JEOL 7600F
Scanning Electron Microscope

User Guide, v08.12

Only experienced SEM users are allowed access to this advanced imaging tool.

Note that the instructions given here are meant to be a guide only – depending on your sample, it may require some extensive experimentation on your part to determine the optimum imaging conditions.

- UCSB Nanofabrication Facility -

1. **Loading your sample.**
   a. Log into Windows on the JEOL SEM PC using the "SEMUser" account if needed.
   b. Click on the ***PC-SEM*** icon located on the desktop, and select your group's JEOL system username from the list and enter the password to open up the Main Window in its initial state (as shown in Fig. 1 below). This window displays status and control features for the SEM in many areas of the window.

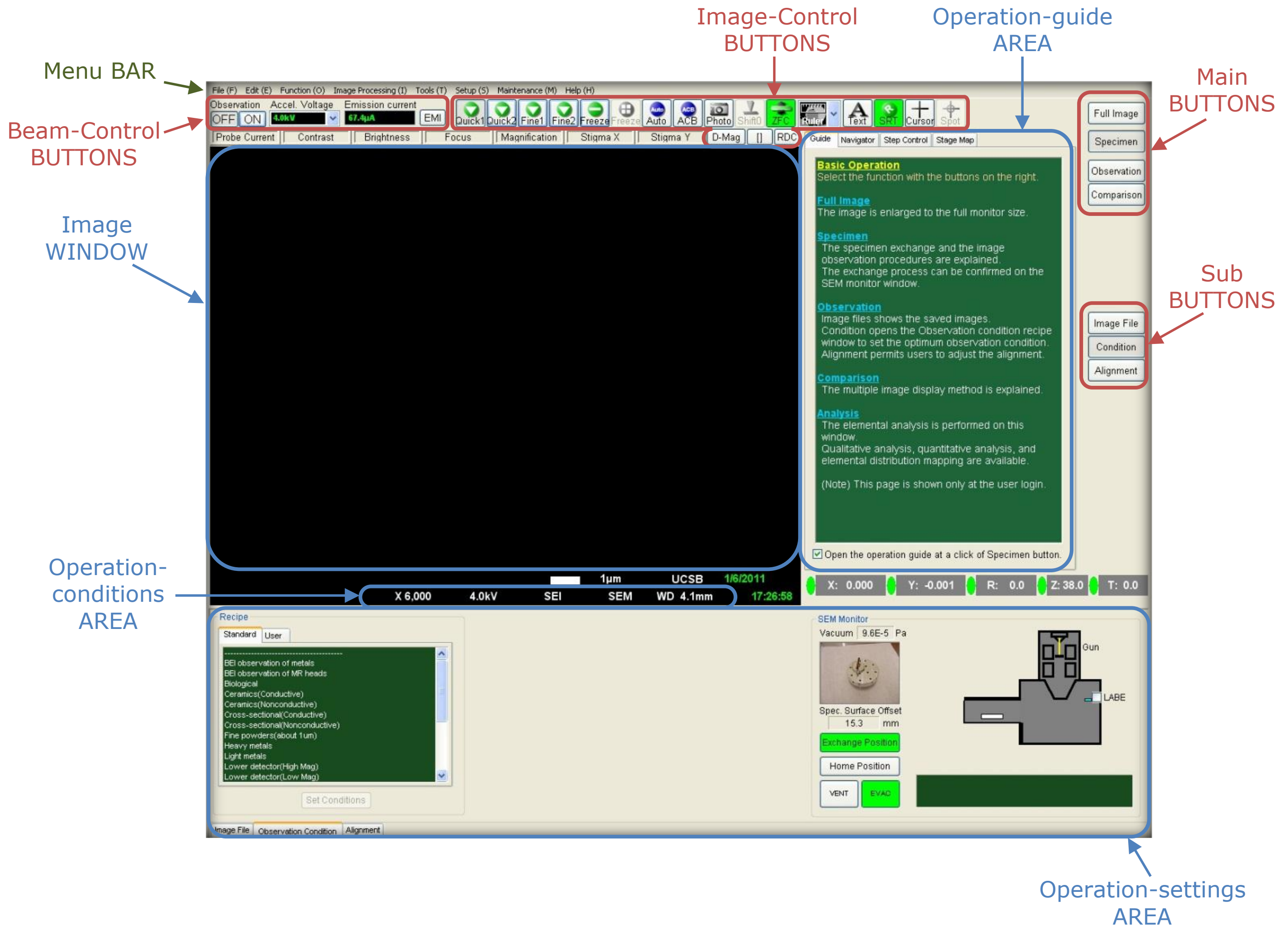

Fig. 1: Main Window layout for the 7600F SEM

   c. First confirm that the SEM is in the correct initial state by checking the buttons on the right-side of the airlock (see Fig. 2 below):
      - the stage indicator lamps: EXCH POSN is lit (green) and HLDR is off, i.e., the stage is in the correct loading position and it is empty,
      - the loadlock control buttons: EVAC is lit (orange) and VENT is off, i.e., the loadlock is under vacuum.

Also, press the F4 button on the keyboard to open the **Camera** window (which shows real-time video of inside the SEM chamber) and confirm that the stage is empty.

Undo the loadlock door clasp and press and hold the loadlock VENT button until it blinks. The isolation valve will close – a solid 'valve' line will appear in the **SEM Monitor** window (located in the right-side of the *Operations-settings AREA*) – and the N2 gas purge will begin.

d. When the VENT button stops blinking, pull and hold open the door. Slide the dovetail holder (with the mount and your sample attached) onto the clamp at the end of the transfer rod (see Sec. 6 for details on the mounts available). Be sure that the dovetail slot on the holder base lies parallel to the rod direction.

e. Ensure that the door o-ring is still in place (as it falls out from time to time). Close the door, secure the clasp, and press and hold the EVAC button until it blinks (which indicates that the loadlock is being pumped down). Wait until the EVAC light stops blinking and stays lit (orange) and you hear the isolation valve open (the solid 'valve' line in the **SEM Monitor** window will have disappeared).

f. Lift the transfer rod vertically upwards until the guide pipe lifts off the metal guide stop and then rotate downwards to the horizontal position (Fig. 2). Push the rod inwards slowly (and carefully!) and fully insert until you feel a firm stop (the **Camera** window will show the holder on the stage). The HLDR button on the loadlock should now be lit green and the **Select specimen holder** window will appear on the screen.

g. Retract the rod until the guide pipe fully comes out of the guide stop (very important to confirm this as the rod may be damaged irreparably if you don't!) and rotate upwards to the vertical. Push into the plastic clamp to secure.

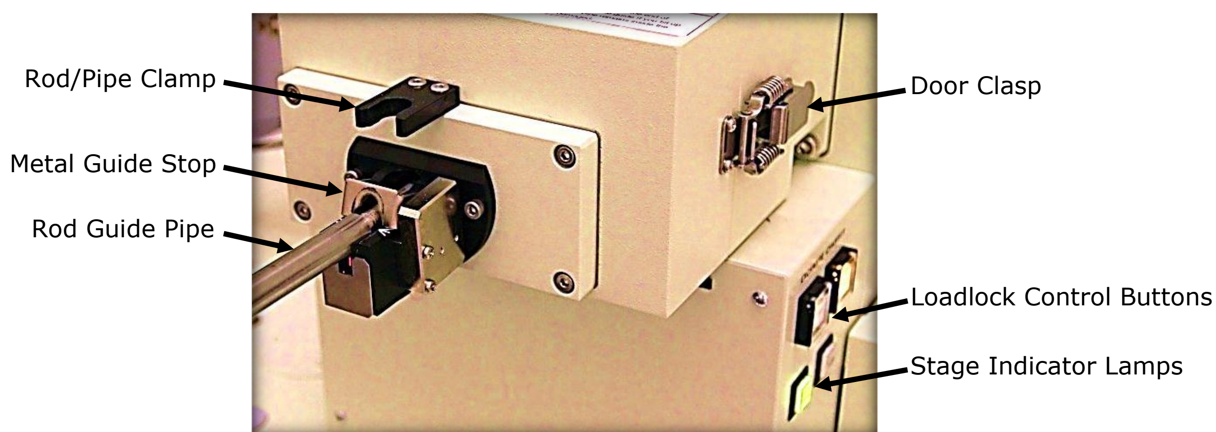

Fig. 2: Loadlock and Transfer Rod Assembly

h. Select the correct mount from the pictures shown in the **Select specimen holder** window and enter the SSO value shown in the label into the *Specimen surface offset* field (and make sure that the correct SSO is set after hitting enter). The SSO initializes the WD value to equal the z-separation between the mounts default highest point and the bottom of the objective lens pole-piece (see Sec 5.d.i for more details).

i. Wait for the pressure readout in the **SEM Monitor** window to fall below 1E-3 Pa before proceeding. This should take no longer than 3-4 minutes.

2. **Preparing to image.**

Refer to the main window layout shown in Fig. 1 to determine the location of the various BUTTONS and AREAS referenced below.

a. Click Condition in the *Sub BUTTONS* to open the "Image Controls" in the *Operation-settings AREA* (see Fig. 3 below). Check the initial settings, particularly that the *Probe Current* is set to LC-8 or 9 and the *r-filter* is set to SB and that the detector is set to SEI in the *Operation-conditions AREA*.

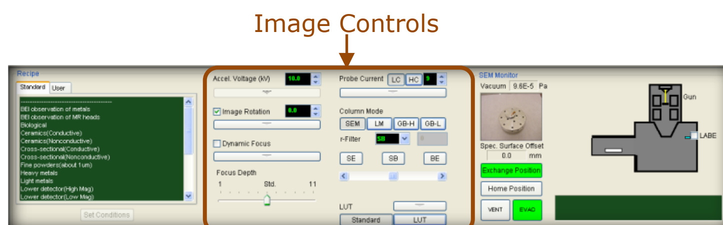

Fig. 3: Operation-settings area using Observation->Condition buttons.

b. Turn the beam on by clicking ON in the *Beam-Control BUTTONS*.

c. Click on the WD value in the *Operation-conditions AREA*, select 8 mm from the drop-down menu and, click OK in the **PC-SEM** window that appears to move the stage upwards (note that the final stage Z-reading will equal 8mm+SSO). Use the **Camera** window to watch the vertical stage motion – if you're nervous, then simply touch the trackball in the external "Stage Trackball" unit to immediately stop the stage Z-motion.

d. Switch to the Low-Mag imaging mode for the largest field-of-view:

- Click the current column mode value in the *Operation-conditions AREA* (should read SEM) and select LM from the drop-down menu, or,
- Click the LM button in the Column Mode section of the "Image Controls", or,
- Press the LOW MAGN button on the external "Instrument Control" unit (button will light).

Note that the WD value equals the stage-Z readout when in the LM mode.

e. Using the external "Instrument Control" unit (eIC), decrease the SEM mag to its lowest value (rotate Magnification knob CCW) and adjust brightness/contrast (either press the ACB button and/or manually adjust the Brightness and Contrast knobs) to bring up the image in the *Image Window*.

f. Using the external "Stage Control" unit (eSC), press and hold the +X/-X and +Y/-Y buttons to move the stage to find the region of interest[1] on your sample. Increase mag (eIC - Magnification knob) to about 2000x and bring image into focus (eIC - Focus knob). Recenter the image using the mouse (left click and drag).

g. Switch back to the high-resolution SEM mode. Either:

- Click the LM value in the *Operation-conditions AREA* and select SEM from the drop-down menu, or,
- Click the SEM button in the Column Mode section of the "Image Controls", or,
- Press the LOW MAGN button on the external "Instrument Control" unit so that it goes out.

Then decrease mag and adjust focus to find the area of interest on your sample (there is always a slight offset in position and focus between the LM and SEM modes).

h. When using an angled mount, and the image is focused on the sample/mount highest point, check the SSO value by subtracting the current WD value from the Z position readout (Sec. 5.d.i). Update if necessary (double click on the holder picture in the **SEM Monitor** window).

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[1] If using an angled mount and the sample sits higher than the flat top of the mount, then this initial region of interest should be the sample highest point to reset the SSO to account for the sample.

3. The Imaging Session.

This section gives a brief step-by-step procedure on how to get an image. There are no details provided for each step as there are many possible options which will have to be worked out by you.
Note that all the focusing/beam optimization processes defined below are easier to do when using the reduced scan option from D-Mag, along with the faster scans, Quick-1 or Quick-2, in the *Image-Control BUTTONS* (the smaller area gives a smoother image).

a. Set the beam current and beam voltage (and focus depth, if required) as detailed in Sec 7.a. Adjust focus/brightness/contrast to restore the image.

b. Set the WD to the desired value (Sec 5.d) and select the electron detector you wish to use (Sec 7.b), then center the feature of interest in the imaging window (Sec 5.a) and adjust focus/brightness/contrast again to get the initial image.

c. Beam optimization, if necessary, can involve 2 steps. *Electronic beam alignment* should be performed only if the image shifts significantly in X and/or Y while adjusting focus. *Astigmatism correction* should be performed if there is significant directionality in the out-of focus distortions when adjusting focus both above and below optimum (the directions will be perpendicular to each other).
Use the knobs/buttons on the external "Instrument Control" unit to perform the adjustments as follows:

i. *Electronic Beam Alignment*:
- Set magnification to > 10,000x and center object; focus the image.
- Press the WOBB button to activate the beam wobbler (the WOBB and ALIGN buttons will blink).
- Reduce the image shift from the wobbler by adjusting the X and Y knobs (side-to-side => adjust X, up-and-down => adjust Y).
- Once centered, turn the beam wobbler off by pressing the STIG button (which will light). The WOBB, ALIGN buttons will then go dark.

ii. *Astigmatism Correction*: For best performance, you may find it necessary to perform this correction many times during your imaging session (especially when using the Gentle Beam column mode).
- Center focus at the "optimum" WD (image may be blurry but there is no distortion directionality).
- Ensure that the STIG button is lit. Adjust the X and Y knobs to obtain the sharpest image. Then readjust focus and repeat until no improvements can be made.

d. To acquire an image: Set the scan to Fine-1 or Fine-2 and quickly set ACB using the *Image-Control BUTTONS* to optimize the image. Then

click the Freeze button to hold the image in the *Image WINDOW* at the end of the scan.

To save an image: Click Image File in the *Sub BUTTONS* which opens the “File Controls” in the *Operation-settings AREA*. In the “File Controls”, first click on the Save button to open the **Save As** window then locate the correct folder (can also use this window to set up new folders) and enter the file name (and select JPEG, TIFF, or BMP formats). Make sure that the Export -> ’Black and white’ option is selected and enter any details in the Comment field that you will want for later reference.

Note that if you right-click on any saved image thumbnail shown in the current folder of the “File Controls”, a drop-down menu with options to move to the stage position or even reset the beam/column conditions that were used when the image was saved will appear.

4. Unloading your sample from the SEM chamber.

a. Turn off the beam and isolate the gun from the sample chamber by clicking OFF in the *Beam-Control BUTTONS*. Return the stage to the exchange position by clicking on the Exchange Position button in the **SEM Monitor** window. Wait till the button turns green.

b. Confirm that the SEM is in the correct unloading state by checking the buttons on the right-side of the airlock:

- the stage indicator lamps: both the EXCH POSN and HLDR are lit (green), i.e., the stage is in the correct unloading position and it is occupied,
- the loadlock control buttons: EVAC is lit (orange) and VENT is off, i.e., the loadlock is under vacuum.

Also, if not already there, press the F4 button on the keyboard to open the **Camera** window.

c. Exactly as for loading, lift the transfer rod vertically upwards until the guide pipe lifts off the metal guide stop and then rotate downwards to the horizontal position. Push the rod slowly (and carefully!) inwards and fully insert until you feel a firm stop. Retract the rod and watch the holder/mount coming off the stage in the **Camera** window (the HLDR button on the loadlock will now turn off). Once the guide pipe fully comes out of the guide stop (very important to confirm this!), rotate upwards to the vertical. Push into the plastic clamp to secure.

d. Undo the loadlock door clasp and press and hold the loadlock VENT button until it blinks (the isolation valve will close – a solid 'valve' line will appear in the **SEM Monitor** window - and the N2 gas purge begins).

e. When the VENT button stops blinking, pull open the door and slide the holder off the clamp at the end of the transfer rod.

f. Close the door (check the o-ring first), secure the door clasp and press and hold the EVAC button until it blinks (indicating the loadlock is being pumped down).

g. Exit the PC-SEM software, by selecting *File* -> *Exit* in the Menu bar.

5. Moving the Stage/Shifting the Image.

a. *Image Shift - X, Y, R*

It is possible to shift the live image field-of-view using the mouse in the *Image WINDOW*. Note that at magnifications ≥ 50kX, the X/Y shift is done electronically using the beam deflectors with high accuracy. At lower magnifications, the shift is done mechanically using the stage (and with much less accuracy!).

i. *X/Y Shift*: 2 options possible.

- Left click, hold, and drag the mouse to shift the image in the X-Y plane. An image shift monitor will appear in the window when the electronic shift is active.
- Right click at any point in the image and select '*Move to image center*' from the menu to shift the selected point to the center of the *Image WINDOW*.

ii. *R shift*: Click on the expand bar in the Image Rotation field of the "Image Controls". First select the Horizontal button then left-click and drag a line on the live image to define any feature. When you release the mouse button, electronic rotation of the field-of-view will occur so that the feature will be horizontal in the image. Further fine (electronic) adjustment can be performed, in steps of 0.1^o, using the up and down arrows next to the rotation readout.

b. *Stage Move - X, Y, R*

There are a few different options available to control the mechanical movement of the stage. Limits are X: ±35mm, Y: ±25mm.

i. *X/Y/R Move*: Using the external "Stage Control" unit, press and hold the +X / -X and +Y / -Y and +R / -R buttons to move the stage in the relevant direction. The speed at which the stage moves is inversely proportional to the magnification. For fine control of the X/Y movement @ higher mags, move the ball in the external "Stage Trackball" unit.

ii. *X/Y/R - Step/Frame Move*: Select the Step Control tab in the *Operation-Guide AREA* of the main window, Fig.1.
Use the UP / DOWN / LEFT / RIGHT arrow keys to move the stage in the X/Y plane. Use the CW / CCW arrow keys to rotate the stage. Selecting the Step button moves the stage in steps, the sizes of which are shown below the keys. Selecting the Frame button moves the stage as a percentage of the field-of-view instead (percentage shown below the keys).
To change the default values, click on the Setup button to open the **Operation Settings** window. Set the X/Y step size in mm's, the R

step size in degrees, and the X/Y frame steps as a percentage of the current field-of-view[2].

An additional stage rotation option is available (and which is similar to the electronic Image Rotation function mentioned above). First select the Horizontal button in this tab and then left-click and drag a line on the live image to define any feature. When you release the mouse button, the stage will rotate to make that feature horizontal.

c. *Stage Move - Tilts*

Tilt the stage only when WD ≥ 8mm and always have the CCD **Camera** window open when doing so (hit F4 on the keyboard). Allowable tilt values are restricted to between -5 and +20°.

i. If not already done, the user must horizontally align (using the stage) that section of the sample to be observed during the tilt (see Sec.5.b.ii above).

ii. Tilt the specimen using the +T / -T buttons on the external "Stage Control" unit. Watch the **Camera** window to make sure that the sample will not touch the pole-piece as the stage is tilted.

No tilting is allowed when using the LABE detector.

d. *Stage Move – Z / Working Distance Adjustments:*

The Stage Z readout on the screen represents the distance between the bottom of the lens pole-piece and the top of the JEOL 'standard' specimen holder (which we don't use and is hence an arbitrary number). The WD reading shown in the *Operations-conditions AREA* always represents the distance from the bottom of the lens pole-piece to the crossover point of the electron beam (i.e., focal point of the beam).

i. *Specimen Surface Offset, SSO*:

Only when the beam is focused on the highest point of the sample/mount will the WD value represent the "true" separation between the specimen and the lens, WD_{TRUE}.

The Specimen Surface Offset, SSO, is utilized to correct the stage Z readout to this WD_{TRUE} value as:

$$\mathbf{WD_{TRUE} + SSO = Stage\ Z} \qquad (2).$$

It is only when a WD value is selected from the drop-down list in the *Operations-conditions AREA* will the safety correction of equation (2) be applied to Z motion. It is for this reason that ALL major stage Z movements must be performed using this WD drop-down list!

Note that when using the top-down mount with no clips, then equation (2) is true for all WD's observed during the imaging

[2] Make sure that both the '*Eucentric Rotation'* and '*X/Y Directions Fixed'* check boxes are ticked in the **Operation Settings** window.

session since the highest point is also the surface of interest for imaging. If using this mount with clips, equation (2) will only be true when focusing on the screw holding the clip (the highest point!) and will underestimate the WD when imaging on the sample surface of interest (since $WD > WD_{TRUE}$).

The default SSO values for each holder given in the **Select Specimen holder** window are defined as follows: [3]

- *2in Flat Holder:* SSO = 0 mm
- *45+45 Degree Holder*: SSO = 10 mm
- *60+75 Degree Holder*: SSO = 10 mm
- *90+30 Degree Holder*: SSO = 10 mm

Note that when the LABE detector is inserted, this SSO value is no longer relevant since hitting the detector, rather than hitting the pole-piece, becomes the issue. Hence, we require that the WD remains greater than 4mm when this detector is inserted.

ii. *Moving WD below 4mm (only available at VB < 10kV)*

For most imaging work with this SEM, WD's ≥ 4mm will be more than adequate (selected using the WD drop-down list). However, there may be some special cases when smaller WD's are needed – particularly, when using GB-H mode on highly insulating samples. In this case, use the following procedure to safely move the sample to smaller WD's:

- Using the focus knob on the external "Instrument Controls" unit, decrease focus to a smaller WD value (say 3.7-3.8 mm to start). The image will now be blurry.
- Using the external "Stage Trackball" unit, rotate the outer white ring that lies around the ball CW. This will slowly move the stage upwards (decreasing the stage Z readout value) until the image comes back into focus at the smaller WD.
- Repeat the 2 steps above until the WD value is finally set to the low value required.

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[3] If the sample sticks above the top of the angled holders, or a clip is used on the flat holder, then the initial SSO value must be reset to the high point of the sample/clip before moving WD < 8 mm.

6. Preparing your sample.

a. There are a few different sample mounts available for use in the JEOL 7600F SEM. They are:

- 2in Flat Mount: ~2" diameter, 0-degree
- 45+45 Degree Mount: 2 x 45-degree
- 60+75 Degree Mount: 1 x 60-degree, 1 x 75 degree
- 90+30 Degree Mount: 1 x 90-degree, 1 x 30 degree

They all have a 14mm diameter plug that inserts directly into the JEOL dovetail slotted holders (we have 2 of them). Use the set screw in the side of the holder to secure the mount.

If using an angled mount, it is OK to use either Cu clips or the double-sided conductive XYZ tape to secure your sample. If using the top-view mounts, it is best to secure your sample using the XYZ tape (see the notes in Sec. 1.b below). Note that clips are OK if you will not be using Gentle Beam mode or LABE detection or will not be requiring imaging WD's less than 6 mm.

b. In the case of the top-view mounts, it is best to avoid using Cu clips altogether because if clips are in the way, then some of the important imaging mode/detector type combinations available with this SEM will not be allowed. Recall that in the absence of clips, the WD measured when imaging on the sample surface will always be a true measure of the mount/sample highest point. So, for example:

- *Low-Angle Backscattered Electron (LABE) Imaging*: Knowing exactly the holder/mount highest point ensures safe insertion and removal of the LABE detector.
- *Ultra high-resolution SEI imaging*: It is possible to move safely to WD's shorter than 4 mm (since resolution scales inversely with WD) when the imaging WD represents the highest point.
- *Gentle Beam (GB) Imaging*: The GB column mode requires that the top sample surface be completely unobstructed to allow proper field setup when biasing the substrate since the GB imaging resolution is extremely sensitive to the local surface fields.

7. Features.

This FEATURES section illustrates most of the bells-and-whistles available to the user when imaging with this SEM and provides some important background information on each of them. Note that here are no "ideal" imaging settings offered as there is no definitive answer – to work out what is best for your sample will require some significant experimentation amongst the many variables introduced below. So get to work!

a. Image Controls

Click on Condition in the *Sub BUTTONS* to bring up these "Image Controls" in the *Operation-settings AREA*. Refer to Fig. 3 for details of its layout.

i. *Accelerating Voltage*:

Click and select the Accel. Voltage (kV) field and manually enter the required value to set the voltage required.
In the standard SEM column mode, the accelerating voltage is identical to the beam voltage. It can be set to any value, in 0.01kV increments below 2.9kV and 0.1kV increments above it, in the range from 0.5kV up to 30kV.
In the Gentle Beam imaging mode (in which the substrate can be negatively biased), the accelerating voltage is equal to the difference between the beam voltage and the substrate voltage (more details below in Sec 7.a.iii). It can be set to any value, in 0.1kV increments, between 0.1kV and 4kV.

Note that it is also possible to switch voltages by selecting the kV voltage value in the *Beam Control BUTTONS* or by clicking on the kV value present in the *Operation-conditions AREA* and selecting from the dropdown list that appears.

ii. *Probe Current*:

To set the current, click the UP and DOWN arrows to the right of the Probe Current field. Note that we are restricting ALL users to the low current, LC, settings only (which covers from as low as 1pA all the way up to 1nA).

LC Value	1	2	3	4	5	6	7	8	9	10
Current (nA)	0.001	0.002	0.0045	0.01	0.02	0.045	0.1	0.2	0.45	1.0

iii. *Column Mode:*

This button set is used to change the imaging mode of the SEM.

- *SEM* is the standard high-resolution imaging mode for the tool in which imaging resolution increases inversely with WD. You are restricted, depending on WD, to magnifications above a

few 100-1000X all the way up to 1,000,000X – and it is clearly seen from the table below, that the largest field-of-view drops rapidly at WD's below 8 mm.

WD (mm)	1.5	3.0	6.0	8.0	15.0
Minimum Magnification	7000X	3000X	1200X	500X	250X

- *LM* is the low-magnification mode to be used when moving around the sample looking for areas of interest since it offers the largest field-of-view. Magnifications as low as 25X can be used.
- *GB-H*, *GB-L* (Gentle Beam – HIGH, LOW) are low accelerating voltage modes that are used for charge-suppressed and/or localized-surface imaging on samples. The acceleration voltage, V_{ACC}, used to probe the sample is a net beam voltage given by:

$$\mathbf{V_{ACC} = V_B - V_{SUB}} \qquad (1)$$

where V_B is the incident beam voltage and V_{SUB} is a negative bias applied to the substrate (between 0 and 2kV). In the Gentle Beam column mode, V_{ACC} is restricted to values between 100V and 4kV

The HIGH mode uses large V_{SUB} values (1.5-2.0kV) which offer higher imaging resolution at very low net voltages. This mode should only be used with flat samples, i.e., top-down imaging, as the imaging fields are very sensitive to the surface condition @ higher substrate bias. This mode is the most difficult to use by virtue of these large V_{SUB} values – continual adjustment of focus, stigmation, and sometimes even beam alignments are required when imaging under GB-H mode.

The LOW mode, utilizing much smaller V_{SUB} values (200-400V), is significantly easier to use but is lower resolution and is used mostly to reduce charging artifacts observed when imaging on tilted samples.

Moreover, clicking on the expand bar allows the user further control of the Gentle Beam effect (for any V_{ACC}) by manually adjusting the Specimen Voltage slider.

Specifically, the benefits of Gentle-Beam imaging result from:

  - Reduced beam penetration into the sample => enhanced near-surface information in the image, as well as reduced charging artifacts (since the enhanced electron emission from the near surface can essentially balance the input current @ the charge neutrality point).
  - Acceleration/repulsion of the emitted electrons away from the surface by the negative substrate bias => reduced charging artifacts.

– Lower net beam voltage @ the surface => reduced electron damage to the substrate.

Note that it is also possible to switch between the 4 column modes by clicking on the mode present in the *Operation-conditions AREA* and selecting from the dropdown list that appears.

iv. *R-filter:*
This filter is used to select the electron energies allowed to reach the upper SEI detector. See Section 7.b.i below for details.

v. *Lookup Table (LUT) – Image brightness and contrast:*
If the Standard button is selected, then the image brightness/contrast is set by the knobs on the eIC unit (which is fine for most cases). However, by selecting LUT and using the expand bar, the user can manually optimize the image brightness using the histogram by dragging the L (black level) and H (white level) sliders. It is also possible to adjust gamma and contrast directly as well as set up a pseudo-color image using this LUT function.

vi. *Aperture Angle Control Lens (ACL)*
The ACL allows the user to manually optimize the spot size/depth-of-focus tradeoff (by adjusting the incident beam angle) per the imaging requirements for the sample.
To adjust, simply move the Focus Depth slider:
- Setting = 1 => the best image resolution/smallest spot size but shortest depth of focus (since the beam angle will be largest),
- Setting = 11 => longest depth of focus (beam angle is smallest) but a reduced image resolution will result.

The default Std setting (=6) is a more than suitable tradeoff between the 2 extremes for most cases and is recommended.

b. Electron Detectors

i. *SEI - Upper/In-Lens Electron Detector*:
This in-lens detector efficiently collects most emitted electrons from the sample @ short WD's (recall small WD => higher imaging resolution). Note that at shorter WD's, the sample is immersed in the B-field of the objective lens so that very little electrons can escape for detection by any other detector.
- *R-filter* allows the user to select/'optimize' the energy range of electrons that reach the SEI detector for imaging.
  SE100 => all low energy SE's in the 10's of eV range for 100% topographical contrast are selected.
  BE100 => all high energy BE's at and slightly below V_B for 100% Z-contrast are selected.

SB0 (default setting) => selects a much wider energy range to include mainly the low energy SE's with some higher energy BE's added in (but excluding V_B electrons) for a mix of both worlds.

You should use the r-filter to enhance the relevant contrast mechanism in the image, e.g., to try reduce sample charging, move the slider from SB0 to the BE side to block those lower energy electrons that exhibit charge contrast.

ii. *LEI – Lower/External Electron Detector:*
The LEI detector works more efficiently at longer WD's (> 6 – 8 mm) as more SE's can then escape the B-field of the objective lens. Imaging with the LEI detector will result in surface topography enhancement (due to shadowing) and can be used to reduce the effect of charging since the SE's that escape the B-field will be higher energy and hence carry less charge contrast.

iii. *LABE – Low Angle Back-scattered Electron Detector:*
This is a retractable solid-state detector that, once in place, detects those higher energy BE's emitted at low angles to the surface that would normally hit the exterior of the lens pole-piece and be lost. This detector is best used at WD's from 4 to 8mm.
To insert or retract, first be sure that the WD is a true measure of the highest point on the sample holder (Sec 5.d) and select WD ≥ 6mm. Click the LABE detector check box in the **SEM Monitor** window (empty to ticked => insert, ticked to empty => retract) and the detector will move in or out accordingly. Once in, it is then OK to move the WD to any value ≥ 4mm.
Specifically, the advantages of the LABE detector are:

- Reduced charging effects in the image since we are imaging only with higher energy BE's.
- The ability, when used in conjunction with the Gentle Beam column mode, to get decent LABE images at beam voltages normally too low for BE imaging (e.g., 2kV or less net voltage!) since the negative substrate bias for the incident beam is also an accelerating field for the emitted electrons.
- Further to the standard Z-contrast in any BE image, additional topographical contrast is possible (as for low energy SE imaging) due to shadowing at these lower emission angles (you will probably need to use the smallest WD of 4mm and smallest net voltages with Gentle Beam to enhance this effect).

iv. *ADD – Multiple Detector Overlays:*
The ADD detector option allows the user to combine the signals from more than one detector in the image.
To setup, first click on <u>Comparison</u> in the <u>*Main BUTTONS*</u> (Fig. 1) to open the "ADD Detector Channels" in the <u>*Operation-settings AREA*</u>.

Click the drop-down arrow for each channel you want to use and select the detector type for that channel. Select the ADD check box if you want this channel to be included when using the ADD detector mode.
And before switching to the ADD detector, be sure to first optimize image brightness and contrast in each of the individual detector modes.

Methods to reduce charging artifacts in the SEM image.

The procedures below give a quick play-by-play on what to do when abnormal contrast due to charging artifacts are observed in your image. The steps given go from easiest to implement to more difficult so start at the top and work your way down the list as needed…

a. Change beam conditions

- Decrease the accelerating voltage (1kV or less!), Sec 7.a.i, to reduce electron penetration depth in the substrate. Note that sometimes even increasing this voltage can help (thin insulator films on the substrate).
- Decrease the probe current, Sec 7.a.ii, to reduce overall net charge incident on the substrate.
- Increase the scan speed - select Quick-1 or Quick-2 in the *Beam Control BUTTONS* – to reduce net charge deposited at any point per unit time. Further, adjust the default scan speeds if further adjustments are needed by opening the **Operation Settings** window (in the Menu bar, select *Setup* -> *Operation Settings*) and select the 'Image/Scan' tab.
- Tilt the specimen, Sec 5.c, to reduce electron penetration depth in the substrate.

b. Change detection mode:

It is mainly those low energy SE's in the 10's of eV range that carry the charge contrast that results in charging artifacts in the image.

- When using the SEI detector, slowly shift the r-filter slider to the BE side, Sec 7.b.i, to suppress the lower energy SE's in the image, or,
- Switch to the LEI detector (if WD is large enough), Sec 7.b.ii, to image with higher energy SE's, or,
- Switch to the LABE detector, Sec 7.b.iii, to image with high energy BE's only.

c. Change column mode

- Change to *Gentle Beam – Low* mode first (substrate bias of only a few 100 V) and see the effect of different V_{ACC} values on the charge contrast, Sec 7.a.iii.
- If charging is still an issue, only then switch to *Gentle Beam – High* mode and adjust V_{ACC}, V_B, and V_{SUB} to optimize. Note that imaging with this mode is extremely sensitive – you will be required to continually readjust beam stigmation, beam alignments and focus as the beam is moved around the surface.