

Operating Manual

Translation of the Original Instructions



BeamMonitor50 HQ LaserDiagnosticsSoftware

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1. Laser safety precautions

Note!

The BeamMonitor50 HQ is designed to make measurements inside or near the beam path of high power laser beams.

The device itself does not emit any laser radiation. However, laser radiation is guided through the device and the radiation is scattered at the device.

Any user must have extensive prior technical training and possess the basic knowledge required to perform any kind of measurement or alignment procedure of laser beam sources, beam guiding equipment or focussing devices in a safe manner.

Use of the PRIMES measuring devices like CompactPowerMonitor, BeamMonitor, BeamMonitor50 HQ, FocusMonitor, LaserQualityMonitor, MicroSpotMonitor, PolarizationMonitor, PocketMonitor, ElectronicCalibrated-PowerMonitor or PowerMonitor for any purpose other than the appropriate form of use specified by the manufacturer is not permitted, and may cause bodily harm, up to and including potentially life threatening injuries or death. The various types of monitors may not be used in a manner which may cause a potential risk to human beings.

As stated in ISO / CEN / TR standards and regulations as described in IEC - 60825-1, 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 like "Laser Safety Basics", "LIA Laser Safety Guide", "Guide for the Selection of Laser Eye Protection, and "Laser Safety Bulletin", published by the Laser Institute of America (Tel: 407-380-1553) and "Guide for the Control of Laser Hazards" from ACGIH, 6500 Glenway Ave. D-5, Cincinnati, OH 45211, when humans are present in a dangerous zone with uncovered visible or invisible laser radiation or particularly uncovered laser beam systems, beam guiding systems or process regions, personal protection is required. This holds true for any use of this equipment. During measurement procedures there is always an unavoidable risk of laser radiation through direct or reflected emissions.

The proper and safe use of any monitoring device inside or nearby the laser beam core diameter REQUIRES ALL OF THE FOLLOWING:

- competent professional knowledge of the type of laser source present.
- competent knowledge and understanding of the measurement device.
- laser safety goggles adapted to the existing wavelength of the laser in use.
- protection to reduce direct laser radiation, back reflection and associated optical radiation to a safe level.
- safeguard and or emergency safety mechanisms which allow immediate closing of the laser shutter of any free running or focused beam.
- a solid mounting surface for the measurement device itself, to reduce the risk of back reflection and avoid any relative movement of the Monitor in relation to the laser beam axis (This is also necessary to ensure the highest possible performance).

In order to comply with national and international regulations, particularly the accident prevention regulations for use, control and alignment of high power laser beams, adequate protection procedures and equipment are required, for example: Use of shielding screens, protective laser safety goggles, beam guiding elements and/or beam traps which do not contain any dangerous materials that can release gases or vapors when heated.

The manufacturer and the suppliers of the monitoring equipment accept no liability for damage or injury of any kind arising from the use of the measuring device or the associated software. The purchaser and user agrees to hold harmless both manufacturer and suppliers of any liability for injury to equipment or person, loss of business revenue, directly or indirectly through use of this equipment.

2. Introduction

2.1 Laser beam measurement

The observation of the laser beam parameters helps to increase the reliability of manufacturing. The laser beam is mainly described by:

- laser power
- beam dimensions and beam position of the unfocussed beam
- beam dimensions and beam position of the focussed beam
- polarization of the laser beam

These fundamental beam parameters have a strong influence on the results of laser materials processing. To ensure highest processing quality, it is necessary to detect any variation of the laser beam parameters. The variations may be induced by:

- errors generated from the laser source, e.g. aging of the optical components or maladjustment of the laser resonator
- effects in the beam guiding-system or the focussing unit e.g. pollution and maladjustment of the mirror or thermal blooming because of the existence of organic gases in the surrounding environment.

The processing results depend mainly on the laser power and power density in the focus. Variation of these parameters can lead to a dramatic decrease of speed and quality of the process. Therefore it is urgent to know the exact position and the power density distribution of the focal region.

The periodic measurement of laser beam parameters helps to make sure that the laser beam always performs excellently as a tool. This is a basic essential for reliable materials processing with lasers, and it ensures high quality of the manufactured products.

2.2 PRIMES - the Company

PRIMES is a manufacturer of laser measuring devices. These devices are used to measure laser beam parameters of high power CO₂-, solide-state and diode-lasers. A wide selection of devices is available for measurement of:

- laser power
- beam dimensions and beam position of the unfocussed beam
- beam dimensions and beam position of the focussed beam
- polarization of the laser beam
- temporal stability of the laser power

Engineering as well as production is done by **PRIMES** itself to provide best quality, excellent service and a short reaction time to fulfill all the demands of our customers.



The PRIMES logo consists of a horizontal red line above the word "PRIMES" in a bold, black, sans-serif font. A small red circle is positioned above the letter "I".
PRIMES Max-Planck-Str. 2 - 64319 Pfungstadt - info@primes.de - www.primes.de

2.3 BeamMonitor50 HQ

Laser beam radius, position and power density distribution in the unfocused beam are of strong influence for the intensity in the focal plane and for any laser materials processing results. To guarantee a reproducible processing quality, it is necessary to know and to detect any changes.



Fig. 2.1 BeamMonitor50 HQ

The **BeamMonitor50 HQ** (Fig. 2.1) is a device to analyze the spatial power density distribution of the raw beam of CO₂ lasers. Results of the measurements are beam radius, beam position and power density profile.

The BeamMonitor50 HQ is using the scanning measuring principle. Its dimensions are adapted to the raw-beam diameter which needs a larger aperture. The BeamMonitor50 HQ has no z-axis. Due to the availability of different detectors and measuring tips, it is possible to use the BeamMonitor50 HQ with a wide range of wavelengths and power densities. As standard the BeamMonitor50 HQ is configured with a pyro-electric detector. The measuring tip is designed to work in a power density range of several kilowatts per cm².

2.4 What is covered by this manual

This documentation is generally for the BeamMonitor50 HQ only.

There are two principal modes of operation for the devices:

- When used to monitor automated production-processes where measurement need to be done automatically by command of an auxiliary control, the whole PRIMES system can be controlled via an PLC by serial communication. In this operational mode the user receive the numeriactal values for beam position and beam dimensions.
- When the devices are operated manually, PRIMES supplies the LaserDiagnostic-Software with access to all functions of the **BeamMonitor50 HQ**. A graphical user interface based on Windows® makes it easy and intuitive to control the devices and to visualize the results in many ways.

This documentation describes in detail both modes of operation of the PRIMES BeamMonitor50 HQ.

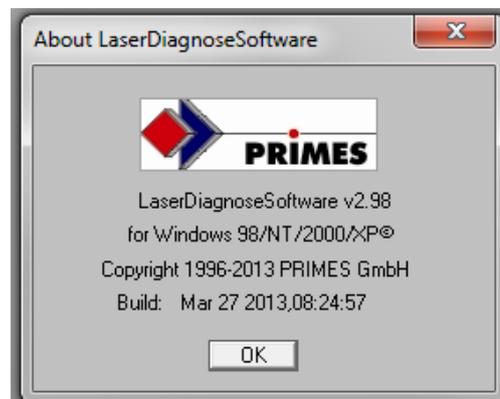
Remark:

Please note that the software is continuously improved to meet all the demands of our customers, so that there may be slight differences between this documentation and your actual software version.

If there are any questions concerning the operation of the system, please be prepared to

- give information about the software version
- the date of set-up
- the Windows® version you are working with

Please find these information within the item **Help/About LaserDiagnoseSoftware**.



3. Setup



It is essential in every measurement operation to follow the safety instructions given below. This will allow safe and reliable operation of the measurement devices.

3.1 Safety Instructions and Mechanical Installation

When working with the **BeamMonitor50 HQ**, leakage radiation can arise. The power densities can exceed more than 100 mW/cm^2 of CO_2 -laser radiation because the beam is reflected by the surface of the measuring tip. It is strongly recommended to wear safety glasses and to shield the measuring environment or the device carefully.

The measuring rotor of the **BeamMonitor50 HQ** operates at a high rotational speed. Please avoid inserting your fingers or any other mechanical tools or parts into the beam entrance of the measuring device. This can damage your health and / or the measuring device.

Please take care that the laser beam is completely absorbed after passing the **BeamMonitor50 HQ**. Fireclay bricks or reflecting surfaces are not suitable to annihilate the beam energy. PRIMES provides different uncooled, air or water cooled types of beam traps. Nearly 100 % of the used laser beam power must be absorbed by the beam trap during the measurement cycle.

Please mount the **BeamMonitor50 HQ** in a correct and stable position in the beam path. This means that the laser beam has to pass completely in the center of the aperture. The to be measured beam diameter should not be greater than 0.7 times the aperture. Bigger beams might lead to dangerous reflection and a heating-up of the housing. The device would be damaged and the measurement results might be falsified.

When mounting the **BeamMonitor50 HQ**, it is recommended to use screws that penetrate the housing **no further than 5 mm**.

Please ensure perpendicular incidence of the laser beam relative to the x-y plane of the device's coordinates. Avoid any movement or acceleration of the **BeamMonitor50 HQ** during the measurement routine. Beyond the measurement routine, it is possible to accelerate the **BeamMonitor50 HQ** up to the tested values of $2 g$.

Please respond the manufacturer if your system could reach more than that.

3.2 Hardware installation



Please connect the BM50 HQ via Ethernet to the PC. Optional connect the converter's RS232 plug to the computer using a cable with two female connectors.

If the PC is connected directly to the PRIMES-Bus, it can be seriously damaged.

Furthermore, do not disconnect cables while the power supply is on. This could cause harm to the communication circuits of the device.

The following describes the basic electrical and mechanical configuration of the system.

There are two options for voltage supply and data transfer:

- Serial / USB (option)
- Ethernet

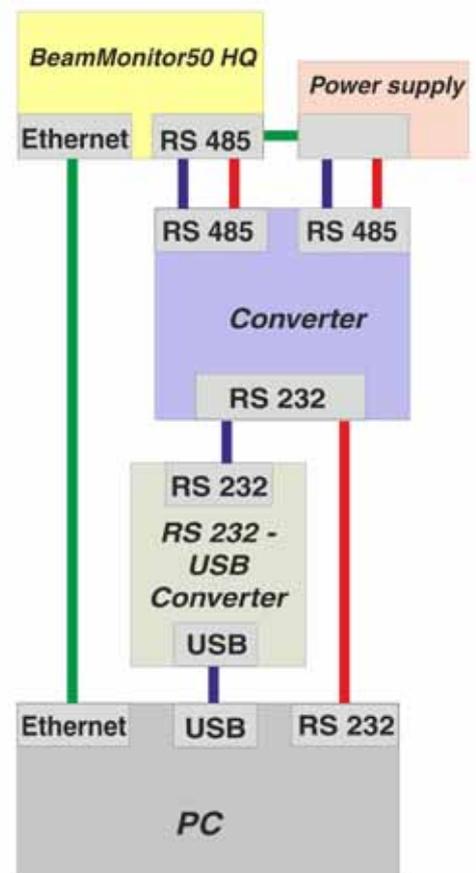
Refer to the diagram.

Serial Interface (red):

The BeamMonitor50 HQ is connected to the PRIMES-Bus for data communication and supply voltage (Sections 3 and 7.2). Data transfer is based on a RS485 bus system using a shielded cable with two male, 9-pin, mini-D connectors (Fig. 3.1). For communication with the PC, the data is converted from RS485 to RS 232 using the PRIMES Converter (Fig. 3.4). A shielded cable with two female, 9-pin, mini-D connectors is used for the connection between the PC and the converter (Fig. 3.1). The PRIMUS-Bus provides a stable supply voltage for the measuring device as well as data transfer.



Fig. 3.1 PRIMES-Bus cable & RS232 serial cable



USB Interface (blue):

This connection to the PC differs only in the use of a RS232 - USB converter. This is placed between the PC output of the PRIMES Converter and the USB port of the computer.

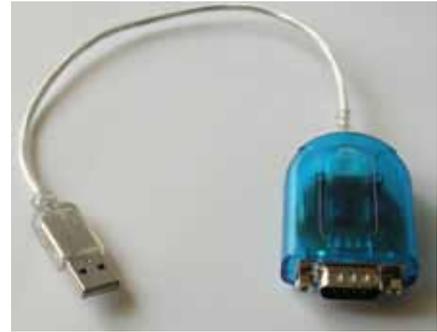


Fig. 3.2 RS 232 - USB converter

Ethernet Interface (green):

The PRIMES Converter is not required if the BeamMonitor50 HQ is connected to the PC via the ethernet interface. The power supply is connected directly to the serial RS485 bus of the BeamMonitor50 HQ. The connection to the computer can be direct using a cross-over cable or through a network using a regular patch-cable.



Fig. 3.3 Cross-over or standard Patch Cable

PRIMES-Converter

The **PRIMES-Converter** has four LEDs to display the current status of the bus. They indicate (from left to right):

- red** *bus power (24 V)*
- green** *measuring device send data on the bus*
- red** *PC send data on bus*
- yellow** *trigger signal (only for service use)*

These signals are helpful to check the system state, especially in case of a malfunction of any device to determine the source of misleading signals.



Fig. 3.4 PRIMES Converter



Fig. 3.5 Power Supply

Figure 3.6 shows how the BeamMonitor50 HQ is connected to a computer and power supply using serial communication and USB converter.

To avoid any voltage drop, the power supply should be directly connected to the BeamMonitor50 HQ using a short cable (2 m). Because data communication with RS232 is susceptible to trouble or signal corruption, the bus connection between the PC and converter should be as short as possible.

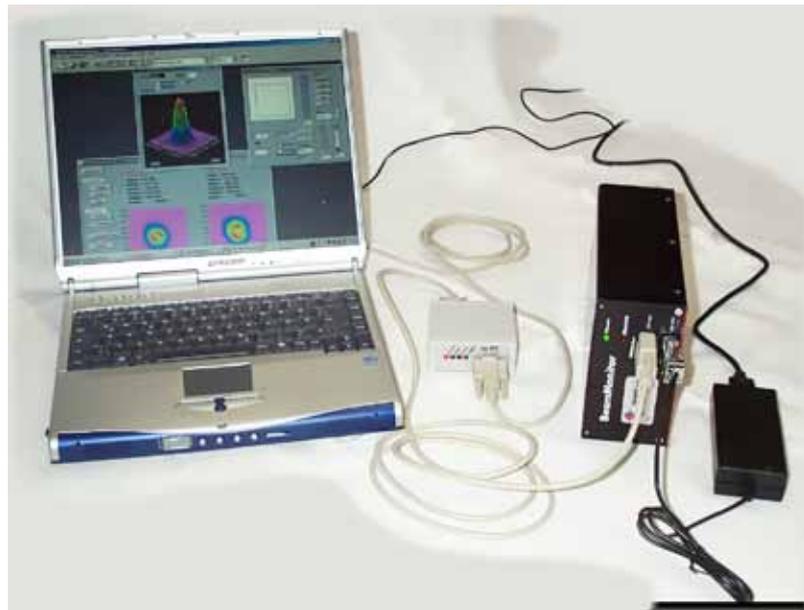


Fig. 3.6 Set-up of the BeamMonitor

3.3 Software installation

The PRIMES LaserDiagnoseSoftware is available for IBM compatible PCs. The software installation is automated using a setup assistant.

3.3.1 System demands

The software requires an IBM-compatible PC (minimum: Pentium II, 500Mhz, 64MB) with Windows® 98 or later installed and an available serial, USB, or ethernet connector.

For good performance, we recommend at least a Pentium or comparable processor with a clock frequency of at least 1 GHz. A 17-inch color monitor with 768 x 1024 pixel resolution is recommended. The PRIMES Converter is required optional for RS485/RS232 data communication.

If you run the system on a notebook computer, disable all power saving options in the system BIOS. Otherwise, you may encounter problems with serial communications during high data rates.

3.3.2 Installing the Software

The menu-driven installation starts from the provided software CD.

After installation is finished, the program is launched by clicking the icon in the new program group PRIMES.

The installation software copies the main program “LDS.exe” into the Programs folder under PRIMES, unless another location was specified. The configuration file “laserds.ini” is also copied to this location. This file contains the setup parameters for the PRIMES LaserDiagnoseSoftware. An example of the “laserds.ini” file is shown in the appendix.

3.3.3 Setting up the USB-converter software (option)

Since fewer computers include a serial RS232 interface, a RS232 - USB converter is included with the BeamMonitor50 HQ.

Installation:

1. Turn off the computer as necessary.
2. Connect the USB converter to a free port.
3. Start the computer.
The “New Hardware Found” window should appear.
4. Insert the included driver CD and select “**Automatic Software Installation**”.



Please note, until Windows® has installed driver, the following message can occur:

Fig. 3.7 Windows® - message window

5. Restart the computer after installation is complete.
6. Finally, under “Device Manager”, check whether the COM port was successfully installed and which number it was assigned (here COM 4).



Fig. 3.8 Device Manager Window

7. This COM port number will be selected later in the LaserDiagnoseSoftware.



Fig. 3.9 Free Communication Window

Be sure to use the same USB port since the COM port number can change.

Further information about the converter can be found at the homepage of the manufacturer:
www.prolific.com.tw

3.3.4 Setting up an ethernet-connection

The **BeamMonitor50 HQ** is equipped with an Interface for ethernet-communication. The ethernet-communication not only enables a faster data transfer (about 1,2Mbits/s instead of 115 Kbits/s) but also makes it easier to connect on a computer.

The **BeamMonitor50 HQ** can be connected on PC directly with the help of a so called "Cross over" patch cable without a secondary converter. It is also possible to use the equipment in a corporate network. The power supply is produced by the **PRIMES-bus**.

• *Configuring an IP Address*

The IP address of the **BeamMonitor50 HQ** is preset according to standard on **192.168.116.85**

Like that, a fast and simple direct connection to a PC with a "cross over" cable is possible.

Then it is necessary to set the IP-address of the computer to a fixed value. Keep in mind: in standard setting, the computer or the network generates an IP-address automatically. This standard setting may not be useful for the operation of the BM. This can be changed in the following way: Within the Windows menu **Control Panel Device Manager**, please select the sub item **Internet Protocol (TCP/IP) Properties** (p.16) and click on: **Use following IP address** and enter: IP address **192.168.116.75** and Subnet mask **255.255.255.0**

The IP-address of the **BM50 HQ** itself is **192.168.116.85**. The first three numbers of the IP-address that you enter for your computer must be identical to the **BeamMonitor50 HQ** address, and the last number must be different.

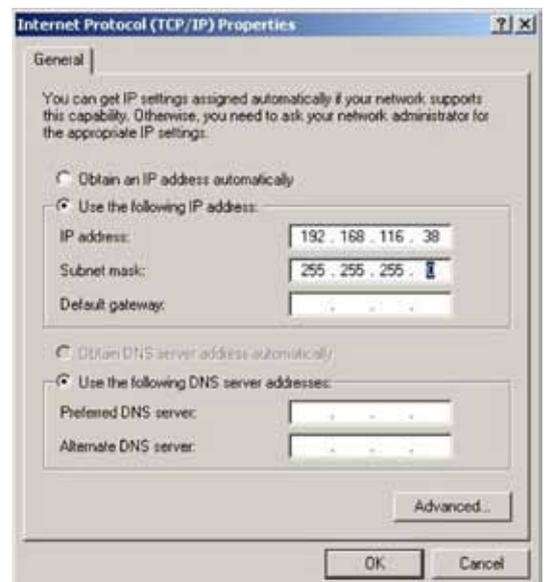
Now you can check and install the Ethernet communication.

Please click on the **connect** button within the menu **Free Communication**. You should receive a message: **Connecting to Device 192.168.116.... CONNECTED**

Then you should find the **ICON** of the **BeamMonitor50 HQ** in the header of the software.

At some computers it is necessary to restart them after changing the IP address.

If the equipment should be merged into a network, please contact us.



3.4 Starting the LaserDiagnosticSoftware

First please connect all the devices properly to the PRIMES Bus and the computer. Then turn on the power and start the software. You should see the green LED from the rear of the BeamMonitor50 HQ and a short blink from the green LED Data light at the converter.

At start up routine, the communication on the bus will be checked and an automatic hardware detection is performed. Symbols for all the measuring devices connected to the bus are displayed on the Toolbar at the upper right position.

Typically, the system needs 30-60 seconds after power-up or software start to detect the initial configuration. After starting, the software scans the system for different logical addresses which correspond to the possibly connected devices BeamMonitor50 HQ, FocusMonitor, BeamMonitor, etc.. Attention, there is no measuring possible during this time. During the scan there is a message box active at the bottom right of the screen. During this software start, you should not get any error messages and the LEDs **Data** and **Send** at the converter should blink several times. After this procedure, you should find the symbol in the toolbar of the software. When the symbol is in the toolbar, the device is ready to start a measurement. All measurement items should be available.

An automatic measurement with the **BeamMonitor50 HQ** can be initiated by the **PRIMES** PLC control if it is connected to the **PRIMES** Bus. In this case, the measuring procedure is done by a run-off-control.

Please refer to the description of the PRIMES PLC control to get more information about this mode of operation. The next chapters show how to operate the PRIMES LaserDiagnosticSystem manually and achieve the best measurement performance.

3.5 Power-up and Change of Configuration

Whenever the power of the **BeamMonitor50 HQ** is switched off and on again (power-up), the user should run a **reset** cycle. The system typically needs about 30 sec to check the system's configuration after power up or starting the software. If you switch on the power supply the BeamMonitor50 HQ moves to reference position where the rotor is stored outside the clear aperture.

Whenever the physical configuration of the devices on the bus is changed (for instance, by addition of a further device), the user should run a **rescan** cycle again. The correct installation of bus connection and communication can be checked by the windows software (see chapter 7 **Communication**)



Do not plug or unplug any cables when the power is on !
! Connect the PC to the measurement system only via the RS232 plug at the PRIMES-Converter!

4. Manual Operation of the BeamMonitor50 HQ

To conduct a detailed laser beam analysis, the manual mode of operation of the BeamMonitor50 HQ is usually used. The handling of the device using the PRIMES LaserDiagnosticSoftware is described in the following chapters.

4.1 Measurement and Presentation - a Short Description

After adjusting or mounting the BeamMonitor50 HQ in the beam path and connecting to the power supply, PRIMES-Converter and computer, the LaserDiagnosticSoftware can be started.

The graphical user interface assists and guides the instrument.

The PRIMES-Bus allows all PRIMES devices to operate without changing any physical connection. With several measuring devices at the bus, it is necessary to select the current device to run a measurement. This is done by choosing the appropriate device name in the menu **Measurement - Sensor Parameters** (Fig. 4.1 and 5.2 Table)

To start a measurement select the item **Measurement - Single Measurement** (Fig. 4.2). Here, the user can adjust the position and the size of the measurement window within the whole accessible measurement range just by dragging and dropping the frame on the desired position.

For the BeamMonitor50 HQ the setting of the size is done by the pop-up menu [x] when a symmetric measurement window is selected, or by [x] and [y] for asymmetric windows. It is sufficient to use the symmetric window for most applications.

The measurement can be started by hitting the button **Measure**. When running the first measurement, it is useful to select a large or the largest measurement window to localize the beam position.

The beam, having been located, can be

analyzed accurately by selecting a small window which fits exactly around it. The Zoom function allows the user to get a good view of the beam.

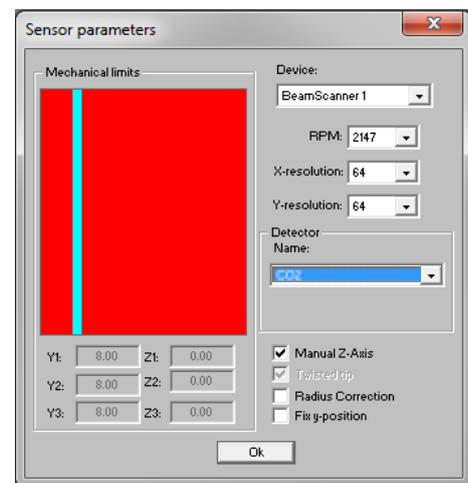


Fig. 4.1 Measurement - Sensor parameters

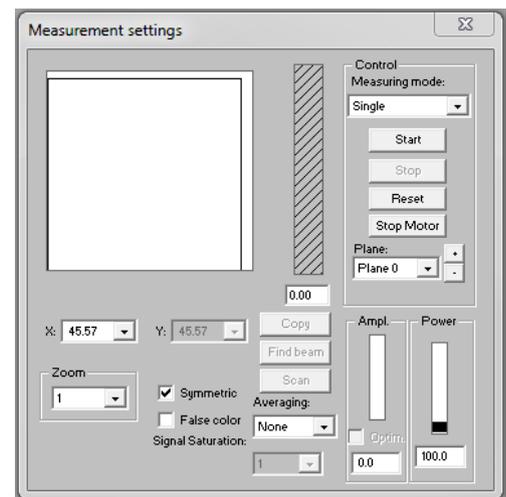


Fig. 4.2 Measurement - single measurement

The presentation of the measured results is for example done by the item **Presentation - Variable Contour Lines**. Here contour lines of the spatial power density distribution in x- and y- directions are shown.

To save the measured data, select **File - Save as** in the pop-up menu.

To quit the program, select the item **File - Quit**.

A more detailed description is given in chapter 5.

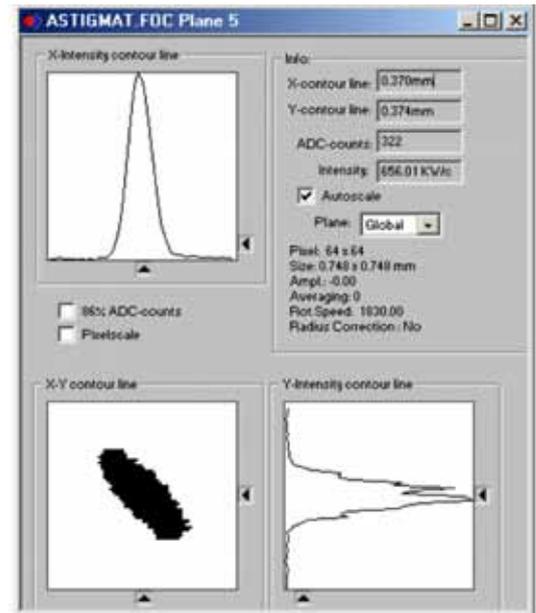


Fig. 4.3 Presentation - Variable Contour Lines

4.2 Operation of the BeamMonitor50 HQ

There are three important steps when operating the BeamMonitor50 HQ

- Mechanical adjustment of the sensor-head and correct installation of the system to ensure safety with regard to leakage radiation
- Performing measurements
- Presentation and documentation of the measured results

4.2.1 Safety with regard to leakage radiation: Mechanical adjustment of the sensor and checking the system configuration

To assure a safe operation of the BeamMonitor50 HQ please consider the following topics carefully

- Take care to get sufficient shielding of the leakage radiation and the complete absorption of the passing beam
- Check the accurate passage of the laser beam through the measuring region to avoid reflections at the housing of the BeamMonitor50 HQ. Keep in mind, there is only one beam entrance.
- The measuring rotor of the BeamMonitor50 HQ operates at a high rotational speed. Please avoid inserting your fingers or any other mechanical parts into the beam entrance of the measuring device. This can damage your health and / or the measuring device
- Provide a perpendicular incidence of the laser beam
- Inspect the electrical connections between the system's components. The PC has to be connected only to the RS232 plug of the PRIMES-Converter. Any other connection of the serial interface of the PC to the system can damage the computer. Also Ethernet connection is possible (option)
- Hard- and software requirements
- Check the communication between the computer and the measuring devices

4.2.2 Performing measurements

There are two possible ways to perform measurements with the BeamMonitor50 HQ.

- Single measurement (manually or automatically adjusted): The position and the size of the measurement window can be adjusted relatively to the whole measuring range. A false color presentation is possible.
- Adjustment mode
Special Measuring mode of the BeamMonitor50 HQ is used for resonator adjustment or laser servicing. This mode of operation is characterized by a simple handling and a clear presentation menu.
The results of the single and the serial measurements are presented in different plans or in special presentations.

4.2.3 Presentation and documentation of the measured results

The PRIMES LaserDiagnosticSoftware offers the following features for visualization, analysis and storage of the measured results:

- 3-D Presentation (Isometry) of the spatial laser power density distribution
- Contour lines in false colors of the spatial laser power density distribution
- Variable contour lines of the spatial laser power density distribution. Eligible are contour lines in x-, y-direction or power density coordinates.
- Fixed contour lines in x-, y-direction at 86%, 80%, 60%, 40%, 20% and 10% of the total power
- Symmetry check (not standard application)
- Review - the following parameters are displayed numerically: date, time, radius, radius in x, radius in y, angle, position in x, position in y, laser power density, laser power, etc.
- Graphical review of various beam parameters
- Export of the numerical measured values after measurement into a tab-separated text-file, readable by Microsoft Excel
- Every measurement is stored in its own layer. The layers can be combined to show the caustic, e.g. when using a FocusMonitor
- Storage of numerical values - beam radius and position - to file or to database.
- Storage of measured data to disk
- Storage of the current settings/preferences to disk
- Printing of every presentation

5. The Operation of the LaserDiagnosticSoftware

Please note that some of the essential windows of the graphical user interface (for measuring and communication) always stay in the foreground. All the presentation windows will be overwritten, when a new window is opened.

5.1 Logical Structure of the Graphical User Interface

The graphical user interface consists of four main subjects:

- **Measuring**
All the settings for single and serial measurement can be done here. The size and position of the measurement window can be adjusted. The spatial resolution, the rotational speed and the number of cases for averaging can also be selected. It is possible to adjust the parameters automatically and store them to disk.
- **Presentation**
The presentation features cover all matters needed to gain maximum information from the data and to classify the measured results. Available are false color presentation, isometry, variable and fixed contour lines and as an additional feature detailed symmetry checks. The numerical values of the results can also be displayed.
- **Data Administration**
The saving and loading of all measured data and measurement settings, high-resolution printout protocol, export and a copy function are included. All windows could be copied to any other windows file simply by copy and paste functions.
- **Communication**
To control the communication on the PRIMES-Bus. This item is necessary to adjust the devices and do troubleshooting.

For parallel handling of several sets of measured data, it is possible to store the results of up to 20 single measurements in one file. Every measurement is written in a single image storage, called plane. Different planes can be used for variation of parameters, such as power or time. It is possible to compare and analyze different planes as well as data from different files.

5.2 The Graphical User Interface

The **PRIMES-LaserDiagnosticSoftware** has a graphical user interface. Different windows can be opened simultaneously. This means that it is possible to open different presentation menus at the same time. Most of the handling can be done by mouse clicks. Often numerical input from the keyboard is also possible.

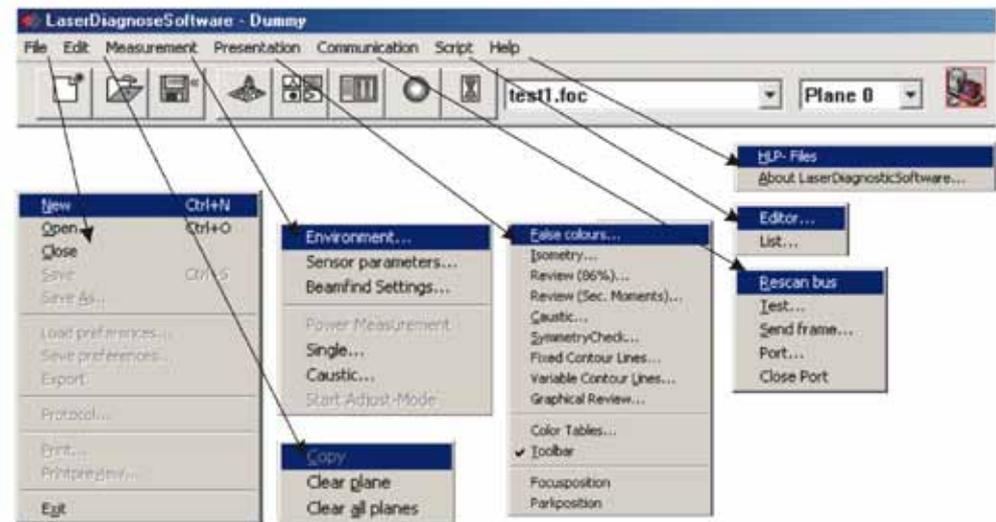


Fig. 5.1 Menu bar and the menus of the ‘LaserDiagnosticSoftware’

A detailed description of all menus is given in chapter 6.

5.3 Adjustment of parameters for measurement

It is possible to operate different measuring devices on the PRIMES-Bus. The device to measure with has to be selected. This is done in the menu **Measurement - Sensor Parameters** (Fig. 5.2) or in the **Toolbar**.

An assignment of devices’ names to the logical addresses is shown in Table 5.1. When only one measurement-device is connected to the PRIMES-Bus no selection is necessary.

Device name in the menu Measurement Sensor Parameter	Logical addresses - relevant for communication
BeamMonitor50 HQ	161, 152, 153
BeamMonitor 1, 2, 3,.....	144, 145, 146
PowerMonitor 1, 2,...	112, 113,...

Table 5.1 Table Device assignment

The pull down bar **Measurement - Sensor Parameters** is also used to select the number of tracks and the number of pixels per track. Thus the spatial resolution of the measurement can be controlled from 32 x 32 up to 256 x 256 - normally 64 x 64 pixel is sufficient.

The cycle - time a measurement needs increases with the number of pixels and tracks, because a higher resolution causes more data to be transferred and displayed. When using the normal spatial resolution of 64 x 64 pixels the measurement time is about < 5 seconds.

The setting of mechanical limits is not relevant for the BM50 HQ.

When the device is connected to the PC, the LaserDiagnosticsSoftware automatically selects the correct detector type. A manual selection is not possible.

The rotational speed is set to a fixed value.

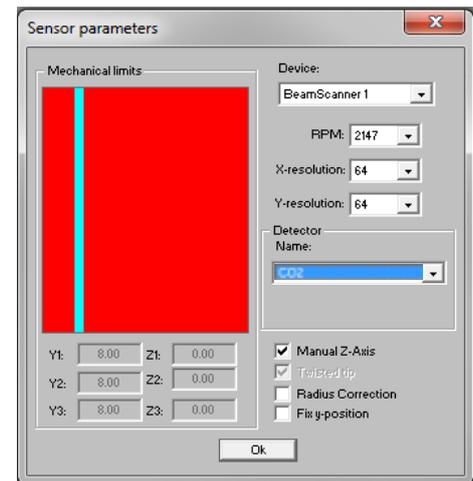


Fig. 5.3 The Item Measurement - SensorParamter

If the user wishes to run a caustic measurement it is possible to enter z-values for every measured plane after clicking the button *Manual z-axis*. Then the z-position can be varied manually, for instance any axis of the laser machine can be used. The movement values are entered manually in the menu *Single Measurement* and the software can calculate on this basis the beam propagation factor in the caustic presentation. This feature can also be used to calculate the beam propagation ratio from raw beam measurements at different distances.

5.4 Measuring

5.4.1 Single Measurement

Here the user can adjust the position and the size of the measurement window within the whole accessible measurement range. The adjustment of size is done by a pop-up menu with [x] for quadratic or [x] and [y] for rectangular windows.

The maximum size of the measurement window for the BeamMonitor50 HQ is 36 mm, resp. 48 mm. The position is controlled by dragging and dropping the window with the mouse.

The slider Power serves to set the actual laser power for the software algorithm to calculate the spatial power density. It can be adjusted to any power up to maximum. Maximum power is entered by choosing **Measurement - Environment**.

One set of measurement data consists of up to 20 single power density distributions which are stored, each for a designated plane. The results can be compared and analyzed easily by using the various presentation features of the PRIMES LaserDiagnosticSoftware.

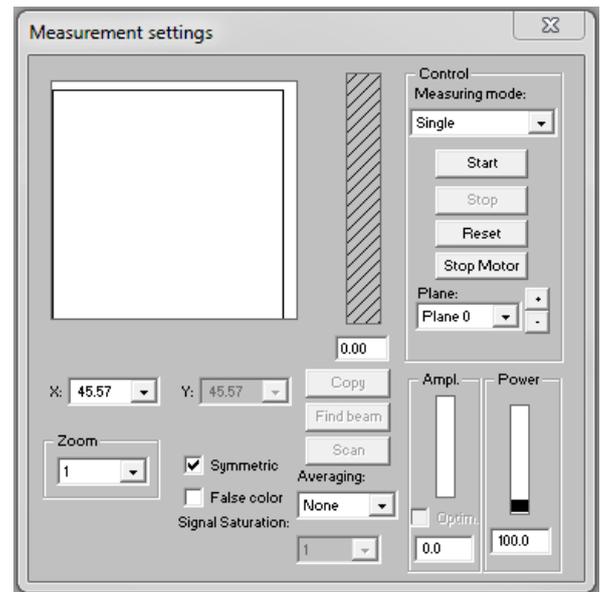
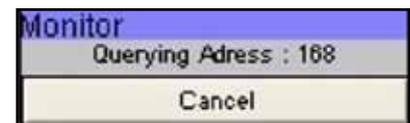


Fig. 5.4: The item Measurement - Single Measurement

During the activity of the system different messages are displayed on the information box at the bottom right of the screen.

During initialization the query demands on the various devices and during measurement the status of the system is displayed. The window displays

- the current measuring plane
- the referencing of the device
- the positioning of the device
- the procedure of measurement
- the transfer of data to the computer
- the number of cases for averaging



Use the button **Cancel** to stop the running measurement if any problem or collision occurs. **Cancel** also stops the monitoring mode. **Stop** stops the measurement. Afterwards, a reset cycle should be run before the next measurement.

The button **Copy** allows the process to take over the settings of measurement window size, power and amplification settings from the previous plane. The settings are copied from the plane with the next lower number.

Averaging of measurements is an important feature to eliminate temporal fluctuations of the laser beam and to reduce the noise inherently included in every measurement.

Laser excitation frequencies might be visualized in the measurement file. The number of cycles to average over (up to 50) can be chosen by the roll-down menu.

There are different modes of averaging available:

- Mean value** real average.
- Max. Pixel** hold the maximum value of pixel during measurement, and
- Max. Trace** hold the maximum value of trace during measurement.

Max. Pixel and **Max. Trace** can be helpful when detecting pulsed laser radiation. The item **Max. Pixel** can lead to some problems with the determination of the beam radius. This is due to a problem with this mode of operation when calculating the zero level. If the zero level is falsified in this mode of operation, then the calculation of the beam radius will fail. The button **Stop** terminates the rotation of the measuring tip.

5.4.2 Environment

This item is to add information about the measurement and specific comments. This will be displayed later on in the **Presentation - Review**.

Laser Power is a reference value for the exact adjustment in the item **Single Measurement**.

The wavelength value can be selected - necessary for the correct calculation of the beam propagation factor. Available are the wavelength of 10.6µm for CO₂ laser radiation, 1.06µm for Nd:YAG laser radiation and 0.632µm for HeNe laser radiation. The default value is 10.6µm for CO₂ laser radiation.

With the item **actuate** it is possible to make changes in the environment setting after the measurement. These changes do not change the original file but could be stored under a new file name.

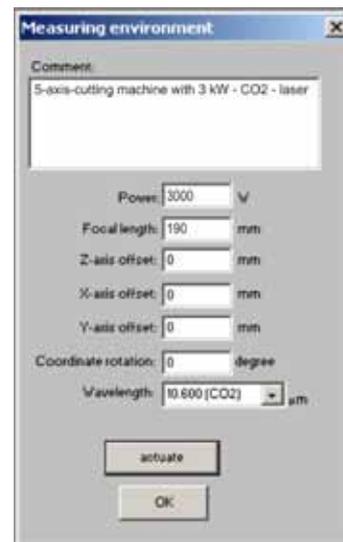


Fig. 5.5 The item **Measurement - Environment**

5.4.3 BeamFind Settings

Setting for the Beam Find algorithm can be done by selecting:

- the spatial resolution in the x- and y- directions. The distance should be much smaller than the expected beam diameter. When running the BeamFind with 8 x 8 mm window and a resolution of 64 x 64 pixels the distance between the pixels is in the range of 120µm. In this case it is difficult to find very small beams. In this case the resolution has to be increased.
- Trigger - depends on zero level of the measuring system

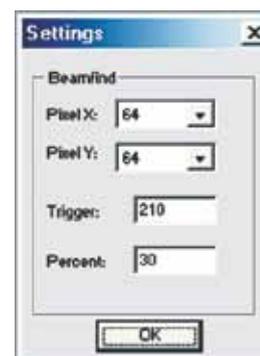
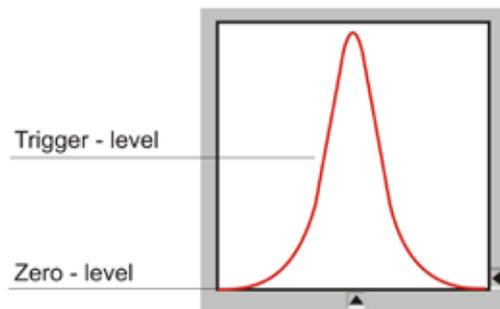


Fig. 5.6 The item **BeamFind Settings**

Trigger and Percent in the BeamFind item

First we define the zero-level. The typical value for the zero-level of our standard BeamMonitor50 HQ detector is 300 AD-counts (ADC) at 12 Bit. It is the offset of the detector. On this zero-level you will find, depending on the type of detector, a noise ratio of 2 (12 Bit) counts with the pyro-electrical detector and around 5 counts with the photo-detector.



5.4.4 Protocol

With this item the User can write measured data directly to a text file.

Written results are:

- Date and time of the measurement
- beam position and beam radius (86% and 2nd Moment definition)

How to activate ? : Click on the button **Write**.
Now the User can enter the file name directly or via **Browse**.

The system is then ready for writing to the database.



Fig. 5.7 The item *Protocol*

5.4.5 AdjustMode

This very special feature is made for the adjustment of laser resonators with the BeamMonitor50 HQ. The parameters displayed are the symmetry of the last measured power density distribution, radii and positions.

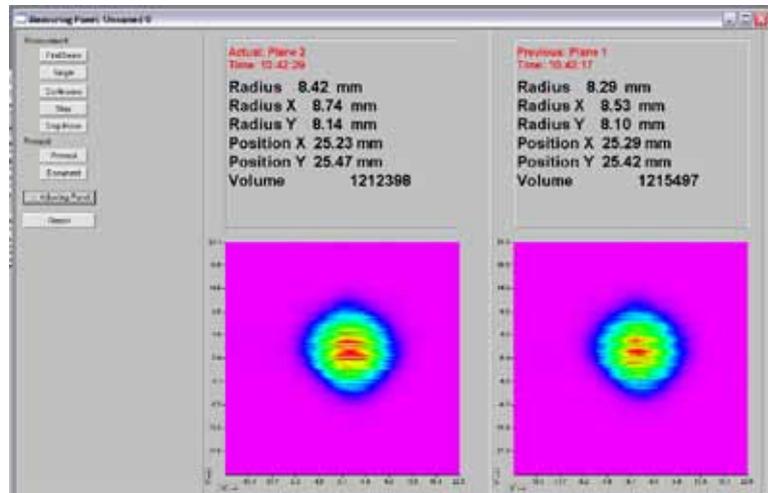


Fig. 5.8 The *Measuring Panel* of the *AdjustMode*

The typical measuring procedure starts with a **FindBeam**. After this please start with **Continuous Measurement**. The results are written one after another to the planes numbered from 0 to 19 (after plane 19 plane 0 is overwritten).

Users can choose between two modes of visualization by using the corresponding buttons in the window.

In the first mode **Measuring Panel**, the false color presentation of the two latest measurements are displayed, combined with the numerical values of beam position and beam radius

The second is the **Adjustment Panel**, which concerns the latest three measurements

Here the symmetry of the laser beam at different power levels is checked (see also chap. 5.5.5), the ratio of Rx and Ry is calculated (according the 2nd order moment method), and the volume of the power density distribution is determined (a relative degree for laser power). The results are displayed with squares in different colors as well as numerically. Green (or gray, in black-and-white images) corresponds to minimum variation from circular symmetry and red (or dark gray) to maximum.

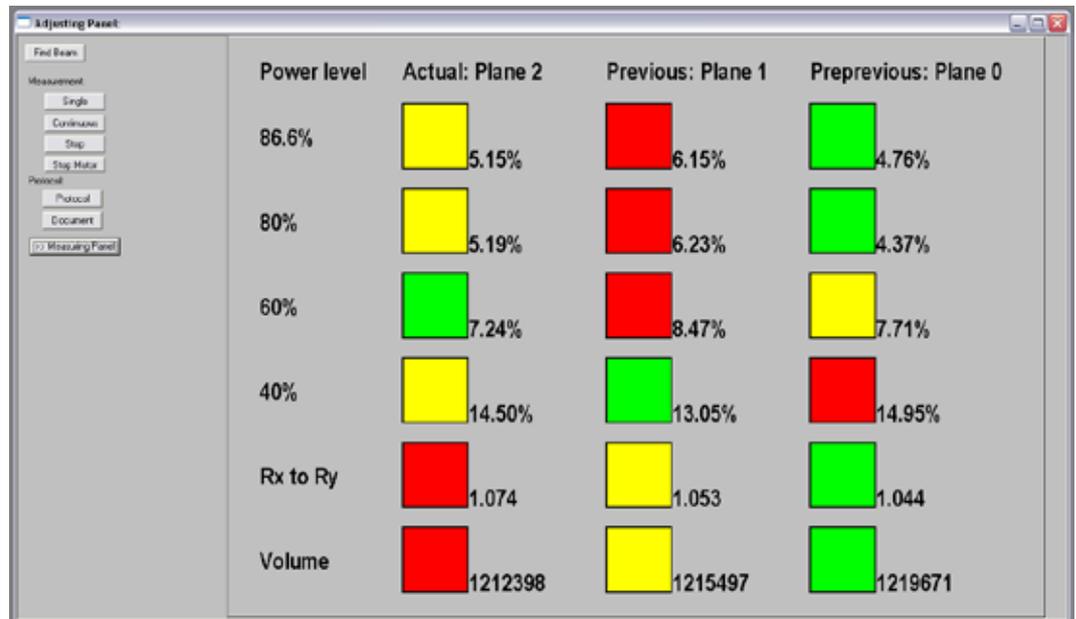


Fig. 5.9 The *Adjusting Panel* of the *AdjustmentMode*

The measured results can be documented automatically either by writing the beam radius and the measured beam position to a protocol file using the **protocol** button (chapter 5.4.5) or by saving the entire measured data using the **document** button. The time-interval between two measurements can be assigned if necessary in the **document** menu.



Fig. 5.10 Document window

The **report** button allows results such as service reports (chapter 5.11) to be saved and printed later. The name of the technician or the company name can also be saved in the settings file laserds.ini.

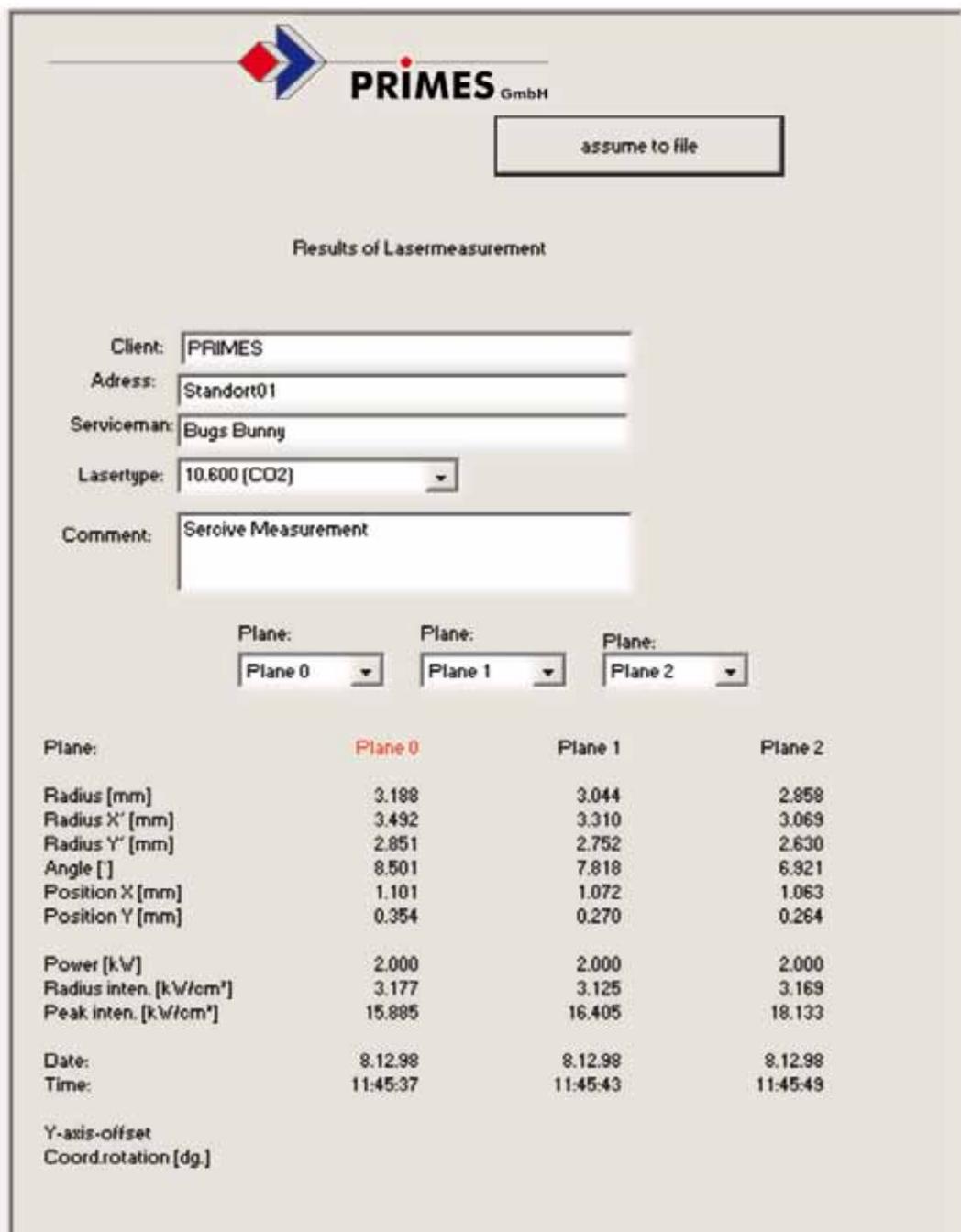


Fig. 5.10 Example of a report page

5.5 Presentation and Documentation of Measured Results

This item describes the visualization and analysis of the measured results and storage of the data.

The Toolbar



It is possible to display different sets of beam diagnostic data with the PRIMES LaserDiagnosticSoftware. Thus the User gets the opportunity to compare measured data with previously recorded data saved on file. The opened files are displayed in the **Toolbar**. To open a presentation menu a file in the **Toolbar** must be selected.

In the header of the presentation window the name of the data file is displayed.

In the **Presentation** items **Variable contour lines**, **Isometry** and **False color** the button **Autoscale** allows one to use the whole dynamic range of the display for visualization. A special feature is the **SymmetryCheck** as an additional analyzing-tool.

Moreover, the item **Planes** allows switching between different measurement planes. By moving the cursor up and down, the User can switch between the planes, provided the button has been selected with the mouse. By setting the plane selection in the Presentation items to **global**, the selection can be controlled by the setting in the header.

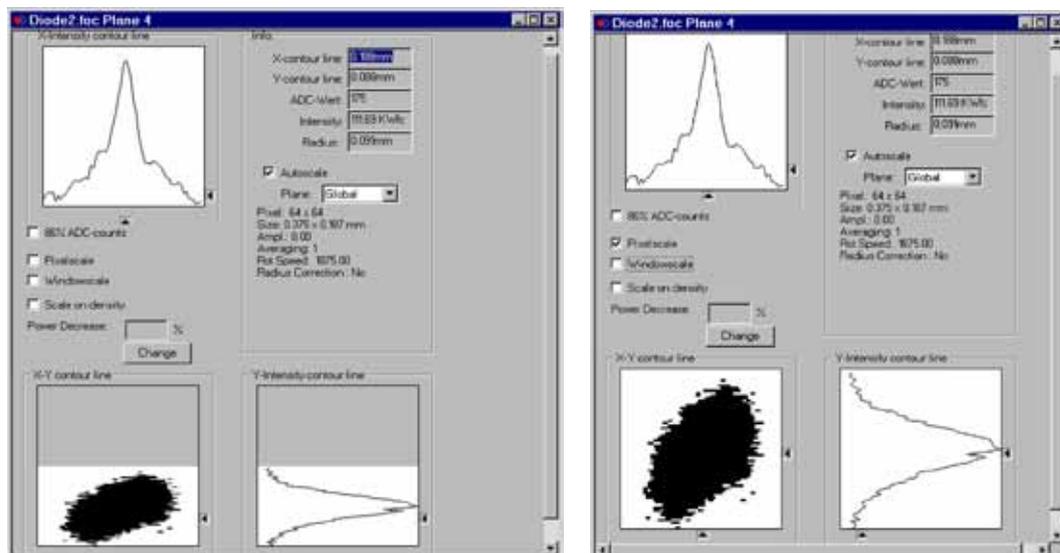
The header of the presentation window displays the name of the presented file.

Explanation of the new features - For the items 5.5.1 – 5.5.4 there are some additional features

1) Pixel scale: This item is only important if you are measuring with no square windows size. For instance: 0.375 mm in x – direction and 0.187 mm in y – direction. If you click in this case on **pixel scale** you will get a presentation according to the pixels not longer to the physical dimensions of the window. Please have a look on the examples.

2) Windows scale: This item scale all the results within one data set to the maximum measuring window which was used. This should help the user to have a better comparison between the results in the various planes.

3) Scale of density: This item scale all the results within one data set to the maximum power density which was measured. This should help the user to have a better comparison between the results in the various planes.



5.5.1 Contour lines

5.5.1.1 Free variable Contour Lines

This presentation shows free adjustable contour lines of the spatial power density distribution. There is a choice between contour lines in the x- and y-direction and power density coordinates. The selection of the contour lines can be done by the mouse or by the keyboard. To select different contour lines in:

- x - direction: press the key **x** to increase and **<shift> x** to decrease the value.
- y - direction: press the key **y** to increase and **<shift> y** to decrease the value
- Power density (Intensity): press the key **i** to increase and **<shift> i** to decrease the value.

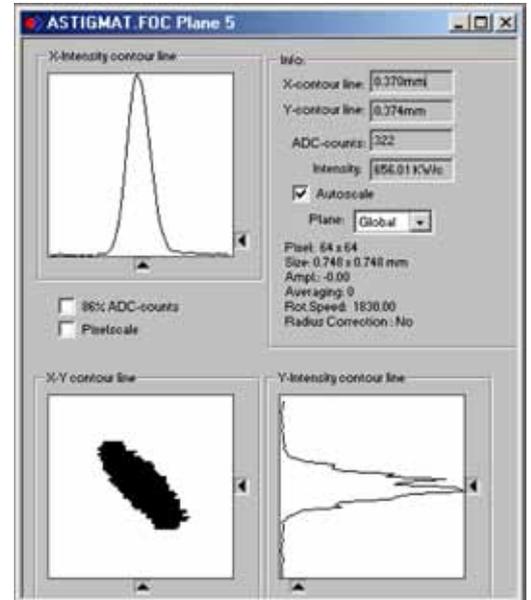


Fig. 5.12 The item *Presentation - Free Variable Contour Lines*

The x-, y- and power density-coordinates can be selected using the sliders: The *message* box in the upper right area of the window shows the actual values represented by the triangular sliders. The range of the x and y contour lines is from zero to the selected measuring-resolution in pixel-coordinates. *ADC-Counts* contains the power density information in absolute counts of the AD-Converter. The maximum value is 4095 Counts.

Also displayed are the spatial resolution in pixel coordinates, the size of the measurement area in mm, the amplification, the number averaging and the rotational speed.

5.5.1.2 Fixed Contour Lines

Contour lines at different power levels are displayed. Contours at: 86%, 80%, 60%, 40%, 20% and 10% are selected.

In this presentation mode it is also possible to measure distances by clicking with the mouse on the screen at the start and end of the desired range.

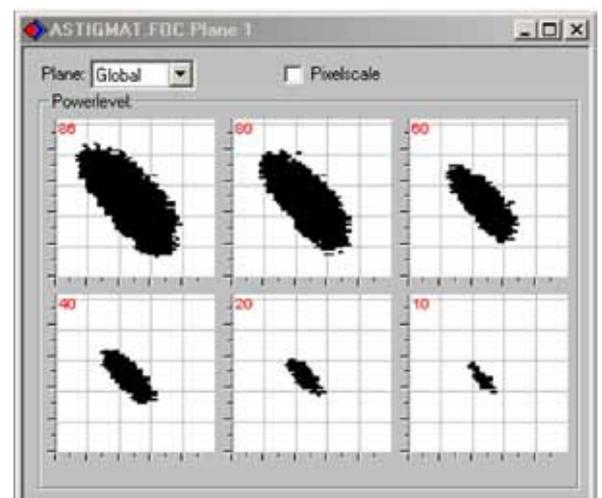


Fig. 5.13 The item *Fixed Contour Lines*

5.5.2 Isometry (3-D Presentation)

Generates a 3-D presentation of the measured distribution of laser power density. With the roll-down-menu *Plane* it is possible to switch between the different measurement planes. The button *False Color* allows to switch between colored and black-and-white presentation.

The button *PixelScale* allows the user to switch between real spatial coordinates and pixel coordinates.

The viewpoint can be rotated by the button *Angle* in steps of 0°, 90°, 180° and 270°.

5.5.3 Pseudo colors

Displays a pseudo-color representation of the measured power density distribution.

The color scale is shown on the left. For higher sensitivity, for example - analysis of diffraction figures, the color scale can be changed under the menu item "**Presentation - Color Tables.**" There are three scale modes in addition to automatic scaling.

Scale on Density Scaling:

All planes of the caustic measurement are scaled to the highest measured power density. This should help better compare the individual planes with each other.

Pixel Scaling:

This scaling can be used when you have unsymmetrical measuring windows or unsymmetrical spatial resolution (for instance 128x64). The display is no longer a function of measurement window size, but of the number of measured pixels.

Window Scaling:

Using this scaling, all measurement windows of the caustic measurement are resized to the largest measurement window. This scaling should also help compare to the individual planes of the caustic measurement better with each other.

5.5.4 Symmetry Check

An important feature for presentation is the symmetry check. It is available as an additional function of the Software.

This feature checks the rotational symmetry of the power density distribution of the laser beam. It can be used for laser adjustment purposes in combination with the *Monitor* feature included in the **PRIMES LaserDiagnosticSoftware**.

The following figures 5. 16 to 5. 19 show two examples for possible results of the SymmetryCheck which are:

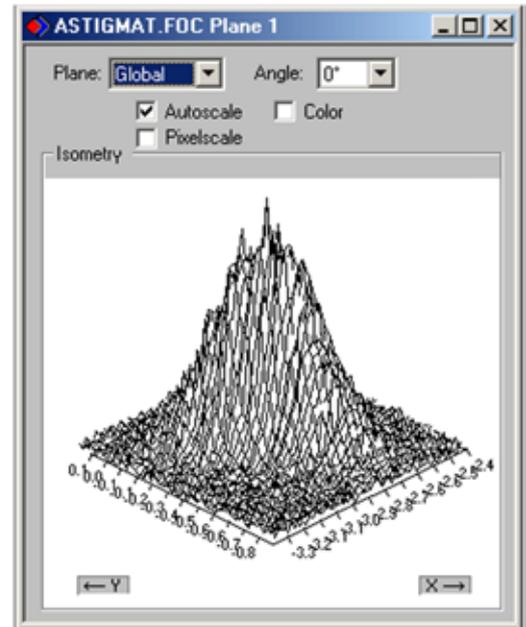


Fig. 5.14 The item *Presentation - 3D Presentation (Isometry)*

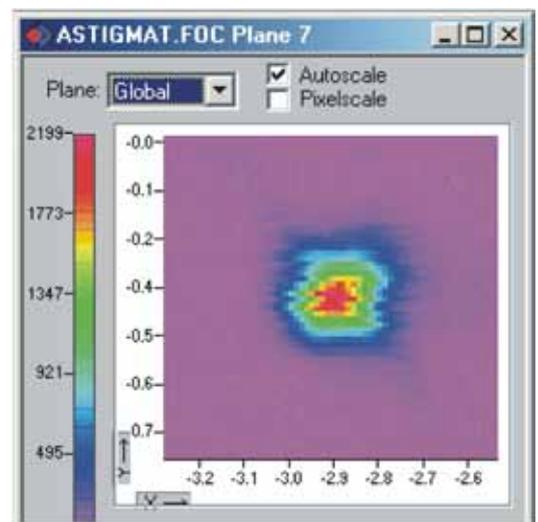
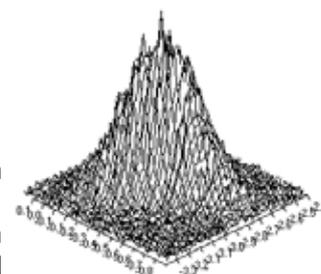


Fig. 5.15 The item *Presentation - False Colors*

- an elliptic beam
- a beam with rotational symmetry over a cut at 86% of maximum power



The displayed power density distribution of an elliptic beam leads to the following results of the **SymmetryCheck**. The x-axis represents the angle and the y-axis the radius which includes different cuts between 86% and 10% of the detected maximum power.

On screen the curves have different colors. The radius is given in pixel values. Minimum and maximum of the radius values can be selected. On the right side the standard deviations of the displayed radius lines are shown. These values give precise information about the symmetry of the measured beam.

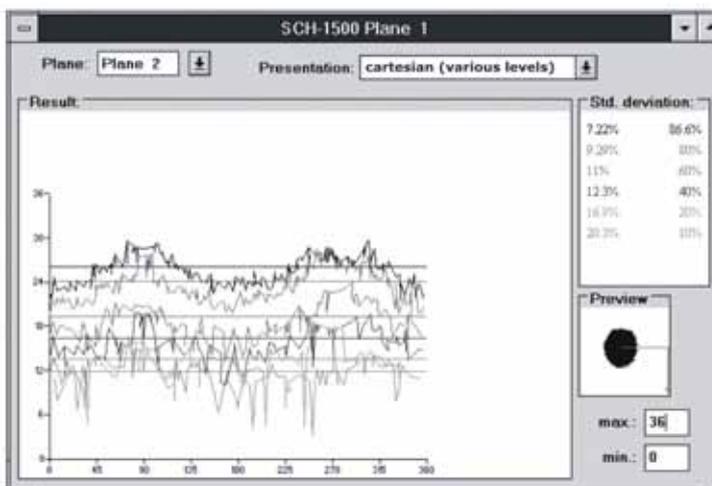


Fig. 5.16 SymmetryCheck in Cartesian Coordinates

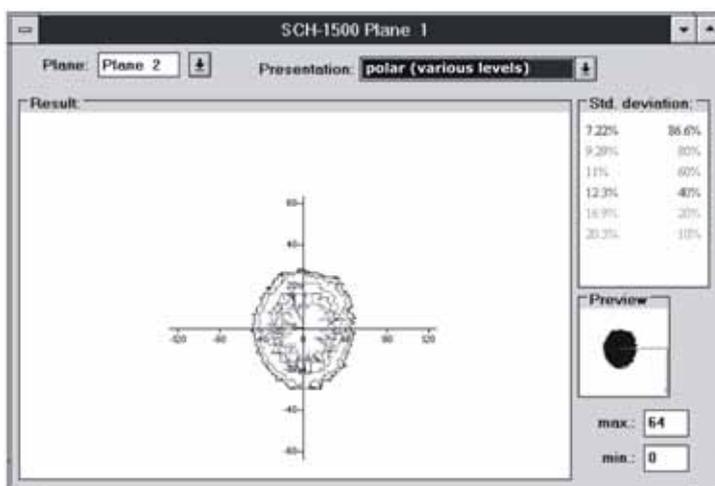


Fig. 5.17 SymmetryCheck in Polar Coordinates

Well adjusted resonators reach standard deviations in the range of 3 % to 5 %

A presentation in polar coordinates is also possible (Fig. 5.17). The displayed graphs include 86% to 10% of the detected power.

On screen, the graphs have different colors. The x- and y-axis are given in pixel values.

5.5.4.1 The Algorithm

For the **SymmetryCheck** the estimated regions are 86, 80, 60, 40, 20 and 10% of the maximum measured laser power density. For the 86% - area the moment of inertia is calculated. This is the center of the whole **SymmetryCheck**. Then a scan is made to obtain

the radius and the angle values of the different power levels. Results are pairs of radii and angles. The maximum values for the radii are finally connected by straight lines.

For the 10% and 20% regions there are often (with a resolution of 64x64 pixel) only a few points left, so the standard deviation value becomes quite uncertain.

In the **SymmetryCheck** presentation the minimum of the TEM₁₀* - mode cannot be seen.

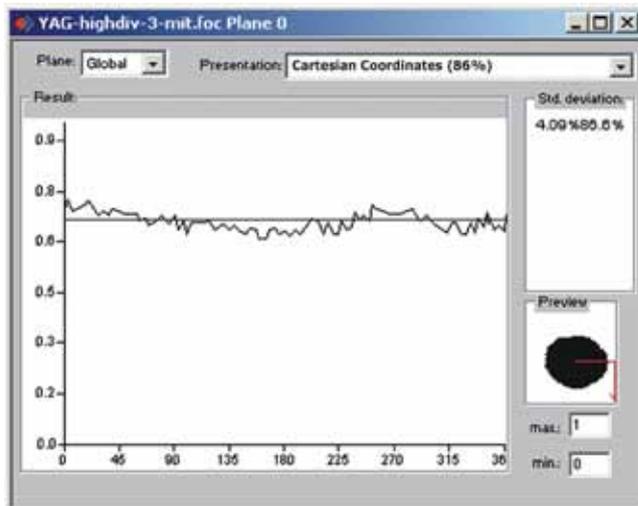
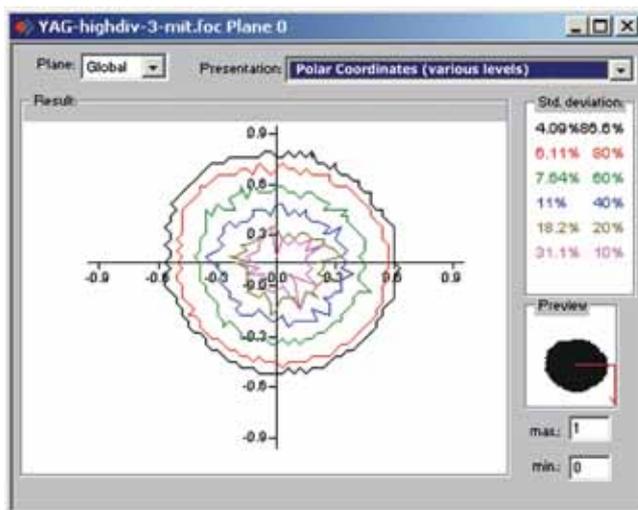


Fig. 5.18 SymmetryCheck in Cartesian Coordinates



A presentation in polar coordinates is also possible (Fig. 5.17). The graphs including contours from 86% to 10% of the detected power are displayed there.

On screen the graphs have different colors. Values x-and y-axis are given in pixel numbers.

Fig. 5.19 SymmetryCheck in Polar Coordinates

5.5.5 Color Tables

It is possible to choose a different color table. The relation between the measured power density and the color circle is changed. This is relevant for any false color presentation.

Three tables are used:

- 1 - linear color table
- 2 - square root color table
- 3 - fourth root color table



This feature can be used for instance for better visualization of a diffraction pattern.

5.5.6 Review - 86% and 2nd Order Moments

ASTIGMAT.FOC- 86% Review						
Plane:	Plane 1	Plane 2	Plane 3	Plane 4	Plane 5	Plane 6
Radius [mm]	0.274	0.223	0.205	0.154	0.138	0.140
Position X [mm]	-2.940	-2.926	-2.928	-2.919	-2.911	-2.897
Position Y [mm]	-0.406	-0.394	-0.388	-0.390	-0.378	-0.374
Position Z [mm]	14.975	15.800	16.200	16.832	17.450	18.069
Zero level [AVD-Cnts]	101.860	100.715	100.860	102.065	101.765	100.280
Power [kW]	1.707	1.707	1.707	1.707	1.707	1.707
Radius inten. [μW/cm²]	184.098	219.786	250.637	533.156	656.013	564.707
Peak inten. [μW/cm²]	2033.033	3545.741	3753.778	5074.611	7089.991	5724.180
Date:	02.09.1996	02.09.1996	02.09.1996	02.09.1996	02.09.1996	02.09.1996
Time:	12:35:36	12:36:46	12:37:43	12:40:06	12:40:53	12:42:53
Focal length [mm]	127.000	127.000	127.000	127.000	127.000	127.000
Z-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000
X-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000
Y-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000
Coordination [deg.]	0.000	0.000	0.000	0.000	0.000	0.000
Wavelength [μm]	10.600	10.600	10.600	10.600	10.600	10.600
Comment:						

Fig. 5.20: Menu Item “Display - Review (86%)”

The following parameters are displayed:

date of measurement, time of measurement, as well as the entries from the menu item “**Measurement - Environment**”: focal length, offsets, and contents of the comment field.

In addition, the following numeric results are displayed.

Beam radius, x beam radius (only for 2nd moments - principle axis), y beam radius (only for 2nd moments - the minor axis), x-position, y-position, and, where appropriate, z-position and power density (based on the power rating settings in the “Measurement” menu).

The difference between overviews is that one presents results based on the 86% power distribution and the other on the 2nd moment in accordance with ISO 11146.

When measurement signals are close to the null level, the results are displayed in gray, not black. In this case, you must verify if the results should be rejected and the test repeated with different settings. The entry power, focal length and wavelength in the comment line can also be changed after a measurement. This is done using the menu item “**Measurement - Environment**.”

ASTIGMAT.FOC- 2. Moments Review						
Plane:	Plane 1	Plane 2	Plane 3	Plane 4	Plane 5	Plane 6
Radius [mm]	0.316	0.274	0.256	0.200	0.190	0.174
Radius X [mm]	0.200	0.177	0.156	0.099	0.098	0.125
Radius Y [mm]	0.400	0.346	0.343	0.279	0.235	0.212
Angle [°]	-50.0	-50.0	-49.9	-48.0	-47.4	-47.0
Position X [mm]	-2.940	-2.927	-2.928	-2.913	-2.905	-2.893
Position Y [mm]	-0.409	-0.392	-0.391	-0.388	-0.377	-0.375
Position Z [mm]	14.975	15.800	16.200	16.832	17.450	18.069
Zero level [AVD-Cnts]	101.860	100.715	100.860	102.065	101.765	100.280
Power [kW]	1.707	1.707	1.707	1.707	1.707	1.707
Peak inten. [μW/cm²]	2033.033	3545.741	3753.778	5074.611	7089.991	5724.180
Date:	02.09.1996	02.09.1996	02.09.1996	02.09.1996	02.09.1996	02.09.1996
Time:	12:35:36	12:36:46	12:37:43	12:40:06	12:40:53	12:42:53
Focal length [mm]	127.000	127.000	127.000	127.000	127.000	127.000
Z-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000
X-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000
Y-axis-offset	0.000	0.000	0.000	0.000	0.000	0.000
Coordination [deg.]	0.000	0.000	0.000	0.000	0.000	0.000
Wavelength [μm]	10.600	10.600	10.600	10.600	10.600	10.600
Comment:						

Fig. 5.21.: The item **Measurement - Review 2nd Order Moments**

When the measured signals are close to the zero level, the results are greyed in the **Review**-window. In this case you should check carefully, whether the calculated values should be rejected and the measurement should be repeated with different settings. It is not possible to make any changes in the **Review**.

For making comments, **the sign '#' should not be used**. This would lead to serious problems when storing the data.

5.5.7 Graphical Review

The Graphical review enables the user to do various presentations. He can select for the y-axis: radius, position x and y and the angle and for the x-axis: power, time, plane and z-position. It is possible to receive 16 different graphs.



Fig. 22 Graphical Review

5.5.8 Data management

Further functions are available for organizing the measured data and the settings of the device

5.5.8.1 Storing and reloading of measured data

To store the measured data to file, the item **File - Save as** has to be used. The user can change between different formats of data storage. The standard type is binary storage, which needs a minimum of storage capacity. The extension for these data files is '.foc'. Alternatively it is possible to store the data into an ASCII format with the extension '.mdf'. More information about .mdf is given in the appendix. Only files with these extensions can be opened by the PRIMES LaserDiagnostic Software. To open a file of measured data go to the item **File - Open**

Stored data can only be reloaded easily, when the file has the extension '.foc' or '.mdf'. Measured data are displayed only when the desired file is selected in the Toolbar.



Fig. 5.23 reloading of measured data

5.5.8.2 Storing of Preferences to file, and opening of such files

To store the current Preferences (i.e. parameter-settings for the measurement) to file, the menu **File - Save Preferences** is to be used. To reload the stored preferences go to the menu **File - Load preferences**. The standard extension for the preferences files is '.ptx'.

5.5.8.3 Printing

The item **File - Print** serves to print the actual selected window. The adjustment of the printer is done by **File - Printer settings**.

To check the layout of the prints the function **Print preview** can be used.

5.5.8.4 Copy

With the item **Edit - Copy** it is possible to export graphics to other programs on the PC. The current window is transferred to the Clipboard.

5.5.8.5 Clear / Clear all

With **Clear** or **Clear all** it is possible to reset the contents of one plane or all planes which is/are selected in the **Toolbar**.

5.5.8.6 Export

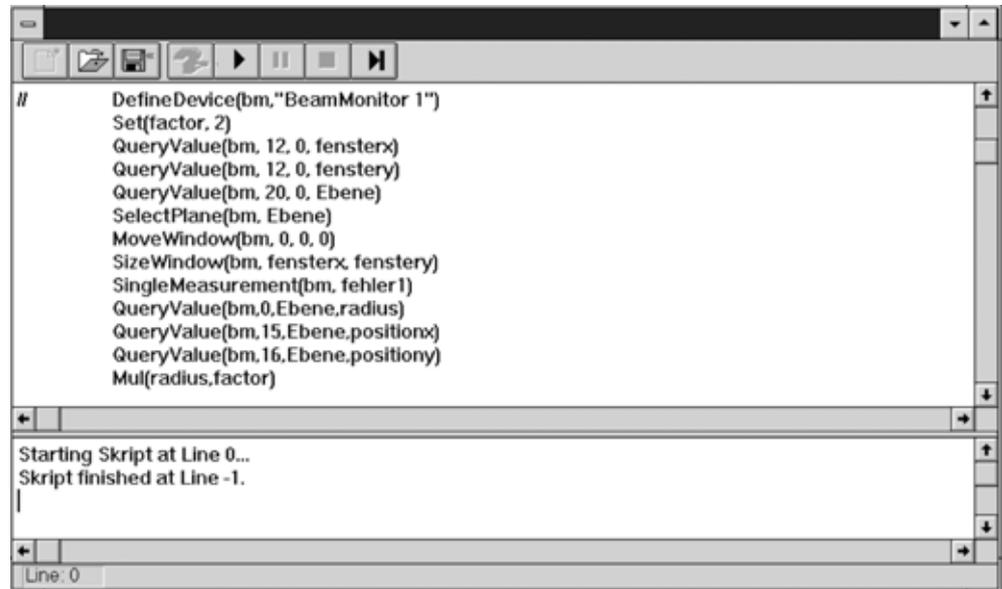
This item writes the numerical results into a tab - separated text file. This file can easily be imported to Microsoft Excel.

5.5.8.7 Quitting the program

To quit the program, select the item **File - Quit**.

5.6 Scripts to run the LaserDiagnosticSoftware

To run automatically a complex measuring procedure, it is helpful to use the PRIMES script generator. Detailed information about programming is provided. As an example, a script for the BeamFind procedure of the BeamMonitor is displayed (Fig. 5.24).



```
# DefineDevice(bm,"BeamMonitor 1")
Set(factor, 2)
QueryValue(bm, 12, 0, fensterx)
QueryValue(bm, 12, 0, fenstery)
QueryValue(bm, 20, 0, Ebene)
SelectPlane(bm, Ebene)
MoveWindow(bm, 0, 0, 0)
SizeWindow(bm, fensterx, fenstery)
SingleMeasurement(bm, fehler1)
QueryValue(bm,0,Ebene,radius)
QueryValue(bm,15,Ebene,positionx)
QueryValue(bm,16,Ebene,positiony)
Mul(radius,factor)
```

Starting Skript at Line 0...
Skript finished at Line -1.

Line 0

Fig. 5.24 Script for Beam Find Procedure

To open the script-file press the Open-symbol. Then choose a file; the script can be run by pressing the ▶ - button . The || - Button stops and ■ close the script.

5.7 Assessment of the Results and Error Analysis

For the correct interpretation of the measured data and the classification of the calculated results, it is important to know some specific features of the measuring devices. Radius definition - detailed information is available.

The program uses two alternate radius definitions.

86% - definition:

The radius of the laser beam is calculated by estimating the beam area containing 86% of the total measured laser power. This value allows one to determine the radius of the circle with the same area.

This definition is valid only when the laser beam is rotationally-symmetric and there are no areas with deep modulation of laser intensity (very low laser intensity) in the beam area.

Second order moments - definition:

The radius of the laser beam is calculated from the second order moment of the power density distribution - as in ISO 11146.

Sometimes it may also be helpful to determine the beam radius according to the 10-90% signal rise from the **Contour lines** Presentation.

Beam position in the measurement window

The position of the measurement window has to be selected so that the whole beam fits in the window. This is the basis for a correct calculation of the beam radius and beam position.

Size of the measurement window

To minimize the measuring uncertainty it is necessary to select an appropriate size of the measuring window. Windows that are too small or too large lead to increasing errors. The beam radius should be between 15 and 35% of the base line of the quadratic measuring area.

Temporal Stability

The BeamMonitor50 HQ is mainly designed to measure continuous wave laser radiation. Temporal fluctuations of the laser power or of the spatial power density distribution cannot be detected efficiently, if the time constants of the variations are smaller than the measuring time of about two seconds.

Repetitively, pulsed laser radiation can be detected, but interference between the laser frequency and the scanning frequency of the BeamMonitor50 HQ may occur.

In many lasers the setting of laser power is done by the modulation of the pulse-width (usually in high frequency excited lasers), which sometimes leads to modulation of the laser power. This can influence the measured results. In rare cases interference between modulation and measurement frequency can be observed. Changing of the spatial resolution changes the rate digitizing (measurement frequency), and may help to avoid the interference.

Transmissive optics (for instance outcouplers and lenses) usually show a temporal variation of the optical parameters after incidence of high power laser radiation. It takes typically 10-20 seconds until the optics reach their thermal equilibrium. During this time the refractive index and thickness of the material changes. Normally these effects lead to a variation of the diameter and the divergence of the laser beam.

If necessary the measurement should be started after the critical time.

To measure temporally modulated beams, it helps to activate the averaging mode or to synchronize the laser on the motion of the measuring tip.

6. Review of some important Features of the Graphical User Interface

6.1 Software Menus

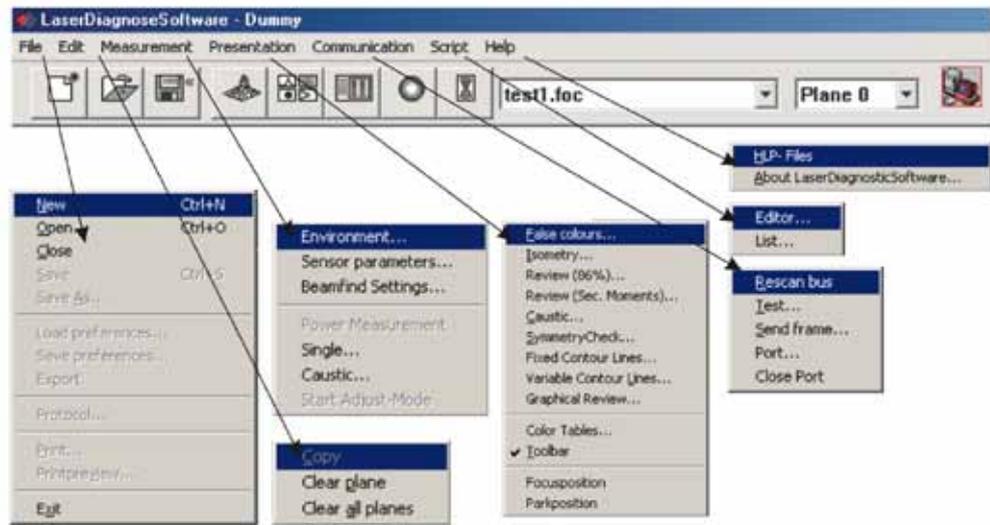


Fig. 6.1: The Menu Structure

File

- New to open a new file for measured data
- Open to reload a file of measured data with the extension '.foc'
- Close to close the file which is selected in the Toolbar
- Save to save a file
- Save as to open the menu for saving the file which is selected in the Toolbar. Only files with the extension '.foc' can be reloaded
- Load preferences to reload a file defining preferences with the extension '.ptx'
- Save preferences to open the menu to store the preferences of last program run. Only files with the extension '.ptx' can be reloaded
- Export to save the file as '.pkl' (protocol)
- Protocol To start a protocol written to file or to database
- Print starts a standard printing menu
- Print Preview shows the expected result of the print job
- Exit terminates the program

Edit

- Copy copies the current window to the clipboard
- Clear plane deletes the data from the plane which is selected in the Toolbar
- Clear all planes deletes all the data from the file which is selected in the Toolbar

Measurement

- Environment here several system values should be entered: For details, please see chapter 6.6
- Sensor Parameter the settings of the devices can be adjusted here: For details, please see chapter 6.4
- Beamfind Settings To adjust the parameters for the BeamFind algorithm

Single Measurement	this item is used to run a single measurement or to start the monitoring mode. The adjustment of the measuring window is done here. For the FocusMonitor an automatic Beam Find algorithm is available.
Caustic Measurement	to run a caustic measurement using the FocusMonitor. When the manually adjusted mode is selected, all the current settings of the planes are used for the measurement. The automatic measurement starts with <i>Find Beam</i> and runs the whole measurement process automatically. Only the measuring range in the z-axis and the number of planes to be measured have to be entered.
Start Adjust-Mode	This item is not relevant for the BeamMonitor50 HQ Starts a special mode of operation of the BeamMonitor 50HQ for an easier adjustment of the laser resonator For details, please see chapter 6.6

Presentation

False color	false color presentation of the spatial power density distribution
Isometry	three dimensional presentation of the spatial power density distribution.
Review (86%)	numerical review of the measured results of the different planes based on the 86% beam radius definition
Review (2nd Moments)	based on the 2nd order moments beam radius definition
Caustic	results of the caustic measurement and the parameters of the calculated fitting curve - which lead to beam propagation ratio, focal position and focal radius
SymmetryCheck	Analysis tool to check the beam symmetry especially for laser adjustment purpose. Available as an additional feature.
Fixed Contour lines	presentation of the contour lines of the spatial power density distribution at six fixed power levels
Var. Contour lines	presentation of free variable contour lines of the spatial power density distribution
Graphical Review	enables different presentations - for instance radius, x- and y-position versus z-position or time
Color Tables	Different color scalings for the detailed analysis for instance of diffraction phenomena.
Toolbar	to display or hide the Toolbar
Focus Position	moves horizontal carrier to the measured focal position
Park Position	moves horizontal carrier to the z-axis zero position

Communication

Rescan bus	to re-run the hardware detection - necessary when the device configuration connected to the PRIMES-Bus has been changed.
Test	checks if the bus-lines are free for transmission or if a fault has occurred
Send frame	here the communication on the bus can be checked in detail. All the devices can be polled by the PC.
Port	allows the User to select one of the communication ports available on the PC.
Close Port	If only one port is available it is automatically opened by the program. to close the serial port

Script

Editor	opens the script editor, a tool to run complex measuring scripts.
List	displays the open windows

Help

Hints	displays additional hints depending on software version and hardware set up
-------	---

6.2 Toolbar

By clicking the icons shown in the **Toolbar** the different software menus can be opened directly.



- 1 - Create a new set of data (file)
- 2 - Open an existing file
- 3 - Store a file
- 4 - Open **Presentation - Isometry** for the selected set of data
- 5 - Open **Presentation - Contour Lines** for the selected set of data
- 6 - Open **Presentation - 86%-Review** for the selected set of data
- 7 - Open **Presentation - False Color** for the selected set of data
- 8 - Open **Presentation - Caustic** for the selected set of data
- 9 - List of files for selection
- 10 - List of planes for selection
- 11 - Symbols to select the devices - when different devices are present at the bus

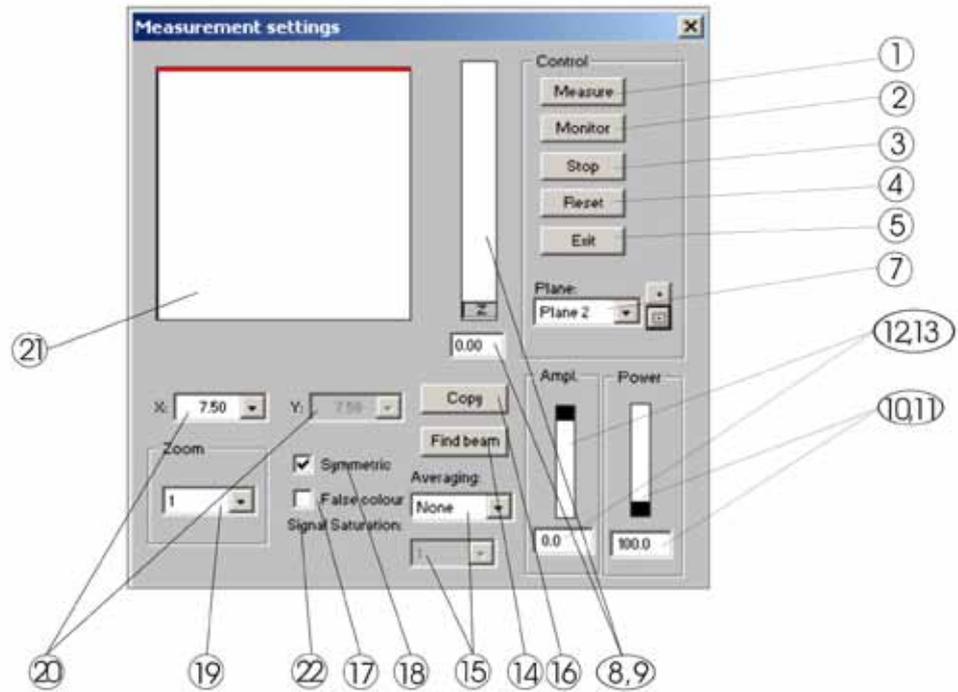
All measured results are written to the file selected in the Toolbar.

Only data from the selected file can be displayed.

After opening a file it has to be made the current file by choosing it in the Toolbar.

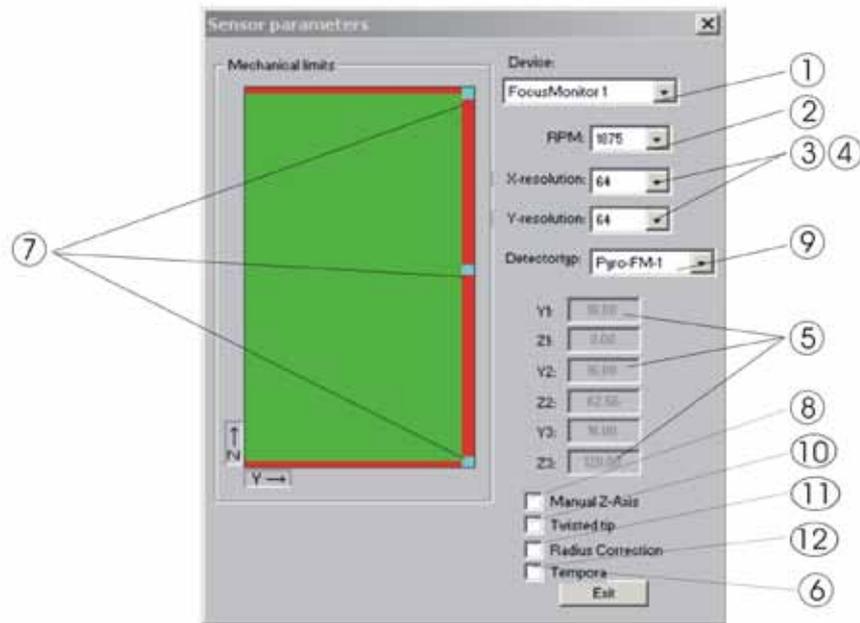
Only the device that is selected is ready to measure!

6.3 Menu item „Measurement, Single measurement, (Measurement settings)“



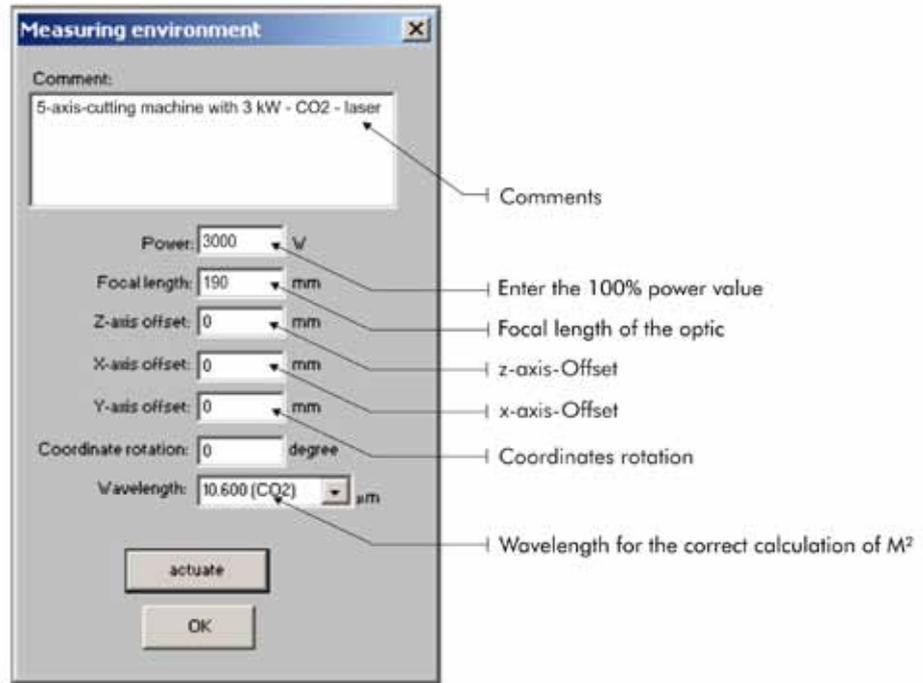
- | | |
|--|---|
| <ul style="list-style-type: none"> 1 - Measure 2 - Monitor 3 - Stop 4 - Reset 5 - Exit 7 - Plane 8,9 - z-position 10,11 - Power 12,13 - Amplification 14 - Find Beam 15 - Averaging 16 - Copy 17 - FalseColor 18 - Symmetric 19 - Zoom 20 - Size of the measurement window 21 - Display for measured results 22 - Signal saturation 23 - Optimize | <ul style="list-style-type: none"> starts a measurement in the currently selected plane starts the monitoring mode - automatic repeat measure mode stops the mechanical motion of the device resets the system closes the window to switch between the different image stores (0-19) not relevant for the BeamMonitor50 HQ recommended slider or by numerical input not relevant for the BeamMonitor50 HQ not relevant for the BeamMonitor50 HQ variable number of measurements for averaging. Different modes are available: mean value, maximum of pixel and maximum of plot to take over settings from the previous plane into the current plane (for instance when plane 3 is selected, copy takes over the setting from plane 2) The display can be changed to false colors. The color reference is given in the item Presentation/Color Table Forces the system to use quadratic measurement areas. Rectangular areas are possible. to select different zoom-factors to get better adjustment of the measuring area on the beam. For BeamMonitor50 HQ and the Monitor the scale depends on the aperture The square shows the current measurement window. The degree of signal saturation is displayed. When the signal reaches 4095 ADC, the spot becomes red. Only for MicroSpotMonitor |
|--|---|

6.4 Menu Item ‘Measurement, Sensor Parameter’

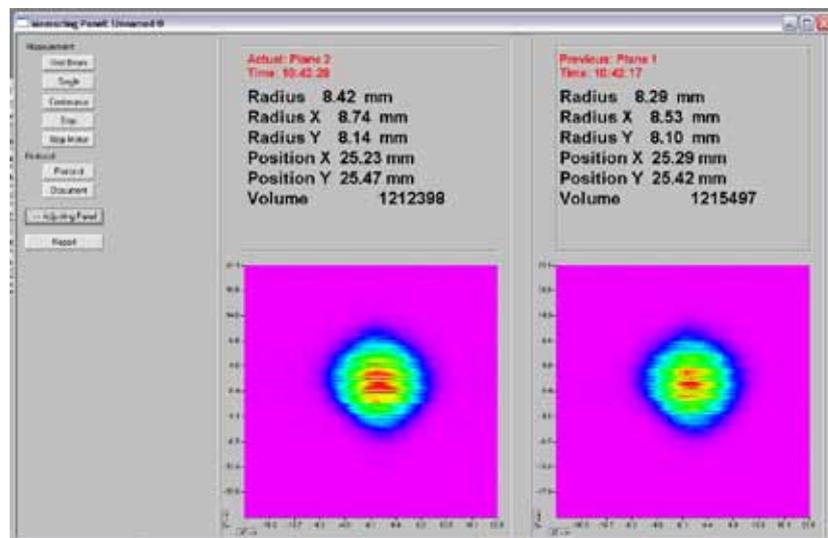


- 1 - **Device** Selection of the device when operating two or more devices at the PRIMES-Bus: **BeamMonitor50 HQ** or **BeamMonitor**, **FocusMonitor** or **MicroSpotMonitor**
- 2 - **Rotational speed** The **BeamMonitor50 HQ** is running at a fixed speed of 2112 rpm.
- 3,4 - **Spatial resolution** in x-direction by the number of pixels per trace -32, 64, 128, 256 in y-direction by the number of traces - 32, 64, 128, 256
- 5 - **Limits of Motion** not relevant for the **BeamMonitor50 HQ**
- 6 - **Exit** will close this window, otherwise it will stay in the foreground.
- 7 - **Setting of the mechanical limits** not relevant for the **BeamMonitor50 HQ**
- 8 - **Manual z-axis** Manual z-axis removes the connection between the z-axis adjustment in the single measurement display/window and the mechanism of the motor.
- 9 - **Detector type** When the device is connected to the PC, the LaserDiagnosticsSoftware automatically selects the correct detector type. A manual selection is not possible. .
- 10 - **Twisted tip:** not relevant for the **BeamMonitor50 HQ**
- 11 - **Radius correction:** Activates the smoothing of the curvature of the scanned traces option.
- 12 - **Temporal:** Allows measurement at a fixed y-position to check the temporal development of the power density. Please have a look also to Appendix III - Line scan.

6.5 Menu Item 'Measurement, Environment'



6.6 Menu Item 'Adjusting Mode'



- Find Beam** starts an automated beam find procedure
- Single** starts a single measurement
- Continuous** starts a continuous measurement
- Protocol** starts the protocol - writing the calculated beam data to file
- Document** opens a document - writing the measured data with all the pixel information to file
- >> Adjustment Panel** switch to the other presentation panel of the adjustment mode
- Report** prepares a text document for measurement report

7. Communication

When a communication problem occurs, the menu **Communication** in the header line will provide help. It allows the user to check the communication between the PC, the BeamMonitor 50HQ, the FocusMonitor and all other PRIMES devices. The item **Communication - Port** allows the user to select one of the available serial ports of the PC. The item *Close port* terminates the assignment of the software to the port.

The item **Communication - Test** is to check whether the PRIMES-Bus is available. The PC sends a signal and waits for an echo. This echo is generated by the PRIMES-devices. When there is no echo the bus has to be checked.

7.1 Test of the serial port

When the PRIMES-LaserDiagnosticSoftware is started the serial port is tested at first.

Possible error message:



It means that the Software could not open the serial port of the PC.

Possible reasons are:

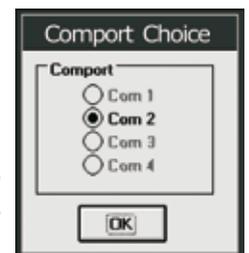
- Another program is running and using the serial port. This could be Fax- or Modem-Software
- The program is trying to open the wrong serial port. The serial port can be selected with the item **Communication - Port**. All available ports are displayed.

The file laserds.ini in the Windows folder determines which port will be selected when starting the PRIMES-LaserDiagnosticSoftware. An example is given in the appendix.

Workaround:

- Quit the LaserDiagnosticSoftware
- Change the port setting in the Laserds.ini and save
- Start the Software again.

When the user wishes to run a program which needs access to the serial port while working with the LaserDiagnosticSoftware it is possible to close the port with the item **Communication Close Port**.

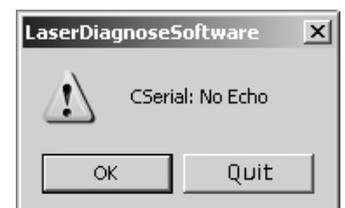


Possible error message:

The message means that there is no communication on the bus so that the connected devices could not communicate.

Possible reasons are:

- The devices are not connected in the correct manner (refer to chap. 2)
- The power supply is off.

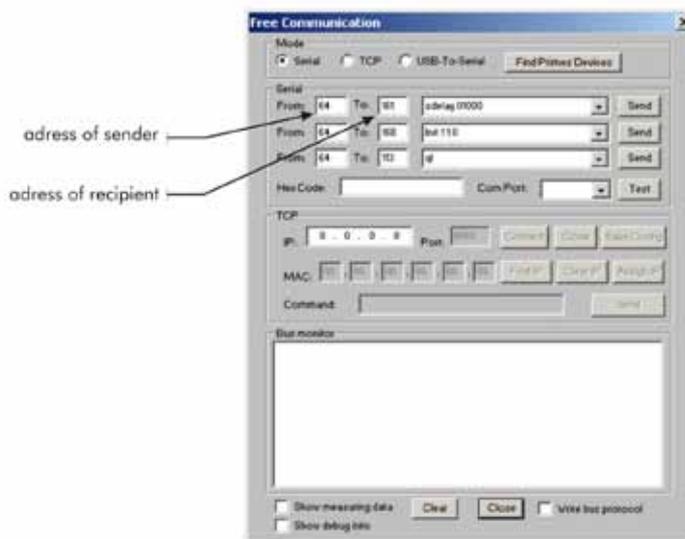


Workaround:

- restart the system by switching the power off and on. After a system-reset the parameters of the connected devices are read. This can be seen in the **control box** button visualized at the lower right screen position.

7.2 Communication between the devices

The communication of the devices connected to the PRIMES-Bus can be tested. Every device on the bus has its own address. With the item **Communication - Free Communication** it is possible to check the links to the devices.



To test the communication of the devices send a test request from the PC to the device by using the item **Communication - Send Frame**.

This is done by entering the address of the sender (always 64 for the PC), address of the recipient and a message. Then click the *Send* button.

The device should reply as described in table 7.1. For the test it is important to use exactly this form of writing - do not type 'QR' or 'query ready'. Do not use the **Enter key** on the keyboard.

7.2.1 Communication - Test Responses

<i>Device: From:</i>	<i>Address:</i>	<i>Test request</i>	<i>Answer</i>
<i>BeamMonitor50 HQ</i>	<i>64</i>	<i>152</i>	<i>qr aID BeamMonitor50 HQ</i>
<i>BeamMonitor</i>	<i>64</i>	<i>144</i>	<i>qr aID BeamMonitor</i>
<i>PowerMonitor</i>	<i>64</i>	<i>112 or 113</i>	<i>qr ready Power Monitor</i>

Table 7.1 Communication-Test Responses

If no message appears on the screen there may be a problem with the communication. Switch off the power supply for the LaserDiagnosticSystem and check the cable connections between the devices in accordance with chapter 3 . Verify that all connectors are plugged-in correctly. Then switch the power on and test again.

Possibly the PC is not configured correctly. This can be seen at the third LED (red) of the PRIMES-Converter. It is connected to the RTS-signal of the serial interface. When the LED is glowing steadily no data transmission is possible. Try to reopen the interface by selecting **Communication - Port** or restart the PC.

When the communication works properly you can open the item **Measurement - Single Measurement** and proceed with the measuring procedure.

8. Maintenance and Error Analysis

8.1 Maintenance

No maintenance is necessary for the device under normal operating conditions.

In a very dusty environment it could be useful to clean the mechanical guiding mechanism with isopropanol and to grease the mechanical guiding mechanism and the ball screw slightly over.

8.2 Error Analysis

When any error occurs check first whether the system installation is correct (chap. 3).

8.2.1 Error in data communication

When there is an **error in data communication** (indicated by a grey button **Measurement** in the item **Measurement - Single Measurement**) it may be helpful to reset the system by switching off/on the 24V power supply and to reboot the computer.

8.2.2 No measuring signal at the BeamMonitor50 HQ

When there is only noise signal on the screen - typically around 800 AD-counts in *Presentation - Variable Contour Lines* - check:

- the device's position and orientation (chap. 3).
Does the beam enter the correct side of the device?

8.2.3 Jitter of the plots

When measuring small beams sometimes a jitter between the different plots of the measured power density distributions is observed.

This jitter is due to small fluctuations in the speed of the rotational drum and the stability of the generation of the trigger signal. The jitter of the traces can be minimized by choosing a beam position strong on the left side of the measuring window. So the temporal distance between trigger signal and the start of the measurement is small and any disturbance can be reduced to a minimum.

Please keep in mind there might be also temporal fluctuations coming out of the laser source. They are detected by the BeamMonitor50 HQ due to the high band of the detector.

9. Appendix I

9.1 Technical Data

9.1.1 Dimensions

The dimensions without connected plugs of the BeamMonitor50 HQ 50 mm are: 182 x 139 x 68 mm

9.1.2 Weight

The total weight of the device is 1500 g

9.1.3 Measuring Range

BeamMonitor50 HQ

Measurable Power range	up to 10 kW
The maximum power density	< 10 kW/cm ²
Clear aperture (CA)	50 mm
Maximum beam diameter to be measured:	35 mm (depending on M ²)

9.1.4 Power Supply

The operating voltage of all devices connected to the PRIMES-Bus is DC 24V \pm 5%.
 Input current for the BeamMonitor50 HQ is 0.7 A - maximum.
 Stand by current for the BeamMonitor50 HQ is 120 mA
 The external power supply has an input voltage range from 90 -264 V/AC 47 - 63 Hz.
 PRIMES measurement devices should be driven by PRIMES power supplies only.

9.1.5 PRIMES-Bus - Assignment of the pins

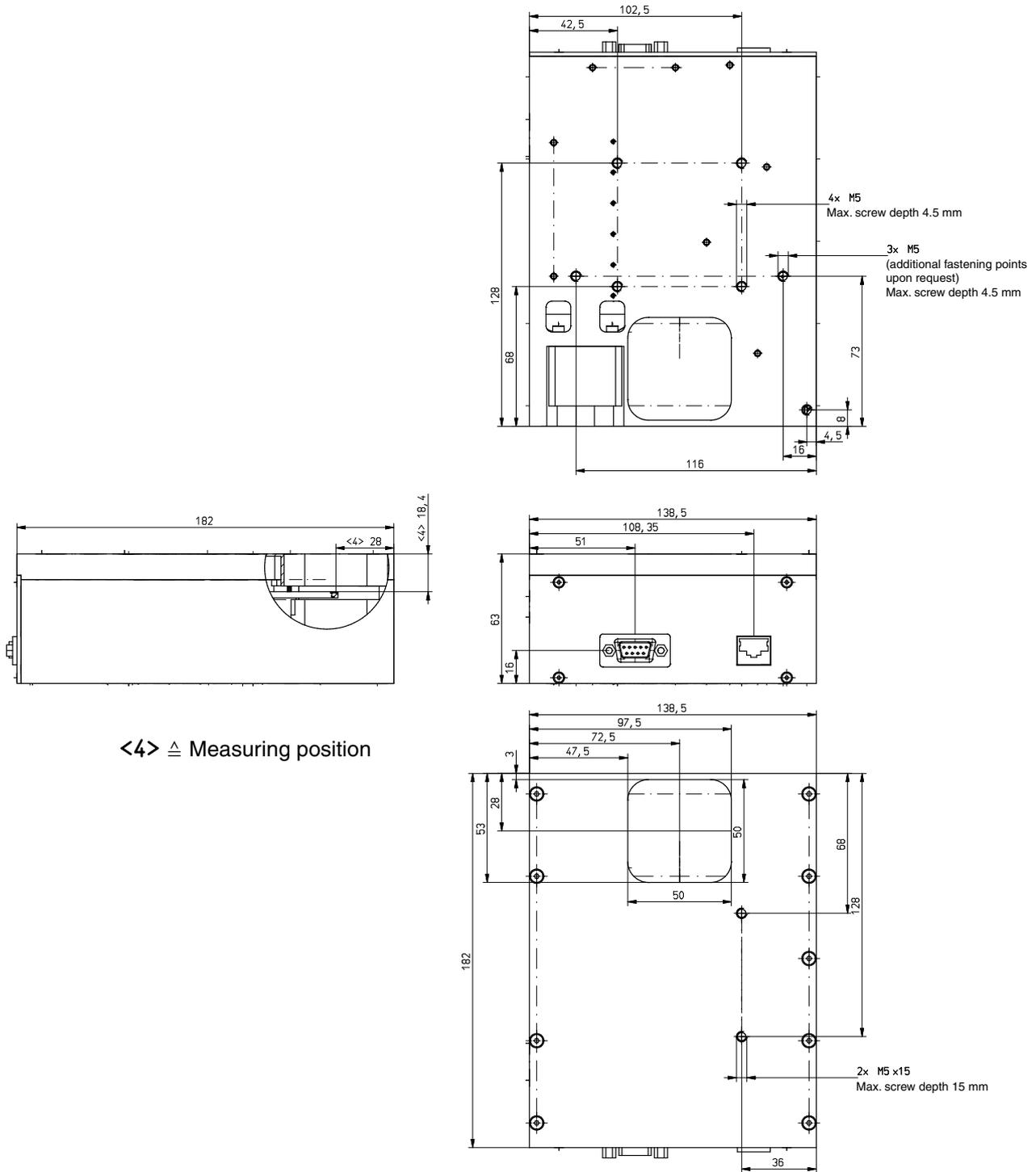
Function	Pin-number	Function	Pin-number
Ground	1 and 6	Trigger RS 485 +	4
Data RS 485 +	2	Trigger RS 485 -	9
Data RS 485 -	7	not assigned	5
DC 24V	3 and 8		

9.1.6 Trigger output - optional

A trigger signal (5V TTL-level) for laser control can be generated by the BeamMonitor50 HQ. It is also possible to use an external trigger unit.

Thus, it is possible to synchronize the laser pulses to the motion of the measuring rotor. An integrated delay unit is also available by option.

9.1.7 Dimensions BeamMonitor50 HQ



9.2 Laserds.ini - an example

The file laserds.ini, located typically in the folder Program/PRIMES, contains the default settings for the communication port and the window position.

```
[Version]
no=7

[Window]
left=-4
top=-4
right=1156
bottom=840

[Comm]
Port=com2
HighBaudrate=1
Rescan=161,144,145,192,112,113

[Address]
Own=64

[Private]
Mode=0

[File]
Default=

[Laser]
Wavelength=0.01060000
Drehzahlnr=0.00000000
Laserleistung=20000.00000000
Brennweite=127.00000000
StrahlsucheTrigger=210
StrahlsucheProzent=30
Funkvorhanden=0
Detektortyp=0
SperrbereichY0=8.00000000
...
SperrbereichZ2=30.00000000
Autoscaleon=0

[Interface]
Startup=0

[Output]
Out0=Port 0
...
Out15=Port 15

[Input]
In0=Port 0
...
In15=Port 15

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

[Service]
Firmenadresse=
Servicetechniker=

[Detectorparameter]
```

If any changes are to be made in the laserds.ini, all programs of the LaserdiagnosticSoftware must first be stopped. Otherwise the new settings can not be assigned for the next program start-up.

- default setting for the serial-port, which is taken from the laserds

- default setting for the wavelength in the calculations

9.3 Interface Devices

9.3.1 PRIMES-Converter

The data communication on the PRIMES-Bus is based on the RS 485 standard. To connect the bus to a serial RS 232-Interface of a Personal Computer a converter is necessary. Additionally the PRIMES-Converter separates the 24 V power-lines of the PRIMES-Bus from the PC.

The PRIMES-Converter has four LEDs to give information about the current bus-state. They have the following significance (from left to right):

red	bus power
green	data on bus
red	PC-sent data on the bus
yellow	trigger signal (only for service use)

9.4 PRIMES PLC - interface

PRIMES offers a standard PLC-interface to be addressed directly via the PRIMES-Bus to integrate the measurement procedure into the production process. This means that a measurement can be external triggered by most of the standard NC controllers.

9.5 Description of the MDF File Format

The MDF file format is a simple ASCII format that contains the most important data of a beam measurement - the spatial power density distribution (PDD). MDF is for 'mailable data format'.

With this unified data format, conversion problems between different analysis software can be reduced so that safer data transmission, for instance by e-mail, is ensured.

The structure of the data is:

1. Line : MDF100 (file identifier)
2. Line : Number of pixels: in x-direction in y-direction
3. Line : Size of the measuring range: dimension in x (mm) dimension in y (mm)
4. Line : Position along the axis of beam propagation: z-position (mm)
5. Line : Transverse position of the center of the measuring range: x-pos y-pos (mm)
6. Line : Amplification of the signal: Amplification (dB)
7. Line : Number of averages: number
8. Line : Offset - value display from the device: Offset - value

In the following lines you find the data: Data
There are at most 80 characters per Line.

Comments:

Lines beginning with a semicolon are treated as comment. Comments can also be added in the lines after the main data

Example:

```
MDF100
;This is an example.
;These lines are comment.
64 64
2 2
11
...
...

1
10
10 10 10 10 10 10 10 10 10
11 12 13 14 15 16 17 18 19 20
20 20 20 20 20 18 16 14 12 10
```

10. Appendix II - Running LineScan (option)

The LineScan feature allows measurements of the laser beam as a function of time. It records a single trace of the power density distribution with a repetition rate of slightly above 30 Hz.

Mechanically, the y-axis of the BeamMonitor50 HQ moves to a steady position and there, it measures a single trace of the beam profile with each rotation of the measurement tip. The data is transferred to the PC via Ethernet. Here, the software offers various analysis tools.

Typically, the user will start by taking a complete 2-dimensional scan of the beam. After this has been done, the user has to switch into the LineScan mode in the combobox **Measuring mode**. The software will show the position of the single trace indicated by a blue line. If necessary, the position of the trace can be modified using a cursor (black triangle to the right of the blue line).

The width of this trace is always the maximum window width of the BeamMonitor50 HQ. The software automatically selects a new measuring file (e.g. 'Unnamed 1') to ensure that no other data is overwritten.

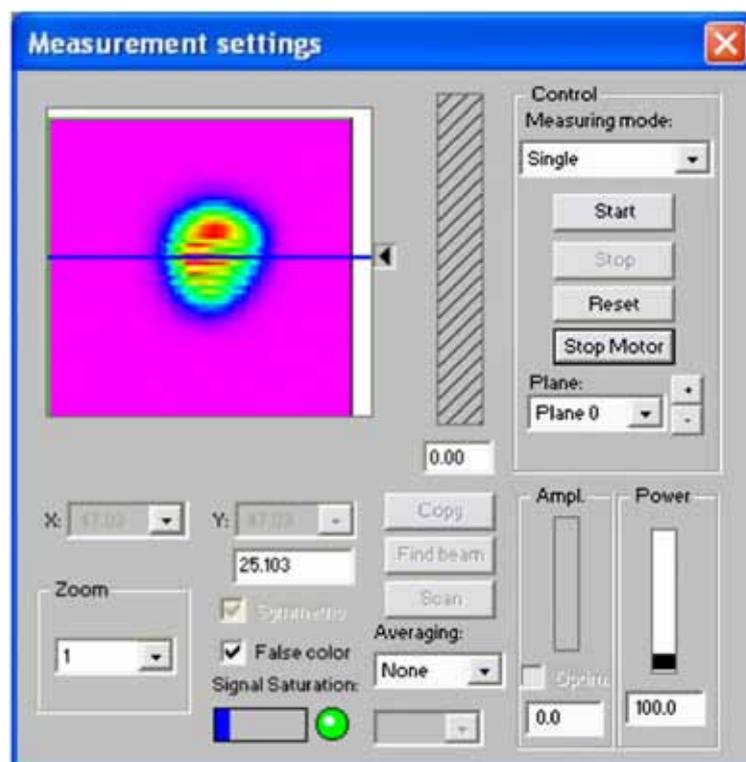


Fig 10.1: determining the trace position for a LineScan measurement.
Use the cursor (black triangle) to move the blue line.

After a trace position has been selected, you will be prompted for the repetition rate and the duration of the measurement. A typical setting to observe for example the switch-on process of a laser could be max. frequency (roughly 33Hz) and 10s time.

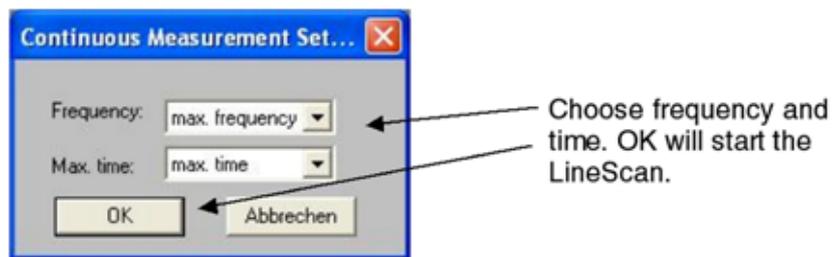


Fig 10.2: menu for repetition rate and measuring time.

The measurement can be stopped any time by pressing the **Cancel (Abbrechen)** button. The transfer of the data from the BeamMonitor50 HQ to the PC is indicated by the small window on the right-hand-side on the bottom of the screen. It can reach the 100% indicator several times – the LineScan data also is arranged in measurement planes, and each time one plane is filled, the indicator shows 100%.

Depending on the speed and workload of the PC, it can happen that a small amount of traces is dropped because the computer is busy while the data is sent from the BeamMonitor50 HQ to the computer. Typically, this is less than 1% and can be ignored. We recommend using CPUs with more than 1 GHz and not running other processes in parallel while measuring at maximum repetition rate.

After a measurement is completed, the data should be saved (menu 'File/Save As').

To display and analyze the collected data, the **Presentation/Continuous View** window is used. While the left side shows a diagram of the variation of the selected beam parameter over time, the right side shows the shape of the trace along the power density at the current cursor position in time (black triangle). There is a table of different beam parameters underneath. The scroll-bar in the center can be used to move through large data files.

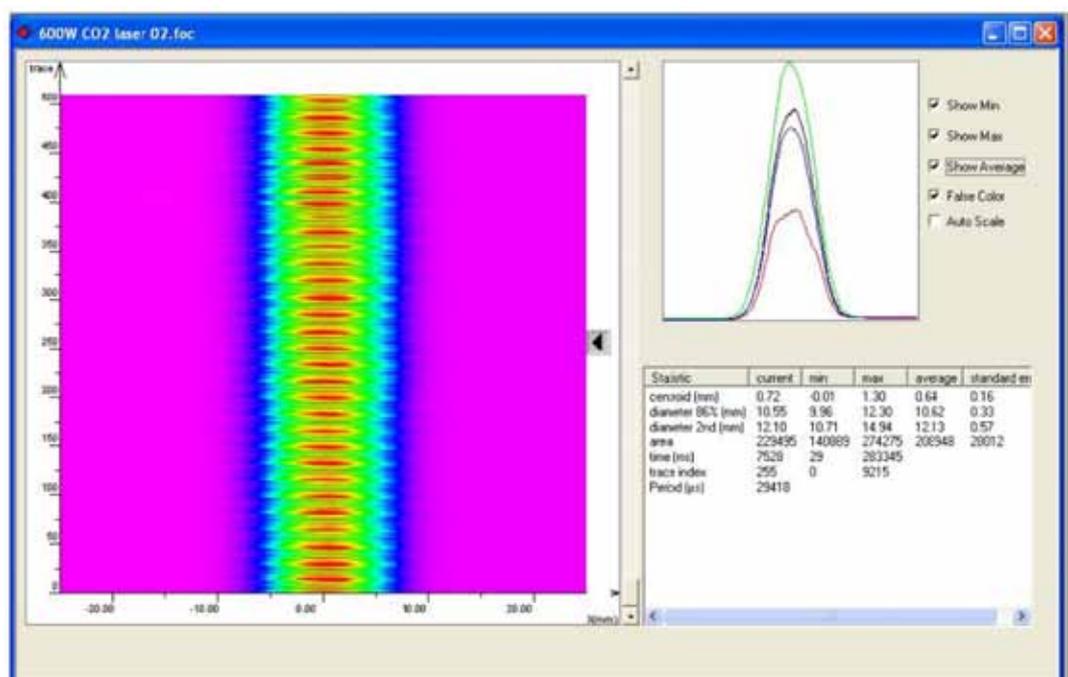


Fig 10.3: Beam parameters as a function of time visualized with the 'Presentation/Continuous View' window.

The diagram on the left side shows a false color representation of the power density of a trace through the beam as a function of the trace number (or time). Red areas in the centre mark traces where maximum power density occurred.

Clearly, the pulse width modulation of the laser can be seen, and traces with high power density are periodically followed by traces with lower power density (3,5kW laser operated at 600W).

The cursor can be moved, and the corresponding trace is shown on the top right hand side. Click on **Show Min**, **Show Max** and **Show Average** to get an idea of the current power density values compared to the min/max/average values of all traces.

To statistically determine the alterations that happen from trace to trace in one measurement, the table on the bottom shows not only the min/max/average value, but also the standard deviations (standard error) for the different parameters.

To display the beam position (centroid), the diameter (86% or 2nd moment) or the area under the curve as a function of time, just click on the desired value on the table and the diagram on the left hand side will show the corresponding graph. Click on **Auto Scale** to change the scaling of the graph.

To see the false color representation of the power density again, click on 'False Color'.

The area under the curve can be a rough approximation for the total beam power. This way, a fast power measurement is possible. When analyzing this data, please keep in mind that the area under the curve can also be affected when the overall power density distribution is changed in the 2D beam profile.

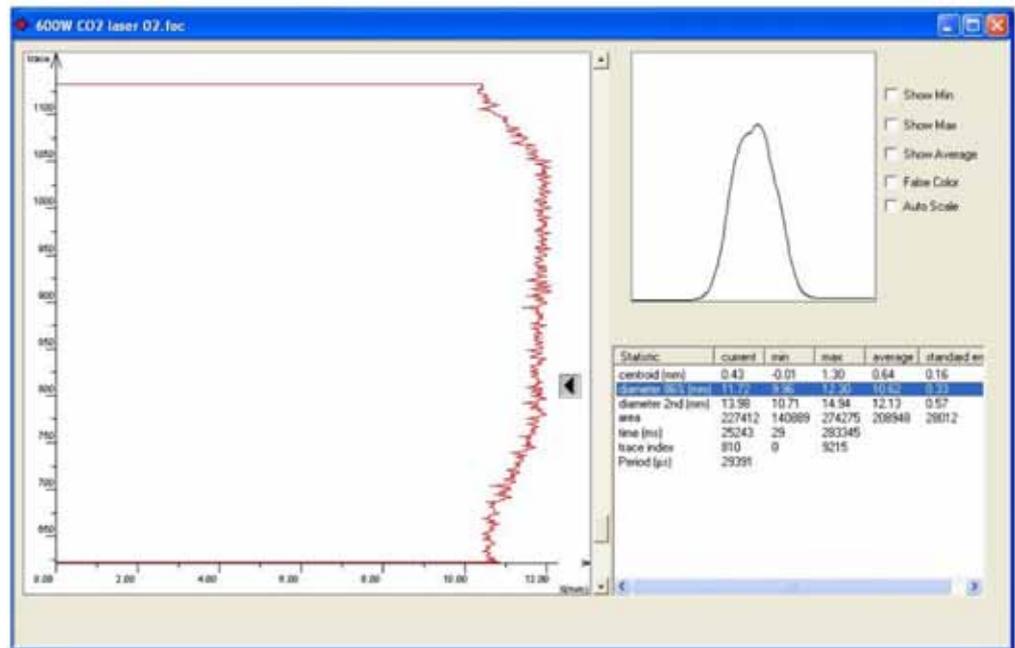


Fig 10.4: A Click on the parameter in the table will display the corresponding graph.

Please note that the 86% values are determined from just one line and may differ noticeably from the values that are determined from a 2D measurement, as a different algorithm is used (for single trace calculations, 6.7% of the area under the curve are cut off from both sides, and the remaining length determines the 86% diameter).

The 2nd moment diameters compare much better to the 2D measurements.

Example

The following LineScan measurement shows the switch-on process of a CO₂-laser with traces of organic solvent vapors in the beam path. Blooming occurs.

Within less than a second, the sharp peak broadens and loses its peak intensity.

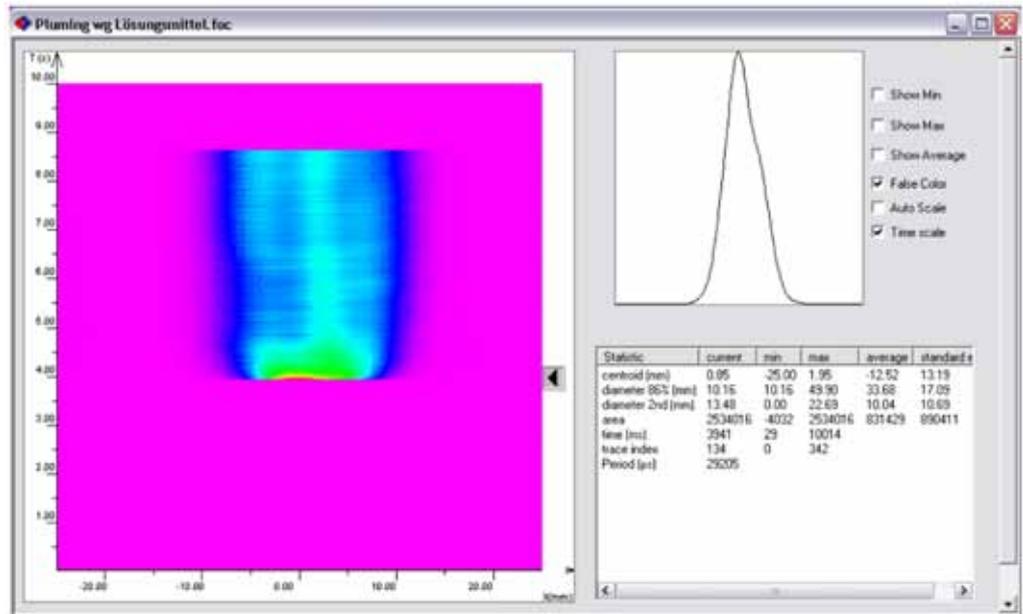


Fig 10.5: Blooming. Power density distribution right at the start of the laser...

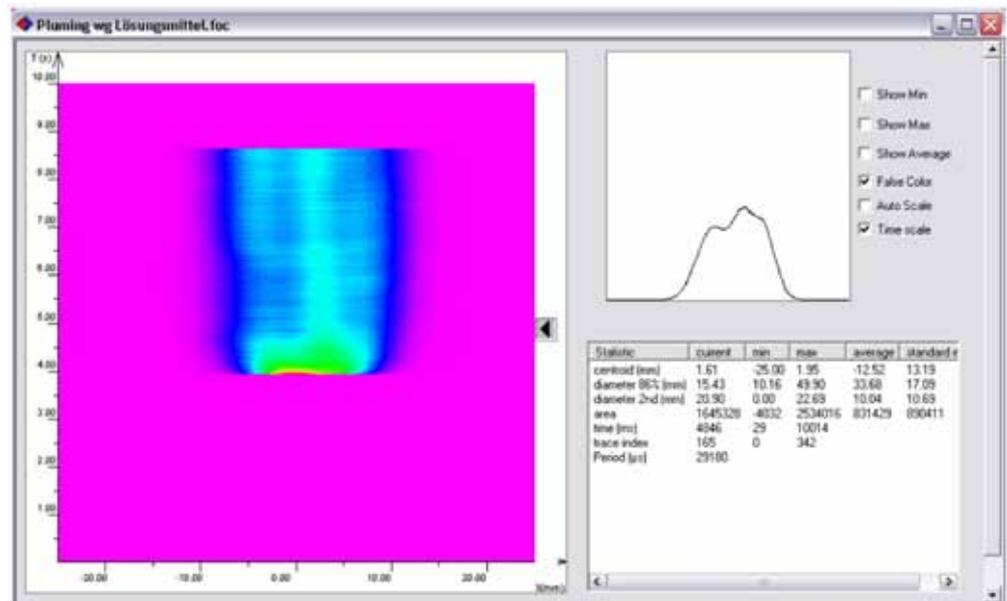


Fig 10.6: ...and 0.9 seconds later.