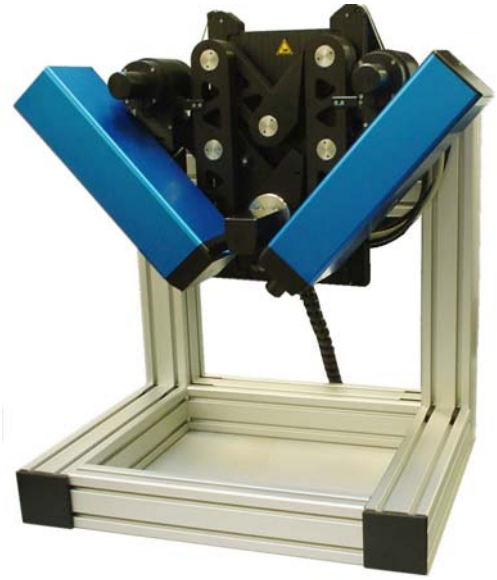


Operating Instructions

EP^3

nanofilm
SURFACE ANALYSIS

Safety Instructions

Laser

Laser radiation

Never look directly into the laser beam!

Laser class: 3B as per DIN EN 60825-1:2001-11 (with optional NPK or safety cabinet: laser class 1 because of the automatic interlock)
Maximum laser power: 50 mW
Wavelength: 532 nm

In the United States of America, lasers are classified according to the 21 CFR (1040.10 Laser Products) directive of the Department of Health and Human Services (DHHS).

Safety regulations and protective measures

Strictly adhere to all country-specific regulations for the prevention of accidents.

Ask your responsible laser protection officer for the safety regulations and protective measures to be observed, e.g. the accident prevention regulation "Laserstrahlung" [laser radiation] (BGV B2), § 5 registration of class 3 b lasers and/or requirements according the 21 CFR directive, paragraph J of the regulations issued by the Department of Health and Human Services.

It is dangerous to look directly into the beam of class 3B lasers.

The accessible radiation of class 3b laser systems is dangerous to the eye and potentially dangerous to the skin.

Be careful in aligning the sample and configuring the measuring station. Reflections on the sample surface can be dangerous! Avoid the specular reflection of radiation, especially when aligning the sample.

The laser light reflected by strongly scattering objects, e.g. a slip of paper, may reach a high intensity. Be careful when looking at your computer monitor, which stands next to the measuring station, as the light that is irradiated from one side may be injurious.

Make use of the existing safety devices!

Always use the shutter to lock the laser before replacing the sample. **It is strongly recommended to use a laser safety cabinet** with an interlock function to shut down the laser when opening the box. Ask the Nanofilm team for more information concerning laser safety measures.
If you have a special enclosure, keep its shutters closed for regular use.

Wear laser safety glasses!

Safety glasses help to reduce the laser intensity, especially for the diffuse scattered reflections from a sample. Choose the appropriate safety glasses for your laser type.

Ultraviolet and infrared light

Lasers or lamps can produce high-intensity ultraviolet or infrared light, which is invisible to the human eye.

Mechanics

Do not touch any of the moving mechanical components!

Do not move or touch any of the measuring system's mechanical components during the measuring process. Do not place any obstacles in the travel path of the mechanical components, e.g. XY-stage or goniometer. Do not reach into the goniometer's scissor mechanism.

XBO lamps

The high internal pressure of the XBO lamps incurs the risk of explosion when hot or cold.

Always use the appropriate protective covers for storing and handling the XBO lamps. If you install or remove the lamps without their protective covers, you should always wear protective clothing (a mask with neck protector and leather gloves with wrist protector).

SE box

The enclosure of the SE box should be opened by skilled personnel only.

The case should only be opened from the top. Any adjustment should be accomplished from the top. **Never** bend down so that your eyes are in the same plane with the lamp.

MW box

The enclosure of the MW box should be opened by skilled personnel only.

The case should only be opened from the top. Any adjustment should be accomplished from the top. **Never** bend down so that your eyes are in the same plane with the lasers.

General remarks

Make yourself familiar with the position of the emergency power-off switch.

Before connection, please check, whether the supply voltage indicated on the type label complies with the local power supply. If not, the measuring station should under no circumstances be connected to the power source!

The system should only be connected to an approved grounded socket. Any extension cables have to comply with the VDE regulations.

The measuring station should only be operated under proper technical conditions. Any trouble that might affect safety has to be eliminated immediately!

Nanofilm Technologie is not responsible for any damages resulting from an improper handling of the instrument!

Index

Date: July 15th, 2005
Software version: 2.05

The following symbols are used in these operating instructions:

General remark.

Important remark. The non-observance may cause incorrect results or damages to the instruments!

1. Principles of nulling ellipsometry

Ellipsometry is a very sensitive optical method, used for about a hundred years to derive information about surfaces. It makes use of the fact that the polarization state of light may change when the light beam is reflected from a surface.

If the surface is covered by a thin film (or a stack of films), the entire optical system film+substrate influences the change in polarization. It is therefore possible to deduce information about the film properties, especially the film thickness. The name ellipsometry implies that it has something to do with an "ellipse": the elliptical state of polarization, where the electrical field vector travels along an ellipse when observed at a fixed point in space, is the most general state of polarization.

The basic components of an ellipsometer are: a light source, some optical components to modify the polarization and a detector. By using imaging technology, one can extend the classical ellipsometer to a new form of visualization tool or a microscope with extreme sensitivity for thin films.

1.1. Polarisation of light

Light is a electromagnetic wave. To describe light one considers the strength and direction of the electric field E, because this has a stronger interaction with matter than the magnetic field. For monochromatic light, at a point in space E can be resolved into three independend harmonic oscillations along a x,y,z-coordinate system.

If the light wave is a plane wave that travels along the z-axis, the E vector is always orthogonal to z, thus it can be described by two harmonic oscillations along x and y. These oscillations have the same frequency, but generally different amplitude and phase. As a result, at a fixed point in space the E vector moves along an ellipse. The behaviour with time of a vector field at a fixed point in space is called polarisation.

Thus, the most general polarisation of (monochromatic) light is elliptical. If the phase of the x and y oscillation is equal, the resulting ellipse degenerates into a straigt line. If the phase difference is +/-90° the ellipse becomes a circle. Thus, the linear and the circular polarisations are limiting cases of the general elliptical state. For all other phase differences, a "true" ellipse evolves.

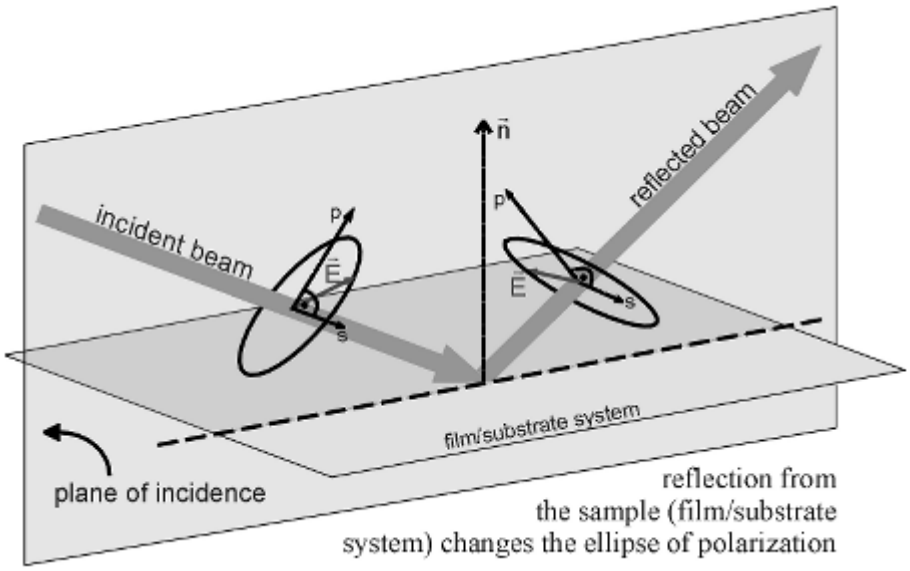
1.2. The proper coordinate system

If a light beam is illuminating a surface under obligue incidence, a plane can be defined by the wave vector k pointing into the direction of travel of the light and the surface normal n. This is called the plane of incidence.

It is now common to define the x and y direction in such a way, that x is parallel to the plane of incidence and y is perpendicular. These directions are referred to by the letters p (=parallel) and s (=vertical) which replace the x,y notation. Thus, the electric field E are resolved into its p and s component.

1.3. Reflection at surfaces

The light is reflected by the surface(s) of the sample. The sample may constitute a complex optical system with various layers of different optical properties. Multiple reflection at the interfaces of the layers superimpose to finally form the reflected light wave with an altered state of polarisation. In particular, the p and s components will undergo different overall phase shifts and also exhibit different reflectivities. Thus, the form and the size of the ellipse of polarization is changed.



Schematic process

This change again is a measure of the properties of the optical system (sample). The incident and reflected E vectors are connected by the reflection matrix R of the sample:

$$\begin{bmatrix} Ep,out \\ Es,out \end{bmatrix} = \begin{bmatrix} Rpp & Rsp \\ Rps & Rss \end{bmatrix} \begin{bmatrix} Ep,in \\ Es,in \end{bmatrix}$$

The concept of ellipsometry is to measure the change of polarization state of the light wave to obtain information about the sample (the matrix R). Note that there are many different ways to do ellipsometry, with the nulling ellipsometry descibed below being only one possibility.

1.4. Optical components used for ellipsometry

The main optical components used in most types of ellipsometers are polarizers and retarders.

A polarizer is a component that produces light of a special state of polarization at the output. Especially linear polarizers are very common components. They work by suppressing on component of the incident light, thus allowing only the other component to pass. By rotating such a polarizer, one can produce from unpolarized incident light a beam of linear polarized light with a direction of polarisation corresponding to the angle of rotation of the axis of the polarizer.

When the incident beam is already polarized, the transmitted intensity will depend on the amplitude of the component of E along the axis of the polarizer. In this case the polarizer is called an analyzer because it allows one to measure the ratio of p and s component. Note that two linear polarizers at an angle of 90° do not transmit light ("crossed polarizers", "no transmission" typically means a background of 10-6 remaining).

Besides the polarizers there are optical retarders. They are used to shift the phase of one component of the incident light. A typical retarder is a "quarterwave plate" which has a "fast" and a "slow" axis leading to a phase shift of 90° for the components of E along these axes. Depending on the orientation of the quarterwave plate it transforms the ellipse of polarisation, e.g. linear polarized light into circular polarized light when set to 45° with respect to the linear polarisation axis. With a not very strict nomenclature these retarders are often called compensators, as we also will do.

For the following it is important to understand that the combination PC of a linear polarizer P and a quarterwave compensator C in rotatable mounts can act as a variable polarisaton filter that can generate every desired elliptical state of polarization at the output (provided equal s and p amplitude at the input).

1.5. Nulling ellipsometry

When linear polarized light with an axis pointing somewhere but not along s or p direction is incident on the sample, the reflected light will in general exhibit an elliptical state of polarization. The other way around, the same elliptical state of polarisation (but with reversed sense of rotation) incident on the surface will generate a linear polarized reflection. More general, using the PC combination from above we can always find an ellipse that produces an exactly linear polarized reflection (if the sample is not depolarising).

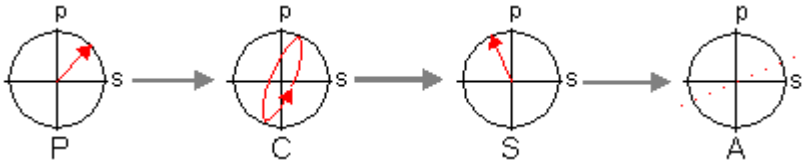
This has a nice consequence: we can easily detect this particular state by using a second polarizer as an analyzer in the reflected beam. For a linear polarised beam it is possible to extinguish the beam by setting the analyzer to a 90° position with respect to the axis of the linear polarisation. Doing this is called "finding the Null" or "nulling". In practice this is equivalent to finding a minimum in the signal of a photodetector.

Thus we have a recipe for a nulling ellipsometer in PCSA arrangement:

Let light pass thru a PC combination, while recording the angular setting of P and C.

Change P and C in such a way that the reflection from the sample S is linear polarised.

Use a photodetector behind an analyzer A to detect this as a minimum in signal.



Iterative routines can be found that allow one to actually find the right angle settings for P,C and A to fullfill the Null condition. Especially, one mostly uses the so-called "fixed compensator nulling scheme" which means that the compensator is fixed at a certain angle and then P and A are rotated. It can be shown that a rotation of P followed by a rotation of A while keeping P at its minimum signal position leads to a Null.

This procedure has to be repeated iteratively to obtain the desired accuracy. One advantage of nulling ellipsometry is the fact that one can measure angles instead of light flux, thus partly avoiding problems of the stability of the light source or non-linearity of the detectors.

1.6. Optical modelling

For isotropic materials, where R is diagonal (Rsp,Rps=0), one defines two so-called ellipsometric angles describing the ratio of the complex reflection coefficients Rpp and Rss, which is actually measured by the ellipsometer:

$$\frac{Rpp}{Rss} = \frac{|Rpp|}{|Rss|} Exp\left[i\left(\delta_{pp} - \delta_{ss}\right)\right]$$

$$\tan \Psi = \frac{|Rpp|}{|Rss|}$$

$$\Delta = \delta_{pp} - \delta_{ss}$$

The meaning of is an angle whose tangent gives the ratio of amplitude change for the p and s component, while denotes the relative phase shift of the p and s component upon reflection.

The result of nulling is a set of angles P,C and A. There are formula that relate these numbers to the ellipsometric angles, thus the reflection matrix R. Symbolically:

However, most people are not interested in R itself. Moreover, they want to know physical quantities of the sample under examination, for example the thickness of a film on a substrate. In general it is not possible to calculate the thickness or whatever directly from the ellipsometric angles, because the formula that describe R as a function of these parameters are complicated and can not be inverted (exept for special simple cases).

Therefore, one has to develop the optical model (i.e. the formula of as a function of the parameters) and fit the output of the model until it equals the measured values of . In the term of the example, one has to change the film thickness in the model until the resulting values of resemble the measured data. This can be a tedious and complicated task, especially if more than one parameter has to be deduced. The optical modelling can be regarded as the most critical point in ellipsometry.

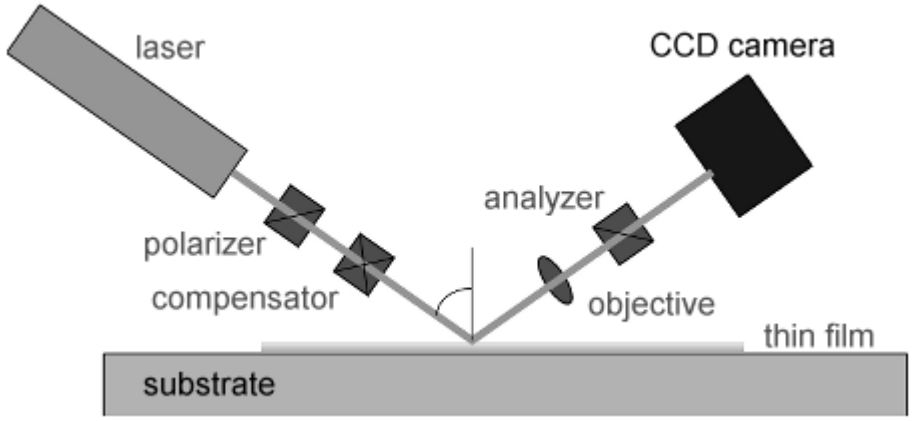
As one can see above, a single nulling can lead to two measurable real quantities. Thus it is in principle possible to measure e.g. a complex index of refraction, or the real index of refraction plus a film thickness or another combination of two real numbers (if the system is "well-behaved"). However, often one needs to measure more than this, e.g. 2 thicknesses plus two refractive indices for a double layer system. To accomplish this task one needs to increase the number of independend measurable quantities. This can be done for instance by doing multiple-angle-of-incidence measurements.

Another way is to measure at different wavelength, where each wavelenght introduces a new unknown refractive index (due to dispersion) but providing two new values. This leads to spectroscopic ellipsometry.

However, even though all this may seem simple at first glance, it requires a huge mathematical apparatus and a lot of numerical calculus, together with experimental obstacles, so that finding of all unknowns for a multilayer system remains a very tricky task. Even more complicated it gets when the sample is anisotropic, thus R is not diagonal. Then the definitions of are not sufficient and have to be extented. This leads to Generalized Ellipsometry, which is far beyond the scope of this introduction.

1.7. Imaging Ellipsometry

To add imaging to an ellipsometer one mainly needs an objective and a spatially resolving detector, e.g. a sensitive CCD camera. The objective images the illuminated area of the sample onto the camera.

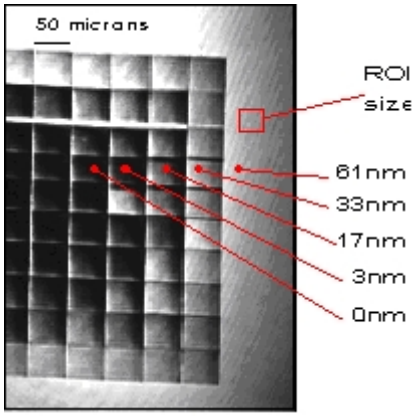


Schematic

As a consequence, areas that have different optical properties cause a different signal in the camera image. Especially those areas that are currently fullfilling the condition of the ellipsometric "Null", i.e. where the optical parameters are such that the light reflected is extiguished for that particular setting of P,C, and A, will appear dark in the image.

Where this condition is not met higher light intensities are incident at the detector, producing brighter image regions. Changing the settings of P,C, and A it is now possible to find the Null for these regions, which will cause the former dark areas to appear bright now. The main advantage of such an imaging ellipsometer is that the signal one gets is not the average over an entire laser beam spot on the sample, but spatially resolved to show the details of the sample.

This is very valuable, because often the sample will exhibit a lateral structure, wanted or unwanted. With the EP^3 one not only gets immediate qualitative information but also it is possible to restrict ellipsometric analysis to a particular region of interest within the field-of-view.



Spincoated photoresist on Si wafer. Illumination thru a square mask with a strong UV laser pulse lead to ablation of the film. By repeated shifting of the sample and subsequently applying a number of pulses, an inverted pyramid was produced.
The EP^3 allows one to set a region-of-interest and constrain ellipsometric analysis to that region. Therefore, the film thickness can be determined for each individual square. Note that the EP^3 image also reveals that the illumination of the mask is not homogeneous, as can be concluded from the brightness gradient within each square

Applying dedicated algorithms allows one to map the Nulls for the entire image, if necessary. This yields a two-dimensional map of the ellipsometric data that can be transformed into a thickness map of the sample, or other quantities.
Furthermore, the EP^3 makes use of a dedicated scanning technique that increases the depth-of-field, which otherwise would be a problem due to the inclined observation angle. It uses a motorized focusing mechanism to collect a series of images with different foci within the field-of-view. A digital image processing system then superimposes these images to generate on overall-focussed image.

2. Ellipsometry System EP^3

Ellipsometers are high-precision opto-electronic measuring instruments used for determining the optical properties of materials (refraction index, extinction coefficient, etc.) and for measuring the thickness of very thin surface layers.

The measurement principle is based on the fact that polarized light changes its polarization state (orientation and ellipticity) when being reflected from the surface of a sample. This change in polarization is used to calculate the optical constants of a material or to determine thickness and optical nproperties of a surface layer.

The ellipsometer system EP^3 is a computer-controlled precision measuring instrument for the measurement and graphical evaluation of layer thickness and optical properties. The "spectroscopic ellipsometry version" of the EP^3 includes an additional box with a monochromator to enable optical parameters to be determined over a wide range of wavelengths.

The system consists of the following components:

- an opto-mechanical unit with aluminum frame,
- an electronic control unit as a separate box,
- a multiple-wavelength box with external lasers (MW box) (*optional*),
- a spectroscopic-ellipsometry box with a monochromator (SE box) (*optional*),
- a Personal Computer with control and evaluation software as well as
- an emergency power-off switch that has to be connected to the control unit and placed within an easy access of the ellipsometer.

2.1. Components

Opto-mechanical unit

The opto-mechanical unit consists of the following components:

– motorized goniometer (mechanics to change the angle of incidence)
– Internal Laser
– Spectroscopic light source (SE box with external laser) (*optional)*
– Multi Wavelegth light source (MW box with external lasers) (*optional)*
– flip mirrors (*optional*)
– attenuator, polarizer, compensator, analyzer
– focus scanner with objectives
– camera
– alignment sensor
– sample holder and/or alignment stage (*optional*)

Electronic control unit

The electronic control unit controls all movements and signal processings in the opto-mechanical unit as well as the video streaming. It connects the opto-mechanical unit with the PC and builds the link between the measuring instrument and the control and evaluation software.

Spectroscopic-ellipsometry box (*optional*)

The spectroscopic-ellipsometry box (SE box) is an optional lightsource of the system.

It includes a Xenon lamp and a monochromator with 48 interference filters. The SE box is connected to the laser goniometer arm by means of a multi mode fiber optic cable.

Multiple-wavelength box (*optional*)

The multiple-wavelength box (MW box) is an optional lightsource of the system.

It includes lasers of different wavelengths and is connected to the laser goniometer arm by means of a single mode fiber optic cable.

Stand-Alone setup (*optional*)

The Stand-Alone design integrates the opto-mechanical unit, electronic unit, optional spectroscopic ellipsometry box or multi wavelength box, alignment and xyz-stage and the emergency stop button into one box without any disturbing cables and open mechanical parts.
With the dark box, the interlock function (laser shuts down when opening the box) and the emission lamp (lights when laser is on) this setup fulfils all common safety regulations to prevent injuries by laser light.

Fig. 2.1-1

Laser safety cabinet (*optional*)

The laser safety cabinet is an optional box with emission lamp and interlock to prevent injuries by laser light.

It is strongly recommended to use a Stand-Alone setup or a laser safety cabinet to avoid any injuries by laser!

2.2. Control and evaluation software *EP3View*

The *EP3View* software runs on Windows 2000® and Windows XP® operating systems and is designed for:

– controlling the measuring instrument.
– logging the measured values.
– evaluating the measuring results.

2.3. Connection diagram

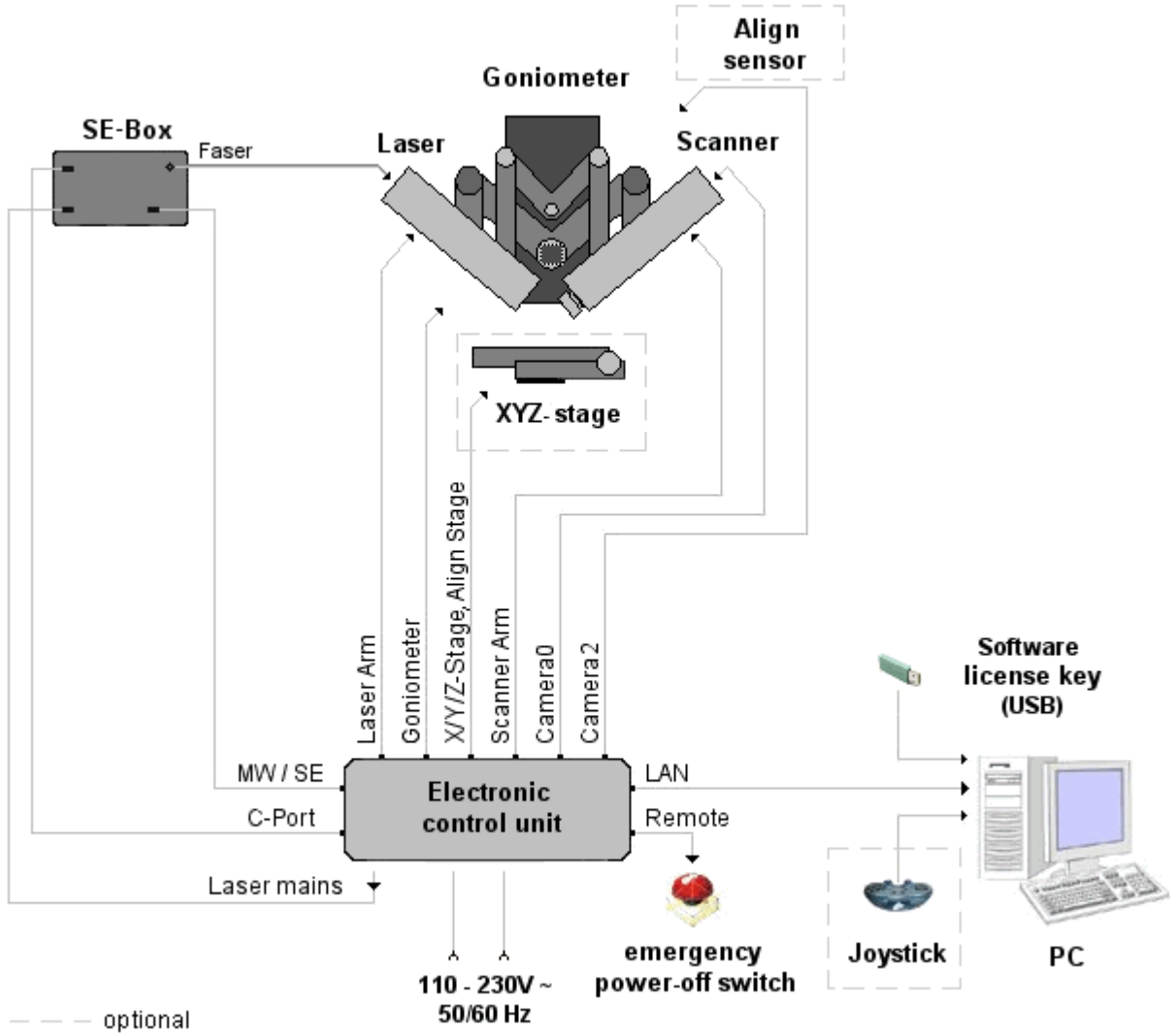


Fig. 2.3-1

3. Start-up

3.1. Unpacking the measuring-station components

- Remove the packaging and the transport protection from the instruments.

  After unpacking, immediately check the measuring-station components for possible visible external damages.

- Remove the upper, lateral screws from the transport box.
- Take off the transport box cover.
- Remove the protective padding material.
- Take the EP^3 out of the transport box and put it into the desired place.

  The EP^3 should be placed on a rigid, robust table (1000 × 600 mm). Due to the movement of the goniometer arms during measurement, the measuring station may require a space of 1 m in width.

- Place the electronic control unit, the emergency power-off switch, the monitor, the computer keyboard, and the joystick close to the measuring station.

  To avoid vibrations, the PC and Keyboard should be put on a separate table.

- Place the SE box on a stable ground.

  Avoid unnecessary transport of the SE box.

- Place the MW box on a stable ground. The MW box should **not** be positioned on the electronic control unit.

  Avoid unnecessary transport of the MW box. Bumps and dislocation can influence the adjustment of the mirrors inside the box and, thus, affect the laser intensity at the fiber output.

3.2. Setting up the Measuring Station

- Remove the transport lock from the goniometer.

Fig. 3.2-1

- Remove the styrofoam material from the goniometer.

Fig. 3.2-2

The goniometer arms can be moved by exerting slight pressure on the motor.

Never put your hands on the mechanics when the system is on or when you move any mechanical parts.

3.3. Connecting the measuring-station components

All connecting cables and sockets are labeled according to their purpose in order to avoid any misconnection between the individual components.

- Connect the SE box to the electronic control unit.
  Use the cables with the appropriate labeling to connect the following ports:
  - "C-Port" (connect to Laser or MW)
  - “Mirror, Filterwheel"
- Connect the fiber output of the optional SE box with the FC plug of the laser goniometer arm.
- Connect the fiber output of the optional MW box with the FC plug of the laser goniometer arm.

  Tighten the plug in the socket as far as it will go, but do not overtighten, as this might cause maladjustment of the output coupler.
- Connect the goniometer to the electronic control unit.
  Use the cables that are labeled accordingly and connect the following ports:
  - "Goniometer"
  - "Camera0"
  - "Laser arm"
  - "Scanner arm"
  - "Camera2"

  Use a cable tie to strap the cables on the backside of the EP^3.

  When mounting the cables leading to the goniometer arms, please make sure that they are not made alive at the end positions of the goniometer arms.

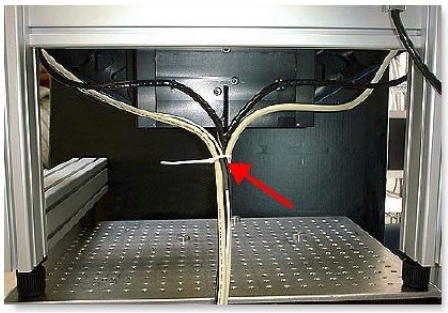


Fig. 3.3-1

- Connect the emergency power-off switch to electronic control unit.
  For this purpose, please use the control unit's "Remote" connector.

  Make sure that the plug is fastened tightly.

- Connect both line cords!
- If required, connect the XYZ-stage and the ALS alignment stage (see chapter "Annex/Accessories").
- Use the enclosed LAN network cable (cross link) to connect the PC network adapter to the electronic control unit.
  – connection designation on the electronic control unit: LAN.
  – connection designation on the PC (if supplied by Nanofilm): EP3.

Fig. 3.3-2

Fig. 3.3-3

If the PC is not included in the delivery of the measuring station, an Ethernet adapter with RJ-45 connector must be installed in the computer to be used.

To connect the computer to an existing local network, a second network adapter has to be installed.

For further details, please contact the responsible IT administrator in your company.

- Connect the monitor, the computer keyboard, the mouse, and the joystick (if provided) to the measuring-station PC.
- Plug the dongle (software license key) into a free USB port of your PC.

- Insert the objective carefully into the goniometer arm on the right.

Fig. 3.3-4

- Connect the power plug to the local power supply (100 to 230 V, 50/60 Hz).

The power voltage is chosen automatically.

- Locate the emergency power-off switch at easy accessible place.
- Release the emergency power-off switch.

To release the emergency power-off switch, pull out the red control button!
As pulling out the control button could be somewhat difficult, do not hesitate to apply a higher force.

Computer ports

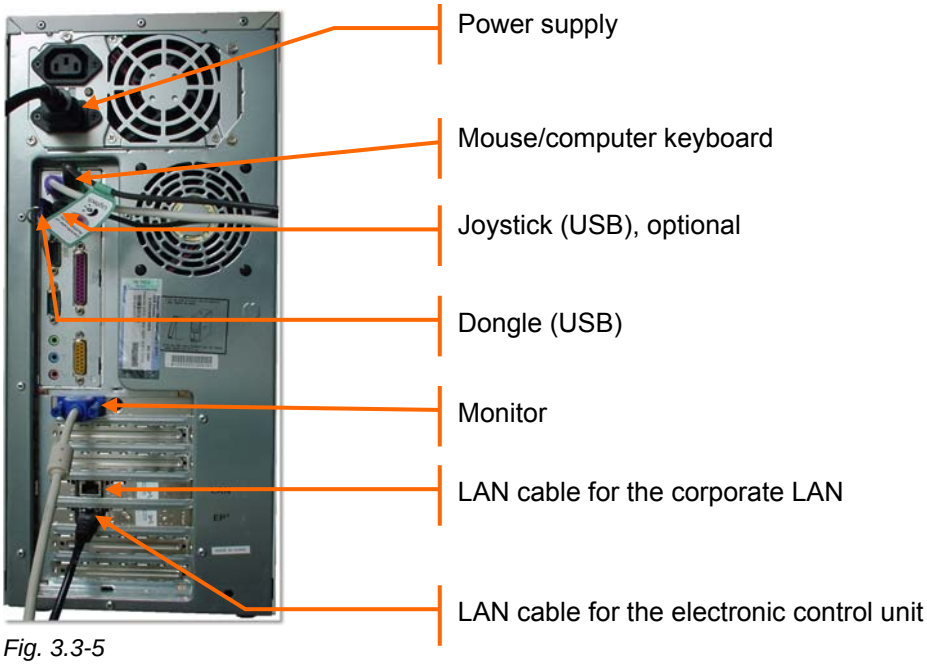


Fig. 3.3-5

3.4. Software

If the PC for the measuring station is provided by Nanofilm, it will be fully configured with the Windows XP prof.® operating system and the control and evaluation software.

To launch *EP3View*, a **LabWindows/CVI** runtime library has to be installed. The ***LabWindows/CVI*** development environment for measurement and automation technology from National Instruments is the basis for the *EP3View* control and evaluation software.
The control and evaluation software includes the *EP3View* and program files as well as the *AnalysR* software from LayTec GmbH.

If the software has already been installed and the system shall be upgraded to the "Spectroscopic Ellipsometry" or "Multiple Wavelength" option, you have to copy the "user xxx" folder from the accompanying CD-ROM into the "c:\EP3View" program folder. The string xxx stands for the corresponding user name. The contents of the existing folder will be overwritten.

System requirements

The PC should have the following minimum configuration:

- 2.0 GHz Pentium processor or equivalent
- 512 MB RAM
- 32-bit true-color graphics adapter, 1280 × 1024 pixels
- CD-ROM drive
- 2 USB interfaces (dongle, joystick)
- 2 × 100 MBit Fast Ethernet network adapters (EP^3, corporate LAN)
- Windows 2000® (Service Pack 3 or higher) or Windows XP®
- Microsoft DirectX 8.1 for Logitech "Wingman" joystick (*optional*)

Installation

If *EP3View* is not installed on the PC or shall be reinstalled, please proceed as follows:

It is important to keep the order of the following points!

- Plug the dongle into a free USB port of the PC, if not already done.
- Turn the EP^3 and the PC on.
- Log on to the Windows2000® or WindowsXP® operating system as administrator.
- Deactivate the firewall.
- If reinstallation is required, you first have to uninstall the software (see chapter "Uninstall").
- If you want to update to the latest software version please backup all files before new installation.
- Close any running applications.
- Insert the installation CD-ROM into the CD-ROM drive.
- Launch the Windows Explorer and click on the CD-ROM drive.
  - The files on the installation CD-ROM are displayed.

Follow these steps to install DirectX:

- Launch the Windows Explorer and click on the CD-ROM drive.

– The files on the installation CD-ROM are displayed.

- Select the folder “directx 9”.
- Double-click the "dx90b_redist-multiling.exe" installation program.

– The "WinZip" dialog appears.

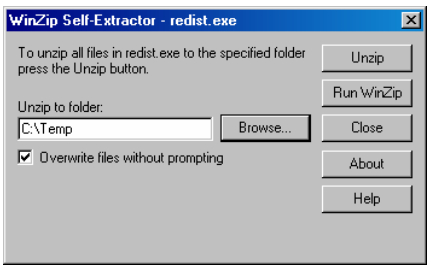


Fig. 3.4-1

- Select the folder C:\Temp to unzip.

– The files are unzipped in the folder “C:\Temp\DirectX9”.

- Double-click the "dxsetup.exe" installation program in the folder “C:\Temp\DirectX9”.
- Follow the on-screen instructions.

The latest drivers are available for download at the following locations:

Microsoft DirectX: *http://www.microsoft.com/directx*

Logitech Wingman driver: *http://www.logitech.com*

Follow these steps to install *AnalysR*:

- Launch the Windows Explorer and select the folder “LaytecAnalysR”.
- Double-click the "hldrv32.zip" file to unzip and run the usb key driver.
- Double-click the "LaytecAnalysR.exe" installation program.

– The "lt_sample_oem Installation" dialog appears.

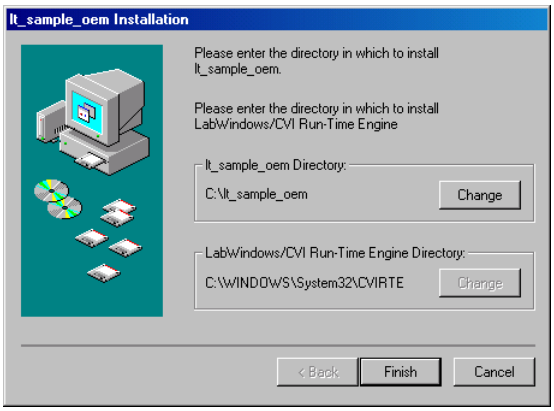


Fig. 3.4-2

- In this dialog, select the folder, where you would like the *AnalysR* software to be installed.

- Click the **Finish** button.

– The *AnalysR* files will be installed into the selected folder.

– During installation, the folder "It_sample_oem" is created in the Windows Start menu. Windows then displays a new program menu with the "Uninstall It_sample_oem" to enable you to uninstall *AnalysR*.

Follow these steps to install the LabView runtime 71 and IMAQ runtime engine:

- Launch the Windows Explorer and select the folder “LabView runtime 71”.
- Double-click the "LVRunTimeEng.exe" installation program.

– A dialog appears, when the installation was successfully completed.

- Press **OK** to finish this installation procedure.

– The folder "CVIRTE" for the **LabWindows/CVI** runtime library, where the files are installed, is created in the Windows System folder.

- Launch the Windows Explorer and select the folder “IMAQ runtime engine\vision70rte updated 701”.
- Double-click the "vision70rte.exe" installation program.

– There will be no message, except of an installation problem.

- copy the complete folder:

  C:\Program Files\National Instruments\Shared\LabVIEW Run-Time\7.0\PlugInControls

  To:

  C:\Program Files\National Instruments\Shared\LabVIEW Run-Time\7.1\PlugInControls

Follow these steps to install *EP3View2.x*:

- Launch the Windows Explorer and select the folder “EP3View V2”.
- Copy or unzip the Folder and subfolders “EP3View V2”

  To:

  C:\

– The file structure should be C:\EP3View V2\...

- For convenience set a shortcut on the desktop for all users:
- Create a shortcut of “EP3View Vxx.exe in the folder:

  “C:\EP3View V2\program\main”

  and move the shortcut to the folder:

  “C:\Documents and Settings\All Users\Desktop\”

– The “Shortcut to EP3View V2.exe” appears on the desktop of all users.

Copies from a CD-ROM result in write-protected files.
Remove all write-protection in the folder and subfolders of \EP3View V2

- Launch the Windows Explorer and select the folder “user xxx V2”.
- Copy or unzip the User-folder and subfolders to “C:\EP3View V2\”

– The installation is completed.

Uninstall

Follow these steps to uninstall *AnalysR* and the ***LabWindows/CVI*** runtime library:

- Select the "lt_sample_oem" folder from the Windows Start Menu and launch the uninstall program "Uninstall lt_sample_oem".
- You are now requested to confirm whether you are sure that you want to uninstall *AnalysR*.
- Press **Yes** to confirm.
- You are now requested to confirm whether you are sure that you want to uninstall the ***LabWindows/CVI*** runtime library.
- Press **Yes** to confirm.
- All program files are uninstalled and the "lt_sample_oem" folder with the entry "Uninstall lt_sample_oem" is removed from the Windows Start Menu.
- A dialog informs you that the program files have been successfully uninstalled.

Follow these steps to uninstall *EP3View* and *EP3Image*:

- To open the "Software Properties" dialog, select the options **Settings/Control Panel** from the Windows Start Menu and double-click the Software icon.
- Select the entry "EP3View" and click the **Remove** button to uninstall the programs. Repeat the same for "EP3Image".
- After having uninstalled the programs, close the "Software Properties" dialog.
- Launch the Windows Explorer and delete the folders that were created during installation.

If you do not want to delete the files created by the user, you first have to copy them to a removable disk or to an appropriate folder.

3.5. LAN Connection

The communication between the PC and the EP^3 is realized via LAN connection. If the PC is not provided by Nanofilm, you have to follow these steps for establishing the connection between the individual components of the measuring station:

The connection requires a crossover patch cable (Cat 5).
If you would like to use the same network adapter for an existing local network and the measuring station, Nanofilm does not guarantee for the proper function of the data transfer to the local network. If required, insert a second network adapter into the PC.

- Select the options **Settings/Control Panel** from the Windows Start Menu, double-click the **Network Connections** icon, right-click the corresponding LAN connection, and select **Properties** from the pull-down menu.
- Set the following parameters for the TCP/IP network connection:
  - IP address: 192.168.88.x
  - subnet mask: 255.255.255.0

  "x" represents the sum of the measuring station's serial number and 100. You will find the serial number on the rear panel of the EP^3 (EP3-y).

Example:
If your measuring station has the serial number EP3-004, the IP address of your measuring-station PC is 192.168.88.104. In this case, the measuring station has the IP address 192.168.88.4.

- Press **OK** to close the dialog. To apply the changes, the PC may have to be restarted.

– If the measuring station is on, you can use the ping command to check, whether the IP address of the measuring station is accessible. The command sends data packages of an adjustable size to a destination system and waits for the response. The response includes the number of milliseconds, which provides information about the connection speed (ping time).

Follow these steps to test the connection between the measuring station and the PC:

- Turn the electronic control unit on and wait approx. 30 seconds.
- Select **Programs** from the Windows Start Menu (and **Accessories**, if necessary) and click the **DOS-Prompt** entry.
- The console window "DOS Prompt" appears.
- Type in the following: *ping 192.168.88.y*

  "y" represents the serial number of the measuring station, i.e. enter *ping 192.168.88.4* for the exemplary serial number EP3-004.
- Press the return key (ENTER).

– As a result, several lines are output in the console window, e.g.

  Received response from 192.168.88.4: Bytes= ...

  In this case, the ping command was successful and the connection between the measuring station and the PC works.

  Otherwise, please contact your IT system administrator, as the ping command was not successful and the connection between the measuring station and the PC probably does not work.

- To close the DOS Prompt, enter *exit* and press the return key.

3.6. Installing the Joystick

Skip the following installation process if the delivered system does not include the joystick (*standard*).

The joystick must be installed, if the measuring station is provided with an XYZ-stage or the ALS alignment stage and if the PC does not belong to the scope of supply.

The PC provided by Nanofilm is already configured for the use of a joystick.

- Insert the installation CD-ROM into the CD-ROM drive.
- Launch the Windows Explorer and click on the CD-ROM drive.

– The files on the installation CD-ROM are displayed.

- Double-click the "DirectX81.exe" setup program "DirectX81.exe" to install Microsoft DirectX 8.1 or higher.
- Follow the on-screen instructions.

- Double-click the setup program "Wingman.exe" to install the Logitech® "Wingman" driver.
- Follow the on-screen instructions.

- Connect the joystick to a free USB port.

– The joystick is automatically detected and installed.

- Follow the on-screen instructions.

If a wireless joystick is connected but not detected, turn the joystick towards the receiver and press the receiver's "Teach" key.

- Change to the *EP3View* program folder, e.g. "c:\EP3View\program\".
- Double-click the "EP3joystick.exe" file to launch the program.

– The "EP3joystick" dialog appears to report that the joystick works properly.
The joystick movements are displayed in this dialog.

- Press **OK** to quit the dialog.

Fig. 3.6-1

3.7. Function Test

The following chapter helps you to record the proper function of the measuring station. Check the corresponding boxes after having successfully completed all of the described steps.

Follow these steps:

- Turn the EP^3, the PC and the SE box on.
- Log on to the Windows2000® or WindowsXP® operating system as Administrator.
- Launch the *EP3View* program.
- Log on to the program as an authorized user.
- Keep an Si wafer with SiO2 layer ready.

Test	Description	Test Parameter	Target value	Ok (value)
Online	• Communication PC – EP³	Online lamp	Green	○
Align Laser	• Put white paper (e.g. business card) on sample holder	Red spot	Red laser spot should be seen on paper	○
Laser	• Open Shutter	Spot	Single spot appears	○
	• Vary laser power		Spot appears brighter if power is increased	○
Multi Wavelength capability	• Each laser switched on individually	Spot	Each laser give a higher signal for ROI than the background	○
SE-Modul capability	• Put white paper on sample holder and switch between the wavelengths	Spot color	The colors on the white paper must correspond to the selected wavelengths (e.g. 589-yellow; 532-green)	○
Motorised Gonio-meter	• Click in goniometer panel • Enter 40	Goniometer setting / position	40	○
	• Enter 59		59	○
	Attention: For higher values the objective may touch the sample and/or the goniometer arms may touch the xyz-stage. Check movable endswitches to reach higher angles.			
Polarizer	• Click in polarizer panel • Enter 1000	Polarizer range	> 100, movement is uniformly	○
	• Enter -1000		< -100	○
Compensator	• Click in compensator panel • Enter 1000	Compensator range	> 60	○
	• Enter -1000		< - 60	○

Test	Description	Test Parameter	Target value	Ok (value)
Analyzer	• Click in analyzer panel • Enter 1000	Analyzer range	> 100	○
	• Enter -1000		< -100	○
XYZ – Stage / Joystick (if available)	• Switch on joystick • Vary velocity	Joystick	Translation stage moves faster / slower	○
	• Drive to x / y end position • Press zero button • Drive to inverse stop position	X x Y range	> 80 mm	○
	• Move z stage	Z- range	> 7mm	○
	• Move xyz-position back to center			
Alignment Sensor	• Put Si-Wafer on sample holder • Open “Live Image” • Press Align Button	Align sensor Spot and deviation indicator	Spot and deviation indicator appears and ROI signal stops	○
Motorised Alignment stage	• Press auto aligment	Live image	Spot moves to centre deviation indicator shows <0,02 and becomes green	○
Alignment stage	• Align manually	Live image	Spot moves to centre deviation indicator shows <0,02 and becomes green	○
Image	• Adjust z-stage (sample hight) • Press focus calib Button • Move focus scanner until sharp appears • Adjust focus calibration line to sharp line • Select focus tool in the live window, click into live window	Live Image	Laser spot centred in the live window Sharp line can be shifted by mouse-click	○
	Settings for test SiO2 on Si: • Goniometer: 54° • Polarizer: 50° • Compensator: 45° • Analyzer: 30° • Press “gain” • Press “Camera-Button” • Open “Map & Image Viewer” window	Image	Image appears sharp in *whole* region. If not, check that the correct Objective is selected	○

Test	Description	Test Parameter	Target value	Ok (value)
	• Set “gain” to 20 • Press “Coarse adjust” • Open Log-file window			
Measurement	• Execute Nulling 1 zone 3 times	Delta and Psi	Reproducibility of Delta and Psi < 0,05°	○
	• Execute Nulling 4 zone	Delta and Psi	Delta and Psi variation should not exceed +/- 5°	○
	• Load standard recipe “sio2_si.saf” • Load data from log-file to model • Double click • Press function “fit”	Fit-Value (Thickness)	Is calculated value correct? (also for MW, variable AOI)	○
	• Change angle of incidence • Execute Nulling 4 zone	Fit-Value (Thickness)	Deviation of thickness results should not exceed 2nm	○
	• Measure with all available wavelengths • Execute Nulling 1 zone	Fit-Value (Thickness)	Deviation of thickness results should not exceed 4nm	○

4. User Interface

4.1. EP3View windows

Main window

The purpose of the main window is to give access to imaging, scripts, data and optical modeling. It also contains the function tree which includes the measurement routines (scripts).
The main window contains the following elements:

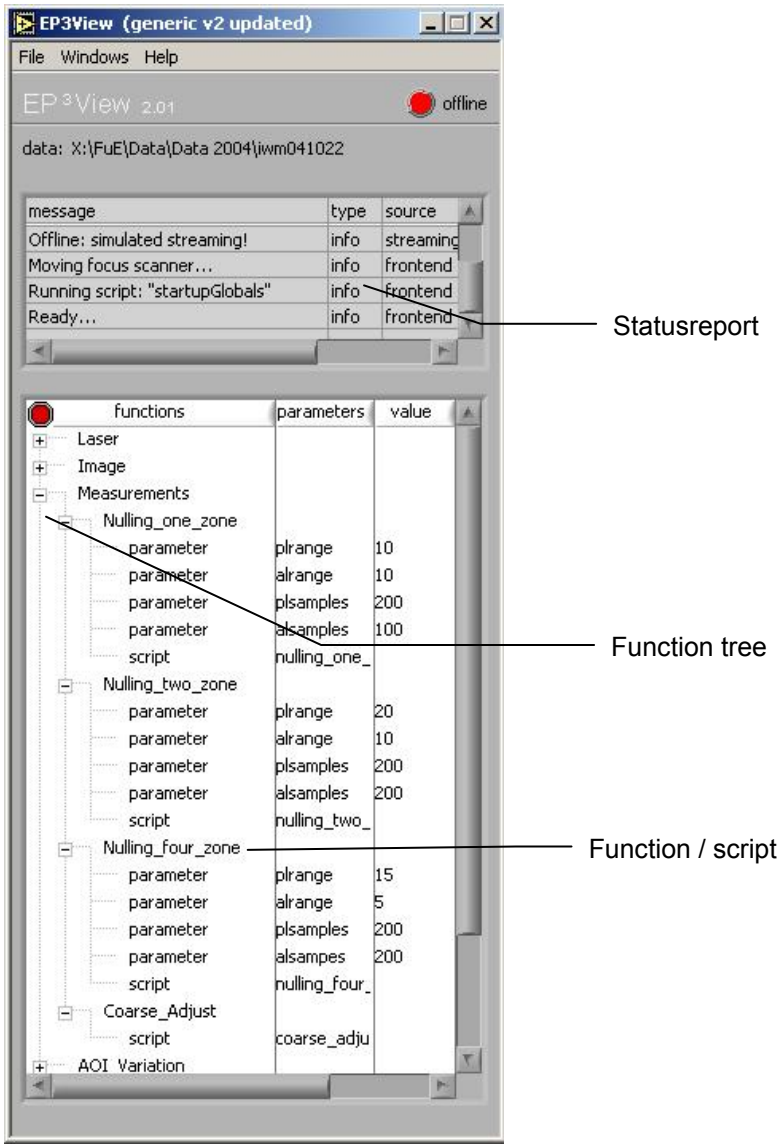


Fig. 4.1-1

“File” bar:

- “Open VI”
  Loads external subroutines, called “virtual instruments” (VI).
- “Change Data Path”
  selects the directory path.

- “Save Function Tree”
  saves the current function tree structure.
- “Exit”
  Ends the program

“Windows” bar:

The front panel windows remember their positions on screen.

- "Live & Control" window
  Control window for opto-mechanical elements of the EP3 and for displaying live video image
- "Map & Image Viewer" window
  for displaying the grabbed and focussed images or calculated 2D or 3D maps
- "Log Editor" window
  contains information and results of the measurement
- "Graph" window
  contains 2D table and 2D graphical representation of data
- "Model" window
  tab controls which are used for the optical modeling of the measurements
- "Mapping" window
  calculation of thickness and refractive index maps
- "Script Editor" window
  fields for editing and viewing EP³ scripts

Break button: the currently executed script is stopped

Modus of the EP³View Programm

- Online modus-green circle, measurements are possible
- Offline modus-red circle, only data-analysis is possible

Function Tree

The Function Tree is a fast and easy “one-button”-method to start scripts written in the script language “EP3Script”. Multiple pre-defined standard functions are included at delivery. This list can be extended easily with user-defined functions.
Left double-click to a function the starts the script that is given in the parameter list.
Important parameter for the function can be defined in the parameter list.
The most important scripts are displayed in Figure “Main window”. Detailed descriptions of the scripts are given in the Annex.

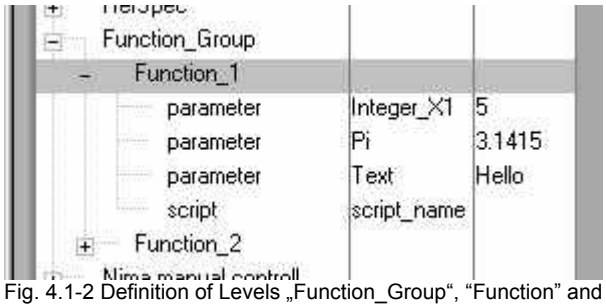


Fig. 4.1-2 Definition of Levels „Function_Group“, “Function” and “Parameter / Script” in the Function tree

Left click on the plus/minus signs opens or closes several function groups and double-click on the function executes the according script.


Break button: the currently executed script is stopped

Right click on the parameter list opens the window “edit tree item”, where type and value of the parameters can be changed or parameters can be defined or deleted. The parameter are set to the given value and format in the moment when the function is executed. Any former value is overwritten, but the variable can be re-defined in the script. Open the script in the “Script Server” to view or edit its functionality.

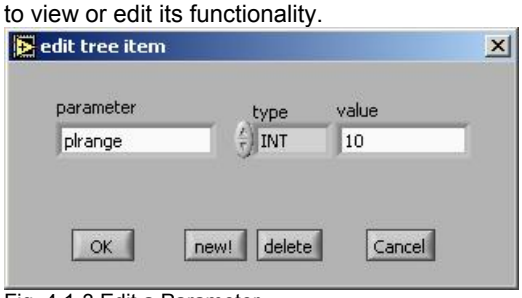


Fig. 4.1-3 Edit a Parameter


It is advantageous to define the parameter in the script once again, but do not change of the value. This avoids error messages “variable not found” if a script is executed manually from the Script Server Window. Use the variable definition without parameter, for example:
REAL plrange
// instead of “REAL plrange 3”

Right click on the script list opens window “edit tree item”, where script that shall be used for this function can be opened.

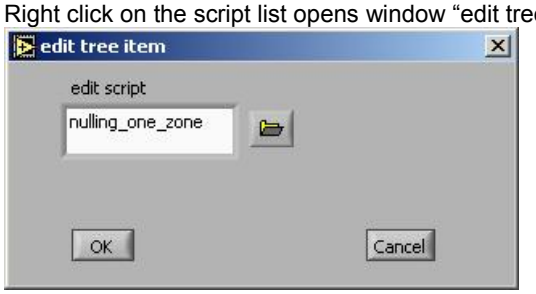


Fig. 4.1-4 edit a script name, or browse existing scripts


The name of scripts must be unique within one user!
Even if scripts are saved in different windows folders they must not have the same name.

Live & Control window

This window contains elements for the control of the hardware.

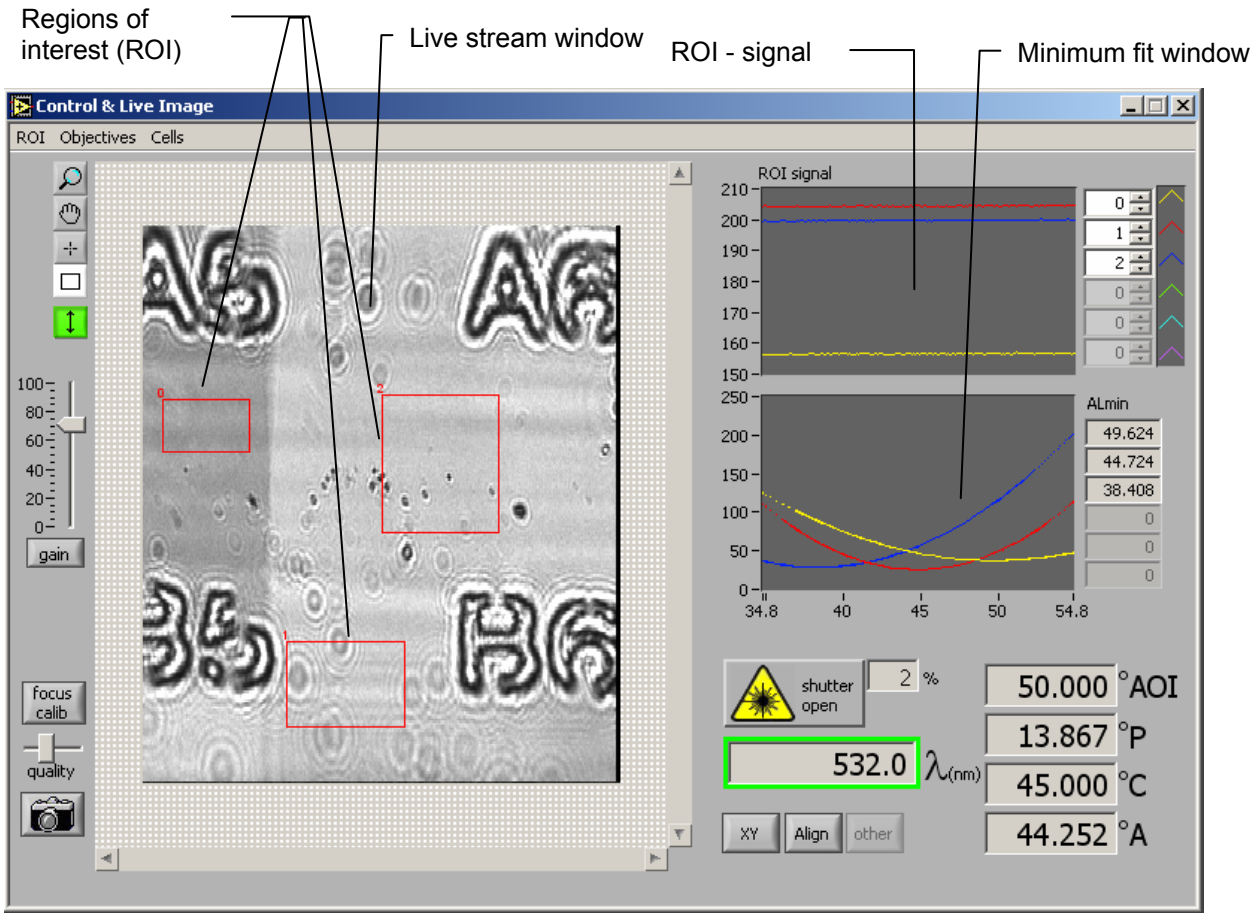


Fig. 4.1-5

“ROI” bar:

- “load ROIs”
  loads a file *.roi.
- “save ROIs”
  saves the active ROI as *.roi
- “load ROIs from defaults”
  loads a default file “..\user xxx\ ROIs*.roi”
- “save ROIs to defaults”
  saves the active ROIs as default file *.roi
- “delete ROI”
  the window “delete a roi”, where you can chosse the index of the roi which should be deleted

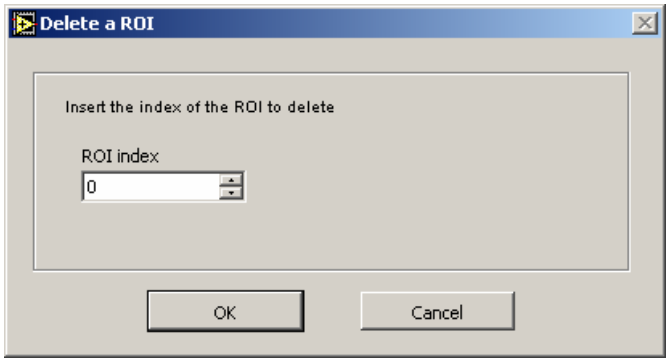


Fig. 4.1-6

“Objective” bar:
for example

- “10x” loads the parameters for the 10x objective

It is necessary to select the correct objective parameters for the used objective to get sharp images.
(See “…\user xxx\config\objectives.ini” and “objectives.txt”)

“Cells” bar:

- here you can choose you cell parameter set (internal angle and focus correction)

(See “…\user xxx\config\ cells.ini” and “cells.txt”)

Live Stream window

This window is displaying the live video image.
Once you calibrated the focus (see focus calibration) a click into the window will adjust the focus automatically for this position. The red rectangles represent the regions-of-interest (ROI) where the measurement is performed. You can choose up to 1000 regions of interest.

ROI signal (only indicator)

Displays the average signal intensity in the selected ROI in the "Live-Stream" window. The index of the ROI corresponds to the index of the ROI in the "Live-Stream" window and can be selected on the right side.

Minimum Fit window (only indicator)

Displays the minimum measured and fitted by a script.

Control elements

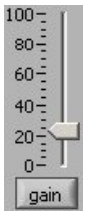
 zooms into the live window, zoom out with <shift>

 moves the active live window

 sets the sharp line to the selected point by moving the Objective Focus Scanner (do focus calibration first)

sets multiple Region of Interest or to change the size of already existing ROIs, set multiple ROI with <shift>

activates/deactivates the scaling function. Scaling is a geometrical correction which accounts for the non-vertical Anle Of View. It enlarges the live window y-size with the AOV.
Whith the scaling off the window size is constant, but x and y axis have different scaling factors. Scaling is switched off automatically at AOV>75°



Slider control adjusts the gain of the camera.
“Gain” button adjusts the gain of the camera automatically.

Image grab Control

defines the number of raw images to be added to a completely sharp image and thus the quality of the picture. The more raw images are taken the higher the image quality. Left position is lowest quality and one single grab of your live image is taken.

takes an image from the current sample, which is displayed in the "Live-Stream" window. The sharp line is moved automatically over the whole sample by moving the focus scanner. For the defined amount raw images are taken. The software adds all these raw images automatically to a single image completely sharp from edge to edge. It is displayed in the "Map & Image Viewer" window.

Focus calibration control

opens the focus window to move and calibrate the focus.

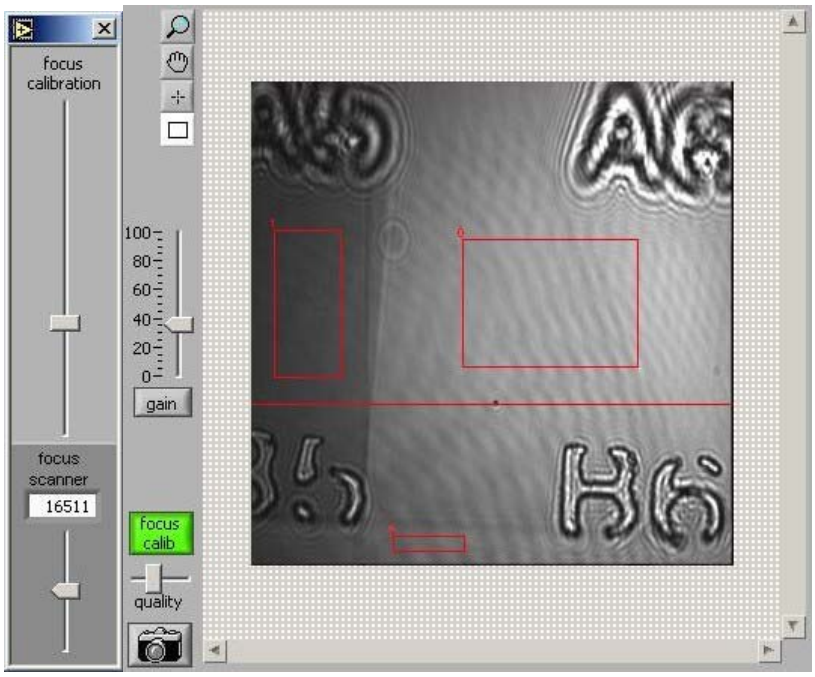


Fig. 4.1-7

With the focus scanner slider control you can move the objective forward and backward in order to get the sharp line in the live window. The indicator shows the current motor position.
The focus calibration slider control corresponds to the red line in the live window. To calibrate the focus move the red line to a sharp point in the live window. Dust particles on the sample may help you to find the focused line as well as structures on the sample.
Right click on the focus calibration control window to close it. The focus is now calibrated.

Angle of incidence

displays the angle of the goniometer (Angle of incidence) and left click opens the “AOI” window to change the angle of incidence.

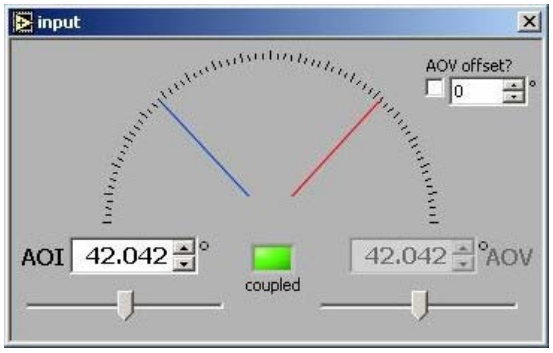


Fig. 4.1-8

Move the slider control of AOI to move the goniometer arms with different velocities or type a value in the window to move to a specified angle.

The input of higher values may cause a collision between the objective and the sample and/or between the goniometer arms and the XYZ-stage.

To move the scanner arm (AOV) separately press the “coupled” button. The AOV controls will appear bright and will be ready to use.
Right click on the control window to close it.

Polarizer

displays the angle of the polarizer and left click opens the “P” window to change the polarizer angle.

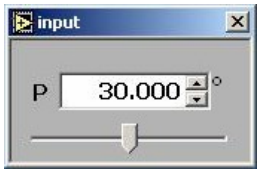


Fig. 4.1-9

Move the slider control of P to rotate the polarizer with different velocities, or type a value in the window to move to a specified angle.
Right click on the control window to close it.

Compensator

displays the angle of the compensator and opens the “C” window to change the compensator angle.

Move the slider control of C to rotate the compensator with different velocities, or type a value in the window to move to a specified angle.
For ellipsometric measurements a setting of 45° is recommended. For Brewster Angle Microscopy (visualization of thin-films on liquids) use 0°.
Right click on the control window to close it.

Analyzer

displays angle of the analyzer and left click opens the “A” window to change the analyzer angle.

Move the slider control of A to rotate the analyzer with different velocities, or type a value in the window to move to a specified angle.
Right click on the control window to close it.

Shutter

opens and closes the shutter

Laser Intensity

displays the relative laser intensity and left click opens the “Laser Intensity” window to change the relative laser intensity.

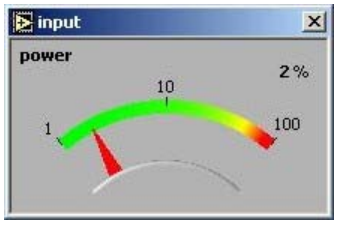


Fig. 4.1-10

Move the slider control to change the relativ laser intensity.

The laser intensity on the sample is controlled by the rotation of the attenuator. The lasers have a constant output intensity.

Right click on the control window to close it.

Wavelength selection

displays the current wavelength and left click opens the “Wavelength” window to select the wavelength (optional for MW or SE systems).

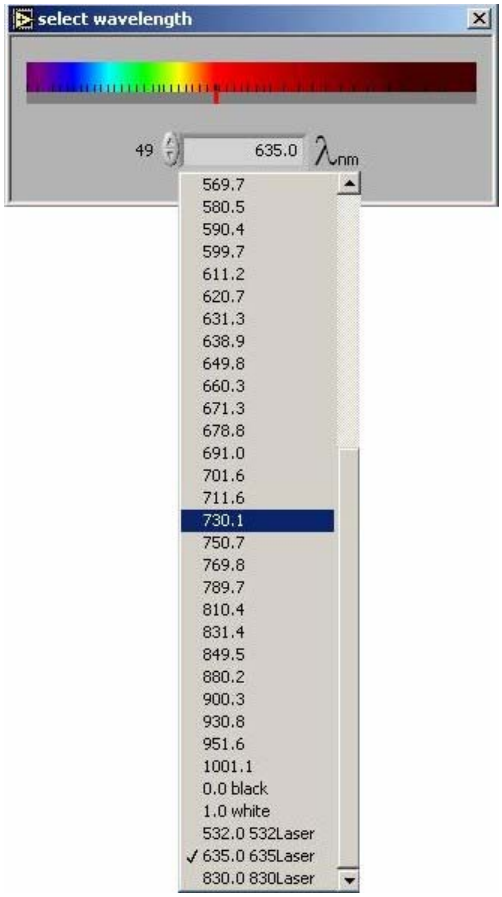


Fig. 4.1-11

Select the wavelength from the scroll bar.
Right click on the control window to close it.

X/Y stage control

opens the “X/Y-control” window (optional for systems with an automatic X/Y stage).

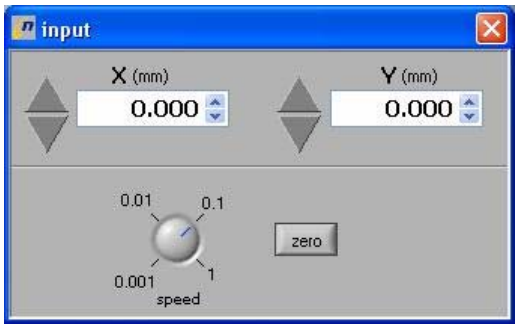


Fig. 4.1-12

Type the position to move to in the control window. Press “zero” to define current position as zero.
Right click on the control window to close it.

Alignment

opens the “Align” window. This window enables to align the sample. A misaligned sample might lead to erroneous results.

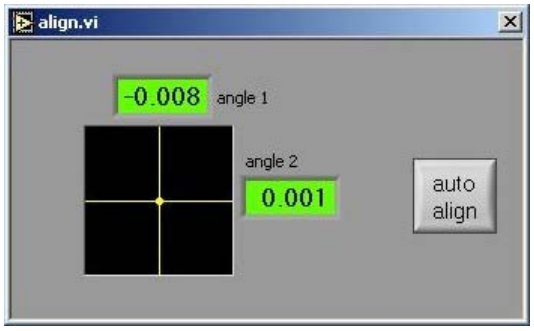


Fig. 4.1-13

By opening the align window the camera automatically switches to the align camera which is situated in the middle of the goniometer over the sample. A control round spot (reflected laser spot) is displayed in the "Live Stream" window.
Use the gain control to reset the gain of the alignment camera. Only the control round spot should be white (saturation level).

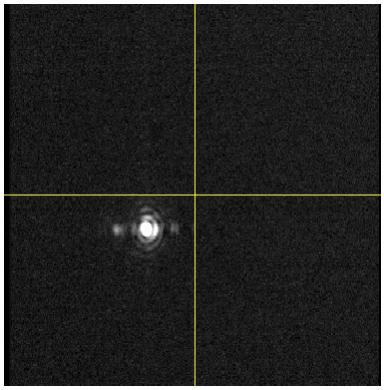


Fig. 4.1-14

It is possible to align the sample stage or the entire instrument.
Align the sample until the center of the spot is overlapping with the yellow cross-hair (+/- a few pixels). If no reflected beam is visible your sample is strongly misaligned or scattering. In this case you have to rely on the flatness of the sample on the sample stage (which could be aligned with a better sample). If the sample is misaligned by more than 1° (the laser spot is not visible) make sure that the instrument is well leveled with a spirit level. You can align the instrument by the screwing the passive damping or by the table. If you have a NPK design you can align the systems by the adjusting stands.
If the laser spot still is not visible in the align window look below the align sensor and you will see the reflection of the red align laser. Try to get the red spot into the hole (where the camera is located) by aligning the stage.
For measurements on liquid surfaces (trough applications) you have to align the whole system related to the surface of the liquid.

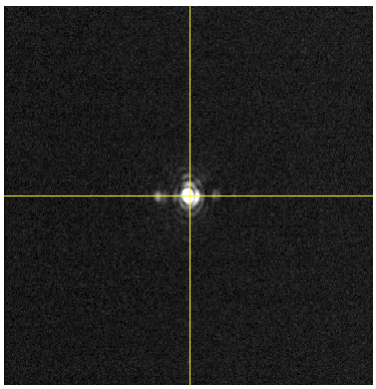


Fig. 4.1-15

If you have the Auto Align Stage ALS the button **auto align** is displayed. Click this button to align the sample automatically.
The current angles are displayed in the control elements.
Right click on the control window to close it.

Z-stage/lift control

ZS

opens the “Z -control” window (optional for systems with an automatic z-stage or z-lift). For systems with a motorized z lift at the goniometer this button is called “ZG”.

Fig. 4.1-16

Press the up/down buttons to move the z-stage/lift, by rotating the knob the speed can be varied.
Right click on the control window to close it.

Map & Image Viewer window

This window displays the grabbed or focussed images and the calculated maps.

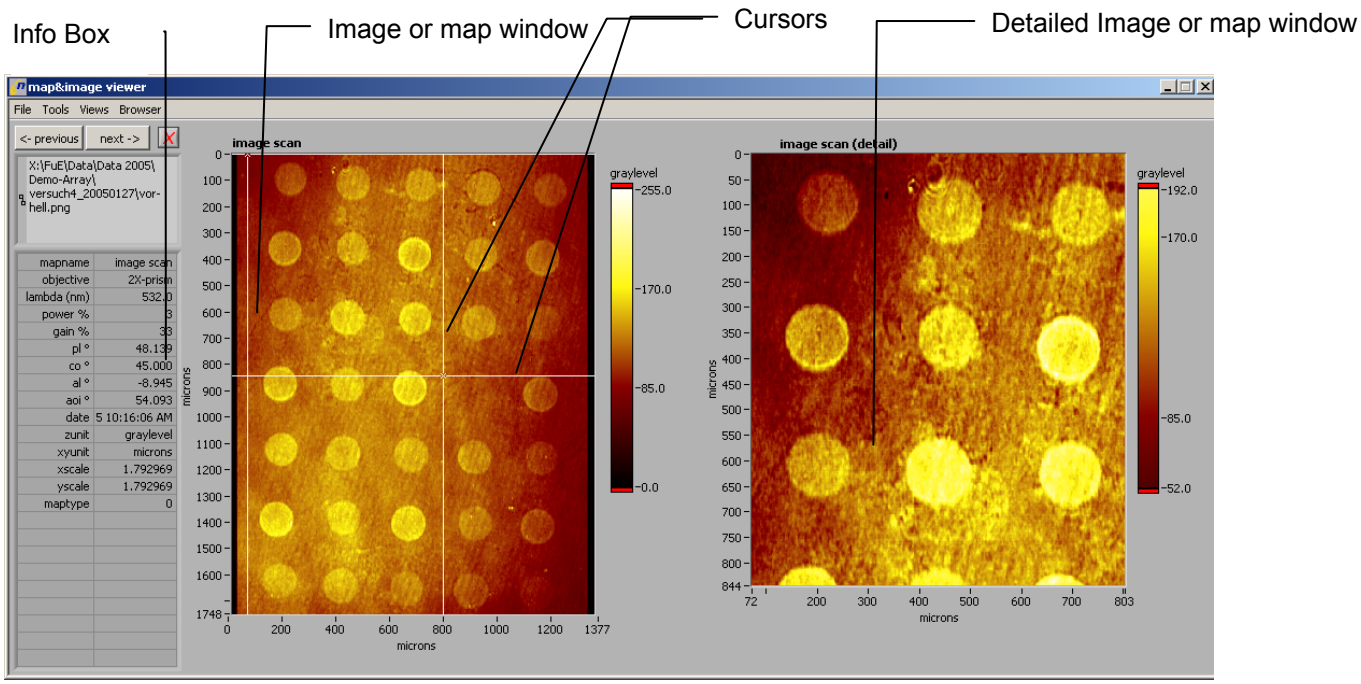


Fig. 4.1-17

<- previous | next ->

for fast switching between the images in the browser

deletes the currently displayed image

X:\FuE\Data\Data 2005\Demo-Array\versuch4_20050127\vor-deltamap.map

displays the data path, where the currently displayed image is saved

“File” bar:

- “load map or image”
  loads a map or an image
- “save”
  saves the currently displayed map or image
- “save panel bitmap”
  saves the whole map&image viewer
- “select image file type”
  you can choose between *.png; *jpg; *bmp or *.16bitTIFF, if nothing is chossen the images are saved as *.png

“Tools” bar:

- “Undo”
  undoes the last action
- “Background correction”
  - ➢ set BG — sets the currently displayed image as background
  - ➢ apply BG — applies the background to the currently displayed image
  - ➢ auto BG for new images — applies automatically the background correction to every new image

- “contrast”
  opens the window “contrast histogram” where you can change the contrast of your image/map by moving the green and yellow line

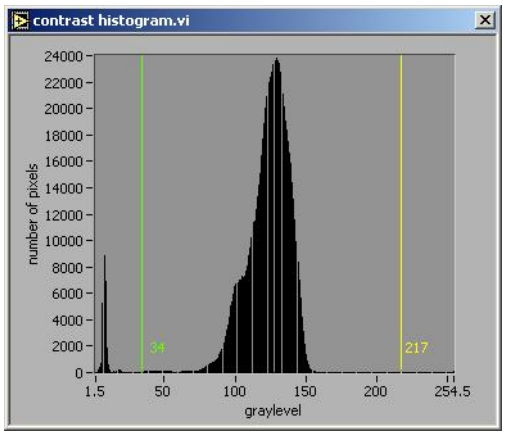


Fig. 4.1-18

- “crop to cursors”
  crops the entire image/map on the left side to the actual cursors position. With this function you will replace the entire image in the left window with the selected area in the right window.

- “Tilted plane”
  opens the window “tilted plane correction” to compensate gradients in vertical and horizontal directions in your image/map

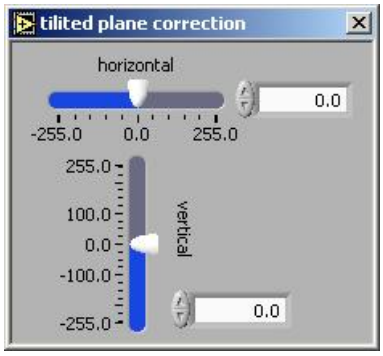


Fig. 4.1-19

- “math”
  opens the window “math” to correct images/maps with mathematical formulas

Fig. 4.1-20

- “Cut-off range to min/max Z-scale”
  first select a minimum/maximum value of the z-scale in the right image; by pressing this function all pixels out of the minimum/maximum range are set to the minimum/maximum value

- “profile”
  displays a profile of your image/map (detailed description see below)

“Views” bar:

- “set color map”
  opens the window “set color map” to select different color tables for your image/map

Fig. 4.1-21

- “set format/precision”
  opens the window “set format&precision” to select different formats and precisions for the z-scale

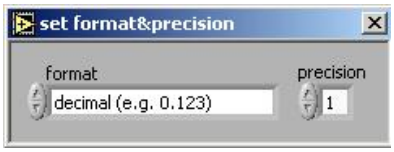


Fig. 4.1-22

- “autoscale Z (colors)”
  the z-axis is scaled automatically
- “3D Viewer”
  opens the window “3D map viewer” where the detailed image/map is displayed 3-dimensional (detailed description underneath)

“Browser” bar:

- “Show”
  opens the window “maps&images” where the last images/maps are displayed

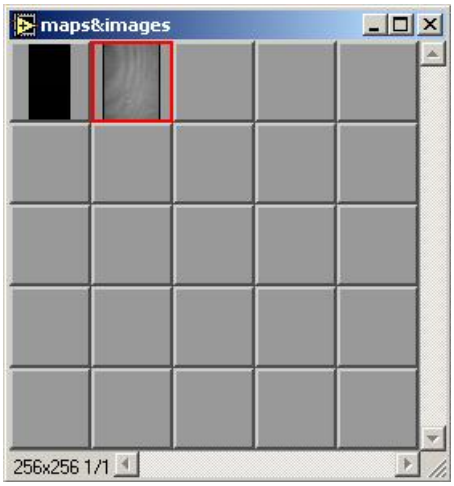


Fig. 4.1-23

- “delete selection”
  the selected image/map in the browser is removed from the browser
- “delete all maps&images”
  the complete browser is cleared

Image or map window

In this window your grabbed or focused image or your recorded map is displayed. The xy- scale is in micron and the z-scale depends on the measured values. Typically, for images the z-scale is in graylevel and for thickenss maps the z-scale is in nm.

Cursors:

The cursors can be moved by holding left click. With these cursors you can select a part of your whole image/map, which is directly displayed in the right image or map window (detailed).

Info Box

In this box information about the actual image/map is displayed, e.g. the used objective for the image, the optical conditions of the measurement etc.
This information is saved as text file with the name of the according image as *.info file.

Detailed image or map window

This image shows the actual selected part of the whole image. The axis is set automatically to the actual values.

Profile

This window can be opened at “Tools” – “Profile” to show a profile/linescan of your image/map.

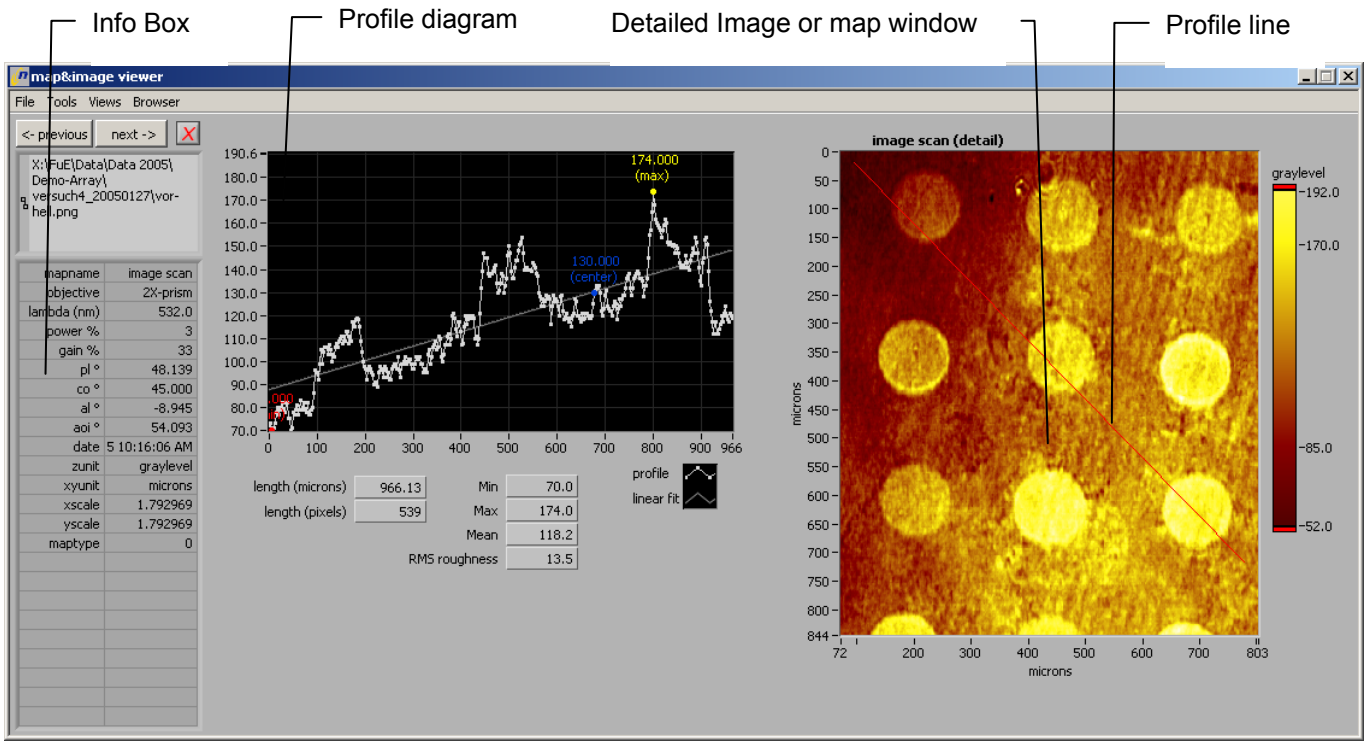


Fig. 4.1-24

Detailed image or map window

This image shows the actual selected part of the whole image. The axis is set automatically to the actual values.

Info Box

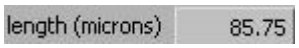
In this box information about the actual image/map is displayed.

Profile Line

The profile line is drawn by holding left click.

Profile diagram

In this window the profile from the profile line is plotted. The x-axis is the length of the line in microns, the y-axis depends on measured values. Minimum and maximum values and the center of the whole line are marked. Values are displayed in the diagram. Furthermore, a linear fit of the profile line is plotted.

	value of the length of the profile line in microns
	the value of the length of the profile line in pixels
	minimum value of the profile line
	minimum value of the profile line
	mean value of the profile line
	surface roughness of the profile line
	to select color, style etc. of your plotted data

3D Viewer

This image can be opened at “Views”-“3D Viewer” and displays the detailed 3D image/map.

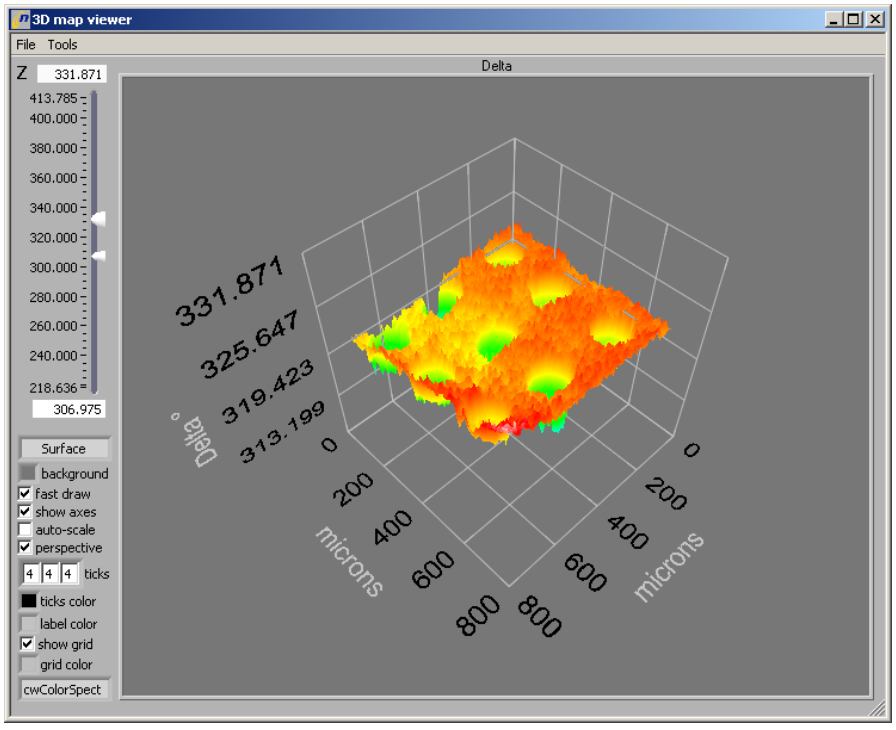


Fig. 4.1-25

“File” bar:

- “save panel image”
  saves the complete window “3D map viewer” as *.png file.
- “Load 3D image”
  loads a file *.3D
- “Save 3D image”
  saves the entire graph including lights, view point and the image data as *.3D

“Tools” bar:

- “ligths”
  opens the window “3D lights” where you can change the lighting of your 3D map

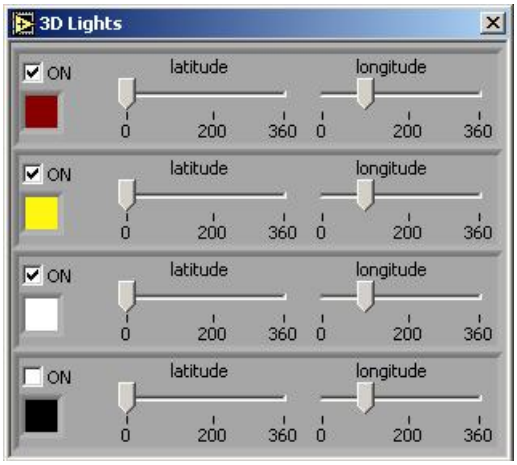
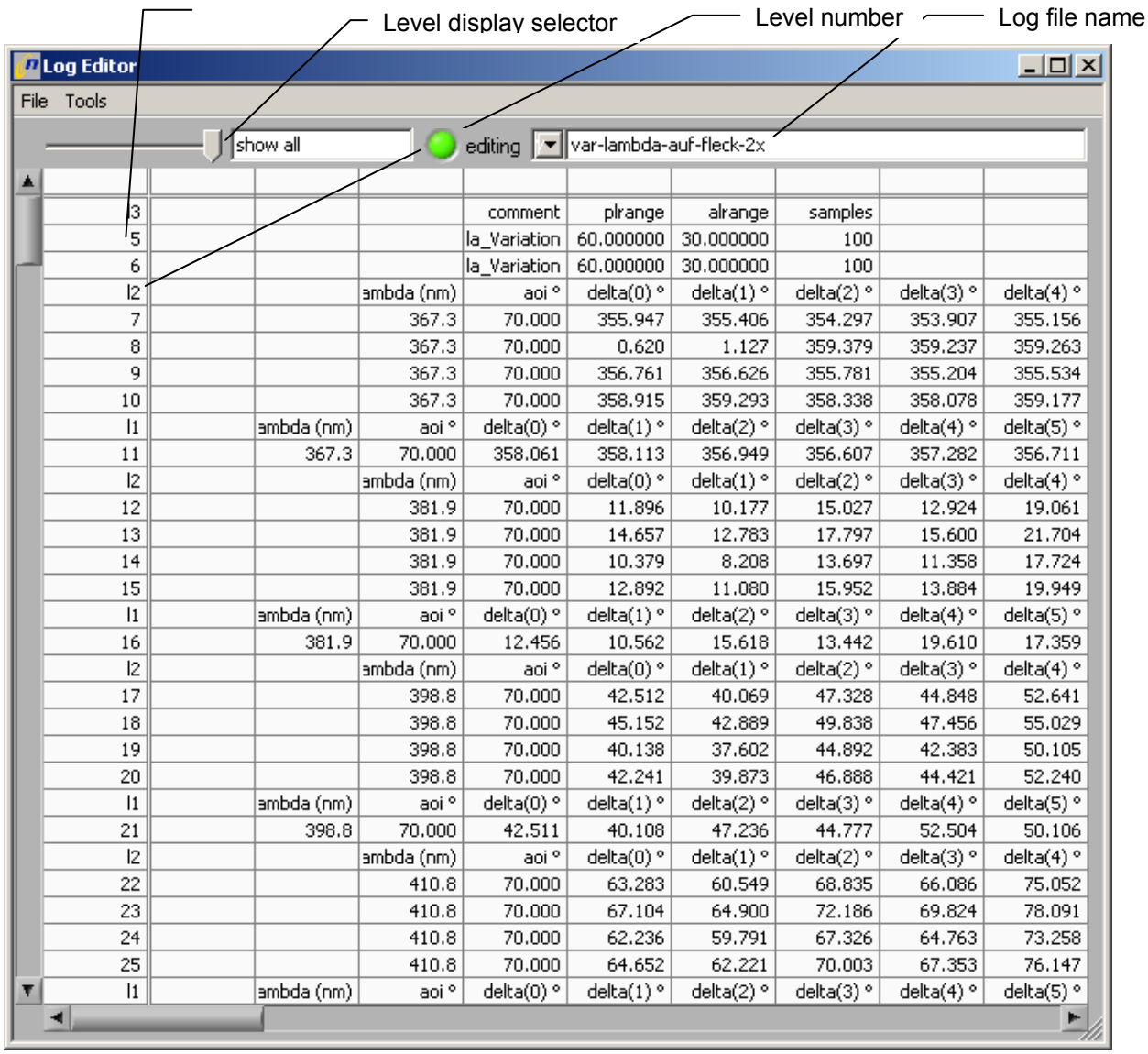


Fig. 4.1-26

Log Editor window

This window displays the data and results of your measurements.
Please note the changes since Version EP3View V2.05! The logfile is automatically created and saved in the folder give in the “data_path”. This functionality improves project-based saving of measurement results.



3				comment	plrange	alrange	samples		
5				la_Variation	60.000000	30.000000	100		
6				la_Variation	60.000000	30.000000	100		
l2			ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °
7			367.3	70.000	355.947	355.406	354.297	353.907	355.156
8			367.3	70.000	0.620	1.127	359.379	359.237	359.263
9			367.3	70.000	356.761	356.626	355.781	355.204	355.534
10			367.3	70.000	358.915	359.293	358.338	358.078	359.177
l1		ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °	delta(5) °
11		367.3	70.000	358.061	358.113	356.949	356.607	357.282	356.711
l2			ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °
12			381.9	70.000	11.896	10.177	15.027	12.924	19.061
13			381.9	70.000	14.657	12.783	17.797	15.600	21.704
14			381.9	70.000	10.379	8.208	13.697	11.358	17.724
15			381.9	70.000	12.892	11.080	15.952	13.884	19.949
l1		ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °	delta(5) °
16		381.9	70.000	12.456	10.562	15.618	13.442	19.610	17.359
l2			ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °
17			398.8	70.000	42.512	40.069	47.328	44.848	52.641
18			398.8	70.000	45.152	42.889	49.838	47.456	55.029
19			398.8	70.000	40.138	37.602	44.892	42.383	50.105
20			398.8	70.000	42.241	39.873	46.888	44.421	52.240
l1		ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °	delta(5) °
21		398.8	70.000	42.511	40.108	47.236	44.777	52.504	50.106
l2			ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °
22			410.8	70.000	63.283	60.549	68.835	66.086	75.052
23			410.8	70.000	67.104	64.900	72.186	69.824	78.091
24			410.8	70.000	62.236	59.791	67.326	64.763	73.258
25			410.8	70.000	64.652	62.221	70.003	67.353	76.147
l1		ambda (nm)	aoi °	delta(0) °	delta(1) °	delta(2) °	delta(3) °	delta(4) °	delta(5) °

Fig. 4.1-27

“File” bar:

- “New log file”
  creates a new and empty logfile named logfile(BE……), last displayed logfile is saved automatically.
- “change data path”
  changes the data path, the last displayed logfile is saved automatically under the last data path
- “save current log file”
  saves the currently displayed log file as *.log
- “save a log file copy (to another location)”

saves the currently displayed log file as *(copy).log in another data path

- “save selection”

  saves the selected lines of the currently displayed log file as*.log

- “delete this log file”

  deletes the complete logfile from the selected data-path

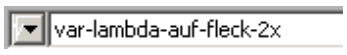
“Tools” bar:

- “delete selection”
  deletes the actual selected lines (marked in blue) from the displayed log file
- “indent selection”
  increase the level of the selection (about one column)
- “outdent selection”
  decrease the level of the selection (about one column)
- “selection → graph”
  transfers the selected rows or/and columns from the log editor to the window “graph” and overwrites the existing rows and/or columns in the window “graph”
- “selection → graph (append rows)”
  transfers the selected rows from the log editor to the window “graph” and appends this rows to existing rows in the window “graph”
- “selection → graph (append columns)”
  transfers the selected colums from the log editor to the window “graph” and appends this columns to existing columns in the window “graph”
- “selection → model”
  transfers the selected rows and columns from the log editor to the window “model” and overwrites the existing rows and colums in the window “model”
- “selection → model (append rows)”
  transfers the selected rows from the log editor to the window “model” and appends this rows to existing rows in the window “model”
- “selection → clipboard
  copies the selected rows/colums to another editor etc.

Control elements

slider to select the different levels. The level slider can be moved by holding left click. Only the rows in the selected and lower level appear in the log editor.

displays the selected levels



name of the currently displayed log file, press arrow to see all logfiles in the selected data path. Edit here to change the logfile name

notifies „Manual Edit Mode“. Edit any Log Editor Cell to enter “Edit Mode”. Finish editing with enter. Press button to disactivate edit mode. Automatic disactivation after 1 minute.

Log file window

This window lists the measured datas and results. Data can be saved or used for calculations and/or graphical display.
The different measurement options (1-zone measurement, 2-zone measurement) give results in several **Level**. The use of Levels improves clearness of the logfile and distinguishes between basic measurements and averages. Typically, the datas from the different zones are displayed in level 2, the mean value of the zones is displayed in level 1 and the results of the fits are displayed in level 0.

To support multiple log files, a pull-down selector displays all logfile in the folder given in the variable **"data_path"**. It gives you easy access to all log file (*.log) in the current data directory. After changing the "data path", all available log files are entered into the selector, and the first one is being displayed. Therefore, the "load log file" menu item has been removed. If you want to manually load a particular log file in another directory, make this directory the current "data path" first (via the File menu item), then use the selector to display the wanted log file.
The "save current log file" item saves the current content of the log without dialog (just for completeliness. This is also done when you change the selected log file or you leave the program).
The "save a log file copy" and "save selection" menu items add an entry to the log file selector (with the new name) only if the copy or saved selection is saved to the current data path. Otherwise, it is saved as a copy without changing or updating the currently displayed log file, nor changing the data path. Some extension to the file name as suggestion is provided for convenience.
You may also change the name of a log file by simply editing the text in the log file selector (without the *.log extension).
The "new log file" menu item opens a new, empty log file. The new log file name contains a unique ID code, which you may modify by typing into the log file selector as mentioned.
The "delete this log file" menu item removes the log file from disk.

The current log file is being saved every time before a new log file is being displayed. If the new data directory does not contain a log file, a new log file is being generated.
Finally, when exiting the program the current log file is automatically saved without a dialog.

Selection

To select several cells click on the upper left cell, then keep the **shift button** pressed and click on the buttom right cell of the desired cell area.
The first cell defines the Level for "Move Selection to other windows" (Selection->Graph). Other level entries are ignored.

Graph window

This window shows the data in a table (Tab control “data”) and plots the data in a 2-dimensional graph (Tab control “graph”)

Tab control “Data”

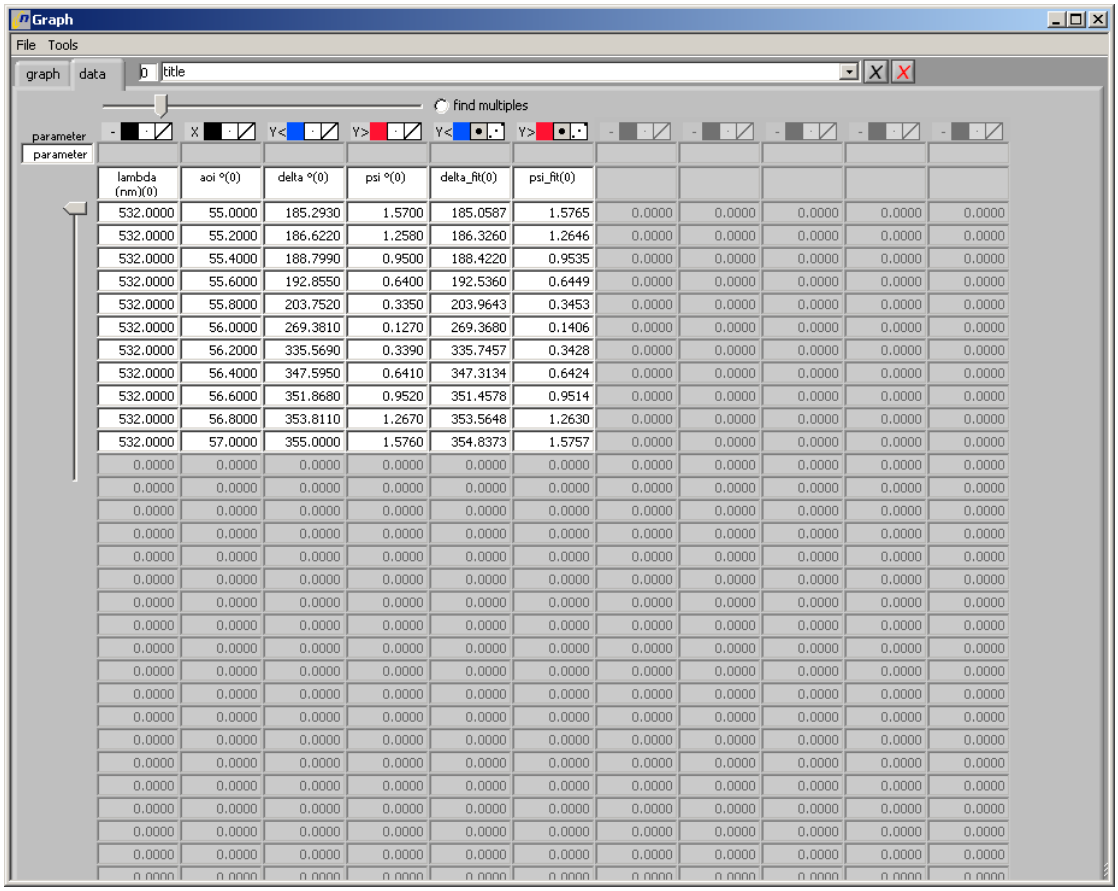


Fig. 4.1-28

“File” bar:

- “save graph(this page)”
  the currently displayed rows and columns in the tab “data” are exported to a *.dat file (saves the data). This is a ASCII file which can be opened with every text editor or imported to data analysis software.
- “save graph(all pages)”
  all rows and columns on every page in the tab “data” are exported to a *.dat file (saves the data). This is a ASCII file which can be opened with every text editor or imported to data analysis software.
- “import graph or data”
  imports a ASCII-file (*.dat) to the tab “data”
- “save panel image”
  saves the active window (“graph” or “data”) as *.png file
- “print graph (default printer)”
  prints the currently displayed tab(graph or data) on your selected default printer

“Tools” bar:

- “new page”
  opens a new and empty page
- “delete all pages”
  deletes all pages of the graph window, a message box appears “Do you want to delete all pages?”
- “show statistics”
  shows statistics like mean value, standard deviation, minimum/maximum values and range of the currently displayed columns in the tab “data”

Control elements

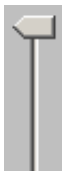

shows the number of the currently displayed page (up to 20)

shows the name of the currently displayed page


clears the content of the currently displayed page

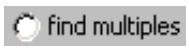

deletes the currently displayed page


to select a column of the data matrix


to select a row of the data matrix

Buttons to select properties of the axis for the different columns

- 
  no axis is selected
- 
  x-axis is selected
- 
  left y-axis is selected
- 
  right y-axis is selected
- 
  selects the colour of the plotted points/curves
- 
  selects the point style of the plotted points
- 
  selects the curve style of the plotted curve



if multiple delta/psi values are transferred to the graph window, this button gives every pair of delta/psi values the same properties for the axis

Tab control “graph”

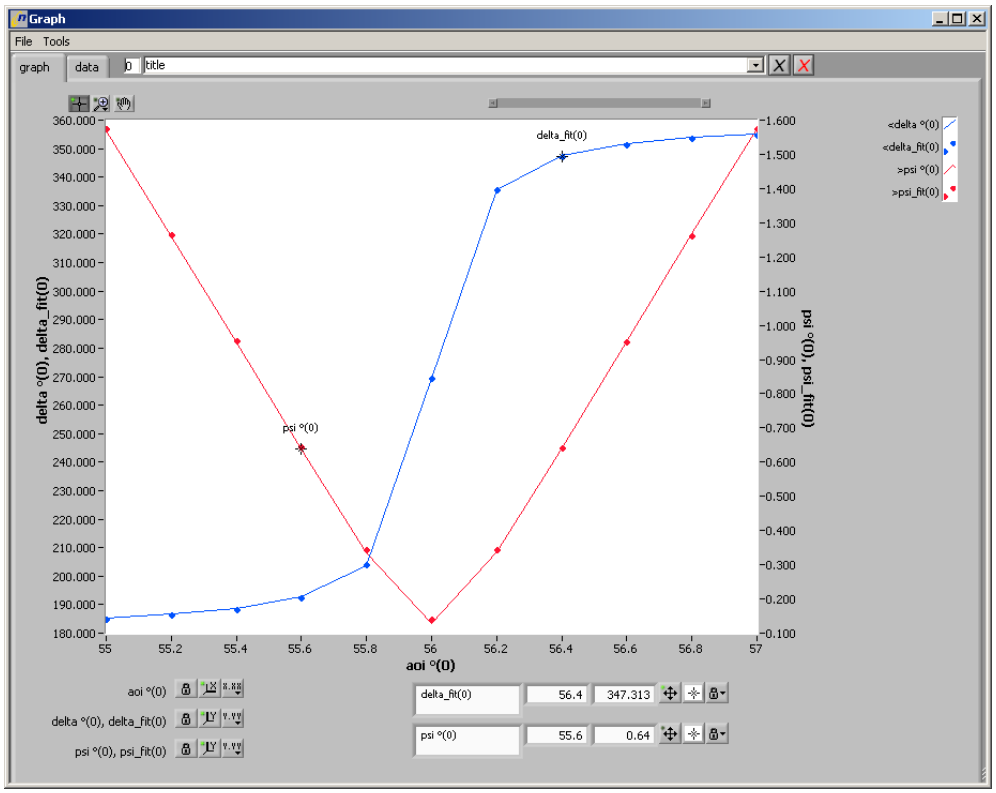


Fig. 4.1-29

Control elements for scaling the graphical display

Button to move cursor in graphical display.

Button to select zooming method for graphical display.

- selects rectangle enlargement area
- selects enlargement area in x direction
- selects enlargement area in y direction
- maximizes by motion with mouse
- minimizes by motion with mouse

Button to move graphs in graphical display.

Button to lock the scale of according axis

Buttons to set lowest value of the x/y-axis to lowest value of data matrix

Buttons to select settings for the x/y-axis.The settings for the axis are:

- selecting format and precision of the scaling values

- selecting mapping mode of the x-axis
- selecting color of the scaling lines
- switching on/off display of scaling values and scale label

without function

Buttons to select settings for the cursors. The settings for the cursors are:

- selecting color and style of the cursor
- selecting style of the cursor point
- selecting style of the cursor line
- selecting width of the cursor line
- positioning cursor

Button to set characteristics of the cursor. The characteristics for the cursor are

- free positioning
- positioning cursor by snaping between the measured points of all plots
- positioning cursor by snaping between the measured points of the current plot
- selecting a plot as the current plot

Model window

Introduction

The ellipsometer measures Delta and Psi as a function of the angle of incidence (aoi) or of the wavelength lambda. Delta is the relative phase shift of p- and s-polarised light upon reflection on the sample. Psi is the relative amplitude ratio of the reflection coefficients of p- and s- polarisation. The optical model simulates Delta and Psi as a function of the optical properties of the sample. The optical model can also look for optical properties ("fit-parameters"), which let the simulated Delta/Psi agree best with the measured Delta/Psi. The parameters with the best agreement are called fit-results.
The simulation of Delta and Psi depends on the optical parameters of the sample. The sample is idealised as a substrate, which reflects light only from its surface. The sample can carry an unlimited number of at least semi-transparent layers. The ambient is above the sample. Ambient, substrate, and all layers consist each of a material, which is characterised by a dispersion functions, refractive index n(lambda) and extinction k(lambda). All material names and dispersion functions, which are part of the sample, are selected in the "materials" page. The material and layer thickness are selected for each of the layers on page "layers". Material of the ambient and the substrate are also selected on this page. The "fit" page contains the table of the fit-parameters. Any of the previously in "materials" and "layers" pages occurring optical parameters can be selected as fit-parameter. After data input from the log-file the "fit"-button executes a numerical search for the best fit of the data. The fit-results and fitted data are displayed on the "fit" page. Fit-results can be written into the log-file. In case of aoi- or wavelength-spectra measured data and fitted data can be displayed in the "Graph", which is accessible from the window option in the task bar of the main window of EP3View. On the "simulation" page one can select among Delta/Psi spectra of all optical parameters of the sample and the dispersion functions of all materials of the sample. Parametric plots and sets of curves can be displayed. The simulation of spectra helps to optimise the conditions, i.e. wavelength range and aoi, and the type of a measurement, i.e. multiple zone measurement, and even the sample composition, if it is an option to change the composition. It is necessary to fill the pages "materials" and "layers" before a fit or a simulation can be executed.

How to find an appropriate optical model?

The physical basis of spectroscopic ellipsometry is well explained in [H.G. Tompkins, W.A. McGahan, Spectroscopic Ellipsometry and Reflectometry, John Wiley & Sons, New York, 1999, ISBN 0-471-18172-2]. There is also a representative collection of applications.

Materials

All material names and dispersion functions, which are part of the sample, are selected in the “materials” page.

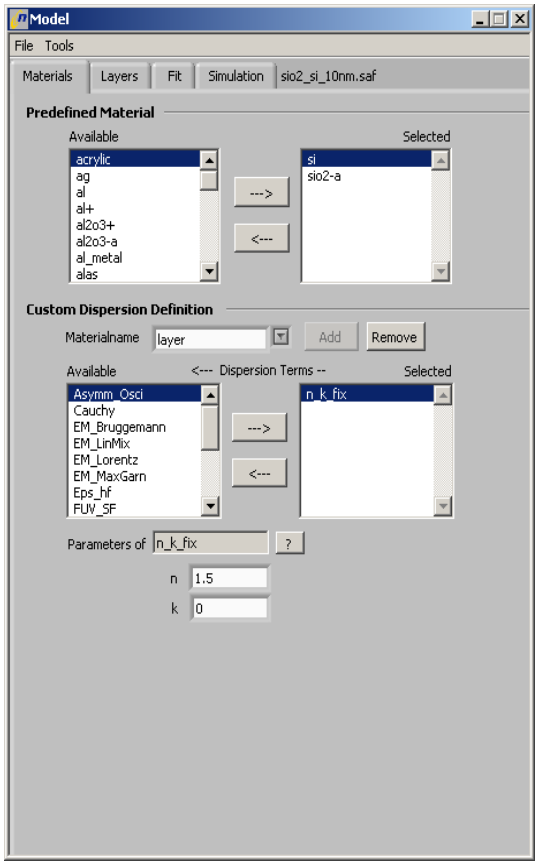


Fig. 4.1-30

“File” bar:

- “new recipe”
  clears the content of the model window, all unsaved changes are lost
- “load recipe”
  loads a recipe *.saf
- “save recipe”
  saves the actual recipe as *.saf (overwrites already existing recipes with the same name)
- “save as recipe”
  saves the actual recipe as *.saf

“Tools” bar:

- “Show Saf”
  shows the actual recipe in a new window
- “Results → Log”
  transfers the results to window “log editor”
- “Results → Graph(for bath fit mode)”
  transfers the results to window “graph”

- "Data&Best Fit → Graph"
  transfers the measured and fitted data to window "graph", if this function is marked the data are transferred automatically to the graph after every new fit procedure
- "Data&Best Fit → Log"
  transfers the measured and fitted data to window "log editor"
- "create dispersion file (*.dsp)"
  saves your own created dispersion file as *.dsp (refractive index and ectinction coefficient vs. lambda)
- "nm – eV- 1/cm calculator"
  calculates wavelength in wavenumber
- "clear data"
  clears the data input on the fit page

By the right arrow ---> or by double click you select **predefined materials** from a database in the upper left list, where the dispersion functions n(lambda) and k(lambda) of these materials are stored. **Selected** materials appear in the upper right list. Materials, which are no longer used can be removed by left arrow <--- or by double click. Most predefined materials without "+" originate from the database of LayTec. See also LayTec's manual under c:\lt_sample_oem\manual for explanation. Some materials without "+" represent dispersion functions measured by Nanofilm. Predefined materials with "+" originate from a database published some years ago on the web-site of SOPRA. If you need a material, whose dispersion function you have e.g. got from a reference, you can create a dispersion file and save it in c:\ep3view v2\ user\dispersions. After the next start of EP3View this dispersion is displayed in the predefined materials list. Please give only names to the materials, which are written with small caps and without special signs e.g. "_". The dispersion file is a table with photon energy [eV], eps1, eps2 in the columns. Each user can modify its own dispersion directory. The path of the dispersion directory is set in the modelling.ini in the …user\config directory.

```
##xunit=PhotonEnergy
##yunits=Eps1 Eps2
Begin
0       11.58993936     0
100     -4.76       4.8
END
```

Tab. 4.1-31 Example of a dispersion file

Alternatively to the predefined materials you can define a dispersion function by means of a sum of mathematical functions, which are displayed in the list of the **material names** of **custom dispersion definitions**. Initially the list is empty. Fill a name in the box Materialname and hit "enter" (!) and press Add. The name appears now in the list of material names. Click on the selector to choose among the materials if you have many. The selected material can be removed by the corresponding button. For the selected material **available** dispersion functions are transferred to the list of selected dispersion functions and vice versa by the arrows or double click. The dielectric functions of all selected dispersion functions are added. When you click on a dispersion function in the list of selected dispersion functions, boxes with the parameters of this dispersion function appear below. Frequently used initial values of these parameters are already in the boxes. If necessary please change them according to your application. Hit the ? button to display an explanation of the applications and of the parameters of this dispersion function. The explanations of the dispersion function are given in the table of the dispersion terms:

Dispersion term	parameters	explanation
LT_File	filename (*.ltd)	Dispersion file from database; contains Kramers-Kronig consistent, inter-band dispersions of frequently used materials in a spectral range from 0.5 to 6.0 eV.
File	filename (*.dsp)	Dispersion file containing a simple epsilon table (photon energy eps1, eps2), which can be easily extended by new publications.
Eps_hf	eps_hf	rough approximation of an oscillator, whose frequency is out of the wave-length spectrum, special case of eps_fix with eps_hf = epsilon1 and epsi-lon2 = 0"
Oscillator	hf^{TO}, f^{Osc}, Γ	harmonic oscillator with frequency hfTO[eV], oscillator strength fOsc[eV^2], and damping Gamma[eV]. The oscillator represents a reso-nance line centered at frequency hfTO, with amplitude fOsc, and with linewidth Gamma. $\varepsilon_1(hf) = f^{Osc}\frac{hf_{TO}^2 - hf^2}{\left(hf_{TO}^2 - hf^2\right)^2 + (\Gamma hf)^2}$ $\varepsilon_2(hf) = f^{Osc}\frac{\Gamma hf}{\left(hf_{TO}^2 - hf^2\right)^2 + (\Gamma hf)^2}$
Oscill/cm	hf^{TO}, f^{Osc}, Γ	harmonic oscillator with TO-frequency[cm^-1], oscillator strength fOsc[cm^-2], and damping Gamma[cm^-1]
Plasmon	n/(meff/me), Gamma	frequently used to simulate the free electron gas of metal, n and k increase almost linearly with the wavelength [nm], plasma-oscillation of free carrier with density n[cm^-3], relative mass m_eff/m_e and damping Gamma[eV] $\varepsilon_1(hf) = \frac{-h^2}{\pi \cdot \varepsilon_0 \cdot m_e} \cdot \frac{n/\left(m_{eff}/m_e\right)\cdot 10^6}{hf^2 + \Gamma^2}$ $\varepsilon_2(hf) = -\varepsilon_1(hf)\frac{\Gamma}{hf}$ $with \frac{-h^2}{\pi \cdot \varepsilon_0 \cdot m_e} \approx 1.7327311 \cdot 10^{-26}$
FUV_SF	E1, E2, A	epsilon2-step function in the far UV (epsilon2=A for E1<hf<E2), which results in a epsilon1-dispersion in the UV-VIS region, suitable for many oxides and nitrides of group-IV elements, the dispersion of k has a maxi-mum at E2 and is zero for hf < E2. The dispersion of n has a maximum at E1 and is zero for hf > E1, E1 and E2 in eV
EM_LinMix	frac, Disp. Name (guest), Disp. Name (host)	Effective medium for a mixture where the constituents guest and host are only mixed in the plane of the sample, but not vertically along the surface normal. In this case epsilon is a linear mean of the epsilon of guest and host: epsilon = frac epsilon_guest + (1-frac) epsilon_host with the volume fraction frac of the guest in the host"
EM_Bruggemann	frac, Disp.	Bruggemann effective medium, applies for a mixture of a guest-material in

	Name (guest), Disp. Name (host)	a host-material as aggregate structure, where the unit cell has epsilon_guest with probability (volume fraction) frac and epsilon_host with probability 1-frac. It descibes a typical roughness-layer on a surface when frac=0.5 and guest is air or voids and host is identical with the material underneath. $\varepsilon = \frac{1}{2}(-z + \sqrt{-z^2 + 2\varepsilon_g\varepsilon_h})$ $z = \frac{1}{2}\left((3f-2)\varepsilon_h + (1-3f)\varepsilon_g\right)$ (fraction f "guest" in "host")
EM_Lorentz	frac, Disp. Name (guest), Disp. Name (host)	Lorentz-Lorenz effective medium, applies for mixed molecular dipoles, it is a good approximation for spheres or particles with volume fraction frac < 0.3 $\varepsilon = \frac{2z+1}{1-z}$ $z = f\frac{\varepsilon_g - 1}{\varepsilon_g + 2} + (1-f)\frac{\varepsilon_h - 1}{\varepsilon_h + 2}$ (fraction f „guest“ in „host“)
EM_MaxGarn	frac, Disp. Name (guest), Disp. Name (host)	Maxwell-Garnett effective medium, good for frac < 0.4, it applies for a microstructure of grains with epsilon_guest embedded in a matrix of host material with epsilon_host. It also represents a unit cell being a coated sphere consisting of a core with epsilon_guest sourrounded by a shell with epsilon_host. The filling factor frac = a^3/b^3 is the volume ratio of the concentric spheres with the radius a of the guest-sphere and radius b of the host-sphere $\varepsilon = \varepsilon_h \cdot \frac{\varepsilon_g(1+2f) + 2\varepsilon_h(1-f)}{\varepsilon_g(1-f) + \varepsilon_h(2+f)}$ (fraction f „guest“ in „host“)
Asymm_Osci	E_0, f^{Osc}, Γ^{Osc}, E_1	asymmetrical (Lorenzian) oscillator like harmonic oscillator with strength fOsc[ev^2] and damping GammaOsc[eV] at center frequency E1[eV], but with enery asymmetry E0[eV] with respect to E1. For E0->0 it is similar to the harmonic oscillator, but E0 = 0 is excluded
FourBloom	n^{hf}, E_g, A, B, C	for amorphous semiconductors according to Forouhi, Bloomer, Phys.Rev. B Vol.34(10), 7018(1986)

		$k(E) = \frac{A \cdot (E - E_g)^2}{E^2 - B \cdot E + C}$ $n(E) = n^{hf} + \frac{B_0 \cdot E + C_0}{E^2 - B \cdot E + C}$ $B_0 = \frac{A}{Q}\left(-\frac{B^2}{2} + E_g \cdot B - E_g^2 + C\right)$ $C_0 = \frac{A}{Q}\left(\left(E_g^2 + C\right)\frac{B}{2} - 2E_g \cdot C\right)$ $Q = \frac{1}{2}\sqrt{4C - B^2}$
Cauchy	*A_n, B_n, C_n, A_k, B_k, C_k*	suitable for transparent materials, n = A_n + B_n/lambda^2 + C_n/lambda^4, k = A_k + B_k/lambda^2 + C_k/lambda^4 with lambda in nm. Cauchy represents the dispersion of material, which has a resonance (oscillator) in the UV out of the measured spectral range. Far from the oscillator the approximation is: k = 0, C_n = 0, Cauchy's dispersion is a finer approximation than n_k_fix, eps_fix, and eps_hf
n_k_fix	n, k	real and imaginary part of the complex refracitve index, ideally suitable for simulation and fitting at a single wavelength or for zero order approximation for transparent materials
eps_fix	epsilon1, epsilon2	real and imaginary part of the dielectric function, ideally suitable for simulation and fitting at a single wavelength or for zero order approximation for transparent materials
old_Disp	material name	for referencing a previously defined dispersion

Tab. 4.1-32 Dispersion terms

Layers

The material and layer thickness are selected for each of the layers on page “layers”.

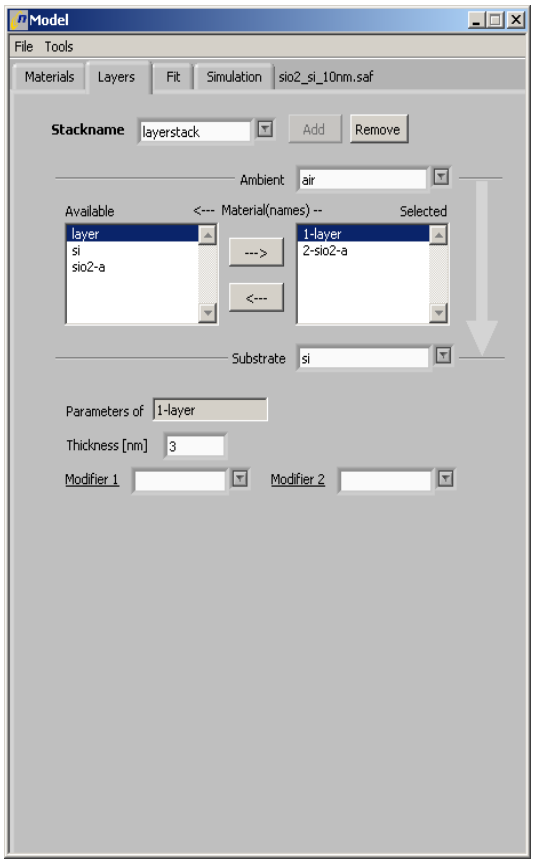


Fig. 4.1-33

Future extensions of the software will be able to fit more than one layer stack simultaneously. Therefore there is already the input box for the list of stack names. In the present software version one and only one layer stack can be used. If there is no layer stack selected please type a name in the **stackname** box, “enter”, and press 

. Select the ambient and the substrate from a list of materials, which appear when you press the selector  . Select an available material for a layer with an arrow or a double click. You can select the same material several times for different layers. The layer’s name begins with the layer number and is followed by the material name. The uppermost layer is counted as no. zero. The no. increases from top to the bottom of the layer stack. Each layer is assumed planar at least in the region of interest (ROI) over which the Delta/Psi are averaged. The ambient is usually air. It can be a liquid like H_2O in case of a solid-liquid-cell, or glass like BK7 or SF10 in case the light of the ellipsometer is coupled through a prism to the sample. When you click on a layer in the list of selected layers, boxes with the parameters of this layer appear below. Please change them according to your application. The thickness must be specified. Optionally you can select up to two modifiers for this layer:

thick!	This layer will be marked as “optically thick” (e.g. glass substrate), i.e. its interference structure is not resolved by the optical system. This modifier can only used once per layer stack.
growing!	This layer is growing with d0 as the layer thickness [nm] at time t = 0 s, r as the growth rate [nm/s], t0 as the start time [s] of the growth, and t1 as the end time [s] of the growth. Additionally to the linear growth an exponential decreasing growth can be simulated when delta and tau are

	both equal 0. The layer thickness is calculated for t0 < t < t1 according: d(t) = d0 + (t – t0)*r + delta*(1-exp(-(t - t0)*tau))
+growing!	This layer is growing with d0 as the layer thickness [nm] at time t = 0 s, r as the growth rate [nm/s], t0 as the start time [s] of the growth, and t1 as the duration [s] of the growth. Times are relative to the end of the last growing layer of the layer stack. Additionally to the linear growth an exponential decreasing growth can be simulated when delta and tau are both equal 0.
aniso_yy!	Defines an optical layer anisotropy. The material, which is selected for the layer, is used both in x (lateral) and z (normal) direction. Disp_y is only used in y (lateral) direction
aniso_zz!	Defines an optical layer anisotropy. The material, which is selected for the layer, is used both in x (lateral) and y (lateral) direction. Disp_z is only used in z (normal) direction
aniso_yz!	Defines an optical layer anisotropy. The material, which is selected for the layer, is used in x (lateral) direction. Disp_y is used in y (lateral) direction. Disp_z is used in z (normal) direction

Tab. 4.1-34 Modifiers

Fit

Fit-parameter selection

The “fit” page contains the table of the fit-parameters. Anyone of the previously in “materials” and “layers” pages occurring optical parameters can be selected as fit-parameter. To do so click on a row in the **fit parameters** table and then click Edit... . To delete a row click Remove .

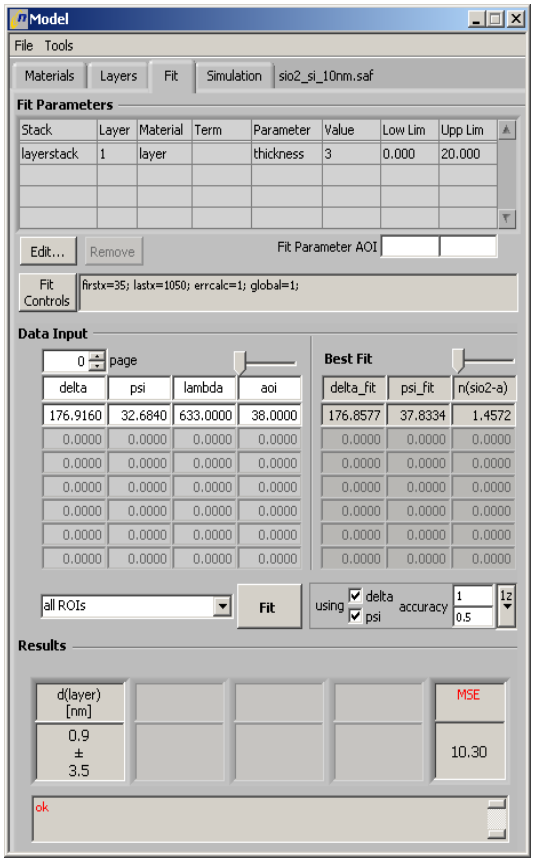
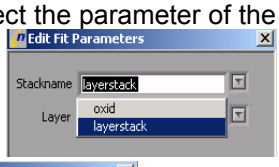
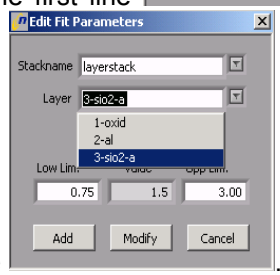


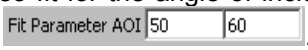
Fig. 4.1-35

After clicking 

, the window 

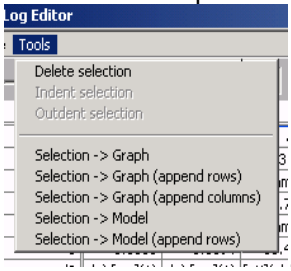
pops up, where you "edit fit parameters" of the particular row. Click on the "Material name" selector  to select a material or the whole layer stack from the list. If you have selected a material by a click you may select a "dispersion term" of this material with the selector  of the second line. With the "Parameter" selector  in the third line you select the parameter of the dispersion term. If you have selected a layer stack name, e.g. layerstack, in the first line 

you may select one of the layer's thickness as fit parameter in the second line 

. The layer's name begins with the layer number and is followed by the material name.
The value of the selected fit parameter is displayed below. The value can only be changed in the materials-page or in the layer-page but not in the fit-page. Lower and upper limits of the fit parameter are displayed. Frequently used initial values of these parameters are already in the boxes. If necessary please change them according to your application. The frequently used values of the limits are calculated in per cents of the parameter value. The percentage can be selected in the file c:\ep3view v2\user\config\modelling.ini if the user likes to set its own preferences. One may also fit for the angle of incidence (AOI), when the upper and lower limits of AOI are filled in the corresponding box 

. The initial value of AOI is included in the **data input** table. In the present software version 2.30 the AOI resulting from the fitting is not displayed. This inconvenience will be removed in a later version.

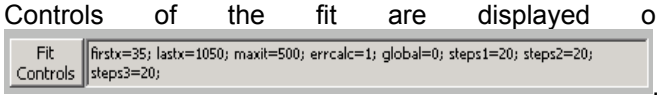
Data input

Selected data are brought from the log-file into the **Data Input** table. The program recognises automatically the type of data, i.e. single data point, AOI-spectrum, wavelength-spectrum, AOI-spectroscopic-Ellipsometry (VASE). In the case of VASE wavelength-spectra with different AOI must stand in columns in the Data Input table. You may record these VASE-spectra and keep them in one log-file, where you select them at once. Alternatively you may record wavelength spectra separately for different AOIs as save them into different log-files. In order to import those different spectra into the Data Input table, use "selection -> Model (append rows)" in the tool of the log-editor 

. You may scroll the data with the horizontal and vertical sliders  . Data, **best fit** data, and Results belong to the ROI, which is selected by the up/down arrows in the box 

.

Fit-control selection

Controls of the fit are displayed on the right of the fit controls button 

. Click the button to select the controls and their values. The control's meaning is explained in the table:

Control	Explanation
firstx	lower limit of x-axis interval that is considered in fit-process, x-axis shows e.g. AOI [deg] in case of a AOI-spectrum, or x-axis shows wavelength [nm] in case of a wavelength spectrum. Fitting of a single data point at fixed wavelength and fixed AOI is interpreted as a AOI-spectrum. Thus firstx should be any small number like 35 deg in this case. Don't forget to switch back to 35 deg when you have changed firstx.
lastx	upper limit of x-axis interval that is considered in fit-process
limitx	Usually not needed. Lower/upper limits are reduced according to averaging over adjacent data points. See also LayTec's manual under c:\lt_sample_oem\manual for explanation.
maxit	maximal number of iteration for fitting
step	only every "step" setpoint is considered for fitting
finall	Unsually not needed. Final overall calculation after accelerated fit process with step <>0, on(1) / off(0) See also LayTec's manual under c:\lt_sample_oem\manual for explanation.
errcalc	error calculation switch on (1) / off (0)
firstcol	Usually not needed. First data column to be fitted
lastcol	Usually not needed. Last data column to be fitted
repeat	repeats the fit-process. Results are starting values for next repeat (0…5)
global	global fit of the first 1, 2, or 3 parameters before the normal (local) fit-process
steps1	number of global fit steps for fit-parameter 1
steps2	number of global fit steps for fit-parameter 2
steps3	number of global fit steps for fit-parameter 3

Tab. 4.1-36 Fit controls

Most of the controls have not to be changed every time you fit. The most important control is global.

You can select whether Delta and Psi shall be fitted by ticking the boxes "using delta/psi" 

. On the right select by  whether your data are the mean of 1, 2, or 4 ellipsometric zones. An accuracy of delta/psi is displayed, which is typical for the number of zones you have specified. The displayed accuracies do not take into account any errors in your model of the sample, e.g. wrong dispersions. Also depolarisation and anisotropy is usually not considered in our model. A low signal/background level during nulling also makes the real accuracy of your data worse than these ideal values. You can type in your particular accuracies for delta/psi when you press the selector  and choose the question mark.

Fit-procedure

In the following you will learn, what the program executes, when you press the Fit button. The MSE is the mean square error of measured data y_i and simulated data $\langle y \rangle_i$ averaged over n data points, where m is the number of fit-parameters.

$$MSE = \frac{1}{n-m-1} \sum_{1}^{n} \left(\frac{y_i - \langle y \rangle_i}{\sigma_i} \right)^2$$

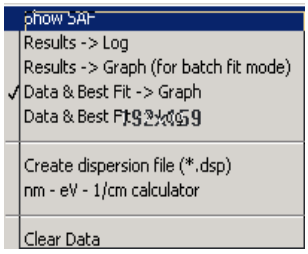
It is assumed, that the accuracy σ_i is constant for all data points. Let us say we fit for thickness d with the option "global=0":
The program starts at the d of the layer as selected on the layer-page, calculates Delta/Psi and the MSE, increases/decreases d and other possible resulting parameters in the direction of the gradient of the MSE with respect to the variable parameter d. The MSE is decreasing until the MSE is in a local minimum under variation of fit-parameter d. Please notice that there are usually more than one local minimum of MSE, which may be found by the program. Therefore it is recommended to keep the number of fit-parameters as small as you can effort, and to specify initial values for the fit-parameters, which should represent a guessed solution of your fit-problem. Be aware that the program may find a mathematical correct solution to your problem, which is physically incorrect. Hence you must check the validity of the obtained solution. To this end

- in case of a single data point compare measured and fitted Delta/Psi on the fit-page. Measured data are displayed in the **Data Input**, fitted data are displayed in **Best Fit**. The difference of the data should be not much larger than the accuracy.
- in case of a spectrum with many data points it is rather convenient to compare fitted and measured data in the graph. To this end select "Data & Best Fit -> Graph" in the "tools" on the task bar. This will send data and fitted data to the graph, where you can graphically examine the fit-quality. Take care that the difference of data and fitted-data is not much larger than the accuracy. If the fit-quality is bad, return to the fit-page and repeat the fitting with a modified model.
- remember the MSE after each fitting. If you have equally well looking fits in the graph, you should prefer the fit with the smallest MSE
- check whether you have resulting fit-parameters with infinite error "n/a". In this case you may have specified too many fit-parameters. Reduce the number of parameters and start again. In spite of the infinite error the fit results are often correct. So it is recommended to use these results as start-values in the next fit-procedure.
- check whether the results are consistent with your physical and chemical knowledge of the sample.
- in case of a fit-result very close to or identical with the upper or lower limit, repeat the fitting with the fit-result as start-value and set a new limit with a reasonable distance to the start-value.
- in case of VASE one wavelength spectrum of Delta/Psi per AOI is plotted in the graph. You can switch through the AOIs by the header of the graph

The uncertainty of the fit results is proportional to the accuracy of delta/psi. It is also proportional to the inverse derivations of Delta/Psi to the fit parameter. Sometimes there is an infinite uncertainty of a fit-result. In this case some of the fit parameters are redundant, i.e. they are strongly correlated and therefore have the same effect on the data set of Delta/Psi. One should keep one of those parameters fixed and fit again for the other parameters. The number of parameters should be reduced in that way until all uncertainties of the results are finite. Infinite uncertainties are displayed as "n/a" in the **results**
If you specify the control "global=1" or "2" or "3" then the MSE is calculated for all steps within "LowLim" and "UppLim", the resulting parameters with the smallest MSE are taken, and a local fit (as with global=0) is made afterwards. It is recommended to start with local fitting (global=0) to save calculation time. If the fit-results seem to be

wrong or insufficient try global fitting. Please consider you upper and lower limits carefully with global fitting. Too large difference between the limits may not have enough resolution in the fit parameter space, or will need too long calculation time if you use a large step number. Too small difference between the limits will have the same effect like local fitting.
There are three common algorithms, which are used to minimize the MSE of simulated and measured data Delta/Psi. The first algorithm is the inverse Hessian matrix method, which takes advantage of the fact that the gradient of the MSE with respect to the variable parameters is zero at the minimum of the MSE. The second algorithm is the gradient method, which just follows the gradient of the MSE with respect to the variable parameters until a minimum of the MSE is reached. This method involves the step size, how far the gradient is followed within one iteration. Close to the final solution the step size could be too large to minimize the MSE.
The third algorithm, which is used by Nanofilm's software, is the algorithm of Levenberg-Marquardt (LM), which is a hybrid of the two other algorithms. In the LM method the Marquardt parameter is the weighting factor between the two basic algorithms. The LM method usually finds the minimum of the MSE within the smallest number of iterations of all methods, except when a strong correlation of fit-parameters exists (s.o.) [H.G.Tompkins, W.A. McGahan, Spectroscopic Ellipsometry and Reflectometry, pp. 195, John Wiley & Sons, 1999, ISBN 0-471-18172-2].

fit-tools

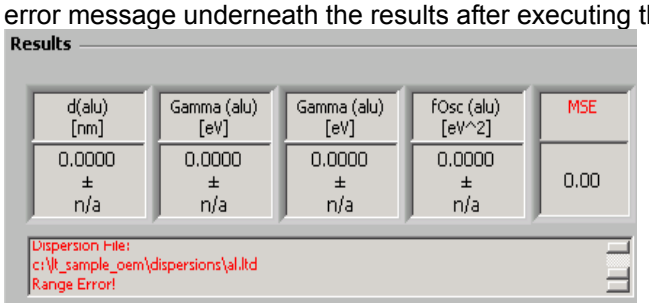
Fit-tools are accessible on the task-bar. 

Show saf	displays the saf-file or recipe of the optical model
Results -> Log	transfers the results to the log-file
Results -> Graph (for batch mode)	transfers the results into the graph
Data & Best Fit -> Graph	transfers Data & Best Fit data into the graph
Create dispersion file (*.dsp)	creates a dispersion file. The dispersion file will be available in the materials-page. It can subsequently used as a material in the layer stack. See also section 3.1 materials
nm – eV – 1/cm calculator	Converts the wavelength from any of these 3 units into the other units
Clear data	clears data when pressed several times

Tab. 4.1-37 Fit tools

Error-messages

If something is inconsistent in the optical model or in the parameters, the program cannot fit and will display an error message underneath the results after executing the fit-button twice.



Error message	Explanation
Dispersion File: c:\lt_sample_oem\dispersions\al.ltd Range Error!	The dispersion file does not have refractive index n and extinction k for the wavelengths of all data points. You may import only wavelength from the log-file, which fit into the wavelength range of the dispersion file. Usually the dispersion range is at least from 350 to 820 nm.
Sorry, the fit interval [26,27] is empty! Fit process is cancelled	You have no data points between firstx and lastx. Change the fit controls firstx and lastx, to confine the wavelength range or the AOI range of you spectrum

Tab. 4.1-38 error messages

Simulation

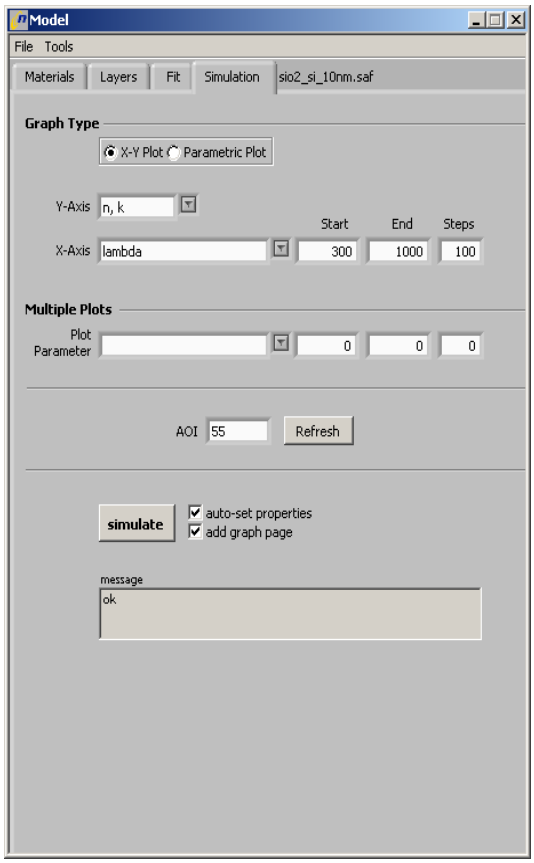
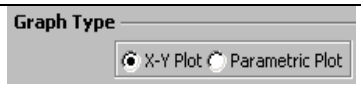
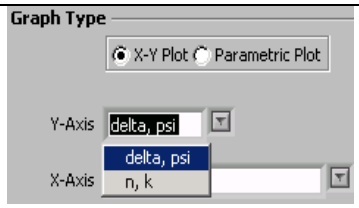
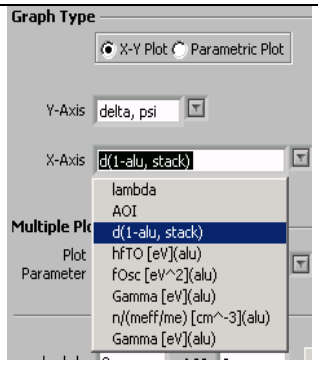
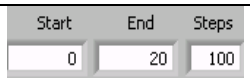
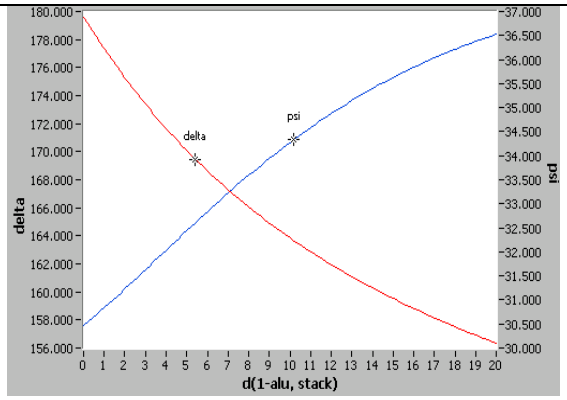
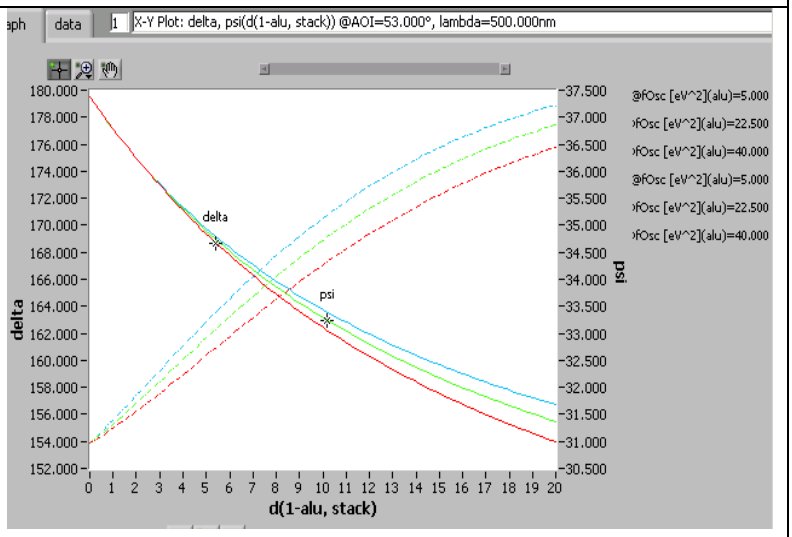
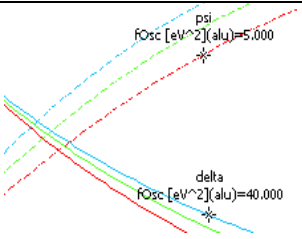
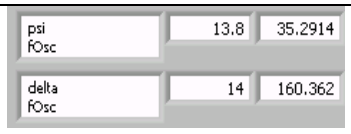
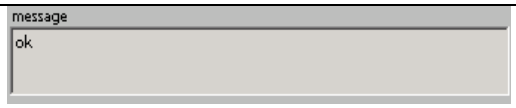


Fig. 4.1-39 Simulation-page

X-Y plot: Delta & Psi vs. any fit-parameter

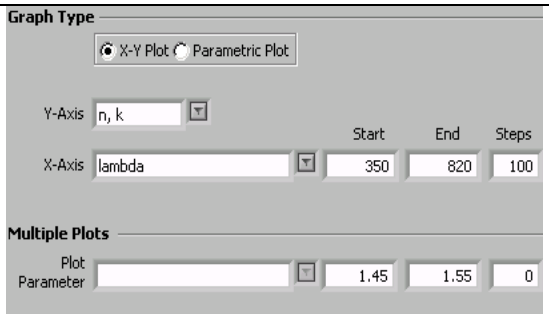
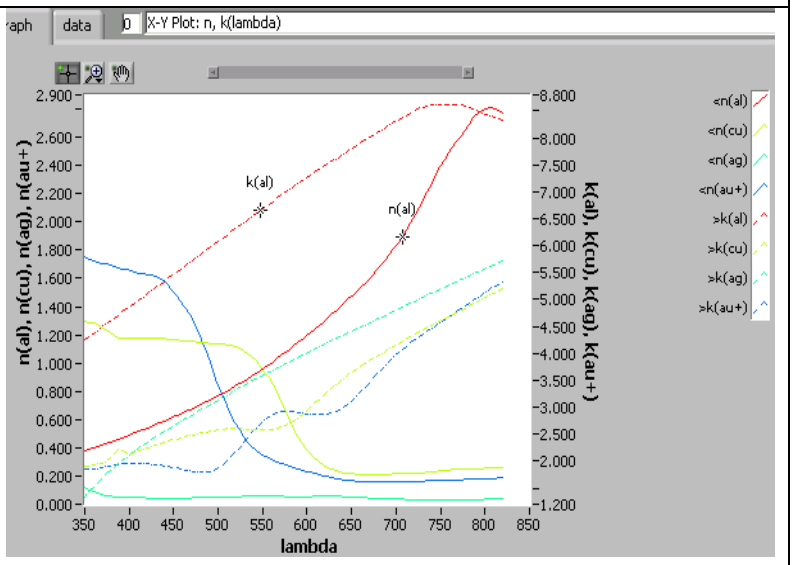
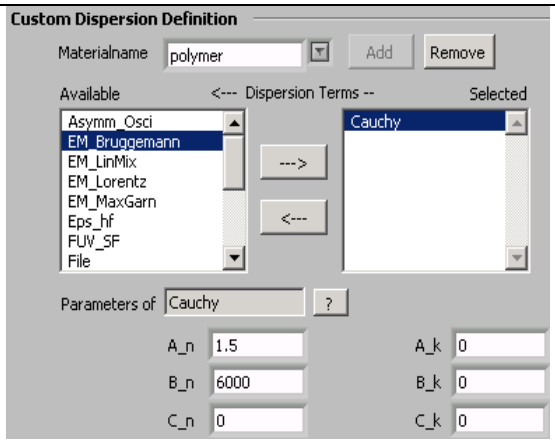
On the “simulation” page one selects between a X-Y plot and a parametric plot.	
X-Y plots display Delta and Psi or refractive index n and extinction k on the Y-axis.	
A Delta/Psi can be plotted against all the optical parameters of the sample. A list of those parameters is available by the selector . Wavelength and AOI can be select to simulate spectra.	

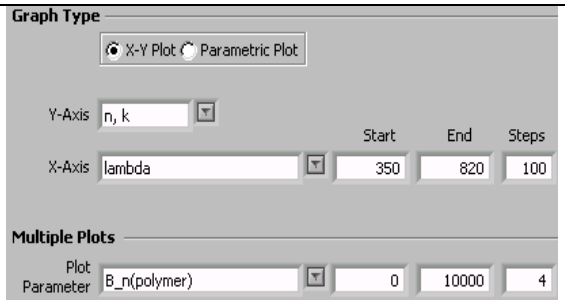
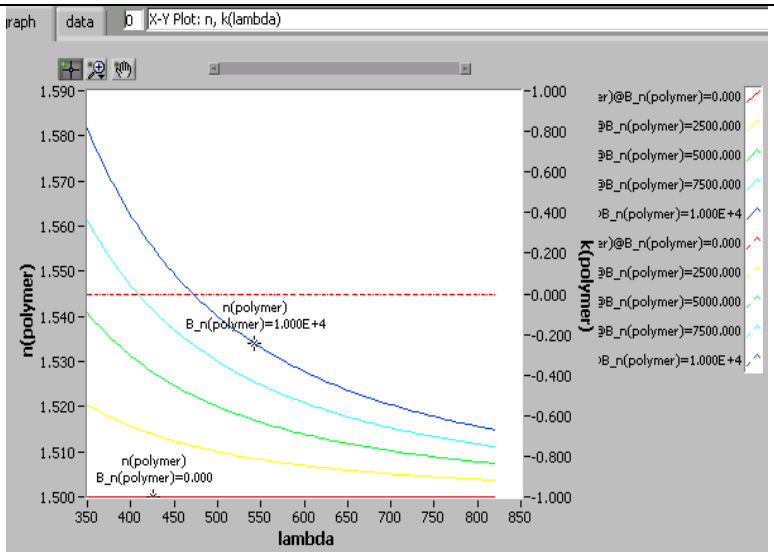
Please specify start, end, and steps of the X-axis, e.g. thickness from 0 to 20 nm in 100 steps.	
refresh the present values for wavelength lambda und AOI from the EP3 or fill in arbitrary values manually	
This plot is shown in the graph, when you press the simulate button.	
It is possible to display a set of these plots as a function of a second parameter from the list of optical parameters, e.g. oscillator strength fOsc from 5 to 40 eV^2 in 3 steps. A large number of steps of the Plot parameter would cause a long calculation time.	
Here is the graph, when you press simulate.	
Click on the plot to actualise the content of the cursors. Drag the cursors on any of the plots to obtain the content of the plot.	
The actual X-Y coordinates of the cursor are displayed below the graph	

If something is inconsistent in the optical model or in the fit-parameters, the program cannot simulate and will display an error message	

Tab. 4.1-40 delta&psi vs. fit parameter

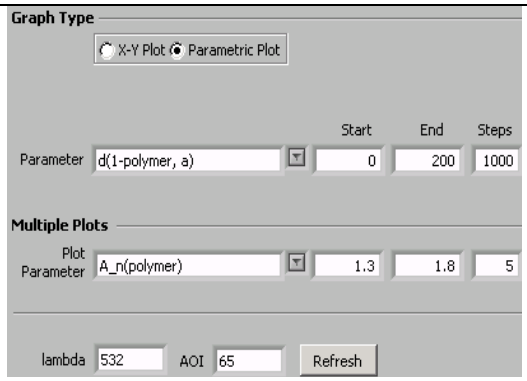
X-Y plot: n & k vs. wavelength lambda

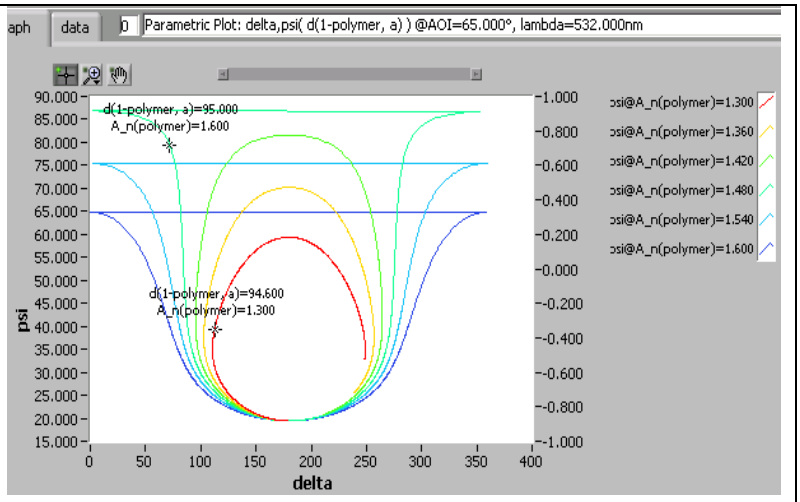
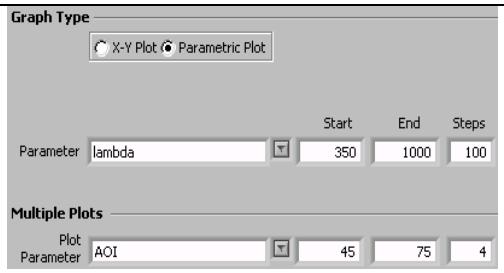
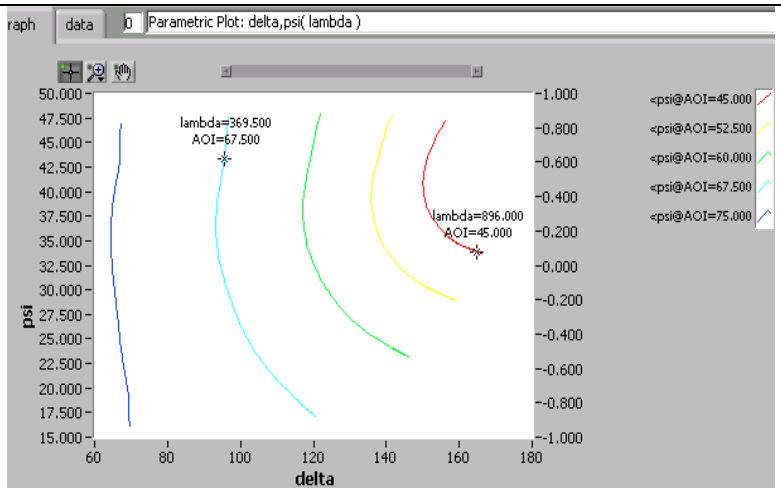
It is now the intension to compare the dispersion functions of some metals. To this end one has to select the metals on the materials-page. On the simulation-page one selects “n, k” on the Y-axis. One is only left with one choice for the X-axis, namely “lambda”. It is recommended to select lambda, otherwise the calculation slows down.	
Pressing simulate plots refractive index n and extinction k of some metals from the list of dispersions. The program plots all dispersions, i.e. **Custom Dispersion Definitions** from the materials-page.	
Let us define a **Custom Dispersion** of a polymer by the Cauchy function on the materials-page:	

In case of a **Custom Dispersion Definitions** it makes sense to use the **Multiple Plots**. The Cauchy B_n parameter is varied from 0 to 10000.	
We observe how the slope of the refractive index increases with the B_n	

Tab. 4.1-41 n&k vs. wavelength

Parametric plots

A parametric plot has Delta on the Y-axis and Psi on the Xaxis. The parameter increases along the trace in the Delta/Psi space. One can any optical parameter along the trace. In this case we have selected the thickness d of a polymer, which has a Cauchy dispersion as in the previous example. The polymer film is on a silicon substrate. Multiple Plots show the dependence of the A_n Cauchy parameter.	

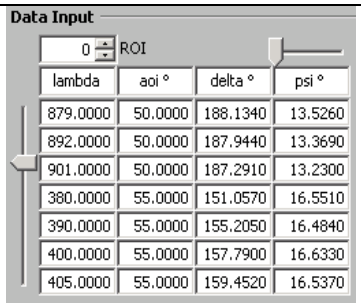
Here is the result.	
Another example: the same polymer on silicon, but the trace is along the wavelength lambda. The different traces represent different AOI.	
Here is the result.	

Tab. 4.1-42 parametric plot

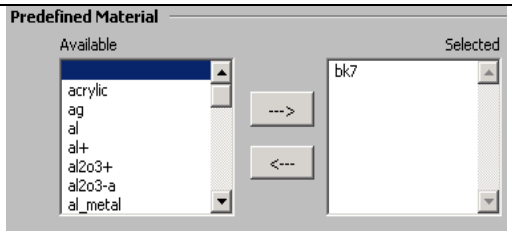
Quick-start-tutorial

In this chapter we like to make a quick tour through the optical model. This tour will be a repetition of the most important steps we have seen before. It will also enable the quick entrance into the program for the advanced user of ellipsometry without reading the previous chapters. Last it will demonstrate how to fit and simulate Variable Angle of incidence Spectroscopic Ellipsometry (VASE). Ordinary spectroscopic or AOI-ellipsometry will be included as a limiting case of VASE.

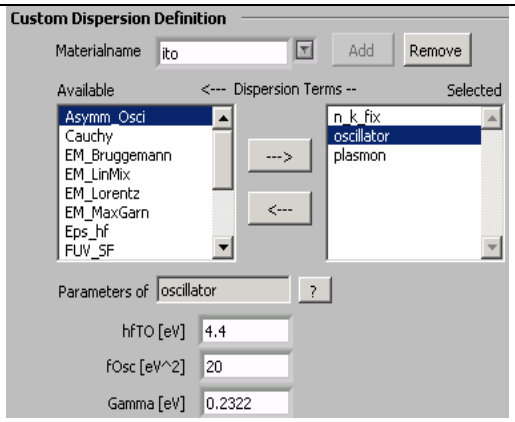
The sample is an ITO layer on a glass slide. We import the first Delta/Psi spectrum measured at 50 deg from the log-file to the model. We switch to the log-file with 55 deg AOI and use “selection -> model (append rows)” in the tools menu of the log-file. We repeat to transfer the spectra of 60 deg and 68 deg into the fit-page. In the **Data Input** these four spectra are aligned under each other. The step from the first to the second spectrum is shown in the figure right.



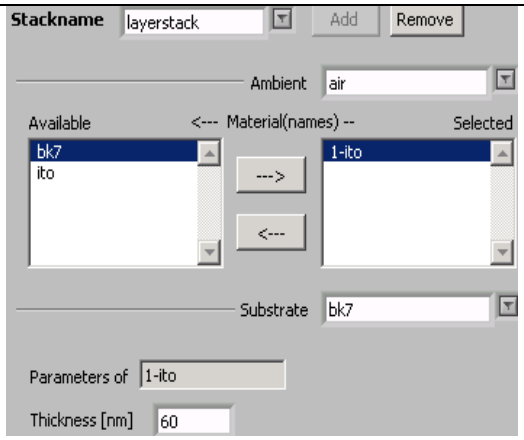
Now let us make the model of the sample. We go on the materials-page and select the **Predefined Material** bk7 by a double click on it. It appears on the right in the list of used materials.



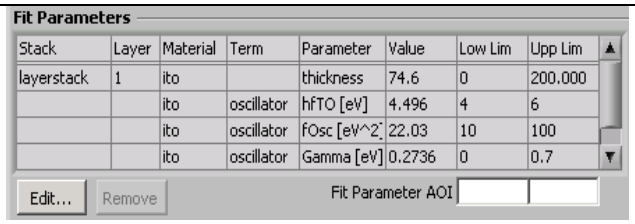
We like to make a Custom Dispersion Definition of the ITO. To this end we type “ito” in the Materialname box, press “enter”, and Add. Now we double click on the available dispersion terms n_k_fix, oscillator, and plasmon. Those terms appear in the list of dispersion terms on the right, whose dielectric constants are added up for the effective dielectric constant of the ITO. We click subsequently on these three dispersions, and fill the parameters of the dispersions into the boxes below.

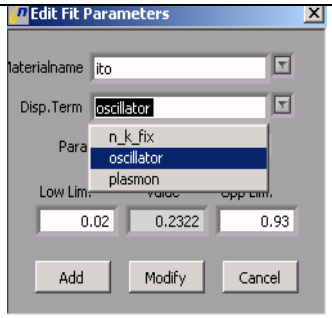
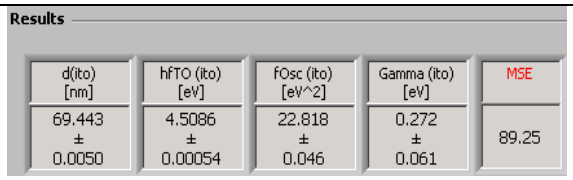
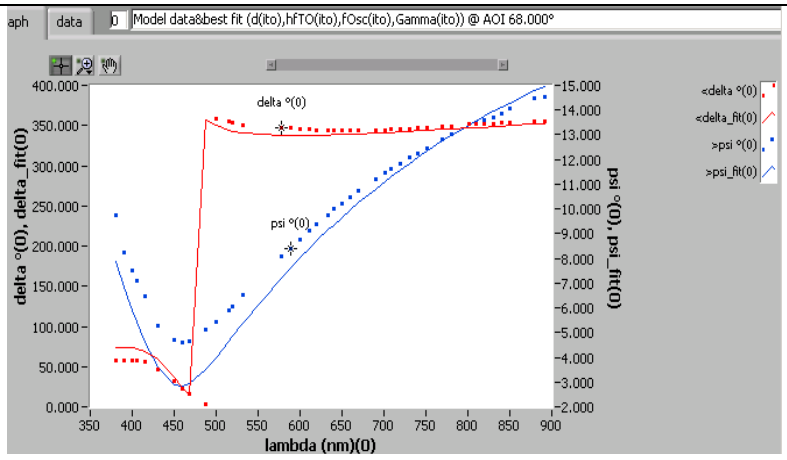
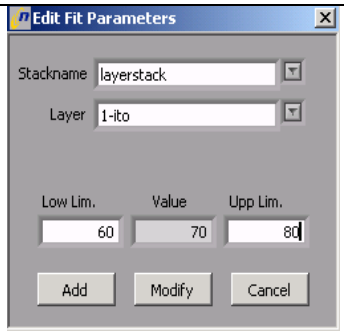
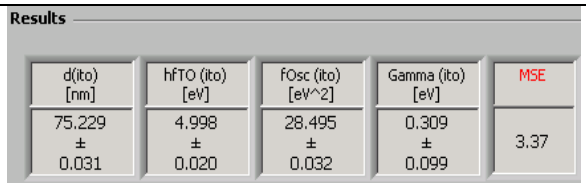


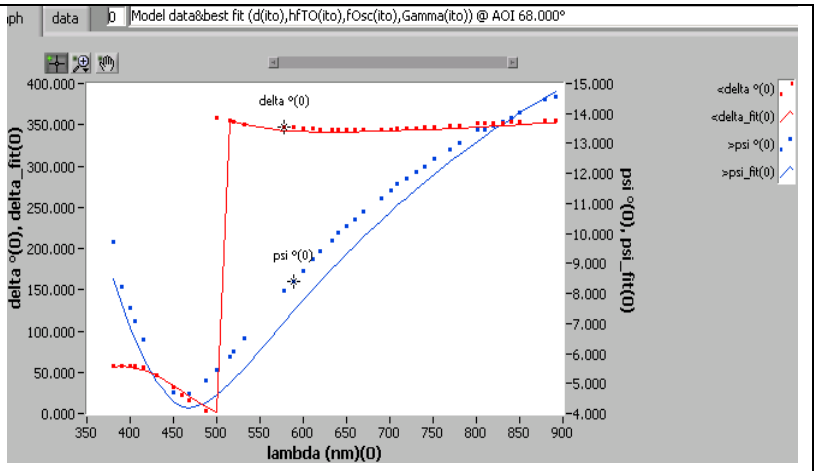
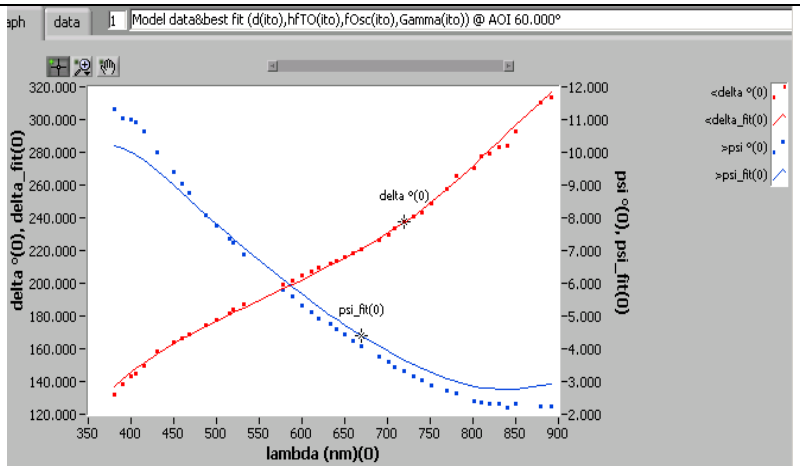
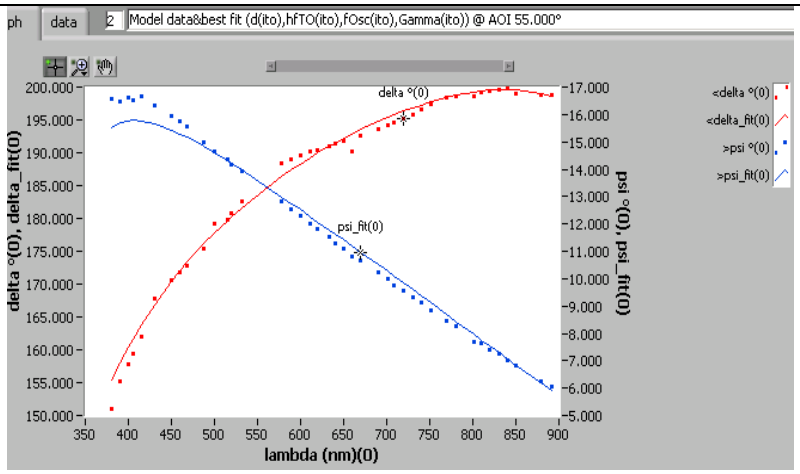
Now we switch to the layers-page, type a name of the stack, e.g. layerstack, “enter”, and Add. We select air as ambient and bk7 as substrate. By a double click on ito we create an ito-layer, where the layer number is used as a prefix of the layer’s name. Clicking on this layer “1-ito”, we type 60 nm as an initial guess value for the thickness of the ito-layer in the box below.

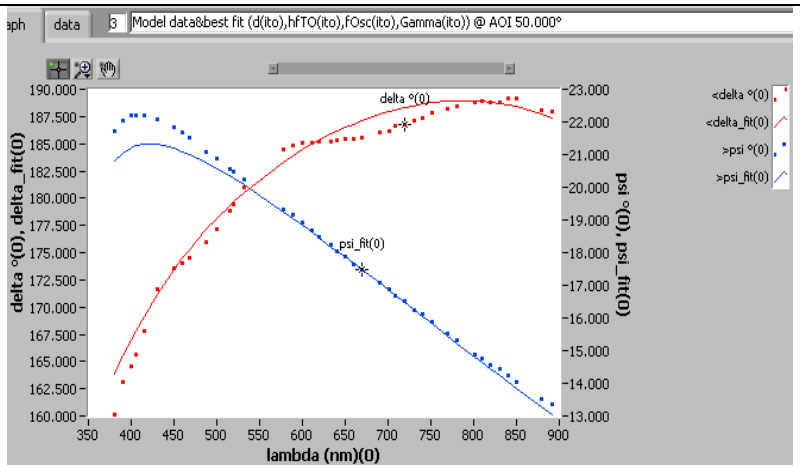
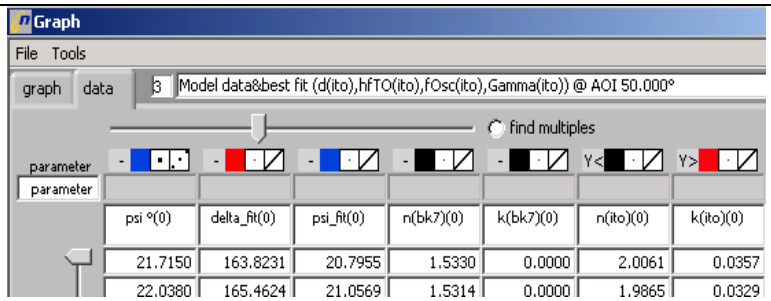
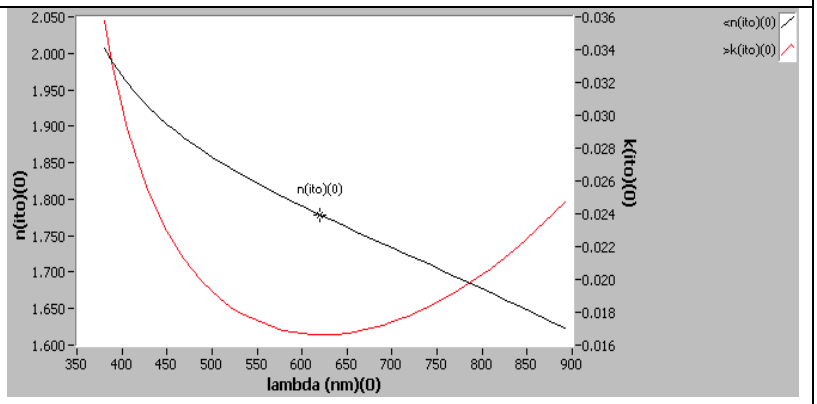


To select or change **fit-parameters**, we click on a line in the corresponding table, and press Edit...



A window pops up, where one selects the layerstack to fit for a layer thickness, or one selects a dispersion term of a material. In the example (right) we get the list of dispersion term of the ito, and select the oscillator. We put reasonable numbers for upper and lower fit-limits or use the automatically generated limits.	
Since we are not sure about the ito-film thickness, we select global = 1 in the **fit controls** and press the fit-button. In this case 20 intermediate values of the thickness from 0 to 200 nm are compared with the measured data before the local fitting start at the data point with best agreement.	
We obtain the results. We notice that the thickness is about 70 nm.	
We transfer the data with the fitted data into the Graph by “data & best fit -> Graph” in the tools menu. We observe that the fit quality is sufficient for a first trial.	
We decrease the thickness range and use 60…80 nm instead of 0 … 200 nm while editing the fit parameters.	
We press the fit-button an obtain a similar result as before, but with a smaller MSE	

We obtain one graph for each AOI. In the following we click on the headline switch through the different angles: here is 68 deg	
here is 60 deg	
here is 55 deg	

here is 50 deg	
We change to the Graph. We scroll with the upper slider to the right and find the refractive index n and extinction k of ito in the table. We click on the header  to select the n(ito) as left Y-axis and k(ito) as right Y-axis. Click on the coloured square to select the colour of the curve. Set the column header of the original Y-axes of Delta and Psi on "-". This won't display them any longer.	
You are left with the dispersion function of the ito film.	

Anisotropic layers

Nanofilm's optical model of the sample assumes normally optical isotropic materials. Uniaxially or biaxially anisotropic films on an isotropic substrate in an isotropic ambient can be treated by the modifiers "aniso", see layers-page, when the optic axes of the film are perpendicular or parallel to the sample surface. In this case the reflection coefficients Rps = 0 = Rsp, i.e. p-(or s-) polarized light is not turned into s-(p-) polarized light after reflection on the sample [1]. This condition means that there is a unique pair Delta/Psi which is the same in all 4 zones. This kind of anisotropy is found in Langmuir-Blodgett layers, which are monomolecular layers of well-oriented molecules, and in vacuum-deposited films with island-like structures [R.M.A. Azzam and N.M. Bashara, "Ellipsometry and Polarized Light", North Holland Physics, 1987, chapter 4.7.3.3, pp. 356-357, and D. den Engelsen, J.Opt.Soc.Am. 61, 1460 (1971)]

Besides this particular anisotropy with Rps = 0 = Rsp there are more general cases of anisotropic samples where the Delta/Psi of the 4 zones are not identical. Sometimes it is even possible that Delta/Psi does not exist in some of the 4 zones. Those cases are not simulated by the software. It is recommended to try to record Delta/Psi in 4 zones. If the standard deviation of the mean values of Delta/Psi over 4 zones exceeds ± 1° in Delta or ± 0.5° in Psi, one should consider whether any anisotropy of the sample could play a role. As long as the Delta/Psi exists in 4

zones, the mean value in Delta/Psi, which is shifted due to anisotropy, can be simulated with the isotropic optical model of the software, where the refractive index is interpreted as effective refractive index.

Mapping window

In this window the calculation of thickness and refractive is executed.

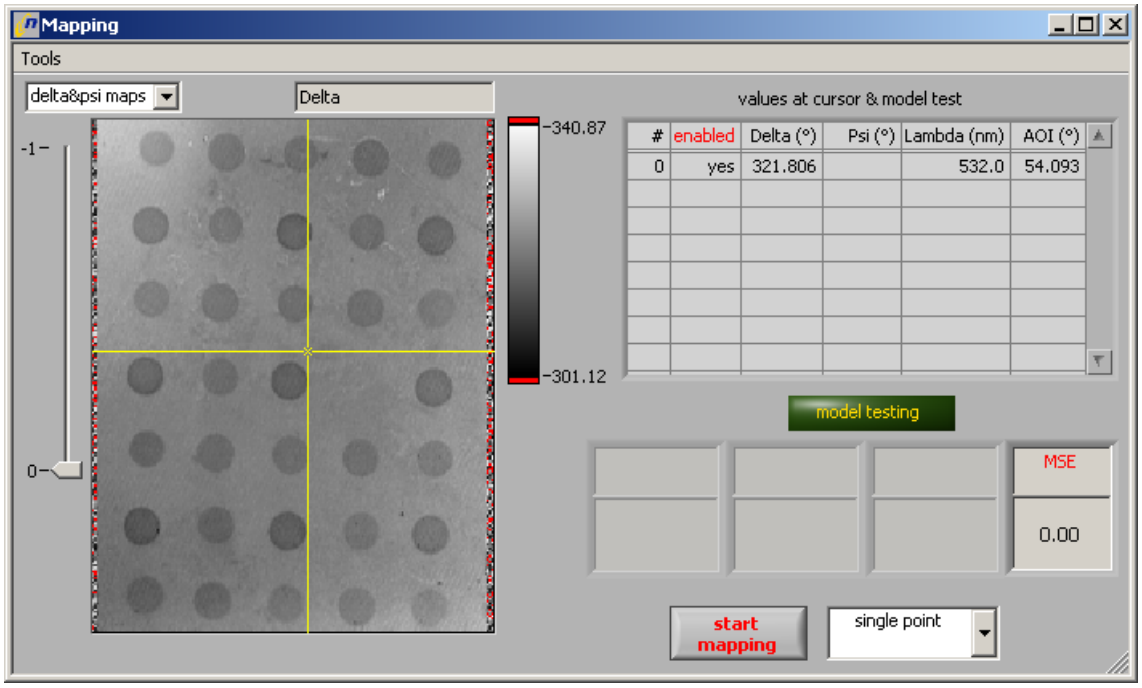
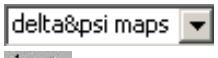


Fig. 4.1-43

“Tools” bar:

- “import map from viewer”
  imports active map from the “map&image viewer”
- “remove unmapped points”
  unmapped points are replaced with an averaged value of the neighbouring points
- “delete map”
  deletes the active map
- “delete all maps”
  deletes all maps in the mapping window
- “crop maps to cursors”
  cursors are shown in the active map used for cropping parts of the map
- “set max map number”
  sets the maximal number of maps allowed
- “subsample maps”
  subsamples the map with a factor of 2, 3, 4 or 5 (decreases the mapping time)
- “selected maps → map viewer”
  the currently displayed map is transferred to the window “map&image viewer” where it can be saved
- “maps → map viewer”
  all maps in the mapping window are transferred to the window “map&image viewer” where they can be saved

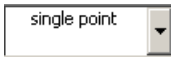


spin button to select which kind of maps (deltaψ result, error, MSE) should be displayed

map tray for maps, left click moves the slider

shows the name of the currently displayed map

The table on the right side shows the values (like aoi, lambda etc.) of the imported maps. By clicking in the enable column the maps are used for the calculation(yes) or not used(no).
By shifting the cursor the calculated values(provided a model is selected) of this point are displayed in the small boxes underneath the model testing button.



to select the calculation method

- Single point is used for calculations of maps using delta and psi simultaneously
- Interpolation can only be used if you have either a delta or a psi map

to start the map calculation

Script Editor window

This window contains a field for editing and viewing scripts written in “EP3Script”-language. .

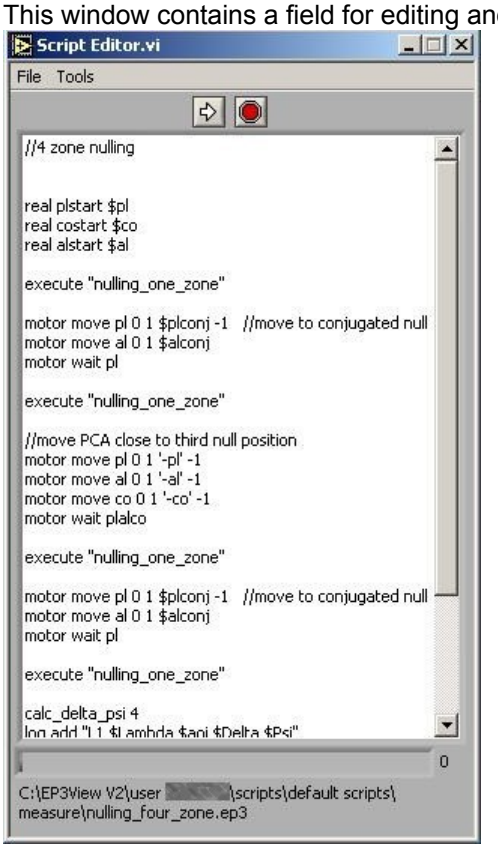


Fig. 4.1-44

“File” bar:

- “load script”
  loads a script
- “save script”
  saves a script

Do not modify the default scripts delivered by Nanofilm.
They are stored in the folder “..\user XXX\scripts\default scripts”.
The “default scripts”-folder is intended to be updated by Nanofilm, any personal setting will be lost.
Save modified scripts in the folder “user XXX\scripts\user scripts” with a different name !

The name of scripts must be unique within one user!
Even if scripts are saved in different windows folders they must not have the same name.

“Tools” bar:

- “script monitor”
  shows the actually executed script and marks the executed line


button to start the currently displayed script


button to break the currently executed script

script file selector

Five different scripts may be edited simultaneously. The currently visible script is the active. Click on the selector bar to change the displayed script. The number of the active script (0 to 4) is displayed behind the selector.

Detailed description of the EP3 View script commands is in the annex.

XY pattern generator

The XY pattern generator is a special tool that is only available for automatic xyz stages.

To install the XY pattern generator execute the following steps:
-add this line to config.ini, section[windows] (lower end); correct the window-number if necessary:
window11="XY pattern generator@tools\xyz stage\xypattern.llb\xypattern.vi"
-copy the xy_scripts to your user into the folder \scripts\tools_scripts\XY_scripts
-add a XY-Function group to your function tree:
main window => open_VI => "C:\EP3View V2\tools\utilities\functiontree_utilities.llb" => "AppendGroup.vi" => "C:\EP3View V2\tools\xyz stage\XY patterns.xml" and save the function tree, if not present please download from the Nanofilm Extranet

The XY pattern generator can be opened in the main “EP³View” Window under the section “windows”. Three types of patterns can be shown.

Type 1:

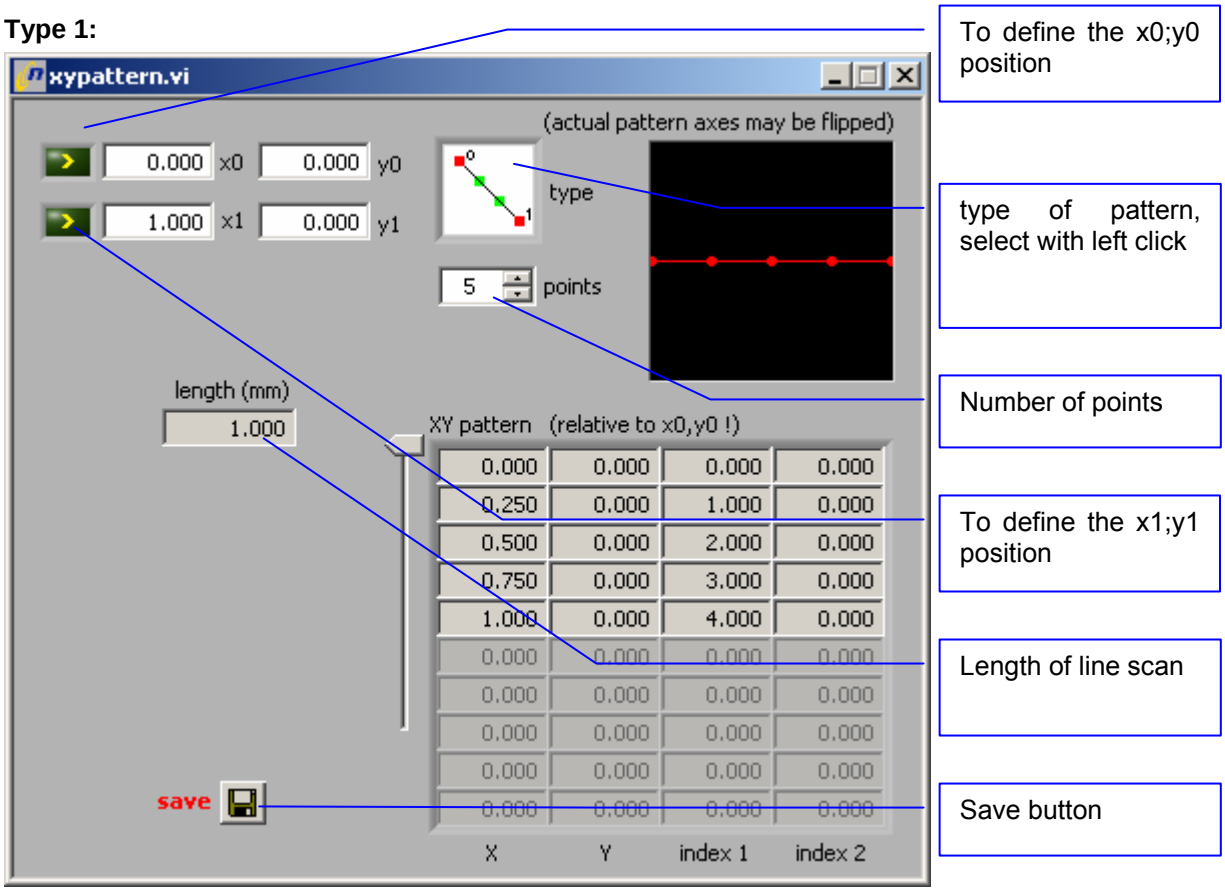


Fig. 4.1-45

If you want to use this type, you have to define your start position(0) and end position(1).
Please move with the automatically XY-stage to the start position, press the yellow arrow beside x0;y0, after that move with the XY stage to the end position and press the yellow arrow beside x1;y1. Then define the number of points you want to measure. Now the XY positions appear in the table and the length of your line scan is displayed. Save this XY-pattern by pressing the “save button”.

Type 2:

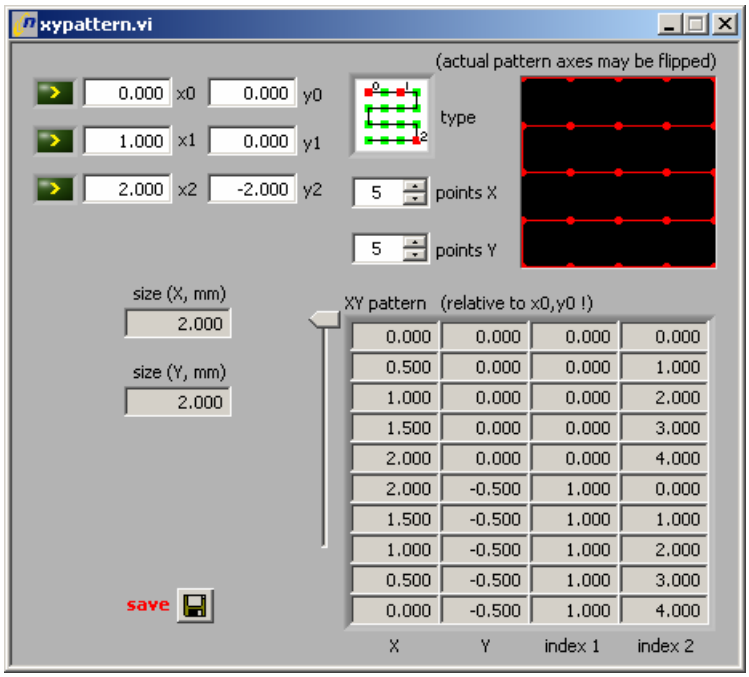


Fig. 4.1-46

When using this type of pattern, you have to define three points as shown in the “type” window. Therefore move with the automatically XY-stage to the start position, press the yellow arrow beside x0;y0, then move to a position in the first row, press the yellow arrow beside x1;y1 and finally move to the end position and press the yellow arrow beside x2;y2. After that define the number of points in x and y direction. Now the XY positions and size of your scan are displayed. Save this XY-pattern by pressing the “save button”.

Type 3:

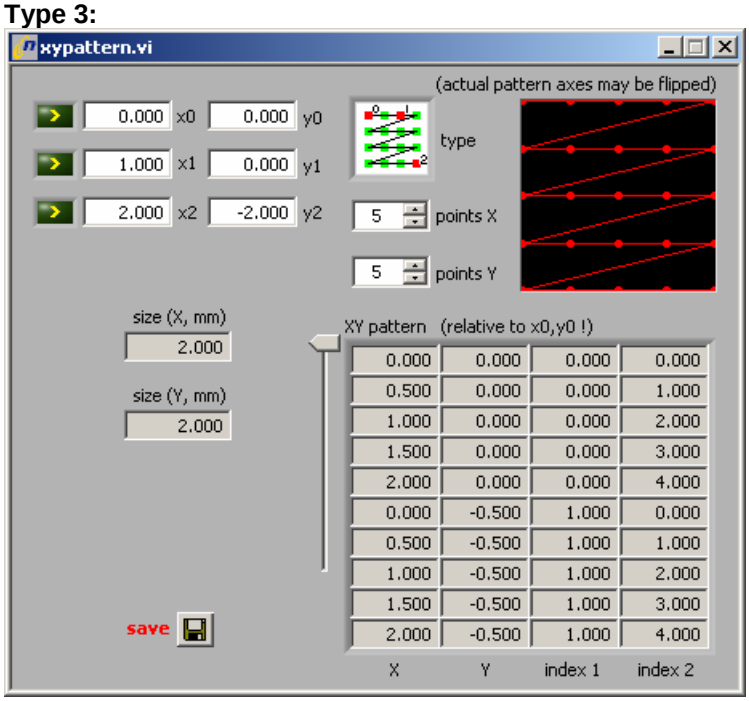


Fig. 4.1-47

Description see type 2

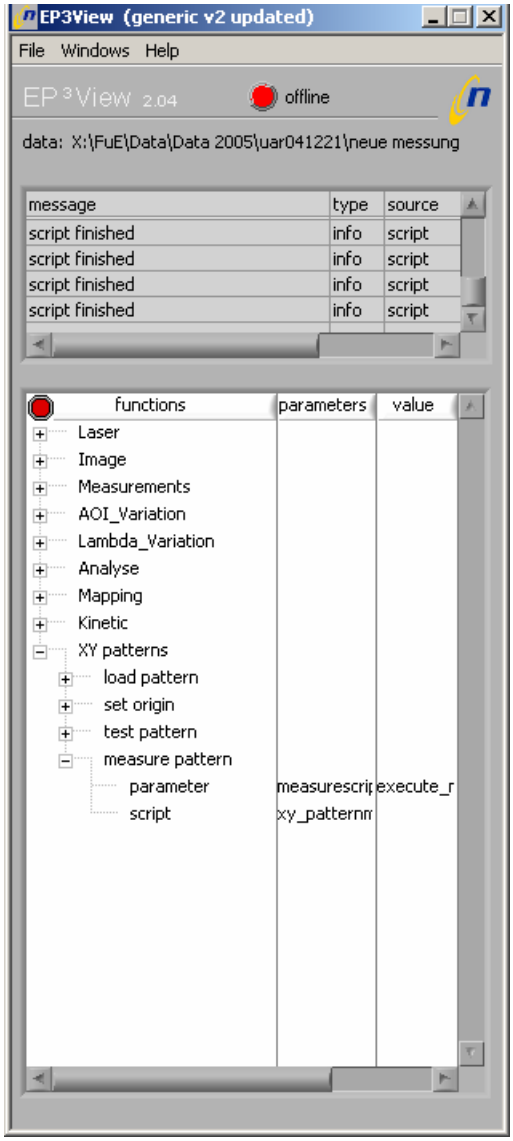


Fig. 4.1-48

After generating the XY pattern the saved XY-patterns can be loaded by double clicking the function “load pattern” in the section “XY patterns” in the function tree. To measure on the the points of the selected pattern open the section “measure pattern” by pressing on the + button, right click on parameter and type in (value input) the measure script (e.g. “execute_nulling_one_zone”) you want to use. Then run the script by double clicking the function “measure pattern”.
Now on every point of your XY-pattern the selected script (e.g. “execute_nulling_one_zone”) is executed automatically.

4.2. Getting started

Login

To work with EP3View select a user from the dialog box. A user profile includes customized function buttons, recipes and user front end.

It is possible to have individual user profiles for multiple operators or hardware configuration.
Every folder in “\RefSpec2” with the first word “user” is offered as user configuration at startup.

To start EP^{3}View:

- Switch on the PC and the EP^3 controller.
- Click **EP3View** in the Windows Start menu or use the icon on the desktop.
- During the program startup (the main window appears), a "user login" dialog box is displayed.

Fig. 4.2-1

- Select an appropriate user profile from the list box. A new user can be generated by creating a copy of the whole folder C:\Ep3View v2\user… into the same folder C:\EP3View. Then you can rename the user.
- Close the dialog box with **login**.

– The software begins to initialize the EP³. All motors are reseted.

If a firewall or a virus scanner is installed, either it has to be deactivated or all access from EP3View must be enabled in the firewall settings. Otherwise the connection will not work.

- The name of the current user profile is displayed in title bar of EP^{3}View.
- Select the check box "work offline", if only modelling or data analysis is to be done.

In order to get used with the functionality of the EP³ we recommend to use a silicon sample in the beginning, e.g. with natural SiO2 layer.
All settings used in the following procedures are recommended values for Si-samples. For further details on the different settings please view the descriptions in the according chapters.

Alignment

- Put a white paper on the sample holder and move the sample stage until the red alignment laser spot is in center.
- Put the Si- sample on the sample stage below the red align laser.
- Align the sample stage as written Align (see page 36).

Z-Position

- Open the shutter.
- Select 50° for polarizer, 45° for analyzer and 30° for analyzer.
- Set 54° for goniometer angle.
- Select high gain and high laser power in order to see the spot in the live window.
- Move the sample stage up and down in order to get the spot to the middle of the live window.
  If you have no idea in which direction to move the z-stage, hold a white sheet of paper in front of the objective to see if the reflected spot is in the middle of the objective. If the reflected spot is higher than the middle of the objective you have to move down the z-stage and vice versa.
- Decrease laser power and click “auto-gain” to avoid saturation.
- Now you should see your sample surface, probably not sharp. Dust particles might give orientation.
- Check the alignment again.

Focus

- Open the focus calibration window and focus on the substrate: Move the red line to a sharp point in the live window. Dust particles on the sample may help you to find the focused line as well as structures on the sample. Right click on the focus calibration control window to close it.

  The focus is now calibrated. For further information view Focus Calibration Control (see page 33).

Now everything is prepared to start measurements.

Imaging

- Move the sample stage to the region on the sample where you want to measure.
- Grab an image by pressing the camera button. For more information view Image grab control (see page 32).
- Open the Map & Image Viewer window (see page 28 and 39) to see the grabbed image, to do image processing and to save the image to disc.

This “ellipsometric contrast” image already gives you qualitative information of your sample surface. It includes the ellipsometric and gives answers to questions like: Is the sample homogeneous? Are wanted or unwanted structures visible? Etc.

4.3. Single Measurement

A typical application for ellipsometry is to measure the film thickness of a layer with known refractive index n and extinction coefficient k. Measure the thickness of the SiO2 layer on the Si-substrate as follows:

Measurement

- Follow the instructions in 4.2. to get started.
- Select the ROI tool on the left side of the live window.
- Move the existing ROIs or draw new ones in the live window. Any time you select a new ROI you will be asked if you want to delete all other ROIs or to add this new ROI to the others. Try to choose a homogeneous region for the measurement.
- Select 50° for polarizer, 45° for analyzer and 30° for analyzer.
- Set 54° for goniometer angle.
- Select the function group “Measurement” in the function tree in the Main window (see page 27).
- Doubleclick on the function “Coarse Adjust”. The software automatically moves polarizer and analyzer close to the “null” condition (minimum of polarizer and analyzer at compensator = 45°).
- Now select a measurement mode, e.g. “nulling_four_zone.ep3”, by doubleclick in function group “Measurement” in the function tree in the Main window (see page 27).

“Nulling_four_zone.ep3” is the procedure for the highest measurement accuracy, “nulling_one_zone.ep3” the most time-effective.

You can find the detailed description of all measurement tools in the Function tree (see page 103). Other automatic measurements can be selected in the Script Editor window (see page 78). Also, new measurement procedures can be programmed by using the script language described in the annex Script commands.

- Check the statusreport in main window if no error messages appear.
- Open the Log Editor window (see page 46) to see all measurement results.
- Save the log file.

Now the raw ellipsometric datas are recorded. You will find delta and psi values for each of the zones and the mean value for all the zones. Wavelength and angle of incidence are also displayed as well as the polarizer, compensator and analyzer angles.
In order to get thickness of the SiO2 layer we have to fit these datas with an appropriate model.

- Mark the line with the delta and psi results (by using “nulling_four_zone” the line with the mean delta and psi results) by clicking on the upper left cell, then keep the shift button pressed and click on the buttom right cell holding left click. The selected lines are marked blue.

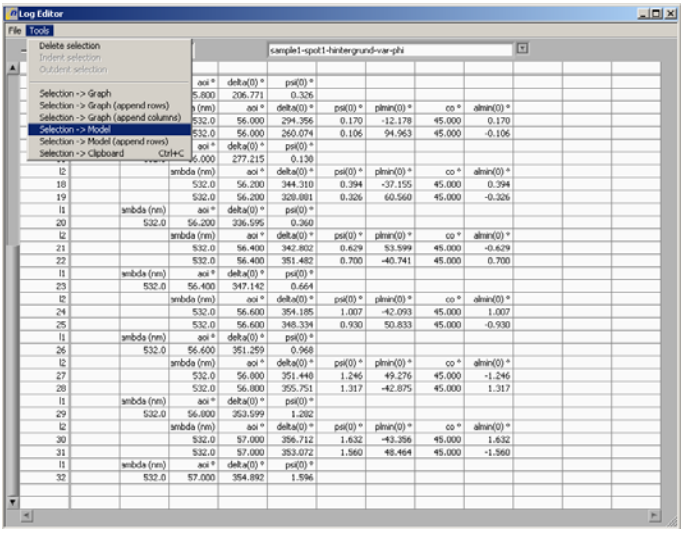


Fig. 4.3-1

- To transfer the marked results to model go to “Tools” - “Selection→Model”
- Open the Model window (see page 53).
- The selected line appears in the window “Model” tab control “Fit”

Fit

- Load the receipe for SiO2 on Si from “C:\EP3View V2\user xxx\recipes” or define a new layer stack. If you load a receipe you can continue with Fit Controls page 88.
- Open the tab control materials (see page 53) in the Model window.
- Select “si” and “sio2-a” from the list of predefined materials.

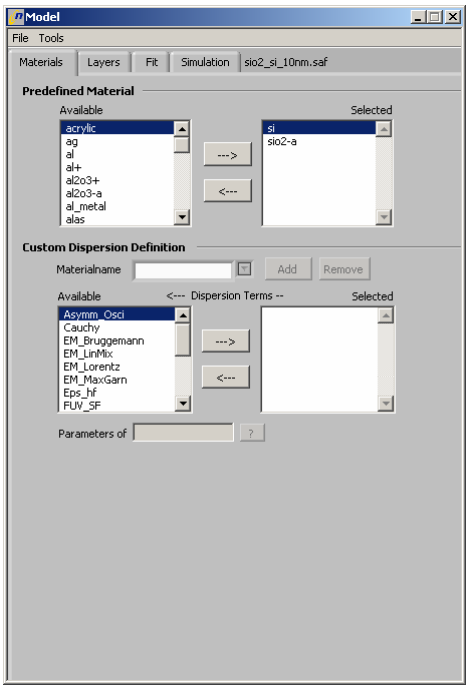


Fig. 4.3-2

- Go to the tab control “Layers”.
- Choose “si” as substrate, “sio2-a” as layer and “air” as ambient.

- Left click on “1-sio2-a” in the “selected” list and type the estimated thickness in the “Thickness” control.

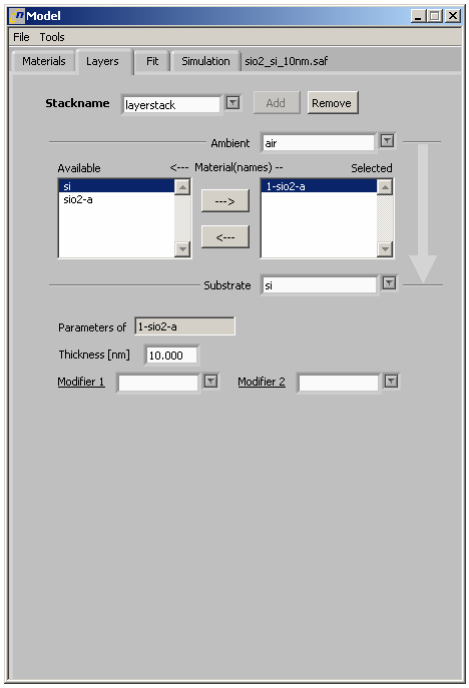


Fig. 4.3-3

- Go to the tab control “Fit”.

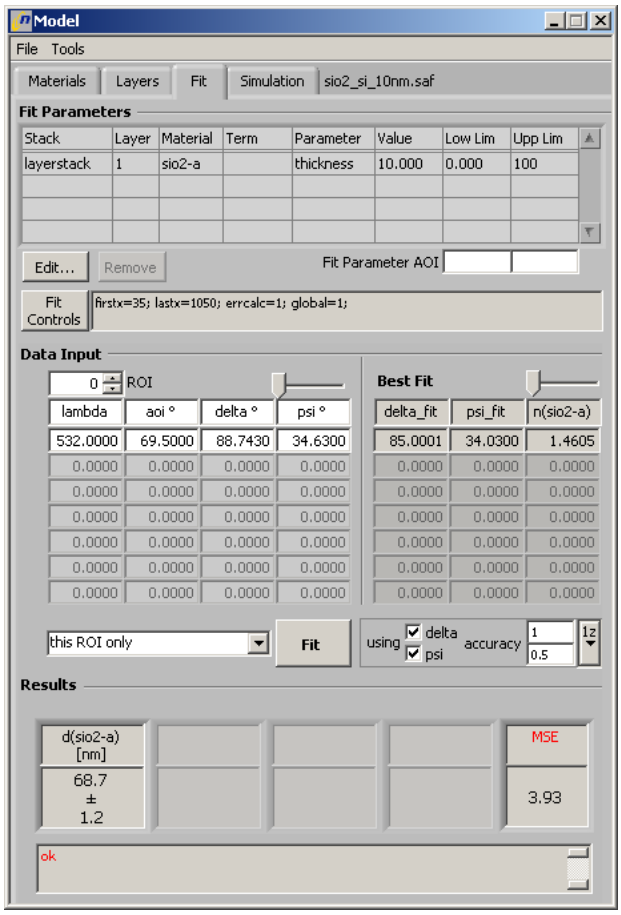


Fig. 4.3-4

- Press “Edit” and define the thickness ranges of your fit (Lower Limit, Upper Limit) in the parameters window, e.g. choose “5” for lower limit and “20” for upper limit.

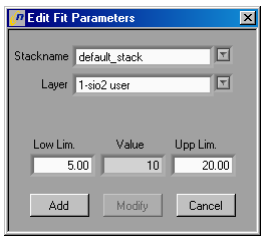


Fig. 4.3-5

- Press the “Fit Controls” button and select the parameters as in the following image. (For a detailed description of each parameters refer to Fit-parameter selection (see page 60). Press ok when finished to close the window.

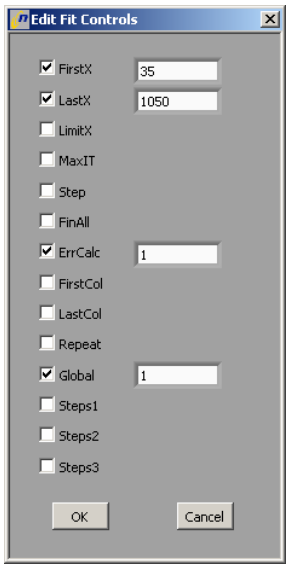


Fig. 4.3-6

- Press the button “fit” in the middle of the window and the results will appear in the lower spreadsheet “fit_results” according to Fig. 4.3-4
- If any parameter for the fit is wrong an error occurs and zero is displayed for the “fit_result”.
- If a fitted value is equal to the limit you set, you have to change the limit.
- To approve the results change the limit values.

Now you have the thickness of your SiO2 layer.
For a natural SiO2 layer one would expect a value between 2 and 4 nm.

- The results can be added to the logfile editor at “Tools” - “Results→Log”.

4.4. Angle of Incidence Spectrum

For the above single measurement we assumed a value for refractive index n and extinction coefficient k of the oxide layer (literature value) and took this into account for the thickness calculation. Of course, a calculation with an assumption can not be as good as if we calculate thickness, refractive index and extinction coefficient independently. For that reason, you have to collect more parameters – e.g. with an angle-of-incidence spectrum.

Measurement

- Follow the instructions in 4.2. to get started.
- Select the ROI tool on the left side of the live window.
- Move the existing ROIs or select new ones in the live window. Any time you select a new ROI you will be asked if you want to delete all other ROIs or to add this new ROI to the others.
- Choose a big homogeneous area since the region-of-interest might shift during angle-of-incidence spectras.
- Select the function group “AOI_Variation” in the function tree in the Main window (see page 27).

For highest accuracy it is recommended to perform angle-of-incidence measurements close to the Brewster Angle. For that reason, a procedure is used to determine the Brewster Angle.

- The Brewster angle depends on n and k of the substrate. For high reflecting substrates (k=0) the bresterangle Phi=arctan (n). The following table contains some typical Brewster angles:

Material	Brewster angle [°]
Thin layer on glas	55-57
Thin layer on gold	64-74
Thin layer on silicon	70-80

- Move the goniometer to 70°.

Make sure that the objective will not touch the sample during the procedure.

- Doubleclick on the function “Brewsterangle”. The software automatically finds the “brewsterangle” of your layer (minimum of intensity at polarizer, analyzer, compensator = 0°).
- If the brewsterangle is outside the range move the goniometer to 75° and try again.
- After getting the brewsterangle, select 5° for polarizer, 45° for analyzer and 30° for analyzer.
- select the “four_zone” at function group “AOI_Variation” in the function tree in the Main window (see page 27). Type “65°” as start and “80°” as end value for the goniometer and “1°” the goniometer steps.

  How to change these parameters see the description of the function tree in section Main window (see page 27).
- The script automatically opens the graph window and transfers the measured data to the window graph, where the measured data is displayed in a spreadsheet.

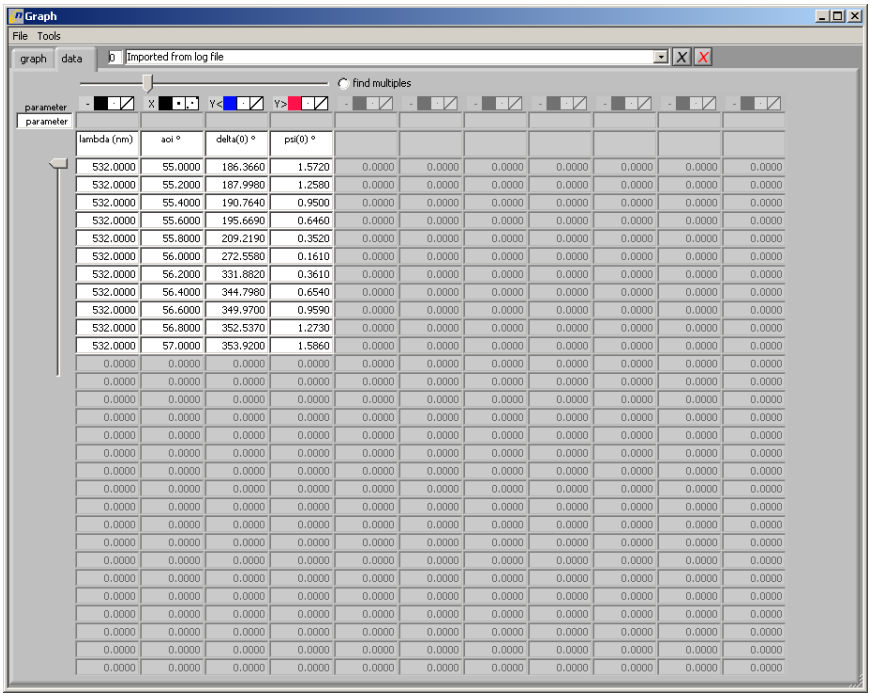


Fig. 4.4-1

- You can see the plot in the tab control “graph”.

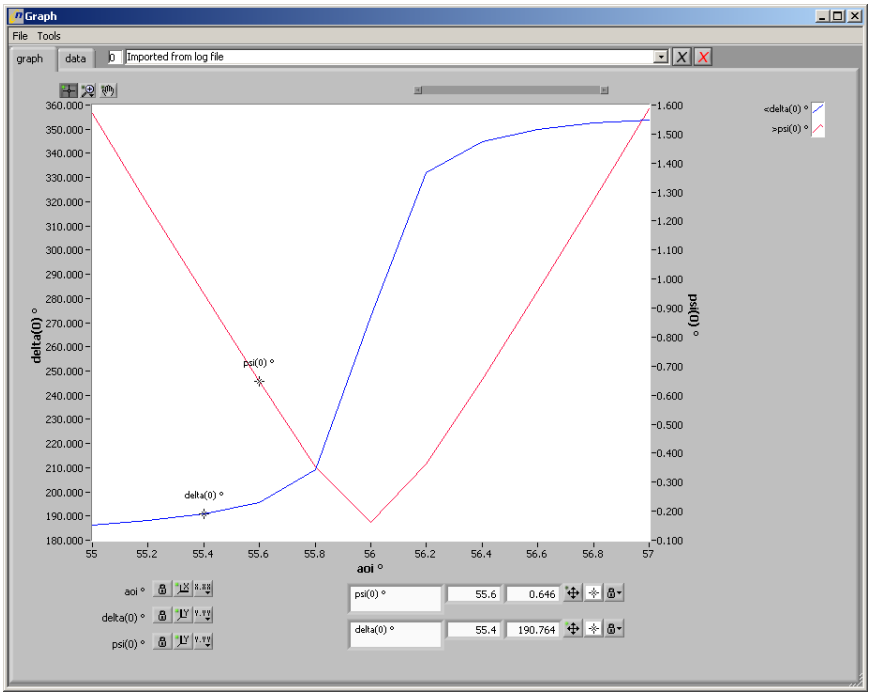


Fig. 4.4-2

Now the raw ellipsometric datas are recorded. You will find delta and psi values for each of the zones and the mean value for all the zones per angle of incidence. Wavelength and angle of incidence are also displayed as well as the polarizer, compensator and analyzer angles.
In order to get refractive index, extinction coefficient and thickness of the SiO2 layer we have to fit these datas with an appropriate model.

- Open the Log Editor window (see page 46) to transfer the measurement results to the model window.
- Mark the lines with the delta and psi results (by using “nulling_four_zone the line with the mean delta and psi results) by clicking on the upper left cell, then keep the shift button pressed and click on the buttom right cell holding left click. The selected lines are marked blue. Also use the slider to show only the mean values as described in the Control elements (see page 47).

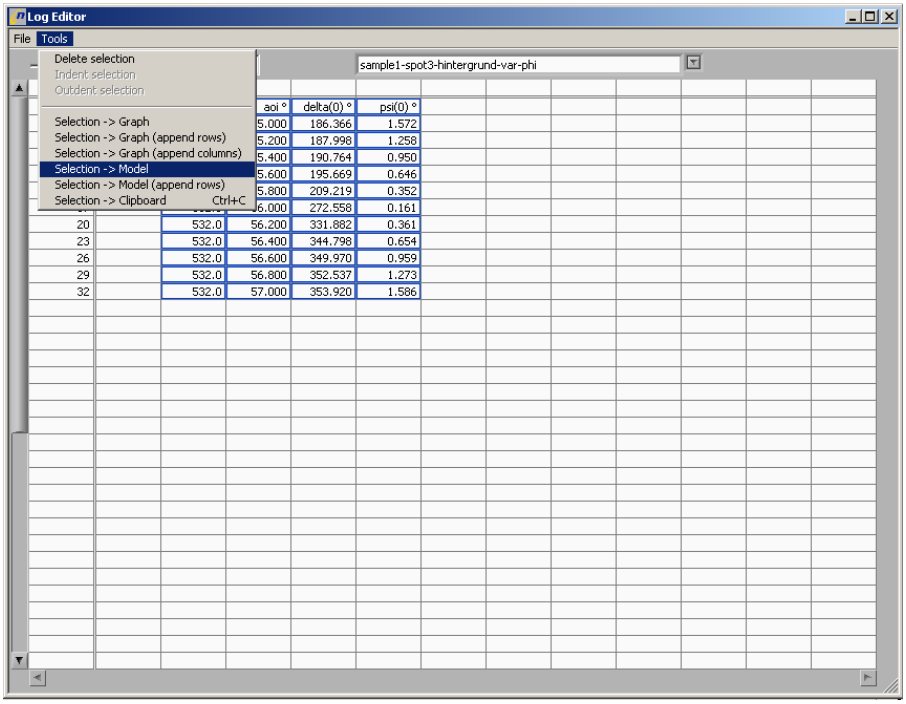


Fig. 4.4-3

- To transfer the marked results to the model select “Tools”- “Selection→Model”.
- Open the Model window (see page 53) to fit the measurement results.
- The selected lines appear in the window “Model“ (see Fig. 4.4-6)

Fit

- Load a predefined receipe or define a new layer stack as follows.
- Open the tab control materials (see page 53) in the Model window.
- Select “si” from the list of predefined materials. Define a new layer stack like “sio2 user”.

If you want to fit for n and k values of your layer you have to define a new user-defined layer.

- Add a dispersion function like n-k-fix for the layer.
- Left click on “1-sio2-a” in the “selected” list and type the estimated thickness in the “Thickness” control.

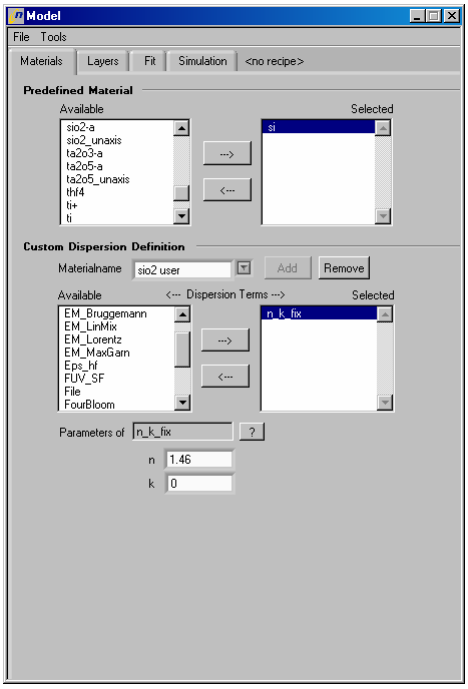


Fig. 4.4-4

- Go to the tab control “Layers”.
- Choose “si” as substrate, “1-sio2 user” as layer and “air” as ambient.
- Left click on “1-sio2 user” in the “selected” list and type the estimated thickness in the “Thickness” control.

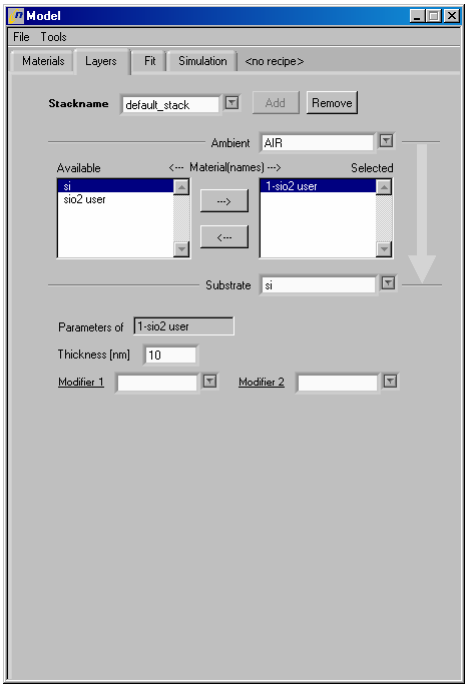


Fig. 4.4-5

- Go to the tab control “Fit”.

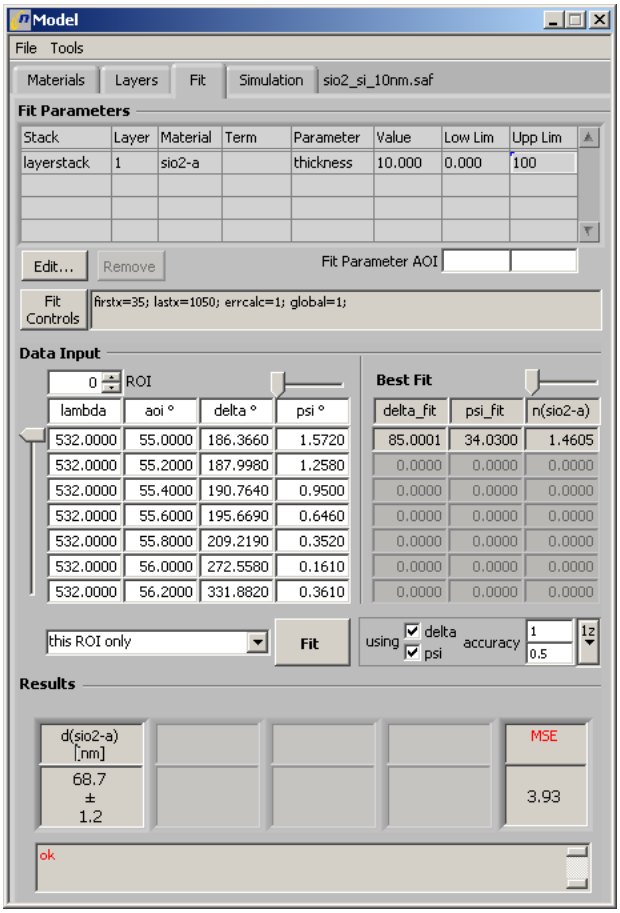


Fig. 4.4-6

- Press “Edit” and define the thickness ranges of your fit (Lower Limit, Upper Limit) in the parameters window, e.g. choose “0” for lower limit and “100” for upper limit.

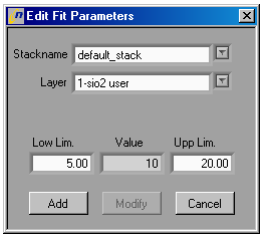


Fig. 4.4-7

- Define the refractive index ranges of your fit (Lower Limit, Upper Limit) in the parameters window, e.g. choose “1.3” for lower limit and “1.5” for upper limit.

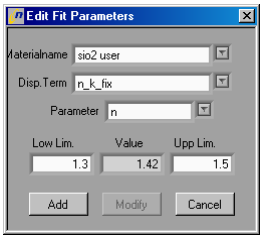


Fig. 4.4-8

- Define the extinction coefficient ranges of your fit (Lower Limit, Upper Limit) in the parameters window, e.g. choose “-0.1” for lower limit and “1” for upper limit.

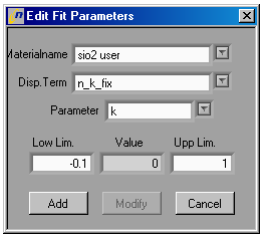


Fig. 4.4-9

- Press the “Fit Controls” button and select the parameters as in the following image. (For a detailed description of eall parameters refer to Fit-parameter selection (see page 60). Press ok when finished to close the window.

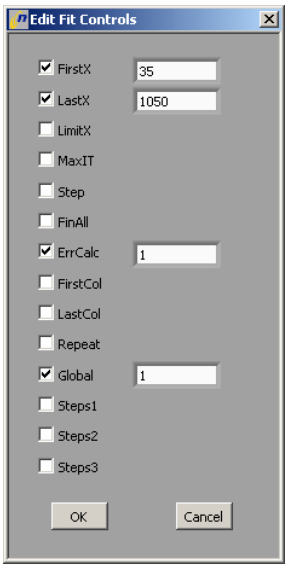


Fig. 4.4-10

- Press the button “fit” in the middle of the window and the results will appear in the lower spreadsheet “fit_results”.
- If any parameter for the fit is wrong an error occurs and zero is displayed for the “fit_result”.
- If a fitted value is equal to the limit you set, you have to change the limit.
- To approve the results change the limit values.
- After the fit you can plot the delta-fit values and psi-fit values together with the delta and psi values in the window graph. If the measured and fitted values correspond the fit is ok.
- To transfer the fitted values to the window graph select “tools” - “Data→Graph”

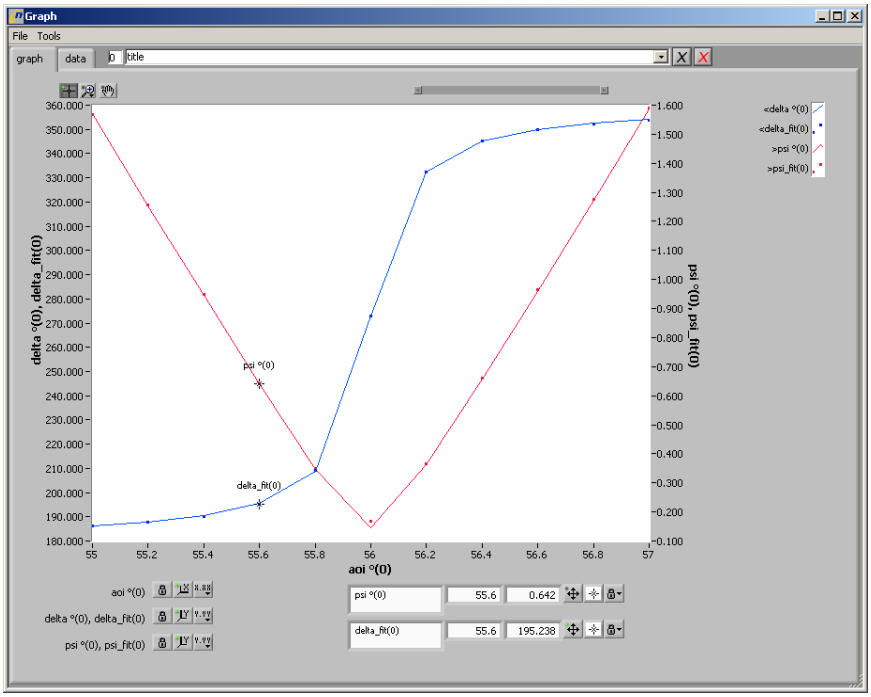

Graph
File Tools
graph
data
title
delta °(0), delta_fit(0)
psi °(0), psi_fit(0)
aoi °(0)
psi °(0)
delta_fit(0)
«delta °(0)
«delta_fit(0)
»psi °(0)
»psi_fit(0)
psi °(0)
55.6
0.642
delta_fit(0)
55.6
195.238

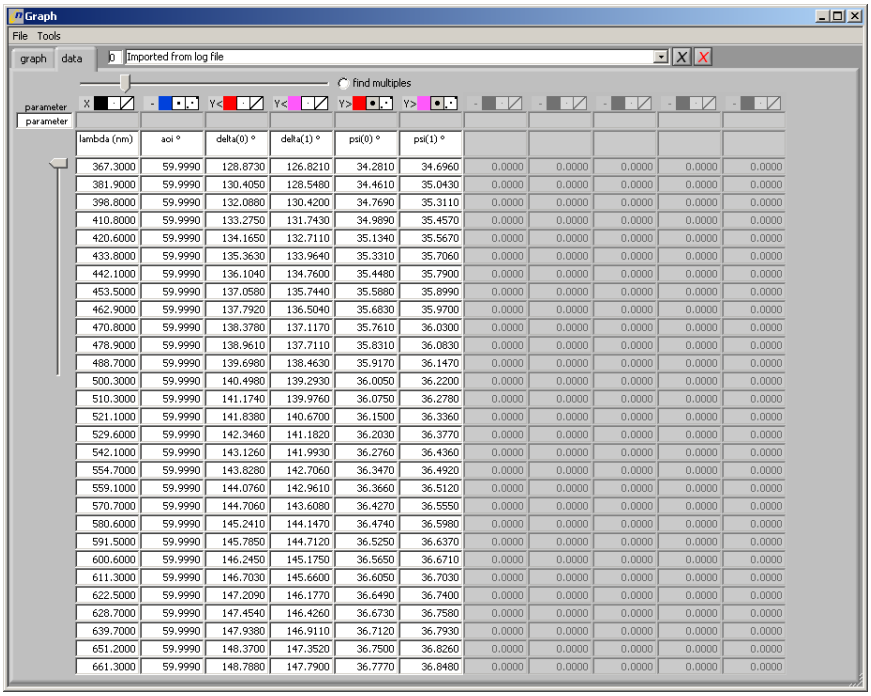
Fig. 4.4-11

4.5. Wavelength Spectrum

Measurement

An alternative to an angle-of- incidence spectrum is a wavelength spectrum – if the spectroscopic option is available. Furthermore, it enables to take material dispersions into account.

- Follow the instructions in 4.2. to get started.
- Select the ROI tool on the left side of the live window.
- Move the existing ROIs or select new ones in the live window. Any time you select a new ROI you will be asked if you want to delete all other ROIs or to add this new ROI to the others.
- Select the function group “Lambda_Variation” in the function tree in the Main window (see page 27).
- Select “one_zone”, “two_zone” or “four_zone” at function group “Lambda_Variation” in the function tree in the Main window (see page 27). Type in start and end values for the wavelength (Note: values are the index numbers for the wavelength, shown in the wavelength selection box) and the wavelength steps. How to change these parameters see the description of the function tree in section Main window (see page 27).
- The script automatically opens graph window and transfers measured datas to the window graph, where the measured data are displayed in a spreadsheet.



lambda (nm)	aoi °	delta(0) °	delta(1) °	psi(0) °	psi(1) °					
367.3000	59.9990	128.8730	126.8210	34.2810	34.6960	0.0000	0.0000	0.0000	0.0000	0.0000
381.9000	59.9990	130.4050	128.5480	34.4610	35.0430	0.0000	0.0000	0.0000	0.0000	0.0000
398.8000	59.9990	132.0880	130.4200	34.7690	35.3110	0.0000	0.0000	0.0000	0.0000	0.0000
410.8000	59.9990	133.2750	131.7430	34.9890	35.4570	0.0000	0.0000	0.0000	0.0000	0.0000
420.6000	59.9990	134.1650	132.7110	35.1340	35.5670	0.0000	0.0000	0.0000	0.0000	0.0000
433.8000	59.9990	135.3630	133.9640	35.3310	35.7060	0.0000	0.0000	0.0000	0.0000	0.0000
442.1000	59.9990	136.1040	134.7600	35.4480	35.7900	0.0000	0.0000	0.0000	0.0000	0.0000
453.5000	59.9990	137.0580	135.7440	35.5880	35.8990	0.0000	0.0000	0.0000	0.0000	0.0000
462.9000	59.9990	137.7920	136.5040	35.6830	35.9700	0.0000	0.0000	0.0000	0.0000	0.0000
470.8000	59.9990	138.3780	137.1170	35.7610	36.0300	0.0000	0.0000	0.0000	0.0000	0.0000
478.9000	59.9990	138.9610	137.7110	35.8310	36.0830	0.0000	0.0000	0.0000	0.0000	0.0000
488.7000	59.9990	139.6980	138.4630	35.9170	36.1470	0.0000	0.0000	0.0000	0.0000	0.0000
500.3000	59.9990	140.4980	139.2930	36.0050	36.2200	0.0000	0.0000	0.0000	0.0000	0.0000
510.3000	59.9990	141.1740	139.9760	36.0750	36.2780	0.0000	0.0000	0.0000	0.0000	0.0000
521.1000	59.9990	141.8380	140.6700	36.1500	36.3360	0.0000	0.0000	0.0000	0.0000	0.0000
529.6000	59.9990	142.3460	141.1820	36.2030	36.3770	0.0000	0.0000	0.0000	0.0000	0.0000
542.1000	59.9990	143.1260	141.9930	36.2760	36.4360	0.0000	0.0000	0.0000	0.0000	0.0000
554.7000	59.9990	143.8280	142.7060	36.3470	36.4920	0.0000	0.0000	0.0000	0.0000	0.0000
559.1000	59.9990	144.0760	142.9610	36.3660	36.5120	0.0000	0.0000	0.0000	0.0000	0.0000
570.7000	59.9990	144.7060	143.6080	36.4270	36.5550	0.0000	0.0000	0.0000	0.0000	0.0000
580.6000	59.9990	145.2410	144.1470	36.4740	36.5980	0.0000	0.0000	0.0000	0.0000	0.0000
591.5000	59.9990	145.7850	144.7120	36.5250	36.6370	0.0000	0.0000	0.0000	0.0000	0.0000
600.6000	59.9990	146.2450	145.1750	36.5650	36.6710	0.0000	0.0000	0.0000	0.0000	0.0000
611.3000	59.9990	146.7030	145.6600	36.6050	36.7030	0.0000	0.0000	0.0000	0.0000	0.0000
622.5000	59.9990	147.2090	146.1770	36.6490	36.7400	0.0000	0.0000	0.0000	0.0000	0.0000
628.7000	59.9990	147.4540	146.4260	36.6730	36.7580	0.0000	0.0000	0.0000	0.0000	0.0000
639.7000	59.9990	147.9380	146.9110	36.7120	36.7930	0.0000	0.0000	0.0000	0.0000	0.0000
651.2000	59.9990	148.3700	147.3520	36.7500	36.8260	0.0000	0.0000	0.0000	0.0000	0.0000
661.3000	59.9990	148.7880	147.7900	36.7770	36.8480	0.0000	0.0000	0.0000	0.0000	0.0000

Fig. 4.5-1

- You can see the plot in the tab control “graph”.

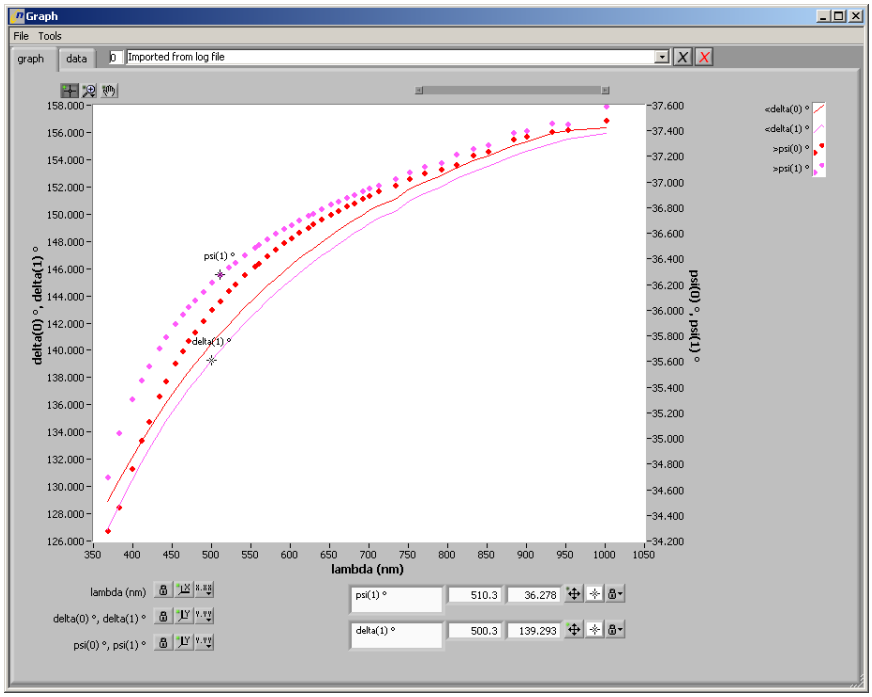


Fig. 4.5-2

- Open the Log Editor window (see page 46) to transfer the measurement results to the model window.
- Mark the lines with the delta and psi results (by using “nulling_four_zone the line with the mean delta and psi results) by clicking on the upper left cell, then keep the shift button pressed and click on the buttom right cell holding left click. The selected lines are marked blue. Also use the slider to show only the mean values as described in the Control elements (see page 47).
- To transfer the marked results to the model select “Tools” - “Selection→Model”.
- Open the Model window (see page 53) to fit the measurement results.
- The selected lines appear in the window “Model”:

Fit

- To fit the wavelength spectrum follow the instructions in section Fit in Angle of incidence spectrum (see page 91).
- After the fit you can plot the delta-fit values and psi-fit values together with the delta and psi values in the window graph. If the measured and fitted values correspond the fit is ok (see Fig. 4.5-2)
- To transfer the fitted values to the window graph select “tools” - “Data→Graph”.

4.6. Mapping

A delta mapping is usually used to calculate a thickness map of an unknown layer.

- Select the ROI tool on the left side of the live window.
- Move the existing ROIs or select new ones in the live window. Any time you select a new ROI you will be asked if you want to delete all other ROIs or to add this new ROI to the others.
- Select the function group “Mapping” in the function tree in the Main window (see page 27).
- Select “Map Delta” under the function group “Mapping” in the function tree in the Main window (see page 27). Type in the number_of_images, the plrange_map and the binning factor for the delta map (binning_map). Detailed description of these parameter see Section 5.2 Function tree. How to change these parameters see the description of the function tree in section Main window (see page 27). For a silicon sample the typical values are: number of images 10, binnig factor 2, plrange 10-20 deg.
- The script automatically finds the nulling condition in your selected zone and records the map
- The delta map is shown in the Map&Image window. Here you can save the delta map
- The script automatically opens the mapping window, where the delta map is also displayed

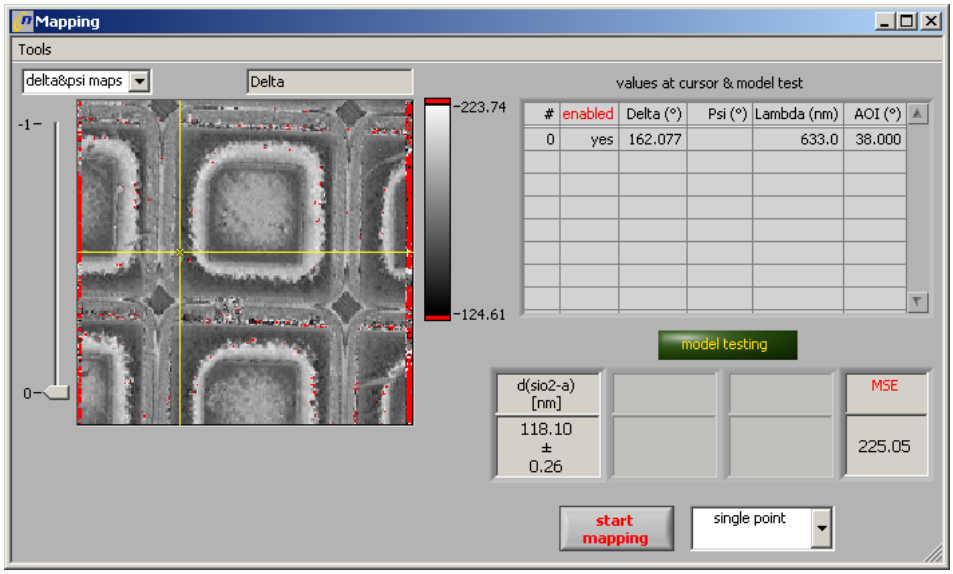


Fig. 4.6-1

- To load your according model follow the instructions in section Fit in Single Measurement (see page 86).
- Choose a method and press the button start in the mapping window. The interpolation method is used for calculation of a delta or a psi map. The single point method is used for calculation of both (delta and psi) maps.
- The software automatically calculates the desired thickness map and displays the map in the mapping window. At tools you can transfer the calculated map to the Map&Image Viewer, where the map can be saved.

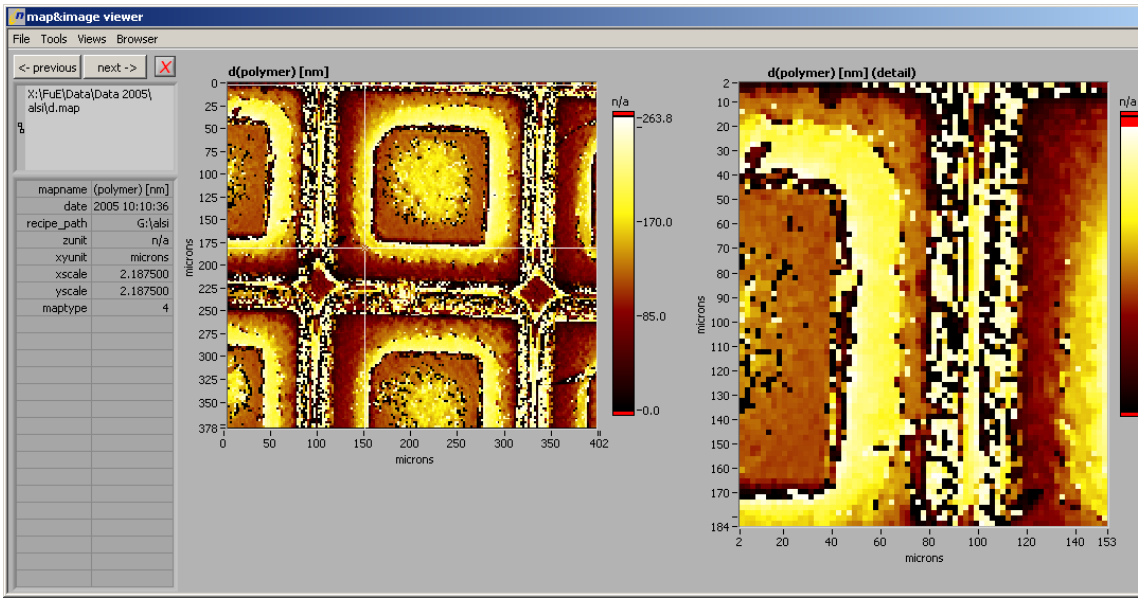


Fig. 4.6-2

- you must not use any image correction since it would modify the measurement results.
- in map&image viewer the calculated map can be displayed as a 3D map (under “views-3D Viewer”) and saved in the 3D Viewer (see section 3D-Viewer)

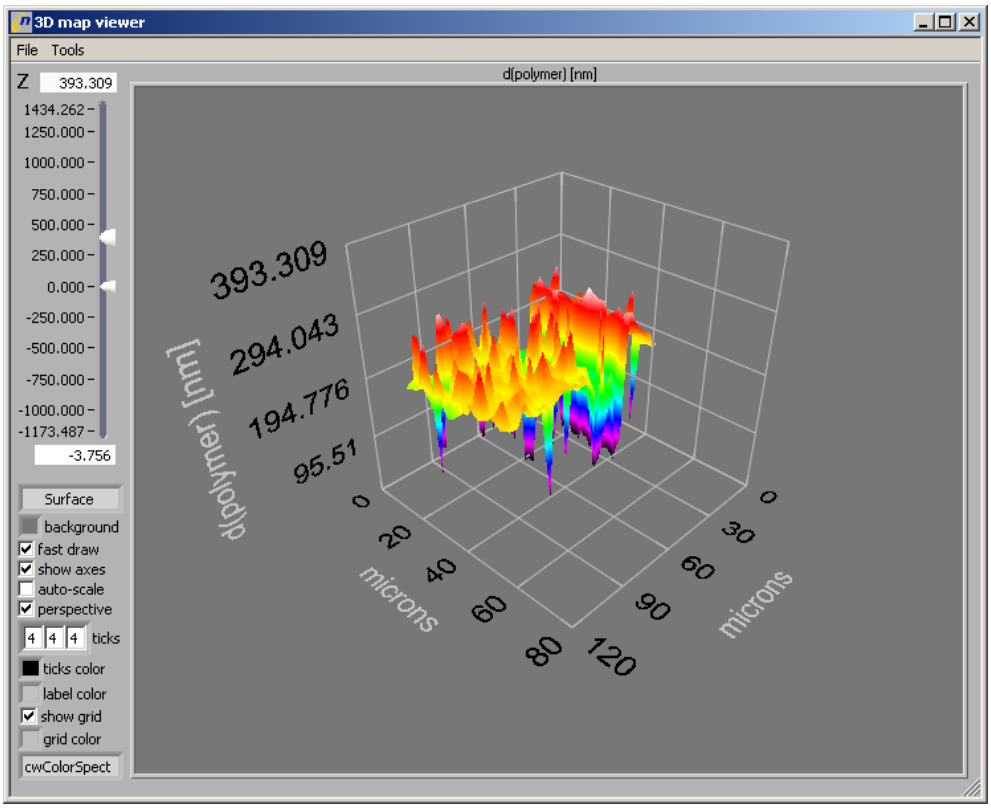


Fig. 4.6-3

5. Servicing and Maintenance

5.1. Personal Computer

Please make sure that you back up the datas of the measurements at regular intervals.

Furthermore, it is recommended to check the hard disk from time to time and to clean it up, if necessary.

For this purpose

- Right-click the drive to be checked.
- Select the menu option "Properties".
- Click the "Tools" tab in the "Properties" dialog and start error checking.

To check the functions of the PC's hardware components, you can use commercial diagnostics software.

5.2. Installed Software

The installed files of the *EP3View* software and Windows should be tested for errors at regular intervals. Errors in the file system might occur in case of power outage, PC shutdown during the writing process, or hardware errors. The testing methods are described in the operating system's manual.

Third-party programs, for which a proper functioning cannot be assured or which might affect the functionality of the *EP3View* software, should not be installed.

It is recommended to take preventive measures for the intrusion of computer viruses and to use adequate programs for regular virus checks.

5.3. Components of the Measuring Station

The components of the measuring station have to be protected against dirt and dust. The maintenance is restricted to the gentle cleaning the instruments' surface.

For removing the dust from the objective, you should use cleansing tissues for optical applications only.

6. Annex

6.1. Accessories

Anti-vibration system

The anti-vibration system is available as a passive or active system.

Basically, the passive anti-vibration system consists of an elastic spring and a vibration absorber. It reduces vibrations. This passive anti-vibration is included automatically.

In the active anti-vibration system, sensitive vibration detectors analyze the vibrations and produce an appropriate counter-movement. It is designed to compensate floor vibrations that are critical for the electronics in sensitive tests.

Please observe the operating instructions of the anti-vibration system in use.

XYZ-stage with ALS

The XYZ-stage consists of an X/Y-stage with vertically adjustable Z-stage for locating the sample, the ALS alignment stage, and a wireless joystick.
The ALS alignment stage is available in a manual or an automatic design. It serves for tilting the sample table in horizontal direction. Tilting is necessary to correct the possible unevenness in the bottom surface of the sample and/or the sample holder or to compensate for the tilting of the entire goniometer.

Automatic XYZ-stage

Follow these steps, if the automatic XYZ-stage shall be used as a sample table:

- Move the goniometer arms into 42 deg. position.
- Move the scanner back so that the XYZ-stage can be easily positioned underneath the goniometer arms.
- Remove the objective.
- In the program folder "c:\EP3View", back up the "user xxx" folder by copying it to another location. The xxx string stands for the corresponding user name.
- Switch off the PC and the EP^3.
- Place the XYZ-stage under the goniometer.

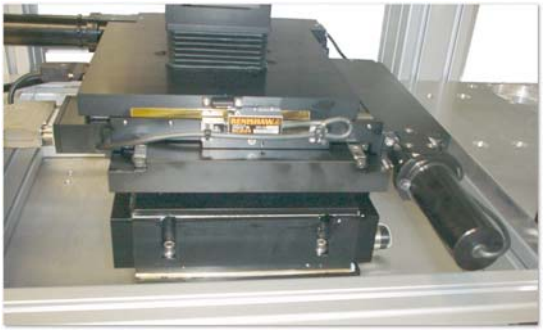


Fig. 6.1-1

- Connect the XYZ-stage to the electronic control unit.
  On the control unit, use the "X/Y/Z-Stage" port.
- Reinsert the objective.
- If the automatic ALS alignment stage is used, it has to be connected to the "Align Stage" port of the electronic control unit.

A goniometer angle exceeding 59 deg may cause the objective and the goniometer arms to collide with the sample. Take care that the sample table and the goniometer arms do not collide during movement!

- Switch on the EP^3 and the PC.
- Unpack the "user xxx" folder from the accompanying CD-ROM and copy it into the program folder "c:\EP3View". The string xxx stands for the corresponding user name.
  The contents of the existing folder is overwritten.
- Launch the *EP3View* program.
- Install the Joystick, if need be (see chapter 2.6. "Installing the Joystick")
- The joystick can be used to position the axes of the XYZ-stage.

Manual XYZ-stage

Follow these steps, if the manual XYZ-stage shall be used as a sample table:

- Move the goniometer arms into 42° position.
- Move the scanner back so that the XYZ-stage can be easily positioned underneath the goniometer arms.
- Remove the objective.
- Switch off the PC and the EP^3.
- Place the XYZ-stage under the goniometer.

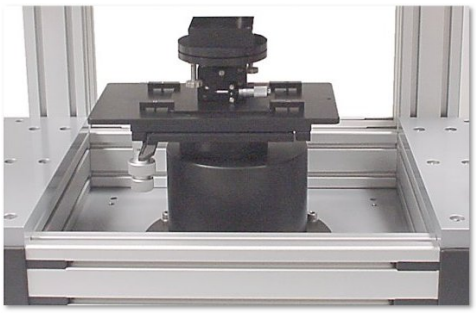


Fig. 6.1-2

- Reinsert the objective.
- If the automatic ALS alignment stage is used, it has to be connected to the "Align Stage" port of the electronic control unit.

A goniometer angle exceeding 59 deg may cause the objective and the goniometer arms to collide with the sample. Take care that the sample table and the goniometer arms do not collide during movement!

- Switch on the EP^3 and the PC and launch the *EP3View* program.

6.2. Function tree

Description of the default scripts used in the function tree. The function tree can modified and extended easily with user defined functions, refer to the section “User Interface”

Do not modify the default scripts delivered by Nanofilm.
They are stored in the folder “..\user XXX\scripts\default scripts”.
The “default scripts”-folder is intended to be updated by Nanofilm, any personal setting will be lost.
Save modified scripts in the folder “user XXX\scripts\user scripts” with a different name !

The name of scripts must be unique within one user!
Even if scripts are saved in different windows folders they must not have the same name.

Function Group: Laser

lightsource_on.ep3
switches on the light source.

Comments:
The actual function is instrument specific, depending on the number of lasers or type of light source. Xe-Lamps in spectroscopic ellipsometers (SE) are sensitive to switching and should be switched on manually.

lightsource_off.ep3
switches off the light source

align_laser_on.ep3
switches on the align laser

align_laser_off.ep3
switches off the align laser to get rid of stray light

lamp_on.ep3
switches on the sample illumination lamp

lamp_off.ep3
switches off the sample illumination lamp

Function Group: Image

image_scan.ep3
scans the focus line through the live image and compose a complete sharp image.

Comments and parameters:

- The image is displayed in the window “map&image viewer” and “image browser”. It is saved in the data path (selected in the EP³View Window) with filename and system time in seconds. An *.info-file with same filename is saved as well. It contains important image parameters like ‘objective’ or scaling factors ‘microns per pixel’. Use a standard editor like ‘Notepad’ to read this text-format.
- **Number of frames**: The number of raw images which are combined to get one sharp image, typical values: “30” (10-100), higher values increase the quality of the image but slow down the scan velocity
- **binning_image**: How many pixels are averaged, e.g. “2” means: 2x2 pixels. Typical value: “2”. Large binning factors reduce the amount of data significantly but also the image resolution.
- **Name**: the actual image is automatically saved in Folder: $data_path+$name+system_time_in_seconds The image is saved as an image file (.png) and an info file (.info)

grab.ep3
live image is transferred to the “Map&Image Viewer” (no focused image)

Function Group: Measurements

In ellipsometric measurements the settings of polarizer and analyzer are varied to find the minimum of intensity in a Region_of_Interest (ROI). The ROI-Signal versus optics position is fitted with a parable to find the exact "nulling"-condition. The ellipsometric parameter Delta and Psi are calculated from the minimum positions.

nulling_one_zone.ep3
finds minimum signal for the ROI by rotating polarizer and analyzer in the selected zone (e.g.: zone: polarizer setting positive, compensator setting positive and analyzer setting positive), calculates delta and psi values and transfers into the window "log editor".

Comments and parameters:

- **plrange** is the range the polarizer moves in one direction starting from the actual polarizer setting. Typical value: "5°"
- **alrange** is the range the analyzer moves in one direction from starting from the actual analyzer setting. Typical value: "5°"
- **samples**: the number of points used for the plrange and alrange, typical values: "100" – "200". There is a single data point per camera frame, at typical camera rates of 25 Hz a samples number of "100" takes four seconds.

nulling_two_zone.ep3
finds minimum signal for the ROI by rotating polarizer and analyzer in the selected (first) zone (e.g : zone: polarizer setting positive, compensator setting positive and analyzer setting positive), calculates delta and psi values and transfers into the window "log editor". Additionally, it finds the minimum signal for the second zone.

Comments and parameters:

- After the mimimum for the first zone is found, the polarizer rotates about 90 degree and the analyzer changes the sign (compensator keeps the position)
- Again the minimum signal for this zone is measured, delta and psi values are calculated and transferred into the window "log editor"
- Mean delta and psi values for the two zones are calculated and transferred into the window "log editor"
- **plrange**, **alrange** and **samples**: see nulling_one_zone

	Polarizer setting	**Compensator setting**	**Analyzer setting**
Zone 1	positive	+45°	positive
Zone 2	negative	+45°	negative
Zone 3	positive	-45°	positive
Zone 4	negative	-45°	negative

Tab 6.2-1: *Ellipsometric nulling condition is fulfilled at four distinguished optic settings. The mean value at two- or four-zone-Measurements is free of multiple systematic errors and increases the accuracy depending on the measurement condition by an order of magnitude.*

nulling_four_zone.ep3
finds minimum signal for four different zones by rotating polarizer and analyzer, calculateds delta and psi values and transfers them into the window "log editor"

Comments and parameters:

- Second zone: Polarizer rotates about 90 degrees, anlayzer changes the sign, compensator keep the position
- Minimum signal for the second zone is found by rotating polarizer and analyzer, is calculated into delta and psi values and transferred into the window "log editor"
- third zone: polarizer, analyzer and compensator change the sign
- minimum signal for the third zone is found by rotating polarizer and analyzer, calculated into delta and psi values and transferred into the window "log editor"

- fourth zone: polarizer rotates about 90 degrees, anlayzer changes the sign, compensator keeps the position
- minimum signal for the fourth zone is found by rotating polarizer and analyzer, is calculated into delta and psi values and transferred into the window “log editor”
- the mean delta and psi values for the four zones are calculated and transferred into the window “log editor”
- **plrange**, **alrange** and **samples**: see nulling_one_zone

coarse_adjust.ep3
rotates polarizer and analyzer and scans for the minimum ROI signal to move polarizer and analyzer close to the minimum signal.

Function Group: AOI_Variation (Angle-Of-Incidence)

Attention: Please ensure that there is no collision between the objective and sample holder or sample cells! Typically, the interesting AOI-ranges are above 60° where the standard objectives may touch the sample plane.

Measure_brewsterangle.ep3
Fast script to find the Brewster angle (or pseudo-brewster angle) of a sample where the delta-value shows a increased sensitivity to sample parameters.

Comments and parameters:
- the script turns polarizer, compensator and analyzer to 0 degree
- moves the goniometer about ± 5 degree from the actual goniometer setting to find the minimum signal for the ROI (brewster angle for the ROI)
- goniometer moves to the minimum setting, which is transfered in the window “log editor”

Move_Correction.ep3
!Only for EP3 with automatic sample handling stage! measures automatically the ellipsometric parameters delta and psi depending on the angle of incidence. This Function automatically corrects any shift of spot due to the different angles of incident by changing x,y,z position anf focus.

Comments and parameters:
- The goniometer setting is varied in a loop from a start- to a stop-value
- The script nulling_one_zone.ep3 is executed in the loop
- The delta and psi values versus AOI are transferred into the window “graph”
- **AOI_start** is the minimum angle of the goniometer, where the measurement should start
- **AOI_end** is the maximum angle of the goniometer, where measurement should stop
- **AOI_step** is the angle step width between two goniometer angles
- **plrange**, **alrange** and **samples**: see nulling_one_zone
- **Zones:** selection of the scripts nulling_one_zone, nulling_two_zones or nulling_four_zones

AOI-Variation_one_zone.ep3
measures automatically the ellipsometric parameters delta and psi depending on the angle of incidence.

Comments and parameters:
- The goniometer setting is varied in a loop from a start- to a stop-value
- The script nulling_one_zone.ep3 is executed in the loop
- The delta and psi values versus AOI are transferred into the window “graph”
- **AOI_start** is the minimum angle of the goniometer, where the measurement should start
- **AOI_end** is the maximum angle of the goniometer, where measurement should stop
- **AOI_step** is the angle step width between two goniometer angles
- **plrange**, **alrange** and **samples**: see nulling_one_zone

AOI-Variation_two_zone.ep3
identical script as above, the only difference is that the script nulling_two_zone.ep3 is executed

AOI-Variation_four_zone.ep3
identical script as above, the only difference is that the script nulling_four_zone.ep3 is executed

Function Group: Lambda_Variation

This section is only valid for Multiple Laser Wavelength (MW) or Spectroscopic Systems (SE). Every wavelength is connected to a wave_index which is displayed in the "live & control"-window or in the file ...\user xxx\config\wavelength.ini

Nulling_one_zone_MW.ep3
measures automatically the ellipsometric parameters delta and psi depending on the wavelength.

Comments and parameters:

- The wavelength is varied in a loop from a start to a stop-value.
- The script nulling_one_zone.ep3 is executed in the loop.
- The delta and psi values are transferred into the window "graph".
- **wave_start** is the index number for the wavelength where measurement should start
- **wave_end** is the index number for the wavelength where the measurement should stop
- **wave_step** is the step size for the wavelength (e.g. "1" means every wavelength between wave_start and wave_end is used for the measurements).

Nulling_two_zone_MW.ep3
identical script as above, the only difference is that the script nulling_two_zone.ep3 is executed

Nulling_four_zone_MW.ep3
identical script as above, the only difference is that the script nulling_four_zone.ep3 is executed

Function Group: Lambda_AOI_Variation

This section is only valid for Multiple Laser Wavelength (MW) or Spectroscopic Systems (SE). Every wavelength is connected to a wave_index which is displayed in the "live & control"-window or in the file ...\user xxx\config\wavelength.ini
Attention: Please ensure that there is no collision between the objective and sample holder or sample cells! Typically, the interesting AOI-ranges are above 60° where the standard objectives may touch the sample plane.

VASE.ep3
measures automatically the ellipsometric parameters delta and psi depending on the wavelength and angle of incidence.

Comments and parameters:

- The wavelength is varied in a loop from a start to a stop-value.
- The goniometer setting is varied in a loop from a start- to a stop-value
- The nulling script is executed in the loop.
- The delta and psi values are transferred into the window "graph".
- **wave_start** is the index number for the wavelength where measurement should start
- **wave_end** is the index number for the wavelength where the measurement should stop
- **wave_step** is the step size for the wavelength (e.g. "1" means every wavelength between wave_start and wave_end is used for the measurements).
- **AOI_start** is the minimum angle of the goniometer, where the measurement should start

- **AOI_end** is the maximum angle of the goniometer, where measurement should stop
- **AOI_step** is the angle step width between two goniometer angles
- **plrange**, **alrange** and **samples**: see nulling_one_zone
- **Zones:** selection of the scripts nulling_one_zone, nulling_two_zones or nulling_four_zones

Function Group: Analyse

In this function group the ellipsometric parameters delta and psi are calculated and analyzed with an optical model.

delta_psi.ep3
delta and psi values are calculated from the last minimum settings or from the actual settings of polarizer, compensator and analyzer and transferred to the window “log editor”

Comments and parameters:

- **mode**:
  min: the last minimum settings of polarizer, compensator and analyzer are used for calculation of delta and psi
  man: the actual settings of polarizer, compensator and analyzer are used for calculation of delta and psi

fit.ep3
the last delta and psi values are transferred to the actual model and fitted with this model. The results are added to the window “log editor”.

Function Group: Mapping

In mapping mode multiple image-scans were taken at different optics positions. The parable fit to find the minimum intensity is done for every Pixel separately. Multiple maps can be combined in the Mapping-Tool to calculate fits according to the chosen model.

delta_mapping.ep3
executes the script nulling_one_zone.ep3 at the actual position for a rough adjustment and records a delta-map.

Comments and parameters:

- For a delta-mapping the analyzer is fixed in the minimum position and only polarizer is moved. At each polarizer position an image is recorded. The recorded images should not be oversaturated (if necessary the gain of the camera has to be changed)!
- For every pixel the minimum of intensity versus polarizer position is fitted. For the minima delta-values are calculated for every pixel. The resulting delta-Map is transferred to the Mapping-Tool. The recorded images will be deleted automatically.
- In the Mapping-Tool the model can be applied to single spots or all pixels. Multiple delta- or psi-maps at different wavelengths can be combined. Simple one-dimensional fits can be run in a fast interpolation-mode. Complex fits may take a longer time.
- **number_of_images**: Number of image scans used for the minimum fit. typical value: “10”.
- **plrange_map**: Range the polarizer rotates in one direction from the actual pl position (the first image is recorded) and than in the other direction (the last image is recorded). typical values: 10°
- **binning_map**: Binning factor for the map, e.g. “2” means, 2x2 neighbouring delta values were averaged to one delta value. typical values: 2 or 4

psi_mapping.ep3
identical script as delta_mapping.ep3, the only difference is that the polarizer stays in the minimum position and only analyzer rotates

Comments and parameters:

- **alrange_map**: the range the analyzer rotates in one direction from the actual al position (the first image is recorded) and than in the other direction (the last image is recorded)

delta_psi_mapping.ep3
this script first executes the script delta_mapping.ep3 and than the script psi_mapping.ep3. both are transferred to the Mapping-Tool

Function Group: Kinetic

A measurement is repeated in a loop to record changes versus time. The 'timer'-command gives a trigger signal to ensure constant time steps.

Kinetic.ep3
executes the script nulling_one_zone.ep3 over a selected time.

Comments and parameters:

- The window "graph" and three dialog windows are open.
- In the first dialog window you can choose if you want to start a new experiment or continue the last experiment.
- In the second dialog window you can choose how long the script should run.
- In the third dialog window you can choose how often the script nulling_one_zone.ep3 should be executed.
- The delta and psi values are displayed in the window "graph" (x-axis is kinetic-time, left y-axis is delta , right y-axis is psi)

6.3. Script commands

Index Script commands

Chapter 1: Script Server syntax

// comment_text

Comments are text elements within a script that contain remarks about the script or the individual statements. They make the script easier to understand.
Individual lines of comments can be created using two slashes (//). The comment can begin at any point and extends to the next line.

Examples:

```
// ##########################################
// #   Comment lines                        #
// ##########################################

int i 5      // comment
```

Keywords

Keywords are dedicated words which are part of the fixed vocabulary of the programming language, e.g.: INT, TIMER, RECORD, ... Do not use keywords for variables and subroutine names.
Motor names and some internal variables are dedicated as well. See the list below.

Variables: INT, REAL, CHAR, CLEAR

Script Server variables must be declared before use. Different data types can be assigned (see list below).

Example:

```
int x1 42                              //integer
real old_position 123.456              //floarting point number
char text “Hello world !”              //string
log add “$x1 $old_position $text”      //call with $
clear x1
```

Variable Syntax: x1, $x1, >x1

At the declaration with data type assignment use the plain variable name (x1).
Some script command have an output of variables, use a **>** in front of the name to assign the output value to a variable (>x1). If the variable does not exist it is declared with a default data type.
When calling the variable use a **$** in front of the name ($x1).
For mathematical formulars use apostrophes **‘ ‘** and do not use $ in front of a variable name. A list of mathematical functions is given below.
For character strings use quotations “ “. If there is no space in the text quotations are not necessary, the string ends at the space.
For handling adding a variable list to transfer to log editor, graph window or model built a string of variable names. Use “$” in front of each variable name.

Example:

```
int x1 42                              //declare without “$”
real x2 $x1                            //call with “$”
real x3 ‘-x1^2+3*x2/sqrt(2)’           //in formular without “$”
log add “$x1 $x2 $x3”                  //in log editor strings use “$”
dialog “insert a number” $x1 >x4       //Assign output value with “>”
```

```
if $x4 gt 666                    //greater than
  int x4 -1
endif
```

A variable is present in the global script server memory and can becalled (or set) from any script, subscript or tool. It must be present when it is called, otherwise an error message comes up and script execution is stopped.
To avoid stopping of a script due to a non-defined variable you can use a special syntax where no value is defined. The variable is defined with the value zero if it does not exist, otherwise it keeps the former value.
Special values of variables are
“NaN” Not a Number
“inf” infinite

Example:

```
int x1                    //define if necessary, otherwise do not change
```

Variables can be assigned as “parameter” in the function tree on the main RefSpec2 window. This assignment is done every time when the function is called by double-click, before the function script is executed.
Multiple variables are pre-defined by RefSpec2. Some can be accessed in a script which automatically runs at startup:
\RefSpec2 V2.00\user xxx updated\scripts\Instrument_Specific\startupGlobals.RefSpec2
For internal variables format and unit are defined in the file “user...\config\var_defs.ini”.
Definition of format, unit and default value is possible in this file for any script server variable. The format uses LabView-convention.

Examples from file “user...\config\var_defs.ini” :

```
//$lambda= 531.1  nm is a REAL type float (f) number with 1 character after the dezimal point, unit (nm)
[lambda]
type=2
format=%.1f
unit=(nm)

//$gain= 50  is a INT Type dezimal (d) number without dezimal point  and without a unit
[gain]
type=1
format=%d
```

Data types

For handling of 1- or 2-dimensional arrays please refer to the script command “array”

Script Server syntax	Type number	internal data type	
	0	none	
int	1	I32	
real	2	DBL	
char	3	char	
int()	4	1D I32	Array
real()	5	1D DBL	Array
char()	6	1D CHAR	Array
int(())	7	2D I32	2 dimensional Array
real(())	8	2D DBL	2 dimensional Array char(())
	9	2D CHAR	2 dimensional Array
	10	PATH	

Internal Variables

The following special names are used for global variables or arrays. Do not use these names for other purposes, some are write protected, some are overwritten by the system. More special variables are defined in “user...\config\var_defs.ini”.

Example:

log add "$Lambda $aoi $delta $Psi "

Name	type	Description
$lambda	real	wavelength in nm
$wave_index	int	index of wavelength (see wavelength.ini)
$aoi	real	Angle of Incidence in degree (correlated to motorposition $gl)
$aov	real	Angle of View in degree (correlated to motorposition $gs)
$pl	real	actual motor position Polariser (pl)
$plrange	real	halfrange for find_minimum
$plsamples	real	number of datapoints for find_minimum
$plmin	real array (1D)	Polarizer minimum (ROI_number)
$plminmean	real	Mean over all ROI
$plconj	real	conjugated null, calculated via calc_delta_psi
$comin	real array (1D)	Compensator position corresponding to plmin
$almin	real array (1D)	Analyzer minimum (ROI_number)
$alminmean	real	Mean over all ROI
$glmin	real array (1D)	Goniometer laser-arm minimum (ROI_number)
$psi	real array (1D)	last calculated value of psi (ROI_number)
$psi_error	real array (1D)	Error of psi (ROI_number)
$psimean	real	Mean over all ROI
$delta	real array (1D)	last calculated value of delta (ROI_number)
$delta_error	real array (1D)	Error value of delta (ROI_number)
$deltamean	real	Mean over all ROI
$fit_results	real array (1D)	caculated by model
$fit_errors	real array (1D)	caculated by model
$fit_labels	real array (1D)	caculated by model
$objective	char	Objective lable
$power	real	laser power in %

$gain	int	camera gain in %
$cameranumber	int	camera-chanel; 0=Standard CCD, 2=Align
$framerate	real	camera frames per second (or samples per second)
$time	real	in milliseconds
$date	char	Date + time-String
$xscale	real	micrometer per Pixel
$roisignal	real array (1D)	mean gray value in ROIs (0 to 255)
$comx	real	Center-Of-Mass in pixel (for alignment)
$comy	real	Center-Of-Mass in pixel
$data_path	char	path for saving data
$recipe_path	char	path for saving recipie

Constants for motor names

For the motors of EP^{3}View the following constants are internal variables. These constants must be set in the corresponding commands as designators, e.g. “”. Script Server variable with the same name contain the actual motor position.

Example:

```
motor move al 1 1 –2                    //motor move NAME MODE SPEED POSITION
log add “$gs  $pl $al“
```

GS	Goniometer focus scanner-arm
GL	Goniometer laser-arm
FS	Focus scanner
AL	Analyzer
CO	Compensator
PL	Polarizer
LP	Laser Power Attenuator
ZS	Z-stage (for sample height)
XS	X-axis of xy-stage
YS	Y-axis of xy-stage
A2	Align stage axis 2
A1	Align stage axis 1
FW	Filter wheel (for spectroscopic EP³)
MW	Multi wavelength mirror or filter wheel
ZG	Z-Lift at the Goniometer

Chapter 2: formular syntax

For calculations in scripts “mathematical expressions” or “formulars” can be used. A formular is written in apostrophes ‘ ‘ , the resulting value is a real number. Script server variables can be used in formulars. “$“ in front of a variable name is not required. A list of mathematical functions is given below.

Examples:

```
real x1 ‘1+1’
real x2 ‘x1*2’                          //use a variable $x1
int x3 ‘2/3’                            //the real value is rounded to integer
real x4 ‘-x3’                           //”real x4 -$x3” does not work!
dialog “calculate:” ‘sin(45/180*pi(1))^2’   //in formulars pi(1) =3.1415
motor move fs 0 1 ‘x1+1.5*10^4’         //use 1*10^4 instead of 1E4
```

Mathematical functions

The mathematical functions are explained below. They occur within expressions. The Variables 'x' and 'z' are the release parameters to these functions. The return value for the functions is the result of the calculation, e.g. REAL y 'abs(12.34)'.

Syntax	Mathematical functions	Example
abs(x)	Returns the absolute value of x. (Argument = REAL; return value = REAL)	REAL x -12.34 REAL y 'abs(x)' // Result: y = 12.34
acos(x)	Calculates the inverse cosine of x. The value of x must be between -1 and +1. The return value is specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: cos(x)	REAL x 0.5 REAL y 'acos(x)' // Result: y = 1.0472 rad
acosh(x)	Calculates the inverse hyperbolic cosine of x. (Argument = REAL; return value = REAL) Refer also to: cosh(x)	REAL x 1.1276 REAL y 'acosh(x)' // Result: y = 0.5000
asin(x)	Calculates the inverse sine of x. The value of x must lie between -1 and +1. The return value is specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: sin(x)	REAL x 0.5 REAL y 'asin(x)' // Result: y = 0.5236 rad
asinh(x)	Calculates the inverse hyperbolic sine of x. (Argument = REAL; return value = REAL) Refer also to: sinh(x)	REAL x 0.5211 REAL y 'asinh(x)' // Result: y = 0.5000
atan(x)	Calculates the inverse tangent of x. The return value is specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: tan(x)	REAL x 0.5 REAL y 'atan(x)' // Result: y = 0.4636 rad
atanh(x)	Calculates the inverse hyperbolic tangent of x. (Argument = REAL; return value = REAL) Refer also to: tanh(x)	REAL x 0.4621 REAL y 'atanh(x)' // Result: y = 0.5000
ceil(x)	The floating point number x is rounded up to the next highest integer which then is returned as a floating point number, as well. (Argument = REAL; return value = REAL) Refer also to: floor(x)	REAL x 12.34 REAL y 'ceil(x)' // Result: y = 13.0000
ci(x)	Calculates the cosine integral of x, where x is any real number. (Argument = REAL; return value = REAL) Refer also to: si(x)	REAL x 0.5 REAL y 'ci(x)' // Result: y = -0.1778
cos(x)	Calculates the cosine of x. The argument must be specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: acos(x)	REAL x 0.5236 REAL y 'cos(x)' // Result: y = 0.8660
cosh(x)	Calculates the hyperbolic cosine of x. Argument = REAL; return value = REAL) Refer also to: acosh(x)	REAL x 0.5 REAL y 'cosh(x)' // Result: y = 1.1276
cot(x)	Calculates the cotangent of x. The argument must be specified in radian measures (rad). (Argument = REAL; return value = REAL)	REAL x 0.5236 REAL y 'cot(x)' // Result: y = 1.7320
csc(x)	Calculates the cosecant of x (1/sin(x)). The argument must be specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: sec(x)	REAL x 0.5 REAL y 'csc(x)' // Result: y = 2.0858
exp(x)	Calculates the exponential function ex of variable x. (Argument = REAL; return value = REAL)	REAL x 4.0 REAL y 'exp(x)' // Result: y = 54.598
expm1(x)	Calculates one less than the value of e raised to the x power ((ex) - 1). (Argument = REAL; return value = REAL)	REAL x 4.0 REAL y 'expm1(x)' // Result: y = 53.598
floor(x)	The floating point number x is rounded off to the next lowest integer which then is returned as a floating point number, as well. (Argument = REAL; return value = REAL) Refer also to: ceil(x)	REAL x 12.34 REAL y 'floor(x)' // Result: y = 12.000
gamma(x)	Calculates the gamma function (x+1) ≈ x! for all natural numbers x. (Argument = REAL; return value = REAL)	REAL x 3.0 REAL y 'gamma(x)' // Result: y = 2.000
getexp(x)	Returns the exponent of x. (Argument = REAL; return value = REAL)	REAL x 12.5 REAL y 'getexp(x)' // Result: y = 3.0000
getman(x)	Returns the mantissa of x. (Argument = REAL; return value = REAL)	REAL x 12.5 REAL y 'getman(x)' // Result: y = 1.5625

int(x)	Rounds x to the nearest smallest integer. (Argument = REAL; return value = INT) Refer also to: intrz(x) ; Refer also to: floor(x)	REAL x 12.5 INT y 'int(x)' // Result: y = 12.0000
intrz(x)	Rounds x to the nearest integer between x and zero. (Argument = REAL; return value = INT) Refer also to: int(x)	REAL x 12.5 INT y 'intrz(x)' // Result: y = 12.0000
ln(x)	Calculates the natural logarithm of x to the base of e. X must have a positive value. (Argument = REAL; return value = REAL)	REAL x 12.34 REAL y 'ln(x)' // Result: y = 2.513
lnp1(x)	Calculates the natural logarithm of (x + 1) to the base of e. X must have a positive value. (Argument = REAL; return value = REAL)	REAL x 12.34 REAL y 'lnp1(x)' // Result: y = 2.5908
log(x)	Calculates the logarithm of x to the base of 10. X must have a positive value. (Argument = REAL; return value = REAL)	REAL x 12.34 REAL y 'log(x)' // Result: y = 1.0913
log2(x)	Calculates the logarithm of x to the base of 2. X must have a positive value. (Argument = REAL; return value = REAL)	REAL x 12.34 REAL y 'log2(x)' // Result: y = 3.6253
max(x, z)	No function yet (V3.02) ! Returns the larger of exactly two variable values. (Arguments = INT; return value= INT) Refer also to: min(x,z) Refer also to: min(x,z)	INT x 5 INT z 3 INT y 'max(x,z)' // Result: y = 5
min(x, z)	No function yet (V3.02) ! Returns the smaller of two variable values. (Arguments = INT; return value = INT) Refer also to: max(x,z)	INT x 5 INT z 3 INT y 'min(x,z)' // Result: y = 3
mod(x, z)	No function yet (V3.02) ! Use: '(x-int(x/z)*z)' Calculates the modulo division of x/z (remainder after division), when the quotient is rounded toward infinity. (Arguments = REAL; return value = INT)	REAL x 7.0 REAL z 3.0 INT y 'mod(x,z)' // Result: y = 1

pi(x)	Returns the value 3.14159 * x.
	(Argument = REAL; return value = REAL)
		REAL y 'pi(1)'
		// Result: y = 3.14159
		
		REAL x 3.5
		REAL y 'pi(x)'
		// Result: y = 10.9956

rand(0)	Generates a random number between 0 and 1.
	(Argument = -; return value = REAL)
		REAL y 'rand(0)'
		// Result: y = 0.4253
		
		REAL y 'rand(0)'
		// Result: y = 0.0603

rem(x, z)	No function yet (V3.02) ! Use: '(x/z)-int(x/z)' Calculates the remainder of x/z, when the quotient is rounded to the nearest integer. (Arguments = REAL; return value = INT)	REAL x 7.0 REAL z 3.0 INT y 'rem(x,z)' // Result: y =
sec(x)	Calculates the secant of x (1/cos(x)). The argument must be specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: csc(x)	REAL x 0.5 REAL y 'sec(x)' // Result: y = 1.1395
si(x)	Calculates the sine integral of x, where x is any real number. (Argument = REAL; return value = REAL) Refer also to: ci(x)	REAL x 0.5 REAL y 'si(x)' // Result: y = 0.4931

sign(x)	Returns one of the following values:
	• 1 if x is greater than 0
	• 0 if x is equal to 0
	• -1 if x is less than 0
	(Argument = REAL; return value = INT)
		REAL x 12.34
		INT y 'sign(x)'
		// Result: y = 1
		
		REAL x -12.34
		INT y 'sign(x)'
		// Result: y = -1

sin(x)	Calculates the sine of x. The argument must be specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: asin(x)	REAL x 0.5236 REAL y 'sin(x)' // Result: y = 0.5000
sinc(x)	Calculates the sine of x divided by x. The argument must be specified in radian measures (rad). (Argument = REAL; return value = REAL)	REAL x 0.5 REAL y 'sinc(x)' // Result: y = 0.9589
sinh(x)	Calculates the hyperbolic sine of x. (Argument = REAL; return value = REAL) Refer also to: asinh(x)	REAL x 0.5 REAL y 'sinh(x)' // Result: y = 0.521

spike(x)	Returns one of the following values:
	• 1 if x is greater than -1 and less than +1
	• 0 for any other value of x
	(Argument = REAL; return value = INT)
		REAL x 12.34
		INT y 'spike(x)'
		// Result: y = 0
		
		REAL x 0.1234
		INT y 'spike(x)'
		// Result: y = 1

sqrt(x)	Calculates the square root of x. X must have a positive value. (Argument = REAL; return value = REAL)	REAL x 25.0 REAL y 'sqrt(x)' // Result: y = 5.0000

square(x)	Returns one of the following values:
	• 1 if the value of x is uneven-numbered
	• 0 if the value of x is even-numbered
	(Argument = REAL; return value = INT)
		REAL x 25.0
		INT y 'square(x)'
		// Result: y = 0
		
		REAL x 26.0
		INT y 'square(x)'
		// Result: y = 1

step(x)	Returns one of the following values:
	• 1 if x is greater than zero
	• 0 if x is less than zero
	(Argument = REAL; return value = INT)
		REAL x 12.34
		INT y 'step(x)'
		// Result: y = 1
		
		REAL x -12.34
		INT y 'step(x)'
		// Result: y = 0

tan(x)	Calculates the tangent of x. The argument must be specified in radian measures (rad). (Argument = REAL; return value = REAL) Refer also to: atan(x)	REAL x 0.5236 REAL y 'tan(x)' // Result: y = 0.5774
tanh(x)	Calculates the hyperbolic tangent of x. (Argument = REAL; return value = REAL) Refer also to: ATANH(x)	REAL x 0.5 REAL y 'tanh(x)' // Result: y = 0.4621

Chapter 3: General commands

do loop

do <statements> ... loop *$int1*

Starts a loop and terminates the loop by specifying a fixed number $int1 of runs.

A loop holds an internal loop counter ($i0), starting from 0 and going to ($int1-1).
Nested loops are possible, $i0 is the outer loop counter, $i1 the next inner counter, $i3….
The statements of the loop are executed $int1 times.
The minimum number of execution is 1.

$int1 *Number of runs*

Examples:

```
INT count 10
do
                                        // Statements here are executed 10 times
                                        // the loop counter goes from 0 to 9
  log add "$time $i0"
  wait 200
loop $count

do
 do
                                        //nested loops
   log add "$i0 $i1"
 loop 3
loop 5
```

do until

do **<**statements**>** **...** until *condition*

Starts a loop and terminates the loop by evaluating a condition.

The statements of the loop are executed until the specified condition is satisfied.
The minimum number of execution is 1.
Known bug: Do not use do..until-loop inside a do..loop, this may corrupt the loop counter $i0 of the outer loop.

Condition:
value1 (= 0: false; any other value: true)
value1 eq *value2* (... equal to ...)
value1 gt *value2* (... greater than ...)
value1 ls *value2* (... less than ...)
value1 neq *value2* (... not equal to ...)
value1 gte *value2* (... greater than or equal to ...)
value1 lse *value2* (... less than or equal to ...)

Examples:

```
INT mx 10
INT z 0
do
                                        // The statements here are executed as long as
                                        // the value of z is not equal to the value of mx
  INT z 'z+1'
  log add "$time $z"
until $z eq $mx

REAL x1 0
do
                                        // The statements here are executed as long as
                                        // the value of z is not equal to 10
  dialog "insert a numbernot equal 0!" $x1 >x1
    log add "$time $x1"
until $x1
```

if/else

if *condition* **<**statements**> else <**statements2**> endif**

The if command is used to perform either the list of statements 1 or the list of statements 2 depending on the value returned by the condition (p1).

If the result of the condition is true (0), the statement or statement block behind the condition term is executed. If the result of the condition is false (= 0), the statement or statement block behind the keyword ELSE is executed. Script execution is continued behind the ENDIF flag if the corresponding statement block has been executed.

The keyword ELSE can be omitted.

```
if <condition>
 <List of statements>
endif
```

If the result of the condition is true (0), the statement or statement block behind the condition term is executed. If the result is false (= 0), the statement block is ignored and the script is continued after the ENDIF flag.

Condition:
value1 (= 0: false; 0: true)
value1 eq *value2* (... equal to ...)
value1 gt *value2* (... greater than ...)
value1 ls *value2* (... less than ...)
value1 neq *value2* (... not equal to ...)
value1 gte *value2* (... greater than or equal to ...)
value1 lse *value2* (... less than or equal to ...)

Example:

```
INT v 1
CHAR ch "test"

if $v
```

```
                                    // The statements here are executed if the
                                    // value of v is true (0)
  if $ch eq "test"
                                    // The statements here are executed if the
                                    // value of eq is equal to the string "test"
  else
                                    // The statements here are executed
                                    // if the values are not equal
  endif
endif

end
```

A (sub-) script is ended. Continue the higher level script.

Example:

```
if $x1 eq 0
end
endif
```

execute *$char1*

Executes an external script (sub-script).
Multiple subscript-levels can be nested. A subscript can use the variables defined in the main script since script server variables are global. Only loop counters (i0, i1,…) are local.

$char1	*Name of the ep3script file* *Enter the file name in quotation marks but without the suffix (.ep3)*

Example:

```
INT v 1
CHAR ch "test"

if $ch eq "test"
  execute "iftest2"                    // The script "iftest2.ep3" will be executed.
else
  end
endif
```

open_vi *$char1*

Opens and runs a subroutine or utility.
Virtual instruments (vi) can be internal tools which are already loaded in EP3View, in this case no path is needed.
For or external files the default path is EP3View V2\program\.

$char1 — *Name and path of the subroutine*

Examples

```
open_vi “live & control”          // opens the window " live&control"
open_vi "Map & image viewer”
open_vi “log editor”
open_vi "graph"
open_vi “model“
open_vi "Mapping"
open_vi “script editor”
open_vi "Mapping"
open_vi "tools\utilities\logV1filesConverter.vi"
                                  //relative path; convert logfiles from EP3View_Version_1
open_vi  "C:\EP3View V2\tools\diagnose\diagnoseDio.vi"
                                  //absolute path
open_vi "var globals.vi”          //view script server variables
```

close_vi *$char1*

Close a subroutine or utility.

$char1 — *Name and path of the subroutine*

Example

```
close_vi "graph"                   // closes the window "graph"
```

dialog *$char1 $real2 >real3 >real4*

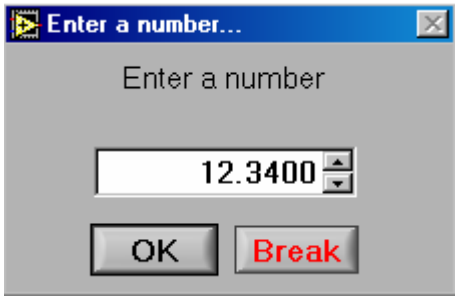
Opens a dialog box to show a message or enter a number.
This command can be used to display a dialog box containing a message for the user or it can be used to enter a number. The entered number can be saved in a variable (return value).
Use quote mark characters ("") for a not used parameter, when other parameters are following, e.g. 'dialog "" $x'
Depending on *$char1* it is possible to have different modes:
Standard mode: Other windows were blocked until one button is pressed; “BREAK” stops script execution
one_button-mode: other windows are accessible; return-value is the time when the button is pressed
two_button-mode: other windows are accessible; OK- and CANCEL-Button, the return-value is 1=OK, 0=cancel
“CANCEL” continues Script.

$char1	*Text to display in the dialog box; blocking other windows*	*shows OK- and BREAK-Button;*
	special text: one_button	*shows OK-Button*
	special text: two_button	*shows OK- and CANCEL-Button*
$real2	*Default value which shall be displayed in the entry field of the dialog box. If a variable shall be used, set the character “$” in front of the name. in one_ or two_button-mode this variable may be a text to be displayed*	
>real3	*Variable for the return value one_button-mode: system time in seconds two_button-mode: OK=1, CANCELED=0*	
>real4	*two_button-mode: system time in seconds*	

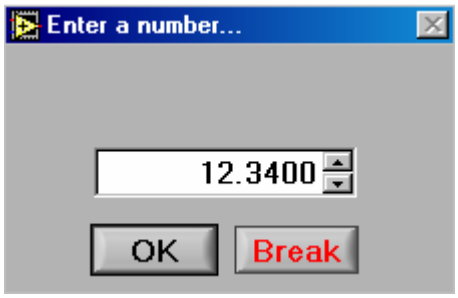
Examples

```
// ...
dialog "Hello World"          // message to display
```

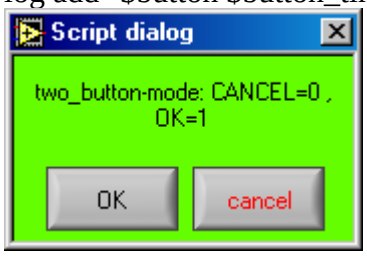

```
// ...
CHAR m "Enter a number"       // text to display
REAL x 12.34                  // default value
REAL y                        // variable for return value
dialog $m $x >y
```



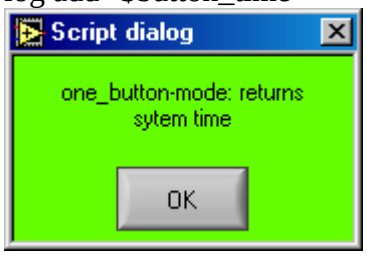

```
// ...
REAL x 12.34                    // value to display
dialog "" $x
```




```
// ...
dialog two_button  "two_button-mode: CANCEL=0 , OK=1"  >button >button_time
log add "$button $button_time”
```




```
// ...
timer zero
dialog one_button "one_button-mode: returns sytem time " >button_time
log add "$button_time
```



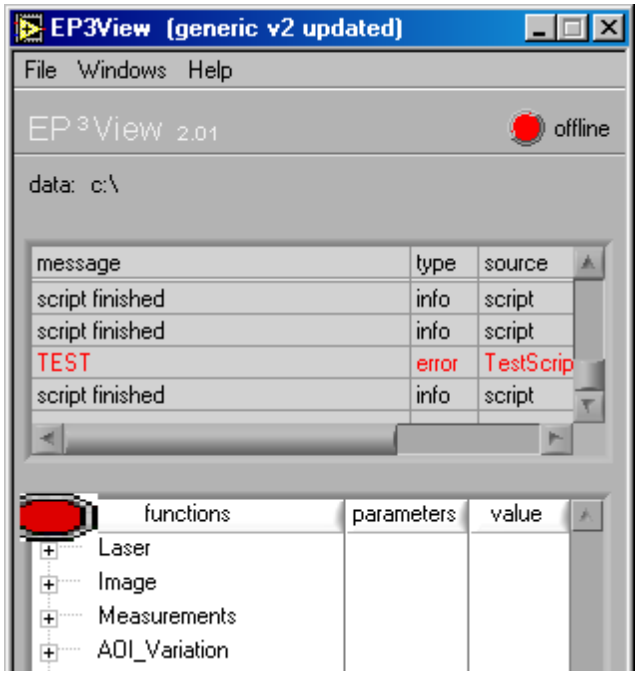
message *$char1 $char2 $char3*

Displays a message in the main window

$char1	*message text*
$char2	*type “info” or “error”*
$char3	*source text*

Examples:

message TEST error TestScript //result see image below



wait *$int1*

Stops the executing of the script for the given time.

$int1	*time to wait in ms.*

array *$char1 $char2 $char3 $char4 $char5 >char6 >char7*

Command to work with 1- or 2-dimensional arrays. Multiple command structures are possible, depending on $char1. An array must be declared with type and dimension using the variable definition commands, e.g. “REAL(()) arrayname” for a 2-dimensional array of real numbers.
Consider that this command mostly needs the names of arrays, not the values of the array-variables. The array-name is given without a “$” !

$char1	*load:*	*load from file*
	save:	*save to file*
	get :	*access one element*
	set:	*set one element (array length must be larger enough)*
	length:	*get the array length*
	append:	*merge two arrays*

	mean:	*calculate average and standard deviation*
	difference:	*calculates the point-by-point distance in an array (or columns of a 2D array);* output is an array (note: length-1)
$char2	*for load:*	*Filename,for "" file dialog. Default is user_path (xy-arrays)*
	else	*array-name*
$char3	*for load:*	*format (e.g. %.1f)*
	for save:	*Filename,for "" file dialog. Default is data_path*
	for get / set	*index #1*
	for append:	*name of second array*
$char4	*for load:*	*delimiter (e.g. " ", \t")*
	for save:	*format (e.g. %.1f)*
	for get / set	*index #2 (only 2D-arrayr)*
$char5	*for save:*	*delimiter (e.g. " ", \t")*
>char6	*for load:*	*name of array to be loaded*
	for get:	*variable for returned value of the element*
	for length:	*variable for retured array lenth in dim #1*
	for mean:	*average value (for a 2D-array average is calculated in columns, result is a 1D-array;)*
>char7	*for length:*	*variable for retured array lenth in dim #2*
	for mean:	*standard deviation (for a 2D-array result is a 1D-array;)*

Examples:

```
real(()) arrayname                                  //define a 2d-array
array load $filename $format $delimiter >arrayname  //load from ASCII-file
array save $arrayname $filename $format $delimiter  //save to ASCII-file (dialog)
array get $arrayname $index1 $index2 >element_output //get one element
array set $arrayname $index1 $index2 $element_input //set one element ( < length for 1D !)
array length $arrayname >length_dim_1 >length_dim_2 //get length
array append $arrayname1 $arrayname2                //merge arrays on the same
                                                    size or append a 1-dimensional line to
                                                    a 2-dimensional array
array mean $arrayname >mean >standarddeviation      //statistics for an array
array difference $arrayname >noise >drift >diffarray //calculate path-length (position-array)


real() x1 "(1.2,3.4,5.678,9.1)                      //define and load a 1-dimesional array
log add "$x1"                                       //1-dim arrays can be displayed in log
                                                    editor


clear 2dtest                                        //clear variable from memory
real(()) 2dtest                                     //define array
do
 do
  array set 2dtest 'i0+i1*4' 0 $i1                  //setting single elements
```

```
  array set 2dtest 'i0+i1*4' 1 $i0
 loop 4
loop 4                                                    //creates a 16x2 pattern
array save 2dtest

//**** Examples for array-command
real x1   //scalar
clear ar1
real() ar1   //array 1D
clear ar2
real(())  ar2   //array 2D


//***********set a 2D-array

open_vi "log editor"
do
   do
      array set ar2 $i0 $i1 'i1+i0*10'
   loop 8
loop 5

//***********get lenth and elemets from 2D-array

real dim1
real dim2
array length $ar2 >dim1 >dim2

do
   do
     array get ar2 $i0 $i1 >x1
      log add "$i0 $i1 $x1
   loop $dim2
loop $dim1

            //remember:
            //1D-array is one line in logfile
            //2D-array cannot be displayed in logfile or graph
            //   devide it into lines and log line by line
            //   or save the 2D-Array to file
            //   and load the file manually to Graph or Logeditor

            array save ar2 "c:\temp\ar2.dat"

            //***********get a 1D-subset from a 2D-array

            //open_vi "graph"
            do
               array get ar2 $i0 >ar1
               log add "$i0 $ar1
               graph add "$ar1" "Y<Y<Y<Y<Y<"
            loop $dim1

            //********calculate mean value and standard deviation
            //for 2D-array this is 1D ( mean for evey column )
            array mean ar2 >ar2mean >ar2std
            log add "L1 $ar2mean
            log add "L1 $ar2std

            //for 1D-array this is scalar
            array mean ar1 >ar1mean >ar1std
            log add "L1 $ar1
            log add "L1 $ar1mean $ar1std
```

```
//**** Examples for array merge-command

        clear ar1
        real() ar1  (4,3,2)   //set array 1D
        clear ar2
        real(())  ar2   //array 2D

        //**********merge values to a 1D-array

        open_vi "log editor"
        do
          real x1 $i0
          array merge ar1 $x1
        loop 5
        log add "L1 $ar1

        //**********merge 1D-arrays to a 2D-array

        do
          array merge ar2 $ar1
        loop 2
        clear ar1
        real() ar1  (5,5,5,5,5,5,5,5,5,5)   //set array 1D
         array merge ar2 ar1

        //********** log the resulting 2D-array
        real dim1
        real dim2
        array length $ar2 >dim1 >dim2
        do
           array get ar2 $i0 >ar1
           log add "$i0 $ar1
           graph add "$ar1" "Y<Y<Y<Y<Y<"
        loop $dim1
```

timer *$char1 $int2*

Starts a timer to trigger timed events, e.g. a measurement every 10 sec. The first call of "timer wait" defines a "start"-time, and pauses the script until the defined time increment has passed. Every further call of "timer wait" pauses the script until the time increment has passed since the last "timer wait". The time increments can be defined as a constant or an array.
In opposite to the "wait"-command the "timer" triggers at absolut points of time.This allows equidistant time step independent of the duration of other commands. If the duration is longer than the timer wait an error message is displayed in the main window.
Typically timer wait is used in loops. Pay attention to the timing of the first and last loop execution.

$char1	*load*	*// To load the timer with the following timer increment or increment_array; includes reset, but no start of timer.*
	reset	*// reset the timer and timer array index, but no start of timer*
	wait	*// start and/or wait until next time increment is reached.*
	zero	*// set system time $time to zero (but no timer reset !)*
$int2	*Time increment in msec: This may be an array with individual waiting times*	

Examples (further examples in kinetic scripts)

```
timer zero                          // set the internal variable $time to zero
timer reset                         // resets the timer (but does not start the timer)
log add "L1 $time"
do
  timer wait 1000                   // start and pauses the script
                                    // untill the time increment of 1 sec passed since last timer wait
  log add "$time"
loop 5

REAL() tm  "(2000,3000, 1000)"      //define and set an array
log add "$tm
timer load $tm                      // loads and resets the timer
do
  timer wait $tm
                                    // stops the executing of the following statements
                                    // untill the given time increment since last timer wait
  log add "$time"
loop 5
```

Chapter 4: Hardware commands

motor

motor *$char1 $char2 $real3 $real4 $real5 $real6 >real 7 >real8*

Moves one or more motors of a component, e.g. polarizer.
As default position moves are synchrone: the script waits for the motor to reach the position. Asynchrone moves are possible: start the movement and continue the script
The actual motor position is available in a Variable with the motor name (use "$")

$char1	*move: moves the selected motor* *read: reads the actual position of the selected motor* *reset: resets the selected motor* *stop: stops the moving of the selected motor* *wait: the script waits until the motor reports "trajectory complete". for asynchrone moves* *zero: set the actual position as zero (very usefull for x,y,z-stage; undo with motor reset)*
$char2	*Constants of motor names, e.g. pl or gsgl* *Do not use the character "$" in front of motor names!* *AOI / AOV : special name for gonio-motors gs /gl, including correction function for prism-cell-measurements. Use separately for every motor !*

$real3	*Mode of positioning* *0 move to absolute position ($real5)* *1 move to relative position ($real5)* *2 start velocity move (always asynchrone)* *or* *mode of stopping:* *0 stop and stay at actual position* *1 stop smoothly* *2 motor off* *3 stop abruptly*
$real4	*Speed for positioning, monic (-1...0...1)* *Higher speeds (e.g. 2)is possible but may cause unpredicted movements*
$real5	*target position for mode 0 and 1 ($real3)*
$real6	*timeout in ms. script waits for "trajectory complete" or until the timeout-value is reached* *0 or undefined: timeout after 60000ms* *–1: asynchrone (script continues imediately)*
>real7	*return value for motor read (real or real())*
>real8	*return value for motor exists (0 or 1)*

Examples:
//Standard: motor move NAME MODE SPEED POSITION

```
execute "nulling_one_zone"
motor move pl 0 1 $plconj -1        //move to the position of conjugated null
motor move al 0 1 $alconj
motor wait pl
execute "nulling_one_zone"
```

```
motor stop all 2                    //set all motors to motor _off.
                                    //position are still registered correctly,
                                    //no reset is needed for reactivation
```

```
motor reset plalco                  //reset three motors paralel
```

```
motor move plal 1 0.33 100 –1       //two motors - relative - 1/3rd speed- 100° - asynchrone
do
  log add "$pl $al $co"             //write positions to logfile every 300 ms
wait 300
loop 30
```

```
motor move AOI 0 1 53.1             //move motor gl (gonio Laser arm), but calculate correction for
motor move AOV 0 1 53.1             //internal Angle_Of_Incidence  (or _View) in prism cells
                                    //use motors separately and only in absolute position mode "0"
```

shutter

shutter *$char1*

Opens or closes the mechanical shutter.

$char1	*on – to open the shutter* *off – to close the shutter*

Example

Shutter on // opens the shutter

camera

camera *$char1 $int2*

Command to set multiple camea parameter.

$char1	*number*	*: change camera chanel*
	gain	*: setting gain (and shuttertime)*
	autoset	*: set gain automatically*
	roi_set	*: transfer coordinates of ROIs*
	show_roi: :show ROIs in Live-image	
	show_cross	*: show crosshair in Live-image (for alignment on camera2)*
	autoalign	*: switch to camera 2 and execute automatic alignment, then to camera 0*
	subsampling: reduce network load and increase live image quality	

$int2	*for number:number of camerchanel 0 ,1 ,2*	
	for gain	*:general gain 0..100%*
	for autoset:	*change general gain until this gray-count is reached in ROI number 0*
	for roi_set:	*one- or two-dimensional array of ROI-coordinates (upper left and lower right corner coordinates, unit: Pixel or normed to full frame)*
	for show_roi	*: 0=off, 1=on*
	for show_cross	*: 0=off, 1=on*
	for subsampling	*:analog to binning in image command. default=2,*

Example:

```
camera number 2                 //switch to align camer; standard camera is 0
wait 200                        //changing camera needs time, better wait before the next command

camera gain 40                  //set general gain
camera autoset 40               //manipulate gain until $roi_signal is 40
int() x1 “(100,100,400,300)
camera roiset $x1               //defining coordinates for ROI in pixel of full resolution image
camera subsampling 4            //only every 4th pixel in x and y-direction is transferd
                                //to live image. This reduces network load by factor 16
camera show_cross 1             //Show alignment crosshair

open_vi “align.vi”              //switch to camera2, set crosshair  open once
camera autoalign                //do automatic alignment
```

dio bits

dio *$char1 $char2 $int >int4*

Access to Digital Input/Output-ports. Ports were defined in \config.ini.

$char1	*get*	*// gets the dio value*
	set	*// sets the dio value*
$char2	*name of the DIO-port*	
$int	*output Value to be set (0 … 255 or on/off)*	
>int4	*input Value read from EP3-Electronic*	

Example list of DIO-Port configuration

NAME	VALUE	OPERATION
shutter	on/off	Light shutter in Laserarm
camera0power	on/off	power standard camera 0
camera0gain	0-255	gain standard camera
camera0shutter	0-255	shutter time standard camera
camera2shutter	0-224	shutter time align camera, 3 bit used
laserswpower	on/off	single Laser power, via C-port to lasercontroller
laserpower	0-112	Laser-Matrix for MW, 3bit via C-port to MW-Box
lamp	on/off	sample lamp scannerprotection
lasermirror	on/off	switching Prism mirror in combined SW+SE-Systems
interlock	Input	high if door is open
scannerprotection	Input	low if scanner collides with sample

Examples:

```
dio set camera0gain 25
int x1 0
dio get shutter >x1
dialog “value of shutter bit:” $x1
```

wavelength

set_wave_index *$int1*

Sets the index of another wavelength. The motor mw moves automatically to the position defined in \wavelength.ini. The script “\instrument specific\set_wave_options.ep3” can be executed afterwards to appliy additional features like switching of mirrors etc.

$int1	*wavelength index, see wavelength.ini*

Examples:

```
set_wave_index  $wave_default          //$wave_default is set in
execute set_wave_options               //\scripts\Instrument_Specific\startupGlobals.ep3


INT wave_start 0                       //assume a MW-Box wit 4 laser wavelength
INT wave_end 3                         //and cycle through the 4 wavelength
INT wave_step 1
do
```

```
  set_wave_index  'wave_start+i0*wave_step*sign(wave_end-wave_start)'
  execute set_wave_options
  log add “$wave_index $lambda $mw“
loop  'abs((wave_end-wave_start)/wave_step)+1'
```

Chapter 5: Analysis commands

record

record *$char1 $int2 $char3*

Starts the data recording. Data were transferred to internal memory (data recorder).

$char1	*Mode:* *Frames // to record camera frames* *Data // to record data*
$int2	*number of samples; standard sample rate is 25Hz,* *100 samples take 4 seconds*
$char3	*async (default): script continues (motors can be moved parallel)* *sync or wait: script pauses untill data is recored*

Example:
record data 1000
record frames 20 wait

find_minimum

find_minimum *char1 $real2 $int3 $int4 >int()5*

Finds the motor position for minimum ROI_signal.
Data acquisition is started. The motor (e.r. pl) starts moving from the actual position for the range, turns around and moves to the other direction, then back to the starting position. Data acquisition is stopped. A parable fit is calculated at the data ROI_signal versus motor position for every ROI. the result is stored in an array with motor name and the ending “min”. If the minimum is found within the range for most ROI the motor moves to the mean minimum position (e.g. $plminmean)

$char1	*Constant of motor name, e.g. pl.* *Do not use the character “$” in front of motor names*
$real2	*Rotatíng Range for the selected motor*
$int3	*Samples: Number of used datapoints*
$int4	*-1 : optional. The data are not transferred to the memory* *for delta-psi-calculation in multiple zones* *number of steps: if a number is give the “stepwise nulling mode” is acivated (see example)*
$int5	*Array of 0 or 1: Minimumin was found or not (Array with ROI-number)*

Examples:
find_minimum *motorname $range $samples $store?_or_stepwise_mode >min_found_array*

real() inrange
find_minimum pl $plrange $plsamples >inrange
log add "$pl $plminmean $plmin $inrange"

find_minimum pl 1 40 20 //Special mode "stepwise nulling":
// in a +/-1 degree range sample 40 ROI signals at 20 pl positions
//the motor does not move continuously but stepwise

Calc_delta_psi

calc_delta_psi *$char1*

Calculates delta and psi from motor positions of the last pl and al minimum for all ROI.
The results will be stored in the arrays delta and psi, in real valiables deltamean and psimean, and the conjugated nulls were estimated.
With the parameter multiple zones can be averaged or actual motor positions instead of measured minima were used for calculation.

	Polariser setting	**Compensator setting**	**Analyser setting**
Zone 1	positive	+45°	positive
Zone 2	negative	+45°	negative
Zone 3	positive	-45°	positive
Zone 4	negative	-45°	negative

Tab: The ellipsometric nulling condition is fulfilled at four distinct optics settings. The mean value at two- or Four-Zone-Measurements is free of multiple systematic errors. This increases the accuracy depending on the measurement condition by an order of magnitude conjugat nulls have the same compensator position: zone 1 and 2 are conjugate, zone 3 and 4 as well.

$char1 *Zones (1,2,4)*
mode "min" (default), simmilar to « 1 »
mode "man" use not minima but the actual positions pl al co

The command find_minimum stores the last measured minima in 2D-arrays plmin, almin and co. ome dimension is the number of ROI. Calc_delta_psi uses the last 1,2 or 4 minima to calculate delta and psi in a 1D-array for every ROI.
The results are stored in the following Script Server Variables:

$delta	1D-Array	delta vs. ROI-Number
$deltamean	real	average value
$psi	1D-Array	psi vs. ROI
$psimean	real	average value
$plconj	real	average value, to estimate start position for next minimum
$alconj	real	average value

In the mode "man" multiple ROI are not sensfull, only one ROI is calculated !

Examples:

```
open_vi "delta&psi globals.vi"          //view the delta-psi-zones memory
execute "nulling_pl_al"
calc_delta_psi                          // calculates for one zone


execute "nulling_one_zone"              //this subscript contains a “calc_delta_psi”
motor move pl 0 1 $plconj -1            //move to conjugated null
motor move al 0 1 $alconj
motor wait pl
execute "nulling_one_zone"              //this subscript contains a “calc_delta_psi”
calc_delta_psi 2                        // calculates the average value for the 2 Zones
```

log commands

log *$char1 $char2*

$char1	*add:*	*add a line to the window ”log editor“*
	clear:	*clear the ”log editor”*
$char2	*string of variables which shall be add to the ”log editor“. For each variable set the character “$” in front of the name. if there is a L1, L2, L3..in the beginning of the string : different levels in the “log editor”, where the variables shall be add*	

Example:

```
log clear                               //clear the log editor
log add "L2 $Lambda $aoi $delta $psi"   // Result in log editor:
```

l2			lambda (nm	aoi °	delta(0) °	psi(0) °
0			532.0	55.000	173.726	4.023

graph

graph *$char1 $char2 $char3*

$char1	*add:*	*add a line to the window ”graph“*
	clear:	*clear the window ”graph”*
$char2	*variable string which shall be add to the window “graph”. For each variable set the character “$” in front of the name. (see command “log”)*	
$char3	*defined the axis for the variables - : no axes is used X : the x-axis is used Y<: the left y-axis is used Y>: the right y-axis is used*	

Example
do

```
 execute "nulling_one_zone"
 REAL kinetic_time '(time-starttime)/60'
 log add "L0 $date $time $kinetic_time $Lambda $aoi $Delta"
 graph add  "$time $kinetic_time $Lambda $aoi $Delta $Psi" "-X--Y<Y>--"
 model add "$Lambda $aoi $Delta $Psi"
 timer wait 'increment*1000'
loop $totalloops
```

model

model *$char1 $char2*

Load data to the model-window or apply the optical model.
The model must be configured for your sample.

$char1	*clear:*	*model data field*
	add:	*load data field*
	fit:	*apply actual model*
$char2	*data string with measured variables*	

Example:

```
open_vi "Model"                          //open model window
model clear                              //clear model data field
model add "$lambda $aoi $delta $psi"     //transfer data
model fit                                //apply the actuial model
```

Chapter 6: Imaging commands

image

image *$char1 $int2 $int3*

$char1	*grab*	*grab the live image to the map&image_viewer*
	scan	*scan live image and store in map&image_viewer*
	save	*saves the current image*
	delete	*deletes the last image from the browser*
	format	*(not working yet, choose in map&image_viewer !)*
$int2	*for grab:*	*number of frames to average*
	for scan:	*number of frames*
	for save:	*name and path of the image file*
	for format	*PNG (recommended), JPG, BMP or 16 bit TIFF*
$int3	*binning factor n. This takes n x n pixel and transfers only the average value. This reduces the amount of data and network load, processor time is reduced, but resolution is reduced as well. Default for image scans is 1 (full resolution)*	

Examples:

```
image scan $number_of_frames $binning_image   //scan and calculate a completely sharp picture
image grab $average_frames                    //grab live image.
                                              //reduce noise by averaging multiple frames
image save $name                              //the image is saved in Folder:
                                              //$data_path+$name+system_time_in_seconds
                                              //saves image file (.png) and an info file (.info)
```

mapping

map *$char1 $int2 $int3*

Take multipe images and calculate a minimum fit to every individual pixel.
Use the mapping tool to apply the model to the map and get a thickness map.

$char1	*clear:*	*clears all maps in the browser*
	Delta:	*the delta values are used for the map*
	Psi:	*the psi values are used for the map*
$int2	*Number of Images used for the map*	
$int3	*binning factor for map. This binning factor multiplies with the binning factor for images*	

Example:

```
map clear
map delta $number_of_images $binning_map
open_vi "Mapping"

//example scripts:
//\user xxx\scripts\default scripts\mapping\delta_mapping.ep3
```

6.4. Technical Data

EP^3

Ellipsometer type	auto-nulling imaging ellipsometer
Ellipsometric resolution	0.001deg (Delta and Psi) absolute accuracy 0.01deg
Relative thickness error (SiO2 on Si)	0.001 nm
Absolute thickness accuracy (SiO2 on Si)	< 0.1 nm
Imaging system	CCD camera with 768 × 572 pixels Highly sensitive CCD camera with 640 x 480 pixels Highly sensitive CCD camera with 1380 x 1024 pixels
Light source	internal solid-state laser max. laser power: 50 mW wavelength: 532 nm laser class: 3B as per DIN EN 60825-1:2001-11
Power supply	100 to 240 VAC, 50/60 Hz, max. 10 A
Dimensions	1000 × 600 × 600 mm (length × width × height)

Electronic control unit

Processor	Pentium-based controller with Matrox Meteor II Frame Grabber
Operating system	Embedded Linux
Interface	100 Mbit Ethernet

SE box

Light source	Xenon arc lamp
Monochromator	filter wheel with 46 interference filters wavelengths: 365 to 1000 nm bandwidth: ± 8 nm
Laser connection	fiber optic link

Motorized goniometer

Angle of incidence	40 to 90 deg
Angle resolution	0.001 deg
Absolute angle accuracy	0.01 deg
Speed of motion	approx. 5 deg/sec

Alignment sensor

Accuracy:	0.01 deg
Range:	± 2 deg

Manual sample stage

Travel range	X/Y:	100 mm
	Z:	10 mm

Automatic sample stage

ALS	typ. 2 sec/deg	
XYZ-stage	travel range	
	X/Y:	>85/90 mm
	Z:	>10 mm
	repeatability:	1µm
Joystick	Logitech® "MS Wingman"	

Personal computer

Processor	> 2.0 GHz Pentium processor or equivalent
RAM	512 MB
Operating system	Windows 2000 Professional™
Display	32-bit true-color graphics adapter, 1280 × 1024 pixels
Interface	100 MBit Fast Ethernet for EP3-Communication
	A second Ethernet card for LAN
Drive	CD-RW drive