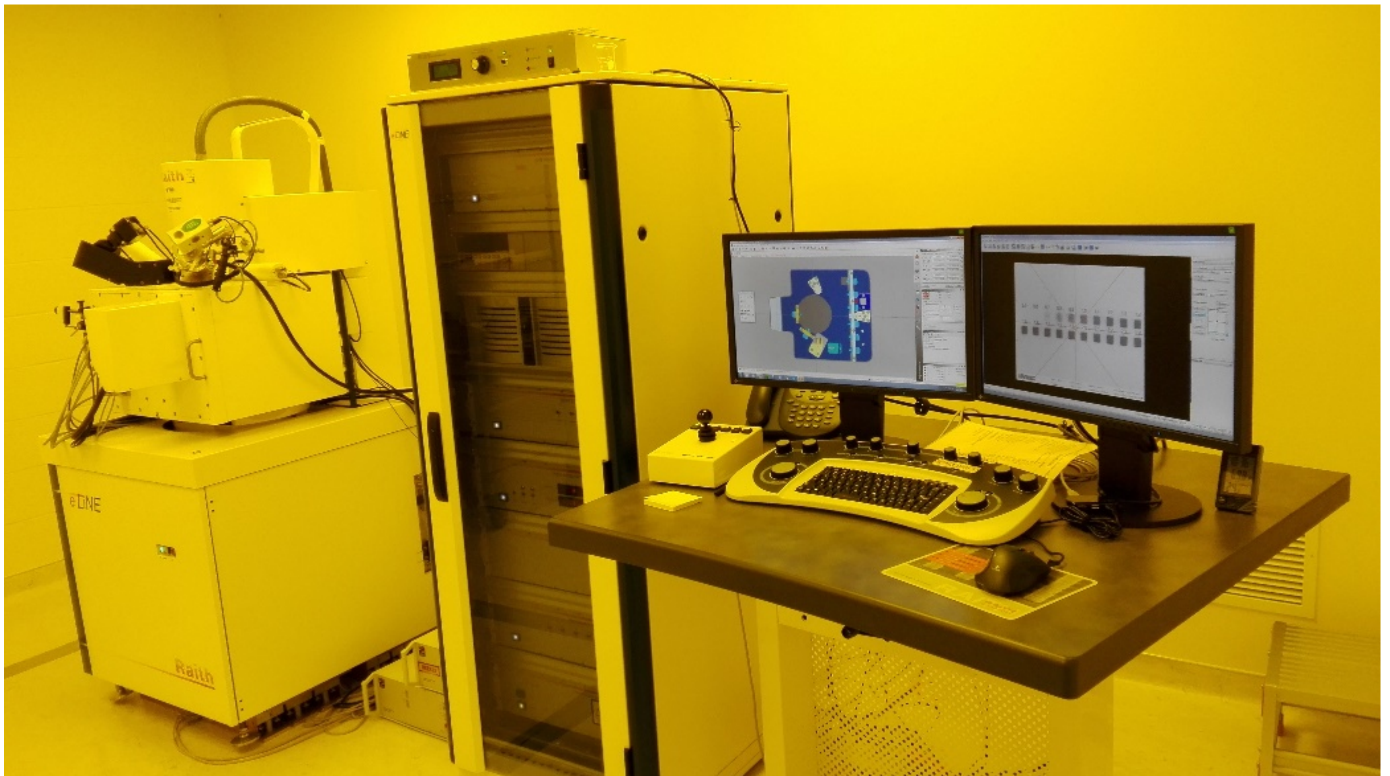
University of Pittsburgh

Nanoscale Fabrication & Characterization Facility

Raith e-line EBL Users Guide

(updated: Aug 2nd, 2017)



Overview:

The Raith e-Line EBL system is designed to write features with critical dimensions as small as 20nm on samples up to 100mm in diameter and 3mm thick. Users can create designs using KLayout, AutoCAD or Raith e-liner editor and then use them on the e-Line system (only accept GDS2 file).

Procedures in general

Task1: Loading sample (through loadlock)

Task2: Activate e-column settings

(Standard)10kV(EHT)/30um(Aperture)/10mm(WD)

Task3: Adjust W=10 mm, WD= 10 mm

Task4: SEM optimization near Faraday Cup

(Focus/Astigmation/aperture alignment)

Task5: Measure beam current

Task6: Coordinate system adjustment on the sample

(Origin/Angle/3-point adjustment)

Task7: Writefield alignment (Standard: 100um writefield)

Task8: Exposure (set parameters/calculate dwell time/do exposure)

Task9: unloading sample

Task1: Loading sample (through loadlock)

1) Log into the "CR-EBL-e_Beam Lithography" through the FOM system.

2) Start the "E-line" lithography software and log in under your user name. The "SmartSEM" software should be running.

3) If at any point the computer must be rebooted, use "user" as both the ID and the password. Always start the column (SEM) software first.

4) Load your sample on the desired sample holder using Carbon/plastic tweezers. Metal tweezers damage the holder. Blow off the sample and the holder with clean N_2 being certain to clean the faraday cup area and the areas on the bottom that contact the stage. Place the holder on the load lock transfer arm. Make certain to

align the rods and the alignment pin. Close the door and tighten the knob to hold the door tightly shut.

5) Click on the "Loadlock" icon located on the right column of the e-line software to open the sample-loading window.

6) Click on the "load sample" button.

7) Confirm that the chamber is empty by viewing the chamber stage with the "TV" CCD camera. Follow all prompts to correctly load the sample. Do not rush the procedure and make certain each task is completed prior to affirming the prompt. Do not run any other computer tasks during the loading or unloading procedure.

8) Be careful when opening and closing the load lock valve. Pull up the lock, turn the handle gently and pull out. It is very simple and does not require a lot of force.

9) If you get a pump down error, make certain the turbo controller is not in alarm. If it is, press the reset button (the 6th module (Loadlock controller) in the rack) to clear the alarm, make certain the outside load lock door is fully closed and tightened, and then retry.

10) Follow the prompts after loading.

'Reset the U,V coordinate system?'→ Yes ;
'Activate previous column settings?'→if 'Yes', it will set previous used column settings: EHT(accelerating voltage)/Aperture/WD(working distance); if 'No', there will be no setting, you will need to set these parameters after loading procedure finished.

Task2: Activate e-column settings

For new users, Start with a lower voltage and a smaller aperture. This allows a larger depth of focus and less damage to the sample. The machine can operate up to 30KV with apertures of 7, 10, 15, 20, 30, 60, and 120 microns. The optimal working distance for this system is 10mm. This focal point corresponds to a W of 10 mm (z-height of around 25mm). The 30um aperture is a good starting point for practicing.

11) Select and activate e-column settings from the column icon on the right panel of e-line software.
Standard settings: 10kV(EHT) /30um(Aperture)/ 10mm(WD). Check to be sure the SEM gun is on and ready to use. Both the gun and the EHT should have a green check mark on the "SmartSEM" bottom bar.

12) At this point, make certain that the chamber vacuum is below 2e-6 Torr and the gun vacuum is below 2e-9 Torr by pressing the "VaCuum/Airlock" icon on the top right of the smart SEM software and reading the values.

13) (Optional)

For optimal stability, click stage control (joystick icon) and use the "find home position window". Home all the axis by clicking "find all". This allows time for the system to settle, stabilize thermally, stabilize the EHT and verifies that the stage is working correctly. This will take a few minutes.

<u>Task3: Adjust W=10 mm, WD= 10 mm</u>

14) Adjust W: set W=10 mm and press 'Start' to move to W=10mm. Then set WD=10mm.

(Optional for first time use)
Focus on the chip, then read the WD (uncheck 'read from CCD')through Coordinate/adjust W/ read -> adjust. The system will adjust W=WD.

Then set W=10 mm and press 'Start' to move to W=10mm. Then set WD=10mm.

Task4: SEM optimization near Faraday Cup

15) Under the stage control "positions" window, click on the faraday cup position for your current holder and press the "go" button. The faraday cup can be used as a known position to start the focus/alignment process and verify system operation.

16) Prepare the SEM to obtain an image.
    a. Turn off the beam blanker in the e-Line software. The blanker is on when it has a red X across the beam icon.
    b. Select the in-lens detector via the detection tab or the sensor toggle button.
    c. Adjust the brightness and contrast to near the 50% level to begin.
    d. Select a scan speed. Scan 2 is usually a good starting point. Right click scan 2 would be optimal for your eyes.
    e. Choose between the coarse and fine adjustments by clicking the bottom tab.
    f. Adjust the magnification, focus(working distance), the brightness and the contrast to achieve an image of the holder and edge of faraday cup.
    g. Use the joystick to adjust the sample position. Note that the buttons on the joystick support block control the speed and the direction as selected.
    h. Locate a small feature, focus and improve the astigmation. Align the aperture until a clear image is obtained.
    i. Perform aperture and astigmatism calibrations at higher magnifications.
    j. Press 'Aperture align' and check 'wobble', do aperture alignment.

Task5: Measure beam current

17) Move to the center of Faraday cup and set Mag= 300 KX. On the exposure parameter window, measure the beam current by pressing and assigning the current location tab and pressing measure. Measure three times to make sure the current is stable. Record the beam current for later use.

Task6: Coordinate system adjustment (Origin/Angle/3-point adjustment)

18) Using the wafer map to navigate the holder.
   a. On the top bar click file.
   b. Select the open wafer map option.
   c. Select the holder that you are using(standard holder: 100mm_ush).
   d. Hold the control button on the keyboard and then click on the desired location on the map and the stage will move to that location.

19) Find your sample:
   a. Remember to be careful not to expose important areas of your sample.
   b. Find the lower left corner of your sample using the joystick control or by typing in the desired position if it is known.
   c. When using the InLens detector, the orientation to the motion of the joystick is direct unless the rotation value in the "smart sem" software is set to something other than 0 degrees.

20) Remember, the e-line system utilizes 4 unique coordinate systems defined in the following ways:

   A) The stage (X,Y). Defined by the motion of the system stage motors and fixed hardware.
   B) The substrate (U,V). Defined by a flat, notch, corner, edge or other feature unique to your given substrate.
   C) The design (u,v). Defined by the coordinate system of the GDSII or Auto-CAD software by which the design was created.

D) The coordinate system defined by the movement of the beam. Zoom, shift and rotation in all axis. These coordinates do not have specific labeling and are designed to calibrate the beam to actual features on your sample.

21) Select the origin correction index tab.

a. If your sample is a square piece, align the lower left hand corner of your sample using the crosshairs and the joystick.

b. Assign the UV coordinate 0/0 by pressing the “adjust” button.

22) Select the angle correction tab.

a. Read (press the eyedropper icon) the XY position as point #1 while noting the microscope magnification setting. Use a minimum of 400X magnification. You will hear a click when it enters that range.

b. Drive to the lower right hand corner of the sample. Read the XY position as point #2 while using the same magnification that was used in point 1.

c. Press the “adjust” button to calculate the transformation angle between the XY and the UV coordinate system. The software assumes the direction along and above the line between points 1 and 2 is the positive direction(U axis).

23) 3-point adjustment

i. Set the mag to 3000X. This allows the viewing of the sample without exposing the critical areas of the sample.

ii. Use the “drive” index tab of the “stage control” to drive to the coordinates where your first alignment mark is expected.

iii. Center on the mark by utilizing the crosshairs feature in the software.
iv. Switch to the "Local" coordinate system.
v. Select the "3-points" index tab of the "Adjust UVW"
vi. Press the read (eyedropper) button to capture the XY coordinates of the current stage position.
vii. Open the actual GDSII design and place Flags(1,2,3) to each point you defined as 3-point markers, respectively. Then the "UV" coordinates of each point are recorded for 3-point adjustment.
viii. Make certain the correct units are used for the appropriate scale and the correct origin is used for the new pattern.
ix. Drive to point 1(P1) and check the box corresponding to P1 to "lock" the XY and the "uv" coordinates pair.
x. Locate the two remaining points(P2 and P3) for 3-point adjustment.
xi. Calculate the coordinate transformation by pressing the "adjust" button and the stage will now drive to the coordinate space defined by the marks that are on the sample.
xii. The stage now drives in the coordinate space defined by the marks on the sample.
xiii. Repeat 3-point adjustment for three times. Finally when you drive to any marker, the marker should be exactly located at the center. Also, focus for each marker should be good.

Task7: Writefield alignment

24) Write-field (WF) alignment is the adjustment of the electromagnetic/electrostatic deflection system inside the column to the X-Y-Z position of the precision laser stage for a given combination of magnification and write-field settings. The software calculates scaling shift and rotation of the write-field.

25) Remember that the write field alignment depends on the current transformation between the sample and the stage. You must establish the coordinate

transformation (UV adjustment) prior to the write field alignment.

26) Manual write field alignment.
   a. Locate a suitable sized reference particle(or one predefined marker) and center it with the aid of the crosshairs. The best size for the particle(better to be less than 200nm) is determined by the desired magnification and the amount of shift required for your write field.
   b. Adjust the contrast and brightness.
   c. Obtain a good image.
   d. Blank the beam to prevent exposure and charging.
   e. Select the "Microscope Control" icon (computer monitor icon) and select and activate the desired magnification and field size. Example: x1000 for a 100 um field size.(in practice corrected for 900X 100um)
   f. Select writefield alignment procedure/manual/100um write field 25um scan, then right click and select 'scan'.
   g. Use the [Ctrl]+ left mouse button to identify the mark each time it is scanned and drag it to an easily identified point on the selected particle or marker.
   h. If the particle is not visible in the image you can reset the wirtefield and then do writefield alignment again.
   i. If the particle is still not visible in the image you can reset all UV transformations. Make certain that the smart SEM software rotation is set to zero. Create a new origin and angle correction for the sample.
   j. Accept the write field correction if you are happy with the changes.
   k. Press the save icon in the "Microscope control" window to add the corrections to the database.
   l. Repeat the align write field procedure with sequentially smaller scan sizes. Do 5um scan then 1um scan. Normally you need to do three times for 1um scan.

m. View the protocol file by loading it from the bottom left windows bar. Make certain that the adjustment is "four zeros", "four nines" or better. (.9999 or .0000 respectively)

Task8: Exposure

27) Make certain the lithography software controls the scanning of the microscope. The icon must display "EXT".
28) For the exposure process open a new position list.

29) Drag and drop the corresponding design or designs from the GDSII database into the position-list. GDSII designs can be created in the GDSII software provided from RAITH or they can be created in Design CAD.

30) If using Design CAD, follow the steps below.

    a. Export your design as an DXF file.
    b. Use Link Cad to convert to the GDS format.
    c. Save the GDS file to a USB flash drive and transfer it to the e-Line computer.

31) By default the exposure is scheduled for the current sample position. The next step is to change the exposure position to the required location.

32) Right click on the position-list line and select the properties tab. Enter the desired location of the exposure into the "Position" tabs and the dimensions for the working area.

33) Use the layer tool to select the layers to expose.

34) Click on the working area button to select the area to expose. "Complete pattern" or partial.

35) With in the "exposure window" enable the line and dot exposures as required by your pattern.

36) If required, press the exposure parameter button and adjust the individual position. This overrides any defaults set from the exposure window. A time estimate can also be calculated.

37) Use the calculator button to display the window for adjusting the current, step size, dwell time and dose.

38) The area dose depends on your resist. PMMA, 950 k molecular weight with a thickness of 100nm@10KV has an area dose of 100uAs/cm2. The line dose should be 300pAs/cm2 and the dot dose should be .08pAs for its dose.

39) Return to the "area" tab and enter a desired step size. .02um for example. Click the calculator button to calculate the dwell time.

40) Return to the "line" tab and enter .01um for the line step and press the calculator next to the dwell time.

41) Return to the "dot" tab and press the calculator button to calculate the dwell time.

42) Adjust the step size if the beam speed is over 10mm/s. It should be 10mm/s or slower for good writing.

43) All the letters in the buttons should be black now and no longer red. Click "OK".

44) Go to the position list window, right click and select properties, exposure parameters and then times. This shows you the time calculation for your exposure.

45) Start the exposure by selecting the desired scan mode from the top pull down menus or by using a right click on the position list line and selecting scan.

Task9: unloading sample

46) Once the scan has completed, press the "loadlock" icon and select the unload button.

47) Follow the directions carefully and acknowledge each command after it has been performed.

48) Unload the sample and close the load lock.

49) Exit the e-line software.

50) Log out of FOM.

Appendix

Sample Preparation Starter Recipe

...Coating with PMMA A4...

1) Log into the lithography **hood 2** through FOM.

2) Pre-clean new surfaces with Acetone/IPA in an ultrasonic bath. Use the N2 gun to dry the solvent from the sample.

3) Heat the substrate on the hot plate at 120C for 3 mins. This drives off the solvent and dries the surface for better resist coating. Wait until cold.

4) Set up and perform the following spinner recipe.

   a. Mount the sample and turn on the vacuum for the spinner.
   b. Using a pipette, coat the sample with PMMA. The amount needed will vary with the sample size. A few drops are normally fine. Be careful not to create bubbles in the resist.
   c. Spin 10 sec @ 600 rpm.
   d. Accelerate for 5 seconds at a factor of 15.
   e. Spin 60 seconds @ a rate of 4000 RPM.
   f. Final Spin 10 sec @ 600 rpm.

g. Prebake for a minimum of 10 minutes @ 175C on the hotplate. Baking in an oven will take several hours but will yield better resist uniformity.

The Thickness should be close to 240nm. If performing metallization after the exposure the thickness should me near 2X the metal thickness and is controlled by the resist concentration, the sample size and the spin speed. If you are using the resist as a wet etch mask then a thickness of around 100 nm should work fine.

5) Log out of FOM.

Post Processing:

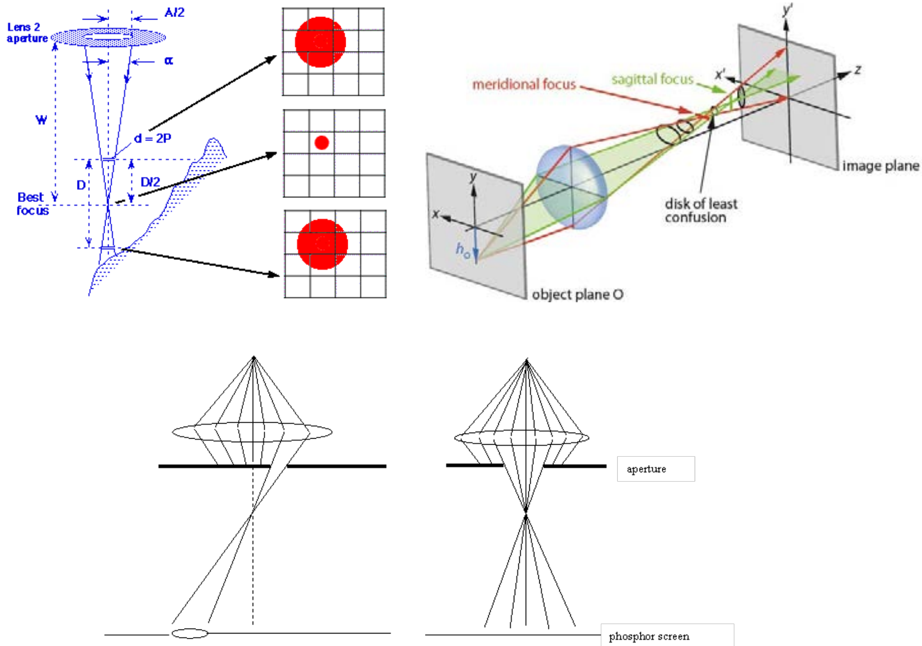
Developing Procedure(standard)

1) Soak the sample in a dish of MIBK-IPA for 1 minute.
2) Soak for 1 minute in IPA or rinse thoroughly with IPA.
3) Blow the sample dry with N2(at least 1 min)

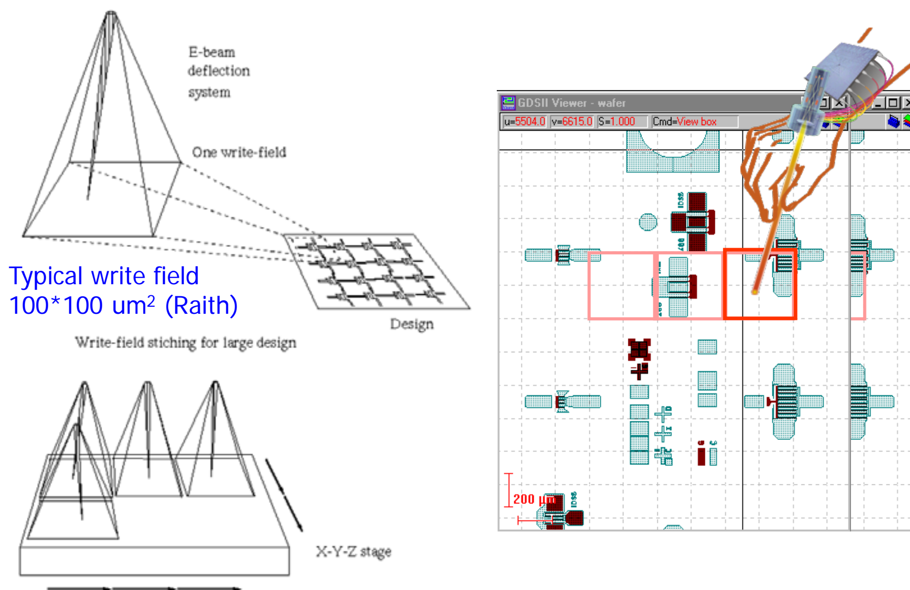
Appendix

SEM (optimization)

Focus/ Stigmatism/Aperture alignment

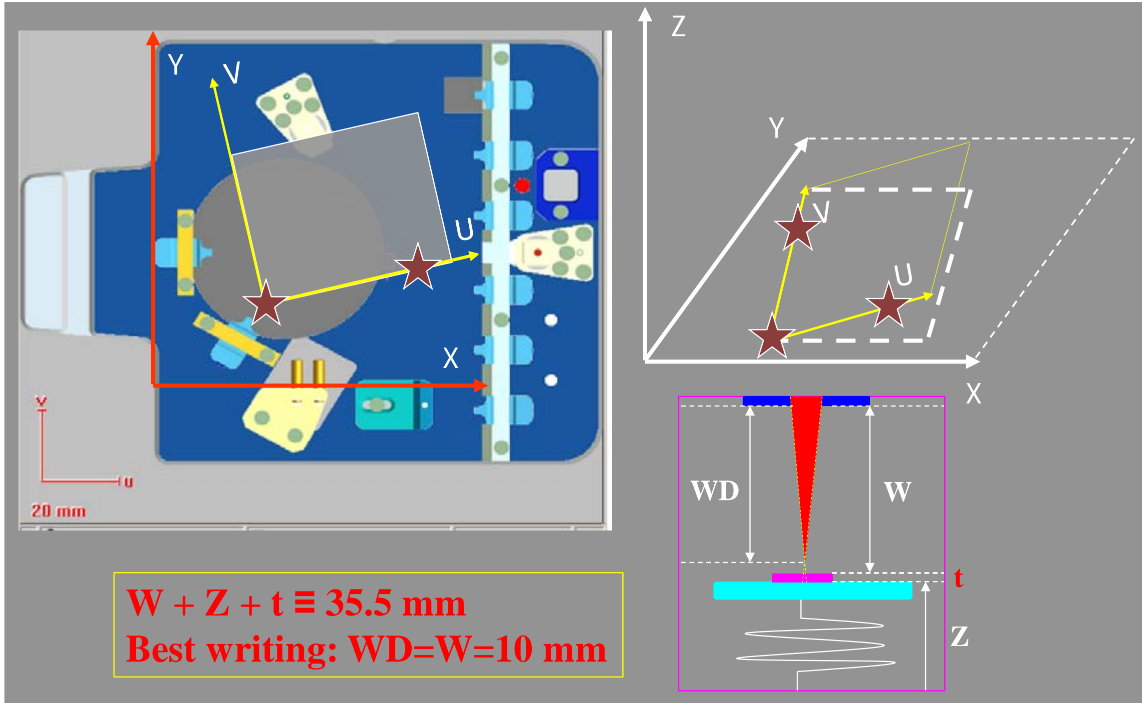


E-beam writing

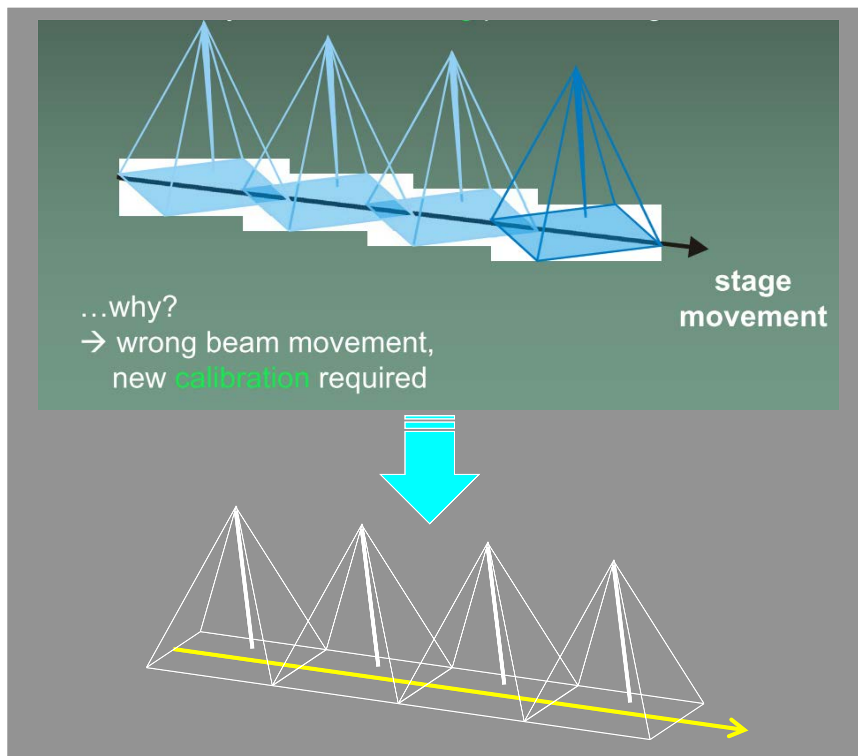


Coordinate system

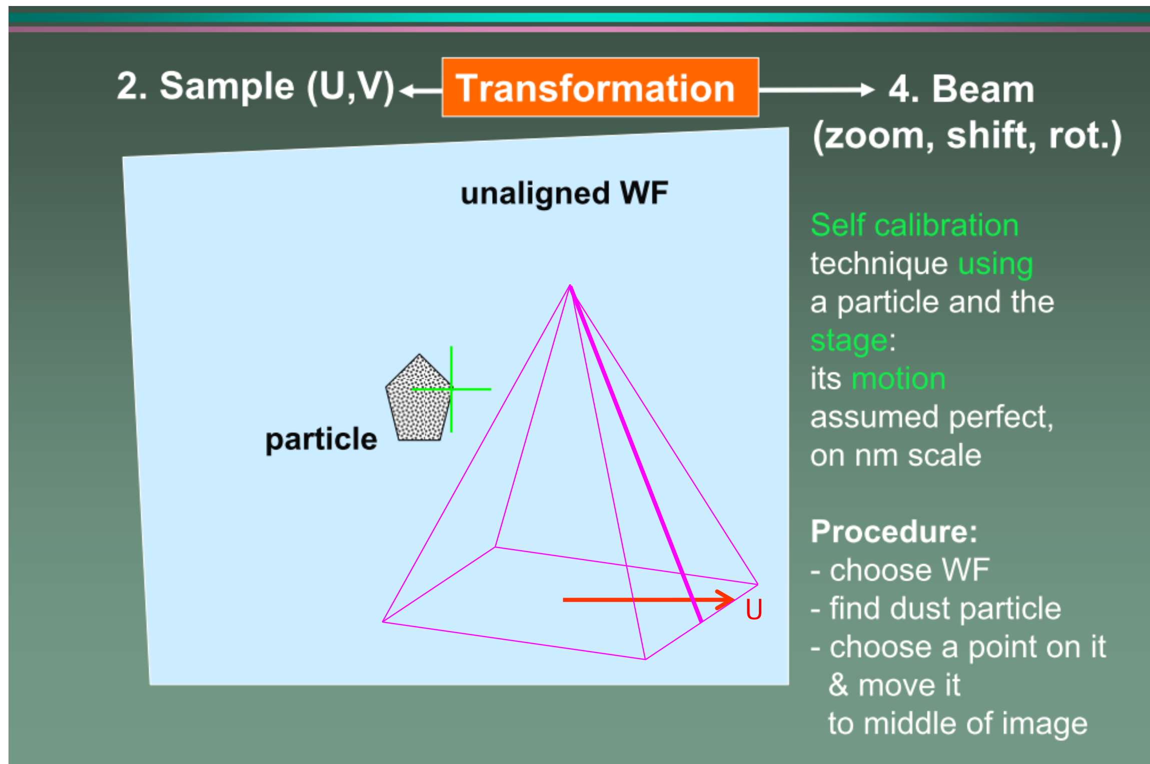
(W adjustment)/ Origin/UV adjustment/ 3-point adjustment



Write field alignment



Write field alignment



Write field alignment