POLOS µPRINTER

USER'S MANUAL FOR POLOS µPRINTER MASKLESS LITHOGRAPHY EQUIPMENT

For Phaos 2.2 or above

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1 GENERAL INFORMATION

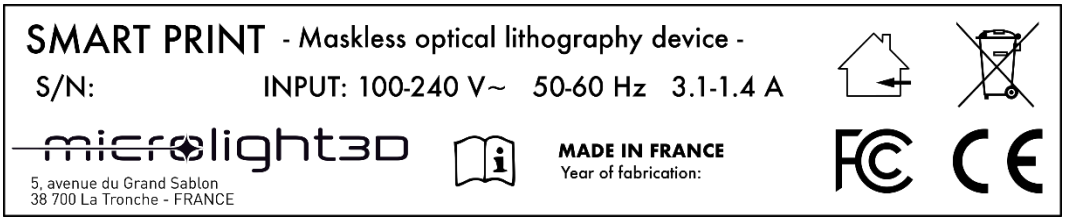
1.1 SAFETY INFORMATION

POLOS µPrinter is designed for safe and efficient operation when used properly and in accordance with this manual. Failure to observe the following precautions could result in serious personal injuries:

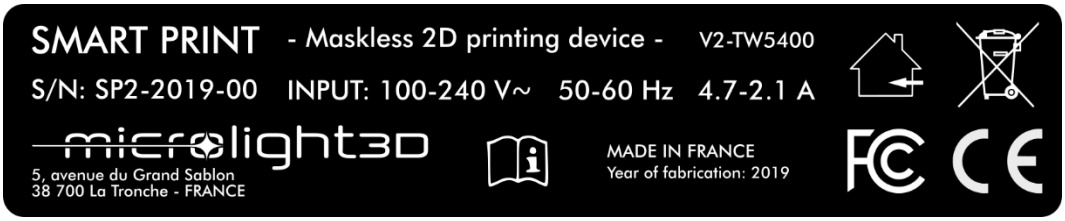
- POLOS µPrinter is an electrical instrument; to avoid electrical shock, please observe all standard precautions, such as not operating the device near water and operating the device at appropriate voltage and frequency.
- Do not remove panels or housing.
- If the equipment is used in a manner that is not specified by the manufacturer, the protection provided by the equipment may be compromised.

POLOS µPrinter integrate a projector EH-TW5300, EH-TW5350 or EH-TW5400 from Epson. All precautions and safety instructions described in the EH-TW5300, EH-TW5350 or EH-TW5400 user guide must be applied.

1.2 IDENTIFICATION MARK



For POLOS µPrinter fabricated before 2019 August



For POLOS µPrinter fabricated after 2019 July

The identification mark is located at the back of the opto-electronic head. It contains the serial number of the equipment (S/N) and the required input power supply.

TECHNICAL SUPPORT

For additional information please contact us between 9 a.m. and 5 p.m. (UTC+01:00):
+33-(0)4-76-54-95-16
or e-mail your questions to: contact@microlight.fr

2 ABOUT POLOS µPrinter

2.1 GENERAL USE

POLOS µPrinter is a multi-purpose maskless photolithography tool based on a beamer technology. It is designed for any application fields requiring surface micro patterning such as microfluidics, biotechnologies, micromechanics and microelectronics. Maskless photo-lithography is a technique allowing the direct exposure of an image on a photosensitive resist.

PRINCIPLE OF OPERATION

- POLOS µPrinter projects, through a dedicated software, a focused image on a flat surface covered with an adapted photosensitive resist.
- The input image may be a “black & white” or grayscale bitmap or equipment specific “.stitch” format
- The image may be focused with variable size and resolution depending on the POLOS µPrinter’s objective used.
- The image is projected with blue light during a user defined time.
- With a time adapted exposure, the projected image can be replicated onto the resist.

2.2 EQUIPMENT DESCRIPTION

2.2.1 OVERVIEW

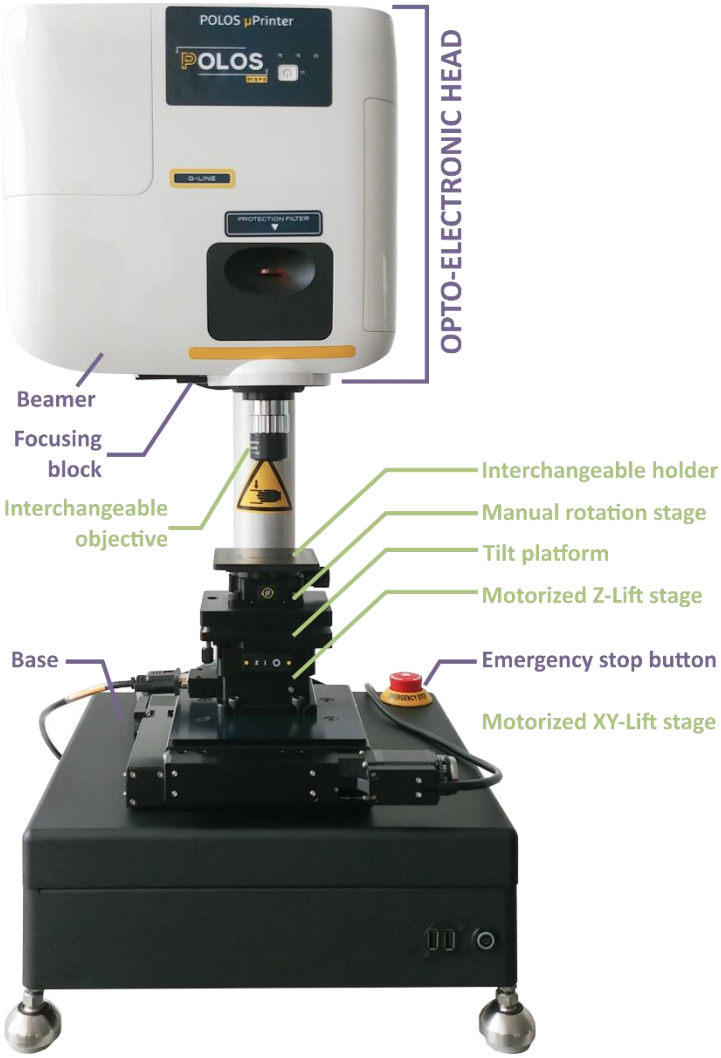


Figure 1 – POLOS µPrinter with its main accessories

2.2.2 OPTO-ELECTRONIC HEAD

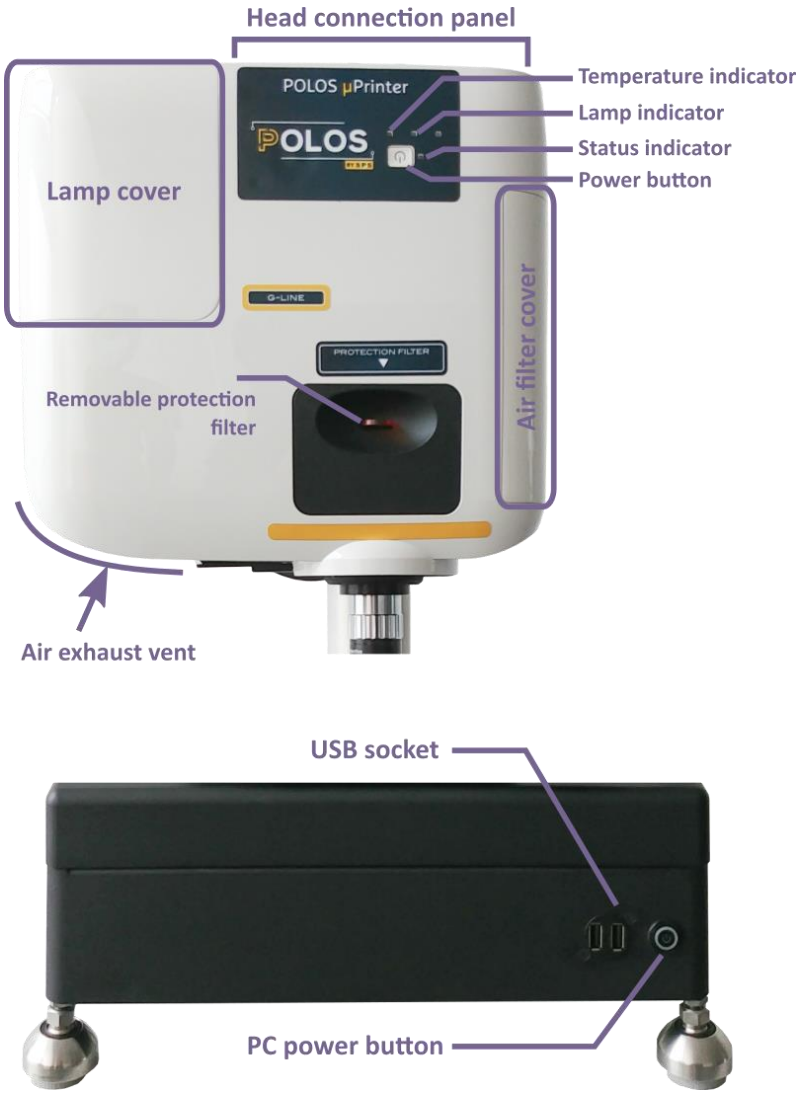


Figure 2 – Front view of the base and opto-electronic head

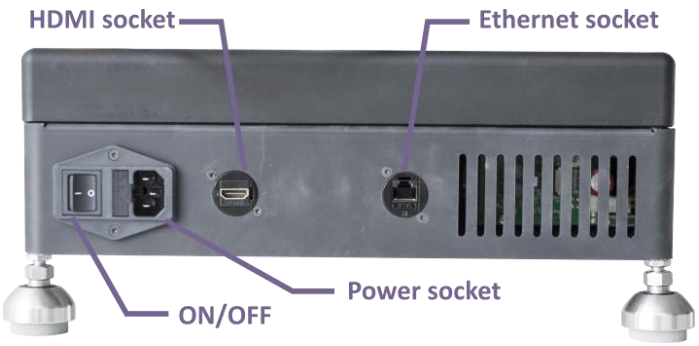


Figure 3 – Back side view of the base

Figure 4 – Connection panel

2.2.3 FOCUSING BLOCK & COLUMN

Figure 5 – Left and right side of POLOS µPrinter

2.2.4 OPTION 1: MANUAL Z-LIFT WITH TILT PLATFORM

It consists in a 3-stack mechanical module (Figure 6) made of: a Z-lift (bottom), a tilt platform (middle) and an interchangeable holder (top).

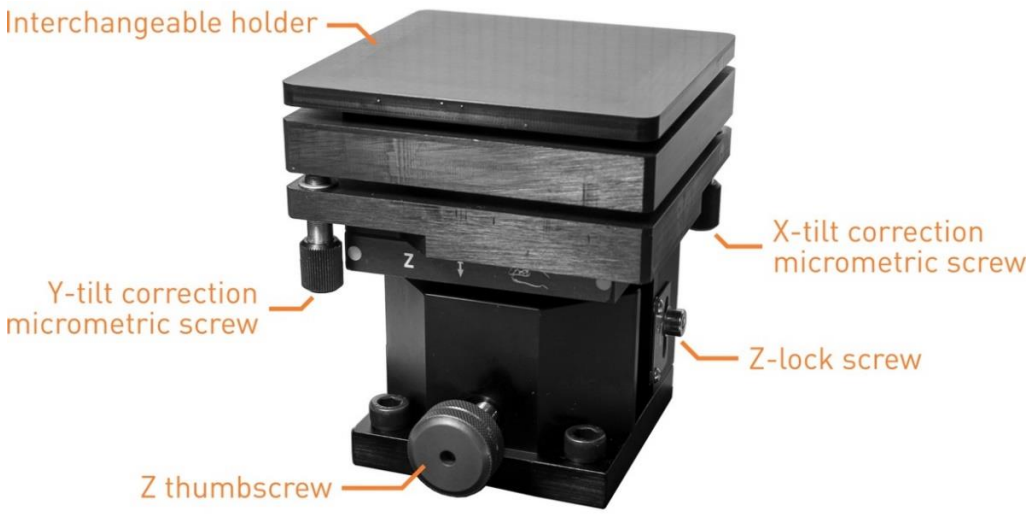


Figure 6 – Manual Z-lift

The manual Z-lift has a motion range of 15 mm. The position in Z of the upper plate is adjustable with a thumbscrew. Position precision is 0.926 µm per degree of rotation. A 1-mm motion is achieved by turning the thumbscrew 3-times completely (1080° rotation). The Z position can be locked by tightening the Z-lock screw.

The tilt platform allows to adjust in both X and Y axis the vertical tilt of the substrate in comparison to the focus plane of projected design. It is a particularly important parameter to adjust when using the high-resolution objectives (x5 and higher) in order to stay in-focus all over the surface of the sample. The angular resolution is 3'' or ΔZ ~1 µm all over the motorized XY stage range (see section below).

This module is provided with an interchangeable flat holder (Figure 7 left). Two other substrate specific holders can be alternatively used (separate order):

- For standard microscope glass slides (25 mm x 75 mm) > Figure 7 middle
- For 4 inches (100 mm) circular wafers with notch or slab > Figure 7 right

CAUTION:
The wafer holder must always be placed as shown in Figure 7 right with the wide curved part toward the head's column. If the holder is not correctly positioned, there is a risk of contact between the wafer and the column that may cause damages to the substrate or to the motorized XY stage if equipped.

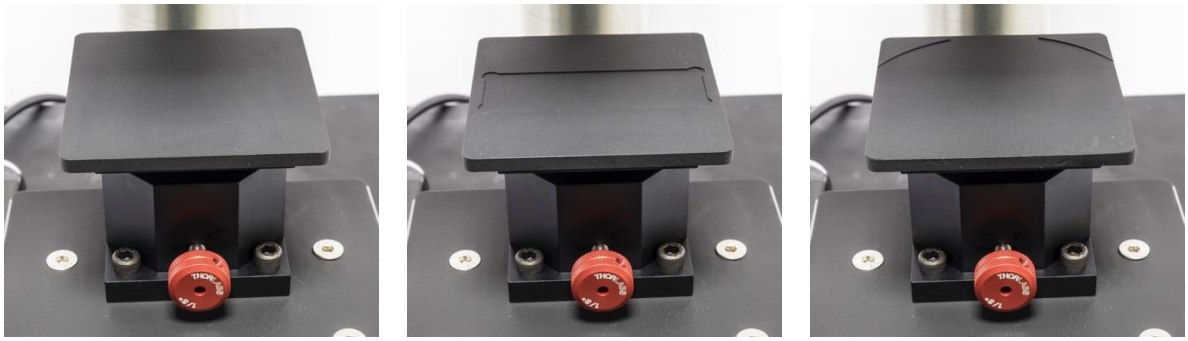


Figure 7 – From left to right: flat holder, microscope glass slide holder and 4'' wafer holder

2.2.5 OPTION 2: MOTORIZED XY STAGE

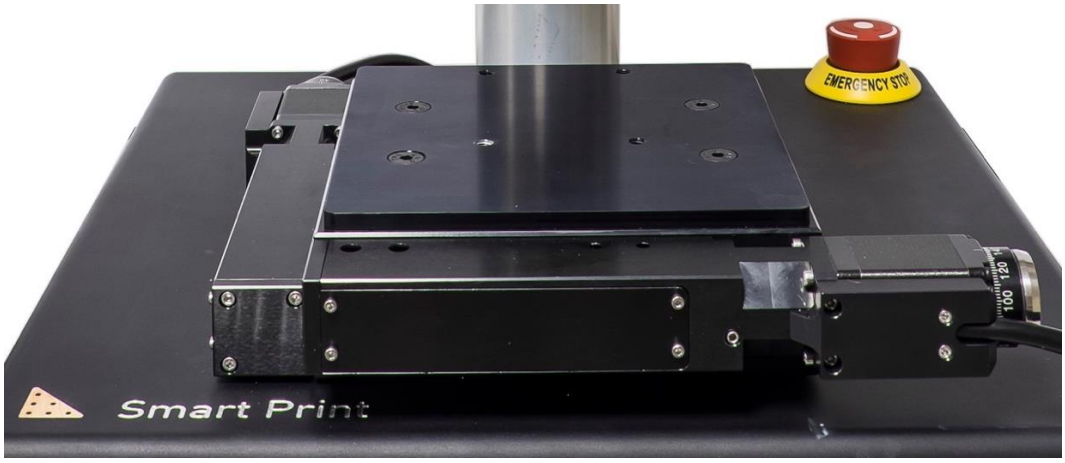


Figure 8 – Motorized XY stage

The motorized XY stage is configured with the following specifications:

- Working range: 74.8 mm x 74.8 mm (max hardware range 75 mm x 75 mm)
- Precision: 0.31 µm
- Repeatability: 2 µm
- Maximum working speed: 2 mm/s

It gives access to additional features such as controlled positioning of the substrate, step-&-repeat exposure, automatic dose tests and design stitching (extending the field of exposure at high resolution).

2.2.6 OPTION 3: MOTORIZED Z LIFT WITH TILT PLATFORM

This module is the semi-motorized version of the option 1. The interchangeable holders are the same and the tilt platform gives access to similar performances.
The motorized Z-lift has the following specifications:

- Working range: 12.6 mm (max hardware range 13 mm)
- Precision: 0.625 µm
- Repeatability: 2 µm
- Maximum working speed: 2 mm/s

Figure 9 - Motorized Z-lift

It gives access to additional features such as full vertical motion control, simplified alignment procedure and autofocus possibilities.

2.3 SOFTWARE DESCRIPTION

The software main interface is composed of 6 panels (Figure 10):

I. **PARAMETER panel.** It contains all *configuration parameters required* to perform a lithography according to user's needs.
II. **IMAGE VIEWER panel.** It displays the drawing to be lithographed for checking before exposure.
III. **EXPOSURE panel.** It is the action area over the equipment. The illumination mode or the exposure start can be chosen here.
IV. **CAMERA VIEW panel.** It displays the view delivered by the embedded camera in real time for focus adjustment and alignment purposes.
V. **SP-UV MONITORING Panel.** Not available with the POLOS µPrinter version.
VI. **STAGE Panel.** It contains the most common stage control options (visible only if POLOS µPrinter is equipped with XY(Z) motorized stage).

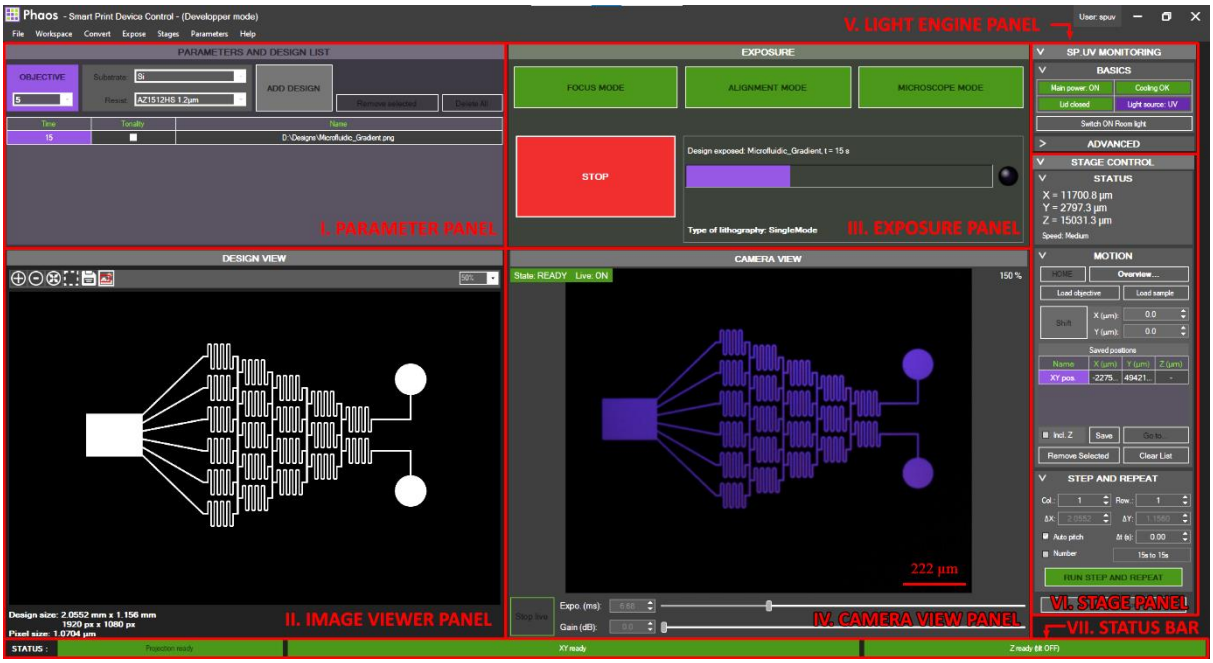


Figure 10 – Phaos main window

The area “status bar” at the bottom of the window displays the communication states between the software and the equipment.

3 PROCESSING WITH POLOS µPRINTER

3.1 INSTALLATION AND HANDLING

The equipment must be installed in an appropriate operational environment:

- Without excessive vibrations from surrounding equipment or atmospheric turbulences.
- On clean environment, without any excessive amount of dust or other contaminants.
- On a flat and robust working surface with a minimum width of 50 cm and depth of 80 cm and a recommended inclination below 1°.
- A free space of at least 50 cm wide must be kept on the left side of the equipment to allow a proper cooling of the optoelectronic head.

For installing the equipment on its working surface or for any other handling operations, it is recommended to follow the instructions below:

- Use an appropriate mechanical or human assistance.
- Proceed in order to avoid abrupt motions and contacts between the equipment and its environment that could degrade its overall performance.

CAUTION:
Lifting or moving an equipment without the appropriate assistance may cause injuries and/or damage the equipment.

3.2 ELECTRICAL CONNECTION

3.2.1 MAIN POWER SUPPLY

- POLOS µPrinter must be connected directly to an appropriate wall outlet from the power inlet on the back side of the base (Figure 3) via the appropriate cable.
- The optoelectronic head must be connected via the power cord coming from the top opening of the column to the power inlet on the head connection panel (Figure 4).

3.2.2 CONNECTIONS TO THE COMPUTER

- The optoelectronic head must be connected to the integrated PC board via the HDMI cable coming from the top opening of the column to the HDMI socket on the head connection panel (Figure 4).
- The computer screen must be connected directly to an appropriate wall outlet via the appropriate cable.
- The screen must be connected to the integrated PC board via an appropriate HDMI cable on the back side of the machine (Figure 3).

CAUTION:
As a precaution, in case of danger, the stage can be powered off instantly by pushing the emergency button located on the bottom right side on the POLOS µPrinter base. To restart POLOS µPrinter, turn the emergency button clockwise until it is back to its initial position. Wait 5 min for the cooling of the lamp before restart.

3.3 QUICK USE WITHOUT MOTORIZED Z-STAGE

- Switch on POLOS µPrinter by pressing the ON/OFF button on the back side of the base (Figure 3), the PC power button on the front side of the base (Figure 2) and the power button on the optoelectronic head (Figure 2) until the status indicator LED becomes blue.
- On the computer, start *Phaos* software.
- On the **PARAMETER** panel (Figure 10), choose your **objective**, **substrate** and **resist** from the corresponding drop-down lists (Figure 11).
- Load a black & white bitmap drawing (png, tif, bmp, jpg) or a ".stitch" file (see section 3.5.3) by clicking on the **ADD DESIGN** button.
- Check that exposure time is correct or adjust it by clicking on the corresponding box in the column **Time** (in s) and entering the new value.

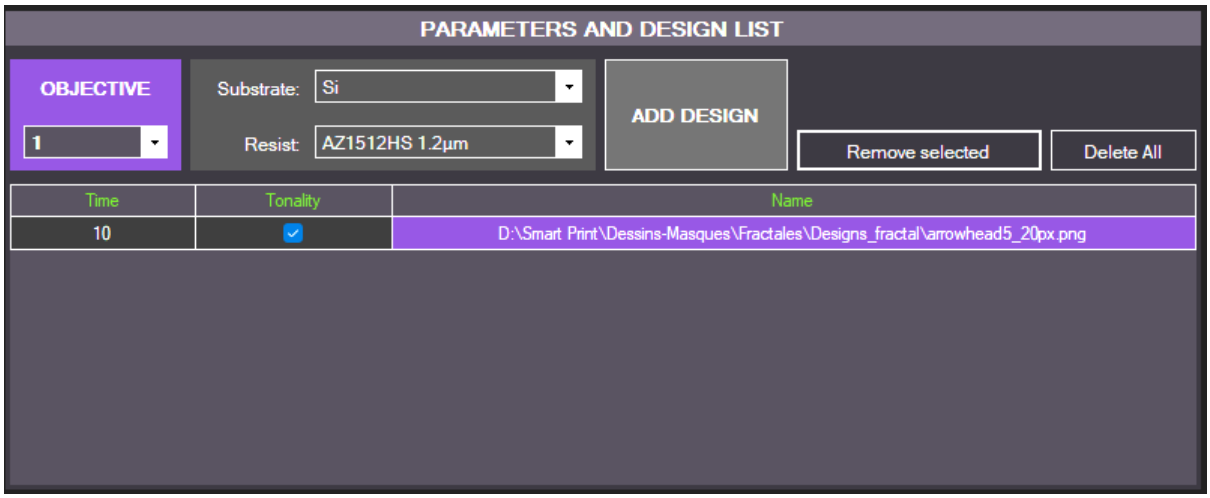


Figure 11 - "PARAMETER" panel

- Focus the image on the sample (more details in section 3.5.5):
  - Load a blank substrate.

    NOTE: the blank substrate must have the same thickness as the sample to be exposed.

  - Click on **FOCUS MODE** in the **EXPOSURE** panel (Figure 10). Ensure that the protection filter is unloaded (Figure 13 left).
  - Adjust the distance between POLOS µPrinter head and the sample by releasing the ***locking handle*** (Figure 5 left) and turning the ***adjustment wheel*** (Figure 5 right) until a sharp image is visible on the **CAMERA VIEW** panel.

    NOTE: With the manual Z-Lift installed, fine focus tuning can be done by turning the thumbscrew (Figure 6 left).

  - Once adjusted, secure the ***locking handle*** and leave the focus mode by clicking on **Stop Focus.**
  - Remove the blank substrate.
- Load the sample to be exposed, click on **EXPOSE SELECTED DESIGN** button (Figure 10) in the **EXPOSURE** panel

  NOTE: Due to lamp heating at startup, it is highly recommended to wait at least 5 min between POLOS µPrinter turning on and the exposure start.

- Once exposure is finished, the sample can be developed and rinsed

3.4 QUICK USE WITH MOTORIZED Z-STAGE

- Switch on POLOS µPrinter by pressing the ON/OFF button on the back side of the base (Figure 3), the PC power button on the front side of the base (Figure 2) and the power button on the optoelectronic head (Figure 2) until the status indicator LED becomes blue.
- On the computer, start *Phaos* software.
- On the **PARAMETER** panel (Figure 10), choose your **objective**, **substrate** and **resist** from the corresponding drop-down lists (Figure 11).
- Load a black & white bitmap drawing (png, tif, bmp, jpg) or a ".stitch" file (see section 3.5.3) by clicking on the **ADD DESIGN** button.

- Check that exposure time is correct or adjust it by clicking on the corresponding box in the column **Time** (in s) and entering the new value.
- Focus the image on the sample (more details in section 3.5.5):
    - Load the sample to be exposed.
    - Click on **FOCUS MODE** in the **EXPOSURE** panel (Figure 10). Ensure that the protection filter is unloaded (Figure 13 left).
    - Adjust the distance between POLOS µPrinter head and the sample by releasing the ***locking handle*** (Figure 5 left) and turning the ***adjustment wheel*** (Figure 5 right) until a sharp image is visible on the panel **camera view**

      NOTE: Use keyboard shortcut ctrl + numpad 9 and ctrl + numpad 3 for fine focus tuning (section **Error! Reference source not found.**).

    - Once adjusted, secure the ***locking handle*** and leave the focus mode by clicking on **Stop Focus**
- Click on **EXPOSE SELECTED DESIGN** button (Figure 10) in the **EXPOSURE** panel

  NOTE: Due to lamp heating at startup, it is highly recommended to wait at least 5 min between POLOS µPrinter turning on and the exposure start.

- Once exposure is finished, the sample can be developed and rinsed

3.5 BASIC OPERATIONS

3.5.1 LOADING/UNLOADING AN OBJECTIVE

POLOS µPrinter's objectives are attached to the opto-electronic head through a precise "quick-release" magnetic system.
To load an objective into the head, insert it vertically inside the bottom head aperture and then rotate it until a resistive force is felt (Figure 12). If well positioned, the objective may be firmly attached in a vertical position.
To unload an objective, follow the same steps in the opposite order.

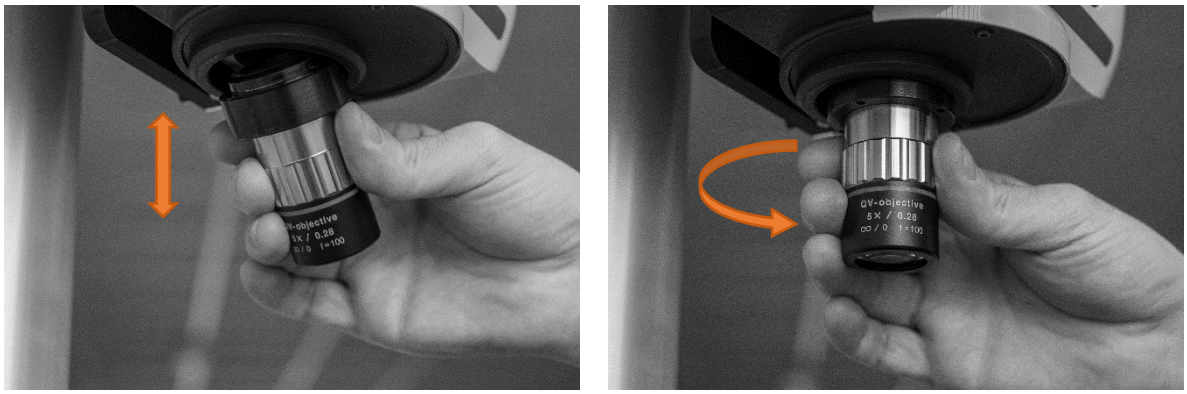


Figure 12 – Two-steps objective loading

> CAUTION:
> Do not put anything else in the bottom head aperture apart from the dedicated objectives. Do not blow air inside or nearby the aperture to avoid damaging the equipment.

3.5.2 LOADING/UNLOADING THE PROTECTION FILTER

Because of beamer contrast limitation, a residual blue light beam is permanently projected by the opto-electronic head even when exposure (blue illumination) is off. The purpose of the protection filter (Figure 2) is to prevent unwanted slow exposure of the samples during all preparation steps and under green illumination (for alignment or focus with motorized Z-lift).

Figure 13 - Left: filter unloaded. Right: filter loaded

To enable the protection, gently push the orange transparent strip up to the end (Figure 13 right). The strip may slightly illuminate. To remove the protection and allow exposure or focusing under blue illumination, gently pull the strip up to encounter a resistance.

3.5.3 EXPOSING A DRAWING WITHOUT STANDARD DIMENSIONS (1920x1080)

CASE OF ".STITCH" FILES

This equipment specific file format obtained from a vector conversion (for more details, refer to section 3.5.9) is a pre-configured design that will automatically handle drawing scaling to get the desired pattern dimensions during lithography. For this reason, a ".stitch" file is objective specific. If the configurated objective is not adapted to the stitch file to be loaded, a warning message will appear and ask for objective change (Figure 14).

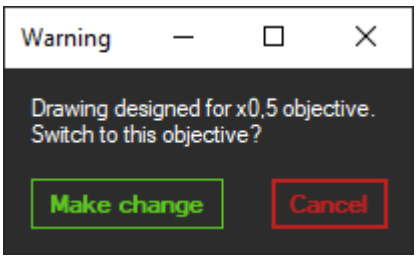


Figure 14 - Bad objective warning message

CASE OF SMALL BITMAP (.PNG, …) DRAWINGS – Dimension < 1920x1080

In that case, the drawing will just be centered during the exposure without any change of its size.

CASE OF BIG BITMAP (.PNG, …) DRAWINGS – Dimension > 1920x1080

If at least one dimension is higher than the standard dimensions, a message will pop-up when the drawing is added to the drawing list (Figure 15). Three options are then available:

- **CROP:** only the central part of the drawing is kept
- **DOWNSIZE:** the drawing is resized through a bicubic interpolation to fit the standard dimensions (original aspect ratio is preserved). Depending on the original drawing dimensions, it may result in a significant image quality reduction
- **STITCH**: the drawing is automatically split into smaller parts that will be sequentially exposed. If the dimensions of the drawing are not a multiple of POLOS µPrinter's resolution (1920x1080), a **(Black)** or **(White)** frame will be added around the drawing

« STITCHING » MODE (XY STAGE REQUIRED)

That mode slices an image and sequentially expose the corresponding stack of sub-images automatically according to an optimized positioning pattern as shown in Figure 16. When the user is facing POLOS µPrinter, the lithography starts at the current coordinates with the START image (top left corner). The motion and exposure of the next sub-images follows a snake-like trajectory.

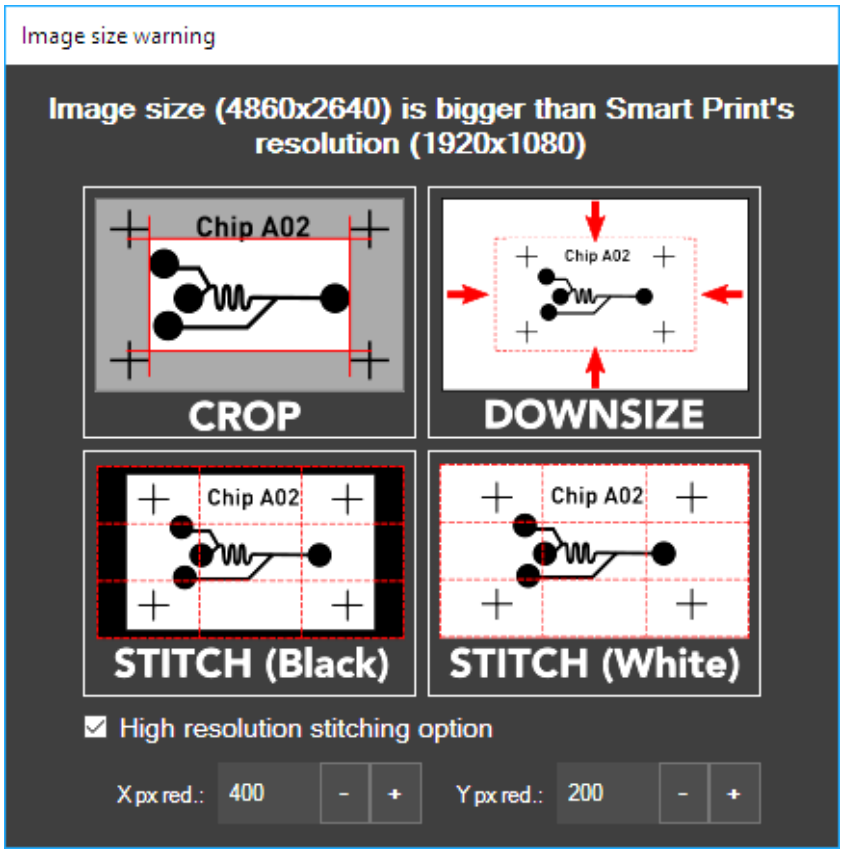


Figure 15 – « Big image » popup dialog

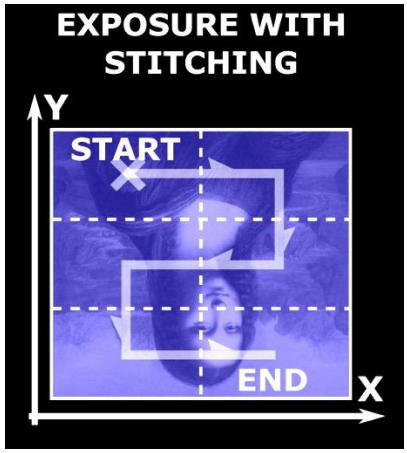
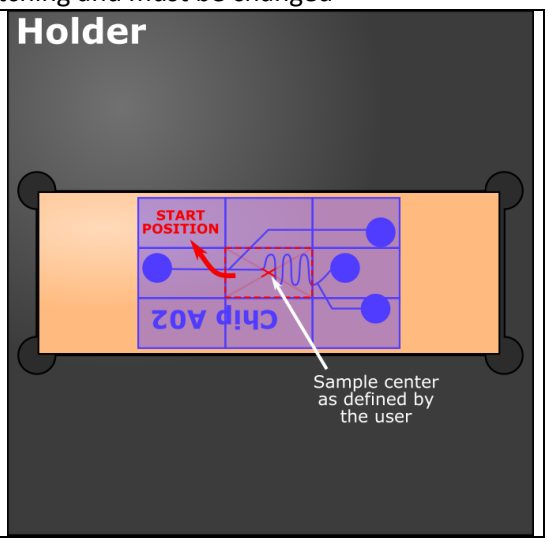


Figure 16 – Exposure principle of the "stitching mode"

In order to expose an image in that mode, proceed as follow:

- In the **PARAMETER** panel (Figure 10), choose an **objective**, a **resist** and a **substrate** in the corresponding dropdown lists.
- Add a bitmap drawing on the drawing list by clicking on the **ADD A DRAWING** button then select **STITCH (Black)** or **STITCH (White)** on the **Big bitmap transformation selection** popup dialog (Figure 15).
  → A ".stitch" file – preconfigured for exposure in stitching mode – can also be directly loaded (for more details, refer to section 3.5.9).
- Adjust the exposure time if necessary and adjust the focus (see section 3.5.5).

- Position the substrate, thanks to the XY stage, at the starting point for a stitched lithography (START position in Figure 16). If the stage status is XY out-of-range, the current start position cannot be used for stitching and must be changed

PRE-POSITIONING: if centering the drawing on the sample is required, you can move on the center of your sample and then go to **Stages** menu, select **Positioning overview** and click on the **Move from current center position to start position** button (see section **Error! Reference source not found.**). The stage will then automatically go to the START position to get your design centered.	

- Click on the **EXPOSE SELECTED DESIGN** button in the **EXPOSURE** panel.

Once the exposure is started, a progress bar displays the remaining time (estimated) in the **EXPOSURE** panel (Figure 17).

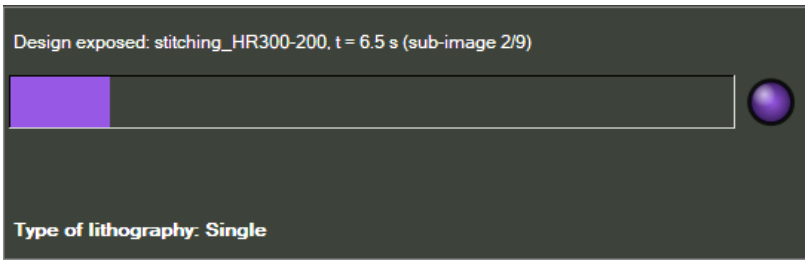
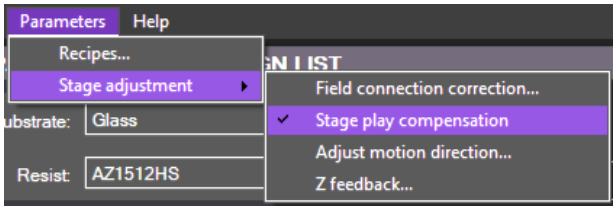


Figure 17 – Progression preview of a stitched lithography

NOTE ON "**HIGH RESOLUTION**" STITCHING: If the high-resolution option is checked on the popup dialog Figure 15, the image will be sliced in smaller sub-images to reduce the impact of the optical geometrical aberrations and then increase the overall quality of the lithography. Yet, the increased number of sub-images will result in a higher number of field connection with their intrinsic error. The key parameters **X px. red.** and **Y px. red.** respectively reduce the width and the height of each sub-image.
High resolution mode is highly recommended when patterns are relatively small compared to the size of the projected pixel (typically smaller than 5 times the pixel size).
Use of the stage play compensation is also recommended for high-resolution stitching.

IMPROVEMENT OF THE FIELD CONNECTION IN STITCHING MODE



Phaos offers two complementary options to improve the field connection in stitching mode. The first one is the stage play (backlash) compensation option. To check/uncheck this option, go to the **Parameters** menu, select **Stage adjustment** and click on **Stage play compensation** If the XY stage status on the bottom left corner of the main window is XY ready (backlash disabled), it means the compensation is disabled. If activated, the status becomes XY ready (backlash enabled).

That option allows to correct the mechanical stage play "backlash" and then *significantly improves the quality and reproducibility* of the field connections in stitching mode. However, it requires to allocate a part of the stage range to that operation and then *reduce the total stage range.* The default stage range loss in compensation mode is 4.5 mm but it can be adjusted in the general settings (section 4.3).

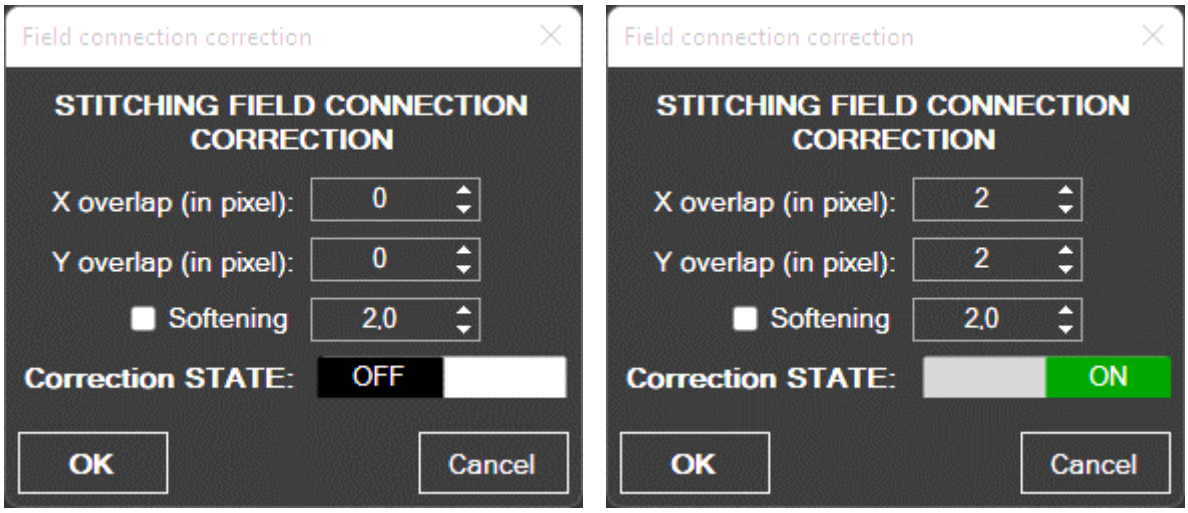


Figure 18 – Field connection adjustment window

The second option to improve lithography in stitching mode is called field connection correction and is only **available for High Resolution** (see the NOTE above) images. POLOS µPrinter is calibrated to minimize the field connection errors (overlaps or gaps) between two successive exposures in stitching mode. The user can still fine tune the field connection by going to the **Parameters** menu, selecting **Stage adjustment** and clicking on **Field connection correction…**. In the **Field connection correction** window (Figure 18), the desired additional overlap values along the X and Y axis can be selected. **Warning**: a negative value will add a gap between each sub-image leading to a small loss of information. Once setup, the correction can be enabled or disabled by clicking on the **Correction STATE** slider.
The **Softening** option is an experimental feature that softens the overlapping edges by lowering their pixel intensity. Pixel intensity is divided by the value at the right side of the option.

When an overlap is configurated and a compatible drawing selected the equipment status (Figure 10) is updated as shown below:

XY stage w/ compensation w/ overlap (2; 1)

3.5.4 DESIGN OPTIONS AND VIEW

DESIGN SETTINGS

For each design added in the design list (Figure 11), three parameters are displayed:

- **Time**: exposure time in seconds for the corresponding design. To edit the value, click on the field and enter a new value on the keyboard. Time precision is 0.01 s.
- **Tonality**: check this option if you want to reverse the tonality (black becomes white and vice versa).
- **File name**: name and file path of the loaded design.

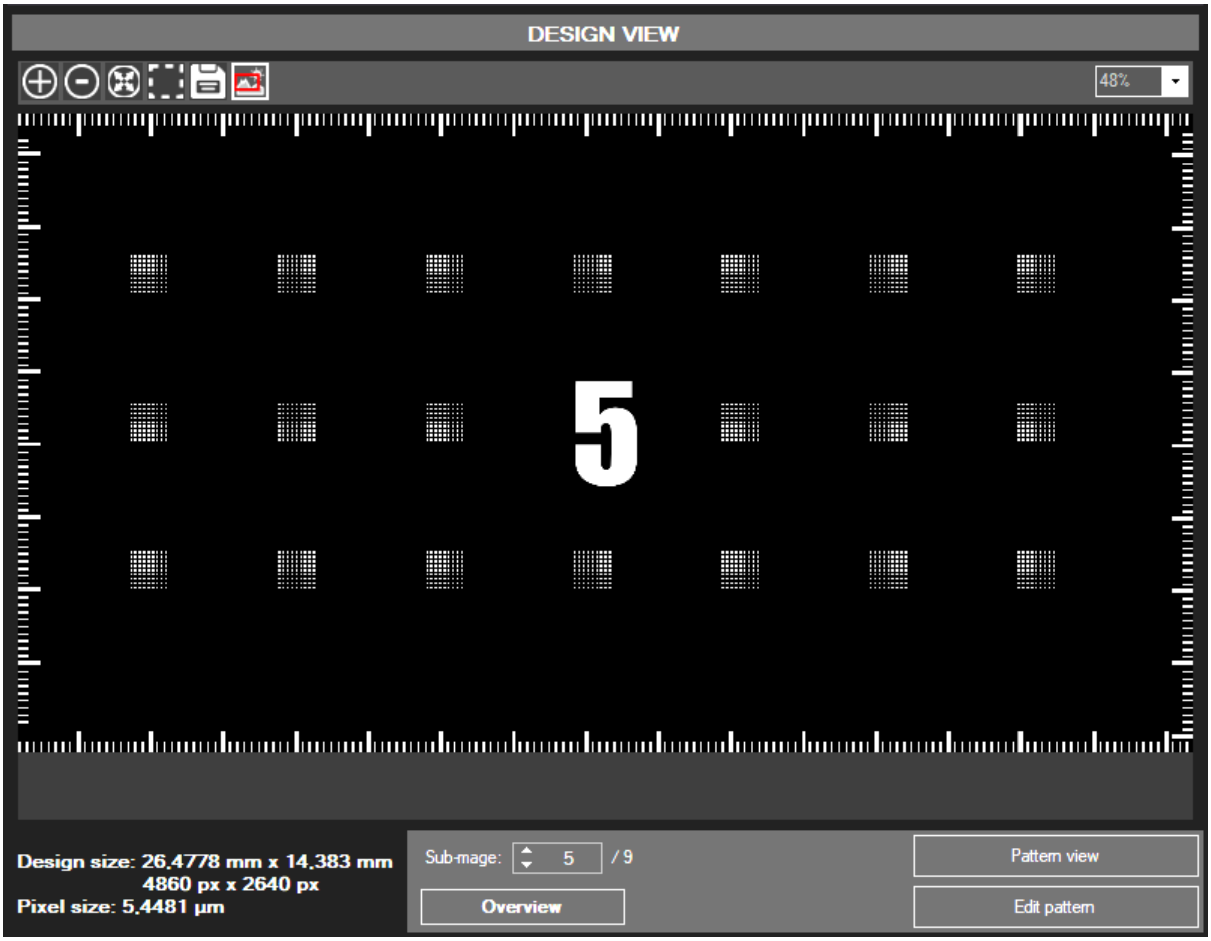


Figure 19 – Image viewer panel

DESIGN VIEW

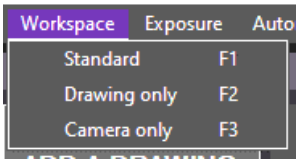
Each selected drawing is directly displayed in the **IMAGE VIEWER** panel (Figure 19). Different actions are possible to navigate into the drawing:

- Zoom In: button
- Zoom Out: button

NOTE: If a mouse is plugged into the computer, the mouse wheel can be used to zoom in and out.

- Fit drawing size to window: button

- Zoom on a selected area: button , then select an area with the cursor
- Move into the image: button , then click and hold on the image and move the cursor in the desired direction
- Save current image: button , then give a name to the image to be saved. This option only saves the currently displayed sub-image in case of stitched drawing. It can then be used to extract a detail into a ".stitch" file
- Show/Hide a preview window: button
- Switch to full screen mode / normal mode: in the **Workspace** menu, select **Drawing only** or press the shortcut F2. To come back to normal mode, select **Standard** on the same menu or press F1



Total dimensions of the design – **Design Size** – are displayed below in pixels and in mm (depends on the selected objective).

When a stitched image is selected, the image viewer will display the stack of sub-images to be exposed. To navigate into the stack and see a specific sub-image, click on the plus/minus buttons on the Stitching sub-panel located on the lower right corner of the viewer (Figure 19) or directly enter its stack number.

Clicking on the **Overview** button will open a navigation window showing the complete stitched image (Figure 20). The currently selected sub-image, displayed in the image viewer, is highlighted by red rectangle. To select another sub-image from the navigator, just click on the desired area.

The **Pattern view** button displays the stitching reminder schematics in Figure 16. Finally, the **Edit pattern** button allows access to more complex design manipulation described later on section 4.2.2.

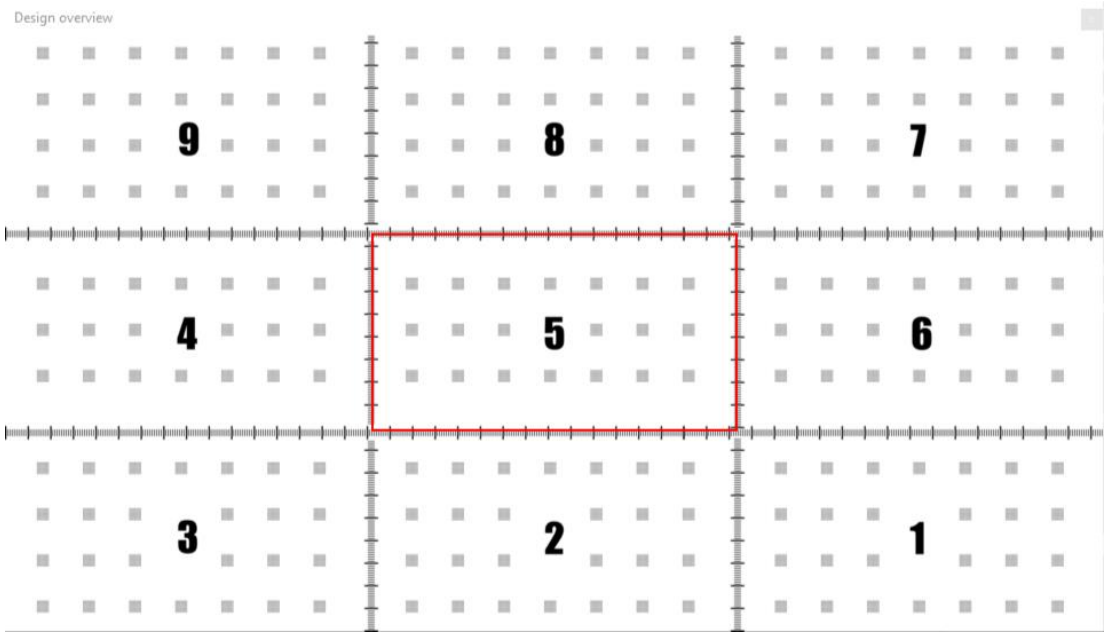


Figure 20 - Overview window corresponding to the stitched image selected in the previous figure

3.5.5 FOCUS ADJUSTMENT

POLOS µPrinter is a projection-based photolithography equipment. Then it requires a precise adjustment of its focus on the photoresist plane.

WITHOUT MOTORIZED Z-STAGE

To adjust the focus, proceed to the steps as described below:

- Load a blank or reference substrate. That one must have the same thickness as the sample to be exposed.
- On the **PARAMETER** panel (Figure 10), choose your objective.
- Click on the button **FOCUS MODE** in the **EXPOSURE** panel (Figure 10). The camera live view will start automatically in the **CAMERA VIEW** panel (Figure 21).
- Pull the protection filter to its unloaded position (Figure 13)
- If the image in camera view is too dark or too bright (area highlighted with yellow/pink color), tune the exposure and the gain sliders or enter new values on their corresponding field. If the **AEG** option is checked, camera parameters will be adjusted automatically (only available for specific model). To switch to full screen mode, go to **Workspace** menu, select **Camera only** or press the keyboard shortcut F3. To come back to normal mode, select **Standard** on the same menu or press F1.

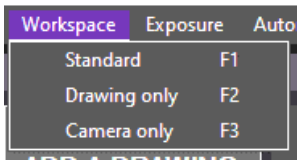


Figure 21 – Camera view panel during focus setting

NOTE: If the image displayed in the camera view is too saturated (some area highlighted in yellow/pink), there is a risk of error in the focus adjustment.

- Adjust the distance between POLOS µPrinter head and the sample by releasing the ***locking handle*** (Figure 5 left) and turning the ***adjustment wheel*** (Figure 5 right) until a sharp image is visible on the **CAMERA VIEW** panel.

> NOTE: if the Manual Z-Lift is installed, fine focus tuning can be done by turning the lift's thumbscrew (Figure 6 left).

- Once adjusted, secure the ***locking handle*** and quit the focus mode by clicking on the **QUIT FOCUS** button in the **EXPOSURE** panel.
- Remove the reference substrate

WITH MOTORIZED Z-STAGE

If configured in the application settings (4.3), this module allows making the focus under safe green illumination (no reference substrate needed). To set the focus, proceed to the steps as described below:

- Push the protection filter to its load position (Figure 13)
- Load the final substrate.
- On the **PARAMETER** panel (Figure 10), choose your objective.
- Click on the button **FOCUS MODE** in the **EXPOSURE** panel (Figure 10). The camera live view will start automatically in the **CAMERA VIEW** panel (Figure 21).
- If the image in camera view is too dark or too bright (area highlighted with yellow/pink color), tune the exposure and the gain sliders or enter new values on their corresponding field. If the **AEG** option is checked, camera parameters will be adjusted automatically (only available for specific model). To switch to full screen mode, go to **Workspace** menu, select **Camera only** or press the keyboard shortcut F3. To come back to normal mode, select **Standard** on the same menu or press F1.

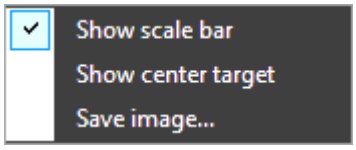
> NOTE: If the image displayed in the camera view is too saturated (some area highlighted in yellow/pink), there is a risk of error in the focus adjustment.

- Coarse adjustment: Adjust the distance between POLOS µPrinter head and the sample by releasing the ***locking handle*** (Figure 5 left) and turning the ***adjustment wheel*** (Figure 5 right) until a sharp image is visible on the **CAMERA VIEW** panel. Once adjusted, secure the ***locking handle***.
- Fine adjustment: Adjust the height of the motorized Z-lift plate, using the software controls described in section **Error! Reference source not found.**, until a sharp image is visible on t he **CAMERA VIEW** panel.
- Quit the focus mode by clicking on the **QUIT FOCUS** button in the **EXPOSURE** panel.

> NOTE: Do not forget to unload the protection filter before an exposure.

EXTRA FEATURES ON CAMERA LIVE VIEW

In addition to the camera adjustment parameters (exposure and gain), a scale bar can be added on the live view by right-clicking on the camera image when it is running and checking **Show scale bar**.



The scale bar depends on the objective selected in the software application.

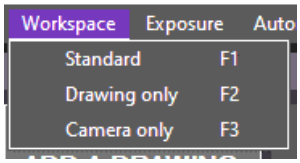
> WARNING: Scale bar may need to be calibrated. Refer to OPTICAL CHARACTERISTICS section in chapter 4.3 for the calibration procedure.

An image can also be captured from the live stream by right-clicking on the camera image when it is running and choosing **Save image…**. The image is saved as shown by the user (i.e. with scale bar if appearing in the live view).

3.5.6 MICROSCOPE MODE

Although POLOS µPrinter optics is not optimized for micro-imaging, it can still be used as a basic microscope without any risk of exposing the sample:

- Ensure that the protection filter is loaded
- Click on the **MICROSCOPE MODE** button in the **EXPOSURE** panel (Figure 10). The camera live view will start automatically in the **CAMERA VIEW** panel (Figure 21).
- If the image in camera view is too dark or too bright (area highlighted with yellow/pink color), turn off the **AEG** (**Auto Exposure and Gain**) option. Then, tune the exposure slider or enter a new value on its right side in milliseconds. If the **AEG** option is checked, camera parameters will be adjusted automatically. To switch to full screen mode, go to **Workspace** menu, select **Camera only** or press the keyboard shortcut F3. To come back to normal mode, select **Standard** on the same menu or press F1.



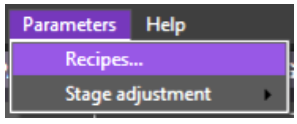
In this mode, the sample is illuminated on the full field-of-view with green light. To add a scale bar or capture an image, refer to the previous section.

3.5.7 RECIPES MANAGEMENT

Phaos is provided with a database of recipes. It contains a list of recommended exposure time for standard combinations of photoresists and substrates according to the objective to be used.

> **NOTE:** the exposure times given in the factory database are only informative. The real optimized exposure times will depend on the photoresist thickness, the development process and the design of the drawing (tonality, structure size and density). Consequently, for better lithography results, it is highly recommended to develop its own recipes.

- To see, add or edit recipes, go to the menu **Parameters** and click on the **Recipes…** button. A window opens showing a list of all registered recipes (Figure 22).



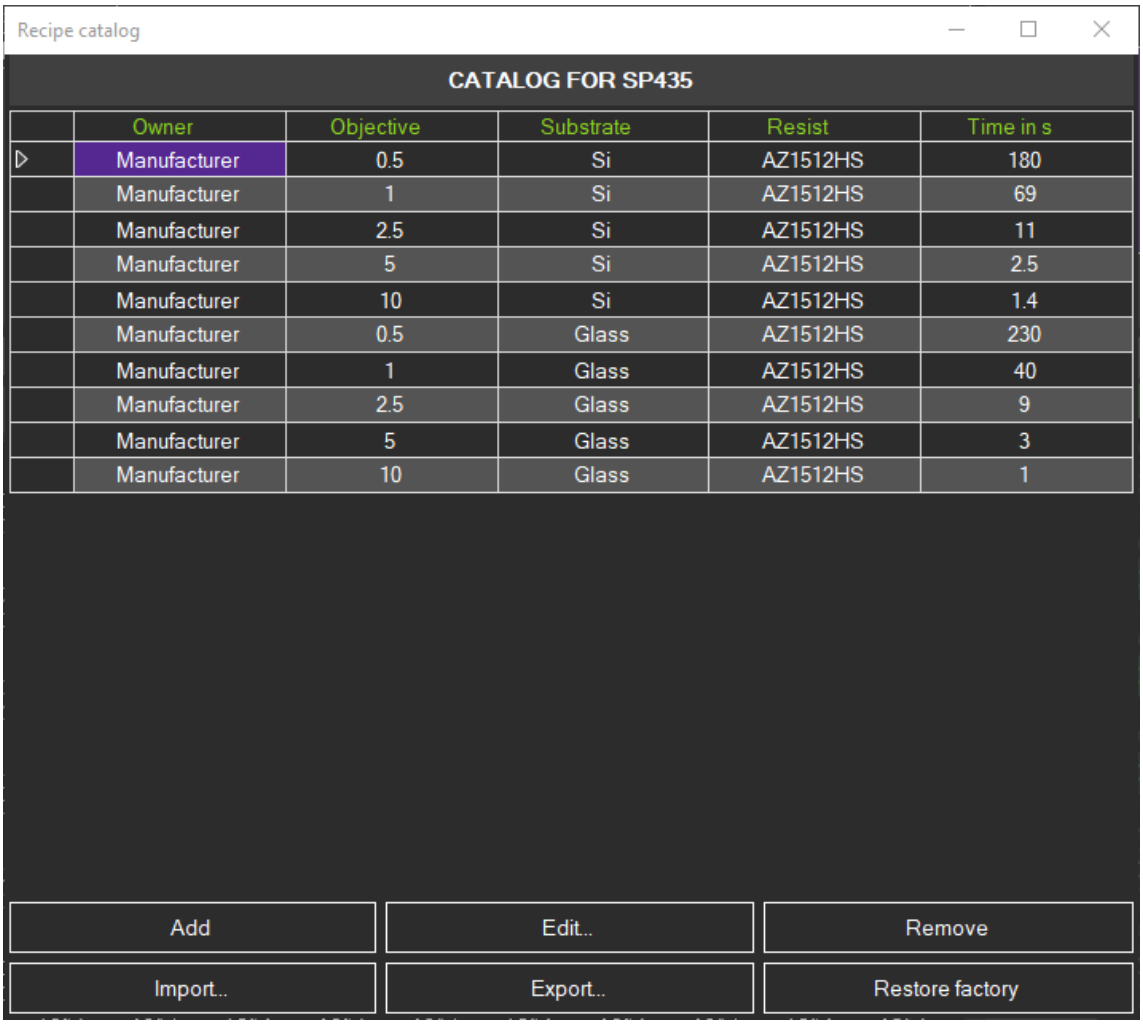


Figure 22 – Recipe database window

SORT AND FIND RECIPES

Recipe entries can be sorted in alphabetic order by Owner, Objective, Substrate or Resist by clicking on the respective column header.
Entries can also be filtered:

- Right-click on the column header to be filtered
- Enter filter value in the text box as shown in Figure 23

Filtered result will be shown in real time. To cancel filtering, empty the value entered in the text box.

	Owner	Objective	Substrate	Resist AZ		Light Power in %
▷	Manufacturer	1	Si	AZ1512HS 1.2...	10	50
	Manufacturer	2,5	Si	AZ1512HS	1	50
	Manufacturer	5	Si	AZ1512HS 1.2...	0,4	50
	Manufacturer	10	Si	AZ1512HS	0,2	50
	Default	1	Si	AZ4562 7µm	10	50
	Default	2,5	Si	AZ4562 7µm	1	50
	Default	5	Si	AZ4562 7µm	0,4	50
	Default	10	Si	AZ4562 7µm	0,2	50
	Default	1	Si	AZ40XT 25 µm	400	50
	Default	2,5	Si	AZ40XT 25 µm	40	50
	Default	5	Si	AZ40XT 25 µm	20	50
	Default	10	Si	AZ40XT 25 µm	10	50
	Default	1	Si	AZ ECI 3012 1....	7,5	50
	Default	2,5	Si	AZ ECI 3012	0,75	50
	Default	5	Si	AZ ECI 3012 1....	0,3	50
	Default	10	Si	AZ ECI 3012	0,15	50
	Default	1	Si	AZ125nXT 35µm	200	50
	Default	2,5	Si	AZ125nXT 35µm	20	50
	Default	5	Si	AZ125nXT 35µm	12	50
	Default	10	Si	AZ125nXT 35µm	6	50

Figure 23 - Example of recipe filtering: show only resist "AZ"

ADD RECIPE

- To add a new recipe, click on the **Add** button. An edition panel will appear as shown in Figure 23. Choose an objective magnification (1, 2.5, 5 or 10) and fill the following fields:
- "Owner": recipe user name
- "Objective": objective to be used
- "Substrate"
- "Resist"
- "Time": exposure time in s
- "Light pwr": not available with the POLOS µPrinter version

Click on the **OK** button to confirm the addition.

EDIT RECIPE

To edit an existing recipe, select it on the list and click on the **Edit…** button. Then follow the same instructions as described to add a new recipe.

To save changes, close the windows and confirm apply change on the warning message.

For backup purpose, the recipe list can be saved on a separated text file by clicking on the **Export…** button. The factory recipe database can also be restored by clicking on the **Restore factory recipes** button. If the database is restored, all added or modified recipes will be deleted.

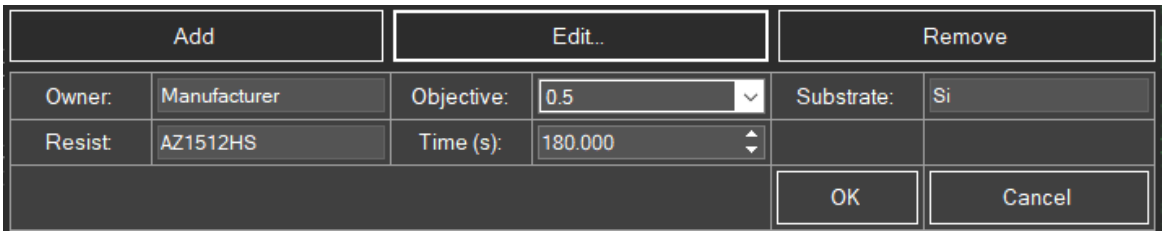


Figure 24 – Add/Edit a recipe panel

3.5.8 EDIT OR ADD LITHOGRAPHY PROCESSES

For users performing regularly the same lithography process, *Phaos* gives access to an editable process database. All key parameters can then be saved and reloaded later.

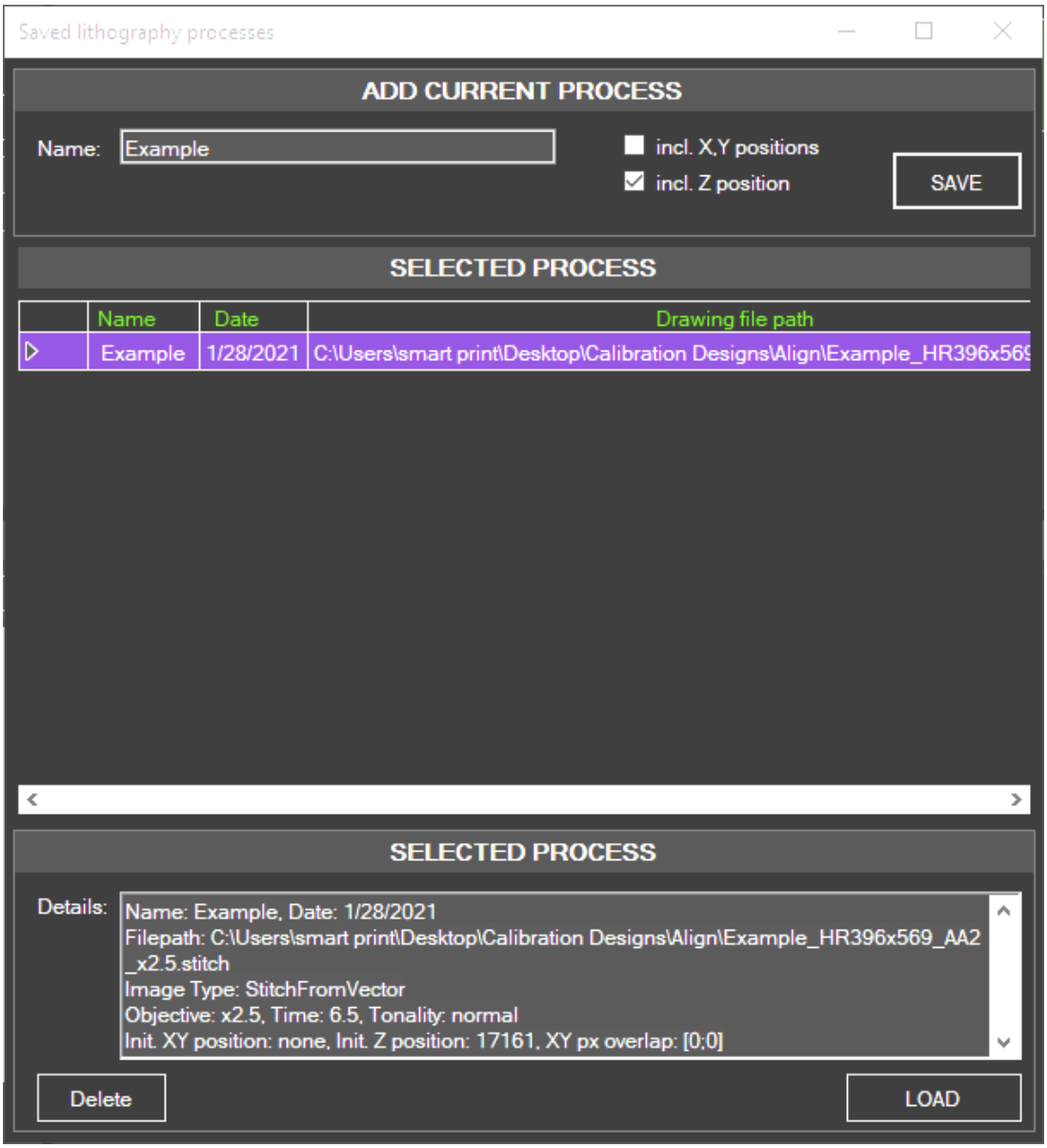
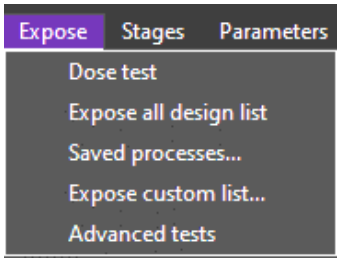


Figure 25 - Process database window

Parameters that can be saved in a process are:

- Selected Design file path
- Objective currently used
- Exposure time
- Drawing tonality
- Inhomogeneity correction
- White background option
- Stage settings: antiplay compensation option, overlap settings and stop position if defined and enabled (section 4.1.8)
- (Optional) XY(Z) current position

CREATE NEW ENTRY IN PROCESS DATABASE



To create a new process, first configure *Phaos* for the lithography you want to save. When all parameters are set, click on **Saved processes…** in the **Expose** menu. On the **Saved lithography processes** window (**Error! Reference source not found.**), enter a process name in the c orresponding field, check **incl. X,Y positions** and **incl. Z position** if you want to save the current XY and Z coordinates as start position. Then click on the **SAVE** button. All current parameters will then be saved and stored in the process list below

CHECK PROCESS DATABASE

To check a process from the database, just select it in the data table. All information relative to the selected process will be displayed below in the **Details** field.

LOAD A PROCESS

To load a process, just select it in the data table and click on the **LOAD** button.

3.5.9 IMPORT A VECTOR DRAWING (GDS, DXF, …)

WORKING PRINCIPLE

POLOS µPrinter is a lithography equipment based on light projection through a matrix of pixels. It then requires bitmap file type (png, tiff, etc.). Yet, *Phaos* can convert a vector drawing (compatible format: gds, dxf, oas and cif) into a bitmap.

For that purpose, a conversion module is included in *Phaos*. The conversion is performed in synergy with the open-source application KLayout (installation and configuration detailed in section 5.3.3). The conversion is based on a two-step operation:

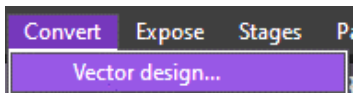
- Extract the total dimension of the vector drawing (**its base unit must be µm or mm**)
- According to the objective selected by the user, a bitmap file with a relevant dimension in pixels is created. Depending on the bitmap size output and the application settings, the

result is an either a lossless .png or a .stitch file (POLOS µPrinter native format optimized for exposure of big images up to 11 gigapixels)

The module converts **the selected layers in black & white**, as shown in KLayout.

QUICK USE

To convert a vector drawing into a compatible bitmap and load it into *Phaos* follow the instructions below:



- In the menu **Convert**, select **GDS2, DXF…**.
- In the vector **Conversion Module** window (Figure 26) click on the **Load GDS, OAS, DXF or CIF…** button and select the drawing to convert. The module extracts the drawing size (operation may take a few seconds). Extracted dimensions are displayed in the **LOAD FILE** panel.
- Choose the appropriate base unit: “mm” or “µm”.
- Select the critical dimension of your design in the **RESOLUTION AND SIZE** panel. The module calculates on-the-fly the dimension in pixels of the output image and the number of exposures required to make the lithography of the whole drawing depending on the objective to be used for the lithography. A preview image of the conversion result is also dynamically generated and displayed (Figure 28). The red dashed grid on the preview image shows how the design will be sliced during conversion.
- In the **LAYER** panel (Figure 27), select the layer(s) to be converted (for multiple layer selection, hold Ctrl and click on the layer you want to add). The selected layers will be stacked and will result in a unique converted file. If layers are to be exposed separately make sure that the conversion has been made for each layer.
- Check the **High-resolution** option to improve the overall quality of the lithography. This option is especially recommended if the patterns are close to the critical dimension (refer to the NOTE about “high resolution” on section 3.5.3 for more information).
- Check the **Antialiasing** option if a smoothing of the edge is wanted (recommended, especially for complex geometries such as curved structures).
- Click on the **CONVERT** button. A “save file” dialog box opens. Enter an output filename or keep the predefined filename. When the conversion is done, the output image is displayed in the image viewer on the right side of the window.
- The converted image can directly be loaded in the drawing list to lithography by clicking on the **Load to drawing list and close** button.

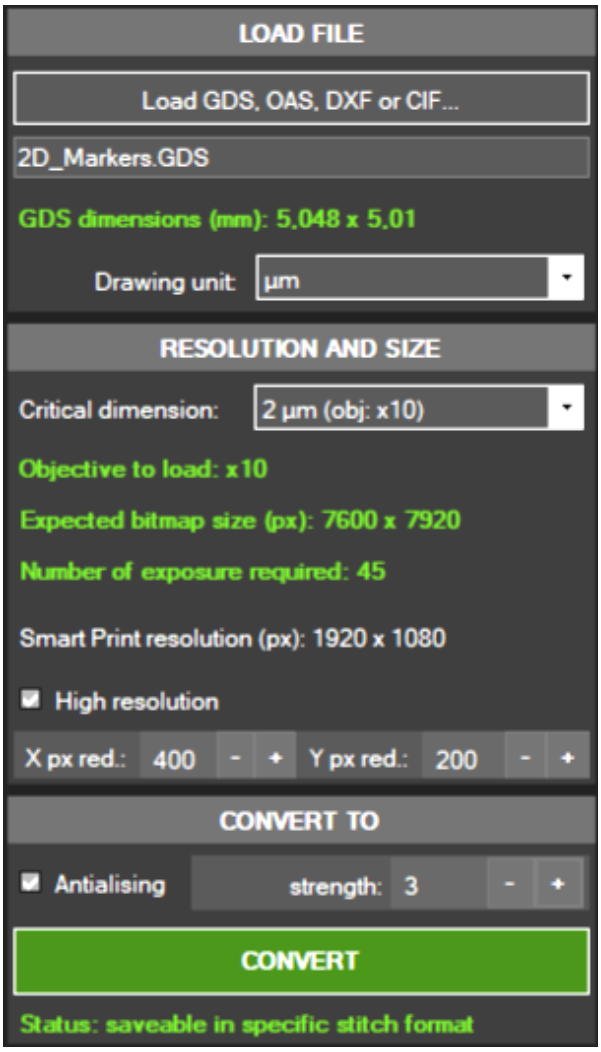


Figure 26 – Vector drawing conversion module – left panel

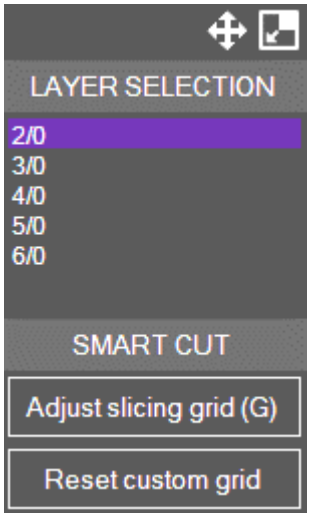


Figure 27 - Layer panel (moveable)

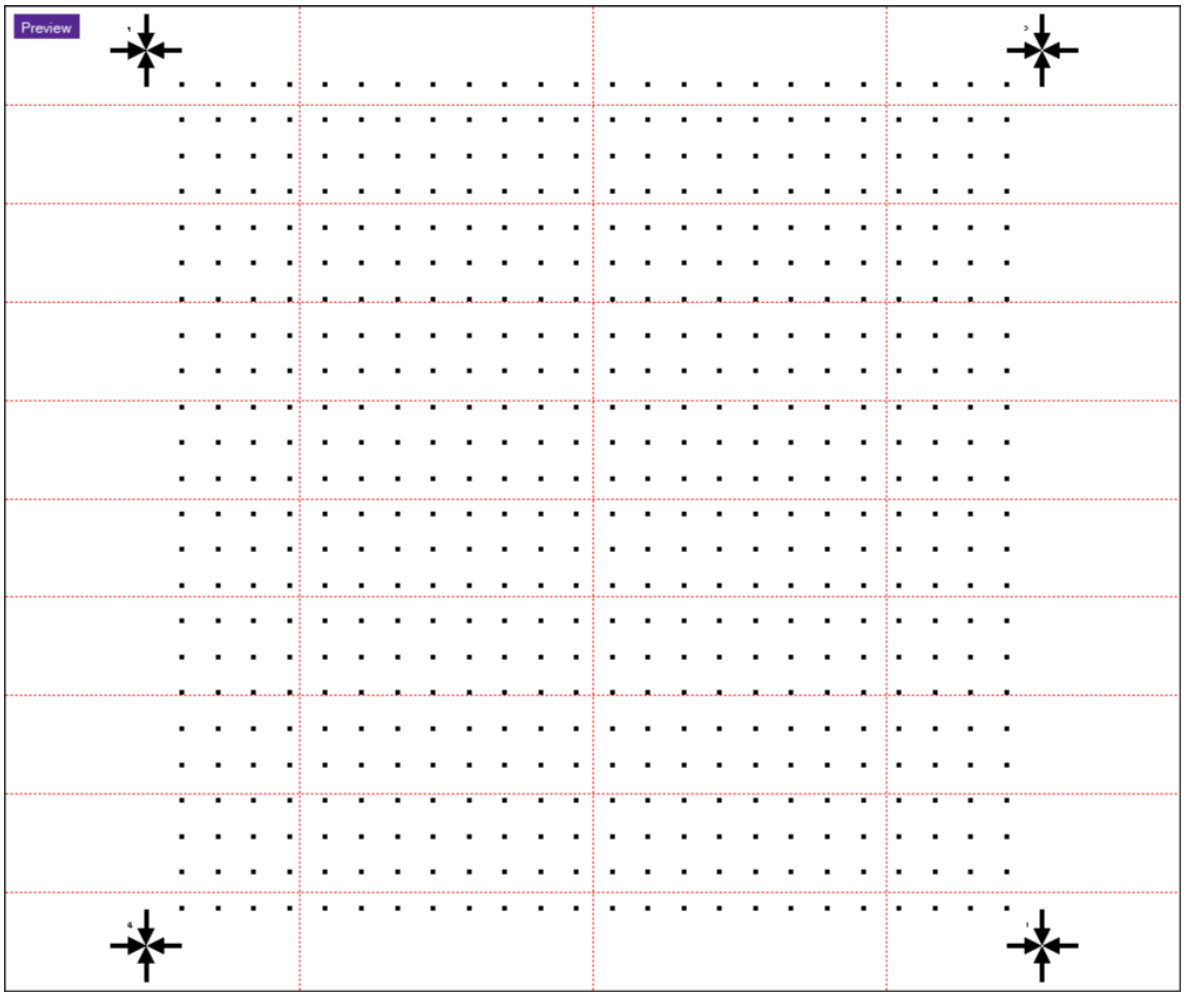


Figure 28 - Example of conversion preview with slicing grid

NOTE about the output format « .png » and « .stitch »:

- If the size of the output image is big (default values: > 10 Mpx or > 2.5 Mpx with antialiasing), « .stitch » will be the output format instead of « .png ». Those limit values can be set in **settings**, **importation** tab (Figure 75 page - 68 -).
- Converting in « .stitch » is recommended, especially for big drawings as it records useful design information that will make the lithography simpler.

If the state before conversion is *saveable as png*, the treatment takes only few tens of seconds. In the case of *saveable in specific stitch format*, the operation can take from few seconds to several minutes depending of the size of the output image.

CUSTOM SLICING OF THE DESIGN

Re-positioning. Sometimes, the slicing grid crosses key patterns on the design. In that case, it can be useful to manually re-position and/or resize the slicing grid. To do so, click on **Adjust slicing grid** button in the **LAYER** panel (Figure 27) or press G on the keyboard to enable the smart cut mode. The slicing grid is now handled with the mouse. Once the slicing grid is re-positioned at the desired location, click to validate the change and leave the Smart Cut mode.

Re-scaling. To adjust the grid size during Smart Cut mode, use the keyboard shortcut described in Figure 29 :

- X and Shift + X to respectively reduce and increase the grid width
- Y and Shift + Y to respectively reduce and increase the grid height
- To adjust the width and height faster hold Ctrl when pressing the above key combinations

The re-scaling operation corresponds in a high-resolution parameter adjustment (refer to the NOTE about “high resolution” on section 3.5.3 for more information).

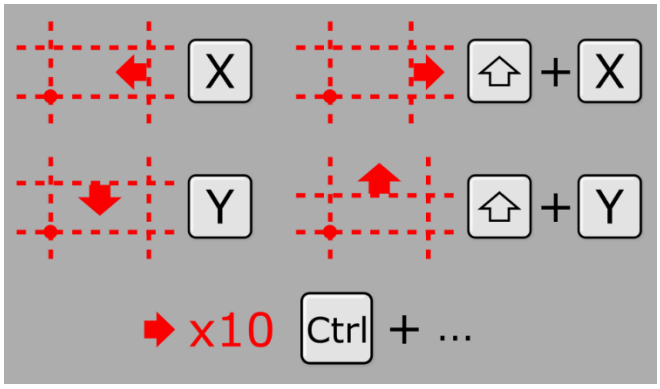
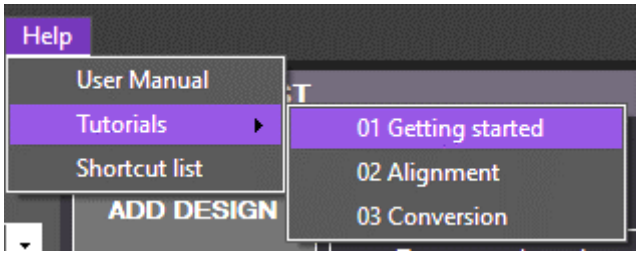


Figure 29 - Smart Cut re-scaling instructions

3.6 HELP AND TIPS



Phaos comes with assistance tools for beginners, regular users and for troubleshooting. They are all accessible from the Help menu or in File → About.

TOOLS FOR BEGINNERS

Three basic interactive tutorials are available in Help → Tutorials. For untrained users, it is recommended to follow the tutorial in the suggested order.

TIPS FOR REGULAR USERS

A list of useful shortcuts is available in Help → Shortcut list (Figure 30). General information about the App and the connected machine can be seen in File → About (Figure 31).

Shortcuts information

SHORTCUTS IN PHAOS

Shortcut	Category	Description
F1	Workspace	Standard mode
F2	Workspace	Design view in fullscreen mode
F3	Workspace	Design view in fullscreen mode
Ctrl+F	Mode	Go/leave focus
Ctrl+A	Mode	Go/Leave alignement
Ctrl+M	Mode	Go/Leave microscope
Escape	Mode	In alignment semi-auto, cancel mouse select action
Ctrl+NumPad4	Stage	Move X up
Ctrl+NumPad6	Stage	Move X down
Ctrl+NumPad8	Stage	Move Y up
Ctrl+NumPad2	Stage	Move Y down
Ctrl+NumPad9	Stage	Move Z up
Ctrl+NumPad3	Stage	Move Z down
Ctrl+Add	Stage	Speed up
Ctrl+Subtract	Stage	Speed down
Ctrl+H	Stage	Go home
Ctrl+Up	Stage	Go to load objective position
Ctrl+Down	Stage	Go to load sample position
Ctrl+F10	Stage	Store M1 position
Ctrl+F11	Stage	Store M2 position
Ctrl+F12	Stage	Store M3 position
F10	Stage	Go to M1 position
F11	Stage	Go to M2 position
F12	Stage	Go to M3 position

Figure 30 - Shortcuts information window

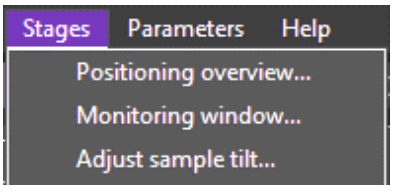
Figure 31 - About window

4 ADVANCED PROCESSING

4.1 AUTOMATED LITHOGRAPHY USING THE MOTORIZED XY STAGE

4.1.1 STAGE CONTROL

To open the stage control interface, go to the **Stages** menu and click on **Monitoring window…**. A new window will open as shown in (Figure 32). This interface can also be launched by clicking directly on XY stage status label XY ready (backlash enabled) at the bottom of the main window.



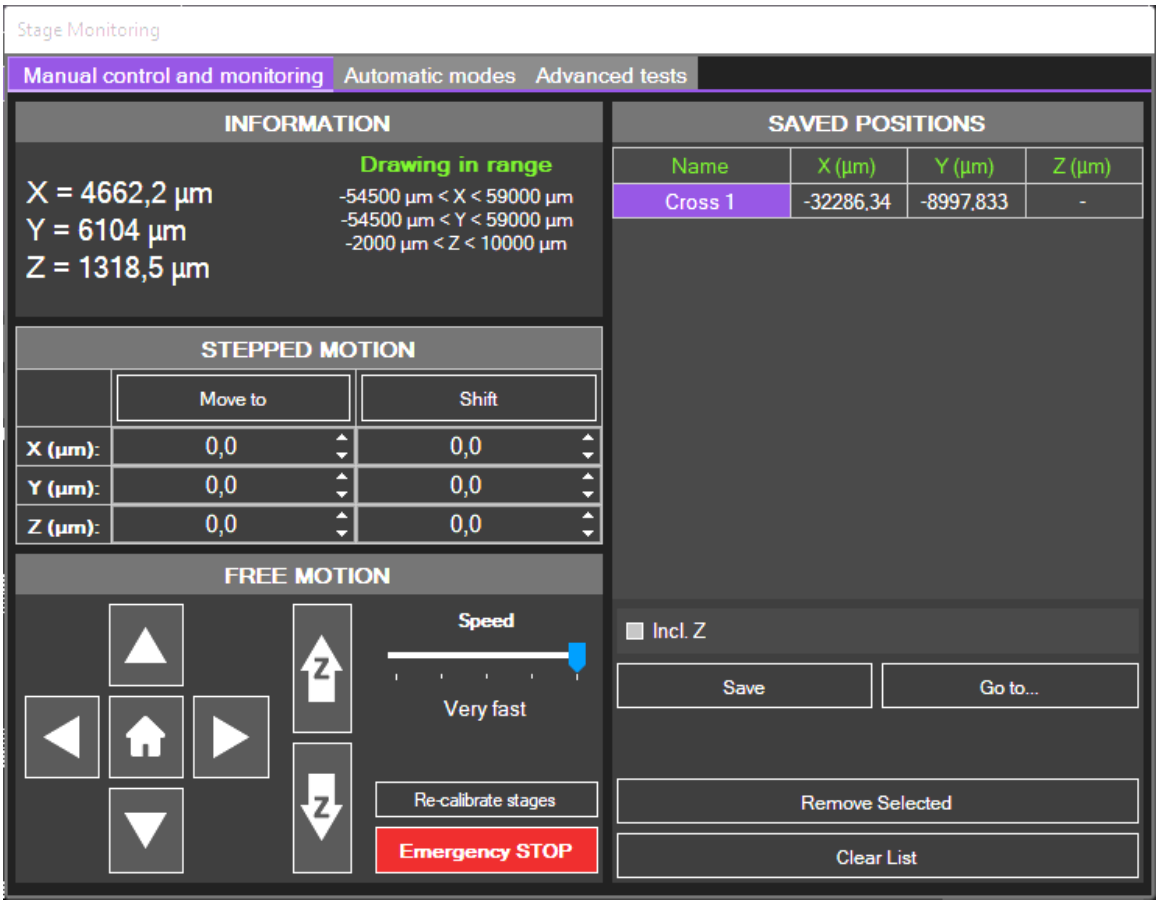


Figure 32 – XYZ stage control and monitoring interface

MONITORING

In the **Manual control and monitoring** tab, the **INFORMATION** panel displays the absolute XYZ position of the stage in real time. The stage working ranges are also stuck up below stage status in regard of the selected drawing. “Drawing in range” indicate that the selected drawing can be lithographed from the current coordinates. If the message “Drawing out-of-range” appears, it means the drawing is too big to be lithographed from the current coordinates.

CONTROL

FREE MOTION. The stage can be manually moved in the XY plane by clicking and holding the **Up**, **Down**, **Left** and **Right Arrow** buttons in the **Free Motion** panel or with the keyboard shortcuts Ctrl + numpad (8), (2), (4) and (6). Clicking on the **HOME** button will move back the stage to its origin position (X = 0 µm, Y = 0 µm). Keyboard shortcut for homing is Ctrl + H.
Motion along the Z axis can be controlled through **Z up arrow** and **Z down arrow** buttons or with keyboard shortcuts **ctrl + numpad 9** and **ctrl + numpad 3**.

STEPPED MOTION. The stage can be positioned to a defined position by entering coordinates in the corresponding X/Y/Z fields and clicking on the **Move to** button (absolute motion).
To shift the stage from its current position, enter X/Y/Z distances in the corresponding X/Y/Z fields and click on the **Shift** button (relative motion).

Speed tuning. The motion speed can be adjusted by moving the **Speed** track bar cursor or with the keyboard shortcuts Ctrl + (+) and Ctrl + (-) on the numpad.

SAVED POSITIONS. Current position can be saved by clicking on the **Save** button in the **Saved Positions** panel. Z position can also be saved by checking the **Incl. Z** option. A custom name can be given by clicking on the desired row in column "Name" and writing a name. A saved position can be recalled by selecting it in the position list and clicking on the **Go to…** button. The stage will then move automatically to the selected position. All registered positions are persistently stored even if the application is closed. To remove one position to the list, select it and click on the **Remove Selected** button. To erase all, click on the **Clear list** button.

Export/Import coordinates. A copy of the position list can be saved by right-clicking on the list box and choosing **Export list…**. All positions will be saved in data file(*.dat) consisting of 2 columns (X and Y) delimited by 1 space character. On the opposite way, a list of coordinates from an external text file (tab or space delimited with no header) can be loaded into the "Saved Positions" list by right-clicking on the list box and choosing **Import list…**. All coordinates located in the "Saved Positions" list will be then replaced by those in the text file.

> **STOP:** if needed, the stage motion can be stopped at any time by clicking on the button **Emergency STOP**. The software will send a hard stop command to the stage that may result in small coordinate reading errors. It is thus recommended to recalibrate the stage after any emergency stop (please refer to section 5.2). After emergency stop and/or re-calibration, all saved positions may be no more relevant.

USER SETTINGS

Motion direction in Free Motion only can be set depending on the user preference as follow:

- In the main window, go to menu **Parameters → Stage adjustment** and click on **Adjust motion direction…**
- In the popup dialog (Figure 33), check the Invert X/Y/Z axis direction option(s) according to your needs
- Click on **Apply** button to save changes

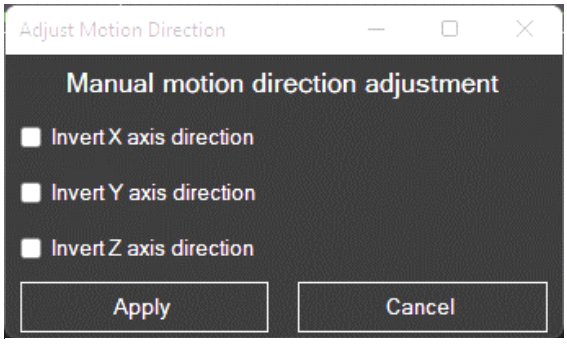


Figure 33 - Manual motion direction setting

4.1.2 SAMPLE TILT ADJUSTMENT

Prior to start the exposure, user must check the planarity of the sample in order to ensure a good focus during the entire lithography process. Two complementary procedures are available:

- Mechanical adjustment: recommended after any change of sample holder or substrate type.
- Software adjustment: recommended only for small adjustment.

MECHANICAL ADJUSTMENT

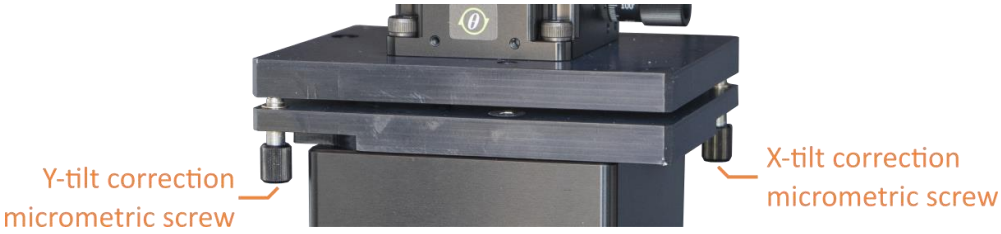


Figure 34 - Tilt correction platform

Use the tilt correction platform (Figure 34) as follow:

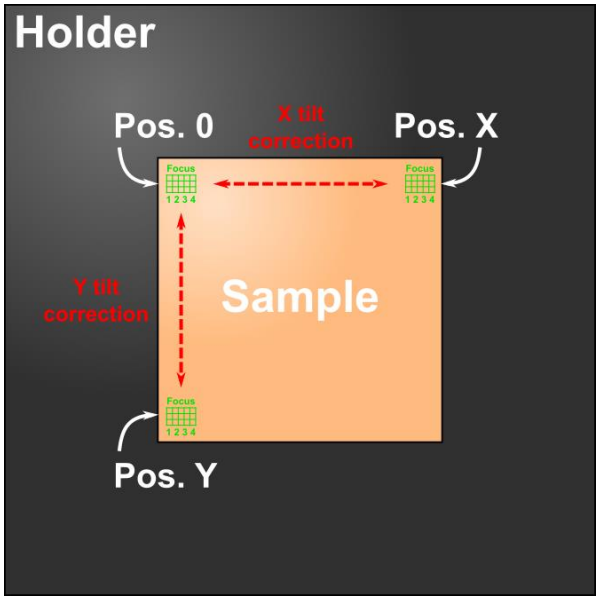


Figure 35 - Tilt correction principle

- Start the **FOCUS MODE** in the **EXPOSURE** panel (Figure 10).
- Position the top left corner of your sample under the projected light using the **XY stage control interface** (see 4.1.1). This position corresponds to the pivot point of the tilt platform (see Figure 35).
- Save the current position. Change the name of the position from XY pos. to Pos. 0 by clicking on the list in the **Saved Positions** panel.
- Adjust the focus using the Z motorized stage.
- Move along the Y axis to position the projected image on the bottom left corner of your sample (see Figure 35). Save the position and rename it by Pos. Y.
- Use the "**Y-tilt correction micrometric screw**" on the left side of the tilt correction platform (see Figure 34) to focus the image then select the saved position Pos. 0 and click on the **Go to…** button in the **Saved Positions** panel.
- Back at the pivot point (Pos. 0), focus the image using the Z motorized stage. Then go back to position Pos. Y using the **Go to…** button.
- Repeat the procedure until the projected image stays in focus when moving from Pos. 0 to Pos. Y.
- From position Pos. 0 move along the X axis to position the projected image on the top right corner of your sample (see Figure 35). Save the position as Pos. X.
- Repeat the previously described procedure to adjust the focus between Pos. 0 and Pos. X using the "**X-tilt correction micrometric screw**" on the right side of the tilt correction platform (see Figure 34) to focus the image at Pos. X.
- Once done, check the focus at the position Pos. Y one last time and adjust it if necessary.
- The tilt correction procedure is now complete.

NOTE: Instead of using the “Saved Positions” panel, it is possible to quickly save and go to specific positions M1, M2 and M3 using the items “QUICK POSITIONS” located in the **Stages menu** of the main window.

SOFTWARE ADJUSTMENT

The software tilt adjustment is faster than mechanical adjustment but it must be used only for small adjustment and does not replace the mechanical procedure.
To perform this procedure:

- Go to **Stages** menu → **Adjust sample tilt…**
- Start the **FOCUS MODE** in the **EXPOSURE** panel (Figure 10).
- Position the top left corner of your sample (P1 in Figure 36 Left) under the projected amber light using the **XY stage control interface** (section 4.1.1) and do the focus (Z adjustment). When done, click on **SetP1**.
- Move to the top right corner (P2), do the focus and click on **SetP2**.
- Move to the bottom left corner (P3), do the focus and click on **SetP3**.
- Buttons SetP1, SetP2 and SetP3 should be green. Roll and pitch angles should also be calculated. If so, click on the **STATE switch button** to enable the real time software tilt correction. The window should look like Figure 36 Right side.

NOTE: to ensure the calculation of the sample tilt, positions P1, P2 and P3 must be separated by at least 100 µm and minimum angle between P1P2 and P1P3 must be at least 5°.

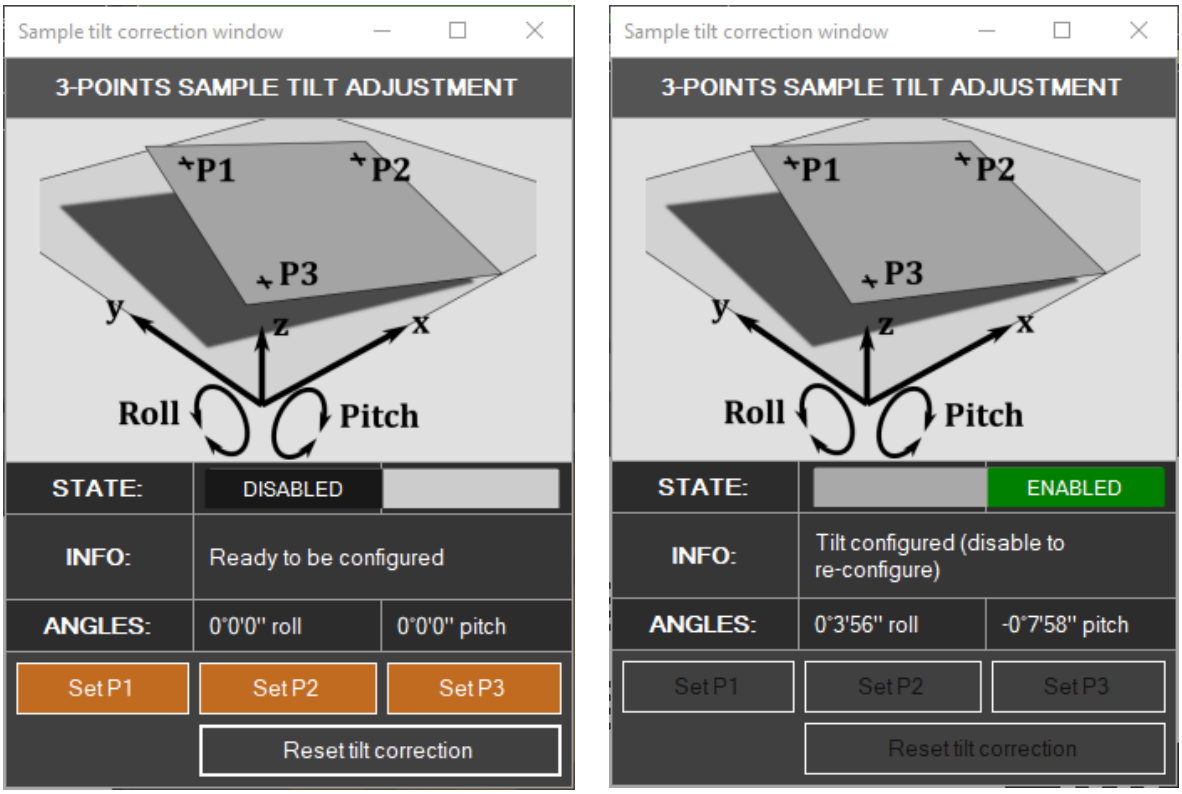


Figure 36 - Sample tilt correction window. Left: not set and disabled. Right: set and enabled

4.1.3 POSITIONING OVERVIEW

The **Positioning Overview** button can be useful for fast positioning of the sample under the projected image but also for alignment steps. I can be accessed on the right side of the software (see Figure 37 surrounded in red). Once clicked it opens the **Position overview** window (see Figure 37 in the middle).

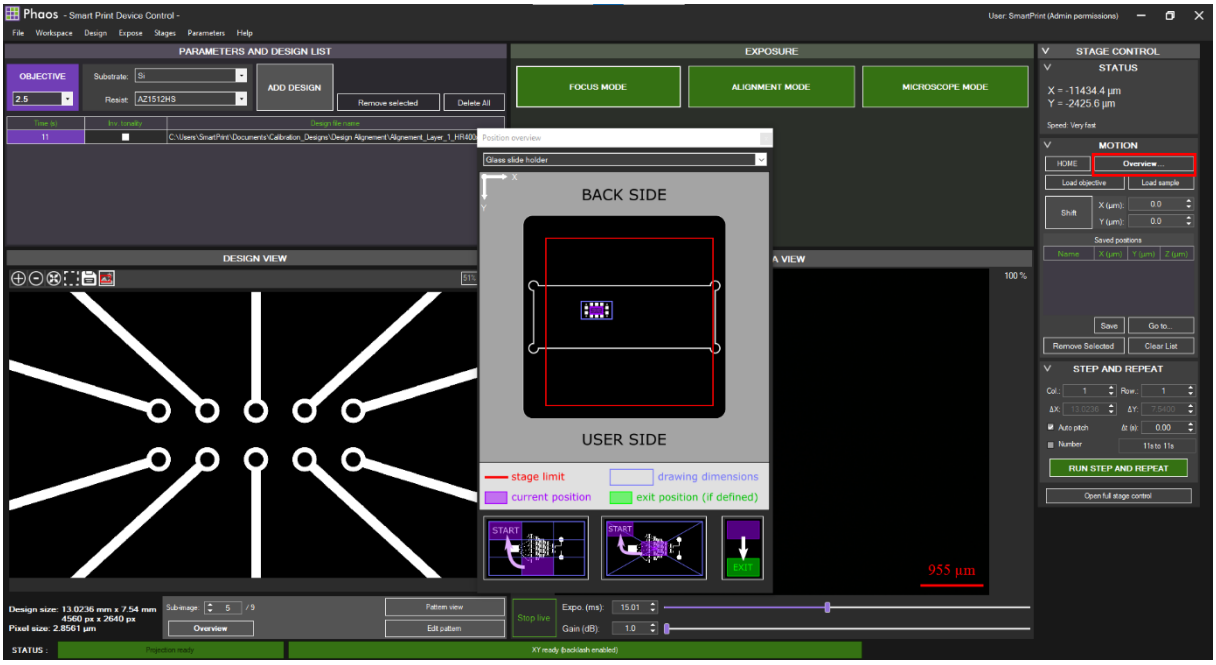


Figure 37 - Opening the positioning overview window

The **Position overview** window (Figure 38) contains:

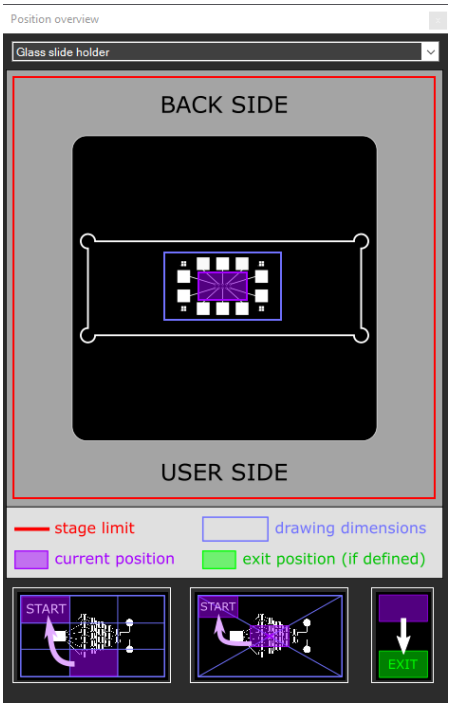


Figure 38 - Position overview window

- **a drop-down menu** to select the holder installed on the machine; Flat, Glass slide and 4 inch wafer for the POLOS µPrinter version.

- **a scheme to scale of the holder** (black square with rounded corners):

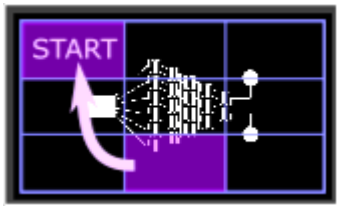
The white frame represent the shape milled in the sample holder (glass slide in the example Figure 38).

The red frame is the stage motion limit. The blue frame is the full projected design to scale (dimensions depends on the selected objective).

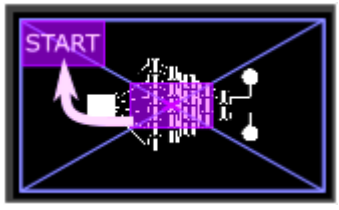
The purple frame is the current XY position. The position of the drawing on the scheme depends on the selected sub-image from the the full design.

User can click on the holder image to move to the desired position. To make sure the design will fit with the motion of the XY stage, selected the correct objective, then select the first sub-image to be exposed (the one on the bottom right corner of the full design). Click on the holder image to set the starting point of the exposure. If the design fits in the red square overlaid on the holder image, the lithography will be in range, othewise the status of the XY stage will turn orange on the main software window. If so, reduce the size of your design or selected an other starting point more on the top left on the holder.

- **3 buttons with different functions** (the associated function can be seen by putting the mouse over the button):

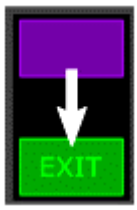


(left) **Move from current sub-image to start position**. This button can be used when aligning with the Free alignment mode (section **Error! Reference source not found.**). Select the sub-image of interest, s tart the Free alignment mode, align the selected sub-image with the correponding lithographed structure. Then open the position overview and click on the left button. The software will calculate the position of the first sub-image to be exposed while keeping the aligned position. Once clicked, close this window then close the alignment mode and start the exposure by clicking on the Expose Selected Drawing on the main window.



(middle) **Move from current center position to start position**. This button can be used to coarsly center the design on the sample. Use the projected amber light (with one of the 3 amber light modes, Focus/Alignment/Microscope) to find the approximate center of the sample. Then open the position overview and click on the middle button. The software will calculate the size of the design and go to the position of the first sub-image to be exposed while keeping the current position as the center of the design.

(right) **Define current position as exit position**. Go to a position away from the sample then click on this button. The current position will be saved as the exit position. After the exposure of the last sub-image of the design the stage will move to this Exit position. This position will be indicated on the **Position overview** window with a rectangular green frame.



4.1.4 STEP-AND-REPEAT & DOSE TEST

DRAWING AND OBJECTIVE SELECTION

Phaos combined to the XY stage offers the possibility to expose one drawing many times in a regular array positioning:

- First, add a drawing or select one from the drawing list in the **PARAMETER** panel.

> **NOTE:** Using big drawing (stitching) is possible.

- Go to the **Expose** menu and click on **Dose test**. A new window opens as shown in Figure 39. The "**STEP & REPEAT / DOSE TEST**" mode should be selected. The "**Design**" and "**Max FOV**" fields respectively indicate which design will be exposed and its dimensions.

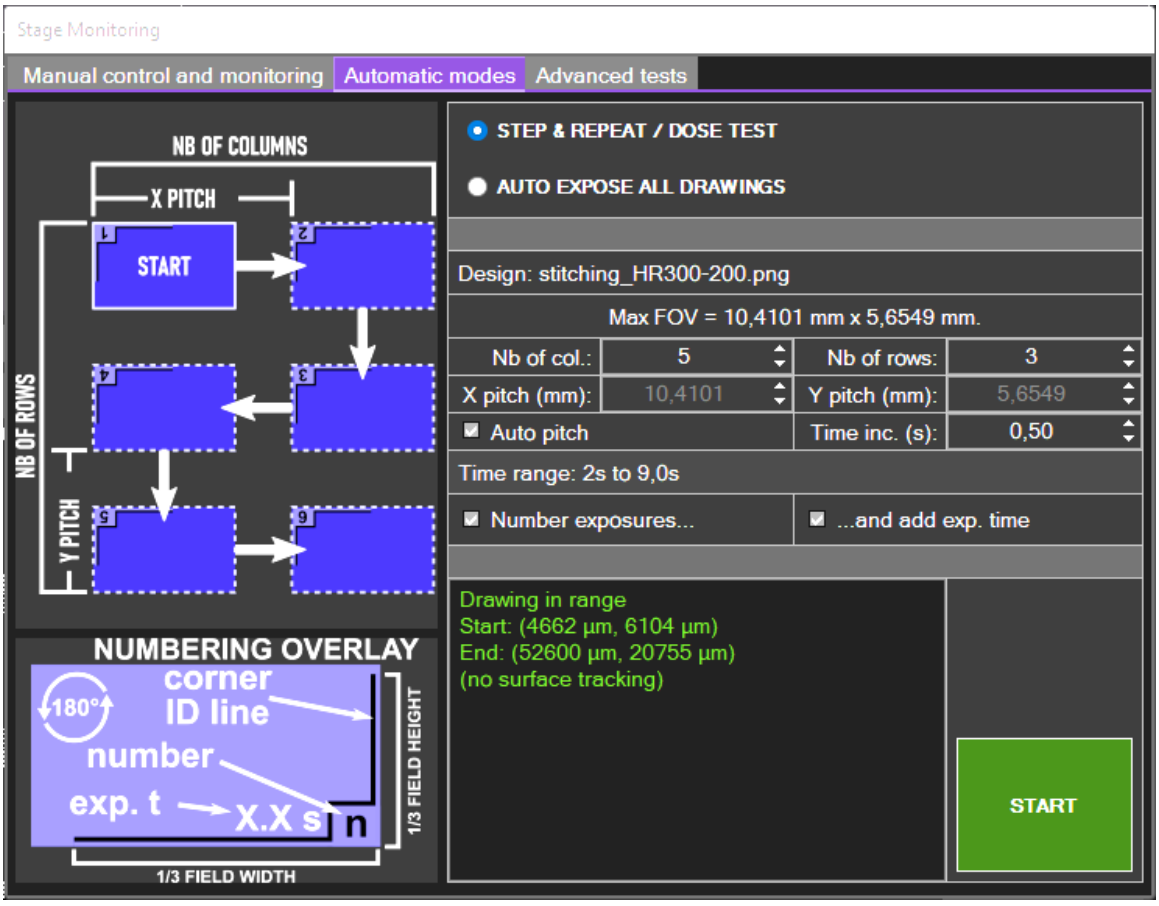


Figure 39 – Automatic mode tab in XY stage window

SETTING OF THE ARRAY

To set the step-and-repeat exposure, adjust the following parameters:

- **Nb of columns** and **Nb of rows**. They define how many times the drawing will be exposed.
- **X pitch** and **Y pitch** (in mm). They define the X and Y step sizes between each exposure. By default, the Auto pitch option is activated, therefore the the X and Y pitch values are optimized depending on the selected objective. To change the values, uncheck this option and correct them manually. The values must be higher than the field-of-view (FOV) to avoid exposure overlap.
- **Time increment** (in s). If it is set to 0, all elements of the drawing will be exposed using the Initial time. To perform a dose test, enter a positive value. Each n-th element (from 1 to N = "Nb of columns" x "Nb of rows") will be exposed with the time $t_n = t_0 + (n-1)\Delta t$ where t_0 and Δt are respectively the initial time and the time increment. The initial time corresponds to the exposure time of the first element of the array (Start position in the schematic Figure 39). By default, the software will use the time indicated in the design list in the **PARAMETER** panel. To change the initial time, simply modify the value in the design list.
- **Time range** (in s). It calculates the initial time for the first exposed design and the final time for the last esposed one using the previously cited parameters.
- **"Number exposures…", "…and add exp. time"** options. Those options respectively add on each design an overlay on their bottom right corner indicating their number order (Figure 40) and their exposure time in s (Figure 41).

NOTE on "Number exposures…" option:

- The overlay design is intended to work on both tonalities (black or white background).
- The overlay design will cover the patterns located on the bottom right corner of the drawing (corresponding to ~1.3% surface covering of a single projection FOV).

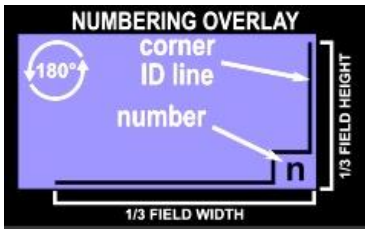


Figure 40 - Step & Repeat mode with "Number exposures" option

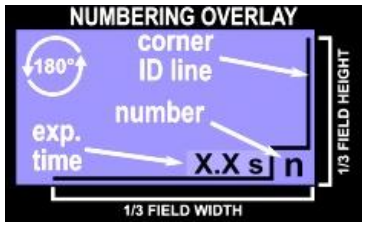


Figure 41 - "Add exposure time on overlay" option

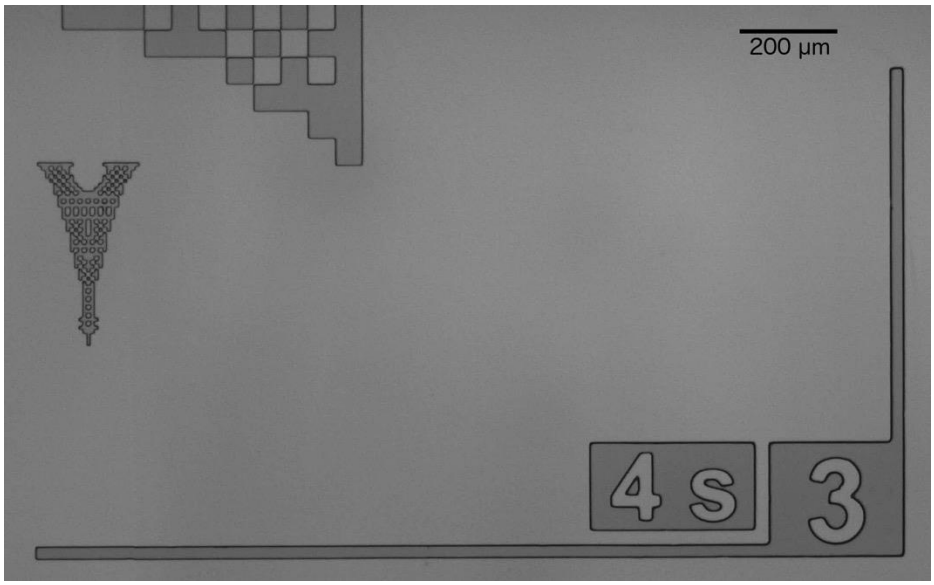


Figure 42 - Optical micrograph of the bottom right corner of the 3rd lithography of a drawing exposed in step-and-repeat mode with numbering and exposure time overlay options

COORDINATES ADJUSTMENT & START

Below the setting fields, on the left side of the **START** button, the real-time stage status shows the top-left starting coordinates ("Start") and the most bottom-right coordinates ("End"). If those coordinates are out of the stage range, the status will switch to red color and the **START** button will be disabled (Figure 43). There are two possibilities to come back to in-range coordinates:

- The starting coordinates correspond to the stage current position. Thus, go to the **Manual control and monitoring** tab and move the stage using the available controls (Figure 32) until the stage status switches back to green color.
- Reduce the size of the array by lowering the "Nb of columns" and/or "Nb of rows" values and/or the "XY pitch values"

Figure 43 – Out of range stage status

Once the array is set correctly and the stage status is green, click on the **START** button. The exposure in array will start immediately. For user information, the exposure status (current exposure time and element number) is displayed in the **EXPOSURE** panel (Figure 44). The automatic exposure can be stopped at any time by clicking on the button **STOP** in the same panel.

NOTE: When an automatic mode is running, do not move the stage using the manual controls as it will result in stage positioning errors and lithography failure.

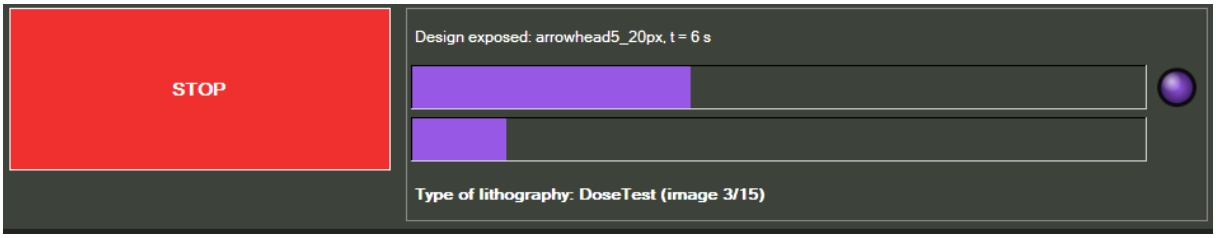


Figure 44 – « Exposure » panel during auto mode

4.1.5 AUTOMATIC EXPOSURE OF A LIST OF DRAWING

For users wishing to make serigraphy or lithography of different separate designs on the same substrate, *Phaos* offer the possibility to automatically expose a list of drawing on step defined array.

Lithography of a list of drawing is performed through the following steps:

- Choose the **objective**, **resist** and **substrate** on the corresponding dropdown lists.
  Add one-by-one drawings by clicking on the **ADD A DRAWING** button in the **PARAMETER** panel.

  NOTE: Using big drawing (stitching) is possible.

- Adjust exposure time and tonality of each drawing if needed and then adjust the focus (see section 3.5.5).
- Go to the **Expose** menu and click on **Expose all design list.**

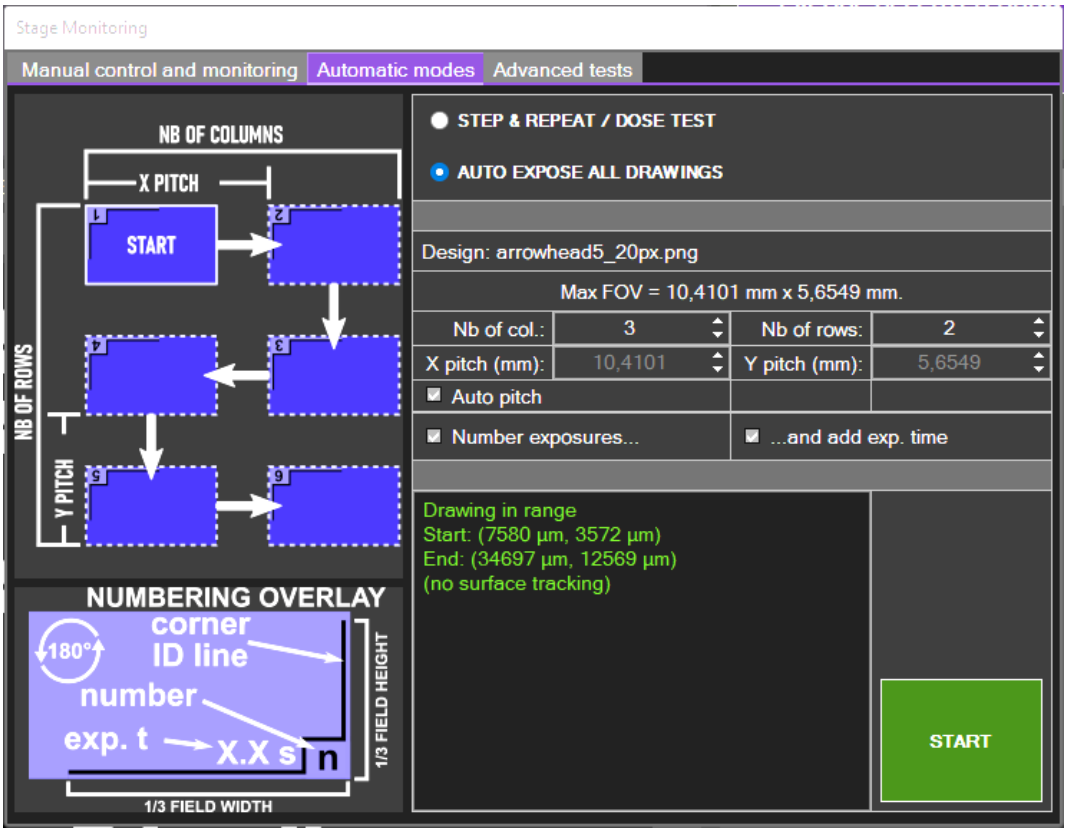


Figure 45 – « Auto Expose all drawings » mode in the stage control window

- The **XY Stage Control** window open in "**AUTO EXPOSE ALL DRAWINGS**" mode.
- Adjust **Nb of columns**, **Nb of rows**, **X pitch** and **Y pitch** (see section 4.1.4 for more information).

NOTE:

1) The "Max FOV" indicates the width and height of the biggest drawing(s) of the list. To avoid lithography overlap, the values for X pitch and Y pitch are higher than the Max FOV if the "Auto pitch" option is checked.

2) If the number of drawing is not enough to fill the whole defined array, the exposure will stop automatically at the end of the last drawing of the list.

3) The "…and add exp. time" option can be uncheck to remove the time overlay on the esposed design as the time will be the same for each exposure.

- If the stage status is green, click on the **START** button to immediately launch the exposures. If the stage status is red, adjust the coordinates as explained in part 4.1.4, paragraph COORDINATES ADJUSTMENT & START

As for the step-and-repeat mode, the exposure status (current exposure time and element number) is displayed in the **EXPOSURE** panel (Figure 44). The automatic exposure can be stopped at any time by clicking on the button **STOP** in the same panel.

4.1.6 ADVANCED AUTOMATIC TESTS

As an extension of the STEP & REPEAT option, *Phaos* offers an "Advanced tests" tab in the Stage Monitoring window (Figure 46) to automatically perform a series of tests with various parameter changes.

Instead of testing a single parameter, the exposure time, two different parameters can be modified together: one along the column axis and the other along the row axis of an array of lithographed design.

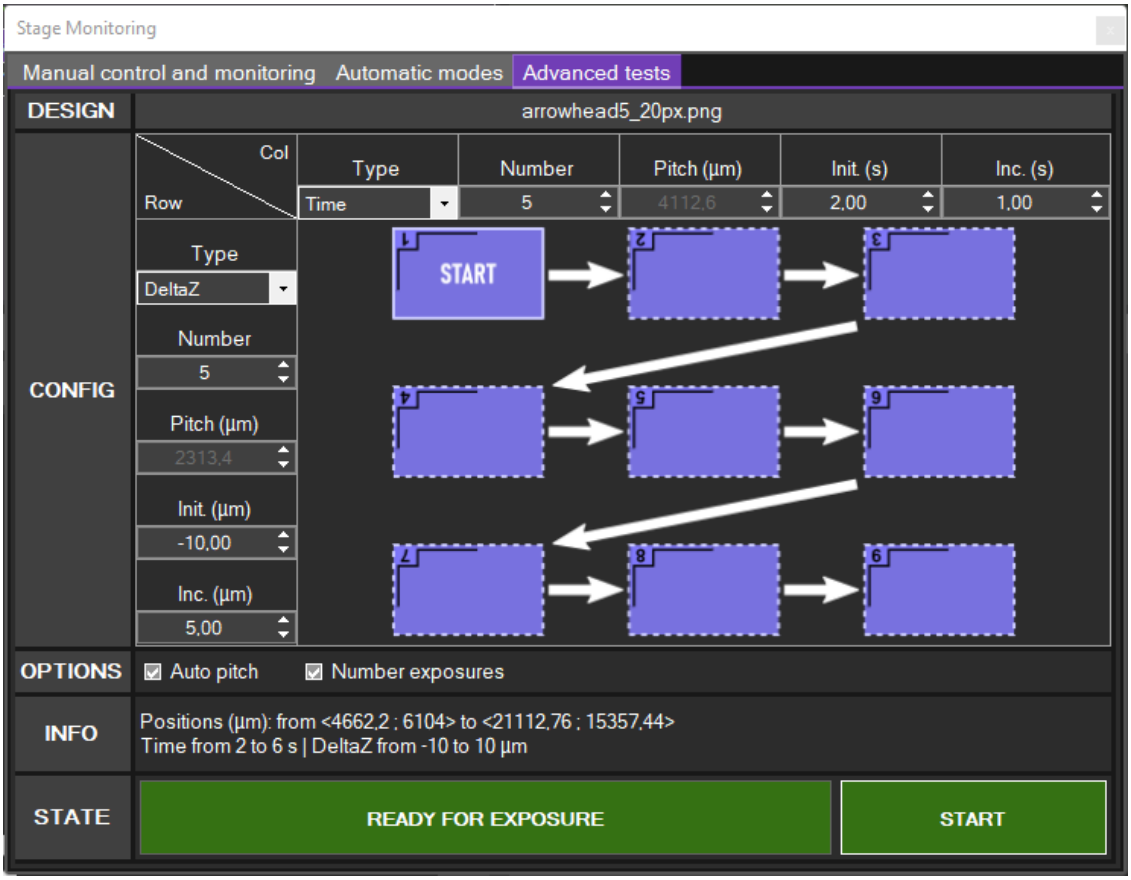


Figure 46 - Advanced tests tab: example of configuration

To use the Advanced test mode:

- Select a sample design in the main window
- In the Advanced tests tab, choose the parameter to test along col axis in the **Type** dropdown list as seen in Figure 47. All available types are described below.
- Adjust the **Number** of columns, the column's **Pitch** (if Auto pitch is unchecked), the **Initial** parameter value and its column's **Increment**
- Repeat the two above steps for **Rows** if desired
- Check the **Number exposures** option to add numbering on the lithographed result
- Ranges of positioning and parameters in the INFO panel. If the lithography is well setup, the STATE panel may display "READY FOR EXPOSURE" as in Figure 46. In that case, click on the **START** button to run the test.

NOTE: the array of test is sequentially exposed on raster scan pattern type as schematized in Figure 47.

DESCRIPTION OF AVAILABLE TYPES:

- **Time**: exposure time in s
- **OverlapX** and **Y**: stitching overlap along X and Y respectively in px (for more details, see section 3.5.3 → improvement of field connection correction)
- **Softening**: edge softening as described in 3.5.3 → improvement of field connection correction

- **DeltaZ**: additional Z shift in µm compared to the in-focus value (available only with a motorized Z stage)
- **LightIntensity**: not available for the POLOS µPrinter version

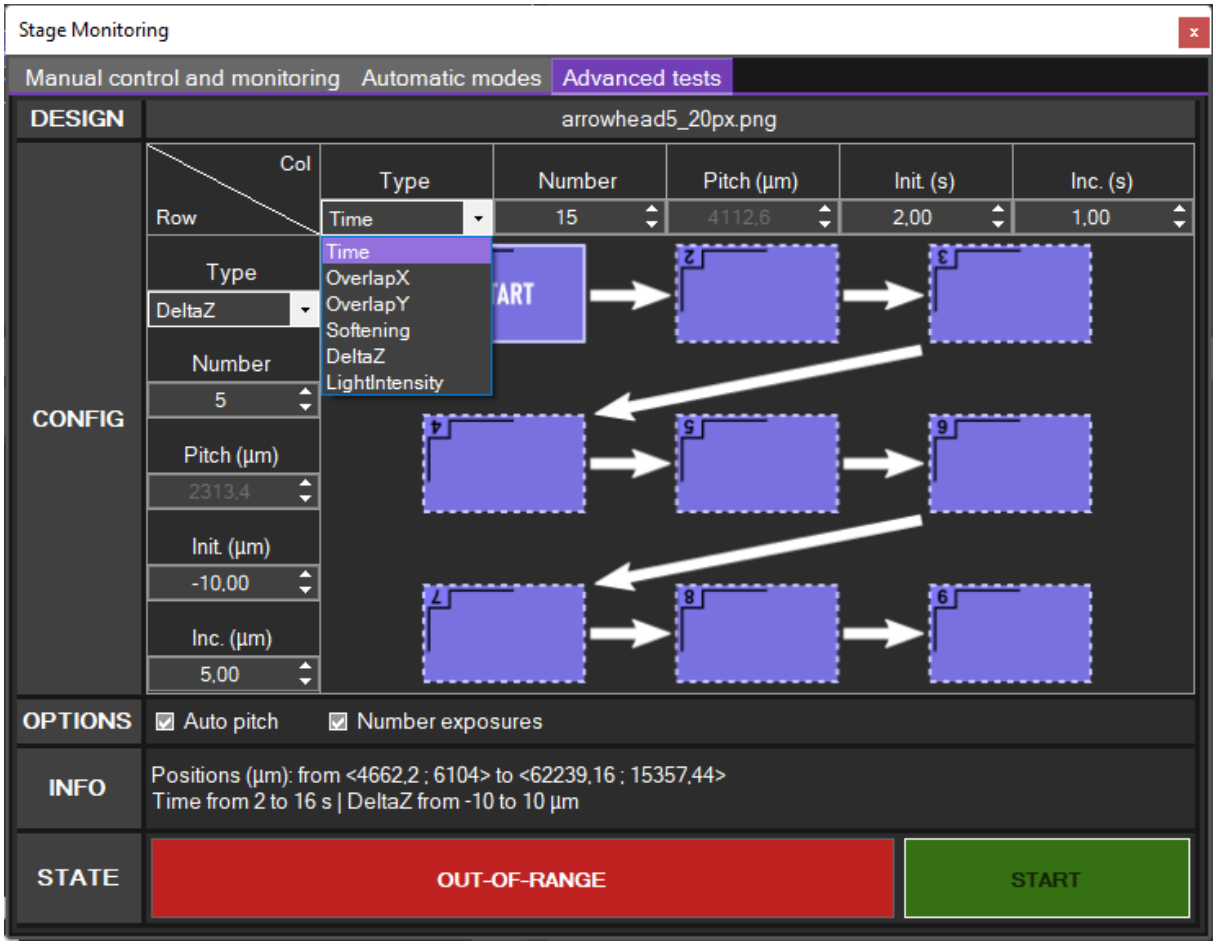


Figure 47 - Advanced tests tab: choice of parameters and warning state

4.1.7 DIRECT STAGE CONTROL FROM THE MAIN WINDOW

The most common operations requiring the motorized stage can be accessed directly from the **STAGE CONTROL** panel in the main window (Figure 48).

STATUS sub-panel. Current position and speed setting are displayed here. Free motion and speed adjustment are accessible using the keyboard shortcut described in section 4.1.1 → CONTROL → **Free motion**.

MOTION sub-panel. It contains three positioning options: home, XY shift and registered motion. The working principle is the same as for the Stage Control window described in the previous sections.

STEP-AND-REPEAT sub-panel. It allows to perform dose test as detailed in section 4.1.4

The user can switch from the simplified stage control panel to the more complete stage control window by clicking on **Open full stage control** button at the bottom of the **STAGE CONTROL** panel. Reciprocally, when the window is closed, the panel is automatically re-opened.

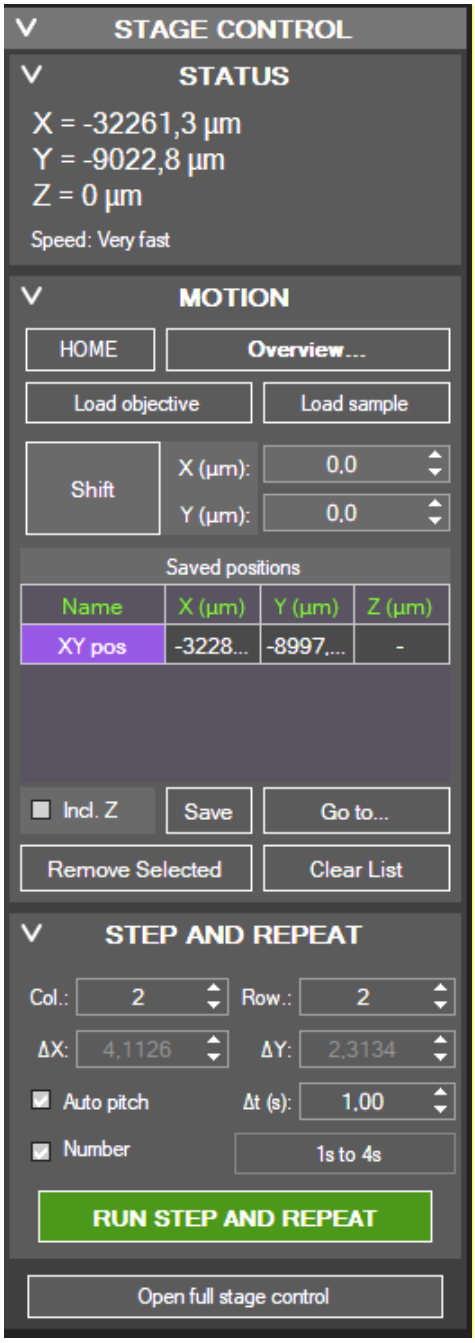


Figure 48 - Stage Control panel in the main window

4.1.8 LONG LASTING EXPOSURE FEATURES

STOP POSITION

For long lasting exposures, *Phaos* offers the possibility to define a stop position. If defined and enabled, the XY stage will move to a safe user defined area at the end of the exposure in order to avoid

unwanted sample exposure when the user is not in front of the equipment at the end of the lithography. Figure 49 shows a typical lithography with stitching and stop position defined out of the substrate. To enable the stop position option, go the desired position using stage controls. Then click on **Positioning overview** in the **Stages** strip menu and select the **Define current position as exit position** button (Figure 50 left). Finally, check the **CUSTOM STOP POSITION** button below of the **EXPOSE SELECTED DRAWING** button (Figure 50 Right).

NOTE: The stop position must be defined when the stage is in-range. When enabled, the stop position will be reached at the end of a lithography or when exposure is manually stopped.

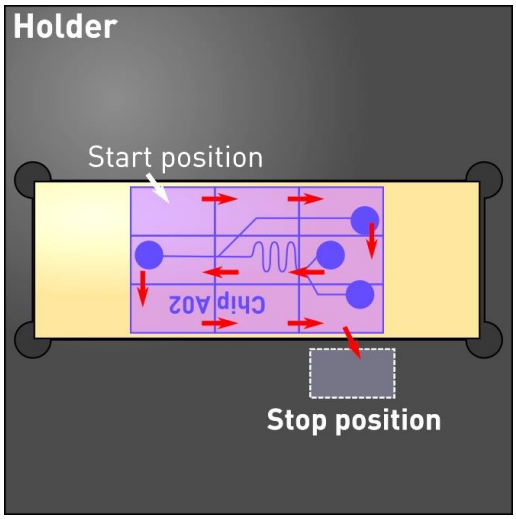


Figure 49 - "Stitched" lithography with used defined stop position

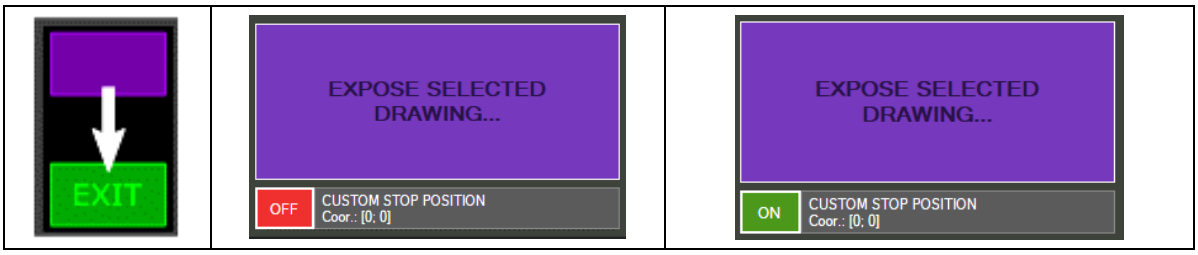


Figure 50 - Left: Stop position button; Middle: Stop position disabled; Right: stop position enabled

END OF LITHOGRAPHY NOTIFICATION (INTERNET CONNECTION REQUIRED)

A user can choose to be notified be e-mail when a lithography is finished or interrupted. To activate this option, when starting the exposure, **right-click** on **EXPOSE SELECTED DRAWING**. In the field appearing just below enter the destination e-mail address and click on **GO** (Figure 51).

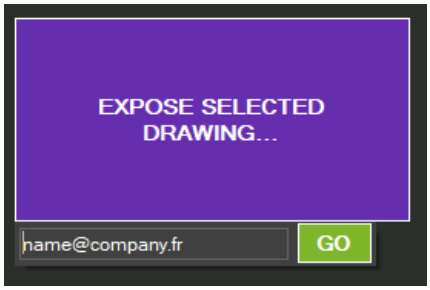


Figure 51 - End of lithography notification field

4.1.9 CUSTOM EXPOSURE (FOR ADVANCED USERS)

Phaos gives the possibility to perform a series of custom lithography automatically from a list of predefined parameters. The parameters must be defined in a tab delimited text file (.txt) with 5 columns corresponding to the following information:

Exposure time in s	Drawing tonality inverted (*true or false*)	Complete file path of the drawing (bitmap or ".stitch" format)	Stage absolute X coordinates (in mm)	Stage absolute Y coordinates (in mm)

Each column must be separated by a tab as shown in the example below (Figure 52).

```
Fichier  Edition  Format  Affichage  Aide
5        false    D:\Smart Print\Dessins-Masques\Premier_design_calib.png -20     2
4        true     D:\Smart Print\Dessins-Masques\trapz2_HR370x140_AA2_x2.5.stitch 10.5    -12,4
6        true     D:\Smart Print\Dessins-Masques\Calibration\Stitching2_inv.png   0       0
```

Figure 52 – Typical parameter file for custom automated lithography

In order to start a custom series of lithography:

- Go to **Automation** menu and click on **Custom auto exposure…**
- In the **Custom exposure** window, select a compatible parameter file by clicking on **Select datafile** (Figure 53)

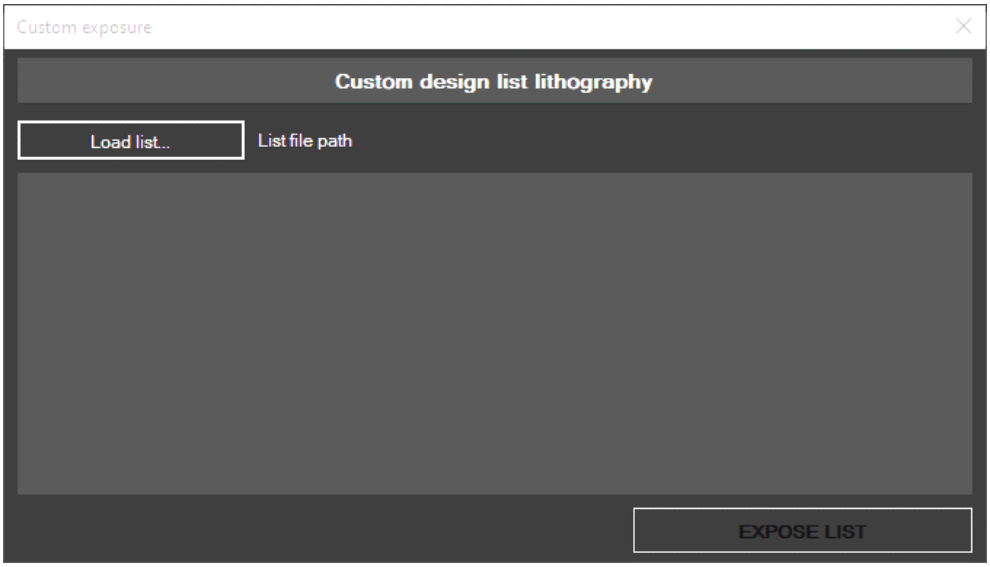
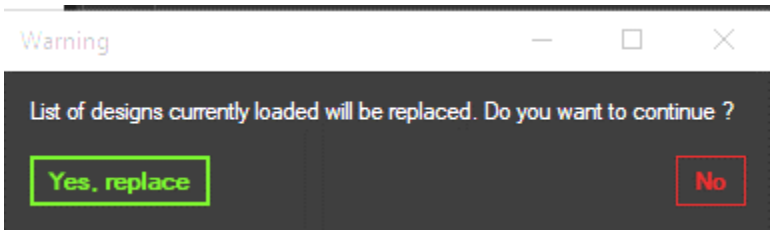


Figure 53 – Custom exposure window at startup

- If the parameter file contains no mistakes (drawing not found, unknown characters, etc.), the file will load on the window (Figure 54) and will update on the main window in the **PARAMETER** panel (Figure 55).

NOTE: if designs are already loaded in the **PARAMETER** panel when a list is loaded, *Phaos* will ask for design list replacement (message below)



- At that stage, exposure time and tonality can be modified directly in the design list (**PARAMETER** panel) if needed.
- Click on the **EXPOSE LIST** button in the **Custom exposure** window (Figure 55)

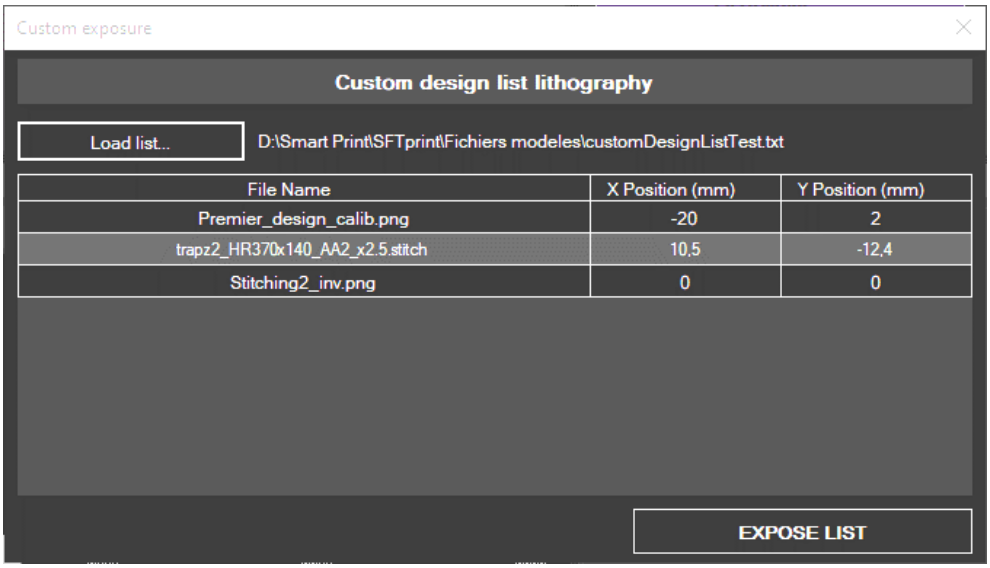


Figure 54 – Custom exposure: parameter file loaded

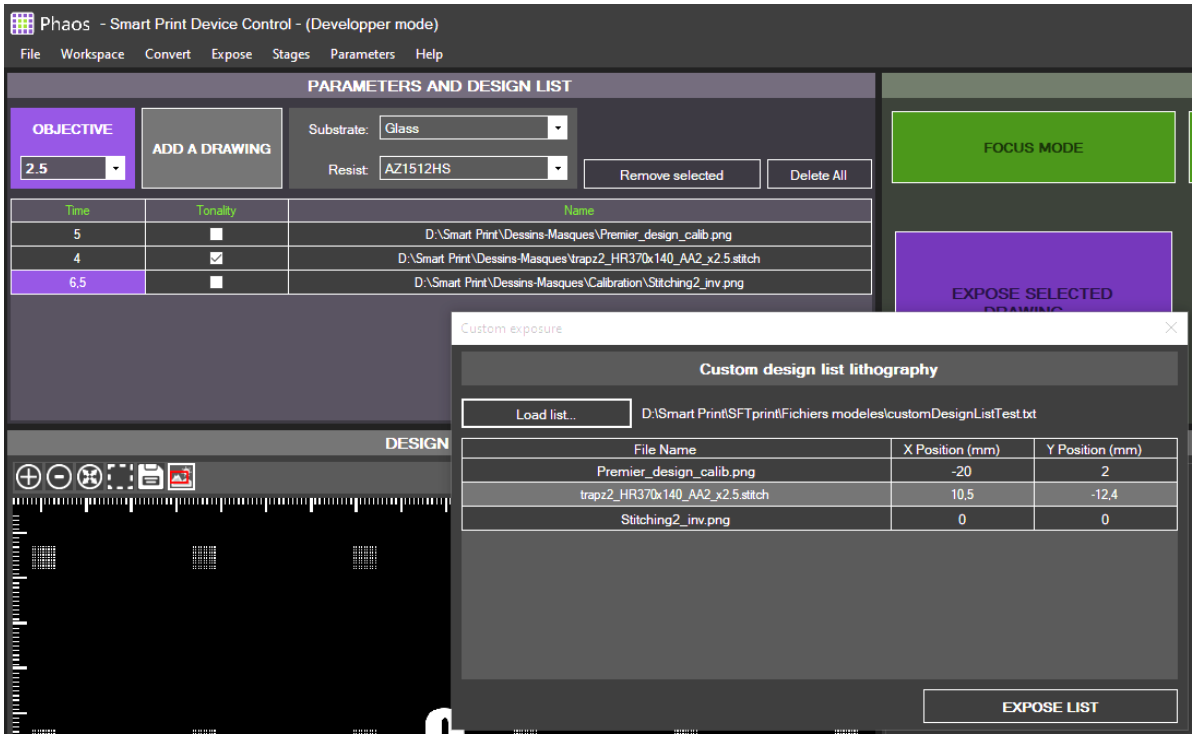


Figure 55 – Custom exposure: data loaded and ready for exposure

Once the automatic exposure is started, **Custom exposure** window close. The lithography progress is displayed in the **EXPOSURE** panel. It can be cancelled at any time by clicking on the **STOP** button.

4.2 ADVANCED LITHOGRAPHY

4.2.1 MULTI-LITHOGRAPHY WITH ALIGNMENT MODE

Phaos can project a drawing under green illumination (wavelength out of the light sensitivity area of the used photoresists) for alignment purposes. The mode is especially adapted if multiple lithography steps are required. It can be used with all objectives and requires the rotation stage module (Figure 56).
Two alignment modes, described later in the section, are accessible to the user: the **Free mode** and the **Semi-automatic mode**.

Figure 56 - Rotation stage module

DESIGN RULES

Details below are just suggested design rules, known to work properly with POLOS µPrinter . Yet, it may exist more optimized design depending on the user's needs.
To get the best aligned lithography, the substrate angular shift *q* must be minimized. In order to reduce its value efficiently, it is recommended to draw on each involved design:

- Two alignment crosses surrounding the area of interest and and located at two opposite corners from each other (Figure 57 right). For each design, the crosses must be at the same relative position
- Add a unique number to each cross (Figure 57 left) to avoid bad substrate orientation

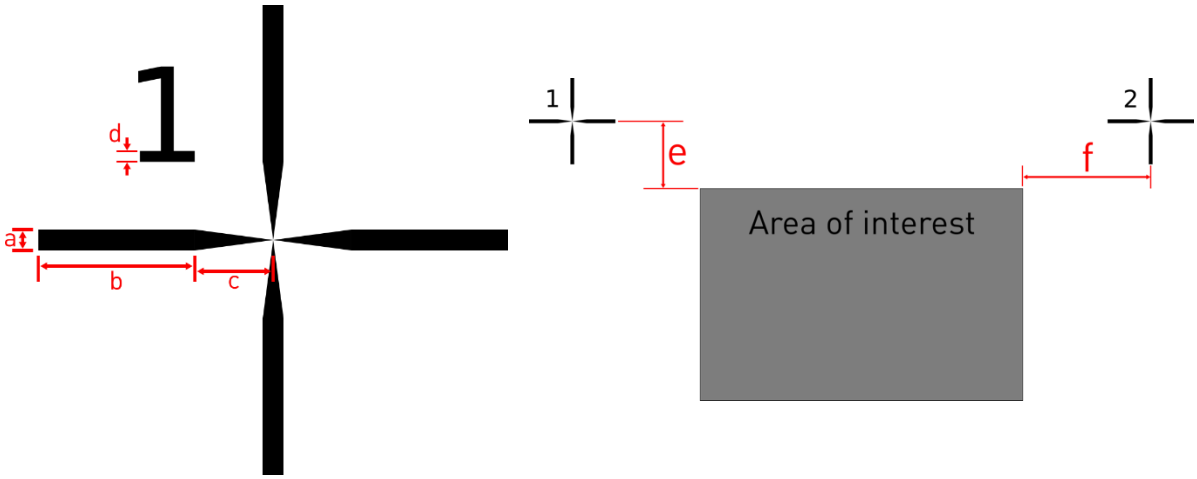


Figure 57 - Design rules. Left: focus on an alignment cross and its key dimensions. Right: cross positioning over the substrate

Tableau 1 - Suggested dimensions for the design in Figure 57

Objective	a (µm)	b (µm)	c (µm)	d (µm)	e (µm)	f (µm)
x 0.5	250	2 000	1 000	> 40	> 7 400	> 13 100
x 1	140	1 000	500	> 20	> 3 850	> 6 900
x 2.5	50	400	200	> 9	> 1 540	> 2 750
x 5	25	200	100	> 5	> 770	> 1 360
x 10	15	100	50	> 2.2	> 390	> 700

The recommended spacing and sizes for the crosses and the numbers are gathered in Tableau 1.

ALIGNMENT: FREE MODE

This fully manual mode is perfectly adapted for alignment of a single area of interest (such as contact electrodes on 2D material flakes).

To perform an aligned lithography in that mode, proceed as described below:

- Load your sample with the first layer already patterned and prepare POLOS µPrinter for a regular lithography (see section 3.3 and 3.4)
- Load a design in *Phaos* by clicking on the **ADD A DRAWING** button and choose the second layer you want to align.
- On the **EXPOSURE** panel, click on the **ALIGNMENT MODE** and set the **toggle switch** below to **FREE** (Figure 58). The selected design will be projected on the sample under green illumination.
- If not already running, start the camera by clicking on the **Start live view** button.
- Select the sub-image of interest using the **Overview** button on the **IMAGE VIEWER** panel (section 3.5.4).
- Adjust the XY stage position and the rotation stage (Figure 56) to match the sub-image of interest of the projected design with the structures present on the substrate.
- Open the **Positioning Overview** window and click on the **Move from current sub-image to start position** button as explained section 4.1.3.
- Quit the alignment mode by clicking on the **QUIT ALIGNMENT** button.
- Start exposure by clicking on the **EXPOSE SELECTED DRAWING** button.

NOTE: (only if equipped with a manual Z stage version) The focus setting is different between blue and green light projection. If possible, proceed to the alignment step without changing the focus setting when alignment mode is ON. Otherwise, a focus adjustment under blue light projection will have to be made after the alignment step.

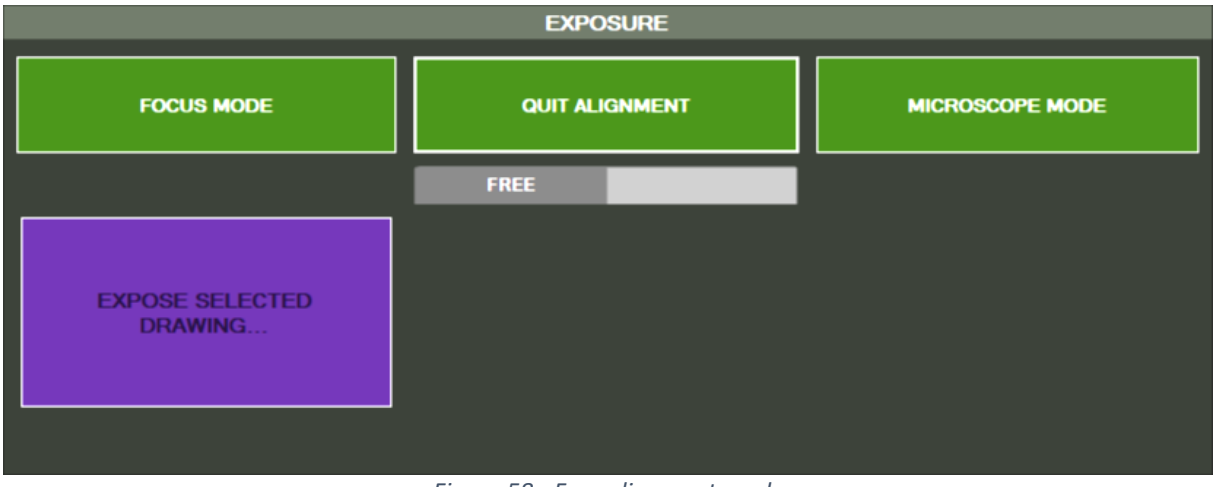
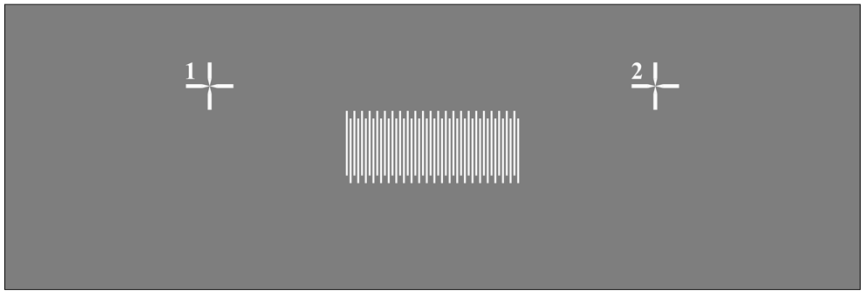


Figure 58 - Free alignment mode

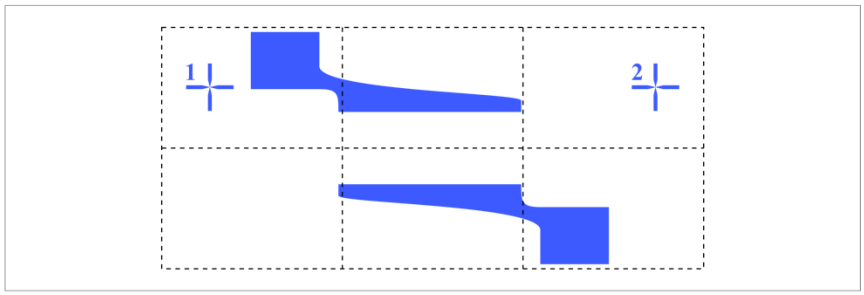
ALIGNMENT: SEMI-AUTOMATIC MODE

This mode is especially recommended when alignment of several regions of interest on a large surface is required. To illustrate how this mode works, a design of interdigitated electrodes with contact pads will be used as example. In this example, the first layer, consisting in the interdigitated electrode alone, has already been processed on a substrate (Figure 59a). Contact pads remains to be lithographed. Their drawing (Figure 59b) has been designed to fit with the patterned electrodes. In this example, the dashed rectangles in Figure 59b show how the original design will be sliced and successively lithographed by *Phaos* using a stitching procedure. The expected result on the substrate after alignment and exposure of the contact pads is illustrated in Figure 59c.

a) Substrate with the 1st level of patterns



b) Drawing of the 2nd level to be lithographed



c) Final result on the substrate

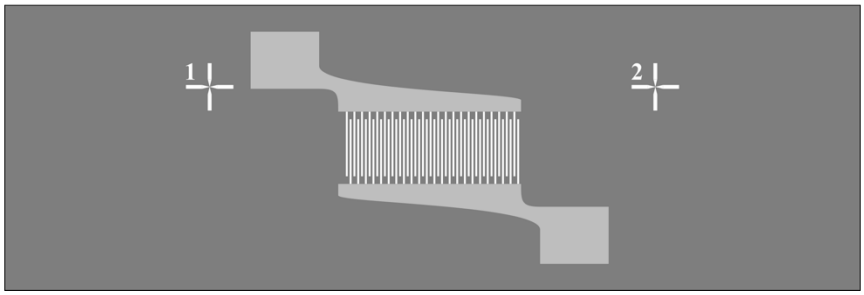


Figure 59 - Example of aligned lithography over already existing patterns

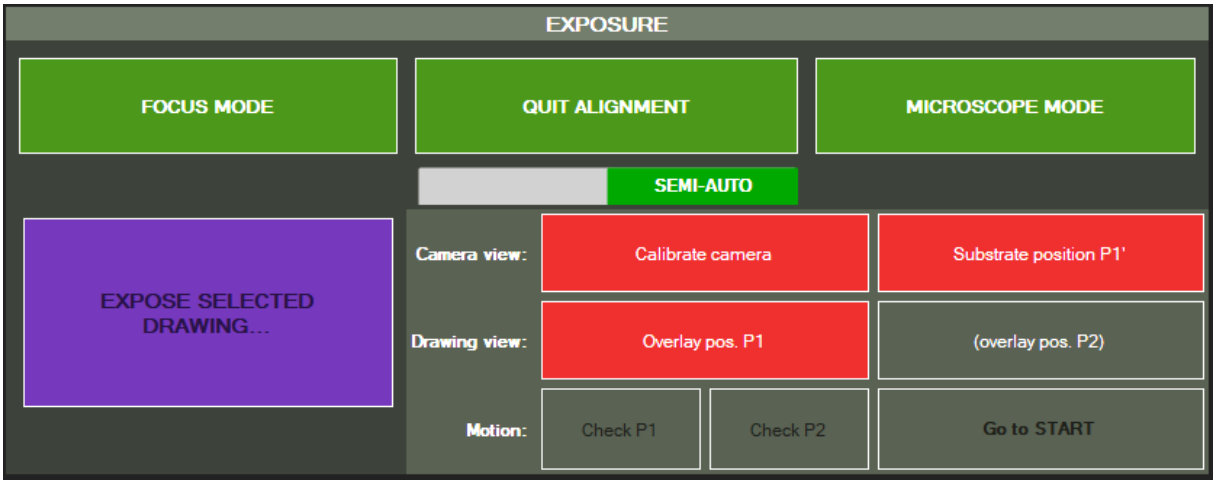


Figure 60 - Semi-automatic alignment mode

To perform an aligned lithography in that mode, proceed as described below:

- Load your sample with the first layer already patterned and prepare POLOS µPrinter for a regular lithography (see section 3.3 and 3.4). Ensure to select the correct objective in the **PARAMETERS AND DRAWING LIST PANEL.**
- Load a design in *Phaos* by clicking on the **ADD A DRAWING** button and choose the second layer you want to align.
- On the **EXPOSURE** panel, click on the **ALIGNMENT MODE** and set the **toggle switch** below to **SEMI-AUTO** (Figure 60).
- Camera calibration (Figure 61a): click on the **Calibrate camera** button. The camera live view may start and the mouse cursor shape may change. In the **CAMERA VIEW** panel**,** click on the central part of the displayed cross (Calibration point) as shown in Figure 62.

  NOTE: 1) If the cross is not visible, adjust the camera settings (see section 3.5.5). 2) The user can also zoom in (mouse wheel) and navigate into the camera view (mouse drag) if required to improve the calibration point selection precision. 3) This calibration step is not necessary but recommended to improve alignment accuracy.

- Selection of point P1' (Figure 61b): click on the **Substrate position P1'** button. As for the previous step, the camera live view may start and the mouse cursor shape may change. Move the stage (see section 4.1.1) until the first patterned cross is visible (numbered "1" in this example), then click on its center (point P1') as shown in Figure 63.

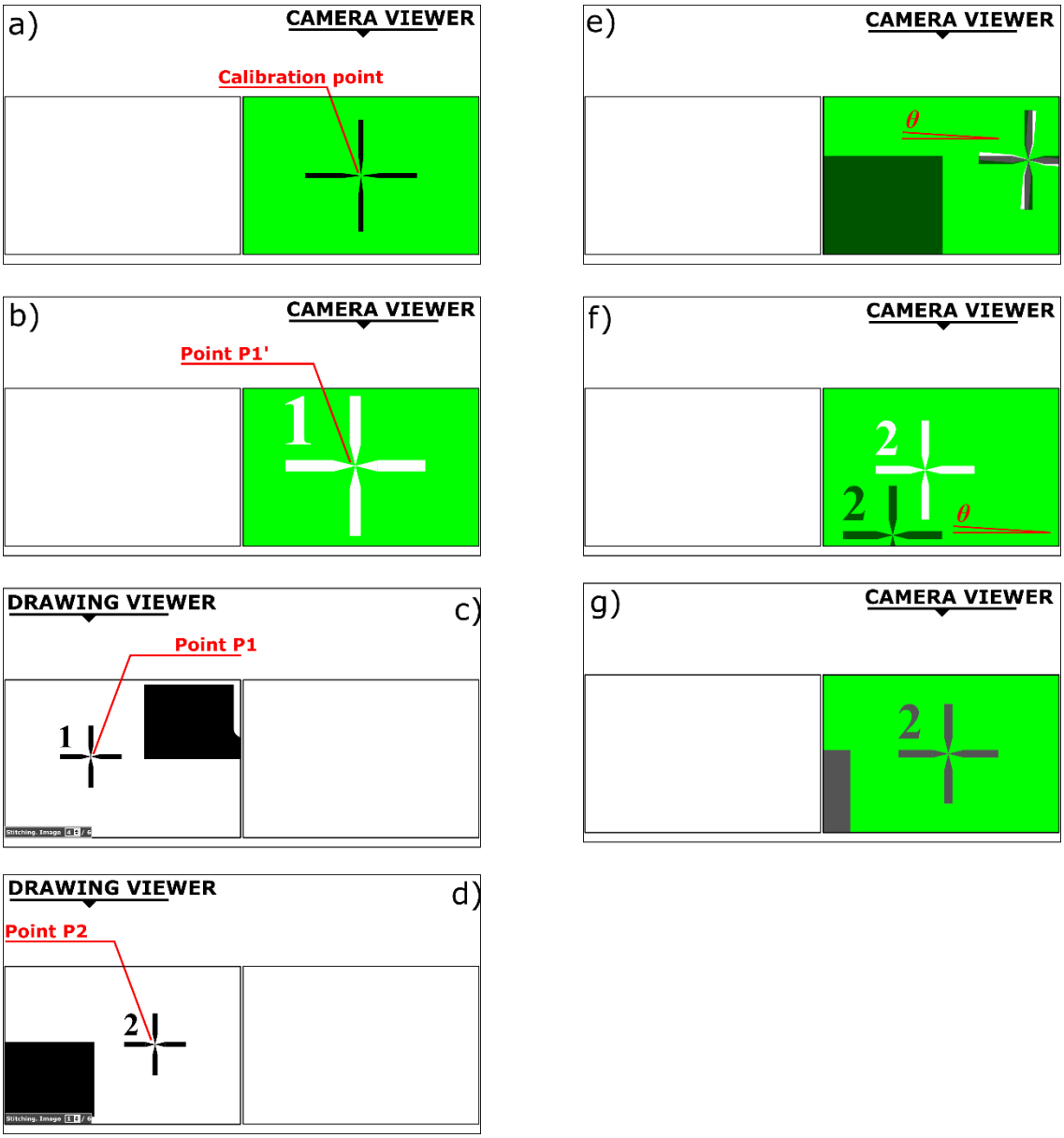


Figure 61 - Semi-automatic alignment main steps

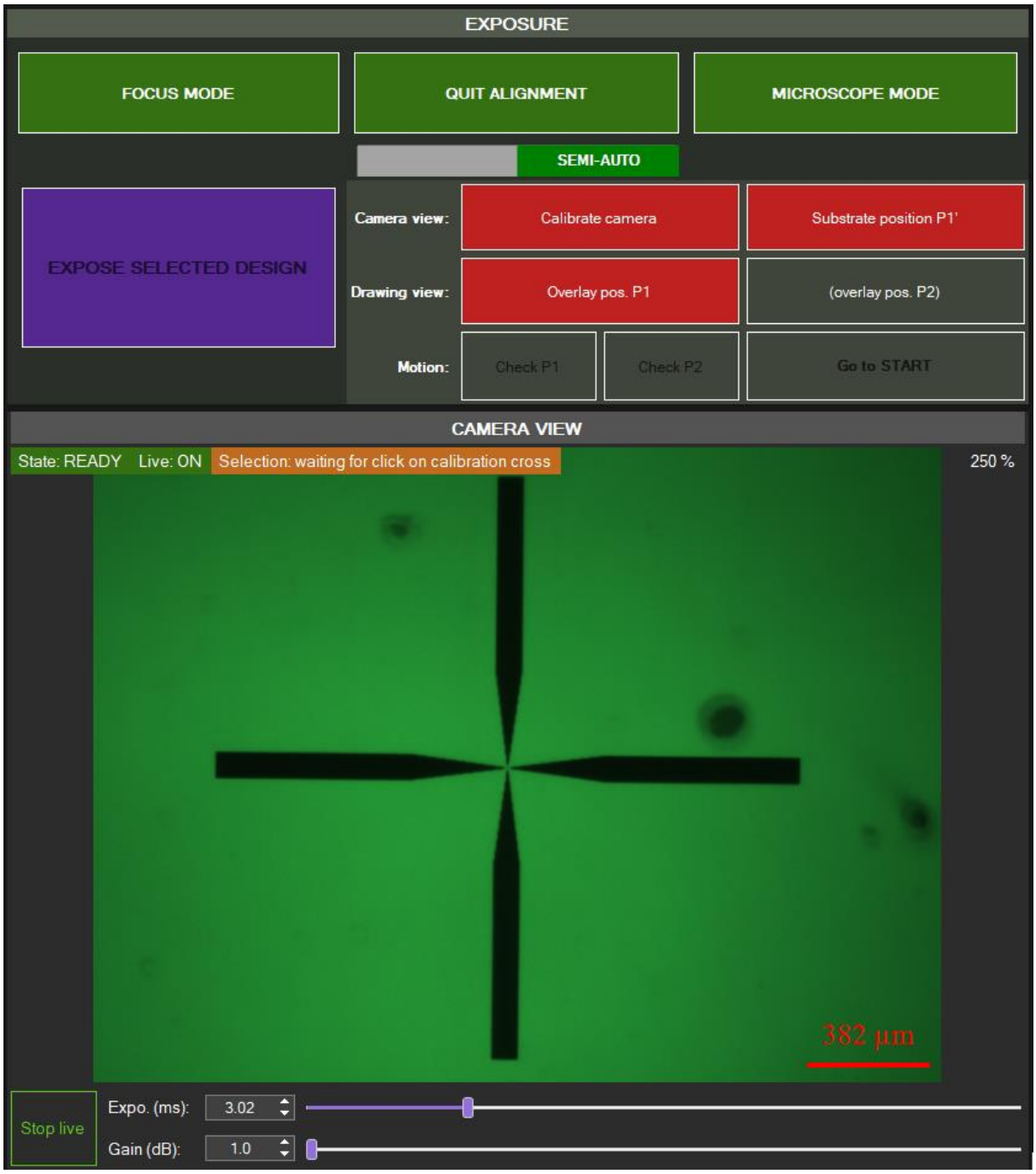


Figure 62 - Semi-auto alignment: camera calibration

- Selection of point P1 (Figure 61c): click on the **Overlay pos. P1** button. The mouse cursor will change to a cross. On the **IMAGE VIEWER** panel, select the point you want to align with P1' as shown in Figure 64
- Selection of point P2 (Figure 61d): selecting a second point of interest will help to improve the substrate rotation adjustment and then the overall quality of the alignment. To do so, click on the **(Overlay pos. P2)** button. Select a point on the **IMAGE VIEWER** panel ideally situated at the opposite of the previously selected P1 as shown in Figure 65
- Alignment checking*:* in order to check the validity of the adjustment, click on the **Check P1** button (Figure 66). The stage will then move to align P1' (on the substrate) with P1 (on the drawing) as shown in Figure 61e. If P1 and P1' are not correctly centered make again the

camera calibration and P1' selection steps. If they are correctly centered but an angle is visible (Figure 61e), it will be corrected by checking P2.

- Angle adjustment: Click on the **Check P2** button. The stage will then move the expected position of P2. If a misalignment is visible as in Figure 61f, the rotation stage must be adjusted. To do so, move the wheel of the rotation stage (Figure 56) until *q* is suppressed. After every change of the rotation stage, P1' position selection must be redone.
- Redo the previously described steps from Figure 61b to Figure 61f until P2 is perfectly aligned as shown in Figure 61g.

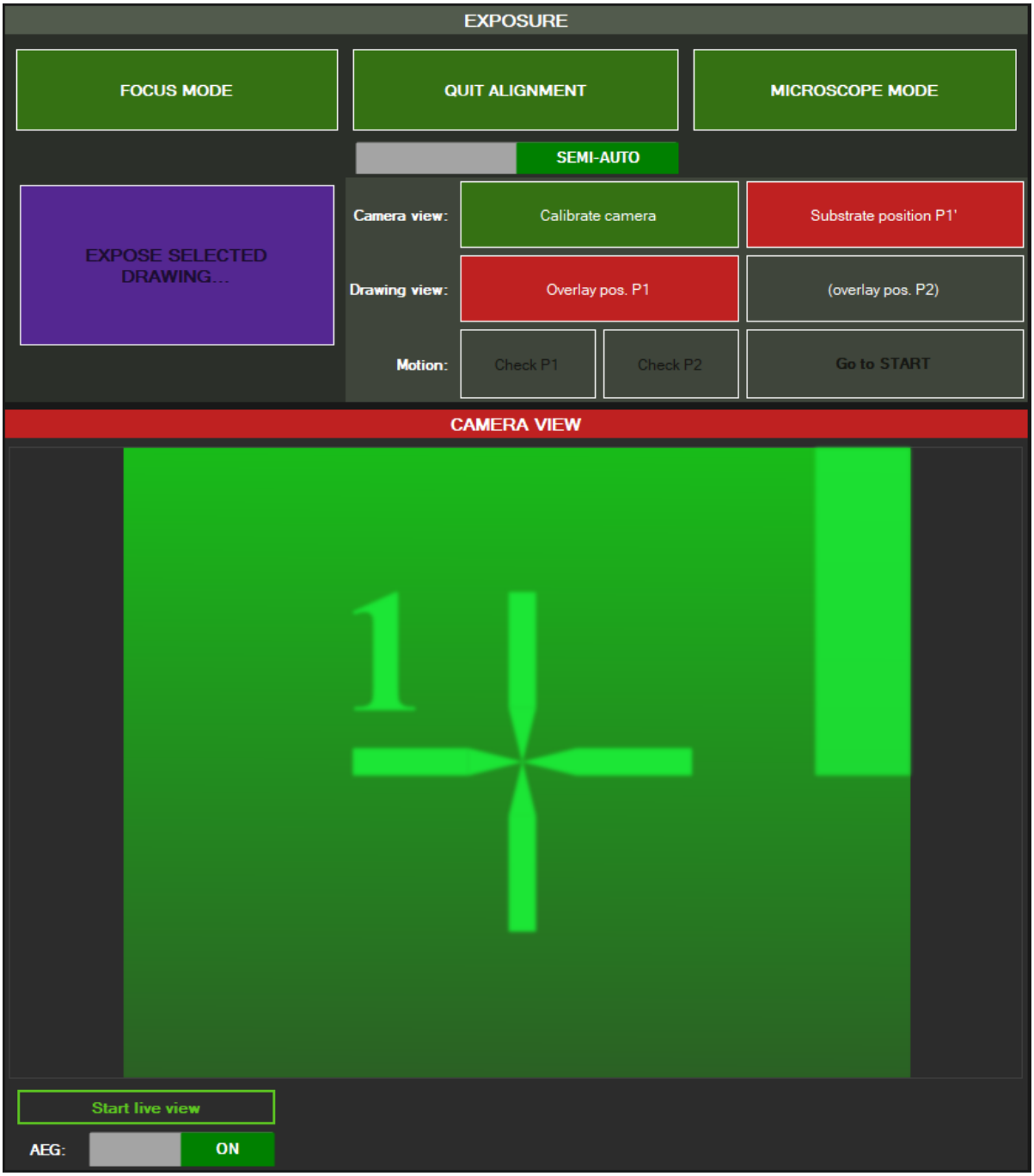


Figure 63 - Semi-auto alignment: defining point P1'

- Finishing the alignment setting: click on **Go to START** (Figure 66) and quit the alignment mode by clicking on the **QUIT ALIGNMENT** button.
- Start exposure by clicking on the **EXPOSE SELECTED DRAWING** button.

KEYBOARD SHORTCUT: the selection modes enabled by clicking on **Calibrate camera**, **Substrate position P1'**, **Overlay pos. P1** or **(Overlay pos. P2)**, can be exited by pressing **esc** key.

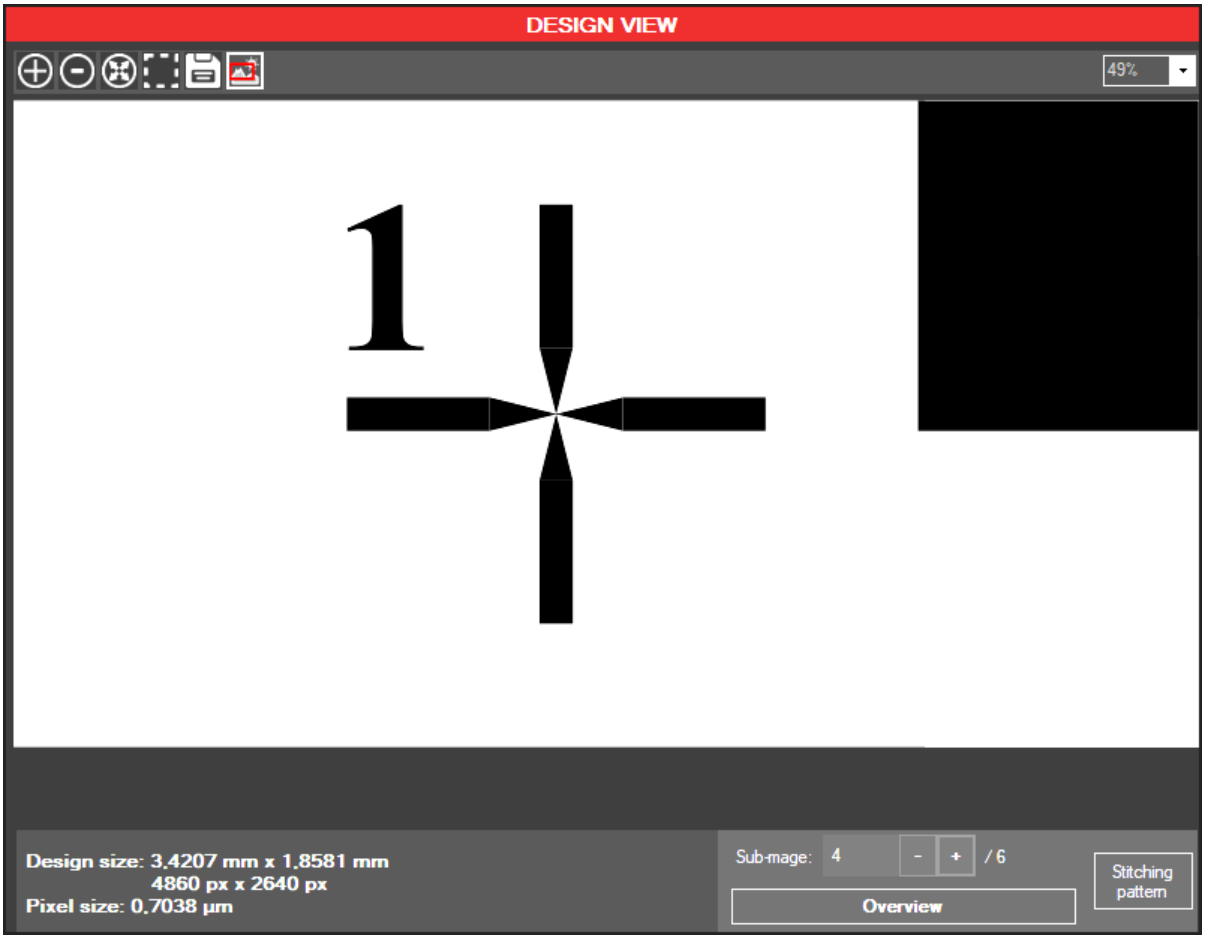


Figure 64 - Semi-auto alignment: defining point P1

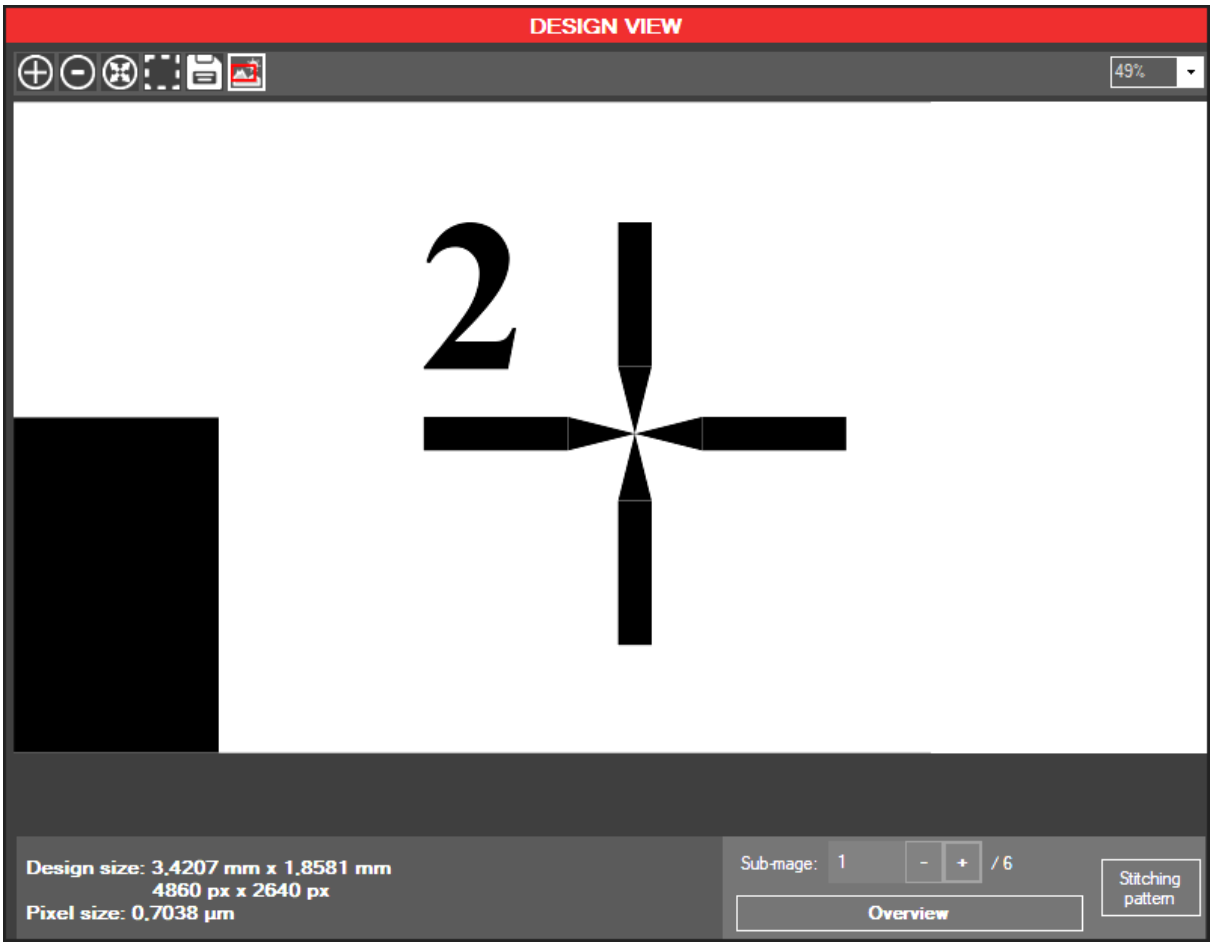


Figure 65 - Semi-auto alignment: defining optional point P2

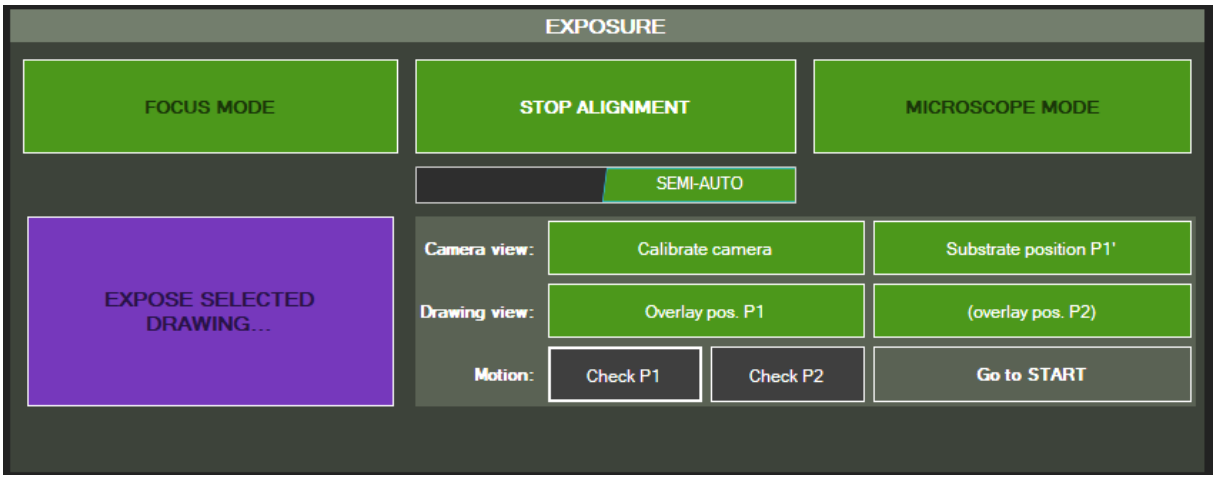


Figure 66 - Semi-auto alignment panel after defining P1', P1 and P2

4.2.2 LITHOGRAPHY PATTERN EDITION

Pattern edition is a feature developed for users needing very precise alignment on a single part of their design or for any users wishing to customize the order in which each sub-image is exposed.
The pattern edition does not change the XY position of a sub-image but **only its placement in the queue for exposure**.

To move a sub-image on the exposure queue, select the sub-image number in the list (Figure 67). Then, buttons from left to right allow you to:

- Move on top
- Move one step above
- Reset any change
- Move one step below
- Move to last position

Example (Figure 67): the sub-image N°12 is the critical part of the design and needs to be perfectly aligned on top of an existing microstructures. This sub-image is then put to the top position of the exposure queue. The alignment step is made with this sub-image (using either free or semi-auto mode). When done, the lithography is started directly on this image, avoiding any stage motion.

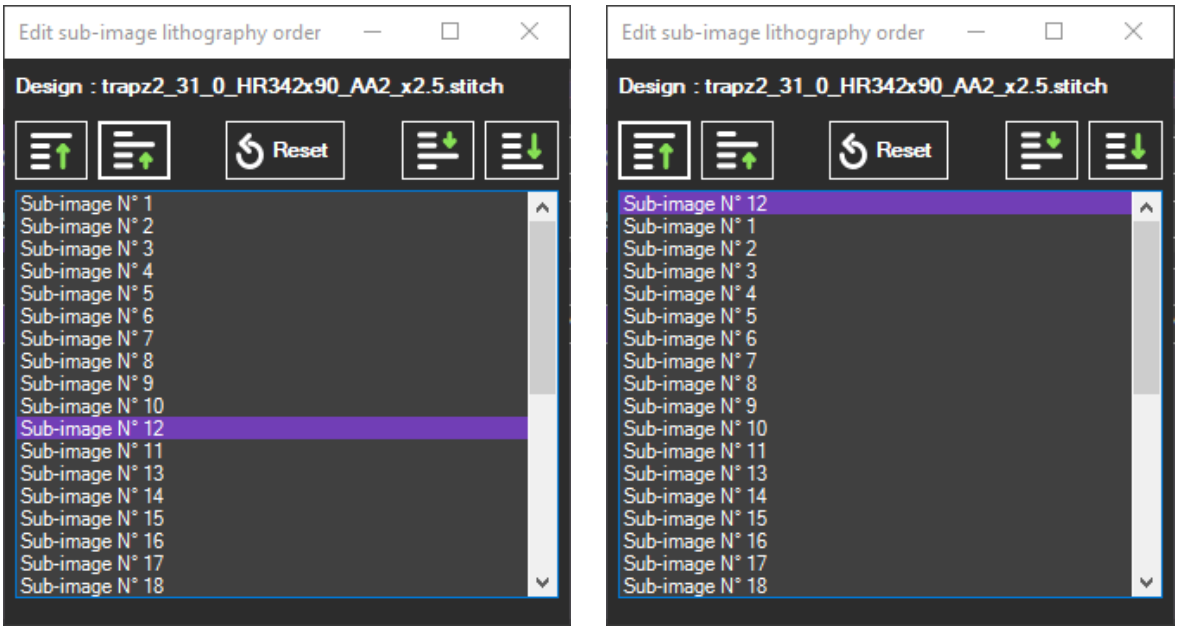


Figure 67 - Edit pattern window example of use: move sub-image n°12 to the first position in the exposure list

4.2.3 GRAYSCALE LITHOGRAPHY

POLOS µPrinter can be used to shape a photoresist in "2.5 dimensions". Indeed, the photoresist local height can be tuned by adjusting the light intensity for each projected pixel (Figure 68).

With POLOS µPrinter, it consists in exposing an 8bit grayscale bitmap drawing with a relevant gray level range on a compatible photoresist.

AZ 4562 positive resist (*MicroChemicals GmbH*) or ma-P 1275G (*micro resist technology GmbH*) are known to work for grayscale lithography. Other resists optimized for such lithography technique

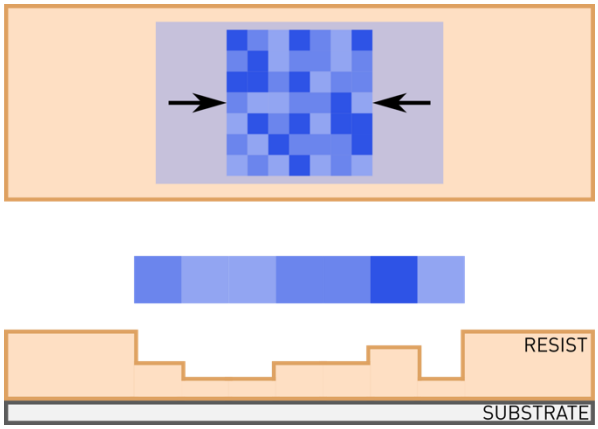
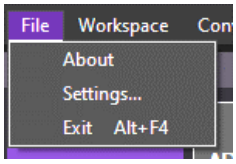


Figure 68 – Principle of grayscale lithography

and with g-line light sensitivity (wavelength between 430 and 470 nm) may also work.

4.3 GENERAL APPLICATION SETTINGS



This section describes all settings available to configure POLOS µPrinter according to user's needs. To open the **General settings** window, go to menu **File** and click on the **Settings…** button.

PERMISSION ACCESS TO SETTINGS

Phaos handles Windows multiple user session. Calibration data and basic equipment settings are shared between all users and only editable with administrator privilege. Some specific settings are associated to each user and can then be modified with current user privilege. The list of user editable settings (described later in this section) are located in:

- **Focus & Projection** tab
- **Camera** tab
- **Importation** tab

By default, when the application is run normally calibration data and basic settings are locked (Figure 69). To edit those parameters, *Phaos* must be run as Administrator. If the application is not running, right-click on the application executable and choose **Run as Administrator**. If the application is running, click on **User** on top right side of the main window and confirm change (Figure 70).

Figure 69 - Settings: admin access locked

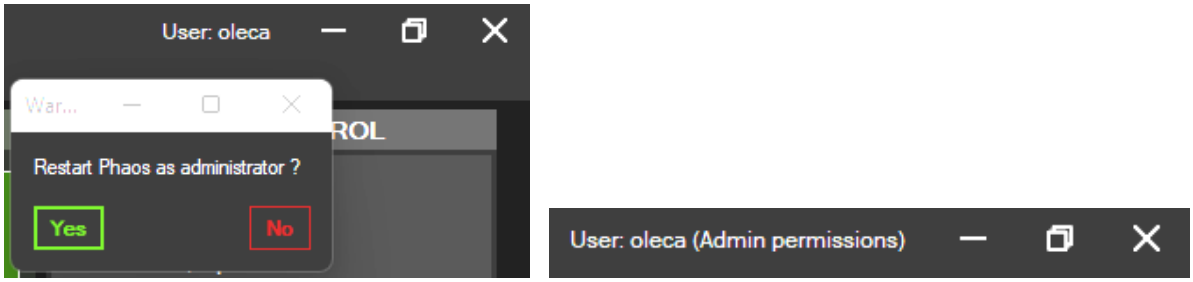
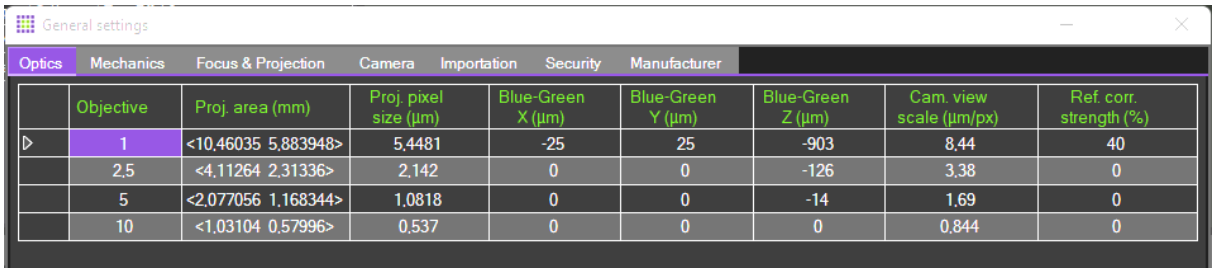


Figure 70 - Left: restart as administrator request. Right: Application running in administrator mode

OPTICAL CHARACTERISTICS
(Editable in administrator mode only)



Objective	Proj. area (mm)	Proj. pixel size (µm)	Blue-Green X (µm)	Blue-Green Y (µm)	Blue-Green Z (µm)	Cam. view scale (µm/px)	Ref. corr. strength (%)
1	<10,46035 5,883948>	5,4481	-25	25	-903	8,44	40
2,5	<4,11264 2,31336>	2,142	0	0	-126	3,38	0
5	<2,077056 1,168344>	1,0818	0	0	-14	1,69	0
10	<1,03104 0,57996>	0,537	0	0	0	0,844	0

Figure 71 – Settings: optical characteristics

The tab **Optics** contains a table with key optical characteristics according to the objective used during lithography (Figure 71):

- *Projected area*: projected image field-of-view in mm (calculated from pixel size)
- *Projected pixel size*: real size of a projected pixel in µm
- *Blue-Green XYZ:* chromatic shift correction between exposure mode (blue light) and other modes (green light)
- *Camera view scale*: camera viewer scale in µm/px
- *Ref. corr strength*: dynamic image correction value (factory calibration)

All optical parameters can be modified directly in the table except “Objective” and “Proj. area”. Any change is applied instantly but the application needs to be restarted to permanently save changes

Calibration procedure of the camera scales:

- Load a sample containing patterns with known dimension, like microscope calibration glass slide
- On *Phaos* main window check if the objective selected corresponds to the one loaded on the equipment
- Click on **MICROSCOPE MODE** (refer to section 3.5.6 for more details)
- Display the camera live scale bar and save an image of your sample (section 3.5.4 for more details)
- Measure the pixel to µm correspondence on the saved image with any image editor (like ImageJ) and adjust the **Cam. view scale** value (Figure 71) for the objective used during the calibration process.

  NOTE: **Cam. view scale** parameter can only be changed in administrator mode.
- To propagate the measured value to all other objectives, a magnification difference factor can just be applied

NOTE: if a fine calibration is wanted, repeat the procedure above for each objective excluding the last point.

FOCUS AND PROJECTION OPTIONS

Focus mode. *Editable only in administrator mode.* In the tab **Focus & Projection**, the drawing used during the focusing step can be set (Figure 72):

- *Default image*: the default optimized design

- *User defined*: a custom 1920x1080 drawing chosen by clicking on the **Choose user defined image…** button and selecting a bitmap file
- *Use the drawing selected in the exposure list*: after at least one drawing added in the drawing list, the selected drawing will be used as focus image

Green illumination for focus must always be checked. It is a feature available only with a motorized stage installed.

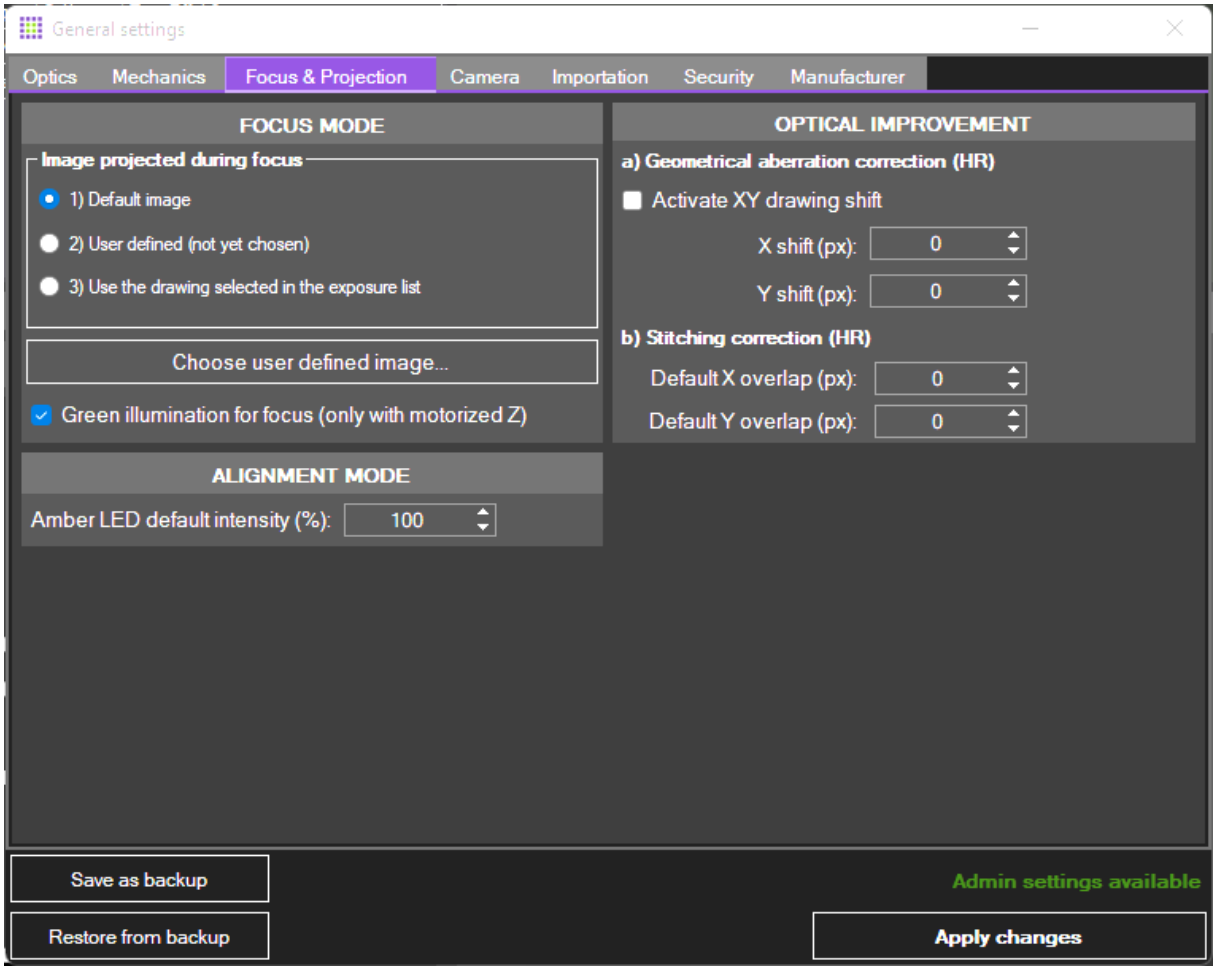


Figure 72 – Settings: focus and projection options

Alignment mode. Default green light intensity when using focus, alignment and microscope mode.

Optical improvements. XY drawing shift is a feature for advanced optimization with small images or sub-images from stitching with "HR" option. It allows to shift the projection of sub-images from the center of the field-of-view to avoid an eventual optical defect.
The default X and Y overlap values are the one loaded by default in the field connection correction window (section 3.5.3 → FIELD CONNECTION CORRECTION).

To save any changes performed in the tab **Focus & Projection**, click on the **Apply changes** button.

CAMERA
(Editable in administrator mode only)

Live image processing. Depending on the machine configuration, the image displayed in the **Live view** panel has to be mirrored horizontally and/or vertically with the options **Flip mode**. It is not recommended to change this parameter.
If the camera is saturated, a yellow/pink overlay will highlight the pixels that are too bright. Those pixels are defined by an intensity above the **Overlay threshold**.

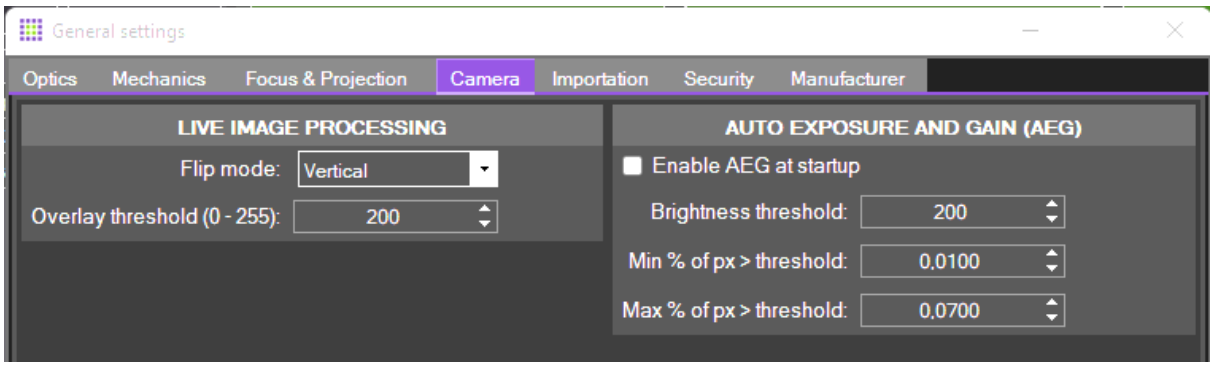


Figure 73 - Settings: camera

Auto Exposure and Gain (AEG). Feature not available on all models. To enable the camera AEG at each startup of the application, check **Enable AEG at startup**. Parameters below allow to fine tune the AEG:

- **Brightness threshold**: define an upper camera exposure value as a percentage of the maximum exposure value of the camera (to reduce camera lag). Default = 10%
- **Min % of px > threshold**: min percentage of saturated pixels tolerated. Default = 2%
- **Max % of px > threshold**: max percentage of saturated pixels tolerated. Default = 4%

To save any changes performed in the tab **Camera**, click on the **Apply changes** button.

MECANICAL SETTINGS

***Axes adjustment and tilt correction*.**
Invert X/Y/Z direction options allow to change the stage motion direction (Figure 74). It is recommended to keep those parameters in their default configuration.
The projected image is slightly rotated in comparison to stage motion direction. This misalignment can result in bad field connections during stitching. The effects of misalignment can be software-corrected by adjusting the **Tilt for obj x1 to x10**. It corresponds to the measured angle between the X-edges of a projected image and the X-axis motion direction, expressed in degree.

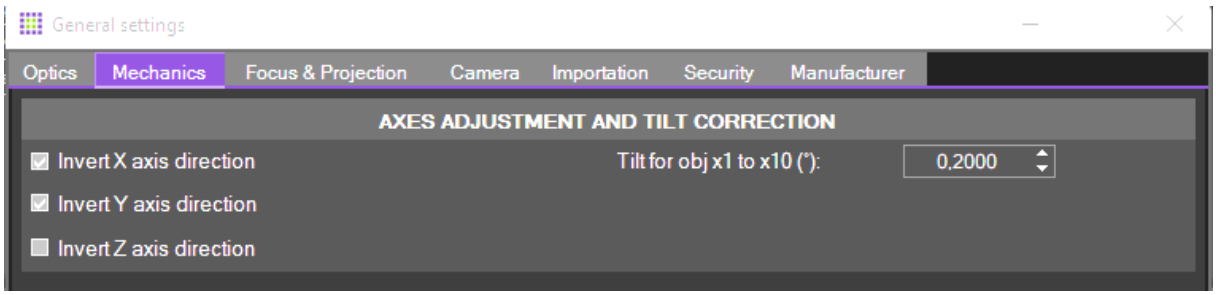


Figure 74 – Settings: motorized XY stage

Any change is applied instantly but the application needs to be restarted to permanently save changes.

IMPORTATION OPTIONS

The vector drawing importation module use a third-party open-source software (KLayout). If KLayout has been installed on its default location (section 5.3.3 for more details), *Phaos* will link automatically to KLayout. If not then click on **Define klayout_app.exe filepath** (Figure 75) and select the file *klayout_app.exe* in the main directory of KLayout (only possible in administrator mode).

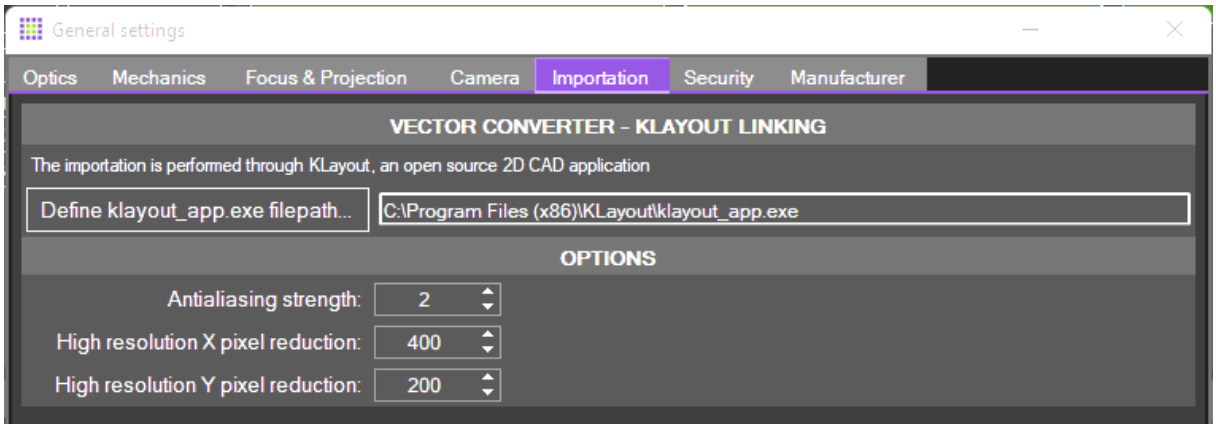


Figure 75 – Settings: vector drawing importation options

Other importation parameters:

- **Antialiasing strength (default value)**: allow to adjust the precision of the antialiasing treatment when the option is checked on the conversion module. The higher the value the better the antialiasing but the conversion will last longer. Range of value is from 2 to 6
- **High resolution X/Y pixel reduction (default values)**: when the high-resolution option is checked during a conversion, a stitch image is created with reduced sub-image size compared to the standard resolution (1920x1080) in order to lower optical geometrical aberration effects. Those parameters allow to adjust the sub-image size reduction

To save any changes performed in the tab **Importation**, click on the **Apply changes** button.

SECURITY OPTIONS

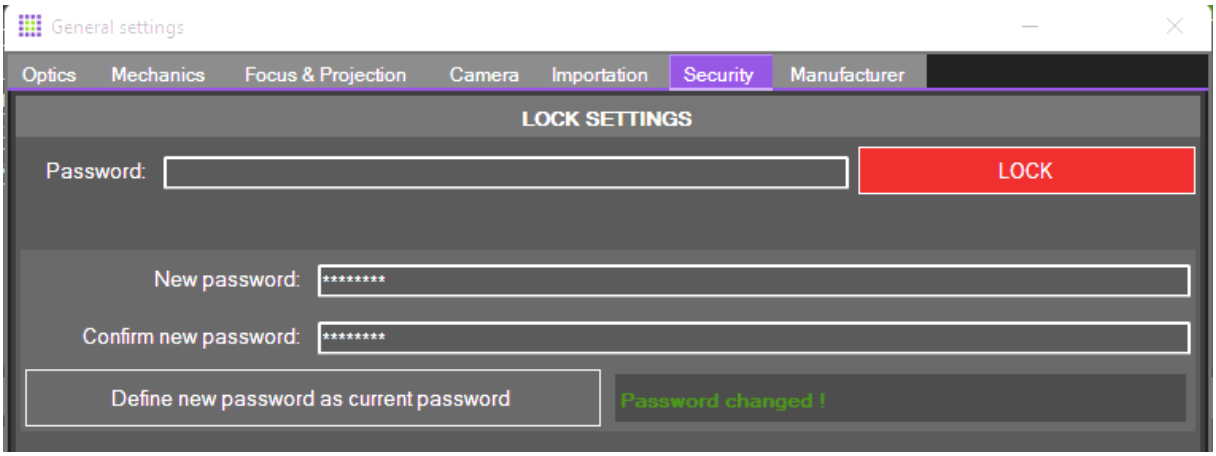


Figure 76 - Settings: security options

Although key settings can only be edited with administrator privilege, all settings can additionally be locked by a password on the **Security** tab (Figure 76). In this objective, a new password must be first defined by filling the fields **New password** and **Confirm new password** and then by clicking on **Define new password as current password**. Once a password defined, click on **LOCK** to avoid any change of the settings. The option **Always lock at exit** automatically lock the general settings when the window is closed.

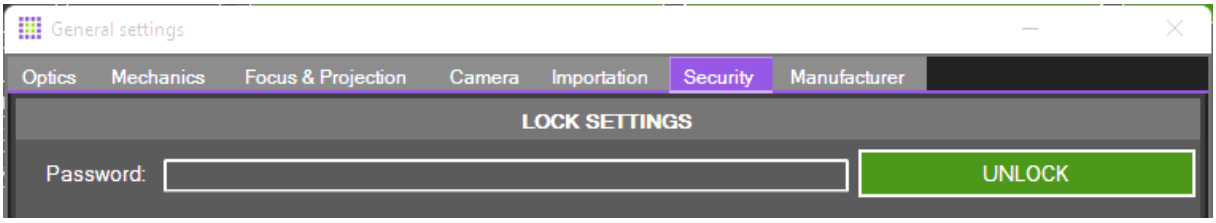


Figure 77 - Settings: unlock

To unlock the settings, enter the password on the field **Password** and click on **UNLOCK** (Figure 77).

ADVANCED MANUFACTURER OPTIONS

The **Manufacturer** tab contains a console-like interface (Figure 78). It is intended for diagnosis and repairing purposes only. DO NOT USE it by yourself.

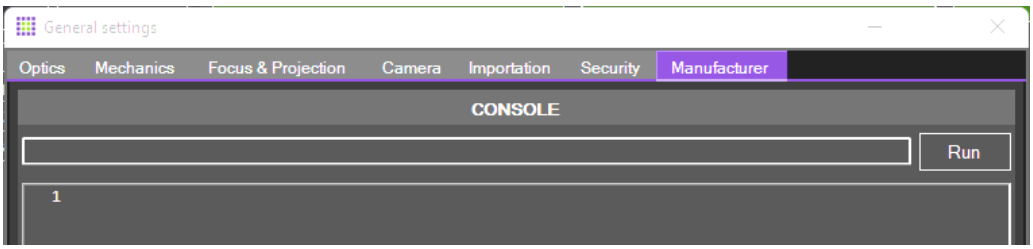


Figure 78 - Settings: Manufacturer

SAVE AND RESTORE DEFAULT SETTINGS (ADMINISTRATOR ONLY)

Default settings is a backup set of data initially defined by the manufacturer. Current settings can be reinitialized to default by clicking on the button **Restore default settings**. All general settings from all tabs will be restored to the backup default settings. In case of change in calibration data, the administrator can save the current set of settings as default settings by clicking on **Save as default settings**.

5 MAINTENANCE & TROUBLESHOOTING

5.1 LAMP REPLACEMENT

After 3900h of use, a message indicating that the lamp must be changed will appear over exposed images. To keep POLOS µPrinter's performances, especially light stability and intensity, the lamp must be replaced.

STEP A: LAMP CHANGE

a. Open the lamp cover (Figure 2) with a Phillips PH1 screwdriver (Figure 79 (1) and (2))
b. Unscrew the lamp block (Figure 79 (3) and (4))
c. Pull out the lamp block (Figure 79 (5) and (6))
d. Follow the previous instruction in the opposite order with the new lamp block (reference: ELPLP88 from *EPSON*)

STEP B: RESETTING LAMP LIFETIME COUNTER

On the projector's remote control, sequentially execute the following series of commands: Menu > Up > Right > Up > Enter > Enter > Menu.

CAUTION:
All precautions and safety measures described in the EH-TW5300 user guide from EPSON must be applied. For any additional information about the lamp replacement, refer to this user guide.

Figure 79 – main steps for lamp replacement

5.2 MONTHLY MAINTENANCE

STEP 1: AIR FILTER CLEANING

To avoid projector over-heating, the air filter (Figure 2) must be checked and cleaned regularly. Open the air filter cover, grip the filter cover tab and pull it straight up (Figure 80). Remove all dusts covering the filter using a vacuum cleaner and replace it in its place.

NOTE: For additional information on air filter cleaning or POLOS µPrinter opto-electronic head cleaning, refer the EH-TW5300 user guide.

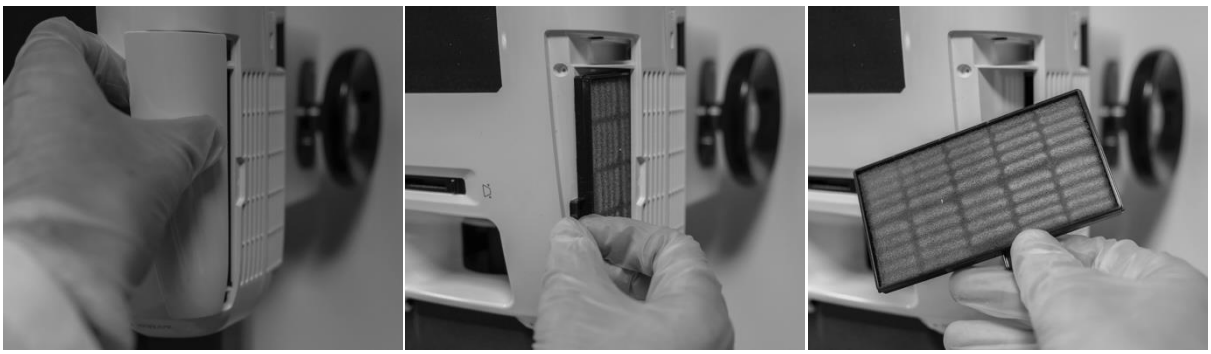


Figure 80 – Air filter cleaning

STEP 2: XY STAGE RE-CALIBRATION

Throughout its use, the XY stage origin may shift slightly. It is then recommended to re-calibrate it regularly. To do so, open the XY stage control window (refer to section 4.1.1) and click on **Re-calibrate stages** (Figure 32).

CAUTION:
During re-calibration, the stage will move at its full range. Before re-calibration, ensure that nothing can disturb the motion of the stage.

5.3 TROUBLESHOOTING

5.3.1 CAMERA ISSUES

Issue	Possible cause	Fixes

No camera detected error message (Figure 81)	POLOS µPrinter's USB cable not connected to the computer	Check and connect the USB cable to the computer
Interruption of the live view (Figure 82)	POLOS µPrinter's USB cable not properly connected to the computer	Check that the cable is well connected on an USB 3.0 port
In focus or alignment mode, the image is always black	Camera under-exposed or illumination lamp off	• Check if POLOS µPrinter is ON (continuous blue light on status indicator Figure 2) • If lamp or temperature indicator are illuminated refer to EH-TW5300 user guide • Adjust the camera exposure time as described in section 3.5.5
In focus or alignment mode, yellow/pink spots appear on the image	Camera over-exposed	Adjust the camera exposure time as described in section 3.5.5

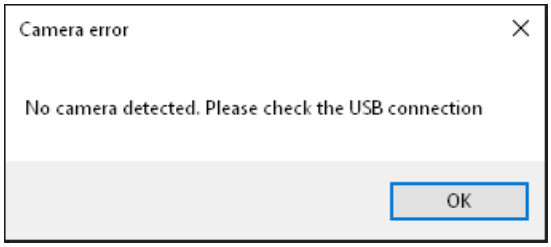


Figure 81 – Camera connection error 1

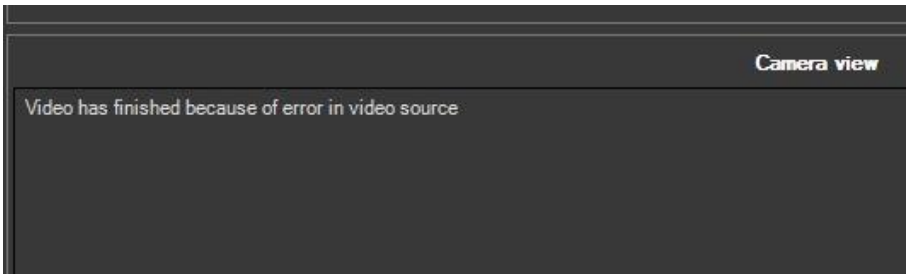


Figure 82 – Camera connection error 2

5.3.2 XY STAGE ISSUES

Issue	Possible cause	Fixes
No stage detected error message (Figure 83)	• Stage not properly connected to the computer • Controller powered off	• Check that the controller is powered on and properly connected to the computer • Check the connection between the stage and the controller
XY stage menu disabled	Stage not connected to the computer	Same as above
Visible stage shift during manual control in the coordinates panel in the XY stage control window (Figure 32)	Software-corrected stage motion activated	*Phaos* displays the corrected coordinates relative to the projected image (not an issue). Stage corrections can be disabled (see section 4.3) but will result in bad image stitching.

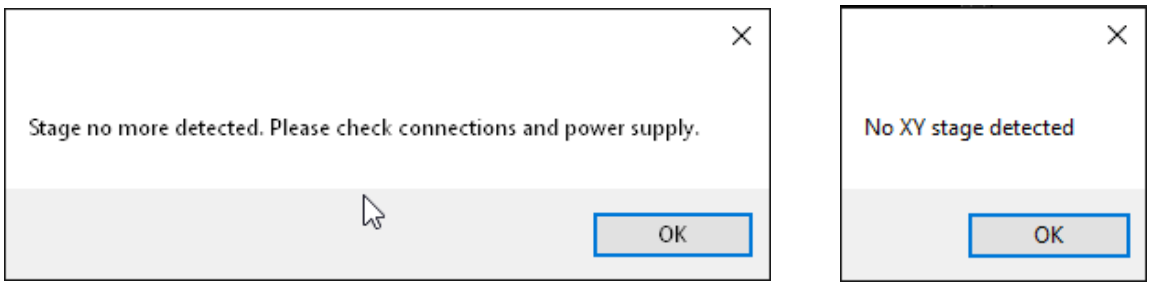


Figure 83 – XY stage connection errors

5.3.3 VECTOR DRAWING CONVERSION ISSUES

Issue	Possible cause	Fixes
The calculated dimensions of the vector drawing do not correspond to the real values	The dimensions calculated by KLayout had not be taken account by *Phaos* (latency problems)	Reload the drawing in the conversion module (button **Load gds, dxf, oas, cif**)
The output image is blank	• Dimension error (refer to the problem above) • The vector file is corrupted or contains unknown elements to KLayout	Open the vector file in KLayout and check the drawing then save it in .gds from KLayout. If KLayout cannot displays some patterns it means the file is probably damaged. If so, try to save it again from the software used for its creation
The patterns of all layers overlap or are hidden by a big black object	All layers (hidden or not) are converted	Open the vector file in KLayout, remove all undesired layers then save changes as a new file. Try the conversion in *Phaos* with the new file
A grid is visible on the output image. The patterns are not filled or not black	KLayout is not correctly configured	Follow the instruction below that table "re-install and configure KLayout"
Conversion failed No conversion	• The vector file is corrupted or contains unknown elements to KLayout • KLayout is not correctly installed/configured	Refer to issue n°2 of that table tableau. If the issue is not fixed, follow the instructions below

RE-INSTALL AND CONFIGURE KLAYOUT

Step 1: KLayout installation

If KLayout is not already installed on the computer, go to https://www.klayout.de/build.html and download the latest version for Windows 64 bit with installer. Once download is finished execute the installer in administrator mode by right-clicking on the installer and choosing **Run as Administrator**. When the installation window is opened click on **Install** (Figure 84). Klayout shortcut is installed in the Window menu or can be found by typing "KLayout" in the Windows search field.

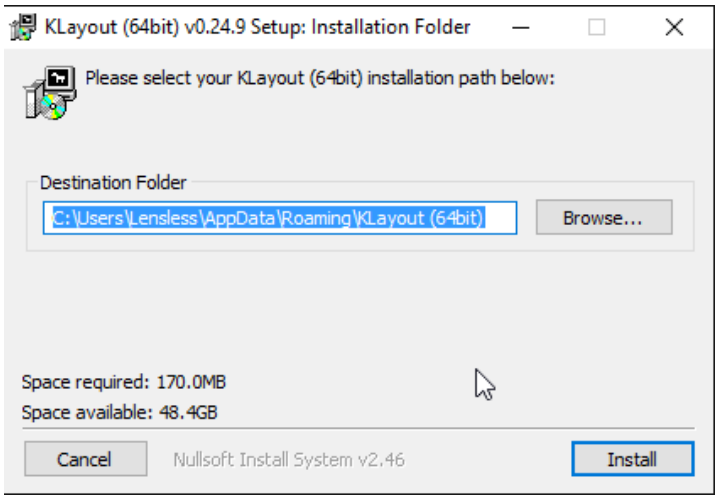


Figure 84 – KLayout installation window

Step 2: Configuration of KLayout

Run KLayout (first start may be longer because of the initialization index). Go to menu **File → Setup** (Figure 85, left). On the **Settings window**, go to **Display → Background** and uncheck **Show background decoration** (Figure 85, right). Click on **Apply** and then **OK**. Close KLayout.

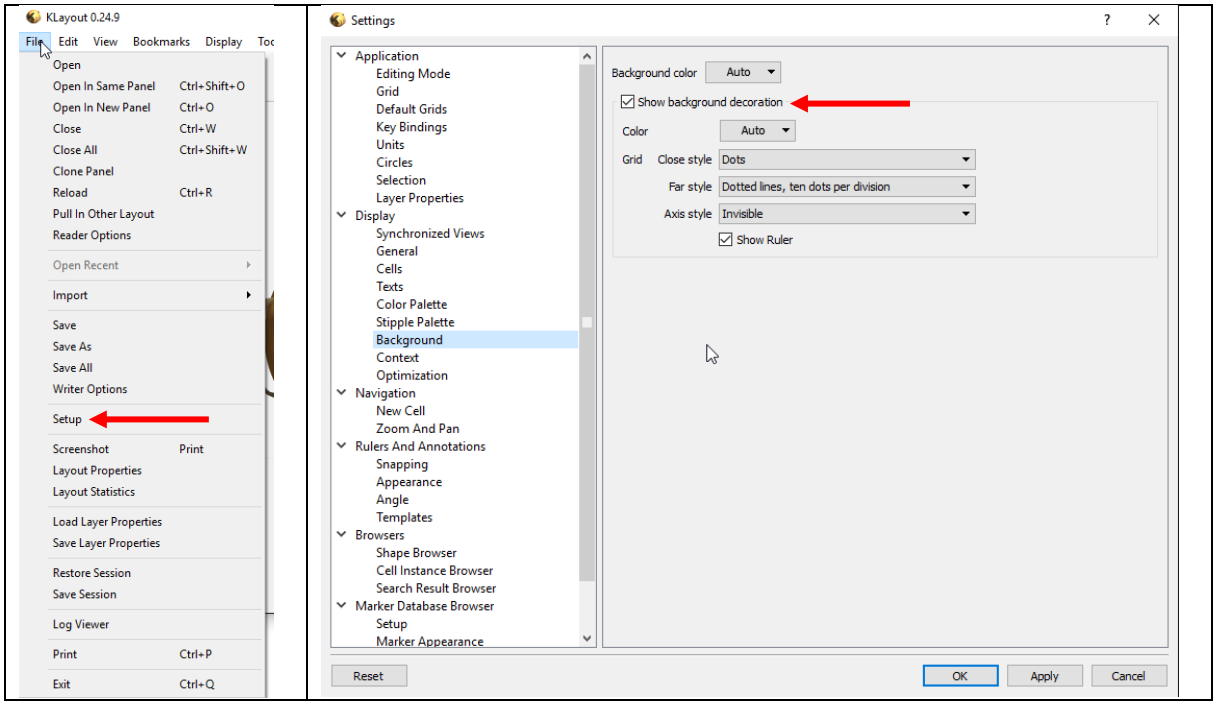


Figure 85 - Configuration of KLayout

Step 3: Configuration of *Phaos* (only required in case of issue)

If the destination folder of KLayout has not been changed by the user, *Phaos* will configure the linking automatically.

If KLayout is not found by Phaos (admin privilege required): Go to the menu **Phaos → Settings**. In the **Importation** tab, click on **Define klayout_app.exe filepath…** (Figure 75). In the **Open** window, find and select the executable file *klayout_app.exe* (Figure 86).

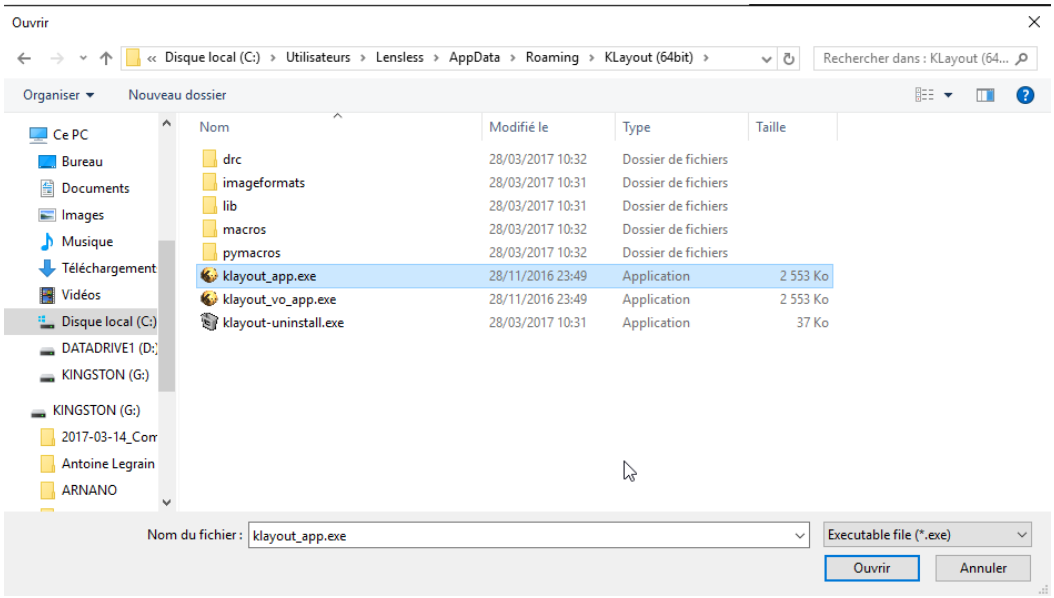


Figure 86 – Folder containing the KLayout executable

6 APPENDIX

6.1 SPECIFICATIONS

LITHOGRAPHY		
	Light illumination	Filtered blue light between 430 and 470 nm Power = 11 mW * or 17.7 mW **
	Lamp lifetime	3900 h
	Resist compatibility	g-line resists (with light sensitivity around 435 nm)
Resists already known to work	AZ1500 Series *(MicroChemicals)*	Positive resist Thickness: 0,5 - 4 µm Typical exposure time (with obj. x2.5): 6 s *
	AZ4562 *(MicroChemicals)*	Positive resist Thickness: 5 - 40 µm Typical exposure time (with obj. x2.5): 11 s *
	AZ5214E *(MicroChemicals)*	Reversible resist (positive or negative) Thickness: 1 - 4 µm Typical exposure time (with obj. x2.5): 10 s *
	AZ125nXT *(MicroChemicals)*	Negative resist Thickness: 35 – 180 µm Typical exposure time (with obj. x2.5): 100 s *
	S1800 Series *(Shipley)*	Positive resist

		Thickness: 0,5 - 4 µm Typical exposure time (with obj. x2.5): 6 s *
	ma-P 1275 G *(Micro Resist Technology)*	Positive resist optimized for grayscale lithography Thickness: 20 – 60 µm Typical exposure time (with obj. x2.5): 40 s *
	Laminar E9220 *(Eternal Mat.)*	Negative resist dry film Thickness: 6 – 100 µm Typical exposure time (with obj. x2.5): 30 s *
	Riston FX930 *(Dupont)*	Negative resist dry film Thickness: 30 µm Typical exposure time (with obj. x2.5): 40 s *
Substrate compatibility	Dimensions	Up to 100 mm wide flat substrates
	Materials	All

Performances

Objective	Field of view (mm)	Pixel size / Precision (µm)	Smallest achievable structure (µm)	Light power density ($mW.cm^{-2}$)	Depth of field (µm)
x 0.5	25.6 x 14.4	13.33	< 40	2.6 * or 4.8 **	2080 ± 220
x 1	13.6 x 7.7	7.12	< 23	10.2 * or 16.9 **	1850 ± 50
x 2.5	5.4 x 3	2.82	< 8	63.7 * or 109 **	155 ± 5
x 5	2.7 x 1.5	1.41	< 4	254.8 * or 437 **	51 ± 7
x 10	1.35 x 0.75	0.705	< 2	1019 * or 1750 **	10 ± 5

CAD AND COMPUTER		
Drawing	Recommended size	1920 x 1080 pixels
	Color	Black & White or 8bits gray levels – without transparency
	Format	.png, .tiff, .bmp, .jpg (lossless) OR after conversion .dxf, .gds, .oas, .cif
Computer requirements	Processor	Intel Core i3 or better
	Memory (RAM and HDD)	4 Go of RAM or better 50 Mo on the HDD
	Ports	1 HDMI port and at least 3 USB ports (including 1 USB 3.0)
	Screen resolution	1920 x 1080
	Display size	At least 17''

MECHANICS		
	Dimensions	80 cm H x 36 cm W x 36 cm D
	Weight	30 kg (without accessories)
	Materials	Aluminum, steel and plastics

POWER REQUIREMENTS

	Supply voltage	100 – 240 V AC ±10%, 50/60 Hz
	Supply current	3.1 – 1.4 A * or 4.7 – 2.1 A **
	Input power	310 – 336 W * or 470 – 504 W **

ENVIRONMENTAL		
	Operating temperature	+5 to +35°C
	Operating humidity	5 to 95 RH, non-condensing
	Maximum altitude	2,000 m (at 25°C)

* for 2019/07 model or earlier

** *for 2019/08 model or later*