**FEI™**

User Operation Manual

Scios 2

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# User Manuals

## FEI Microscope Systems Safety Manual

The safety manual provides information for personal safety and maintenance procedures while operating this FEI system.

This manual is required reading for the end user.

## User Operation Manual

The User Manual is delivered in the electronic PDF file only. However, it is possible to print parts of the manual if this is desired.

It is recommended to read the appropriate User Manual section before operating any microscope function. Most importantly, you should locate the topics necessary to operate the microscope in the proper way to safely achieve the best results.

The manual is divided into the following chapters:

1. *System Overview* (this chapter)
   gives overview of the user manuals and system capabilities.
2. *System Control*
   describes the system hardware (interface elements, vacuum system, system states, equipment).
3. *Software Control*
   describes the interface that sets and controls system operation, giving the function of each tool, menu item and control page.
4. *Alignments*
   explains how to align the equipment to achieve the optimal performance.
5. *Operating Procedures*
   gives procedures for how to use the system features.
6. *Maintenance*
   gives allowed step by step cleaning and maintenance procedures.
7. *System Options*
   explains relevant options that can be integrated into or accessory to the system.

One can take advantage of the searching and navigation possibilities within the PDF file. In addition, the following conventions are applied:

- A reference to the specific software element is highlighted in italic. For instance:
  "Clear the *Stage* menu / *Beam Shift Reset* item."
- Some software functions use shortcuts, which are given beside the heading in the brackets
  (for instance: *Save (Ctrl + S)*) and in the *Help* menu / *Keyboard Shortcuts*.

# System Capabilities

The Scios is a combination of two systems:

- Scanning Electron Microscope (SEM): produces enlarged images of a variety of specimens achieving magnification over 100 000× providing high resolution imaging in a digital format.
- Focused Ion Beam (FIB) system: 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.

This important and widely used analytical tool provides exceptional field of view, minimal specimen preparation, and the ability to combine the technique with X-ray microanalysis.

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 provide an expanded range of capabilities not possible with separate FIB and 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
- Focused electron beam charge neutralization during FIB milling
- High resolution elemental microanalysis of defect cross sections
- Imaging of sample surfaces with the electron beam during navigation without erosion or gallium implantation from the ion beam
- TEM sample preparation with *in situ* conductive coating

## System Performance

The equipment is intended as a standalone system.

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. 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 photons, converts them into a digital signal which is then sent to the control PC and shown on the monitor.

**FIGURE 1-1**  *Column Schematic Overview*
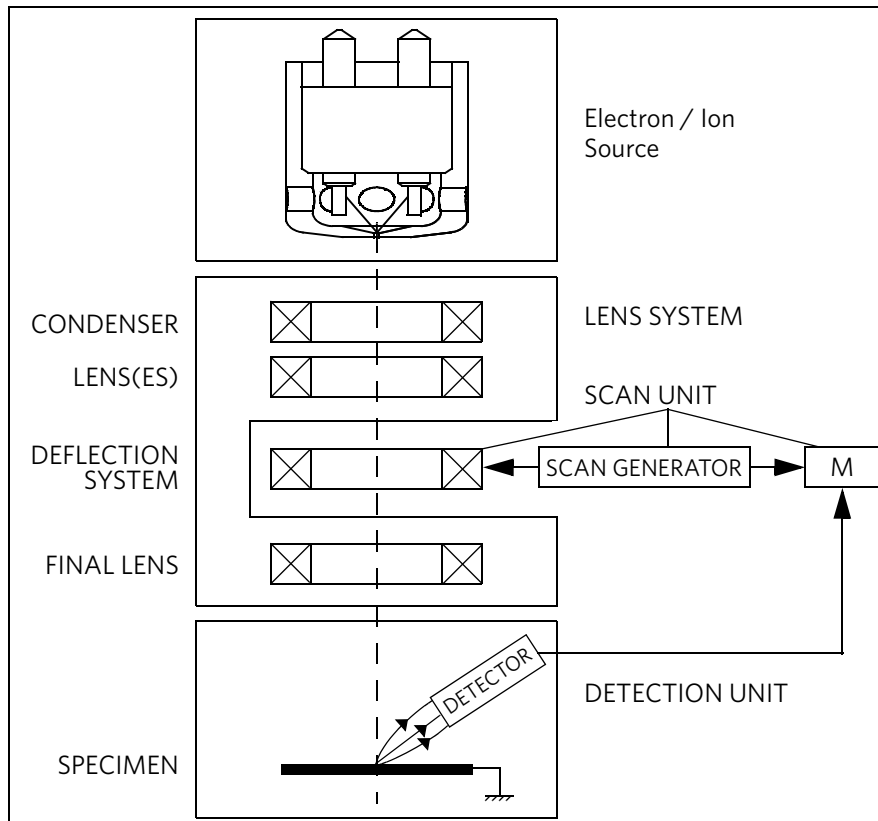


## Computer Control

The xT microscope Server and Microscope Control (User Interface) software integrate SEM and FIB functionality within a Windows 7 operating environment.

This software consists 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 particle path from a source to specimen must be under vacuum so that the particles do not collide with air molecules.

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.

### High Vacuum (HiVac)

This is the conventional operating mode associated with all scanning electron microscopes.

### Low Vacuum (LoVac)

In the gaseous mode the electron column is under lower pressure than the specimen chamber. This mode can use water vapours from a built-in water reservoir, or an auxiliary gas which is supplied by a user and connected to the gas inlet provided for this purpose. Observation of outgassing or highly charging materials can be made using this mode without the need to metal coat the sample, which would be necessary for conventional HiVac mode.

## Stage

The Scios has a computer-controlled high-accuracy five-axis stage for small samples. It offers precision specimen computer controlled manipulation and automation of all axes for overall spatial orientation on highly repetitive or extremely irregular samples.

Specimen exchanges take place through a chamber door which exposes the specimen stage when opened or through the Quick Loader (option). An exchange time takes a few minutes, with the Quick Loader an exchange is much more faster. Software and interlocks protect the system against a damage and users against an injury.

## Image Viewing and Capture

Because the amplified detector signal is shown synchronously with the beam scanning, there is a relation 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.

## Beams Control

DualBeam systems ideally position the point of interest for simultaneous ion beam cross-sectioning and electron beam viewing. Separate scan generators for the two beams 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 milled cross sections to atmospheric contaminants.

## Gas Injection System (GIS)

Multiple FEI 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 gallium FIB source ions simultaneously.

The GIS can also contain etching precursor for fast material removal with minimal re-deposition, preferential etching of cross-section surfaces prior to SEM imaging, and rapid milling of TEM sections.

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.

## Analysis Capability

Convergence of the SEM, FIB, and X-ray detection system (e.g. EDX – Energy Dispersive X-ray – option) at short working distance allows precision "slice-and-view" cross-sectioning and chemical analysis at high resolution of surface and subsurface features.

Various vendor options are compatible with the instrument (see Chapter 7).

# *System Control*
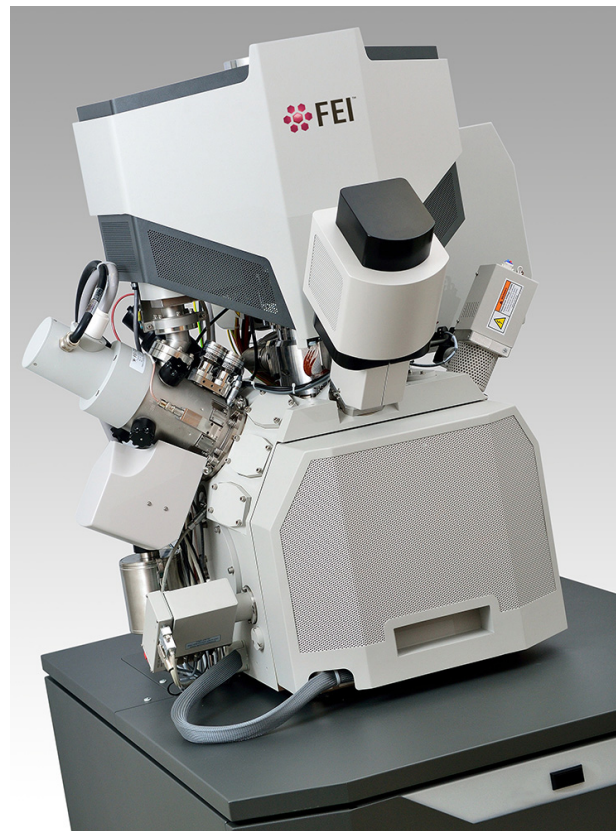
This chapter describes the layout of the system, interface elements and equipment.

## System Layout

The basic system layout is based around the dedicated Microscope PC with the LCD monitor, Microscope console and Electrical console. Optionally it is possible to have a second LCD monitor with the Microscope PC or the Support PC with LCD monitor and the switch box with keyboard and mouse to switch between the two PC's.

**FIGURE 2-1**   *Scios Standard Layout Scheme*
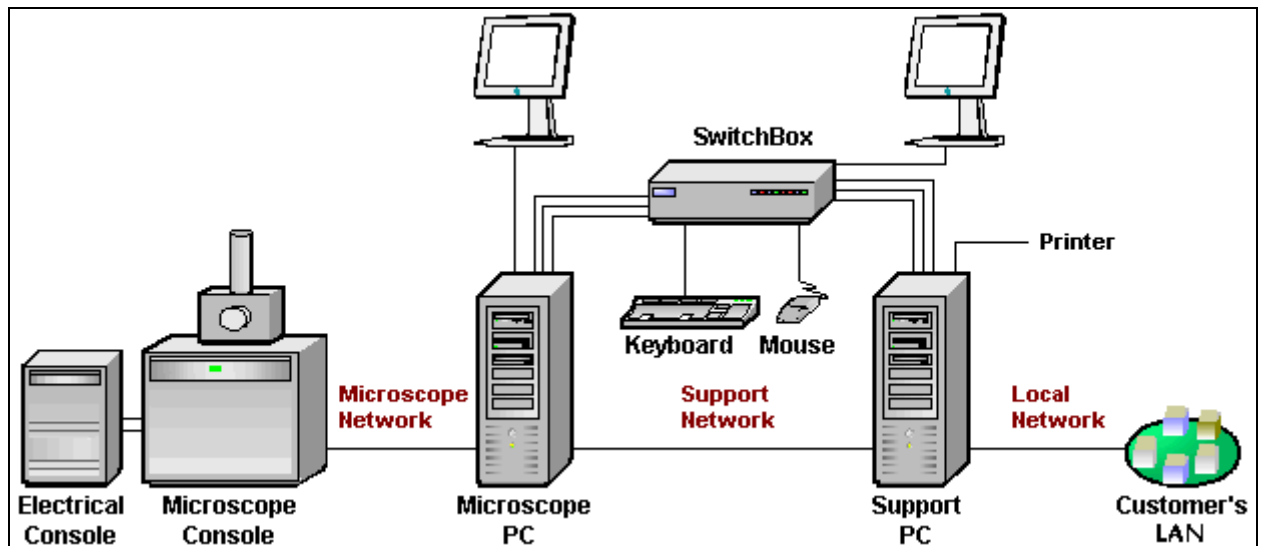


*C a u t i o n !*

*If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.*

*Mains power must be connected to a grounded socket that is visible and easily accessible!*

*A user must not disconnect any parts of the equipment or connect any equipment not approved in this manual or in the FEI Microscope Systems Safety Manual!*

*All power and external equipment connectors should be covered by stoppers (part of delivery) when not used!*

### Other Software and Hardware

Call a FEI authorized service engineer for advice before installing software or hardware that is not required for system operation. Other software, such as screen savers or hardware network cards, may corrupt the xT microscope Server / Microscope Control software under some circumstances and may invalidate warranty.

For more detailed information about Windows 7™, refer to the *Microsoft® Windows™ User's Guide* shipped with your system.

# Interface Elements

## Software

The software control contains graphic applications within Windows 7™ operating environment:

- *xT microscope Server:* starts and stops basic microscope functions
- *Microscope Control* software (*UI* – User Interface): controls all system functions including imaging, image and movie gathering / manipulation / output, detection and analysis, scanning, magnification, stage navigation, chamber and column pressure, etc.
- *FEI Account Manager* software: ensures for the particular users admission to both the operating system Windows 7 and the Microscope Control software
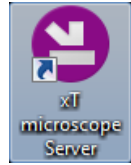
For information on all features of these applications see Chapter 3.

### Password Policy

After the FEI software installation there are two initial users / passwords common for the OS Windows and the Microscope Control software (UI):

- User: supervisor / Password: supervisor
- User: user / Password: user

At the first time log in the operating system Windows 7 a user is automatically forced to change their password. After that the UI accepts it and enables to log in from that point on.

Each password (either for any new user or after the 90 day period expiration) has to meet the following conditions:

- at least 7 characters long
- the stem must be significantly different from a previous password and shouldn't contain complete dictionary word and user name
- must contain at least one character of each of these character groups:
    - Uppercase letter
    - Lowercase letter
    - Number
    - Symbol (/, *, -,+ etc.)

## Hardware

The system is computer controlled and as such has a Microscope PC which must be turned on (use the power button on the PC) to operate the microscope by means of the software. The Support PC can hold some other software utilities. The switch box switches the keyboard and the mouse to either of the two PC's. The control software facilities and data are shown graphically on the LCD monitor and are superimposed around and on the image. The other LCD monitor is used either as an extended desktop of the Microscope PC or as the Support PC monitor. To control software utilities one can use a keyboard, mouse, joystick (option) or the Manual User Interface (option).

### Power Button

The console / system power is activated by pressing the power button located on the microscope console front panel. This switches the sub-systems on and allows the interface and communication with the Microscope PC, from which most of the functions are activated via the software control.

The power button indicates several system states:

- *green lit* – the Full Operation state
- *amber lit* – the Standby system state (considered as an abnormal system state)
- *no lit* – the Complete shutdown system state

**FIGURE 2-2**  *Control Panel Power Button*

### Final Lens Aperture Strip

The strip is made from a Mo coated Si. The Automatic Aperture System (AAS) automatically controls the final lens aperture selection according to imaging needs when working with the electron and ion beams (see Chapter 5).

*Note*
*The aperture holes edges cleanness is very important, exchange or clean them if necessary (see Chapter 6). When performing the E-Column: Aperture Selection alignment (see Chapter 4) there are knobs accessible on the aperture mechanism on each column enabling the fine adjustment of the strip hole.*

**FIGURE 2-3**  *Automatic Aperture System Control Knobs Electron / Ion column*
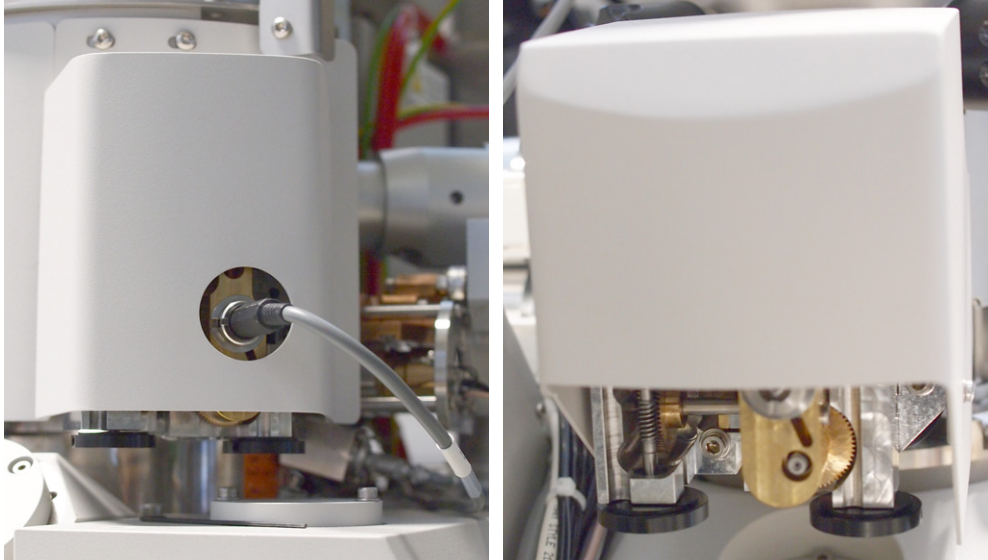


### External Connectors panel

It is located at the back side of the microscope console.

It is used to connect 3rd party equipment to the following connectors:

#### CONTROL SIGNALS / E-BEAM SCAN INPUT / VIDEO OUT

These connectors are used for connection of EDX, WDX and lithography systems, provided by 3rd party suppliers. Do not connect anything else in these connectors!

#### SPECIMEN CURRENT

This connector is used together with the Keithley picoamper meter (option) equipment.

#### Ground point

The point is intended for a defined ground connection between a microscope and a 3rd party module. This connection is not a safe ground!

#### ELPHY SCAN & BLANKING IN

Not used.

## Mains Switchboard

Breakers and connectors placed at the cabinet back:

- **Mains switch S1** – entire system mains power switch
- **PVP Breaker F1/5A** – pre-vacuum pumps power switches
- **Mains Breaker F2/10A** – system pumps power switches
- **Main input 230 VAC** – input mains power cord
- **PVP X5** – output power supply for pre-vacuum pumps
- **X1** – not used
- **X2** – optional equipment output power supply
- **X3** – optional equipment output power supply
- **X4** – output power supply for Microscope PC, LCD 1, optionally for Support PC,LCD 2, LCD 3

**FIGURE 2-4** *Mains Switch Board*
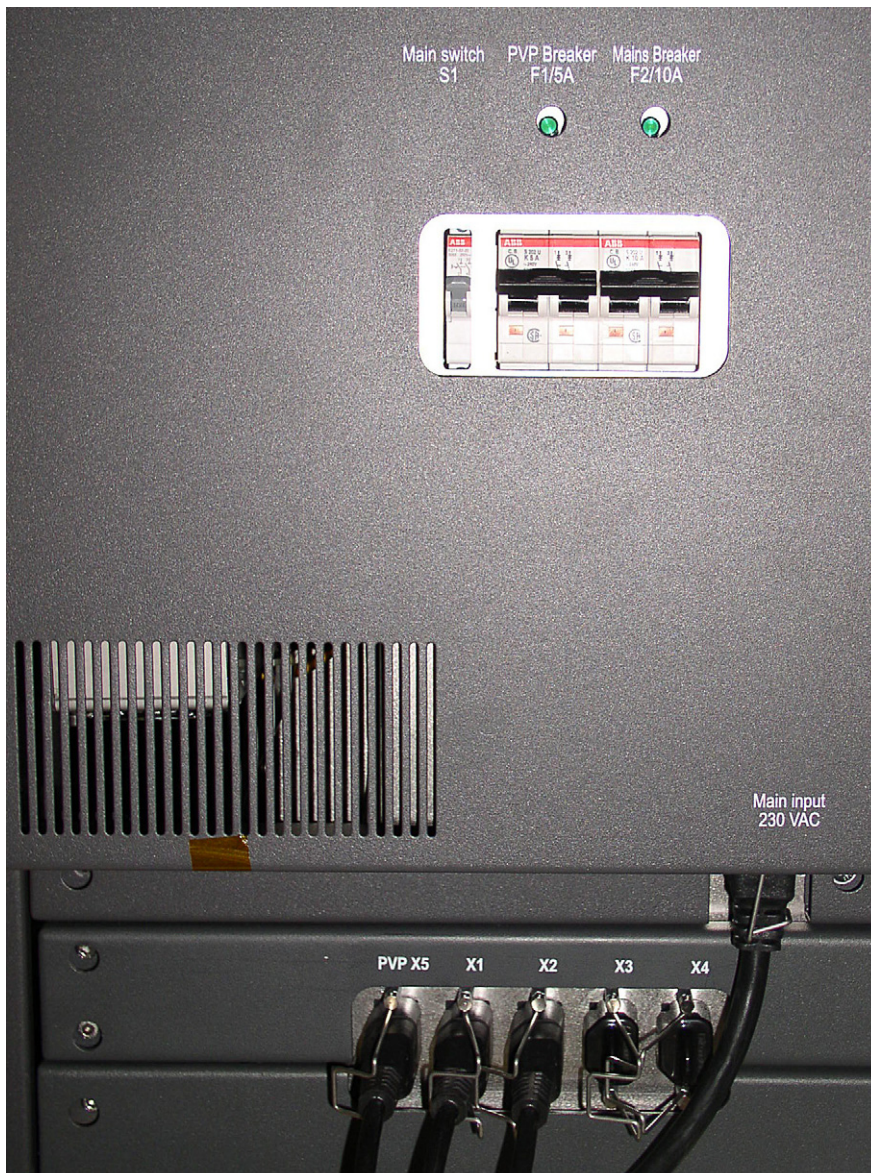


*C a u t i o n !*
*Always keep all control elements accessible! This is especially important in case of emergency.*

**Power Off**

The system has protection against power failures in the sense that the different components of the system are not likely to be damaged. However, a power failure is never good for the system. It might affect the ultrahigh vacuum levels of the columns and the overall stability of the system.

Take sufficient measures to avoid power failures. If it occurs while the instrument is completely operational, the microscope comes down to a safe state and the following happens:

- Both electron and ion accelerating voltages are switched off.
- Both electron and ion emissions are switched off.
- The specimen chamber vents gently, automatically.
  The vacuum in the instrument is no longer supported by running pumps, the column isolating valves close to save the vacuum in the sources areas.
- The Microscope PC and the Support PC are switched off, the momentary adjustments of all system parameters (accelerating voltage, magnification, stage positions etc.) are lost if they were not saved.

*Note*
*If the mains failures occur occasionally it is recommended to use the Uninterruptible Power Supply (UPS – option).*

**Emergency Off**

To switch off the electrical power completely in case of emergency, follow this quick and safe procedure:

**1.** Push the red *EMERGENCY OFF* (EMO) button (option – see the Safety Manual).

If the button is not installed proceed as follows:

**2.** Switch off the *Main switch S1* breaker, which is placed at the very left side in the row of three, or disconnect the power cord *Main input 230 VAC*.

If this is not easily accessible:

**3.** Turn off the mains wall switch (if present), and / or disconnect the mains plug from the mains socket.

## *W A R N I N G !*

*The microscope console water chiller (option – separate device in the microscope vicinity) is powered separately via the individual power cord. The hazardous voltages may be present on this equipment even when the microscope power plug is disconnected!*

*Because the electron column IGP's are supported by internal batteries, some parts of the microscope are still under power.*

# System States

There are several system states:

- *Complete shutdown* – service and emergency reasons
- *Standby* – not using the system for a longer period
  This is an abnormal system state.
- *Overnight* – not using the system overnight
- *Full operation* – all microscope equipment and accessories are in use or ready to use
  The system is intended for continuous operation.

The Complete shutdown system state can be set only by a supervisor.
See detailed description of all following processes and elements further in this manual.

# System Startup

In the *Complete shutdown* state the system is disconnected from all sources used for an operation. Connect the following sources:

- electrical – power cord
- pneumatic – compressed air inlet
- cooling water – hose flanges
- operating gas – nitrogen inlet

The amber color *Power* button on the Microscope console panel starts to shine.

To bring the system to the *Full operation* state follow the procedure:

1. Push the amber *Power* button on the Microscope console panel – it changes to the green one [a].

2. Switch on the Microscope PC. The operating system [b] Windows 7™ loads and shows the appropriate icons on the monitor desktop.

3. Double-click on the *xT microscope Server* icon to start the software (all seeming LED's should be green – Initialized).

4. Click on the *Start* button to start the server. Wait until all elements are fully functional (green – Initialized).

5. Click on the *Start UI* button to start the *Microscope Control* software. The main window appears behind the *UI Log On* dialog.

*Note*
 *This step can take place automatically, if Advanced / Autorun UI check box is ticked.*

6. Enter your *Username* and a *Password* [b].

7. Start the electron column IGP pumps with the use of the *5 – Emitter Startup* alignment, Step 1 of 2. This procedure takes a few minutes and the final *IGP Upper* pressure should be < $5.10^{-7}$ Pa to start the emitter.

8. Switch on the Emitter with the use of the *5 – Emitter Startup* alignment, Step 2 of 2. This procedure can take about 2 or 40 minutes (short or long procedure) depending on emitter conditions.
   If this is not possible, call a FEI authorized service engineer!

9. Start the ion column IGP pump with the *100 – ION: Source Control* alignment.
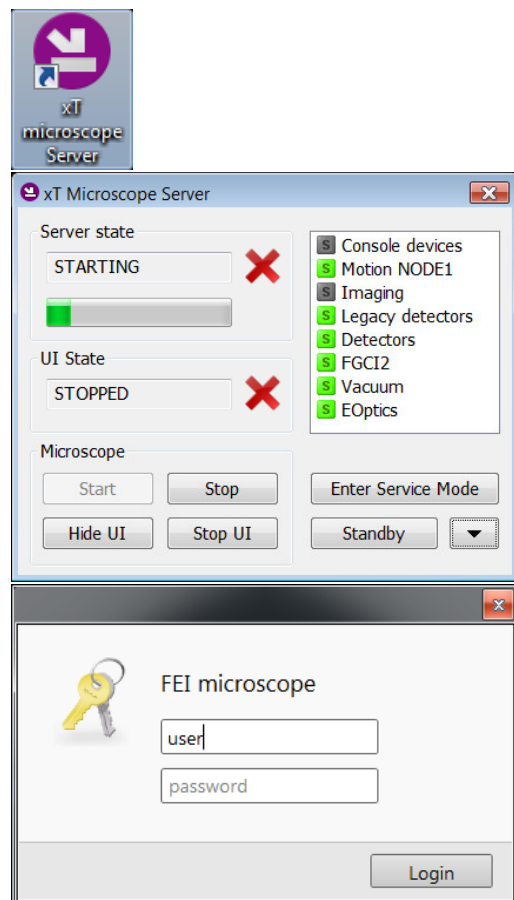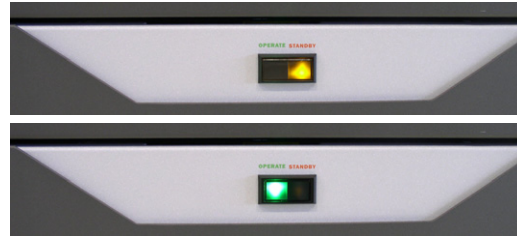
10. Select the desired *Vacuum* module / *Vacuum mode* radio button and click on the *Vacuum* module / *Pump* Button. Wait for the *Pumped* status.

11. Click on the *Column* module / *Beam On* button to start the selected beam only or the *System* module / *Wake Up*[(c)] button to start both beams. A *Column* module source awaking progress bar indicates the actual status and the button turns orange when finished.

See Chapter 5 to set desired imaging conditions.

*Note*

[a)] *When switching the console on (starting from the Standby state), the SEM aperture becomes heated. It may take several (5–10) minutes before it is at the proper temperature. Do not make any adjustments during this interval (aperture, source or lens alignment)! The microscope could become misaligned when the aperture reaches the operational temperature.*

[b)] *Once you have your user account set up via FEI Account manager software (see Chapter 3), you can use your name and password to access both Windows 7 system and the Microscope Control software. Take note of the Password policy (see above), which helps to protect individual settings and results.*

[c)] *Usually, the Scios remains on with the vacuum system in operation, but typically the ion emitter and accelerating voltages for both columns remain off. The system starts with the setting in use when the Microscope Control software was closed. This allows quick resumption of daily operation.*
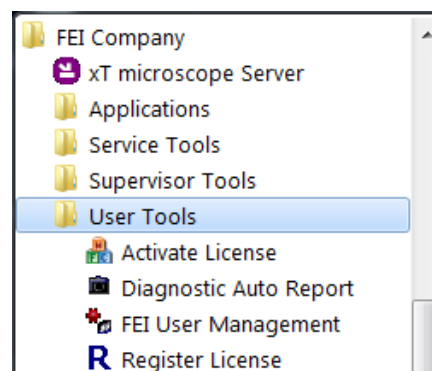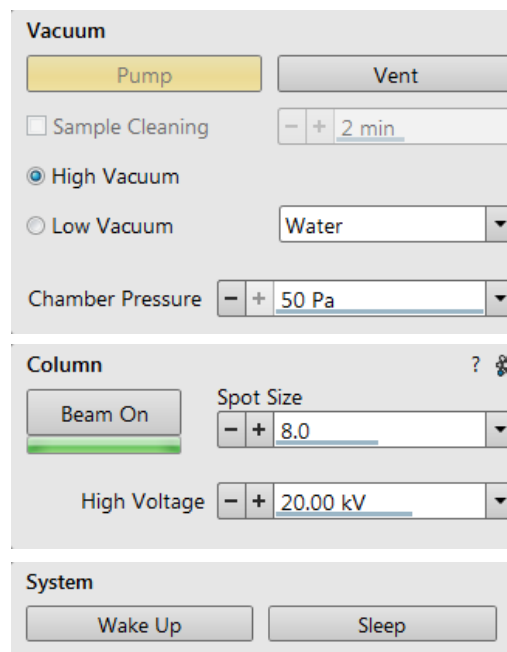
## Overnight and Standby

When leaving the system, it is advisable to bring it to the *Overnight* state by following the procedure:

1. Click on the *System* module / *Sleep* button to switch off both beams and to stop the ion source.
2. If one needs to remove the sample, select the *Stage* menu / *Tilt 0°* (Ctrl + E). Click on the *Vacuum* module / *Vent* button. Wait for the *Vented* status and remove your sample.
3. Click on the *Vacuum* module / *Pump* button to pump to the High Vacuum. [(d)]
4. Select [(e)] the *File* menu / *Log Off* to log off the present user and to provide the *Log On* dialog for entering another one. Switch off the monitor.

Now the system is in the Overnight state, to proceed to the *Standby* state follow the procedure:

5. Click on the *xT microscope Server* window / *Standby* button.

   This stops the UI, the xT microscope Server application services and switches off the console (the green *power* button on the microscope front control panel changes to amber one).

In the Standby state the electron emission is on and the chamber vacuum is maintained by running vacuum pumps.
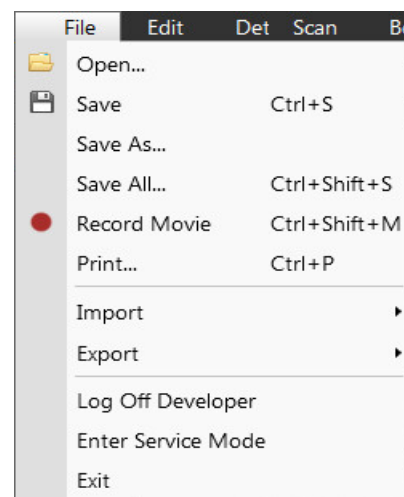
To bring the system back to an operation, follow the procedure:

## *Caution!*

*When the Standby state was just entered, wait 10 s at minimum before starting microscope operation again (pressing the power button on the microscope front control panel)!*

1. Push the amber *Power* button on the Microscope console panel – it changes to the green one [a].

2. Double-click on the *xT microscope Server* icon to start the software (all seeming LED's should be green – Initialized).

3. Click on the *Start* button to start the server. Wait until all elements are fully functional (green – Initialized).

4. Click on the *Start UI* button to start the Microscope Control software. The main window appears behind the *UI Log On* dialog.

*Note*

*This step can take place automatically, if Advanced / Autorun UI check box is ticked.*

Now the system is in the Overnight state, to proceed to the *Full operation* state follow the procedure:

5. Enter your *Username* and a *Password* [b].

6. Click on the *Column* module / *Beam On* button to start the selected beam only or the *System* module / *Wake Up*[c] button to start both beams. A *Column* module source awaking progress bar indicates the actual status and the button turns orange when finished.

*Note*

[d] *It is strongly recommended to always leave the chamber evacuated when not being used. When the sample chamber is left in the LoVac mode, water vapour is likely to accumulate in it, PVP lifetime decreases and the water reservoir or gas cylinder empties prematurely.*

[e] *Waiting for a new user leaves the status of the Microscope Control software non-operational and only the xT microscope Server software is active. Therefore changing a user does not require Logging off / Logging on at Windows 7™ level.*
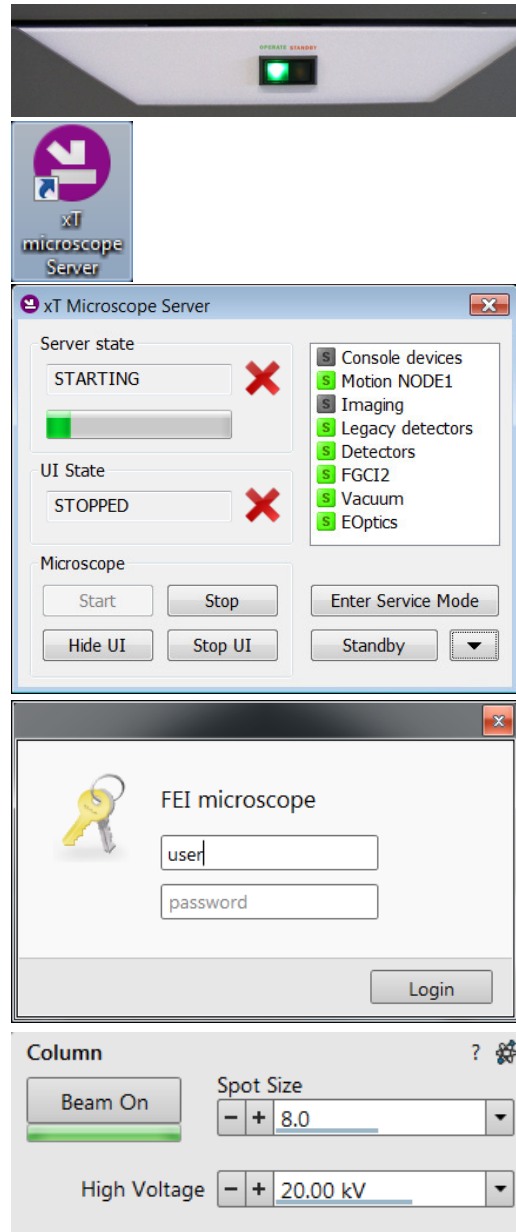
## System Shutdown

In case of emergency bring the system to the *Complete shutdown* state by following the procedure:

1. Click on the *System* module / *Sleep* button to stop the accelerating voltage for both beams. A *Column* module source progress bar indicates the actual status and the button turns grey when finished.
2. Click on the *Vacuum* module / *Vent* button to vent the chamber.
3. Switch off the Emitter with the use of the *5 – Emitter Startup* alignment, Step 2 of 2. [f]
4. Click on the *xT microscope Server* software / *Standby* button.

   This stops the UI, the xT microscope Server application services and the console (the green *power* button on the microscope front control panel changes to amber one).
5. Shutdown the *Windows 7™* and switch Off the monitor. [g]
6. If there is a demand, disconnect the power cord and any other input / output if used. [h]

*Note*

[f] *Switching off the console when Emitter is On is not optimal and sparing way for the emitter – it may deteriorate the filament lifetime. Supervisor should use the xT microscope Server Standby button only in case of emergency.*

[g] *The system can be left in this state if electrical power is supplied to the instrument because the pumps are running and pumping the column.*

[h] *The Complete shutdown procedure brings the system to the non-powered state, where the vacuum in the column area is no longer supported by running pumps. All valves are closed, and the electron column and specimen chamber areas are vented. Normally it is used for a system transportation or for service actions, like repair to essential systems (electrical and air supplies).*
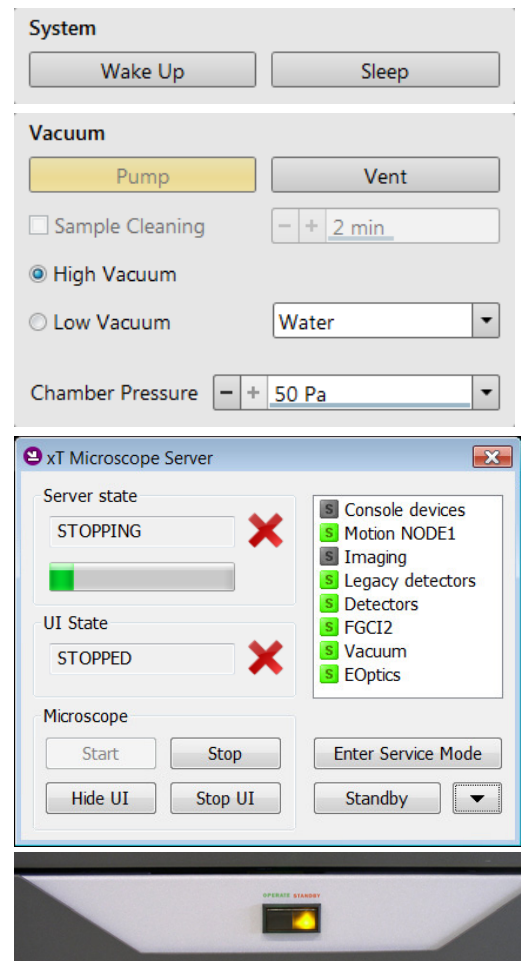
# Vacuum System

### *Model difference*

There are the High Vacuum and Low Vacuum variations of the Scios system. This manual describes the Low Vacuum model, for the High Vacuum one there are some controls missing and a functionality is modified accordingly.

Within the system there are the following vacuum sections:

- Electron source
- Electron column
- Ion source
- Ion Column
- Specimen chamber

In operation the electron and ion sources and columns sections are always under high vacuum. The specimen chamber is at the pressure required for the given state (Pump / Vent) or mode (HiVac / LoVac).
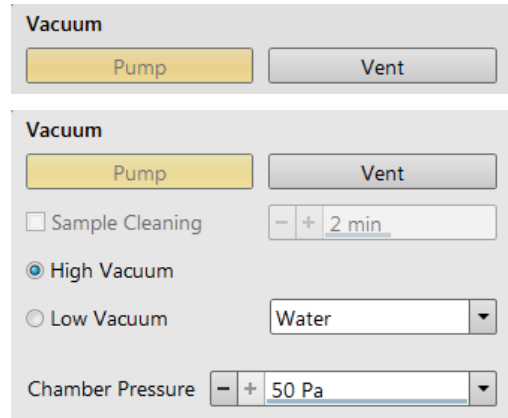
*Note*

*The ion beam can only be operated in HiVac. When a gaseous mode is chosen, the ion column CIV is closed. All valve and pump operations are fully automatic.*

**FIGURE 2-5** *Scios HiVac / LoVac Vacuum system*
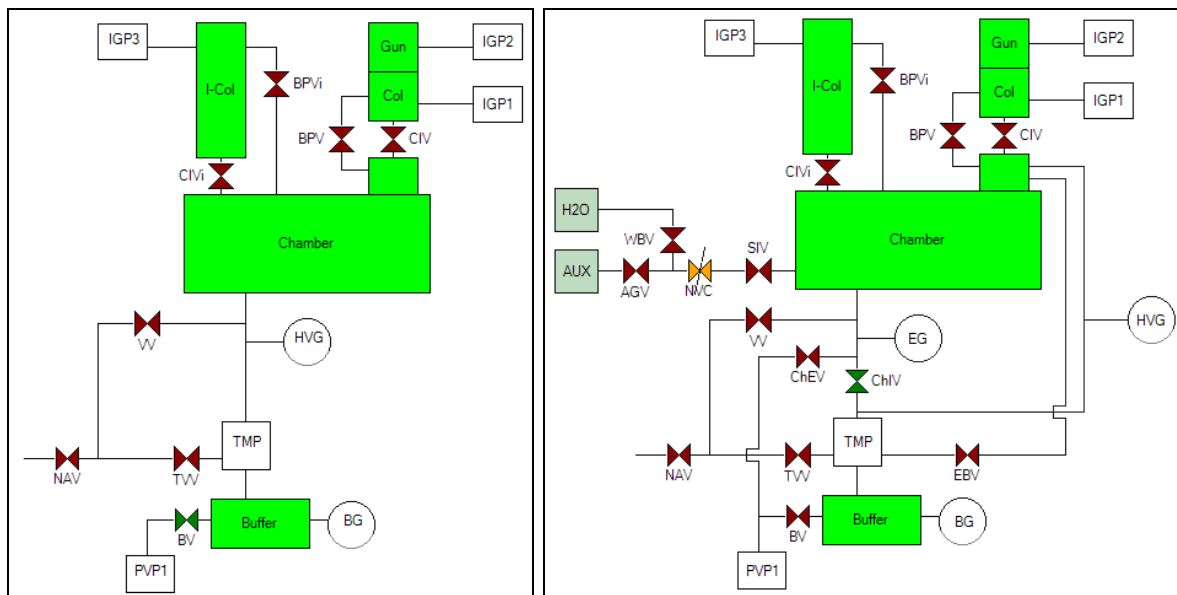


| | |
|---|---|
| **ABV** . . . . . . . Auxiliary Bypass Valve | **ChIV** . . . . . . . Chamber Isolation Valve |
| **AGV** . . . . . . Auxiliary Gas Valve | **IGP** . . . . . . . . Ion Getter Pump |
| **BPV** . . . . . . . By Pass Valve | **NAV** . . . . . . . Nitrogen Admittance Valve |
| **BG** . . . . . . . . Buffer Gauge | **NVC** . . . . . . . Needle Valve Control |
| **BV** . . . . . . . . Buffer Valve | **PVP** . . . . . . . Pre Vacuum Pump |
| **HVG** . . . . . . High Vacuum Gauge | **SIV** . . . . . . . . Servo Isolation Valve |
| **CIV** . . . . . . . Column Isolation Valve | **TMP** . . . . . . . Turbo Molecular Pump |
| **EG** . . . . . . . . ESEM Gauge | **TVV** . . . . . . . Turbo Venting Valve |
| **EBV** . . . . . . . Environmental Backing Valve | **VV** . . . . . . . . Venting Valve |
| **ChEV** . . . . . . Chamber Evacuation Valve | **WBV** . . . . . . Water Bottle Valve |

## Vacuum Status

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

At the bottom right side of the status bar the actual vacuum status is represented by the colored icon, which may have three possible colors with the following meanings:

- *Green: PUMPED* to a desired vacuum mode
- *Orange: TRANSITION* between vacuum modes (pumping / venting / purging)
- *Gray: VENTED* to atmospheric pressure
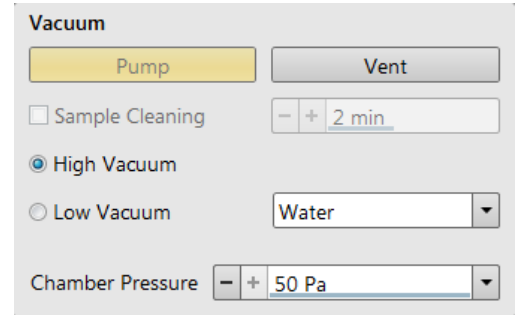
### Pump button

When the *Pump* button is clicked and the status is *Vented* or when changing the vacuum mode, the system starts to pump. The target pressure depends on the selected vacuum mode. The Pump button is highlighted and not accessible.

For *High Vacuum,* the system achieves the lowest pressure possible. For the *Low Vacuum* it achieves the pressure specified in the *Vacuum* module / *Chamber Pressure* adjuster. The purge function can be defined in the *Preferences...* dialogue / *Low Vacuum* tab (see Chapter 3).

When the *Pump* button is clicked and the status is *Transition* (venting), the venting procedure stops and the system immediately starts to pump to the actually selected vacuum mode.

### Vent button

When the *Vent* button is clicked and the status is *Pumped*, the confirmation dialog appears. After confirmation, the system switches off the detector voltages, high voltage supplies, vacuum pumps and uses the appropriate valves to vent the system with the use of the dry Nitrogen brought to the *Nitrogen Inlet*. Nitrogen is recommended to obtain the better vacuum for high resolution imaging in HiVac mode.

The *Sample Exchange* window and progress bar are shown, the Vent button is highlighted and not accessible. After a specified venting time the venting valve closes and the vacuum status should indicate *Vented* (see *Preferences...* dialogue / *General* tab / *Venting valve opening time* item). The chamber door can be opened and the button is again enabled.

When the *Vent* button is clicked and the status is *Transition* (pumping), the dialog appears. After confirmation, the pumping procedure stops and the venting procedure starts.

When the *Vent* button is clicked and the status is *Vented*, the dialog appears. After confirmation, the venting valves re-open for the specified venting time and then the valves close.

*Note*

*If you vent the system in order to change a detector, wait until the icon with a gray specimen chamber appears in the Status module. Otherwise there is a risk of a detector assessment malfunction, and as a result the PLA will not be known by the system.*
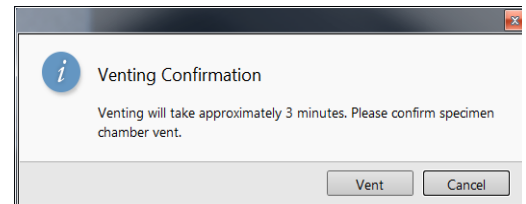
# Vacuum Modes

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

When changing the vacuum mode from one mode to another, a confirmation dialog appears.

## High Vacuum (HiVac) Mode

For *High Vacuum* the system achieves the lowest pressure possible throughout the column and specimen chamber. The typical pressure value is within the order of $10^{-2}$ to $10^{-4}$ Pa.

## Low Vacuum (LoVac) Mode

In this mode, the column section is under lower pressure than the specimen chamber, where the pressure ranges from 10 to 500 Pa (0.08 to 4 Torr). This mode uses water vapor from a built-in water reservoir, or a gas from an auxiliary gas inlet (the dropdown list).

When entering the LoVac mode from the vented state or when changing the gas type, chamber pressure goes to the HiVac value and subsequently to the desired LoVac value, so the old gas mixture in the chamber is first exhausted and then replaced by gaseous atmosphere. Entering the HiVac mode can by unwanted for highly outgassing samples (see the *Preferences...* dialogue / *Low Vacuum* section / *Fast Low Vacuum Pumping Through High Vacuum* check box functionality).

The system automatically detects any Low Vacuum detector installed (LVD and GAD) and offers to switch to the LoVac vacuum mode. If a relevant detector is not in place, a warning appears informing a user that the detector should be installed for the mode selected. However, the system will not abort the pump sequence.

## Pressure

The *Chamber Pressure* adjuster is used to set and show the target chamber pressure. Pascal, Torr or Millibar units are available and can be selected in the *Preferences...* dialogue / *Units* tab.

When the system is in LoVac mode and the *Chamber Pressure* value is changed, the pressure automatically changes to the new value. When the system is in any other status and the chamber pressure value is changed, the new value is used as the target pressure when the system starts pumping to a Low Vacuum mode again.

The actual specimen chamber pressure is shown in the *Status* bar / *Chamber Pressure* field.

### PLA (Pressure Limiting Aperture) Accessories

When the *LoVac* mode is entered from the *HiVac* mode or from the *Vented* status, the system prompts a user with the *PLA Accessories* dialogue. This happens only for the first time after a particular Vent procedure.

*Note*

*The number and types of accessories within the* PLA Accessories *dialog vary according to the actual system configuration.*

The maximum allowed specimen chamber pressure in LoVac mode is determined by the size of the PLA cone and a gas type. The *PLA Accessories* dialogue prompts to inform the system about the PLA cone size (a part of a dedicated gaseous detector) according to the figure when pumping or switching to LoVac mode. Along with a gas type, this information sets pressure limits and rates for pressure changes.

Clicking the appropriate accessory button informs the system that it is mounted on the final lens. The system starts pumping to the LoVac mode. From that point on, this information is automatically used until the system is vented again, when the PLA is set to "unknown". Clicking the *Cancel* button leaves the system in its actual status mode (Pumped or Vented).

- *X-Ray Cone* (500 µm aperture) is used for EDX analysis (option) and for the LoVac and low voltage imaging (i.e. below 5 kV) to reduce beam loss in the gas. For EDX samples are scanned at 7 mm working distance, which is the
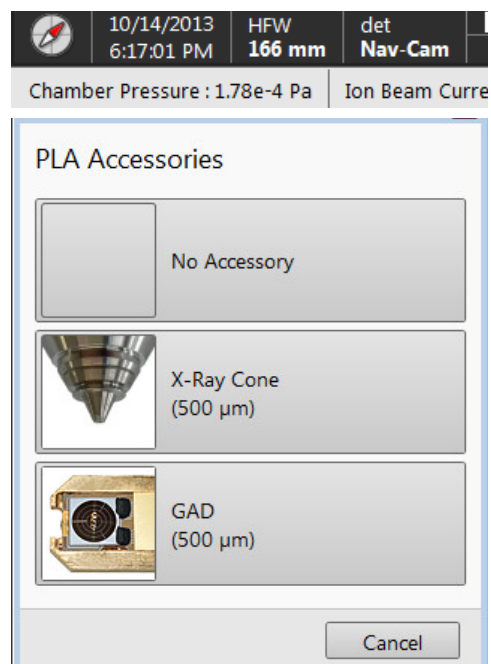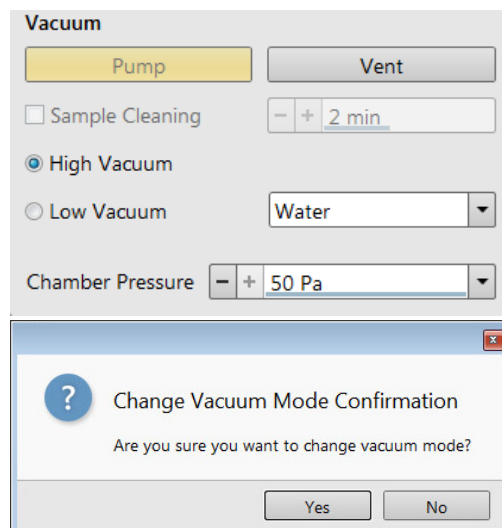
stage eucentric position and the collection point of the EDX detector. The cone height is 5.5 mm and restricts a field of view. See Chapter 5 for the cone mounting procedure.

The longer profile of this cone minimizes the low voltage beam dispersion and skirting of the primary beam in the gaseous environment of the chamber, allowing more electrons to interact with the specimen when focused and increasing the signal to noise ratio.

- *GAD Cone* (option – 500 µm aperture, see Chapter 7). The cone height is 5.5 mm.

*Note*

*The PLA also acts as a final or objective aperture so the pressure over it is considered to be very low. Any pollution that accumulates on the aperture edge greatly affects the imaging. If astigmatism is not possible to correct, it is usually a sign that this aperture needs to be cleaned or replaced (see Chapter 6).*

### W a r n i n g !

*Applying a cone or a detector with an integrated cone scales down the space between the top sample surface and the cone (at the particular working distance) by the value equivalent to a cone height.*

#### Using Gas

The Low Vacuum mode allows a user to image samples in a gaseous atmosphere, which can be selected in the drop down list box:

- *Auxiliary* gaseous environment supplied via the inlet placed on the back of the console.
- *Water* vapour from a built-in water reservoir located on the left side of the microscope console.
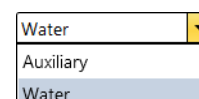
*Note*

*On occasion the water reservoir needs to be filled (see Chapter 6).*

### C a u t i o n !

*Maximum overpressure for the Auxiliary gas and Nitrogen inlets is 10 kPa (0.1 bar). The Nitrogen inlet is used only for venting the chamber with air or the nitrogen preferably.*

When using a particular pressure limiting aperture, there are pressure limits for different gasses.

**Table 2-1**    *Maximal Chamber Pressure [Pa (Torr)] under Different Gaseous Environment*

| Working Gas | Maximum Chamber Pressure [Pa] (Torr) |
|---|---|
| Water – $H_2O$ | 50 (0.4) |
| Nitrogen – $N_2$ | |
| Air | |
| Carbon Dioxide – $CO_2$ | |
| Nitrogen Dioxide – $NO_2$ | |
| Helium – He | 25 (0.2) |
| 70 % He + 30 % $H_2$ | 20 (0.15) |
| Argon – Ar [**] | 16 (0.1) |
| $C_xH_y$ [*] | 50 (0.4) |

### C a u t i o n !

*The system doesn't watch the limits and higher overpressure (especially for gasses not listed) set by a user! It could switch off the emitter! In some cases the system needs to be started up by a FEI authorized service engineer.*

*Note*

*\*) Combustible gases (acetylene for instance) must always be used with respect to safety issues.*
*\*\*) The argon use should be minimized to a short time, because the IGP's are not optimized for pumping of it at all.*

#### Purging

During this procedure the specimen chamber is automatically pumped down to a lower pressure to remove the old gas, then it is flooded with the new gas (selected in the Vacuum module) to a higher pressure. This takes place several times, until the old gas is removed and the chamber is mostly filled with the new gas. This is applied when the system is in the LoVac mode and the Purge button is pressed (see the *Preferences... dialogue / Low Vacuum* section).

The procedure is also started automatically with factory preset in these situations:

- when the LoVac mode was not used for 1 week and more;
- after the Water bottle venting when refilling the water level (see Chapter 6).

*Note*

*The automatic procedure can take a while (up to 10 minutes). Wait until Vacuum status indicates Pumped, because detectors do not start operation till desired pressure is reached.*

# Equipment

## Detector Types and Application

There are several system detectors, either standard or optional. The *Detectors* menu shows all installed detectors, accessibility / inaccessibility of detectors (black / grey label) depends on the actual system conditions.

*Note*

*For settings and handling of particular standard (S) / optional (O) detectors see Chapter 5 / 7.*
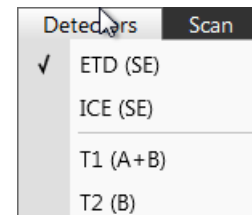


**Table 2-2** *Scios detectors list*

| Detector Name | Tag | Vacuum Mode | Detected Signal | Note |
|---|---|---|---|---|
| Everhart-Thornley | ETD | HiVac | SE (tunable energy) / BSE | S |
| T1 | T1 | HiVac / LoVac | BSE (for OptiTilt and OptiPlan column Use cases) | S |
| T2 | T2 | HiVac / LoVac | SE (for OptiTilt and OptiPlan column Use cases) | S |
| Low Vacuum | LVD | LoVac | SE | S |
| CCD camera | CCD | | light, infra-red light | S |
| External | EXT | | detector-dependent | S |
| T3 | T3 | HiVac | SE (for OptiTilt and OptiPlan column Use cases) | O |
| Ion Conversion and Electron | ICE | | electron beam: SE / BSE ion beam: SE / SI | O |
| Retractable Directional Backscattered (DBS) | ABS / CBS | HiVac | BSE | O |
| Directional Gaseous Analytical (05/2015) | GAD – ABS / GAD – CBS | LoVac | BSE | O, LM |
| Retractable Annular STEM | STEM 3 STEM 3+ | HiVac | TE | O |

SE = secondary electrons, SI = secondary ions, BSE = back scattered electrons, TE = transmitted electrons,
S = standard, O = optional, L = Low Vacuum model only

*Note*

*In case the vacuum safety interlock is activated, the confirmation of switching the detector voltage on after pumping the system is necessary.*

**FIGURE 2-6** *Safety Interlock Messages*
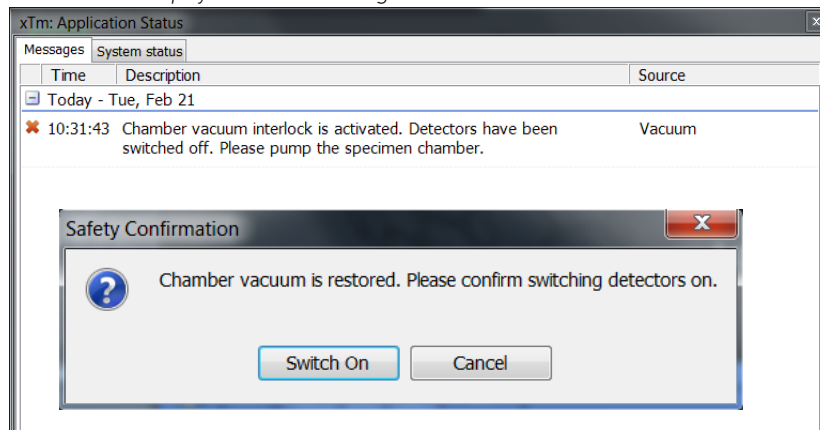
## Stages and Accessories

The chamber is equipped with the 110 × 110 mm stage, which can be oriented with reference to five axes: *X*, *Y*, *Z*, *Rotation* and *Tilt*. All movements are motorised, software controlled (an integrated part of the *Microscope Control* software). Stage positions are shown on the screen.

**FIGURE 2-7**  *110 × 110 mm Chamber*
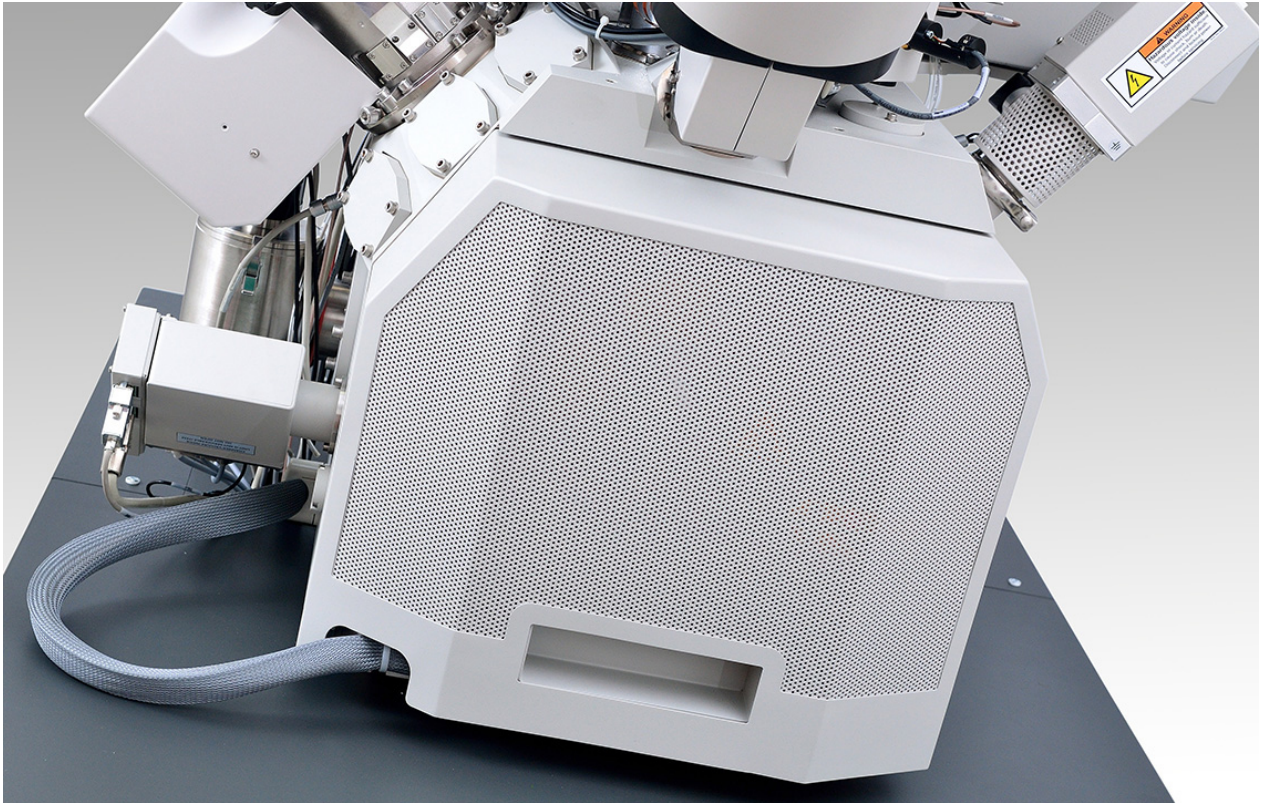


### Standard Stub Holder

This is the universal stub holder with a lot of numbered position for insertion of stubs with attached samples.
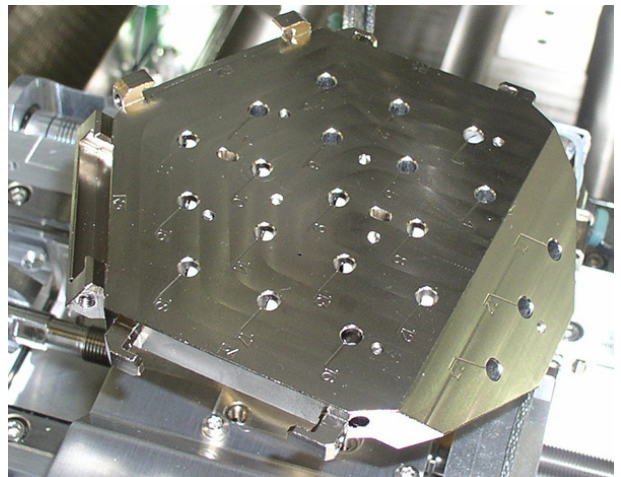
## Stage movement limits

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 imaging can be repositioned either by the stage movement or by the *Beam Shift*.

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

**FIGURE 2-8**   *Stage Movement Schema*



Stage side view
(from chamber door side)

Stage top view

Display view
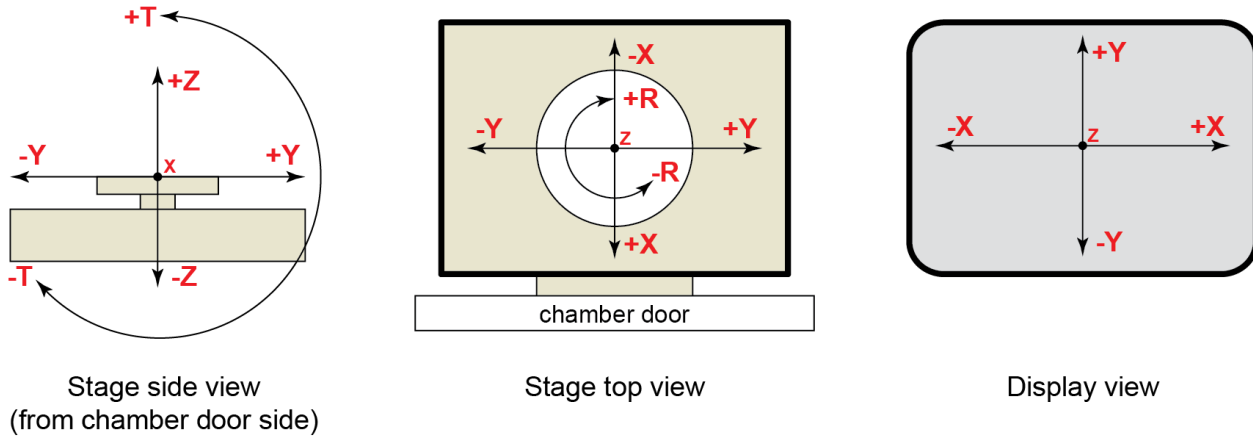
**Table 2-3**   *Stage Features and Limits*

| Item | 110 × 110 mm | Note |
|---|---|---|
| X | -55 to +55 mm | |
| Y | -55 to +55 mm | |
| Z | 66 mm | |
| R | 360° | continuous |
| T | -15° to +90° | maximally |
| Eucentric distance | 7 mm / 19 mm | Electron / Ion beam |
| Maximum sample weight | No restriction: 500 g | including stub holder |
| | No Tilt: 2 000 g | |
| | X and Y movements only: 5 000 g | |

*C a u t i o n !*
*The positive Z value direction depends on the Link Z to FWD status (see Chapter 5).*

*C a u t i o n !*
*If the maximum sample size is near to the limit, stage tilt can be limited. Beware of hitting the objective pole piece!*

**3**

*Software Control*

This chapter describes the functionality of each part of the user software interface within the Windows 7™ operating system:

- *xT microscope Server*
- *Microscope Control* (*UI* – User Interface)
- *FEI Account Manager*

# Software Interface Elements

## Icons

*Icons* are small symbols indicating a specific software application. Double-click on the icon placed on the desktop or within a folder to activate the program.

There are also *functional icons* in the toolbar for selecting some software functions quickly. Clicking on them causes it to be highlighted and activated, clicking on them again or clicking on another one (depending on a particular case) causes it to become normal and deactivated.

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

There are also some *informational icons* in the status bar, for instance, that indicate some particular system statuses.
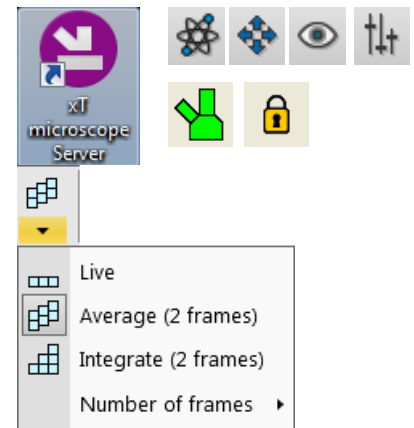
## Tool-Tips

This functionality activates 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 it.
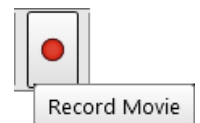
## Pull-down Menus

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 show 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 items followed by the ellipsis (...) indicate that this is a command and a dialog box will show. A right arrow on the right side indicates that an additional submenu of choices will show. If a selection is a parameter value, the new value is updated immediately and a check mark appears in the pull-down menu.

### Context Menus

Right-click on some items to call out the context menu with another corresponding choices.
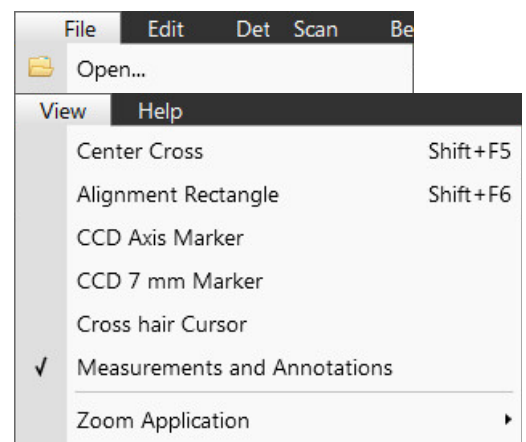
**Using the Mouse**

The click on / right-click on / wheel-click on represents click on with the left / right / wheel mouse button on the item throughout this manual. The click on & drag / right-click on & drag / wheel-click on & drag means holding the mouse button during the action.

Click on & drag the cursor down the menu to a desired item and then release the mouse button.

**Using the Keyboard**

Press Alt + the underlined letter (for example, *Alt + F* for the File menu), and then select from the choices by clicking on it or by hitting the *Enter* button after its location with the up / down (left / right for submenus) arrow keys.

Some often-used commands can be quickly 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 (see *Help* menu / *Keyboard Shortcuts* item).

# Command Buttons

carry out or cancel functions. They activate when clicked and some are highlighted (color background) to show the corresponding function activity.

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

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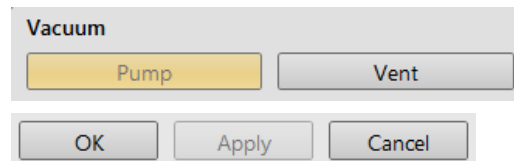
# Property Editor

Here is the list of related parameters and their values. A user should click on 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.
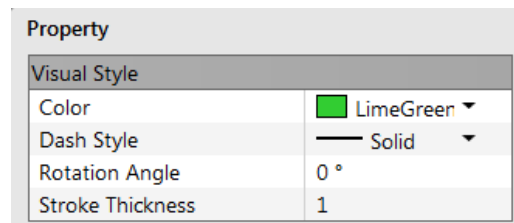
# Edit Boxes

One can input text information (such as passwords, labels or precise numbers) using the keyboard within an corresponding edit box. Some edit boxes, which are not part of a dialog, require to confirm the input by pressing the *Enter* key. If you press the *Esc* key before leaving the edit box, its previous value is restored.
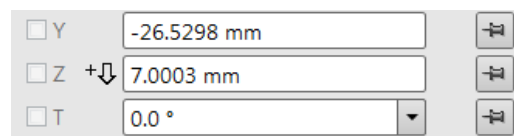
# Radio Buttons / Check Boxes

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

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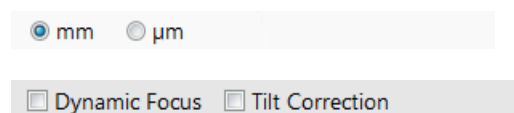
# Adjusters

Adjusters allow the user to change parameters (such as contrast, brightness etc.) in a continuous way.

Right-clicking on the adjuster shows a context menu with choices. Checking / not-checking the *Slider Mode* option switches two possible ways of slider control. Checking the *Mode Switch* option adds the mode switch button to the right side of the slider, which enables to quickly switch between these modes.

### Slider Mode

In this mode adjusters always have a label and a readout at the upper right corner – double-clicking on it enables to enter a precise value and a unit in particular cases using the keyboard.

Clicking on & dragging the middle adjuster button or clicking on the bar is used for coarse adjustments, while clicking on small end arrows is for fine adjustments (single step increments).

- *Slider Mode* (*Non-linear Slider* clear) – the adjuster button position always corresponds to the actual parameter value within an available range.
- *Slider Mode* (*Non-linear Slider* checked) – has an exponential response – the further from the center is the adjuster button pulled, the larger is the relative change. The adjuster button always snaps back to the center of the slider, but a dimension of the small bar under the slider corresponds to the actual parameter value.

It is possible to increase / decrease the *Slider Mouse Speed* (sensitivity) by dragging the context menu slider to the right / left.

### Not Slider Mode – Drop Down List Boxes

This mode is used for values that have both a continuous range and list of presets. It also offers direct value editing to achieve total control.

Clicking on the - / + sign selects previous / next value from the predefined list (see appropriate Preferences) but only shows one value in the text area. Clicking on the down arrow on the right side of the adjuster or the value itself expands a drop down list of available values – if it extends further than is visible, a scroll bar appears. Clicking on a value from the list enters it as the actual one, the drop down list automatically closes and the change of the setting is immediate.

Double-clicking on a value in the text area enables to edit it. It is also possible to click on & drag the small bar under the numerical value to continuously change the setting (where applicable).
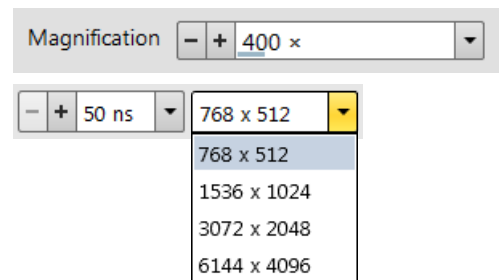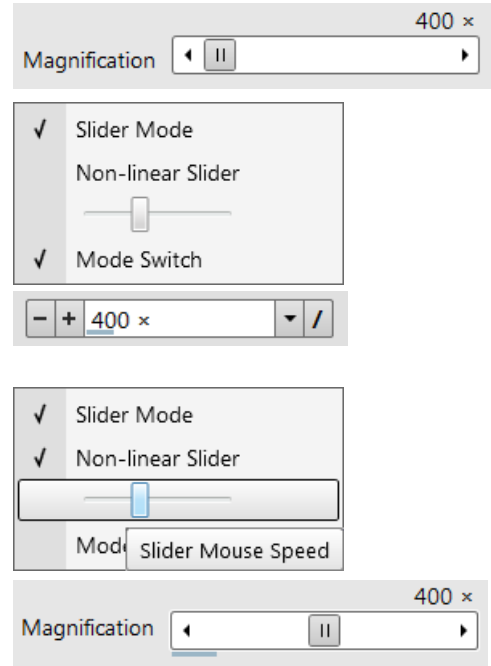
## 2D Controls

This way of control is 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.

Clicking on & dragging anywhere inside the box changes the active display cursor to the 4-ended arrow and positions it to the screen point corresponding to the actual control value (minimum in the middle of the screen and maximum at the edges). It can be dragged in four directions. Clicking on & dragging directly on the X / Y axis changes the active display cursor to the 2-ended arrow, which can be dragged in the corresponding direction only. To apply the values, release the mouse button.
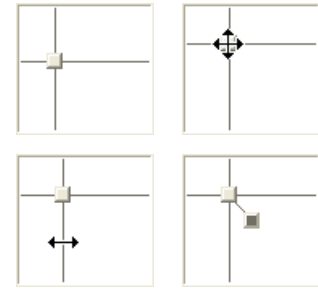
The right-clicking on the 2D box opens a context menu with choices:

- *Coarse / Normal / Fine* item – sets the mouse sensitivity from long to short mouse path necessary for the full range cursor move.
- *Adaptive Sensitivity* item – adjusts the mouse control response to be the same at any magnification.
- *Zero* item –brings the control value to zero and the cursor to the center of the box.
- *Clear Memory* item – clears condition values, which have been remembered automatically during the considered 2D control use. These remembered values are used to estimate new values, which have not been remembered yet.
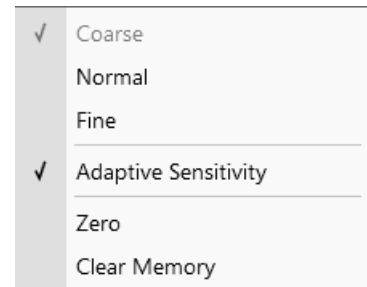
The menu may contain less or some other functions that are actually available for the particular parameter. Selecting the corresponding menu item activates the function.

## Modules

Visually combine various software elements, which are related into a labelled group. Complex software elements like Control pages or dialogs are typically composed of modules.
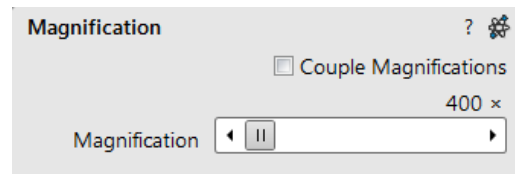
## Dialogs

An dialog appears when the system needs more information from you before it can carry out a command, or wants to give you some important information. Some dialogs 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 dialog can remain opened while performing other tasks).
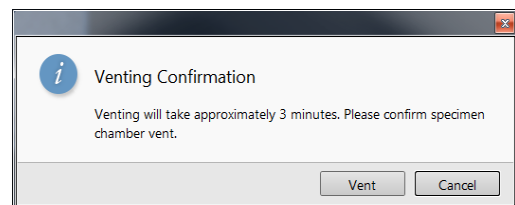
## Tabs

In modules or dialogs 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 on the Tab brings it to the foreground showing the corresponding group of interface elements. Tabs where some parameters were changed are highlighted (orange background).
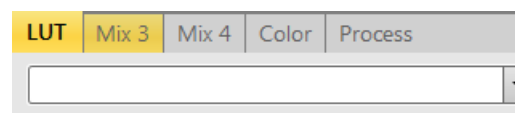
## Progress Bars

An progress of long ongoing procedures over time is indicated in a dedicated dialogs or modules.

# 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) *Microscope Control* software.

Start the *xT microscope Server* from the Windows Start menu or by double-clicking the icon.
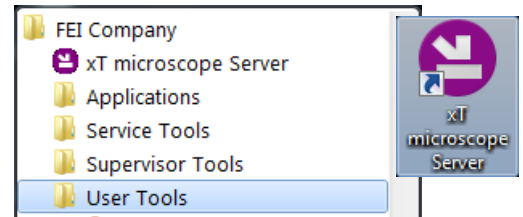
**FIGURE 3-1** *xT microscope Server window*
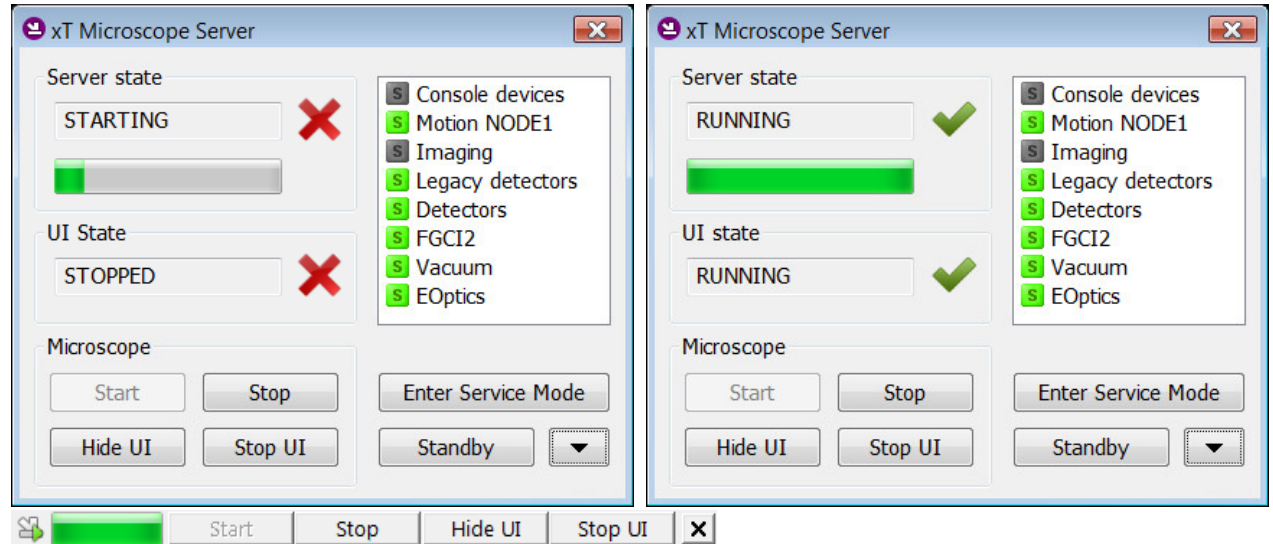
Right-clicking on the title bar opens a context menu with options. Double-clicking on the title bar switches the full and tiny view. Some Microscope area buttons change its label and behaviour depending on the actual state.

- *Server State / UI State* area – shows the *STARTING / RUNNING / STOPPING / STOPPED* state of the xT microscope Server / Microscope Control software service.
- Clicking on the *Start / Stop* button starts / stops xT microscope Server services. If the UI is running, the Stop button closes it first.
- Clicking on the *Start UI / Stop UI* button starts / stops the UI.
- Clicking on the *Show UI / Hide UI* button shows / hides the UI main window.
- Clicking on the *Enter Service Mode* button starts the special mode intended for service actions.
- Clicking on the *Standby* button closes the UI, stops the xT microscope Server services and brings the console to the *Standby* state (see Chapter 2).
- Clicking on the *Up / Down* arrow shows the *Administration* area containing information helpful for a service intervention. (specifying the software operation / hardware function state).

    When the *Autorun UI* checkbox is ticked (default), the Start button automatically starts UI after starting the xT microscope Server.
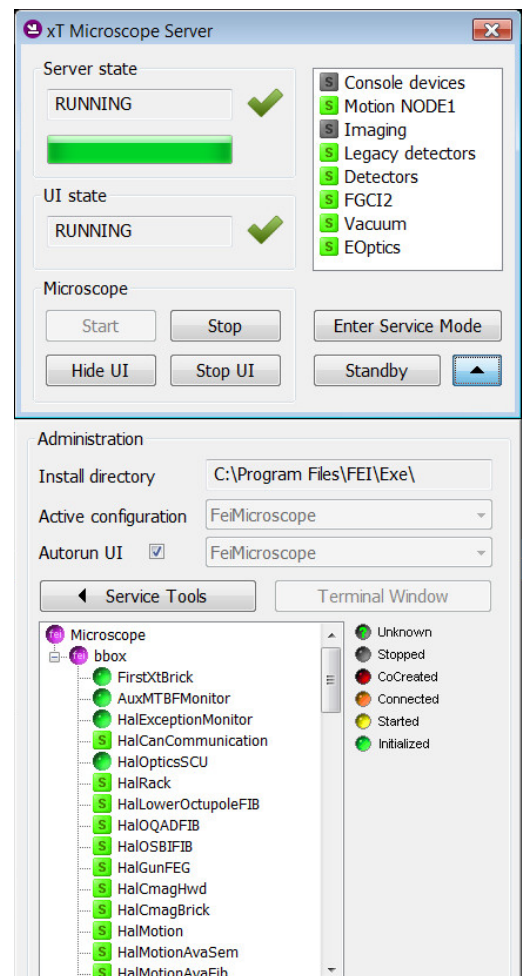
# Microscope Control Software

The Microscope Control software – simply User Interface (UI) – is made up of several elements which compose the main window, showing status and control features within the Windows 7 operating system.

*Note*
*To ensure correct representation of all UI entries (dialog and edit boxes, info fields etc.) within the Windows 7 environment choose the FEI 01 screen theme.*

**FIGURE 3-2**  *Microscope Control Window*
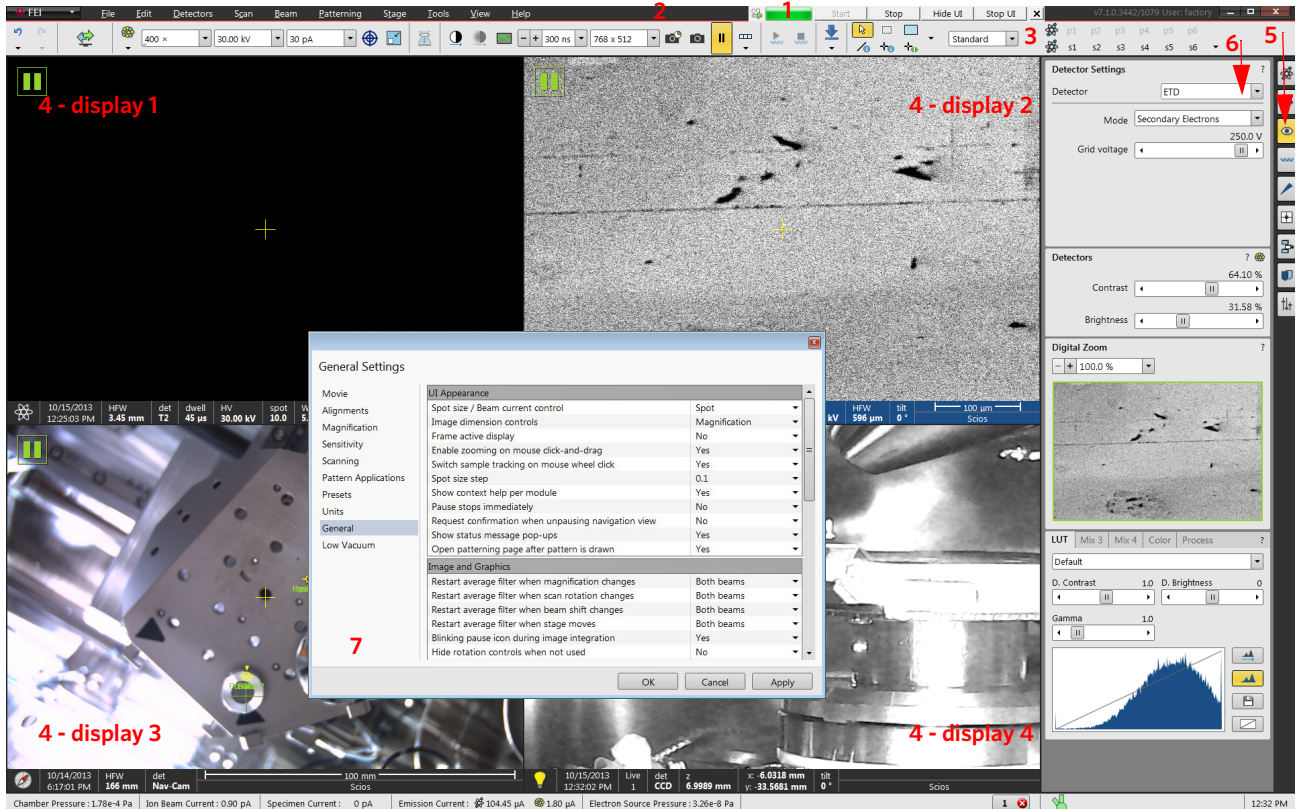


1. *xT microscope Server* – minimized application window
2. *Menu bar* – contains all operation menus and submenus
3. *Toolbar* – functional icons for the most frequently used microscope controls
4. *Imaging area* – shows with adjustable Databar
5. *Control pages* – set of modules
6. *Modules* – microscope and imaging control elements
7. *Preferences dialog* – presetting of operating conditions

## Workspace customization

It is possible to change the UI layout by right-clicking any free toolbar or sidepane (pages) area and selecting *Customize…* item.

A user can save / load layouts by selecting the *Export / Import Workspace…* item to / from the Workspace configuration (*\*.workspace*) file.

Clicking the *Reset to Default Workspace* item restores the factory UI layout, which is the one described in this manual.
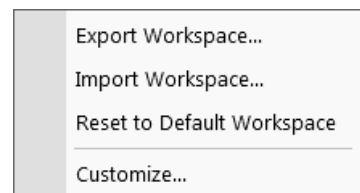
### Toolbar customization

Selecting the *Toolbar* tab adds a red triangle to each toolbar item enabling to change its size. By clicking & dragging any item it can be moved to a new position within the toolbar area; dragging it out from the toolbar area to the customization window eliminates it from the layout. Clicking & dragging a new item from the Toolbar tab to the toolbar area adds it to the layout.

**FIGURE 3-3**  *Toolbar customization*
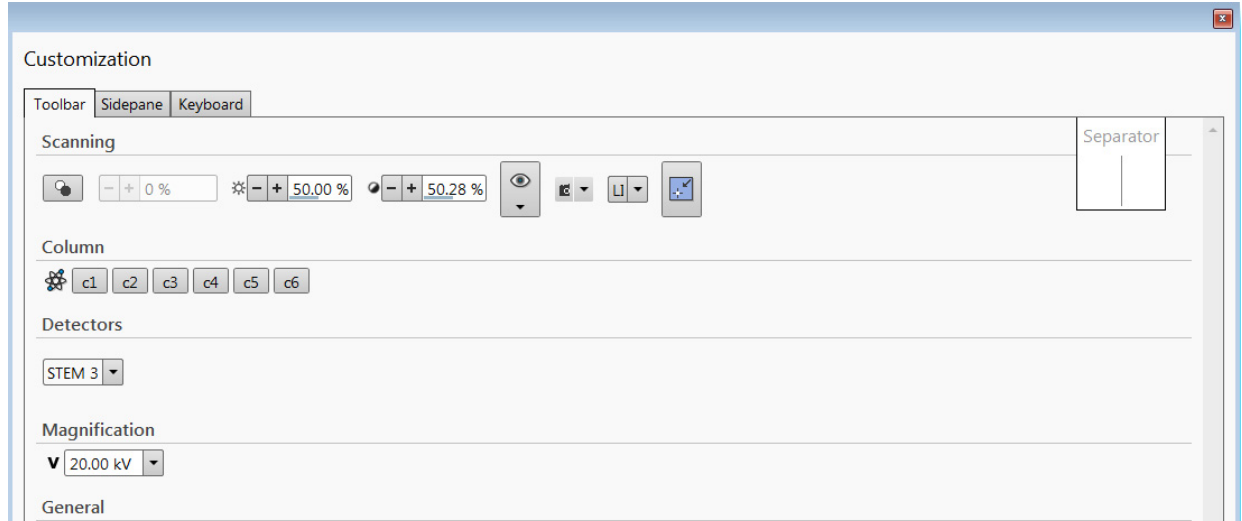


### Sidepane (Pages) customization

Selecting the *Sidepane* tab adds a red border to the pages area. By clicking & dragging any module it can be moved to a new position within the pages area; dragging it out from the pages area to the customization window eliminates it from the layout. Clicking & dragging a new item from the Sidepane tab to the page area adds it to the layout.

By clicking the + page button calls the dialogue requiring a *New page name* input; by clicking the *OK* button a custom page is created.
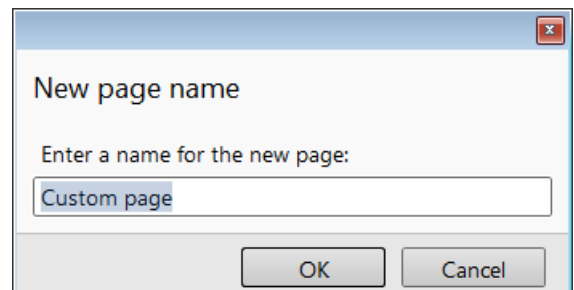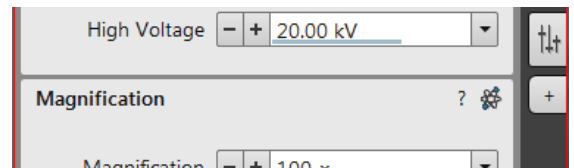


**FIGURE 3-4**  *Pages customization*
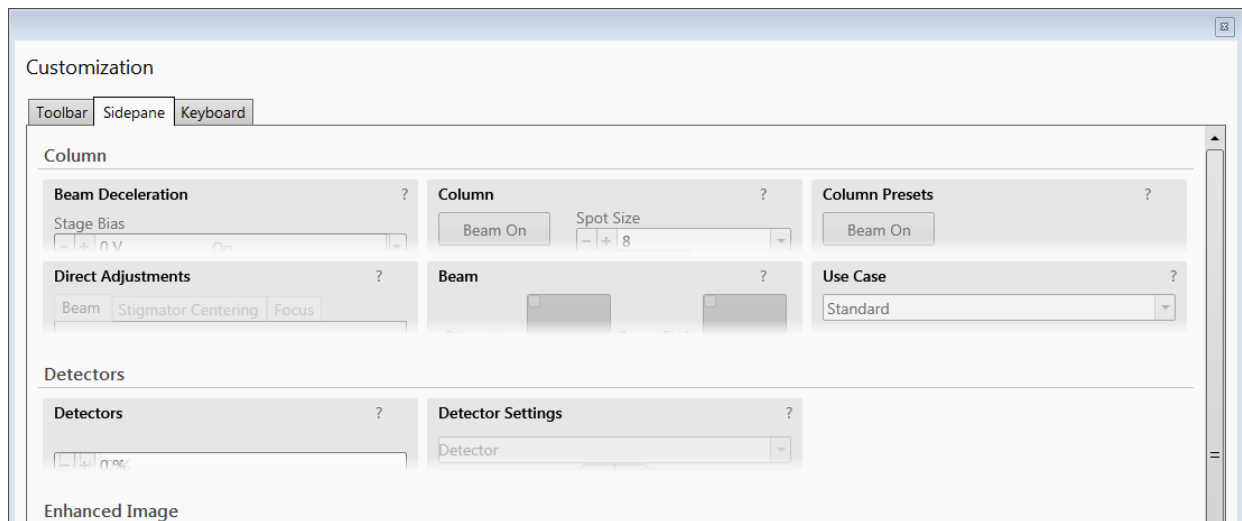
## Keyboard (Shortcuts) customization

It is possible to customize factory shortcuts within the *Kayboard* tab. To change the factory setting search a desired functionality, enter a *New Shortcut* to the edit field and click the *Assign* button. To revert to the factory setting click the *Default* button.

**FIGURE 3-5** *Shortcuts customization*
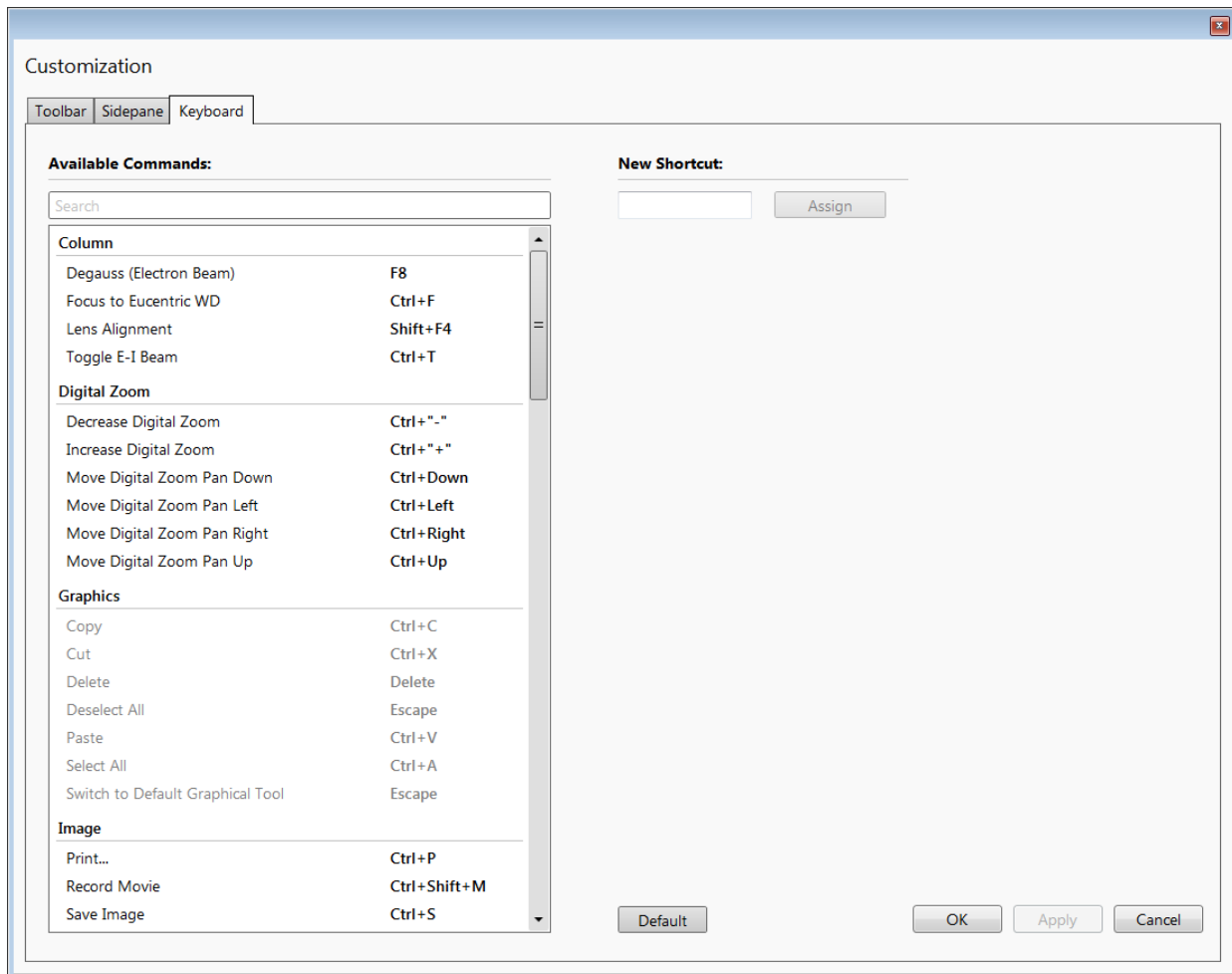
# Menu Bar

The pull-down menus are shown across the screen.

**FIGURE 3-6** *The Menu Bar*
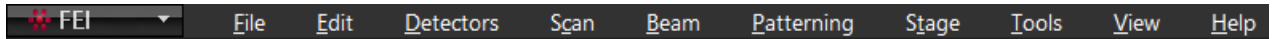


Select pull-down menus from the menu bar by:

- clicking on the Menu title
- Alt + underscored keyboard letters
- Alt + keyboard arrows + Enter button

*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.*

### FEI Menu

Standalone applications for particular use are listed here and ready to start.

- Movie creator
- Movie Creator
- Diagnostic AutoReport
- Working folder
- Service Tools



### File Menu

opens File menu administrative functions:

#### Open

shows a standard dialog for opening images previously stored to a media. Supported digital file formats are TIF8/16/24, JPG and BMP (see Chapter 5). The dialog shows, by default, the location (path) last used to open or save files from the UI.

#### Save (Ctrl + S)

saves the image using the format, location and base of name set by the last used *Save As* function in that display. An incremental suffix with a selectable number of digits ensures that every image is saved as a new file, e.g. Name_001.tif, Name_002.tif, etc.
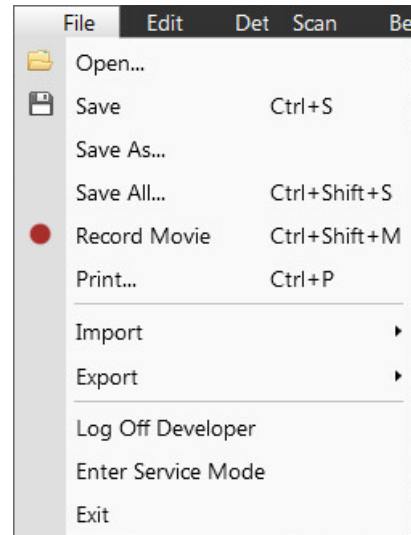


#### Save As

opens a dialog for saving images, which provides an opportunity to change the file name and location. An image can be saved in *TIF8/16/24*, *JPG* or *BMP* file format.

The dialog shows, by default, the location and the name last used to save / open a file in the selected display. A user can change a location, name base or suffix, select different image format (*Save as type*), and also choose whether to *Save* the *image with /* without *Databar* and *with /* without *overlaid graphics* by ticking / clearing the appropriate check box. The settings is remembered per display and used for the subsequent Save actions.
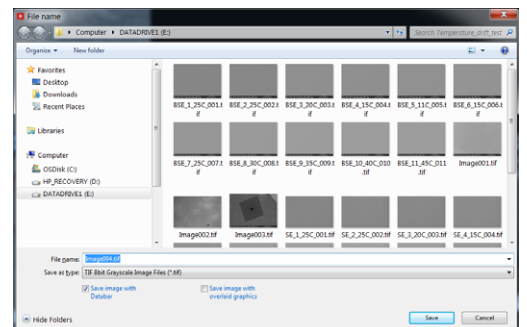
### Save All (Ctrl + Shift + S)

opens common dialog for saving images from each display, providing an opportunity to change the file names and locations.

### Record Movie (Ctrl + Shift + M)

allows a user to make digital video files (AVI) for dynamic experiments. The corresponding icon next to this menu item – red circle / square indicates the movie recording is stopped / in progress (see Chapter 5).

### Print (Ctrl + P)

opens the print dialog enabling a choice of printer and settings suitable to print an image.

### Import / Export

opens a sub-menu with selection of importable / exportable items. Selecting an item opens standard Open / Save As dialog for choosing location and file name. Following items can be imported (i.e. loaded and used) / exported:

- *Stage Positions* (*.stg* files) – stored stage positions
- *Patterns* (*.ptf* files) – active display parameters of (all) pattern(s)
  By importing these parameters (all) exported pattern(s) is/are drawn back in active display.
- *Scanning Presets* (*.scp* files) – preset scanning parameters
- *Display Presets* (*.qps* files) – active display parameters: Beam type / Detector type / Detector Mode / Detector contrast & brightness / Digital Contrast / Digital Brightness parameters
- *System Parameters* (*.par* files)
  Wide range of selected actual microscope settings is stored, including most of above mentioned ones. When importing them back likewise only selected ones are loaded.

### Log Off #user name#

logs off the present User and provides the *Log On* dialog for the next microscope user. When a user logs off the system goes to a safe state: the accelerating and detector voltages are switched off automatically.

### C a u t i o n !

*Logging off the actual user does not close all microscope operations! (see Chapter 2)*

### Enter Service Mode

starts the special mode intended for service actions.

### Exit

closes the Microscope Control software (the actual user is automatically logged off first) and leaves a user in the operating system environment. xT microscope Server is still running and controls the microscope in operation.
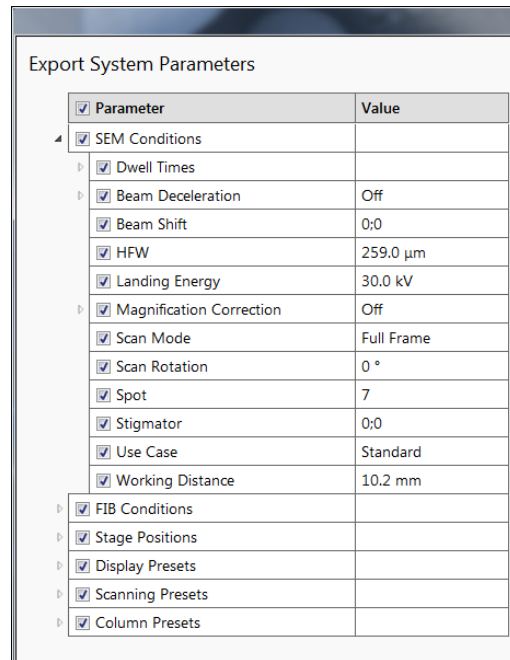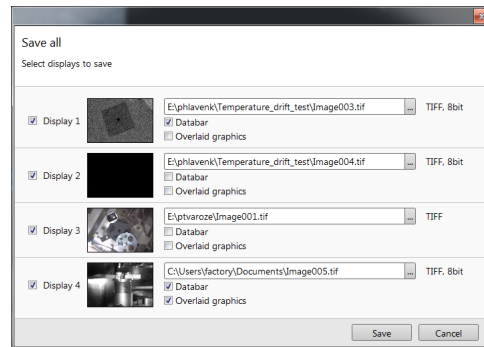
## Edit Menu

opens some helpful functions:

### Undo (Ctrl + Z) / Redo (Ctrl + Y)

reverts / restores some of the last used actions back.

### Copy (Ctrl + C) / Cut (Ctrl + X) / Paste (Ctrl + V)

These functions represent commonly used operating system functionality.

### Select All (Ctrl + A)

selects All graphics in the active display.

### Delete (Delete)

deletes all selected graphics in the active display.
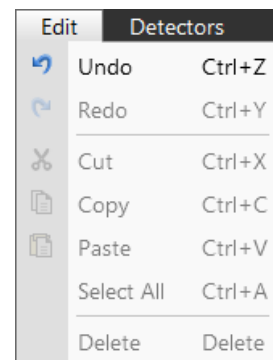
### Detectors Menu

opens the selection and setting of all installed Detectors (see Chapter 5 and Chapter 7).

**Detector list**

contains various detectors for the microscope operation. Detectors not mounted or not serviceable under actual microscope conditions are disabled (greyed out). The selected detector is remembered for the selected display, shows a tick next to its label and its mode acronym is shown beside in brackets.

- The 3rd party detector / video signal can be selected, which is indicated as "*External*" also in the databar. Contact a FEI authorized service engineer about connection details.
- The *CCD* camera reflects the inner space of the specimen chamber.
- The *Mix* sets a possibility to interfuse signals from 2 or 3 detectors.
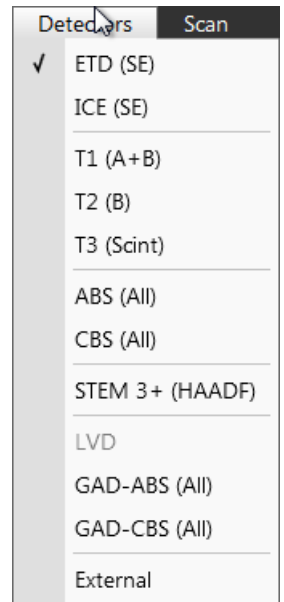
### Scan Menu

opens the scanning control functions:

**Pause (F6)**

pauses the imaging. This function is used automatically with Snapshot and Photo functions.

Select the Scan menu / Pause or press the F6 button or click on / double-click on the toolbar pause icon to stop scanning at the end of the actual frame / immediately.

When the imaging is going to be paused at the end of a frame the toolbar pause icon becomes highlighted (orange background) and there is a frame around it. When the imaging is paused the icon is highlighted (orange background) and the green pause icon appears in the corresponding display.

Select *Scan* menu / *Pause* item or press F6 button or click on the pause icon at the toolbar or in the display to release the pause function (the icon background becomes grey) and to return the scanning to the previous state.

Shift + clicking on the toolbar pause icon pauses / activates all displays at once just in case the detectors in different displays are mutually compatible.

**Snapshot (F4; Ctrl + F4) / Photo (F2)**

activates a preset scan (see the *Preferences / Scanning* section) to acquire an image.

*Note*
*There are two hotkeys for the Snapshot: F4 for an electron and Ctrl + F4 for an ion imaging (not mentioned in the Scan menu). The Photo hotkey F2 works with an active imaging beam.*

**Active Preset Snapshot (Ctrl + F2)**

This item starts acquiring a snapshot with parameters corresponding to the active (highlighted by orange background) toolbar *Scanning Preset* button (labelled *s#)* (see further).

*Note*
*Shift + clicking on the Photo (Snapshot) icon / Scanning Preset button or when pressing Shift + F2 (F4) / Ctrl + Shift + F2 (F4) key takes actual beam Photo (Snapshot) / Scanning preset snapshot from all displays with the same beam at once.*

**Videoscope (F3)**

This function shows the video signal intensity along the actually scanned horizontal line for correcting the contrast and brightness.
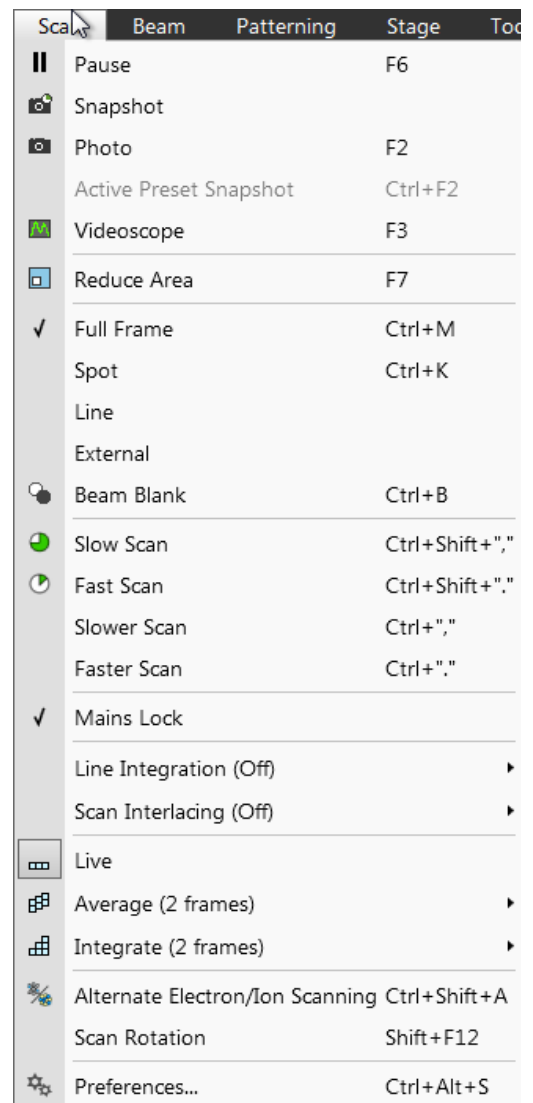
### Reduced Area (F7)

This mode is useful when focusing and correcting astigmatism as the imaging update is faster in the smaller area. When Reduced area is chosen, the green frame appears at the last used place onscreen, which can be adjusted by clicking on it & dragging. It is also possible to adjust scan parameters independently on the full-frame setting.

- *Moving:* Place the mouse cursor over the selected area. The cursor changes to a 4-ended arrow. Click on & drag the selected area to the desired position and release the mouse button.
- *Changing the size:* Place the mouse cursor over the edge of the selected area. The cursor changes to a 2-ended arrow, either horizontal or vertical. A corner can also be used to move two sides. Click on & drag the side out or in to obtain the desired size and release the mouse button.

When the Reduced area frame is being manipulated, it turns yellow until released, then it reverts to green.

### Full Frame (Ctrl + M)

is the default scanning mode, typical for navigation and imaging.

### Spot (Ctrl + K)

When starting this mode, actual beam position is represented by a green cross in all electron or ion imaging displays. You can click on & drag it or click on anywhere around the screen to change its position.

### Line

In this mode, the green horizontal line is shown in all electron or ion imaging displays. The beam scans along this line. You can click on & drag it or click on anywhere around the screen to change its position.

### External

switches to activate an external control of the scanning system, such as EDX system beam control. The external scanning mode is indicated by the External label shown in the upper right corner of all imaging displays.
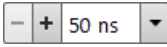
### Beam Blank (Ctrl + B)

When the functionality is active, it is shown next the scan menu item by the icon. It deflects the beam off axis high in the column and protects the specimen from unnecessary exposure. Selecting the item again releases the blanker and returns the beam to scan the specimen.

### Slow / Fast Scan (Ctrl + Shift + , / .)

brings the scanning condition to the preset Slow / Fast scan value (see the Preferences / Scanning section).

### Slower / Faster Scan (Ctrl + , / .)

sets the scanning condition to the next preset Slower (-) / Faster (+) value (see the *Preferences / Scanning* section). The adjuster shows the actual dwell time, but does not enable to edit directly its value, which can be selected from the drop-down list (see the Preferences / Scanning section).

### Mains Lock

When ticked, the scanning (line sawtooth signal) is synchronized with the mains AC oscillation. This greatly diminishes blurring and jittering of the electron imaging resulting in smooth image edges at higher magnifications and slow scan conditions.

### Line Integration

With this function each line scan is repeated several times (from 2 to 255) before proceeding to the next line. Signal data collected from these passes are integrated and shown as an actual image line.

This imaging method reduces sample charging (in comparison with single pass with longer dwell time) and improves overall image quality.

### Scan Interlacing

This function splits an imaging area into large number of blocks defined by the number of lines (from 2 to 8). The first line of each block is scanned followed by the second one etc. This imaging method significantly reduces sample charging.

*Note*

*When two above mentioned functions are active, it is represented in the toolbar dwell time adjuster with the letters LI / SI.*

### Live

is the default mode, leaving the imaging unfiltered for collecting raw direct images – one frame follows another.

### Average

Filter continuously averages a specified number (2 or more) of frames, resulting in a better signal-to-noise ratio. This process continues until stopped by changing the scanning condition or by pausing the imaging.

This is used mostly for fast scanning to reduce imaging noise. During averaging, the image is updated continuously and actions such as focusing, moving the stage, etc. can still be performed.

*Note*
*The Average is set independently also for the optical window, but using averaging with more than 4 frames is not recommended, especially when moving the stage.*

### Integrate

Filter allows accumulative noise reduction by true integration over a specified number (2 or more) of frames. This process continues until the selected number of frames is reached and then pauses the imaging automatically.

This can be used as an alternative to slow scanning to obtain high quality images of slightly charging specimens.

*Note*
*Clicking on the down arrow below the toolbar icon shows menu items Live / Average (# frames) / Integrate (# frames) / Number of frames enabling to select number of averaged or integrated images (depending on the actually active filter indicated by the icon for the selected display). Clicking on the toolbar icon itself changes the Live / Average / Integrate filter in cycle.*

The *Number of frames* is set and remembered independently for the Average and Integrate filters. Both the filter and Number of frames is set and remembered per display, so live and filtered imaging can run at the same time. Settings are particular for the *Reduced Area*, *Full Frame* and for the *Line* scan also. The *Photo / Snapshot* function uses the Integrate and Number of frames pre-set (see the *Preferences / Scanning* section).

As the scanning can take a significantly long time period, one can restart scan from its beginning by pressing the Ctrl + R keys.
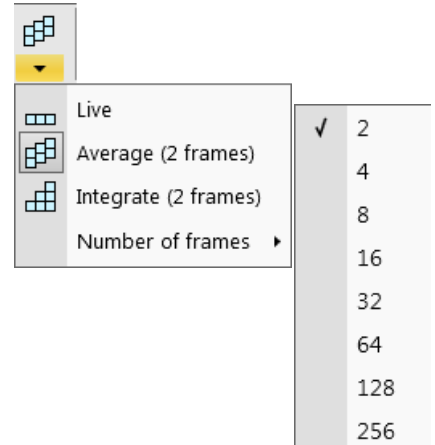
#### Alternate Electron/Ion scanning (Ctrl + Shift + A)

When ticked, the scanning alternates between the electron and ion imaging in two separate displays after completion of each frame. A label is shown in affected displays.

#### Scan Rotation (Shift + F12)

The on-screen tool is activated to rotate the scan field. It has no effect on the stage movements and is solely a scan coil/electrode function used to orient the imaging relative to a specimen feature and/or detector direction.

A non-zero scan rotation is indicated by an icon in the *Status bar*, and its value can be also shown in the optical displays.
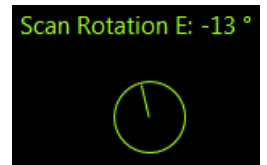
#### Preferences (Ctrl + O – letter)

See further.

## Beam Menu

opens the Beam menu functions:

#### SEM Aperture

This item is not available for the user / supervisor accounts, it is intended for a service interventions.

#### Home SEM Apertures

This function sends the SEM final lens aperture (Automatic Aperture System – see Chapter 2) to its home position in case of troubles.

#### Home FIB Apertures

This function sends the FIB automatic aperture system to its home position in case of troubles.

#### Show FIB Heat Alert

When ticked, the system informs a user 1 minute prior to the automatic FIB Heat procedure (started when ion emission beam is lower then approx. 2 μA) and enables to stop it.

#### Degauss (Electron Beam) (F8)

This feature triggers the procedure which puts all actually used electron lenses to a normalized state by removing their hysteresis effects. For a few seconds while the procedure is running all live imaging disappear or turn fuzzy, and then return back.

Use this function with (almost) focused imaging to obtain the most accurate Magnification, Horizontal Field Width (HFW) and Working Distance (WD) readouts.
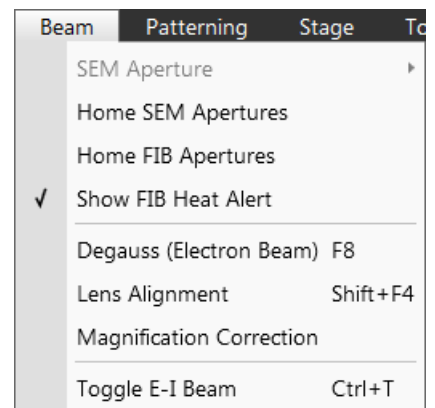
### Lens Alignment (Shift + F4) ⊕

This feature activates / deactivates the final lens alignment mode for the fine alignment of the electron beam only. The scanning conditions change to the last selected value, lens modulator turns on and the alignment cross appears in the respective position in all imaging displays.

Clicking on & dragging within a display activates a 4-ended arrow cursor and starts the final lens alignment.

### Magnification Correction

Applies the *Magnification Correction* alignment influences on imaging. The letter "c" is added to the appropriate image databar fields (Mag, HFW) and the *Magnification Correction* text is added to the imaging display.

### Toggle E–I Beam (Ctrl + T)

Quickly toggles electron and ion beams to be used in the selected display for imaging.

## Patterning Menu

opens the Patterning menu functions (see Chapter 5):

### Start / Pause / Resume Patterning in Display # (Pause button)

starts / pauses patterning of the enabled pattern(s) in the active display. The menu item and the corresponding toolbar icon changes according to actual condition.

### Reset Patterning in Display # (Ctrl + Pause button)

cancels the patterning procedure.

### Next Pattern (Shift + P)

In the serial patterning mode the actual patterning is stopped and the procedure continues with the next pattern (if present).

### Next Line (Ctrl + N) / Previous Line (Ctrl + Shift + N)

When milling a Cleaning Cross Section pattern type, milling of the actual line is cancelled and continues with the next one / previous one.

### Sleep After Patterning

applies the *System* module / *Sleep* command when patterning process finishes.

### Autostart Real Time Monitor

When selected, it releases the pause function for the display with patterns enabling automatic start of the real time monitoring (RTM) of the milling process.

### Auto-Start/Stop Electron Acquisition for iSPI

When ticked and the *Advanced Patterning* module / *iSPI* tab (intermittent Switching between Patterning and Imaging) / *On* check box is ticked, the iSPI starts automatically when starting patterning. The electron beam display is released, when paused. When not ticked, nothing happens.

### Live RTM after Snapshot

After acquiring a snapshot RTM feature continues automatically.

### Blackout Pattern Area for RTM

In case the Real Time Monitor is running, the area not milled is darkened to enhance the visibility of the RTM information. The visibility of the individual patterning pixels is greatly enhanced (this is especially important for patterns with extremely large pitch or very thin lines).
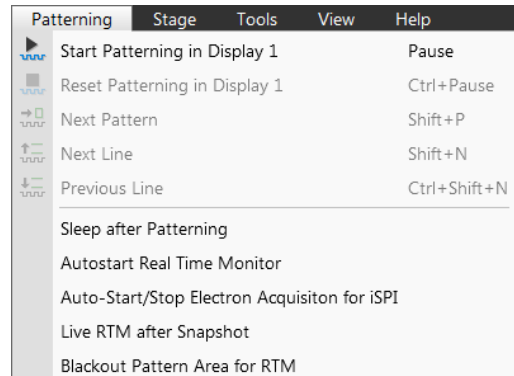
**FIGURE 3-7** *Imaging with / without Blackout Pattern Area*
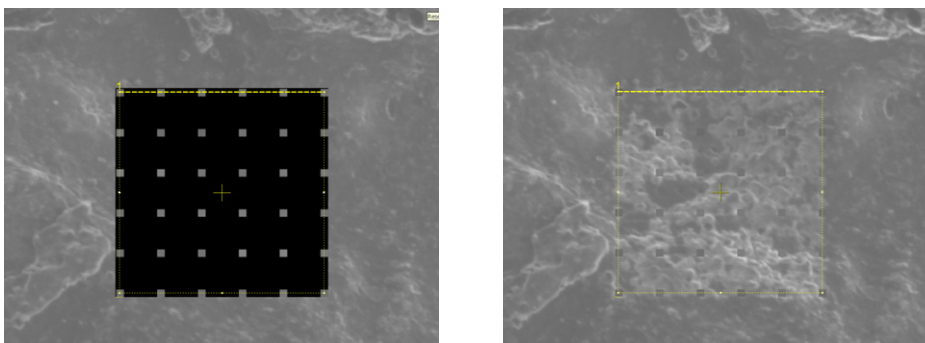
### Stage Menu

opens the stage and sample navigation functions
(see Chapter 5):

#### Align Feature

opens the procedure that helps to set a stage position for any
elongated feature (extending off the screen at the desired
magnification). The procedure uses the stage rotation.

#### Compucentric Rotation (F12)

places a green circle in the selected display. By rotating the circle a
different viewing orientation of the sample area can be achieved
by a physical stage rotation and adjustment of X and Y axes. Stage
rotation keeps the observed feature in the center of the field of
view. If this does not occur, an alignment should be performed to
locate the stage center and calibrate the stage (see Chapter 4).

#### Define User Units

activates a procedure guiding a user to determine User Units for
X and Y stage axes. These are used for relative stage movements
associated with the regular features mapping (in particular
integrated circuit applications).

#### User Units

organizes the stage software to recognise the defined user units
rather than the default metric measurements. The X and Y
coordinates now operate in User Units which are indicated in the
*Stage* module by the UU symbol.

#### Beam Shift Reset

zeroes the beam shift. A feature observed with a non-zero Beam
Shift is automatically moved back to the imaging center using the
stage.

#### Auto Beam Shift Zero

automatically resets the beam shift each time it reaches the maximal value during the Get function (the point-to-
point stage movement) and corrects the imaging position with a stage movement.

#### Home Stage (Shift + F3)

starts procedure which moves all motorized axes to their
hardware limits and ensures that the physical stage position
agrees with the coordinates readout. During the home stage
procedure the *Stage Homing* dialog shows its progress. The stage
axes are moved to their end-switches in the following order:

*1. Z* (lowest position), *2. T* (tilt), *3. X, Y* and *R* (rotation) at the
same time.

When the stage is homed correctly it ends up in the following
position:

*X / Y* position is set to the factory pre-set stage rotation centre
*R* = 0°
*T* = 0°
*Z* = preset long working distance

#### Home Stage Without Rotation

executes Home Stage function without rotation. When the stage is homed without rotation the stage Rotation
reference is greyed out. This is useful when a large specimen is inserted and stage rotation can cause a collision
with equipment inside the chamber.

#### Center Position (Ctrl + 0 – digit)

moves the stage to coordinates X = 0, Y = 0.

#### Recovery to Safe Position

If the stage position is out of a safe zone, the dialog warns and refers to run this functionality.

#### External Current Measurement

When you need to use an external measuring device (option) click on this item. The *Status* bar / *Specimen Current*
value shows *N/A* from that point on.

---

### Unlink Z to FWD

This feature functions in the opposite way as the following one. The Z coordinate value represents then the distance from the Z home position (stage base). The dialog warns you about the stage Z-axis positive move direction.



### Link Z to FWD (Ctrl + L)



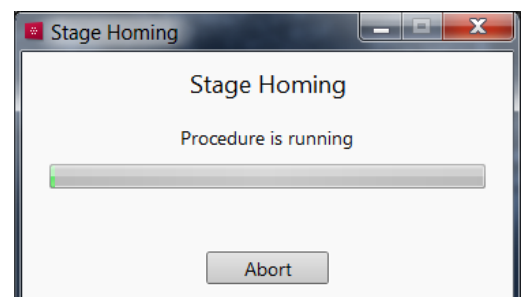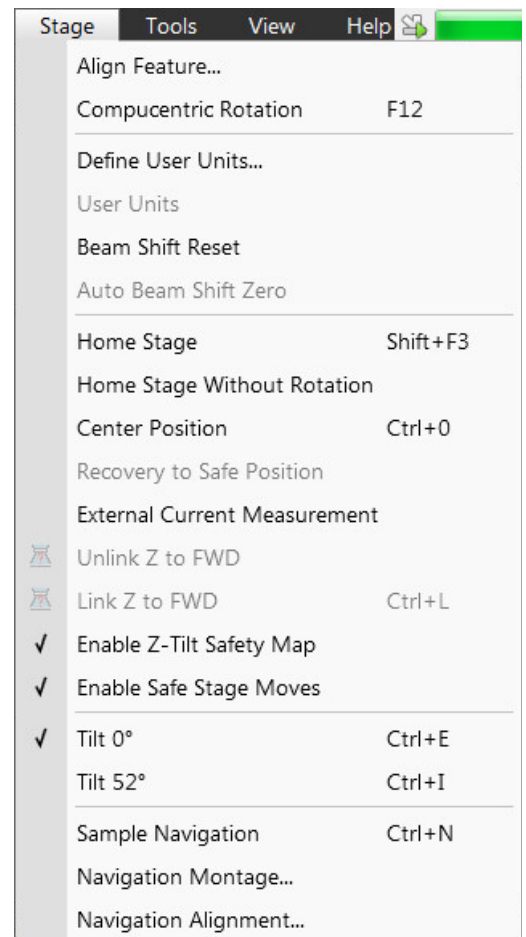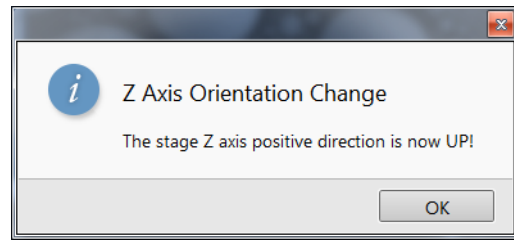This functionality provides the system with definite stage positioning to perform accurate and secure movement between the sample top surface and the end of the objective lens. It sets the Z coordinate value to the actual Free Working Distance (FWD) value. The related toolbar icon changes according to the Z-coordinate status:



- *Greyed icon*: the function is disabled – the tooltip gives a reasons (for instance high voltage is switched off, all displays are paused, beam is not on…).
- *Red question mark*: the function is enabled – Z is not linked to FWD. Use this function as soon as possible, after a proper focus.
- *Red circle arrow*: the function is enabled – Z is roughly linked to FWD, but it needs correction. It happens e.g. after: pumping the chamber when specimens were exchanged, focusing and linking Z to FWD at a long WD and then moving the stage to a short WD. In this case focus carefully at a WD around 7 mm and use this function again.
- *Green 2-ended arrow*: the function is enabled – Z is properly linked to FWD. Now it should be safe to change the working distance by setting the Z coordinate in the Stage module.
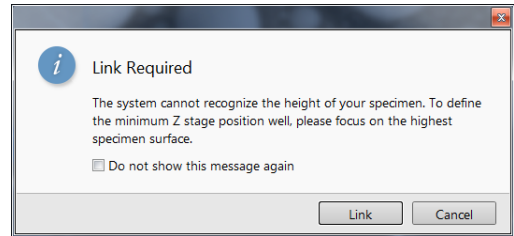
*Note*

*The Do not show this message again check box disables this notice once for ever.*

### Enable Z-Tilt Safety Map

Some movements of the tilted stage are not safe because of a possible collision with the final lens. The table (not user editable) with pairs of values indicates the maximum safe Tilt angle for a certain Z value when linked. It can be used to guarantee safe usage of the stage (tilt restriction) for flat samples only and when a proper Link Z to FWD is established.

### Enable Safe Stage Moves

When ticked the software takes into account all accessories installed inside the chamber. That's why the stage doesn't move to the target position following the straight path. When the magnification is large and stage movements are expected to be tiny, it is not necessary to switch on this functionality.

### Tilt 0° (Ctrl + E) / Tilt 52° (Ctrl + I)

tilts the stage to 0° / 52°.

### Sample Navigation (Ctrl + N)

toggles on / off function that enables to navigate electron / ion imaging (scan field) towards desired places on a specimen using either paused or loaded sample image (usually captured at much lower magnification).

The Sample Navigation can be selected independently for any display, regardless of its actual content and status. A tick next to the menu item indicates that the function is selected for the selected display. As soon as this imaging is paused, the Sample Navigation indicator appears in the upper right corner of the display. The indicator is green as long as the paused imaging can be used to navigate the live one, otherwise turns red.



### Navigation Montage

This procedure enables to capture the sample Navigation image to be used in the Sample Navigation.

### Navigation Alignment

This procedure aligns the Navigation image according to the live reference image.

## Tools Menu

opens the Tools menu functions:

### *Image Registration*

This functionality is used to interconnect images of the same area of interest acquired from different sources or at different conditions (for instance images acquired from optical and SEM microscopes, images acquired at various depth of focus etc.).

Click the *Tools* menu / *Image Registration* item and follow the prompts at the top of the window:

**1.** Select the display with the *Reference* image.

**2.** Select the display with the *Target* image (the one that will be transformed).

**3.** Select 1, 2 or 3 corresponding pairs of points in both the reference and target images.

*Note*
*When selecting 1 point, image is shifted only, 2 points shifts and rotates it and by selecting 3 points it is skewed furthermore.*

**4.** Click the *Register* button to apply the transformation.

Click the *Close* button to close the Image Registration window.

Click the *Start Again* button to repeat the procedure in the same way with the changed (or another) target and reference images placed in the same or different displays. Clicking the *Undo* button restores the image to the situation before the last transformation.

Clicking the *Overlay* check box shows a copy of a registered target image (in selected *Color*) over the reference image which reveals a quality of the registration and enables to compare information from both images. The *Threshold* value (0 to 255) determines which gray levels of the target image are shown in the overlay and the *Edges Only* check box ensures to display only the edge outlines.

After registration the micron bar and magnification of the target image take on the same values of the reference image. Any operation that is applicable to an acquired SEM image can be applied to a transformed image, including saving a file.
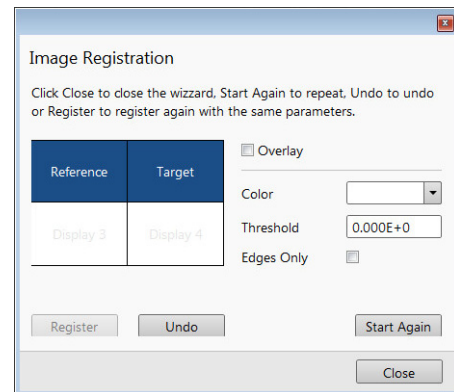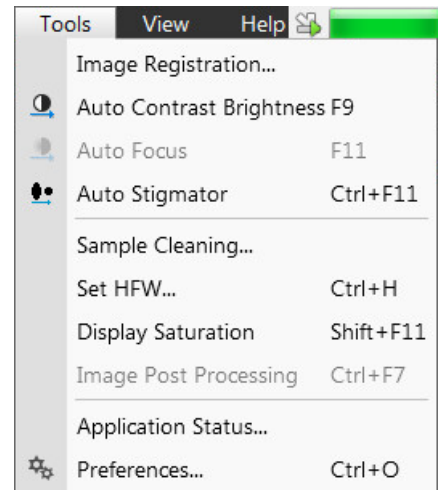
### *Auto Contrast Brightness (F9)*

activates the automatic contrast and brightness routine. The system attempts to set the Contrast and Brightness of the selected detector in the selected display to suit the actual sample and conditions so that the majority of grey levels is shown. This functionality is available for both beams and for paused imaging also.

*Note*
*Pressing the Shift + F9 hot key starts the Auto Contrast Brightness functionality in all live displays.*

### *Auto Focus (F11)*

activates the automatic focus routine for either beam. The system attempts to correct focus at any working distance.

### *Auto Stigmator (Ctrl + F11)*

activates the automatic procedure to correct an astigmatism.

*Note*
*Auto-functions are only enabled during live imaging.*

### *Sample Cleaning*

This feature starts the sample cleaning procedure according to the *Plasma Cleaning* alignment (see Chapter 4). The procedure removes thin contamination layers which could typically be formed by hydrocarbons residues remaining on vacuum parts after conventional cleaning or could be transferred into the microscope chamber with a sample.
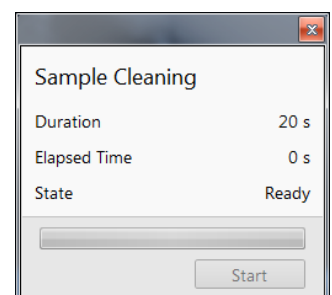
### Set HFW (Ctrl + H)

enables to set the desired Horizontal Field Width, i.e. the width of the scanned area. This is an alternative to the setting of magnification.

### Display Saturation (Shift + F11)

shows signal clipping in the selected display by means of replacing the full black / white with dark blue / yellow color. The function can be used both for electron and ion imaging, but cannot be applied to the optical imaging.

This functionality can be selected independently for each display.
A tick next to the menu item indicates whether the function is active for the selected display.
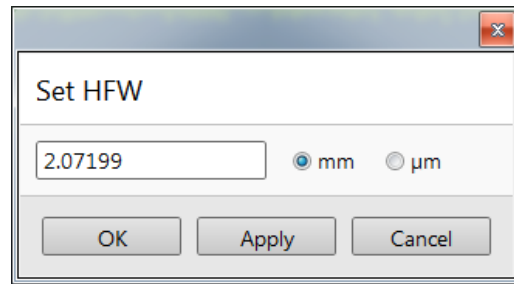
### Image Post Processing (Ctrl + F7)

Starting this function changes image appearance according to the *Enhanced Image* module / *Process* tab setting.

### Application Status

The dialog is showing continuously updated system *Messages*. The *System status* tab offers information about the system, that are used for a FEI authorized service engineer.

- *Show this window on* (Info / Warning / Error / Never) specifies kind of messages which are automatically called up onscreen.
- Three icons enable to separately switch on (orange background) / off (grey background) showing of Error / Warning / Information messages.
- *Clear* button clears all actual messages from the window.
- *Hide* button hides Application Status window.

**FIGURE 3-8**  *Application Status*
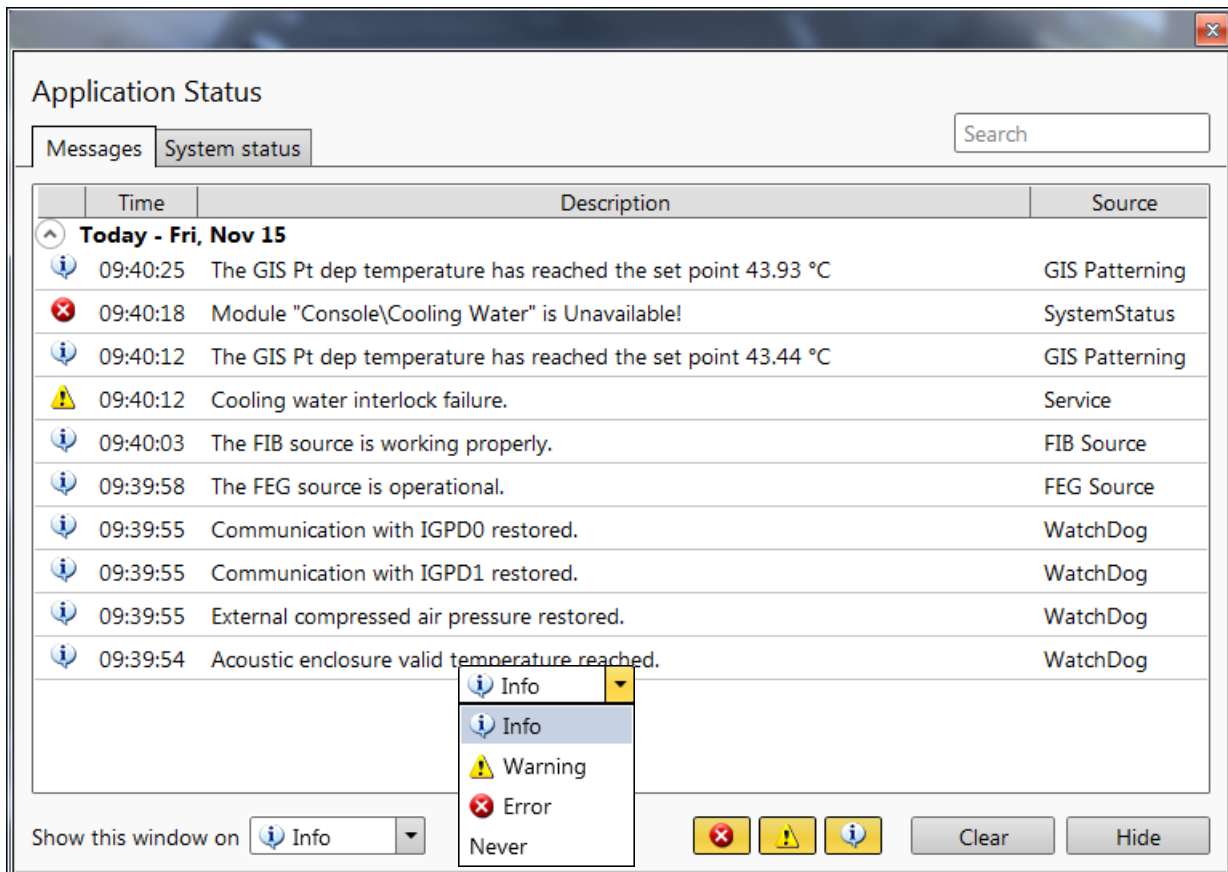


### Preferences (Ctrl + O – letter)

See further.

## View Menu

opens the Window menu functions:

### Center Cross (Shift + F5)

places a cross in the center of all imaging displays. This function is automatically used in Alignment procedures to aid the centering of features and can be used to align a sample against a stored image in another display.

### Alignment Rectangle (Shift + F6)

places a dashed rectangle in the center of all electron imaging displays. This function is used for some Alignment procedures automatically.

### CCD Axis Marker

places axes indicator in all optical imaging displays to help user with 3D orientation.

### CCD 7 mm Marker

places a short horizontal line with 7 mm label in all optical imaging displays to help user with a sample positioning to a correct working distance and with the first focusing. Only Supervisor is allowed to change the marker position by double-clicking on a new position.

### Crosshair Cursor

shows the cursor as a rectangular cross through the entire display.

### Measurements and Annotations

Checking this item enables to use the measurements and annotations functionality within all displays. Not checking this item makes dedicated toolbar icons inactive and hides all measurements and annotations graphics, which is convenient during working with patterns.

### Zoom Application

This functionality enables to enlarge / reduce the Microscope Control application controls size (labelling texts, icons etc.).

### Undo / Redo Zoom #

When any Digital zoom is applied, this functionality switches between this zoom factor and no zoom (factor 1).

*Note*
*To revert the last step use the Edit menu / Undo (Ctrl + Z) functionality, which is also available at the toolbar.*
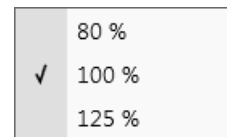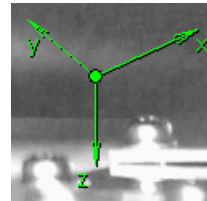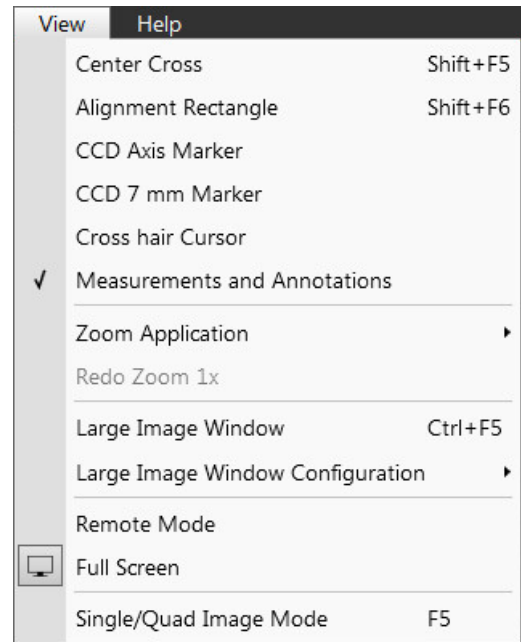
### Large Image Window (Ctrl + F5)

This function activates / deactivates the full screen imaging on the secondary monitor.

**FIGURE 3-9**  *Large Image Window*
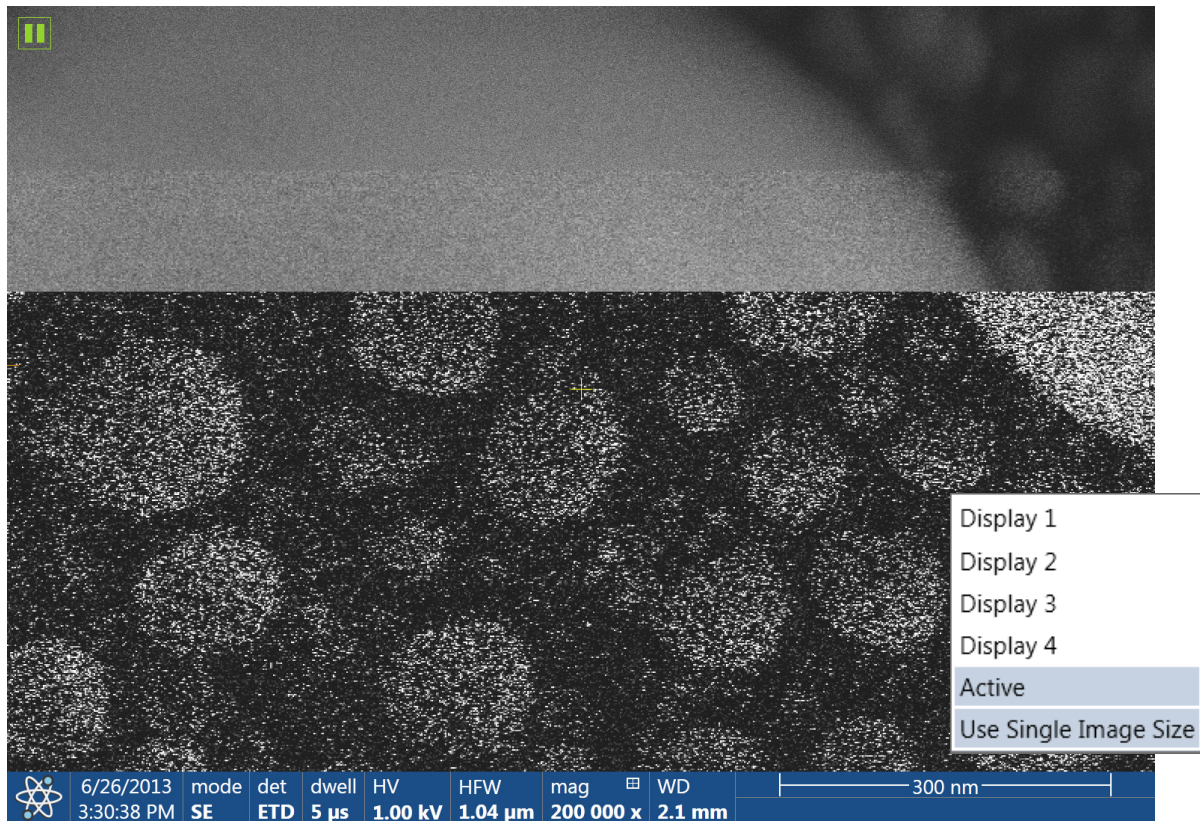


### Large Image Window Configuration

Here one can select, whether to show the *Active* display, or any selected one. Activating the *Use Single Image Size* option sets the imaging window size corresponding to Single Image mode size. These options are also available in the bottom right corner of the large image window.

### Remote Mode

When ticked this feature enables a correct UI imaging at the remote site. It is also used for a remote servicing. Use of this function decelerates slightly UI performance.

### Full Screen

Selecting this option sets the application to be shown full screen, de-selecting it shows the application as a window within the screen.

### Single / Quad Image Mode (F5)

toggles the imaging area between two possibilities:

- *Single Image mode* shows one display over the whole UI imaging area – useful for observing details.
- *Quad Image mode* is useful for comparing imaging of the same sample area taken with different beams, detectors or scan conditions.

In the Single Image mode, the selected display fills up the screen.

## Help Menu

opens the Help menu and system information functions:

### Documentation (F1) / Safety Manual

The complete *User operational manual / FEI Microscope Systems Safety Manual* in PDF format is opened using an embedded Acrobat Reader, with its useful navigation, search, and selection facilities. The window remembers its position and size for the next time it appears.

*Note*
*It's a must for any microscope operator to read the FEI Microscope Systems Safety Manual before using a microscope for the first time.*

**FIGURE 3-10** *Online Documentation*



### Keyboard Shortcuts

Clicking on this item starts Adobe Reader to show the shortcuts list. It is advisable to print out this document and place it visibly nearby a microscope workplace.

**FIGURE 3-11** *Keyboard Shortcuts*

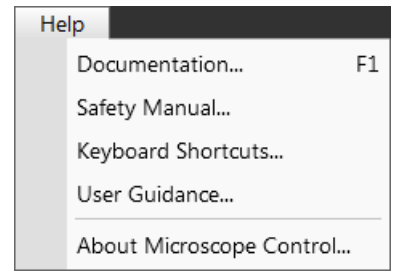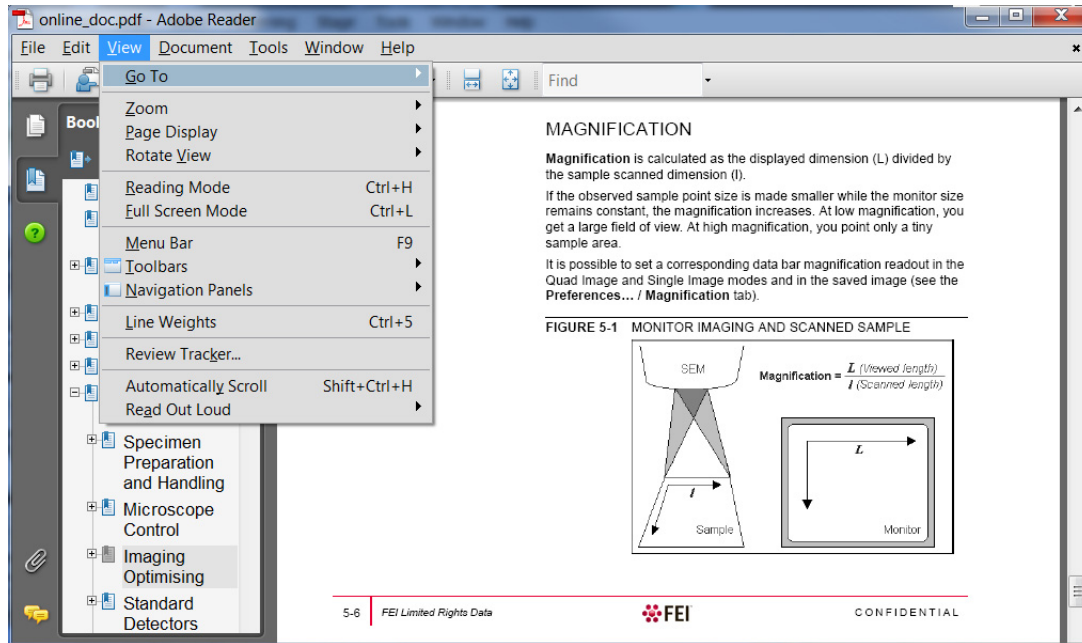| ENTERING COMMANDS – USING KEYBOARD | | | | |
|---|---|---|---|---|
| Microscope Control (UI) Function & Specific Keys | | | | |
| **Key(s)** | **Function** | | **Key(s)** | **Function** |
| F1 | displays documentation | | Ctrl + H | sets Horizontal Field Width (HFW) |
| Shift + F1 | displays Image properties | | Ctrl + I | tilts stage to 52° |
| (Shift +) F2 | starts Photo with active beam (in all displays with the same beam at once) | | Ctrl + K | sets Spot mode conditions |
| | | | Ctrl + M | sets Full Frame scanning conditions |
| Ctrl + (Shift +) F2 | starts / stops Active Preset Snapshot (from all displays at once) | | Ctrl + Shift + M | starts movie recording |
| (Ctrl +) F3 | toggles Videoscope On / Off (in all displays) | | Ctrl + N | toggles Sample Navigation On / Off |
| Shift + F3 | starts Home Stage procedure | | (Ctrl +) Shift + N | starts to mill (previous) next pattern line |
| (Ctrl +) F4 | starts / stops electron (ion) imaging Snapshot from active display | | Ctrl + O *letter* | opens Preferences dialog |
| Shift + F4 | starts / stops Lens Alignment procedure | | Ctrl + P | opens Print dialog |
| F5 | toggles Single / Quad Image mode | | Shift + P | proceeds with next pattern |
| Ctrl + F5 | toggles Large Image Window mode | | Ctrl + R | restarts scan |
| Shift + F5 | toggles Center Cross display | | Ctrl + (Shift +) S | saves image (from all displays) |
| F6 | pauses / releases scanning | | Ctrl + T | toggles Electron and Ion beams imaging for active display |
| Shift + F6 | toggles Alignment rectangle display | | Ctrl + Y | redo last operation |
| F7 | toggles Reduced On / Off | | Ctrl + Z | undo last operation |
| Ctrl + F7 | starts Image Post Processing | | Ctrl + Shift + Z | starts Take Nav-Cam Photo procedure |
| F8 | starts Degauss procedure | | (Ctrl +) Pause *keyboard key* | starts / stops (/ resets) patterning |
| (Shift +) F9 | starts Auto Contrast and Brightness procedure (in all live displays) | | Ctrl + (Shift +) , | sets one step slower (slowest) scanning |
| F11 | starts Auto Focus procedure | | Ctrl + (Shift +) . | sets one step faster (fastest) scanning |
| Ctrl + F11 | starts Auto Stigmator correction procedure | | Ctrl + (Shift+) Tab | activates displays stepwise (backward) |
| Shift + F11 | toggles Display Saturation function | | Ctrl + Page Up / Down | switches within Control pages stepwise |
| (Shift +) F12 | toggles Compucentric (Scan) Rotation tool | | Ctrl + 1 / 2 / 3 ... *letter keyboard* | selects the particular page (the number corresponds to the page icon sequence) |
| Ctrl + 0 *number* | moves stage to X=0, Y=0 – Center Position procedure | | (Ctrl +) + / – *keypad* | increases / decreases the magnification 2× (Digital Zoom) |
| Ctrl + Shift + A | starts / stops alternating of electron and ion imaging | | * *keypad* | rounds off the magnification / HFW to a nearest round value |
| Ctrl + B | toggles Beam Blank function | | Ctrl (+ Alt) + arrow | moves the digital zoom area (the pattern) by one screen pixel in the respective direction |

### User Guidance

The window containing instructions for electron column Use cases, Cross section preparation, High resolution imaging and TEM sample preparation.

**FIGURE 3-12** *User Guidance*
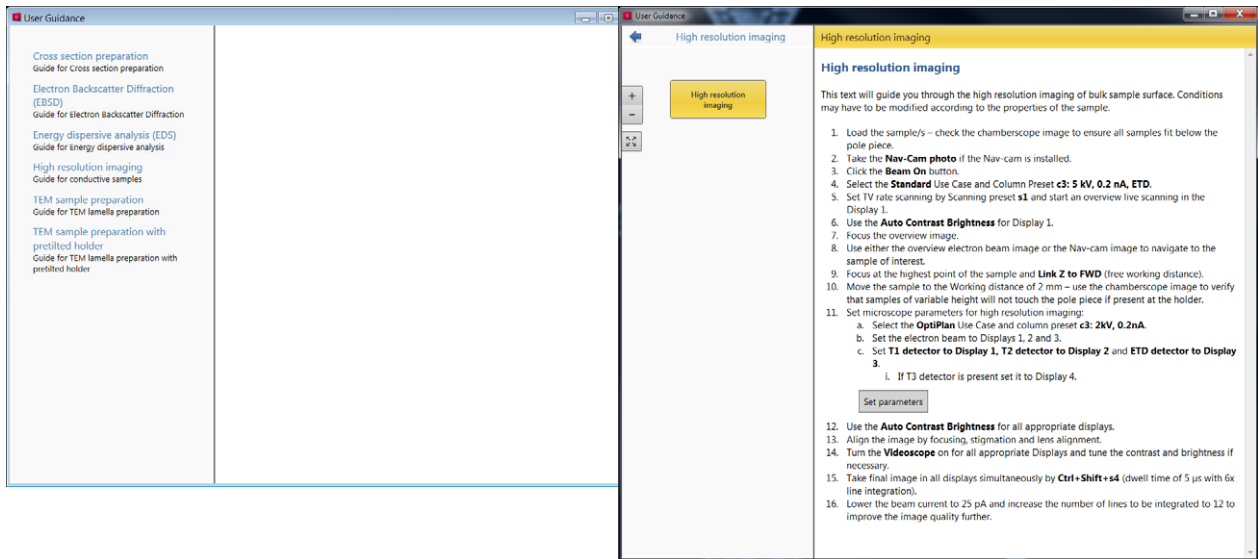


### About Microscope Control

The window containing information about the product version is shown. It automatically disappears after the first click on anywhere.

# Toolbar

The toolbar is shown below the Menu bar is made up of functional graphical elements (icons, adjusters etc.) linked to the most frequently used system controls.
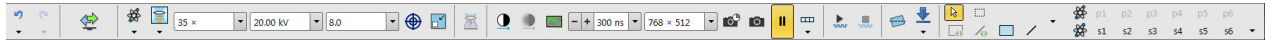


Rest the cursor over the icon for two seconds without clicking on it to see its explanatory tool-tip. Right-clicking on some toolbar icons calls up a context menu with other functionality choices, for instance a user can move directly to the *Preferences* setting (by clicking on the *Edit* item) or to change a mode of value depiction.

Whenever a function is selected the corresponding icon is highlighted (orange background) to indicate the function is active.

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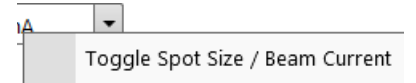


### Undo / Redo

The undo / redo buttons assist to return / re-run the last actions. Actions used in history are accessible by clicking the down arrow and they can be re-used separately or any continuous sequence of actions can be selected and re-used as a group.

*Note*
*Some particular actions (alignments etc.) cannot be returned and sometimes the system clears the history.*

### Sample Exchange

The window containing complete instructions for sample exchange and information about the system vacuum status. In addition it is possible to set various working environment and start-up actions (see Chapter 5):

- Working folder for images storing with subfolders for each display
- Setting *Sample cleaning* when pumping the chamber down
- Selecting Vacuum modes (*High Vacuum / Low Vacuum*) and associated parameters
- *Take Nav-Cam Photo* automatically
- Starting the sample chamber *Purge* process
- Stage *Holder* selecting
- Set System to *Wake Up* and to *Sleep* states
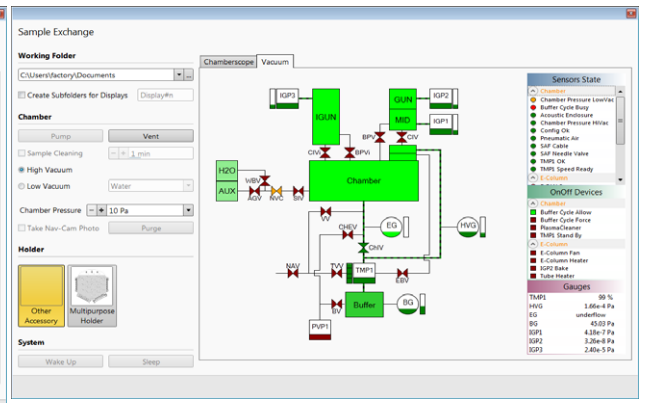
### Electron Beam / Ion Beam / Camera / Nav-Cam

Selecting an item from the drop down list makes the display or single screen active to the *Electron Beam / Ion Beam / Camera / Nav-Cam* with respect to the source, column, scanning, and detector settings. Only one is active at any time, but can be operated independently for each display.

Another possibility to change the beam for the particular imaging is clicking on the image databar beam icon.
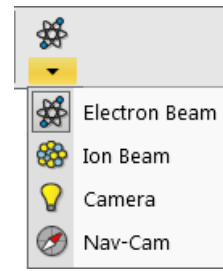
### Column Use Cases

The electron column can be operated in different column Use Cases optimized for specific applications. Selection of a desired Use case can be made by the *toolbar* drop down list and also within the Use Case module (see further).
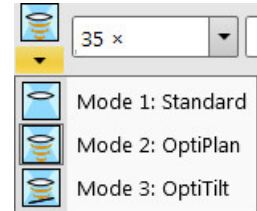
### Magnification (HFW) / High Voltage / Spot Size (Beam current) List Boxes

Click on the list box to expand a list of pre-set and actually allowed values. Choose one by clicking on it and it is applied immediately (see the *Preferences / Presets* section).

- The *Spot* is defined as the actual electron beam diameter on the specimen surface and it is expressed by a relative number. The optional way (representable in the toolbar) to the Spot size number is the electron *Beam Current* value (see the *Preferences / General* section). Both physical quantities are related. The electron beam current shown in the toolbar list box (and optionally in the image databar) is approximate and valid only if the microscope is well aligned.
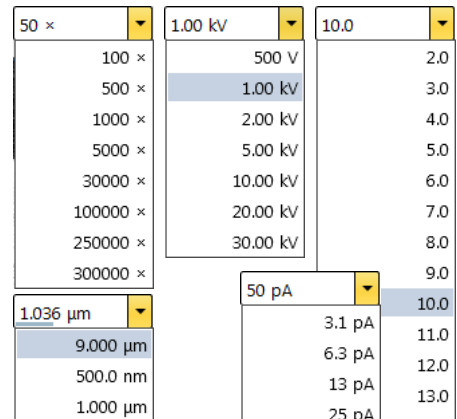
### Imaging Pixel Resolution List Box

This list contains available imaging pixel resolutions (also used for captured images). Selecting a new resolution results in the immediate change of the scanning raster and since the present dwell time remains unchanged, the actual scanning frequency (both Line and Frame time) changes.
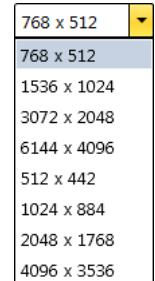
### Patterns / Measurements / Annotations



There are 2 pointers (from top left): normal cursor (white arrow) and selection cursor (grey rectangle – all objects included within its area are selected). Other icons represent 4 shapes last time used.

Clicking the down arrow enables to reveal more ones and enables to quickly access the *Patterns / Measurements / Annotations* tool. Clicking on the icon activates (orange background) / deactivates (grey background) the appropriate functionality.

To deactivate the drawing mode at any time it is possible to press the Esc key (keyboard).

The numerical values of linear distances, diameters, angles, or areas of the image are updated while drawing and shown alongside or within the finished measured item. The Measurement tool dimensions scales with the image; when changing magnification, the shown tools change their size accordingly. On the contrary, the Annotation shapes and texts have their sizes fixed relatively to the display.

The *Measurements / Intensity profile* delineates the imaging profile across a freely drawn line.
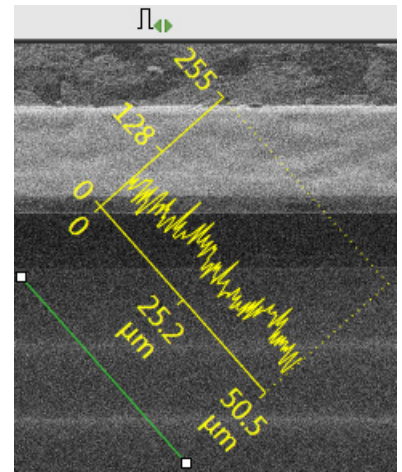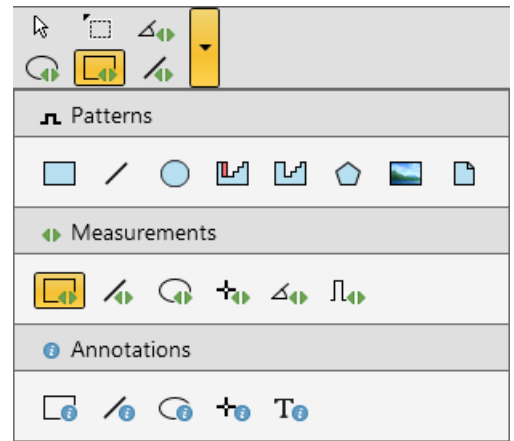


### Pattern presets

By default there are 6 empty toolbar *Pattern presets* (labelled *p#)* for each (electron / ion) beam. Any one can be assigned to an individual .ptf file with all patterning parameters exported via the *File* menu / *Export* / *Patterns* item. Clicking on any one loads parameters from this file and corresponding patterns are drawn in the active display. To start patterning under loaded conditions follow the patterning process.



The toolbar Pattern Presets assignment to the particular .ptf file can be saved or loaded by the *File* menu / *Export* or *Import / System Parameters* item.

---
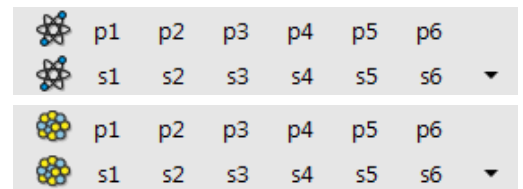
## Scanning presets

By default there are 6 factory toolbar *Scanning presets* (labelled *s#)* for each (electron / ion) beam. Clicking on any one starts image acquiring with corresponding parameters.

Right-clicking on any Scanning preset button calls up the context menu:
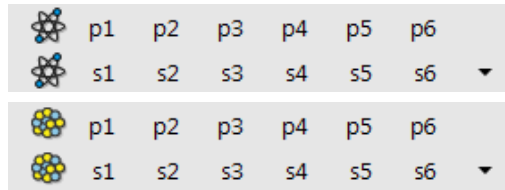
| | p1 | p2 | p3 | p4 | p5 | p6 |
|---|---|---|---|---|---|---|
| | s1 | s2 | s3 | s4 | s5 | s6 |
| | p1 | p2 | p3 | p4 | p5 | p6 |
| | s1 | s2 | s3 | s4 | s5 | s6 |

| Activate | Click |
|---|---|
| Multiple Activate | Shift + Click |
| Snapshot | Ctrl + Click |
| Multiple Snapshot | Ctrl + Shift + Click |
| ☆ Update with Current Settings | |
| Edit... | |
| Import Scanning Presets... | |
| Export Scanning Presets... | |
| Reset to Default | |

**Scanning presets** ×

**Basic Setup**

| Name | LiSlowScan_001 |
|---|---|
| Resolution | 768 × 512 |
| Dwell Time | 300 ns |
| Bit Depth | 8 bit |

**Filter Setup**

| Scan Interlace | 1 |
|---|---|
| Line Integration | 1 |
| Frame Average | 8 |
| Frame Time | 121 ms |

**Image Acquisition**

| Integrate | 1 |
|---|---|
| Drift Correction | No |
| Continuous Scan | No |
| Action | Save As |
| Acquisition Time | 968 ms |

**Shared Settings**

| Mains Lock | No |
|---|---|
| Start scan on left click | Yes |

Close

- Clicking on the *Activate* item highlights the button (orange background) and starts image acquiring or just activates the preset according to the *Scanning presets* property editor / *Shared Settings* section / *Start scan on left click* item setting (Yes / No). The *Multiple Activate* item has the same functionality in all compatible displays (same beam).

  To start image acquiring is possible also using the *Scan* menu / *Active Preset Snapshot* (Ctrl + F2) item.

- Clicking on the *Snapshot / Multiple Snapshot* item starts snapshot acquiring from selected / all compatible displays.

- Clicking on the *Update with Current Settings* item updates selected Scanning preset with actual scanning settings.

- Clicking on the *Edit* item opens selected Scanning preset property editor. It is also possible to use the toolbar dpwn (expand) / up (hide) arrow with the same effect.

- It is possible to *Import / Export Scanning Presets* from / to a file (.scp).

- Clicking on the *Reset to Default* item brings all settings to the factory presets.

A tooltip is shown when leaving mouse cursor over any preset button giving parameters overview. Parameters color indicates:

- Green: actual microscope setting matches the column preset

- Brown: actual microscope setting differs from the column preset

- Grey: Value is not relevant when respective component is switched off

LiSlowScan_002
**Basic Setup**
 Resolution: 1536 × 1024
 Dwell Time: 100 ns
 Bit Depth: 8 bit
**Filter Setup**
 Scan Interlacing: 1
 Line Integration: 100
 Frame Average: 1
 Frame Time: 00:00:16
**Image Acquisition**
 Integrate: 1
 Drift Correction: Yes
 Continuous Scan: No
 Action: Save As
 Acquisition Time: 00:00:16
**Shared Settings**
 Mains Lock: No
 Automatic Start: Yes

## Imaging Area

The Microscope Control software (UI) uses 4 independent displays for imaging samples. Each display can contain imaging from any detector (including External and CCD), paused imaging or images loaded from a file. Additionally, display 3 can show a mix of imaging from displays 1 and 2, and display 4 can show a mix of imaging from display 1, 2 and 3.

There are shown either 4 displays at the same time – *Quad Image* mode or one display over the UI imaging area – *Single Image* mode.

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

At any time, just one display is selected (has focus), and all functions (related to it – Pause, Sample Navigation, image processing) applies only to imaging in this display. The selected display is marked by the highlighted (blue) Databar and optionally also by the blue frame (see *Preferences / General*).

Depending on the display 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), Contrast & Brightness, lens alignment, Scan / Compucentric Rotation, XY-move (get or track mode)

- *Ion imaging* (incl. External and Mix): focus, astigmatism correction, Beam Shift, magnification change (coarse, fine), zoom (in / out), Contrast & Brightness, Scan / Compucentric Rotation, XY-move (get or track mode)

- *Optical imaging*: 7 mm Marker placement, Compucentric Rotation, Z-move (track), Tilt

    The optical imaging is automatically activated (if it is paused), when the venting procedure starts. When it is paused and any stage movement takes place, the pause icon turns red and a list of changed axes is shown.
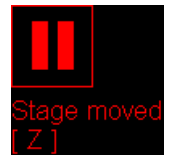


*Note*
*Due to hardware limitations, some detectors cannot be used simultaneously. They can still be selected for different displays at the same time, but if one of them is started, the other imaging with incompatible detectors are automatically paused.*

### Image Databar

Optional instrument, imaging and labelling information are shown at the base of all displays. The configuration and available items differ for the beam selected (Electron / Ion / Optical / Nav-Cam) for the selected display.

**FIGURE 3-13** *The Databar Examples*



Selected electron display

Not selected electron display

Not selected optical display

Selected Patterning display

Not selected Patterning display

Selected Nav-Cam display (option)

*Note*
*The Databar information is always related to the actual imaging. If the imaging is paused or an image is loaded from a file, they can differ from the actual system conditions.*

Clicking on some of the image databar fields induces an active menu related to it with appropriate choices.

Clicking on the label field induces the label editing menu.

Double-clicking on the micron bar induces the Image properties window – multiple parameters at which an image was captured. Same functionality is caused by pressing the Shift + F1 keys.

To set information included in the databar right-click on any display databar and click on & drag desired *Available Item* to the *Visible Items* field. Items can be placed in any order (by dragging the item up / down within the list) and expand or contract automatically to fit the display width as long as there is enough room, which influences all displays with the same beam.
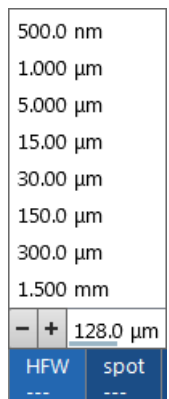
**FIGURE 3-14** *Databar configuration / Image properties*
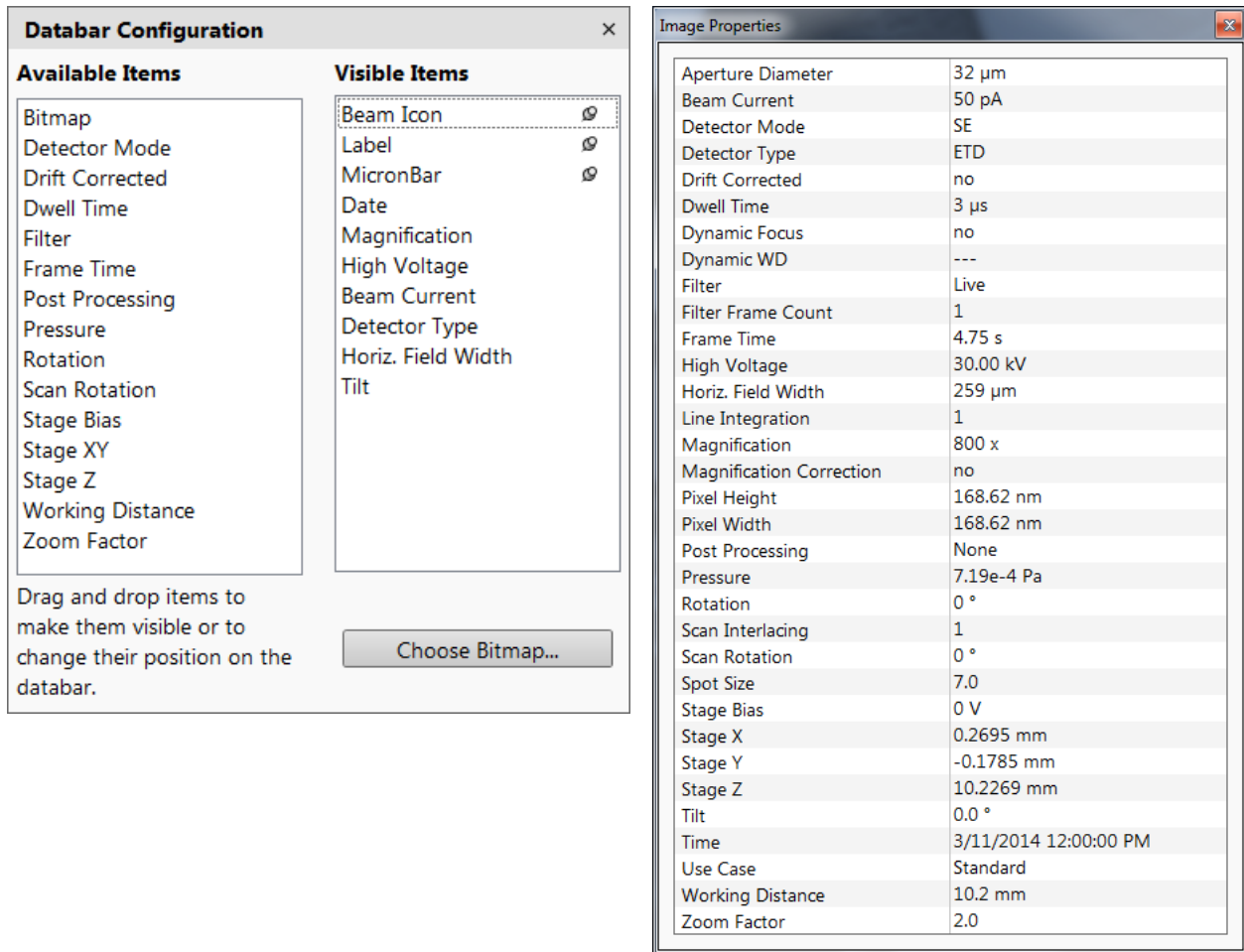


To label databar, double-click on the Label field and fill in the dialog. It can be set independently for each display.

The *Micronbar* area scales to the magnification.

Clicking on the *Choose Bitmap* item opens a dialog to select a bitmap to be loaded into the databar (if the *Bitmap* item is ticked).
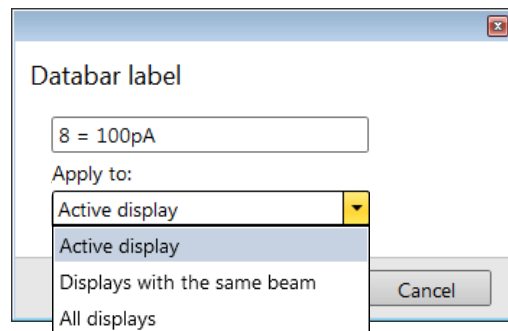
## Status Bar

The Status bar can be found at the base of the UI screen and it contains several user selectable items and information about running system processes (patterning for instance).

**FIGURE 3-15** *Status Bar (divided to left / right part)*

| Chamber Pressure : 6.43e-4 Pa | Ion Beam Current : 0.02 pA | Specimen Current : 0 pA | Emission Current : 103.73 µA 2.19 µA | Electron Source Pressure : 2.66e-8 Pa |

| Pattern 1 | 1 ⊗ | 3:33 PM |
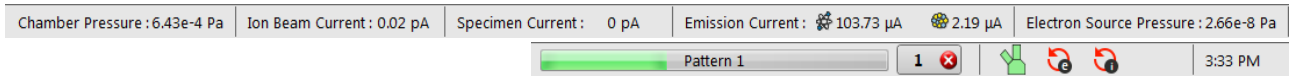
Right-click on the Status bar and check items to be shown:

- *Chamber Pressure* – the specimen chamber pressure
- *Ion Beam Current* – correct ion beam current value in case the beam is blanked
  When it reverts into operation (unblanked), the value has no point.
- *Specimen Current* – the electron current reaching the specimen
- *Emission Current* – the electron / ion current leaving the source
- *Electron Source Pressure* – pressure in the corresponding vacuum system section
- *Clock* – can be shown at the bottom right window corner
- *Messages* – Application Status incoming notice can be shown

| ✓ | Chamber Pressure |
| ✓ | Ion Beam Current |
| ✓ | Specimen Current |
| ✓ | Emission Current |
| ✓ | Electron Source Pressure |
| ✓ | Clock |
| ✓ | Messages |
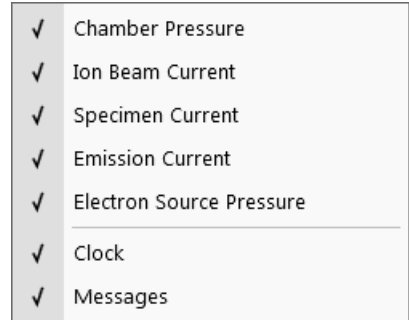
The system conditions are shown by means of the icons:

**Table 3-1** *Status Icons*

| Icon | Status |
|------|--------|
| | Source space Vacuum / Chamber Vented |
| | Source space Vacuum / Chamber Pumping or Venting |
| | Source space Vacuum / Chamber Vacuum (ready for the microscope operation) |
| | Stage axes – Lock (any one) |
| | Dynamic Focus is On (Electron) |
| | Tilt Correction is On (Electron and/or Ion) |
| | Scan Rotation is not zero |
| | External scanning mode is On |

When you hover the mouse over any icon, a corresponding tooltip appears with actual status for the parameter(s) or just an information.

E Source: 4.54E-7 Pa
E Middle: 1.22E-6 Pa
I Source: 1.65E-5 Pa
Chamber: 10 Pa

Locked stage axes: Y

Dynamic Focus: 0.1°

Electron Scan Rotation: 11.5°

External scanning
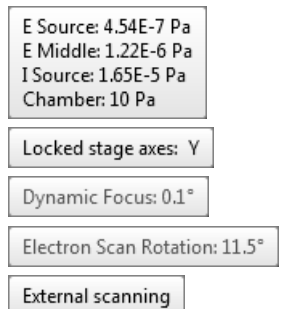
# Control Pages and Modules

The software controls on the right side of the screen are organized into *Control pages*, which are divided into *Modules* holding specific functions. The required page can be selected either by clicking on the corresponding icon button or with the use of short-cuts (see further). The Control pages and modules available for the system are:

- *Beam Control* page
  1. Vacuum, 2. System, 3. Column, 4. Magnification, 5. Beam, 6. Beam Deceleration, 7. Scan Rotation, 8. Detectors

- *Navigation* page
  9. Stage, 10. Stage Z, 11. Tilt Correction

- *Detectors* page
  12. Detector Settings, 8. Detectors, 13. Digital Zoom, 14. Enhanced Image (LUT / Mix 3 / Mix 4 / Color / Process)

- *Patterning* page
  15. Patterning Control, 16. Properties, 17. Selective Mill, 18. Gas Injection,
  19. Advanced Patterning (iSPI / Monitor / Drift Suppression)

- *Direct Adjustments* page
  20. Direct Adjustments (Beam / Stigmator Centering / Focus), 8. Detectors

- *Sample Preparation* page
  15. Patterning Control (reduced), 16. Properties, 17. Selective Mill, 18. Gas Injection, 9. Stage (reduced)

- *Column Presets* page
  21. Use Case, 22. Column Presets, 8. Detectors

- *Microscope Alignments* page
  23. Alignments (Instructions / Individual steps)

*Note*

*The number in front of the module name represents an order in which the modules are introduced in the following text.*

*Some of the module controls are beam dependent. In this case, an active beam type is indicated by the corresponding icon at the right-hand side of the module.*

## 1. Vacuum Module

The module is used to control the pressure in the specimen chamber. Clicking on the *Pump* button starts the pump-down procedure for the specimen chamber and the column. The system allows to switch the accelerating voltage on only when the chamber is sufficiently evacuated. Clicking on the *Vent* button starts chamber venting for a sample or detector exchange after a user confirmation.

Ticking the *Sample Cleaning* check box pumps the system, makes the Sample Cleaning procedure (duration can be set) and keeps column pumped.

The Mode radio buttons bring the system to:

- the *High Vacuum* mode, which is the conventional operating mode (associated with all scanning electron microscopes), used for observing conductive specimens that can withstand low pressure conditions and do not release gas.

  In this mode the system pumps continuously to achieve the lowest possible pressure.

- the *Low Vacuum* mode for observing not coated and not conductive or partially conductive specimens.

  In this mode, the chamber pressure is controlled using the *Chamber Pressure* adjuster, while the column is at a much lower pressure. The gas environment can be selected from the list box.

The system automatically switches to one of the modes when the chamber is Vented and a dedicated detector is installed. If no dedicated detector is installed, user is asked to determine a detector mounted by *PLA accessories* dialog (see chapter 2).

## 2. System Module

Here is the possibility to carry out several operations in one click on:

***Wake Up Button***

- starts the Ion source
- starts the Electron source (if it is switched off)
- switches the electron and ion beam accelerating voltage on

***Sleep Button***

- switches the electron and ion beam accelerating voltage off
- stops the ion source

## 3. Column Module

contains controls for setting the electron / ion beam conditions:

***Beam On Button***

switches the accelerating voltage on (orange background) / off (grey button). If the source is not started (empty progress bar), this button starts the electron / ion source first (green progress bar).
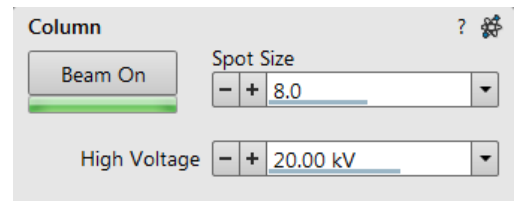
*Note*
*The ion source start procedure need not be successful at the first attempt. If this happens, try it again.*

***Beam Current / Spot size Adjuster***

enables to adjust an electron *Beam current / Spot size* with a selectable accuracy (see the *Preferences / General* section). The actual value (from the factory preset list) is shown in the adjuster text area, toolbar and imaging databar (if selected). Only values applicable for actual imaging conditions are shown.

*Note*
*The Spot size influences both the focused electron beam area and the beam current. The lower is the Spot size, the lower is the beam current.*

For the ion beam there is only possible to use the Beam current.

***High Voltage Adjuster***

enables to adjust the overall electron / ion beam accelerating voltage (from 350 V / 500 V to 30 kV) either continuously or using the pre-set values (see the *Preferences / Presets* section). The actual High Voltage value is shown in the adjuster text area, toolbar and imaging databar (if selected).

## 4. Magnification Module

The adjuster offers a variety of ways to control the imaging magnification. The magnification range changes dynamically according to the working distance and can also be controlled with the use of other tools.

***Magnification Control***

The *Couple Magnification* check box ensures the same magnification for electron and ion beams. If it is not accessible, the magnification cannot be coupled for various reasons, including different limit values for the two beams.

- Clicking on the *right / left arrow* increases / decreases magnification by *5%*.
- Clicking on the left / right between the *arrow* and the *button* increases / decreases magnification by *20%*.
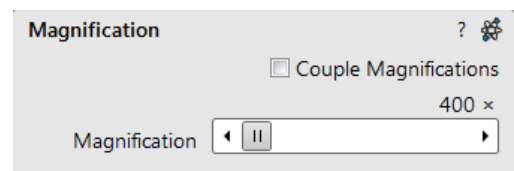
## 5. Beam Module

### Stigmator 2D Control

enables to correct image astigmatism. The crosshair indicator indicates the actual setting.

Shift + Right-clicking on an imaging display triggers the astigmatism correction. Unlike the 2D box control, this is magnification sensitive and therefore it suits for fine corrections at high magnifications, or employ the Adaptive Sensitivity functionality.

### Beam Shift 2D Control

indicates and controls the beam shift with respect to the objective lens axis. It is useful for fine imaging shifts without stage movement.

Shift + Clicking on an imaging display triggers the Beam Shift function. The standard mouse cursor changes to the "hand" cursor and the imaging is dragged over the screen. Because of a limited Beam Shift range, this works well only for high magnifications, or employ the Adaptive Sensitivity functionality.

*Note*
*Right-clicking on the 2D box opens a context menu with the following particular choices (more see above):*

- The *Reset* sets the Beam Shift value to zero and moves the stage to compensate the resulting imaging shift (same as the *Stage* menu / *Beam Shift Reset* function).
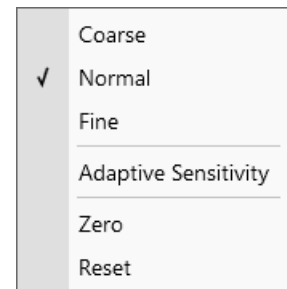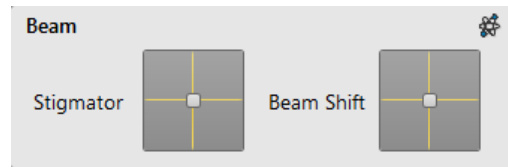
## 6. Beam Deceleration Module

In the Beam Deceleration mode a potential (Stage Bias) is applied on the stage, which influences both primary and detected electrons. The Stage Bias ranges from +50 V to -50 V, optionally to -4 000 V.
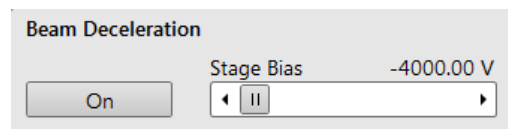
## 7. Scan Rotation Module

controls and shows the Scan Rotation value.
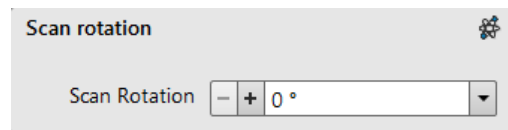
## 8. Detectors Module

contains adjusters to control the active detector *Contrast* (electronic gain) and *Brightness* (voltage offset). The values are remembered for each detector. The adjusters are disabled if the detector is not available or cannot be controlled (e.g. CCD camera or an External detector).

### Contrast / Brightness / Enhance Adjusters

Regardless of the detector actual gain range, the Contrast & Brightness range is always 0–100% and the small / large step size is 0.1 / 1 (the Brightness step size may differ for some detectors in order to achieve a sufficient sensitivity). A direct value can be entered by double-clicking on the Contrast / Brightness value.

The Ctrl + clicking on & left-right / up-down dragging within an electron or ion beam display controls the Contrast / brightness.

The Low Vacuum detectors could have the Detectors module with specific controls.
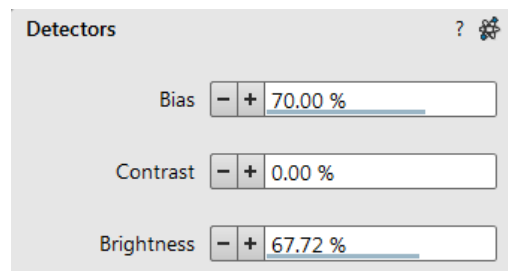
**9. Stage Module**

consists of elements enabling to:

- show numerical values of a particular position
- show the stage positions location in a visual map form and as a list for selection
- navigate across the sample surface

*Note*
*The stage movement can be aborted by pressing the keyboard Esc key. Don't hesitate to do so if you are not sure that the initiated movement is safe!*

**Stage**     ?

| Actual ▼ | | Go To |

☐ X    16.1984 mm    ⊣
☐ Y    -26.5298 mm    ⊣
☐ Z +⇩ 7.0003 mm    ⊣
☐ T    0.0 °    ▼    ⊣
☐ R    -91.3 °    ⊣

☐ Compucentric Rotation   ☐ Z-Y Link

| Last Position | Add |
| Position 1 | Update |
| Position 2 | Remove |
| jzel_tinballs | |
| Position 3 | Remove All |

ICE   DOOR   ETD   1x

**10. Stage Z Module**

This module enables to slowly move the stage in the Z-axis direction. The more the slider is pushed to the each side, the faster is the stage motion. Clicking on the slider bar moves the stage by a small step.

**Stage Z**

Down            Up

**11. Tilt Correction Module**

This module enables to correct the imaging distortion for the electron and/or ion beams when tilting the stage.

**Tilt Correction**

☐ Dynamic Focus   ☐ Tilt Correction

Tilt Angle | Automatic   ▼

       0.0 °
Manual

       0 °
Specimen Pre-tilt

**Tilt Correction**   ?

☐ Tilt Correction

Tilt Angle | Automatic   ▼

       0.0 °
Manual       /

       0 °
Specimen Pre-tilt      /

## 12. Detector Settings Module 👁

enables to choose the selected imaging detector and adjust its parameters.

The *Detector* list box contains list of detectors actually available for the selected display (the same as enabled items in the Detectors menu). The detector actually used in the selected display is always shown.

The rest of the module dynamically changes according to the selected detector and its parameters, which may change from display to display.
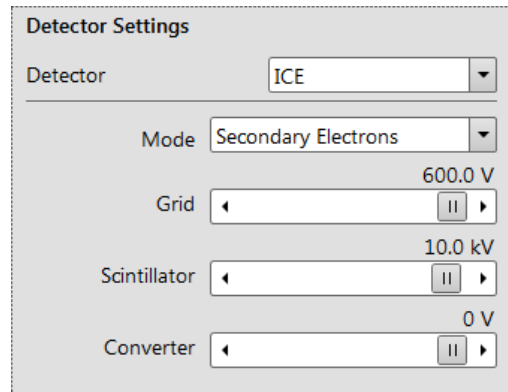
## 13. Digital Zoom Module 👁

The procedure takes place in the computer memory only and helps to navigate across the enlarged view. Click on the *+ / -* button to enlarge / reduce the view in a selected display or select a zoom factor from the drop-down list. Click on the *Undo* button at the top right side of the module (visible only when applicable) to switch between a digital magnification last used and a normal view.

Click on & drag the green bordered area inside the Digital Zoom image or move it by Ctrl + keyboard arrows to change an observed area in the selected display. Change the observed area by dragging the green borders. Press the *Ctrl + + / -* keyboard button to enlarge / reduce imaging in the selected display. When the digital zoom is applied, the magnifying glass icon appears in the appropriate display.
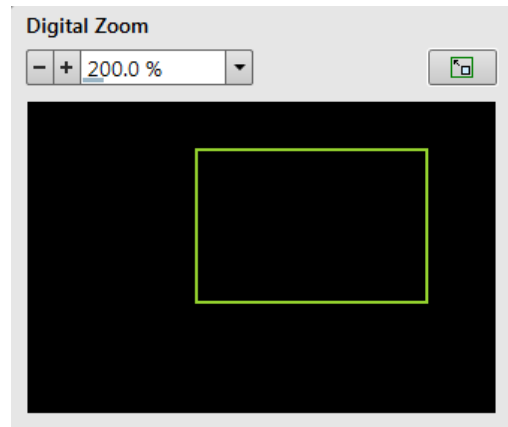
## 14. Enhanced Image tab Modules 👁

consists of tabbed sections offering various digital image enhancements, (in contrary to the *Detector* module / *Contrast* and *Brightness* functionality). These enhancements are applied only to the active display independently of any other. In case a user changes the default settings of *LUT / Color / Process* tab, its background changes to orange. The digital processing can be applied to any live, paused or loaded image, including an optical one.

**FIGURE 3-16** *Enhanced Image Module*
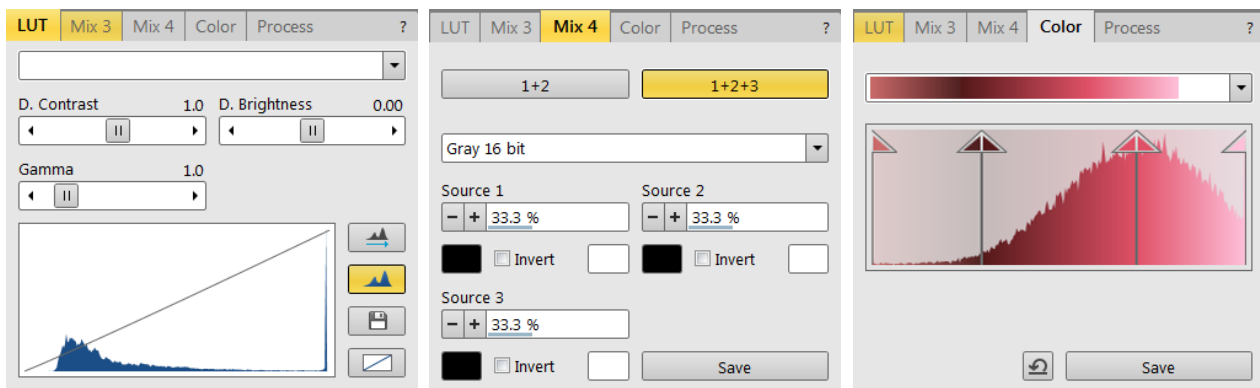
### 15. Patterning Control Module

A pattern type can be selected and handled by using the icon buttons at the top of the module. It can be drawn in the selected display and then it is shown in the pattern list with a number. The pattern properties can be changed via *Property* module. The *Progress* indicator shows the *Overall / Current* (pattern) *Progress* (over time) of the active patterning.

**Patterning Control**

1 - Rectangle 1

Total Time: 6:33
Overall Progress
Current Progress
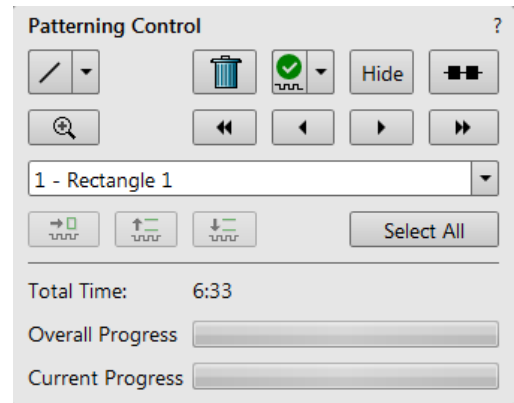
### 16. Properties tab Module

Some features (Measurements, Annotations, Patterns) require an individual set of parameters which are editable within this module by clicking on the edit field or the down arrow to select a value.

**Properties** | **Selective Mill**

| Visual Style | |
| --- | --- |
| Color | LimeGreen |
| Dash Style | Solid |
| Rotation Angle | 0 ° |
| Stroke Thickness | 1 |
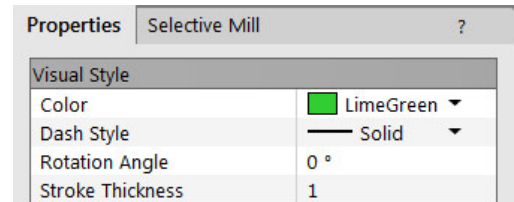
### 17. Selective Mill tab Module

It is possible to mill only selective grey levels of the imaging (see Chapter 5).

Properties | **Selective Mill**
Pattern 1

☑ Enabled      Scan

Interval  − +  2.0 s
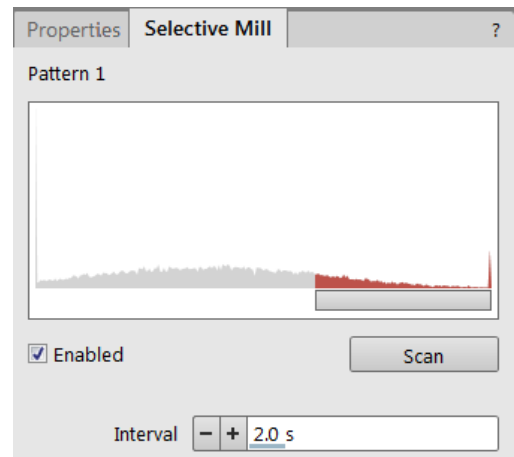
### 18. Gas Injection Module

Some applications require a special gaseous environment, which is provided directly to the required area by the GIS's (Gas Injection System) installed on your system.

**Gas Injection**

| Gas | Insert | Heat | Flow |
| --- | --- | --- | --- |
| ○ C dep | ☐ | Warm | Closed |
| ● Pt dep | ☐ | Warm | Closed |
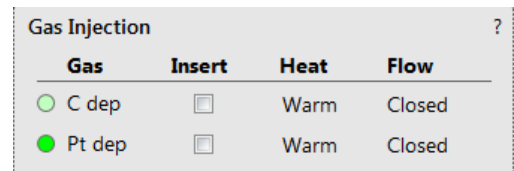
## 19. Advanced Patterning tab Modules

In this section it is possible to monitor a milling process in detail and to grab inspection images during the progress.

- *iSPI* tab module – it is possible to start and set the iSPI mode, in which the ion beam is paused during electron imaging to minimize the interferences.
- *Monitor* tab module – illustrates the milling progress as a colored graphical display, showing the accuracy for depth or material changes over the whole milled area.
- *Drift Suppression* tab module – enables to start a special electron beam mode used for ion beam imaging of non-conductive samples.

**FIGURE 3-17** *Advanced Patterning Module*



## 20. Direct Adjustments Module

This control page serves for fine-tuning of the beam geometry to achieve the best focus and brightness (see Chapter 5).

**FIGURE 3-18** *Direct Adjustments Module*
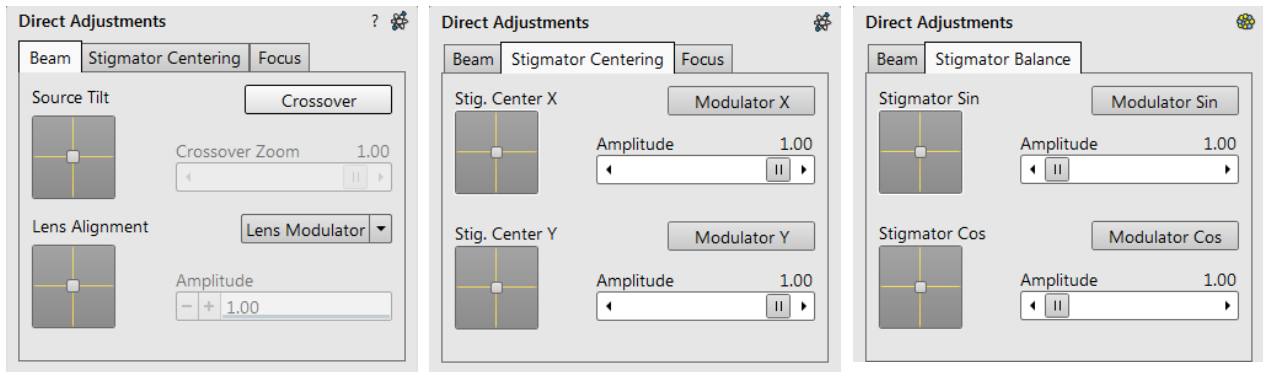


## 21. Use Case Module

Use the drop down list box to select desired Use case for specific application (see Chapter 5).

*Note*

*In addition to restoring factory Column presets, this function also sets some other microscope parameters.*
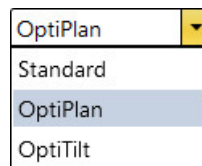
## 22. Column Presets Module

Column presets, in combination with Use cases (see above), simplifies microscope operation to users. Microscope software comes with pre-defined sets of various column parameters for the actual beam and Use case represented by the Column Presets buttons labelled c#. A user can change these settings to easily choose the operating conditions according to his needs.

The column preset is applied with a click, a progress dialog is shown. The button becomes highlighted (orange background) when all actual microscope settings match the preset parameters. The bold labeled button indicates the last applied column preset. Note the behavior that is not obvious:

- Beam is not switched on automatically when a column preset is applied.
- It can happen that a column preset cannot be completely applied because it is not possible to set some parameter (particular detector not available, stage bias value out of the range). In such a case an application status error message is shown.
- Tooltip dialog / *Detector settings* line contains information in format <detector>, <detector mode>. Particular settings of a detector custom mode is not supported in column presets
- *Mix* detector cannot be used for a column preset.

Right-clicking on any preset button calls up the context menu:

| | |
|---|---|
| √ | Edit |
| ☆ | Update with Current Settings |
| | Rename... |
| | Import Column Presets... |
| | Export Column Presets... |
| | Reset to Default |

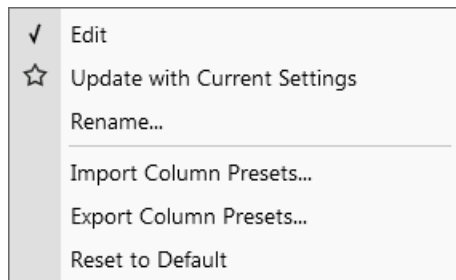- Clicking on the *Edit* item opens selected preset button properties for editing with sections *Column / Beam Deceleration / Detector Settings / Beam Corrections*. It is also possible to use the down / up arrow next to the preset buttons with the same effect.
- Clicking on the *Update with Current Settings* item updates selected preset button with actual settings.
- Clicking on the *Rename* item enables to rename the selected preset button.
- It is possible to *Import / Export Column Presets* from / to a file (.clp).
- *Reset to Default* button – restores the default settings for all column presets (for both beams and all use cases).

A tooltip is shown when leaving mouse cursor over any preset button giving parameters overview divided into 3 areas (*Preset name / Key parameters / Other parameters*). Parameters are colored, which indicates:

- Green – actual microscope setting matches the column preset
- Brown – actual microscope setting differs from the column preset
- Grey – Value is not relevant when respective component is switched off

**Column Presets**

Beam On

c1 · c2 · c3 · c4 · **c5** · c6

**Column**

Spot Size — + 9.0

High Voltage — + 5.00 kV

☑ A-Tube Voltage — + 8.00 kV

**Beam Deceleration**

Stage Bias

On — + -4000.00 V

**Detector Settings**

Detector T2

○ Segment A
○ Segment B
● A + B

**Beam Corrections**

Beam Shift $WD_{REF}$ = 6.999 mm
$WD_{CORR}$ = -1.582 mm

**Rename Column Preset**

Column preset 4

Rename | Cancel

Column preset 2
Key parameters
High voltage: 10.00 kV
Spot size: 9.0
Detector settings: ETD, SE
Beam deceleration: Off
Stage bias: 0 V
A-Tube: Off
A-Tube voltage: 0 V
Other parameters
Beam shift correction: 0 m, 0 m
WD correction: 0 m
Contrast: 50.00 %
Brightness: 50.00 %
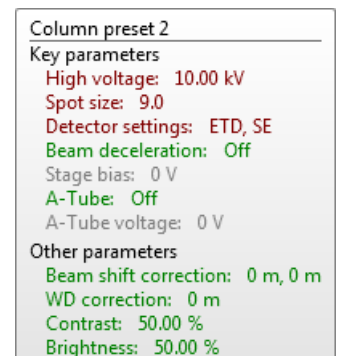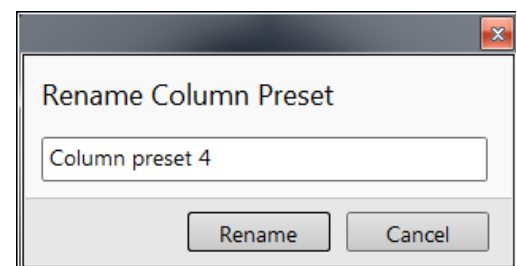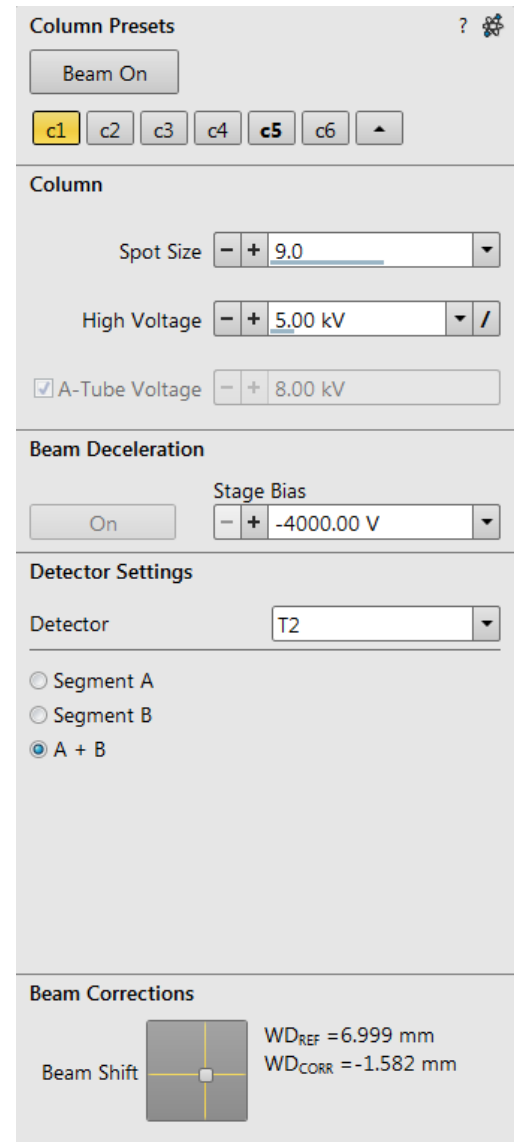
### 23. Alignments Module

contains alignments which enable to optimize the system performance (see Chapter 4).

The list box contains list of Alignment procedures available for the actual user level (user or a FEI authorized service engineer).

### *C a u t i o n !*

*A user must understand the procedures at the appropriate level before proceeding with any adjustment. Improper alignments can make the system difficult to use.*

Note
*Some alignment modules may have some features distributed differently than others, but functionality is the same, if it is not mentioned.*

| Alignments | ? |
| --- | --- |
| **– Electron Beam** | |
| Magnification Correction | |
| E-column: Aperture Selection | |
| E-column: Preventive Maintenance | |
| E-column: Supervisor Alignments | |
| **– Ion Beam** | |
| 100 - ION: Source Control | |
| I-column: Aperture Management | |
| I-column: Manual Beam Alignment | |
| I-column: Alignments | |
| **– Stages** | |
| Stage Alignments | |
| **– Others** | |
| 154 - Water Bottle Venting | |
| External Plasma Cleaning | |
| Pump Buffer | |
| Vacuum Actions | |
| Plasma Cleaning | |
| GIS Alignment | |

# Preferences Dialog

This dialog can be opened by selecting *Preferences (Ctrl + O – letter)* from the pull-down menus: *Scan* and *Tools*. The Preferences dialog consists of sections listed at the left side of the window, the menu from which it is chosen dictates the section opened on entry.

Once the Preferences dialog is opened, any section can be chosen. Clicking on a required one opens it and allows changing and presetting conditions for a group of related functions. 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.

**Movie**

For a detailed description see Chapter 5.

**Alignments**

It is possible to enable visibility of alignments in the *Alignments* page / *Alignments* list by checking the *Visible* check box next to an alignment name.

**FIGURE 3-19** *Alignments Preferences*
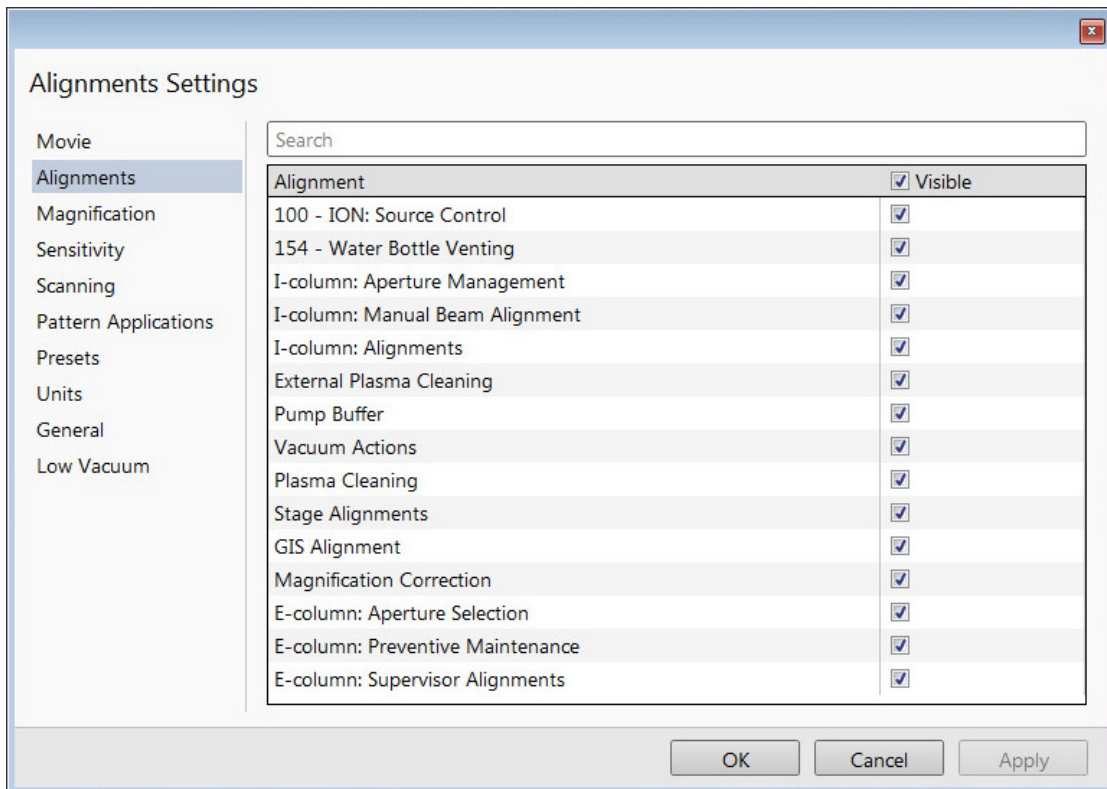
## Magnification

When storing / printing an image (while in a Single / Quad image mode / Large Image Window) the databar magnification representation may not be correct.

**FIGURE 3-20** *Magnification Preferences*
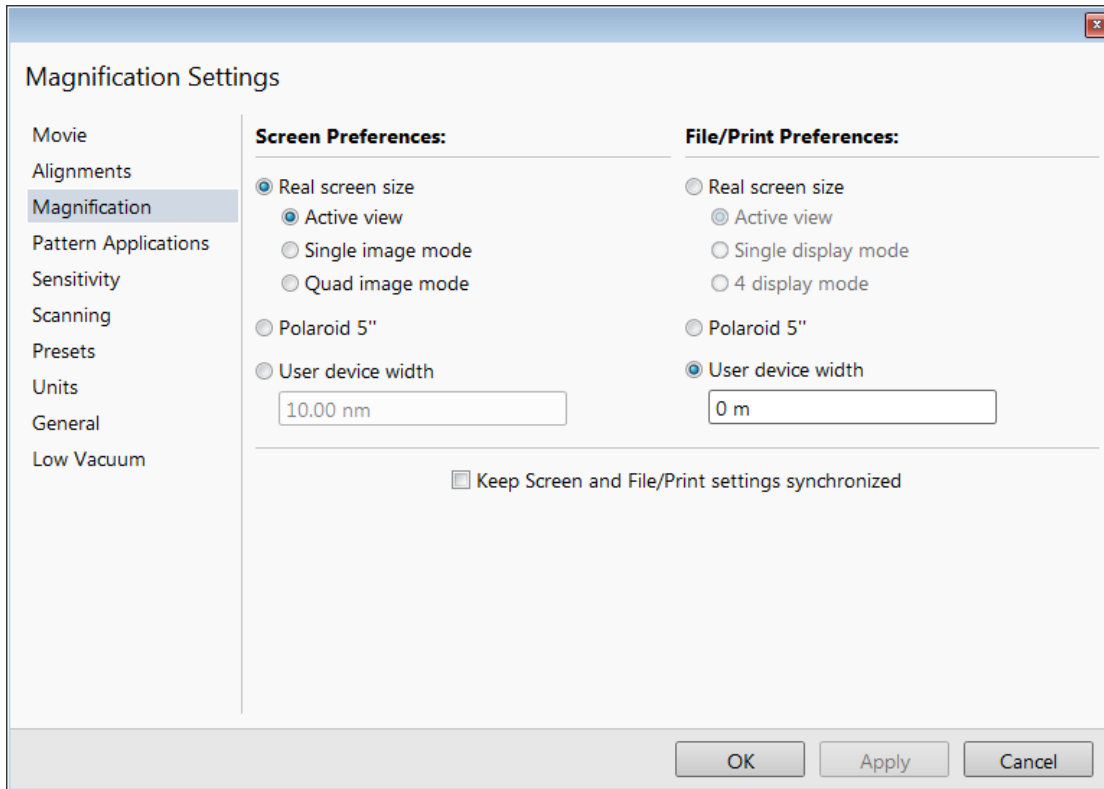


The *Screen preferences* area sets the imaging databar magnification representation behaviour while the *File / Print preferences* area sets the storage / printing databar magnification representation behaviour. Selecting the radio button activates its functionality:

- *Real screen size*: the imaging pixel width is handled.

  – *Active view*: the databar magnification value depends on whether the Single or Quad Image mode is selected. It is shown in the image databar and stored / printed with an icon representing the Single / Quad Image mode.



  – *Single display mode*: Single image mode magnification value is shown in the databar and stored / printed with an image.

  – Quad image / *4 display mode*: Quad image mode magnification value is shown in the databar and stored / printed with an image.

- *Polaroid 5"*: Polaroid film width is handled. A recalculated magnification value is shown in the databar and stored / printed with an image.



- *User device width* (set by a user via the edit box): A recalculated magnification value is shown in the databar and stored / printed with an image.



The *Keep Screen and File / Print settings synchronized* check box keeps both settings identical.

### Pattern Applications

It is possible to enable / disable visibility of pattern applications in the *Patterning* page / *Property* module / *Application* item by checking the check box next to an application name.

**FIGURE 3-21** *Sensitivity Preferences*
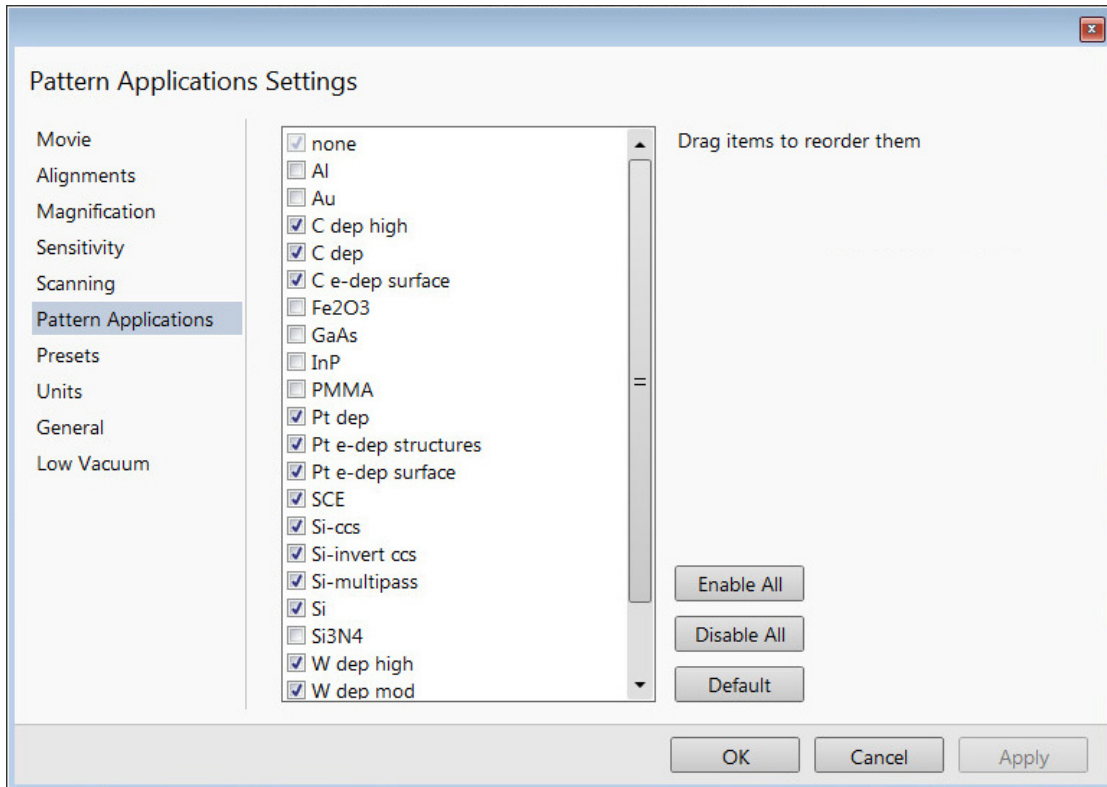


The *Default* button sets the original settings.

## Sensitivity

The preset sliders control the sensitivity of the Manual User Interface (*MUI* – option). The setting differs for the beam (electron / ion) selected for the active display.

**FIGURE 3-22** *Sensitivity Preferences*
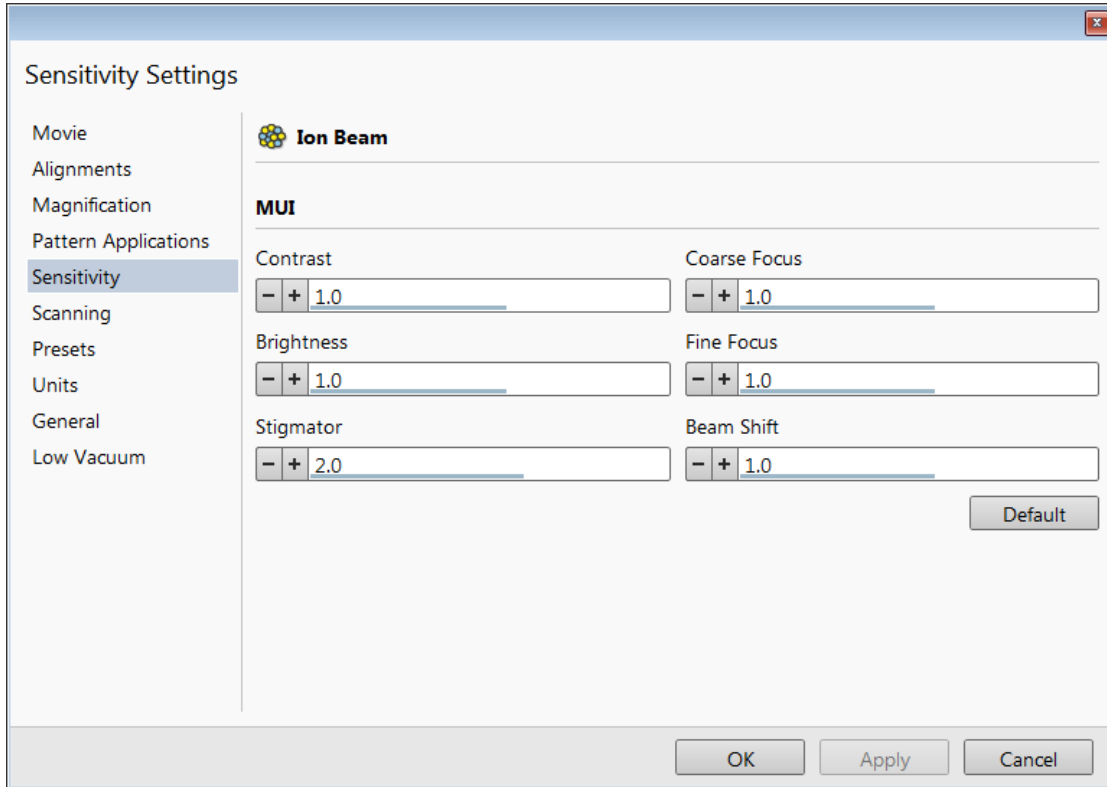


All MUI controls are represented except the Magnification. The *Default* button sets the original settings.

## Scanning

allows a user to change the toolbar dwell-times (scanning speeds) table and to set-up the Slow scan / Fast scan / Snapshot / Photo function. The configuration and available items differ for the beam (electron / ion) selected for the display.

**FIGURE 3-23** *Scanning Preferences*
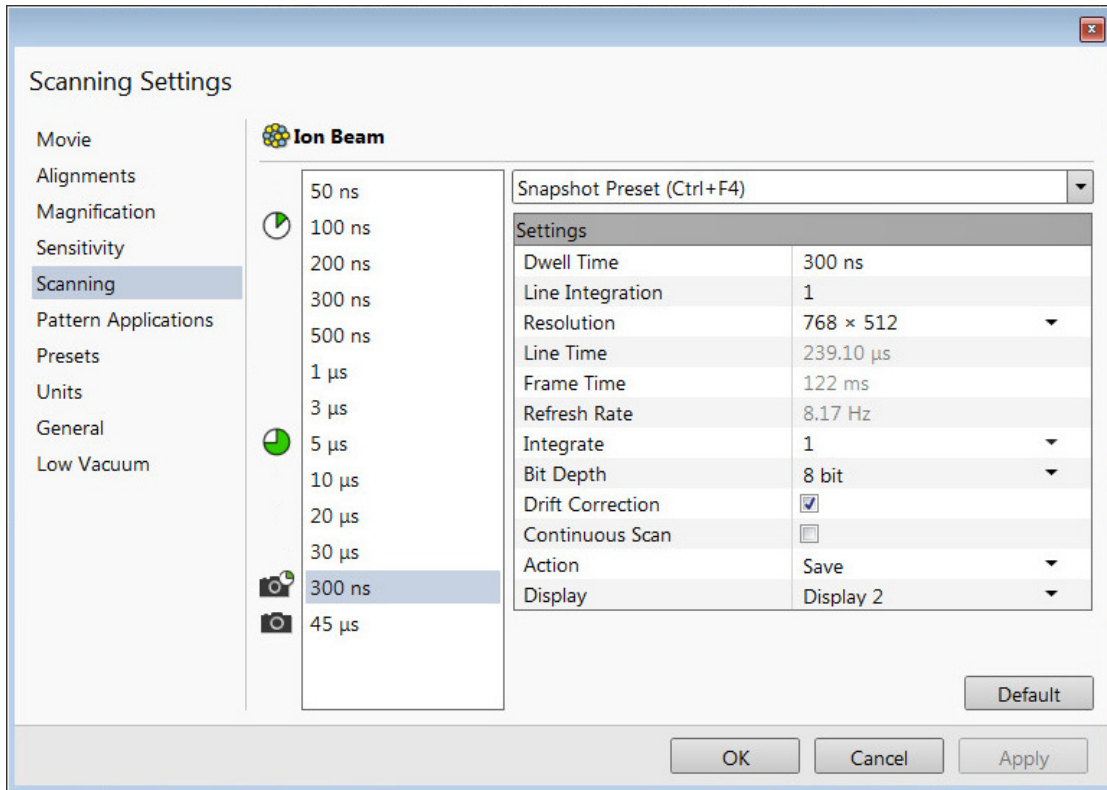


On the left side of the module there is a dwell-time preset list with the fixed number of entries. Selected *Preset* values can be changed in the Property editor on the right side of the module. The following properties are editable (depending on the kind of the preset):



- *Dwell Time* – a period of time during which the beam remains at the scanned point
- *Line Integration* – number of line scanning repetitions
- *Resolution* – number of points, Width × Height (imaging resolution)
- *Integrate* – number of integrated frames in the range from 1 to 512
- *Bit Depth* – (8 bits / 16 bits) sets the captured image bit depth
- *Drift Correction* (Yes / No) – corrects imaging drifting when integration filter is active
  When activated, the text below the blinking pause icon within the display notifies a user.
- *Continuous Scan* (Yes / No) – when set to yes and the Snapshot / Photo function is started during a scanning, this scanning finishes and resulting image is acquired according to the preset.

  This functionality requires the same scanning conditions for the scan in progress and the Snapshot / Photo preset (Dwell time, Line integration, Resolution, Bit depth...). If they are not, the Application status warning message is shown. The functionality is convenient for charging samples.

- *Action* – activated at the end of Photo / Snapshot function:
  *Save* saves the image using an automatic file name and format
  *Save As* opens the Save As dialog to save the image
  *None* just pauses imaging

The following properties are informative and non-editable:

- *Line Time* – line scan duration time
- *Frame Time* – display scan duration time
- *Refresh Rate* – imaging refresh frequency
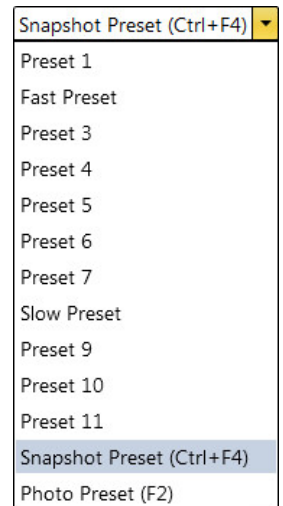
*Slow* (large green sector) / *Fast* (small green sector) preset icon indicates the matching dwell-time value. To change it move an icon up or down just by clicking on & dragging it.

*Snapshot* (camera with small green sector) / *Photo* (camera) preset icon indicates the matching dwell-time value. Set all possible properties in the Property editor.

The *Default* button restores the default dwell-time list and preset settings.

## Presets

allows a user to change the pre-set values in the *High Voltage* and *Magnification* drop-down lists. The configuration and available items differ for the beam selected (electron / ion) for the selected display. Any value can be changed by clicking on it in the list and entering a new one. The new value replaces old one and is immediately sorted into the list. The number of entries in the list remains fixed.

**FIGURE 3-24** *Presets Preferences*
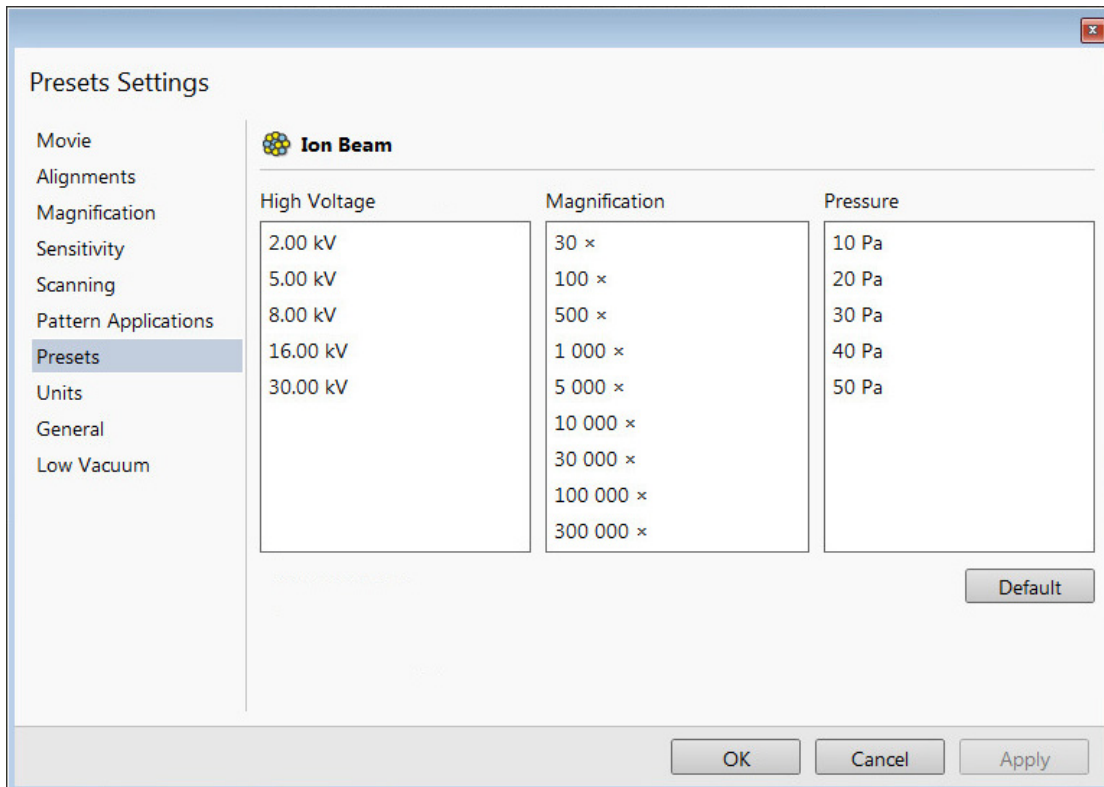


The *High Voltage* list can be changed to span any values from 350 V / 500 V to 30 kV for the electron / ion beam. The values must be entered in kilovolts (0.5 means 500 V).

The *Magnification* list can be changed to hold frequently used magnifications. Values that are in the pre-set list but cannot be applied to the actual SEM conditions are not shown in the toolbar / Magnification list box. Magnification range is from 20× to 1 000 000×.

*Note*
*Alternatively the Magnification could be shown as the Horizontal Field Width (see the Preferences... dialog / General section / Image dimensions control item).*

The *Pressure* list can be changed to hold specific values frequently used in the Low Vacuum mode in the range from 10 to 500 Pa (from 0.08 to 4 Torr).

### Units

allow a user to change the Units of *Measure, Pressure* and *Temperature.* The choices affect the Stage module input boxes, the databar display, the status bar and so on.

**FIGURE 3-25** *Units Preferences*
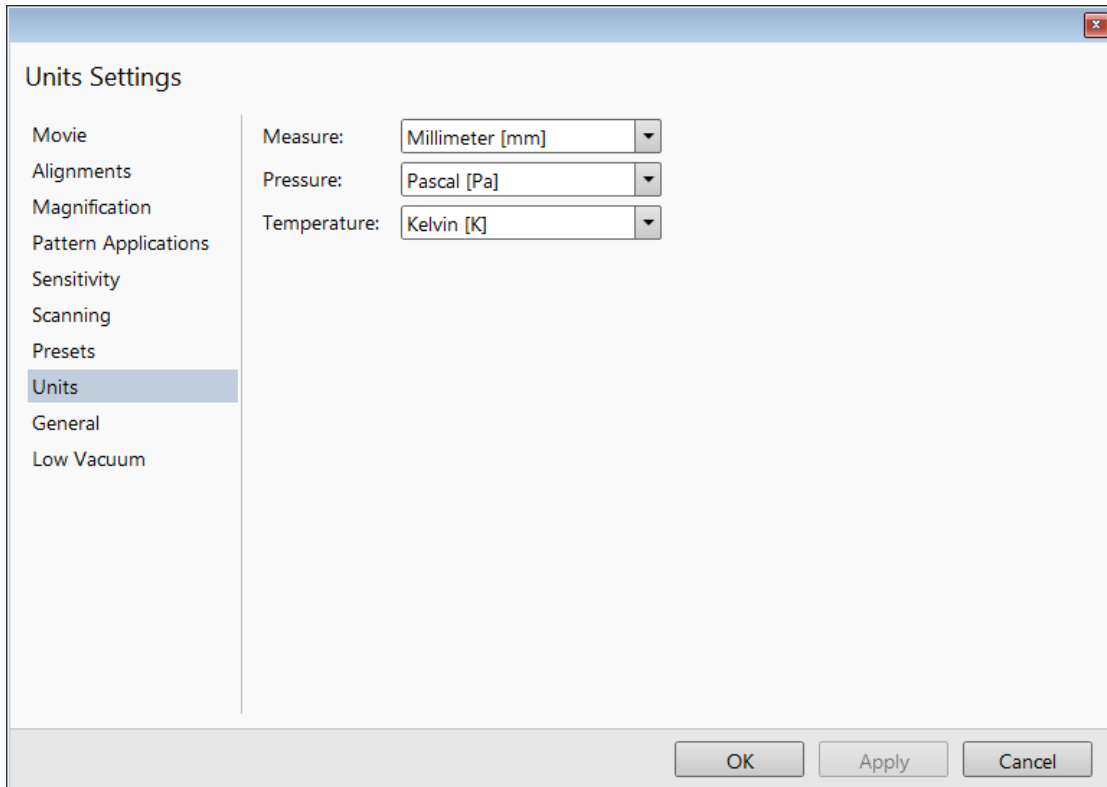


Selection possibilities are:

- *Measure:*          millimeter [mm] / micrometer [μm]
- *Pressure:*          Pascal [Pa] / torr [Torr] / millibar [mbar]
- *Temperature:*     Kelvin [K] / Celsius [°C] / Fahrenheit [°F]

## General

contains variety of user settings of both UI behaviour and microscope operation, which do not logically belong to other Preferences section.

**FIGURE 3-26** *General Preferences*
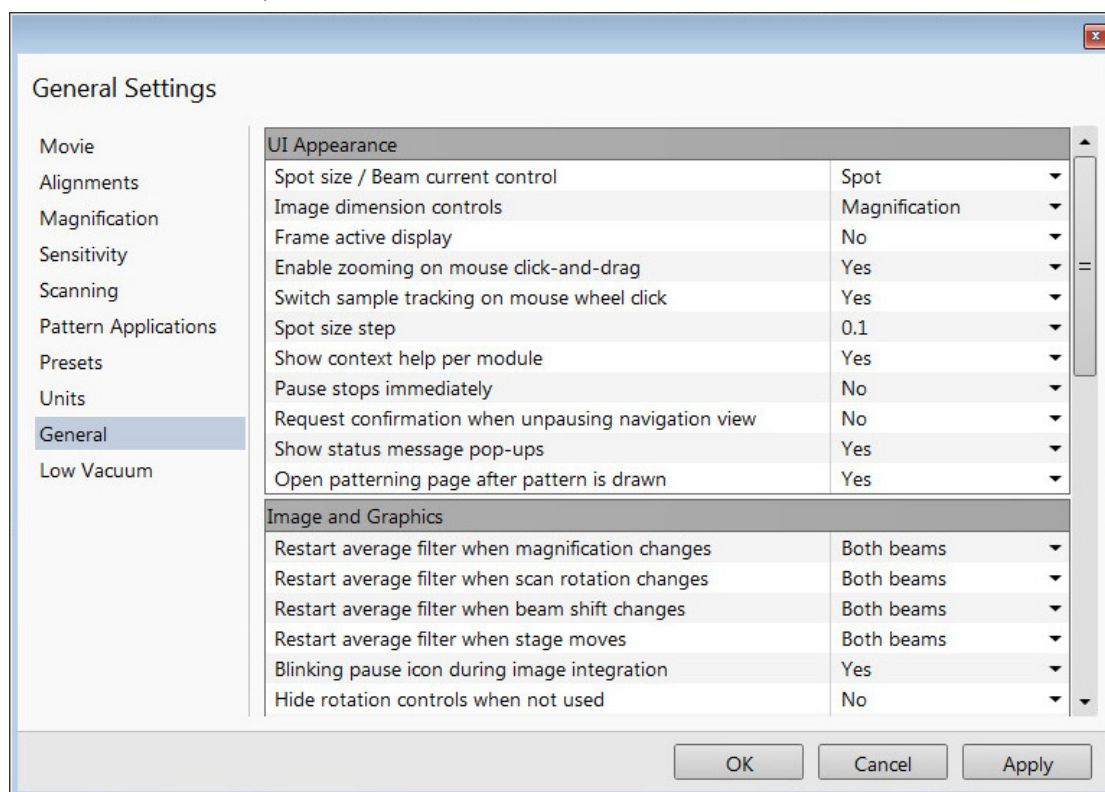


Each item of the General Preferences is represented by single line shown in the property editor. Clicking on the corresponding *Value* shows a drop-down list with the settings available for that item.

*Note*

*Some of the items are model dependent and some of them are intended for options.*

To make navigation among the number of preferences easier, they are divided into three groups:

### UI Appearance

- *Spot size / Beam current control* (Spot / Current)
  Choice of way of representation values in the toolbar list box and Column module.
- *Image dimensions control* (Magnification / HFW)
  Selects a way of the magnification representation and control.
- *Frame active display* (Yes / No)
  Switches on / off additional highlighting of the active display.
- *Enable zooming on mouse click-and-drag* (Yes / No)
  Set an option of mouse zooming.
- *Switch sample tracking on mouse wheel click on* (Yes / No)
  Switches the stage movement (tracking) control between the wheel-click on and move and wheel-click on & drag modes.
- *Spot Size Step:* (0.1 / 0.01 / 0.001)
  This enables to set the accuracy of the spot size setting.
- *Show context help per module* (Yes / No)
  Shows / hides the question mark button in the module header.
- *Pause stops immediately* (Yes / No)
  The Pause function acts instantly / waits for the complete scan.

- *Request confirmation when unpausing navigation view* (Yes / No)
  When releasing (unpausing) navigation imaging, confirmation could be switched on / off.
- *Show status message pop-ups* (Yes / No)
  Switches the status messages pop-up on / off.
- *Open Patterning page after pattern is drawn* (Yes / No)
  When a pattern shape was created with the use of a toolbar icon and *Yes* is set, the patterning page activates automatically.

### Image and Graphics

- *Restart average filter when magnification changes* (*)
- *Restart average filter when scan rotation changes* (*)
- *Restart average filter when beam shift changes* (*)
- *Restart average filter when stage moves* (*)
  * – (No / Electron Beam / Ion Beam / Both Beams)
  These items enable to choose whether the imaging averaging should be restarted when the indicated parameter changes. Restarting the average filter causes the imaging to blink and get noisier; on the other hand, the averaging slows down the imaging response to the changed parameter.

| Image and Graphics |
| --- |
| Restart average filter when magnification changes |
| Restart average filter when scan rotation changes |
| Restart average filter when beam shift changes |
| Restart average filter when stage moves |
| Blinking pause icon during image integration |
| Hide rotation controls when not used |
| Show scan rotation in Camera displays |
| Show Stage Map in Navigation display |
| Save digitally zoomed image as |
| Show legacy scanning resolutions |
| Post Processing |

- *Blinking pause icon during image integration* (Yes / No)
  If Yes is selected, the blinking Pause symbol is shown in displays which are being stopped. Otherwise, the Pause symbol appears only after the image acquisition has actually stopped.
- *Hide rotation controls when not used* (No / 10 seconds / 30 seconds / 60 seconds)
  Specifies if and when the onscreen Scan / Compucentric Rotation control should be automatically switched off.
- *Show scan rotation in Camera displays* (Yes / No)
  This item specifies if the Scan rotation indicator and value should be permanently shown in the optical display(s); only non-zero values are shown.
- *Show Stage Map in Navigation display* (Yes / No)
  shows saved positions in any navigation image, which is available (Nav-Cam, Navigation Montage, Navigation Alignment).
- *Save digitally zoomed image as* (Entire image / Zoomed area)
  When saving an image, this option enables to save only the zoomed area or the entire scanned area.
- *Show legacy scanning resolution* (Yes / No)
  enables to show old format screen resolutions in the toolbar drop-down list, scanning presets and Photo / Snapshot presets.
- *Post Processing* (None / Standard / Custom #)
  Select an image post processing preset to be applied.

### Microscope Operation

- *Interactive Databar* (On / Off)
  Turns image databar fields to be active (directly editable when possible) / inactive.
- *Scan Rotation Sensitivity* (0.1 /0.01)
  Choose the Scan Rotation setting sensitivity.
- *E-Beam Working Distance databar precision*
  (0.1 millimeters / 0.1 micrometers)
  It is possible to set the precision of the WD setting.

| Microscope Operation |
| --- |
| Interactive Databar |
| Scan rotation sensitivity |
| E-Beam Working Distance databar precision |
| Lower stage when venting the chamber |
| Change magnification when pumping |
| Switch off CCD automatically |

- *Lower stage when venting the chamber* (No / By 10 mm / Full down)
  Specifies if the stage should automatically lower when venting the chamber. This is recommended, because it greatly diminishes the chance of hitting the final lens when closing the chamber doors after mounting a higher specimen.
- *Change magnification when pumping* (No / Set to 100× / Set to 200×)
  Specifies whether the magnification for electron and ion imaging should be automatically set to a low value when the chamber is being pumped (presumably after replacing the specimen).
- *Switch off CCD automatically* (No / 1 minute / 10 minutes / 30 minutes / 1 hour / 2 hours / 6 hours)
  Specifies if and when the CCD camera and infrared LED's should be automatically switched off. The countdown starts when resuming the optical imaging and continues regardless of the operator activity.

- *Pause beam displays when switching off HV* (Yes / No)

  Specifies if the electron and ion imaging should be automatically paused when switching the High Voltage off.

- *Use measured I-beam current for patterning* (Yes / No)

  If yes, calculates the total patterning process time based on the actual measured ion beam current no matter what the nominal beam current value is for the selected aperture. This feature should prevent patterning inaccuracies caused by aperture wear. If the measured beam current differs from the nominal value by more than 20%, a dialog box appears to ask if you want to recalculate.

- *Continuous reduced area scanning in iSPI mode* (Yes / No)

  If yes is selected, the *iSPI* tab module / *On* check box is ticked, the *Paterning* menu / *Auto-Start/Stop Electron Acquisition for iSPI* item is checked and the reduced area is defined in the electron imaging display, the electron scanning of the reduced area after the *iSPI* tab module / preset *Time* (or *CCS Line*) *Interval* continues until a user pauses it. At this point the system switches to a ion beam and continues patterning for another preset interval. If no is selected, normal iSPI functionality is in operation either for full screen or defined reduced area.

- *Allow Beam Shift in Get mode* (Yes / No)

  Enables / disables automatic using of Beam Shift when a user requires very small point-to-point movements (double-click on the sample point at high magnifications).

- *Blank E / I beam during long stage moves* (Yes / No)

  Specifies if the electron and ion beams should be automatically blanked during long software controlled stage movements. This may protect extremely sensitive samples from exposure to the beam in undesired areas.

- *Unpause CCD camera for large Z movement* (Yes/No)

  Specifies if the optical camera should be automatically released during large Z-axis stage movements. This may prevent a collision between the stage and final lens pole.

- *Enable Joystick movement* (Yes/No)

  Enables a possibility to control stage movements by the joystick.

- *Reverse Joystick movement* (Yes / No)

  Normally the joystick movement direction corresponds to the stage movement, so the imaging moves in the opposite direction. This setting changes the stage response to the joystick movement direction.

- *Auto switch stage measurement system* (Yes / No)

  Automatically switches the stage measurement systems off when not used to avoid light interference with 3rd party equipment (EDS detectors etc.).

- *Optimized collection efficiency* (Yes / No)

  If yes, the inactive (paused) SE detector is prevent from taking the SE signal to the active one (related to the ETD and ICE detectors). This is not recommended to use while patterning, which can cause image quality decrease in SPI and iSPI mode.

- *Chamber illumination* (Yes / No)

  If Yes and the in-chamber Nav-Cam is installed, inner chamber illumination is on when the chamber is vented.

- *Show sample exchange window on pump/vent* (Yes / No)

  When starting to pump or vent the chamber, the Sample exchange window opens automatically.

- *Venting valve opening time* (value)

  prolongs the venting time (default value is 180 s) to eliminate residual vacuum which makes impossible to open the chamber door or shortens the venting time.

- *Default display for Nav-Cam image* (Display 1 / Display 2 / Display 3 / Display 4 / Active)

  This option sets the default Nav-Cam imaging display, which is automatically selected when taking the Nav-Cam photo.

| |
|---|
| Pause beam displays when switching off HV |
| Use Measured I-beam current for patterning |
| Continuous reduced area scanning in iSPI mode |
| Allow beam shift in Get Mode |
| Blank E-beam during long stage moves |
| Blank I-beam during long stage moves |
| Unpause CCD camera for large Z movement |
| Enable joystick movement |
| Reverse joystick movement |
| Auto switch stage measurement system |
| Optimized collection efficiency |
| Chamber illumination |
| Show sample exchange window on vent |
| Venting valve opening time |
| Default display for Nav-Cam image |

### Low Vacuum

The specimen chamber purging procedure (see Chapter 2) can be customized at this section.

FIGURE 3-27 *Low Vacuum Preferences*
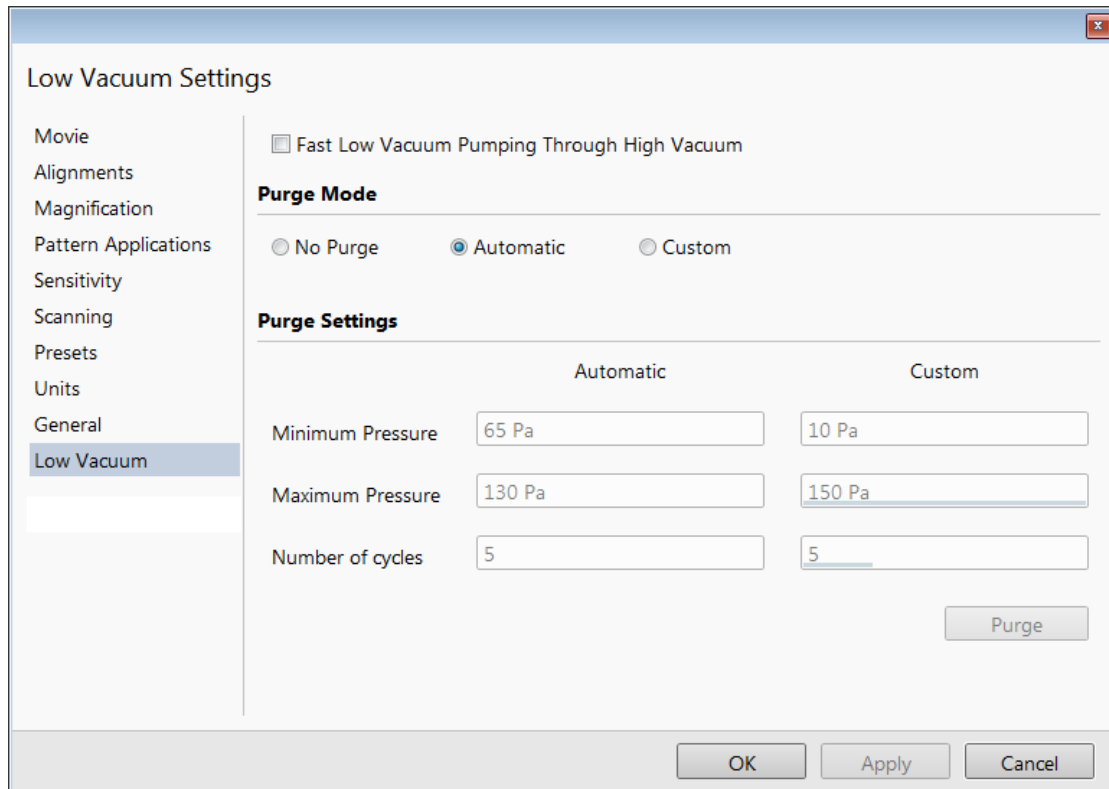


For highly outgassing samples the procedure can take very long time. In this case the *Fast Low Vacuum Pumping Through High Vacuum* check box must be cleared; the specimen chamber is then pumped to a pressure slightly lower then a desired LoVac pressure (see custom settings bellow) and proper purging ensures good water vapor or gaseous atmosphere in the chamber.

*Purge Mode* area contains following radio buttons:

- *No Purge* – the purging is switched off and the chamber pressure goes directly to the set Low Vacuum mode value. The gas mixture in the chamber slowly changes to the new gas type.
- *Automatic* – all purging parameters are set automatically, according to the mounted Low Vacuum detector (Cone).
- *Custom* – custom settings (see below) are used.

*Purge Settings* area contains following *Automatic / Custom* settings and controls:

- *Minimum Pressure*
- *Maximum Pressure*
- *Number of cycles*
  Set above three parameters desired values for the procedure.
- The *Purge* button enables to start the purging (using the actual Purge Settings) manually when the system is already pumped to the Low Vacuum; otherwise, the button is disabled. When the purging is running, the Purge button becomes highlighted. Clicking on the highlighted button stops the actual purging procedure and returns the system to operation in Low Vacuum.

*Note*
  *During the purging procedure, the chamber pressure is not ready for SEM operation (the vacuum status is Pumping). Therefore, clicking the Purge button automatically switches off the accelerating voltage.*

  *The Purge Settings is not remembered separately for each user. If it is of any importance, please check these Preferences before starting the Low Vacuum operation.*

# FEI Account Manager application

The *FEI Account Manager* application allows to a Supervisor (accounts manager) to organize user accounts. It allows the creation and removal of user accounts, settings, passwords, as well as their descriptions. User accounts ensure for all users admission to both the operating system Windows 7 and the xT microscope Server / Microscope Control software.

## Accounts control

You can start the software by clicking the *FEI* menu / *Service Tools* / *Account Manager* icon:
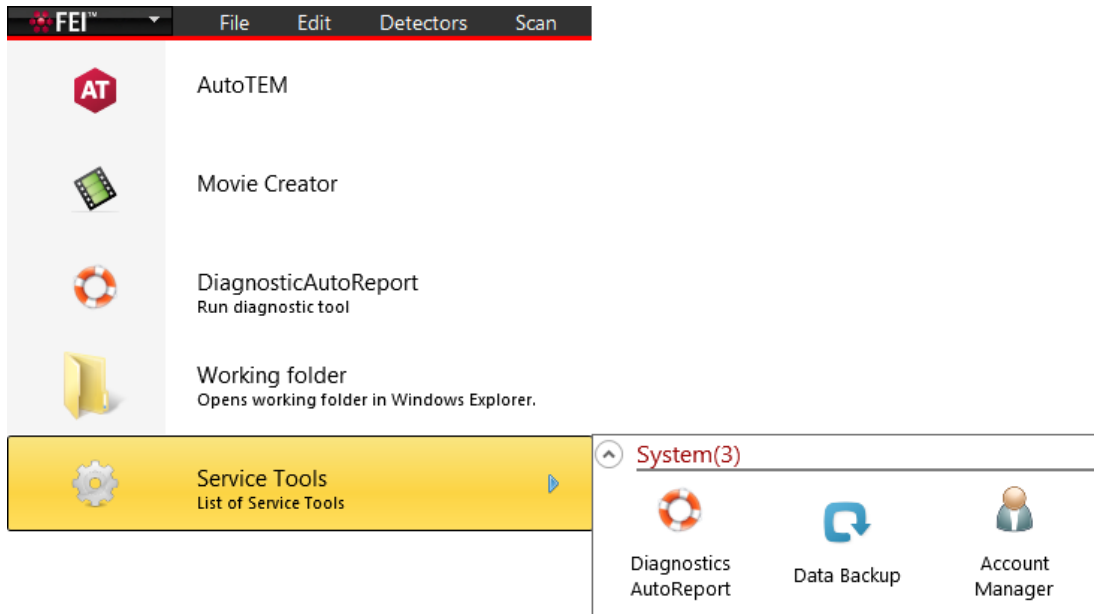


This brings up the *Log On* dialog box, containing *User* and *Password* text fields, for entering the FEI Account Manager. For the first time log on with the Supervisor / Supervisor credentials; the application window appears.
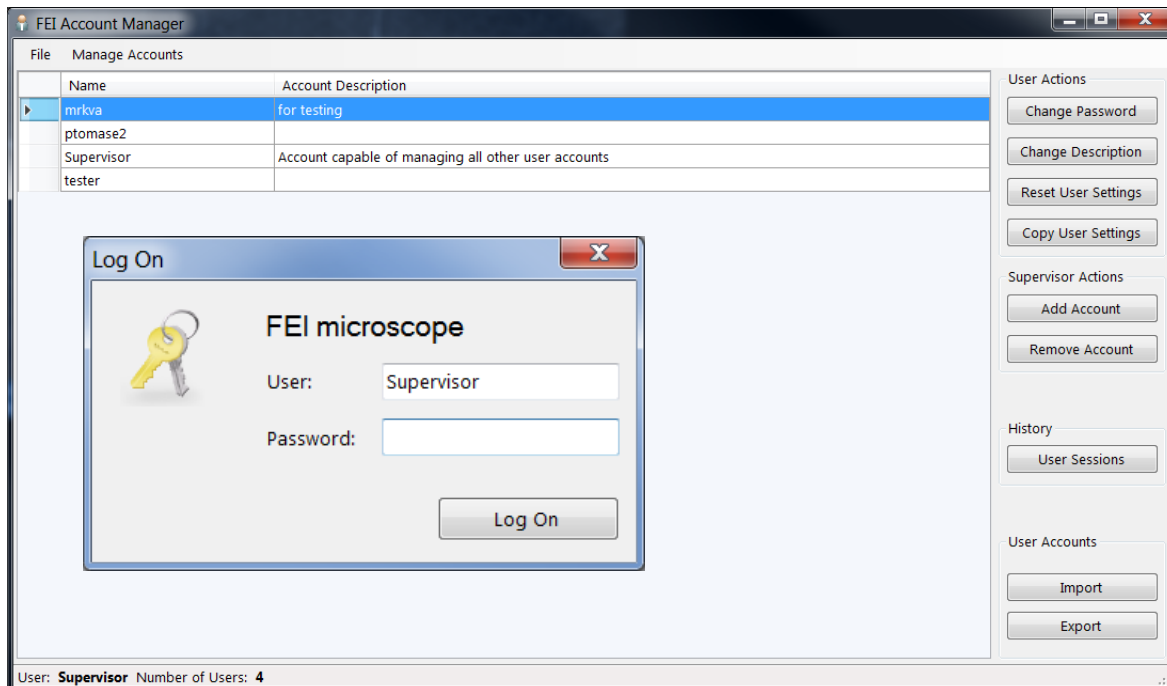


The *Supervisor* (default) account can not be deleted and only the Supervisor can manage it; it has the right to create and delete user's accounts and to change all their settings. Particular users has a limited right to manage only its own account.

The *File* and *Manage Accounts* menus contains the same controls (with a few exceptions), as the buttons placed at the right side of the window. Some actions are intended for supervisor only.
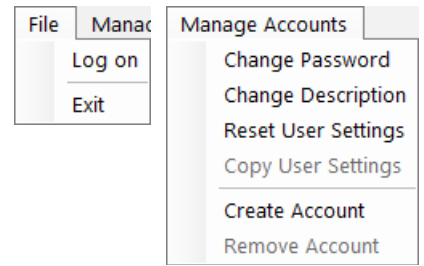
Clicking the button / menu item starts the action for a selected (highlighted) account.

- *Log on* – logs on a new user (an actual user is logged out)
- *Exit* – exits the application

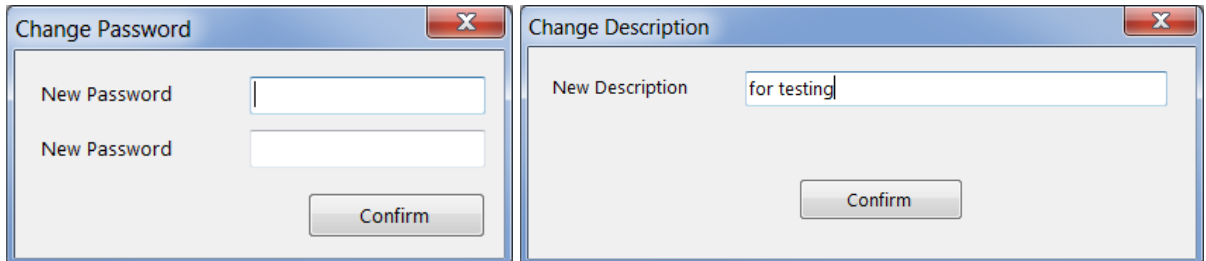- *Change Password / Description* – sets a new password / account description.

- *Reset User Settings* – restores user account setting to the factory default.
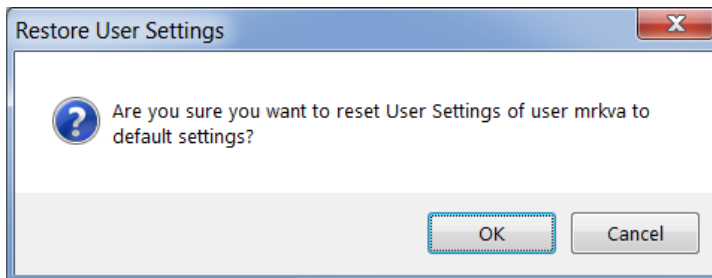
- *Copy User Settings* – select a user account from which settings are copied.
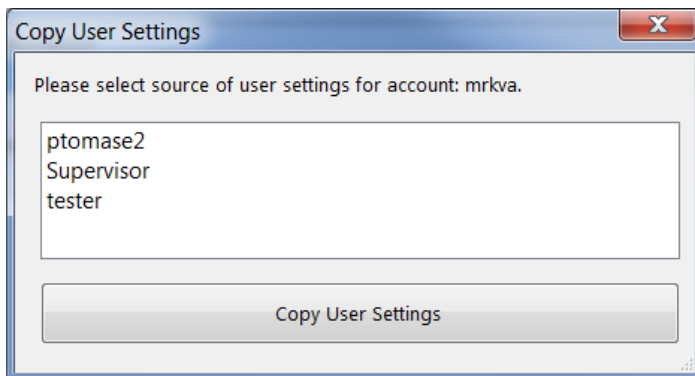
- *Add (Create)* (Supervisor) / *Remove Account* (Supervisor) – enter information to create a new user account. To remove user account the confirmation is needed.
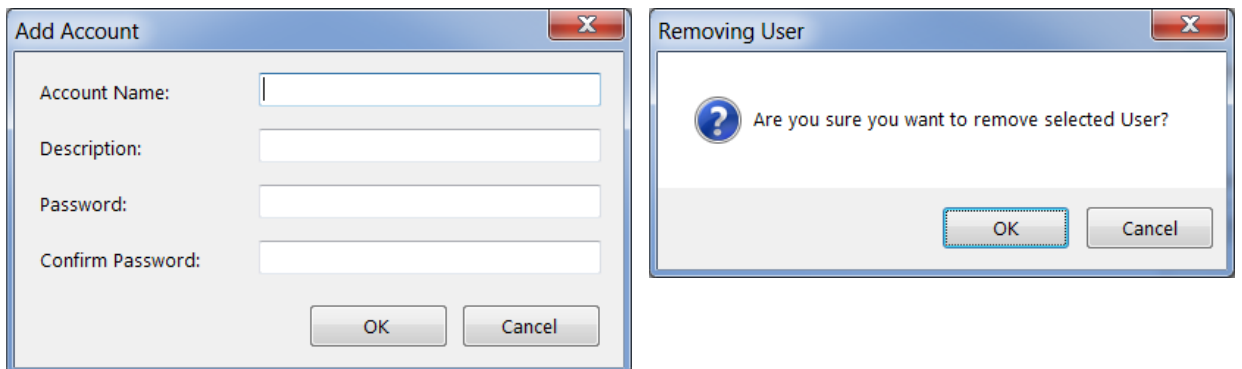
- *User Sessions* (Supervisor) – shows the login (.CSV) file for all user accounts.

- *Import* (Supervisor) / *Export* – imports selected user(s) from a previously exported (.REG) file.
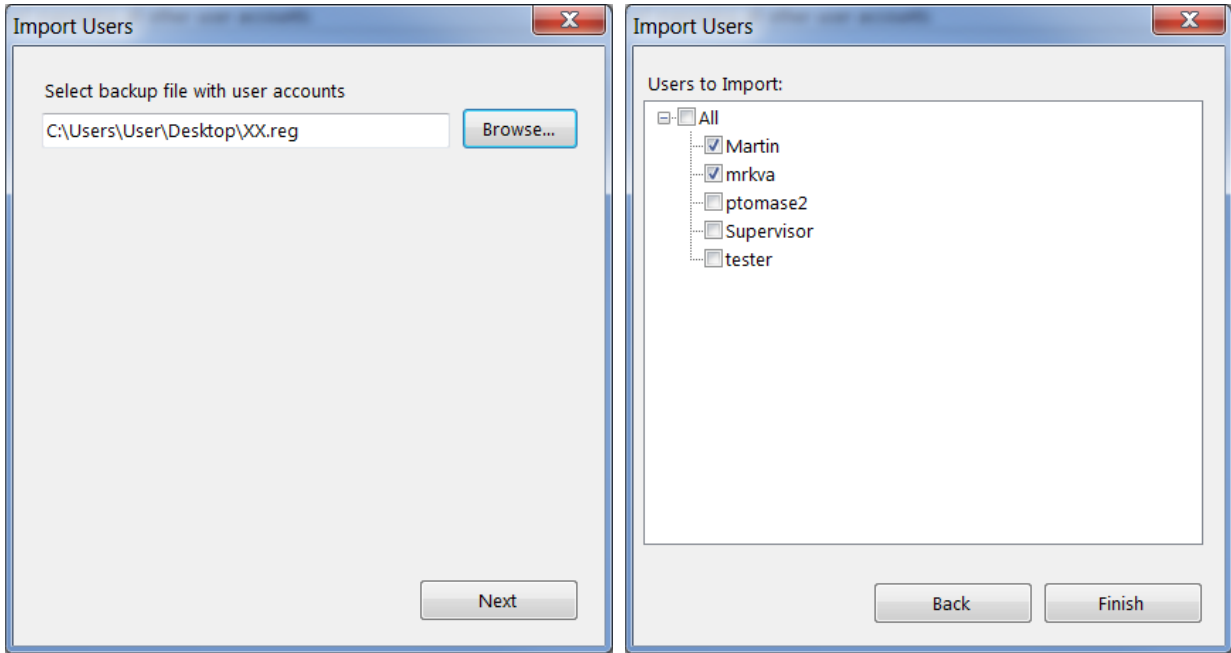
# User Logins and Account Settings

Each user login account stores a variety of configuration data in the registry. These values are then restored when that user logs back into the system.

### Overall layout and settings for the UI

Overall stored settings:

- Electron and ion beam settings (HV, current, HFW)
- Dwell, resolution, position for each beam in full frame, reduced area, line, and spot modes
- Detector settings (bias voltages, etc.)
- Preferences
- Workspace (toolbar, side pan – pages, keyboard – short cuts)

Stored settings for each display:

- Active beam (electron, ion, optical)
- Image save file path
- Image save settings (databar or overlays included)

Stored settings for each beam in each display:

- Active detector
- Detector subsettings for all detectors (is CDEM in SE or SI mode)
- Detector mixing settings
- Digital brightness/contrast/gamma settings
- Databar text
- Zoom and pan (shift) values for digital zoom mode

Others

- Various patterning settings

# Entering Commands in Summary

## Using Mouse

**Table 3-2** *Mouse Keys*

| Keyboard + Mouse button | Function |
|---|---|
| **(Shift +) Click on**<br>*arrow cursor* | selects / activates a control element(s)<br>(toolbar pause icon: pauses / releases all displays<br>Photo icon / Snapshot icon / Scanning preset button:<br>activates appropriate enhanced / alternative<br>functionality) |
| **(Ctrl +) Click on**<br>*arrow cursor* | selects a graphical item within an imaging area<br>(adds another one to the selection) |
| **Click on & drag (+ Shift)**<br>*arrow cursor*<br>*with + / - magnifying glass icon* | selects an area to zoom<br>in (dragging the mouse down-right) /<br>out (dragging the mouse down-left, up-left, up-right) |
| **Ctrl + click on & drag** | controls the detector contrast / brightness<br>by dragging the mouse left-right / up-down |
| **Shift + Click on & drag**<br>*hand-cursor* | activates the Beam Shift |
| **Double-click on** | *Electron / Ion Imaging:*<br>Get mode: moves a point to the display center<br>*Optical Imaging:*<br>places 7 mm marker |
| **Right-click on & drag**<br>*2-ended arrow cursor* | focuses by dragging the mouse left-right |
| **Ctrl + right-click on & drag**<br>*4-ended arrow cursor with circles* | activates the Lens Alignment |
| **Shift + right-click on & drag**<br>*4-ended arrow cursor* | corrects imaging astigmatism by dragging the mouse<br>left-right – X stigmator or up-down – Y stigmator |
| **Ctrl + wheel-roll up / down** | increases / decreases the magnification coarsely |
| **Shift + wheel-roll up / down** | increases / decreases the magnification finely |
| **Ctrl + Shift + wheel-roll up / down** | increasis / decreasis the digital zoom magnification |
| **(Ctrl+) Wheel-click on & drag** | *Electron / Ion Imaging:*<br>Track mode: moves the stage (joystick-like control)<br>*Optical imaging:*<br>moves the stage in Z-axis direction (tilts the stage) by<br>dragging the mouse up / down (left / right) |

*Note*
   *The given sequence of the key press and mouse button click on is important for some functions.*

**❖❖ FEI**™
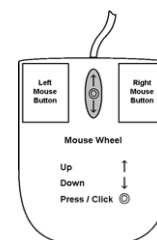
## Using Keyboard

**Table 3-3**    *Windows System Keys*

| Key (+ Key) | Function |
| --- | --- |
| **Enter** | equivalent to the OK button in dialogs |
| **Esc** | equivalent to the Cancel button |
| **Tab** | switches between entry fields within dialog boxes |
| **Arrows** | selects an item within list boxes |
| **Alt (F10)** | accelerator keys (underlined menu bar item characters) – by hitting it a corresponding menu list is expanded directly, subsequently another accelerator key can be selected |
| **Alt + Tab** | Switches between running applications: each time the Tab key is hit while holding the Alt key pressed a pointer jumps to another application icon. Releasing the Alt key at any time makes application just listed active. |
| **Alt + F4** | closes active application or Windows operating system |
| **Del(ete)** | deletes a selection, texts or graphics |
| **Ctrl + A** | selects all items, texts or graphics within an active window |
| **Ctrl + C (Ctrl + Insert)** | copies a selection to the clipboard – temporary memory |
| **Ctrl + V (Shift + Insert)** | pastes content of the clipboard at the pointer position – text / to a window – graphics |
| **Ctrl + X (Shift + Delete)** | cuts a selection to the clipboard – copies and deletes it |

**Table 3-4**    *Function and Specific Key Short-cuts*

| Key (+ Key) | Function |
|---|---|
| *Esc* | stops the stage motion at that point<br>*Note*<br>    *During particular procedures, Home Stage for instance,*<br>    *use the software Cancel or Stop button!* |
| *F1* | shows documentation |
| *Shift + F1* | shows Image properties |
| *(Shift +) F2* | Starts Photo with an active beam<br>(in all displays with the same beam at once) |
| *Ctrl + (Shift +) F2* | starts / stops Active Preset Snapshot (from all displays at once) |
| *(Ctrl+) F3* | toggles Videoscope On / Off (in all displays) |
| *Shift + F3* | starts Home Stage procedure |
| *(Ctrl +) F4* | Starts / Stops electron (ion) imaging Snapshot from active display |
| *Shift + F4* | starts / stops Lens Alignment procedure |
| *F5* | toggles Single / Quad Image mode |
| *Ctrl + F5* | toggles Large Image Window mode |
| *Shift + F5* | toggles Center Cross show |
| *F6* | pauses / releases scanning |
| *Shift + F6* | toggles Alignment rectangle show |
| *F7* | switches Reduced Area On / Off |
| *Ctrl + F7* | starts Image Post Processing |
| *F8* | starts Degauss procedure |
| *(Shift +) F9* | starts Auto Contrast Brightness procedure (in all live displays) |
| *F11* | starts Auto Focus procedure |
| *Ctrl + F11* | starts Auto Stigmator procedure |
| *Shift + F11* | toggles Display Saturation function |
| *(Shift +) F12* | toggles Compucentric (Scan) Rotation tool |
| *Ctrl + 0 – number* | moves stage to X=0, Y=0 – Center Position procedure |
| *Ctrl + Shift + A* | starts / stops alternating of electron and ion imaging |
| *Ctrl + B* | toggles Beam Blank function |
| *Ctrl + E* | tilts stage to 0° |
| *Ctrl + F* | sets Electron / Ion beam focus to eucentric WD (7 mm / 19 mm) |
| *Ctrl + H* | sets Horizontal Field Width (HFW) |
| *Ctrl + I* | tilts stage to 52° |
| *Ctrl + K* | sets Spot mode conditions |
| *Ctrl + M* | sets Full Frame scanning conditions |
| *Ctrl + Shift + M* | starts movie recording |
| *Ctrl + N* | toggles Sample Navigation On / Off |

**Table 3-4**     *Function and Specific Key Short-cuts*

| Key (+ Key) | Function |
|---|---|
| *(Ctrl +) Shift + N* | starts to mill (previous) next pattern line |
| *Ctrl + O – letter* | opens Preferences dialog |
| *Ctrl + P* | opens Print dialog |
| *Shift + P* | proceeds with next pattern |
| *Ctrl + R* | restarts scan |
| *Ctrl + (Shift +) S* | saves image(s) (from all displays) |
| *Ctrl + T* | toggles electron and ion beams imaging for active display |
| *Ctrl + Y* | redoes last operation |
| *Ctrl + Z* | undoes last operation |
| *Ctrl + Shift + Z* | starts Take Nav-Cam Photo procedure |
| *Pause* | starts / stops patterning |
| *Ctrl + Pause* | resets patterning |
| *Ctrl + (Shift +) ,* | sets one step slower (slowest) scanning |
| *Ctrl + (Shift +) .* | sets one step faster (fastest) scanning |
| *Ctrl + (Shift +) Tab* | activates displays stepwise (backward) |
| *Ctrl + Page Up / Down* | switches within Control pages stepwise |
| *Ctrl + 1 / 2 / 3 …* <br> *– letter keypad* | selects the particular page <br> (the number corresponds to the page icon sequence) |
| *(Ctrl +) + / -* | increases / decreases the magnification 2× (Digital Zoom) |
| *\** | rounds off the magnification / HFW to a nearest round value |
| *Ctrl (+ Alt) + arrow* | moves the digital zoom area (the pattern) <br> by one screen pixel in the respective direction |
| *(Shift +) Arrows* | moves the stage approximately by (40%) 80% <br> of the field of view in corresponding direction |

**4**

# *Alignments*

On the *Microscope Alignments* page select an alignment procedure available from the list box. Always follow the instructions given in the *Instructions* module. The *Step* shows the present control step number and the total number of steps. You can find some additional explanation in this chapter.

## Common Rules

Alignments should be performed in the display 1. In other case it is not possible to ensure the correct functionality of the Contrast, Brightness and Auto functions used on the Microscope Alignments page.

Before aligning the Electron column, be sure that the final lens aperture is clean and properly centred.

During adjustment procedures it is allowed to change the magnification, the scanning speed, to use reduced area and to optimize image contrast / brightness. It is also possible to correct astigmatism and to focus an image (for a particular alignment this is forbidden).

During adjustment procedures it is not allowed to change a Vacuum Mode, a Spot size and a High Voltage. Do not use the Beam Shift at any time during the adjustment procedures, as this is set to the zero value at each alignment section. All specimen movements can be made using the stage where appropriate.

## Buttons and Control Elements

The following buttons and control elements have the same behavior for all alignment procedures, when available:

- *Start* button – starts the procedure and proceeds with following dialogs.
- *End* button – moves a user to the last step (after clicking on the *Next* button) to be able to finish the alignment procedure.
- *Finish* button – saves new settings, ends the procedure and closes the dialog.
- *Save* button – saves new settings at that point without closing the dialog.
- *OK* button – applies all changes made in the dialog and closes it.
- *Apply* button – saves and applies new settings at that point without closing the dialog.
- *Cancel* button – discards all changes (made from the last save) and closes the dialog. It has the same effect as closing the dialog with the cross (Alt + F4).
- *Next* button – moves a user to the following dialog after necessary settings have been done.
- *Previous* button – moves a user to the previous dialog when settings need to be changed.
- *Contrast / Brightness* adjusters – enable to optimize the image quality during alignment.
- *Auto* button – executes the appropriate alignment action automatically for a particular voltage / spot / direction (whatever suitable) with the use of the *Image Recognition* software. If this utility does not recognize image features well, the procedure is aborted and Warning message appears onscreen. In this case change the imaging conditions (better focus, slower scanning, or lower magnification) and try again.
- *Crossover* button – activates the Crossover mode, where the onscreen image shows the electron source tip instead of the sample.
- *Modulator* button – starts automatic parameter oscillation to facilitate the process.
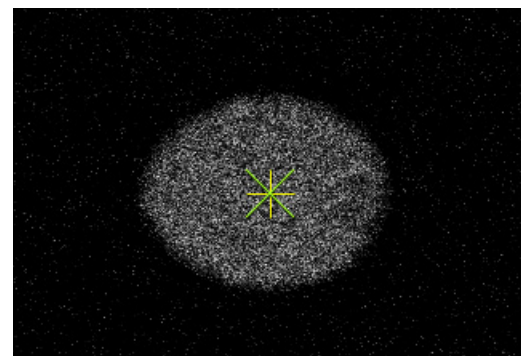
# Alignments List

Grouped alignments lists are possible to roll down / up by clicking the + / - sign:

### Electron Beam
- *Magnification Correction*
  User magnification calibration (see Beam menu item).
- *E-Column: Aperture Selection*
  Enables to set a second set of final lens apertures in case the image quality deteriorates (one or more actually used apertures are worn out).
- *E-Column: Preventive Maintenance*
  The user level electron beam adjustment procedure.
- *E-Column: Supervisor Alignments*
  Set of Supervisor level electron beam adjustment procedures.

### Ion Beam
- *100 – ION: Source Control*
  Used for ion source starting and heating, LMIS recovering, LMIS state monitoring.
- *I-Column: Aperture Management*
  Controls the ion beam aperture strip holes condition.
- *I-Column: Manual Beam Alignment*

- *I-Column: Alignments*

### Stages
- *Stage Alignments* – set of utilities:
  – *Stage Rotation Center* – sets the stage rotation centre for the compucentric rotation.
  – *Eucentric Height* – defines the eucentric position.
  – *R Zero Alignment* – sets zero rotation position of the holder for STEM range definition.
  – *Tilt Zero Alignment* – sets the stage tilt zero position.
  – *Tilt-X Correction* – sets the correction in X direction when tilting the stage.

### EasyLift
- *EasyLift Needle Exchange/Calibration* (option – see Chapter 7)

### Others
- *154 – Water Bottle Venting*
  Enables to vent the water bottle in case of refilling.
- *External Plasma Cleaning / Plasma Cleaning*
  Enables the chamber plasma cleaning and sets duration of the specimen plasma cleaning.
- *Pump Buffer*
  Enables to pump down the vacuum buffer.
- *Vacuum Actions* (U) – set of utilities:
  – *Start / Stop IGPs* – enables to start / stop vacuum pumps in case of power failure, emergency or service actions
  – *Pump / Vent Actions* (U) – enables to pump / vent particular vacuum system sections
- *GIS Alignment* (option)
  Resets the GIS crucible filling lifetime counter after its exchange, sets the GIS heating temperature and performs GIS mechanical alignment.

#### Model difference
Scios 2 High Vacuum has a slightly modified alignments list.
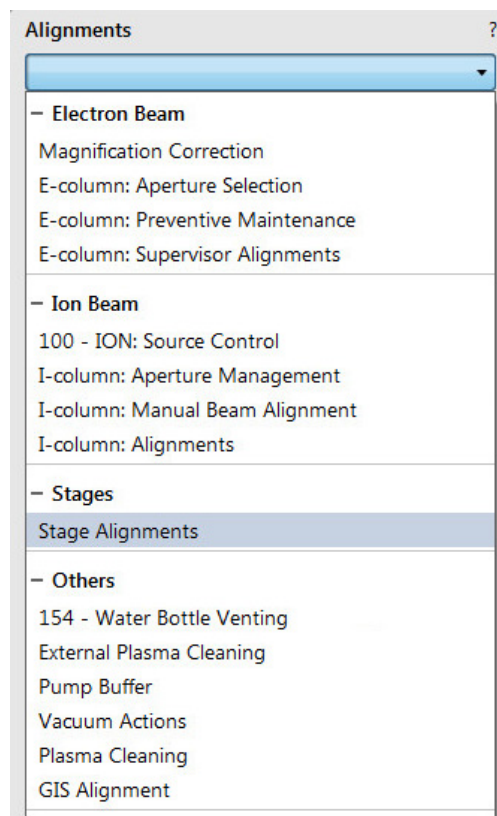
# Automatic Alignments

Some of Alignments (or a set of alignments) have a different approach and most of the procedures can run automatically by checking the *Automatic* check box placed at the bottom of the alignment module. Automatic progress can be started / stopped at any time during the procedure. Accessible informational windows can be turned on / off by the *Show / Hide Window* button. The alignment sequence can be cancelled / continued by the Cancel / *Next* button.

### *C a u t i o n !*

*Read carefully the instructions provided by the system before proceeding with any alignment!*

If you have any e-beam alignment procedure selected and you want to select any other one, you must *Finish* or *Cancel* an actually opened procedure first. To start alignment procedure or to stop one in progress right-click on the red circle and select required action (*Start / Stop* – variable) from the context menu. A confirmation dialog is shown.
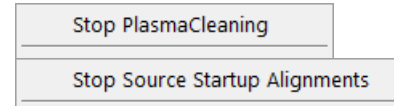
When interrupting any alignment (clicking on the *Cancel* button, selecting the *Stop* item in the menu, closing the UI) nothing is saved. In all cases the alignment windows disappear and the *Stop Execution* dialog appears.
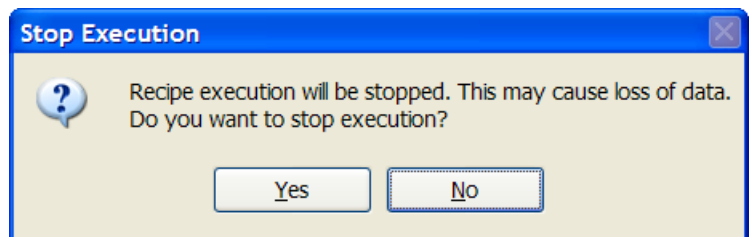
The last page of every alignment offers one or more of following choices:

- *Restore old values and finish*: undoes the adjustments, nothing will be saved.
- *Save new results and finish*: keeps new adjustment values and saves them.
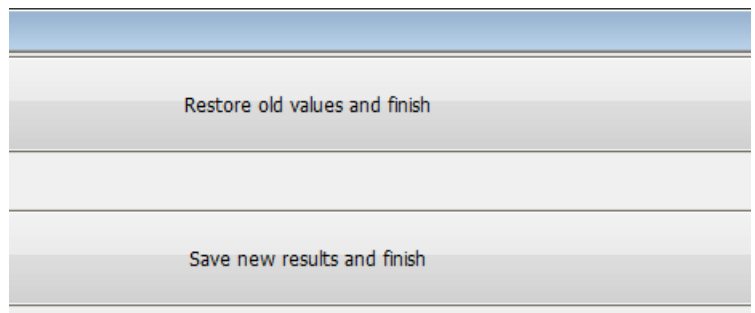
# Results

The result of every step is shown by means of an icon in the result list when performing alignment steps.

**FIGURE 4-1** *Alignments Results*



- *Unavailable*:
  The result has never been obtained, at least not by this procedure. This may mean that it has never run, or that it failed to do anything meaningful (the difference between these two is not important).

- *Reliable*:
  The result is trusted by the automatic procedure or a user has passed the alignment step manually.

- *Unreliable*:
  The automatic procedure has done meaningful work, but cannot decide whether the obtained result can be trusted. This suggests to review the result manually.

- *Out of range*:
  The automatic procedure trusts that the optimal outcome is outside the range of the variable to be aligned. A value is set that is near the border of the range.

# Magnification Correction

This utility is intended to enhance factory calibration accuracy under particular, user selectable conditions.



**Note**

*Switch the Beam menu / Magnification Correction item on only for calibrated conditions, otherwise it can worsen magnification accuracy.*

# E-Column: Aperture Selection

Try to change the aperture when imaging is poor.

# E-Column: Preventive Maintenance
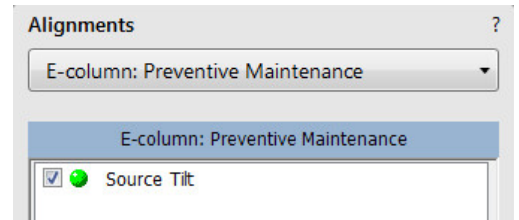


### Source Tilt & Shift (Fast)

This user level alignment ensures to center electron beam in the column and should be executed regularly (on a weekly basis). It takes around 15 to 20 minutes. If it is not successful, run the supervisor level alignment *Source DPA & Tilt & Shift*.
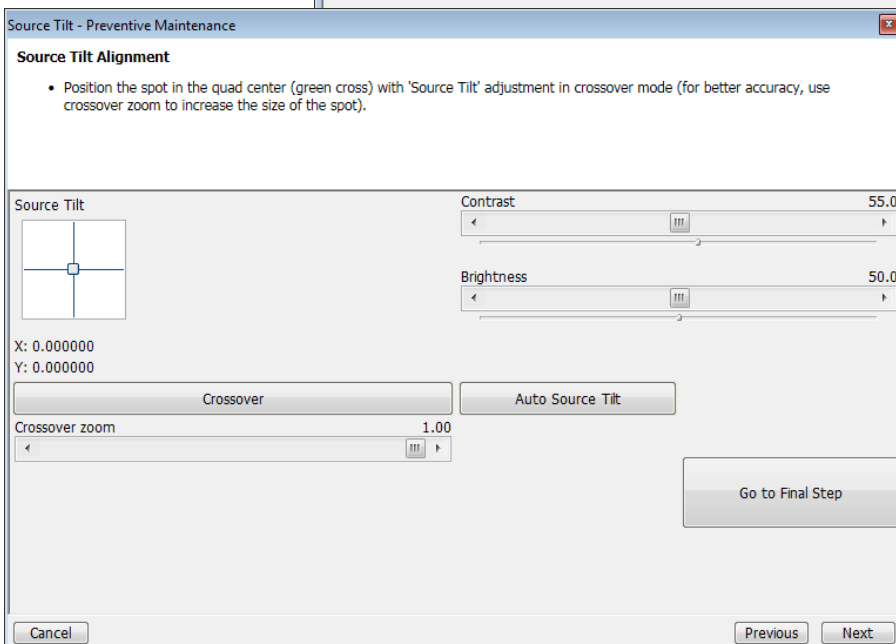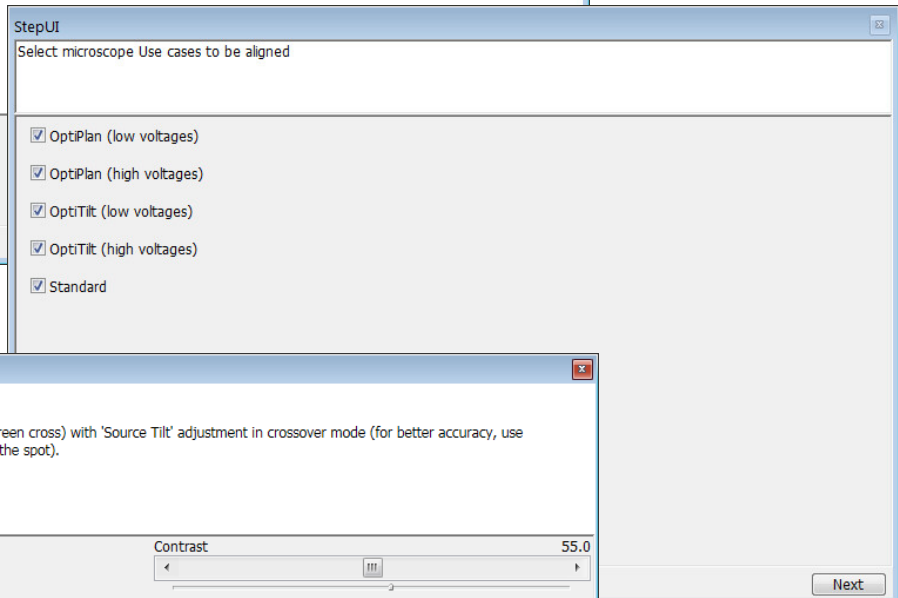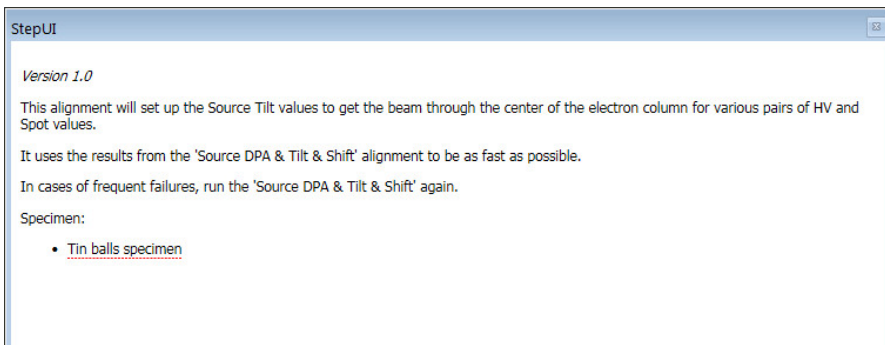
# E-Column: Supervisor Alignments

This set of alignments enables the following actions:
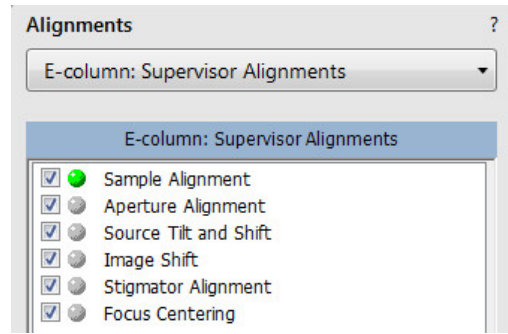


### Sample Alignment

First alignment of this set allows a user to find appropriate sample locations within the sample holder and save them. These positions are used in the following procedures.
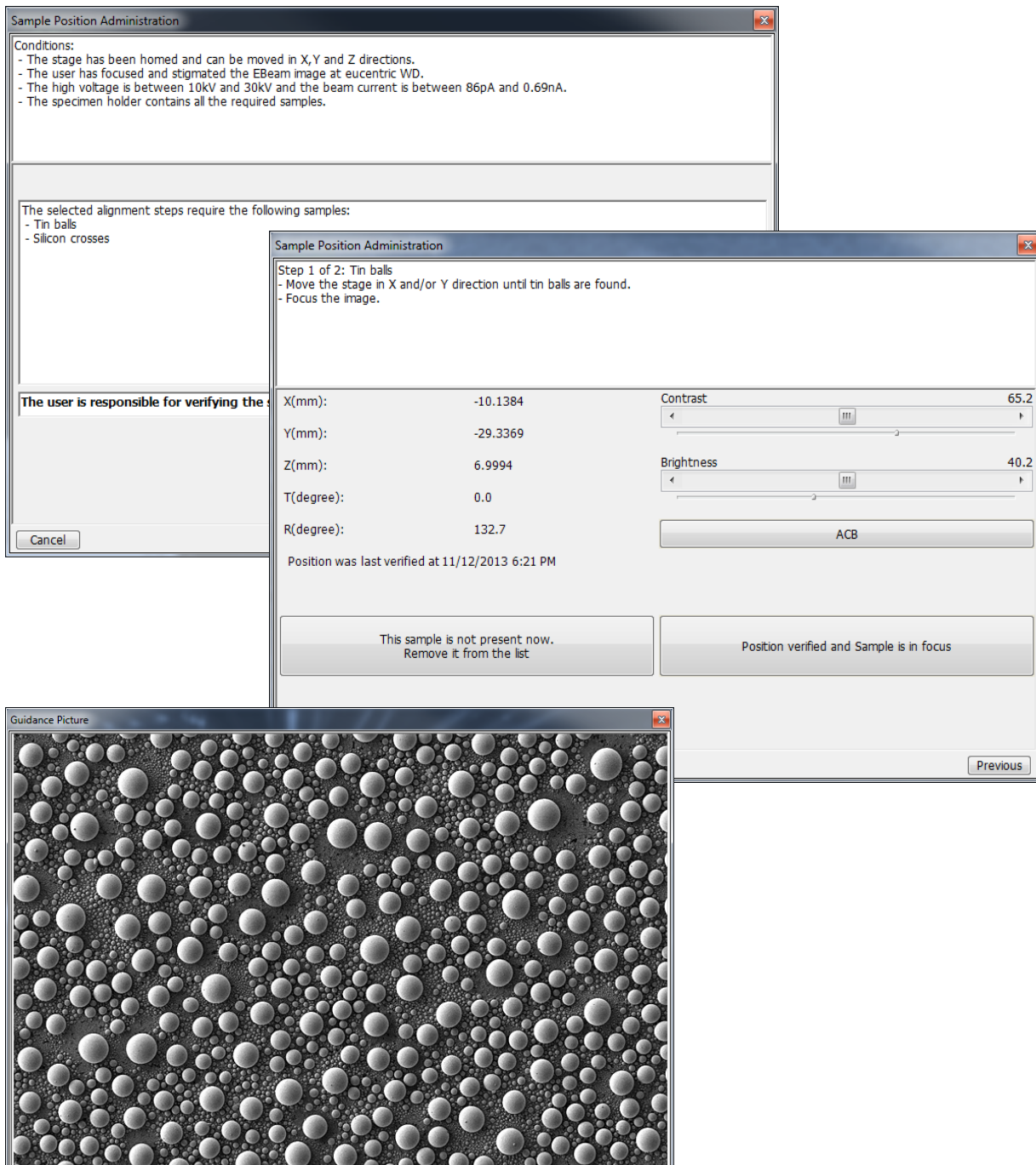
### Aperture Alignment

This procedure mechanically centers different electron apertures (on the aperture strip module) in the column.

### Source Tilt & Shift

This procedure takes from 2 to 3 hours and should be executed when necessary. It centers the electron beam in the column using three variables:

- *DPA* (Differential Pumping Aperture – separates high vacuum column part from chamber vacuum) – centers electron beam to pass through the column without any cutoff.
- *Tilt* – centers the beam on the optical axis.
- *Shift* – centers the beam on the center of the final lens.
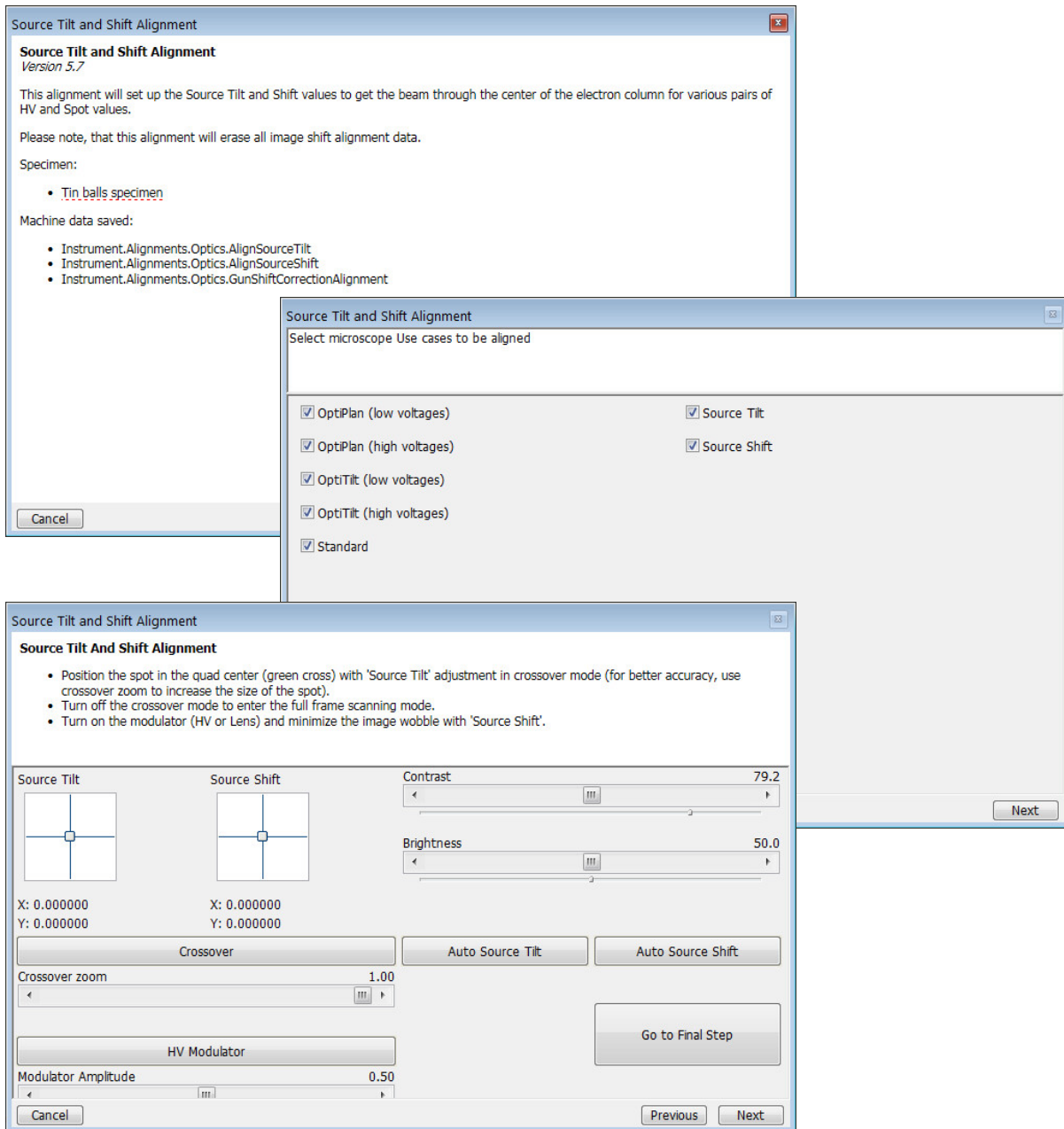
### *Image Shift*

Correct imaging shift when changing accelerating voltage and/or Use case.
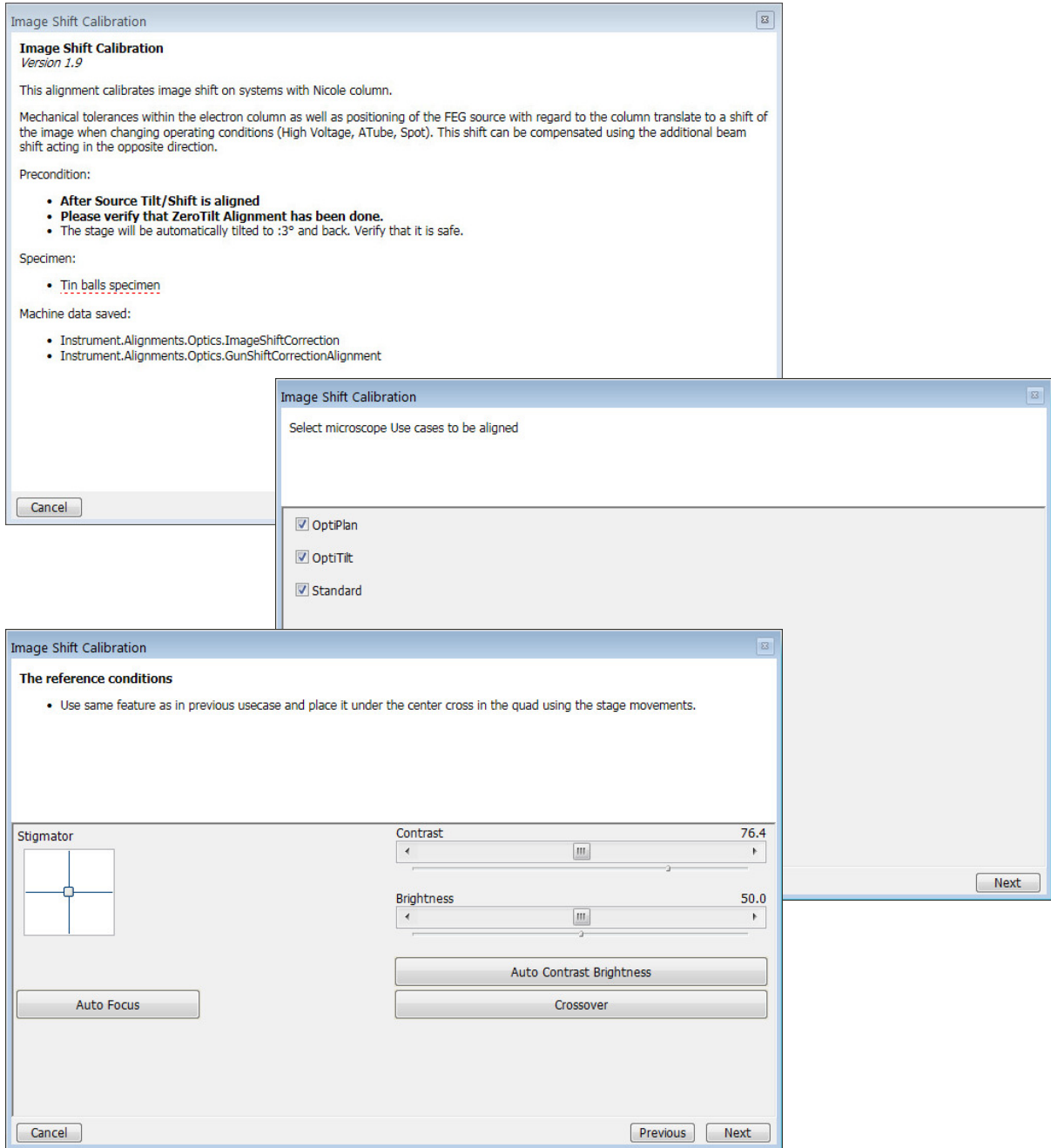
### Stigmator Alignment

Stigmator Centering

**Stigmator Centering**
*Version 0*

This alignment aligns stigmator centering for the whole microscope.

Specimen:

- Tin balls specimen

Machine data saved:

- Instrument.Alignments.Optics.StigmatorPreValueCross
- Instrument.Alignments.Optics.StigmatorCenterXPreValueCross
- Instrument.Alignments.Optics.StigmatorCenterYPreValueCross
- Instrument.Alignments.Optics.DStigCenterXDGunShiftXCross
- Instrument.Alignments.Optics.DStigCenterXDGunShiftYCross
- Instrument.Alignments.Optics.DStigCenterYDGunShiftXCross
- Instrument.Alignments.Optics.DStigCenterYDGunShiftYCross
- Instrument.Alignments.Optics.StigmatorXPosCenter
- Instrument.Alignments.Optics.StigmatorYPosCenter
- Instrument.Alignments.Optics.MaxMagneticIndInDipoleXCoef
- Instrument.Alignments.Optics.MaxMagneticIndInDipoleYCoef

Cancel

Stigmator Centering

**Optimize the image**

1. Focus, lens align and stigmate the image.
2. Click the 'Next' button to continue.

Lens Alignment

Stigmator

Contrast                     78.7

Brightness                   50.0

Auto Contrast Brightness

Auto Focus

Auto Lens Align

Next

Stigmator Centering

**Stigmator Centering**

1. Align Stigmator Centering X and Y.
2. Use HFW at least 4μm.
3. Click the 'Next' button to continue.

Stigmator Centering X

Stigmator Modulator X

Modulator X Amplitude     1.00

X: 0.000000
Y: 0.000000

Stigmator Centering Y

Stigmator Modulator Y

Modulator Y Amplitude     1.00

Contrast                     78.7

Brightness                   50.0

Auto Contrast Brightness

Auto Stigmator Centering XY

Cancel                  Previous    Next

### Focus Centering
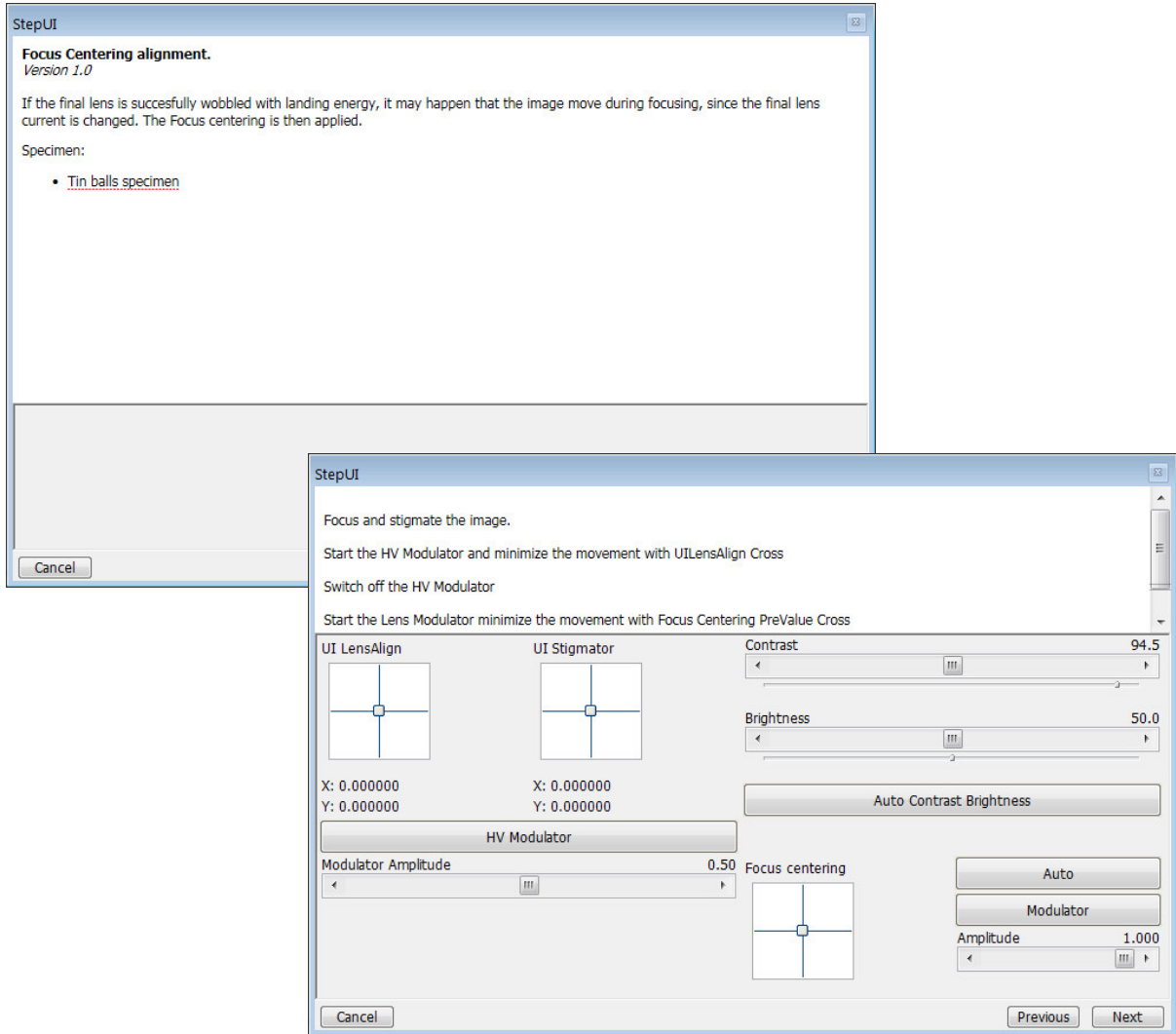
# 100 – ION: Source Control

This procedure enables to start and stop the Ion source emission, to monitor LMIS status, to heat the Ion Source in cases when ion source doesn't start, spontaneously switches off or was not used for longer time.



## Particular Control Elements

### *Ion Emission*

- *On / Off* button – starts / stops the ion source emission. The behaviour is similar to clicking on the Wake Up / Sleep button without influencing to the Electron source.

  *Note*
  *The ion source start procedure may not be successful at the first attempt. If this happens, try it again.*

- *Emission Current* slider – enables to set its size which is automatically maintained. Emission Current may be set before ion emission is started or directly during the ion emitting. Default emission current setting is 2 µA (the slider range is from 1.5 to 2.5 µA). After each UI or microscope server restart the default value is automatically set.

- *Gun Control Status* – possible states are: (Offline / Disabled / Idle / Maintain / Heating / Shutting Down)

### LMIS (Liquid Metal Ion Source) Heating

The Heat procedure is started by clicking on the *Heat* button. It is needed to supply the gallium to the emitting region of the ion source when:

- ion source is frequently spontaneously turning off
- suppressor voltage approaches + 2 000 V
- LMIS was exposed to air
- starting a new LMIS for the first time
- emission current is fluctuating

*Note*

*Heating is automatically done by Gun Control Steadfast Algorithm, so it is mostly not necessary to perform a manual heating by clicking on the Heat button.*

*Emission current stabilizes 2–4 hours after heating.*

*Heating causes gallium evaporation which reduces the LMIS lifetime.*

## WARNING!

**Beware of multiple manual heating in short time period! The LMIS may be damaged by such a multiple heating!**

### Ion Source Status

This module contains *Emission Current [µA]*, *Extractor* voltage *[V]*, *Suppressor* voltage *[V]* and *LMIS Lifetime [hours]* readouts.

*Note*

*LMIS lifetime counts all the time when LMIS emission is maintained (awake). The times when Beam is ON or OFF is irrelevant to LMIS lifetime.*

If very high Extractor voltage (up to 15 000 V) is needed for maintaining of ion emission and if this voltage doesn't decrease after heating, then the LMIS end of life was probably reached (the gallium reservoir is empty).

# I-Column: Aperture Management

This alignment procedure controls the ion beam aperture strip holes condition.

**Alignments**        ?

I-column: Aperture Management ▼

Aperture Management

Please turn on the beam so that current measurement functionality can work.

Click 'Next' when the ion beam is turned on.

---

**Alignments**        ?

Aperture Management ▼

Aperture Management

Beam energy is < 30 kV -- read energy: 500.

Beam must be on.

Set beam to 30 kV and click [Next].

---

Aperture Management

**Aperture Management**

- Disable apertures once they are eroded and the current exceeds the nominal current.
- When installing a new aperture strip, Click 'Reset lifetimes and enable all apertures' to reset all lifetimes and save a record of the old aperture strip use.

Click 'Finish' to exit.

| Name | Diameter | Lifetime | Nominal Current | Last Measured | Difference | Enabled | |
|---|---|---|---|---|---|---|---|
| | | | | | | | 1.5 pA / index: 0 ▼ |
| | | | | | | | Selected aperture |
| | | | | | | | Index: 0 |
| 1.5 pA | 8.0 µm | 0.0 s | 1.5 pA | 1.6 pA | 3.4 % | ☑ 0 | Diameter: 8.0 µm |
| 10.0 pA | 16.0 µm | 0.0 s | 10.0 pA | 10.0 pA | 0.0 % | ☑ 1 | Lifetime: 0.0 hr |
| 30.0 pA | 25.0 µm | 0.0 s | 30.0 pA | 30.0 pA | 0.0 % | ☑ 2 | Enabled: Yes |
| 50.0 pA | 32.0 µm | 0.0 s | 50.0 pA | 50.0 pA | 0.0 % | ☑ 3 | Live current: 1.7 pA |
| 100.0 pA | 42.0 µm | 0.0 s | 100.0 pA | 100.0 pA | 0.0 % | ☑ 4 | |
| 300.0 pA | 68.0 µm | 0.0 s | 300.0 pA | 300.0 pA | 0.0 % | ☑ 5 | |
| 500.0 pA | 87.0 µm | 0.0 s | 500.0 pA | 500.0 pA | 0.0 % | ☑ 6 | |
| 1.0 nA | 118.0 µm | 0.0 s | 1.0 nA | 1.0 nA | 0.0 % | ☑ 7 | |
| 3.0 nA | 198.0 µm | 0.0 s | 3.0 nA | 3.0 nA | 0.0 % | ☑ 8 | Last lifetime reset date: |
| 5.0 nA | 251.0 µm | 0.0 s | 5.0 nA | 5.0 nA | 0.0 % | ☑ 9 | |
| 7.0 nA | 294.0 µm | 0.0 s | 7.0 nA | 7.0 nA | 0.0 % | ☑ 10 | Reset lifetimes and enable all apertures |
| 15.0 nA | 420.0 µm | 0.0 s | 15.0 nA | 15.0 nA | 0.0 % | ☑ 11 | |
| 30.0 nA | 600.0 µm | 0.0 s | 30.0 nA | 30.0 nA | 0.0 % | ☑ 12 | Refresh measurements on all apertures |
| 50.0 nA | 750.0 µm | 0.0 s | 50.0 nA | 50.0 nA | 0.0 % | ☑ 13 | |
| 65.0 nA | 1.0 mm | 0.0 s | 65.0 nA | 65.0 nA | 0.0 % | ☑ 14 | |

Cancel        Finish

Cancel        Next

    **FEI**     *C O N F I D E N T I A L  –  FEI Limited Rights Data*

# I-Column: Manual Beam Alignment

The purpose of alignment is to position the beam through the column for maximum beam transmission with minimum beam aberrations, minimizing image motion when you change or wobble lens voltage.

---

**Alignments**   ?

I-column: Manual Beam Alignment ▾

I-column: Manual Beam Alignment

**I-column: Manual Beam Alignment**
*Version 1.1*

ION Beam alignment. Allows setup:

- Aperture Position
- Quad Steering
- Stigmator Sine
- Stigmator Cosine
- Stigmator
- Beam Shift

Click 'Next' to continue.

Specimen:

- Silicon crosses specimen

---

**Alignments**   ?

I-column: Manual Beam Alignment ▾

I-column: Manual Beam Alignment

**I-column: Manual Beam Alignment**
*Version 1.1*

**Preparation steps:**

- Set the Eucentric Working Distance
- Tilt the Stage to 52 deg
- Optimize the image with Focus, Contrast and Brightness
- Bring a recognizable feature under the center cross with the stage
- Select required High Voltage

You can also use buttons below to delete to previous values from tables.

After you choose required High Voltage you can Align conditions for each aperture index (selected in menu bar).

In-between saving/loading of the whole alignment table is possible by pressing the 'Save'/'Load' button.

*Note:* Aperture Position is available only for 30kV

Press 'Finish' to store all modified alignments.

| 30 kV |
|---|
| 16 kV |
| 8 kV |
| 5 kV |
| 2 kV |

Erase Tables

| Clear FIB Beam Shift Table |
|---|
| Clear FIB Stigmator Table |
| Clear FIB Stigmator Sin/Cos Table |
| Clear FIB Quad Steering Table |

| Save | Load |
|---|---|

---

**StepUI**   ⊠

**Beam Shift (8 kV, 0.5 pA, aperture index 0)**

Adjust Beam Shifts of all Beam Currents using the 30kV and aperture index #5 (counting from 0) as a reference

| Aperture Position |
|---|
| Quad Steering |
| Stigmator Sine |
| Stigmator Cosine |
| Stigmator |
| Beam Shift |

X: 0.000000
Y: 0.000000

Contrast    96.8
◄ � ►

Brightness    50.0
◄ information ►

Auto Contrast Brightness

L2 Correction    0
◄ information ►

---

# I-Column: Alignments
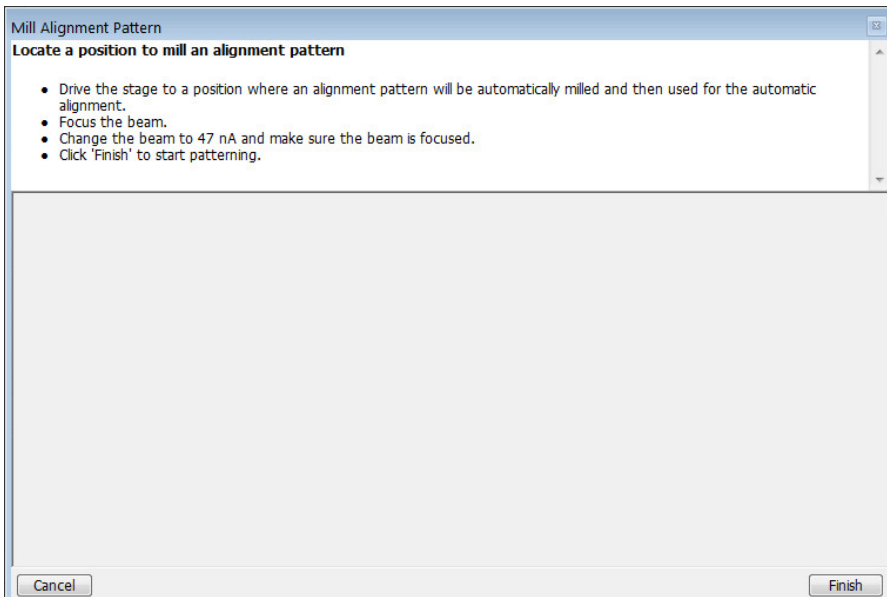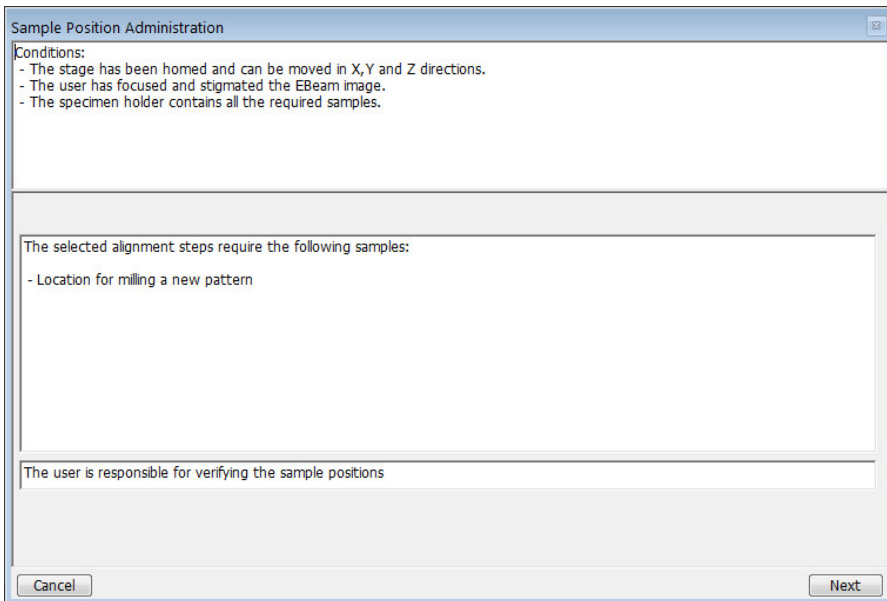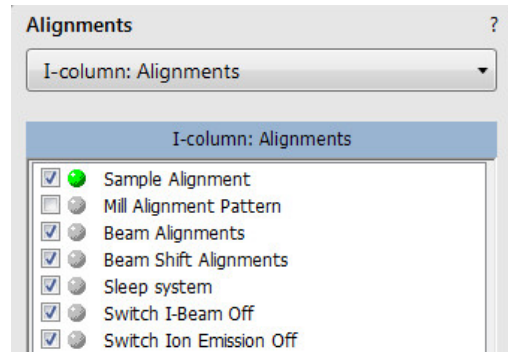
**Ion Column Alignment**

**Ion Column Alignment**

This alignment includes:

- Aperture Alignment (for 30kV)
- Quad Alignment (for less than 30kV)
- Focus and Stigmator corrections
- Stigmator Sin and Cos

Prepare the system for automatic alignment by setting the following conditions.

Instructions:

- Load the Graphite Sample.
- Move to the center of one of the graphite stalks.
- Set sample height to eucentric, and tilt stage to 52 degrees.
- Select CDEM or ICE detectors, if unavailable select the ETD.
- If using a dual beam system align the index aperture used for I-column to E-column coincidence point.

The alignment may be run in a Manual mode, or fully Automatic mode. To run in automatic mode from any point, check the Automatic box on the bottom-right corner and click next.

☐ Clear tuning data (for source replacement)

Cancel

**Ion Column Beam Shift Alignments**

Ion Column Beam Shift Alignments - System setup

Prepare the system for automatic alignment by setting the following conditions.

Instructions:
- Load sample.
- A sample with lots of non-periodic information works best.
- Graphite stalks work well.
- If using a dual beam system align the index aperture used for I-column to E-column coincidence point.
- For single beam systems, set sample at eucentrick.
- Select 512x442 resolution

(Dwell time and magnification will be set automatically.)

☐ Sleep system at end

Cancel                                                                 Next

**Sleep system**

**Sleep system**

☐ Sleep the system

Check the box to sleep the system and click 'Finish'.

Cancel                                                                 Finish

# Stage Alignments

The set of stage alignments allows complete adjustment of the stage and the universal holder.
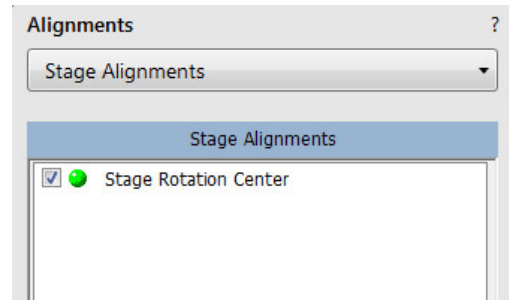


***Stage Rotation Center***

The stage rotation has a mechanical center and it is controlled by the *Stage* module / *R* value: the stage moves around its mechanical center. In some cases this is not desired because a rotation around the field of view center would be more useful – use this alignment to set this situation.

Make sure the stage tilt is zero during alignment. The magnification should be from 500× to 2 000× and the sample should have a well recognisable feature at least 10 mm from the center to improve accuracy.
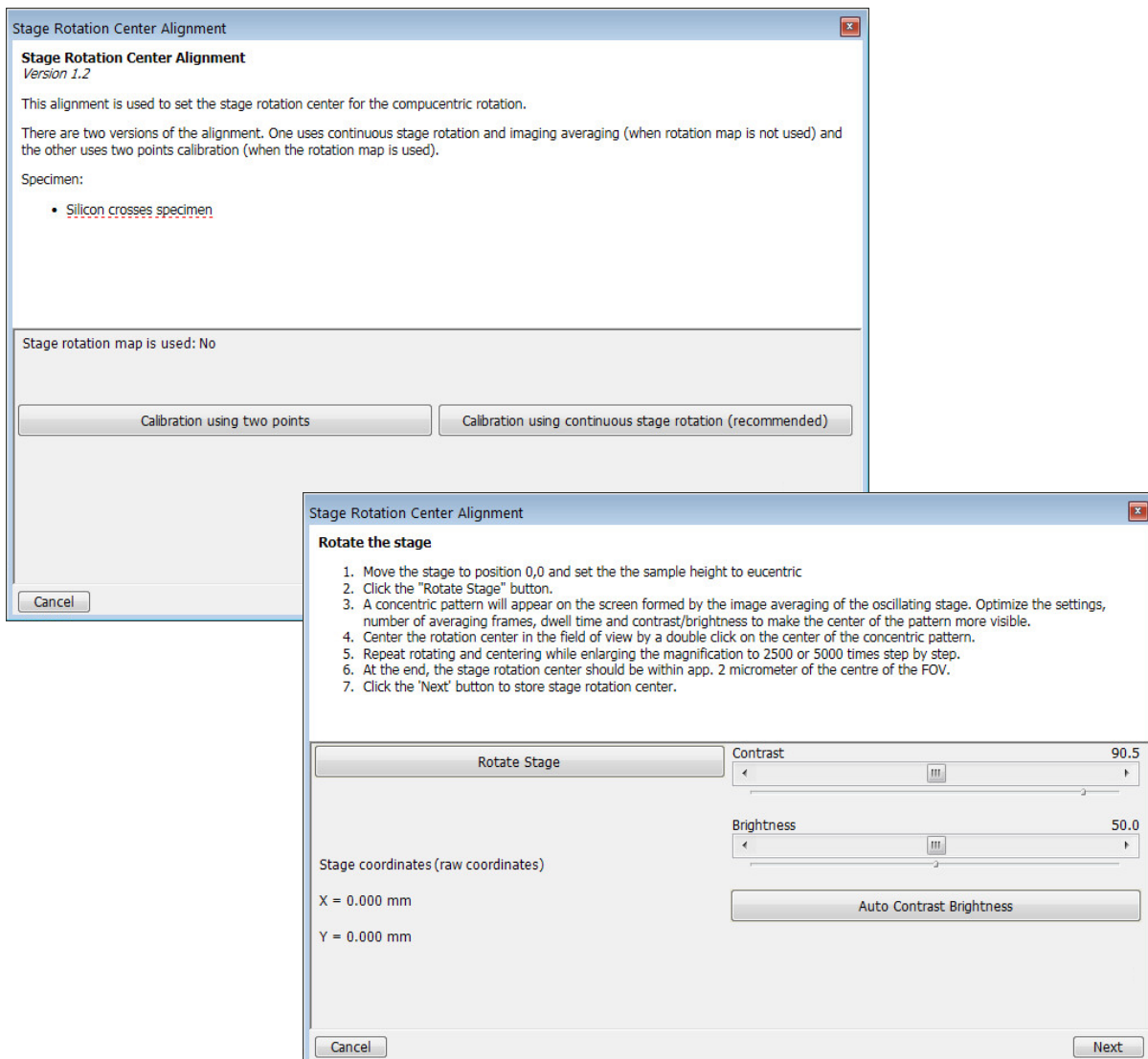
# 154 – Water Bottle Venting

See Chapter 6.

| Alignments | ? |
| --- | --- |
| 154 - Water Bottle Venting ▼ | |
| | Start |

**Instructions**

This procedure vents the water bottle to allow refilling.

No step

| Alignments | ? |
| --- | --- |
| 154 - Water Bottle Venting ▼ | |
| | Finish |

**Instructions**

Click the button to vent the water bottle.

This action connects water bottle to auxiliary gas inlet for a while.

Step 1 of 1

Vent water bottle

Cancel

# Plasma Cleaning / External Plasma Cleaning

When repeated *Tools* menu / *Sample Cleaning* procedure is not effective, click on the *Start / Stop Chamber Cleaning* button to start / stop the procedure, *Duration* of which is much longer.

If longer plasma cleaning time is needed it is recommended to use several shorter plasma cleaning cycles separated by pumping the chamber down to HiVac mode. Residuals created during plasma cleaning are pumped away and following plasma cleaning is more effective. Adjust the *Cycle duration*, *Clean cycles* and *Pumping time between cycles*.

*Note*

*If there is an external Evactron plasma cleaner, follow the External Plasma Cleaning alignment instruction and the Evactron user manual!*



**WARNING!**

*Do not use Chamber cleaning when the EDS / WDS / EBSD system is mounted! If you need to clean the system with EDS detector mounted, use 1 mm collimator and do not exceed 30 minutes once a week at most.*

*Do not exceed 30 minutes of chamber cleaning once a week at most when the DBS detector is installed.*

*Do not leave sensitive samples (including Au-C resolution test samples) in the chamber during Chamber Cleaning (they may be damaged).*

# Pump Buffer

The vacuum buffer is automatically pumped down after a specific time interval (5 hours approximately) and it can harm the highest image quality. To prevent this behaviour, user can run *Pump Buffer* alignment in advance (it takes about a minute) and start image acquiring after the buffer is pumped down.
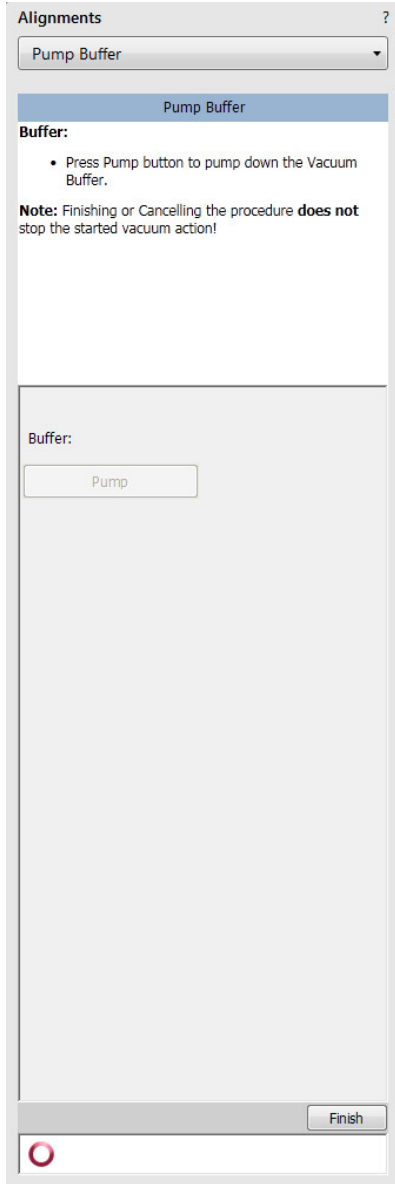
# Vacuum Actions

- Start / Stop IGP's
- Pump / Vent Actions

# 254 – GIS Alignment (option)

The *Valve Open Time* and the *Heat Time* items show operation periods for an installed GIS at *Port #*. Click on any of the *Lifetime reset* buttons to reset a corresponding GIS lifetime records.

Change target crucible temperature for a particular GIS by the *T* slider.

The *Heat / Open / Insert* Needle buttons are used for service operations. The *Working Temperature* unit varies according to *Preferences / Units* setting, but the Actual Temp. unit is always °C.

**5**

<div align="right">

*Operating Procedures*

</div>

This chapter describes how to use the Microscope system from an application point of view. The following subjects are covered:

- Specimen preparation and handling
- Optimizing imaging
- Standard detectors
- Capturing and handling a Single image
- Recording movies (saving multiple images)
- Stage control
- Measurement and annotation functions
- Patterning & milling

*C a u t i o n !*
*These procedures assume you are familiar with the xT microscope Server and Microscope Control software (see Chapter 3), which are necessary to start and operate the microscope.*

# Specimen Preparation and Handling

The sample material must be able to withstand a high vacuum environment without outgassing. It must be clean and conductive. Oil, dust, or other materials may cause sample charging or contaminate the chamber, which could hinder or even prevent evacuation.

*Note*
*Always wear lint- / powder-free clean room gloves when manipulating inside the specimen chamber to minimise oils, dust, or other contaminants pollution of the chamber environment.*

## Needed Items

- Class 100 clean-room gloves
- Specimen stubs and conductive adhesive material
- Tweezers
- 1.5 mm hex wrench
- Prepared sample

## 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.

## 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 makes the imaging sharper and reduces beam penetration. 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*, 3rd ed. by Joseph Goldstein et al., Springer, 2003.

## Mounting Specimen on 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 or silver paint. The specimen must be electrically grounded to the sample holder to minimize specimen charging. If you are using another way to mount a specimen, 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 allowing to measure the specimen current.*

*C a u t i o n !*
*Store samples and sample holders in a dry nitrogen storage cabinet. Dust on samples can get drawn into the electron / ion column, degrading performance and requiring a FEI authorized service engineer to correct a problem.*

## Specimen Baking Unit

The Specimen baking unit is intended to bake out the microscope specimens (up to 60 mm diameter) mounted on the specimen holders.

### *Caution!*

*Read and follow all following instructions carefully!*

*Read and follow instructions stated in the FEI Microscope Systems Safety Manual carefully! (installed with your Microscope control software)*

*Place instructions in a safe place for future reference.*

*Note the safety labels and engravings on the baking unit, read them and be careful to understand their meaning!*

*Do not allow anyone who has not read and understood these instructions and who cannot follow them to operate and / or service the Specimen baking unit!*

*Failure to comply with the precautions and instructions provided with this unit, can result in bodily injury and property damage from hazards of fire or burn.*

### *WARNING!*

*Do not leave the unit unattended when it is ON!*

*Do not open the lid when the unit is ON! Be extremely careful to avoid bodily injuries from burning.*

*When opening / closing the lid always use the plastic knobs, otherwise there is risk of burning!*

*When replacing the halogen bulb always wear protective gloves and safety googles!*

### *Warranty disclaimer*

*The unit must not be used for any other purposes than it is intended to otherwise the warranty claims cannot be accepted.*

**FIGURE 5-1** *Baking unit / Baking unit with opened lid*
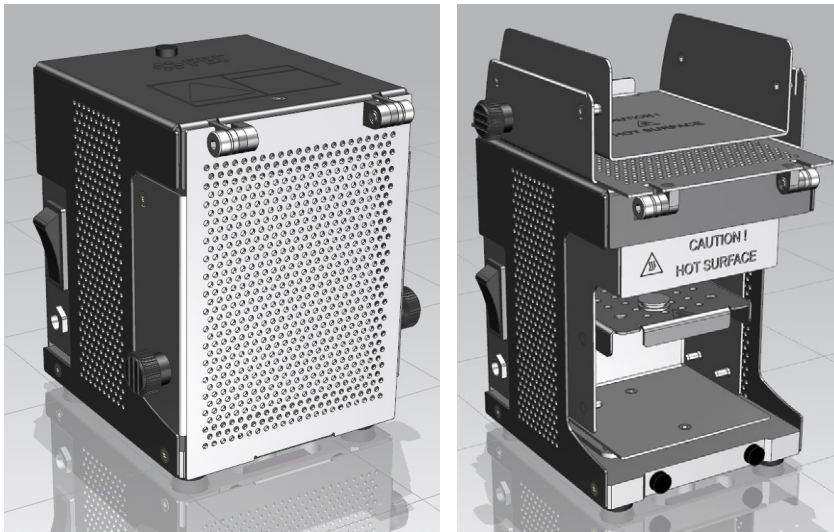


### Installation instructions

The unit should be placed away from the flammable materials.

Do not put any objects on the top side of the unit – the unit becomes warm when in operation.

The unit is supplied with the voltage 12 V DC. The adaptor has a replaceable plug to fit in various mains sockets. Connect the supply voltage cable connector to the unit and plug the adaptor to the mains voltage 110–230 V AC.

**FIGURE 5-2**  *Power supply adaptor with removed plug / with mounted plug*



## Operation

The inner surface of the unit is polished and vacuum-clean. Avoid contamination of the inner surface otherwise the specimens may become contaminated during the baking cycle.

### *C a u t i o n !*

*Always wear clean lint-free gloves when handling the unit and the specimens! Be sure the working desk is free from impurities that can cause the unit or specimen contamination.*

*The working desk must be covered with a material with a melting temperature higher than 250 °C!*

### *W A R N I N G !*

*Do not look directly at the operating bulb for any period of time! This may cause serious eye injury.*

*For support tray manipulation (sample loading for instance) always use the special tool delivered! Risk of burning!*
*Never touch the inner surface of the baking unit including the trays and specimens with bare hands or hands in gloves.*

**FIGURE 5-3**  *Support tray Handling tool / Removal of Support tray*
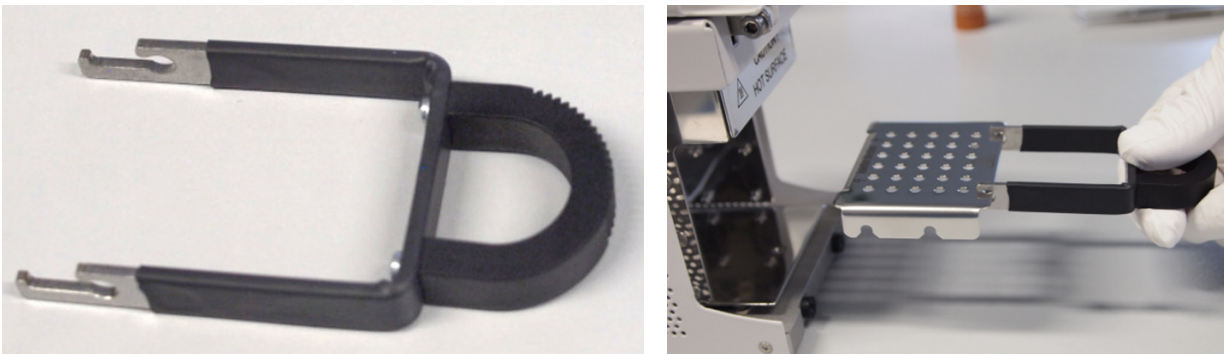


1. Open the lid and remove the support trays from the unit using the special tool.
2. Put the support tray on the working desk and put one or more specimens on it so that the specimen stub pin enters the hole in the tray.
3. Put the tray back in the unit and close the lid.

   There are two possible slots for the tray insertion. The specimen will be exposed to the temperature of 160 °C in the upper position and of 120 °C in the bottom position.

**FIGURE 5-4** *Support tray mounting positions*
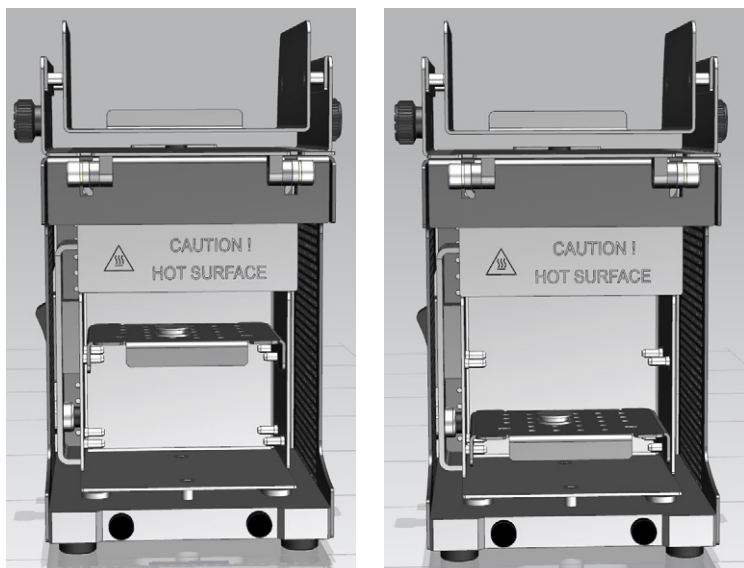


4. Press the rocker switch on the unit to switch the unit ON.
5. Wait at least 3 hours and switch OFF the unit by pressing the rocker switch.
6. Carefully open the lid, remove the tray with the specimens and put it on the working desk.
7. Carefully hold the specimen with a pair of tweezers and mount it in the microscope chamber while hot.
8. Start the pumping cycle right after mounting a sample into the microscope chamber.

   To make the baking process most efficient it is recommended to mount the sample in the microscope chamber immediately after the baking cycle was stopped. Let it cool down to the room temperature inside.

*Note*
*For high resolution observation, let its temperature stabilize for approximately 30 minutes.*

## Maintenance

The unit does not require any maintenance except of cleaning as necessary. When cleaning the unit use the vacuum compatible cleaning agents (isopropyl, ethanol) and lint-free tissues. The support tray can be cleaned in an ultrasonic bath.

### *C a u t i o n !*
*Do not clean the Baking unit in the ultrasonic bath!*

#### *Halogen bulb replacement*

### *W A R N I N G !*
*Bulb operates at extremely high temperatures that can cause serious physical injuries and property damage! Never touch bulb when it is on, or soon after it has been turned off, as it is hot and may cause serious burns!*

*When replacing the halogen bulb always wear protective gloves and safety googles!*

### *C a u t i o n !*
*Bulbs are very fragile, do not drop, crush, bend or shake them! Vibration or impact will cause filament breakage and short bulb life.*

*Do not touch bulb surface with your bare hands! Use clean gloves or lint-free cloth for installation and removal. Oils from skin can lead to breakage or shorten the life of the bulb.*

*Do not use other type of the bulb than specified as it can cause overheating of the baking unit or inefficiency of sample baking procedure.*

1. Press the rocker switch on the unit to switch the unit OFF. Wait until the bulb is cooled down completely.
2. Remove the bulb from the baking unit.
3. Insert the new bulb into the baking unit.

You can use spare bulb delivered together with the unit. Always use only bulb with the following specification:

| | |
|---|---|
| Type: | Low voltage halogen bulb, G4, 12V, 20W |
| Supplier: | OSRAM |
| Product ID: | 64428 |

# Microscope Control

It is assumed that the microscope is in the Full operation state (see Chapter 2).

## Operation Pre-Check

To ensure correct operation check the following list before continuing. After obtaining a preliminary imaging, you can then experiment with your own settings.

**Table 5-1**  *Scios Setup Conditions*

| Adjustment | Electron Beam Setting | Ion Beam Setting |
|---|---|---|
| *Vacuum mode* | *High Vacuum*: conductive samples<br>*Low Vacuum*: nonconductive, mixed or contaminating samples | *High Vacuum* |
| *Column Use Case* | Standard | Standard |
| *Accelerating Voltage* | Select voltage relative to specimen type:<br>– low kV for surface imaging, beam-sensitive samples and slightly charging samples<br>– high voltage for conductors, high resolution, composite info (BSE, X-ray)<br>For example:<br>– biological sample HV = 1–10 kV<br>– metal sample HV = 1–30 kV | 30 kV for imaging, milling, depositing<br>5 kV for cleaning<br>5–10 kV for large field of view |
| *Beam Current Spot size* | 100 pA at 30 kV<br>*High Vacuum / Low Vacuum*: 5–6 | 100 pA at 30 kV |
| *Scan rate* | *High Vacuum*: fast scan (dwell time 0.1–0.3 μs)<br>*Low Vacuum*: slow scan (dwell time about 3 μs) | Fast scan |
| *Working Distance (FWD)* | Set the highest specimen point to approximately 7 mm, tilt to 0°<br>(yellow mark in an optical imaging display)<br>and press Ctrl + F (set FWD to 7 mm function). | Set the stage into the eucentric position and tilt to 52°. |
| *Eucentric Position* | 7 mm | 19 mm |
| *Magnification* | Set to lowest – from 20× to 200× | Set to lowest – about 210× |
| *Standard Detector* | *High Vacuum*: ETD (SE)<br>*Low Vacuum*: LVD / ICE (SE) | ETD (SE) / ICE (SE) |
| *Filtering* | *High Vacuum*: Average (2–4 frames for fast scans)<br>*Low Vacuum*: Live | Live |
| *Contrast and Brightness* | With contrast at minimum value adjust brightness to just show a change in intensity to the screen. Increase the contrast to produce a reasonable imaging. Increasing brightness and decreasing contrast produce softer imaging and vice versa. | See Electron beam setting |

## Inserting / Exchanging Specimen

**1.** Click on the *Vacuum* module / *Vent* button. The confirmation dialog appears.

After switching a High Voltage off, the vacuum system switches off the pumps and opens appropriate valves to vent the system. After a specified venting time the venting valve will close.
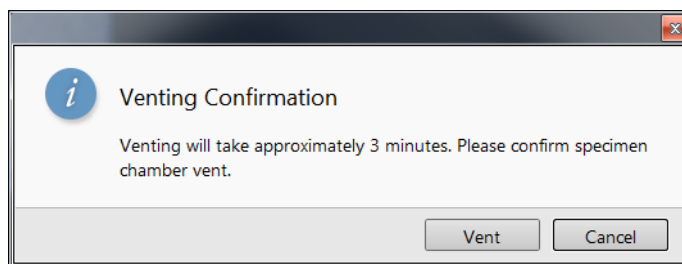
*Note*

*If the venting valve closes before the chamber is at the atmospheric pressure (the door is not possible to open), click on the Vent button once more to open it again.*

**2.** When vented, open the specimen chamber and, using lint-free gloves or tweezers, place a specimen into the specimen holder.

**3.** Close the specimen chamber door and click on the *Vacuum* module / *Pump* button.

Instructions for a sample exchange are also shown within the informational window by clicking on the toolbar icon.

## Selecting Vacuum Mode

When a specimen and appropriate detector(s) are installed correctly, continue the procedure (see above):

**4.** Check the *High Vacuum* module / *Low Vacuum* or *High Vacuum* mode radio button.

For the Low Vacuum mode select the appropriate gas from the drop down list and the target *Chamber Pressure* that the system pumps to.
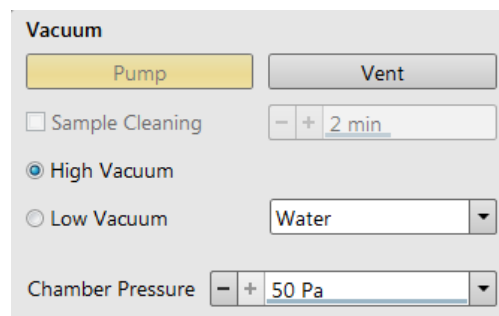
### *W A R N I N G !*

*The system can be damaged by using the Low Vacuum mode without an appropriate PLA. Do not select a PLA Cone which is not actually used (see Chapter 2)!*

### X-Ray Cone Mounting / Dismounting Procedure

Under normal operation, the system will know the PLA cone size for the detector installed in the LoVac mode. This will allow the system to set automatic pressure range limits for the aperture installed, thus avoiding vacuum errors when setting chamber pressure.

For the optional *GAD cone* – see Chapter 7.

The X-Ray cone is stored in the provided installation tool. The large arresting screw releases working part so it can slide along the skid. A little spring is a conductive contact with the final lens pole.
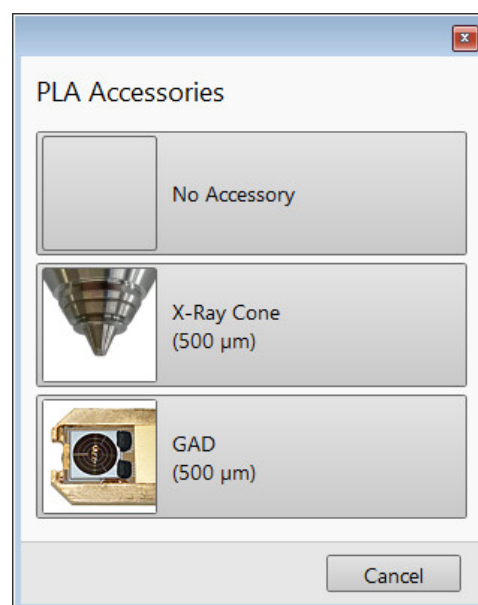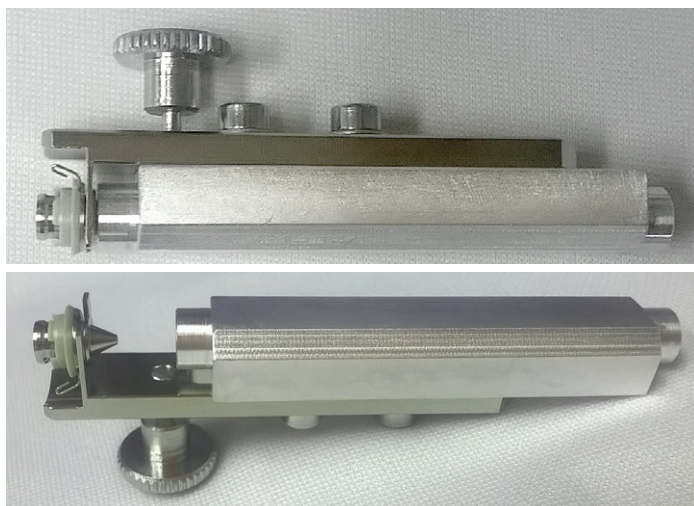
**FIGURE 5-5** *X-Ray Cone mounting Procedure*



**5.**    **6.**    **7.** **X-Ray cone installed**

To mount the *X-Ray Cone* follow the procedure:

**5.** Push the cone attached in the tool to the final lens pole in its axis direction.

**6.** Release the arresting screw, slide the working part down and pull the tool to the side.

**7.** Turn the tool by 180° and push the cone again to ensure it is sealed well.

To dismount the cone follow steps 5. and 6. in reverse.

*Note*
   *Do not touch the cone or the mounting tool by hand. Store it attached to the mounting tool in a clean plastic bag.*

**8.** Select an appropriate cone and click the *Vacuum* module / *Pump* button. While pumping, choose the highest specimen point and bring it to the 7 mm Working Distance (yellow line in CCD display).

## Imaging Onscreen

Continue the procedure:

**9.** When the vacuum status is PUMPED (see the *Status* bar), click on the *System* module / *Wake Up* button to ramp up the electron / ion beam acceleration voltage.



**10.** Select an appropriate column Use case and the detector and resume the active display, where an imaging appears.

**11.** Focus the imaging and *Link Z to FWD.*    

**12.** Adjust to a suitable magnification, optimize the imaging using the *Contrast & Brightness, Focusing, Astigmatism Correction* etc.

# Optimizing Imaging

## Principles of SEM Imaging

All scanning beam microscopes show with the same fundamental technique. The primary beam is scanned across the specimen surface in a regular pattern called 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. 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 shown 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 shown 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 an image.

## Magnification

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

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

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

**FIGURE 5-6** *Scanned sample and monitor imaging*
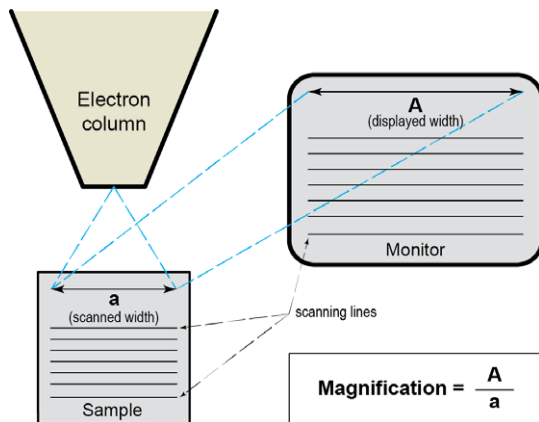


### Changing Magnification

- *Toolbar* list box – used to select from predefined values
- *Keyboard* control (+ / - / *) – the numeric pad plus key (+) / the minus key (-) increases / decreases the magnification 2× and rounds the value. The star (*) key rounds the magnification value (e.g. 10 063× becomes 10 000×).
- *Mouse wheel* control – coarse / fine control can be operated by the Ctrl / Shift key and rolling the mouse wheel up / down to increase / decrease the magnification.
- Selected Area Zooming In / Out – a quick way of zooming in / out on an area of interest. Click on inside the imaging area & drag to make a dotted box over the area of interest (the cursor changes to a magnifying glass with a + sign). Release the mouse button and the selected area increases to fill the whole imaging area with respect to the sides ratio. Clicking on & dragging + Shift consecutively reverses the above described technique (the cursor changes to a magnifying glass with a - sign). The *Esc* key cancels the operation at any time.
- *Magnification* module
- *Digital Zoom* module

## Scan Speed

To obtain a good imaging with acceptable signal to noise ratio it is necessary to find a balance among scan speed, sample charging and/or damage.

A noisy imaging can be improved by decreasing the scan speed. If sample charging and/or damage is the limiting factors it is better to use a higher scan speed in a combination with noise and charge reducing tools, like *Average* or *Integrate* filter, *Line Integration*, *Scan Interlacing*.

## Contrast & Brightness

The contrast & brightness can be set manually either by adjusting the *Detectors* module controls, using the mouse (Ctrl + click on & dragging – horizontal / vertical direction adjusts the contrast / brightness) or using the MUI (option):



1. Select a medium scan speed in an active display.
2. Reduce the contrast to zero. Adjust the brightness to a level corresponding with the last grey level detectable by eye before the screen goes black.
3. Increase the contrast unless the imaging of the observed structure appears.
4. If necessary, adjust the brightness level to improve the imaging.
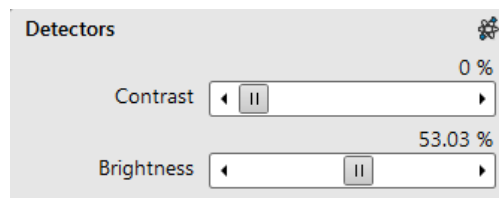
### Videoscope (F3)

This tool can facilitate contrast and brightness optimization to utilize full greyscale imaging range.

Three yellow horizontal lines (placed over the display) indicate white (top line), grey (middle line) and black (bottom line) levels. The oscillogram signal amplitude / central position reflects the contrast / brightness of the just scanned line. If the oscillogram is cut by the bottom / top line, the signal level is clipped in black / white. This should be avoided because the imaging details are lost in the clipped areas.

Tuning the oscillogram exactly between the top and bottom lines for a feature of interest (with the use of the reduced area) results in the full detailed imaging. The signal clipping may be used to obtain harder contrast conditions when more black and white is needed. The signal amplitude lowering decreases the contrast, i.e. the imaging looks softer.

1. Select a slow scan in an active display.
2. Activate the Videoscope in an active display (F3 / clicking on toolbar icon / Scan menu) or in all live displays (Shift + clicking on toolbar icon).
3. Reduce the contrast to zero and adjust the brightness level to the lower dashed line (black).
4. Increase the contrast so that the signal level just touches the upper dashed line (white).
5. If necessary, adjust the brightness level so that the average signal level is roughly in the middle.
6. The high and low peaks should just touch the dashed lines.

Repeating the contrast & brightness optimization helps to improve the imaging quality.

*Note*

*Use also the following functions to optimize the Contrast / Brightness: Auto Contrast Brightness (F9), Display Saturation (Shift + F11).*

## Focusing

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

1. When the mouse cursor is over an imaging area, *right-click on & drag* (the mouse cursor changes to a 2-ended arrow). Move the mouse from side to side until the selected object is sharp, then release the mouse button.

2. The focus function is active over the whole screen without any interference with other controls. If the full mouse motion is not sufficient to get the focus: release the mouse button at one side of the screen, move the mouse cursor to the opposite one and right-click on & drag again (over an imaging area) to continue focusing.

3. If necessary (for example when new specimen was loaded), run the *Link Z to FWD* function.

Focusing at a higher magnification makes the result more precise. For example, for an output at the 2 000× magnification focus at 4 000× – 8 000× magnification.

To avoid scanning too long and contaminating or even damaging the sample before you take the final image, move away from the feature of interest with the X and Y stage controls, and focus until the image is sharp on an adjacent area.

### 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: Reduced area (F7), Auto Focus (F11).*

## Correcting Astigmatism

This optical aberration is caused by different focal lengths for rays of various orientation, resulting in a directional imaging blur ("X and Y rays" are not focused to the same plane what is well visible on the edges of observed sample structures). Stigmator serves for correction of this imperfection, which is usually better visible at higher magnifications (3 000× or more).

When imaging conditions are changed, use the following procedure to correct an astigmatism:

1. Focus an image.

2. Bring the imaging just slightly out of focus. The imaging appears to become sharper in one direction whereas in perpendicular direction blur increases (blurring or stretching).

3. Bring the imaging just slightly out of focus in the other direction to observe the opposite directional blur.

4. Focus to the midpoint between the two directions, where the blur is visible.

5. Use the *Beam* module / *Stigmator* 2D control.

    The *Mouse*: shift + right-click on & drag while in the selected display. This results in a 4-ended arrow cursor appearing in the screen center. Move the cursor around the screen to achieve maximum sharpness. When you are satisfied, release the mouse button.

    The *MUI* (optional): adjust imaging sharpness with the stigmator *X* and *Y* knobs until the best result is achieved.

6. Repeat steps 1–5 as necessary.

If astigmatism is severe and the cross is close to the edge of the screen when nearing correction, release the mouse button and reposition the cross in the centre of the screen. Then repeat the procedure above to perform further astigmatism correction. You can use reduced area advantageously.

If astigmatism cannot be corrected, there may be some other reason, usually the final lens aperture is dirty (see Chapter 6), the magnification may be too high for the beam spot size or the sample is charging (apply conductive layer or use the Low Vacuum mode).

*Note*

*For normal astigmatism correction use the automatic procedure (Ctrl + F11).*

# Direct Adjustments

This control page serves for fine-tuning the beam geometry to achieve the best focus and brightness.

## Electron Beam tab

- *Source Tilt* 2D box – serves for correction of signal intensity by changing an effective angle of the beam coming from the source into the electron column.

  Move the crosshair in order to get the electron beam spot into the display center.
- In the *Crossover* mode (activated with the button) the imaging shows the electron source position instead of the sample surface.
- *Crossover Zoom* slider – set the Crossover image magnification.
- *Lens Alignment* 2D box – optimizes the primary beam passage through the final lens so the image shift during focusing is suppressed.

  Try to minimize the image shift by the crosshair movement.
- *Lens Modulator* (useful for HV > 3 kV) / *HV Modulator* (useful for HV ≤ 3 kV) button – starts automatic objective current / accelerating voltage oscillation (periodically under- and over-focuses imaging in a narrow range) to facilitate the above mentioned optimization.

  When the accelerating voltage is above 3 kV, Lens Modulator is automatically selected, otherwise the HV Modulator is. One can choose any one manually.
- *Amplitude* slider – sets the modulation amplitude.
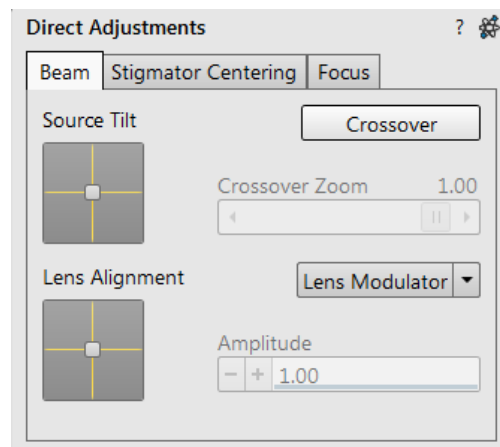
## Electron Stigmator Centering tab

- *Stig. Center X / Y* 2D box – serves for minimization of image shift during astigmatism correction. The crosshair indicates the actual stigmator setting.

  Try to minimize the image shift by the crosshair movement.
- *Modulator X / Y* button – starts automatic modulation of the respective stigmator to enable stigmator centering procedure. Modulation occurs in a narrow range around the current stigmator setting.
- *Amplitude* slider – sets the modulation amplitude.
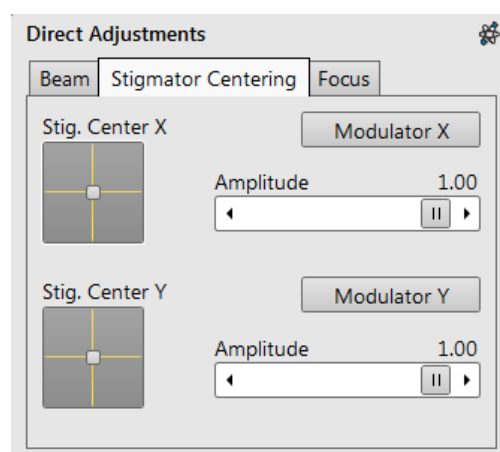
## Electron Focus tab

- *Focus Centering* 2D box – serves for minimization of an imaging shift during focusing if HV ≤ 3 kV. It is a complementary function to Lens Alignment and it is not applied for HV > 3 kV.

  Try to minimize the image shift by the crosshair movement.
- *Modulator* button – starts modulation of corresponding electron optical components to enable focus centering procedure.
- *Amplitude* slider – sets the modulation amplitude.
- *Apply Focus Centering* check box – if selected, the result of focus centering procedure is applied.

Note

*Ion beam Direct Adjustments are available only for accelerating voltages under 8.06 kV.*
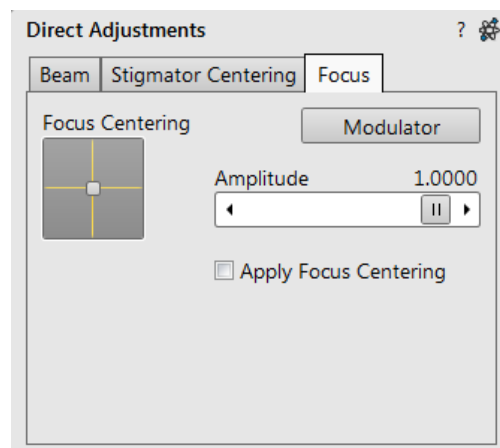
### Ion Beam tab

- *Quad* 2D box – serves for minimization of image shift during focusing.
- *L2 Modulator* button – starts automatic L2 voltage oscillation (periodically under- and over-focuses imaging in a narrow range) to facilitate the process.
- *Amplitude* slider – sets the modulation amplitude.
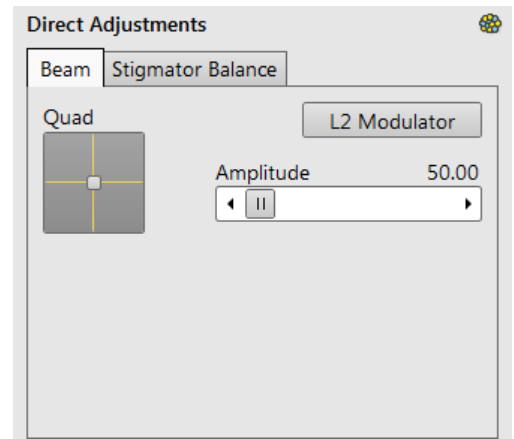
### Ion Stigmator Balance tab

- *Stigmator Sin / Cos* 2D box – serves for minimization of image shift during astigmatism correction. The crosshair indicates the actual stigmator setting.
  Move the crosshair to suppress the imaging shift.
- *Modulator Sin / Cos* button – starts modulation of the respective stigmator.
- *Amplitude* slider – sets the modulation amplitude.
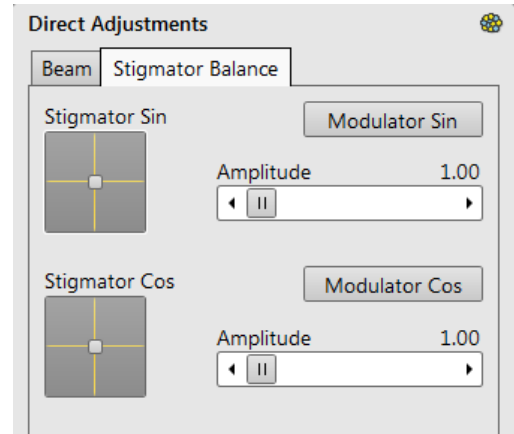
# Digital Imaging Enhancement / Imaging Mixing / Coloring

The Enhanced Image module offers various digital imaging enhancements.

Note

*When saving an image with the digital enhancements applied, be sure to choose the correct Digital file format (see further).*

### LUT (Look-Up-Table) tab Module

enables to monitor and modify a grey level distribution (histogram).



- *Presets* list box – enables to select the Digital Contrast, Digital Brightness and Gamma values using pre-defined or custom presets.
- *D. Contrast* adjuster – sets a digital contrast in the range from -10 to +10 (negative values lead to an inverse imaging).
- *D. Brightness* adjuster – sets a digital brightness in the range from -2.0 to 2.0.
- *Gamma* adjuster – corrects image brightness non-linearly in the range from 0.1 to 10.
- *Graph* area – graphically shows the applied modification via the grey line. Horizontal / Vertical axis represents the input / output values.
- *Auto Levels* button – sets automatically D. Contrast, D. Brightness and Gamma to optimize actual imaging.
- *Histogram* button – switches on / off the grey level distribution (corresponding to the active imaging) illustration. The left / right side corresponds to black / white original image pixels. The height of the blue line is proportional to the number of pixels with the corresponding grey level.
- *Save* button – saves the actual setting as the custom preset.
- *Default* button – restores the default values.
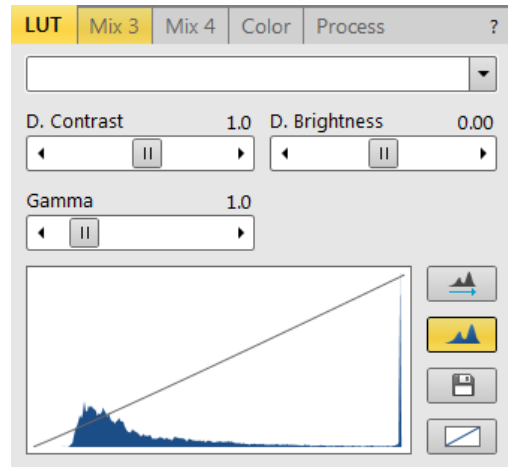
### Mix 3 / Mix 4 tab Module

The Mix feature operates in display 3 / display 4 and is automatically enabled when clicking the *1 + 2 / 1 + 2 + 3* button. Any combination of live and paused images can be mixed together, providing all mixed images have the same pixel resolution. However, there are some logical limitations and behaviours related to the Mix display:



- Average and Integrate filters are disabled.
- Pause / Activate functionality influences the mixed imaging only, not its sources. The Mix display is always paused immediately regardless of the actual scanning status.
- Optical imaging is not mixed.

Note

*In the Mix 3 tab the Source 3 controls and the 1+2+3 button are not available.*

- *1 + 2 / 1 + 2 + 3* button – switches on / off mixing of corresponding displays, also restores detectors or automatically selects suitable ones in appropriate displays.
- *Presets* list box – enables to select the mixing ratios and colors using pre-defined or custom presets.
- *Source 1 / 2 / 3* adjuster – tunes the mixing ratio of display 1 / 2 / 3 imaging. The adjuster % value influences correspondingly the resulting image and the other ones change automatically to reach the 100% sum.
- Clicking on the *Color* control areas (below each Source adjuster) enables to select a color, replacing the source image black (left) / white (right) one. The image grey scale is linearly transformed to a new color spectrum before it is mixed with other image(s).

Note

*Colorized imaging (see the Color tab) is converted to greyscale one before mixing.*

- *Invert* check box – inverts a corresponding source spectrum. It has the same effect as exchanging the left and right colors selection.
- *Save* button – saves the actual setting as the custom preset.
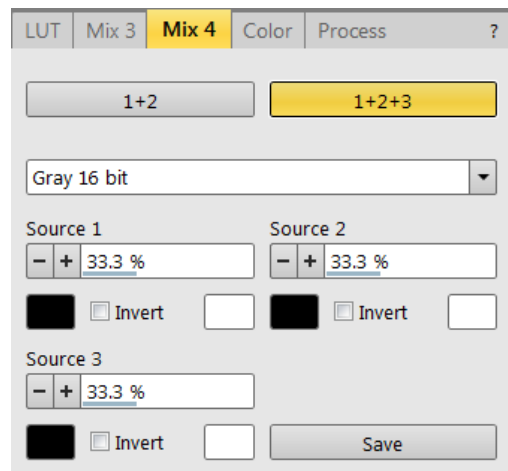
### Color tab Module

enables to colorize a grey scale imaging. An imaging already colored with the use of the Mix 3 / Mix 4 tab cannot be colored again, the Color tab is disabled.

- *Presets* list box – enables to select the color profile using pre-defined or custom presets.
- *Coloring Control* area – shows the selected imaging histogram and enables to edit a color profile.

  Clicking on the histogram area adds the vertical borderline with a divided triangle at the top (right-clicking on an existing one removes it). Clicking on & dragging a borderline changes its position along the histogram. Clicking on the left / right part of the triangle selects the left / right border color. The part of histogram between two borderlines is linearly transformed to a new color spectrum.

- *Reset* button – sets the modified color profile to its original state.
- *Save* button – saves the actual setting as the custom preset.
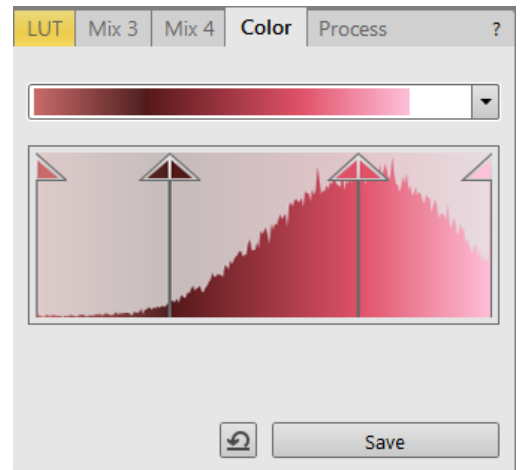
### Process tab Module

Here a user can set parameters, which adapt image when clicking on the *Apply* button, or when selecting the *Tools* menu / *Image Post Processing* (Ctrl + F7).

- *Denoising strength* (Off / 1 / 2 / 3 / 4) – determines the image noise suppression.
- *Sharpening strength* (Off / 1 / 2 / 3 / 4) – influences the image sharpness.

Changes in the *Custom #* presets are saved automatically.

*Note*

*This functionality works only with greyscale images (not colored via Color tab), images which are paused or with loaded saved ones.*
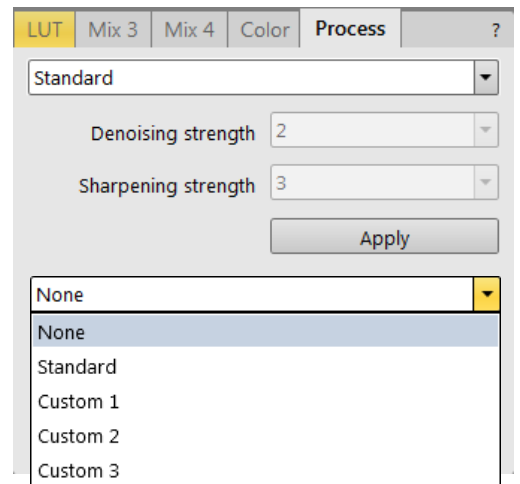
# Accelerating Voltage and Beam Currents

The choice of accelerating voltages – in the UI named High Voltage (HV) – and Beam Currents for the active display is possible via the toolbar dropdown list boxes and depends on the active beam type:

- For the *electron* beam, HV and current are independent, so any change of the voltage will not influence the current.
- For the *ion* beam, currents available are dependent on the HV selected; for example at 30 kV the current is 100 pA, however, the current reduces to 13 pA when the HV is set to 5 kV, even when used ion beam aperture remains the same.

### Changing High Voltage

Besides a normal list box behaviour an intermediate value can be entered into the toolbar editable HV text box or set by the *Column* module / *High Voltage* adjuster on the Beam control page. This provides a calculated range of beam current / spot values. Default values in the list box are set in the *Preferences* dialog / *Presets* section.
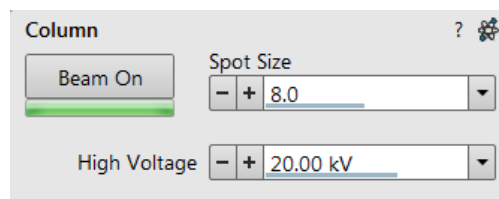
## Electron Beam Current

This is one of the basic operating parameters. In other way it is represented as the function of the electron beam diameter (usually presented as the *Spot* size, expressed by a relative number from 1 to 20 in the *Standard* Use case (depending also on the accelerating voltage) and from 2 to 18 in the *OptiPlan* and *OptiTilt* column Use cases), 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 5-2** *Spot sizes and recommendation of their use*

| SEM Column Use Case | Spot size | Best Use |
|---|---|---|
| *Standard / OptiTilt / OptiPlan* | *1–4* | Very low currents, charging and sensitive samples |
| *Standard / OptiTilt / OptiPlan* | *4–6* | High resolution |
| *Standard / OptiTilt / OptiPlan* | *6–12* | Standard imaging |
| *Standard / OptiTilt / OptiPlan* | *12 and more* | High current imaging, X-ray analysis with SDD detectors |

### Changing Electron Beam Current

Either electron *Beam Current* or *Spot Size* can be shown within the User Interface. This can be set in the *Preferences* dialog / *General* section or by right-clicking on the toolbar text box and selecting the desired context menu proposal.

An intermediate value can be set by the *Column* module / *Beam current/Spot size* adjuster on the Beam Control page. Default values in the list box are set in the *Preferences* dialog / *Presets* section.
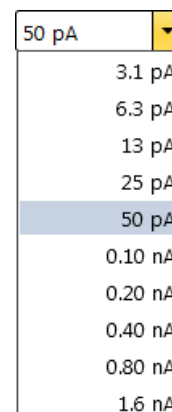
## Ion Beam Current

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

Use the following suggestions for choosing optimal ion beam currents:

**Table 5-3**    *General Ion Beam currents*

| Beam Current [pA] | Best Use |
|---|---|
| *1.5 – 10* | High resolution |
| *30 – 50* | Standard imaging |
| *> 100* | Milling |

| 65 nA |
|---|
| 1.5 pA |
| 10 pA |
| 30 pA |
| 50 pA |
| 0.10 nA |
| 0.30 nA |
| 0.50 nA |
| 1.0 nA |
| 3.0 nA |
| 5.0 nA |
| 7.0 nA |
| 15 nA |
| 30 nA |
| 50 nA |
| 65 nA |

### Changing Ion Beam Current

There are 15 possible beam limiting apertures and so are 15 ion beam currents, selectable from the toolbar list and from the *Column* module / *Beam current* adjuster on the Beam Control page. The current values and so the beam diameters depend on the accelerating voltage value (see the following table).

**Table 5-4**    *Ion beam diameters vs. HV and Ion beam current*

| 30 kV | 1.5 pA | 10 pA | 30 pA | 50 pA | 0.1 nA | 0.3 nA | 0.5 nA | 1.0 nA | 3.0 nA | 5.0 nA | 7.0 nA | 15 nA | 30 nA | 50 nA | 65 nA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 nm | 13 nm | 17 nm | 19 nm | 24 nm | 31 nm | 35 nm | 44 nm | 66 nm | 85 nm | 102 nm | 182 nm | 260 nm | 300 nm | 400 nm |
| 16 kV | 1.0 pA | 4.0 pA | 11 pA | 23 pA | 50 pA | 0.15 nA | 0.25 nA | 0.50 nA | 1.5 nA | 2.5 nA | 3.6 nA | 7.5 nA | 15 nA | 25 nA | 42 nA |
| | 12 nm | 19 nm | 25 nm | 29 nm | 34 nm | 45 nm | 54 nm | 66 nm | 93 nm | 113 nm | 130 nm | 240 nm | 343 nm | 395 nm | 527 nm |
| 8 kV | 0.5 pA | 2.0 pA | 6.0 pA | 12 pA | 25 pA | 75 pA | 0.12 nA | 0.24 nA | 0.75 nA | 1.2 nA | 1.7 nA | 3.5 nA | 7.5 nA | 12 nA | 20 nA |
| | 12 nm | 16 nm | 22 nm | 26 nm | 30 nm | 41 nm | 50 nm | 63 nm | 90 nm | 110 nm | 133 nm | 240 nm | 342 nm | 395 nm | 527 nm |
| 5 kV | 0.3 pA | 1.3 pA | 3.9 pA | 7.7 pA | 16 pA | 48 pA | 77 pA | 0.15 nA | 0.48 nA | 0.77 nA | 1.1 nA | 2.3 nA | 4.8 nA | 7.7 nA | 13 nA |
| | 20 nm | 27 nm | 35 nm | 41 nm | 48 nm | 67 nm | 80 nm | 96 nm | 143 nm | 179 nm | 207 nm | 373 nm | 532 nm | 614 nm | 819 nm |
| 2 kV | 0.2 pA | 0.7 pA | 2.1 pA | 4.3 pA | 8.9 pA | 27 pA | 43 pA | 86 pA | 0.27 nA | 0.43 nA | 0.61 nA | 1.3 nA | 2.7 nA | 4.3 nA | 7.1 nA |
| | 39 nm | 51 nm | 65 nm | 77 nm | 92 nm | 126 nm | 150 nm | 195 nm | 299 nm | 374 nm | 432 nm | 775 nm | 1.1 µm | 1.3 µm | 1.7 µm |
| 1 kV | 0.6 pA | 2.2 pA | 5.1 pA | 8.0 pA | 14 pA | 34 pA | 56 pA | 0.10 nA | 0.28 nA | 0.46 nA | 0.63 nA | 1.3 nA | 2.6 nA | 4.0 nA | 7.1 nA |
| | 47.9 nm | 68.9 nm | 90.2 nm | 105 nm | 126 nm | 182 nm | 223 nm | 290 nm | 469nm | 590 nm | 690 nm | 987 nm | 1.4 µm | 1.8 µm | 2.6 µm |
| 500 V | 1.5 pA | 6.1 pA | 15 pA | 24 pA | 42 pA | 0.11 nA | 0.17 nA | 0.31 nA | 0.83 nA | 1.3 nA | 1.8 nA | 3.7 nA | 7.5 nA | 12 nA | 21 nA |
| | 163 nm | 321 nm | 498 nm | 637 nm | 836 nm | 1.4 µm | 1.7 µm | 2.5 µm | 5.6 µm | 9.6 µm | 14.5 µm | 39.8 µm | 39.8 µm | 39.8 µm | 39.8 mm |

*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.*

# Column Use Cases

The electron column can be operated in different Use Cases optimized for specific applications. To select desired Use case use the toolbar / *Use Case* module drop down list box.

You can immediately switch from one Use Case to the other. If high voltage or beam current is out of the operating range of the new Use Case, it sets automatically to the closest possible value. If the newly set conditions do not allow imaging, (e.g. it is not possible to focus), transition is not allowed and warning is shown in the application status window.

In the *OptiTilt* and *OptiPlan* Use Cases primary electrons are accelerated by the potential of the Acceleration tube (A-Tube) and pass through the column at high energy. They are decelerated back in between the T1 detector and the sample. Secondary as well as backscattered electrons are also collimated into the final lens by the A-Tube electrostatic field and detected by the Trinity detectors (T1, T2, T3).

- **Standard**

  This is the survey and TEM sample preparation mode. It is ideal for navigating and reviewing sites at lower magnifications. The A-Tube is on the ground potential and the default detector is the ETD in the Secondary Electron mode. Maximum probe current is limited to 13 nA.

*Note*

*For detailed Cross section preparation workflow see the Help menu / User Guidance item / Cross Section preparation.*

- **OptiPlan**

  This mode is used for ultrahigh resolution electron imaging of the sample at short working distances (1 – 2 mm). The A-tube is at the highest potential and the T1 and T2 detectors should be used. Full range of the Beam Deceleration mode (if installed) is available for this Use case.

- **OptiTilt**

  The OptiTilt Use Case is optimized for operation at eucentric working distance. It is ideal for FIB cross section preparation and subsequent ultra-high resolution electron imaging at low accelerating voltages. The A-Tube is on the high potential, the T2 or ETD detectors are used to obtain topographical images and T1 to gain the composite information. Small positive stage bias to improve the image quality is applied automatically when the stage is tilted.

*Note*

*For detailed high resolution electron imaging see the Help menu / User Guidance item / High Resolution Imaging.*

### Model difference

The LoVac mode can be used only with *OptiPlan* and *Standard* Use Cases.
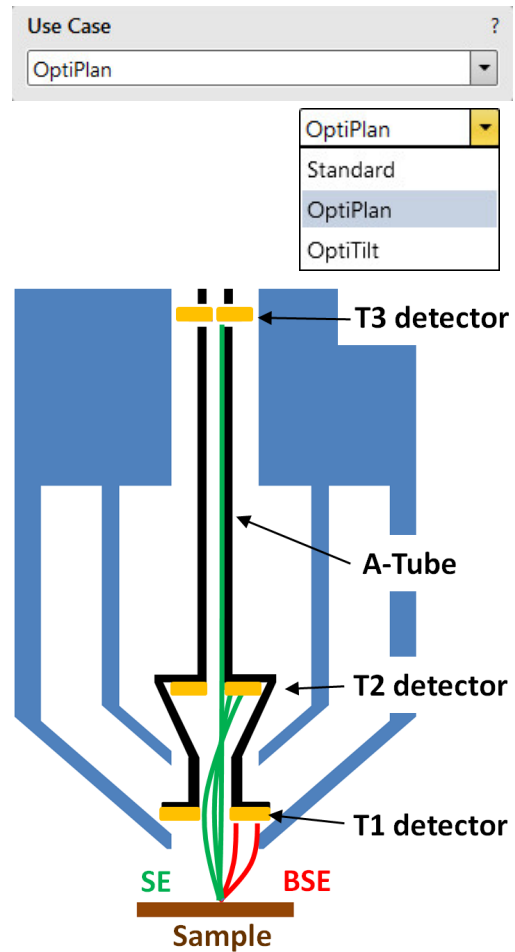
# Standard Detectors

The *Detectors* menu and *Detector Settings* module / *Detector* list box show all installed detectors, the selected one has a tick mark next to its label. When a *Detector Settings* module / *Mode* is selected, its acronym is shown beside the detector label in the Detectors menu. Availability of detectors (full color label) depends on the actual conditions.

Detector selection is related to the display and to the active beam – the system always reverts to the last detector used for that beam in that display and remembers its Contrast & Brightness settings.

In addition to the standard detectors available, there may be optional ones available for your system (see Chapters 2 and 7).

*Note*
*If any detector which is not compatible with the actual vacuum mode is selected, the imaging display cannot be activated.*

*Images from individual segments / detectors can be acquired simultaneously in up to four different displays.*

### C a u t i o n !
*When patterning or milling a large volume of material at higher ion currents, it is recommended to remove any detector if it is not used. There is a risk of its efficiency decrease by a material deposition.*

### W A R N I N G !
*To prevent stubbing with an EasyLift needle (option) follow the procedure described in the EasyLift section (see Chapter 7)!*
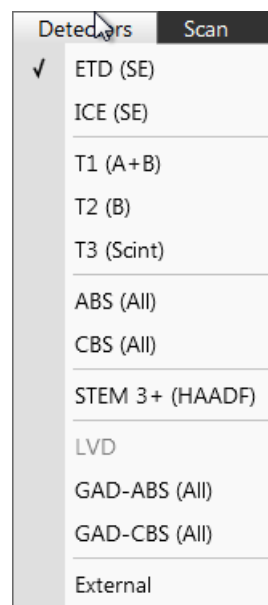
## Everhart Thornley Detector (ETD)

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 over and to one side of the sample. It works in *Mode*s:

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

**ETD Settings**

The *Detector Settings / Mode* list box enables to choose an *SE / BSE* mode (the *Grid Voltage* is set to +250 V / -150 V) or a *Custom* mode, for which the Grid Voltage can be set by the adjuster in a range from -240 to +260 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.
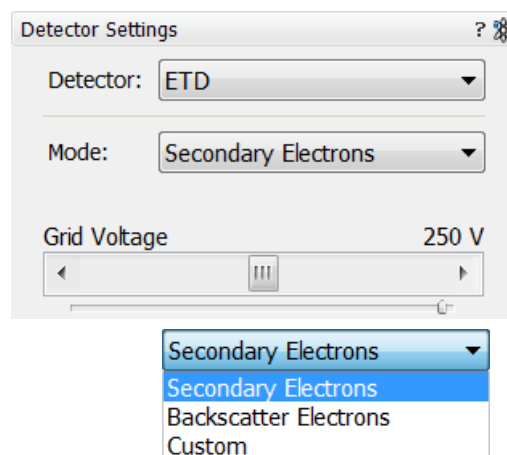
## Infrared CCD Camera

Imaging obtained with this camera assists in overall sample and stage orientation by viewing the inner space of the specimen chamber (an optical imaging display). It helps to protect the objective lens and retractable detectors against collision when moving (especially in the Z-direction) or tilting the stage. IR LED's are used to light the specimen chamber interior.

## Low Vacuum Detector (LVD)

This detector is standard and optimal for general imaging at Low Vacuum mode in the whole pressure range from 10 to 500 Pa (0.08 to 4 Torr), its signal contains both secondary and back-scattered electrons. It is installed permanently inside the chamber.

The LVD detector limits the field of view to about 1 mm at the 10 mm working distance. The minimum working distance is limited to about 3 mm.

| Detector Settings | ? |
|---|---|
| Detector | LVD ▾ |
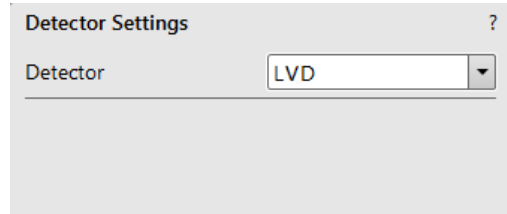
**FIGURE 5-7**  *Low Vacuum Detector (LVD)*



### LVD Settings

After pump down and purge process switch on the accelerating voltage. The modified Detectors module / Bias slider is automatically activated.

Adjust Bias if necessary to increase signal or to stop possible discharges. At the lowest possible magnification, adjust the Contrast and Brightness if necessary, until the bright circle of the LVD cone can be seen in the center of the image. Increase magnification and adjust Contrast and Brightness more precisely.

| Detectors | ? |
|---|---|
| Bias | − + 70.00 % |
| Contrast | − + 0.00 % |
| Brightness | − + 67.72 % |
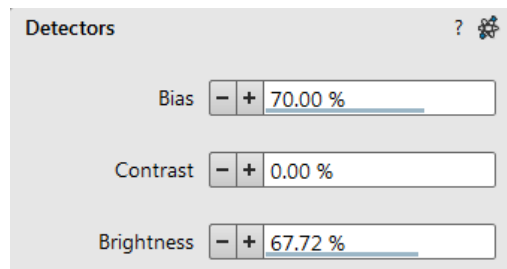
## Trinity Detectors T1 / T2

Electrons generated by a primary beam can be collected by the in-lens Trinity detectors T1 and T2, which are located inside the final lens.

*Note*
*Whenever the T1 or T2 is selected, the optical display is paused (the CCD camera infra-red LED's are switched off not to emit the photons supersaturating the detector).*

### T1

The T1 detector is primarily designed to collect backscattered electrons (BSE) and provides composite sample contrast. In the OptiTilt and OptiPlan column Use cases, it detects backscattered electrons through the whole range of accelerating voltages thanks to the A-Tube at high potential that accelerates the BSE towards the detector. In the Standard column Use case, the T1 provides strong BSE contrast at accelerating voltages of 5 kV and higher.

*Note*
*Use of the X-Ray Cone (see Chapter 2) blocks BSE to reach the T1 detector.*

The active detector area is split into two halves and the detector can be operated in four modes. Apart from the composite mode *A + B* the detector can be operated in the topographical mode *A - B*, where a pseudo-topographical imaging with suppressed atomic number contrast and maximum topographical contrast is obtained. Signal from each half can be also collected separately in mode *Segment A / B*.

### T2

The T2 detector is primarily designed to collect secondary electrons (SE) and provides information of the sample topography in the OptiTilt and OptiPlan column Use cases. Thanks to the high potential of the A-Tube, the SE are accelerated and collimated to the T2 detector. It can be operated with the grounded A-tube as well – Standard column Use case. In this case, backscattered electrons are collected, but the accelerating voltage must be 5 kV at least. Intensity of the signal in the Standard column Use case is dependent on the beam current and working distance – the higher the beam current and shorter the WD the higher the T2 signal.

## T3 (option)

Electrons generated by a primary beam can be collected by the in-column Trinity detector T3 which is located inside the column, just below the aperture strip (see Chapter 7).
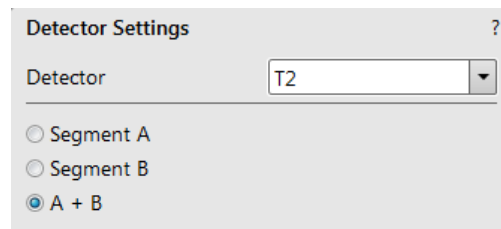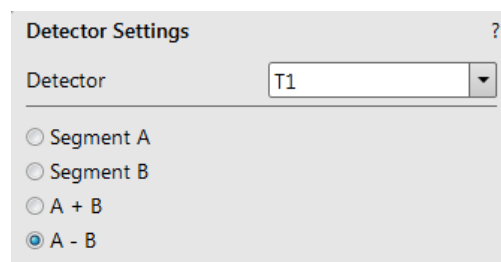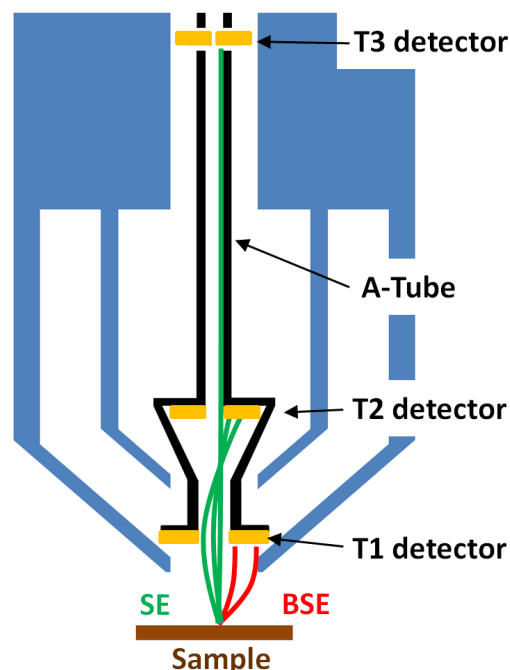
# Capturing and Handling Single Image

After acquiring a quality image, it can be paused (F6 or the toolbar icon) and saved (the *File* menu / *Save* item).

Setup the file name label and harddrive destination for the image to be saved using the next available label / number prior to the capture session. Set the databar information important for the archiving by right-clicking on the image databar.

The conditions for good image quality are:

- Slow scan speed (longer dwell time or fast dwell time together with line or frame integration) of the beam.
- Select a pixel resolution from the drop down list box to suit the detail in the image, i.e. no tearing pixelated edges.
- Move the stage next to the area of interest, increase the magnification at least 2× above the desired value, focus, correct the astigmatism and lens alignment (using the reduced area), then return the magnification and stage position back.
- Use the Videoscope to set the Contrast and Brightness accurately, otherwise use the Auto Contrast Brightness procedure.
- Use Pause / Snapshot / Photo / Scanning preset / filtering functions.

## Image Types

A computer perceives an image as a two-dimensional array of numbers – bitmap. Each array element is called a pixel and is represented as an integer value. Frequently, the pixel is represented as an unsigned 8-bit integer in the range [0, 255], with 0 / 255 corresponding to black / white and shades of grey distributed over the middle values. A 16-bit representation produces up to 65 536 different shades of grey (it is not possible to distinguish onscreen), which may be crucial for obtaining accurate data in analysis.

The raw scanned image is always a greyscale bitmap. The colors are possible to add digitally as a result of particular features. The UI is able to show and save images with a various bit depth:

- *Greyscale* 8 / 16 bit image – offers 256 / 65 536 levels of grey.

  Live / Averaged and Integrated images are scanned as 8 / 16 bit ones. For the Mix display images a selection between the 8 or 16 bit mode is possible.
- *Color* 24 bit image – offers 256 levels of each primary color (red / green / blue).

  Digital colors coming from the Display Saturation feature, Enhanced Image module / Color tab, Mix display with color mode set change an image bit depth so the image must be saved as a color one. When user wants to acquire the image without these color enhancements, it is necessary to turn off respective UI functions.

  An image is possible to be saved with / without colored digital overlaid graphics (Measurements, Annotations, Patterns, Videoscope) (see the respective checkbox in the Save As dialog). Other types of overlaid graphics over an image are never saved (icons, controls, etc.).

### Digital File Formats

The image captured can be saved in various digital formats, depending on the resulting color and bit depth needed. Generally there is no reason to save an image with a higher bit and color depth than available in an original one. In addition against saving an image with a lower bit and color depth than available leads to the loss of information. The message is shown in this case onscreen.



- *TIF* 8 / 16 file – greyscale only image type, full data format
- *TIF* 24 file – color image type, full data format

  A file contains active processing information, which can be utilized for a databar setting.
- *JPG* file – color image type, compressed data format

  A lossy compression algorithm is used resulting in the small file size with a little loss of information, depending on the particular image appearance and the compression level (factory preset to 80%). The 8 / 24 bit depth is automatically selected when saving the greyscale / color image file.
- *BMP* file – color image type, full data format. The 8 / 24 bit depth is automatically set when saving the greyscale / color image file.
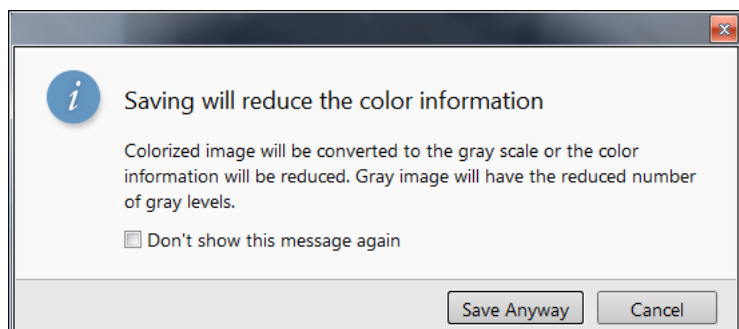
## Saving / Opening / Printing

The following universal file handling functions can be used:

### Image Capturing

1. Select the area of interest and set the *Magnification*, the *Scan condition*, the image pixel *Resolution* and the Databar information that are required in the saved image.
2. Make the best image using any suitable method you are familiar with.
3. Use the *Pause* (F6) / *Snapshot* (electron F4, ion Ctrl + F4) / *Photo* (F2) / *Active Preset Snapshot* (Ctrl + F2) / *Scanning Preset* function. The scan makes one display pass (or several passes when the number of integrated frames is larger) and pauses.

*Note*
*When applying the Shift key together with above mentioned acquiring functions, it works in all displays with the same beam simultaneously.*
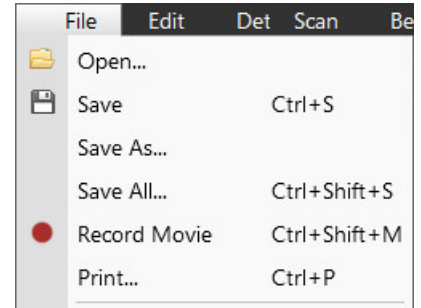
### Image Saving

- *Save* (Ctrl + S): stores the image to the predetermined location with the last used filename including an incremental number.
- *Save As:* opens a dialog for saving images (this provides an opportunity to change the file name, its location, and the possibility to save also Databar and overlaid graphics). Both functions can be linked to the Snapshot / Photo function (see the *Preferences / Scanning* section).
- *Save All:* (Ctrl + Shift + S) behaves the same way as Save As functionality, but enables to save images from all four displays at once.
- *Open:* opens a single image file into the selected display. The dialog shows, by default, the location used in the last Save As utilization.

### Image Printing

1. Capture the image or open a saved one.
2. Click on the *File* menu / *Print* (Ctrl + P), the printer setup dialog appears so that the choice of printer and settings can be established to print the selected display.
3. Complete the print setup and click on the *OK* button to activate the printer and print an image.
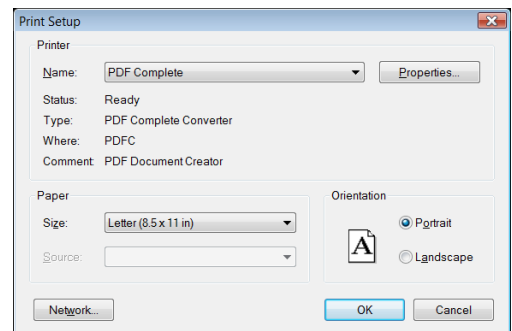
# Recording Movies (Saving Multiple Images)

This function captures dynamic experiments performed with the microscope and creates the digital video files (AVI). Up to 4 imaging displays (not the optical one) can be recorded simultaneously with a synchronized start. It is possible to switch between single and quad image mode while the video is recording. The movie has the following embedded features:

- Resolution 768 × 512 or 1536 × 1024 (512 × 442 or 1024 × 884 for the 4:3 view)
- Databar image optionally included in the video
- Average or Integration changeable during recording
- Scan speed changeable during recording
- Reduced area pauses recording of all displays
- Remaining time indicator
- Single frame TIF images recordable during video sequence
- Compressed AVI (*.avi) formats
- Start, Stop and Pause onscreen indicators
- Preferences set-up dialog

*Note*
*For the display(s) with the Enhanced Image module / Color tab / Enable check box ticked, the Movie recording is paused, the colored TIF files are stored anyway if selected.*

## Movie Settings Dialog

The *Preferences / Movie* provides selections to set-up conditions for timing and save conditions for the resultant movie.

**FIGURE 5-8** *Movie Preferences*

### Movie Timer

The parameters in this section can be changed when the digital video is inactive, but are disabled during recording. The digital video is recorded asynchronously to the scanning.

- *Save AVI Movie* check box – *Period* list box:
  After the *Period* time, the image of each active display is stored immediately (even in the middle of the frame) as a new frame in the video stream.
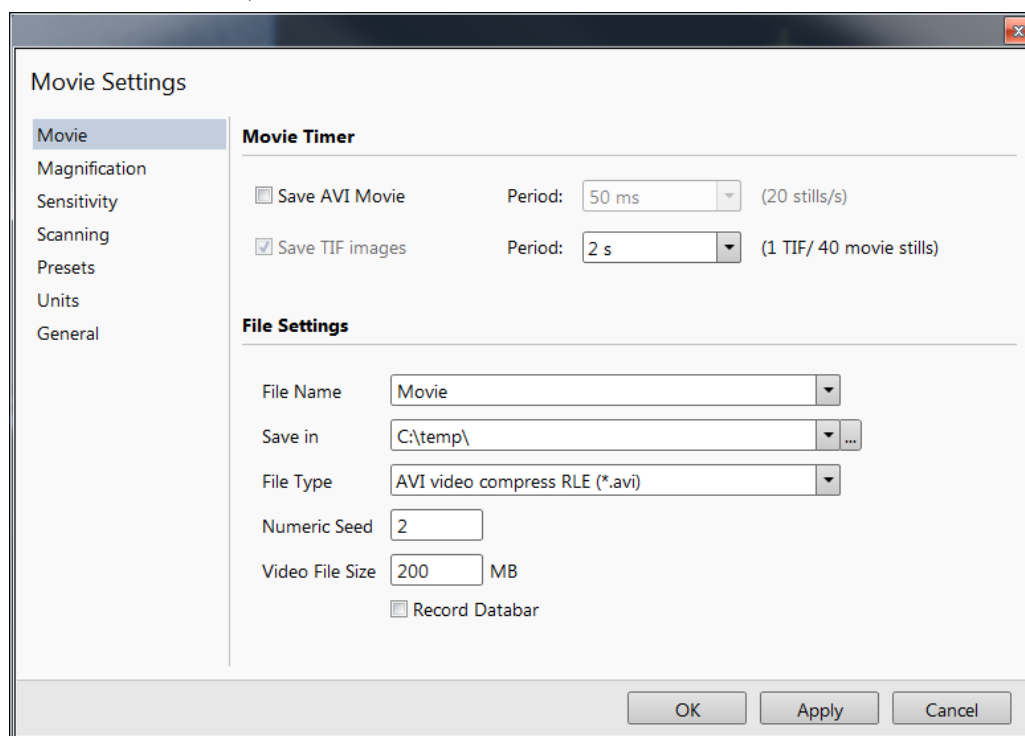- *Save TIF Images* check box – *Period* list box:
  After the Period time, series of each active display images are stored at the end of the running scan in TIF format.

If both TIF and Movie check boxes are ticked, AVI and also TIF files are stored. In this case the AVI file is not reconstructed from TIF files, which means the directly recorded movie can be different from the movie reconstructed from TIF files.

*Note*

*TIF files are better to save in many cases as they can be built into a faster AVI and the databar can be customized when building an AVI file.*

*If both AVI and TIF are recorded, the AVI may be jerky due to delays when writing TIF files to a disk. TIF delay must always be longer than or equal to the Movie delay.*

| 500 ms ▼ | 10 s ▼ |
|---|---|
| 25 ms | Every Frame |
| 50 ms | 0.1 s |
| 100 ms | 0.2 s |
| 200 ms | 0.5 s |
| 500 ms | 1 s |
| 1 s | 2 s |
| 2 s | 5 s |
| 5 s | 10 s |
| 10 s | 20 s |
| 20 s | 60 s |
| 60 s | 300 s |
| | 600 s |

### File Settings

Names of Movie [TIF] files are composed as follows:
*File name*, (display name), *Numeric seed*, [- series number].avi [tif]

For example: *MovieName (Channel1) 015 [- 00023]. avi [tif]*
[The series number always has five digits form with leading zeros.]

- *File Name* – enter a generic file name here. Do not use punctuation, dashes or other non alpha-numeric characters, otherwise the movie maker is not able to build an AVI.
- *Save in* – enter a path to an existing folder here. Use the *Browse* button to find the location.
- *File Type* – the list box with supported video compression format types. Try to change the format if the resulting movie files are too big or if the system is overloaded during the movie recording.
- *Numeric Seed* – enter any number from 1 to 999 which is converted to the three digit form with leading zeros. The numeric seed is automatically incremented after the recording has stopped or the video file size limit has been reached.
- *Video File Size* – the maximum AVI video file size (lower than 2 000) in MB must be entered here, otherwise the Movie section cannot be closed. After reaching this size, the video file is closed and a new one is automatically created, without interruption of the recording process. A warning dialog appears if the hard drive lacks sufficient free space.
- *Record Databar* check box – allows the databar to be included in the video (tif files).

## Movie Procedure

The *File* menu */ Record Movie* item (Ctrl + Shift + M) starts / stops recording of all active displays at the same time – no video / images are stored for paused imaging. When an imaging in any display is paused during the video recording, the storing of the video frames is interrupted but the video streams keep synchronization for the next recording. The *File* menu */ red dot* icon changes to *red square* when movie recording starts and vice versa. Video recording is stopped in all displays and all video files are closed.

The red dot with the timer (shown in the top right-hand corner) indicates that recording is active in this display. The Pause symbol indicates that the recording is paused and the data from this display are not stored.
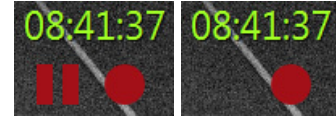
The timer indicates the time estimation (in the hh:mm:ss format) remaining to the end of the video. This is calculated from the average disk space consumption and the disk free space.

1. Open the *Preferences / Movie* section. In the *Movie Timer* module tick the *Save AVI Movie* and/or *Save TIF Images* check boxes and select the desired *Period* (time between stored frames).

2. In the *File Settings* module fill in the *File Name* and give the *Save in* folder path. Fill in the *Numeric Seed* value and the *Video File Size*. Select the *File Type* and choose whether to record the databar with the *Record Databar* check box.

3. Pause those imagings which you don't want to record. Set up the imaging parameters.

4. Select the *File* menu */ Record Movie* or press keyboard key combination Ctrl + Shift + M to start the movie recording. When the scan resolution is higher than 1536 × 1024 the dialog appears.
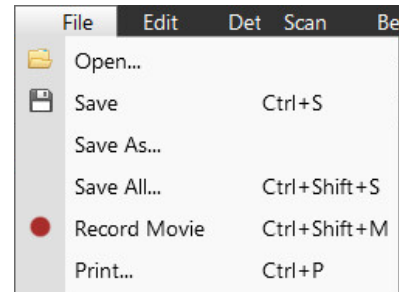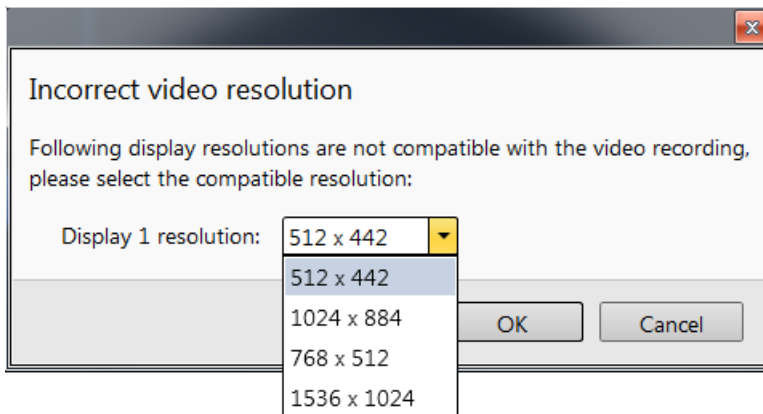
5. Choose either of the offered *Resolution* values at which the movie starts to record.

6. Select the *File* menu */ Record Movie* again or press keyboard key combination Ctrl + Shift + M to stop the movie recording.

## Movie Creator

This is a separate program that creates a single AVI movie file from a sequence of TIF images. Click on the *FEI* menu / *Movie Creator* to activate the tabbed dialogs.

The following items are common for all tabs:

- *Databar Preview* – shows the databar created within the Databar tab.
- *Status* – shows the progress of movie creation process.
- *Create Movie* button – opens the *Movie Creator* dialog.
- *Stop* button – stops the movie creation process.
- *Close* button – closes the *Movie Creator* program.
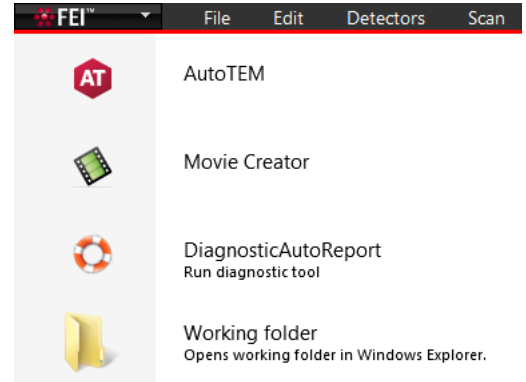
**File Tab**

**FIGURE 5-9** *Movie Creator dialog / File tab*
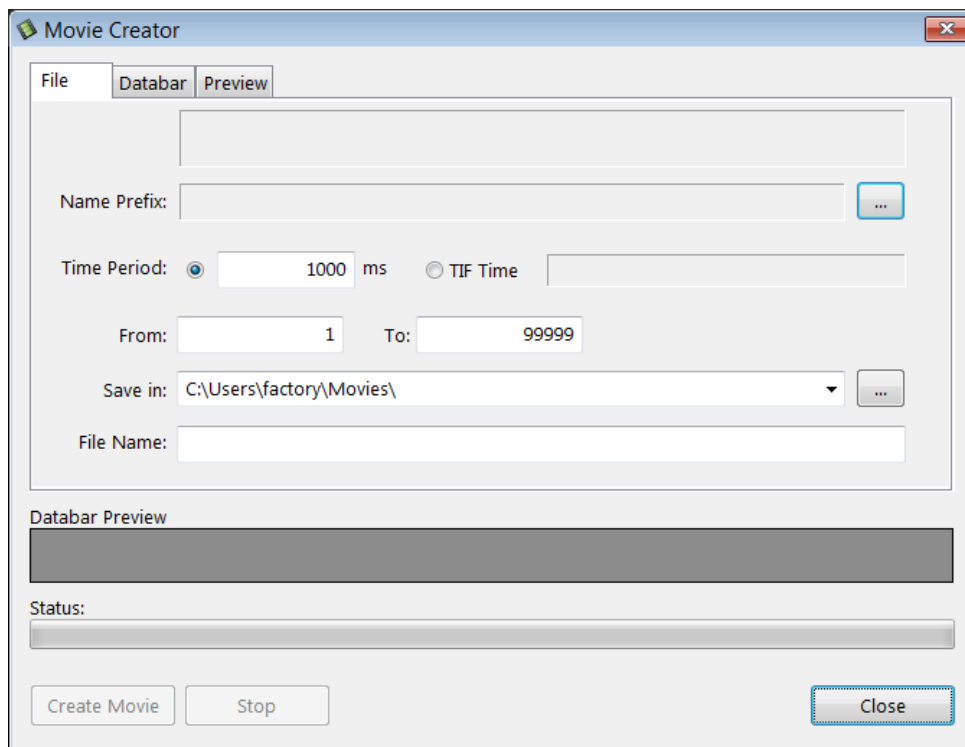
- *Name Prefix* – click on the ... button to browse the TIF files (with the desired sequence prefix) folder. It is not necessary to choose the first file in a row.
- *Time Period* – click the [*ms*] radio button to select a custom timing for the movie playback.

  One may experiment for instance: 200 ms/per image (good for most movies to speed it up) for 100 images results in 20 second total movie duration.
- *Time Period* – click the *TIF Time* radio button to select a timing for the movie playback.
- *From / To* – enter the number of the starting / ending frame. This field is filled automatically with the first / last frame available.
- *Save in* – enter the path where the AVI file should be saved. Click on the ... button to browse it.
- *File Name* – enter the resulting AVI file name. This field is filled automatically with the first image file name.

**Databar Tab**

Settings made in this dialog does not affect the databar or units settings used in the UI.

*Note*

*The Databar Preview does not show any item until you enter the File tab / Name Prefix field.*

**FIGURE 5-10** *Movie Creator dialog / Databar tab*
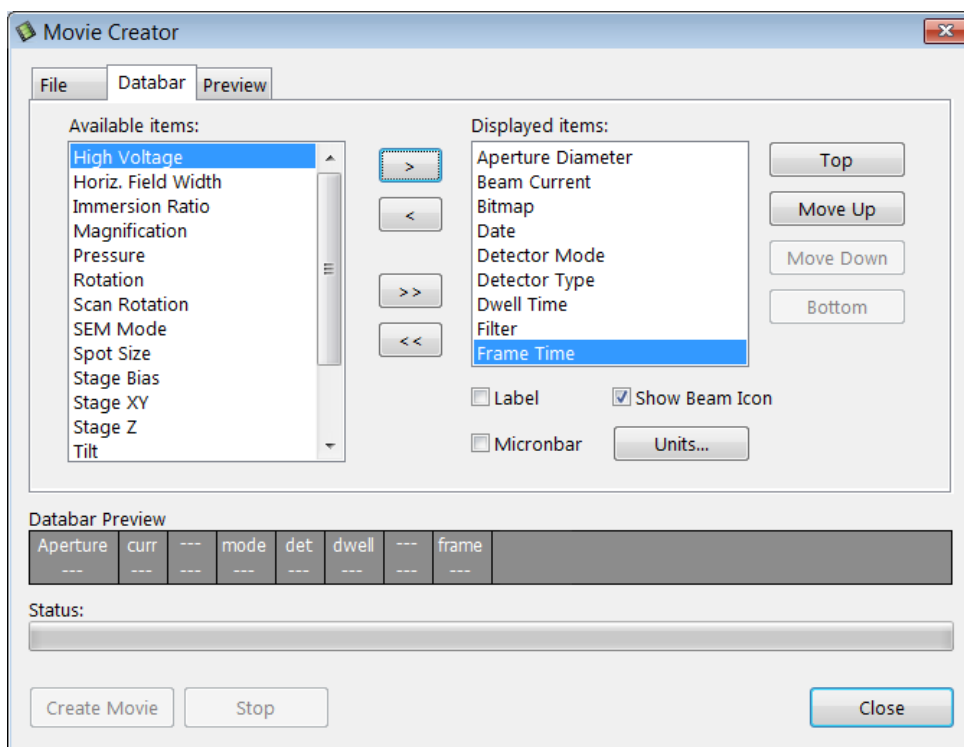


- *Available / Displayed items:* lists – all items that can be entered in the databar / are already present in the databar.
- *> / >> (< / <<)* button –add one / all item(s) from the Available list to the Displayed list (removes one / all item(s) from the Displayed list back to the Available list).

  Since there is a finite amount of the databar space, the area expands or contracts as other items are added to or removed from the Databar. The item exceeding the allowable space is ignored.
- *Move Up / Move Down / Top / Bottom* button – moves a position up / a position down / to the top / to the bottom in the *Displayed* list (a position to the left / a position to the right / to the left / to the right in the *Databar Preview*).
- *Label / Show Beam Icon / Micronbar* check boxes – set the show of the appropriate items in the Databar. The Micronbar scales to the magnification.
- *Units* button – sets the Units of Measure / Pressure / Temperature used in the movie Databar.

### Preview Tab

Once the movie is set-up, opening the Preview tab automatically shows the first image of the movie sequence.

**FIGURE 5-11**  *Movie Creator dialog / Preview tab*
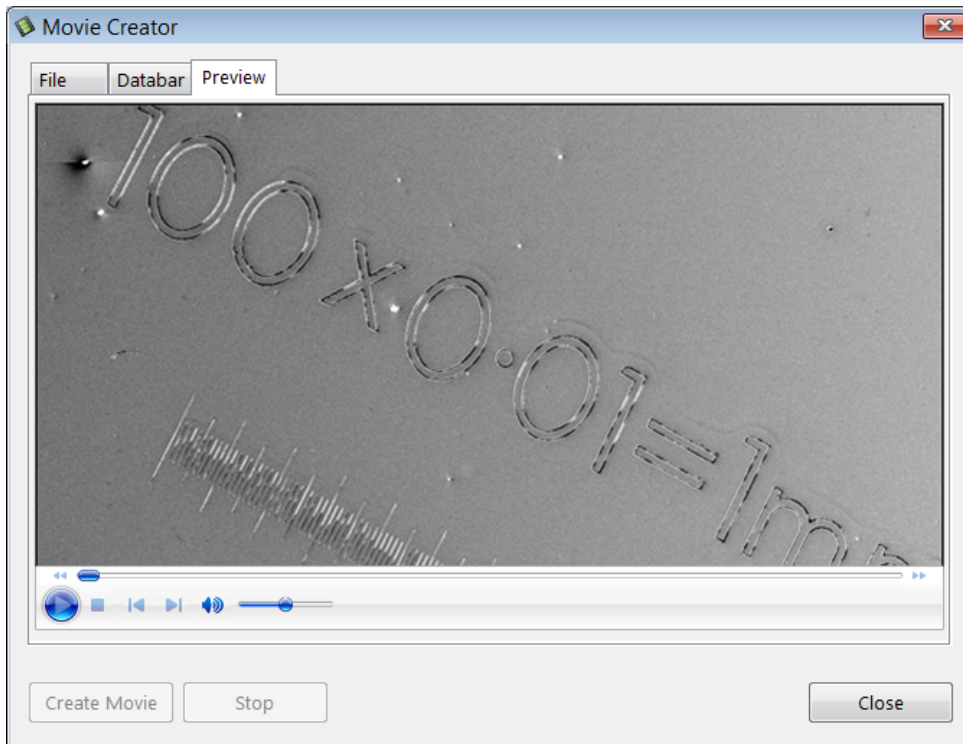


- *Start / Pause / Stop* button – starts / pauses / stops the movie play back. By dragging the adjuster one can run forward or backward through the movie.

### Playing a Movie

The AVI file movie can be played in the Windows Media Player or any another more advanced movie editing program recognising the *.avi file type.

# Stage Control

## Eucentric Position

Establishing the eucentric position is an important part of setting up a sample for observation or modification.

At the eucentric position, the stage tilt and the 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, EasyLift).

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 5-12** *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.
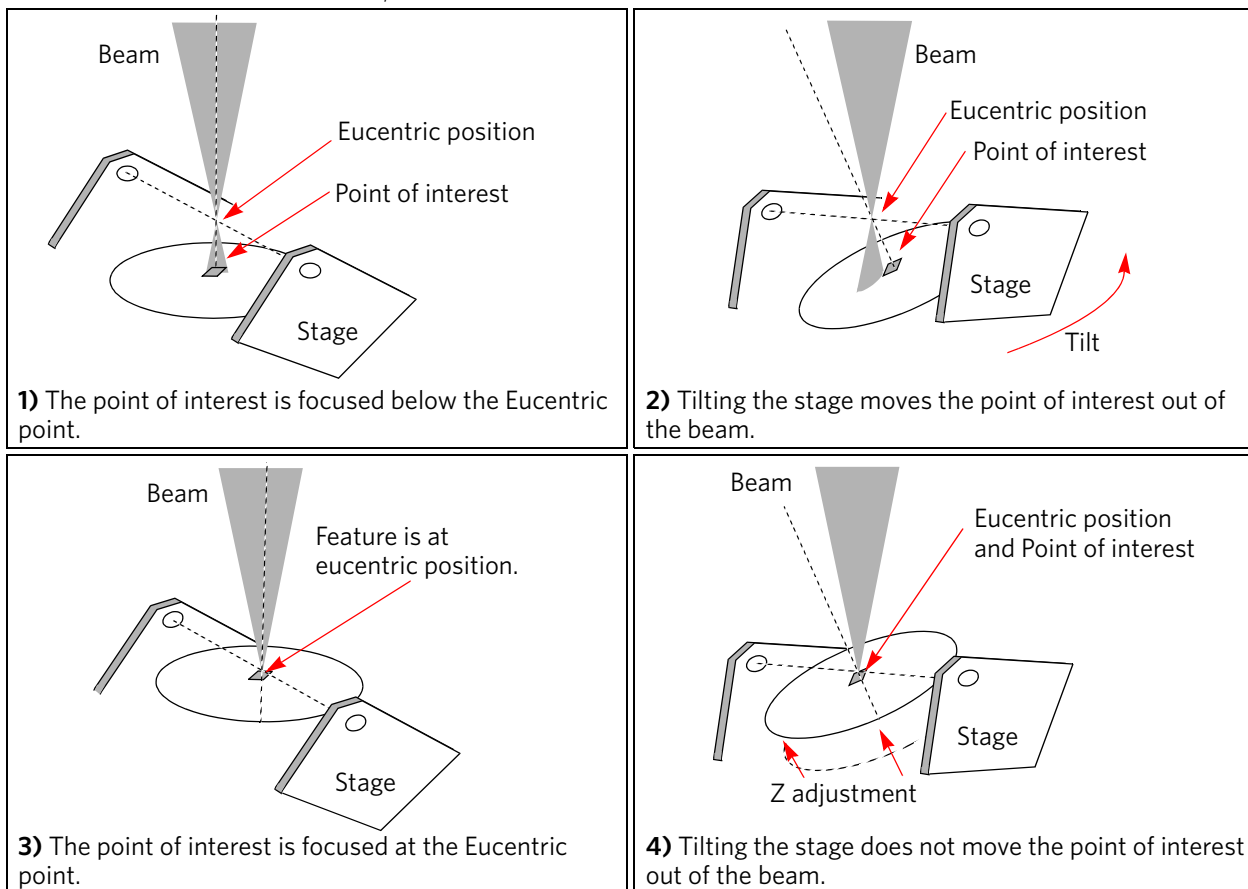
### Sample Top Surface Positioning

The distance between the observed sample and the stage rotation head surfaces must be properly set to bring the stage to the eucentric position. This procedure also prevents the specimen to touch the final lens when moving the stage in the Z-axis direction.

With the standard specimen holder it is possible to move the sample (its top surface) along the Z-axis up / down if required (holder movement). This allows a flexibility to load large height specimens onto the stage.

1. Load a specimen onto the specimen holder.
2. Adjust the Z so that the highest specimen point is approximately 7 mm below the lens by using the optical display.
3. Close the chamber and pump it down.
4. Switch on the beam, focus the specimen top surface and run the Link Z to FWD function.
   The FWD is now recognised by the system as the *Stage* module Z value.

The Z coordinate can now be changed via the software Z control around the eucentric position and further, but not less than 1 mm from the lens for safety reasons.

**Eucentric Position Setting Procedure**

1. Apply the *Stage* menu / *Auto Beam Shift Zero* function.
2. Show the *Window* menu / *Center Cross* (Shift + F5).
3. Focus an image. *Link Z to FWD* and go to 7 mm WD.
4. Set stage tilt to 0°.
5. Using the Z-control, coarsely focus the image.
6. Set the magnification to 1 000×, find a recognisable feature and center it under the yellow cross by moving the stage.
7. Watching the feature, change the stage tilt to 10°. Using the Z-control, bring the feature back under the cross.
8. Change the stage tilt to 30°, and bring the same feature back under the cross using the Z-control.
9. Change the tilt to 0°. The feature should not shift significantly. If the shift is > 5 μm, repeat steps from 6 to 9.

**Beams Coincidence Setting Procedure**

The electron and ion columns are mounted as illustrated (the stage is tilted to 52°). Beams coincidence occurs ideally at the eucentric position, but in fact it is shifted in the order of tens of μm.
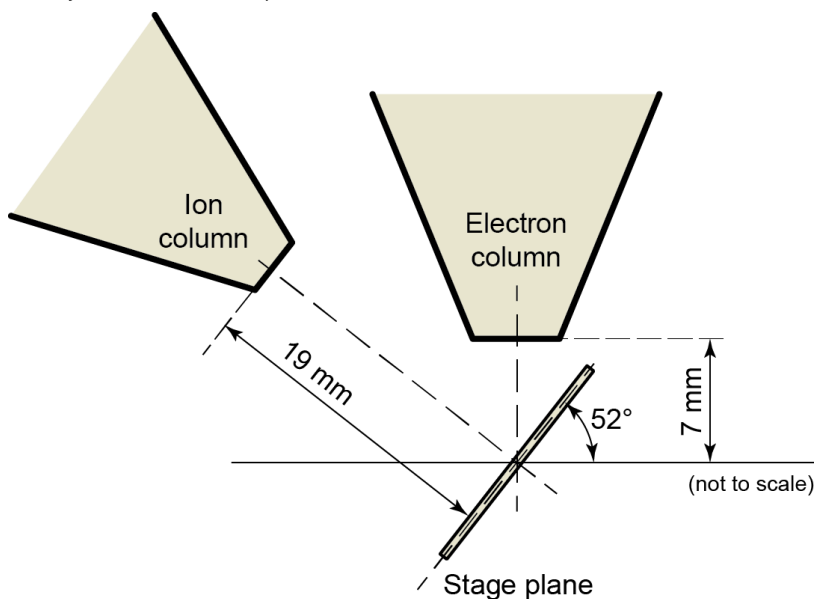


The following procedure brings your stage to the beams coincidence; it is assumed that your stage is at eucentric position and that both beams are on:

1. Switch to the Electron Beam imaging.
2. Tilt the stage to 52°.
3. While imaging with the electron beam, and at 1 000× magnification, find a distinct feature and move it under the center cross by moving the stage.
4. Switch to the Ion Beam imaging.
5. Using image shift, bring the same feature back under the center cross.

   If it is not possible to align two images, re-check the eucentric position with the manual procedure.

***Test Pattern***

A test pattern can be made with a simple pattern using the ion beam, observing it afterwards with the Electron beam to check that the beams coincidence is correct (see further).

# Software Control

The *Navigation* page contains the *Stage*, *Stage Z* and *Tilt Correction* modules, which control the stage movements that locate the position of the specimen by reference to coordinate points.

## Stage module

Three modes are possible via the list box:

- *Actual* mode (default) – shows actual position coordinates in the edit boxes.
- *Target* mode – activates when clicking on a stored position or when editing a coordinate value.
- *Relative* mode – used to move stage by a given value and to repeat it several times if needed.

Clicking on the *Go To* button drives the stage to a new location. This only acts on just edited coordinates (with a tick mark). Pressing the Enter key after editing of any coordinate value works as the Go To button short-cut. Double-clicking on a stored location moves the stage to the desired position immediately.

During the stage motion the *Go To* button changes to the *Stop* button, which stops the stage immediately.

### Coordinates X, Y, Z, R, T

Edit boxes for *X, Y, Z, R* and *T* coordinates are filled with the selected or actual position values. The value changed is automatically ticked.

### *Caution!*

*Danger of hitting the final lens! The Link Z to FWD procedure did not pass. The red up arrow next the Z axis alerts the positive Z-axis stage moving direction is up. It means raising a value in the Z axis edit box causes moving the stage up towards the final lens.*

After running the *Link Z to FWD* procedure the symbol and the stage moving direction changes. The black down arrow next the Z axis indicates the positive Z-axis stage moving direction is down.

The units of measure follow the *Preferences / Units* setting, unless the *Stage* menu / *User Units* function is active, in which case UU is shown for X and Y.

The software *locks* prevent inadvertent stage movement of selected axes during particular applications. The edit boxes for locked axes are disabled and the stage does not move in these directions. When any or all axes are locked the *Status* bar shows the closed lock icon.

When any axis is locked and the stage movement is required in that direction (trying to move to the stored position), the warning dialog appears.

When the *Compucentric Rotation* check box is ticked, the *R* coordinate operates as the Compucentric Rotation function (see further) and does not physical rotate the stage.

When the *Z-Y Link* check box is ticked and the stage is tilted, the system compensates for the observed point of interest shifting during stage move, which allows to make a Z-axis move with a tilted stage while keeping the point of interest in the field of view. This makes it much easier when imaging with electron beam at shorter working distances to accurately reach the beams coincidence (milling position).
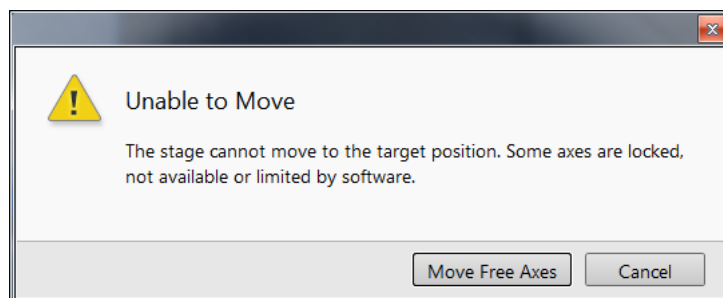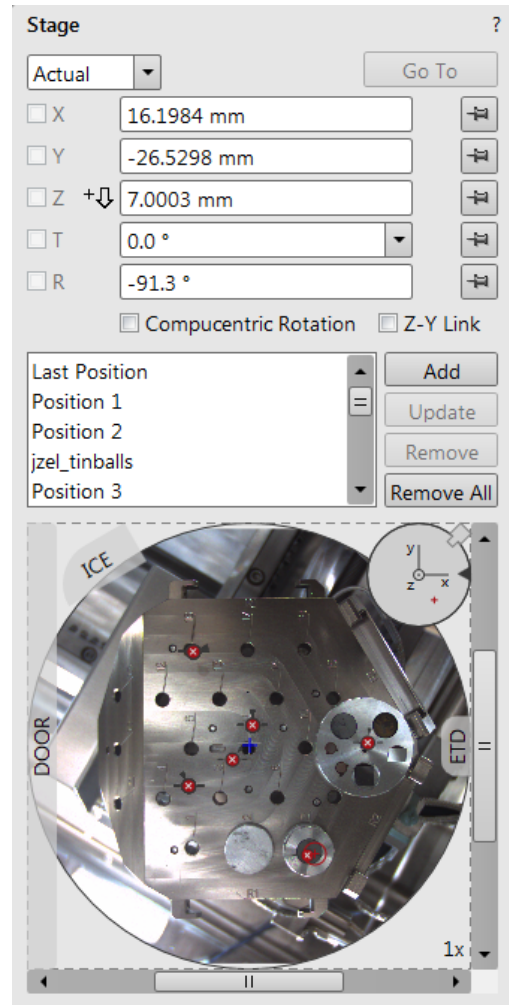
### Location list

The *Location* list shows stored stage positions. When expanded the scrollbar is available. There is the *Last Position* (the stage position before latest movement) in the list by default, which is updated during stage operations.

The position selected becomes the actual active position and it is highlighted in the list and also in the map area (12).

Clicking on a position name allows a user to edit it. Pressing the *Enter* key or clicking on a different item confirms the new name, pressing the *Esc* key restores the old name.

It is possible to load / save stage positions (stg file) with the use of *File* menu / *Import / Export* functions.

### Map area

In the map area, the stage schema is represented showing all stored positions, which are listed in the *Location* list.

**FIGURE 5-13** *Map Area Elements*
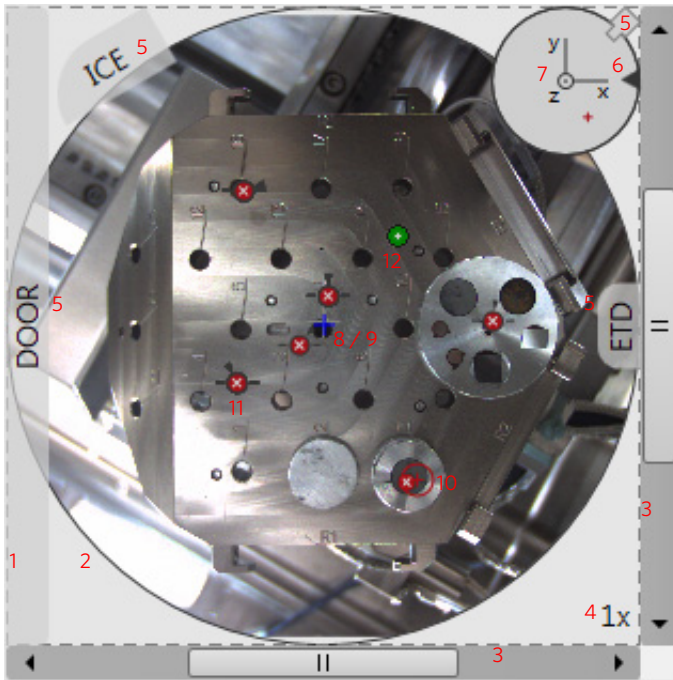


**Table 5-5:**  *Map Area Elements*

| Number | | Function |
|---|---|---|
| 1. | | *Light gray rim (dashed line):* physical limit of the stage movement along the X and Y axes |
| 2. | | *Dark rim (continuous line):* the sample holder outline |
| 3. | | *X / Y scroll bar:* to move the map area at different magnification factors |
| 4. | | *Magnification* factor of the map area (1× – 100×) |
| 5. | | *Stage rotation overlay:* Chamber door / ETD / ICE / CCD camera |
| 6. | | *Notch (black triangle):* rotation marking (active control within the Radar view) |
| 7. | | *Radar view X / Y / Z (perpendicular lines):* stage axes |
| 8. | ╬ | *Gray +:* mechanical stage center: X = 0, Y = 0 |
| 9. | ✛ | *Blue +:* map area center |
| 10. | ⊕ | *Red + in a red circle / Red + (Radar view):* actual stage position |
| 11. | ✗ | *White × on a red background:* a stored location (rotation noted by the black triangle) |
| 12. | ● | *Black ● on a green background*: a stored position selected (highlighted in the location list) |

Double-clicking on anywhere in the circle area marks a new location (*10*) and moves the stage to that position.

Right-clicking on the Map area provides the context menu.

- *Add Current Stage Position* – adds a new Location list entry, using the actual position. The new entry is named *Position (X)* (X = 1, 2, 3...). When renaming and the name already exists, a number increment is added after the name.

  The *Add* button has the same functionality.

- *Update to Current Stage Position* – stores the (edited) coordinate values under the selected name (an overwriting confirmation dialog appears).

  The *Update* button has the same functionality.

- *Remove Selected Position* – deletes the selected location(s) from the map and from the Location list.

  The *Remove* button has the same functionality.

- *Magnification* – provides a menu allowing the *Map* area magnification factor (*4* – from 1× to 100×) to be selected. Scroll bars (*3*) appear if necessary to move over the whole Map area.

| Add Current Stage Position | |
|---|---|
| Update to Current Stage Position | |
| Remove Selected Position | |
| Magnification ▸ | ✓ 1x |
| | 2x |
| Center View | 5x |
| Auto Center on Target | 10x |
| ✓ Show Radar View | 25x |
| ✓ Zero Radar View | 50x |
| ✓ Stage Location Overlay | 100x |
| Show Notch on Map | |
| ✓ Show Nav-Cam Image on Map | |
| ✓ Show Stored Positions in Navigation Displays | |
| Show Sample Holder Image on Map | |

- *Center view* – brings the actual stage position (*10*) to the map area center (*9*).

- When the *Auto Center on Target* item is ticked, the actual stage position (*10*) remains in the map area center (*9*).

- *Show Radar View* (*7*) – switches the radar view show in the map area On / Off.

- *Zero Radar View* – resets the Radar view X / Y axes rotation representation to 0°.

  The radar view conveys the stage rotation at any time either by the stage axes or by the notch. To rotate the stage, click on the notch (black triangle), drag it around the radar view perimeter, and release the mouse button at the desired position – the stage rotates accordingly.
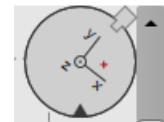
- *Stage Location Overlay* (*5*) – toggles the representation of the detector(s), chamber door, and CCD camera in a mutual relationship.

- *Show Notch on Map* (6) – switches representation of the black triangle in the map area On / Off; it gives quick information about the stage rotation.

- *Show Nav-Cam Image on Map* – switches representation of the Nav-Cam image in the map area On / Off

- *Show Sample Holder Image on Map* – switches the sample holder schema representation in the map area

- *Show Stored Positions in Navigation Displays* – switches representation of stored positions in navigation displays On / Off.
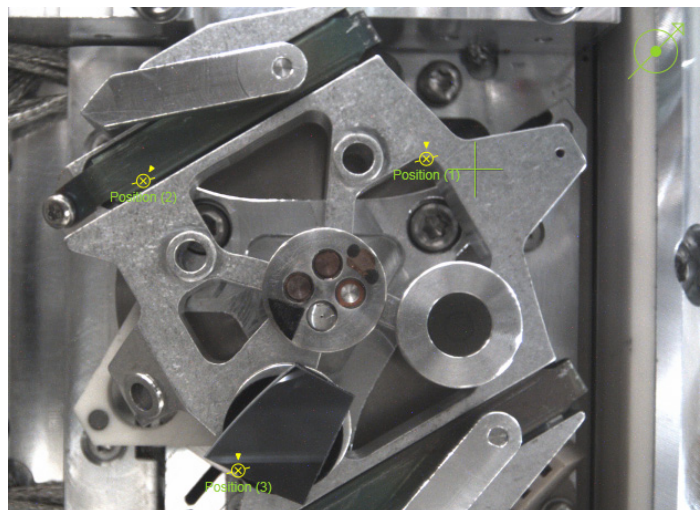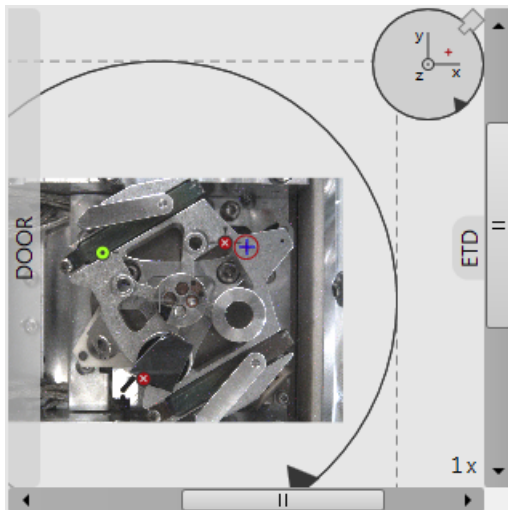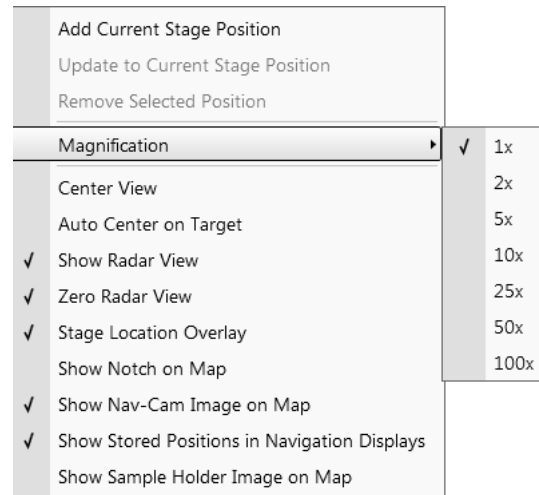
### Stage Z Module

This module enables to slowly move the stage in the Z-axis direction. The more the slider is pushed to the each side, the faster is the stage motion. Clicking on the slider bar moves the stage by a small step.

### Tilt Correction Module

When the appropriate and available check box is ticked, the function becomes active.

- *Dynamic Focus* check box ticked – the focus automatically changes as the beam scans from the image top to its bottom, trying to follow the tilted specimen working distance change.
- *Tilt Correction* check box ticked – the flat specimen foreshortening compensation is on (in one direction, at a known tilt angle, when the tilt axis is parallel to the stage XY plane).

   Because the image is a two-dimensional representation of a three-dimensional object, certain distortions occur. For instance, a square grid image appears rectangular when you tilt the specimen. This function corrects the aspect ratio and restores the square appearance.

- *Tilt Angle* list box – enables to choose among 3 modes.

   In the *Automatic* mode the *Tilt Angle* is equal to the stage tilt plus the *Specimen Pre-tilt* adjuster value (a Tilt Angle correction in case the specimen is not parallel to the stage XY plane).

   In the *Automatic (Cross Section)* mode 90° is added to enable observing of the cross section perpendicular to the sample surface.

   When in the *Manual* mode, the adjuster enables to manually set the Tilt Angle from -90° to +90°. It is useful when the Dynamic Focus with Automatic Tilt Angle does not give satisfactory results (or cannot be used at all because the specimen is tilted in direction different from the stage Tilt).

When switching from Automatic to Manual mode, the actual Tilt Angle is not changed. When switching to Automatic mode, the Tilt Angle is set to the actual stage tilt.

*Note*

   *Both Dynamic Focus and Tilt Correction work properly only if the specimen (scanned area) is tilted around the X-axis (in the same direction as the stage Tilt). Therefore they cannot be used with Automatic Tilt Angle in combination with a non-zero Scan Rotation. If the specimen is tilted in a different direction, you have to align the tilt axis horizontally using the Scan Rotation and then optimize the image focus by tuning the Manual Tilt Angle.*

   *Both functions are also disabled (check box cleared) in the Crossover mode.*

   *Due to the limited range of the dynamic focusing, the overall conditions should be in certain limits. If the dynamic focus would be out of the range, an information sign next to the check box becomes visible. Leaving the mouse over this sign calls up a tool tip giving advice with information what must be done to enable it again (usually increase dwell time or resolution).*
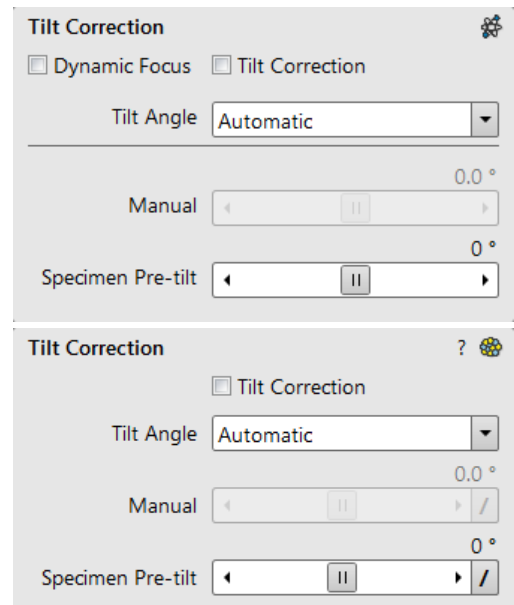
## Stage Related Functions

### Stage Movements – Keyboard Shift

The stage can be moved by 80% / 40% of the field of view in perpendicular direction by pressing / Shift + pressing the appropriate keyboard arrow key.
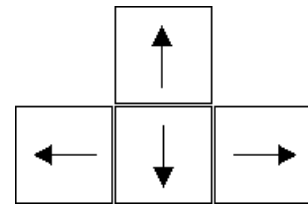
### Stage Movements – Track mode

This function allows continuous directional stage movements at a variable speed (see *Preferences / General* section / *Switch sample tracking on mouse wheel click on* item):

- *Wheel-click on & drag* mode – the yellow *dot* appears onscreen in an active display at the mouse cursor point. Move the mouse to the direction intended for an observation – a yellow *arrow* appears onscreen denoting the direction opposite to the stage motion. The motion speed raises with the distance between the arrow and the dot, the direction can be changed by moving the mouse. When you come to the place of interest, release the mouse wheel – the action stops.

- *Wheel-click on & move* mode – the mouse wheel does not need to be held, just click on the desired direction to start the Track motion and click on again to stop it.

In the optical imaging display clicking on the mouse wheel activates the stage Z movement, which can be seen live.

- *Wheel-clicking on & dragging* the mouse up / down – moves the stage up / down (Z-coordinate).

- *Ctrl + Wheel-clicking on & dragging* the mouse left / right – tilts the stage in positive / negative direction.

The direction is indicated by a yellow arrow, either pointing up / down from the horizontal line or left / right from the vertical line.
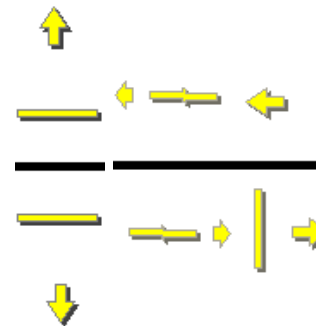
### Stage Movements – Get mode

This function brings an image point of interest to the screen center.

Double-click on an image point. The object is mechanically centered onscreen by moving the stage, which is suitable for lower magnifications. When working at higher magnifications, beam shift can be also employed (see the *Preferences / General* section). In this case the object is electronically centered onscreen by moving the electron beam. When the beam shift comes to a limit in any direction, its value resets and the necessary stage movement adapts the observed point position.
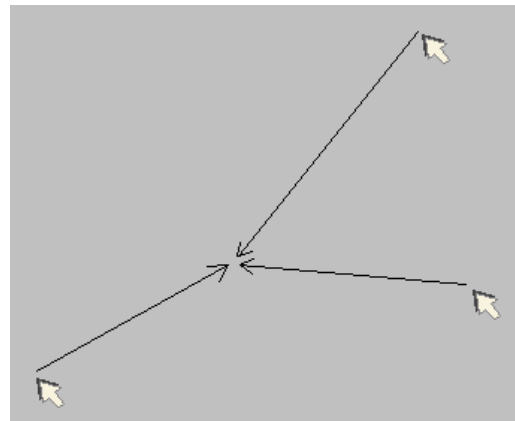
#### *Beam Shift*

When you want to employ the beam shift only (which is suitable for higher magnifications), shift + click on an image point. Drag the *Hand* cursor to move the imaging area in any direction.

When the limit of the beam shift has been reached, either the *Stage* menu / *Auto Beam Shift Zero* or the *Beam Shift Reset* function needs to be applied. In this case the beam shift is reset and the observed point position is adapted by the stage movement.

Releasing the mouse button stops the action.
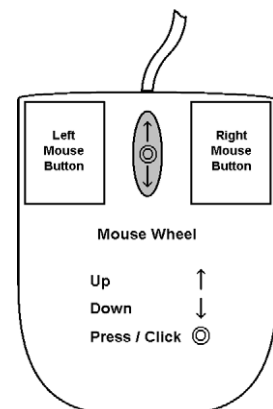
### Align Feature

This utility is designed specifically for long features, extending off the screen at the magnification required for an observation. It applies the mapping process bringing the long feature either to the horizontal or vertical stage axis to make the navigation easier. This can be performed at any point within the stage field limits and takes into account the stage rotation offset.

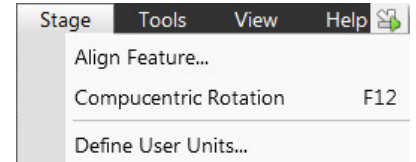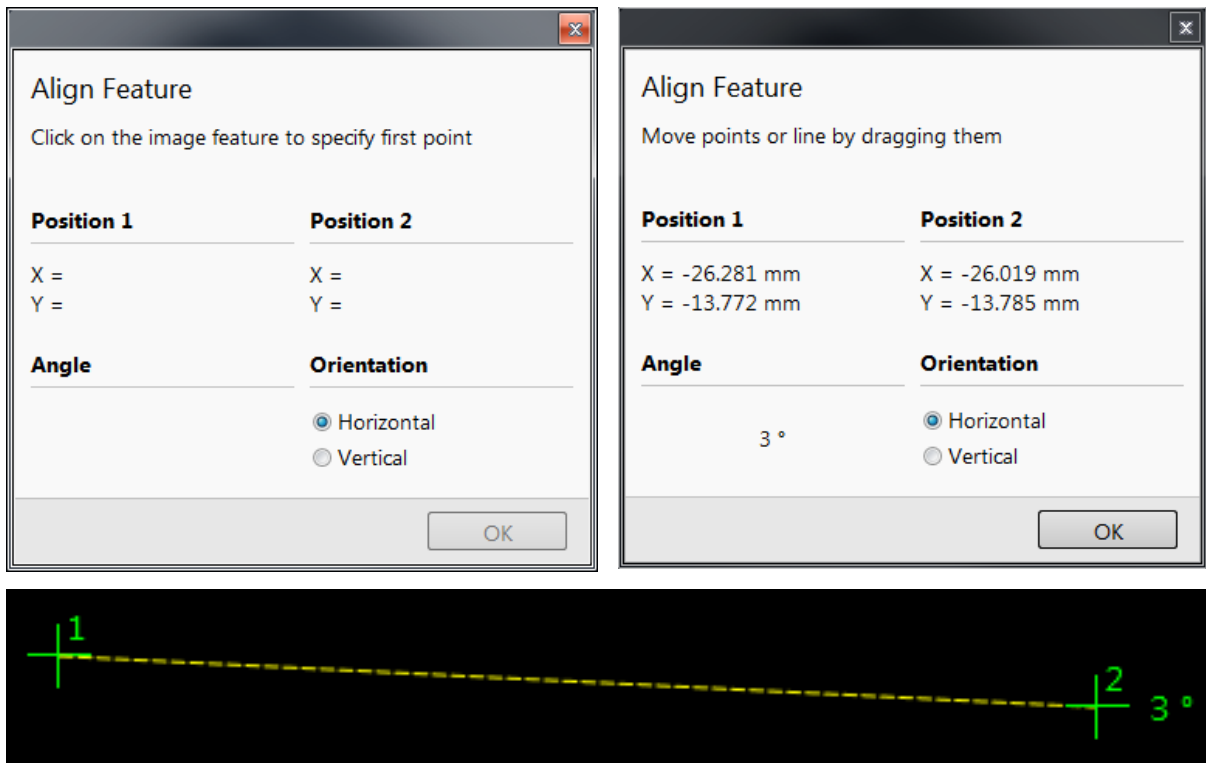| Stage | Tools | View | Help |
|---|---|---|---|
| Align Feature... | | | |
| Compucentric Rotation | | | F12 |
| Define User Units... | | | |

*Note*

*Align Feature works best at the eucentric position (see above). Longer distances result in a greater accuracy.*

**C a u t i o n !**

*Watch the obstacles significantly extending from the sample plane, as these may interfere with equipment under the lens.*

1. Select a long feature of interest on the sample.
2. Click on the *Stage* menu / *Align Feature.*
3. Choose *Orientation* either *Horizontal* or *Vertical*, which relates to the desired final orientation of the feature.
4. Click on the first point along the feature, the *Position 1* coordinates update.
5. Moving the mouse updates *Position 2* coordinates continuously, by clicking anywhere along the feature they are stored. The *Angle* shows value which is used to correct alignment of the feature along the horizontal / vertical axe. Right-clicking on the imaging area (anywhere) deletes points, enabling to define them again.

**Align Feature**

Click on the image feature to specify first point

| Position 1 | Position 2 |
|---|---|
| X = | X = |
| Y = | Y = |

| Angle | Orientation |
|---|---|
| | ⦿ Horizontal |
| | ○ Vertical |

OK

**Align Feature**

Move points or line by dragging them

| Position 1 | Position 2 |
|---|---|
| X = -26.281 mm | X = -26.019 mm |
| Y = -13.772 mm | Y = -13.785 mm |

| Angle | Orientation |
|---|---|
| 3 ° | ⦿ Horizontal |
| | ○ Vertical |

OK

6. Drag any point to change its position, if needed. Click on the *OK* button to finish the setting.

## Scan Rotation Align Feature

This procedure helps to navigate along a feature that is rotated disadvantageously. Unlike the Align Feature the rotation is performed by scan coils instead of the stage.

**1.** Select a long feature of interest on the sample.

**2.** Click on the *Stage* menu / *Scan Rotation Align Feature.*

**3.** Choose *Orientation* either *Horizontal* or *Vertical*, which relates to the desired final orientation of the feature.

**4.** Click on the first point along the feature, the *Position 1* coordinates update.

**5.** Moving the mouse updates *Position 2* coordinates continuously, by clicking anywhere along the feature they are stored. The *Angle* shows value which is used to correct alignment of the feature along the horizontal / vertical axe. Right-clicking on the imaging area (anywhere) deletes points, enabling to define them again.
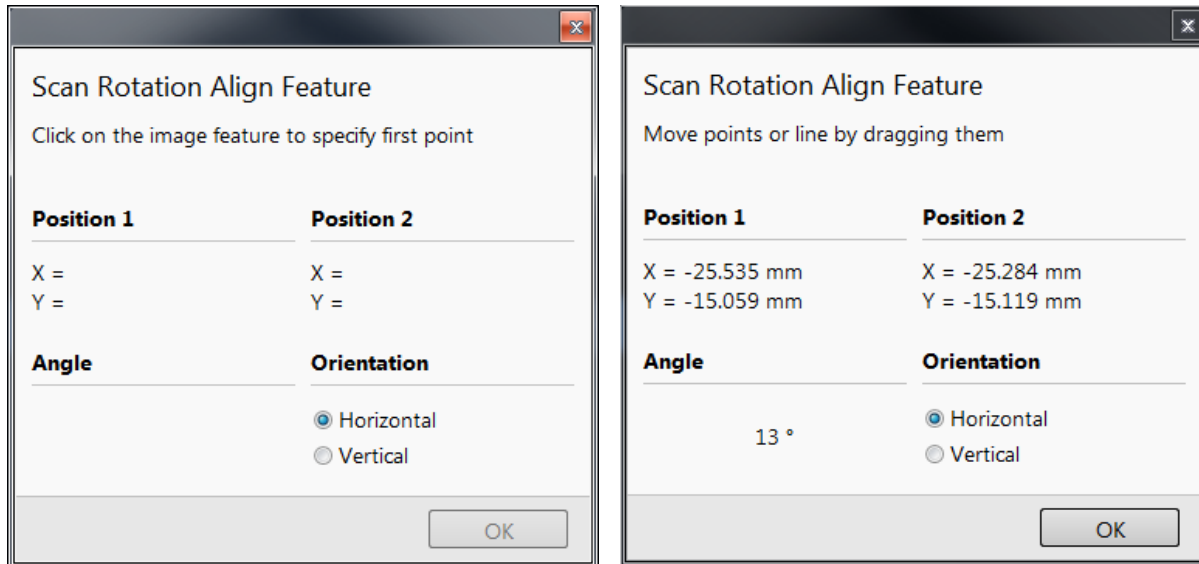


**6.** Drag any point to change its position, if needed. Click on the *OK* button to finish the setting.

## Compucentric Rotation (F12)

Clicking on the *Stage* menu / *Compucentric Rotation* places a green circle in the image window. The green triangle on its perimeter denotes, by its position, the sample rotation relative to its original position when mounted on the stage. Initially, this is in the 12 o'clock position.

The readouts shown at the image window bottom provide information about the *Actual Rotation* (original position) and the *Target Rotation* (the selected position).

Click on & drag it around the circle to choose a new sample rotation. Releasing the mouse updates the stage position to bring the original field of view (rotated to the Target Rotation position) onscreen. With a sample at the eucentric position this can be performed at any sample point irrespective of the mechanical stage center.

Clicking on the written angles around the circle perimeter (0° / 90° / 180° / 270°) or the perimeter anywhere drives the stage to that rotation position and the green triangle updates onscreen.

Clicking on the framed + / – sign increases / decreases the rotation angle by an incremental value.
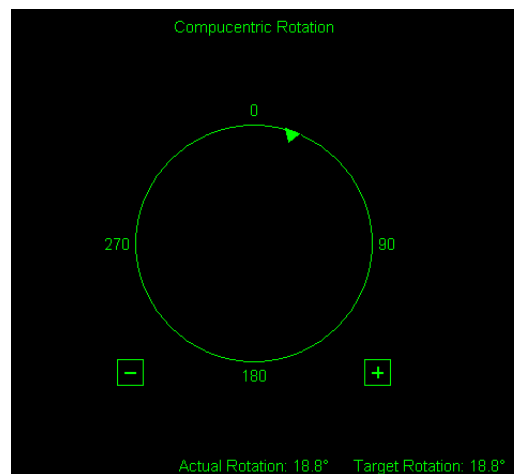
## User Units

Clicking on the *Stage* menu / *User Units* item (a tick mark appears next to it) activates user defined units as the basis of the stage coordination system. The *UU* appears in the *Stage* module next to the X and Y values and the stage coordinate system activates the last defined user units.

### Define User Units Procedure

This procedure assigns user-defined points to stage points. The stage coordination system can be anchored to either 1, 2 or 3 points, depending on the sample management or application. For example, if you choose a (0,0) position, you can drive the stage relative to that origin using user defined units (0,1 / 1,0 points), which may equal to some repeated sample structures etc.

It is possible to end the procedure by clicking the *Finish* button when point(s) (0,0) / (1,0) / (0,1) are defined, an overview of the point(s) just defined is shown. The *Details* button shows actual coordinates with the possibility to browse them (*Go to* button) and to edit values.

1. Select a sample surface feature and view it at an appropriate magnification to check its relation to other structures.

2. Click on the *Stage* menu / *Define User Units* item. The dialog appears to choose the desired operation:

- *Define new User Units* – defining of new User Units
- *Redefine User Units* – changing or updating User Units
- *Redefine User Units with shift* – as above with the use of the Beam Shift
- *Reset User Units so that they are equal to the Stage Units*

3. Click on the sample user point (0,0), its coordinates appear in the *Details* module. Proceed by clicking the *Next* button.

4. Repeat step 3 for the sample user point (1,0) and (0,1) if needed.
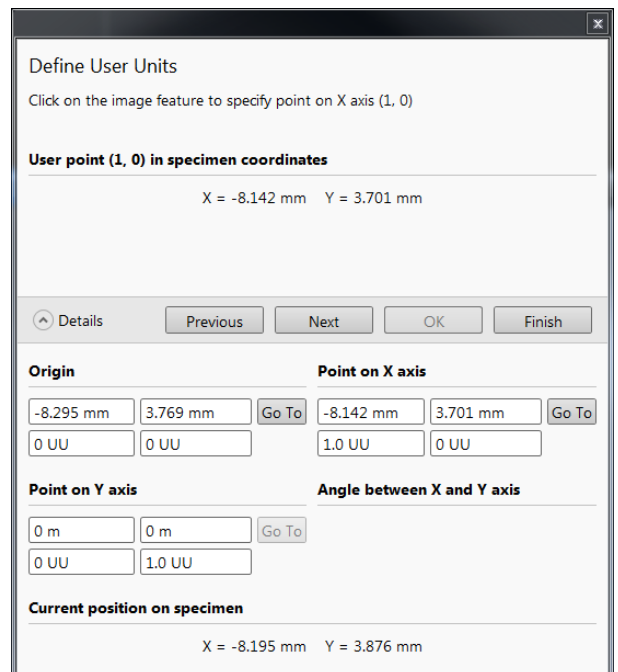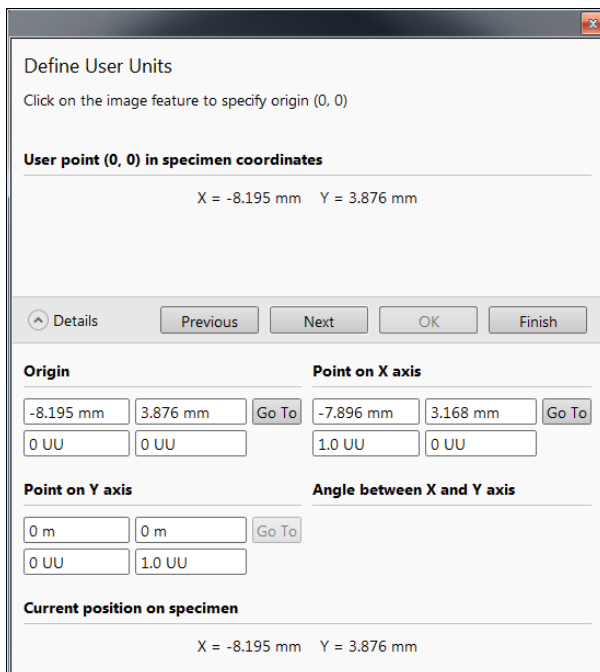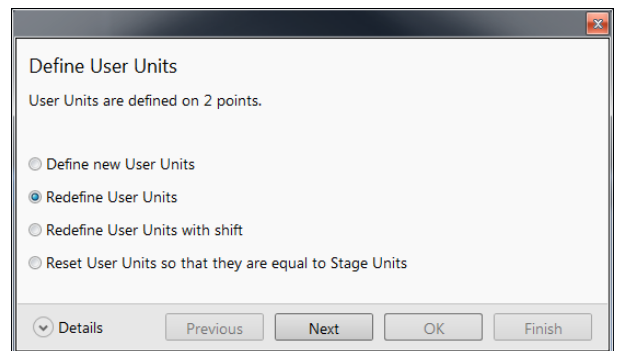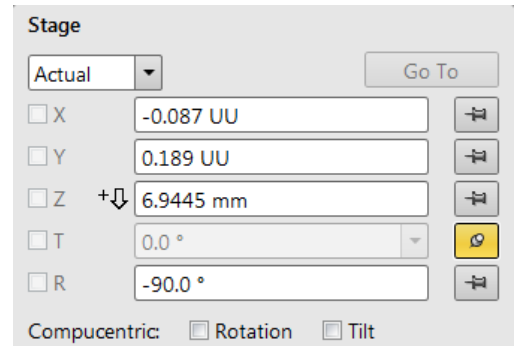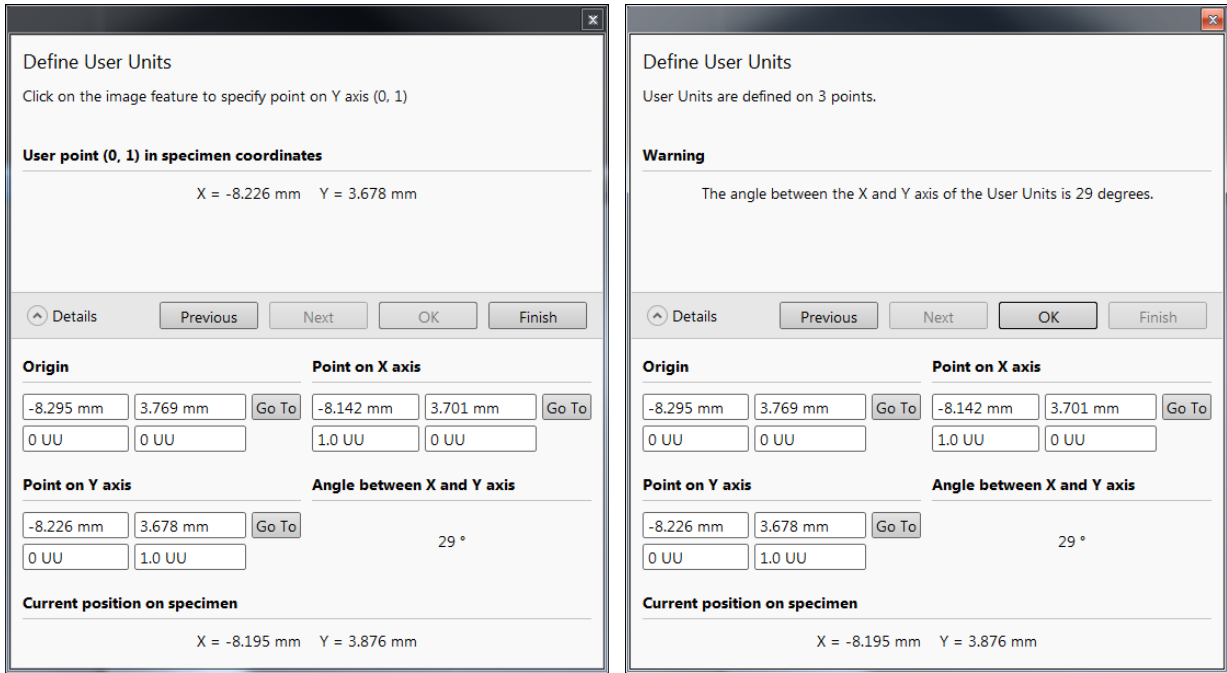
*Using 1 / 2 / 3 Point(s) Alignments*

**Table 5-6**    *Alignment Type Differences*

| Use | 1 Point Alignment | 2 Points Alignment | 3 Points Alignment |
|---|---|---|---|
| *Major Use* | Aligning to new point directly offset from the existing location | Aligning the stage axes with the specimen X–Y orientation to correct any distortion | Transforming to nonstandard units on dies or RAM arrays; to correct any distortion |
| *Change in Scale* | None | Scales the axes together | X can be scaled differently from Y |
| *Change in Orientation* | None | Rotates both axes with a fixed 90° angle between axes | X and Y orientation can be different |

**Sample Navigation**

The *Stage* menu / *Sample Navigation* (Ctrl + N) software feature enables to navigate along the sample surface when the field of view is smaller than desired (limited by an aperture for instance). For this purpose various sample navigation images can be dynamically and independently selected, regardless of its actual content and status (paused, saved, loaded).



As soon as the selected imaging is paused, the Sample Navigation icon appears in the upper right display corner to indicate the functionality. This indicator is green and the paused imaging can be used to navigate along the live one. Otherwise it turns red and indicates no functionality in the respective display.



A green rectangle showing the actually selected field of view (in the selected display) appears with the size corresponding to the magnification. In display(s) using Sample Navigation the Selected Area Zooming and the Get features can be used.

To employ the Sample Navigation there are three possible techniques to acquire (or to use) a Navigation image:
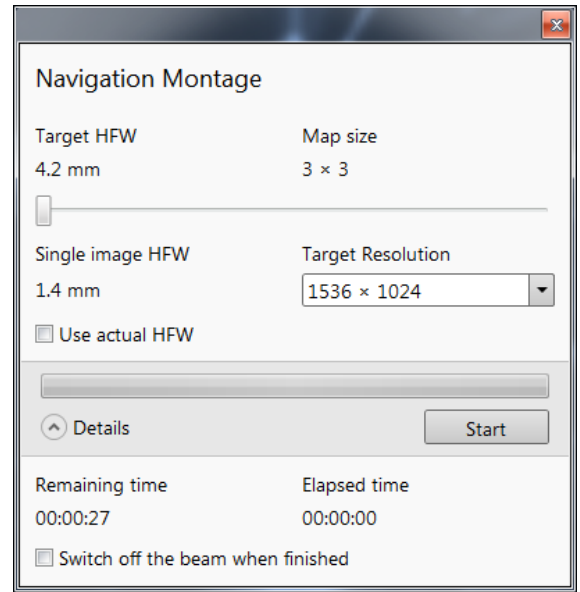
- Navigation Montage
- Navigation Alignment
- Nav-Cam (option)

### Navigation Montage

Set the *Target HFW* (Horizontal Field Width) by the slider, which influences some information fields values:

- *Map Size* – the number of tiles
- *Single Image HFW* – HFW of each tile
- *Remaining / Elapsed Time* – time still needed for the procedure completion / elapsed
- *Target Resolution* – navigation image pixel resolution
- *Use actual HFW* check box – when ticked the system does not use automatically the HFW according to the hardware configuration and sets the user one

    This is convenient when the image corners are rounded and imaging does not cover an entire area.
- *Switch off the beam when finished* check box

    This is convenient to use in case a large Target HFW and long dwell times are used to capture the Navigation image, because the process can take a significant time to complete.

Click the *Start* button to run the procedure. After a process completion the Sample Navigation is then automatically set on.

### Navigation Alignment

This procedure in comparison to the Navigation montage or Nav-Cam (option) enables to use any loaded or paused Navigation image, which is calibrated according to the live Reference image.

Follow the instructions given within the process (6 dialogs) and calibrate 4 image points. If 2 points are sufficient for desired purposes, click on the *Compute 2pt alignment* button to finish the process after setting 2 align points.

When any point setting does not satisfy system requirements an Warning message informs a user.
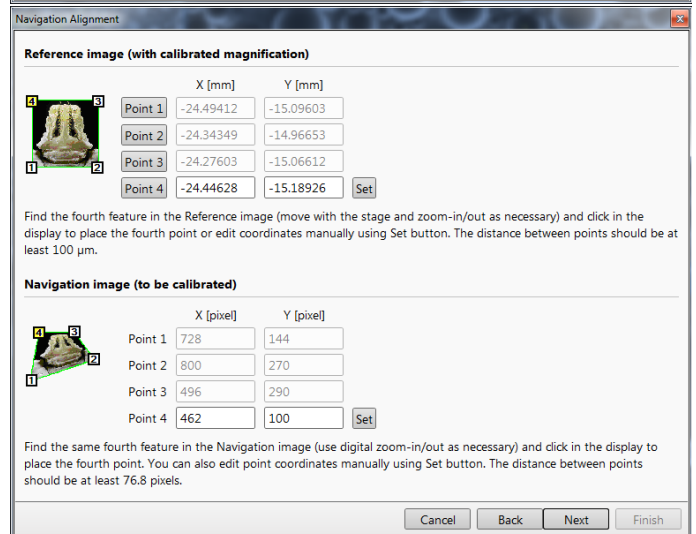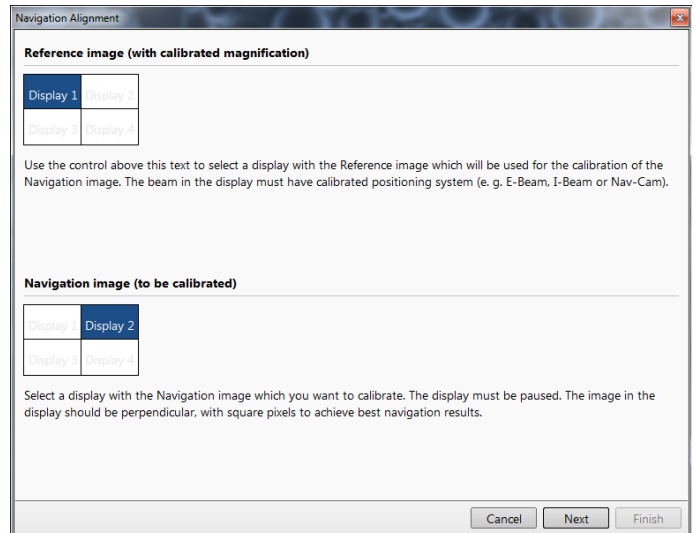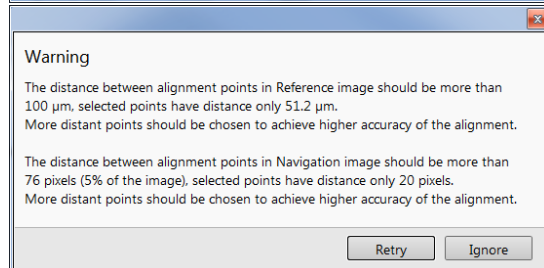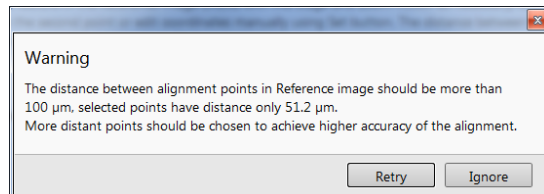
## Scan Rotation (Shift + F12)

The *Scan* menu / *Scan Rotation* function activates the onscreen tool to rotate the scan and align the image. Because it is solely functionality of the electronic optics, it has no effect on the stage movements. It is used to orient the image relative to mechanical rotation and detector direction.

Clicking on the *Scan* menu / *Scan Rotation* places a green circle in the image window. The green triangle on its perimeter denotes, by its position, the sample rotation relative to its original position when mounted on the stage. Initially, this is in the 12 o'clock position. Click on & drag it around the circle perimeter to choose a new sample rotation.

The readouts shown at the image window bottom provide information about the *Actual Rotation* (original position) and the *Target Rotation* (the selected position).

Clicking on the written angles around the circle perimeter (0° / 90° / 180° / 270°) or the perimeter anywhere drives the stage to that rotation position and the green triangle updates onscreen. Clicking on the framed + / – sign increases / decreases the rotation angel by an incremental value.





The smaller circle in the top right of an optical imaging display remains onscreen when the Scan Rotation angle is different from 0°. This can be set in the *Preferences* dialog / *General* section / *Display scan rotation in CCD displays* item.
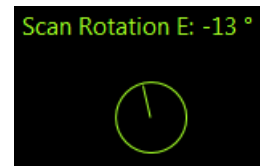
# Patterns / Measurements / Annotations

The toolbar *Patterns / Measurement / Annotation* items give a user many capabilities to draw pattern shapes, to measure distances, angles, diameters and areas as well as locating and labelling items that are of significant interest on the sample area.

Selected tool is shown as the toolbar icon. Clicking on it activates (drawing mode – orange background) / deactivates (white arrow cursor – normal background) the tool. Clicking on the down arrow icon opens the list of available tools, the chosen one is activated from that time on and the object can be drawn onscreen. To deactivate the drawing mode at any time is possible by pressing the *Esc* (keyboard).

Each tool shows its description as a tooltip.

- *Patterns* – enable to create various pattern objects, which are prepared for subsequent processing.
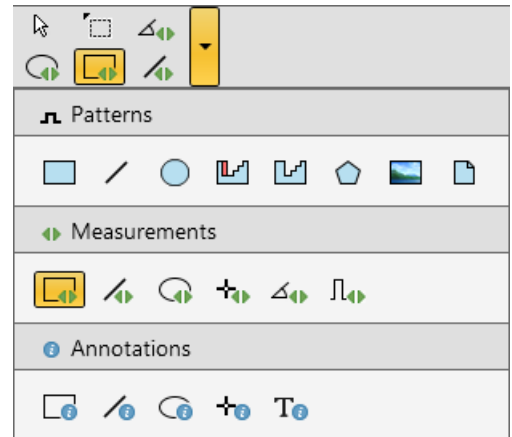- *Measurements* graphics – enable to gain dimension information about a specimen feature by overlaying it with a measurement object of different shapes. By changing the magnification these objects resize accordingly.
- *Annotations* graphics – enable to graphically highlight and label items of interest with different shapes.

## Shape Creating

**1.** Choose the suitable *Patterns / Measurements / Annotations* graphic tool.
**2.** Draw the graphic over the area of interest.
   This can be done by:

- clicking on & dragging the cursor in any direction – create a rectangle shape
- Shift + clicking on & dragging the cursor to any direction – create a rectangle shape starting to grow from the point where you have clicked as from the center

To create a text label click the *T* annotation tool, create a rectangle area into which a text should fit and start writing.

## Shape Editing

Once a Pattern / Measurement / Annotation object has been drawn, it can be correctly adjusted in size and position over the area of interest. A number of appropriate properties are available in the Property editor, which can be changed by a selection from a drop down list or by direct precise editing of a text or a value.

To select all objects in the active display press *Ctrl + A*. To delete selected object(s) press the *Delete* key.

Selected object is denoted by the addition of resizing handles (white rounded or square points) to the graphic outline. Moving mouse point cursor in the vicinity of these points forces the cursor to change:
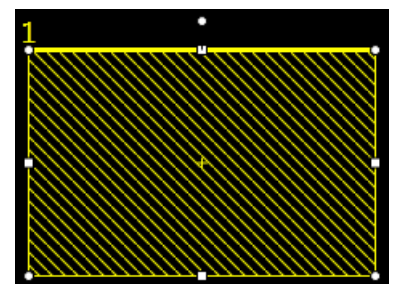
- *Moving:* click on inside the boundary of the object and drag it.
   *Note*
   Holding the Ctrl + Alt keys while hitting any arrow key moves the pattern in a corresponding direction by a fixed distance.
- *Rotating:* click on the object rotation control (white point in the middle above the graphic) and drag it.

- *Resizing:* click on & drag the resizing handle until the desired size is reached (horizontal / vertical / diagonal resizing cursor). Holding the Ctrl key while dragging forces dimensions to be changed proportionally.
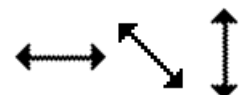
# Patterning

Patterning is the process of moving a beam over the defined pattern along the specimen surface (while leaving other areas untouched) with the purpose of:

- *milling* – removing well-defined amounts of existing material (the pattern is shown in yellow color)
- *deposition* – adding of well-defined amounts of new material (the pattern is shown in color appropriate to the gas selected)

The electron beam is generally used for deposition while the ion beam for both processes.

The *Patterning* menu and the *Patterning Control* module control the entire process.

### *C a u t i o n !*

*When patterning or milling a large volume of material at higher ion currents, it is recommended to remove any detector if it is not used. There is a risk of its efficiency decrease by a material deposition.*

| Patterning | Stage | Tools | View | Help |
|---|---|---|---|---|
| ▶ Start Patterning in Display 1 | | | | Pause |
| ◼ Reset Patterning in Display 1 | | | | Ctrl+Pause |
| →▢ Next Pattern | | | | Shift+P |
| ↑ Next Line | | | | Shift+N |
| ↓ Previous Line | | | | Ctrl+Shift+N |
| Sleep after Patterning | | | | |
| Autostart Real Time Monitor | | | | |
| Auto-Start/Stop Electron Acquisiton for iSPI | | | | |
| Live RTM after Snapshot | | | | |
| Blackout Pattern Area for RTM | | | | |

The system provides additional monitoring possibilities:

- *Simultaneous Patterning and Imaging (SPI)*

  The SPI provides an electron imaging (in a display different from patterning) during patterning (typically by ions). It is strongly influenced by secondary electrons generated by the ion beam (SE imaging), so the imaging quality is not perfect. The higher electron currents (higher spot numbers) and averaging help to improve the imaging. In case the BSE detector is used this interference is less important (BSE imaging). The system remembers the brightness and contrast setting separately for SPI or normal imaging.

- *Intermittent Switching between Patterning and Imaging (iSPI)*

  Unlike the SPI this mode provides an electron imaging (in a display different from patterning) when patterning is paused, so the electron imaging quality is perfect. This functionality can run automatically according to settings in the iSPI tab module, Patterning menu and Preferences.

- *Integrated Real Time Monitor (RTM)*

  The RTM provides an immediate imaging (in the same display with patterning) of the patterning process. The patterned area is observed and in case of relatively slow scanning, the scan trajectory can be inspected.

  RTM is typically used as an end pointing device by observing brightness differences in the detector signal. These result from contrast differences (when milling through layers of different composition on a stack of multiple materials or releasing a TEM foil from the EasyLift needle).

  RTM can be used with electron or ion beam and with any of the pattern types that are available in the UI. When starting patterning with the RTM activated, the pattern in the UI will be updated with real time image information. The patterned area information is updated based on the detector signal which is shown in synchronization with the beam trajectory.

  Because the detector signal is synchronized with the scan of the patterning beam (usually FIB), the other beam cannot be used to make a live imaging while patterning. As an alternative, it is of course possible to grab snapshot with the electron beam during FIB patterning while using RTM.

*Note*

*The acquired data are matched to the calculated positions of the corresponding milling points, the pixels shown on the screen may not therefore directly match to what is happening on the sample surface and some imaging artefacts (due to milling points and screen pixels mismatch) can occur. To prevent this try to change the field of view.*

## Patterning Control Module

There are several tool icons and the progress monitoring area within the module.
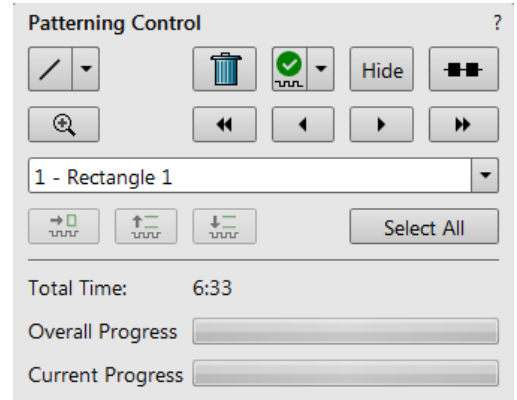
### Tool Icons

Clicking on the icon activates (highlighted with an orange background) / deactivates (normal background) the tool. If no icon is selected, the pattern selection cursor (arrow) is active.

- *Pattern type* selector (see Toolbar icons also) – clicking on the down arrow next to the icon reveals the drop down list to select a pattern type:
  *Rectangle / Line / Circle / Cleaning Cross Section / Regular Cross Section / Polygon / Bitmap / Stream File*
- *Trash Can (Delete)* button – deletes the selected pattern(s)
- *Pattern / Exclusion Zone* (overlapping area of the two patterns) *Enabled / Disabled* button – sets selected pattern / exclusion zone between two patterns to be / not to be processed
  Corresponding icon and pattern graphics color changes.
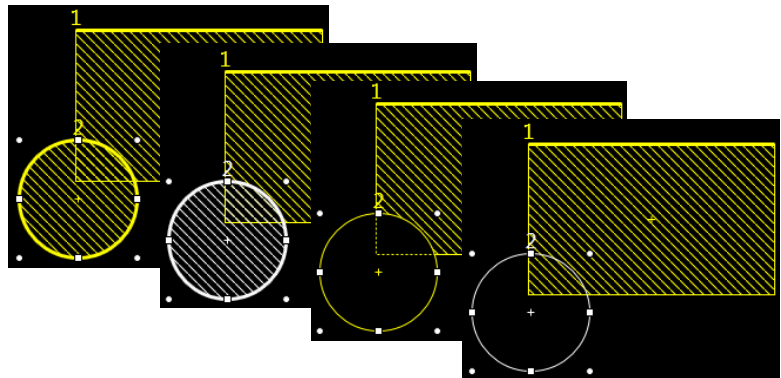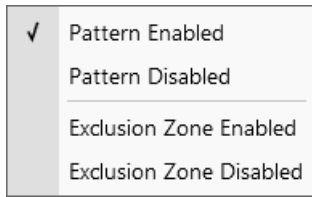
- *Hide* button – hides / shows all patterns, the button becomes highlighted / normal background
- *Patterning Serial / Parallel sequence* button – switches between two possibilities
- *Zoom* button – enlarges selected pattern / patterns to fill entire display
- *Patterning sequence* buttons – set the process order of the selected patterns

  Patterns are milled in the order they are created. Numbers are shown close to the pattern and in front of its name to indicate the actual milling order. This can be changed by clicking on the left / right arrow to move the selected pattern one position up / down and by clicking on the left / right double arrow to move it to the first / last position.
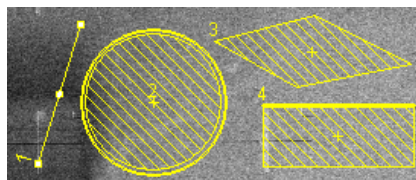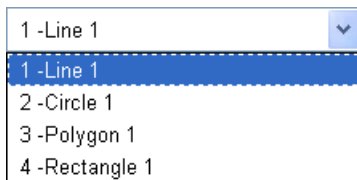
### Pattern Types

Patterns are automatically assigned to one or more particular processes. They are distinguishable by a different cross-hatch.

The **Rectangle / Line / Circle / Polygon** pattern is dedicated to both milling and deposition.

The **Cleaning Cross Section** pattern is processed line by line (each line with set number of passes).

The **Regular Cross Section** pattern has two possibilities selectable in the Property editor:

- *Scan Method: Multipass* – processes entire pattern and starts again (with set number of passes)
- *Scan Method: Stairstep* – the pattern is created as a compilation of five rectangles with specified overlap between them. Each one is processed with the set number of passes.

The **Bitmap** pattern enables importing bitmaps as a pattern. It must be 24 bit RGB bitmap, each pixel consists of:

- *Red* component – actually not used
- *Green* component – determines if the beam is blanked.
  Any value other then 0 activates the beam
- *Blue* component – determines the dwell time per pixel:
  If the value is 0, the pixel is skipped (no milling or deposition proceeds).
  If the value is 1 (border), the dwell time is the lowest (approx. 100 ns).
  If the value is 255 (border), the dwell time is identical as it is set for the pattern.
  The dwell time for values in between the border values is linearly interpolated.
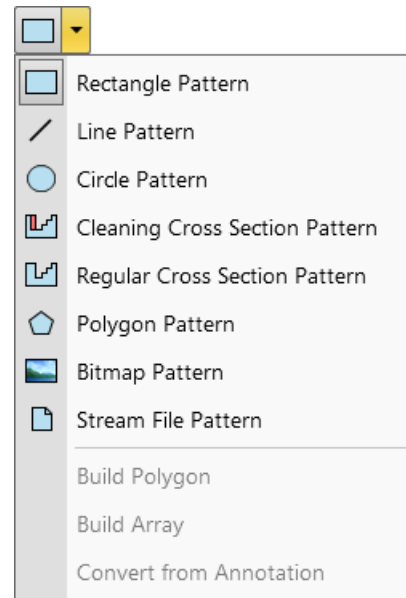
*Note*

*When drawing a bitmap, we recommend using black (0 / 0 / 0) for no milling points and white (255 / 255 / 255) for milling points.*

*Do not forget to optimize other properties such as the Application file, Z size, leading edge etc.*

The **Stream File** pattern is created as an ASCII text or binary file that addresses directly the patterning DAC (Digital Analog Converter) and produces custom pattern files. The 16-bit DAC is used so the patterning field is divided into 65 536 steps in both X- and Y-axis,

| s16 | 96 2867 2867 | 96 1639 2048 | 96 2457 1639 |
|---|---|---|---|
| 40 | 96 1229 2457 | 96 2048 2048 | 96 2867 1639 |
| 25 | 96 1639 2457 | 96 2457 2048 | 96 1229 1229 |
| 96 1229 2867 | 96 2048 2457 | 96 2867 2048 | 96 1639 1229 |
| 96 1639 2867 | 96 2457 2457 | 96 1229 1639 | 96 2048 1229 |
| 96 2048 2867 | 96 2867 2457 | 96 1639 1639 | 96 2457 1229 |
| 96 2457 2867 | 96 1229 2048 | 96 2048 1639 | 96 2867 1229 |

The file must begin with an *s*, indicating a stream file. The second line defines the number of loop repeats (*40×*). The third line indicates the total number of X, Y coordinates (pixels) in one loop (5 × 5 = *25* in this case). The *96* figure represents dwell time in units of 100 ns (=9.6 μs).

*Note*

*Stream files cannot be created directly from UI, use any suitable text processor. There are several stream file types, which are recognizable by the first header line (s16 / s16,25ns / s16,DAC / s16,25ns,DAC).*

When two patterns are overlapping, it is possible to join them into one pattern by use of the *Build Polygon* functionality.

Selected patterns can be multiplied by the use of *Build Array* functionality. The Dimension / Pitch means number of repetition / distance.

It is possible to convert any selected Annotation or Measurement graphic to a Bitmap type pattern shape with the use of *Convert from Annotation* item.
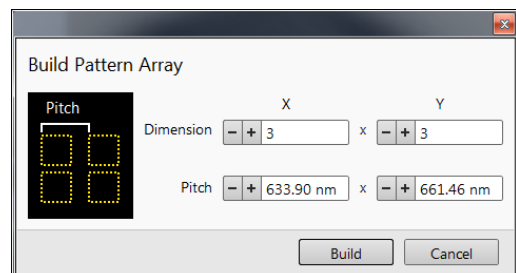
***Serial Patterning***   

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.

***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 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 shown in the image window.

When a user switches to the Parallel mode, the following pattern properties in the group must necessarily be the same: *Beam*, *Gas Type* and *Passes*. The first selected pattern determines these values for all other ones.

Other properties (*Application*, *Z size, Overlap, Saturation Sputter Rate* and *Refresh Time*) are also all set to those of the first selected pattern to avoid confusion, even though they can theoretically remain unchanged. Restoring Serial mode does not undo these changes; the properties remain as in the Parallel mode.

## Progress area

Information updated as the milling progresses can be found here (captions change according to a running process):



- skip to a next pattern in order
- Skip to a previous / next line
  (available only with Cleaning Cross Section)
- *Total Time* – estimated total patterning time
- *Overall Progress* – related to the total patterning time of all patterns
- *Current Progress / CCS Line Progress* – related to the actual pattern in progress
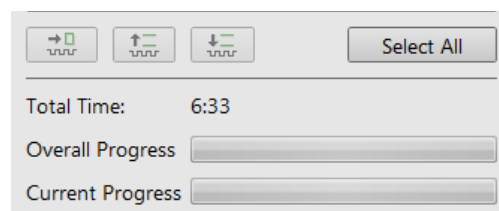
*Note*
  *When patterning is paused in one display it is possible to start patterning in another one. Similarly when patterning finishes there may still be a paused patterning in another display.*

It is possible to acquire an image from the signals generated during patterning. All imaging parameters are dictated by the patterning requirements. Much better images can be acquired by a Snapshot during patterning. In this case patterning is paused, an image is grabbed and patterning resumes.

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

# Patterns Processing

Once a pattern shape has been drawn, it can be modified (see Shapes editing above).

## Importing / Exporting Patterns

User created patterns may be imported or exported (saved) via the *File* menu / *Import* or *Export / Patterns* item. The saved file (.ptf) contains all parameters found at the Patterning property editor (Basic / Advanced) for all patterns drawn in the active display. Six (for each beam) toolbar *Pattern Presets* (labeled p#) can be individually assigned to any of these .ptf file.

Right-clicking on the selected button calls up the menu:

- *Apply* item – selects appropriate button (highlighted with an orange background) and starts the patterning with the preset parameters (the same as clicking on the button directly)
- *Edit* item – opens the *Assign Pattern File* (.ptf) window to assign desired parameter file to a selected button

The toolbar Pattern Presets assignment to the particular .ptf file can be saved or loaded by the *File* menu / *Export* or *Import / System Parameters* item.
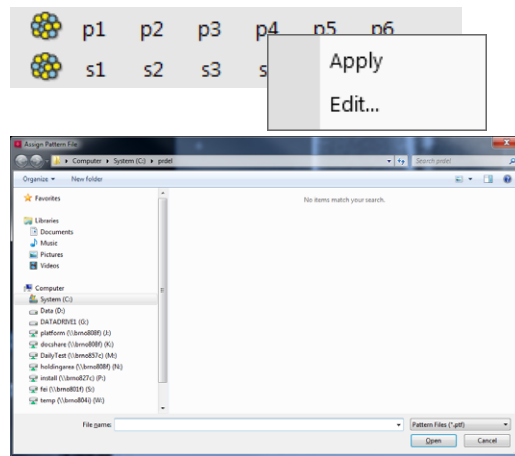
## Property tab Module

A certain pattern can be selected from the list box with many associated parameters which can be set via the *Property* module:

- *Application* – clicking on the value slot enables a down arrow bringing a drop down list of applications. Choosing the required one sets the subsequent properties.
- *X / Y / Z size* – dimensions of the pattern
- *Scan Direction* – scan movement direction (Bottom to Top; Top to Bottom)
- *Dwell Time* – a time the beam spends on a single pixel per pass (rounded to a multiple of 25 ns).
- *Beam* – the beam used for patterning
- *Time* – required to process this pattern
- *Position X / Y* of the pattern relative to the origin (the display center)
- *Rotation* of the patterns (the positive direction is clockwise)
- *Gas Type* – the gas to be used to process the pattern (or None if no gas is to be used). This determines the pattern color onscreen.
- *GasDutyCycle* –
- *GasNeedlePosition* –
- *OverlapX / Y* – sets the beam diameter overlap. The value of the overlap can be positive or negative depending on a particular application. The overlap parameter influences the Area Calculation and the Dose.
- *PitchX / Y* – sets the pitch between two spots
- *Area Calculation* – defines how the patterning area will be calculated in order to get the most accurate value of the *Dose*. This value is related with the OverlapX/Y. The Pattern (default) / Array are set for positive / negative overlaps.
- Dose –
- *Volume per Dose* – the volume of material that is removed per charge
- *Saturation Sputter Rate* – the maximum linear sputter rate for a given gas. For Gas = None this is 0 (actually not used).
- *Refresh Time* – the minimum loop time that must at least elapse before the next pass, so that the adsorbed gas can be refreshed
- *Loop Time* – the time required for a single pass (read only)
- *Area* – the surface area of the pattern (read only)
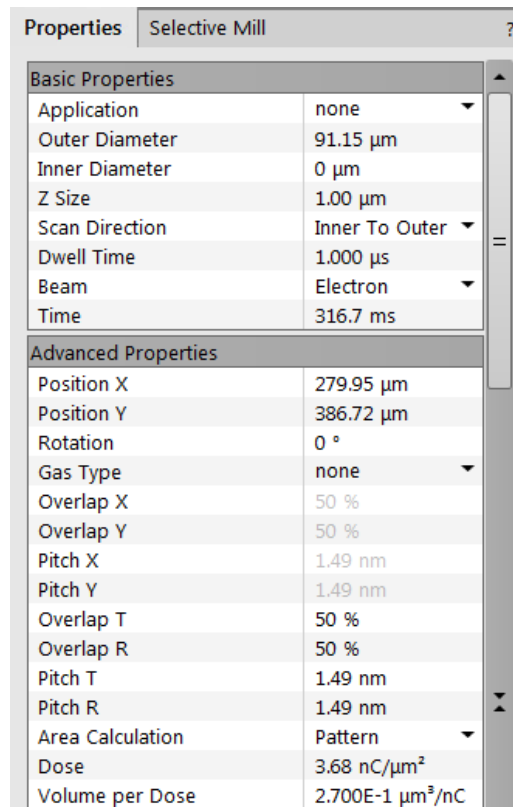
- *ScanType* – the *Serpentine* means the beam proceeds from left to right and back from right to left, while the *Raster* scans from left to right, then the beam returns to the left starting point
- *Fill Style* – one can choose either to mill a *solid* (area) or just a *frame* (box and circular types only)
- *Passes* – a number of the beam scans over the pattern
- *Defocus* of the beam (WD change) – influences the Total Diameter and Area Calculation. It allows focusing above / below (negative / positive value) the sample surface
- *Blur* – like Defocus, but specifying the (additional) diameter of the blurred spot
- *Interaction Diameter* for an infinitely small beam – influences the Total diameter
- *Total Diameter* – the combination of the beam diameter and interaction diameter influences the OverlapX/Y and PitchX/Y values (read only)

| | |
|---|---|
| Loop Time | 3.9 ms |
| Area | 6524.74 µm² |
| Scan Type | Circular ▼ |
| Fill Style | Solid ▼ |
| Passes | 82 |
| Defocus | 0 µm |
| Blur | 0 µm |
| Interaction Diameter | 0 µm |
| Total Diameter | 3.0 nm |
| Maximum Dose per Area | 0 nC/µm² |
| Saturation Current Density | 1.000E-18 A/nm² |
| Total Volume Sputter Rate | 2.700E+7 nm³/s |
| Selective Milling Enabled | ☐ |
| Selective Milling Time Interva | 2.000000 |
| Min Contrast Threshold | 0.000000 |
| Max Contrast Threshold | 1.000000 |

- *Maximum Dose per Area* – describes the adsorbed gas layer, allowing a certain dose to be deposited at a higher rate than the saturation current density, allowing a temporary higher rate (actually not used)
- *Saturation Current Density* – the current at which 63% of the saturation sputter rate is reached (actually not used)
- *Total Volume Sputter Rate* – the speed at which material is removed or deposited (actually not used)
- *Selective Milling Enabled / Selective Milling Time Interval / Min Contrast Threshold / Max Contrast Threshold* items – correspond to the *Selective Mill* tab module elements: *Enabled* check box / *Interval* adjuster / left / right border of the grey level to be processed for the selected pattern

## Selective Mill tab Module

It is possible to set a given grey level range to be processed in the extent of the selected pattern area.

- *Scan* button – reads the pattern area grey level histogram
  Move the vertical black line to a desired grey level position and also move the red rectangle edges to set the grey level extent.
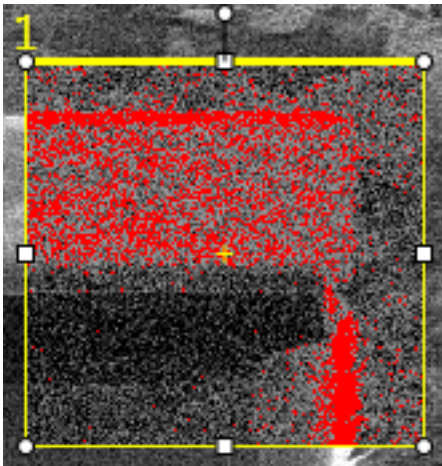
- *Enabled* check box – when ticked the selective milling is enabled
- *Interval* adjuster – sets the time [s] after which the histogram is actualised

# Advanced Patterning tab Modules

The advanced patterning modules gives visual feedback on the progress of a milling process. It shows the specimen current (charge absorbed in the specimen) and enables to monitor the specimen current changes as the ion beam interacts with different materials in the sample. For example the differences encountered when milling through some dielectric and striking another one are usually very subtle, but once the beam begins milling into metal, a dramatic difference in absorbed charge can be observed on the *Monitor* tab.
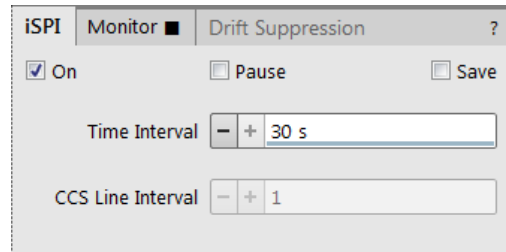
## iSPI tab Module
## (intermittent Switching between Patterning and Imaging)

- *On* check box – when ticked it starts the iSPI mode, in which the ion beam is paused during electron imaging to minimize the interferences

    If the *Paterning* menu / *Auto-Start/Stop Electron Acquisition for iSPI* item is checked the system runs this functionality automatically, otherwise a user must release the electron beam display during patterning in another one.

    *Note*
    *When the On check box is not ticked, system runs in the SPI mode.*

- *Pause* check box – when ticked it pauses the patterning process after each electron image acquisition according to the *Time* (or *CCS Line*) *interval* slider, which sets the interval after which the system acquires an electron image
- *Save* check box – when ticked it starts storing of all images acquired during the patterning process (from all live displays)

    The name, destination and type of stored images are set in the *Preferences / Movie* section / *File Settings* area.

- *Time interval* slider – sets the time in seconds after which the system acquires an electron image and pauses the electron imaging

    For all patterns except the Cleaning Cross Section: select a Time Interval to acquire an electron image every "x" number of seconds.

- *CCS Line interval* slider – sets the number of lines after which the system acquires an electron image and pauses the electron imaging

    For the Cleaning Cross Section only.

## Monitor tab Module

illustrates the milling progress as a colored graphics, showing the accuracy for depth or material changes over the whole milled area.

The graph of milling progress starts automatically to draw when patterning starts. When patterning is paused or stopped / resumed it stops / continues drawing the graph.

Clicking on the black rectangle next the Monitor label provokes / hides a separate large graph window labelled *Endpoint Monitor Plot*.

When serial patterning mode is set, there is only one graph, when parallel one is set, there can be more of them.

Each time patterning is started a new graph is started automatically. Pausing / resuming of a patterning stops / continues to plot the graph.

Right-clicking on the Endpoint Monitor Plot window provokes the context menu with choices:

- *X-axis* menu (*Dose Accumulated / Depth Penetrated / Time Elapsed*): offers the choice for X-axis description. At least and only one can be selected at a time.

- *Y-axis* menu (*Stage Current / Gray Scale*): offers choices for Y-axis description. No, any or both can be selected.
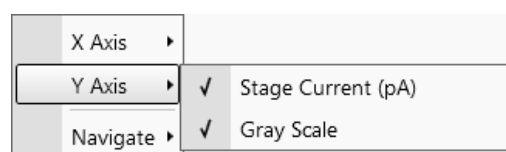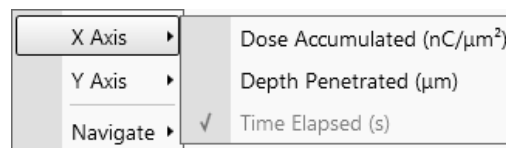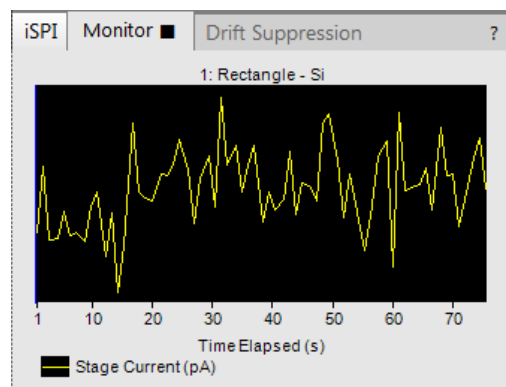
- *Navigate* menu (*Zoom In / Zoom Out / Reset*): it is possible to zoom in / out and reset a scale to default. A tooltip is given with another possibilities also.

  Initially the graph is auto-scaled, meaning that the minimum and maximum of both axes are computed automatically so that the graph is completely visible. As points are added during patterning the graph may rescale to achieve this. Dragging a rectangle in the graph when in Zoom In mode zooms in that rectangle and the graph switches to a fixed-zoom. Switching back to auto-zoom is possible via the Reset item.
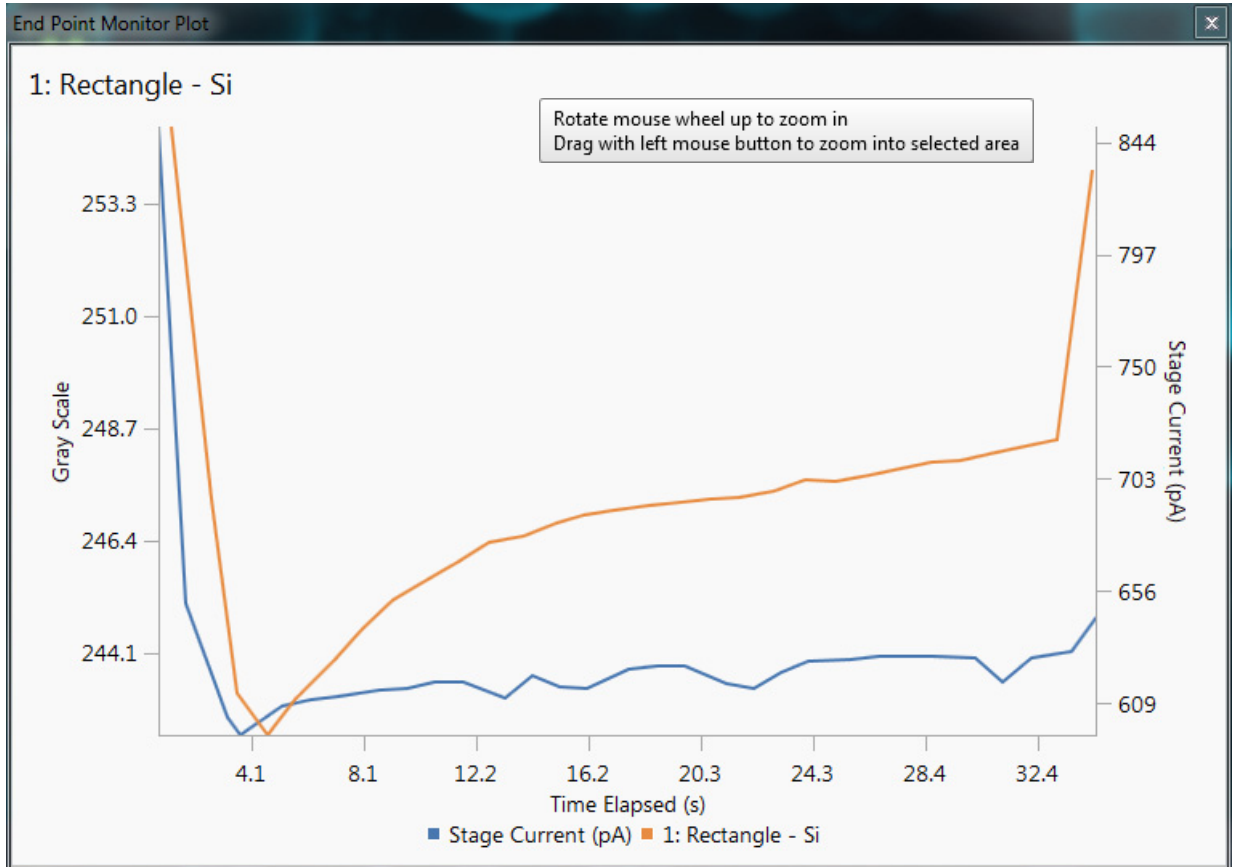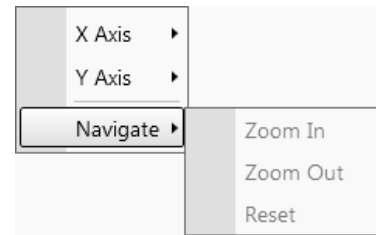


## Drift Suppression tab Module

Clicking on the *On* button switches the *Drift Suppression* mode on (the *Drift Suppression* tab becomes highlighted in orange) / off. This is a special electron beam mode used for ion beam imaging of non-conductive samples and also for patterning.

The ions can positively charge the sample causing an imaging drift and spoiling the beam probe quality. In the Drift Suppression mode, the electron beam (produced by the electron beam column) is used to compensate for the positive charging. The electron beam is activated and set to the spot mode automatically during the milling.
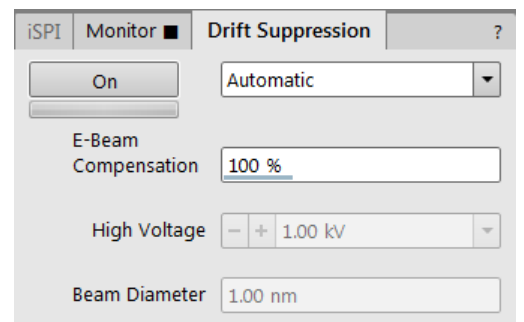
If the *Automatic* is selected, the system uses preset *E-beam Compensation*, *High Voltage* and *Beam Diameter* values. If any of several *Custom* modes is selected and changed to find the optimal setting, values are saved automatically.

To optimize the Drift Suppression parameters so that there are no charging effects visible in the ion beam imaging (it must be stable in position, focus and brightness), move the *Scan* menu / *Spot* mode point in the electron imaging display by clicking on a suitable place. Set the *High Voltage* to about 1 kV and the *E-Beam Compensation* to 100%. When using high spot size numbers (> 6) optimize the current with the source shift. If the neutralization is not sufficient increase the high voltage. Try to find the optimal electron *Beam Diameter* value.

Check periodically (using the Snapshot – Ctrl + F4) if the ion beam patterning does not drift.

When the message *Drift Suppression out of range* is shown in all active I-beam displays (image acquisition or patterning), the tooltip informs the user about the situation:
*Drift Suppression is active. For optimal performance, decrease the ion beam current to 15 nA or less.*

This message will disappear when the I-beam current is decreased below 15 nA.

# Gas Injection Module (option)

Patterns have many associated parameters, such as the gas that can optionally be used during patterning to deposit desired material which is delivered by a Gas Injection System (GIS) on the sample surface.

As different applications require different gases, there can be more GIS's installed on your system. One can 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. A pattern must be defined before the material file is selected.

The GIS can be selected manually, but note that overlap, dwell time and an appropriate gas type should be set carefully to avoid disappointing results.

## Setting up the GIS

The *Gas Injection* module enables to control installed GIS's. A *Gas* type is allocated to each GIS (several injectors may be mounted according to the configuration, its color depends on the gas type). A tool tip info is given about the selected GIS line:

- *Port #* – GIS connection position
- *Lifetime* – time of GIS employment

A right-clicking on the installed GIS module line opens a context menu.

Before the patterning with the GIS starts, the gas reservoir must be heated by selecting the *Heat* column context menu / *Warm* item. The *Cold* status is replaced by a progress bar, which in turn is replaced by the *Warm* status when the GIS is fully heated. To cool down a reservoir, proceed in reverse order.

To insert the GIS needle manually click on the *Insert* check box (a tick mark). A confirmation dialog appears. Clicking on the *Insert* check box again retracts (clear box) the GIS.

## C a u t i o n !

*Confirm the insertion if you know there is nothing obstructing its travel.*

*Beware of stage moves while GIS is inserted! The GIS needle can be damaged by incautious stage movements!*

To open / close the GIS valve click on the *Flow* column / *Closed* / *Open* status. This will not be possible until the *Heat* column / *Warm* status is reached.

*Note*

*If any Property tab module / Gas Type is chosen, the opening / closing of GIS valves is done automatically during patterning.*

Some conditions must be fulfilled before the insertion is enabled, user is notified by a tool tip.

When not in use, the GIS should be closed (to save 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.

## C a u t i o n !

*Logging off an actual user does not change conditions of GIS's.*

*It can be Warm, In and Opened even if the Microscope Control software is closed!*

*When the vacuum status is vented, GIS needles are retracted automatically. In spite of that retract it/them manually before you start any activity inside the chamber (specimen exchange, detector mounting etc.).*

## Application Files

There are several application files delivered with the system which are intended for different use. Each one incorporates multiple parameters for particular patterning. Some of these application files use GIS's. With multiple GIS's installed on your system you can select a suitable application file for a given pattern. Processing 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. There are pre-defined (non-editable) and user-defined (saved) files.

*Note*
*A pattern must be defined before the Application file is selected, the pattern type automatically predetermines the set of possible application files (therefore a gas type).*

*Within the application files compilation there are former Si application file with Volume per Dose value determined in the past and the Si New application file with values corrected for use with the silicon. Be aware of different results using these application files!*

### Application Files Editing

New application file can be created or an actual Application file can be edited in the Windows Notepad® in case any parameter of the process is insufficient. Application files (*.xml extension) are located in the *C:\Program Files\Fei\data\patterning application files\* folder.

*Note*
*If any Application file is to be changed it is recommended to make a copy of the original one. Server restart is necessary after placing a new Application file to the above mentioned folder to be functional.*

#### *Examples*

For clear arrangement there are comment lines within xml files:

- *comment line* filter
  <!-- Application file for milling silicon (Si) without any gas -->

In order to make the application files selection more comprehensible several filters has been implemented:

- *beam type* filter
  The system only shows application files which are related to a beam type set (if an ion beam pattern type is selected, application files which have it designated are shown).
  <Beam xmlns:dt="urn:schemas-microsoft-com:datatypes" dt:dt="string">Ion</Beam>
  This setting filters out all application files related to the electron beam. If the command is left blank the file is shown for both beams.

*Note*
*The I in ion or E in electron must be capitalized.*

- *pattern type* filter
  The system only shows application files which are related to a given pattern type.
  <!-- Optional type, must be "Line, Circle, Rectangle, RCS, Bitmap, StreamFile, Polygon", can be a combination -->
  <PatternType xmlns:dt="urn:schemas-microsoft-com:datatypes"dt:dt="string"> CCS</PatternType>
  Multiple patterns can be designated in a list separated by commas. If the command is left blank the file is shown for all pattern types.

- *GIS type* filter
  The system only shows application files depending on GIS's installed on the system.

It is possible to edit / add / remove parameters (for instance Refresh Time – for filling vias, Blur – for depositing large areas etc.) if required for certain applications.

- *Volume per Dose* variable
  <VolumePerDose xmlns:dt="urn:schemas-microsoft-com:datatypes" dt:dt="r8">
  $0.15e^{-9}$
  </VolumePerDose>
  The Volume per Dose is material dependent. Using any application file for milling different material substrates results in a different *Z size*. The actual value can be measured and subsequently a new Volume per Dose value can be defined / set.
  When using the ion beam (without any gas environment at 30 kV) the Volume per Dose values (Sputter Rates) for various materials can be found in the following table.

**Table 5-7**   *Material Sputter Rates at 30 kV*

| Material | Volume per Dose [$\mu m^3$ / nC] | Material | Volume per Dose [$\mu m^3$ / nC] |
|---|---|---|---|
| *C* | 0.18 | *Au* | 1.50 |
| *Si* | 0.27 | *MgO* | 0.15 |
| *Al* | 0.30 | *SiO$_2$* | 0.24 |
| *Ti* | 0.37 | *Al$_2$O$_3$* | 0.08 |
| *Cr* | 0.10 | *TiO* | 0.15 |
| *Fe* | 0.29 | *Si$_3$N$_4$* | 0.20 |
| *Ni* | 0.14 | *TiN* | 0.15 |
| *Cu* | 0.25 | *Fe$_2$O$_3$* | 0.25 |
| *Mo* | 0.12 | *GaAs* | 0.61 |
| *Ta* | 0.32 | *Pt* | 0.23 |
| *W* | 0.12 | *PMMA* | 0.40 |

*Note*
*PMMA – PolyMethylMetaAcrylat*

### Application Files Examples

The *non-gas* assisted milling – the *Si New* application file:

- Beam Type: Ion
- Dwell Time (the time the beam spends on a single pixel per pass): $1.0\ e^{-6}$ s
- Overlap (the beam diameter overlap): 50%
- Volume per Dose (the amount of material volume removed per charge): $0.27\ e^{-9}$ m$^3$/nC
  This is called sputter rate in previous dual beam tools.

The *gas-assisted* application file – the *Tungsten* application file:

- Beam Type: Ion
- Dwell Time: $250\ e^{-9}$ s
- Overlap: -50%
- Volume per Dose: $0.025\ e^{-9}$ m$^3$/nC
- Refresh Time (the waiting time after each pattern pass): 0
- Blur (beam defocus – to increase deposition for large areas): 0

If the overlap is positive the mill time can be calculated based on the volume per dose parameter and the beam current:

$$Volume\,per\,dose = \frac{volume}{charge} = \frac{cubic\,microns}{nano\,coulom\,b} = \frac{cubic\,microns}{beam\,current \times time}$$

$$mill\;time = \frac{cubic\,microns}{beam\,current \times Volume\,per\,dose}$$

For example, create a filled box pattern (5 × 5 × 2) μm (X × Y × Z, the desired material volume to be milled is 50 μm$^3$) and choose 0.5 nA, which is 0.5 nC/s.

Therefore:

$$mill\;time = \frac{50\,cubic\,microns}{0.5\,nanocloumbs\,per\,second \times 0.15} = 666.6\;sec. = 11\,min.\,6\,sec.$$

Doubling the Z size – the desired volume would be twice larger and the milling time twice longer, doubling the beam current cuts milling time by half.

# Milling

To mill a pattern on the sample material set the stage (the sample area of interest) to the eucentric position and tilt it to the 52°. Follow the procedures below.

## Process optimizing

Use the Beam shift (MUI *Shift X / Y* knobs) to fine tune an imaging. It is used in many applications, such as fine milling of cross sections to give a clean, vertical face to the section. Use it also to adjust for drifting or charging of the sample. Acquire an image to monitor any change in mill position or carefully monitor the process via the real time imaging.

### Beam currents & Milling times

The appropriate beam current value depends on the sample to be milled and your experience with the sample material. Lower beam currents are less destructive but take longer to mill. The following are guidelines only. Specific parameters depend on your sample material and objectives.

**Table 5-8**    *Beam Currents / Milling Times by Application*

| Milling Application | Suggested Beam Current / Milling Time |
|---|---|
| **Typical cross sections (< 20 µm wide)** | Try for a total time of 5–15 minutes, using 2–5 nA of current. Larger currents cause more damage around the recess and fewer vertical walls. |
| **Large cross sections (very wide or deep ones)** | Raise milling time to 15–20 minutes or more (beware of drifts), using 5–20 nA current. |
| **Cleaning cross section** | Use a value no less than one quarter to one half of the main current (500, 300, 100, 50 pA). |
| **Drilling or cutting tracks** | A drilling time from 1–4 minutes is adequate. The main limitations of short drilling times are difficulty in doing End Point Detection and the possibility of causing charge damage. |

## Milling a Pattern

1. Select a desired pattern from the *Patterning* page / *Pattern Type* selector, draw a pattern on the area to be milled in the selected display. If necessary, use the MUI *Shift X / Y* knobs or resize the pattern to correct positioning.
2. Store this position in the *Stage* module / *Location* list (you can easily return here after optimizing the imaging).
3. Focus and correct the beam astigmatism at the area adjacent to the pattern (not to affect the area of interest).
4. Select a beam for patterning and set its current value.
5. Set the *Property Editor / Z size* value in µm.
6. Acquire an image by clicking on the *Snapshot* button to confirm the pattern position.
7. To start the milling click on the toolbar *Start Patterning* icon.

   At any time you can stop a progress by clicking on the toolbar *Pause Patterning* icon.

   To release (restart) patterning from where it was left off click on the toolbar *Resume Patterning* icon.

   To reset patterning click on the toolbar *Reset Patterning* icon when patterning is stopped (paused).

   If patterning is reset and started again by clicking on the toolbar *Start Patterning* icon (not regarding any modification was done), it starts from the first pattern and all patterning clocks are set to zero.
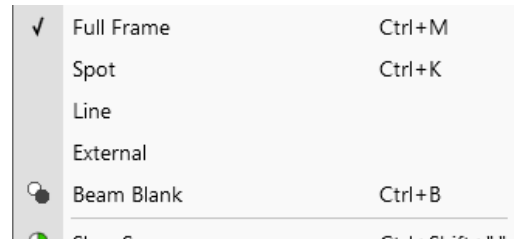
## Milling in Spot Mode

This procedure is convenient to drill holes with diameter depending on the beam size.

1. Select the *Scan* menu / *Spot* mode. In this mode no scanning takes place.

   The single spot (green cross) cursor appears directly in the center of the screen. If the cursor is not moved the milling process will take place here otherwise click anywhere on the image to move the spot to another position.

2. Move the feature to be drilled to the green cross cursor.

3. Start the beam.

4. To acquire an image, click on the *Snapshot* button.

5. Release (unpause) active display to proceed with milling.

6. To exit spot mode, select the *Scan* menu / *Full Frame* item.

| | | |
|---|---|---|
| ✓ | Full Frame | Ctrl+M |
| | Spot | Ctrl+K |
| | Line | |
| | External | |
| 🔘 | Beam Blank | Ctrl+B |

## Creating Cross Sections

Cross sections are cut in a stair step way to allow the exposed layers to be seen with the electron beam when the stage is tilted to 52°. Typically this process runs in two or three stages.

- The first stage is to mill a *Regular Cross Section* with five superimposed box patterns sharing common edges.
- For the second (optional) stage use either pattern type with *Property* tab module / *Fill Style* set to *Solid* or the *Cleaning cross section* at a reduced current. (If the cross section is large, the second cleaning may be required at a lower current.)
- For the third stage, use the *Cleaning Cross Section*.

The following figure shows the relation of these pattern areas and their relative sizes.

**FIGURE 5-14** *Typical Cross Section*
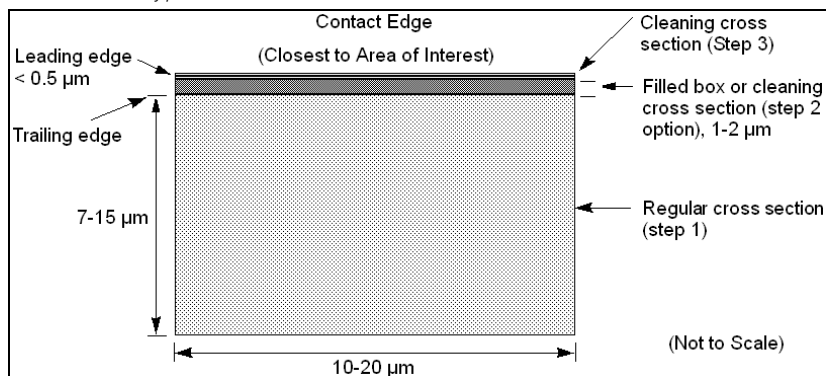


A typical cross section is 10–20 μm wide by 7–15 μm high with the dimensions and depth appropriate to the size of the target area of interest.

Use caution in positioning boxes if you are sectioning a very specific point. Use fine milling to expose the exact area of interest. For example, 2 μm offset should be enough at 2 nA beam current.

Calculate the outline as the height of the box relative to the depth to be milled. If you intend to view at 52° and see details 3 μm from the surface, then the original box should be at least 3 μm high.

### First stage

Mill a *Regular Cross Section* with five superimposed box patterns sharing common edges.

1. Select the display 1, the electron beam and start the beam.
2. Perform the eucentric position setting procedure.
3. Move the stage to where you want to mill the cross section.
4. Tilt the stage to 52°.
5. Store this position in the *Stage* module / *Location* list.
6. Move the stage to an adjacent position for optimization of the ion beam imaging.
7. Perform the Beams coincidence setting procedure.
8. Select the display 2 and set the ion beam current to 150 pA – 5 nA, depending on the size of the cross section.
9. Optimize the ion beam imaging.
10. Move the stage to the stored position (see the step No. 5).
11. Set magnification and the sample position.
12. Acquire a ion beam *Snapshot* image.
13. Select the *Patterning Control* module / *Pattern type* selector / *Regular Cross Section*.
    Draw a rectangular box about 2 μm from the area of interest.
14. Set the *Property* tab module / *Application* item / *Si New* and the *Property* tab module / *Z size* value as needed.
15. Acquire a ion beam *Snapshot* image.
16. Click on the toolbar *Start patterning* icon.
17. Acquire an electron or ion beam *Snapshot* image as desired to monitor the process.

### Secon stage (optional)

1. Perform the Beams coincidence setting procedure.
2. Set the ion beam current to approximately ¼ of the beam current used for the first stage.
3. Acquire a ion beam *Snapshot* image.
4. Select the *Patterning Control* module / *Pattern type* selector / *Cleaning Cross Section* and draw a rectangular box. Adjust its size so that its leading face is approximately 0.2 μm from the target area and the trailing edge extends just beyond the rough cut.

*Note*
> *Remember to set the Property tab module / Z size value*

5. Acquire another ion beam *Snapshot* to check positioning of the pattern to the feature.
6. Click on the toolbar *Start Patterning* icon.
7. Acquire an electron *Snapshot* image in a different display.

### Third stage

1. Acquire a ion beam *Snapshot* image in the display where milling takes place. Focus as needed.
2. If the cut is too rough, change the ion beam current to 100 pA – 1 nA.
3. Select the *Patterning Control* module / *Pattern type* selector / *Cleaning Cross Section* item and draw a rectangular box. Adjust its size so that its leading face crosses the target area and the trailing edge extends just beyond the rough cut.
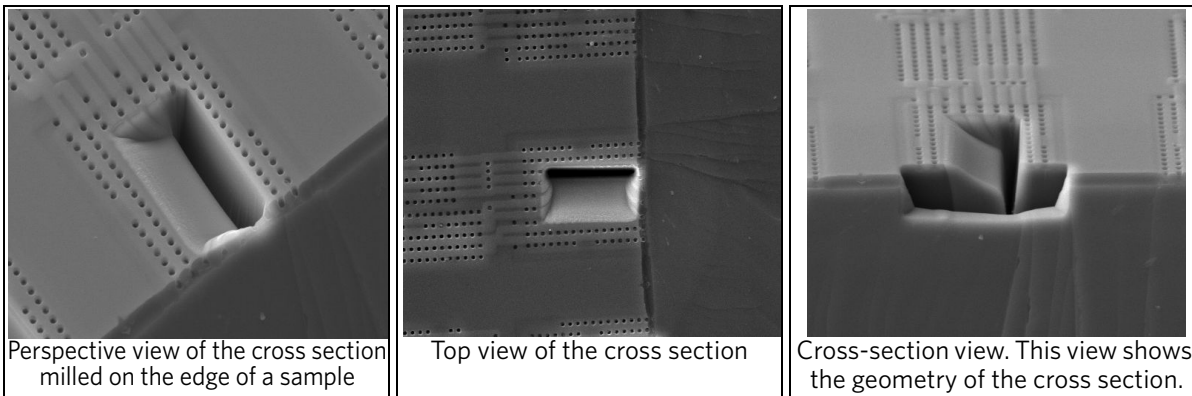
*Note*
> *Remember to set the Property tab module / Z size value*

4. Acquire a ion beam *Snapshot* image.
5. Click on the toolbar *Start Patterning* icon.
6. Acquire an electron *Snapshot* image in a different display. A BSE detector (T1) is suitable for electron imaging during ion patterning.
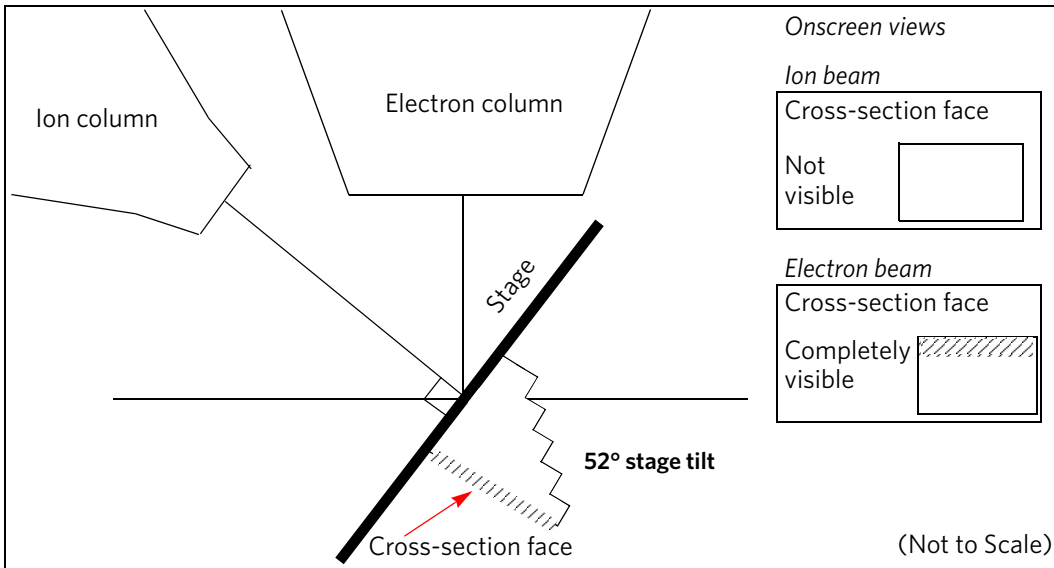
# Viewing Cross Sections

After cutting the cross section, lower the ion beam current to 10 or 30 pA and tilt the stage to 52° to view the cross section with the ion beam. The following figure shows examples of some typical milling of a cross section.

**FIGURE 5-15**  *Cross-Section Views*



| Perspective view of the cross section milled on the edge of a sample | Top view of the cross section | Cross-section view. This view shows the geometry of the cross section. |

The following figure shows the relation of the columns and stage to the face of the cross section during milling and how this is viewed onscreen, depending on whether you are imaging with the electron or ion beam.

**FIGURE 5-16**  *Cross-Section Viewing during Milling*

The following figure shows the onscreen view with the stage at 0° tilt, with both the electron and ion beam imaging views.

**FIGURE 5-17** *Cross-Section Viewing at 0° Tilt*
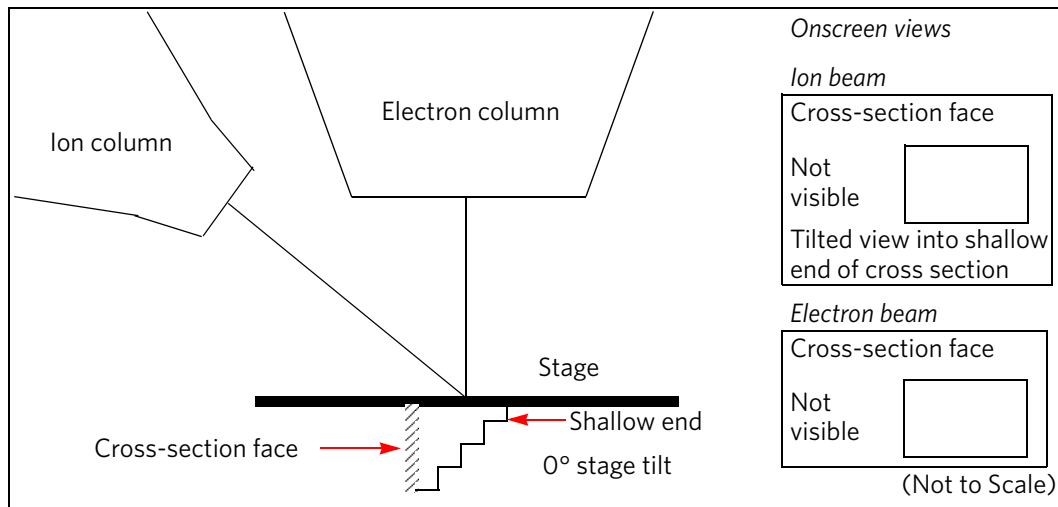


The following figure shows the onscreen views with the stage still at 0° tilt, but with both stage and ion beam scan rotation at 180°.

**FIGURE 5-18** *Cross-Section Viewing at 0° Tilt Rotated 180°*