Quanta 3D 200i

FEI COMPANY™

The Quanta 3D 200i System Capabilities

The Quanta 3D 200i is a combination of two systems:

- A Scanning Electron Microscope (SEM) produces enlarged images of a variety of specimens achieving magnification over 100 000x providing high resolution imaging in a digital format.
- A Focused Ion Beam (FIB) system is capable of fast and precise milling of the specimen material, revealing the structure under the surface layer, making cross sections, deposition layers, etc. The ion system produces high resolution images as well.

The integration of both systems yields a powerful analytical tool for obtaining any data from any sample in three dimensions.

Users can switch between the two beams for quick and accurate navigation and milling. Convergence of the SEM and FIB at a short working distance allows precision “slice-and-view” cross-sectioning and analysis at high resolution. The instrument provides optimum throughput, resolution and automation.

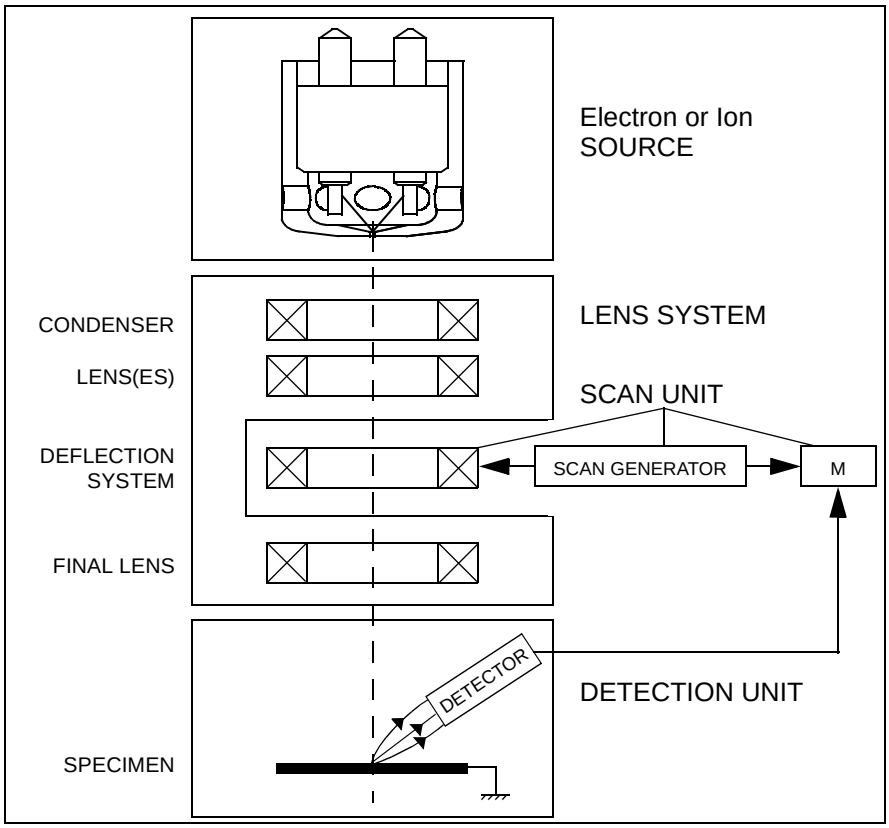
FIB/SEM instrument provides an expanded range of capabilities not possible with separate FIB or SEM tools:

- High-resolution electron beam images of FIB cross sections without eroding the feature of interest
- Real-time cross-section images and videos with the electron beam during FIB milling
- Electron beam Drift Suppresion during FIB milling or imaging
- High resolution elemental microanalysis of defect cross sections
- Imaging of sample surfaces with the electron beam during navigation without erosion or implantation of FIB source ions
- A Transmission Electron Microscopy (TEM) sample preparation with *in situ* conductive coating

The main instrument components used for imaging of the samples are:

- **Electron / Ion source**
  The beam of electrons or ions (particles) is emitted within a small spatial volume with a small angular spread and selectable energy.
- **Lens system**
  The beam enters the lens system consisting of several electromagnetic or electrostatic lenses and exits to hit the specimen surface.
- **Scan unit**
  The scan generator signal, fed to the deflection systems, moves the beam in a raster pattern over the specimen area. The electrical voltage changes as it rasters. This signal, modulated by the detection system signal produces the onscreen imaging of the specimen surface.
- **Detection unit**
  Particles striking the specimen react with atoms of the sample surface in various manners:
  – The electron beam produces electrons and photons (X-rays).
  – The ion beam produces ions, electrons and photons (X-rays).
  The detector system picks up the particles or fotons, converts them into an amplified electrical signal which is then sent to the control PC and displayed on the monitor.

FIGURE 1-1 COLUMN SCHEMATIC OVERVIEW



COMPUTER CONTROL

The xT microscope Server and xT microscope Control (User Interface) softwares integrate SEM functionality within a Windows XP™ operating environment.

These softwares consist of programs defining specific instrument settings for particular applications, ensuring reproducibility of complex procedures (for instance imaging, management of image capture, storage, and data output devices etc.). They also control instrument hardware (the column, detector(s), stage, EDX, vacuum functions etc.).

VACUUM SYSTEM

The entire electron path from gun to specimen must be under vacuum so that the particles do not collide with air molecules. The Quanta 3D 200i has the following operating vacuum modes to deal with different sample types:

- **High Vacuum** (HiVac)
- **Low Vacuum** (LoVac)
- **ESEM**™ (Environmental SEM)

Various levels of vacuum are necessary, so a Turbo Molecular Pump (TMP) backed by a scroll pre-vacuum pump (PVP), obtains the necessary specimen chamber pressure.

In the gaseous modes (LoVac, ESEM), the electron column is under lower pressure than the specimen chamber, where the pressure ranges from 10 to 130 Pa (0.1 to 1 Torr) for LoVac or from 10 to 2700 Pa (0.1 to 20 Torr), with auxiliary gas up to 4000 Pa (30 Torr) for ESEM. Either mode can use water vapours from a built-in water reservoir, or an auxiliary gas which is supplied by a user and connected to a gas inlet provided for this purpose. Observation of outgassing or highly charging materials can be made using one of these modes without the need to metal coat the sample, which would be necessary for conventional HiVac mode. In the LoVac and ESEM modes only the electron imaging can be operated.

Specimen exchanges take place through a chamber door which exposes the specimen stage when opened. The exchange takes a few minutes. Software and interlocks protect the system against a damage and users against an injury.

IMAGE VIEWING AND CAPTURE

Because the amplified detector signal is displayed synchronously with the beam scanning, there is a correspondence between brightness of an image point on the monitor screen and the signal detected at the corresponding point on the specimen.

Magnification is the ratio of the size of the viewing monitor screen to the size of the area scanned on the specimen. Higher magnification is achieved by reducing the size of the area scanned on the specimen.

STAGE POSITIONING

A choice of computer-controlled high-accuracy multi-axis stages offers precision specimen manipulation and automation for overall spatial orientation on highly repetitive or extremely irregular samples.

BEAM CONTROL

FIB/SEM instrument position the point of interest ideally for simultaneous ion beam cross-sectioning and electron beam viewing. Separate scan generators for each beam permit coupled or independent scan patterns and magnifications. Imaging while milling aids in defining milled features.

Immediate electron beam images of cross sections are possible without stage motion or sample transfer. Immediate high-resolution SEM imaging after FIB milling also prevents exposure of the milled cross sections to atmospheric contaminants.

The ion system works only in the HiVac mode.

GAS DEPOSITION

Multiple FEI Gas Injection System (GIS - option) can be installed for material deposition in conjunction with either electron or ion beam pattern definition. Electron beam-induced deposition offers the advantage of not sputtering the deposited material or implanting FIB source ions simultaneously.

Several GIS chemistries can be installed on the instrument, depending on a system configuration. This self-contained apparatus allows the material to be contained entirely within the vacuum system for simple, flexible, and safe operation.

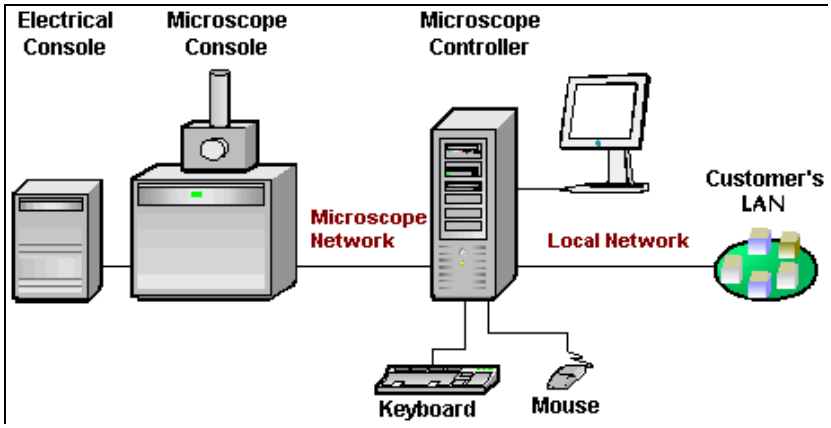
FIGURE 1-2 QUANTA 3D 200i SYSTEM

SYSTEM OVERVIEW

The standard layout is based around a dedicated microscope controller (PC) along with an electrical console to power the microscope console (vacuum, gun, column, and stage).

The support computer contains various other items that are generally accepted as essentials or are dedicated to particular optional applications (such as forensics or failure analysis).

FIGURE 2-1 QUANTA 3D 200I STANDARD LAYOUT SCHEME



SYSTEM COMPUTER

The system is computer controlled and as such has a **Microscope Controller** which must be turned on to operate the microscope by means of the software. The power button on the microscope PC must be used to turn it on. The control software facilities and data are displayed graphically on the **LCD monitor** and are superimposed around and on the image. To control software utilities one can use **keyboard, mouse, joystick** (option) or **Manual User Interface** (option).

SYSTEM CONTROL PANEL

The console / system power is activated by pressing the front panel **power button** located on the microscope console. This switches the sub-systems on and allows the interface and communication with the microscope controller. Most of the functions are activated via the software control.

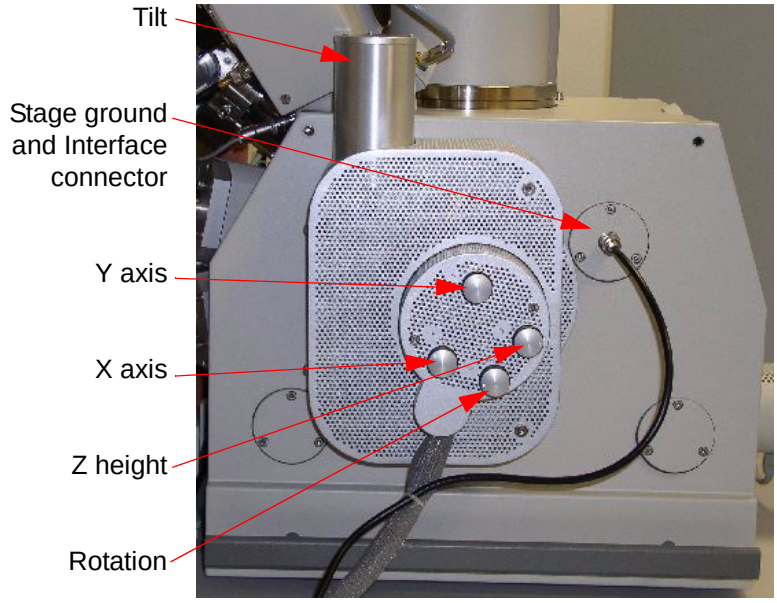
FIGURE 2-2 SYSTEM CONTROL PANEL POWER BUTTON

The stage is software or manually controlled. The software control is an integrated part of the **xT microscope Control** software (see Chapters 3 and 5).

50 MM STAGE (5-AXIS MOTORISED)

The stage has the **X, Y, Z, Rotation** and **Tilt** movements motorised, all (except the tilt) with manual override. All coordinates are displayed on the screen, under the software control.

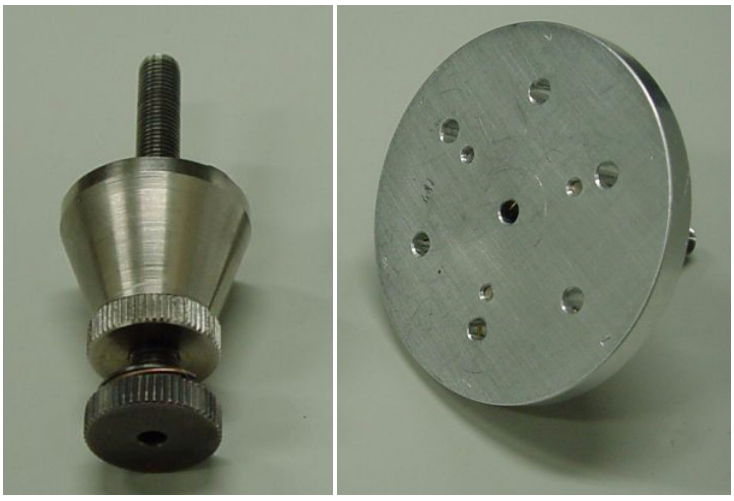
FIGURE 2-3 QUANTA 3D 200I STAGE CONTROLS (5-axis Motorised)



Standard Sample Holder

The single stub holder and the multiple holder (7-stub holding disc) are provided with the microscope. The single holder has a spring clip fitting and a secure-fitting screw. The multiple holder has a spring clip fitting only.

FIGURE 2-4 STANDARD SAMPLE HOLDERS



It has the threaded shaft which screws into the stage rotation head

center and can be securely attached to the stage by means of the conical locking piece.

STAGE MOVEMENT LIMITS

The motorised movements of the stage can be operated under software control for more advanced location mapping. This includes **Shift**, **Get**, **Track** and the **Stage** module functionality. A live image can be repositioned either by the stage movement (manual or software) or by the **Beam Shift** (see Chapter 5).

Note:
When moving the stage or tilting the specimen, the magnification may need to be reduced not to move the feature of interest off the screen.

FIGURE 2-5 STAGE MOVEMENT SCHEMA

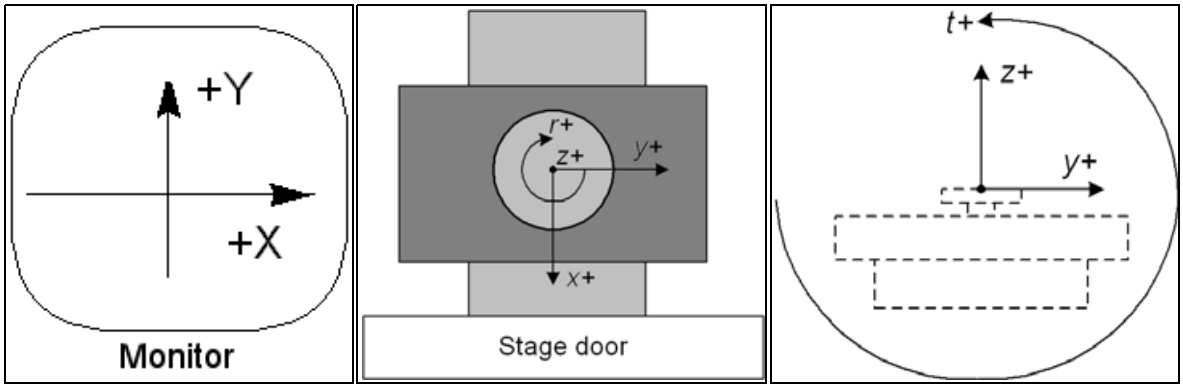


TABLE 2-1 STAGE FEATURES AND LIMITS

Item	50 mm Stage	Note
X	-25 to +25 mm	
Y	-25 to +25 mm	
Z	25 + 25 mm	internal + external
R	360°	continuous
T	-10° to +60°	Check the sample size
Eucentric Position	Electron column: WD = 15 mm Ion column: WD = 27 mm	
Clamp	No	
Maximum sample weight	250 g	for all tilt angles
	1 000 g	at Tilt = 0°

C a u t i o n !
If the maximum sample size is near to the limit (100 x 50 x 50 mm), stage tilt could be limited. Beware of hitting the objective pole piece!

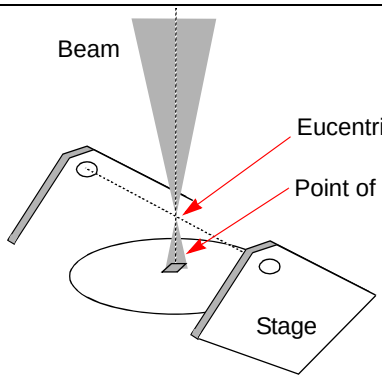
Eucentric Position Adjustment

At the eucentric position, the stage tilt, the electron beam and the ion beam axes intersect. When the stage is tilted or rotated in any direction, this point remains focused and almost does not shift. At the eucentric position, one can use various system components in a safe and optimal way (e.g. GIS, Omniprobe).

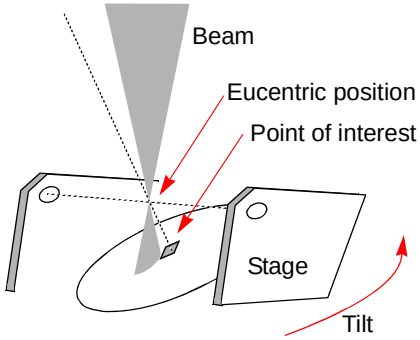
Eucentric position should be adjusted after loading any new sample, as the sample loading clears all position information.

Note:
For electron imaging of non-tilted sample the eucentric position adjustment is not necessary. But it is still required to run the Link Z to FWD procedure.

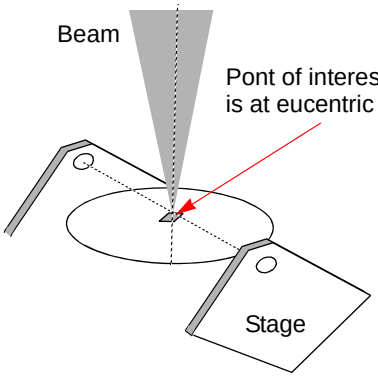
FIGURE 2-6 EUCENTRIC POSITION PRINCIPLE



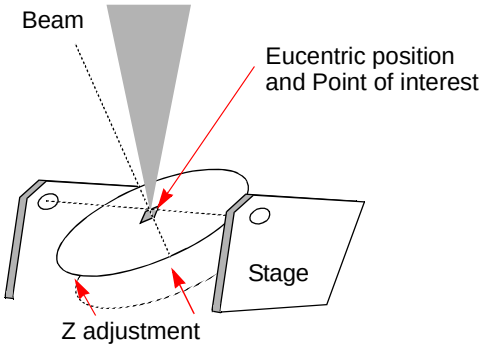
1) The point of interest is focused below the Eucentric point.



2) Tilting the stage moves the point of interest out of the beam.

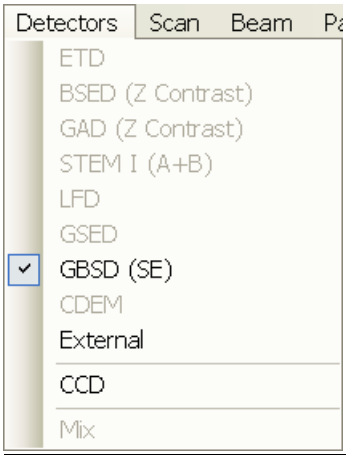


3) The point of interest is focused at the Eucentric point.



4) Tilting the stage does not move the point of interest out of the beam.

Detector Types and Usage



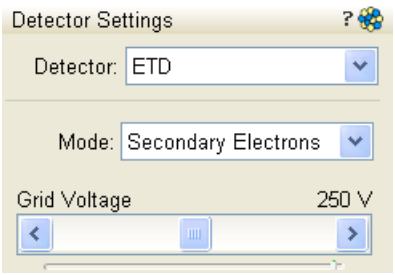
The **Detectors** menu shows all detectors, the selected one has a tick mark next to its label. Availability of detectors (full colour label) depends on the actual vacuum mode. The system remembers the last detector used for a particular vacuum mode, beam and its Contrast & Brightness settings.

Note:
If any detector which is not compatible with the current mode is selected, the imaging quad cannot be activated.

TABLE 2-4 QUANTA 3D 200i DETECTORS

Detector Name	Tag	Vacuum Mode	Detected Signal	Maximum Pressure [Pa]	Note
Everhart-Thornley	ETD	HiVac	SE (tunable energy) BSE, SI, BSI	3 x 10^{-2}	S
Large Field	LFD	**LoVac**, ESEM	SE + BSE	200	S
Gaseous Secondary Electron	GSED	LoVac, **ESEM**	SE	1000 µm aperture: 950 500 µm aperture: 2600	S
Gaseous Back-Scattered	GBSD	ESEM	SE, BSE	500 µm aperture: 2600	O
External	EXT	detector-dependent	detector-dependent	detector-dependent	
CCD camera	CCD	any	light, infra-red light	any	S
Backscattered Electron	BSED	**HiVac**, LoVac	BSE	200	O
Gaseous Analytical	GAD	HiVac, LoVac, ESEM	BSE	2700	O
STEM	STEM I	HiVac, LoVac, **ESEM**	TE	any	O
Continuous Dynode Electron Multiplier	CDEM	HiVac	SE, SI	5 x 10^{-3}	O

EVERHART THORNLEY DETECTOR (ETD)



It is a scintillator photo-multiplier type detector collecting electrons generated by the primary beam interaction with the specimen surface. It is permanently mounted in the chamber above and to one side of the sample. It works in three **Mode**s:

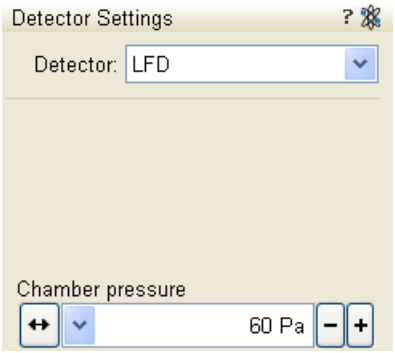
- Secondary Electrons (SE)
- Backscattered Electrons (BSE)
- Custom

ETD Settings

The **Detector Settings** / **Mode** list box enables to choose a **SE** / **BSE** mode (the **Grid Voltage** is set to +250 V / -150 V) or a **Custom** mode, for which the Grid Voltage could be set by the adjuster in a range from -240 to + 260 V (the **Default Grid Voltage** button sets the voltage to 0 V). When the voltage is negative (use a range of -25 to - 240 V), SE are repelled from the ETD detector and only BSE are detected.

Note:
When CDEM is mounted on a system, its **Collector Grid** and **Front End** voltages may decrease the signal collected by the ETD. For the best ETD performance, zero these voltages.

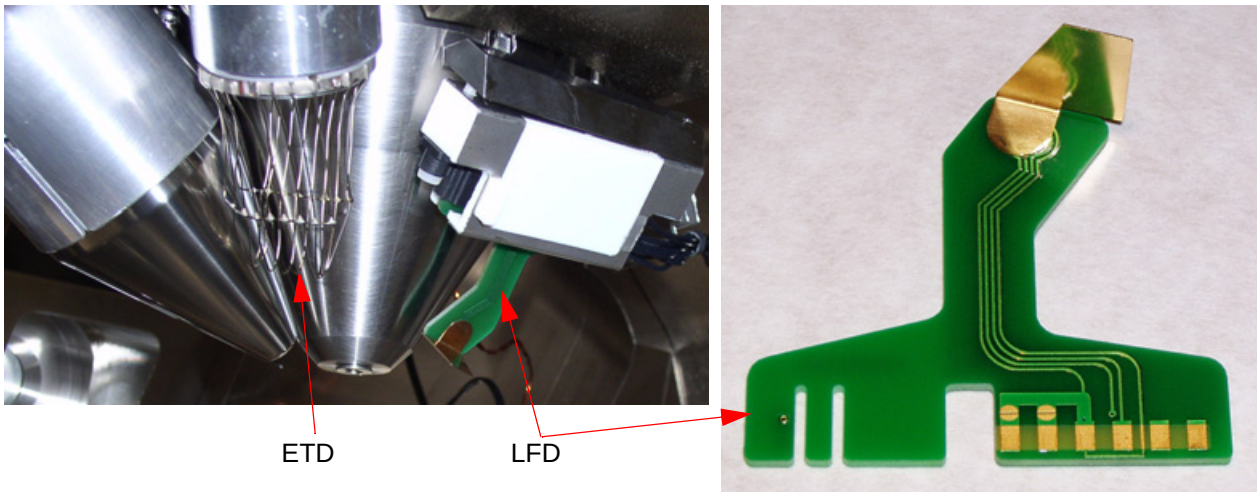
LARGE FIELD DETECTOR (LFD)

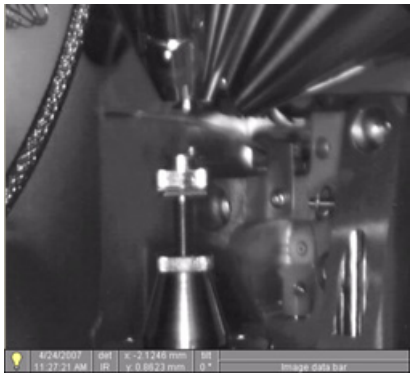


This detector is mounted in the chamber above a sample. The field of view is unrestricted and the magnification range is identical to that of HiVac mode (assuming no other pole-piece accessory is mounted).

The signal from the LFD contains more BSE information than the GSED signal. The detector is ideal for general imaging. The field of view is unrestricted and the magnification range is identical to that of HiVac mode (assuming no other pole-piece accessory is mounted).

FIGURE 2-7 ETD AND LFD INSTALLED





Note:
After selecting the LFD, **Preferences…** / **ESEM** tab / **Purge mode** changes to **Automatic** despite any previous selection. This ensures that the proper chamber environment is achieved (see Chapter 4).

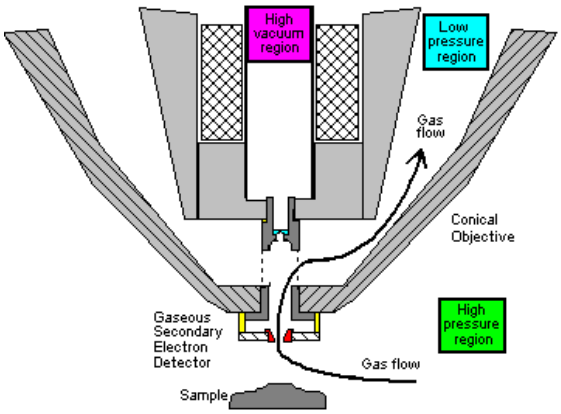
INFRARED CCD CAMERA

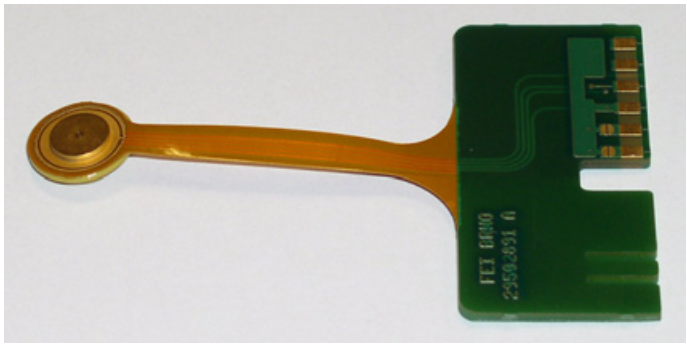
enables to view the inner space of the specimen chamber (an optical quad). It assists with an overall sample orientation and during a stage movement to prevent its collision with the lens pole. IR LED's are used to light the specimen chamber interior.

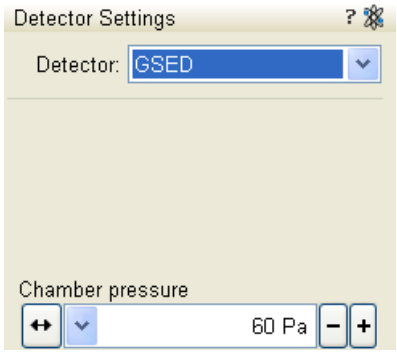
GASEOUS SECONDARY ELECTRON DETECTOR (GSED)

The GSED is integrated into a flexible printed circuit board and plugs into the signal connector behind the conical lens. It is used for general wet imaging and for high pressure imaging with auxiliary gases.

FIGURE 2-8 GSED AND ITS SCHEMA







The overall imaging consists of a very pure SE signal with very little BSE signal component, due to the detector design and chamber geometry. This pure SE signal makes this detector best suited for resolution imaging. The field of view is less than the LFD at the lowest magnification. The lower magnification range is about 240x at 7 mm WD.

To influences a detected signal use the **Detector Settings** module / **Chamber Pressure** adjuster.

Vacuum

There are following vacuum sections:

- Electron column
- Ion column
- Specimen chamber

In operation the electron and ion columns are always pumped to high vacuum. The specimen chamber is at the pressure required for the given state (Pump / Vent) or mode (HiVac / LoVac / ESEM).

Electron Column and Specimen Chamber sections are vented for a sample or detector exchange.

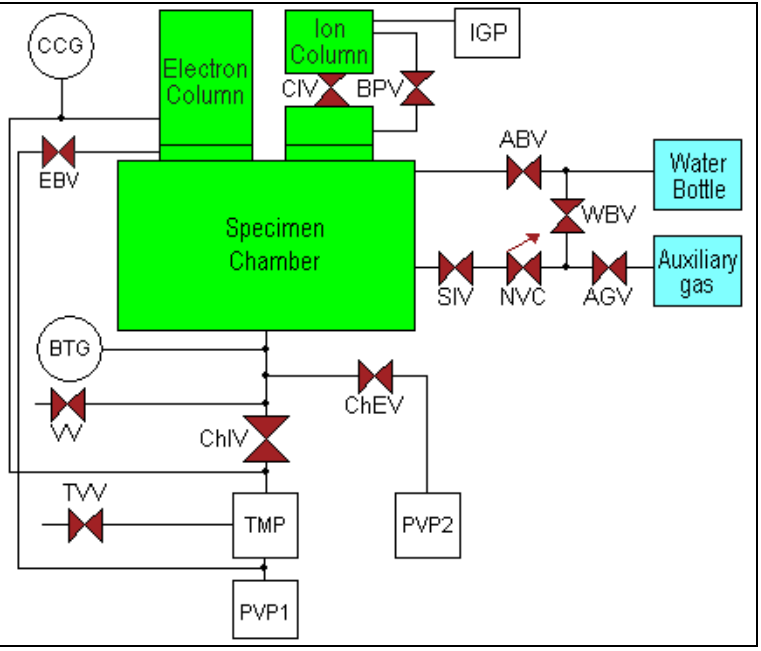
All valve and pump operations are fully automatic.

Note:
The ion beam can only be operated in HiVac. When LoVac or ESEM mode is chosen, the ion column CIV is closed.

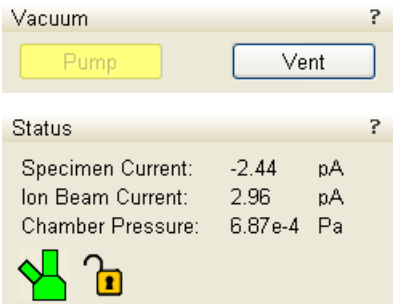
FIGURE 2-10 THE QUANTA 3D 200i VACUUM SYSTEM

Legend:

AGV . . . . Auxiliary Gas Valve
BPV . . . . Bypass Valve
BTG . . . . BaraTron Gauge
. . . . . (Capacitance Gauge)
CCG . . . . Cold Cathode Gauge
CIV . . . . . Column Isolation Valve
ChEV . . . Chamber Evacuation Valve
ChIV . . . . Chamber Isolation Valve
EBV . . . . Environmental Backing Valve
IGP . . . . . Ion Getter Pump
PVP . . . . Pre Vacuum Pump
SIV . . . . . Servo Isolation Valve
TMP . . . . Turbo Molecular Pump
TVV . . . . . Turbo Venting Valve
VV . . . . . Venting Valve
WBV . . . . Water Bottle Valve



VACUUM STATUS

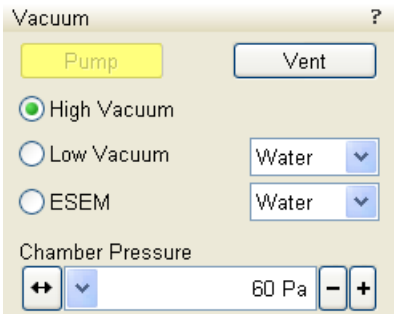


The vacuum status controls are in the **Vacuum** module. The **Pump** button starts pumping for the operating pressure and the **Vent** button starts venting for a sample or detector exchange.

In the **Status** module at the bottom of any page the actual vacuum status is represented by the coloured icon, which may have three possible colours with the following meaning:

- **Green: PUMPED** to the desired vacuum mode (see below)
- **Yellow: TRANSITION** between two vacuum modes (pumping / venting / purging)
- **Grey: VENTED** for sample or detector exchange

VACUUM MODES



The **Vacuum** module / **High Vacuum** or **Low Vacuum** or **ESEM** radio button is used to select the instrument target operating mode when a **Pump** sequence is initiated.

High Vacuum (HiVac) Mode

The high vacuum condition is common throughout the column and specimen chamber. The pressure should be below 6.10^{-2} Pa.

Low Vacuum (LoVac) and ESEM Modes

In these modes, the column section is under the lower pressure than the specimen chamber where the pressure ranges from 10 to 130 Pa (LoVac) or from 10 to 4000 Pa (ESEM). These modes uses water vapour from a built-in water reservoir or a gas from an auxiliary gas inlet.

TABLE 2-5 MAXIMAL CHAMBER PRESSURE [PA (TORR)] UNDER DIFFERENT GASEOUS ENVIRONMENT

Working Gas	500 µm Aperture	1000 µm Aperture
Water - H_2O	2 700 (20)	750 (5.5)
Nitrogen - N_2	4 000 (30)	750 (5.5)
Air		
Carbon Dioxide - CO_2		
Nitrogen Dioxide - NO_2		
Helium - He	2 000 (15)	500 (4)
70 % He + 30 % H_2	1 500 (12)	400 (3)
Argon - Ar **)	1 000 (7)	200 (1.5)
C_xH_y *)	4 000 (30)	750 (5.5)

SOFTWARE CONTROL

This chapter describes the functionality of each part of the user interface.

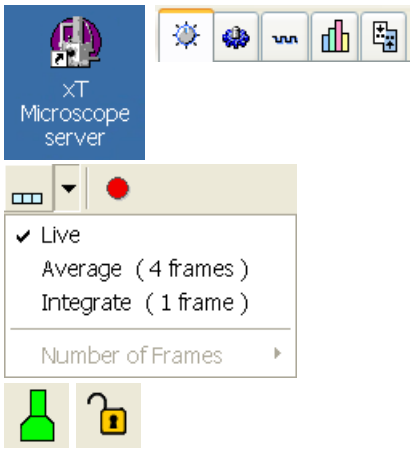
SOFTWARE INTERFACE

The software control contains graphic applications within Windows XP™ operating environment. **xT microscope Server** starts and stops the basic microscope functions.

It makes possible to open and close the **xT microscope Control** software (**UI** – user interface or sometimes **xTUI** in the dialogue boxes) which controls system functions including imaging, image and movie gathering / manipulation / output, detection and analysis, scanning, magnification, stage navigation, chamber and column pressure, etc.

All user account levels are created via **FEI User Management** software, ensuring for the particular users admission to both the operating system Windows XP and the xT microscope Control software.

Software Interface Elements



ICONS

are small symbols indicating a specific software application. Double-click the icon to activate the program.

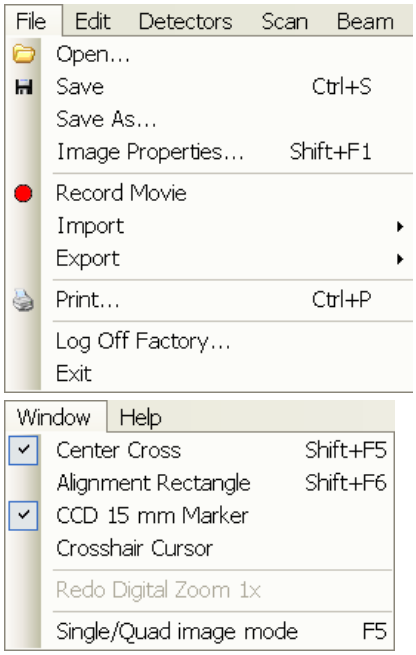
There are also **functional icons** in the toolbar for selecting some software functions quickly. Clicking causes it to press in and activate, clicking it again or clicking another one (depending on a particular case) causes it to spring out and deactivate.

Some functional icons have additional down-arrow next to the right side. Clicking the arrow displays a pull-down menu with choices, while clicking the icon performs a particular function (cyclic changeover of choices, setting the default parameters etc.).

There are also some **informational icons** in the status field, for instance, that indicate some particular system status.

TOOL-TIPS

are activated when the cursor is left over an item on the user interface for more than two seconds. A short explanation of the item appears until the cursor is moved away from the item.



PULL-DOWN MENUS

The microscope uses menu-oriented software; you perform functions by choosing items from the **Menu bar**. The Menu bar selections contain pull-down menus that display grouped listings of available commands or settings. Some menu items are shown in grey and cannot be selected because of the system immediate condition.

Pull-down menu selections followed by the ellipsis (…) indicate, that a dialogue box will display (the same behaviour occurs when the selection is a command). Selections with a right arrow indicate that an additional submenu of choices will display. If a selection is a parameter value, the new value is updated immediately and a check mark appears in the pull-down menu.

Using the Mouse

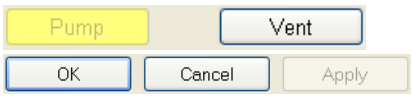
Click on the menu item in the Menu bar, then drag the cursor down to the desired selection and release the left mouse button.

Using the Keyboard

Press ALT plus the underlined letter (for example, **ALT + F** for the File menu), and then select from the choices with the left mouse button or with the up / down (left / right for submenus) arrow keys.

Some often-used commands can quickly be activated with the use of shortcut keys (a combination of simultaneously pressed keys) at any time. This possibility is given by a particular button combination on the right side of the pull-down menu adjacent to the appropriate command.

COMMAND BUTTONS

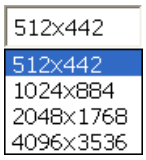


carry out or cancel functions. They press in when clicked and some change colour to show the corresponding function activity.

Command buttons have labels that describe the actions performed by clicking them. The most common ones, which are typically used in dialogues are:

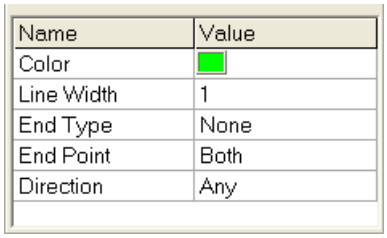
- The **OK** button applies all changes made in the dialogue and closes it.
- The **Finish** button saves new settings, ends the procedure and closes the dialogue.
- The **Save** button saves new settings at that point without closing the dialogue.
- The **Apply** button saves and applies new settings at that point without closing the dialogue.
- The **Cancel** button discards all changes (made from the last save) and closes the dialogue. It has the same effect as closing the dialogue with the cross (Alt + F4).
- The **Next** button moves an user to the following dialogue after necessary settings have been done.
- The **Previous** button moves an user to the previous page when settings need to be changed.

LIST BOXES



contain available choices, such as screen resolution, magnification settings, etc. Click the **List** box to roll down a list of available values, then click the desired one. The dropdown list automatically closes and displays the new value as the actual one. The change of the setting is immediate.

PROPERTY EDITORS

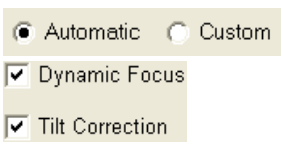


group list of related parameters and their values. The editable parameters have a white background, the fixed parameters are shaded. An user should click in the **Value** side of the relevant property **Name** and then select its value from the drop down list or enter it using a keyboard.

EDIT BOXES

let you input text information (such as passwords, labels or precise numbers) using the keyboard. Some edit boxes, which are not part of a dialogue, require to confirm the input by pressing **Enter**. If you press **Esc** before leaving the edit box, its previous value is restored.

RADIO BUTTONS / CHECK BOXES



Within a group of related round **Radio buttons**, only one selection can be made active at any time by clicking in the individual box.

A single one or a group of square **Check boxes** can be ticked / cleared by clicking inside the individual one.

ADJUSTERS

allow to change parameters, such as contrast, brightness, gamma etc. in a continuous way by clicking and dragging the middle adjuster or clicking in the grey bar. They always have a label in the upper left and right corners for readout information. Double-click the value in the upper right corner enables to enter a precise value (and the unit in particular cases) using the keyboard.

Continuous Adjuster

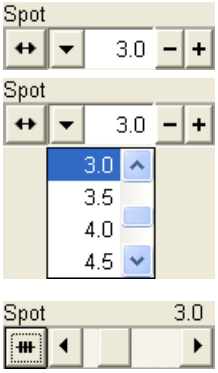
- The **large adjuster** – for relative adjustments
  It has exponential response – the further from the center the adjuster button is pulled, the larger is the relative change.
  The adjuster button always snaps back to the center of the slider.
- The **slider** (grey bar) – for larger adjustments.
- The **end arrows** – for finer adjustments, single step increments.
- The **small adjuster** – for linear adjustment, continuous response
  The adjuster button position always corresponds to the actual parameter value within an available range.

Linear Continuous Adjuster

This is a linear response adjuster. Behaviour is the same, as for the Small adjuster (see above).

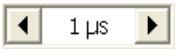
Preset / Continuous Adjuster

is used for values that have both a continuous range, a list of presets and direct value editing to achieve total control over one function. The button on the left side of the adjuster toggles between modes:



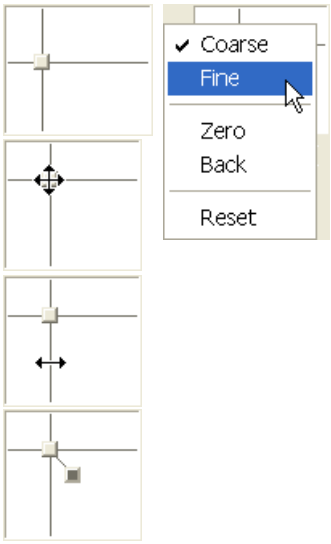
- **Drop-down list:**
  clicking the -/+ buttons on the right of the drop-down menu steps through the pre-set values Up / Down in the list, but only shows one value in the text area. Clicking the down-arrow rolls down the whole list of values. If the list extends further than is visible, a scroll bar appears. Clicking a value in the list enters it as a current value in the text area displayed at the top.
  Double-clicking a value in the text area enables to edit it.
- **Adjuster mechanism:**
  The adjuster has a fine control (see above).

Spinner



allows to change a parameter in an incremental way from a list of pre-defined values by clicking on an arrow.

2D CONTROLS



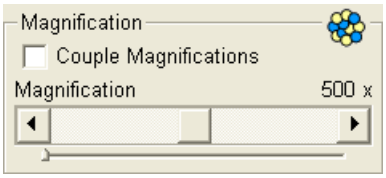
are represented by an X-Y box. The position of the crosshair corresponds to the actual parameter value with respect to its full range being represented by the perimeter of the box.

Click and hold down the crosshair with the left mouse button to display a 4-axis arrow cursor in the imaging area, which can be moved in four directions that correspond to the X / Y screen values. Clicking the X / Y axis in the same way displays a 2-axis arrow cursor, which can be moved in the corresponding direction. To fix the values, release the mouse button and the position of the crosshair is updated.

Clicking inside the 2D box with the right mouse button opens a dialogue showing the choices:

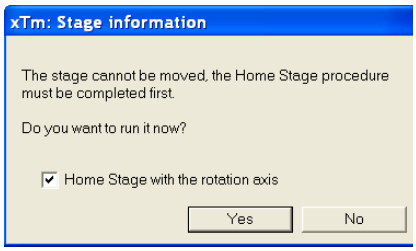
- **Coarse** / **Fine** switches the 2D control sensitivity.
- **Zero** – brings the 2D control to the center of the box.
- **Back** – brings the 2D control one step back (only one step is remembered).

The menu may contain also other functions that are actually available for the particular parameter. Select the corresponding menu item to activate the function.



MODULES

visually combine various software elements, which are related into a labelled group. Complex software elements like UI pages or dialogues are typically composed of modules.



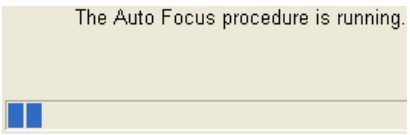
DIALOGUES

appear when the system needs more information from you before it can carry out a command, or want to give you some important actual information. Some dialogues do not let you access other functions until you close them, other ones let you perform other tasks while they remain onscreen and active (for example, the Preferences dialogue can remain opened while performing other tasks).

TABS

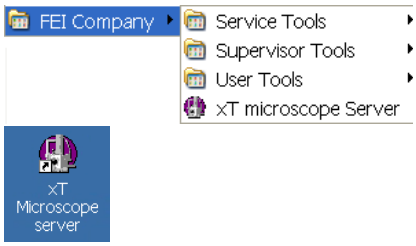
In modules or dialogues containing more interface elements than would fit into the limited area the **Tabs** are used. These related elements are split into the groups (sections) and each one is supplemented with the labelled Tab. Clicking the Tab brings it to the foreground displaying the corresponding group of interface elements.

PROGRESS BARS



indicate progress of a long ongoing procedure over time. It is often displayed in a dedicated dialogue.

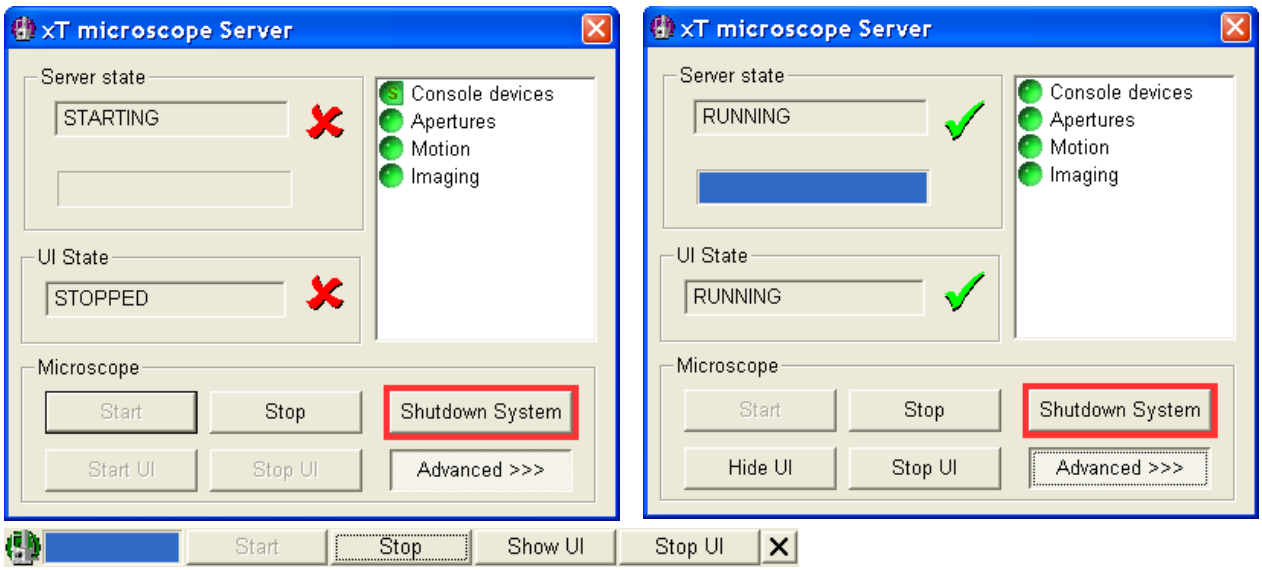
xT microscope Server Software

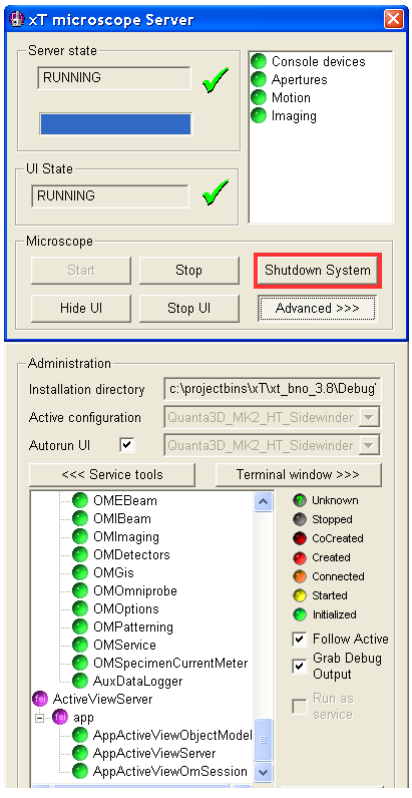


The **xT microscope Server** application starts and stops the software service controlling basic microscope functions and also the user interface (UI) software **xT microscope Control**.

Run the **xT microscope Server** (from the Windows Start menu or double-click the icon) – the application window appears. The title bar right mouse button clicking opens a dialogue that offers the option to minimize the server to the UI top bar.

FIGURE 3-1 xT MICROSCOPE SERVER WINDOW





- The **Server State** / **UI State** modules display the **RUNNING** or **STOPPED** state of the xT microscope Server / xT microscope Control software services. During a transition between these states **STARTING** or **STOPPING** is displayed.
- Some **Microscope** module buttons change its label and behaviour depending on the actual state.

  The **Start / Stop** button starts / stops xT microscope Server services. If the xT microscope Control (UI) is running, Stop button closes it first.

  The **Start UI / Stop UI** button opens / closes xT microscope Control (UI) software.

  The **Show UI / Hide UI** button calls / hides the UI main window.

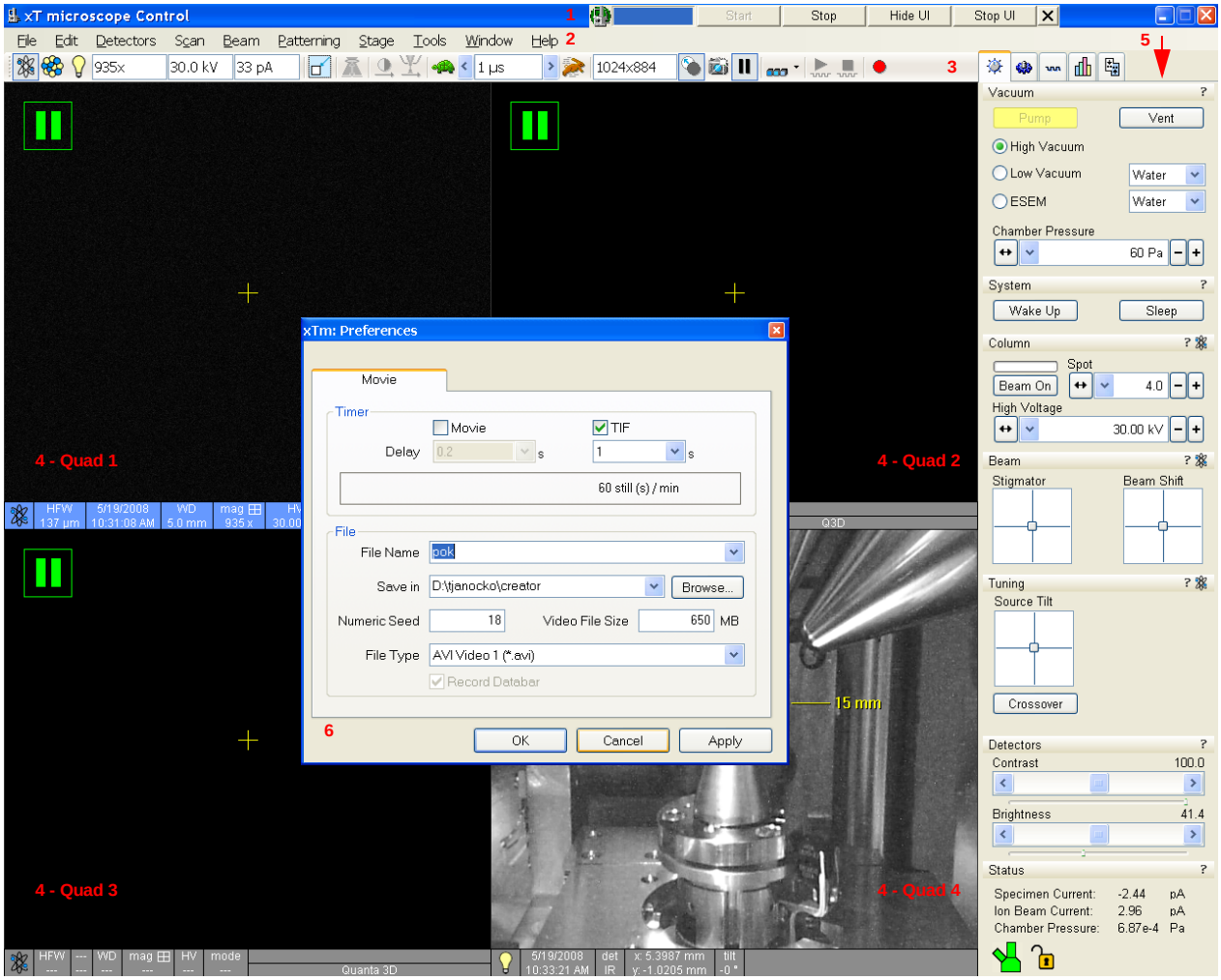
  Shutdown System button shuts down xT microscope Server software in three steps: 1) same as **Stop UI** button, 2) same as **Stop** button, 3) switches power off (reverse procedure to pushing **power** button found on the microscope console control panel)

  The **Advanced** button displays the **Administration** module containing information helpful when calling the service (specifying the software operation / hardware function state).

  - The **Autorun UI** checkbox: when ticked (default), the Start button automatically starts xT microscope Control after starting the Server.

xT microscope Control – also called User Interface (UI or xTUI) – is made up of several elements which compose the main window, displaying status and control features.

FIGURE 3-2 THE MAIN WINDOW



1. The **Title bar** – labels the application
2. The **Menu bar** – contains all operation menus and submenus
3. The **Toolbar** – contains functional icons for the most frequently used microscope controls and for the fast access to the Pages
4. The **Imaging area** – quads with adjustable Databar
5. **Pages and Modules** – microscope and imaging control elements organized into modules making up the pages
6. The **Preferences dialogue** – presetting of operating conditions

TITLE BAR

displays the application icon and name plus the standard Windows buttons: **Minimize** and **Close**, which are enabled.

FIGURE 3-3 THE TITLE BAR

The Close button quits the xT microscope Control software (accelerating and detectors voltages are switched off for the security reasons).

MENU BAR

displays pull-down menus across the screen below the Title Bar.

FIGURE 3-4 THE MENU BAR

Select pull-down menus from the menu bar by pressing:

- the left mouse button on the Menu title
- ALT + underscored keyboard letters
- ALT and then use keyboard arrows

Note:
Some menu functions have their equivalents in the toolbar. In such cases, the corresponding toolbar icon is shown next to the function title in the following text.

TOOLBAR

displayed below the Menu bar is made up of functional icons linked to the most frequently used system controls. It also contains group of icons for quick switching between UI Pages. The toolbar can be a bit different in content or style (see the **Preferences…** / **General** tab).

FIGURE 3-8 THE TOOLBAR

Rest the cursor above the icon for two seconds without clicking it to see its explanatory tool-tip.

Whenever you select a function the corresponding icon is highlighted to indicate that the function is active (except of auto-functions, which display a progress dialogue).

Note:
If any icon represents a menu function, refer to the corresponding menu for its description.

IMAGING AREA

The xT microscope Control software uses 4 independent image windows – quads for imaging samples. Each quad can contain imaging from any detector (including External and CCD), paused imaging or images loaded from a file. Additionally, quad 3 can display a mix of imaging from quads 1 and 2, and quad 4 can display a mix of imaging from quad 1, 2 and 3.

It can be displayed either 4 quads at the same time – **Quad Image** mode or one quad over the UI imaging area – **Single Image** mode.

Each quad consists of its imaging area, adjustable Databar containing the imaging parameters, selectable overlay (user-defined colouring, annotations, measurement) and some status symbols (Pause, Sample Navigation, etc.).

At any time, just one quad is selected (has focus), and all functions (related to a single quad – Pause, Sample Navigation, image processing) applies only to imaging in this quad. The selected quad is marked by the highlighted (blue) Databar.

Depending on the quad content and the status, some mouse functions are available over its area:

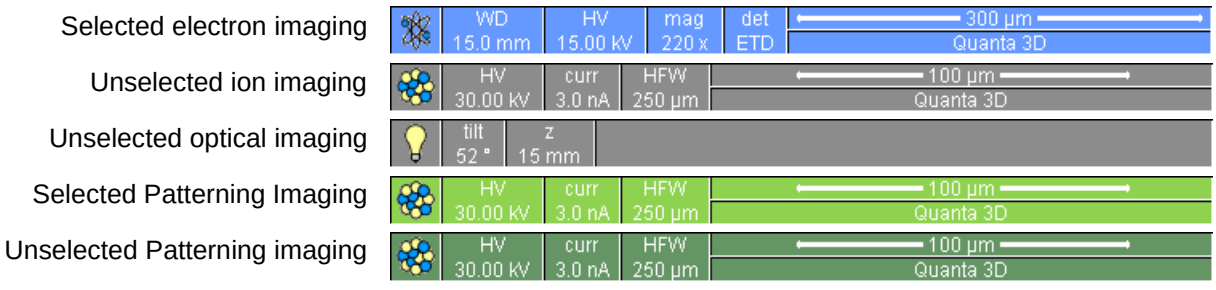
- **Electron imaging** (incl. External and Mix): focus, astigmatism correction, Beam Shift, magnification change (coarse, fine), zoom (in / out), lens alignment, Scan / Compucentric Rotation, XY-move (get or tracking mode)
- **Ion imaging** (incl. External and Mix): focus, astigmatism correction, Beam Shift, magnification change (coarse, fine), zoom (in / out), Scan / Compucentric Rotation, XY-move (get or tracking mode)
- **Optical imaging**: 15 mm Marker placement, Compucentric Rotation, Z-move (tracking), Tilt

Note:
Due to a hardware limitations, some detectors cannot be used simultaneously. They can still be selected for different quads at the same time, but if one of them is started, the other quads with incompatible detectors are automatically paused.
The optical imaging is automatically activated (if it is paused), when the venting procedure starts.

Image Databar

displays Instrument, Imaging and labelling information. This can be a combination of Date, Time, HV, Detector, Stage coordinates for instance. They can be placed in any order and expand or contract to fit the quad width as long as there is enough room (see the **Preferences… / Databar** tab).

FIGURE 3-9 THE DATA BAR EXAMPLES



PAGES (ALT + P) AND MODULES

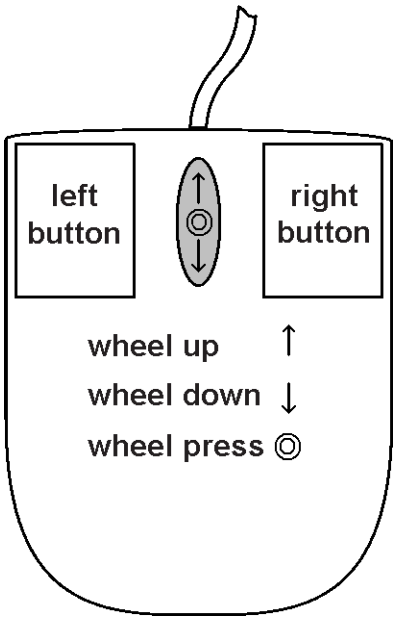
The software controls on the right side of the screen are organized into **Pages**, which are divided into **Modules** holding specific functions. The required page can be selected either from the Pages menu, by pressing the corresponding icon button or with the use of short-cuts (see below).

TABLE 3-1 PAGES AND MODULES LIST





Pages	Modules (Tabs)
Beam Control	1. Vacuum / Mode, 2. System, 3. Column, 4. Beam, 5. Tuning, 6. Detectors, 7. Status
Navigation	8. Stage (Map / Coordinates / Tilt / Navigation), 9. Magnification, 10. Detector Settings, 6. Detectors, 7. Status
Patterning	11. Pattern / Progress (Basic / Advanced / DS), 12. End Point Monitor (iSPI / Graphs / Options / Scaling), 7. Status
Processing	13. Measurement / Annotation, 14. Digital Zoom, 15. Enhanced Image (LUT / Mix 3 / Mix 4 / Color), 6. Detectors, 7. Status (reduced)
Alignments	16. Alignments (Instructions / Individual steps), 7. Status



USING MOUSE

TABLE 3-3 MOUSE BUTTON FUNCTIONS

Key + Button	Function
Left	**Control Areas:** *makes selection* in control areas (single arrow cursor). **On Screen:** click and drag a *selected area* to *zoom in* magnification to fill the imaging area with the selection (see the **Preferences…** / **General** tab). ***Double Click:*** **Electron / Ion imaging:** *moves the selected point* to the middle of the quad. **Optical imaging:** *15 mm marker placement*.
Left + Shift	**On Screen:** click and drag a *selected area* to *zoom out* imaging to fit the selected area.
Shift + Left	1. Activates *Beam Shift* (hand cursor). 2. Pauses / Activates all quads when clicking the toolbar pause icon.
Right	To *focus* with the mouse, press and move the mouse to the left or right (double ended arrow cursor).
Shift + Right	To *correct imaging astigmatism*, press and move the mouse (four-ended arrow cursor) to the left / right (X stigmator), or up / down (Y stigmator).
Ctrl + Right	Activates *Lens Alignment* (4-arrow cursor).
Shift + Wheel Up / Down	**Fine Control:** moving the wheel *increases / decreases the magnification*.
Ctrl + Wheel Up / Down	**Coarse Control:** moving the wheel *increases / decreases the magnification*.
(Ctrl+) Wheel Press	**Electron / Ion imaging:** with the wheel pressed like a button the *TRACK mode* for joystick-like movement over the sample surface is activated. **Optical imaging:** activates the *stage Z movement (stage Tilt)*. With the wheel pressed, moving the mouse up or down / left or right moves the stage up or down / tilts the stage left or right.

Note:
The given sequence of key and button pressing is important for some functions.

TABLE 3-4 WINDOWS SYSTEM KEYS

Key (+ Key)	Function
Enter	Equivalent to *OK* in a dialogue box.
Esc	1. Equivalent to the *Cancel* button. 2. *Cancels the click* and drag function. 3. Stops the stage motion at that point. **Note:** During some procedures (Home Stage for instance) use the software Cancel or Stop button!
Tab	*Step key* to highlight items in a dialogue box.
(Shift +) Arrows	1. Use to *select between items* in a group when in a list box. 2. When quad is active and selected, the stage moves approximately (40%) 80% of the field of view in any direction by clicking the appropriate keyboard **Arrow key**.
Alt (or F10)	Activates menu of the active application. Pressing the underlined character in the menu bar pulls-down the corresponding menu.
Alt + Tab	Use to *switch between running applications*. This starts from the last used one, continue to press the **TAB** key (while holding down the **ALT** key) and applications are shown one by one. Releasing the ALT key at any time makes application just listed active.
Alt + F4	*Exits active application* or Windows operating system.
Del(ete)	*Deletes* selected text or items.
Ctrl + A	Select all items
Ctrl + C (Ctrl + Insert)	*Copy* to clipboard
Ctrl + V (Shift + Insert)	*Paste* from clipboard
Ctrl + X (Ctrl + Delete)	*Cut* to clipboard

TABLE 3-5 FUNCTION AND SPECIFIC KEY SHORT-CUTS

Key (+ Key)	Function
F1	Displays documentation
Shift + F1	Displays Image properties
F2	Starts / Stops Photo
F3	Toggles Videoscope On / Off
Shift + F3	Starts Home Stage procedure
F4	Starts / Stops Electron Snapshot
Ctrl + F4	Starts / Stops Ion Snapshot
F5	Toggles Single / Quad Image mode
Shift + F5	Toggles Center Cross display
F6	Pauses / Activates scanning
Shift + F6	Toggles Alignment rectangle display
F7	Toggles Reduced Area / Full Frame Mode
F8	Degauss
F9	Starts Auto Contrast and Brightness procedure
Shift + F9	Link Z to FWD
F11	Starts Auto Focus procedure
Ctrl + F11	Starts Auto Stigmator procedure
Shift + F11	Toggles Display Saturation function
F12	Toggles Compucentric Rotation tool
Shift + F12	Toggles Scan Rotation tool
Pause	Starts / Pauses / Resumes patterning
Ctrl + Pause	Resets patterning
Ctrl + 0 - number	Moves stage to X=0, Y=0
Ctrl + B	Toggles Beam Blank function
Ctrl + E	Tilt stage to 0°
Ctrl + F	Sets FWD to Eucentric Position (15 mm)
Ctrl + I	Tilt stage to 52°
Ctrl + M	Sets Full Frame scanning conditions
Ctrl + N	Toggles Sample Navigation
Shift + N	Starts to mill next line
Ctrl + Shift + N	Starts to mill previous line
Ctrl + O - letter	Opens Preferences dialogue
Ctrl + P	Opens Print dialogue
Shift + P	Proceeds with next pattern
Ctrl + R	Restarts scan
Ctrl + S	Save image

TABLE 3-5 FUNCTION AND SPECIFIC KEY SHORT-CUTS

Key (+ Key)	Function
Ctrl + T	Toggles Electron and Ion beams
Ctrl + Z	Moves stage to the Last position
Ctrl + (Shift +) ,	Set one step slower (slowest) scanning
Ctrl + (Shift +) .	Set one step faster (fastest) scanning
Ctrl + (Shift+) Tab	(Backward) steps between quads
Ctrl + Page Up / Down	Left / Right steps between pages
Ctrl + 1 / 2 / 3 … - letter keypad	Selection of the particular page (the number corresponds to the toolbar page icon sequence)
+ / -	Increases / Decreases the magnification 2x
*****	Rounds off the magnification to the nearest round value
Ctrl + + / -	Scales up / down the imaging 2x (Digital Zoom)
Ctrl + arrow	Moves the digital zoom area

Preferences… Dialogue

This dialogue can be opened by selecting **Preferences… (Ctrl + O - *letter*)** from the pull-down menus: **Scan** and **Tools**. The opened menu from which it is chosen dictates the tab opened on entry. Once the Preferences dialogue is opened, any of the tabs can be chosen.

The Preferences dialogue consists of tabbed sections. Clicking the required tab opens a section that allows changing and presetting conditions for a group of the related functions. Only one tab can be opened at any time.

The items changed remain valid (for a specific user) until changed for the next time.

Some of the preference controls are beam dependent. In this case, an active beam type is indicated by the corresponding icon and items change accordingly.

The specimen material for High Vacuum mode must be able to withstand a low pressure environment (without outgassing) and the bombardment by electrons. It must be clean and conductive. Oil and dust may contaminate the chamber environment, which could hinder or even prevent evacuation to the level needed for standard SEM operation.

Note:
Always wear lint- / powder-free clean room gloves when reaching into the specimen chamber to minimise oils, dust, or other contaminants left inside the chamber.

NEEDED ITEMS

- Class 100 clean-room gloves
- Specimen stubs and conductive adhesive material
- Tools: tweezers, 1.5 mm hex wrench
- Prepared or natural specimen

NATURAL SPECIMEN

If no coating is desired the Low Vacuum mode can be used to stabilise the specimen for observation. This mode is useful if there is a suspicion that a coating might alter the specimen.

If the specimen contains any volatile components, such as water or oil, and therefore will not withstand coating, then the ESEM mode can be utilised with the proper environment gas and pressure to allow observation of the specimen in its natural state.

COATED SPECIMEN

If the specimen is nonconductive (plastic, fibre, polymer or other substance with an electrical resistance greater than 10^{10} ohms) the specimen can be coated with a thin conductive layer. This conductive layer reduces beam stir due to sample charging and improves imaging quality.

For successful imaging, rough surfaced specimens must be evenly coated from every direction. Biological, cloth and powder specimens may require carbon or other conductive painting on portions of the specimen that are hard to coat.

Coating reduces beam penetration and makes the imaging sharper. It may mask elements of interest for X-ray analysis (thus the use of carbon for geological and biological specimens).

For more information on specific preparation techniques, see *Scanning Electron Microscopy and X-Ray Microanalysis, 2nd ed.* by Joseph Goldstein et al., Plenum Press, New York, 1992.

MOUNTING SPECIMEN TO THE HOLDER

Wafers and PGA devices have individual sample-mounting procedures. If you are using a wafer piece or other sample, attach the specimen to the specimen holder using any suitable SEM

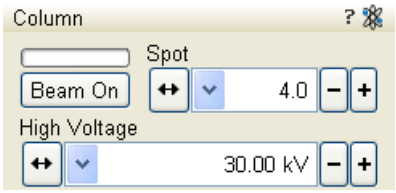
vacuum-quality adhesive, preferably carbon paint. The specimen must be electrically grounded to the sample holder to minimize specimen charging. If you are using a vice mechanism or double-sided tape, make sure the specimen is conductively attached to the holder.

Note:
The sample holder is not directly grounded to the chamber ground because it is connected to the BNC feed on the chamber door. This allows to measure the specimen current.

C a u t i o n !
Store samples and sample holders in a dry and dust free environment. Dust on samples can get drawn into the electron column, degrading imaging and requiring an FEI Customer Service.

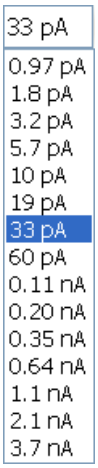
HIGH VOLTAGE AND BEAM CURRENTS

The High (accelerating) Voltage and the Beam Current are related; a HV change causes a beam current change. A selected HV provides an individual set of beam currents. The choice of High Voltages and Beam Currents (toolbar dropdown list boxes) depends on the active beam type, either Electron or Ion.



Besides a normal list box behaviour an intermediate value can be entered into the editable High Voltage text box and this provides a calculated range of beam current / spot values. The last entered value is also remembered in the preset list.

The values can also be chosen using the **Column** module / **Spot** / **High Voltage** preset continuous adjusters (see below).



Electron Beam Current

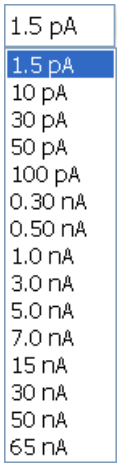
This is one of the basic operating parameters. In other way it is represented as the function of the electron beam diameter on the speciment surface (usually presented as the **Spot** size, expressed by a relative number), the final lens aperture diameter and its opening angle set by the condenser. It is considered to be close to ideal when spot edges just touch the neighbouring one. If it is too large, overlaps occur and the image appears out of focus. If it is too small, electronic noise appears in the image.

A suitable beam current value for a particular magnification can be determined easily, when good focus and astigmatism correction is achieved.

TABLE 5-3 SPOT SIZES AND RECOMMENDATION OF THEIR USE

Spot size	Best Use
1.0 – 3.4	Very low currents, charging and sensitive samples
3.5 – 4.5	High resolution
4.6 – 6.0	Standard imaging
5.0 – 7.0	High current imaging, X-ray analysis with SiLi detectors
7.0 – 9.0	Extreme currents, Drift Suppression
1.0 – 5.0	Standard imaging (not sensitive samples), X-ray analysis with drift detector

Note:
When changing the spot size, adjustment of the Detector module / Contrast and/or Brightness may be necessary to optimize the imaging. An alternate approach is to use the Auto Contrast Brightness (F9) function.



Ion Beam Current

A suitable **Ion beam** current value is determined by an application. A particular beam limiting aperture is used to obtain a desired Ion beam current. The larger aperture is applied, the higher is a current. In general, use a smaller aperture for high resolution imaging and a larger one for faster milling.

There are 15 possible Ion beam currents (apertures) selectable from the toolbar list. The set is variable according to the accelerating voltage.

TABLE 5-4 ION BEAM CURRENTS (at 30 kV) and CORRESPONDING BEAM DIAMETERS

Beam current [pA]	Beam Diameter [nm]	Usage
1.5	**7**	Very high resolution, High aspect ration holes, Pt via filling
10	**13**	Quick imaging, Fast Pt via filling
30	**17**	Navigation imaging, Milling submicron holes, Final milling on cross sections
50	**19**	
100	**24**	Milling micron-sized holes, Intermediate / final milling on cross sections, Short Pt strap deposition
300	**31**	Milling micron-sized holes, Intermediate milling on cross sections, Medium Pt strap deposition
500	**35**	
1 000	**44**	Initial milling for small cross sections, Long Pt strap deposition
3 000	**66**	Initial milling for medium cross sections, Longer Pt strap deposition
5 000	**85**	Initial rough milling for medium-large cross sections, Pt probe pad deposition (40 µm x 40 µm)
7 000	**102**	
15 000	**182**	
30 000	**260**	Initial rough milling for large cross sections, Pt bond pad deposition (50 µm x 50 µm)
50 000	**300**	
65 000	**400**	

Imaging Optimising

PRINCIPLES OF SEM IMAGING

All scanning beam microscopes screen with the same fundamental technique. The primary beam is scanned across the specimen surface in a regular pattern called a raster. Normally, this raster consists of a series of lines in the horizontal (X) axis, shifted slightly from one another in the vertical (Y) axis. The lines are made up of many dwell points and the time of each dwell point can be shortened or prolonged (dwell time). The number of points per line can be increased or decreased as well as the number of effective lines (resolution). The result is a picture point (pixel) array. Low or high resolution imaging can be obtained by changing these factors. The larger the pixel array, the higher the imaging resolution. The imaging is created pixel-by-pixel in the computer memory and displayed on a monitor screen.

The signal emitted by the specimen surface as it is illuminated with the primary beam is collected by the detector, amplified and used to adjust the intensity of the corresponding pixel. Because of this direct correspondence, the pixels displayed on the monitor are directly related to the specimen surface properties.

The raster consists of many (typically one million) individual locations (pixels) that the beam visits. As the beam is scanned, the signal emitted by the sample at each beam position is measured and stored in the appropriate digital memory location. At any time after the beam scan, the computer can access the data and process it to change its properties, or use it to generate a display.

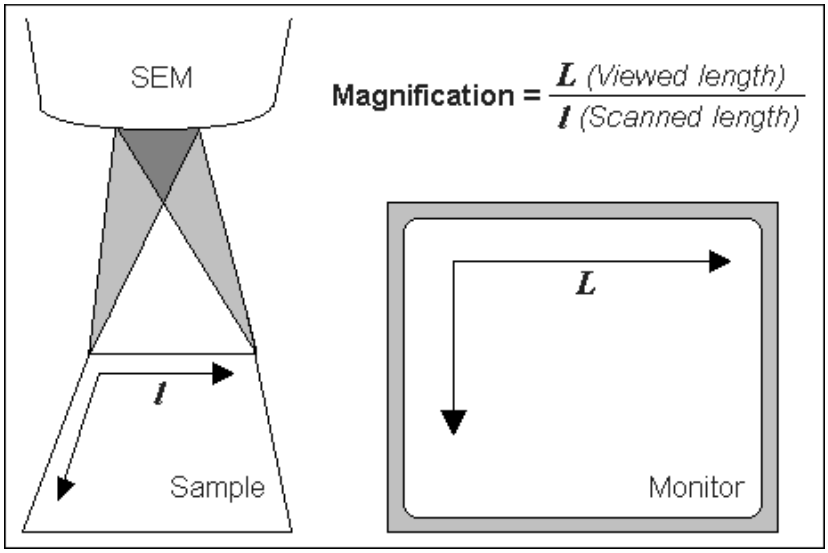
MAGNIFICATION

Magnification is calculated as the displayed dimension (L) divided by the sample scanned dimension (l).

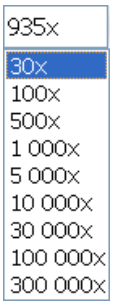
If the observed sample point size is made smaller while the monitor size remains constant, the magnification increases. At low magnification, you get a large field of view. At high magnification, you point only a tiny sample area.

It is possible to set a corresponding data bar magnification readout in the Quad Image and Single Image modes and in the saved image (see the **Preferences…** / **Magnification** tab).

FIGURE 5-1 MONITOR IMAGING AND SCANNED SAMPLE



Changing Magnification



- The **Toolbar** list box is used to select from a predefined values.
- The **Keyboard** control (**+** / **-** / *****): the numeric pad plus key (+) / the minus key (-) increases / decreases the magnification 2x and rounds the value. The star (*****) key rounds the magnification value (e.g. 10 063x becomes 10 000x).
- The **Mouse wheel** control: Coarse / fine control can be operated by holding the Ctrl / Shift keyboard key and moving the mouse wheel up / down to increase / decrease the magnification.
- The **Selected Area Zooming In / Out** is a quick way of zooming in / out on an area of interest. Click with the left mouse button into the imaging area, hold it and drag to make a dotted box over the area of interest (the cursor changes to a magnifying glass with a + sign). Release the button and the selected area increases to fill the whole quad (window) with respect to the sides ratio. Using the left mouse button + Shift key consecutively reverses the above described technique (the cursor changes to a magnifying glass with a - sign).
  The escape button cancels the operation at any time.
- The **Magnification** module (see Chapter 3)

SCAN SPEED AND FILTERING

To make a good imaging it is necessary to find a balance between scan speed, charge, sample damage and signal to noise ratio.

A noisy imaging can be improved by decreasing the scan speed. If charge or sample damage are the limiting factors it is better to use a faster scan speed in combination with an **Average** or **Integrate** filter (see Chapter 3).

FOCUSING

Find a feature of interest with distinct edges on a specimen. Use a combination of contrast, brightness and magnification adjustments to maximize the imaging quality.

To avoid scanning too long and contaminating or even damaging the sample, move away from a feature of interest with the stage, and focus until the imaging is sharp on an adjacent area.

Focusing at a higher magnification makes the result more precise. For example, for an output at the 2000x magnification focus at 4000x – 8000x magnification.

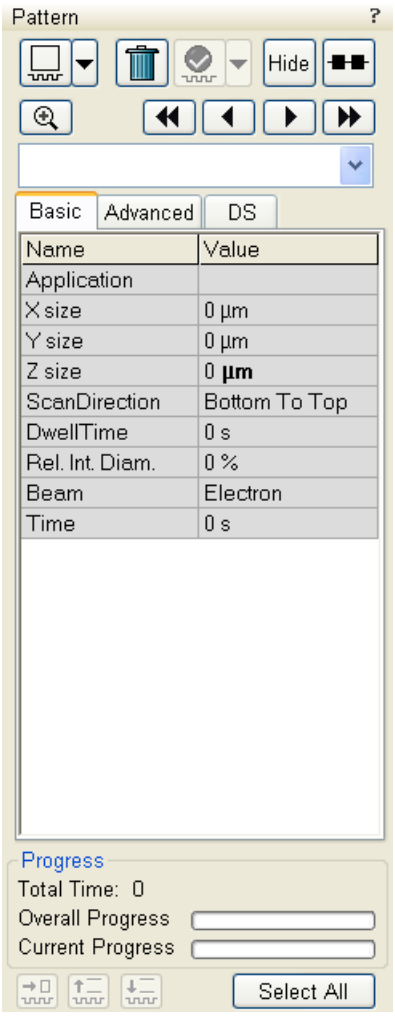
Note:
Particularly in case of ion imaging you must be aware of the fact that higher magnification increases the risk of damage to the sample.

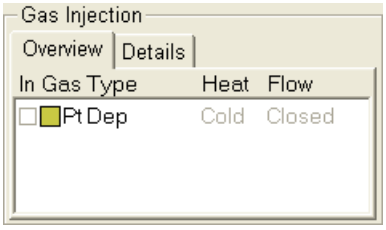
Focusing with MUI (option)

Use **coarse** and **fine** focus knobs. The imaging immediately responds to the MUI.

Note:
Use also the following functions to focus
(see Chapter 3): **Reduced area** (F7), **Auto Focus** (F11).

Patterning





Patterning is the process of moving a beam over the specimen with the purpose of:

- the **milling** – removing well-defined amounts of existing material
- the **deposition** – depositing well-defined amounts of new material

at well-defined locations (the shapes such as rectangles or circles), leaving other areas untouched. While patterning can be done with either beam, the electron beam is generally used only for imaging and sometimes for deposition with patterns.The Ion beam is used to cut cross sections and tracks, drill vias, and deposit new material.

Shapes have many associated parameters, such as the beam (ion or electron) that will be used for patterning and especially the gas that can optionally be used during patterning to increase the speed of the process. As different applications require different gases, there could be multiple GIS's (Gas Injection System) installed on your system. You select an application file for a given pattern in Patterning property editor. It automatically sets the appropriate GIS, the dwell time and overlap, calculates the proper dose appropriate to the beam chemistry.

The GIS can be selected manually also, but note that overlap and dwell time should be set carefully with particular gases in mind to avoid disappointing results. Before the patterning with the GIS starts, the GIS needle must be inserted manually and the gas reservoir must be heated. The GIS valves opening / closing is automatic during patterning.

SPI (Simultaneous Patterning and Imaging) mode

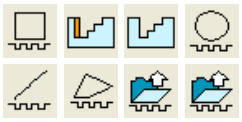
An electron imaging is possible during patterning, but it is strongly influenced by secondary electrons generated by the ion beam (SE imaging). The higher electron currents (higher spot numbers) and averaging help to improve the imaging. In case the BSE dector is used this interference is less important (BSE imaging). The system remembers the brightness and contrast setting for each modes (SPI or normal imaging).

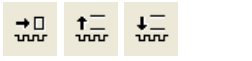
Note:
When patterning is paused in one quad it is possible to start patterning in another one. Similarly when patterning finishes there may still be a paused pattern in another quad.

Note:
If the magnification is too high, milling certain patterns can use too much memory needed for the control system to run. The pattern corners become rounded and the edges become jagged. A good rule of thumb is to pick a magnification where your pattern fills 35-50% of the screen.

PATTERN / PROGRESS MODULE

Patterning Tools





The selected icon (denoting a tool for patterns handling and setting) is displayed with a black staggered line surrounding.

- The **Pattern selector:** Clicking the arrow next to the icon activates the dropdown list. When a selection is made, the area displays an appropriate icon (**Rectangle / Cleaning Cross Section / Regular Cross Section / Circle / Line / Polygon / Bitmap / Stream File** see below) with an yellow background, enabling to draw a pattern. Clicking the selected icon again brings a normal background colour and the pattern selection cursor (arrow) is active.
- The **Trash Can (Delete)** button deletes the selected patterns.
- The **Enable / Disable** button sets the selected pattern(s) enabled or disabled for patterning. When the enabled and disabled patterns are selected together, the icon with the question mark is displayed.
- The **Hide / Show** button hides the currently selected pattern.
- The **Patterning Serial / Parallel sequence** button switches between two possibilities (see below).
- The **Magnifying glass** button zooms in / out the selected pattern(s) to fill the entire image quad.
- The **Order** buttons set the pattern milling order (see below).
- The **Next Pattern / Next Line / Previous Line** buttons control the patterns or lines milling during Cleaning Cross Section (see below).
- The **Select All** button selects all patterns available.

Bitmap Pattern 

From the patterning page a pattern is available that allows you to import bitmaps as a pattern. In this 24 bits RGB bitmap each pixel consists of:

- The **Red** component – currently not used.
- The **Green** component – determines if the beam is blanked. Any other value then 0 activates the beam.
- The **Blue** component – determines the dwell time per pixel. If blue is set to 0 the dwell time of a pixel is 100 ns. If blue is set to 255 the maximum UI dwell time is used. The dwell time for the pixels in between these values is linearly interpolated and then rounded to the value from a (fixed) dwell time table with 124 entries.

Note:
When drawing a bitmap it is recommended to use black (0 / 0 / 0) for none milling points and white (255 / 255 / 255) for milling points.
Do not forget to optimize other properties such as application file, depth, leading edge etc.

Stream File Pattern 

A stream file, created as an ASCII text or binary file that addresses the patterning DAC directly, produces custom pattern files. Because a 12-bit DAC is used, the patterning field of view is divided into 4096 steps. The range in X is 0-4095, but in Y is approximately 280-3816. Y values outside of this range will be off the image area and may not scan correctly.

Serial Patterning 

All patterns defined on the screen are processed *consecutively*; milling / deposition is completed on one pattern before moving to the next one. Serial patterning is always used with cleaning cross section milling. This is the default patterning mode.

Note:
In Serial mode, a series of patterns could even be a combination of some to be milled and some to be deposited, but in general this is not recommended.

Parallel Patterning 

All patterns defined on the screen are processed *concurrently*, one pass of the beam is completed on all patterns before moving to the second pass. Parallel patterning is typically used with regular cross section milling and to avoid a redeposition of material on the adjacent areas.

With parallel patterning, the mill time is recalculated to include all the patterns that are displayed in the image window.

When an user changes to the Parallel mode, the following shape properties in the group must necessarily be the same: Number of Passes, Beam, and Gas properties. The first selected shape determines these values for all other ones.

Other properties (Material File, Overlap, Sputter Rate, Recovery Time and Depth) are also all set to those of the first selected shape to avoid confusion, even though they could theoretically remain unchanged. Restoring Serial mode does not undo these changes; the properties remain as in the Parallel mode.

APPLICATION FILES

Each application file sets multiple parameters for particular patterning. There are pre-defined (non-editable) and user-defined (saved) files. Some of these application files use GIS's. With multiple GIS's installed on your system you can select between Pt deposition, Enhanced Etch, etc. by selecting a suitable application file for a given pattern. Milling on specific materials without gas can be done by using no application file or more efficiently with the appropriate scanning conditions using the dedicated Application file for that material.

Note:
The appropriate application file should be used with the gas type it was specified for. A pattern must be defined before the Application file is selected.

A list of common Volume per Dose values (Sputter Rates) for various materials can be found in the following Table.

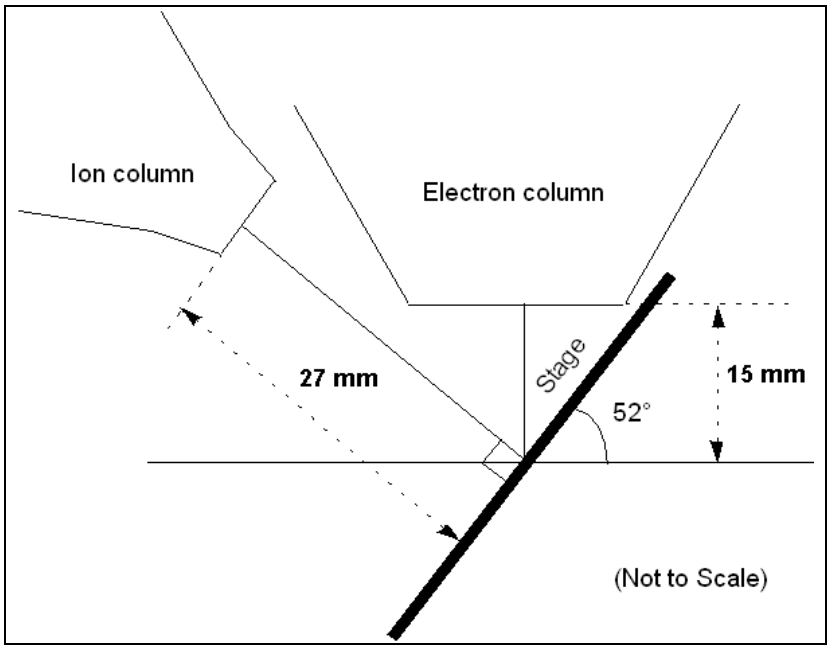
TABLE 5-21 MATERIAL SPUTTER RATES AT 30 kV

Material	Volume per Dose [µm^3 / nC]	Material	Volume per Dose [µm^3 / nC]
C	0.18	**Au**	1.50
Si	0.27	**MgO**	0.15
Al	0.30	**SiO_2**	0.24
Ti	0.37	**Al_2O_3**	0.08
Cr	0.10	**TiO**	0.15
Fe	0.29	**Si_3N_4**	0.20
Ni	0.14	**TiN**	0.15
Cu	0.25	**Fe_2O_3**	0.25
Mo	0.12	**GaAs**	0.61
Ta	0.32	**Pt**	0.23
W	0.12	**PMMA**	0.40

BEAMS COINCIDENCE

The Electron and Ion columns are mounted as illustrated in the following figure, which shows the stage tilted to 52°. Coincidence of the beams occur at the eucentric tilt axis.

FIGURE 5-16 BEAM COINCIDENCE



Milling Procedure

Caution:
When milling a large volume of material (ion current 30 nA and higher) it is recommended to remove the BSE detector from the lens insert (if not used). There is a risk to damage it by a material deposition.

Bring the sample to the eucentric position and to the 52° tilt. Now you can start to mill a pattern on the sample material. The procedure is as follows.

Manual User Interface

The Manual User Interface (MUI) provides knobs to perform functions that can also be performed with the software. It is connected to the USB connector located on the microscope controller.

FIGURE 7-1 MUI

The MUI offers additional flexibility for controlling magnification, beam shift, focus, astigmatism, contrast and brightness.

Omniprobe

The Omniprobe micro manipulator allows you to extract a TEM sample in-situ. An area containing the feature is milled to a thickness of about 2 µm or less, lifted out using the Omniprobe, and transferred to a TEM grid, all inside the system chamber. Once on the grid, the membrane can be thinned to the desired thickness. After TEM or STEM analysis, the membrane can be returned to the system and thinned further if needed.

Omniprobe Coordinate Axes

The Omniprobe is capable of movement in three axes. Because the Omniprobe is mounted at an angle relative to the stage, however, its coordinate axes are rotated relative to the stage coordinate axes.

To align the probe and to contact it to a particular site, manoeuvre the Omniprobe in X, Y, and Z as necessary. Combine Y and Z movements to keep the probe tip over the site as you lower it.

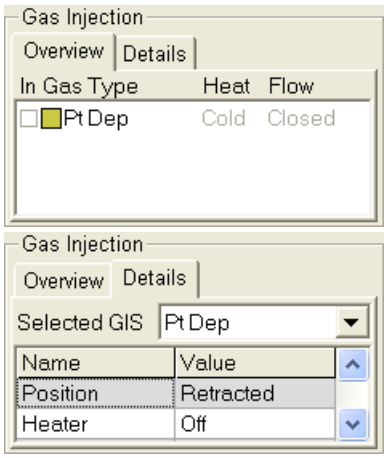
Note:
It is also possible to perform the tip to contact a particular site so that the Omniprobe tip is brought to the eucentric height and the stage is moved so that the site you want to contact is directly beneath the tip. Then raise the stage. For best results, use the manual stage knobs on the chamber door to initiate stage movements.

INSERTION AND RETRACTION

Whenever you insert the Omniprobe, there is a risk of collision with the sample if the Omniprobe and the sample are not positioned as expected. You can reduce this risk, however, by following these guidelines for system setup and Omniprobe technique.

- Make sure the Omniprobe tip is aligned correctly. When inserted, the tip should never reach below eucentric height.
- Before inserting the Omniprobe, save the stage location and lower the stage 2 mm below the eucentric height.

Gas Injection System (GIS)



Some applications require a special gaseous environment, which is provided directly to the required area by the GIS's installed on your system. Controll of this system is via the **Gas Injection** module (**Overview** or **Details** tabs).

SETTING UP THE GIS

The GIS to be used should be set up before patterning is started. It must be held heated and inserted but not open until it is necessary to use.

When not in use, the GIS should be closed (to save filling lifetime), cold and retracted. Leaving it closed, heated but retracted is also an option so that reheating is not necessary if it is to be used over several patterns.