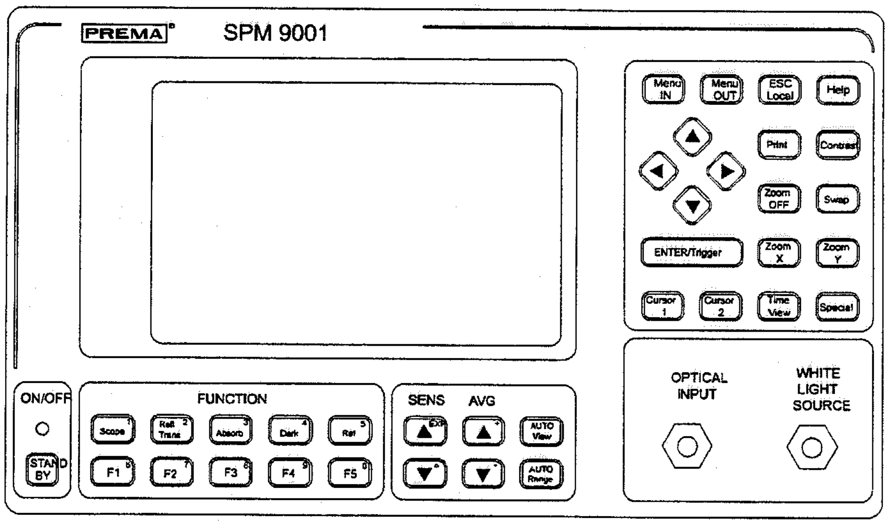
SPM 9001

Spectrometer with Visual Instrumentation®



SPM 9001

Preliminary User's Manual

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1 Introduction

The SMP 9001 belongs to a new generation of measuring instruments. Optical measurements, which were formerly time-consuming and possible only with expensive instruments, are now easily and quickly possible. As table-top instrument the SPM 9001 is easy and simple to use. The signal to be measured is connected via a flexible light waveguide cable to a SMA plug connector on the front panel. The extensive software provided with the instrument permits numerous kinds of measurements and applications. This manual has been written to help you to make best use of the SPM 9001 for your particular purposes.

1.1 Features and Applications

The spectrometer can be used, on the one hand, for general purpose spectral analysis. A spectrum can be measured with a resolution of 256 points (3.3 nm) in the wavelength range from 300 nm to approx. 1000 nm. The internal light source and the glass fiber input connector make the instrument immediately ready for operation. On the other hand, the extensive software also make the instrument usable as a layer thickness measuring device or a color recognition system, and it can be used for process control without requiring an additional PC.

Applications:

- Transmission / reflection measurements on surface coating, colorations, glasses, optical filters
- Color measurements on plastics, paints, lacquers, in the printing industry, ceramics and glass, in the textile industry, foodstuffs and cosmetics
- Emission spectroscopy, e.g. plasma etching, testing of optical components, welding flame monitoring, metal melts, lamp production
- Concentration analysis (gases and liquids)
- Layer thickness measurement of transparent layers in the range from 300 nm to 20 µm, e.g. photo-resist on semiconductor wafers

1.2 The structure of the SPM 9001

The extensive software of the SPM 9001 is sectioned into several modules for clear overview of the functionality.

The individual modules are:

General applications
Measurement of emission, reflection, transmission and absorption spectra.

Color applications
Assignment of color dimension numbers to a color spectrum

Layer thickness measurement
Determination of the thickness of thin (300nm to 20 μm) transparent layers

Process application
Setting the parameters required for a process control system

Remote control
Remote control of the spectrometer from a computer; operation in an equipment system

Photo archive
Loading of stored measured curves

Utility programs
For resetting and loading project/factory data

System configuration
Setting printer parameters, switch-on and switch-off of the loudspeaker, setting the date and time

German/English
Switching over from German to English language dialog

1.3 Important safety instructions

Please read the user manual

It is possible to work with the instrument in the proper intended manner only after reading attentively and understanding all instructions, warnings and explanations given in this manual. This is true in particular with regard to the safety instructions.

If you do not understand something in this manual or find that some of the instructions, procedures and safety regulations are unclear, please get in touch with PREMA before commencing operation of the instrument.

This manual has been written and organized such that after you have read it you will understand the instruments and will be able to use them properly in the intended manner. This manual contains important instructions for safe, correct and economical operation of the instruments.
Only by observing these instructions can dangers be avoided, repair costs and failure times reduced and the service life of the instruments increased. The user manual must always be available at the place where the instruments are operated.
Improper operator control and/or failure to observe the instruction in this manual can endanger persons (also third parties) or lead to material damage.

The personnel commissioned to operate the instruments must have read this user manual attentively and must be familiar with all safety instructions contained therein. In addition to this user manual, the general regulations for the prevention of accidents at the place of operation and the technically relevant rules for safety and proper working procedure apply too.

Further safety instructions

Safety instructions are contained in the chapter headed "Commissioning". The warning instructions and symbolic rules of behavior attached to the instrument and the instructions for recognizing specific sources of danger, are explained in that chapter.
It is essential to observe and comply with all safety instructions.

Forseeability of hazards

The manufacturer cannot anticipate all possible sources of danger.
If a working process is not carried out in the recommended manner, the operator himself must ensure that this entails no danger for himself or other persons.
He should also make sure that the method he has chosen for operating the instrument will not damage or endanger it.
This user manual is not a service and repair manual. When repairs are necessary, the instrument should be sent-in to the manufacturer for factory repair.

Proprietary rights

Declaration of conformity

PREMA has issued an EC declaration of conformity for this instrument. This declaration certifies that this instrument complies with all applicable requirements of the EC directives.

Proper utilization as intended

These instruments have been built according to the approved technical safety regulations. Nevertheless, if they are not used in the proper intended manner, danger for body and life of the user or third persons and/or damage to the instruments and other material damage can result.
The instrument may therefore be used only in technically perfect condition in the proper intended manner with due attention to safety and awareness of possible hazards, observing the instructions contained in the user manual and the regulations for the prevention of accidents. The instrument may be used only for the purposes and tasks described in this user manual.

All faults of the instruments which impair the safety of the user or third persons must be remedied immediately.
PREMA cannot accept any liability for damage arising from improper utilization of this instrument for which the user alone must carry the risk.

Availability of the user manual

The user manual must always be available at the operating place of the instruments. The personnel commissioned with operating the instruments must be familiar with all task sequences and all safety instructions described in the user manual.
No modifications, attachments or conversions may be carried out on the instruments without approval by PREMA, otherwise the certification of conformity becomes void.

2 Commissioning

2.1 Delivery

Every PREMA instrument is carefully and thoroughly checked for perfect condition and compliance with all technical specifications before it is released for shipping Therefore the instrument should be in perfect mechanical and electrical condition on arrival.

To exclude transport damage, the instrument should be checked immediately after arrival. In the case of any complaints,, write a damage report together with the person delivering the instrument.

Please check the following list to make sure that everything is complete:

☞
1. Mains cable
2. Manual, English
3. Calibration certificate with date and signatures
4. Product registration card; please fill out and return to PREMA
5. Any options and accessories you have ordered

Please also check that the instrument is set for the correct mains input voltage and fitted with the corresponding mains fuse (see under "2.2 Connecting the instrument to the mains").

Important: Please do not discard the packaging material!
In the case of return to the factory for recalibration or repair, ship the instrument in the original packaging material which gives adequate protection against damage.

2.2 Safety instructions

Please read the safety instructions in the chapter headed „Introduction“.

These instruments may be operated only when they are in perfect condition. The regulations for the prevention of accidents and environmental protection must thereby be observed (VBG 4 = Regulations of the trade guilds for the prevention of accidents).
All switch-on and switch-off operations described below must be observed and carried out exactly as described.
Defects such as loose connections, damaged or singed cables, oxidized contacts and blows fuses must be repaired immediately by trained persons.
Provision must be made for safe and environmentally compatible disposal of consumable materials and replaced parts.
Use only original replacement parts, otherwise the manufacturer's warranty and the conformity certification of the instruments will become void.
Modifications producing functional changes must be carried out by the manufacturer, or by the customer only after approval and authorization have been given by the manufacturer.

Possible applications

These instruments may be used exclusively for the measuring functions specified in the "Technical data" section.

2.3 Accident prevention

When operating this measuring instrument it is essential to observe the general precautions for preventing accidents related to measuring instruments.

2.4 Connecting the instrument to the mains

This PREMA measuring instrument is intended for power supply from the AC mains and expects a mains frequency of 50 Hz or 60 Hz.
A DIN connector for cold equipment is provided for making the mains input connection on the rear of the instrument. This connector has a safety grounding contact.

Before connecting the instrument to the mains, make quite sure that it is set to the correct voltage as specified on the nameplate and insert a corresponding fuse cartridge.

The mains frequency is recognized and automatically accepted by the instrument in the range from 47 Hz to 63 Hz.

The input voltage selector switch is combined with the mains fuse and located in the left part of the cold equipment connector. The present voltage setting is visible; 220 V stands for any voltage in the range from 220 V to 240 V and 110 V for any voltage in the range from 100 V to 120 V.
Proceed as follows to change over between 220 V and 110 V main input voltage.

☞
1. Disconnect the mains input plug.
2. The mains fuseholder is located between the mains input connector and the voltage selector. For 110 V input voltage fit a 110V/0.4A slow-blow fuse. The corresponding rating for 220V is 220V/0.2A. To remove the fuse cartridge, prise it out with a slot-blade screwdriver.
4. Insert the correct fuse cartridge into the holder and then push the holder back in.
5. Use a slot-blade screwdriver to turn the voltage selector to the required position such that the white arrow above it points to the wanted mains voltage. The associations are:

Setting	**Accepted mains input voltage range**
110 V	90 V_{rms} to 130 V_{rms}
220 V	180 V_{rms} to 265 V_{rms}

Table: Mains input voltage range

2.5 Grounding

To protect the user. the case of the instrument is grounded when the mains cable is connected to a power outlet with grounding contact.
The case is electrically isolated from the measuring circuit sockets and from the interfaces.

An additional grounded chassis terminal marked with the symbol

is provided on the rear of the instrument.

2.6 Warranty

PREMA guarantees proper functioning of the instrument for the duration of two years after delivery.
Any repairs which become necessary during this period will be carried out without charge.
The **Hard Disk and the LCD screen** are excluded from the two-year warranty period. PREMA gives warranty for half a year on these items.

Damage caused by improper usage of the instrument or by overshooting the specified limiting data is not covered by warranty.
We also point out that all liability for consequential damage (e.g. data loss) is ruled out.

2.7 Switch-on

The spectrometer is switched-on as soon as the mains cable is connected. The instrument then requires approximately 40 seconds to reach the normal operating state. The display screen is blank during this time.
Press the STANDBY KEY TO SWITCH THE INSTRUMENT OFF.
The transformer remains connected to the mains voltage. The 9001 is now in standby mode. The red LED at the bottom left on the front panel is lit. The analog circuitry is provided with power supply voltage in standby mode so that no warm-up time has to elapse before operation can be resumed after switching from standby to normal operating mode.
Otherwise it is necessary to let the instrument warm-up for 1 hour.

Note: Switching-off the instrument with the STANDBY KEY does not discon nect the power transformer from the mains voltage.
Never disconnect the mains plug during running operation. Always first press the STANDBY KEY !

2.8 Connecting the light waveguide cable

Two SMA connectors marked *Optical Input* and *White Light Source* are located on the front of the SPM 9001. The *White Light Source* input can be used to couple the light from the internal halogen lamp (electric power rating 2W) into a light waveguide fiber.
The optical input connects the internal light waveguide fiber leading to the optical module, to the external light waveguide fiber which brings the light which is to be measured to the instrument. The diameter of the internal fiber is 0.5 mm. When connecting light waveguide fibers to the instrument, always make sure that they are not subjected to unnecessary tension or bending forces. Do not undershoot the minimum bending radius specified by the manufacturer of the light waveguide fiber.
Various types of light waveguide fibers are available as accessories.

2.9 Rack mounting

A 3 height units equipment rack mounting adapter is available for the SPM 9001.
The instrument has a width of half 19 inch and can be combined with another half 19 inch device. Further details for rack mounting are given in Appendix A, Accessories.

When mounting the instrument in a 19 inch cabinet, make sure that the ventilation openings on the rear are not covered. Also provide an EMERGENCY SHUTDOWN switch in the vicinity of the instrument for switching off the power supply voltage in the case of danger.

3 The measuring principle

This section describes the measuring principle on which the SPM 9001 is based. The emphasis is on familiarising you with the optical components and to explain their basic functioning. The exact technical data differ according to the version of the spectrometer and are described in the chapter on technical data.

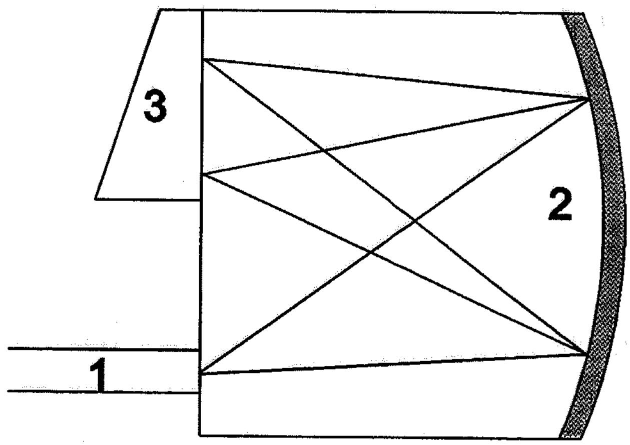


Fig. 3-1 Schematic depiction of the utilised optical module

3.1 The measuring principle

A measuring process can be considered in three parts:

1. The light which is to be examined is split into its spectral components.
2. The intensity of the light is converted by the row of diodes into electric signals.
3. The analog electric signals are converted to digital signals by an A/D converter and displayed on the LCD screen (depending on the measuring mode, after further processing by the internal processor).

3.2 The optical module

The optical system of the spectrometer is shown schematically in the bottom diagram and chiefly consists of three elements:
The light waveguide (1), the self-focusing grating (2) and the row of diodes (3).

The light which is to be examined is coupled into the light waveguide. A fibre optic cross-section converter (not illustrated) provides optimum illumination of the grating.

The grating separates the coupled-in light into its spectral components. A row of diodes (consisting of 256, 512 or 1024 silicon diodes, depending on the version of the instrument) is used to analyse the spectrum. the grating is designed such that the spectrum is focused onto the row of diodes. This avoids the need for further optical components such as lenses.
The individual components are permanently connected together. In comparison with a conventional spectrometer this has the advantage that the sensitive optical components are well-protected against dust and other ambient influences. Another advantage is that incorrect adjustment is virtually impossible.

3.3 The resolution of the spectrometer

The spectral resolution of the spectrometer is determined by the number of diodes in the row and the spectral resolution range of the grating.

In the standard module the spectral range extends from 300 to 1140 nm. With 256 diodes this gives a pixel resolution of approx. 3 nm, i.e. the measuring points lie at intervals of 3 nm.
At least 3 pixels are required to resolve two adjacent spectral lines, so the effective resolution of the instrument (according to Rayleigh) is about 10 nm.
The wavelength accuracy, that is the precision with which the absolute spectral position λ can be determined, is considerably greater and has the order of magnitude 0.3 nm.

3.4 The row of diodes

The photosensitive element of the module is a row of diodes consisting of a line of adjacent silicon diodes. A capacitor is connected in parallel with the inversely biased diodes. The capacitor is discharged to an extent proportional to the incident light. The time-integral of the charging current is proportional to the incident light intensity. The individual diodes are sensed successively via a common line using a multiplexed procedure. The charging process is set running with a start pulse. The time interval between the individual start pulses determines the integration time and thus the sensitivity of the system.

4 General operating instructions

4.1 Settings in the main menu

The Spectrometer 9001 has several independently operating modules which have been adapted for various applications and can be selected in the main menu of the instrument (see illustration of the main menu of the SPM 9001).

Five different modules are available to the user for recording spectra; they differ with respect to *general applications, colour applications, layer thickness measurements, process applications and process layer thickness measurements.*
The other modules are provided for changing instrument parameters and administering stored images.
The individual options of the main menu hereby have the following functions:

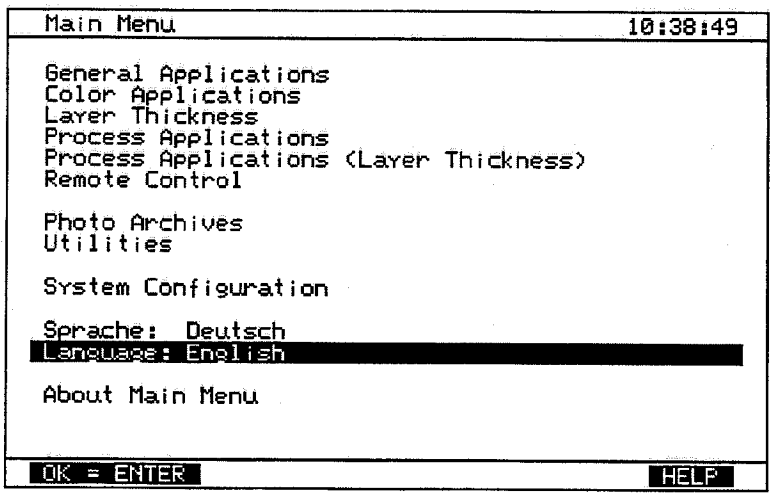


Fig. 4-1 Main menu of the spectrometer

General applications

General optical measurements such as emission, absorption, reflection and transmission measurements can be carried out with this module. This module is also called-up for making a dark current compensation or measuring a reference spectrum.

Colour application

This module is required for recording colour spectra. It provides the facilities for reading colour values in various coordinate systems directly on the display screen.

Layer thickness measurements

The module for layer thickness measurements permits determination of the thickness of transparent layers. The basis of this procedure is the recording of a white light interference spectrum. The interference spectrum and the Fourier component which corresponds to the thickness are shown one below the other on the display screen. The layer thickness can be read directly on the display screen.

Process applications

The trigger output can here be event-controlled, i.e. different conditions for producing the trigger signal can be set by the user. The intensities of two wavelengths are measured and can be used for process control.

Remote control

The remote control module permits setting of the Baud rate for a data link between the SPM 9001 and a PC.

Photo archive

Under the menu option **photo archive** you can recall and print the display screen contents which you have previously saved.

Utility programs

The **utility programs** provide you with some useful tools such as software updating from your PC.

System configuration

The date, time, loudspeaker and printer can be configured in the **system configuration**.

Language

The language setting of the SPM 9001 is selected here. Move the cursor onto this option and then press the ENTER KEY.

Information in the main menu

This menu option shows you information concerning the version number and date of the firmware of your SPM 9001.

4.2 Manual control elements of the spectrometer

The user-friendly design of the front panel permits quick and efficient working with this instrument. The keyboard gives direct access to important functions of the instrument such as function settings and contrast adjustment of the liquid crystal display (LCD), and complex settings can be made easily with the cursor and menu control system.

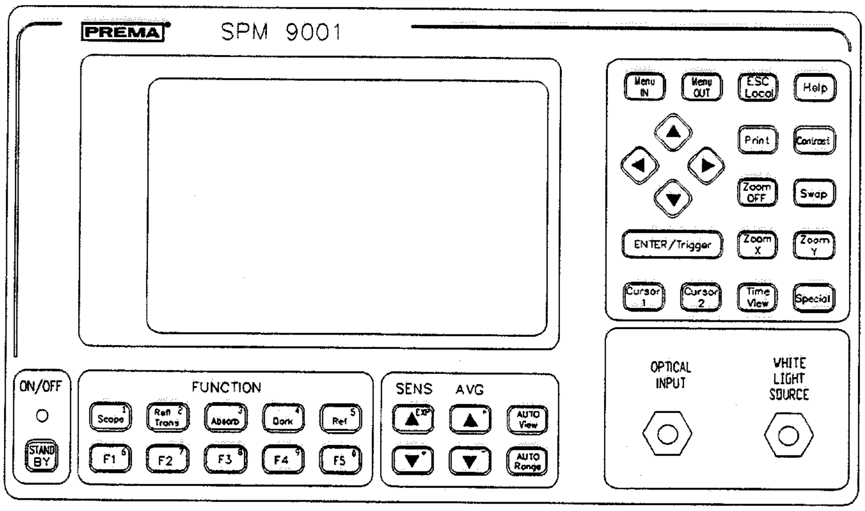


Fig. 4-2 Front view of the SPM 9001

The following functions are assigned to the individual keys:

STANDBY: Switches the processor section of the instrument on and off. The electronic circuits are still provided with the power supply voltages in standby status so that the instrument is sooner ready for operation with full accuracy after switching-on again.

Function, range and measuring time key block

In addition to the normal functions assigned to them, a second function is also assigned to these keys according to their blue legend. The second function is activated when entry of numerical values is required, for example wavelengths. The individual keys have the following functions:

Key	Key function
SCOPE	The absolute radiation power with dark current subtracted is displayed in the "general applications" menu.
REFL/ TRANS	The reflection or transmission is measured in the "general applications" menu, with dark current subtracted, relative to a reference.
ABSORB	The absorption is displayed in the "general applications" menu.
DARK	Measurement of the dark current.
REF	The reference spectrum is determined in the menu "general applications" and "Layer thickness measurement"". The reference colour is determined for colour difference measurements according to CIELAB.
F1	Switches-on the internal halogen lamp. In colour applications: XYZ values
F2	Triggering ON / OFF In colour applications: xy values
F3	General measurements: Saves the spectrum to the hard disk. In colour applications: uv values
F4	General measurements: Loads the spectrum from hard disk. In colour applications: Lab/Ch values
F5	In colour applications: Luv/ChS values
SENS	Adjusts the sensitivity
AVG	Sets the number of averaged readings
AUTO VIEW	Zooms to optimum range
AUTO RANGE	Sets optimum sensitivity

MENU IN	Menu selection
MENU OUT	Go one menu higher or quit menu
ESC LOCAL	Takes over former value when entering values
HELP	Help key
PRINT	Makes a display screen hard copy when a printer is connected
CONTRAST	Adjusts the contrast of the display screen
ZOOM OFF	Switches-off all zoom factors (Auto View, Zoom X , Zoom Y)
SWAP	Several spectra are displayed simultaneously in the "general applications" menu.
ZOOM X / Y	Zooms in X or Y direction by a factor of 2 around the preselected cursor position
CURSOR 1 / 2	Selects the active cursor; the active cursor appears at the bottom right in the display.
TIME VIEW	The wavelength selected with the active cursor can be displayed as a function of time.
SPECIAL	„General applications“: Starts periodic measurements „Colour applications“: White compensation „Save spectrum menu“ and „Photo module“: Deletes the selected file

4.3 Online help system

The context-related online help system of this instrument provides you with comprehensive information and assistance for the currently active function.

To call the help system. press the HELP KEY in the cursor field. To read help for the help system, press the HELP KEY again.

Operating the help system

Within the help pages you can scroll up or down with the ⇧ and the ⇩ KEY. The line in which the pointer is currently located is indicated with a fat arrow in the first column before the help texts.

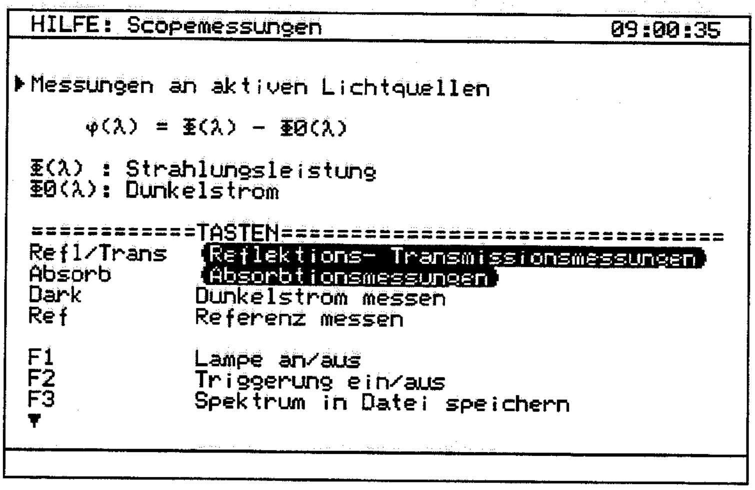


Fig. 4-3 Help menu

If the help item you have requested extends over more than one page of text, this is indicated with an arrow at the left bottom or left top edge of the display screen.
The next help page appears automatically when you move the pointer further down.
Move the pointer up again if you wish to see the previous page again.

Cross-references in the help system

Cross-references and keywords pointing to referenced further help topics are displayed inverse. To go to a referenced page, put the help line pointer in the referencing line and then press the ENTER KEY.
Up to 5 help topics can be nested in this manner. To go back to the previous help topic, press the ESC KEY (Backtrace) for one step back at a time.

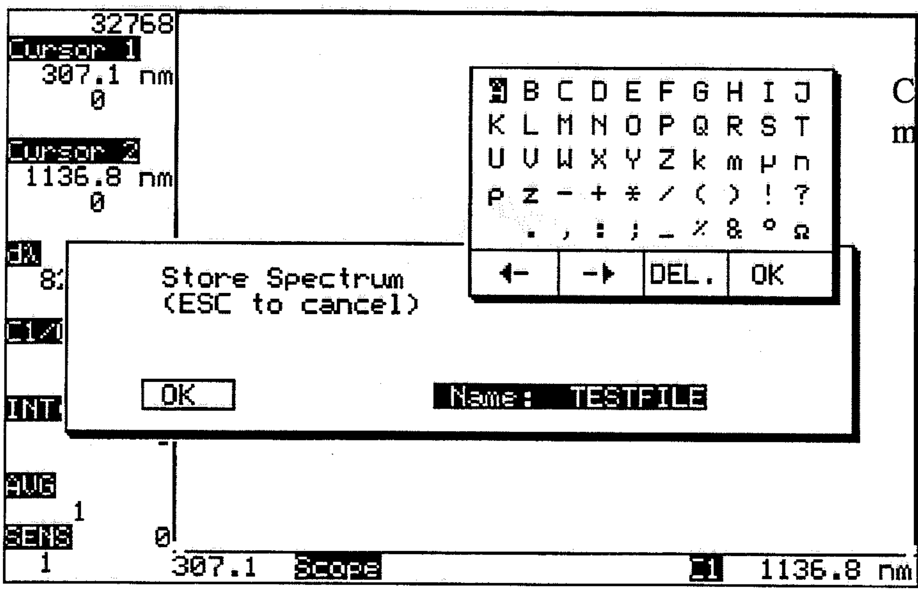
Exit from the help system

Immediate exit from the help system takes place on pressing the MENU OUT KEY and the ESC KEY. The instrument returns to the display/function from which you called for help.

4.4 Using the setting menus

Entering numbers and alphanumeric characters

The Spectrometer 9001 permits entry of numbers as well as alphanumeric characters which are displayed as entered in a corresponding window called the character matrix (see illustration below). This function lets you assign names to certain instrument settings or note fields so that they can later be associated in a very simple manner.



Character matrix

Fig. 4-4 Entry field for alphanumeric character input (here saving a measured spectrum)

General instructions for character input

Use the CURSOR KEYS to move around in the character matrix . However, you **cannot** move with the CURSOR KEYS into the field for name entry and you cannot delete any characters. For this purpose use the arrows and the DEL field of the character matrix, by going to the corresponding field and then pressing the ENTER KEY.
The currently active field or also the character is displayed inverse in the character matrix.

Proceed in detail as follows:

☞ 1. Go with the cursor to the desired field for the name entry.

2. Press the ENTER KEY. This makes the character matrix appear. Now move around in this matrix with the ordinary CURSOR KEYS of the manual control keyboard.

3. Go to the desired characters and confirm each individual entry by pressing the ENTER KEY.

4. To confirm the entire name entry, go to the OK field and confirm there too by pressing the ENTER KEY.

Switches and buttons within the setting menus

Apart from the alphanumeric entries, it is also necessary to configure certain switches within the setting menus. The following switches are available for this purpose:

Radio button:

Round switch symbols for setting certain functions and conditions in the menus. When the switch symbol is filled the corresponding function is active. The function is inactive when the switch symbol is empty. If several radio buttons are present, only one at a time can be active.

Check button:

Rectangular switch symbols for selecting functions. Several of these can be active at the same time.

Acknowledge button:

Rectangular switch symbol filled with text, e.g. "OK" or "Load", etc. These buttons start the inscribed function immediately on pressing the ENTER KEY.

4.5 Capturing, administering and printing the display screen contents

Capturing and printing the display screen contents

The Spectrometer 9001 has the ability to capture the current display screen contents

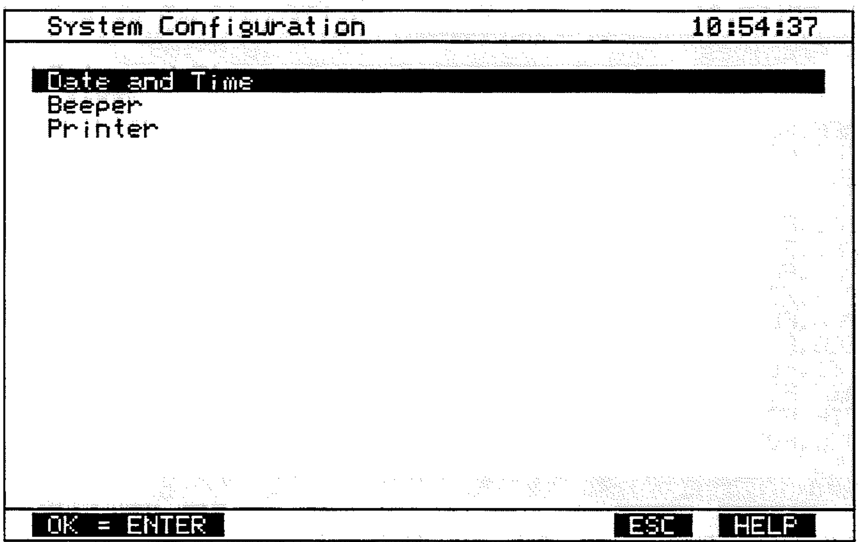


Fig. 4-5 The display screen contents under the menu option system configurations

with the PRINT KEY. In the print menu window which opens on pressing the PRINT KEY, you can then print-out these contents directly as hardcopy, or you can save them under an assigned name for printing later. The menu also shows which printer driver is active. You can change this setting in the main menu under the system configuration option.

Photo archive

The functions for administration of captured images are in the main menu under the menu item "photo archive". Here you can get a list of the names of the captured images. Go to the desired image with the cursor and then press the ENTER KEY to select it.

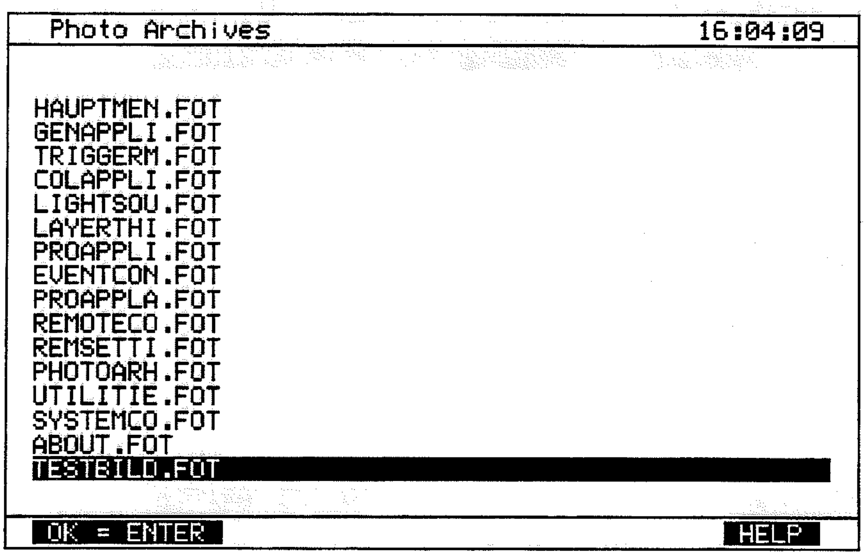


Fig. 4-6 A list of saved images

To print the image, press the PRINT KEY and press the ENTER KEY to confirm the "printing" key.

To delete individual images, select the image to be deleted with the cursor keys and then press the SPECIAL KEY.

4.6 Utility programs

Download

This menu lets you make a software update of your instrument. For this purpose you require the following items:

• a PC with RS232 interface, a 3.5" diskette drive and DOS as operating system
• a RS232 data transmission cable (null modem), see under accessories
• the update diskette

Please follow the instructions and the description provided with the diskette.

Reset

Resetting the individual modules brings them into a well-defined initial state.

Note: This cancels all saved states of the instrument!

Reset to factory setting

This menu sets all modules back to a well-defined initial state which is the status as delivered. This means that:

Note:

All measurement sequences are deleted!
All instrument settings are cancelled!
All images in the photo archive are deleted!
This process takes about two minutes!

5 General applications

This chapter describes how to make optical measurements under the menu option "General applications".

5.1 Measurements under the setting Scope

(SCOPE KEY)
In the scope setting the spectral intensity is plotted against the wavelength. The display screen shows the following information items in addition to the spectrum:

- Intensity and wavelength of the spectrum at the active cursor position
- The spectral separation between the two cursors 1 and 2 ($d\lambda$)
- The ratio of the intensities at the cursor positions 1 and 2 (C_1/C_2)
- The area under the curve between the cursor positions 1 and 2 ($INT(C_1,C_2)$)
- The number of averaged readings for each measurement (AVG)
- The sensitivity (SEN)

An asterisk under the x-axis indicates whether the instrument is in continuous operation and which one of the two cursors is currently active.

The light intensity at the diode is displayed, with dark current subtracted:

$$\Phi(\lambda) = \Phi_{raw}(\lambda) - \Phi_{dark}(\lambda)$$

$\Phi(\lambda)$: Light intensity
$\Phi_{raw}(\lambda)$: Light intensity before dark current correction
$\Phi_{dark}(\lambda)$: Dark current

5.2 Reflection/transmission measurements

(Key Refl/Trans)

The fraction of reflected or transmitted light is here displayed relative to a reference spectrum.

Spectral pure transmission factor::

$$\tau(\lambda) = \frac{\Phi_a(\lambda) - \Phi_{dark}(\lambda)}{\Phi_e(\lambda) - \Phi_{dark}(\lambda)}$$

$\Phi_a(\lambda)$: outcoming/reflected light intensity (measured spectrum)
$\Phi_e(\lambda)$: incoming/incident light intensity (reference spectrum)
$\Phi_{dark}(\lambda)$: dark current

Transmission and reflection are calculated by the same methods, so they can be measured under the same measuring menu.

5.3 Absorption

(KEY ABSORB)

In this application the absorbed component of the light is displayed. The absorption factor or the extinction can be displayed for this purpose.

Spectral pure absorption factor:

$$\alpha(\lambda) = 1 - \tau(\lambda)$$

Extinction, decimal logarithmic measure of spectral absorption:

$$E(\lambda) = -\lg \tau(\lambda)$$

5.4 Functions of the keys

SCOPE	Switchover to Scope mode
REFL/TRANS	Switchover to Transmission/Reflection measuring mode
ABSORB	Switchover to absorption mode
DARK	Measuring the dark current data
REF	Measuring a spectrum for comparison (reference). A new measurement is made immediately after recording the reference spectrum and the result is shown on the display screen.
SENS	Sensitivity from 1 to 256
AVG	Number of averaged readings
AUTO VIEW	Optimum graphic zoom
AUTO RANGE	Optimum sensitivity setting
F1	Switches the internal halogen lamp on and off (can also be done in the menu)
F2	Switchover between continuous/individual measurements (can also be done with the menu option "trigger settings".
F3	Saves a spectrum in ASCII format. The corresponding dark current and reference spectrum are saved in each case too.
F4	Loads a saved spectrum. Caution: The dark cur-

rent and reference data belonging to the loaded spectrum are loaded too, so that the present dark current and reference data are lost.

SPECIAL — Starts a periodic measurement. The parameters for the periodic measurement are set in the menu under the menu option "Periodic measurements".

SWAP — Switches over between normal and multiple spectrum display (up to 100 spectra recorded in periodic measuring mode can be displayed in 2D (superimposed) or in 3D (isometric) representation).

5.5 The menu "General applications"

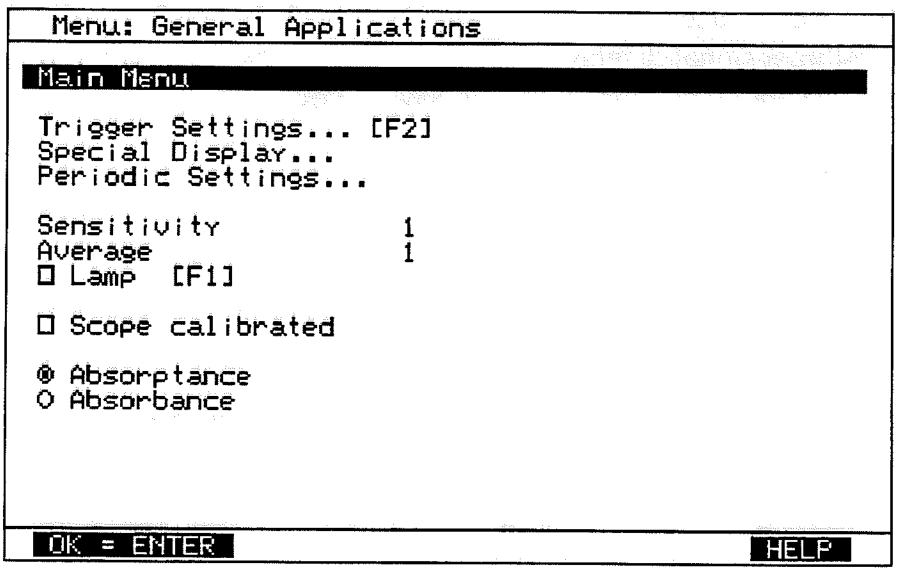


Fig. 5-1 Screen printout: General applications menu

Main menu
Switchover to the main menu

Trigger settings
The various trigger possibilities can be set under this menu option.

Trigger On/Off
Here you can choose between manual measuring mode (trigger on) and automatic measuring mode (continuous operation, trigger off).

Trigger key
The ENTER/TRIGGER KEY functions as triggering device.

Trigger socket
The trigger socket (on the rear panel) can also be used for triggering. All 4 channels must be LOW to produce a trigger. See under "Technical Data" for the pin assignments.

Special display

Provided for setting the SWAP display for periodic measurements.
Either one data set or several data sets simultaneously can be displayed.
2D superimposes the curve traces.
3D produces a three-dimensional display.
Switchover between 2D and 3D is done with the SWAP key.

Periodic measurements

Number of measurements (1..100)
Determines the number of curve traces to be stored.

Period for measurements (max 4000 s)
Determines the time separation of the start instants of successive measurements.

Sensitivity

The individual pixels of the row of diodes are capacitors which are discharged by the incident light. The time integral over the discharge current is proportional to the incident light intensity. The sensitivity setting adjusts the integrations time.
The greatest possible sensitivity should always be chosen for optimum drive of the spectrometer. Bear in mind that after every change of the sensitivity setting a new dark current compensation should be made and a new reference spectrum should be measured.
The sensitivity setting can also be changed with the SENS KEYS.

Number of averaged values

Several measurement readings can be averaged to improve the signal/noise ratio. Settings are possible for averaging up to 128 readings. The number of averaged readings can also be changed with the AVG KEY.

Lamp

Switches the internal halogen lamp on and off. The lamp can also be switched on and off by pressing the F1 key.

Scope calibrated

In this mode a spectrally corrected spectrum is displayed on the screen.
The displayed spectrum is thereby corrected with the calibration coefficient. Calibration coefficients can be loaded into the instrument from a PC via the RS232 data communication interface. The provided calibration coefficients have been chosen such that spectral correction is made as from the glass fibre input of the spectrometer.

Absorption/Extinction

Selection can be made here whether the absorption coefficient or the extinction is displayed in absorption measuring mode.

5.6 Time view display mode

Switchover is possible between time view and wavelength depiction by pressing the key TIME VIEW . In time view the change of light intensities with time is recorded for two wavelengths onto which the cursors have been set.
Note: To display the "General applications" menu it is first necessary to switch back to wavelength display (by pressing the TIME key).

5.7 Loading and saving a spectrum

A spectrum data set can be saved as ASCII file in the spectrometer by pressing the KEY F3 and loaded again later by pressing the KEY F4. The dark current data and the data of the reference spectrum file are saved together with the current spectrum data. When a saved set of data is loaded again later, the associated dark current and reference data are loaded too (**Caution**: The existing dark current and reference data are lost after loading a formerly saved set of data with the F4 KEY).

5.8 Example: Measuring the transmission factor of an optical filter

This section describes a simple example of a transmission measurement.
The following graphic shows the measuring set-up:

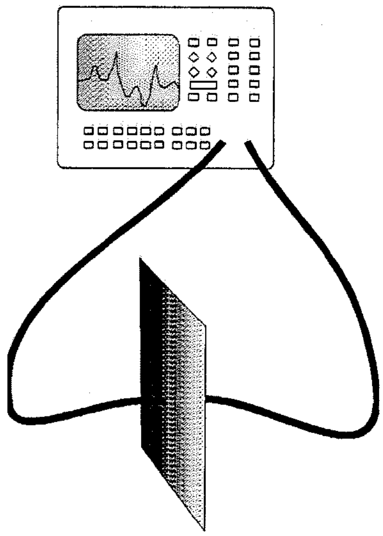


Fig. 5-2 Transmission measurement for an optical filter

Light waveguide 1 is connected to the output of the internal light source (white light source). Light waveguide 2 is connected to the optical input of the spectrometer. The following steps must be carried out to make the measurement:

I. Finding the suitable measuring range
   A. Remove the filter out of the light path
   B. Press the F1 key to switch-on the lamp
   C. Press the auto-range key. The spectrometer then automatically finds the right measuring range.

II. Measuring the dark current
   A. Darken the light waveguide
   B. Press the DARK KEY to save the dark current signal

III. Recording the reference spectrum
   A. Press the F1 KEY to switch-on the internal light source
   B. Switch over to the REFL/TRANS measuring mode
   C. Measure the reference spectrum

Note: A straight line should now be seen in the centre of the display screen. There may be some slight noise on this line at the edges due to the lower sensitivity of the silicon diodes at very short and very long wavelengths. The signal/noise ratio can be improved by averaging (can be set with the AVG KEY*).*

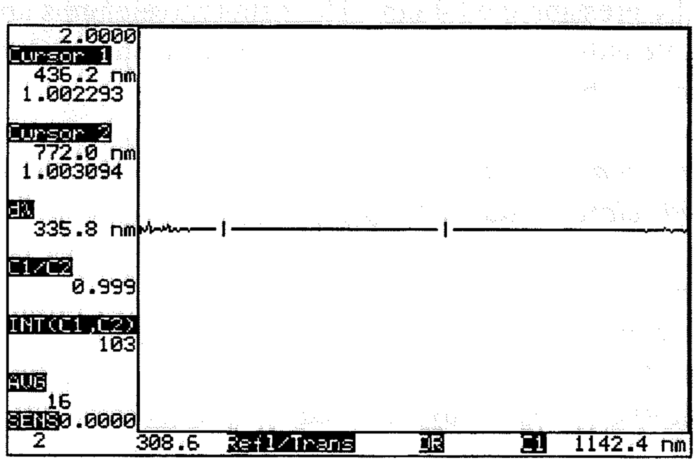


Fig. 5-3 Recording a reference spectrum

IV. Making the measurement
- A. Place the filter in the light path
- B. Start a single measurement by pressing the ENTER/TRIGGER KEY or press the F2 KEY to switch over to continuous measurements.

V. Reading data points on the screen
- A. The wavelengths and intensities at the cursor positions are displayed at the left on the screen. Initially the two cursors are at the left and right edges of the screen. The currently active cursor can be moved by one data point at a time (approx. 3.3 nm) to the left or right with the cursor

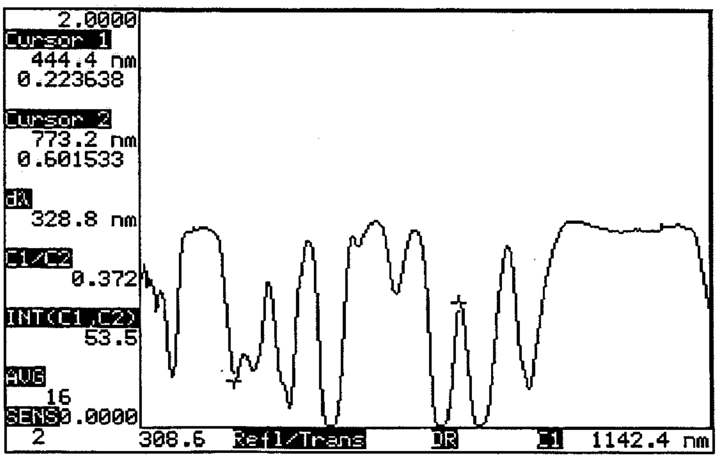


Fig. 5-4 Transmission measurement for a BG20 -Filter (™Schott)

keys ⇨⇦ .

VI. Saving the data in ASCII format

A. The data can be saved as two-column data set in ASCII format by pressing the F3 KEY. The time at which the measurement was made and the present reference and dark current spectrum are stored together with the measured spectrum data. The saved data can be loaded again at any later time by pressing the F4 key. The data (wavelengths and corresponding intensity values) can also be transferred to a PC via the serial data communication interface.
CAUTION: When a saved spectrum is loaded again, the corresponding dark current and reference data are loaded too so that the existing dark current and reference data are lost.

VII. Printing the screen contents

A. The screen contents can be printed directly on a connected printer by pressing the PRINT KEY. Alternatively, the screen contents can be saved as pixel file and re-loaded to the screen or printed later.

6 Colour applications

Colour measurements can be made in the colour applications module. The colour measure numbers are calculated by the SPM 9001 for each spectrum and output simultaneously to the display screen.

6.1 The display screen contents

The spectrum (intensity as a function of wavelength) is plotted on the display screen for the wavelength range from 380 to 780 nm. The colour values are shown to the left of the spectrum. Their meaning is described in Section 7.3.

6.2 The function assignments of the keys

F1	X Y Z
F2	x y
F3	u' v'
F4	L* a* b*
F5	L* u* v*
DARK	Measuring the dark current data
REF	Measuring the reference colour for colour difference measurements according to LAB
SENS	Sensitivity
AVG	Number of readings used for calculating averages
AUTO VIEW	Optimum zooming of the graphic
AUTO RANGE	Sets the optimum sensitivity range
SPECIAL	White light compensation adjustment

6.3 The menu for colour applications

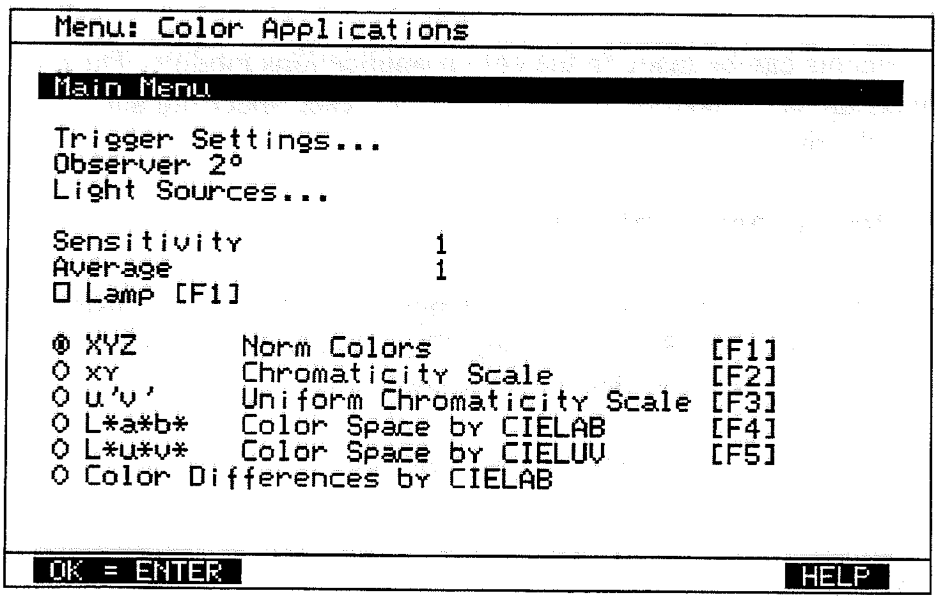


Fig. 6-1 Main menu for colour measurements

Observer 2° / 10°

The standard observer is an observer whose spectral value functions correspond to those defined by the CIE.

For technical colour measurements use either the colorimetric 2° standard observer CIE 1931 (valid for a field of view up to 2°) or the colorimetric 10° (large field) standard observer CIE 1964 (valid for a field of view exceeding 2°).

Standard light types and light kinds

Standard light types:
D65 natural daylight
A artificial illumination
C artificial daylight

Light kinds:
B Sunlight
G Vacuum incandescent lamp light

P Petroleum and candle light
Xe High pressure xenon short arc discharge lamp

Equal energy spectrum

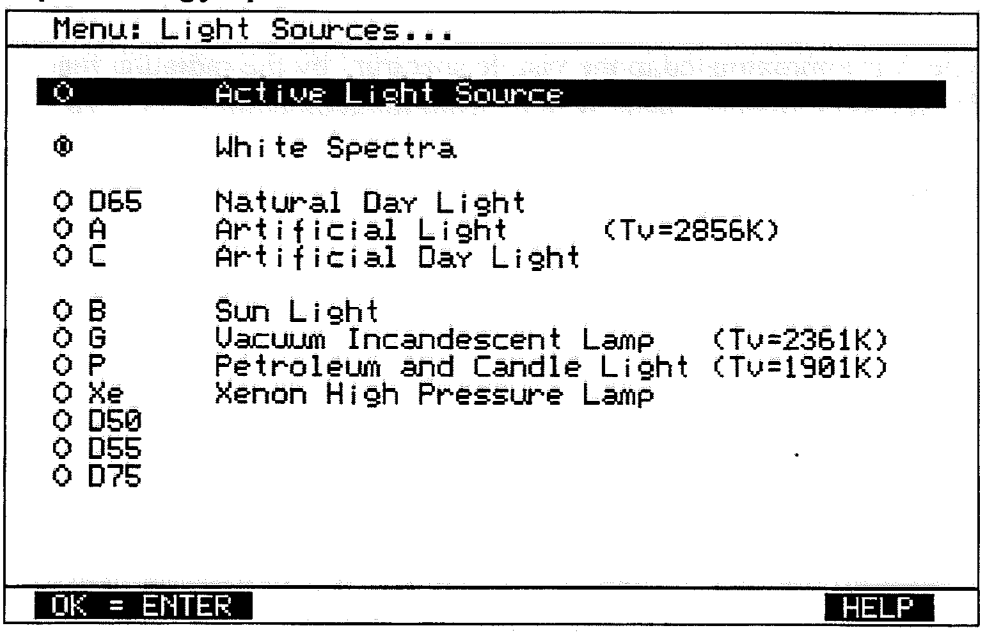


Fig. 6-2 Available standard light types

x = 0.3333 y = 0.3333

The colour type of the equal energy spectrum is not a light kind in the strict sense and is used for making colour measurements of light colours.

It is characterised by equal magnitude components of X, Y, Z.

Standard light type D65

2° observer	x=0.3127 y=0.3209
10° observer	x=0.3138 y=0.3310

No artificial light source have as yet been recommended by the International Illumination Commission (CIE) for the standard light type D65.

Note: Filtered xenon lamps metal filament halogen valour lamps can only approximate the radiation function of D65.

Standard light type A

2° observer	x=0.4476 y=0.4074
10° observer	x=0.4512 y=0.4059

Standard light type A is approximated in the visible spectrum by the radiation function of a gas-filled tungsten filament lamp with distribution temperature Tv = 2856K.

Standard light type C

2° observer	x=0.3101 y=0.3162
10° observer	x=0.3104 y=0.3190

Standard light type C is approximated in the visible spectrum by the radiation function of a gas-filled tungsten filament lamp with distribution temperature Tv = 2856K together with a C-filter.

Light type B

2° observer	x=0.3484 y=0.3516
10° observer	x=0.3498 y=0.3527

Light type B is approximated in the visible range of the spectrum in the same manner as for the standard light type. Thereby a B-filter is used instead of the C-filter.

Light type G

2° observer	x=0.4898 y=0.4149
10° observer	x=0.4936 y=0.4135

Light type G is approximated in the visible range of the spectrum in the same manner as for the standard light type. Thereby the lamp must be set to a distribution temperature of Tv = 2361K.

Light type P

2° observer	x=0.5376 y=0.4113
10° observer	x=0.5407 y=0.4104

Light type P is approximated in the visible range of the spectrum in the same manner as for the standard light type. Thereby the lamp must be set to a distribution temperature of Tv = 1901K.

Light type Xe

2° observer	x=0.3249 y=0.3271
10° observer	x=0.3251 y=0.3294

Light type Xe is approximated by a high pressure short arc xenon discharge lamp (the entire lamp).

X Y Z standard colour values

A colour hue is described by the 2°/10° standard colour values X, Y, Z.

X red component
Y green component (=100 for normalisation with respect to white)
Z blue component

x y standard colour coefficients

The standard colour coefficients x, y, z can be derived from the standard colour values X, Y, Z (whereby usually only x and y are used in most cases because x+y+z = 1).

$$x = \frac{X}{X+Y+Z} \quad \Rightarrow \quad y = \frac{Y}{X+Y+Z}$$

u' v' standard colour coefficients

The equal separation colour space is calculated as follows from the standard colour values X, Y, Z:

$$u' = \frac{4X}{X+15Y+3Z} \qquad v' = \frac{9Y}{X+15Y+3Z}$$

L* a* b* colour space

This approximately equally separated colour space according to physiological sensation is defined by the following rectangular coordinates:

$$L^* = 116 \cdot \sqrt[3]{\frac{Y}{Yn}} - 16$$

$$a^* = 500 \cdot \left(\sqrt[3]{\frac{X}{Xn}} - \sqrt[3]{\frac{Y}{Yn}} \right)$$

$$b^* = 200 \cdot \left(\sqrt[3]{\frac{Y}{Yn}} - \sqrt[3]{\frac{Z}{Zn}} \right)$$

The standard colour values Xn, Yn, Zn are the standard colour values of the perfectly white body under the given type of illumination and define the non-coloured point.

A polar representation L* C* h° is derived as follows:

$$C^* = \sqrt{a^{*2} + b^{*2}}$$

$$h^\circ = \arctan \frac{b^*}{a^*}$$

v* colour space

This approximately equally separated colour space according to physiological sensation is defined by the following rectangular coordinates:

$$L^* = 116 \cdot \sqrt[3]{\frac{Y}{Yn}} - 16$$

$$u^* = 13L \cdot (u' - u_n')$$

$$v^* = 13L \cdot (v' - v_n')$$

The standard colour values u_n' and v_n' are the standard colour values of the perfectly white body under the given type of illumination and define the non-coloured point.

A polar representation L* C* h° is derived as follows:

Colour intensity: $C^* = \sqrt{u^{*2} + v^{*2}}$

Colour hue angle: $h^\circ = \arctan \frac{v^*}{u^*}$

An expression corresponding to the saturation is defined as follows:

Saturation: $S^* = \frac{C^*}{L^*}$

Colour separation measurement

Colour separations in the CIELAB colour space can be determined herewith.

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

Using the indices p (sample) and r (reference) for the colours which are to be compared, we have:

$$\Delta L^* = L_p{}^* - L_r{}^*$$
$$\Delta a^* = a_p{}^* - a_r{}^*$$
$$\Delta b^* = b_p{}^* - b_r{}^*$$

The reference is thereby determined with the REF KEY.

For some purposes it is appropriate to split ΔE* into and intensity component ΔL*, a colour intensity contribution ΔC* and a colour hue component ΔH*, such that ΔE* can be represented as:

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta C^{*2} + \Delta H^{*2}}$$

6.4 Colour measure coefficients and colour spaces

Colour measure coefficients are used to unambiguously designate a colour value. For this purpose always three mutually independent numerical values are necessary and sufficient. Thus a colour value can be represented as a point or as a position vector in a three-dimensional space, the so-called colour space.

CIE 2° and 10° standard observers

The light-adapted eye of a human observer with normal colour vision assesses the incident radiation (the colour stimulus) primarily according to three mutually independent sensitivity functions (spectral value functions). These three evaluation functions are independent of the intensity of the incident radiation within the scope of normal sampling conditions.
For technical colour measurements, use either the colorimetric 2° standard observer CIE 1931 (valid for fields of view up to 4°), or the colorimetric 10° (large field of view) standard observer CIE 1964 (valid for fields of view greater than 4°).

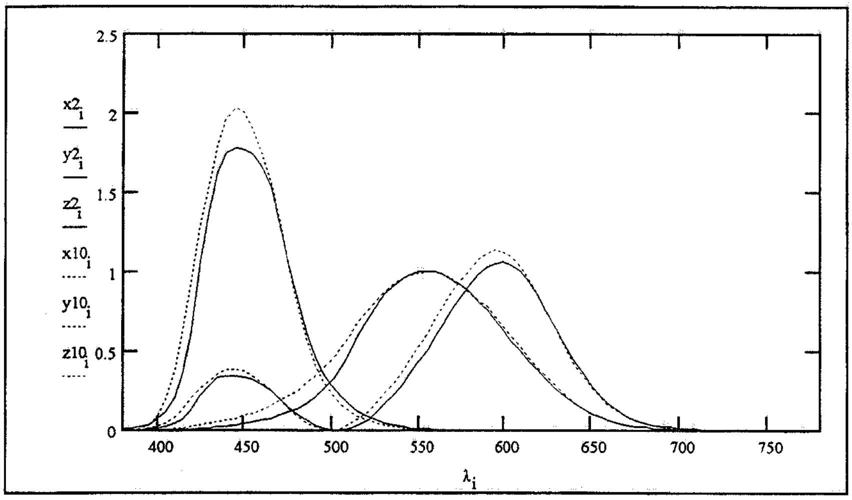


Fig. 6-3 Assessment functions of the normal vision human eye for the 2° and for the 10° observer

$$X = k \cdot \int_{380nm}^{780nm} \varphi_\lambda \cdot \bar{x}(\lambda)\, d\lambda$$

$$Y = k \cdot \int_{380nm}^{780nm} \varphi_\lambda \cdot \bar{y}(\lambda)\, d\lambda$$

$$Z = k \cdot \int_{380nm}^{780nm} \varphi_\lambda \cdot \bar{z}(\lambda)\, d\lambda$$

The normalisation factor *k* is defined for body colours under illumination with a certain type of light with radiation function S_λ such that for the
perfectly mat white body ($\beta(\lambda) = 1$) the standard colour value Y_{White}=100 always results for every type of light:

$$k = \frac{100}{\int_{380nm}^{780nm} S_\lambda \cdot \bar{y}(\lambda)\, d\lambda}$$

CIE 1931 (Yxy) colour diagram

Y corresponds to the luminance reference value, xy describe the standard colour value components:

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z}$$

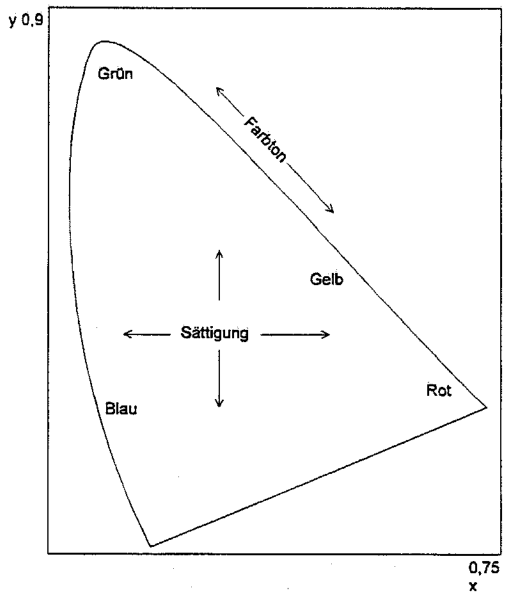


Fig. 6-4 CIE 1931 colour space

CIE 1976 L*a*b* (CIELAB)

$L^* = 116 \cdot \sqrt[3]{\frac{Y}{Y_n}} - 16$ Intensity (luminance)

$a^* = 500 \cdot \left(\sqrt[3]{\frac{X}{X_n}} - \sqrt[3]{\frac{Y}{Y_n}} \right)$ $b^* = 200 \cdot \left(\sqrt[3]{\frac{Y}{Y_n}} - \sqrt[3]{\frac{Z}{Z_n}} \right)$

$C^*_{ab} = \sqrt{a^{*2} + b^{*2}}$ Colour intensity

$h°_{ab} = \arctan\left(\frac{b^*}{a^*}\right)$ Colour hue angle

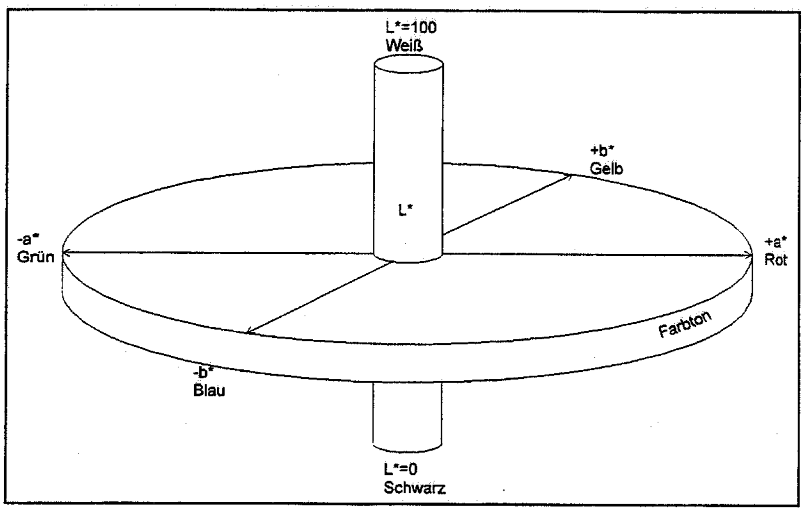


*Fig. 6-5 CIE 1976 L*a*b* colour space*

CIE-UCS 1976 (u',v') colour diagram

Equidistant colour type scale: Equal separations of physiological sensation correspond to equal separations of the numerical values.

$$u' = \frac{4X}{X + 15Y + 3Z} = \frac{4x}{3 - 2x + 12y}$$
$$v' = \frac{9Y}{X + 15Y + 3Z} = \frac{9y}{3 - 2x + 12y}$$

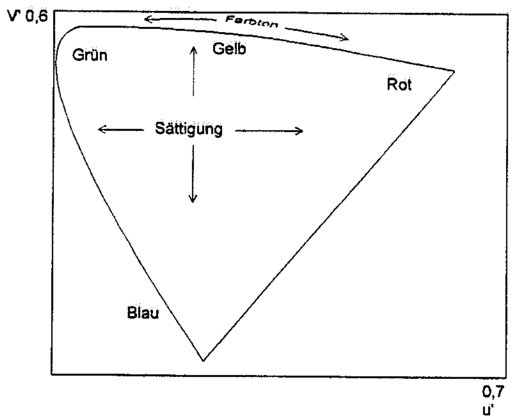


Fig. 6-6 CIE-UCS 1976 (u'v') colour space

CIE 1976 L*u*v* (CIELUV)

$L^* = 116 \cdot \sqrt[3]{\frac{Y}{Y_n}} - 16$ Intensity (luminance)

$u^* = 13 \cdot L^* \cdot (u' - u_n')$ $v^* = 13 \cdot L^* \cdot (v' - v_n')$

$C^*_{uv} = \sqrt{u^{*2} + v^{*2}}$ Colour intensity

$h°_{uv} = \arctan\left(\frac{v^*}{u^*}\right)$ Colour hue angle

$S^*_{uv} = \frac{C^*_{uv}}{L^*}$ Saturation

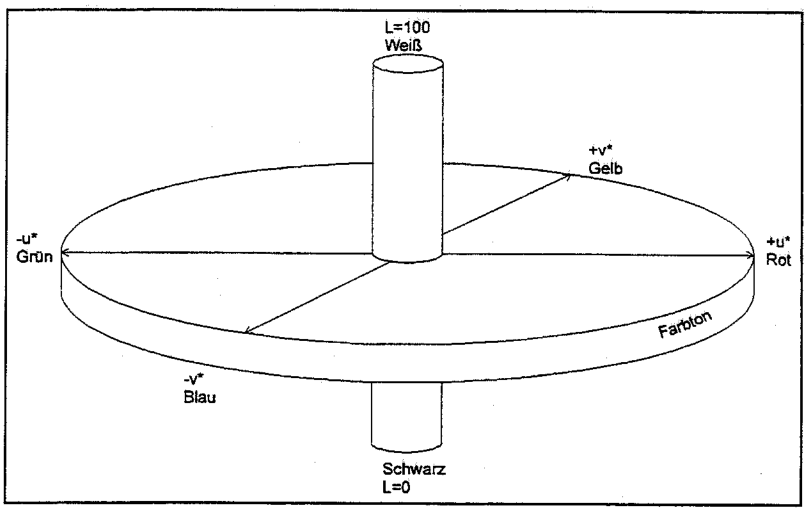


*Fig. 6-7 CIE 1976 L*u*v**

7 Layer thickness measurements

When a reflection measurement is made with white light on a thin layer, a typical spectrum is produced by interference. This spectrum is evaluated with a Fourier transform from which the corresponding layer thickness is calculated.

7.1 The display screen contents

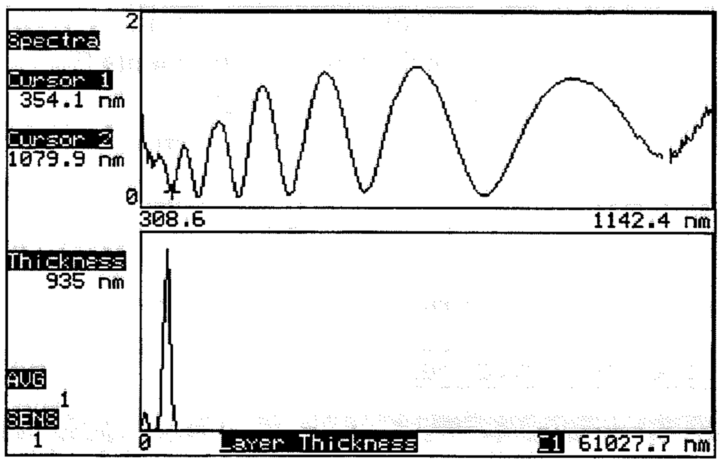


Fig. 7-1 Measuring the thickness of a transparent layer

The upper window displays the measured spectrum and the lower window shows the Fourier transform and the calculated layer thickness.

To be able to obtain a sensible measurement result for the layer thickness, the Fourier transform must contain a dominant value.

The actual cursor positions are shows to the left of the spectra. The layer thickness in nm is indicated below the cursor position values.

7.2 The key function assignments

AUTO VIEW	Optimum zoom of the graphic display
F1	Switches the internal halogen lamp on and off (can also be done in the menu)
F2	Switchover between continuous and single measurements (can also be done with the trigger settings menu option)

7.3 The menu for layer thickness measurements

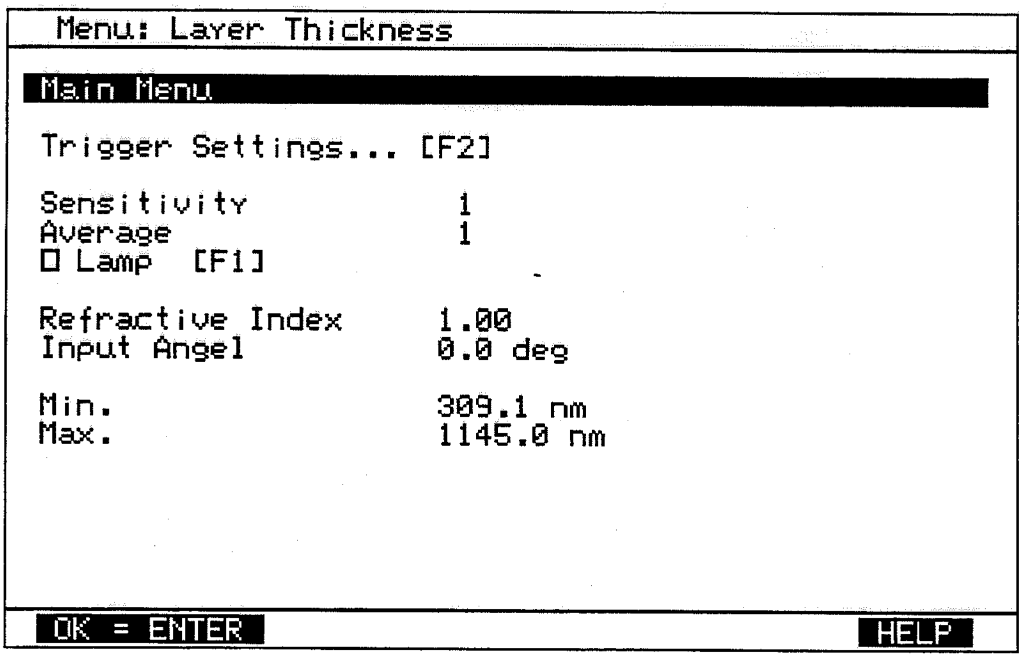


Fig. 7-2 Menu for layer thickness measurements

Trigger settings

Triggering On/Off

Here you can select between manual measuring mode (trigger On) and automatic measuring mode (continuous measuring mode, trigger Off).

Trigger key

The ENTER/TRIGGER KEY is used as trigger source.

Trigger socket

The trigger socket (on the rear panel) can also be used to trigger measurements. All 4 channels must be LOW to produce a trigger.

Sensitivity

The individual pixels of the row of diodes constitute capacitors which are discharged by the incident light. The time integral of the subsequent charging current is proportional to the incident light intensity. The integration time is varied via the sensitivity setting.
For optimum drive of the spectrometer, always choose the highest possible sensitivity. Bear in mind that a new dark current compensation measurement and a new reference spectrum measurement must be made after every change of the sensitivity setting.
The sensitivity setting can also be changed with the SENS KEY.

Number of averaged readings

Several measurement readings can be averaged to improve the signal/noise ratio. Settings can be made for averaging up to 128 readings. The number of readings averaged can be set with the AVG KEY.

Lamp

Switches the internal halogen lamp on and off. The lamp can also be switched on and off by pressing the F1 KEY.

Refractive index

The refractive index of the material must be entered for determining the exact layer thickness.

Refraction angle

The layer thickness calculation is also affected by the angle of the reflected light (measured with respect to the perpendicular to the measured layer). The angle is 0° when measuring with the Y light waveguide which is available as accessory device.

Min/Max

The minimum and maximum wavelengths used for calculating the layer thickness. Only the part of the spectrum is analysed which lies between the set minimum and maximum wavelengths. These wavelengths can also be set with the cursors.

7.4 Physical principles of layer thickness measurements

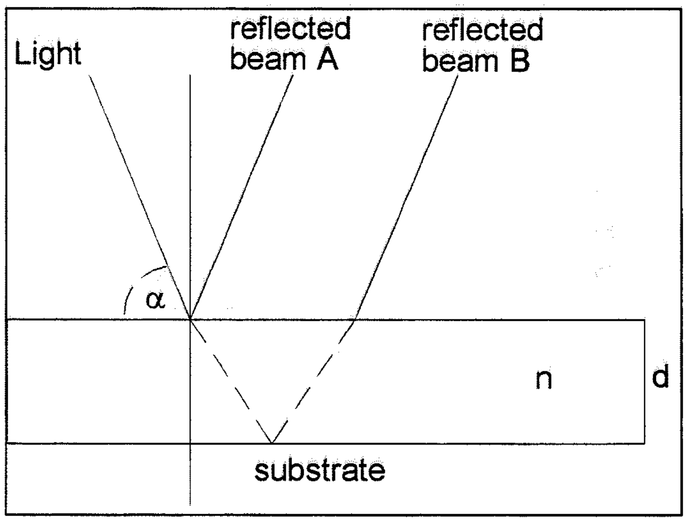


Fig. 7-3 The principle of making layer thickness measurements

Monochromatic light incident on a thin transparent layer is partially reflected at the boundary between the air and the layer.

Some of the light penetrates into the layer and is reflected at the boundary between the layer and the substrate. The two reflected components A and B are superimposed and produce increase or decrease of the light intensity seen at the location of the observer, depending on the mutual phase relationship. The intensity is modulated as a function of the wavelength when white light is used instead of monochromatic light. The following relationship thereby results for the intensity:

$$I = I_A + I_B + 2\sqrt{I_A I_B}\cos(\frac{2\pi}{\lambda}\Delta)$$

Here λ is the wavelength and Δ is the phase difference (= optical path difference) between the two reflected beams.
The phase difference can be expressed as:

$$\Delta = 2d\sqrt{n^2 - \sin^2\alpha} + \frac{\lambda}{2}$$

where d = layer thickness, n = refractive index of the measured layer and α = angle between the incident light beam and the perpendicular to the layer surface.
The layer thickness can be calculated from the two equations stated above by means of a Fourier transformation.

7.5 Example: Determining the thickness of a photo-resist layer on a silicon chip

The procedure for measuring the thickness of a transparent layer will now be described step by step for a typical example.

I. Measuring the dark current spectrum and the reference spectrum
  - A. Switch to the general applications menu
  - B. Switch-on the internal light source (F1)
  - C. Wafer without photo-resist layer (in most cases it is best to use as reference a sample of the same material without a coating layer)
  - D. Press the AUTO RANGE key to set the optimum sensitivity range
  - E. Change to the Refl/Trans measuring mode (REFL/TRANS KEY)
  - F. Switch-off the internal light source
  - G. Make the dark current measurement (DARK KEY)
  - H. Switch-on the internal light source (F1 KEY) and measure the reference spectrum

    Note: A straight line should now appear in the centre of the display screen. There may be strong noise at the beginning and end of the spectrum. The signal/noise ratio can be improved by automatic averaging over several measurements. The number of averaged measurements can be increased by pressing the +-AVG KEY. The dark current spectrum and the reference spectrum should be measured again after increasing the number of averaged measurements.

  - I. Place the wafer under the Y light waveguide. An interference spectrum should now appear on the display screen.

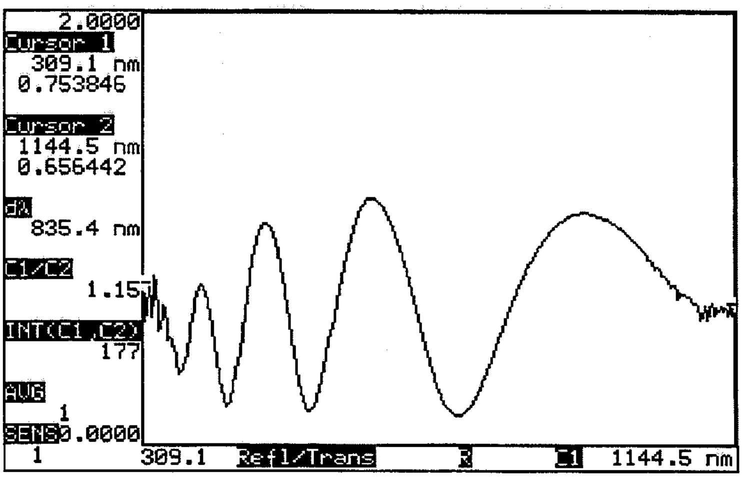


Fig. 7-4 Interference spectrum on a thin layer

II. Determining the layer thickness

A. Change to display of the general applications menu (key Menu IN)

B. Select the main menu item and then press the ENTER/Trigger key

C. Select the menu option for layer thickness measurements.
The interference spectrum is now shown in the upper window on the display screen (as for the Refl/Transmission display). The lower window shows the Fourier transform of the spectrum in the upper window. The layer thickness is displayed to the left of the lower window on the screen.

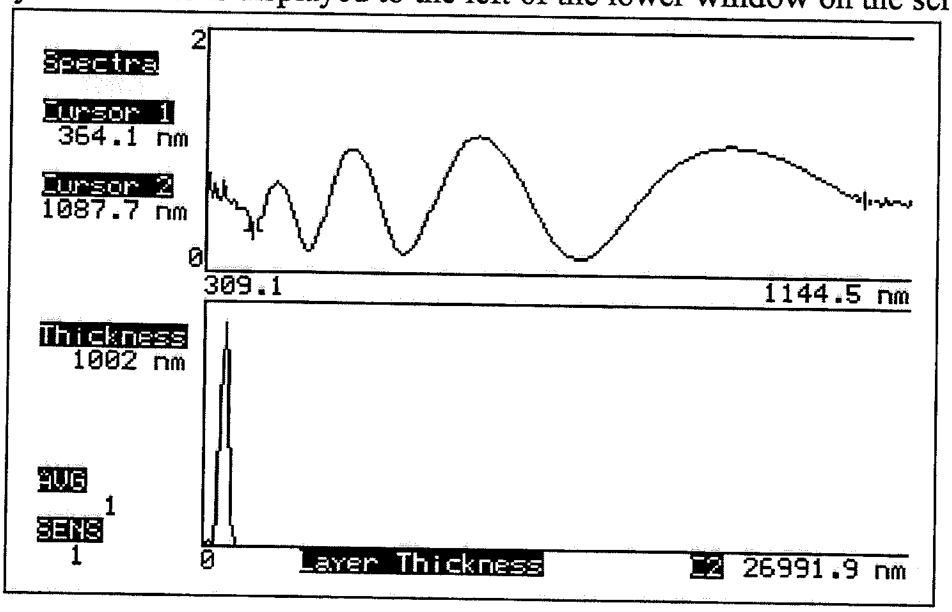


Fig. 7-5 Only the part of the spectrum between the two cursors is evaluated

D. Only the part of the spectrum between the cursors is evaluated to determine the layer thickness. If the interference spectrum has a lot of superimposed noise at the beginning and end, move the cursors (with the arrow keys) to a more favourable wavelength range.

8 Process applications menu

The external trigger output can be event-driven in this module. Therewith it is possible to use the spectrometer for control functions. With the present software version colour values cannot be used for process control. Process control tasks depending on a layer thickness are described in the next chapter.

8.1 The display screen contents in the process applications menu

The display on the screen shows the light intensity as a function of the wavelength. The two crosses mark the present cursor positions.

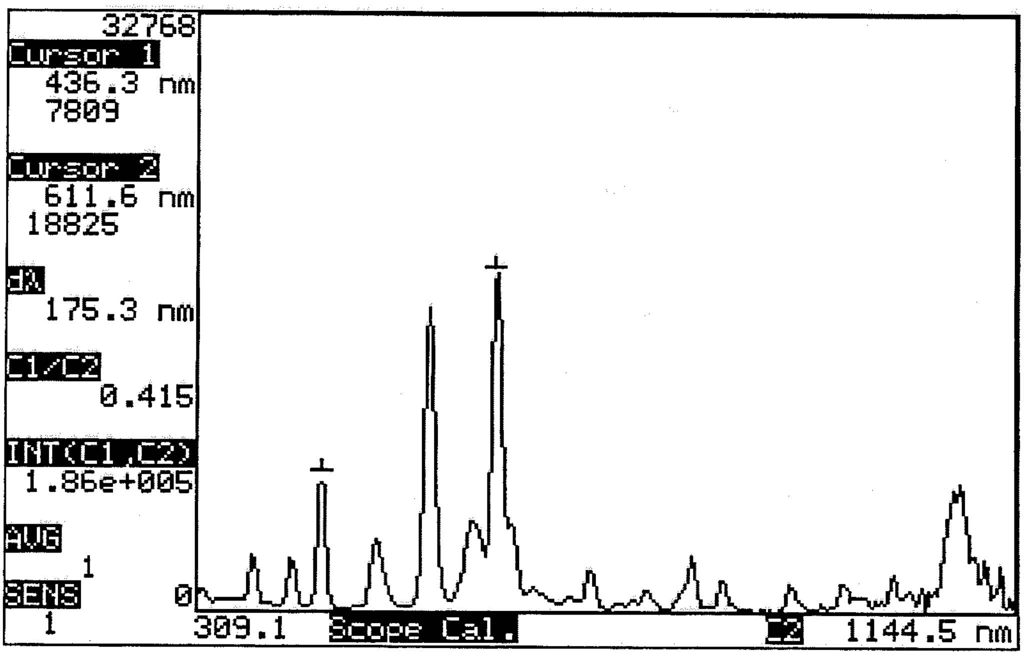


Fig. 8-1 The cursors mark wavelengths and intensities

Note: In the process applications menu the cursor positions cannot be changed with the cursor keys. They must be set in the menu.

The information items displayed to the left of the spectrum have the following meanings:

Φ1 : Light intensity at cursor position 1

$\Phi 1/\Phi 2$: Ratio of the light intensities at cursor position 1 and cursor position 2

$\Delta\Phi 1$: Difference of the intensities at cursor position 1 between the last two previous measurements

$\Delta(\Phi 1/\Phi 2)$: Difference of the ratio of the two intensities between two measurements

$\lambda 1$: Wavelength at cursor position 1

$\lambda 2$: Wavelength at cursor position 2

The following information appears under the spectrum:

Not triggered	Measuring mode not active; the instrument is waiting for a trigger signal
Pretrigger	Pretrigger appeared
Event Wait	The instrument is in measuring mode and is waiting for fulfilment of the event criterion
Posttrigger	The event criterion is fulfilled. The instrument awaits elapse of the delay time, after which the trigger pulse is produced.

8.2 Function assignments of the keys

F1	Switches the lamp on and off
F2	Switches over between continuous measurements and single measurements
TIME VIEW	Switches over to time display. In time display the changes of intensity at the two cursor positions are displayed as a function of time.

8.3 The process applications menu

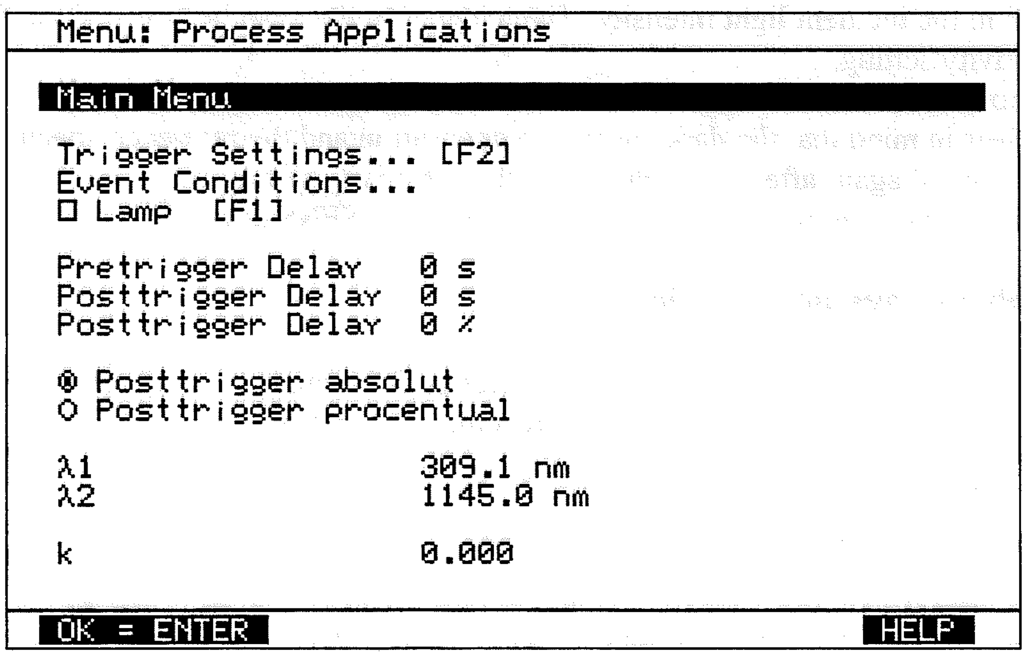


Fig. 8-2 The process applications menu

Trigger settings

Triggering On/Off

Here you can select either manual measuring operation (Trigger On) or automatic measuring mode (continuous measurements, Trigger Off).

Trigger key

Die ENTER/Trigger key can be used as trigger source.

Trigger socket

The trigger input socket (on the rear panel) can also be used as trigger source. All 4 channels must be LOW (TTL levels) to produce a trigger.

Sensitivity

The individual pixels of the row of diodes constitute capacitors which are discharged by the incident light. The time integral of the subsequent charging current is proportional to the incident light intensity. The integration time can be adjusted via the sensitivity setting.
For optimum drive of the spectrometer, always choose the highest possible sensitivity. Bear in mind that the dark current compensation and the reference spectrum must be measured again after every change of the sensitivity setting.
The sensitivity setting can also be changed with the SENS keys.

Number of averaged readings

Up to 128 measurement readings can be averaged to improve the signal/noise ratio. The number of averaged measurement readings can also be changed with the AVG KEY.

Lamp

Switches the internal halogen lamp on and off. The lamp can also be switched on and off by pressing the F1 KEY.

Event criteria

The criteria to be fulfilled to produce a trigger are defined in this menu. The following trigger criteria are available:

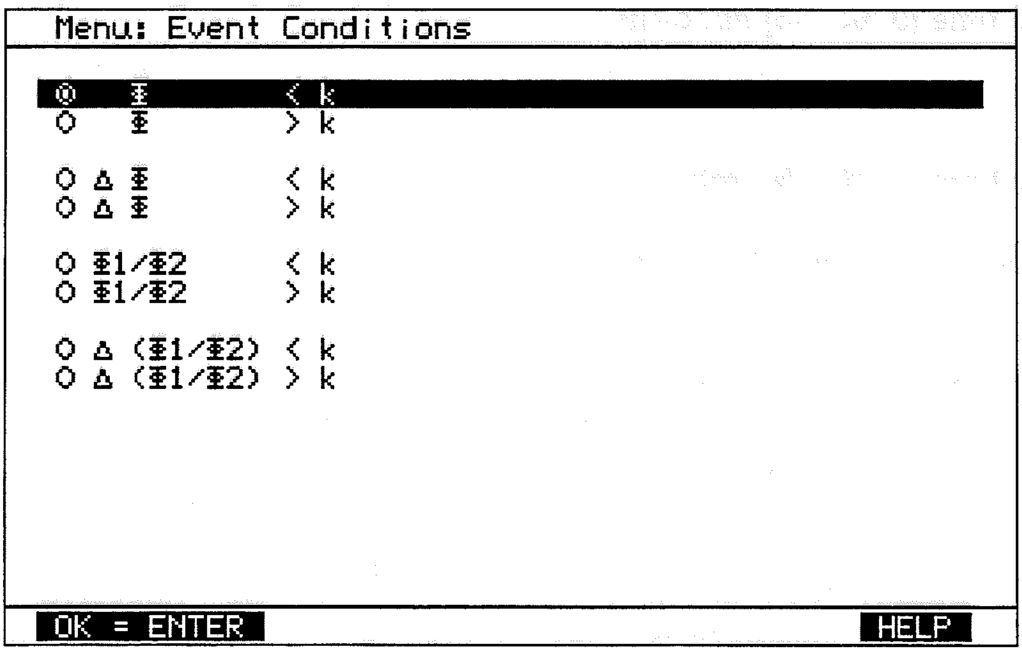


Fig. 8-3 Event criteria menu

Φ stands for the intensity at the wavelength λ_1, Φ_2 for the intensity at the wavelength λ_2. $\Delta\Phi$ stands for the difference $\Phi(\lambda_1)$ between 2 measurements. The ratio of the two intensities at the wavelengths 1 and 2 or the difference of the ratios can also be chosen as event criteria for triggering.

Lead time (0..65535s)

The adjustable variable time which must elapse before fulfilment of the trigger condition is expected.

Delay time (0..65535) absolute

The time interval whose elapse is awaited before the trigger signal is produced.

Delay time (0..1000%) relative

The delay time is here related to the time of waiting for the event criterion to be fulfilled.

Delay time absolute/relative

Switchover between absolute and relative delay time.

λ_1/λ_2

Specification of the wavelengths λ_1 and λ_2 at which the respective intensities Φ_1 and Φ_2 are measured.

8.4 Example: End point detection in a plasma etching process

In this section it will be shown with a practical example how the SPM 9001 can be used to determine the end point of a plasma etching process. The individual steps described below depend strongly on the particular process.

Preliminary remarks

The plasma spectrum is measured at various times during the etching process. The spectrum shown below was recorded in the middle of a plasma etching process during which a photo-resist layer is removed from a silicon wafer. Two dominant spectral lines are seen at 656nm and 777nm which can be associated with atomic hydrogen (from the photo-resist) and oxygen (the etching gas). The following physical-chemical process is used to determine the end point: The relative amount of photo-resist detached from the photo-resist is observed in the plasma (via the hydrogen line). The intensity of the hydrogen line declines towards the end of the etching process. At the same time the etching gas will be present in increasing amounts in the plasma so that the oxygen line will rise to the initial intensity.

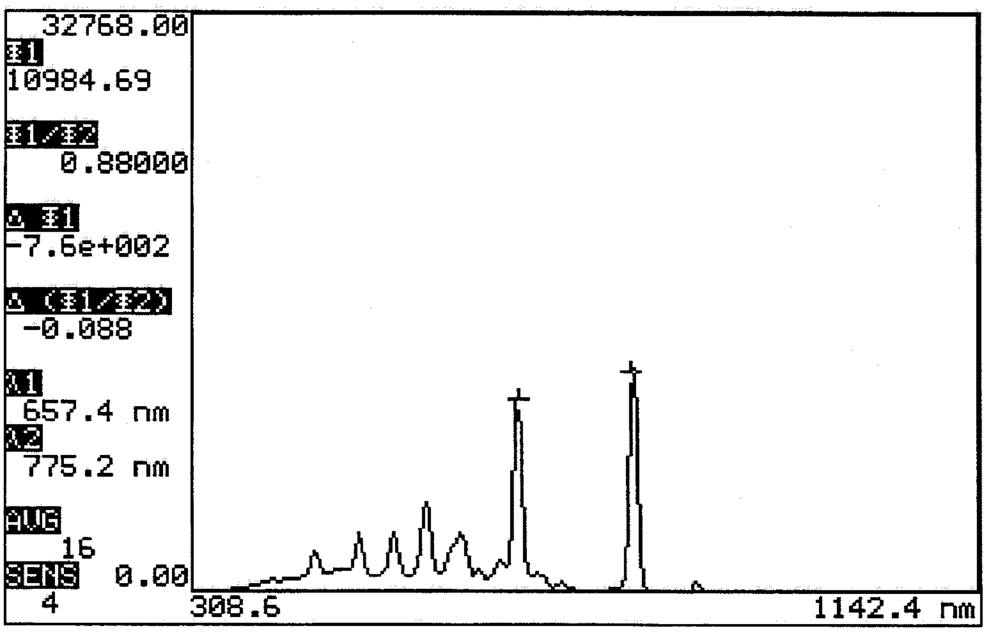


Fig. 8-4 Plasma spectrum of a photo-resist etching process

Procedure

I. Measuring the initial spectrum

A. Switch to the general applications menu.

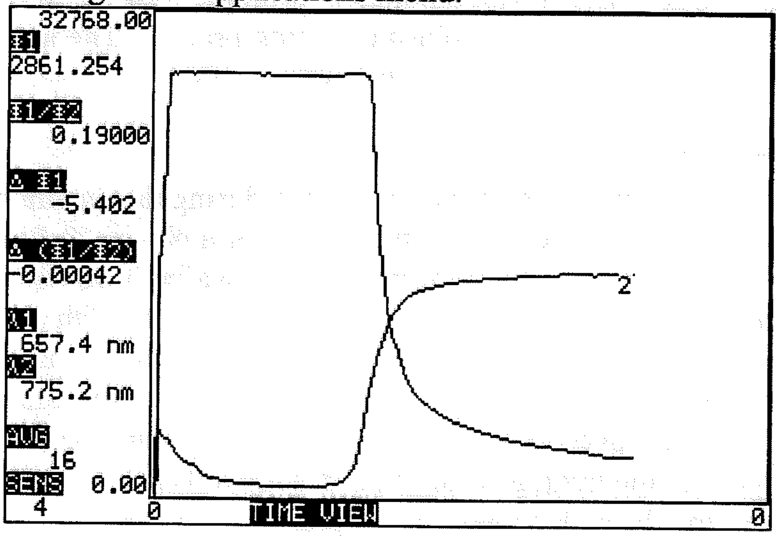


Fig. 8-5 Intensity changes of the oxygen and hydrogen emission lines in the course of time

B. Attach the light waveguide to the observation window of the reaction chamber.

C. Make the plasma luminous and set the optimum sensitivity range (by pressing the AUTO Range key).
If insufficient light couples directly into the optical fibre, focus the light emitted by the plasma onto the glass fibre with a suitable lens.

D. Disconnect the SMA plug of the light waveguide from the optical input of the spectrometer and darken the optical input. Make the dark current compensation measurement (DARK key).

E. Place the cursor onto the dominant spectral lines and read the values.

II. Observation of the intensity changes of the dominant wavelengths in the course of time.

A. Switch over to Time View Mode (press the Time View key).
The time functions of the light intensity at the two wavelengths marked with the cursors are now displayed on the screen. The following illustration shows such a display for the example taken here. The etching process should be terminated 30 seconds after the two lines A and B intersect.

III. Setting the event conditions
   A. Switch over to the main menu (Press the key Menu IN).
   B. Switch to the process applications menu.
   C. Press the MENU IN KEY. Set the wavelengths λ_1 and λ_2. Set the k value.
      In this example λ_1 is set to the value 656nm, λ_2 is set to the value 777nm and k is set to the value 1..
   D. Switch to the event criteria submenu and set the event criteria. *here $\Phi_1/\Phi_2 > k$*
IV. Set the lead time and the delay time
   A. Set the lead time (the time elapse between the start signal and the wait for trigger state)
   B. Set the delay time (the time elapse between fulfilment of the event criteria and production of the trigger signal)
V. Start the measurement
   A. Select either continuous measuring mode or single measurements mode (via the menu or with the F2 KEY)
   B. In single measurements mode each measurement is started via the external trigger input or by pressing the ENTER/TRIGGER KEY.

9 Process applications (layer thickness)

The functions and settings of the layer thickness process applications module have some similarities with respect to the process applications module described in the previous chapter. In the module described here, overshoot or undershoot of a preset layer thickness can be used to control a process.

9.1 The display screen contents

The display screen contents are here very similar to those for layer thickness measurement, but with the following difference:

Cursor positions: The cursor positions as set in the layer thickness measuring module are here taken over. The cursor positions cannot be changed with the cursor keys.

Some information items concerning the present measuring status are displayed below the spectrum. These are:

Not triggered Measuring function not active; the instrument is waiting for a trigger signal.

Pretrigger A trigger has been issued. The instrument is waiting until the time interval set under lead time has elapsed and will then start the measurement.

Event Wait The instrument is in measuring mode and is waiting for fulfilment of the event criterion.

Posttrigger The event criterion has been fulfilled. The instrument is waiting until the delay time has elapsed and will then issue the trigger pulse.

9.2 Function assignments of the keys

F1 Switches the lamp on and off.

F2 Switches over between continuous measurements and single measurements

9.3 Menu in the process applications module (layer thickness)

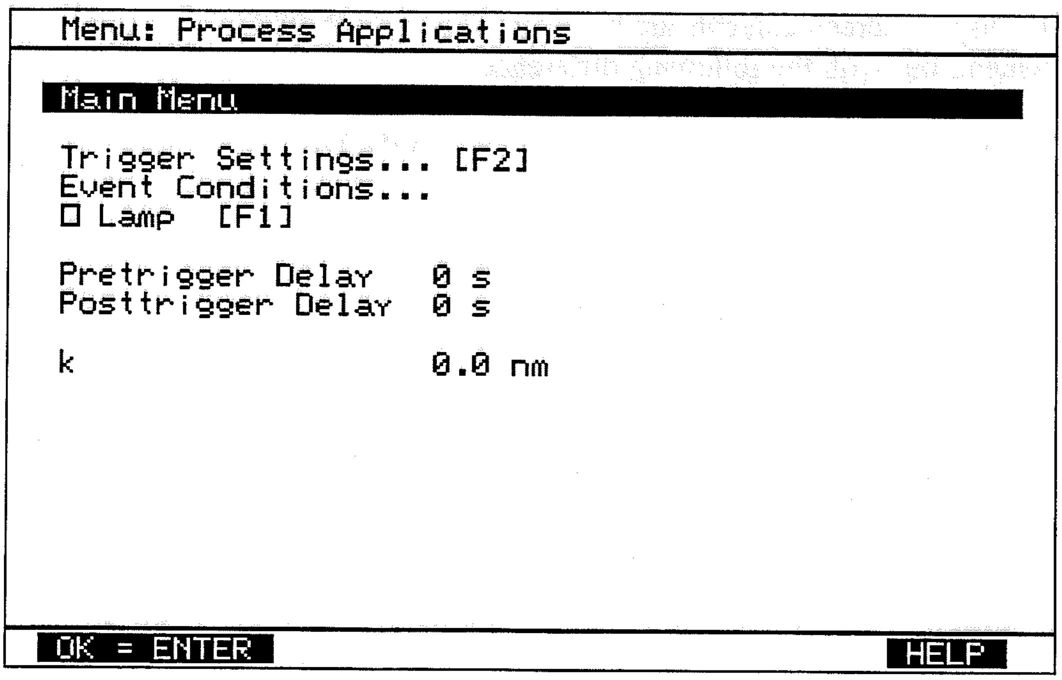


Fig. 9-1 Menu in layer thickness measurement process applications

Trigger settings

Triggering On/Off

Here you can choose between manual measuring mode (trigger On) and automatic measuring mode (continuous measuring mode, trigger Off).

Trigger key

The ENTER/Trigger key serves as trigger initiator.

Trigger socket

The trigger socket (on the rear panel) can also be used to issue a trigger. All 4 channels must be LOW to issue the trigger signal.

Event criteria

D<k
The trigger signal is issued when the actual layer thickness D becomes less than the value k.

D>k
The trigger signal is issued when the actual layer thickness D exceeds the value k.

Lamp
Switches the internal halogen lamp on and off (this can also be done in display mode by pressing the F1 key).

Lead time
The time which shall elapse between the start signal and the start of the measurement.

Delay time
The time which shall elapse between fulfilment of the event criterion and issue of the output trigger signal.

k
The layer thickness k with which the actual layer thickness is compared.

10 Remote control

The SPM 9001 can be remotely controlled from a PC via the serial data communication interface. Details of the hardware requirements for this are given in the Technical Description chapter (Chapter 11). The control commands are explained in the present chapter. To switch to remote control mode, select the remote control menu in the main menu. The Baud rate can here be set to a value in the range from 110 to 115200 as additional option.

10.1 Input and output formats

<STRING>	Character string enclosed in double quotes <"> (ASCII 34 decimal).
<NR1>	Number in format **±dddddd**
<NR2>	Number in format **±ddd.ddd**
<NR3>	Number in format **±d.dddddE±eee**
<Boolean>	**ON**|**OFF**|<NRf>
<NRf>	Is rounded to integer. Any value differing from zero is interpreted as **1** . To improve readability, **ON** and **OFF** are accepted as entries. The returned value is always **1** or **0** .

10.2 General commands

*CLR	[no query]	Clear error numbers
*IDN?	[query only]	Query type label plate
*RST	[no query]	Reset device

***CLR**

This clears the error status register without first reading its contents.

***IDN?**

Returns the following <STRING> :

<manufacturer>,<model>,<serial_number>,<firmware_level>

Example: "PREMA,SPM 9001,10002,1.16"

***RST**

The device is reset to the initialised state whereby the following commands are executed:

```
:CAL:SPEC:STAT ON
:CONF:SPEC:SCOP 1
:SENS:AVER:COUN 1
```

```
:SENS:COL:ANGL 2
:SENS:THIC:REFR 1.0
:SENS:THIC:ANGL 0
:SENS:WAV:MODE LIST
:SENS:WAV:RANG:DEF
:SENS:COL:WHIT DEF
*CLR
```

10.3 Preparations for the measurement

Prepare for measuring, set sensitivity

:CONF
:DARK <numeric_value> [no query] dark current (all measurements)
<numeric_value> : Sensitivity 1..256

:SPEC
:ALIN <numeric_value> [no query] Absorption linear (Absorbance)
:ALOG <numeric_value> [no query] Absorption Logar. (Absorptance)
:REF <numeric_value> [no query] Reference (TRAN, ALIN, ALOG)
:SCOP <numeric_value> [no query] Scope
:TRAN <numeric_value> [no query] Transmission/Reflection
:COL
[:IMM] <numeric_value> [no query] Colour measurement
:REF <numeric_value> [no query] Reference for colour comparison measurement
:WHIT <numeric_value> [no query] White adjustment
:THIC
[:IMM] <numeric_value> [no query] Layer thickness measurement
:REF <numeric_value> [no query] Reference for layer thickness measurement

Data acquisition

:INIT
[:IMM] [no query]

Calculation and transmission of measured data

:FETC?			
:SPEC?	[query only]	Spectrum (also dark current)	
:COL			
:XYZ?	[query only]	Colour measurement	XYZ
:XY?	[query only]	Colour measurement	xy
:UV?	[query only]	Colour measurement	u'v'
:LAB?	[query only]	Colour measurement	L*a*b*
:LUV?	[query only]	Colour measurement	L*u*v*
:THIC?	[query only]	Layer thickness	

Measuring, calculating and transmitting data (INIT[:IMM]+FETC?)

:READ?			
:SPEC?	[query only]	Spectrum (also dark current)	
:COL			
:XYZ?	[query only]	Colour measurement	XYZ
:XY?	[query only]	Colour measurement	xy
:UV?	[query only]	Colour measurement	u'v'
:LAB?	[query only]	Colour measurement	L*a*b*
:LUV?	[query only]	Colour measurement	L*u*v*
:THIC?	[query only]	Layer thickness	

Preparations, measurement, calculation and transmission (CONF+READ?)

```
:MEAS
   :DARK?     <numeric_value> [query only] Dark current
                           (all measure-
                                        ments)
   :SPEC
      :REF?   <numeric_value> [query only] Reference
                                        (TRAN, ALIN,
                      ALOG)
      :SCOP?  <numeric_value> [query only] Scope
      :TRAN?  <numeric_value> [query only] Transmission/Reflection
      :ALIN?  <numeric_value> [query only] Absorption,
                                        linear
              (Absorption)
      :ALOG?  <numeric_value> [query only] Absorption
                 Logarithmic
   (Extinction)
   :COL
      :XYZ?   <numeric_value> [query only] Colour measure-
                                        ment XYZ
      :XY?    <numeric_value> [query only] Colour measure-
                                        ment xy
      :UV?    <numeric_value> [query only] Colour measure-
                                        ment u'v'
      :LAB?   <numeric_value> [query only] Colour measure-
                 ment L*a*b*
      :LUV?   <numeric_value> [query only] Colour measure-
                                        ment L*u*v*
   :THIC?     <numeric_value> [query only] Layer thickness
```

:CONF:DARK <numeric_value>
Preparations for measuring the dark current for the sensitivity setting *<numeric_value>*.

:CONF:SPEC:ALIN <numeric_value>
Preparations for the absorption measurement with linear range of values for the sensitivity setting *<numeric_value>*.

:CONF:SPEC:ALOG <numeric_value>
Preparations for the absorption measurement with logarithmic range of values (extinction) for the sensitivity setting *<numeric_value>*.

:CONF:SPEC:REF <numeric_value>
Preparations for measuring the reference spectrum (for transmission/absorption measurements) for the sensitivity setting *<numeric_value>*.

:CONF:SPEC:SCOP <numeric_value>
Preparations for the scope measurement with the sensitivity setting *<numeric_value>*.

:CONF:SPEC:TRAN <numeric_value>
Preparations for the transmission measurement with the sensitivity setting *<numeric_value>*.

:CONF:COL[:IMM] <numeric_value>
Preparations for the colour measurement with the sensitivity setting *<numeric_value>*.

:CONF:COL:REF <numeric_value>
Preparations for measuring the reference spectrum for the sensitivity setting *<numeric_value>*.

:CONF:COL:WHITE <numeric_value>
Preparations for the white compensation for the sensitivity setting *<numeric_value>*.

:CONF:THIC[:IMM] <numeric_value>
Preparations for thickness measurement with the sensitivity setting *<numeric_value>*.

:CONF:THIC:REF <numeric_value>
Preparations for the reference spectrum measurement for thickness measurements with the sensitivity setting *<numeric_value>*.

:INIT[:IMM]
The measuring process (which was prepared with **:CONF**) is started. The result is stored internally in the device and can subsequently be calculated and transmitted according to the output format.

:FETC?
The measured data (**:INIT**) are calculated and transmitted according to the output format. The most recently set format is used.

:FETC:SPEC?
Calculation and transmission of the measured spectrum. The dark current spectrum and the reference spectrum are transmitted too. The format and the number of spectra transmitted are set in the **SENS** subsystem.

:FETC:COL:XYZ?
Calculation and transmission of the standard colour values X, Y and Z (<NR3>). X, Y and Z represent the red, green and blue components of the standard colour value respectively.
<X>,<Y>,<Z>

:FETC:COL:XY?
Calculation and transmission of the standard colour value components x and y (<NR3>).
<x>,<y>

:FETC:COL:UV?
Calculation and transmission of the standard colour components u' and v' (<NR3>).
<u'>,<v'>

:FETC:COL:LAB?
Calculation and transmission of the L* a* b* measurement readings (<NR3>).
<L>,<a*>,<b*>,<C>,<h>*

:FETC:COL:LUV?
Calculation and transmission of the L* u'* v'* measurement readings (<NR3>).
<L>,<u'*>,<v'*>,<C>,<h>,<S>*

:FETCH:THIC?
Calculation and transmission of the layer thickness (<NR3>).

:READ?
Corresponds to **:INIT:IMM+FETC?** The most recently set format is used.

:READ:SPEC?
Corresponds to **:INIT:IMM+FETC:SPEC?**

:READ:COL:XYZ?
Corresponds to **:INIT:IMM+FETC:XYZ?**

:READ:COL:XY?
Corresponds to **:INIT:IMM+FETC:XY?**

:READ:COL:UV?
Corresponds to **:INIT:IMM+FETC:UV?**

:READ:COL:LAB?
Corresponds to **:INIT:IMM+FETC:LAB?**

:READ:COL:LUV?
Corresponds to **:INIT:IMM+FETC:LUV?**

:READ:THIC?
Corresponds to **:INIT:IMM+FETC:THIC?**

:MEAS:DARK? <numeric_value>
Corresponds to **:CONF:DARK <numeric_value>+:READ:SPEC?**

:MEAS:SPEC:ALIN? <numeric_value>
Corresponds to **:CONF:SPEC:ALIN <numeric_value>+:READ:SPEC?**

:MEAS:SPEC:ALOG? <numeric_value>
Corresponds to **:CONF:SPEC:ALOG <numeric_value>+:READ:SPEC?**

:MEAS:SPEC:REF? <numeric_value>
Corresponds to **:CONF:SPEC:REF <numeric_value>+:READ:SPEC?**

:MEAS:SPEC:SCOP? <numeric_value>
Corresponds to **:CONF:SPEC:SCOP <numeric_value>+:READ:SPEC?**

:MEAS:SPEC:TRAN? <numeric_value>
Corresponds to **:CONF:SPEC:TRAN <numeric_value>+:READ:SPEC?**

:MEAS:COL:XYZ?
Corresponds to **:CONF:COL[:IMM] <numeric_value>+:READ:XYZ?**

:MEAS:COL:XY?
Corresponds to **:CONF:COL[:IMM] <numeric_value>+:READ:XY?**

:MEAS:COL:UV?

Corresponds to **:CONF:COL[:IMM] <numeric_value>+:READ:UV?**

:MEAS:COL:LAB?
Corresponds to **:CONF:COL[:IMM] <numeric_value>+:READ:LAB?**

:MEAS:COL:LUV?
Corresponds to **:CONF:COL[:IMM] <numeric_value>+:READ:LUV?**

:MEAS:THIC? <numeric_value>
Corresponds to **:CONF:THIC <numeric_value>+:READ:THIC?**

10.4 CALCulate subsystem

:CALC
  DATA? [query only] read calculated data (colour measurement)

:CALC:DATA?

Transmission of the colour difference values according to CIELAB in the following format:

<*ΔL*>,<*Δa*>,<*Δb*>,<*ΔC*>,<*ΔE*>,<*ΔH*>

All numerical formats in <NR3>.

10.5 CALibration subsystem

:CAL
  :SPEC
    :DATA <arbitrary_block_program_data> Calibration coefficient for the sensitivity.
    :STAT <Boolean> Scope calibrated/uncalibrated
  :WAV
    :DATA <arbitrary_block_program_data> Association wavelength/pixel

:CAL:SPEC:DATA <arbitrary_block_program_data>

This command is provided for reading or writing the calibration of the wavelength-dependent sensitivity. The data format is:

<*wave_length0*> <*coefficient0*>,<*wave_length1*> <*coefficient1*>...

<*wave_length*> in format <NR2>, increasing from approx. 300 nm...1100 nm
<*coefficient*> in format <NR3>

For writing the calibration use the same wavelength as determined during readout. The tolerance error of the wavelengths must be less than 0.1 nm.

:CAL:SPEC:STAT <Boolean>

<Boolean> equals **1**: The calibration of the wavelength-dependent sensitivity is taken into account. This option is switched-on automatically for colour measurements.

<Boolean> equals **0**: The calibration of the wavelength-dependent sensitivity is not taken into account.

:CAL:WAV:DATA <arbitrary_block_program_data>

This command is provided for reading or writing the calibration of the association of wavelength and pixel number. The data format is:

<B0> <B1> <B2> <B3> <B4>,<C0> <C1> <C2> <C3> <C4>

All numbers in format <NR3>.

$n = B0 + B1 \cdot \lambda + B2 \cdot \lambda^2 + B3 \cdot \lambda^3 + B4 \cdot \lambda^4$; Pixel number

$\lambda = C0 + C1 \cdot n + C2 \cdot n^2 + C3 \cdot n^3 + C4 \cdot n^4$; Wavelength

$n = 1 \ldots 256$; $\lambda \approx 300$ nm ... 1100 nm

As far as possible this calibration should not be changed.

10.6 MMEMory (mass storage) subsystem

The Mass MEMory Subsystem is provided for transmitting saved spectra.

:MMEM		
CAT?	[query only]	Read directory
DATA?	<file_name> [query only]	Read file

:MMEM:CAT?
The CATalog command returns the directory entries of the stored spectra. The output format is as follows:
<numeric_value>,<numeric_value>{,<file_entry>}

The first two parameters of type <NR1> are always zero and serve for compatibility with the SCPI syntax. <file_entry> of type <STRING> shows the complete filename, file type and file size of each file in the directory:
<file_name>,<file_type>,<file_size>

<file_name> contains the complete filename including the filename extension. <file_type> is output as **ASC** (ASCII text file). <file_size> shows the size of the file in bytes.

:MMEM:DATA? <file_name>
This command returns the wavelength and spectrum of the file <file_name>. <file_name> is of type <STRING> and consists of the complete filename including the filename extension. The output format is as follows:
<wave_length> <data>{,<wave_length> <data>}

<wave_length> is the wavelength in nanometres, <data> is the spectral value for this wavelength. Both values are output in format <NR3>.

10.7 SENSe subsystem

:SENS:LIST and :SENS:WAV apply to the measurements which end on ...:SPEC? .

```
[:SENS]
  :AVER
    :COUN       <numeric_value>     Number of readings averaged
  :LIST
    :WAV        <numeric_value>{,<numeric value}     List of wavelengths to be set
    :POIN?      [query only]   Determine number of points
  :COL
    [:WHIT]     A|B|C|D50|D55|D65|D75|G|P|XE|DEF     White correction
    :ANGL       <numeric_value>     Standard observer (2° or 10°)
  :THIC
    :ANGL       <numeric_value>     Angle of incidence
    :REFR       <numeric_value>     Refractive index
  :WAV
    [:FIX]      <numeric_value>     Single wavelength
    :MODE       FIX|LIST
    :RANG
      [:UPP]    <numeric_value>     Maximum Wavelength
      :DEF      [no query]          Default: from 300nm...1100nm
      :LOW      <numeric_value>     Minimum wavelength
```

[:SENS]:AVER:COUN <numeric_value>

The number of readings which are averaged to increase the signal/noise ratio can be set with this command. The format is <NR1>.

[:SENS]:LIST:WAV <numeric_value>{,<numeric value}

Specifies the wavelengths (format <NR2>) in the list.

10.8 [:SENS]:LIST:WAV:POIN?

This query returns the number of points in the current wavelength list. This is particularly useful after a command :SENS:WAV:RANG.

[:SENS]:COL[:WHIT] A|B|C|D50|D55|D65|D75|G|P|XE|DEF

Defines the illumination type for colour measurements on objects which are not self-luminous.

Command	Designation	2° observer		10° observer	
		x	y	x	y
A	Standard light A (artificial illumination)	0.4476	0.4074	0.4512	0.4059
C	Standard light C (artificial daylight)	0.3101	0.3162	0.3104	0.3190
D65	Standard light type D65 (natural daylight)	0.3127	0.3290	0.3138	0.3310
B	Light type B (sunlight)	0.3484	0.3516	0.3498	0.3527
G	Light type G (vacuum filament lamp light)	0.4898	0.4149	0.4936	0.4135
P	Light type P (petroleum and candle light)	0.5376	0.4113	0.5407	0.4104
XE	Light type Xe (Xenon lamp)	0.3249	0.3271	0.3251	0.3294
D50	Light type D50	0.3457	0.3585	0.3477	0.3595
D55	Light type D55	0.3324	0.3474	0.3341	0.3487
D75	Light type D75	0.2990	0.3149	0.2997	0.3174
DEF	Colour type of the equal energy distribution spectrum (not a light type)	0.3333	0.3333	0.3333	0.3333

[:SENS]:COL:ANGL <numeric_value>

Sets the standard observer for colour measurements (2 or 10 for 2° or 10° standard observer respectively).

[:SENS]:THIC:ANGL <numeric_value>

Sets the incidence angle of the light ray (with respect to the perpendicular) for layer thickness measurements.

[:SENS]:THIC:REFR <numeric_value>
Sets the refractive index for layer thickness measurements.

[:SENS]:WAV[:FIX] <numeric_value>
Determines the wavelength whose spectrum is to be transmitted on :SENS:WAV:MODE FIX .

[:SENS]:WAV:MODE FIX|LIST
Determines whether only the spectrum on one wavelength (FIX) or the spectrum on all wavelengths in the list (LIST) is to be transmitted.

[:SENS]:WAV:RANG[:UPP] <numeric_value>
Sets the upper limit of the wavelength list.

[:SENS]:WAV:RANG:DEF
Sets the wavelength list to the entire available spectrum of the instrument.

[:SENS]:WAV:RANG:LOW <numeric_value>
Sets the lower limit of the wavelength list.

SYSTem subsystem

:SYST		
:ERR?	[query only]	Error interrogation
:LAMP	<Boolean>	Lamp on/off

:SYST:ERR?
Reads the contents of the error queue. The output format has the following structure
<Error/event number>, "<Error/event description>"

0,"No error"
No error has occurred.

-100,"Command error"
- The parser has detected a syntax error
- An unknown header has been received

-200,"Execution error"
- A parameter is out of range
- -256,"File name not found"
- -257,"File name error"

-300,"Device specific error"
All errors which are not a *command error*, *query error* or *execution error.*

-400,"Query error"
A problem has arisen with the *message exchange protocol.*

:SYST:LAMP <Boolean>
<Boolean> equals **1** switches-on the internal halogen lamp, <Boolean> equals **0** switches it off.

10.9 Program examples

Query type specification label

```
*IDN?
```

Query configuration

```
:CONF?
```

SCOPE measurement, calibrated - one measurement

- Reset instrument
- Measure the dark current
- Take and transmit a reading

```
*RST
:CONF:DARK 10
:INIT
:MEAS:SPEC:SCOP? 10
```

SCOPE measurement, calibrated - several measurements

- Reset instrument
- Measure the dark current
- Take and transmit readings

```
*RST
:CONF:DARK 10
:INIT
:CONF:SPEC:SCOP 10
READ:SPEC?
READ:SPEC?
READ:SPEC?
...
```

Calibration with standard light source

- Reset instrument
- Measure the dark current
- Select scope, uncalibrated
- Take and transmit a reading
- Transmit the pixel/wavelength association
- Calculate the calibration coefficients from the known spectral distribution and the measurement readings (using linear interpolation)

- Transmit the calibration coefficients to the spectrometer

```
*RST
:CONF:DARK 5
:INIT
:CAL:SPEC:STAT OFF
:MEAS:SPEC:SCOP? 5
:CAL:WAV:DATA?
... (calculation of the calibration coefficients)
:CAL:SPEC:DATA 300.3 13.324,303.4 10.834,...
```

Transmission measurement on a filter with averaging

- Reset the instrument
- Switch-on the lamp
- Set the number of values to be averaged
- Measure the dark current
- Measure the reference spectrum
- Take and transmit the reading

```
*RST
:SYST:LAMP ON
:AVER:COUN 100
:CONF:DARK 1
:INIT
:CONF:SPEC:REF 1
:INIT
:MEAS:SPEC:TRAN? 1
```

Extinction measurement for a liquid at selected wavelengths

- Reset the instrument
- Enter the desired wavelengths in the list
- Measure the dark current
- Measure the reference spectrum
- Take and transmit the reading
- Enter all wavelengths in the list

```
*RST
:LIST:WAV 380.0 560.0 570.0 780.0
:CONF:DARK 3
:INIT
:CONF:SPEC:REF 3
:INIT
:MEAS:SPEC:ALOG? 3
:WAV:RANG:DEF
```

Absorption measurement with arbitrary individual wavelengths

- Reset the instrument
- Measure the dark current
- Measure the reference
- Take the measurement reading
- Set FIX mode
- Transmit the measurement results at individual wavelengths
- Set the range
- Switch to list mode
- Transmit the measurement results for the range

```
*RST
:CONF:DARK 4
:INIT
:CONF:SPEC:REF 4
:INIT
:CONF:SPEC:ALIN? 4
:INIT
:WAV:MODE FIX
:WAV 300
:FETC?
:WAV 400
:FETC?
:WAV 500
:FETC?
:WAV:RANG:LOW 700
:WAV:RANG:UPP 900
:WAV:MODE LIST
FETC?
```

Colour measurement on luminous bodies with u' v'

- Reset the instrument
- Measure the dark current
- Take and transmit the reading (u' v')

```
*RST
:CONF:DARK 1
:INIT
:MEAS:COL:UV? 1
```

Colour measurement on surfaces with L*a*b*

- Reset the instrument
- Set the white reference value
- Measure the dark current
- Provide the white reference
- Measure the white level
- Provide the sample
- Take and transmit the reading (L a* b* C* h*)

```
*RST
```

```
:COL:WHIT D65
:CONF:DARK 1
:INIT
:CONF:COL:WHIT 1
:INIT
:MEAS:COL:LAB? 1
```

Colour comparison measurement according to CIELAB

- Reset the instrument
- Set the white reference value
- Measure the dark current
- Provide the white reference
- Measure the white level
- Provide the sample
- Take the reading
- Provide the sample
- Take the reading
- Calculate and transmit the result

```
*RST
:COL:WHIT A
:CONF:DARK 10
:INIT
:CONF:COL:WHIT 10
:INIT
:CONF:COL:REF 10
:INIT
:CONF:COL 10
:INIT
:CALC:DATA?
```

Layer thickness measurement

- Reset the instrument
- Measure the dark current
- Switch-on the lamp
- Enter the refractive index
- Enter the angle of incidence
- Mount the uncoated sample - measure as reference
- Mount the coated sample - measure the layer thickness

```
*RST
:CONF:DARK 1
:INIT
:SYST:LAMP ON
:SENS:THIC:REFR 1.5
:SENS:THIC:ANGL 10
:CONF:THIC:REF 1
:INIT
:MEAS:THIC? 1
```

10.10 Command abbreviations

ANGL angle
ALIN absorption linear
ALOG absorption logarithmic
AVER average
CALC calculation
CAL calibration
COL colour
CONF configure
COUN count
DARK dark current
DATA data
DEF default
ERR error
FETC fetch
FIX fix
IMM immediate
LAB L* a* b*
LAMP lamp
LIST list
LOW lower
LUV L* u* v*
MEAS measure
MMEM mass memory
MODE mode
POIN points
RANG range
READ read
REF reference
REFR refractive index
SCOP scope
SENS sense
SPEC spectrum
STAT status
SYST system
THIC thickness
TRAN transmission
UPP upper
UV u' v'
WAV wavelength
WHIT white

XY xy
XYZ X Y Z

11 Technical description

11.1 Optical specifications

Wavelength range

Module	displayed	specified
Standard	305 - 1150	360 - 900
UV-VIS	305 - 1150	305 - 900
VIS-NIR	305 - 1150	400 - 1150
UV-VIS-2	190 - 735	220 - 735
UV-VIS-2	200 - 400	220 - 400

Wavelength tolerance (standard module)

absolute 0.3nm

relative 0.1nm

Pixels (standard module) 256

Spectral resolution (standard module)

Rayleigh criterion 10nm

Intensity resolution

Y-axis 32768 (15 bits)

Sensitivity (standard module)

at 600 nm 10^{13} counts/Ws

Grating

Lines 366 lines/mm

Blaze wavelength	≈460 nm (standard module)
Entrance slit	2.5 x 70 µm
Temperature drift	< 0.02 nm/ °C
Light guide value	0.157 mm^2sr
Fibre cross-section	0.5 mm^2

11.2 Internal halogen lamp

Electrical ratings	2.6 V, 0.85 A
Light output	12 lumens
Colour temperature	2840 K
Service life	4000 h

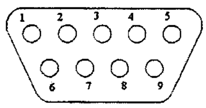
11.3 Serial data communication interface RS232

DATA FORMAT: 8 bit data format 8N1 (1 start bit, 8 data bits, no parity bit, 1 stop bit)

BAUD RATE: selectable 110 to 115200 Bd

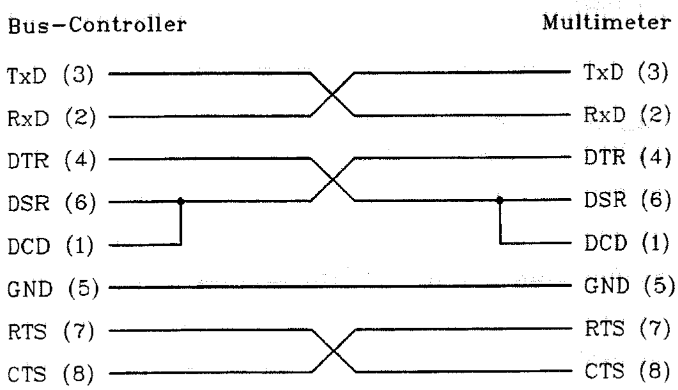
PLUG CONNECTOR TYPE: 9-pole Sub-D socket

PINOUT



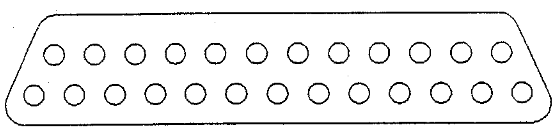
PIN No.	Direction	Signal	Description
1	Input	DCD (Data Carrier Detect)	
2	Input	RD (Receive Data)	Received data
3	Output	TD (Transmit Data)	Transmitted data
4	Output	DTR (Data Terminal Ready)	
5		GND	Signal ground
6	Input	DSR (Data Set Ready)	
7	Output	RTS (Request to Send)	
8	Input	CTS (Clear to Send)	
9	Input	RI (Ring Indicator)	

Plug connector pinout of RS232 cable



11.4 Printer interface, Centronics

PLUG CONNECTOR TYPE	25-pole SUB-D socket
CONFIGURATION	Various printers are supported
PLUG CONNECTOR PINOUT	Standard Centronics format



11.5 Digital I/O interface

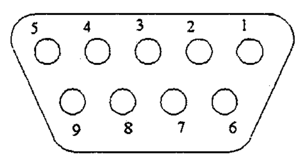
PLUG CONNECTOR TYPE 9-pole SUB-D socket

NUMBER OF LINES 8

INPUT VOLTAGE
Active Low:
VIH Min. -0.V Max. 0.V
VIL Min. 2.V Max. 5.V

OUTPUT VOLTAGE
VOH Max 0.4V
IOH 2.5mA
VOL Min. 3.0 V
IOL - 2.5mA

Plug connector pinout of the digital I/O interface



PIN	9	8	7	6	5	4	3	2
Signal	In	In	In	In	OUT	OUT	OUT	OUT

PIN 1 = Ground

11.6 Mass storage

HARD DISK	2 ½ inch hard disk with 80 MB storage capacity
MTBF	> 50 000 hours
MECHANICAL SHOCK	will tolerate up to 5 G in operation
VIBRATION	in operation (half sinewave)
5 to 27 Hz	0.25 mm (double amplitude)
28 to 500 Hz	0.5 G (peak)

11.7 General

SAFETY Complies with EN61010. The mains ground line is galvanically connected to the cabinet.

WARM-UP TIME ....approx. 1 hour

AMBIENT TEMPERATURE

In operation .... 10°C to 45°C
In storage.............................. -25°C to 60°C

RELATIVE HUMIDITY

In operation .... 20% to 75% (0°C to 25°C)
20% to 65% (25°C to 45°C)
In storage .... 10% to 90% (40°C)
Transport .... 5% to 95% (40°C)
in all cases non-condensing

POWER SUPPLY

Voltage .... 230V (can be switched over for 115V)

115V +15%, -22%
Mains fuse ratings 0.4A/115V

230V +15%, -22%
Mains fuse ratings 0.2A/230V

Power consumption .... typ. 30 VA /max. 40 VA
Frequency .... 47 to 63 Hz

WEIGHT .... approx. 8 kg

CABINET .... ½ 19-inch cabinet, 3 HU
Pressure die-cast aluminium

DIMENSIONS

Height	approx. 140 mm with feet
	approx. 135 mm without feet
Width	approx. 225 mm
Depth	approx. 375 mm

DIMENSIONS OF SHIPPING CARTON

Height	approx. 280 mm
Width	approx. 360 mm
Depth	approx. 510 mm

The packaging material is 100% suitable for recycling.

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