMM (read only)"	352+354	376+378	48+49	60+61	PMM result: remaining_capacity		4 byte	lword		20 Byte	20 Byte
	356+358	380+382	50+51	62+63	PMM result: absorber temperature		4 byte	lword			
	360+362	384+386	52+53	64+65	PMM result: housing tempera-ture 1		4 byte	lword			
	364+366	388+390	54+55	66+67	PMM result: housing tempera-ture 2		4 byte	lword			
	368+370	392+394	56+57	68+69	PMM result: housing tempera-ture 3		4 byte	lword			
	372+374	396+398	58+59	70+71	PMM result: measured energy		4 byte	lword			
	376+378	400+402	60+61	72+73	PMM result: measured power		4 byte	lword			
	380+382	404+406	62+63	74+75	PMM result: measured irradiation time		4 byte	lword			
	384+386	408+410	64+65	76+77	PMM result: measured power uncorrected		4 byte	lword			
	388+390	412+414	66+67	78+79	PMM result: temperature differ-ence		4 byte	lword			

14.2 Outputs

Out	FPM	FPM with caustic option	FPM	FPM with caustic option		Unit/ Rep.rate	Length	Type	Sign
	Address		Register address						
Command (set by ProfiBus)	256.0	256.0	0 high	0 high	Setup 1			bool	
	256.1	256.1			Setup 2			bool	
	256.2	256.2			Setup 3			bool	
	256.3	256.3			Setup 4			bool	
	256.4	256.4			Start measurement			bool	
	256.5	256.5			Measurement finished -> calculate Caustic			bool	
	256.6	256.6						bool	
	256.7	256.7			Reset			bool	
	257.0	257.0	0 low	0 low	Measurement mode: bit 0			bool	
	257.1	257.1			Measurement mode: bit 1			bool	
	257.2	257.2			Evaluation algorithm: bit 0			bool	
	257.3	257.3			Evaluation algorithm: bit 1			bool	
	257.4	257.4			Flag: unit of integration control			bool	
	257.5	257.5			Flag: Automatic exposure control			bool	
	257.6	257.6			Flag: Caustic measurement			bool	
	257.7	257.7			Flag: Simplified measurement			bool	
	258.0	258.0	1 high	1 high	Flag: external trigger			bool	
	258.1	258.1			Trigger mode: bit 0			bool	
	258.2	258.2			Trigger mode: bit 1			bool	
	258.3	258.3			Read Setup Params			bool	
	258.4	258.4			Save Setup Params			bool	
	258.5	258.5			Do FTP			bool	
	258.6	258.6						bool	
	258.7	258.7						bool	
	259.0	259.0	1 low	1 low	PMM command: start measurement			bool	
	259.1	259.1			PMM command: do open shutter			bool	
	259.2	259.2			PMM command: do close shutter			bool	
	259.3	259.3						bool	
	259.4	259.4						bool	
	259.5	259.5						bool	
	259.6	259.6			PMM command: do program			bool	
	259.7	259.7			PMM command: do reset			bool	
Single plane global settings (write only)	260	260	2	2	BeamFind: counts	counts	2 byte	word	
	262	262	3	3	BeamFind: percentage	%	2 byte	word	
	264	264	4+5	4+5	Trigger delay	µsec	4 byte	lword	
	268	268	6	6	Trigger level (0-4095)	counts	2 byte	word	
"Single plane variable (write only)"	270	270	7	7	Attenuation; if flag "automatic exposure control" (optimizer) is set: start value for optimization	dB * (-10)	2 byte	word	
	272	272	8+9	8+9	Integration time; if flag "automatic exposure control" (optimizer) is set: start value for optimization	µsec	4 byte	lword	
	276	276	10	10			2 byte	word	
	278	278	11	11	deflect position	µm	2 byte	word	
	280	280	12	12	resolution in x	Pixel	2 byte	word	
	282	282	13	13	resolution in y	Pixel	2 byte	word	
	284	284	14	14	window size in x	µm /per meas. cycle	2 byte	word	
	286	286	15	15	window size in y	µm /per meas. cycle	2 byte	word	
	288	288	16	16	window position in x	µm /per meas. cycle	2 byte	word	
	290	290	17	17	window position in y	µm /per meas. cycle	2 byte	word	

Out	FPM	FPM with caustic option	FPM	FPM with caustic option		Unit/ Rep.rate	Length	Type	Sign
	Address		Register address						
"Caustic var. (write only)"	292	292	18+19	18+19	plane position in z	µm	4 byte	lword	+/-
	296	296	20	20	plane index (0-29)		2 byte	word	
"Environmental variable (write only)"	298	298	21	21	Nominal laser power	W	2 byte	word	

14.3 Error Flags

14.3.1 Error Detection Hardware

Group message “Error Hardware“ is set.
„Measurement Failure“ is set.

Error		Identification
Xilinx or ExtXi error		0x0001
EE-CRC not correct		0x0002

14.3.2 Error Detection Parameter Selection

Group message “Error Parameter Selection“ is set.
„Measurement Failure“ is set.

Error	Error Condition	Identification
Window (in X) too small	mess_x == 0 or (anz_x>512)&&((mess_y/anz_y)*projection) < (pixelpitch_y*2)	0x0001
Window (in Y) too small	mess_y == 0	0x0002
Window (in X) too big/too far to the right	((pos_x+mess_x)*projection) > ((pixelnumberx*pixelpitchx)/1000)	0x0004
Window (in Y) too big/too far up	((pos_y+mess_y)*projection) > ((pixelnumbery*pixelpitchy)/1000)	0x0008
Resolution (in X) too small	anz_x == 0	0x0010
Resolution (in Y) too small	anz_y == 0	0x0020
Resolution (in X) too big (for LDS)	anz_x > 1024	0x0040
Resolution (in Y) too big (for LDS)	anz_y > 1024	0x0080
Resolution (in X) too big	((mess_x/anz_x)*projection) < (pixelpitchx)	0x0100
Resolution (in Y) too big	((mess_y/anz_y)*projection) < (pixelpitchy)	0x0200
smallest y-window at x_ anz==1024	((mess_y/anz_y)*projection) < (pixelpitchy * 2)	0x0400
Too many pixel for array sample_data	((anz_x+25)*anz_y) > 550000	0x0800
Attenuation too strong	amp < -85.1;	0x1000
Integration time or delay too big	tInt > 217026µs; tDelay > 217026 µs	0x2000
Inadmissible BeamFind-parameters	counts > 4095 oder percent > 99	0x4000
Other inadmissible parameter	Evaluation algorithm > 1; Trigger mode > 2; Measuring mode>3;	0x8000

14.3.3 Error Detection Single-Plane Measurement

Group message “Error Single-Plane Measurement“ is set.
„Measurement Failure“ is set.

Error	Error Condition	Identification
Trigger-Timeout occurred	No laser pulse within 2 s after start.	0x0001
Error with upstream measurement	Problem of FPGA process.	0x0002
Error with raw data measurement		0x0004
Error with underground measurement		0x0008
Timeout measurement	Measurement not executed within 4 s.	0x0010
		0x0020
		0x0040
		0x0080
Timeout calculation	Calculations after measurement not executed within 4 s Possible cause: FTP transfer enabled, but no FTP server found.	0x0100
No beam found with BeamFind	Laser was off during measurement time.	0x0200
		0x0400
		0x0800
Volume negative	Beam parameters couldn’t be calculated. Sensor signal not plausible. Probably Laser was off during measurement time, or inappropriate integration time.	0x1000
beamdata.r2E < 0 (2. moments)		0x2000
beamdata.x2E < 0 (2. moments)		0x4000
beamdata.y2E < 0 (2. moments)		0x8000

14.3.4 Error Detection Caustic

Group message “Error Caustic“ is set.
„Measurement Failure“ is set.

Error	Error Condition	Identification
No focal length presetting	No focal length transmitted.	0x0001
Plane counter: Input incorrect	Plane number < 0 or >= 30.	0x0002
Too little planes for caustic evaluation	Less than 3 planes taken during cauctic measurement.	0x0004
		0x0008
		0x0010
		0x0020
		0x0040
		0x0080
Evaluation error; not calculable	Caustic fit not successfull.	0x0100

14.3.5 Warning Detection Single-Plane Measurement

Group message “Warning Single-Plane Measurement“ is set.
“Irradiation failure” is set.

Warning	Warning Condition	Identification
Beam on the left edge	Calculated subwindow or pos_x - r on the left edge	0x0001
Beam on the right edge	Calculated subwindow or pos_x + r on the right edge	0x0002
Beam on the lower edge	Calculated subwindow or pos_y - r on the lower edge	0x0004
Beam on the top edge	Calculated subwindow or pos_y + r on the upper edge	0x0008
Oversaturated	Raw data at impact (4095 counts) > 5 % Reference surface: Calculated beam surface (if beam radius could be calculated; otherwise: Subwindow, if BeamFind successful; otherwise: window surface)	0x0010
Undersaturated	Raw data < 2500 counts	0x0020

14.3.6 Warning Detection Caustic

Group message “Warning Caustic“ is set.
“Irradiation failure” is set.

Warning	Warning Condition	Identification
No power presetting	No power value or power value == 0 transmitted	0x0001
		0x0002
		0x0004
		0x0008
		0x0010
		0x0020

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 or calibration. If the device is used only sporadically, the maintenance interval can also be extended up to 24 months.

15.1 Exchanging the Protective Window

In order to protect it from pollution, the FPM is delivered with a protective window inside the beam path. The protective window is inside an exchangeable cartridge, which can be exchanged fast and without any tools.

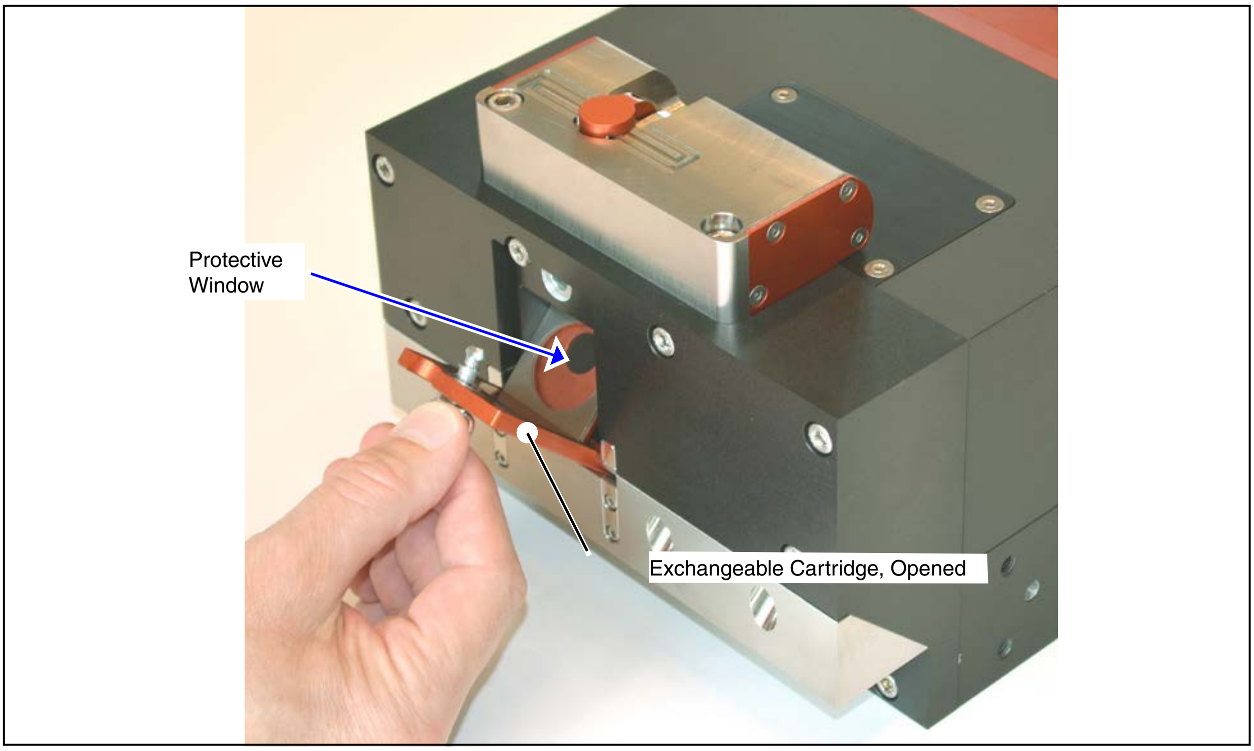


Fig. 15.1: Protective window inside the exchangeable cartridge

Demounting/Mounting

1. Turn the cassette shutter by 90° in order to unlock it.
2. Open the cassette and take it out of the housing.
3. Put in the new cassette.
4. Close the cassette and lock by turning it by 90° (the shutter locks into place audibly).

15.2 Exchanging or Cleaning the Protective Window

The protective window in the protective window cartridge is an expendable part, which can be exchanged when necessary.

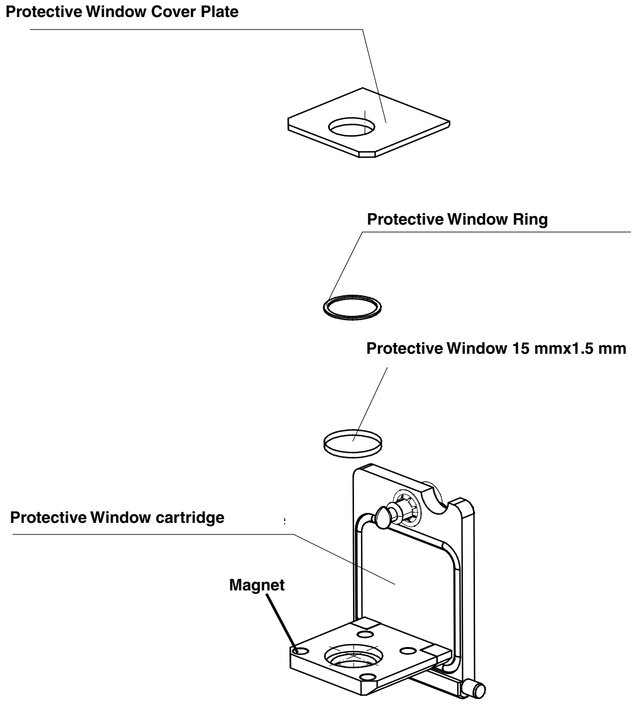


Fig. 15.2: Exploded view protective window cartridge

In order to clean or exchange the protective window, the cartridge can be dismantled. The protective window is held in the cartridge by means of four magnets and the cover plate.
The cover plate can be removed from the cartridge against the magnetic attraction. Concerning the reassembly please ensure that the protective window ring (see Fig. 15.2) is inside the cover plate and that the cover plate is flush to the side of the cartridge.

For the cleaning of the protective window we recommend acetone and optical paper.

16 Measures for the Product Disposal

According to the Electrical and Electronic Equipment Act (ElectroG) PRIMES is obliged to dispose PRIMES measuring devices manufactured after August 2005 free of charge. PRIMES is registered as a manufacturer with the EAR foundation (German register for electronic waste). Our registry number is the following: WEEE-reg.-no. DE65549202.

You are welcome to return PRIMES measuring devices that are to be disposed free of charge to our address:

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

17 Accessories

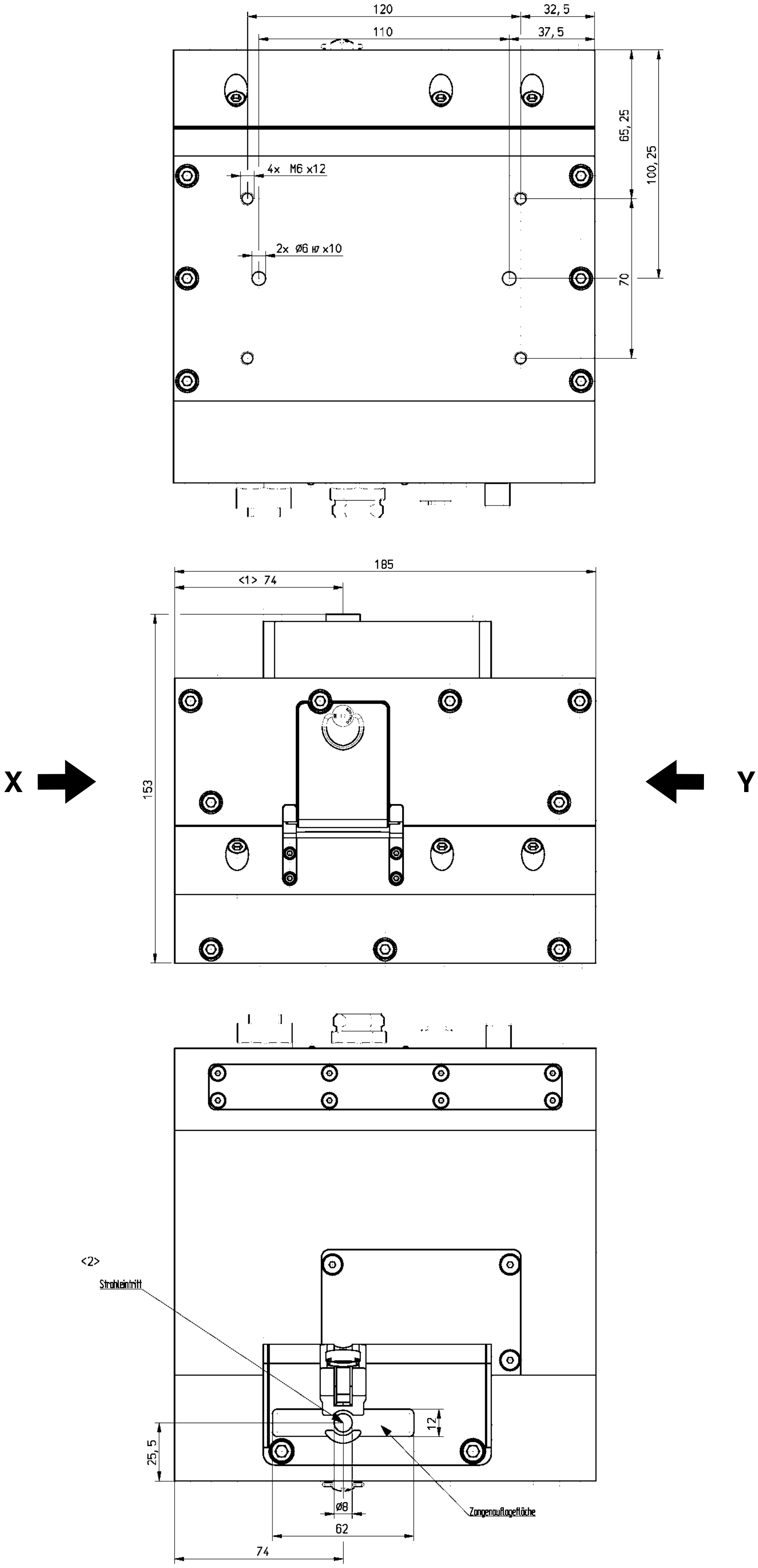
Article	Order Number
Protective window cartridge	200833
Protective window (diameter 15 mm; thickness 1.5 mm)	200834

18 Technical Data

Supply Data		
Supply voltage, DC Maximum current consumption	V mA	24 ± 5 % < 500
Compressed air (cleaned, oil free, dry particle < 10 nm) Flow rate Min. pressure Max. pressure	 Liter/min bar bar	 10 ... 15 1 2
Characteristics Measurement		
Focus diameter	µm	50 ... 1000
Wavelength range	nm	1030 ... 1090
Max. laser power (300 ms; 3000 J)	kW	8
E_{Min} per measuring cycle[1)]	J	100
E_{Max} per measuring cycle [1)]	J	3000
Max. beam divergence	mrad	60 or 120
Max. peak intensity I_{Max} (60 mm below the entrance aperture)	MW/cm²	typ. 1
Max. spot diameter at the entrance aperture	mm	2
Position of the focus inside the device, maximum	mm	15
Laser pulse duration	s	0.3 ... 1
Communication		
PROFIBUS	–	plug/socket 5-pole; M12-SPEEDCON; B-coded
PROFINET	–	AIDA compatible RJ45 connectors
Ambient Conditions		
Operating temperature range Storage temperature range	°C °C	+15 ... +40 +5 ... +50
Reference temperature	°C	+22
Admissible relative humidity (non-condensing)	%	10 ... 80
Dimensions and Weight		
L x W x H (without cables or plugs)	mm	210 x 185 x 153
Weight, approx.	kg	10
Protection		
Type of protection (with a closed shutter)	–	IP64
Protection category	–	III

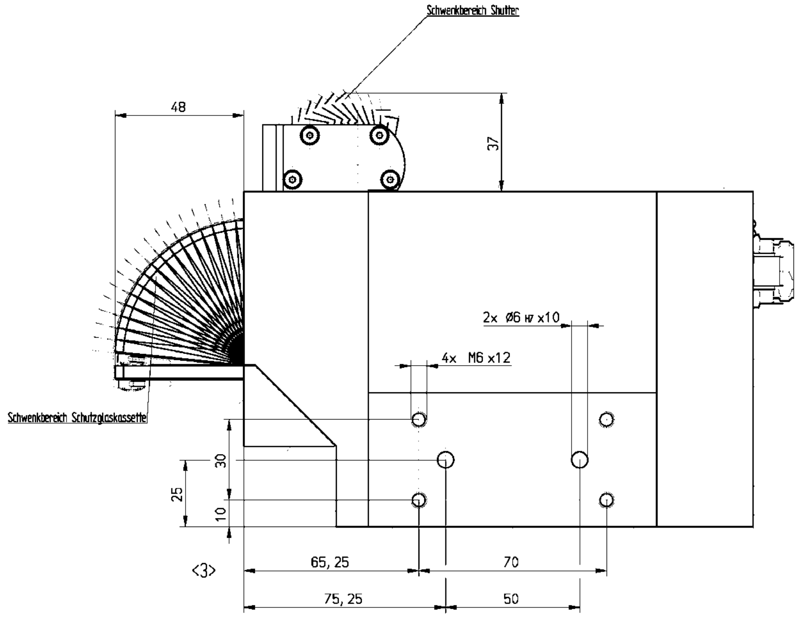
[1)] Depending on the absorber temperature

19 Dimensions

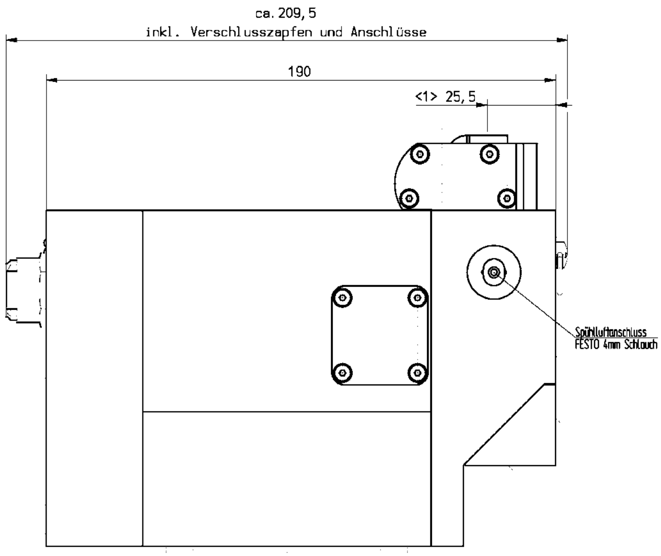


All dimensions are given in mm
Dimensions (Continuation)

View X



View Y



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

20 Declaration of incorporation for partly completed machinery

Original Declaration of Incorporation of Partly Completed Machinery

according to the Machinery Directive 2006/42/EC, Annex II B

The manufacturer: PRIMES GmbH, Max-Planck-Straße 2, 64319 Pfungstadt, Germany
hereby declares, that the partly completed machine with the designation:

FocusParameterMonitor (FPM)

Types: FPM

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-Str. 2, 64319 Pfungstadt, Germany

The technical documentation according to Annex VII Part B of the Machinery Directive which belongs to the partly completed machinery was drawn up. 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.

This partly completed machinery is intended for the integration into a laser system. An initial operation is strictly prohibited until it was ensured that the complete machine, into which the partly completed machinery was integrated, is in compliance with the requirements of the EC-Directive 2006/42/EC as well as the Laser Safety, e.g. the DIN EN ISO 12254, the DIN EN 60825 and TROS.

Pfungstadt, April 26, 2017

Dr. Reinhard Kramer, CEO