LEO 1550 Scanning Electron Microscope

(leo)

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1.0 Introduction

1.1 Overview

The LEO 1550 is a high performance Schottky field emission SEM. It is capable of holding whole wafers making it a good tool for process control. The LEO has a resolution of 2-5 nm depending on the sample, current column conditions and skill of the operator.

1.2 LEO Qualification Policy

1.2.1 Microlab members wishing to use the LEO SEM must pass a written test and qualify with one of the LEO superusers.

1.2.2 Before qualifying, users will need to attend a 3-hour class/demonstration that is scheduled by demand. To get yourself added to the Leo Class email list, send a request to evan@eecs.berkeley.edu.

1.2.3 To maintain their LEO qualification current, users will need a minimum of 10 hours of LEO use every 3 months. If not met, user will have to requalify by taking the written test again.

1.2.4 Users who did not work at all on the LEO for 3 months, will have to go through training again, as described in step (2), and then take the test, same as all new users.

1.3 LEO Reservation Policy

During business hours (8:00 am - 5:00 pm, M - F): 2 hours maximum. On weekends: 3 hours.

2.0 Hardware

2.1 Overview

The left table of the LEO system contains the column, the high vacuum pumps, the control firmware, and high voltage supplies. The column consists, from top to bottom, of the tip (gun), apertures, objective lens, detectors, and stage.

The right table contains the I/O devices, the computer, monitor, printer and joystick. On the right computer panel below the tabletop are the three main control buttons of the SEM. Normally one of these buttons will be on to indicate the status of the LEO.

- ► The green button will turn on the computer and column (if required). The green lamp ON is the normal state.
- ► The yellow button will put the SEM in standby mode. In standby the computer will be turned off but the column electronics will be left on. This mode is not used.
- ► The red button will completely turn the SEM off, immediately shutting down the power to the column, pumps and computer. It is only used by staff for maintenance or in an emergency.

2.2 The Column

2.2.1 Column Design

The column design of the LEO is unusual. Traditional SEMs have a condenser lens that focuses the electrons onto an aperture. The condenser lens lets the operator choose a beam current by magnifying the source. Since a condenser lens focuses the beam it introduces a **crossover** point in the column, a point where all the electron paths meet. Crossover points cause beam broadening because electrons tend to scatter from each other by coulombic repulsion when focused into a small spot. To limit this form of beam broadening, the LEO column design eliminates the condenser lens crossover. The condenser lens is used only to collimate the beam at low beam voltage values (EHT: Extra High Tension). The result is a simple lens system in which electrons have no crossover between the tip and the focus point on the sample. Its only serious drawback

is that the user has no fine control of the beam current. The beam current can be adjusted coarsely through the use of the apertures.

2.2.2 Electron Gun

The LEO is a Schottky field emission SEM. The Schottky field emission is a new category that fits somewhere in between the traditional field emission and thermal emission SEM types. The LEO tip uses both an electric field and a relatively small heating current to drive electrons off the tip. As a result it provides an intense, coherent beam without the need to periodically flash the tip.

2.2.3 Beam Booster

Below the tip is the beam booster. It accelerates the electrons that are extracted from the tip to an energy 8 keV higher than the EHT. The EHT, which is the final energy with which the electrons strike the sample, is just the difference between the acceleration voltage and the 8keV deceleration voltage of the final electrostatic lens. The reason for this design is that it keeps the electrons moving quickly through the column even at low EHTs. Low energy electrons are more likely to interact with each other and produce aberrations.

2.2.4 Aperture

The aperture lies inside the beam booster. The aperture plate has apertures between 7.5 and 120 microns in diameter. When doing the aperture alignment, the actual aperture is not moved. The beam is deflected into the aperture center by special beam shift coils. The 30 um aperture has a center that coincides with the optic axis. As a result it does not suffer from the aberrations caused by moving the beam off axis. The apertures can be used to adjust the beam current. A small aperture will let fewer electrons through than a big one. However, a larger aperture will also increase the minimum beam spot size, and reduce depth of focus.

2.2.5 Stigmator

The stigmator is a system of coils positioned radially near the beam that reshapes astigmatism in the beam. It does this by manipulating the beam along two axes. Beam astigmatism can be caused by a non-planar sample, particles in the column and poor beam alignment, or magnetic samples or fields.

2.2.6 Objective Lens

The objective lens focuses the beam down to a point on the sample. Changing the current in the objective lens will move the point of focus up and down. The clearance or distance between the focus point and the bottom of the objective lens is called the working distance (WD). It is important to remember that on the LEO, the WD readout is accurate only when the beam is focused on the highest part of the sample. When you turn on the working distance readout, it shows the last reading, not the current distance. You have to focus on the highest point of the sample for correct WD reading. Keep this reading (i.e. clearance) above 3 mm. The objective lens has limits: it cannot, for example, focus low energy electrons at a large WD.

2.2.7 Detectors

Inside the objective lens is the primary detector, also aptly called the in-lens detector. The final electrostatic lens that slows down incident electrons also collects secondary electrons emitted from the sample and accelerates them to the detector. There is another secondary electron detector off to the side of the column. It gives lower resolution than the in-lens detector but gives a better indication of topography.

2.2.8 Stage

The stage has five axes driven by independent motors, z-axis, x-axis, y-axis, rotation, and tilt. The stage will not operate prior to initialization and will freeze whenever contact between it and either the column or the chamber wall is detected. The stage rests on the extension of the sample chamber door and slides out when the sample chamber is opened. This allows samples or holders to be put directly on the stage without the use of special tools. Unfortunately, this setup also makes the stage vulnerable to vibrations. Low frequency acoustic vibrations can often be seen. To limit floor vibrations the SEM is mounted on an air table.

2.3 Vacuum System

The vacuum system of the LEO is simple. There are basically two chambers: the gun chamber and the sample chamber. The gun chamber is pumped by an ion-pump and must be kept at UHV conditions, $1e^{-8}$ torr or lower, at all times. The system chamber is pumped by a turbo-pump, roughing pump combination. All the vacuum valves are automatically switched by the system, so the user has only two options: pump and vent. The SEM takes appropriate actions depending on which command is given.

One valve that deserves special mention is the gun isolation valve. It is located inside the column and separates the gun chamber from the sample chamber. The gun isolation valve opens only when the sample chamber pressure is sufficiently low. Once it is open, the EHT can be turned on. This occurs at a pressure of ~ 2×10^{-5} torr.

3.0 Interface

3.1 Interface Hardware

The LEO is controlled with a windows-PC interface connected to the SEM through specialized hardware. This hardware prevents the SEM from executing actions that are obviously wrong such as opening the gun isolation valve when the main chamber pressure is high. The hardware can also take fast action when a problem occurs to limit the damage. Again, using the example of the isolation valve: if the valve is opened and a high- pressure condition is detected due to pump failure or seal leak, the isolation valve is immediately closed, sealing the gun off. Users do not need to be aware of all the interlocks. However, if some action is not allowed, it is most likely because the right SEM conditions do not exist. In some situations the hardware will take the necessary steps to generate the right SEM conditions, when given a request. For example, the isolation valve automatically closes before the chamber is vented. When the user incorrectly shuts down or turns on the beam the control hardware will attempt to correct their actions. For example, if the user decides to shut down the gun when the EHT is on, the hardware will first shut down the EHT then the gun. This does NOT mean that users can be careless about the operating procedure or use hardware interlocks as shortcuts during SEM operation.

3.2 Interface Software

The control hardware communicates with the **User Interface Program** (UIP) through the LEO server program, the text window program that runs before you log in. The more important messages that the server receives or sends to/from the control hardware are displayed in the server program window. These messages include any errors detected, so if something is going wrong; check the server window for clues. If, at anytime, the server program is halted either through an internal error or user intervention, the SEM will stop responding to the UIP commands. In such a case, it is best to close the UIP and restart both programs by double-clicking on the LEO icon.

3.2.1 Windows

The main screen of the UIP is the display of the SEM. It shows the signal of the current detector, or the chamber image as seen by the CCD camera. Above the main screen is the macro bar; the macros are shortcut commands for common tasks done during routine operation. The menus contain more detailed options and open specialized pop-up windows. The most commonly used pop-up window is **SEM control**, available through the Vacuum-Vacuum Status menu choice and several other places. This window has seven tabs, displaying commonly used information about the SEM. Each tab contains information about a specific group of SEM controls. There are tabs for the vacuum system, the detectors, the apertures, the stage, the x-ray (not available on our model) detectors, the gun controls, and scanning. See Appendix A for a description of the commonly used pop-ups.

3.2.2 Mouse Control

The mouse controls most of the analog inputs such as focus, brightness, contrast, beam shift, and magnification. The only notable exception is the EHT, which has to be typed in. Obviously the mouse cannot control all of these inputs at once. Normally two analog parameters are prescribed to the mouse at any one time; one is adjusted by dragging the mouse with the right mouse button depressed, the other with the middle button depressed. Moving the mouse without a button pressed does not affect the SEM. For one-dimensional inputs like focus and brightness only right and left mouse motion is considered. Drag the mouse in one direction with the button depressed to increase the value of the corresponding parameter and drag it in the other direction to decrease it. For two-dimensional inputs like stigmation and beam shift both the horizontal and vertical motion of the mouse is significant.

The parameters prescribed to the mouse buttons can be changed using macros. The green and yellow text boxes at the bottom of the UIP indicate the parameters currently controlled by the mouse. The sensitivity of the inputs to the mouse movement can be toggled between fine, for small changes, and coarse, for large changes, by clicking on the fine/coarse indicator at the bottom of the UIP. The macros are below the menu bar. They can be customized; the list below consists only of the standard set of macros, listed from left to right. Note that many of the macros control the function of the mouse:

- Go to last known good condition - NOT USED
- Exchanges Specimen - Used to vent when at vacuum, and pump when vented.
- Activate this macro with the middle mouse button.
- Reset stage limits - NOT USED
- Toggle detector - Toggles between the in-lens and the side detector.
- Reduced view - Toggles the scanning rectangle.
- Beam shift - Assigns beam shift function to mouse LB, middle button zeros shift.
- Scan rotate - Assigns scan rotate function to the mouse LB, middle button zeros rotation.
- Frame average - Takes a running average of the picture.
- Frame integrate - Integrates the picture for a set amount of time, and freezes the image. A frozen image is indicated by a blue dot in the right portion of the tool bar.
- Slow scan - Scans the image at a low speed.
- Restore scan - Scans the image at a fast speed.

- Save image - Saves the current scan to a file in your image directory.
- Chamber view - Toggles between camera view and the current detector.
- Stigmation - Assigns stigmation controls to the LB, and focus to the MB.
- BC - Assigns contrast control to the LB, and brightness to the MB.
- Mag/Focus - Assigns magnification control to the LB, and focus to the MB.

3.2.3 Status Display

The bottom right corner of the UIP contains summary information about the status of the vacuum, gun, and EHT. Each of these systems has a green check, red x, yellow-red x, or a gray x/check next to it. In general a green check indicates the system is on and functioning correctly, a red x means that the system is either off or not ready, a yellow-red x means that the system is in transition between not ready and ready. These three indicators communicate crucial information to the user so it is important to know exactly what they mean.

3.2.3.1 Vacuum Display

- A red vacuum x means that the vacuum is not low enough for the EHT or gun to be turned on. Normally this means that the sample chamber is vented; however, it could also be an indication of a bad vacuum in the gun chamber.
- A green vacuum check means that both the sample chamber and the gun chamber vacuum are below their set points, and the gun isolation valve is open. It is also an indication that the vacuum is now ready for the gun and EHT to be turned on.
- A red-yellow vacuum x means that the system is pumping down.
- A gray x by the vacuum system means that the system is not responding. This does not occur during normal operation.

3.2.3.2 Electron Gun Display

- A red **gun** x means that the gun is turned off, the heating current is zero, and the gun is not emitting electrons.
- A green gun check means that the gun heating current is on, and the gun is ready for EHT.
- A red-yellow gun x indicates that the gun filament current is being ramped up; this can take 1-3 minutes.
- A gray gun x indicates that the gun is off and may not be turned on; normally this means that the vacuum is not ready. However, it could be an indication that the acceleration voltage supply in not functioning or connected properly.

3.2.3.3 Gun Voltage Status (EHT)

- A red EHT x indicates that the EHT is off. The EHT stands for Extra High Tension, and refers to the voltage with which the electrons hit the sample. Turning the EHT on establishes the correct acceleration/deceleration fields along the electron beam path for the EHT the user requested. The EHT must be between 20 kV and 200 V. When the EHT is turned on it defaults to the last saved value.

- A red EHT x indicates that the EHT is off, the EHT should not be turned on without the gun being on.

- A gray EHT x means that the system cannot turn on the EHT at this time, normally, because the vacuum is not ready.

By right clicking on the three indicators the user can bring up a menu of commonly used commands for each system. The gun and EHT commands are grouped in one menu, they are: Shutdown (gun off), gun on, EHT off, and EHT on. Only the choices that are applicable are displayed. The Vacuum commands are vent and pump. It is recommended that SEM users use these two menus during SEM operation because the three indicators provide an immediate and clear summary of the system status.

3.2.4 Annotation

Annotations are very useful on-screen measuring bars that can add valuable data to your SEM picture. CTRL-A toggles the annotation pop-up window on and off. Annotations are added to the screen by choosing the type of annotation form the window and dragging the measurement from one point to the other with the left mouse button pressed (the normal SEM control function of the mouse is suspended when an annotation is being added). The segments of the annotation can be individually moved, and the whole annotation can be removed by selecting it and pressing the delete button.

4.0 Operating Procedure

4.1 Stand-by and Turn-on

The LEO should be in operating mode with the green button lit before you begin. If the red-button is on, check the faults to make sure that there is no problems posted that would explain the off state. If the LEO is in standby, or off state without a problem report, turn it on by pressing the green button. Make sure you report the off state on faults, even if everything works. The computer should boot up the operating system and display the desktop. You can then enable the LEO, which will power-up the monitor.

Once the LEO is enabled, double-click on the LEO icon on the desktop. This will run the server (if one isn't running already) and UIP. Note the messages that the server program displays as its loads, any errors will be displayed in the server window. Before the UIP is launched you will need to log in; LEO accounts are set up on the LEO PC by the superuser when you qualify.

4.2 Checks

Once the UIP is launched you will need to perform several quick checks:

4.2.1 Note the state of the system by looking at the three system indicators at the bottom right corner of the UIP.

4.2.2 Turn on the chamber camera using the appropriate macro to view the sample chamber. Normally at this point the system should be vacuum ready with the gun on and EHT off. If the EHT is on, turn it off before you vent.

4.2.3 If the vacuum is not ready but pumping down (indicated by a yellow-red vacuum x), the SEM is probably just pumping down from the last user. Check that the gun vacuum is below its set point, 1e-8 torr, and continue. If the vacuum status is a red x, check the door and the vacuum status in the vacuum menu. If the gun chamber is above its set point, report it as a problem. DO NOT operate the SEM or vent the sample chamber. If the sample chamber is vented (door opens), report it as a problem, but load your sample and continue the operating procedure from there.

4.3 Venting Sample Chamber

Vent the sample chamber by middle clicking on the sample exchange macro, or choosing vent from the vacuum system menu available by right clicking on the green vacuum indicator check. Venting takes about a minute, once the chamber is at atmospheric pressure the door should slide open several millimeters. If the system does not vent properly, make sure it is enabled.

4.4 Loading Sample

Put on latex gloves and gently slide open the sample chamber door. Put your sample holder on the stage, and make sure it is secure with flats on the stage and holder against each other.

There are two sample holders available: the 4" wafer holder, and the individual sample holder. If your sample is a wafer you can put it directly on the wafer holder. Fasten it with the available spring holder; do not use any type of paste on the wafer holder, since the spring keeps it in place. If you have a small sample, you should use an individual sample holder; it holds sample stubs that can be obtained from the Microlab office. Attach your sample on the stub with carbon paint; let it dry for at least a half-hour prior to your SEM session. Put the leg of your stub into a holder location after loosening the appropriate screw. The individual sample holder has 8 places for stubs on the perimeter. This will allow using the rotate axis to move between multiple samples. If you want to look at your sample at a 90 deg. angle, use a 90 deg. sample holder.

Once your sample is on the stage, close the door and pump the sample chamber by pressing the sample exchange macro with the middle mouse button. This is a two-handed operation; one hand should be gently holding the door closed as the other presses the mouse button.

4.5 Sample Pump Down

- ► The sample chamber takes 8 to 15 minutes to pump down. While waiting for the chamber to reach vacuum, you should initialize the stage, by giving the stage initialize command from the stage menu.
- ► While pumping down, use the chamber view TV monitor to position your sample; tilt first, then raise the Z, then approximately set x and y.
- ► Once the chamber is pumped, you will hear the gun isolation valve open, and the vacuum indicator should become a green check.

4.6 Gun Operation

If the gun is not on, turn it on now using the bottom right gun menu. Once the gun is on, turn on the EHT using the same menu. The EHT can be changed by double-clicking on the EHT value in the data zone, and entering the value desired. If the data zone is not visible, it can be turned on with CTRL-D, or through the view menu. Move the z-axis to the appropriate height with the joystick while watching the camera. Make sure you have clearance.

The gun tab contains information and controls pertaining to the operation of the electron gun. The top window displays the EHT, for Extra High Tension, or your beam voltage. This is the only variable parameter available to users. The other user-selectable item is the fifth window down from the top, the Beam State window.

If the gun was off, you will find this window displaying **Beam State = Shutdown**. To start operation, select **Gun On** and the software will start up the gun. The window will read: **Beam State = Running Up**. You can follow its progress by the bar graph near the bottom of the screen. When the run-up is complete, check the Extractor Current (the third window from the top). If this value is less than 100 uA or more than 200 uA, write a Faults report briefly describing this. You may continue to operate, but write the report first! The extractor current will have to be reset.

When the gun is running, you will see the Beam State window switch to **Beam State = EHT Off.** Select **EHT On** to run up the actual beam. As before, the bar graph indicates progress.

To change to beam voltage, or EHT, use the slider at the bottom of the Gun Tab, the **EHT Target**. Do not change the Extractor Voltage Target, the slider in the window second to the bottom.

See the Help section on beam voltage selection, by selecting: **Help** from the toolbar at the top, then **LEO Help**, then **Operation of Instrument**, then: **Use of Different High Voltages**.

4.7 Sample Viewing

Turn on the in-lens detector by clicking on the macro that toggles the camera view. The first signal obtained is usually just noise. The following steps are suggested to obtain an image:

(1) Maximize the brightness.

(2) Adjust the contrast until the image is gray.

(3) Decrease the magnification to the lowest available.

(4) Focus until you see something.

It helps to have a large feature to focus on. If you're looking at a flat clean wafer with tiny features, you might have trouble obtaining the correct focus. Try using the edge of the wafer for initial focus.

Once an image is obtained, find your region of interest, choose the right magnification, focus, and obtain the image either with the printer or the save image macro. If the image is poor, even when the focus is optimized, a stigmation or beam alignment might be needed. For details of these procedures, see Appendix B. The EHT will also significantly impact the image. A large EHT improves resolution, but leads to deeper beam penetration. If only the surface is of interest, a low EHT often works better. A lower WD also helps the resolution, but remember to stay above 3 mm, and always turn the camera on when moving the z-axis or tilt.

4.8 Sample Removal

Once you are done with your sample inspection, turn off the EHT. Turn the camera view on, lower the z-axis, and zero the tilt. Position the stage in the middle of the chamber and vent, using the sample exchange macro or vacuum control menu.

Once the system vents, with gloves, open the sample chamber and remove your sample. If the next user is waiting, let them load their sample/holder, otherwise close the door and pump down. Do not wait for the system to reach vacuum to continue with the shutdown procedure. Once it is pumping, the control hardware will take appropriate actions even with the software exited.

4.9 Shutdown

Quit the UIP by logging off in the file menu. If another user is waiting, he/she can log in by double-clicking on the LEO desktop icon

Points of Cleanliness

- ► Wear gloves when touching anything that will go into the vacuum system, including your sample. Grease and oil are great for clogging up apertures and reducing base pressure. If your sample is contaminated with oil, wash it in acetone prior to loading.

- ► Do not eat or drink in the LEO room: Remember you are working on a system worth almost half a million dollars.

- ► Report broken wafers or lost samples to staff: Wafer bits left in the chamber could fall into the turbo-pump intake.

- ► Keep the area around the column free of clutter, and never lay any object against the column.

5.0 Actions Dangerous to the LEO SEM - What Everyone Should Know by Heart

Touching the column with either the sample or the stage can permanently decrease the resolution. To prevent accidents from occurring please keep in mind the following rules:

5.1 Stage Sensitivity

The stage is a mechanically sensitive component of the SEM, please treat it with care. When mounting a holder on the stage, never use excessive pressure or rapid motions. When closing the SEM door, be gentle, do not slam it! Hold the SEM door closed as you press the pump button. If left alone, it slides out a few millimeters.

The stage has a wide range of motion: It is possible to hit the stage against the side of the SEM chamber when opening the door. To avoid any risk of this, users should lower the stage, zero the tilt, and move the x, y parameters to within 10 mm of 50, in that order, before opening the door. The x, y setting of 50, 50 is the origin of the stage, more or less directly under the SEM column.

5.1.1 Z-axis and Tilt

Changing the Z-axis or Tilt with the computer stage controller, either in absolute or relative mode, is not allowed. The Z-axis or Tilt should only be changed with the joystick. When controlling the stage with the joystick, it is useful to remember that the stage responds to the magnitude of the joystick deflection. A large deflection of the joystick will move the stage quickly. A small deflection will result in slower stage motion. The stage speed is also inversely proportional to the magnification. Since the camera view has the smallest magnification, it has the largest stage speed maximums. Users should be very careful and use minimum joystick deflection when operating anywhere nears the column.

When changing the Z-axis or Tilt settings, the user must be in camera mode, watching the clearance (the distance between the sample and the column) that is left. Before moving the stage to a clearance below 8 mm, the user must know the clearance for certain. Guessing the clearance is not permitted. The two ways to directly observe the clearance are:

(1) Watch the reflection of the column in the wafer. The distance between the column and its reflection is twice the clearance. This method will only give you an empirical feel for the clearance.

(2) Focus on the highest part of your sample, the WD is your clearance.

5.1.2 Stage Movement Limits

Never tilt the sample so that it gets closer to the column, when the clearance is less than 8 mm. If you need to tilt your sample in this direction, lower the stage first, tilt the sample, check the clearance and only then, raise the sample to the appropriate clearance.

Using clearances less than 2 mm is not allowed for any sample.

5.2 Outgassing

Substances that out-gas, have poor vacuum compatibility, or can form loose particles in the SEM are not allowed in the chamber. If you have any doubts, ask a staff member for approval of your material. The following materials are allowed in the LEO: standard semiconductor materials, metals, hard-baked photo resist, carbon-paint with over 1 hour drying time. Exceptions to this list are delaminating semiconductor or metal films.

Anything else is not allowed, particularly substances that are wet, sticky, greasy, or are in a form of a powder. This includes: silver paste, any type of tape, anything touched without gloves, and any thin film that might have flakes or shows flake-like delaminating.

5.3 Extraction Voltage

Changing the extraction voltage is very bad for the tip; it will either ruin the current or burn the tip too quickly. Never change this parameter. Unfortunately, the extraction voltage is easy to confuse with the EHT, the final energy of the electrons hitting the sample. Please be aware that these two are not equivalent. The only place where the extraction voltage appears is in the Gun tab of the SEM control pop-up. Since all of the other functions on that tab can be accomplished elsewhere, the users should not use this tab at all. The EHT should be changed by double-clicking on the data zone EHT value. Gun on/off, EHT on/off controls are available by right clicking on the gun and EHT indicators in the bottom right-hand corner of the screen.

5.4 Shutdown Precautions

Turning off the pumps can ruin the gun vacuum and damage the gun. Users should never press the red button during the normal operation of the SEM. The red button immediately shuts down the entire system, pumps, and all. It should only be used in emergencies and in rare cases when severe hardware problems can only be corrected by **going to red**. Users will be notified of any such problem through the wand's fault system. They will always be specifically flagged with the note that **going to red** is the only way to correct them. If the user then encounters exactly the same problem, they should attempt to first shut down the EHT, then the gun, properly go to standby, and only then, shut down the SEM by pressing the red button. After a few seconds of off time, the user should turn the SEM back on by depressing the green button. Never leave the SEM in the off state.

6.0 FAQ (Frequently Asked Questions)

What is stigmation?

Stigmation is a procedure that asymmetrically stretches and squishes the beam until it is circular. When a beam is improperly stigmated the beam often will be elliptical leading to images that have sharp edges in one direction and fuzzy edges in the other. One sure way to see if your beam needs stigmation is to go through focus on a small feature. If the feature stretches in one direction when it is under focused, and then stretches in the orthogonal direction when it is over focused, stigmation needs to be adjusted.

I am having trouble stigmating. What is the secret to getting optimum stigmation?

Unfortunately stigmation is both crucial and difficult. The standard stigmation procedure is to stigmate in the x first. Obtain the narrowest beam in the corresponding direction, then stigmate in the y and do the same thing. The problem is that the **corresponding direction** is as a rule, not the direction you are stigmating. This can be fixed by rotating the image so that the stigmation directions correspond to x and y. Take your time when trying to find the optimum stigmation values, it takes practice. Poor stigmation is the number one cause of bad images.

How do I change the EHT?

The easiest way to change the EHT is to double click on the EHT value in the data zone and enter a new value. The data zone can be toggled on and off with CTRL-D. The EHT can also be changed through the accelerating voltage choice in the beam menu.

My image is degrading with time, what can I do?

There can be many causes of this problem. For high-resolution pictures you might need to stigmate periodically. Your sample could be charging; gold coating the sample helps. Your sample could be getting damaged; if you are looking at sensitive materials, try lowering the EHT.

The computer froze up, what do I do?

Determine if it is the UIP, server, or the operating system that is frozen. If it is just the UIP or server, kill those programs in the task bar, and restart them. If it is the operating system, press CTRL-ALT-Delete and shutdown. If that does not help, reboot the computer by pressing the YELLOW button, waiting for shutdown and then pressing the green button to reboot.

I cannot see any of my features!

This is a common problem for samples with small or faint features. Remember that some things that are readily visible optically are practically impossible to see under an electron beam. Scratching your sample near the region of interest will help to provide identifying marks. In general, try to find a large feature on low magnification, do a coarse focus and only then go to high magnification.

My scan turns into a sequence of bright and dark lines when I slow down the scan speed!

Auto brightness/contrast control causes this problem; turn it off in the Detectors tab of the SEM control window.

The UIP freezes when I press the fast scan macro while in camera view!

That's right, so do not press it.

How do I get more information on the LEO?

There is on-line help available in the UIP, just look in the help menu. If you do not find the answer there, e-mail a superuser.

APPENDIX A

Pop-up Window Summary

SEM Status Window

A commonly used window is the SEM status pop-up. This window available through the view menu is a fully customizable information window. The first tab shows you the currently selected parameters; double-clicking on a modifiable parameter lets you edit its value. The other tab on the window lets you choose which of the hundreds of parameters you want to display in the status window. Under NO circumstances alter extractor voltage or Fil I (filament current)!

SEM Control Window

The SEM control window is a convenient way to control a majority of features that are used in the typical SEM session. It is available through the vacuum menu - vacuum status choice.

This window has seven independent tabs, each one containing a group of parameters pertaining to a common SEM task. The Vacuum tab contains parameters that pertain to the vacuum system; similarly the stage, gun, aperture, detection, scanning, and x-ray tabs contain parameters relevant to each system. The aperture tab actually contains all of the beam alignment parameters, not just aperture align. Since our LEO is not equipped with x-ray detectors the x-ray tab is useless.

Aperture Tab

The text window at the top contains the current aperture size, click on the arrow to the right of it to see the other apertures. The 30 um aperture is standard, and any user that changes to a non-standard aperture should remember to switch back. Checking the box to the left of the focus wobble turns on the wobbler. Wobbling amplitude can be adjusted with the slider bar. The Emission/Normal toggle puts the SEM in emission mode for gun alignment and normal mode for standard operation. The box in the lower right of the tab is a graphical indication of the settings of the current alignment. The red dot can be

dragged or moved with arrows at the box corners to change the current alignment. The new parameters go into effect immediately so that the user can see their effect on the image. Depressing the buttons to the right of the box changes the current alignment between: aperture align, gun align, stigmation, beam shift, and mag/focus.

Detection Tab

Signals A and B can be changed between the three detectors: in-lens, SE side detector, and the camera. For the side detector the collector bias can be changed to differentiate between high and low energy electrons. Mixing lets you mix the A and B signals with a different ratio to get the maximum information on one SEM picture. Signal adjust is the auto brightness and contrast control, some users like it, some do not. B lets the computer control brightness only, C lets the computer control contrast only, with BC the computer controls both, and OFF turns off automatic brightness/contrast control.

Gun Tab

This tab contains the gun operating parameters. Displays include: EHT, in KV, the beam voltage; Extractor V and Extractor I and Fil I, all of which are used to set up the gun; Beam State, the primary gun control window for the user; Fil target and Extractor V target sliders-not to be changed by users! And, at the bottom, the EHT target slider, where you adjust the beam voltage. In addition, there are two selectors that should both be checked, **Leave Gun On at Shutdown** and **EHT Off at Log Off**.

Scanning Tab

Operating mode shows the current display type. **Normal** is the standard full screen display of signal A. **Split** splits the screen in two, one side shows the image from signal A, and the other from signal B. **Reduced** scans a subsection of the screen. The standard stored image resolution and size is 1024x768. Please do not change it. Scan speed indicator lets you choose the speed of the scan, larger values are slower. The cycle time is the length of time for integrating in frame integrate and continuous averaging modes. The noise reduction method lets you choose between the signals processing style Frame integrate averages the frames at the chosen scan rate for the time set by the cycle time, and then freezes the image. Continuous average works in a similar way except it does not freeze the image, just drops frames older then the cycle time from the averaging buffer. Finally, pixel noise reduction just displays the newest frame of data, taken at the current scan rate, without any fancy post processing. **NOTE**: A **frozen** image is indicated by a blue dot at the lower right-hand corner of the data zone, bottom of the screen.

Stage Tab

This tab contains the stage information. Values can be directly typed into the stage controller. Relative motions of the stage are done through the xy button, note that the image shifts in the negative direction for positive relative movements of x and y. NEVER use the stage controller to change the z or tilt value, you run the risk of crashing the stage into the lens. Likewise NEVER use the stage controller when your sample is tilted in such a way that ANY part of it or the stage/holder is above the final lens. If the stage freezes or is busy pressing the stop stage button sometimes helps. A more comprehensive stage control window is available under the stage menu.

Vacuum Tab

System pressure - The pressure in the sample chamber, if grayed out the pressure is too high to be registered by the gauge. The set point of the isolation valve is 1.5e-5 torr.

Gun pressure - The pressure in the gun chamber. This pressure should be lower then 1e-8 torr. This tab also contains several logical parameters on the status of the vacuum system. The two buttons at the bottom of the tab allow for pumping and venting of the system. Only one button should be available at any one time.

APPENDIX B

Beam Alignment

Normally the beam just requires focus and stigmation. However, if sub 10nm resolution is needed, an entire beam alignment might be necessary. Before a beam alignment is done choose the EHT, aperture, and working distance desired. Also, zero the beam shift. Focus on a small bright object that has features in both x and y directions, and bring up the aperture tab of the SEM control window.

Beam alignment is done from the top down, so start with the gun shifts. Toggle the gun align button the pop-up and the red dot to the right will indicate the current gun position. Also put the SEM in emission mode by depressing the emission button. The screen should now show the pattern of the aperture and a cross mark indicating the center of the field.

Increase the brightness control if the aperture is not round. Once you see a round aperture image place the cross marks in the center by moving the red dot. Put the SEM out of emission mode by pressing the normal button. The aperture alignment is next. Press the aperture-align button the red dot will now control the aperture position. Now turn on the wobbler by clicking on the check box. The wobbler will cause the image to go in and out of focus. Move the red dot until the image is not moving from side to side as it goes in and out of focus. It is important to do this at a high magnification for fine adjustment. Now turn off wobbling by clicking on the check again.

The beam should be aligned: stigmation and focus are still required. Stigmation is a tricky procedure and must be practiced several times. Here are some guidelines. Round objects are the best for stigmation because they have edges in all directions. Stigmation can change from one region of the sample to the next.