NanoFocus®

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Operating Manual

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System Description

General

The NanoFocus® µSurf® measurement principle is based on the white light confocal technique and is specially designed for quality control of technical surfaces as a completely independent 3D video measurement system.

It consists of a compact confocal measurement head which is mounted on a stable stand and is motor-driven in the vertical direction (z-axis). The sample is placed on a computer controlled x-y precision slide.

system arrangement

For non-contact measurement of surface topography, the sample is positioned by the precision slide and the confocal unit is moved stepwise in the z-direction.

NanoFocus® µSurf® confocal microscope is automated, using software working under Microsoft® Windows2000/XP®. The surface topography data can be graphically presented and analysed in various ways.

NanoFocus® µSurf® confocal microscope offers the unique possibility to precisely measure optically complex surface structures with high vertical and lateral resolution. The number of optical artefacts is minimised. The measurement results and comparisons using surface roughness standards of the “Physikalisch Technische Bundesanstalt” (PTB, German national authority for calibration) show an unique correspondence with the tactile

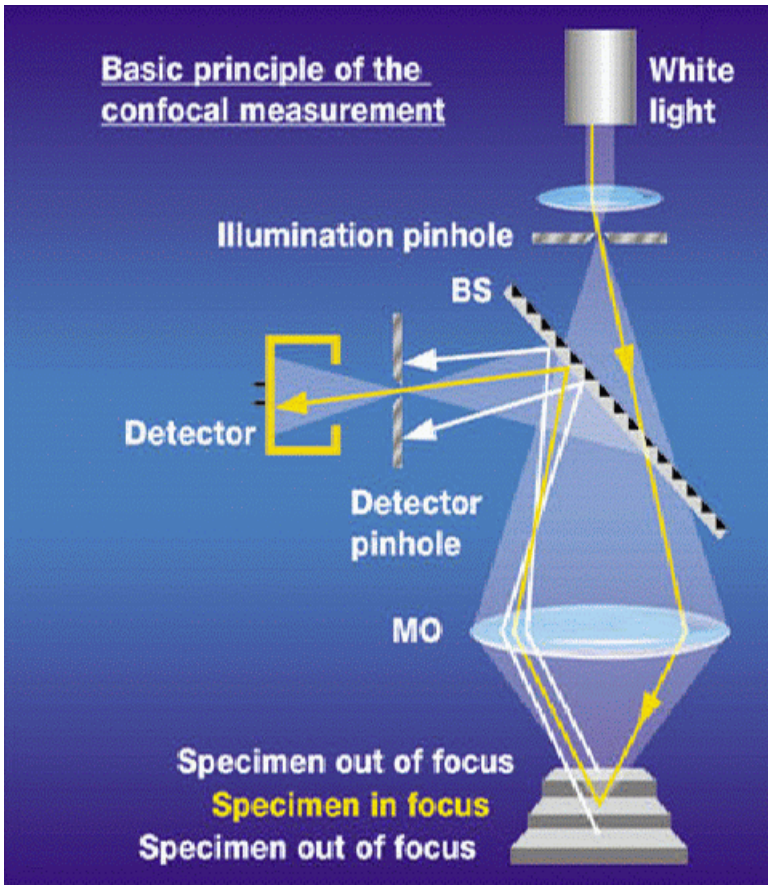
instruments. NanoFocus® µSurf® enables fast, careful and non-contact characterisation, which is most important for sensitive surfaces.

Large samples can automatically be measured by stitching basic fields.

Measurement Procedure

Measurement principle

The measured value is obtained using a confocal white light optical microscope. For this, either the whole sensing head moves vertically on a linear table or only the objective moves in the vertical direction (z-axis) by means of a piezo drive. The unit scans a batch of various height levels of the surface to be measured (topography). As whole areas are usually measured, the sample is not moved laterally during a measurement. The size of the measurement area depends on the applied objective. For detailed information see 'Physical Parameters', p. 56.



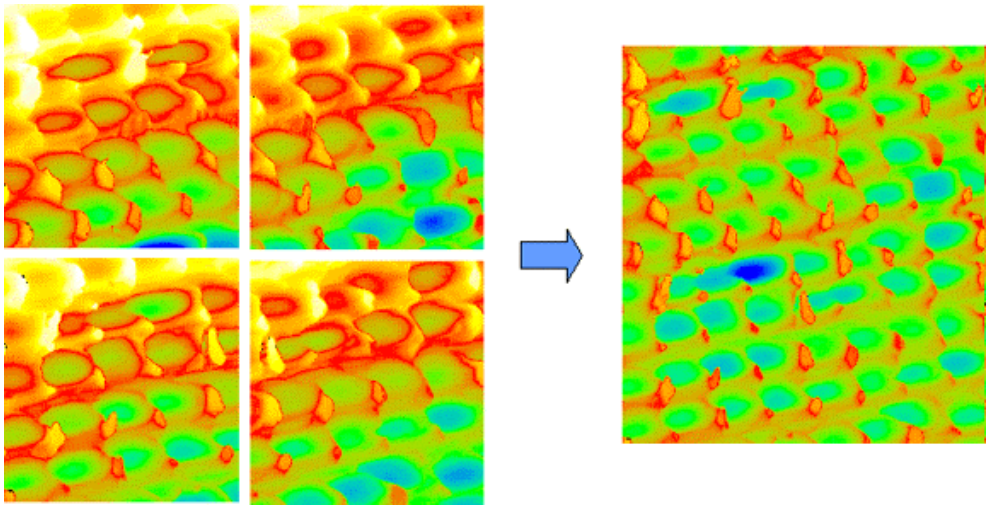
Principle of confocal spot sensor

The surface to be measured is illuminated through the microscope by an external xenon light source. Only those light beams which are focused on the detector (CCD chip) reach it. All unfocused light beams; i.e. all which are not at the same height are disabled by a pinhole. In such a way, a single point can be measured.

The pinhole of the µSurf® measurement head consists of a rotating Nipkow disk with approximately 120 000 pinholes. Surface areas which are at the same height level are mapped on the CCD chip. These height level records can then be joined to form a 2 or 3 dimensional image.

Stitching

In order to investigate larger measurement areas, it is possible to stitch. Stitching means lining up adjacent base fields in x and y directions. Using the microscope, some complete individual measurements are carried out. The sample is moved by a computer-controlled x/y measurement table. During stitching, the measurement values of adjacent borders are compared, mathematically overlapped and combined to form a larger measurement area.



stitching

Measurement set-up

Basically, the measurement set-up consists of a confocal measuring head which is moved in the z-direction by a linear step drive positioner (positioning range: 100 mm). Additionally a piezo drive, which only moves the objective, can move over a stroke of 350 µm (standard version). Both drives can be used for measuring. The piezo has a higher velocity and the best possible resolution.

The sample is positioned by an x/y stage. This is carried out by joystick control. The base of the system is a solid granite stone slab for damping oscillations.

The required white light is generated in an external xenon light source, and transmitted by a fibre light guide to the measuring head.

The motion control and the recording of measurement data is handled by the controller unit and the PC.

Typical performance of a measurement

The first step is to select the most suitable objective. The objective determines e.g. the available size of the measurement area, the distance between objective and surface (working distance), the lateral and vertical resolution as well as the performance on sloping surfaces (see 'Physical

Parameters', p. 56).

The measurement object is aligned on the plane table below the selected objective. In standard microscope mode (see ‘Doing a measurement’, p. 17) the focus plane, i.e. a sharp picture of the sample surface, should be found by moving the measuring head up and down by means of the joystick. Then switch over to confocal mode, i.e. click the appropriate button in the software. The Nipkow disk is now situated in the light path. Look for the brightest area while moving through the confocal levels and adjust the lighting. Then search for the upper and lower limits of the measurement range and enter these data. As desired, enter some further measurement parameters and start the measurement.

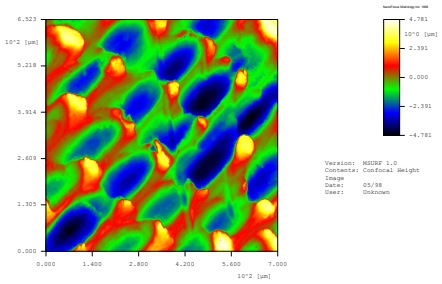
The software now controls the further course of measurement. A number of up to 1000 pictures are recorded by the frame grabber and stored in the computer for further processing.

Output of measurement values

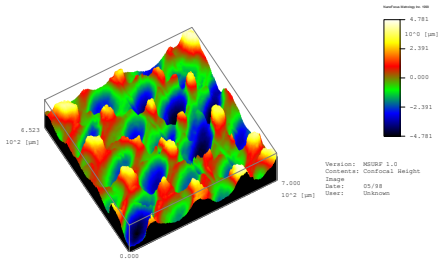
Topography data can be displayed as coloured graphics in 2D- or 3D-view. Also any profile sections can be output to screen or printer. In addition, you have data access by the clipboard or by several public file formats.

Surface parameters like profile geometry, roughness, waviness etc. can be calculated and displayed. Details can be found in the paragraph 'Software', p. 28.

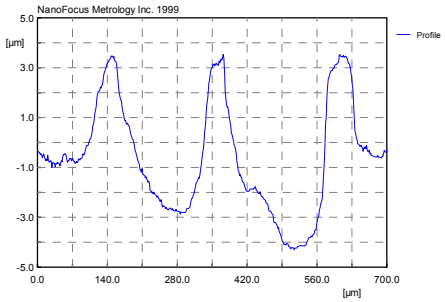
For particular evaluation purposes, further software is available.



2D-view



3D-view



profile view

System components

Versions

The standard configuration of the system contains a sample stage sized 100x100 mm^2 with electric drive and a motion range of 50x50 mm^2.

The sample stage and also the vertical linear axis with the measurement head are mounted onto a solid granite stone L-holder. A base plate with a gantry is available as special version.

There is a choice of 7 objectives in all. The following table gives an overview over their different properties.

Microscope objective *	1600-S	800-S 800-L	320-S 320-L	160-S 160-L
Measurement field [µm] × [µm]	1600 x 1544	800 x 772	320 x 309	160 x 154
Maximum area in stitching mode [mm^2]	187,3	46,8	7,5	1,9
Working distance [mm]	10,1	3,1 12,0	0,66 10,6	0,31 3,4
Numeric aperture	0,30	0,46 0,40	0,80 0,50	0,95 0,80
Maximum surface slope for specular reflection [°]	8,7	13,7 11,7	26,6 15,0	35,9 26,6
Vertical measurement range [µm]	<1000	<400	<100	<80
Vertical resolution** [nm]	20	5 6	2 4	1,5 2

* xxx-S = standard type, xxx-L = long working distance
**piezo driven measurement

System set-up

Functionality:

The measuring system is mounted onto an L-holder or a gantry station. Both versions are manufactured from granite and provide a stable, perpendicular and vibration-free set-up. The set-up stands on vibration damping feet.

Sensor

Functionality:

The sensor is completely computer controlled.

It contains the confocal white light microscope with the objective and piezo drive at the bottom. The CCD camera is mounted on top. Next to the CCD camera there is an inlet for the fibre guide from the light source.

The microscope can be used in standard microscope mode and in confocal mode. The standard mode is suitable for looking at the surface and finding the focus. The confocal mode must be selected for the measuring process.

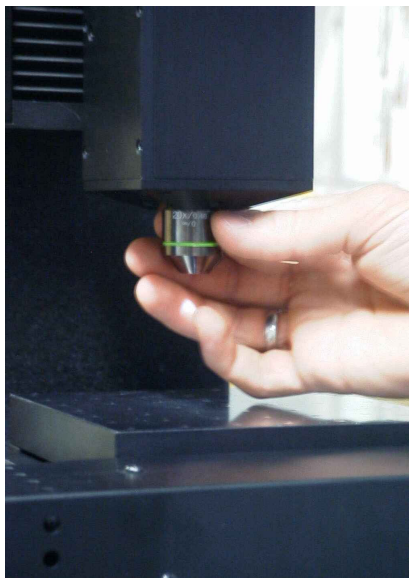
Inside the casing there is an adjusting device for sensitive adjustment of the illumination intensity.

For normal high accuracy and high speed measurement with less than 350 µm vertical range the sensor head remains stationary, and only the objective is moved by the piezo drive. The piezo drive is particularly preferable for measurements with a 320- or 160-objective as opposed to the stepping motor.

If a vertical range greater than 350 µm is needed, the stepping motor can drive the whole sensor vertically for measuring.

Changing the objective is done by manually screwing out the fitted objective and screwing in another one.

µSurf® sensor head



Objective change

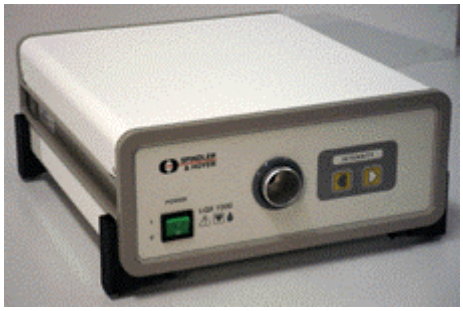
Connections:

- light guide
- camera
- µSurf® plug

Light source

Functionality:

A xenon cold light source in its own casing is used to illuminate the sample. Light intensity can be preset at the box. Light is guided through an optical fibre into the sensor.



Light source

Operating elements at front:

- power switch
- Touch controls: intensity
- Connection: light guide

Operating elements at back:

- Connection: mains supply (230V / 50Hz) or (115V / 60Hz)

Keep the unit running for at least 30 minutes, because shorter periods can significantly reduce the life expectancy of the special xenon lamp.

For more information e.g. for replacement of the lamp, see the attached manual for the xenon cold-light source. Wear goggles for eye protection!

µSurf® controller

Functionality:

The controller contains control electronics and power supply for the sensor: 3-axes control for x/y and z-axes, control for the piezo actuator and for the Nipkow disk drive.

Control elements at front:

- toggle switch for joystick: automatic mode (controlled by software) or manual mode (joystick)

Control elements at back:

- power switch with fuse.

Connections:

- Mains (230V / 50Hz or 115V / 60Hz)
- Motor X
- Motor Y
- Motor Z
- Joystick
- µSurf® => sensor
- Video sync. => sensor
- external sync. n.c.
- Com1 => PC Com1
- Com2 => PC Com2
- PC DAC n.c.

Front view of system computer and µSurf® controller unit

System computer

Functionality:

The system computer and the µSurf® controller unit jointly comprise the hardware part of the system control.

The system computer is based on an IBM compatible personal computer of the state of the art at the time of delivery. Part of the equipment is also an image processing card (frame grabber).

Input devices are keyboard, mouse and joystick. Output devices are monitor, network connection, CD-writer and printer (optional).

More information about the system computer can be found in the attached operating manual.

Joystick

Functionality:

The joystick serves to control the two motor driven axes of the sample stage (x- and y-axis) and the vertical sensor axis (z-axis). Tilting the joystick moves the stage forward, backward or sideways. Turning the joystick clockwise moves the measuring head upward. Turning it anticlockwise moves it downward.

Using the'joystick' toggle switch on the front of the *µ*Surf® controller unit, the operating mode can be set. The default setting is “automatic”. The axes can be moved independent of the software control in “manual” mode, but exclusively for service purposes.

joystick

Software µSurf® and Dongle

Functionality:

The software µSurf® serves both for the control of the measurement process and the basic evaluation of measurement results. As delivered, the software is prepared for use. For security, a CD with the entire software is included.

The program only runs if the dongle, which is used as software protection, is plugged in. Dependent on type the dongle is either plugged into the USB port or into the parallel interface of the computer. In the latter case the printer cable is to be connected to the dongle.

Installation

Delivery

Standard system

The standard configuration of the NanoFocus® µSurf® white light confocal microscope consists of:

- working table with integrated control cabinet
- measuring platform of solid granite
- µSurf® sensor unit
- microscope objective
- xenon cold light source
- z-axis linear drive with step drive and brake, adjustable distance 100 mm
- sample stage 100x100 mm^2 with electric drive, operating range 50x50 mm^2
- 3 axes joystick
- protective cover
- system computer with monitor, keyboard, mouse, network connection, CD-writer, preinstalled Windows2000/XP® and on CD, preinstalled software µSurf® and on CD
- µSurf® controller unit
- copy protection plug (dongle)
- numerous connection cables
- this operating manual
- operating manuals of the built-in components

Additional options

To complement or alter the standard system configuration following accessories are available:

- numerous microscope objectives (see ‘Versions’, p.8)
- calibration standards for lateral and vertical dimensions
- sample stage 210x260 mm^2 with electric drive, operating range 100x100 mm^2
- printer
- software for particular evaluation purposes
- software interfaces for automated measurements

Set-up Environment

Environmental conditions

The system does not require a specific measurement room. Nevertheless, vibration and low-frequency production resonance (e.g. heavy press or punching machines etc.) could affect the measurement and reduce the accuracy. Apart from that, normal operational conditions for electronic devices will suffice.

Avoid:

- oscillations and vibrations
- ambient temperatures above 40°C and below 10°C; fast temperature changes
- humidity above 85%, water splashes
- corrosive or explosive vapours or gases
- extreme electromagnetic fields
- intensive electromagnetic discharges
- direct sun light
- measurement of living objects
- The measuring system is not designed for outside use.

Space requirement

For setting-up the system a surface area of 1,60 x 0,80 m^2 excluding the printer is required. For maintenance, access to the back is recommended.

Installing and setting up the system

By reason of safety and proper function the measurement system must be installed or de-installed only by NanoFocus staff or appropriately trained personnel.

If disconnecting a plug or cable is necessary, be sure that all devices and also the master control is switched off.

Cable connections and plugs can be misplaced, so pay attention to the labelling! Never press a plug into a socket by force!

Always secure any connection by correct attachment of the screws or by turning the plug in its housing!

Do not switch on devices unless all connections are made and screwed on.

Starting Up

Switching on the system

Before first start-up, make sure that all cables are connected and screwed in and also remove the transportation lock of the linear tables if necessary.

To switch on the units follow this sequence. Start with the light source, if it is plugged in separately. Wait until the light source is completely ignited. Afterwards you can push the main switch at the top of the front panel.

In standard configuration the computer boots automatically after power is on. In alternative configurations it must be switched on manually with the “POWER”-switch behind the front panel of the computer.

As delivered, the Windows2000/XP® user name for login is “Administrator”. There is no password defined.

Initialising the drives

After logging in to the Windows2000/XP® operating system, the µSurf® software can be started.

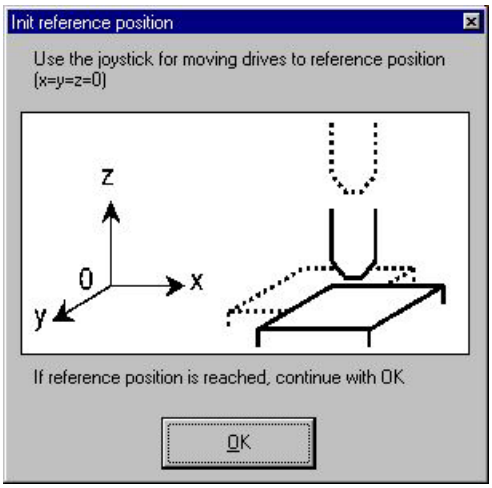
Be sure the ‘joystick’ switch at the front side of the *µ*Surf® controller unit is switched to “automatic” mode!

Then just double-click the µSurf® symbol on the desktop.

A request for initialising the reference position of the drives will appear. The reference position is the home position of the sample stage (x- and y-axis) and the linear axis of the sensor (z-axis). The coordinates of the home position are x = y = z = 0.

If the master control has just been switched on, this request should always be answered with “Yes”.

Next the window for setting the home position is displayed. In this state the joystick is activated and it is possible to move the x-, y- and z-axis to the home position.



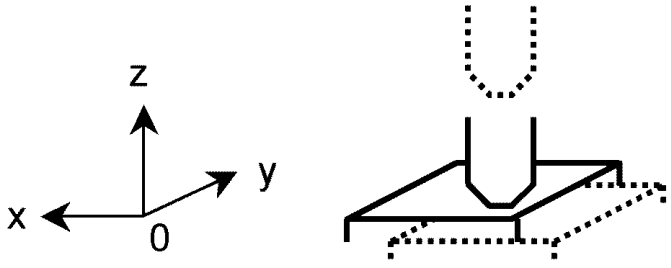
Setting home position for a x/y-table 100 x 100 mm

Initial state of the xy-stage

The motion areas differ (50x50 mm^2 or 100x100 mm^2), according to the different sizes of the available stage versions. Because of their varying x- and y-directions there are also several initial states of the tables.

- xy-stage of 100x100 mm^2 range should be driven to the right (x-axis) and the front (y-axis) up to the limit. In this position the objective is pointing at the back left corner of the stage.
- xy-stage of 50x50 mm^2 range should be driven to the left (x-axis) and the back (y-axis) up to the limit. In this position the objective is pointing at the front right corner of the stage.

The motion direction of the drives in the home position of the 100x100 mm^2 table is shown in the upper illustration. The orientation of the 50x50 mm^2 table is shown in the illustration below.



Setting the home position of a x/y-table 50 mm x 50 mm

Move the x- and y-drives to the limits. This is necessary in order to use the full length of the axes afterwards.

Initial state of the sensor axis (z-axis)

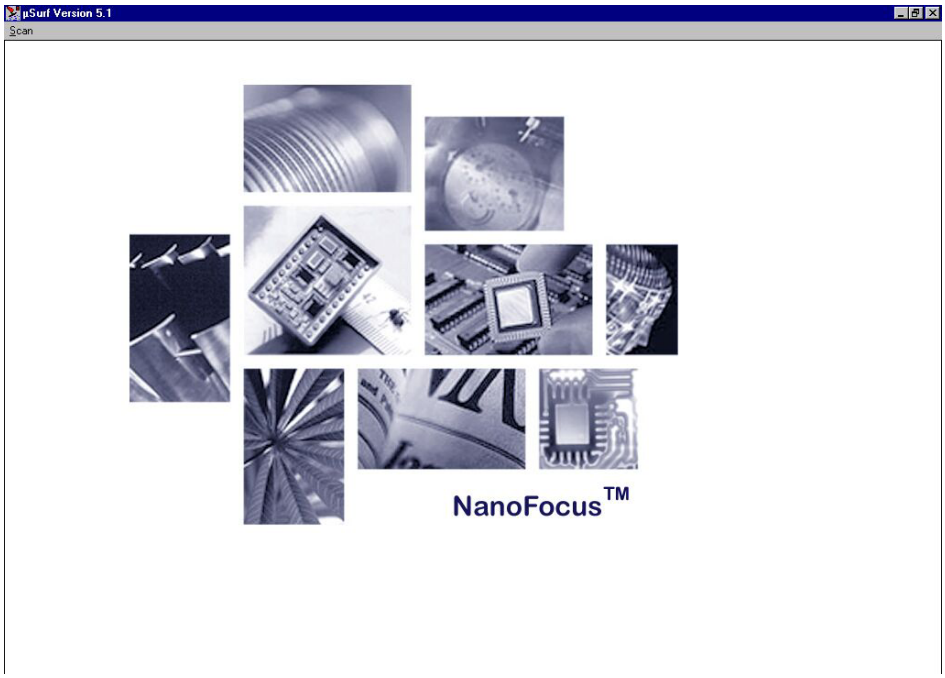
Although the vertical axis is also equipped with limit switches to limit the motion, the lowest position might be defined by the upper surface of the stage or the attached sample and the lower edge of the objective.

For this reason the z-axis has to be moved carefully downwards with the joystick. Stop movement at the latest when the focal plane corresponds with the stage or sample surface.

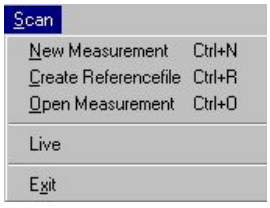
By setting the reference position a software stop is initialised, because the software doesn't accept negative coordinates. In case of an accurate setting of the reference position, an accidental collision of the objective and the x/y-stage can be prevented.

Doing a measurement

After drive initialisation the main window is displayed. At this state only menu item 'Scan' can be selected.



Start window



Menu 'Scan'

New Measurement

To take a new measurement, the control wizard will be started.

Create Reference file

To create a new reference file for a selected objective
(see 'Creating new reference files', p. 54)

Open Measurement
To open a measurement from archive for further processing.

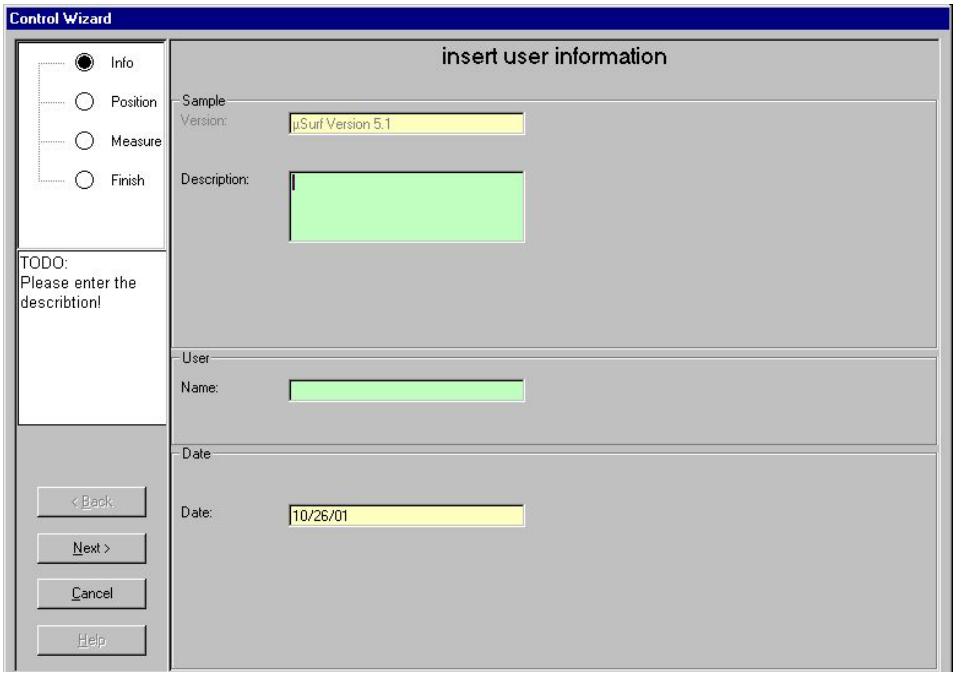
Live
Shows a live image of the CCD-camera (only available after at least one measurement has been taken in the current session).

Exit
To close the µSurf® program.

Control wizard – insert user information

After clicking 'New Measurement' the Control Wizard leads the user step by step through the required settings for a new measurement.

In the 'Info' frame detailed information about the measurement to be performed can be entered. This information will be saved in the measurement data file.



Control wizard

Confirming the entries with 'Next' leads you to the frame 'Position'.

Control wizard – set start and end position

At this state you can move the motor axis!

In the second frame 'Position' of four frames in all, the joystick is activated (see 'Joystick', p. 12) and also a live picture of the camera is displayed. In this state the start and end positions of the measurement are set, and the illumination is adjusted.

- Selecting objective and mounting specimen

Before attaching the specimen to the stage, move the stage roughly to centre position and the sensor head upward, if necessary, by twisting the joystick clockwise. Also select a suitable objective (see p. 56, 'Physical Parameters').

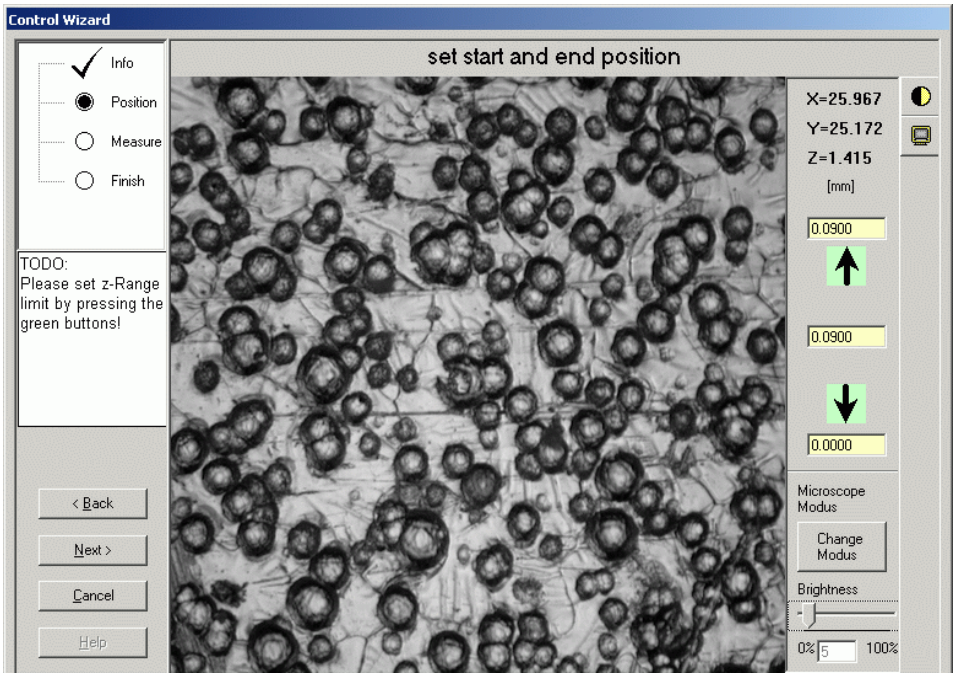
- Finding the focus plane

Set the sensor to standard microscope mode by clicking the button ‘Change modus’. Then adjust the brightness, first with the touch controls of the light source, then tune it with the slider control ‘brightness’ (or arrow keys ← and →) until you see some red coloured pixels on the screen. The red pixels indicate that the camera is fully modulated. This action facilitates the search for the correct working distance.

Twisting the joystick clockwise ➔ upward motion

Now, try to focus the surface to be measured by moving the vertical drive. If the red area increases, you are approaching the focus plane. Otherwise you should change direction. Reduce brightness and approach the focus plane by turns, until you can see the surface of the sample clearly.

Take care not to touch the sample with the objective. Move the sensor head slowly!



Control wizard: surface of specimen in standard microscope mode

- Setting the measuring field

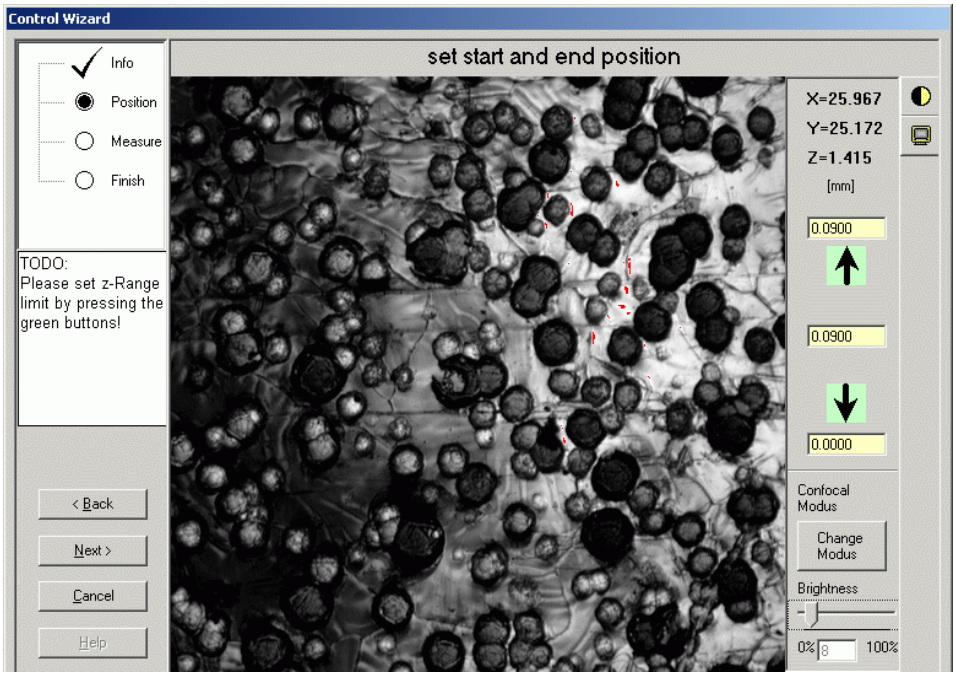
With a sharp image of the sample surface the exact measurement location can be found by moving the x-y-table with the joystick. Small readjustments of the z-axis may be necessary to maintain a sharp picture.

The stitching feature allows the user to measure areas larger then the measuring field of the used objective. Up to 100 pictures can be stitched together as described in paragraph ‘Stitching’, p. 24.

- Switching over to confocal mode

Switch over to confocal mode by clicking the ‘Change modus’ button. Now a height section of the sample topography is displayed. If you only see an almost black screen, the surface hasn’t been focused sufficiently precisely in standard mode.

Search for the height section with the best contrast in vertical range by twisting the joystick with care. As long as a part of the picture is sharply present in the measuring field, the sensor head still moves within the measuring range. Where necessary readjust the light intensity close to the point of overdriving the CCD-camera. A few red pixels won’t disturb the measurement. The CCD-camera shouldn’t be overdriven across the complete measuring range.

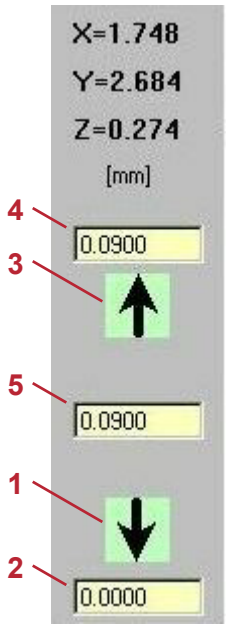


Control Wizard: Surface of Specimen in Confocal Mode

- Setting the vertical measuring range by joystick and mouse

Search the lower limit of the measuring range by twisting the joystick to the left. When there’s no longer any height section present in the measuring field, the lower limit of the measuring range is reached.

Ensure the objective doesn’t touch the sample!



Set the lower limit by clicking button **1** (arrow pointing down). The height value of the z-axis is transferred automatically to frame **2**.

The upper limit can be set in a similar manner by twisting the joystick clockwise and clicking button **3** (arrow pointing up). Then the z-value of the upper limit is displayed in frame **4** and frame **5** contains the vertical range

- Setting the vertical measuring range by keyboard

As an alternative, it is possible to insert the height values with the keyboard in the yellow frames. The inserted values must correspond with the actual z-coordinates in millimetres. Start with editing the lower limit in field **2**.

In order to provide an accidental collision with the sample or the stage, the inserted value of the lower limit can't be less then 0.2 mm underneath the actual position of the z-axis. If it is, an error message is displayed. Check the position of the z-axis and the inserted value.

Subsequently the upper limit has to be set. Either fill in the absolute z-position directly into field **4** or fill in the range into field **5**. In the latter case the upper limit value will be calculated automatically.

This procedure is particularly useful when you already have an idea of the vertical structure of the sample.

- Combined joystick and keyboard setting of the measuring range

Furthermore you can combine the joystick and keyboard setting method. Move to the lower limit by using the joystick an click the button **1**. Afterwards fill in the stroke into field **5**.

- Tips

For repeating a measurement the saved data of the preceding measurement can be reused. It isn't necessary to reinsert the values of the measuring range.

For stitching (see 'Stitching', p. 24) the measuring range must include all height sections of the full stitching area.

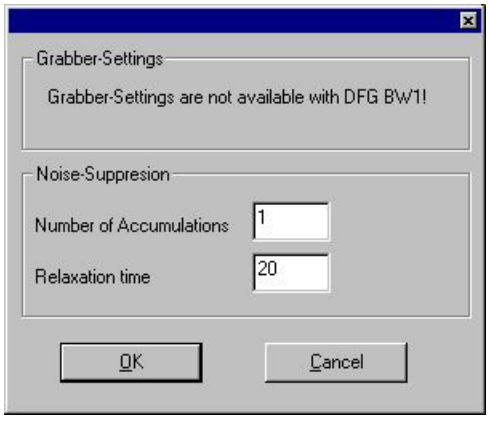
- Compatibility with old hardware versions

Refresh 

Older frame grabber versions had to be reset manually after being overdriven by too high intensity. To keep compatibility with older hardware, the current software version still contains the 'Refresh' button and also the 'Contrast' button. The 'Refresh' button has no function with current hardware.

Contrast 

Clicking the 'Contrast' button opens a form for grabber settings and for noise suppression. With up-to-date hardware the grabber settings (contrast) are deactivated as well.



Although making any changes for noise suppression is not recommended, in the relevant frame the number of accumulations and the relaxation time can be set.

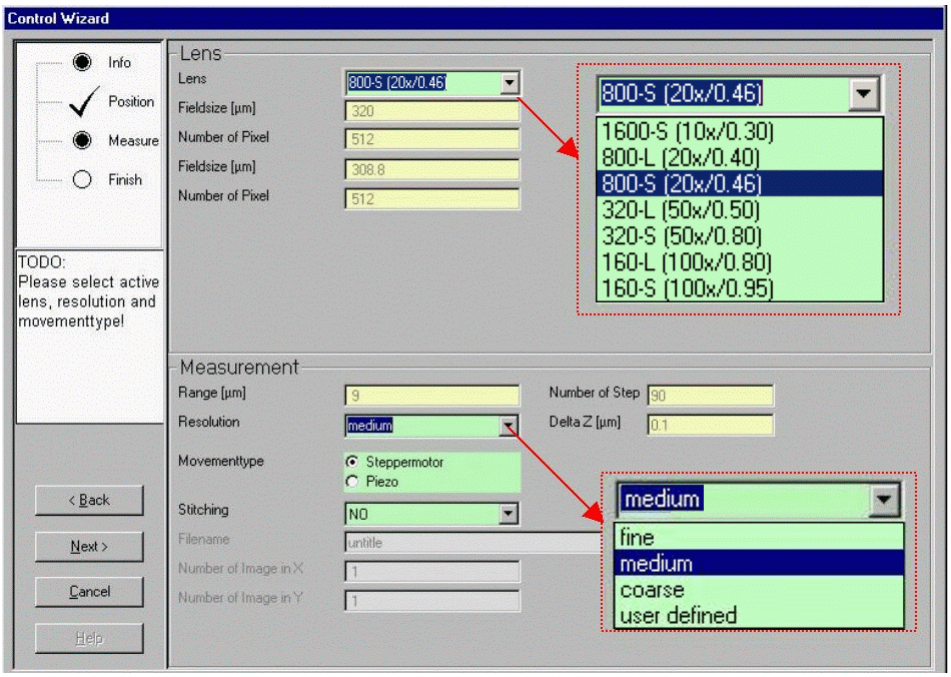
The number of accumulations is the number of images for every single height measurement of which a mean value is calculated.

The relaxation time, entered in milliseconds, is the time the software waits after taking one picture and before taking the next picture.

The standard values are sufficient for most of the measurements. Changing the standard values usually increases the measuring time.

Control wizard - setting the measurement parameters

Clicking the 'Next' button opens the 'Measure' window as the next step in the control wizard.



Control wizard: Objectives and Measurement Parameters

- Selecting the objective

Select the microscope objective in the upper frame. The corresponding field sizes and pixel numbers are indicated.

- Set the vertical step size for measuring procedure

In the lower frame the vertical step size ('resolution') can be adjusted. The step size Delta z depends on the selected objective and on the three available standard resolutions fine, middle, coarse. You can also enter a user defined step size.

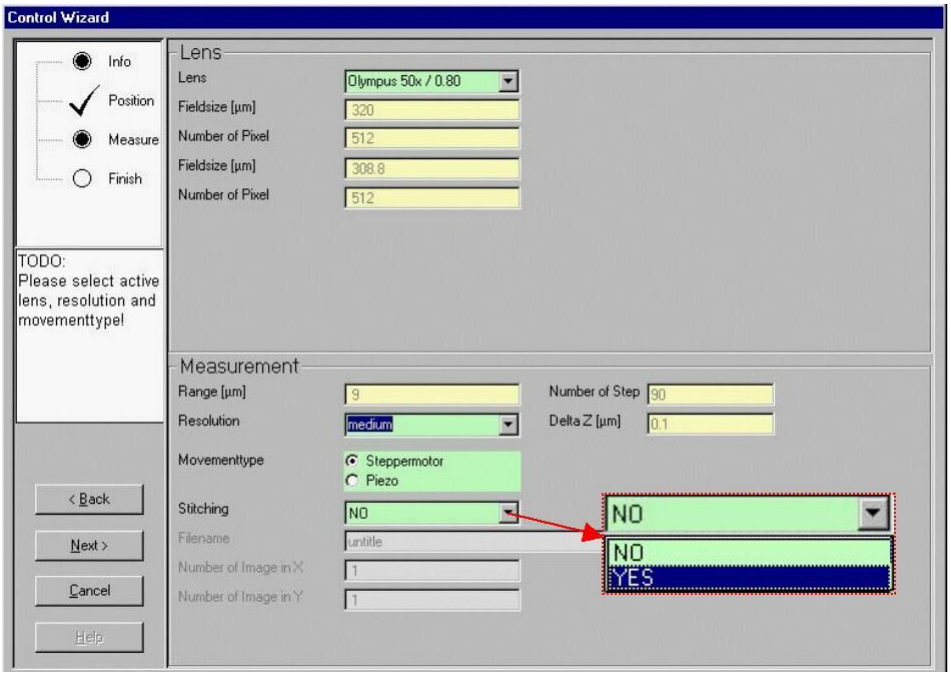
Corresponding to the step size and the stroke, the total number of steps for the measurement is displayed in the field 'number of steps'. This number must not exceed 1000.

- Drive selection

If the measuring stroke is less than the piezo drive range (350 µm), it is possible to choose between step drive and piezo drive. Piezo is the preferable setting, because velocity is higher and accuracy is better.

- Stitching

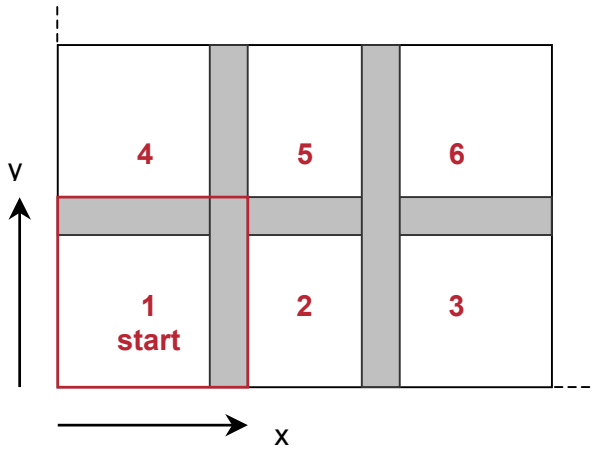
In order to activate the stitching function, select 'yes' in the field 'Stitching'.



Control wizard: activating the stitching mode

The area of a stitched measurement is always rectangular. Its total size is defined by the objective field size and the number of pictures in x- and y-direction, which can be edited in the last two text boxes.

A stitching measurement always starts at the current stage position that has been adjusted in the frame 'Position' one step before. The automatic measuring order – line by line – is shown in the illustration below. Adjoining measurements are proceeded with an overlap of 15%.

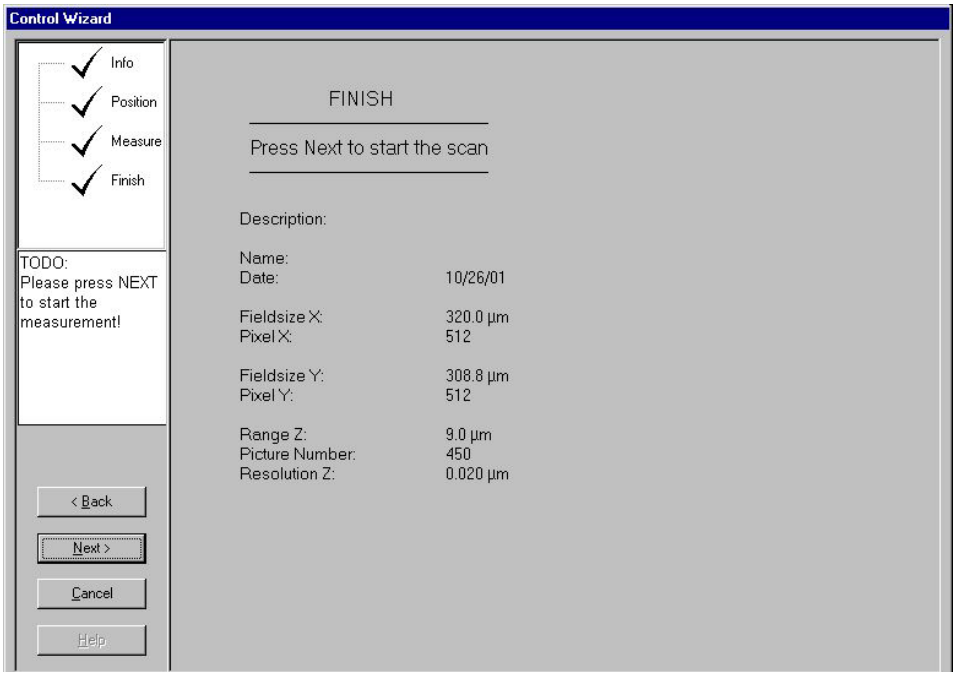


Stitching: order of measurement recordings

Control wizard – Finish

- Final check of the measurement parameters

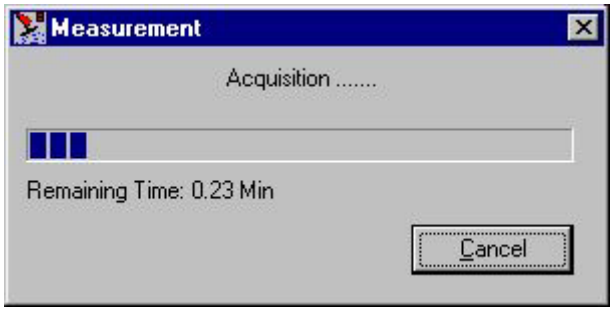
All important measurement parameters are listed in the last frame 'Finish' of the control wizard.



Control wizard: finish

- Starting to measure

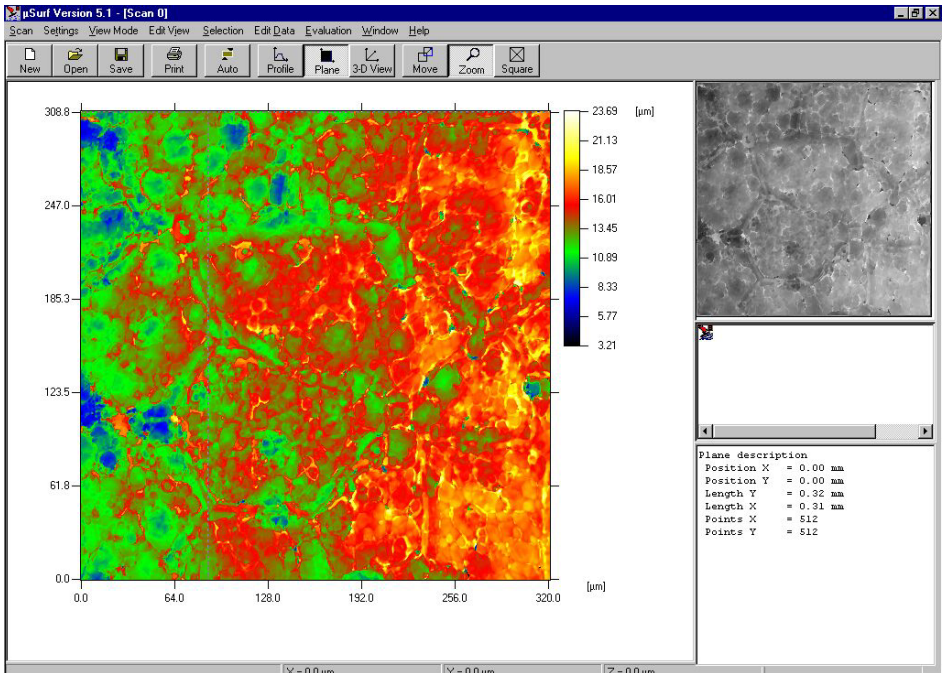
Start the measurement with the 'Next' button. Any further measurement procedures are automatic.



Measurement progress

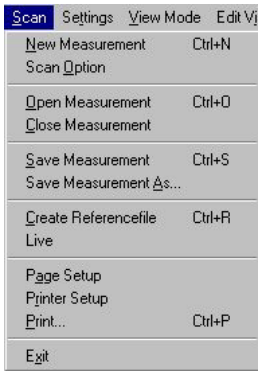
When the measurement is finished, the topographic view is displayed. Various procedures and evaluations are now possible (see 'Software', p. 28).

Saving the measurement before going further is recommended. As long as a default name like ‘scan0’ is indicated in the title, the measurement has not been saved to the hard disk.



Finished measurement

Saving measurement data



You can save measurement data under 'Save Measurement' or 'Save Measurement As' in the standard format NMS Files (*.nms).

If some data will be processed in other software, you can save it in the following formats:

- ASCII Files (*.txt)
- Origin Files (*.dat)
- SDF Files (*.sdf)

Switching off the system

To avoid losing unsaved measurement data, never switch off single components or the total system before the measurement software is correctly closed.

To switch off the system proceed in the following order:

1. Remove any objects from the measurement table.
2. Close the µSurf® software.
3. Shut down Windows and wait for the message ‘You can now switch off your computer.’
4. Switch off the master control.
5. Switch off the light source (only if it is plugged in separately).

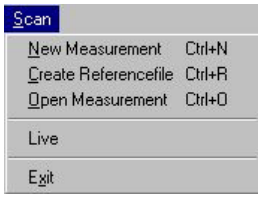
Software

The software is generally structured like any Windows application. The operation is similar to other Windows programs (menu bars, pull-down menus, mouse clicks etc.).

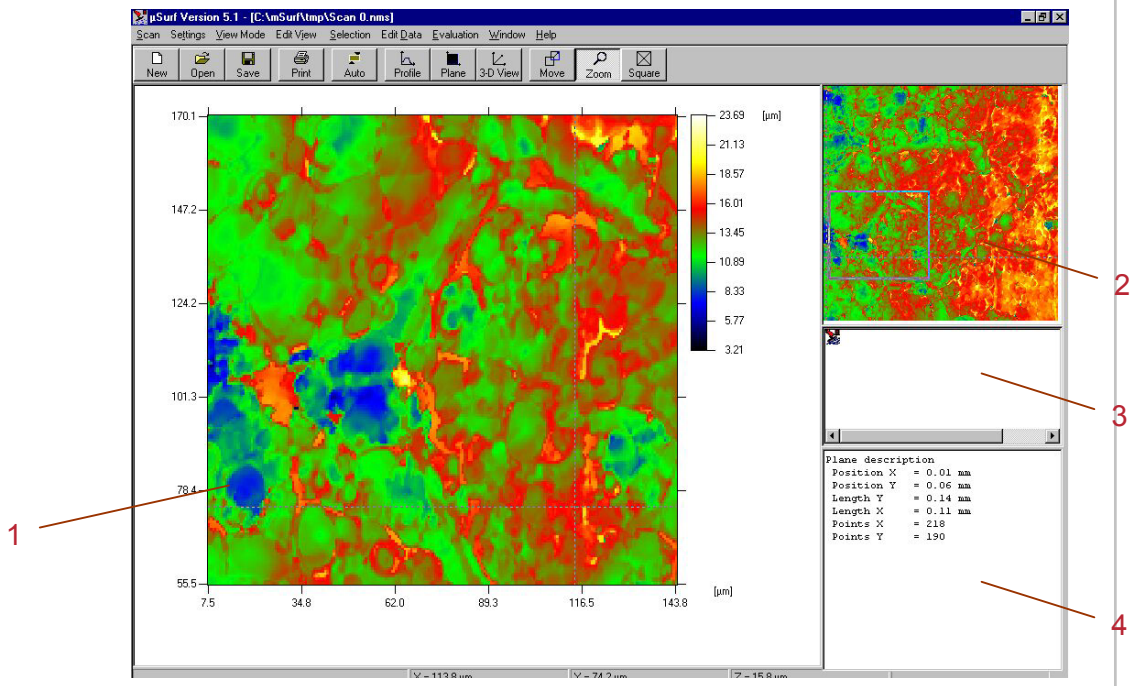
Selection, Processing, Evaluation

Arrangement of the window – 4 regions

In order to evaluate a measurement, it has to be displayed in the main-window. This is the standard window in which a measurement is displayed after finishing a measurement.



Already saved measurements can be displayed within the function “Open measurement”.



View of a measurement: main frame consisting of four sub frames

1 The largest area is the evaluation window. Here you adjust various views (Profile, Surface, 3D-View) and a detailed analysis of the measurement can be carried out.

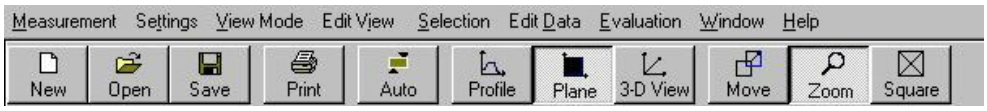
2 At the top right there is the overview frame. In this window the entire measured surface is displayed. You can select specific profiles or areas which are then displayed in the evaluation window. If the evaluation window is set to Surface or 3D, you can select any area by holding the left mouse button and dragging the mouse. This area is then displayed in the

evaluation window in magnified form. You can carry out the selection as often as you like.

3 Below you see the navigation frame, a small window which is not active in this illustration. In case of stitched measurements, the names of the individual images are listed up in this window.

4 At the bottom right corner is the information frame. There you see any information you have entered in the Scan Wizard. In the course of the evaluation, new data of the current analysis are added here.

In addition, you can see the extended menu bar on top and a bar with function keys.



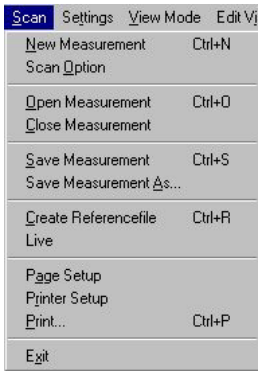
Tool bar

The first three and the last two menus are active with any kind of evaluation, and always remain unchanged.

The other menus work in a context-sensitive manner. In other words, depending on the selected evaluation 'Profile', 'Surface' or '3D-View', some menu items are deactivated or completely different menus are displayed.

Menu contents

Menu 'Scan'



In addition to the already discussed menu items, the menu is extended by the items 'Save' and 'Print'. The menu items correspond completely with those of normal Windows functions.

New Measurement
Starts a new measurement

Scan options
The measurement wizard including the measurement parameters of the latest measurement is opened. **Attention:** The current measurement data as shown in the main window will be overwritten!

Open Measurement
Opens an existing file.

Close Measurement
Closes an opened measurement without saving it

Save Measurement
Saves a measurement with its current name

Save Measurement as
Saves the measurement under a new name entered by you

Create Reference File
Creates new reference file (see calibration section, p. 54)

Live
Opens a window with a live image of the CCD-camera

Page Set-up
Selection of language for printer output

Printer Set-up
Selecting and setting-up a printer

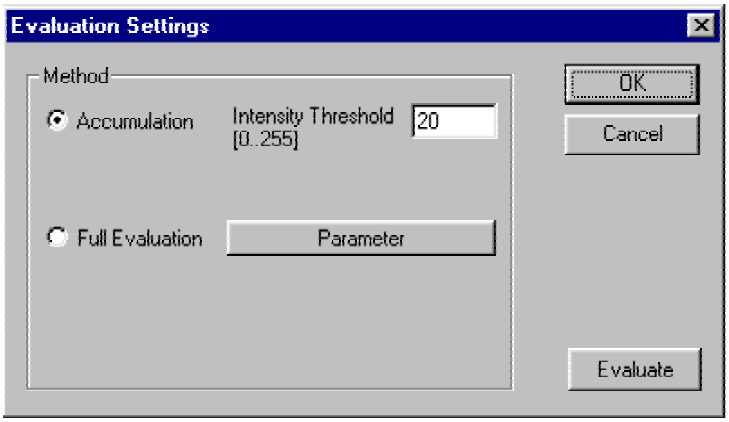
Print
Print-out of current image

Exit
Closing the µSurf®-program

Menu 'Settings'

Settings

This item is only available if the active window contains the latest measurement. You can either re-evaluate the measurement from the current raw data in the memory ('Evaluate') or you might only change the evaluation settings for the next measurement ('OK').



Evaluation Settings

- Accumulation

The accumulation algorithm is the default method to evaluate the sample's topography from the raw data. It is fast and delivers optimum results in most applications.

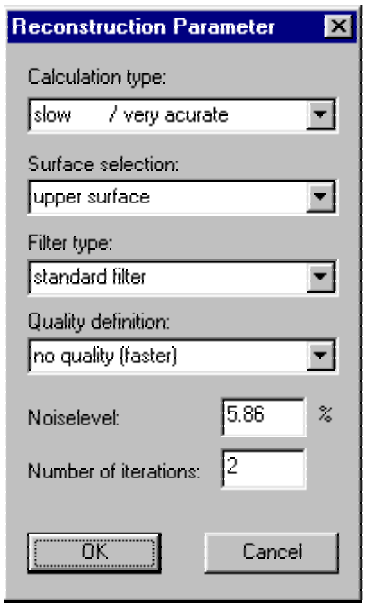
To optimise results with low signal noise ratio (SNR) the 'Intensity threshold', i.e. the noise peak height, can be adjusted.

- Full Evaluation

'Full Evaluation' is the preferred algorithm for samples with transparent or semitransparent coatings. The more flexible parameter options allow better

control of the results in case of double reflections. The reconstruction parameters can be changed in the Setting menu.

- Reconstruction parameters for full evaluation



Calculation type
Selects a mathematical procedure. (The slower the procedure, the more precise the evaluation).

Surface selection
In case of (semi-) transparent coatings a second reflection peak from the surface might be detected. In this case the algorithm must know if the upper (‘upper surface’), the lower (‘lower surface’) or the brightest reflection (‘all layers’) has to be evaluated.
The latter option is also recommended for samples with steep edges.

Filter type
Selects the type of filter for the raw data. (For noise corrupted measurements).

Quality definition
not implemented

Noise level
Sets the senitivity for peak detection. The default value is 3.8 %.

Number of iterations
Only for calculation type = slow: Sets the number of iterations.

Menu ‘View Mode’

Here you select how a measurement is to be displayed.
Not all menu items are always active. This depends on the kind of display ’Profile’, ’Surface’, ’3D-View’.

Profile
Presents the measurement as a 2-dimensional profile

Plane
Presents the measured surface as top-view with colour-coded height indication.

3D-View
Presents the measurement as a 3-dimensional projection

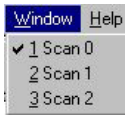
Copy to Clipboard
Copies the image in the evaluation window into the clipboard

Export Metafile
Saves the image of the evaluation window as an Enhanced Metafile (*.emf) under any name.

Menu 'Selection', 'Edit View', 'Edit Data', 'Evaluation'

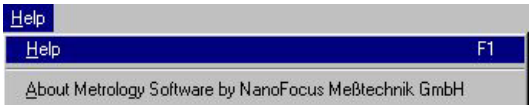
By means of these menus the display and evaluation of the measurement is controlled. They are described in detail in the following paragraphs.

Menu 'Window'



When you have carried out several new measurements or loaded them from archive, you can toggle between them using this menu.

Menu 'Help'



Here you find the help function as well as further information about the µScan software.

Tool bar

The icons of the quick-access tool bar correspond with the menu items of the menus in the menu bar. Only menu items which are used very often, have a key to call the function directly.

Tool bar

The tool bar is also context-sensitive. The first three and the last two menus are active with any kind of evaluation, and always remain unchanged.

The other menus work in a context-sensitive manner. In other words, depending on the selected evaluation 'Profile', 'Surface' or '3D-View', some menu items are deactivated or completely different menus are displayed.

Pop-Up Menus

When you place the cursor on one of the regions in the main window and press the right mouse button, a so called Pop-Up Menu opens. This menu is different in every area (evaluation, information, overview window) and depends also how the measurement is displayed. The menu items in these menus correspond to the menu items in the upper menu bar, however, they are faster and more conveniently accessible.

Full screen view

When you double-click on the left mouse button with the cursor in the evaluation window, you get a full-screen view. To return to standard view, click twice.

Menu 'Selection',

In this menu you define which profile or which section of the surface you want to view. There are three available menu items at your command.

Profile

Free Profile
Click on the spot in the overview window where the profile should start, hold the left mouse button down, move the cursor to the desired end point of the profile and release the left mouse button. The profile of this line is displayed in the evaluation window.

X-Profile
Here you define a profile in the x-direction on your measurement area. Click on the selected position in the survey window. Hold the left mouse button down and move the cursor in the y-direction. At the left you will see the changing profile. When you release the left mouse button, the profile between these two positions is displayed in the evaluation window.

Y-Profile
Here you define a profile in the y-direction on your measurement area. Click on the selected position in the survey window. Hold the left mouse button down and move the cursor in the x-direction. At the left you see the changing profile. When you release the left mouse button, the profile of the line selected is displayed in the evaluation window.

Plane

Zoom

Hold down the left mouse button in the overview window and use it to draw a rectangle of any size, release the mouse button. This marked section is displayed magnified in the evaluation window.

Move

If you click into the rectangle in the overview window and hold the mouse button down, you can shift the rectangle in any direction. The evaluation window displays the current section.

Square

With this function you again select an area, but it is always automatically a square, thus it fits best into the evaluation window and the aspect ratio remains unchanged.

Menu 'Edit *View*'

At the left are the menu items available for profile and surface evaluation.

- Scale

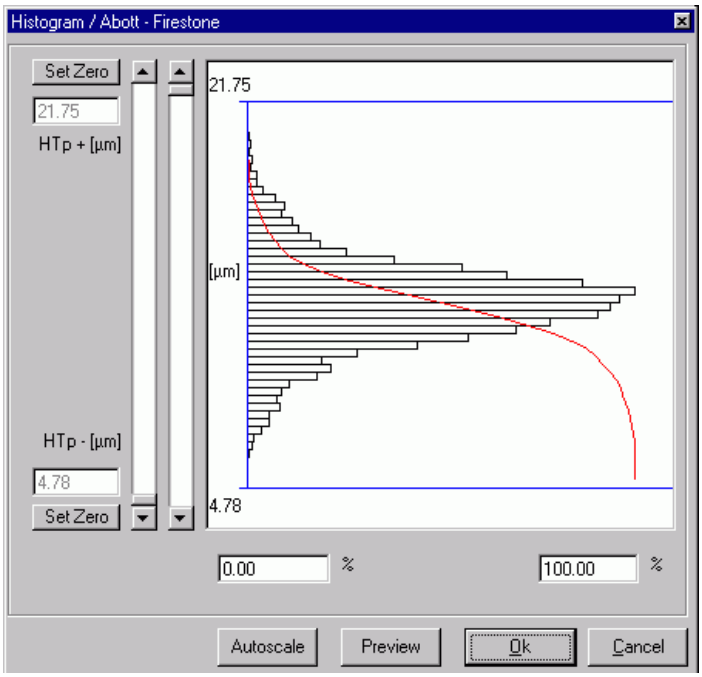
Opens up a window for scaling of the displayed image.

- Auto scale

Carries out automatic scaling of the displayed image with respect to the z-axis.

- Histogram

This function shows the frequency distribution of all the height values of the displayed image. A cumulativ Pareto curve is displayed in red.



Histogram

The z-range can be restricted using the slider bars. The buttons “Set 0” set the relevant slider to the highest/lowest value.

“Auto” sets the scaling of the z-axis automatically. The result equals the standard display.

“Preview” shows the new z-axis-scaling. With “OK” the new settings are accepted.

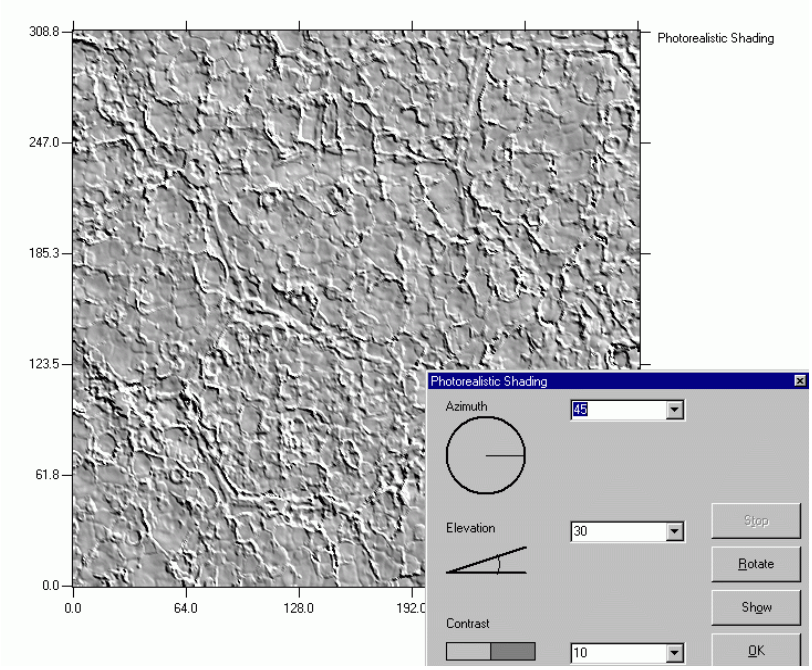
- Title

You can enter a name for the image. This name is displayed as title in the evaluation window.

- Palette

Selection of false colour palette for height indication. In principle, the height data are represented with a 256 color palette.

„Photorealistic shading“ is an exception. It shows no height values, but a three-dimensional impression of the measurement. The view parameters (angle of incidence) for the evaluation and the azimuth of the virtual light-source as well as the contrast can be changed in the Menu ‘Edit View/Shading Options’.



Photorealistic shading

- Zoom

Switches to zoom mode: draw a frame in the evaluation window with the mouse across the area which you want to enlarge. As soon as you release the left mouse button, the selected section appears in the evaluation window.

- Unzoom

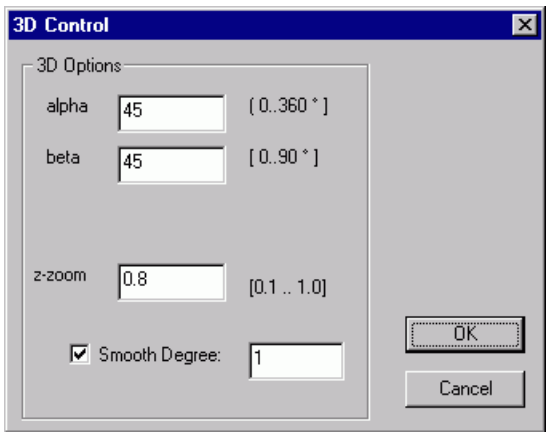
Undoes the last zoom operation (max. 10 steps)

- Mark Data Points (View Mode = Profile)

Makes measurement points on the curve visible

- 3D-Options (View Mode = 3D-View)

Opens a window for changing of viewing angle in 3-D view



Control for 3D view

alpha

Enter an angle value between 0 and 360° in the 'alpha' box. In this way you rotate the azimuth (the apparent viewing angle) around the x-y surface by the entered value: from front view (alpha = 0°), through rear view (alpha = 180°) and back to the front view in a complete turn (alpha = 360°).

beta

Enter an angle value between 0 and 90° in the beta box to change the apparent elevation of the viewing point. With beta = 0 you are on the x-y surface, beta = 45° means a scan view at 45° and with beta = 90° you get a bird's view of the scan, which corresponds to the 'Surface' view.

z-zoom

Enter in the 'z-zoom' box a value between 0.1 and 1.0. In this way you scale the z-axis: 0.1 presents the scan very flat, 1.0 stretches the scan strongly in the z-direction.

Smooth Degree

Smooths out the transitions between the measurement points.

Menu 'Edit Data'

Surface manipulation

View Mode = Plane

The menu 'Edit Data' contains the following menu items :

- Undo

This function cancels the previous processing step.

- Interpolation

This function interpolates the data record to any number of measuring points between 0 and 2048, i.e. the point density of the data record can be mathematically increased in both directions. You can indicate the number of points separately for x- and y-axis.

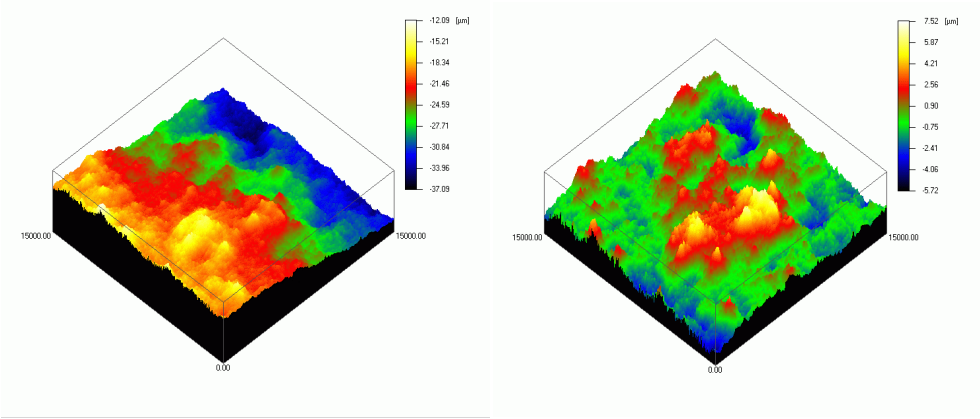
If your data record contains many measuring points, you can decrease the number by means of this function, e.g. to reduce memory usage.

- Cut

With this command you can cut a section of interest out of the data record which is displayed in the evaluation window. The rest of the measuring values is no longer considered for further calculations. The cut area is displayed in the overview window. If you save the data recorded after using the command 'Cut', all data outside this area are deleted.

- Levelling

With this function you can level out a slope of the measurement surface. An average surface is calculated and is then subtracted from the data record.



Leveling of a tilted surface

The ‘Levelling’ function modifies the tool bar.

Quick access tools for levelling

Use the left mouse button to draw the area(s) which will be used as the basis in the evaluation window. Click on the top left margin of the first section, hold down the mouse button and release it at the bottom right margin of the section. Repeat this procedure with as many sections as needed. If you don’t mark any section, the levelling will be based on the full range.

If you then click on button ’Level’, the levelling process is started and the plane is levelled.

Button ’Clear’ removes any sections from the evaluation window.

With the two middle buttons you select the optional adaptation for the topography. ’1st Order’ aligns linear slopes. The mathematical base is the regression calculation 1st order: straight plane.

‘2nd Order’ transforms curved shapes into level planes. The mathematical base is the regression calculation 2nd order: parabola.

You leave the levelling menu with the button ’Back’ and return to the standard view.

- Filtering

Mean filter

This function carries out a calculation of the mean value on the basis of a moving average. This is carried out as follows:

A mean value is calculated which contains one measuring value and all its surrounding measuring values. The original measuring value is replaced by the calculated value. In this way, the entire data record, i.e. any measurement values of the measurement, is processed.

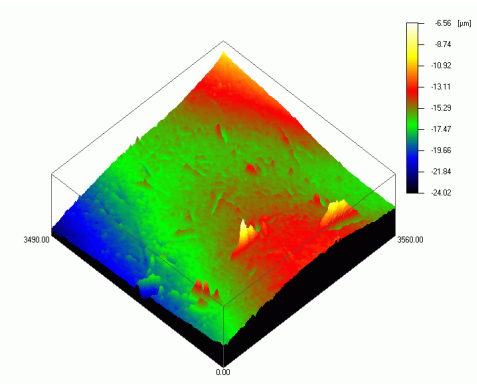
The purpose of this function is to mathematically smooth out the measured data. Thus excessive roughness can be faded out. The more often you use this function, the smoother the surface becomes.

Gauss filter

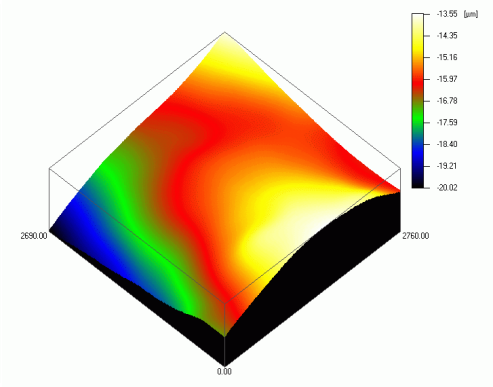
The function 3D Filtering allows filtering of the complete data record (not only a selected profile) with either a high-pass or a low-pass filter. The mathematical base is Gaussian filtering.

With this function, you can filter out shapes of higher mathematical order (>2). If you use the low-pass, fine structures are filtered out (e.g. scratches are suppressed), the shape of the surface is highlighted.

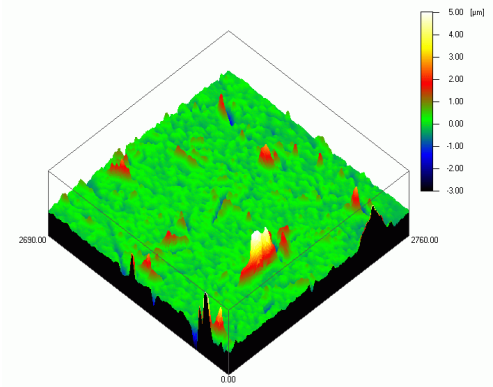
With a high-pass rough structures are filtered out, i.e. scratches are highlighted and the shape of the surface is suppressed.



Measured surface



Surface after low-pass filtering



Surface after high-pass filtering

Median

This filter makes it possible to eliminate high peaks in both directions.

- Offset

You can shift the point of reference of the height values at will. There are four options.

Manual

A window opens where you can enter the distance from the current zero point. You have to confirm with 'OK' to start the calculation of the offset and its definition as the new zero point.

Minimum

The lowest point of the surface is defined as zero point. All height values are based on that point.

Mean

The average of all height values of the surface is defined as zero point. All height values are based on that point.

Maximum

The highest point of the surface is defined as zero point. All height values are based on that point.

Profile manipulation

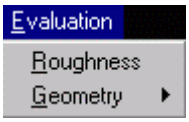
View Mode = Profile

In profile view mode only two options can be selected in the 'Edit Data' menu. They correspond to the menu items in plane view mode (see 'Surface manipulation', p. 37).

Menu 'Evaluation'

Profile evaluation

View Mode = Profile



In profile view mode, the 2-dimensional functions for analysis can be accessed from the 'Evaluation' menu, i.e. only profiles can be analysed.

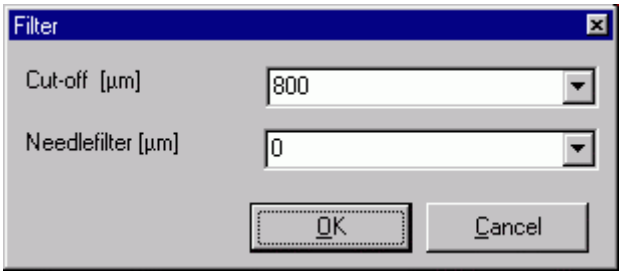
- Roughness

This menu item automatically opens a submenu. The buttons Profile, Roughness, Waviness, Filter and Back appear in the toolbar:

Toolbar roughness

Filter

The Filter button serves to set the cut-off wavelength λ_c according to DIN EN ISO 4287 or to any user defined conditions.



Setting filter for roughness and waviness evaluation

- Cut-off wavelength λc

The cut-off value represents the limit wave length in µm. The smaller the Cut-off is set, the more the waviness approaches the measured profile. By definition roughness is the difference between waviness and measured profile, thus the setting the cut-off directly influences both the roughness value and the waviness value.

Corresponding with the standard, the cut-off depends on the expected mean roughness value R_a or on the maximum roughness profile height R_z.

	Ra	Rz	Cut-off [µm]	Measurement Distance DIN [mm]
	<0,02	<0,1	80	0,48
	0,02 .. 0,1	0,1 - 0,5	250	1,25
Standard:	0,1 - 2,0	0,5 - 10,0	800	4,8
	2 .. 10	10 - 50	2500	12,5
	>10	>50	8000	48,0

With periodical surface structures the cut-off ought to be 2 to 6 times as big as the groove depth.

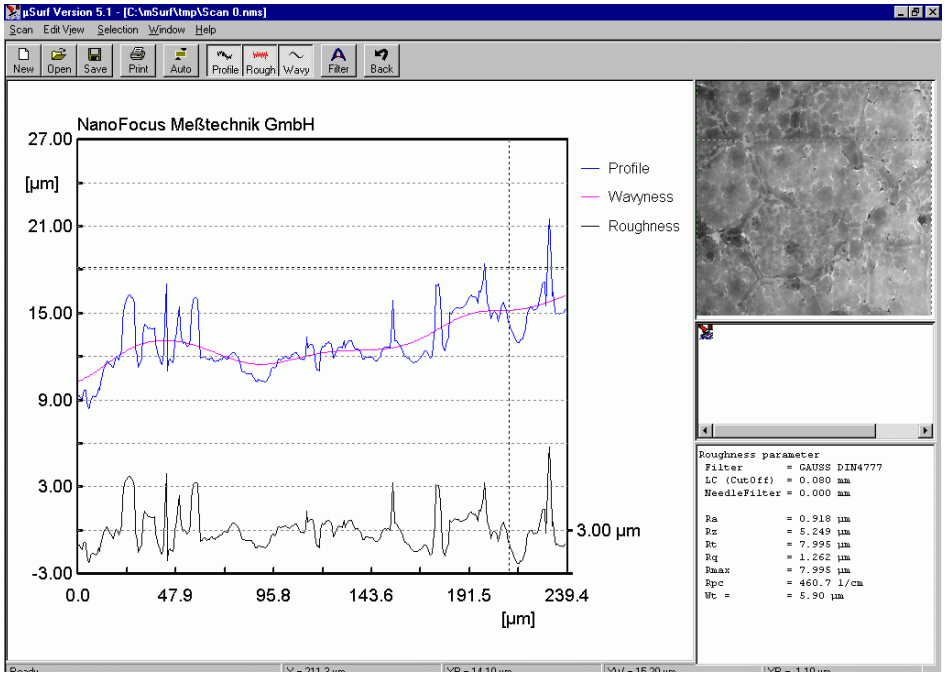
	Groove Distance [µm]	Cut-off [µm]	Measurement Distance DIN [mm]
	10 .. 40	80	0,48
	40 .. 130	250	1,25
Standard:	130 .. 400	800	4,8
	400 .. 1300	2500	12,5
	1300 .. 4000	8000	48,0

Needle filter

Here you can simulate how roughness and waviness would look like, if you used a tactile sensor with a specific diameter at the tip of the needle (e.g. 5 µm). Enter the desired needle diameter and confirm with 'OK'.

Profile, Roughness, Waviness

By default the evaluation window displays the Roughness profile of the profile selected before. This basing profile can be added by clicking on the button Profile. In the same manner the Waviness can be displayed.



Profile roughness evaluation

The related data is displayed in the information frame. If you click the right mouse button in the information frame, you can select between three different data sets: user information, profile information and evaluation data.

Look at the filter settings, because they strongly influence the results. More details about specific parameters defined in DIN EN ISO 4287 are noted in the appendix (see ‘Surface characteristics and measuring conditions’, p. 57).

Back

The ’Back’ button closes the toolbar submenu ‘Roughness evaluation’.

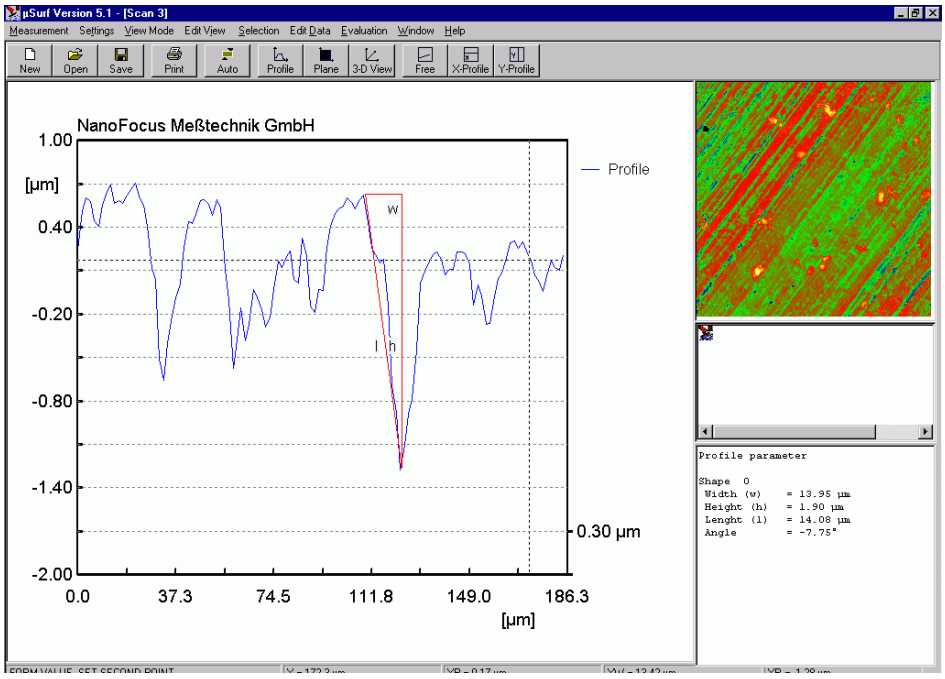
- Geometry

‚Evaluation/Geometry’ takes you to the geometry submenu.

Clear (F5)

Removes all sections, markings and data from the evaluation window.

Shape



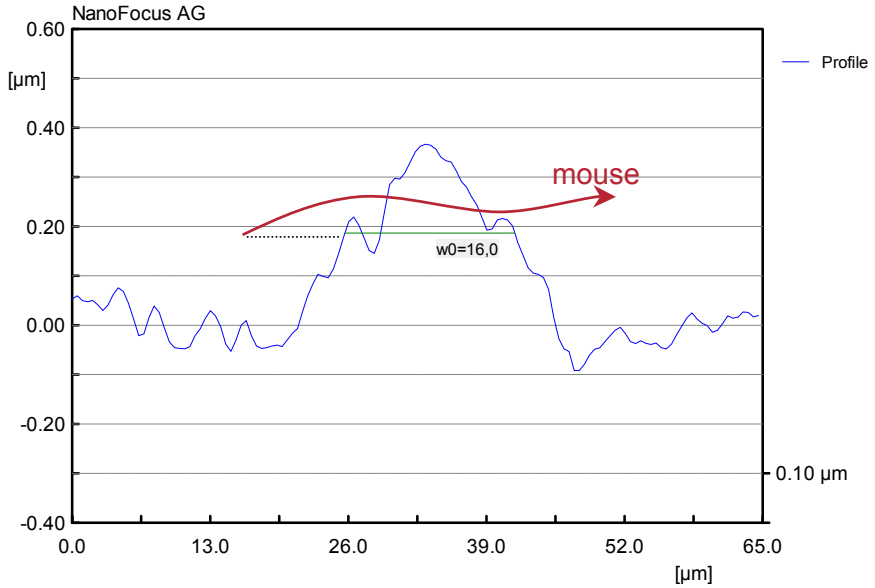
Shape measurement

With these functions you can calculate angles of gradient, height and width differences and lengths in a profile. The angle obtained by drawing a straight line through 2 points is calculated as well. All the values are listed numerically in the information window.

Shape, Free:
Draw a straight line by holding the left mouse button between two points.

Shape, Catch:
Select with depressed mouse button two points along the x-axis, and the program will automatically „catch“ the corresponding values on the y-axis.

Width



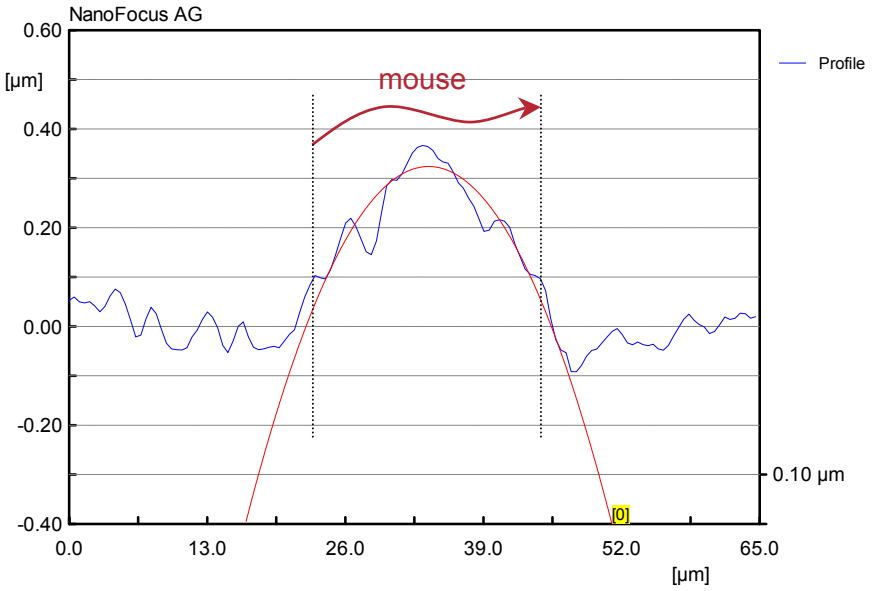
Width measurement

‘Width’ serves to calculate distances of edges or slopes in a profile. Click at the height level of interest and draw a roughly horizontal line with depressed left mouse button. The horizontal range must include at least two crossings of the profile. The width between the most distant crossings is calculated.

Circle

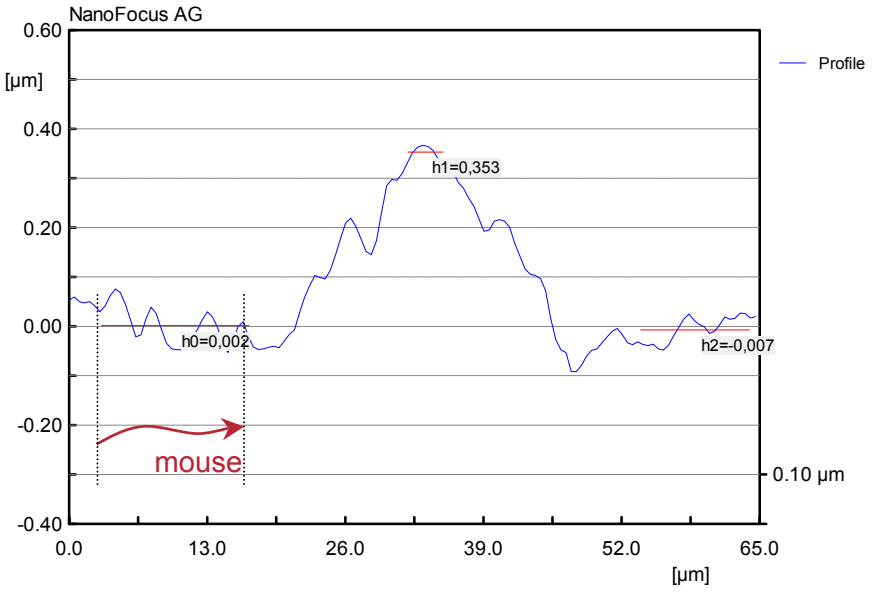
This approximates a circle to a selectable range of a profile. Select two points on the x-axis with depressed left mouse button. The corresponding y values of the profile are given automatically.

The screen shows a parabola, because the scaling of x- and y-axis is different.



Radius measurement

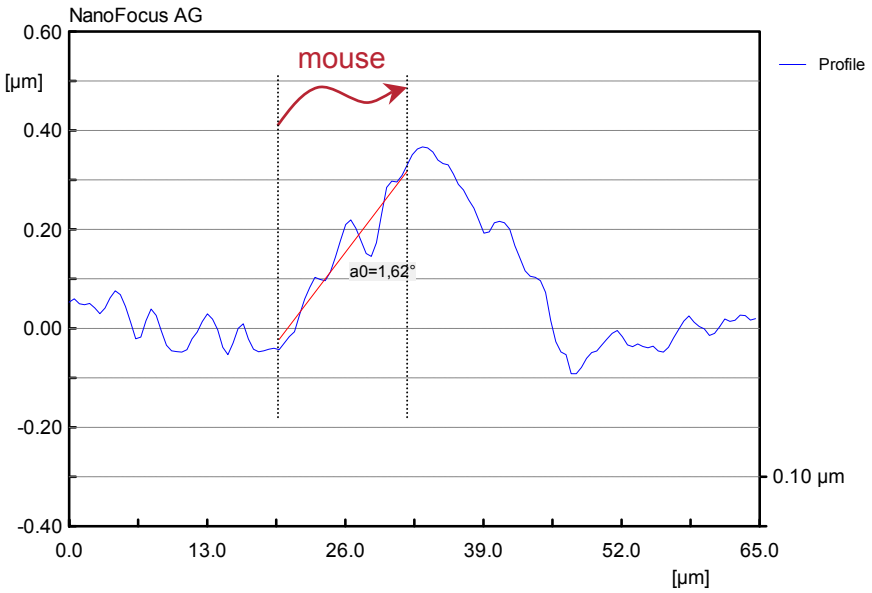
Height



Height measurement

Determines the mean height of a selectable section in a profile.

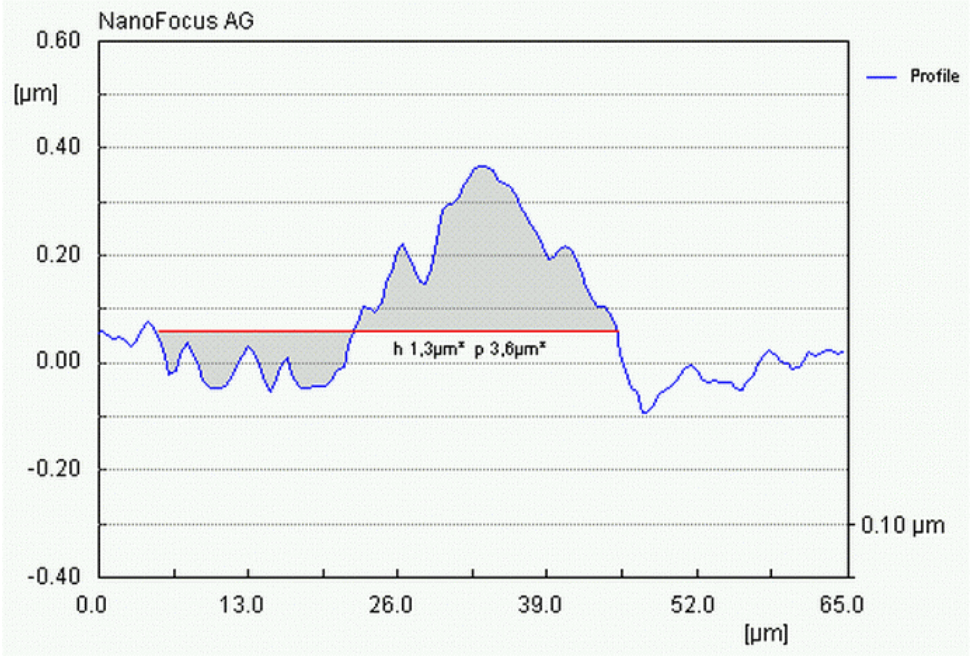
Angle



Angle measurement

The mean angle of gradient between two selectable points of the profile is calculated. Select two points on the x-axis with depressed left mouse button. The corresponding y values of the profile are given automatically.

Area



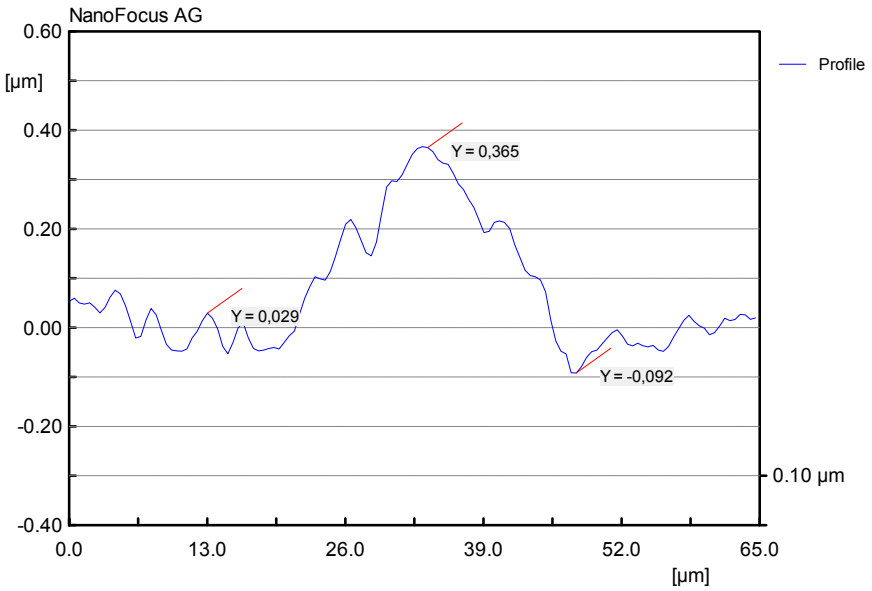
Area measurement

This function calculates areas using an auxiliary horizontal line in the profile. Move the mouse pointer to the intersection of the profile with the assumed auxiliary line. Click the left mouse button and hold it down, while you move the mouse to the opposite intersection.

The result is given as peak area and hole area, depending on whether the area is situated above or below the auxiliary line.

If the beginning or end of the auxiliary line does not fit with the profile, the area will be completed by an imaginary vertical line.

Point



Point measurement

The horizontal and vertical coordinates of a selectable point are output.

Move the mouse horizontally. The cursor follows the profile. When you click the left mouse button, the current point will be caught.

Surface evaluation

View Mode = Plane

Evaluation
Roughness

Using the 2D roughness analysis function

In plane view mode the 'Roughness' analysis is carried out with 3Ddata sets of topographies.

A new window ’ Roughness Analysis’ is opened.

At first in the left half the grey scaled topography of the current measurement is displayed.

The top right frame contains the calculation parameters.

- dR max = +/-

Tolerance ellipse with 95% of its area

- n

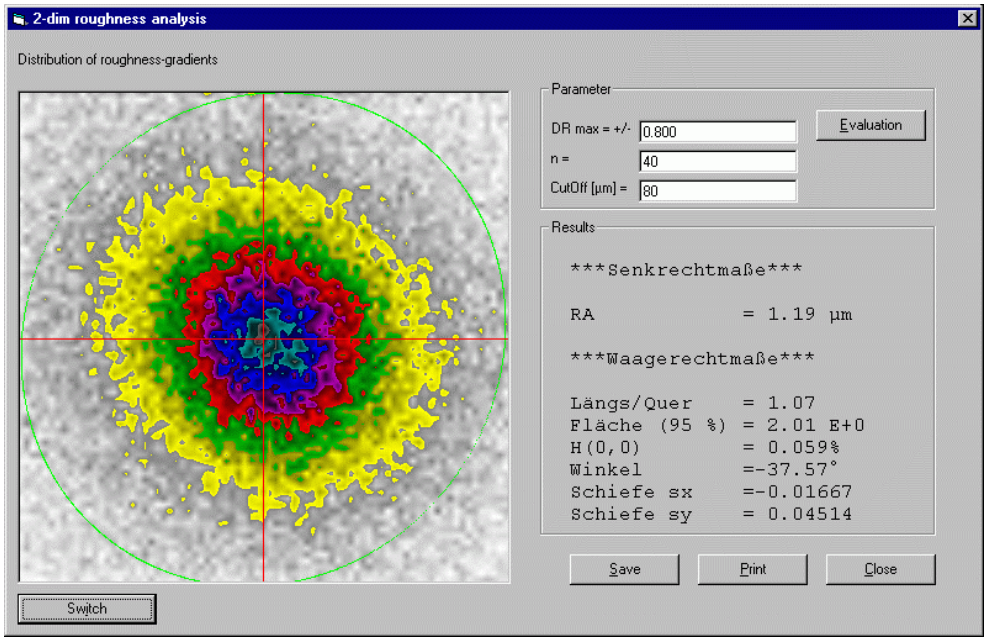
Scale in x- and y-directions, number of classes for calculation

- Cut-off

For cut-off wavelength λ_c see ‘Cut-off wavelength λc’, p. 41.

The calculation is carried out by clicking on ’Calculate’.

The left frame shows the colour coded distribution of the roughness gradients of the sample. The result values are displayed in the bottom right frame.



Distribution of roughness gradients

With the ‘Switch’ button you can toggle between the distribution view and the high-pass filtered topography view.

Description

This special surface evaluation is based on a two-dimensional frequency analysis. At first the measured surface is low-pass filtered with a defined Cut-off wavelength to suppress the long-wave parts.

Then the so called gradient matrix is formed, whose properties are expressed in the so called horizontal dimensions. The gradient matrix assumes at first the local differentiation of heights (also called roughness values R) in both dimensions x and y. Calculation of the frequency distribution reveals a figure for the values which are inside the value range dR + delta. A maximum value range dRmax has to be entered and is then subdivided into n classes. The result of the total of the classes is consequently the two-dimensional gradient matrix.

The image viewed during evaluation shows the colour coded shape of the gradient matrix. A symmetric shape (circular) shows symmetrical roughness gradients related to the axes. In case of inhomogeneity, an ellipse shape appears.

The horizontal dimensions result from the statistical description of this matrix. The shape of the ellipse is described by the longitudinal transverse ratio of the main axes and their angles.

A 'local homogeneity' H(0,0) is the number of values in relation to the total number, whose roughness gradient disappears in the origin within the accuracy of the class width (dR = 0). Thus high values represent 'smooth' surfaces.

The area (95%) of the so called 'tolerance ellipse' describes the one area within which 95% of the gradient values fall.

The oblique values sx and sy represent the asymmetry ('inclination') of the distribution, separated in both directions.

Data record processing

Save data records

To store the evaluated data record, click on the menu 'File' in the upper menu bar and then on 'Save'. If saving this data record for the fist time, the usual dialog 'Save as…' for saving files will appear. Find the folder in which the data are to be saved, enter a precise, unique name, and confirm with 'Save'.

If the measurement has already been saved in the course of evaluation, this window will not be displayed. The former data set will be overwritten by the newest version.

At any state of evaluation you can save the data under a different name with 'Save as …' command in the 'Scan' menu.

Like in any other Windows programs, you can split up the files in several subdirectories to ensure good clarity. Use the "Create new Folder" button in the Save dialogue box to do this.

Import-export filter

Files can be saved in the default binary format *.nms as well as in the European standard format for surfaces *.sdf.

Files can be exported in format *.oms, *.sdf, *.dat, and as ASCII-file

Print out

If a printer is connected, you can print out data and images along with measurement control information with a click on the 'Print' buttons in the toolbar or the 'Print' command in the 'Scan' menu.

Memory capacity

The built-in hard disk provides at least 40 GBytes capacity. A scan requires 3 Bytes memory space per measurement point (i.e. 1,5 kBytes for a profile with 512 values and 768 kBbytes for a measurement.). In case of stitched measurements, the memory requirement increases by a factor of the number of measured images (e.g. 2 × 2 stitching; 4 × 768 kbytes = 3MBytes)

Software Updates

NanoFocus AG will inform you about new high performance updates of the software. You may then decide to upgrade your system or not.

General Information

Warranty

According to NanoFocus AG's general terms and conditions, the system is warranted for 12 months. Different warranty periods of purchased equipment, e.g. monitors, remain as supplied.

Important note:

Modifications of computer software and/or hardware components are not permitted and RESULT IN LOSS OF ANY LIABILITY CLAIMS!

Licence agreement

Important notes:

µSurf® Operating Manual

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Service / Contact

If you have questions about your system or if you want to discuss special applications, please contact the company branch below.

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EG-Declaration of Conformity

CE

in accordance with EU Regulations
Machines 89/392/EWG, Appendix IIA,
Electromagnetic Compatibility 89/336/EWG,
Low Voltage 73/23/EWG

The design of the machine

Type: **µSurf®**

Type designation, serial number: _____

is developed, designed, and manufactured in accordance with the above mentioned EG-Regulations, for which the following company is exclusively responsible :

Company:

NanoFocus AG

Im Lipperfeld 33

D-46047 Oberhausen

The following harmonised standards apply:

DIN EN 292, Safety of machines, devices, and installations
DIN EN 60204-1, Electrical equipment for industrial machines

The assessment of the device concerning its electromagnetic compatibility was based on the following standards:

DIN EN 50081-2 1993
DIN EN 50081-2 1995

Technical documentation is available.

The machine related operating manual is available.

Location, date	Signature	Dr. Hans Hermann Schreier President

Calibration and Specific System Data

Lateral coordinates

The measurement fields of the different microscope objectives are depicted in the µSurf® measurement microscope to 512 × 512 pixels. The lateral measurement field sizes which belong to the respective objectives were measured with calibrated meters and are stored in the Windows registry.

Vertical coordinates

The vertical coordinate of a height section is

- in the case of stepper motor driven linear axis via the axial pitch of the fine-threaded spindle (2mm pitch) a resolution of 0.1µm
- in the case of the piezo, via its characteristic curve (calibration information annexed) a resolution of 0.01µm .

The algorithm for calculating the topography allows better resolution compared with the distance of height steps (sub-distance resolution), see ‘Physical Parameters’, p. 56.

Curvature of the image region

Cause and countermeasure

Each measurement field in the µSurf® measurement microscope is depicted by the accompanying microscope objective in a curved frame. This effect is known as Petzval curvature. The curvature of this image field depends only on the optic, not on the measurement object.

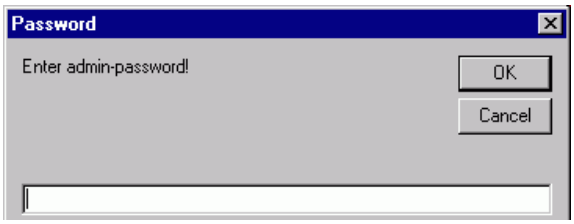
Curvature of the image fields of the different microscope objectives were recorded through measurements on a plane mirror (quality λ/10) and stored in the directory “c:\mSurf\cif\”. After each topographic measurement, the curvature of the image field assigned to the selected microscope objective will be subtracted automatically from the topography. In this way the topographic data, corrected by the curvature of the image field is generated.

If unexpected curvatures in the topographic data occur through major temperature changes, the curvature files of the image field must be recorded again.

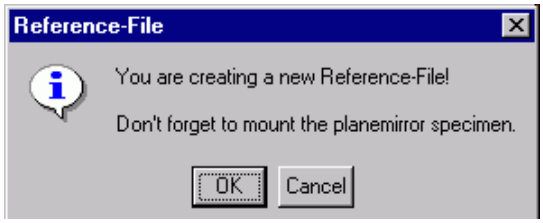
Creating new reference files

The procedure is as follows:

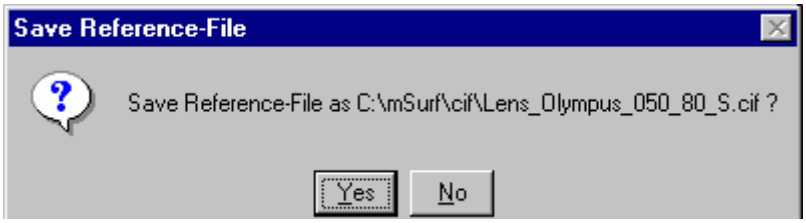
- Select the microscope objective
- Select ‘New Reference-File’ in the Popup menu ‘Scan’
  If password protection is active, you will be asked for the password.



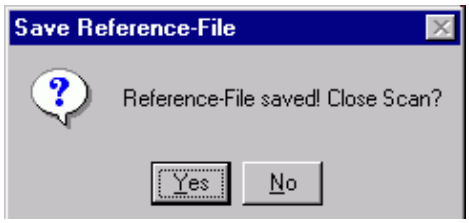
- After you have entered the password or if the protection is de-activated the following window appears.



- Put the plane mirror (λ/10 quality) as a sample to be measured on the x-y-table
- Confirm with OK
  The Wizard will be opened. Start a measurement of the mirror surface and carry it out in the usual way. The measurement will be repeated automatically five times and the results will be averaged.
- At the end of the measurement, the position and name of the reference (CIF) file is displayed. Confirm with 'Yes' to save the reference file as shown.



- Afterwards you will be asked, if you want to close the measurement.



Choose 'Yes' for closing the file.

If you want to check the file, or if you haven't saved and you changed your mind, then choose 'No'.

Physical Parameters

The measurement field values, working distance, resolution and other optical parameters of your µSurf® measurement microscope are:

Microscope objective *	1600-S	800-S 800-L	320-S 320-L	160-S 160-L
Measurement field [µm] × [µm]	1600 x 1544	800 x 772	320 x 309	160 x 154
Maximum area in stitching mode [mm^2]	187,3	46,8	7,5	1,9
Working distance [mm]	10,1	3,1 12,0	0,66 10,6	0,31 3,4
Numeric aperture	0,30	0,46 0,40	0,80 0,50	0,95 0,80
Maximum surface slope for specular reflection [°]	8,7	13,7 11,7	26,6 15,0	35,9 26,6
Vertical measurement range [µm]	<1000	<400	<100	<80
Vertical resolution** [nm]	20	5 6	2 4	1,5 2

* xxx-S = standard type, xxx-L = long working distance
**piezo driven measurement

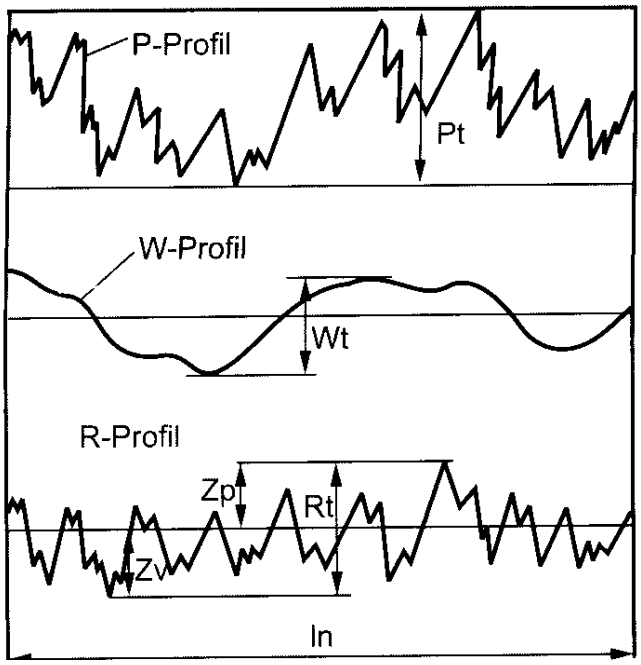
Appendix

Surface characteristics and measuring conditions

The following data are taken from DIN EN ISO 4287 without comment.

Pt, Wt, Rt
Surface profile - total height of the profile

Using the measuring instrument, the surface profile in elevation (2-dimensional) (P-profile), the roughness profile (R-profile), and the waviness profile (W-profile) is determined. Parameters are defined for the profiles which are marked respectively with the capital letters P, R, and W.



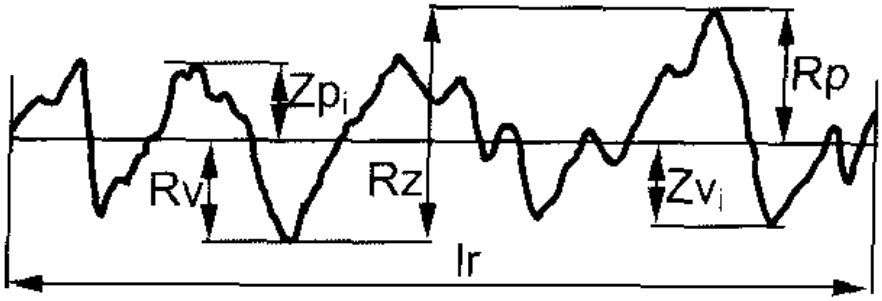
The parameters of DIN EN 180 4287 apply to the roughness profile as well as to primary and waviness profiles. For example, the total height Pt, Wt and Rt of the primary, waviness, and roughness profiles are defined as the sum of height Zp of the highest profile tip and depth Zv of the deepest profile low within the evaluation range.

The reference line for definition of parameters within the evaluation range lp, lr and lw is the centre line. The evaluation range is the measurement length used for profile evaluation. If not defined otherwise, determination of roughness and waviness parameters is carried out with ln = 5 lr and/or ln = 5 lw.

Rz
Maximum roughness profile height

DIN EN ISO 4287

Sum of the height of the highest profile tip Rp and the depth of the deepest profile low Rv of the roughness profile within the single measurement range.



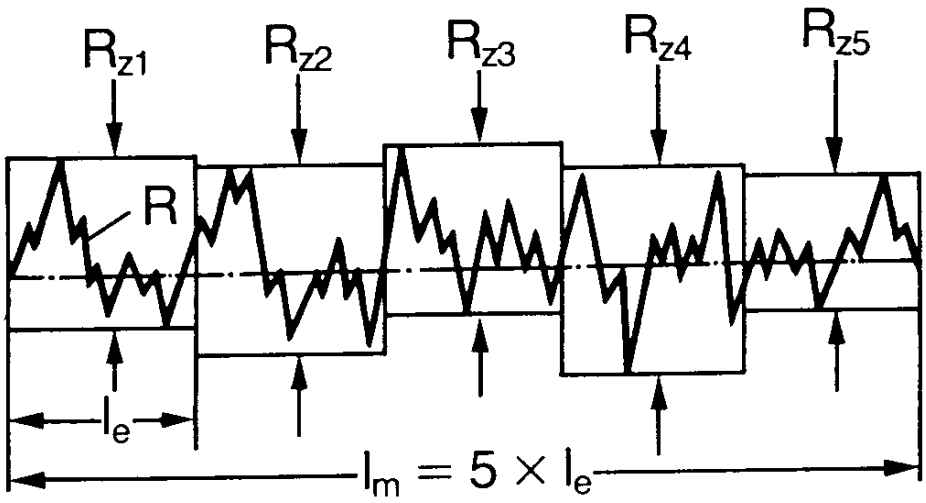
Rz is the value of the scatter range of the roughness ordinate values, measured as vertical distance between highest and deepest profile points.

As a rule, Rz is calculated as arithmetic average of the maximum profile heights of 5 single measurement ranges lr in the roughness profile. This parameter corresponds with the mean surface roughness of DIN 4768. Rp corresponds with the formerly defined finish depth of DIN 4762.

Rmax
Maximum surface roughness

DIN 4768

The maximum surface roughness Rmax is the largest of the 5 single roughness values which form Rz.

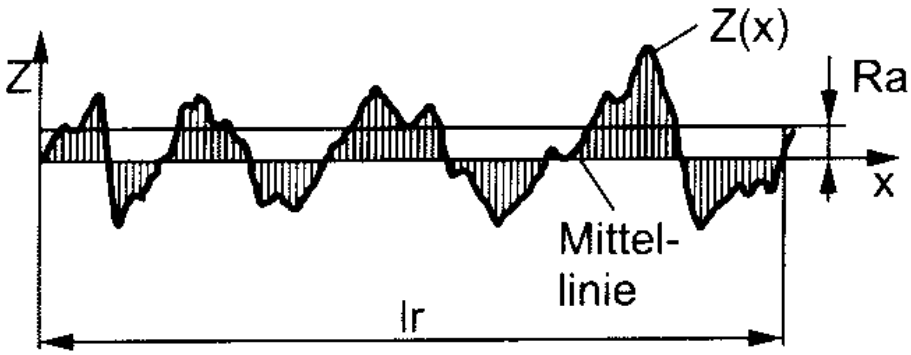


Ra
Automatic mean roughness value

DIN EN ISO 4287

This is the average arithmetical absolute sum of ordinate roughness profile values

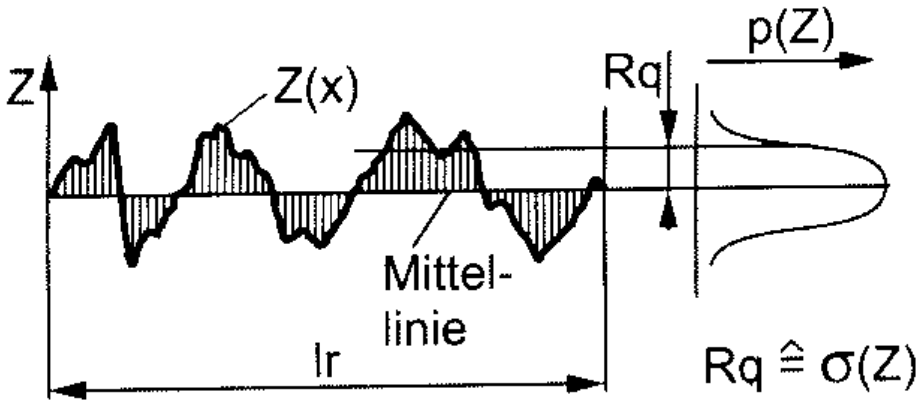
From statistical point of view, Ra is also the mean arithmetical deviation of the roughness-ordinate values taken from the centre line. The meaning of Ra is small. Ra is insensitive against extreme profile peaks and valleys.



Rq
Quadratic mean value

DIN EN 180 4287

Quadratic mean value of the ordinate roughness profile values



The average quadratic deviation of the roughness-ordinate values from the centre line Rq is the standard deviation of the profile ordinates and is therefore statistically much more representative than Ra.