## RAITH e-LiNE OPERATING INSTRUCTIONS

1) LOADING A SAMPLE

     a. Start the system

         i. On the Column PC (Right side monitor [R]), select the **SmartSEM** icon to on the desktop to begin the column software.

         ii. On the Litho PC (Left side monitor [L]), select the **e_LiNE** icon on the desktop to begin the lithography software and enter your user name and password.

     b. Loading procedure

         i. Mount the sample on the sample holder, noting the sample orientation and clip location relative to the Faraday cup position.

         <u>Important</u>: Use the diamond scribe to create a scratch in the lower left-hand corner of the sample. This will provide the particles necessary to focus the beam in later steps.

         <u>Note</u>: Always use latex gloves and plastic tweezers when handling the holder!!

         ii. Set the holder on the mounting rods of the loadlock door and carefully close it, sealing the door shut using the thumb screw.

         iii. On [L], click on the **Navigator Loadlock** icon

         iv. Select "via Loadlock" → choose "Load sample" → Select "Ok"

         v. Click "Ok" to indicate that the loadlock door is closed as prompted. This will initiate the loadlock vacuum.

         vi. When the loadlock is pumped down, open the loadlock valve as prompted

            1. Lift the loadlock valve locking pin

            2. Turn the locking lever from "Locked" to "Open" and pull out to open the loadlock valve

         vii. Slide the sample into the chamber using the transfer rod and click "Ok" → Stage will lift sample holder off the transfer rod

         viii. Remove the transfer rod when prompted → Click "Ok"

         ix. Close loadlock valve as prompted → Click "Ok" → Loadlock will vent and column chamber valve will open

         x. Click "Yes" when prompted to "Reset u,v adjustment?". This will reset the u,v coordinates to match the physical x,y coordinate of the sample holder.

         xi. Enter a name for your sample

Sample Clip   Faraday Cup   Loadlock Door   Thumb Screw   Transfer Rod   Locking Pin   Locking Lever
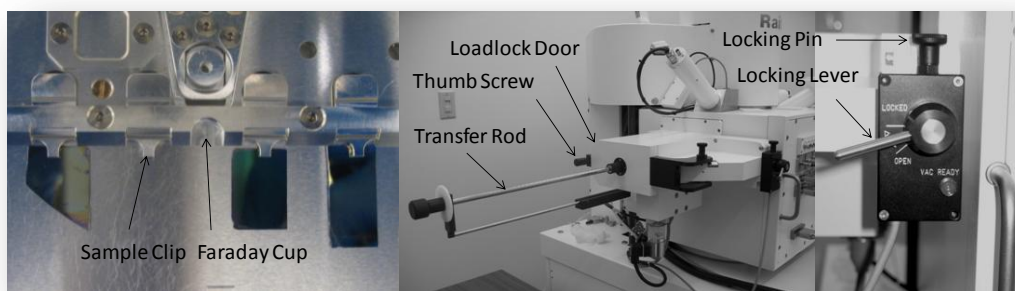
2) **TURNING ON THE BEAM**
    a. Choose an accelerating voltage and aperture
        i. On [L], select the **Column Control** icon 🔲 → in the active mode window choose the aperture size and accelerating voltage. The aperture size will greatly impact the current and spot size of the beam, impacting the write time and resolution, respectively. Table 1 indicates the expected values for the beam current at a given aperture size and high current option selection.

Beam Current (pA)	Aperture Size (μm)	High Current
25	7.5	no
51	10	no
52	7.5	yes
102	10	yes
172	20	no
341	30	no
349	20	yes
677	30	yes
1522	60	no
3084	60	yes
6119	120	no
10284	120	yes

Table 1. Beam current values corresponding to aperture and high current option selections. All values were generated using a commonly used accelerating voltage of 20kV.

    b. Move to the Faraday cup and adjust the working distance (WD) to ~18.0 mm to bring the sample into focus.
        i. On [L], click **Adjustments** icon 🔲 → In the "Stage Control" window, click the "Positions" tab → Select "Faraday cup on holder" → Click "Go"
    c. Turn on the EHT
        i. Right click on the red EHT button [L] → Select "EHT on"
    d. Turn on the SEM
        i. On [R], select "Detectors" tab → select "Signal A = InLens" if the accelerating voltage is under 20kV and "Signal A = SE2" if above 20kV
        ii. Turn off the beam blanker on [L] using the beam blanker icon 🔲

3) **ALIGNING THE STAGE TO THE SAMPLE ORIENTATION USING U,V COORDINATES**
    a. Single layer or first layer write process
        i. Drive to the lower left-hand corner of the sample using the joystick and focus on a particle on the sample surface close to the scratch created in step 1)b.i.
        ii. Set the working distance (WD)
            1. On [R}, click the "Apertures" tab → Select "Mag/Focus" → Focus on the a particle somewhere on the sample surface
            2. Once focused go to [L] → click "Adjustments" icon → "Adjust W" tab →Sample current W position with dropper icon → Click "Adjust"

3. Under "Stage Control" → click "Drive" tab → In the "W" field enter desired WD and with the "Absolute" and "mm" radio buttons selected and press "Start". The stage will adjust to the entered working distance.
4. Change focus on [R] to the WD value entered in step 3. The sample should now be in focus at the new WD.

iii. Define the origin in relative (u,v) coordinates
1. Move to a defined edge feature in the lower left-hand corner of the sample. You can define it more accurately by selecting the **Crosshairs** icon ⊕ on [R]
2. On [L], click **Adjustments** icon → "Origin Correction" tab → Select "Adjust" to set u,v to 0,0.
   Note: All writing operations and absolute stage movement will be performed relative to this origin

iv. Correct for the sample angle
1. Select the "Angle Correction" tab → For "Label 1" select the eye dropper to sample the x,y coordinates at the defined origin
2. Drive stage to lower right-hand corner of the sample → Under "Label 2", select the eye dropper to sample the x,y coordinates at this location → system will now show a given "Calculated angle" in red → Select the "Adjust" button and this angle will be accepted (Calculated angle will turn green to indicate this).
   Note: A straight edge of the sample should be oriented along the x-direction to allow for an accurate adjustment of the sample angle.
   → The relative u,v coordinate system axis will now be adjusted to account for the angle of sample rotation

4) **FINE FOCUS ADJUSTMENT – BURNING A CONTAMINATION DOT**
   a. Move to a location along the scratch that is closest to area you will actually be writing.
   b. Find an isolated particle → click the **Reduced Raster** icon 🖼 on the [R] toolbar Minimize the window, centering it on the particle, to increase the refresh rate
   c. On [R], under "Apertures" tab → adjust "Mag/Focus", "Aperture Align" (Use Focus Wobble), and "Stigmation", using the arrows by the scroll bars for minor adjustments.
   d. On [R] toolbar click **Spot short/Spot long** icon 🔲 and either:
      i. Spot Long: Press middle button (wheel) on mouse (dot burning begins) → let it burn a dot for about 30-60 sec and click the button again to stop the dot from forming (Spot long procedure)
      ii. Spot Short: Click the left mouse button to burn a dot for a few seconds
   e. Correct focus, aperture alignment, and stigmation as necessary to get a nice round dot.
   f. Optional: Having now set up an appropriate set of conditions for your sample at the chosen acceleration voltage, aperture setting, and sample thickness you can save the conditions for future writes

→ On [L], click the **Column Control** icon → right click on the Aperture you are using → select "New Dataset" → Give it a name → Click "Current Values".

5) **WRITE FIELD ALIGNMENT**
    a. Set write field size and magnification under the **Microscope Control** icon on [L]. These values should multiply together to equal 100,000 to ensure maximum magnification for a given write field size.
    b. Adjust Brightness and Contrast to get a good image
    c. Open a position list: On [L] click "File" → New Position List
    d. For an unpatterned sample
        i. Focus on a particle or group of particles
        ii. Click **Microscope Control** icon → "Scan Manager" section → Alignment Write Field Procedures → Manual → right click "100µm WF – Manual ALWF 25µm marks"→ press calculator buttons to update your manual working field list, if tabs are red → drag and drop write field into the position list → right click in position list and click " scan"
        iii. A captured image will appear on [L] with the object of focus centered between a set of green crosshairs. While holding Ctrl, left click on the location of the contamination dot on this image. Do this a total of three times as prompted. This allows the system to better align the write field to the stage position.
        iv. Repeat ii-iii for "100µm WF – Manual ALWF 5µm marks" and "100µm WF – Manual ALWF 1µm marks" – write field alignment will get better after each iteration.
        v. On [L] on desktop toolbar, click the **Protocol** icon to check parameters

→ This process done properly will align and train the beam deflection so that it is properly calibrated for a given write field size.

6) **SETTING UP EXPOSURE PARAMETERS**
    a. *Without* changing the focus, alignment, or stigmation (i.e. changing magnification only), drive to Faraday cup (2ai) → unblank beam → zoom out using magnification to make sure you are in the Faraday cup → zoom in until your SEM view is only in the Faraday cup (black)
    b. On [L], click the **Exposure** icon → Press the "Measure" button under Beam Current to get the beam current value
    c. In the "Exposure" window enable line and dot exposure, if needed (typically just use area exposure)
    d. Press Calculator button to set up sizes and dwell times in agreement with the beam current and dose. Red lettering will turn black when as parameters are recalculated and come into agreement.

→ Perform calculations for each index tab displayed in red (area, line, and/or dot). For reasonable results, the beam speed should not exceed 10 mm/sec (5 mm/sec is good, 1 mm/sec is optimal).

7) **EXPOSING A SAMPLE**
   a. Open a new Position list
   b. Drag-and-drop the corresponding design(s) from the GDSII Database into the Positionlist
       i. Your designs should be stored on [L] in your user folder:
           C:\e_LiNE\User\jtsmith\GDSII
       ii. Access your designs on [L] by selecting the **Design** icon → Choose "Open" → Find your design file
       iii. Verify the layout of your design, if necessary
       iv. Drag-and-drop the file into the Positionlist
   c. Right-click the file once in the Positionlist → Select "Properties"
   d. Press the **Layer** icon to select the layers you wish to expose
   e. Use the "Working Area" tool to select a predefined area of the file to expose
   f. Type in the "U" and "V" coordinates corresponding to the center of your first write field
   g. If needed, press "Exposure Parameter" button to adjust parameters for an individual position. This will override any defaults set from the "Exposure" window. You can also perform a time estimation of the exposure by clicking the "Times" button.
   h. Start the exposure by right clicking the file in the Positionlist and selecting "Scan".