Microscope alignment

Measurement

Website: https://maxpeemdocs.maxiv.lu.se/index.html

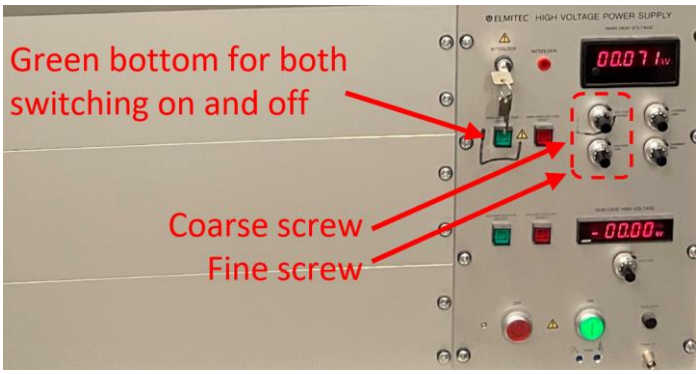
Version: 2024/11/25

Microscope alignment

For detailed alignment, one can start with UV-PEEM for aligning intermediate column and image column with field of view typically > 50 µm, without influence from illumination column.
For simple alignment, one can directly start with LEEM or XPEEM with a smaller field of view (< 50 µm).
The setup inherited from the previous week is normally well-aligned, allowing for a simple alignment check first.
During alignment, one can always use 'undo' to return to previous setting of lens, but not manipulator motors.

Prepare the setup for high voltage

1. **Position the Manipulator Head (3mm to objective lens) and Use aluminum foil to temporarily fix the position of the head.**
2. **Check the pressure of chambers (Main chamber < $2*10^{-9}$ torr), X-ray valve is closed, electron gun is off and the Start voltage is set to 0 V. Camera can be at acquisition mode. Check the sample temperature if it has been heated.**
3. **Set the coarse screw to a lower value (e.g. 5) and turn on high voltage rack. Increase slowly with eyes on pressure**



High voltage rack.

UV-PEEM for adjusting the sample tilt and aligning the intermediate and imaging columns

For rough alignment, all apertures and slit in the beam path should be removed.

Prepare the setup for UV-PEEM

1. **Be sure the electron gun is OFF: Wehnelt potential as -290 V by default**
2. **Prepare the UV Lamp with mechanical iris being closed**
3. **Monitor the Microscope Image and Main Chamber Pressure and Slowly open the iris partially.**

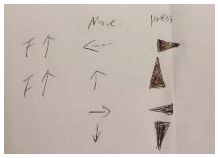
!!! Be mindful of scattering and reflection of UV light.!!!

Alignment of intermediate column

1
1. **Find the Optical Axis and set marker**
   i. Wobble the **Mirror Transfer Lens 1 (MTL1)**, Identify the "breathing" center and set a marker on it.
2
2. **Adjust the Sample Tilt (based on marker)**

*** Start voltage is set to 0V when start aligning tilt.**

   i. Wobble the **Objective Lens** and Align the breathing center to the previously set marker, minimizing image movement behind the marker.
      * The marker represents the optical axis. Keep in mind that image features may change while aligning the sample tilt.



A trick to align the tilt:
Observe the direction of feature movement with increasing value of objective lens and click on the corresponding bottom in the motor control panel.

3. **Move the Feature to the Optical Axis**
3
4. **Wobble Mirror Field Lens 1 (MFL1) and check**
   i. X direction: Outer sel; Y direction: MFL1 Align Y
4
5. **Wobble Mirror Field Lens 2 (MFL2)**
5
6. **Wobble Mirror Transfer Lens 2 (MTL2)**

Alignment of imaging column

6
1. **Wobble the Transfer Lens (TL)**
   i. X-axis: Mouter Se; Y-axis: Sec2 Align
7
2. **Wobble Minner Se and minimize the motion of reference point with FL value.**
8
3. **Wobble the Field Lens (FL) and align towards the opposite direction of breath center**
9
4. **Wobble the Intermediate Lens (IL)**
   i. Align X if wobble in Y direction and align Y if wobble in X direction.
10
5. **Wobble Projective Lens 1 (P1)**

Alignment in energy analyzer and projection system

11
1. **Wobble the Inner Lens (instead of RL)**
   i. X and Y axes: RL Align
12
2. **Wobble the Acceleration Lens (AL)**
   i. Center it with Sel+/-
   ii. Can try adjusting AL Align A, B but it might not help alignment
13
3. **(Not necessary) Wobble Sel +/- and minimize the motion with the Acc. Lens value**
14
4. **Wobble Projective Lenses 2**
15
5. **Wobble Projective Lenses 3**
   i. Breathing center should be centered in the image window.

* Go back and check the whole column, make corrections if required. During alignment, P3'x and y can be used for moving reference feature (optical axis) to center of view.

LEEM alignment with electron gun for smaller FoV

Prepare the setup

Set start voltage as 0 V and Slowly decrease Wehnelt potential to observe MEM image.
!!! Do not set the Wehnelt voltage below -240V.!!!

(16) Align Electron Gun Incidence Perpendicular to Sample

1. **Set start voltage to a value that provides a uniform dark spot within the bright image, and Use the ILUDX, Y deflectors to maximize and center the dark spot.**
2. **Decrease start voltage and repeat step 1 until reaches the lowest STV value (low enough value e.g., 0.5V).**

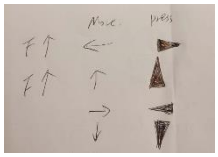
Alignment of intermediate column

(1)
1. **Find the Optical Axis and set marker**
   i. Wobble the **Mirror Transfer Lens 1 (MTL1)**, Identify the "breathing" center and set a marker on it.

(2)
2. **Adjust the Sample Tilt (based on marker)**

*** Start voltage is set to 0V when start aligning tilt.**

   i. Wobble the **Objective Lens** and Align the breathing center to the previously set marker, minimizing image movement behind the marker.
      * The marker represents the optical axis. Keep in mind that image features may change while aligning the sample tilt.



A trick to align the tilt:
Observe the direction of feature movement with increasing value of objective lens and click on the corresponding bottom in the motor control panel.

3. **Move the Feature to the Optical Axis**

(3)
4. **Wobble Mirror Field Lens 1 (MFL1) and check**
   i. X direction: Outer sel; Y direction: MFL1 Align Y
   ii. The incidence angle will be affected by **X-direct alignment**, so do previous steps to adjust back to normal incidence.

(16,1, 2) Repeat the steps for perpendicular incidence (16), finding the optical axis (1), and adjusting the sample tilt (2) until no further adjustments are needed
* Step 3 may need to be checked.

(16,1→15) **Check and repeat the alignment of all lens until no further adjustments are needed**

----------Decrease FoV ----------

(16,1→15)
1. **Decrease FoV and repeat over the checking and alignments if needed, until the desired FoV is reached.**

***** FoV can be aligned as UVPEEM (100 µm, then 50 µm, sometimes can try 25 µm), then LEEM (50 µm, 25 µm, 10 µm). The setup inherited from previous week is normally well-aligned, and possibly standby with FoV as 10 µm. Most likely, due to the change of sample, the tilting is the most needed to be aligned.

(S1)
2. **Check the astigmatism of objective lens by adjusting Obj. stigm A, B to observe a sharper image.**

***** One may need to adjust the objective lens to refocus. Since the Obj. stigm is to some extent coupled to illum. Defl, so check that too if using electron gun.

3. **P3 can be used to enlarge the field of view without changing lens alignment**
   i. Record the P3 value beforehand, so that later the value can be typed in to adjust back.

Modes	SAA	CA	Slit	
Imaging mode (LEEM, PEEM)		☑	☑	*Energy slit must be inserted in LEEM mode. * SAA is normally not inserted when observing full image.
Dispersive plane mode (XPS)	☑	☑		* Slit must be removed for spectrum acquisition.
μ-ARPES (PEEAD)	☑		☑	* CA is not needed when obtaining angular information.
LEED	IA		Y/N	* IA is preferred than SAA so that angular information is not partial cut out.

SAA = Select area aperture; CA = Contrast aperture; Slit = Energy slit; IA = Illumination aperture; Y/N = can remove the slit, PEEAD = photoelectron emission angular distribution.

Frequently used parameters:
Select area aperture = 100 / 50 μm (real image size = SAA/20), Contrast aperture = 30μm, Energy slit = 60 μm, Illumination aperture = 30 μm.

The apertures and slit are inserted in the sequence determined by their position along the path.

IA

1. Insertion of illumination aperture (LEEM, LEED)
Location: In the first beam separator, between electron gun and sample

i. Observe the mirror image and move the aperture mechanism
   * Move the aperture and try to put it close to the center of the observed image. (Yellow) Allen key might be needed. Don't use too much force when adjusting.
ii. Check if the aperture is in focus otherwise correct the objective lens a little bit.
iii. After both operations are finished check once more the image column and make corrections if required.

CA

2. Observe the PEEM/LEEM image on the screen and move the contrast aperture CA (LEEM, PEEM)
*** TL value and Diffraction Stigmator (S2) can be used for optimization.**
Trick: One can remember the TL value and increase the TL value for observing image before CA insertion, e.g. 550 to 720 or even up to 800 mA. One can also remember the P3 value (e.g. 2200) and decrease it to have a larger view (e.g. 1700+).

i. Insert the aperture (e.g. 30 μm or larger) and center it with CA motion and CA correction in CA control panel.
   * One can try 100 in one direction (step=20) and change to the opposite direction if image not found. Decrease the step size and correct it until step = 2.

Slit

3. Insert the energy selection slit (must in LEEM mode)
* Can be done with UVPEEM but LEEM is easier.

i. You should see a uniformly illuminated image. If not, adjust position in the slit panel, from step=20 to fine step, e.g. step=2.
ii. (Normally not needed) If uniformly illuminated image cannot be achieved, one can try adjusting **P1 value**. Focus the image with FL value if needed. In DP mode, slit can be inserted for adjusting P2 and P3 to observe a sharp edge.

SAA

4. Insert the select area aperture SAA
* The image is enlarged 20 times, so that the real scale of observed sample image is (the size of SAA)/20.

----------LEEM to **XPEEM** ----------

check valve to X-ray, Wehnelt voltage (off), Start Voltage, Value of Objective lens, X-ray alignment, Value of Acc. Lens (normally not needed)

----------LEEM to **DP** ----------

1. **Save the LEEM setting** in case of changing back to imaging mode later, normally with FoV ~ 10 µm.
2. **Insert SAA (100/50 µm) in LEEM mode.**
3. **Set the Start Voltage to desired values if known**, e.g. (Pt4f) hv=250 eV with peaking at STV=174.6 and 171.6 V. **Or set the Start Voltage to a higher value if targeting at secondary electron**, e.g. (Au WF) hv=150 eV, STV = 40 V and later (after finishing rest of steps) decreases to 9 V for measuring work function.
4. **Set to D.P. mode.**
5. **Adjust P2 value and P3' x and y deflectors to observe the sharp edge of slit.**
6. **Remove Slit. Careful about setting start voltage!**
7. Remember to turn off the electron gun and check the X-ray alignment. X-ray alignment (M1_pitch) can be done with viewing DP signals if M4 alignment has been checked.

----------LEEM to **LEED** ----------

1. **Save the LEEM setting** in case of changing back to imaging mode later, normally with FoV ~ 10 µm.
2. Insert illumination aperture **IA = 30 µm** or other value based on requirements.
3. **Set the Start Voltage to a higher value (e.g. 40 V).**
4. **Set to LEEDMOFF mode.**
5. **Remove Slit. Careful about setting start voltage!**
6. **Remove CA.**
7. **Decrease start voltage accordingly for measurement while observing LEED pattern.**
8. Use **P3'x and y deflectors** to centralize LEED pattern.
9. **Normal incidence might be changed and needs to be checked.**
10. Use the **diffraction stigmator** to make the pattern circle. One can use the marker generated by clicking three points to guide eyes. However, this step might make the (0, 0) being away from the center of LEED pattern.
11. **Alignments on lenses after Field Lens need to be checked.** Try to centralize the (0, 0) dot in pattern. If all the lenses are aligned well but the (0, 0) is still not in the center, one can use RI'x and y deflectors (without toggle Inner Lens) to manually centralize the (0, 0).

* The plot can be visualized with LEED(log) mode for clearer judgement.

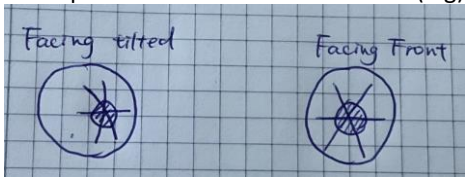
----------LEEM to **ARPES** ----------

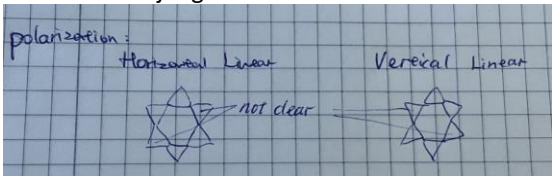
LEED = electron gun + LEEDMOFF mode; ARPES = X-ray + LEEDMOFF mode

* If coming from LEED mode, remember to remove illumination aperture.

1. **Save the LEEM setting** in case of changing back to imaging mode later, normally with FoV ~ 10 µm.
2. **Insert SAA (100/50 µm) in LEEM mode.**
3. **Set to LEEDMOFF mode.**
4. **Insert Slit (25 µm) in LEED mode.**
5. **Remember to turn off the electron gun and check the X-ray alignment.**
6. The patten should be like facing front instead of tilted. **Toggle IL** (which is most important for facing front) and **P1** for optimization. Adjustments on **P1's value**, **acc. Lens' value** might also be needed. Alignment on Ana. Stigmators is normally not needed.
7. **Toggle Acc. Lens and correct it with Sel+/-.**
8. Toggle Sel+/- and correct it with Acc. Lens when slit is not in the path, otherwise with very small amplitude for toggle or skip this step.
9. The start voltage can be adjusted accordingly for measurement.

* Due to the polarization of beam, the ARPES patten will be partially unclear.
* The plot can be visualized with LEED(log) mode for clearer judgement.





----------Changing sample in Main chamber----------

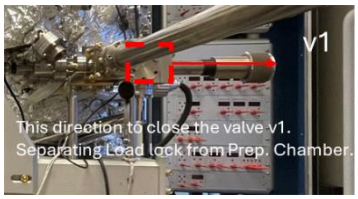
!!!Turn off the high voltage rack before changing sample!!!

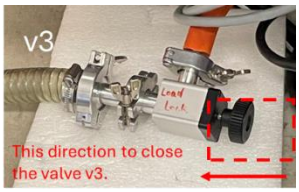
One can change back to LEEM or XPEEM mode for checking if the beam or targeted area are still in position.

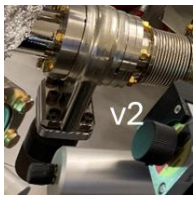
* Remove slit and apertures.
* Close valve to beam, turn off electron gun (-290 V) and iris of UV lamp accordingly.
* When inserting or removing sample from manipulator in main chamber, always remember to initialize the position (X, Y) and tilt of manipulator to 0. (X, Y, tilt = 0) Double check the value in software and manipulator head physically.
* Before moving transfer arm, remember to check the location of holder in prep chamber (not hit it), and open the valve between prep chamber and main chamber. Always be aware of the location of transfer arm and the objects in the path that it may pass through.
* If the microscope has been aligned, most likely the alignment is good enough for measurements after correcting the sample tilt.
* The standby mode generally is FoV = 10 µm and STV = 0V.

----------Inserting sample ----------

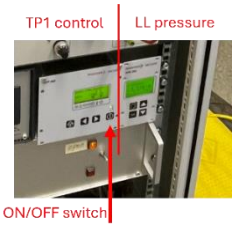
1. Check that the valve from load lock to prep chamber (v1), and valve to forepump (v3), and valve from prep chamber to main chamber (v2) are closed.







2. Turn off the small turbo pump (TP1): The green light above the switch will start blinking and speed will decrease from 1500 Hz.



3. Loose the bolts of load lock but keep them in the holes.

4. Set the nitrogen gas regulator (v4) around 0.4-0.6 on the low-pressure side (clockwise to open). You will hear the nitrogen flowing through the load lock.

5. Fully remove the load lock bolts and flange when LL pressure reads 1000 mbar -- insert sample (gloves must on) -- stop the nitrogen flow via v4 -- close the Load lock bolts (one up right, one down left) and flange. Hand tighten the two bolts instead of using a wrench, to avoid over-tightening.

Start pumping:

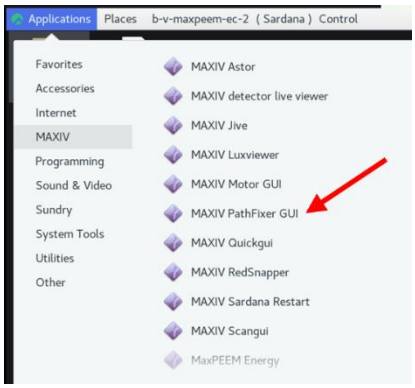
6. Slowly open valve to forepump (v3) and switch on small turbo pump TP1. Hear the noise from forepump pumping.
7. Slowly close v3 when reads 50 mbar on load lock pressure.
8. Wait until the load lock pressure reads at least $3*10^{-6}$ mbar to transfer the sample into prep chamber. This might take 15-30 minutes.
9. Leave sample in prep chamber to degas. Close v1 to separate load lock and prep chamber.

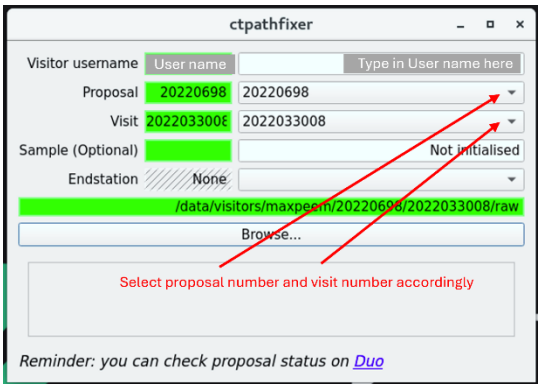
----------To-do before measurements----------

1. User-related information (type in before measurements)

Application – MAXIV – PathFixer GUI // ctpathfixer – user type in username (DUO) and select the proposal and visit accordingly.

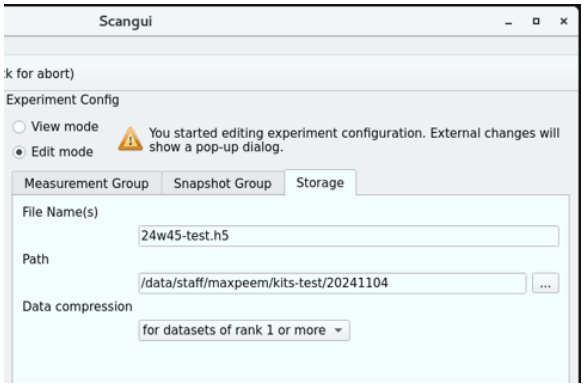
The scanning data will be automatically saved in the 'raw' folder in this Visit folder. Cut out '.dat' files into user defined folder or rename after each measurement, but leave '.h5' file which contains reference spectra and will be automatically updated after each measurement.





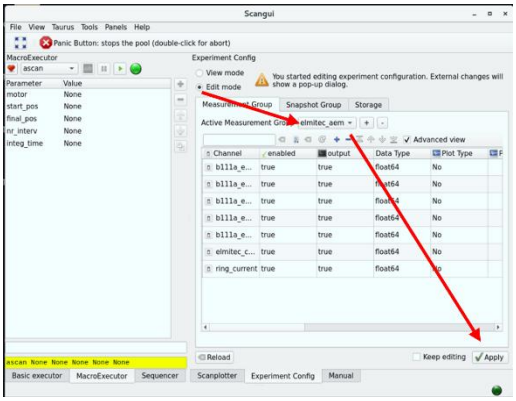
2. Storage location of data (check before starting the sequence)

Edit mode – Storage – Change the path and file name accordingly.

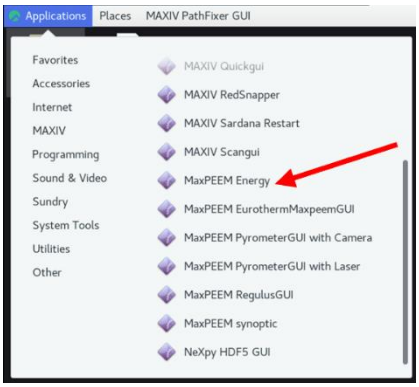


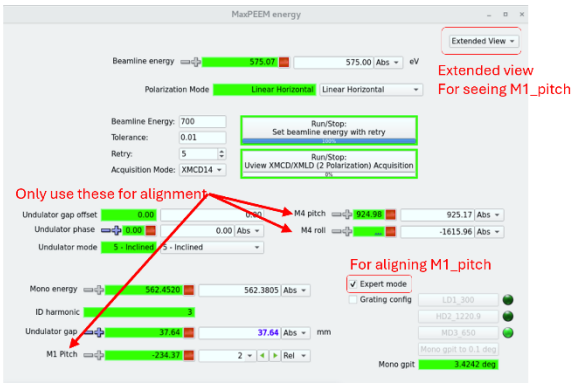
3. Active measurement Group: elmitec_aem

Edit mode – select elmitec_chan – apply



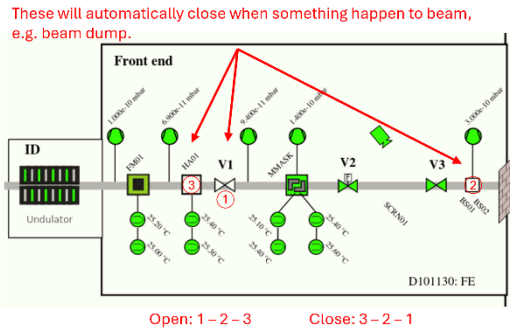
Open the panel (MaxPEEM energy):
Application – MAXIV – MaxPEEM energy (during measurements, use the standard mode only)
Extended view with Expert mode is used for aligning M1_Pitch.

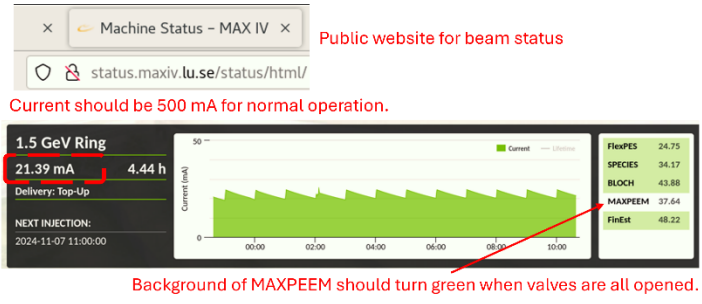




1. Maximize beam intensity using ‘M1_pitch’, step=2
* One can use the photodiode in beam path (value=78 means photodiode is inserted).
2. Localize beam at center of image and make it uniform using ‘M4_pitch’ (step = 2) and ‘M4_roll’ (step = 10)
If defocusing is needed, use ‘M4_yaw’

When Beam dump unfortunately happened: valves automatically closed and beam current was not 500 mA. Check the chat panel for updates.





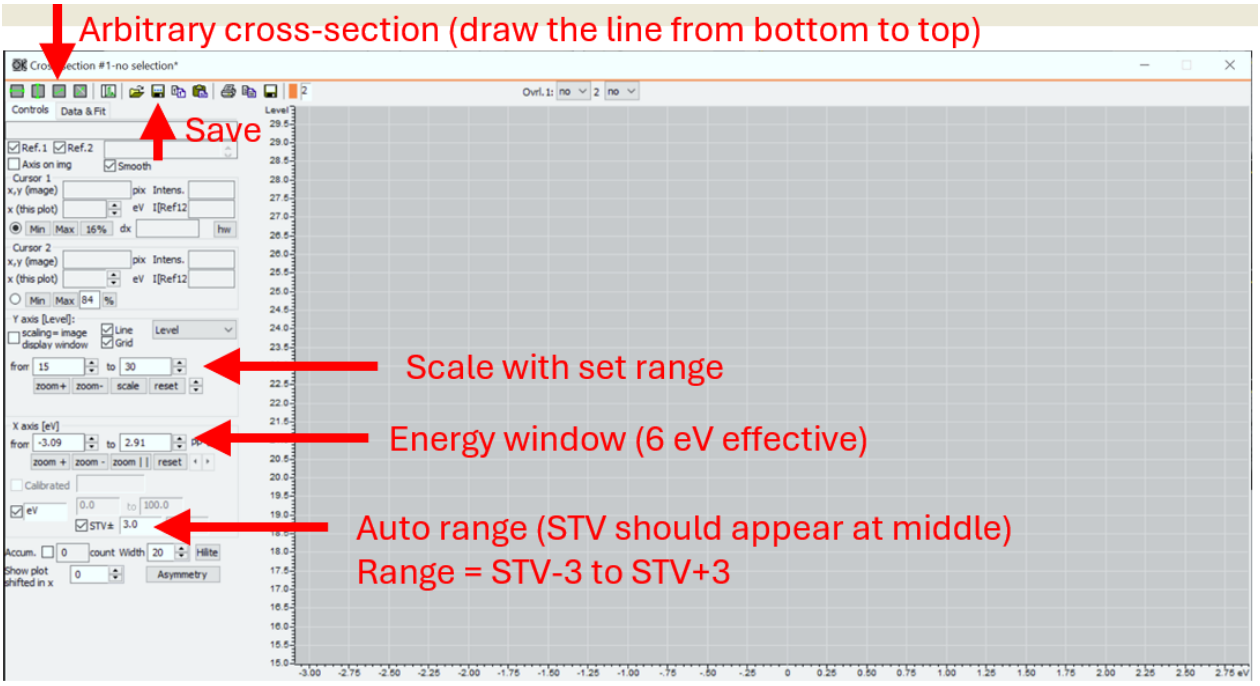
* HA-01 and BS01 are used for blocking beam, and V1 is used for isolating the vacuum of storage ring.

To open: V1, BS-01, HA-01
To close: HA-01, BS-01, V1
* The beam is opened or closed in this order to prevent direct illumination of beam on V1, which is metal and might melt under illumination.

---------- μ-XPS (DP mode) ----------

U-view – Arbitrary cross-section – draw a line from bottom to top – (if available) adjust start voltage to see Au doublet with energy difference ~3.6 eV *Save the spectrum as reference!
Since the energy slit is not in the path, be careful about setting Start Voltage! **!!!CAREFUL!!!**
Useful values: Available energy window: ~ 6 eV; Work function: ~ 4.85 eV

* Energy window is limited to 6 eV (effective range) but the energy resolution (~ 0.2 eV, depends on SAA, can be better) is better than XPS in XPEEM mode (~ 0.5 eV, depends on step setting and signal intensity).
* Steps for determining the measurement parameters are same as XPS in XPEEM mode.
* Click on the box for eV and STV±3, so that the set STV should appear at middle of energy range.
* Click on Hilte, which can change the line width with maximum as 40. Intensity is integrated from the area marked by the line, so increasing line width can provide strong signal.

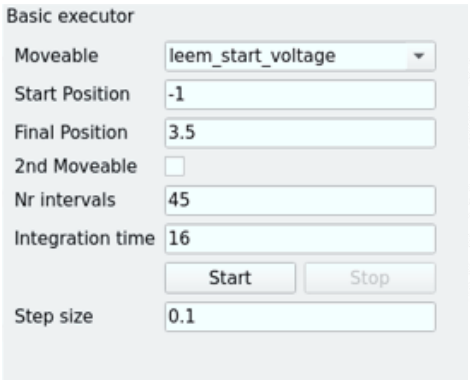


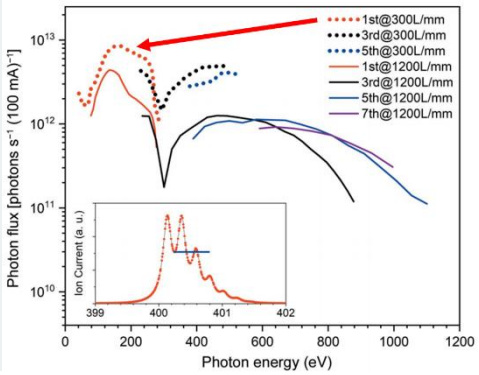
----------XPS (XPEEM mode) ----------

Moveable in scan = leem_start_voltage

1. Check the coefficient plot of desired element, e.g.Pt. Determine the target orbit, e.g. Pt 4f based on the plot.
2. Determine the photon energy (e.g. hv = 250 eV) based on the binding energy and beam intensity profile, e.g. Pt 4f has binding energies as 74.5 and 71.2 eV.
3. Calculate the corresponding start voltage 170.5 (250-5-74.5) and 173.8 (250-5-71.2) V.
4. Set up scangui / script / IPython to scan the range.

* If the signal is too weak, one can use the 'IntensityVsTime' in LEEM2000 software, with selecting a large area on sample. Change the start voltage slowly in the calculated range and observe the change in intensity. Write down the values for determining the scan range later. In addition, the written down values can be compared to the calculated values as checking.



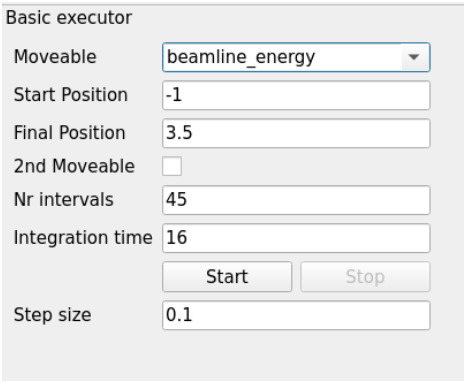


Insert of the right figure indicates photon energy resolution of beamline.

----------XAS (XPEEM mode) ----------

Moveable in scan = beamline_energy

1. **Set the start voltage to a higher value.**
2. **Set photon energy accordingly**, e.g. 75 eV for Al as scan range (written on the paper on wall behind the screen) is Al 75 to 100 eV.
3. **Decrease the start voltage to find the secondary electron peak**.
4. Set up scangui or script or ipython to scan the range.



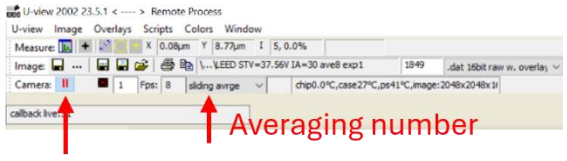
----------Scangui----------

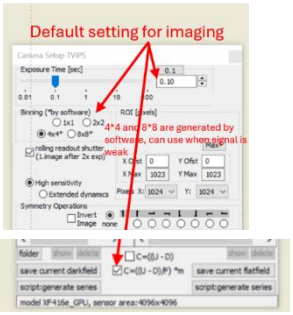
*** During acquisition (before progress reaches 100%), don't hit any part of setup which will cause vibrations and blur the image, e.g. transfer arm, concrete base of setup, etc.**

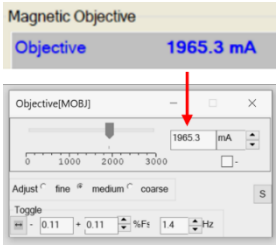
* **Check the storage location of data files.** Filename can be changed.

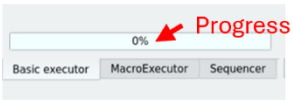
* **Parameters need to be matched between camera setting and scangui setting.** For example, the integration is set as 80. In U-view (microscope software), the image is collected with 'average 16' and exposure time is 5. So that parameters are matched as 80=16*5.

* Camera **must not** be in collecting mode when starting scan. !!!!!









Two commonly used ways to set up the sequencer:

Basic executor: normally only one moveable is used, but the second one can be activated if needed

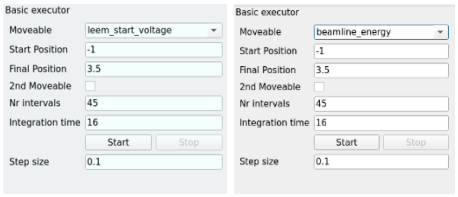
MacroExecutor: more customizable functions can be used, e.g. ascan, IVCurve, mesh, mv, uview_acquisition, uview_ascan, uview_xmcd_xmld_acquisition, etc. Move moveables can be added from panel.

Select the moveable, type in start and final positions, type in integration time (averaging number*exposure time) and step size. The Nr internals will be calculated automatically based on the set parameters.

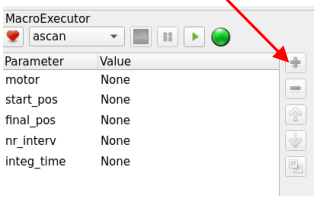
Check the storage and change filename if needed.

* Camera **must not** be in collecting mode when starting scangui. !!!!!

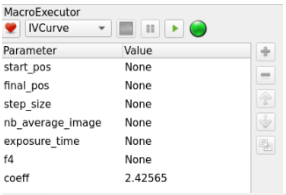
Basic executor:

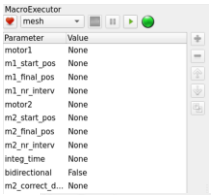


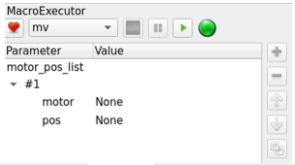
Basic executor ≈ ascan

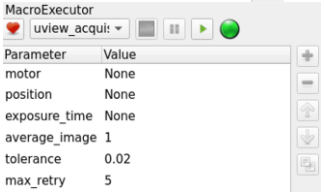


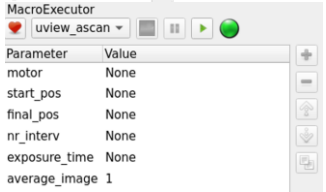
MacroExecutor:

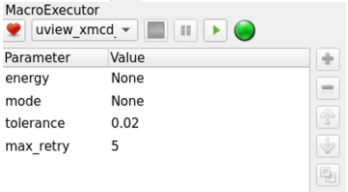






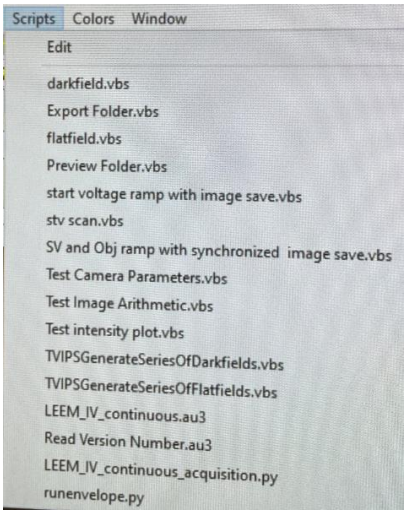






----------Scripts----------

*Data can only be written into ‘This PC’ instead of online user folder.

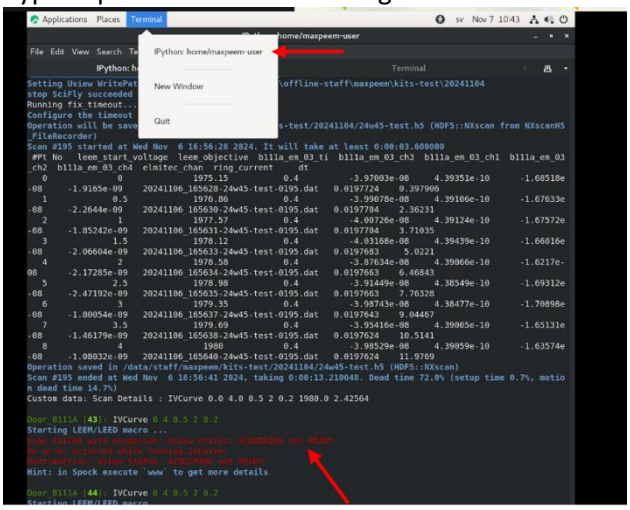


Detailed info: To be updated

----------IPython----------

For users who prefer to scan via Terminal:

Type in parameters as if in scangui



Scan will not start if microscope is at acquisition mode

Drift correction

----------ImageJ----------

Import sequence: File – Import – Image sequence

Check spectra: Image – Stack – Plot z-axis profile

Adjust image: Image – Adjust – Brightness/Contrast

Drift correction: select a rectangle area – Plugins – Template Matching – Align slices in stack – search area 20 (100) pixels for small (large) drift

Plugins:
https://sites.imagej.net/Template_Matching/plugins/

----------Igor----------

Igor package: Athina
For details and other functions, check Evangelos's manual about Athina. Printed manual available in Lab.
Manual and Package are also available at GitLab: https://gitlab.com/evangelosgolias/athina

Drift correction: import in folder and stack – select the folder – select area and expand (Right click) – Drift: Linear (for thermal drift)

Image sum-up: Image operation – sum stacks – (Right click) New image

----------Naming data files----------

Naming of data file: Mode name (XPEEM/LEEM/DP/ARPES/LEED) + Sample name + Element + Orbit + Photon energy + Start Voltage + IA value (if used) + SAA value (if used) + CA value (if used) + Slit value (if used)
Naming of data folder for sequence: Mode name (XPS/XAS) + Sample name + Element + Orbit + Photon energy (or range) + Start Voltage (or range) + Integration time (averaging number + exposure time in U-view software) + Step size + IA value (if used) + SAA value (if used) + CA value (if used) + Slit value (if used)

*If sample has been moved more than hundreds of μm (1-2 mm) at any direction, alignment needs (has) to be double checked.

Example for Values needed before starting sequences:

Photon energy, Start Voltage, Slit and Apertures, Averaging time and Exposure time, Value of Objective lens for each sequence

----------Examples for mapping ranges----------

Work function of setup ~ 4.85eV
Remember to find the focus (Value of Objective lens) for each sequence:

$$When\ KE = 0, f = f_0$$
$$f = f_0 + \alpha\sqrt{KE}, \qquad \alpha = 3.576$$

	E_{Ph}	STV	Exposure	Average	Step	Objective value	BE (eV)
XPS (XPEEM)							
Au4f	250	155.8 to 156.4	5	16	0.2	1867	84
Au VB (5d)	70	55 to 68 (65)	2	16	0.2	1857	
Au WF	70	-3 to 4	0.1	16	0.1	1835	
PED (ARPES)							
Au+Graphene	70	63 to 66.5 (65)	5	8	0.1		
PES (DP mode)							
Si 2p	150	44	PES Si2p SAA=50um CA=30um hn=150eV STV=44V				
Si 2p	200	94	(add 50 eV in photon energy and start voltage)				
Au 4f (doublet)	200	109	Use the energy difference of doublet (3.6 eV) to calibrate pixel				
Au VB (+SiC, C)	200	194					
C 1s	350	61.5					
VB	100	94	Beam at 100 eV is stronger at 200 eV, so measure with stronger signals. 100=200-100, 94=194-100. Same spectrum with better S-N.				

XAS (XPEEM) scan by moving photon energy			
Mn (L)	635-660	Fe (L)	703-730
Cr (L)	570-595	Ni (L)	847-880
Co (L)	770-810	O (K)	528-553
Ti (L)	458-479	Ca (L)	345-360
N (K)	395-440	S (L)	150-190?
Al (L)	75-100	Si (L)	100-125
Zn (M)	325-360		

Examples for naming data and setting scan range