

# Scanning Electron Microscope

**MIRA<sup>3</sup>**  
FEG-SEM

## Instructions for Use

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We have checked the contents of this manual for agreement with the hardware and software described. Since deviations cannot be precluded entirely, we cannot guarantee full agreement.

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# 1 Introduction

The MIRA 3 series is a family of high-quality; fully PC-controlled scanning electron microscopes equipped with a Schottky Field Emission electron gun designed for high vacuum or variable pressure operations.

The most important features of the microscope are:

- High brightness Schottky emitter for high-resolution / high-current / low-noise imaging.
- Unique three-lens Wide Field Optics™ design offering the variety of working and displaying modes embodying the Tescan proprietary Intermediate Lens for the beam aperture optimization.
- Real time In-Flight Beam Tracing™ for the performance and spot optimization integrating the well established software Electron Optical Design.
- A powerful In-Beam detector of secondary electrons located in the objective lens enabling work at very short working distances for high resolution.
- Fast imaging rate.
- High-throughput large-area automation, e.g., automated particle location and analysis.
- Fully automated microscope set-up including electron optics set-up and alignment.
- Sophisticated software for SEM control, image acquisition, archiving, processing and analysis.
- Network operations and built-in remote access/diagnostics.

This manual provides an overview of the components, the operational principles and the use of MIRA 3 scanning electron microscopes. Not all parts of this manual may apply to a given installation nor should be taken laterally in all cases. Details of the MiraTC software may also vary according to the actual setting and thereby differ slightly from what is shown in the figures.

Since MIRA 3 is installed and maintained by trained specialists, technical details and installation procedures are limited to a short overview. In case of necessary maintenance, reinstallation, hardware changes, etc. the appropriate service authorities or your local supplier must be contacted for further assistance and instructions.

## 2 Safety Information

The microscope is equipped with an uninterruptible power supply (UPS). The following steps are necessary to remove voltage from all the parts of the microscope:

1. Unplug the mains power cord of the UPS from the mains socket.
2. Switch the mains switch of the UPS to the off position.

Only a service engineer can perform operations with the microscope mains switch, UPS mains power cord or UPS mains switch.

The user is liable to make himself familiar with the care of the device and with the safety rules valid in the country of the user. The microscope works with electric voltages that can be dangerous to life.

Any operations with the device which are not mentioned in these instructions, especially the removal of the housing and manipulation with the electric parts of the microscope, may be carried out only by an authorized person. It is also forbidden to substitute a part of the microscope for any other part that is not original and is not delivered by the microscope producer (e.g. the substitution of the original steel blinds on the flanges of the microscope chamber for light alloy blinds can cause an emission of dangerous ionizing radiation!)

The microscope is provided with a number of automatic protections making unsuitable use impossible (e.g., it is not possible to switch on high voltage sources if the specimen chamber or electron gun space are open or are not evacuated to the working vacuum). The deactivation of these protections can cause destruction of the machine and endanger of the health of the operating staff.

The symbols used meet the regulation standard ČSN EN 61010-1, except the symbol



marking the connectors with high voltage that are not dangerous in aspect of the mentioned regulation standard (accidental touch can only cause electrical shock).

In the documentation there will two type of additional information given: Notes and Warnings,

Notes are designated thus:

Note:

In Italics and Blue print.

Warnings are designated thus:

WARNING:

In Italics and Red print.

## 3 Installation and Microscope Repairs

### 3.1 Transport and Storage

The method of delivery is defined in the contract and it is determined individually according to the destination. The method of delivery must be approved by the manufacturer. The instrument is delivered partially disassembled and packed. The purchaser is obliged to check the status of the boxes after handover by the delivery company. In the case of any damage it is necessary to catalogue the damage and inform the manufacturer of the situation. The packed instrument must be stored in a dry and clean place with a temperature range from  $-20^{\circ}\text{C}$  to  $+40^{\circ}\text{C}$  and must not be exposed to corrosive substances which can cause oxidation (acid vapours etc.).

### 3.2 Installation Instructions

The microscope is delivered including installation. Installation must be ordered from the seller. The customer shall inform the seller of the readiness of the laboratory for the installation. Once the laboratory is ready, technicians of the manufacturer or technicians of an approved company will carry out the installation, connection to the mains and user training. The customer is not allowed to connect the microscope to the mains or do any other manipulation, except moving the microscope to the storage place. The installation company will fill in the installation protocol. The warranty period will start from this date and the user can start using the instrument normally as described in this manual.

### 3.3 Fuse Replacement

The instrument does not contain any fuses which can be replaced by the user. All fuses are located under the covers, which can be removed only by a service technician from the manufacturer or a service technician of an approved company. The fuses can be replaced only by exactly the same type; the type is described in the documentation or on the fuse holder.

### 3.4 Instrument Repair and the Spare Parts Usage

It is only permitted to use original spare parts delivered by the manufacturer. Repair and maintenance which exceed the procedures mentioned in this manual can be performed only by the manufacturer's service technician or a service technician from an approved company.

## 4 Description of the Microscope

### 4.1 Electron Column

The scanning electron microscope displays the examined object by means of a thin electron probe. The column forms the electron probe (beam) and sweeps the beam over the examined specimen located in the microscope chamber. Most imaging qualities of the microscope depend on the parameters of this electron beam: *spot size*, *aperture angle* and *beam intensity*.

**The spot size** determines the resolution of the microscope as well as usable magnification at stable picture sharpness. It is mainly considered that the spot is circular and has a Gaussian intensity profile. We can specify its size for example with half the width of the intensity distribution. The spot size is determined by the demagnification of the primary electron source, optical aberrations of the final lens (objective) and the diffraction aberration on the final aperture. The spot size is smaller at shorter working distances.

The incident electron beam is cone-shaped. The vertex angle of the cone is determined by the **aperture angle**. The wider the cone, the lower the depth of focus.

**The beam intensity** (BI) is determined by the number of electrons passing through the probe in a defined time. The image noise of the electron microscope depends on the number of electrons used for the information collected from each picture element. It is necessary to use more time for image scanning at low beam intensity and vice versa.

It is evident that the incident beam parameters influence each other. The optical system of the microscope allows operation in different modes when some parameters of the beam can be preferred and the others can be kept down. Here are some typical examples:

- *Work on high magnification.* It is necessary to reach a high resolution; therefore a low beam intensity, short working distance and slow scanning speed should be used. We recommend using the RESOLUTION mode, working distance not more than 7 mm and scanning speed 7 or slower. See chapter 4.1.1.
- *Work with high intensity.* Resolution is small and useful magnification is low but fast scanning can be used because the signal to noise ratio is better. In any mode, use the function BI. The higher the BI index, the higher the beam intensity (the current of electrons in the beam). The exact value of the intensity can be set by function BI continually.
- *Work with high depth of focus.* The aperture angle must be small. Use the Depth mode.

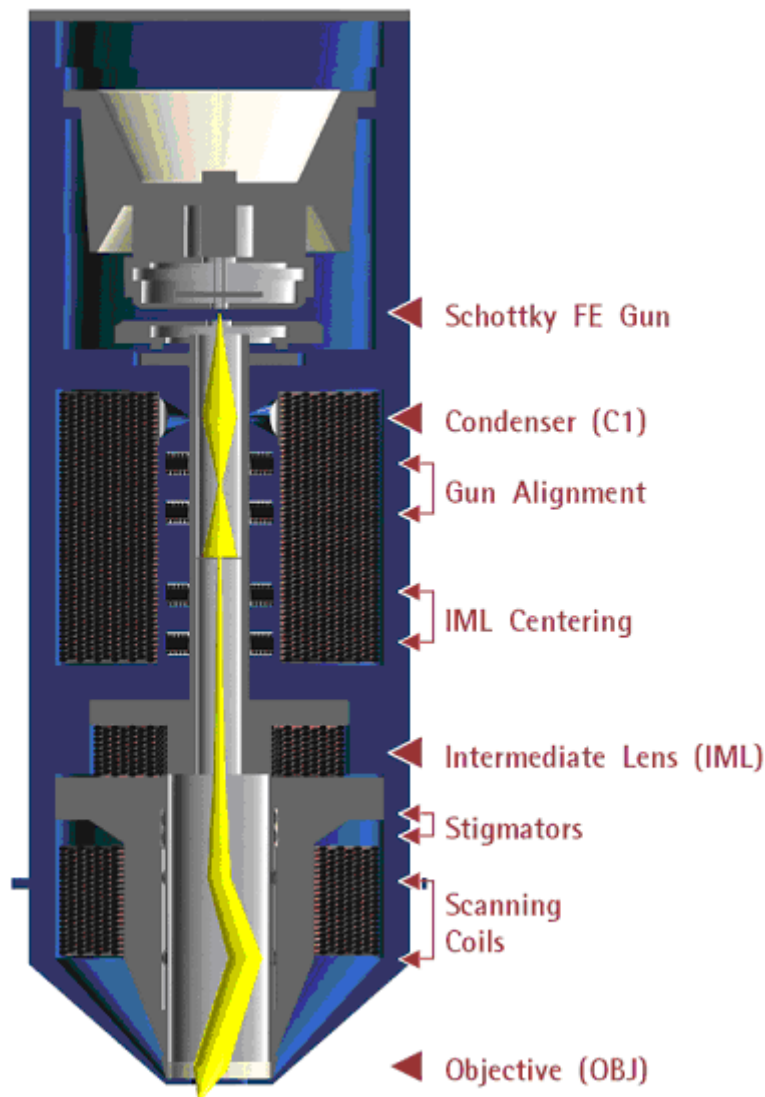
**The column of the microscope MIRA 3** consists of the following main parts:

- **The electron gun** is the source of accelerated electrons. It consists of a suppressor, an extractor and an anode. The filament tip is connected to the negative electric potential while the anode is on zero potential. The filament tip is made of a tungsten wire with about 0.5  $\mu\text{m}$  radius sharp peak. The filament tip is fixed to the tungsten wire heated to a temperature of 1800 K. Electrons are emitted by the tunneling through the surface barrier with contribution of the strong electrostatic field with an intensity of  $10^8 \text{ V/m}$  (Schottky effect).



The tip's high temperature helps to prevent contamination of the tip and together with an atomic layer of the ZrO on the surface helps improve conditions for electron emission. The extractor ensures a high electrostatic field on the filament tip. It is located right in front of the filament tip and it has a positive voltage potential of several kilovolts (extracting voltage).

The MIRA 3 cross section and schematic representation of the optical elements:



The electron flow from the gun is specified by the *emission current*, which depends on the extracting voltage. Electron emission from the side of the filament is suppressed by the suppressor, which is located right behind the filament tip. The suppressor potential is several hundreds volts lower than the filament tip potential. The *accelerating voltage* between the cathode and the anode determines the overall energy of the electrons.

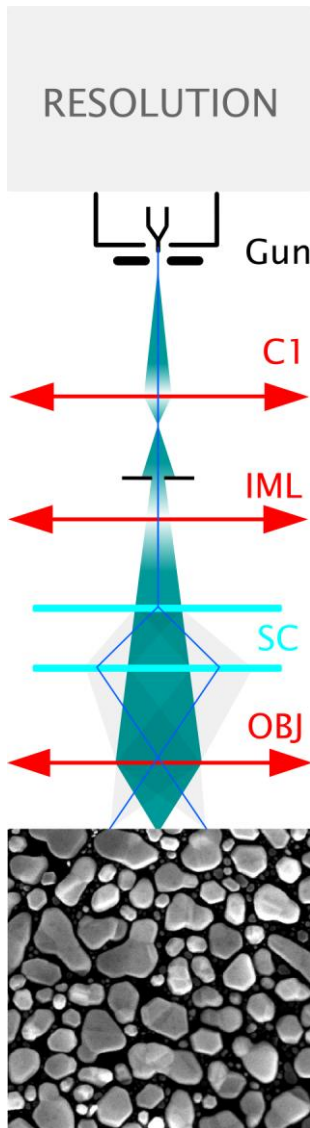
The whole system behaves as an electron virtual source located in the region of the end of the tip with a characteristic size of approximately 20 nm, energy of the electrons in the range of 200 eV to 30 keV, emission current up to 300  $\mu$ A and solid angle from 0.2 mrad/srad to 0.35 mrad/srad.

- **The condenser C1** is a strong magnetic lens which controls the amount of electrons passing through the aperture diaphragm. The higher the condenser excitation, the shorter the focal distance and thus the beam cross-over is further from the aperture diaphragm. By moving the cross-over towards the aperture diaphragm the beam current becomes higher. The condenser current and thus its focal length can be controlled by means of preset BI (Beam Intensity, BI 1 – BI 20) steps, or by entering the direct beam current value (BI Continual) or by the spot size value (Spot Size) which is strictly related to the beam current.
- **The gun centering** is formed by a system of electromagnetic deflection coils under the gun. It is intended for tilting the electron beam emitted from the gun, so that it enters the axis of the optical system of the column. It is controlled by the function **Gun Tilt**. The gun can be centered optimally by the automatic function which can be activated by the button "Adjustment >>> /Auto gun centering".
- The fixed **aperture diaphragm** trims the final displaying beam. It is located under the condenser and gun centering coils. The size of the diaphragm is chosen according to the optimal aperture angle of the electron beam and determines the maximum resolution ability of the column.
- The auxiliary **IML lens** is a magnetic lens used for the aperture change of the beam entering the objective lens or for beam displaying if the objective lens is off. The change of the IML excitation causes a shifting of the electron beam across the optical axis and it is therefore necessary to compensate this shifting by means of the centering coils **IML Centering**.
- **The stigmator** is an electromagnetic with an octupole design. It is intended for compensation of astigmatism in all the modes.
- **The scanning coils** are formed by two stages of the deflection coils. A scanning ramp is connected to the coils. The ramp frequency determines the scanning speed of the electron beam; the amplitude determines the microscope's field of view and the magnification.
- **The objective** is the last magnetic lens of the column that forms the resulting electron beam. In the usual modes the excitation of the OBJ determines the working distance – the distance between the focused specimen surface and the lower objective pole piece. In the Mira 3 with In-Beam technology the lens is combined electrostatic-magnetic for further improvement in microscope performance.

### 4.1.1 Electron Column Displaying Modes

#### RESOLUTION Mode

This is the basic and most common displaying mode. The IML lens is switched off, the OBJ lens is excited and it focuses the final electron beam.



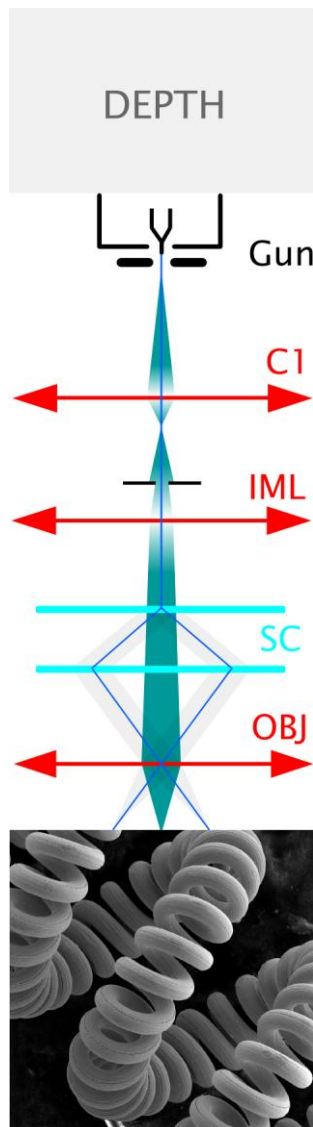
#### Characteristic:

- high resolution
- low depth of focus

The MIRA 3 works like the other common three lens microscopes without IML in this mode. The aperture is nearly optimal for lower BI values (small spot size, low beam current) short working distances (4 – 5 mm) and for the accelerating voltage 30 kV. The pivot point of the scanning and the electric image shifts are close to the principal plane of the objective OBJ so that the curvature of the field, distortion and field of view are as good as possible. The centering of the objective OBJ is performed by defined beam tilt of the central electron beam, which does not cause image shift. This mode is intended for displaying with the highest resolution.

## DEPTH Mode

The DEPTH mode differs from the previous mode by the auxiliary lens IML being switched on.



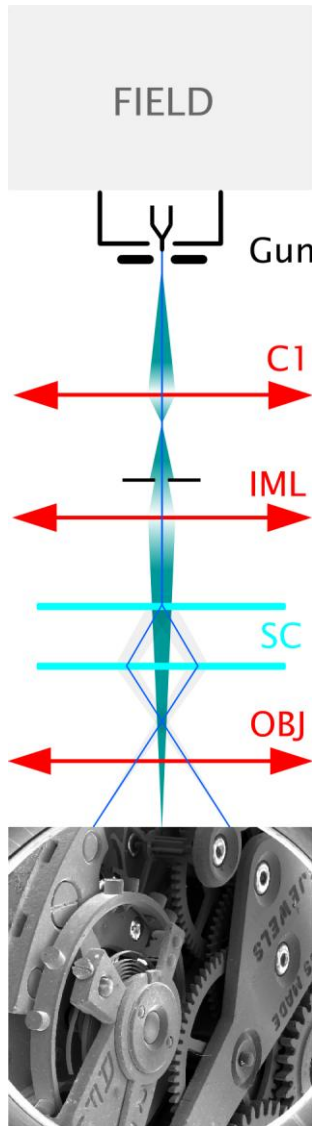
### Characteristic:

- good resolution
- increased depth of focus

The aperture of the final beam is lower, but the spot size is bigger in comparison with the RESOLUTION mode. The beam in the probe stays unchanged. This mode is used if it is necessary to have a greater depth of focus.

## FIELD Mode

The FIELD mode utilizes the intermediate lens IML for the electron beam focusing while the objective OBJ is off.



### Characteristic:

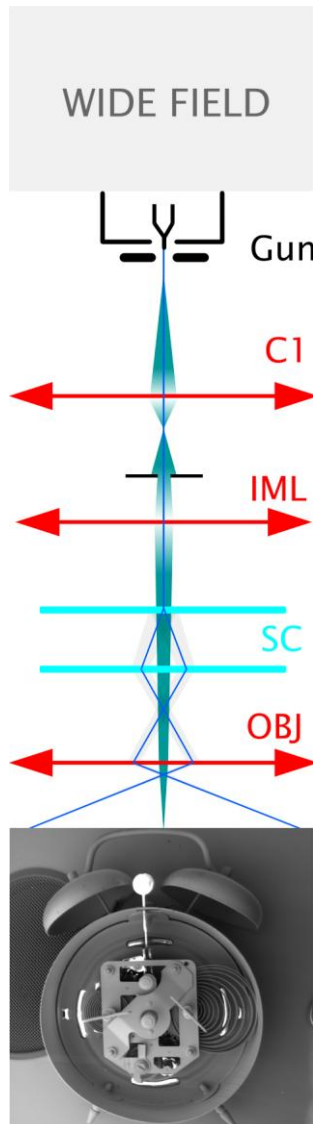
- large field of view
- high depth of focus
- worse resolution

The beam aperture is very small and the depth of focus is usually higher than the field of view. As the objective OBJ is off in this case, it does not affect the middle beam and thus does not need to pass near the centre of the objective OBJ. The position of the pivot point of scanning is optimized according to the field of view. The centering coils IML center the supplemental intermediate lens IML to avoid image movement during focusing. The DC component of the scanning coils is set up so that no image shift occurs if switched from the RESOLUTION mode to the FIELD mode.

The disadvantage of this mode is bigger spot size; the maximum magnification used is a few thousand. The mode is used for the searching of the parts of the specimen to be examined.

## WIDE FIELD Mode

The WIDE FIELD mode uses the intermediate lens IML for focusing the electron beam, while the objective OBJ is excited to a high value.



### Characteristics:

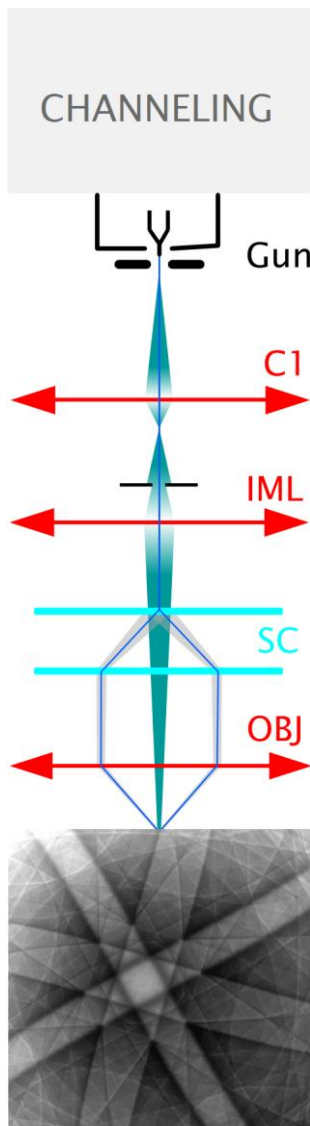
- extra large field of view
- image distortion is corrected and minimized
- only available for post-2007 devices

Highly excited objective multiplies the deflection of the beam. The aperture of the beam is very small and the depth of focus is very high. The IML Centering coil serves for minimizing the image shift when focusing.

The mode is used for to search for the part of the specimen to be examined. To know the proper magnification value, the objective must be well focused. This might be a little difficult due to the high depth of focus.

## CHANNELING Mode

In the CHANNELING mode, the scanning and lens focusing is controlled so that the electron beam touches the same point of the specimen surface all the time. By means of scanning the beam, only the angle of incidence of the electron beam is changed.



### Characteristic:

- the position of the specified point in the image depends on the beam tilt
- it is the mode for ECP acquisition – Electron Channeling Pattern

The resulting image is the amount of electrons dependent on the impacting beam angle. The excitation ratio of the scanning coils is set up so that the beam utilizes the whole area of the objective lens bore and enters the lens parallel to the optical axis.

All electron beams parallel to the optic axis are focused by the lens into a single point on the specimen surface. As a consequence, the scanning is transformed into beam tilting, i.e. the resulting pivot point of the scanning lies on the specimen surface plane.

The intermediate lens focuses the beam into the upper focal point of the objective lens. The result is that the beam, after its passing through the objective lens, is parallel and the angular resolution of ECP (Electron Channeling Pattern) images is at its maximum.

The mode is intended for the examination of crystallographic materials. In consideration of the optical abilities of the MIRA 3 column, the minimum size of crystals is 100 – 150  $\mu\text{m}$ .

*Note: ECP patterns are produced by back scattered electrons, it is preferable to use BSE detector for imaging if available.*

### 4.1.2 Electron Column Centering

To reach high quality images it is necessary to center the electron optics of the column. The centering is electronic and fully controlled by the PC.

Each microscope is factory centered and this setup is stored in the **Default configuration**. By using the function Load default configuration from the menu Options -> Configurations ► the user will save time in the case he gets lost, loses his configuration completely etc. This default configuration file is also used when a new user is created as his initial configuration.

There is factory preset for four accelerating voltages, one for each HV index. Switching among them the MiraTC software remembers all settings so the user does not need to make any further adjustments. However, changing the voltage within single HV index requires performing centering of the microscope:

1. centering of the gun (see chapter 4.1.2.1) ;
2. centering of the column, either automatic (see chapter 4.1.2.2) or manual (see chapter 4.1.2.3) for work on high magnifications.

***Note:** Every user can save his own configurations in menu Options -> Configurations ►. Save as. Using of various configurations can save user's time when switching between various voltages within the same HV index.*

#### Recommended centering conditions

The centering is always performed by means of a special **centering specimen**, which is included in the microscope accessories and is marked as **ADJ**. The surface of this specimen has a fine structure, making the centering easier. If this specimen is not available, it is possible to use a common specimen stub. Once you start centering, the image must be focused perfectly.

Mode	Working Distance (WD)	Beam Intensity (BI)	Magnification (Mag)
Resolution	actual WD on what you want to acquire images	actual BI on what you want to acquire images	2000 – 5000 x
Depth	actual WD	actual BI	2000 x
Field	actual WD	actual BI	500 x
Wide Field	actual WD	actual BI	max. Mag



#### 4.1.2.1 Centering of the Electron Gun

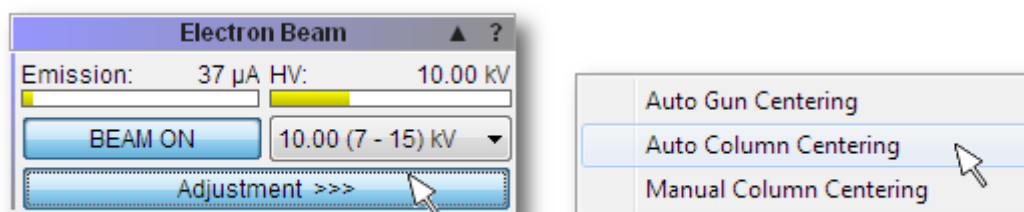
The centering is performed by automatic procedure. It is always necessary to perform this auto centering after the high voltage value changes inside a specified range with the item High Voltage on the Pad panel.

1. Insert the centering specimen.
2. Set up the recommended working conditions.
3. Use the function Adjustment >>> **Auto gun centering** in the Electron Beam panel (see **Figure 16**).

#### 4.1.2.2 Automatic Centering

The automatic procedure of column centering is very fast and suitable for low magnifications. For very precise work at high magnifications the manual centering is more suitable.

1. Insert the centering specimen.
2. Set up the recommended working conditions and focus the image in **RESOLUTION** mode.
3. Use the function Adjustment >>> **Auto column centering** in the Electron Beam panel.



#### 4.1.2.3 Manual Centering

1. Insert the centering specimen.
2. Set up the recommended working conditions and focus the image in **RESOLUTION** mode.

*Note: Manual centering is for experienced users.*

*Note: In case of MIRA 3 with InBeam detector check the item **InBeam mode** in the SEM menu.*

3. Use the **Adjustment >>> Manual column centering** function in the Electron Beam panel. The image starts wobbling that is, periodically changing the working distance. Press the **Next>>** button.
4. Minimize the image movement by changing the **OBJ Centering** (select in the Pad panel) using the trackball and keys F11 and F12. Press the **Finish** button.

It might also be necessary to have FIELD or DEPTH modes precisely centered if working on higher magnifications. If needed proceed with the following steps:

5. Switch to FIELD mode. Set the same magnification for RESOLUTION and FIELD modes. Use the **Adjustment >>> Manual column centering** function in the Electron Beam panel. Minimize the image movement by changing the **IML Centering** (select in the Pad panel) using the trackball and the F11 and F12 keys. Set the same field of view by changing the **OBJ Centering** using the trackball and the F11 and F12 keys.
6. Switch to DEPTH mode. Use again the procedure with **Manual column centering** and **OBJ Centering** (steps 3. and 4.).
7. Switch to WIDE FIELD mode and set the same magnification for RESOLUTION and FIELD modes. Use again the procedure with **Manual column centering** and **OBJ Centering**.

#### MIRA 3 with InBeam detector:

It is recommended to work with enabled InBeam mode all the time. However, there is the possibility to use purely magnetic objective lens. Proceed with following:

1. Uncheck the item **InBeam mode** in the SEM menu.
2. Select the SE detector on the Detectors & Mixer panel.
3. Switch to RESOLUTION mode and center the mode as usual. Ensure that the image is correctly stigmated; especially at low beam voltages (it is applicable also for other modes).

*Note: RESOLUTION mode is the basic and most common displaying mode. The procedure described above is sufficient for working in Resolution mode on high magnifications.*

It might also be necessary to have FIELD or DEPTH modes precisely centered if working on higher magnifications. If needed proceed as follows:

1. Switch to DEPTH mode and centre this mode as usual.
2. Switch to FIELD mode and **only** set the same field of view by changing the **OBJ Centering**.
3. Switch to WIDE FIELD mode and center this mode as usual.

*Note: If you want to align field of view for DEPTH mode exactly with RESOLUTION mode (for magnifications > ~10000), set the same magnification in RESOLUTION and DEPTH modes and then set the same field of view by means of changing the IML Centering parameter.*

***WARNING:** This procedure has a strong influence on the other centering parameters and thus is recommended only for experienced user.*

#### 4.1.2.4 Electron Column Precentering

The column is factory precentered. It is also precentered after every filament exchange by the service technician. Further precentering can be performed only by an **expert level user**. This can be an advantage at lower accelerating voltages ( $HV < 5 \text{ kV}$ ). On the other hand, incorrect precentering can cause a situation where the objective and stigmators cannot be corrected at all.

There are four HV indexes, which should be precentered with care:

HV index	The range of beam voltage [kV]	The beam voltage for centering [kV]
1	0.2–3	2
2	3–7	5
3	7–15	10
4	15–30	20

#### Instructions:

1. Set the HV index and the correct HV for precentering according to the preceding table and change the scanning mode to RESOLUTION. Set the values of **Stigmators**, **IML centering** and **OBJ centering** in the Pad panel to 0 %.
2. Focus the image on the centering sample at magnification >> 1kx (for example 4kx).
3. Use Manual column centering and check the option "**Use OBJ Precentering**".
4. Minimize the image movement by the **OBJ Precentering**.
5. Switch to FIELD mode and center this mode (follow the wizard).
6. Switch to RESOLUTION mode, focus and centre the mode as usual (not checking the option **OBJ Precentering**).
7. Center the stigmators: use the **Stigmator A/B Centering** function in the main menu SEM and follow the wizard for **Stigmator A** and **Stigmator B** (use trackball).
8. Switch to DEPTH mode, focus and centre this mode (follow the wizard).
9. Switch to WIDE FIELD mode and centre this mode (follow the wizard).
10. Repeat steps from 1. to 9. for each of four HV indices.

*Note: In case of MIRA 3 InBeam detector, check the item InBeam mode in the SEM menu.*

#### MIRA 3 with InBeam detector:

1. Uncheck the item **InBeam mode** in the SEM menu.
2. Select the SE detector on the Detectors & Mixer panel.
3. Switch to RESOLUTION mode and centre this mode as usual.
4. Switch to DEPTH mode and centre this mode as usual.
5. Switch to FIELD mode and **only** set the same field of view by changing the OBJ Centering.
6. Switch to WIDE FIELD mode and center this mode as usual.
7. Repeat steps from 3. to 6. for each of four HV indexes.

## 4.2 Chamber and Sample Stage

The chamber is a sealed space under the column for placing your specimen for investigation. The specimen is fixed on the sample stage, thus allowing you to move your sample during the investigation process. The chamber must be evacuated during investigation.

The sample stages are divided into two basic types:

- motorized
- manual

Manipulators have *electrically isolated specimen holders*. The specimen holder is connected to pA-meter. The pA-meter also works as an acoustic contact indicator of the specimen to the chamber. If contact between the specimen holder and the chamber body occurs, all motorized axes will stop and an audible sound will indicate the contact.

### The chamber and sample stage types

Type	Motorized axes	Manual axes	Eucentricity
LM	X, Y, Z, Rotation, Tilt	–	automatic
XM	X, Y, Z, Rotation, Tilt	–	automatic
GMH	X, Y, Z, Rotation, Tilt	–	automatic
GMU	X, Y, Z, Rotation, Tilt	–	automatic

**The eucentric position** is such a position of the specimen, where the observed area of the sample does not move when tilting the sample itself. The auto-eucentric function can be activated by checking the **Keep View Field** box on the Stage Control panel in the MiraTC software.

## 5 Vacuum Modes

The microscope allows the investigation of specimens in a pressure range of 0.005 Pa to 150 Pa.

Mode	Pressure [Pa]	Microscope type	Note
high vacuum	0.005	LMH, XMH, GMH LMU, XMU, GMU	
low vacuum	7 – 150	LMU, XMU, GMU	aperture in the objective

There is a differential pumping aperture in the objective. Sample observation is possible with chamber pressure up to 150 Pa.

### 5.1 High Vacuum Mode

In high vacuum mode, it is possible to investigate both conductive and non-conductive samples; however non-conductive samples require previous metal coating (Cr, Au, Au-Pd, Pt). All displaying modes are available.

### 5.2 Low Vacuum Mode

The low vacuum mode is intended for the investigation of non-conductive samples.

1. Vent the microscope and insert the aperture into the objective (see chapter 9.2).
2. Switch the microscope to Low vacuum mode (pressure range 1 – 150 Pa) using the **UniVac** button on the Low Vacuum Mode panel.
3. Enter the chamber pressure in the Vacuum panel.
4. Pump the microscope.
5. Enter the requested pressure value in the field next to the UniVac button and click on the OK button.
6. Only **RESOLUTION** and **DEPTH** modes are allowed to be used.
7. To return to the high vacuum mode, click on the UniVac button, vent the microscope and remove the final aperture from the objective.

## 6 Detectors

The detection system may contain a set of detectors designed for detecting various signals resulting from electron beam interaction with the sample surface. The microscope is always delivered with the SE detector.

### Switching on

- In the case of adjustment of the required detector, select the appropriate one from the list box in the Detectors & Mixer panel (see **Figure 4**). This procedure is valid for all detectors except the LVSTD, where further procedures are needed (see chapter 6.3). In the case of the InBeam detector, check the item InBeam mode in the SEM menu first.

### 6.1 SE Detector

*The detector works in high vacuum only.*

Secondary electrons enhance topographic contrast as opposed to material contrast of back-scattered electrons. The secondary electron (SE) detector is a basic standard detector always present in the microscope.

The SE detector is of an Everhart-Thornley type. The grid on the front part of the detector has positive potential. This attracts and accelerates the low-energy secondary electrons arising on the specimen surface and focuses them onto the scintillator. The light flashes, which result from the impingement of the electrons on the scintillator, are transferred through the light guide to the photo-multiplier outside the chamber of the microscope.

### 6.2 In-Beam SE Detector

*The detector works in high vacuum only.*

The so-called In-Beam detector is located in the objective lens and detects secondary electrons. It attracts electrons emanating from the sample surface into the objective lens and catches them there. This type of detection is sometimes called “in-lens” or “through-the-lens” in the literature.

This allows for the observation of specimens at very short working distances (WD) and thus with improved resolution. The standard SE detector at a short WD would not have a good signal because the path of secondary electrons from the specimen to the standard SE detector would be shielded by the column. Moreover, the combined electrostatic-magnetic lens gives further improvement of microscope performance.

In-Beam technology works in its own mode of the column (the item *Enable InBeam mode* in the SEM menu is checked). Therefore, objective centering and stigmator parameters are different from the condition of disabled InBeam mode. The software automatically remembers the set of parameters when switching between these two. All optical modes are available in the In-Beam regime (Resolution, Field, Depth, Wide Field, and Channeling) and all detectors may be used (InBeam, SE, BSE and others). We recommend working with the InBeam mode enabled all the time.

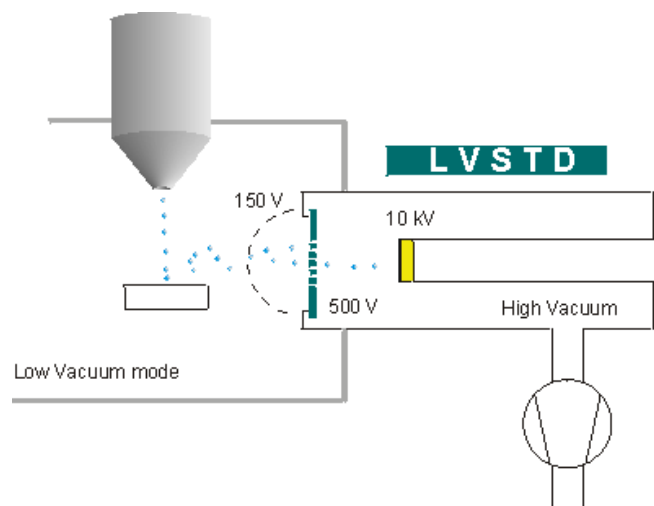
Images taken by the SE detector and the In-Beam detector may differ because the In-Beam detector observes a specimen from the top whereas the SE detector from the side. The resolution is better at a short WD using the In-Beam detector. The signal also varies with WD. It is generally recommended preferring the In-Beam detector at a WD shorter than about 5 mm and the standard SE detector at a WD longer than 5 mm. At a short WD be very careful not to hit the objective with the specimen.

### 6.3 LVSTD Detector

*The detector works in low vacuum only.*

The LVSTD detector (*Low Vacuum Secondary Tescan Detector*) is a detector of secondary electrons, specially designed for low vacuum mode. It is suitable for the investigation of non-conductive samples.

The LVSTD consists of a standard Everhart-Thornley detector situated in a separated detector chamber. This detector chamber is pumped by a small turbo molecular pump.



#### Switching on

1. Check that the UniVac mode is switched on and check that the required value of the pressure in the chamber has been set lower than ~150 Pa.
2. To switch on the detector click on the LVSTD button on the **Low Vacuum Mode** panel (see **Figure 13**).
3. Now the detector chamber is automatically pumped down. This may take about 2 minutes. The blinking message "LVSTD detector not ready yet" appears in the panel. Wait until this message disappears.
4. In the **Detectors & Mixer** panel select LVSTD detector from the list box (**Figure 4**).

#### Switching off

The detector can be switched off by simply clicking on the LVSTD button on the **Low Vacuum Mode** panel.

The detector is automatically switched off:

- if the pressure in the chamber exceeds value higher than 150 Pa.
- if the UniVac mode is switched off.

The detector needs to be switched on manually if automatic detector switch-off occurs.

*Note: The stability of the signal from the LVSTD depends strongly on the pressure inside the chamber. In order to obtain an image with stable brightness, it is necessary to have stable pressure in the chamber. Therefore, after a change of the required pressure value, it might be necessary to wait a while until the pressure reaches the new level and becomes stable.*

*Note: The secondary electrons, in contrast with backscattered electrons, are much more sensitive to specimen surface charging, as they are of very low energy. There are several ways how to eliminate charging: using a higher pressure in the chamber, using a lower accelerating voltage of primary electrons or using lower electron beam current.*

## 6.4 BSE Detector

***The detector works in both high and low vacuum.***

Back-scattered electrons (BSE) enhance material contrast of the sample. The BSE detector is of the scintillation type. An annular (YAG) mono-crystal scintillator with a conductive surface is placed in the optical axis directly under the lower pole extension of the objective. The high energy back-scattered electrons impinge the scintillator without any additional acceleration and excite the scintillator atoms that emit visible radiation photons successively. The photons are carried, by means of the light guide, through the side outlet of the scintillator to the cathode of the photo-multiplier. They are then processed in the same way as the signal coming from the secondary electrons.

The BSE detector is manufactured in an R-BSE (Retractable BSE) version. This modification allows the retraction of the detector from under the pole piece position if the detector is not used. This allows the specimens to be moved as close as possible to the objective when viewed by other detectors.

## 6.5 CL Detector

***The detector works in high as well as low vacuum.***

The cathodoluminescence detector is available in two versions depending on the wavelength range of the detected light: 350 – 650 nm range (mainly visible and near UV light) or 185 – 850 nm range (UV, visible and near IR light). The first version is made either as a stand-alone detector or exchange CL / BSE detector.

The IR camera (Chamber View) must be switched off during operation of the CL detector.

### 6.5.1 Exchange of CL for BSE Lightguide

(Only available in exchange CL / BSE of 350 – 650 nm range version.)

1. Retract the current detector fully (i.e. it is close to the chamber wall, not under the column).

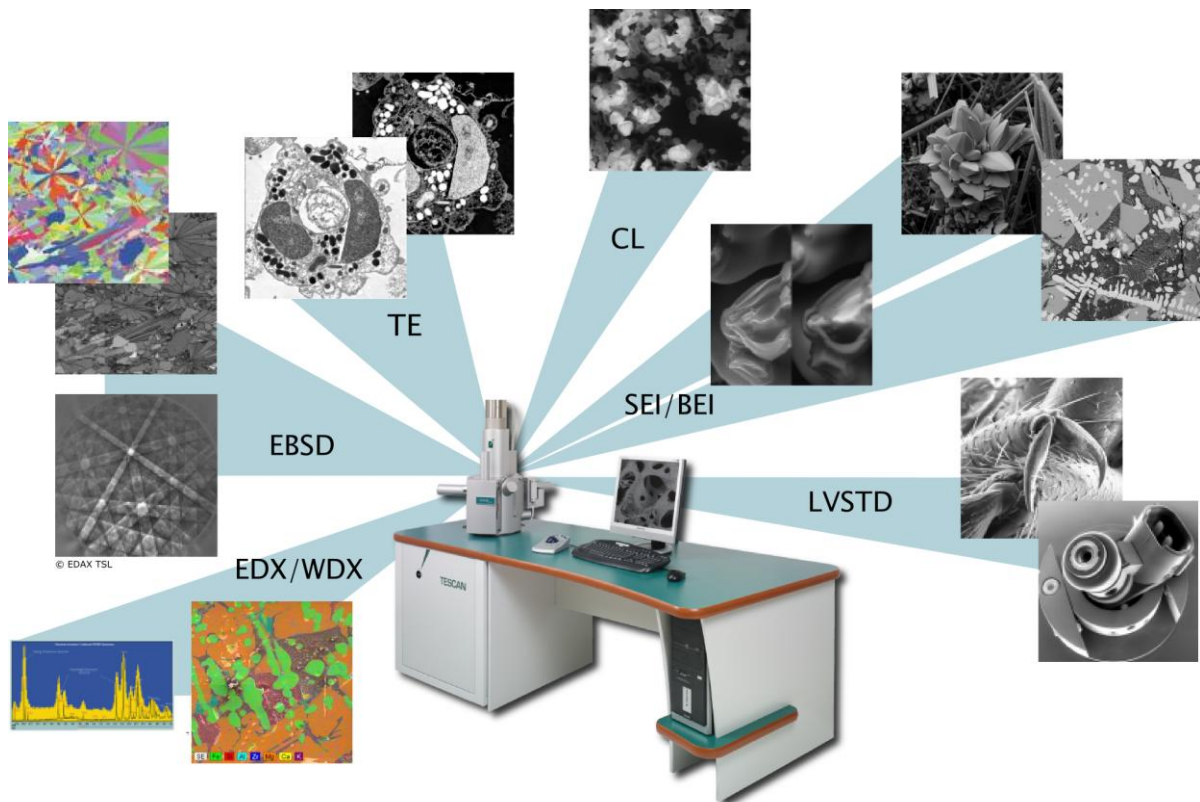


2. Put on gloves and open the chamber. Rotate the light guide by hand around its axis by about 30 degrees.
3. Move the current lightguide horizontally in the direction of its axis towards the objective until it is released.
4. Insert the new lightguide in exactly the opposite way: rotated by about 30 degrees from its working position, move it in the direction of its axis horizontally towards the photomultiplier until the stop.
5. Rotate the new lightguide by hand to its fixed position.
6. Return the detector carefully to its working position using the retraction mechanism and observe whether the new lightguide sits well and does not hit the objective.



## 6.6 Other Detectors

TESCAN provides other special detectors, which can be attached to the microscope. It is possible to obtain the list from the manufacturer.



## 7 Control Elements

### 7.1 Keyboard

The keyboard is used for text and numeric input. Its usage does not differ from the system Windows practice.

Keyboard shortcut	Command
Ctrl + O	Open...
Ctrl + S	Save As...
Ctrl + P	Print...
Alt + X	Exit
Ctrl + H	View Header...
Ctrl + C	Copy to Clipboard...
Ctrl + V	Paste from Clipboard...
Ctrl + Alt + PgUp	Zoom All In
Ctrl + Alt + PgDn	Zoom All Out
Ctrl + PgUp	Zoom In
Ctrl + PgDn	Zoom Out
F1	Help – Contents
F11 hold down	Blocks the changing of the right parameter of the active function.
F12 hold down	Blocks the changing of the left parameter of the active function.

## 7.2 Mouse

The mouse usage follows the Windows system practice.

### Mouse functions during normal scanning:

- Double-click with the left mouse button on the SEM Scanning window switches the Focus window on/off.
- Turning the mouse wheel changes the scan speed (the SEM Scanning window needs to be active).
- If the microscope is scanning over the whole SEM Scanning window, then
  - clicking the right mouse button opens the context menu for simple program control.
- If the microscope is scanning only in the Focus window, then
  - holding down the right mouse button and dragging the mouse cursor in the SEM Scanning window changes the dimensions of the Focus window.
  - holding down the left mouse button and dragging the mouse cursor in the SEM Scanning window moves the Focus window.
  - double-clicking the right mouse button on the Focus window moves this window to the center of the image.
  - clicking the right mouse button out of the Focus window opens the context menu.
- Clicking the mouse wheel on a selected object in the SEM Scanning window moves the stage so that the object lies in the center of the SEM Scanning window.
- Holding down the mouse wheel on a selected object and dragging the cursor to any position in the SEM Scanning window moves the object to the selected position in the SEM Scanning window.
- Holding down the mouse wheel on a selected object in the SEM Scanning window for longer than 0.8 seconds moves the stage so that the object lies in the centre of the SEM Scanning window and the magnification is increased by the factor set in the SEM -> Options -> Center Zoom.

*Note: If an additional software module is active, the functions of the buttons can be different.*

## 7.3 Trackball

The trackball is often used with the Pad panel.



Turning the trackball in the direction of the axis X changes the first parameter of the active function; turning the trackball in the direction of the axis Y changes the second parameter of the active function. Holding the F11 key locks the first parameter of the active function; using the F12 key locks the second parameter of the active function.

## 7.4 Control Panel

The Control Panel has several knobs and colour touch screen. It was developed by TESCAN exclusively for SEM control. It is not a standard SEM part.




The manual knob set provides the user with a simple and straightforward way of operating the microscope. It can control the stage, magnification, focus, beam intensity, scanning speed and other parameters.

Most common functions have dedicated knobs. The three upper knobs have variable function; their actual function is shown at the bottom of the touch screen. Several important parameters are shown in the middle of the display. There are also shortcuts to the automatic functions (focus, brightness/contrast, image acquisition) in the header.

## 8 Getting Started

*Note: Prior to using the MIRA 3 FEG the user should read this entire chapter and be familiar with all the information contained herein.*

### 8.1 Microscope Starting

A desktop icon  serves for starting the MiraTC software. To log in, a user name and password are required. Each user has his own profile.

The field emission electron gun is permanently switched on, unless a non-standard situation occurs (long term power supply interruption, servicing of the microscope, etc.). This ensures stability of electron emission without interruption for the whole lifetime of the Schottky cathode (several thousand hours).

Monitoring of the gun emission conditions runs in the background of the software and hence the gun can be switched off safely in the case of a mains power failure. Therefore, the MiraTC software should be permanently running. In the case that the software is completely switched off (computer restart for example), it is necessary to start the software.


1. Click on the MiraTC icon  on the Windows desktop. The **MiraTC – Log in** screen is displayed with prompt for user name and password.
2. In the case that the microscope is in **Standby mode** (see **Figure 1**), click on the **STANDBY** button on the **Vacuum** panel to initialize the microscope. Start the pumping procedure using the **PUMP** button (**Figure 2**). It takes usually around 3 minutes to reach vacuum ready – status, meaning that microscope is ready to use. If there is a need to exchange the specimen, follow instructions in chapter 8.2.
3. Load the default configuration using **Configuration ► Load Default Configuration** function from the Options menu.

Figure 1

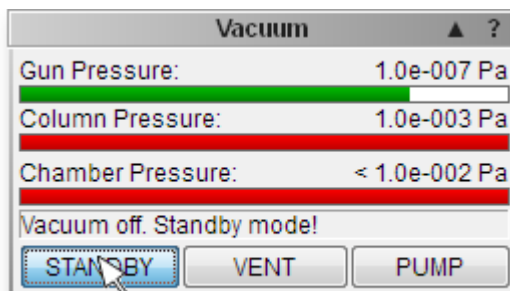
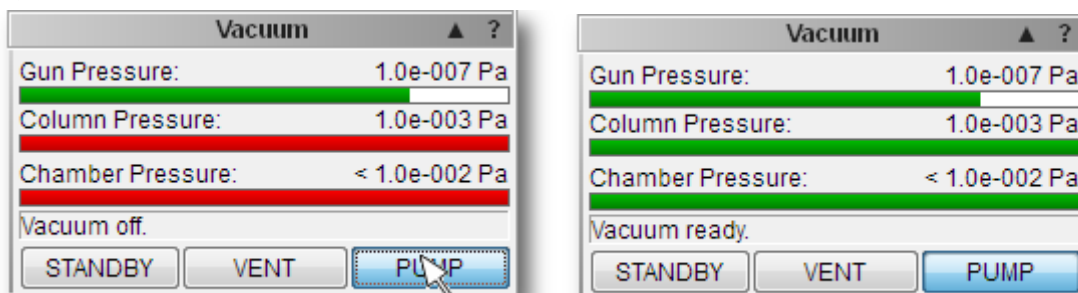


Figure 2



## 8.2 Specimen Exchange

The specimen should somehow be fixed or glued to the specimen stub, before it is inserted into the chamber. It is possible to use 12.5 mm specimen stubs or any other specimen holders, delivered as microscope accessories.

If the specimen is examined in the high vacuum mode, it should be conductive or should be made conductive using one of the methods described in the technical information. The conductive surface of the specimen must be conductive contacted to the stub.

Non-conductive samples can be examined in the low vacuum mode.

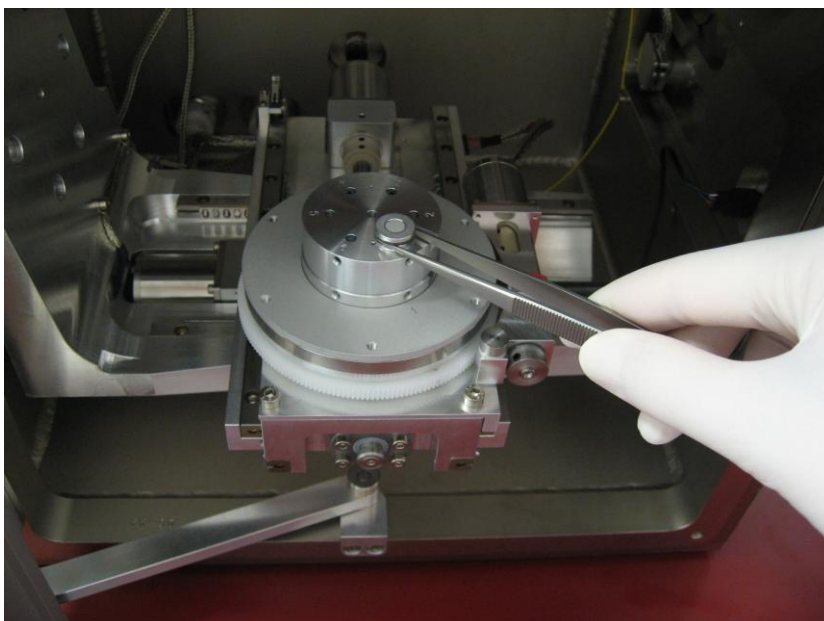
1. Vent the microscope by using the **VENT** button on the **Vacuum** panel. Wait until the pressure is at atmospheric level.
2. Open the chamber door by gently pulling it.
3. The automatic positions set up in the **Stage Control** panel can be used, which are intended for the specimen position exchange. To select the sample position click on the appropriate number button on the carousel. At this time the button background is red to indicate the specimen exchange mode.

***WARNING:** If the specimen stage is moving, do not touch any of its parts. The moving manipulator can cause health injuries. During the changing of the specimen use the suitable gloves for prevention of pollution of inner microscope parts.*

4. Loosen the screw holding the specimen stub on the specimen stage. Remove the specimen stub by lifting the stub upwards. It is recommended that suitable tweezers be used (**Figure 3**).
5. Use the previous steps in reverse order to place the new specimen in position. Once the specimen stub is fastened with the specimen, make sure that it will not touch any interior part of the chamber. Contact between the specimen and the chamber will be indicated by an acoustic buzzer.

***WARNING:** Collision of the specimen with any of the parts of the chamber interior can cause damage to the microscope.*

Figure 3





*Note: Contact between the specimen and any part of the chamber is indicated by a special electric circuit. This circuit is based on the measuring the electric current. It works only if the specimen is conductive.*

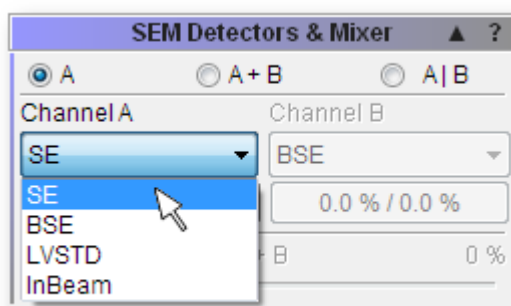
6. Close the chamber door by pushing it towards the chamber.
7. Start the pumping procedure by clicking on the **PUMP** button on the **Vacuum** panel, where the actual pressure and pumping progress are also displayed. Ensure that the chamber door is tightly closed.

### 8.3 Images at Low Magnification

There are four factory presets for the accelerating voltage (2, 5, 10, 20 kV), one for each HV index. The user does not need to perform any further adjustments by switching between them and using magnification up to 4000x.

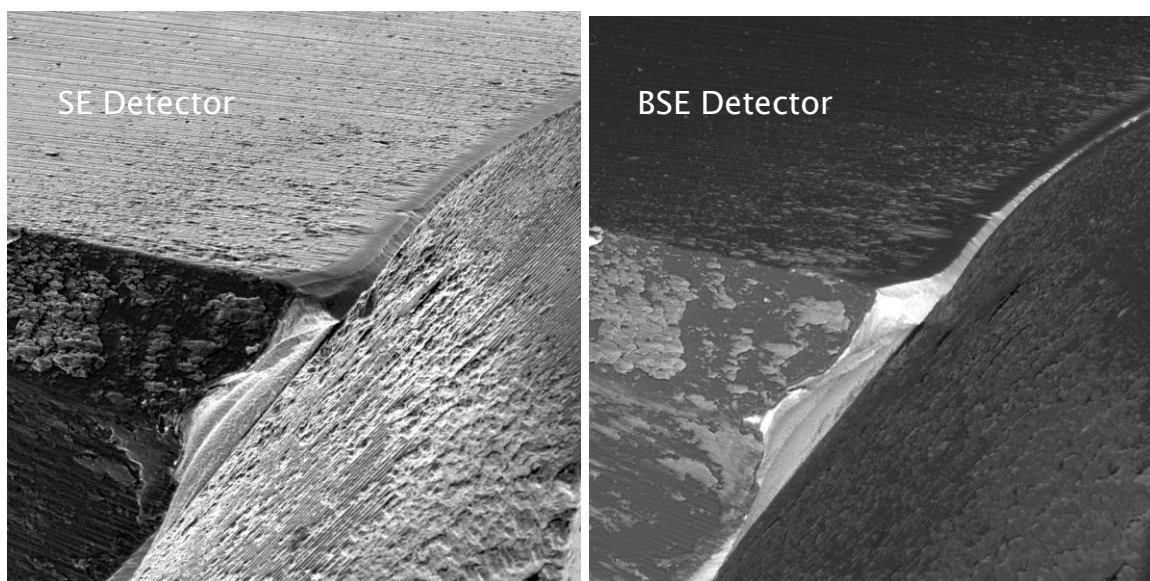
1. In the **SEM Detectors & Mixer** panel select the appropriate detector from the list box (**Figure 4**). Using the SE or BSE detector is recommended. When the BSE detector is used, ensure that the detector is not retracted! See chapter 6 for detailed information.

Figure 4



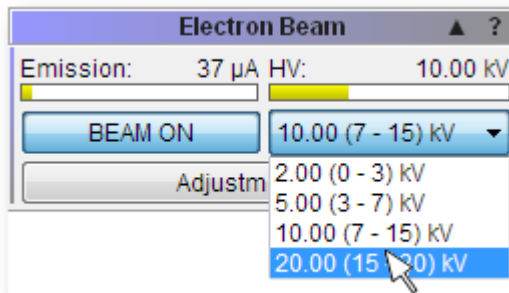
*Note: Notice the difference between SE and BSE images below (Figure 5).*

Figure 5



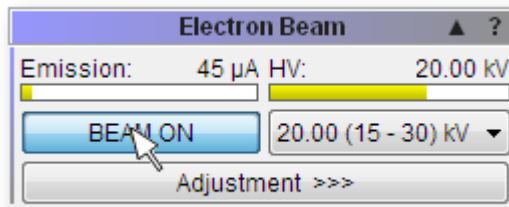
2. Select the accelerating voltage (20 kV recommended) using combo box on the **Electron Beam** panel (Figure 6).

Figure 6



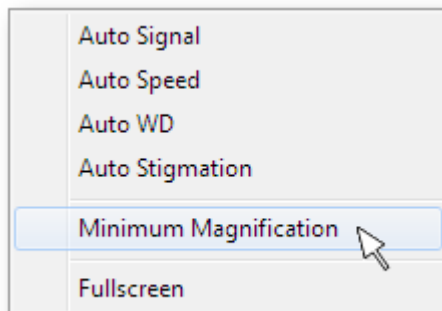
3. Clicking on the **BEAM ON** button on the **Electron Beam** panel turns the electron beam on (Figure 7).

Figure 7



4. Right-click in the SEM Scanning window to open menu and select the **Minimum Magnification** function (Figure 8).

Figure 8



5. Right-click in the SEM Scanning window to select the **Auto signal** function to set brightness and contrast (Figure 8).



6. Clicking on the WD icon on the Toolbar and turning the Trackball from left to right (or vice versa) focuses the image (alternatively use the **Auto WD** function for focusing (Figure 8)). Double-clicking in the SEM Scanning window opens the Focus window. To remove the Focus window double-click anywhere in the SEM Scanning window.
7. Focus in the Resolution mode (click on the **Scan Mode** function in the **Info Panel** and select RESOLUTION).




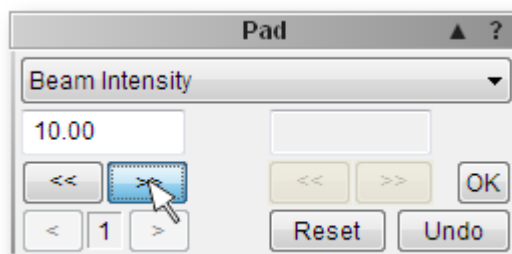
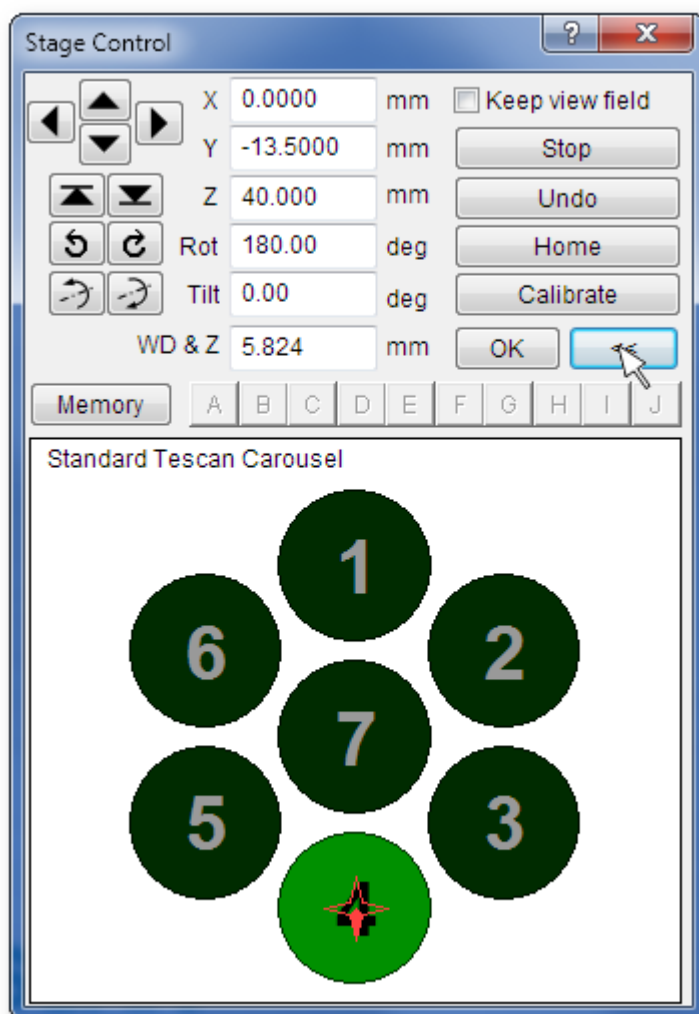
8. To select beam intensity (BI 10 recommended), first left-click on the BI icon  on the Toolbar and then use arrows on the **Pad** panel (**Figure 9**).

Figure 9





9. To select the sample position on the **Stage Control** panel, click on appropriate number button on the carousel (**Figure 10**).


Figure 10



10. Placing the cursor over the SEM Scanning window and clicking the mouse wheel move that area on the stage into the centre of the image. See chapter 7.2 for other mouse actions.

11. To magnify the image click on the Magnification icon  on the Toolbar and turn the Trackball from left to right.

12. Once the area of interest is magnified and focused as desired, right-click on the Speed icon  on the Toolbar and select appropriate scanning speed.

13. Clicking on the **Acquire** button on the **Info Panel** (Figure 11) or on the icon  on the Toolbar saves the image. Fill in the note, sign and description field if necessary. Choose a folder in which to store the image. To change the parameters of the image use the **Image Parameters** function in the SEM menu.


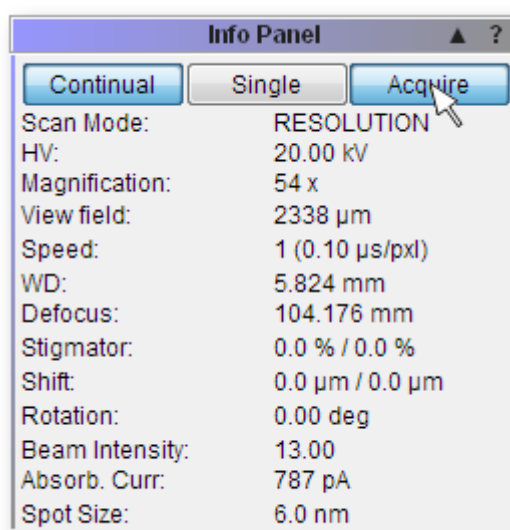
14. Clicking on the icon  opens the dialog for saving the actual adjustment of the microscope. It is possible to restore the saved adjustment of the microscope later.

Figure 11



## 8.4 Imaging in Low Vacuum Mode

An ordinary SE detector is not available in the low vacuum operations (see chapter 6), therefore Tescan have developed the LVSTD detector that gives topographical information from the sample in low vacuum. The BSE detector is available for both modes (LowVac, HiVac) and gives compositional information.

1. Insert the final aperture into the objective according to the instructions in chapter 9.2 or in the help file in the MiraTC software.
2. Switch the microscope to the Low vacuum mode (pressure range 1 – 150 Pa) using the **UniVac** button on the **Low Vacuum Mode** panel (Figure 12).

3. Enter the desired pressure value in the field next to the **UniVac** button and click on the **OK** button.

Figure 12

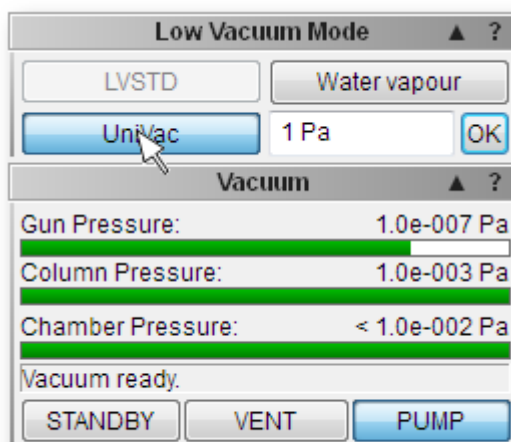
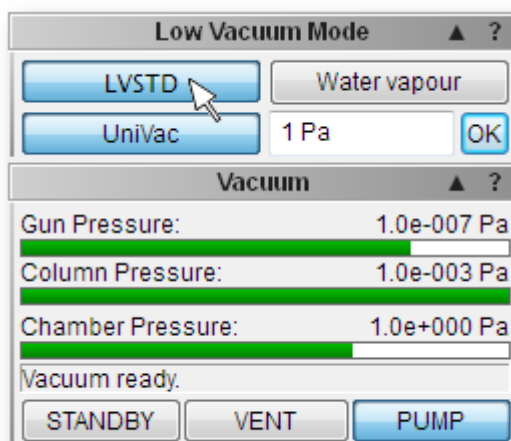



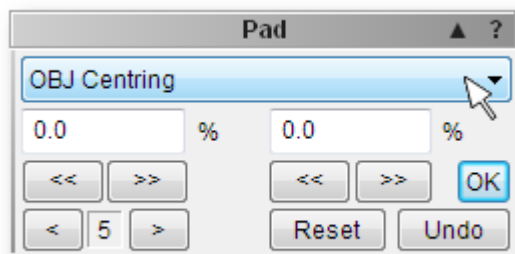
Figure 13



4. If LVSTD is attached to the chamber, there is the **LVSTD** button present (Figure 13).
5. To switch between detectors use the **Detectors & Mixer** panel and select the appropriate detector (BSE or LVSTD) from the list box (see Figure 4).
6. Turn on electron beam by clicking on the **BEAM ON** button on the **Electron Beam** panel (Figure 7).
7. Set minimum magnification.
8. To select beam intensity (BI 10 recommended), first left-click on the BI icon  on the Toolbar and then use arrows on the **Pad** panel (Figure 9).
9. Use the **Auto Signal** function to set suitable brightness and contrast.

10. Select the **OBJ Centring** function from the combo box on the **Pad** panel (**Figure 14**) and turn the Trackball to set the brightest area into the centre of the SEM Scanning window.

Figure 14

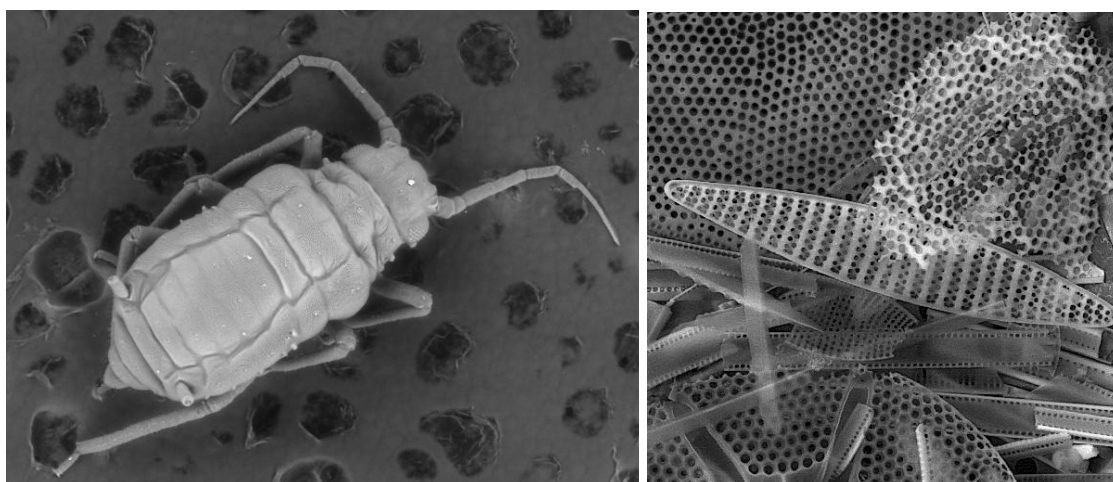


11. Follow the instructions 9. – 14. in chapter 8.3.

*Note: Some non-conductive samples, which are not too sensitive to the beam, can be handled at lower voltages in the high vacuum mode. Different high voltages can be selected from the Electron beam panel.*

*Note: See LVSTD images obtained at low vacuum mode of organic sample without coating (Figure 15).*

Figure 15

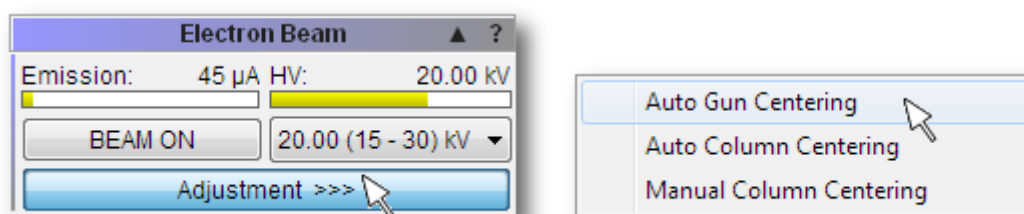


## 8.5 Images at High Magnification

1. Insert an appropriate sample for high magnification images (e.g., tin on carbon sample, (**Figure 20**)).
2. The best resolution is achieved at the highest accelerating voltage (30 kV) of the primary electrons. Select the fourth HV index using the combo box on the **Electron beam** panel (15 – 30 kV). Select the High voltage function from the combo box on the **Pad** panel or click on HV in the **Info Panel**. Type value 30 kV into the **Pad** panel.
3. Turn on the electron beam.

4. Select the **Auto gun centering** function using the combo box on the **Electron beam** panel after clicking on the **Adjustment** button (Figure 16).
5. Focus in the Resolution mode (click on the **Scan Mode** function in the **Info Panel** and select **RESOLUTION** or use the **Continual Wide Field** option – switches automatically between Wide Field and Resolution Mode and vice versa when increasing or decreasing magnification).
6. For the best resolution, it is necessary to work at a short working distance (WD). The optimum WD is about 5 mm for the SE detector and 1 – 2 mm for the InBeam detector (in the case that the BSE is not mounted underneath the objective lens). For BSE images the optimum WD is about 8.5 mm. To change the working distance together with Z axis without defocusing the image use the **WD&Z** function on the **Stage Control** panel (Figure 17).

Figure 16




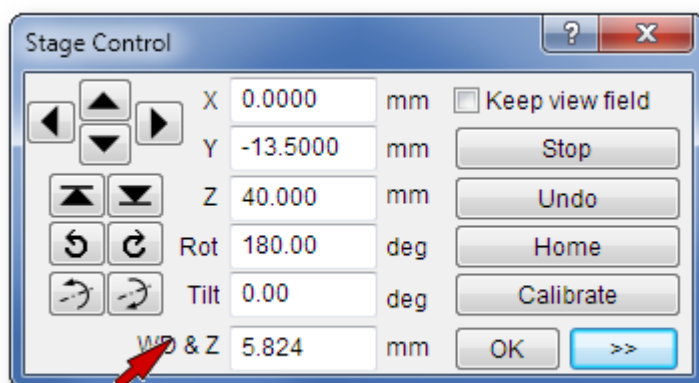
*Note: Before changing WD&Z or WD use the degauss function by means of the  icon. The image should remain in focus.*

Figure 17



7. Gradually magnify and focus the image to achieve 10kx magnification. In the case that the image is moving during focusing, it is necessary to check the centering of the objective. Select the **Manual column centering** function using combo box on the **Electron beam** panel after clicking on the **Adjustment** button (Figure 18). The Manual Centering Wizard window will appear (Figure 19). Clicking on the **WOB** button opens the Focus window in the SEM Scanning window. Click on the **Next>>** button to obtain the next instructions. The function of centering has two adjustable values. To be sure just one value is changing hold down the F12 key to change only X movement at the Trackball and the F11 key to change only Y movement.

Figure 18

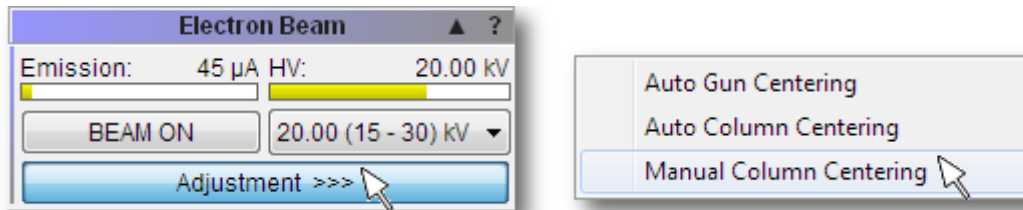
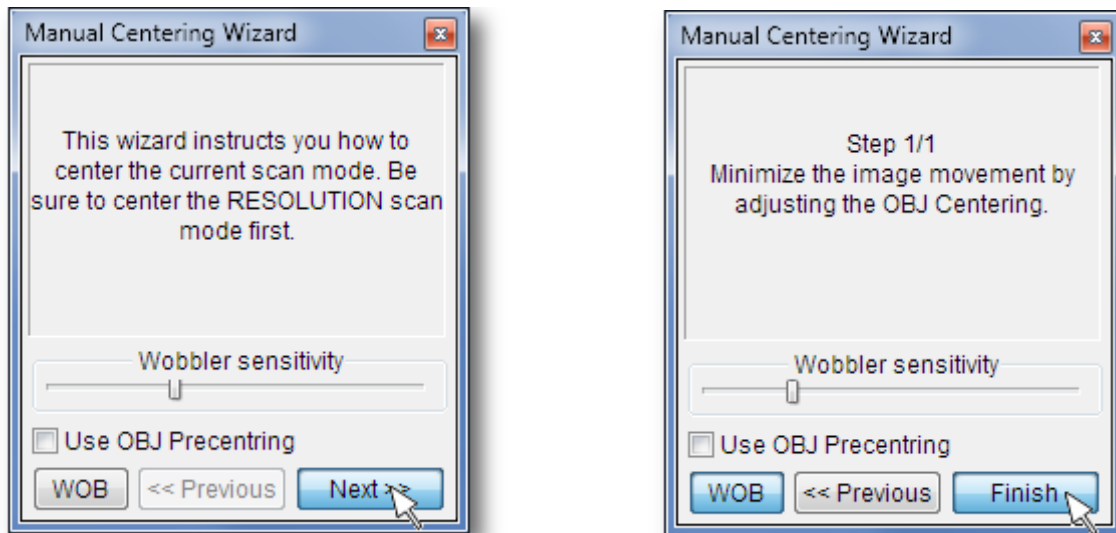


Figure 19





8. Each time that the image is too dark or light it is necessary to use the **Auto Signal** function (see **Figure 8** or use the icon  ). To set the contrast and brightness manually, click on the icon  and use the Trackball.
9. At higher magnifications (>10kx) it is necessary to check if astigmatism (**Figure 20 (a), (b)**) is precisely corrected (**Figure 20 (c)**). To correct astigmatism click on the **Stigmator** function in the **Info Panel (Figure 21)**. For precise correction use the Focus window (in the SEM Scanning window) and the F11 and F12 keys in the same way as in point 8.
10. Select the appropriate scanning speed and save the image.

Figure 20

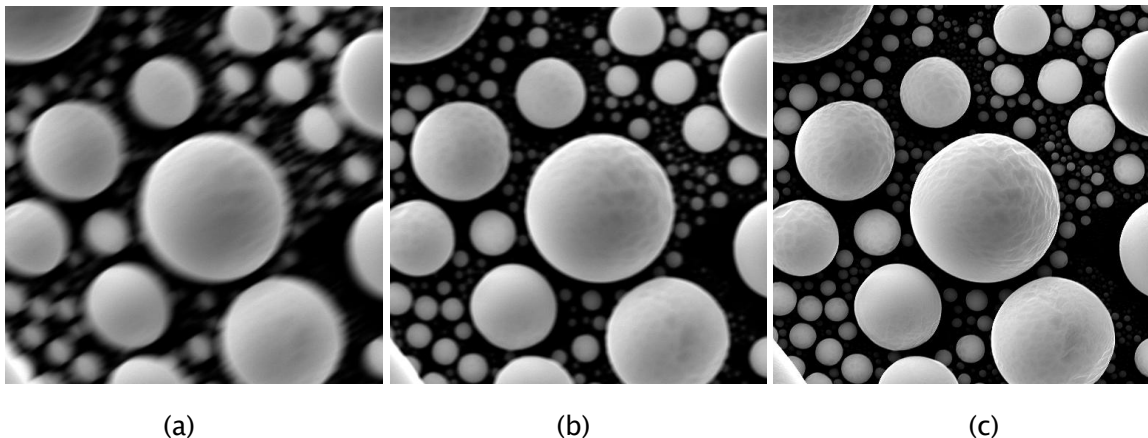
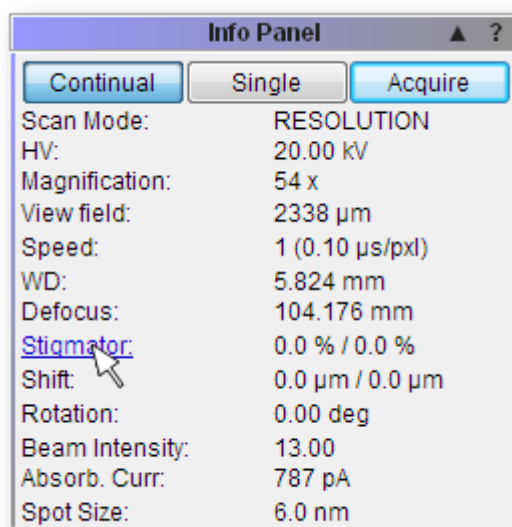



Figure 21



11. Clicking on the icon  open the dialog for saving the current adjustment of the microscope. It is possible to restore the saved adjustment of the microscope later.

## 8.6 Microscope Stopping

If it is necessary to interrupt work with the microscope for longer period of time, it is possible to switch the microscope to **STANDBY** mode. Part of the control electronics and the pumping of the chamber are *off*. The ultra vacuum electron gun is *divided off* the high vacuum by the valve so that the electron beam can not enter the chamber.

Since the electronics are *off*, the column is not heated by the power dissipation of the magnetic coils, and the filament itself works in better vacuum conditions, thus extending the filament lifetime. The power consumption is approximately half in comparison to normal operation. When reinitializing the microscope (switch off the **STANDBY** mode) the temperature drift can cause lower time instability of the image on extremely high magnifications. It is thus recommended to use the **STANDBY** mode only in the case of long work interruption (at least overnight).

It is also possible to *switch on* the pumping system in the **STANDBY** mode using the PUMP button and keep the chamber under minimal pressure. The disadvantage is a reduction in the lifetime of the pump and higher power consumption.

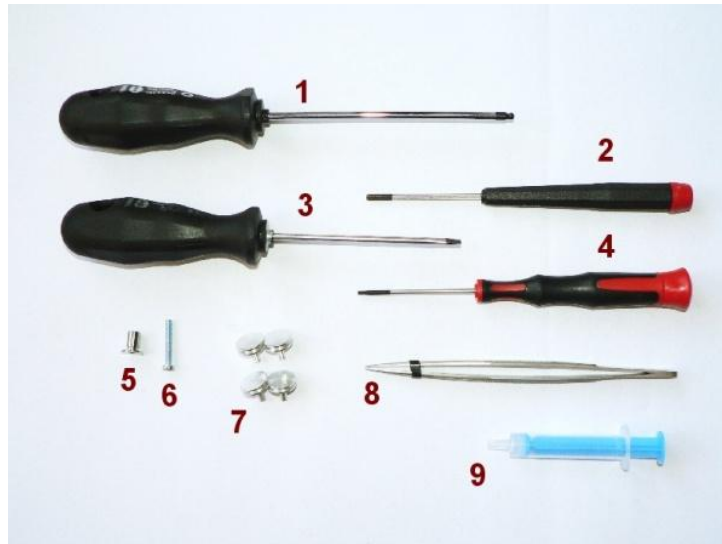
1. The **STANDBY** mode is *switched on* by clicking on the button on the Vacuum panel.
2. To keep the chamber pumping system on (it is switched off by default) switch it on by clicking on the PUMP button on the Vacuum panel.

As well as the MiraTC control software, the gun continues to run all the time. After switching to the **STANDBY** mode, the user just logs off (File->Log off...). If the user wishes to use the system again, he can log on by entering his user name and password. The microscope then loads the settings of the user.

## 9 Microscope Maintenance

### 9.1 Basic Microscope Accessories

This document describes the use of the most important tools included in the microscope accessories. The exact list is attached to the packaging list of the microscope.

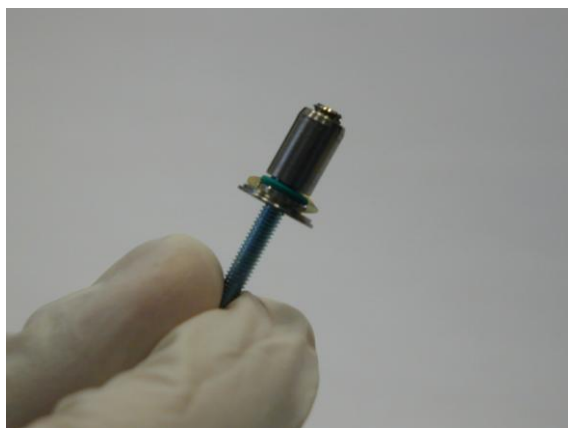


1. Hexagonal screwdriver, size 3.0 mm – general use, mainly various flange screws, the most common size used for screws.
2. Hexagonal screwdriver, size 2.5 mm – used for mounting / dismounting sample stage Z extensions (LS, LM chambers) and the stub holder (XM chamber).
3. Flat screwdriver, size 3.2 mm – general use.
4. Hexagonal screwdriver, size 1.5 mm – used for fixing the screws in the sample stage.
5. Low vacuum aperture holder.
6. Screw, size M3x25 – used for the removal of the low vacuum aperture holder.
7. Basic specimen stubs.
8. Flat tweezers – general use.
9. Vacuum grease – used for sealing of the o-rings.



## 9.2 Insertion of the Final Aperture for the Low Vacuum Mode

This aperture is inserted into the objective and it is accessible from the microscope chamber.



1. Before inserting the aperture into the objective, move out the BSE detector.
2. Open the chamber door and insert the aperture holder into the objective with the wider part down.
3. To remove the aperture holder use the screw included in the microscope accessories. Place the screw in the aperture holder and by pulling down the screw, take out the aperture holder.

The apertures become contaminated during microscope usage, which can cause a reduction in the optical qualities of the column. It is necessary to clean them from time to time or exchange them.

## 9.3 Cleaning of the Final Aperture

Contamination and impurities taken into the microscope appear during the exchange of specimens. They cause degradation of the optical qualities of the microscope. That is why it is necessary to clean aperture from time to time.

The frequency and the method of cleaning depend on the operation conditions. Under normal conditions, cleaning the aperture every 3 – 6 months is recommended.

The final aperture is made of platinum and therefore it needs special treatment. Recommended cleaning steps:

1. Place the aperture into a beaker filled with isopropyl alcohol, ethanol or coleman fuel. Wash the aperture in the ultrasonic bath for about 10 minutes.
2. Anneal the clean aperture in the alcohol burner. Use only clean ethanol for the burner to prevent the combustion products to polluting the aperture.
3. Place the aperture into the aperture holder and blow the assembled holder with the aperture with clean compressed air or nitrogen.

## 9.4 Specimen Holders

The specimen holders differ according to the type of microscope delivered, here is only an overview of the possible types.



**Standard specimen holder  $\varnothing 12.5$  mm, height 3 mm:**

the most common holder suitable for smaller specimen. The specimen is normally glued with conductive glue or stuck on with double-side sealing tape.



**Specimen holder GM163-A,  $\varnothing 14$  mm, height 20 mm:**

extension for small specimen holders for work at very short working distances.



**Specimen holder HM113:**

for small round-shaped samples up to a max. diameter of  $\varnothing 12$  mm.



**Specimen holder HM116:**

for round-shaped samples up to a max. diameter of  $\varnothing 20$  mm.



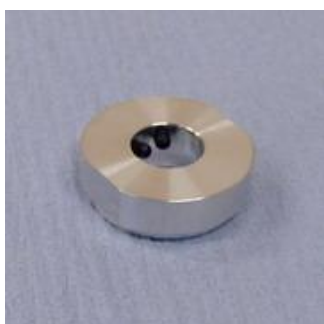
**Specimen holder TE0038B:**  
for standard  $\varnothing 30$  mm samples.



**Specimen holder HM114:**  
for flat samples up to the width of 20 mm.



**Specimen holder GM153:**  
replacement of the standard seven-position specimen holder (the seven-position holder must be removed). Designed for rod shaped samples of diameter up to 26 mm.



**Specimen holder HM154-A:**  
CAMSCAN  $\varnothing 12.5$  mm specimen holder adaptor.