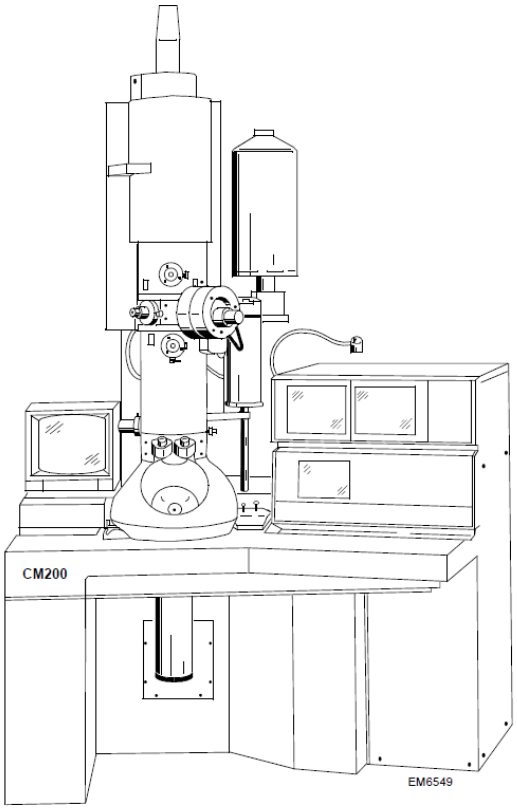
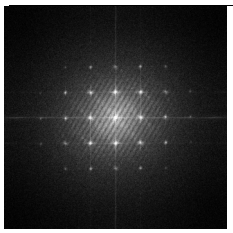
FEI™ Explore. Discover. Resolve.



CM 200
Operating Instructions



105053
Modification date: 17-Dec-2013

INTRODUCTION

The aim of this manual is to fulfill the needs of both the experienced Electron Microscope user who is familiar with the CM series and the first-time user. Detailed explanations of the controls and their functions are given together with information for starting up and obtaining the first image. Where necessary, descriptions are given of the optical and physical principles which are relevant to specific modes of operation.

The manual comprises the following sections:

Chapt. 1. : STARTING THE MICROSCOPE UP AND OBTAINING THE FIRST IMAGE

The instrument control logic is introduced and the path from instrument start up to obtaining the first image is shown as an example.

Chapt. 2. : MICROSCOPE OPERATION - THE TEM MODES

The various TEM modes are described. The instructions emphasise the electrical controls and are structured in a mode-by-mode sequence.

Chapt. 3. : MICROSCOPE OPERATION - THE SCANNING MODES

The various modes and their operation are described as in Chapt. 2. **They are only applicable to the CM200/STEM system.**

Chapt. 4. : MICROSCOPE OPERATION - MECHANICS AND VACUUM

Describes the handling of the specimen holders, the goniometer and the apertures. The operation of the vacuum system concerns handling the camera, filament exchange and the exchange of apertures.

Chapt. 5. : MAINTENANCE AND CLEANING

The design features of the CM200 ensure that maintenance activities are kept to a minimum. However, a few simple cleaning operations are included to ensure that the microscope is maintained at its optimum operating level.

Chapt. 6. : THE COMPUSTAGE

A full description of the features and use of the CompuStage, the five-axis motor driven goniometer. The method of working with various types of holders is explained, and also certain software aspects such as the Microcontroller screens and selectable function descriptions.

Chapt. 7. : ELECTRICAL AND MECHANICAL CONTROLS - LOCATION AND DESCRIPTION.

A listing of the controls, their names and functions. This section also includes an alphabetical index of the softkey labels on the control screen.

Chapt. 8. : HANDLING SF_6 GAS

Information concerning the handling of SF_6 gas which is used as insulating medium in the high-voltage tank and emission chamber of the CM200. See **WARNING** on the next page.

APPENDIX A : TROUBLE-SHOOTING LIST

This lists the possible error messages that may be displayed together with a description and what action to take to return to normal operating mode.

APPENDIX B : ALIGNMENT OF THE TRANSMISSION ELECTRON MICROSCOPE

A self-contained description covering the complete alignment of the CM series TEMs, grouped according to ***type*** - deflection coils, objective lens, stigmators, etc. - and not their physical ***location*** in the microscope or their position in the overall sequence of alignments. Intended as a guide to the understanding of general principles

USER'S COMMENTS FORM

It is an important part of Electron Optics policy of continuous improvement to encourage the user to advise us of any comments concerning specific questions of using the microscope or about this manual.

The comments form is located in the Appendix and should be addressed to:

Philips Electron Optics
Application Laboratory
Bldg. AAE-p
5600 MD Eindhoven
Eindhoven - The Netherlands

WARNING!

1) ***X-Ray safety***
To ensure security from ionising radiation, the CM200 is equipped with specially designed shielding and covers. These should only be removed when carrying out service procedures (see Service Instructions). *DO NOT SWITCH ON THE HIGH TENSION SUPPLY AT ANY TIME WHEN THE COVERS OR SHIELDING ARE REMOVED.*

2) ***Working with SF_6 gas***
SF_6 gas is used as an insulating gas in the high voltage tank and emission chamber of the CM200. When a fixed gas supply is not installed, follow the procedure advised by your local service engineer.
Full information concerning the correct handling of SF_6 gas is given in Sect. 8.

CONTENTS

CONTENTS (CONT'D)

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CONTENTS (CONT'D)

ILLUSTRATIONS

ILLUSTRATIONS (CONT'D)

LIST OF TABLES

1 STARTING THE MICROSCOPE UP AND OBTAINING THE FIRST IMAGE

1.1 INSTRUMENT CONTROL LOGIC - THE OPERATOR'S CONSOLE (see Fig. 7.2)

One of the major design features of the CM200 is the simplification of the control components which has led to a significant reduction in their number. These controls form three groups:

- Knobs
- Pushbuttons
- Keys

There are knobs which can be turned, pushbuttons in various positions and a set of 18 keys around the control screen on the right-hand panel. Two of these keys have permanent labels (RESET and READY) but the remaining eight keys on either side of the control screen only receive labels when the microscope is switched on. Each label is displayed next to the key it describes. There follows a short explanation on the use of these controls.

Using the knobs

The controls can be explained in terms of a basic electron microscope having the primary functions of Magnification, Intensity (image brightness) and Focus (image sharpness). These functions correspond to three dedicated lenses:

Function	Performed by
Magnification	Projector lens
Intensity	Condenser lens
Focus	Objective lens

In modern microscopes, these lenses can be two or more lenses working together. The specific function assigned to one lens, e.g. focussing, can change when the microscope is being used under different optical conditions. However, the three basic functions will always be involved when obtaining an image and it is logical to assign the function names MAGNIFICATION, INTENSITY, FOCUS and to ensure that the correct lenses or combinations are addressed in the various microscope modes. To be consistent, there cannot be a fixed connection between the function knob and a specific lens since the lens which is used for the function changes with the different modes selected. As an example, the lenses assigned to the focussing function are shown below. The focussing function is dependent on the optical mode of the microscope.

Mode	Focussing performed by
Imaging in M/SA magnification range	Objective lens
Imaging in LM magnification range	Diffraction lens
SA Diffraction	Diffraction lens

In the case of the scanning mode in a TEM/STEM system, the focussing functions are as shown below:

Mode	Focussing performed by
Imaging in HM magnification range	Objective lens
Imaging in LM magnification range	Second condenser lens

The CM200 uses a microprocessor to interpret input so the user does not have to record the particular optical working conditions.

The same principle as applied to FOCUS is used with the MAGNIFICATION knob to control the magnification of any type of image or diffraction pattern. The actual magnification is displayed in the information field of the control screen using the usual dimensions, i.e .....X for the image magnification and .....mm for the magnification of the diffraction pattern related to camera length.

The Multifunction knobs

The FOCUS and MAGNIFICATION knobs use the concept of assigning various optical components to a certain knob to achieve the same function in every condition. The MULTIFUNCTION knobs expand this concept in that the function itself may change. This change can be caused automatically by the microscope control system or manually by the operator.

An example of automatic change occurs with all the alignment procedures. Most of the alignments in the CM200 can be carried out electromagnetically. When stepping through an alignment procedure, a number of different alignment functions must be performed. These functions will be automatically assigned to the MULTIFUNCTION knobs so the user only needs to use the same set of two MULTIFUNCTION knobs. The alignment instruction will say:

Centre the illumination with the MULTIFUNCTION knobs

The operator may also assign functions to the MULTIFUNCTION knobs by using the STIG, DF and ALGN pushbuttons. The STIG (Stigmator) pushbutton controls the appropriate stigmator for the objective or diffraction lens and DF (Dark Field) provides beam tilt for Dark Field imaging. The ALGN (Alignment) pushbutton calls up the alignment function referred to previously. In order to indicate that one of these functions is active on the MULTIFUNCTION knobs, the green LED above the pushbutton is lit whenever that function is selected.

Using the Pushbuttons

When a pushbutton is pressed, it gives a single information pulse to the microscope control system which then performs the requested action. To switch off or stop this action, it is necessary to press the button a second time. An example is if the STIG button is pressed, the green LED lights up and the (optically appropriate) stigmator function will be assigned to the MULTIFUNCTION knobs. To terminate this function, the same STIG button must be pressed once again. A green LED above each of these buttons indicates if they are on or off.

A pushbutton may be switched off by the microscope when a conflict arises, e.g. when ALiGNment is selected with Dark Field on or the WoBbLer when an exposure is made.
Some pushbuttons are only used to generate a single pulse and do not need switching off. Those pushbuttons either have no associated LED or the LED does not light up. Examples are the ReSeT button to the left of the FINE INTENSITY control (this focusses the electron beam) or the EXPOSURE button when the main screen is down (performing a lens normalisation).

Using the Keys and Control Screen

The third type of control element is the keys associated with the Control Screen. These 16 keys are located on either side of the screen. The label for each key is displayed next to it on the screen. Because these labels can change, the keys are described as Softkeys.

The Microcontroller

The control screen, softkeys, pushbuttons and knobs give access to the functions of a microprocessor-based control system which records all operator inputs and directs them to the relevant device associated with the selected mode. It also ensures that user-defined settings of lenses and alignments are automatically recalled when switching between different modes. The interactive control screen and associated systems are known as the Microcontroller. The Microcontroller has two basic functions:

- Provide microscope status information
- Accept commands from the operator

The main difference between the softkeys and the pushbuttons is that the pushbuttons are used during operation in a specific mode while the Microcontroller softkeys can change the operational mode. The operator can select or change a parameter for the working mode. The Microcontroller is also used to instruct the instrument to employ some initial settings, i.e. the information to be printed on the photographic plates or details of the apertures which are installed in the aperture holders.

A typical screen display is shown in Fig. 1.1. All such displays are headed by a title and referred to as a Page. The central part of the Page between the two vertical lines contains details of the most significant parameters of the present state of the microscope. The text underneath Fig. 1.1 explains the content of the information fields.

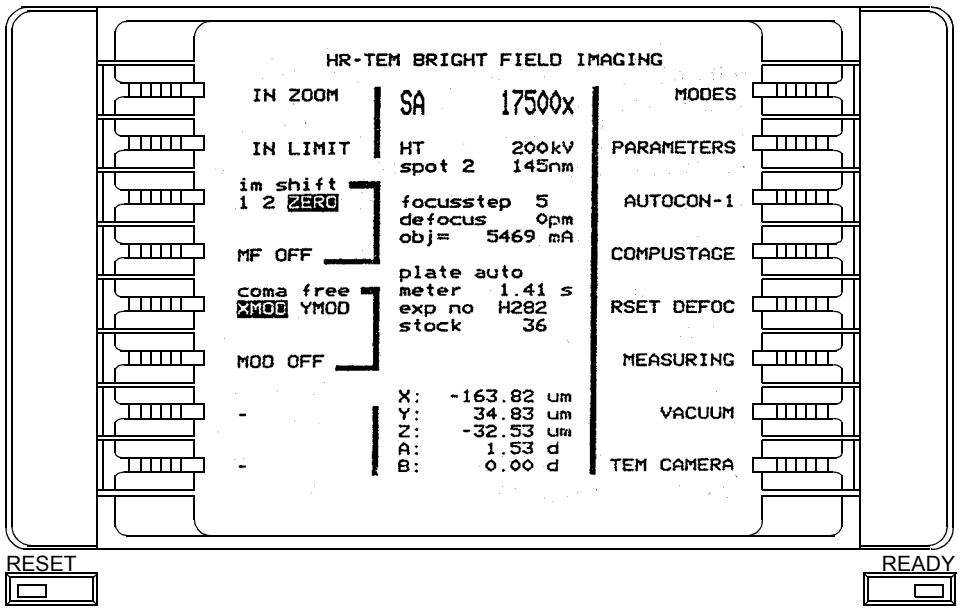


Fig. 1.1, TEM BRIGHT-FIELD page

The central information field

- **17500x** is the magnification in use.
- **SA** indicates the **S**elected **A**rea mode is in use.
- The **H.T.** selected is **200 kV**.
- The SPOT SIZE knob is set to step **2** giving a **SPOT** size of **145 nm** when the beam is focussed on the specimen.
- The value of under or overfocus is given (**defocus 0 pm**).
- The **FOCUS STEP** is the sensitivity of the FOCUS knob (focus change per click).
- The recording medium selected is the **PLATE** camera
- The exposure timer is in **AUTO**matic mode
- The exposure **METER** determines an exposure time of **1.41 s**.
- The **EXP**osure **No.** (number) of the last plate exposed is **H282**. This number will be increased by one digit for each plate recorded
- The **stock** of unexposed plates is **36**

The softkey labels and the highlight facility

The softkey labels identify the selections available to the respective keys. When a softkey is pressed, the system can acknowledge this in two ways:

- The contrast of a label is reversed, i.e. changed to black letters on a bright background (highlighting) or vice versa.
- The page content changes.

When a label is highlighted, this indicates that the corresponding function is operational. For example, INT ZOOM could be highlighted indicating that the illumination system will automatically zoom the intensity control so that the brightness on the observation screen is kept constant when changing the magnification (within a certain range). To disable the INT ZOOM feature, press the key again and the highlighting will disappear.

Setting parameters

Another page would be displayed if PARAMETERS was keyed (see Fig. 1.2). On this PARAMETERS page several operational parameters can be set to the desired value. Again, the value which is currently valid is highlighted.

In this example, the EMISSION is set to 1 and the HIGH TENSION is set to 200 kV. To change these parameters, press the left-hand key to move the highlight to the left and the right- hand key to move the highlight to the right.

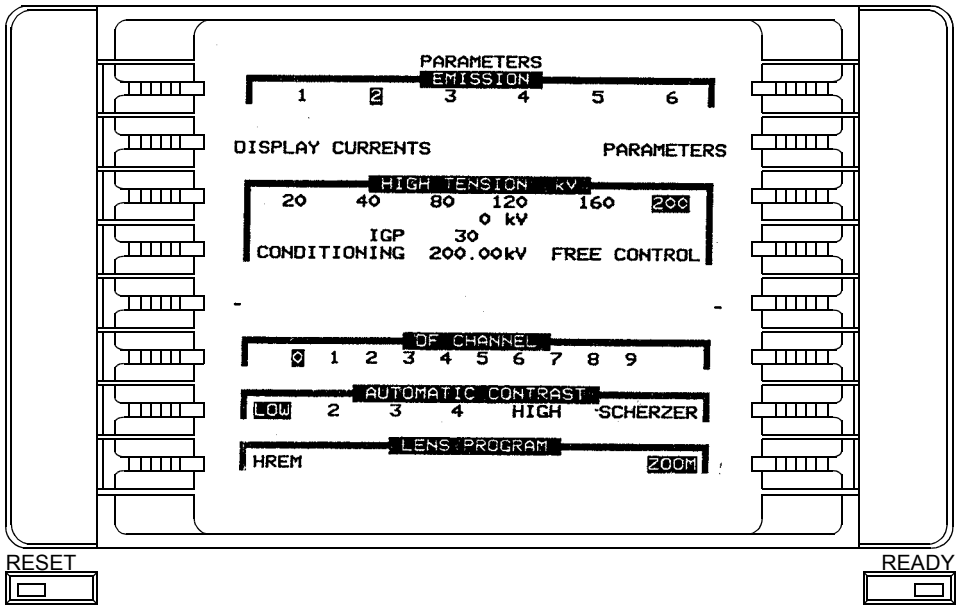


Fig. 1.2, PARAMETERS Page

The CAMERA INITIATION page (see Fig. 1.3) shows another way of setting a parameter . The EXPosure number printed on the last plate used is E009. This number appears on the central information field. It also appears under the EXP NO label on the left-hand side of the screen. To begin with another exposure number, key the appropriate figures using the associated softkeys.

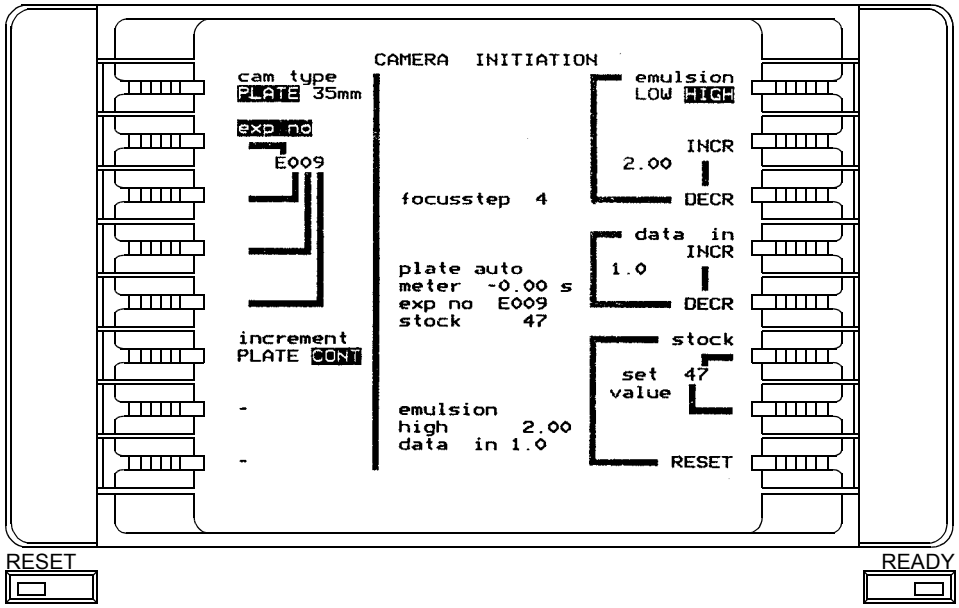


Fig. 1.3, CAMERA INITIATION Page

RESET, READY and the LEDs

When the operator has finished an action and wishes to continue, the READY key should be pressed. This will occur, for example, after having set the PARAMETERS or after carrying out the CAMERA INITiation. The instrument will then return to the operational page displayed previously.

In an alignment procedure, the READY key is used to instruct the Microcontroller that a particular step has been carried out and that the next should be taken.

The RESET key is used to clean the control screen after the Microcontroller has issued a message that has overwritten a part of the current page. The RESET key can also be used to set the MULTIFUNCTION knob values to a default (central) position.

The yellow LEDs in the RESET and READY keys indicate whether these keys are active and able to respond to commands. If there is nothing to be reset or no reason to indicate that a procedure is ready to proceed further, the instrument will not expect a READY or RESET input and the LEDs will be switched off.

The Microcontroller also uses the BEEP (sound) signal when it wishes to communicate with the operator. The BEEP will be heard when a pushbutton being pressed or a control knob being turned is inactive, e.g. the filament when the high tension is still off or when a knob has reached the end of its range. There is no mechanical stop and further rotation of the knob is harmless. The BEEP signal ceases as soon as the turning stops. When turned in the opposite direction, it is immediately in range again. (This facility applies to all knobs with the exception of the GONIOMETER control knobs on the left-hand panel). The BEEP signal is also used as a warning before the electron optical configuration of the microscope is radically changed, e.g. the LM-M magnification change and vice versa.

1.2 OPERATIONAL EXAMPLE: THE TEM BRIGHT FIELD IMAGING MODE

The following example is an introduction to the operational features of the CM200 and describes the basic steps required to obtain a TEM Bright Field image and make a TEM micrograph.

1. Start the microscope up by pressing the MICROSCOPE ON button. (If more information about start up is required, see Sect. 4.1.1).

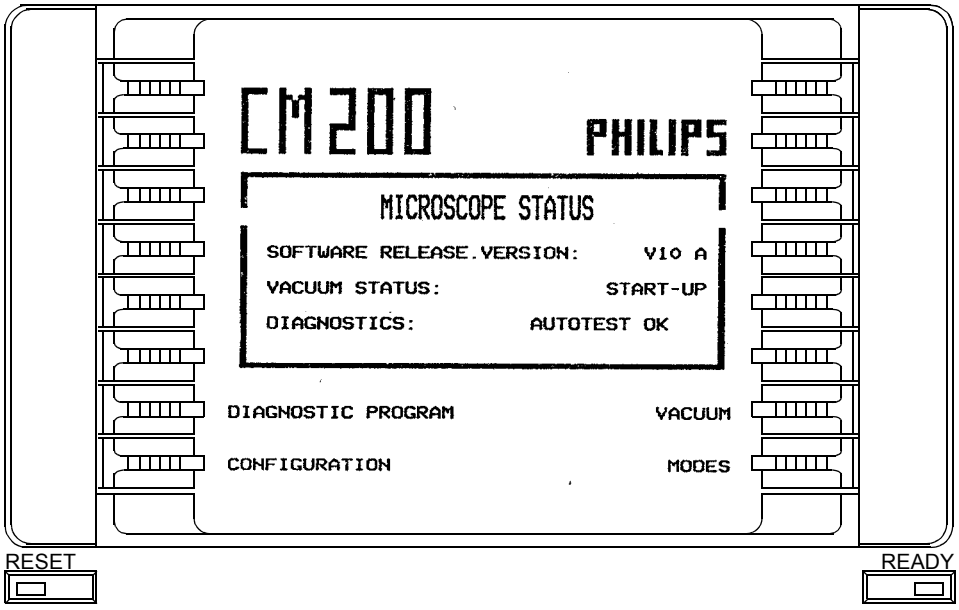


Fig. 1.4, START UP page

2. Key MODES on the START UP page and display the MODE SELECTION page.

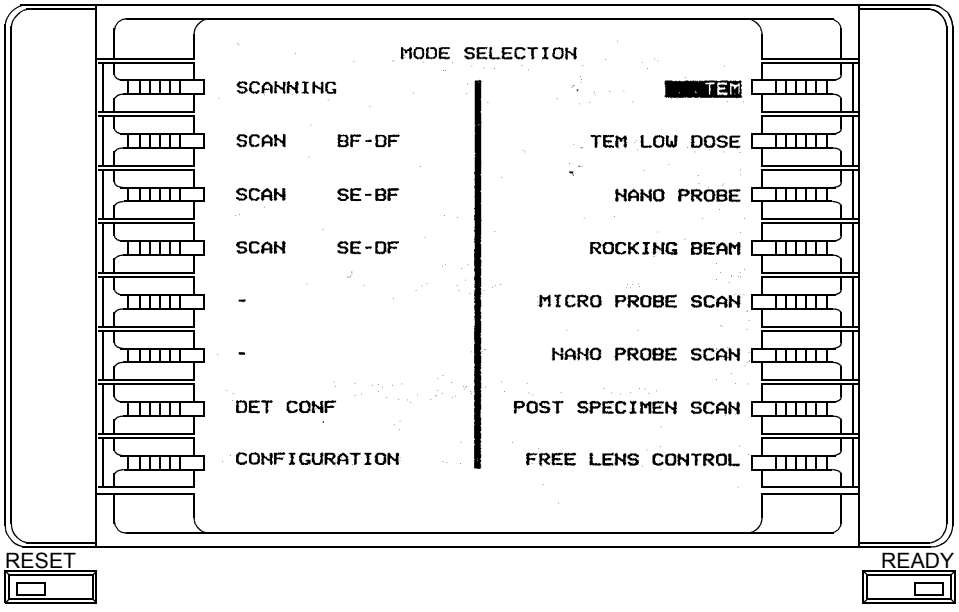


Fig. 1.5, MODE SELECTION page

Note: The page shown in Fig. 1.4 may contain different softkey labels than those shown. This is dependent on the configuration of the microscope.

3. Key TEM on the MODE SELECTION page. If TEM mode was previously selected, the letters TEM will be highlighted. Key TEM and the TEM BRIGHT FIELD page will be displayed immediately. If another mode was selected previously, the letters TEM will not be highlighted. In this case, proceed as follows:

   - Key TEM once and the letters TEM will become highlighted, indicating that the TEM mode is selected.
   - Key TEM a second time and the TEM BRIGHT FIELD page will be displayed.

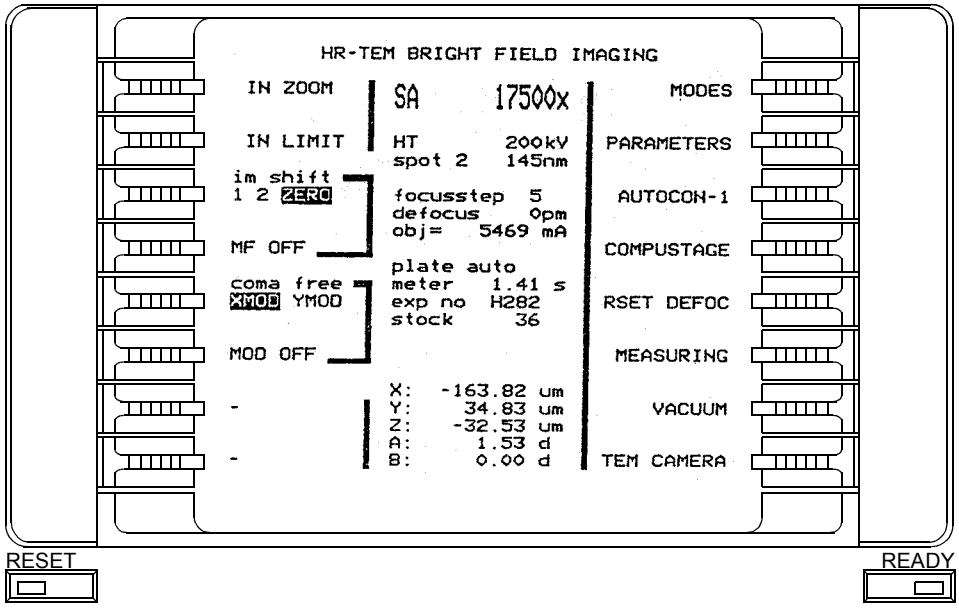


Fig. 1.6, TEM BRIGHT FIELD page

4. Observe the information field and define the H.T. required. The H.T. can be changed on the PARAMETERS page.
5. Key PARAMETERS on TEM BRIGHT FIELD page. The PARAMETERS (1) page will be displayed.
6. Key operating ranges/conditions on the PARAMETERS (1) page.
   To adjust a numerical range, key as follows:

   - Left-hand side for lower value
   - Right-hand side for higher value

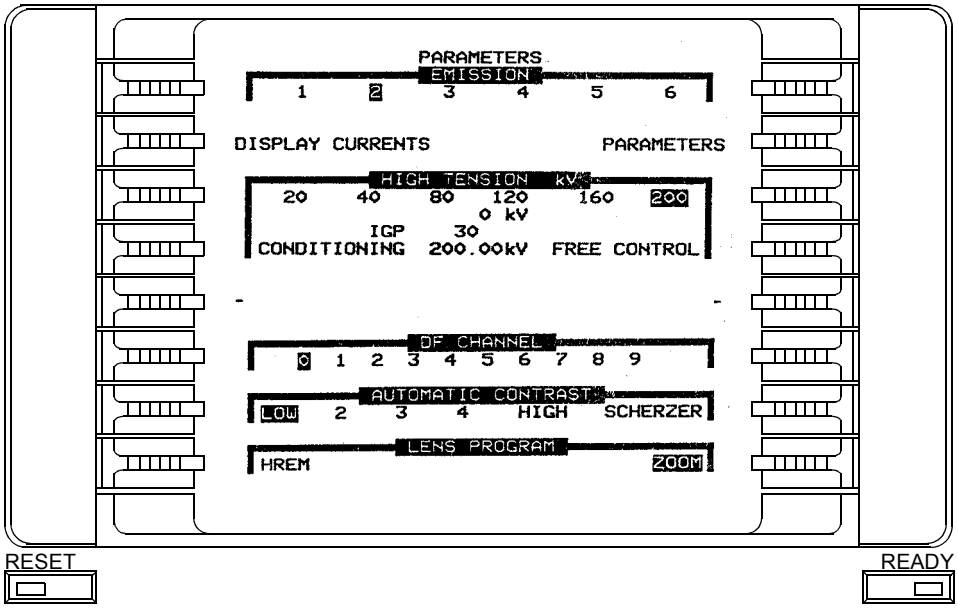


Fig. 1.7, PARAMETERS page

7. After setting the parameters press the READY key to return to the TEM BRIGHT-FIELD page.
8. Check that UHV (Ultra-High Vacuum) indicator is illuminated (if not, wait until it is).
   Press the HIGH TENSION ON/OFF button. The HIGH TENSION indicator will illuminate indicating that the high voltage is switched on.

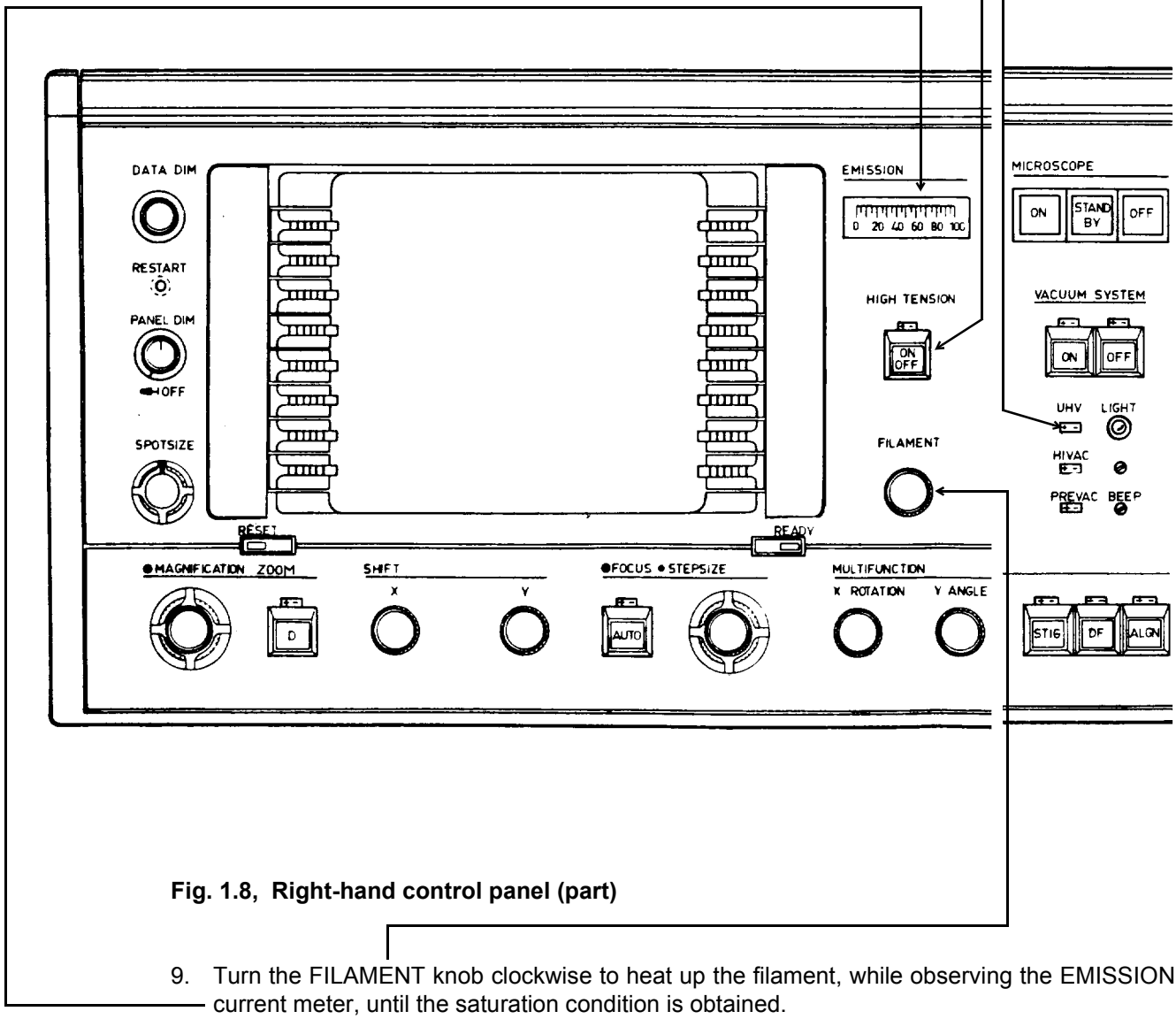


Fig. 1.8, Right-hand control panel (part)

9. Turn the FILAMENT knob clockwise to heat up the filament, while observing the EMISSION current meter, until the saturation condition is obtained.
   The Microcontroller will emit the BEEP signal when the filament heating has reached the FILAMENT LIMIT which is preset on the CONFIGURATION page.

   Note: The MICROCONTROLLER will increase the filament current at a rate which ensures a smooth warming-up of the filament. The delay time per FILAMENT step is 0.1 s with TUNGSTEN and 5 s with LaB_6. If LaB_6 is selected on the CONFIGURATION page, the MICROCONTROLLER will run the filament more slowly to the desired value. This is to safeguard LaB_6 filaments against thermal stress. The FILAMENT knob may be turned more quickly, since the MICROCONTROLLER memorises the number of steps selected. (For further information, see Sect. 2.4).

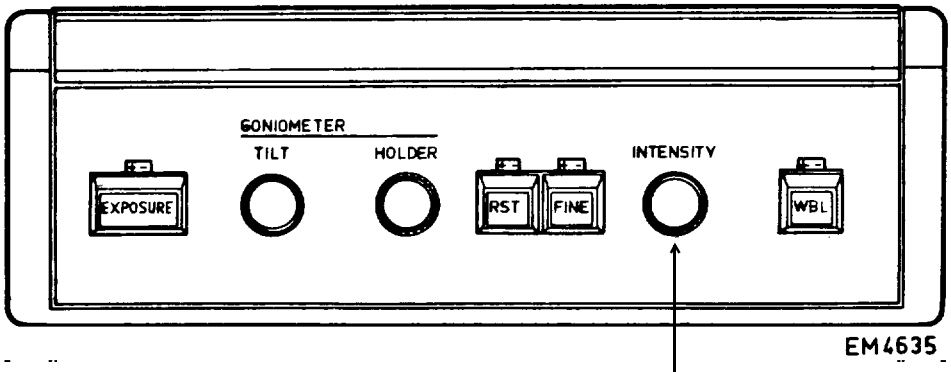
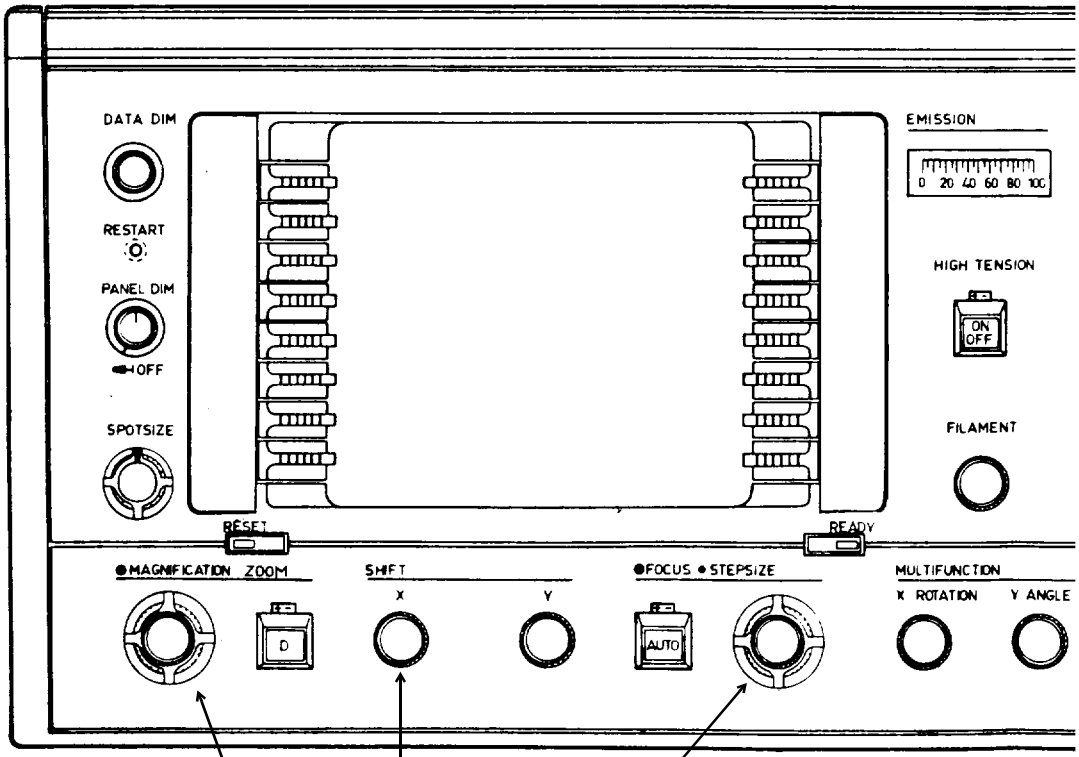


Fig. 1.9, Left-hand control panel

10. Use the INTENSITY and SHIFT knobs to adjust the illumination



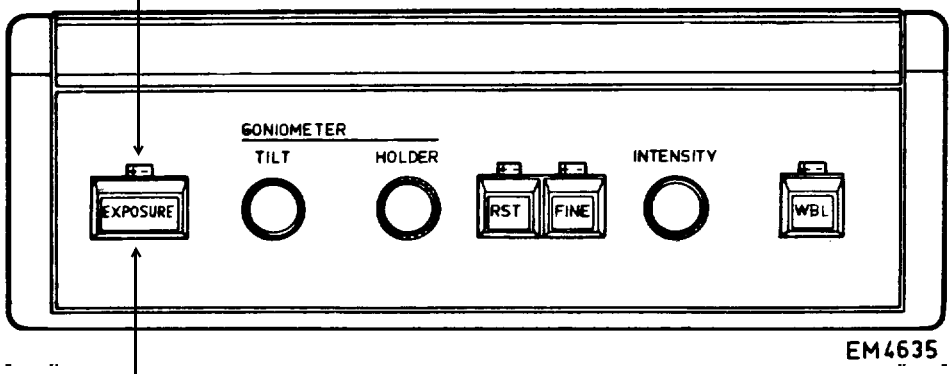
and the MAGNIFICATION and FOCUSSING knobs to adjust the image as required. To insert a specimen, see Chapter 6.

11. Raise the main projection screen or bring the 35 mm camera into position. The EXPOSURE indicator will light up to indicate that everything is ready to take a micrograph. However, the system will recognise when the illumination condition is not suitable:

    - The meter indication on the information display will read XXX.

    When there is no recording material available for the camera selected:

    - The stock indication on the information display will read 00.



12. Press EXPOSURE button:

    - The EXPOSURE indicator is extinguished.
    - The exposure is made.
    - The EXPOSURE indicator illuminates.

13. Lower the main projection screen or remove the 35 mm camera from the beam.

14. For more information about the system status or to change parameter settings, key PARAMETERS.

15. Press the READY key to return from the PARAMETERS page to the TEM BRIGHT FIELD page.

    When a specimen image has been obtained in the TEM Bright Field mode, it is then easy to obtain and optimise other types of images. The following section descibes the procedure for the other common mode of operation available on the standard STEM instrument.

1.3 OBTAINING THE FIRST SCANNING BF/DF IMAGE

This section is an example to illustrate the instrument control logic. It describes the path from the TEM image (obtained as a result of following the instructions given in Sect. 1.2) to the Bright Field/ Dark Field scanning image.

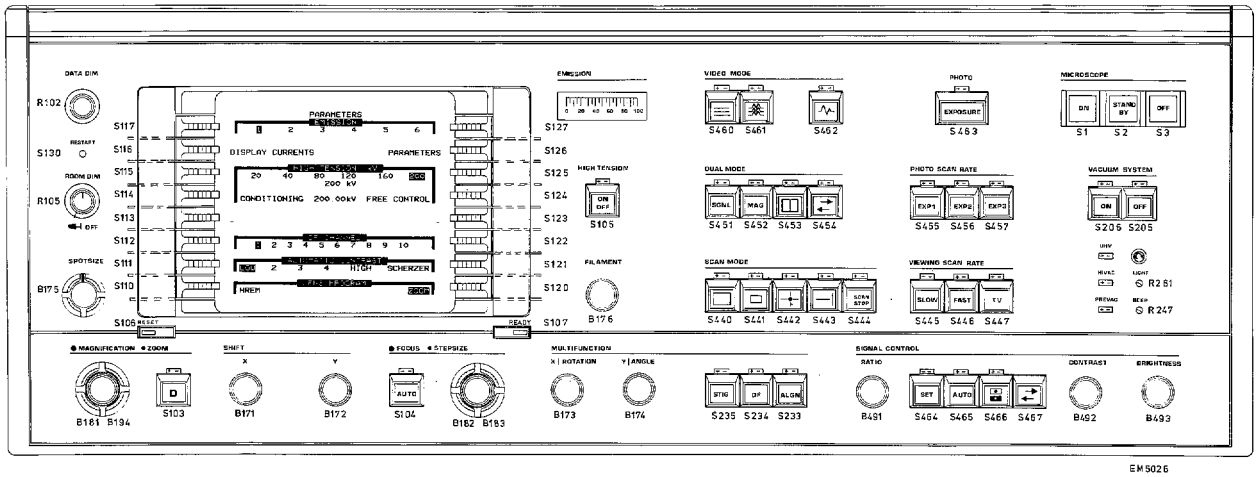


Fig. 1.10, Right-hand control panel

1. Obtain a TEM image as described in Sect. 1.2 and accurately centre a Condenser aperture (e.g. 50 mm, see Sect. 2.6.4).

2. Key MODES. The MODE SELECTION page will be displayed.
   Key SCAN BF-DF. The SCANNING page will be displayed.
   Remove the Objective aperture.

3. If necessary, centre the diffraction pattern on the main screen. Press the ALiGNment button and shift the diffraction pattern (DIF SHIFT) using the MULTIFUNCTION knobs. Once the diffraction pattern is centred, press the ALiGNment button again to leave the alignment page.

4. Select the required magnification and a suitable spot size, e.g. magnification 10 000x and spot size 6).

5. Select FAST scan rate (the line time and number of lines can be adjusted on the PARAMETERS 2 page) and cover the projection chamber window or reduce the light level in the microscope room. Operate at dimmed room-light level.

6. Lift the main screen. The spot should be shifted to the near-axis position as the screen is lifted. If this does not occur, press the ALiGNment button and select DET ALIGN then shift the spot to the appropriate position using the MULTIFUNCTION knobs. Also check the defaults under the DET CONF page (see Sect. 2.7).

7. Adjust Contrast and Brightness for the activated monitor, i.e. the monitor with the green LEDs illuminated. Keying DETECTOR CONTROL exchange (S467) will switch the LEDs to the other monitor.

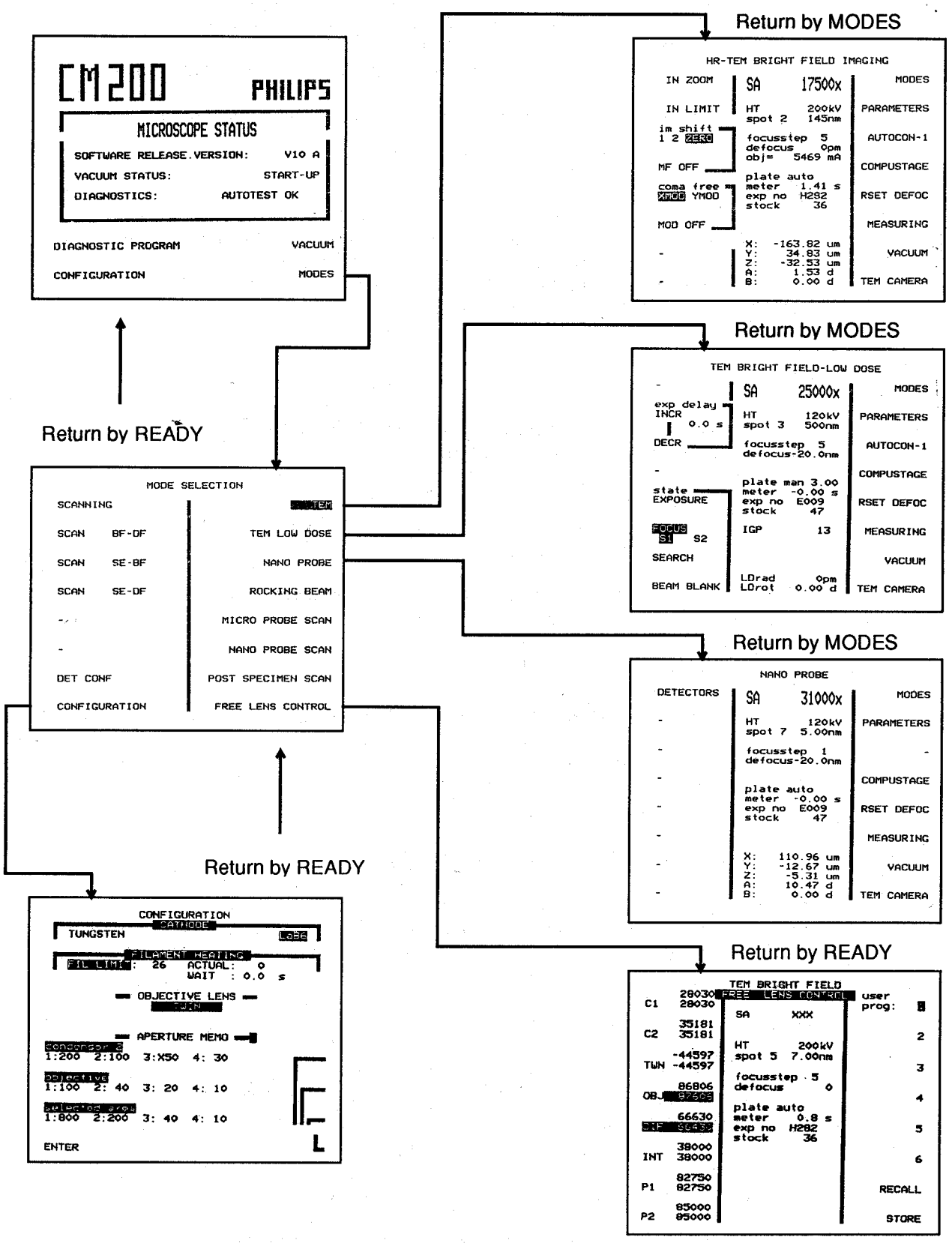
8. Press SIGNAL CONTROL SET (S464) to quickly set contrast and brightness levels. Wait until the SET LED is extinguished. If necessary, adjust the SIGNAL CONTROL CONTRAST (B492) and BRIGHTNESS (B493) knobs to optimise the bright field image.
   Press the DETECTOR CONTROL exchange button (S454) to switch the image controls to the dark field image on the right-hand monitor. The LEDs below this monitor will be illuminated indicating that it is active.
   Press SET and wait until the LED is extinguished. Adjust the CONTRAST and BRIGHTNESS controls to optimise the dark field image.

9. SHIFT X,Y knobs shift the image on the monitor.
   MULTIFUNCTION X/ROTATION knob rotates the image on the monitor when the ALiGNment and STIGMator buttons are inactive.

   Refer to Sect. 7.1.3 for further explanation of the STEM mode controls on the right- hand control panel.

2 MICROSCOPE OPERATION - THE TEM MODES

2.1 MODE SELECTION



Mode page selection overview - TEM modes, Fig. 2.1a

2.2 TEM OPERATIONAL MODES - OVERVIEW OF THE AVAILABLE PROCEDURES

The MODE SELECTION page gives access to the different operational modes available. Fig. 2.1 shows an overview of all possible page relations from the MODE SELECTION for a CM200/STEM microscope that has been configured for all available functions. Underneath each page is an indication of how to return to the MODE SELECTION page.
A similar overview for the SCANNING modes (for CM200 with STEM) is shown in Fig. 3.1.

The sections referred to in parentheses describe the operational procedures.

Bright Field Imaging (2.2.1)

- TEM imaging of the specimen with the Objective lens as the first magnifying lens (high magnification) indicated by M or SA on the control screen display.
- TEM imaging of the specimen with the Diffraction lens used as an objective lens (low magnification) indicated by LM on the readout.

HR-TEM (2.2.1b)

- Minimizes change in electron optical Parameters in HM range
- Fine image shift in High Resolution mode
- Scherzer focus

Bright Field Diffraction (2.2.2)

- TEM imaging of the diffraction pattern formed by the Objective lens in the M-SA mode (standard diffraction mode).
- Low-angle diffraction.

Dark Field Imaging (static and conical) and Diffraction (2.2.3, 2.2.4, 2.2.5 and 2.2.6)

- The illuminating beam in M-SA or LM is set at an angle to the microscope axis. The angular deviation can be set in x, y or in azimuth and tilt.

Low Dose (2.2.7 and 2.2.8)

- For beam-sensitive specimens, a photographic exposure can be carried out with exposure conditions, area of the specimen selected and magnification setting different from those used for the initial adjustments.

Free Lens Control (2.2.9)

- The values of all lens currents can be arbitrarily chosen. The starting values are those of the last mode selected. It is not possible to enter values that are harmful to the microscope.
- Up to 6 different lens settings can be stored and recalled at will.

Nanoprobe (2.2.10)

- M-SA imaging by a symmetric condenser-objective lens with the possibility to form very small spots (mini-condenser lens switched off).

2.2.1 HR-TEM Bright field imaging

The HR-TEM BRIGHT FIELD mode is the basic imaging mode.An extended operational example is discussed in Sect. 1.2.

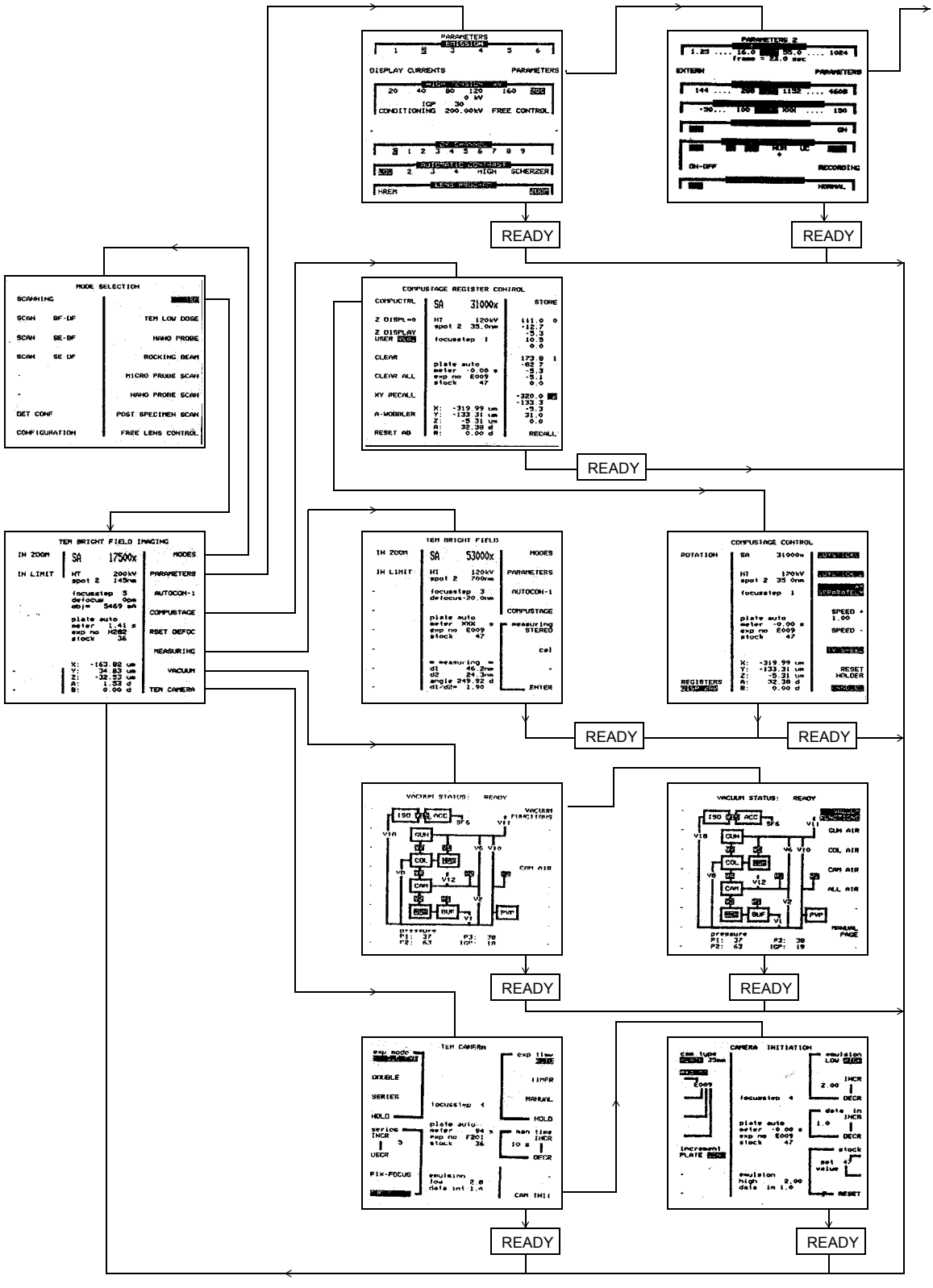
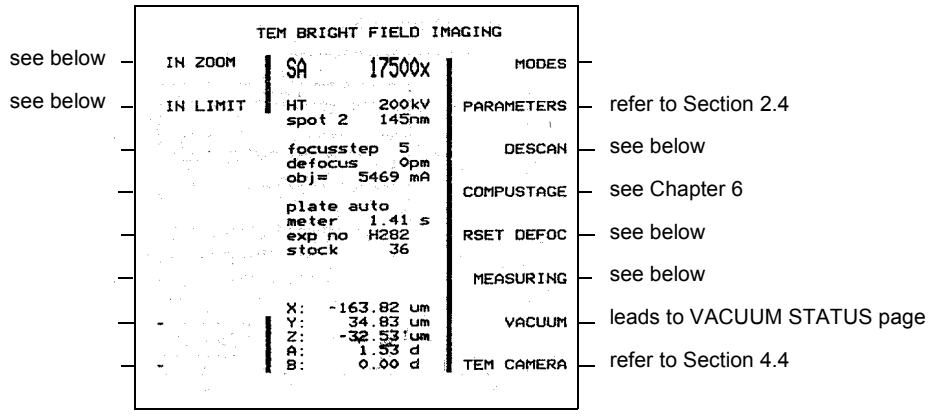


Fig 2.1b, Overview of the TEM Bright Field page showing the other pages which can be selected

Entering the HR-TEM mode the Microcontroller displays the following page:



FUNCTION OF THE SOFTKEYS

INT ZOOM

Function : When highlighted, the image brightness on the screen is kept constant when the magnification is changed. However, when going to very high magnifications, the screen brightness will start to decrease when the fully focused illumination condition is reached.

Operation : After the screen brightness is set to the desired level by using the **`Intensity`** and SPOT SIZE controls, press INT ZOOM. The function is active when highlighted.

INT LIMIT

Function : Protects a beam-sensitive specimen from an excessively high current density.

Operation : Overfocus the **`Intensity`** (turn clockwise) and then go towards focused illumination. When the required maximum current density is reached, key INT LIMIT. As long as it is active (highlighted), focusing the illumination further than this preset limit will be prevented and the microscope beeps.

AUTOCON-1...5/SCHERZER

Function : If activated, automatically applies a preselected amount of underfocus of the objective lens for contrast control.

Operation : Focus the image (using the wobbler focussing aid, if desired) to minimum contrast. Then key AUTOCON/SCHERZER to activate the underfocus. On the first PARAMETER page, one of the six available automatic contrast settings can be chosen. Pressing the softkey again deactivates the function and sets the focus back to the previous value.

Note: The AUTOCON/SCHERZER defocus is automatically suspended if the WoBbLer pushbutton is pressed. This allows checking and readjusting of the focus while AUTOCON/SCHERZER is selected. When AUTOCON/SCHERZER is highlighted and refocussing has been carried out, the amount of defocus displayed in the information field is incorrect.

COMPUSTAGE

Function : Leads to COMPUSTAGE REGISTER CONTROL page if 2D & 5D recall function is incorporated. Access to storage/recall of positions and α-wobbler. If no 2D & 5D recall function is installed, this softkey leads to the CompuStage page with access to the α-wobbler and to all other functions for controlling the CompuStage, such as speed and rotation correction. Detailed information about the operation of the CompuStage can be found in chapter 6.

Operation : Key **COMPUSTAGE**.

RSET DEFOC

Function : Resets the defocus readout on the microcontroller screen page to 0 pm. This does not change any lens currents.

Operation : Key **RSET DEFOC**.

Note: Defocus is automatically set to 0 pm if the wobbler is used for focussing.

MEASURING

Function : On-line image measurement of distances and angles between image points.

Operation : See Sect. 2.3.6 for detailed explanation and examples like on-line thickness determination.

2.2.1b The HR-TEM operating mode

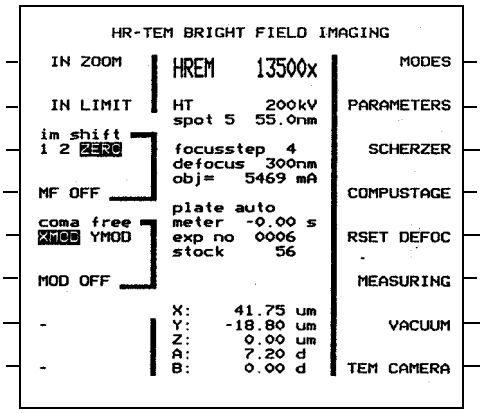
Three different types of lens programs are selectable on the PARAMETERS page (see Fig. 1.7). For high tension voltages ≤160kV the STEREO and ZOOM programs are available, while for 200kV the lens programs HREM and ZOOM are selectable. The ZOOM program minimises the change in defocus with change in magnification, while the HREM program minimises the change in electron-optical parameters in the high magnification range.

The ZOOM program contains from low to high magnification first several M magnifications, then a large number of SA magnifications and then again several M magnifications. In the SA magnification range, the first intermediate image plane coincides with the Selected Area (SA) aperture plane, which is the optimum condition for selected area diffraction. The lowest and highest magnifications cannot be achieved in SA mode, hence the M magnifications at the low and high ends.

At the switch-over point between SA and M magnifications, the objective lens current is changed somewhat, leading to possible changes in objective lens alignment , especially defocus and astigmatism. In order to avoid these changes in high-resolution imaging, the dedicated HREM lens program has been implemented. This lens program provides an almost continuous M magnification range, eliminating the switchover point. It is therefore advisable to work in the HREM range for high-resolution imaging. It is, however, perfectly acceptable to work in the ZOOM lens program, especially when the magnifications used remain below the switch-over point.

The HREM lens program is not compatible with the nanoprobe mode and the microscope will display an error message when switching from HR-TEM to nanoprobe with the HREM lens program active. Simply proceed to the PARAMETERS page and switch from HREM to ZOOM. The message is removed by pressing the **`Reset`** button.

The HR-TEM mode offers several additional functions that are useful for high resolution imaging. On activating HREM on the PARAMETER page, the microcontroller shows the following display:



High-resolution image shift (softkey **`im shift`**
`1 2 ZERO`*)*

For very fine movements of the image over small distances with a very fine control, an image shift is available on the HR-TEM operational page. In order to retain the optimum imaging conditions, the image shift is combined with a beam shift so that the area observed is always illuminated by the centre of the beam. The image shift is limited to a few hundreds of nanometres.

The image shift has a ZERO setting (no shift) and two independent channels 1 and 2, each of which has its own image shift setting and a coupled beam shift. With the two channels it is possible, e.g., to set one channel at the edge of the specimen to check for astigmatism, coma-free alignment and focus, and the other setting to move around on the specimen to search for a suitable area for high-resolution imaging.

In general, the image shift should be left at ZERO when not at high magnification, and the channels 1 and 2 should be reset to the zero position periodically.

Calibration of the image/beam shift is done in the IMAGE/BEAM procedure on the SERVICE CALIBRATION page in the ALIGNMENTS. Press **ALGN, SERVICE CALIBRATE** and **IMAGE/ BEAM** to start the procedure, and follow the instructions.
When the **Multifunction** X-Y knobs are needed for another function such as alignment and stigmation, they will be switched automatically from image shift when the new function is selected (the reverse contrast highlight of image shift is turned off), but the image shift will remain active. Sometimes it is necessary to switch the **Multifunction** knobs off, e.g. when operating in dark-field with an image shift active. In this case the softkey **MF OFF** must be pressed and the highlight will be removed from the image shift softkey label. The image shift itself will remain as set.

Direct coma-free alignment (softkey **coma free)**
XMOD YMOD

Since coma-free alignment should be checked periodically, the low-frequency wobbler function in X and Y modulation is available directly on the operating page.

Objective lens current read-out

The current through the objective lens provides a good reference point for the specimen height in the objective lens. The current is therefore displayed underneath the defocus display.

Stigmator read-out

In order to provide a reference for the stigmator settings employed, a stigmator value is indicated on the STIGMATOR CONTROL page (displayed when **Stig** is active) for the stigmator selected.

Scherzer (softkey - **SCHERZER)**

Scherzer defocus is a focus setting often used in high-resolution imaging. It is the defocus where the largest number of diffracted beams have the same phase shift and therefore the image in thin parts of the specimen will look similar to a projection of the structure. In order to easily find the Scherzer defocus there is a preset function on the microscope that is switched on and off by a softkey.

Three defocus settings are important for high-resolution microscopy: Gaussian (absolute) defocus, minimum contrast defocus and Scherzer defocus.

Gaussian defocus	:	0 nm
Scherzer focus	:	$-1.2 \times (C_s \lambda)^{0.5}$
Minimum contrast focus	:	~0.4 x Scherzer

Of these three only minimum contrast defocus is recognisable by the user at high magnification and is therefore the only one that can be used as a reference point. However, it should be realised that the uncertainty in the setting of minimum contrast focus is about 5 to 10 nm.

The Scherzer function should be activated after setting the defocus to minimum contrast (**Defocus**) and pressing **RSET DEFOC**. The microscope will then defocus the objective lens the correct amount to reach Scherzer defocus and display the correct value on the microcontroller screen. When Scherzer is switched off, the focus will return to minimum contrast and the defocus display will read the corresponding value. By pressing **SCHERZER** the defocus display therefore goes from a relative setting (relative to the last time **RSET DEFOC** was pressed) to an absolute

setting! The following table summarizes the sequence.

	1 **RSET DEFOC** **SCHERZER off**	**2** **SCHERZER on**	**3** **SCHERZER off**
Objective lens setting	minimum contrast	Scherzer	minimum contrast
Display reading	0 pm	Scherzer	minimum contrast

If the focus is changed by using the focus knob while **SCHERZER** is active, the change in focus will be added to or subtracted from the value displayed for Scherzer focus, respectively. If Scherzer is then turned off, the defocus difference between Scherzer and minimum contrast defocus will be added to the displayed value.

Note: Since the wavelength λ is included in the formula of the Scherzer defocus, changing the high tension changes the Scherzer defocus. For the major high tension steps (200-160-120-80, etc. kV) the software of the CM200 takes that into account automatically. It does not, though, correct the defocus for the free high tension steps.

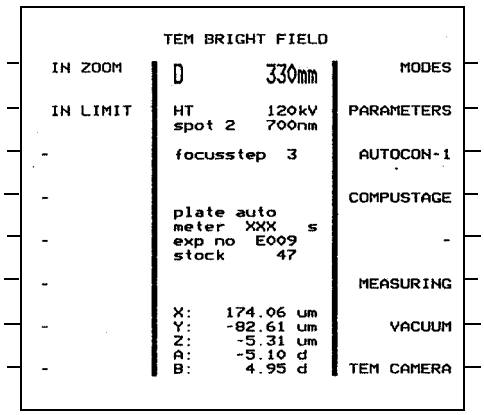
2.2.2 TEM Bright field diffraction

The HR-TEM BRIGHT FIELD DIFFRACTION mode is obtained by activating the D pushbutton (LED on).
Depending on the magnification range in which the image was viewed, two different types of diffraction pattern are obtained:

1. Activating the D pushbutton while in the LM range will lead to the Low Angle Diffraction (LAD) condition in which the objective aperture selects the diffracting specimen area.
   Before leaving the LAD mode, press the AUTOfocus button in order to set the objective lens current to a fixed value which is optimum for LM-TEM imaging.

2. Activating the D pushbutton while at a higher magnification will project the diffraction pattern formed at the back-focal plane of the objective lens onto the viewing screen. The area selection can be carried out by restricting the illumination to the desired area, or by using the selected area (SA) aperture. With fully focused illumination, a convergent- beam diffraction pattern is obtained. This corresponds wth the standard diffraction ray path

In the TEM BRIGHT FIELD DIFFRACTION mode, the Microcontroller will display the following page:



Softkeys

MEASURING

Function : Allows measurement of d-spacings and interplanar angles in the diffraction pattern.

Operation : Refer to Sect. 2.3.7.

Relevant DIRECT ALIGNMENTS

DIF SHIFT: Centring of the diffraction pattern using the **`Multifunction`** knobs.

Note: In TEM BRIGHT FIELD DIFFRACTION Mode, the **`Multifunction`** knobs are active (they control the value of DIF SHIFT) and shift the diffraction pattern (unless overruled by a specific function that makes use of the **`Multifunction`** knobs, such as STIG or **`Df`**).

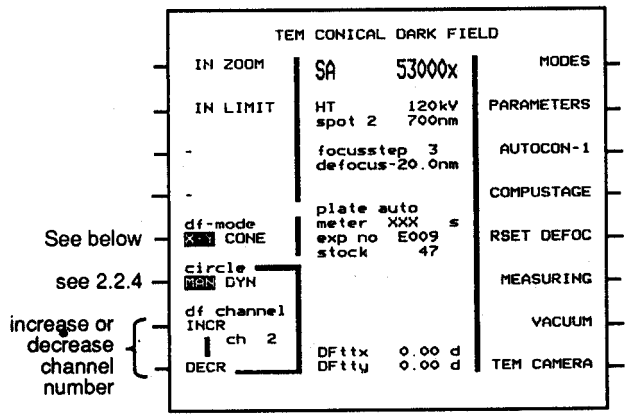
DIF ALIGNM: Alignment of diffraction patterns for all camera lengths.

2.2.3 TEM Dark field imaging

The TEM DARK FIELD mode allows images and diffraction patterns to be obtained with tilted illumination so that the diffracted beam(s) pass along the optical axis of the microscope. This mode can be activated from the TEM BRIGHT FIELD imaging or diffraction modes by pressing the **Df** button. Once the **Df** mode has been selected, the **Multifunction** knobs take over control of beam tilt, while the SHIFT knobs continue to control illumination shift: this shift is an additional shift which is only added in Dark Field mode.
There are a total of 20 Dark Field channels available for storing Dark Field settings (both beam tilt and shift). 10 are present in the high magnification range and 10 in the low. These channels can be selected on the first PARAMETER page (see Sect. 2.2.6) or directly when working in **circle MAN** with **INCR** to increase the channel number or **DECR** to decrease it.

In the TEM DARK FIELD imaging mode, the Microcontroller will display the following page:

CM200/STEM



Softkeys

df-mode X-Y/CONE

Function : The beam can be tilted in either:
- Two perpendicular directions (X-Y).
- A conical (CONE) configuration (ROTATION and ANGLE).

Operation : Press the key to toggle between X-Y and CONE.

Information field

The standard information field content is extended with the readout of the beam tilt according to the tilt mode selected. The X-Y tilt and the azimuth angle are measured with respect to the optical axis (Bright Field illumination axis). The Rotation is measured with respect to an arbitrary direction in the specimen plane.

Reset

Pressing the **Reset** button sets the Dark Field tilt (**DFttx**, **DFtty**, **DFtlt** and **DFrot**) and the additional Dark Field shift values in the active Dark Field channel back to zero.

Note: 1) Ten Dark Field channels exist. These are described in Sect. 2.2.6.

2) The objective stigmator settings in channels 1 and 2 are identical to those in the Bright Field mode and can be adjusted freely in both modes.

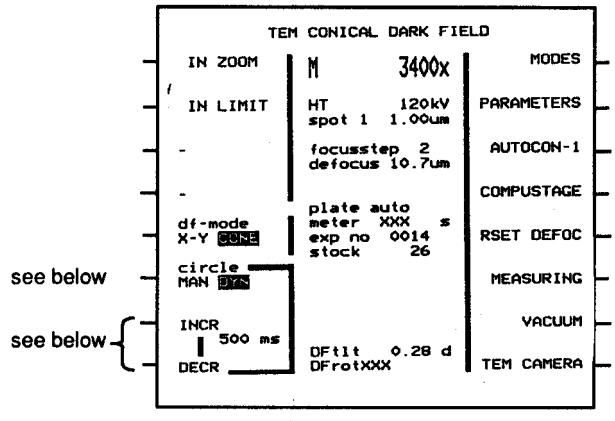
Relevant DIRECT ALIGNMENTS

The alignment function is not accessible in the Dark Field mode. The pivot point X,Y can only be adjusted in the Conical Dark Field mode by pressing the ALiGNment button, see Sect. 2.3.4). Refer to Sect. 2.3.3 for the Static Dark Field mode .

2.2.4 TEM Conical dark field for CM200/STEM

The TEM CONICAL DARK FIELD mode offers the possibility to obtain Dark Field TEM images that are formed by the integration of all electrons scattered/diffracted under the same angle but in different directions, e.g. into a diffraction ring from a partly crystalline specimen. This is achieved by rotating the tilted beam on a fixed area of the specimen such that only electrons that are diffracted back to the optical axis can pass the (small) objective aperture.

In this mode the Microcontroller will display the following page:



Softkeys

`circle MAN DYN`

Function : When MANual is highlighted, the normal TEM situation, described in Sect. 2.2.3 and 2.2.5, is obtained.

When DYNamic is highlighted, CONE will also be highlighted and the beam is scanned automatically in a conical pattern on the selected specimen area. The tilt angle is given in the information field by DFtlt and can be adjusted between 0 and 5 degrees by turning **`Multifunction Y`**. The DFrot adjustment is changed with **`Multifunction X`**..

Operation : Key circle MAN DYN to toggle between MAN and DYN.

`INCR-DECR`

Function : The scan time of one complete rotation can be adjusted between 10 ms and 32 s.

Operation : Key INCRease to obtain a longer scan time and DECRease to obtain a shorter scan time.

`Reset`

Pressing the **`Reset`** button sets the Dark Field tilt (DFttx, DFtty, DFtlt and DFrot) and the additional Dark Field shift values in the active Dark Field channel back to zero.

Note: 1) Ten Dark Field channels exist. These are described in Sect. 2.2.6.

2) The objective stigmator settings in channels 1 and 2 are identical to those in the Bright Field mode and can be adjusted freely in both modes.

Relevant DIRECT ALIGNMENT

PIVOT POINT X,Y

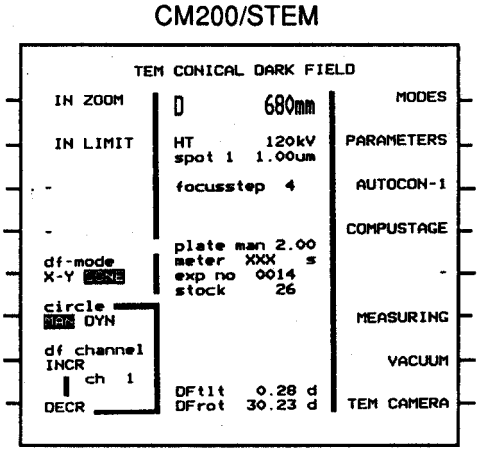
Function : The pivot points are accessible in dynamic CONICAL DARK FIELD to keep the beam centred during operation.

Operation : See Sect. 2.6.6. for a step-by-step procedure of this alignment.

2.2.5 TEM Dark field diffraction

The TEM DARK FIELD DIFFRACTION mode is used for setting up the scattering or diffraction condition for the Dark Field imaging mode.

In the TEM DARK FIELD DIFFRACTION mode, the Microcontroller will display the following page:



Softkeys

see TEM BRIGHT FIELD DIFFRACTION.

`Reset`

Pressing the `Reset` button sets the Dark Field tilt values (DFttx, DFtty, DFtlt and DFrot and the additional Dark Field beam shift) in the active Dark Field channel back to zero.

Note: Ten Dark Field channels exist. These are described in Sect. 2.2.6.

Relevant DIRECT ALIGNMENT

The alignment function is not accessible in the Dark Field mode.

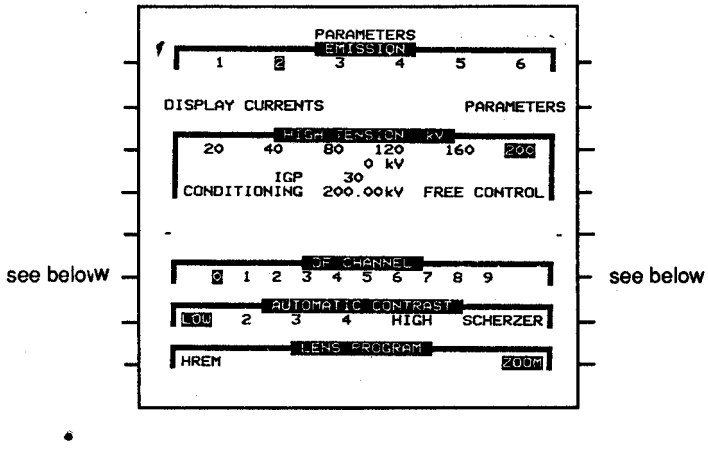
Also refer to Sect. 2.3.3 for this mode.

2.2.6 TEM Dark field: multiple channels

There are 10 independent Dark Field channels in the high magnification range and 10 more in the low magnification range available for storing values of the Dark Field tilt and additional Dark Field beam shift. These are accessed as follows:

- On TEM systems on the operational page (bottom left softkeys, see 2.2.3) or the first PARAMETERS page (see display below).

- On STEM systems on the operational and first PARAMETERS pages in MANUAL mode, or on the first PARAMETERS page in DYNAMIC mode. In the latter case the speed control occupies the bottom left softkeys.



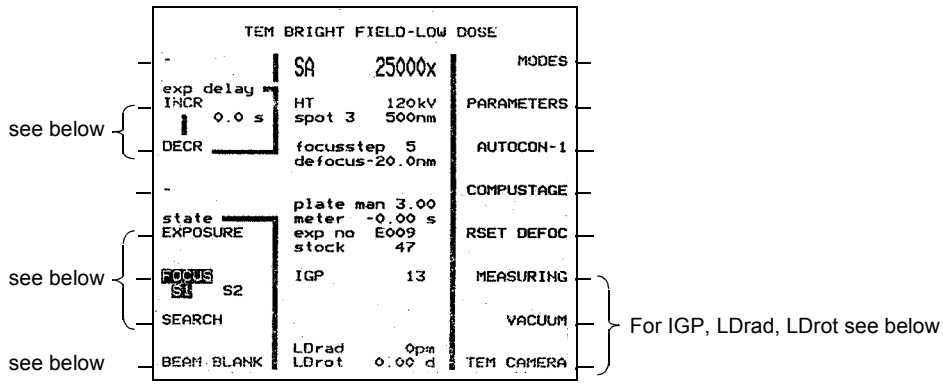
The active Dark Field channel is shown in reversed video. The channel is selected by keying the soft keys to the left and right of the Microcontroller screen which, in this application, respectively decrease or increase the number of the channel selected.

In each of the ten channels, in addition to their respective dark field tilt values, different values of beam shift are stored. See Sect. 2.3.3 for further details.
Pressing the **Reset** button when the TEM DARK FIELD page is displayed will set the Dark Field tilts (DFttx, DFtty, DFtlt and DFrot) and the additional beam shift in the active dark field channel, back to zero.

2.2.7 TEM LOW-DOSE mode (optional) to be checked by Uwe L.

Usage: The TEM LOW-DOSE mode is used for photographing undamaged areas of beam-sensitive specimens. It gives the possibility to set up the instrument and get it ready for recording while illuminating and viewing a specimen area remote from where the micrograph is to be taken. For ultimate specimen protection, one can activate a beam blanker whenever not actually observing an image.

On entering the LOW-DOSE mode, the Microcontroller will display a page similar to the one below (the settings may be different as they depend on the conditions at the time of leaving the LOW DOSE mode):



Softkeys

`state`
`EXPOSURE`

Function : The EXPOSURE state is selected to set up the exposure conditions for photography (magnification and illumination: spotsize, intensity and beam shift).

Operation : Highlight the exposure label by keying EXPOSURE and adjust the parameters as desired for the photographic exposure.

`Focus`
`S1 S2`

Function : The **`Focus`** state is selected to carry out focussing and astigmatism corrections on areas of the specimen adjacent to the area selected for photography. The focus and stigmator settings will be taken over to the image recorded under the exposure conditions selected in the EXPOSURE state. The two substates S1 and S2 can be assigned different image shifts and beam shifts.

Operation : Press softkey to select **`Focus`** state **`S1`** or **`S2`**. Set image shift in **`S1`** (and in **`S2`** if desired).
Select magnification and illumination suitable for optimising the image. Focus image and correct astigmatism.

`SEARCH`

Function : The SEARCH state allows search conditions to be set with magnification and illumination independent of the EXPOSURE and **`Focus`** states.

Operation : Generally, a lower magnification and/or dimmer illumination than in the other states will be used to minimise damage and allow a good overview of specimen areas of interest.

BEAM BLANK

Function : The beam blanker deflects the beam away from the specimen to allow absolute specimen protection whenever illumination is not needed.

Operation : Press softkey to activate (text highlighted) or deactivate.

Caution! The beam blanker will be deactivated when an exposure is made from the **Focus** state, but **not** when an exposure is started from SEARCH or EXPOSURE states.

exposure
DELAY +
DELAY -

Function : Defines the delay time between recentring of the beam and image deflection and the subsequent opening of the exposure shutter. As this represents an additional irradation, the time should be kept to a minimum, preferable zero. This allows the introduction of a specimen setting time (for photographic exposure times of 0.2 sec or longer).

Operation : Select the desired time by increasing (**DELAY +**) or decreasing (**DELAY -**) the displayed value.

Information field

IGP:
Presents the Ion-Getter Pump readout (from VACUUM page) as an extra check on vacuum conditions during CRYO work.

LDrad (in **Focus** S1 or S2):
Represents a linear image shift, controlled by the **MF-Y** knob. Movement is parallel to the specimen tilt axis when LDrot = 0 or 180 deg. Independent for S1 and S2.

LDrot (in **Focus** S1 or S2):
Represents a rotational image shift, controlled by the **MF-X** knob, in conjunction with LDrot. Independent for S1 and S2.

Relevant DIRECT ALIGNMENTS:

Same as in TEM. Note that some alignments are inactive in the **Focus** state.
For an accurate read-out of LDrad and LDrot, MEASURING calibration and AXIS calibration should have been done. These calibrations can be performed directly when in MEASURING (cal) and in measuring STEREO (AXIS-cal).

2.2.8 TEM LOW DOSE DIFFRACTION (optional)

The TEM Low-Dose **Diffraction** mode is obtained by activating the D pushbutton (LED on) when in Low-Dose imaging.

Selection between imaging and diffraction will always be the same for the EXPOSURE and **Focus** states but may be different for the SEARCH state (thus SEARCH may be in diffraction while EXPOSURE and **Focus** are in image mode). This allows using the image in the central diffraction spot (while intensity and image magnification are extremely low) in the SEARCH state to scan the specimen at very low dose while leaving the **Focus** and EXPOSURE states in imaging.

The TEM Low-Dose **Dark-Field** mode (imaging or diffraction) is obtained by activating the **Df** pushbutton (LED on) when in Low-Dose Bright-Field.

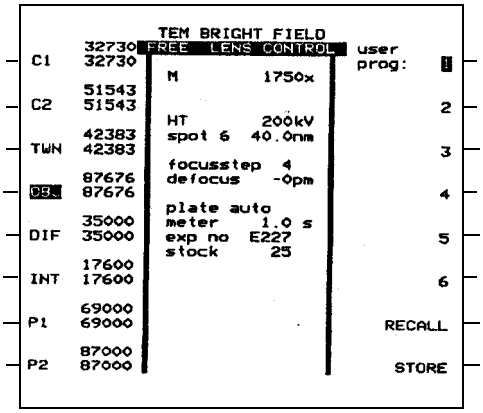
Please note that switching between the X-Y and CONE Dark-Field modes, when desired, should be done in the TEM mode prior to entering the LOW DOSE mode, as the softkeys are not accessible in LOW DOSE.

When activated in Low-Dose, Dark-Field will be active in all states, as well as in the TEM mode, until deactivated.

2.2.9 Free lens control (optional)

The Free Lens Control mode allows the adjustment of the current for all lenses to operator-desired values. The starting conditions are those of the last mode operational before FREE LENS CONTROL was entered. There are six lens current memories in each of which a full set of lens currents can be stored.

When free lens control is activated, the Microcontroller will display the following page:



Softkeys

C1.....P2

Function : Shows the settings of the currents through the corresponding lenses (Condenser 1, Condenser 2, TWiN, OBJective, DIFfraction, INTermediate, Projector 1, Projector 2). Each lens is characterised by two values. The upper one denotes the settings which were assigned in the last operational mode before entering FREE LENS CONTROL. The lower one shows the actual settings. The numbers represent the lens currents in arbitrary units (to display real currents, key **DISPLAY CURRENTS** on the PARAMETERS page).

Operation : Highlight the name of the lens which should be available for free control, by pressing the appropriate softkey. Use the **Focus** knob to change the lens current value. The step size selector changes the sensitivity of the **Focus** knob for lens- current change.

1.....6

Function : Denotes the lens current memories for user programming.

Operation : Put the highlight onto the desired lens current memory from which the lens currents should be recalled or where new settings should be stored.

RECALL

Function : Recall the lens current values which are stored in one of the six user-programmable lens-current memories.

Operation : Key **RECALL** to recall the lens currents from the highlighted memory and assign them to the lenses. The display of the actual lens current values will change accordingly.

STORE

Function : Stores the actual lens-current values in one of the six user-programmable lens current memories. When activated, the previous contents of the memory are overwritten.

Operation : Key **STORE** to transfer the actual lens settings into the highlighted memory.

Information Field

As soon as lenses are controlled, leading to optical conditions different from those in the information field, the corresponding information will be blanked, e.g. magnification.

Relevant DIRECT ALIGNMENT

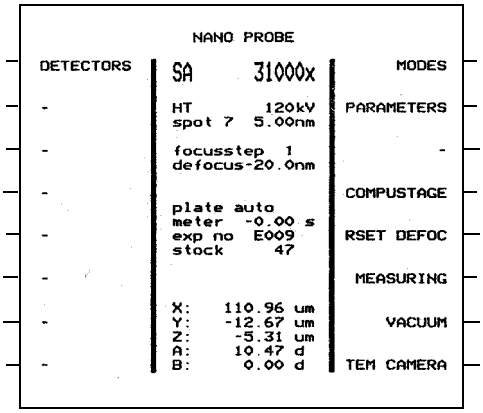
The alignment function is not accessible in the Free Lens Control mode.

2.2.10 Nanoprobe mode

In the NANOPROBE mode the objective lens is operated in the Condenser-Objective mode. This allows much smaller probes to be achieved compared to the MICROPROBE (HR-TEM) mode. The NANOPROBE mode can also be used for high-resolution TEM imaging of small areas because, with defocused, parallel illumination the area illuminated by the beam is much smaller giving higher image brightness.
The interrelationships between the NANOPROBE and MICROPROBE modes vary with respect to the following parameters:

- Magnification is changed for both modes simultaneously, irrespective of the mode selected at the time.
- The Objective stigmator setting is defined in the MICROPROBE mode (TEM).
- Objective lens current and condenser stigmator are controlled independently of the optical mode selected.

In NANOPROBE mode, the microcontroller screen will display the following page:



Softkeys

All softkeys operate as in the TEM (microprobe) mode. Refer to Sect. 2.2.1, TEM bright field imaging and 2.2.2, DIFFRACTION modes.

Information field

The NANOPROBE mode has its own set of spot size values related to the spot size number.

Relevant DIRECT ALIGNMENT

Refer to the sections describing the TEM Bright Field imaging and diffraction modes (2.2.1 and 2.2.2) as appropriate.

Nanoprobe spot sizes

The effective spot size in NANOPROBE mode is, to a large extent, defined by two parameters:

1. The geometric demagnification of the beam diameter at the level of the electron gun (D_{geom}) which can be varied by the Spot size.
2. The influence of the spherical aberration of the final lens (D_{cs}) which is dependent on the condenser 2 aperture selected.

The two parameters can be related to the effective spot size (D_{eff}) as follows:

$$D_{eff} = \sqrt{(D_{geom})^2 + (D_{cs})^2}$$

D_{cs} values are listed in Table 2.2 for a range of condenser 2 aperture sizes enabling other values of effective spot size to be calculated.

Spot size selector	D_{geom} (nm)		Advised C_2 apert. (μm)		D_{eff} nano-probe (nm)	
	T	ST	T	ST	T	ST
1	55	35	90	70	62	55
2	38	24	90	70	53	48
3	28	18	70	60	33	32
4	20	13	60	50	23	20
5	14	9	60	50	18	17
6	10	6.5	50	40	12	10
7	7.5	5	50	40	10	9
8	5.5	3.5	40	30	6	5
9	4	2.5	40	30	5	4
10	3	2	30	20	4	2
11	2	1.5	20	20	2	2

Table 2.1, Range of effective spot sizes for the TWIN (T) and SuperTWIN (ST) objective lenses in the nanoprobe mode for selected condenser 2 apertures (standard tungsten filament) in eucentric goniometer height position

C_2 aperture (μm)	D_{cs} TWIN (nm)	D_{cs} SuperTWIN (nm)
5	0.006	0.015
10	0.05	0.12
15	0.17	0.41
20	0.40	0.98
30	1.4	3.3
40	3.3	7.8
50	6.4	15.3
60	11	26
70	17	42
80	26	63
90	37	89
100	51	122
150	171	412
200	406	977

Table 2.2, Spherical-aberration values in the nanoprobe mode for a range of condenser 2 apertures

Note: 1) When a LaB_6 filament is used, geometric spot sizes will be 2 - 4 times smaller, depending on the make of filament.

2) Spot size is defined as the full-width at half-maximum value of the electron density distribution.

3) D_{cs} values for the SuperTWIN lens are larger than for the TWIN lens because of the shorter focal distance, which increases the aperture angle for the same aperture diameter. Hence, smaller C_2 apertures are used with the SuperTWIN lens.

2.3 TEM OPERATIONAL MODES - STEP-BY-STEP PROCEDURES

2.3.1 Bright Field mode

This is the basic operational mode of the microscope (see Sect. 1.2).

2.3.2 Obtaining a Selected-Area Diffraction Pattern

The complete procedure is as follows:

- Obtain a TEM Bright Field image in the SA magnification range.
- Select required field of view.
- Insert a Selected-Area aperture of appropriate diameter.

Note: The smallest aperture diameter is in general not smaller than 10 μm, which will give a distortion-free diffraction pattern from an area of the specimen of about 400 nm in diameter.

- Remove the objective aperture.
- Press D button (green LED on).
- Select required camera length (**`Magnification`**).
- **`Focus`** the diffraction pattern.
- Adjust **`Intensity`** of illumination to a suitable level by turning clockwise to reduce the intensity.
- Refocus the diffraction pattern if necessary.

Note: Recording the diffraction pattern should be carried out with manual exposure- time selection (see Sect. 4.3) as automatic exposure readings are not reliable in the diffraction mode. The time is best judged from experience gained from a series of test exposures obtained with fixed illumination conditions (emission, high tension, intensity and spot size) for the different sizes of selected-area apertures.

For recording the diffraction pattern, the beam stop may be used to block the central diffraction spot when this is much more intense than the remainder of the pattern. Remove the beam stop after about 90% of the exposure time has elapsed.

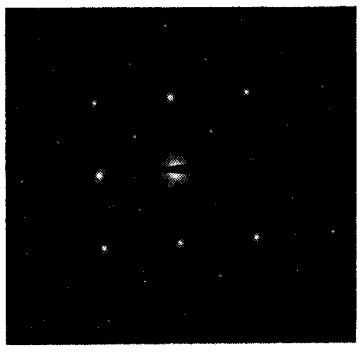


Fig. 2.2, Selected-area diffraction pattern showing use of beam stop
To regain a TEM Bright Field image:

- Adjust **`Intensity`** to give reasonable brightness level in the diffraction pattern.
- Introduce and centre Objective aperture around the central beam.
- Remove the Selected Area aperture.
- Press the **`D`** button (green LED off).
- Adjust **`Intensity`** to give satisfactory level of illumination.

Low Angle Diffraction

This mode can only be entered by choosing Diffraction while in the TEM Low Magnification mode. Before leaving the LM mode, ***press the AUTO button next to the `Focus` step size selector*** in order to set the objective lens current to a fixed value which is optimal for low- magnification TEM imaging. (If an EDAX detector is mounted, this will also ensure that the backscattered-electron shutter in front of the detector will function properly).

2.3.3 Axial Dark Field imaging

Two different methods can be used for dark field imaging:

- Off-axis imaging by aligning the objective aperture around the diffraction spot of interest.
- Axial dark field imaging by tilting the incident beam so that the diffracted beam passes through the objective aperture along the microscope axis.

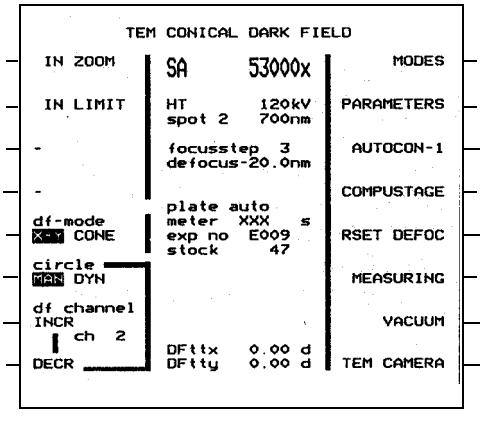
The axial dark field method is preferred because of the higher image quality obtained with on-axis imaging and ease of use through simple change-over between bright field and dark field. This method is described below.

Initial setting up:

- Centre the beam with the **`Shift X`** and **`Y`** knobs.
- Press **`Df`** while in HR-TEM BRIGHT FIELD mode in the SA magnification range.
- Select a Dark Field channel on the PARAMETERS page.
- Set DFttx and DFtty to 0.00 by pressing **`Reset`**. The corresponding dark field beam shift will also be set to zero.

Obtaining a dark field image:

- In TEM BF mode, select required field of view in the SA magnification range.
  Obtain a selected-area diffraction pattern of chosen area.
- Centre the diffraction pattern on the screen with the **`Multifunction`** knobs.
- Decide from which Bragg reflection (or section of a polycrystalline ring) a dark field image is to be obtained.
- Press the **`Df`** button (green LED on). The TEM DARK FIELD page will be displayed.
- Key **`df-mode X-Y`** to highlight X-Y.
- Decrease **`Intensity`** until a large illuminated area is obtained on the specimen, but retaining sufficient intensity to see the diffraction pattern clearly.
- Use **`Multifunction`** X and Y knobs to bring the Bragg reflection opposite to the one selected to the point where the central beam was originally positioned (this should be the centre of the screen).
- Key **`Df`** to return to Bright Field Diffraction mode.
- Introduce an objective aperture and centre it accurately around the central spot.
- Key **`Df`** to return to Dark Field Diffraction mode.



- Centre chosen diffraction spot accurately in the objective aperture using the **Multifunction** X and Y knobs. The objective aperture must be small enough to isolate the chosen spot from neighbouring diffractions.
  The information area of the page will show the X and Y tilt angles of the beam.
- Remove the selected-area aperture.
- Press D button (LED off) and a dark field image of those crystal planes causing the selected diffraction spot will now appear (see Fig. 2.3b).
- Carry out **Magnification**, **Intensity**, beam **Shift** and **Focus** adjustments as for a Bright Field image.
- Stigmate the dark field image (the dark field mode has its own objective stigmator setting).
- Switching between Dark and Bright Field images may be achieved simply by successively pressing the **Df** button.

See following sections for notes on TEM conical dark field imaging and see Sect. 3.3.7 for a step-by-step procedure of conical dark field imaging.

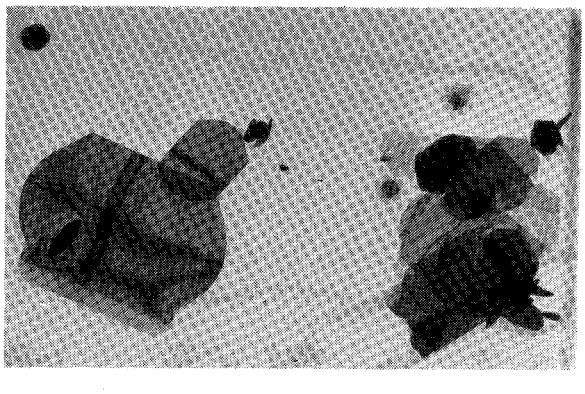


Fig. 2.3a. Bright Field image

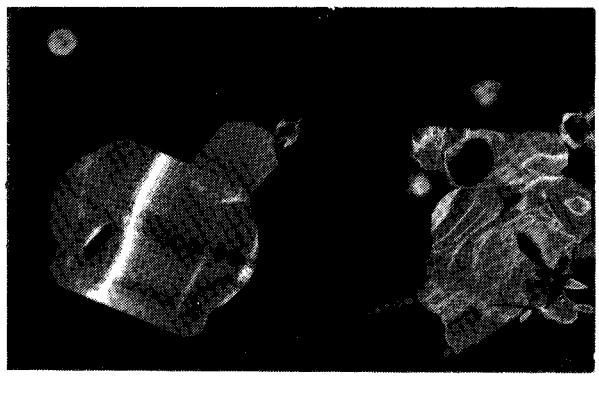


Fig. 2.3b. Dark Field image

2.3.4 TEM conical dark field imaging

- Proceed as for normal dark field imaging (see Sect. 2.3.3) but select **df-mode CONE** and use the **Multifunction** X and Y knobs to select the required **Df** tilt angle.
- Key circle **DYN** to select dynamical scan and select the required scan time. All points on the chosen diffraction ring will now be moved sequentially onto the optical axis. Decreasing the scan time increases the integration at which the sequence of **Df** images may be viewed.
- Carry out **Magnification**, **Intensity**, beam **Shift** and **Focus** adjustments as for a bright field image.
- Focussing the beam with the **Intensity** control may produce a ring or ellipse of illumination instead of a focused spot. If this is the case, adjust the **beam coils PIVOT Point X** and **Y** on the direct ALiGNment (**ALGN**) page so that only one spot is obtained.

Note: If the diffraction spots in conical dark field diffraction do not describe circles but ellipses, the dark field tilts have not been calibrated. This calibration is performed in the TEM Service Calibration procedure:

- Press **Df** to go to HR-TEM BRIGHT FIELD mode.
- Press the **ALGN** button and the soft keys **service CALIBRATE** and **TEM**.
- Execute the beam tilt part of the procedure.

The calibration must be performed using a specimen with known diffraction spacings, but as a fast remedy for correcting ellipses in conical dark field, the following procedure can be used:

- Centre the diffraction pattern accurately in step 049 and 050.
- In step 051, use the **Multifunction X** knob to move the central spot to the 4 cm circle on the screen and note the dark field tilt displayed.
- In step 052, again use the **Multifunction X** knob to move the central spot to the 4 cm circle on the screen (this will be in the perpendicular direction) and set the same tilt as noted above, using the **Multifunction Y** knob.
- Press **Ready** key once again in order to correctly complete this alignment procedure.
- Press **ALGN** button (LED off) to exit and **Df** button (LED on) to re-enter the Dark Field mode.

2.3.5 Diffraction and X-Ray/Electron Energy Loss Spectrometer (EELS) analysis with small probes

Small areas can be selected with a focused electron beam for diffraction or for analysis when the optional X-Ray analyser is incorporated. The beam is focused on the specimen using the **Intensity** knob, enabling the size of the area to be selected directly by choosing a suitable spot size.

Note: To ensure low system background, X-Ray analysis must always be performed in Nanoprobe or Scanning mode, **never** in Bright Field mode.

Generally, small-probe work is started in image mode. This imaging mode should be in the M or SA magnification range (except in the case of Low-Angle Diffraction (LAD). Using the **Intensity** knob, the beam diameter can be continuously varied to cover the desired area. The minimum spot size for a given **Spot size** setting is achieved with a focused electron beam.

Small probes down to 10 nm in diameter can be achieved in the MICROPROBE mode (HR-TEM) for the higher spot size settings. In the NANOPROBE mode the smallest spot size is about 1.5 nm (see also Sect. 2.2.10).

Proceed as follows:

- Obtain a TEM BF image in the SA magnification range.
- Adjust the **Spot size** to give the required diameter.
- Focus the beam on the specimen using the **Intensity** knob, maintaining the beam spot on the area of interest, if necessary, using the **Shift X-Y** knobs.
- Focus the specimen as accurately as possible.
- Remove objective lens aperture from the beam.

Procedure for X-Ray analysis:

- Use a top-hat condenser aperture.
- Ensure that the specimen is mounted in a low-background holder.
- Tilt the specimen towards the X-Ray detector, if possible by 20°.
- If necessary, readjust the **spot size**.
- Start collecting a spectrum.

Procedure for diffraction work:

- Press D button.
- Select required **Magnification**.
- **Focus** the diffraction pattern (in focussing a convergent-beam pattern, the edges of the diffraction discs become sharp; the discs should not be focused into spots).

Procedure to regain the image mode:

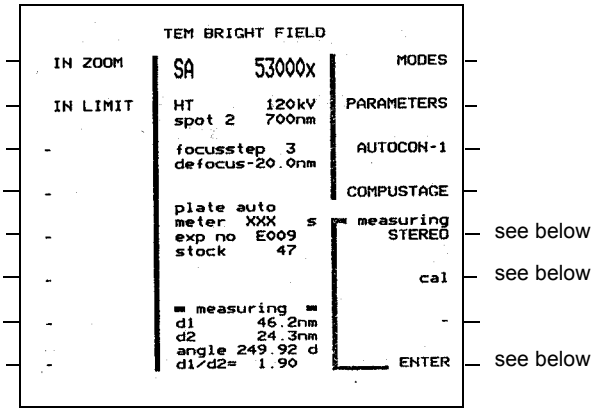
- Re-insert objective lens aperture.
- Press D button.
- Adjust **Spot size** and **Intensity**.

Note: For the safety and good performance of the Si-Li crystal, the EDAX detector is equipped with a shutter which protects it from backscattered electrons (BSE). This shutter will operate when the microscope is in the LM mode. In LM mode, the optimal value for the objective lens current for low magnification imaging is contained in a preset. The procedure to obtain this is as follows:

- Go to LM and select Diffraction (LAD).
- Press the AUTO button beside the **Focus** knob.
- Return to the operational mode.

2.3.6 Measuring in Image Mode

The image measuring functions are accessed by keying **`Measuring`** while in image mode. On entry, the microcontroller displays the following page:



Softkeys

measuring
STEREO

Function : When activated, this calls the STEREO thickness measuring procedure.

Operation : Keying when required.

cal

Function : When activated, this calls the calibration routine.

Operation : Key cal and execute the procedure when necessary.

ENTER

Function : Inputs current measuring values into memory.

Operation : Keying when required (see below): a double beep will sound.

Information field

Below the title **measuring**.

d1 : distance between the two previous reference points.

d2 : denotes the distance between the actual selected reference point on the specimen and the previous one.

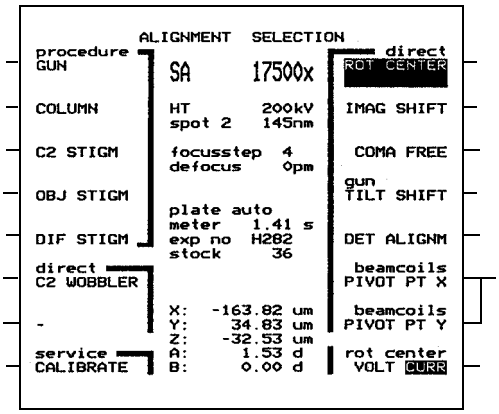
angle : displays the angle between the directions given by d1 and d2.

d1/d2 : distance ratio.

Note: For accurate measurement in image mode, the specimen must be in the eucentric position and the microscope measurement system must have been calibrated. There are four different calibration memories for different magnification ranges: LM, low M, SA and high M. The calibration procedure must be performed by changing the magnification in the calibration procedure for the SA range manually on each page to the appropriate M magnification after having performed the calibration procedure in the SA range once.

Relevant DIRECT ALIGNMENTS (ALiGN button)

- In M/SA magnification range



Objective lens rotation centring

Image shift adjustment between the magnifications in the LM range, low M range and in the high M range relative to the SA range

Selects coma-free alignment for objective centring of HREM (see 2.6.8)

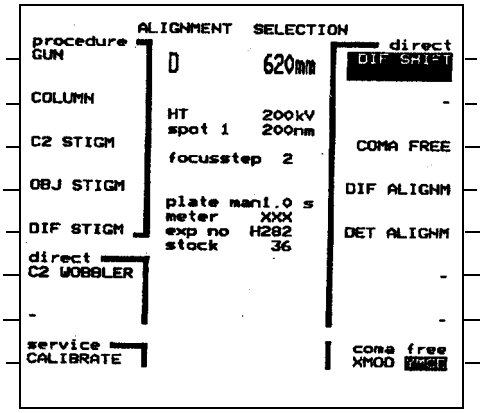
Gun

To align image onto off-axis TV or near-axis STEM detector

Adjust pivot point in specimen plane for wobbler and Dark-Field applications

Selects objective centring mode: high-voltage (VOLT) or objective current (CURR) modulation

- In M/SA diffraction range (D)



Shifts diffraction pattern (this causes shifts for all camera lengths simultaneously)

Selects coma-free alignment for setting the amplitude

Aligns diffraction pattern for all camera lengths separately to the same position at the screen/plate centre and resets DIF SHIFT to zero

Aligns diffraction pattern for all camera lengths separately onto the off-axis TV or near axis STEM detector

Selects coma-free X or Y direction

For further explanation of alignment, see Sect. 2.6. Step-by-step procedures for direct alignments are given in Sect. 2.6.6.

a) Step-by-step procedure for distance measuring

The principle of the measuring procedure is that the points between the distances to be measured are shifted to a reference point. This image shift is performed by the SHIFT knobs which, in this case, control the post-specimen beam deflection. The amount of beam deflection necessary to adjust the points of interest to the reference point is used to determine the distance.

Example: To measure the length and width of a fibre (Fig. 2.4).

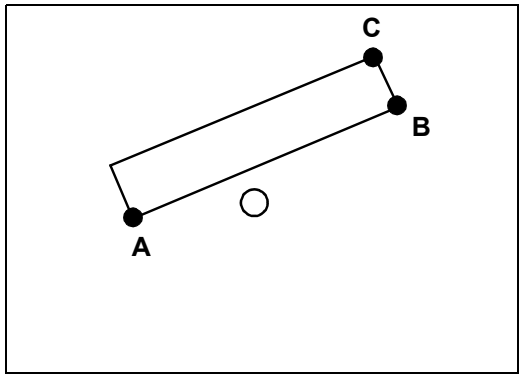


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Fig. 2.4. Measuring length and width of a fibre

- Move an image point A to a reference point, e.g. a small circle on the main observation screen or the tip of the inserted beam stop, using the SHIFT knobs.
- Key ENTER to store the coordinates of image point A.
- Move image point B to the reference point using the SHIFT knobs. When turning the SHIFT knobs, the distance of the reference point from the image point A is displayed continuously.
- When B is moved to the reference point, key ENTER to store the distance AB under d1.
- To measure BC, move the image point C to the reference point.

The distances AB and BC have now been measured and the fibre aspect ratio is displayed as d1/ d2. In addition, the angle between directions AB and BC is displayed.

- The next time ENTER is keyed, the data starts to scroll:

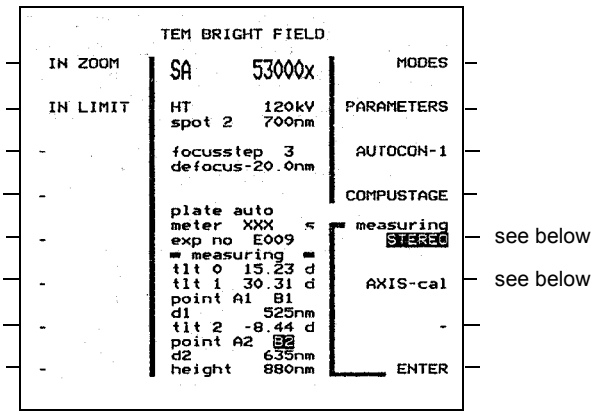
  - The original point A is lost.
  - The original point B becomes point A.
  - The original point C becomes point B, etc.

To leave the measuring procedure, key READY.

b) Step-by-step procedure for stereo measurement

The stereo height measurement is based on parallax effects on the projected distance between two image points that lie on either side of a thick specimen. The data required for this measurement are the specimen tilt together with the projected distance between two representative image points.

Key STEREO to activate the STEREO measuring procedure. The MICROCONTROLLER displays the following page:



Softkeys

STEREO

Function : When highlighted, the STEREO procedure is activated.

Operation : Key to activate STEREO measuring procedure.

AXIS-cal

Function : Determination of the tilt axis relative to the image (the tilt axis is parallel to the direction of the X movement). This calibration should be executed before stereo measurements are started.

Operation : Key AXIS-cal. The procedure is self-explanatory.

Information field

tlt 0 : The specimen tilt at which the height is to be determined (this does not have to be 0°).
This can be adjusted by turning MF-Y.

tlt 1 : The specimen tilt for the first distance measurement.
This can be adjusted by turning MF-Y.

point A1 B1 : The image points for the first tilt. These are highlighted during the procedure.
For image shift use **SHIFT XY** knobs.

d1 : The projected distance between A1 and B1 at tilt 1.

tlt 2 : The specimen tilt for the second distance measurement.
This can be adjusted by turning MF-Y.

point A2 B2 : The image points for the second tilt.
For image shift use **SHIFT XY** knobs.

d2 : The projected distance between A2 and B2 at tilt 2.

height : The calculated height value.

Note: The specimen must be in the eucentric position and the image measuring system must have been calibrated for accurate height measurement.

Example: Measure specimen thickness using an image point on either side of the specimen (see Fig. 2.5).

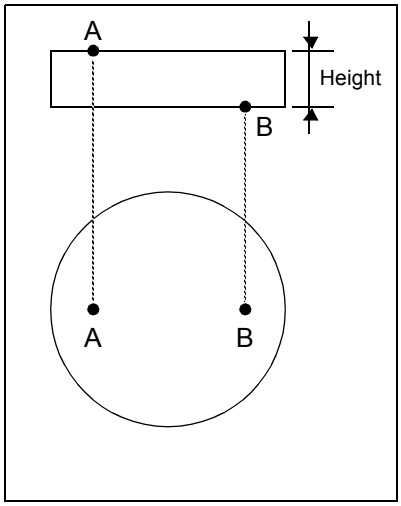
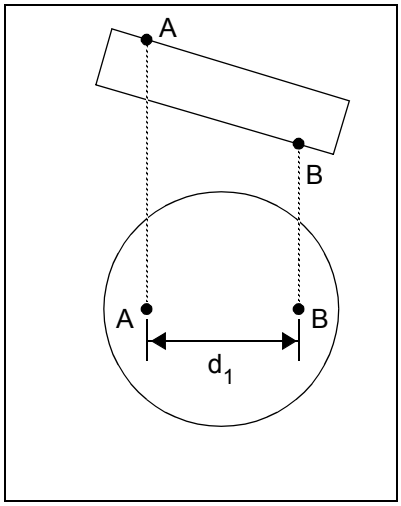


Fig. 2.5. Measuring specimen thickness - specimen at tilt 0

- Ensure that STEREO is highlighted then locate recognisable points in the image above and below the specimen.
- Read the specimen tilt angle from the goniometer. Input this tilt angle into the MICROCONTROLLER by turning the **Multifunction** Y/ANGLE knob until tlt 0 reads the desired value. Ensure that the Y/ANGLE knob is turned in the same direction as the goniometer (clockwise is taken as positive, anti-clockwise as negative). Key ENTER.
- Tilt the specimen clockwise, as much as possible, in order to achieve the greatest accuracy.

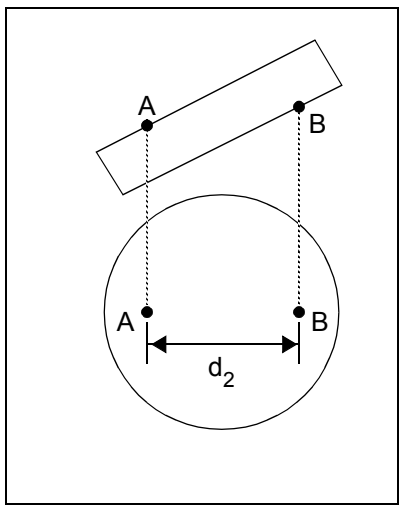


Specimen cross-section with image points on both surfaces at tilt 1 position

projected image

Fig. 2.6. Measuring specimen thickness - specimen at tilt 1

- Read the specimen tilt angle from the goniometer and input it under tlt 1 by turning the **`Multifunction`** Y/ANGLE knob until tlt 1 indicates the desired value. Ensure that the Y/ ANGLE knob is turned in the same direction as the goniometer. Key ENTER (two beeps).
- Measure the distance AB as described in Sect. a). After point B1 is entered, d1 will indicate the projected distance AB.
- Tilt the specimen to the opposite tilt angle (through the tilt 0 position).
- Read the specimen tilt angle from the goniometer and input it under tlt 2 by turning the **`Multifunction`** Y/ANGLE knob until tlt 2 indicates the desired value. Ensure that the Y/ ANGLE knob is turned in the same direction as the goniometer. Key ENTER (two beeps).



Specimen cross-section with image points on both surfaces at tilt 2 position

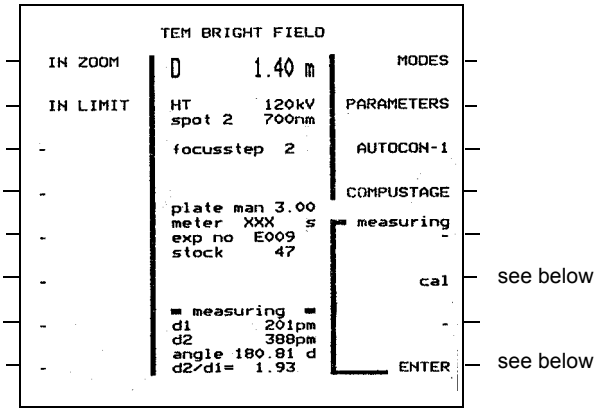
projected image

Fig. 2.7. Measuring specimen thickness - specimen at tilt 2

- Measure the distance AB as described in Sect. a). After point B2 is entered, d2 will indicate the projected distance AB. Simultaneously, height will indicate the calculated specimen thickness (see Fig. 2.7).
- To exit the measuring procedure, key READY.

2.3.7 Diffraction measuring

The diffraction measuring functions are accessed by keying MEASURING while in diffraction. On entry, the MICROCONTROLLER displays the following page:



Softkeys

cal

Function : When activated, this calls up the calibration routine.

Operation : Key cal and execute the procedure when necessary.

ENTER

Function : Inputs the current measuring values into the memory. Two beeps will sound to confirm the entry has been accepted by the microcontroller.

Operation : Use when required (see below).

Information field

Below the title **measuring**:

d1, d2 : The d-values measured.

angle : The angle between d1 and d2.

Note: The specimen must be in the eucentric position and the microscope measurement system must have been calibrated for accurate measurement in the diffraction mode. There is a separate calibration procedure for the LAD and D range.

a) Step-by-step procedure for diffraction measuring

The principle of the measurement is that the diffraction spots, whose spacings must be measured, are shifted to a reference point, e.g. the small circle on the large observation screen or the tip of the beam stop. The diffraction pattern shift is performed using the SHIFT knobs.

Example:

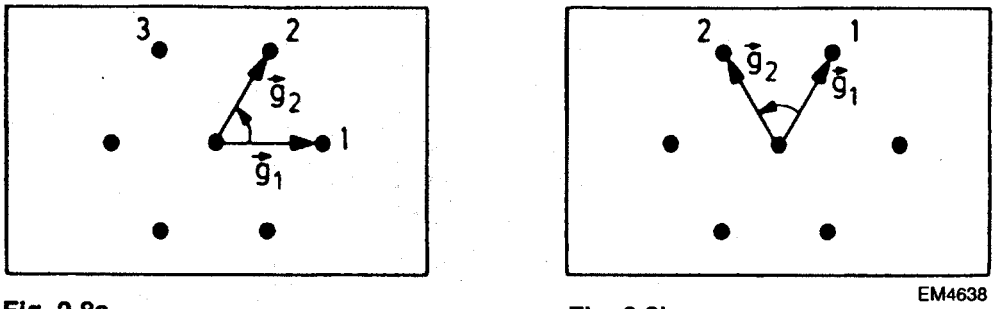


Fig. 2.8a **Fig. 2.8b**

Fig. 2.8a and 2.8b. Procedure for diffraction measuring

The procedure is as follows:

- Move the central diffraction spot to the reference point using the **`Multifunction`** X, Y controls.
- Key ENTER to store the location of the central spot (two beeps).
- Move the first diffraction spot (1 in Fig. 2.8a) to the reference point using the SHIFT controls.
- Key ENTER (two beeps), the vector g_1 forms the basis for the following measurements. The d-value for g_1 is displayed under d_1.
- Move the second desired diffraction spot (e.g. 2 in Fig. 2.8a) to the reference point. The d-value for g_2 is displayed under d_2. The ratio of d_2/d_1 and the angle between g_1 and g_2 are displayed.
- In order to perform the same type of measurement between g_2 and g_3, key ENTER. On the display the data start to scroll. The above value d_2 becomes d_1. The old d_1 is lost. The new d_1 (i.e. the old d_2) is now the new reference vector g_1 (see Fig. 2.8b).
- Shift the third desired diffraction (e.g. 3 in Fig. 2.8a) to the reference point.
- The results are displayed immediately.

Note: All measurements are performed relative to the central diffraction spot first entered, even when more than two diffraction measurements are performed. The measurements are:

	ENTER	Measurement data on information field of display
1st	CS (central spot)	
2nd	d_1	CS - d_1
3rd	d_2	CS - d_1; CS - d_2; angle (CS-d_1) - (CS - d_2): ratio (CS - d_2)/(CS - d_1)
4th	d_3	CS - d_2; CS - d_3; angle (CS-d_2) - (CS - d_3): ratio (CS - d_3)/(CS - d_2) etc.

2.3.8 Low-Dose operation

TEM low-dose operation can be performed by two different techniques:

i) Focusing on an area away from the area to be photographed
ii) Focusing on the same area but with low beam intensity

The three states SEARCH, **Focus** and EXPOSURE are completely independent of each other (magnification, illumination). While the EXPOSURE mode is used only once to define the exposure conditions, the user normaly switches between the search mode to identify the interesting areas (low magnification, spot size as small as possible for low beam intensity) and the **Focus** mode to focus the specimen and correct astigmatism on an area close to but not overlapping with the interesting area. In this way the TEM low dose operation consists of two steps:

1. **Setting up procedure** with
- Definition of magnification and illumination for SEARCH, **Focus** and EXPOSURE
- Definition of image shift between **Focus** and EXPOSURE
- Check that there is no image shift between SEARCH and EXPOSURE

2. **Obtaining low-dose exposures** with the typical procedure
- SEARCH state: finding an interesting area
- **Focus** state : focus area close to the interesting one and correct astigmatism
- Exposure buttom: Exposure of the interesting area, for the exposure the microscope switches automatically from the **Focus** state to the predefined conditions of the EXPOSURE state.

1. Setting up procedure for low dose:

- Insert and centre a C_2 aperture.
- Select **TEM LOW DOSE** mode.
- Key **SEARCH**.
- Set magnification and/or camera length (**MAGN**), and illumination conditions (**SPOT SIZE, Intensity, SHIFT-X, Y**) that will not cause damage and are suitable to overview specimen areas of interest.
- Activate BEAM BLANK.
- Insert specimen.
- Deactivate BEAM BLANK.
- Adjust specimen to eucentric height.
- Select a part of the specimen that will not be used later, and move it to the centre using the XY joystick.
- Key **EXPOSURE**. Set magnification and/or camera length, and illumination conditions desired for photographic exposure.
  If necessary, activate **BEAM BLANK**.
- If desired, the image in SEARCH can be shifted (**MF-X, Y**) to align it with respect to the EXPOSURE state.
  To set an image shift to zero, press **Reset** button.
- Key **Focus** **S1**. Select magnification and/or camera length, and illumination suitable for focussing and astigmatism correction. The magnification should be the same as or a bit higher than that at which the micrograph will be taken; the intensity should be adjusted in such a way that only the specimen area seen on the viewing screen is illuminated.
- Adjust image shift as desired (MF-X,Y). To set an image shift to zero, press the **Reset** button. First shift the image with the **Multifunction** knob MFy (LDrad) to an off-axis position which does not overlap with the EXPOSURE state. In practice this could be done by shifting an image feature on one edge on the viewing screen to the opposite side, as illustrated in figure 2.9. The **Multifunction** knob MFy is used to define the radius of a circle. This radius gives the distance between the EXPOSURE state and the **Focus** state and has to be big enough to prevent overlapping. Once adjusted one can now use the **Multifunction** MFx to change the position (rotation angle) on this circle to find a good image feature for focusing, while the

distance to the EXPOSURE state LDrad is kept constant to avoid overlapping.
- A different image shift may be stored in **Focus S2**, e.g. in case of a tilted specimen: optimum focus for exposure will then be close to the mean of the two focus settings at opposite sides of the location to be photographed.
- Check all settings in the EXPOSURE and **Focus** states once again.
- Key **SEARCH**.

2. Obtaining low dose exposures:

- In SEARCH state, select area of interest by centring with the XY joystick.
- Key **Focus** S1. Optimise image (**Focus**, **STIG**). If a different image shift in **Focus** S2 is used (tilted specimen), set **Focus** halfway the optimal settings for **Focus** S1 and **Focus** S2.

Note: The direction of LDrad is parallel to the specimen tilt axis when LDrot = 0 or 180 deg. If necessary, activate BEAM BLANK.

- Key **TEM CAMERA**. Select exposure mode and (MANUAL) exposure time.
  If automatic exposure time selection is desired for the next exposure or series only, key AUTO (AUTO+HOLD will maintain this condition until another choice will be made).
- Press READY button. Adjust **exp delay** value as desired.

Note: Pre-irradiation of the specimen will only be executed for exposure times over 2 sec).

- While still in the **Focus** state, lift the screen and press the **EXP** button (i.e. the normal camera shutter control). The image will now be photographed in the EXPOSURE state.

Note: i) In TEM LOW DOSE, the wobbler (WBL), stigmator (STIG), dark field (**Df**), and alignment (ALGN) pushbuttons may be activated: the **MF-X, Y** knobs and **Reset** button will then work as in TEM.

ii) When DARK FIELD has been selected, it will be active in all states simultaneously. Switching between the X-Y and CONE modes, if desired, must be done in the TEM mode.

iii) During the **exp delay** time, the specimen is pre-irradiated immediately prior to photographic exposure, allowing stabilisation of specimens that initially begin to move when suddenly illuminated by the electron beam. Such a delay should always be as short as possible, preferably zero, to prevent damage.

iv) When parameters and illumination in all states have been set, it is recommended to check them to allow normalisation of the illumination lenses initiated by switching between states. Small beam shift adjustments (SHIFT-X, Y) may be needed after switching for the first time in a new situation.

v) Depending on the active state, pressing the EXPOSURE button will result in the following actions:
   - In SEARCH state: SEARCH area will be photographed (BEAM BLANK must be off because beam blanking will only be switched off when an exposure is started from the **Focus** state).
   - In **Focus** state: EXPOSURE area will be photographed (BEAM BLANK may be on or off).
   - In EXPOSURE state: EXPOSURE area will be photographed (BEAM blank must be off because beam blanking will only be switched off when an exposure is started from the **Focus** state).

vi) A through-focus series in TEM Low Dose starts with an in-focus exposure. Every following exposure is made at one step further underfocus.

The following **parameters** will be **memorized** in TEM LOW DOSE and will not be lost when leaving this mode:

- Last selection of **magnification range** when in imaging (**LM or M/SA**): same for EXPOSURE and **Focus** ; independent for SEARCH.
- Last selection of **magnification**. If in the LM range: same for EXPOSURE and **Focus**; independent for SEARCH. If in the M/SA range: independent for all states.
- Last selection of **camera length** in low angle diffraction (**LAD**): same for EXPOSURE and **Focus** ; independent for SEARCH.
- Last selection of **camera length** in normal diffraction (**D**): same for EXPOSURE and **Focus**; independent for SEARCH.

- **Illumination** conditions (**`SPOT SIZE`**, **`Intensity`**, SHIFT-X, Y) in **LM/LAD**: independent for all states.
- **Illumination** conditions in **M/SA/D**: independent for all states.
- **Image shift** in **LM**: independent for **`Focus`** S1, **`Focus`** S2, and SEARCH.
- **Image shift** in **M/SA**: independent for **`Focus`** S1, **`Focus`** S2, and SEARCH.
- **Focus** setting and step size in **LM**: same for EXPOSURE and **`Focus`**; independent for SEARCH.
- **Focus** setting and step size in **LAD**: same for all states.
- **Focus** setting and step size in **M/SA**: same for EXPOSURE and **`Focus`**; independent for SEARCH.
- **Focus** setting and step size in **D**: same for all states.

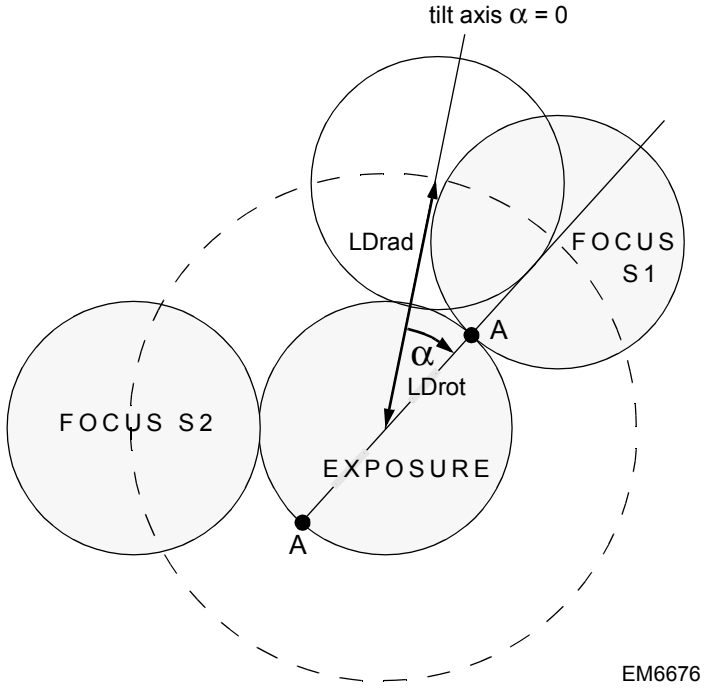


Fig. 2.9. `Focus` and EXPOSURE mode. Shaded circles correspond to the viewing screen

2.4 OPTIMISING THE OPERATIONAL PARAMETERS

This section describes techniques used for optimising the image. These techniques are not related to the electron-optical alignment procedures which are dealt with in Section 2.6.

2.4.1 Filament saturation

For a self-biased gun as used in this microscope, there is a recognisable condition of the filament temperature (FILAMENT knob) at which the brightness is at maximum and does not appreciably increase with an increase in temperature (FILAMENT setting). This is called the saturation condition.

Generally, the gun should be operated in the saturation condition or very close to it. This condition is recognised as follows:

- On the EMISSION meter as a maximum reading obtainable.
- On the projection screen as a maximum intensity.
- In the focused electron spot which loses all structure.

If the gun is not operated in the saturation condition, the stability and brightness of the beam may suffer. However, it is important to recognise that considerable loss in filament life can occur through oversaturation (for example, two steps of the FILAMENT knob can reduce filament lifetime by a factor of 2).

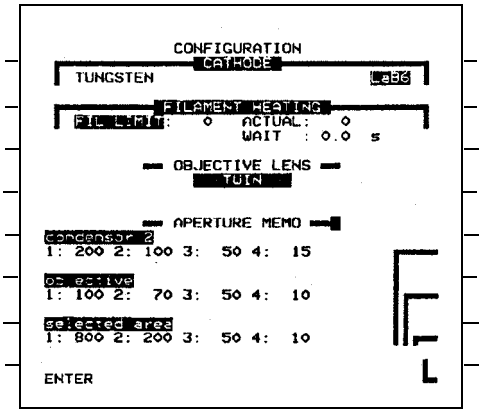
With an undersaturated filament, the spatial coherence and energy spread of the electron beam are improved. In applications such as high-resolution imaging and electron energy-loss spectroscopy where these factors affect the resolution, it may be advisable to work with a slightly undersaturated filament.

Note: 1) With a LaB_6 filament, it can occasionally happen that some slight structure remains visible in the focused spot after saturation. In this case it is better to operate with a slightly overfocused **`Intensity`** setting than to try and eliminate the structure by oversaturation. No deterioration of the image will result.

2) When the Emission parameter is changed to higher values or when the high tension is changed, resaturation may be necessary.

To readjust the FILament LIMIT setting for saturation of a filament which has already been in use and maintained continuously under vacuum, select the CONFIGURATION page by keying MODES and CONFIGURATION. The CONFIGURATION page is shown below.

see below



Softkeys

FIL LIMIT

Function : When highlighted, the filament limit is activated.

Operation : De-activate FIL LIMIT (highlight removed). An increase or decrease of the FILAMENT setting will now be displayed beside the FIL LIMIT label and the ACTUAL value. When the desired filament saturation is reached, the saturation point may be set by keying FIL LIMIT.

Normal heating of a filament. When a filament is heated, the MICROCONTROLLER ensures that the temperature increase rate is limited. The delay time per step is as follows:

- Tungsten : 0.1 s.
- LaB_6 : 5 s (the delay time is 15 s for a new LaB_6 filament).

If the operator increases the filament setting more quickly than the above delay times, the MICROCONTROLLER will memorise the steps which have been selected but execute them with the speed appropriate to the cathode selected on the CONFIGURATION page (if FIL LIMIT is not set, the Microprocessor will proceed only a maximum of two steps at a time to prevent the filament overheating). A bleep signal will be sounded if the filament limit is reached. During the heating-up procedure, the MICROCONTROLLER will display the following message:

startup of a W/LaB_6 cathode.

2.4.2 Setting the filament limit

The FILament LIMIT facility selectable on the CONFIGURATION page sets the maximum level for filament heating. The FILAMENT LIMIT should be re-checked from time to time since the filament characteristics may change with ageing. Proceed as follows:

- Select CONFIGURATION page.
- Key FILament LIMIT to de-activate the limit function (label highlight disappears).
- Focus the beam (`Intensity`). Turn the FILAMENT knob until filament saturation is observed. The actual step number of the FILAMENT range is indicated on the page under the FILAMENT HEATING line.
- The saturation point may be set by keying FIL LIMIT. FIL LIMIT will be automatically activated when the CONFIGURATION page is left (except when the ALiGN button is pushed, in order to allow centring of the gun tilt while heating the filament); use the READY key to return to MODE SELECTION.

The filament limit ensures that the filament cannot be oversaturated when an operational page is displayed.

Note: After venting the gun, the FILAMENT LIMIT is automatically reset to zero because the instrument assumes that a new filament has been installed (see Sect. 4.4.8). ***After changing the filament, conditioning should be carried out before using the filament in the 160-200 kV range (see Sect. 4.4.8).***

2.4.3 Emission settings for different magnifications

It is possible to extend filament life by reducing the gun brightness while working at lower magnifications by choosing a lower EMISSION setting.

Note: With a LaB_6 filament, brightness at emission setting 1 is generally sufficient for normal operation. Emission may be increased up to emission current readings of about five (meter at top right of Microcontroller screen). Higher emissions can be used for short periods but this will reduce filament lifetime.

The following procedure is recommended for emission adjustment to magnification:

- Take the specimen out to the halfway position in the airlock.
- Set MAGNIFICATION one position higher than the maximum required.
- Adjust **`Intensity`** to obtain a slightly overfocused illumination condition.
- Reselect EMISSION current value (PARAMETERS page) until a satisfactory intensity of illumination is obtained on the projection screen.
- Reset MAGNIFICATION to required value and re-insert specimen. At this magnification and below, the intensity will be adequate and a longer filament lifetime will result.

2.4.4 Adjusting the filament

The filament is normally adjusted for correct operation as part of the replacement procedure (see Sect. 4.4). This includes setting of the distance between the tip of the filament and the centre of the Wehnelt aperture. The recommended distance for normal operation is 0.15 - 0.20 mm.

2.4.5 Filament life

A clean, high-vacuum design ensures long life for a filament that is just saturated but the operating parameters used will also have an influence.

Indications of filament failure are:

1. No intensity on the projection screen under any circumstances (low magnification, specimen removed, Objective and Selected-Area apertures removed from the beam).
2. No EMISSION current at any setting of the FILAMENT and EMISSION parameter knobs.
3. No EXP TIME reading.

Note: 1) Once an image has been obtained or regained following filament change, carry out the ALIGNMENT procedures for GUN SHIFT and TILT and C2 STIGMator (see Sect. 2.6).

2) If the beam cannot be found after changing the filament, select a low magnification then heat the filament to a normal operating value (about 20) and choose GUN TILT on the ALiGNment page. Move one of the **`Multifunction`** knobs to the limit of its range (denoted by a beep) then turn the second **`Multifunction`** knob through its whole range. If the beam is not found, adjust the first **`Multifunction`** knob a little and again turn the second through its whole range. Repeat until the beam is found. If a beam is found, but the optimum GUN TILT appears to be out of range, the true GUN TILT centre usually lies at the other end of the range of the **`Multifunction`** knob that has reached its limit. If this is not the case, the filament is not centred in the Wehnelt.

2.4.6 Selecting the magnification

The magnification value selected is displayed on the Microcontroller screen. The magnification can be varied by means of the MAGNIFICATION knob on the right-hand panel. When the main screen is lifted, the magnification/camera length displayed is the one valid for the plate camera. When the 35 mm camera is brought into operation, the appropriate magnification/camera length is displayed.

LM mode

The diffraction lens is used to focus the image and is controlled by the **Focus** knobs. The objective lens is fed with a low fixed current that is set to image the diffraction pattern in the plane of the selected-area aperture. The apertures should be positioned as follows:

- Condenser : Inserted.
- Objective : Removed since, depending on its size, it will eventually cause field-of- view limitations.
- Selected area : removed, if only a general view of the specimen is required; inserted, for good LM image contrast, e.g. when taking a photograph. The selected area aperture acts as the LM objective aperture.

M mode

The apertures should be positioned as follows:

- Condenser : Inserted.
- Objective : Inserted.
- Selected area : Removed.

SA mode

The objective lens excitation remains at a virtually fixed value for which the image is always focused in the plane of the selected-area aperture. Thus precise area selection for electron diffraction is possible in this mode.
Aperture positioning: as in M mode.

2.4.7 Calibrating the magnification

In normal operation (i.e. with the specimen in the eucentric position), the accuracy of magnification will be within ±5% of that indicated on the display. To obtain more accurate values, a calibration curve must be made for the microscope using the normalisation facility for each magnification value. This facility momentarily increases the excitations of all magnifying lenses to a maximum level thereby making lens hysteresis conditions consistent and therefore reproducible. Once such a calibration has been carried out, reproducibility to within 1.5% of the calibrated value is obtained.

Normalisation is obtained by operation of the EXPOSURE/Normalisation pushbutton with the main projection screen lowered, that is, in the observation position.

The calibration procedure can be carried out over the whole range: (LM, M, SA). A suitable method is by taking photographs of standards over the following magnification ranges:

50x to 1500x	:	Grid with a mesh of the order of 1500.
1500x to 100 000x	:	Reliable diffraction grating replica.
>100 000x	:	It is necessary to determine the ratio of the distances between the same two particles (or points) on two photographs taken at two different magnification settings. In this way it is possible to extrapolate from an accurately calibrated low magnification to the top of the range. Alternatively, obtain high-resolution micrographs with a known lattice spacing.

- Ensure that the grating replica has first been checked by light microscopy.
- Ensure that the specimen is in the eucentric position.
- Begin the calibrations at a very low magnification to enable the elimination of random faults in the grating.
- Do not use a grid opening in which tears occur.
- At the intermediate magnifications, check the spacings of the actual lines used against the same lines in the lower magnifications, again to eliminate random errors.
- Do not attempt an accurate calibration with less than 5 lines and only then if they can be checked as described in the previous point above.
- At higher magnifications, calculate the ratios between steps of the magnification range by photographing two particles at the two magnifications and comparing their separations, or use high-resolution micrographs of a specimen with a known lattice spacing.
- Ensure that, at each step of the calibration, the EXPOSURE/Normalisation button has been activated with the main projection screen lowered.

2.4.8 Selecting the lens program

The CM200 combines three specifically designed lens programs which provide benefits for various applications. The selection can be made on the bottom line of the last PARAMETERS page. The main points of the three programs are as follows:

ZOOM

- Available at all H.T. settings.
- The nanoprobe can be used to its highest performance.
- Over the full SA range, the first intermediate image is in the SA phase allowing optimum SA diffraction.
- The focus and astigmatism remain virtually fixed in the full SA range allowing adjustments at high magnifications.

HREM

- Available between 160 and 200 kV.
- This lens program has been optimised for High Resolution Electron Microscopy specialist work. The objective lens is at a fixed excitation for magnifications between 4000 and 750 000 times (TWIN values) which ensures stable alignment over this range.

STEREO

- Available between 0 and 160 kV.
- The tilt axis is maintained virtually parallel to the long or short side of the photographic plate over two successive ranges of magnification.

Note: The objective lens excitation is changed by a default value when switching between the first and second highest magnifications (so the SA and high M change in ZOOM). The default value can be overwritten and optimised in the column alignment procedure. The alignment should be performed for each lens program separately.
The best results are obtained if these steps are carried out for each of the following situations (only those in regular use should be performed):

1. ZOOM and 200 kV.
2. ZOOM and 160 kV.
3. ZOOM and 120 kV.
4. HREM and 200 kV.
5. STEREO and 160 kV.
6. STEREO and 120 kV.

2.4.9 Focussing

This section describes two important aids for focussing; the wobbler and the combination of the small projection screen and binoculars. Even with these aids, the ability to focus correctly at high magnification will depend on the interpretation of image phenomena to determine the true and false characteristics. In some cases this can be simply achieved by using the THRough **`Focus`** exposure series facility on the TEM CAMERA page.

a) The Wobbler

The function of the wobbler is to deflect the beam alternately to either side of the optical axis. When the objective lens is focused exactly on the specimen plane, no change in the image is apparent (see Fig. 2.10). However, when the objective lens is focused above or below the specimen plane there is an apparent double image so that the device is very useful for emphasizing focussing errors. The wobbler is fed with a square-wave alternating current. The upper limit to which it can be usefully employed depends on the specimen.

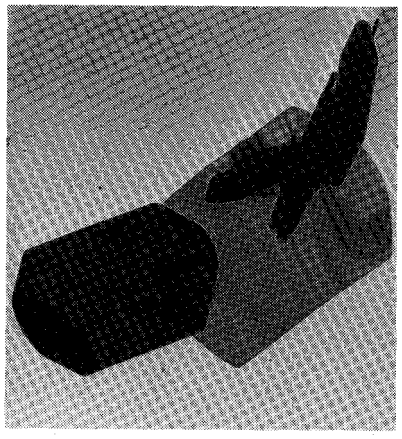
The direction of the wobbler effect should be selected perpendicular to the direction of the structures to be focused. This is adjusted using the **`Multifunction`** X/ROTATION knob.

The amplitude of the wobbler effect is adjusted using the **`Multifunction`** Y/ANGLE knob. This angle should be adapted to the size of the objective lens aperture otherwise loss of intensity will occur when the wobbler is operated.

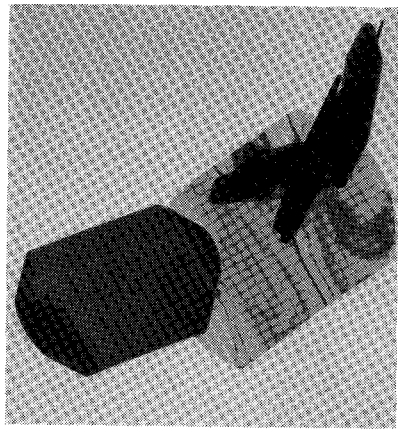
The procedure is as follows:

- Insert a specimen, adjust its height and focus the image.
- Press D pushbutton (LED on).
- Select a camera length of approximately 600 mm.
- Focus the illumination using the **`Intensity`** knob.
- Ensure that the objective aperture is correctly centred.
- Press the WoBbLer pushbutton: two spots should appear within the area of the objective aperture. If not, lower the wobbler amplitude until they do. The wobbler tilt and rotation angles are displayed on the Microcontroller screen (centre bottom of the information field).
- Press D pushbutton (LED off) and focus the image to minimum blur.
- When finished, press the WoBbLer button once again to switch it off.

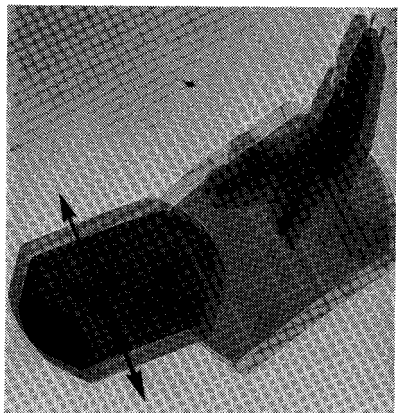
Note: If the wobbler is not switched off by the operator, it will be switched off automatically when a photographic procedure is started. For highly accurate focussing use a small wobbler tilt, i.e. typically less than 0.5°.



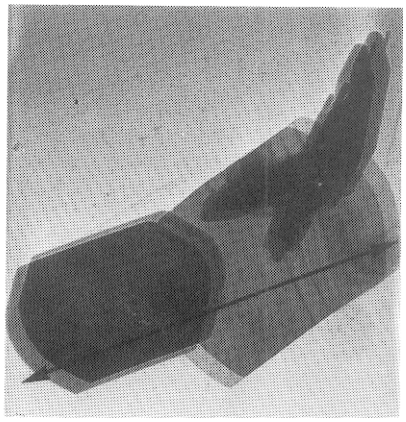
a. Focus without use of wobbler



b. Focus after use of wobbler



c. Out of focus - wobbler acting in a chosen direction



d. Out of focus - wobbler acting perpendicular to the direction chosen in c

Fig. 2.10. Wobbler effect on image

b) The small screen and binoculars

The binoculars can be used over the whole magnification range and for many different types of images (e.g. bright field, dark field, diffraction) as an aid to more accurate observation and focussing. They give a magnification of 12x and are used together with the small screen as follows:

- Introduce the small screen fully into the beam.
- Adjust the interocular distance for maximum comfort.
- Focus the binoculars on the small screen making use of the ocular adjustment controls.

Note: Focussing must be carried out for each eye separately and the eyes should be focused at infinity, fully relaxed.

(If the adjustment is out of range, the binoculars can be lowered or raised by loosening the two hexagonal screws with hemispherical heads).
As an aid to focussing the binoculars, insert the beam stop. When its shadow is sharp, the binoculars are focused and the stop can be removed.

2.5 ASTIGMATISM

Astigmatism is an aberration which is present in all electromagnetic lenses. It is caused by asymmetry of the lens field which can result from inherent asymmetries or from asymmetrical charges on regions close to the beam, e.g. the specimen. There are three possible astigmatism corrections:

Stigmator	Applies correction to:
C2 STIGM	Illumination system
OBJ STIGM	Objective lens
DIF STIGM	Diffraction lens

Astigmatism of the Illumination System

In the TEM mode, astigmatism of the illumination system is corrected in the filament image. In the (optional) STEM mode astigmatism of the illumination system is corrected in the STEM image.

Astigmatism of the Objective lens

In the TEM mode, the Objective Lens Stigmator corrects image astigmatism in the M-SA magnification range.

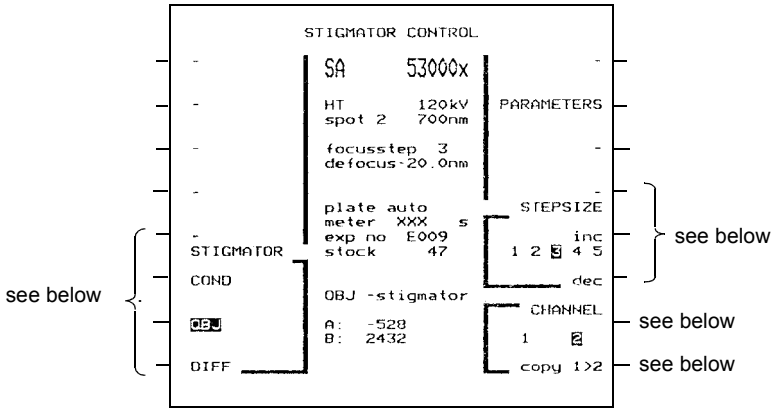
Astigmatism of the Diffraction Lens

In the TEM mode, the Diffraction Lens Stigmator corrects image astigmatism in the LM magnification range. In the diffraction mode, the Diffraction Lens Stigmator corrects astigmatism in the diffraction pattern.

All image astigmatism corrections are performed using the **`Multifunction`** controls. When the STIGMATOR button is pushed, the stigmators appropriate to the operating mode selected are automatically applied.

2.5.1 Stigmator control

When the Stig button is pushed (green LED on), the STIGMATOR CONTROL page is displayed:



The **`Multifunction`** X and Y knobs will also become active and allow changes to be made to the settings of the chosen stigmator. On pushing the STIG button in any given mode, ***the stigmator normally required in that mode is automatically preselected*** and is shown in reverse video on the left-hand side of the Microcontroller screen.

The stigmators which become active automatically are:

- TEM M and SA magnifications : OBJ
- TEM LM magnification : DIFF
- TEM D : DIFF
- TEM LAD : OBJ
- NANOPROBE : COND
- SCANNING : COND

This preselection ensures that the correct stigmators are chosen for the mode in use. However, the user has the option to alter the selection, for example, in TEM imaging the normal requirement is to adjust the image astigmatism (with objective stigmators) but it may be necessary to alter the beam astigmatism with the condenser stigmators. This can be carried out using the soft keys (see below).

In order to provide a reference for the stigmator settings employed, a stigmator value is indicated on the STIGMATOR CONTROL page (displayed when STIG is active) for the stigmator selected. In order to allow rapid updating of the MICROCONTROLLER screen the value is a software value, not a stigmator current. The value lies between -50000 and +50000, which defines the total range of the stigmator.

Soft keys

STIGMATOR
COND
OBJ
DIFF

Function : Permits selection of alternative stigmators to those preselected. The operative stigmator is shown in reverse video.

Operation : Push softkey adjacent to required stigmator.

STEPSIZE
inc
1 2 3 4 5
dec

Function : Permits the user to increase or decrease the coarseness (i.e. decrease or increase the sensitivity) of the **Multifunction** X and Y controls.

Operation : Push the softkeys to increase or decrease step size. The active step size is highlighted.

CHANNEL
1 2

Function : Allows access to one of the two independent channels for storing or adjusting the chosen stigmator.

Operation : Push soft key to toggle between channels 1 and 2. The active channel is highlighted.

copy 1>2 or 2<1

Function : To copy the values of the stigmator settings present in the inactive channel into the active channel.

Operation : Push softkey. For example, if channel 2 is in use but the values are very inaccurate, whereas those in channel 1 are reasonable, pushing the copy soft key will transmit these better values into channel 2.
Both channels now contain the same settings and the settings in channel 2 can now be altered in the knowledge that channel 1 still contains reasonable values.

Reset

Function : **Reset** values in active stigmator channel to default values, which are close to zero.

Operation : Select required stigmator type and channel and press **Reset** button.

Relevant DIRECT ALIGNMENTS

Alignments are not available when the STIGMATOR CONTROL is activated. Pushing the ALGN button automatically switches off the STIGmator button. However, the stigmators are accessible in alignment by pressing the STIGmator button. Pressing STIGmator once again returns to the active alignment page.

2.5.2 STIGMATOR memories

In addition to the options described in Sect. 2.5.1, a number of independent stigmator memories exist. For example, independent adjustments of the diffraction stigmators can be made in LM imaging and normal diffraction.

When the chosen stigmator is adjusted for any given mode or set of conditions the value is automatically stored and will become active whenever that mode or set of conditions is in use, or until it is altered by the user. Stigmator adjustments are defined in Sect. 2.5.1 and detailed procedures are given in Sect. 2.5.3 to 2.5.6.

The various stigmator memories are as follows:

CONDENSER STIGMATOR

Separate values for the stigmator settings (in x and y) for each spot size may be stored independently for TEM modes, nanoprobe modes (including STEM) and SACP in scanning. For example, once settings have been chosen for STEM and TEM, the user can move between these two modes without the need to readjust the condenser stigmator. Also in STEM, when the condenser stigmator has been adjusted for all spot sizes, the spot size can be changed without the need to readjust the condenser stigmator. Channels 1 and 2 may also be used, thus giving six independent memories for the condenser stigmator for each spot size (or 11 x 6 = 66 in total)

		x + y channel 1 1 2 3...10 11	x + y channel 2 1 2 3...10 11
Condenser Stigmator Memories	TEM		
	Nano (inc.STEM)		
	SACP		

OBJECTIVE STIGMATOR

Separate values for the objective stigmator settings (in x and y) may be stored independently as follows for:

- M magnifications or Diffraction
- LAD

		x + y channel 1	x + y channel 2
Objective Stigmator Memories	M/SA/D		
	LAD		

DIFFRACTION STIGMATOR

Separate values for the diffraction stigmator settings (in x and y) may be stored independently as follows for:

- Diffraction modes, D
- Low magnification imaging, LM

		x + y channel 1	x + y channel 2
Diffraction Stigmator Memories	D		
	LM		

2.5.3 Correcting condenser astigmatism

- Select the TEM BF mode, ensure that the specimen is eucentric and that the image is focused.
- Remove the specimen and the objective aperture from the beam.
- Push the STIG button (green LED on).
- Select COND with softkey (COND highlighted).
- Astigmatism is corrected when the focused beam remains as circular as possible when going through beam focus (**`Intensity`**). Adjust this using the **`Multifunction`** X and Y control knobs. Alternatively, the filament can be undersaturated until structure is visible in the focused beam. Astigmatism is corrected when this structure is as sharp as possible (adjust **`Intensity`**, **`Multifunction`** X and Y).

2.5.4 Correcting image astigmatism in the M/SA magnification range

Three factors cause image astigmatism:

1. Asymmetry of the objective lens.
2. Dirt on the objective aperture.
3. The specimen itself. The influence of the specimen on the observed astigmatism can be considerable, particularly in cases where an insulating specimen collects charge, either as a whole or locally. Magnetic specimens also cause strong astigmatism.

Astigmatism is most easily observed on the screen when viewing Fresnel fringes. These fringes result from diffraction phenomena that occur at sharp edges of a specimen when the objective lens is slightly underfocused or overfocused. When the image is underfocused (objective lens weaker than focus), the Fresnel fringe appears as a bright line round the edge of the detail selected. If the detail is a hole, the line will appear on the inside. When the image is overfocused (objective lens stronger than focus), the Fresnel fringe appears as a dark line but otherwise has the same characteristics as in the underfocused condition. With a perfectly symmetrical objective lens field, the fringes will be of uniform width. With an asymmetrical (astigmatic) objective lens, the fringes will also be asymmetrical and, close to the focus, part of the hole will have a bright fringe and the other part a dark fringe associated with it.

For more information about astigmatism in electron lenses, reference is made to the many text books on electron optics, for example:

- Elektronenmikroskopische Untersuchungs- und Präparationsmethoden, Edited by L. Reimer, Springer Verlag, Berlin.

- The Electron Microscope, Edited by M.E.Haine, E. & F.N. Spon Ltd., London.

- Transmission Electron Microscopy (2ed.), L. Reimer (1989), Springer-Verlag, Berlin.

- Experimental High Resolution Electron Microscopy (2ed.), J. C. H. Spence, Oxford University Press, New York, Oxford.

A typical test specimen for measurement and correction of astigmatism is a very thin carbon support film with small perforations. This film must be of a conducting material, because of the high magnifications and thus high beam intensities that will be used and great care should be taken to ensure that the film adheres firmly to the supporting grid.

Very small spherical particles can also be used, but this is not advisable because of the possibility that the projected periphery of the particles may not originate from a single plane. In that case, there will be an inherent change of focus around the particle which cannot be distinguished from astigmatism and will thus be corrected when correcting the astigmatism.

In general, accurate correction of astigmatism can be made only at high magnification and under good image visibility conditions. This implies high beam intensity on the specimen.

In order to compensate for objective lens astigmatism applicable to the M and SA magnification range, an electromagnetic astigmatism corrector is built into the microscope below the objective lens. There are two possible methods for correcting the astigmatism. In the first, use is made of the special test specimen described above. In the second, use is made of the fact that, at high magnification, all thin objects have a substructure in the size range 0.3-0.2 nm and use is then made of the point/focal line phenomena. The latter method is preferred because of the influence of the specimen itself, causing astigmatism to vary for different areas of the specimen. The method requires some experience, however, and it is recommended that this experience be gained, where necessary, by comparing the effect of the two methods on the special test specimen.

Method 1

This method is illustrated in Fig. 2.11 which shows two focal series with astigmatism uncorrected (2-10a, b and c) and corrected (2-10d, e and f). The procedure is as follows:

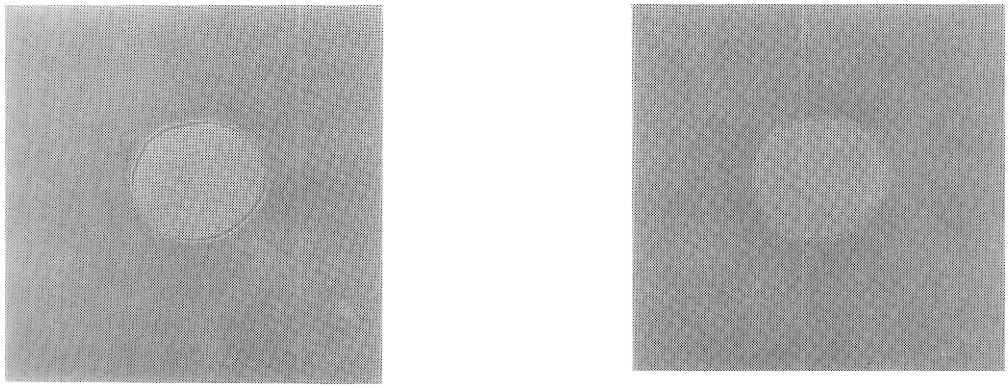
- Obtain a TEM BF image of the test specimen at high magnification (around 100 000x).
- Press STIGmator pushbutton (LED illuminated).
- Select a very small hole. This should be of such a size that it is visible in its entirety through the binoculars at the highest magnification used.
- On the STIGMATOR CONTROL page, adjust the OBJective STIGMATOR STEP SIZE to position 1, 2 or 3, depending on the amount of astigmatism.
  Generally, the lowest possible setting consistent with complete correction should be chosen. The image astigmatism correction is then at its most sensitive setting and accurate correction can be obtained.

  Note: When the astigmatism is so strong that position 4 or even 5 must be selected and the objective stigmator currents displayed on the DISPLAY CURRENTS page exceed 30 mA (key DISPLAY CURRENTS on the first PARAMETERS page) then this is an indication that the specimen, specimen holder and/or the objective lens aperture and holder should be checked for cleanliness.

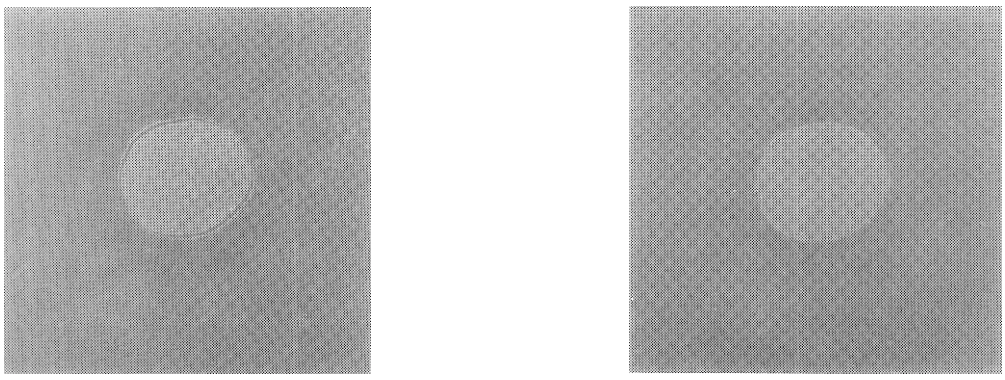
- Adjust the **`Focus`** until the entire hole is overfocused yet close enough to focus for the fringe asymmetry to be visible (black fringe inside the hole, Fig. 2.11a). Change of focus (lower excitation of the objective lens) produces the images in Fig. 2.11b and c.
- Adjust the **`Multifunction`** knobs so that the Fresnel fringe is symmetrical when the objective lens is very slightly overfocused, i.e. one step at position 4 of the FOCUS STEP SIZE knob (see Microprocessor screen).
- To perform this procedure, start adjustment by turning one of the **`Multifunction`** knobs until the setting for minimum astigmatism is obtained (best symmetry for overfocused image). Then adjust the other knob for minimum astigmatism.
- Repeat the preceding step at a higher magnification and with smaller focussing step sizes until adequate correction is obtained (Fig. 2.11d). The criterion for this is that no asymmetry of the fringe can be seen at one or two step positions overfocus of the finest step size. Change of focus (lower excitation of the objective lens) gives rise to the images in Fig. 2.11e and f.

  Note: If the **`Multifunction`** X, Y ranges are insufficient, then the OBJ STIGMATOR SENSITIVITY must be increased one or more steps.

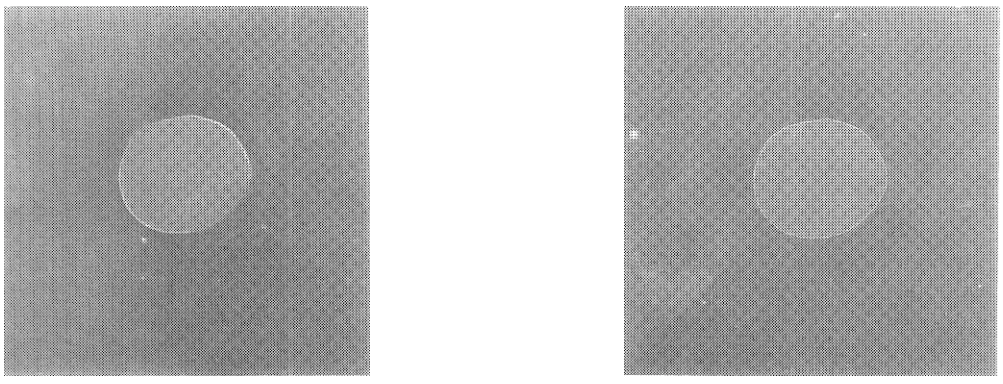
Method 1
Uncorrected **Corrected**



a. **d.**



b. **e.**



c. **f.**

0.1 μm

Fig. 2.11. Image astigmatism correction (Magnification 100 000x)

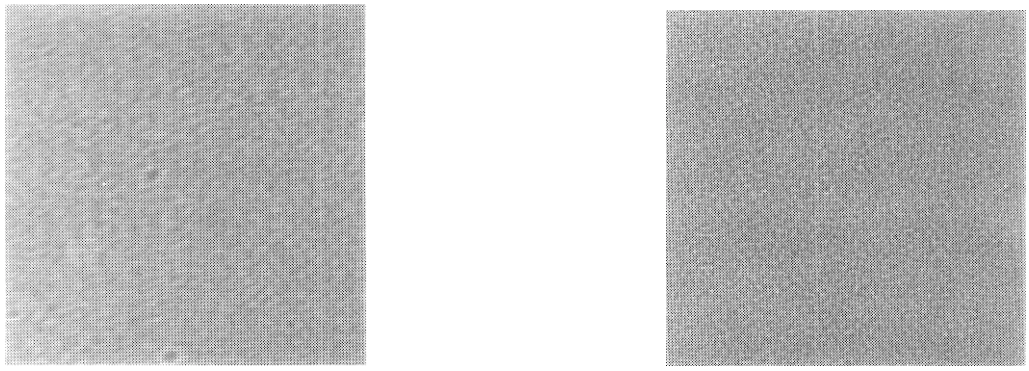
Method 2

This method is shown in Fig. 2.12 which shows two focal series with astigmatism uncorrected (Fig. 2.12a, b and c) and corrected (Fig. 2.12d, e and f).
The procedure for correction of the astigmatism on the specimen sub-structure is as follows:

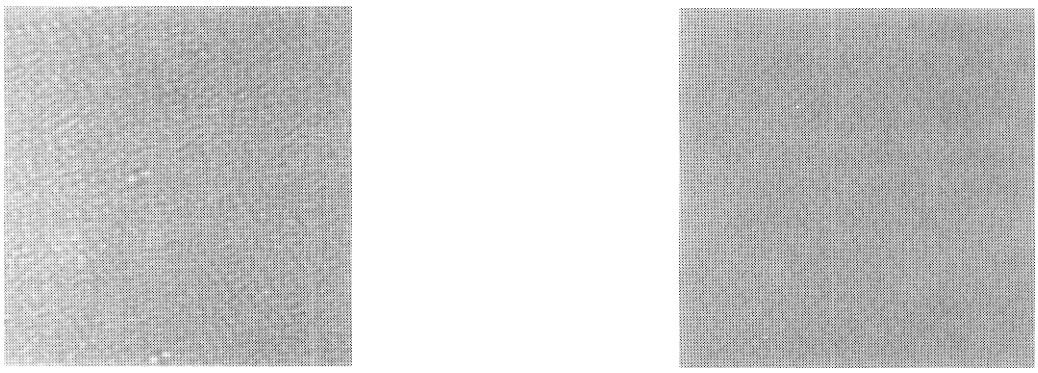
- Select and centre a small C2 aperture (50 μm).
- Set the MAGNIFICATION to a high value (about 200 000x).
- Set the **SPOT SIZE** to step 3 and reduce the **Intensity** as far as possible to be consistent with good visibility of the structure (the contrast of the substructure disappears if the beam is focused too much).
- Select a thin part of the specimen showing fine structure.
- Select FOCUS STEP 2 and with the **Focus** knob, vary the objective lens from slightly overfocused to slightly underfocused (total change in focal length less than 1 μm).
- Look for the line foci (Fig. 2.12a, b and c). Set the **Focus** knob halfway between the settings for these two foci (Fig. 2.12b).
- Press the STIGmator pushbutton (LED illuminated).
  Adjust the two **Multifunction** knobs one at a time to decrease the apparent size of the background structure and at the same time reduce the line effect (Fig. 2.12d, e and f) on changing to over and underfocus.
- Repeat the preceding step (at a higher magnification if desired) until the focal distance between the line foci is as small as required (3 nm or even smaller is possible).

Note: With very thin specimens the substructure disappears from the visual image at focus. This can be used as a very sensitive check on the final correction. The two **Multifunction** knobs are then used to reduce the contrast of the substructure until it finally disappears at focus.

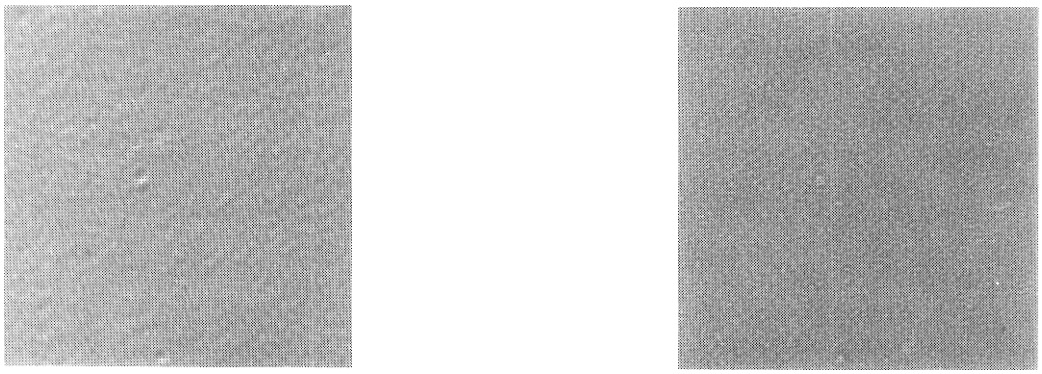
Method 2
Uncorrected **Corrected**



a. **d.**



b. **e.**



c. **f.**

0.1 μm

Fig. 2.12. Image astigmatism correction (Magnification 300 000x)

2.5.5 Correcting image astigmatism in the LM magnification range

When operating in the LM mode, it is possible that some astigmatism will be observed at the higher magnifications. If it is required to make photographs in this mode, astigmatism in the image can be corrected by one of the following methods.

In this case the **Multifunction** knob functions are connected to the diffraction lens stigmator.

Note: Correction of astigmatism in a diffraction pattern requires a different procedure (see Sect. 2.5.6)

Method 1

This method is the same as for objective lens astigmatism (Sect. 2.5.2) and illustrated by Fig. 2.11 which shows two focal series with astigmatism uncorrected (Fig. 2.11a, b and c) and corrected (2-10d, e and f).

- Ensure that a platinum aperture not smaller than 150 μm is mounted in the selected-area aperture holder and that it is clean.
- Insert a test specimen (as described in the introduction to this section).
- Insert and centre the selected-area aperture.
- Press STIGmator pushbutton (LED illuminated).
- Select the highest LM magnification. At this stage, Fresnel diffraction fringes should be observed around the inside of the holes in the specimen.
- If these fringes are not symmetrical, correct the astigmatism using the **Multifunction** knobs.
- Adjust the **Focus** until the entire hole is slightly overfocused, yet close enough to focus for the fringe asymmetry to be visible (black fringe inside hole).
- Adjust the **Multifunction** knobs one at a time so that the Fresnel fringe is symmetrical when the image is very slightly overfocused, i.e. one step at FOCUS STEP position 4 or below. This is achieved by turning the two **Multifunction** knobs until a setting for minimum astigmatism is obtained.

Method 2

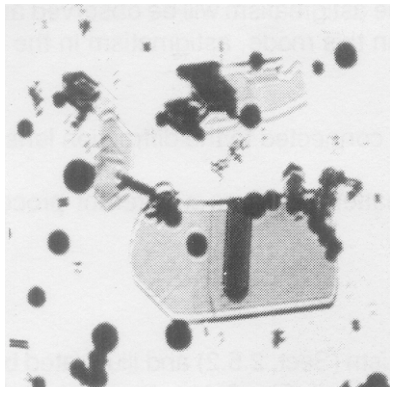
This method is illustrated by Fig. 2.13 which shows:

a) : An overfocused image with asymmetrical Fresnel fringes indicating astigmatism;
b, c, d) : A through-focus series with wobbler in use with astigmatism uncorrected;
e, f, g) : A through-focus series with wobbler in use with astigmatism corrected;
h) : A corrected, focused image, wobbler not in use.

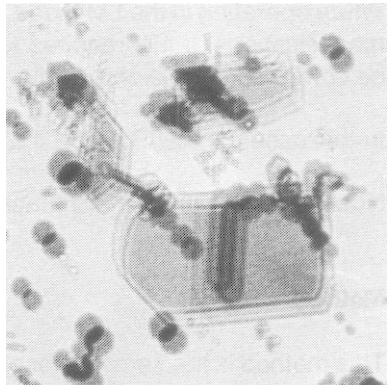
- Ensure that a platinum aperture not smaller than 150 μm is mounted in the selected-area aperture holder and that it is clean.
- Insert a specimen and centre a suitable detail.
- Centre the selected-area aperture.
- Press STIGmator pushbutton (LED illuminated).
- Select MAGNIFICATION to the highest LM value.
- Press the WoBbLer pushbutton.
- Focus the image so that the blurred image details (Fig. 2.13c) are as nearly coincident as possible.
- Adjust the **Multifunction** knobs until the image details are coincident (Fig. 2.13f).
- Repeat the last two steps.

Method 2

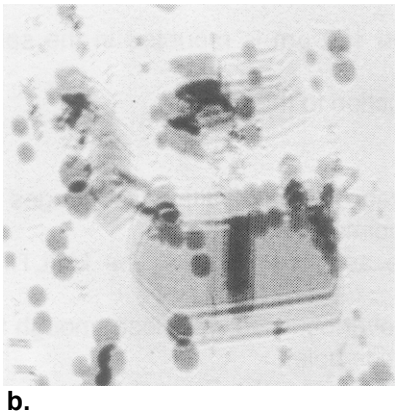
Uncorrected **Corrected**



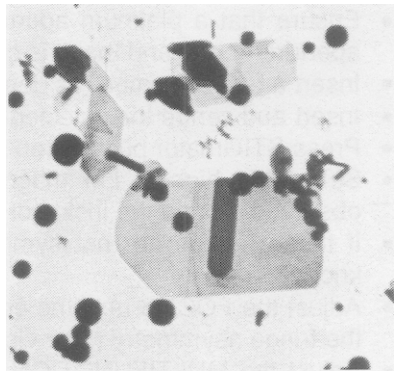
a.



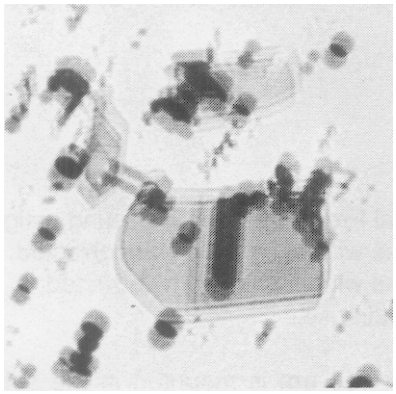
e.



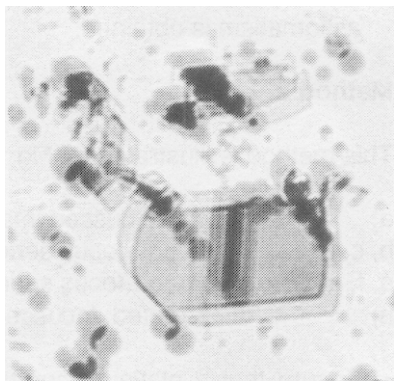
b.



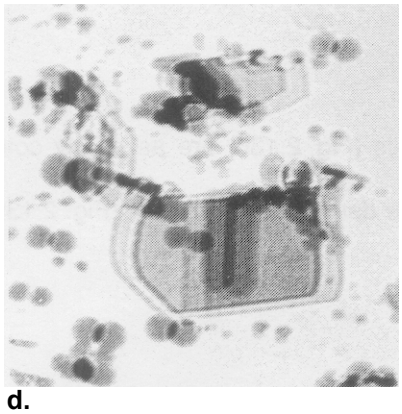
f.



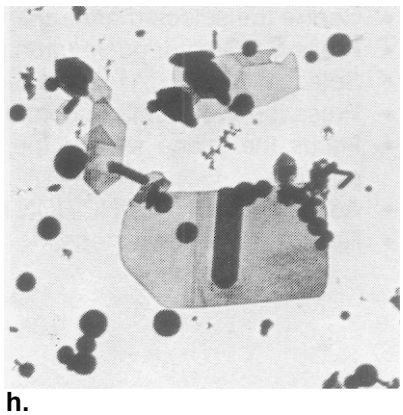
c.



g.



d.



h.

Fig. 2.13.Image astigmatism correction for LM mode

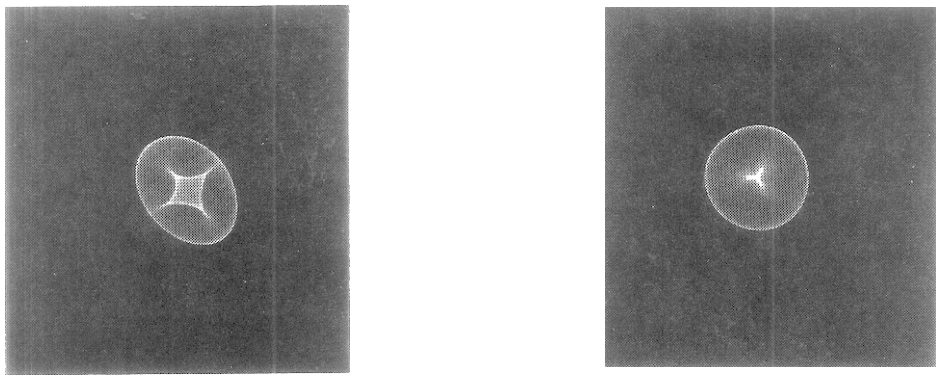
2.5.6 Correcting diffraction pattern astigmatism in the SA diffraction mode

It is possible that some astigmatism will be observed in the diffraction pattern when operating in the Diffraction mode. This astigmatism can be corrected by making the crossover image of the diffraction lens symmetrical. In this case the **Multifunction** knob functions are connected to the diffraction lens stigmator.

Diffraction pattern astigmatism correction

- Obtain a TEM BF image of a specimen in the SA magnification range.
- Remove specimen and objective aperture from the beam.
- Press D button and adjust the MAGNIFICATION knob to obtain the required camera length.
- Set **SPOT SIZE** knob to position 4.
- Turn **Intensity** knob until a low illumination intensity is obtained on the screen.
- Adjust the **Focus** knob until the diffraction crossover image is obtained (Fig. 2.14a).
- Press STIGmator pushbutton (LED illuminated).
- Adjust the **Multifunction** knobs until a symmetrical 3-pointed image is obtained (Fig. 2.14b).

This correction should be made for the camera length being used.



a. Uncorrected **b. Corrected**

Fig. 2.14. Correction of diffraction lens astigmatism for selected-area diffraction

2.6 ALIGNMENTS

2.6.1 Reasons for carrying out an alignment procedure

When the beam is focused and centred on the projection screen and the image is well-focused at a magnification in the middle of the range (i.e., in the order of 30 000x), the following can be expected from a well-aligned electron microscope:

1. A change of the spot size should not produce a significant beam shift. If the beam moves, then GUN SHIFT alignment must be checked using the alignment procedure (aligning spot sizes 3 and 9) or may be optimised for the spot sizes that will be used.

2. An increase or decrease of the magnification setting should not produce an appreciable movement of the beam or of the image. If the image moves out of centre during the transitions from LM to M and back and from SA to the two highest M positions and back, then COLUMN ALIGNMENT is required. Alternatively, the direct alignment IMAGE SHIFT can be used.

3. The image should not move during focussing. If the image moves out of centre during focussing, ROTation CENTRE ALIGNMENT is required.

   Note: Two methods are available for the ROTation CENTRE, voltage centring and current centring. In the former, the high tension is modulated, while in the latter the objective lens current is modulated. Both give an image shift if the beam is not along the optical axis of the microscope. The current centring method is set as the default position. The strength of the modulation is set by the FOCUS STEP SIZE.

4. The image should not move during astigmatism correction. If the relevant image moves out of the centre of the screen during any astigmatism correction, i.e. using the C2, objective or diffraction stigmators, the corresponding STIGMator needs re-ALIGNMENT.

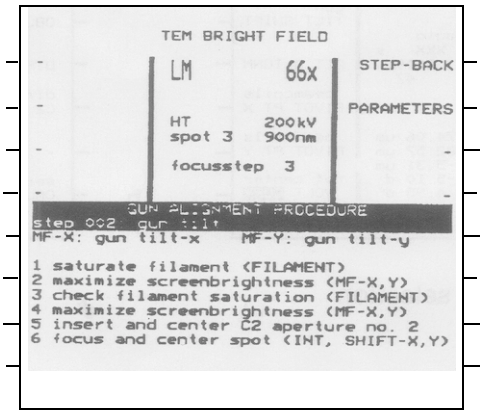
5. The electron beam should remain along the optical axis during beam shift. If a shift of the beam is accompanied by a tilt, or vice versa, PIVOT POINT ALIGNMENT is required. The beam tilt PIVOT POINT (Wobbler) can be aligned by direct PIVOT POINT alignment. The shift PIVOT POINT must be aligned in the COLUMN alignment procedure.

2.6.2 Direct alignments and alignment procedures

Alignments can be carried out as so-called DIRECT ALIGNMENTS or in ALIGNMENT PROCEDURES. The DIRECT ALIGNMENTS give immediate access to the alignment coils needed to correct the detected misalignment. The required functions are assigned to the **`Multifunction`** knobs by the selection of direct alignment. These assignments are operational as long as the ALIGNMENT SELECTION page is displayed and the function in question is highlighted. The ALIGNMENT SELECTION is called up by activating the ALiGNment button. The direct alignments are listed on the right-hand column of the page (see Fig. 2.15a and b).

For further information about direct alignments, please refer to the related mode descriptions in Sect. 2.6.6. The user is strongly recommended to use the DIRECT ALIGNMENTS if a specific misalignment is recognised and the alignment criterion is known. The DIRECT ALIGNMENTS provide a very efficient way of correcting a single misalignment. The alignment procedures can be selected on the ALIGNMENT SELECTION page. These procedures are independent of the actual operating mode.

The alignment procedures should be used when a general microscope alignment is required. The procedures are selected on the left-hand column of the ALIGNMENT SELECTION page. The general layout of an alignment page is as follows:



On each procedure page there are two softkeys:

STEP BACK : Allows a return to the previous procedure step.
PARAMETERS : Allows a check or change of the microscope parameters.

The Information Field displays the status to which the microscope is automatically brought to allow the required test and correction.

The lower half of the procedure page is headed by the highlighted procedure name, in the example given above this is GUN ALIGNMENT procedure. This is followed by the procedure title below which is the procedure step number and the step title. The first line in the instruction field explains which function is performed by the **`Multifunction`** knobs. This is followed by detailed operator instructions.

2.6.3 Operational procedure for carrying out alignments

The alignment procedures provide a complete sequence of alignment steps for aligning a major part of the microscope.

Press the ALiGNment button (LED on). An ALIGNMENT SELECTION page will be displayed.

- If an imaging mode was previously selected, the page illustrated in Fig. 2.15a will be obtained.
- If a diffraction mode was previously selected, the page illustrated in Fig. 2.15b will be obtained.

To use the alignment procedure:

- Press the desired softkey. The label will be highlighted. Up to this point no changes of the microscope settings will have occurred.
- Key the selected label a second time to call up the first page of the procedure. Fig. 2.16 shows an example for carrying out the GUN ALIGNMENT PROCEDURE.

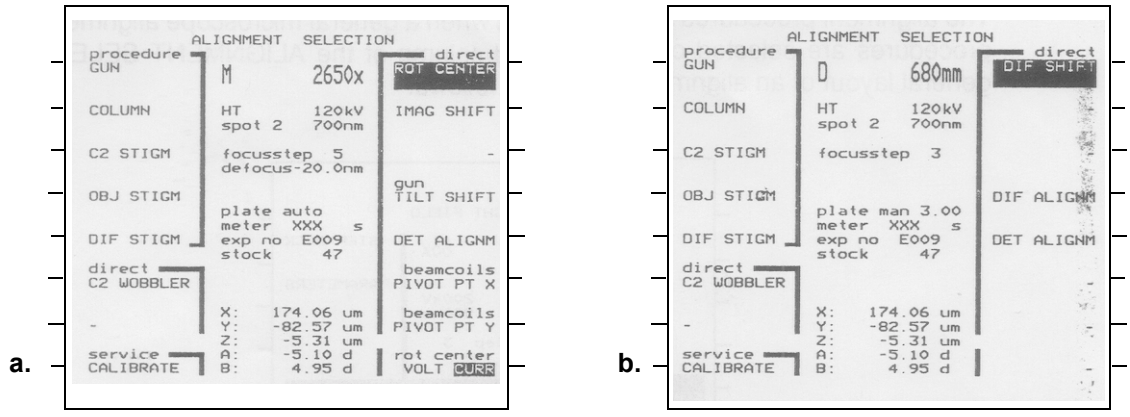


Fig. 2.15. Alignment selection

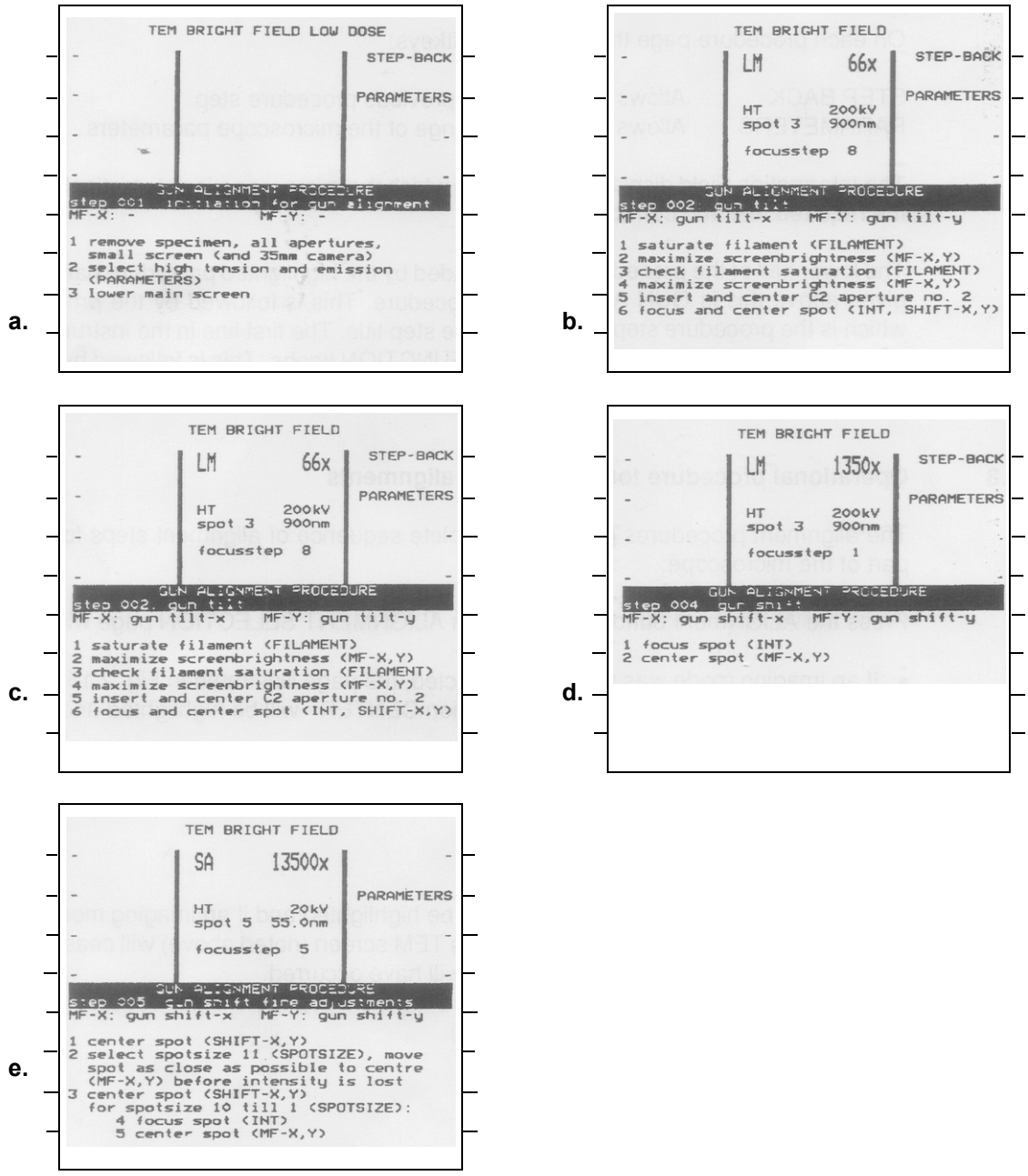


Fig. 2.16. Gun alignment procedure

- Perform the instructions given on the lower of the microcontroller screen.
- When the instructions are completed, press the Ready button to obtain the next page of the ALIGNMENT PROCEDURE (Fig. 2.16b).

  Note: At any point alignments previously made in the series can be checked by keying STEP-BACK.

- Carry out the instructions on the microcontroller screen and press Ready.
- Repeat the same for step 3 and 4 (Fig. 2.16c and d) and press Ready.
- In step 5 (Fig. 2.16e) the procedure recommends to do all the steps on that page for the Spot sizes 11 to 1. After this step is finished pressing Ready brings the ALIGNMENT SELECTION page back and the Gun Alignment procedure is completed (Fig. 2.15a).
- Select the next procedure required or leave the ALIGNMENT SELECTION page by de-activating the ALiGN button.

  Note: 1) Carry out only those procedures for which re-alignment is necessary.

  2) A number of alignments must be carried out iteratively. The Microcontroller will, in each of these cases, repeat the required steps as often as necessary.

The procedures may be selected as required, e.g. gun alignment after a filament change. A total microscope alignment sequence should include all procedures in the sequence listed on the left-hand side of the ALIGNMENT SELECTION page, carried out from top to bottom. The selectable alignment procedures are on the subsequent pages. The same operational procedure as outlined above should be carried out.

2.6.4 Supplementary mechanical alignments

Condenser aperture centring

- Obtain a TEM BF image in the SA magnification range.
- Remove the specimen.
- Focus the illumination using the **`Intensity`** knob and centre the beam, as necessary, using the **`SHIFT X, Y`** knobs.
- Defocus the illumination clockwise. The illuminated area should still be around the centre of the screen. If not align the condenser aperture using the mechanical aperture controls to achieve this condition. (An **`Intensity`** wobbler is available on the ALiGNment page: press C2 WOBBLER).
- Repeat the last two steps until the illuminated area remains centred and becomes concentrically smaller or larger on changing the setting of the **`Intensity`** knob.

  Note: For the smaller C2 aperture, the beam may shift in different directions when going from underfocus to overfocus. If this is the case, align the aperture by keeping the beam centred when going from focus to overfocus by turning the **`Intensity`** knob clockwise.

Objective aperture centring

- Obtain a TEM BF image in the SA magnification range.
- Focus the illumination using the **`Intensity`** knob.
- Obtain a diffraction pattern at a camera length of approximately 600 mm.
- Introduce the required objective aperture into the beam and centre it around the central beam spot using the mechanical aperture controls.

Note: If the objective aperture is smaller than the central diffraction disc, use either a smaller C2 aperture or a larger objective aperture. Alternatively, obtain a selected area diffraction pattern using a selected area aperture and defocused beam.

2.6.5 Complete Microscope alignment procedure

There are two different situations in which the operator can decide to carry out a total alignment sequence:

a) Normal case:

The first situation is where, in one or more modes, the function of the microscope is not optimal and the operator is not able to optimise the microscope by using direct alignments or one or more of the alignment procedures.

b) Exceptional case:

The second situation is when the Random Access Memory (RAM) which contains the alignment, is initialised by a RAM INIT (the factory alignment will now be loaded and will need the usual fine trimming). A RAM INIT can occur in two ways:

1) After an extremely strong flashover the microprocessor may detect that the RAM values are damaged during a diagnostic test (which is always carried out automatically during the start-up procedure) and will execute the RAM INIT procedure.

2) The operator may decide that the total alignment is lost and then proceed as follows:

- Press RESTART button (which is positioned between ROOM DIM and DATA DIM) with the point of a pencil. No RAM INIT is performed.

Caution! The operator must continue beyond this point **only** if the above procedure **does not** restore the correct alignment.

- Go to the CONFIGURATION page (press MODES and CONFIGURATION) and make a written note of all the important information such as aperture sizes and type of gun, because RAM INIT will not only clear the alignment parameters in the non-volatile RAM, but the data on this page as well. Also make a note of the camera EMULSION and DATA INT values.
- Press **`service CALIBRATE`** on ALIGNMENT page to obtain the Service calibration procedures.
- Press RAM INIT, which will become highlighted.
- Press RESTART button. The diagnostic program will give the message:

  Default RAM Initialisation.

- Press the **`Reset`** button to remove the message RUN INITIALISATION from the screen and perform the total alignment sequence.

When executing the total alignment sequence, as described below, the operator should realise that, in the case of situation 2 RAM INIT all parts of the sequence should be executed. In case of situation 1 all procedures which are part of the service CALIBRATION page in principle don't need to be executed because they should still be unaltered, though checking them is advisable.

c) Total alignment sequence:

- For optimum alignment accuracy choose the highest high-tension value.
- Press the ALiGNment button.
- Execute the GUN procedure.
- Bring the specimen to the eucentric height.
- Choose service CALIBRATION page and execute image coils PIVOT POINTS procedure.
- Press Ready button to go back to Alignment page and execute the procedure COLUMN.
  The Nanoprobe alignment procedure - steps 007 to 012 of the column procedure - needs some extra attention. In step 007, focussing the image is difficult when the objective lens is far from the focused condition. Proceed as follows:
  - Key PARAMETER then key DISPLAY CURRENTS. Turn the **Focus** knob until the objective lens current is close to 5500 (at 200 kV) and overfocus the **Intensity** (C2 current approx. 900). The twin lens current should be approx. -2450.
  - Turn **Focus** knob until the condenser aperture is visible.
  - Focus the condenser aperture (determined by a sharp profile of the illuminated disc on the specimen).
  - Focus the spot on the specimen (**Intensity**).
- Perform steps 008 to 012 and step back to 006 and forward to 007.
- Perform the Nanoprobe alignment steps 007 to 012 once again.
- Carry out the STIGMATOR procedures on the Alignment page.

  Note: If astigmatism causes problems during any alignment procedure, the STIGMATOR CONTROL page can be activated by pushing the STIGmator button (green LED on). The relevant stigmator can now be selected and the **Multifunction** controls will become stigmator controls and the astigmatism can be corrected.

- Perform the Service Calibrations that have not yet been carried out on the SERVICE CALIBRATION page.

d) Additional alignments

- The Low-Magnification Scanning (LMS) images may be distorted and the magnification may be incorrect because the pivot points X and Y of the LMS are not perfectly aligned. Go to LMS between 70 and 200X and key pivot point X or Y on the right-hand side of the alignment page and optimise the image with the **Multifunction** knobs. **Multifunction X** serves to acquire an image of the total specimen with homogeneous intensity and **Multifunction** Y serves to remove image distortion. Toggle between pivot point X and Y to optimise the image. This should be performed as accurately a possible.

- The High and Low Magnification Scanning images are shifted with respect to each other. This can be corrected by adding an additional image shift to the LMS images.

  - Select HMS 4800x and position a recognisable image feature with the specimen drives at the centre of the monitor screen.
  - Go to LMS (3000x or lower), key IMAGE SHIFT on the alignment page and centre the recognisable detail feature with the **Multifunction** knobs.
  - Similarly, an image shift between TEM and high Magnification Scanning can be corrected by centring a recognisable image feature in TEM Bright Field, switching to SCANNING and centring the feature using IMAGE SHIFT.

- In the case of a near-axis STEM detector an additional diffraction pattern shift is needed to obtain images from the BF/DF detector. This alignment must be performed for all camera lengths of 100 mm and higher that will be used.
- Check that the DETector CONFiguration has been set correctly (see Sect. 2.7).
  - Key DET ALIGNMent on the ALIGNMENT SELECTION page while in scanning mode (in the case of Rocking Beam, use DIFF SHIFT for one camera length).

  - Shift Diffraction pattern to the location of the near-axis detector (25 mm from the centre in the 2 o'clock direction) by using the **Multifunction** knobs. If the diffraction pattern is not visible, press the **Reset** button.

2.6.6 Step-by-step procedures for direct alignments

Note: All alignments should be performed with the specimen at the eucentric position.

beamcoils
PIVOT PT X, Y

Function : Align beam deflection coils pivot points.

Present in : TEM BF mode, TEM LOW DOSE mode, NANOPROBE mode.

Used in : All the above.

Operation :

- Focus specimen (**Focus**), Focus beam (**Intensity**), Key PIVOT PT X and adjust **Multifunction** X,Y until spot movement is minimised (two bright spots overlap).
- Key PIVOT POINT Y and minimise spot movement.

DET ALIGNM

Function : Shifts images onto the desired detector.

Present in : All modes.

Used in : All modes.

Operation : See Chapt. 2.7.

DIF ALIGNM

Function : Aligns diffraction patterns for all camera lengths.

Present in : TEM BF Diffraction (not in LAD), TEM LOW DOSE Diffraction, NANOPROBE Diffraction.

Used in : All the above.

Operation :

- Select Diffraction mode (D button) and key DIF ALIGNM on ALIGNMENT SELECTION page.
- Select smallest camera length (MAGNIFICATION).
- Focus diffraction pattern (**Focus**) and centre central beam spot using **Multifunction** X and Y.
- Increase camera length, focus and centre central spot.
- Repeat for all camera lengths. Press **Reset** if central spot is invisible.

DIF SHIFT

Function : Shifts the diffraction pattern.

Present in : TEM BF Diffraction, TEM LOW DOSE Diffraction, NANOPROBE Diffraction.

Used in : All the above.

Operation :

- Select Diffraction mode (D button).
- Key DIF SHIFT on ALIGNMENT SELECTION page and centre diffraction pattern using **`Multifunction`** X and Y.

  Note: This function is the same as using the **`Multifunction`** knobs in diffraction when alignment is not active.

GUN SHIFT

Function : Aligns for beam shift for different spot sizes.

Present in : TEM BF mode, TEM LOW DOSE mode, NANOPROBE mode.

Used in : All the above.

Operation :

- Go to a low magnification in the SA range.
- Key GUN SHIFT on the ALIGNMENT SELECTION page and select spot size 9.
- Focus beam (**`Intensity`**) and centre spot using **`SHIFT X, Y`**.
- Select spot size 3 and centre spot using **`Multifunction`** X and Y.
- Repeat until beam remains centred for both spot sizes. If necessary, other spot sizes than 9 and 3 can be selected.

  Note: 1) Owing to the low C_1 currents for spot sizes 1 and 2, it may not be possible to remove all spot shifts for these spot sizes using the GUN SHIFT alignment.
  2) Gun shift alignments for all spot sizes can only be performed in the last step of the GUN procedure.

GUN TILT

Function : Maximises brightness of incident beam.

Present in : TEM BF Image, TEM LOW DOSE Image, NANOPROBE Image.

Used in : All the above.

Operation :

- Select low magnification in the SA range.
- Press GUN TILT on ALIGNMENT SELECTION page.
- Focus Beam (**`Intensity`**).
- Maximise screen brightness. If necessary recentre the beam using the **`SHIFT X, Y`** knobs.

IMAG SHIFT

Function : Align images in different magnification ranges.

Present in : TEM BF Image, TEM LOW DOSE Image, NANOPROBE Image.

Used in : All the above

Operation :

- Key IMAG SHIFT on ALIGNMENT SELECTION page.

- Go to high SA magnification and centre a recognisable image feature on screen centre using specimen stage controls.
- Proceed to highest SA magnification and, if necessary, recentre image feature with specimen stage controls.
- Focus image (**Focus**) then increase the magnification one step (to the high M range).
- Centre the image feature using the **Multifunction X, Y** knobs (if feature not visible on screen, first centre the beam **with the Multifunction X, Y knobs**, the feature will move along with the beam centre).
- Focus image (**Focus**) then go to lowest M magnification (below the SA range).
- Centre a recognisable image feature with the specimen stage controls.
- Focus image (**Focus**) and centre beam (**Intensity**, **SHIFT X, Y**).
- Go one step down in magnification to the highest LM magnification and centre the image feature with **Multifunction** X, Y knobs, focus image (**Focus**) and centre beam (**Intensity**, **SHIFT X, Y**).

Note: Image shift alignments for all magnifications can only be performed in the COLUMN procedure. Similarly, the focus correction for SA to high M can only be done in the COLUMN procedure.

IMAGE/BEAM ALIGNMENT

In TEM Low Dose and the HR-TEM operating modes a coupled image/beam shift is applied to observe off-axis areas with the beam centred on the viewing screen. Because there are differences between individual microscopes, a calibration is needed of the beam shift as a function of image shift. This calibration is (and must be!) done in the IMAGE/BEAM alignment procedure, which is found on the service calibration page (lower left-hand softkey on the ALIGNMENT SELECTION page). Press IMAGE/BEAM twice to enter the procedure and follow the instructions.

ROT CENTER

Function : Aligns the objective lens rotation centre.

Present in : TEM BF Image, TEM LOW DOSE Image, NANOPROBE Image.

Used in : All the above

Operation :

- Go to intermediate magnification in SA or LM range (these have different rotation centres) and select ROT CENTER on ALIGNMENT SELECTION page.
- Select FOCUS STEP 5 or 6.
- Minimise image movement using **Multifunction** X and Y.
- Increase FOCUS STEP to 7 or 8 and repeat.

2.6.7 Help information for alignment procedures

This chapter contains help information for every alignment step of the COLUMN, C_2 STIGM, OBJ STIGM and DIF STIGM alignment procedures, the GUN procedure is explained in 2.6.3. This information is intended for users who are interested in detailed information concerning the purpose, importance and method of every alignment step. The whole text is also available as on-line help when running the remote control program TRANS or CM Alignment Help under Windows. This programs steps the operator through the different alignment procedures with on-line help available for every step.

Step 007: prep for nanoprobe alignment

Purpose: Finding focus and a centred beam for the nanoprobe (small-probe) mode.
Importance: ESSENTIAL as otherwise the steps following will be impossible.
Method: Focus the image and shift the beam to the centre.

Note: Focus can be difficult to find for the nanoprobe mode. Two methods may help:

1) Focus until the objective lens current (DISPLAY CURRENTS) is nearly the same as in TEM mode;
2) Focus the beam (INT) and minimise the fuzzy ring around it (**`Focus`**).
   If the image moves strongly during focusing, proceed to step 012 (rotation centre) and then Step-BACK to here. If necessary repeat the nanoprobe part (steps 007-012) of the COLUMN procedure to get the correct alignment.

Step 008: pivot of nano-deflection-x

Purpose: Make sure that the beam does not tilt when it is shifted in the x direction.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two spots visible in the diffraction pattern should overlap.

Note: The nanoprobe shift pivot point is identical to the direct alignment pivot point for scanning.

Step 009: pivot of nano-deflection-y

Purpose: Make sure that the beam does not tilt when it is shifted in the y direction.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two spots visible in the diffraction pattern should overlap.

Note: The nanoprobe shift pivot point is identical to the direct alignment pivot point for scanning.

Step 010: pivot point of nano tilt-x

Purpose: Make sure that the beam does not shift when it is tilted in the x direction.
Importance: ESSENTIAL for keeping the beam centred during rotation centre alignment.
Method: A tilting beam must remain centred on the specimen (= tilt pivot point). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Note: Unlike the shift pivot (previous two steps), the tilt pivot point is sensitive to objective lens focus and is therefore also available as a direct alignment.

Step 011: pivot point of nano tilt-y

Purpose: Make sure that the beam does not shift when it is tilted in the y direction.
Importance: ESSENTIAL for keeping the beam centred during rotation centre alignment.
Method: A tilting beam must remain centred on the specimen (= tilt pivot point). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Note: Unlike the shift pivot (previous two steps), the tilt pivot point is sensitive to objective lens focus and is therefore also available as a direct alignment.

Step 012: nanoprobe rotation centring

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimising the effects of aberrations on the small spot.
Method: The microscope 'wobbles' the objective lens current, making the image and beam go through focus. The 'focus wobble' can be made smaller or larger with the FOCUS Step SIZE knob. Because the spot and not the image is important in nanoprobe, optimise the spot by first setting the 'wobble' to the smallest step (focus step 1), focus the beam (INT) and increase the wobble (focus step). Adjust the rotation centre until the beam expands and contracts concentrically.

Step 013: preparation for HM-TEM alignment

Purpose: Set up microscope for aligning the column.
Importance: ESSENTIAL to make sure that the alignment is done for the correct conditions: centred C_2 aperture, eucentric height and specimen in focus.
Method: C_2 aperture centring: focus spot and centre it on the screen. Turn **`Intensity`** over-focus (clockwise) and centre aperture until illuminated area is symmetrical around screen centre. Eucentric height: Go to COMPUSTAGE, select the A-WOBBLER and change the Z-position until the image doesn't move anymore.

Note: C_2 aperture no. 2 is the second smallest (usually 50 μm). SA aperture no. 3 (not on CM10) is the second largest (200 μm).

Step 014: twin lens current adjustment

Purpose: Set the focal length of the twin lens at the front-focal plane of the objective lens. The diffraction pattern is then always in focus at the level of the objective aperture.
Importance: ESSENTIAL for proper nanoprobe and scanning operation.
Method: First set up by focusing the diffraction pattern (smallest diffraction spots). Now press Reset to put the TWIN lens current to its optimum value of 90% of its maximum. This value should only be changed with MF-X for special applications.

Step 015: pivot point of HM-TEM deflec.-x

Purpose: Make sure that the beam does not tilt when it is shifted in the x direction.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two spots visible in the diffraction pattern should overlap.

Note: The shift 'wobble' may have one beam position blocked by the SA aperture or the specimen. If no second beam is visible when turning MF-X, then (re)move the aperture and/or specimen.

Step 016: pivot point of HM-TEM deflec.-y

Purpose: Make sure that the beam does not tilt when it is shifted in the y direction.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself means that it must always go through the front-focal point (= shift pivot point) of the objective lens. This plane is conjugate to the back-focal (diffraction) plane and can thus be seen in diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so the two spots visible in the diffraction pattern should overlap.

Note: The shift 'wobble' may have one beam position blocked by the SA aperture or the specimen. If no second beam is visible when turning MF-X, then (re)move the aperture and/or specimen.

Step 017: HM-TEM wobbler alignment x

Purpose: Make sure that the beam does not shift when it is tilted in the x direction.
Importance: ESSENTIAL for keeping the beam centred during objective lens alignment and dark-field imaging.
Method: A tilting beam must remain centred on the specimen (= tilt pivot point). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Note: Unlike the shift pivot (previous two steps), the tilt pivot point is sensitive to objective lens focus and is therefore also available as a direct alignment.

Step 018: HM-TEM wobbler alignment y

Purpose: Make sure that the beam does not shift when it is tilted in the y direction.
Importance: ESSENTIAL for keeping the beam centred during objective lens alignment and dark-field imaging.
Method: A tilting beam must remain centred on the specimen (= tilt pivot point). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Note: Unlike the shift pivot (previous two steps), the tilt pivot point is sensitive to objective lens focus and is therefore also available as a direct alignment.

Step 019: rotation centring HM-TEM

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimising lens aberrations and image movement during focusing.
Method: The microscope 'wobbles' the objective lens current, making the image go through focus. Make the sideways movement of the image as small as possible with the rotation centre (= tilting the beam to the optical axis).
The 'focus wobble' can be made smaller or larger with the FOCUS Step size knob.

Note: For proper high-resolution alignment of the objective lens on the CM200 and CM300, rotation centre is only suitable as a first step. Direct alignment COMA-FREE should be used as the final objective lens alignment.

Step 020: HM-TEM camera length range al.

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the centre when the camera length is changed.
Importance: CONVENIENCE
Method: Centre the diffraction pattern for the smallest camera length, increase the camera length (Magnification) and centre the pattern, etc.

Note: In order to make the diffraction pattern position reproducible the microscope normalizes the lenses when switching between different camera lengths for each camera length.

Step 021: preparation for M-alignment

Purpose: Find some feature in the specimen that can be recognised at high magnifications to align images.
Importance: CONVENIENCE (a recognisable image feature may be difficult to find at high magnification).
Method: Move the required feature in the specimen to the centre with the specimen stage.

Note: If large specimen stage movements are necessary to find a recognisable feature, then check the eucentric height and wait until drift has stopped.

Step 022: preparation for M-alignment

Purpose: Fine centring of the image feature and setting the auto-focus preset at the eucentric height.
Importance: CONVENIENCE for finding the image at the high M magnifications and having the auto-focus at the eucentric height.
Method: Centre the recognisable image feature with the specimen stage and focus the image.

Note: For better reproducibility the microscpe normalizes the lenses. For CM200 and CM300 microscopes, different M image shifts are remembered for the three highest high tension steps. Repeat steps 021, 022 and 023 for these voltages separately.

Step 023: TEM M-alignment

Purpose: Aligning the M-magnification image with SA and finding the difference in focus.
Importance: CONVENIENCE for being able to find the image at high magnifications.
Method: Centre the recognisable image feature from the previous step.

Note: The 'centre illumination' instruction with the MF-X,Y is correct! The beam will still be centred on the image feature but the whole image may be shifted off. Bringing the beam to the centre first by shifting the image - not the beam - allows one to see the image feature and then centre it.
If focus is difficult to find, Step-BACK and look at the OBJ current (DISPLAY CURRENTS), then press READY again and turn focus until about the same current is obtained.
Lens normalisation is again advised.

Step 023a: SA image shift correction

Purpose: Aligning all SA and M images with each other.
Importance: CONVENIENCE so that the image remains centred when the magnification is changed.
Method: Centre the recognisable image with the specimen stage. Then lower the magnification one step, centre the image, and repeat for all magnifications.

Step 024: preparation for LM-TEM alignm.

Purpose: Aligning the LM-magnification image with the M image.

Importance: CONVENIENCE for finding the same image feature centred when crossing from M to LM (or vice versa).
Method: Focus the image (M magnification) and centre the recognisable image feature with the specimen stage.

Note: For better reproducibility a normalisation is carried out automatically.

Step 025: LM-TEM image shift

Purpose: Aligning the LM-magnification image with the M image.
Importance: CONVENIENCE for finding the same image feature centred when crossing from M to LM (or vice versa).
Method: Focus the image (LM magnification) and centre the recognisable image feature with MF-X,Y.

Step 025a: LM image shift correction

Purpose: Aligning all LM images with each other.
Importance: CONVENIENCE so that the image remains centred when the magnification is changed.
Method: Centre the recognisable image with the specimen stage. Then lower the magnification one step, centre the image, and repeat for all magnifications.

Step 026: pivot point of LM beam tilt-x

Purpose: Make sure that the beam does not shift when it is tilted in the x direction.
Importance: ESSENTIAL for keeping the beam centred during objective lens alignment and focusing using the wobbler.
Method: A tilting beam must remain centred on the specimen (= tilt pivot point). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Step 027: pivot point of LM beam tilt-y

Purpose: Make sure that the beam does not shift when it is tilted in the y direction.
Importance: ESSENTIAL for keeping the beam centred during objective lens alignment and focusing using the wobbler.
Method: A tilting beam must remain centred on the specimen (= tilt pivot point). The tilt wobble done by the microscope should give no beam shift, so only one spot should be visible in the image.

Step 028: LM rotational alignment

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimising lens aberrations and image movement during focusing.
Method: The microscope 'wobbles' the objective lens current, making the image go through focus. Make the sideways movement of the image as small as possible with the rotation centre (= tilting the beam to the optical axis).
The 'focus wobble' can be made smaller or larger with the FOCUS Step size knob.

Step 031: C2 stigmator adjustment

Purpose: Set up for C2 stigmator alignment.
Importance: CONVENIENCE
Method: Set up conditions where the image is in focus and the beam can be seen.

Note: The alignment of the C2 stigmator means finding the relation between a change in stigmator setting

and beam shift. During operation the microscope then corrects a stigmator-induced beam shift with a shift by the beam deflection coils.

Step 032: alignment C2 stigmator X

Purpose: Find the beam shift as a function of C2 stigmator in the x direction.
Importance: CONVENIENCE
Method: Focus the beam (INT) until the 'wobble' on the stigmator gives two short lines at right angles. Make the lines intersect in a cross (each one goes through the middle of the other one, compare Fig. 36 in Appendix B).

Note: The alignment of the C2 stigmator means finding the relation between a change in stigmator setting and beam shift. During operation the microscope then corrects a stigmator-induced beam shift with a shift by the beam deflection coils.

Step 033: alignment C2 stigmator Y

Purpose: Find the beam shift as a function of C2 stigmator in the y direction.
Importance: CONVENIENCE
Method: Focus the beam (INT) until the 'wobble' on the stigmator gives two short lines at right angles. Make the lines intersect in a cross (each one goes through the middle of the other one).

Note: The alignment of the C2 stigmator means finding the relation between a change in stigmator setting and beam shift. During operation the microscope then corrects a stigmator-induced beam shift with a shift by the beam deflection coils.

Step 034: C2 stigmator adjustment

Purpose: Make sure that beam astigmatism is corrected (can also be done directly by selecting the COND stigmator on the stigmator page).
Importance: CONVENIENCE
Method: Beam astigmatism is corrected when the beam remains round when it is defocused with the `Intensity` knob.

Step 035: objective stigmator adjustment

Purpose: Set up for objective stigmator alignment.
Importance: CONVENIENCE
Method: Set up conditions where the image is in focus.

Note: The alignment of the objective stigmator means finding the relation between a change in stigmator setting and image shift. During operation the microscope then corrects a stigmator-induced image shift with a shift by the image deflection coils.
It is advised to perform this procedure with a specimen that has few, easily recognisable features (not something like gold islands on carbon).

Step 036: alignment obj-stigmator X

Purpose: Find the image shift as a function of objective stigmator in the x direction.
Importance: CONVENIENCE
Method: Make the two images produced by the 'wobble' on the stigmator overlap.

Note: The alignment of the objective stigmator means finding the relation between a change in stigmator setting and image shift. During operation the microscope then corrects a stigmator-induced image shift with a shift by the image deflection coils.

Step 037: alignment obj-stigmator Y

Purpose: Find the image shift as a function of objective stigmator in the y direction.
Importance: CONVENIENCE
Method: Make the two images produced by the 'wobble' on the stigmator overlap.

Note: The alignment of the objective stigmator means finding the relation between a change in stigmator setting and image shift. During operation the microscope then corrects a stigmator-induced image shift with a shift by the image deflection coils.

Step 038: objective stigmator adjustment

Purpose: Make sure that image astigmatism is corrected (can also be done directly by selecting the OBJ stigmator on the stigmator page).
Importance: CONVENIENCE
Method: Image astigmatism is corrected when the image contains no preferential direction during focusing (see OPERATING INSTRUCTIONS for further details).

Step 039: dif-stigmator adjustment

Purpose: Set up for diffraction stigmator alignment.
Importance: CONVENIENCE
Method: Set up conditions where the LM image is in focus.

Note: The HM diffraction pattern and the LM image are focused with the diffraction lens. Their stigmator is therefore also the same: the diffraction stigmator.
The alignment of the diffraction stigmator means finding the relation between a change in stigmator setting and diffraction pattern/LM image shift. During operation the microscope then corrects a stigmator-induced diffraction pattern/LM image shift with a shift by the image deflection coils.

Step 040: alignment dif-stigmator X

Purpose: Find the diffraction pattern/LM image shift as a function of diffraction stigmator in the x direction.
Importance: CONVENIENCE
Method: Make the two images produced by the 'wobble' on the stigmator overlap.

Note: The HM diffraction pattern and the LM image are focused with the diffraction lens. Their stigmator is therefore also the same: the diffraction stigmator.
The alignment of the diffraction stigmator means finding the relation between a change in stigmator setting and diffraction pattern/LM image shift. During operation the microscope then corrects a stigmator-induced diffraction pattern/LM image shift with a shift by the image deflection coils.

Step 041: alignment dif-stigmator Y

Purpose: Find the diffraction pattern/LM image shift as a function of diffraction stigmator in the y direction.
Importance: CONVENIENCE
Method: Make the two images produced by the 'wobble' on the stigmator overlap.

Note: The HM diffraction pattern and the LM image are focused with the diffraction lens. Their stigmator is therefore also the same: the diffraction stigmator.
The alignment of the diffraction stigmator means finding the relation between a change in stigmator setting and diffraction pattern/LM image shift. During operation the microscope then corrects a stigmator-induced diffraction pattern/LM image shift with a shift by the image deflection coils.

Step 042: dif-stigmator adjustment

Purpose: Make sure that LM image astigmatism is corrected (can also be done directly by selecting the DIF stigmator on the stigmator page).
Importance: CONVENIENCE
Method: Image astigmatism is corrected when the image contains no preferential direction during focusing (see OPERATING INSTRUCTIONS for further details).

Step 072: prep for HM-SCAN alignment

Purpose: Finding focus and a centred beam for the scanning mode.
Importance: ESSENTIAL as otherwise the steps following may be difficult.
Method: Focus the image and shift the beam to the centre.

Note: In this step the regular TEM image is used. It is advisable to centre the beam on an easily recognisable image feature.

Step 073: HM-SCAN image alignment

Purpose: Aligning the scanning image with the TEM image.
Importance: CONVENIENCE as otherwise the scanning image may be of a different area than the TEM image.
Method: Focus the image and shift the beam to the centre (or better, the recognisable image feature).

Note: In this step the TEM image in scanning mode is used. The image shift can also be set by direct alignment IMAGE SHIFT in scanning. Often this is a better alignment, because the alignment here in the COLUMN procedure usually is set for the wrong focus (focused TEM image instead of focus scanning beam).

Step 074: HM-SCAN beam tilt alignment

Purpose: Make sure that the beam is along the optical axis of the objective lens.
Importance: ESSENTIAL for minimising the effects of aberrations on the small spot.
Method: The microscope 'wobbles' the objective lens current, making the beam go through focus. The 'focus wobble' can be changed with the FOCUS Step SIZE knob. The image feature from the previous steps should be visible in the diffraction disc. Move the disc with the MF-X,Y knobs in the direction from where the image feature seems to come during expansion. If necessary shift the specimen stage to keep the feature inside the disc. The sideways movement of the image feature must be minimised.

Note: This alignment sets the scanning rotation centre.

Step 075: HM-SCAN camera length range al.

Purpose: Determine the shifts necessary for aligning all camera lengths, so that the diffraction pattern remains in the centre.
Importance: CONVENIENCE
Method: Centre the diffraction pattern for the smallest camera length, increase the camera length and centre the pattern, etc.

Note: A focused aperture disc is a disc with a sharp edge, which does not move. The disc should not be contracted to a spot!
In order to make the diffraction pattern position reproducible, it is advisable to press the EXPOSURE button with the screen down (lens normalisation) for each camera length. When the microscope is switched to scanning later, pressing the EXPOSURE button (screen down!) again will centre the pattern.

Step 076: prep for LM-SCAN alignment

Purpose: Aligning the LMS scanning image with the HMS scanning and LM and M TEM images.
Importance: CONVENIENCE.
Method: Focus the image and move the beam to the centre with the MF-X,Y knobs.

Note: Because the position of the LM TEM image in this alignment is not set as defined in alignment step 025, the correct LM image shift alignment (beam position) is often not visible on the viewing screen. If this is the case, simply go through without changing the MF-X,Y settings and later perform the direct alignment IMAGE SHIFT in scanning relative to the HMS scanning image.

Step 077: pivot pnt adjustment LM-SCAN-X

Purpose: Make sure that the beam does not tilt when it is shifted in the x direction.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself in LM scanning means that it must always go through the front-focal point (= shift pivot point) of the diffraction lens. This plane is conjugate to the back-focal plane and can thus be seen in LAD diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so no LAD diffraction pattern shift should visible. Adjust the MF-X knob until the line contracts into a disc.

Step 078: pivot pnt adjustment LM-SCAN-Y

Purpose: Make sure that the beam does not tilt when it is shifted in the y direction.
Importance: ESSENTIAL for keeping the beam parallel to the optical axis when shifting.
Method: Shifting a beam parallel to itself in LM scanning means that it must always go through the front-focal point (= shift pivot point) of the diffraction lens. This plane is conjugate to the back-focal plane and can thus be seen in LAD diffraction. The shift 'wobble' done by the microscope should give no beam tilt, so no LAD diffraction pattern shift should visible. Adjust the MF-X knob until the line contracts into a disc.

Step 079: LM-SCAN diffraction al. x and y

Purpose: Centre the LM scanning diffraction on the screen.
Importance: CONVENIENCE
Method: Shifting the diffraction pattern to the centre of the screen.

Note: It is advised to press the EXPOSURE button with the screen down (lens) normalisation) to make the LMS diffraction pattern position reproducible.
Later during operation when going to LMS scanning again press the EXPOSURE button (screen down) to centre the pattern accurately.

2.6.8 Step-by-step procedure for objective lens centring for high resolution imaging by coma-free alignment

This section describes the coma-free alignment of the objective lens, an alignment that is particularly important in high resolution applications. Coma-free alignment employs a slow (1 Hz) wobbler function for alignment of the objective lens rotation centre. The defocus introduced by the coma-free wobbler beam tilt provides an effective and accurate criterion for the alignment.

For information about the electron optical and image theory background to this technique, the reader is referred to:

Zemlin F., Weiss K., Schiske P., Kunath W., Herman K.H.
Ultramicroscopy, 3 (1978), 49

Smith D.J., Saxton W.O., O'Keefe M.A., Wood G.J., Stobbs W.M.
Ultramicroscopy, 11 (1983), 263

The procedure is as follows:

1. Ensure that the microscope is well-aligned and operating in the HR-TEM Bright Field mode.

2. Insert a specimen that will give a good granular image when viewed at high magnification (carbon thin film or similar).

3. Ensure that the objective aperture is removed.
4. Adjust the specimen height for eucentricity.

5. a. Ensure that the standard objective rotation alignment (current) has been carried out correctly.
   b. Select a magnification between 200.000x and 400.000x

6. Focus the image using the minimum contrast and ensure that the objective lens astigmatism is corrected (see Fig. 2.17).

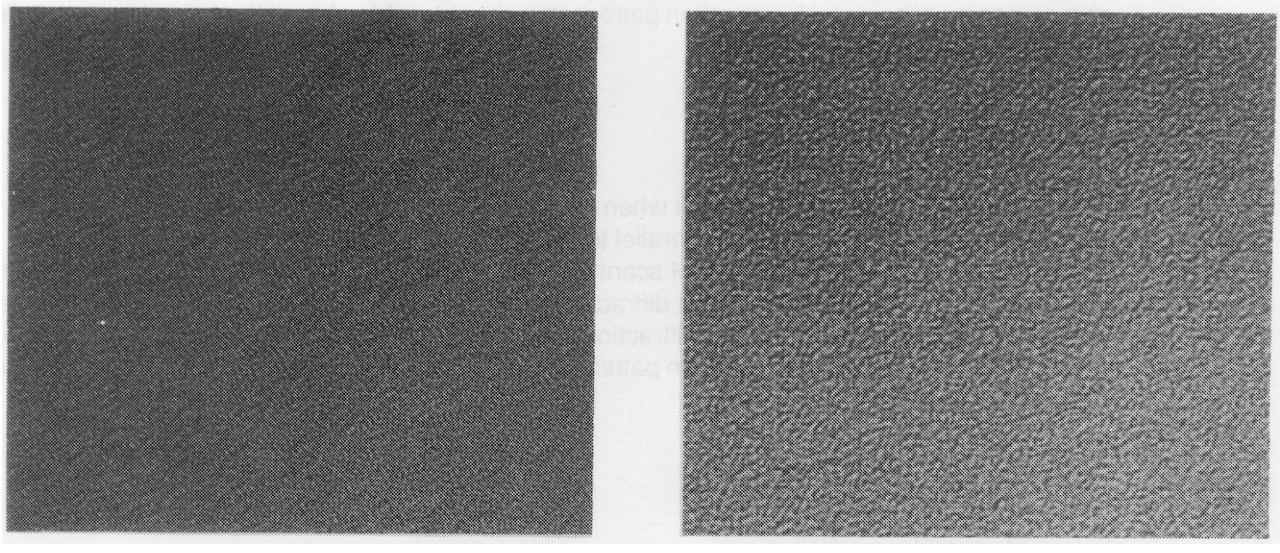
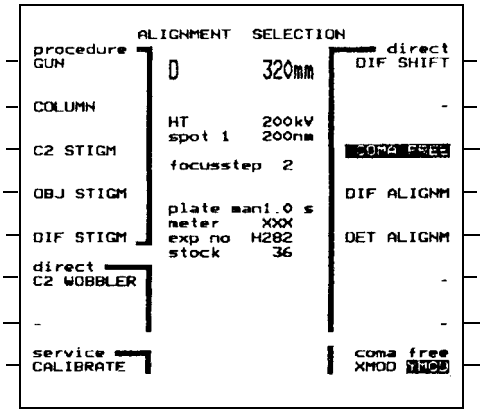


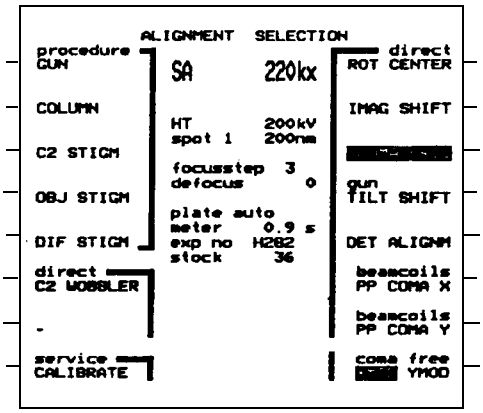
Fig. 2.17. Carbon foil images, objective lens under-focused, astigmatism corrected

7. Select the diffraction mode D, call up the ALIGNMENT page by pressing ALIGN.
   The MICROCONTROLLER will display the following page:



- Centre the diffraction pattern accurately.
- Select COMA-FREE and X MODulation (highlighted) and observe the movement of the diffraction pattern which is caused by tilting the beam in the specimen plane. Use the **Multifunction** knob X to adjust the amplitude until it matches half the angle of the carbon ring.
- Select COMA-FREE Y MODulation (highlighted) and adjust the amplitude using the same **Multifunction** knob X until it also matches half the angle of the carbon ring (0.34nm).

8. Reselect the imaging mode. The MICROCONTROLLER will display the following ALIGNMENT SELECTION page.
   The COMA-FREE alignment is also directly available on the HR-TEM Bright field page



- Reselect COMA-FREE and X MODulation. Unless the pivot point alignment is precise, the screen will not be illuminated. If necessary, repeat the pivot point adjustment after selecting PIVOT POINT X. Repeat for PIVOT POINT COMA Y.

  Note: **1)** It is essential that alignment of the PIVOT POINT is carried out with a focused image of the specimen, correctly adjusted for eucentricity, since the beam tilt pivot plane must coincide with the specimen plane.

  2) It is also advisable to ensure that the adjustment is executed for the magnification at which the coma-free alignment is intended to be performed. This refers to the different objective lens preset values in the SA, M or HREM magnification ranges.

9. Reselect COMA-FREE and observe the change in the contrast appearance of the carbon foil granularity. In general it will show different types of contrast at the two incident beam directions provided by the COMA FREE wobbler (see Fig. 2.18).

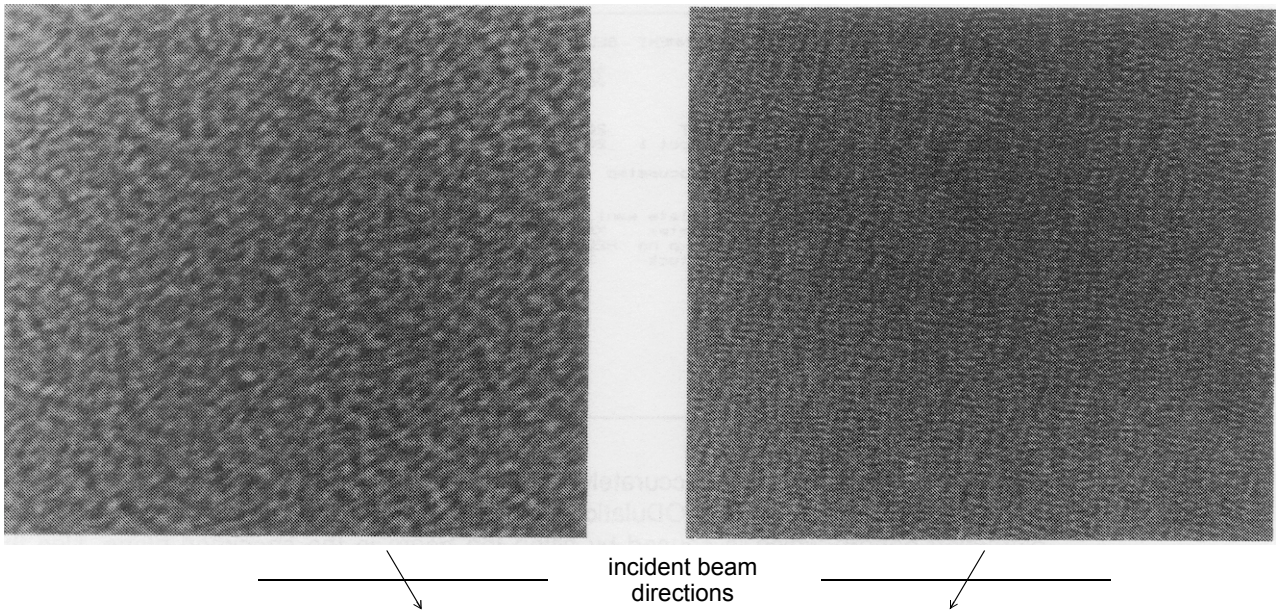


Fig.2.18. Carbon foil images obtained at two different angles of the incident beam, objective lens (rotation) alignment uncorrected

10. Adjust the **`Multifunction`** X knob until the contrast (which is actually the change in focus induced by the beamtilt) is similar for both beam tilt directions set by the coma-free wobbler.

11. Select Y-MODulation and adjust the **`Multifunction`** X knob until the contrast for both beam tilt directions is again similar.

12. Repeat steps 8 to 11, alternating for the X and Y MODulation, until a similar granular appearance with minimum contrast is achieved for both incident beam directions in X and Y directions (see Fig. 2.19).

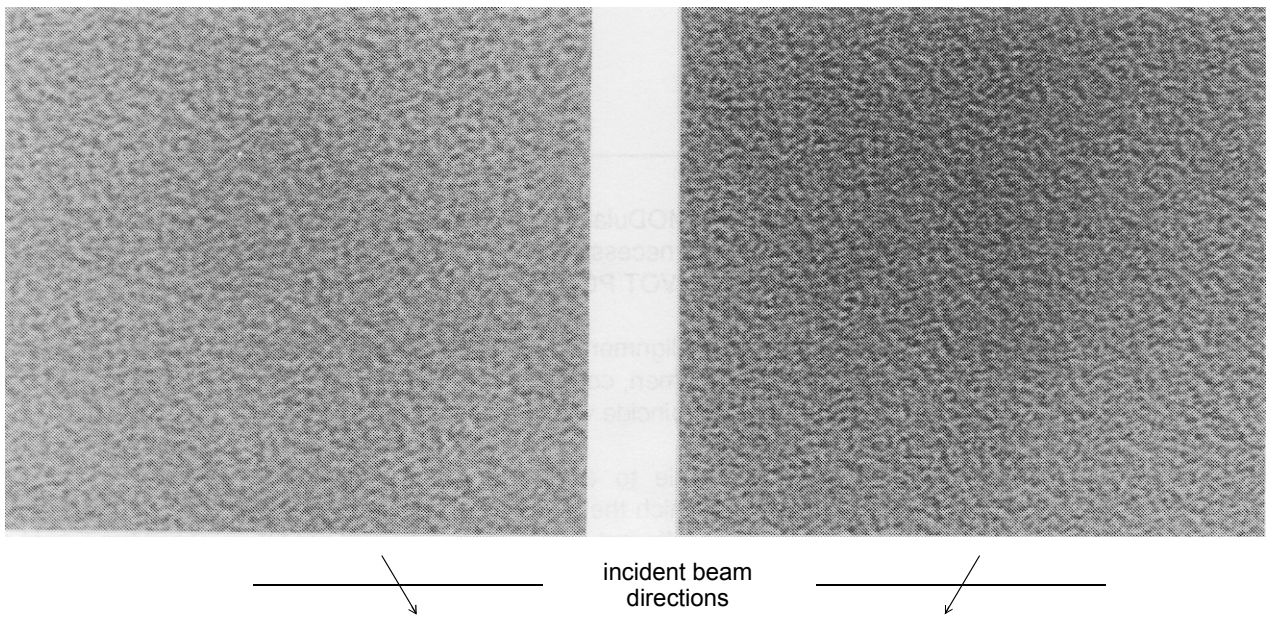


Fig.2.19. Carbon foil images obtained at two different angles of the incident beam, objective lens (rotation) alignment corrected

13. After the correction, press the ALIGNment button to exit alignment mode, refocus the image and correct the astigmatism to obtain minimum contrast appearance of the granularity.

2.7 DETECTOR CONFIGURATION: TV, (P)EELS, STEM

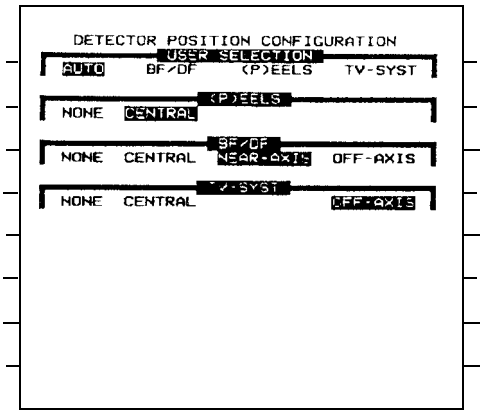
The CM200 can have all the following detectors installed below the bottom plate of the column.

- STEM Bright Field and Annular Dark Field Detector at the near-axis position (25 mm from the centre in the 2 o'clock direction).
- TV system in the off-axis position (75 mm from the centre in the 10 o'clock position).
- (P)EELS, TV system or slow-scan CCD camera in the central position (on-axis).
- An Annular Dark Field Detector around the central position.

It is important to specify which detector is to be used and to correctly shift the image or diffraction pattern onto that detector after lifting the main screen in order to obtain the correct signal from that detector.

2.7.1 Detector configuration

The detectors can be selected via the MODE SELECTION page. When DET CONF is pressed the following page will be displayed:



The actual positioning of the detector is performed by pressing the appropriate softkey.

USER SELECTION

Select AUTO unless one of the detectors will always be used, independent of the mode of operation. (see Detector selection, Sect. 2.7.2).

(P)EELS

If installed, the P(EELS) detector can be selected by keying CENTRAL. If no (P)EELS detector is present, key NONE.

BF/DF

On a TEM system key NONE. On the CM200/STEM select NEAR-AXIS if simultaneous Bright Field and Dark field imaging using the near-axis system is required. If the (optional) Dark Field detector is installed, it can be selected by keying CENTRAL.

TV system

If the TV system is installed, determine if it is in the CENTRAL or OFF-AXIS position and make the appropriate selection.

2.7.2 Detector selection

After lifting the fluorescent screen, the image or diffraction pattern will be shifted to one of the following four positions:

1. Central position (no image shift).

2. Near-axis position to obtain a STEM BF/DF image.

3. Off-axis position (to obtain an image on the TV system if positioned off-axis).

4. None (in this case, the camera shutter is closed so no image is visible).

Note: When making a TEM photo exposure, the image shift mentioned above will be deactivated during the exposure in order to obtain an identical image to that viewed on the fluorescent screen when the screen is down.

The actual image shift when lifting the screen is dependent on the mode of operation and the detector configuration. When the SELECTION on the DETECTOR CONFIGURATION page is set to AUTO, one of the three detectors (TV, BF/DF or (P)EELS will become the default choice and, depending on mode, the image will be shifted onto one of these detectors. The image will be shifted onto NONE if the detector is not present.
The most important default choices are made when AUTO is active. These are:

- TEM imaging : TV
- TEM diffraction : None (to ensure that TV damage will not occur).
- Scanning/diffraction : BF/DF
- Scanning/descanning : (P)EELS
- Nano probe image : TV

The choice of default when USER SELECTION is AUTO can be overwritten by setting the USER SELECTION on either the (P)EELS, TV or BF/DF on the DETECTOR CONFIGURATION page. In that case, the image will be shifted (when the screen is lifted) automatically, independent of the mode of operation.

2.7.3 Image shift alignment

Two separate DETector ALiGNMents to shift the image onto either the off-axis or the near-axis positions are available. These cover all the magnifications (LM, M, SA and M) and camera lengths (LAD and D). The alignment procedures are as follows:

1. Off-axis alignment (for use with an off-axis TV system)

- Select TV as USER SELECTION on the DETector CONFiguration page and chose DETector ALiGNment on the alignment page.
- Shift the image onto the off-axis TV system for magnification and camera length by adjusting the **`Multifunction X/Y`** knobs.

Note: This alignment is not possible in the first three LM, first 2 M nor in the first seven shortest diffraction camera lengths in D and first two LAD.

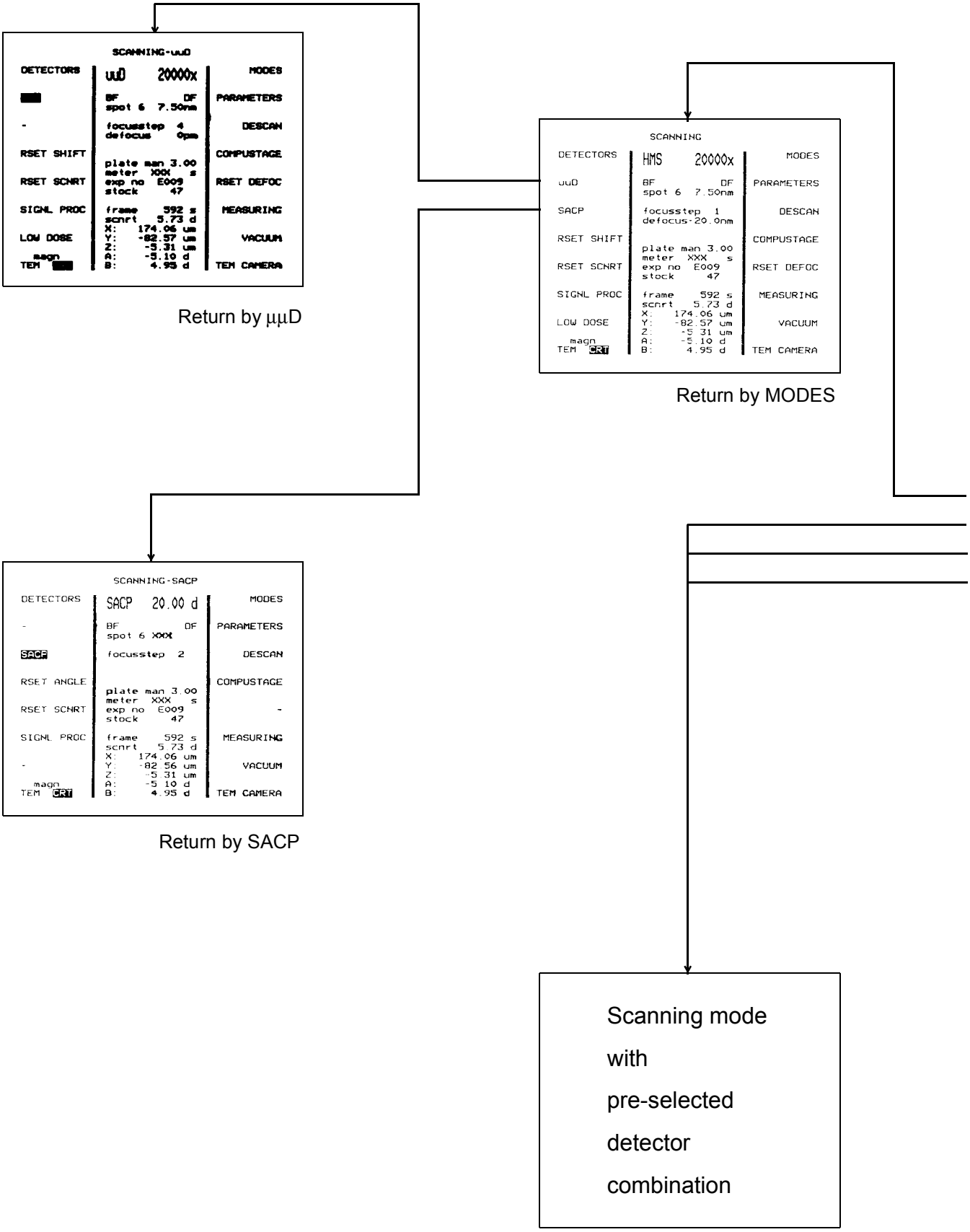
2. Near-axis alignment (for use with the near-axis STEM detectors)

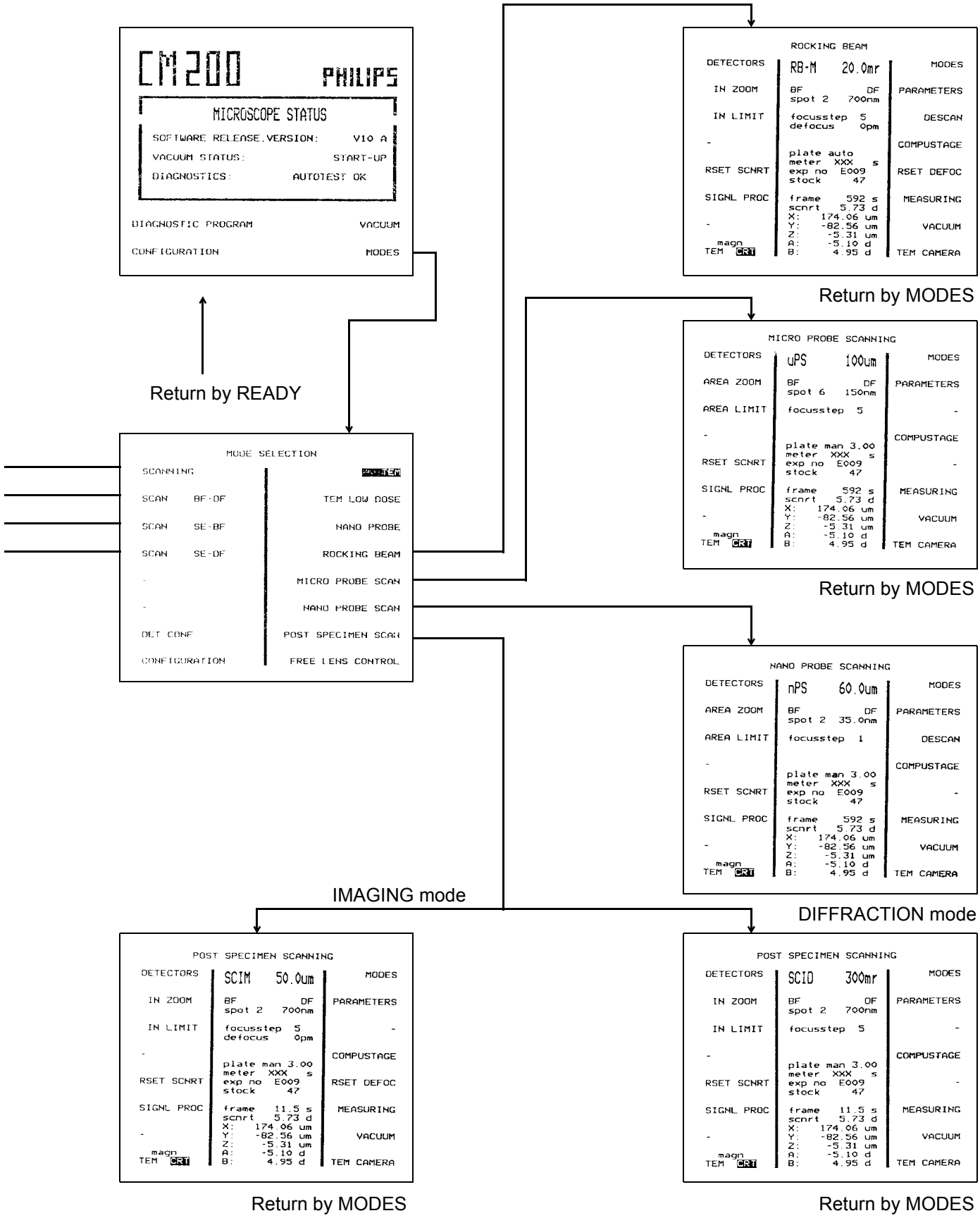
- Select BF/DF or AUTO as USER SELECTION on the DETector CONFiguration page and enter the SCANNING mode.
- Key DETector ALiGNment on the alignment page.
- Shift the diffraction pattern onto the near-axis detector for each camera length of above 100 mm. The camera length can be varied by changing the MAGNification when MAG TEM CRT is set to TEM.

Caution! If the microscope emits a beep every time an action is performed after lifting the screen, key DETector ALiGNment on the ALiGNment page and press the **`Reset`** button below the microcontroller screen. The image can now be shifted, using the **`Multifunction`** X/Y knobs, onto the required detector unless the camera length is too small to allow for this shift.

3 MICROSCOPE OPERATION - THE SCANNING MODES

3.1 MODE SELECTION





Mode page selection overview - scanning modes, Fig. 3.1.

3.2 STEM OPERATIONAL MODES - OVERVIEW OF THE AVAILABLE PROCEDURES

The mode selection gives access to the different operational modes available. Fig. 3.1 gives an overview of all relationships from the mode selections exclusive to the SCANNING page for a CM200/STEM electron microscope that has been configured for all available functions.

Note: How to return to the MODE SELECTION page is indicated under each page and the sections referred to in parentheses describe the operational procedures.

To understand the different STEM operational modes, it is important to distinguish between the following beam probes:

- Coherent or parallel illumination for high angular resolution or TEM imaging.
- Focussed probes.

A focussed electron probe enables the generation of a variety of electron-induced signals on a very localised area of the specimen. These signals include the transmitted electron signal of the unscattered electrons (bright field), or the elastically scattered electrons (dark field), the secondary emitted electrons or the backscattered electrons. Another secondary signal emitted is the X-Ray signal resulting from inelastic scattering in the specimen.

With a stationary probe, the X-Ray signal is generally only collected in order to obtain the X-Ray spectrum from the specific specimen location. With a dynamically scanned probe and the signal display on the video monitor, scanning images are obtained. Each of the above-mentioned signals can be used for generating a (two-dimensional) image, provided the required detectors are available. (Only the STEM BF/DF detector is standard).

A different application from those mentioned above is the use of a stationary probe on small areas for analysis using electron diffraction. For this technique see Sect. 2.3.5.

There are three probe modes used for scanning:

1. Microprobes with spot sizes down to about 15 nm and the mini-condenser lens strongly excited. A wide range of spot size and convergence flexibility is obtained because both the C2 and the Objective lens can be adjusted freely.
2. Nanoprobes have the same flexibility as microprobes but the spot sizes are smaller because the Minicondenser lens is nullified.
3. STEM probes are nanoprobes with fixed C2 current, offering small spot sizes down to about 2 nm with the SuperTWIN lens depending on the C2 aperture selected.

Bright-Field/Dark-Field Scanning (3.2.1)

The STEM-probe is scanned across the specimen and the undiffracted transmitted electrons are focussed by the Diffraction lens onto the Bright-Field detector disc underneath the main screen. The diffracted transmitted electrons are collected by the annular Dark-Field detector.

Micro-Micro-Diffraction (μμD) (3.2.2)

This mode provides the facility to obtain diffraction patterns from very small areas with selectable angular resolution (adjustable nanoprobe).

Selected-Area Channelling Pattern (SACP) Scan (3.2.3)

This mode allows crystalline structure information to be obtained, even from thick specimens, by rocking a parallel nanoprobe beam on a small area and analysing the signal from the (optional) Backscattered-Electron Detector. The signal can also be obtained from the BF/DF detector when the descanning facility is used.

Rocking Beam (3.2.4)

This technique rocks the microprobe beam over a selectable angular range (plus and minus degrees rocking amplitude) in the X and Y directions onto a specific area of the specimen. This scanning mode can be used to remove strong diffraction contrast (extinction contours) in a TEM image.

Descan (3.2.5)

This mode allows the matching of the pre-specimen and post-specimen scanning functions in such a way that scanning or tilting the beam above the specimen is counteracted by the sub-specimen coils.

Measuring (3.2.6)

This function offers the possibility to measure distances, heights and angles directly in a monitor image.

STEM Low Dose (3.2.7)

This function enables the photography of (beam-sensitive) specimens with a minimum of electron irradiation on the specimen area selected.

Microprobe Scanning (μps) (3.2.8)

In this mode, a microprobe (TEM) illumination is scanned over the specimen. The imaging mode is TEM BRIGHT FIELD or DARK FIELD.

Nanoprobe Scanning (nps) (3.2.9)

In this mode, a nanoprobe (TEM) illumination is scanned over the specimen. The imaging mode is TEM NANO PROBE.

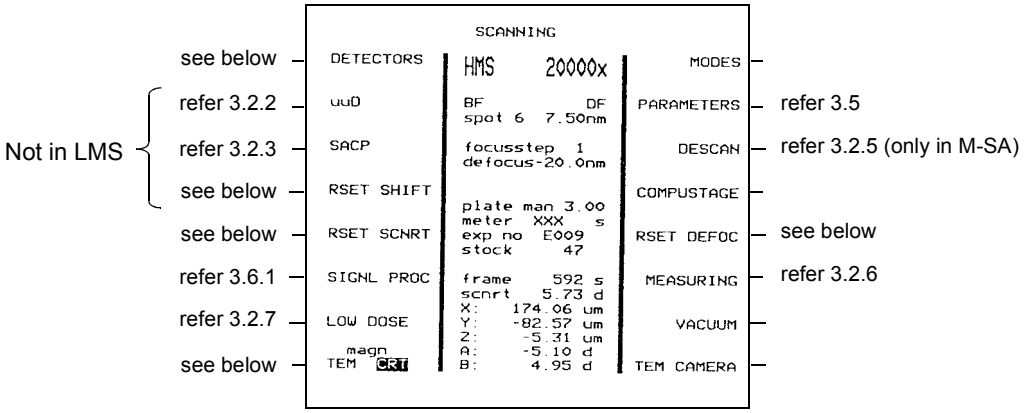
Post Specimen Scanning (3.2.10)

A TEM image or diffraction pattern is scanned across the BF detector and can be observed on the CRT. The sub-modes are SCanning in IMaging (SCIM) and SCanning In Diffraction (SCID).

3.2.1 SCANNING in Bright Field and Dark Field

In scanning images, an important parameter concerning resolution is the size of the electron probe which is scanned across the specimen. It is therefore essential for Bright Field (BF), Dark Field (DF), Secondary Electron (SE), Backscattered Electron (BS), Energy-dispersive X-Ray (EDX) and Electron Energy Loss Spectroscopy (EELS) images to choose the desired spot size (1st Condenser lens) and to focus the beam on the specimen in the eucentric position by adjusting the Objective lens current.
In the High Magnification Scanning (HMS) range, the diffraction pattern in the Objective back-focal plane is enlarged (Camera Length) and focussed onto the BF/DF detector underneath the Main Screen, which offers the facility to acquire the Bright Field and the Dark Field image simultaneously.

On the MODE selection page, key SCAN BF-DF twice to obtain the SCANNING page.



Softkeys

DETECTORS

Function : Allows the direction of any available detector signal or an adjustable mixture of two or more signals to any viewing facility.

Operation : Refer to Sect. 3.6.2.

RSET SHIFT

Function : Resets the image shift that can be applied by means of the X-Y shift knobs.

Operation : Key RSET SHIFT.

Note: 1) This image shift (and its re-setting) can only be performed in the High Magnification Scanning range.

2) The SHIFT step size depends on the HM-TEM magnification used previous to the SCANNING mode, that is, coarse for low magnifications and fine for high. To change, key magn TEM CRT so that TEM is highlighted. Press D button to go to image mode and select a magnification. Press D button to go back to diffraction and press magn TEM CRT so that CRT is highlighted again.

RSET SCNRT

Function : Resets the SCaN RoTation that can be applied by turning the Multifunction knob X/ Rotation.

Operation : Key RSET SCNRT.

magn
TEM CRT

Function : Changes the function of three control knobs and the corresponding information on the information field from SCANNING to TEM mode.

Operation : Pressing softkey toggles between TEM and CRT.

Exact changes:

- Magn : In CRT, the scan image magnification can be adjusted while in TEM the camera length is changed.
- Focus : In CRT, the focussing concerns the beam probe on the specimen (Objective lens current), while in TEM the diffraction pattern is focussed by adjusting the Diffraction Lens current.
- Stig : In CRT, the condenser stigmator is the default choice while in TEM (D active) it is the diffraction astigmatism.

	General scanning operation	Not used in general scanning applications		
Knob	CRT D active	TEM D active	TEM D inactive	CRT D inactive
Application	Scanning Images	Diffraction Pattern focus and alignment		
MAGNification	Scan Image Magn.	Camera Length	TEM Magn.	Scan Image Magn.
FOCUS	Scan Image	Diffraction Pattern	TEM Image	Scan Image
STIGMator default	Condenser astigmatism	Diffraction astigmatism	Condenser astigmatism	Condenser astigmatism

Table 3.1, Scanning - adjustable parameters

RSET DEFOC

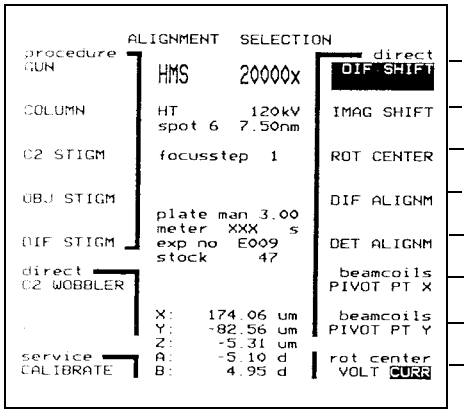
Function : Resets the Defocus readout on the page to 0 pm. This does not change any lens current.

Operation : Key RSET DEFOC.

Relevant Direct Alignments (ALiGN button)

Also refer to Sect. 3.3.11.

In diffraction:
In imaging, only image shift and HMS rotation centre can be adjusted.



1 Shifts diffraction pattern for all camera lengths simultaneously

2 Aligns LMS with HMS image and HMS with TEM image

3 Objective lens rotation centring (HMS only)

4 Shifts diffraction pattern of the camera length in use, to position it around the screen centre

5 Shifts diffraction pattern of the camera length in use to position it relative to the detector below the screen

6, 7 Adjusts the pivot points of HMS or LMS

8 Selects high-VOLTage modulation or Objective-lens CURRent modulation for rotation centring

Information Field

The second line (underneath the magnification value) is reserved for the detectors which are selected. Frame indicates the total time needed for one frame scan which equals the number of lines x line time. The bottom line is reserved for scan rotation angle (SCNRT).

Note: 1) Pressing the AUTOFOCUS button in SCANNING gives the Objective lens a preset value, which cannot be adjusted by the operator. In general this Objective lens setting is not far from focus for a specimen in the eucentric position.

2) The calibration of the STEM distance measurement must be executed on the SERVice CALibrate page under the heading SCANNING.

Near-axis BF/DF detector

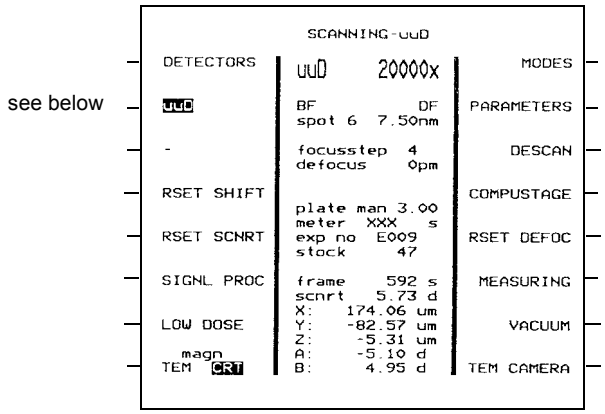
When a TV camera or EELS system is placed on-axis below the main screen, the scanning BF/DF detector must be placed near-axis. In this case, the diffraction pattern must be aligned with the BF/DF detector by keying **DET ALIGN** on the right-hand side of the alignment page and using the MF X-Y knobs. It is possible to use ***camera lengths of 100 mm or more*** because of the small shift involved. To obtain a dark field scanning image, it is important to separate the BF and DF electrons in the BF/DF detector which in practice means that either a C2 aperture of 30 μm maximum should be used with one of the smaller camera lengths (100 - 300 mm) or the central dark field detector (option) could be used.

For bright field images only, at low HMS magnifications, homogeneous illumination can be obtained by defocussing the diffraction pattern (FOCUS with magn TEM CRT such that TEM is highlighted.
For easy near-axis detector alignment, first centre the diffraction pattern accurately on the screen centre using DIF ALIGNM, then lift the screen and optimise the bright field and dark field image using DET ALIGNM. Once set up, re-centre the diffraction pattern on the screen centre using DIF ALIGNM, each time the scanning mode is entered.
The reason for this procedure is that the absolute position of the diffraction pattern can change but is easily aligned on the screen centre while the near-axis shift is very stable.

3.2.2 SCANNING-μμD: Micro-Micro-Diffraction

This mode is only available in HMS and provides a special technique for obtaining diffraction patterns from very small, selected areas with selectable angular resolution. The second Condenser lens adjusts the beam convergence together with the C2 aperture selected.

When μμD is keyed in the scanning mode, the Microcontroller displays the following page:



Softkeys

μμD

Function : On entering μμD, the C2 current will be set to the last C2 value in μμD, so that this current is independently controllable for μμD in addition to the parameters already known from STEM BF/DF.

Operation : Press the key to toggle between SCANNING and μμD.

Relevant DIRECT ALIGNMENT (ALiGN button)

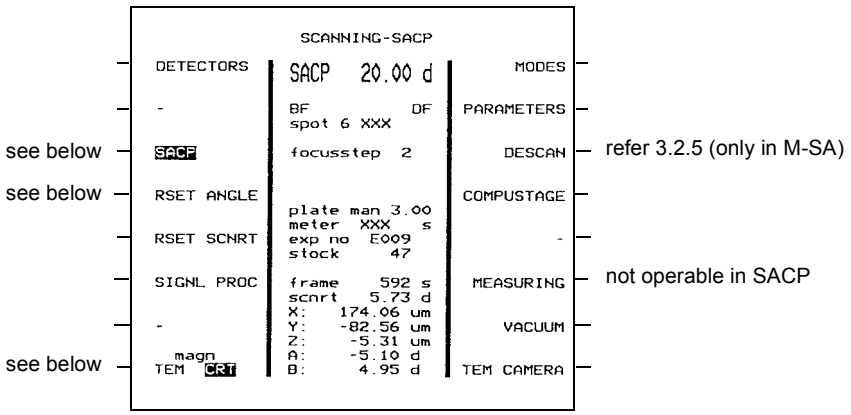
See Sect. 3.2.1.

Note: The SHIFT X, Y knobs shift the beam on the specimen.

3.2.3 SCANNING SACP: Selected Area Channelling Patterns

A channelling pattern shows the electron intensity as a function of the electron incidence angle. This is a diffraction effect that allows crystallographic information to be obtained. The electron signal used is, in general, the (optional) backscattered electron signal. The transmitted electron signal (BF/DF) may be used in the descanned SACP mode.
The nanoprobe electron beam is formed into a small but parallel beam which is moved in a rectangular pattern over the specimen.

On the SCANNING page when SACP is highlighted, the following is displayed:



Note: The spot size is determined by the second condenser current and the aperture. When a truly parallel beam is obtained by adjusting the second condenser lens, the spot size will be equal to the size of the condenser aperture ÷ 30 for the TWIN lens and condenser aperture ÷ 48 for the Super TWIN lens.
For more information refer to Sect. 3.5.4.

Softkeys

SACP

Function : This mode has its own setting for the following parameters: second condenser lens current, rocking angle, central beam angle, scan rotation, spot size and spot shift.

Operation : Key SACP to toggle between SCANNING and SACP.

RSET angle

Function : Resets a pre-tilt of the central beam as set by the SHIFT X, Y knobs.

Operation : Key RSET ANGLE.

magn
TEM CRT

Function : When CRT is highlighted, the rocking angle can be changed by turning the MAGNIFICATION knob.
When TEM is highlighted, the MAGNIFICATION knob changes magnification or camera length.

Operation : Key magn TEM CRT to toggle between CRT and TEM.

	General SACP operation		Not used in general SACP applications	
Knob	CRT D active	TEM D active	TEM D inactive	CRT D inactive
Application	Channelling Patterns	Diffraction Pattern focus and alignment		
MAGNification	Rocking Angle	Camera Length	TEM image magn.	Rocking angle
FOCUS	Channelling Pattern	Diffraction Pattern	TEM Image	TEM Image
STIGMator default	Diffraction astigmatism	Diffraction astigmatism	Objective astigmatism	Condenser astigmatism

Table 3.2, SACP - adjustable parameters

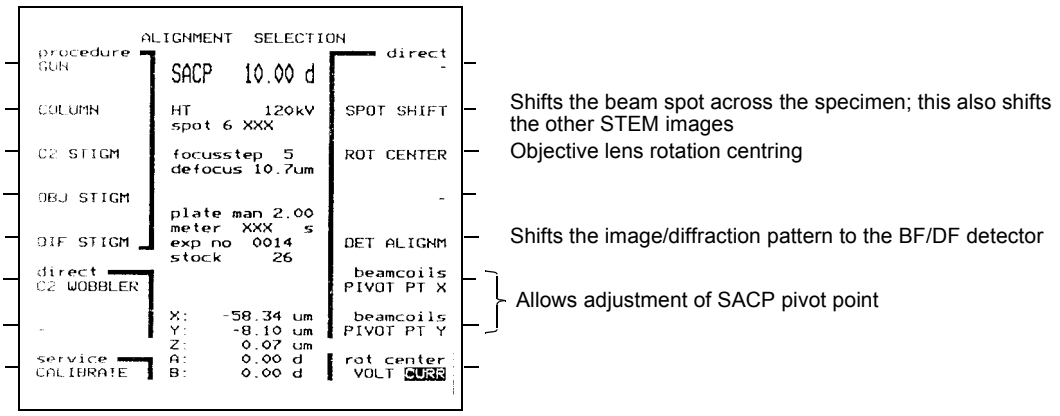
Some important operational controls

- SHIFT X, Y knobs shift the beam on the specimen.
- MULTIFUNCTION X knob rotates the angle scan pattern. The rotation can be reset by pressing RSET SCNRT.

Step-by-step procedures are given in Sect. 3.3.3.

Relevant direct alignments (ALiGN button)

When the ALiGN button is pressed (LED on), the microcontroller displays the following page:



The beam movement on the specimen due to spherical aberration in SACP and Rocking Beam (see Sect. 3.2.4) can be minimised for the rocking angle being used as follows:

1. Press the ALiGNment button in the imaging mode (D-LED is off).

2. Press line scan. The lines should be at the centre of the monitor screen.

3. Key beam coils pivot point x.

4. Minimise the width of area being scanned by turning Multifunction X, Y knobs.

5. Key beam coils pivot point y.

6. Minimise the width of area being scanned by turning Multifunction X, Y knobs.

7. Select spot size and intensity setting such that the beam probe on the specimen is larger than the beam movement.

8. If necessary, adjust INTENSITY to sharpen the image (small adjustments can also be made with the FOCUS knob).

3.2.4 Rocking Beam

In the Rocking Beam mode, the beam is tilted with the pivot point at the intersection of the optical axis and the specimen plane, over a selectable angular range (plus and minus degrees rocking amplitude) in the X and Y directions. This beam tilting is performed continuously at an adjustable scanning rate and rocking amplitude (<70 mR = 4 d).

The main application of the Rocking Beam mode is the removal of diffraction contrast (extinction contours) from the TEM BF image.
The specimen illumination with static beam in Rocking Beam mode is similar to the normal TEM (LM-M-SA) coherent microprobe beam.
The second condenser lens can be used, as in the conventional Bright Field mode, to adjust the spot size and intensity of the parallel illumination or even to focus the beam onto the specimen.

On the CRT, a diffraction pattern is observed that arises from the area selected by the selected-area aperture if the microscope is operating in the D-mode, or otherwise from the area which is projected onto the STEM detector.

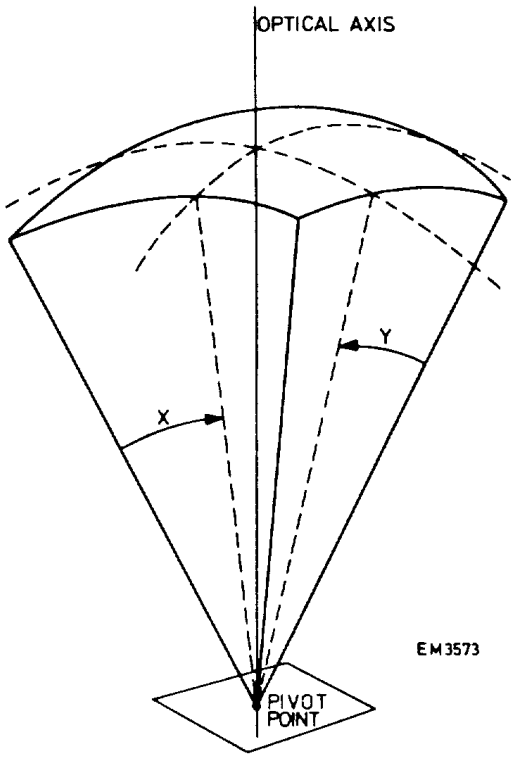
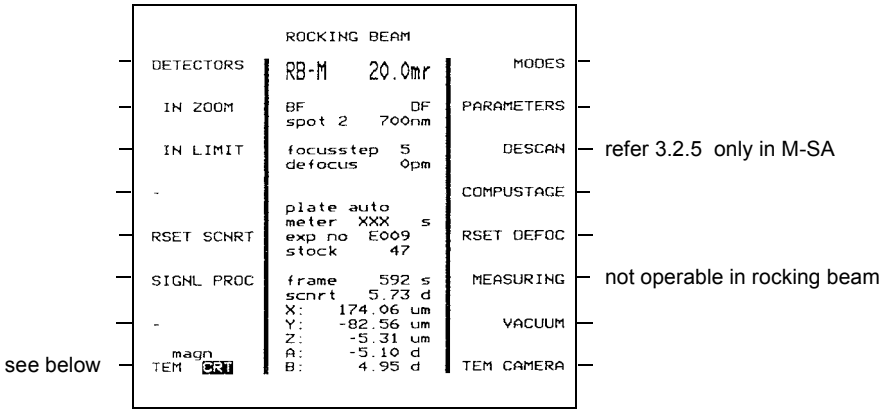


Fig. 3.2, Spherical projection of angular motion in X, Y directions with the pivot point in the specimen plane

When ROCKING BEAM on the MODE SELECTION page is keyed twice, the Microcontroller displays the following page:



Note: The rocking angle, given in milliradians (1 mr = 0.0573d), is the half-angle of the horizontal scan.

Softkeys

magn
TEM CRT

Function : When CRT is highlighted, the Rocking Angle can be changed by turning the MAGNIFICATION knob.
When TEM is highlighted, the MAGNIFICATION knob changes magnification or camera length.

Operation : Press the key to toggle between TEM and CRT.

Knob	CRT D active	TEM D active	TEM D inactive	CRT D inactive
Application	Scanning RB Selected-Area Diffraction Patterns	Diffraction Pattern focus and alignment	Bragg contrast removal	RB Micro-area Diffraction Pattern
MAGNification	RB angle	Camera Length	TEM magn.	RB angle
FOCUS	Diffraction Pattern	Diffraction Pattern	TEM Image	TEM Image
STIGMator (default)	Objective astigmatism	Objective astigmatism	Objective astigmatism	Condenser astigmatism

Table 3.3, Rocking beam - adjustable parameters

Some important operational controls

- SHIFT X,Y knobs shift the beam across the specimen in full frame mode.
- SHIFT X,Y knobs tilt the beam on the specimen when selected-area, spot mode (press crosshairs button twice) or line scan are selected.
- MULTIFUNCTION X knob rotates the scan pattern. The rotation can be reset by pressing RSET SCNRT.

Relevant direct alignments (ALiGNment button)

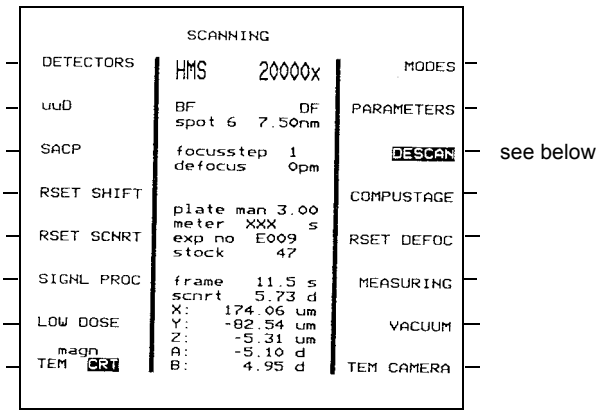
- In LM and HM imaging ranges, the alignment page is the normal TEM ALIGNMENT page (see Sect. 2.2.1). For direct alignment in the Rocking Beam mode, the beam must be stopped by pressing the scan stop button (LED is on).
  It should be realised that the pivot points in the LM and HM ranges are different for each mode but they are the same as those used, respectively, for the Dark Field mode and the Wobbler function. These pivot points for rocking beam should be adjusted in imaging mode (D LED off).

  Step-by-step procedures are given in Sect. 3.3.5.

3.2.5 SCANNING: DESCAN sub-mode

The Descan mode, which uses the post-specimen scan coils, can be used with any scanning mode in the M-SA range that uses the pre-specimen scan coils. In the case of area scanning for obtaining normal BF/DF images, the central spot of the diffraction pattern from any area on the specimen is brought to the optical axis by the imaging lens system in the diffraction mode. In the imaging mode, the image of the spot which is scanned across the specimen, moves across the microscope screen. The descan generator is capable of counteracting this image movement by deflecting the beam back to the optical axis. In the case of angle scanning (Rocking Beam or SACP), the descan generator is capable of counteracting the scanning of the diffraction pattern across the microscope screen by deflecting the undiffracted electrons back to the optical axis.

When DESCAN is keyed in the scanning mode, the following page is displayed:

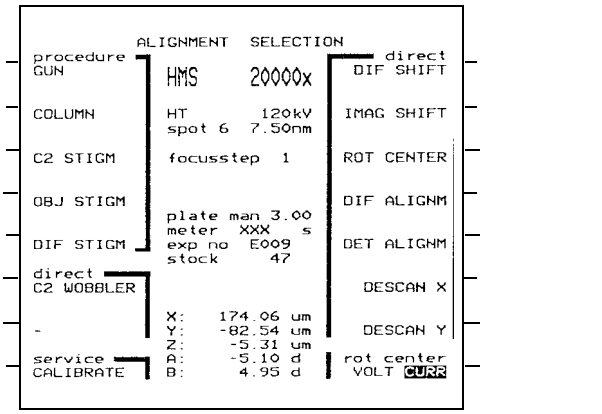


The only change in this page, compared to the normal scanning page, is that DESCAN is highlighted. All control knobs have the same function as before.

The post-specimen scan coils are synchronised with respect to the beam scan coils which means, for example, that scanning amplitude, rotation angle and scan rate are similar for both coils.

Relevant direct alignments (ALiGNment button)

When the ALiGNment button is pressed in a descan mode (highlighted), the following page is displayed:



Descan alignment pages are similar to the alignment pages of the underlying scanning modes of the specimen coils (scanning, SACP, RB etc., with or without the D-button illuminated), except that DESCAN X,Y selection replaces beam coils pivot point X,Y. The DESCAN X,Y of an area scanning mode can be adjusted by minimising spot movement on the microscope screen when the D LED is off. The DESCAN X,Y of an angle scanning mode can be adjusted in the same way as when the imaging lens system is in the diffraction mode.

A step-by-step procedure is given in Sect. 3.3.3.

3.2.6 Measuring

The image measuring functions for distances and heights are accessed by keying MEASURING while in an image mode. Crosshairs appear on the monitor which can be shifted over the image using the SHIFT knobs. The amount of crosshair shift between two points is related to the pre-specimen scan deflection, determining the distance.

The calibration procedures, which are self-explanatory, must be carried out for TEM and STEM separately. In contrast to the possibility to enter the calibration procedures for TEM measurements directly in the TEM mode, the calibration procedure for STEM distance measurements cannot be chosen in the STEM-measurement mode (cal softkey inactive) but should be performed on the SERVice CALibration page (ALiGNment) by selecting the softkey SCANNING.

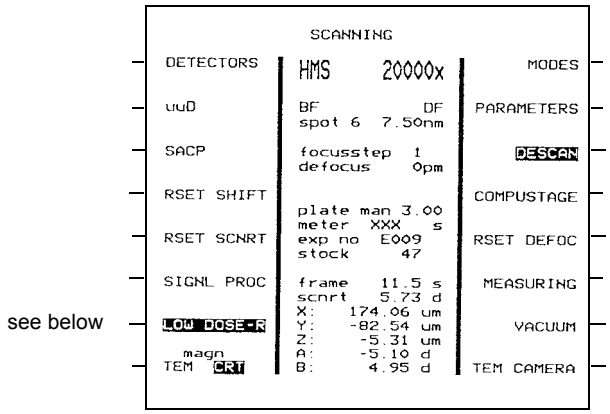
The operating procedures are exactly the same as those described for TEM images in Sect. 2.3.6 and 2.3.7. The measuring information is displayed on the Microcontroller screen in the information field and at the bottom of the image on the left-hand monitor or on the photograph.
A marker is placed at each position in the image that has been selected by means of the crosshairs and ENTER key (with a maximum of three).

Caution! At the fastest scan rates (shortest line times) the measurement system is less accurate due to small distortions especially at the left-hand side of the monitors.

3.2.7 SCANNING: LOW DOSE sub-mode

The STEM LOW DOSE mode is used for photographing beam-sensitive specimens. It provides the possibility to set up the instrument and prepare for recording while scanning an area on the specimen that is situated two frames left or right of the area from which the photo is to be taken.

When LOW DOSE is keyed in an area scanning mode at a magnification greater than or equal to 350x (LMS) OR 15 000x (HMS), the following page is displayed:



LOW DOSE-R appears highlighted on the page. The area that will be scanned when the EXPOSURE button is pressed, is situated two frames to the right of the area that is scanned at the moment.

Keying LOW DOSE-R again, leads to highlighted LOW DOSE-L which means that the final picture is taken from an area two frames to the left of the area scanned at the moment.

It is possible to select a different area by means of the specimen movement controls or by image shift (SHIFT X, Y), then to optimise the new image and press the exposure button.

Softkeys

LOW DOSE (-R/-L)

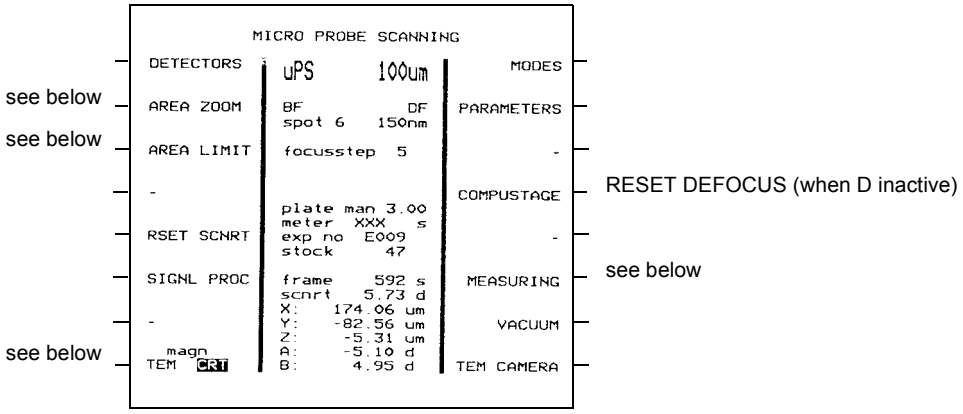
Function : The beam scans an area different from where the exposure is made.

Operation : Key LOW DOSE (-R/-L) to switch the area being scanned.

A step-by-step procedure is given in Sect. 3.3.4.

3.2.8 MICROPROBE SCANNING (optional)

This mode provides the facility to scan the TEM illumination (= microprobe) over the specimen in a rectangular pattern to obtain either a dynamic TEM image on the main screen or the camera or a scanning image, from any detector, on the CRT.
When MICROPROBE SCAN is keyed twice on the mode selection page, the Microcontroller displays the following page:



Information field: The length of the horizontal (X) scan is given on the first line.

Softkeys

magn
TEM CRT

Function : Changes the function of three control knobs and the corresponding information on the information field from μPS to TEM mode.

Operation : Press the key to toggle between TEM and CRT.

Knob	TEM D inactive	CRT D inactive	TEM D active	CRT D active
Application	TEM image viewing with Magn. control	TEM image viewing with illuminated area control	Diffraction Pattern viewing with CL control	Diffraction Pattern viewing with illumination control
MAGNification	TEM Magn.	Illumination Scan amplitude	Camera Length	Illumination Scan amplitude
FOCUS	TEM Image	TEM Image	Diffraction Pattern	Diffraction Pattern
STIGMator (default)	Objective astigmatism	Objective astigmatism	Diffraction astigmatism	Diffraction astigmatism

Table 3.4, Microprobe scanning - adjustable parameters

Softkeys

Measuring

Function : When the D-button is active, the measurements of the diffraction pattern (lattice spacings) can be performed. When D is inactive, scan image measurements are available.

Operation : See Sect. 3.2.6.

AREA ZOOM

Function : When highlighted, the area illuminated on the TEM main screen is kept constant during the magnification change. However, when going to very low magnifications, the illuminated area may start to shrink.

Operation : After the screen frame size has been set to the desired size on the viewing screen by using the MAGNIFICATION control while on the CRT, press AREA ZOOM. Press magn TEM CRT so that TEM becomes highlighted.

AREA LIMIT

Function : Protects a beam-sensitive specimen from an excessively high current density due to very small scan frames on the specimen, e.g. at high TEM magnifications.

Operation : Selects the minimum frame size allowed for the application by using the Magnification control while on CRT. Key AREA LIMIT. As long as this is highlighted, a frame size smaller than the minimum selected cannot be obtained.

Relevant DIRECT ALIGNMENTS (ALiGN button)

See Sect. 3.2.1.

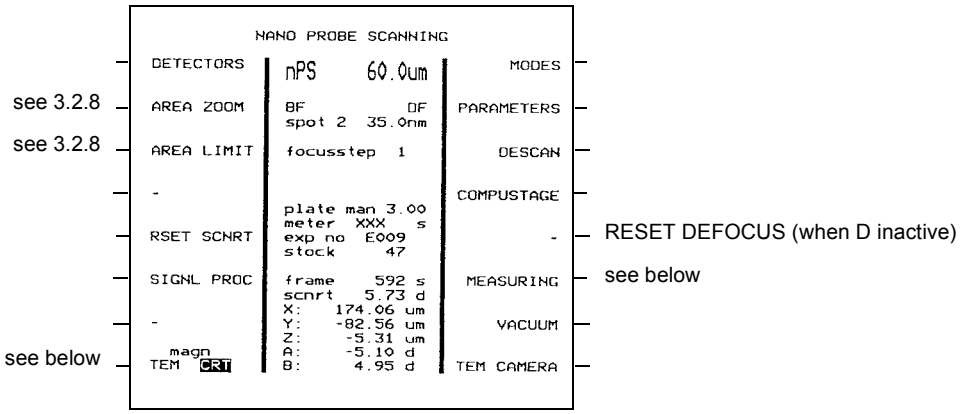
Note: SHIFT X, Y knobs can be used to shift the scan area on the specimen. Rotating MF-X rotates the scan area.

A step-by-step procedure is given in Sect. 3.3.8.

3.2.9 NANOPROBE SCANNING (optional)

This mode provides the facility to scan a nanoprobe over the specimen in a rectangular pattern to obtain a TEM image (dynaprobe) on the main screen or TEM camera.

When NANOPROBE SCAN is keyed twice on the mode selection page, the microcontroller displays the following page:



Softkeys

Magn
TEM CRT

Function : Changes the function of three control knobs and the corresponding information in the information field from nps to TEM mode.

Knob	TEM D inactive	CRT D inactive	TEM D active	CRT D active
Application	TEM image viewing with Magn. control	TEM image viewing with illuminated area control	Diffraction Pattern viewing with CL control	Diffraction Pattern viewing with illumination control
MAGNification	TEM Magn.	Illumination Scan amplitude	Camera Length	Illumination Scan amplitude
FOCUS	TEM Image	TEM Image	Diffraction Pattern	Diffraction Pattern
STIGMator (default)	Condenser astigmatism	Condenser astigmatism	Diffraction astigmatism	Diffraction astigmatism

Table 3.5, Nanoprobe scanning - adjustable parameters

Measuring

Function : With TEM highlighted, in D mode, the measurements of the diffraction pattern (lattice spacings) can be performed. Image measurements are available in image mode.

Operation : See Sect. 3.2.6.

Relevant DIRECT ALIGNMENTS (ALiGN button)

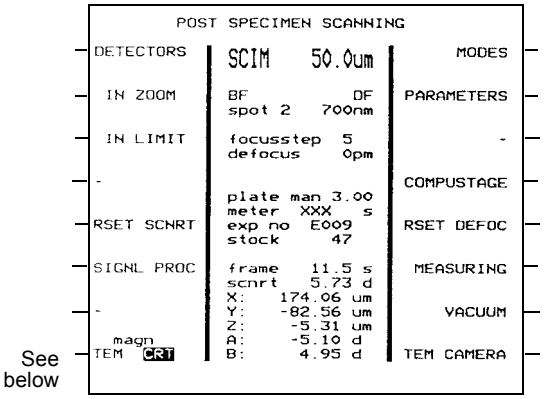
See Sect. 3.2.1.

A step-by-step procedure is given in Sect. 3.3.9.

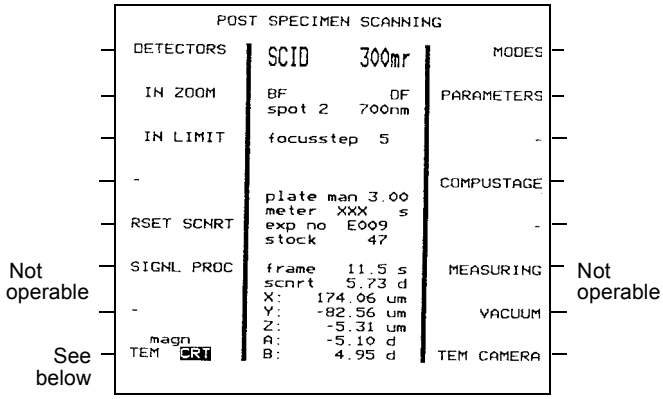
3.2.10 POST SPECIMEN SCANNING in imaging and diffraction (optional)

This mode provides the facility to scan any TEM image (SCIM) or diffraction pattern (SCID) across the BF detector below the screen, in order to observe the image on one of the CRT monitors and to make a micrograph on the high-resolution photomonitor with freely adjustable contrast and brightness.

When POST SPECIMEN SCAN is keyed twice on the mode selection page, the Microcontroller displays one of the following pages:



SCanning in **IM**aging



SCanning **I**n **D**iffraction

The length of the horizontal (X) scan is given on the first line in nanometres/micrometres (SCIM) or milliradians (SCID).

Softkeys

Magn
TEM CRT

Function : Changes the function of three control knobs and the corresponding information in the information field from Post Specimen Scanning to TEM mode.

Operation : Press the key to toggle between TEM and CRT.

Knob	TEM D inactive	CRT D inactive	TEM D active	CRT D active
Application	SCIM TEM image magn. change	SCIM with CRT image magn. change	SCID pattern TEM camera length change	SCID with CRT camera length change
MAGNification	TEM magn.	Scan amplitude	Camera length	Scan amplitude
FOCUS	TEM image	TEM image	Diffraction pattern	Diffraction pattern
STIGMator (default)	Objective astigmatism	Objective astigmatism	Diffraction astigmatism	Diffraction astigmatism

Table 3.6, Post specimen scanning - adjustable parameters

Note: 1) The SHIFT X-Y knobs shift the beam across the specimen.

2) If the scan magnification is large enough and the signal-to-noise ratio not too low, the resolution in the CRT image is determined primarily by the BF detector diameter (7.5 mm) divided by the TEM magnification/camera length. Enlarging the TEM image will thus give finer details in the scan image.

Relevant Direct Alignments (ALiGN button)

These alignments are equal to TEM (Sect. 2.2.1) except:

- If the BF/DF detector is positioned off-axis, an additional image shift is added which can be adjusted using the parameter DET ALIGNM.
- Beam coils PIVOT PT X, Y is replaced by Image coils PIVOT PT X, Y. These alignments, which are related to the sets of deflection coils below the specimen, are very important and are also part of the TEM alignment procedure under SERVice CALibrations. The image coils pivot points are used either purely to shift a diffraction pattern (with no accompanying image shift in the SA plane) or purely to shift the image in the diffraction plane (without shifting the diffraction pattern). These post-specimen deflection coils make use of the pivot points for:

  1. Aligning images for different magnifications or camera lengths onto each other.
  2. The on-line TEM measuring system (see Sect. 2.3.6 and 2.3.7).
  3. The post-specimen scanning and descanning.

Caution! Changing these pivot points has a large influence on all these application modes.

A step-by-step procedure is given in Sect. 3.3.10.

3.3 STEM OPERATIONAL MODES - STEP-BY-STEP PROCEDURES

3.3.1 BF/DF Scanning Image

This operational mode is already described in detail in Sect. 1.3.

If the diffraction pattern moves on the main screen during scanning, perform the following procedure:

1. Key magn TEM CRT so TEM becomes highlighted and FOCUS diffraction pattern (if necessary press SCAN STOP).
2. Check PIVOT POINTS (see Sect. 3.3.11).
3. Press SCAN STOP to resume scanning and magn TEM CRT so that CRT becomes highlighted.

   For optimum STEM results, centre the Condenser 2 aperture in STEM or NANOPROBE mode. In STEM mode, press magn TEM CRT so that TEM becomes highlighted.

1. Lower the main screen.
2. Press CROSSHAIRS button twice to stop the scanning.
3. Press the D button (LED off) to go to image mode.
4. Centre the beam with the SHIFT X, Y knobs (reduce the magnification if necessary).
5. Press μμD to access the INTENSITY control. Make the beam expand symmetrically by centring the C2 aperture.
6. Press ALIGN and ROT CENTER. Adjust the rotation centre.
7. Press μμD to exit micro-microdiffraction.
8. Press D button (LED on).
9. Resume scanning by pressing the FULL FRAME button.
10. Press magn TEM CRT so that CRT becomes highlighted.
11. Raise the main screen.
12. Focus the image (FOCUS) if necessary.

3.3.2 Obtaining a diffraction pattern in μμD

1. Select spot size and Condenser 2 aperture as required (see Sect. 3.5.4).
2. Ensure that the Condenser 2 aperture is correctly centred by making the beam expand concentrically to the centre of the main screen in the TEM mode.
3. Ensure that the rotation centre is set accurately.
4. Obtain a BF/DF scanning image.
5. Press Cross/point button (green LED on).

6. Shift crosshairs to area of interest by turning the SHIFT X,Y controls.
7. Press the Cross/point button (green LED on) to fix the beam on the area of interest.
8. Lower the main screen and observe the convergent beam diffraction pattern on the screen.
9. Key μμD to make Condenser 2 freely adjustable (μμD is highlighted).
10. If necessary, centre the diffraction pattern as follows:
    - Press ALiGNment button (LED is on).
    - Shift pattern using Multifunction X-Y knobs and press ALiGNment button again (LED is off).
11. Adjust the size of the diffraction discs/spots with the INTENSITY. For the best possible angular resolution in the diffraction pattern, adjust the INTENSITY (Condenser 2) so that the beam probe becomes parallel and the diffraction discs are focussed to spots.
12. Focus the beam on the specimen. Lift the main screen, select FULL FRAME or SELECTED AREA scan and FOCUS the BF/DF scanning image.
13. Additional focussing and camera length adjustment of the diffraction pattern can be obtained by adjusting the diffraction lens system:
    - Key magn TEM CRT (TEM is highlighted).
    - FOCUS diffraction pattern, adjust MAGNIFICATION and key magn TEM CRT (CRT is highlighted);
14. Remove astigmatism by pressing the STIGmator button (LED on) and using the MULTIFUNCTION knobs, adjust the central spot in the pattern until it is as near circular as possible.

    Note: 1) With the BF/DF detector mounted off-axis, the diffraction pattern visible on the main screen will shift to the detector position when the main screen is raised. However, when the exposure button on the left- hand console is pressed for recording the μμD pattern, the diffraction pattern will shift back to the centre of the screen.

    2) Changing the angular resolution of the μμD diffraction pattern implies that the area illuminated by the beam will change as well. The smallest area is obtained with the beam fully focussed, giving discs in the diffraction pattern. The size of the beam can be checked by referring to the resolution obtained in the STEM BF mode.

    To regain the BF/DF scanning image:

15. Key μμD (μμD is not highlighted).
16. Lift main screen.
17. Press the full screen button (LED on).
18. If necessary, reset camera length and diffraction shift and FOCUS the image.

3.3.3 Step-by-step procedure in SACP

Basic procedure:

1. Insert and centre the smallest condenser aperture.
2. Obtain an HMS STEM image of the specimen.
3. Key SACP.
4. Lower the main screen.
5. Select spot size 3 or larger (numbers 1 or 2).
6. Select magn TEM CRT so that CRT is highlighted.
7. Select an intermediate tilting angle, e.g. 10°.
8. Select magn TEM CRT so that TEM is highlighted.
9. Press SCAN STOP (LED on) and FOCUS the image.
10. Press SCAN STOP (LED off).
11. Select FAST scan rate.
12. Observe the movement of the beam on the specimen. At high beam-tilt angles, the beam is typically V-shaped due to (unavoidable) spherical aberration and jumps at the end of the frame. If the movement of the point of the V is excessively large, align the pivot points (direct ALiGNment)
13. Defocus the beam (INTENSITY).
14. Select the BS detector (if present, otherwise see below).
15. Adjust the detector CONTRAST and BRIGHTNESS to obtain an image.
16. If necessary, focussing can be done using the INTENSITY.

Procedure with descanning for using the BF/DF detector:

14. Select the BF/DF detectors.
15. Press the D button (LED on).
16. Press descanning softkey. The diffraction pattern should now remain stationary. If the diffraction pattern moves excessively, press ALiGN and adjust the DESCAN X and Y pivot points.
17. Lift the main screen and obtain the BF/DF images.

Fine-tuning the BF and DF images can be performed as follows. In both cases, the movement of the diffraction pattern on the screen at high rocking angles is inevitable. Defocussing the diffraction pattern enlarges the illuminated area so that the detector is illuminated more evenly. Use a longer camera length for the BF image (this will avoid moving the BF disc partly off the detector) and a shorter camera length for the DF image (so that the BF disc does not overlap on the DF detector).

3.3.4 Step-by-step procedure in scanning LOW DOSE mode

In the scanning LOW DOSE mode, the area scanned during exposure differs from that used for focussing and stigmation. This is to avoid beam damage to the specimen prior to exposure. The area scanned during exposure is offset two frame sizes left (LOW DOSE-L) or right (LOW DOSE-R) of the area scanned for focussing, provided that the scan rotation is set to zero. The scanned areas left and right physically remain the same but with scan rotation at any other angle, the focussing areas no longer appear to be in those positions relative to the image observed on the monitor screen.

For observing the behaviour in LOW DOSE:

1. Lower main screen.
2. Select an HMS scan magnification of 15000 or more.
3. Select magn TEM CRT so that TEM becomes highlighted.
4. Press D button (LED off) to go to image mode.
5. Select a MAGNIFICATION low in the SA range.
6. Observe the scan areas while pressing the LOW DOSE softkey to go from LOW DOSE to LOW DOSE-R and LOW DOSE-L.

To regain a scanning image, lift the main screen, press D button (LED on) and press magn TEM CRT so that CRT becomes highlighted.

Operational procedure for LOW DOSE:

1. Ensure that the specimen tilt is set to zero for the best results.
2. Select an area for exposure while scanning at a low HMS magnification. Centre the area with the specimen translation controls (or the SHIFT X, Y knobs, if the area is not too far off-centre).
3. Select magn TEM CRT so that CRT is highlighted.
4. Increase the HMS magnification to 15000 or higher and immediately press the LOW DOSE softkey. Now LOW DOSE-R becomes highlighted and the scanned area is displaced.
5. FOCUS and STIGmate the image.
6. Press LOW DOSE-R. Now LOW DOSE-L becomes highlighted and the area scanned lies on the other side of the area of interest.
7. Check the FOCUS. If the specimen is flat and at zero tilt angle, the focus should not change. If the FOCUS is correct for LOW DOSE-R and LOW DOSE-L, the focus should be correct for the exposure as well unless the specimen is severely bent. If it is required to go back to LOW DOSE-R, press the LOW DOSE-L softkey twice (it will pass through LOW DOSE without highlight which means that the exposure area is scanned).
8. Prepare the exposure by selecting the proper EXPosure scan rate and by preparing the camera. Press EXPOSURE button to start the exposure. The scan frame will automatically be set to the area between the left and right frames. After the exposure, the scan will return to the LOW DOSE displacement that was active before the exposure.

3.3.5 Step-by-step procedures in ROCKING BEAM mode

a) Use of the Rocking Beam mode to decrease the contrast caused by extinction and thickness contours in crystalline specimens

1. Obtain a TEM image of the crystalline specimen as required.
2. Obtain a selected-area diffraction pattern (Sect. 2.3.2).
3. Introduce the required Objective aperture and centre it accurately around the central spot.
4. Key ROCKING BEAM mode on MODE SELECTION page twice and press D button (LED on).
5. Increase rocking angle by decreasing the setting of the MAGNIFICATION control until the rectangle scanned by the bright-field spot on the microscope screen fills the image of the objective aperture.
6. Reselect Imaging mode (D-LED off).
7. If required, the selected-area diffraction aperture may now be removed from the beam.
8. Key magn TEM CRT (TEM is highlighted). Carry out MAGNIFICATION, INTENSITY, beam SHIFT and FOCUS adjustments as for a normal TEM image.
9. The normal TEM image can be obtained by keying MODES and TEM.

b) Use of the Rocking Beam mode to obtain Rocking Beam Diffraction

Note: Both the Bright Field and the Dark Field detectors can be used in Rocking Beam but they will yield the same type of signal. In principle, the BF detector provides better spatial resolution since it is smaller than the annular DF detector but in practice no large difference is found and the different response of the solid-state DF detector may give better performance in some cases.

1. Obtain a TEM image of the crystalline specimen as required.
2. Obtain a selected-area diffraction pattern.
3. If a diffraction pattern is required, introduce the required Objective aperture ($\pm$10 μm) and centre it accurately around the central spot. If the objective aperture is not used, a Rocking Beam pattern with Kikuchi lines is obtained.
4. Key ROCKING BEAM on MODE SELECTION page twice.
5. Lift the main screen and adjust CONTRAST AND BRIGHTNESS of the Bright-Field signal.
6. Adjust the rocking angle by turning the MAGNIFICATION knob until the diffracted beams will pass through the objective aperture and a diffraction pattern can be observed on the monitor.

Area selection can also by achieved by placing the TEM image on the BF or DF detectors, then the diffraction pattern comes from the area on the detectors.

7. Press D button (D LED is off).

8. Key magn TEM CRT (TEM is highlighted) and lower the main screen. Adjust MAGNIFICATION until the image area from which the diffraction pattern is to be obtained has the size of the BF detector (7.5 mm) or of the DF detector.

9. Lift the main screen and adjust the CONTRAST and BRIGHTNESS of the Bright Field and Dark Field signals.

   Note: 1) The diffraction pattern displayed on the STEM monitor screen is generated from the specimen area selected by the STEM Bright Field detector. Its diameter is given by:

   d = entrance aperture of STEM detector/TEM magnification in the detector phase

   = 7.5 mm/TEM magnification readout with screen lifted.

   2) The angular resolution of the diffraction pattern is controlled by the diameter of the objective aperture. Decreasing the diameter increases the angular resolution but on the other hand may cause the signal-to-noise ratio to deteriorate. This can be compensated by increasing beam intensity, line time and number of lines.

c) Use of the Rocking Beam mode to obtain Dark Field Images

1. Carry out the procedure for obtaining Rocking Beam diffraction (see Sect. b).

2. Press the crosshairs button and SHIFT the crosshairs to the chosen reflection in the diffraction pattern.

3. Press the crosshairs button once more to stop the beam rocking and lower the main screen.

4. In the imaging mode (D LED is off), the corresponding Dark Field image will be obtained on the microscope screen.

3.3.6 Descan with EELS

This section describes the use of the DESCAN mode, in conjunction with the SCANNING mode, to obtain energy-filtered STEM images with the help of an electron energy loss spectrometer.

1. Obtain a BF/DF image on the monitor screens (see Sect. 1.3).

2. Lower the main screen and press D button (LED off).

3. Key DESCAN which will then be highlighted.

4. Press ALiGN button (LED on) and key DESCAN X.

5. Select slow scan rate and minimise the length of line scan on main screen using MULTIFUNCTION X, Y knobs. To minimise the line length accurately, select a high SA magnification (or low HMS magnification).

6. Key DESCAN Y and repeat step 5.

7. Press D-button and if necessary, SHIFT the diffraction pattern using the MULTIFUNCTION X, Y knobs, to the position on the screen directly below where the entrance aperture of the spectrometer is situated.

8. Select the EELS detector.

9. Lift the main screen.

Note: The EELS signal can be employed in scanning by connecting the auxiliary EELS output signal (the primary is connected to the X-Ray microanalysis system) to a universal detector board (UDTB) in one of the UDTB slots of the electronics rack (information request to Philips service engineers).

3.3.7 Conical Dark Field Imaging

Note: The Dark Field beam shift is an increment added to the Bright Field beam shift. The beam shift is set correctly by centring the beam in Bright Field mode, pressing DF and recentring the beam. The Dark Field stigmation may be difficult to observe at the low image intensities. For the best results, first correct the objective astigmatism in Bright Field using the same objective aperture as in Dark Field. If this result is unsatisfactory for Dark Field, further optimise the astigmatism correction in the Dark Field mode.

a) Dark field imaging

1. In the TEM-BF mode, select the required field of view in the SA magnification range.

2. Obtain a selected-area diffraction pattern of the chosen area.

3. Decide from which Bragg reflections (or polycrystalline ring) a DF image is required.

4. Press the DF button (LED on).
   - If necessary, key d/mode X-Y CONE so that CONE is highlighted.
   - Turn MULTIFUNCTION Y to adjust DF tilt = 0.00 d.

5. Toggle between BF and DF to centre the diffraction pattern accurately with the MULTIFUNCTION X, Y knobs (the beam stop can be used as a reference point)

6. Introduce an objective aperture and centre it accurately around the central spot.

7. Turn MULTIFUNCTION X to adjust DF tilt to the chosen value or, when this value is unknown, remove the objective aperture and bring the selected Bragg reflection or ring to the centre of the screen (MAN must be highlighted) and re-introduce the objective aperture.

8. If necessary, key circle MAN DYN so that MAN is highlighted.

9. Press D button (LED off) and a dark field image of those crystal planes that cause the diffraction spot that passes the objective aperture at that time will appear.

10. If required, the selected-area Diffraction aperture may now be removed from the beam.

11. Carry out MAGNIFICATION, INTENSITY, beam SHIFT, FOCUS and STIGmator adjustments as for a Bright-Field TEM image and select the required scan time.

    Note: 1) For focussing, it should be noted that the conical dark field image is sensitive to height in the specimen. If strong height variations occur, it may be impossible to bring the whole specimen into focus. The sensitivity increases with the dark field tilt angle (similar to the wobbler).

    2) For more information concerning pivot point adjustment for dynamical Conical Dark Field and for cases where the diffraction pattern describes a circle rather than an ellipse, see Sect. 2.3.4.

12. Switching between Conical Dark Field and Static Bright-Field images can be achieved simply by successively pressing the DF button.

b) Use of conical dark field to remove diffraction contrast

1. Obtain a selected-area diffraction pattern of the chosen area.

2. Press DF button. Select d/mode X-Y CONE such that CONE is highlighted and, if necessary, key circle MAN DYN such that MAN is highlighted.

3. Set DFtlt to ca. 0.1 d.

4. Key circle MAN DYN such that DYN is highlighted.

5. Insert an objective aperture of such a size that the circle described by the central spot falls inside the aperture.

6. Press D button to regain TEM image mode.

7. Carry out MAGNification, FOCUS, INTENSITY, beam SHIFT and STIGmator adjustment as for a TEM bright field image.

3.3.8 Step-by-step procedure for MICROPROBE SCANNING

The purpose of this mode is to obtain a photographic exposure with a scanning microprobe beam instead of the static TEM beam. Scanning the beam may reduce beam damage to the specimen.

1. Obtain a TEM Bright Field image of the area of interest with defocussed beam (INTENSITY). Select the objective aperture required. FOCUS and STIGmate image. If necessary, move the area of interest away temporarily to reduce beam damage by using the specimen translation controls.

2. Press MODES and MICROPROBE SCAN to enter the Microprobe scanning mode.

3. If necessary, press SCAN STOP to stop the scanning of the beam.

4. Select magn TEM CRT so that TEM is highlighted.

5. Select the required TEM magnification.

6. Press magn TEM CRT so that CRT becomes highlighted.

7. Select a scan frame size (MAGNIFICATION) appropriate for the TEM magnification in use (small frame at high magnifications, large frame at low magnifications).

8. Select an EXPosure scan rate and adjust the line time and the number of lines on the PARAMETERS 2 page. The number of lines selected for the frame should be such that individual scanning lines do not appear in the image (the number of lines should be equal to or larger than the ratio of magnification and spot size indicated).

9. Adjust the scan frame size (MAGNIFICATION) so that the frame is larger than the plate markers on the main screen. If necessary, rotate the scan (MULTIFUNCTION X) to align the frame with the plate markers.

10. If the area of interest was moved away, bring it back to the centre of the screen.

11. Select TV scan rate. Insert the small focussing screen and read off the automatic exposure time. Adjust the emission and/or spot until an exposure measurement is obtained that is at least ten times the selected EXPosure frame time.

12. If necessary, focus the beam (INTENSITY).

13. Press the selected EXPosure scan rate button.

14. Lift the main screen and press exposure.

3.3.9 Step-by-step procedure for NANOPROBE SCANNING

The purpose of this mode is to obtain a photographic exposure with a scanning nanoprobe beam instead of the static TEM beam. Scanning the beam may reduce beam damage to the specimen.

1. Obtain a TEM Bright Field image of the area of interest with defocussed beam (INTENSITY). Select the objective aperture required. FOCUS and STIGmate image. If necessary, move the area of interest away temporarily to reduce beam damage using the specimen translation controls.

2. Press MODES and NANO PROBE SCAN to enter the Nanoprobe scanning mode.

3. If necessary, press SCAN STOP to stop the scanning of the beam.

4. Select magn TEM CRT so that TEM is highlighted.

5. Select the required TEM magnification.

6. Press magn TEM CRT so that CRT becomes highlighted.

7. Select a scan frame size (MAGNIFICATION) appropriate for the TEM magnification in use (small frame at high magnifications, large frame at low magnifications).

8. Select an EXPosure scan rate and adjust the line time and number of lines on the PARAMETERS 2 page. The number of lines selected for the frame should be such that individual scanning lines do not appear in the image (the number of lines should be equal to or larger than the ratio of magnification and spot size indicated).

9. Adjust the scan frame size (MAGNIFICATION) so that the frame is larger than the plate markers on the main screen. If necessary, rotate the scan (MULTIFUNCTION X) to align the frame with the plate markers.

10. If the area of interest was moved away, bring it back to the centre of the screen.

11. Select TV scan rate. Insert the small focussing screen and read off the measured exposure time. Adjust the emission and/or spot until an exposure measurement is obtained that is at least one second.

12. If necessary, focus the beam (INTENSITY).

13. Press the selected EXPosure scan rate button.

14. Lift the main screen and press exposure.

3.3.10 Step-by-step procedures for POST SPECIMEN SCANNING

Note: The Bright Field and the Dark Field detectors can be used in SCIM and SCID but they both yield the same type of signal. In principle the BF detector provides better spatial resolution (since it is smaller than the annular DF detector) but in practice no large difference is found and the different response of the solid-state DF detector may give better performance in some cases.
If available, the EELS detector can be used to obtain energy filtered SCIM images and SCID patterns. Depending on the EELS entrance aperture, the resolution obtained can be up to 10x better with the STEM BF detector but with accompanying loss in the signal-to-noise ratio.

a) SCanning in IMaging (SCIM)

This mode is used to obtain a TEM image on the STEM monitor with or without photographic recording. This can be used, for instance, to obtain a quick recording of the TEM image to mark analysis positions. It should be noted that the signal-to-noise ratio and resolution of SCIM images are usually not as good as STEM images.

Operational procedure:

1. Press MODES and POST SPECIMEN SCAN to enter the post-specimen scanning mode.

2. Press SCAN STOP to obtain a TEM image.

3. Select magn TEM CRT so that TEM becomes highlighted.

4. Select a MAGNIFICATION in the high SA range around 100 000x (the resolution in the SCIM image depends in the magnification used, the higher the magnification, the better the resolution but the poorer the signal-to-noise ratio).

5. FOCUS and STIGmate the image.

6. Select magn TEM CRT so that CRT becomes highlighted.

7. Select a low MAGNIFICATION.

8. Press SCAN STOP to start scanning and lift the main screen.

9. Adjust detector CONTRAST and BRIGHTNESS until an image is obtained. If the image has dark corners, defocus the INTENSITY, otherwise focus the INTENSITY until the dark corners are just outside the scan frame for better signal.

10. Go to the required MAGNIFICATION. The resolution of the image can be improved by raising the TEM MAGNIFICATION (press magn TEM CRT so that TEM becomes highlighted). The INTENSITY can be adjusted to the size of the scan frame. The scanned area can be shifted using the SHIFT X, Y knobs in FULL FRAME scan (in SELECTED AREA scan, CROSSHAIRS or LINE scan mode, the SHIFT X, Y knobs control the selected area, crosshairs or line).

b) SCanning In Diffraction (SCID)

This mode is used to obtain an image of a diffraction pattern on the STEM monitor, with or without photographic recording. However, two limitations exist:

1. The intensity in the BF disc or spot should not exceed the intensities in the diffraction pattern as a whole because the dynamic range of brightness levels that can be displayed is limited.

2. The intensity in the diffraction pattern should be fairly high in order to get a good signal-to-noise ratio on the monitor. Hence convergent beam patterns can be displayed much more easily than low-intensity selected-area diffraction patterns.

Operational procedure:

1. Press MODES and POST SPECIMEN SCAN to enter the post specimen scanning mode.

2. Press SCAN STOP to obtain a TEM image.

3. Obtain a selected area or convergent beam diffraction pattern.

4. Select magn TEM CRT so that TEM becomes highlighted.

5. Select the highest camera length available with the MAGNIFICATION knob (the camera length decides the resolution in the SCID diffraction pattern).

6. If necessary, FOCUS and STIGmate the diffraction pattern.

7. Select magn TEM CRT so that CRT becomes highlighted.

8. Select the largest SCID scanning angle (MAGNIFICATION).

9. Press SCAN STOP to start scanning and lift the main screen.

10. Select FAST scan rate.

11. Adjust the SPOT SIZE and detector CONTRAST and BRIGHTNESS until the required diffraction pattern is displayed on the monitor screen.

12. Select SLOW scan rate. This will reduce the tail on intense diffractions that is caused by afterglow of the detector.

13. The size of the diffraction pattern can be adjusted by changing the SCID MAGNIFICATION (CRT highlighted) or by changing the camera length (MAGNIFICATION with TEM highlighted, but with decrease in resolution). The pattern can be shifted on the screen using the SHIFT X, Y knobs in FULL FRAME scan mode (in SELECTED AREA scan, CROSSHAIRS or LINE scan, the SHIFT knobs control the movement of the selected area, crosshairs or line).

Note: In many cases it is instructive to display the SCID pattern in Y- modulation. Proceed as follows. Press PARAMETERS softkey twice to go to PARAMETERS 2 page. Select the smallest number of scan lines per frame. Press Y-display pushbutton to obtain Y modulation image. The Z (intensity) modulation is still superimposed on the Y modulation. If required, press Z- display pushbutton to obtain Y modulation only.

3.3.11 Step-by-step procedures for direct alignments, scanning modes

Note: All alignments should be performed with the specimen at the eucentric position.

Softkeys

beamcoils
PIVOT POINT X, Y

Function : Align beam deflection coils pivot points. In imaging, the beam tilt pivot point on the specimen can be aligned and in diffraction, the beam shift pivot point can be aligned.

Present in : Rocking Beam Image, MICROPROBE SCAN Diffraction, NANOPROBE SCAN Diffraction, SCANNING Diffraction, SACP Image.

Used in : Rocking beam Image, MICROPROBE Diffraction, NANOPROBE Diffraction, SCANNING Diffraction, SACP Image.

Operation :

In Image

- Select Image mode (D button LED off) and select magn TEM CRT so that TEM becomes highlighted.
- Lower main screen and focus image (FOCUS).
- Key PIVOT POINT X on ALIGNMENT SELECTION page (press SCAN STOP if scanning continues: LED on).
- Adjust MULTIFUNCTION X and Y until beam movement is minimised.
- Key PIVOT POINT Y and adjust MULTIFUNCTION X and Y until beam movement is minimised.
- Press ALiGN button and SCAN STOP (LED off) then raise main screen.

In Diffraction

- Select Diffraction mode (D button LED on) then lower main screen.
- Focus image on CRT (= beam on specimen).
- Key PIVOT POINT X on the ALIGNMENT SELECTION page (press SCAN STOP if scanning continues, LED on).
- Focus diffraction pattern or objective aperture (FOCUS). When focussed, the diffraction pattern consists of discs, not spots.
- Minimise movement of diffraction spot with MULTIFUNCTION X and Y knobs.
- Key PIVOT POINT Y and minimise movement of diffraction spot with MULTIFUNCTION X and Y knobs.
- Raise main screen if CRT image is required then press SCAN STOP (LED off) to resume scanning.

Softkeys

DESCAN X, Y

Function : Aligns the descanning generator of the image deflection coils below the specimen so as to counteract the scanning generator of the beam deflection coils above the specimen.

Present in : ROCKING BEAM Image and Diffraction with DESCAN activated, HM SCANNING Image and Diffraction with DESCAN activated, SACP with DESCAN activated.

Used in : ROCKING BEAM Diffraction, HMS Image, SACP Diffraction.

Operation :

In Image

- Select scan magnification to be used for DESCANNING then lower main screen.
- Select Image mode (D button LED off).
- Select DESCAN X on ALIGNMENT SELECTION page and minimise spot movement with MULTIFUNCTION X, Y knobs.
- Select DESCAN Y and minimise spot movement.
- Repeat DESCAN X and Y if necessary.

In Diffraction

- Select magn TEM CRT so that TEM becomes highlighted.
- Select camera length to be used (D mode should be active) then lower main screen.
- Select DESCAN X on ALIGNMENT SELECTION page and minimise movement of central diffraction spot using the MULTIFUNCTION X, Y knobs.
- Select DESCAN Y and minimise spot movement.
- Repeat DESCAN X and Y if necessary.

Note: If the above procedure does not give a stable diffraction pattern and stable image, check the image coils pivot points under Service Calibration (press ALIGN button, SERV CAL softkey and image coil pivot points).

DET ALIGNM

Function : Aligns image or diffraction pattern with BF/DF detector (important only with off-axis or near-axis detector).

Present in : ROCKING BEAM Diffraction, MICROPROBE SCAN Diffraction, NANOPROBE SCAN Diffraction, SCIM, SCID, HM SCANNING Diffraction, SACP Image and Diffraction.

Used in : All above.

Operation :

In Image

- Press CROSSHAIRS/SPOT button and shift crosshairs to screen centre.
- Press CROSSHAIRS/SPOT button again to stop scan.
- Key DET ALIGNM on ALIGNMENT SELECTION page and shift the bright area to the detector position using the MULTIFUNCTION X,Y knobs.

Note: If the MULTIFUNCTION knobs are turned out of range, the beep will sound until they are in range again. Press RESET to shift the central spot to a position within range.

In Diffraction

- First centre the diffraction pattern accurately on the screen centre using DIF ALIGN.
- Key DET ALIGNM on ALIGNMENT SELECTION page then move central spot to detector position using the MULTIFUNCTION X and Y knobs. If necessary, do fine adjustment while observing the image. In general, the diffraction pattern is aligned with the highest intensity in the BF image and the lowest in the DF image. The videoscope signal provides a visual guide.
- From then on, always align the detector by centring the diffraction pattern on the screen with DIF ALIGNM.

DIF ALIGNM

Function : Aligns diffraction patterns for all camera lengths.

Present in : ROCKING BEAM Diffraction, MICROPROBE SCAN Diffraction, NANOPROBE SCAN Diffraction, SCID, HM SCANNING Diffraction.

Used in : All the above.

Operation :

- Select Diffraction mode (D button, LED on).
- Stop scan by pressing SCAN STOP (LED on) button.
- Key DIF ALIGNM on ALIGNMENT SELECTION page; Select smallest camera length (MAGNIFICATION).
- Focus diffraction pattern (FOCUS) and centre central beam spot using MULTIFUNCTION X and Y.
- Increase camera length, focus and centre central spot.
- Repeat for all camera lengths. Press RESET if central spot is invisible.

DIF SHIFT

Function : Shifts the diffraction pattern at the chosen working camera length.

Present in : ROCKING BEAM Diffraction, MICROPROBE SCAN Diffraction, NANOPROBE SCAN Diffraction, SCID, HM SCANNING Diffraction, SACP Diffraction.

Use in : All the above.

Operation :

- Select Diffraction mode (D button).
- Key DIF SHIFT on ALIGNMENT SELECTION page.
- Centre diffraction pattern using MULTIFUNCTION X and Y.

Softkey

GUN SHIFT

Function : Aligns different spot sizes.

Present in : ROCKING BEAM Image, MICROPROBE SCAN Image, NANOPROBE SCAN Image, SCANNING Image.

Use in : All the above.

Operation :

- Select magn TEM CRT so that TEM becomes highlighted.
- Press CROSSHAIRS button twice to stop scan then go to a low magnification in the SA range.
- Key GUN SHIFT on the ALIGNMENT SELECTION page and select spot size 9.
- Focus beam (INTENSITY) and centre spot using SHIFT X, Y.
- Select spot size 3 and centre spot using MULTIFUNCTION X and Y.
- Repeat until beam remains centred for both spot sizes. If necessary, other spot sizes than 9 and 3 can be selected.

GUN TILT

Function : Maximises brightness of incident beam.

Present in : ROCKING BEAM Image, MICROPROBE SCAN Image, NANOPROBE SCAN Image, SCANNING Image

Used in : All the above.

Operation :

- Select magn TEM CRT so that TEM becomes highlighted.
- Press CROSSHAIRS button twice to stop scan and select low magnification in the SA range.
- Press GUN TILT on ALIGNMENT SELECTION page.
- Focus Beam (INTENSITY).
- Maximise screen brightness. If necessary recentre the beam using the SHIFT X, Y knobs.

image coils
PIVOT POINT X, Y

Function : Align image deflection coils pivot points.

Present in : Post-specimen scanning SCIM, SCID.

Used in : All the above.

These alignments, which are related to the sets of deflection coils below the specimen, are very important and are also part of the TEM alignment procedure under SERVice CALibrations. The image coils pivot points are used either purely to shift a diffraction pattern (with no accompanying image shift in the SA plane) or purely to shift the image in the diffraction plane (without shifting the diffraction pattern). These post-specimen deflection coils make use of the pivot points for:

1. Aligning images for different magnifications or camera lengths onto each other.
2. The on-line TEM measuring system (see Sect. 2.3.6 and 2.3.7).
3. The post-specimen scanning and descanning.

Caution! Changing these pivot points has a large influence on all these application modes.

Operation :

In Image

- Select magn TEM CRT so that TEM becomes highlighted then lower main screen.
- Focus image (FOCUS) and focus beam (INTENSITY).
- Key PIVOT POINT X on ALIGNMENT SELECTION page (press SCAN STOP if scanning continues, LED on).
- Minimise spot movement using MULTIFUNCTION X and Y knobs.
- Key PIVOT POINT Y and minimise spot movement using MULTIFUNCTION X and Y knobs then raise main screen.
- Press ALiGN and SCAN STOP (LED off) buttons to resume scanning.

In Diffraction

- Select Diffraction mode (D button LED on) then lower main screen.
- Key PIVOT POINT X on the ALIGNMENT SELECTION page (press SCAN STOP if scanning continues, LED on).
- Minimise movement of diffraction spot with MULTIFUNCTION X and Y knobs.
- Key PIVOT POINT Y and minimise movement of diffraction spot with MULTIFUNCTION X and Y knobs.
- Raise main screen if CRT image is required and press SCAN STOP (LED off) to resume scanning.

IMAG SHIFT

Function : Align images in different magnification ranges or between TEM and STEM.

Present in : ROCKING BEAM Image, MICROPROBE SCAN Image, NANOPROBE SCAN Image, SCIM, SCANNING Image and Diffraction.

Used in : All the above.

Operation :

In Image

- Select magn TEM CRT so that TEM becomes highlighted.
- Press CROSSHAIRS button twice to stop scan. If necessary centre beam with SHIFT X, Y knobs.
- Key IMAG SHIFT on ALIGNMENT SELECTION page then go to high SA magnification and centre a recognisable image feature on screen centre using specimen stage controls. Proceed to highest SA magnification. If necessary, recentre image feature with specimen stage controls.
- Focus Image (FOCUS) and increase the magnification one step (to the high M range).

- Centre the image feature using the MULTIFUNCTION X, Y knobs (if feature not visible on screen, first centre the beam **with the MULTIFUNCTION X, Y knobs**, the feature will move along with the beam centre).
- Focus image (FOCUS) then go to lowest M magnification and centre recognisable image feature with specimen stage controls.
- Focus image (FOCUS) and centre beam (INTENSITY, SHIFT X, Y).
- Go one step down in magnification to the highest LM magnification and centre image feature with MULTIFUNCTION X, Y knobs.
- Focus image (FOCUS) and centre beam (INTENSITY, SHIFT X, Y).

In Diffraction

- Select magn TEM CRT so that TEM becomes highlighted.
- Select magnification in the SA range and lower main screen.
- Select TEM mode and centre a recognisable image feature using the specimen translation controls.
- Select SCANNING mode and raise the main screen.
- Select IMAG SHIFT on the ALIGNMENT SELECTION page and centre a recognisable feature from TEM image on monitor screen with the MULTIFUNCTION X, Y knobs.
- Select magn TEM CRT so that CRT becomes highlighted then lower magnification to LMS range and centre a recognisable image feature on monitor screen.

ROT CENTER

Function : Aligns the objective-lens rotation centre.

Present in : ROCKING BEAM Image, MICROPROBE SCAN Image, NANOPROBE SCAN Image, SCIM, SCANNING Image and Diffraction, SACP Image and Diffraction.

Used in : All the above.

Operation :

In Image

- Select magn TEM CRT so that TEM becomes highlighted.
- Press the CROSSHAIRS button twice to stop scan and lower main the screen.
- Go to intermediate magnification in SA or LM range (these have different rotation centres).
- Select ROT CENTER on ALIGNMENT SELECTION page and select FOCUS STEP 5 or 6.
- Minimise image movement on main screen using MULTIFUNCTION X and Y and increase FOCUS STEP to 7 or 8 and repeat.

In Diffraction

- Select magn TEM CRT so that CRT becomes highlighted.
- Select a FAST scan rate then select ROT CENTER on the ALIGNMENT SELECTION page.
- Select FOCUS STEP 5 or 6.
- Minimise image movement on monitor screen using MULTIFUNCTION X and Y then increase FOCUS STEP to 7 or 8 and repeat.

SPOT SHIFT

Function : Shift the spot on the specimen (normal shift is beam tilt in SACP).

Present in : SACP Image and Diffraction.

Used in : SACP Image and Diffraction.

Operation :

In Image

- Select Image mode (D button LED off) then lower the main screen. If necessary, press SCAN STOP (LED on).
- Key SPOT SHIFT on ALIGNMENT SELECTION page then shift beam on specimen with MULTIFUNCTION X, Y knobs.

In Diffraction

- Select Diffraction mode (D pushbutton LED on) then lower the main screen
- Key SPOT SHIFT on ALIGNMENT SELECTION page then move image spot using MULTIFUNCTION X and Y knobs until the required intensity distribution in the diffraction pattern is obtained (shifting in diffraction mode may be useful in the case of a bent specimen).

3.4 OPTIMISING THE STEM SIGNAL

Once a signal has been obtained (see Sect. 1.3), its amplitude and level should be correctly adjusted to an internally-generated standard ensuring a maximum number of grey levels in the image, as well as being optimised for astigmatism and focus. The procedures described are, in principle, applicable to all signals from electron detectors.

3.4.1 Adjusting CONTRAST and BRIGHTNESS levels

The optional Videoscope provides an easy-to-use, continuous display of the detector signal between clearly defined reference levels. When the Videoscope is not incorporated, press the waveform button  (LED on) to obtain the signal of the left-hand image on the right-hand monitor; the line time should be at least 35 ms and the Dual mode should be switched off.

1. Ensure that the monitor CONTRAST and BRIGHTNESS controls (adjacent to the monitor) are set correctly (key GREYSCALE on the DETECTORS page and adjust until the maximum range and maximum number of grey levels are obtained).

2. Press fast scan mode (frame time typically less than 2 s) to obtain a full frame signal.

   Note: 1) The Videoscope is hard-wired to the left-hand monitor.

   2) The left and right-hand images can be interchanged by pressing the interchange  button (under Dual mode heading).

   3) The signal CONTRAST and BRIGHTNESS controls (at the bottom right-hand side) adjust the detector signal on the monitor underneath which the LEDs are illuminated. This is the so-called ‘active’ channel. These controls can be switched to the other monitor by pressing the Signal Control interchange button  which is positioned to the left of the CONTRAST knob.

3. Press the signal AUTO button (LED is on). After repeated measurements of signal intensity at a fixed number of pixels within a time period of 40 ms, the contrast and brightness settings of the active signal will be optimised automatically within a few seconds.

4. The AUTO function can remain active (LED on) during further optimisation of the image, e.g. changing spot size, correcting astigmatism, focussing, changing magnification and/or specimen area, camera length etc. and will continuously ensure appropriate adjustment of the contrast and brightness of the image.

   If the frame exceeds 40 ms and large differences in contrast and or brightness between different parts of the image exist, the contrast and brightness settings will be changing continually and a stable optimum setting will not be obtained. In this case, it is advised that the AUTO facility should be switched off or a reduced raster scan selected.

5. In cases where a top-quality full frame image is required, e.g. for taking a micrograph, switch off the AUTO button and either select full frame, or position the reduced raster around the specific features of interest and select the appropriate line time.

   Press the SET button (LED on). This function optimises the contrast and brightness settings of the full image within the scan frame by continuously measuring the signal at a fixed number of pixels within the actual scan frame.

After a time period of between a few tenths of a second and some tens of seconds, the SET function will have taken place and will be switched off automatically.

6. Check the contrast and brightness settings at the chosen area with the selected line time.

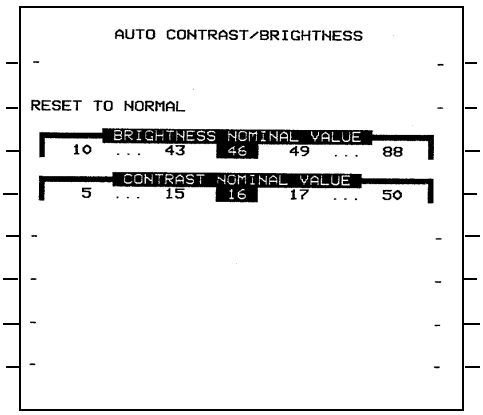
   - The signal should be evenly contained within the upper (WHITE) and lower (BLACK) reference levels on the Videoscope. In the absence of a Videoscope, the Normal\Inverted signal selector  can be used to reverse the signal; there should be no accompanying vertical shift of the signal boundary levels.

   - In order to use the full range of grey levels, i.e. optimum contrast, the signal should extend to the maximum and minimum level with unclipped peaks.

   In cases where the automatic contrast and brightness settings are not optimum, two approaches are possible:

   - When this is only applicable to a specific image or when the result is only slightly less than optimum, adjust the CONTRAST and BRIGHTNESS controls manually.

   - When this is applicable to a wide range of images, select the last PARAMETER page "ACB" and adjust the NOMINAL VALUES for BRIGHTNESS and CONTRAST. The default values which can be obtained directly by keying RESET TO NORMAL, are 46 and 16 respectively. Augmenting one of these values by keying at the right-hand side of the row will alter the effect of the automatic contrast and brightness functions AUTO and/or SET towards images having a higher brightness or contrast; lowering these NOMINAL VALUES will have the reverse effect.



7. If dual mode has been selected, switch the CONTRAST and BRIGHTNESS controls from the optimally adjusted signal to the signal on the second monitor by pressing the SIGNAL CONTROL Interchange button and optimise this signal by repeating steps 2 - 6.

Notes on the use of the Automatic Contrast and Brightness (ACB) functions AUTO and SET:

1. Neither of these ACB functions can be activated if one of the following conditions is true:

   - The microscope is in TEM mode.
   - No detector is chosen.
   - An exposure is in progress.
   - Scan stop, point mode or line scan is active. This means that the ACB functions work on both full frame and any reduced raster.
   - External X, Y control is active.

   If one of the above conditions is met, SET will be switched off and AUTO will be delayed. If the TEM mode is entered, AUTO will be switched off as well. If SET is switched on while AUTO is in progress, AUTO will be delayed.

2. While the AUTO and SET functions are in progress, all controls (knobs, buttons and softkeys) are allowed to be active or can be activated without any limitation. AUTO and/or SET can be deactivated at any moment by pressing the respective buttons (LED is 'off'). Some delay in switching off may occur.

3. When the scanning function is not performed at the fastest scan rate and SET is switched on, the scan rate is automatically switched to the rate available on the PARAMETERS 2 page which has the shortest line time and smallest number of lines. As soon as the SET function has been performed, the scan rate originally selected will become active again. The operator is allowed to choose any other scan rate acceptable to the SET functions, simply by selecting the scan rate while the SET function is in progress. Since the SET function measures contrast and brightness of the full scan frame before performing one contrast and one brightness adjustment, the process of reaching the optimum setting will take a proportionally longer time.

4. The SET function will terminate automatically if either the contrast and brightness settings, which have been measured on the full scan frame, are in accordance with the values on the last PARAMETERS page or if 100 adjustments of contrast and brightness setting have been performed.
   One of the three situations described below may prevent even 100 adjustments from providing the optimum settings. In such cases, pressing SET (LED 'on') a second time will lead to further ACB adjustments for more than two frame times.

   - Initial contrast and brightness settings far from optimum. The best solution is to re- run the AUTO function until a reasonable contrast and brightness setting is obtained.
   - The combination of spot size, emission and condenser aperture, gives either an exceptionally strong or exceptionally weak detector signal, for which contrast and brightness cannot be optimised, automatically or manually. This can also occur if the image is totally out of focus or if no specimen, or a specimen without contrast, is present! These situations should be avoided by selecting better parameters that will result in better images, either through increased resolution at the same signal-to- noise ratio, or better signal-to-noise ratio at the same resolution;

5. When the fluorescent screen is lowered, the screen current measurement momentarily interrupts the Automatic Contrast and Brightness adjustment process, resulting in a slow response of the microscope to operator input. If the fluorescent screen is raised and the exposure meter indicates XXX, the same slow response will be observed. This can also happen when the CURRENT or VACUUM page has been selected. The operator should try to avoid these combinations by switching off the AUTO and SET functions in such cases.

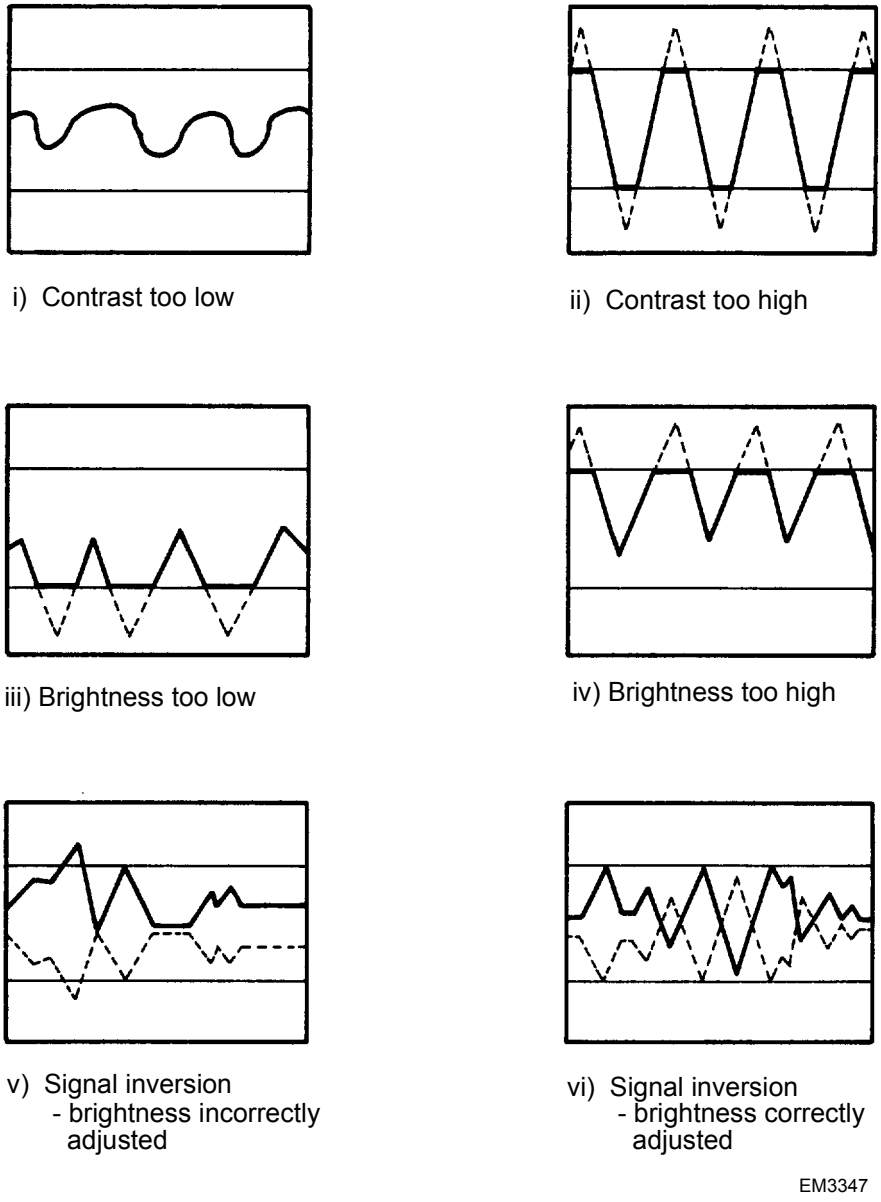


Fig. 3.3, Adjusting the STEM signal for contrast and brightness

3.4.2 Operation of the Contrast and Brightness controls

When a solid-state detector is being used for the detection of Dark Field or Backscattered electrons, the operator will notice that changing the contrast may induce, at some contrast levels, a sudden jump in brightness. The cause of this jump is related to the fact that the total contrast gain range is divided in a number of zones. The rate at which the contrast gain can be changed is proportional to this gain and differs for each zone. For reasons of flexibility the contrast zones overlap.

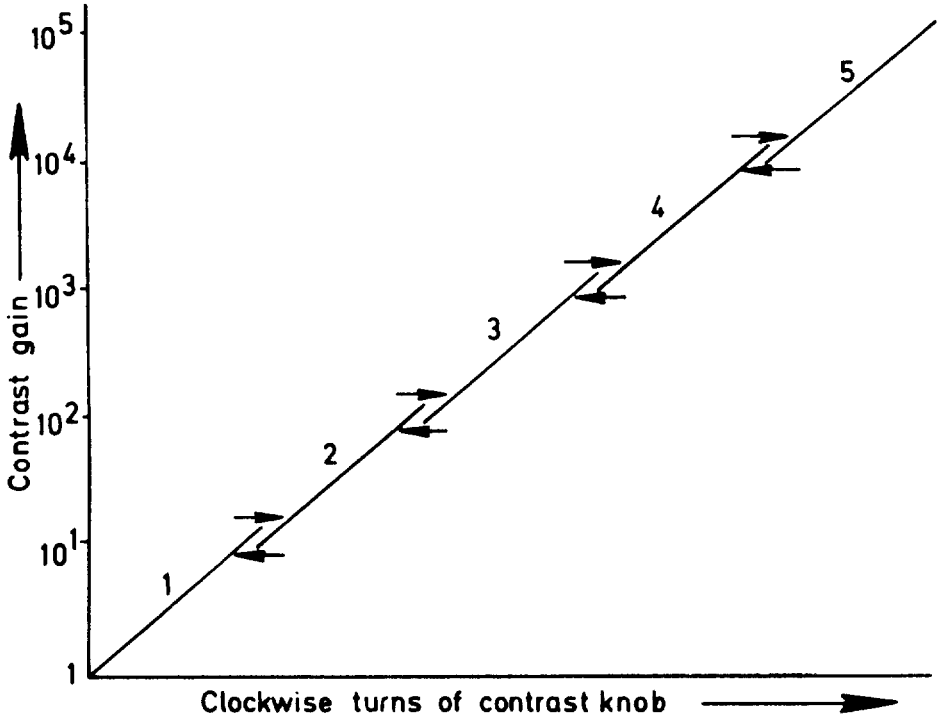


Fig. 3.4, Contrast gain characteristics: The contrast gain range is divided in 5 zones and each time the next zone is entered, a jump in brightness will be observed

3.4.3 Adjusting FOCUS in the STEM mode

Adjusting focus in a STEM image is achieved by focussing the beam probe on the specimen by adjusting the Objective lens current. The smallest image details that can be seen in a correctly focussed and stigmated image (see Sect. 3.4.4) are equal to the spot size (see Sect. 3.5.4).

To track the optimum focus:

1. Adjust the CONTRAST and BRIGHTNESS controls (see Sect. 3.4.1).

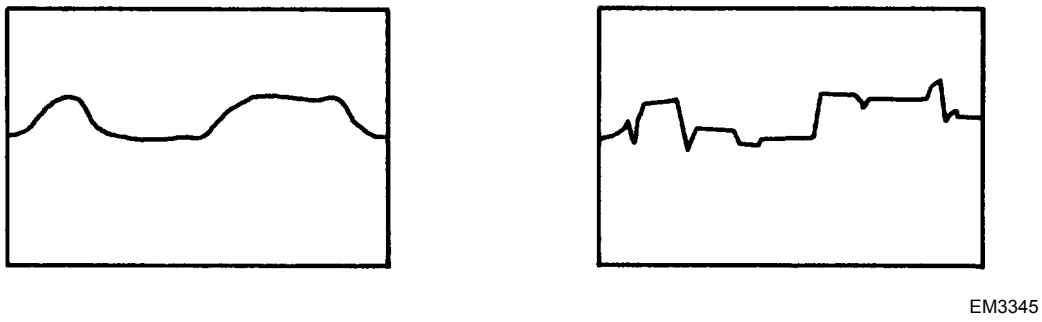
2. Press the FOCUS AUTO (to the left of the FOCUS knob).

   If the expected result is not obtained, proceed further as follows:

   - While observing the image, adjust the FOCUS knob using an appropriate step size, until best image resolution is obtained.

In some situations the following procedure may be helpful:

- While observing the signal on the (optional) Videoscope or Monitor, adjust the FOCUS knob at a small step size setting until the peaks in the signal are sharpest (fastest possible rise time, see Fig. 3.5).



EM3345

i) Unfocused ii) Focused

Fig. 3.5, Pre-focussing using the signal

3.4.4 Adjusting astigmatism and final focus in the STEM mode

When operating above 25.000x magnification, astigmatism should be corrected. Astigmatism in the scanned image is characterised by apparent lengthening of specimen detail which indicates an out-of-focus condition in one direction in the image when the perpendicular direction is in focus. Between conditions of underfocus and overfocus, a change of 90° in the direction of elongation will be observed. This is caused by beam astigmatism and can therefore be corrected by use of the Condenser stigmator.
A separate condenser stigmator can be stored in Channel 1 or 2 for each spot size. These settings are the same as for Nanoprobe mode.

Method 1

1. Advance the MAGNIFICATION selector one step higher than the value required for photography.

2. Choose SELECTED-AREA SCAN MODE (LED on) and select a line time and number of lines (see Sect. 3.5.1) that will give the best signal-to-noise ratio (e.g. 5 ms, 576 or 1152 lines).

3. Find a small particle or repeated granular fine structure in the image, if necessary by manipulating the SHIFT knobs. The size of the area selected can be changed by pressing the (selected area) button a second time and turning the SHIFT knobs.

4. Set the FOCUS STEP SIZE selector (coaxial with the FOCUS control) to a position such that a few steps clearly influence the focus of the image.

5. Adjust the FOCUS control to obtain the two settings in which the image is in focus in one direction only. These two directions should be mutually perpendicular.

6. Count the focussing steps between these two positions and set the FOCUS control to a point mid-way between them.

7. Press the STIG button and key COND stigmator (unless this was the default setting). Turn the MULTIFUNCTION X,Y knobs, which operate the Condenser stigmator, one at a time, to obtain the best focus of the image.

8. Adjust the FOCUS control to obtain a de-focussed condition. If astigmatism reappears, repeat steps 5 to 7.

9. Readjust the FOCUS control to obtain best fine focus.

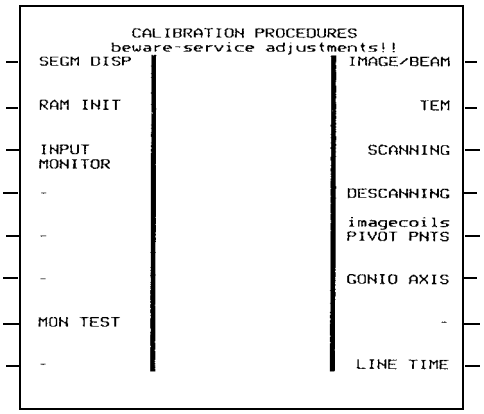
Method 2

As the electron optical modes of STEM and Nanoprobe are almost the same (except for a small difference in C2 lens current), the optimum Condenser stigmator settings for both modes are almost the same.
Usually, optimisation of Condenser astigmatism correction (as well as Condenser diaphragm and rotation centring in Nanoprobe) will give an optimum image in SCANNING and the alignments in Nanoprobe are much easier to perform.

3.4.5 Correction of scanning magnifications

Benefits: The SCANning AMPLitude correction enables accurate matching of the magnification of the image as seen on the CRT, in the X and Y directions independently, to the magnification value displayed on the Microcontroller screen.
Individual deviations of the scanning magnification from the displayed value can now be eliminated.

Before carrying out this new alignment, ensure that the SCANNING calibration (under SERVICE CALIBRATE on the ALIGNMENT page) is satisfactory. Using the same specimen as for SCANNING calibration, i.e. a cross grating specimen, select a convenient scanning magnification and rotate the image (MF-X) to align the cross grating lines parallel to the CRT edges. Measure the spacing of the lines on the CRT in both directions, using a ruler. If adjustment of the magnification is desired, press the ALIGN button and the SERVICE CALIBRATE softkey. The following text will then be displayed:



The actual magnification on the CRT can be adjusted when the SCAN AMPL softkey is activated. Adjustment can be performed for the horizontal and vertical directions (x-corr and y-corr) independently, using the MF-X and MF-Y knobs.

After adjustment of SCAN AMPL, check whether SCANNING calibration is still satisfactory. If necessary, iterate between SCANNING calibration and SCAN AMPL adjustment.

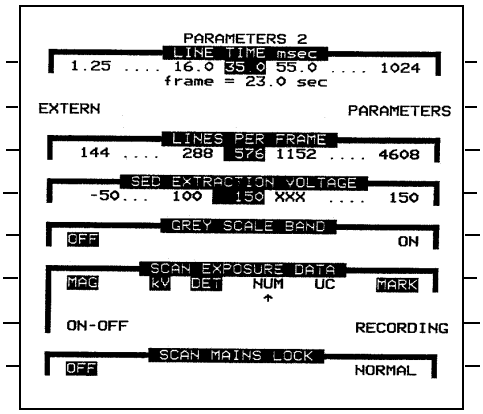
3.5 STEM IMAGING PARAMETERS

3.5.1 Scan rate

Given a certain focussed beam probe, the scan rate which is the reciprocal of the field frame time (= number of lines x line time) determines the signal-to-noise ratio and the ultimate final image resolution.

There are five SCAN RATE buttons on the right-hand control panel. The three buttons marked EXP1, EXP2, EXP3 are intended for photography and two for monitor viewing (SLOW and FAST). The first five scan rates have freely adjustable line times and lines/frame. To change a scan rate, proceed as follows:

- Press the SCAN RATE button required for re-adjustment (LED on).
- Key PARAMETERS twice. The microcontroller will then display the following page:



- Select the LINE TIME and LINES PER FRAME.
- The FRAME TIME, which is displayed on the second line, will always be displayed in the information field of a SCANNING page.
  To leave the PARAMETERS page, press the READY key.

The following recommendations are made, depending on the required operational activity:

- Specimen orientation and location:

  - FAST scan rate typically 288 lines, line time 2.5 ms.

- Viewing:

  - Mostly FAST scan rate. For fine details (in reduced raster), about 1152 lines, line time 5-10 ms.

- Photography:

- EXP 1-3 about 2000 lines, line time 16-35 ms.

- Y-modulated display:

  - For intensity measurements, select the minimum number of lines to provide a clear separation.

    Note: 1) At the slowest scan rates (line times > 375 ms), the image is not displayed on the monitors to avoid damage to the screen phosphors.

    2) At the shortest line times, there will be a small image shift due to distortion which could cause inaccurate results when using the on-line measuring function. In this case, select a line time > 10 ms.

Line scans

In the case where a slow single line scan is required for X-ray scanning or a clear Y- modulated signal of a line is needed, the operator can choose between two ranges:

1. Normal line scans having line times smaller than 1024 msec can be selected by pressing  and choosing the appropriate line time on the PARAMETERS 2 page.

.

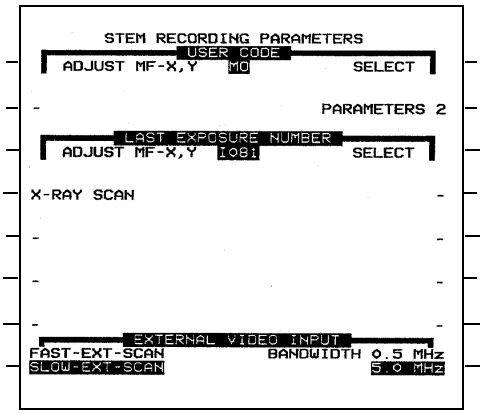
2. Longer line scans having line times up to 4000 s can be selected by keying RECORDING on the PARAMETERS 2 page and keying X-RAY SCAN (which will be displayed in reverse video).

   If this scan mode is selected, full frame becomes active automatically ( LED on) and the total frame time (= indicated line time x indicated number of lines on PARAMETERS 2 page) becomes the actual line time. The position of the line scan can be shifted by turning the SHIFT-Y knob.
   This X-RAY SCAN will be selected in the active scan rate (EXP1, EXP2, EXP3, slow or fast) until the moment that X-RAY SCAN) will be de-selected by keying X-RAY SCAN (normal video) on the RECORDING page. The X-RAY SCAN cannot be selected if the external XY control (option) is selected under the current scan rate. If the line time is greater than 375 ms then the brightness will be reduced.

   Note: 1) A bright dot may appear on the Videoscope (option) after switching from an active X-RAY SCAN in SCANNING to TEM mode. In order to prevent damage to the crt, switch between SCANNING and TEM once or twice until the bright dot disappears or switch to a different scan mode (not X-RAY SCAN or EXTERNAL scan) then back to TEM.

   2) To prevent the crt burning, the SCANNING mode should never be left in an EXTERNAL SCAN.

   3) The SCANNING data that is displayed at the bottom of the CRT will interfere with the X-RAY SCAN. It is therefore advisable to either switch off this information display at the PARAMETERS 2 page or select a line number less than 300.



3.5.2 SED extraction voltage

The secondary electrons emitted by the specimen are guided along the axis of the magnetic lens field, through the pole-piece bore, to the detector which is mounted above the lens field. When the lens is weak, as occurs mainly in LM mode, secondary electrons may move away from the axis and not reach the detector. To compensate for this straying of the secondary electrons, a collection electrode is mounted below the upper pole piece of the objective lens.

The voltage of the electrode can be adjusted between +150 and -50 V (line 3 on PARAMETERS 2 page). The positive voltage range can be used to improve the collection efficiency for secondary electrons, while the negative range can be used to prevent secondary electrons from reaching the detector, so that only backscattered electrons will be detected.
If an additional solid-state backscattered-electron detector is mounted, it is combined with the secondary-electron collection electrode.

3.5.3 Magnification

In general, the magnification chosen should be sufficient so that the area or detail of interest is just contained within the field of view. This condition is best achieved by beginning with a low value of magnification and manipulating the specimen until the required area is centred on the viewing screen.

Additional (small) shifts of the area being scanned can be carried out using the SHIFT X, Y knobs. The MULTIFUNCTION X knob can be used to rotate the image.
The magnification can now be easily adjusted to the most suitable value by turning the MAGNIFICATION control and the superimposed ZOOM control, for still finer adjustment (1.1x - 8x).

3.5.4 SPOT SIZE and Convergence

a) The (effective) spot size in the STEM mode

The area and angular resolution in the final image of an optimally-adjusted microscope are completely determined by the spot size and the convergence angle of the beam probe on the specimen. In general, the spot chosen should be comparable in size to the detail that should be resolved, with respect to the magnification setting employed.

For a given value of M, r can be derived as a guide to the useful spot size, to which it is closely related (spot size is < r) * where:

M = magnification
R = distance resolved by the eye (of the order 0.2 to 0.3 mm)
r = resolution referred to the specimen

A graph of M = R/r for R = 0.2 and 0.3 mm is shown in Fig. 3.6

* **Note:** When using the STEM BF/DF detector, the spot size is adjusted to give good signal-to-noise ratios. With an LaB_6 filament, spot sizes 8 or 9 are generally suitable.

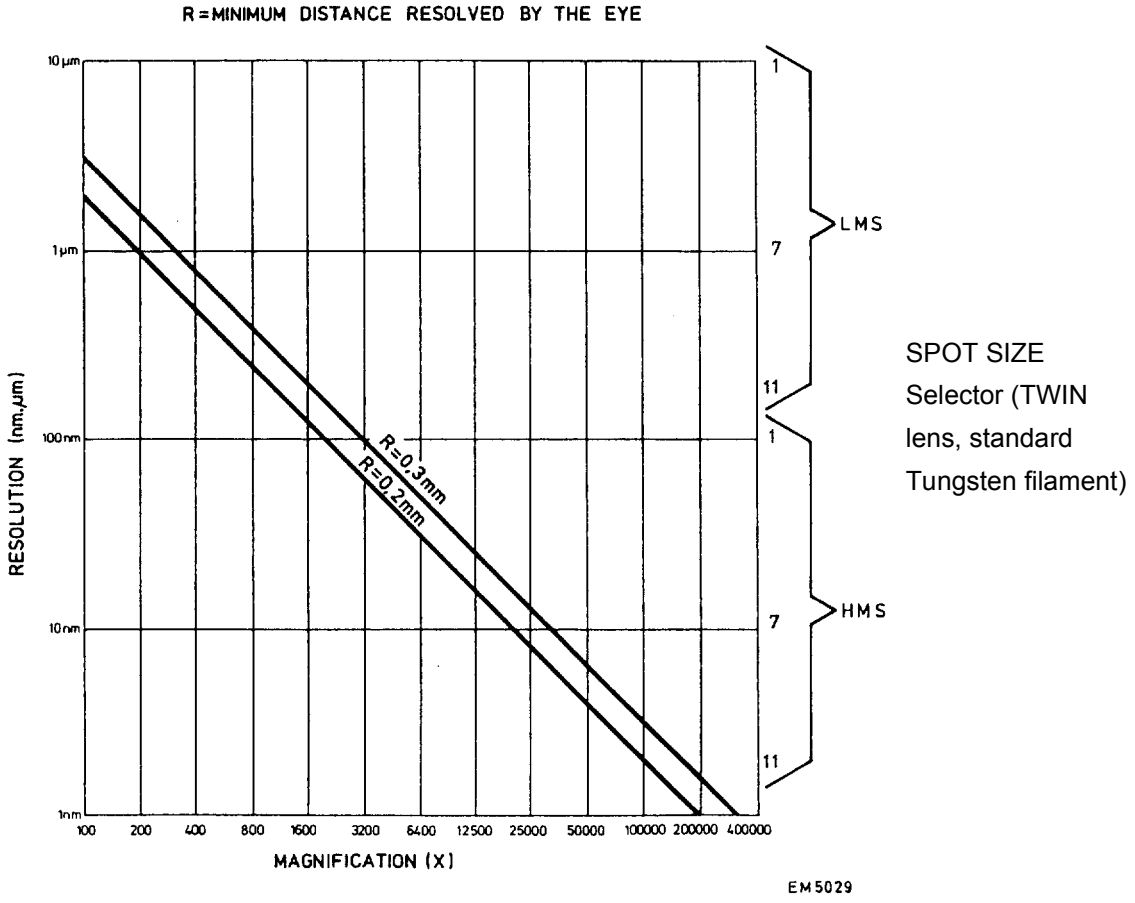


Fig. 3.6, Minimum useful magnification for a particular resolution

i) In the High-Magnification Scan range of the STEM mode

In this mode, the effective spot size is largely defined by two parameters:

1. The geometric demagnification of the beam diameter at the level of the electron gun (D_{geom}) which can be varied by the Spot Size.
2. The influence of the spherical aberration of the final lens (D_{cs}) which is dependent on the Condenser 2 aperture selected.

The two parameters can be related to the effective spot size (D_{eff}) as follows:

$$D_{eff} = \sqrt{(D_{geom})^2 + (D_{cs})^2}$$

D_{cs} values are listed in Table 3.8 for a range of Condenser 2 aperture sizes enabling other values of effective spot size to be calculated.

Spot size selector	D_{geom} (nm)		Advised C2 aperture (μm)		D_{eff} S(T)EM mode (nm)	
	T	ST	T	ST	T	ST
1	55	35	90	70	62	55
2	38	24	90	70	53	48
3	28	18	70	60	33	32
4	20	14	60	50	23	20
5	14	9	60	50	18	17
6	10	6.5	50	40	12	10
7	7.5	5	50	40	10	9
8	5.5	3.5	40	30	6	5
9	4	2.5	40	30	5	4
10	3	2	30	20	4	2
11	2	1.2	20	20	2	2

Table 3.7, Range of effective spot sizes for the TWIN (T) and SuperTWIN (ST) objective lenses in the S(T)EM mode for selected Condenser 2 apertures (standard tungsten filament) in eucentric goniometer height position

C2 aperture (μm)	D_{cs} TWIN (nm)	D_{cs} SuperTWIN (nm)
5	0.006	0.015
10	0.05	0.12
15	0.17	0.41
20	0.40	0.98
30	1.4	3.3
40	3.3	7.8
50	6.4	15.3
60	11	26
70	17	42
80	26	63
90	37	89
100	51	122
150	171	412
200	406	977

Table 3.8, Spherical aberration values in the S(T)EM mode for a range of Condenser 2 apertures

Note: 1) When a LaB_6 filament is used, geometric spot sizes will be 2 - 4 times smaller, depending on the make of filament. This means that the C2 apertures used for LaB_6 should be a factor of about 1.5 times smaller in size for optimum results.

2) Spot size is defined as the full width half maximum value of the electron density distribution.

3) D_{cs}values for the SuperTWIN lens are larger than for the TWIN lens because of the shorter focal distance, which increases the aperture angle for the same aperture diameter. Hence, smaller C2 apertures are used with the SuperTWIN lens.

ii) In the Low Magnification Scan range of the STEM mode

In this mode, the effective spot size (D_{eff}) can be defined by the geometric demagnification of the beam at the level of the electron gun, which can be varied by the SPOT SIZE selector. The influence of spherical aberration is negligible when Condenser 2 apertures smaller than 100 μm diameter are used. Table 3.9 lists the range of effective spot sizes thus obtained.

Selector	D_{eff} LMS-D mode
1	3.5 μm
2	2.5 μm
3	1.8 μm
4	1.3 μm
5	950 nm
6	700 nm
7	500 nm
8	350 nm
9	250 nm
10	185 nm
11	130 nm

Table 3.9, Range of effective spot sizes in the LMS-D mode for condenser apertures smaller than 100 mm diameter

Note: When a LaB_6 filament is used, spot sizes will be 2-4 times smaller, depending on the make of filament.

b) Spot size and Convergence in the μμD mode

As both the Objective and Condenser 2 lens are adjustable in this mode, continuous variation of spot size and convergence can be obtained. Table 3.10 (below) gives the smallest possible spot sizes (defining the smallest selected areas) which are similar to the STEM spot sizes, without the spherical correction.
If, however, the intensity (Condenser 2 lens current) is increased and the focussing control is adjusted to keep the STEM image as well focussed as possible, the beam will become less convergent, the discs in the diffraction pattern will become smaller and the area selected will increase.
The smallest possible convergence, i.e. best angular resolution, is obtained when the diffraction discs are at their smallest. In this case, the area selected is defined by the ***C2 aperture diameter*.**

Spot size selector	Smallest possible spot size (nm)	
	T	ST
1	55	35
2	38	24
3	28	18
4	20	13
5	14	9
6	10	6.5
7	7.5	5.0
8	5.5	3.5
9	4	2.5
10	3	2
11	2	1.5

Table 3.10, Smallest possible spot sizes in the μμD mode

c) Spot size and Convergence in the SACP mode

The spot size and angular resolution in SACP are similar to that in the μμD mode (see Table 3.10) except for an additional spot shift due to spherical aberration of beams which pass the upper objective lens a distance D from the centre. This distance D is defined by the tilt angle and the objective focal distance f.

$D = \alpha \cdot f$

This means that the spot location is influenced by the tilt angle according to $a \cdot C_s \cdot \alpha^3$, where a depends on the focussing plane and is between 1/4 and 1.

Note: Since the size of the illuminated area with parallel illumination (best- resolution SACP image) does not depend on the spot size setting selected, large spot size settings can be used to obtain high signal-to-noise ratios. Adjust the spot size to the lowest setting (largest spot) that provides contrast and brightness within the range of the controls. t should be realized that the angular resolution is determined by the size of the crossover in the front focal plane of the oblective lens which is itself determined by the first condenser lens C1 (= SPOTSIZE). The higher the spot size number, the better the angular resolution/beam coherency.

d) Spot size and Convergence in Rocking Beam mode

The basic beam probe of this mode is the LM beam probe and microprobe with a freely adjustable second condenser lens and a minimum spot size similar to that of the TEM mode (Table 3.11). The spot shift due to spherical aberration of the outer beams (as in SACP) is much less in this mode due to the small rocking angle[<5° (TWIN) and <8° (Super TWIN)] and is, in any case, of minor importance in relation to the larger spot sizes.

When the Rocking Beam mode is used to obtain a Rocking Beam Diffraction pattern on the STEM monitor, the angular and area resolution are related to the objective aperture and the entrance aperture of the BF detector, as described in Sect. 3.3.5, part b.

Spot size selector	Spot size LM-mode	Spot size Microprobe mode (M-SA)
1	3.5 µm	400 nm
2	2.5 µm	290 nm
3	1.8 µm	210 nm
4	1.3 µm	150 nm
5	950 nm	110 nm
6	700 nm	80 nm
7	500 nm	55 nm
8	350 nm	40 nm
9	250 nm	30 nm
10	185 nm	20 nm
11	130 nm	15 nm

Table 3.11, Minimum spot sizes in LM and Microprobe modes

3.5.5 kV setting

The effect of different choices of kV setting is related mainly to the application.

The following conditions are typical:

20 to 200 kV : For very thin, low contrast specimens in the TEM and STEM modes.
200 kV : For very thick biological specimens and materials science specimens.

3.5.6 Apertures

In Sect. 4.3, the mounting and dismounting of apertures and aperture holders, as well as the selection of aperture sizes for TEM use, is discussed. A guide to the apertures available and how they should be selected for STEM use is also given in that section. Apertures should be selected and centred in the TEM mode before obtaining and optimising the STEM signal. Final adjustments may be made in STEM mode (press CROSSHAIRS button twice (spot mode), µµD (highlight on), D (LED off), lower main screen, centre beam if necessary (SHIFT X, Y), centre aperture (mechanically), then press D (LED on), raise main screen, press µµD (highlight off) and FULL FRAME).

3.5.7 Camera length

When imaging with the STEM BF/DF detector, camera-length selection represents an important contribution to image contrast and effectively determines the distinction between the undiffracted electrons in the BF detector (7.5 mm) and the diffracted electrons in the annular DF detector (diameter 20 mm).

When large spot sizes (and thus high currents) are used for STEM and X-ray analysis, it may be necessary to increase camera length to the maximum value in order to obtain suitable conditions for optimising the BF image.
In general, a camera length should be chosen such that the size of the image of the Condenser aperture (= central spot in diffraction pattern) on the BF/DF detector is equal to the size of the BF detector.

When the camera length of an imperfectly aligned microscope is changed, it may be necessary to shift the diffraction pattern (direct ALiGNment, either DIF SHIFT or DET ALIGNM) using the MULTIFUNCTION X, Y knobs to optimise the BF/DF image on the monitor.
In cases where the BF/DF detector has been placed near-axis in order to position a TV or EELS on-axis, camera lengths longer than 100 mm should be used so as to allow the centre of the diffraction pattern to be shifted onto the detector.

3.5.8 Scan modes

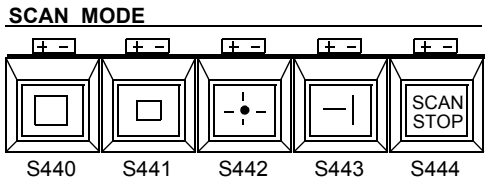


Fig. 3.7, SCAN MODE pushbuttons on the right-hand control panel

Pushbuttons

(S440) Full-frame

Function: Selects full-frame video display. The image can be shifted using SHIFT X, Y knobs.

(S441) Selected-Area

Function: Selects partial-frame video display.

When pressed once (or an odd number of times), the partial frame can be moved across the full-frame display using the SHIFT X, Y knobs;
When pressed twice (or an even number of times), the size of the partial frame can be adjusted using the SHIFT X, Y knobs.

(S442) Crosshairs/Spot

Function: Superimposes crosshairs on the last scan mode selected when pressed an odd number of times.

When using slow scan rates, pressing the button once more stops the beam exactly at the intersection of the crosshairs. The position of the lines and spot can be changed using the SHIFT X, Y knobs.

(S443) Line

Function: Selects horizontal line scan on the Y-position of the spot when pressed an odd number of times.

Pressing the button once more gives the vertical line scan. The position of the lines can be changed using SHIFT X, Y.

(S444) Scan Stop

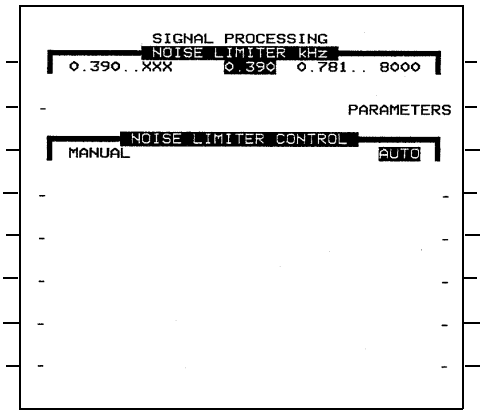
Function: Stops the scan.

3.6 STEM IMAGING FACILITIES

3.6.1 Signal processing

Both channels can be limited in bandwidth to the same value, which can be varied to optimise image details/electronic signal-to-noise ratio in the image.

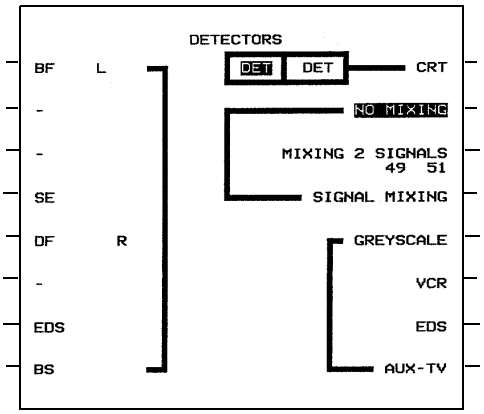
When SIGNal PROCessing is keyed on one of the scanning pages, the microcontroller displays the following page:



When MANUAL is highlighted on the second line, the operator can choose an upper band limit between ***400 Hz and 5 MHz.***
If AUTO is highlighted (which is advisable for normal daily use) filters are introduced according to the line time selected.

3.6.2 Detector-monitor selection and signal mixing

On the MODE SELECTION page, if SCAN BF-DF is keyed twice and then DETECTORS is keyed once, the microcontroller will display the following page (Secondary Electron detector, Energy Dispersive system and Backscattered Electron detector are all three optional:



This page gives the following information:

The BF-signal is directed to the left-hand monitor channel and the DF-signal is directed to the right-hand monitor channel. The signals are not mixed and the Contrast and Brightness controls act on the left-hand detector channel.

The following changes can be made:

- Keying CRT will switch the signal controls from the left-hand detector channel to the right-hand detector channel. This has the same effect as pressing the EXCHANGE button(⇄ bottom right).

- Keying BF, SE, EDS or BS will direct the keyed signal to the detector channel that is highlighted.

- Pressing the EXCHANGE button ⇄ (under DUAL MODE) switches the images on the two monitors.

- Keying GREYSCALE directs the greyscale signal to the monitors.

  Keying:

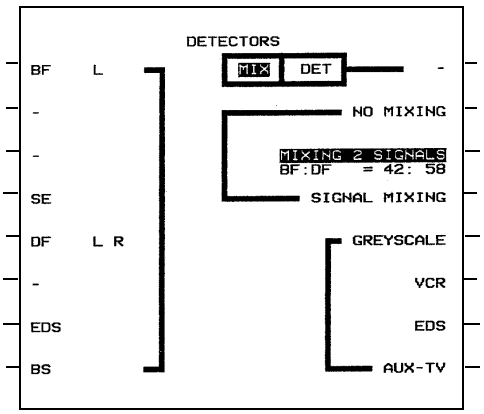
  VCR = Video Cassette Recorder,
  EDS = Energy-Dispersive System, or
  AUX-TV = Auxiliary Television,

  connects the appropriate system.
  Pressing the highlighted key a second time will select the last selected detector-monitor combination.

- When the signal INVerting key ◧ is pressed (LED is on), the contrast in the signal of the DETector channel which is highlighted, is inverted.
  Above the corresponding signal at the left-hand side of the screen, the label INV will be displayed.
  This signal inversion facility enables signals to be subtracted (50-50 mix of normal signal #1 and inverted signal #2).

- MIXING 2 SIGNALS, 42:58

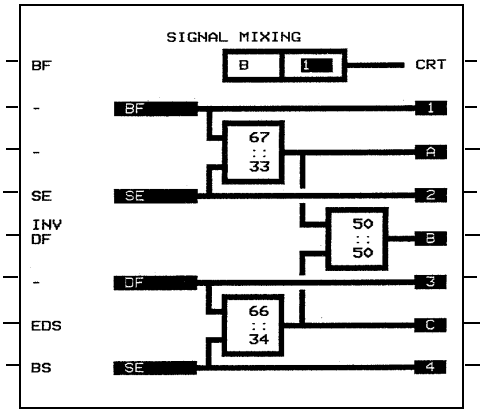
  When this heading is keyed, the BF/DF signal which is mixed in the ratio 42% BF to 58% DF will be directed to the first monitor, as is shown on the page which is displayed on the microcontroller:



  The ratio between the two signals selected can be changed by turning the RATIO knob (to the right of the ALiGN button).
  NO MIXING must be keyed to regain the last detector-monitor combination.

² SIGNAL MIXING

When this heading is keyed twice, the microcontroller displays the following page:



This page gives the following information:

² The DF signal is INVerted.

² BF (= Signal 1) and SE (= Signal 2) are mixed in the ratio 67:33 and the resulting signal is Signal A.

² INV-DF (= Signal 3) and SE (= Signal 4) are mixed in the ratio 66:34 and the resulting signal is Signal C.

² Signal A and Signal C are mixed in the ratio 50:50. This means that the resulting signal (Signal B) consists of the same amount of SE, BF and INV-DF signal. This signal is displayed on the left-hand monitor. The right-hand monitor displays the BF signal (Signal 1).

The following changes can be made:

² Key one of the right-hand signals to direct this channel to the CRT monitor that is highlighted.

² When signal channel 1, 2, 3 or 4 has been keyed, key one of the left-hand detectors to place this detector signal in the channel last keyed.

² Key channel A, B or C to adjust the corresponding ratio by turning the RATIO knob.

The READY button always offers the possibility to leave the DETECTOR pages and return to the SCANNING page.

3.6.3 Scan exposure data

It is possible to display and photograph the relevant scanning data on the left-hand monitor.

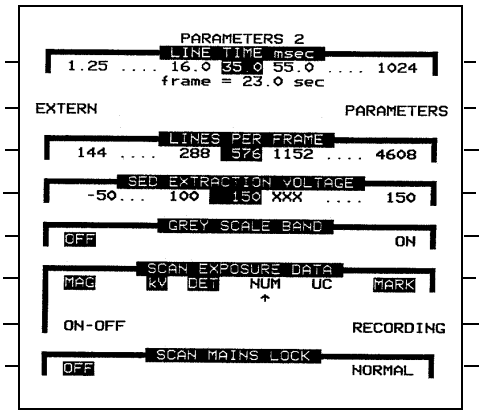


Fig. 3.8a, PARAMETERS 2 page

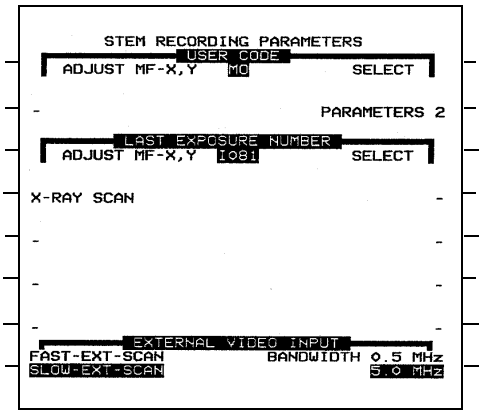


Fig. 3.8b, STEM RECORDING PARAMETERS page

The last line but one on the PARAMETERS 2 page, Fig. 3.9a (SCAN EXPOSURE DATA) offers the facility to display:

- MAGnification
- High Tension (kV)
- DETector
- User Code
- Exposure NUMber
- µ-MARKer

The information which is highlighted will be displayed on the monitor and thus on the photograph. The information selected can be changed by moving the small arrow (by keying left or right on this line) to the chosen information and keying ON/OFF.

The information content of NUM (Number) and UC (Cursor code) can be changed as follows:

- Key RECORDING, the microcontroller displays the STEM RECORDING PARAMETERS page (Fig. 3.9b).
- Key SELECT on the line of either NUM or UC, depending on which is required to be changed.
- Adjust the content of chosen sign by turning MULTIFUNCTION-X, Y.
- Key PARAMETERS 2 or press the READY button to leave.

Note: Any additional information can be displayed on the left-hand monitor and the photomonitor using the keyboard facility (option).

3.6.4 Display modes

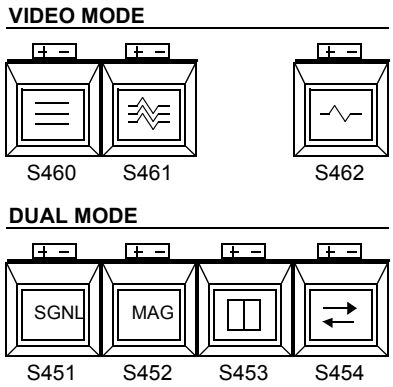


Fig. 3.9, Video and Dual mode pushbuttons on right-hand control panel

Pushbuttons

(S460) Z-display

Function : Displays the normal video image (LED is on).

(S461) Y-display

Function : Displays the Y-modulated image which is particularly applicable to intensity measurement. When both the Y- and Z-display LEDs are on, the Y-modulated image is superimposed on the normal video image.

(S462) Waveform

Function : Selects the video signal mode on the viewing monitor. This can only be obtained in the horizontal line scan mode with a minimum line time of 35 ms and Dual-Mode buttons inactive. The waveform mode displays the image intensity in Y-modulation around the central line of the monitor.

(S451) Dual-Signal

Function : Selects Single signal (LED off) or Dual signal (LED on).

(S452) Dual-Magnification

Function : When this button is illuminated, one of the two images displayed and centred at the same point on the specimen can be enlarged using the ZOOM-magnification knob (1.1x - 8x) which is superimposed on the Magnification control. The magnified area can be shifted with the SHIFT X, Y knobs.

(S453) Split-screen

Function : Selects full screen (LED off) or split screen (LED on) display.

(S454) Exchange

Function : Selects interchange of Channels 1 and 2.

The display modes of all combinations of pushbuttons, referred to above, are shown in Figs. 3.10a and b.

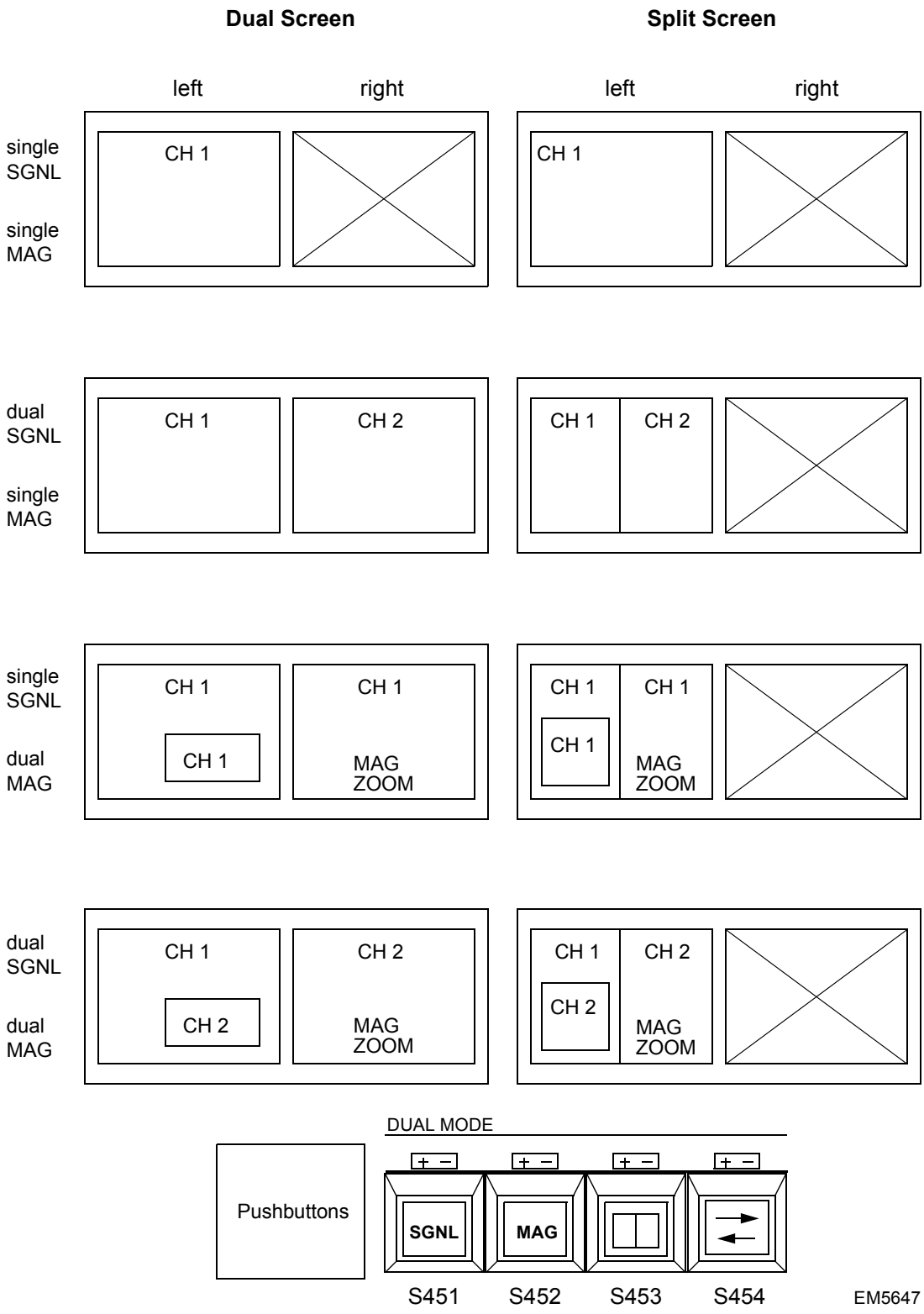


Fig. 3.10a, Display modes - grey level or Y-modulation

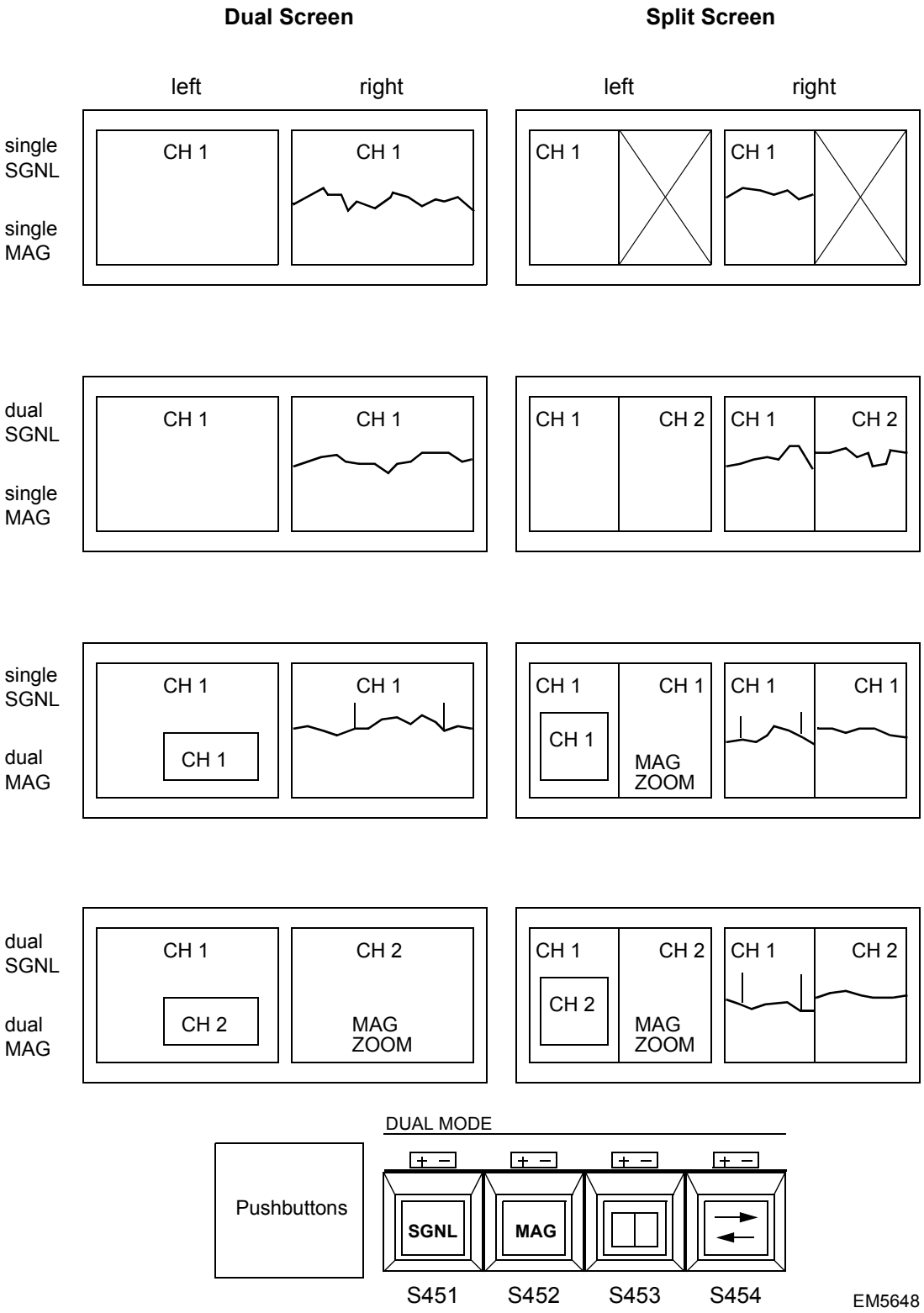


Fig. 3.10b, Display modes - one channel grey level or Y-modulation selected;
- the other channel waveform selected

3.6.5 External TV and VCR signals

An external TV-signal can be displayed on the right-hand monitor (and optionally on the left-hand one), when AUX-TV is highlighted on the DETECTORS page.
In this case the microscope operates in the stand-alone mode (MASTER is highlighted on the bottom line of the fourth PARAMETER page).
Both monitors have an external channel which allows direct video cassette recording (VCR).
When VCR is highlighted on the DETECTOR page, the microscope is in the SLAVE condition of the master/slave mode. In this mode, the microscope image on the first monitor is synchronised to the VCR image on the second monitor and it is possible to compare and combine these images.

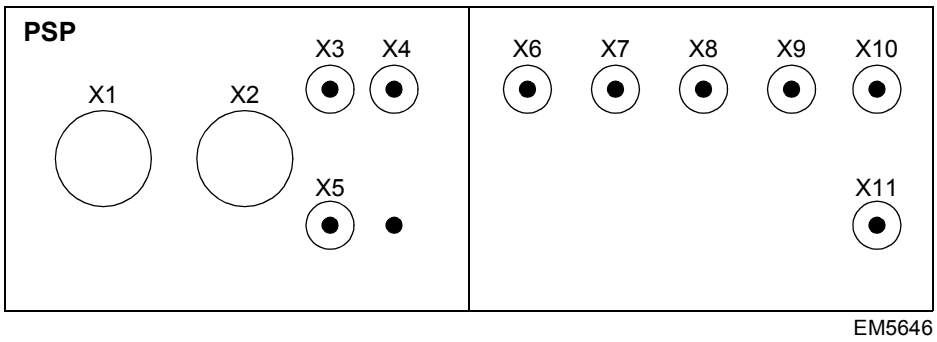


Fig. 3.11, External connections for TV and VCR (back panel of the microscope, right-hand side when facing the front of the microscope)

The BNS in/output connections on the PSP panel (Fig. 3.11) are as follows:

X1 - X11External signals:

- X1 - X5 : High-resolution photomonitor
- X6/X7 : Image on left/right-hand monitor to external TV
- X8 : VCR
- X9 : EDS TV standard signals that can be switched to Channel 2
- X10 : AUX-TV
- X11 : Dot/Pixel clock

3.7 STEM PHOTOGRAPHY

Successful photography of the STEM image is dependent on two basic operational procedures:

1. Accurate calibration of the total recording system - photomonitor, camera, photographic materials - to provide a full range of recorded image contrast.
2. Accurate adjustment of the detector signal to ensure that the information required is matched to the calibration of the recording system.

The first procedure is a once-only activity for work with:

- The same photographic material, developer and processing conditions.
- The same camera and lens aperture setting.
- the same number of lines/frame (approx. 2000 lines will normally be selected).

Since a full description of the first procedure is given in Sect. 3.7.3, this section will be concerned with the second procedure - the adjustment of the detector signal together with the actual process of taking the photograph itself.

Note: When printing TEM images which are to be compared with scanning images, the TEM plate should be positioned with the emulsion upwards, away from the photographic paper, otherwise the TEM image will be mirrored compared to the scanning image.

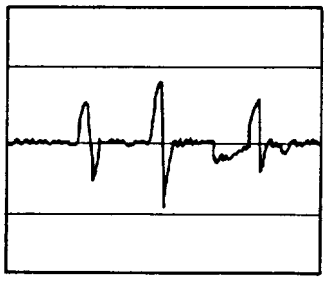
3.7.1 Final adjustment of the detector signal for photography

Basic procedures for optimising signals from electron detectors are described in Sect. 3.4. Final adjustment of the contrast and brightness levels is very much dependent on individual specimen characteristics and particular information requirements.
The advantage of using amplitude-modulated single line scans (especially when the optional Videoscope is available) is the possibility of obtaining reproducible results. Use of the (line scan) mode, however, should be limited to short periods when studying specific line scans in order to prevent specimen damage.

Note: Whenever possible, the LOW DOSE facility should be used to avoid damage to beam sensitive specimens.

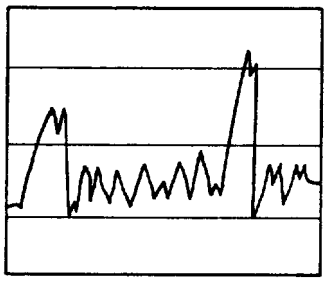
Some simple examples are shown in Fig. 3.12.

a)



The basic part of the signal should be set to the middle of the greyscale range. Signal amplitude should then be adjusted to give the best combination of contrast and signal-to-noise ratio.

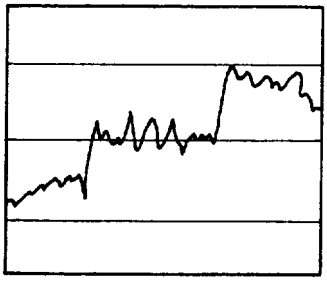
b)



This signal has one obviously important area of relatively constant grey level which usually is the background signal level. The basic part of the signal should be set to about 20% above the black level.

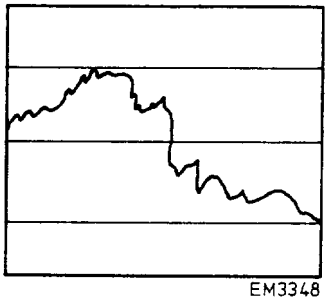
Signal amplitude should then be adjusted to give the best overall rendering of detail.

c)



This signal shows 3 areas of different average grey level, each containing important detail. In general, the signal should be optimised overall as shown, but if any one of the 3 areas is of particular interest, the signal can be optimised for that particular area.

d)



This signal shows no obvious area of constant grey level. In general, it should be optimised overall, as shown.

Fig. 3.12, Optimising signals for individual characteristics

3.7.2 Taking the photograph

1. Adjust the signal for photography (see Sect. 3.7.1).

2. Load the camera.

3. Choose scan rate EXP 1, 2 or 3 to obtain an optimum signal-to-noise ratio (about 30 ms and 2000 lines) for which the photographic system has been calibrated.

   Note: The LED of the scan rate EXP button selected will remain highlighted. If the EXPOSURE button is pushed while SLOW or FAST scan rate is active, the scan rate corresponding to the EXP will be used for the exposure. When the exposure is finished, the scan rate will revert to the scan rate used before the exposure.

4. Check CONTRAST and BRIGHTNESS settings of the High-Resolution Photomonitor.

5. Open the Polaroid envelope or camera shutter, as appropriate.

   Note: When using a camera with an automatic control connection, step 5 will not be necessary.

   Caution! When using the standard Photo/Display monitor for photography, first ensure that the screen is completely clear of residual persistence from the last obtained image or signal otherwise unevenly-exposed photos will be obtained.

6. Press the EXPOSURE button (S463, right-hand panel). The associated LED and the RECORDING indicator lamp on the High-Resolution Photomonitor will light up, showing a scan in progress.

7. When the scan is completed, as indicated by extinguishing of the EXPOSURE LED and the RECORDING indicator lamp:

   - Close the Polaroid envelope and remove it from the camera
     or
   - Transport the film (and close the camera shutter if non-automatic) as applicable.

   Note: Double (or more) exposures on one frame (e.g. X-Ray line scan on image or elemental map) can be made by repeatedly pressing the EXPOSURE button.

3.7.3 Calibration of the photographic system

The photographic system comprises the total combination of photomonitor/camera/ photographic materials.
Calibration of this system is required to ensure that all detector signals, correctly adjusted to the standard references for amplitude (image contrast) and level (image brightness), will be recorded over the complete greyscale range.
Calibration is a one-time operation for a particular combination of camera and photographic materials. Careful and systematic procedures will ensure consistent production of photographs containing maximum information, thus minimising film wastage and time spent per photo.
This section describes a basic calibration procedure using the Greyscale Generator, which provides an internal standard for calibration, and the optional High-Resolution Photomonitor.

Note: Although primarily referring to the use of a Polaroid (one-shot) system, this procedure can easily be adapted to roll film by making a series of exposures using a wider combination of variables before developing the film.

The basic procedure is as follows:

1. Key:
   - DETECTORS on a scanning page.
   - NO MIXING, so that it is highlighted.
   - GREYSCALE.

2. Select:
   - Full-frame scan.
   - Z-display button on.
   - Y-display button off.

3. Select EXP1, 2 or 3 button having the combination of line time (± 30 ms) and number of lines (± 2000) giving optimum signal-to-noise ratio.

4. Position/select the following settings on the High-Resolution Photomonitor:
   - BRIGHTNESS knob : 0
   - CONTRAST knob : -2

   Note: These settings will be approximately correct for Polaroid 52 film (ASA 400, DIN 27). Check the ASA or DIN rating of the film to be used and reset the BRIGHTNESS knob so that it is reduced a few steps for faster films or advanced a few steps for slower films. (Films of the same ASA or DIN rating but of different manufacture do not necessarily have the same response to the greyscale.)

5. Turn the CONTRAST knob counterclockwise some steps from the initial setting established in step 4, above. For roll film, set to position 11.

6. Load the camera.

7. Lock the camera in position and ensure that the recommended lens aperture for the particular camera type is set correctly.

   Note: Aperture 8 is generally used.

8. Open the Polaroid envelope or expose the film, whichever is applicable.

   Note: This step will not be necessary when using a camera with automatic control.

9. Press the EXPOSURE button, the associated LED and the RECORDING indicator lamp on the High-Resolution Photomonitor will light up to show scan in progress.

10. At 10 s intervals, turn the photomonitor CONTRAST knob one step clockwise until the scan is completed, indicated by extinguishing of the EXPOSURE LED and the RECORDING indicator lamp.

11. When using roll film, advance the film one frame and repeat steps 8 - 10 to complete the full range of settings of the CONTRAST knob.

12. When the scan is completed, close the Polaroid envelope (or the camera shutter when using other types of film and without automatic shutter control) and record the brightness setting and range of contrast settings.

13. Remove and develop the exposed film and assess the results obtained, choosing from the steps made the one showing the best range of contrast (i.e. black, white and as many grey levels as possible).

14. Set the CONTRAST knob to the position chosen.

15. Repeat steps 6 - 13, but this time switching the BRIGHTNESS knob over a range of steps using the initial setting established in step 4 as the mid-point. For roll film, set to position 11.

16. Remove and develop the film and assess the results obtained, choosing from the steps made the one showing the widest range of grey levels (i.e. black, white and a complete series of uniformly graded levels of grey in between).

17. If a satisfactory result is not obtained, repeat the procedure systematically for new ranges of contrast and brightness either side of the original settings. Take care to record the control settings used in making each exposure.

    Note: When assessing a series of exposures, first select the photograph showing the best ranges of grey levels, then make a choice of the best steps in the photographs selected.

18. Set the CONTRAST and BRIGHTNESS knobs to the positions finally selected.

    Note: The final settings of the CONTRAST and BRIGHTNESS knobs obtained by the above procedures should be used for all future work with:

    1) The same photographic material, developer and processing conditions.

    2) The same camera and lens aperture setting.

4 MICROSCOPE OPERATION - MECHANICS AND VACUUM

4.1 STARTING THE MICROSCOPE UP AND CLOSING IT DOWN

4.1.1 Starting the microscope up

Starting from cold : Begin here

1. Turn on the water and pneumatic supplies to the microscope.
2. Switch on the electrical supply to the microscope. The MICROSCOPE STANDBY button will illuminate.

Starting from Standby (see Sect. 4.1.2) : Begin here

3. Press the MICROSCOPE ON button. The rotary vacuum pump will start up. The MICROSCOPE OFF button will illuminate red indicating its emergency function (this is active when the instrument is in operation.
4. Press VACUUM ON pushbutton (VACUUM OFF LED illuminated). The microscope will now be pumped down automatically until the operational vacuum is reached (after 20 - 30 min.).
5. Check the Dewar vessel of the Cooling Device. If necessary, remove the vessel, refill with liquid Nitrogen and then replace.

Caution!
1) Do not allow liquid Nitrogen to spill on the viewing windows of the specimen chamber as this may cause the glass to crack.
2) Ensure that no part of the cooling conductor or insulating cap comes into contact with the Dewar. At the same time, ensure that the evaporation area is kept to a minimum (see Sect. 4.7, Use of the Cooling Device).

6. Once the UHV indicator is illuminated, operational vacuum has been reached.

Note: After operational vacuum has been reached, the rotary pump will run occasionally for short periods in order to maintain the vacuum level of the buffer tank.
This buffer cycle is suppressed during a photographic exposure. If a very long exposure time is required (e.g. during X-Ray mapping), press the VACUUM ON button once before beginning the exposure sequence in order to bring the buffer vacuum well below its critical level.

4.1.2 Continuous pumping

If possible, it is recommended that the microscope is pumped continuously to improve the quality of the vacuum and thereby reduce specimen contamination. There are two possibilities:

1. Leave the microscope switched on.
2. Set the microscope to the energy-saving STANDBY mode, as follows:

Standby mode

1. Switch H.T. off.
2. Press STANDBY button.

In the standby condition, the ion getter pump continuously pumps the microscope column, but:
- The camera airlock valve is closed.
- The oil diffusion pump valve is closed.
- All electronics except those for the ion getter pump are switched off.
- The cooling water stops flowing through the lens coils.

Note: 1) The ion getter pump is protected against any type of malfunction in the standby condition and will switch off if the maximum pressure allowed is exceeded. If this occurs, the microscope starting up procedure (Sect. 4.1.1) must be repeated from the beginning.

2) When the microscope is switched on, the following startup settings are automatically selected:

- H.T. : lowest value.
- EMISSION : position 1.
- Gun : LaB_6.
- Filament limit : unchanged.

4.1.3 Closing the microscope down

When the microscope is to be closed down completely, proceed as follows:

1. Wait until any automatic pumping sequence is completed.
2. Operate the MICROSCOPE OFF button.
3. Switch off the electrical supply to the microscope.
4. After approximately 30 minutes, turn the water supply off.
5. Turn off the pneumatic supply.
6. Turn off the Nitrogen gas supply, if in use.

4.2 APERTURE HOLDERS AND CHOICE OF APERTURES

4.2.1 Types of aperture holder

Two types of aperture holder are employed:

- The Diffraction and Objective lens aperture holders are identical and constructed of copper-aluminium.
- The Condenser aperture holder is thicker and constructed of copper.
- As an option a special Objective lens aperture holder for the SuperTwin lens (SuperTwin Analytical) is available, which is thinner than the normal holder to allow a greater tilt angle. This holder contains 8 apertures of different sizes.

Holders should not be exchanged between lenses, even when mechanically identical, since the adjustment of the end stops for the axial fine centering movements are made individually for each holder.

Caution! **1) All aperture holders should be replaced in the lenses from which they were taken.**

2) The aperture holders operate in high vacuum and should therefore be handled carefully using nylon gloves.

3) In the case of a CM200 Super Twin fitted with an EDAX detector, a special three-position objective aperture holder must be used. This is specially designed for use in this configuration to avoid damage occurring to either the detector or the holder.

4.2.2 Types of apertures

Three types of apertures are used:

Type	Lens	Advantages	Maintenance
Platinum (normal)	Objective Diffraction	No electron leakage; low cost; low contamination.	Cleaning sometimes required
Platinum (thick)	Condenser 2 when carrying out X-Ray work.	Stops all unwanted electrons and hard X-Rays.	Cleaning sometimes required.
Thin foil	Objective aperture	Remains clean; very well defined edge; available in a wide range of sizes; long life.	At high voltages; electron leakage, thus loss of contrast; white spot effect at low magnification.

Note: Thin foil apertures should be checked to ensure that they do not contain additional perforations.

Table 4.1, Aperture materials and applications

4.2.3 Dismounting aperture holders

1. Set the HIGH TENSION pushbutton to off.

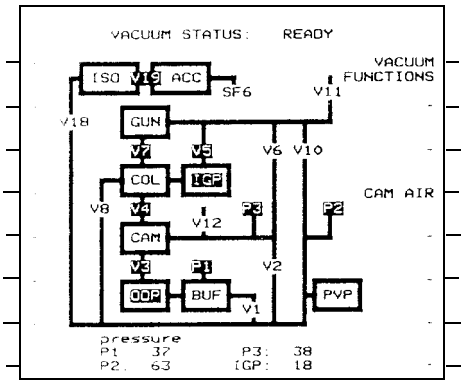
2. Remove the specimen from the microscope.

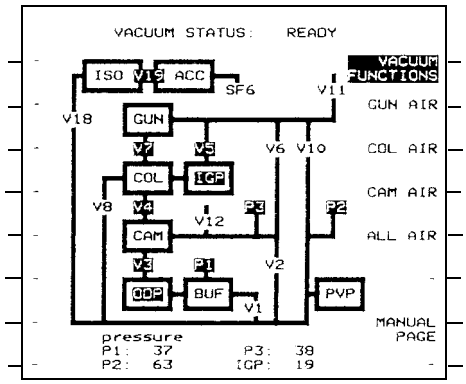
3. Operate the aperture-displacement levers as necessary, to remove the objective and selected area apertures from the beam. Select the largest condenser aperture.

Caution! **Steps 2 and 3 must be carried out in order to avoid possible damage to the specimen and apertures when venting the column.**

4. Key VACUUM; the VACUUM STATUS page is displayed

5. Key VACUUM FUNCTIONS to get access to COL AIR





On the VACUUM FUNCTIONS page, key COL AIR and wait for the column to reach atmospheric pressure.

Note: It is strongly advised that Nitrogen flushing be applied to the inlet on the column to prevent moisture from condensing on the inner surfaces of the microscope (see Sect. 5.1).

WARNING! **Make sure that the N_2 pressure is very low (<0.1 Bar), otherwise the holder may be forced out with great speed which could be very dangerous.**

6. To take out the aperture holder, completely unscrew the knob at the end and carefully pull straight out.

4.2.4 Remounting aperture holders

1. Replace the holder in the column (in the same lens from which it was taken) ensuring that the guide pin on the holder engages the slot in the column.

2. Screw in the knob at the end of the holder until it is really tight.

3. Key COL AIR. The column will now be pumped down again.

4. Close Nitrogen flushing (if applied).

4.2.5 Selecting the aperture sizes

Each aperture holder incorporates an aperture selector enabling a choice of four different aperture sizes.
Recommended aperture sizes are as follows:

a) Normal use

One complete set of platinum apertures as listed in the table below is supplied mounted in the microscope. Spare apertures are also delivered, three of each size listed, except for the 800 μm aperture.

Aperture selector	Aperture sizes (μm) installed in in each position on delivery			
	1	2	3	4
Condenser 2	200	100	50	30
Objective	100	40	20	10
Diffraction	800	200	40	10

Table 4.2, Recommended aperture sizes for general use

b) Special use

The Condenser 2 aperture size should be chosen with regard to the application. In general, the larger the aperture, the greater the intensity for a given set of conditions, but the less the coherence of the illumination.
If extremely low intensities are required, together with small spot sizes (e.g. for beam sensitive specimens), a very small aperture should be used.
For X-Ray analysis, special low-background apertures are available (PW6142).

Recommended condenser-aperture sizes for special purpose use are as follows:

- 100 μm - High-intensity operation with thick specimens.
- 50 μm - General observation; TEM X-Ray work; low-intensity operation.

Caution! Thin-foil Au apertures must never be used in the CM200.

The optimum **Objective aperture size** is a compromise between the small aperture required to limit spherical-aberration effects and the large aperture needed to eliminate the diffraction error (the so-called Abbe limit). It is not always necessary or even desirable to use the optimum aperture size as the choice can also be influenced by contrast conditions. Theoretically, the larger the aperture size, the lower the contrast of the image and thus small structures are less visible. Consequently, for a specimen of low contrast, it is advisable to use a very small aperture in order to improve the contrast at a given accelerating voltage.

Recommended objective-aperture sizes for special purpose use are as follows:

- 100 μm : High-resolution work.
- 40 μm : Materials science.
- 20 μm : Thin biological specimens.
- 20 μm : Thick biological specimens and dark-field imaging.

The **Diffraction aperture** size is selected either for optimum imaging in the LM mode or for diffraction work.

Recommended aperture sizes for special purpose use are as follows:

- 800 µm - LM contrast.
- 220 µm -
- 40 µm - } selected-area diffraction.
- 10 µm -

4.2.6 Removing and replacing apertures in the holders

Caution! The aperture holders operate in high vacuum and should therefore be handled carefully using nylon gloves. The apertures should be handled with clean, pointed tweezers.

1. Take the holder in one hand as shown in Fig. 4.1.
2. Using the thumbnail, push the ring (1) against the spring to the left.
3. Raise the tip of the holder slightly and tap gently to allow the aperture to slide down the guide towards the opening (2).
4. Using tweezers in the other hand, take the apertures out through the opening (2). Take care not to damage the apertures with the tweezers.
5. Apertures are replaced by reversing the above procedure, taking care that the plain side of the aperture, in each case, is facing upwards towards the electron source and the conical side downwards (Fig. 4.2).

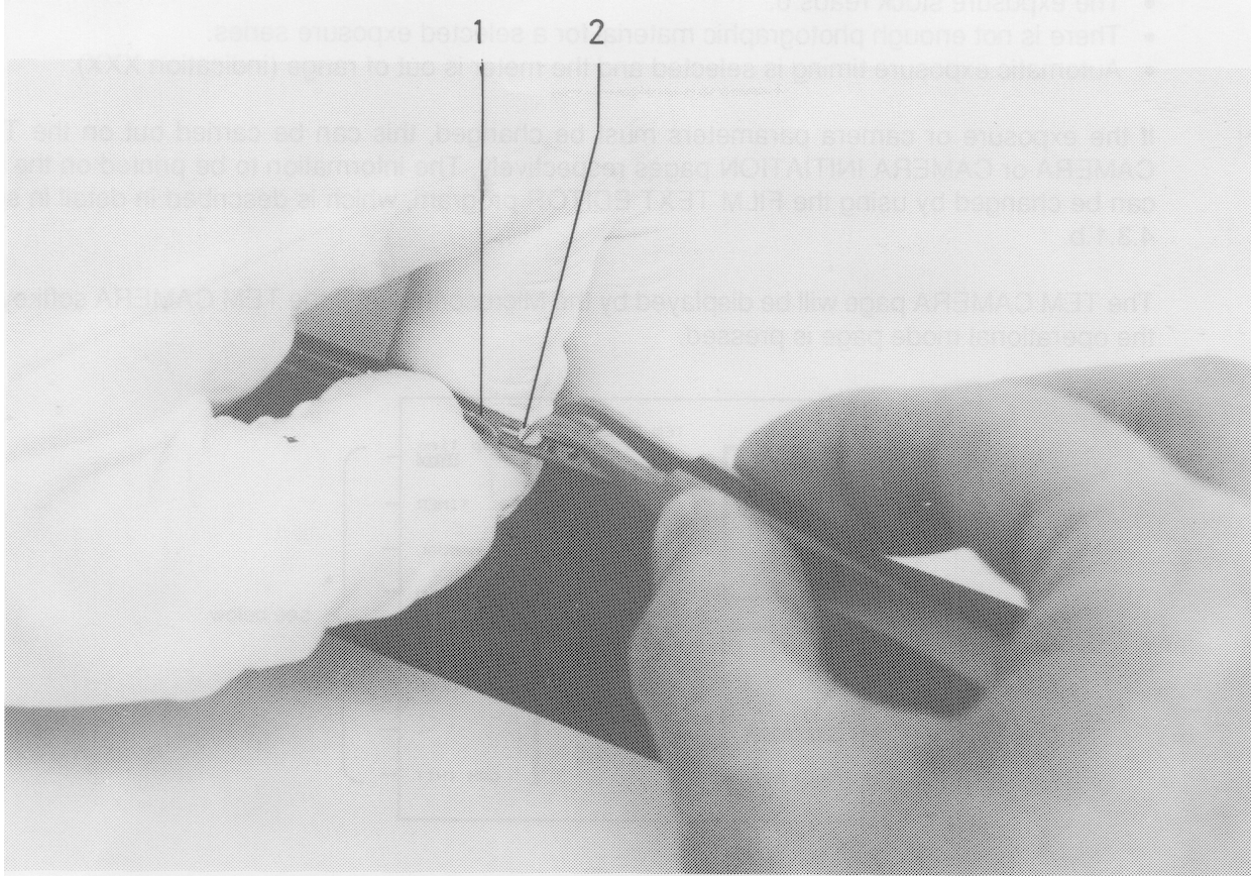


Fig. 4.1, Changing apertures

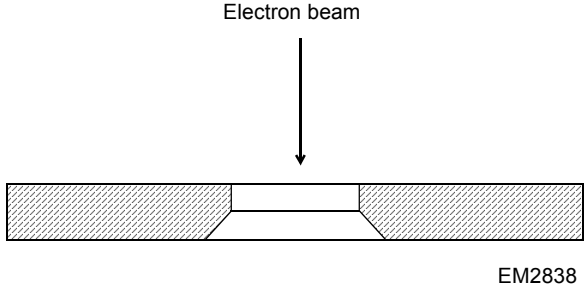


Fig. 4.2, Aperture cross-section showing profile of aperture

4.3 PHOTOGRAPHY OF IMAGES AND DIFFRACTION PATTERNS

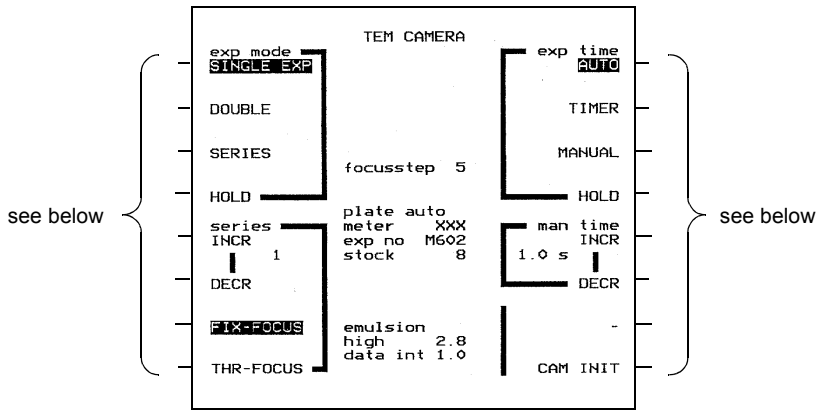
The microscope is equipped with a plate camera, a 35 mm camera or both depending on the model ordered. Facilities are available to retrofit either system at a later date.

The general procedure for recording a micrograph has been described in the example given in Sect. 1.2. The recording system is fully automatic and operated by a single pushbutton (EXPOSURE). This system is, however, blocked when one of the following conditions applies:

- The exposure stock reads 0.
- There is not enough photographic material for a selected exposure series.
- Automatic exposure timing is selected and the meter is out of range (indication XXX).

If the exposure or camera parameters must be changed, this can be carried out on the TEM CAMERA or CAMERA INITIATION pages respectively. The information to be printed on the film can be changed by using the FILM TEXT EDITOR program, which is described in detail in sect. 4.3.1.b.

The TEM CAMERA page will be displayed by the Microcontroller, if the TEM CAMERA softkey on the operational mode page is pressed.



Softkeys

exp mode
SINGLE EXP

DOUBLE

SERIES

Function : Selects the exposure mode, single, double or series. If SERIES is selected, INCR/ DECR defines the number of exposures in the series.

Operation : The highlighted mode is active. If DOUBLE is selected, the plate or film remains in the exposure position following the first exposure. While the shutter remains active, microscope parameters, e.g. the mode, can be changed. By pressing the exposure button a second time, the same plate or film will be exposed once more.

HOLD

Function : If hold is not active, the exposure mode will automatically be reset to SINGLE EXP after the current operation is complete.

series
INCR/DECR

Function : Sets number of exposures in a series.

Operation : Key the desired number of exposures. This number should not exceed the exposure stock.

FIX-FOCUS

Function : With FIX-FOCUS highlighted, an exposure series will be taken at constant focus setting.

THR-FOCUS

Function : With THR-FOCUS highlighted an exposure series will be taken with automatic focus change.

Operation : The exposure series is fully automatic. The operator starts it by pressing the EXPOSURE button. The number of exposures in the series is defined by the series INCR-DECR number.
A THRough-FOCUS series always starts with the exposure furthest below the operator-set focus and then proceeds upwards through it. The focus step size applied is selected by the FOCUS STEP SIZE knob.
The through-focus series is taken symmetrically below and above the operator focus and includes operator focus. If an even number of exposures is selected, there will be one more exposure taken at underfocus than at overfocus.

AUTO

Function : Automatic control of exposure time. The time is derived from measurement of the total electron current falling on either the main screen or the small projection screen.

Out of range conditions, i.e. intensity of illumination too low for the range of automatically selected exposure times, result in an automatic block of the exposure/ transport system, indicated on the control screen by XXX instead of the exposure time. If required, this block can be bypassed by use of the TIMER or MANUAL exposure time.

Note: The measurement of the exposure time is best performed using the small focussing screen because the electron dose there usually corresponds most closely to that on the plate. **Do not** withdraw the small screen but just lift the main screen a short distance which will cause withdrawal of the small screen while retaining the exposure-time measurement of the small screen.

TIMER

Function : A timer is started when the exposure begins. The exposure is terminated and the timer stopped by a second operation of the EXPOSURE button. Elapsed exposure time is indicated continuously on the Microcontroller screen.

MANUAL

Function : An exposure will be taken with the manually pre-selected exposure time.

Operation : AUTO, TIMER and MANUAL are mutually exclusive. Key the mode desired.

HOLD

Function : HOLD will override any preprogrammed automatic selection, retaining the method selected.

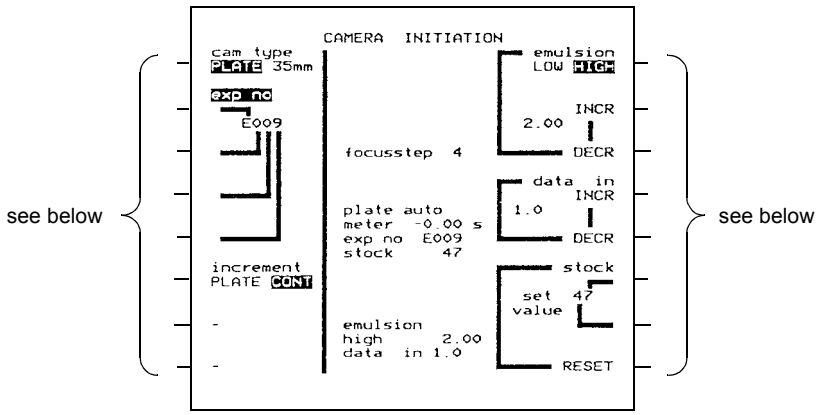
man time
INCR/DECR

Function : Selects MANUAL exposure time from 0.2 - 99 s.

Information field :

Contains the standard information relating to the camera and exposure conditions only.

The CAMERA INITIATION page is obtained from the TEM CAMERA page if the CAMera INIT softkey is pressed.



cam type
PLATE/35mm

Function : Selects the camera type.

Operation : The selector toggles between plate and 35 mm camera when both are installed.

exp no (See also sect. 4.3.1.b)

Function : Sets the starting value for the exposure number.

Operation : Key the desired start value of the exposure number decreased by 1.

Example : If the next exposure should be numbered A001, key in A000.

emulsion
LOW/HIGH

Function : Two sensitivities for the emulsion of the photographic material and the development process can be stored.

Operation : The key toggles between emulsion LOW and HIGH.

INCR/DECR

Function : Assigns the emulsion sensitivity in the LOW or HIGH selection.

Operation : Key in the required sensitivity. Higher step values correspond to the longer exposure times required for less sensitive emulsions and vice versa.
A calibration exposure series should be made for the camera(s) emulsion and developer in use.

data int
INCR/DECR

Function : Sets exposure intensity of plate numbering device.

stock
set value

Function : Initialises the number of available plates/35 mm exposure.

Operation : The exposure stock should be reset after exchange of the entire camera assembly. If the exposed magazine is removed and the camera is not reloaded, do not reset the stock set value (preferably set the stock value to zero).

stock
RESET

Function : Resets the stock readout in the information field to the number assigned in SET VALUE.

Operation : The exposure stock should always be reset after exchange of the photographic material.

increment
PLATE CONT

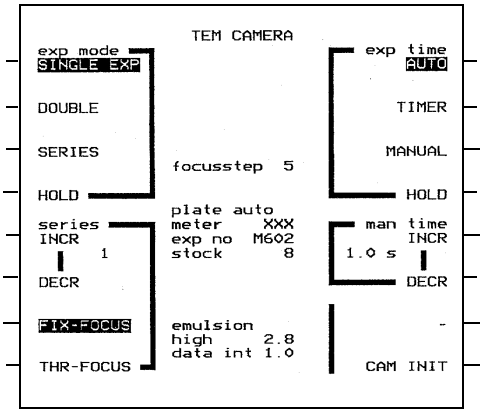
Function : **CONT:** If plate camera and 35 mm camera are used alternately, the plate numbering is automatically increased by one with every exposure independent of the camera type.
PLATE: the plate numbering is only increased for every exposure if the plate camera is used, for the 35 mm camera the plate number does not change.

Information field
In addition to information shown on the TEM-BF page, the valid emulsion settings are displayed.

4.3.1 Selecting the exposure and camera parameters

A typical sequence for making an exposure is briefly described in Sect. 1.2 assuming that the required exposure parameters have been pre-selected. The full sequence is as follows:

On the TEM CAMERA page:



1. Select the EXPosure MODE.

2. If SERIES is selected, select also:

   - The number of exposures in the series.
   - Whether FIXed or THRough focus.

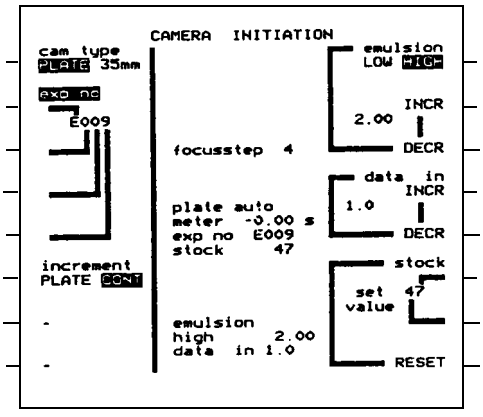
3. Select the EXPosure time:

   - If MANUAL mode is selected, ensure that the correct MANual TIME has been selected;
   - If AUTO mode is selected, the measurement can be made either on the main or on the small projection screen.

     Note: If the EXPosure time or mode is to be maintained, select the appropriate HOLD function.

4. Select CAMera INITiation. The exposure time measured is displayed on the Control Screen.

On the CAMERA INITIATION page:



5. Select the **cam**era **type** required and check that:

   - EXP No.
   - EMULSION.

- DATA INT.
- STOCK.

are correct for the camera type.

Note: There is no exposure number printed on the 35 mm exposures. The exposure number displayed on the info-field is the number of the last photograph taken.

On the main projection screen:

7. Raise the main screen or insert the 35 mm camera. Once all actions have been performed correctly, the EXPOSURE indicator (on the left hand panel) will light up.

   Note: If the EXPOSURE indicator does not light up, this is an indication that the stock is exhausted or that the automatic exposure time measured is out of range (see introductory paragraphs to Sect. 4.3)

8. Press the EXPOSURE button.
   The transport/exposure sequence proceeds automatically:

   - During the transport and exposure phase the illumination of the data screen, panel and spot light is dimmed.
   - When the sequence is finished, the illumination is restored.

9. Lower the screen(s) or withdraw the 35 mm camera to restore the microscope to the normal viewing condition, if no more exposures are required.

   Note: If the main screen is lowered too quickly, a warning message will flash on the information field. Press RESET to return to the usual information field.

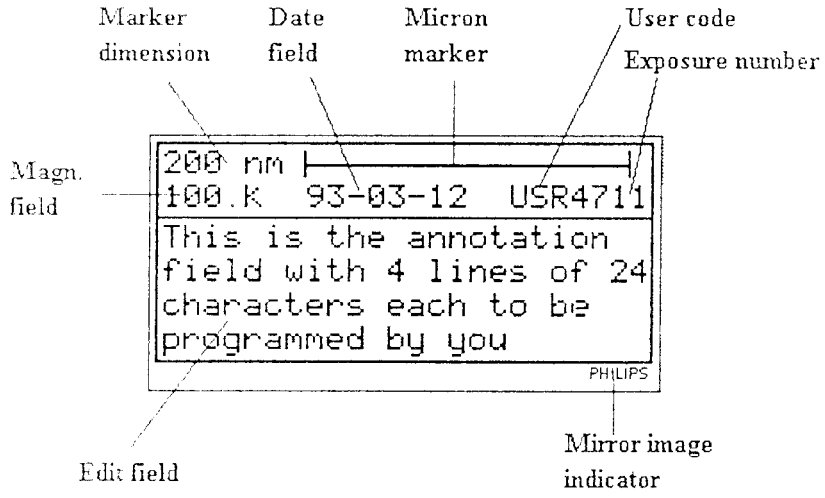
4.3.1.b Information printed on the plate using the film text editor

GENERAL

The Film Text Editor is a Microsoft Windows® application program executing on a PC by which additional user information can be formatted and sent to the plate numbering device. In addition to the standard system menu and minimize box, a system menu provides selection facilities for:

- File operations;
- Editing the display contents;
- Choosing the communication channel to the display device.

When starting the film text editor program under Microsoft Windows®, the following window is visible:

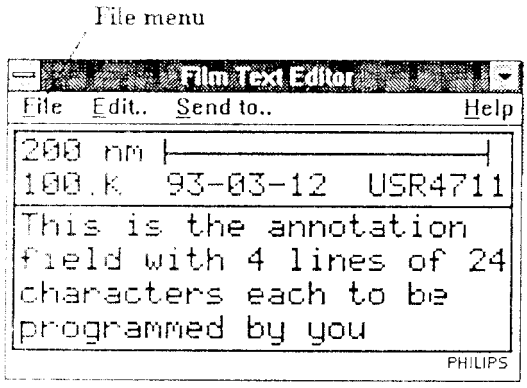


The CM Plate Numbering Device prints information onto the micrograph in order to support archiving and retrieval.

In addition to the:

1. magnification value and
2. four digit exposure number,
   which are provided by the CM microcontroller, when a PC is connected from one of its serial ports directly to the film text electronics board inside the CM, the plate numbering device also provides:
3. a user-programmable edit field holding 4 lines of 24 characters each;
4. a user-programmable three-character user code field which can be used to extend the numerical range to numbers greater than 9999 or to add the user's initials;
5. a date field containing the exposure date in one of three international formats;
6. a micron marker which is automatically set according to the magnification value.

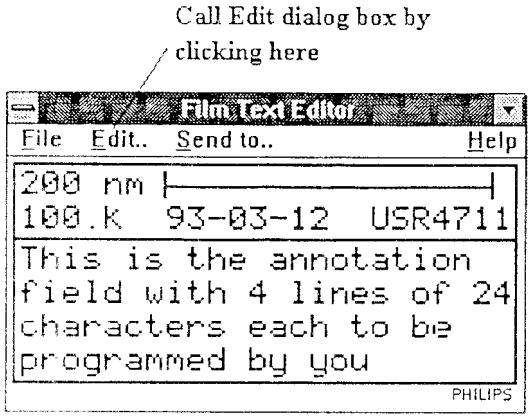
Each of the information items 1 to 6 can be switched on or off selectively. The total display area can be shown normally or mirror-imaged.



This menu provides facilities for saving, retrieving and printing the contents of the display area including all settings, and for exiting the application.

New	Clear the display leaving only the standard items (magnification and exposure number)
Open..	Open a file which contains a previously saved display contents. A dialog box prompts for a file name.
Save	Save the display contents in a file with the same file name as used previously. The systems prompts for a file name if none has been used before.
Save as..	Save the display contents in a new file. The systems prompts for a file name if none has been used before.
Copy to clipboard	The contents of the display can be copied to the clipboard. From there it can be retrieved into other Windows programs such as wordprocessors.
Exit	Shut down the Plate Numbering Editor Application. The user is prompted whether he/she wants to save the display contents in a file before the application is shut down.

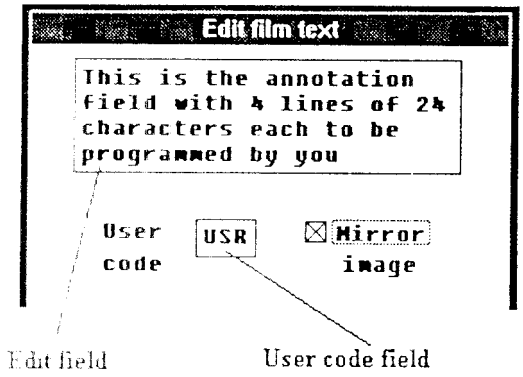
"Edit" DIALOG BOX



Information which the CM microscope cannot provide is chosen by the user in this dialog box for printing on the micrograph. This information consists of:

- **user programmed items**
  He/she can also choose which
- **Automatically inserted items**
  should be included.
- **Display modifiers**
  determine whether or not the total annotation should be mirror-imaged.

User programmed items

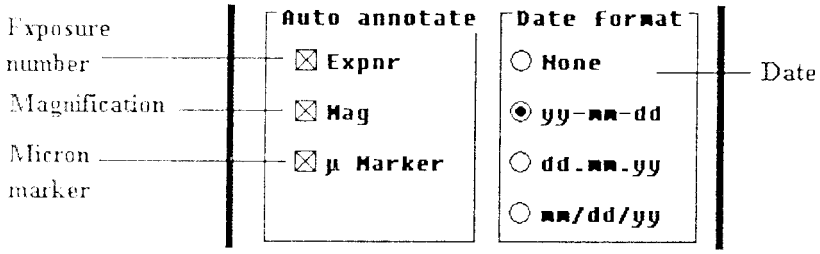


This part of the Edit dialog box is used to enter free-formatted text and the user code

Text
The text field of 4 lines of 24 characters each can be entered here. The elementary edit keys backspace, delete and insert may be used. To create a new line, press the <Ctrl>+<Enter> keys.

User code
Three characters to be printed in front of the normal 4 digit exposure number can be entered here. These characters can represent, for example, the user's initials, or be used to extend the range of the exposure number beyond 9999. Note that in the latter case, the extra exposure numbers will not be incremented when the exposure number switches from 9999 to 0000.

Automatically inserted items



In this part of the Edit dialog box the automatically inserted items can be switched on or off. These are the exposure number, the magnification, the date, and the micron marker.

Exposure number
The four digit exposure number can be suppressed or displayed. The actual value is set by the CM microscope's microcontroller screen.

Magnification
The magnification display can be suppressed or enabled.The actual value is set by the CM microscope.

Date
Today's date can be displayed in one of three possible formats, or switched off.
- None Date display off
- yy-mm-dd Year-month-day (international)
- dd.mm.yy Day.month.year (European)
- mm/dd/yy Month/Day/Year (US)

Micron Marker
The display of the micron marker can be enabled or suppressed. The length of the micron bar and the unit to be used is automatically calculated according to the microscope magnification.

Display modifier

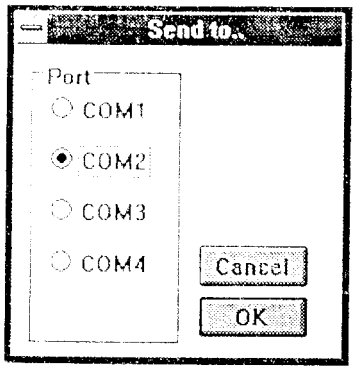
This part of the Edit dialog box is used to modify the total display as it is photographed. The possibilities are as follows:

Mirror image
The total display area is mirrored. This setting is used to make the annotation readable from either the front or the back of the negative.
The setting is shown symbolically by the small logo in the bottom right corner of the display which can show the following combinations:

normal

mirrored

"Send to.." DIALOG BOX



This dialog is used to set the communication channel between the PC and the display device.

Port
The possible choices are:
COM1, COM2, COM3, and COM4.

Baud rate
The baud rate is automatically adjusted to 9600, the value required for the CM film text printing device.

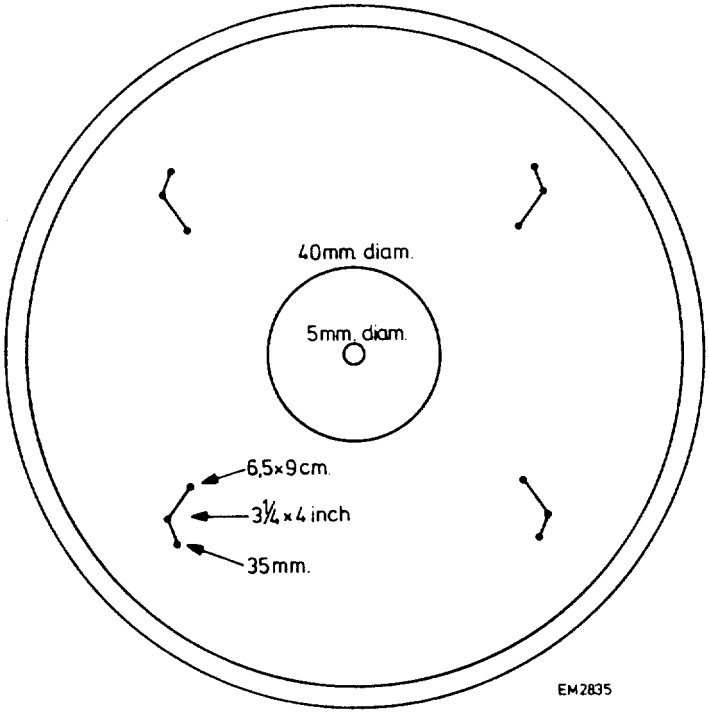


Fig. 4.3, Markings on the main screen and camera frame-size dimensions

4.3.2 Double exposures

The automatic transport system ensures that inadvertent double exposures cannot be made. However, it is possible to make two exposures on the same frame deliberately by use of the DOUBLE exposure function (TEM CAMERA page) which prevents transport after the first exposure.

If image changes are required:

- When the EXPOSURE lamp relights to indicate that the first exposure has been completed, lower the main projection screen or remove the 35 mm camera from the beam and apply the image changes before making the second exposure.
- The second exposure is made by carrying out the normal sequence for making a single exposure.

Multiple exposures can also be made by activating the DOUBLE exposure before each exposure is made until the final exposure, when only the EXPOSURE button should be operated.

Note: If the DOUBLE exposure function is activated inadvertently, it can be cancelled by pressing the softkey a second time.

4.3.3 Through-focus series

The basic operations for taking a through-focus series, exposure, transport, change focus, counting exposures etc. are fully automated. Once set up, the EXPOSURE button initiates the complete sequence of operations. As many exposures can be made in a series as there is recording material in stock. The desired number of exposures can be made as selected by the THR-FOCUS function with a choice of number of steps as selected by the series INCR/DECR function and step size by the FOCUS STEP SIZE function.

The sequence starts with the exposure furthest below the selected plane of focus and then

proceeds upwards through it. Only in the TEM Low Dose mode the sequence starts with an in-focus exposure while every following exposure is made at one step further under-focus. At the conclusion of the sequence, the focus as set by the operator is regained.

If an odd number of exposures is selected, such as nine, four exposures will be made below the plane of focus, one in it and four above it. If an even number of exposures is selected, such as six, three will be made below the plane of focus, one in it and two above (Fig. 4.4).

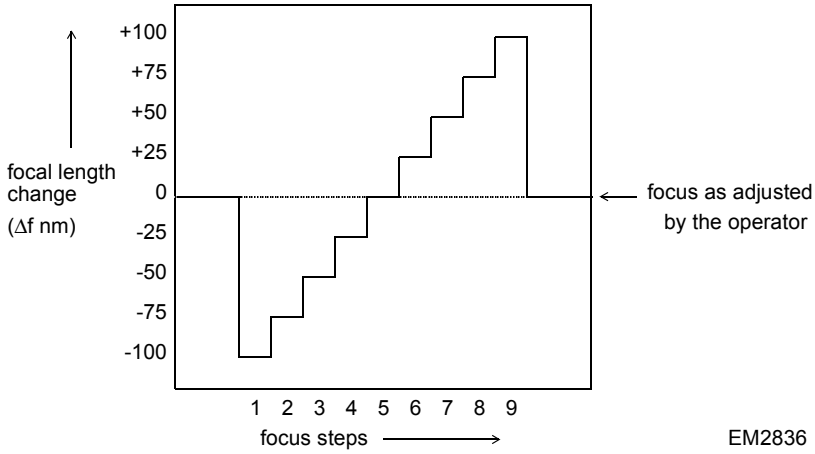


Fig. 4.4, Automatic through-focus series - example showing 9 steps in step sizes of 25 nm

Note: A through-focus series in TEM Low Dose starts with an in-focus exposure. Every following exposure is made at one step further under-focus.

4.3.4 Recording DARK FIELD images and DIFFRACTION patterns

Care should be taken with the exposure measurement. The exposure meter is applicable only to TEM Bright Field photography but it may be used as a reference. Initially, the exact exposure time should be determined by taking a series of photos over a range of exposure times.

In the case of a **Dark Field image**, the contrast between the image itself and the background is in general extremely high, thus if the average intensity of the field is taken, overexposure of the bright areas can occur.

In the case of the s**elected-area diffraction pattern**, use of the automatic exposure timing facility is, in general, not applicable due to the high intensity of the small diffraction spots. Because of this the Microcontroller will select the MANual exposure mode as soon as Diffraction is active. The user is expected to adjust the manual exposure time on the TEM CAMERA page. AUTO can be reselected by the operator since it may be used successfully in specific applications as in Convergent-Beam diffraction with large disc sizes.

In general, a manual time of about five seconds should be selected for a spot pattern and the diffraction pattern intensity adjusted by the SPOT SIZE control (overfocus - clockwise - for decreasing intensity). With some experience, however, it will be noticed that the optimum manual time is a constant fraction of that indicated by METER in the information field, e.g. for an indication of 50 s, a choice of five seconds will give an optimum diffraction pattern density on the photographic material.

The exposure parameters are selected on the TEM CAMERA page. On the CAMERA INITIATION page, the photographic material data and stock reset are selected.

4.3.5 The Plate Camera

Introduction

The magazine for sheet film has a maximum capacity of 56 sheet-film exposures. This magazine replaces the one holding 36 glass plate or sheet-film exposures. Both types of magazines can be used on EM400 series (EM400, EM410, EM420, EM430) and CM series microscopes.

Caution! The 56-holder magazine (referred to here as the new magazine) for unexposed sheet film and its sheet film holders are physically different from the 36-film magazine (referred to as the old magazine). **NEW SHEET-FILM HOLDERS ARE INCOMPATIBLE WITH THE OLD MAGAZINE AND VICE VERSA**, since the new sheet-film holders are thinner and therefore the exit slit of the magazine is smaller. Mixing old and new magazines will invariably result in plate jams. In order to distinguish old and new magazines in the dark room, new magazines have been fitted with a fluorescent sticker (observable in the dark room), as well as a number plate.

Magazine parts description

Refer to figure 4.5.

The complete magazine consists of a top part carrying the unexposed film material, a transport tray in the middle, and a bottom part to receive the exposed plates. The plates are carried in the middle tray, which is pushed out by a pneumatically powered rod in the microscope. On leaving the magazine, the tray will transport one plate. A pin in front of the projection chamber causes plate supports to retract, allowing the plate to fall down to the bottom of the plate tray. The exposure will then be made. After the exposure the tray will be moved back into the magazine again. The exposed plate will then fall into the receiving magazine. The tray is secured by a spring so that it doesn't fall out during transport.

The blanking plates may be used to split the magazine in room light conditions so that a fresh receiving magazine can be put underneath the magazine for unexposed plates when the latter still contains unexposed material. To do this, slide both blanking plates into the slits provided above and below the plate tray, with the top plate having its curved grip facing upward, and the lower one with its grip facing downward. Release the clips from the **lower**, receiving magazine, remove it and replace it with a fresh receiving magazine. **Do not take off the top cover as this will expose the unexposed material to light!**

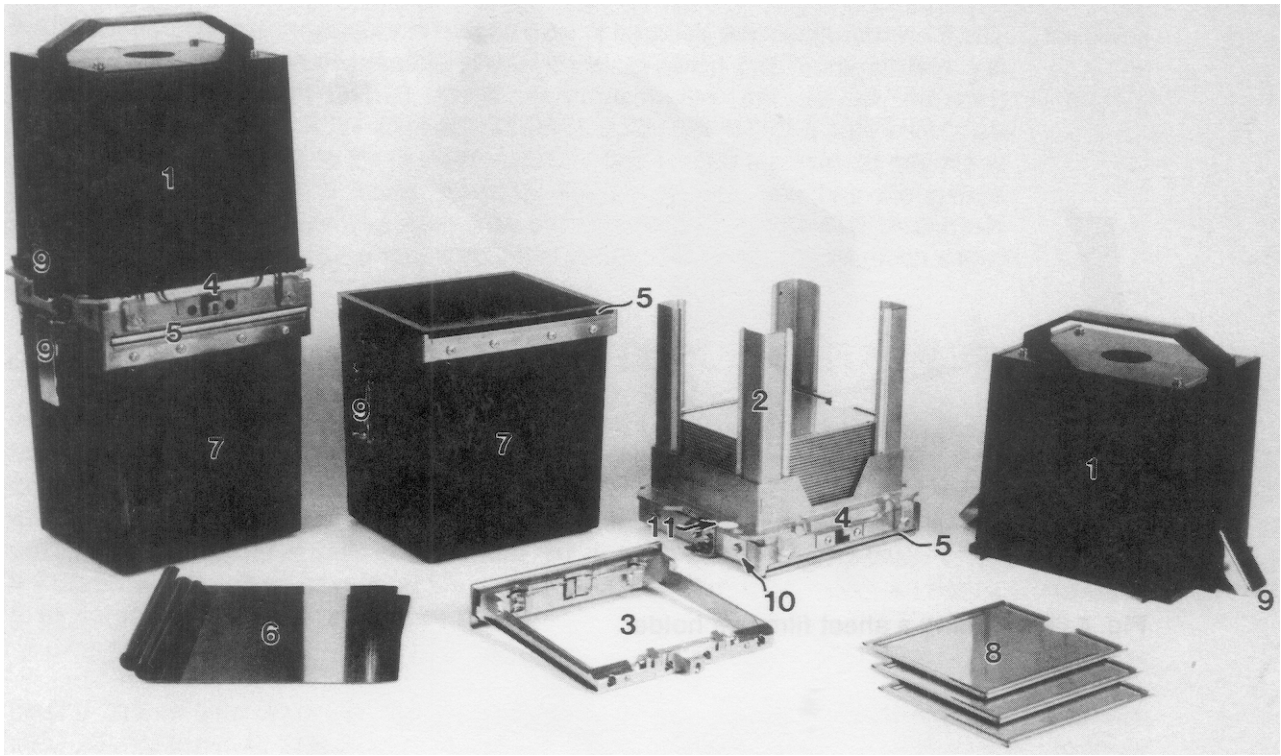


Fig. 4.5; An assembled and disassembled plate-camera magazine

Legend:

1 Magazine for unexposed plates, cover
2 Magazine for unexposed plates, plate-stack guide rack
3 Plate tray
4 Tray securing spring
5 Blanking plate slit
6 Blanking plates for top and bottom magazines
7 Receiving magazine
8 Sheet-film holder
9 Securing clip of magazine covers
10 New magazine marker plate
11 Fluorescent sticker

Inserting sheet film in a holder (in dark room only!), Fig. 4.6a

1. Take the sheet-film holder in one hand with the finger slot at the top.

2. Take hold of the top edge of a sheet film with the other hand and with the emulsion side upward (the small notch in the sheet film should be on the top right-hand side).

3. Slide the sheet film downward underneath the securing rims until the top of the sheet film fits below the rim inside the holder.

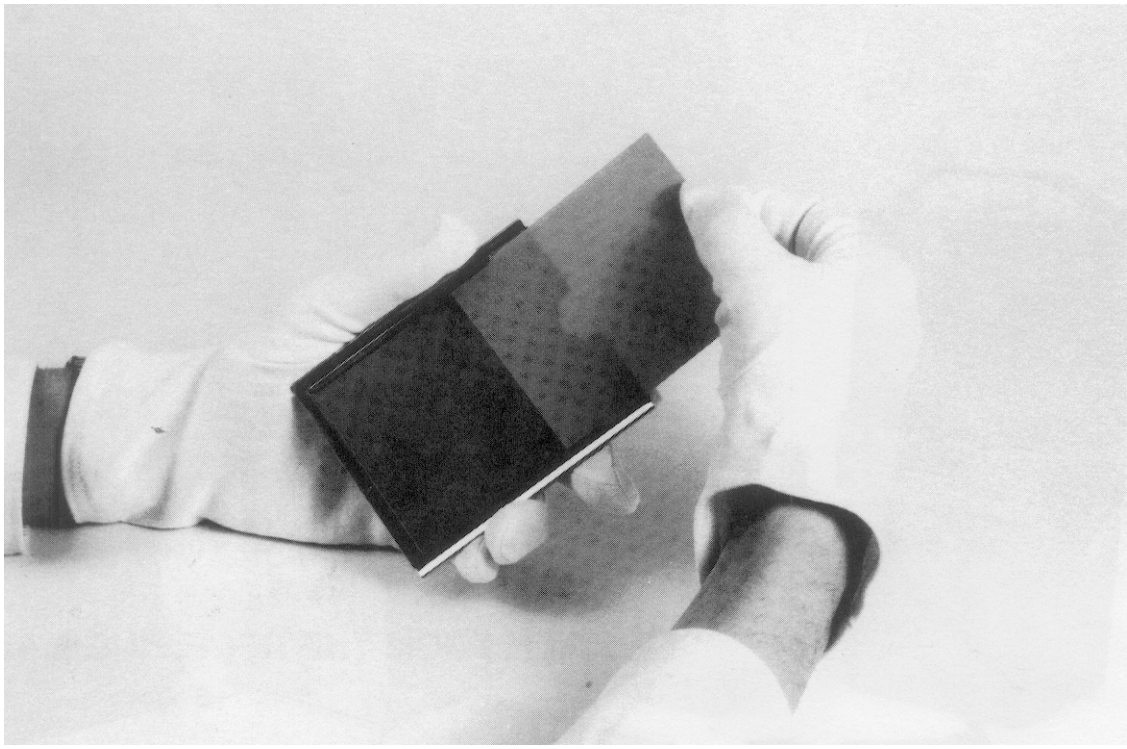


Fig. 4.6a; Loading a sheet film in a holder

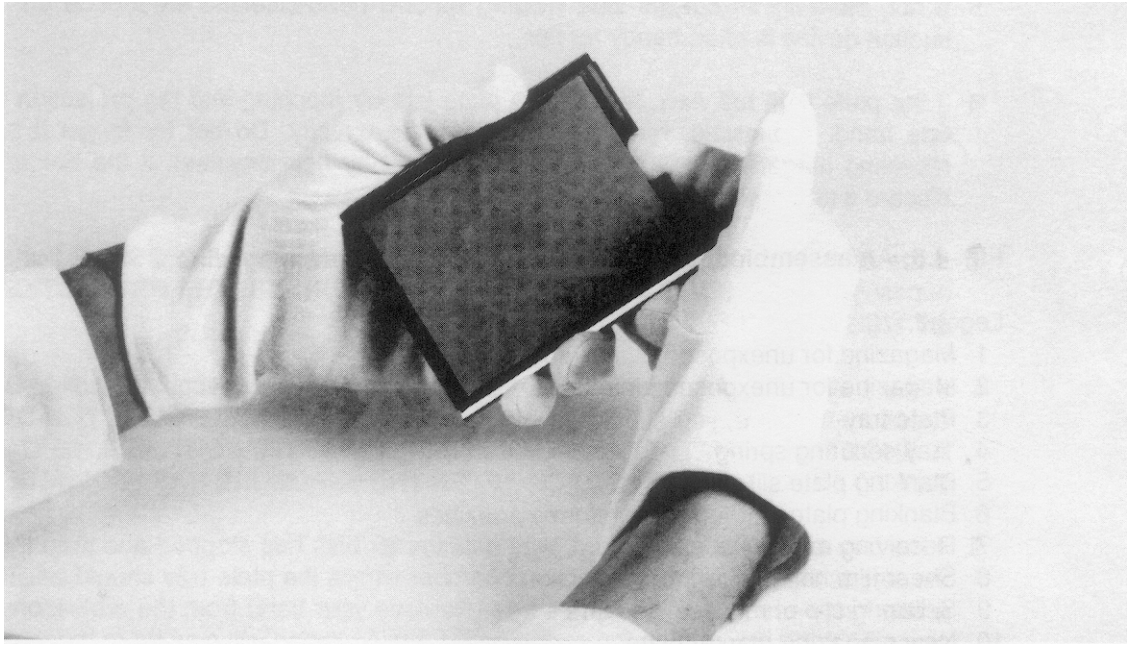


Fig. 4.6b; Removing a sheet film from a holder
Loading the sheet-film magazine (in dark room only!), Fig. 4.6c

1. Remove the upper magazine cover by releasing the clips and pulling the cover off upwards.

2. Stack the required number of sheet-film holders between the guides, with the emulsion (sheet film) upward. The total stack of holders should not exceed the height of the guides.

3. Replace the upper cover and fix the securing clips. Note that the cover only fits in one way (otherwise the clips are misaligned).

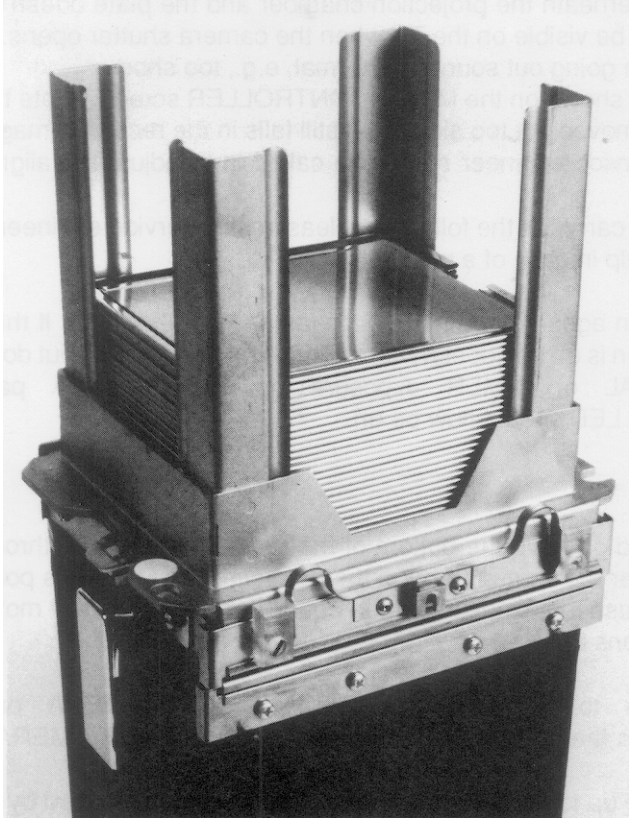


Fig. 4.6c; The plate stack between the guides of the magazine for unexposed plates

Removing exposed film from the receiving magazine (in dark room only!)

1. Remove the lower magazine by releasing the clips. The top part can now be put aside on the plate tray.

2. If a blanking plate is used, pull it out.

3. Take the exposed plates carefully out of the receiving magazine. Sometimes it helps to tilt the magazine slightly. The exposed plates rest on a spring-supported platform that will automatically rise when the plates are removed.

4. When the magazine is empty, replace the top part and secure the clips. Note that the clips will only fit on one way (otherwise the clips are misaligned).

Removing sheet film from a holder (in dark room only!), Fig. 4.6b

1. Take the sheet-film holder in one hand with the finger slot at the top. With a finger from the same hand, press against the sheet film through the finger slot so that the film comes up.

2. Take hold of the top edge of the sheet film with the other hand and retract it upward out of the holder.

Troubleshooting

A plate jam is often recognised by the following symptoms:
- The movement of the plate's going in doesn't sound normal; e.g., the air hiss may stop too soon or it may sound as if the plate is scraping.
- When a TV is mounted underneath the projection chamber and the plate doesn't move in far enough, the TEM image will be visible on the TV when the camera shutter opens.
- The hiss of air from the plate going out sounds abnormal, e.g., too short.
- A message "plate unload" is shown on the MICROCONTROLLER screen. (Note that the latter occurs also when the plate moved out too slowly but still falls in the receiving magazine. If this happens repeatedly, the service engineer should be called in to adjust the alignment of the sliding rails.)
  If you feel you are unable to carry out the following, please call a service engineer. Otherwise, the following actions may help in case of a plate jam.

1 Push the EXPOSURE button again to see if the plate jam will resolve itself. If the light (LED) above the EXPOSURE button is off and doesn't come on when the screen is put down and lifted again, switch to MANUAL or TIMER exposure on the CAMERA page of the MICROCONTROLLER. The LED should now be on.

If the first step doesn't help:

2 Switch the room light on and observe the bottom of the projection chamber through the side window - if available - or over the screen through the front window. Often it is possible to see part or all of the plate tray. Push the exposure button again. If the plate doesn't move in and out properly, follow the instructions below.

3 Switch the plate camera to TIMER and HOLD on the CAMERA page of the MICROCONTROLLER. Turn the beam and high tension off and press CAMERA AIR on the VACUUM page.
4 When the camera has come up to air pressure, check that the tray is jammed by lifting up the lid of the plate camera. If the plate camera magazine can be lifted out and the tray is inside the magazine, the plate jam resolved itself.

5 If not, carefully lift out the side viewing window (lead-shielded steel plate on the CM30). A suction device is often handy for this.

6 If the plate is in full view, resolve the plate jam by reaching into the projection chamber with one hand. If possible, remove the faulty plate directly. Do not try to get it back in to the receiving magazine (it is exposed to room light by now anyway). If the holder is damaged, discard it and replace it with a new one.

7 If the slide tray and holder are not within reach, press the EXPOSURE button to start an exposure. **MAKE SURE YOUR HANDS ARE NOT INSIDE THE PROJECTION CHAMBER AT THIS STAGE!**

8 If the tray and holder come forward, clear the jam as described above. By having the exposure on timer, you should have ample time to work. **MAKE SURE YOU DO NOT HAVE A SHORT AUTOMATIC OR MANUAL EXPOSURE TIME SET AS THE CAMERA WILL TRY TO MOVE THE PLATE BACK AFTER THE EXPOSURE HAS FINISHED!**

9 If the tray doesn't come forward, wait until the air hiss has stopped and then try to reach into

the slot at the back of the projection chamber where the plate tray should be. Try to nudge it a little sideways to see if it comes free. Remove your hand from the projection chamber and press EXPOSURE to stop the exposure. The microscope will now try to move the plate back. You can start and stop another exposure to see if it will then move. **ALWAYS REMOVE YOUR HANDS FROM THE PROJECTION CHAMBER WHEN DOING THIS!**

If none of the above helps, call the service engineer.

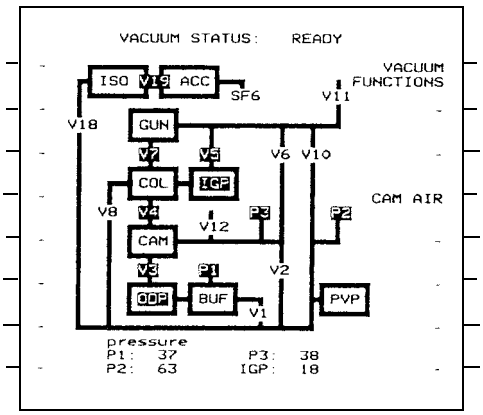
10 If removed, replace the side viewing window, making sure that the O-ring fits tightly in the recess in the projection chamber. In the case of a CM30, the notch on the inside of the window should be positioned at the top, opposite the place where a pin protrudes from the projection chamber.
Press CAMERA AIR on the VACUUM page.

When both new and old magazines are in use: possibly new and old sheet-film magazines or holders have been interchanged. In the case of old holders in new magazines, the plate does not come out at all. In the case of new holders in old magazines sometimes two plates come out on top of each other or get jammed in the exit slit. Solve the plate jam as described above and immediately separate the old and new parts in the dark room.

4.3.6 Exchanging the magazine in the microscope (Fig. 4.7)

1. Ensure that the microscope is at working vacuum (UHV indicated).

2. Key VACUUM:



On the VACUUM STATUS page key CAM AIR and wait for the projection chamber to reach atmospheric pressure.

3. Lift the plate-camera cover:

- Remove the magazine and replace with another one containing unexposed plates.

  Note: The magazine only fits in one way: with the pins of the camera housing going through the holes alongside the magazine.

- Ensure that the blanking plates (4, 5) have been removed. Replace the cover.

  Note: If a spare, refilled magazine is not available, proceed as follows:

- Lift the plate-camera cover:

  - Remove the magazine and replace the cover.
  - Key CAM AIR to start the automatic pumping procedure.
  - Once the magazine is refilled, key CAM AIR again and wait for the projection chamber to reach atmospheric pressure.
  - Replace the refilled magazine and replace the cover.

4. Key CAM AIR to start the automatic pumping sequence.

5. Press READY key - the operational page last selected will be obtained.

6. Reset camera stock and, if needed, change photographic parameters:

   - Select TEM CAMERA page.
   - Select the CAMERA INITIATION pageand carry out the required parameter changes.

7. Press READY key. The operational page last selected will be obtained.

8. Wait for the microscope to attain working vacuum (UHV indicated).

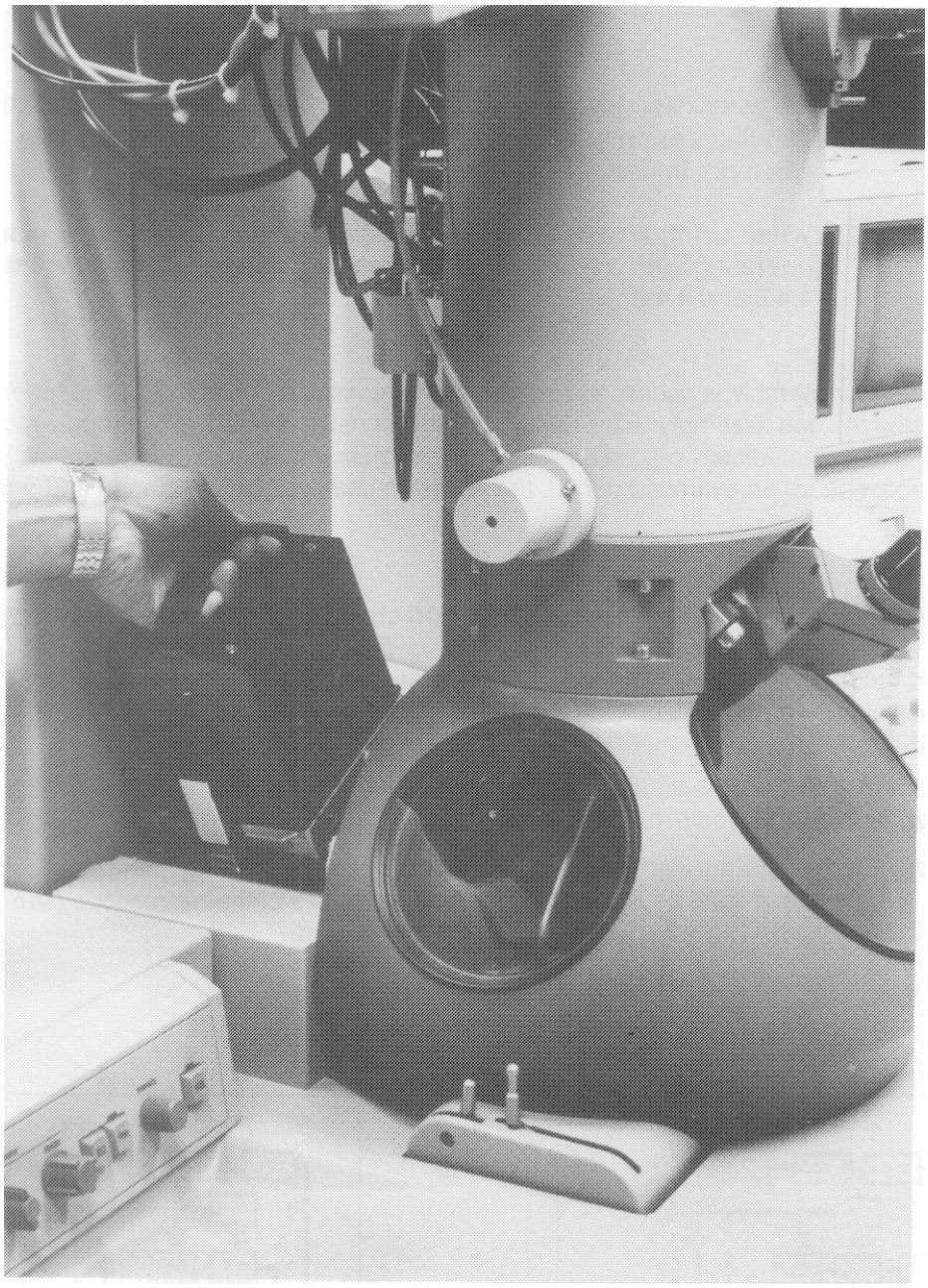


Fig. 4.7 Inserting the plate-camera magazine into the microscope

4.4 EXCHANGING THE FILAMENT (AND WEHNELT APERTURE)

The procedures that follow refer to the Universal Wehnelt assembly designed for use with either the standard tungsten filament or high-brightness filaments, e.g. pointed tungsten or LaB_6.

Wehnelt aperture exchange is included in this section as a recommended procedure. Used apertures should be retained for cleaning when maintenance is carried out (see Sect. 5).

Caution! **1) All parts described operate in ultra-high vacuum and should therefore be handled carefully using nylon gloves and stored in suitable containers when not in use.**

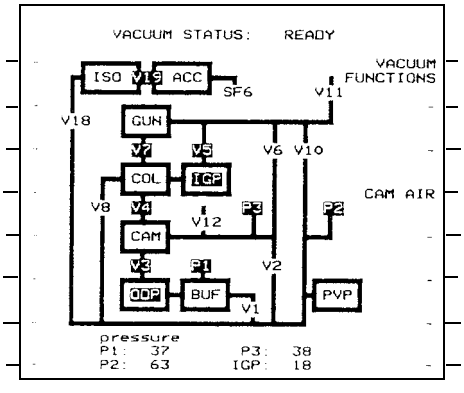
2) When using a LaB_6 filament, special care must be taken in mounting and operating with a new filament. A running-in procedure is included in Sect. 4.4.8 and 4.4.9.

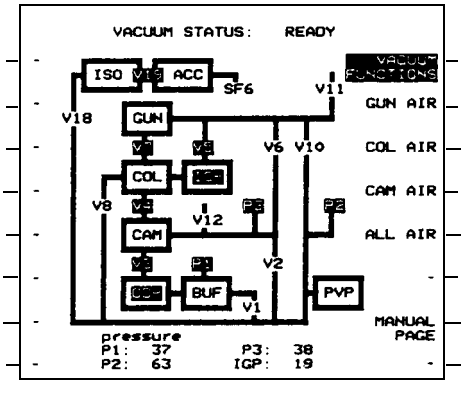
The Wehnelt assembly is accessed by bringing the emission chamber to atmospheric pressure and raising the gun assembly. After removing the Wehnelt assembly, it is strongly recommended that the gun is immediately placed back into the emission chamber. If the Wehnelt is kept outside the microscope for an extended period, the emission chamber can be closed and pumped down again.

4.4.1 Removing the gun assembly from the emission chamber (see Fig. 7.5, Sect. 7.2.1)

1. Move the gun lifting lever (item 103) to its operational position by pushing it from the inside to the outside, so it projects outside the body of the microscope, and can be used to lift the gun assembly.
2. Ensure that the High Tension is switched OFF; Check that the pressure of the nitrogen gas (if used), does not exceed 0.1 Bar.

   Note: It is strongly advised that Nitrogen flushing be applied to the air inlet on the column to prevent moisture condensing on the inner surfaces of the microscope (see Sect. 5.2).
3. Key VACUUM:
4. Key VACUUM FUNCTIONS to get access to GUN AIR





First valve V19 will close, then valve V18 will open and the SF_6 gas in the gun isolation chamber will be pumped out by the prevacuum pump. At this moment unscrew the red-capped gun securing screws one or two turns. This is done now as the pressure from the SF_6 has been released and the pressure from flushing nitrogen gas has not had time to build up.
When the pressure in the gun isolation chamber is low enough, valve V11 (gun air inlet valve) will open automatically.

Caution! **Do not attempt to raise the gun assembly while the gun isolation chamber is being pumped down (valve V11 is still closed).**

4. Completely unscrew one of the red-capped gun securing screws and insert this in the gun-lifting position (hole at 90^{o} to the gun securing positions, towards the front of the microscope). Screw it down until the movement begins to feel stiff, then release the other gun securing screw by one turn.
   Continue tightening the first screw and releasing the second screw until the gun assembly is released. The vacuum seal between the assembly and the microscope is now broken and the flow of nitrogen gas is audible. This procedure is needed so that the pressure difference in the gun chamber, either due to the nitrogen gas, or the vacuum left after the SF_6 is pumped away, is released in a controlled manner.

5. Raise the gun assembly using the lifting lever (item 103, Section 7.2), shift the lever towards the rear of the microscope and then further to the left until it locks in position. The gun is now clear of the emission chamber and the wehnelt cylinder can be dismantled or remounted as described in Sections 4.4.2 and 4.4.3.

The gun assembly can be replaced as described in Section 4.4.4.

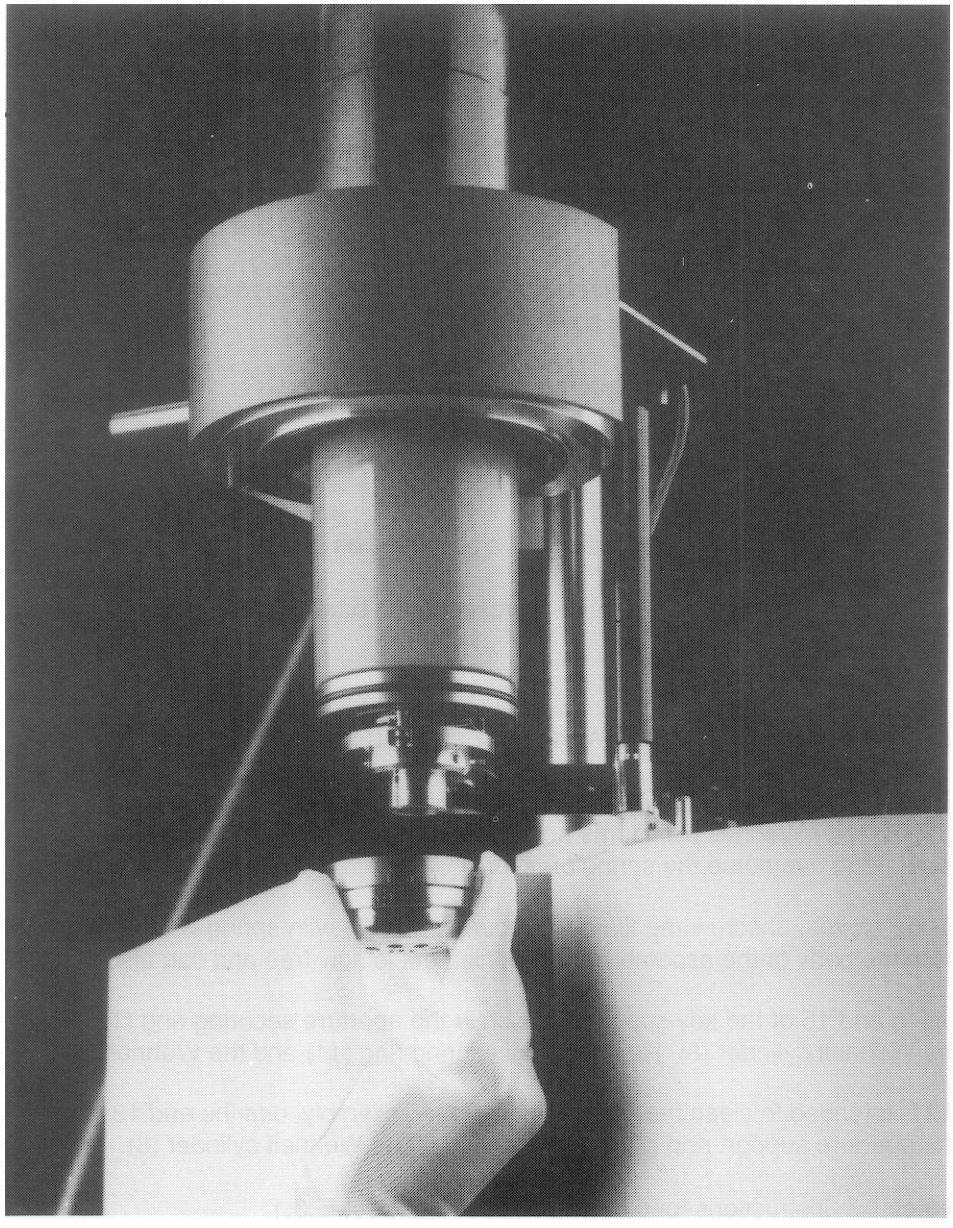


Fig. 4.10, Dismounting and remounting the Wehnelt assembly

4.4.2 Dismounting the Wehnelt assembly (Fig. 4.10)

Grasp the Wehnelt assembly with one gloved hand and pull to detach it from the gun assembly. The Wehnelt assembly is held in place by an internally mounted spring ring. A small amount of force will be required to overcome the spring pressure.

Caution! The use of clean gloves for this operation is essential.

4.4.3 Remounting the Wehnelt assembly (Fig. 4.14)

1. Replace the Wehnelt assembly on the receiver, ensuring that the pin (1) on the receiver engages with the slot in the Wehnelt assembly.

2. Press firmly into place. This is a reasonably tight fit and the two parts must be placed together carefully.

4.4.4 Replacing the gun assembly in the emission chamber (see Fig. 7.5, Sect. 7.2.1)

1. Replace the gun in the emission chamber by raising the gun-lifting mechanism a few millimetres, turning it towards the front of the instrument and then to the right as far as it will go and allowing it to descend so that the insulator fits into the emission chamber. Check that the earthing strip does not obstruct its path.

2. Insert the two gun-securing screws in the gun-securing holes and screw them down, consecutively and equally, a few turns at a time, until they are hand-tight.

   Note: Tightening the gun-securing screws must be carried out by hand. Never use any tool to exert force on the screws.

3. Key GUN AIR to restart the automatic pumping sequence.

4. When the sequence is finished and the gun is under vacuum, re-tighten the gun-securing screws (by hand!).

   Note: Conditioning is required before switching on the H.T. above 160 kV (see Sect. 4.4.8).

When the vacuum levels in the entire microscope are back to normal, check that the SF_6 pressure is higher than 5 Bar.

4.4.5 Dismounting the filament and Wehnelt aperture (Fig. 4.11)

1. Prise the Wehnelt cylinder (8) off the main body of the Wehnelt assembly (1) with the tools (17,18). The Wehnelt cylinder is held in place by a spring-clip arrangement and some force is required to overcome the spring pressure.

2. Using gloves, unscrew the filament securing ring (6) with spring washer (7) and remove them from the body of the assembly (1). The filament is now free and can also be removed.

3. Using end 15 of the key supplied, unscrew the aperture securing ring (11) from the outside of the Wehnelt cylinder (8). Remove the securing ring (11) and the Wehnelt aperture (10).

4. If it is intended to clean the components of the assembly, use the end 16 of the key to unscrew the aperture support ring (9) from the inside of the Wehnelt cylinder (8).

   Note: Instructions for cleaning are given in Sect. 5.3.1.

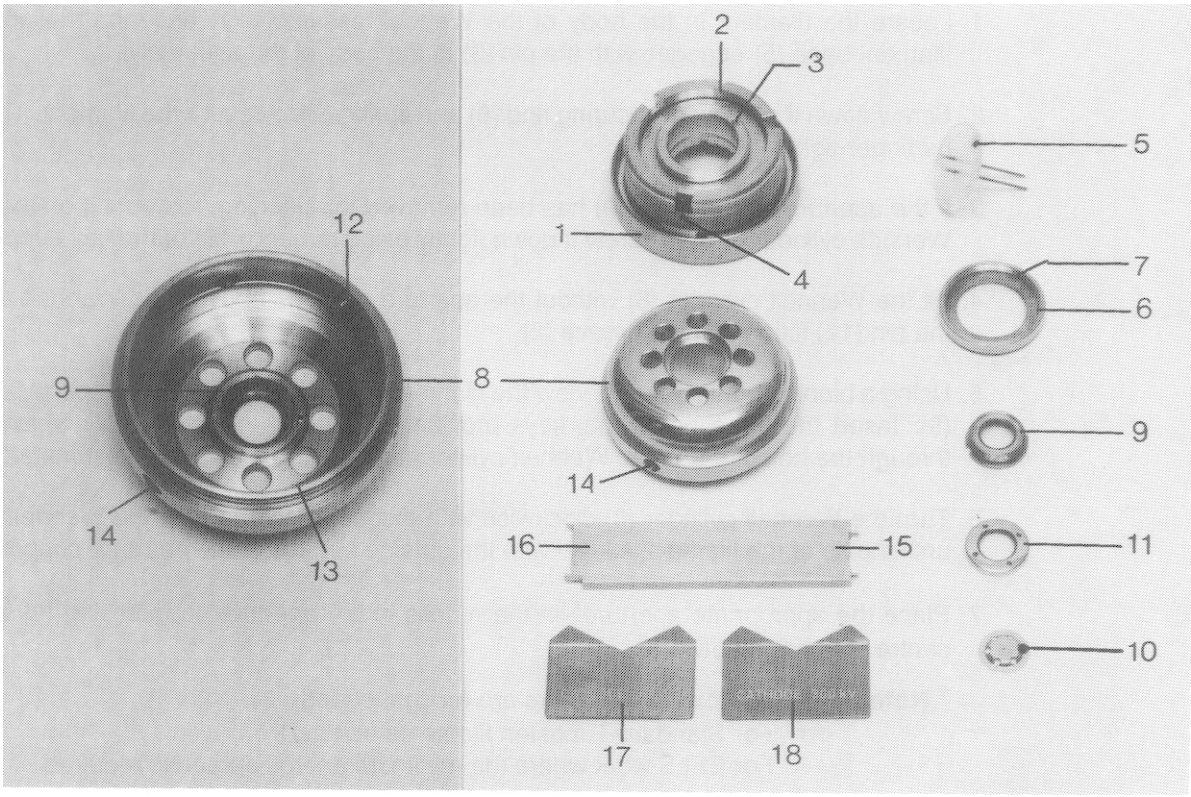


Fig. 4.11, Wehnelt assembly - Component parts and key for mounting and dismounting the aperture

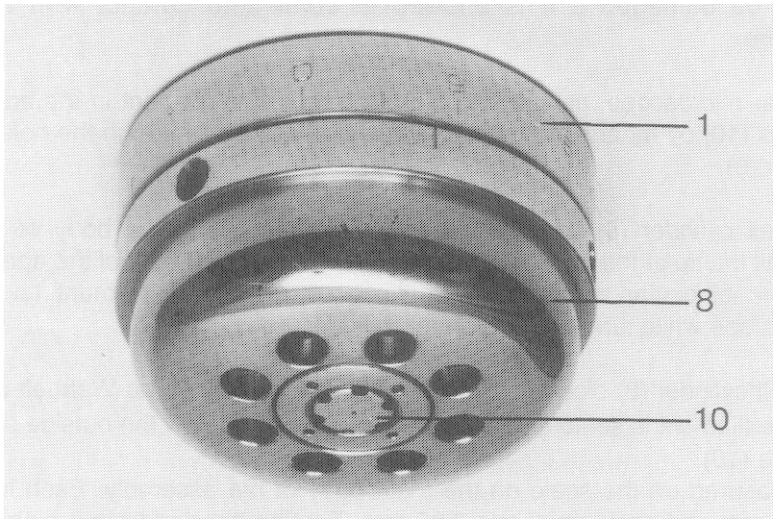


Fig. 4.12, Adjusting the filament-to-Wehnelt distance

4.4.6 Remounting the filament and Wehnelt aperture (Fig. 4.11)

Caution! When mounting a LaB_6 filament, great care must be taken when handling the filament, particularly when adjusting the filament-to-Wehnelt distance. If the filament tip is allowed to come into contact with the Wehnelt aperture, it can very easily be damaged.

1. Locate the filament in the body of the Wehnelt assembly (1) ensuring that the slot on the filament base (5) engages with the pin (3) in the body of the assembly.

2. Screw down the filament securing ring (6) and spring (7) to secure the filament. The ring should be finger-tight.

3. If the aperture support ring (9) has been removed for cleaning, remount it on the inside of the Wehnelt cylinder (8) and screw it down tightly using the end (16) of the key supplied.

4. Fit the Wehnelt cylinder (8) without the aperture onto the body of the Wehnelt assembly with the pin (12) fitting into the groove (2).

5. Using a binocular microscope, view the filament tip in the opening of the aperture securing ring (9). Insert the three hexagonal keys provided into the three screws (4) which are reached through the holes (14) in the Wehnelt cylinder then adjust the tip to an estimated centre point.

6. Turn the Wehnelt cylinder (8) clockwise with respect to the body of the Wehnelt assembly (1) until the tip of the filament is level with the outside surface of the aperture support ring (9).

7. Place the appropriate aperture* in the recess in the aperture support ring (9) with its raised centre protruding outwards.

   * **Note:** The following diameters are recommended:
   - For Standard Tungsten filaments and LaB_6 : 0.5 mm.
   - For EELS work where the minimum energy spread is required : 0.3 mm.

8. Replace the aperture securing ring (11) and screw it down using the end (15) of the key.

9. Using the binocular microscope, check that the filament tip is visible through the aperture (10). If not, remove the aperture and repeat steps 6 - 8 as necessary.

4.4.7 Setting the position of the filament (Figs. 4.11, 4.12 and 4.13)

Caution! **Great care should be taken with this operation as the filament tip can very easily be damaged if it is allowed to come into contact with the Wehnelt aperture.**

1. Using a binocular microscope, accurately centre the tip of the filament in the aperture of the Wehnelt aperture (10) by means of the three screws (4) reached through the holes (14) in the Wehnelt cylinder (8).

2. Turn the Wehnelt cylinder (8) counter-clockwise with respect to the body of the Wehnelt assembly (1) until the tip of the filament is level with the outside surface of the aperture (10) as seen through the binocular microscope. Continue observing the filament tip through the binocular microscope while turning the Wehnelt cylinder.

3. Turn the Wehnelt cylinder (8) clockwise with respect to the body of the Wehnelt assembly (1) until the tip of the filament is set to a position 0.15 to 0.2 mm* below the outside surface of the Wehnelt aperture (10).
   This can be measured on the scale on the main body of the assembly. Each large division represents 0.10 mm and each small one 0.05 mm. Turning the ring from a higher to a lower indication retracts the filament.

* **Note:** A distance of this order is recommended as optimum for normal operation. Shorter

distances will give greater brightness but decreased filament life and larger energy spread of the electrons in the beam. The minimum distance (which can vary from one microscope to another) is determined by the maximum allowed emission current (8 μA at emission step 1, 16 μA at 2, etc., doubling each time). If this emission current is exceeded, a safety in the high tension tank will lower the high tension (note that the LED above the high tension button will remain on). The emission will then be reduced and the safety will be released. If the emission then again exceeds the safety value, the same sequence will follow, giving a typical up-down-up-down effect. Increase the filament-to-wehnelt distance if this occurs.

4. Re-centre the filament if necessary (see step 1).

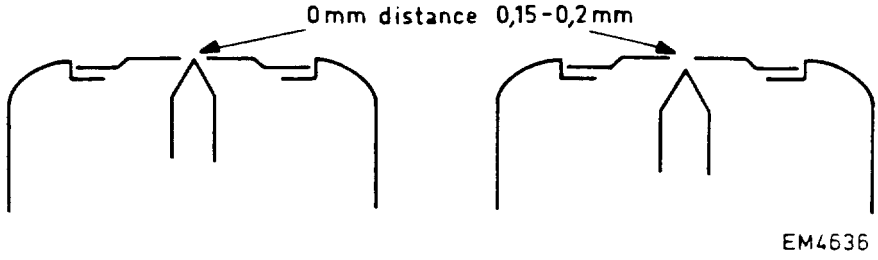


Fig. 4.13, Setting the position of the filament

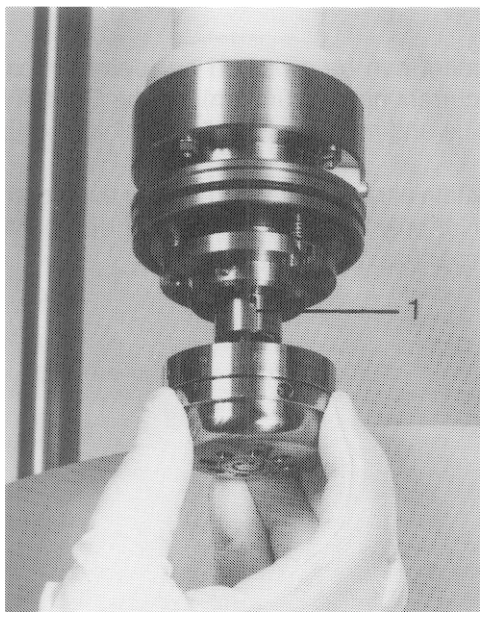


Fig. 4.14, Securing the Wehnelt assembly

4.4.8 Conditioning the gun

After venting the gun, conditioning is necessary for attaining High Tension. Proceed as follows:

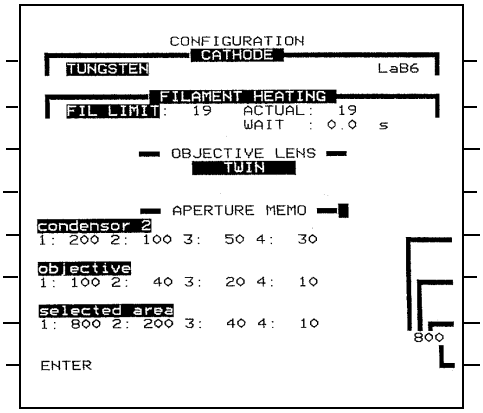
1. Select FOCUS STEP SIZE 6.
2. Key PARAMETERS.
3. Select H.T. setting 40 kV.
4. Wait until vacuum status allows switching on the H.T.
5. Press HIGH TENSION button (LED on).
6. Wait until the H.T. measurement (displayed on the PARAMETERS page just above the indication to the right of the CONDITIONING label) indicates 40 kV (±5 kV).
7. Increase H.T. to 160 kV slowly, each time waiting until the emission meter reading has settled down. If severe discharges occur (strong fluctuations of the emission-meter reading), go one step down in H.T. and proceed as listed below.
8. Press CONDITIONING softkey (highlighted). The H.T. will now be raised by 10%.
9. Turn the focus knob one step clockwise. The H.T. displayed will increase by about 1 kV. If the step is larger, turn the FOCUS STEP SIZE knob one or more steps counter-clockwise.
10. Continue turning the FOCUS knob clockwise, thereby increasing the H.T.. If the emission reading increases more than by about 5 scale readings, wait until it settles down.
11. When the H.T. has reached 220 kV, leave the microscope in this setting for about 15 minutes. The H.T. should stabilise during this period.
12. Press the CONDITIONING softkey (highlight off). The H.T. will go to 200 kV and the microscope is ready for use.

Note: 1) During conditioning the filament can be switched on (optimum conditioning is performed with the filament current near saturation) but the GUN SHIFT controls are set to their maximum value and no intensity will be visible on the screen.

2) Leaving the microscope to attain ultra-high vacuum for an extended period is no substitute for conditioning. Not only is conditioning more efficient for obtaining ultra-high vacuum, it also prevents extreme discharges.

4.4.9 New filament - heating-up procedure

After venting the gun, the MICROCONTROLLER assumes that a new filament has been inserted. It therefore sets the FILament LIMIT automatically to zero. The filament cannot be heated up without a new definition of FILament LIMIT. The FILament LIMIT is accessed on the CONFIGURATION page (key MODE, then CONFIGURATION).



Softkeys

TUNGSTEN

Function : When highlighted, indicates to the MICROCONTROLLER that a tungsten filament has been installed.

LaB_6

Function : When highlighted, this indicates that a lanthanum hexaboride (LaB_6) filament has been installed.

Operation : Before any action on the filament heating, the cathode should be selected according to the one installed.

- Switch on the H.T.
- Turn the FILAMENT knob clockwise to increase the filament heating.

With a new filament the maximum acceptable speed for heating the filament is:

- Tungsten: 0.1 s per step.
- LaB_6 : 15 s per step.

In order to ensure that this heating speed is not exceeded, the MICROCONTROLLER takes care that the delay time between steps is always adhered to. The delay time remaining is continuously displayed at the label WAIT and a message is displayed at the bottom of the CONFIGURATION page:

Start up new W/LaB_6 cathode

(according to the type of cathode selected).

The delay time will be hardly noticeable in the case of Tungsten, but in the case of LaB_6 it will count down in the range 15 - 0 s. The message label will be flashing during the delay time. When the delay time has counted down to zero, the instrument will accept the next increase in the FILAMENT knob setting.
While filament heating is in progress, the main screen of the microscope should be observed carefully in order to see when the gun starts to illuminate the screen.
When the filament has reached the desired saturation point the filament limit may be set by keying

FIL LIMIT. FIL LIMIT will be automatically activated, if the CONFIGURATION page is left by keying READY. This ensures that there is always a filament limit set when an operational page is displayed.

Caution! FILAMENT LIMIT

The operator must ***never leave the CONFIGURATION page directly by entering the ALIGNMENT page (by pressing the ALiGNment button) and performing an Alignment procedure, by entering the STIGMATOR page (by pressing the STiGMator button) or by entering the DARK FIELD mode (by pressing the Dark Field button) without first having set the FILament LIMIT (reversed video).***

Failure to observe this procedure will mean that protection against burning down the cathode has not been set when the ALIGNMENT procedure, STIGMATOR page or DARK FIELD mode is left.

Never exceed filament heating step 20 if no intensity becomes visible on the screen. Choose GUN TILT on the ALiGNment page. Move one of the MULTIFUNCTION knobs to the limit of its range (indicated by a beep) and turn the second MULTIFUNCTION knob through its whole range. If the beam was not found, adjust the first MULTIFUNCTION knob a little and again turn the second through its whole range. Repeat until the beam is found. If a beam is found, but the optimum GUN TILT appears to be out of range, the true GUN TILT centre usually lies at the other end of the range of the MULTIFUNCTION knob that has reached its limit. If not, the filament is not centred in the Wehnelt.

4.5 EDX DETECTOR PROTECTION (optional)

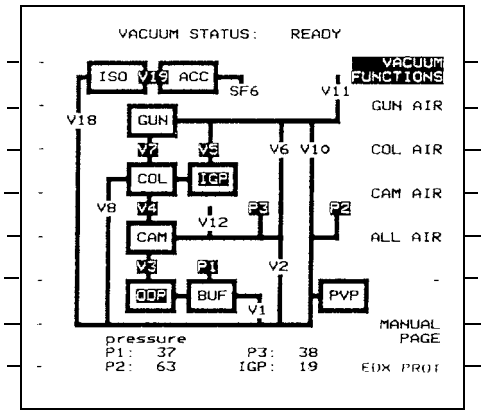
On the VACUUM page a function is available for protection of an EDX X-ray detector. The EDX PROTECTION function aims at preventing damage to the detector by backscattered electrons (relevant for all detectors without shutters) and by poor vacuum (relevant to windowless detectors).

With the EDX PROTECTION function activated, the following operations are forbidden and rejected with a beep:

- Vacuum operations that affect the vacuum near the detector, e.g. COL AIR.
- Switching on a mode where the objective lens only receives a low current, for example LM magnification range.
- In cases where the objective lens is used as the focussing lens, the lowering of the lens current below a preset value.
- In FREE LENS CONTROL, the lowering of the objective current below a preset value.

The EDX PROTECTION cannot be switched on when the vacuum situation UHV is not reached and in one of the forbidden modes listed above.

The EDX PROTECTION function is activated by keying EDX PROT on the VACUUM page:

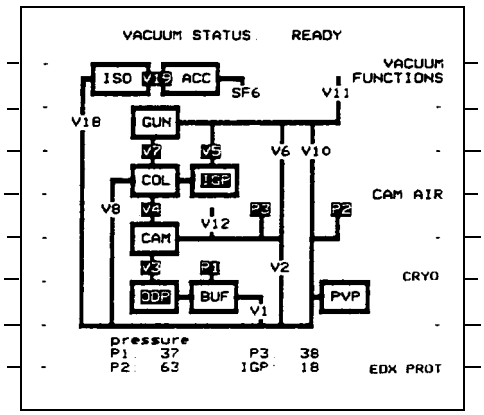


see 4.5

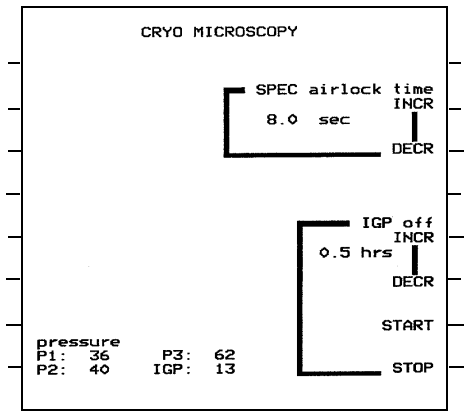
4.6 CRYO MICROSCOPY (Option)

Introduction: Cryo microscopy is a technique that enables observation of specimens at a very low temperature in the microscope. As work is carried out under certain circumstances with a pre-cooled cryoholder, transfer of specimens through the air will result in condensation of water vapour on the holder. On introduction of the cryoholder into the microscope, the condensate (ice) will partially evaporate due to a rise in temperature caused by the contact between the cryoholder and the warmer parts of the microscope. The ice will sublimate in the vacuum of the microscope and can contaminate the specimen area. To minimise this contamination effect in the high vacuum part of the microscope, different airlock pumping times are available.
Also during observation of cryo specimens, the water will condense on the cold traps inside the microscope. After some hours of working, the temperature of the cold trap will increase, the water vapour pressure inside the microscope will temporarily rise, and significant amounts of water will have to be pumped. As the ion getter pump is a good but very slow pump for water vapour, the cryo option alllows the ion getter pump to be switched off for a certain period. In this period, the oil diffusion pump takes over the pumping action. The ion getter pump switches on automatically after the chosen "IGP off" time.

Usage: If the CRYO accessory has been installed, the VACUUM page on the Microcontroller screen will have the following layout:



The CRYO features can be accessed by pressing the CRYO softkey. The following page will then be displayed:



The two features of CRYO MICROSCOPY which can be distinguished are:

- **SPEC airlock time**
  The normal specimen airlock pumping time is 30 seconds. This time can be increased (**INCR** softkey) as necessary. Please note that the newly selected pumping time will be maintained until a new selection is made (**INCR** or **DECR** softkey). For non-cryo applications, the normal 30 seconds pumping time is recommended.

If a time other than 30 seconds has been selected, on inserting a new specimen the message "Specimen airlock time is not standard" will be displayed on the MICROCONTROLLER screen to remind the user of this non-standard selection. Pressing the RESET button will erase this message.

- **IGP off**
  A time can be specified during which the Ion Getter Pump will remain switched off (**INCR** or **DECR** softkey). This is intended to enable removal of gases by the diffusion pump when the cooling device in the specimen chamber is warmed up after working with heavily-outgassing specimens. Actual switching off will not occur, however, until the **START** softkey has been activated.
  When the Ion Getter Pump is off (which is shown by "off" in reverse video and zero IGP pressure), the normal vacuum pumping cycle can be activated again anytime by pressing the **STOP** softkey. The Ion Getter Pump will then be switched on as soon as allowed (VACUUM STATUS: READY).

Additional controls:

- **RESET** button: can be used as normal to erase any messages on the microcontroller screen.

- **READY** button: this button can be pressed to leave the CRYO MICROSCOPY page on the Microcontroller screen (the VACUUM page will then be entered). Leaving this page will not affect any CRYO activities in progress).

4.7 USE OF THE COOLING DEVICE

Use of the Cooling Device ensures maximum specimen throughput. This facility rapidly removes the water vapour following specimen exchange, enabling optimum vacuum conditions in the specimen area to be regained as quickly as possible.

To use the Cooling Device, first remove the Dewar vessel (1, Fig. 4.15). Fill it with liquid nitrogen and replace.

Caution! **Do not allow liquid nitrogen to spill onto the viewing windows of the specimen chamber, as this may cause the glass to crack.**

The effective use of the Cooling Device (Fig. 4.15) depends on careful adjustment to ensure that vibrations caused by the liquid nitrogen are not transmitted to the column of the microscope. At the same time the evaporation should be kept to a minimum to prevent the formation of ice which will create a vibration contact. This means that the Dewar (1) should not come into direct contact with either the copper wires, the conductor (3) or the insulating cap (2) while maintaining the smallest possible space through which evaporation can occur. Should this prove to be unobtainable for any reason (e.g. exchange of Dewar), then the height of the support table (4) can be adjusted by removing the screw securing it to the drip tray (5) and adding or subtracting spacing washers (6).

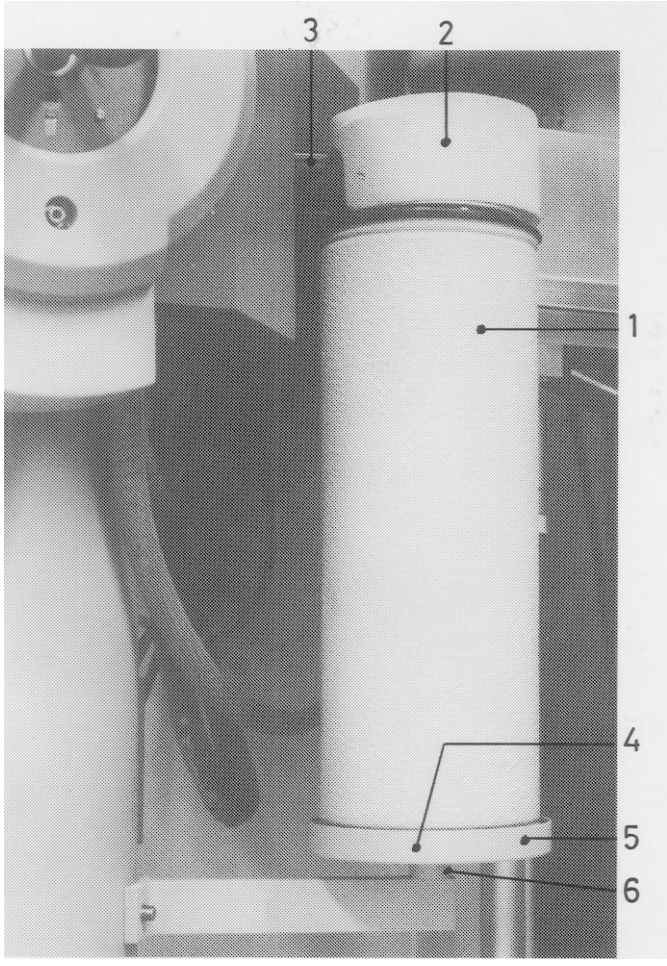


Fig. 4.15, Cooling device

5 MAINTENANCE AND CLEANING

The table below summarises a series of maintenance activities which can be performed by the operator. Some of these combine the appropriate cleaning procedures, which are described later in this chapter, with standard operational sequences already described.

Caution! All parts operating in vacuum should be handled carefully using nylon gloves and stored in suitable containers when not in use.

Maintenance activity	Sect.	Procedures required
Flushing with dry Nitrogen	5.1	Flushing with dry Nitrogen
Cleaning the Wehnelt	4.4 5.3.1	Exchanging the filament (and Wehnelt aperture) Cleaning the Wehnelt assembly
Cleaning apertures and aperture holders	4.2.3 4.2.6 5.3.2 5.3.3 4.2.4	Dismounting aperture holders Removing and replacing apertures in the holders Cleaning aperture holders Cleaning apertures Remounting aperture holders
Cleaning specimen holders	6.10 5.3.4 6.8	Removing a specimen holder from the microscope Cleaning specimen holders Inserting a specimen holder into the microscope
Cleaning film and plate holders	5.3.5	
Cleaning viewing surfaces	5.3.6	

Table 5.1, Operator maintenance

5.1 FLUSHING WITH DRY NITROGEN

In all cases where the high-vacuum parts of the electron optical column must be opened, e.g. when the Wehnelt assembly or aperture holders have to be removed, dry-nitrogen flushing is strongly recommended.

The inlet to the emission chamber is provided with a suitable connector for this purpose. Dry-nitrogen supply should be delivered by a flexible tube and the supply regulated to a pressure of 0.1 to 0.2 Bar.

Flushing should be continuous from the moment of operating:

- GUN AIR.
- COL AIR.
- ALL AIR.

Once the emission chamber or column tube has been opened, it is recommended to continue flushing until evacuation begins again (when the inlet will again be closed).

Note: This will not apply when, for any reason, the column is to be left open for a longer period of time.

5.2 GENERAL CLEANING PROCEDURE

Regular checks are essential to maintain the best performance.
It is stressed that cleaning is more successful if carried out before heavy deposits of contamination have been allowed to build up.
Moreover, charge effects on parts that have become heavily contaminated by the electron beam eventually cause instability of the image or illumination.
The goal is to clean the microscope parts with maximum efficiency during corrective or preventive maintenance, using a minimum of instruments, consumables and chemicals. The topics described in the text following are:

- Cleaning equipment and materials required
- Brand names for "JIF"
- Warnings, danger classification and safety advice
- Code of practice
- Five-phase cleaning flow chart
  Explanation of the chart
- Summary

This is a five-phase cleaning procedure, highly effective, using a minimum of equipment and materials, and producing good results when the instructions are strictly followed.

Note: The instructions given here supersede all previous cleaning instructions. Ignoring these, or only carrying them out in part will result in poor performance of the microscope and will necessitate recleaning.

5.2.1 Cleaning equipment and materials required

INSTRUMENTS:

- Ultrasonic cleaner
- Ultrasonic vapour degreaser (if available)
- Storage bottles (1l. size)
- Beakers, EM liner tube size and smaller
- Petri dishes
- Stereo light microscope (magn. 5x to 50x)
- Tweezers
- IR heating lamps
- EM special tools (removing of liner tube and diaphragms)

CONSUMABLES:

- Rubber gloves
- Safety goggles
- Lint-free clothes
- Lint-free gloves
- Dust-free tissue paper
- Grease-free cotton wool
- Wooden spills
- Aluminium foil
- "Gas Jet Duster" spray can

CHEMICALS:

- De ionised or distilled water
- Ethanol - C_2H_5OH
- Ethanol Pro Analysis (99.8% pure) - C_2H_5OH
- KOH (Potassium Hydroxide) or NaOH (Sodium Hydroxide)
- EXTRAN - MA02 (neutral cleaning fluid)
- JIF* or SOFT SCRUB (household fine abrasive cleaner)

Note: Only use recommended solvents.

Brand names for JIF

JIF	-	UK
		AUSTRALIA
		JAPAN
		NETHERLANDS
CIF	-	ITALY
		FRANCE
		AUSTRIA
VIF	-	SWITSERLAND
VIM	-	FINLAND
VISS	-	GERMANY
SOFT SCRUB	-	USA

E. MERCK - Darmstadt - W. Germany
or 84 MERCK representatives.
Worldwide supplier of:

Ethanol
KOH
NaOH
EXTRAN MA02

Danger Classification:

R11 : Highly inflammable
R35 : Cause severe burns

Safety advice:

S2 : Keep out of reach of children
S7 : Keep stored under sealed conditions
S16 : Keep away from igniters
Do not smoke
S26 : By contact to the eyes, rinse profusely with water,
S37/39 : Wear protective gloves and facial protection devices

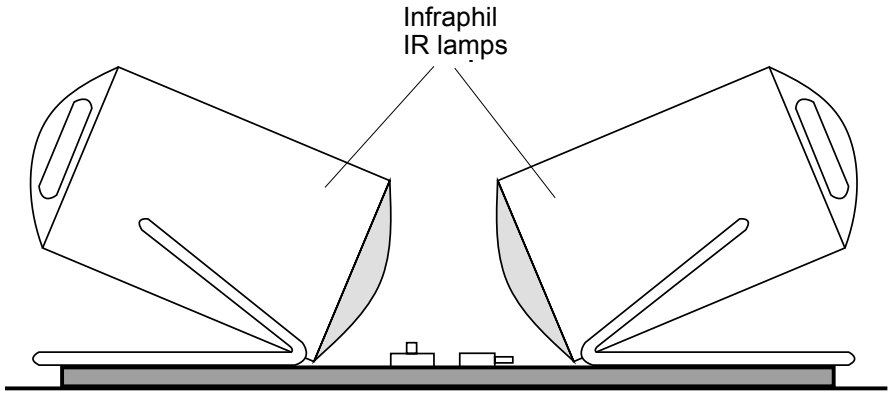
WARNING! **As cleaning solvent Ethanol is highly inflammable, do not use open flames, or smoke while cleaning.**

KOH and NaOH are corrosive solvents, prevent skin contact.

Ventilate the room properly.

5.2.2 Code of practice

- Do not open the column unless it is really necessary, but check the performance regularly; see Chapt. 4.
- Always work in a clean and ***ventilated*** room
- Use a clean working table with good illumination
- Wear lint-free clothes
- Always wear clean gloves when handling "vacuum" parts
- Always use CLEAN solvent
- Before mounting, inspect parts under a light microscope
- Be sure that special tools are clean before use and packed after use in aluminium foil
- Do not mix materials of different compositions in the cleaning baths
- Strip the assemblies as far as possible
- Pack items in aluminium foil after cleaning
- Collect all cleaning items and have them on site before opening column
- Vacuum parts that cannot be remounted immediately can best be wrapped in aluminium foil and kept under an infra-red lamp.



Drying electron optical items with IR lamps

FOR EXPLANATION OF THE FLOWCHART - SEE NEXT PAGE.

EXPLANATION OF THE FLOW CHART

PHASE 1:

Heavily polluted metal parts:

Rub cleaning must be done using "JIF" or "SOFT SCRUB", a household fine abrasive.
Rinsing in water.

Wehnelt (cylinder, apertures):

Ultrasonically cleaned for 30 min. in a 6% dilution of NaOH or KOH in distilled water at 20 °C, rinsing done in water.
The KOH and NaOH dilutions are corrosive solvents, prevent skin contact. Use a fume cupboard.
Raising the water temperature increases the cleaning effect.

PHASE 2:

Less polluted metal parts and parts coming from phase 1:

Ultrasonically cleaned for 5 min. in a 5% dilution of "EXTRAN MO2" in water. Raising the temperature increases the effect.
This soap solution binds the dirt and removes it from the surface of the part.
Rinsing is done in distilled water; raising the water temperature increases the effect.

PHASE 3:

O-rings, synthetic materials and assemblies (which cannot be stripped down in the field) start their cleaning sequence from this point.

Ultrasonic cleaning in Ethanol for 5 min. at 20 °C, to remove the water.
Rinsing in a new clean bath of Ethanol for 2 min.

Ethanol is highly flammable, do not use open flames, or smoke while cleaning.

PHASE 4:

This phase must be skipped for ***O-rings and synthetic materials.***

Ultrasonic cleaning in Ethanol - pro analysis (99.8% pure), to be sure all water and traces left by Ethanol in phase 3 are removed.
Rinsing for 2 min. in a new bath with Ethanol p/a.

If available, an ultrasonic vapour degreaser can be used.

PHASE 5:

The parts must be dried with the aid of two 150 W Infra Red lamps (INFRAPHIL). To reach a temperature of 80 °C, heating by the IR lamps must be maintained for a minimum of 15 min., or, for heavy items and the emission chamber, for 2 hrs or more.

If available, a vacuum oven can be used and set to 80 °C.

When mounted into the microscope and external heating is applied, the temperature must kept under 100 °C, otherwise damage to encapsulated items will occur.

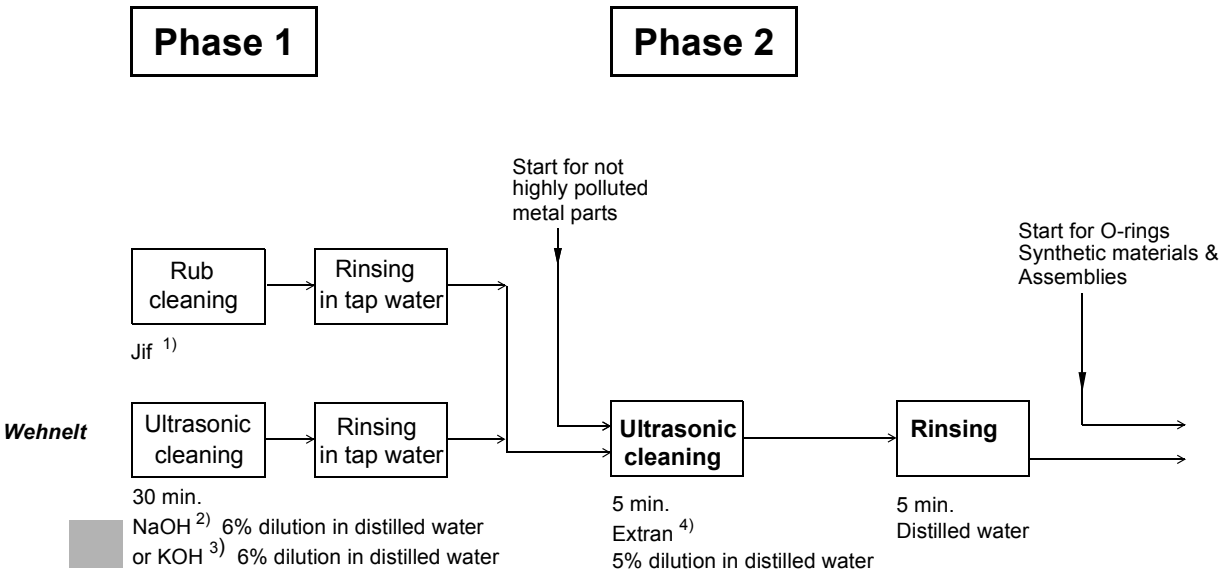
O-rings must not become warmer than 70 °C and can best be dried in air.

Parts should only be handled after they have cooled down below 50 °C.

Spray the part with a gas jet duster, to remove any dust particles or fibres before inspection.

After inspection under a light microscope, mount the parts directly into the Electron Microscope and spray with the gas jet duster again before closing the microscope.
If parts are not mounted but stored, pack them in aluminium foil.

General cleaning procedure for Electron Optical Instruments;
for parts that are in contact with the **electron beam**
and are in **vacuum**.



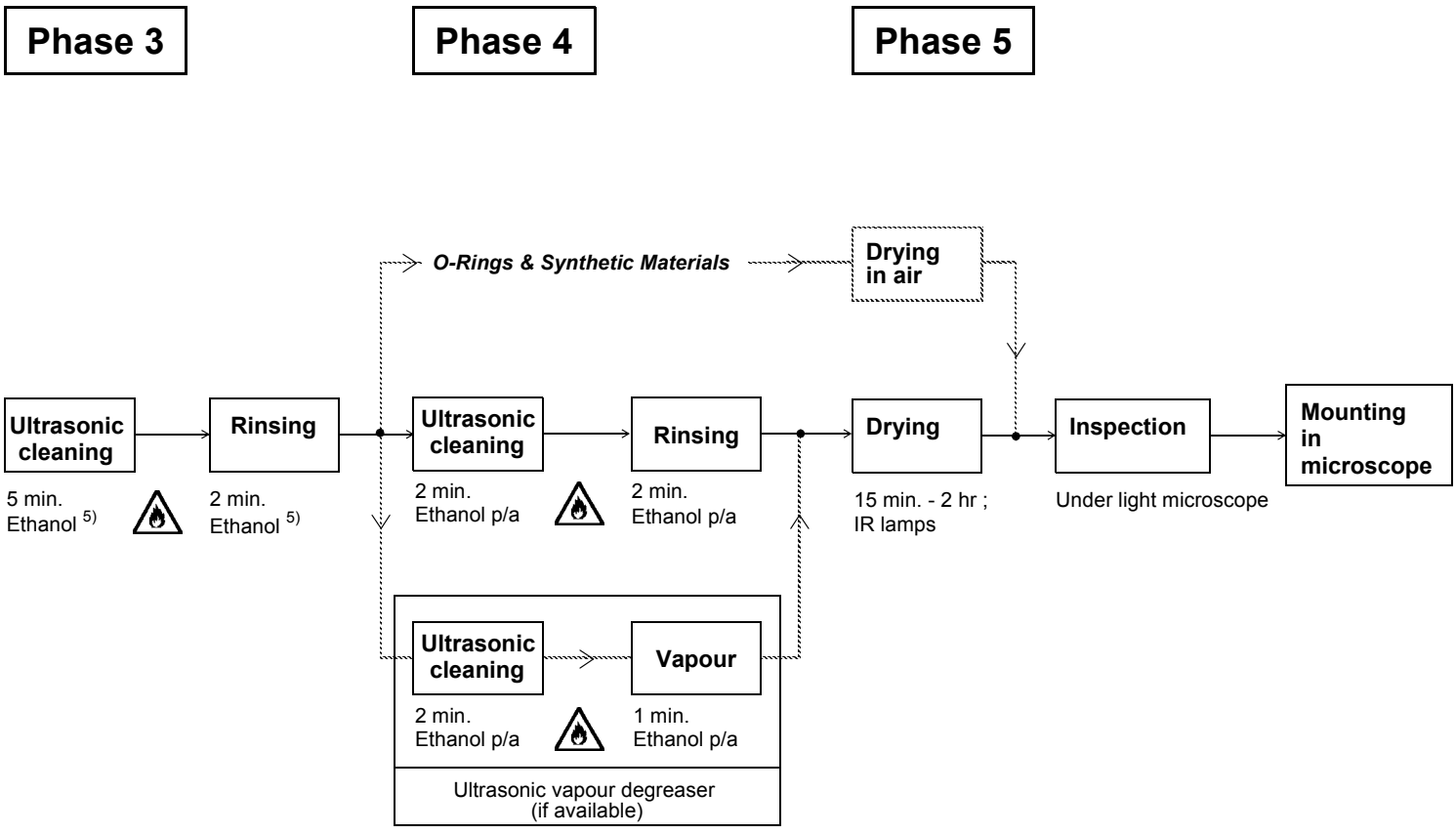
1) Jif or Soft Scrub: household fine abrasive

2) NaOH: Sodium Hydroxide

3) KOH: Potassium Hydroxide

2) 3) R: 35 S: 2-26-37/39

4) Extran: Industrial soap (neutral)
for instruments cleaning
- Extran MA02 - (non reactive cleaning fluid)
- Raised water temperature increases the effect



5) Ethanol: C_2H_5OH

R: 11 S: 7-16

Ethanol p/a: C_2H_5OH

R: 11 S: 7-16

5.3 SPECIFIC CLEANING PROCEDURES

The frequency of cleaning required will depend on many factors. The following check list is a recommendation only.

Components	Frequency
Projection chamber windows	As necessary
Binoculars	As necessary
Wehnelt aperture	Every new filament
Wehnelt assembly	Once a year (W) Once every three years (LaB_6)
Aperture holders Apertures Specimen holder (and specimen)	As necessary, depending on astigmatism

Table 5.2, Frequency of cleaning components

5.3.1 Cleaning the Wehnelt assembly

a) Wehnelt cylinder and aperture (Fig. 5.1, items 8 and 10)

1. Remove the Wehnelt aperture-securing ring (11) and support ring (9) together with the Wehnelt aperture (10).
2. Remove the spring ring (13).
3. Follow the general cleaning procedure given in sect. 5.2, starting with phase 1.

b) Wehnelt main assembly (1): filament-securing ring (6) and spring washer (7); aperture support (9) and securing ring (11); Wehnelt cylinder spring ring (13) (Fig. 5.2)

Clean, following the procedures given in section 5.2 starting with phase 2.

Note: When changing a filament, it is advised that the Wehnelt aperture should be changed at the same time and save cleaning of the apertures until the complete Wehnelt assembly is cleaned.

5.3.2 Cleaning aperture holders

Follow the procedure given in section 5.2, starting with phase 1 or 2 depending on the degree of pollution.

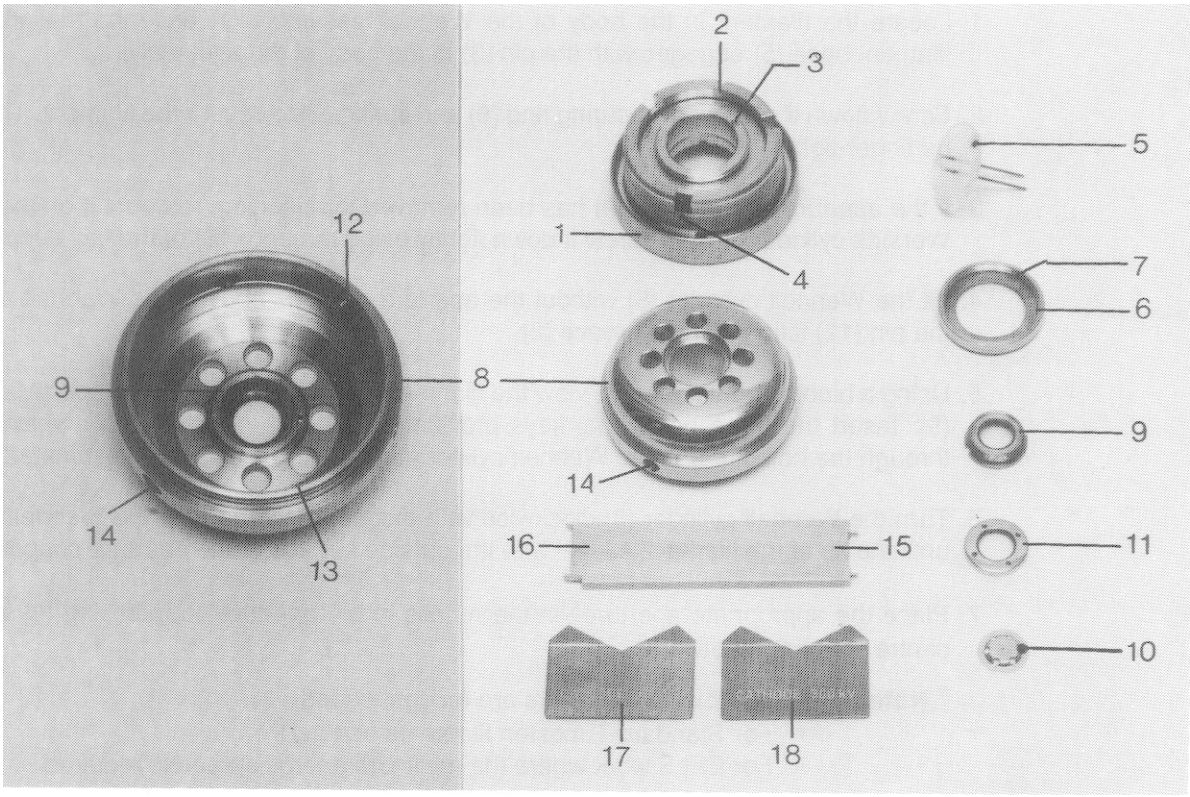


Fig. 5.1, Wehnelt assembly - Component parts and key for mounting and dismounting the aperture

5.3.3 Cleaning apertures

a) 3 mm Platinum type

Use one of the following methods:

Method 1

1. Heat the aperture (held in special tweezers with platinum points) in a clean gas flame until white hot.
2. Ensure that the aperture does not melted or become stuck to the tweezers.

Method 2

1. Connect a V-shaped (approx. 2 cm long) platinum-foil boat across the low-voltage secondary winding of a transformer, e.g. shadow coating unit, and heat until white hot.
2. Place the aperture on the white-hot foil for a few seconds.
3. Take care that the aperture does not melt or become stuck to the foil.

Method 3 (see Fig. 5.2)

1. Place the aperture on edge in a V-shaped platinum-foil boat (approx. 2 cm long) and hold the boat in a clean gas flame, using the special platinum-tipped tweezers, until the aperture is heated to a white colour. Maintain colour for 15 - 30 s.

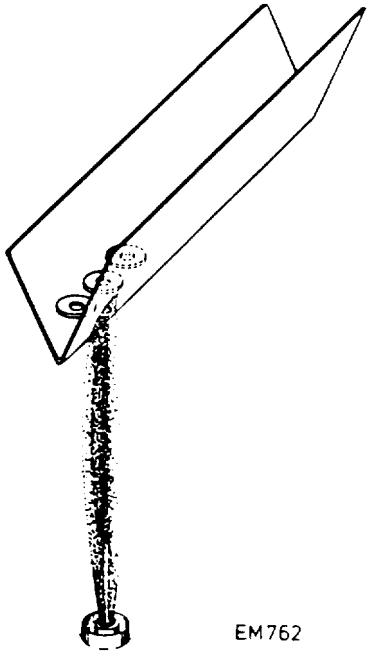


Fig. 5.2, Cleaning apertures

Method 4

1. Place the aperture on a V-shaped piece of molybdenum foil which has been connected to the source leads of a shadow coating unit using a vacuum of 10^{-5} Torr.

2. Heat the aperture to a cherry red colour and maintain this condition for 30 seconds. Allow the aperture to cool and then remove it from the foil.

b) Thin-foil type

In general, these do not need cleaning. The manufacturer suggests that, if necessary, they can be cleaned in the microscope by heating the edge with the focussed beam. Care is required in this kind of treatment or they could be melted.

Caution! 1) These apertures are very fragile and are easily damaged by tweezers or sudden rushes of air into the vacuum system.

2) Do not clean using the techniques described for platinum apertures.

5.3.4 Cleaning specimen holders

Since contamination of the specimen holder can have a considerable adverse influence on the image quality, a regular check of cleanliness is necessary.
When mounting a specimen, it is advisable to check whether there are (in general brown) deposits or parts of former specimens remaining on the holder. If there are, cleaning is necessary.
It is strongly advised that this is done by the service engineer during a preventive maintenance visit.

5.3.5 Cleaning film and plate holders

During normal operation in a laboratory, the containers for photographic material (plate holder, plate magazine) will be stored for longer or shorter periods in the darkroom where the conditions are, in general, not ideal for components which are intended for high-vacuum use. Even normal handling will introduce skin grease and humidity into the vacuum system.
Therefore, ensure that these components are free of such contamination before introducing them into the vacuum and to check their cleanliness regularly. If necessary they should be cleaned with a degreasing solvent such as ethanol p.a. in an ultrasonic cleaner.

5.3.6 Cleaning viewing surfaces

Clean the outside of the viewing chamber windows and the outside of the binocular glasses regularly. This is done by rubbing with a soft cloth or lens paper. Excessive dirt or grease is removed by using any commercial domestic glass cleaning solvent.

6 COMPUSTAGE GONIOMETER

6.1 INTRODUCTION

The CompuStage is a motor-driven goniometer, which provides computer-controlled movement of the specimen on all five axes (X, Y, Z, α, ß). The CompuStage consists of the following basic elements:

- Hardware called the goniometer, including motors and measuring system, which continuously measures the actual specimen position.
- Control electronics GNCB. The motors are controlled by a microcontroller located on the GoNiometer Controller Board (GNCB).
- Software for the user interface which translates the operator input into CompuStage actions. Operator commands are made via softkeys on the CompuStage control pages displayed on the microcontroller screen.
- Joystick pad for control of X, Y (one joystick) and Z (second joystick) movement. The alpha-tilt and beta-tilt motors are driven via knobs on the left-hand panel.

The CompuStage has some unique features, which make its use very easy, safe and effective:

MaxiTilt system
This system ensures that for every specimen position the physical maximum accessible tilt is allowed with complete safety of holders and pole pieces.
The maximum tilt angle for a given specimen depends on the combination of the types of pole pieces, the dimensions of the specimen holder, and the X, Y, Z position of the specimen. The exact dimensions of the pole pieces and the holder actually used are stored in the memory of the microscope. A direct measuring system measures the specimen coordinates and allows the operator to achieve the maximum possible tilt for every position. Just before the holder reaches an unsafe position, the microscope gives an acoustic signal and stops the movement of the specimen to prevent damage to either the holder or the pole pieces.

SafeEntry system (see Chapter 6.7)
This system prevents insertion of non-compatible holders and extraction of holders under unsafe conditions.
The SafeEntry system consists of a SafeEntry key defining the holder dimensions and a SafeEntry lock defining the pole piece dimensions. The SafeEntry key consists of a characteristic (in size and shape) pin on the specimen holder while the SafeEntry lock is a switch on the CompuStage.

5D recall (option, see Chapter 6.13.2)
Makes it possible to store and recall all five coordinates (X, Y, Z, α, ß) of up to 25 positions. All coordinates are also accessible via user definable external remote control software.

Rotation Correction (see Chapter 6.13.3)
After alignment, the joystick positions and image movements are related to each other. It means that if the joystick is held in a particular direction, the specimen movement will follow this direction.

TV speed (see Chapter 6.13.3)
With this softkey activated, the speed of specimen movement automatically decreases when the fluorescent screen is raised to enable the use of a TV system.

A-wobbler (see Chapter 6.13.2)
This function is used for adjusting the eucentric height. The α-tilt is changed continuously between ±15° (for UltraTWIN ±5°).

Speed +/– (see Chapter 6.13.3)
It is possible to change the specimen speed on the screen for a given joystick position depending on the demands of the operator. For a specific setting this speed is nearly independent of the magnification.

6.2 USE OF SPECIMEN HOLDERS - GENERAL INFORMATION

The following general instructions apply to all specimen holders:

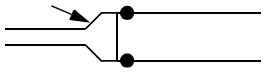
1. When handling parts of the specimen holders that enter the vacuum (i.e. beyond the sealing O-ring), always use clean nylon or similar gloves.

2. The specimen, spacing washers and clamping devices should only be manipulated using pointed tweezers and the special tools provided. These should be maintained in a clean condition.

3. The O-ring on the rod should be checked for possible dirt and excessive quantities of grease, although it must not be completely dry. A very light coating of Fomblin grease (delivered with the microscope) is advised. Take care not to apply grease to the conical part of the holder next to the O-ring.

4. When a specimen holder is not in use, either cover it with the protective cover provided and store it in its box, or reinsert it into the microscope. Keep the specimen support clean and store it in the box when not in use.
   Keeping the holder in the microscope minimizes temperature differences between the holder and the microscope, and thereby reduces drift after holder insertion.

5. The conical surface between the thick and thin diameters of the specimen holder rod (see illustration) seats against the CompuStage. therefore always keep this surface clean to prevent drift problems.



6.3 TYPES OF HOLDERS

The CompuStage allows the use of a wide range of holders with the Safe Entry lock in the "SELECT" position. Just before inserting a holder completely into the microscope the user is automatically asked to choose the correct holder on the holder selection page (see Fig.6.1). On pressing the softkey "MORE", the user is shown successively a list of all available holders. Holders which are compatible with the EM400/CM200-series are indicated by "MANUAL" for the manual goniometer, while CompuStage holders are indicated by "COMPUSTAGE". Further abbreviations on the holder selection page are "PH" for Philips holders, "GAT" for Gatan holders and "OX" for Oxford holders.

6.3.1 CompuStage holders

CompuStage holders are easy to recognize by their Safe ENTRY key (see Fig. 6.2). The Safe ENTRY key is a pin which characterizes the dimensions of the holder and, together with the Safe ENTRY lock on the CompuStage, prevents introduction of holders whose dimensions are not compatible with the actual pole piece. While the standard single tilt holder for the TWIN and SuperTWIN lens is identified by a small rectangular pin, all other holders have a circular Safe ENTRY key whose diameter depends on the holder dimensions. The Safe ENTRY key fits into a hole or a slit in the Safe ENTRY lock of the CompuStage which characterizes the actual pole piece (TWIN, SuperTWIN or UltraTWIN, see also Sect. 6.8). In this way it is, for example, never possible to insert into the UltraTWIN a holder other than the special UltraTWIN double tilt holder, which is much thinner than the other holders. CompuStage holders can be inserted into the microscope by using either the "SELECT" or the "NON SELECT" position on the Safe ENTRY lock.

6.3.2 Manual holders

Manual holders are Philips holders of the EM400 or CM200 series or third-party holders. These holders have a sapphire on the tip and no Safe ENTRY key. While these holders are compatible with the CompuStage there are also some disadvantages so that special care is needed, viz:

1. Because these holders have no Safe ENTRY key, the insertion of a non-compatible holder is not prevented by the Safe ENTRY system.

   Caution! Always use the SELECT Position of the Safe ENTRY lock for insertion of a manual holder. Only in this way can the microscope use the dimensions of the actually used manual holder, which is of vital importance for the MaxiTilt system.

2. The sealing O-rings for CompuStage holders are slightly thicker than those for manual holders which fit into the manual stage. This means that the O-ring must be changed every time when going from the manual stage to the CompuStage, and vice versa.

   Caution! Always exchange the sealing O-ring when using a manual holder in the CompuStage and vice versa. Remove the O-ring from the holder by squeezing the O-ring across its outer diameter between the thumb and forefinger, so as to create a bulge. Roll the bulge towards the tip of the holder with a finger of the other hand. In this way the O-ring can be removed wthout damage. Do not use metal tools (e.g. tweezers, screwdriver) to lever the O-ring out of its groove, as this often results in damage to both the O-ring and the holder.

3. The construction of CompuStage holders is optimized in order to minimize specimen drift, which is specially important for high-resolution work.

   Note: The short-term drift for manual holders may be higher than that for CompuStage holders.

6.4 THE SINGLE-TILT SPECIMEN HOLDER (FIG. 6.2)

(CM200, TWIN and SuperTWIN).

This holder is designed for general purpose use and will accept 3.05 mm Ø grid-supported or disc-shaped specimens with edge thickness up to 0.34 nm. The holder accepts standard 3 mm grids as well as a specially shaped grid which can only be inserted into the holder in one specific way (see Fig. 6.2.d). With this reproducibly insertable grid it is possible to retrieve areas of interest in a particular specimen even after the specimen has been removed from the holder.
The holder comprises a rod (1) with a Safe ENTRY key (2) and a tip at the end (3) in which the specimen is located. A viton O-ring (4) seals the goniometer airlock entry and a pin (5) opens the airlock to allow insertion of the holder into the microscope.

6.5 MOUNTING A SPECIMEN IN THE SINGLE-TILT HOLDER (FIG. 6.2)

(CM200, TWIN and SuperTWIN).

1. Check that the tip of the holder and the clamping device are clean and dry.
2. Rest the holder on its support (6) with the spring clamp (7) horizontal and uppermost, ensuring that the tip (3) is properly supported by the recess in the block (8).
3. Fit the tool (9) (stored in the support) into the hole in the front of the clamp then lift the clamp (7) to its fullest extent.
4. Carefully place the specimen in the carrier (10).
5. Carefully lower the clamp onto the specimen (or grid) using tool (9). Make sure that the specimen remains correctly in position.

   Caution! The specimen-securing clamp must be lowered carefully, otherwise the specimen can be damaged, resulting in specimen/image instability.

6.6 REMOVING A SPECIMEN FROM THE SINGLE-TILT HOLDER (FIG. 6.2)

(CM200, TWIN and SuperTWIN).

1. Rest the specimen holder on its support.
2. Lift the clamping device.
3. Remove the specimen by inverting the holder over a Petri dish or filter paper.
4. Store the holder with the specimen securing clamp closed.

6.7 THE SAFE ENTRY SYSTEM

The CompuStage has a so-called Safe ENTRY system that prevents insertion of non-compatible holders, and extraction of holders under unsafe conditions. The Safe ENTRY system consists of a Safe ENTRY key, which is a pin projecting from the specimen holder (Fig. 6.2), and the Safe ENTRY lock (Fig. 6.3). The Safe ENTRY lock is a switch on the CompuStage with an opening in which the Safe ENTRY key should fit. If the Safe ENTRY key does not fit it means that this holder is not compatible with the pole pieces of the microscope; thus it is not possible to insert the holder. The Safe ENTRY lock is illustrated in Fig. 6.3. Two different positions of the switch are possible, i.e. the **SELECT** and the **NON-SELECT** positions.

The **SELECT** position.
In the SELECT position the user is obliged to make a choice from a list of holders (holder identification). The exact dimensions of every holder are stored in the memory of the microscope and are recalled when identifying the holder. With this information the "MaxiTilt system " measures the actual 5D position 800 times a second and stops the movement of the specimen when a physical boundary in 5D space is passed by one of the sides of the holder actually inserted. The SELECT position must be used for manual holders because the NON-SELECT position does not prevent insertion of non-compatible manual holders (lack of Safe ENTRY key). The SELECT position must also be used for all CompuStage holders except the standard single tilt holder, otherwise (in the NON-SELECT position) it is not possible to insert the holder.

The **NON-SELECT** position
This position may be used for routine work with the standard single tilt holder. In this position the user can insert the holder without holder identification (no holder selection page is visible). Insertion of a holder other than the standard single tilt CompuStage holder is not possible in the NON-SELECT position. The user is then forced to switch over to the SELECT position and to select the correct holder on the holder selection page.

Caution! The safety switches (SELECT, NON-SELECT) do not prevent or detect any unwanted insertion of manual holders without a Safe ENTRY key (Philips holders or third party holders).

6.8 INSERTING A SPECIMEN HOLDER INTO THE MICROSCOPE

Caution! The following instructions apply to all specimen holders and must be followed completely, or damage to the airlock, specimen holder or specimen stage may result.

The holder is inserted through a pre-pumped airlock which ensures that air, introduced with the holder, is pumped away before the airlock is opened to the microscope column.

Note: 1) Although it is not necessary to switch off the filament or H.T. when changing specimens, care must be taken that the beam intensity on a new specimen is not too high in order to prevent beam damage to the specimen. It is advisable to reduce filament emission by 5 to 10 steps before inserting holders.
To prevent dangerous X-ray radiation from leaking out through the airlock, the GUN SHIFT controls are set to their maximum values when no specimen holder is in the goniometer. Even though the filament may be on, no intensity will be visible on the

screen. The beam will return to its normal position when a specimen holder is inserted into the airlock.

2) Always carry out the complete insertion procedure. If the specimen is left in a retracted position, vacuum leakage can occur with consequent contamination.

Insertion Procedure (Fig. 6.4)

1. Choose the SELECT or NON-SELECT position on the Safe ENTRY lock of the CompuStage.

   NON-SELECT for routine work with the standard single tilt CompuStage holder.
   SELECT for all other holders (CompuStage and manual holders without Safe ENTRY key).

2. Hold the specimen holder with the airlock-opening pin (Fig. 6.2) parallel to the small slit in the goniometer-cap (Fig. 6.3). Carefully insert the end of the specimen holder into the airlock entry and slide it in until a stop is reached. At this point pre-pumping of the airlock commences as indicated by illumination of the red airlock indicator light.

3. For a double tilt or rotation holder: Connect cable plug. Ensure that the goniometer holder knob is in the central position.

   Caution! As long as the red airlock indicator lamp is illuminated, the specimen holder may neither be inserted nor extracted.

   If the Safe ENTRY lock is in the "NON-SELECT" position continue with 4).
   If the Safe ENTRY lock is in the "SELECT" position the microcontroller display will show the holder selection page (for a detailed description see 6.13.1). Choose the correct holder by pressing the corresponding softkey and **confirm with "READY"**. The holder selection page is then removed from the screen.

4. Wait until the airlock indicator light is extinguished, rotate the holder about 120° counter-clockwise (see Fig. 6.4) as far as it will go, then allow it to slide in as far as it will go.

   Caution! Maintain a firm grip on the holder during insertion. If it is allowed to enter the column too quickly, due to suction by the vacuum, damage to the goniometer movements and holder can occur.

   If the Safe ENTRY key does not fit into the Safe ENTRY lock it is not possible to insert the holder completely. There could be two reasons for this, i.e.:

   1. The Safe ENTRY lock is in the "NON-SELECT" position and another than the standard single tilt holder is used. In this situation choose the "SELECT" position.

   2. The Safe ENTRY lock is in the "SELECT" position. In this situation the holder is not compatible with the pole piece, and must not be used in this microscope.

5. Carefully tapping the holder with the finger may help to improve the short-term drift.

6.9 ADJUSTING THE SPECIMEN HEIGHT TO THE EUCENTRIC POSITION

After changing specimens or field of view, it is necessary to readjust the specimen height to bring the centre of the field of view onto the tilt axis. This is needed to bring the specimen to the optimum optical position relative to the objective lens. Thereafter, when the specimen is tilted, the centre of the field of view will remain at the centre of the screen with the precondition that the tilt axis intersects the optical axis (see Fig. 6.5).

Note: The tilt axis is adjusted in the factory and should only be reset by the service engineer.

There are two possibilities for adjusting the eucentric height:

1. Using the AUTOfocus (only applicable if alignment has been carried out correctly)
   - Press the AUTOfocus pushbutton. This automatically brings the focal plane of the objective

lens onto the tilt axis. Focus the image using the Z-joystick. If z-movement does not work, activate Z-joystick on the CompuStage Control page.

2. Using the A-wobbler

   - Key CompuStage to switch over to the CompuStage Register Control page
   - Key A-wobbler; the specimen is now tilted continuously from +15° to -15° and back.
   - Minimize image movement at the screen centre using the Z-joystick
   - Key A-wobble again to stop α-tilt.

   Note: If the microscope beeps during use of the A-wobbler, the maximum tilt angle for the given specimen position has been reached. Readjust the X, Y, Z, beta position close to zero and press A-wobbler again. If the microscope beeps again during tilting, the actual holder does not allow ±15°. Insert the single tilt holder and press A-wobbler again. If the microscope still beeps during tilting, call service.

6.10 REMOVING A SPECIMEN HOLDER FROM THE MICROSCOPE

Whenever it is inadvisable to extract the specimen holder, the red airlock indicator is lit: this occurs whenever the holder is not in a safe position.

1. Make sure that the holder is in a safe position by
   pressing **RESET AB** or **RESET holder** for the TWIN and SuperTWIN lens and
   pressing **RESET holder** for the UltraTWIN lens
2. Pull the holder out as far as it will go then rotate it clockwise as far as it will go.
3. Carefully extract the holder from the airlock.
4. For double tilt and rotation holders disconnect the cable plug.

Caution! Always remove the holder completely from the specimen airlock. If the specimen is left in a retracted position, vacuum leakage can occur with consequent contamination.

6.11 SPECIMEN TILT

Specimen tilt along the holder axis (α) is accomplished via the Tilt-knob on the left hand panel. The direction of turning gives the direction of tilt (+ = right, – = left) . The + tilt direction is defined as clockwise when viewing along the holder (towards the EDX detector). The speed of tilt increases continuously between zero and the maximum position. From Figure 6.6 it can be seen that for a small range around zero the speed remains zero. In this way the knob indicates the tilt direction last used.

6.12 OPERATION OF BUILT-IN SPECIMEN HOLDER MOVEMENTS

Several specimen holders incorporate a movement which is driven by a built-in motor and gearbox. Control of the drive is achieved by means of a footswitch and the GONIOMETER HOLDER knob.
The cable between the holder and the CompuStage must be connected before making a choice for a special holder on the holder selection page (see Chapt. 6.8 step 3). The GONIOMETER HOLDER knob varies the speed and direction of the drive. The footswitch allows the immediate arrest of the movement without the time lag associated with returning the control to its zero position.
The operational procedure is as follows:

1. Ensure that the GONIOMETER HOLDER knob is in the central position.
2. Press on the footswitch.
3. Adjust the GONIOMETER HOLDER knob to the desired direction and speed of drive.

6.13 THE COMPUSTAGE PAGES

There are two extra pages (microscopes without 2D & 5D recall) or three extra pages (microscopes with 2D & 5D recall) on the microcontroller which are related to the CompuStage. These are the CompuStage control page, the CompuStage register control page, a combination of these two pages for microscopes without 2D & 5D recall, and the specimen holder selection page which is only visible when inserting a holder in the SELECT position. The page sequence is shown in Fig. 6.7.

6.13.1 The specimen holder selection page

The purpose of this page is to oblige the user to select the holder which is to be inserted. When a specific holder is chosen, the exact dimensions of this holder are loaded. In this way it is ensured that the "MaxiTilt system" works correctly. The specimen holder selection page is automatically displayed when the user starts the insertion of a specimen holder with the Safe ENTRY lock in the "SELECT" position. If no holder is chosen, and "READY" is pressed, it is not safe to insert a holder if the red airlock led remains lit. The page for various situations is shown in Fig. 6.8a, b, c.
Fig. 6.8a shows the holder selection page after a default RAM init. The page shows only the softkey function "MORE". On pressing this key, the page changes to that shown in Fig. 6.8b, and the seven softkeys on the right are then instantly labelled with holder names. On pressing "MORE" repeatedly, this page shows successively all the various holders available, including all CompuStage holders and all manual holders from Philips and third party holders. If the name of the correct holder is found, one can select it by pressing the corresponding softkey followed by "READY". Only after the softkey combination "holder name - READY" is made will the holder selection page vanish from the screen. In practice it is not desirable to go through all the available holders in order to find the holder to be inserted. Instead, it is possible to make a set of user defined specimen holders which are normally used in the microscope, and to place this set on the left side of the screen (Fig. 6.8c).

Making a user-defined set of specimen holders

- press "MORE" repeatedly until the desired holder name becomes visible
- press the corresponding softkey
- press the softkey on the left side of the screen where you wish to locate this holder name.

Changing the user-defined set of specimen holders

- press "MORE" repeatedly until the desired holder name becomes visible
- press the corresponding softkey
- press the softkey on the left side of the screen labelled with the holder to be replaced (this could also be a free field).

Removing a holder from the user-defined set of specimen holders

- Select a softkey on the right side labelled with spaces
- Press the softkey on the left side labelled with the holder name to be deleted.

The insertion of a holder from the user defined set works in the same way as that described above: activate the desired holder by pressing the corresponding softkey on the left side followed by "READY".

6.13.2 The CompuStage register control page (CM200 with 2D & 5D recall)

The CompuStage register control page is activated by pressing the softkey "CompuStage" on the main menu. The page is shown in Fig 6.9 together with a short explanation of the various softkeys. The bottom five centre lines display the current position of the CompuStage. While X, Y gives the actual specimen position, Z gives the height of the specimen, A gives the α-tilt and B the ß-tilt of the specimen. If the current selected specimen holder has no tilt, the B-value is defined (and thus displayed) as zero.

The right part of the display is used to save, restore and display the points of interest. The maximum number of points that can be saved is 25. The stored location is characterized by the five (or two) coordinates for X, Y, Z, α, ß that are displayed on the right side of the screen.

Storage of positions "STORE"

- Move with the joystick to the desired position; coordinates are displayed at the bottom-centre of the screen
- Press "STORE". The currently selected register (reversed video) will be updated with the values of the current location. If the currently selected register already contains another position, the first empty register after the one currently selected will be updated with the actual coordinates. This register then becomes the currently selected register.

Recall of positions "RECALL", Changing displayed position

- Activate the desired position by pressing the corresponding softkey. If the desired position is not displayed (only 3 or 6 positions with 5 or 2 coordinates, respectively, can be displayed, see Chapter 6.13.3) press the softkey corresponding to the top or bottom displayed register twice. In this way one pages the positions up or down. Pressing the softkey labelled with the top register while this position is current causes a page down of the position: the bottom register then becomes the top one. In the same way one pages up by pressing the softkey corresponding to the bottom register while this position is current.
- Press the "RECALL" softkey. The CompuStage moves to the currently selected position. If there are no values stored in the currently selected position or a RECALL is already being performed, a beep will be sounded. As long as the CompuStage is busy with the required recall, the word RECALL is highlighted in inverse video.

Note: One can improve the reproducibility of the XY recall by reaching the point of interest A always from the same direction. This could be done by storing another point B close to the one of interest, then reaching point A always via point B.

Z DISPL REAL/USER

Real: The real Z-coordinate is displayed. This value is an absolute value and depends only on the physical position of the holder between the pole pieces.

User: The Z-coordinate is a relative value depending on the user wishes. The user setting is helpful if, for example, all movements in the z-direction should be related to the eucentric height. The user can then define the eucentric height as zero by pressing **Z DISPL=0** and all further displays in Z will be related to this setting.

Z DISPL=0

If the Z DISPL=0 button is pressed, the Z-value of the current location is defined as the origin of the Z-axis. All displayed Z-values are then related to this null point.

CLEAR

On pressing this softkey once, the currently selected register is displayed in reversed video. On pressing it a second time, the register will be cleared. If another softkey is pressed directly after pressing CLEAR, the function is cancelled.

CompuStage

This softkey is used to switch to the Compustage control page.

CLEAR ALL

On pressing this softkey once it will be displayed in reversed video. If it is pressed again all registers will be cleared. If another softkey is pressed directly after pressing CLEAR ALL, the function is cancelled.

XY RECALL

This is a toggle key. When it is off (normal video), the RECALL function acts on all five parameters. When it is on (inverse video), the RECALL function acts only on the X and Y parameters: the values of ZAB will be ignored.

Note: This function only affects the RECALL button; with the STORE button one will still save all five parameters.

A-WOBBLER
This function is mainly used to adjust the eucentric height with the Z-joystick. On activating this function (inverse video) α is continuously changed between ±+ and -15° (for UltraTWIN + and -5°)

RESET AB
On activating this softkey α and ß are reset to zero, for example to bring the specimen holder to a safe position before removing it from the microscope.

6.13.3 The CompuStage control page (CM200 with 2D & 5D recall)

Fig. 6.10 shows the CompuStage control page with a short description of the various functions. These softkeys are explained in more detail below.

ROTATION
This softkey is needed for rotation correction of the xy joystick. With this alignment the movement of the joystick is correlated to the movement in the image. It means that when the joystick is held in a particular direction, the image also moves in this direction. This alignment should be carried out once for every magnification and then, if possible, stored on a remote control computer. These values only need to be recalled from the remote computer after a RAM init. The rotation correction procedure comprises two steps:

- centre a recognizable point and press "ROTATION"
- move the recognizable point to the top of the screen and press "ROTATION" again.

Using the locations of these two positions, the microscope calculates the rotation of the image with respect to the specimen. The inaccuracy of this alignment is max ±45° when using XY SEPARATELY, which is recommended for higher magnifications. For low magnifications one can deactivate XY SEPARATELY; the inaccuracy is then much less.

REGISTERS DISPLAY ZAB
This softkey influences the display of the position coordinates on the CompuStage register page.

Activated: For each position all 5 coordinates XYZαß are displayed. Therefore only three position can be displayed at the same time.
Non active: Display only XY-coordinates. In this way it is possible to display 6 positions at a time.

The display does not effect the other functions: all STORE and RECALL actions are active on all five axes.

JOYSTICKS
This softkey enables (inverse video) and disables the use of the XY-joystick and the α, ß-tilt. This may be useful, for instance, if the CompuStage is controlled by another program or if the specimen should not be moved.

JOYSTICK Z
This softkey enables (inverse video) and disables the use of the Z joystick, to prevent unwanted movement in Z (e.g. if the joystick is touched by accident).

XY SEPARATELY
This key changes the functioning of the XY joystick. If activated (inverse video) X and Y movements will not be performed simultaneously. Joystick movements in the area between 45°-135° and between 225°-315° result in X or Y movements only (depending on rotation correction). Joystick movements in the remaining areas will result in a perpendicular movement only. The practical use becomes clear from Fig. 6.11. Fig. 6.11.a shows the image movement from point A to B with XY SEPARATELY off. With the joystick held in the direction AB the movement occurs in small x/y steps. For low magnifications this appears as a fluid movement because the steps are very small. On increasing the magnification the steps become more and more visible. At a certain magnification, it will normally be easier for the operator to proceed with XY SEPARATELY on, first in one direction followed by a perpendicular movement in order to reach

the desired image feature. This is illustrated in Fig. 6.11b. This mode is thus very helpful for higher magnifications where the specimen movements are made in visible small steps. For low magnifications, however, where the x/y steps are too small to be seen, XY SEPARATELY should not be activated.

SPEED+ / SPEED–
With these softkeys it is possible to change the speed range of the specimen movement to a personal preference. While 1 is a default value which gives nearly the same image speed on the fluorescent screen for all magnifications, this value can be changed to a maximum of 8 (eight times faster) and a minimum of 0.125. The maximum speed for low magnifications (LM range) is about 0.1 mm/sec. and is given by the maximum speed of the XY-motors. It cannot be increased with **SPEED+**.

TV SPEED
If this function is activated (inverse video), the speed of the specimen movement is reduced by a factor of three when lifting the fluorescent screen. In this way one can compensate for the additional magnification of a TV system, which makes a lower image speed necessary. If a wide angle TV camera is mounted it is also advisable to lift the screen in order to reduce the image speed.

RESET HOLDER
If this softkey is activated (inverse video) all axes are reset to zero. This softkey is used, for example, for the UltraTwin before removing the holder from the stage in order to bring it to a safe position.

ENABLED (see also Chapter 6.14)
This key is normally activated (inverse video) which means that the Goniometer-control unit (GNCB) is active and communicates with the microscope. This key is only (automatically) deactivated by the microscope in unusual circumstances, for example if the error message "Message GNCB no communication" is displayed (see Chapter 6.10), meaning that the GNCB is switched off. In this case all CompuStage functions are deactivated. The user should now press ENABLE to switch the GNCB on. If there is a specimen holder in the microscope, the user will be requested to remove it. After removal, and 5 seconds delay time, a so-called homing procedure will follow in which XYZα are calibrated. When the homing procedure is finished, the red airlock indicator lamp is switched off, and a holder can be inserted.

6.13.4 The CompuStage page (CM200 without 2D & 5D recall)

This page, which is a combination of the CompuStage control page and the CompuStage register page, is only present in microscopes without 2D & 5D recall. Fig. 6.12 shows this page. There are no other softkeys than the ones already described. A detailed description of the softkeys is given in Sections 6.13.2 and 6.13.3, describing the CompuStage control and the CompuStage register pages.

6.14 ERROR MESSAGES

Three error messages can be displayed, viz:

- Message GNCB no communication	The communication between the microscope and goniometer control unit fails
- Message GNCB encoder error	The measuring system is not working
- Message GNCB tracking error	Something is wrong with the movement of the CompuStage

If one of these errors occurs, the ENABLE softkey will be deactivated by the microscope (normal video), meaning that there is no communication between the GNCB and the microscope. One should now press the ENABLE softkey in order to open the communication between the GNCB and the microscope. As a consequence the microscope will perform a homing procedure (see Sect. 6.13.3). If the same error occurs again, a service engineer should be called.

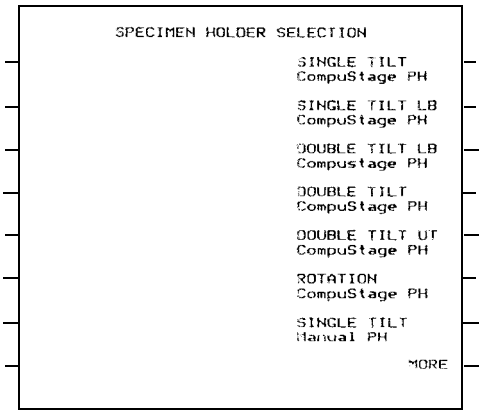
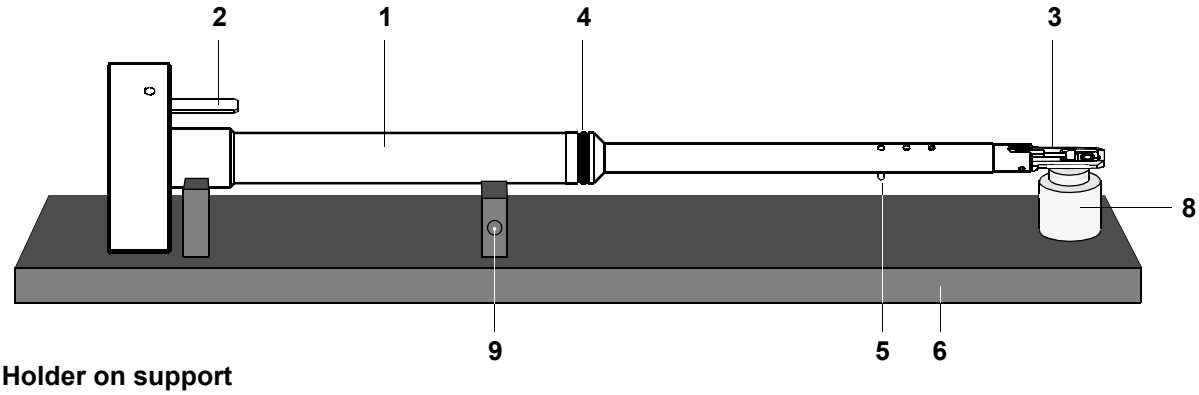
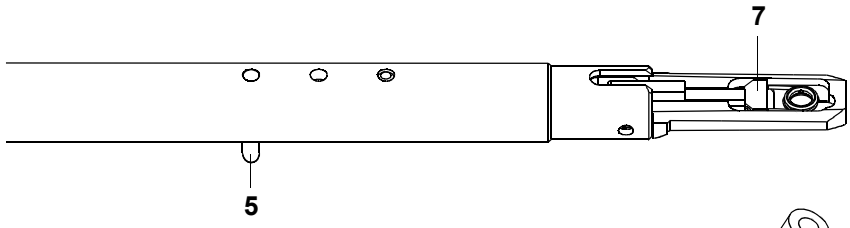


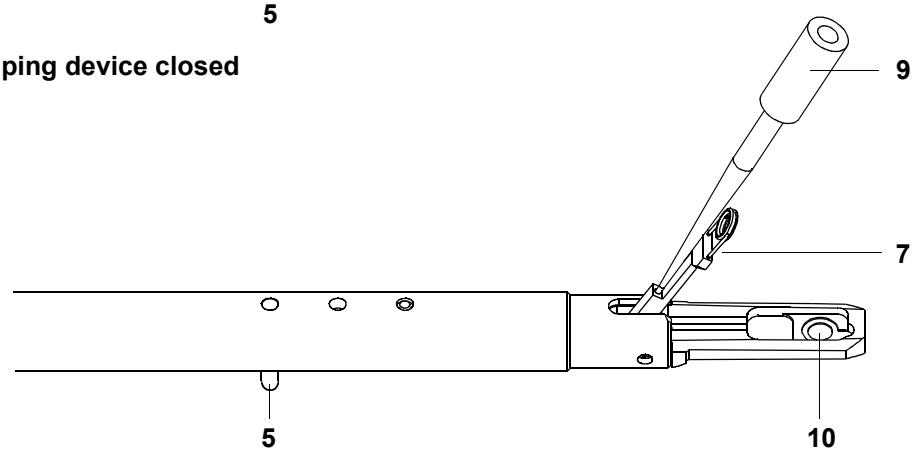
Fig. 6.1, Holder selection page



a) Holder on support



b) Holder tip, clamping device closed



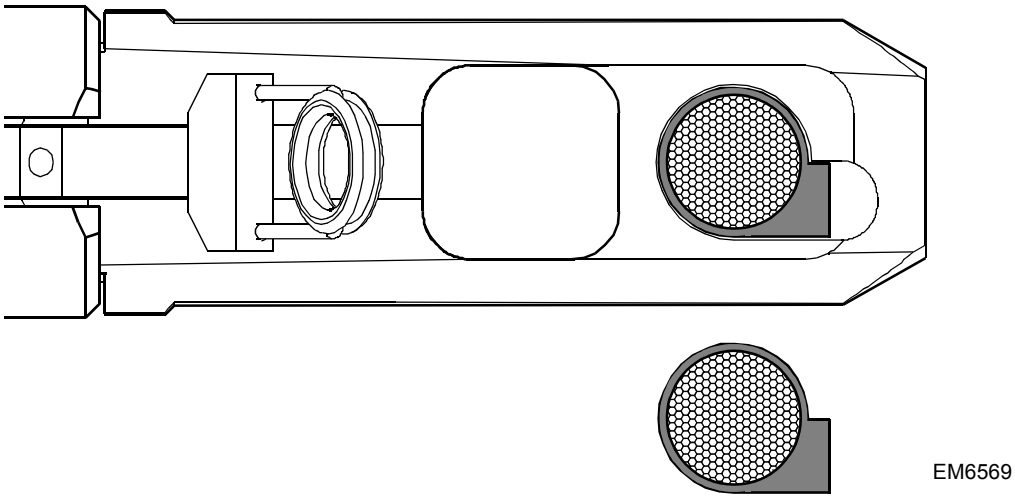
c) Holder tip, clamping device open, with tool

EM6565

Legend:

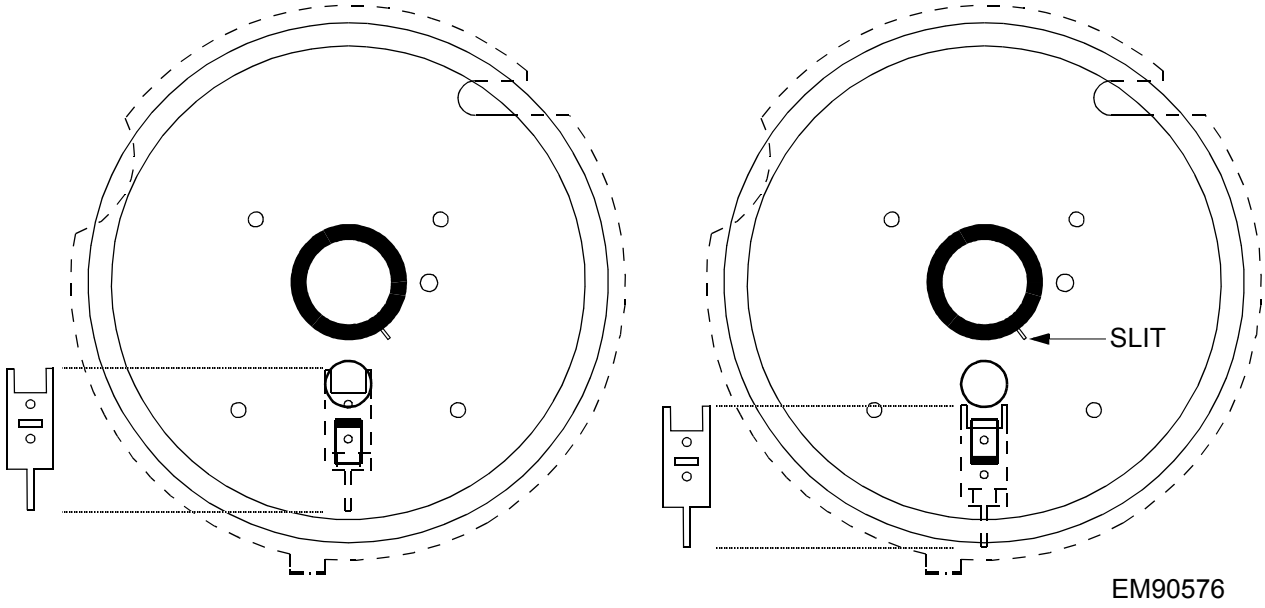
1	Rod	5	Pin that opens airlock	9	Opening tool
2	Safe ENTRY key	6	Support	10	Carrier
3	Tip	7	Spring clamp		
4	O-ring	8	Block on support		

Fig. 6.2, Single-tilt specimen holder



d), Reproducibly insertable grid

Fig. 6.2, Single-tilt specimen holder (cont'd)



NON - SELECT **SELECT**

Fig. 6.3, Safe ENTRY - Lock

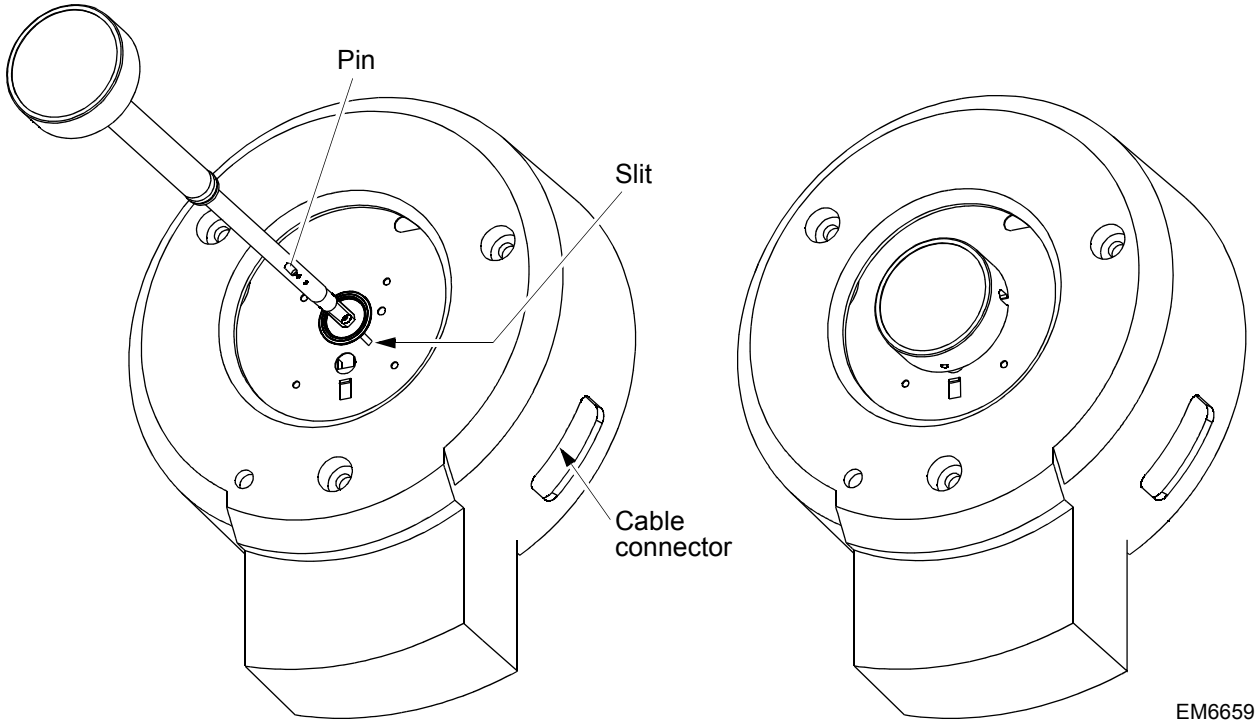


Fig. 6.4, Insertion procedure

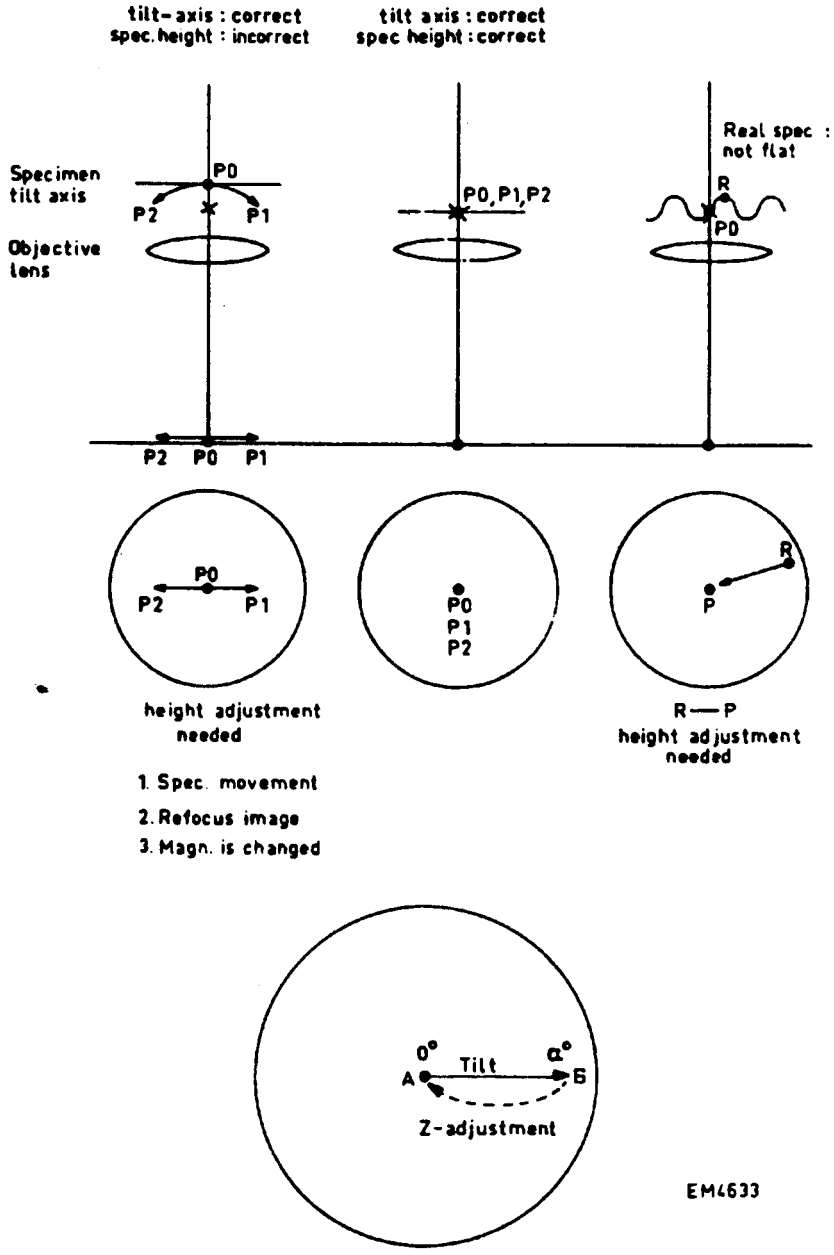


Fig. 6.5, Specimen height adjustment to bring the centre of the field of view onto the tilt axis

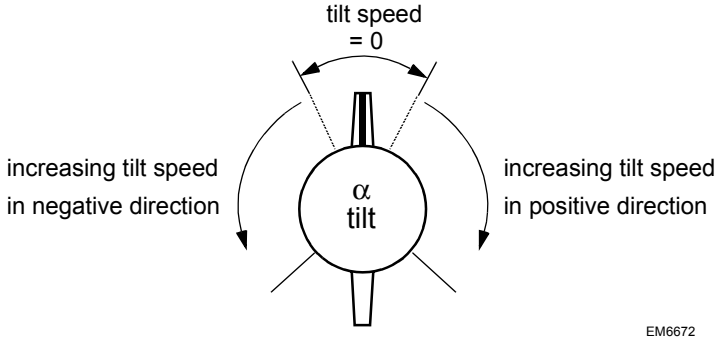


Fig. 6.6, Function of Tilt knob

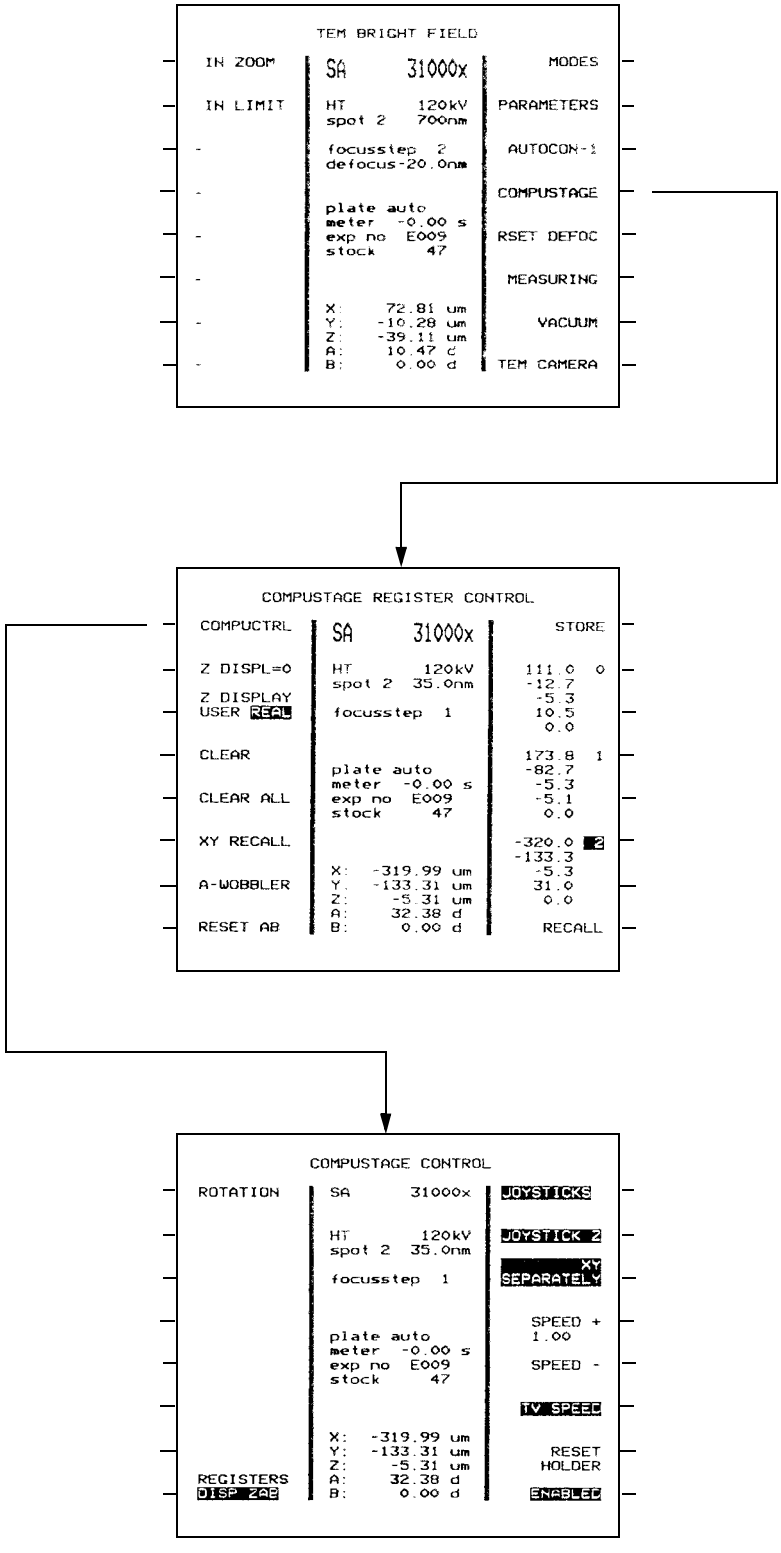
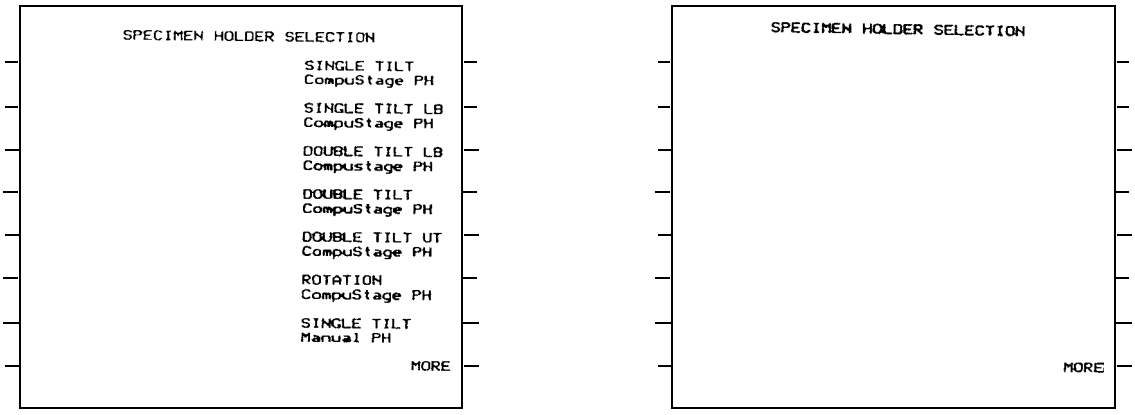


Fig. 6.7, Page sequence for CompuStage pages



(a) **(b)**

Figs. 6.8a) and b), Holder selection page after RAM init (a) and after pressing MORE (b)

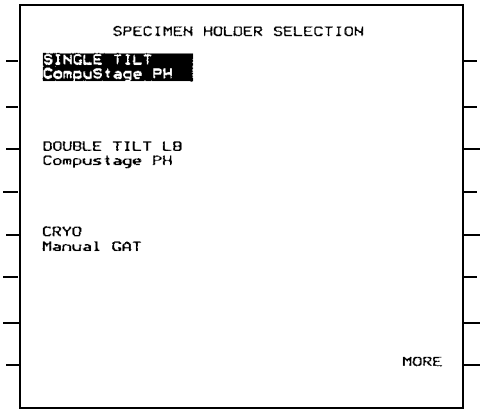


Fig. 6.8.c, Holder selection page with user defined specimen holders

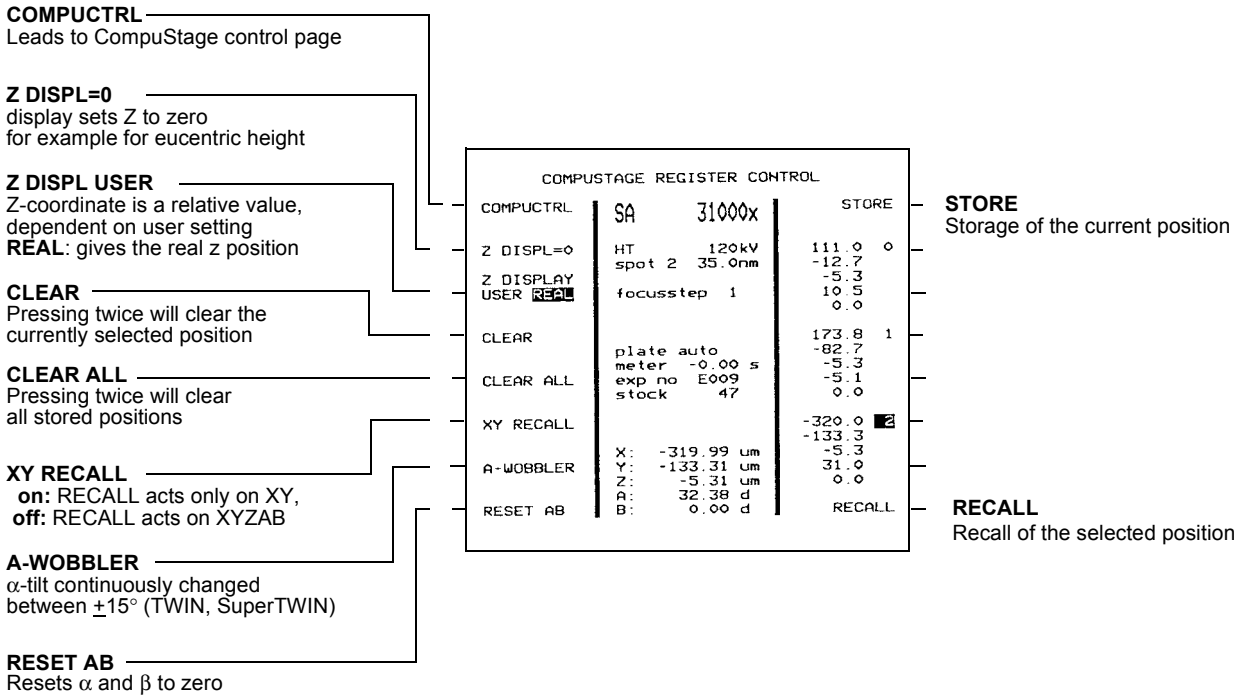


Fig. 6.9, CompuStage Register Control

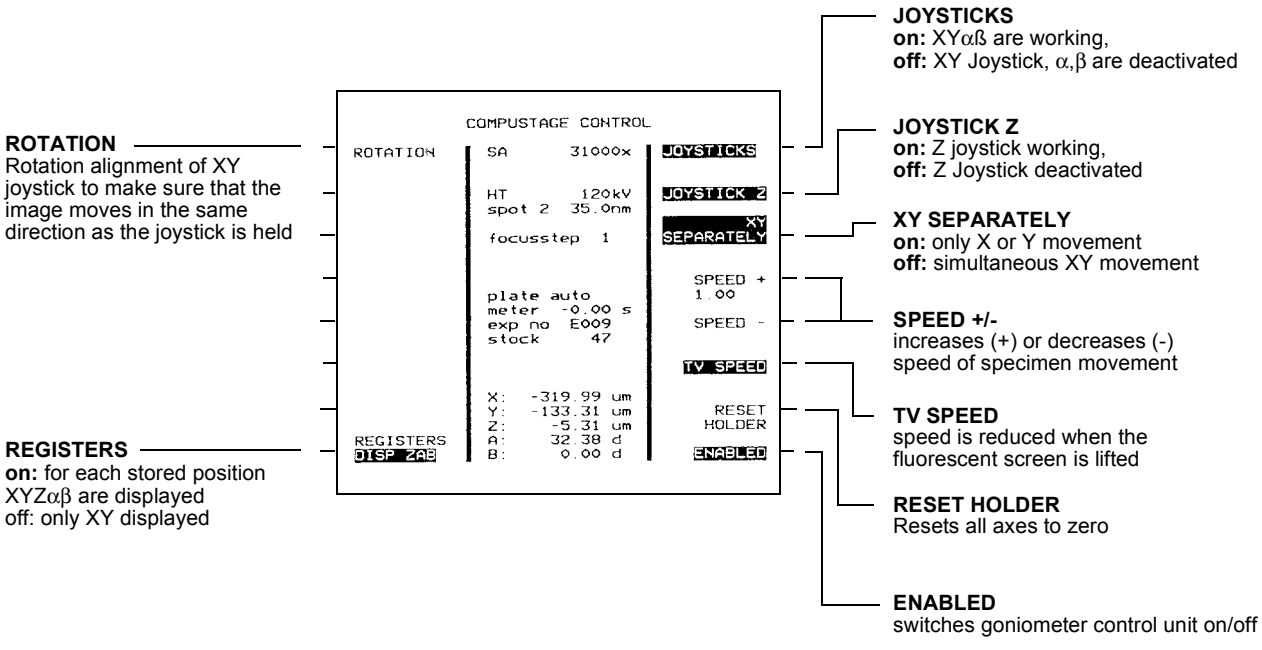


Fig. 6.10, CompuStage Control

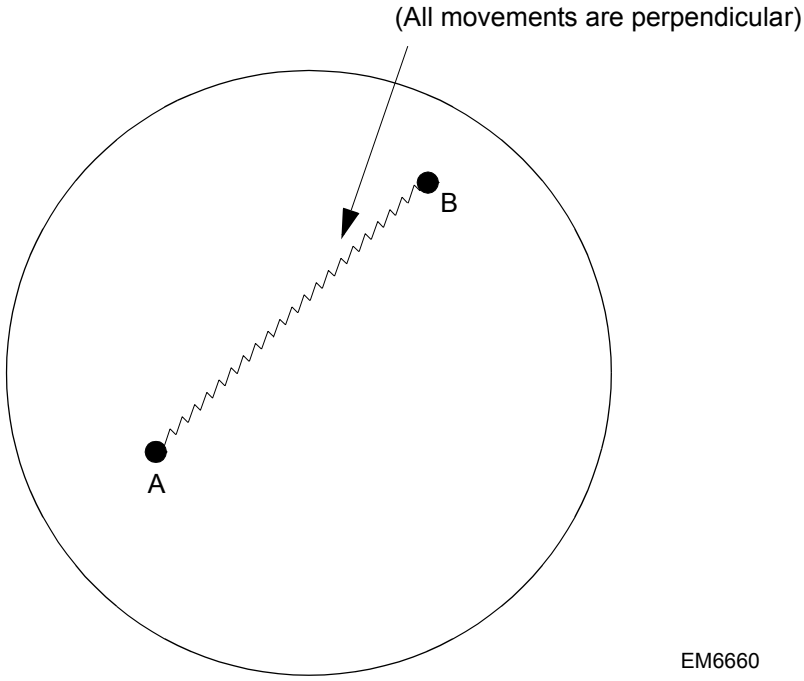


Fig. 6.11.a), XY - movement for XY SEPARATELY off

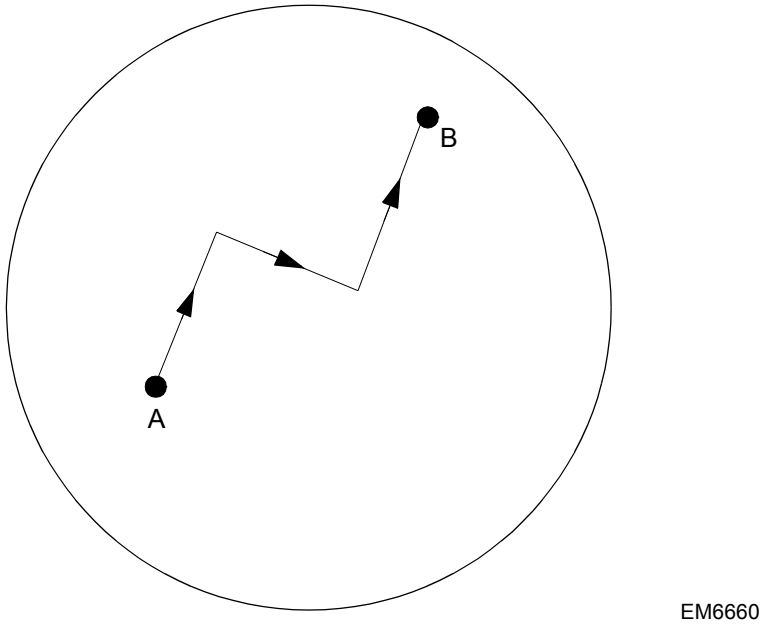


Fig. 6.11.b), XY - movement for XY SEPARATELY on

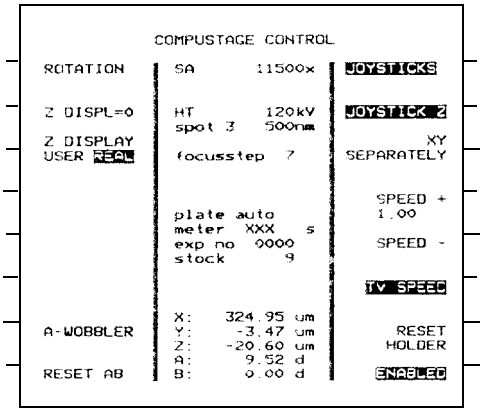
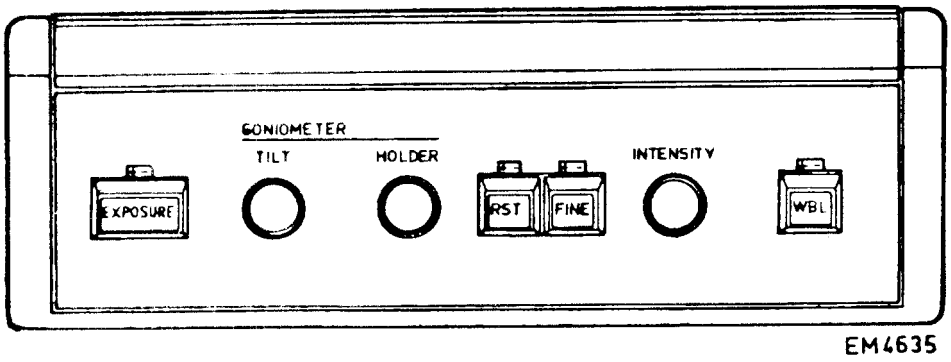
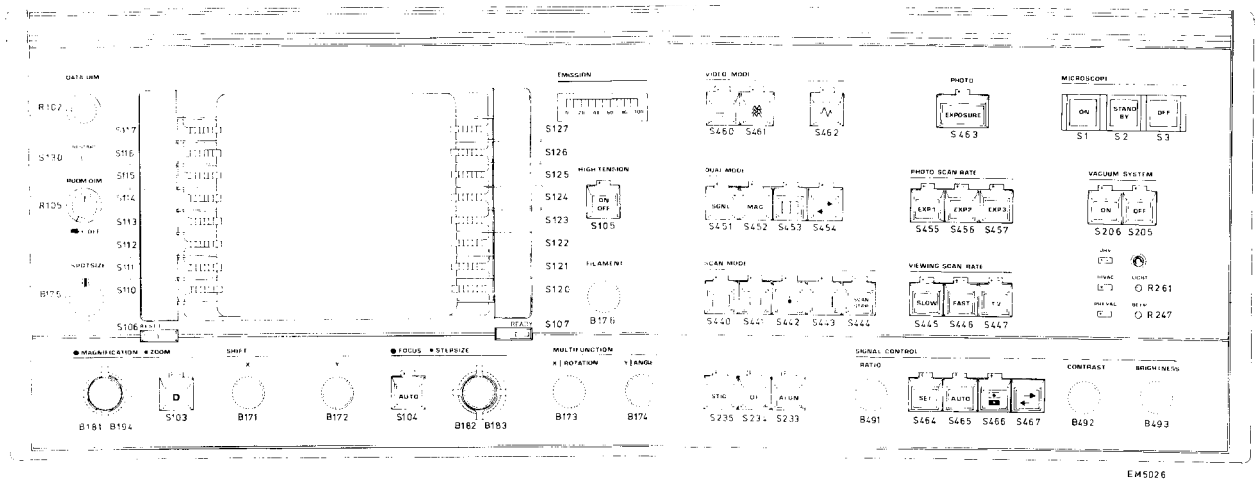


Fig. 6.12, CompuStage page for microscopes without 2D & 5D recall



Left-hand control panel, Fig. 7.1



Right-hand control panel, Fig. 7.2

7 ELECTRICAL AND MECHANICAL CONTROLS - LOCATION AND DESCRIPTION

7.1 PANEL CONTROLS AND INDICATORS

- Pushbuttons (except for the Microscope ON/STANDBY/OFF buttons which are internally illuminated to specific safety requirements) operate in association with a green indicator lamp which, unless otherwise specified, illuminates to show an active condition.
- Stepped and continuously variable rotary controls are referred to as knobs.
- Preset controls are referred to as presets.

7.1.1 Left-hand control panel (see Fig. 7.1)

S274) EXPOSURE/Normalisation button

Green light on - triggers a TEM exposure procedure.
Green light off - triggers a normalisation procedure for the magnification range.

GONIOMETER controls

R2) TILT knob

Controls tilt motor drive.

R1) HOLDER knob

Controls internal movement of special holders, e.g. double tilt and rotation.

S375) RST (Reset) button

Resets intensity to give fully focussed illumination.

S376) FINE button

Selects:

- Fine intensity control range - green light on.
- Coarse intensity control range - green light off.

B384) INTENSITY knob

Controls the current density on the specimen and the brightness on the screen.

S377) WBL (Wobbler) button

Controls the Wobbler focussing aid.

7.1.2 Right-hand control panel - basic TEM system (Fig. 7.2)

MICROSCOPE controls

S1) ON button

White light on - STANDBY button is ON.

S2) STAND BY button

Yellow light on - ON button is ON.

S3) OFF button

Red light on - ON button is ON.

VACUUM SYSTEM controls

S206) ON button

Switches the vacuum system on.

S205) OFF button

Switches the vacuum system off.

UHV indicator

Green light on when operational ultra-high vacuum is attained.

HIVAC indicator

Green light indicates:

- Standby mode when VACUUM SYSTEM ON button is not operational.
- That the high-vacuum pumping sequence is in progress when VACUUM SYSTEM ON button is operational.

PREVAC indicator

Green light on when pre-vacuum pumping is in progress.

R261) LIGHT preset

Controls the brightness of the panel lights.

R247) BEEP preset

Beep volume control

EMISSION indicator and controls

Emission current indicator

Scaled from 0 to 100 μA.

S105) HIGH TENSION ON/OFF button

Switches the H.T. on and off.

B176 FILAMENT current knob

Controls the filament current level.

R102) DATA DIM knob

Controls brightness of data monitor screen.

S130) RESTART preset button.

Restarts computer.

R105) ROOM DIM/OFF knob

Controls the room lighting level.

B175) SPOT SIZE knob

Selects spot size. This defines the total beam current.

MAGNIFICATION/ZOOM Controls

B181) Outer knob

Controls image and diffraction-pattern magnification.

B194) Inner knob

Controls zoom function.

S103) D (Diffraction) button

Selects:

- Diffraction mode - green light on
- Imaging mode - green light off

SHIFT controls

B171) X knob
B172) Y knob

Control:

- Beam shift in TEM modes.
- Image shift in STEM modes.

FOCUS/STEPSIZE controls

S104) AUTO pushbutton

Selects automatic focus for the specimen at the eucentric height.

B182) Focussing knob

Controls the focussing lens current.

B183) Step size selector

Selects the amount of focus current change.

MULTIFUNCTION controls

B173) X/ROTATION knob

Continuous control used in conjunction with Wobbler, STIGmator, Dark-Field and AliGNment buttons. Standard operation in SCANNING is Scan Rotation.

B174) Y/ANGLE knob

Continuous control used in conjunction with Wobbler, STIGmator, Dark-Field and AliGNment buttons.

B235) STIG (Stigmator) knob

Assigns stigmator function to MULTIFUNCTION X and Y knobs

S234) DF (Dark-Field) button

Assigns beam tilt function to MULTIFUNCTION X and Y knobs.

- Dark-Field mode - green light on
- Bright-Field mode - green light off

S233) ALGN (Alignment) button

Selects ALIGNMENT selection page and assigns priority alignment to MULTIFUNCTION X. and Y knobs

S106) RESET key

Resets error messages and adjusts settings to mid-position where applicable.

S107) READY key

Returns to previous operational mode or steps forward in alignment procedures.

Softkeys (Left S110-S117)

For data and function selection from display pages (Right S120-S127).

7.1.3 Right-hand control panel - STEM mode controls (see Fig. 7.2)

Video Mode controls

S460) Z-display button 

Displays normal video image.

S461) Y-display button 

Displays Y-modulated image.
Enables a normal image to be superimposed on a Y-modulated image when normal (Z display) and Y-modulated images are obtained simultaneously.

S462) Waveform button 

Selects video signal mode on the viewing monitor.

PHOTO control

S463) EXPOSURE button

Starts a STEM photo exposure - green light on when ready.

DUAL MODE control

S451) SGNL (Signal detector) button

Selects signal mode:

Single detector signal - green light off.
Dual detector signal - green light on.

S452) MAG (Magnification) button

Selects zoom magnification mode:

Single - green light off.
Dual - green light on.

S453) Split-screen button 

Selects screen display:

Full - green light off.
Divided - green light on.

S454) Exchange button 

Selects interchange of left/right channels.

PHOTO SCAN RATE controls

S455) EXP1 button
S456) EXP2 button
S457) EXP3 button

Select three sets of preselected photo parameters

SCAN MODE controls

S440) Full-frame button 

Selects full-frame video display.

S441) Selected-area button 

Selects partial-frame video display.

S442) Crosshairs/Spot button 

Selects:

Crosshairs mode - press once.
Spot mode - press once more.
Return to crosshairs-press again.

S443) Line button 

Selects:

Horizontal line -press once.
Vertical line - press once more.
Return to horizontal-press again.

S444) SCAN STOP button

Selects scan stop.

VIEWING SCAN RATE controls

S445) SLOW button
S446) FAST button

Select two sets of preselected viewing parameters (slow and fast scanning).

S447) TV button

Inactive. The TV rate scan is not available on the CM200.

SIGNAL CONTROL controls

B491) RATIO knob

Continuous control for mixing signals.

S464) SET button

High quality automatic contrast and brightness function on full frame.

S465) AUTO button

Fast automatic contrast and brightness function.

S466) Invert button 

Inverts black and white for the video display of the chosen channel/detector.

S467) Exchange button 

Selects/deselects the interchange of the two detector channels.

B492) CONTRAST knob

Controls monitor contrast.

B493) BRIGHTNESS knob

Controls monitor brightness.

7.1.4 DISPLAY MONITOR controls (see Fig. 7.3)

Left *Right*

A1) **A5)** **CONTRAST knob**

Controls monitor contrast.

A2) **A6)** **BRIGHTNESS knob**

Controls monitor brightness.

A3/A4) **A7/A8)** **Indicator lamps**

In split screen, operate individually. In full screen, operate together.

7.1.5 VIDEOSCOPE controls (Fig. 7.3)

A9) **INTENSITY preset**

Sets Videoscope screen intensity.

A10/A11) **X-POSITION-Y presets**

Set Videoscope X-Y ranges

A12) **Y-GAIN preset**

Sets Videoscope Y-gain range

7.1.6 HIGH-RESOLUTION PHOTOMONITOR controls (see Fig. 7.4)

A13) **CONTRAST selector**

Selects photomonitor contrast.

A14) **BRIGHTNESS selector**

Selects photomonitor brightness.

A15) **CAM. CONTROL**

Connector for camera with automatic shutter control.

A16) **RECORDING indicator lamp**

Illuminates during exposure.

A17) **ON indicator lamp**

Indicates photomonitor switched on.

A18) **MAPPING indicator lamp**

Indicates mapping sequence in progress.

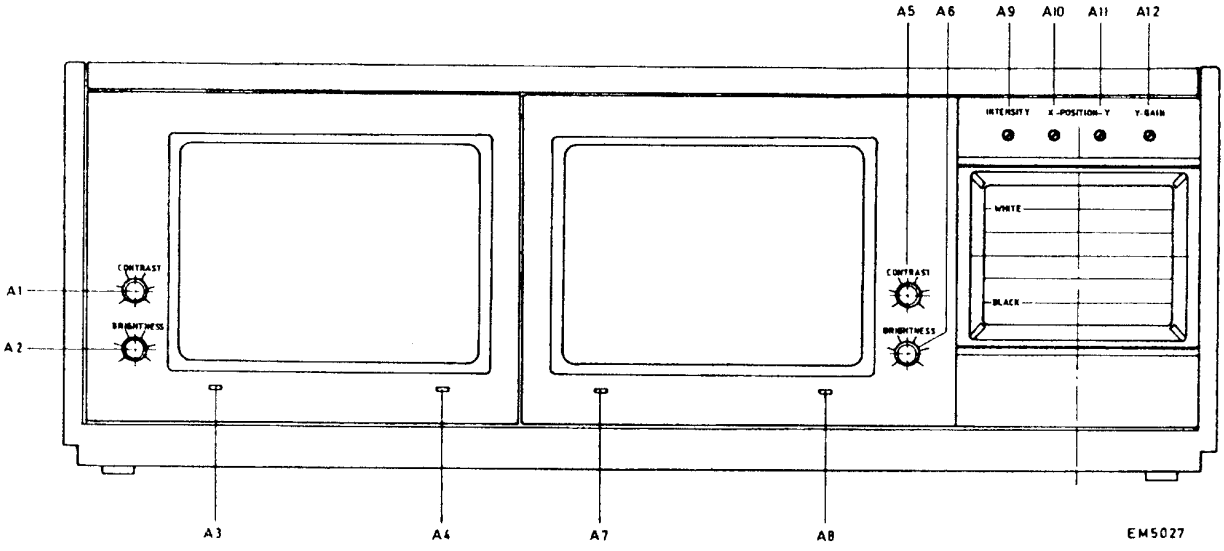


Fig. 7.3, Panel controls - Display monitors and Videoscope

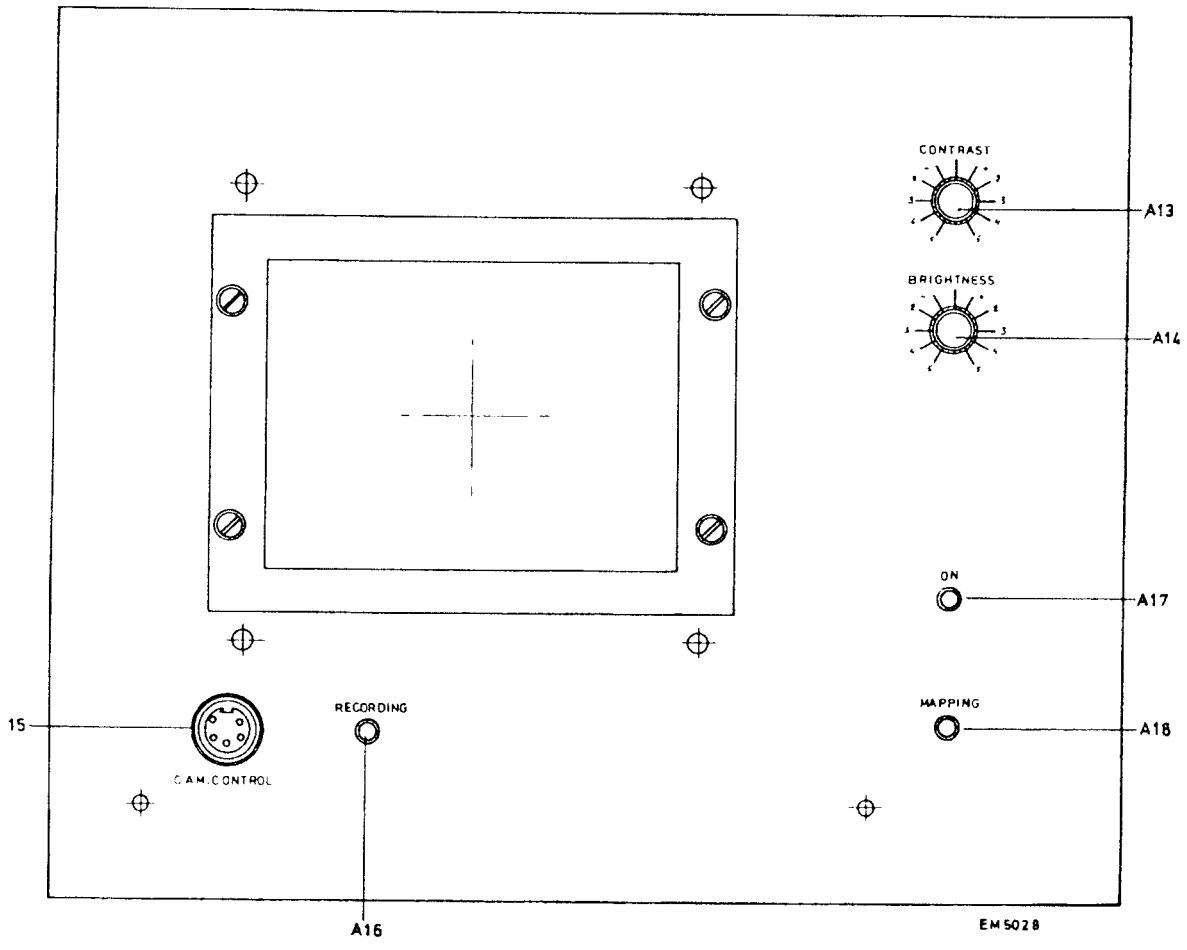


Fig. 7.4, Panel controls - High resolution Photomonitor

7.2 MECHANICAL CONTROLS

The reference numbers associated with each control refer to annotations in Figs. 7.3 to 7.8 inclusive.

Caution! All mechanical controls operate smoothly and can be adjusted without particular effort. If a high mechanical resistance is encountered, do not force the control otherwise damage may result. First find the cause of the resistance and, if necessary, call your local service organisation.

7.2.1 Electron gun and column (Fig. 7.5)

Earthing strip

Discharges to earth any residual charge on the electron gun when the gun is withdrawn from the emission chamber. This is not visible until the gun has been withdrawn from the emission chamber.

102) Electron gun securing screws

Two red-capped screws securing the gun to the emission chamber. Before the gun can be removed they must be loosened completely. When the gun has been replaced they must be tightened completely.

Note: Do not loosen the double nuts that are used for aligning the gun assembly with the column (factory alignment).

103) Gun-lifting lever

Lifts the gun assembly from the emission chamber (once air has been admitted).
Once the securing screws (102) are completely loosened and the vacuum has been broken by placing one of the gun securing screws in the gun lifting position (refer to Sect. 4.4.1), push the lever up as far as it will go, then turn it towards the back of the microscope and turn to the left until it locks in position. Ensure that the gun is in contact with the earthing strip. The gun assembly is lowered into the emission chamber in the reverse order.

An associated microswitch automatically switches off the lens currents and high tension when the lifting mechanism is operated.

Caution! This control should only be used in conjunction with the Service Instructions. Unauthorised attempts to operate it can activate the microswitch. This point should be checked if at any time the high tension and lens currents cannot be obtained when starting to use the microscope.

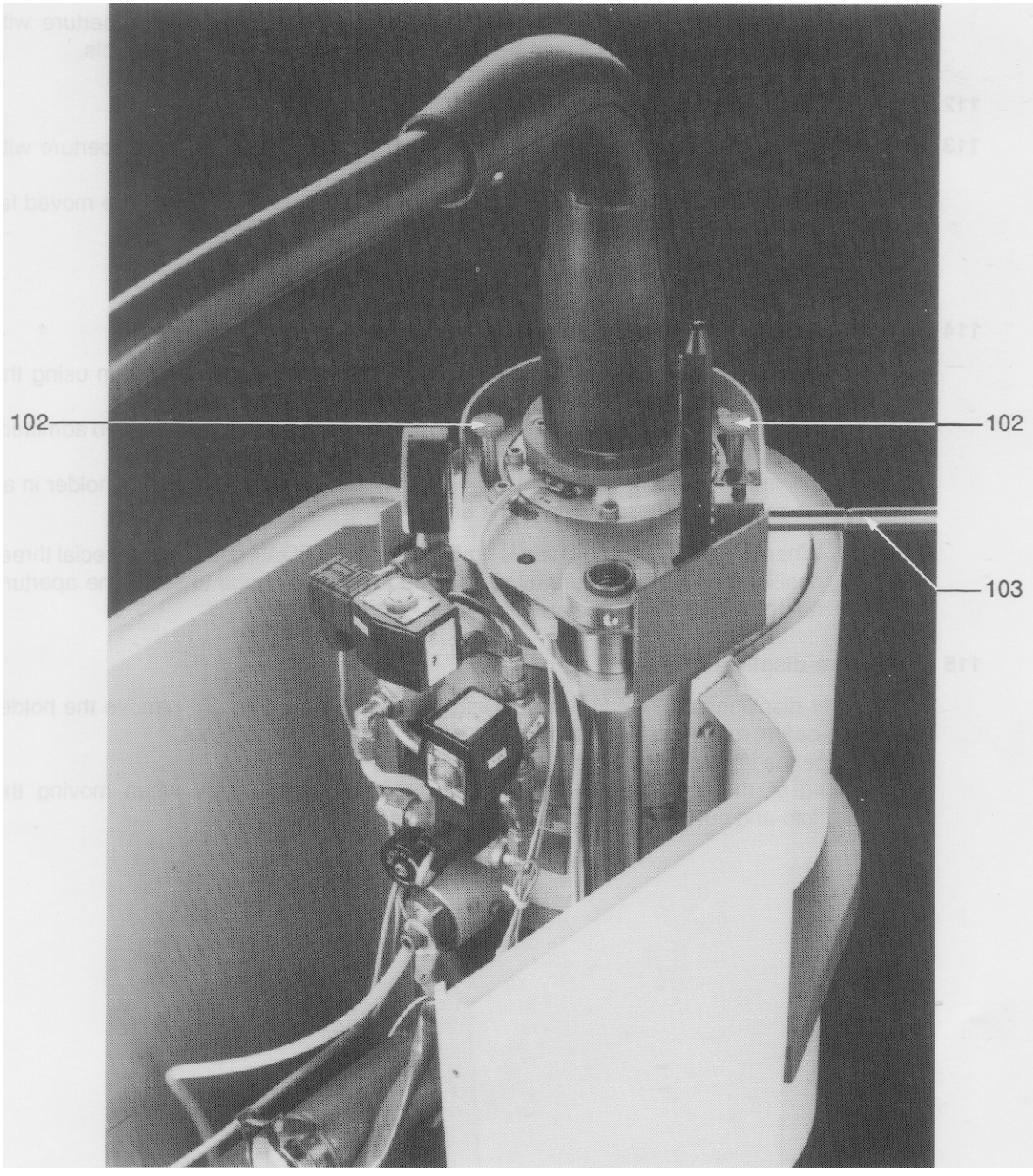


Fig.7-5, Electron gun - mechanical controls

7.2.2 Lens apertures (Fig. 7.6)

The following controls are identical for the:

- 2nd condenser lens **C2**
- Objective lens **Obj.**
- Diffraction lens **Diffr.**

111 Aperture selector

This has four click stop positions. In each position, one of the four apertures held in the holder is positioned on the microscope axis. Accurate centring of each aperture with respect to the microscope axis is carried out using the aperture-centring controls.

112 Aperture-centring controls

113 These knurled knobs operate in two perpendicular directions to centre the aperture with respect to the microscope axis.
The range of movement is limited by end stops so that the aperture cannot be moved far from the centred position.

Caution! **Do not try to force the controls beyond these stops.**

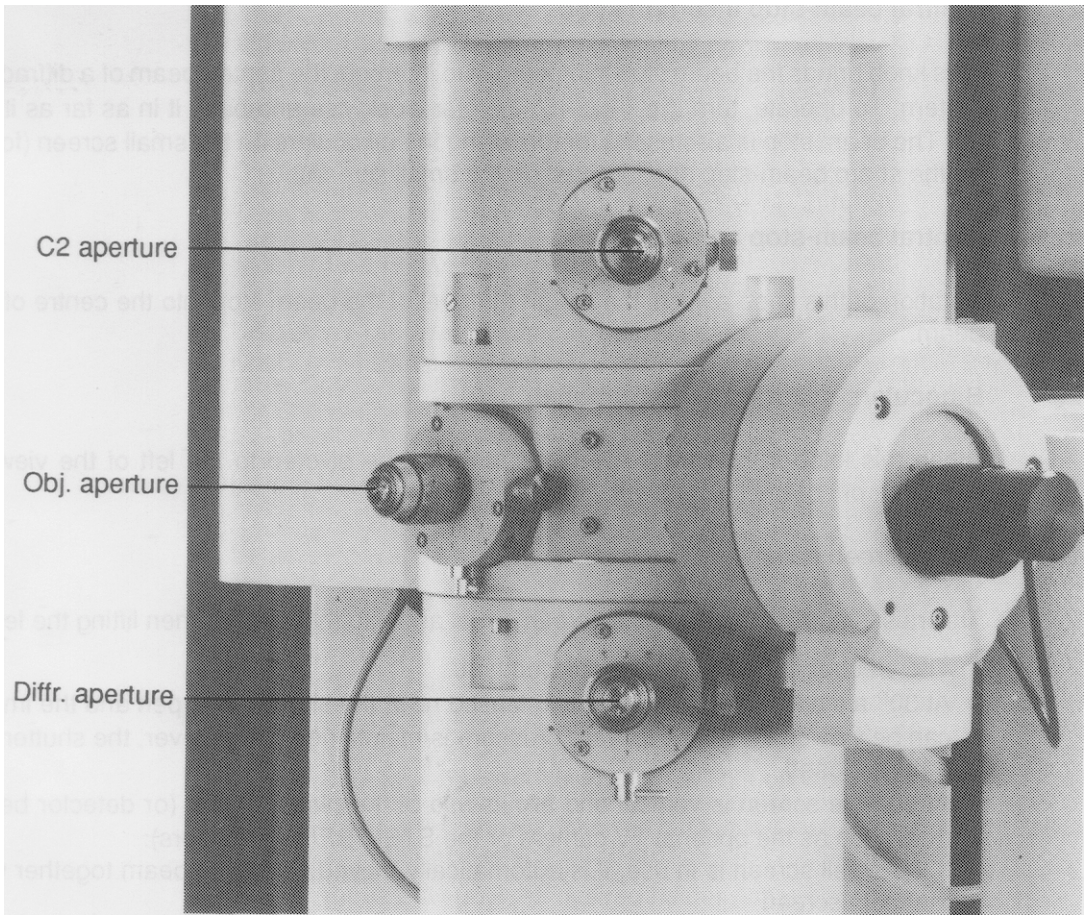
114 Aperture holder

Contains four apertures which can be introduced successively into the beam using the selector.
The holder itself can be removed from the microscope column (once air has been admitted) by first unscrewing the knurled end and then carefully pulling it straight out.
When replacing the holder ensure that the guide pin enters the slot. Push the holder in as far as it will go, then firmly screw up to the end.

Note: When the CM200 Super Twin is equipped with an EDAX detector, a special three-position objective aperture must be used to avoid damage to either the aperture holder or the EDX detector.

115 Aperture-displacement lever

This lever displaces the aperture holder into and out of the beam. To remove the holder from the beam, rotate the lever to the right.
To replace the holder in the beam, rotate the lever to the left.
Recentring of the last aperture selected is generally unnecessary when moving the aperture into and out of the beam using the displacement lever.



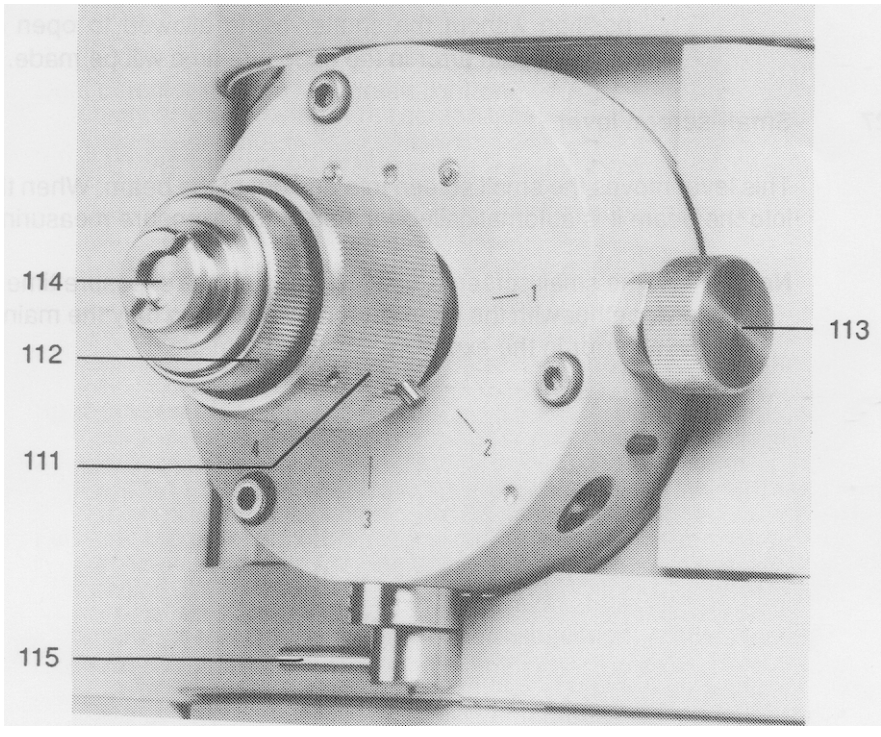


Fig. 7.6, Lens aperture controls

7.2.3 Viewing chamber (Fig. 7.7a and 7.7b)

121 Central beam-stop insertion knob

This knob brings the beam stop into position to intercept the central beam of a diffraction pattern. To operate, turn the knob 45° counter-clockwise and push it in as far as it will go. The beam stop is also useful for focussing the binoculars on the small screen (focus on the sharp beam-stop shadow cast on the small screen).

122 Central beam-stop adjuster knob

Rotation of this knob adjusts the length of travel of the beam stop into the centre of the beam.

125 Binoculars-securing knob (optional)

When this knob is loosened, the binoculars can be pivoted to the left of the viewing chamber, out of the line of sight.

126 Main-screen lever

This raises and lowers the main screen out of and into the beam. When lifting the lever:

- The electromagnetic shutter is closed first.
- At 30° a stop is felt. If the lever is released now, the shutter will open and the image can be viewed closely. If upward pressure is maintained on the lever, the shutter will remain closed.
- At 90° the screen is vertical and allows use of the plate camera (or detector below that, such as the optional TV camera or the STEM BF/DF detectors).
- If the small screen is in use, it is automatically moved out of the beam together with the main screen.

Note: Exposure measurements using the main screen must be made with the screen in the horizontal position. It must then be raised to the vertical position without the shutter being allowed to open at the 30° position, otherwise an error in the exposure time will be made.

127 Small-screen lever

This lever moves the small screen into and out of the beam. When the screen is brought into the beam it is automatically switched to the exposure measuring system.

Note: If the small screen is used to measure the exposure time, it must be removed together with the main screen by operating only the main-screen lever 124 or an error in the exposure time will be made.

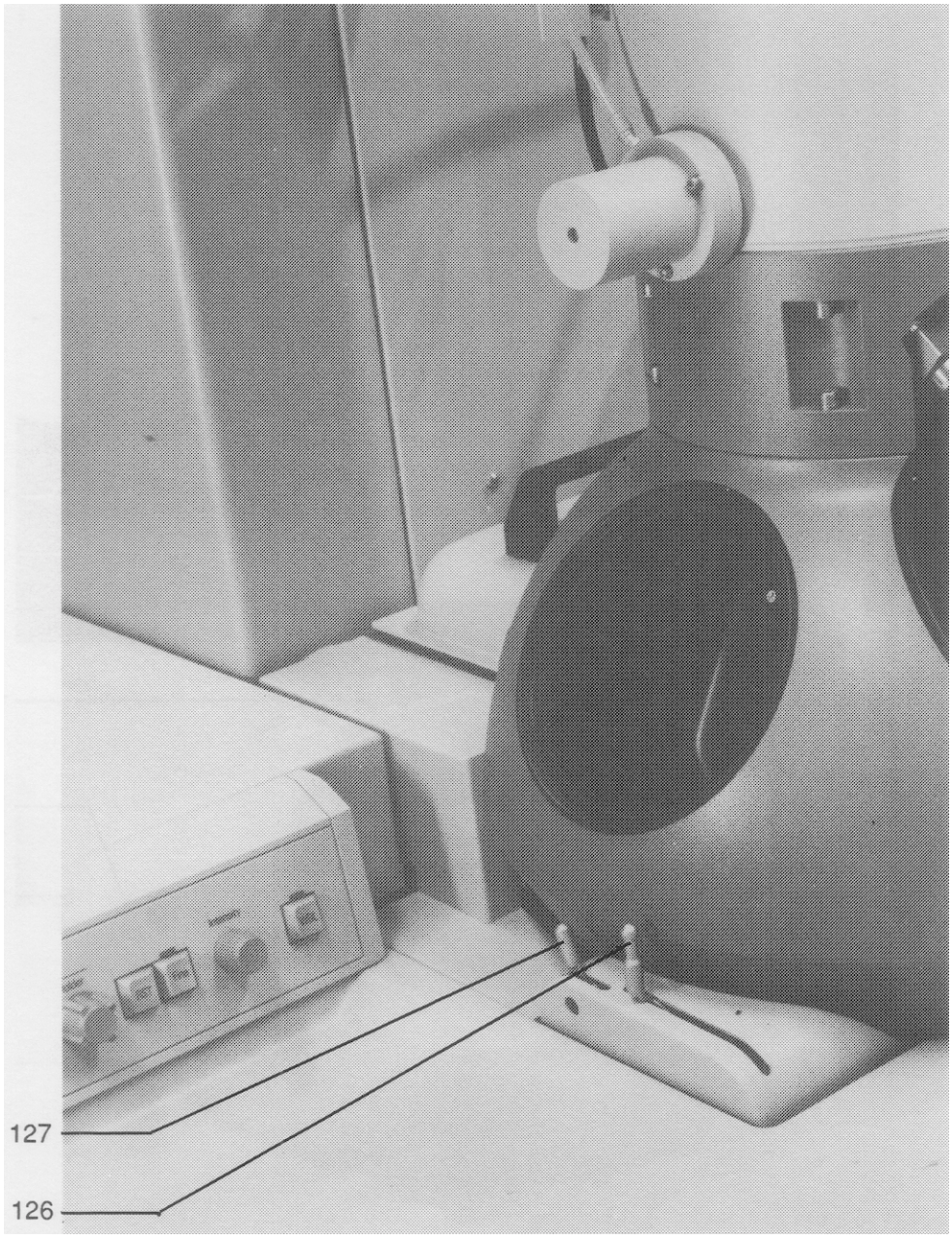


Fig. 7.7a, Viewing chamber - left

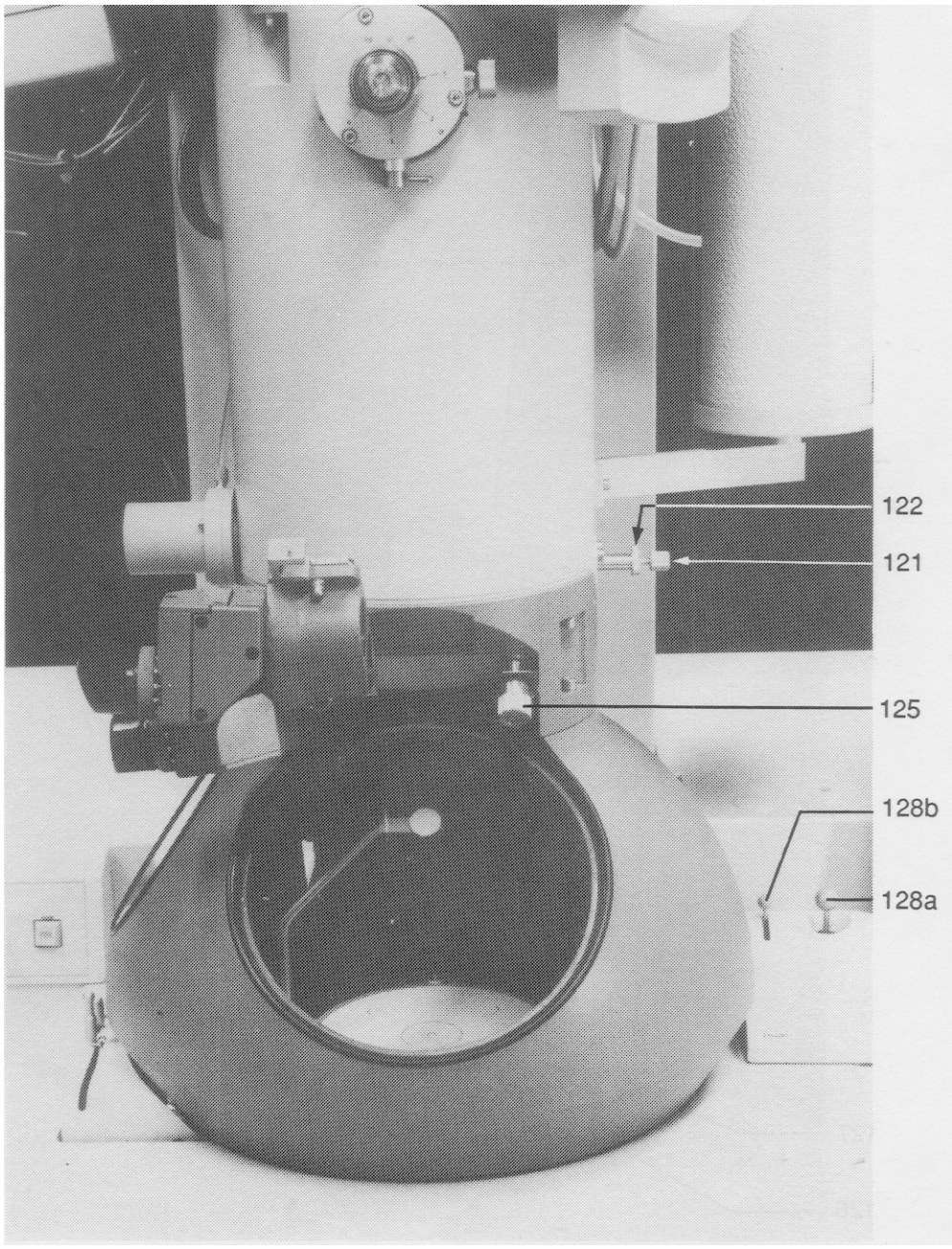


Fig. 7.7b, Viewing chamber - right

128 Joystick pad for specimen movements

a) XY joystick provides continuous displacement in X direction (direction of the tilt axis) and the perpendicular Y direction. Speed of the movement and other parameters can be changed by activating the CompuStage pages (Softkey COMPUSTAGE, see chapter 6).

b) Z joystick for specimen movement in Z direction to adjust specimen height..

7.3 INDEX OF SOFTKEY LABELS WITH DESCRIPTIONS

7.3.1 Softkey labels TEM

LABEL	*MODE/ACTION/SELECTION*
ALIGNMENT	ALIGNMENT selection page
ALL AIR	Admits air to all sections of the column
AUTO	Automatic exposure timing of the TEM camera. In conjuncion with DET CONF, AUTO defines the default diffraction/image shift onto detectors placed at the base of the projection chamber depending on the microscope mode of operation
AUTOCON-1	Defocus possibilities: magnification-dependent in AUTOCON 1 - 5 and fixed underfocus in SCHERZER
AXIS-cal	Axis calibration for stereo measurements
A-WOBBLER	α-tilt continuously changed between +15° (TWIN, SuperTWIN)
beamcoils PIVOT PT X, Y	Direct alignment of beam coils pivot points
BF/DF	BF/DF STEM detector installed/not installed
C1	First condenser lens in free lens control
C2	Second condenser lens in free lens control
C2STIGM	C2 stigmator alignment procedure or direct alignment
C2 WOBBLER	Wobbler for C2 aperture alignment
CAM AIR	Admits air to projection chamber/plate camera
CAM INIT	CAMERA INITIATION page
cam type PLATE 35 mm	Inactive (PLATE camera always selected)
cal	Calibrate submode in measuring
CLEAR	Pressing it twice, the currently selected position will be cleared
CLEAR ALL	Pressing it twice, all stored positions will be cleared
CENTRAL	Allows the user to inform the system which detector is placed on-axis at the base of the projection chamber
COL AIR	Admits air to column section
COLUMN	Column alignment procedure
COMA FREE	Coma-free objective lens centring
COMPUCTRL COMPUSTAGE	Lead to CompuStage control page
CONDITIONING	HT setting for gun conditioning

LABEL	*MODE/ACTION/SELECTION*
CONFIGURATION	CONFIGURATION page
CRYO	Leads to vacuum functions for cryo microscopy
CURR INCR DECR	Current modulation for objective rotation centredata intExposure intensity of plate numbering device
DECR	Parameter decreases one step each time the key is pressed
DET ALIGNM	Aligns the DP/image with the BF/DF near axis detector or the on/off-axis TV system
DET CONF	Allows the user to input current configuration of detectors positioned at the base of the projection chamber
df mode X-Y **CONE**	Rotation and tilt type of beam tilt in dark-field mode, conical operation
df mode **X-Y** CONE	Dark-field beam tilt mode in x-y operation
DIAGNOSTIC PROGRAM	Hardware diagnostic program (for service procedures only)
DIF	Diffraction lens in free lens control
DIF ALIGNM	Direct alignment of diffraction pattern for all camera lengths
DIF SHIFT	Direct alignment of diffraction pattern
DIF STIGM	Diffraction lens stigmator alignment procedure
DISPLAY CURRENTS	CURRENT READOUT display page for all lens and deflection coils
DOUBLE EXP	Double exposure on the TEM camera
EDX PROT	COLUMN AIR and LM-mode are prohibited
emulsion LOW HIGH INCR DECR	Sensitivity of the film emulsion (two different sets can be entered per camera)
ENABLED	Switches goniometer control unit (GNCB) on/off
ENTER	Enters a position in the measuring mode or a lens setting in the free lens control mode
exp delay INC 0.5 s DECR	Required shutter delay

LABEL	*MODE/ACTION/SELECTION*
exp factor INC mode 1.5 DECR	Required factor by which the measured exposure time in the low-dose focus state is multiplied to determine the exposure time in the exposure mode
exp mode SINGLE EXP DOUBLE EXP SERIES HOLD	Exposure mode for the TEM camera • single (this is the default setting) • double • fixed or through-focus series • prevents switching back to the default setting following request for Double or Series exposure
exp no	Exposure number to print on photo
exp time AUTO TIMER MANUAL HOLD	Method of timing for a photo procedure: • automatic measurement and exposure when recording • open shutter manually and measure elapsed time • set exposure time manually (for example in Diffraction mode) • holds a measured exposure timing method
EXPOSURE	Exposure state in the TEM low-dose mode (excludes FOCUS and SEARCH)
FIL LIMIT	Sets maximum filament heating level
FIX FOCUS	Photo series with fixed focus setting (TEM camera)
FOCUS	Focus state in the TEM low-dose mode (excludes EXPOSURE and SEARCH)
FREE CONTROL	Free control of high tension in steps of 50 V to 20 kV
FREE LENS CONTROL	FREE LENS CONTROL page
GONIO AXIS	Goniometer service alignment procedure
GUN	Gun alignment procedure
GUN SHIFT	Gun shift direct alignment
GUN TILT	Gun tilt direct alignment
GUN AIR	Admits air to gun section
IGP	Manual switching of the ion getter pump (for service procedures only)
IMAGE/BEAM	Performs beam/image shift calibration procedure (on service calibration page)
IMAG SHIFT	Direct alignment of image shift for different magnification ranges
imagecoils PIVOT PNTS	Image coils pivot points service alignment procedure
im shift 1 2 zero	Electrical image shift for high magnifications with multifunction knobs MFX/Y. Two different areas can be stored in "1" and "2".
INC	A parameter is increased

LABEL	*MODE/ACTION/SELECTION*
increment PLATE CONT	CONT: If plate camera and 35 mm camera are used alternately, the plate numbering is automatically increased by one with every exposure independent of the camera type. PLATE: the plate numbering is only increased for every exposure if the plate camera is used, for the 35 mm camera the plate number does not change.
INT	Intermediate lens to act on in free lens control
INT ZOOM	Intensity zoom mode
INT LIMIT	Intensity limit mode
JOYSTICKS	on: XYαß are working; off: XY Joystick, α,ß are deactivated
JOYSTICK Z	on: Z joystick working; off: Z Joystick deactivated
LaB_6	Enter type of cathode installed
LOW DOSE	Image area to left or right of the central area, during exposure only
man time INCR 20 s DECR	Manual setting of the photo exposure time for the TEM camera
MANUAL MANUAL PAGE	Manual setting of photo exposure time for the TEM camera Vacuum system control, for service engineer only
MEASURING	MEASURING page
MODES	MODES page
NANO PROBE	TEM nanoprobe mode
NEAR-AXIS	Allows the user to inform the system that the BF/DF detector is situated in the near-axis position
OBJ	Objective lens in free lens control
OBJ STIGM	Objective stigmator alignment procedure
ODP	Manual switching of the oil diffusion pump (for service procedures only)
OFF-AXIS	Allows the user to inform the system that TV is situated in the off-axis position.
P1 P2	First projector lens in free lens control Second projector lens in free lens control
PARAMETERS	PARAMETERS page
(P)EELS	(P)EELS detector installed/not installed
POST SPECIMEN SCAN	Post-specimen scan mode
READY	Page changes to operation page

LABEL	*MODE/ACTION/SELECTION*
RECALL	Recall of the selected position
REGISTERS DISPLAY ZAB	on: for each stored position XYZαß are displayed off: for each stored position only XY are displayed
RESET AB	Resets α and ß to zero
RESET HOLDER	Resets all axes to zero
ROT CENTER	Objective lens rotation centre direct alignment
ROTATION	Rotation alignment of XY joystick to make sure that specimen moves in the same direction as that in which the joystick is held
RSET DEFOC	Indicated defocus value in the information field is set to zero. No change of focus
RSET SHIFT	An image shift is cancelled
SCHERZER	Scherzer defocus
SEARCH	Search state in low-dose mode (excludes FOCUS and EXPOSURE)
SERIES	Photo series with the TEM camera
series INCR 1 DECR	Number of exposures for a photo series on the TEM camera
service CALIBRATE	Access to service calibration procedures
SINGLE EXP	Single exposure with the TEM camera
SPEED +/-	Iincreases (+) or decreases (-) speed of specimen movement
STEREO	Three-dimensional program when measuring
stock set value RESET	Initialises the number of available plates
STORE	Storage of the current position
SUPER TWIN	Displays type of polepieces installed when Super Twin lens installed
TEM	Conventional TEM mode/TEM calibration service procedure
TEM CAMERA	TEM CAMERA subpages (camera initiation, film and film coding initiation)
TEM LOW DOSE	TEM low-dose mode
THR-FOCUS	A photo series with varying focus settings for the TEM camera
TIMER	Exposure mode with manual opening and closing of the shutter, instrument gives time elapsed

LABEL	*MODE/ACTION/SELECTION*
TUNGSTEN	Enters type of cathode installed
TV	TV system installed/not installed
TV SPEED	Speed is reduced when the fluorescent screen is raised
TWIN	Enters type of polepieces installed
TWN	Mini-condenser lens in free lens control
USER	Under DET CONF, allows the user to define the diffraction/image shift onto the detector placed at the base of the projection chamber independent of the microscope mode of operation
V1...12	Manual operation of vacuum valves (accessible to Service Engineer only)
VACUUM	VACUUM subpages
Vacuum function	Leads to vacuum functions
VCR	Video cassette recorder
VOLT	Voltage modulation for objective rotation centre
XY CTRL	Specimen relocation system (optional)
XY RECALL	on: RECALL acts only on XY; off: RECALL acts on XYZαß
XY SEPARATELY	on: only X or Y movement; off: simultaneous XY movement
Z DISPL=0	Sets Z to zero for example for eucentric height
Z DISPL USER REAL	Z-coordinate is a relative value, dependent on user setting The real Z-coordinate is displayed (absolute value)
ZOOM	Lens program with optimum focus setting

7.3.2 Softkey labels STEM

LABEL	*MODE/ACTION/SELECTION*
AREA ZOOM	Scan area zoom in the micro or nano probe scanning mode
AREA LIMIT	Scan area limit mode, where the minimum area of the scanning pattern is limited in the micro or nano probe scanning mode
AUX DETECTOR-1	First (optional) auxiliary detector for STEM
AUX DETECTOR-2	Second (optional) auxiliary detector for STEM
AUX TV	Input channel for TEM TV cameras
BS	STEM backscattered-electron detector
BF L R	STEM bright-field detector for mixing
BRIGHT FIELD	STEM bright-field detector
BS	STEM backscattered-electron detector for mixing
CRT **DET**	Corresponding video channel is used for a detector signal or a mixture of detector signals
CRT **AUX**	Corresponding video channel is used for a TV rate monitor for an auxiliary signal, e.g. VCR
CRT SELECT **L** R	CRT channel to which a detector signal is to be connected (left, right)
DARK FIELD	STEM dark-field detector
DESCAN	Descan in a scanning mode
DESCAN X,Y	Alignment of descanning pivot points
DESCANNING	Descanning calibration service procedure
DET ALIGNM	Aligns the diffraction pattern/image with the BF/DF detector
DETECTORS	DETECTOR SELECTION page (also for external TV channel selection)
DF L R	Dark-field detector for mixing (left, right)
EDS	EDAX monitor signal as a video input
EDX	EDAX mapping signal
ELS	EELS mapping signal
ENERGY LOSS	EELS signal as a STEM detector signal
EXT TV	External TV signal as a video input signal
GREYSCALE	Greyscale generator output as a video input signal
LINE TIME	Scanning line time calibration, service alignment

LABEL	*MODE/ACTION/SELECTION*
LOW DOSE-L	The area to the left of the central area is selected during a STEM photo exposure. Thereafter the central area is displayed again.
LOW DOSE-R	The area to the right of the central area is selected during a STEM photo exposure. Thereafter the central area is displayed again. The LOW DOSE settings are cycled each time this key is pressed in the order: LOW DOSE-L, LOW DOSE, LOW DOSE-R, LOW DOSE, LOW DOSE-L - and so on
magn	The Magnification knob acts on the scan circuits TEM **CRT**
magn	The Magnification knob acts on the lenses **TEM** CRT
MAN **DYN**	Dynamic - automatically scanned - conical beam tilt for TEM dark-field imaging, DF mode selected
MAN DYN	Static - manually controlled - conical beam tilt for TEM dark-field imaging, DF mode selected
MICRO PROBE SCAN	Microprobe scanning mode
MIXING 2 SIGNALS	Mixing mode in scanning
MIXING	CONTROL page for mixing 4 scan signals
MON TEST	Monitor test, service alignment
NANOPROBE SCAN	Nanoprobe scanning mode
NO MIXING	No mixing of signals from different detectors in scanning
POST SPECIMEN SCAN	Post-specimen scan mode
ROCKING BEAM	Rocking beam mode
RESET SHIFT	An image shift that was previously chosen is cancelled
RESET SCNRT	The scan rotation is changed by 90° in the case that no manual rotation has been carried out, otherwise the line scan direction is set parallel to the specimen tilt axis
SACP	Selected area channelling mode in the STEM mode
SCAN BF-DF SCAN SE-BF	Scanning Bright Field/Dark Field Scanning secondary electrons/Bright Field
SCAN SE-DF	Scanning secondary electrons/Dark Field
SCANNING	A scanning main mode/Scanning calibration service procedure
SE	Secondary Electron Detector

LABEL	*MODE/ACTION/SELECTION*
SIGNL PROC	SIGNAL PROCESSING page
SIGNAL MIXING	Mixing of different detector signals in scanning
SPOT SHIFT	Moves the spot in SACP mode
TEM TV	TEM TV chain as video input signal
μμD	Micro-microdiffraction mode
VCR	Video cassette recorder
X-RAY EDS	EDAX mapping signal as a STEM detector input

8 HANDLING SF_6 GAS

8.1 INTRODUCTION

SF_6* gas is used as insulating gas in the high-voltage tank and the emission chamber of the CM200. This gas has been used for many years in many industrial environments. It is non-poisonous at temperatures below 250°C.

* SF_6 : Sulphur-hexafluoride gas, colourless, odourless, non-flammable, non-poisonous if not heated above 250°C.

The high-voltage tank and emission chamber of the CM200 are both sealed volumes and normally there will be no leakage of gas from these parts. Nevertheless, International Regulations require that certain safety procedures regarding SF_6 gas must be known and implemented by the person responsible for the installation. Additionally, any local regulations concerning SF_6 gas must also be observed.

WARNING! **In the event of fire, SF_6 will decompose to highly poisonous fluorine if the temperature exceeds 250°C. Ensure that the relevant local regulations are obeyed.**

(This rest of this page has been left blank intentionally for the insertion of local fire regulations).

GENERAL

- SF_6 gas is heavier than air.
- The gas causes suffocation at high concentration levels.
- The gas breaks down when overheated (above 250°C, see Sect. 8.2.1 and 8.2.3) giving off highly toxic fluorine gas.

THEREFORE:

- The ventilation system (see Sect. 8.2.1) must run (extract) **continuously**.
- **Smoking** in SF_6 sensitive areas is strictly **prohibited**.
- The SF_6 detector (see section 8.2.2) must always be in operation.
- Gas masks (2x) and rubber gloves (2 pairs) must be present. Gas masks should have filters of active charcoal and incorporated dust filter.

WHAT TO DO IN THE EVENT OF GAS LEAKAGE

- Switch off all heat sources (including any heat-producing lights).
- Ventilate the area by opening all windows. **Do not open the door**, since this allows the heavy gas to flow into the building.
- Switch off all heat sources.
- Trace and stop the leakage.
- All parts contaminated with solid decomposition products must be handled with rubber gloves.

WHAT TO DO IF SF_6 DECOMPOSES AND FLUORINE IS GIVEN OFF

Note: Even the presence of very low concentrations of fluorine can be detected by smell.

- Put on a gas mask.
- Ventilate the area (open windows, but keep door closed!).
- Switch off all heat sources.
- Trace and stop the SF_6 gas leakage.
- All parts contaminated with solid decomposition products must be handled with rubber gloves.

8.2 SAFETY PRECAUTIONS

8.2.1 Ventilation of the area

- As SF_6 is heavier than air, it will sink and stay at floor level. Therefore, there should be an extraction ventilation channel opening about 10-15 cm above the floor. This ventilation channel should open directly to outside air and **may not be connected to the central ventilation system of the building under any circumstance.**
- All holes in the floor giving possible access to lower floors in the building should be closed.
- When a filament (Wehnelt) of the CM200 is replaced, a certain amount of SF_6 gas must be pumped away with the pre-vacuum pump of the microscope. Because of this, the outlet of the pre-vacuum pump should be connected in such a way that the pump vents directly to the atmosphere outside the building and under no circumstances to the central ventilation system of the building.

8.2.2 SF_6 detection

For full safety, an SF_6 detector should be present and operated continuously. The detector must be a suitably calibrated instrument based on the thermal conductivity principle.

8.2.3. Illumination of the area

As SF_6 gas decomposes when heated to temperatures above 250°C, fluorescent-tube illumination should be used and not conventional tungsten lamps.

8.3 SPECIFICATIONS

The SF_6 gas used must meet the following specifications:

	SF_6 (IEC)		Esaflon
SF_6 minimum contents	Weight %	99.9	99.94
Air	Weight %	max. 0.05	max. 0.01
CF_4	Weight %	max. 0.05	max. 0.05
Water	Weight ppm	max. 15	max. 2
Acidity, calculated as HF	Weight ppm	max. 0.3	max. 0.3
Hydrolysable fluoride, calculated as HF	Weight ppm	max. 1	max. 1
Mineral oil	Weight ppm	max. 10	max. 1

The MONTEDISON company is a manufacturer of SF_6 gas.

APPENDIX A

TROUBLE-SHOOTING LIST

Possible messages

a) General

There are two possibilities:
No previous error: The new error message will be displayed instantly.
Previous error message present: The new error message will be stored in a message queue.
As soon as the displayed message is removed, the next message in the message queue will be displayed.

A message is removed from the data display monitor in two ways:
- by pressing the RESET button, causing the next error message in the waiting list to appear;
- automatically when the message is no longer appropriate (e.g. "Calibrating the line times" disappears automatically).

If, for example, the message "Default RAM initialisation" is displayed during start-up and the STEM is calibrated at the same time, after completion of the line time calibration, the message "Calibrating the line times" is removed from the waiting list. If during calibration RESET is pressed it will become visible and will then be removed automatically after completion.

Note: Do not operate the microscope during any automatic calibration action.

b) Possible error and other messages

	Message	Description / Action
B	Battery back-up failed	Contact service department
	Battery back-up unreliable	Contact service department
C	Calibrating the line times	Calibration of the line times during start-up, or after pressing Line Calibrate on the Service Calibrate page.
	CBP	Critical backing pressure ODP was reached, this means buffer pressure P1>58 Pa. Press Vacuum ON
D	DAC output failed	Contact service department.
	DAS error bit set	Contact service department.
	Default Ram initialization	Non-volatile Ram contains preset alignment parameters. (no longer specific instrument alignment parameters).
		Restore alignment from Remote Control computer or follow alignment procedure if necessary.
E	EDX protection active	Generated if EDX PROT is active and column air is pressed or when going from HM to LM.
	Error in calibrating the line times	Contact service department.
	Error power fail sense	Contact service department.
	Exposure time out of range	Insufficient or too much light to make an exposure. Adjust C2.
F	Film stock 0	No film stock left. Check if film material is off; if not, reset film stock to the correct number.
G	Gonio: Connect cable plug.	When a double tilt holder is selected the user is requested to connect the cable.
	Gonio: remove specimen holder.	During the special extraction procedure the user is requested to remove the specimen holder.
	Gonio: No GNCB communication.	Press ENABLED on the CompuStage Control page. If this does not help, contact service department.
	Gonio: Tracking error X. Gonio: Tracking error Y.	Mechanical problem with motor. Try movement again - if

	Message	Description
	Gonio: Tracking error Z. Gonio: Tracking error A. Gonio: Tracking error B. Gonio: Encoder error. X Gonio: Encoder error. Y Gonio: Encoder error. Z Gonio: Encoder error. A Gonio: Encoder error. B	the same message appears, contact the service department. Encoder problem with motor. Contact the service department
H	HREM series not compatible with nanoprobe	If the HREM range is selected (only for CM200 at 160--200 kV) in nanoprobe the magnification range is not correct . Select zoom range.
I	IGP interlock	Contact the service department.
K	Keyboard not responding	Contact the service department.
M	Main screen handle	The main screen is moved downward during a plate camera exposure cycle. Press Reset.
	Memory test MMB checksum error	Contact the service department.
	Memory test, inverse check sum error	Contact the service department.
	Memory test R/W data Ram error	Contact the service department.
	Memory test R/W NV Ram error	Contact the service department.
	Mismatch baud rate printer	The baud rate of the printer and the microscope do not match. Match Baud rate via Parameter page.
	Mismatch instrument number	Contact the service department.
	Mismatch key number	Contact the service department.
	Mismatch version number	Contact the service department.
	Message queue full.	More than 15 messages in the message queue. Read messages and press Reset
N	Not allowed because vacuum not ready	CRYO operations only possible after the vacuum status ready.
O	ODP circuit	Contact the service department.
	ODP oil	Thermal switch ODP S31 switches from warm to cold. See also Appendix B.
	ODP water	Thermal switch S30 (ODP cooling water temperature >60 °C) switches. See also Appendix B.
P	Plate stock 0	No film left for plate camera (checked directly after an exposure). Check if plates are off; if not, reset plate stock to correct number.
	Plate unload	Plate camera does not transport or Reed relay S20 is not activated. Check camera.
	Pneumatics	Pneumatic pressure is $<4 \times 10^5$ Pa. Check pressure.
	Printer	The microscope is receiving the wrong data from the printer. Check communications (Baud rate, cable).
	Printer not selected	Trying to print, but printer jumper not set on SDB. Contact the service department.
S	Solid state key	Mismatch solid state key and non-volatile Ram. Contact the service department.
	Spec. airlock time is not standard	Only for CRYO operation and the airlock pumping time is unequal to 32 seconds (standard time)
	Start-up of a (new) LaB_6 cathode	Each time a filament is heated without its limit switched on. And when interchanging filaments new is lit.
	Start-up of a (new) Tungsten cathode	Each time a filament is heated without its limit switched on. Also when switching from LaB_6 to Tungsten new is lit.
	System definition or BTR error	Contact the service department.
V	Vacuum interlock	Contact service department.
	Valve	Contact service department.

c) Program hang-up after a H.T. flashover

With an extremely strong flashover, the control program may experience a hang-up. If this occurs, proceed as follows:

1. Press STANDBY, then if necessary RESTART. In general IGP will then remain on, ensuring retention of high vacuum in column. Wait for the full microscope start up.

2. Check the overall instrument alignment. If the instrument performs as expected, continue with normal operation. If the alignment appears to be lost, and only then, proceed with the RAM INIT procedure and the Total Alignment Sequence (see Sect. 2.6.5).

d) No H.T.

If everything else is normal, check the 24 V power supply inside the Power Supply cabinet. In order to test this, open the left-hand door with the key provided and check the two LEDs on the two lower rows of the power supplies. These should be lit. If one of them is not lit, loosen the four screws approx. 2 cm and pull the unit out. Leave it disconnected in this position for 30 seconds. After this period, push the unit back into the rack, return to the operating panel and re-activate the H.T. button.

e) No emission

This could be due to one of the following:

1. If H.T. conditioning is selected on the first PARAMETERS page, it is not possible to heat up the filament.

2. After an extremely strong H.T. flashover, the 24 V filament current power supply in the power supply cabinet may have switched off. If this is the case, continue as described in d) No H.T., or if the control program is hang-up, proceed first as described in c).

3. Filament has broken down. Exchange filament.

f) Spot size limited

When there is no specimen holder in the microscope, the spot size will be set to 5 and a spot size indication of XXX will appear on the microcontroller screen. As soon as a holder is introduced into the goniometer airlock, the spot size can be controlled again.

g) No lens currents

If there are no lens currents measurable when DISPLAY CURRENTS is selected on the PARAMETERS page, the column lifting safety circuitry which automatically switches off the lens currents and H.T. may be active.
Unauthorised attempts to operate the column lifting mechanism can activate the microswitch which controls the safety circuitry.
This point should be checked if the lens currents cannot be obtained when starting to use the microscope.
Check water flow and if necessary reset it to the correct value.

h) No operation of microscope and control panel

If this condition occurs, first check the main power switch then the fuses behind the right hand door of the Power Supply cabinet. Replace any blown fuses and reset the main power switch to on.
If all LEDs on the operating panels are unlit, the ROOM DIM knob may be in the off position.

i) Continual beeps from most controls when adjustments to a specific mode are attempted

This indicates an incorrect combination of parameters, mostly due to an attempt to set a certain deflection current to a value that the current supplies cannot deliver. Check the deflection CURRENT values on the CURRENT DISPLAY page (key PARAMETERS then key DISPLAY CURRENTS and if one or more are excessively high, attempt to reduce them as follows (depending on the mode in use):

1. In Dark Field, reset the DF tilts.

2. In STEM with an off-axis detector, reset the DET. ALIGNMENT parameter.

3. If the beeps do not occur at all spot sizes, reset the Condenser stigmator for those spot sizes where beeps are given.

j) Photo plate mechanism becomes jammed

Refer to section 4.3.5 for instructions on how to remove jammed photo plates

WARNING! **Do not attempt to remove plates without first reading section 4.3.5!**

WARNING!

1) ***Objective aperture holder***
In the case of a CM200 Super Twin equipped with an EDAX detector, a special 3-position objective aperture holder must be used. It is specially designed for use in this configuration to avoid damage occurring to either the detector or the holder.

2) ***Filament limit***
The operator must never leave the CONFIGURATION page directly by entering the ALIGNMENT page (by pressing the ALiGNment button) and performing an Alignment procedure, by entering the STIGMATOR page (by pressing the STiGMator button) or by entering the DARK FIELD mode (by pressing the Dark Field button) without first having set the FILament LIMIT (reversed video).

Failure to observe this procedure will mean that protection against burning down the cathode has not been set when the ALIGNMENT procedure, STIGMATOR page or DARK FIELD mode is left.

3) ***X-Ray safety***
To ensure security from ionising radiation, the CM200 is equipped with specially designed shielding and covers. These should only be removed when carrying out service procedures (see Service Instructions). *DO NOT SWITCH ON THE HIGH TENSION SUPPLY AT ANY TIME WHEN THE COVERS OR SHIELDING ARE REMOVED.*

4) ***Working with SF_6 gas***
SF_6 gas is used as an insulating gas in the high voltage tank and emission chamber of the CM200. When a fixed gas supply is not installed, follow the procedure advised by your local service engineer.
Full information concerning the correct handling of SF_6 gas is given in Sect. 8.

APPENDIX B

ALIGNMENT OF THE TRANSMISSION ELECTRON MICROSCOPE

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