

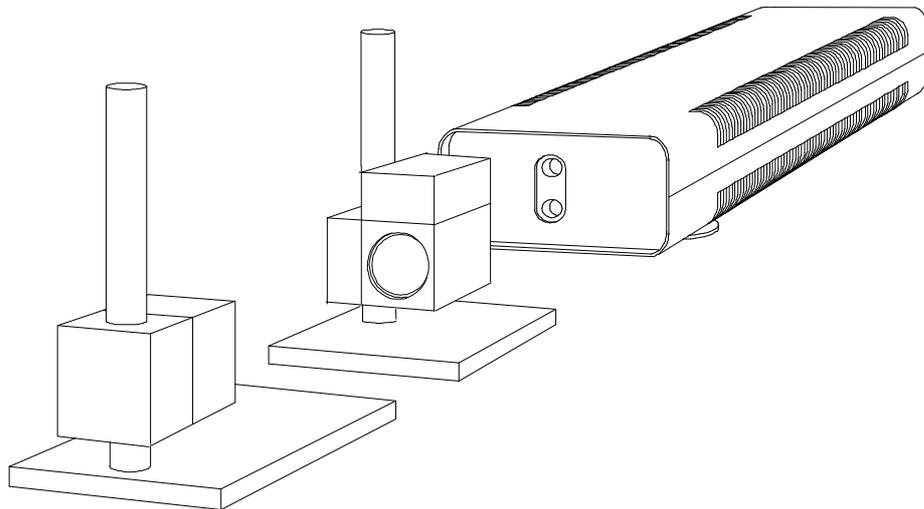


Double-frequency Laser Distance Measuring System

ZLM 700/800/900

Manual of the Software Package
Version 2.5

- Part I -



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**DO NOT STARE INTO THE LASER BEAM, NEITHER WITHOUT
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Class II Laser Product.

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A Overview

A 1 The capabilities of the ZLM 700/800 Software

The software for the ZLM 700/800/900 Laser Interferometer comprises two program groups:

Calibration Software: With the Calibration Software you can check and calibrate coordinate measuring machines and machine tools.

Dynamic Measurement Software: The Dynamic Measurement Software can be used for most of the measurement jobs that do not fall into the above category, and especially for laboratory measurements.

The acquisition and analysis of measurement data are effected in different ways with the various programs, while the documentation and archiving of measurement results are identical for all programs.

Documentation The documentation of measurement results can be handled through a document (record) editor, which allows diagrams, tabled measurement data and comments to be compiled into a record and then printed or plotted.

The contents of a record may be transferred to word processors.

Archiving Measured data together with the record are archived in a card file system. In addition, measured data can be filed as a list.

A 1.1 Calibration software

The programs can be used to determine position uncertainty, pitch angle, yaw angle, straightness, squareness and flatness according to standards and recommendations issued by national and international standardization panels.

In general these standards provide for static measurements, i.e. acquisition of measurement data is effected while the measured object is at rest. To a minor extent, the programs can also be used for dynamic measurements (with data acquisition frequencies up to 10 Hz).

The following overview shows which program can be used for what kinds of measurement task.

Program	Calibration software ZLM Position	Calibration software ZLM Angle/ Straightness	Calibration software ZLM Stat	Calibration software ZLM Flatness
Quantity	Position uncertainty according to - VDI/DGQ 3441, - VDI/VDE 2617, - ISO 230 and - NMTBA	Pitch angle, yaw angle, straightness and squareness according to VDI/VDE 2617, straightness according to ISO 1101	Position uncertainty according to - VDI/DGQ 3441, - VDI/VDE 2617, - ISO 230 and - NMTBA, pitch and yaw angles, and straightness acc. to VDI/VDE 2617	Flatness and straightness according to ISO 1101
Diagram	Standard diagram according to standard, and presentation of individual measuring cycles	Standard diagram according to standard, and presentation of individual measuring cycles	Standard diagram according to standard, and presentation of individual measuring cycles. Simultaneous presentation of data measured on several axes.	Dimetric, isometric and three-dimensional presentation with any pitch and yaw angles.
Number of axes	1	1	2 to 6	1
Optical components supported	Distance optics with cube corner or plane mirror reflector	Angle optics with cube corner or plane mirror reflector, 2m and 10m straightness optics	Distance and angle optics with cube corner or plane mirror reflector, 2m and 10m straightness optics. Individually selectable for each axis.	Angle optics with cube corner or plane mirror reflector, 2m and 10m straightness optics
Triggering of data reading	Automatic (with standstill control), TTL pulse and space bar	TTL pulse and space bar	Automatic (with standstill control), TTL pulse, space bar and incremental encoder	TTL pulse and space bar
Environmental compensation	Manual entry or automatic with AUK 500	Not necessary	Manual entry or automatic with AUK 500 (for distance measurement)	Not necessary

A 1.2 Dynamic measurement software

The programs can be used for the measurement of distances, velocities, accelerations, angles and angular velocities.

Data acquisition can be triggered by
 the pulse of a timer located on the ZLM counter card,
 external read-in signals or
 hitting a key of the PC keyboard.

The maximum sampling frequency is 70 kHz for the ZLM 500.
 Long-time measurements over hours and days are also possible.

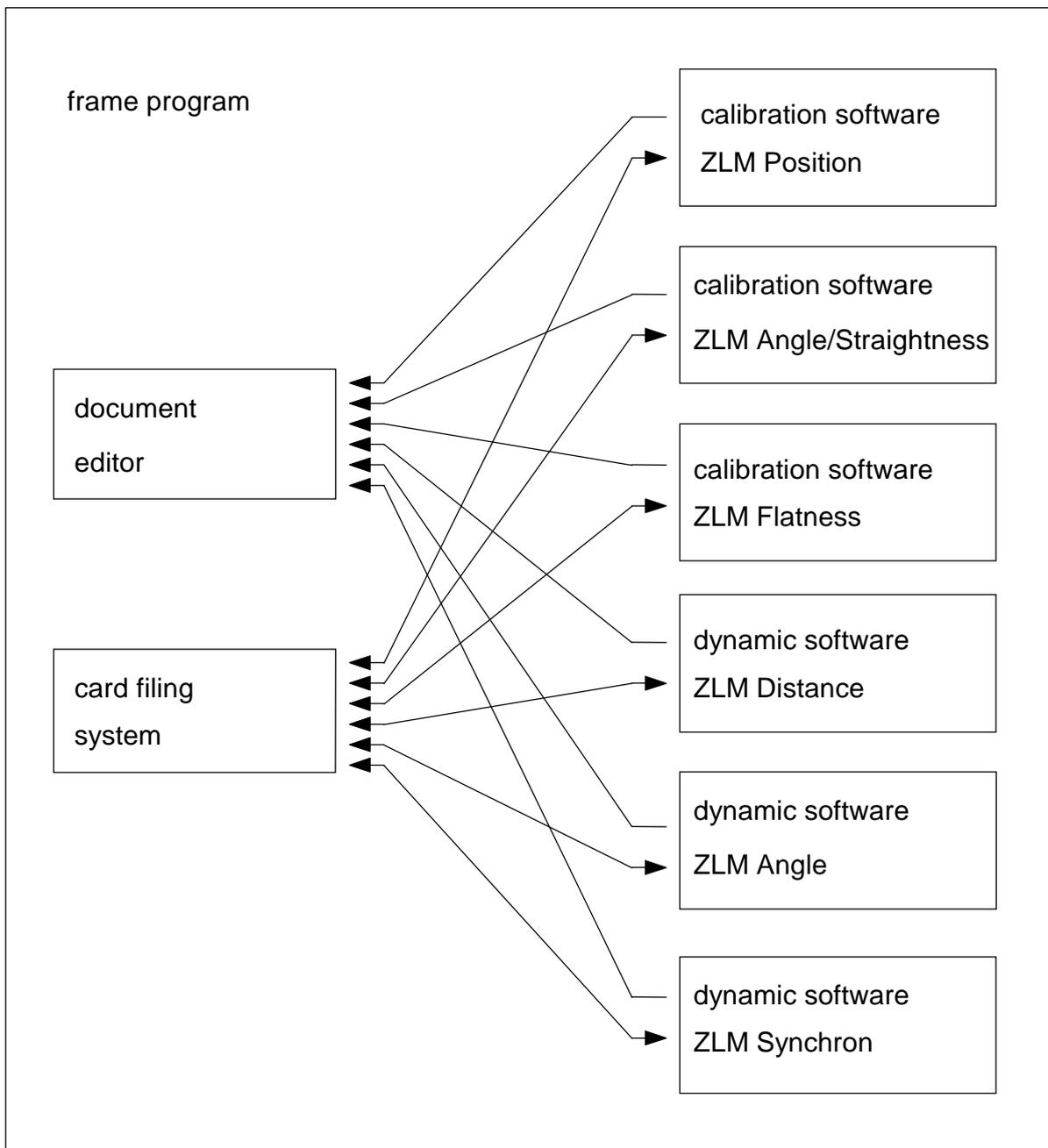
Program	Dynamic software ZLM Distance	Dynamic software ZLM Angle	Dynamic software ZLM Synchron
Quantity	- Distance - Velocity - Acceleration	- Angle - Angular velocity	- Distance - Velocity - Acceleration - Angle - Angular velocity
Diagram	Distance-vs.-time, velocity-vs.-time, acceleration-vs.- time, distance deviation from expected val- ues, Fourier analysis	Angle-vs.-time, angular velocity-vs.-time, angle deviation from expected values, Fourier analysis	Distance-vs.-time, angle-vs.-time, angular velocity-vs.-time, deviation from expected values, Fourier analysis Simultaneous presentation of data measured on several axes. Data measured on several axes as a function of the data meas- ured on one axis.
Number of measuring axes	1	1	2 - 6
Optical compo- nents supported	Distance optics with cube corner or plane mirror reflector	Angle optics with cube corner or plane mirror reflector	Distance and angle optics with cube corner or plane mirror re- flector, 2m and 10m straightness optics Separate selection for each axis
Environmental compensation	Manual entry or automatic with AUK 500	Not necessary	Manual entry or automatic with AUK 500 (for distance measure- ments)
Comment			Data acquired by an incremental encoder with digital "A quad B" output can be proc- essed.

A 2 Software structure

Since the ZLM 700/800 Laser Interferometer is designed for many different tasks, the software structure is modular. The management program "Esox" contains all program sections that are required for every kind of measurement. These are the framework program, the document (record) editor and the card filing system. The management program is extended by various measurement programs as required for a particular measurement task. This modularity has the following advantages for the user:

- ### more straightforward installation of the software,
- ### less hard disk space required by the program,
- ### similar operation of all modules in the management program, and
- ### quick change between measurement programs.

The management program "Esox" has been given a highly generalized configuration so that it will even support measurement programs for other measuring instruments.



A 3 What do I find where in the manuals?

This manual describes the calibration software and the dynamic measurement software. The **Manual of the basic equipment**, which has been supplied together with the equipment, should be read first.

The following table gives an overview of where to find what information.

Subject	Important for ...	Where to be found?
Laser handling Measuring principle of ZLM 700/800 Starting the instrument Assembling measurement set-ups	... all programs	Manual of the basic equipment
Installation of the software	... all programs	Section B
Starting the software Basic information on program handling	... all programs	Section C
Dynamic distance measurement	Dynamic software ZLM Distance	Section D
Dynamic angle measurement	Dynamic software ZLM Angle	Section E
Synchronized multiple-axis measurement	Dynamic software ZLM Synchron	Section F
Measurement of position uncertainty	Calibration software ZLM Position	Section G
Static measurement of angle Static measurement of straightness Squareness measurement	Calibration software ZLM Angle/Straightness	Sections G and H
Multiple-axis measurement of position uncertainty, angle (static) and straightness (static)	Calibration software ZLM Stat	Section I
Flatness measurement	Calibration software ZLM Flatness	Section J
Archiving of results	... all programs	Section K
Compiling measurement records (documents)	... all programs	Section L

Sections D to J describe the measuring programs. As you will presumably use one of the measuring programs, i.e. ZLM Distance, ZLM Position, ZLM Synchron or ZLM Stat, these programs are described in great detail in the respective sections. Several Instructions, such as how to analyse measurements made some time back, will be found in several of these sections. The manual is organized in such a way that you only need to read the sections describing the measurement program you want to work with.

B Installation

B 1 Minimum computer configuration required

For operating the measurement system a computer is required. The following table gives an overview of computer systems and operating systems which can be used.

Computer	Operating system
IBM-compatible PC with Intel Celeron or AMD Athlon processor.	MS-Windows 2000
IBM-compatible PC with Intel Pentium 4 or greater	MS-Windows XP or MS-Windows Vista

Appropriately compiled programs can be supplied for each of the computer / operating system combinations listed. Attempts to install the programs on other operating systems supporting MS-Windows (e.g. OS/2) will not be successful.

B 1.1 Programs for Windows 2000

The table below specifies the hardware configuration required. **The "Recommendation" column describes a configuration allowing comfortable operation.**

	Requirements	Recommendation
Processor	Intel Pentium 4	Intel Pentium 4 or AMD Athlon 2000+
Main memory	128 Mbyte	512 MByte
Space on hard disk	1,5 MByte + 1 MByte per measurement program + space for data.	512 MByte
Pointer device	MS compatible mouse, trackball or touchscreen.	MS compatible mouse, trackball or touchscreen.
Graphics card	VGA colour, 640 x 480 pixels. With "ZLM Synchron" dynamic software and more than 3 measurement axes: 800 x 600 pixels.	VGA colour, 640 x 480 pixels. With "ZLM Synchron" dynamic software: 800 x 600 pixels.

For successful work with your ZLM software, observe the following notes.

Networks

We want to emphasize particularly that this program is not a network version. Installation of this program in a network is possible, but it can be run only on one workstation at a time.

B 1.2 Programs for Windows XP / VISTA

The table below lists the computer hardware requirements. The only software requirement is the successful installation of MS-Windows XP or VISTA.

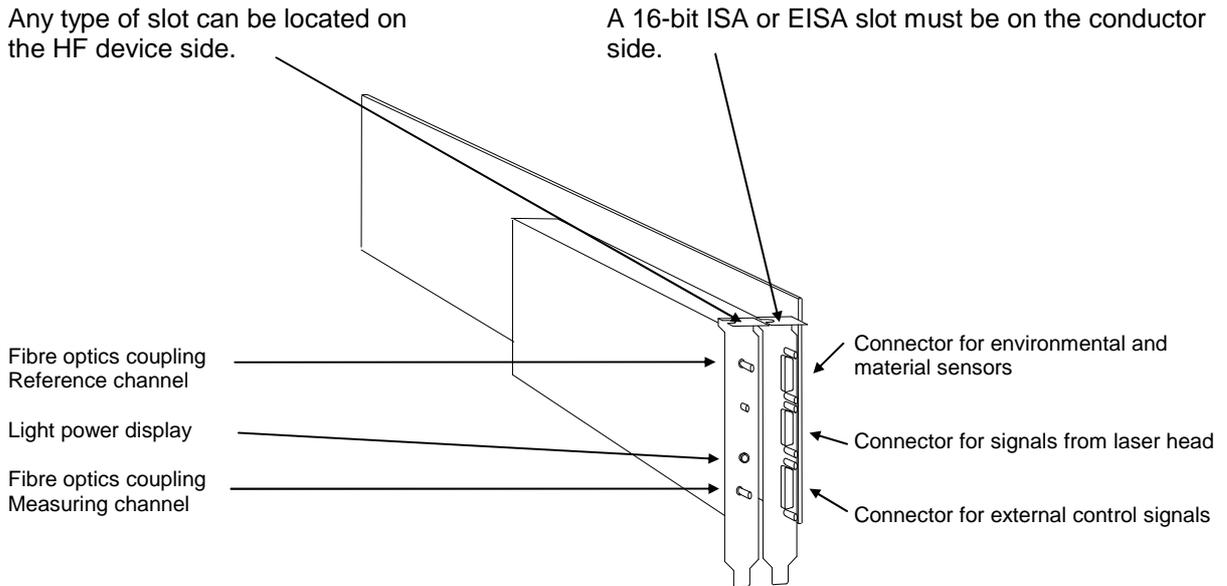
	Requirements	Recommendation
Processor	Intel Pentium 4 or greater AMD Athlon 2300+ or greater.	Intel Pentium 4 or greater AMD Athlon 2300+ or greater.
Main memory	512 MByte	1024 MByte
Space on hard disk	1,5 MByte + 1 MByte per measurement program + space for data.	512 MByte
Pointer device	MS compatible mouse, trackball or touchscreen.	MS compatible mouse, trackball or touchscreen.
Graphics card	VGA colour, 640 x 480 pixels. With "ZLM Synchron" dynamic soft- ware and more than 3 measurement axes: 800 x 600 pixels.	VGA colour, 640 x 480 pixels. With "ZLM Synchron" dynamic software: 800 x 600 pixels.

B 2 Hardware installations for ZLM 700/800

B 2.1 Required Slots

ZLM 700/800 multi-axis systems are described in the "Manual on multi-axis laser interferometer systems". The following refers to the single axis ZLM 700/800 data acquisition card.

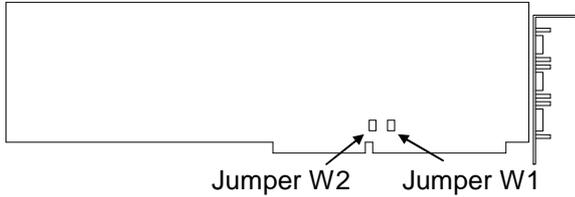
The ZLM data acquisition card contains all electronic components which are required for measurement data analysis. For installing this card you need two slots adjacent to each other.



B 2.2 Storage addresses (only ZLM 500)

The ZLM data acquisition card can be accessed via a storage area. To ensure error-free function of the card, this storage area must not be used by any other hardware components. Especially SCSI-devices are using the storage area from C8000 up to CFFFF. That's why you have to change the factory pre-selected setup.

Unscrew the HF electronics. Then the storage address area can be selected via Jumper W1 and W2. We recommend, however, to have the storage address area changed by one of our service technicians.

ZLM 500 data acquisition card		
Jumper W2	Jumper W1	Storage area (RAM)
open	open	C8000 - CBFFF (hex), factory pre-selected
open	connected	CC000 - CFFFF (hex)
connected	open	D0000 - D3FFF (hex)
connected	connected	D4000 - D7FFF (hex)

Configuration with EISA computers On a computer with an EISA bus system you can assign memory addresses to the slots. In general, free slots are pre-assigned by the computer manufacturer or dealer to the memory addresses not in use. Therefore the system configuration does not need to be changed.

Along with the computer, the computer manufacturer provides a system configuration program on floppy or hard disk. This program finds out whether the provided memory addresses of the ZLM 500 data acquisition board are in use or not. If they are in use, we recommend the memory addresses of the new cards to be changed.

If you want to exploit all the advantages of the EISA bus system and obtain information about reserved and free system resources when installing additional cards, you need to configure the slots with the memory addresses of the card to be installed.

The manuals of EISA computers contain a detailed description of the configuration program. No special configuration files are available for the ZLM data acquisition card. For its configuration, use the "General ISA adapter" configuration file and type in the memory addresses used.

Before installing the cards, you should find out about the available resources. Then plug in the cards and note down the numbers of the slots used for the conductor side of the cards, written above the slots on the computer rear panel. Then configure the system with the system configuration program.

B 2.3 Installation of the card

Open the computer housing according to the description in your computer manual.

Use a screwdriver to unscrew the slot covers from the desired slots on the computer rear panel.

If necessary, set the memory address space of the card. If you change it, Note down the new memory address space.

Plug the card into the slots and fix it with the screws.

Close the computer housing.

B 3 Installing the software

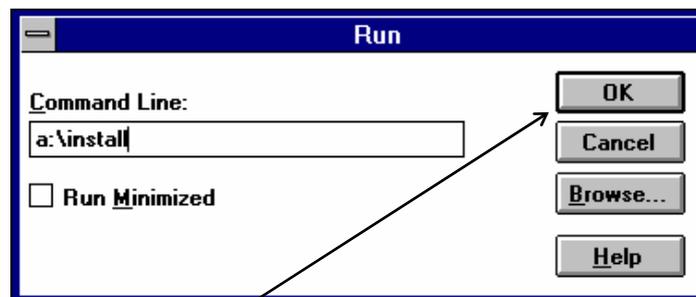
Three different cases of installation must be distinguished:

- | | |
|-----------------------------------|---|
| Initial installation | Section "B 3.1 Initial installation" describes how to proceed if none of ZLM program modules has been installed yet. |
| Complementary installation | Section "B 3.2 Complementary installation" describes how to proceed when the installation of additional measurement programs is required. |
| Update | If no installation instructions are sent with an Update, see section "B 3.3 Update" for instructions. |

B 3.1 Initial installation

Start of installation program

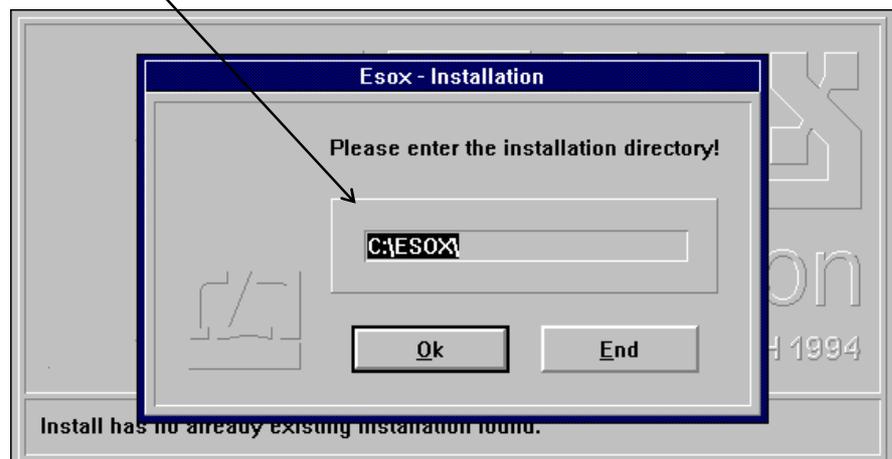
1. Insert the "Esox installation" disk into drive A or B. With the MS-Windows Program Manager being active, activate the "File" menu and choose the "Run..." option.
2. Type "A:\install" or "B:\install" in the dialog box, depending on whether the floppy disk is in drive A or B.



3. Click the  button to confirm.

Typing in the installation directory

The installation program searches all drives for any previous versions of this program. If no such version is found, you are asked to type the installation directory into the dialog box.



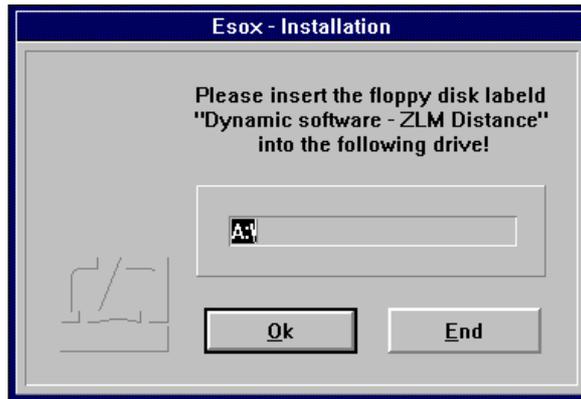
Choose a drive with sufficient free disk space (see section B1).

1. Type in the name of the directory in which you want to install the programs.
2. Confirm this entry by clicking the button.

Subsequently, the program files of the first disk will be copied.

Inserting the next floppy disk Then you will be asked to insert the next disk.

1. Insert the respective disk.

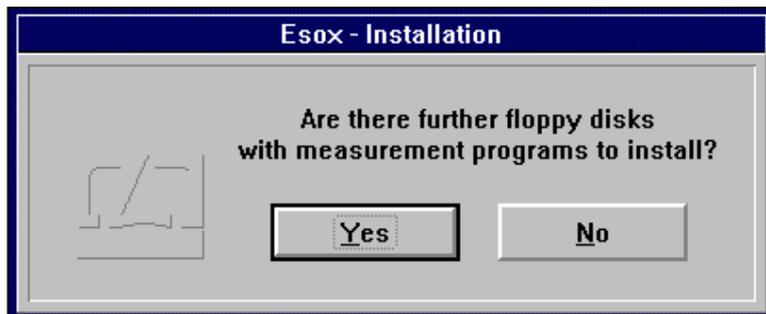


2. Confirm that the disk has been inserted, by clicking the button.

Depending on the number of measurement programs purchased, this step may have to be repeated several times.

Installation of further measurement programs

The installation program asks you if you want to install further disks.



If you have purchased more than one measurement program, it may be possible that not all of the disks had to be inserted in the copying process so far.

If so, insert the next disk and click the button.

If you are not sure whether you copied a certain disk already, just insert it (again) to find out. The installation program will copy only program files that have not been copied yet.

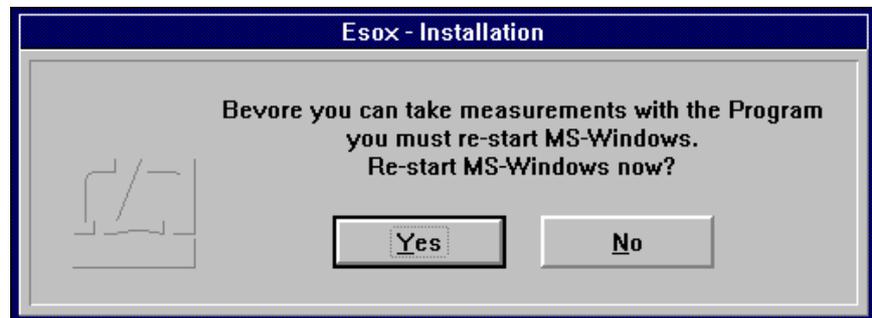
If there are no further disks to be installed, click the button.

Program icon

The installation program creates a program group "Carl Zeiss" in the Program Manager with the program icon of the Esox management program. A message box informs you about the successful completion of the installation.

**Re-start of MS-Windows**

Before you can make measurements with the installed program, you must re-start MS-Windows. Just before the installation program is completed, it will ask you whether you want to re-start MS-Windows now or continue working with MS-Windows without re-start.



In the latter case, you have to exit MS-Windows and re-start before you start working with the measurement program.

B 3.2 Complementary installation

In two cases a complementary installation will be necessary:

1. You have purchased an additional measurement program.
2. A measurement program was not installed during the initial installation.

In a complementary installation, more than one measurement program can be installed at the same time.

Starting the installation program

1. Insert the (first) measurement program disk into drive A or B depending on the disk format.
2. In the MS-Windows Program Manager activate the "Run..." option of the File menu.
3. Depending on the drive used, type in either "A:\install" or "B:\install" in the respective dialog box.
4. Confirm the entry by clicking the  button.

Directory of installation

The installation program searches your hard disk(s) for already installed management programs. When the directory with the management program is found, you are asked if you want to install the new measurement program on this directory.



Click the button. The disk program files will be copied.

Installation of further measurement programs

The installation program asks you if you want to install further disks. If you want to add more than one measurement program, insert the next disk into the drive and click the button.

If there are no further disks to be installed, click the button.

Re-start of MS-Windows

Before working with the new measuring program(s) you should re-start MS-Windows. If you respond with to the question of the installation program for a re-start of MS-Windows, you have to exit and re-start MS-Windows before you start to work with the measurement program.

B 3.3 Updating

The installation program can replace an old program version by a new version without having to delete the old version.

Starting installation program

1. Insert the "Esox Installation" disk in the respective drive (A or B) Choose the menu item "File-Run" of the program manager.
2. Enter "A:\install" or "B:\install" depending on whether you inserted the disk in drive A or B.
3. Press the button to confirm.

Installation directory

The installation program searches your hard disk(s) for management programs already installed. When the directory with the management program is found, you are asked if you want to install the new measurement program in this directory.



Click the button. The disk program files will be copied.

For the further steps, proceed same as in a first installation.

NOTE: If you prefer to delete the old program version from the hard drive before you start installing the new one, be sure not to delete your measured data. The measured data file "esoxm.dat" is located in the old installation directory. The measured data files for the drives are named "\ESOXDAT\esox.dat" and are located in the respective drive.

B 3.4 Changed hardware resources

If you change the hardware resources before installing the cards, the program needs the respective information to work properly.

The procedure differs depending on your operating system.

B 3.4.1 Operating system MS-DOS with MS-Windows 3.x

Retrieve the MS-Windows program "Notepad" in the program group "Accessories" of the program manager. For instructions on how to handle "Notepad" see your MS-Windows manual.

Retrieve the data file "system.ini" from the directory in which MS-Window was installed.

Find the section "[386Enh]" of the Windows system initialization data file, and enter the message that the storage address area of the card is not available as a standard work area.

Find the entry "EMMExclude".

If you cannot find this entry, add "EMMExclude".

EMMExclude = mmmm-nnnn

"mmm-nnnn" stands for the hexadecimal storage segment area of the card

Storage address area	Entry
C8000-CBFFF	EMMExclude = C800-CC00
CC000-CFFFF	EMMExclude = CC00-D000
D8000-DBFFF	EMMExclude = D800-DC00
DC000-DFFFF	EMMExclude = DC00-E000

If the storage area already exists, it must be combined with the new excluded storage area so that afterwards both storage areas will be excluded.

Some MS-DOS drivers will probably try to reserve the storage area of the data acquisition card for themselves. These drivers may have been installed during installation of different MS-DOS programs. MS-Windows has no use for these drivers. If you only have MS-Windows programs installed on your computer, you can disregard the following information.

The drivers can be retrieved via the data files "C:\conf.sys" or "C:\autoexec.bat". These drivers can be stopped from occupying storage area by using the following options:

Driver name	Activated via	Option	Example
emm386.sys	C:\config.sys	X=....-....	device=emm386.sys X=C800-CC00
emm386.exe	C:\autoexec.bat	X=....-....	emm386 X=C800-CC00
386max.sys (Qualitas Inc.)	C:\config.sys	EXCLUDE=....-....	device=386max.sys EXCLUDE=C800-CC00
qemm386.sys (Quarterdeck Inc.)	C:\config.sys	X=....-....	device=qemm386.sys X=C800-CC00

All changes in the "C:\conf.sys" or "C:\autoexec.bat" data files can be performed in the "Notepad" program. Changes in these data files require re-start of the computer before they become effective.

B 3.4.2 Operating System MS-Windows NT/9x

PC-card:

No changes are necessary. The driver finds out the storage area automatically (B 2.2).

ZLM500 with IEEE488-interface:

The driver looks for information about IEEE488-interface in the registry. You must fill in the correct information of your hardware installation.

In the MS-Windows NT/9x operating system all system configuration information is filed in a data file named "Registry". You can retrieve the required "regedit.exe" program via "Start" "Run...".

Choose on the left side of the program window the key

\HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\Zlm500\Resources

Values for ZLM 500 (default values):

(Standard)	(No values)
AddressStep488	0x00000400(1024)
BaseAddress488	0x000003e1(737)

To change the entry, double-click on the respective entry. A dialogue field will appear in which you can make the necessary change. The changes will become effective when you next restart the system.

C Handling the "Esox" Management Program

C 1 Starting the management program

The program can be started with

- the **"Esox" program icon** in the "Carl Zeiss" program group of the Program Manager,
- the **command line** of the "Run" option in the "File" menu of the Program Manager, or
- the **File Manager**.

The program file name of the management program is "esox.exe".

Consult your MS-Windows User Manual for detailed information about starting programs via Program Manager and File Manager.

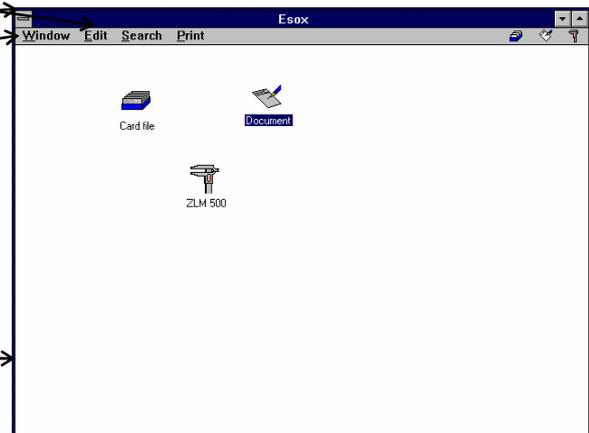
C 2 Windows of the management program

After having started the management program, a program window appears on the screen. This window contains different sub-windows.

C 2.1 Program window

The program window occupies the full screen and contains the following features:

- Title bar with program title "Esox",
- Control Menu button ,
- Menu bar,
- Minimize Window button ,
- Maximize Window button  and
- Window borders permitting window resizing (expansion and contraction of window height and width).

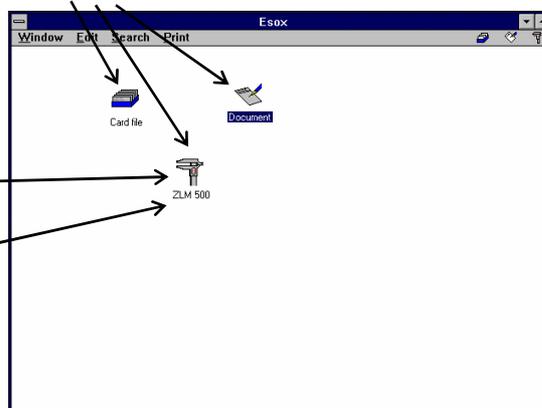


C 2.2 Application windows

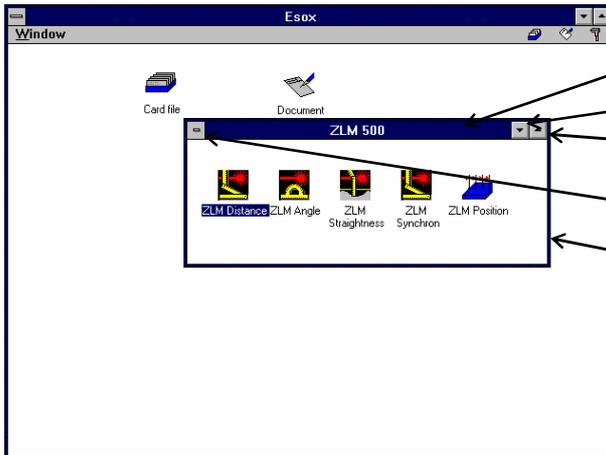
The program window contains different application windows.

When the management program is started the first time all application windows are reduced to an icon (minimized window) and contain

- program item icon,
- title bar with the program item name.



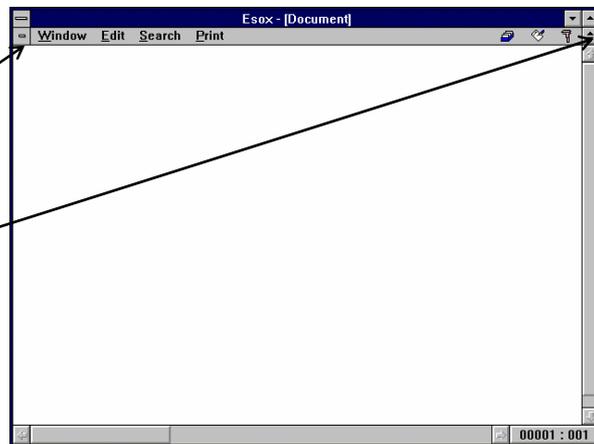
The minimized application windows can be restored to regular size by double-clicking and then contain:



- title bar with program item name,
- Minimize window button ,
- Maximize window button ,
- Control Menu button  and
- window border for window resizing.

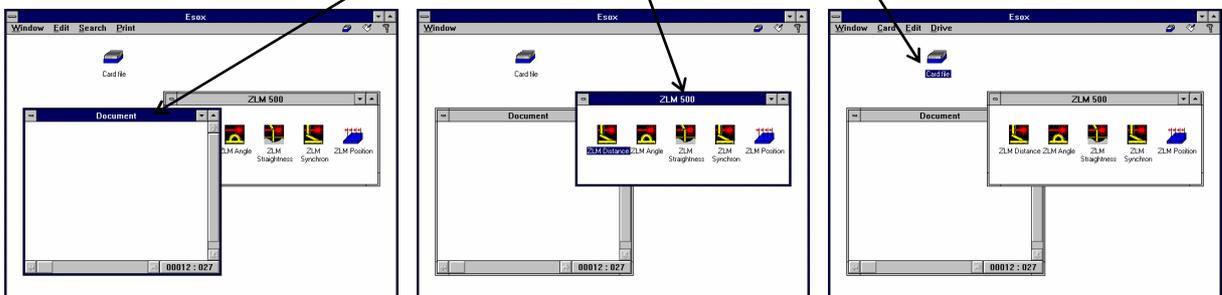
Only one application window each can be maximized at a time. In this case the program item name complements the program name in the title bar of the program window. The menu bar contains a Control Menu button 

and a Restore button  for the application window.



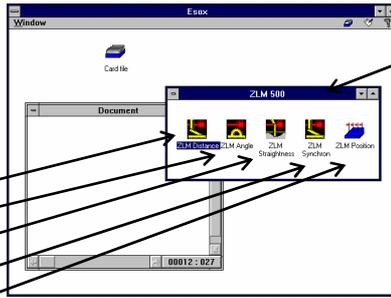
NOTE: The operation of the management program is similar to that of multi-document programs (such as Program Manager or File Manager). The difference is that the "document windows" here always have different contents. Therefore the term "application window" is used here.

Only one of the application windows can be active at a time. The active window is distinguished by its highlighted title bar.



Only the active window will respond to entries via the keyboard.

When the management program is started, the measurement programs are not active yet.

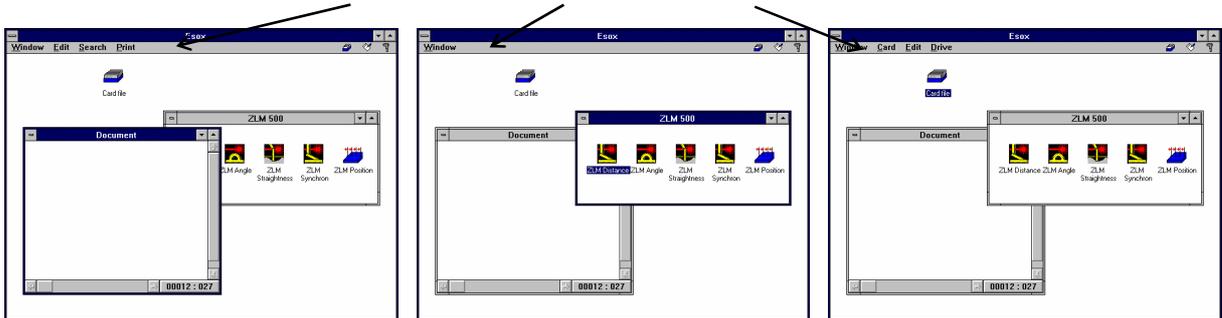


For each measuring instrument, the installation program creates a separate application window.

For each measurement program, a program item icon exists in one of the application windows.

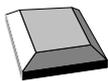
C 2.3 Working with menus

The menu bar of the program window is also used for all application windows. Since each application window has specific menu items that make sense only for this window, the menu bar changes when you activate a different application window.

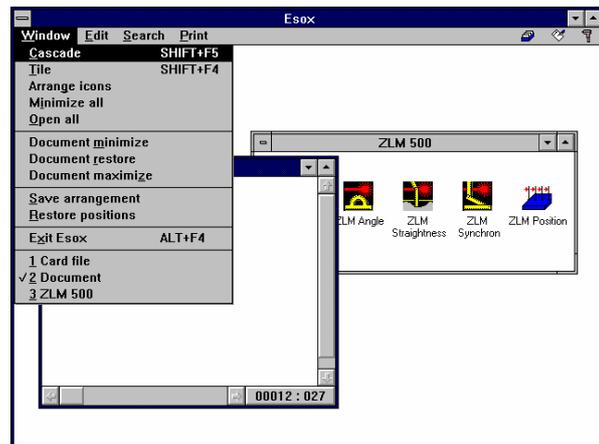


The first menu item, "Window", is common to all application windows. Via this menu option you can access all functions required for arranging or resizing the active application window or activating another application window.

C 2.4 Activating application windows



Choose the "Window" menu and open it. At the bottom of the submenu you can find a list with the names of the application windows. Choose the name of the application window to be activated.

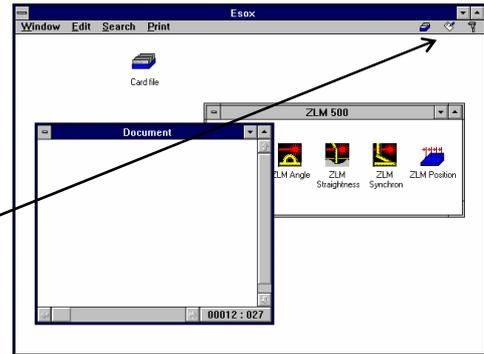


Another possibility is to press the key combination **Ctrl** + or the key combination **Ctrl** + **F6** several times until the respective application window is activated. When all application windows are minimized to an icon, you can activate an application window by pressing the keys , , , and .

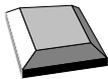


Click the application window you want to activate or use the mouse to choose the "Window" menu; from its pull-down menu select the option with the name of the application window to be activated.

The icons at the right menu border can also be used to activate an application window. Click a menu icon, and the respective application window will be maximized.



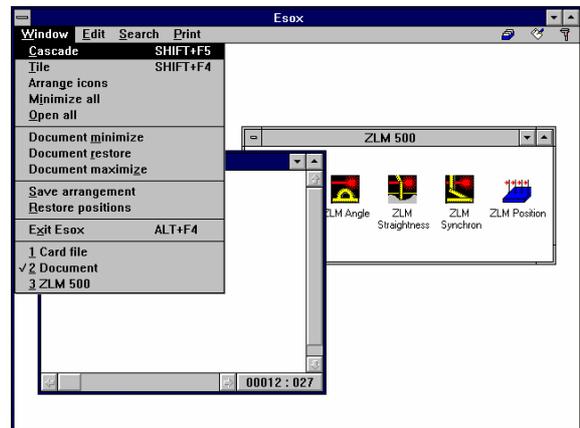
C 2.5 Changing the size of application windows



The "Window" menu contains three sizing options: **minimized, maximized and regular size.**

If the application window to be resized is not active, you must first activate it.

Then choose the "Window" menu and then the desired submenu option.



To open an active application window in minimized (icon) size, simply press the key.

For **resizing a regular size application window:**

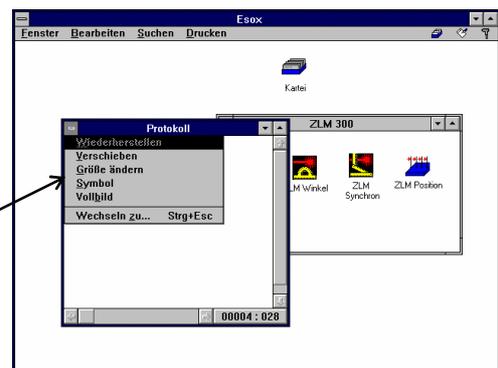
- open the Control Menu of the program window by pressing the key combination + .

- By pressing the keys and you can open the Control Menus of the application windows.

- Open the Control Menu of the application window to be resized.

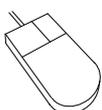
- Choose the menu option "Size".

- Then press the key and the key.



- By pressing the keys , , , and you can now resize the application window.

- Complete the size change by pressing the -key.



Icon ### regular size

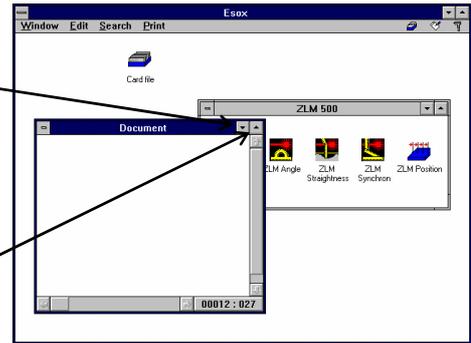
If the icon of the application window is not visible, first activate the application window. Then double-click the icon.

Regular size ### minimized (icon) size

If the  button of the application window is not visible, activate the application window first. Then click the  button.

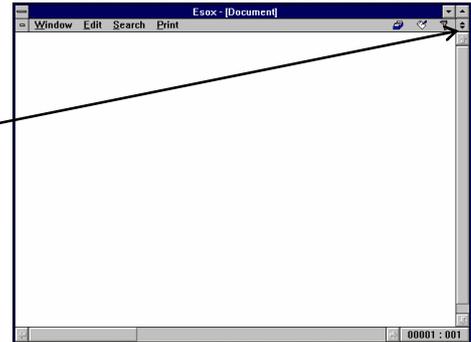
Regular size ### maximized (full-screen) size

If the  button of the application window is not visible, activate the application window first. Then click the  button.



Maximized size ### regular size

Click the  button.



Resizing regular size application windows

Move the mouse cursor to the border of the application window to be resized. The mouse cursor becomes a double-headed arrow. Press the left mouse button and keep it depressed. Now drag the mouse to resize the application window. Then release the mouse button.

C 2.6 Moving application windows

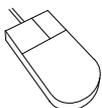
Regular size or minimized application windows can be moved within the work area of the program window.



- The Control Menu of the program window can be opened by pressing the key combination  + .
-
- By pressing the keys  and  you can open the Control Menu of the application window to be moved.
- Choose the menu option "Move".
- To move the application window, press the keys , ,  and .

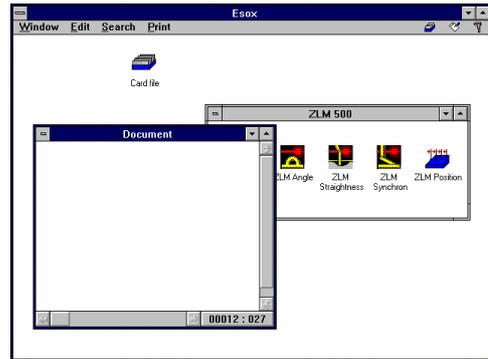


- Complete the movement by pressing the  key.



- With regular size application windows move the mouse pointer to its title bar. With minimized application windows, move the mouse pointer to the icon.

- Press the left mouse button and drag the window or icon to the desired position.
- Then release the mouse button.



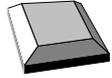
C 2.7 Menu options for arranging several application windows

The "Window" menu contains some options which permit multiple application windows to be arranged at once.

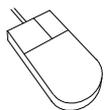
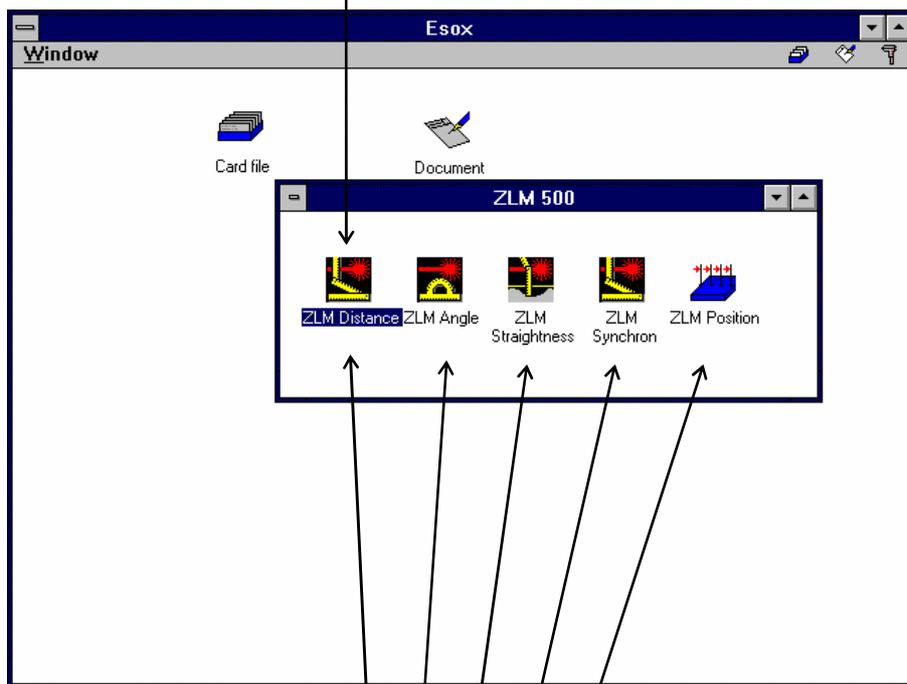
"Window - Cascade"	All regular size application windows are arranged so that the title bar of each application window is visible.
" Window - Tile"	If this option is activated, all application windows that have regular size are shown approximately equally sized in non-overlapping arrangement, filling the available work area of the program window.
" Window - Arrange Icons"	On activating this menu option, icons contained in the active application window are arranged from left to right in one or more rows. In any other case the icons of application windows that were minimized before this option was activated are arranged from left to right in one or more rows.
" Window - Minimize all "	All application windows are minimized to icons.
" Window - Open all "	On activating this option all minimized application windows (icons) are opened to regular or maximized size.
" Window - Save arrangement"	Positions and sizes of all application windows are saved in a file. When the management program is started the next time, the application windows will adopt the stored positions and sizes.
" Window - Restore positions"	The application windows will adopt the positions and sizes saved last by means of the menu option "Save arrangement".

C 3 Starting measurement programs

For each measurement program an icon exists in one of the application windows. The installation program creates a special application window for each measuring instrument. Activate the application window containing the icon of the measurement program to be started. Then customize or maximize this application window.



The program name of one of the program item icons is highlighted. For highlighting and thus choosing the icon of the measurement program to be started, press the keys , ,  or  and then the  key to open it.

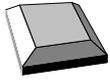


Double-click the icon of the program item to be started.

After the start of the measurement program, all the other program item icons are removed from the application window. Now, the content of the application window is managed by the measurement program. Before another measurement program can be started for the same measuring instrument, the current measurement program must be exited. Consult the section describing the respective measurement program on how to exit it.

C 4 Exiting the management program

Exit the management program "Esox" before switching off the computer to avoid the loss of the contents of the measurement document (record).

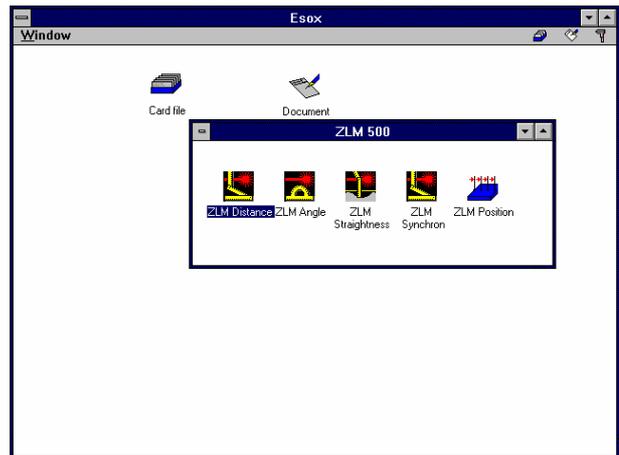


Choose the option "Exit Esox" of the "Window" menu or press the key combination 

+ .



Double-click the Control Menu button  of the program window.



D "ZLM Distance" - Dynamic Measurement Software

With this program module the distance, velocity and acceleration data of a test object can be recorded and analysed.

This section describes the basic measurement procedure, which comprises three steps: **Preparation** (subsection D3), **Measurement** (D4), and **Analysis** (D5).

The **archiving** of measured data and **printing** of results are not part of the "ZLM Distance" measurement program. For these functions, see the "Cardfile" and "Document" program modules described in sections K and L of this manual.

D 1 Starting the "ZLM Distance" program module

When the "Esox" management program is started, the "ZLM Distance" program module is not active yet. To start this program module,

1. activate the "ZLM" application window (as described in detail in Section "C 3 Starting measurement programs") and open it to regular or maximized size.

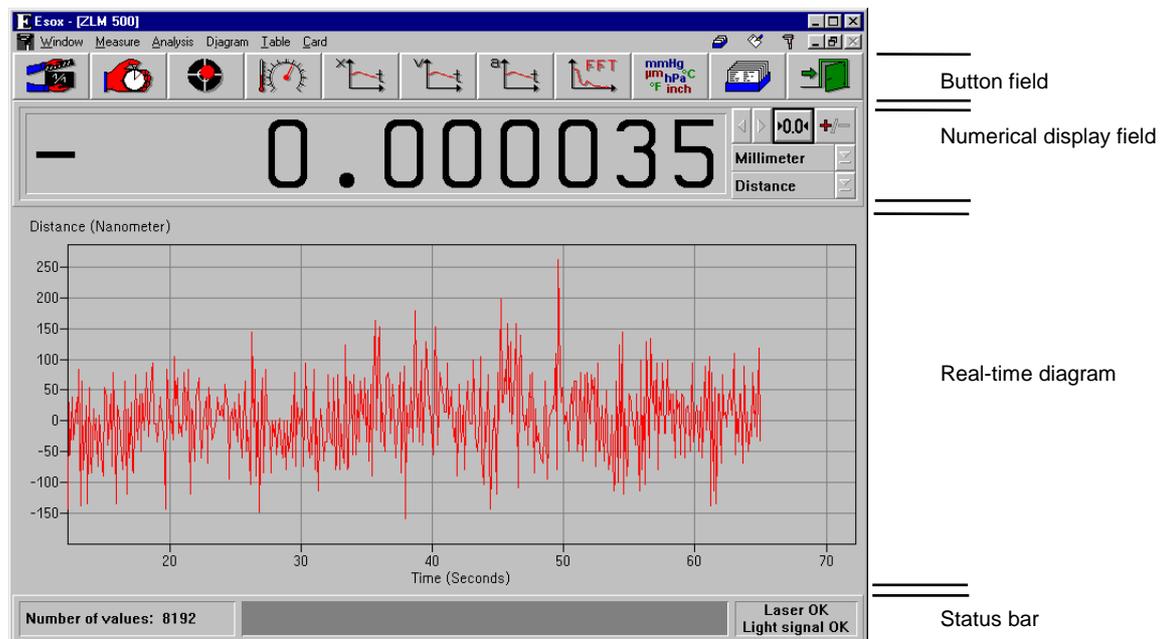
2. Now, either double-click the "ZLM Distance" icon with the mouse or use the keys

, , , or  to activate this icon and then press the  key.

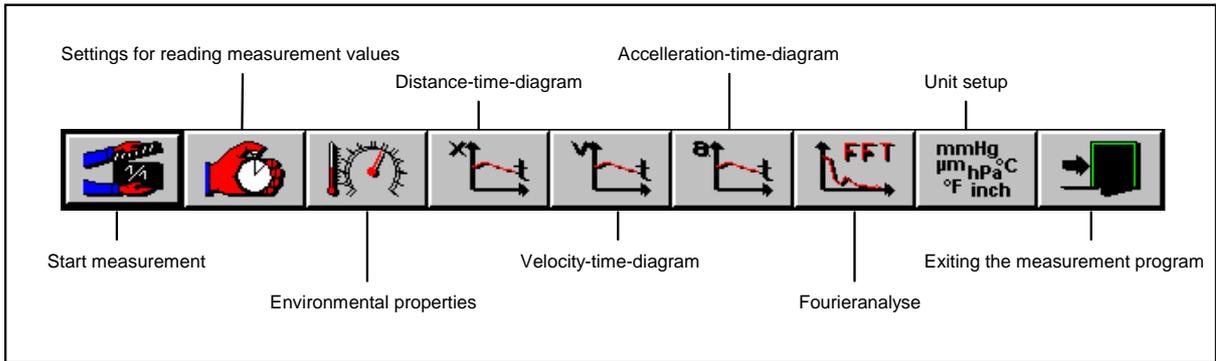
D 2 Elements of the "ZLM Distance" window

If you want to work with the "ZLM Distance" measurement program for a longer time, we recommend to maximize its window after having started it.

Within the window four fields can be distinguished:



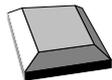
D 2.1 Button field



With these buttons you can activate specific functions of the program, such as start of data recording, setting options for data recording, and data evaluation by diagrams. All these functions can also be started via menu commands. They are explained in detail in the following subsections.



Clicking a button with the mouse activates the function assigned to this button.



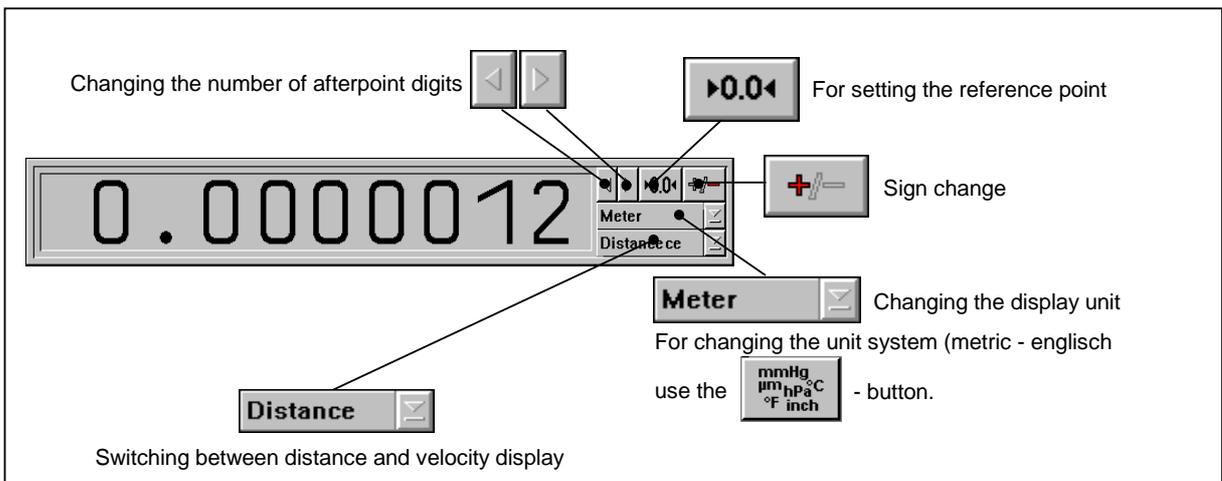
On program start, the first (left) button  is made active as is indicated by the

thicker black frame around it. By pressing the  key you can make the next button active. The function assigned to the active button is released by pressing the  key.

D 2.2 Numerical display field

The numerical display field shows the current distance or velocity. The displayed numerical value is updated 10 times per second unless the computer is overloaded by other tasks.

Several operating elements are located at the right margin of the numerical display field.





The button functions (, ,  or ) are released by clicking the button with the mouse.

To change the active option in a drop-down list box, click on the underlined arrow right of the list box. This opens the list box and allows you to click the desired option.



Press the  key until the wanted list box or button is marked and thus active. Active

buttons are displayed with a thicker black frame around the button (, ,  or

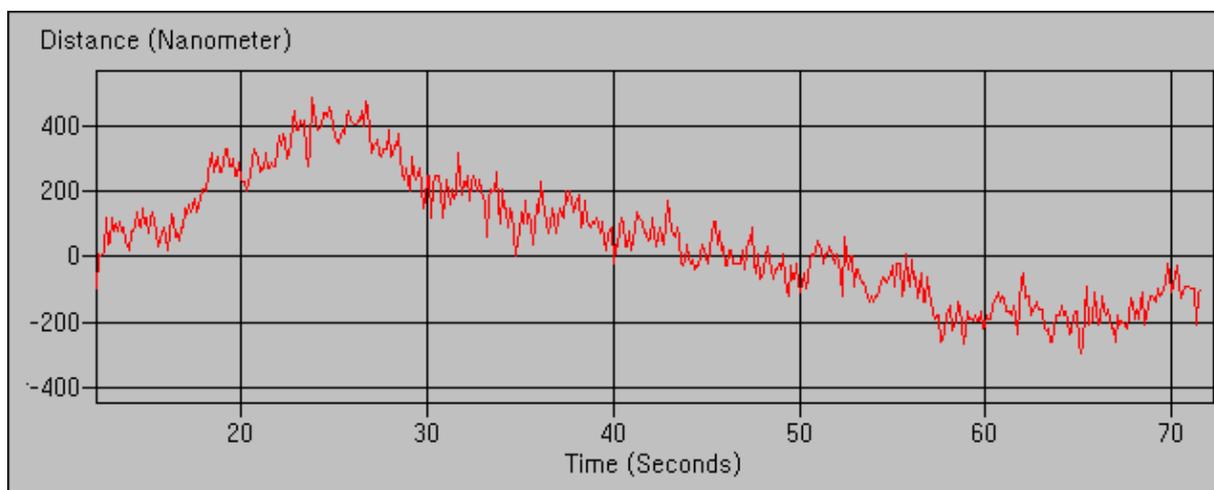
). Active list boxes are marked by highlighted entries. To open the pull-down list,

press the key combination **Alt** + . By pressing the  or  keys you can choose

the wanted option. To confirm your choice, press the  key.

To release a button function, press the  key.

D 2.3 Real-time diagram



The real-time diagram presents the distance as a function of time for the last 60 seconds approximately. The current distance value is added 10 times per second unless the computer is overloaded by other tasks. The scale graduation is automatically determined from the measured data, so you need not preselect it.

Any change of the sign with the  button has an effect also on the measured data recorded before and is reflected by the diagram.

D 2.4 Status line



At the left end of the status line you will see the number of measured data currently stored in the memory (This figure refers to the number of permanently stored data, not to those of the real-time diagram). In the middle of the status line you can find a bar that indicates how many of the preselected number of readings have currently been taken. At the right end of the status line there is a field telling you whether the laser is stabilized or not. With program functions taking a longer time, such as measurements or fast Fourier transformation, the appearance of the status line changes as will be described in detail in the respective sections of this manual.

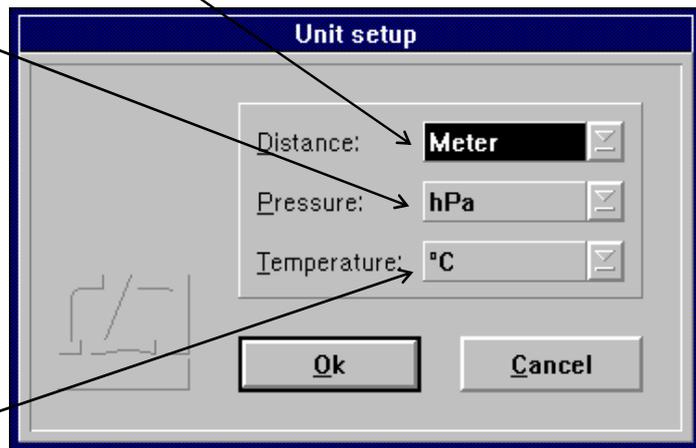
D 2.5 Unit systems

Units of distance, atmospheric pressure and temperature can be selected in the "Unit setup" dialogue box.

Open this box by clicking the  button or selecting the "Units" option of the "Measure" menu.

The program can show distances and quantities derived from them in either metric (metre) or imperial (Inch) measure. Switch between them in the "Distance" list box.

In the "Pressure" list box you can select between "Hectopascal" and "Millimetre mercury".
(1000 hPa = 100 kPa = 1000 mbar,
and
1 mmHg = 1 torr)



In the "Temperature" list box you can select between "Degree Celsius" and "Degree Fahrenheit".

If you selected a metric or imperial unit for the numerical display of the current reading, the same unit will also be used for the diagrams.

D 3 Preparation for a measurement

The data displayed numerically and in the real-time diagram will not be saved permanently, nor can they be analysed any further. Analysable data will only be read in and stored upon a specific command.

Whenever mention is made below of the acquisition or recording of measurement data (readings), this means the acquisition of data to be permanently saved.

In preparation for a measurement you need to specify

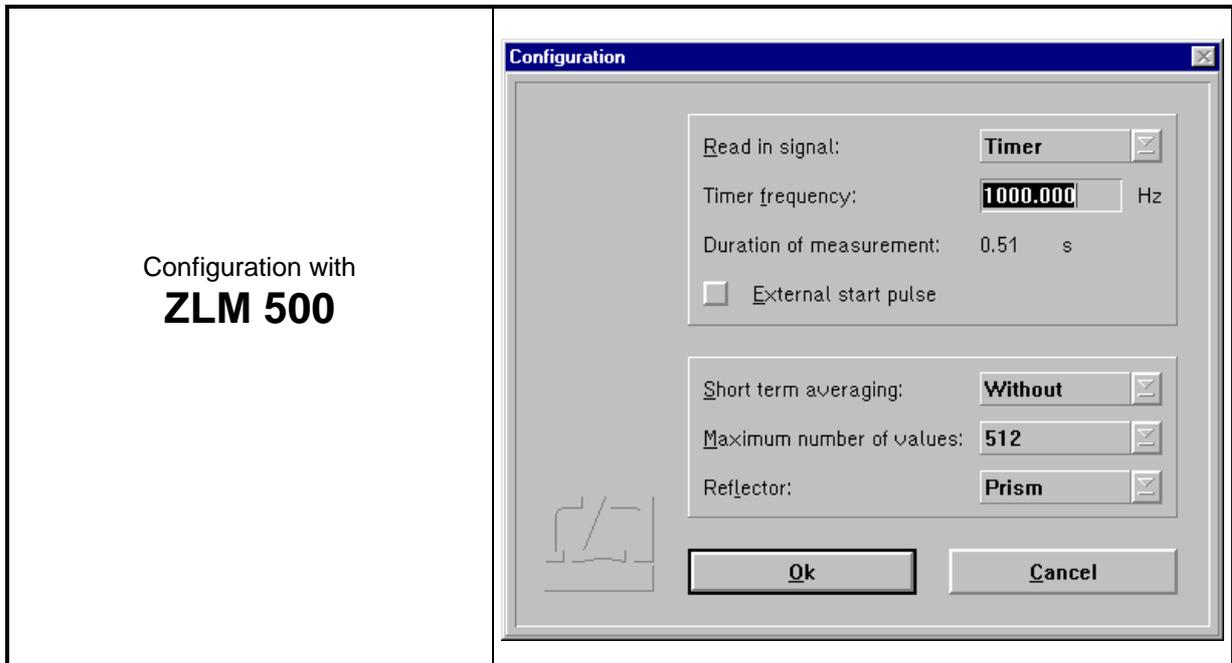
- the time at which the readings are to be taken,
- the type of interferometer used,
- the maximum number of readings to be taken, and
- the required mode of compensation for environmental influences.

For this purpose, use the "Configuration" and "Environment" dialogue boxes.

D 3.1 Parameter setting for measurement data acquisition

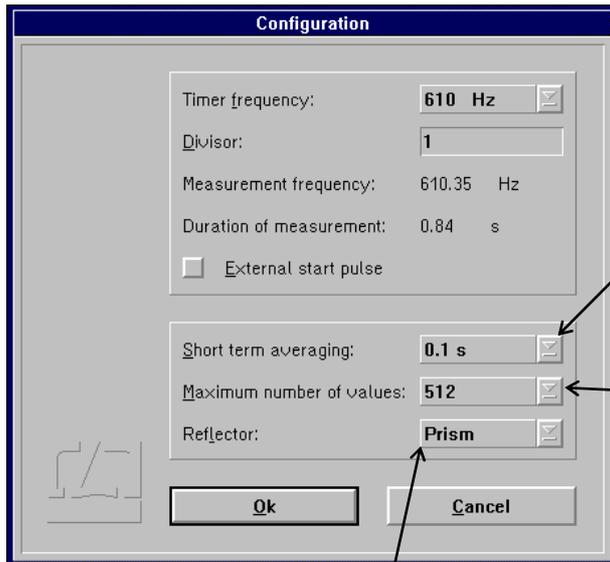
Access the "Configuration" dialogue box by opening the "Measure" menu and choosing the "Configuration" option or by clicking the  button.

Select the times for data reading in the top part of the dialogue box. You need to choose between three possible trigger sources for data reading.



Configuration with
ZLM 500

<p>Triggering by the timer</p>	<p>In the drop-down list box "Read-in signal" select the "Timer" entry. In the "Timer frequency" dialogue box enter the desired frequency of readings. The button "External start pulse" determines which event is to trigger the measurement.</p> <p>When this <input type="checkbox"/> button is not checked:</p> <p>The measurement is started by activating the "Measure" menu and choosing the menu option "Start measurement" or by clicking the  button.</p> <p><input checked="" type="checkbox"/> button is checked:</p> <p>The measurement is started by an external trigger pulse connected to the respective input. Annex I shows where the respective external signal lead must be connected to.</p>
<p>Triggering by an external read-in signal</p>	<p>In the drop-down list box "Read-in signal" select the "External" entry. Annex I shows where the external signal lead must be connected to.</p> <p>The "External start pulse" button has no function in this mode.</p>
<p>Triggering by pressing the  of the keyboard</p>	<p>For this mode open the drop-down list box "Timer frequency" and choose the option "Space bar".</p> <p>The "Divisor" and "External start pulse" settings will be ignored by the program in the measurement.</p>



In static measurements, the program can filter out vibrations by time averaging. The time over which an average is to be obtained can be set in the "**Short term averaging**" list box. In dynamic measurements, however, use the entry "**without**".

The pull-down list box "**Maximum number of values**" displays the number of measured values to be read before the software stops a measurement automatically. Of course, you can stop a measurement by command at any time before this number of values has been reached. Section "D 4.3 Cancelling the measurement" contains detailed information on this topic. The options, i.e. the numbers of readings listed in the pull-down list box "Maximum number of values", allow Fourier analysis to be carried out as efficiently as possible.

In the pull-down list box "**Reflector**" choose the interferometer type used. With cube corner reflector interferometers, choose the option "**Prism**", and with plane mirror interferometers choose the option "**Mirror**". The **Manual on the basic equipment** describes the design of these interferometers and their properties.

D 3.2 Compensation of environmental influences

The accuracy of a distance measurement made with a laser interferometer depends on whether the refractive index of the ambient air is known and allowed for. The ZLM Distance program can compute the refractive index from properties of the atmospheric environment and correct the measurements accordingly.

The ZLM Distance software can further allow for the thermal expansion of the test object as a function of its temperature, and correct the measured data so that they represent the readings that would have been obtained with the test object having a temperature of 20 °C.

The necessary settings can be made in the "**Environment**" dialogue box.

This is accessible by opening the "**Measure**" menu and choosing the "**Environment**" option, or by

clicking the  button.

All the settings made in this box have an effect both on the taking of readings as well as on the numerical display and the real-time diagram.

D 3.2.1 Atmospheric properties

In the top part of the "Environment" dialogue box you can choose how to compensate for the effects of atmospheric properties on the refractive index and thus on the measured result.

Manual Correction Choose the "**Manual**" option of the pull-down list box "**Correction type**". You will have to enter the atmospheric properties in the respective text boxes.



Keys that facilitate inputs:

Coarse setting - and

Fine setting - and



1. Move the mouse pointer to the field where you want to make an entry.
2. Press the left mouse button and keep it depressed.
3. Drag the mouse until the thermometer column or the pointer indicates the desired value.
4. Release the mouse button.

Consult Annex III for information about the accuracy required for the measurement and entry of atmospheric properties.

Automatic Correction When you use the AUK 500 Automatic Environment Detector to measure the atmospheric properties, choose the option "**Automatic**" of the pull-down list box "**Correction type**".

The screenshot shows the "Environment" dialog box with the following details:

- Properties of air:**
 - Correction type: **Automatic**
 - Temperature: 22.1 °C
 - Pressure: 985 hPa
 - Humidity: 49%
- Expansion:**
 - Correction type: **Automatic**
 - Coefficient of expansion: 11.0 $\times 10^{-6} \text{K}^{-1}$
 - Expansion 1: 22.7 °C
 - Expansion 2: 22.3 °C
 - Expansion 3: 22.7 °C
 - Expansion 4: --- °C
 - Expansion 5: --- °C

D 3.2.2 Material temperature

In the bottom part of the "Environment" dialogue box you can choose whether and how the measured values are to be corrected for thermal expansion (material temperature). With correction activated, the readings are converted into readings that would be obtained at a material temperature of 20 °C.

Without correction If you want to work without this correction, choose the option "**None**" of the pull-down list box "**Correction type**".

Manual correction If you want to enter the material temperature manually, choose the option "**Manual**" of the pull-down list box "**Correction type**".

In the text box "**Coefficient of expansion**" type in the linear expansion coefficient of the test object.

The material temperature can be entered in the same way as the manual entry of atmospheric temperature (see Section "D 3.2.1 Atmospheric properties").

Automatic correction If you want to use the AUK 500 Automatic Environment Detector for compensating the errors due to material expansion, choose the option "**Automatic**" of the pull-down list box "**Correction type**".

In the temperature display boxes, temperature sensors that are not connected are indicated by "---". In the figure, material temperature sensors 4 and 5 are not connected.

You have the possibility to select from the available sensors those you want to use for the correction. For this purpose, every temperature display field has a button at the top left.

Button is not checked:

The respective material temperature sensor is excluded from correction and - on colour screens - the temperature value is displayed in grey instead of in black colour. In the figure, material temperature sensors 2 and 5 are not included in the correction of material expansion.

Button is checked:

The sensor reading enters the correction if the sensor is connected.

With automatic correction activated, the program reads the data of the material temperature sensors once per second. The program computes the mean value of all the measured values of the sensors that are connected and activated via the respective button of the display field. This value is used by the program to correct the data for material expansion.

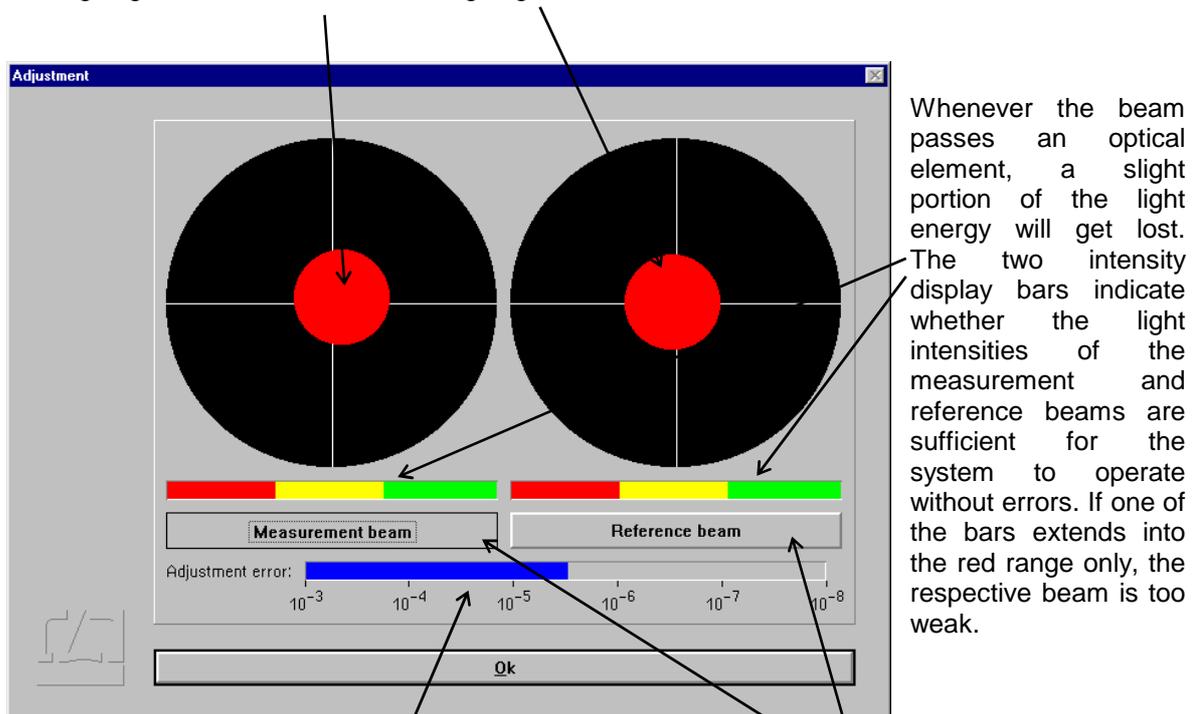
If none of the sensors is connected and activated, the measured values are not corrected. In the example shown in the figure, the mean value of the temperatures detected by sensors 1 and 3 is used for the correction. Sensors 4 and 5 are not connected. Sensor 2 is deactivated.

D 3.3 Laser aligning aid

The laser head of the ZLM 500 contains two quadrant detectors. This feature allows alignments to be made and aligning errors to be estimated even over great distances.

Click the  button to open the "Alignment" window.

The upper two fields in this window indicate the positions of the re-entering measurement and reference beams. In a standard setup, the left-hand figure represents the measurement beam, and the right-hand one the reference beam. When aligning the laser, try to keep the two red spots at the centres of the crosshairs throughout the distance travelled. See the Basic Equipment manual for the aligning elements to be used for aligning the laser head.



When the measuring reflector is moved, the program can compute the alignment error from the change in position of the returning beam portions and the distance travelled. An alignment error of $1 \cdot 10^{-6}$ means that misalignment between the laser beam and the travelling path causes a measurement error of $1 \mu\text{m}$ per 1 m of distance. This alignment error is allowed for and displayed at every reversal of the travelling direction. In order to obtain highly reliable information on alignment, move the measuring reflector back and forth several times without keeping it at prolonged standstills between the strokes.

The ZLM 500 Laser Interferometer operates at two different wavelengths. In precise measurements ($< 1.4 \mu\text{m/m}$), you need to tell the program which beam is used as the measurement beam. To do so, simply intercept the measurement beam with your hand, so that one of the two red spots disappears from the screen. Click on the button on the respective side so that it reads "Measurement beam". With a standard optical arrangement, the measurement beam is invariably shown on the left side.

D 4 Measurement procedure

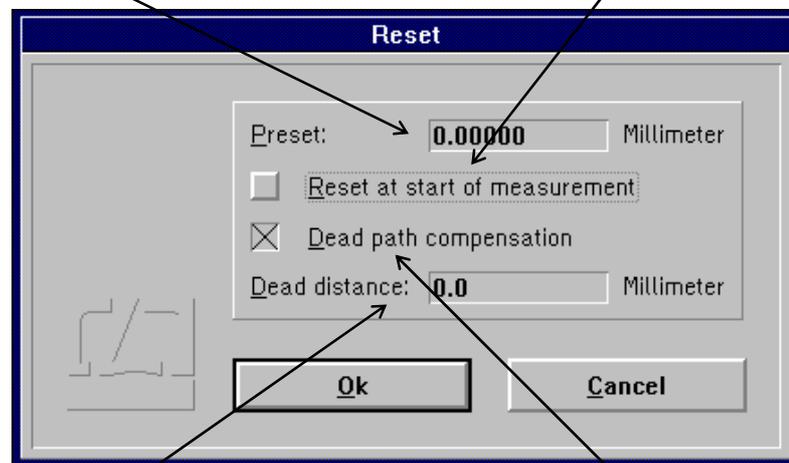
The ZLM 500 Laser Distance Measuring System is a "relative" measuring system. A defined position of the test object is assigned a certain distance value. The measured values are read and indicated relative to this position. Therefore, this reference point must be set before any measurement is taken.

D 4.1 Setting the reference point and specifying the dead distance

For setting the reference point, move the test object to the reference position. Then either activate the  button or choose the "Reset" option of the "Measure" menu. The screen displays the "Reset" dialogue box.

In the "**Preset**" text box you can preset the distance value to be assigned to the present position.

If the button "**Reset at start of measurement**" is on , the preset value will be assigned to the instantaneous position at the time you start a measurement.



In the "**Dead distance**" box you can enter the distance between the reflectors. See Annex III for a detailed explanation of the term "dead distance".

The dead distance is of significance only in high-accuracy measurements with the environmental properties changing during the measurement. If you specify a dead distance, mind the correct sign. Specify the dead distance so that, after resetting, the sum of measurement readout and dead distance has always the same amount as the distance between the two reflectors.

If it can be assumed that the environmental conditions will not change during a measurement, the "**Dead path compensation**" button can be switched off ().

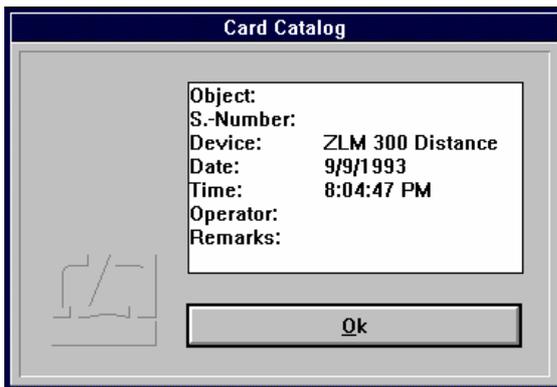
The reference point is only assigned when the  button is activated.

D 4.2 Starting the measurement

You can start a measurement by opening the "Measure" menu and choosing the "Start measure" option or by clicking the  button. While the measurement is running, the status bar indicates the number of readings currently taken. The display of laser stability at the right end of the status bar is replaced by the  button. This button is active, as indicated by its black frame, so that the measurement can be stopped immediately by clicking this button with the mouse, or by pressing the -key.

In the case of measurements over longer periods, you can switch to other program modules or run other MS-Windows programs.

After a successful measurement, the measured values are saved on a card of the card file. For this purpose, a dialogue box "Card Catalog" is displayed, containing already entries for the measuring instrument used and the date and time of the start of the measurement. You can type in the remaining items via the keyboard.



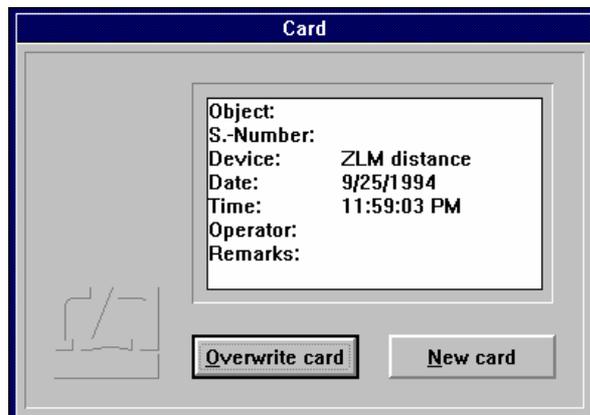
Annex II contains the list of special function keys and key combinations for typing in text boxes.

Additionally, the following keys can be used:

-  -moves the text cursor to the next entry of the file card in the same line.
-  -moves the text cursor down to the next entry of the file card.
-  -moves the text cursor up to the previous entry of the file card.

On clicking the  button, the file card is created. Filing of file cards is handled by the "Cardfile" program module (see Section K).

If a card already exists in the main memory, the program provides the possibility to overwrite this card with new measured values.



D 4.3 Cancelling a measurement

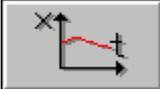
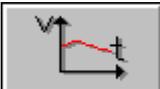
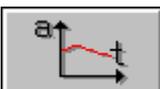
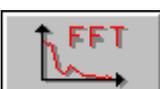
In the following cases the program cancels the measurement before all readings have been taken:

- The laser is unstable or becomes unstable while the measurement is running.
- The light power at the receiver is too low or becomes too low while the measurement is running.
- You have cancelled the measurement by clicking the  button.

You have the option of saving the readings taken until the moment of cancelling the measurement.

D 5 Analysis of a measurement

The measurement is analysed in the form of diagrams. Four different types of diagrams can be created. For every diagram type a button is available in the button field at the top margin of the window. In addition, corresponding menu options are accessible via the "Analysis" menu.

Type of diagram	Activation
Distance-vs.-time diagram	 button or "x-t diagram" option of "Analysis" menu
Velocity-vs.-time diagram	 button or "v-t diagram" option of "Analysis" menu
Acceleration-vs.-time diagram	 button or "a-t diagram" option of "Analysis" menu
Fourier analysis (amplitude-vs.-frequency diagram)	 button or "Fourier analysis" option of "Analysis" menu

If measurement data acquisition is triggered by external read-in signals or by pressing the keyboard's , the program cannot assign a time to the individual readings. Therefore, on the abscissa of the diagrams the point number is plotted in place of the time and - with Fourier analysis - the unit "per point number" in place of frequency.

D 5.1 Controls for diagram handling

After calling a diagram the measurement program window is completely changed. Abscissa and ordinate are scaled automatically by the program.

The options include zooming of defined sections of the diagram, marking of points on the diagram to display the individual measured values numerically, and plotting of new diagrams from sections of the "mother" diagram. With the option buttons at the top left you can choose the action to be taken next

The buttons allow

the indication of statistical data,

the opening of a table of measured data,

the transfer of diagram and table into a record, and

quitting the diagram presentation.

With the scroll bars the visible diagram section can be moved.

To move from one button to the next, press the  key.

In addition to these controls, you can also use some submenu items of the "Diagram" and "Table" main menus.

D 5.2 Zooming of diagram sections

The option button "**Zoom**" or the "**Zoom mode**" option of the "**Diagram**" menu permits a section of the diagram to be magnified for viewing more details.



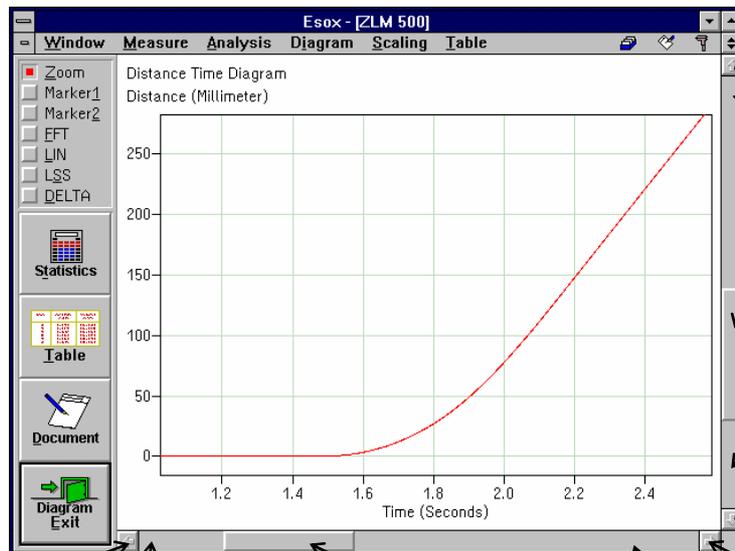
Move the mouse cursor to a corner of the section of the diagram you want to magnify. Press the left mouse button and keep it depressed. Move the mouse until the movable frame encloses the diagram section of interest. Release the mouse button. After pressing the **right mouse button** the full diagram is displayed again.



	Expansion by factor 2	Contraction by factor 2
horizontally	Ctrl +	Ctrl +
vertically	Ctrl +	Ctrl +

D 5.3 Scrolling

From the scroll bars on the right and at the bottom of the window you can see which segment of the diagram is displayed. Shifting of the visible segment is always possible regardless of which option button is active.



To scroll **up** by 10%.

To scroll **up** by one windowful.

To scroll **to any desired position vertically**: Click and hold the left mouse button. Drag the mouse until the square is in the wanted position.

To scroll **down** by one windowful.

To scroll **down** by 10%.

To scroll **to the left** by 10%.

To scroll **to the left** by one windowful.

To scroll **to any desired position horizontally**: Click and hold the left mouse button. Drag the mouse until the square is in the wanted position.

To scroll **to the right** by one windowful.

To scroll **to the right** by 10%.



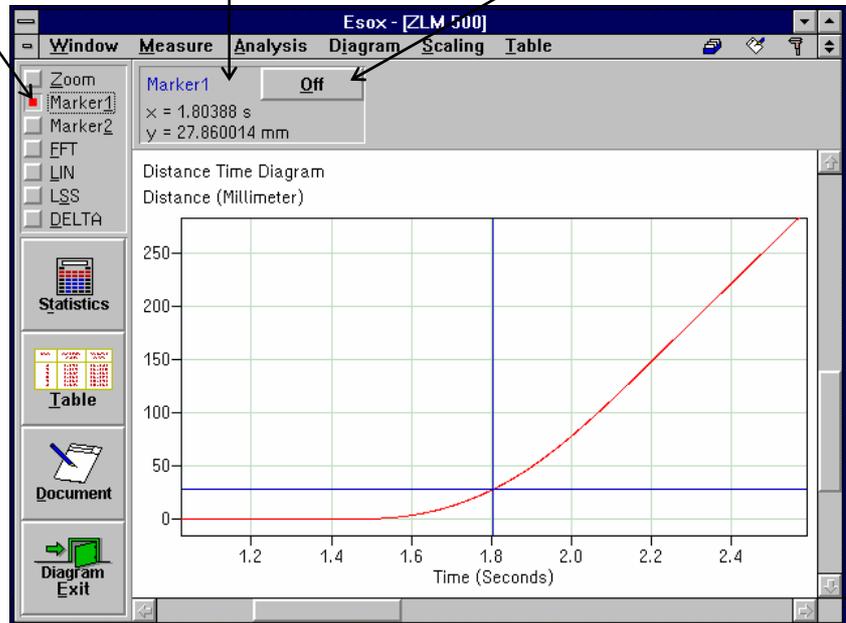
Scrolling	to the right	to the left	up	down
by 10%	+	+	+	+
by one windowful	Ctrl + PgUp	Ctrl + PgDn	PgUp	PgDn

D 5.4 Marker cross-hairs

On activating the "Marker 1" option button or "Diagram - Mode Marker1" menu option a marker cross-hair appears in the diagram.

In this field the measured value will be numerically displayed.

By clicking the button the marker cross-hair can be removed from the screen.



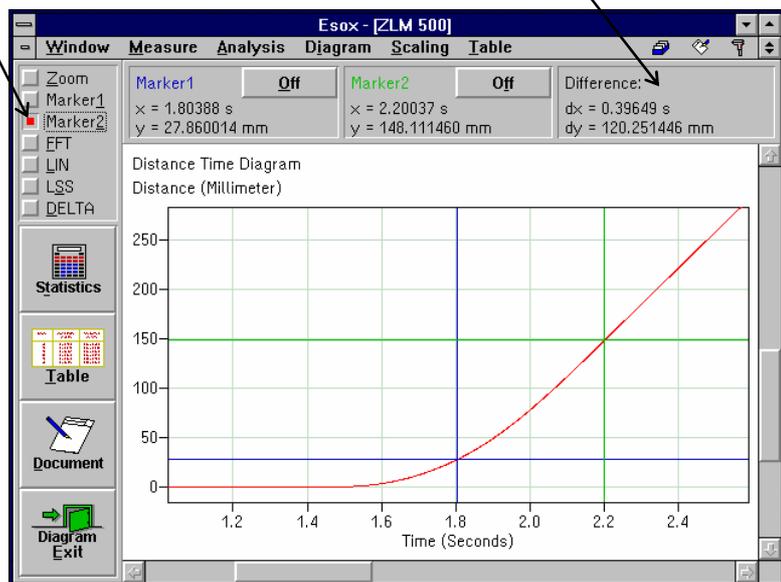
With a mouse click on a point in the diagram, the vertical line of the cross-hair is moved to this point. The horizontal line of the cross-hair is positioned according to the value measured at this position. That value appears in the numerical display field.



You can move the marker cross-hair with the and keys.

The option button "Marker2" or the menu option "Mode Marker2" permits a second marker cross-hair to be displayed. It is handled in the same way as the first marker cross-hair.

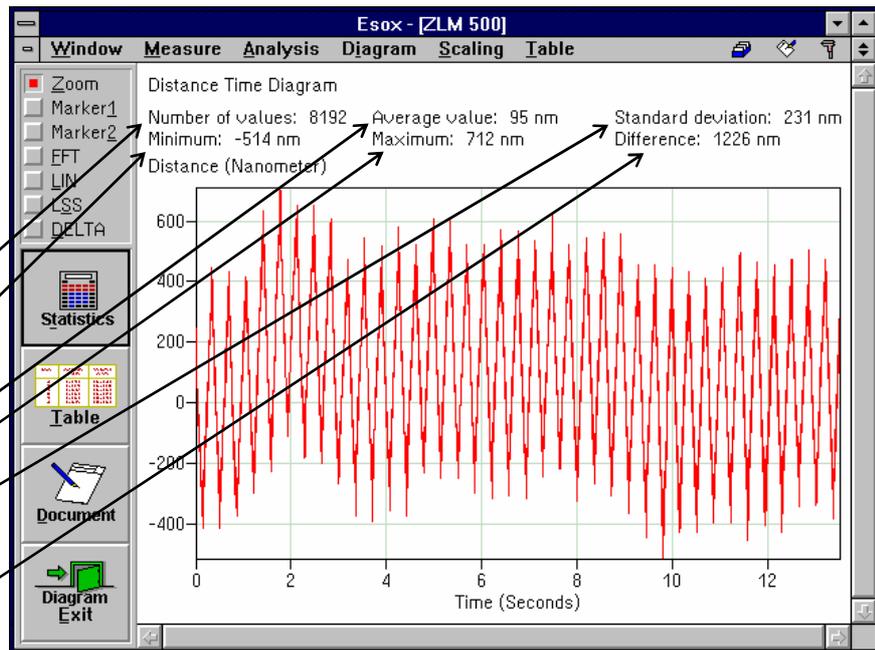
When both marker cross-hairs are active, the difference between the measured values marked by the cross-hairs is displayed.



D 5.5 Statistics

Activation of the "Statistics" button or the "Statistics" option of the "Diagram" menu displays

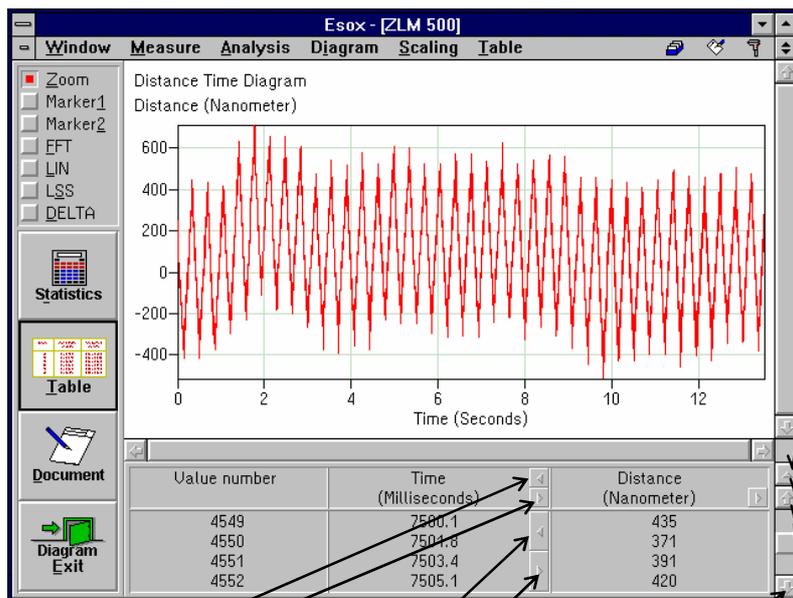
- the number of readings
- the minimum reading
- the mean value
- the maximum reading
- the standard deviation
- and the maximum-to-minimum variation.



All these data is calculated from the currently visible diagram segment. When you move the diagram, the data are recalculated for the new diagram segment and displayed accordingly. The clicked button will lock. Click it again to remove the display of mean value and standard deviation.

D 5.6 Tables

By clicking the "Table" button while a diagram is displayed, a table with the measured data can be displayed in addition. The clicked button will lock. Click it again to remove the table.



Button for maximizing the table

To scroll up by one line.

To scroll up by one windowful.

To scroll to any desired position vertically:

Click and hold the left mouse button. Drag the mouse until the box is in the wanted position.

Switch buttons for unit to be displayed.

Switch button for number of decimal places.

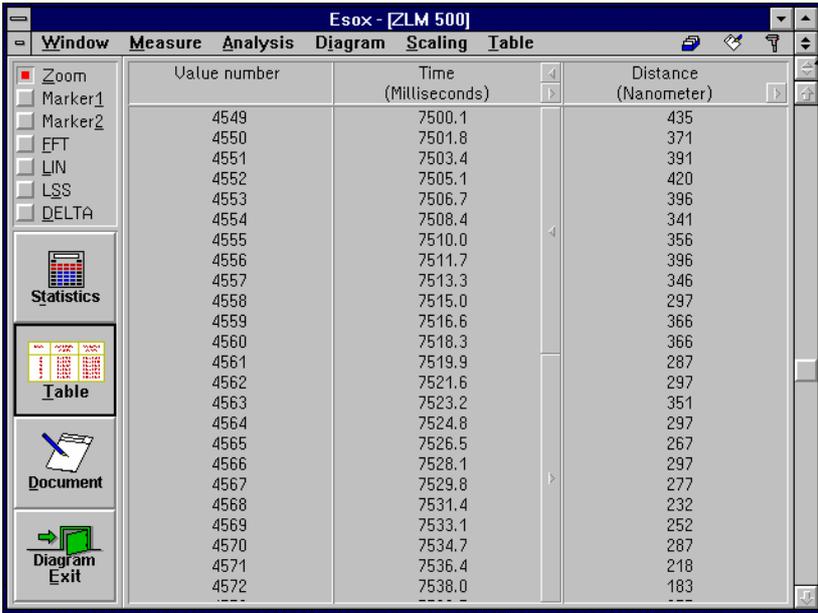
To scroll down by one line.

To scroll down by one windowful.

The table may occupy either the bottom right section or almost all of the program window. In the second case, the diagram is hidden behind the table. For switching between normal-size and full-window presentation of the table, click the button at the top right table margin.

The functions described above are accessible with the keyboard as well, if you select, in the **"Table"** menu, the options

- ### "No table",
- ### "Small table" or
- ### "Big table"



Value number	Time (Milliseconds)	Distance (Nanometer)
4549	7500.1	435
4550	7501.8	371
4551	7503.4	391
4552	7505.1	420
4553	7506.7	396
4554	7508.4	341
4555	7510.0	356
4556	7511.7	396
4557	7513.3	346
4558	7515.0	297
4559	7516.6	366
4560	7518.3	366
4561	7519.9	287
4562	7521.6	297
4563	7523.2	351
4564	7524.8	297
4565	7526.5	267
4566	7528.1	297
4567	7529.8	277
4568	7531.4	232
4569	7533.1	252
4570	7534.7	287
4571	7536.4	218
4572	7538.0	183

Button for switching back to normal-size presentation of the table



The visible segment of the table can be shifted by means of the vertical scroll bar at the right margin of the table.



shifts the visible table segment up by one line.



shifts the visible table segment down by one line.



shifts the visible table segment so that the first line is displayed.



shifts the visible table segment so that the last line is displayed.



shifts a full-screen table segment up by so many lines as there are lines visible.



shifts a full-screen table segment down by so many lines as there are lines visible.

D 5.7 Compiling a record (document)

The "Document" part of the program serves for printing the record and for compiling the record contents. It is there that the arranging of the record contents and the printing of the record are carried out, rather than in the measuring program. Diagrams, tables and statistical data can be transferred from the measuring program to the "Document" program module. For further information on the "Document" program module, see section "L - Program module "Document"".

Click the  button or call the "Prepare document" option of the "Diagram" menu to display the "Prepare document" dialogue box.

If the "Diagram" switch is activated () , the diagram displayed on the screen immediately before the "Prepare document" dialogue box was called is transferred to the "Document" program module.

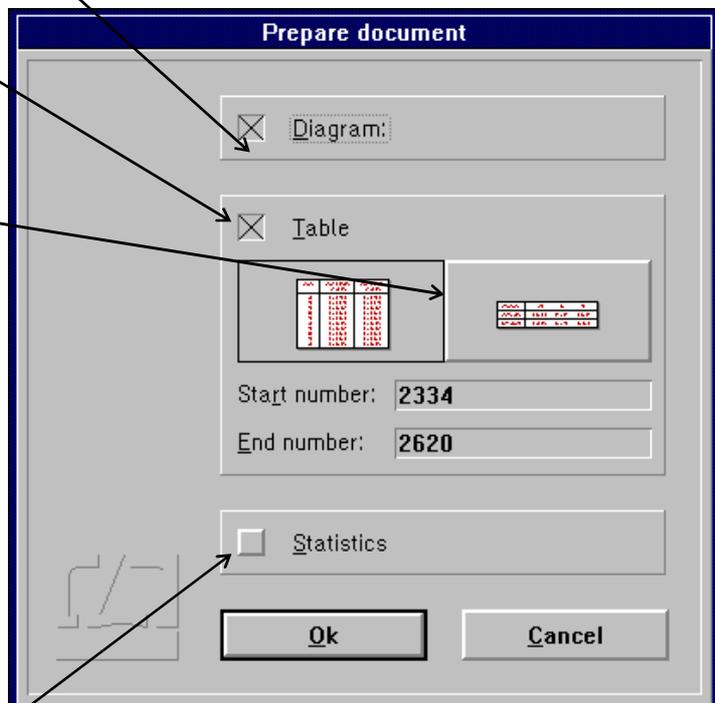
If the "Table" switch is activated, the buttons



can be clicked to select between horizontal and vertical arrangement of measured data in the table.

In case of horizontal arrangement, the table is split up and transferred to the "Document" program module in the form of several tables if all the measured data do not fit into one line. When recording a table, please mind that a printed text page has about 60 lines. If a great number of readings have been taken, you should select which of them to be transferred into a table. For this you can use the "Start number" and "End number" input boxes.

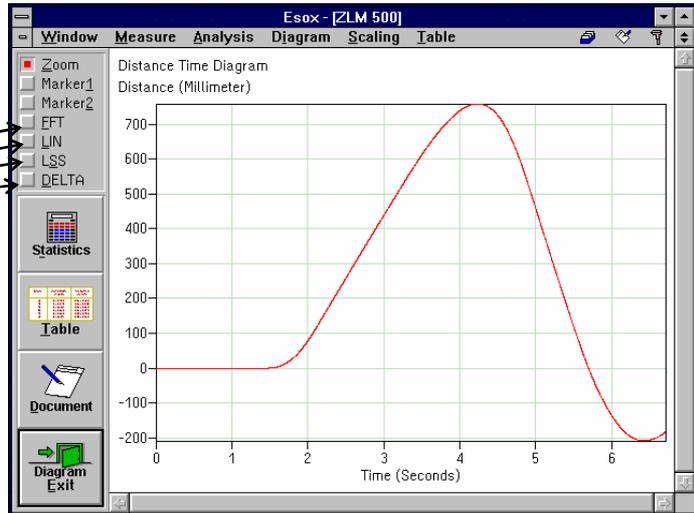
If the number of measured data between the first and last readings entered exceeds 1000, the program will restrict the table to 1000 readings.



Click the "Statistics" switch to transfer to the "Document" program module the number of readings, the mean value, the standard deviation, the maximum reading, the minimum reading and the maximum-to-minimum variation of the readings that were visible in the diagram immediately before the "Prepare document" dialogue box was called.

D 5.8 Fourier analysis, least squares line, and deviation from nominal positions

With some diagrams, further analyses are possible for part of the measured data, i.e. a segment of the diagram. These functions are also accessible via option buttons. Selection of the diagram section is only possible with the mouse.

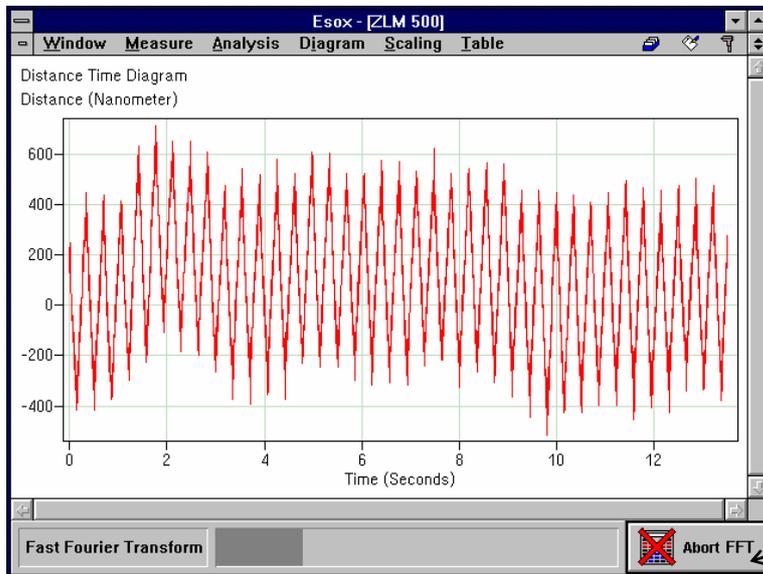


Move the mouse cursor to a corner of the diagram segment to be further analysed. Click and hold the left mouse button. Then drag the mouse until the movable frame encloses the diagram segment of interest. Release the left mouse button.

The functions released by the option buttons after selection of the diagram segment are explained in the sections below.

D 5.8.1 Fourier analysis

With an active "FFT" option button or "Fourier analysis mode" option of the "Diagram" menu, a Fourier analysis is carried out for the diagram segment selected.



Since Fourier analysis takes a longer time with a greater number of measured data, a status bar with an abort button is displayed at the bottom of the window.

While the fast Fourier transformation is running, you can switch to another program module or another Windows program.

D 5.8.2 Linear deviation

With an active "LIN" option button or "Linear deviation mode" option of the "Diagram" menu, a diagram is generated showing the distance deviation from a straight line with preselected ascent (gradient).

Enter the ascent into the dialogue box.

Use the "Centre diagram" button to define whether

- the amount of the first reading is to be maintained or
- the absolute term of the straight line is to be determined by the program so that the maximum and the minimum of the calculated deviation have the same amount but different signs

Use these radio buttons for selecting the kind of diagram required, i.e. distance deviation-vs.-time, distance deviation-vs.-expected distance, or distance deviation-vs.-measured distance.

D 5.8.3 Deviation from least squares line

With an active "LSS" option button or "Least square straight mode" option of the "Diagram" menu a diagram is generated with a distance deviation from a straight line with preselected ascent.

D 5.8.4 Deviation from nominal positions ("expected values")

With an active "DELTA" option button or "Expect. value deviation mode" option of the "Diagram" menu it is possible to generate diagrams showing the deviation from nominal positions. These need not be equidistant from each other. But if they are, the "Deviation from linear ascent" mode (see D 5.8.2 Linear deviation) will produce the same effect faster.

Use the mouse to select the data to be processed. The screen will then display the "Deviation from expected values" dialog box.

Key in the nominal positions in the "Expected distance" column. Use the  and  keys to move from one nominal input field to that for the next or previous measurement reading.

The last column of the table indicates the result of the nominal-actual comparison.

If you have selected more than ten readings, use the vertical scroll bar to the right of the table to scroll the visible table segment.

Value number	Time (Seconds)	Expected distance (Nanometer)	Measured distance (Nanometer)	Distance deviation (Nanometer)
2375	3.91496	0	297	297
2376	3.91661	0	391	391
2377	3.91826	0	415	415
2378	3.91991	0	316	316
2379	3.92156	0	336	336
2380	3.92321	0	371	371
2381	3.92486	0	326	326
2382	3.92651	0	307	307
2383	3.92816	0	331	331
2384	3.92981	0	321	321

Distance deviation time diagram
 Distance deviation expectation diagram
 Distance deviation measured diagram

Ok Automatic Const. Dev. Cancel

Use the radio buttons to select the kind of diagram required.

In special cases the expected (i.e. nominal or desired) positions can be calculated by the computer after activating the "Automatic" button.

Click the "Const. Dist." button to easily generate equidistant nominal positions.

Use the "Const. Dist." button to generate equidistant nominal positions for selected successive readings. In the dialog box you can specify "Start value", "Distance", "First value number" and "Last value number".

Equidistant expected values

Start value: nm

Distance: nm

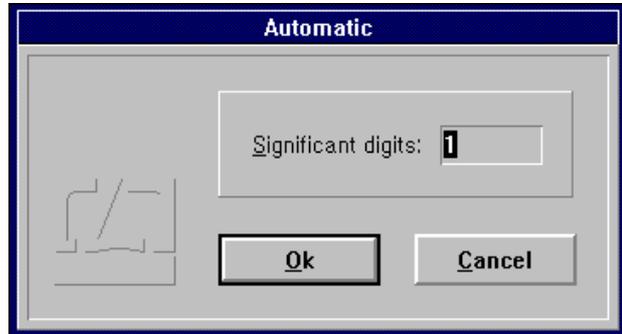
First value number:

Last value number:

Ok Cancel

By clicking the **Automatic** button you can effect calculation of the nominal positions from the measured data by rounding off to a preset number of decimal places. Clicking the button will call the "Automatic" dialog box.

After you press the **Ok** button in this dialog box, the program will identify the reading that has the greatest absolute amount. The reading will be rounded to as many decimal places as you have preset in this dialog box. All other measured data will be rounded to the same number of places.



Example: The following readings have been taken:

Number of reading	Distance (millimetres)
1	0.0000
2	100.0082
3	250.0125
4	800.0853
5	1200.1734

If you preset "Significant digits: 2", rounding is effected to 100 mm (the reading having the greatest absolute amount is 1200.1734 mm), and you obtain the following nominal positions:

Number of reading	Nominal position (mm)	Deviation (mm)
1	0	0.0000
2	100	0.0082
3	300	-49.9875
4	800	0.0853
5	1200	0.1734

The desired result is only obtained if you preset "Significant digits: 3" or "Significant digits: 4":

Number of reading	Nominal position (mm)	Deviation (mm)
1	0	0.0000
2	100	0.0082
3	250	0.0125
4	800	0.0853
5	1200	0.1734

D 5.9 Evaluation of previous measurements

After the measurement a file card is created containing the measurement results. These cards are managed by the program module "Cardfile". In this program module you can load the card of an earlier measurement as current card. The measurement program is informed about this and will load the measured values assigned to this card automatically. Now you can start evaluating the measured values of this previous measurement. The program module "Cardfile" is described in detail in Section „J Program module „Cardfile““.

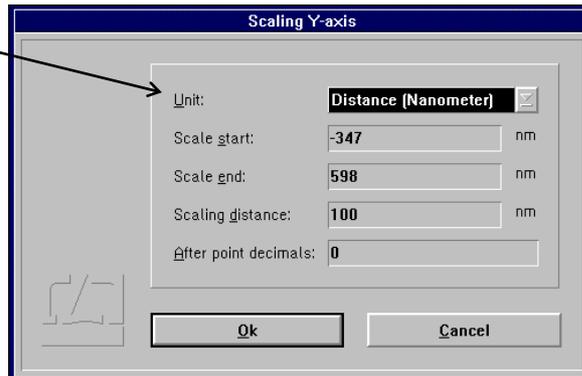
D 5.10 Changing the scaling of diagram axes

The program has an automatic algorithm for the automatic scaling of diagram presentations. If you want to change the unit of measurement or the coordinate scales to be applied to the display before you transfer a diagram to the "Document" program module for documentation (see sect. D 5.7 "Compiling a document"), use the menu options "Diagram - Abscissa scaling" or "Diagram - Ordinate scaling". Such a change will only remain valid until the visible diagram segment is changed by zooming or scrolling.

Upon the calling of the menu option "Scaling - Abscissa scaling" or "Scaling - Ordinate scaling", the "Scaling x-axis" or "Scaling y-axis" dialog box will appear on the screen.

The list box "Unit" can be opened to change the unit.

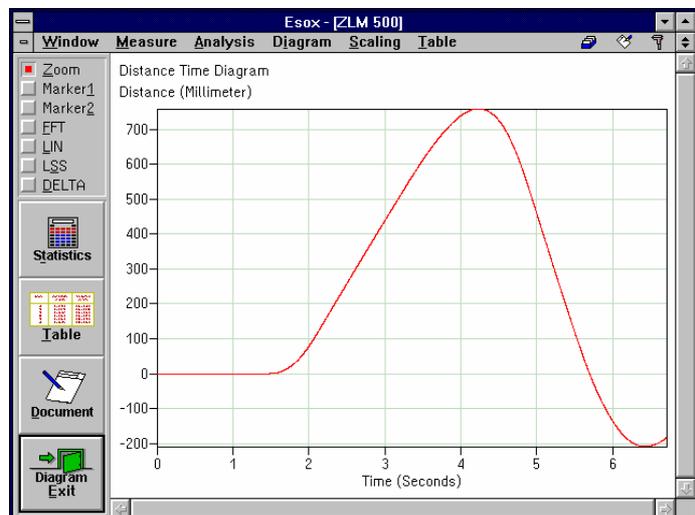
In the four input boxes below this you can specify the required scaling.



D 5.11 Exiting the diagram presentation

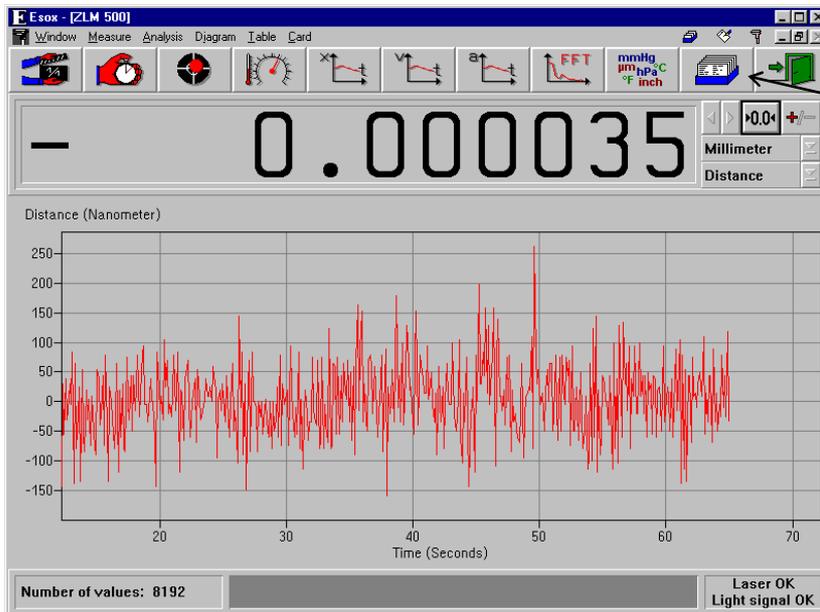
To exit the diagram presentation and return to the display of the current distance or velocity value, activate

the  button or choose the "End diagram" option of the "Diagram" menu.



D 6 Analysis of previous measurements

After the measurement a file card is created and the measurement results written on it. These cards are managed by the program module "Cardfile". It lets you load the card with the results of an earlier measurement so that you can analyse them in the ways described in section D 5.



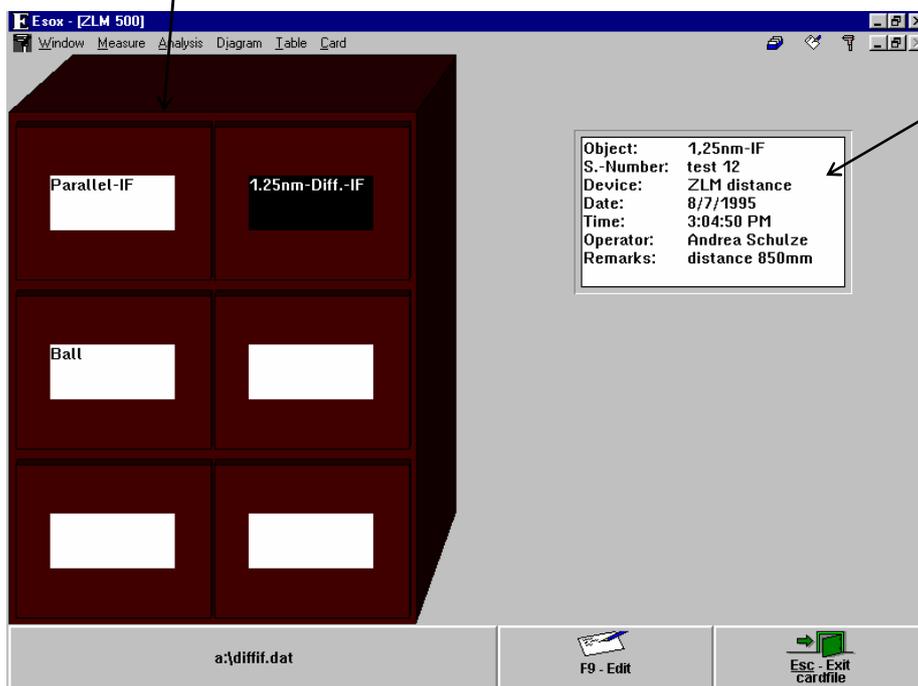
To load a card, first click the



button or select the "Card" option of the **Cardfile** menu.

This will change the screen display.

The left half of the window shows a file cabinet with 6 file boxes (drawers).



The right half of the window contains a field with one file card - the one whose data can presently be processed by the program.

If you want to process the data obtained in one of the previous measurements, you need to open the cabinet drawer containing the desired card, select the card from the drawer and move it into the field on the right.

The following subsections briefly describe how card boxes are opened and closed, and how cards are shifted, loaded into the main memory and placed back into the cabinet. For further details of handling file cards, see section "K - Cardfile / Archiving of measurement Results".

D 6.1 Changing the selected (highlighted) card field

One card field or one card box label field is shown highlighted, i.e. white lettering on black background.



With the cursor keys , ,  and  you can move from one card field or card box label to another.

With the  key you can move from the previously highlighted card field on one side of the screen to the card field on the other side of the screen that was highlighted there last.



Click on the card field or card box label you want to highlight. Please note: Clicking on an already highlighted box label will open the respective box.

D 6.2 Opening and closing a card box

	Opening	Closing
	If the label of the card box is not highlighted, use  ,  ,  and  to move to this label. Then press  .	If necessary, press  ,  or  to move to the respective side of the screen. Then press  .
	If the label of the card box is not highlighted, click on the label once to highlight it; click on the label again to open the box. If the label of the card box is already highlighted, click on it once to open the box.	Click the  button at the bottom right or left of the window to close the right or left card box.

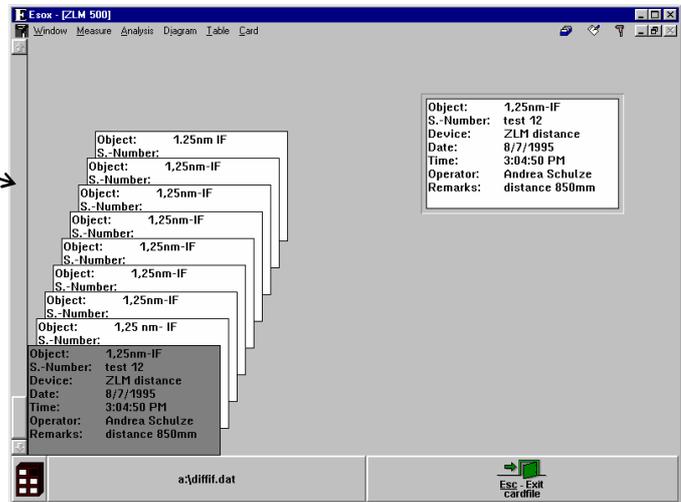
D 6.3 Shifting of file cards

The cards in an open card box can be shifted to activate (and highlight) another card. Cards arranged in front of the current card are not displayed.

The vertical scroll bar shows the location of, and the amount of space occupied by, the current card with respect to all cards of the box.



The vertical scroll bar can be used to shift the cards.



Shifting the card with the keyboard requires that the first card on the left is highlighted.

-  The file cards are shifted backward by one position. The card in the order before the card that was current last becomes the new current card.
-  The file cards are shifted forward by one position. The card in the order behind the card that was current last becomes the new current card.
-  The file cards are shifted backward by one screen page. The first card of the previous page becomes the new current card.
-  The file cards are shifted forward by one screen page. The first card of the next page becomes the new current card.

D 6.4 Loading and unloading of file cards



The easiest way of loading a card is by using the mouse. Move the mouse pointer on the source card, click and hold the left mouse button down. Now drag the mouse pointer with the file card to the target position, then release the mouse button.

If the main memory already contains a card, the program will automatically put it back to its previous position in the card box.

Proceed analogously when putting a loaded card back into its box. Click on the card and drag it to its target position. By dragging the mouse pointer with the card up to the upper or lower margin of the window you can shift the card stack in the box on the left.

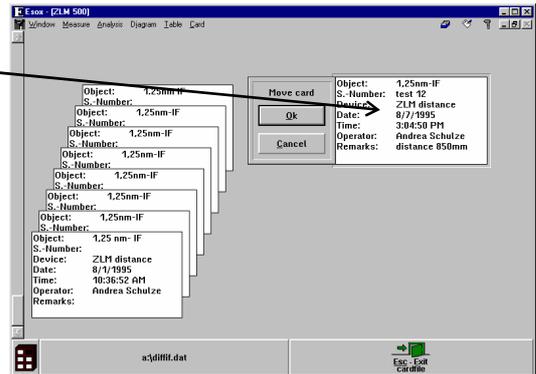


Loading a card with the keyboard requires that the card must first be highlighted on the left half of the screen.

Now select the "**Load**" option from the "**Cardfile**" menu.

The screen shows a field with the card to be loaded.

Press the  key.

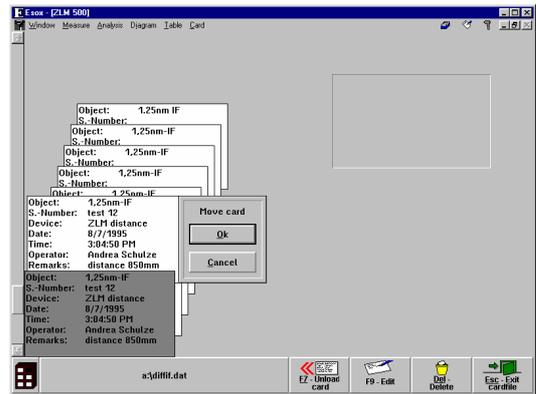


Putting a card back requires that it must first be highlighted in the main memory field represented on the left half of the screen.

Then select the **"Move"** option from the **"Cardfile"** menu.

The target position can be selected with the direction keys.

Conclude by pressing the  key.



Instead of the menu options "Load" and "Move" of the "Cardfile" menu you can also use the



or

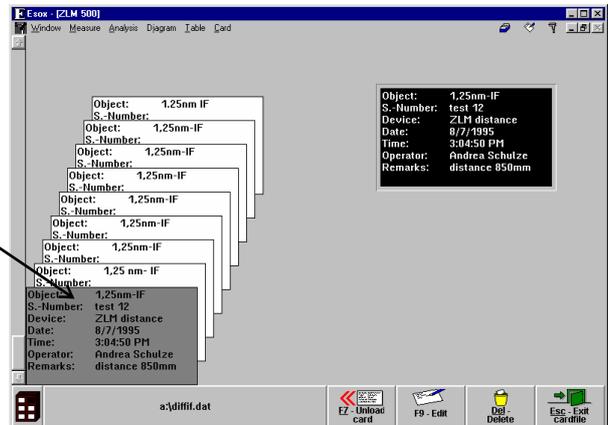


button at the bottom of the screen.

The target position can alternatively be selected with the scroll bar on the left margin. The keys ,  and  can be used to page up and down for finding remote target positions. It is thus possible to move a card from a left-side source position to a left-side target position, for the purpose of rearranging the cards.

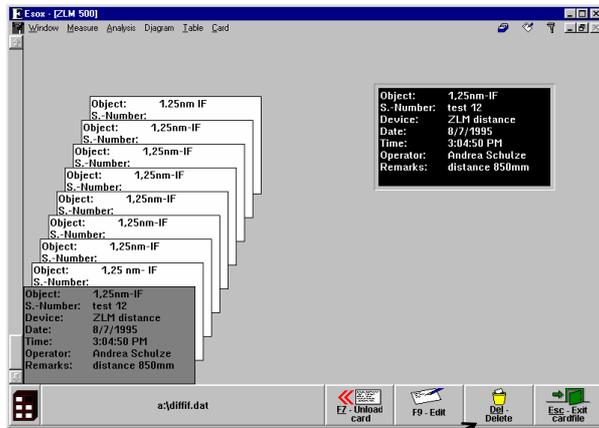
If a card has been loaded into the main memory, it still remains also visible at its source position on the left side, but it is shown here with black lettering on a grey background.

Such a "greyed-out" card cannot be moved from its place.



D 6.5 Deleting a file card

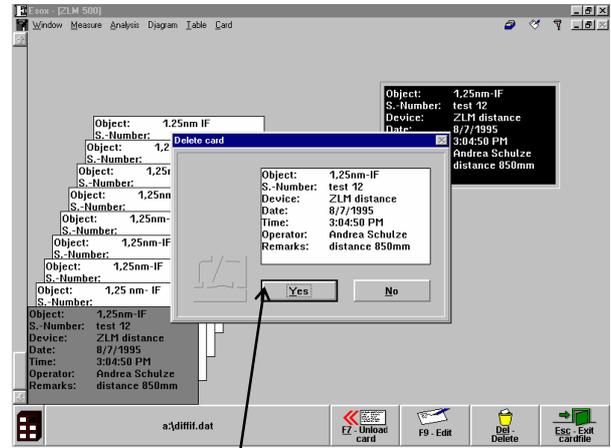
A card you want to delete must first be highlighted.



Select the **"Delete"** option from the **"Cardfile"**



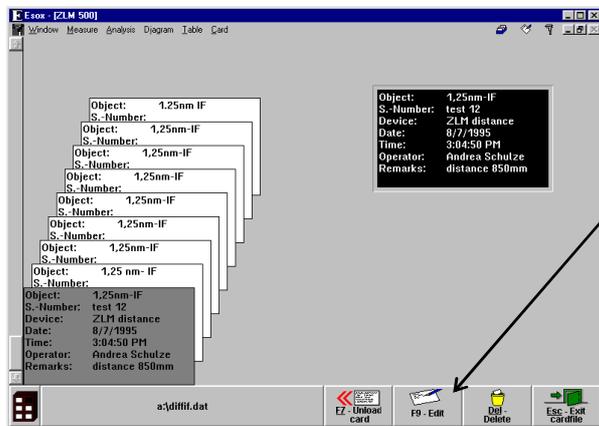
menu or click the **Del - Delete** button. This opens a dialog box.



Click the **Yes** button to delete the highlighted card.

D 6.6 Editing of cards and card box labels

First highlight the card or the card box whose inscription you want to edit.



Start the text input mode by selecting the **"Edit"** option from the **"Cardfile"** menu or by clicking the **F9 - Edit** button.

Annex III contains a list of keys and key combinations that have special functions in the editing of text boxes. In addition you can use the following keys for moving within a card:



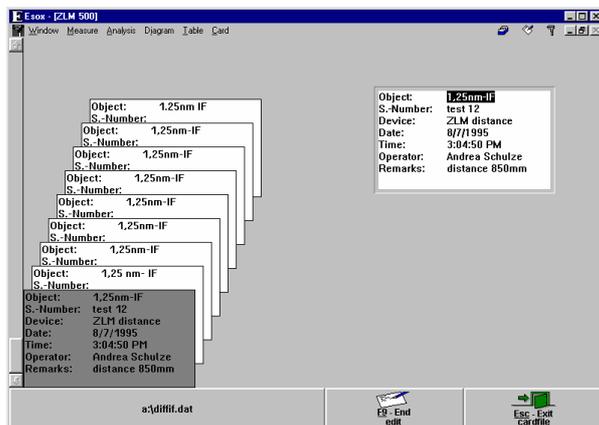
- moves the text cursor to the next card entry in the same line.



- moves the text cursor to the next lower card entry.



- moves the text cursor to the next upper card entry.



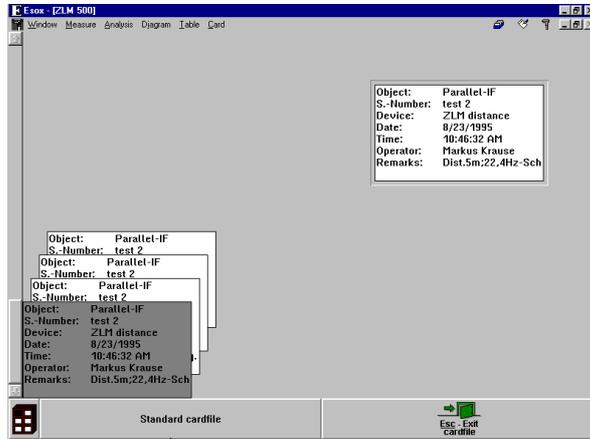
With editing finished, you need to quit the text input mode by selecting **"End edit"** in the **"Cardfile"** menu or clicking the



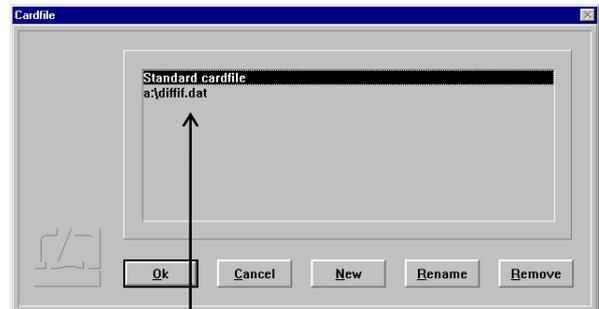
F9 - End edit button.

D 6.7 Creating, renaming and deleting a card file

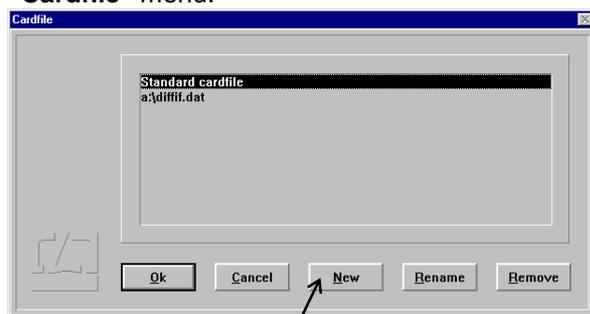
When the program is started first, it creates a card file named "Standard Cardfile" in the system data file "esoxm.dat" located in the installation path. It is possible to create further data files. Each data file comprises a card file cabinet with six card boxes.



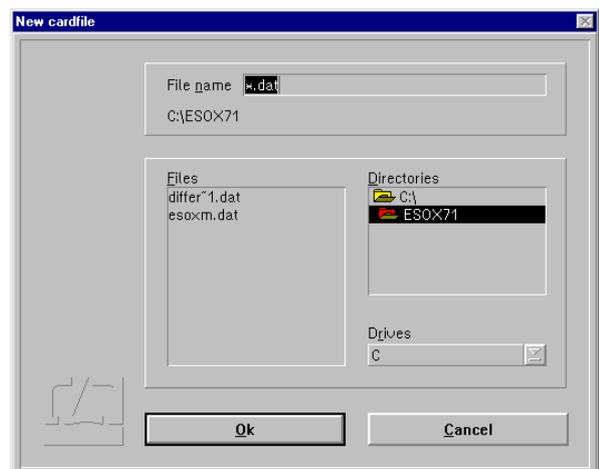
To create a new card file, click on the file name button at the bottom left window margin, or select the menu option "Open cardfile" from the "Cardfile" menu.



This opens a list showing the names of all existing card files in a dialog box.



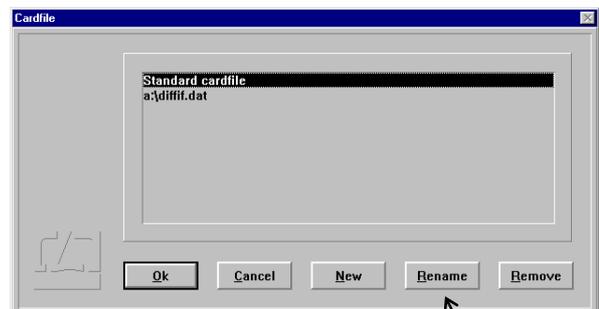
Click the **New** button if you want to create a new card file.



This opens another box in which you must enter the name of the data file.



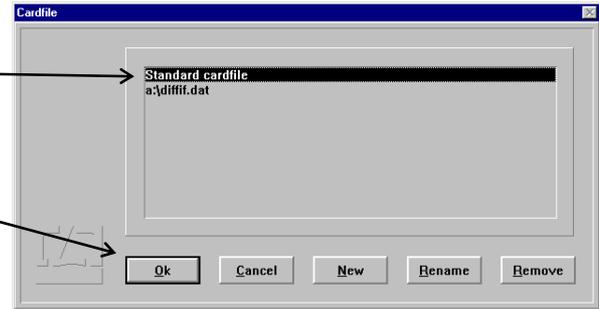
Click the **OK** button to open another dialog box, in which you must enter a card file name, which then appears in the card file list.



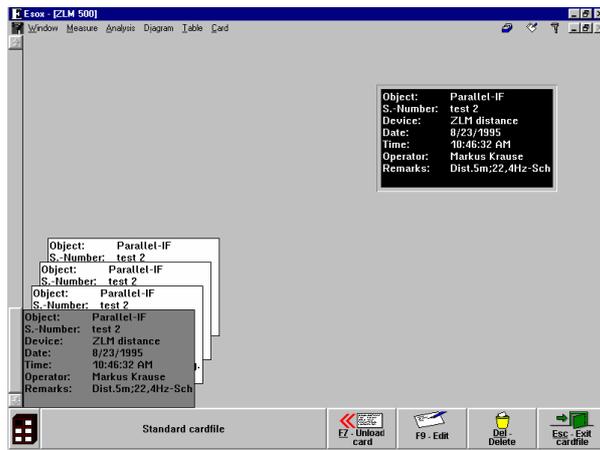
The same dialog box is opened if you use the **Rename** button to rename a card file.

Click the **Remove** button if you want to delete a card file from the card file list. This will not, however, delete the data file from the memory. For deleting the data file, use the file manager.

To select a card file from those created, highlight the file name in the list box and then click the **Ok** button.

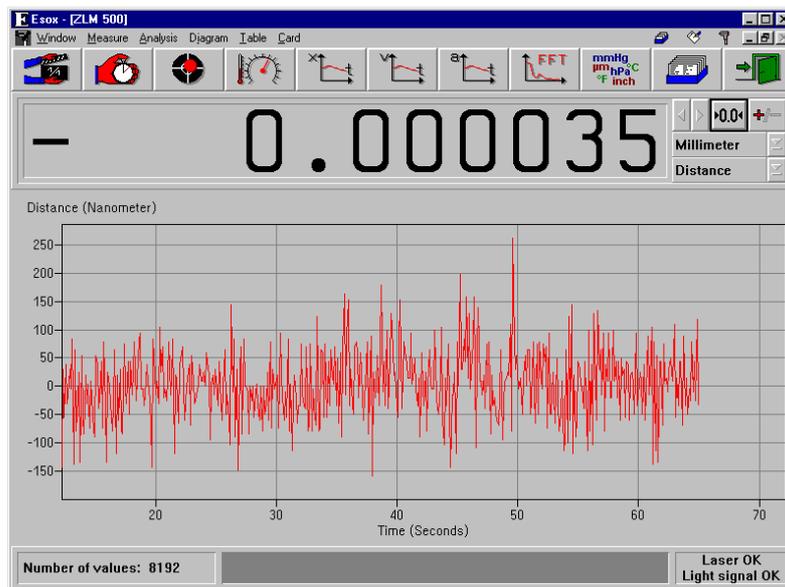


D 6.8 Quitting the Cardfile menu



To quit the Cardfile menu, click the **Esc - Exit cardfile** button or select the "Exit" option from the "Cardfile" menu.

D 7 Exiting the measurement program



To exit the "ZLM-Distance" program module, activate the

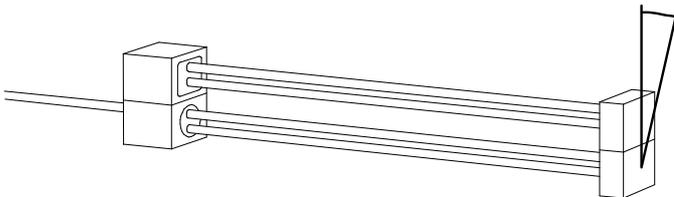


Exit measurement program button or choose the "Exit measurement program" option of the "Measure" menu.

E "ZLM Angle" - Dynamic Measurement Software

The operation of the "ZLM Angle" program module differs little from that of "ZLM Distance". Normally, users of "ZLM Angle" also use "ZLM Distance", which is described in detail in section D. Please read this before the present section, which only describes the few differences between the two modules.

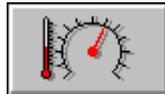
In angle measurement, the two partial laser beams, separated by a polarizing beam splitter, are directed at a double reflector. One of the partial beams has to be deflected. The path difference between the two partial beams is used for computing the angle.



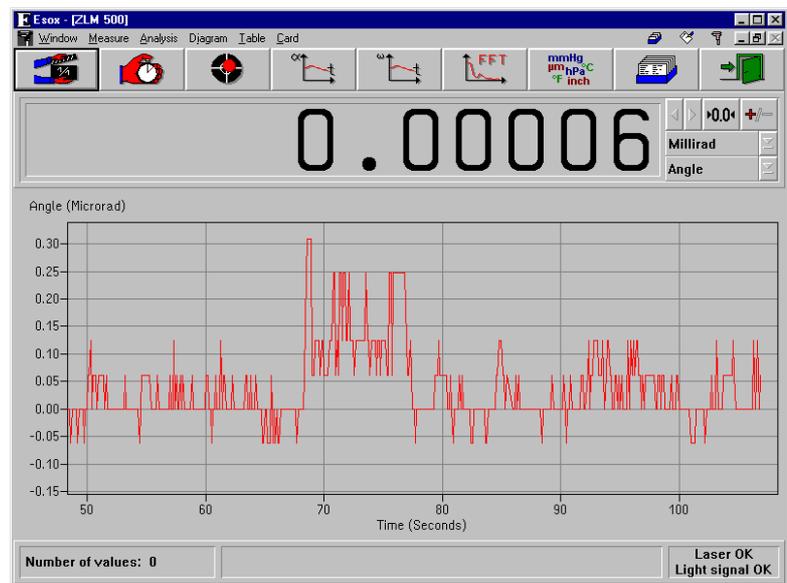
The double reflector may be of either the cube corner or the plane mirror type.

The path difference resulting from the tilting of the reflector and used for determining the angle is minimal, so that changes in the refractive index of the ambient air have no appreciable influence on the result of measurement. Therefore the "ZLM Angle" measurement program has no facility for entering environmental parameters.

Except that the

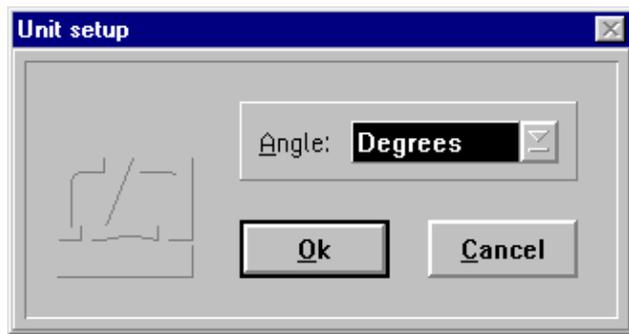


button is missing and that the diagram control buttons concern angular quantities, the "ZLM Angle" window is equal to the "ZLM Distance" window.



E 1 Preparation for a measurement

Click the  button or select the "Units" option from the "Measure" menu to open the window for selecting the unit of measurement. In the "ZLM Angle" module you only need to select the angle unit (rad, degrees, minutes or seconds of arc).



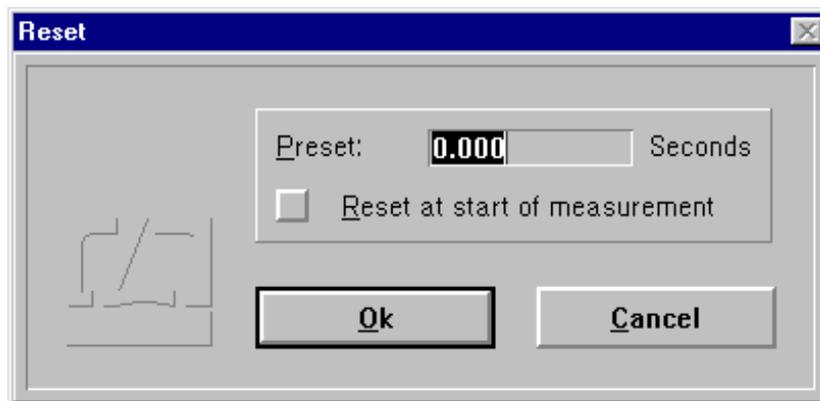
In preparation for a measurement (same as in the "ZLM Distance" program module), you need to specify

- the time at which the readings are to be taken,
- the type of interferometer used, and
- the maximum number of readings to be taken.

For this purpose, use the "Configuration" dialog box. Proceed as described in section D 3 for the "ZLM Distance" program module.

E 2 Measurement

To define the zero point, move the test object so that the line connecting the two reflectors is at right angles to the laser beams. Then click the  button or select the "Reset" option from the "Measure" menu to open the "Reset" dialog box.



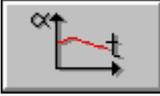
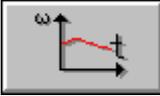
In this dialog box you can enter a preset value, which from now on will be added to the angle determined from the counter value. The addition then supplies the "reading". As the angle has to be determined via a sine function, it is imperative for the line connecting the two reflectors to be at right angles to the laser beams, or else the setting of the zero point will introduce an error resulting from the non-linearity of the sine function.

The entry of a dead distance as in the "ZLM Distance" program module is neither possible nor necessary.

The operation of the program during a measurement is not different from that of "ZLM Distance".

E 3 Analysing the measurement

The measurement is analysed in the form of diagrams with angle-specific units.

Type of diagram	Activation
Angle-vs.-time diagram	 button or "Angle-time diagram" option of "Analysis" menu
Angular velocity-vs.-time diagram	 button or "Angular velocity-time diagram" option of "Analysis" menu
Fourier analysis (amplitude-vs.-frequency diagram)	 button or "Fourier analysis" option of "Analysis" menu

The operation of the "ZLM Angle" program during diagram presentation does not differ from that of "ZLM Distance".

F "ZLM Synchron" - Dynamic Measurement Software

The "ZLM Synchron" program module combines the capabilities of the distance and angle measuring modules. It can acquire and analyse distance, velocity, acceleration, angle and angular velocity measurement data. The software can be used in conjunction with distance and/or angle measuring optics of standard or enhanced resolution, as well as with 2m or 10m straightness optics. The program module is primarily intended for multi-axis interferometer arrangements. The quantity to be measured and the optics used can be individually selected for each axis involved.

This section describes the basic procedure, which comprises three steps: **Preparation** (subsection F4), **Measurement** (F5), and **Analysis** (F6).

F 1 Starting the "ZLM Synchron" program module

When the "Esox" management program is started, the "ZLM Synchron" program module is not active yet. To start this program module, proceed as follows (see also the detailed description in section C 3 "Starting measurement programs"):

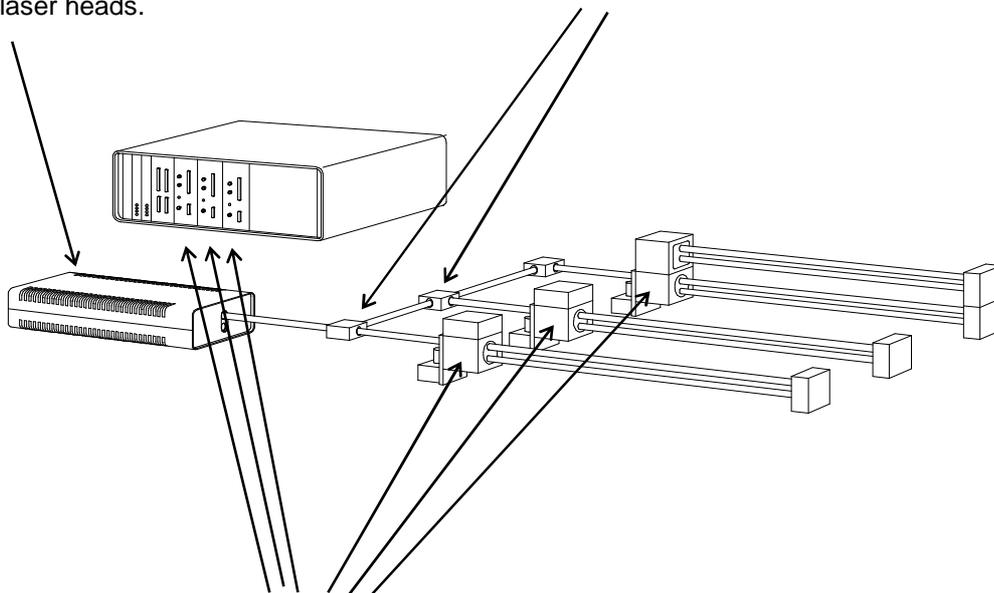
1. Activate the "ZLM" application window and open it to regular or maximized size.
2. Either double-click the "ZLM Synchron" icon with the mouse or use the keys , , , or  to activate this icon, and then press the  key.

F 2 Measuring axes and channels

The "ZLM Synchron" measurement program is generally sold in conjunction with a multi-axis measuring system.

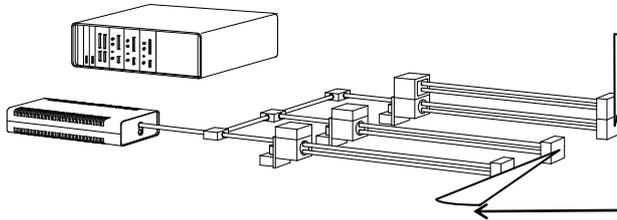
Such a system may include either one or several laser heads.

The laser beam is divided by beam splitters.



You need one interferometer and one counter card for each measuring axis.

Measurement data can be formed from the counter reading of one measurement axis or from a combination of the counter readings of several measurement axes.



An angle measurement, e.g., can be carried out with one optical angle measuring component

or

by computing the angle from the counter readings of two axes equipped with distance measuring components.

The program uses the term "channel" for all measurement data acquired and displayed. This is because the data measured in one channel may be compiled from the counter readings taken along several measuring axes.

F 3 Elements of the "ZLM Synchron" window

If you want to work with the "ZLM Synchron" measurement program for a longer time, we recommend to maximize its window after having started it.

Within the window the following areas can be distinguished:

Display and setting boxes for the various channels

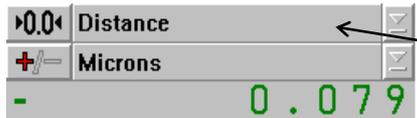
Numerical display field for a selected channel

Column of control buttons

Status line

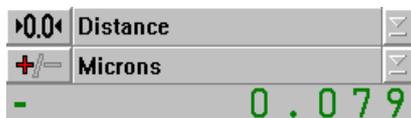
F 3.1 Display and setting boxes

At the upper margin of the window there is an area with boxes for the most frequently used settings. At the far left you find the boxes for channel 1, with the boxes for the next channels following in succession from left to right. The number of channels is preconfigured to match the number of measuring axes. Further settings for the channels can be made in the "Configuration" dialog box. These are described in section F 4.1 "Parameter setting for measurement data acquisition".



In the upper drop-down list box you can select the unit of measurement to be assigned to the channel.

List box option	Explanation
"Off"	No measured data are displayed for the respective channel. During the acquisition of data for permanent storage, this channel is ignored.
"Distance"	The n-th display from the left indicates the distance computed from the counter reading of the n-th measuring axis.
"Angle"	The n-th display from the left indicates the angle computed from the counter reading of the n-th measuring axis.
"Straightness"	Use this option if you want to measure a transverse displacement with an optical straightness measuring component at the n-th measuring axis, to be indicated in the n-th display box from the left.
"Displacement m-n"	The n-th display box from the left indicates the distance computed from the difference between the counter readings of the m-th and n-th measuring axes.
"Displacement m+n"	The n-th display box from the left indicates the distance computed from the sum of the counter readings of the m-th and n-th measuring axes.
"Angle m-n"	The n-th display box from the left indicates the angle computed from the difference of the counter readings of the m-th and n-th measuring axes via the arc tan function. You need to enter the required reflector spacing in the " Beam spacing " line of the "Configuration" dialog box for the n-th axis.



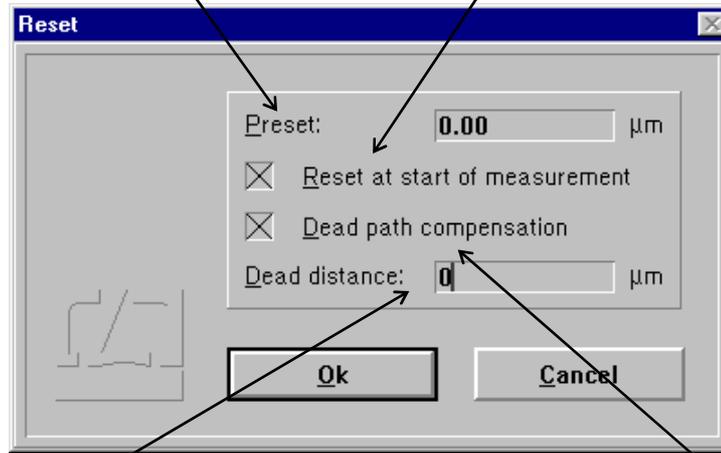
In the lower drop-down list box you can select the unit of measurement for the display. See section F 3.6 "Unit systems" for information on how to change from one system of units to another (metric or imperial measure, or degrees/minutes/seconds/radian).

Use this button to open a dialog box "Reset", in which you can set the reference point and the dead distance.



In the "**Preset**" text box you can preset the distance or angle to be assigned to the present position.

If the button "**Reset at start of measurement**" is on , the preset value will be assigned to the instantaneous position at the time you start a measurement.



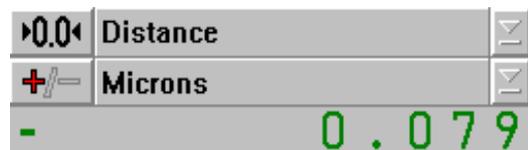
In the "**Dead distance**" box you can enter the distance between the reflectors. See Annex III for a detailed explanation of the term "dead distance".

The dead distance is of significance only in high-accuracy measurements with the environmental properties changing during the measurement. If you specify a dead distance, mind the correct sign. Specify the dead distance so that, after resetting, the sum of measurement readout and dead distance has always the same amount as the distance between the two reflectors.

If it can be assumed that the environmental conditions will not change during a measurement, the "**Dead path compensation**" button can be switched off ()

The reference point is only assigned when the button is activated. The actions and settings made in this dialog box only act on the respective measuring axis.

With this button you can change the sign.

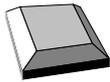


The bottom line indicates the current reading. It is updated 10 times a second, unless the computer is overloaded by other tasks.



To release a function with the or button, click on it.

To change the active option in a drop-down list box, click on the underlined arrow right of the list box. This opens the list box and allows you to click the desired option.



Press the  key until the wanted list box or button is marked and thus active. Active buttons ( or ) are displayed with a thicker black frame around the button. An active drop-down list box is marked by a highlighted (white on black ground) entry. To open the pull-down list and see the options available, press the key combination  + . By pressing the  or  keys you can choose the wanted option. To confirm your choice, press the  key.

To release a button function, press the  key.

F 3.2 Large numerical display

This display box indicates the instantaneous reading of a channel with large digits. Use the drop-down list box on the right of the display to select the channel.



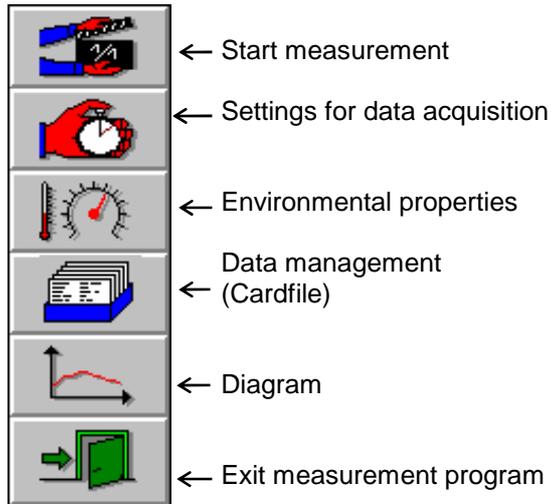
Use the button below the list box to set the reference point simultaneously for all measuring axes. Clicking this button opens the "Reset" dialog box. In this box you can make the same settings as in the Reset boxes of the individual channels, but here they act on all measuring axis simultaneously.



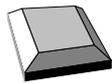
Upon actuating the  button, assignment of the reference points is made simultaneously for all measurement axes.

F 3.3 Column of buttons

With these buttons you can activate specific functions of the program, such as start of data recording, setting options for data recording, and data evaluation by diagrams. All these functions can also be started via menu commands. They are explained in detail in the following subsections.

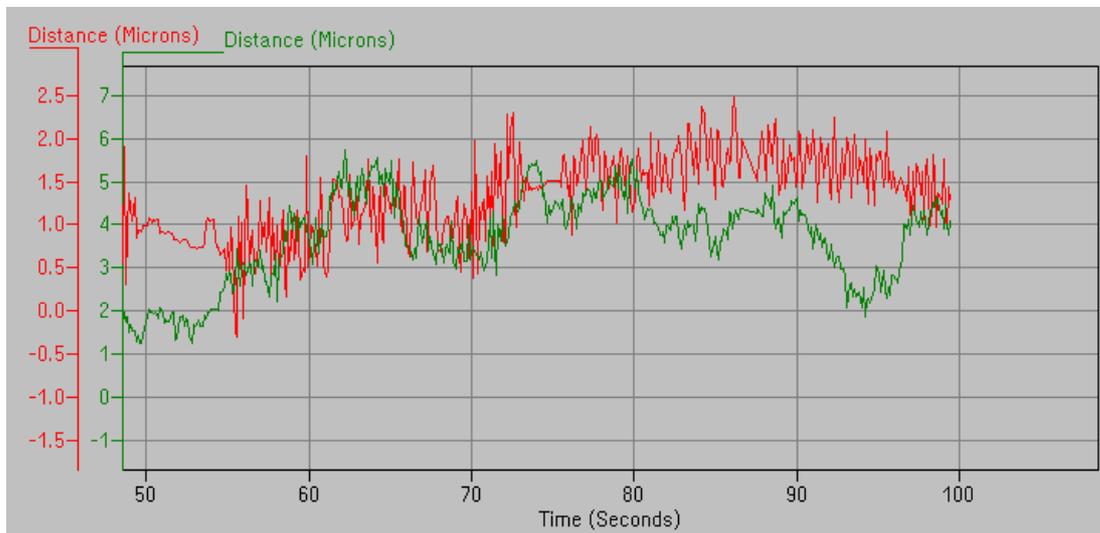


Clicking a button with the mouse activates the function assigned to this button.



(Repeatedly) press the  key until the desired button is marked as active by the thicker black frame around it. The function assigned to the active button can then be released by pressing the  key.

F 3.4 Real-time diagram



The real-time diagram presents the distance as a function of time for the last 60 seconds approximately. The current distance value is added 10 times per second unless the computer is overloaded by other tasks. The scale graduation is automatically determined from the measured data, so you need not preselect it.

F 3.5 Status line



At the left end of the status line you will see the number of measured data currently stored in the memory (This figure refers to the number of permanently stored data, not to those of the real-time diagram).

In the middle of the status line you can find a bar that indicates how many of the preselected number of readings have currently been taken. At the right end of the status line there is a field telling you whether the laser is stabilized or not. With program functions taking a longer time, such as measurements or fast Fourier transformation, the appearance of the status line changes as will be described in detail in the respective sections of this manual.

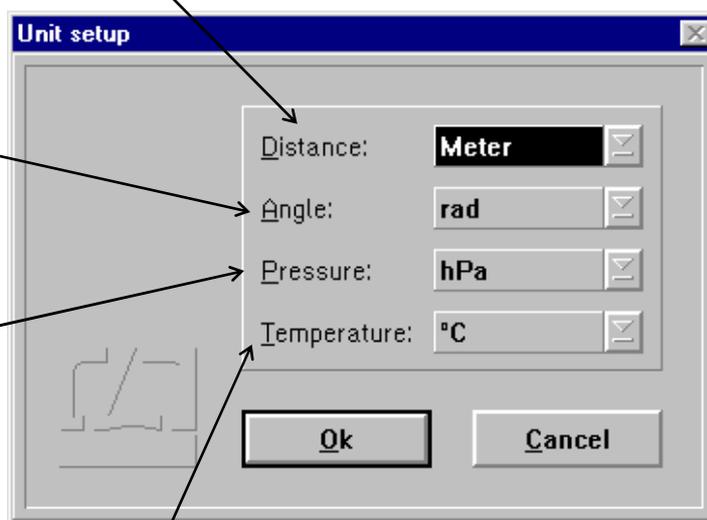
F 3.6 Unit systems

Units of distance, atmospheric pressure and temperature can be selected in the "Unit setup" dialog box. Open this box by selecting the "Units" option of the "Measure" menu.

The program can show distances and quantities derived from them in either metric (metre) or imperial (Inch) measure. Switch between them in the "Distance" list box.

In the „Angle“ module you only need to select the angle unit (rad, degrees, minutes or seconds of arc)

In the "Pressure" list box you can select between "Hectopascal" and "Millimetre mercury".
(1000 hPa = 100 kPa = 1000 mbar, and
1 mmHg = 1 torr)



In the "Temperature" list box you can select between "Degree Celsius" and "Degree Fahrenheit".

F 4 Preparation for a measurement

The data displayed numerically and in the real-time diagram will not be saved permanently, nor can they be analysed any further. Analysable data will only be read in and stored upon a specific command. Whenever mention is made below of the acquisition or recording of measurement data (readings), this means the acquisition of permanently saved data.

In preparation for a measurement you need to specify

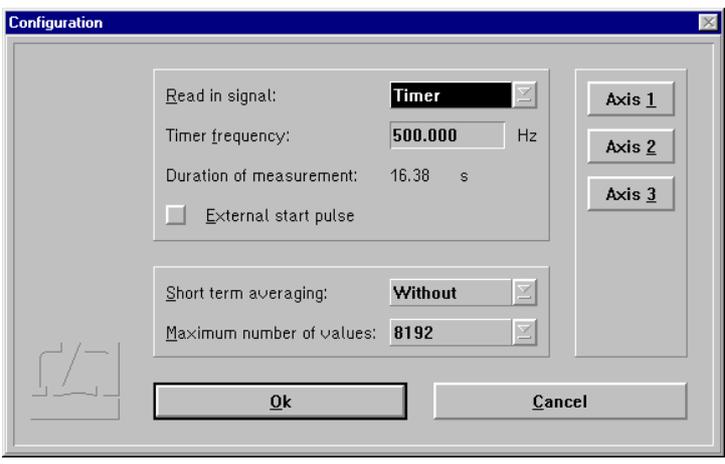
- the time at which the readings are to be taken,
- the type of interferometer used,
- the maximum number of readings to be taken, and
- the required mode of compensation for environmental influences.

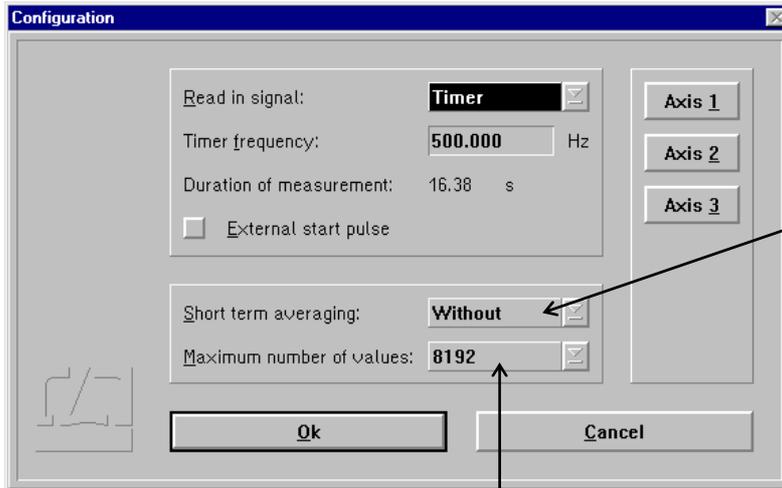
For this purpose, use the "Configuration" and "Environment" dialog boxes.

F 4.1 Parameter setting for measurement data acquisition

Access the "Configuration" dialog box by opening the **"Measure"** menu and choosing the **"Configuration"** option or by clicking the  button.

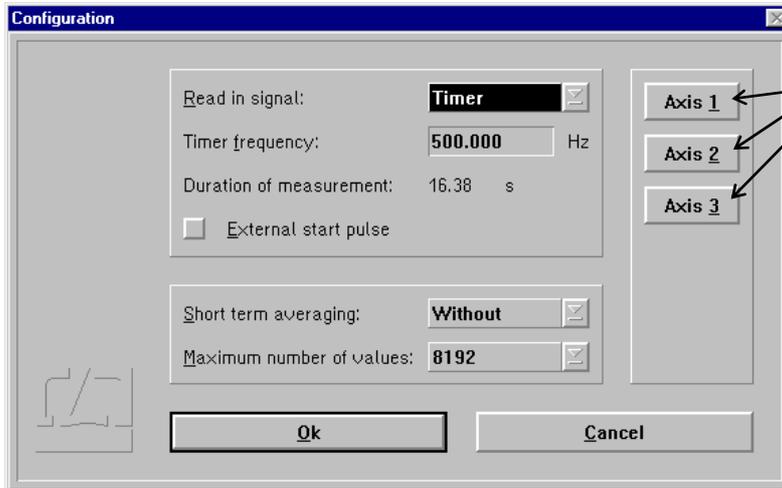
Select the times for data reading in the top part of the dialog box. You need to choose between three possible trigger sources for data reading.

<p>Configuration with ZLM 500</p>	
<p>Triggering by the timer</p>	<p>In the drop-down list box "Read-in signal" select the "Timer" entry. In the "Timer frequency" dialog box enter the desired frequency of readings.</p> <p>The button "External start pulse" determines which event is to trigger the measurement.</p> <p>When this <input type="checkbox"/> button is not checked:</p> <p>The measurement is started by activating the "Measure" menu and choosing the menu option "Start measurement" or by clicking the  button.</p> <p><input checked="" type="checkbox"/> button is checked:</p> <p>The measurement is started by an external trigger pulse connected to the respective input. Annex I shows where the respective external signal lead must be connected to.</p>
<p>Triggering by an external read-in signal</p>	<p>In the drop-down list box "Read-in signal" select the "External" entry. Annex I shows where the external signal lead must be connected to.</p> <p>The "External start pulse" button has no function in this mode.</p>
<p>Triggering by pressing the  of the keyboard</p>	<p>For this mode open the drop-down list box "Timer frequency" and choose the option "Space bar".</p> <p>The "Divisor" and "External start pulse" settings will be ignored by the program in the measurement.</p>



In static measurements, the program can filter out vibrations by time averaging. The time over which an average is to be obtained can be set in the "**Short term averaging**" list box. In dynamic measurements, however, use the entry "**without**".

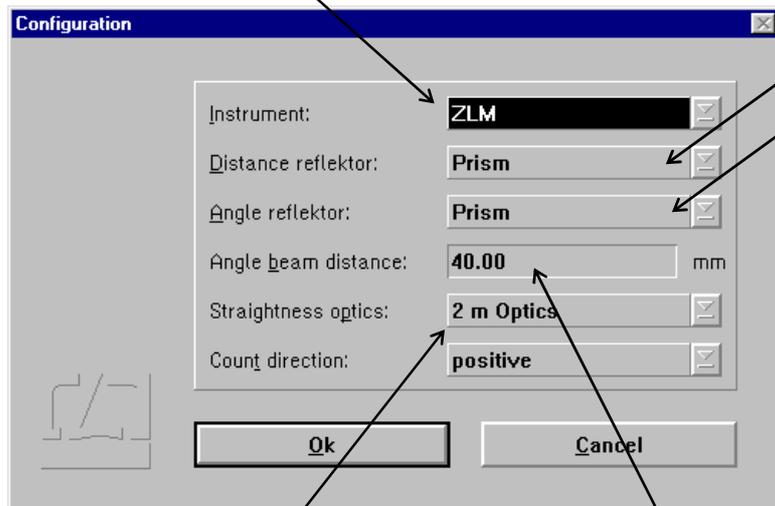
The pull-down list box "**Maximum number of values**" displays the number of measured values to be read before the software stops a measurement automatically. Of course, you can stop a measurement by command at any time before this number of values has been reached. Section "F 5.2 Cancelling the measurement" contains detailed information on this topic. The options, i.e. the numbers of readings listed in the pull-down list box "Maximum number of values", allow Fourier analysis to be carried out as efficiently as possible.



These buttons on the right allow you to make further settings for the individual measuring axes. Each button opens a new dialog field.

Apart from the ZLM 500 Laser interferometers, the measurement software can also process readings taken with incremental shaft encoders having digital 0° and 90° outputs. See the "Manual on multi-axis laser interferometers" for information on how to connect these encoders to the ZLM electronic system.

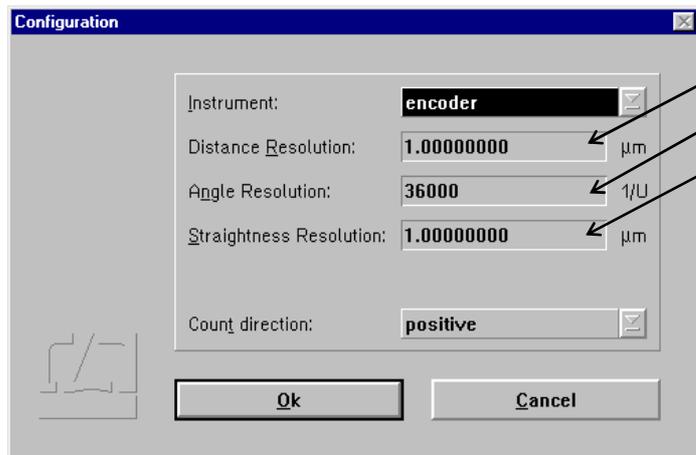
In the "Instrument" list box you can tell the program which kind of measuring system is connected.



In the "Distance reflector" or "Angle reflector" list box you need to specify which kind of interferometer is used for a distance or angle measurement. Select "Prism" in case of a corner cube interferometer, "Mirror" in case of a plane mirror interferometer. See the "Manual of multi-axis laser interferometers" for suitable interferometer arrangements.

In the "Straightness optics" list box you need to select which set of optical straightness measuring components is used, if you want to measure transverse displacements with straightness optics.

In angle measurements, you need to specify in the "Angle beam distance" text input box the reflector distance as a basis for angle computation. If you use channel "n" for an angle measurement by way of forming the difference between two measuring axes, the reflector distance must be entered in the n-th field of the axis setting dialog.



In case you use an incremental shaft encoder, you need to tell the program the resolution (least count) of the encoder. For an incremental shaft encoder divided into 1000 increments without interpolator, e.g., enter $4 \times 1000 \text{ r.p.m.} = 4000 \text{ r.p.m.}$, as the software evaluates both flanks each of the 0° and 90° signals.

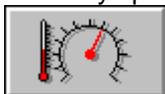
F 4.2 Compensation of environmental influences

The accuracy of a distance measurement made with a laser interferometer depends on whether the refractive index of the ambient air is known and allowed for. The ZLM Distance program can compute the refractive index from properties of the atmospheric environment and correct the measurements accordingly.

The ZLM Distance software can further allow for the thermal expansion of the test object as a function of its temperature, and correct the measured data so that they represent the readings that would have been obtained with the test object having a temperature of 20°C .

The necessary settings can be made in the "Environment" dialog box.

This is accessible by opening the "Measure" menu and choosing the "Environment" option, or by

clicking the  button. All the settings made in this box have an effect both on the taking of readings as well as on the numerical display and the real-time diagram.

No compensation is required for angle measurements and for measurements with straightness optics, where the influence of the environment is below the measurement resolution.

F 4.2.1 Atmospheric properties

In the top part of the "Environment" dialog box you can choose how to compensate for the effects of atmospheric properties on the refractive index and thus on the measured result.

Manual Correction Choose the "**Manual**" option of the pull-down list box "**Correction type**". You will have to enter the atmospheric properties in the respective text boxes.



Keys that facilitate inputs:

Coarse setting -  and 

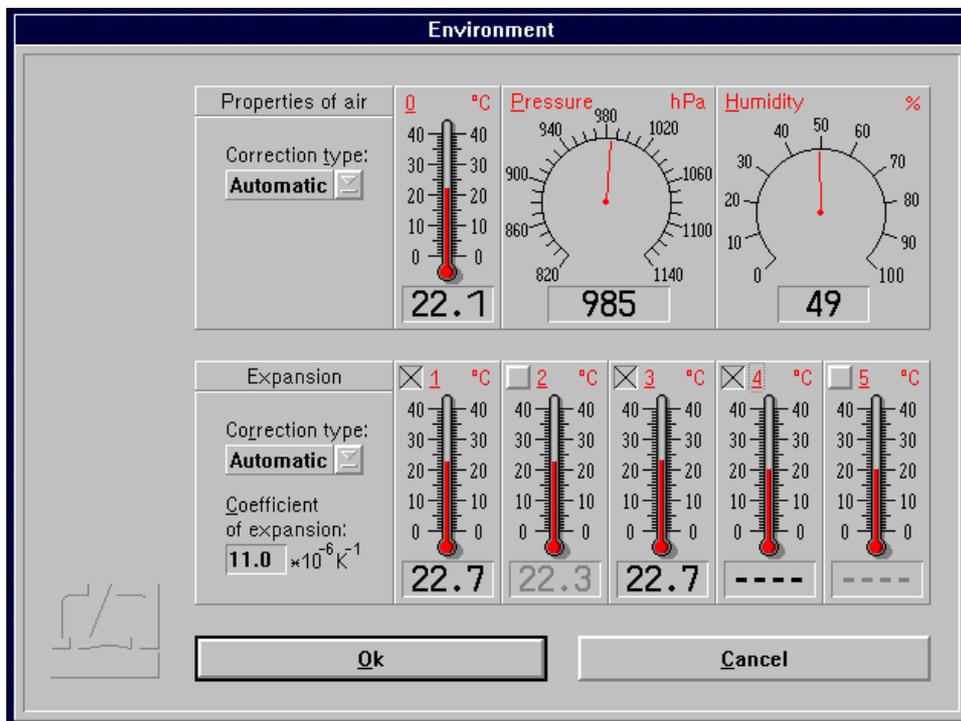
Fine setting -  and 



1. Move the mouse pointer to the field where you want to make an entry.
2. Press the left mouse button and keep it depressed.
3. Drag the mouse until the thermometer column or the pointer indicates the desired value.
4. Release the mouse button.

Consult Annex III for information about the accuracy required for the measurement and entry of atmospheric properties.

Automatic Correction When you use the AUK 500 Automatic Environment Detector to measure the atmospheric properties, choose the option "**Automatic**" of the pull-down list box "**Correction type**".



F 4.2.2 Material temperature

In the bottom part of the "Environment" dialog box you can choose whether and how the measured values are to be corrected for thermal expansion (material temperature). With correction activated, the readings are converted into readings that would be obtained at a material temperature of 20 °C.

Without correction If you want to work without this correction, choose the option "**Without**" of the pull-down list box "**Correction type**".

Manual correction If you want to enter the material temperature manually, choose the option "**Manual**" of the pull-down list box "**Correction type**".

In the text box "**Coefficient of expansion**" type in the linear expansion coefficient of the test object.

The material temperature can be entered in the same way as the manual entry of atmospheric temperature (see Section "F 4.2.1 Atmospheric properties").

Automatic correction If you want to use the AUK 500 Automatic Environment Detector for compensating the errors due to material expansion, choose the option "**Automatic**" of the pull-down list box "**Correction type**".

In the temperature display boxes, temperature sensors that are not connected are indicated by "---". In the figure, material temperature sensors 4 and 5 are not connected.

You have the possibility to select from the available sensors those you want to use for the correction. For this purpose, every temperature display field has a button at the top left.

Button is not checked:

The respective material temperature sensor is excluded from correction and - on colour screens - the temperature value is displayed in grey instead of in black colour. In the figure, material temperature sensors 2 and 5 are not included in the correction of material expansion.

Button is checked:

The sensor reading enters the correction if the sensor is connected.

With automatic correction activated, the program reads the data of the material temperature sensors once per second. The program computes the mean value of all the measured values of the sensors that are connected and activated via the respective button of the display field. This value is used by the program to correct the data for material expansion.

If none of the sensors is connected and activated, the measured values are not corrected. In the example shown in the figure, the mean value of the temperatures detected by sensors 1 and 3 is used for the correction. Sensors 4 and 5 are not connected. Sensor 2 is deactivated.

F 5 Measurement

The settings to be made per channel in case of making measurements with permanent data saving are identical to the channel settings to be made for mere data display. With a channel switched "Off", no data will be recorded for that channel.

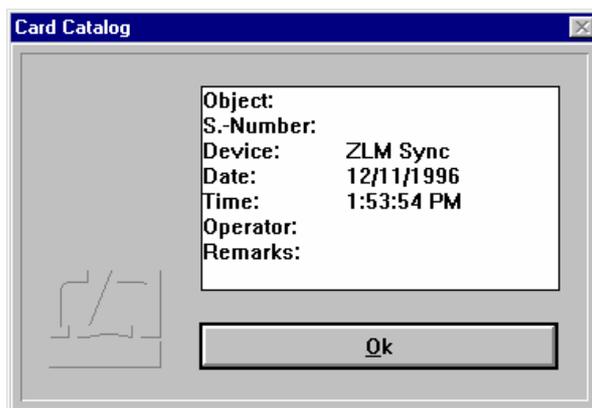
Before starting you need to set the reference value for each channel. You can do this either simultaneously for all channels with the  button in the large numerical display field, or individually per channel with the  button in the display and setting fields for the channels.

F 5.1 Starting the measurement

You can start a measurement by opening the "Measure" menu and choosing the "Start measure" option or by clicking the  button. While the measurement is running, the status bar indicates the number of readings currently taken. The display of laser stability at the right end of the status bar is replaced by the  button. This button is active, as indicated by its black frame, so that the measurement can be stopped immediately by clicking this button with the mouse, or by pressing the  key.

In the case of measurements over longer periods, you can switch to other program modules or run other MS-Windows programs.

After a successful measurement, the measured values are saved on a card of the card file. For this purpose, a dialog box "Card Catalog" is displayed, containing already entries for the measuring instrument used and the date and time of the start of the measurement. You can type in the remaining items via the keyboard.



Annex II contains the list of special function keys and key combinations for typing in text boxes.

Additionally, the following keys can be used:



- moves the text cursor to the next entry of the file card in the same line.



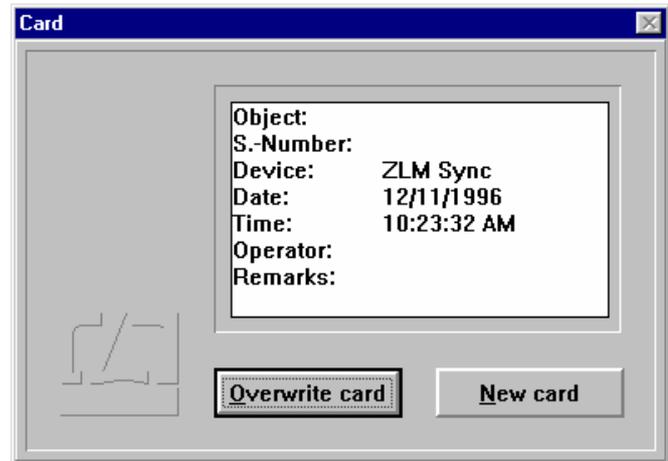
- moves the text cursor down to the next entry of the file card.



- moves the text cursor up to the previous entry of the file card.

On clicking the  button, the file card is created. Filing of file cards is handled by the "Cardfile" program module (see Section K).

If a card already exists in the main memory, the program provides the possibility to overwrite this card with new measured values.



F 5.2 Cancelling a measurement

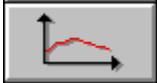
In the following cases the program cancels the measurement before all readings have been taken:

- The laser is unstable or becomes unstable while the measurement is running.
- The light power at the receiver is too low or becomes too low while the measurement is running.

- You have cancelled the measurement by clicking the  button.

You have the option of saving the readings taken until the moment of cancelling the measurement.

F 6 Analysis of a measurement

The measurement is analysed in the form of diagrams. A click on the  button or selection of the "Diagram" item in the "Measure" menu opens the diagram window.

F 6.1 Controls for diagram handling

If measurement data have been acquired in more than one channel, the diagram will have one ordinate axis for each channel. The colour of an ordinate axis is the same as that of the respective graph showing the series of data measured.

In case of measurements triggered by the timer, the abscissa axis represents time. In measurements triggered by external read-in signals or by pressing the **Space bar**, the program cannot assign any time to the individual readings. In the respective diagrams, the abscissa is divided by point numbers instead.

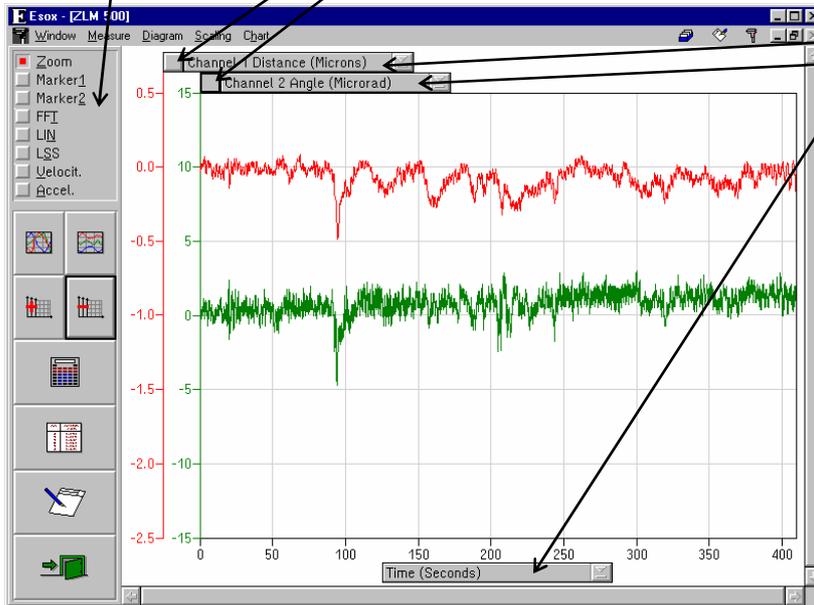
Abscissa and ordinate are scaled automatically by the program.

The options include zooming of defined sections of the diagram, cross-marking of points on the diagram to display the individual measured values numerically, and plotting of new diagrams from sections of the "mother" diagram.

With the option buttons at the top left you can choose the action to be taken next

Several operations cannot be performed simultaneously on more than one series of measurements. Therefore each ordinate has a button at its upper end with which the "active" ordinate can be selected.

In the drop-down list boxes you can select which series of measurements or which quantity is to be shown.



Use the scroll bars to shift the visible diagram segment. Vertical scrolling is limited to the graph with the currently active ordinate.

The buttons allow automatic scaling,

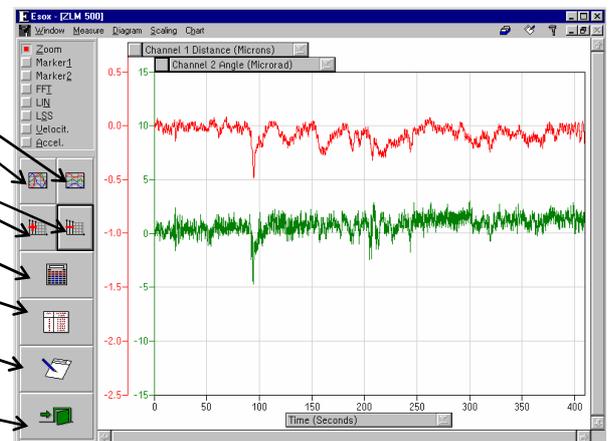
adding and removal of ordinate axes,

the display of statistical data,

the opening of a table of measured data,

transfer of the diagram and the tabular data into a record (document), and

exiting the diagram presentation.

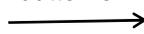


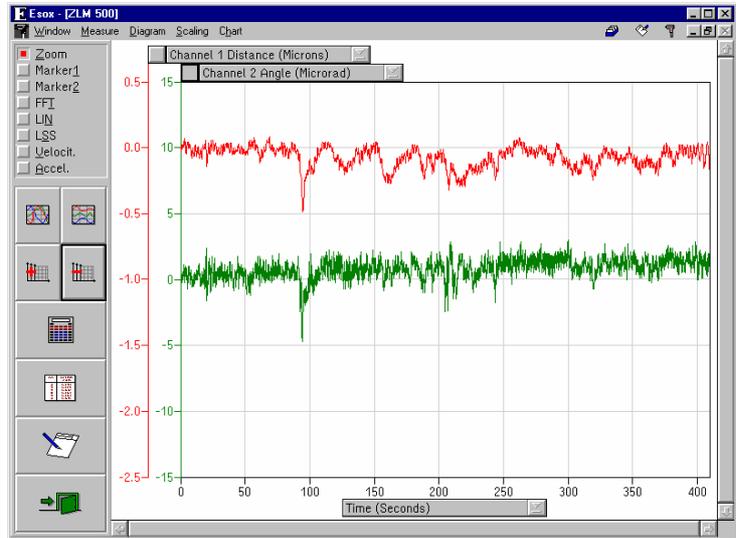
Use the  key to change from one button to the next.

In addition to these buttons you can also use some submenu items of the "Diagram", "Table" and "Scaling" menus.

F 6.2 Zooming of diagram segments

Any zooming action will only act on the series of data belonging to the currently active ordinate. Therefore, first select the data series to be zoomed, by clicking the button of the respective ordinate.

Then click the "Zoom" option button or the "Zoom mode" option of the "Diagram" menu. 



Move the mouse cursor to a corner of the section of the diagram you want to magnify. Press the left mouse button and keep it depressed. Move the mouse until the movable frame encloses the diagram section of interest. Release the mouse button.

After pressing the **right mouse button** the full diagram is displayed again.



	Expansion by factor 2	Contraction by factor 2
horizontally	 + 	 + 
vertically	 + 	 + 

F 6.3 Scrolling a diagram

From the scroll bars on the right and at the bottom of the window you can see which segment of the diagram is displayed. Shifting of the visible segment is always possible regardless of which option button is active.

To scroll **up** by 10%.

To scroll **up** by one windowful.

To scroll to any desired position vertically: Click and hold the left mouse button. Drag the mouse until the square is in the wanted position.

To scroll **down** by one windowful.

To scroll **down** by 10%.

To scroll **to the left** by 10%.

To scroll **to the left** by one windowful.

To scroll to any desired position horizontally: Click and hold the left mouse button. Drag the mouse until the square is in the wanted position.

To scroll **to the right** by one windowful.

To scroll **to the right** by 10%.

Scrolling	to the right	to the left	up	down
by 10%	+	+	+	+
by one windowful	Ctrl + PgUp	Ctrl + PgDn	PgUp	PgDn

Vertical scrolling acts only on the series of measurement data belonging to the currently active ordinate.

F 6.4 Autoscaling

After a diagram has been zoomed and/or scrolled, press button or to revisualize all measured data.

or the "**Autoscaling overlapping**" option of the "**Scaling**" menu: The graphs of the data series may overlap.

or the "**Autoscaling non-overlapped**" option of the "**Scaling**" menu: The graphs of the data series are arranged one below the other.

F 6.5 Adding and deleting of ordinates

Before you can delete an ordinate you need to tell the program which ordinate to delete, by clicking the  button at the top end of the respective ordinate.

Then either click on this button  or select the **"Delete ordinate"** option of the **"Diagram"** menu. This will cause deletion of both the ordinate and the graph of the data series belonging to it.

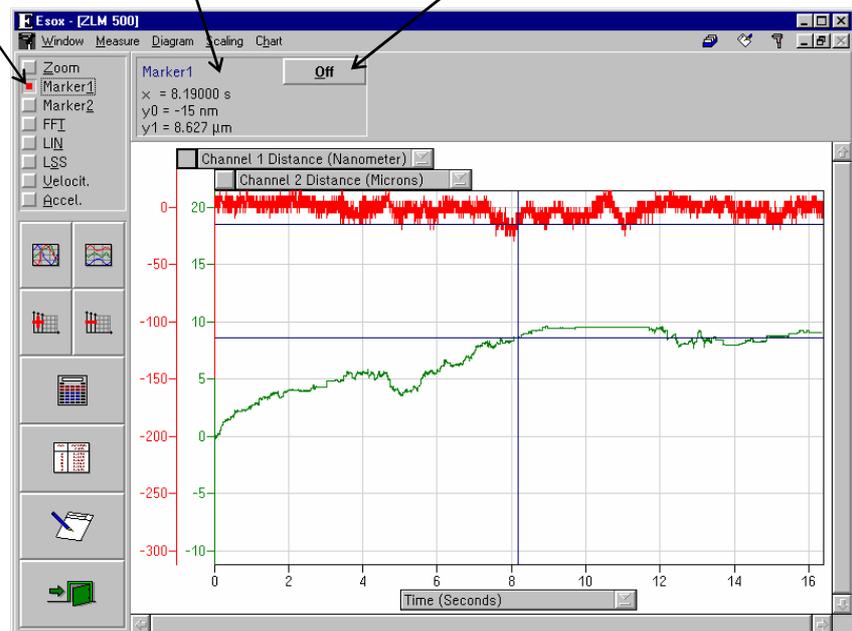
Click on button  or select the **"New ordinate"** option of the **"Diagram"** menu to add another ordinate. The new graph appearing with it represents the measured data of the first of the series of measurements that were not visible before.

F 6.6 Marker cross-hairs

On activating the **"Marker 1"** option button or **"Diagram - Mode Marker1"** menu option the diagram shows a marker cross-hair for each data series shown.

In this field the measured data will be numerically displayed.

By clicking the  button, marker cross-hairs can be removed from the screen.



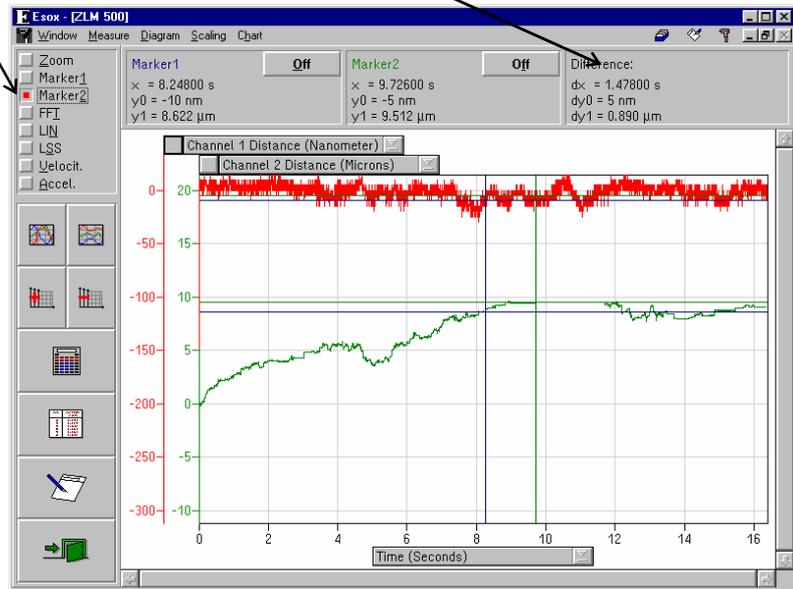
With a mouse click on a point in the diagram, the vertical line of a cross-hair is moved to this point. The horizontal line is positioned according to the value measured at this position. That value appears in the numerical display field.



You can move a marker cross-hair with the  and  keys.

The option button "**Marker2**" or the menu option "**Mode Marker2**" permits a second marker cross-hair to be displayed for each series of measurements. It is handled in the same way as the first marker cross-hair.

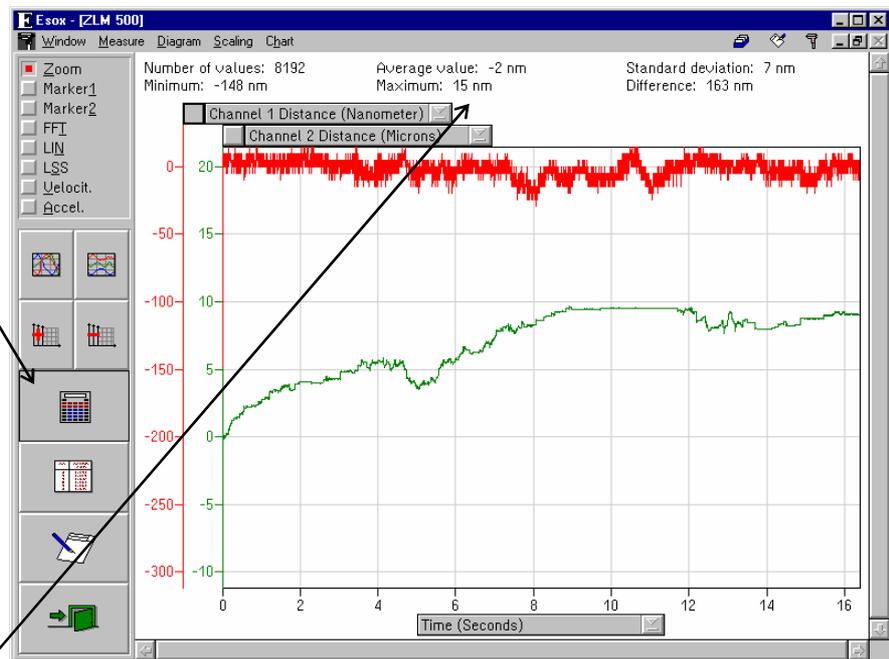
When both marker cross-hairs are active, the difference between the measured values marked by the cross-hairs is displayed.



F 6.7 Statistics

Activation of the  button or the "**Statistics**" option of the "**Diagram**" menu displays

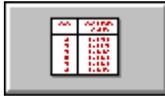
- the number of readings
- the maximum reading
- the mean value
- the minimum reading
- the standard deviation
- and the maximum-to-minimum variation.

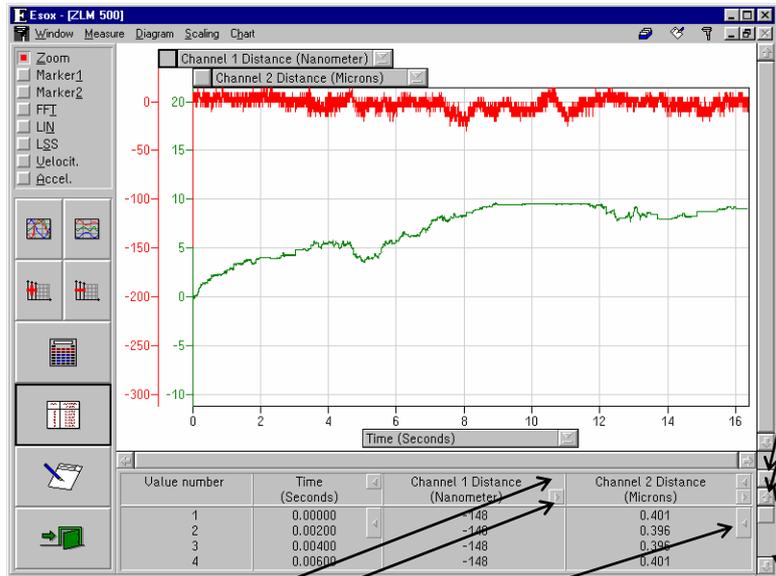


All these data is calculated from the data series belonging to the currently active ordinate and the currently visible diagram segment.

If you activate another ordinate or when you scroll or zoom the diagram, the data are recalculated and displayed accordingly. The clicked button will lock. Click it again to remove the display of mean value and standard deviation.

F 6.8 Tables

By clicking the "Table"  button while a diagram is displayed, a table with the measured data can be displayed in addition. The clicked button will lock. Click it again to remove the table.



Button for **maximizing** the table

To scroll **up by one line**.

To scroll **up by one windowful**.

To scroll to any desired **position vertically**: Click and hold the left mouse button. Drag the mouse until the box is in the wanted position.

Switch buttons for unit to be displayed.

Switch button for number of decimal places.

To scroll **down by one line**.

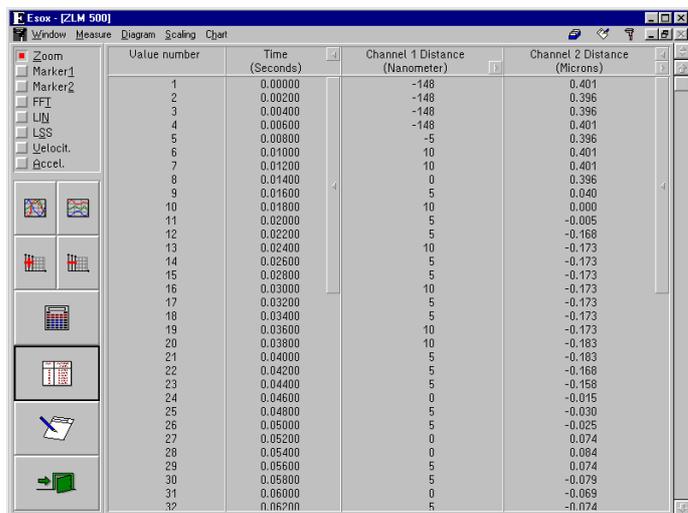
To scroll **down by one windowful**.

The table may occupy either the bottom right section or almost all of the program window. In the second case, the diagram is hidden behind the table. For switching between normal-size and full-window presentation of the table, click the button at the top right table margin.

By means of the menu items

- ### "Table - no table",
- ### "Table - small table" and
- ### "Table - big table"

the functions described above are accessible with the keyboard as well.



Button for switching back to normal-size presentation of the table



The visible segment of the table can be shifted by means of the vertical scroll bar at the right margin of the table.



shifts the visible table segment up by one line.



shifts the visible table segment down by one line.



shifts the visible table segment so that the first line is displayed.



shifts the visible table segment so that the last line is displayed.



shifts a full-screen table segment up by so many lines as there are lines visible.



shifts a full-screen table segment down by so many lines as there are lines visible.

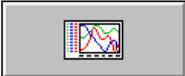
F 6.9 Compiling a record (document)

The "Document" part of the program serves for printing the record and for compiling the record contents. It is there that the arranging of the record contents and the printing of the record are carried out, rather than in the measuring program. Diagrams, tables and statistical data can be transferred from the measuring program to the "Document" program module. For further information on the "Document" program module, see section L: The "Document" Program Module.

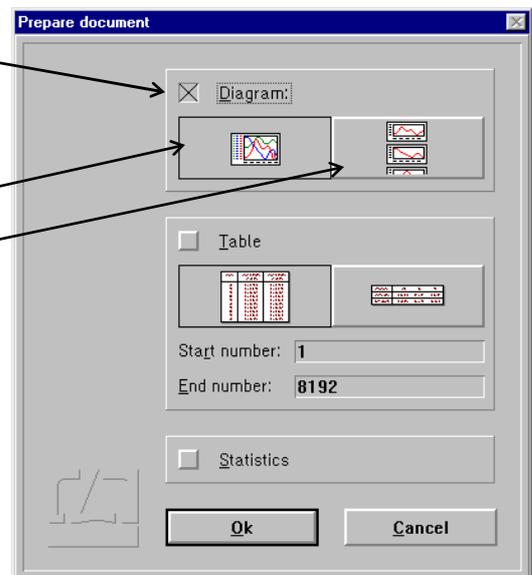


Click the button or call the "Prepare document" option of the "Diagram" menu to display the "Prepare document" dialog box.

If the "Diagram" switch is activated () , the diagram displayed on the screen immediately before the "Prepare document" dialog box was called is transferred to the "Document" program module.

With the buttons  and  you can select whether all series

of measurements are to be presented in one diagram or whether you want to have each series of measurements to be represented by an extra diagram and transferred to the "Document" program module. The latter option is recommended if you use a black-and-white printer, since the great number of measured data does not allow the printing of dashed lines.



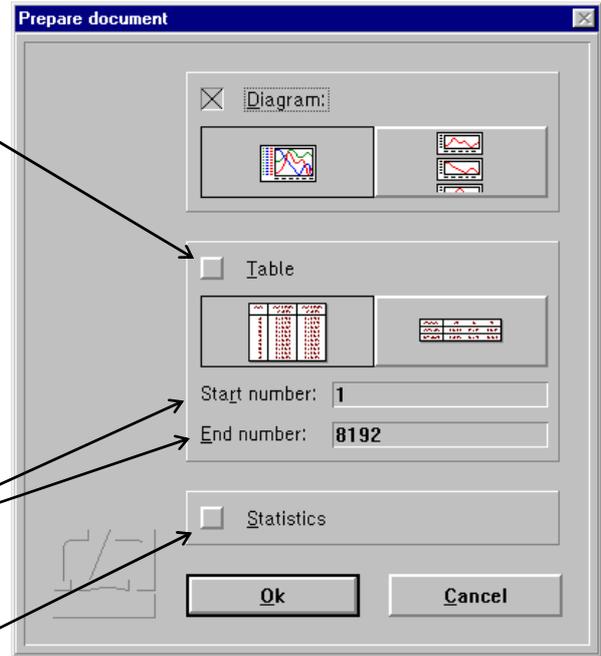
If the "Table" switch is activated, the buttons



and

can be clicked to select between horizontal and vertical arrangement of measured data in the table. In case of horizontal arrangement, the table is split up and transferred to the "Document" program module in the form of several tables if all the measured data do not fit into one line. When recording a table, please mind that a printed text page has about 60 lines. If a great number of readings have been taken, you should select which of them to be transferred into a table. For this you can use the "Start number" and "End number" input boxes.

If the number of measured data between the first and last readings entered exceeds 1000, the program will restrict the table to 1000 readings.



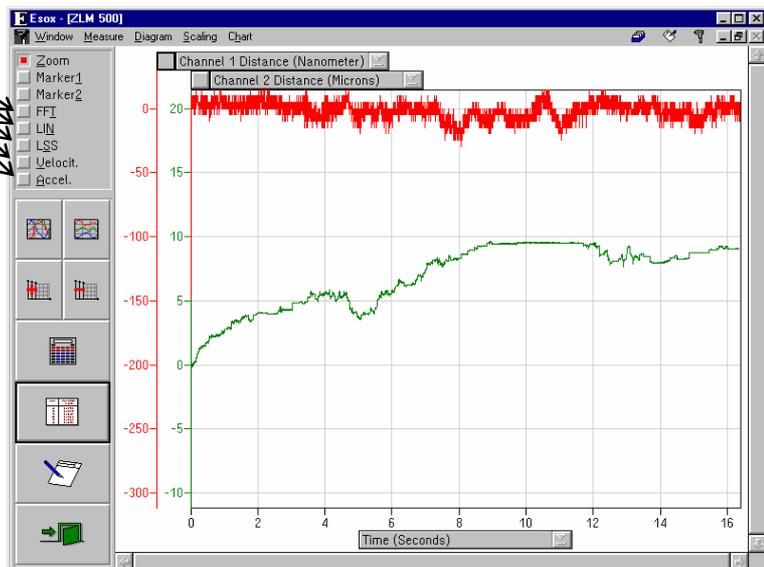
Click the "Statistics" switch to transfer to the "Document" program module the number of readings, the mean value, the standard deviation, the maximum reading, the minimum reading and the maximum-to-minimum variation of the readings that were visible in the diagram immediately before the "Prepare document" dialog box was called.

F 6.10 Velocity, acceleration, Fourier analysis, least-squares line and deviation from expected (nominal) positions

A section of the graph of a measurement series can be selected and subjected to a variety of operations to obtain further data. Before you can select such an operation you need to tell the program which series of measurement you want to operate on. Do this by clicking the button at the top end of the respective ordinate.

Next, select the kind of operation by clicking the respective option button.

Now select the desired section of the data series. This is only possible with the mouse.





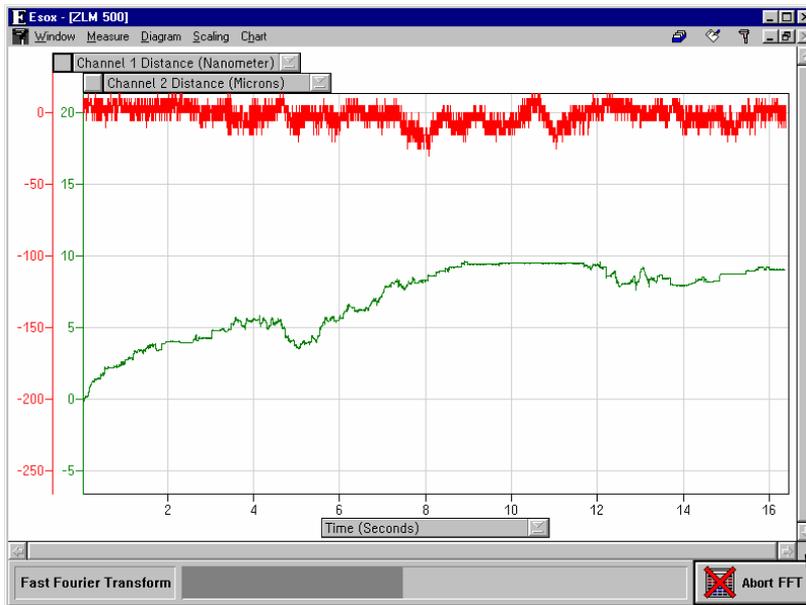
Move the mouse cursor to a corner of the diagram section to be further analysed. Click and hold the left mouse button. Then drag the mouse until the movable frame encloses the diagram section of interest. Release the left mouse button.

Except for the Fourier analysis, the data series newly computed is shown in the diagram with a new ordinate.

The functions released by the option buttons after selection of the diagram section are explained below.

F 6.10.1 Fourier analysis

With an active "FFT" option button or "**Fourier analysis mode**" option of the "**Diagram**" menu, a Fourier analysis is carried out for the diagram segment selected.



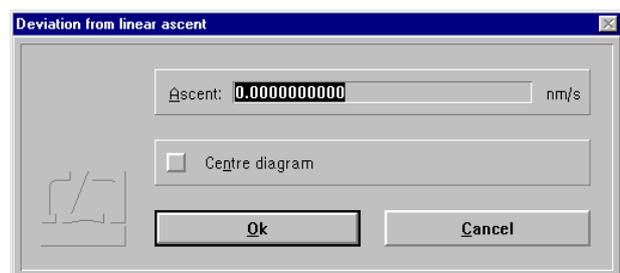
Since Fourier analysis takes a longer time with a greater number of measured data, a status bar with an abort button is displayed at the bottom of the window.

While the fast Fourier transformation is running, you can switch to another program module or another Windows program.

F 6.10.2 Linear deviation

With an active "**LIN**" option button or "**Linear deviation mode**" option of the "**Diagram**" menu, a diagram is generated showing the distance deviation from a straight line with preselected ascent (gradient).

Enter the ascent into the "Deviation from linear ascent" dialog box.



F 6.10.3 Deviation from least-squares line

With an active "LSS" option button or "Least square straight mode" option of the "Diagram" menu, a new diagram is generated from the selected section of the activated series of measurements, which shows the deviations from a least squares line.

F 6.10.4 Velocity and acceleration

With the "Veloc(ity)" or "Accel(eration)" option button activated, or the "Velocity mode" or "Acceleration mode" option selected in the "Diagram" menu, the program computes from the selected segment of the active series of measurement data a series of velocity or acceleration data, respectively.

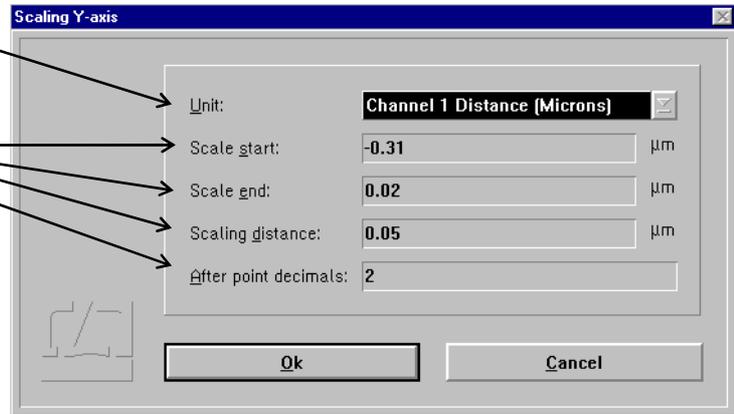
Velocity can be computed from measured distance or angle data, but not from linear or angular deviations. Acceleration can be computed from measured distance data or from velocity data.

F 6.11 Rescaling of diagram axes

The program has an automatic algorithm for the automatic scaling of diagram presentations. If you want to change the unit of measurement or the coordinate scales to be applied to the display before you transfer a diagram to the "Document" program module for record compiling and printing (see sect. F 6.9 "Compiling a record"), use the menu options "Diagram - Abscissa scaling" or "Diagram - Ordinate scaling". Such a change will only remain valid until the visible diagram segment is changed by zooming or scrolling. Before you rescale an ordinate axis you need to select the respective ordinate by clicking the  button at its top end.

The drop-down list box "Unit" can be opened to change the unit.

In the four input boxes below this you can specify the required scaling.



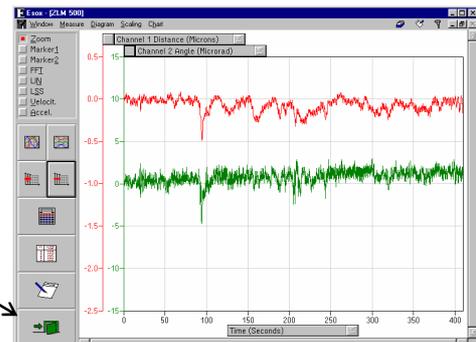
F 6.12 Exiting the diagram presentation

To exit the diagram presentation and return to the display of the current

readings, activate the



button or choose the "End diagram" option of the "Diagram" menu.



F 7 Analysis of previous measurements

After the measurement a file card is created and the measurement results written on it. These cards are managed by the program module "Cardfile". It lets you load the card with the results of an earlier measurement so that you can analyse them in the ways described in section F 6.



To load a card, first click the  button or select the "Card" option of the "Cardfile" menu.

This will change the screen display.

The left half of the window shows a file cabinet with 6 file boxes (drawers).

The right half of the window contains a field with one file card - the one whose data can presently be processed by the program.

If you want to process the data obtained in one of the previous measurements, you need to open the cabinet drawer containing the desired card, select the card from the drawer and move it into the field on the right.

The following subsections briefly describe how card boxes are opened and closed, and how cards are shifted, loaded into the main memory and placed back into the cabinet.

For further details of handling file cards, see section "K - Cardfile / Archiving of measurement Results".

F 7.1 Changing the selected (highlighted) card field

One card field or one card box label field is shown highlighted, i.e. white lettering on black background.



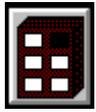
With the cursor keys , ,  and  you can move from one card field or card box label to another.

With the  key you can move from the previously highlighted card field on one side of the screen to the card field on the other side of the screen that was highlighted there last.



Click on the card field or card box label you want to highlight. Please note: Clicking on an already highlighted box label will open the respective box.

F 7.2 Opening and closing a card box

	Opening	Closing
	If the label of the card box is not highlighted, use  ,  ,  and  to move to this label. Then press  .	If necessary, press  ,  or  to move to the respective side of the screen. Then press  .
	If the label of the card box is not highlighted, click on the label once to highlight it; click on the label again to open the box. If the label of the card box is already highlighted, click on it once to open the box.	Click the  button at the bottom right or left of the window to close the right or left card box.

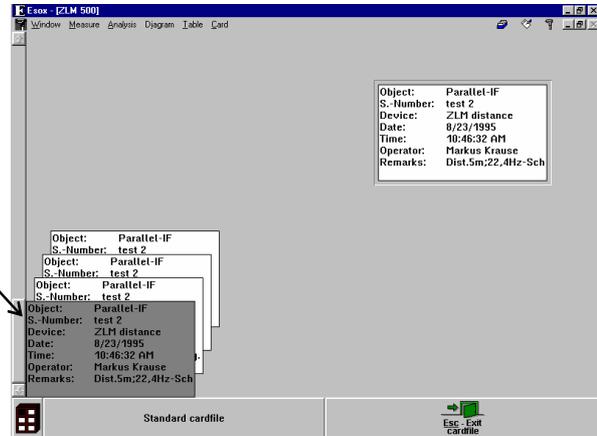
F 7.3 Shifting of file cards

The cards in an open card box can be shifted to activate (and highlight) another card. Cards arranged in front of the current card are not displayed.

The vertical scroll bar shows the location of, and the amount of space occupied by, the current card with respect to all cards of the box.



The vertical scroll bar can be used to shift the cards.



Shifting the card with the keyboard requires that the first card on the left is highlighted.



- The file cards are shifted backward by one position. The card in the order before the card that was current last becomes the new current card.



- The file cards are shifted forward by one position. The card in the order behind the card that was current last becomes the new current card.



- The file cards are shifted backward by one screen page. The first card of the previous page becomes the new current card.



- The file cards are shifted forward by one screen page. The first card of the next page becomes the new current card.

F 7.4 Loading and unloading of file cards



The easiest way of loading a card is by using the mouse. Move the mouse pointer on the source card, click and hold the left mouse button down. Now drag the mouse pointer with the file card to the target position, then release the mouse button.

If the main memory already contains a card, the program will automatically put it back to its previous position in the card box.

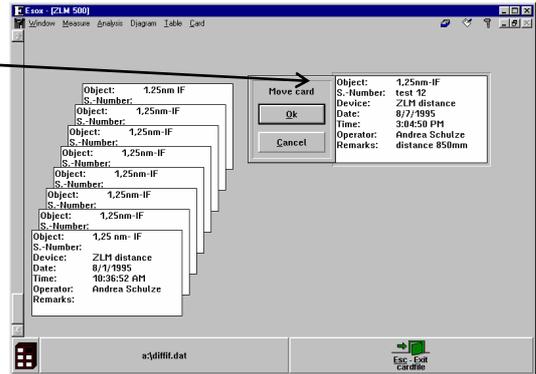
Proceed analogously when putting a loaded card back into its box. Click on the card and drag it to its target position. By dragging the mouse pointer with the card up to the upper or lower margin of the window you can shift the card stack in the box on the left.



Loading a card with the keyboard requires that the card must first be highlighted on the left half of the screen.

Now select the "**Load**" option from the "**Cardfile**" menu.

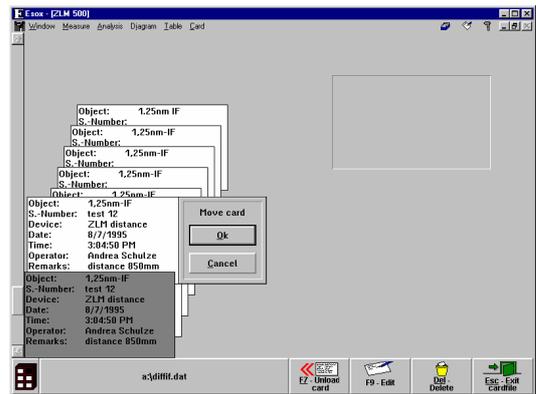
The screen shows a field with the card to be loaded.
Press the  key.



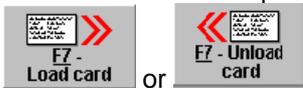
Putting a card back requires that it must first be highlighted in the main memory field represented on the left half of the screen. Then select the **"Move"** option from the **"Cardfile"** menu.

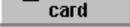
The target position can be selected with the direction keys.

Conclude by pressing the  key.



Instead of the menu options "Load" and "Move" of the "Cardfile" menu you can also use the



or  button at the bottom of the screen.

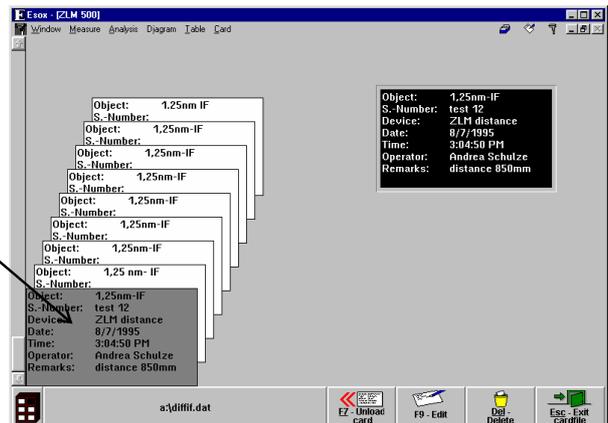
The target position can alternatively be selected with the scroll bar on the left margin.

The keys ,  and  can be used to page up and down for finding remote target positions.

It is thus possible to move a card from a left-side source position to a left-side target position, for the purpose of rearranging the cards.

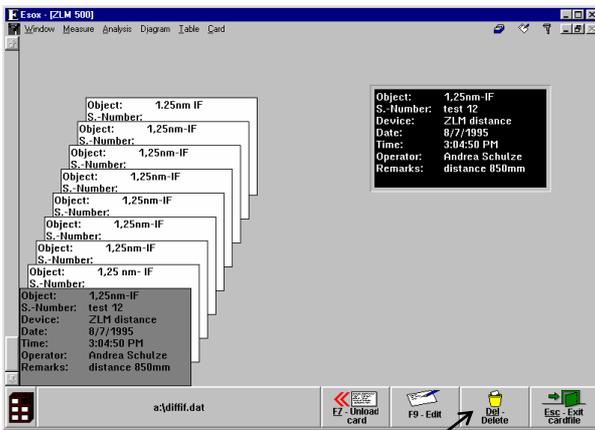
If a card has been loaded into the main memory, it still remains also visible at its source position on the left side, but it is shown here with black lettering on a grey background.

Such a "greyed-out" card cannot be moved from its place.

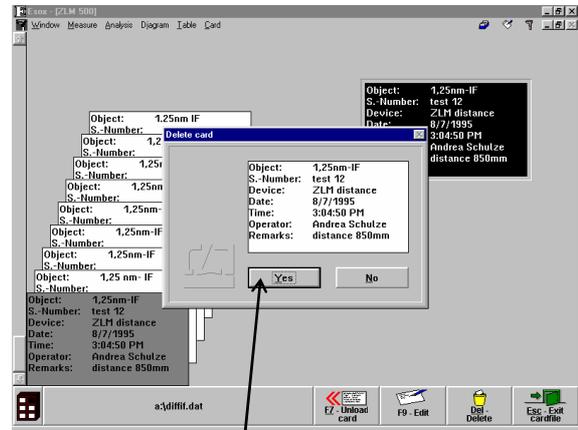


F 7.5 Deleting a file card

A card you want to delete must first be highlighted.



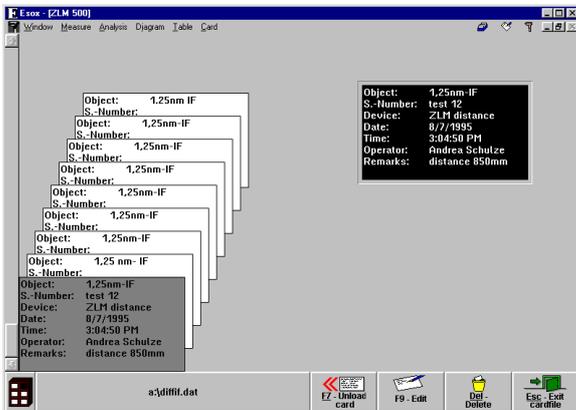
Select the **"Delete"** option from the **"Cardfile"** menu or click the  button. This opens a dialog box.



Click the  button to delete the highlighted card.

F 7.6 Editing of cards and card box labels

First highlight the card or the card box whose inscription you want to edit.



Start the text input mode by selecting the **"Edit"** option from the **"Cardfile"** menu or by clicking the  button.

Annex III contains a list of keys and key combinations that have special functions in the editing of text boxes. In addition you can use the following keys for moving within a card:



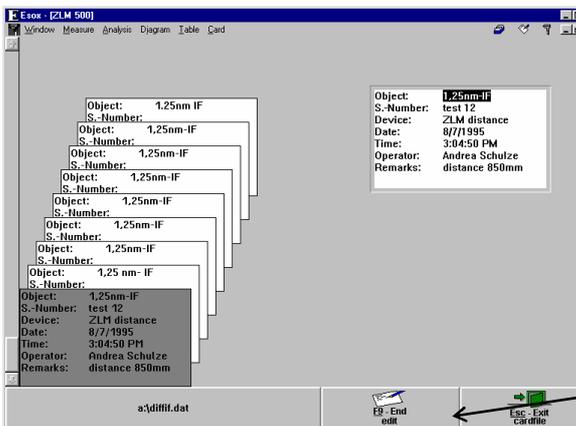
- moves the text cursor to the next card entry in the same line.



- moves the text cursor to the next lower card entry.



- moves the text cursor to the next upper card entry.

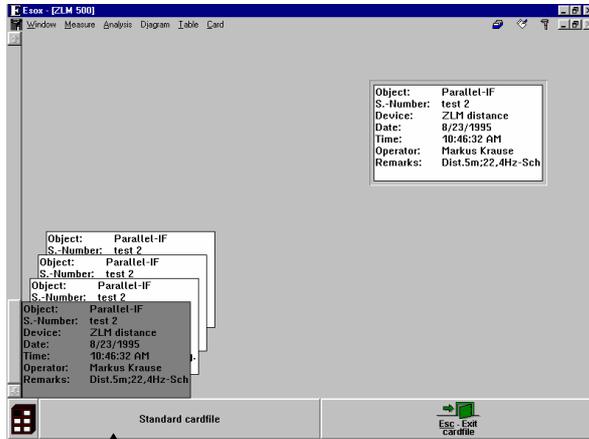


With editing finished, you need to quit the text input mode by selecting **"End edit"** in the **"Cardfile"**

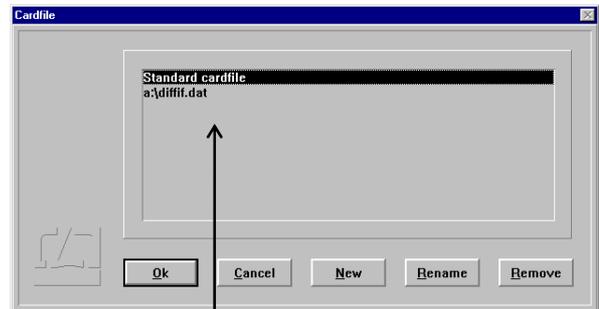
menu or clicking the  button.

F 7.7 Creating, renaming and deleting a card file

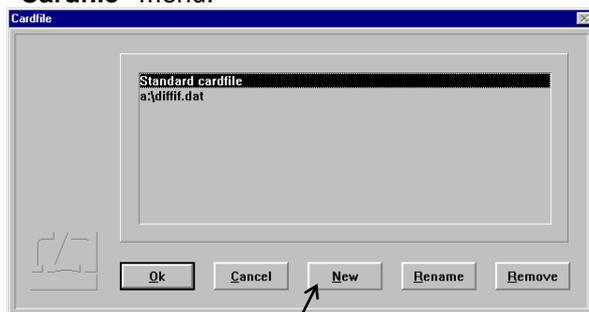
When the program is started first, it creates a card file named "Standard Cardfile" in the system data file "esoxm.dat" located in the installation path. It is possible to create further data files. Each data file comprises a card file cabinet with six card boxes.



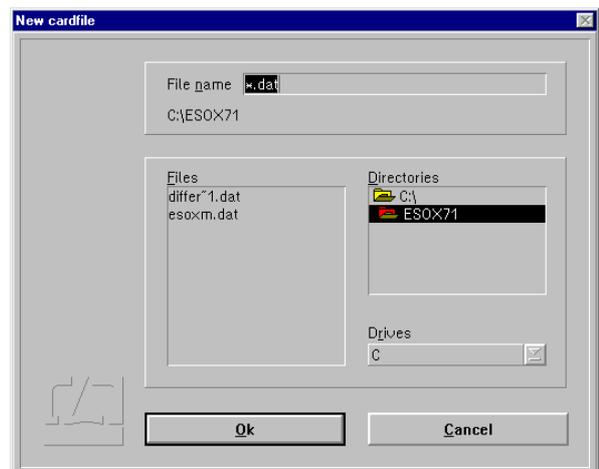
To create a new card file, click on the file name button at the bottom left window margin, or select the menu option "Open cardfile" from the "Cardfile" menu.



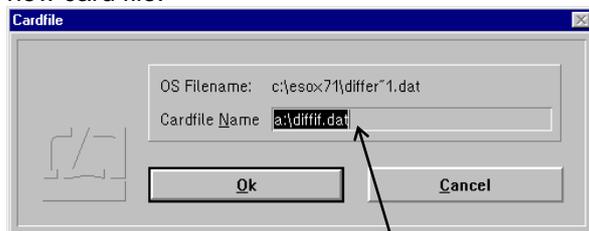
This opens a list showing the names of all existing card files in a dialog box.



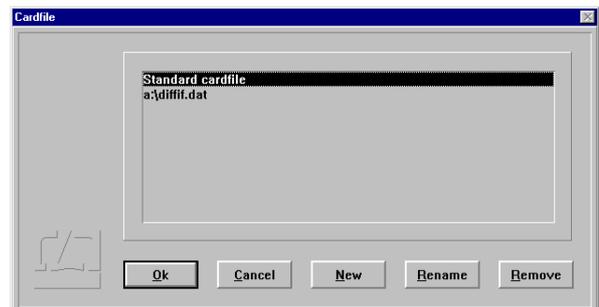
Click the **New** button if you want to create a new card file.



This opens another box in which you must enter the name of the data file.



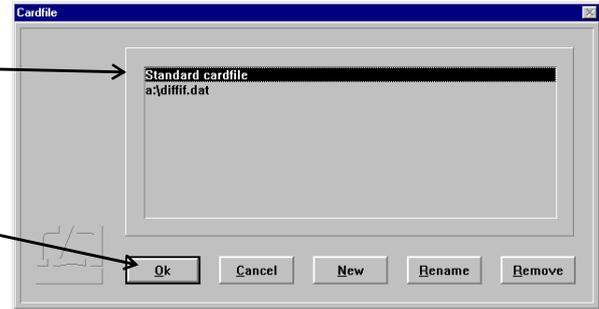
Click the **Ok** button to open another dialog box, in which you must enter a card file name, which then appears in the card file list.



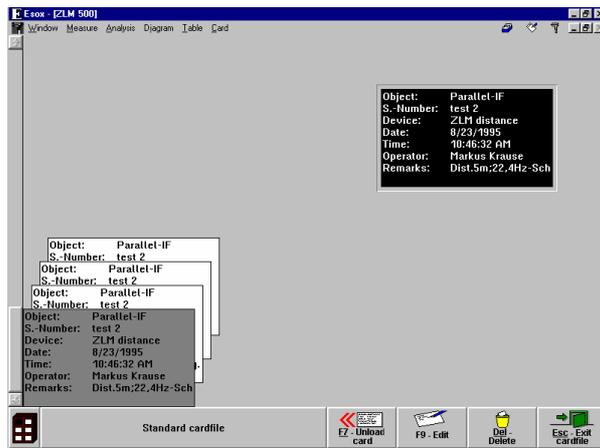
The same dialog box is opened if you use the **Rename** button to rename a card file.

Click the **Remove** button if you want to delete a card file from the card file list. This will not, however, delete the data file from the memory. For deleting the data file, use the file manager.

To select a card file from those created, highlight the file name in the list box and then click the **Ok** button.



F 7.8 Quitting the Cardfile menu



To quit the Cardfile menu, click the **Esc - Exit cardfile** button or select the "Exit" option from the "Cardfile" menu.

F 8 Exiting the measurement program



To exit the "ZLM-Synchron" program module, activate the **Esc - Exit cardfile** button or choose the "Exit measurement program" option of the "Measure" menu.

G “ZLM Position” - Calibration Software

A number of standards authorities and institutions have issued standards and recommendations for the inspection of coordinate measuring machines and machine-tools.

The "Position" measuring program is designed for the inspection of coordinate measuring machines and machine-tools in accordance with the following standards,

- ISO 230
- VDI/DGQ 3441
- VDI/VDE 2617
- NMTBA

by means of position measurements and their statistical analysis. The VDI/VDE 2617 recommendation also covers straightness, squareness and angle measurements, for which other programs within the range of ZLM software are available.

The first part (G 1) of this chapter on the "Position" measuring program deals with the principles of the measurement and analysis procedures. The second part (G 2) describes the operation of the measurement program.

G 1 Principles of Measurement and Analysis

Objective of measurement in inspecting machine-tools: Assessment of the accuracy to which components can be machined

Objective of measurement in inspecting coordinate measuring machines: Assessment of the machine's measuring accuracy

Result of a measurement: Relevant standards define parameters and recommend graphs by which the systematic and random deviations from the ideal state of a machine can be assessed. The present program supplies these parameters and diagrams as results of measurements.

The standards and recommendations quoted above specify **identical measurement methods**. They differ mainly by their ways of calculating the parameters and presenting the results graphically.

G 1.1 Methods of measurement

Along a line corresponding to the path of a laser beam, the software moves the machine under test to a number of positions, each from both directions.

For the acquisition of measurement data, the following points should be minded:

- Establish at least one line parallel to each machine axis of interest, along which measurement positions can be moved to.
- Measurement positions should be distributed throughout the range of travel.

Further recommendations on selecting measurement positions are given by the standards quoted.

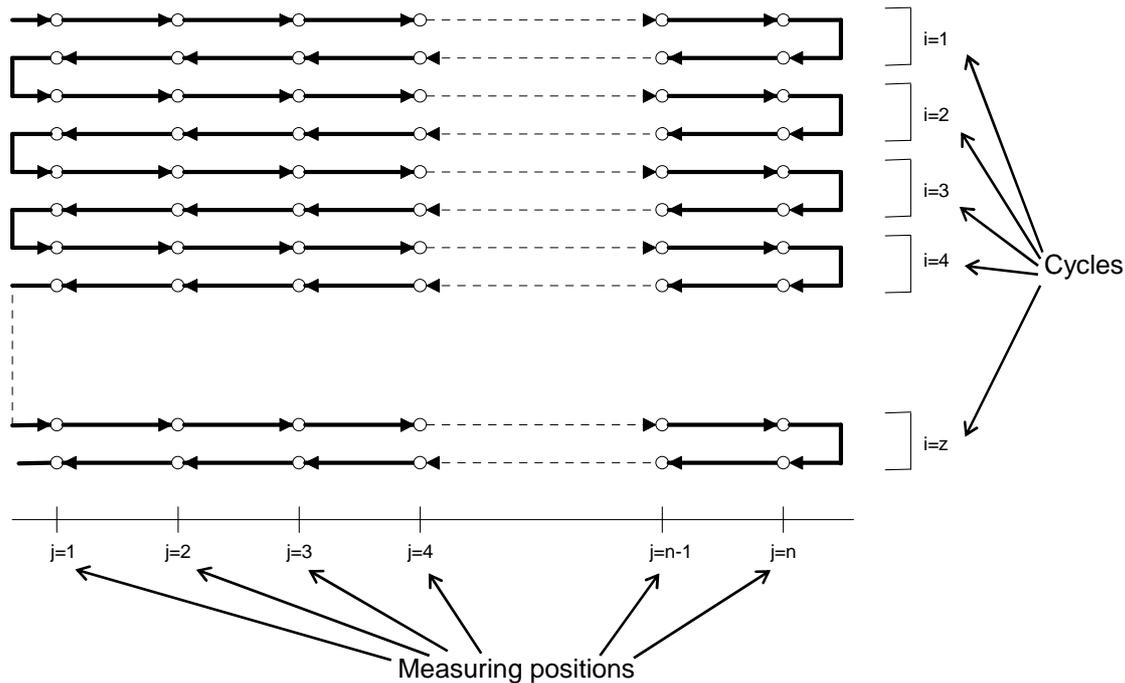
Standard	Minimum number, absolute	Minimum number per scale element	Equation for establishing nominal positions
ISO 230	5 (for measured lengths up to 1 m) 5 per metre (for measured lengths up to 2 m)	1	$P_j = N \cdot p \cdot r$ P_j - nominal position N - integer r - random decimal fraction p - greatest period
VDI/DGQ 3441	10 per metre + 1 (for measured lengths up to 2 m)	1	
VDI/VDE 2617	11	2	

G 1.2 Positioning methods

In order to yield statistical information on its positioning behaviour, the object under test must be moved to a number of positions several times. Among the positioning methods used in practice, the program supports the linear, unidirectional linear, oscillation (also called "pendulum-step") and quasi-pilgrim step ("quasi-pilger") methods.

G 1.2.1 Linear method

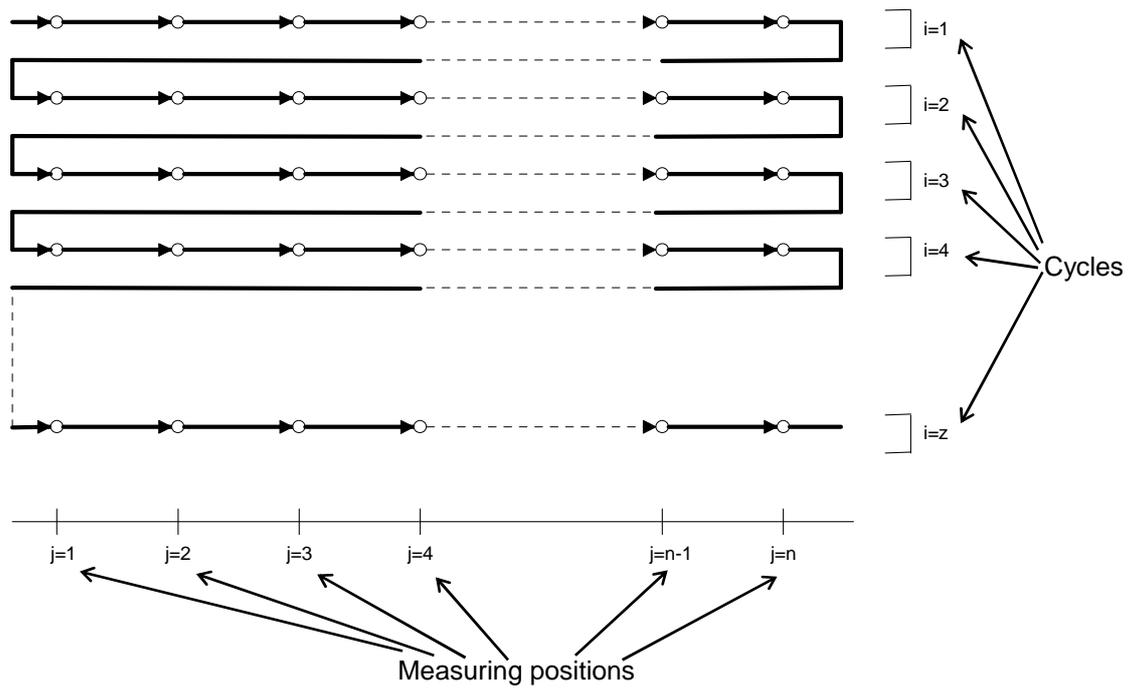
With the linear method, all positions are first travelled to in succession in the positive direction and then again in succession in the negative direction. The whole procedure is repeated several times (cycles).



In order to ensure that the first and last positions in each cycle are travelled to from the correct direction, it is necessary to provide an approach length at the start of the procedure, and a return loop at the end of each half-cycle.

This positioning method is easy to program. With great distances between positions, however, the total measurement takes considerable time. Greater temperature variations during that time will affect both the backlash error (reversal span) and the position spread (see section G 1.3).

G 1.2.2 Unidirectional linear method

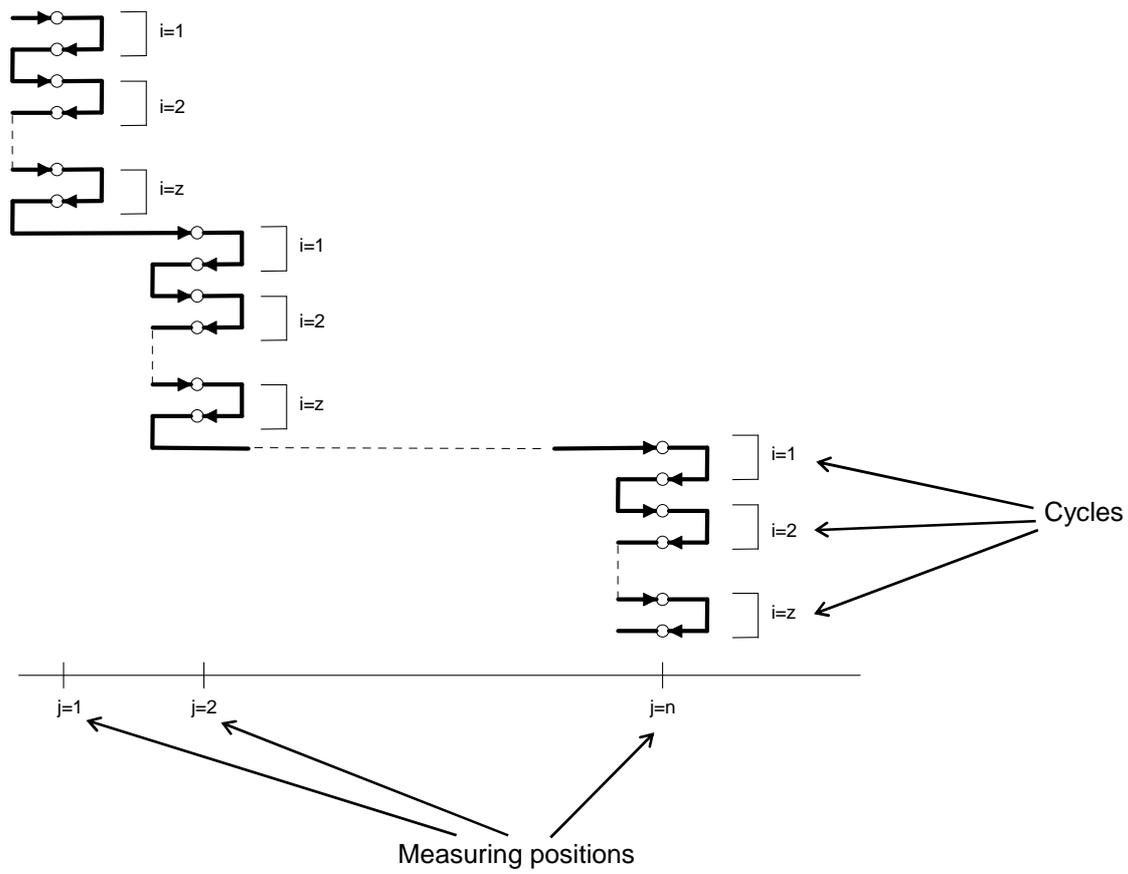


If it can be assumed that the differences between positioning in positive and positioning in negative directions are negligible (i.e. a small backlash error (reversal span)), the unidirectional linear method suggests itself.

In an extreme case one might also make a single-cycle rapid test.

Mind, however, that the standard analysis procedures issued by the standardization bodies (described in section G 1.3) do not provide for this positioning method.

G 1.2.3 Oscillation ("Pendulum-step") method

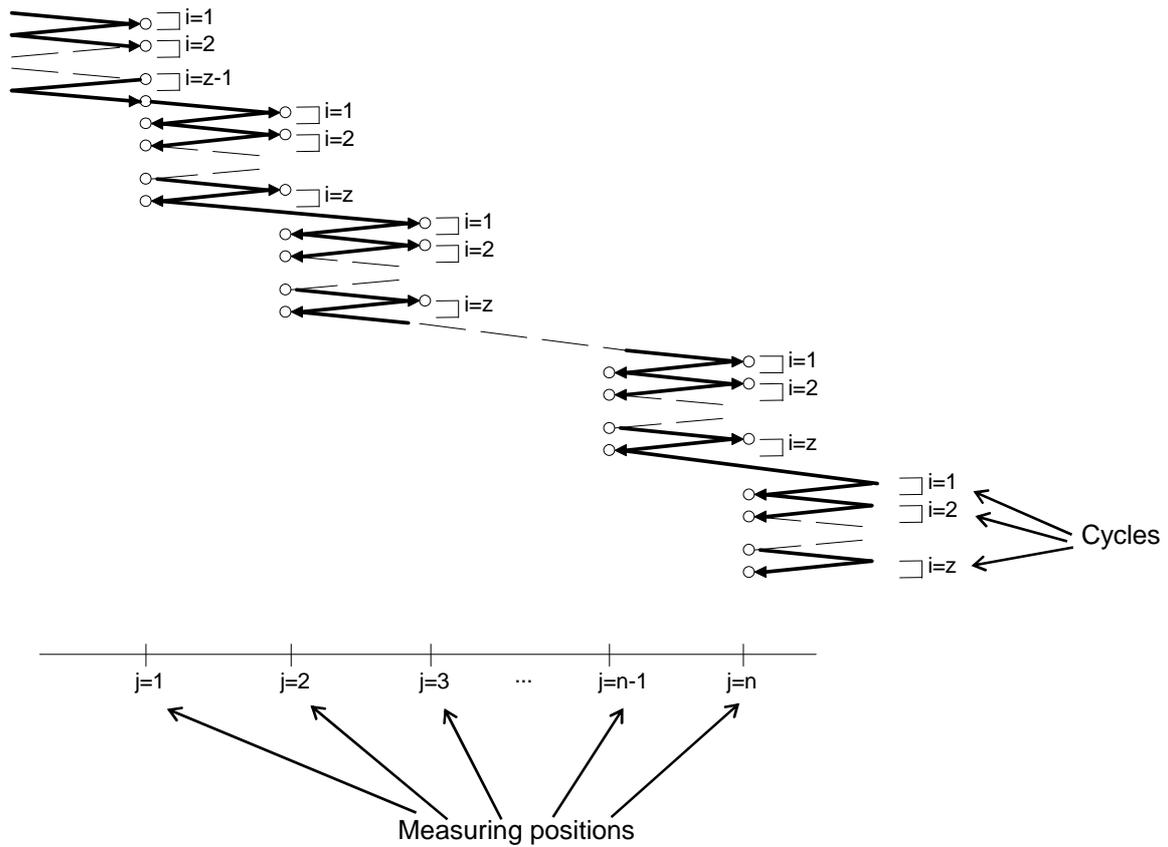


With this method, each measurement position is repeatedly travelled to, alternatingly from the positive and negative directions, before the measurement proceeds with the next position.

Of all the methods described, the Oscillation method involves the shortest total length of travel. This is of advantage especially where the positions are spaced far apart.

Great temperature variations during the measurement affect neither the backlash error (reversal span) nor the position spread (see sect. G 1.3). However, because of the long time passed between measuring the first and measuring the last position, thermal and other influences occurring during that time enter the measurement as systematic errors.

G 1.2.4 Quasi-pilgrim step ("Quasi-pilger") method



With this method, the first measurement position is travelled to several times in positive direction. Next, alternating travels are performed to the second position in positive direction and to the first position in negative direction. The pattern of alternating travels to the j^{th} and $(j+1)^{\text{th}}$ positions is continued until the last position has been travelled to repeatedly in the positive direction. Finally, the last position needs to be travelled to repeatedly in the negative direction.

Same as with the Oscillation method, great temperature variations during the measurement do not affect the backlash error (reversal span) nor the position spread, but enter the measurement as systematic errors.

G 1.3 Standard analysis procedures

The relevant standards and recommendations differ greatly in their procedures of computing the parameters and in their modes of presenting the result graphically.

What they all have in common is that they define a set of parameters that separately characterize

- systematic position deviations,
- random position deviations, and
- composite (systematic plus random) deviations.

These three kinds of parameters can also be obtained separately from the graphs established according to all the standards concerned.

Let the significance of the parameters be explained by the example of a machine-tool:

Systematic position deviations:

The standards concerned, except ISO 230, define a "**Position deviation**". With a certain quantity of like parts being machined on a machine-tool, the "Position deviation" indicates the average machining error to be expected for the parts.

The standards concerned, except for NMTBA, specify a "**Backlash**" (ISO) or "**Reversal span**" (the other standards). The "Backlash" or "Reversal span" indicates the average effect to be expected if in the machining process a position is travelled to from one position instead of the other.

Random position deviations:

The "**Position spread**" indicates the maximum differences to be expected in at least 99.5% of the machined parts. (As an exception, VDI/VDE 2617 specifies the position spread for coordinate measuring machines, computed for 95% of the reading errors to be expected.)

Composite position deviations:

The "**Position uncertainty**" indicates the machining error to be expected in a 99.5% yield, irrespective of the positioning direction.

The charts on the following pages show how the parameters and graphs are computed according to the different standards.

VDI/DGQ 3441	z - Number of measuring cycles	x_{ij} - Deviation (actual-nominal) at position j during cycle i
	n - Number of positions	↑ - Positive travel direction
	i - Cycle number	↓ - Negative travel direction
	j - Position number	

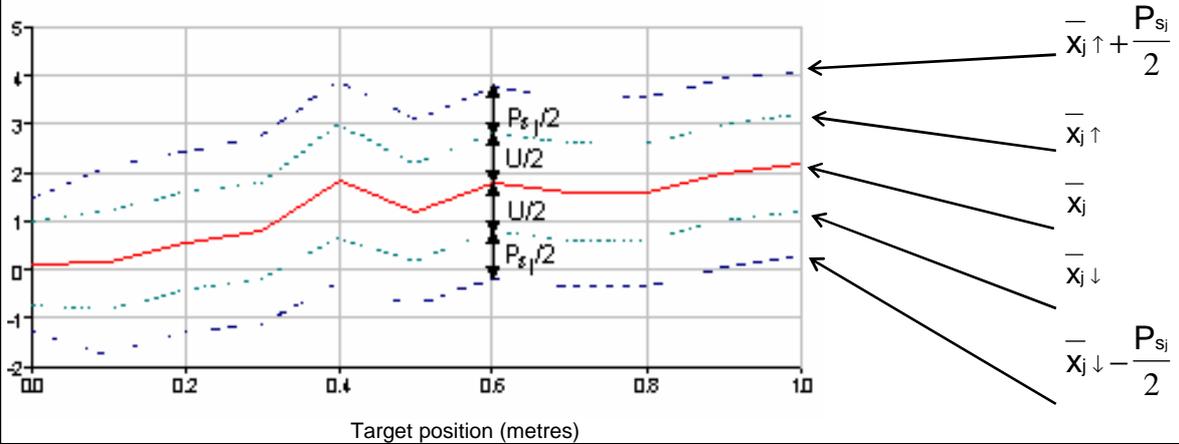
Diagram:

Average deviation: $\bar{x}_{j\uparrow} = \frac{1}{z} \sum_{i=1}^z x_{ij\uparrow}$ $\bar{x}_{j\downarrow} = \frac{1}{z} \sum_{i=1}^z x_{ij\downarrow}$ $\bar{x}_j = \frac{\bar{x}_{j\uparrow} + \bar{x}_{j\downarrow}}{2}$

Position spread: $P_{sj} = 3 \cdot \left(\sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\uparrow} - \bar{x}_{j\uparrow})^2} + \sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\downarrow} - \bar{x}_{j\downarrow})^2} \right)$

Reversal span: $U_j = |\bar{x}_{j\uparrow} - \bar{x}_{j\downarrow}|$

Deviation (micrometers)



Parameters:

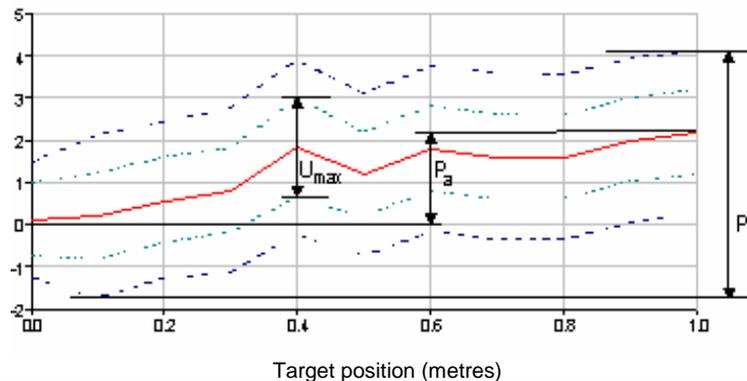
Position spread $P_{s\max} = \max[P_{sj}]_{j=1}^n$ $P_{s\mit} = \frac{1}{n} \sum_{j=1}^n P_{sj}$

Reversal span $U_{\max} = \max[U_j]_{j=1}^n$ $U_{\mit} = \frac{1}{n} \sum_{j=1}^n U_j$

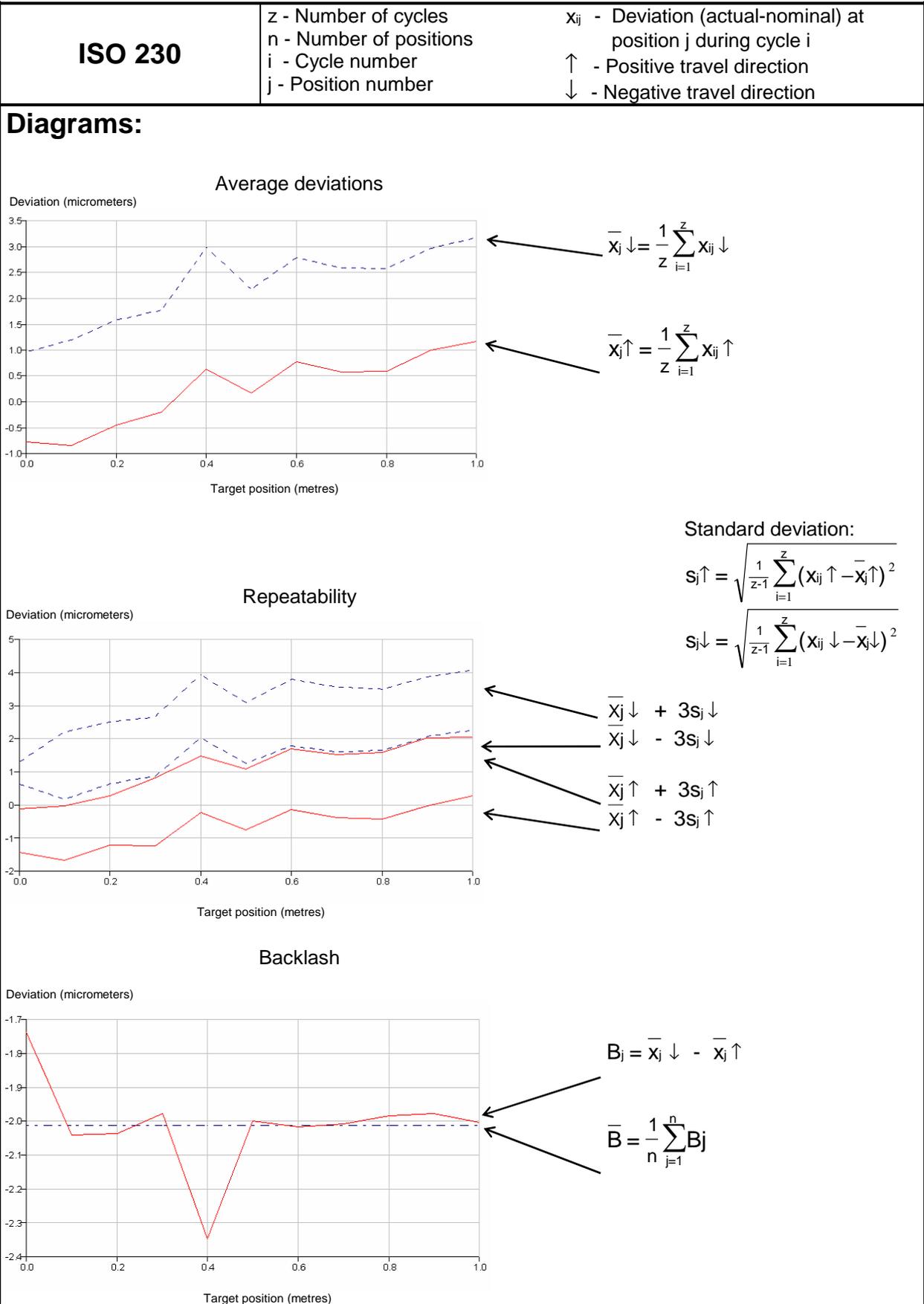
Position deviation $P_a = \left| \max[\bar{x}_j]_{j=1}^n - \min[\bar{x}_j]_{j=1}^n \right|$

Position uncertainty $P = \max \left[\bar{x}_j + \frac{1}{2}(U_j + P_{sj}) \right]_{j=1}^n - \min \left[\bar{x}_j - \frac{1}{2}(U_j + P_{sj}) \right]_{j=1}^n$

Deviation (micrometers)



VDI/VDE 2617	<p>z - Number of cycles n - Number of positions i - Cycle number j - Position number</p>	<p>x_{ij} - Deviation (actual-nominal) at position j during cycle i ↑ - Positive travel direction ↓ - Negative travel direction</p>
Diagram:		
Average deviation:	$\bar{x}_{j\uparrow} = \frac{1}{z} \sum_{i=1}^z x_{ij\uparrow} \quad \bar{x}_{j\downarrow} = \frac{1}{z} \sum_{i=1}^z x_{ij\downarrow} \quad \bar{x}_j = \frac{\bar{x}_{j\uparrow} + \bar{x}_{j\downarrow}}{2}$	
Position spread:	$P_{sj} = 2 \cdot \left(\sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\uparrow} - \bar{x}_{j\uparrow})^2} + \sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\downarrow} - \bar{x}_{j\downarrow})^2} \right)$	
Reversal span:	$U_j = \bar{x}_{j\uparrow} - \bar{x}_{j\downarrow} $	
Deviation (micrometers)		
<p>The graph plots deviation in micrometers (y-axis, -2 to 5) against target position in metres (x-axis, 0.0 to 1.0). It features several data series: a solid red line for average deviation \bar{x}_j, dashed blue lines for $\bar{x}_{j\uparrow} + \frac{P_{sj}}{2}$ and $\bar{x}_{j\downarrow} - \frac{P_{sj}}{2}$, and dotted green lines for $\bar{x}_{j\uparrow}$ and $\bar{x}_{j\downarrow}$. Vertical arrows indicate $U/2$ (reversal span), $P_{sj}/2$ (position spread), and U_j (total reversal span) at a target position of 0.6 metres.</p>		
Parameters:		
Position spread	$P_{s\max} = \max[P_{sj}]_{j=1}^n \quad P_{s\mit} = \frac{1}{n} \sum_{j=1}^n P_{sj}$	
Reversal span	$U_{\max} = \max[U_j]_{j=1}^n \quad U_{\mit} = \frac{1}{n} \sum_{j=1}^n U_j$	
Position deviation	$P_a = \left \max[\bar{x}_j]_{j=1}^n - \min[\bar{x}_j]_{j=1}^n \right $	
Position uncertainty	$P = \max \left[\bar{x}_j + \frac{1}{2}(U_j + P_{sj}) \right]_{j=1}^n - \min \left[\bar{x}_j - \frac{1}{2}(U_j + P_{sj}) \right]_{j=1}^n$	
Deviation (micrometers)		
<p>This graph is similar to the one above but highlights overall parameters. A vertical arrow labeled U_{\max} indicates the maximum reversal span, P_a indicates the maximum position deviation, and a large vertical arrow labeled P indicates the total position uncertainty across the entire range of target positions.</p>		



Standard deviation:

$$s_{j\uparrow} = \sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\uparrow} - \bar{x}_{j\uparrow})^2}$$

$$s_{j\downarrow} = \sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\downarrow} - \bar{x}_{j\downarrow})^2}$$

ISO 230	z - Number of cycles	x_{ij} - Deviation (actual-nominal) at position j during cycle i
	n - Number of positions	↑ - Positive travel direction
	i - Cycle number	↓ - Negative travel direction
	j - Position number	

Parameters:

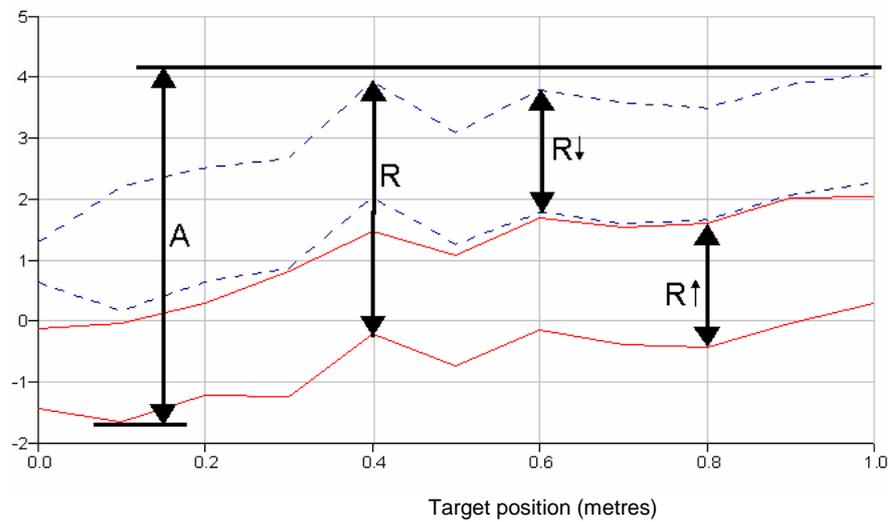
Position spread: $R = \max \left[\max \left[6s_j \uparrow, 6s_j \downarrow, 3s_j \uparrow + 3s_j \downarrow + |B_j| \right] \right]_{j=1}^n$

$R \uparrow = \max [6s_j \uparrow]_{j=1}^n$

$R \downarrow = \max [6s_j \downarrow]_{j=1}^n$

Position uncertainty $A = \max \left[\max \left[\bar{x}_j \uparrow + 3s_j \uparrow, \bar{x}_j \downarrow + 3s_j \downarrow \right] \right]_{j=1}^n - \min \left[\min \left[\bar{x}_j \uparrow - 3s_j \uparrow, \bar{x}_j \downarrow - 3s_j \downarrow \right] \right]_{j=1}^n$

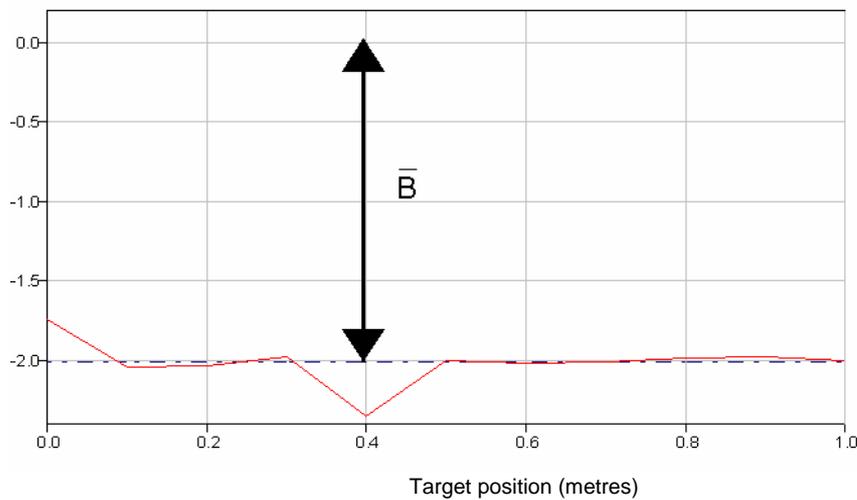
Deviation (micrometers)



Mean backlash

$$\bar{B} = \frac{1}{n} \sum_{j=1}^n (x_j \downarrow - x_j \uparrow)$$

Deviation (micrometers)



NMTBA	z - Number of cycles	x_{ij} - Deviation (actual-nominal) at position j during cycle i
	n - Number of positions	↑ - Positive travel direction
	i - Cycle number	↓ - Negative travel direction
	j - Position number	

Diagram:

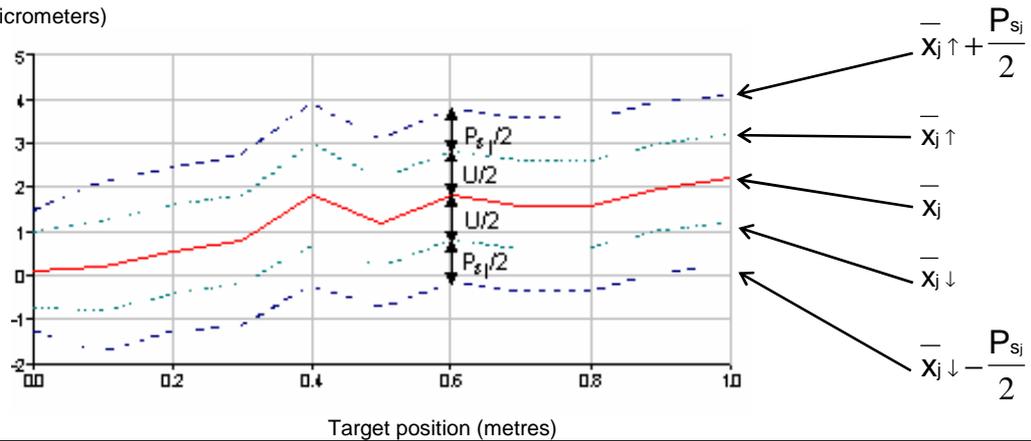
Average deviation:

$$\bar{x}_j = \frac{1}{2 \cdot z} \sum_{i=1}^z (x_{ij \uparrow} + x_{ij \downarrow})$$

Position spread:

$$P_{sj} = 6 \cdot \sqrt{\frac{1}{2 \cdot z - 1} \sum_{i=1}^z \left\{ (x_{ij \uparrow} - \bar{x}_j)^2 + (x_{ij \downarrow} - \bar{x}_j)^2 \right\}}$$

Deviation (micrometers)



Target position (metres)

Parameters:

Position spread

$$P_{s \max} = \max [P_{sj}]_{j=1}^n \quad P_{s \text{ mit}} = \frac{1}{n} \sum_{j=1}^n P_{sj}$$

Offset

$$O = -\frac{1}{2} \cdot \left(\max \left[\bar{x}_j + \frac{P_{sj}}{2} \right]_{j=1}^n + \min \left[\bar{x}_j - \frac{P_{sj}}{2} \right]_{j=1}^n \right)$$

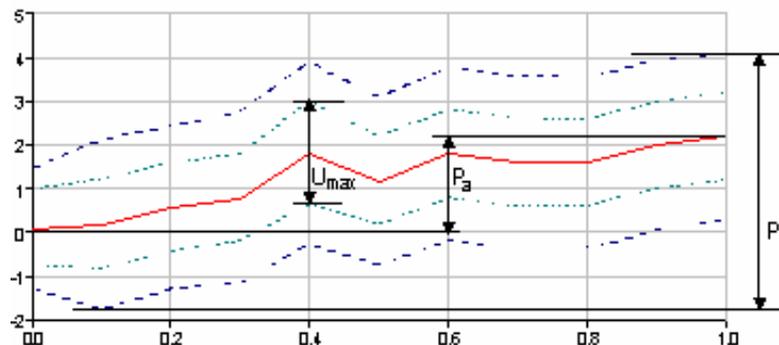
Position deviation

$$P_a = \left| \max [\bar{x}_j]_{j=1}^n - \min [\bar{x}_j]_{j=1}^n \right|$$

Position uncertainty

$$P = \max \left[\bar{x}_j + \frac{P_{sj}}{2} \right]_{j=1}^n - \min \left[\bar{x}_j - \frac{P_{sj}}{2} \right]_{j=1}^n$$

Deviation (micrometers)



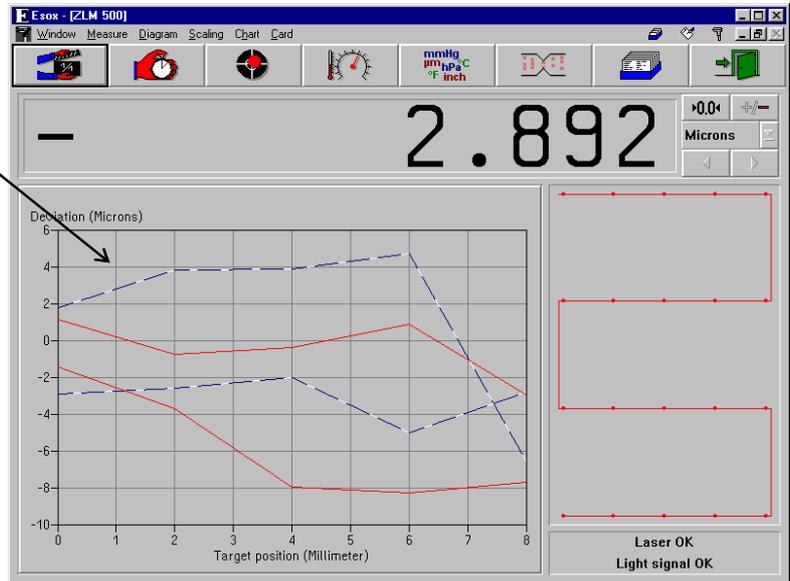
Target position (metres)

G 2.6 Analysis of a measurement

For analysing the measurements you can select between the diagrams and parameters according to the standard applied. Also available are tabulated measurement data.

After completion of a successful measurement, the bottom left portion of the screen shows a large diagram which constitutes a button.

A click on this button, or selection of the "Diagram" item in the "Diagram" menu, opens the analysis mode window.



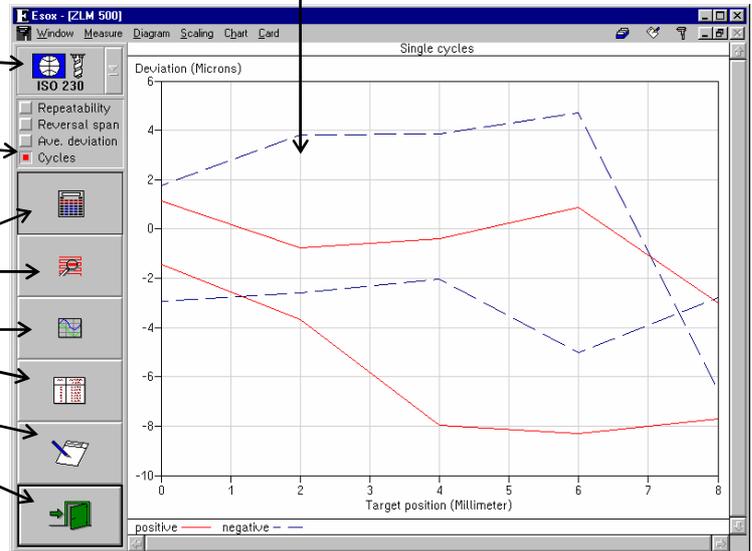
G 2.6.1 Controls for diagram handling

After calling a diagram the measurement program window is completely changed. Most of the screen area is now occupied by a diagram.

Use the drop-down list box to select the standard applicable.

In the box below this, you can select the type of diagram to be displayed.

- The buttons below this are intended for
- Displaying the parameters
- Selection of the measured data to be included in the analysis
- Autoscaling
- Opening a table of measured data
- Compilation of a record
- Quitting the diagram presentation



To move from one button to the next, press the  key.

In addition to these controls, you can also use some submenu items of the "Diagram", "Scaling" and "Table" main menus.

G 2.6.2 Selection of standard and type of diagram

The standard applicable to the analysis of the measurements can be selected at several stages of the program:

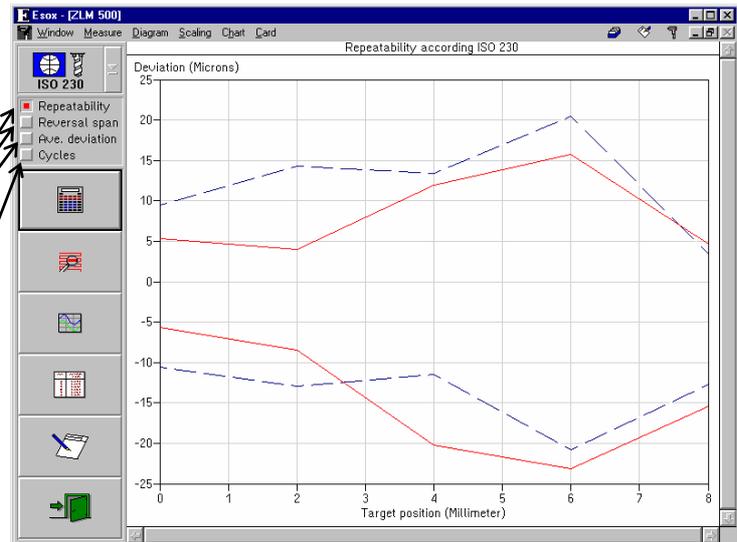
1. During preparation for measurement, in the "Parameters" dialog box.
2. By selecting the menu items "**Diagram-ISO 230**", "**Diagram-VDI 3441**", "**Diagram-VDI 2617**" and "**Diagram-NMTBA**".
3. In the drop-down list box during diagram presentation.

A change made in any of these ways will act on the entire program. Even if data of earlier measurements are read in, they will first be presented in accordance with the standard currently active.

While the standards "VDI/DGQ 3441", "VDI/VDE 2617" and "NMTBA" provide only one diagram each for analysis, the "ISO 239" standard lets you choose between three diagrams.

Use these buttons to select which diagram you want to be shown.

A click on the last of these buttons produces the numerical indication of the individual readings. This is possible with each of the standards selected.



Selection between diagram types can also be made with the following items in the "**Diagram**" menu:

- "**Position uncertainty**" (not with ISO 230)
- "**Repeatability**" (with ISO 230 only)
- "**Backlash**" (with ISO 230 only)
- "**Average deviation**" (with ISO 230 only)
- "**Cycles**"

See section G 1.3 - "Standard analysis procedures" for an explanation of the curves shown in the diagrams, and the equations for their calculation.

G 2.6.3 Parameters

By clicking the  button you can display the parameters below the diagram. The button will lock. Click it again to remove the parameter display.

Parameter display can also be activated by selecting the "Parameters" item in the "Diagram" menu.



The symbols stand for the following parameters:

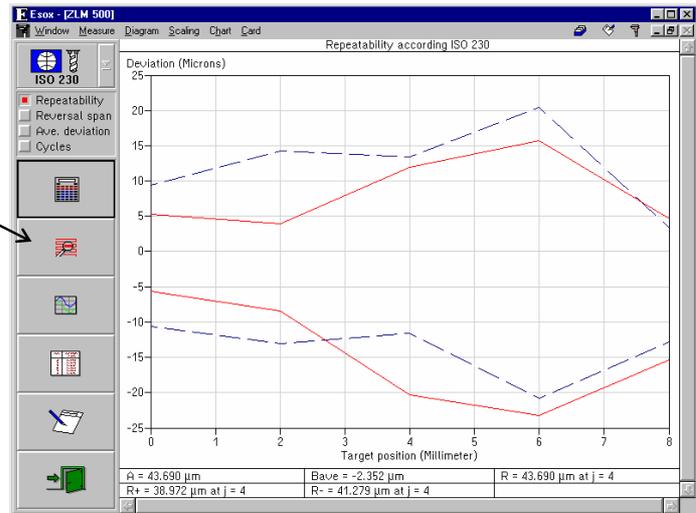
VDI / DGQ 3441 and VDI / VDE 2617	P Pa Bmax Bave Psmax Psave	Position uncertainty Position deviation Maximum reversal span (backlash) Average reversal span (backlash) Maximum position spread Average position spread
ISO 230	A Bave R R+ R-	Position uncertainty (Accuracy) Average backlash Maximum position spread (Repeatability) Maximum position spread (Repeatability), positive travel direction Maximum position spread (Repeatability), negative travel direction
NMTBA	P Pa Psmax Psave O	Position uncertainty Position deviation Maximum position spread Average position spread Offset

See section G 1.3 "Standard analysis procedures" for the equations for computing the parameters.

G 2.6.4 Selection of the measured data to be included in the analysis

If you want to analyse a partial range rather than all of the data measured,

click the  button or activate the "**Select positions/Cycles**" item in the "**Diagram**" menu to open a selection dialog.



The "**Selection of measured values**" dialog box permits you to enter the numbers of the first and the last of the cycles you want to include in the analysis. The n-th cycle means all data measured with the respective position travelled to for the n-th time from the positive direction, or for the n-th time from the negative direction.

After you change the default settings in the "Start position number" and "End position number" boxes, the analysis will only include the data measured at positions whose numbers lie between the selected limits.

In bidirectional measurements, the data measured in one of the two travel directions can be excluded from the analysis.

G 2.6.5 Zooming and scrolling of the visible diagram segment

For zooming the diagram segment shown on the screen you can use either the mouse or the keyboard.



Move the mouse cursor to a corner of the section of the diagram you want to magnify. Press the left mouse button and keep it depressed. Move the mouse until the movable frame encloses the diagram section of interest. Release the mouse button.

After pressing the **right mouse button** the full diagram is displayed again.

	Expansion by factor 2	Contraction by factor 2
horizontally		
vertically		

Use the scroll bars on the right and at the bottom of the window to shift the visible diagram portion. The slider boxes in the scroll bars indicate the location of the visible portion within the diagram.

To scroll up by 10%.

To scroll up by one windowful.

To scroll to any desired position vertically:
Click and hold the left mouse button. Drag the mouse until the square is in the wanted position.

To scroll down by one windowful.

To scroll down by 10%.

To scroll to the left by 10%.

To scroll to the left by one windowful.

To scroll to any desired position horizontally:
Click and hold the left mouse button. Drag the mouse until the square is in the wanted position.

To scroll to the right by one windowful.

To scroll to the right by 10%.

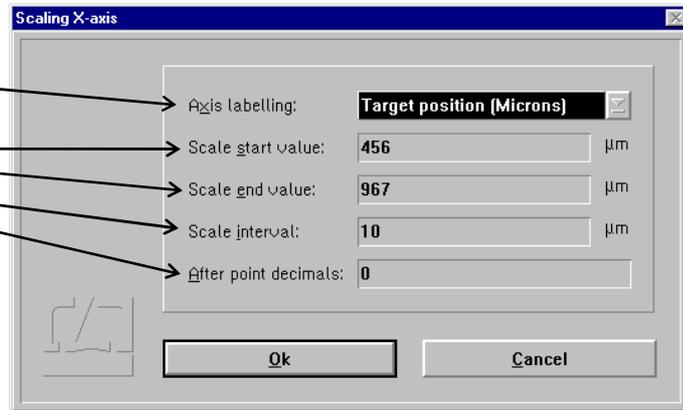
Scrolling	to the right	to the left	up	down
by 10%				
by one windowful				

G 2.6.6 Rescaling the diagram axes

When the diagram presentation is started, the program automatically scales the diagram axes. If you want to change the unit of measurement or the coordinate scales, use the options "**Scaling abscissa**" or "**Scaling ordinate**" in the "**Scaling**" menu. Such a change will only remain valid until the visible diagram segment is changed by zooming or scrolling.

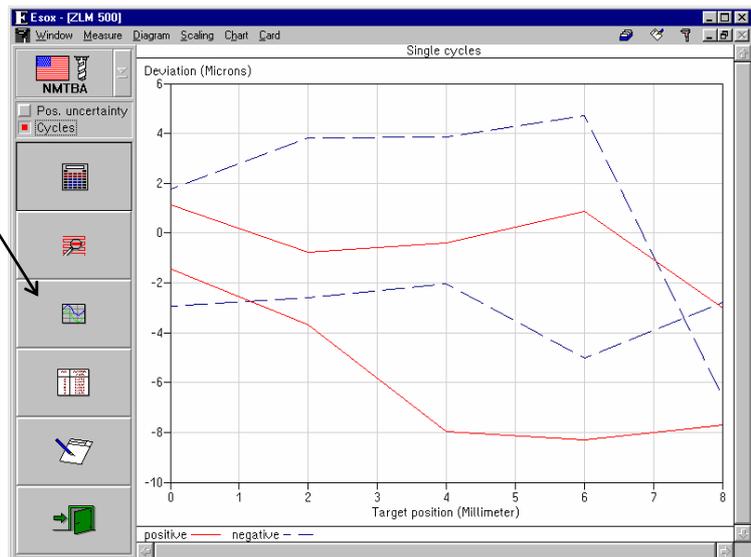
The list box "**Axis labelling**" can be opened to change the unit.

In the four input boxes below this you can specify the required scaling.



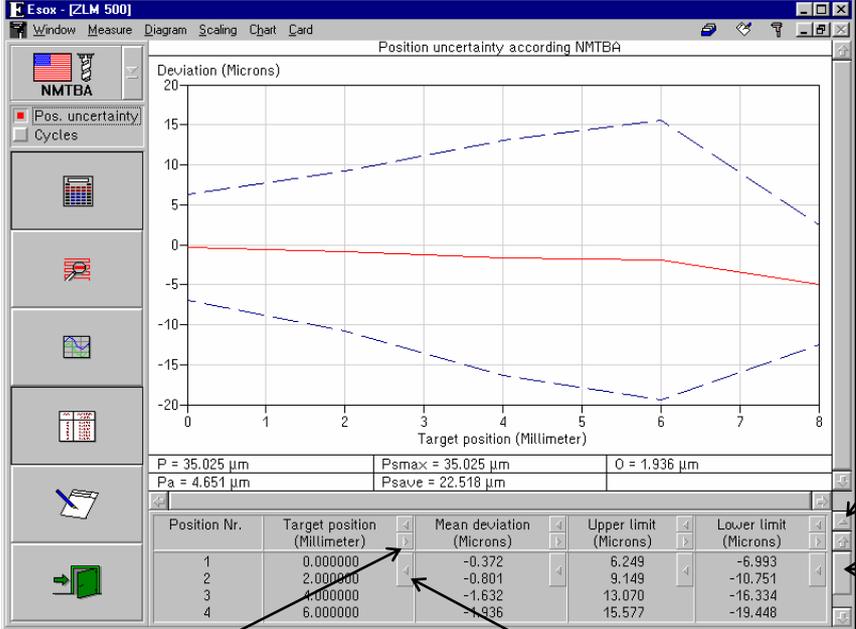
Automatic scaling (scaling same as when the diagram presentation is started) can be released

- with the  button,
- with the "**Autoscaling**" item of the "**Scaling**" menu, or
- by clicking the right mouse key on the diagram.



G 2.6.7 Tables

By clicking the  button while a diagram is displayed, a table with the measured data can be displayed in addition. The clicked button will lock. Click it again to remove the table.



Position uncertainty according NMTBA

Deviation (Microns)

Target position (Millimeter)

P = 35.025 μm P_{max} = 35.025 μm O = 1.936 μm
 Pa = 4.651 μm Psave = 22.518 μm

Position Nr.	Target position (Millimeter)	Mean deviation (Microns)	Upper limit (Microns)	Lower limit (Microns)
1	0.000000	-0.372	6.249	-6.993
2	2.000000	-0.801	9.149	-10.751
3	4.000000	-1.632	13.070	-16.334
4	6.000000	-1.936	15.577	-19.448

Button for **maximizing** the table

Scroll bars for shifting the visible portion of the table

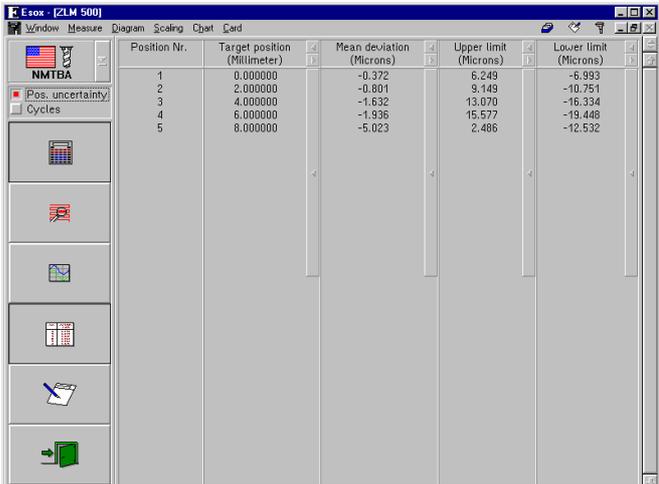
Click these buttons to select the unit of measurement.

Click these buttons to select the number of decimal places.

The table may occupy either the bottom right portion (normal size) or the entire right portion (maximum size) of the program window. In the second case, the diagram is hidden behind the table. For switching between normal-size and maximized presentation of the table, click the button at the top of the right table margin.

The functions described above are accessible with the keyboard as well, if you select, in the **"Table"** menu, the options

- ### **"No table"**,
- ### **"Small table"** or
- ### **"Big table"**



Position Nr.

Target position (Millimeter)

Mean deviation (Microns)

Upper limit (Microns)

Lower limit (Microns)

Button for switching back to normal-size presentation of the table

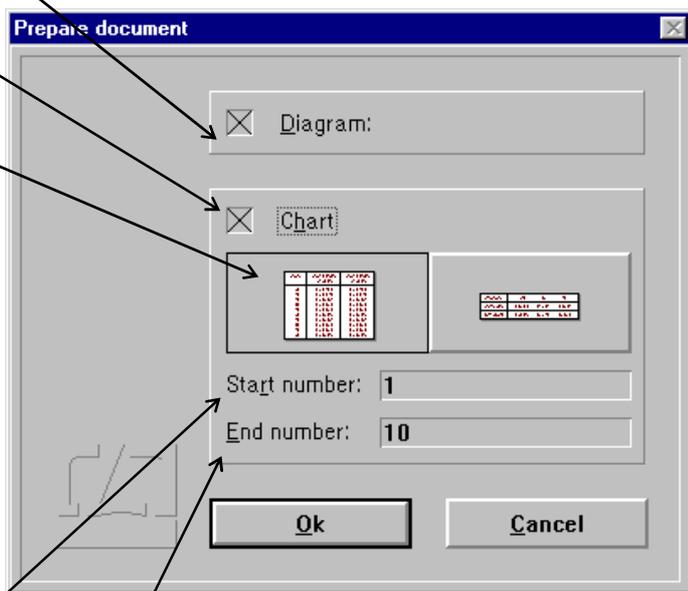
G 2.6.8 Compiling a record (document)

The "Document" part of the program serves for printing the record and for compiling the record contents. It is there that the arranging of the record contents and the printing of the record are carried out, rather than in the measuring program. Diagrams, tables and statistical data can be transferred from the measuring program to the "Document" program module. For further information on the "Document" program module, see section L - Program module "Document"

Click the  button or call the "Prepare document" option of the "Diagram" menu to display the "Prepare document" dialog box.

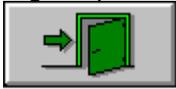
If the "Diagram" switch is activated (), the diagram displayed on the screen immediately before the "Prepare document" dialog box was called is transferred to the "Document" program module.

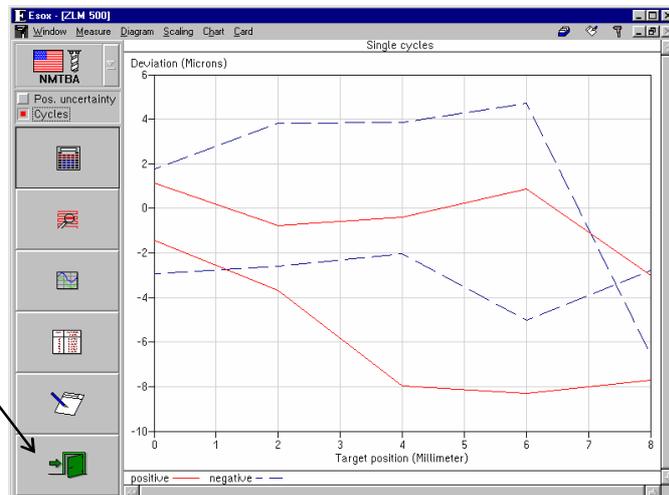
If the "Table" switch is activated, the buttons  and  can be clicked to select between horizontal and vertical arrangement of measured data in the table. In case of horizontal arrangement, the table is split up and transferred to the "Document" program module in the form of several tables if all the measured data do not fit into one line. When recording a table, please mind that a printed text page has about 60 lines. If a great number of readings have been taken, you should select which of them to be transferred into a table.



For this you can use the "Start number" and "End number" input boxes. If the number of measured data between the first and last readings entered exceeds 1000, the program will restrict the table to 1000 readings.

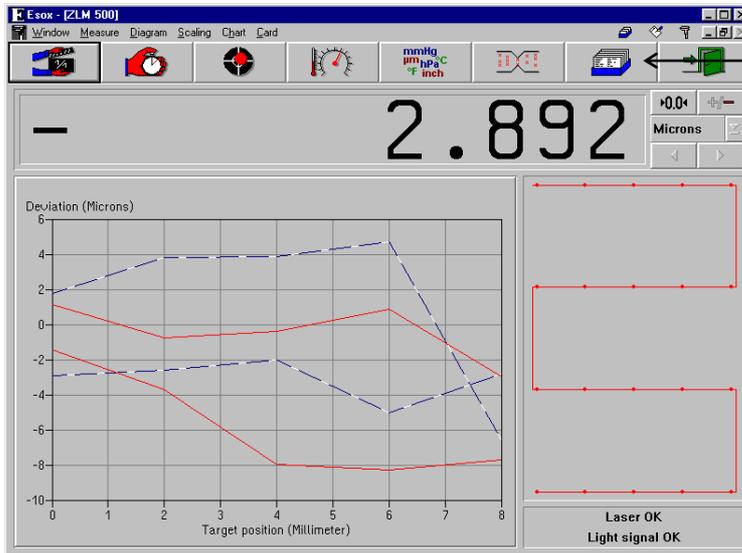
G 2.6.9 Exiting the diagram presentation

To exit the diagram presentation, activate the  button or choose the "End diagram" option of the "Diagram" menu.



G 2.7 Analysis of previous measurements

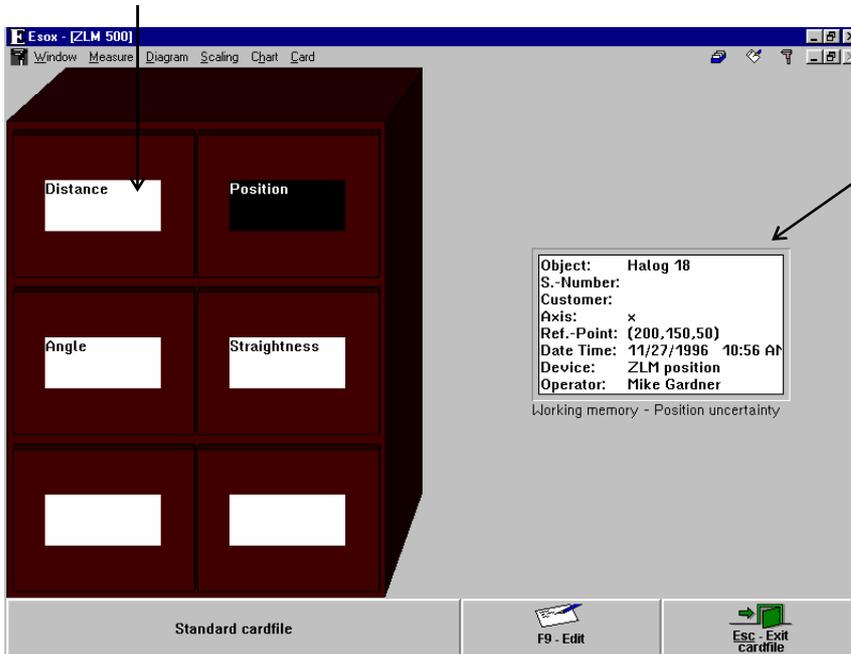
After the measurement a file card is created and the measurement results written on it. These cards are managed by the program module "Cardfile". It lets you load the card with the results of an earlier measurement so that you can analyse them in the ways described in the previous subsection.



To load a card, first click the  button or select the "Card" option of the "Cardfile" menu.

This will change the screen display.

The left half of the window shows a file cabinet with 6 file boxes (drawers).



The right half of the window contains a field with one file card - the one whose data can presently be processed by the program.

If you want to process the data obtained in one of the previous measurements, you need to open the cabinet drawer containing the desired card, select the card from the drawer and move it into the field on the right.

The following subsections briefly describe how card boxes are opened and closed, and how cards are shifted, loaded into the main memory and placed back into the cabinet.

For further details of handling file cards, see section "K - Cardfile / Archiving of measurement Results".

G 2.7.1 Changing the selected (highlighted) card field

One card field or one card box label field is shown highlighted, i.e. white lettering on black background.



With the cursor keys , ,  and  you can move from one card field or card box label to another.

With the  key you can move from the previously highlighted card field on one side of the screen to the card field on the other side of the screen that was highlighted there last.



Click on the card field or card box label you want to highlight. Please note: Clicking on an already highlighted box label will open the respective box.

G 2.7.2 Opening and closing a card box

	Opening	Closing
	If the label of the card box is not highlighted, use  ,  ,  and  to move to this label. Then press  .	If necessary, press  ,  or  to move to the respective side of the screen. Then press  .
	If the label of the card box is not highlighted, click on the label once to highlight it; click on the label again to open the box. If the label of the card box is already highlighted, click on it once to open the box.	Click the  button at the bottom right or left of the window to close the right or left card box.

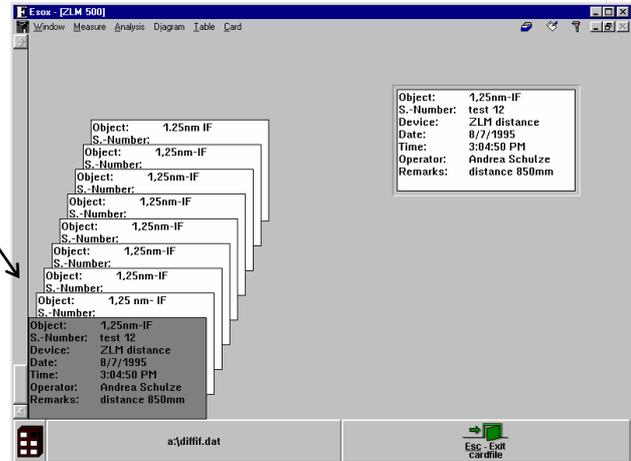
G 2.7.3 Shifting of file cards

The cards in an open card box can be shifted to activate (and highlight) another card. Cards arranged in front of the current card are not displayed.

The vertical scroll bar shows the location of, and the amount of space occupied by, the current card with respect to all cards of the box.



The vertical scroll bar can be used to shift the cards.



Shifting the card with the keyboard requires that the first card on the left is highlighted.

-  The file cards are shifted backward by one position. The card in the order before the card that was current last becomes the new current card.
-  The file cards are shifted forward by one position. The card in the order behind the card that was current last becomes the new current card.
-  The file cards are shifted backward by one screen page. The first card of the previous page becomes the new current card.
-  The file cards are shifted forward by one screen page. The first card of the next page becomes the new current card.

G 2.7.4 Loading and unloading of file cards



The easiest way of loading a card is by using the mouse. Move the mouse pointer on the source card, click and hold the left mouse button down. Now drag the mouse pointer with the file card to the target position, then release the mouse button.

If the main memory already contains a card, the program will automatically put it back to its previous position in the card box.

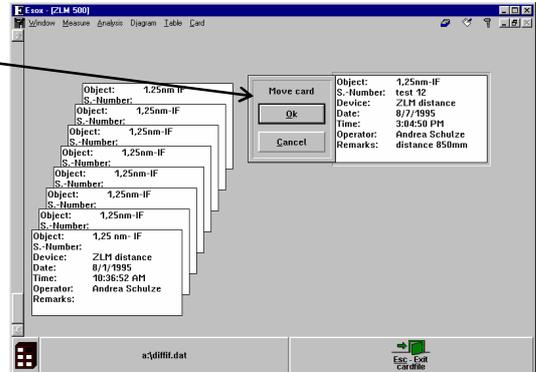
Proceed analogously when putting a loaded card back into its box. Click on the card and drag it to its target position. By dragging the mouse pointer with the card up to the upper or lower margin of the window you can shift the card stack in the box on the left.



Loading a card with the keyboard requires that the card must first be highlighted on the left half of the screen.
Now select the **"Load"** option from the **"Cardfile"** menu.

The screen shows a field with the card to be loaded.

Press the  key.

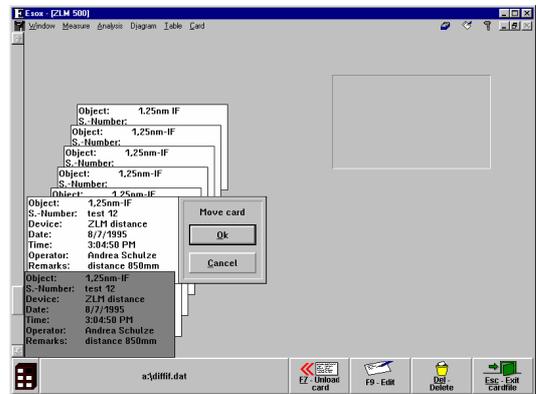


Putting a card back requires that it must first be highlighted in the main memory field represented on the left half of the screen.

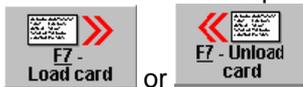
Then select the **"Move"** option from the **"Cardfile"** menu.

The target position can be selected with the direction keys.

Conclude by pressing the  key.



Instead of the menu options "Load" and "Move" of the "Cardfile" menu you can also use the



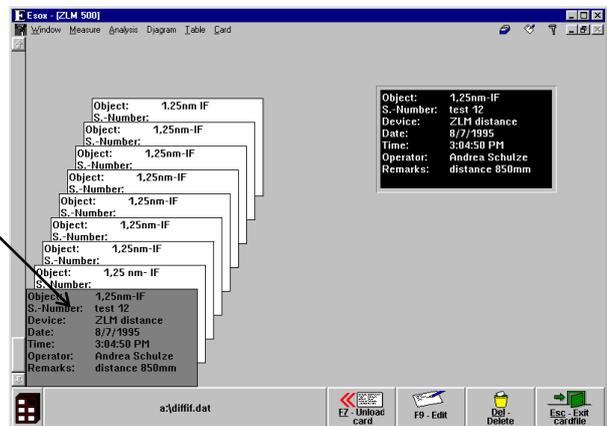
button at the bottom of the screen.

The target position can alternatively be selected with the scroll bar on the left margin.

The keys ,  and  can be used to page up and down for finding remote target positions. It is thus possible to move a card from a left-side source position to a left-side target position, for the purpose of rearranging the cards.

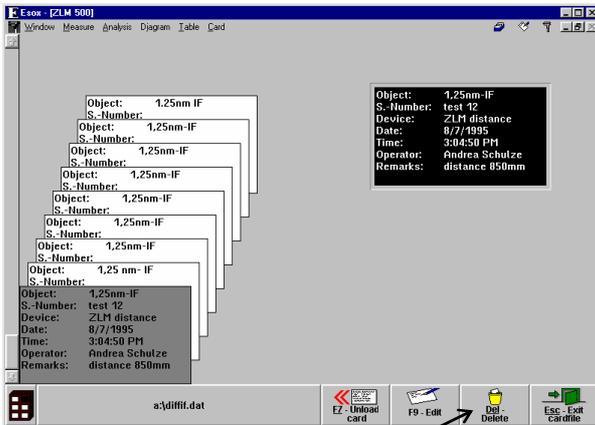
If a card has been loaded into the main memory, it still remains also visible at its source position on the left side, but it is shown here with black lettering on a grey background.

Such a "greyed-out" card cannot be moved from its place.



G 2.7.5 Deleting a file card

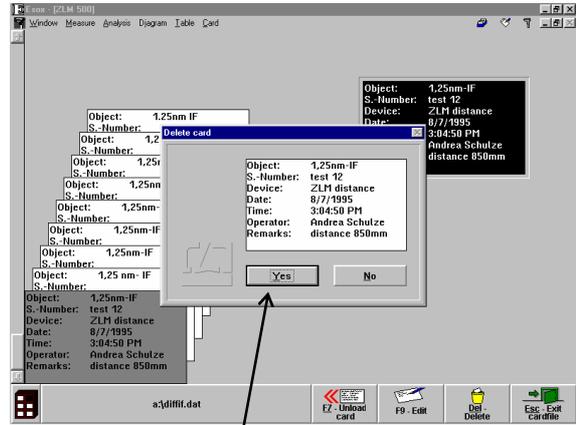
A card you want to delete must first be highlighted.



Select the **"Delete"** option from the **"Cardfile"**



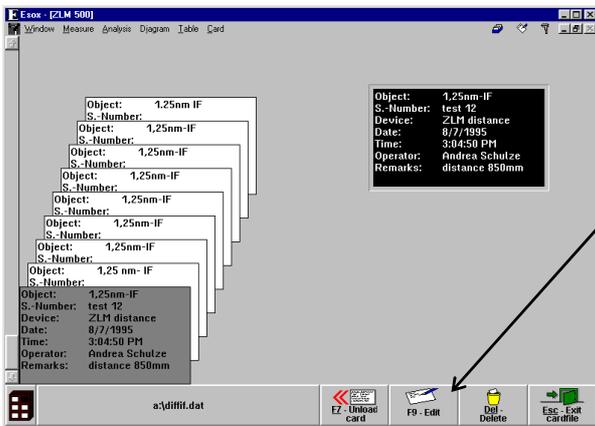
menu or click the **Delete** button. This opens a dialog box.



Click the **Yes** button to delete the highlighted card.

G 2.7.6 Editing of cards and card box labels

First highlight the card or the card box whose inscription you want to edit.



Start the text input mode by selecting the **"Edit"** option from the **"Cardfile"** menu or by clicking the



Edit button.

Annex III contains a list of keys and key combinations that have special functions in the editing of text boxes. In addition you can use the following keys for moving within a card:



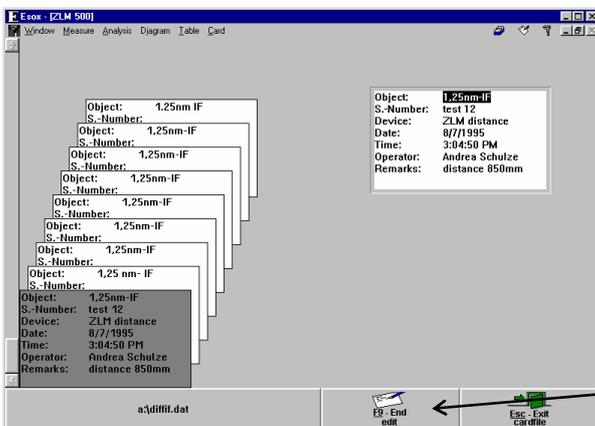
- moves the text cursor to the next card entry in the same line.



- moves the text cursor to the next lower card entry.



- moves the text cursor to the next upper card entry.



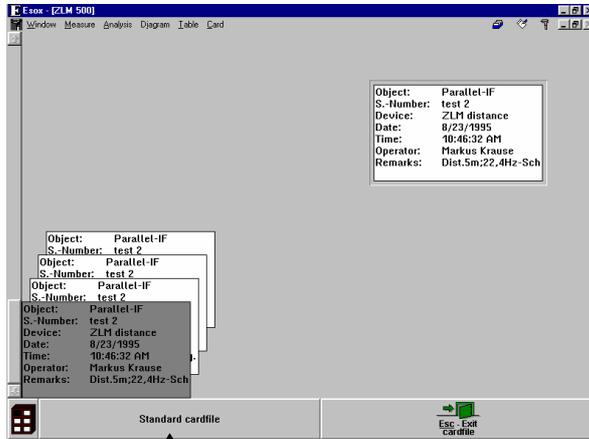
With editing finished, you need to quit the text input mode by selecting **"End edit"** in the **"Cardfile"** menu or clicking the



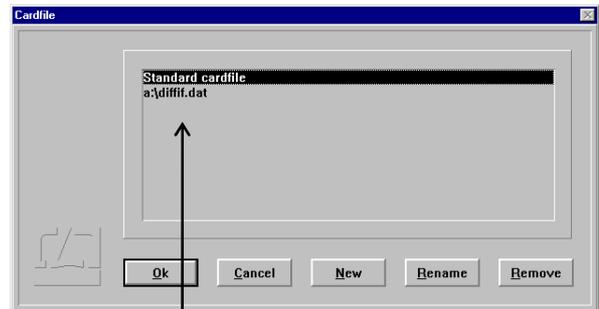
End edit button.

G 2.7.7 Creating, renaming and deleting a card file

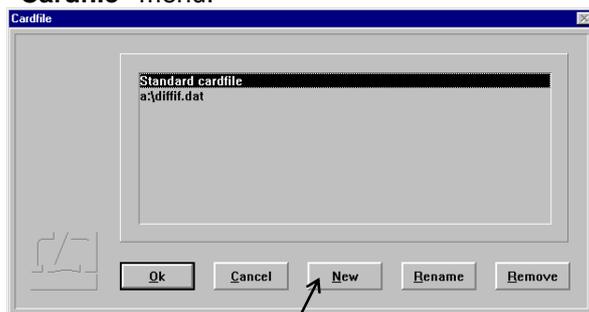
When the program is started first, it creates a card file named "Standard Cardfile" in the system data file "esoxm.dat" located in the installation path. It is possible to create further data files. Each data file comprises a card file cabinet with six card boxes.



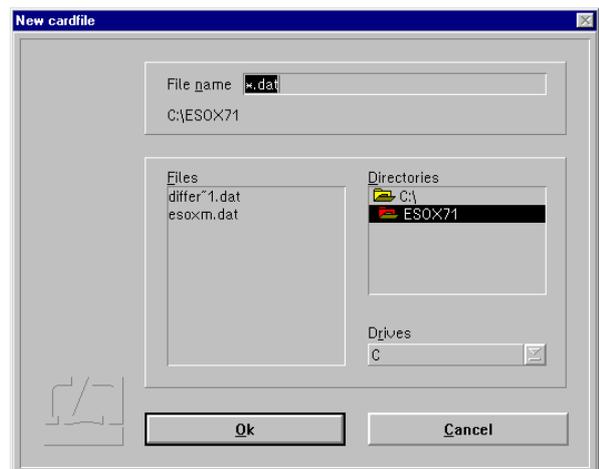
To create a new card file, click on the file name button at the bottom left window margin, or select the menu option "Open cardfile" from the "Cardfile" menu.



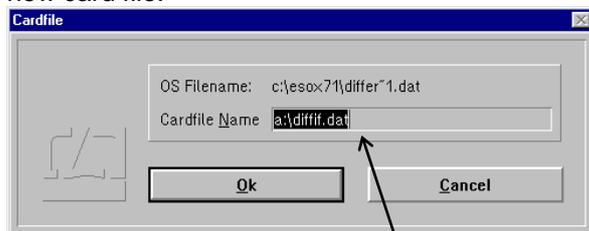
This opens a list showing the names of all existing card files in a dialog box.



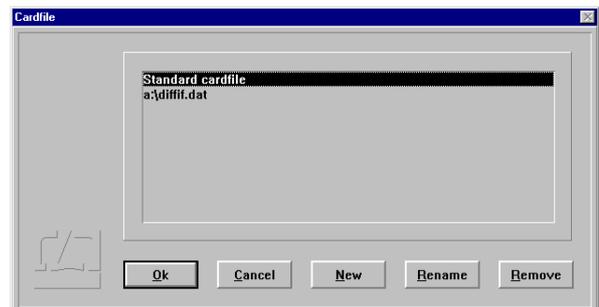
Click the **New** button if you want to create a new card file.



This opens another box in which you must enter the name of the data file.



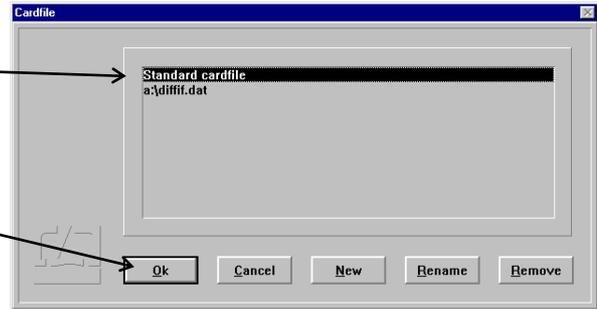
Click the **OK** button to open another dialog box, in which you must enter a card file name, which then appears in the card file list.



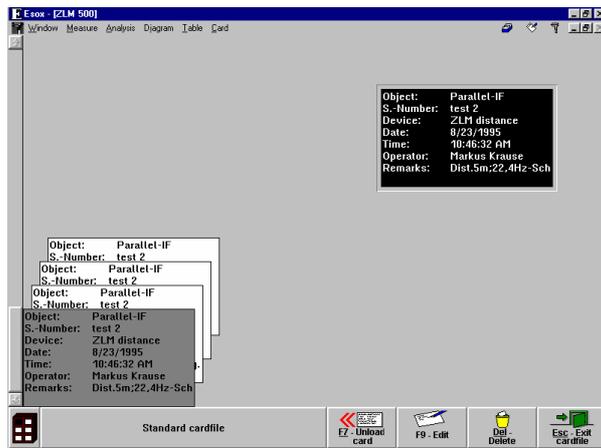
The same dialog box is opened if you use the **Rename** button to rename a card file.

Click the **Remove** button if you want to delete a card file from the card file list. This will not, however, delete the data file from the memory. For deleting the data file, use the file manager.

To select a card file from those created, highlight the file name in the list box and then click the **OK** button.

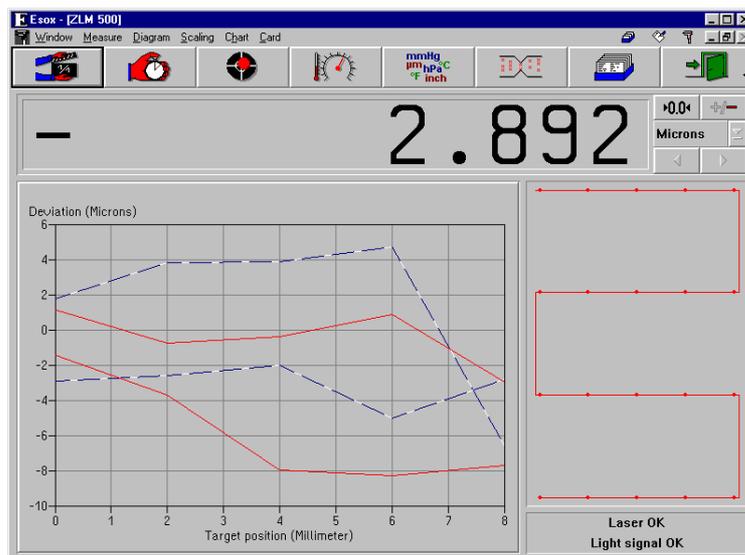


G 2.7.8 Quitting the Cardfile menu



To quit the Cardfile menu, click the button or select the "Exit" option from the "Cardfile" menu.

G 2.8 Exiting the measurement program



To exit the "ZLM-Position" program module, activate the button or choose the "Exit measurement program" option of the "Measure" menu.



G 3 Analysis of position measurements by the template method

Users testing coordinate measuring machines not only require the information gained with the statistical methods described in section G1, but also need to know the machine's length-dependent measuring error. This aspect is allowed for in the "VDI/VDE 2617" standard, which describes a "template method" of analysing a position measurement.

G 3.1 Procedure

With the template method, the program checks, for all measured pairs of position deviations x_i, x_j whether the condition

$$A_p + K_p \cdot |x_i - x_j| \leq B_p$$

applies. A_p , K_p and B_p are positive constants specified by the machine to characterize the accuracy of the measuring machine.

A_p is a basic measuring error to be expected irrespective of the size of the testpiece.

K_p is the length-dependent measuring error, and

B_p is the maximum measuring error occurring with the measuring machine model concerned.

Manufacturers of coordinate measuring machines frequently specify an error in this form:

$$F = \left(1 + \frac{l}{1000}\right) \mu\text{m} \quad , \text{ with } l \text{ in mm.}$$

For converting the manufacturer's specification $F = \left(U + \frac{l}{V}\right) \mu\text{m}$ (with l in mm) into parameters conforming to VDI/VDE 2617, you can use the equations

$$A_p = U \quad \mu\text{m},$$

$$K_p = \frac{1000}{V} \quad \mu\text{m/m} \quad \text{and}$$

$$B_p = U + \frac{1000}{V} \cdot L \quad \mu\text{m} \quad , \text{ or } B_p = A_p + K_p \cdot L \quad , \text{ with } L \text{ being the maximum length measured.}$$

Examples: (1) $F = \left(1 + \frac{l}{1000}\right) \mu\text{m}$ with l in mm and a maximum measured length $L = 1000$ mm,

yields

$$A_p = 1 \quad \mu\text{m},$$

$$K_p = 1 \quad \mu\text{m/m} \quad \text{and}$$

$$B_p = 2 \quad \mu\text{m}.$$

(2) $F = \left(5 + \frac{l}{100}\right) \mu\text{m}$ with l in mm and a maximum measured length $L = 600$ mm,

yields

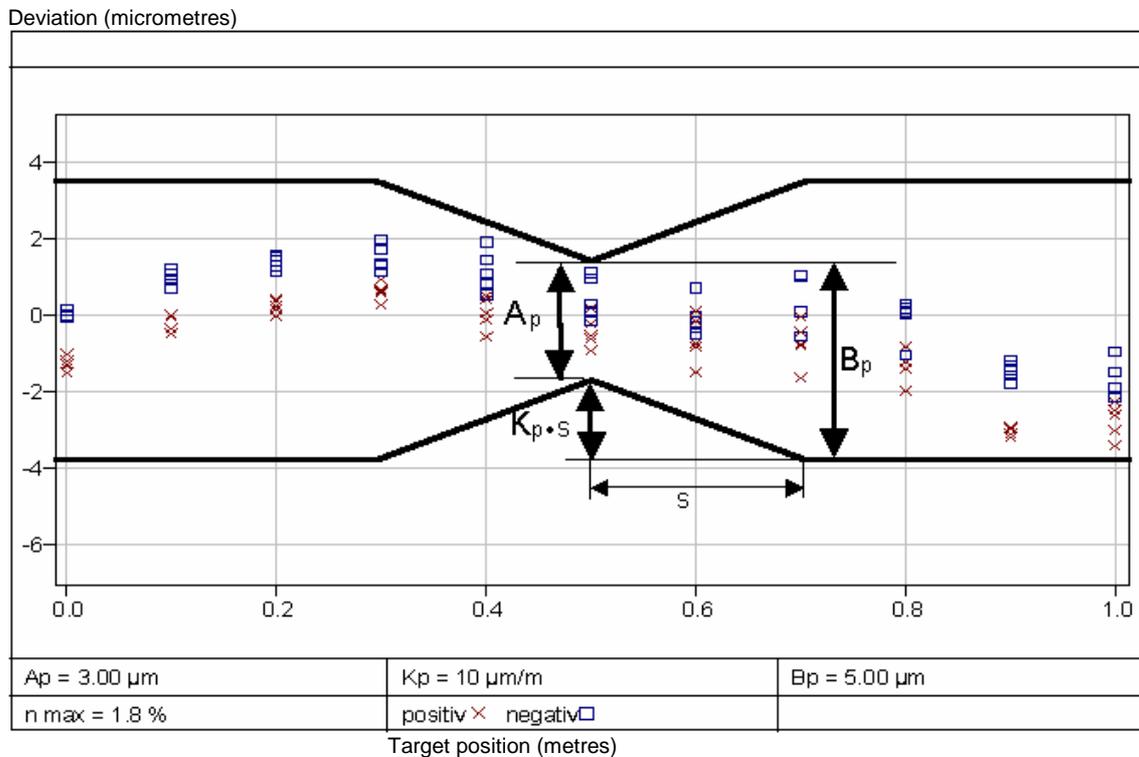
$$A_p = 5 \quad \mu\text{m},$$

$$K_p = 10 \quad \mu\text{m/m} \quad \text{and}$$

$$B_p = 11 \quad \mu\text{m}.$$

For illustrating the condition $A_p + K_p \cdot |x_i - x_j| \leq B_p$, a template can be made that represents the parameters A_p , K_p and B_p .

Position uncertainty - Template method acc. to VDI/VE 2617



Shift the neck of the template to the position of reading x_j ; then try to shift the template vertically to find a position in which the readings x_i and x_j lie within the template. If this is possible, the two readings x_i and x_j satisfy the condition $A_p + K_p \cdot |x_i - x_j| \leq B_p$.

1. The manufacturer's specification is satisfied if the inequality $A_p + K_p \cdot |x_i - x_j| \leq B_p$ is true for all position deviations x_i, x_j .
2. If this is not the case, determine all reading numbers "i" for which there is at least one reading number "j" at which $A_p + K_p \cdot |x_i - x_j| \leq B_p$ is not satisfied. If the percentage " n_{max} " of the quantity of the reading numbers "i" thus determined in the total number of readings is not greater than 5%, a repeat measurement can be made.
3. If " n_{max} " is greater than 5 %, the machine does not conform to the manufacturer's specification.

The condition $n_{\text{max}} \leq 5\%$ can also be illustrated with the template. First shift the neck of the template to the first measuring position. Then shift the template vertically until the number of readings lying outside the template is minimum. Mark the readings lying outside the template. Proceed in the same way when shifting the template neck to the other measuring positions. Finally, count the number of marked readings and determine the percentage n_{max} of the counted readings in the total number of readings.

For measurement you can use the Linear, Oscillation ("Pendulum-step") or Quasi-pilgrim step method (see section G 1). Specify at least 11 measuring positions distributed over the whole measuring length. Travel to each position at least five times from both directions.

If a repeat measurement is necessary, measure another 20 cycles. Instead of travelling to all positions it is sufficient now to measure at those positions whose readings were outside the template. At these positions you have then at least 25 readings for either direction.

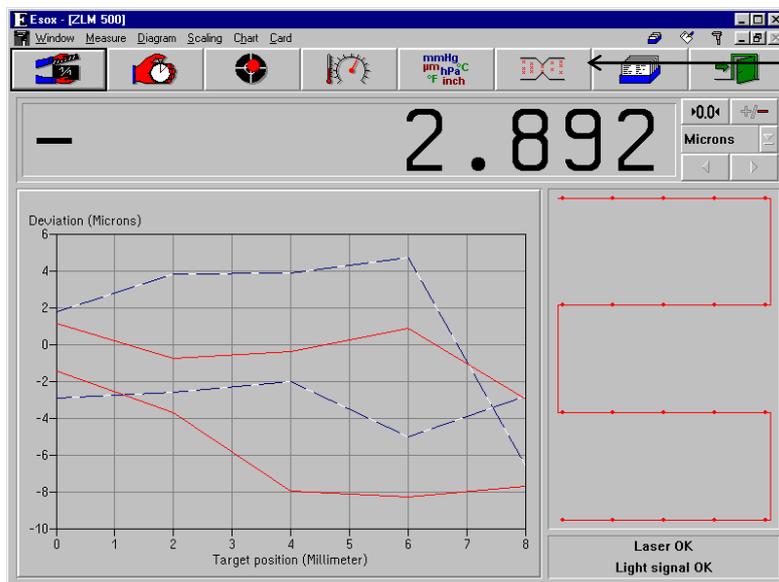
In the period between the first and the repeat measurement, neither the readout of the measuring machine under test nor that of the laser interferometer may be reset, and no interruption of the laser beam may have occurred.

The analysis of the repeat measurement may reveal one of three cases:

1. When determining n_{\max} you find that one reading of a position at which no repeat measurement was made is outside the template area. In this case the machine does not satisfy the manufacturer's specification.
2. If n_{\max} is greater than 5%, the machine does not satisfy the manufacturer's specification.
3. For determining n_{\max} the readings taken at the neck position are scrutinized. The program determines the percentage "ü" of the number of neck readings lying outside the template, in the total number of neck readings. If the maximum \ddot{u}_{\max} of the "ü" readings for all neck positions is greater than 5%, the machine does not satisfy the manufacturer's specification.

VDI/VDE 2617 provides for a table for manual analysis, but the "ZLM Position" software already supplies the n_{\max} and \ddot{u}_{\max} values, as well as the information "Values of first measurement outside" as a measurement result.

G 3.2 Start of analysis

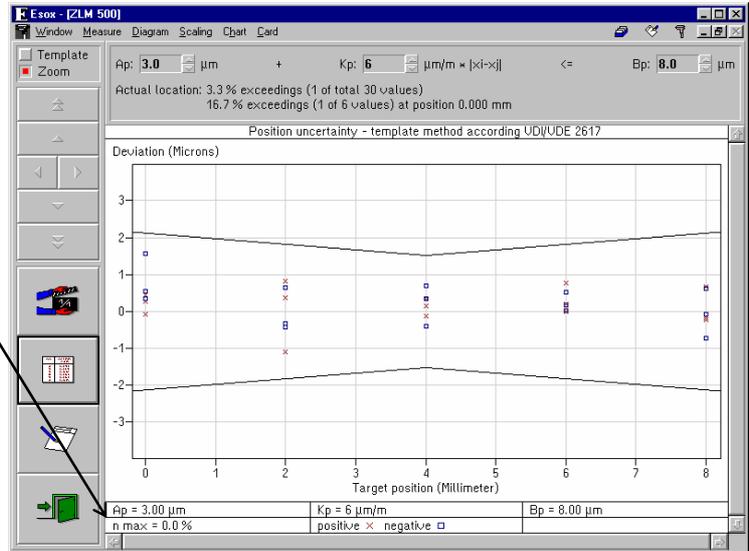


Click the  button or select the "Template" option in the "Diagram" menu to activate the template method of analysis.

G 3.3 Operation of the template method

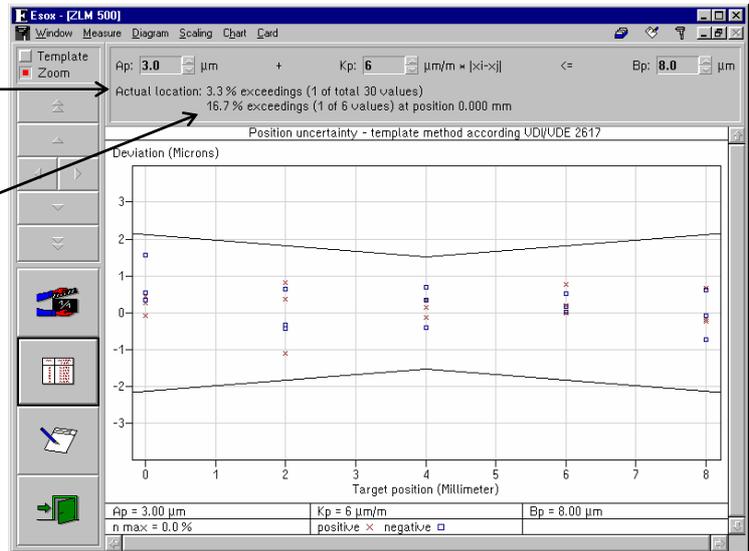
In the text boxes at the top you can enter the parameters A_p , K_p and B_p .

This box at the bottom shows the maximum number n_{max} of outlying readings per neck position. This is the result of the measurement. It is determined by the program from the specified parameters A_p , K_p and B_p , all readings and all neck positions; it is independent of the target currently displayed.



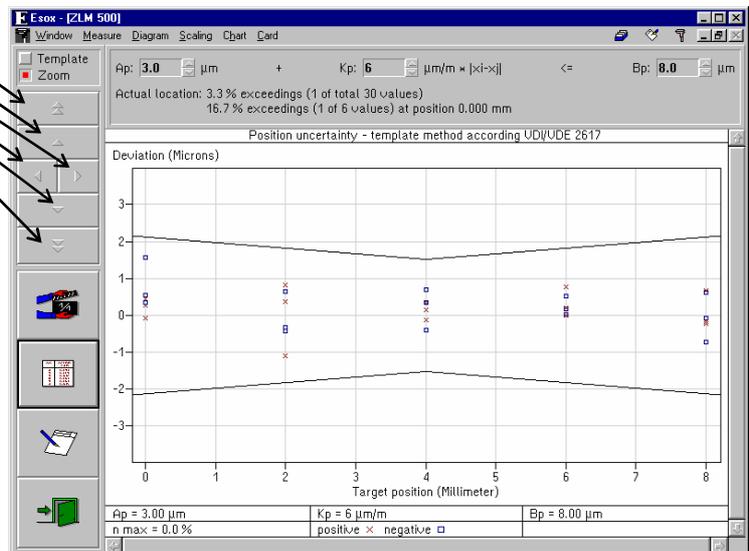
The first line below the parameters indicates how many readings are lying outside the area of the template currently displayed.

The second line is only significant in a repeat measurement. It indicates the position at which the greatest number of readings lie outside the template area, and the percentage of outlying readings at this position relative to all readings taken at this position.



Use the arrow buttons to shift the template.

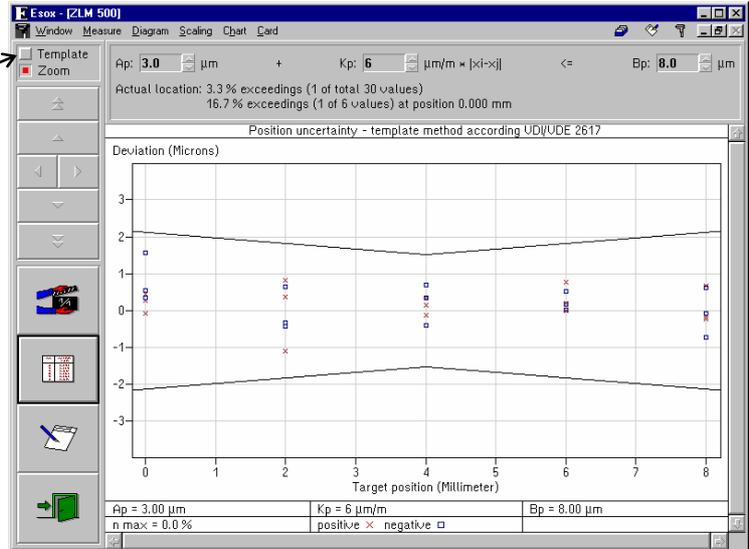
When you shift the template horizontally, the program determines the optimum vertical position for the neck position selected.



You can also shift the template with the mouse.

To enable this option, press the **"Template"** button.

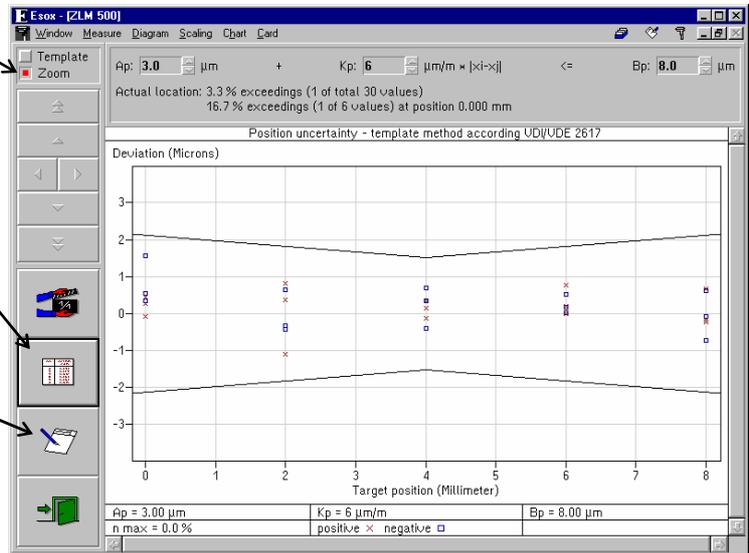
Click on the diagram. Keep the left mouse key depressed and drag the template as required, then release mouse key.



If you click the **"Zoom"** button you can zoom diagram segments same as described in section G 2.6.5.

A click on the  button displays the table of measured data.

Click on the  button if you want to have a record compiled.



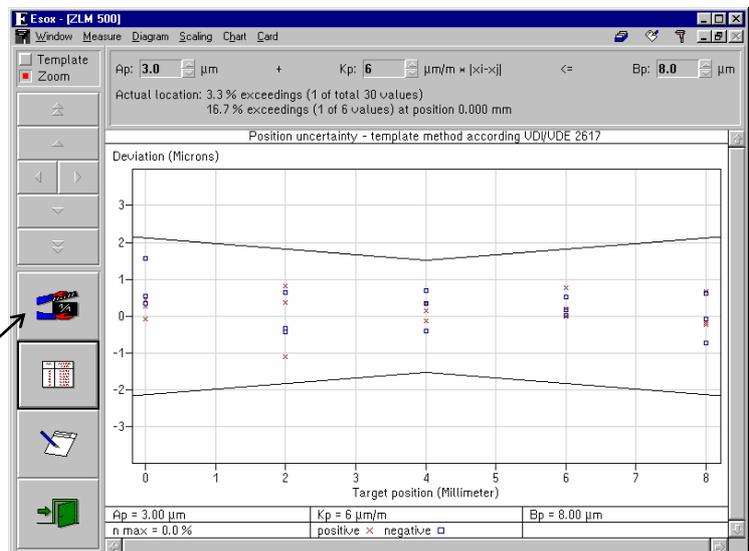
G 3.4 Repeat measurement

If the maximum percentage of outlying readings per neck position (see "n max" at bottom of screen) is zero, the machine satisfies the manufacturer's specification. If it is greater than 5%, the machine does not satisfy the manufacturer's specification. In the third case (n_{max} greater than 0 % and smaller than or equal to 5%), you can make a repeat measurement.

To do this, click the

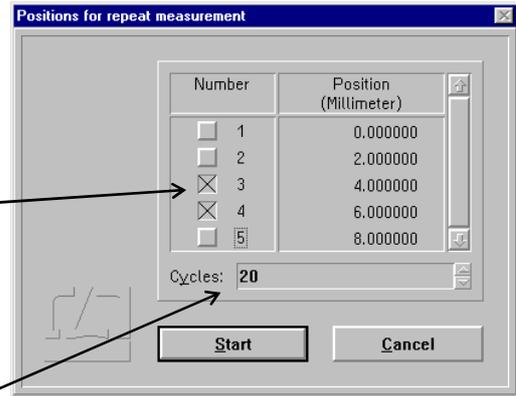


button, or select the **"Repeat measure(ment)"** item in the **"Measure"** menu.



First select the positions at which you want to make a repeat measurement.

In the dialog box **"Positions for repeat measurement"**, the program selects those positions where repeat measurements are absolutely necessary. You may select additional positions or remove positions selected by the program. Mind, however, that after repeat measurement all readings first measured must be within the template area. Therefore, program-selected positions should only be removed if you intend to change the parameters A_p , K_p and B_p after the repeat measurement.



VDI/VDE 2617 recommends 20 runs for the repeat measurement. The total number of cycles for the first and repeat measurements should be 25.

For the repeat measurement, the program uses the same positioning method as for the first measurement, but travels to the selected positions only.

On completion of the repeat measurement, the program saves the data on the same file card as the readings taken in the first measurement.

The repeat measurement data are only available for analysis by the template method. They are not available for the normal position uncertainty analysis, as this assumes the same number of readings for each position measured.

To return to the template analysis method, click the



button or select "Template" in the "Diagram" menu.

In the drop-down list box in the top left corner you can select between presentation and analysis of the first measurement or of the repeat measurement.

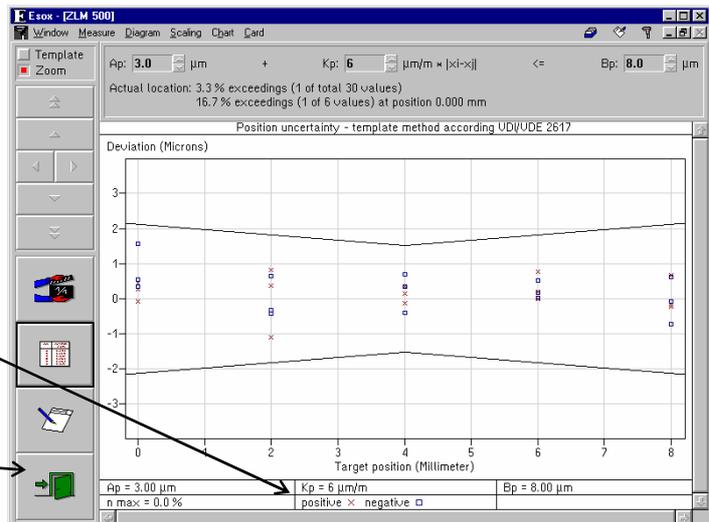
In the repeat measurement presentation, the bottom line not only shows "n max" but also the maximum number "ü max" of outlying readings at the measurement positions.

To exit the template display window,

click the



button.



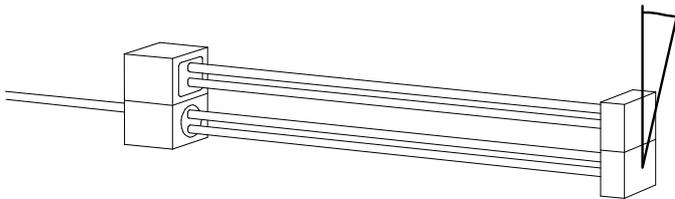
H "ZLM Angle / Straightness" Calibration Software

VDI, the German engineers' association, issued the "VDI/VDE 2617" standard for the determination of angular and straightness deviations in coordinate measuring machines. The two measurement programs "ZLM Angle" and "ZLM Straightness" allows coordinate measuring machines to be automatically inspected in accordance with this standard. "ISO 1101" is a standard applying to straightness measurements on workpieces. The "ZLM Straightness" program handles straightness measurements according to this standard as well; and it also can be used for measuring squareness and parallelism deviations.

As the two measuring programs "ZLM Angle" and "ZLM Straightness" are sold as a package and as their operation is largely the same, they are described in this section together. Normally, users of "ZLM Angle" and "ZLM Straightness" also use the "ZLM Position" program described in section G, which has much in common with the two programs described here. Therefore, you will find references to section G throughout this section.

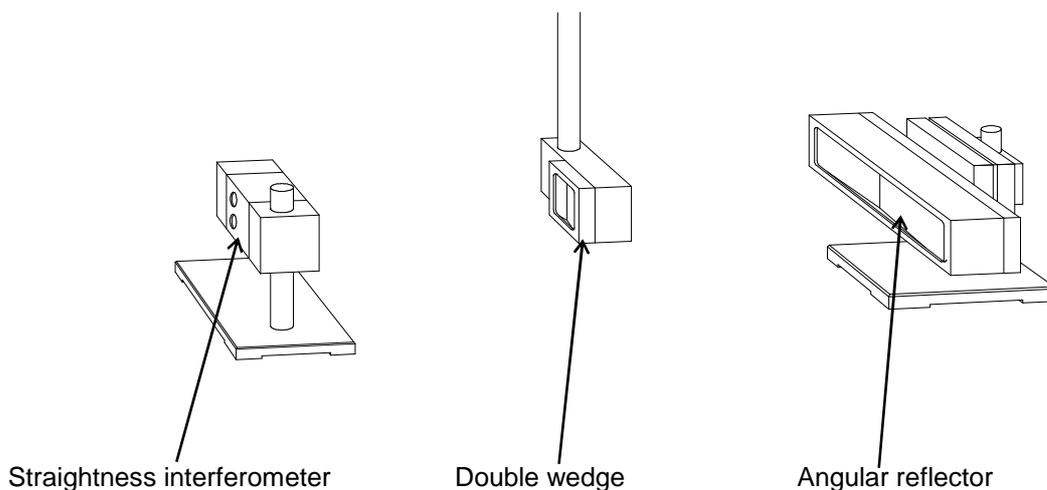
H 1 Measurement procedure

In angle measurement, the two partial laser beams, separated by a polarizing beam splitter, are directed at a double reflector. One of the partial beams has to be deflected. The path difference between the two partial beams is used for computing the angle.



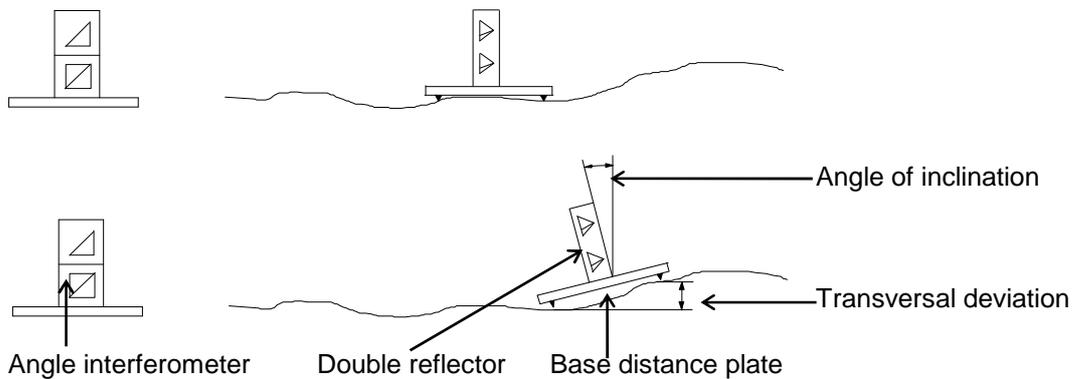
In straightness measurement, two methods can be distinguished:

The 1st method uses special optical components.



A displacement of the double wedge (in the illustration: horizontal displacement) changes the optical path lengths of the two beam portions separated by the straightness interferometer.

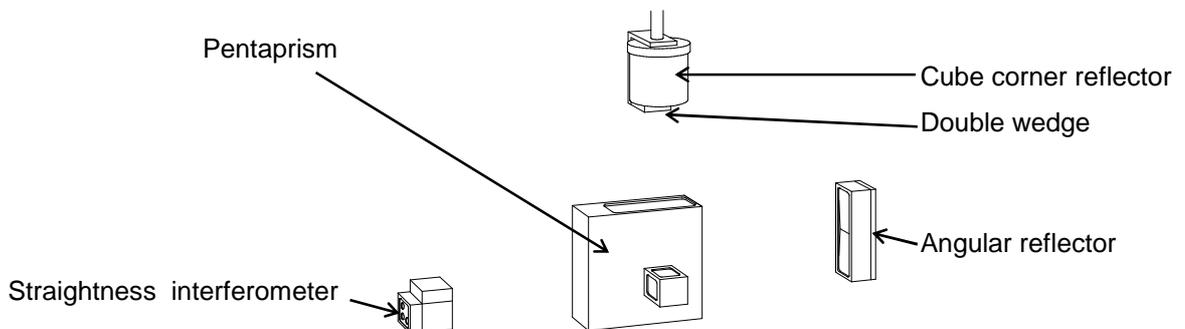
The 2nd method is a straightness measurement of workpieces by means of angle optics and a base distance plate. A double reflector mounted on the base distance plate is displaced repeatedly by the distance of the two support points of the plate. From the angles measured, the program determines the transversal deviation.



The procedure of measuring rotatory and straightness deviations is similar to the ascertainment of position uncertainty: Several measuring positions along a line corresponding to the laser beam path are travelled to from both directions. The program expects a positioning sequence by the linear method (see section G 1.2 "Positioning methods"). The program also supports the unidirectional linear method, although this is not provided for in the "VDI/VDE 2617" standard.

According to "VDI/VDE 2617", rotatory and straightness deviations must be ascertained in both coordinate directions on a measuring line located approximately at the centre of the measuring volume. At least 11 positions must be measured per measuring line. The positions must be distributed all over the measuring range and be spaced at different intervals.

For squareness measurement, first make a straightness measurement relative to one measuring axis. The use a pentaprism to deflect the beam by very precisely 90°, and make a straightness measurement relative to the second measuring axis (normal to the first one).

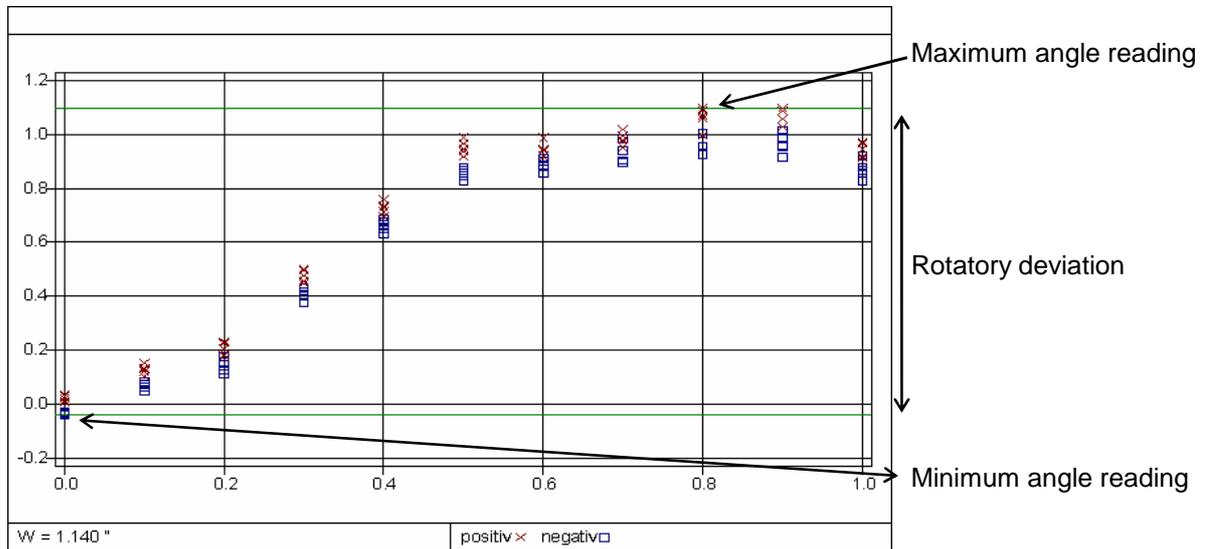


A parallelism measurement can be carried out with two pentaprisms. Here, too, first make a straightness measurement relative to one measuring axis. The effect a beam offset with two pentaprisms, and make a straightness measurement relative to the second measuring axis.

A parallelism measurement with a normal straightness measuring arrangement is feasible in such a way as to displace the double wedge first and the angular reflector afterwards. Please mind, however, that a tilt introduced during displacement of the angular reflector will give rise to a considerable measuring error. Therefore, first check the axis on which the angular reflector is mounted for any rotatory deviations.

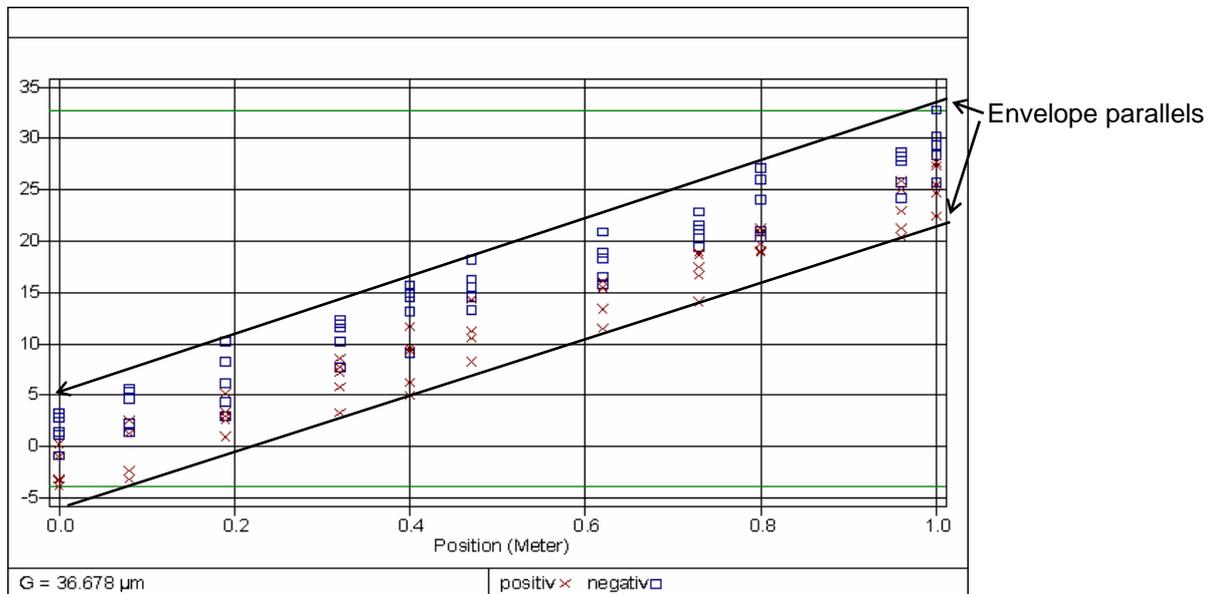
H 2 Parameters

In an angle measurement, a number of angle readings are taken at each measuring position. The "Rotatory deviation A" is the difference between the greatest and smallest of all angle readings taken, irrespective of the position and travel direction.

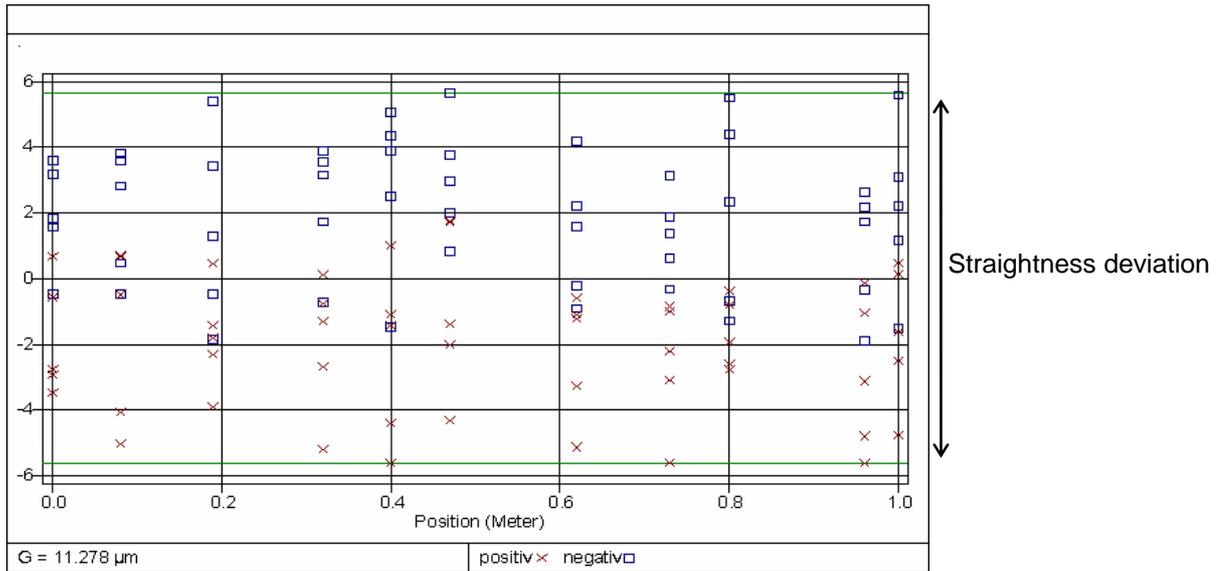


In a straightness measurement, the laser beam usually is not exactly aligned with the axis being measured. This would cause major errors if the difference between maximum and minimum readings were defined as a parameter.

Therefore, a "Straightness deviation S" has been defined as the distance between two parallels that include between them all measuring points while having the minimum possible distance from one another. The program calls these straight lines "envelope parallels".



When fitting the envelope parallels, the program transforms all readings in such a way that after transformation the two lines are approximately parallel with the ordinate axis.



The program also offers a least-squares fitting procedure, in which a straight line is determined for which the sum of the squares of distances from the line is minimum. This procedure, too, is followed by a transformation aimed at placing the straight line in parallel with the ordinate axis. But in this case, the difference between maximum and minimum is always either greater than or equal to the difference between maximum and minimum in envelope parallel fitting.

H 3 Operation of the "ZLM Angle" and "ZLM Straightness" program modules

Start these program modules just as you would start the "ZLM Position" module (see sections G 2.1 and C 3).

H 3.1 Window elements

The window elements of the "ZLM Angle" and "ZLM Straightness" modules hardly differ from those of "ZLM Position".

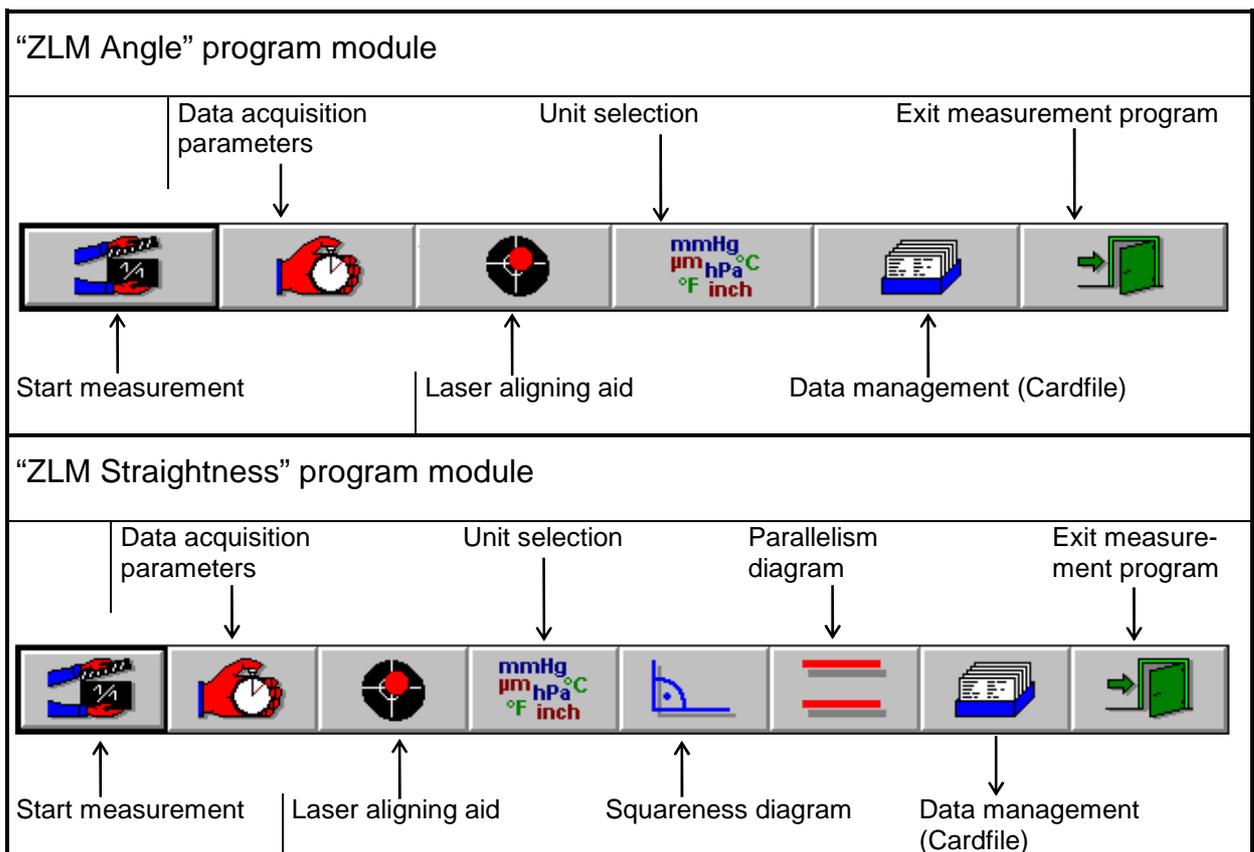
Row of buttons

Display of the current reading

Large button showing a diagram generated from the measured data currently in the memory

Display of the number of readings currently in the memory and the positioning method

Indication of laser stability and light intensity



The controls for data display and unit selection are operated same as in "ZLM Position".

H 3.2 Preparation for measurement

In measurements of rotatory and straightness deviations, the program does not correct the measured data for the influences of atmospheric properties and material temperature, because these influences are that low that a compensation would not improve the measurement results.

Access the "Parameters" dialog box by opening the **"Measure"** menu and choosing the **"Configuration"** option or by clicking the  button.

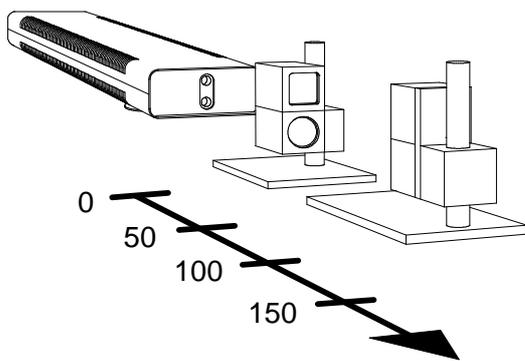
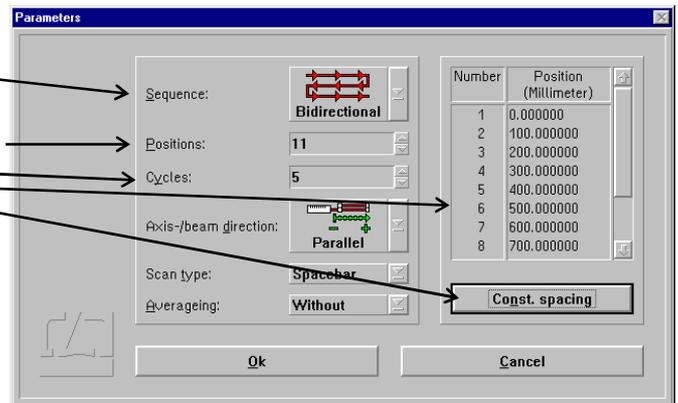
H 3.2.1 Preparation for an angle measurement

In angle measurement, the program only supports the linear and unidirectional linear methods.

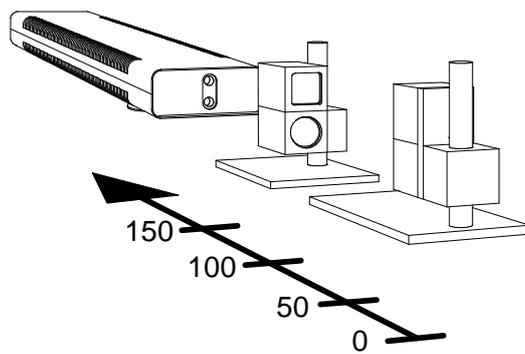
Select the positions same as in "ZLM Position".

The ZLM 500 laser interferometers use a high-frequency heterodyne method.

For an accurate angle measurement (better than 7 seconds of arc per metre), therefore, the program needs to know the position of the measuring axis relative to the laser beam in order to introduce an equivalent correction.



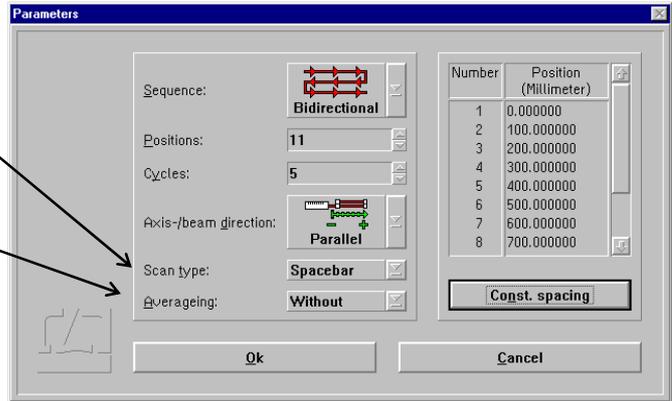
Axis and beam directions parallel



Axis and beam directions antiparallel

Taking a reading (data acquisition) can be triggered by the **Space bar** of the computer keyboard or by an external signal. Select this in the **"Scan type"** list box.

It is recommended to use time averaging in order to filter out vibrations. In the **"Short term averaging"** list box, select the averaging period somewhat shorter than the expected standstill time of the object under test.

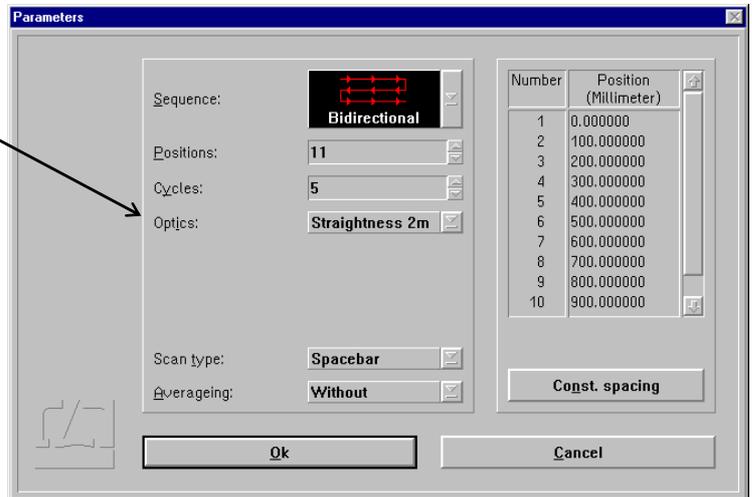


As the program has no position information, it cannot effect automatic reading, nor can it recognize errors in the positioning sequence.

H 3.2.2 Preparation for a straightness measurement

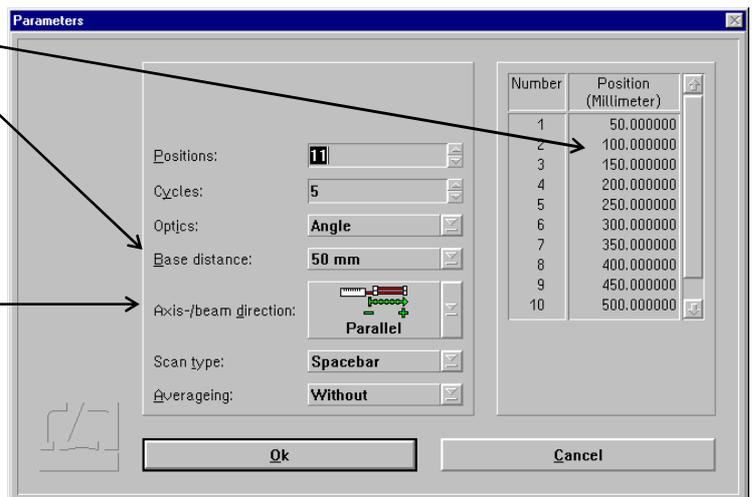
First specify whether you want to measure straightness with the straightness optics or the angle optics and base distance plate.

If you use straightness optics, enter positioning method and measuring positions same as in a position or angle measurement.



If you use angle optics, the measuring positions are determined by the selection of the base distance plates.

Same as in a "normal" angle measurement, specify the position of the measuring axis relative to the laser beam.



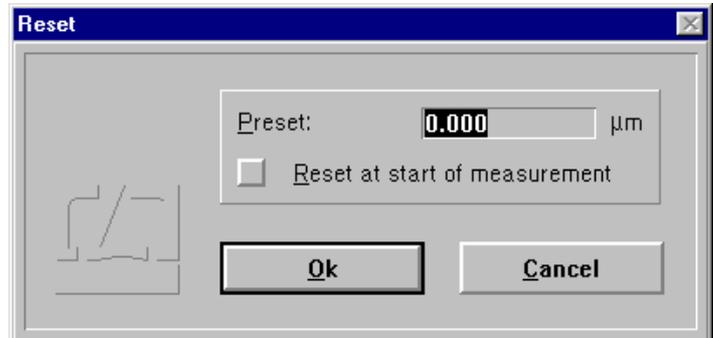
The facilities for setting the type of data acquisition triggering and time averaging are identical to those in angle measurement.

H 3.3 Measurement

In a measurement, the operation of "ZLM Straightness" and "ZLM Angle" is similar to the operation of "ZLM Position" (see section G 2.5). The paragraphs below only describe the differences from "ZLM Position".

For angle and straightness measurements, dead distance compensation is neither possible nor needed.

Therefore, the "Reset" dialog box has no dead distance input boxes.



If in an angle measurement you expect angular deviations greater than 1° , take care to ensure at the time of resetting that the reflectors are positioned normal to the measuring axis, since otherwise the program has to determine the angle by trigonometric functions.

During the measurement, only two additional displays are presented on the screen: target position, and maximum deviation among the readings taken so far. The current deviation can be seen from the large-size numerical display.

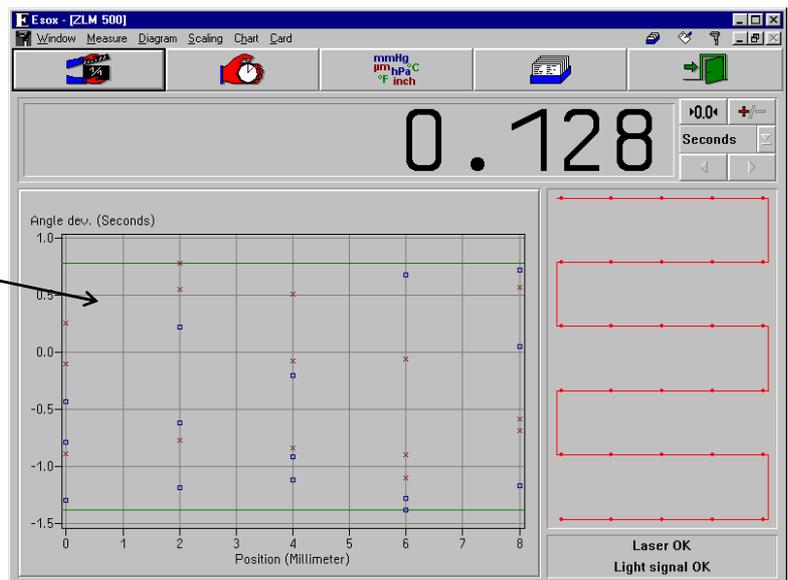
The programs cannot check whether the positions are travelled to in the correct sequence. An interruption of a measurement may be due to either of the following events:

1. The laser is unstable or becomes unstable during the measurement.
2. The light intensity received by the detector is too low or becomes too low during the measurement

In angle and straightness measurements, too, the measurement can be continued after an error, provided that the reading is re-referenced to the readings taken before (see section G 2.5.4).

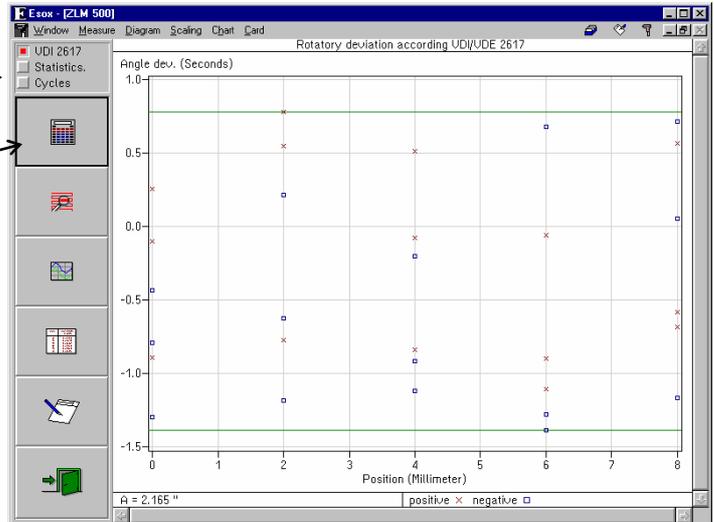
H 3.4 Analysis of a measurement

Same as in "ZLM Position", diagram presentation can be started by clicking the large button in the bottom left corner, or by selecting the "Diagram" option in the "Diagram" menu in angle measurement, or the "Straightness" menu in the "Diagram" menu in straightness measurement.



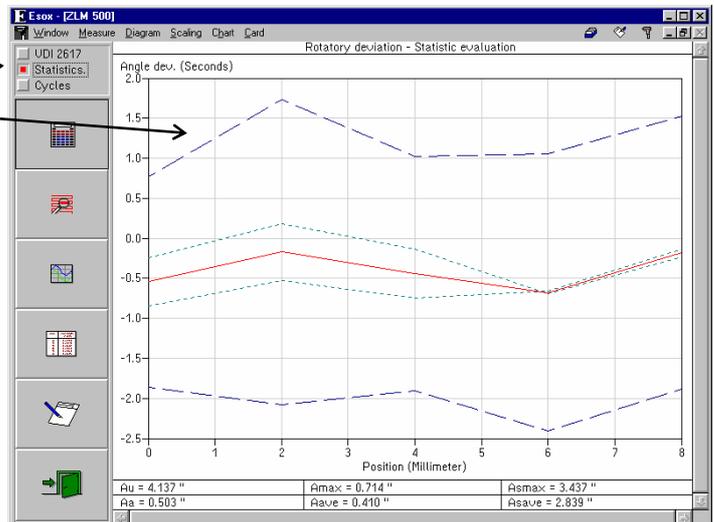
The top left portion of the window differs between "ZLM Angle" and "ZLM Straightness".

In "ZLM Angle" you can select between diagram presentation conforming to VDI/VDE 2617, statistical analysis, and presentation of individual readings.



In case of the VDI/VDE 2617 diagram, the button below the selection field can be clicked to display the value of the "Rotatory deviation A".

With static analysis selected, a diagram is shown that is analogous to the analysis of a position measurement according to VDI/VDE 2617.



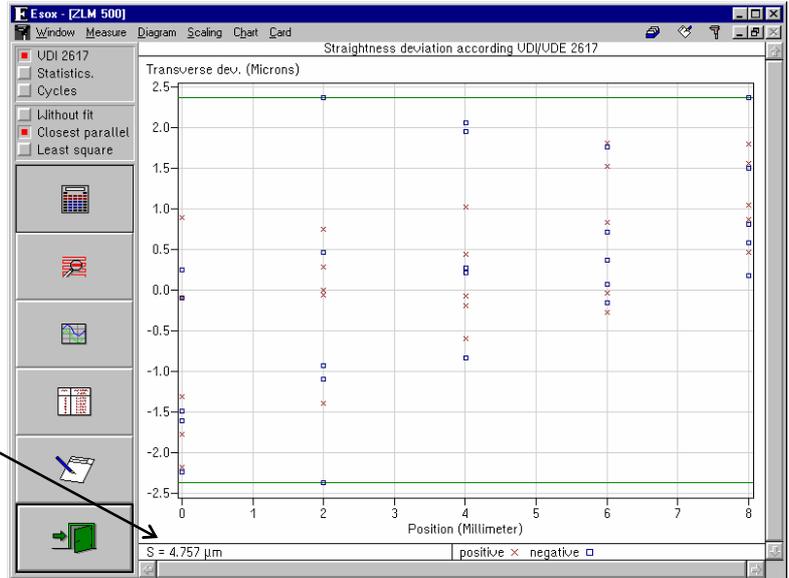
Please mind that this presentation is not included in VDI/VDE 2617 itself.

The quantities at the bottom margin of the screen are determined analogously to the parameters of VDI/VDE 2617.

Quantities in angle measurement		Analogous quantity in position measurement	
Au	Angle uncertainty	P	Position uncertainty
Aa	Angle deviation	Pa	Position deviation
Bmax	Maximum backlash	Bmax	Maximum backlash
Bave	Average backlash	Bave	Average backlash
Asmax	Maximum angle spread	Psmax	Maximum position spread
Asave	Average angle spread	Psave	Average position spread

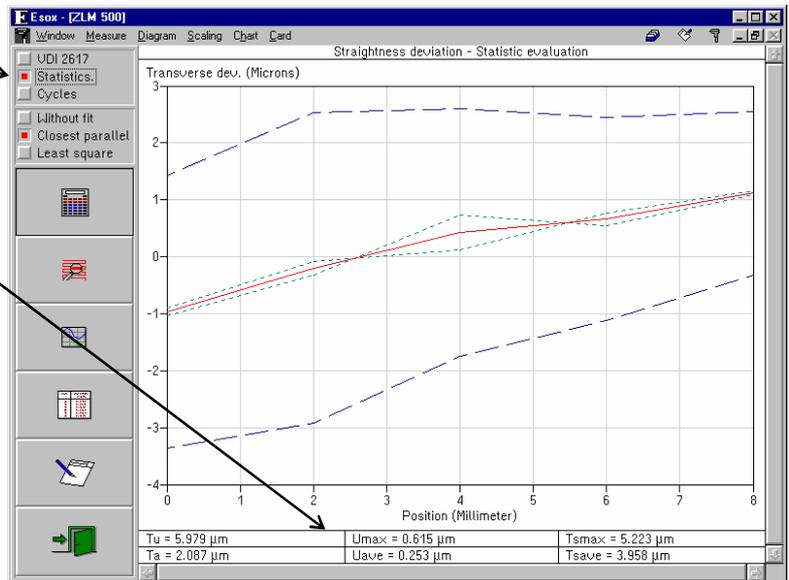
In "ZLM Straightness" you have an additional option besides VDI/VDE 2617, Statistics and Cycles: you can select between fitting methods (see section H 2 "Parameters"). For the standard analysis, you should use the "Envelope parallels" option.

With VDI 2617 selected in the top field, the "**Straightness deviation S**" is displayed on the bottom margin. The value is computed from the difference between the maximum and minimum readings of the diagram points displayed.



In a statistical analysis of a straightness measurement, too, the diagram and parameter computation are analogous to position measurement according to VDI/VDE 2617.

Here, too, this presentation is not contained in VDI/VDE 2617 itself.

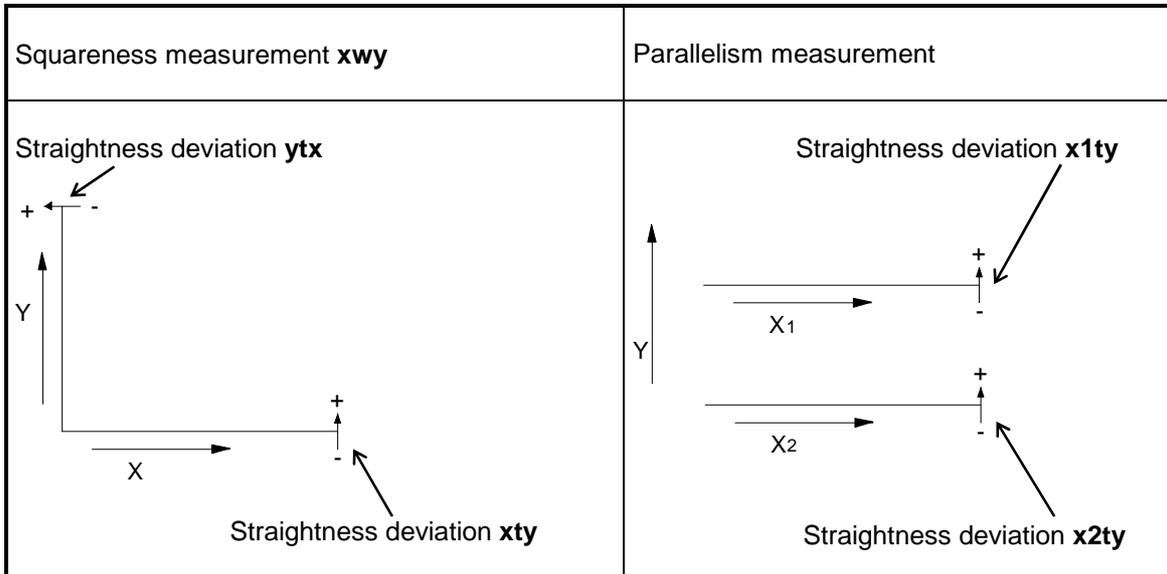


Quantities in straightness measurement		Analogous quantity in position measurement	
Tu	Transversal position uncertainty	P	Position uncertainty
Ta	Transversal position deviation	Pa	Position deviation
Bmax	Maximum backlash	Bmax	Maximum backlash
Bave	Average backlash	Bave	Average backlash
Tsmax	Maximum transversal position spread	Psmax	Maximum position spread
Tsave	Average transversal position spread	Psave	Average position spread

H 3.5 Determination of parallelism and squareness deviations

To determine deviations of parallelism or squareness, make two straightness measurements along two measuring axes. The program will then combine the data records of the two measuring axes and find the squareness or parallelism deviation.

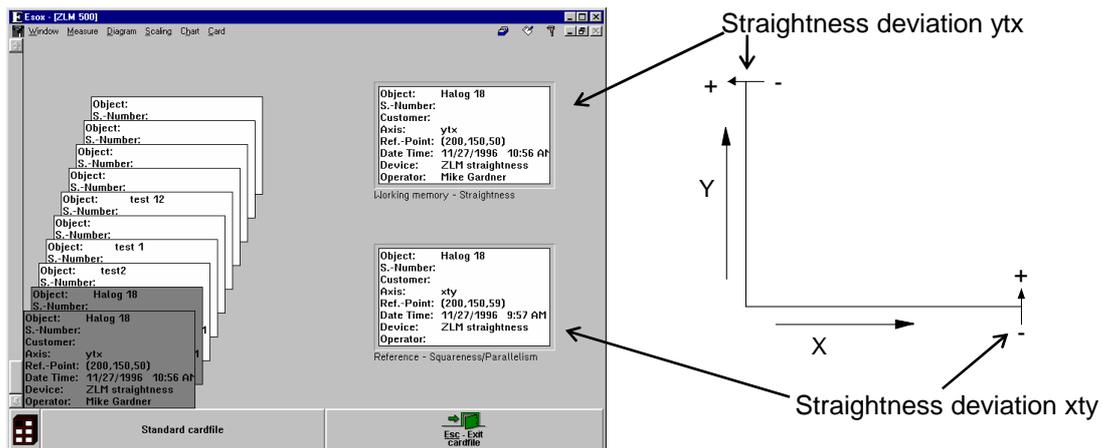
In the straightness measurements, mind the signs of the transversal deviations. The illustrations below show how to select the signs.



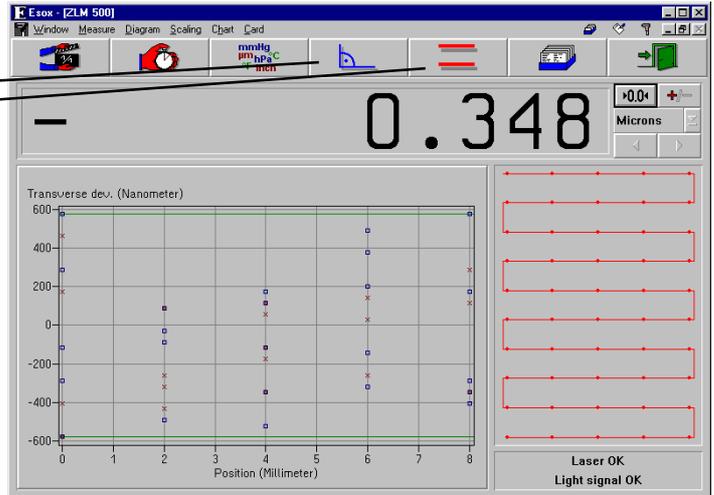
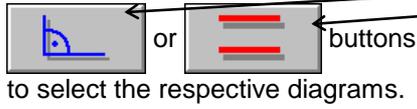
Before a measurement, shift the double wedge to check whether the correct sign has been set; correct it, if necessary, by the numerical display.

After the measurement, load the two card files for straightness measurement into the computer's main memory.

Only in squareness measurement it is important to position either card in its proper place.

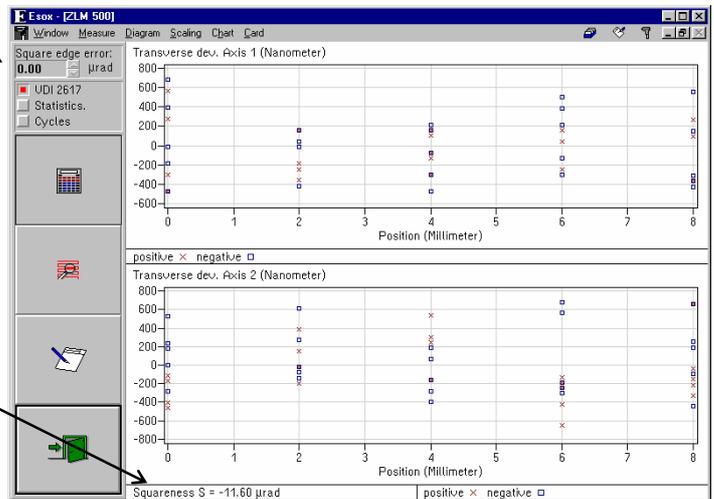


Use the "Squareness" or "Parallelism" items in the "Diagram" menu or the

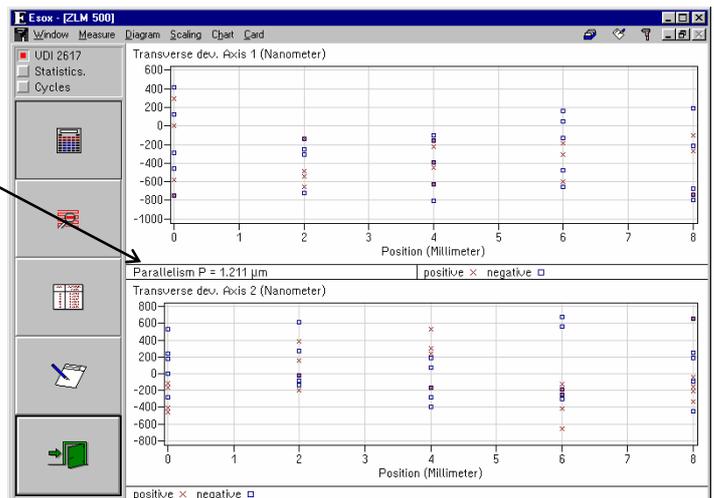


In squareness measurement you can enter the deviation of the pentaprism from 90°

At the bottom margin, the amount of the squareness deviation is displayed.



In parallelism analysis, the parallelism deviation is indicated below the upper diagram.



I "ZLM Stat" - Measurement Software for Statistical Analyses

The "ZLM Stat" program module lets you measure and analyse both position and angle data of an object to be tested. The module works in conjunction with distance and angle optics of standard or extra-high resolution, as well as with 2m or 10m straightness optics. ZLM Stat is primarily used if the object under test is to be positioned to a number of points several times each, in order to yield statistical information about the positioning process. Compared with the "ZLM Position", "ZLM Angle (static)" and "ZLM Straightness" modules (sections G and H of this manual), "ZLM Stat" offers the advantage that measurement data can be acquired along several axes of a multi-axis laser interferometer in synchronism. The parameter to be measured and the optics to be used can be chosen independently for each axis.

I 1 Standard measurement and analysis procedures

The information on positioning methods and standard data analysis procedures given in this section is similar to the information in section G about the "ZLM Position" calibration software.

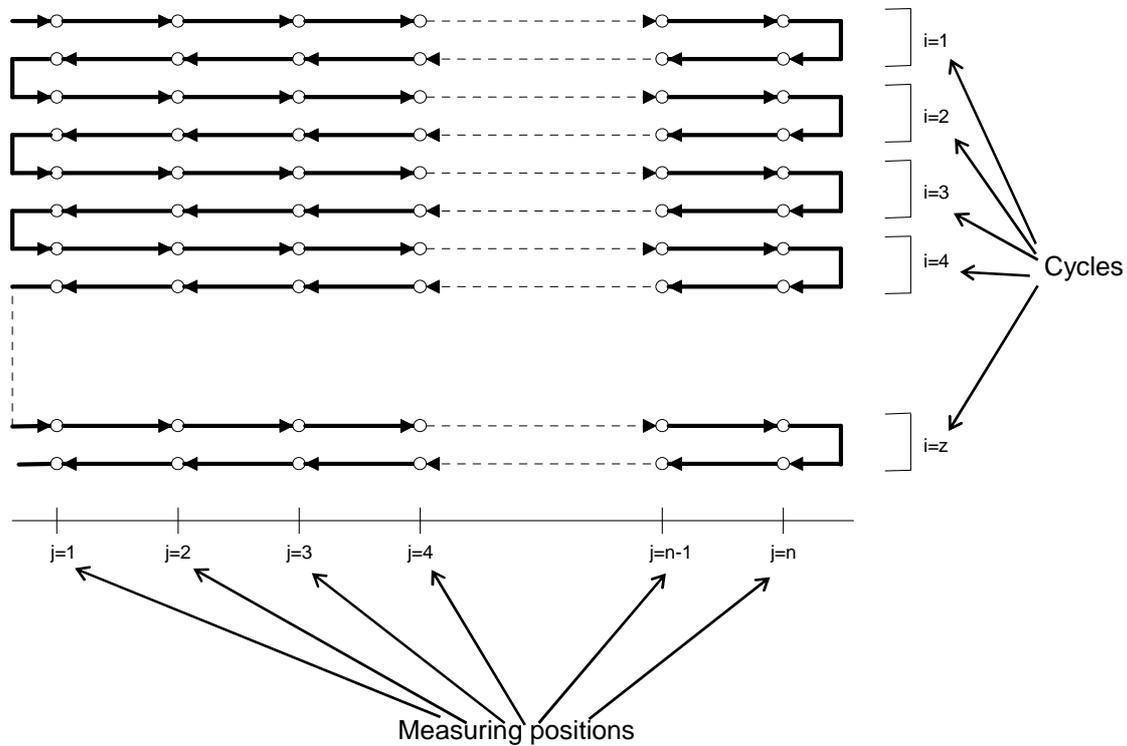
The positioning and analysis procedures described there can also be used with several measurement axes. The relevant standards describe statistical analysis methods only for distance measurements, but these methods can be generalized for application to rotatory quantities and transverse deviations.

I 1.1 Positioning methods

In order to yield statistical information on its positioning behaviour, the object under test must be moved to a number of positions several times. Among the positioning methods used in practice, the program supports the linear, unidirectional linear, oscillation (also called "pendulum-step") and quasi-pilgrim step ("quasi-pilger") methods. To facilitate understanding, the positioning sequences are described as applied to linear measurements, but they can also be applied to rotation axes; the program will support such application.

I 1.1.1 Linear method

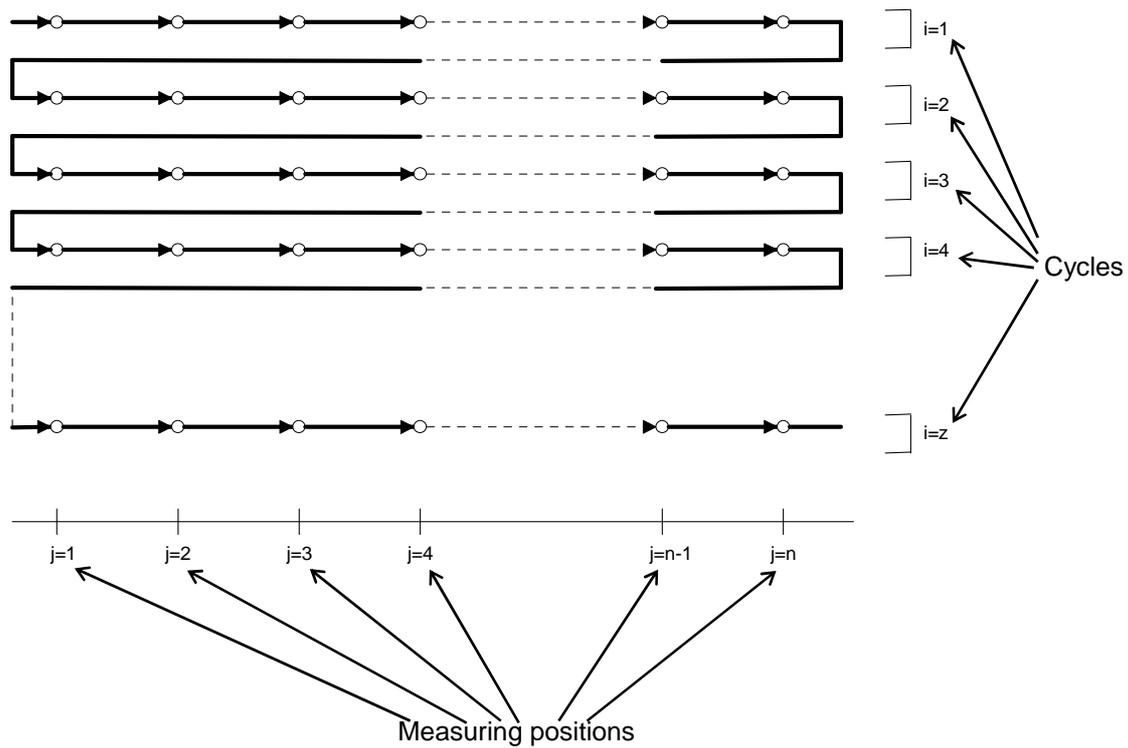
With the linear method, all positions are first travelled to in succession in the positive direction and then again in succession in the negative direction. The whole procedure is repeated several times (cycles).



In order to ensure that the first and last positions in each cycle are travelled to from the correct direction, it is necessary to provide an approach length at the start of the procedure, and a return loop at the end of each half-cycle.

This positioning method is easy to program. With great distances between positions, however, the total measurement takes considerable time. Greater temperature variations during that time will affect both the backlash error (reversal span) and the position spread (see section I 1.2).

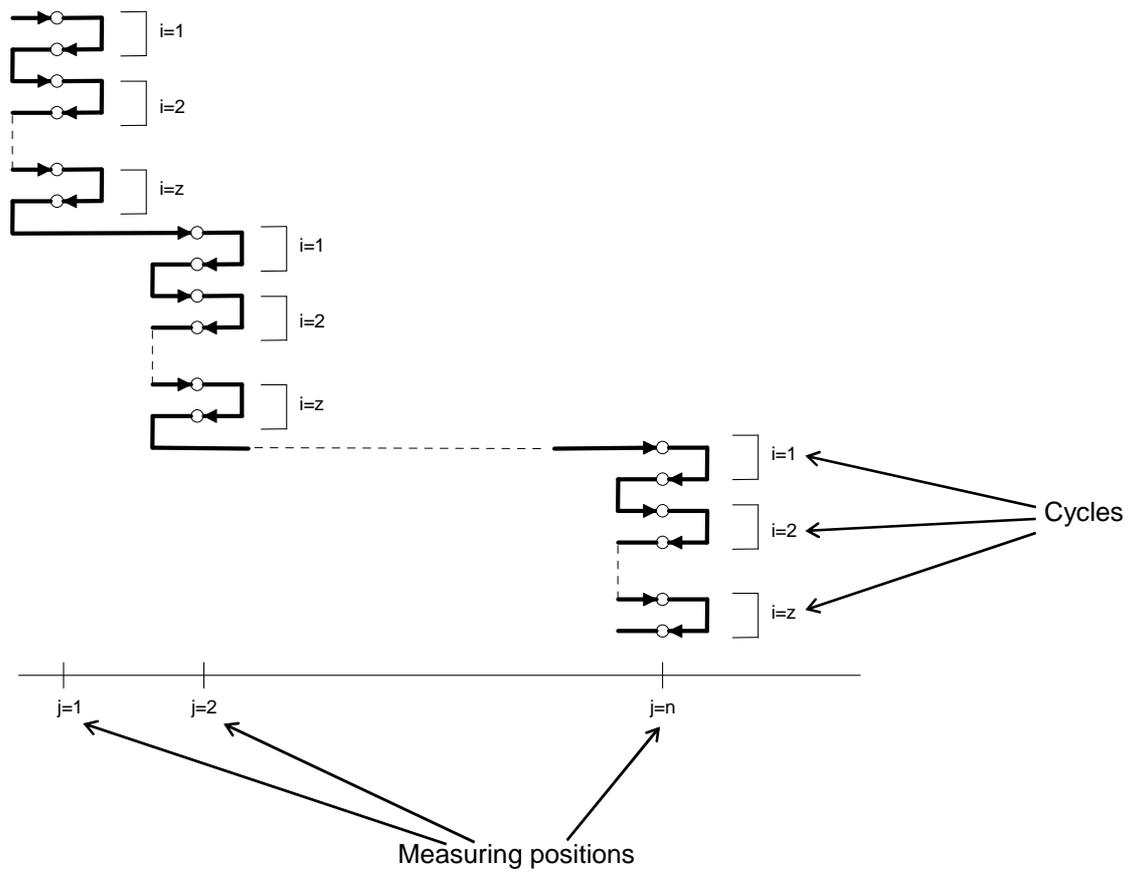
I 1.1.2 Unidirectional linear method



If it can be assumed that the differences between positioning in positive and positioning in negative directions are negligible (i.e. a small backlash error (reversal span)), the unidirectional linear method suggests itself.

In an extreme case one might also make a single-cycle rapid test. Mind, however, that the standard analysis procedures issued by the standardization bodies (described in section I 1.2) do not provide for this positioning method.

I 1.1.3 Oscillation ("Pendulum-step") method

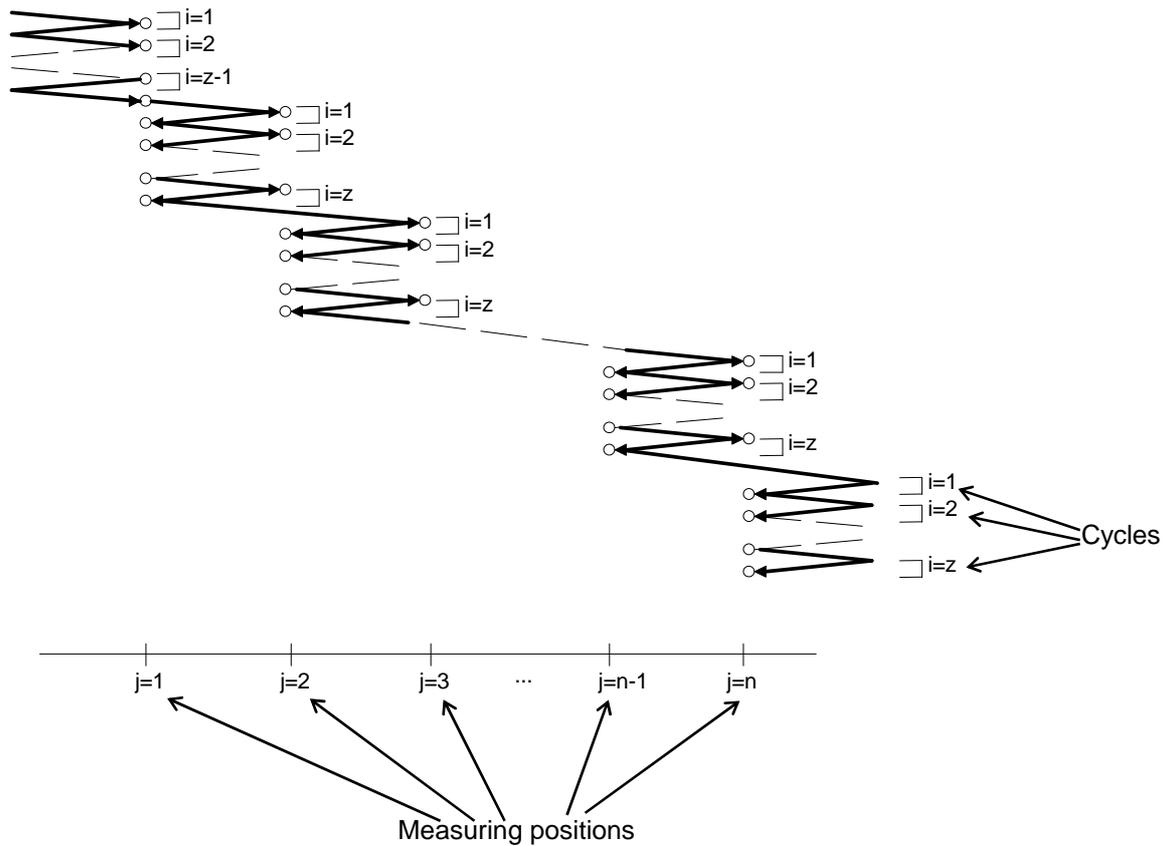


With this method, each measurement position is repeatedly travelled to, alternatingly from the positive and negative directions, before the measurement proceeds with the next position.

Of all the methods described, the Oscillation method involves the shortest total length of travel. This is of advantage especially where the positions are spaced far apart.

Major temperature variations during the measurement affect neither the backlash error (reversal span) nor the position spread (see sect. I 1.2). However, because of the long time passed between measuring the first and measuring the last position, thermal and other influences occurring during that time enter the measurement as systematic errors.

I 1.2.4 Quasi-pilgrim step ("Quasi-pilger") method



With this method, the first measurement position is travelled to several times in positive direction. Next, alternating travels are performed to the second position in positive direction and to the first position in negative direction. The pattern of alternating travels to the j^{th} and $(j+1)^{\text{th}}$ positions is continued until the last position has been travelled to repeatedly in the positive direction. Finally, the last position needs to be travelled to repeatedly in the negative direction.

Same as with the Oscillation method, great temperature variations during the measurement do not affect the backlash error (reversal span) nor the position spread, but enter the measurement as systematic errors.

I 1.2 Standard analysis procedures

Several standards authorities and institutions have issued standards and recommendations for the inspection of coordinate measuring machines and machine-tools.

The "ZLM Stat" measuring program is designed for the inspection of coordinate measuring machines and machine-tools in accordance with the following standards,

- ISO 230
- VDI/DGQ 3441
- NMTBA

for the inspection of machine tools, and

- VDI/VDE 2617

for the inspection of coordinate measuring machines.

The standards mainly differ by the computation of parameters and the graphical presentation of the results.

All these standards deal with position measurements. VDI/VDE 2617 also covers straightness and angle measurements, but does not describe any methods of statistical analysis for such measurements. The "ZLM Stat" program module supplies diagrams and parameters for straightness and angle measurements that closely follow the analysis methods described for position measurements. The overview charts in this section, however, contain only those analysis equations that are described in the standards.

Objective of measurement in inspecting machine-tools: Assessment of the accuracy to which components can be machined

Objective of measurement in inspecting coordinate measuring machines: Assessment of the machine's measuring accuracy

Result of a measurement: Relevant standards define parameters and recommend graphs by which the systematic and random deviations from the ideal state of a machine can be assessed. The present program supplies these parameters and diagrams as results of measurements.

For the acquisition of measurement data, the following points should be minded:

- Establish at least one line parallel to each machine axis of interest, along which measurement positions can be moved to.
- Measurement positions should be distributed throughout the range of travel.

Further recommendations on selecting measurement positions are given by the standards quoted.

Standard	Minimum number, absolute	Minimum number per scale element	Equation for establishing nominal positions
ISO 230	5 (for measured lengths up to 1 m) 5 per metre (for measured lengths up to 2 m)	1	$P_j = N \cdot p \cdot r$ P_j - nominal position N - integer r - random decimal fraction p - greatest period
VDI/DGQ 3441	10 per metre + 1 (for measured lengths up to 2 m)	1	
VDI/VDE 2617	11	2	

The relevant standards and recommendations differ greatly in their procedures of computing the parameters and in their modes of presenting the result graphically.

What they all have in common is that they define a set of parameters that separately characterize

- systematic position deviations,
- random position deviations, and
- composite (systematic plus random) deviations.

These three kinds of parameters can also be obtained separately from the graphs established according to all the standards concerned.

Let the significance of the parameters be explained by the example of a machine-tool:

Systematic position deviations:

The standards concerned, except ISO 230, define a "**Position deviation**". With a certain quantity of like parts being machined on a machine-tool, the "Position deviation" indicates the average machining error to be expected for the parts.

The standards concerned, except for NMTBA, specify a "**Backlash**" (ISO) or "**Reversal span**" (the other standards). The "Backlash" or "Reversal span" indicates the average effect to be expected if in the machining process a position is travelled to from one position instead of the other.

Random position deviations:

The "**Position spread**" indicates the maximum differences to be expected in at least 99.5% of the machined parts. (As an exception, VDI/VDE 2617 specifies the position spread for coordinate measuring machines, computed for 95% of the reading errors to be expected.)

Composite position deviations:

The "**Position uncertainty**" indicates the machining error to be expected in a 99.5% yield, irrespective of the positioning direction.

The charts on the following pages show how the parameters and graphs are computed according to the different standards.

VDI/DGQ 3441	<p>z - Number of measuring cycles n - Number of positions i - Cycle number j - Position number</p>	<p>x_{ij} - Deviation (actual-nominal) at position j during cycle i ↑ - Positive travel direction ↓ - Negative travel direction</p>
---------------------	---	--

Diagram:

Average deviation: $\bar{x}_{j\uparrow} = \frac{1}{z} \sum_{i=1}^z x_{ij\uparrow}$ $\bar{x}_{j\downarrow} = \frac{1}{z} \sum_{i=1}^z x_{ij\downarrow}$ $\bar{x}_j = \frac{\bar{x}_{j\uparrow} + \bar{x}_{j\downarrow}}{2}$

Position spread: $P_{sj} = 3 \cdot \left(\sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\uparrow} - \bar{x}_{j\uparrow})^2} + \sqrt{\frac{1}{z-1} \sum_{i=1}^z (x_{ij\downarrow} - \bar{x}_{j\downarrow})^2} \right)$

Reversal span: $U_j = |\bar{x}_{j\uparrow} - \bar{x}_{j\downarrow}|$

Deviation (micrometers)

The graph plots Deviation (micrometers) on the y-axis (from -2 to 5) against Target position (metres) on the x-axis (from 0.0 to 1.0). It features several data series: a solid red line for the average deviation \bar{x}_j , dashed blue lines for the upper and lower average deviations $\bar{x}_{j\uparrow}$ and $\bar{x}_{j\downarrow}$, and dotted green lines for the position spread P_{sj} . A vertical double-headed arrow at $x = 0.5$ indicates the reversal span U_j . Labels on the right side of the graph point to the following values: $\bar{x}_{j\uparrow} + \frac{P_{sj}}{2}$, $\bar{x}_{j\uparrow}$, \bar{x}_j , $\bar{x}_{j\downarrow}$, and $\bar{x}_{j\downarrow} - \frac{P_{sj}}{2}$.

Parameters:

Position spread: $P_{s\max} = \max[P_{sj}]_{j=1}^n$ $P_{s\mit} = \frac{1}{n} \sum_{j=1}^n P_{sj}$

Reversal span: $U_{\max} = \max[U_j]_{j=1}^n$ $U_{\mit} = \frac{1}{n} \sum_{j=1}^n U_j$

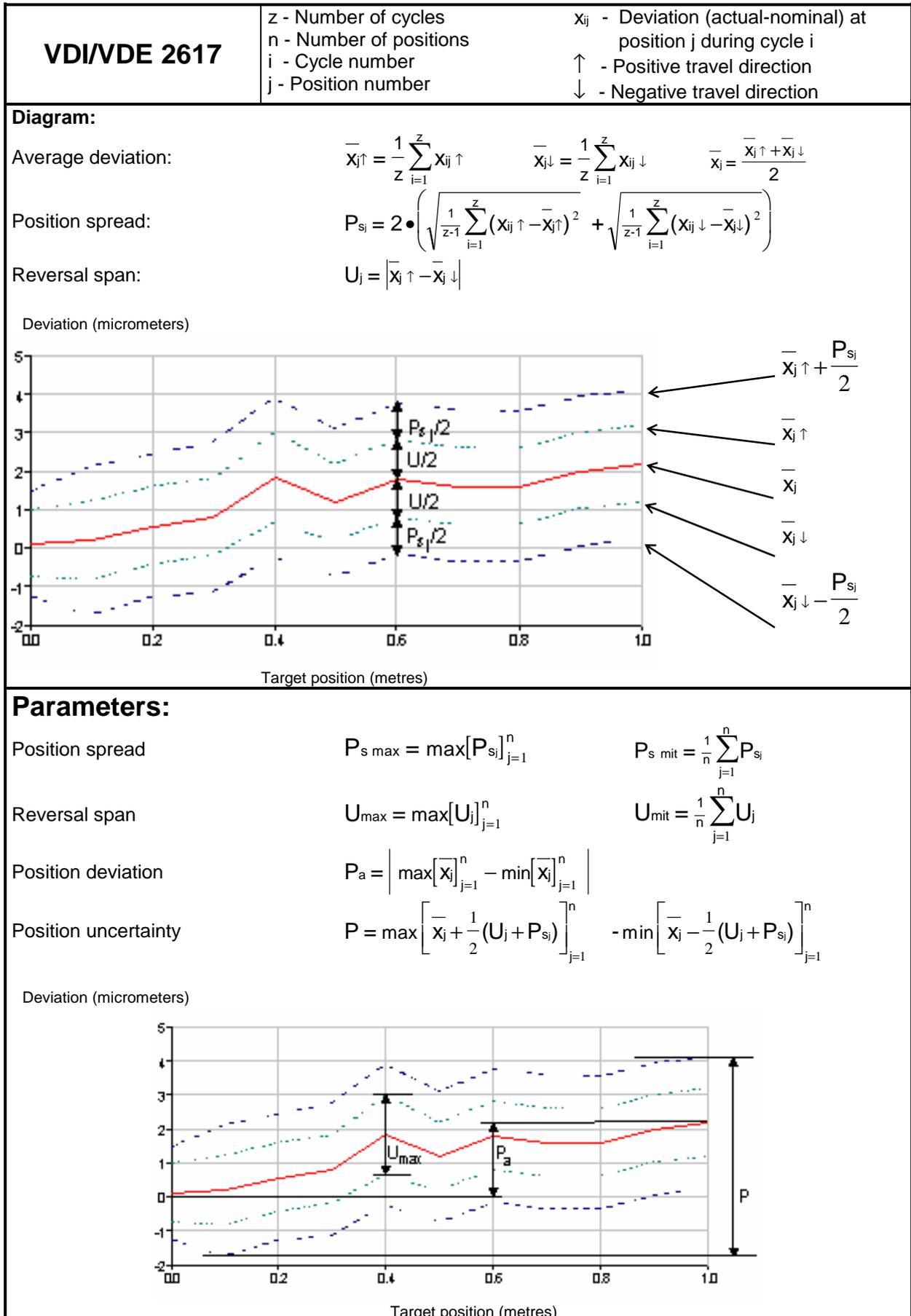
Position deviation: $P_a = \left| \max[\bar{x}_j]_{j=1}^n - \min[\bar{x}_j]_{j=1}^n \right|$

Position uncertainty: $P = \max \left[\bar{x}_j + \frac{1}{2} (U_j + P_{sj}) \right]_{j=1}^n - \min \left[\bar{x}_j - \frac{1}{2} (U_j + P_{sj}) \right]_{j=1}^n$

Deviation (micrometers)

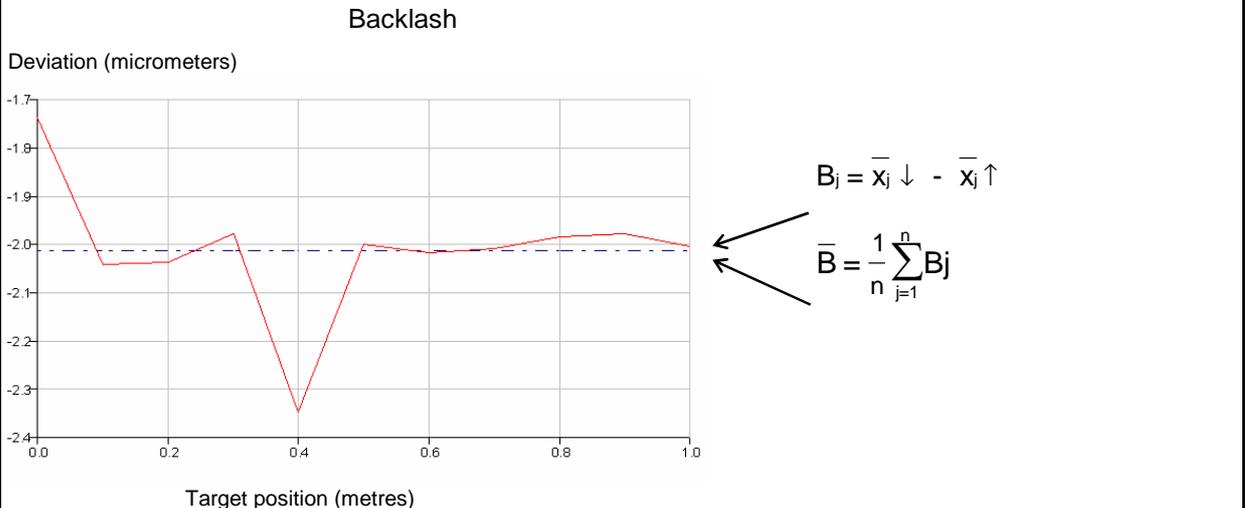
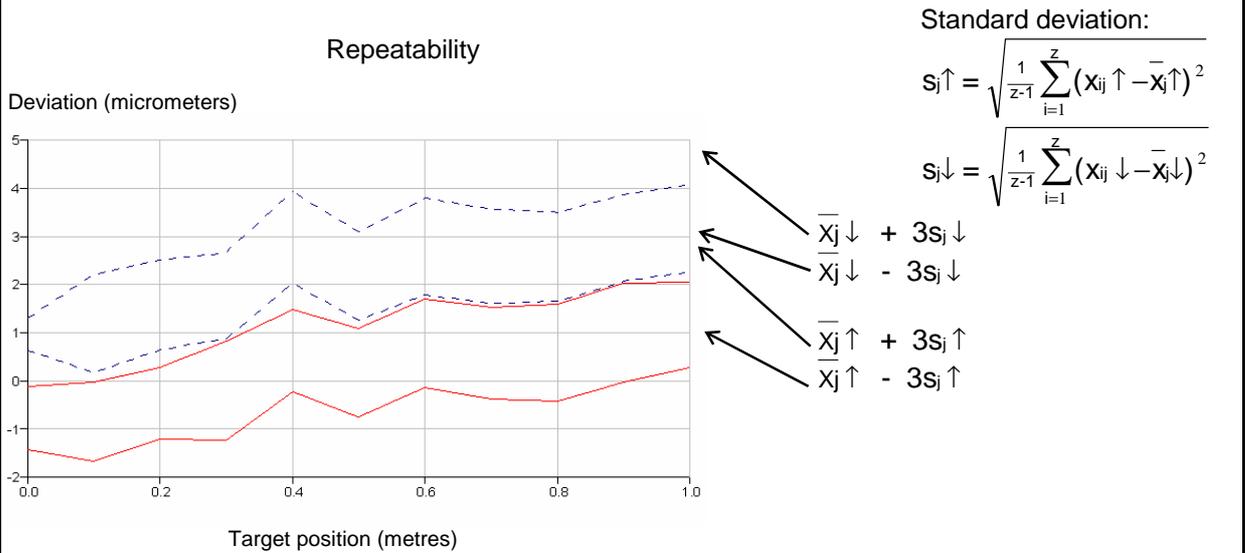
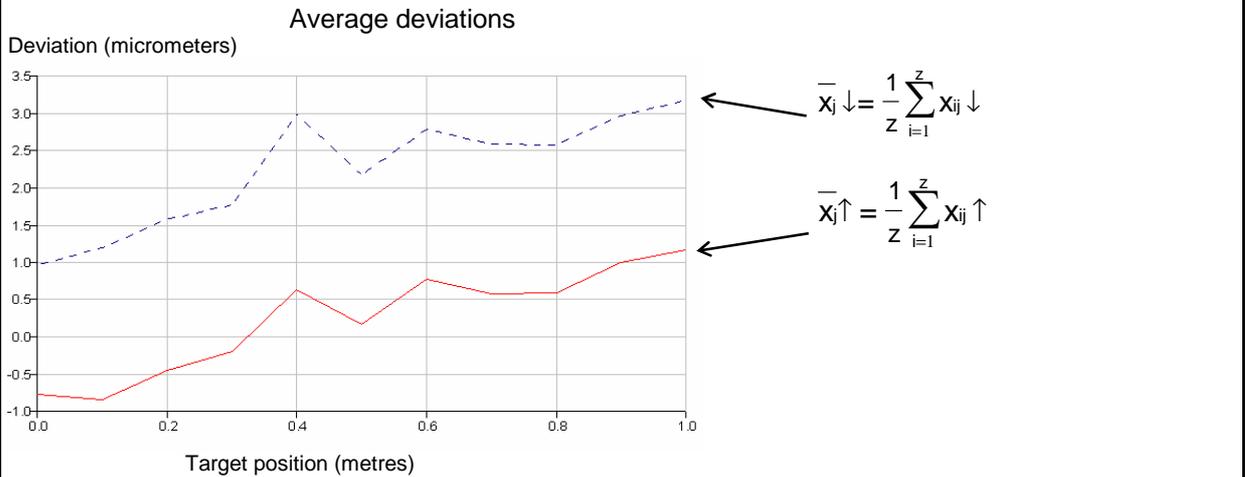
This graph is similar to the one above but highlights specific parameters. It shows U_{\max} as the largest reversal span and P_a as the range of average deviations. A large vertical double-headed arrow on the right indicates the total position uncertainty P .

Target position (metres)



ISO 230	z - Number of cycles	x_{ij} - Deviation (actual-nominal) at position j during cycle i
	n - Number of positions	\uparrow - Positive travel direction
	i - Cycle number	\downarrow - Negative travel direction
	j - Position number	

Diagrams:



ISO 230	z - Number of cycles	x_{ij} - Deviation (actual-nominal) at position j during cycle i
	n - Number of positions	↑ - Positive travel direction
	i - Cycle number	↓ - Negative travel direction
	j - Position number	

Parameters:

Repeatability

$$R = \max \left[\max \left[6s_{j\uparrow}, 6s_{j\downarrow}, 3s_{j\uparrow} + 3s_{j\downarrow} + |B_j| \right] \right]_{j=1}^n$$

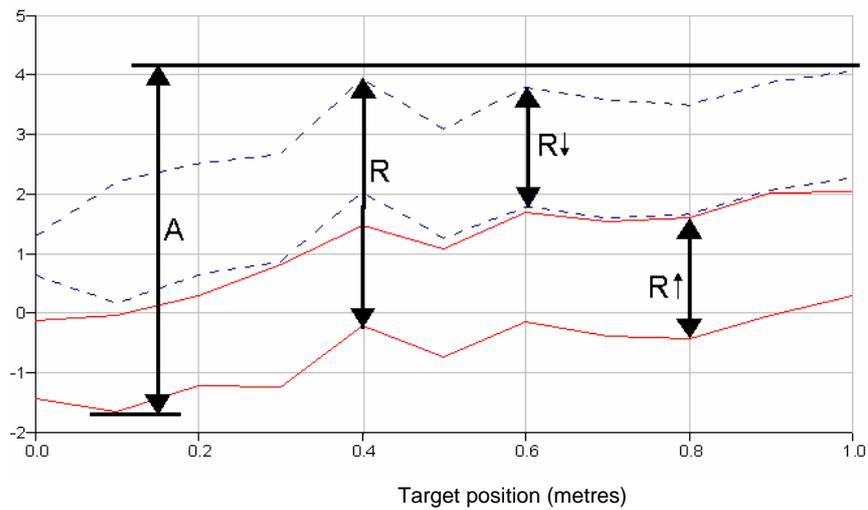
$$R\uparrow = \max \left[6s_{j\uparrow} \right]_{j=1}^n$$

$$R\downarrow = \max \left[6s_{j\downarrow} \right]_{j=1}^n$$

Accuracy

$$A = \max \left[\max \left[\bar{x}_{j\uparrow} + 3s_{j\uparrow}, \bar{x}_{j\downarrow} + 3s_{j\downarrow} \right] \right]_{j=1}^n - \min \left[\min \left[\bar{x}_{j\uparrow} - 3s_{j\uparrow}, \bar{x}_{j\downarrow} - 3s_{j\downarrow} \right] \right]_{j=1}^n$$

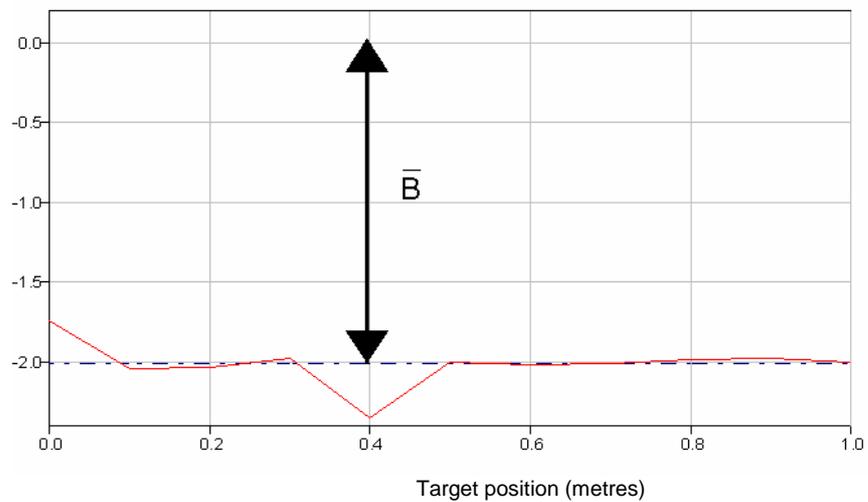
Deviation (micrometers)



Mean backlash

$$\bar{B} = \frac{1}{n} \sum_{j=1}^n (x_{j\downarrow} - x_{j\uparrow})$$

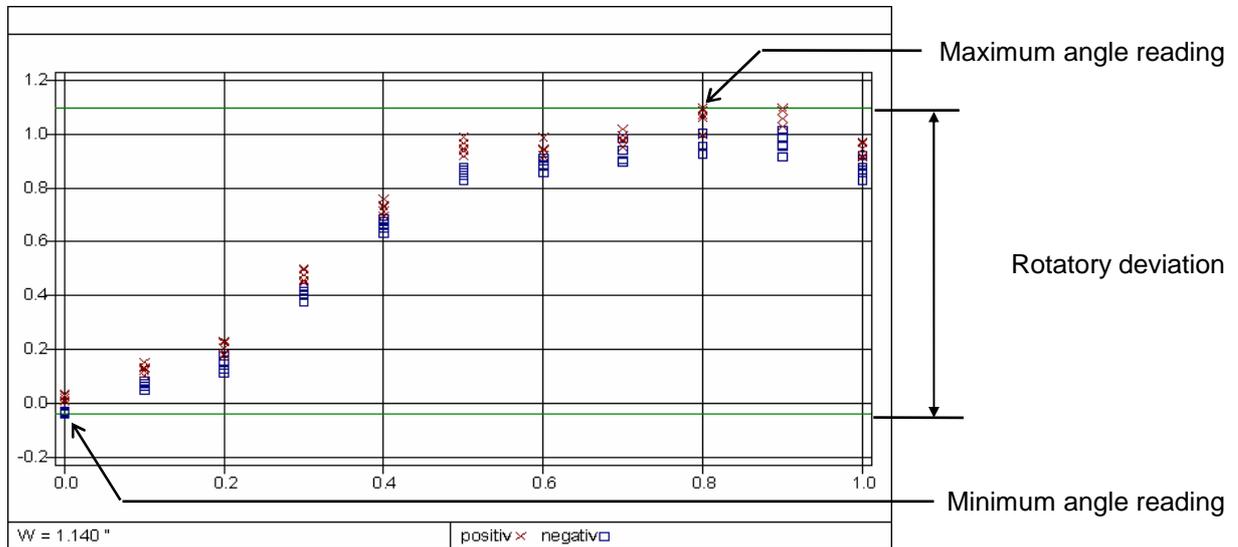
Deviation (micrometers)



NMTBA	<p>z - Number of cycles n - Number of positions i - Cycle number j - Position number</p>	<p>x_{ij} - Deviation (actual-nominal) at position j during cycle i ↑ - Positive travel direction ↓ - Negative travel direction</p>
Diagram:		
Average deviation:		$\bar{x}_j = \frac{1}{2 \cdot z} \sum_{i=1}^z (x_{ij} \uparrow + x_{ij} \downarrow)$
Position spread:		$P_{sj} = 6 \cdot \sqrt{\frac{1}{2 \cdot z - 1} \sum_{i=1}^z \left\{ (x_{ij} \uparrow - \bar{x}_j)^2 + (x_{ij} \downarrow - \bar{x}_j)^2 \right\}}$
<p>Deviation (micrometers)</p>		
Parameters:		
Position spread	$P_{s \max} = \max[P_{sj}]_{j=1}^n$	$P_{s \text{ mit}} = \frac{1}{n} \sum_{j=1}^n P_{sj}$
Offset	$O = -\frac{1}{2} \cdot \left(\max \left[x_j + \frac{P_{sj}}{2} \right]_{j=1}^n + \min \left[x_j - \frac{P_{sj}}{2} \right]_{j=1}^n \right)$	
Position deviation	$P_a = \left \max[x_j]_{j=1}^n - \min[x_j]_{j=1}^n \right $	
Position uncertainty	$P = \max \left[x_j + \frac{P_{sj}}{2} \right]_{j=1}^n - \min \left[x_j - \frac{P_{sj}}{2} \right]_{j=1}^n$	
<p>Deviation (micrometers)</p>		
<p>Target position (metres)</p>		

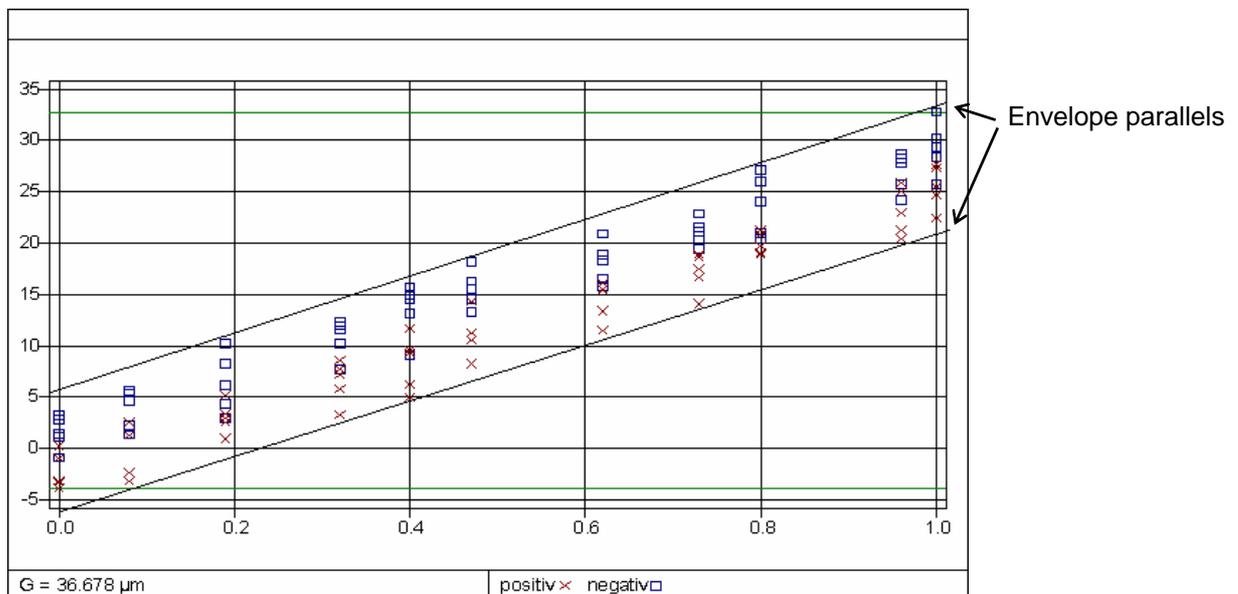
In addition to the statistical analysis of position measurements, ISO 230 specifies procedures for determining "Rotatory deviations" and "Straightness deviations".

In an angle measurement, a number of angle readings are taken at each measuring position. The "Rotatory deviation A" is the difference between the greatest and smallest of all angle readings taken, irrespective of the position and travel direction.

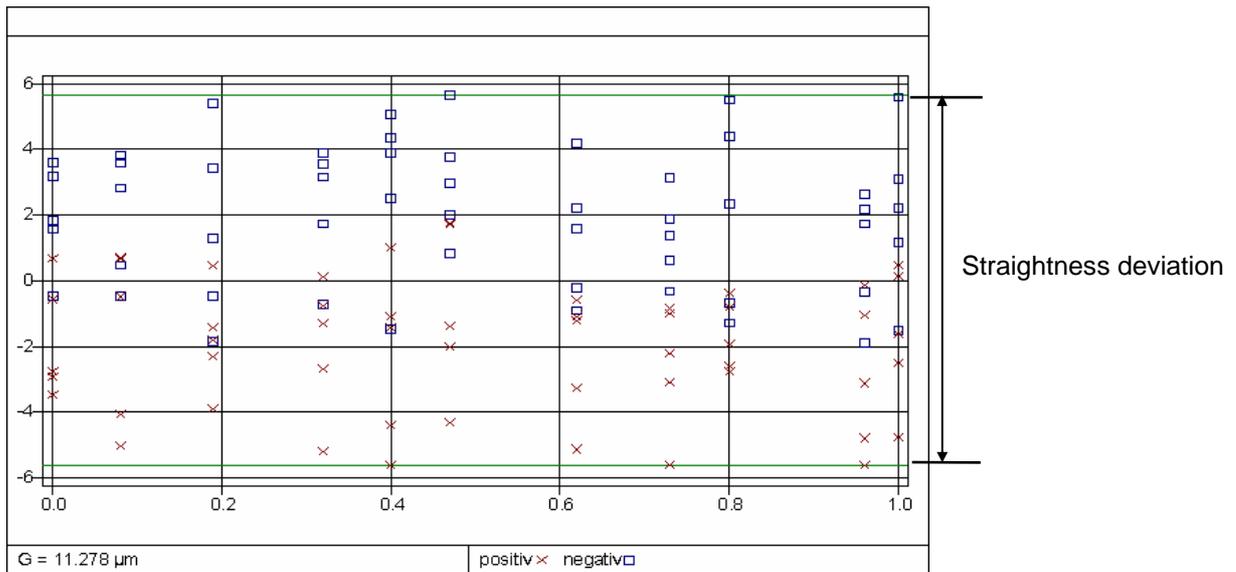


In a straightness measurement, the laser beam usually is not exactly aligned with the axis being measured. This would cause major errors if the difference between maximum and minimum readings were defined as a parameter.

Therefore, a "Straightness deviation S" has been defined as the distance between two parallels that include between them all measuring points while having the minimum possible distance from one another. The program calls these straight lines "envelope parallels".



When fitting the envelope parallels, the program transforms all readings in such a way that after transformation the two lines are approximately parallel with the ordinate axis.



The program also offers a least-squares fitting procedure, in which a straight line is determined for which the sum of the squares of distances from the line is minimum. This procedure, too, is followed by a transformation aimed at placing the straight line in parallel with the ordinate axis. But in this case, the difference between maximum and minimum is always either greater than or equal to the difference between maximum and minimum in envelope parallel fitting.

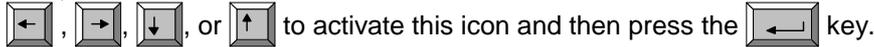
I 2 Operation

I 2.1 Starting the "ZLM Stat" program module

When the "Esox" management program is started, the "ZLM Stat" program module is not active yet. To start this program module,

1. activate the "ZLM" application window (as described in detail in Section "C 3 Starting measurement programs") and open it to regular or maximized size.

2. Now, either double-click the "ZLM Stat" icon with the mouse or use the keys



I 2.2 Elements of the "ZLM Stat" window

If you want to work with the "ZLM Stat" measurement program for a longer time, we recommend to maximize its window after having started it.

Within the window, several fields can be distinguished:

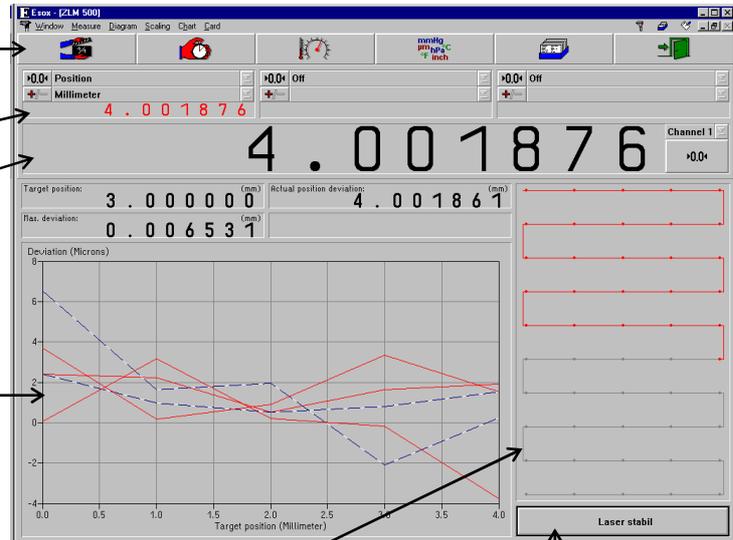
The top margin shows a row of buttons.

Below this there are display and setting fields showing the current readings of the various measuring channels. The reading of one channel can be shown enlarged.

The bottom left portion of the window is occupied by a large button showing a diagram generated from the measured data currently in the memory. This field is empty if no data are in the memory.

The field to the right of the diagram shows the number of readings currently in the memory and the positioning method by which the readings were obtained. With no data in the memory, this field is empty, too.

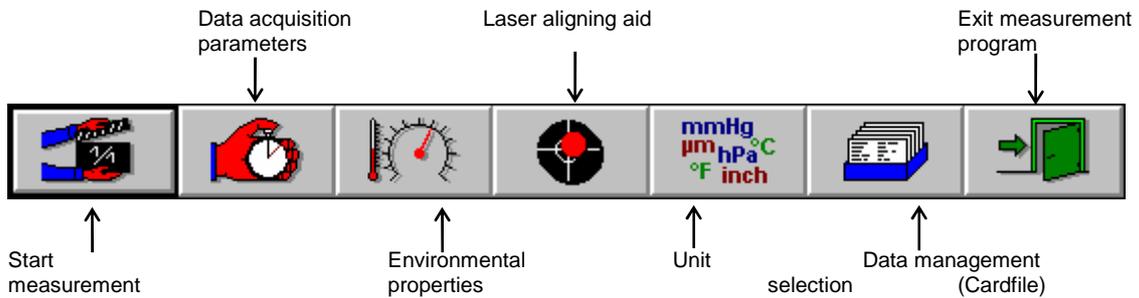
The field in the bottom right corner indicates if the laser operates stably and which light intensity hits the detector.



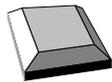
During the measurement and diagram analysis processes the appearance of the window changes, as described in detail in the following subsections.

I 2.2.1 Button field

With these buttons you can activate specific functions of the program, such as start of data recording, setting options for data recording, and data evaluation by diagrams. All these functions can also be started via menu commands. They are explained in detail in the following subsections.



Clicking a button with the mouse activates the function assigned to this button.



On program start, the first (left) button  is made active as is indicated by the thicker black frame around it. By pressing the  key you can make the next button active. The function assigned to the active button is released by pressing the  key.

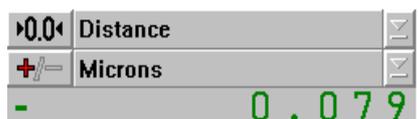
I 2.2.2 Display and setting boxes

Below the row of buttons, each measurement channel has a set of boxes for the most frequently used settings. At the far left you find the boxes for channel 1, with the boxes for the next channels following in succession from left to right. The number of channels is preconfigured to match the number of measuring axes. Further settings that can be made for the channels are described in section I 2.4.1 "Channel settings".



In the upper drop-down list box you can select the unit of measurement to be assigned to the channel.

List box option	Explanation
"Off"	No measured data are displayed for the respective channel. During the acquisition of data for permanent storage, this channel is ignored.
"Distance"	The n-th display from the left indicates the distance computed from the counter reading of the n-th measuring axis.
"Angle"	The n-th display from the left indicates the angle computed from the counter reading of the n-th measuring axis.
"Straightness"	Use this option if you want to measure a transverse displacement with an optical straightness measuring component at the n-th measuring axis, to be indicated in the n-th display box from the left.
"Displacement m-n"	The n-th display box from the left indicates the distance computed from the difference between the counter readings of the m-th and n-th measuring axes.
"Displacement m+n"	The n-th display box from the left indicates the distance computed from the sum of the counter readings of the m-th and n-th measuring axes.
"Angle m-n"	The n-th display box from the left indicates the angle computed from the difference of the counter readings of the m-th and n-th measuring axes via the arc tan function. You need to enter the required reflector spacing in the " Beam spacing " line of the "Configuration" dialog box for the n-th axis.



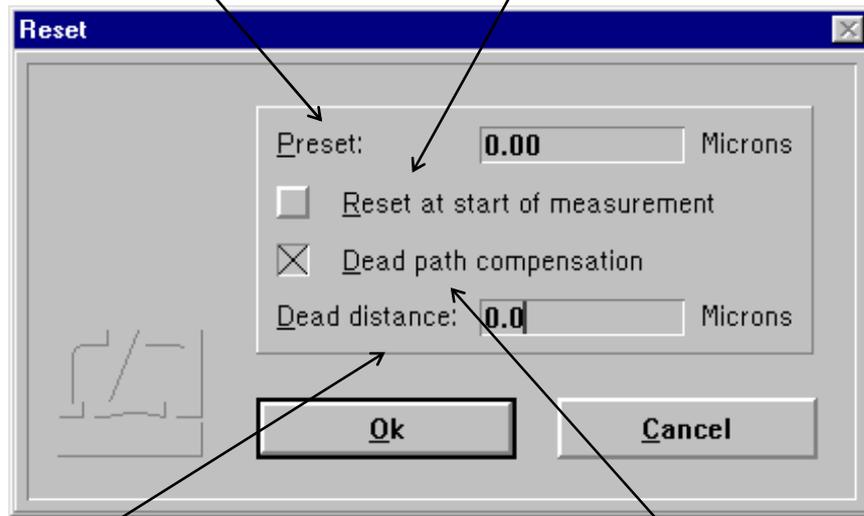
In the lower drop-down list box you can select the unit of measurement for the display. See section I 2.3 "Unit systems" for information on how to change from one system of units to another (metric or imperial measure; degrees/minutes/seconds/radians).

Use this button to open a dialog box "Reset", in which you can set the reference point and the dead distance.



In the "Preset" text box you can preset the distance or angle to be assigned to the present position.

If the button "Reset at start of measurement" is on , the preset value will be assigned to the instantaneous position at the time you start a measurement.

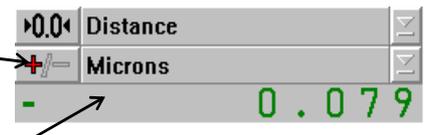


In the "Dead distance" box you can enter the distance between the reflectors. See Annex III for a detailed explanation of the term "dead distance".
The dead distance is of significance only in high-accuracy measurements with the environmental properties changing during the measurement. If you specify a dead distance, mind the correct sign. Specify the dead distance so that, after resetting, the sum of measurement readout and dead distance has always the same amount as the distance between the two reflectors.

If it can be assumed that the environmental conditions will not change during a measurement, the "Dead distance compensation" button can be switched off ()

The reference point is only assigned when the button is activated. The actions and settings made in this dialog box only act on the respective measuring axis.

With this button you can change the sign.

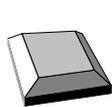


The bottom line indicates the current reading. It is updated 10 times a second, unless the computer is overloaded by other tasks.



To release a function with the  or  button, click on it.

To change the active option in a drop-down list box, click on the underlined arrow right of the list box. This opens the list box and allows you to click the desired option.



Press the  key until the wanted list box or button is marked and thus active. Active buttons ( or ) are displayed with a thicker black frame around the button. An active drop-down list box is marked by a highlighted (white on black ground) entry. To open the pull-down list and see the options available, press the key combination  + . By pressing the  or  keys you can choose the wanted option. To confirm your choice, press the  key.

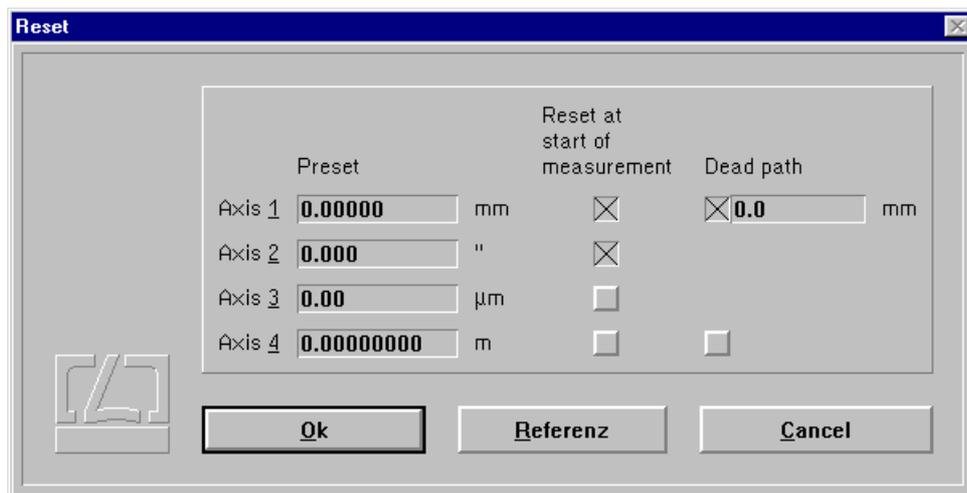
To release a button function, press the  key.

I 2.2.3 Large numerical display

This display box indicates the instantaneous reading of a channel with large digits. Use the drop-down list box on the right of the display to select the channel.



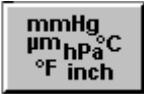
Use the button below the list box to set the reference point simultaneously for all measuring axes. Clicking this button opens the "Reset" dialog box. In this box you can make the same settings as in the Reset boxes of the individual channels, but here they act on all measuring axis simultaneously.



Upon actuating the  button, assignment of the reference points is made simultaneously for all measurement axes.

I 2.3 Unit systems

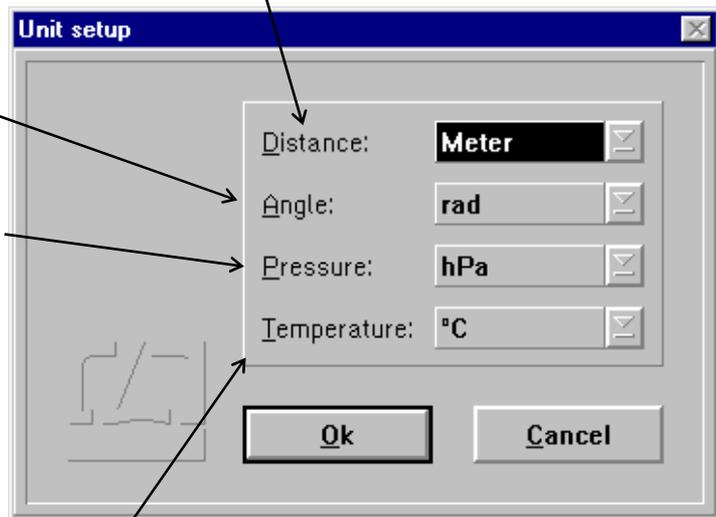
Units of distance, atmospheric pressure and temperature can be selected in the "Unit setup" dialog box.

Open this box by clicking the  button or selecting the "Units" option of the "Measure" menu.

The program can show distances and quantities derived from them in either metric (metre) or imperial (Inch) measure. Switch between them in the "Distance" list box.

In the „Angle“ module you only need to select the angle unit (rad, degrees, minutes or seconds of arc)

In the "Pressure" list box you can select between "Hectopascal" and "Millimetre mercury".
(1000 hPa = 100 kPa = 1000 mbar,
and
1 mmHg = 1 torr)



In the "Temperature" list box you can select between "Degree Celsius" and "Degree Fahrenheit".

I 2.4 Preparation for a measurement

In preparation for a measurement you need to specify

- the positioning method to be used,
- the number of readings to be taken at each position,
- the type of event by which a reading is to be triggered, and
- the required mode of compensation for environmental influences.

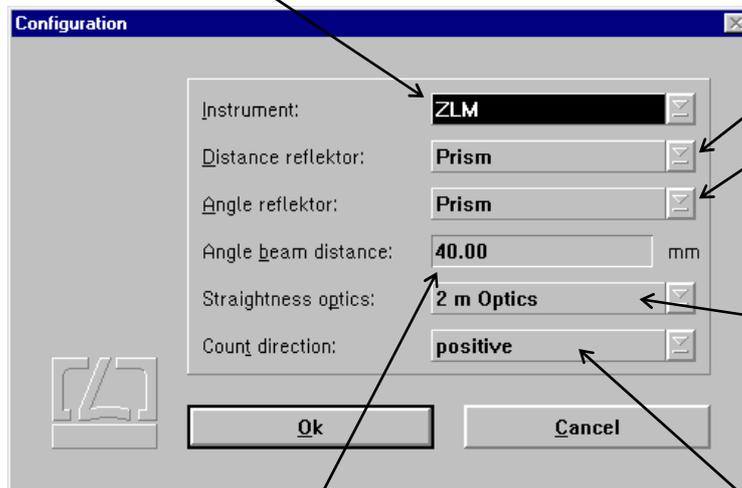
For this purpose, use the "Parameters" and "Environment" dialog boxes to enter general settings acting on all channels.

Use the "Parameters" dialog fields to enter specific settings for each channel.

I 2.4.1 Channel settings

In the "Measure" menu, select the "Setup channel 1", "Setup channel 2" ... options in order to open a "Parameters" dialog box for the respective measuring channel.

In the "Instrument" list box you can tell the program which kind of measuring system is connected.



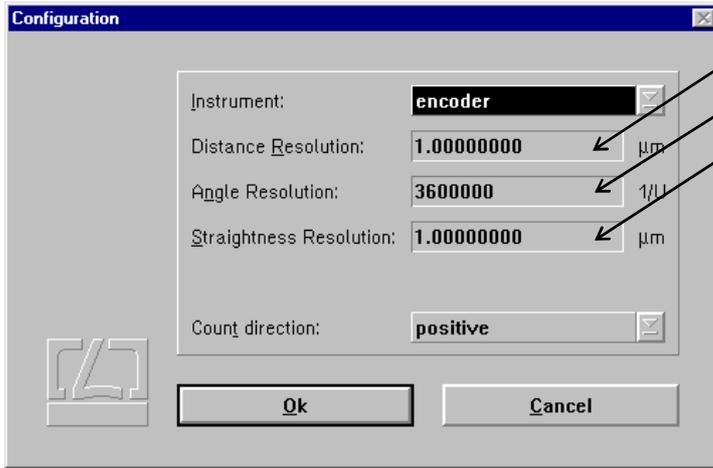
In the "Distance reflector" or "Angle reflector" list box you need to specify which kind of interferometer is used for a distance or angle measurement. Select "Prism" in case of a corner cube interferometer, "Mirror" in case of a plane mirror interferometer. See the "Manual of multi-axis laser interferometers" for suitable interferometer arrangements.

In the "Straightness optics" list box you need to select which set of optical straightness measuring components is used, if you want to measure transverse displacements with straightness optics.

In angle measurements, you need to specify in the "Angle beam distance" text input box the reflector distance as a basis for angle computation. If you use channel "n" for an angle measurement by way of forming the difference between two measuring axes, the reflector distance must be entered in the n-th field of the axis setting dialog.

In the "Count(ing) direction" list box you can reverse the sign. A sign set here becomes effective before any positions are being computed from the readings.

A sign reversal made by clicking the  button in the display field becomes only effective after the positions have been computed.



In case you use an incremental shaft encoder, you need to tell the program the resolution (least count) of the encoder. For an incremental shaft encoder divided into 1000 increments without interpolator, e.g., enter 4 x 1000 r.p.m. = 4000 r.p.m., as the software evaluates both flanks each of the 0° and 90° signals.

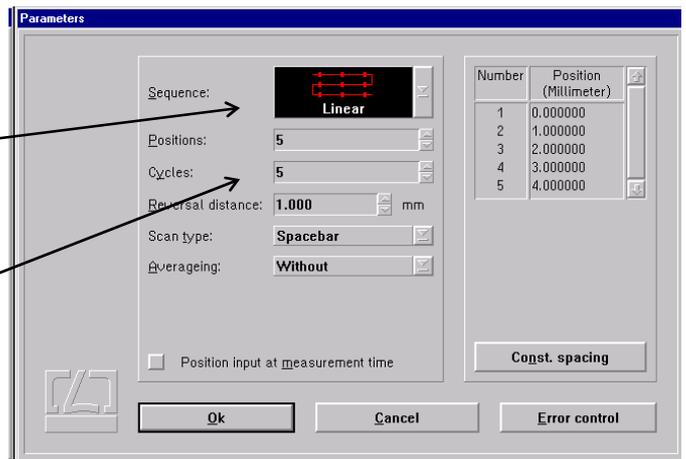
I 2.4.2 Parameter setting for measurement data acquisition

Access the "Parameters" dialog box by opening the "Measure" menu and choosing the "Configuration" option or by clicking the  button.

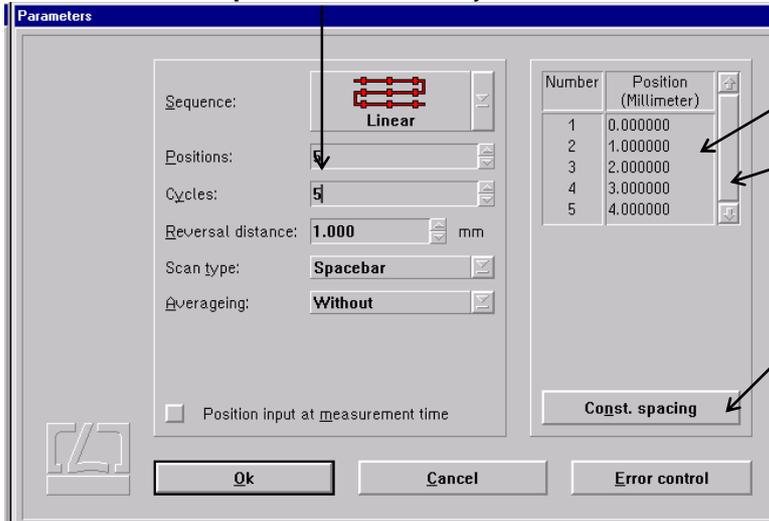
In the "Method" list box you can select between the four positioning methods described in section I 1:

- Linear
- Unidirectional linear
- Pendulum-step (Oscillation) and
- Quasi-pilger step (Quasi-pilgrim)

In the "Cycles" text box you can enter the number of times each position is to be travelled to from one direction.



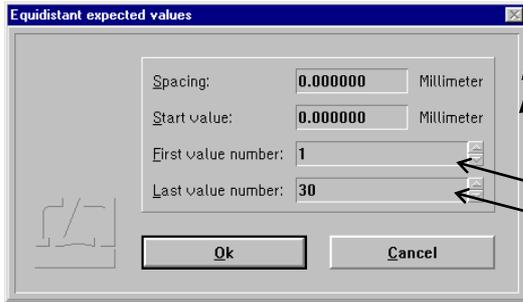
In the "Number of positions" text box you can enter the number of nominal positions to be measured.



In the right column of this dialog box you can enter the individual nominal positions.

Use the vertical scroll bar on the right margin to access positions not visible in the list.

If you want to have the nominal positions equally spaced, use the "Constant spacing" button for fast setting.



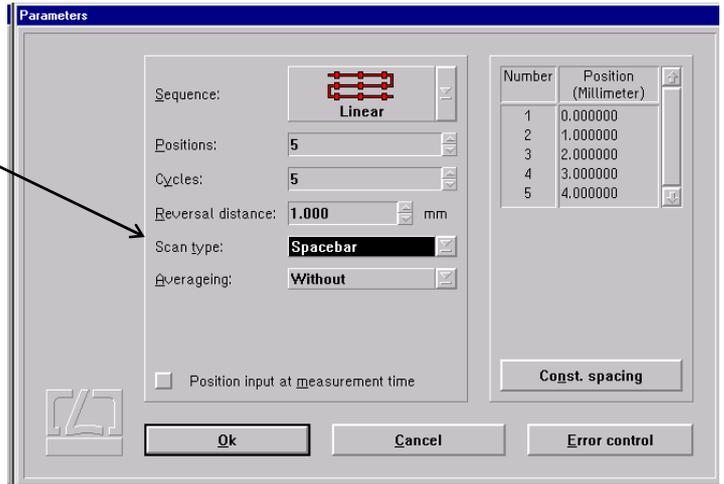
Clicking the "Constant spacing" button opens a dialog box headed "**Equidistant expected values**", in which you can enter the constant interval and the start position.

If you want a certain range of positions rather than all positions to be constantly spaced, you can specify this range in the boxes headed "**First value number**" and "**Last value number**".

In the "**Scan type**" list box you can select the event which is to trigger data acquisition.

This setting also determines whether the nominal positions have to be preset as linear (distance) or angular values.

The table below explains the entries in this list box.



Entry	Explanation
"Space bar"	Data acquisition takes place when you press the Space bar of the computer keyboard after starting the measurement. Nominal positions are preset as distances.
"External"	Data acquisition is triggered by pressing a remote (cable-connected) pushbutton or by a TTL signal. See Annex I for information where to connect the respective signal line. Nominal positions are preset as distances.
"Space bar / Angle"	Data acquisition takes place when you press the Space bar of the computer keyboard after starting the measurement. Nominal positions are preset as angles.
"External / Angle"	Data acquisition is triggered by pressing a remote (cable-connected) pushbutton or by a TTL signal. Nominal positions are preset as angles.
"Automatic, channel ..."	With this entry selected, the program recognizes when the object under test is at standstill and automatically effects data acquisition at this moment. Thus the measurement can be completely automated, provided that the object tested has a control system that allows the execution of a control program for the selected positioning sequence. To recognize standstill, the program only uses the readings of the channel specified. Nominal positions are preset as required by that channel.
"Encoder, channel ..."	If a special counter is used for a channel, data acquisition can be triggered by the hardware at the moment when actual and nominal positions are found to be equal. This method is useful if a lot of data are to be acquired in a short time and can be correctly obtained without requiring the object to stop moving. Nominal positions are preset as required by that channel.

If your setting in the "Scan type" list box specifies distances as nominal positions, these nominal positions will be subtracted from the measured value of each channel set for "Distance". If angles are specified as nominal positions, these positions will be subtracted from the measured value of each channel set for "Angle".

A problem involved in automatic data acquisition is the recognition of standstill at such positions in the programmed sequence that are travelled to immediately before the tested object reverses the direction of its movement. Therefore, you can tell the program in the "**Reversal distance**" text box what is the minimum travel of the tested object between the last nominal position and the reversing point.

Number	Position (Millimeter)
1	0.000000
2	1.000000
3	2.000000
4	3.000000
5	4.000000

When using automatic data acquisition, you are confronted with one of two cases:

1. You want to make a successful measurement with the least possible number of positions.
2. You want to be informed about any problem cropping up during the measurement as early as possible by means of an error message.

Therefore you can select which errors the program is to recognize and display.

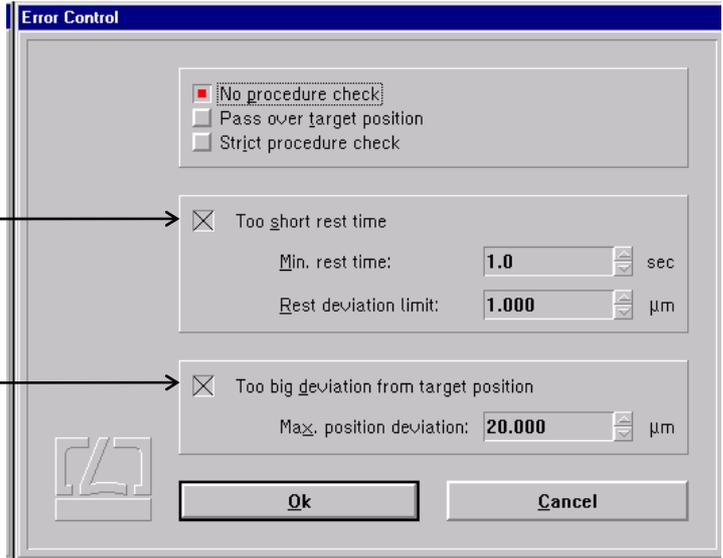
Clicking the "**Error control**" button in the bottom right corner of the "Parameters" dialog box opens the "Error control" dialog box. When you start the program for the first time, all error messages are switched off, and during a measurement the program will try to find the measuring positions under any circumstances.

If you select "**Passed over target position**", an error message will appear if a position has been reached prematurely, i.e. before its scheduled place in the positioning method selected. This error is an indication that probably the correct target position has not been recognized.

If you select "**Strict procedure check**", the program additionally checks whether the tested object travels in the correct direction according to the positioning method chosen, and whether it performs the correct return loops.

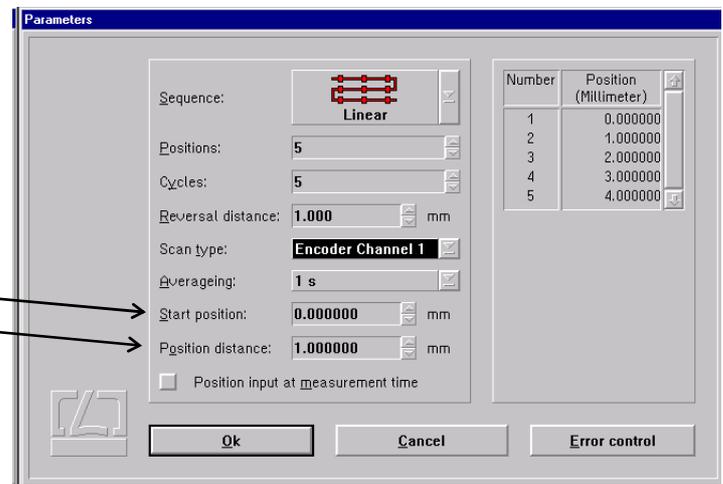
Option	Value	Unit
Min. rest time	1.0	sec
Rest deviation limit	1.000	µm
Max. position deviation	20.000	µm

If you want to make sure that readings are only taken if the tested object moves not farther than a certain distance over a given time, you can activate the "**Rest time too short**" switch and enter the maximum permissible standstill error and the minimum permissible dwell time.



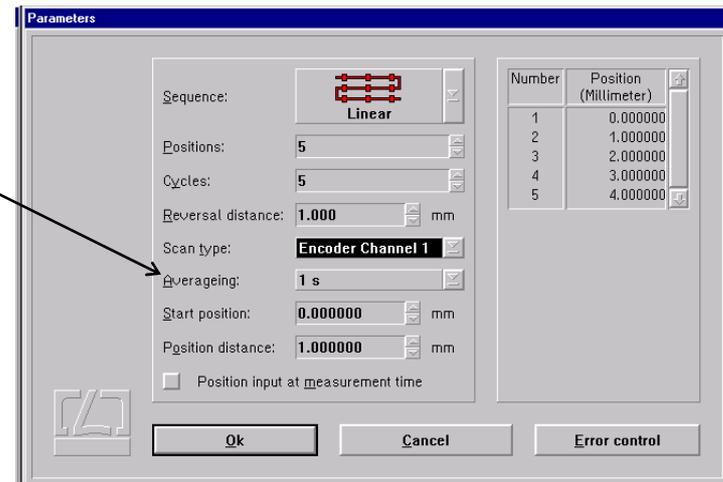
If you expect the tested object to satisfy a certain accuracy, you can enter a maximum deviation of the readings from the nominal positions and have an error message displayed if the maximum is exceeded.

In measurements triggered by "Encoder, channel ..." (hardware comparison), nominal positions must be equidistant.



Therefore, enter the start position and the constant interval (position distance).

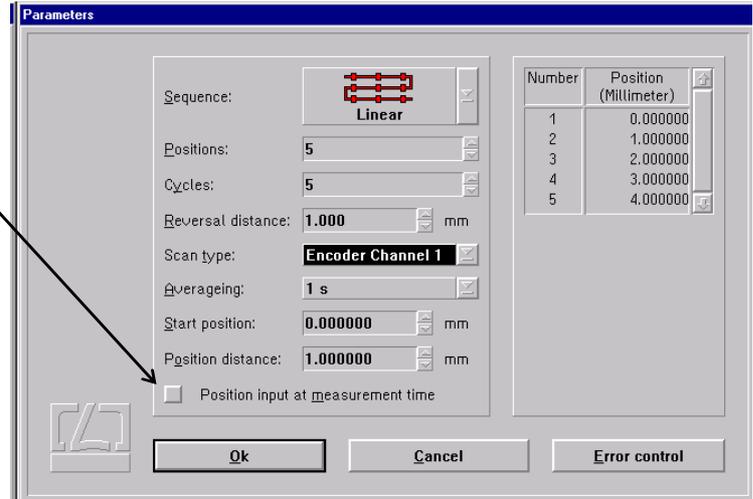
The program can filter out vibrations during a measurement by time averaging. The time over which an average is to be obtained can be set in the "**Short term averaging**" list box.



In a measurement with automatic data acquisition, the optimum entry is 0.1 s, because during standstill the program takes a reading every 0.1 s and then forms the average of these readings. Longer times for averaging might create problems in standstill recognition.

With the "Space bar" and "External" data acquisition triggering modes, select a time that is somewhat shorter than the standstill period to be expected of the tested object.

With some objects it is not possible without unreasonable effort to travel to a nominal position so that the object itself indicates this position (e.g., certain one-coordinate length measuring machines). If you activate the button **"Position input at measurement time"**, a text box will appear during the measurement immediately after each reading, in which you can enter the value indicated by the object as the nominal position.



I 2.4.3 Compensation of environmental influences

The accuracy of a distance measurement made with a laser interferometer depends on whether the refractive index of the ambient air is known and allowed for. The program can compute the refractive index from properties of the atmospheric environment and correct the measurements accordingly.

The software can further allow for the thermal expansion of the test object as a function of its temperature, and correct the measured data so that they represent the readings that would have been obtained with the test object having a temperature of 20 °C.

The necessary settings can be made in the **"Environment"** dialog box.

This is accessible by opening the **"Measure"** menu and choosing the **"Environment"** option, or by

clicking the  button.

All settings made here will be effective in data acquisition, numerical display and the real-time diagram.

Angle measurements and measurements using the straightness optics do not need environmental compensation, as its effect would be far below the system's resolution.

I 2.4.3.1 Atmospheric properties

In the top part of the "Environment" dialog box you can choose how to compensate for the effects of atmospheric properties on the refractive index and thus on the measured result.

Manual Correction Choose the "**Manual**" option of the pull-down list box "**Correction type**". You will have to enter the atmospheric properties in the respective text boxes.



Keys that facilitate inputs:

Coarse setting -  and 

Fine setting -  and 



1. Move the mouse pointer to the field where you want to make an entry.
2. Press the left mouse button and keep it depressed.
3. Drag the mouse until the thermometer column or the pointer indicates the desired value.
4. Release the mouse button.

Consult Annex III for information about the accuracy required for the measurement and entry of atmospheric properties.

Automatic Correction When you use the AUK 500 Automatic Environment Detector to measure the atmospheric properties, choose the option "**Automatic**" of the pull-down list box "**Correction type**".

The screenshot shows the "Environment" dialog box with the following data:

Property	Value
Temperature (°C)	22.1
Pressure (hPa)	985
Humidity (%)	49
Expansion Coefficient 1 (°C)	22.7
Expansion Coefficient 2 (°C)	22.3
Expansion Coefficient 3 (°C)	22.7
Expansion Coefficient 4 (°C)	---
Expansion Coefficient 5 (°C)	---

I 2.4.3.2 Material temperature

In the bottom part of the "Environment" dialog box you can choose whether and how the measured values are to be corrected for thermal expansion (material temperature). With correction activated, the readings are converted into readings that would be obtained at a material temperature of 20 °C.

Without correction If you want to work without this correction, choose the option "**None**" of the pull-down list box "**Correction type**".

Manual correction If you want to enter the material temperature manually, choose the option "**Manual**" of the pull-down list box "**Correction type**".

In the text box "**Coefficient of expansion**" type in the linear expansion coefficient of the test object.

The material temperature can be entered in the same way as the manual entry of atmospheric temperature (see Section I 2.4.2.1 "Atmospheric properties").

Automatic correction If you want to use the AUK 500 Automatic Environment Detector for compensating the errors due to material expansion, choose the option "**Automatic**" of the pull-down list box "**Correction type**".

In the temperature display boxes, temperature sensors that are not connected are indicated by "---". In the figure, material temperature sensors 4 and 5 are not connected.

You have the possibility to select from the available sensors those you want to use for the correction. For this purpose, every temperature display field has a button at the top left.

Button is not checked:

The respective material temperature sensor is excluded from correction and - on colour screens - the temperature value is displayed in grey instead of in black colour. In the figure, material temperature sensors 2 and 5 are not included in the correction of material expansion.

Button is checked:

The sensor reading enters the correction if the sensor is connected.

With automatic correction activated, the program reads the data of the material temperature sensors once per second. The program computes the mean value of all the measured values of the sensors that are connected and activated via the respective button of the display field. This value is used by the program to correct the data for material expansion.

If none of the sensors is connected and activated, the measured values are not corrected. In the example shown in the figure, the mean value of the temperatures detected by sensors 1 and 3 is used for the correction. Sensors 4 and 5 are not connected. Sensor 2 is deactivated.

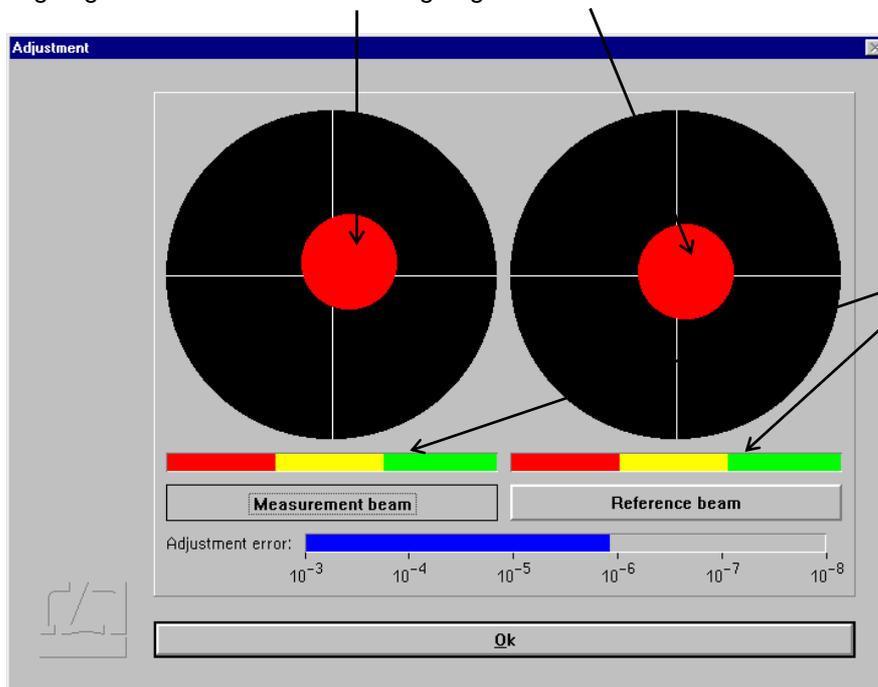
I 2.5 Measurement procedure

I 2.5.1 Laser aligning aid

The laser head of the ZLM 500 contains two quadrant detectors. This feature allows alignments to be made and aligning errors to be estimated even over great distances.

Click the  button to open the "Alignment" window.

The upper two fields in this window indicate the positions of the re-entering measurement and reference beams. In a standard setup, the left-hand figure represents the measurement beam, and the right-hand one the reference beam. When aligning the laser, try to keep the two red spots at the centers of the crosshairs throughout the distance traveled. See the Basic Equipment manual for the aligning elements to be used for aligning the laser head.

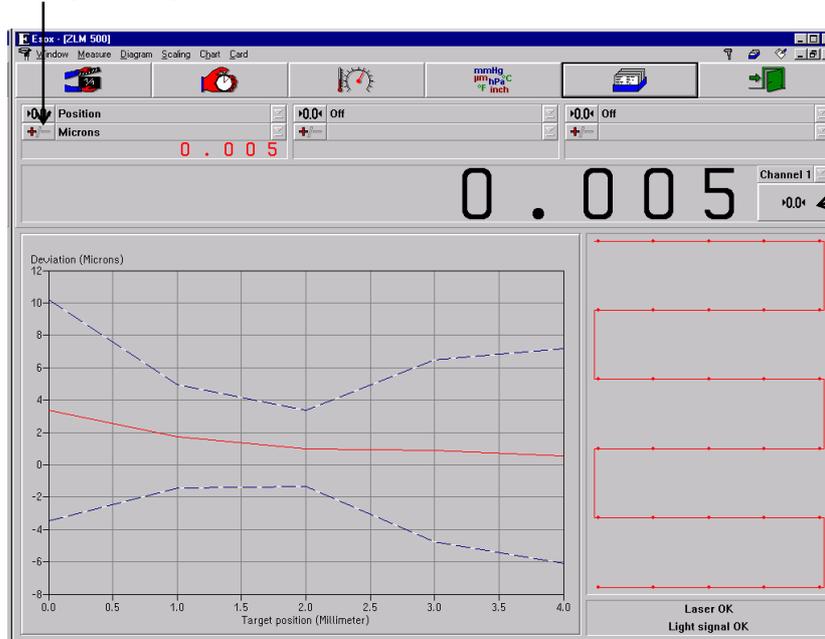


Whenever the beam passes an optical element, a slight portion of the light energy will get lost. The two intensity display bars indicate whether the light intensities of the measurement and reference beams are sufficient for the system to operate without errors. If one of the bars extends into the red range only, the respective beam is too weak.

I 2.5.2 Synchronizing the displays

Normally, at least one channel of the laser interferometer measures a quantity that is also displayed by the object tested, although at a different level of accuracy. Before you can start a measurement, make sure that the numerical displays of the laser interferometer and the object under test are in synchronism.

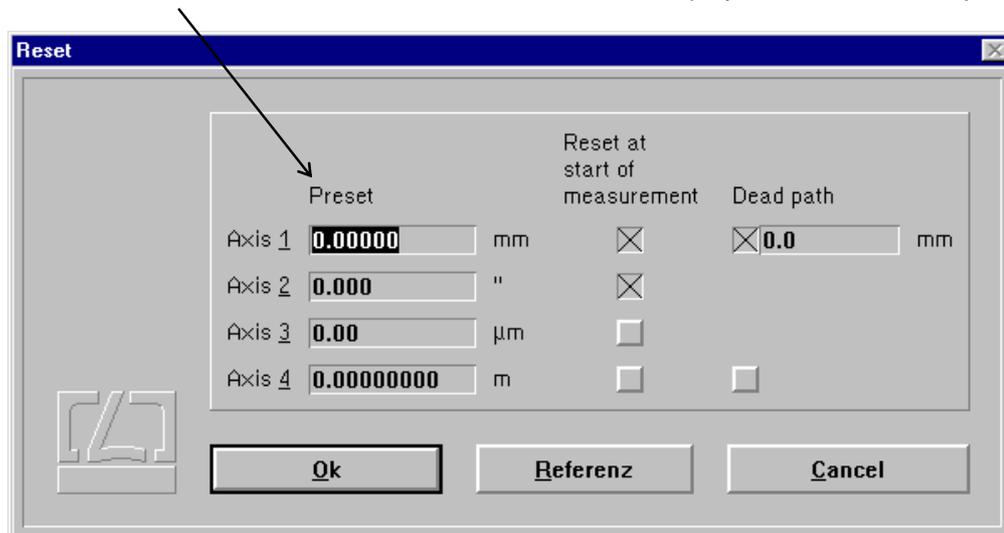
First check, for each channel where the respective quantity is available also on the object, whether object travel in positive direction increases the readout of the laser interferometer. If necessary, change the sign of the interferometer display.



Then move the object to the first nominal position. Click on the

0.0 button or select "Reset" in the "Measure" menu to open the "Reset" dialog box.

In the "Preset" text boxes, enter the current readouts displayed on the tested object.



If you select "Encoder, channel ..." as data acquisition triggering event under "Scan type" in the "Parameters" dialog box, you can enter the preset values for the position at which the scale system triggers a reference pulse. The click the **Referenz** button; the program now waits for a reference pulse coming from the scale. Take care to ensure in this case that the "Reset at start of measurement" buttons are off, since otherwise the preset values will be displayed again at the start of the measurement.

I 2.5.3 Starting the measurement

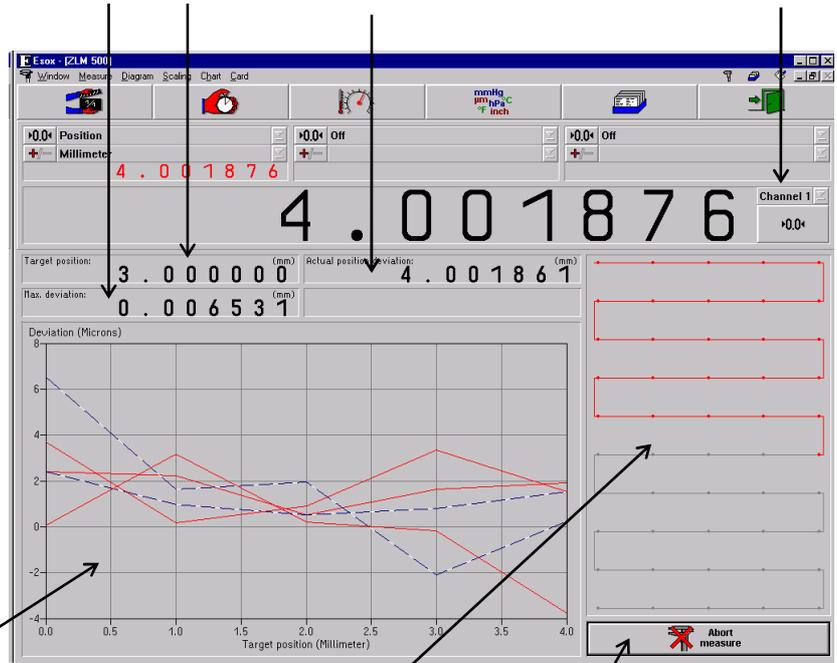
You can start a measurement by opening the "Measure" menu and choosing the "Start measure" option or by clicking the  button.

The screen now presents additional displays for the channel selected in the large numerical display field.

Depending on the channel selected, the following information can be displayed:

- Current deviation,
- Target position,
- Minimum dwell time for the data acquired so far (in automatic measurement only),
- Maximum deviation for the data acquired so far.

Minimum dwell time and maximum deviation tell you whether any problems were encountered during measurement.

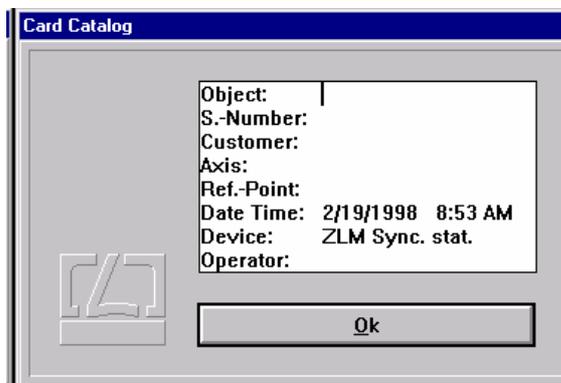


The diagram shows the position data so far measured in the channel selected.

The positions already measured are shown in red.

Click this button if you want to abort the measurement.

After a successful measurement, the measured values are saved on a card of the card file. For this purpose, a dialog box "Card Catalog" is displayed, containing already entries for the measuring instrument used and the date and time of the start of the measurement. You can type in the remaining items via the keyboard.



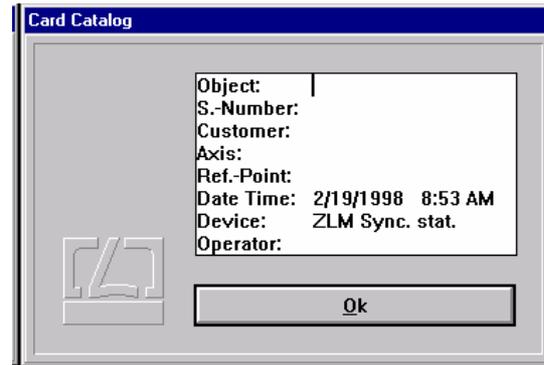
Annex II contains the list of special function keys and key combinations for typing in text boxes.

Additionally, the following keys can be used:

-  - moves the text cursor to the next entry of the file card in the same line.
-  - moves the text cursor down to the next entry of the file card.
-  - moves the text cursor up to the previous entry of the file card.

On clicking the  button, the file card is created. Filing of file cards is handled by the "Cardfile" program module (see Section K).

If a card already exists, the program provides the possibility to overwrite this card with new measured values.



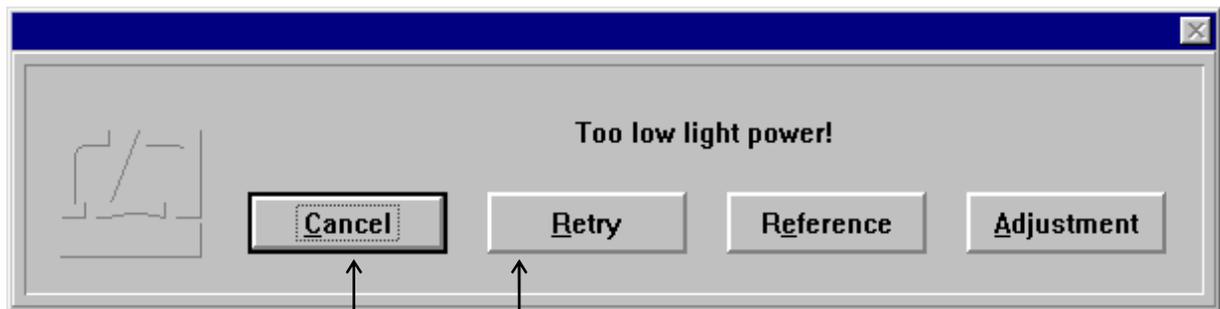
I 2.5.4 Errors occurring during a measurement

By clicking the  button you can abort a measurement. If by that time a sufficient number of readings have been taken to make an analysis meaningful, you have the option to save the readings already taken.

In the following cases the program stops the measurement before all readings have been taken:

- The laser is unstable or becomes unstable while the measurement is running.
- The light power at the receiver is too low or becomes too low while the measurement is running.
- An error occurred during the measurement and you have selected the option of having it reported by a message (see section I 2.4.2 - Parameter setting for measurement data acquisition).

If the program stops the measurement, a dialog box is displayed, which describes the error that occurred.

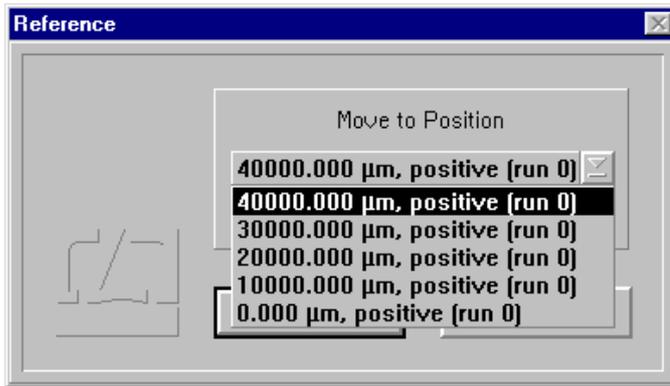


You can either abort the measurement or ignore the error.

In case of measurements that take a long time it seems reasonable to continue a measurement even if a serious error occurs. It may happen, e.g. that the laser beam is interrupted just before the last reading in a many hours' measurement job is to be taken.

In such a case, click the  button to make sure that the laser is still properly aligned. The click the  button.

In case of a beam interruption it is to be assumed that the display of the laser interferometer is no longer correct. It is therefore necessary to re-reference the displayed value to the readings taken so far.



To do this, select a position that has already been measured. Travel to this position in the same manner as when you first measured this position.

Then click the button.

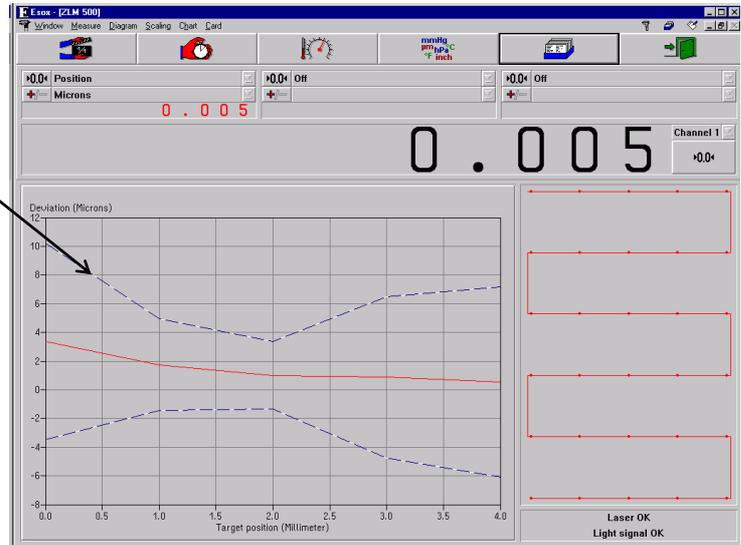
The program then compares the "old" reading with the "new" one and corrects the display accordingly.

I 2.6 Analysis of a measurement

For analysing the measurements you can select between the diagrams and parameters according to the standard applied. Also available are tabulated measurement data.

After completion of a successful measurement, the bottom left portion of the screen shows a large diagram which constitutes a button.

A click on this button, or selection of the "Diagram" item in the "Diagram" menu, opens the analysis mode window.



I 2.6.1 Controls for diagram handling

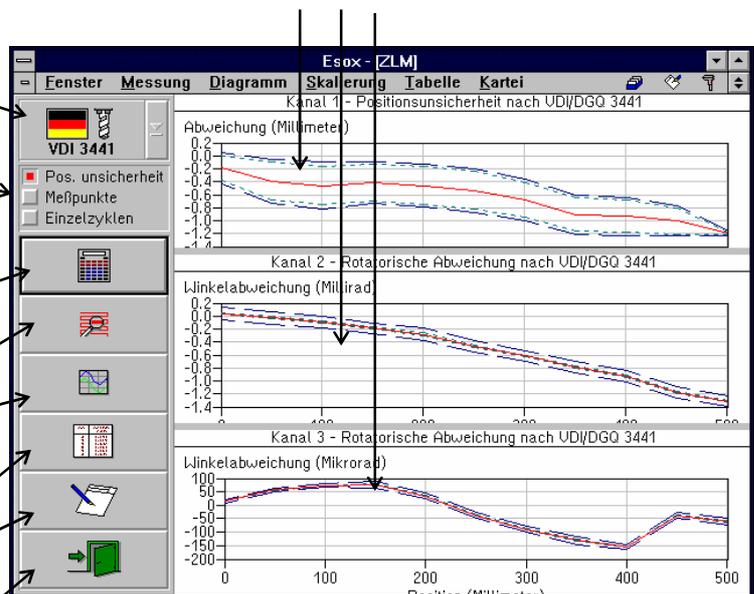
After calling a diagram the measurement program window is completely changed. Most of the screen area is now occupied by a diagram.

Use the drop-down list box to select the standard applicable.

In the box below this, you can select the type of diagram to be displayed.

The buttons below this are intended for:

- Displaying the parameters
- Selection of the measured data to be included in the analysis
- Autoscaling
- Opening a table of measured data
- Compilation of a record
- Quitting the diagram presentation



To move from one button to the next, press the  key.

In addition to these controls, you can also use some submenu items of the "Diagram", "Scaling" and "Table" main menus.

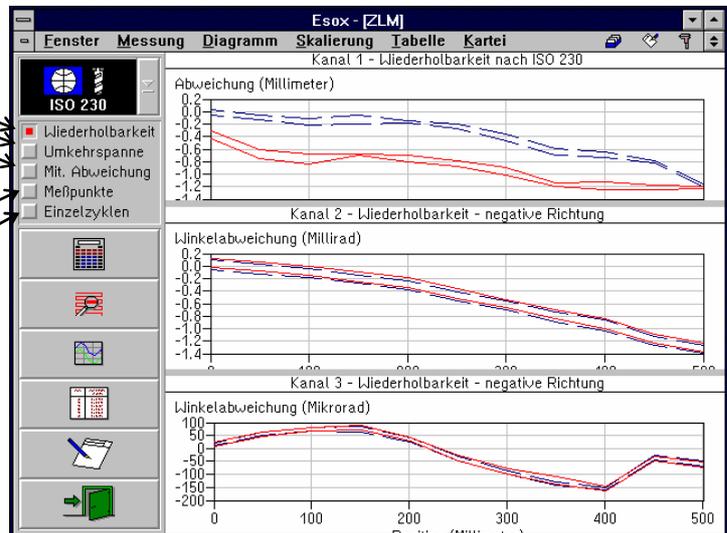
I 2.6.2 Selection of standard and type of diagram

The standards "VDI/DGQ 3441", "VDI/VDE 2617" and "NMTBA" only specify one diagram each for the analysis of position measurements, whereas "ISO 230" provides for three diagrams for the statistical analysis of position measurements. None of the standards quoted is concerned with the statistical analysis of angle and straightness measurements. The "ZLM Stat" program, by contrast, presents and computes angle and straightness diagrams and parameters, analogously to the diagrams and parameters of a position measurement.

Use these buttons to select which diagram you want to be shown.

The first buttons correspond to the diagrams specified by the standards.

A click on the last two buttons lets you display the measured point data individually, or connected by lines.



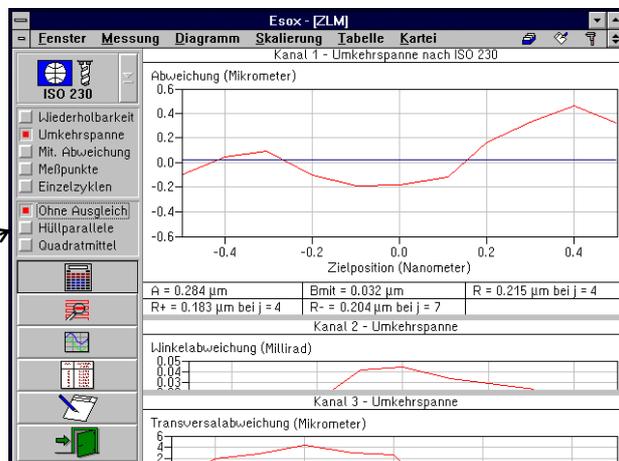
If you select the "Readings" button, the program supplies a diagram for angle and straightness measurements that conforms to the respective standard but does not contain any statistical information.

Selection between diagram types can also be made with the following items in the "Diagram" menu:

- "Position uncertainty" (not with ISO 230)
- "Repeatability" (with ISO 230 only)
- "Backlash" (with ISO 230 only)
- "Average deviation" (with ISO 230 only)
- "Readings"
- "Cycles"

See section I 1.3 - "Standard analysis procedures" for an explanation of the curves shown in the diagrams, and the equations for their calculation.

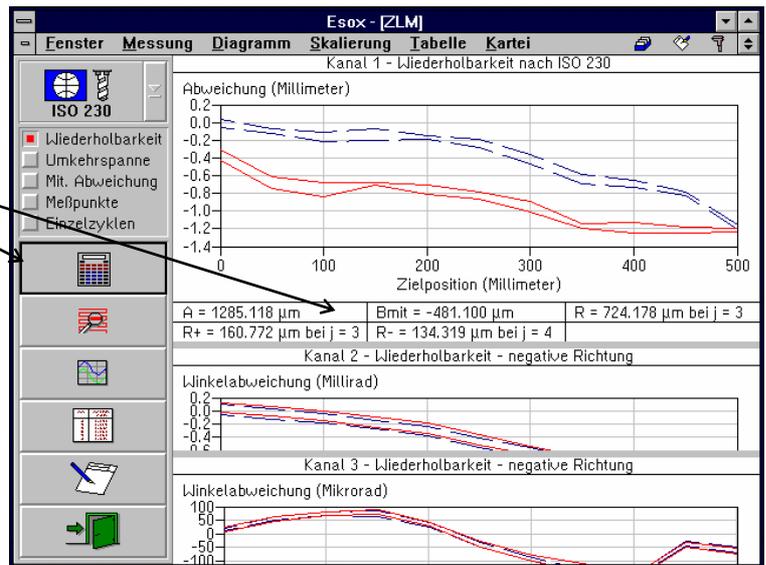
If a transverse deviation was measured with at least one measuring axis (straightness measurement), you will find an option for curve fitting (see section I 1.1 "Parameters"). For standard analysis, you ought to choose the "Envelope parallels" button.



I 2.6.3 Parameters

By clicking the  button you can display the parameters below the diagram. The button will lock. Click it again to remove the parameter display.

Parameter display can also be activated by selecting the "Parameters" item in the "Diagram" menu.



The symbols stand for the following parameters:

Position measurement		
VDI / DGQ 3441 and VDI / VDE 2617	P Pa Bmax Bave Psmax Psave	Position uncertainty Position deviation Maximum reversal span (backlash) Average reversal span (backlash) Maximum position spread Average position spread
ISO 230	A Bave R R+ R-	Position uncertainty (Accuracy) Average backlash Maximum position spread (Repeatability) Maximum position spread (Repeatability), positive travel direction Maximum position spread (Repeatability), negative travel direction
NMTBA	P Pa Psmax Psave O	Position uncertainty Position deviation Maximum position spread Average position spread Offset

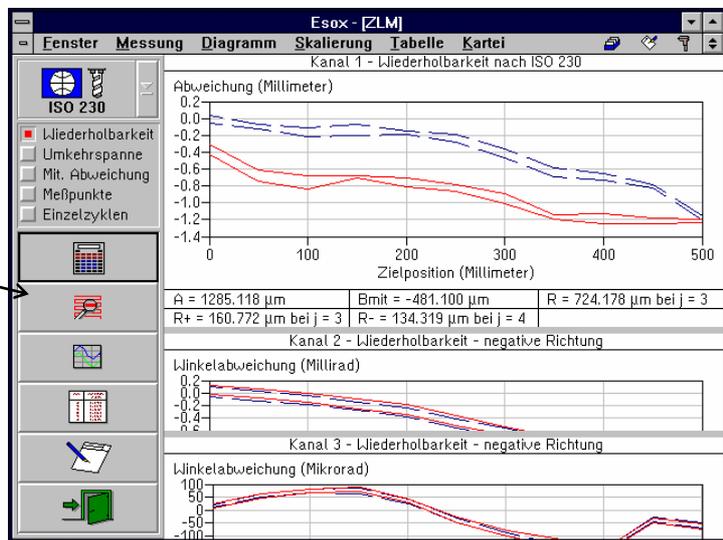
Angle measurement			
Quantities in angle measurement		Analogous quantity in position measurement	
Au	Angle uncertainty	P	Position uncertainty
Aa	Angle deviation	Pa	Position deviation
Bmax	Maximum backlash	Bmax	Maximum backlash
Bave	Average backlash	Bave	Average backlash
Asmax	Maximum angle spread	Psmax	Maximum position spread
Asave	Average angle spread	Psave	Average position spread
A	Rotatory deviation (acc. to VDI/VDE 2617: R)		

Straightness measurement			
Quantities in straightness measurement		Analogous quantity in position measurement	
Tu	Transversal position uncertainty	P	Position uncertainty
Ta	Transversal position deviation	Pa	Position deviation
Bmax	Maximum backlash	Bmax	Maximum backlash
Bave	Average backlash	Bave	Average backlash
Tsmax	Maximum transversal position spread	Psmax	Maximum position spread
Tsave	Average transversal position spread	Psave	Average position spread
S	Straightness deviation (acc. to VDI/VDE 2617: G)		

See section I 1.2 "Standard analysis procedures" for the equations for computing the parameters.

I 2.6.4 Selection of the measured data to be included in the analysis

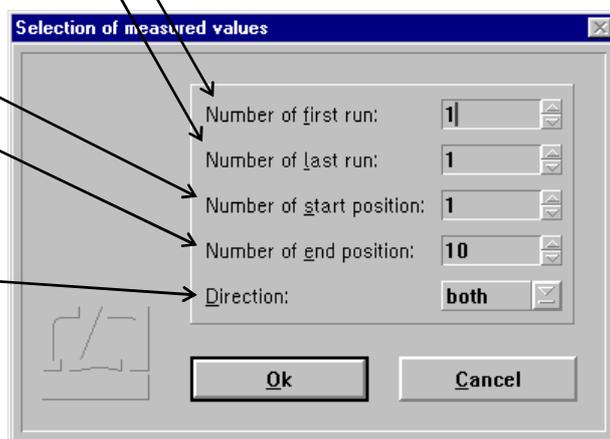
If you want to analyse a partial range rather than all of the data measured, click the  button or activate the "Select positions/Cycles" item in the "Diagram" menu to open a selection dialog.



The "Selection of measured values" dialog box permits you to enter the numbers of the first and the last of the cycles you want to include in the analysis. The n-th cycle means all data measured with the respective position travelled to for the n-th time from the positive direction, or for the n-th time from the negative direction.

After you change the default settings in the "Start position number" and "End position number" boxes, the analysis will only include the data measured at positions whose numbers lie between the selected limits.

In bidirectional measurements, the data measured in one of the two travel directions can be excluded from the analysis.



I 2.6.5 Zooming and scrolling of the visible diagram segment

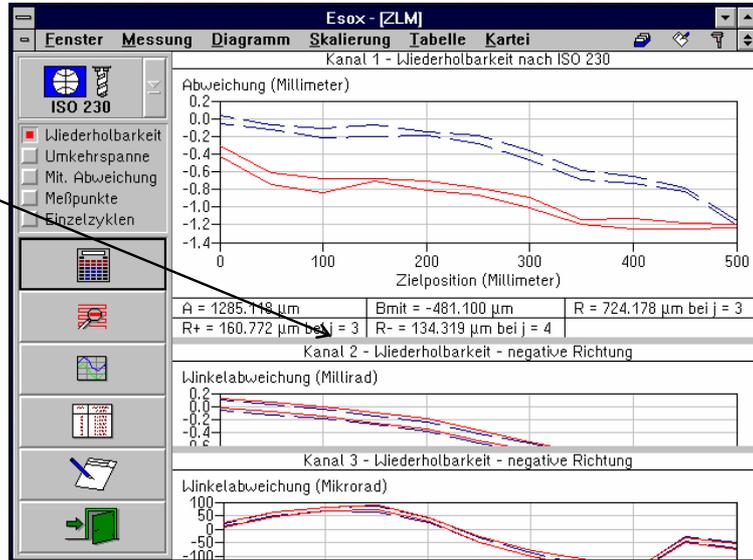
For zooming the diagram segment shown on the screen, use the mouse.



Move the mouse cursor to a corner of the section of the diagram you want to magnify. Press the left mouse button and keep it depressed. Move the mouse until the movable frame encloses the diagram section of interest. Release the mouse button.

After pressing the **right mouse button** the full diagram is displayed again.

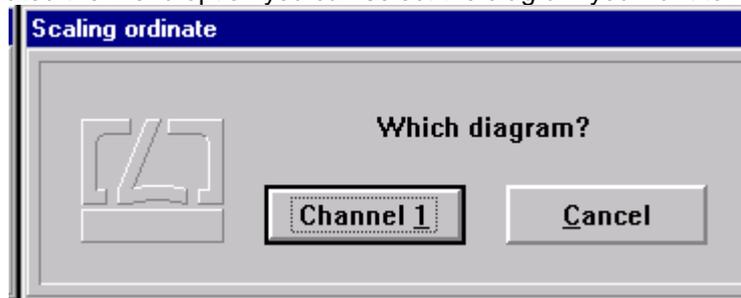
Especially with low-resolution monitor screens it may happen that parts of a diagram remain invisible. Use these horizontal bars to shift the diagrams vertically. To do this, put the mouse pointer on the bar. Press the left mouse button and hold it, dragging the bar up or down to the desired position. Then release the mouse button.



I 2.6.6 Rescaling the diagram axes

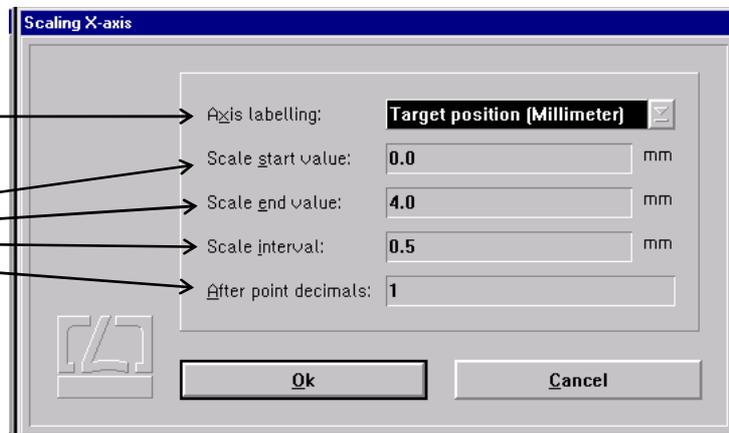
When the diagram presentation is started, the program automatically scales the diagram axes. If you want to change the unit of measurement or the coordinate scales, use the options "**Abscissa scaling**" or "**Ordinate scaling**" in the "**Scaling**" menu. Such a change will only remain valid until the visible diagram segment is changed by zooming or scrolling.

After you have activated the menu option you can select the diagram you want to rescale.



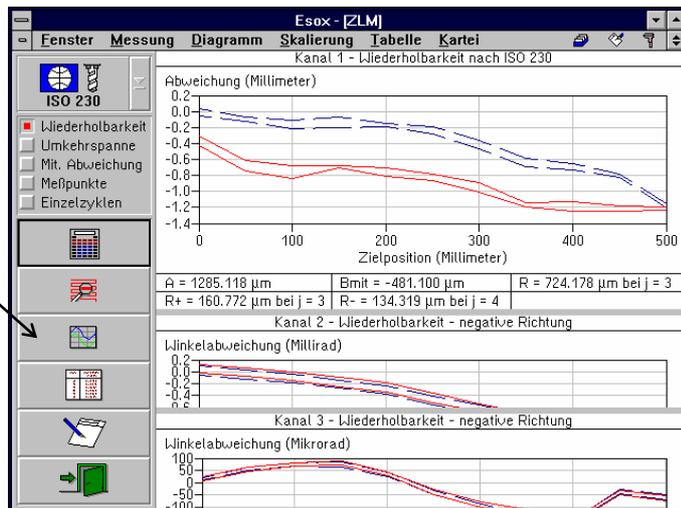
The list box "**Unit**" can be opened to change the unit.

In the four input boxes below this you can specify the required scaling.



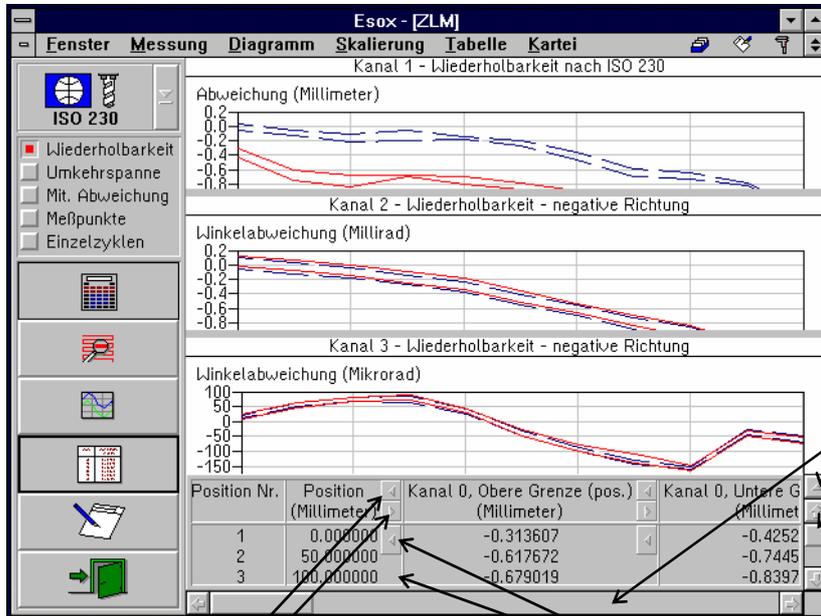
Automatic scaling (scaling same as when the diagram presentation is started) can be released

- with the  button,
- with the "**Autoscaling**" item of the "**Scaling**" menu, or
- by clicking the right mouse key on the diagram.



I 2.6.7 Tables

By clicking the  button while a diagram is displayed, a table with the measured data can be displayed in addition. The clicked button will lock. Click it again to remove the table.



Button for **maximizing** the table

Scroll bars for shifting the visible portion of the table

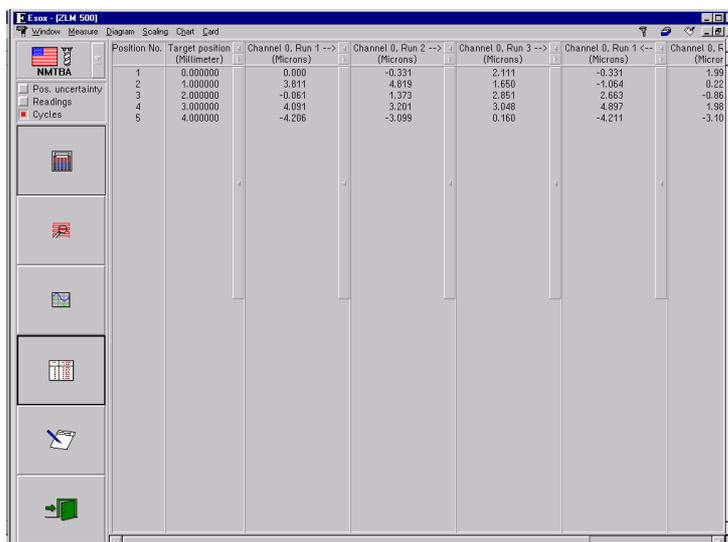
Click these buttons to select the unit of measurement.

Click these buttons to select the number of decimal places.

The table may occupy either the bottom right portion (normal size) or the entire right portion (maximum size) of the program window. In the second case, the diagram is hidden behind the table. For switching between normal-size and maximized presentation of the table, click the button at the top of the right table margin.

The functions described above are accessible with the keyboard as well, if you select, in the "Table" menu, the options

- ### "No table",
- ### "Small table" or
- ### "Big table"



Button for switching back to normal-size presentation of the table

I 2.6.8 Compiling a record (document)

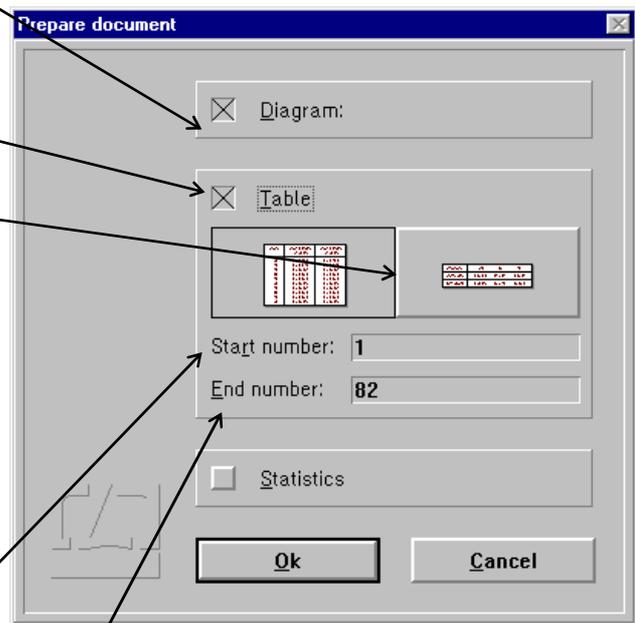
The "Document" part of the program serves for printing the record and for compiling the record contents. It is there that the arranging of the record contents and the printing of the record are carried out, rather than in the measuring program. Diagrams, tables and statistical data can be transferred from the measuring program to the "Document" program module. For further information on the "Document" program module, see section L - Program module "Document"

Click the  button or call the "Prepare document" option of the "Diagram" menu to display the "Prepare document" dialog box.

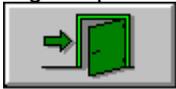
If the "Diagram" switch is activated (), the diagram displayed on the screen immediately before the "Prepare document" dialog box was called is transferred to the "Document" program module.

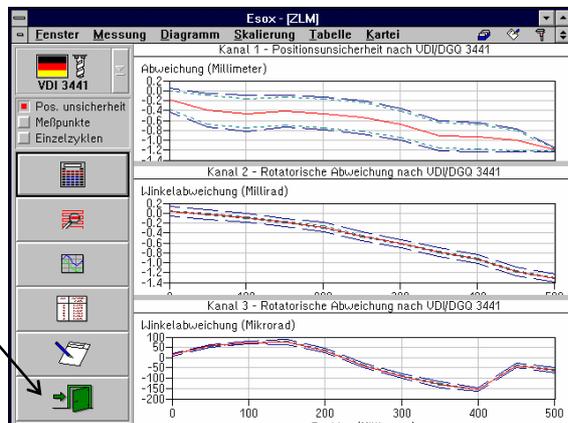
If the "Table" switch is activated, the buttons  and  can be clicked to select between horizontal and vertical arrangement of measured data in the table. In case of horizontal arrangement, the table is split up and transferred to the "Document" program module in the form of several tables if all the measured data do not fit into one line. When recording a table, please mind that a printed text page has about 60 lines. If a great number of readings have been taken, you should select which of them to be transferred into a table.

For this you can use the "Start number" and "End number" input boxes. If the number of measured data between the first and last readings entered exceeds 1000, the program will restrict the table to 1000 readings.



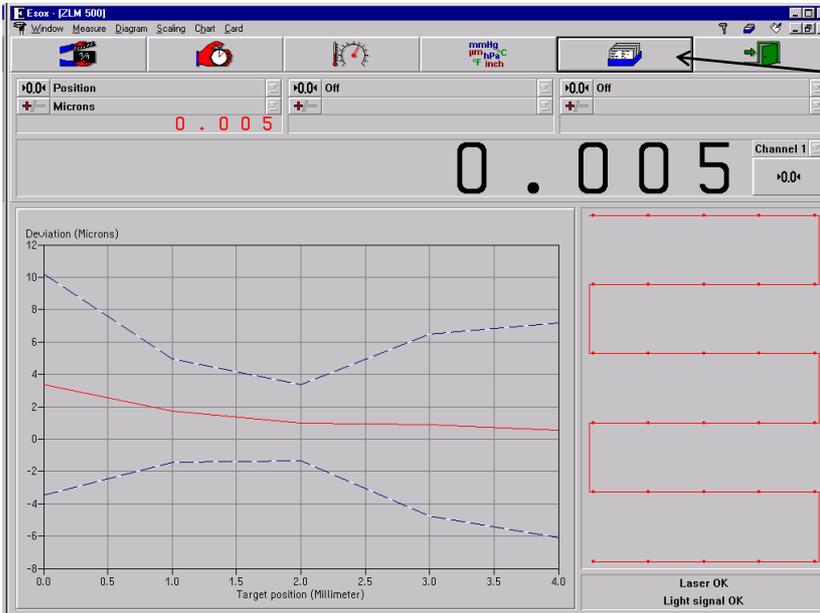
I 2.6.9 Exiting the diagram presentation

To exit the diagram presentation, activate the  button or choose the "End diagram" option of the "Diagram" menu.



I 2.7 Analysis of previous measurements

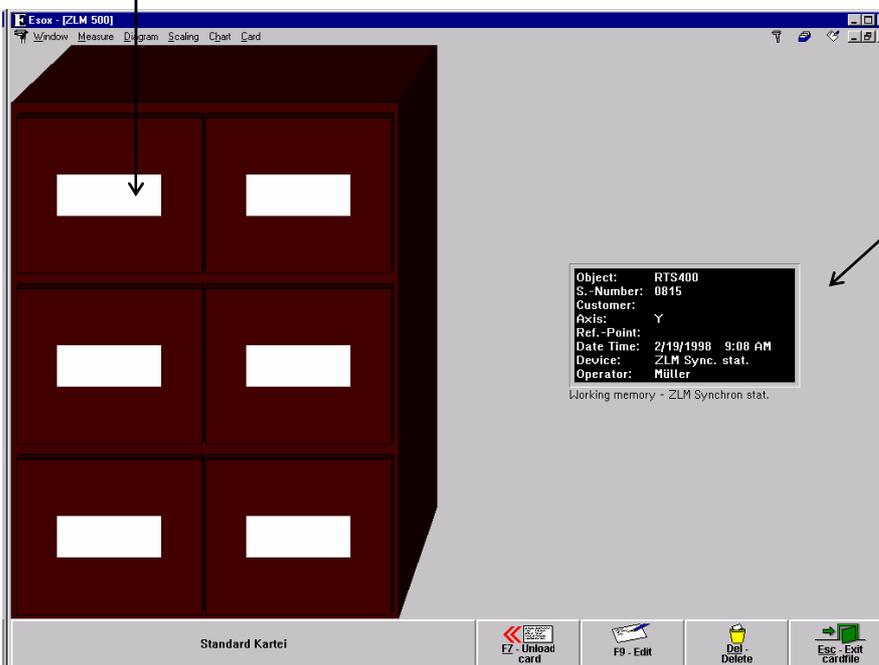
After the measurement a file card is created and the measurement results written on it. These cards are managed by the program module "Cardfile". It lets you load the card with the results of an earlier measurement so that you can analyse them in the ways described in the previous subsection.



To load a card, first click the  button or select the "Card" option of the "Cardfile" menu.

This will change the screen display.

The left half of the window shows a file cabinet with 6 file boxes (drawers).



The right half of the window contains a field with one file card - the one whose data can presently be processed by the program.

If you want to process the data obtained in one of the previous measurements, you need to open the cabinet drawer containing the desired card, select the card from the drawer and move it into the field on the right.

The following subsections briefly describe how card boxes are opened and closed, and how cards are shifted, loaded into the main memory and placed back into the cabinet.

For further details of handling file cards, see section "K - Cardfile / Archiving of measurement Results".

I 2.7.1 Changing the highlighted card field

One card field or one card box label field is shown highlighted, i.e. white lettering on black background.



With the cursor keys  ,  ,  and  you can move from one card field or card box label to another.

With the  key you can move from the previously highlighted card field on one side of the screen to the card field on the other side of the screen that was highlighted there last.



Click on the card field or card box label you want to highlight. Please note: Clicking on an already highlighted box label will open the respective box.

I 2.7.2 Opening and closing a card box

	Opening	Closing
	If the label of the card box is not highlighted, use  ,  ,  and  to move to this label. Then press  .	If necessary, press  ,  or  to move to the respective side of the screen. Then press  .
	If the label of the card box is not highlighted, click on the label once to highlight it; click on the label again to open the box. If the label of the card box is already highlighted, click on it once to open the box.	Click the  button at the bottom right or left of the window to close the right or left card box.

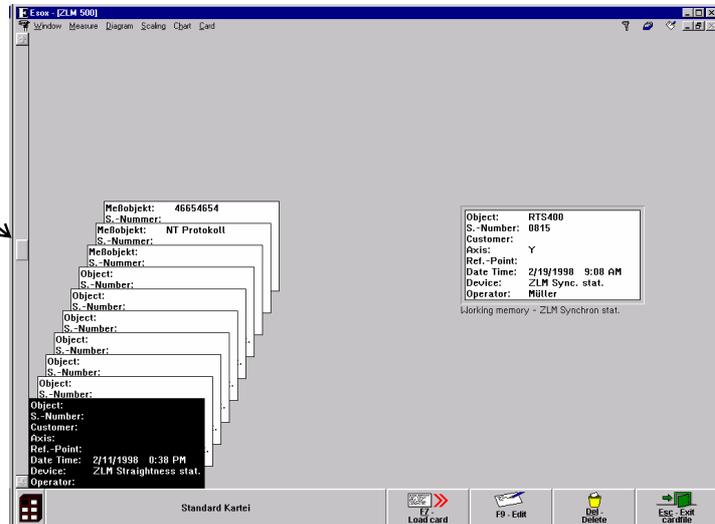
I 2.7.3 Shifting of file cards

The cards in an open card box can be shifted to activate (and highlight) another card. Cards arranged in front of the current card are not displayed.

The vertical scroll bar shows the location of, and the amount of space occupied by, the current card with respect to all cards of the box.



The vertical scroll bar can be used to shift the cards.



Shifting the card with the keyboard requires that the first card on the left is highlighted.

-  The file cards are shifted backward by one position. The card in the order before the card that was current last becomes the new current card.
-  The file cards are shifted forward by one position. The card in the order behind the card that was current last becomes the new current card.
-  The file cards are shifted backward by one screen page. The first card of the previous page becomes the new current card.
-  The file cards are shifted forward by one screen page. The first card of the next page becomes the new current card.

I 2.7.4 Loading and unloading of file cards



The easiest way of loading a card is by using the mouse. Move the mouse pointer on the source card, click and hold the left mouse button down. Now drag the mouse pointer with the file card to the target position, then release the mouse button.

If the main memory already contains a card, the program will automatically put it back to its previous position in the card box.

Proceed analogously when putting a loaded card back into its box. Click on the card and drag it to its target position. By dragging the mouse pointer with the card up to the upper or lower margin of the window you can shift the card stack in the box on the left.

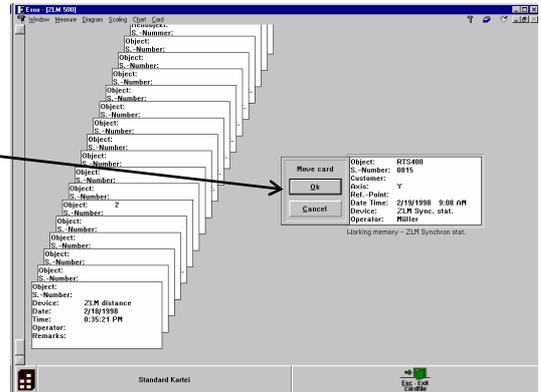


Loading a card with the keyboard requires that the card must first be highlighted on the left half of the screen.

Now select the "Load" option from the "Cardfile" menu.

The screen shows a field with the card to be loaded.

Press the  key.

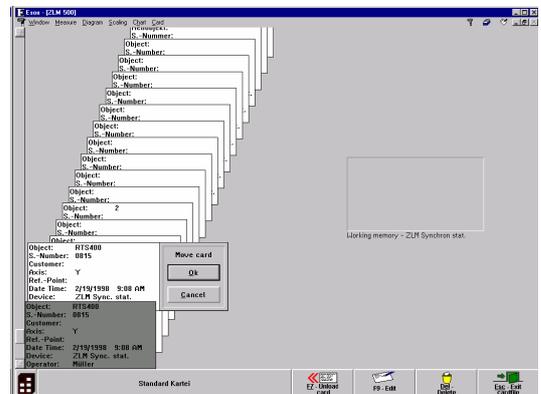


Putting a card back requires that it must first be highlighted in the main memory field represented on the left half of the screen.

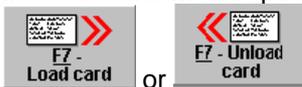
Then select the "Move" option from the "Cardfile" menu.

The target position can be selected with the direction keys.

Conclude by pressing the  key.



Instead of the menu options "Load" and "Move" of the "Cardfile" menu you can also use the



button at the bottom of the screen.

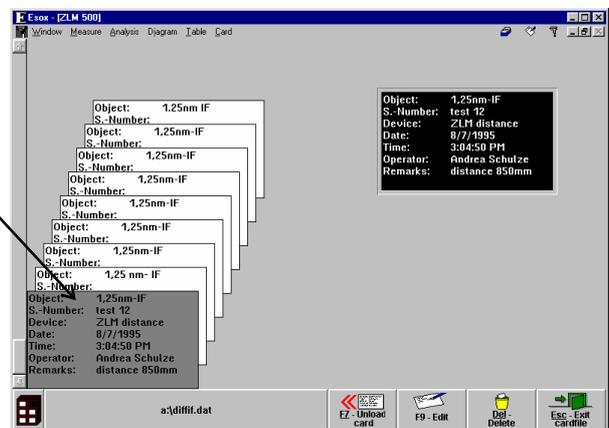
The target position can alternatively be selected with the scrollbar on the left margin.

The keys ,  and  can be used to page up and down for finding remote target positions.

It is thus possible to move a card from a left-side source position to a left-side target position, for the purpose of rearranging the cards.

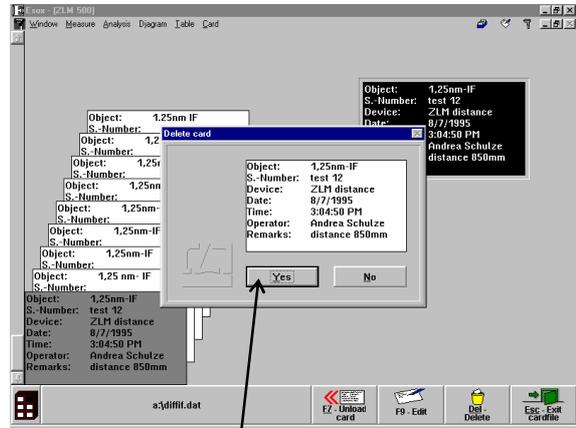
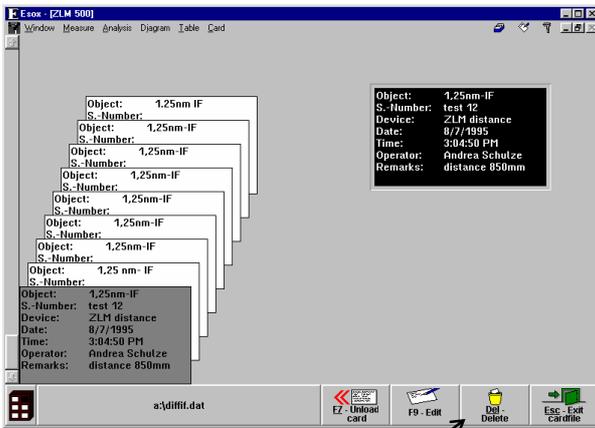
If a card has been loaded into the main memory, it still remains also visible at its source position on the left side, but it is shown here with black lettering on a grey background.

Such a "greyed-out" card cannot be moved from its place.



I 2.7.5 Deleting a file card

A card you want to delete must first be highlighted.



Select the **"Delete"** option from the **"Cardfile"**

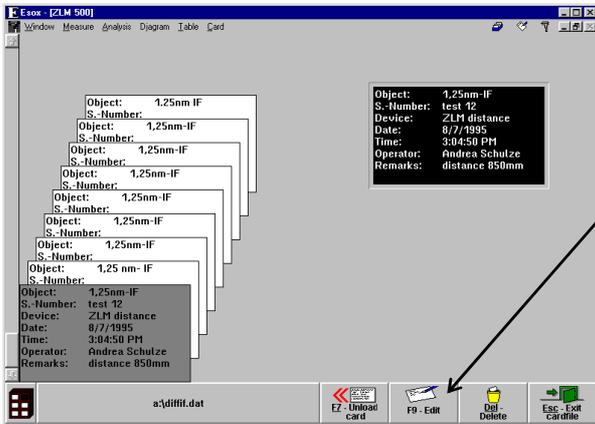


menu or click the **Delete** button. This opens a dialog box.

Click the **Yes** button to delete the highlighted card.

I 2.7.6 Editing of cards and card box labels

First highlight the card or the card box whose inscription you want to edit.



Start the text input mode by selecting the **"Edit"** option from the **"Cardfile"** menu or by clicking the



Annex III contains a list of keys and key combinations that have special functions in the editing of text boxes. In addition you can use the following keys for moving within a card:



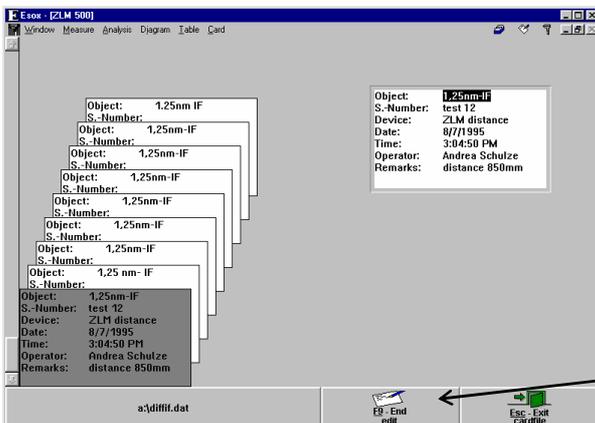
- moves the text cursor to the next card entry in the same line.



- moves the text cursor to the next lower card entry.



- moves the text cursor to the next upper card entry.



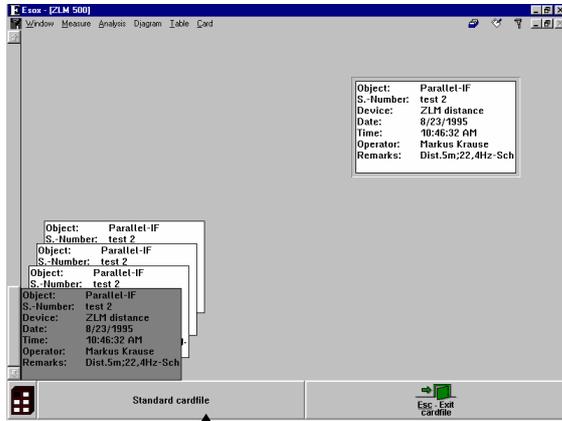
With editing finished, you need to quit the text input mode by selecting **"End edit"** in the **"Cardfile"** menu or clicking the



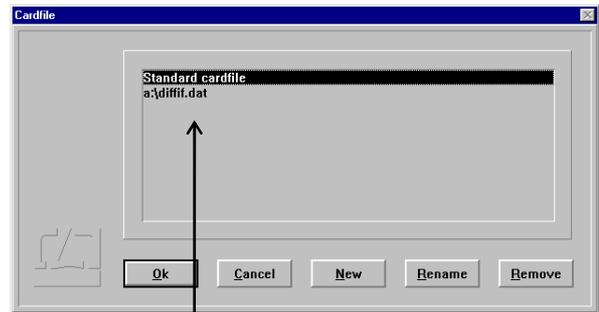
button.

I 2.7.7 Creating, renaming and deleting a card file

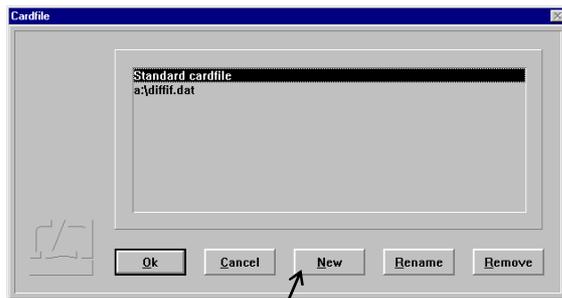
When the program is started first, it creates a card file named "Standard Cardfile" in the system data file "esoxm.dat" located in the installation path. It is possible to create further data files. Each data file comprises a card file cabinet with six card boxes.



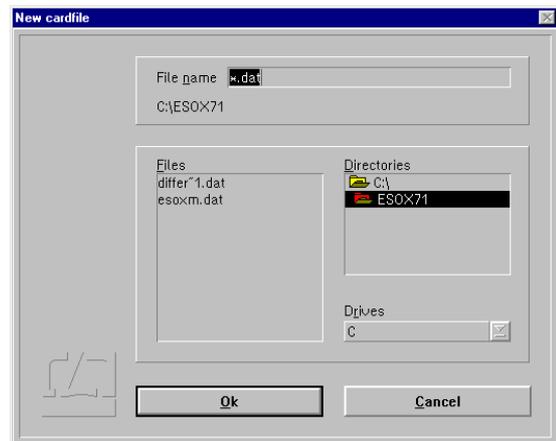
To create a new card file, click on the file name button at the bottom left window margin, or select the menu option "Open cardfile" from the "Cardfile" menu.



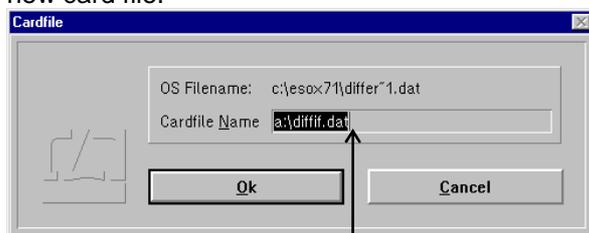
This opens a list showing the names of all existing card files in a dialog box.



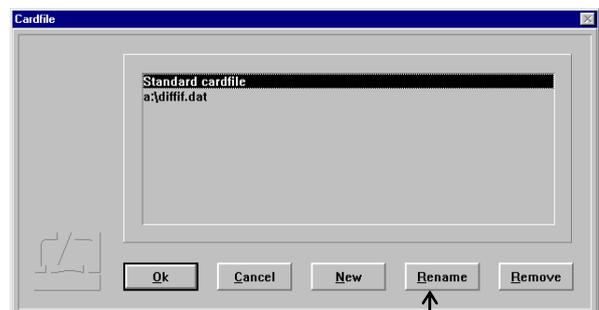
Click the **New** button if you want to create a new card file.



This opens another box in which you must enter the name of the data file.



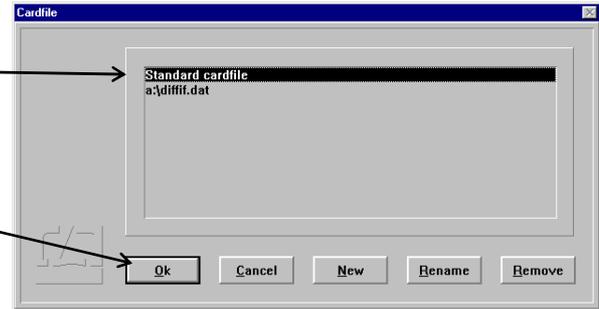
Click the **OK** button to open another dialog box, in which you must enter a card file name, which then appears in the card file list.



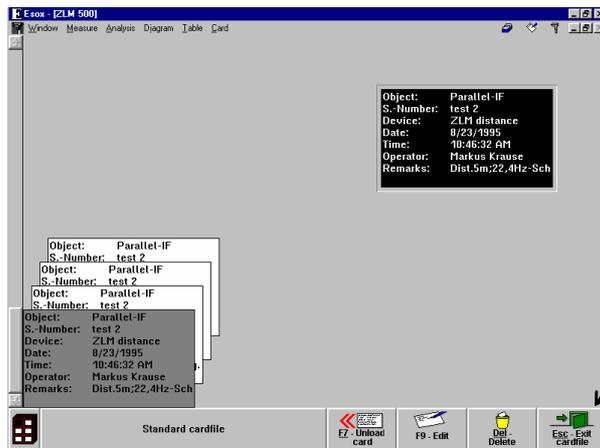
The same dialog box is opened if you use the **Rename** button to rename a card file.

Click the **Remove** button if you want to delete a card file from the card file list. This will not, however, delete the data file from the memory. For deleting the data file, use the file manager.

To select a card file from those created, highlight the file name in the list box and then click the **OK** button.



I 2.7.8 Quitting the Cardfile menu



To quit the Cardfile menu, click the **Esc - Exit cardfile** button or select the "Exit" option from the "Cardfile" menu.

I 2.8 Exiting the measurement program



To exit the "ZLM-Stat" program module, activate the **Esc - Exit cardfile** button or choose the "Exit measurement program" option of the "Measure" menu.

J "ZLM Flatness" Calibration Software

The ZLM Laser Interferometer can be used to ascertain the flatness error of plate-shaped components by measuring the deviations normal to the object plane along a pattern of measuring lines. Flatness deviations are dealt with in the "ISO 1101" standard.

Normally, a user of the "ZLM Flatness" measurement program will also use the "ZLM Position" program, which is described in section G. As the operation of "ZLM Flatness" has much in common with "ZLM Position", the reader of the present section will be referred to section G wherever appropriate.

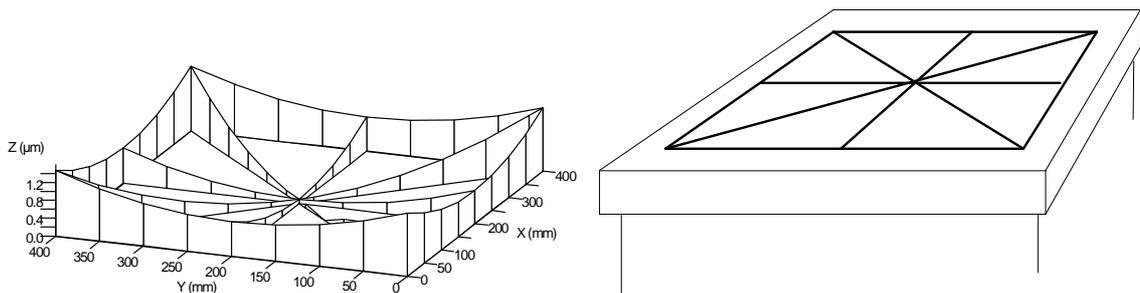
J 1 Measurement methods

Along a specified pattern of lines placed over the object under test, the program measures height deviations normal to the object plane. The acquisition of measurement data on any one measuring line is similar to data acquisition in a straightness measurement. By combining the data measured on all measuring lines, the software determines the flatness error.

Either of two patterns of measuring lines may be used:

1. "Union Jack"

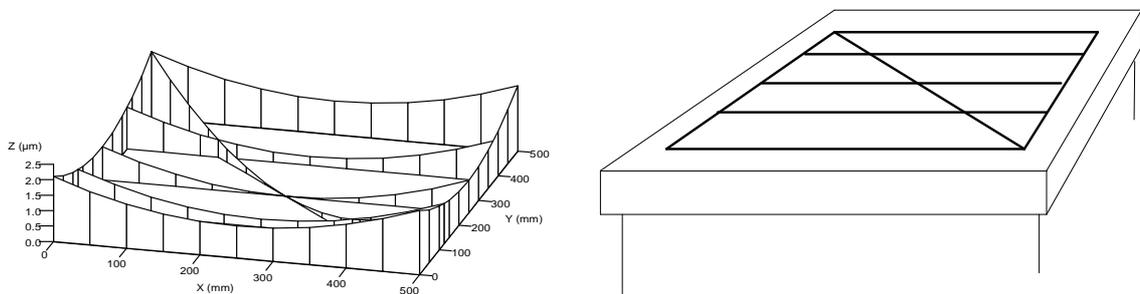
The "Union Jack" pattern invariably consists of eight measuring lines.



2. "Cross Jack"

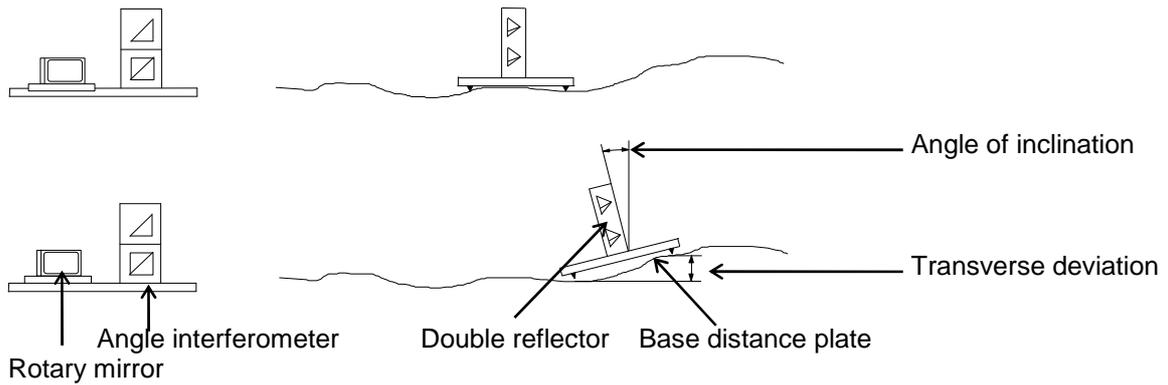
The "Cross Jack" pattern may consist of six or more lines (the illustration shows a case with eight lines).

The number of measuring lines parallel to the X axis may be varied (the illustration shows five). These lines are spaced at equidistant intervals.



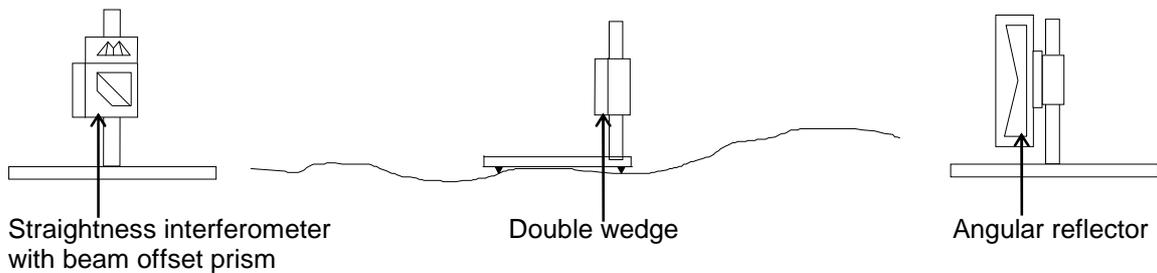
To determine the deviations normal to the plane, you can use either the angle or straightness optics, same as in straightness measurement. Use of the angle optics involves less mounting work. Mount the double reflector on a base distance plate. During a measurement, displace the base distance plate repeatedly along a measuring line by the distance between the two rest points of the plate.

From the angles measured at a position, the program determines the deviation normal to the plane at that position.



The angle interferometer can be mounted on a base plate with rotary mirror. The rotary mirror facilitates conversion when you have completed the measurements on one measuring line and want to proceed with another, as the laser head will hardly ever have to be relocated if the mirror is used. A drawback of this arrangement is that you need to take great care to ensure that you displace the reflector in the correct direction. Shifting in the wrong direction will supply measurements with the sign reversed.

If you prefer to use the straightness optics, you need a straightness interferometer with beam offset prism, a double wedge and an angular reflector.



The program directly measures the displacement of the double wedge normal to the plane.

J 2 Parameters

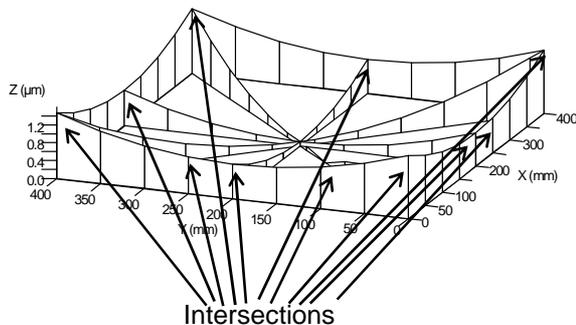
ISO 1101 defines the flatness deviation as the minimum distance between two parallel planes that include between them all measured data.

As measurement data are acquired on individual measuring lines, the software has to assign the measured data to positions. It does so by taking advantage of the axiom that the deviations normal to the plane, measured on two intersecting measuring lines, ought to be equal at the point of intersection of the two lines.

For determining the flatness deviation, the program proceeds in three steps.

1. Interpolation and extrapolation:

When the program links a measuring line that is parallel to one of the coordinate axis with one that is diagonal, it may happen that the intersection between the two lines comes to lie somewhere between points at which data were measured, rather than coinciding with such a point. In such a case the program interpolates the value at the intersection from the values measured at the neighbouring points. At the corners of the measuring area, the value for the intersection with a diagonal line is extrapolated.



2. Approximation at the intersections:

After extrapolation and interpolation, deviation data exist for all intersections between all measuring lines.

The program now determines the tilts and displacements of each measuring line normal to the object plane, approximating the measuring lines in such a way as to minimize the sum of the squares of deviations at the intersections. Only the "Cross Jack" method using six measuring lines guarantees that the deviations at the intersections can be approximated to zero. In all other cases the values at the intersections may deviate from zero.

The maximum deviation is registered as "maximum approximation error". It can be regarded as a measure of the accuracy of the measurement.

3. Determination of the flatness error:

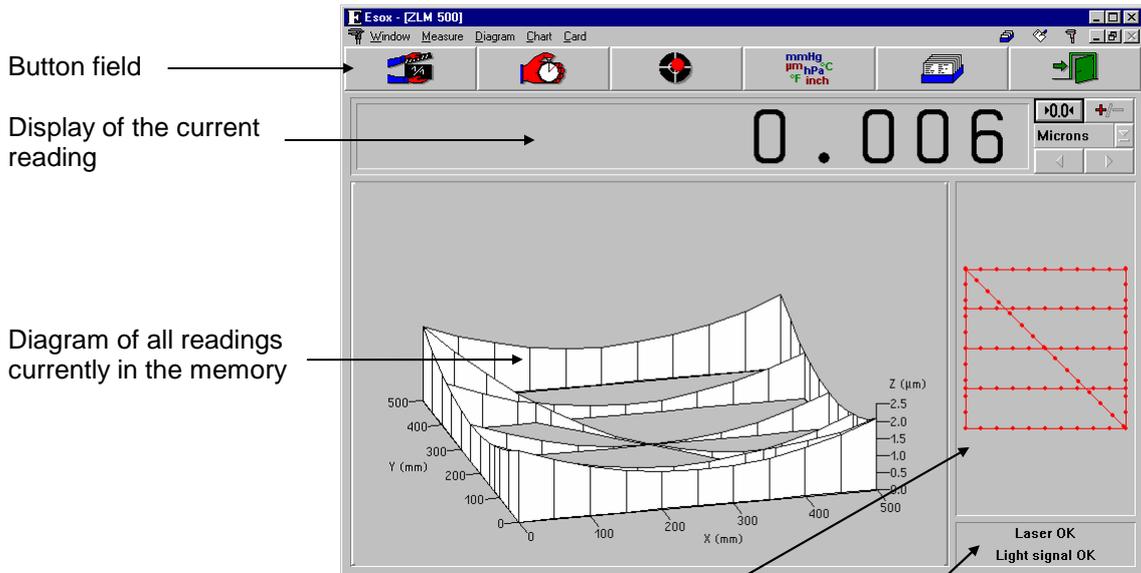
After the measured data have been assigned to positions, the program determines the flatness deviation according to ISO 1101.

J 3 Operation

To start "ZLM Flatness", proceed as in starting "ZLM Position" (see sections G 3.1 for starting "ZLM Position" and C 3 for general information on starting a measurement program).

J 3.1 Elements of the "ZLM Flatness" window

The element of the "ZLM Flatness" window are arranged similarly to those of the "ZLM Position" window.



Button field

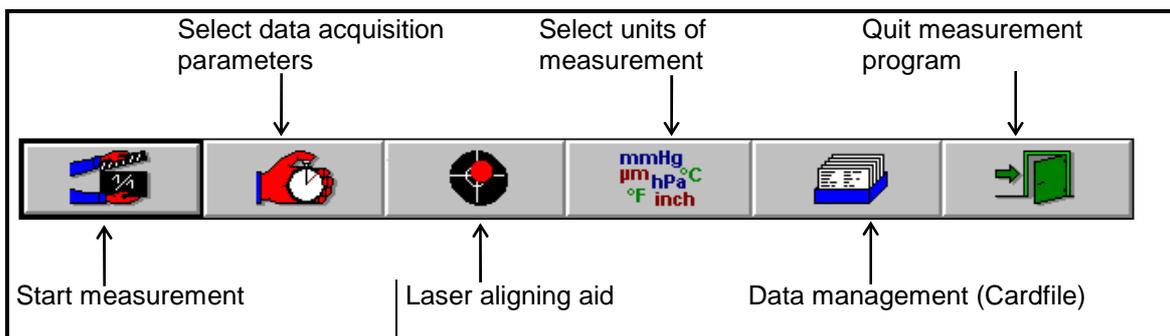
Display of the current reading

Diagram of all readings currently in the memory

Number of readings currently in the memory, and display of the pattern of measuring lines

Display of laser stability and light intensity detected.

To operate the display of readings and to select the units of measurements, proceed as in the "ZLM Position" program module.



J 3.2 Preparation for a measurement

Select the **"Configuration"** option in the **"Measure"** menu or click the

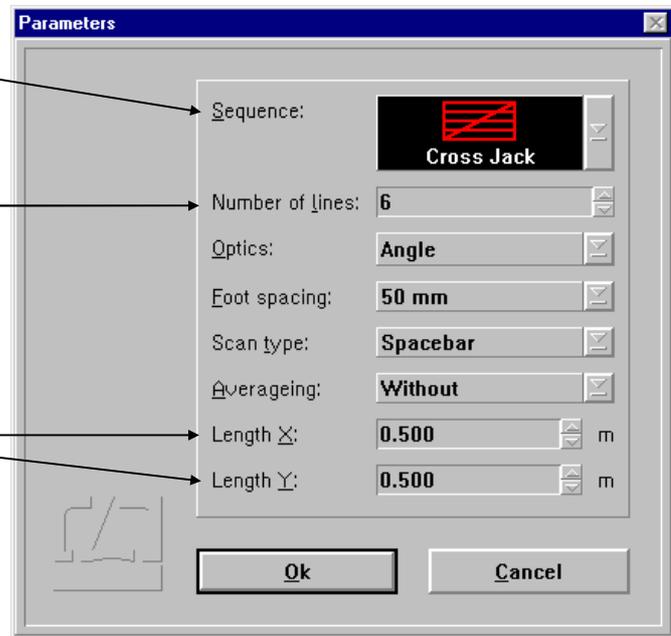


button to open the **"Parameters"** dialog box.

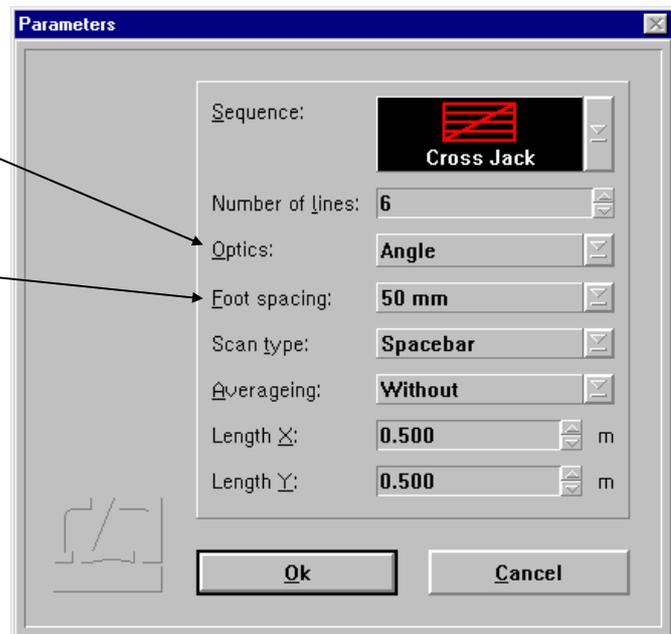
In the drop-down list box **"Method/Sequence"**, select whether readings are to be taken with the "Union Jack" or "Cross Jack" pattern of measuring lines.

If you select "Cross Jack", you need to enter the total number of measuring lines.

In the two text boxes at the bottom, specify the size of the measuring area.

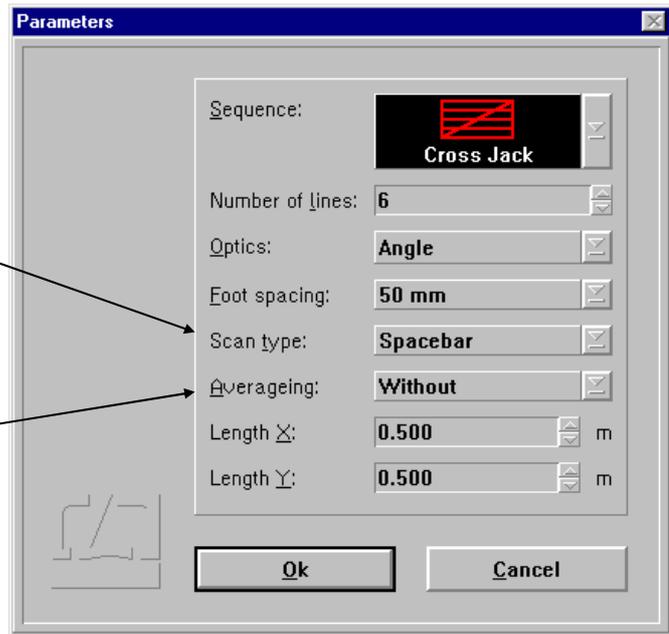


In the **"Optics"** drop-down list box you can select between using angle optics and the 2m or 10m straightness optics. If you use angle optics, you need to specify the base distance plate to be used. The value set here determines the interval of the grid of measuring points, no matter whether you use angle or straightness optics.



In the "Scan type" list box you can select the event to trigger data acquisition, i.e. either by hitting the space bar of the computer keyboard or by an external signal (remote control).

It is recommended to work with **short term averaging** in order to filter out any vibrations. The options are the same as in the "ZLM Position" program module.



J 3.3 Measurement procedure

Start the measurement by selecting the "Start measure(ment)" option in the "Measure" menu or by clicking the  button.

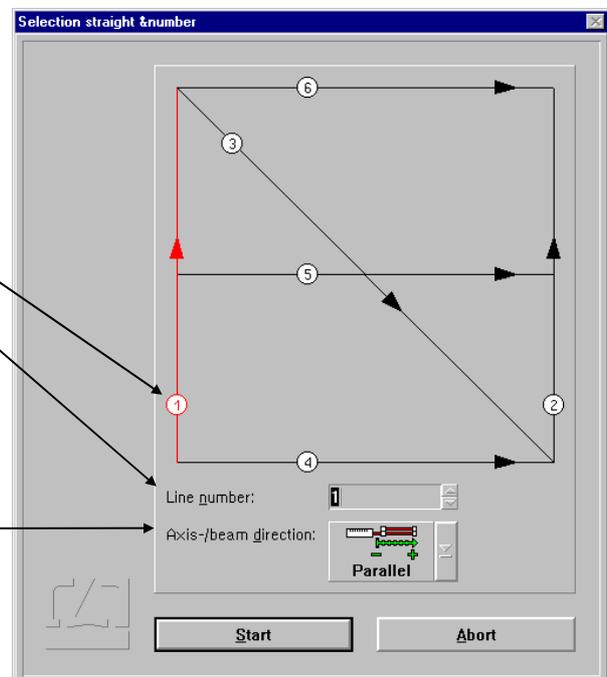
This opens the dialog box "Selection of line number".

In the "Line number" text box you can enter the number of the measuring line you want to begin with. This selection can also be made by clicking on the encircled number in the line pattern display. A colour monitor will show the line selected in red.

The program expects that you move from one position to the next invariably in the direction indicated by the arrow.

If you use angle optics, the direction from which the laser beam arrives is important. In the "Axis/beam direction" list box you need to specify whether the directions of displacement and laser beam are parallel or antiparallel (i.e. in opposite directions).

A wrong setting here will attach the wrong sign to the readings taken on the line selected, causing a wrong measurement result.

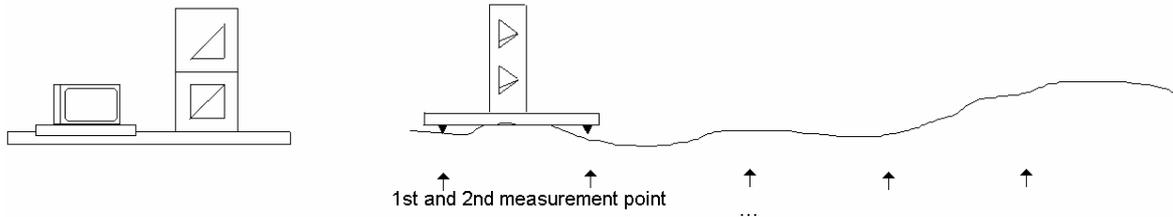


With all settings made, you can start to set up the equipment for measurement on the line selected. Clicking the **Start** button makes the laser aligning aid feature available. (select the

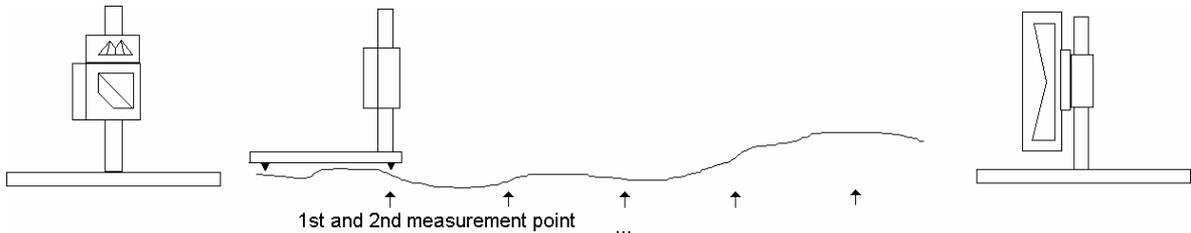
"Adjustment" item of the "Measure" menu or click the  button).

After setting up and laser alignment, move the base distance plate to the first measuring position. This position differs, depending on whether you are using angle or straightness optics.

Angle optics: The feet of the plate rest on the first and second measuring points.

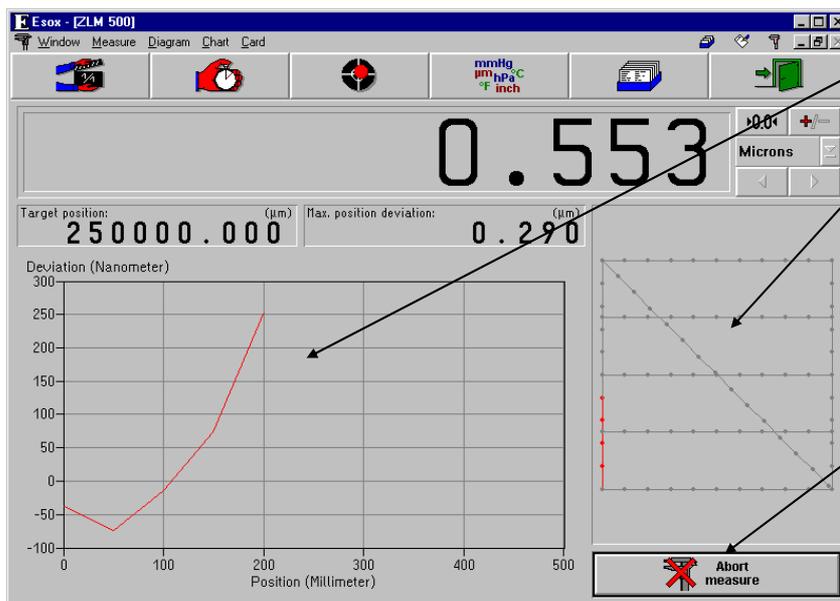


Straightness optics: The double wedge is above the first measuring point.



Then either click the  button or select the "Reset" item of the "Measure" menu to set the display to zero.

Now you can trigger the first measurement with either the  or the remote control pushbutton. Then shift the base distance plate to the second measuring position and trigger the next reading, etc.



The diagram shows the readings so far taken on a measuring line.

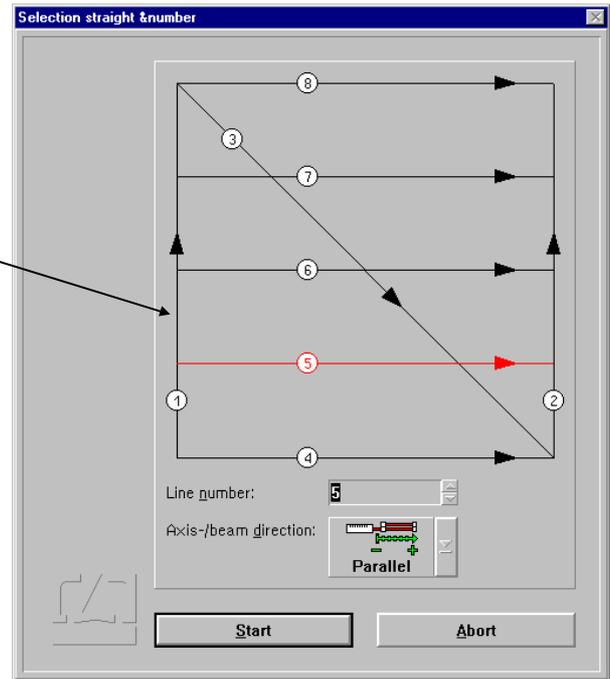
From the graph on the right you can see which positions have already been measured.

Taking readings on a measuring line can be terminated at any time by clicking the  button. This does not abort the complete measurement but gets you back to the measuring line selection box.

When all positions on a measuring line have been measured, the measuring line selection box reappears, and you can select the next measuring line.

In the line selection box, lines already measured will be shown in grey by a colour monitor.

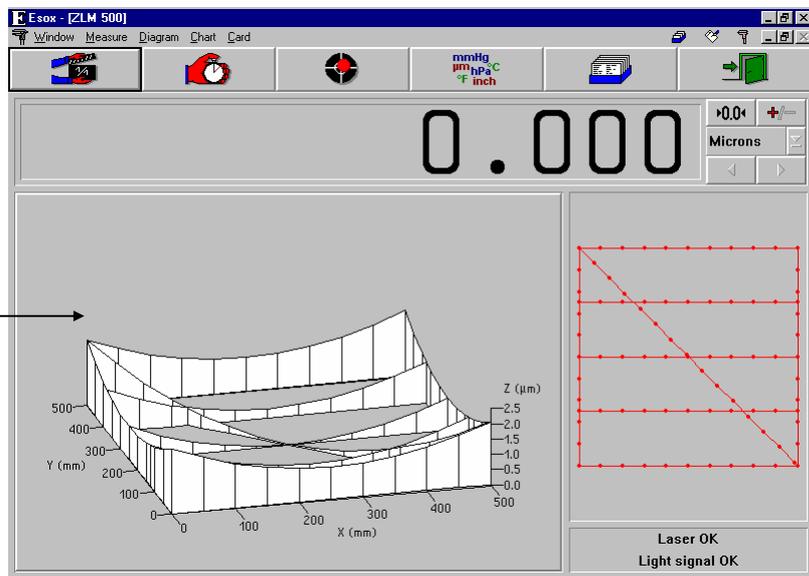
If you should have noticed any error, you can select the respective line again and repeat all measurements on that line.



When all readings on the last line have been taken, the readings are saved on a card file, same as in the "ZLM Position" program module.

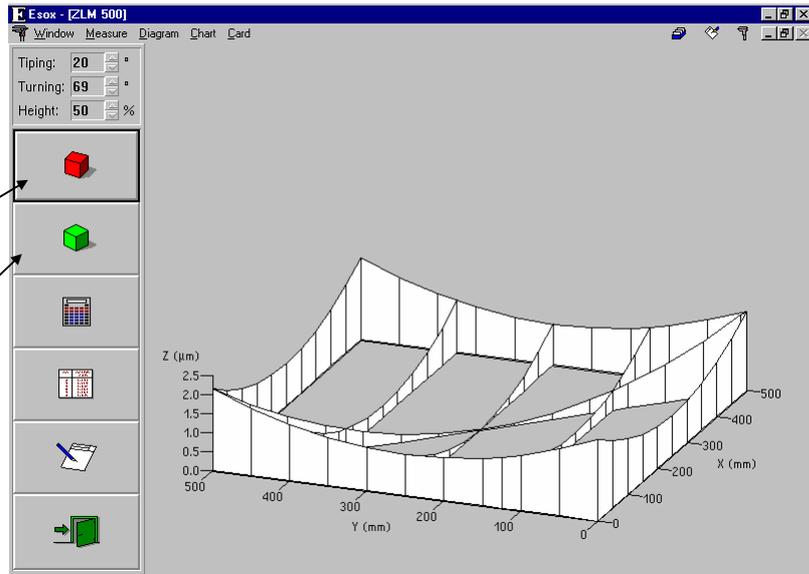
J 3.4 Analysis of a measurement

To open diagram presentation, click the large button, or select the "Diagram" item in the "Diagram" menu.



Tilt, rotation and height (Z expansion) of the diagram shown can be changed in the text input boxes in the top left portion of the window.

To select between dimetric and isometric presentation, click the  or  button, respectively.

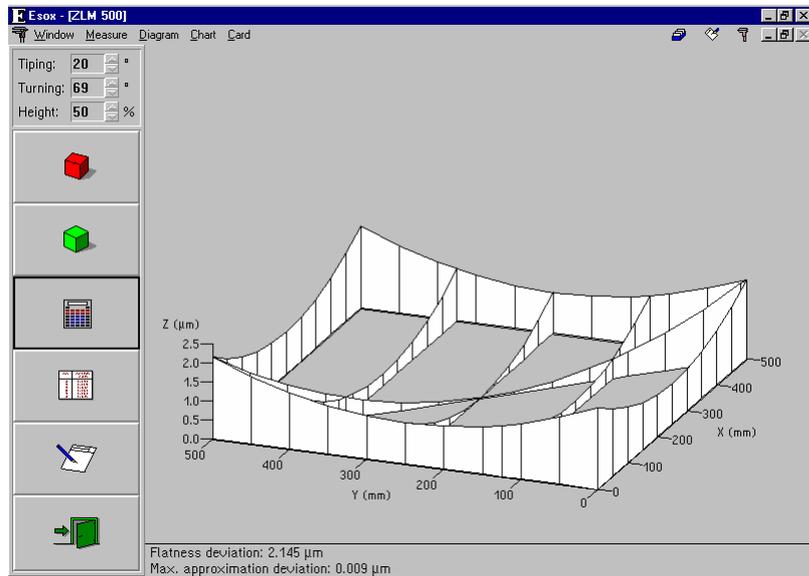


By clicking the



button or selecting the "Parameters" item of the "Diagram" menu you can have the flatness deviation and the maximum approximation error displayed below the diagram.

See section J2 "Parameters" for the meaning of the maximum approximation error.



The display of a table of measured data, the recording of measurement results, exiting the diagram presentation and the loading of data measured earlier can be carried out in the same manner as described for the "ZLM Position" program module.

K "Cardfile" Program Module

At the end of a measurement, a file card is created and the measured values are allocated to this card. If a measurement document was generated based on measured values it will also be assigned to this card. Measurement-specific information (i.e. specimen, serial no., measurement instrument, operator) can be typed on the card.

Chapters D, F, G and I describe how stored file cards can be loaded back into a measurement program. Within a measurement program, however, you cannot copy or move a card from one card file to another. The "Cardfile" program module allows cards to be relocated and sorted at liberty.

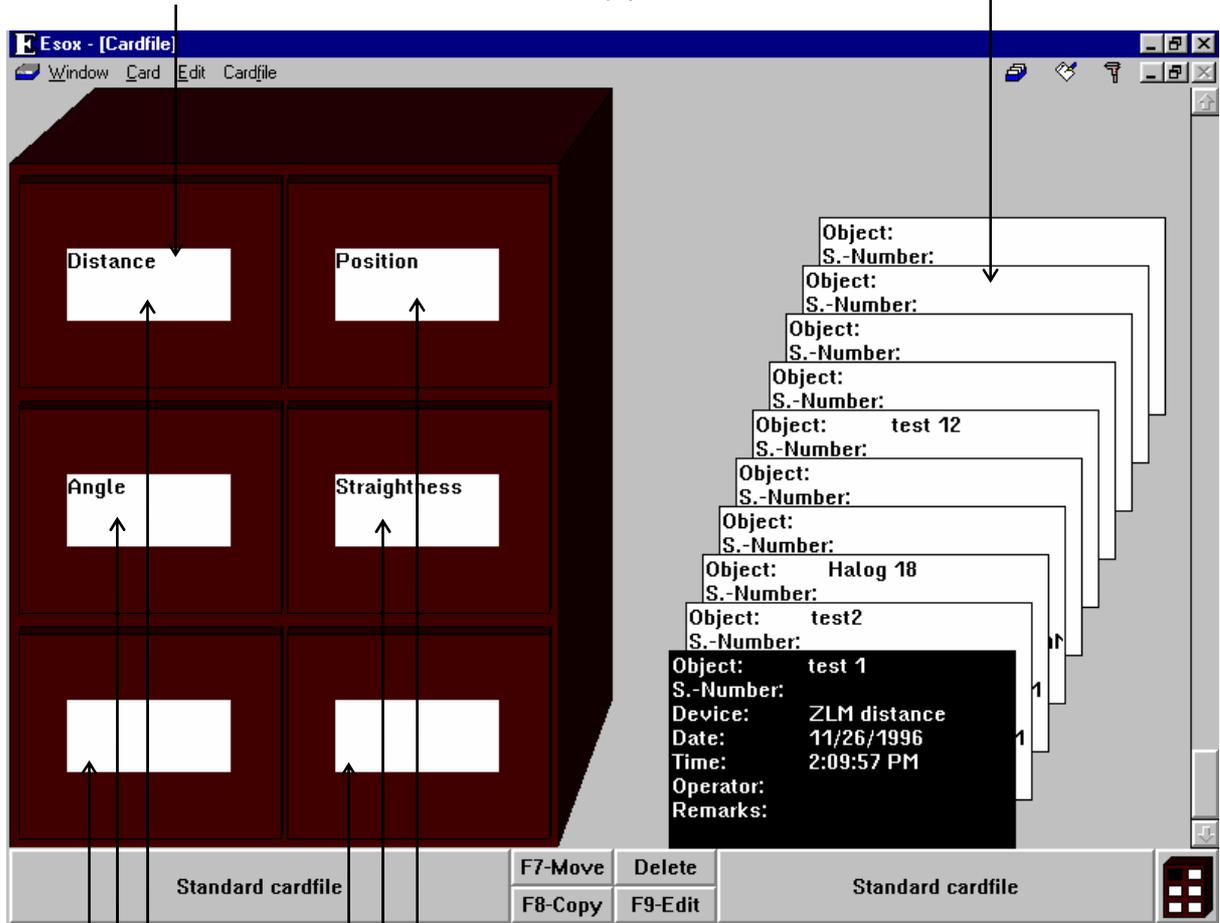
K 1 Fields of the "Cardfile" window

The work area of the "Cardfile" module window is subdivided into two fields showing card boxes and one field of buttons.

K 1.1 Fields with card boxes

Depending on the program status in the two upper fields, a filing cabinet with closed file card boxes

or an open box with a vertical scroll bar may be displayed. In specific cases this field may also stay empty.



Each filing cabinet has six card boxes. Each card box is provided with a label.

Open card boxes contain a number of cascading card fields. On top of the stack is the latest card with its entire text visible. All other cards are partially or completely out of view.

K 1.2 Button field

The buttons are located on the bottom of the screen. The number and types of buttons depend on the current field contents for the card boxes.

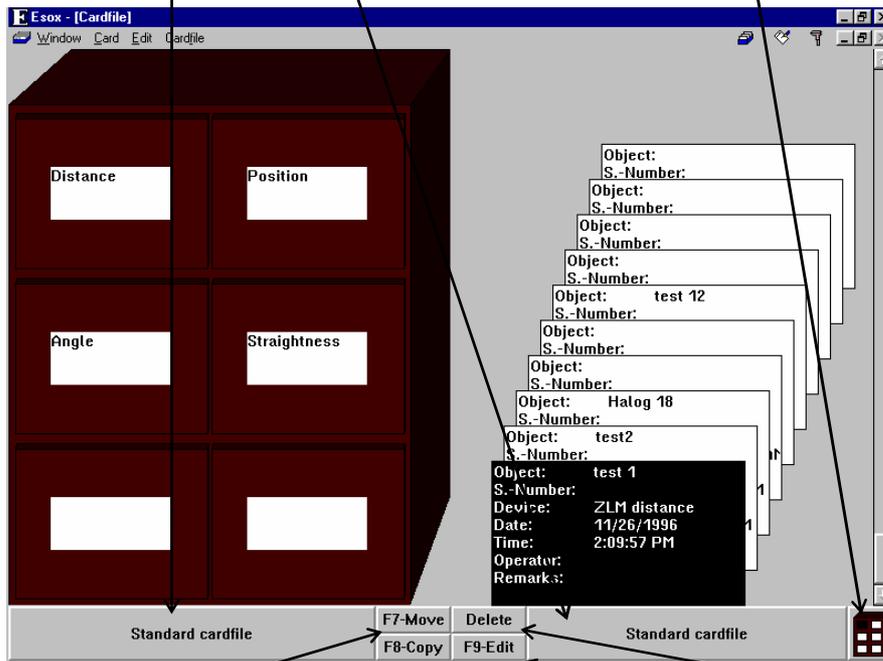
These two large buttons are labelled with the name of the card file. Use them to select the card file you want to view.



at the right or left side indicates an open card box in the right or left bay of the filing cabinet. The open box is black (in this example, the top right box is open). Use this button to close the card box.



on the right or left side indicates that the card box of the main memory is displayed on the right or left side. This box cannot be closed, since the main memory does not have a filing cabinet.



F7-Move

can be used to move a file card from one box to another or to re-arrange file cards.

F8-Copy

copies a file card.

F9-Edit

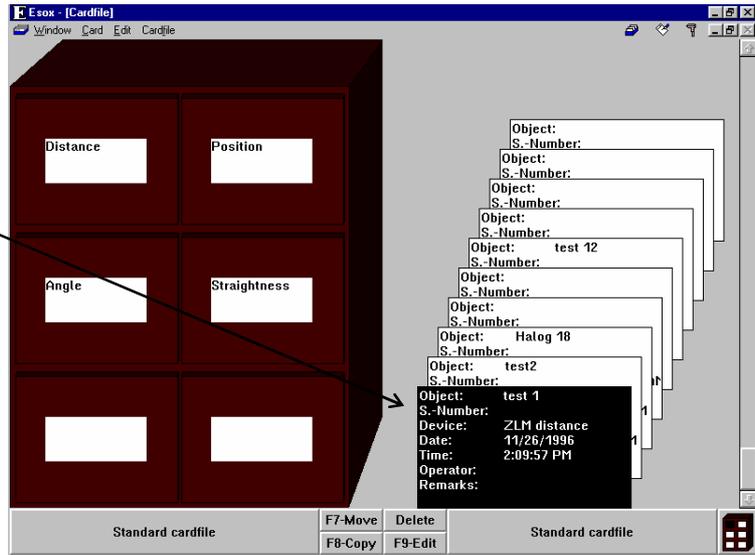
edits the text on a file card or on the label of a card box.

Delete

deletes a file card.

K 2 Changing the selected (highlighted) card field

When you activate the commands "Delete", "Move", "Copy", or "Edit", you must identify the object the command applies to. The program highlights the respective card field or card box label by presenting it with white lettering on a black background. In the figure the file card in the card box on the right is highlighted.



To select or highlight another field, you can use either keyboard or mouse.



With the cursor keys , , and you can move from one card field or card box label to another.

With the button you can move from the previously highlighted card field on one side of the screen to the card field on the other side of the screen that was highlighted there last (i.e. changing from the drive or main memory on the left-hand side to the drive or main memory on the right-hand side and vice versa).



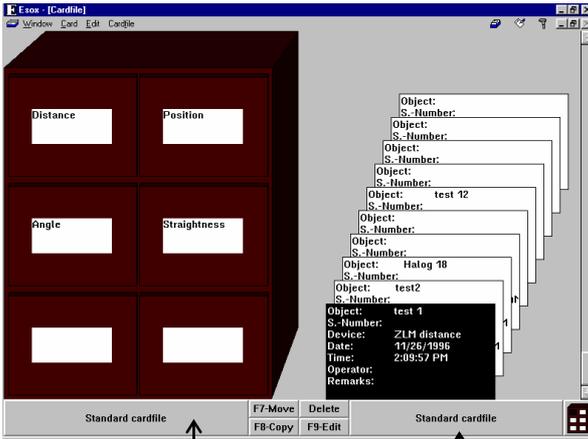
Click on the card field or card box label you want to highlight. Please note: Clicking on an already highlighted box label will open the respective box.

K 3 Opening and closing a card box

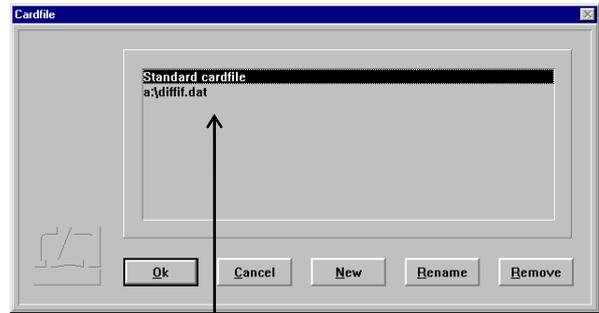
	Opening	Closing
	If the label of the card box is not highlighted, use , , and to move to this label. Then press .	If necessary, press , or to move to the respective side of the screen. Then press .
	If the label of the card box is not highlighted, click on the label once to highlight it; click on the label again to open the box. If the label of the card box is already highlighted, click on it once to open the box.	Click the button at the bottom right or left of the window to close the right or left card box.

The card box of the main memory cannot be closed, since the main memory has only one box.

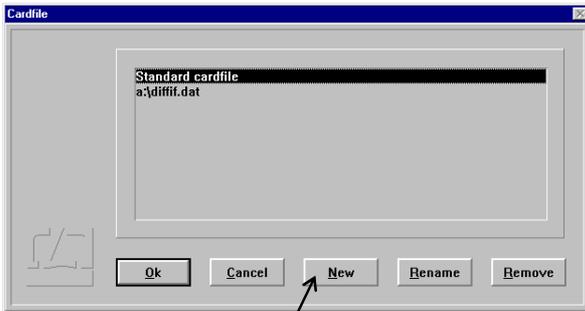
K 4 Creating, renaming and deleting a card file



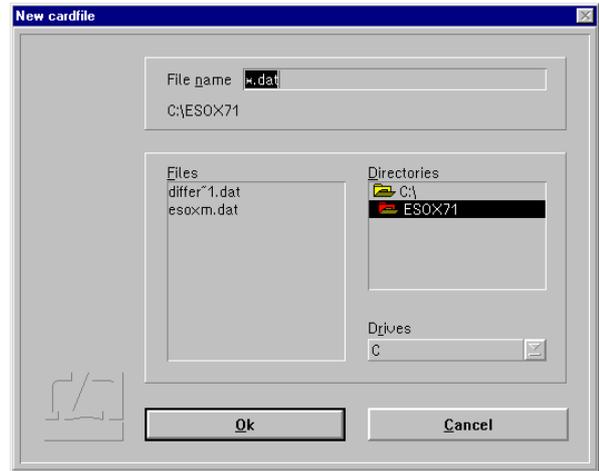
To create a new card file, click on the file name button on the side where you want the new file to be shown, or select the menu option "File cabinet - right" or "File cabinet - left".



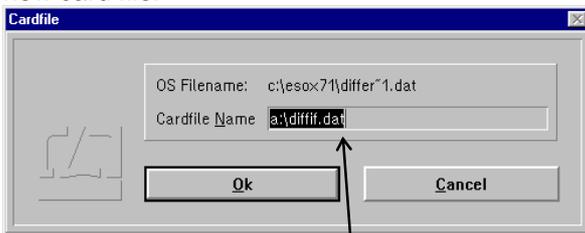
This opens a list showing the names of all existing card files in a dialog box.



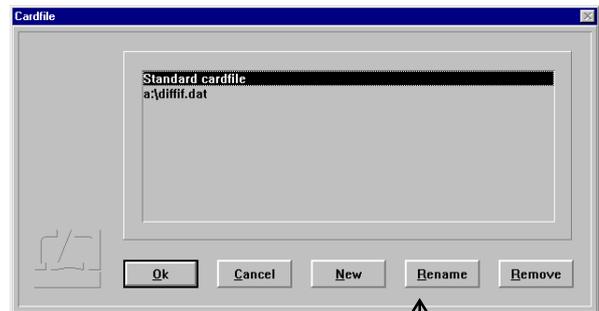
Click the **New** button if you want to create a new card file.



This opens another box in which you must enter the name of the data file.



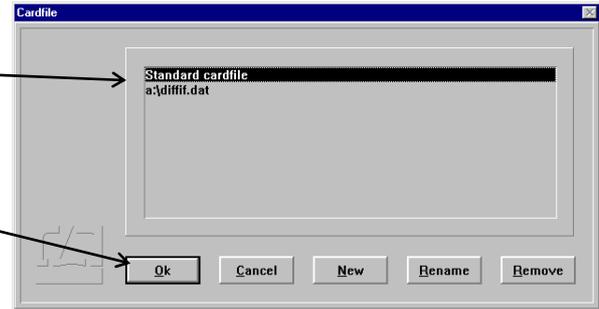
Click the **OK** button to open another dialog box, in which you must enter a card file name, which then appears in the card file list.



The same dialog box is opened if you use the **Rename** button to rename a card file.

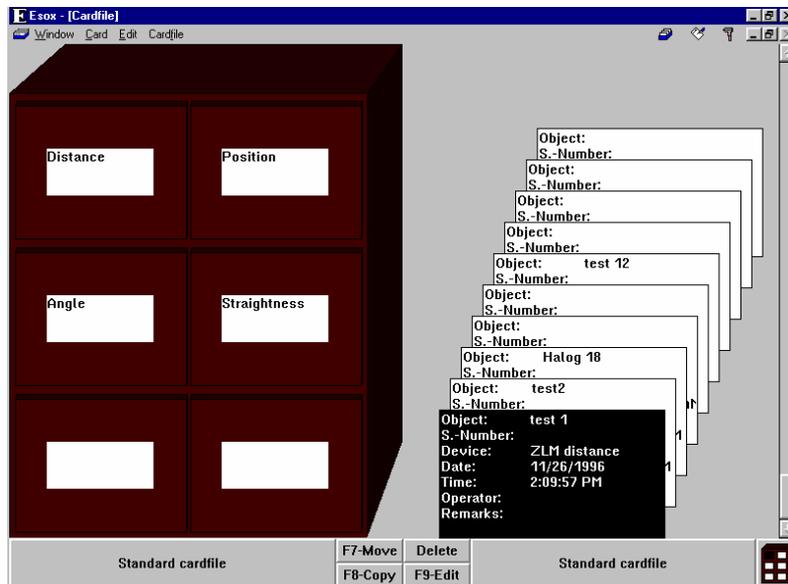
Click the **Remove** button if you want to delete a card file from the card file list. This will not, however, delete the data file from the memory. For deleting the data file, use the file manager.

To select a card file from those created, highlight the file name in the list box and then click the  button.



K 5 Shifting of file cards

The cards in an open card box can be shifted to activate (and highlight) another card. Cards arranged in front of the current card are not displayed.



The vertical scroll bar shows the location of, and the amount of space occupied by, the current card with respect to all cards of the box.

- 


The file cards are shifted backward by one position. The card in the order before the card that was current last becomes the new current card.
- 

The file cards are shifted forward by one position. The card in the order behind the card that was current last becomes the new current card.
- 

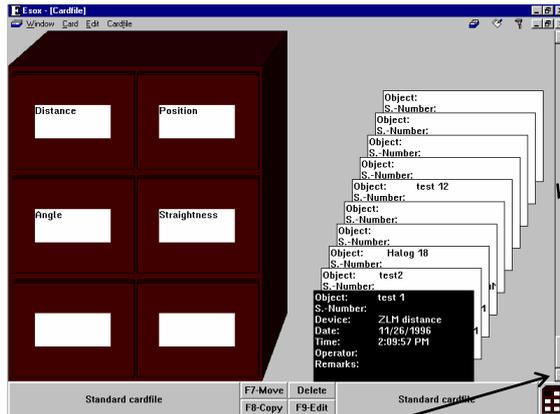
The file cards are shifted backward by one screen page. The first card of the previous page becomes the new current card.
- 

The file cards are shifted forward by one screen page. The first card of the next page becomes the new current card.



Click on the scroll arrow , to shift the file cards **forward by one position**. The card behind the card that was current last becomes the new current card. When you hold the left mouse button depressed for a longer time, the cards are scrolled continuously.

Click on the space between the scroll arrow  and the sliding box to shift the file cards **backward by one screen page**. The middle of the sliding box will never be moved beyond the place you clicked. If this place is too close to the sliding box, the cards will be shifted by less than one screen page. When you click and hold the left mouse button for a longer time, the cards will be scrolled page by page until the middle of the sliding box is located at the place you clicked.



To shift the cards **to an optional position**, move the mouse cursor to the sliding box. Click and hold the left mouse button. The sliding box is now framed by a black rectangle. Drag the mouse until the rectangle is in the wanted position. Release the left mouse button again.

Click on the scroll arrow , to shift the file cards **backward by one position**. The card before the card that was current last becomes the new current card. When you hold the left mouse button depressed for a longer time the cards are scrolled continuously.

Click on the space between the scroll arrow  and the sliding box to shift the file cards **forward by one screen page**. The middle of the sliding box will never be moved beyond the place you clicked. If this place is too close to the sliding box, the cards will be shifted by less than one screen page. When you click and hold the left mouse button for a longer time, the cards will be scrolled page by page until the middle of the sliding box is located at the place you clicked.

K 6 Editing of file cards and card box labels

Select and highlight the file card or the card box you want to edit. The edit mode can be started with either the key board or mouse:



Select the **"Edit"** option from the **"Card"** menu.



Click **F9-Edit** at the bottom centre of the window.

Annex III contains a list of keys and key combinations that have special functions in the editing of text boxes.

In addition you can use the following keys for moving within a card:



- moves the text cursor to the next card entry.



- moves the text cursor to the next lower card entry.



- moves the text cursor to the next upper card entry.

In the edit mode you can use the commands of the "Edit" menu.

- "Copy" The highlighted text is copied to the clipboard.
- "Cut" The highlighted text is copied to the clipboard and deleted in the text box.
- "Delete" The highlighted text is deleted from the text box.
- "Paste" The text saved in the clipboard replaces any highlighted text or is copied at the current position of the text cursor.
- "Undo" Undoes the last text edit action.

Disable the edit mode at the end of all edit action.



Choose the "End Edit" option from the "Card" menu.



Click  at the bottom centre of the window.

K 7 Copying of file cards

To copy a file card, you must first select a source card. Then select a target position. The source file card must be highlighted and the target card box open.



Choose the "Copy" option from the "Card" menu.



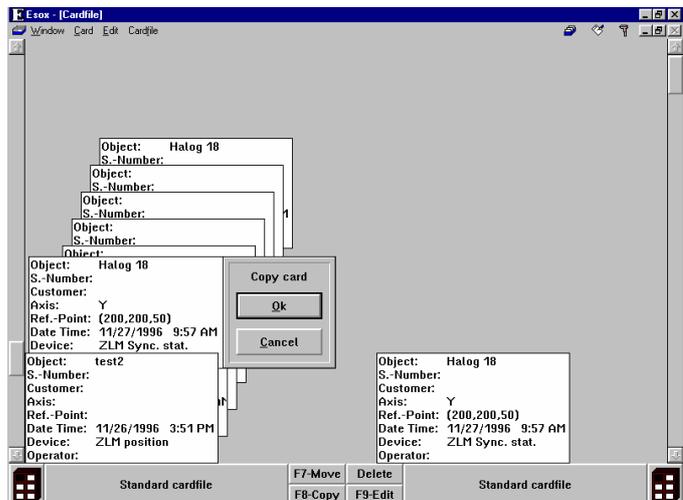
Click on .

The screen displays a window with the card to be copied, as shown in the figure.

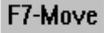
You can use the cursor keys or click with the mouse pointer on the scroll bar to change the destination of the card. The cards are moved in the same way as described in Section "K 5 Shifting of file cards". In addition, you can change the screen side for the target position by using



Click the  button to confirm and trigger the copy process.



K 8 Moving of file cards

To move file cards, choose the **"Move"** option from the **"Card"** menu or click the  button. Now you can use the same steps as described in the "Copy" process. The source card is deleted after this process.

You can also move the card by using the mouse. Move the mouse pointer on the source card, click and hold the left mouse button down. Now drag the mouse and the file card to the target position. During this process you can shift the other file cards by dragging the file card with the mouse pointer to the top or bottom of the window. Release the left mouse button when the card is at the target position.

K 9 Deleting of file cards

Highlight the card to be deleted.



Choose the **"Delete"** option from the **"Cardfile"** menu.



Click the  button.

K 10 Record (document) of a file card

As records are compiled in a separate program module, the question may arise as to which card a currently displayed record relates to. Two cases can be distinguished.

If a measurement program is active, the record shown is that of the card currently in the main memory of the measurement program. If no card is there, no record is displayed.

With no measurement program active, the record shown is that of the card highlighted in the "Cardfile" program module.

K 11 Condensing of card files

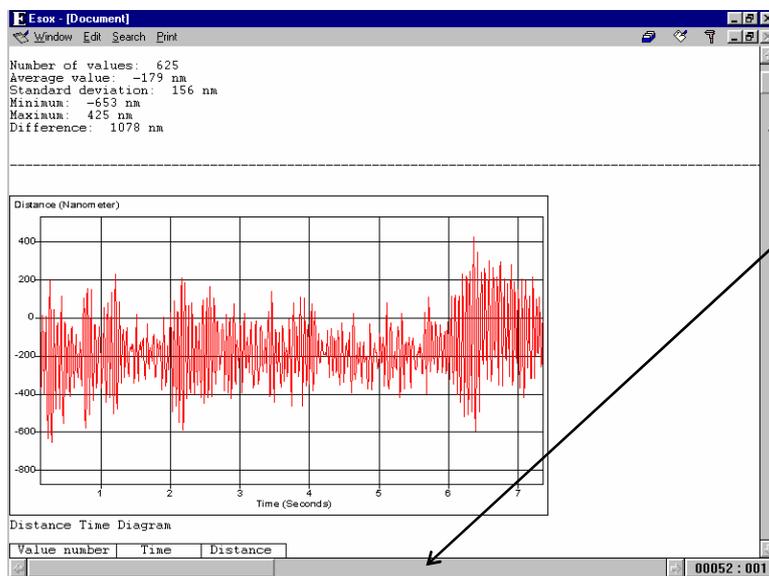
Every card file is saved only in one data file of the operating system. When the program was developed, data integrity and speed, rather than minimum file size, were accorded top priorities. This gives rise to a secondary effect: After several card deletions, the file is larger than necessary. With the **"Compress Card File"** option of the **"Cabinet"** menu, you can condense the card file to a minimum. This process takes some time and requires free memory capacity for the size of the condensed card file in at least one of the drives C and upwards.

L "Document" Program Module

The "Document" program module is a text editor which can also edit graphics and tables. On command, the measurement program transfers diagrams and text on command to the "Document" program module. There a document, i.e. a record is compiled which can be edited, i.e. graphics, tables and text can be arranged and supplemented as requested and the text be modified. The record compiled in this way can afterwards be printed. Every page of the printed record has a heading containing the most important information regarding the measurement. The record is stored on the file card that also carries the respective measured data. Thus, the records of measurements taken longer ago are also accessible.

L 1 Elements of the "Document" window

The major part of the window of the "Document" program module is occupied by the workspace of the editor, in which text, tables and graphics are displayed.



From the two scroll bars at the right and bottom margins of the window you can read roughly which share and position the record portion displayed has within the total record. Use the scroll bar control buttons to move other record portions into the window.

At the bottom right corner of the window the current position of the Windows text cursor (insertion point) is indicated by a line and column display.

L 2 Editor concept

Text editors are based on one of two different concepts:

1. Editors which take into account the width of printer paper and therefore use word wrapping when the page margin would be exceeded. Here, the text cursor (insertion point) cannot be moved behind the last character in a line. To insert text at the far right end of a line, many blank characters (space) or some tabs must be typed in previously. Most word processors use this type of editor.
2. Editors whose text cursor can be moved to any place wanted by using the direction keys. Here, typing beyond the page margin is possible.

Since it may be necessary to quickly insert, for instance, a caption on the right side of the record, the ZLM document editor is based on the second concept without word wrapping at the end of a line. Problems with page width, that might arise when changing the printer driver used, are avoided by using a character set with characters that all are of the same width. All printer drivers always work with the same number of characters per line unless the used paper size varies considerably.

A line may contain either characters or graphics and tables. Graphics and tables are treated just as characters as far as cursor operations and the menu commands "Copy", "Cut", "Paste", "Delete" and "Undo" are concerned.

With the editor a maximum of 250 columns (characters), 99,000 lines and 1,000 graphics or tables can be edited.

L 3 Positioning the text cursor (insertion point)

Here is a list of the keys and key combinations that can be used for moving the cursor (insertion point).



Key / key combination	Moves the cursor ...
	... one line down.
	... one line up.
	... to the left by one character.
	... to the right by one character.
	... to the beginning of the line.
	... to the current end of the line.
	... down by a windowful, i.e. by as many lines as are visible on the workspace.
	... up by a windowful, i.e. by as many lines as are visible on the workspace.
	... to the left by one word, table or graphic.
	... to the right by one word, table or graphic.
	... before the first character, table or graphic in the line.
	... behind the last character, table or graphic in the line.
	... to the right by a windowful, i.e. by as many columns as are visible on the workspace.
	... to the left by a windowful, i.e. by as many columns as are visible on the workspace.



You can also change the position of the cursor by clicking the mouse on the position desired for the cursor. When clicking on a graphic, the graphic is selected (highlighted) additionally. Consult Section "L 9 Changing the size of graphics" for detailed information regarding this effect.

L 4 Selecting text, tables and graphics

The functions "Copy", "Cut" and "Delete" can be made to act on a block of characters and to graphics or tables. You need to tell the program which block the function is to act on. For this purpose you need to select (highlight) the respective characters, tables or graphics. Selected characters are displayed white against a black background. A selected diagram is presented in inverse colours if you have selected more than this one diagram. If only one diagram has been selected, a frame will be shown around it, allowing its size to be changed. This operation is described in Section L 9 "Changing the size of graphics".

The selection (highlighting) can be undone by a mouse click or by pressing any cursor moving key or key combination.

If a key for text entry is pressed while any characters, tables or graphics are highlighted, the highlighted characters, tables or graphics are replaced by the character typed in.



Key / key combination	Highlights ...
 + 	... the character left of the cursor.
 + 	... the character right of the cursor.
 + 	... the text one line down.
 + 	... the text one line up.
 + Home	... the text left of the cursor up to the beginning of the line.
 + End	... the text right of the cursor up to the last character of the line.
 + PgDn	... as many lines down as are visible on the workspace.
 + PgUp	... as many lines up as are visible on the workspace.
 + Ctrl + 	... one word left of the cursor.
 + Ctrl + 	... one word right of the cursor
 + Ctrl + Home	... the text left of the cursor up to the first character of the text.
 + Ctrl + End	... the text right of the cursor up to the last character of the text.
 + Ctrl + PgDn	... as many columns right of the cursor as are visible on the workspace.
 + Ctrl + PgUp	... as many columns left of the cursor as are visible on the workspace.



To select text with the mouse, move the mouse cursor (I-beam) behind the last character of the text block to be selected. Click and hold down the left mouse button. Drag the mouse cursor to the other end of the block and release the button.

L 5 Scrolling the record

From the scroll bars at the right and at the bottom of the window you can read which portion of the record is currently displayed on the workspace of the editor.



To scroll the visible portion of the record with the keyboard, you can use the keys and key combinations for cursor operation (see Section L 3 "Positioning the text cursor").



To move **up one windowful**.

To move **up one line**.

To move **to a specific position**:

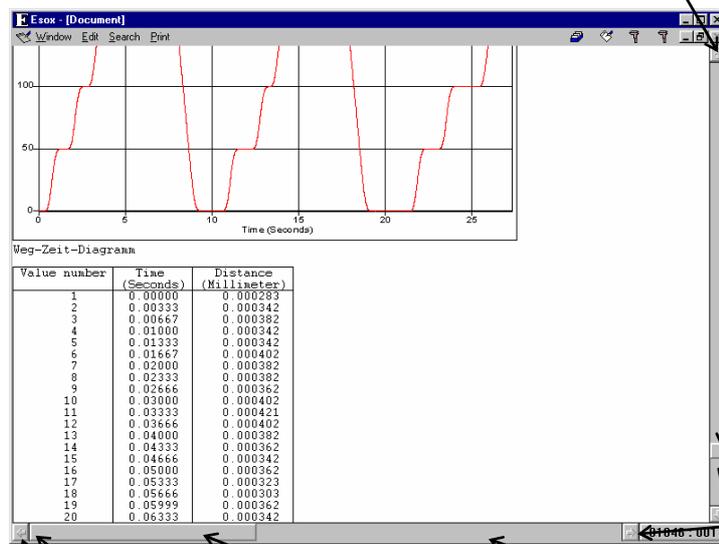
Place the mouse pointer on the slider box.

Click and hold down the left mouse button. A square appears around the slider box. Drag the box with the mouse until the box is in the desired position. Release the mouse button.

To move **down one windowful**

To move **down one line**

To move **forward one column**



To move **backward one column**.

To move **backward one windowful**

To move **to a specific position**: Place the mouse pointer on the slider box. Click and hold down the left mouse button. A square appears around the slider box. Drag the box with the mouse until the box is in the desired position. Release the mouse button.

To move **forward one windowful**

L 6 Functions for editing text blocks

For editing text blocks, five options are available in the "Edit" menu.

Delete With the "**Delete**" option, selected (highlighted) text with characters, tables and graphics can be erased. If neither characters, tables nor graphics are highlighted, the delete command is applied to the character, table or graphic being right of the cursor. If the cursor is positioned right of the last character, table or graphic of the line, all characters, table or graphics of the following line are arranged behind the cursor. All the following lines are shifted up by one line.

Pressing the  key releases the same operation as the "Delete" option of the "Edit" menu.

You can also erase all highlighted characters, tables and graphics by pressing the  key.

If neither characters, tables nor graphics are highlighted when the  key is pressed, the character, table or diagram left of the cursor is erased. If the cursor is positioned at the beginning of a line, the characters, tables or graphics of this line will be arranged behind the last character, table or graphic of the previous line. All the following lines are shifted up by one line.

In delete actions the program takes care that characters, tables and graphics do not appear simultaneously in one line.

Copy With the "Copy" option of the "Edit" menu you can copy a highlighted text block with characters, tables and graphics to the clipboard.

Cut Same as with the "Copy" option the "Cut" option of the "Edit" menu copies the highlighted text to the clipboard. Subsequently however the highlighted text is deleted from the original record.

Paste With the "Paste" option of the "Edit" menu you can replace any highlighted text by the text, tables or graphics currently stored in the clipboard after "Copy" or "Cut" commands. If no text is highlighted when you activate the "Paste" command, the contents of the clipboard is inserted at the current cursor position.

Undo With the "Undo" option of the "Edit" menu you can reverse the very recent
copy,
cut,
delete,
paste, or
text entry
action.

L 7 Transfer of record contents to other Windows programs

Record contents can be transferred for further processing via the Clipboard (see MS Windows manual). As a prerequisite for such transfer, the external program must know the data format in which the "Document" program module transfers the record contents to the clipboard.

ANSI text	Text without illustrations (diagrams) and without tables can be transferred to a word processor without problems.
Windows metafile	Illustrations (diagrams) are accepted by most word processors and graphics processors.
RTF (Rich Text Format)	Tables and record portions containing text, tables and graphics can only be processed by word processors having import filters for the "Rich Text Format".

To transfer record contents to another Windows program, proceed as follows.

1. Use the mouse or keyboard to highlight the record part to be transferred (see sect. L 4. "Highlighting text, tables and graphics").
2. Use the "Copy" option in the "Edit" menu to copy the record part to the clipboard.
3. Change to the target Windows program.
4. Insert the record part there. The corresponding menu item there usually is "Edit - Paste".

If the attempt should be unsuccessful, check whether the menu option for pasting (inserting) is deactivated in the target program (grey text). In this case the target program cannot process the data format concerned. Many programs (usually word processors), when being installed offer the option of installing or not installing import filters. In many cases it will be possible to subsequently install an import filter without having to re-install the whole program. For detailed information see the manual of the respective program.

The capacity of the clipboard is limited. If there are problems with transferring an extensive portion of a record, split it up into smaller units and transfer them one after the other. Tables in RTF format, in particular, occupy a great amount of space. Therefore avoid the generation of tables having more than 100 lines.

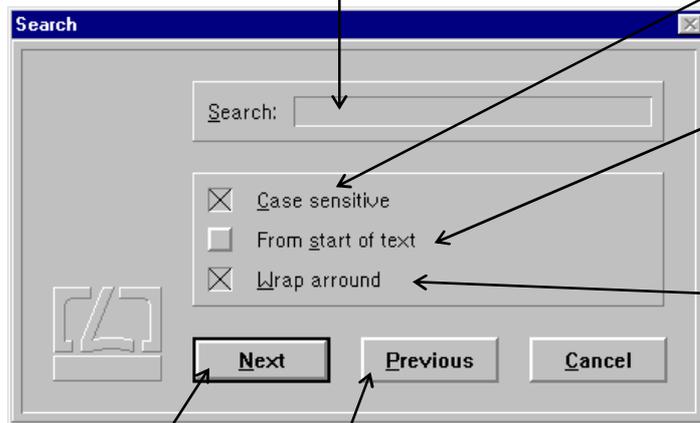
Via the "Paste" option of the "Edit" menu, the "Document" program module can import text (data format: ANSI text) or an illustration (data format: Windows Metafile) copied on the clipboard by other programs. The "Document" program module will not accept foreign text and foreign illustrations together, nor data in other formats, nor foreign tables.

L 8 Searching text

With comprehensive records it is advantageous that the computer can search for a defined text, if necessary. For this, the **"Search"** menu is available in the "Document" program module.

On calling the **"Find"** option of the "Search" menu, the following dialog box appears on the screen.

Type the text to be found in the "Search:" text box. The program can find the text only if it is arranged on one line in the record. It is not possible to search for graphics or tables. If, on activation of the "Find" option of the "Search" menu, text is highlighted, the program will type the highlighted text into the text box.



If the check box **"Case sensitive"** is not checked (- checked, - not checked), the search routine will find the word independent of your uppercase or lowercase spelling in the "Search:" text box.

If the check box "From start of text" is checked, the search is started from the first character of the record. If not, the search is started from the current cursor position.

If the check box "Wrap around" is checked, the forward search - if it was started at the current cursor position somewhere in the text - will be continued at the beginning of the text up to the starting point of the search after arriving at the end of the record. In the reverse search mode, the search will be continued at the end of the record after arriving at the beginning of the record.

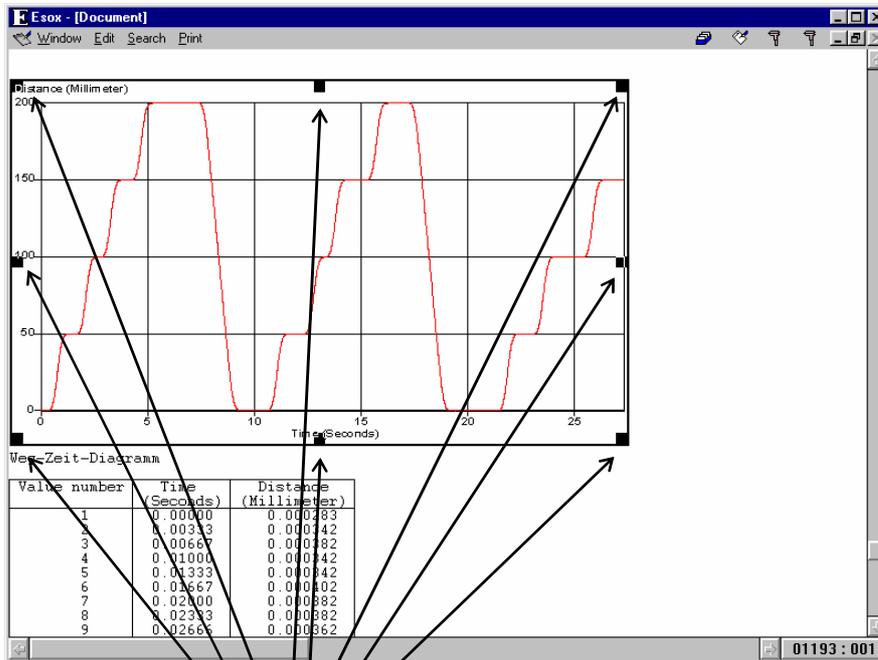
Next
starts the forward search.

Previous
starts the reverse search.

With the options **"Next"** or **"Previous"** of the **"Search"** menu the previously carried out search operation can be repeated in either forward or reverse mode with the options "Case sensitive" and "Wrap around" of the "Search" dialog box being applied as previously set. With the options "Next" and "Previous" the search is always started at the current cursor position.

L 9 Zooming of graphics

You can change the size of graphics with the mouse only. First click the diagram you want to zoom. At the edges of the diagram there appear two small black squares for vertical zooming, two black squares for horizontal zooming, and four black squares for simultaneous vertical and horizontal zooming.



1. Move the mouse pointer onto the diagram field you want to zoom.
2. Click and hold the left mouse button. A grey frame appears around the diagram.
3. Drag the mouse until the frame has the size desired for the diagram.
4. Release the left mouse button.

NOTE: A diagram surrounded by a square for zooming is "highlighted", i.e. selected in the sense that pressing any text character key will replace the diagram with the character typed.

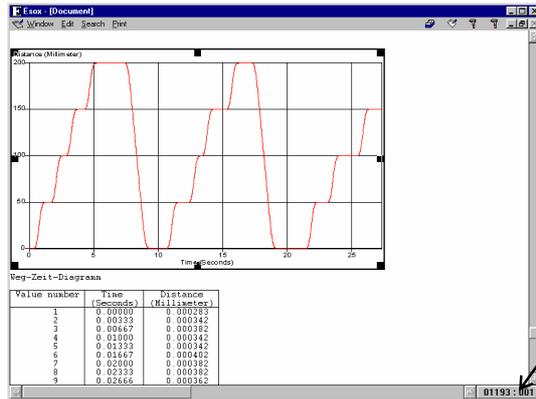
L 10 Page margins

You can make the margins of the printer paper visible on the workspace of the editor. They are indicated by red lines in accordance with the current printer driver settings.

The presentation of the margins on the screen can be activated/deactivated both with the mouse and the keyboard.



Choose the **"Page margins"** option from the **"Print"** menu.



Click on the display field at the bottom right of the window containing the current page, line and column figures.

Margin presentation active:

0001 : 27 : 011

Page number of the current cursor position.

Line number of current cursor position relative to start of page.

Column number of current cursor position.

Margin presentation inactive:

00027 : 011

Line number of current cursor position relative to start of page.

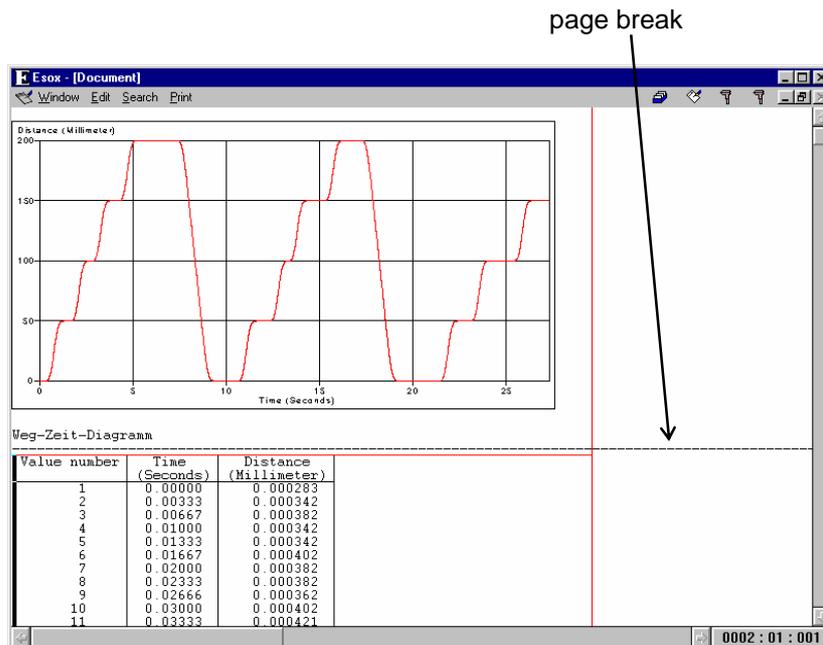
Column number of current cursor position.

L 10.1 Inserting page breaks

If a paragraph of the record is to begin on a new page, you can insert a page break before this paragraph. The measurement programs work with page breaks in transferring diagrams and text. Page breaks are presented on the workspace of the editor by a broken line.

You can insert page breaks with the **"Insert page break" option** of the **"Edit" menu**. In the page margin presentation mode the page breaks are taken into consideration and displayed accordingly.

With all cursor, highlighting, text editing and text block functions, page breaks are treated by the editor as lines that neither contain text nor can be written on.



L 10.2 Deleting page breaks

For deleting a page break move the text cursor (insertion point) to the line showing the page break and press the **Delete** key. Another way to delete page breaks is to place the text cursor just before the first character, table or graphic in the line that directly follows the page break, and press the

← key there.

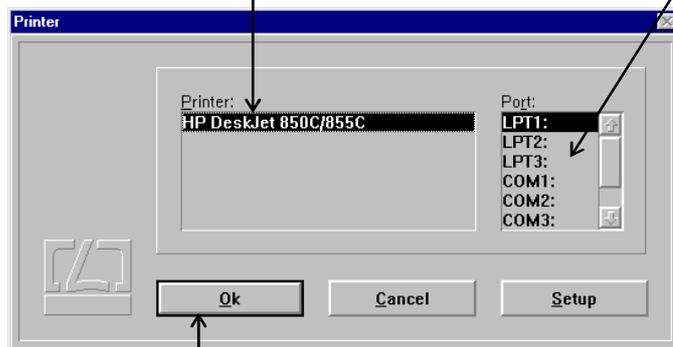
L 11 Printing

Records are printed with a record heading on every page followed by the contents of the compiled record. For printing, the program employs the installed printer drivers provided with MS-Windows or supplied by the printer manufacturer.

L 11.1 Print setup

The **"Printer installation"** option of the **"Print"** menu serves for choosing the printer and the print options to be used.

You can choose the printer to be used from the "Printer" list box.



In the "Port" list box you can either select the printer port to be used for printing, or activate the creation of a print file containing the print commands for later printout.

If you want to change the printing options (for instance, paper size), activate the

Setup button. In this case, another dialog box ("Options") is superimposed on the "Printer" dialog box, which is created by the printer driver for setting print options. Read the User Manual of MS-Windows or that of the printer to find information about the available print options.

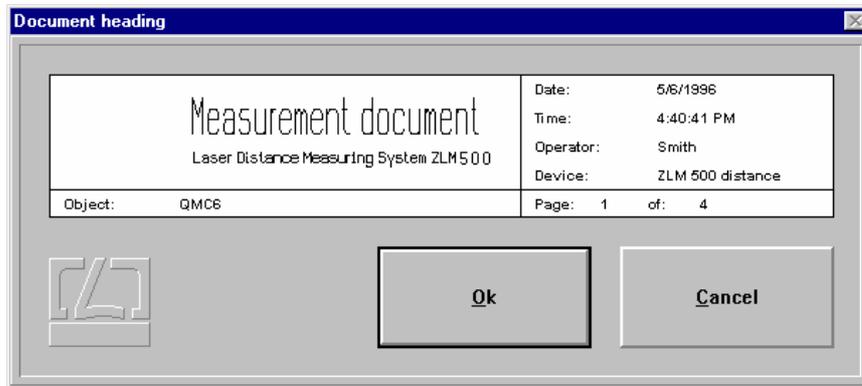
Confirm the printer and printer port selections by clicking the **Ok** button. The selections remain effective until you exit the "Esox" program.

After having chosen the printer from the "Printer" list box, the "Ports" list box automatically highlights that port that was specified for this printer under the MS-Windows Control Panel. Therefore, first choose the printer and then, if necessary, the port.

When this program is activated the next time, the default printer of MS-Windows is preset as printer for record printouts. You can change the default printer with the "Control Panel" utility integrated in MS-Windows. If, in future, you want to use another printer without the need of activating the "Printer installation" option of the "Print" menu, select this printer as default printer in the MS-Windows "Control Panel" utility. Consult your MS-Windows User Manual for information about the operation of this utility.

L 11.2 Record heading

On every page of the record printout a heading will be printed. You can change the entries of this record heading using the **"Document heading"** option of the **"Print"** menu. On activation of this option a dialog box appears in the middle of the screen.



The mask for the record heading is created by the measurement program and transferred to the "Cardfile" program module. This mask cannot be changed. The entries (date, time etc.) in the heading originate from the respective file card. When you change the entry in the record heading, this change will be automatically transferred to the respective file card.

You can jump between the text boxes of the heading by pressing the  key. The possible cursor movements, highlighting and delete functions are listed in Annex III. A click on the

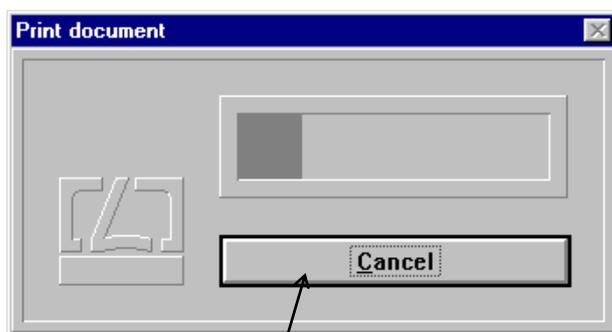
 button confirms the changes made. When you click the  button instead of the  button, the previously made changes are cancelled.

L 11.3 Starting the printing process

To start the printing process choose the **"Print" option** from the **"Print" menu**. On activation of this option, first the dialog box "Document heading" appears giving you the chance to edit the entries in the record heading.

By clicking the  button in the "Document heading" dialog box, you can abort all editings made. If you only want to edit the entries but not print the record, use the **"Document heading"** option in the **"Print"** menu.

To start the printing process, click the  button.



On clicking of the  button, the "Print document" dialog box is displayed, providing the possibility to abort the printing process by clicking the abort button, if any printer problems should occur.

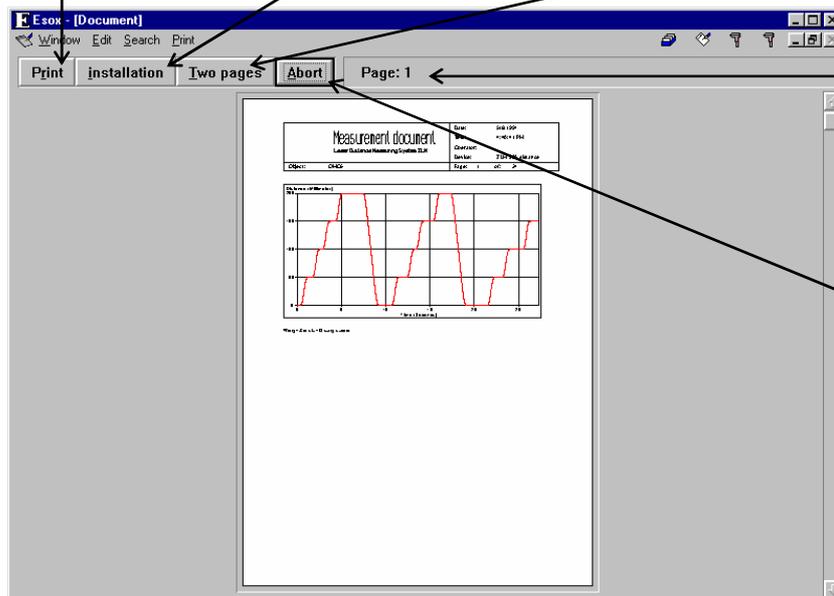
L 12 Print page preview

The "Print preview" option of the "Print" menu allows you to preview the printed record pagewise on the screen.

Start the printing action with the "Print" button.

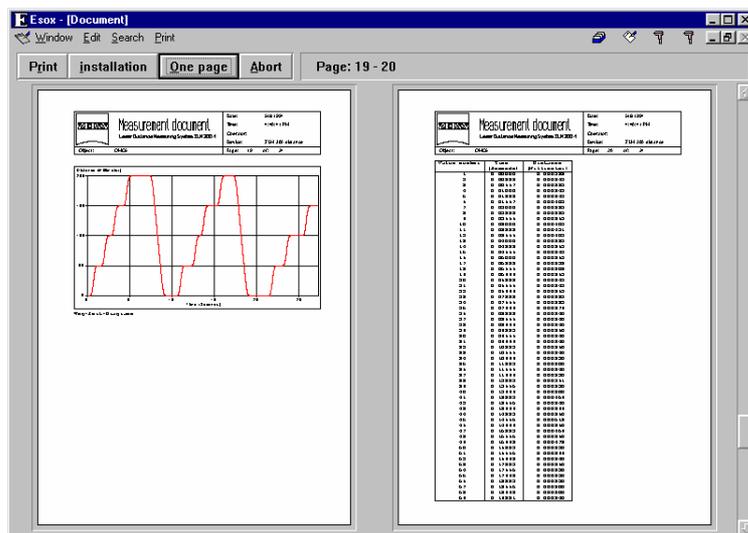
Here you can open the dialog box for selecting the printer and setting the printing options. (See L 11.1 "Printer installation").

Use this button to select between a one-page and a two-page preview.



This box indicates the page number(s) of the page(s) viewed.

Click the Abort button to return to the normal presentation.



Use the vertical scroll bar for paging through the record.

Home - gets you back to page one.

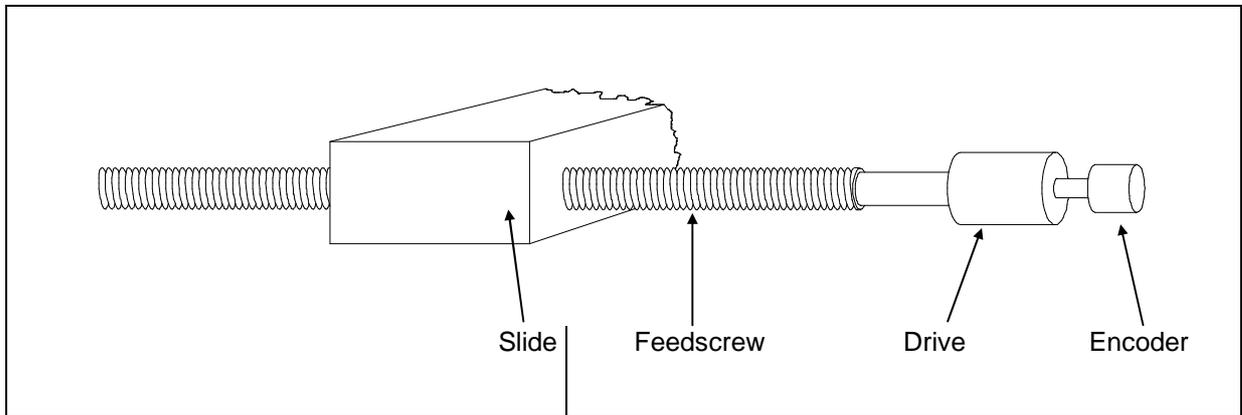
End - gets you on to the last page.

PgDn - gets you to the next page.

PgUp - gets you back to the previous page.

N **Feedscrew pitch error compensation for machine-tools featuring “Sinumerik Series 800” controls**

For positioning along the machine axes, machine tools usually have feedscrews fitted with incremental rotary encoders that measure position. Since rotary encoders do not register inaccuracies of the screw thread, these inaccuracies deteriorate the positioning accuracy of the machine-tool.



With Sinumerik Series 800 Control Systems, feedscrew errors can be largely compensated. For this purpose, the error curves of the machine axes are established by measurements with a laser interferometer setup. The "ZLM Position" program module determines the compensation values and transmits them to the machine control system.

When a machine-tool thus compensated is being positioned, the respective compensating value is added to the position reading of the encoder, resulting in higher position accuracy.

N 1 **Ascertaining the position errors of the machine axes**

The "ZLM Position" calibration software module of the ZLM 500 Laser Interferometer allows the positioning errors of machine axes to be ascertained. For each axis the program creates a file card with the position errors.

When measuring the position errors, mind the following instructions:

1. The machine must be measured in non-compensated state.

In order to inactivate already existing compensation values, set the compensation value for the respective axis to zero (MD 3280 for 1st axis, MD 3281 for 2nd axis etc.).

Whenever you change machine data, be sure to note down the old data.

Certain machine data changes will only become effective after you switch on the machine the next time. Therefore we recommend to turn the machine off and on again after changing any data.

2. Each machine axis has a reference position. The control system assigns to this position the position value "zero". On the command "Travel to reference position", each machine axes homes in to its reference position.

You need not test the full length of the machine axis for errors, but may limit the test to the range in which high positioning accuracy is essential. **In any case, however, the reference position must be within the range tested.**

It is recommendable to set the laser interferometer to zero in the reference position. Otherwise you need to **note down the reading of the laser interferometer in the reference position**. For this purpose the file card contains the item "**Ref(erence) point**".

Moreover, be sure that the **sign of the laser interferometer reading is identical with the machine-internal sign of the machine axis**.

3. In order to avoid later misunderstandings, always enter the designation of an axis just tested into the "Axis" field of the file card.

4. In the machine control system, the machine axes are numbered consecutively. For obtaining the compensation you need to find out the correlation between axis designation and axis number.

You also need to find out the axis resolution, i.e. the machine increment in terms of μm for each axis.

The operation of the "ZLM Position" program module is described in detail in section G of the ZLM Software handbook.

N 2 Start of the "ZLM Compensation" program module

A separate program module termed "ZLM Compensation" is available for the computation of compensation data and their transfer to the machine control system.

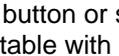
Look for the "ZLM Compensation" icon in the "ZLM" application window. You can start this module same as any of the measuring program modules.

N 3 Reading in the measurement data

Either click the  button or select the "**Card**" option of the "**Cardfile**" menu to open the card file management.

The loading of cards is equal to the loading of cards in the measuring programs, except for the fact that here you can load several cards into the main memory at a time.

Use of a "Sinumerik Series 800" control requires that the compensation data for all machine axes must be computed and transferred together. Therefore you need to load the file cards of all axes of the machine-tool under test.

To end card selection, click the  button or select the "**End cardfile**" option of the "**Cardfile**" menu. The screen will then display a table with compensation parameters.

N 4 Compensation parameters

To ensure successful compensation, you need to tell the program certain properties of the machine axes (axis number, resolution, reference position, start and end of the travelling range). As the machine control system has a limited storage capacity for compensation data, a number of parameters can be specified that help reduce the storage space required.

The name of the respective machine axis appears in the 2nd column.

In the machine control system, the axes are numbered consecutively. In the 1st column you need to enter which axis has which number.

The entry “-” is only of importance if a storage space problem occurs in the CNC system during compensation. It is then possible with this entry to exclude machine axes from compensation.

To ensure successful compensation, you need to specify in the "Resolution" column the μm equivalent of one machine increment for each axis.

In the "Tolerance" column, enter the width of the permissible tolerance zone for the position errors of the machine axis after compensation. First you should enter the resolution of the axis. If this should cause storage space problems in the CNC system, increase the tolerance for the individual axes depending on their accuracy priorities.

The “Sinumerik Series 800” control systems are capable to effect different compensations for the two travel directions of a machine axis.

In the “**Direction-dependent**” column you can specify whether you want the compensation to be effected depending on direction.

In case of storage space problems you can switch off direction dependence for selected axes.

In the “**Reference point**” column you need to enter the reading of the laser interferometer with the respective machine axis in the reference position.

It is not possible to test a machine axis throughout its length, because a reversing distance must be travelled at either end of the range tested. Compensation data can only be computed for the axis range tested. There remains the question of how the control will respond in the two untested end ranges.

It is desirable that the machine's positioning behaviour in these end ranges should be the same as before compensation. In order to achieve this with a Sinumerik control system, zero compensation values must be entered for these ranges. If you fail to do this, the machine will compensate by the values just contained in the memory for the respective positions. In order to enable the program to fill the end ranges with zero compensation values, you need to tell the program the limits of the compensated range of the respective axis, in terms of **“Start comp(ensation)”** and **“End comp(ensation)”**.

In the “Start comp.” and “End comp.” columns, the program first enters which range of the machine axis has been tested. These values always refer to the readings of the laser interferometer.

Here you should change the compensation range so that the machine axis will be compensated throughout its length.

In cases where the control system instantaneously lacks storage space for compensation data, the beginning and end of compensation can be restricted to a range in which highly accurate positioning is most essential. This may lead, though, to a degradation of positioning accuracy in the other ranges, compared with the non-compensated state.

A few units of the Sinumerik Series 800 controls compensate with signs reversed. Unfortunately it is not possible to identify these units by their serial numbers. Therefore, the following strategy should be adopted:

1. First have the program compute the compensation data the way they are required for most of the Sinumerik Series 800 units.
2. If this is not successful, have the compensation data computed with the signs reversed.

To reverse the signs for compensation, either

click the  button or select the

"**CNC make**" item of the "**Compensation**" menu. The upper entry in the "CNC make" dialog box applies to the majority of the Sinumerik Series 800 control units.

N 5 Computation of compensation data

To release computation of the compensation data, either

click the 

button or select the "**Compute data**" item of the "**Compensation**" menu.

In the bottom part of the screen you will then see the compensation data in the format used by the control system. Use the scroll bar to page through the data.

When computing the compensation data, the program checks whether the control system has sufficient storage space for the compensation data. In the negative case an error message will be issued.

In such a case you may make either of the following changes in the parameter settings:

1. Broaden the tolerance zone.
2. Select "no" for direction dependence.
3. Exclude one or more machine axes from compensation (enter "-" under "**Axis number**").
4. Reduce the compensation range under "**Start comp.**" and "**End comp.**".

N 6 Transfer of compensation data to the control system

Data transfer is via the RS-232 interface port.

It is important that all interface parameters of the PC and the control system are matched to each other. To select the interface port and interface parameters of the PC, either click the



button or choose the "RS 232

parameters" item in the "Compensation" menu.

This will open the "RS-232 parameters" dialog box.

In addition, the **Xon/Xoff Protocol** at the control unit must be switched off.

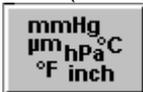
Then either click the  button or select the "Transfer to CNC" item of the "Compensation" menu to start data transfer.



The compensation data will only become effective after the machine has been switched on the next time and made to travel to the reference points. In any case you should check the compensation effect. With some CNC makes, compensation in MD 5016 must be activated via bits 1 and 2 (MD 5016: xxxxx11x).

N 7 Systems of units

To select between metric and imperial units (metres - inches), click the



button or choose the "Units" item in the "Compensation" menu.

N 8 Quitting the program module

To quit the program module,

either click the



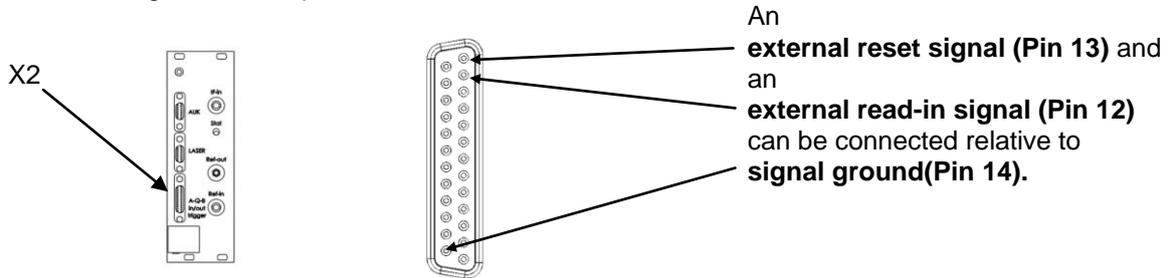
button or select the "End compensation program" item of the "Compensation" menu.

Annex I Connectors for real-time interface and external read-in signal

ZLM 800 CPCI

Connector for external signals

For external signals the 25-pin connector „X2“ can be used.

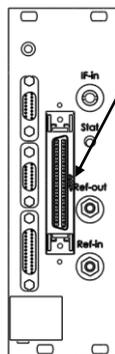


The TTL input of both signals respond to High-Low signal edges and must be at low level for at least 40 ns. The response time is 100ns for the external reset signal and 0.5 μs for the external read-in signal.

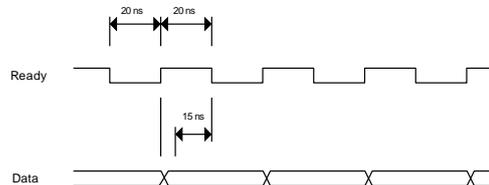
ZLM 800 CPCI

Connector for real-time interface

Extern Connector „X6“



The real-time interface supplies the current 32-bit counter value via the connector „X6“. The output values are valid as long as the "Ready" signal is "Low". The 32-bit value of the real-time interface is not older than 0.5 μs. The „High-Low“ edge can be used to latch the 32-bit value since the value will be updated immediately after the „Low-High“ edge.



Pin	Signal	Pin	Signal	Pin	Signal	Pin	Signal
1	Counter value 0	11	Counter value 8	21	Counter value 16	31	Counter value 24
2	Counter value 1	12	Counter value 9	22	Counter value 17	32	Counter value 25
3	Counter value 2	13	Counter value 10	23	Counter value 18	33	Counter value 26
4	Counter value 3	14	Counter value 11	24	Counter value 19	34	Counter value 27
5	Counter value 4	15	Counter value 12	25	Counter value 20	35	Counter value 28
6	Counter value 5	16	Counter value 13	26	Counter value 21	36	Counter value 29
7	Counter value 6	17	Counter value 14	27	Counter value 22	37	Counter value 30
8	Counter value 7	18	Counter value 15	28	Counter value 23	38	Counter value 31
9	Signal ground	19	Signal ground	29	Signal ground	39	Signal ground
10	Signal ground	20	Signal ground	30	Signal ground	40	Signal ground

Annex II Keys and key combinations for editing text boxes

Cursor movement	
Key / key combination	Moves the cursor ...
	... left by one position.
	... right by one position.
	... to the beginning of the line.
	... after the last character of the line.
 + 	... left by one word.
 + 	... right by one word.
 + 	... right by one width of the text box.
 + 	... left by one width of the text box.
	... with multiple-line text boxes down to the next line.
	... with multiple-line text boxes up to the previous line.
 + 	... with multiple-line text boxes before the first character of the text.
 + 	... with multiple-line text boxes to the end of the text.

Line break	
	Inserts a line break in multiple line edit controls.

Highlighting text

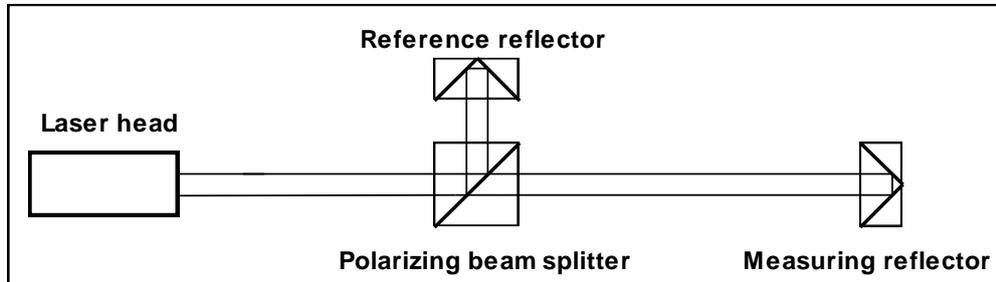
Key / key combination	Highlights ...
 + 	... the character left of the cursor.
 + 	... the character right of the cursor.
 + 	... the text left of the cursor up to the beginning of the line.
 + 	... the text right of the cursor up to the last character of the line.
 +  + 	... the word left of the cursor.
 +  + 	... the word right of the cursor.
 +  + 	... with multiple-line text boxes up to the first character of the text.
 +  + 	... with multiple-line text boxes up to the last character of the text.

Delete text

Key / key combination	Deletes ...
	... the character left of the cursor or any highlighted text.
	... the character right of the cursor or any highlighted text.

Annex III Influence of atmospheric properties and specimen temperature on the measurement result

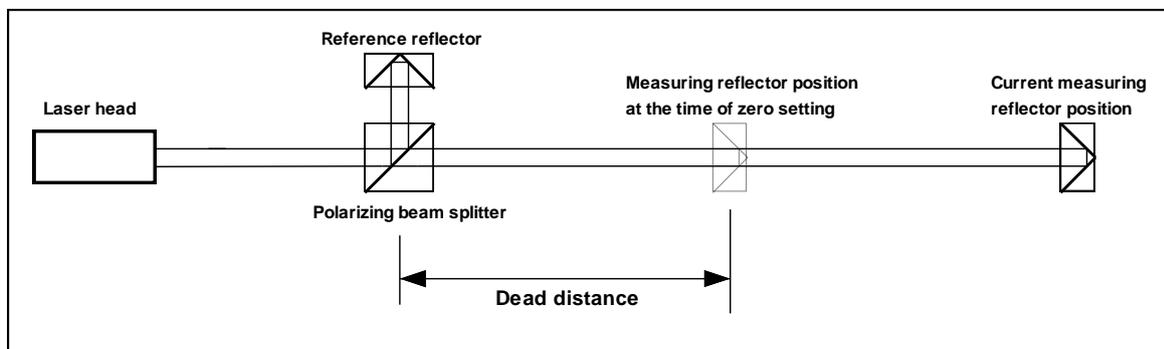
The ZLM 800 Laser Distance Measuring System operates on the interferometer principle after MICHELSON. A polarizing beam splitter divides the laser beam into two legs directing the partial beams onto a reference reflector and a measuring reflector.



The air gap between laser head and polarizing beam splitter has no influence on the measurement result. If the reference reflector is mounted directly to the polarizing beam splitter, the gap between polarizing beam splitter and reference reflector will not cause measuring errors either. Variations of atmospheric properties in the leg between polarizing beam splitter and measuring reflector, however, will produce measuring errors.

The following considerations base on a set-up with the reference reflector being mounted directly onto the polarizing beam splitter.

The ZLM 800 Laser Distance Measuring System is a system taking relative measurements. From the distance between polarizing beam splitter and measuring reflector the system only knows the partial distance between the current position of the measuring reflector and the position of the measuring reflector at the time of zero setting. The remaining distance between the position at the time of zero setting and the polarizing beam splitter is termed "dead distance".



If the atmospheric properties do not vary during a measurement, the dead distance is insignificant. In this case the atmospheric properties have an influence only on the distance between the current position and that of the time of zero setting. In the other case, the entire distance between the current position of the measuring reflector and the polarizing beam splitter must be taken into consideration for the estimation of errors.

From this, two conclusions can be drawn:

- **The polarizing beam splitter should always be arranged as close to the specimen as possible.**
- **The measuring time should be kept as short as possible to exclude larger variations of atmospheric properties.**

Following are the specifications for the accuracy that is required for the measurement and for the entry of atmospheric parameters in the case of manual correction.

Air temperature:

A deviation of the entered temperature from actual temperature of 1 Kelvin results in a measuring error of approximately 1 ppm.

Atmospheric pressure:

A deviation of the entered pressure from actual pressure of 1 hectopascal results in a measuring error of approximately 0.3 ppm.

Relative humidity:

A deviation of the entered relative humidity from actual relative humidity of 1% of the entered value results in a measuring error of approximately 0.013 ppm.

When the atmospheric properties remain constant during the measurement, the measuring errors specified above can be referred to the traverse during the measurement. When the atmospheric properties, however, change during the measurement, then the distance between the two reflectors must be used to estimate the error.

Between the mounting point of the polarizing beam splitter and the mounting point of the measuring reflector a measuring error may be caused by thermal expansion. The software can compensate for these type of errors to a limited extent only due to the diverse possible measuring set-ups and thus varying influence of thermal expansion. Please note:

- **Avoid, if possible, temperature variations of the specimen and of the component that connects the polarizing beam splitter with the measuring reflector** (unless this is the object of the measurement).
- **Keep the distance between polarizing beam splitter and measuring reflector as short as possible.**

When you have activated material temperature correction (either manual or automatic mode), the sum of the specified dead distance and the distance between polarizing beam splitter and measuring reflector is used as the basis for the correction of the measured values. This means, the correction is based on the assumption that both the dead distance and the traverse of the reference reflector are subject to the same linear expansion coefficient.

With manual entry of the temperature value, the relative measuring error results from the product of the linear expansion coefficient and the deviation of the entered value from the actual material temperature.

Example:

With an actual linear expansion coefficient of $11 \cdot 10^{-6} \text{ K}^{-1}$ and a material temperature entered with an error of 1 K the resulting measuring error is $11 \cdot 10^{-6} \text{ K}^{-1} \cdot 1 \text{ K} = 11 \text{ ppm}$.

To avoid any uncertainties regarding material temperature correction, below the equations are specified that are employed by the program for the determination of the measured values.

With the correction of atmospheric properties and the correction of material temperature being activated the measured value is computed with the following equation:

$$x = \frac{\lambda \cdot z}{i \cdot (1 + \alpha \cdot (\vartheta_a - 20^\circ \text{C})) n_a} + \left(\frac{(1 + \alpha \cdot (\vartheta_i - 20^\circ \text{C})) \cdot n_i}{(1 + \alpha \cdot (\vartheta_a - 20^\circ \text{C})) \cdot n_a} - 1 \right) \cdot t ,$$

where

- x - measured value,
- z - counter value (from ZLM 800 data acquisition board),
- t - dead distance,
- i - interpolation factor (128 with corner cube reflector and 256 with plane mirror reflector),
- λ - laser wavelength in vacuum,
- α - linear expansion coefficient,
- ϑ_a - current material temperature,
- ϑ_i - material temperature at the time of zero setting,
- n_a - current refractive index of atmosphere, and
- n_i - refractive index of atmosphere at the time of zero setting.

When only material temperature correction is activated, the equation is

$$x = \frac{\lambda \cdot z}{i \cdot (1 + \alpha \cdot (\vartheta_a - 20^\circ \text{C})) n_n} + \left(\frac{1 + \alpha \cdot (\vartheta_i - 20^\circ \text{C})}{1 + \alpha \cdot (\vartheta_a - 20^\circ \text{C})} - 1 \right) \cdot t ,$$

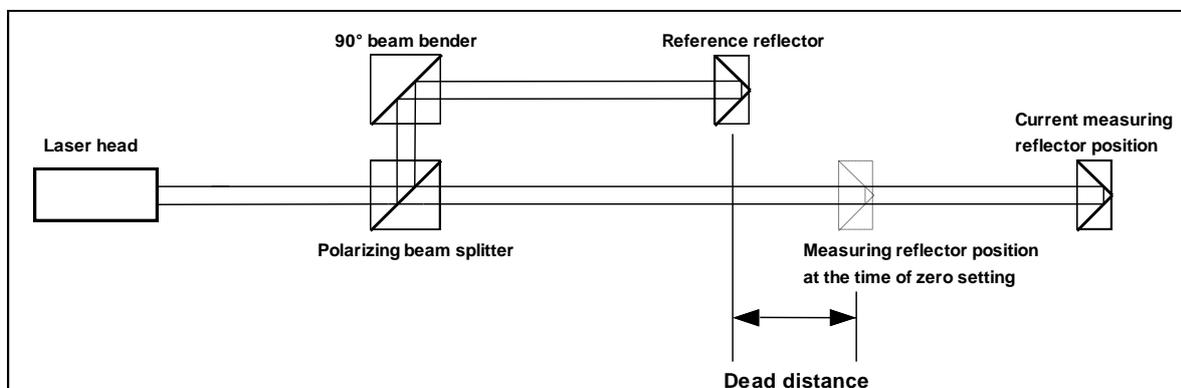
where

- n_n - refractive index of normal atmosphere.

When only the correction of atmospheric properties is activated, the equation is

$$x = \frac{\lambda \cdot z}{i \cdot n_a} + \left(\frac{n_i}{n_a} - 1 \right) \cdot t .$$

If it is impossible to arrange the polarizing beam splitter very close to the specimen, you can also employ a 90° beam bender and mount the smaller and lighter reference reflector near the specimen.



In this way, the dead distance can be reduced considerably.