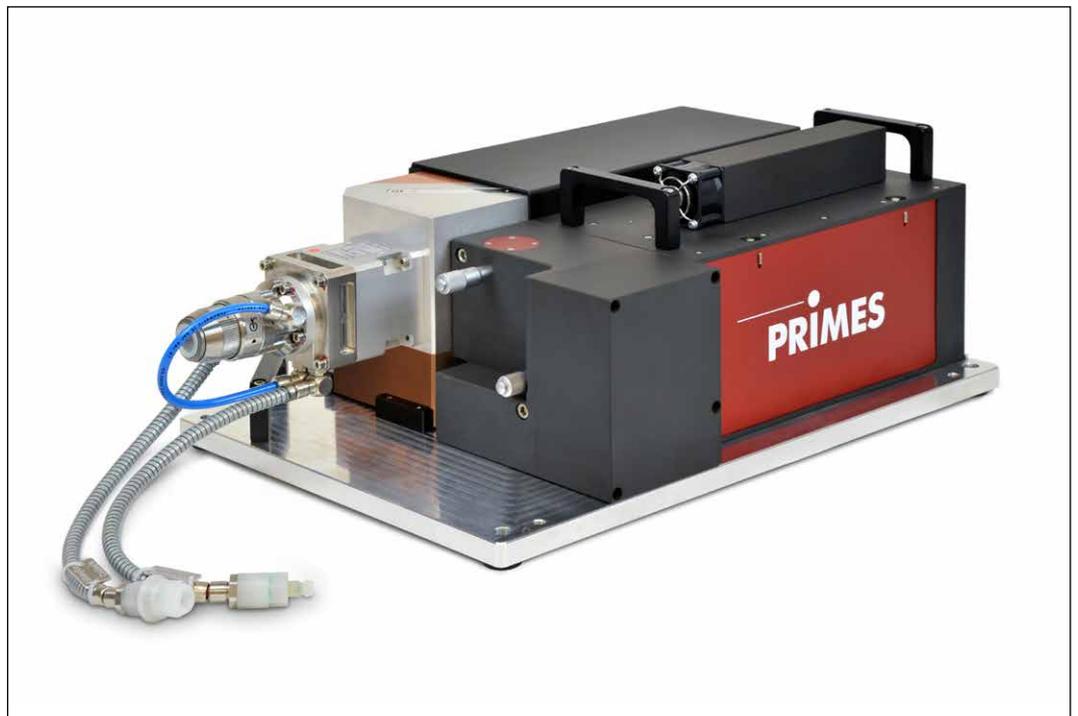


Operating Manual

Translation of the original instructions



LaserQualityMonitor LQM+

LQM+ 20, LQM+ 200/500, LQM+ HP (10/20 kW)

LaserDiagnosticsSoftware LDS

IMPORTANT!

READ CAREFULLY BEFORE USE.

KEEP FOR FUTURE USE.

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PRIMES - The Company

PRIMES manufactures measuring devices used to analyze laser beams. These devices are employed for the diagnostics of high-power lasers ranging from CO₂ 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

PRIMES is responsible for both the development, production, and calibration of the measuring devices. 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 LaserQualityMonitor LQM+ is exclusively intended for measurements which are carried out in or nearby the optical path of high power lasers. Please mind and adhere to the specifications and limit values given in chapter 17 „Technical data“ on page 49. Other forms of usage are 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.

In measuring mode, the laser control's safety interlock must be connected with the device.

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



DANGER

Serious eye or skin injury due to laser radiation

During the measurement the laser beam is guided on the device, which causes scattered or directed reflection of the laser beam (laser class 4).

The LaserQualityMonitor LQM+ cannot be operated in any of the available configurations without taking the following precautions. All precautions must be taken, even when the fiber is in the collimator or fiber adapter.

► **Please take the following precautions.**

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:

- Connect the laser control's safety interlock to the device. Check that the safety interlock will switch off the laser properly in case of error.
- 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 is 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 **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:



Components susceptible to ESD



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 LaserQualityMonitor LQM+ and the execution of measurements with the LaserDiagnosticsSoftware LDS.

The LaserDiagnosticsSoftware LDS must be installed on the PC for measuring operation of the LaserQualityMonitor LQM+. 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.

5 Introduction

5.1 System description

The LaserQualityMonitor LQM+ is used to measure the beam properties of a beam source either by measuring the open beam across several meters or with a fiber placed in a fiber holder or collimator. Cw lasers can be measured and pulsed lasers can also be measured using an internal trigger.

The electronics and all optical components shown are installed in the LQM+ 20 basic device. The LQM+ 20 basic device can be supplemented by a front-end module with a beam splitter, an absorber and an alignment unit, which enables the use of the device even in the multikilowatt range. Fiber retainers, collimators, neutral density filters as well as additional measuring objectives are available upon request.

The laser power can also be measured with the integrated power meters in the 1st and 2nd attenuator (only LQM+ 500 and LQM+ HP).

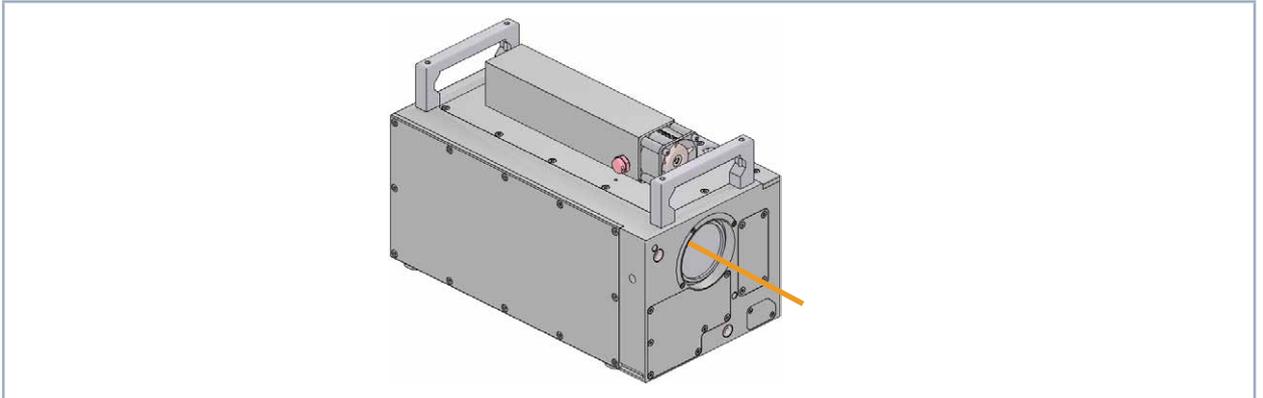


Fig. 5.1: Components of the LQM+ 20 basic device

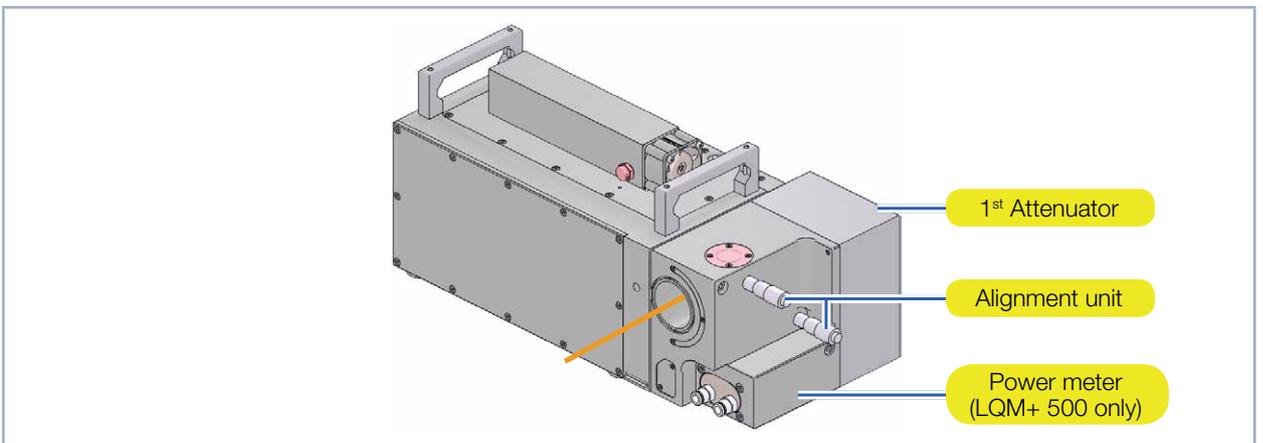


Fig. 5.2: Components of the LQM+ 200/500

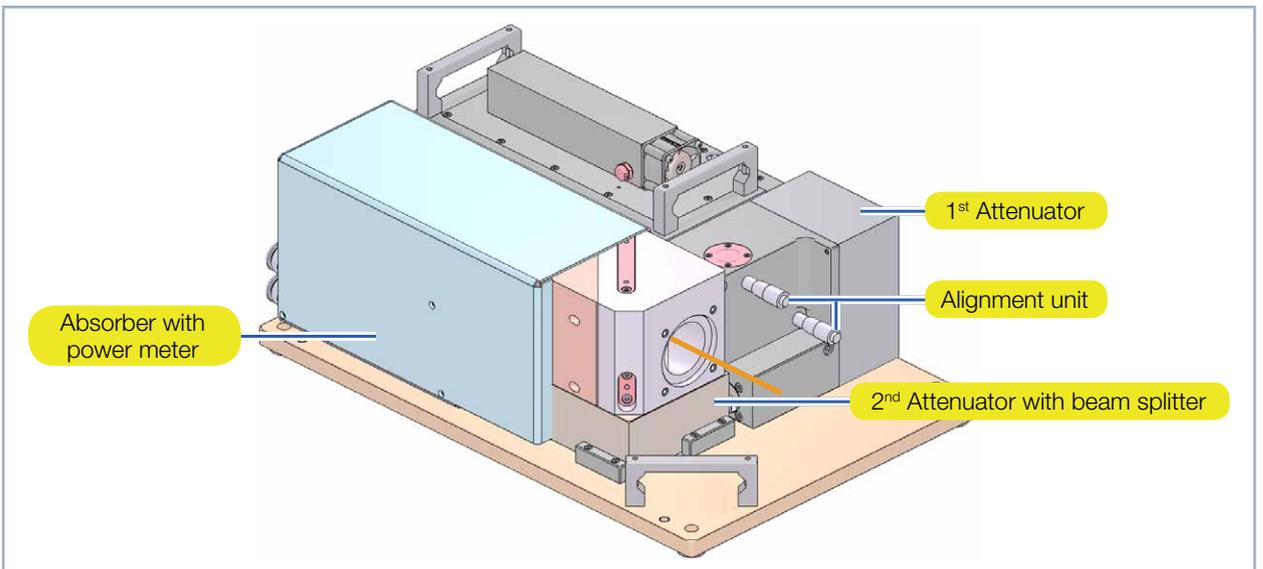


Fig. 5.3: Components of the LQM+ HP (10/20 kW)

5.2 Measuring principle

Due to the very long measuring path of three to six Rayleigh lengths, a lot of measuring is needed to characterize a collimated laser beam. The LaserQualityMonitor LQM+ therefore generates a compact caustic inside the device by focusing the irradiated collimated laser beam with a focussing optic. In the process, the focused beam is weakened as it passes through an integrated prisms and OD filter and then appears on the CCD sensor, enlarged by a measuring objective.

The LaserDiagnosticsSoftware LDS software determines the radius, location, and orientation of the laser beam by moving the prisms inside the device and measuring the two-dimensional power density distribution repeatedly at various positions. The electronic integration time control of the CCD sensor expands the system's dynamic area. As a result of this, it generally isn't necessary to adjust the filter during a measurement.

The following laser sources can be measured:

- All cw and pulsed laser sources in the wave length area of 340 – 360 nm/515 – 545 nm/1 030 – 1 090 nm with medium power from approx. 1 mW up to multikilowatt ranges with an M^2 ranging from 1 to approx. 50.
- The beam diameter at the aperture of the measuring system can vary in the range of 1.5 mm to 15 mm (22 mm only for LQM+ HP 20 kW), with divergence below 10 mrad.

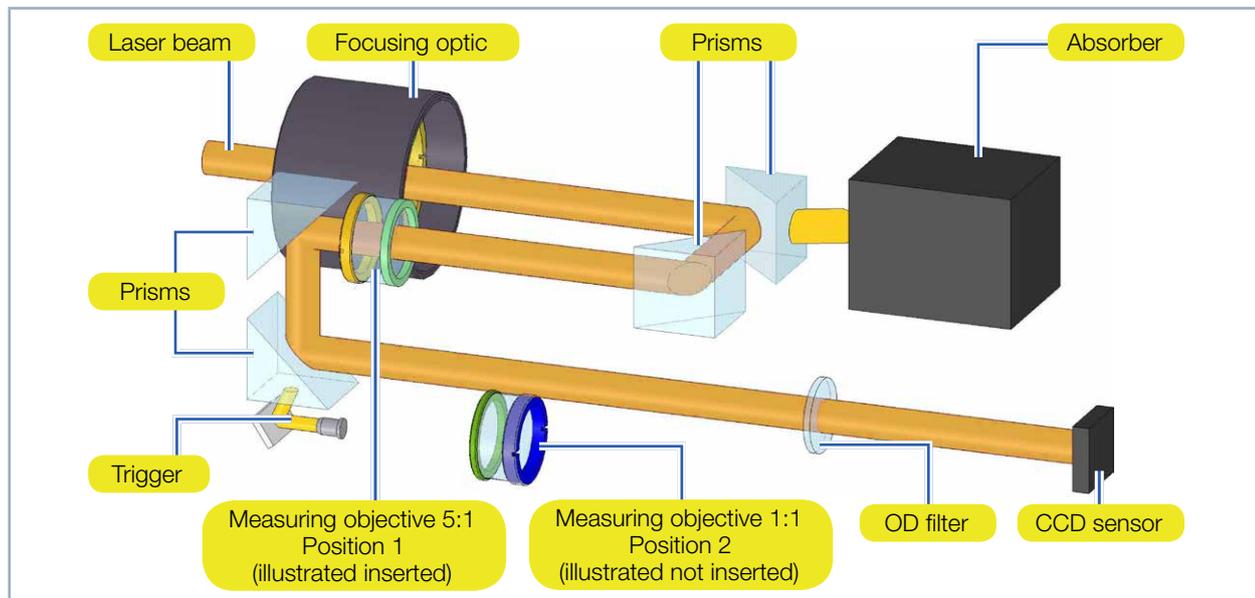


Fig. 5.4: Optical assembly of the LQM+ 20 basic device

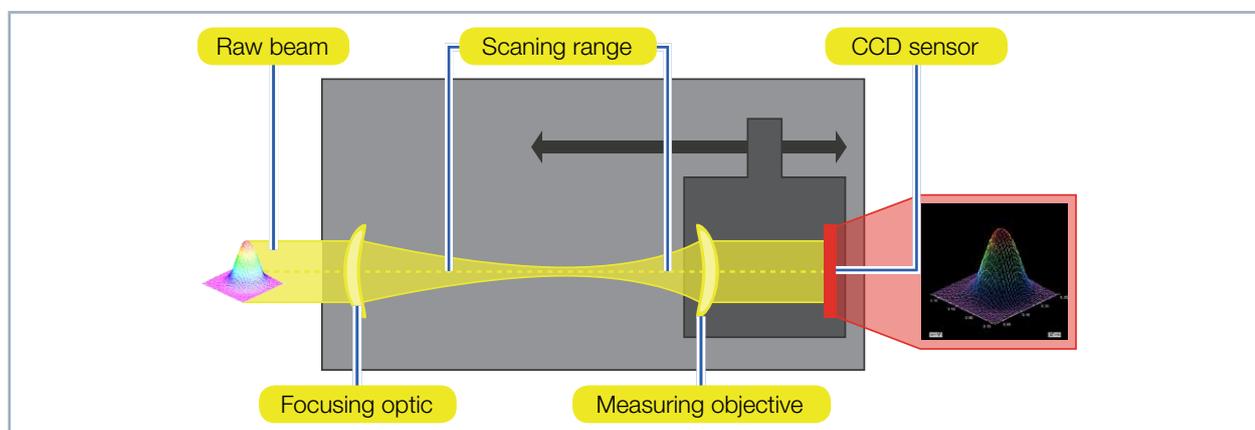


Fig. 5.5: Measuring Principle

5.3 Short overview installation

<p>1. Installing the LaserDiagnosticsSoftware LDS on the computer</p> <ul style="list-style-type: none"> • Software is part of the scope of delivery 	See separate Operating Manual of the LaserDiagnosticsSoftware LDS
<p>2. Taking safety precautions</p>	Chapter 1 on page 7
<p>3. Prepare Installation (only during open beam measurement)</p> <ul style="list-style-type: none"> • Make preparations • Set the installation position • Align the device manually 	Chapter 7 on page 14
<p>4. Connect the water-cooling (LQM+ HP and LQM+ 500 only)</p> <ul style="list-style-type: none"> • Connection diameter • Observe flow rate 	Chapter 8 on page 20
<p>5. Power supply</p> <ul style="list-style-type: none"> • Connect power supply • Connect safety interlock 	Chapter 9 on page 24
<p>6. Connection with the computer</p> <ul style="list-style-type: none"> • Via Ethernet or LAN 	Chapter 9.4 on page 28
<p>7. Complete Installation (only during open beam measurement)</p> <ul style="list-style-type: none"> • Align the device with the LaserDiagnosticsSoftware LDS according to chapter 11.4 on page 35. • Mount the device firmly in accordance with chapter 7 on page 14 	Chapter 11.4 on page 35
<p>8. Measure</p> <ul style="list-style-type: none"> • Follow the safety instructions • Select and use the measuring objective and neutral-density filter • Check the device's alignment with the LaserDiagnosticsSoftware LDS • Perform a test measurement 	Chapter 11 on page 30

6 Transport



WARNING

Risk of injury when lifting or dropping the device

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

- ▶ Use a lifting device to lift and position the device.

NOTICE

Damaging/destroying the device

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

- ▶ Handle the device carefully when transporting or installing it.
- ▶ To avoid contamination, cover the apertures with the provided lid or optical tape.
- ▶ Only transport the device in the original PRIMES transport box.

NOTICE

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

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

- ▶ Empty the lines of the cooling circuit completely.
- ▶ Don't use any compressed air to empty the cooling circuit.
- ▶ Even when the lines of the cooling circuit have been emptied, a small amount of residual water will remain in the device at all times. This may leak out and end up inside the device. Close the connector plug of the cooling circuit with the included sealing plug.

7 Installation

7.1 Preparation and installation position

Check the space available before mounting the device, especially the required space for the connection cables and hoses (please see chapter 18 „Dimensions“ on page 50). The device must be firmly assembled and must be mounted with screws (see chapter 7.3 on page 17).

The LaserQualityMonitor LQM+ can be mounted and operated in any position. During open beam measurement, the LaserQualityMonitor LQM+ must be aligned with the laser beam. The steps taken for installation can be found in chapter 5.3 on page 13.

7.2 Manually aligning the LaserQualityMonitor LQM+

For an open beam measurement, the LaserQualityMonitor LQM+ must be aligned with the alignment tool to the laser beam. The inlet aperture must be aligned centrally and at a right angle to the laser beam:

1. Align the LaserQualityMonitor LQM+ manually with a pilot laser and the alignment tool.
 - The LaserQualityMonitor LQM+ is properly aligned when the pilot beam is centered through the holes in the alignment tool.
2. Check the alignment as specified in chapter 11.4 on page 35 with the alignment mode of the LaserDiagnosticsSoftware LDS.

7.2.1 Alignment tool

An alignment tool is provided for the various LaserQualityMonitor versions that can be used for all aperture diameters. After inserting the alignment tool into the aperture, it is fastened to a metal half ring with magnets.

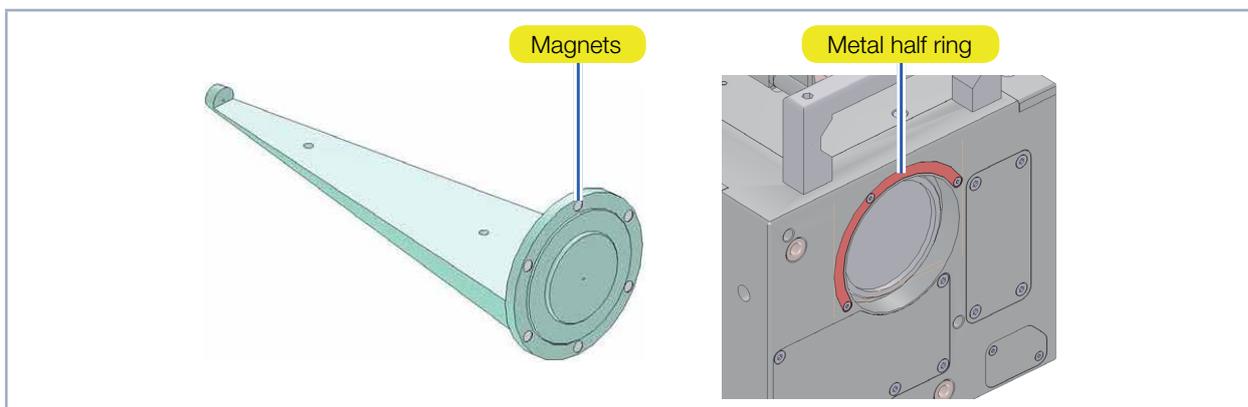


Fig. 7.1: Alignment tool for aligning the LQM+ versions with various apertures

7.2.2 Manual alignment of the LQM+ 20 basic device and the LQM+ 200/500 with 1st attenuator

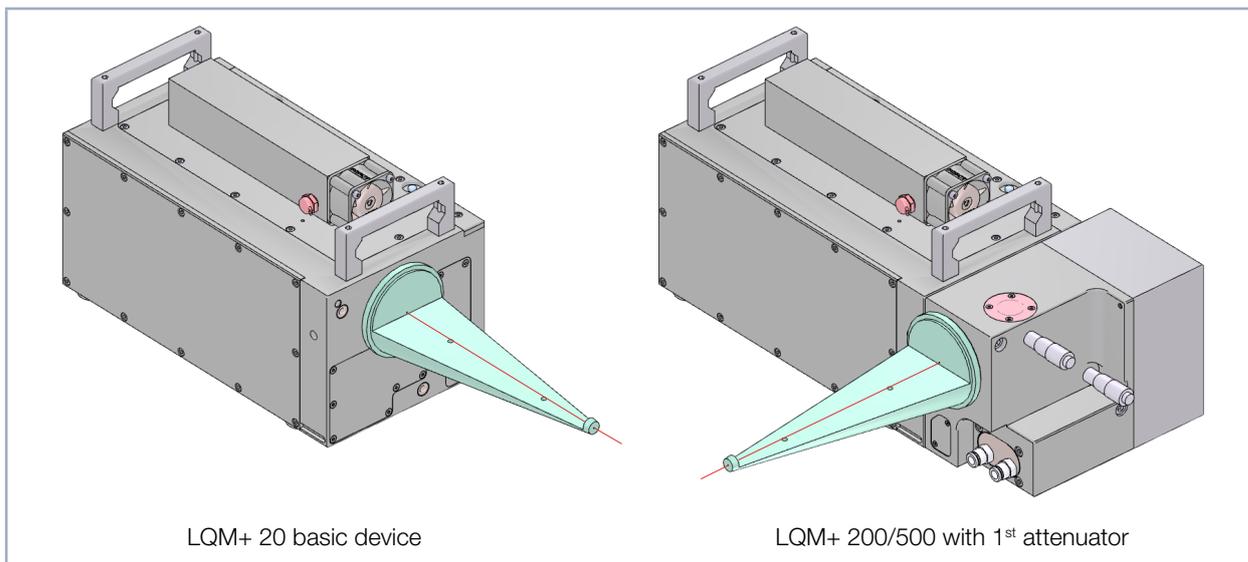


Fig. 7.2: Alignment tool mounted on the LQM+ 20 basic device and the LQM+ 200/500 with 1st attenuator

7.2.3 Fine adjustment at the 1st attenuator

With the 1st attenuator, the angle of incidence of the laser beam can be finely adjusted to the appropriate angle with two integrated micrometer screws (see Fig. 7.3 on page 16).

The laser beam can thus be aligned within the boundaries for the LaserQualityMonitor LQM+. The feedback to change the beam position through fine adjustments is issued via the LaserDiagnosticsSoftware LDS (see chapter 11.4 on page 35).

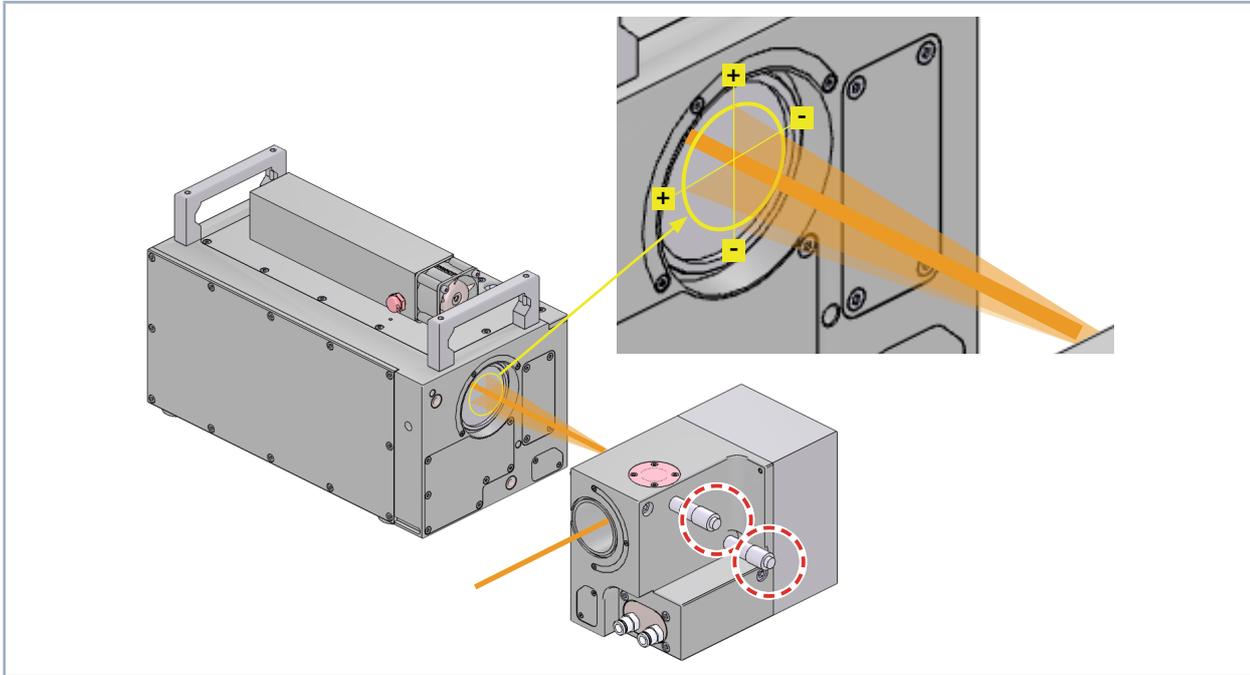


Fig. 7.3: Micrometer screws on the 1st attenuator module for fine adjustment (for the example of the LQM+ 500)

7.3 Install the LaserQualityMonitor LQM+



DANGER

Serious eye or skin injury due to laser radiation

For an open beam measurement, the LaserQualityMonitor LQM+ must be aligned to the laser beam.

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

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

7.3.1 Install the LQM+ 20/200/500 without bottom plate

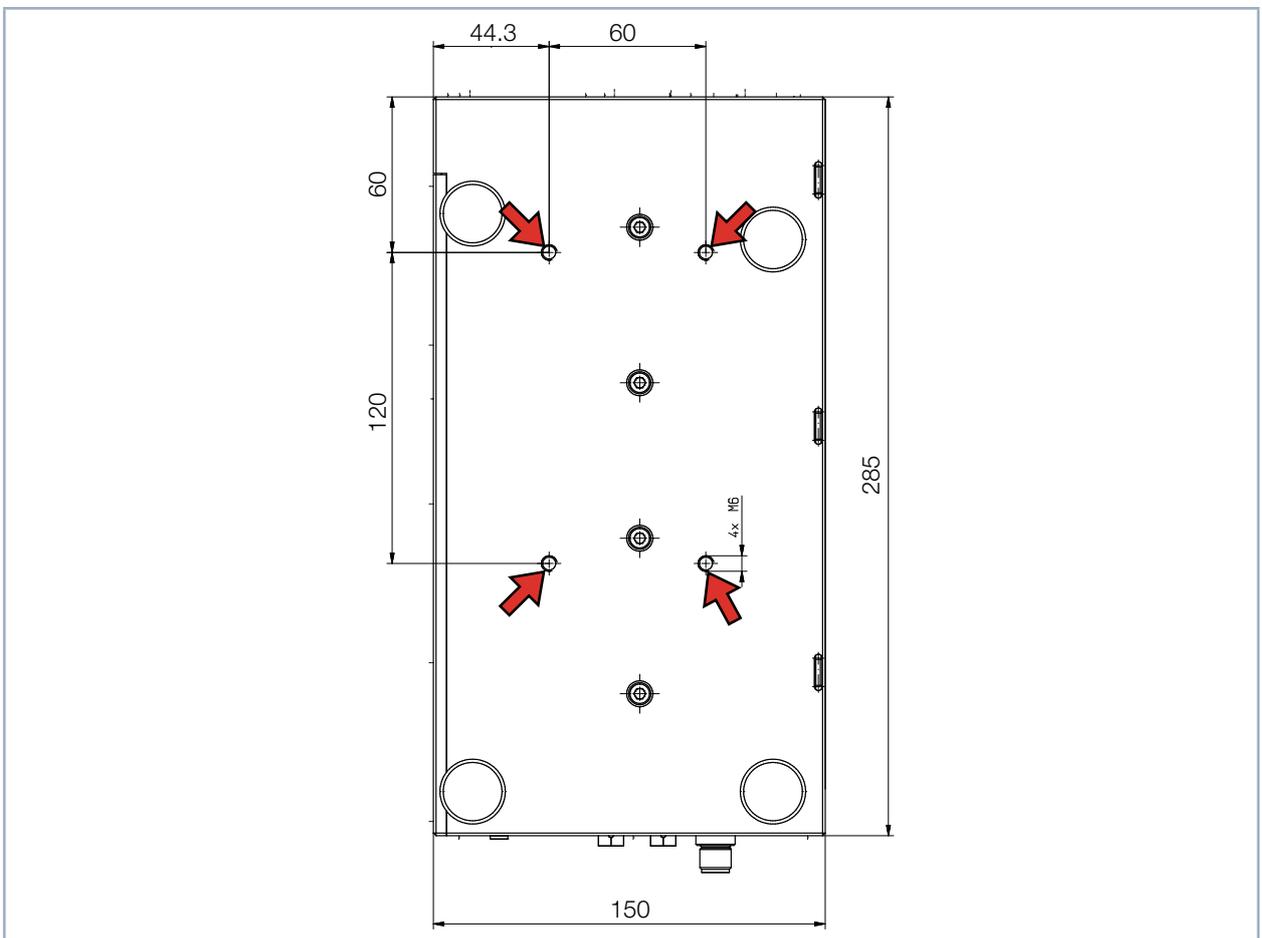


Fig. 7.4: Fastening threaded holes LQM+ 20/200/500 without bottom plate

There are four M6 mounting threads on the underside of the device for fastening it onto a holder provided by the customer. We recommend screws of the strength class 8.8.

 4 threaded holes M6

7.3.2 Install the LQM+ 200/500 with bottom plate

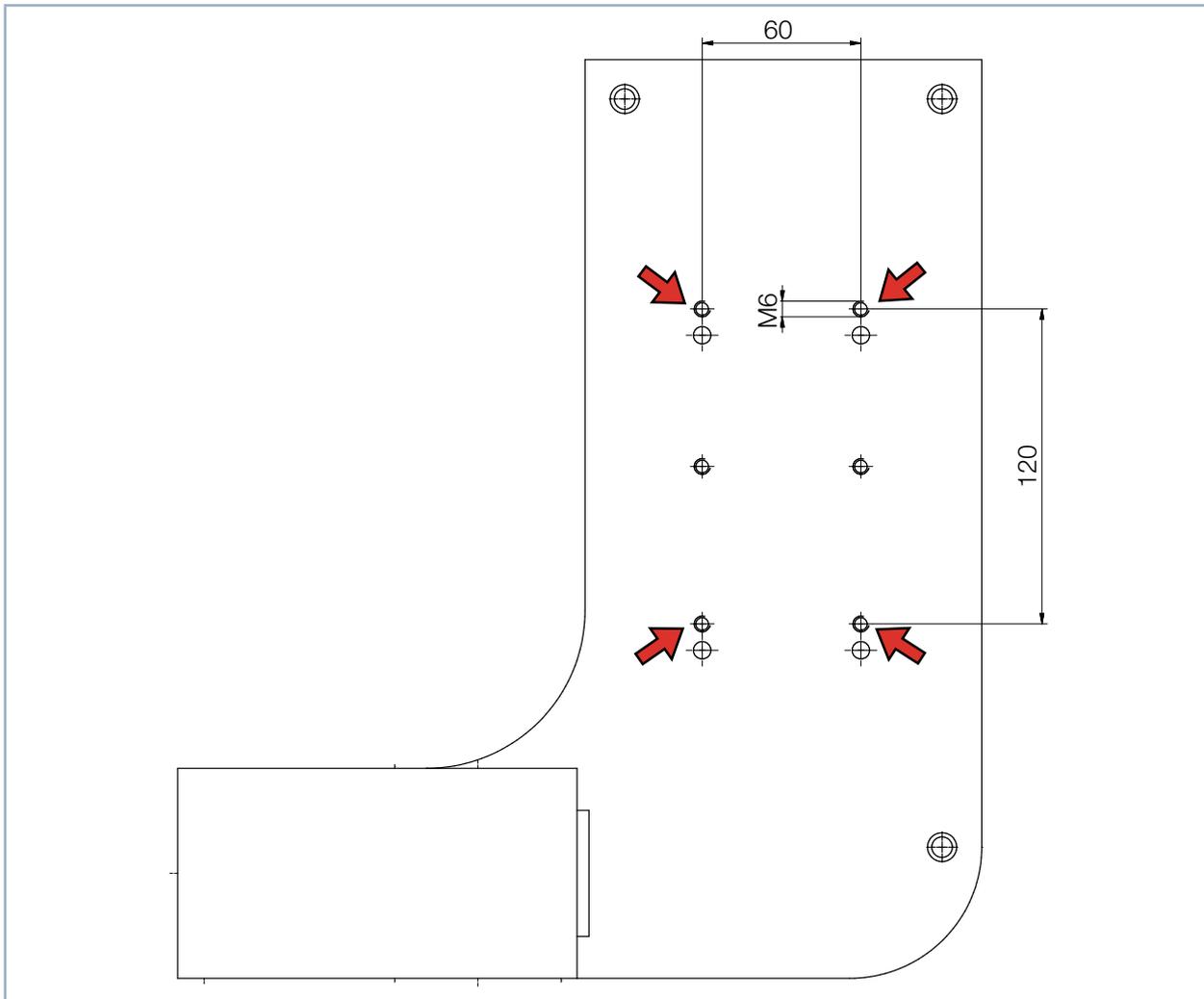


Fig. 7.5: Fastening threaded holes LQM+ 200/500 with bottom plate

For the connection of a customer specific part, there are four threads M6 in the bottom plate. We recommend screws of the strength class 8.8.

➔ 4 threaded holes M6

7.3.3 Install the LQM+ HP with bottom plate

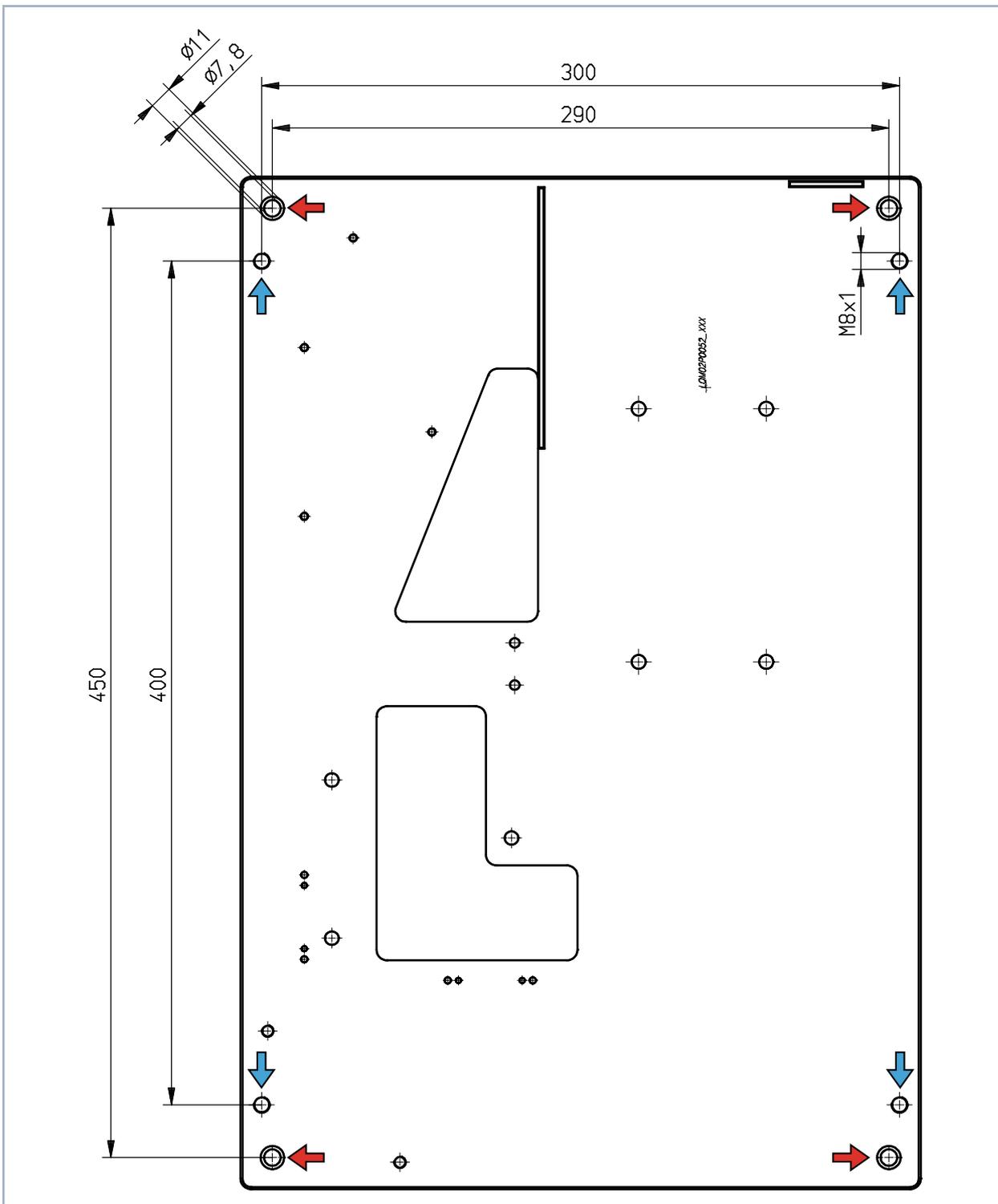


Fig. 7.6: Fastening bores and alignment threads LQM+ HP with bottom plate

- 4 mounting holes Ø 7.8 mm
- 4 threaded holes M8 for the alignment

8 Connect cooling circuit (LQM+ HP and LQM+ 500 only)



DANGER

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

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

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

8.1 Water quality

NOTICE

Damage/Destruction of the device due to different chemical potentials

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

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

- The device can be operated with tap water as well as demineralized water.
- Do not operate the device on a cooling circuit containing additives such as anti-freeze.
- Do not operate the device on a cooling circuit in which aluminum components are installed. Especially when it comes to the operation with high powers and power densities, it may otherwise lead to corrosion in the cooling circuit. In the long term, this reduces the efficiency of the cooling circuit.
- Should the cooling fail, the device can withstand the laser radiation for a few seconds. In this case, please check the device as well as the water connections for damages.
- Large dirt particles or teflon tape may block internal cooling circuits. Therefore, please thoroughly rinse the system before connecting it.

8.2 Water pressure

Normally, 2 bar primary pressure at the entrance of the absorber are sufficient in case of an unpressurized outflow.

NOTICE

Damage/Destruction of the device due to overpressure

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

8.3 Humidity

- The device must not be operated in a condensing atmosphere. The humidity has to be considered in order to prevent condensates within and outside the device.
- The temperature of the cooling water must not be lower than the dew point (see Tab. 8.1 on page 21).

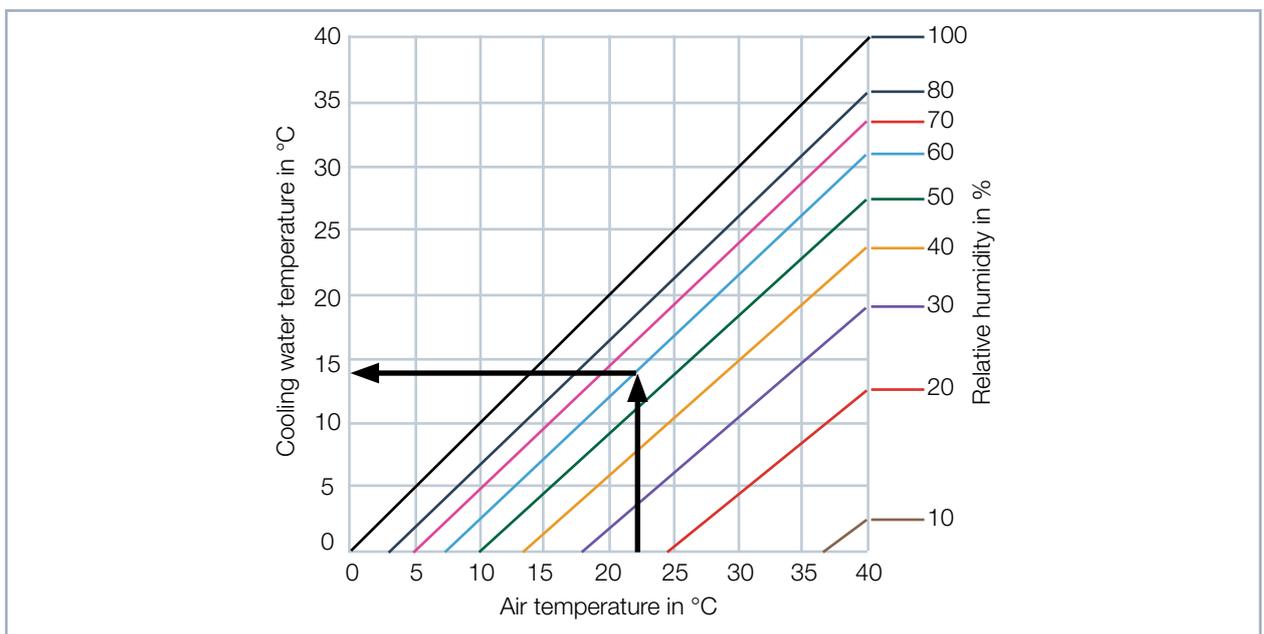
NOTICE

Damage/Destruction of the device due to condensing water

Condensation water inside of the objective will lead to damage.

- ▶ **Mind the dew-point in Tab. 8.1 on page 21.**

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



Tab. 8.1: Dew point diagram

Example

Air temperature: 22 °C
Relative humidity: 60 %

The cooling water temperature cannot fall below 14 °C.

8.4 Water connections and water flow rate

8.4.1 LQM+ HP (10 kW and 20 kW)

LQM+ HP (10 kW)		
Connection diameter	Recommended flow rate	Minimum flow rate
PE hoses 16 mm	7 l/min – 8 l/min (1 l/(min · kW))	Not lower than 4.5 l/min
LQM+ HP (20 kW)		
Connection diameter	Recommended flow rate	Minimum flow rate
PE hoses 16 mm	16 l/min – 20 l/min (1 l/(min · kW))	Not lower than 14 l/min

8.4.2 LQM+ 500

LQM+ 500	
Connection diameter	Recommended flow rate
PE hoses 6 mm	1.5 l/min (1 l/(min · kW))

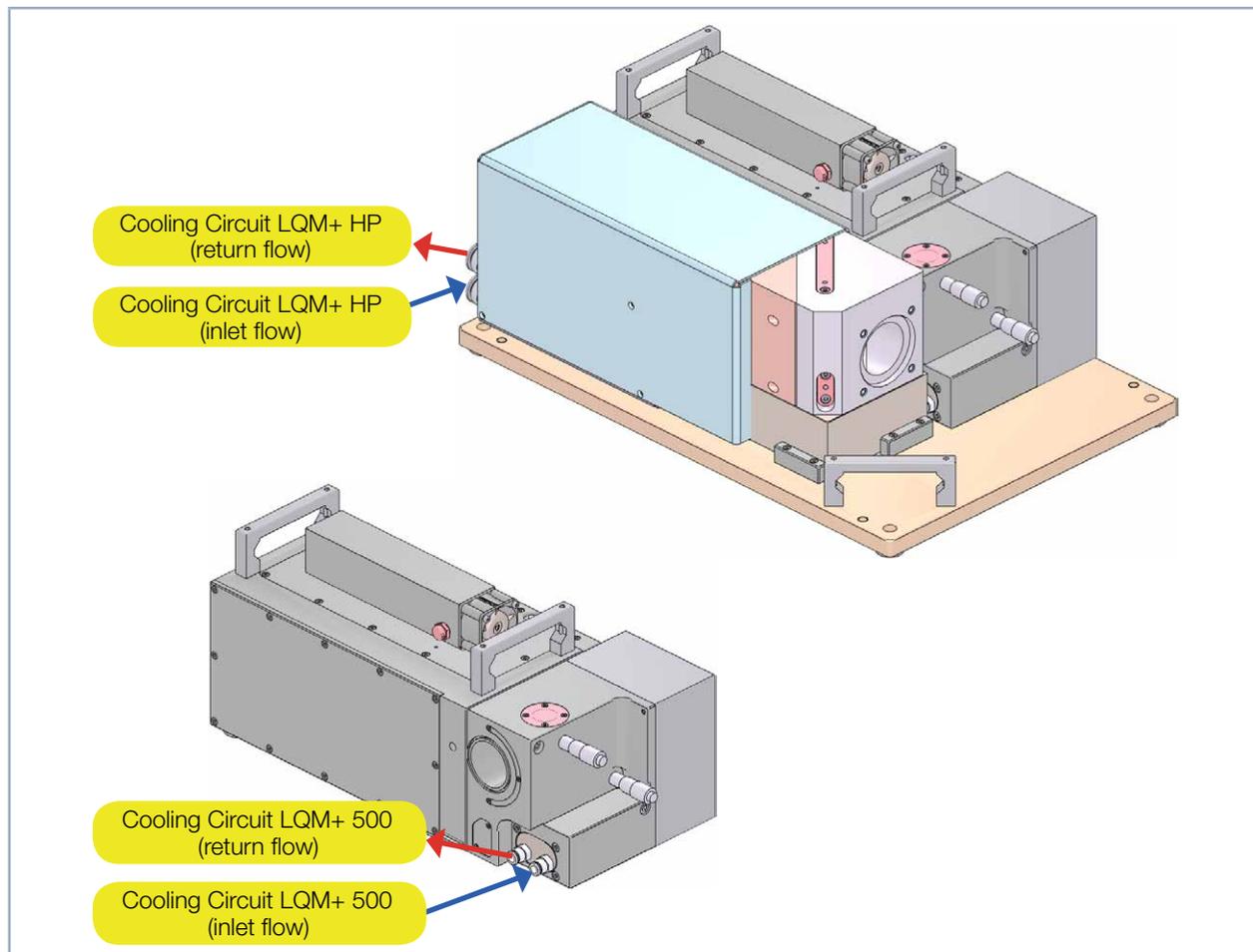


Fig. 8.1: Water connections of the LQM+ HP and the LQM+ 500

8.4.3 Remove the sealing plugs of the water connections

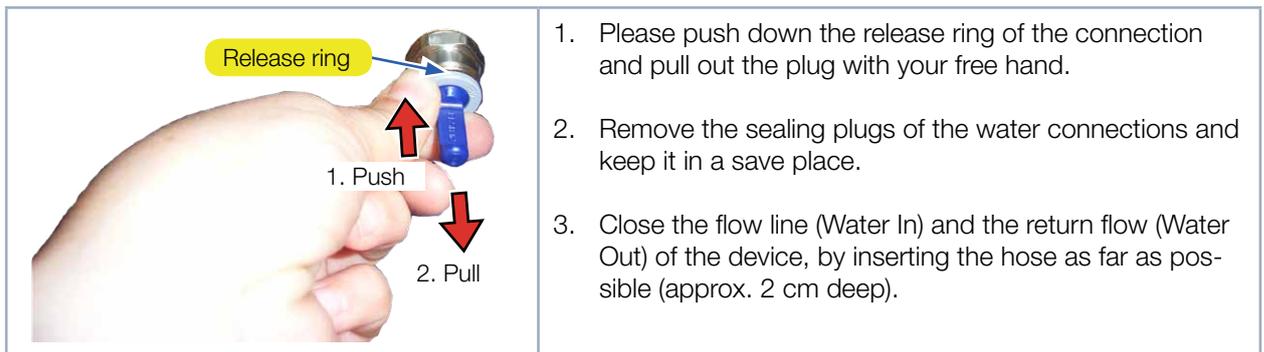


Fig. 8.2: Remove the sealing plugs of the water connections

9 Electrical connection

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

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



Please ensure that all electrical connections have been established and switch the device on before starting the LaserDiagnosticsSoftware LDS.
The LaserQualityMonitor LQM+ serves as a dongle for the software on the computer in order to enable certain software functions.

9.1 Connections

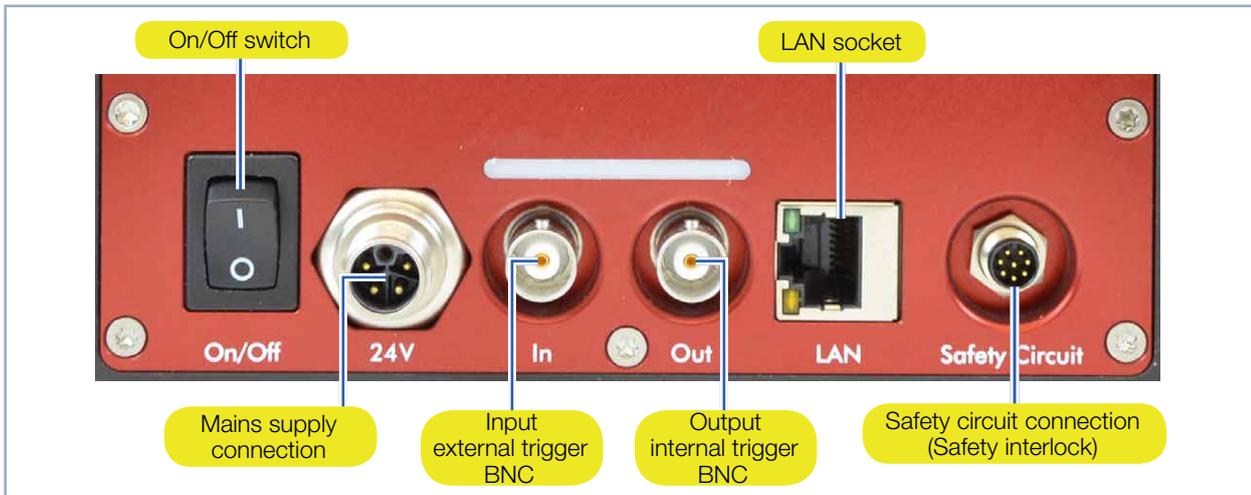
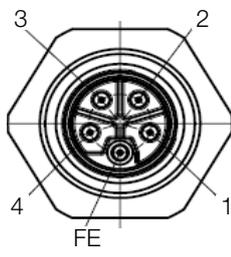


Fig. 9.1: Connections

9.2 Pin assignment

9.2.1 Power supply

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

Tab. 9.1: Connection socket for the PRIMES power supply in the connection panel

9.2.2 Inlet external trigger

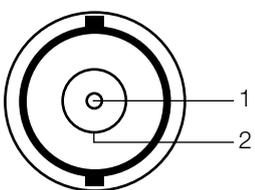
BNC connector (view: connector side)		
	Pin	Function
	1	+5 V (Trigger signal)
	2	GND

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

9.2.3 Outlet internal trigger

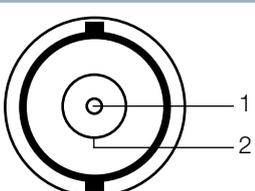
BNC connector (view: connector side)		
	Pin	Function
	1	+5 V (Trigger signal)
	2	GND

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

9.3 Safety facilities

9.3.1 Monitoring side access to the measuring objective and neutral-density filters

A safety switch monitors the side frame plates. When the frame plate is removed, the laser will switch off if the safety interlock is connected.



DANGER

Serious eye or skin injury due to laser radiation

When the safety interlock is not connected, radiation (Laser class 4) reflected during measuring operation may escape from the device when the side frame plate is open.

- ▶ Only operate the device with a mounted side frame plate.



Fig. 9.4: Device with side frame plate removed

9.3.2 Temperature control

The 1st and 2nd attenuators each have a temperature switch built into them that will trigger a warning message in the LaserDiagnosticsSoftware LDS when a temperature of 75 °C is exceeded. If the safety interlock is connected, the laser will be turned off.

NOTICE

Damage/Destruction of the device

Without a safety interlock connected, the device may be damaged or destroyed when subjected to excess temperatures.

- ▶ Operate the device only with a connected safety interlock.
- ▶ The LaserQualityMonitor LQM+ should never be left unattended while taking measurements.

9.3.3 Safety interlock

The port for a safety interlock, which monitors the 1st and 2nd attenuator for excess temperature and whether or not the side frame plates are opened, is integrated into the LaserQualityMonitor LQM+ 20 basic device.

⚠ DANGER

Serious eye or skin injury due to laser radiation; Damage/Destruction of the device

If the safety interlock is not connected, the safety equipment of the device will not be monitored.

- ▶ **Connect the laser control to terminals 1 to 4 so that the laser shuts off when these connection is interrupted.**



Fig. 9.5: Safety interlock device plug in the connection panel

Binder M8; 86 6119 1100 00008	
Pin	Function
1	Safety interlock (potential free). Connected with pin 2 when ready for operation. Connected with pin 3 when not ready.
2	Safety interlock (potential free). Connected with pin 1 when ready for operation.
3	Safety interlock (potential free). Connected with pin 1 when not ready for operation.
4	Safety interlock (potential free). Connected with pin 5 when ready for operation. Connected with pin 6 when not ready.
5	Safety interlock (potential free). Connected with pin 4 when ready for operation.
6	Safety interlock (potential free). Connected with pin 4 when not ready for operation.
7	+ 24 V
8	Safety interlock GND

Tab. 9.2: Pin assignment safety interlock

When connecting the safety interlock with pin 1 and pin 3 or with with pin 4 and pin 5, it has to be ensured that the laser is turned off when this connection is interrupted.

To be able to identify a connected safety interlock, pin 7 and pin 8 have to be bridged in the cable socket. If the cable socket is not connected and the safety interlock is thus not active, a warning message in the LaserDiagnosticsSoftware LDS is issued. A suitable 8-pole cable socket is part of the scope of delivery.

9.4 Connection to the PC and connect power supply

NOTICE

Damage/Destruction of the device

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

► Please turn off the PRIMES power supply before disconnecting the cables.

1. Connect the device with the PC via a crossover cable or with the network via a patch cable.
2. Plug the power supply into the connector socket for the power supply.

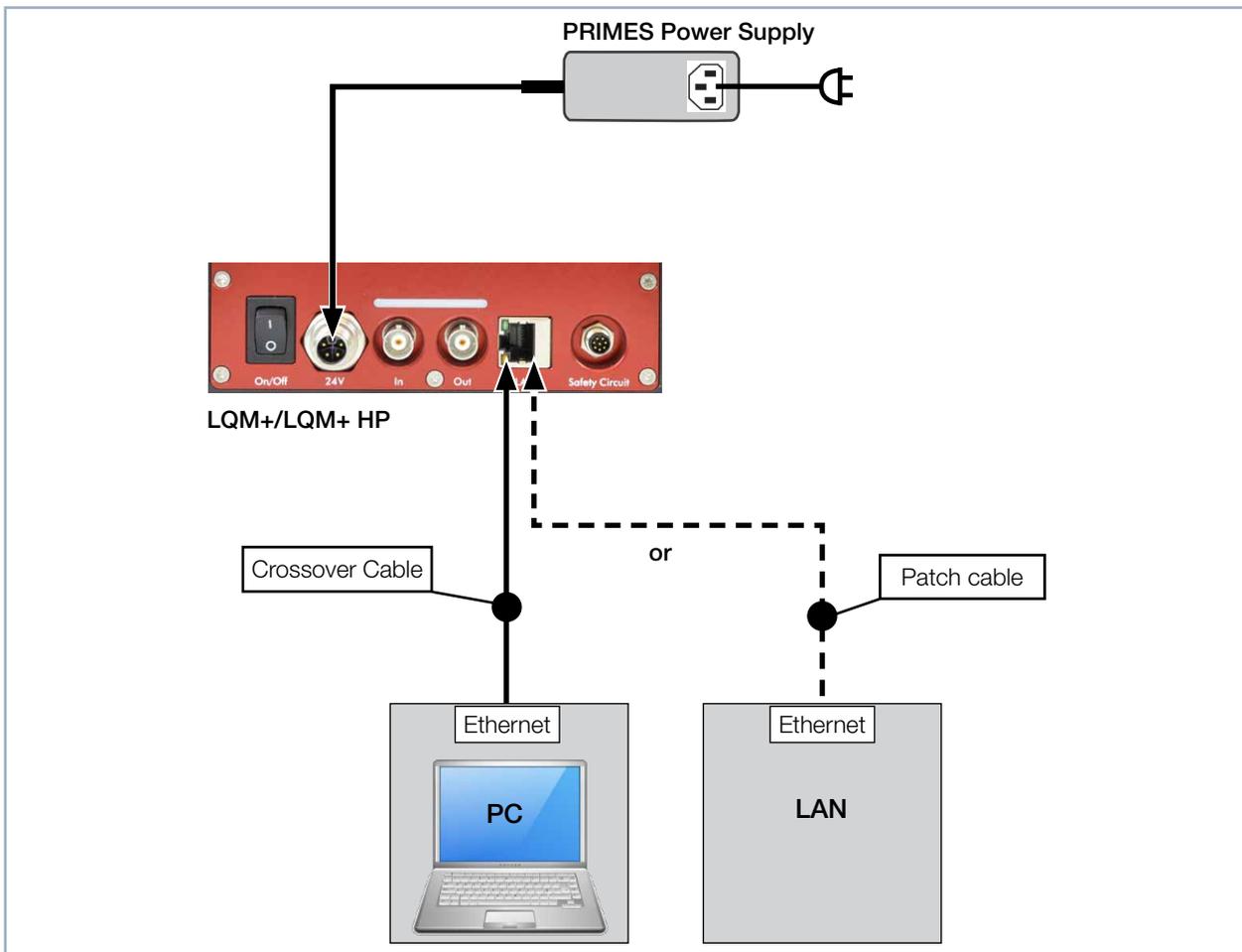


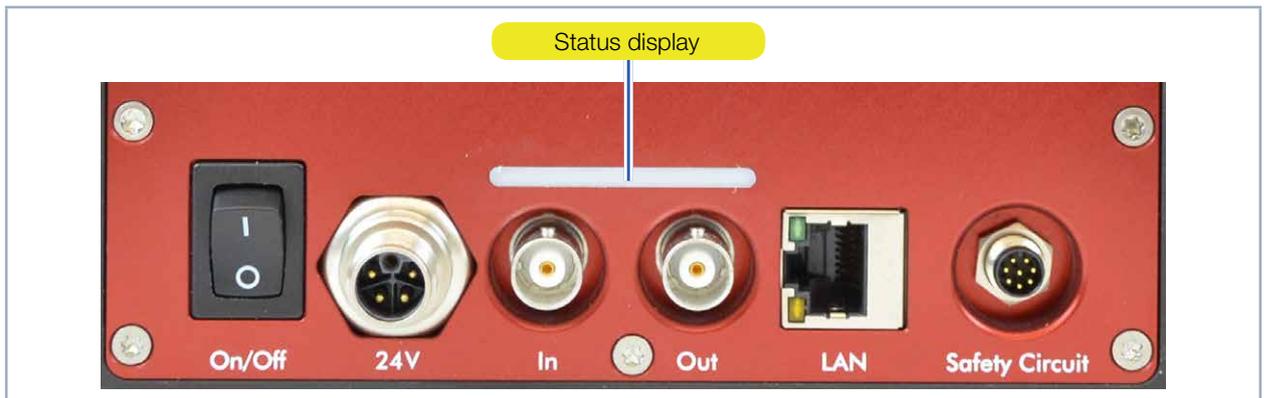
Fig. 9.6: Connection via Ethernet with a PC or a local network

10 Status display

The status display consists of an indicator field that indicates the various states of the LaserQualityMonitor LQM+ with various colors.

Color	Meaning
White	The device is switched on and operational
Yellow	Measuring
Red	Lights up briefly while the measuring plane is being recorded. Staying lit signals a device error. The device error is shown in the LaserDiagnosticsSoftware LDS.

Tab. 10.1: States of the status display



Tab. 10.2: Status display

11 Measurement

11.1 Safety instructions



DANGER

Serious eye or skin injury due to laser radiation

During the measurement the laser beam is guided on the device, which causes scattered or directed reflection of the laser beam (laser class 4).

The LaserQualityMonitor LQM+ must not be operated in any of the available configurations without taking the following precautions. All precautions must be taken, even when the fiber is in the collimator or fiber adapter.

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



DANGER

Serious eye or skin injury due to laser radiation

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

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



DANGER

Serious eye or skin injury due to laser radiation

When the safety interlock is not connected, radiation (laser class 4) reflected during measuring operation may escape from the device when the side frame plate is open.

- ▶ Connect the device's safety interlock to the laser control. Check that the safety interlock will turn off the laser properly in case of error.
-

NOTICE

Damage/Destruction of the device

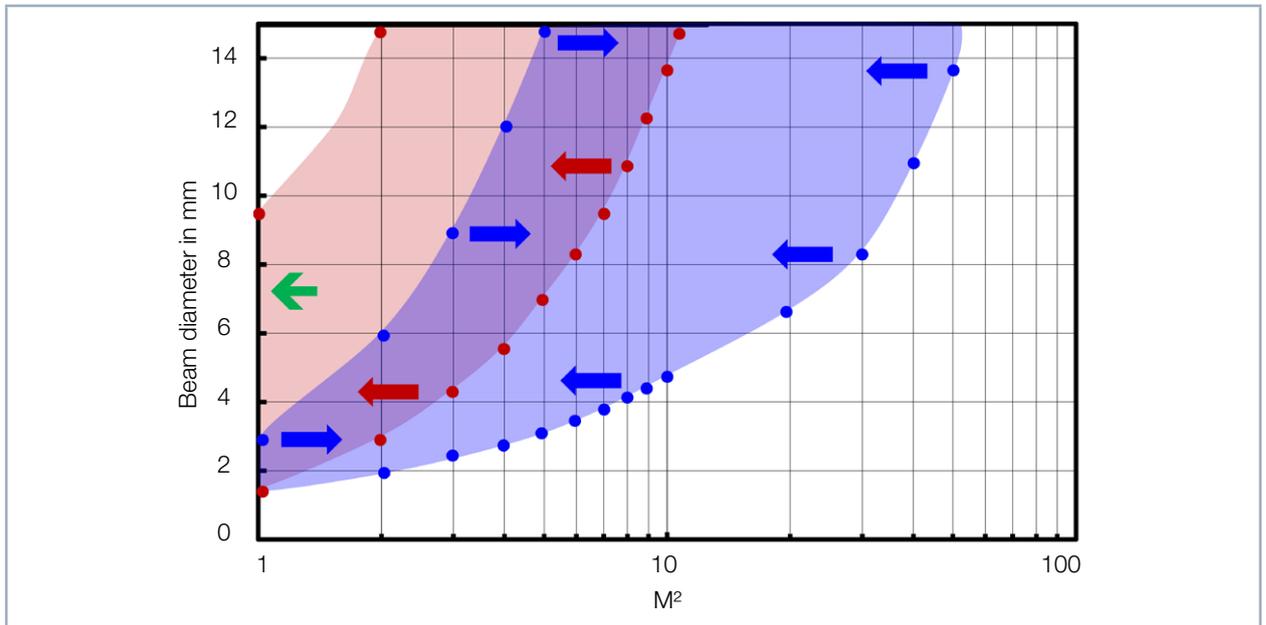
Without safety interlock connected, the device may be damaged or destroyed when subjected to excess temperatures.

- ▶ Connect the device's safety interlock to the laser control. Check that the safety interlock will turn off the laser properly in case of error.
 - ▶ The LaserQualityMonitor LQM+ should never be left unattended while taking measurements.
-

11.2 Selection and change of the measuring objective and the neutral density filter

11.2.1 Selection of the measuring objective

The selection of the correct measuring objective is of vital importance for the measurement quality. The limitation of use for the 1:1 or 5:1 measuring objectives is shown in the diagram Tab. 11.1 on page 31.



Tab. 11.1: Range of application of the LQM+ objectives

Blue area → 1:1 measuring objective
 Red area → 5:1 measuring objective

$$d_{foc} = \frac{4 \cdot \lambda}{\pi} \cdot \frac{f_{200mm}}{d_{rawbeam}} \cdot M^2$$

Example

The following example explains how a measuring objective is selected based on the minimum beam diameter in the LaserQualityMonitor LQM+ and the number of lit pixels to be achieved depending on the measuring objective (MOB).

λ = 1 064 nm
 M^2 = 1
 $d_{rawbeam}$ = 7.3 mm

→ $d_{foc} = 37.10 \mu\text{m}$ (d_{foc} = Focus diameter of the internal caustic)

For a fill factor of 35 % and a resolution of 64 pixel minimum 22 illuminated pixels are needed.

Quantity of illuminated pixels at 4.4 μm pixel pitch = $\frac{d_{foc}}{4.4 \mu\text{m}} \cdot \beta$ (Magnification of the measuring objective 1 or 5)

MOB 1:1 --> $37.1 \mu\text{m} / 4.4 \mu\text{m} \cdot 1 = 8$ ✗
 MOB 5:1 --> $37.1 \mu\text{m} / 4.4 \mu\text{m} \cdot 5 = 42$ ✓

11.2.2 Exchanging the measuring objective or the neutral density filter

For changing a measuring objective or the neutral-density filter, the plate on the side of the LaserQualityMonitor LQM+ has to be opened:

1. Turn off the laser.
2. Press down two locking bolts (see Fig. 11.1 on page 32):
 - The plate on the side will then jump out.
 - The safety interlock is triggered (see chapter 9.3.1 on page 26).

Optical components can be slid into the optical path of the LaserQualityMonitor LQM+ at three locations (see Fig. 11.1 on page 32, Positions 1, 2, 3).

Slot	Optical Component
1	5:1 Measuring objective
2	1:1 Measuring objective
3	Neutral density filter (OD-Filter)
4 5 6	Storage slots for unused components

Tab. 11.2: Slot positions of the optical components



Important:

In order to prevent measurement errors, there should only ever be one measuring objective in the optical path at a time.

All insertions are coded differently via two dowels in order to keep the measuring objective and neutral-density filter from getting mixed up. The measuring objective and OD filter are also equipped with an electronic memory chip (EEPROM). The EEPROM contains information on the measuring objectives and the OD filters that is displayed in the metadata of the LaserDiagnosticsSoftware LDS.

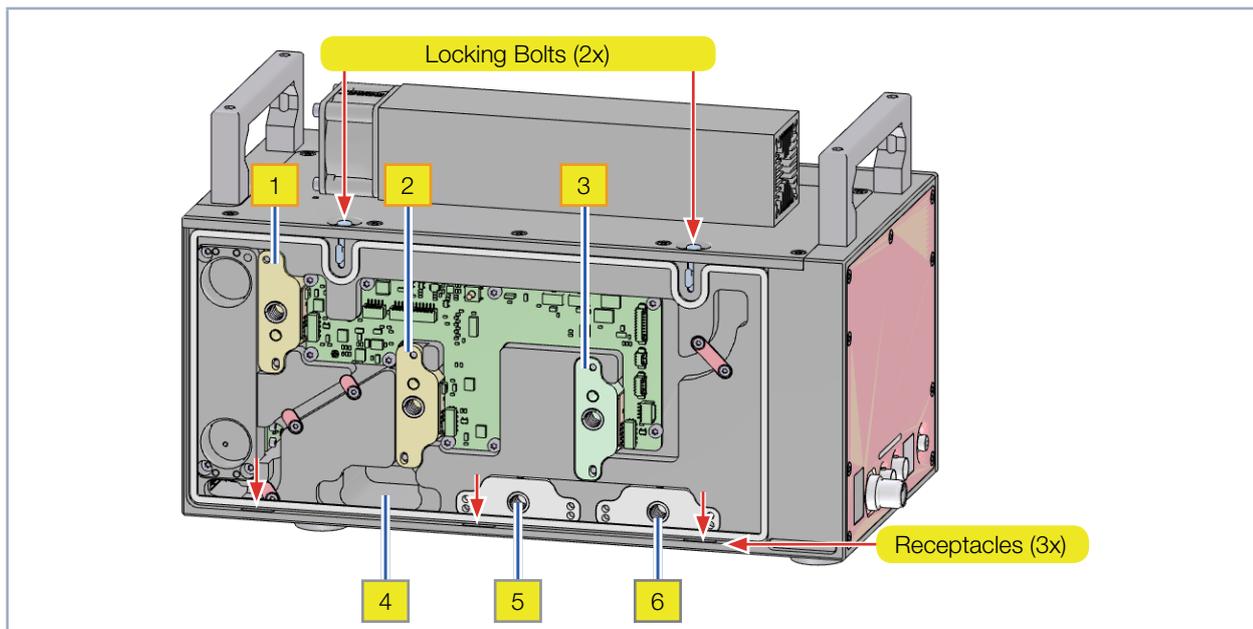


Fig. 11.1: Slot positions for the optical components

NOTICE

Damage of the device

Contamination in the device can damage the optical components.

- ▶ Seal unused slots with the provided dummy inserts.



Fig. 11.2: Dummy insert



DANGER

Serious eye or skin injury due to laser radiation

When the safety interlock is not connected and the the side frame plate is opened, radiation (Laser class 4) reflected during measuring operation may escape from the device.

- ▶ Only operate the device with a mounted housing plate.

3. Place the housing plate in the receptacles (see Fig. 11.1 on page 32).
4. Flip the housing plate up until the two locking bolts clip into place.
5. Check that the housing plate is plan on the casing.

11.2.3 Neutral density filter

Depending on laser beam source and configuration of the LaserQualityMonitor LQM+, it can be necessary to reduce the power once more.

This is done with a neutral density filter which is able to go into the beam path in front of the CCD sensor. The optical density of the filter can be varied between 1 (1:10) and 5 (1:100 000).

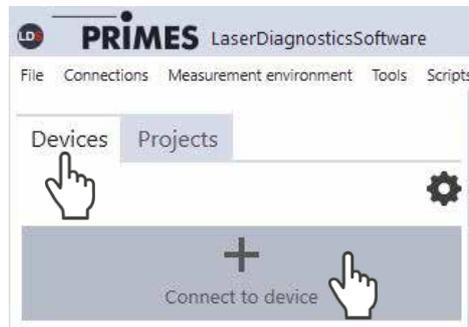


Fig. 11.3: Neutral density filter

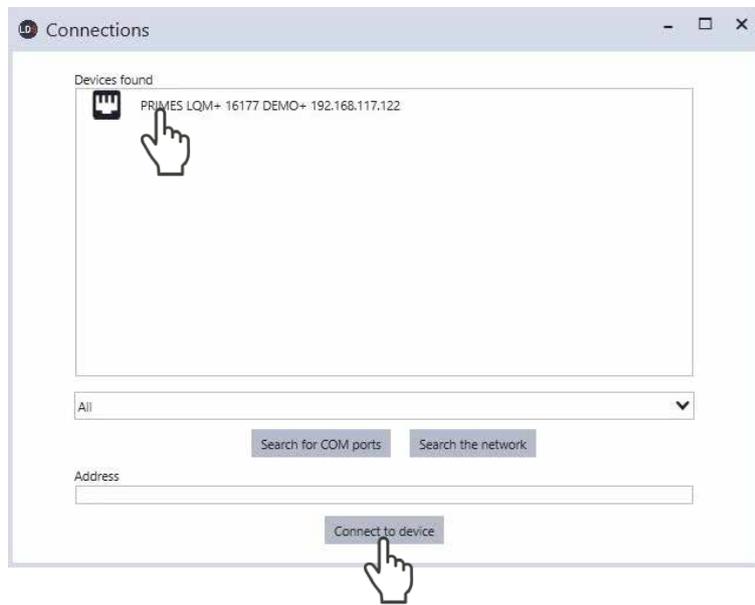
11.3 Connect the LaserQualityMonitor LQM+ with the LaserDiagnosticsSoftware LDS

11.3.1 Connect device

1. Turn on the LaserQualityMonitor LQM+.
- 👁 The operating mode is shown in the status display (see chapter 10 on page 29).
2. Start the LaserDiagnosticsSoftware LDS.
3. Click on the **Devices** tab.
4. Click on the **+ Connect to device** button under the tab.



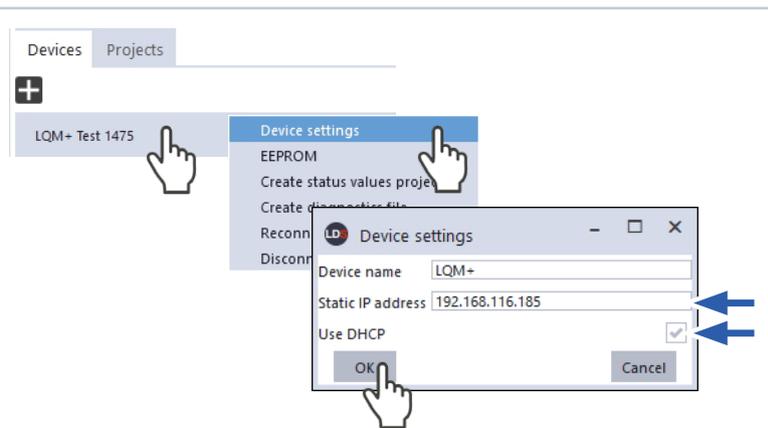
- 👁 The **Connections** window appears.
5. Click on the desired device.
6. Click on the **Connect to device** button.



11.3.2 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 LaserQualityMonitor LQM+ off and on again.

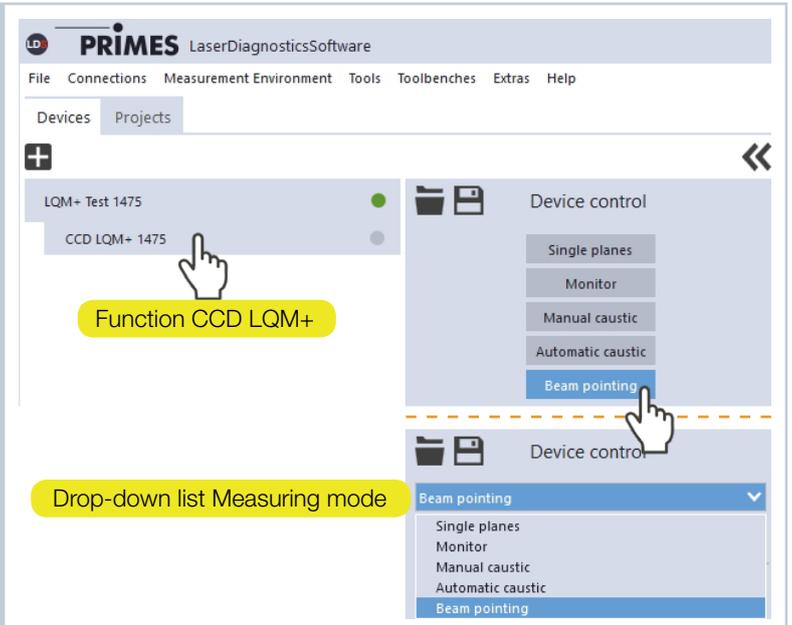


11.4 Set up the LaserQualityMonitor LQM+ with the LaserDiagnosticsSoftware LDS

After performing manual alignment with the alignment tool as described in chapter 7.2 on page 15 (only for an open beam measurement) or after inserting the fiber, you can check the alignment using a function of the LaserDiagnosticsSoftware LDS.

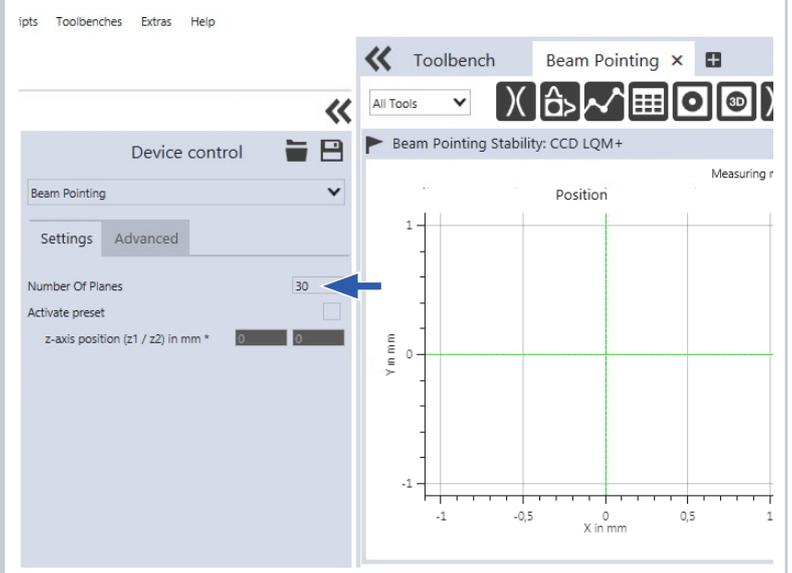
11.4.1 Choose the beam pointing function

1. Connect the device according to chapter 11.3 on page 34 with the LaserDiagnosticsSoftware LDS.
 - 👁️ The LaserQualityMonitor LQM+ is displayed as a connected device.
2. Click on **CCD LQM+**.
 - 👁️ The menu **Device control** opens.
3. Click on the **Beam pointing** button or on the drop-down list measurement mode and **Beam pointing**.



- 👁️ The corresponding **Device control** opens.
- 👁️ The **Beam pointing** workbench opens with the following tools:
 - **Beam pointing stability** with the windows: **Position** and **Angle**
 - **False-color image**

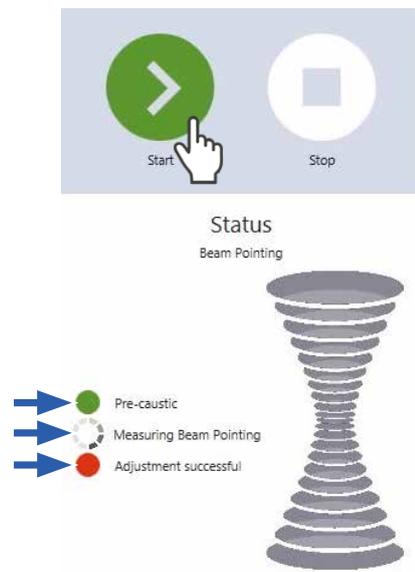
Number of measuring points (planes)
Enter the number of measuring points shown in the **Beam position** workbench. It is preset to 30 planes.



11.4.2 Start beam search

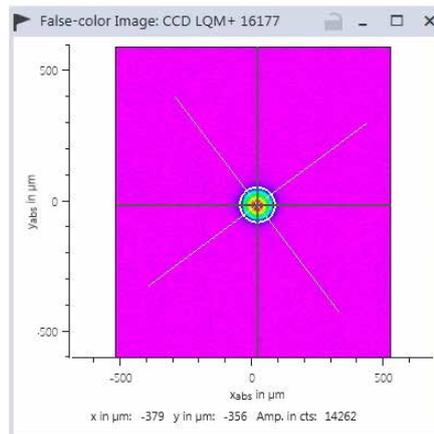
1. Follow the safety instructions in chapter 11.1 on page 30.
2. Turn on the laser.
3. Click on the **Start** button.

👁 The progress of beam pointing determination is indicated when **Pre-caustic**, **Measuring beam pointing** and then **Adjustment successful** are displayed in the notifications:



Pre-caustic

During the pre-caustic, the optimal z_1 and z_2 positions along the beam propagation are identified in the **False-color image** window (see also Fig. 11.4 on page 39).



Measuring beam pointing

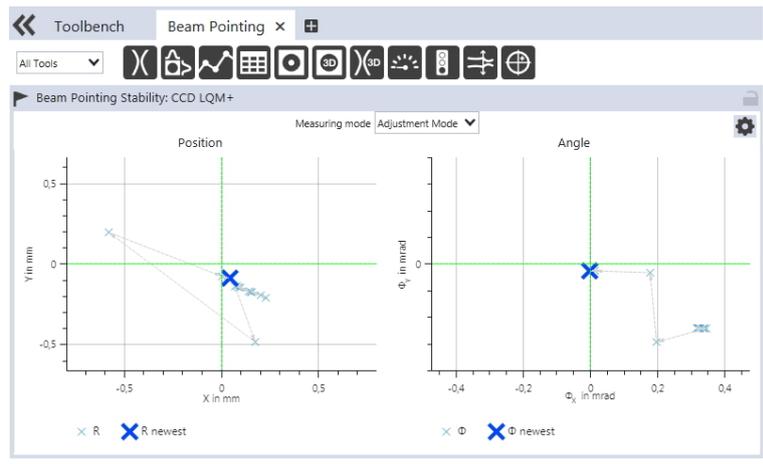
During the measurements, measuring points are constantly recorded at the positions z_1 and z_2 .

The current position of the beam is marked with a large X, with previous positions being marked with a small x.

Align the laser beam so that the current measuring point X is centered in the crosshairs as accurately as possible in the **Position** and **Angle** windows.

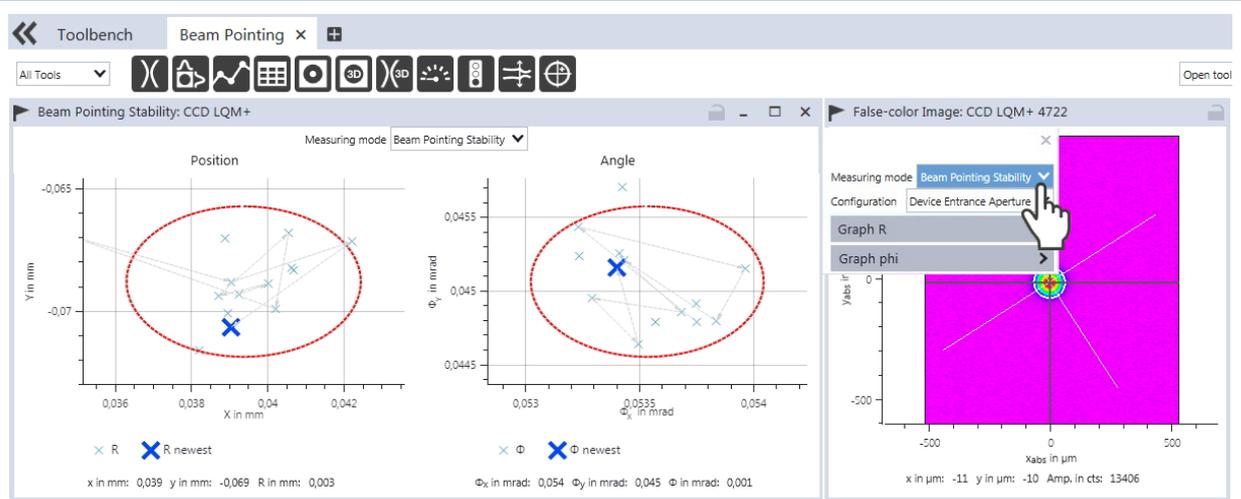
Only for a 1st attenuator:

Use the adjusting screws on the 1st attenuator module.



👁 The display of the beam position in the **Position** and **Angle** windows can be switched to a display of **Beam pointing stability** by clicking on the gear icon ⚙.

You can reset the values for beam position stability in the **Position** and **Angle** windows by pressing the **Reset** button. You can log the **Beam pointing stability** as described in chapter 11.4.3 on page 38.



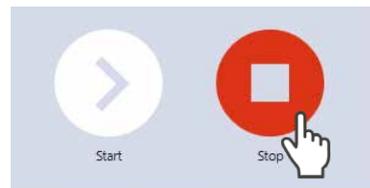
Adjustment successful

As soon as the laser beam has been properly aligned, the message **Adjustment successful** will appear

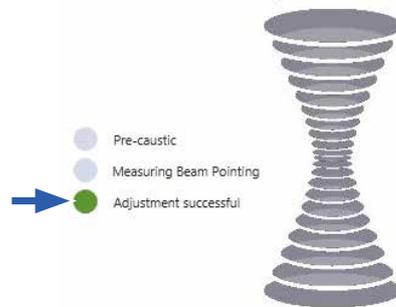
👁 The display circle will change from red to green.

4. Click on the **Stop** button.
5. Turn off the laser.

If the automated beam search is unable to find the laser beam, enter the positions of the measurements z1 and z2 for a manual beam search in accordance with chapter 11.4.4 on page 39.



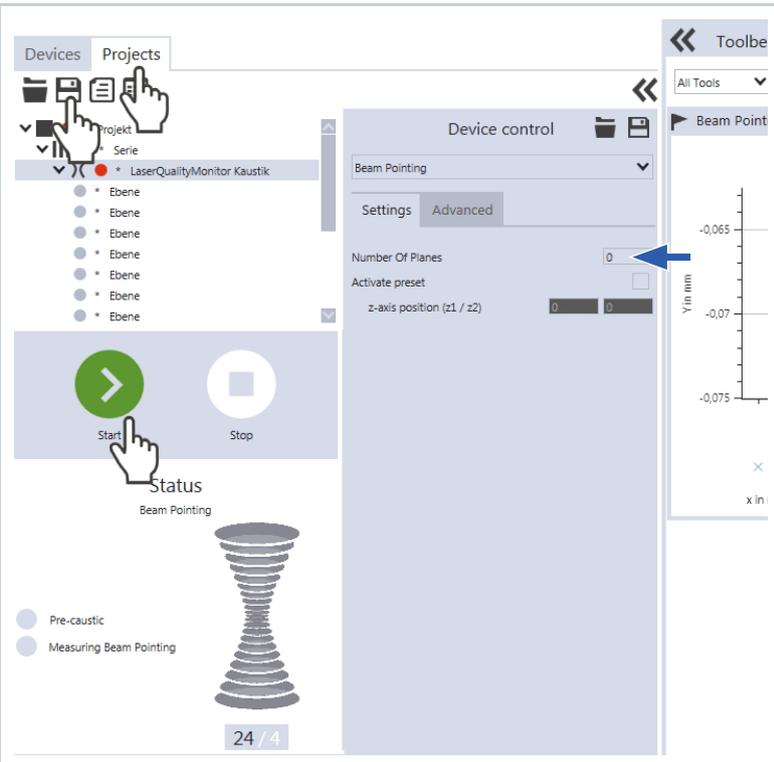
Status
Beam Pointing



11.4.3 Log beam pointing stability

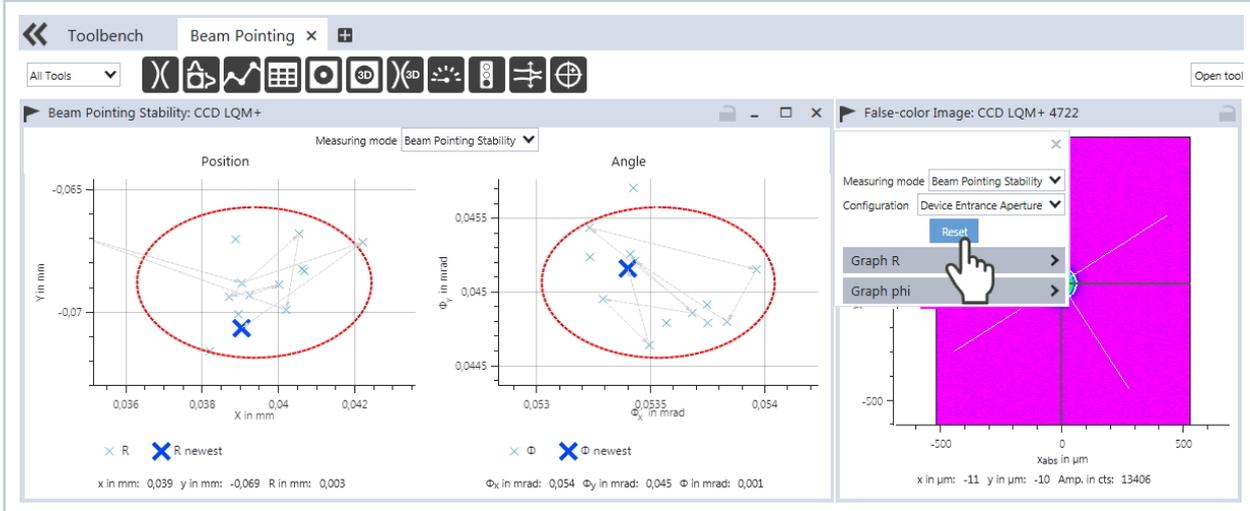
You can log the beam pointing stability under **Device control > Settings:**

1. Enter the value of 0 in the **Plane quantity** field.
2. Click on the **Projects** tab.
3. Click on the **Start** button.
 - Continuous measurement data for beam position stability is generated in the project tree.
4. Click on the **Stop** button.
5. Click on the **Save** icon in order to save the measurement data.



👁 The measuring points in the **Position** and **Angle** windows can be deleted by clicking the gear icon ⚙ and the **Reset** button.

The measured data in the project tree is not deleted in the process.



11.4.4 If the laser beam is not found

If the laser beam isn't found during the automatic beam search or if the laser beam is too large for the measuring area (the laser beam exceeds the size of the CCD sensor), you can manually enter the position of the measurements z_1 and z_2 into the LaserDiagnosticsSoftware LDS for the beam search. The positions z_1 and z_2 define the scan range for the laser beam search.

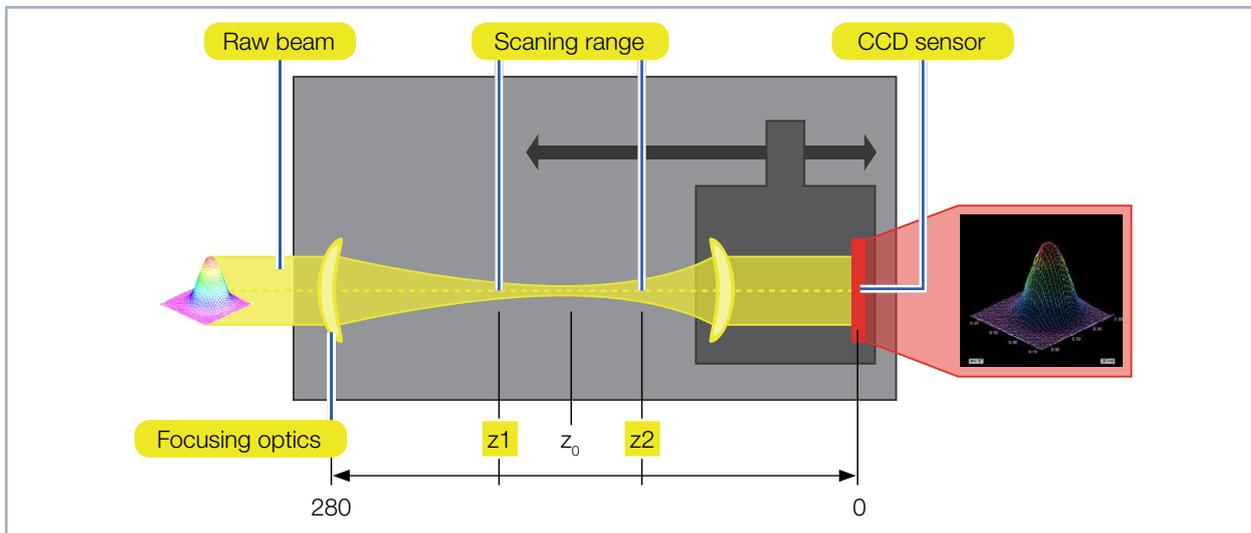
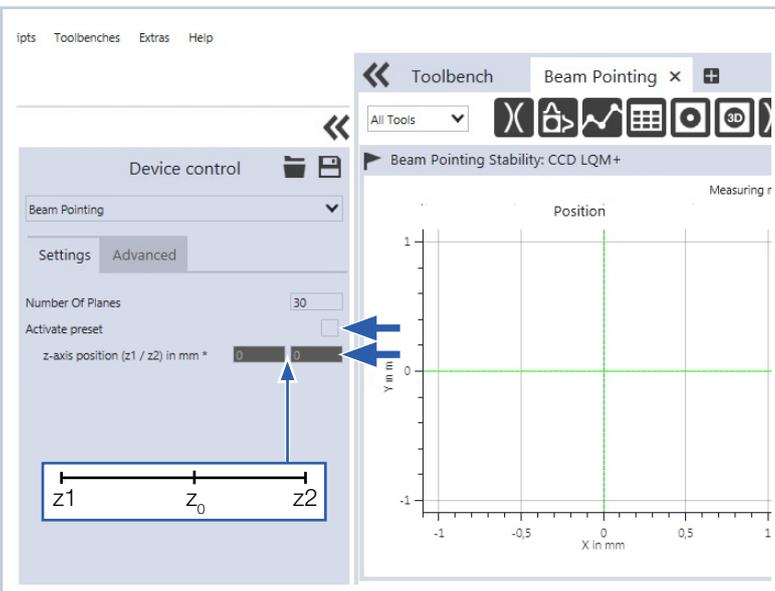


Fig. 11.4: Position of the measurements z_1 and z_2 for entry into the adjustment preset fields

You can enter the measuring positions for the beam search under **Device control > Settings:**

1. Mark the checkbox **Activate preset.**
2. Enter the measurement positions for z_1 and z_2 into the **z-axis position (z_1/z_2)** fields.
3. Start the beam search according to chapter 11.4.2 on page 36.
 - If the laser beam still isn't found, enter the modified values into the **z-axis position (z_1/z_2)** fields.



11.5 Perform an automatic caustic measurement

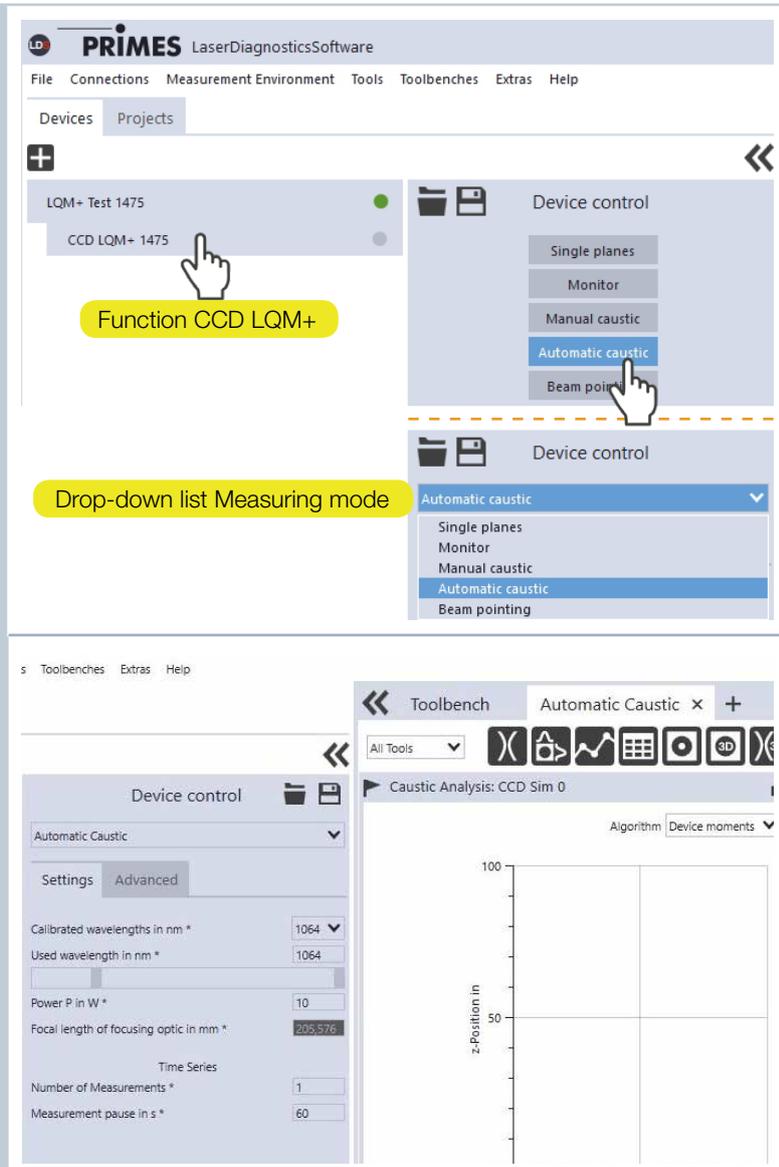
For the purpose of getting to know the LaserQualityMonitor LQM+, this chapter describes an automatic caustic measurement with the LaserDiagnosticsSoftware LDS as an example. For a detailed description of the software installation, file management and evaluation of the measured data, please refer to the separate operating manual LaserDiagnosticsSoftware LDS.

11.5.1 Choose automatic caustic measurement mode

1. Connect the device according to chapter 11.3 on page 34 with the LaserDiagnosticsSoftware LDS.
2. Click on **CCD LQM+**.
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** toolbench opens with the following tools:

- **Caustic analysis**
- **Plane analysis**
- **Raw Beam Analysis**

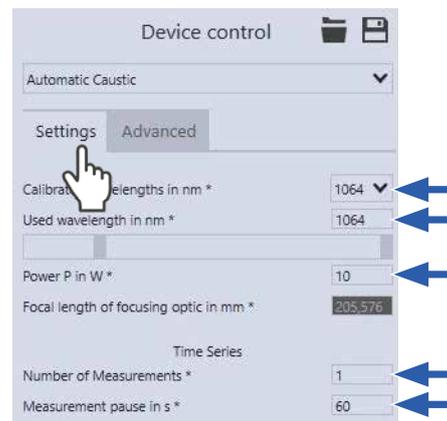


11.5.2 Configure settings (*Device control > Settings*)

1. Click on the **Settings** tab.
2. Select the calibrated wavelength of your LQM+ in nm.
3. Enter the laser wavelength used in nm.
4. Enter the laser output in W.

Only when measuring a time series

5. Enter the number of automatic caustic measurements.
6. Enter the measuring break between automatic caustic measurements in s.



11.5.3 Configure advanced settings (*Device control > Advanced*)

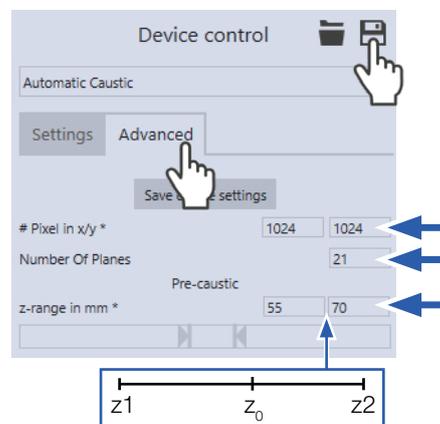
1. Click on the **Advanced** tab.
2. Enter the number of pixels in the x/y-direction in order to configure the resolution on the CCD sensor.
3. Enter the number of planes. Specifying 21 planes already generates a valid measurement.

Save preset

You can save information on the beam position in a file with preset.

If the laser beam isn't found

1. Enter the determined values for z_1 and z_2 from the z-axis position into the entry fields in the **Pre-caustic** area as described in chapter 11.4.4 on page 39.
2. Click on the **Save** icon in order to save the entry.



11.5.4 Starting an automatic caustic measurement

1. Follow the safety instructions in chapter 11.1 on page 30.
2. Turn on the laser.
3. Click on the **Start** button.

👁 The progress of the measurement is shown in the **Pre-caustic**, **Measurement caustic** displays and then in **Measurement ended**:

Pre-caustic

As the indication is being displayed, the optimal measuring parameters such as measuring window position, measuring window size, integration time, and the z-range (measuring range along the beam propagation) are determined automatically.

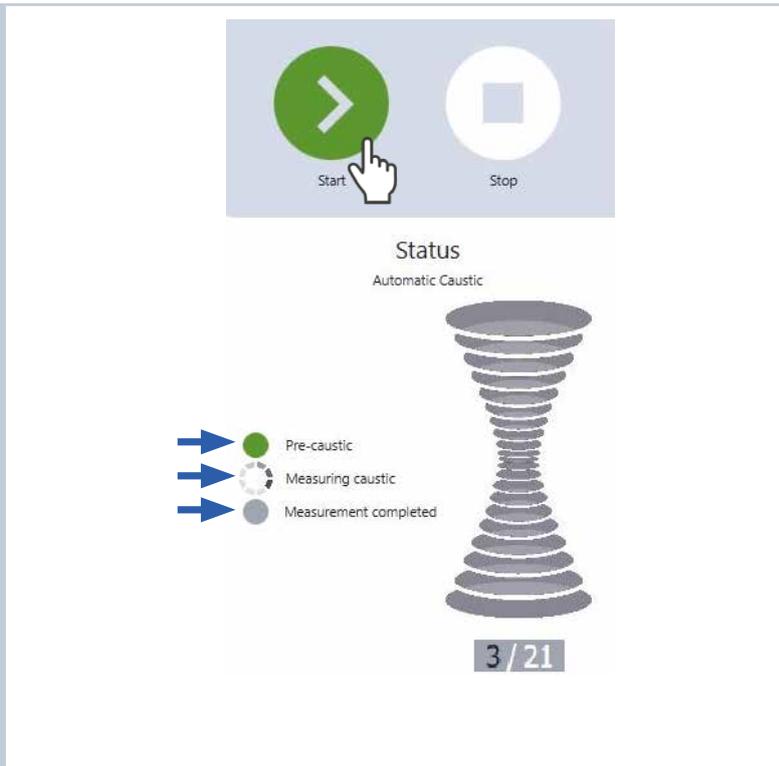
Measuring caustic

The actual measurement is carried out during the indication.

Measurement completed

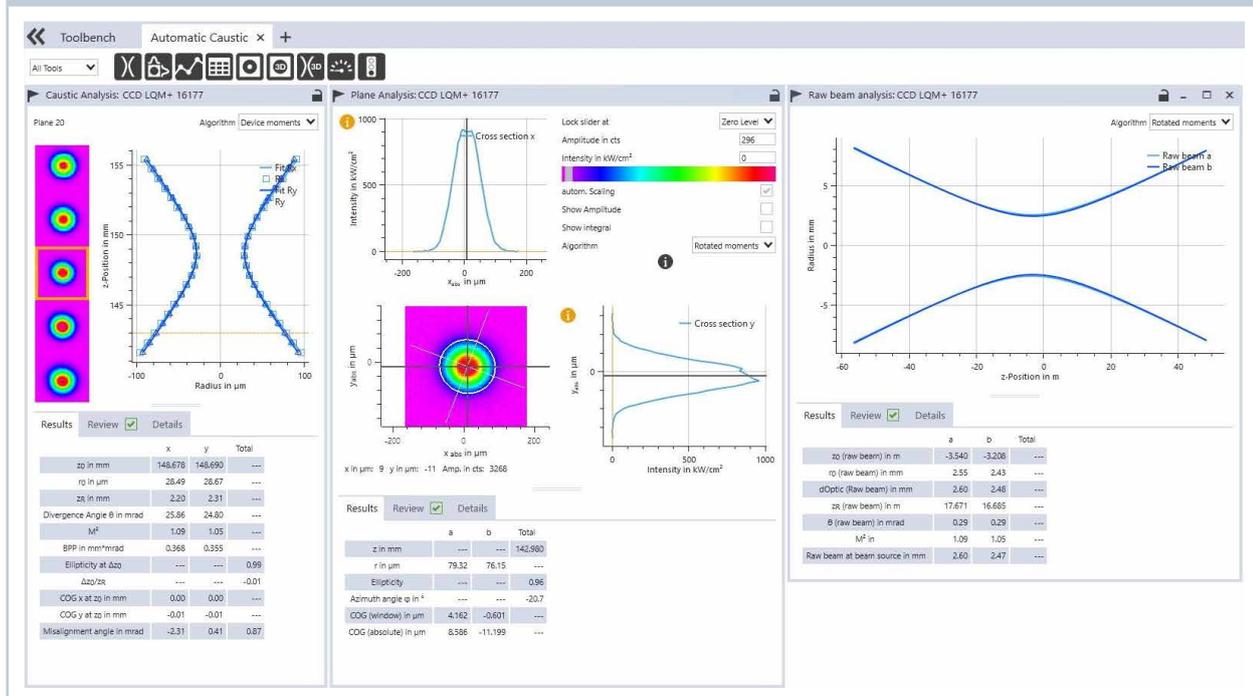
The measurement has been completed.

4. Turn off the laser.



11.5.5 Measurement results display

👁 The measurement results are shown in the opened tools after the measurement is 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.



11.6 Perform power measurement

With LaserQualityMonitor LQM+ devices, the power measurement can be performed at 500 W with a 1st attenuator. When there is an additional 2nd attenuator, the power can be measured separately at the 2nd attenuator. The measurements at the 1st and 2nd attenuators are performed in the same way.

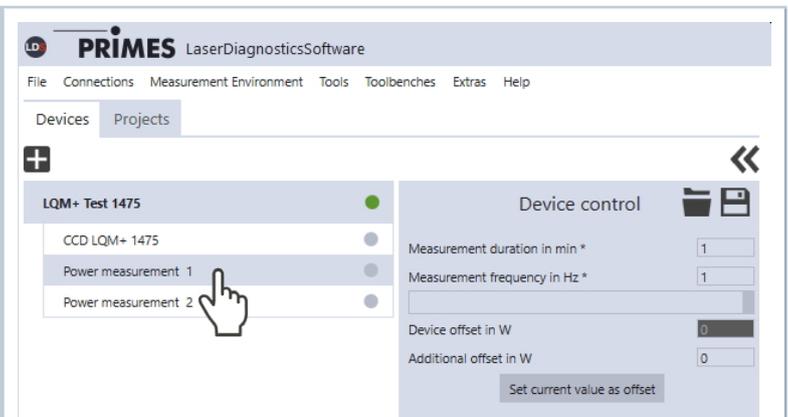
Separately from the power measurement described in this chapter, the power measurement values are automatically recorded for a single plane, caustic, or automatic caustic measurement and shown under the Details table in the workbenches.

For the purpose of getting to know the LaserQualityMonitor LQM+, this chapter describes a power measurement with the LaserDiagnosticsSoftware LDS as an example.

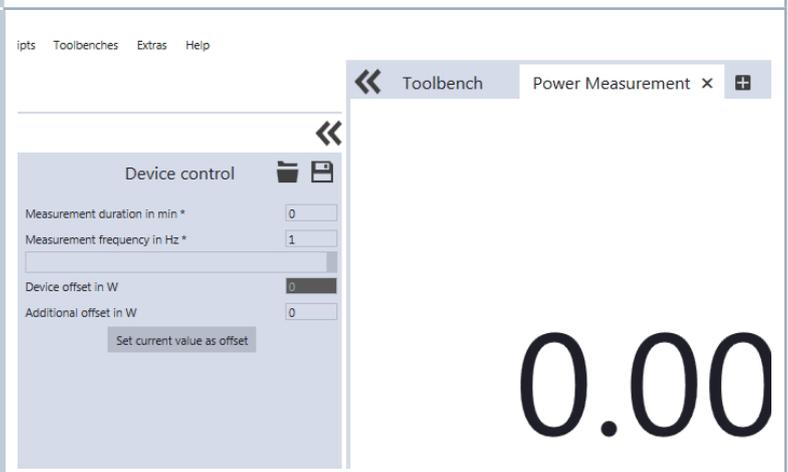
You can find more detailed information on LaserDiagnosticsSoftware LDS in the separate operating manual for the LaserDiagnosticsSoftware LDS.

11.6.1 Choose power measurement mode

1. Connect the device according to chapter 11.3 on page 34 with the LaserDiagnosticsSoftware LDS.
 - 👁️ The LaserQualityMonitor LQM+ is displayed as a connected device.
2. Click on **Power measurement 1**.
 - The measurement is performed for the 1st attenuator.



- 👁️ The corresponding **Device control** opens.
- 👁️ The **Power Measurement** toolbench opens.

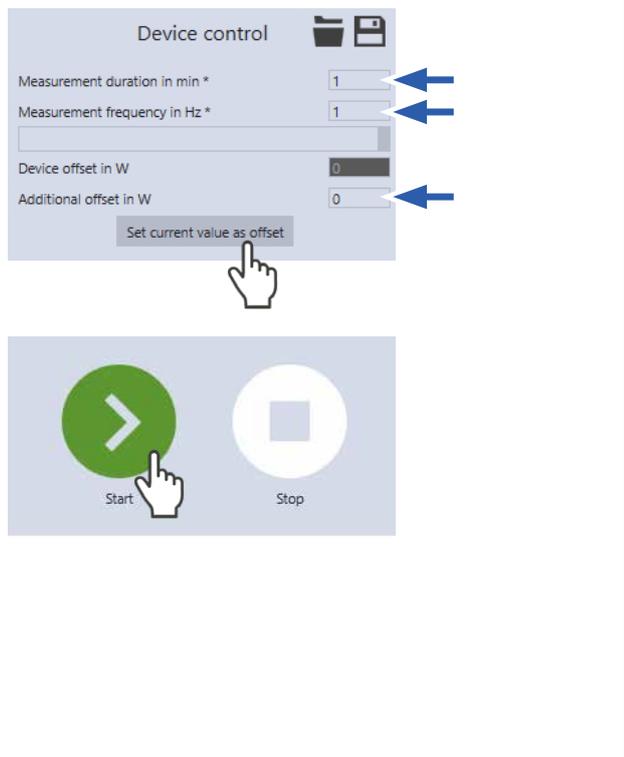


11.6.2 Configure settings (*Device control*)

1. Start and end a measurement as described in chapter 11.6.3 on page 44.

Before the device offset can be determined, the device must go through a thermalization period.

2. After a measurement has ended and without the laser turned on, press the **Start** button.
3. After the display in the **Power Measurement** tool stabilizes, click on the **Stop** button.
4. Click on the **Set current value as offset** button.
 - The value will show up in the **Additional Offset in W** entry window.
 - The device offset can also be entered manually.
5. Enter the measurement duration in min.
 - If a measurement duration is not entered, the power will be measured indefinitely.
6. Enter the **Measurement frequency in Hz**.

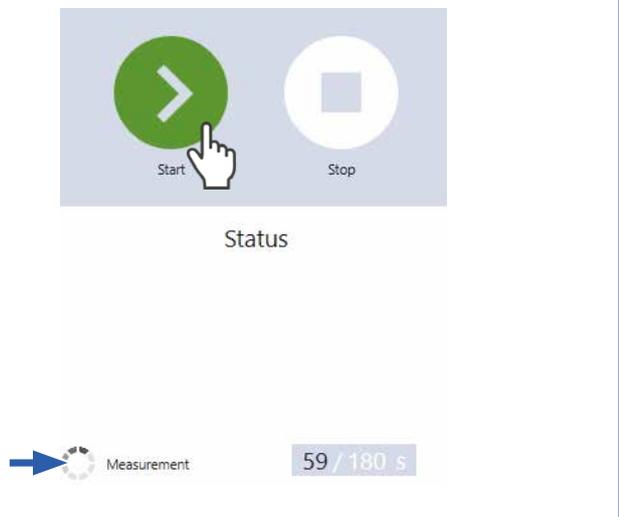


11.6.3 Starting a power measurement

1. Follow the safety instructions in chapter 11.1 on page 30.
 2. Turn on the laser.
 3. Click on the **Start** button.
- 👁 The progress of the measurement is displayed.

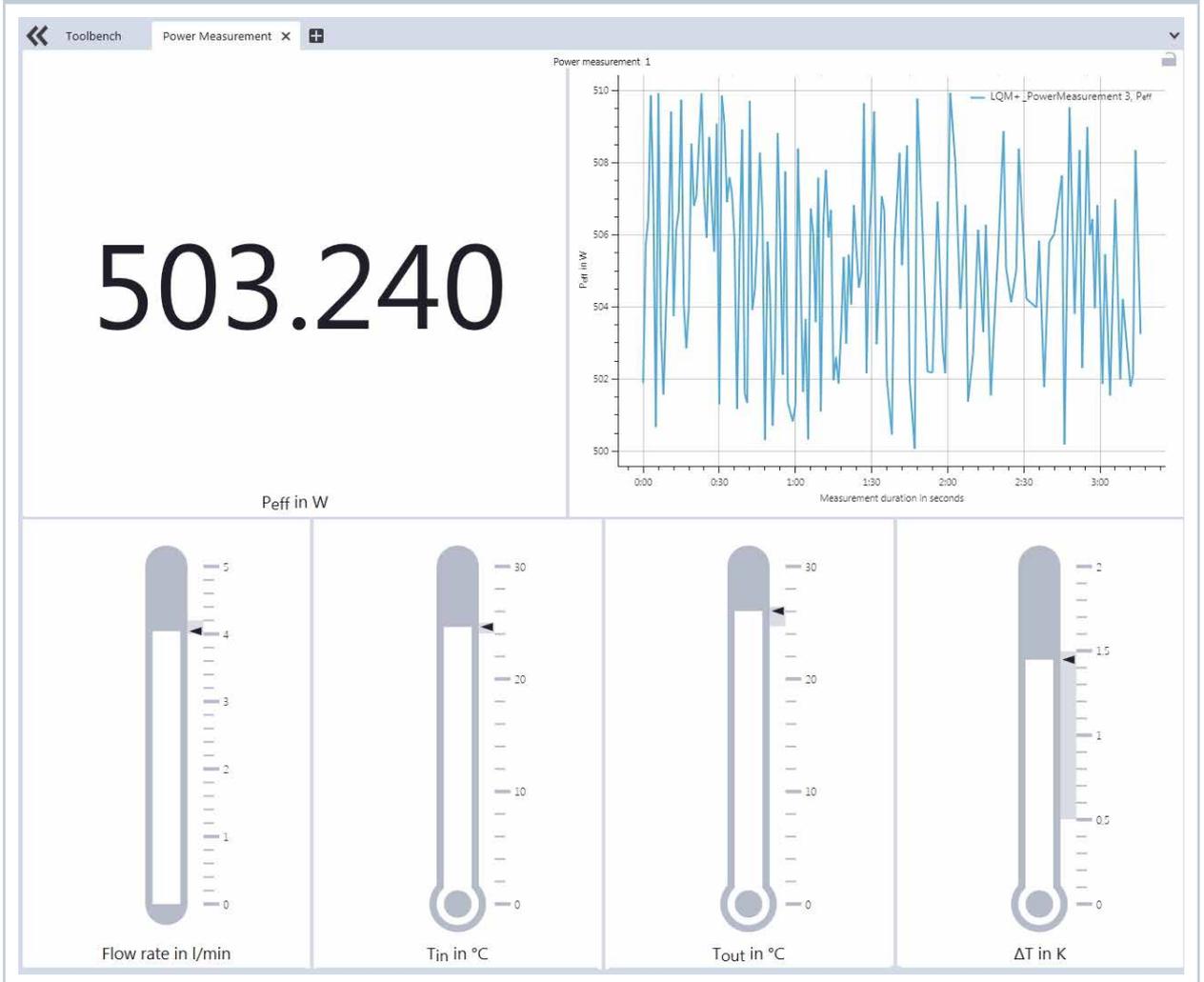
When a measuring period is entered in the **Device control > Measurement duration in min.** entry window, the measurement is terminated automatically.

4. Click on the **Stop** button.
 - The measurement is completed.
5. Turn off the laser.



11.6.4 Measurement results display

👁️ The measurement results are shown in the opened tool **Power Measurement** after the measurement is 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.



12 Troubleshooting

Error	Possible cause	Remedy
Error during a measurement	<ul style="list-style-type: none"> Data transmission error Processor crash in the measuring system Program execution error 	<ol style="list-style-type: none"> Restart the software. Turn off the supply voltage, turn it on again, and start another reset cycle. Restart the computer.
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 safety interlock has been triggered.	The side frame plate is not closed.	Close the side frame plate.
	The temperature sensor in the device is measuring a temperature > 60° C.	<ol style="list-style-type: none"> Turn off the laser immediately. Check the cool water supply (only LQM+ HP and LQM+ 500 (cooled by water)).
Error messages in LaserDiagnosticsSoftware LDS	Possible cause	Remedy
Attention, the casing is open! Please close the casing again after changing the measuring objectives.	The side frame plate is not closed.	Close the side frame plate.
No measuring objective or two measuring objectives detected.	A measuring objective has not been inserted or two measuring objectives have been inserted into the device.	Insert only one measuring objective. Check the position of the measuring objective.
The measuring objective used is not calibrated for this device, the accuracy can be increased considerably.	A measuring objective from a different device may have been inserted.	Check the inserted measuring objective. PRIMES should calibrate the measuring objective for higher accuracy.
Measurement can't be taken, the connection with the camera head has been disrupted. Please turn the device off and on again.	The device wasn't able to initialize the camera head.	Turn the device off and on again.
Error in saving the user-defined device settings, the parameters must be reset.	It wasn't possible to save the device settings in the device.	Save the device settings again.
Internal device error. Turn the device off and on again. Device moves to the start position during this process.	The device is experiencing an internal error.	Turn the device off and on again.

Tab. 12.1: Troubleshooting

13 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.

14 Storage

Please note before storing devices with water cooling circuit:

NOTICE

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

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

- ▶ **Empty the lines of the cooling circuit completely.**
- ▶ **Don't use any compressed air to empty the cooling circuit.**
- ▶ **To avoid contamination, please cover the apertures with the provided lid or optical tape.**
- ▶ **Even when the lines of the cooling circuit have been emptied, a small amount of residual water will remain in the device at all times. This may leak out and end up inside the device. Close the connector plug of the cooling circuit with the included sealing plug.**
- ▶ **Store the device in the original PRIMES transport box.**

15 Measures for the product disposal

Due to the Electrical and Electronic Equipment Act ("Elektro-G") PRIMES is obliged to dispose PRIMES measuring devices manufactured after August, 2005, free of charge.

PRIMES is a registered manufacturer in the German "Used Appliances Register" (Elektro-Altgeräte-Register "EAR") with the number WEEE-reg.-no. DE65549202.

Provided that you are located in the EU, you are welcome to send your PRIMES devices to the following address, where they will be disposed free of charge (this service does not include shipping costs):

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

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:

LaserQualityMonitor (LQM)

**Types: LQM 20; LQM 200/500; HP-LQM II
LQM+ 20; LQM+ 200/500; LQM+ HP**

is in conformity with the following relevant EC Directives:

- Machinery Directive 2006/42/EC
- EMC Directive EMC 2014/30/EU
- Low voltage Directive 2014/35/EU
- Directive 2011/65/EC on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment
- Directive 2004/22/EC on measuring instruments

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

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

Pfungstadt, May 20, 2019



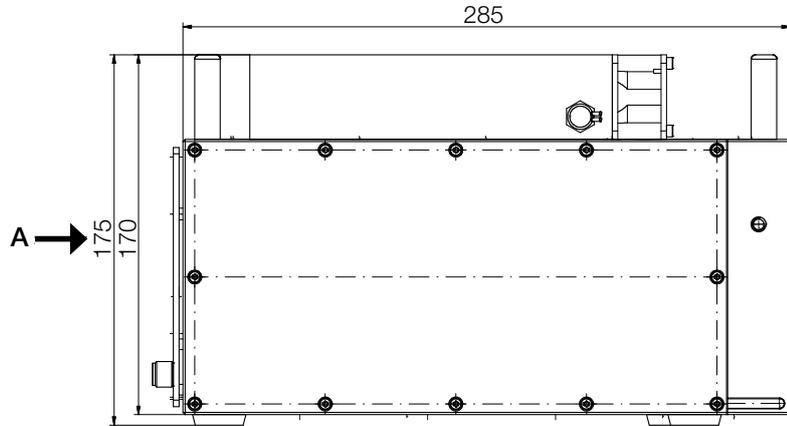
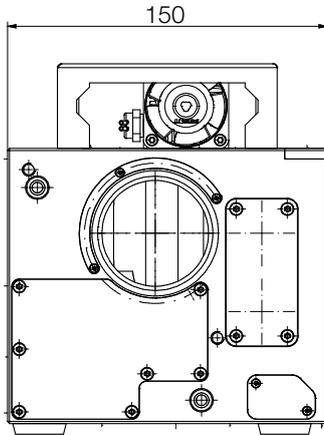
Dr. Reinhard Kramer, CEO

17 Technical data

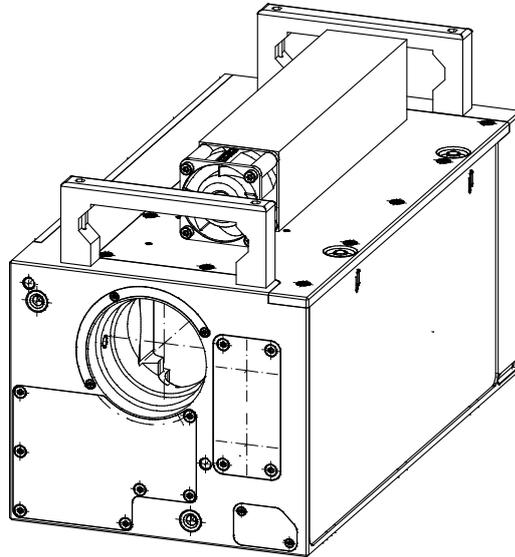
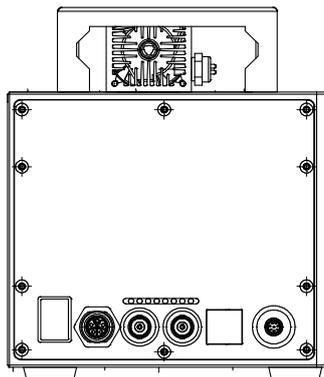
Measurement Parameters	LQM+ 20	LQM+ 200/500	LQM+ HP (10 kW)	LQM+ HP (20 kW)
Power range for 1064 nm	20W	200 W (opt. 500 W)	$M^2 < 5 = 3 \text{ kW}$ $M^2 > 5 = 10 \text{ kW}$	$M^2 < 5 = 5 \text{ kW}$ $M^2 > 5 = 20 \text{ kW}$
Pulse duration	100 fs - cw			
Wavelength range	340–360 nm (UV)/ 515–545 nm (Green)/ 1 030 – 1 090 nm (NIR)		532 nm on request/ 1 030 – 1 090 nm (NIR)	1 030 – 1 090 nm (NIR)
Beam dimensions	1.5 – 9 mm			Single mode: 14 – 16 mm Multi mode: 18 – 22 mm
Beam quality factor M^2	1 - 50			
Max. beam divergence	10 mrad			
Determined parameters				
Power density distribution	2D, 3D			
Supply Data				
Power supply	24 V DC \pm 5 %, max. 1.8 A			
Cooling	Air cooling	Air cooling (opt. Water cooling)	Water cooling	Water cooling
Cooling water pressure	---	2 bar primary pressure with an unpressurized outflow, max. 4 bar		min. 4 bar
Min. Cooling water flow rate	---	1,5 l/min	7 l/min	18 l/min
Cooling water temperature $T_{in}^{1)}$	--	Dew point temperatur $< T_{in} < 30 \text{ }^\circ\text{C}$		
¹⁾ Please consult with PRIMES before doing anything that does not comply with this specification.				
Communication				
Interface	Ethernet			
Dimensions and Weight				
Dimensions (L x W x H)	285x190x180mm	350x230x190mm	480x300x190mm	495x320x190mm
Weight	approx. 10 kg	approx. 18 kg	approx. 35 kg	approx. 35 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

18.1 LQM+ 20

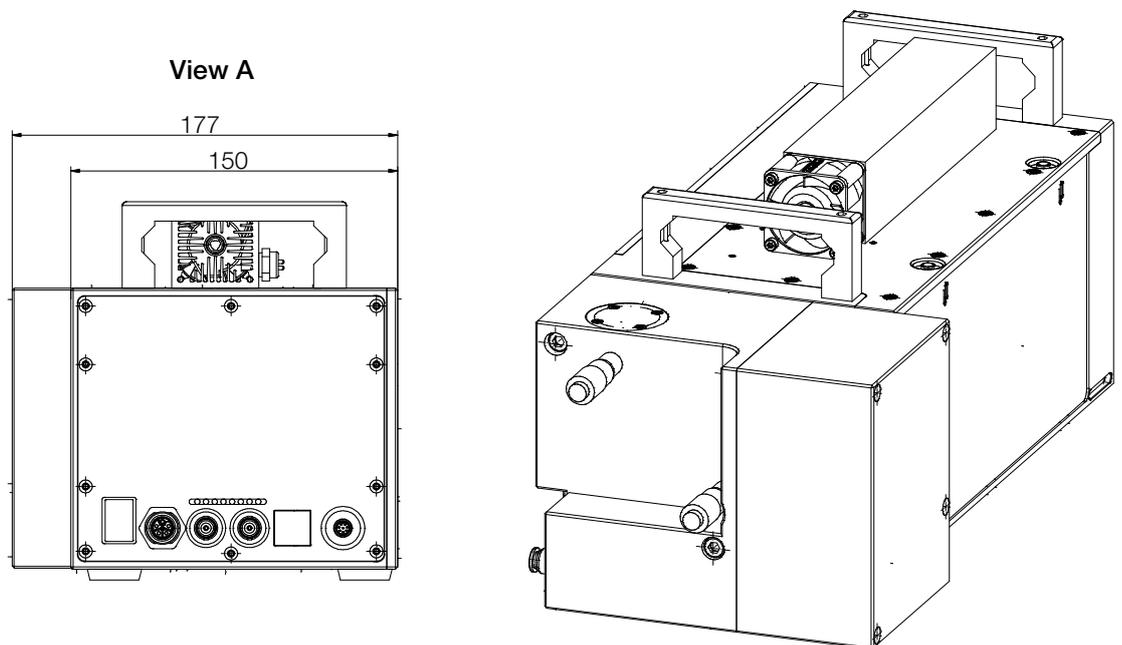
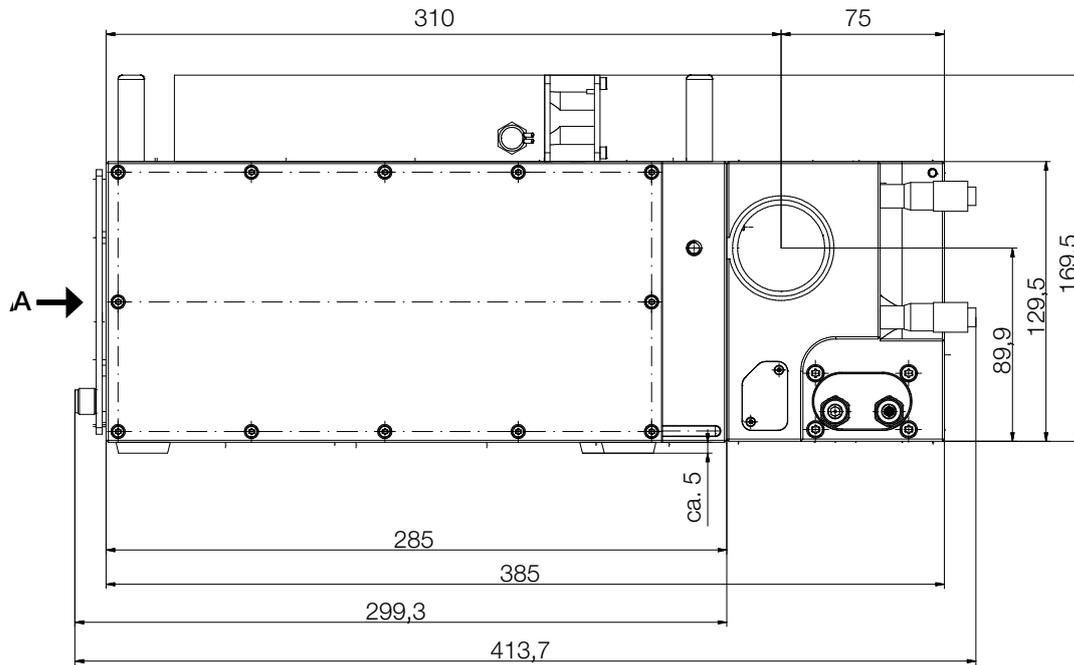


View A



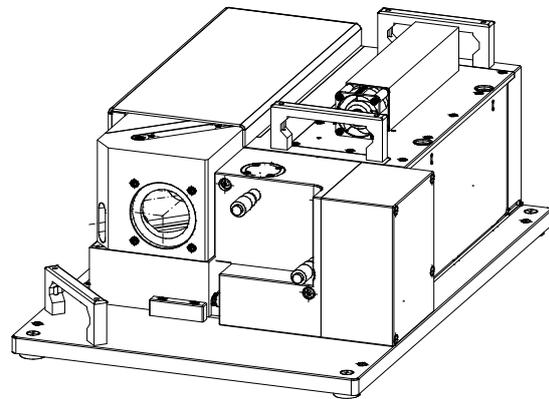
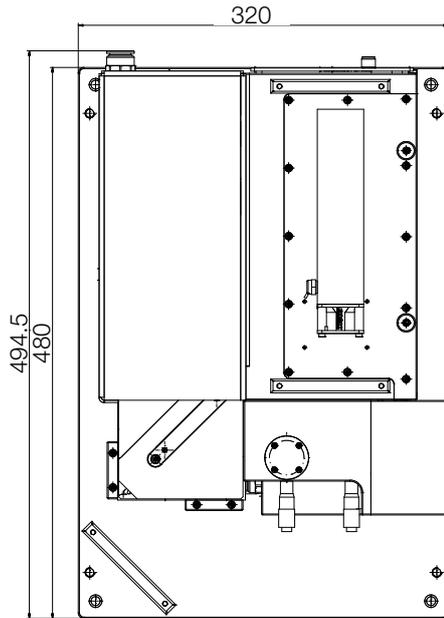
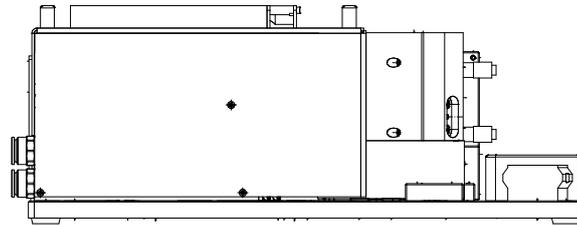
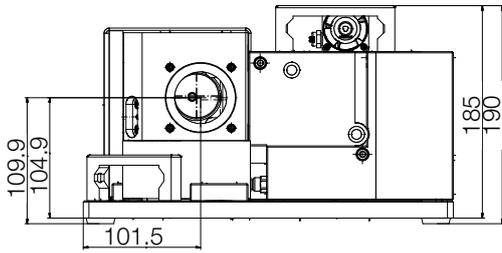
All dimensions in mm (general tolerance ISO 2768-v)

18.2 LQM+ 200/500 (without bottom plate)



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

18.3 LQM+ HP



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

19 Appendix

19.1 Changing the factory setting on the LQM+ 20/200UV

NOTICE

Damage/Destruction of optical components

Changing the factory settings may lead to damages to the device during the measuring operation.

- ▶ **Changing the factory settings for positioning range is only allowed by well trained and experienced personnel. In case of any doubt, please contact PRIMES service.**

The length of the internal beam path is influenced by the movement of prisms inside the device. Depending on the optical properties and the pulse parameters of a laser source, damages to the internal optical elements can occur. Especially in case of short pulsed UV-lasers the damages are foreseen. To prevent the device from getting damaged and to avoid a positioning of a prism close to the internal focus, a shortened positioning range can be chosen.

The LaserQualityMonitor LQM+ 20/200UV is typically delivered with the shortened positioning range as a factory setting. Factory settings for standard and shortened positioning range are preset by a jumper, see picture below.

You can change the positioning range by replugging a jumper in the device.



DANGER

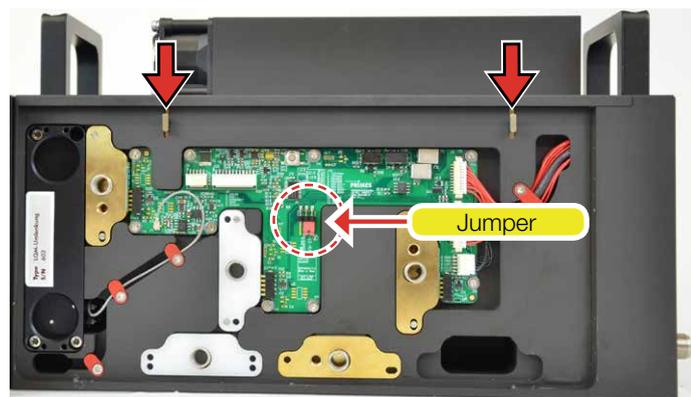
Serious eye or skin injury due to laser radiation

If a safety interlock is not connected, a reflected beam (Class 4 Laser) may escape from the device when the laser is turned on and the side frame plate is open.

- ▶ **Turn off the laser before removing the housing plate.**

1. Turn off the laser.
2. Turn off the power supply of the LQM+.
3. Remove the housing plate on the side of the device by pressing down the two locking bolts (see red arrows).

 The housing plate will then jump out.



NOTICE

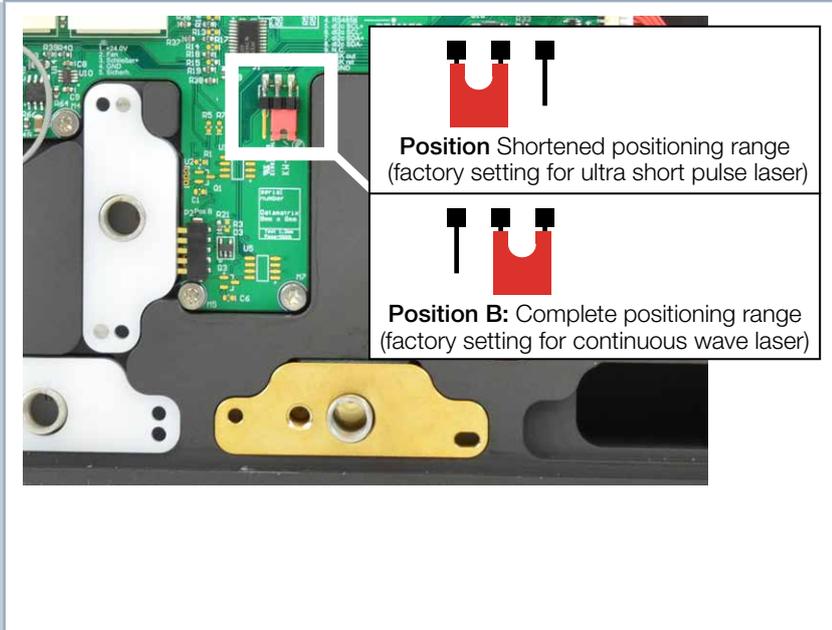


Component susceptible to electrostatic discharge

The circuit board could be destroyed by electrostatic discharge.

- ▶ Before reconnecting the jumper, put on an ESD armband.

4. Before switching the jumpers, put on an ESD armband.
5. On the board you can find a jumper which has to be brought into the desired position.
6. Place the housing plate in the receptacles (see Fig. 11.1 on page 32) in the casing.
7. Flip the housing plate up until the two locking bolts clip into place.
8. Check that the housing plate is plan on the casing.
9. Turn on the LaserQualityMonitor LQM+.
 - The device moves the prism carriage to a reference point and stops.
 - After referencing is initiated, the prism carriage will be located within the allowable range.



19.2 HighYAG collimation module up to 6 kW



DANGER

Serious eye or skin injury due to laser radiation

During the measurement the laser beam is guided on the device, which causes scattered or directed reflection of the laser beam (laser class 4).

The LaserQualityMonitor LQM+ cannot be operated in any of the available configurations without taking the following precautions. All precautions must be taken, even when the fiber is in the collimator or fiber adapter.

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

As an option PRIMES offers a 67 mm HighYAG collimation module which can be mounted directly to the 2nd attenuator of the LQM+ HP.

Specifications	
Max. power	6 kW (multi mode)
	3 kW (single mode)
Focal length	67 mm
Acceptable divergence	160 mrad (half angle)*
Wavelength range	1 025 – 1 080 nm
Design wave length	1 064 nm
Fibre core diameter	10 – 1 000 µm
Fibre socket	LLK-D & QBH (LLK-B on request)
* If the 67 mm collimation module is operated with LQM+ HP the divergence (half angle) cannot be more than 110 mrad.	

Tab. 19.1: Specifications of the 67 mm HighYAG collimation module up to 6 kW

19.2.1 Key data for the cooling system for the HighYAG collimation module

Specifications	
Max. cooling water pressure	6 bar
Min. cooling water flow rate	2 l/min
Cooling water quality	Deionized water with corrosion inhibitor
Filter mesh	< 100 µm

Tab. 19.2: Specifications of the cooling system



Fig. 19.1: Water connections

19.2.2 Schematic of the cooling system for the HighYAG collimation module



Important: The collimator cannot be connected to the cooling circuit of the LQM+ HP, but rather to the cooling circuit of the fiber.

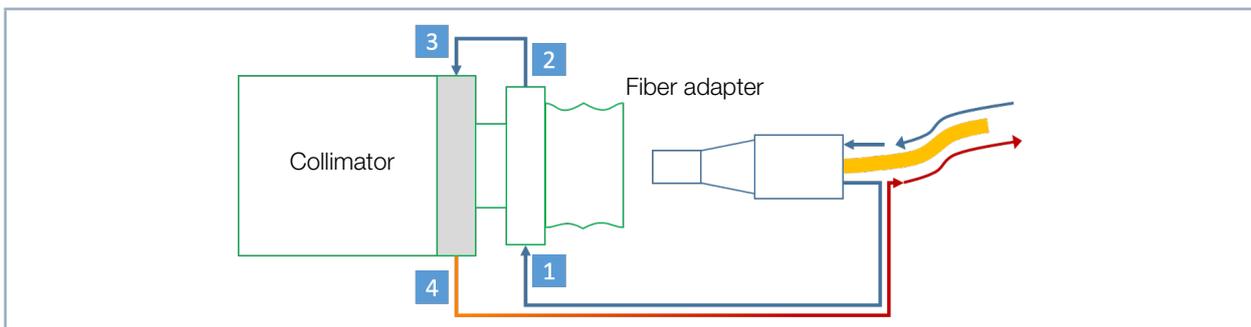


Fig. 19.2: Scheme cooling circuit collimation module

19.2.3 Remove/Install the HighYAG collimation module

Necessary tools:

- Allen key, a. f. 2.5 mm
- Allen key, a. f. 3 mm

NOTICE

Damage/Destruction of optical components

A contaminated measuring objective can heat up, change optical properties and potentially be damaged.

- ▶ To avoid contamination, only perform work in a clean environment.

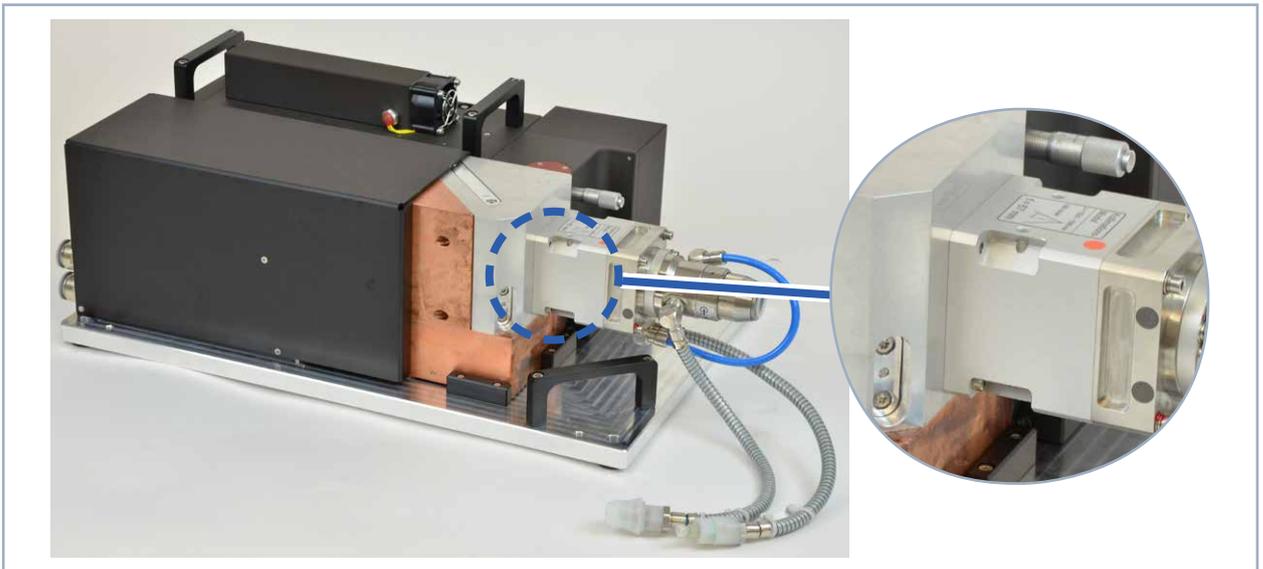
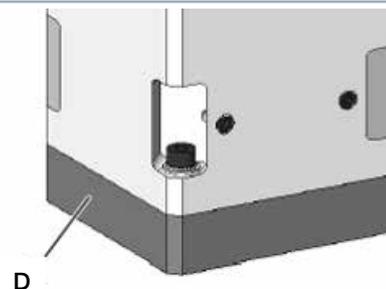
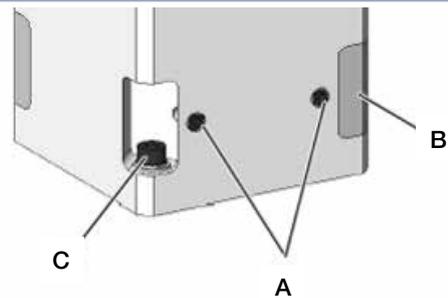


Fig. 19.3: Position of the collimation module

1. Turn off the power supply of the LQM+.
2. Loosen four set screws A by using the provided allen key (a. f. 2.5 mm).
3. Remove four covers B.
4. Remove four screws C by using the provided allen key (a. f. 3 mm)
5. Install the protective cover D for storage of the collimation module.
6. After disassembling the collimation module, install the fiber adapter to the attenuator module again.
7. Protect the aperture of the fiber adapter against dust by the red cap or with optical tape.



19.2.4 Choosing the measuring objective with a HighYAG collimation module installed

Example 1:

- λ = 1 030 nm
- M^2 = 12
- $d_{\text{fibercore}}$ = 100 μm
- f = focal length

$$d_{\text{foc}} = d_{\text{fibercore}} \cdot \frac{f_{\text{LQM}}}{f_{\text{col}}}$$

$d_{\text{foc}} = 299 \mu\text{m}$

To enable a measurement within $\pm 3 z_R$ the estimated number of illuminated pixels at the focus should be less than 350.

Quantity of illuminated pixels at 4.4 μm pixel pitch = $\frac{d_{\text{foc}}}{4,4 \mu\text{m}} \cdot \beta$ (Magnification of the measuring objective 1 or 5)

Measuring objective (MOB) 1:1 --> $299 \mu\text{m} / 4,4 \mu\text{m} \times 1 = 68$ ✓

Measuring objective (MOB) 5:1 --> $299 \mu\text{m} / 4,4 \mu\text{m} \times 5 = 340$ ✓

Example 2:

- λ = 1 064 nm
- M^2 = 5.5
- $d_{\text{fibercore}}$ = 50 μm

$$\Theta = \frac{4 \cdot \lambda \cdot M^2}{\pi \cdot d_{\text{fibercore}}}$$

$\Theta = 150 \text{ mrad}$

$$d_{\text{rawbeam}} = \frac{\Theta \cdot f_{\text{col}}}{1 \text{ m}}$$

$d_{\text{rawbeam}} = \frac{150 \text{ mrad} \cdot 67 \text{ mm}}{1 \text{ m}} = 10.05 \text{ mm}$

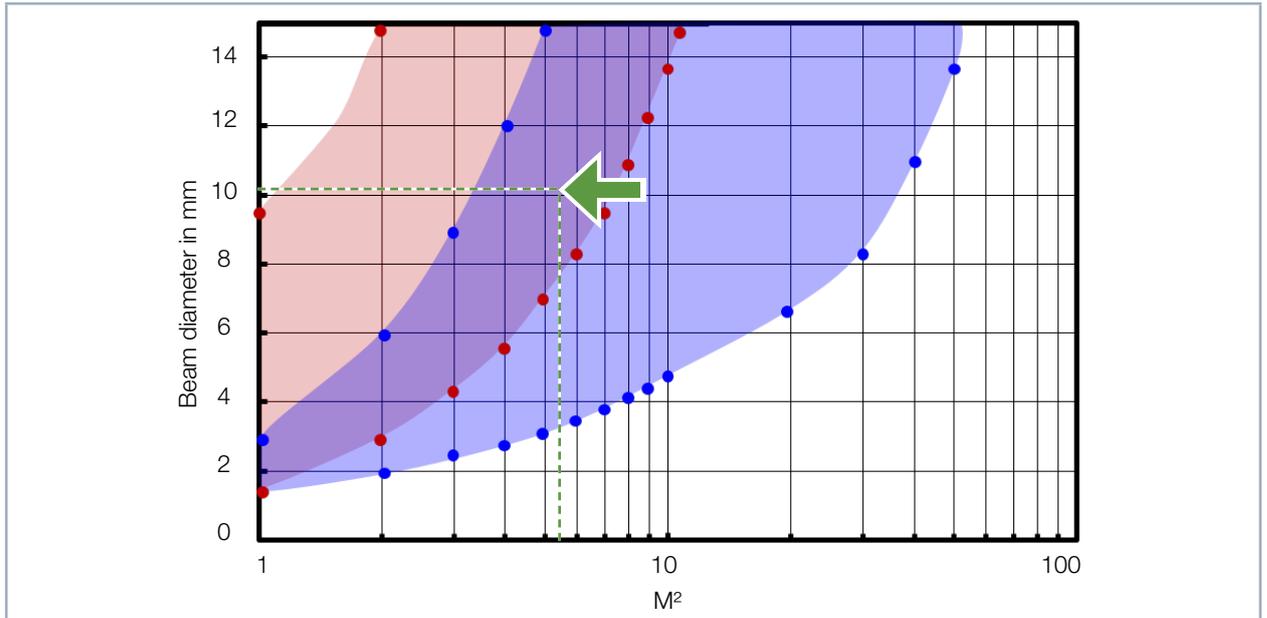


Fig. 19.4: Range of application of the LQM+ measuring objectives

Measuring objective (MOB) 1:1 --> ✓

Measuring objective (MOB) 5:1 --> ✓

The two examples demonstrates the calculation of beam parameters based on a given collimator focal length. The calculation can also be done using other collimator focal lengths.

19.3 IPG collimation module up to 20 kW



DANGER

Serious eye or skin injury due to laser radiation

During the measurement the laser beam is guided on the device, which causes scattered or directed reflection of the laser beam (laser class 4).

The LaserQualityMonitor LQM+ cannot be operated in any of the available configurations without taking the following precautions. All precautions must be taken, even when the fiber is in the collimator or fiber adapter.

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

As an option PRIMES offers a IPG collimation module which can be mounted directly to the 2nd attenuator of the LaserQualityMonitor LQM+.

Specifications					
Max. power	20 kW (Multi mode)				
	5 kW (Single mode)				
Focal length	100 mm	120 mm	160 mm	180 mm	200 mm
Acceptable divergence	220 mrad	190 mrad	140 mrad	110 mrad	110 mrad
Design wave length	1 070 nm				
Fibre socket	HLC 8 und HLC 16				

Tab. 19.3: Specifications of the IPG collimation module up to 20 kW

For the measurement of a divergent beam emerging from a fiber, the user is free to combine the LQM+ HP (20 kW) with any collimator that is suitable for the required power range and produces a minimum of artifacts.

At the date of issue (August 2018), we are only aware of one supplier (IPG Photonics) delivering collimator units with a specification of 20 kW. As an option, PRIMES can combine the LQM+ HP with a collimator from that supplier.

The following table lists the available collimators from that source and the numerical aperture that can be measured if these collimators are combined with the LQM+ HP (20 kW).

19.3.1 Possible combinations of the LaserQualityMonitor LQM+ HP (20 kW) with IPG collimators

Possible combinations of the LQM+ HP (20 kW) with IPG collimators and resulting numerical aperture (NA) for a measurement. Color code is corresponding to the resulting diameter of the collimated light.

Light green: diameter suitable for single mode measurement ($< 2 \text{ mm} \cdot \text{mrad}$),

Dark green: diameter suitable for multi mode measurement ($> 2 \text{ mm} \cdot \text{mrad}$).

NA	(Full angle)	Focus (Collimator) / mm				
	Divergence / rad	100	120	160	180	200
0,03	0,0600	6,00	7,20	9,60	10,80	12,00
0,035	0,0700	7,00	8,40	11,20	12,60	14,00
0,04	0,0800	8,00	9,60	12,81	14,41	16,01
0,045	0,0900	9,01	10,81	14,41	16,21	18,01
0,05	0,1000	10,01	12,01	16,02	18,02	20,02
0,055	0,1100	11,01	13,22	17,62	19,82	22,03
0,06	0,1200	12,02	14,42	19,23	21,63	24,04
0,065	0,1301	13,02	15,63	20,84	23,44	26,05
0,07	0,1401	14,03	16,84	22,45	25,25	28,06
0,075	0,1501	15,04	18,05	24,06	27,07	30,08
0,08	0,1601	16,05	19,26	25,67	28,88	32,09
0,085	0,1702	17,06	20,47	27,29	30,70	34,11
0,09	0,1802	18,07	21,68	28,91	32,52	36,14
0,095	0,1902	19,08	22,90	30,53	34,35	38,16
0,1	0,2003	20,09	24,11	32,15	36,17	40,19

Tab. 19.4: Possible combinations of the LaserQualityMonitor LQM+ HP (20 kW) with IPG collimators

19.3.2 The use of the measuring objectives 1:1 and 5:1

Using measuring objectives of two different magnifications, the range of beam quality M^2 values that can be measured is extended. The following table lists the combination of beam diameters and beam quality M^2 values that are accessible, and which measuring objective must be used for this combination.

Dark grey: Single mode beam, diameter too large.

Light grey: Multi mode beam, spot diameter in internal beam path too large.

		Beam quality M^2															
		1	1,2	1,4	1,6	1,8	2	4	5	6	10	15	20	25	30	40	45
Beam diameter / mm (second moment method)	8	42	51	59	67	76	84	169	211	253	422	633	844	1054	1265	1687	1898
	9	37	45	52	60	67	75	150	187	225	375	562	750	937	1125	1500	1687
	10	34	40	47	54	61	67	135	169	202	337	506	675	844	1012	1350	1518
	11	31	37	43	49	55	61	123	153	184	307	460	613	767	920	1227	1380
	12	28	34	39	45	51	56	112	141	169	281	422	562	703	844	1125	1265
	13	26	31	36	42	47	52	104	130	156	260	389	519	649	779	1038	1168
	14	24	29	34	39	43	48	96	121	145	241	362	482	603	723	964	1085
	15	22	27	31	36	40	45	90	112	135	225	337	450	562	675	900	1012
	16	21	25	30	34	38	42	84	105	127	211	316	422	527	633	844	949
	17									119	198	298	397	496	595	794	893
	18									112	187	281	375	469	562	750	844
	19									107	178	266	355	444	533	710	799
	20									101	169	253	337	422	506	675	759
21									96	161	241	321	402	482	643	723	
22									92	153	230	307	383	460	613	690	

Tab. 19.5: The use of the 5:1 (dark green) and 1:1 (light green) measuring objective

The numbers correspond to the spot diameter (unit μm) in the internal beam path, which must be below $700 \mu\text{m}$. Up to 1.2 mm internal spot size, a measurement is possible with higher uncertainty of measurement yellow, (<10% diameter deviation, less than 3 Rayleigh-lengths of measurement range in z will be available).

19.3.3 Maximum Power

This table is a summary of the tables above and lists the maximum power the LQM+ HP can measure as a function of beam quality M^2 and beam diameter.

		Beam quality M^2															
		1	1,2	1,4	1,6	1,8	2	4	5	6	10	15	20	25	30	40	45
Beam diameter / mm (second moment method)	8	1,5	1,5	1,5	1,5	1,5	1,5	2,0	3,0	4	4	4	4	4			
	9	2,0	2,0	2,0	2,0	2,0	2,0	2,5	4,0	5	5	5	5	5	5		
	10	2,5	2,5	2,5	2,5	2,5	2,5	3,5	4,5	6	6	6	6	6	6		
	11	3,0	3,0	3,0	3,0	3,0	3,0	3,5	5,5	7	7	7	7	7	7		
	12	3,5	3,5	3,5	3,5	3,5	3,5	4,5	7,0	9	9	9	9	9	9	9	
	13	4	4	4	4	4	4	5,5	7,5	10	10	10	10	10	10	10	10
	14	5	5	5	5	5	5	7	9	12	12	12	12	12	12	12	12
	15	5	5	5	5	5	5	8	11	14	14	14	14	14	14	14	14
	16	5	5	5	5	5	5	9	12	16	16	16	16	16	16	16	16
	17									18	18	18	18	18	18	18	18
	18									20	20	20	20	20	20	20	20
	19									20	20	20	20	20	20	20	20
	20									20	20	20	20	20	20	20	20
21									20	20	20	20	20	20	20	20	
22									20	20	20	20	20	20	20	20	

Tab. 19.6: Maximum power

19.4 Optical path in LQM+ HP (with IPG Collimator)

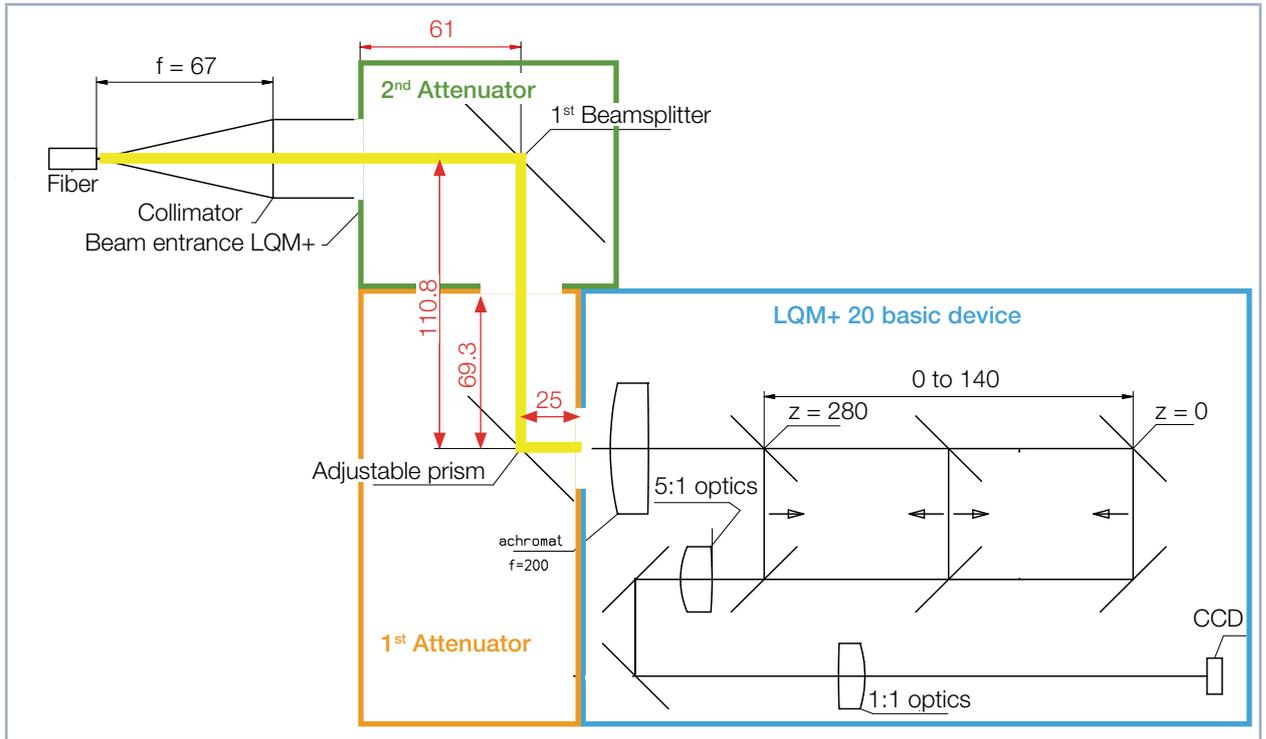


Fig. 19.5: Optical Path in LQM+ HP (with IPG Collimator)

Length of the optical path ():

1st Attenuator <--> LQM+ = 25 mm + 69.3 mm = 94.3 mm

2nd Attenuator <--> LQM+ = 25 mm + 110.8 + 61 mm = 196.8 mm

20 Formula and algorithms for raw beam back calculation

To calculate the raw parameters from the measured beam parameters of the focus, the formula given in ISO11146 is used. Index F describes the beam parameters of the focus.

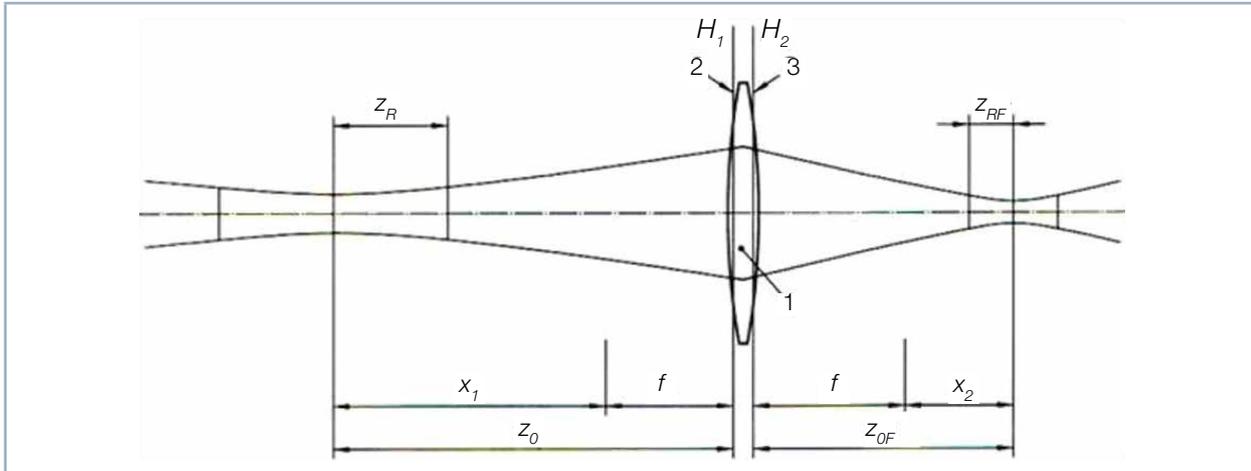


Fig. 20.1: Raw beam back calculation

Beam waist radius within the raw beam

$$w_0 = \frac{f}{\sqrt{z_{RF}^2 + \Delta^2}} \cdot w_{0F}$$

Far field divergence

$$\Theta = \frac{\Theta_F \cdot \sqrt{z_{RF}^2 + \Delta^2}}{f}$$

Position of beam waist within the raw beam

$$z_0 = \frac{f^2}{z_{RF}^2 + \Delta^2} \cdot \Delta + f$$

Rayleigh length within the raw beam

$$z_R = \frac{f^2}{z_{RF}^2 + \Delta^2} \cdot z_{RF}$$

With focus position difference

$$\Delta = z_{0F} - z_{ref}$$

Beam diameter onto the focusing lens

$$d_L = \Theta_F \cdot (f + z_{ref} - z_{0F})$$