SMART PRINT UV

USER'S MANUAL FOR SMART PRINT UV MASKLESS LITHOGRAPHY EQUIPMENT

For Phaos 2.0 or above

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1 GENERAL INFORMATION

1.1 SAFETY INFORMATION

Smart Print UV 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:

- Smart Print UV 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.

1.1.1 SAFETY SYMBOLS

The following symbols and messages can be marked on the unit or used in this manual. Observe all safety instructions that are associated with a symbol.

Symbol	Description
	See the user's manual for instructions on handling and operating the unit safely.
	Indicates hazardous motorized moving parts
	Indicates hazardous voltages

1.1.2 WARNING AND CAUTION SYMBOLS

WARNING	When you see a warning, it denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in *injury or death.* Do not proceed beyond a warning until the indicated conditions are fully understood and met.

CAUTION	When you see a caution, it denotes a hazard. It calls attention to an operating procedure practice, or the like, which, if not correctly performed or adhered to, could result in damage to or *destruction of part or the entire product.* Do not proceed beyond a caution until the indicated conditions are fully understood and met.

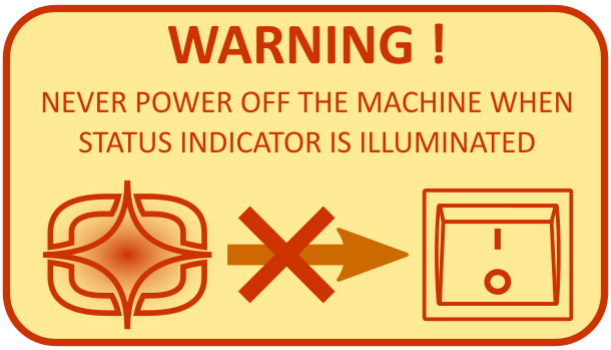
1.1.3 ELECTRICAL SAFETY PRECAUTIONS

Smart Print UV is offered as CE certified machine.

	**Warning** The protective housing of the machine SHOULD NOT be removed. Removal of the protective housing **is prohibited** and should not be performed under any circumstances. NO SERVICEABLE PART INSIDE.

The electrical safety hazards of Smart Print UV should not be ignored, as they are as great as other electrical systems operating from AC power lines. The voltages involved and the current available have the potential to cause fatal electric shock.

 	**Warning** Although the Smart Print UV conforms to CE electrical requirements and additional safety features have been included in their design, the following safety precautions should be noted and observed under the control of the responsible authority after contacting the Microlight3D engineers: 1. Your machine is intended for operation only with the protection lid in place except during loading and unloading your sample. 2. For the sake of safety, NEVER depend upon any electrical safety device or interlock but carefully make other determinations that all power is off and components are de-energized before working on the electrical connections of the machine. 3. Do not allow anyone to perform electrical maintenance on the machine. 4. The IEC connector: **This is a safety feature**. It may be used to disconnect the machine from the mains. It **MUST** remain accessible by the user at any time. 5. The mains cord must be plugged in a socket comprising the earth connection. Disconnection of the earth is forbidden as it may impair the electrical protection and renders the equipment.
 	**Caution** Never disconnect the main cord or switch off the power switch when the machine is ON (front logo indicator is illuminated Figure 10). The machine must be plugged on back-up power protection solution in order to avoid unexpected power failure during use. In case of non-respect of those recommendations, permanent damage of the UV light engine may occur and will be out of scope of manufacturer warranty!

Responsible Authority is defined as an individual or a group of people responsible for the good use or preventive maintenance or servicing of the equipment and whose task is to assure that all person having to use or operate the system is properly trained.

The user's responsible authority of the Smart Print UV should be aware that by operating the product without due regards to the here mentioned precautions, or in a manner that is not compliant with procedures recommended here in this document or with any of the Smart Print UV specification, the protection provided by the equipment may be impaired and cause unsafe operating conditions.

1.1.4 SAFETY RECOMMENDATIONS FOR USING THE SMART PRINT UV

Warning 	When operating the Smart Print UV, it is recommended that you observe the following safety precautions: 1. **UV-A (wavelength = 385 nm) LIGHT SOURCE INSIDE** 2. When operating on the machine, always wear protective glasses adapted to the above light source. 3. Logo indicator (Figure 2): **This is a safety feature**. It MUST BE clearly visible by operator or anyone situated within confined machine environment when operated or not. 4. Protection lid (Figure 2): **This is a safety feature**. The lid must be kept closed as much as possible.

Caution 	The motorized XY stage is the only source of mechanical hazard of the Smart Print UV. Take care of: 1. Movements of the XY stage that are in automatic mode in most cases 2. No obstacles should be placed in the movement trajectory of the XY stage 3. A warning label is attached and visible on the XY stage to prevent mechanical hazard during stage movements. 4. It is highly recommended to perform XY stage motions with the

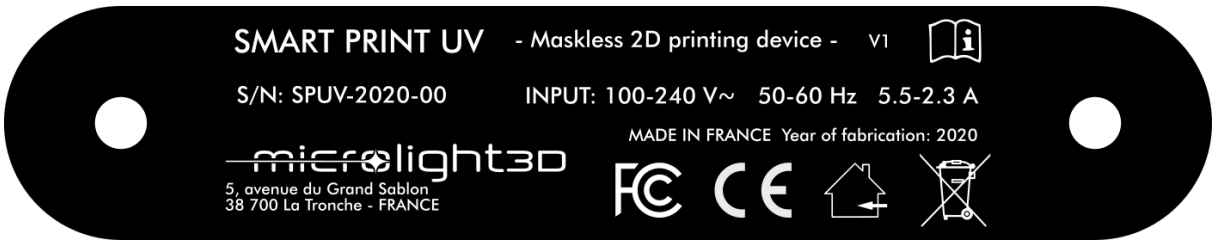
	protection lid closed
Warning 	Never put your hands and fingers along the motion trajectories of the XY stage as it may result in crushing injuries

1.1.5 USE LIMITATIONS OF THE MACHINE

	1. The various modes of operation are: - Fabrication Mode - Observation Mode - Maintenance Mode (please contact Microlight3D) 2. Operation of the machine is allowed in industrial or non-industrial environment. Domestic operation is FORBIDDEN. 3. Machine operation by a people having a partial blindness is strongly discouraged.

	The employer is a security officer of his employees and has to implement any necessary mean to guarantee this safety. Formation to UV light safety is one of this mean.

1.2 IDENTIFICATION MARK



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

WARRANTY AND WORLDWIDE SERVICES

For sales and service information, contact Microlight or your local representative

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Telephone: +33 476 549 516

E-mail: contact@microlight.fr

Please visit our web site at http://www.microlight3d.com/

Available Monday through Friday, 9:00 AM-6:00 PM (GMT-2)

Please contact Customer Service to get a quote, place an order, or check on the status of an order. A team of dedicated customer service professionals is on hand to answer your questions and provide the service and support you need.

2 ABOUT SMART PRINT UV

2.1 GENERAL USE

Smart Print UV is a multi-purpose maskless photolithography tool based on a UV light engine 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

- Smart Print UV 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 Smart Print UV’s objective used.
- The image is projected with UV 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 – Smart Print UV complete setup

2.2.2 FRONT VIEWS

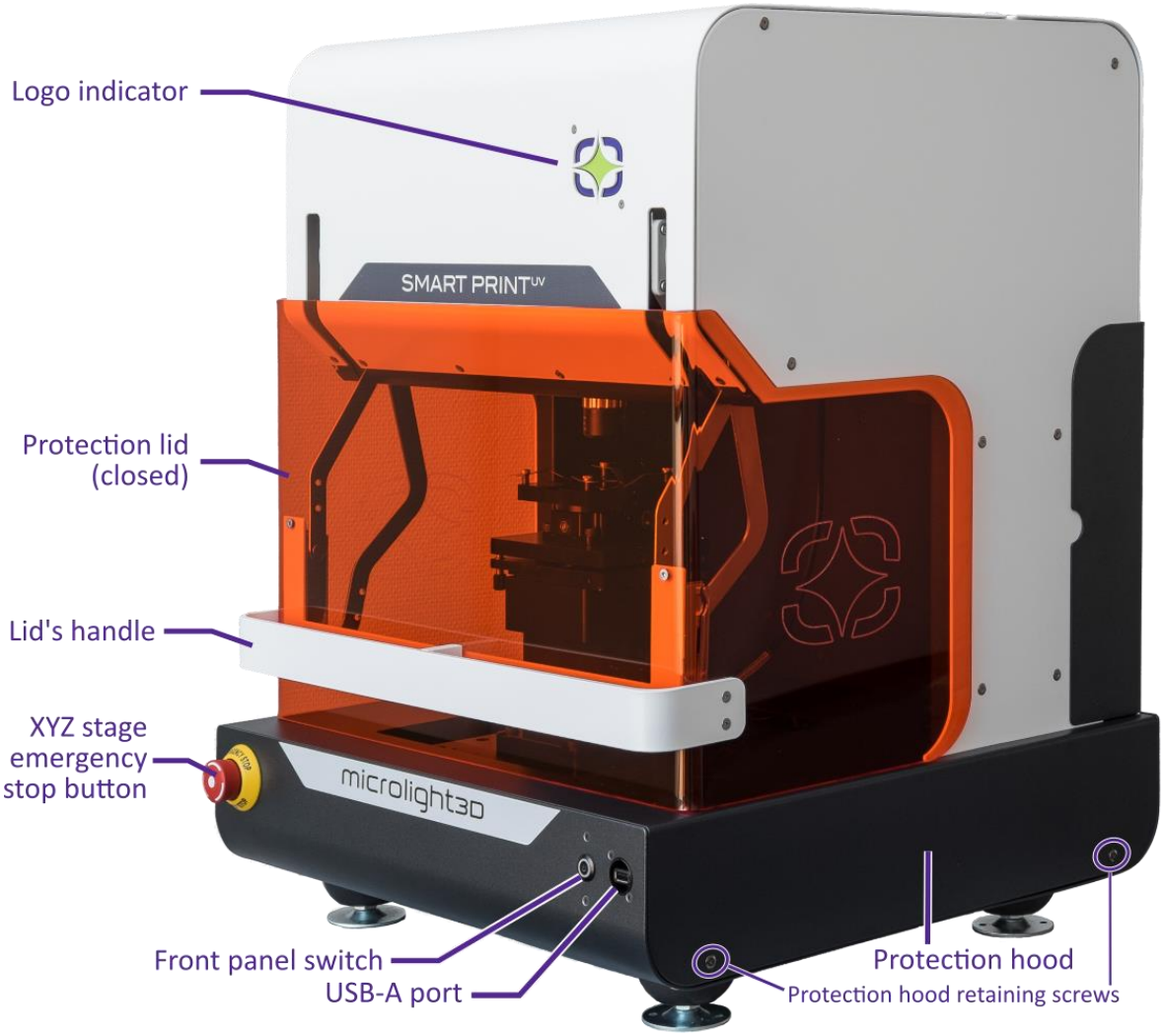


Figure 2 – Front view with protection lid closed

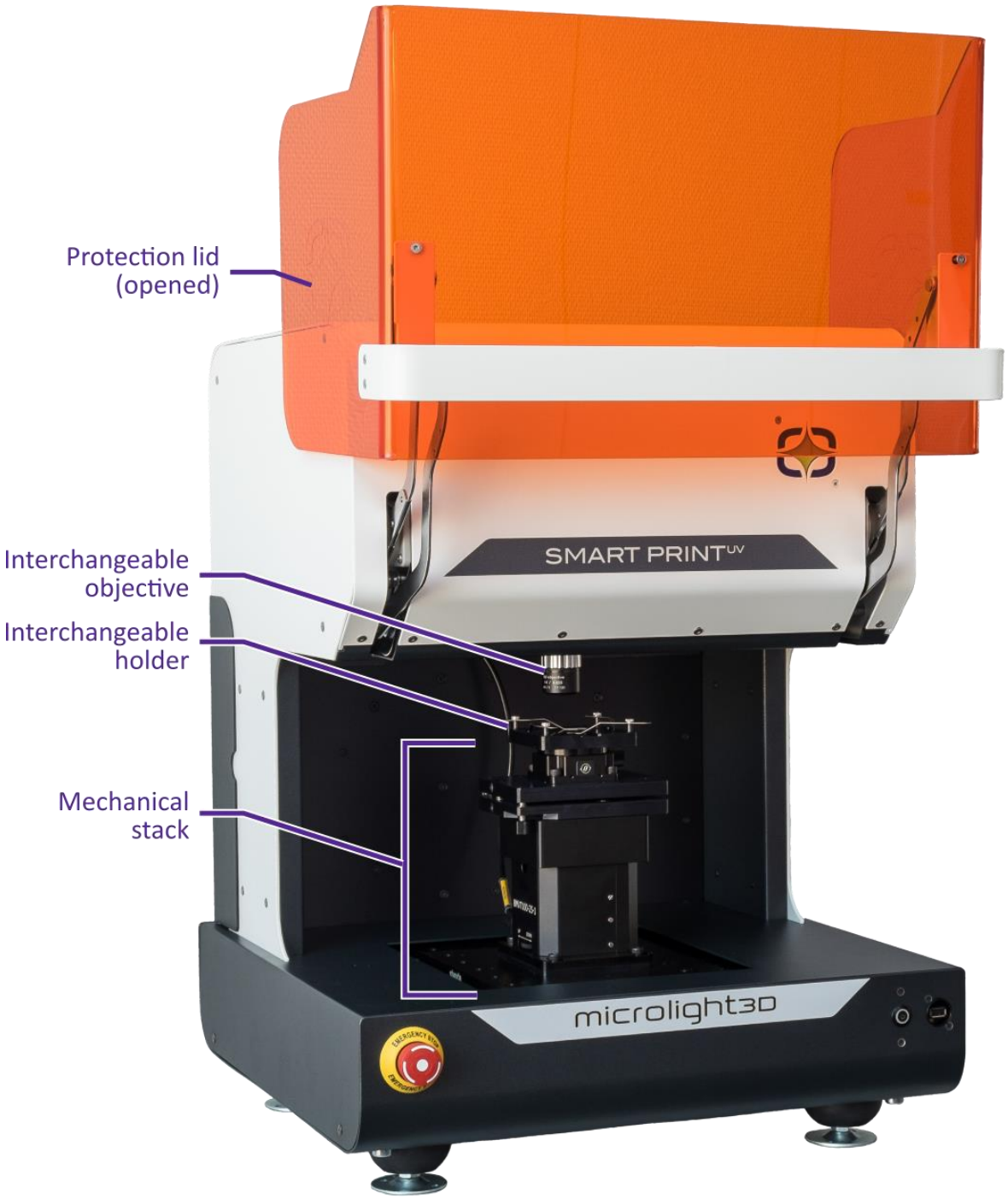


Figure 3 – Front view with protection lid opened

2.2.3 BACK AND TOP VIEWS

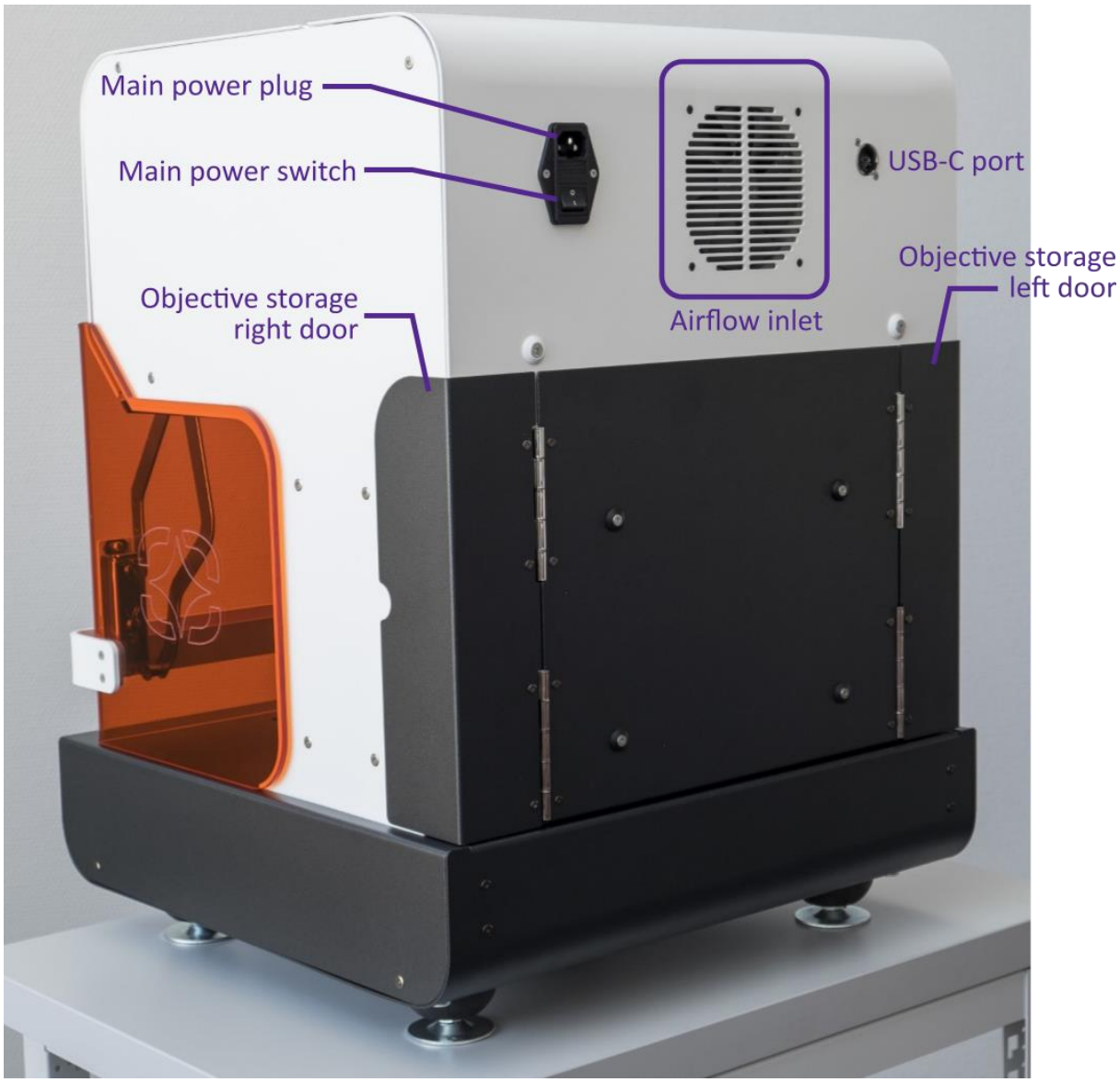


Figure 4 – Back view

Figure 5 - Top view

2.2.4 SMART PRINT UV STANDARD: MECHANICAL CONFIGURATION

It consists in a 5-stack mechanical module (Figure 6) made of (from bottom to top): a motorized XY stage, a motorized Z-lift stage, a manual tilt platform, a manual rotation stage and an interchangeable holder.

The motorized XY stage is configured with the following specifications:

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

The motorized Z-lift has the following specifications:

- Motors: stepper
- Working range: 25 mm (max hardware range 25.4 mm)
- Resolution: 0.625 µm
- Repeatability: 2 µm
- Maximum working speed: 2.5 mm/s

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 ~1.1 µm all over the motorized XY stage range.

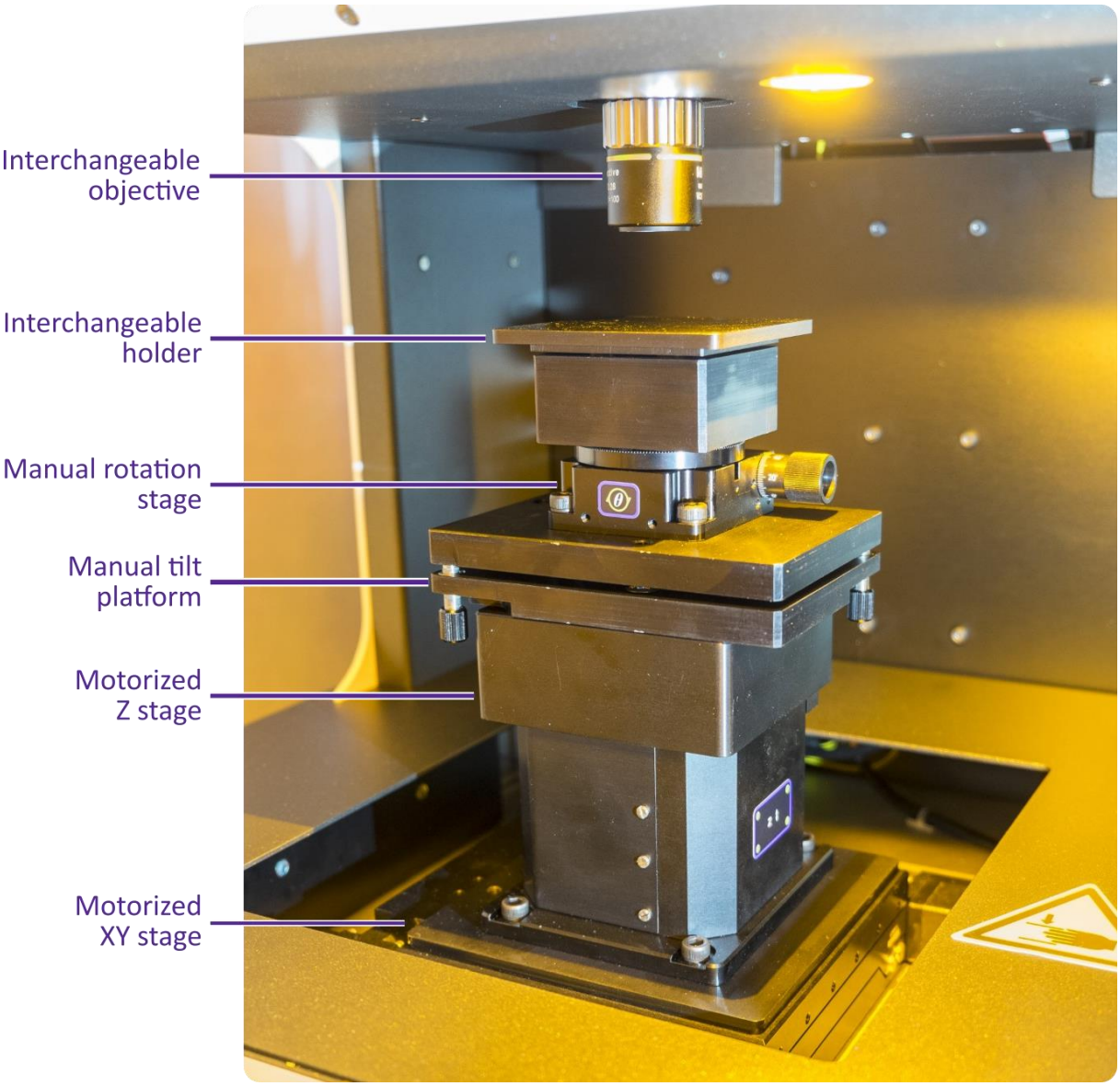
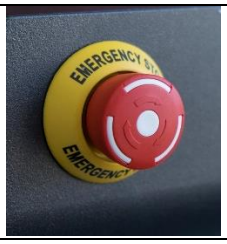


Figure 6 - Inner view of Smart Print UV Standard

WARNING:
As a precaution, in case of danger, the stage can be powered off instantly by pushing the emergency button located on the front side of the equipment. To restart Smart Print UV, turn the emergency button clockwise until it is back to its initial position. Exit *Phaos* software application and restart the computer



2.2.5 SMART PRINT UV ADVANCED: MECHANICAL CONFIGURATION

It consists in a 5-stack mechanical module (Figure 7) made of (from bottom to top): a motorized XY stage, a motorized Z-lift stage, a manual tilt platform, a manual rotation stage and an interchangeable holder.

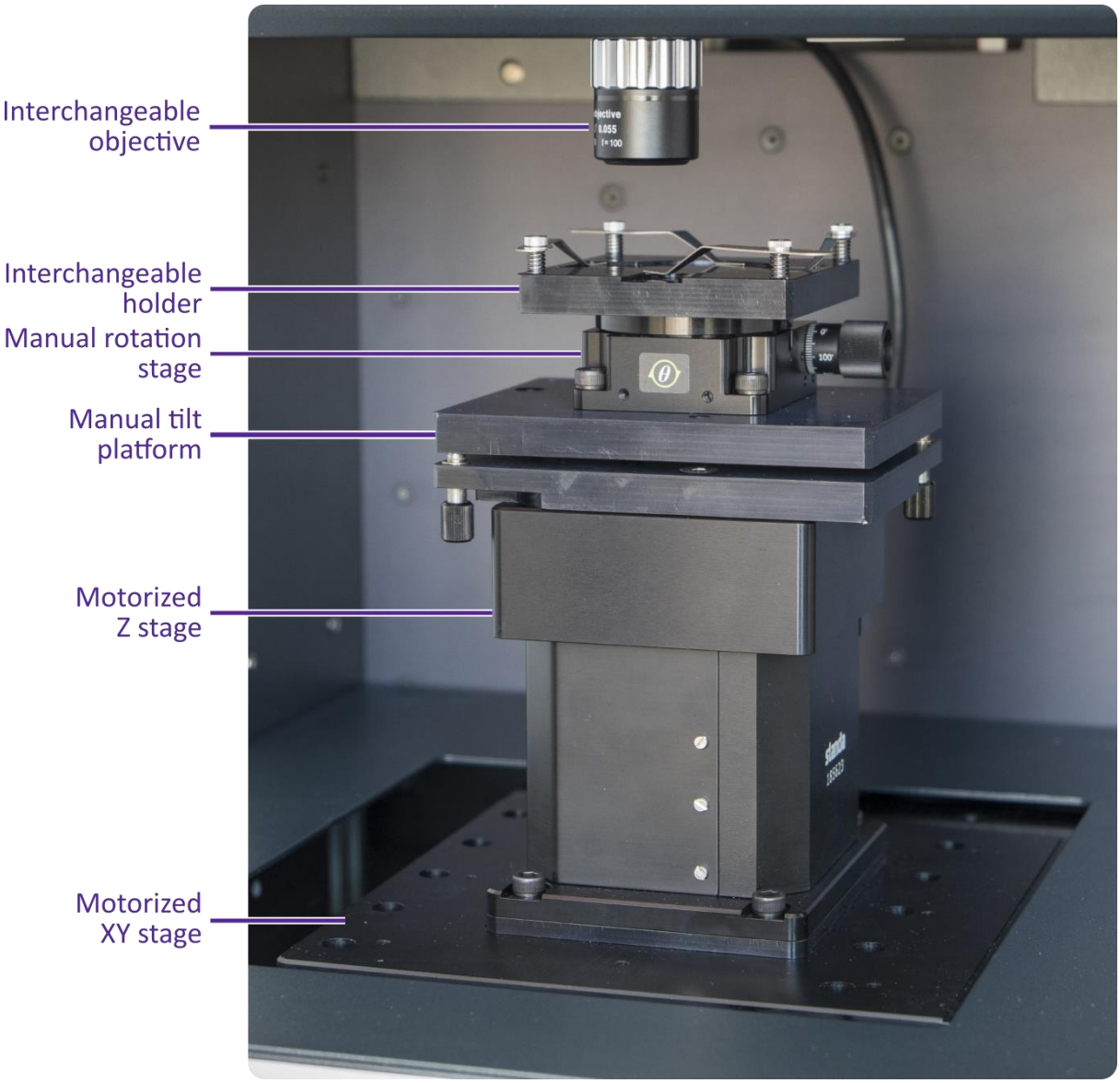


Figure 7 – Inner view of Smart Print UV Advanced

The motorized XY stage is configured with the following specifications:

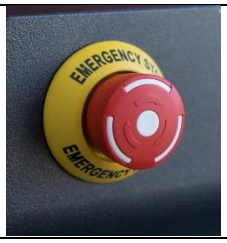
- Motors: brushless DC linear
- Working range: 118 mm x 118 mm (max hardware range 120 mm x 120 mm)
- Resolution: 0.1 µm
- Repeatability: 0.25 µm
- Maximum working speed: 50 mm/s

The motorized Z-lift has the following specifications:

- Motors: stepper
- Working range: 25 mm (max hardware range 25.4 mm)
- Resolution: 0.625 µm
- Repeatability: 2 µm
- Maximum working speed: 2.5 mm/s

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 ~1.7 µm all over the motorized XY stage range.

WARNING:
As a precaution, in case of danger, the stage can be powered off instantly by pushing the emergency button located on the front side of the equipment. To restart Smart Print UV, turn the emergency button clockwise until it is back to its initial position. Exit *Phaos* software application and restart the computer



2.2.6 SMART PRINT UV STANDARD: INTERCHANGEABLE HOLDERS

This configuration is provided with an interchangeable flat holder (Figure 8 left). Two other substrate specific holders can be alternatively used (separate order):

- For standard microscope glass slides (25 mm x 75 mm) → Figure 8 middle
- For 4 inches (100 mm) circular wafers with notch or slab → Figure 8 right

Figure 8 - From left to right: flat holder, microscope glass slide holder and 4'' wafer holder

2.2.7 SMART PRINT UV ADVANCED: INTERCHANGEABLE HOLDERS

Two interchangeable holders are available with the advanced version (Figure 9):

- **For small samples.** Designed for standard glass slides (75 mm x 25 mm or 3" x 1"), for 2" wafers or any smaller samples
- **For large samples (separate order).** Designed for the following standardized substrates:
  - 25 mm wide circular glass coverslips
  - Glass slides (75 mm x 25 mm or 3" x 1")
  - 2" and 4" wafers
  - 4" and 5" squared glass window

CAUTION:
Holder should be placed in front (purple arrow) of the user as shown in Figure 9. If it is not set correctly, there is a risk of unwanted motion during the use of the motorized XY stage.

Figure 9 – Left: holder with clips for small samples, Right: holder with magnetic plate for large samples

2.3 EQUIPMENT STATE

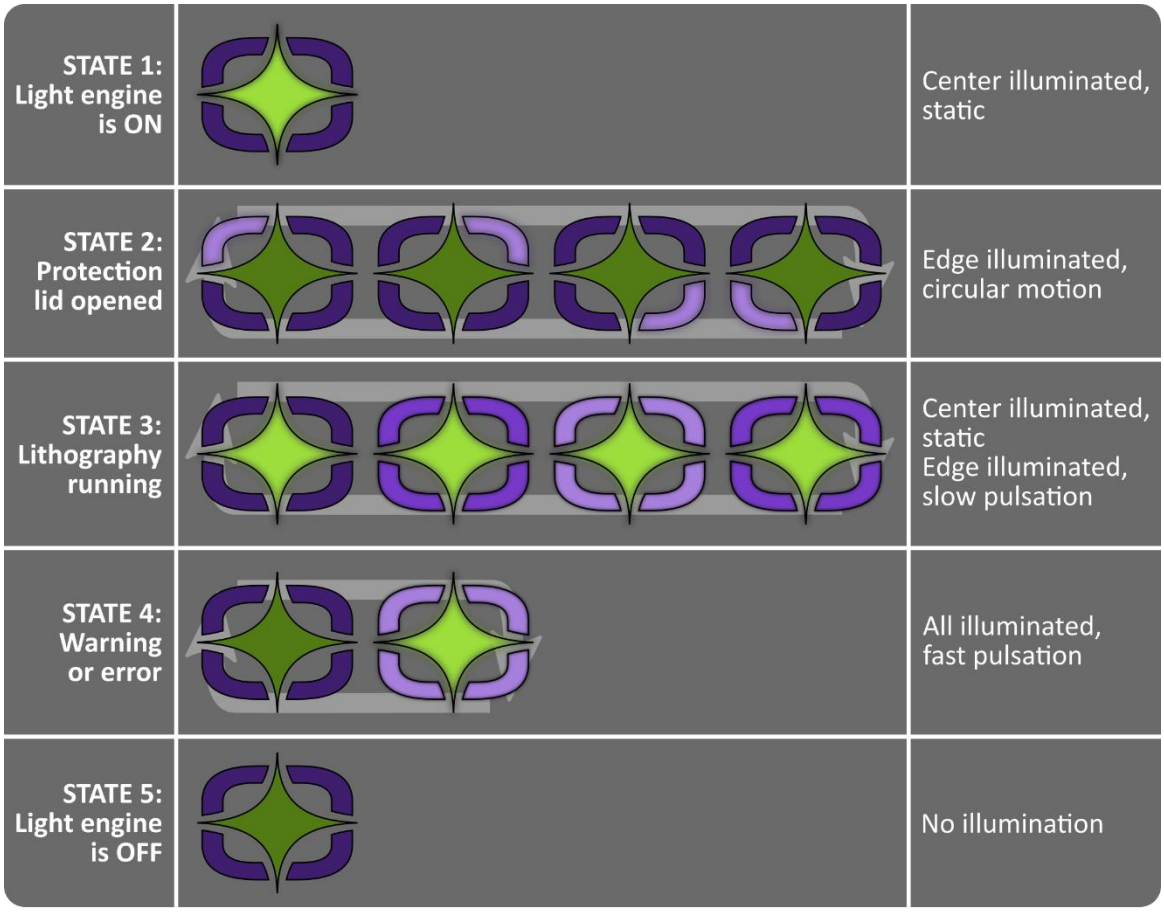


Figure 10 - Logo indicator states

2.4 SOFTWARE DESCRIPTION

The software main interface is composed of 6 panels (Figure 11):

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.** It contains the light engine general state, the access to the room lighting and the setup for each illumination source.
VI. **STAGE Panel.** It contains the most common stage control options (visible only if Smart Print UV is equipped with XY(Z) motorized stage).

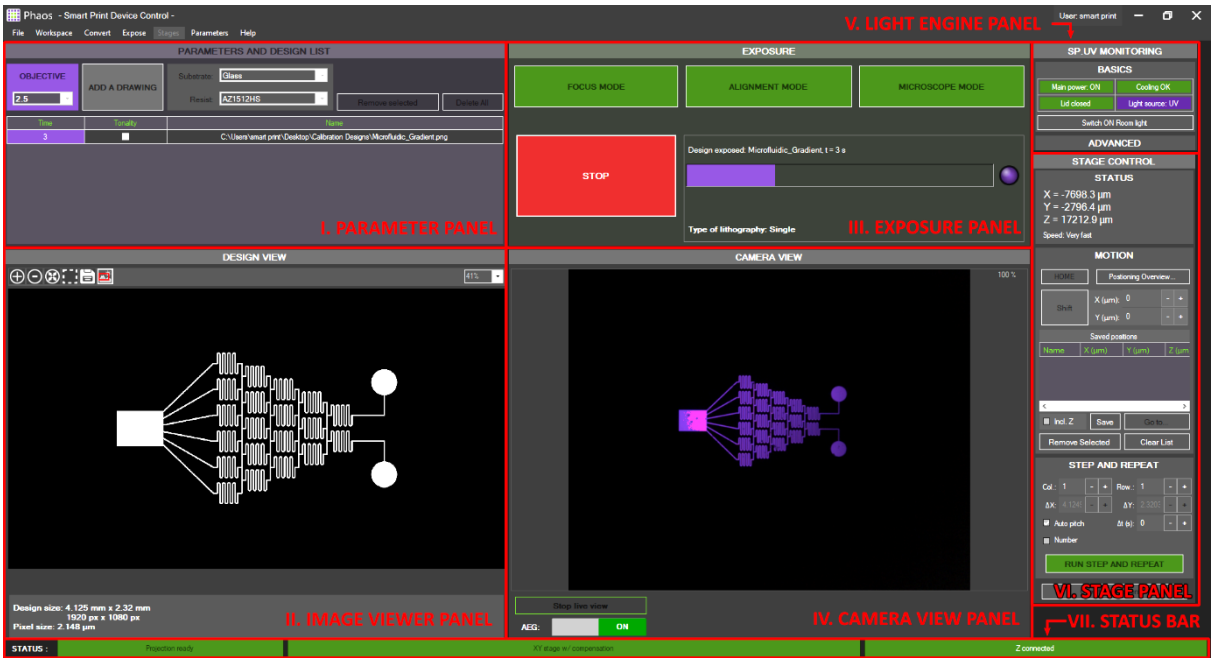


Figure 11 – Phaos main window

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

3 PROCESSING WITH SMART PRINT UV

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 75 cm and depth of 80 cm and a recommended inclination below 1°. The working surface must be adapted to support the weight of the equipment (100 kg). Recommended max tolerated weight for the support is 250 kg.

- A free space of at least 15 cm wide must be kept on the back side and top side of the equipment to allow a proper cooling of the optoelectronic head and access to the main power cable.

WARNING:
The main power cable must be easily accessible as it may be used to disconnect the machine from the mains.

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.

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

RECOMMENDED PROCEDURE

To remove the equipement from its carrying case and install it on its working surface, a stacker with adjustable fork separation and a load capacity above 120 kg can be directly used.
In the absence of adapted mechanical handling machine, follow the above instructions:

- To remove the equipment from its carrying case, use the harnesses and straps provided. To do this, two persons of similar size should put on the harnesses in a crouching position and then stand up simultaneously. The two wearers can then move, while holding the equipment with their hands, close to the working surface ideally placed near the transport box.
- To lift the equipment and place it on the working surface, use the handles located under the base of the equipment. It is recommended to perform this operation with four persons.

3.2 ELECTRICAL CONNECTION

3.2.1 MAIN POWER SUPPLY

Smart Print UV must be connected directly to an appropriate wall outlet from the main power plug on the back of the machine (Figure 4) via the appropriate cable.

3.2.2 PERIPHERAL CONNECTIONS

- The provided monitor must be connected via its USB-C cable to the USB-C port on the back of the machine (Figure 4).
- The keyboard and mouse must be connected via USB to the monitor.
- Internet access can be provided be plugging a Gigabit Ethernet (RJ45) cable to the monitor.

3.2.3 UNLOCKING THE MOTORIZED XY STAGE (SP-UV ADVANCED ONLY)

To avoid damage during transportation, the XY stage is locked with two fixing flanges. The flanges must be removed before the equipment is powered. The procedure is the following:

1. Unplug the Z-motorized stage cable.
2. Unscrew the stage protection hood (4 Torx T8 screws) in Figure 2.
3. Carefully remove the hood.
4. Unscrew the two flanges (4 Hex M4 screws per flange) located on the right and back of the stage (Figure 12).
5. Put back the hood with its screws.
6. Plug the Z-motorized stage cable.

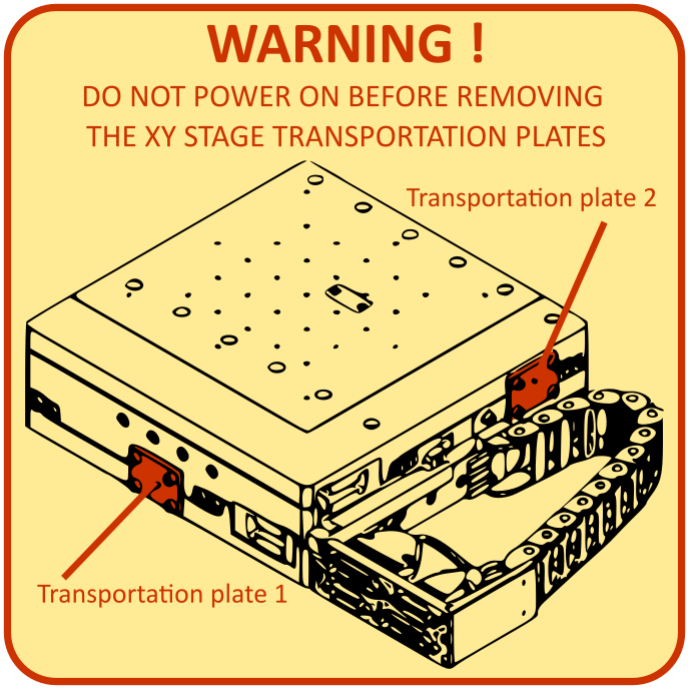


Figure 12 - Fixing flanges' location

	CAUTION: Not respecting the above procedure may occur permanent damage the XY stage.

3.3 QUICK USE

- Switch on Smart Print UV by pressing the main power switch on the back side of the machine (Figure 4) and the front panel switch on the front side of the machine (Figure 2).
- Open the protection lid (Figure 2).
- Place your substrate on the appropriate sample holder.
- On the computer, start *Phaos* software.
- Click on the **DO HOMING** button on the homing warning message (Figure 13) and wait the end of the procedure.

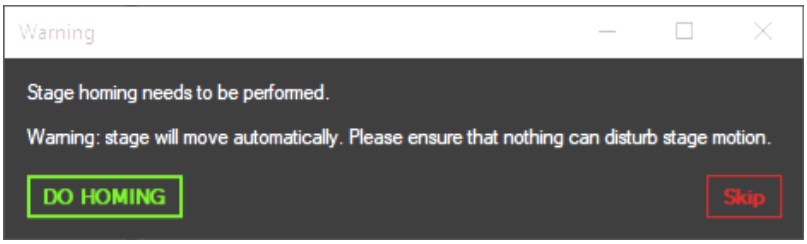


Figure 13 - Homing warning message

- On the **PARAMETER** panel (Figure 11), choose your **objective**, **substrate** and **resist** from the corresponding drop-down lists (Figure 14).

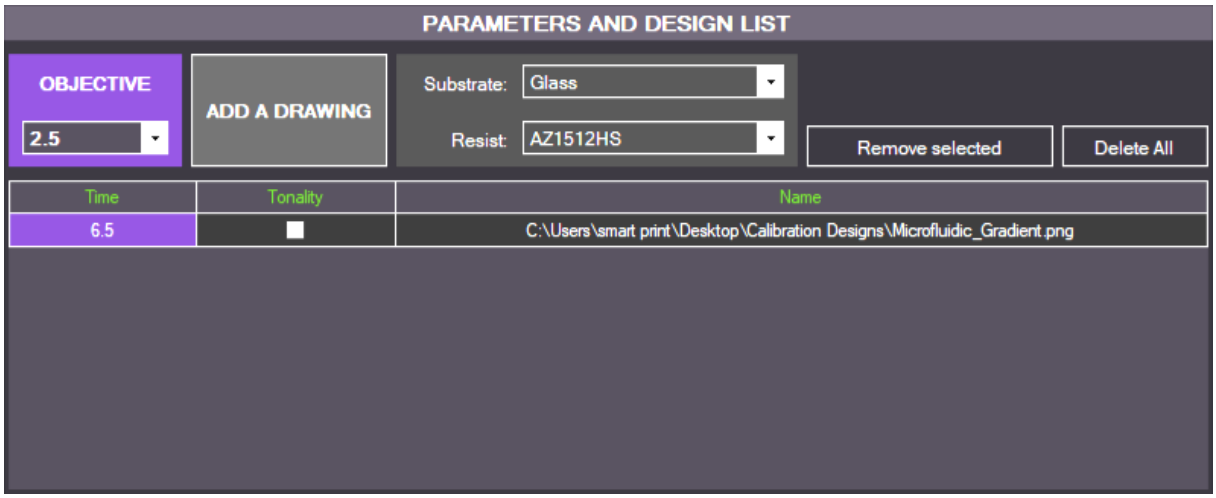


Figure 14 - "PARAMETER" panel

- Load a black & white bitmap drawing (png, tif, bmp, jpg) or a ".stitch" file (see section 3.4.2) by clicking on the **ADD A DRAWING** button.
- Check that exposure time is correct or adjust it by clicking on the corresponding box in the column **Time (s)** and entering the new value.
- Focus the image on the sample (more details in section 3.4.4):
    - Load the sample to be exposed
    - Click on the **FOCUS MODE** button in the **EXPOSURE** panel (Figure 11)
    - Adjust the distance between the objective and the sample using keyboard shortcut ctrl + numpad 9 and ctrl + numpad 3 (section 3.4.4) until a sharp image is visible on the **CAMERA VIEW** panel
- Click on the **EXPOSE SELECTED DRAWING** button (Figure 11) in the **EXPOSURE** panel.
- Once exposure is finished, the sample can be developed and rinsed.

3.4 BASIC OPERATIONS

3.4.1 LOADING/UNLOADING AN OBJECTIVE

Smart Print UV's objectives are attached to the machine via a precise "quick-release" magnetic system.
To load an objective into the head, insert it vertically inside the top aperture into the enclosure of the equipment and then rotate it until a resistive force is felt (Figure 15). 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 15 – 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.

3.4.2 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 3.4.8) 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 16).

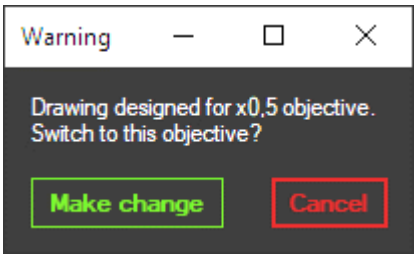


Figure 16 - Wrong objective warning message

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 17). 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 Smart Print UV's resolution (1920x1080), a **(Black)** or **(White)** frame will be added around the drawing

« STITCHING » MODE

This mode slices an image and sequentially expose the corresponding stack of sub-images automatically according to an optimized positioning pattern as shown in Figure 18. When the user is facing Smart Print UV, 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.

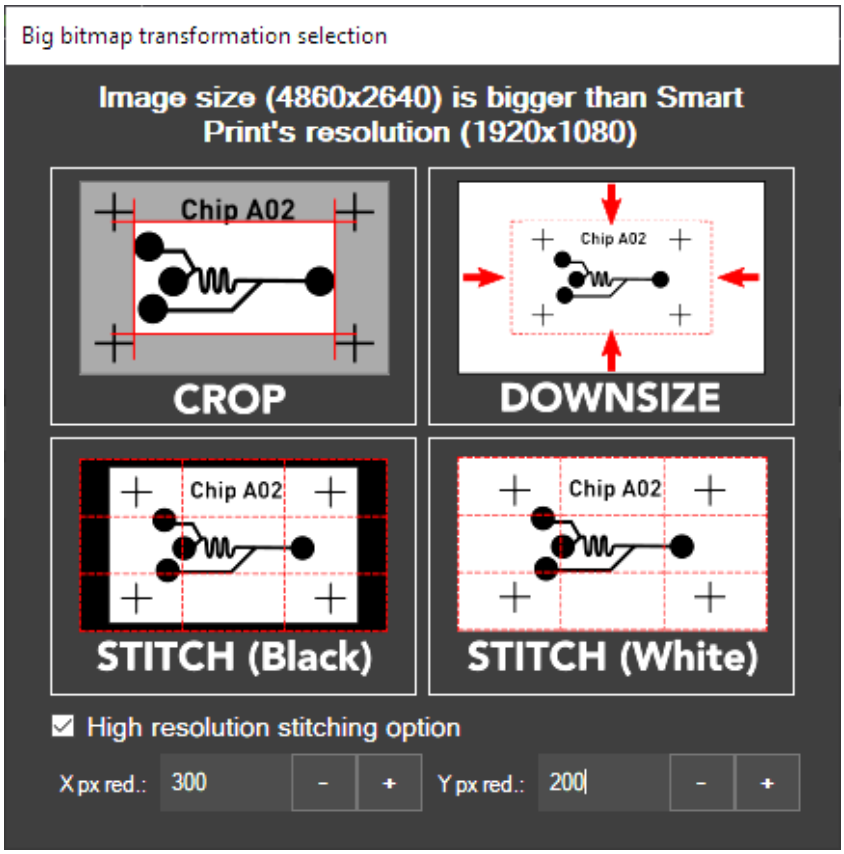


Figure 17 – "Big bitmap transformation selection" popup dialog

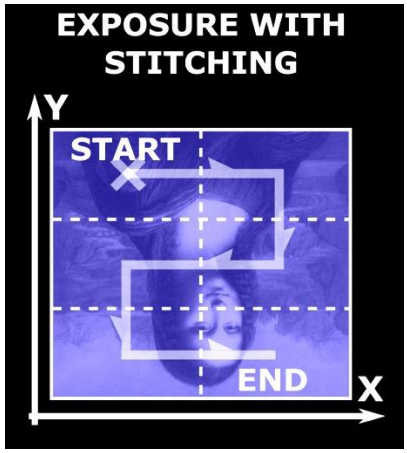
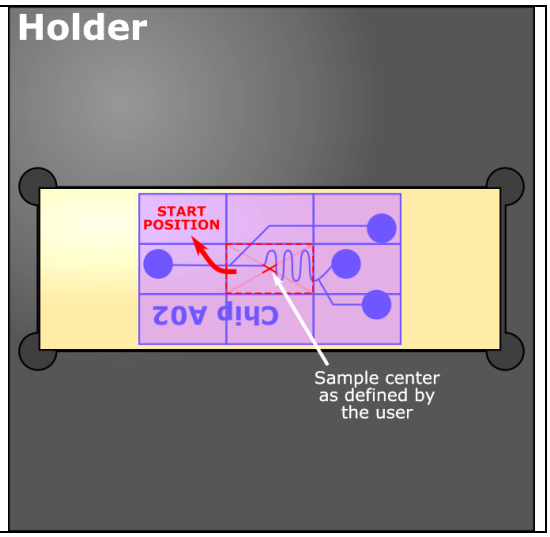


Figure 18 – Exposure principle of the "stitching mode"

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

- In the **PARAMETER** panel (Figure 11), 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 17).
  → A ".stitch" file – preconfigured for exposure in stitching mode – can also be directly loaded (for more details, refer to section 3.4.8).
- Adjust the exposure time if necessary and adjust the focus (see section 3.4.4).

- Position the substrate, using the XY stage, at the starting point for a stitched lithography (START position in Figure 18). 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 4.1.4). The stage will then automatically go to the START position to get your design centered.	

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

Once the exposure is started, a progress bar displays the remaining time (estimated) in the **EXPOSURE** panel (Figure 19).

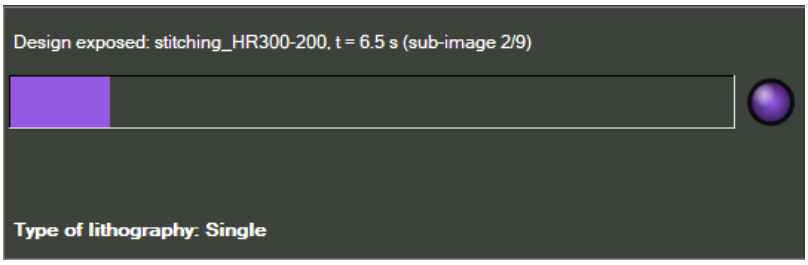
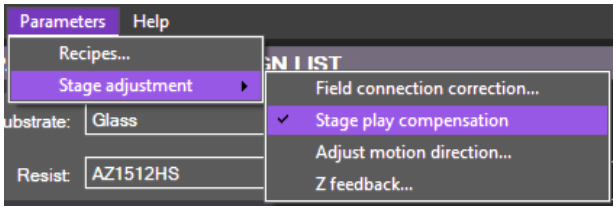


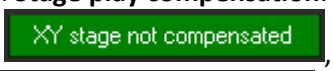
Figure 19 – Progression preview of a stitched lithography

NOTE ON "**HIGH RESOLUTION**" STITCHING: If the high-resolution option is checked on the popup dialog Figure 17, 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).

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. It is only useful for Smart Print UV Standard (equipped with XY stepper motors). 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 

, it means the compensation is disabled. If activated, the status becomes 

.
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 4.4).

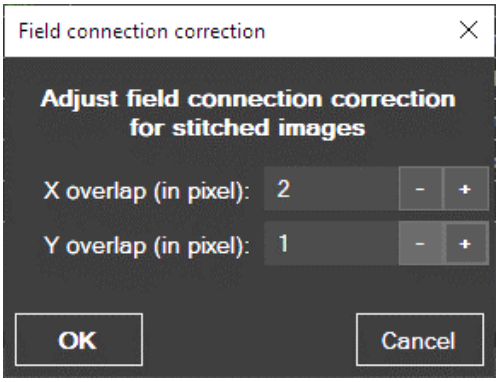


Figure 20 – Field connection adjustment window

The second option to improve lithography, relevant for any Smart Print UV's configuration, in stitching mode is called field connection correction and is only **available for High Resolution** (see the NOTE above) images. Smart Print UV 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 20), 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.
When an overlap is configurated and a compatible drawing selected the equipment status (Figure 11) is updated as shown below:

3.4.3 DESIGN OPTIONS AND PREVIEW

DESIGN SETTINGS

For each design added in the design list (Figure 14), 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.
- **Invert 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.

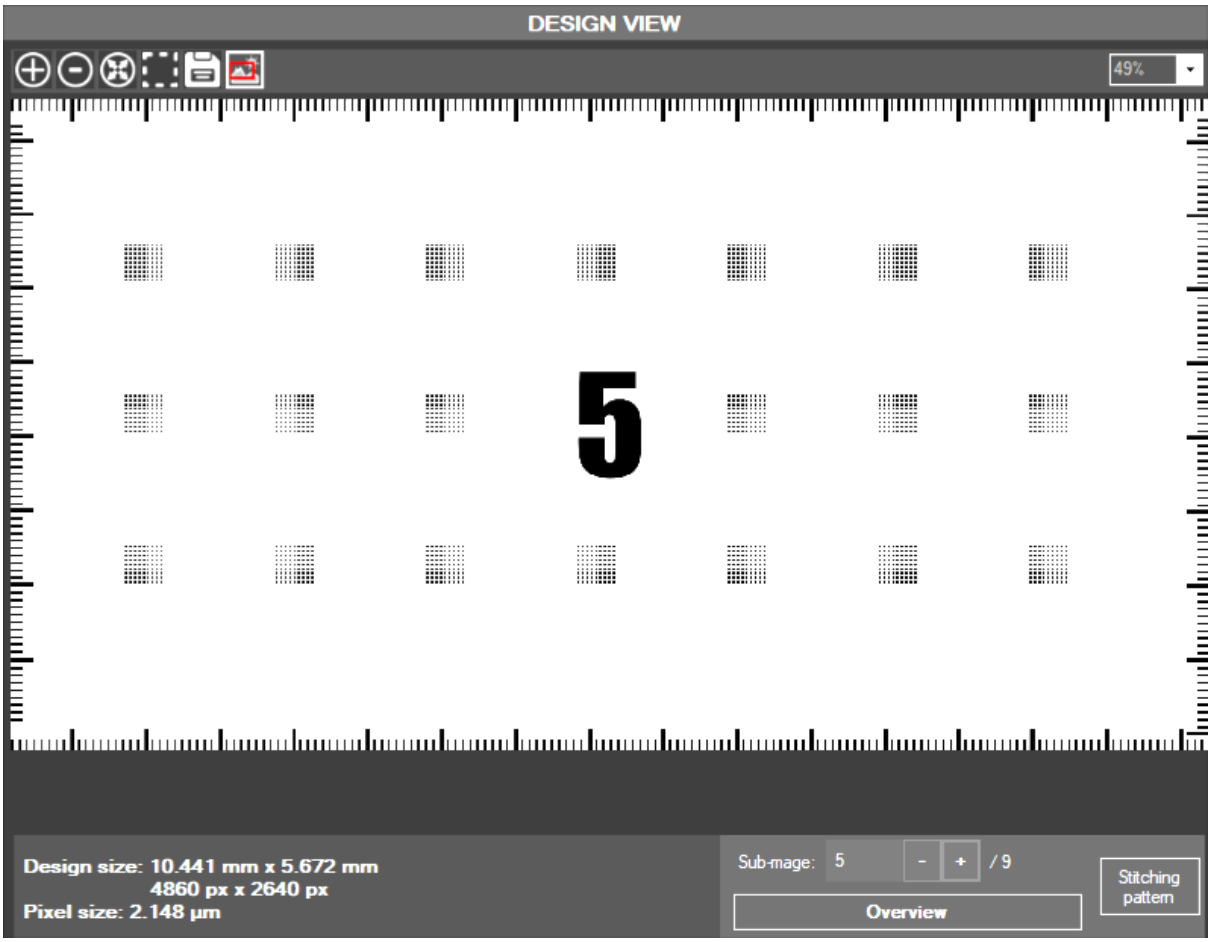


Figure 21 – Image viewer panel

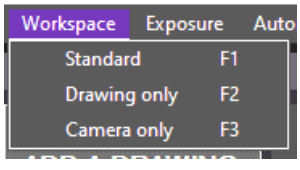
DESIGN PREVIEW

Each selected design is directly displayed in the **IMAGE VIEWER** panel (Figure 21). 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 design 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 mm and in pixels (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 21) or directly enter its stack number.

Clicking on the **Overview** button will open a navigation window showing the complete stitched image (Figure 22). 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.

Finally, the **Stitching pattern** button displays the stitching reminder schematics in Figure 18.

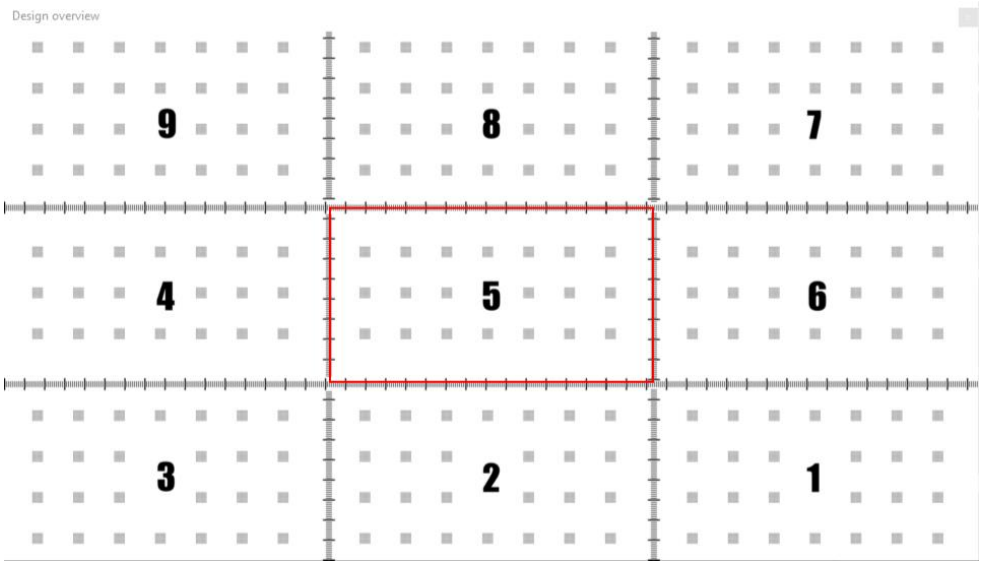


Figure 22 - Overview window corresponding to the stitched image selected in the previous figure

3.4.4 FOCUS ADJUSTMENT

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

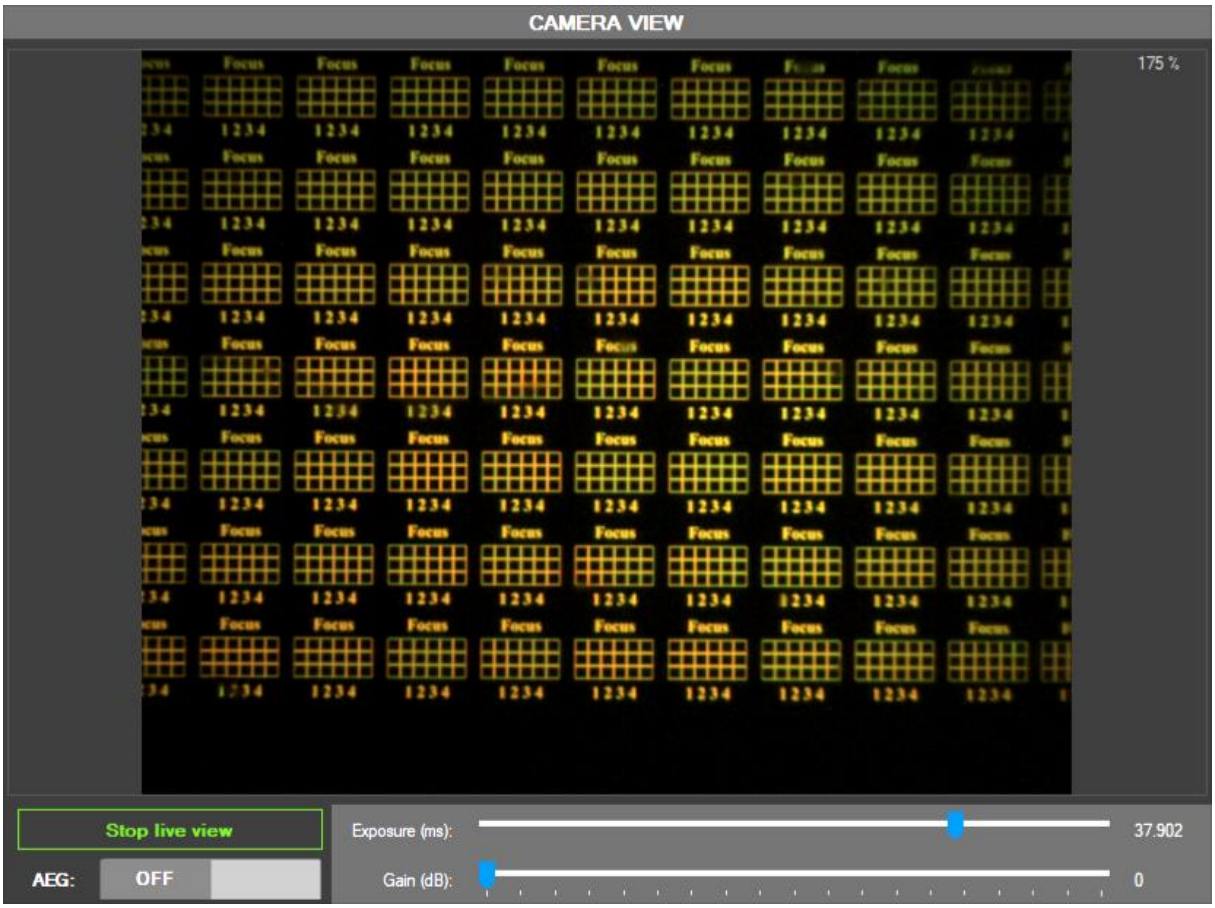
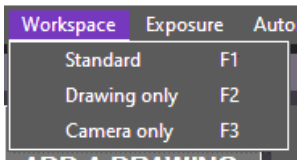


Figure 23 – Camera view panel during focus setting

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

- Load the substrate on the appropriate sample holder.
- On the **PARAMETER** panel (Figure 11), choose your objective.
- Click on the **FOCUS MODE** button in the **EXPOSURE** panel (Figure 11). The camera live view will start automatically in the **CAMERA VIEW** panel (Figure 23).
- If the image in camera view is too dark or too bright (area highlighted with yellow 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.

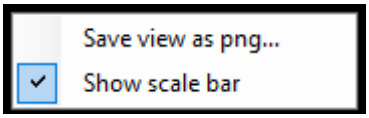


NOTE: If the image displayed in the camera view is too saturated (some area highlighted in yellow), there is a risk of error in the focus adjustment.

- Adjust the distance between the objective and the sample using keyboard shortcut ctrl + numpad 9 and ctrl + numpad 3 (section 3.4.4) until a sharp image is visible on the **CAMERA VIEW** panel.
- Quit the focus mode by clicking on the **QUIT FOCUS** button in the **EXPOSURE** panel.

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.



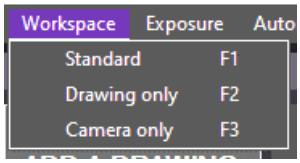
WARNING: Scale bar may need to be calibrated. Refer to OPTICAL CHARACTERISTICS section in chapter 4.4 for the calibration procedure.

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

3.4.5 MICROSCOPE MODE

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

- Click on the **MICROSCOPE MODE** button in the **EXPOSURE** panel (Figure 11). The camera live view will start automatically in the **CAMERA VIEW** panel (Figure 23).
- If the image in camera view is too dark or too bright (area highlighted with yellow 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.



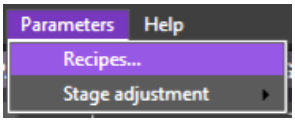
In this mode, the sample is illuminated on the full field-of-view with amber light. To add a scale bar or capture an image, refer to the previous section.

3.4.6 EDIT OR ADD RECIPES

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 your 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 24).



To add a new recipe, click on the **Add** button. An edition panel will appear as shown in Figure 25. Choose an objective magnification (1, 2.5, 5 or 10) and fill the “Substrate”, “Resist” and “Exposure Time” fields. Click on the **OK** button to confirm the addition.

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, click on the **Apply changes and close** button. The window will close automatically.

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.

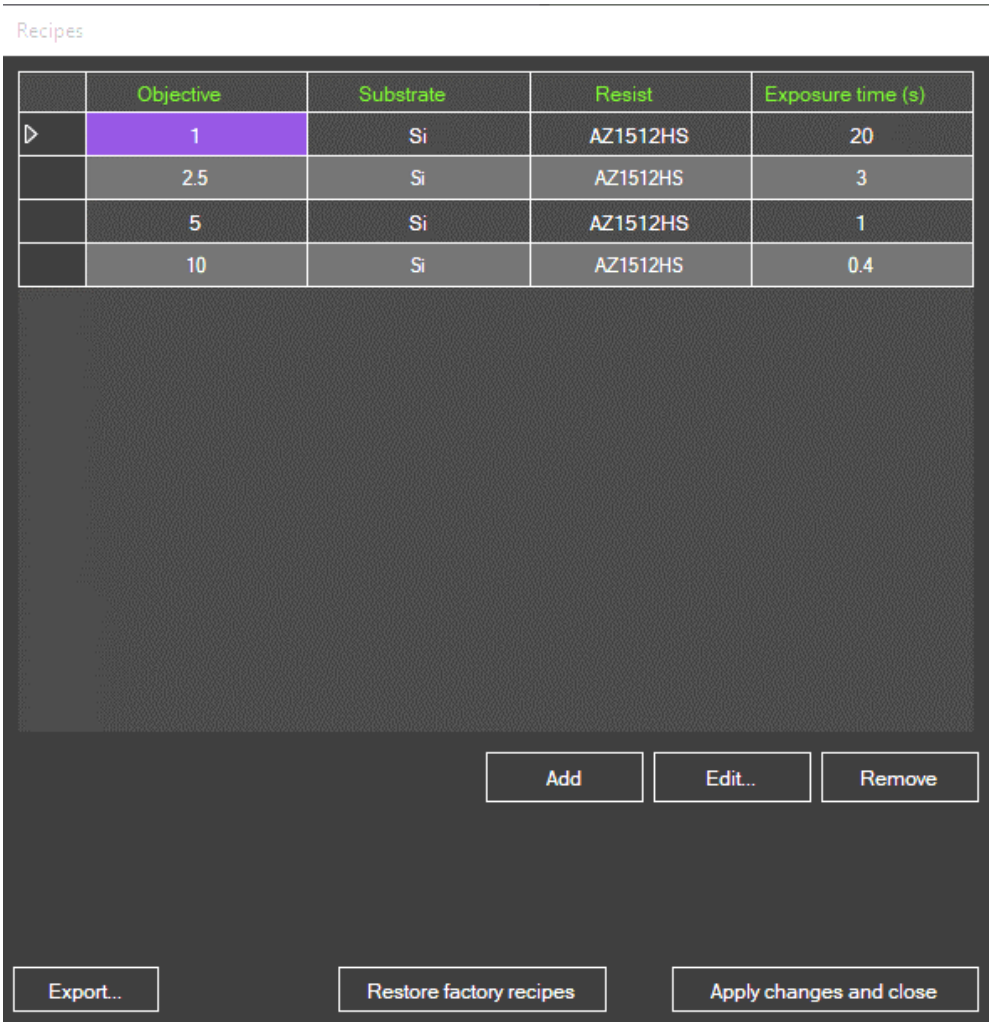


Figure 24 – Recipe database window

Figure 25 – Add/Edit a recipe panel

3.4.7 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.
Parameters that can be saved in a process are:

- Selected design file path
- Objective currently used
- Exposure time
- Design 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

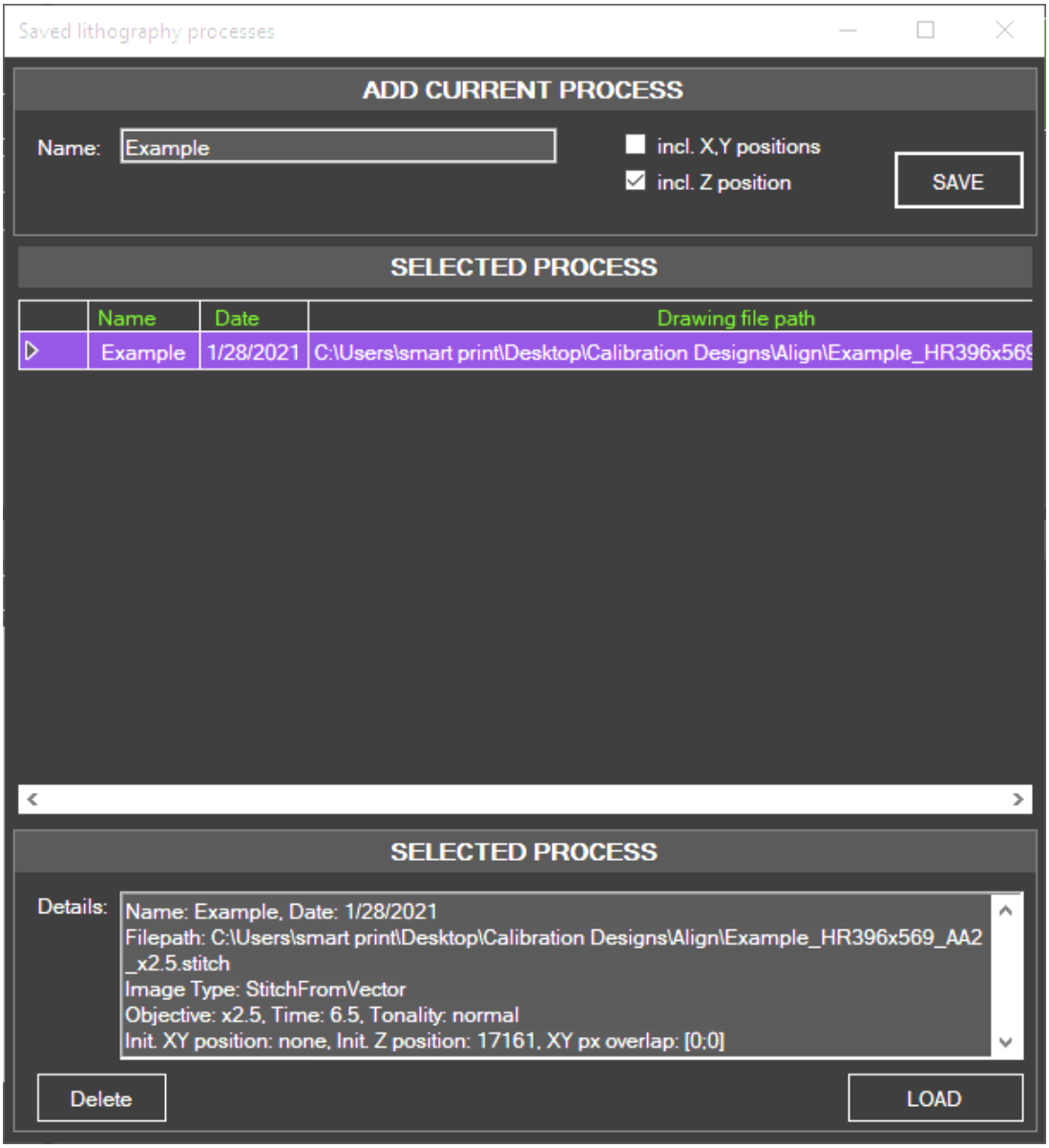
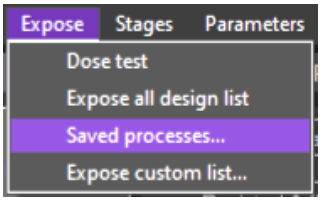


Figure 26 - Process database window

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 (Figure 26), enter a process name in the corresponding 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.

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

WORKING PRINCIPLE

Smart Print UV 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.

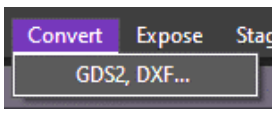
For that purpose, a conversion module is included in *Phaos*. The conversion is performed in synergy with the open-source software application KLayout (installation and configuration detailed in section 5.2.4). The conversion is based on a two-step operation:

- 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 (Smart Print UV 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 27) 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 29). The red dashed grid on the preview image shows how the design will be sliced during conversion.
- In the **LAYER** panel (Figure 28), 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 3.4.2 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.

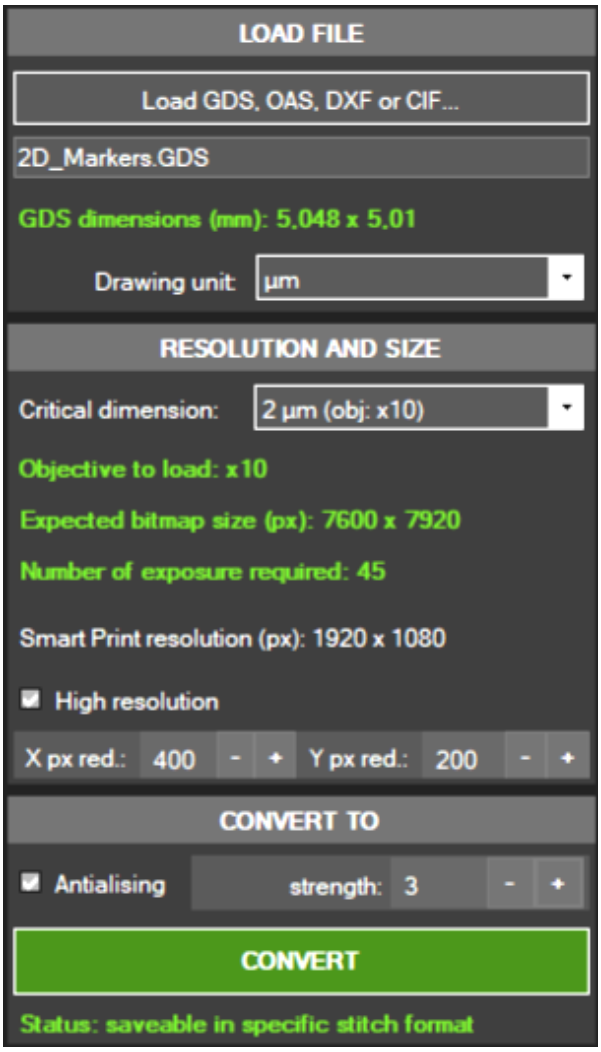


Figure 27 – Vector drawing conversion module – left panel

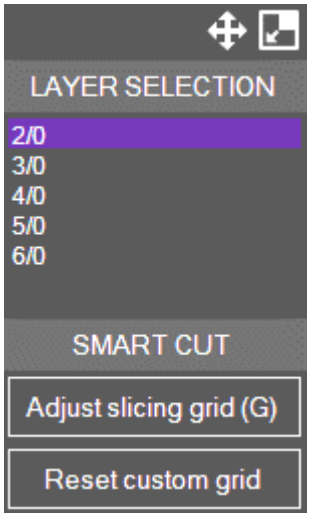


Figure 28 - Layer panel (moveable)

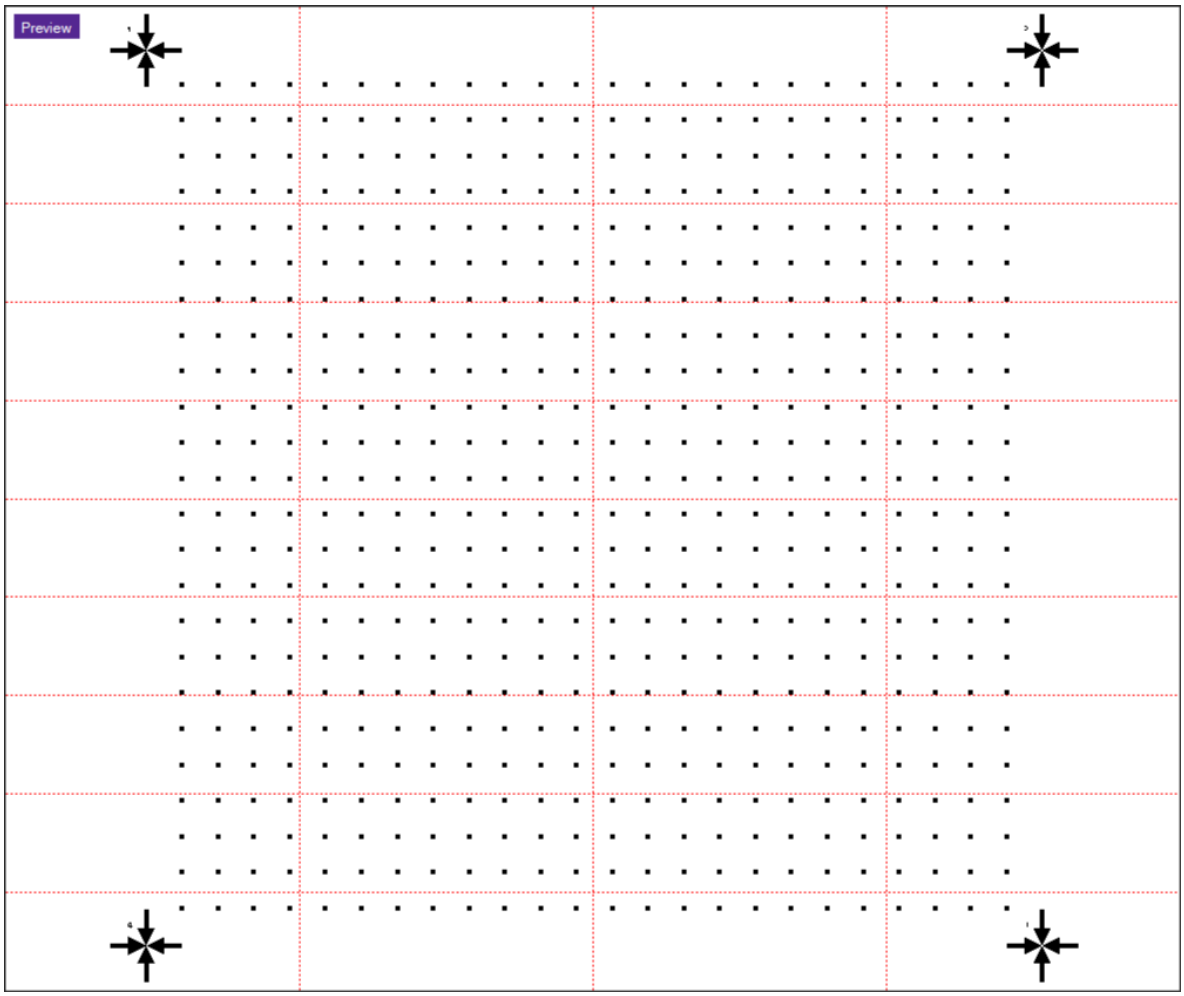


Figure 29 - Example of conversion preview with slicing grid

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 71 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 the **Adjust slicing grid** button in the **LAYER** panel (Figure 28) 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 30 :

- 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 3.4.2 for more information).

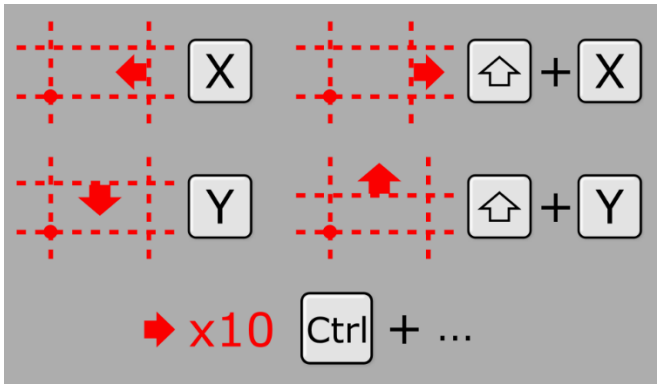


Figure 30 - Smart Cut re-scaling instructions

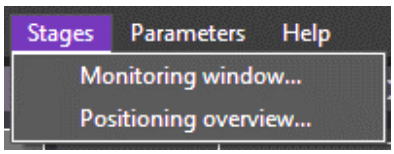
4 ADVANCED PROCESSING

4.1 AUTOMATED LITHOGRAPHY USING THE MOTORIZED XYZ STAGE

4.1.1 STAGE CONTROL: XY

To open the XY stage control interface, go to the **Stages** menu and click on **Monitoring window…**. A new window will open as shown in (Figure 31). This interface can also be launched by clicking directly on XY stage status label 

at the bottom of the main window.



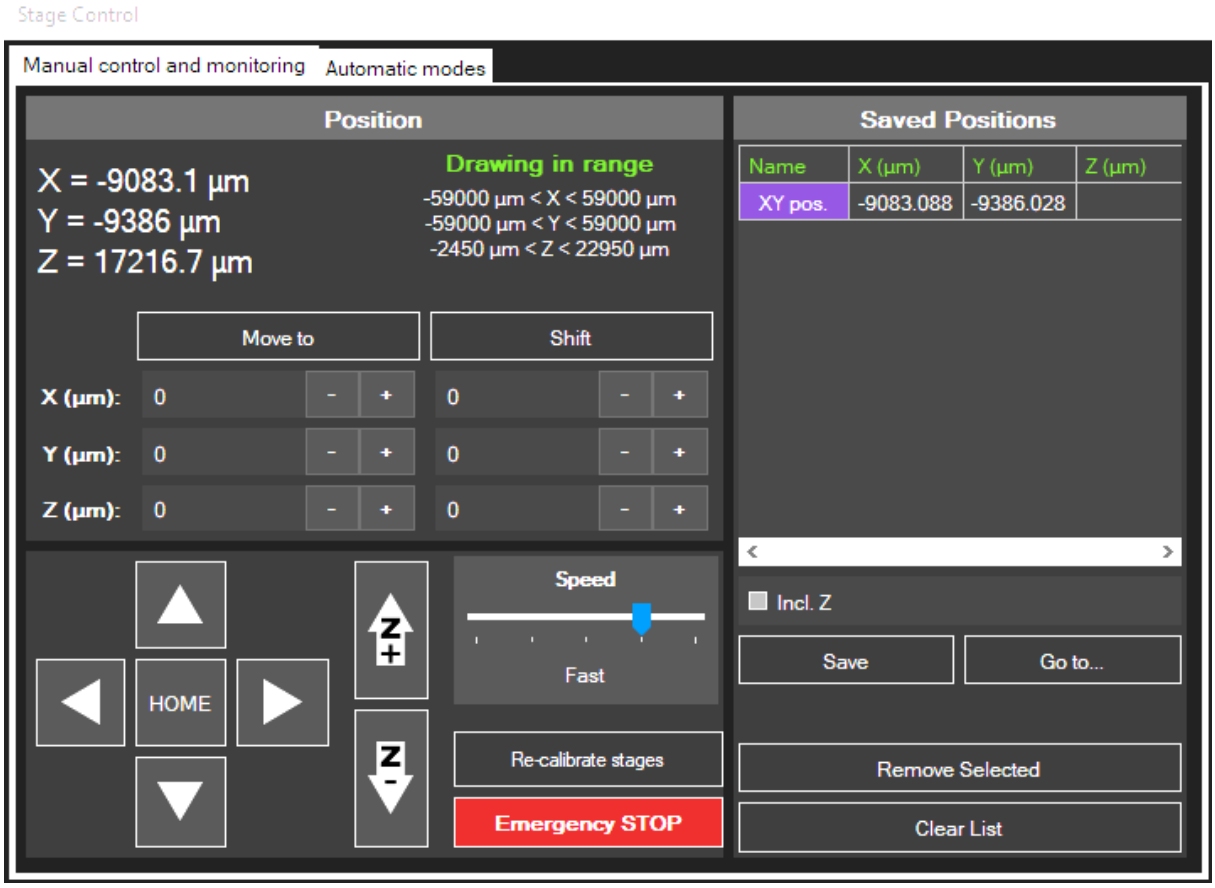


Figure 31 – XYZ stage control and monitoring interface

MONITORING

In the **Manual control and monitoring** tab, the **Position** panel displays the absolute XY 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 by clicking and holding the **Up**, **Down**, **Left** and **Right Arrow** buttons in the **Joystick** 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.

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

Registered motion. 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 **Emergency STOP** button. 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 5.1). After emergency stop and/or re-calibration, all saved positions may be no more relevant.

4.1.2 STAGE CONTROL: Z

The motorized Z stage can be accessed in the same way as for the XY stage, via the **Manual control and monitoring** tab (Figure 31). Motion along the Z axis can be controlled through **Z+** and **Z-** buttons or with keyboard shortcuts **ctrl + numpad 9** and **ctrl + numpad 3**.
As for the XY axis, controlled motion can be performed with the **Move To** (absolute coordinates) or the **Shift** (relative coordinates) buttons.

Z position can also be saved by checking **Incl. Z** and clicking on the **Save** button. If Incl. Z is checked when clicking on the **Go to…** button, the stages will move to the selected XYZ coordinates. If not, only XY coordinates will be reached.

4.1.3 SAMPLE TILT ADJUSTMENT

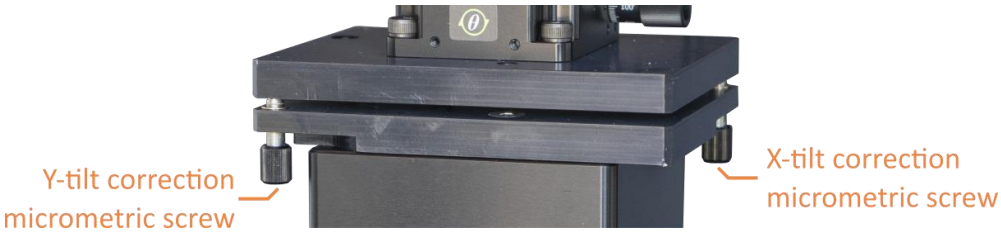


Figure 32 - Tilt correction platform

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. To do so, use the tilt correction platform (Figure 32) as follow:

- Start the **FOCUS MODE** in the **EXPOSURE** panel (Figure 11).
- Position the top left corner of your sample under the projected amber light using the **XY stage control interface** (section 4.1.1). This position corresponds to the pivot point of the tilt platform (Figure 33).
- 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 (Figure 33). Save the position and rename it by Pos. Y.

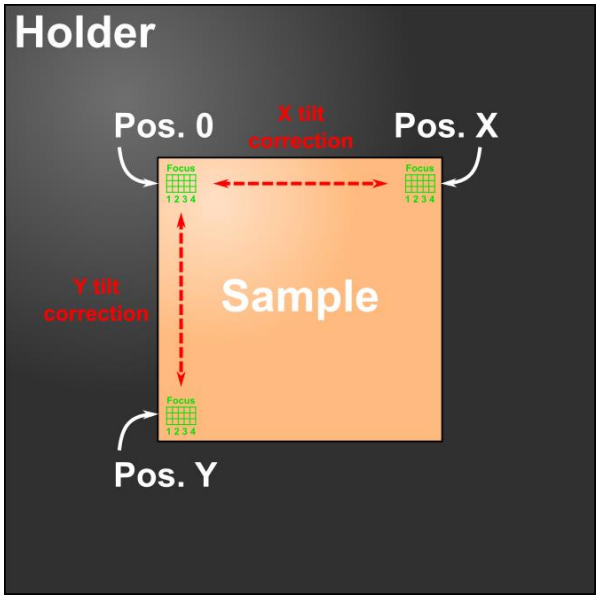


Figure 33 - Tilt correction principle

- Use the "**Y-tilt correction micrometric screw**" on the left side of the tilt correction platform (Figure 32) 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 (Figure 33). 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 (Figure 32) 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.

4.1.4 POSITIONING OVERVIEW

The **Positioning Overview** button on the right side of the software (Figure 34 surrounded in red). Once clicked it opens the **Position overview** window (Figure 34 in the middle).

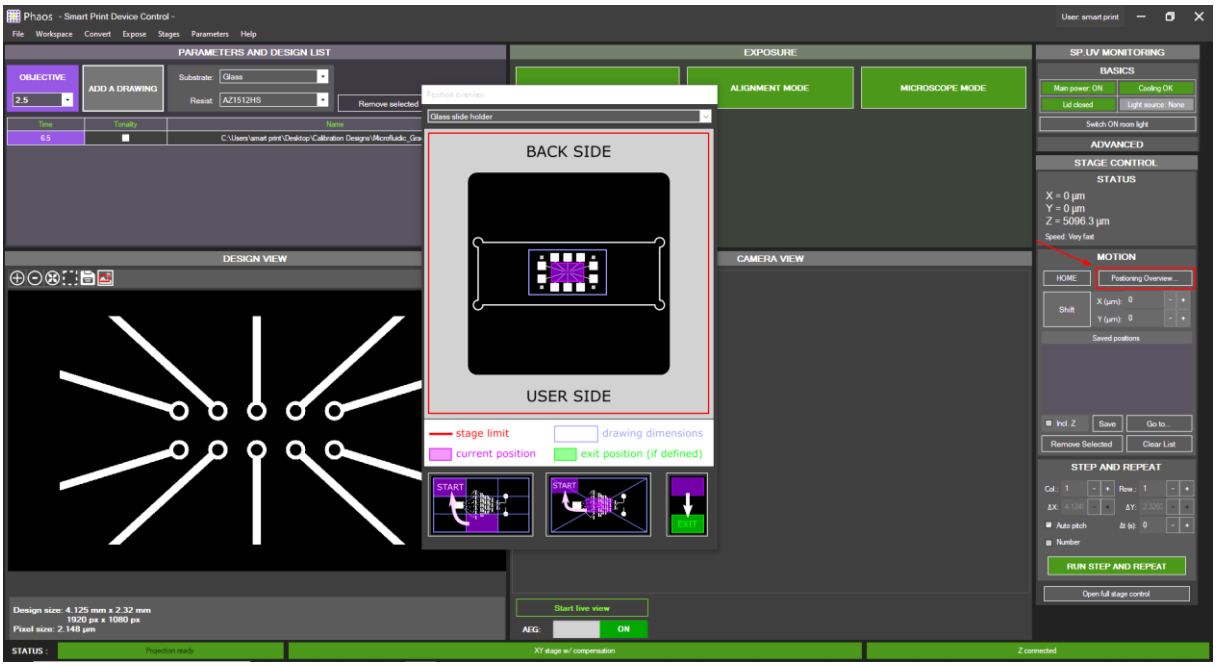


Figure 34 - Opening the positioning overview window

The **Position overview** window (Figure 35) contains:

- **a drop-down menu** to select the holder installed on the machine; Flat, Glass slide and 4 inch wafer for the Standard SP-UV version or Small sample and Standard sample for the Advanced SP-UV version.

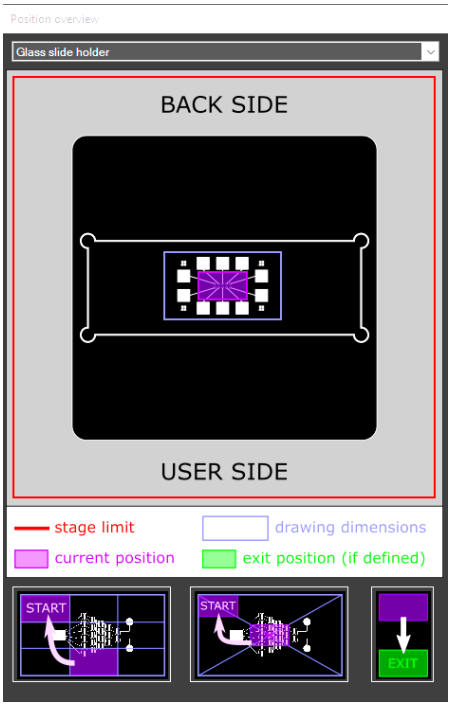


Figure 35 - Position overview window

- **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 35).

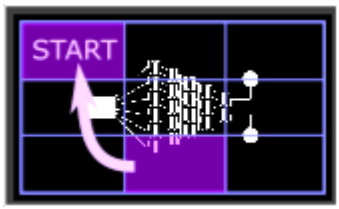
The red frame is the stage motion limit.

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

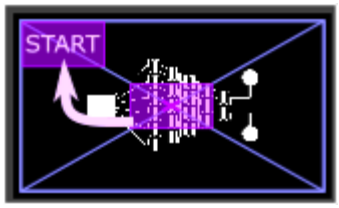
The purple frame is the current XY position. The position of the drawing on the scheme depends on the selected sub-image from the the full design.

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 appropriate 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

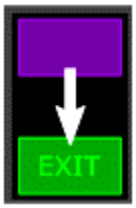
orange on the main software window. If so, reduce the size of your design or selected an other starting point more on the top left on the holder.
- **3 buttons with different functions** (the associated function can be seen by putting the mouse over the button):



(left) **Move from current sub-image to start position**. This button can be used when aligning with the Free alignment mode (section 4.3.1). Select the sub-image of interest, start 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.

4.1.5 STEP-AND-REPEAT & DOSE TEST

DESIGN AND OBJECTIVE SELECTION

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

- First, add a design or select one from the design 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 36. 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.

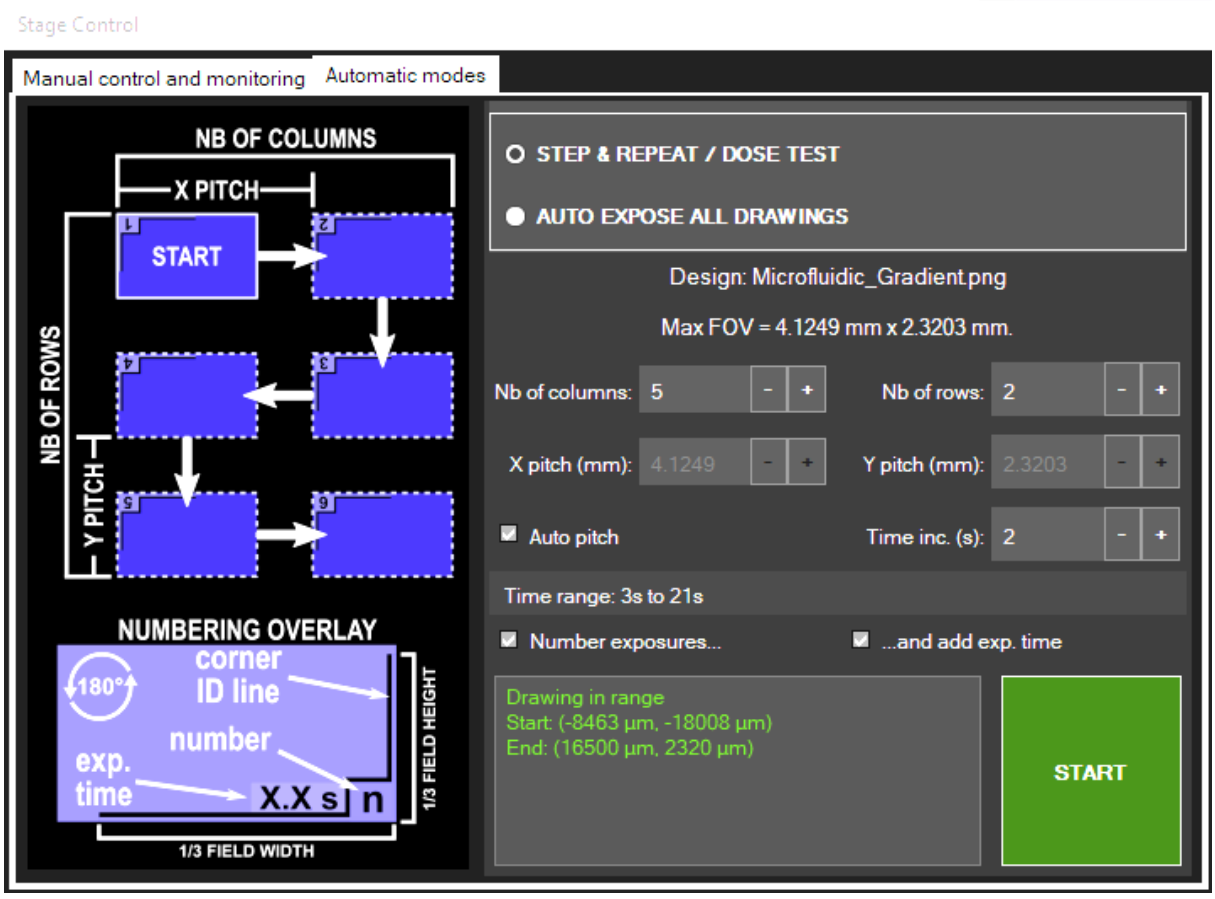


Figure 36 – Automatic mode tab in XY stage window

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 design 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 manualy. 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 36). 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 37) and their exposure time in s (Figure 38).

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).

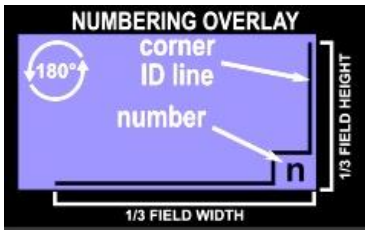


Figure 37 - Step & Repeat mode with "Number exposures" option

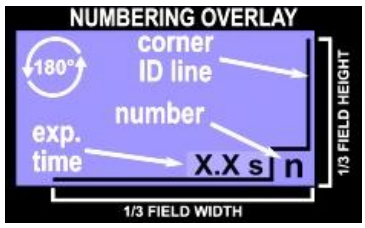


Figure 38 - "Add exposure time on overlay" option

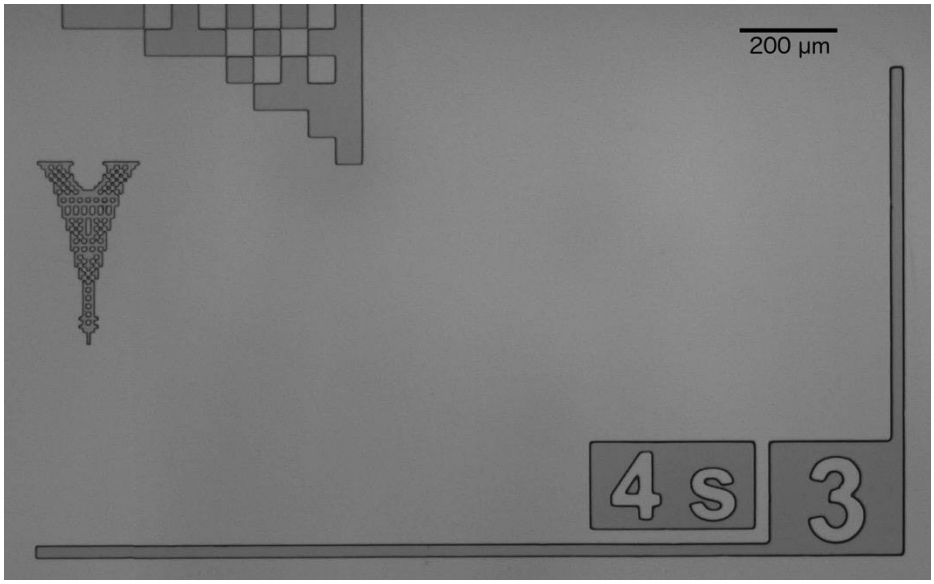


Figure 39 - Optical micrograph of the bottom right corner of the 3rd lithography of a drawing exposed in step-and-repeat mode with numbering and exposure time overlay options

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 40). 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 31) 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 40 – 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 41). The automatic exposure can be stopped at any time by clicking on the **STOP** button 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 41 – "Exposure" panel during auto mode

4.1.6 AUTOMATIC EXPOSURE OF A LIST OF DESIGN

For users wishing to make serigraphy or lithography of different separated designs on the same substrate, *Phaos* offer the possibility to automatically expose a list of design on a 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 3.4.4).
- Go to the **Expose** menu and click on **Expose all design list.**

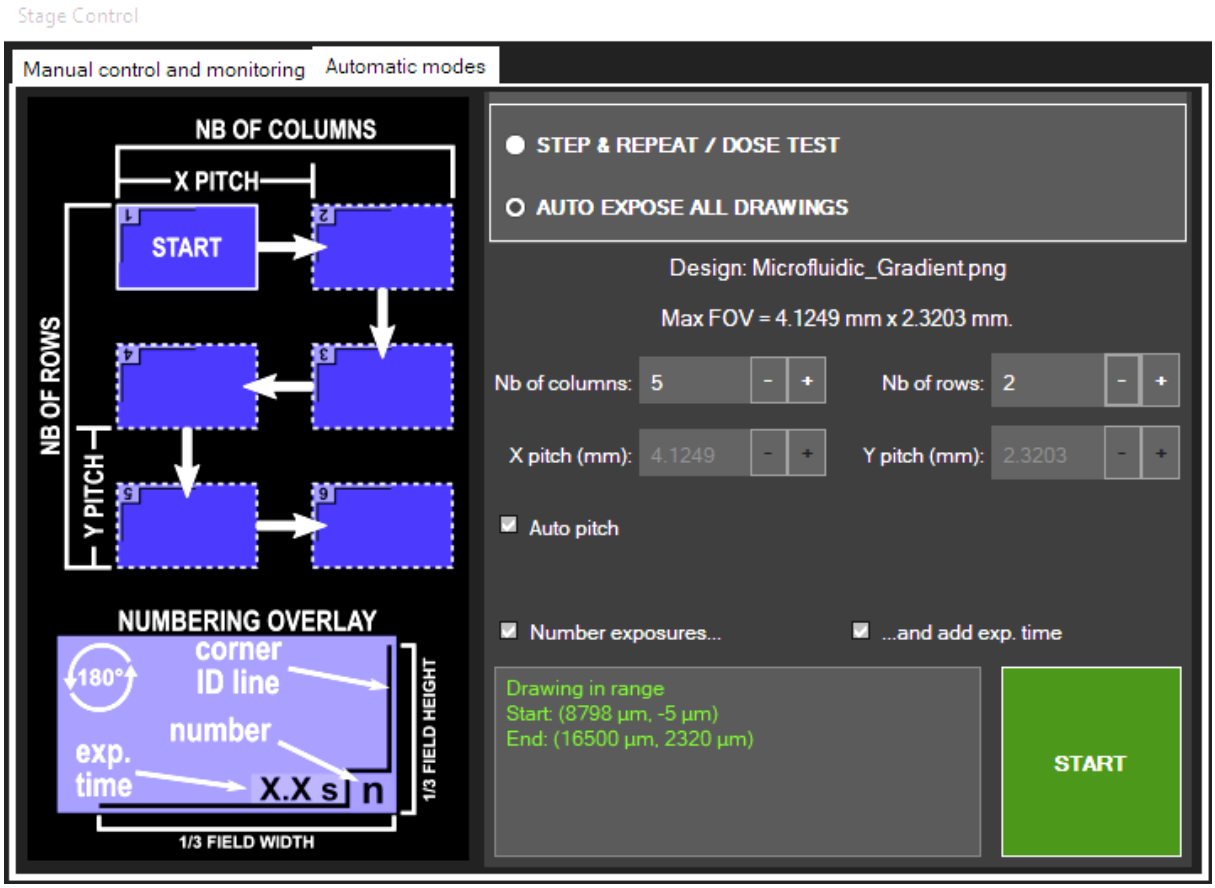


Figure 42 – "Auto Expose all drawings" mode in the stage control window

- 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 4.1.5 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 section 4.1.5, 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 41). The automatic exposure can be stopped at any time by clicking on the **STOP** button in the same panel.

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 43).

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 four positioning options: HOME, Positioning Overview, 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 4.1.5.

The user can switch from the simplified stage control panel to the more complete stage control window by clicking on the **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.

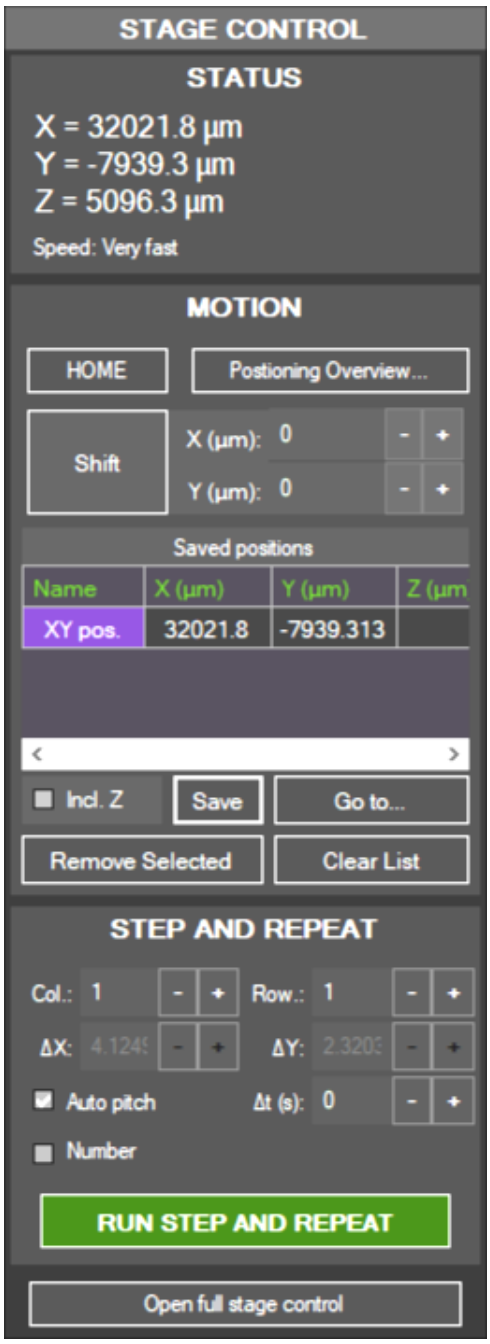


Figure 43 - Stage Control panel in the main window

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 position at the end of the exposure. Figure 44 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 45 left). Finally, check the **CUSTOM STOP POSITION** button below of the **EXPOSE SELECTED DRAWING** button (Figure 45 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.

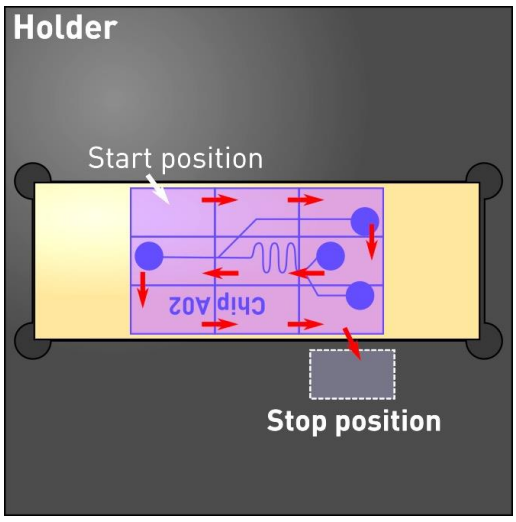


Figure 44 - "Stitched" lithography with used defined stop position

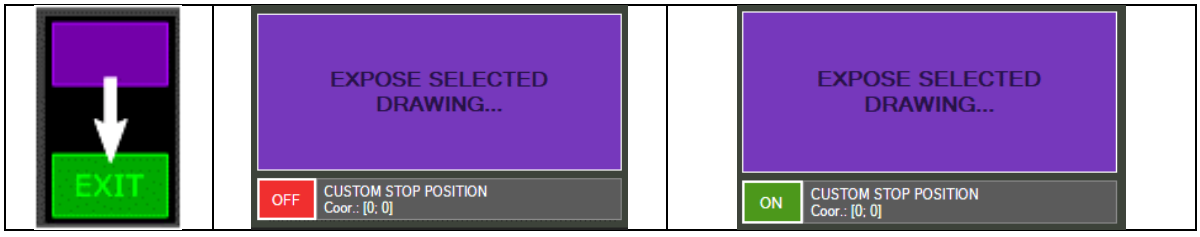


Figure 45 - Left: Stop position button; Middle: Stop position disabled; Right: stop position enabled

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, **right-click** on the **EXPOSE SELECTED DRAWING** button before starting the exposure. In the field appearing just below enter the destination e-mail address and click on the **GO** button (Figure 47).

Figure 46 - 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"	Stage absolute X coordinates (in mm)	Stage absolute Y coordinates (in mm)

		format)		

Each column must be separated by a tab as shown in the example below (Figure 47).

```
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 47 – Typical parameter file for custom automated lithography

In order to start a custom series of lithography:

- Go to the **Automation** menu and click on **Custom auto exposure…**.
- In the **Custom exposure** window, select a compatible parameter file by clicking on the **Load list…** button (Figure 48).

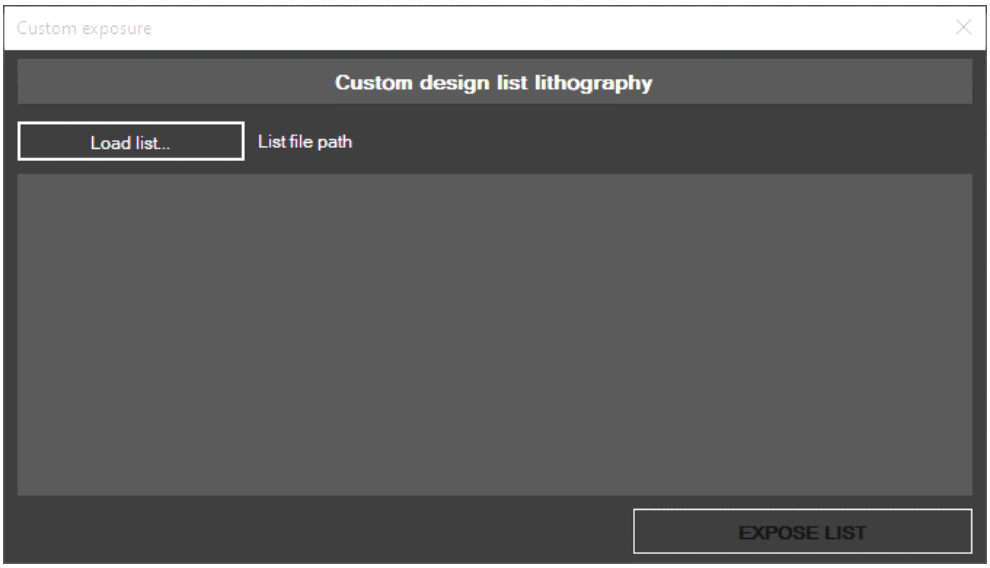
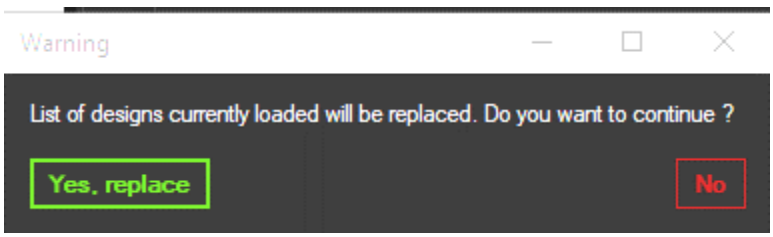


Figure 48 – Custom exposure window at startup

- If the parameter file contains no mistakes (drawing not found, unknown characters, etc.), the file will load on the window (Figure 49) and will update on the main window in the **PARAMETER** panel (Figure 50).

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 50)

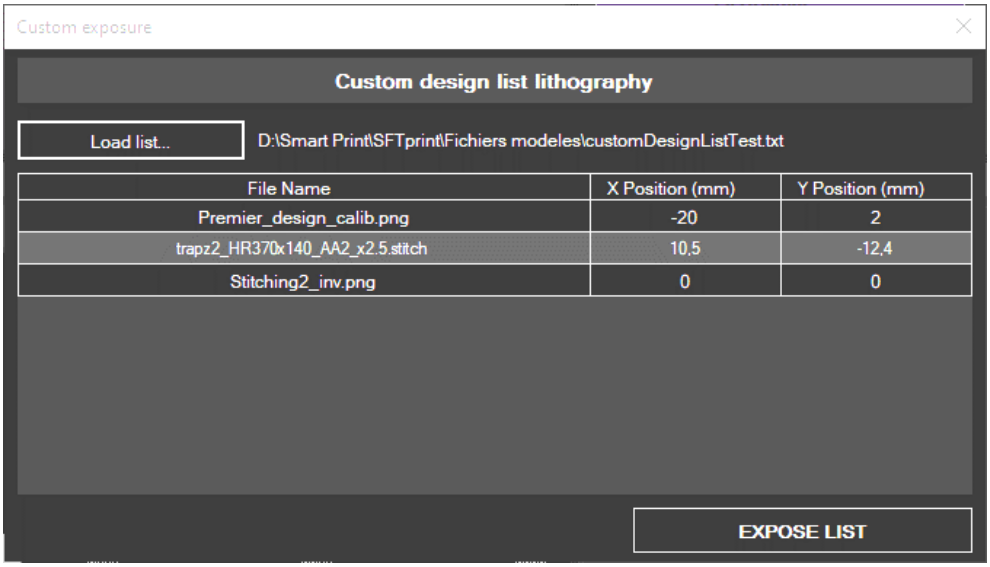


Figure 49 – Custom exposure: parameter file loaded

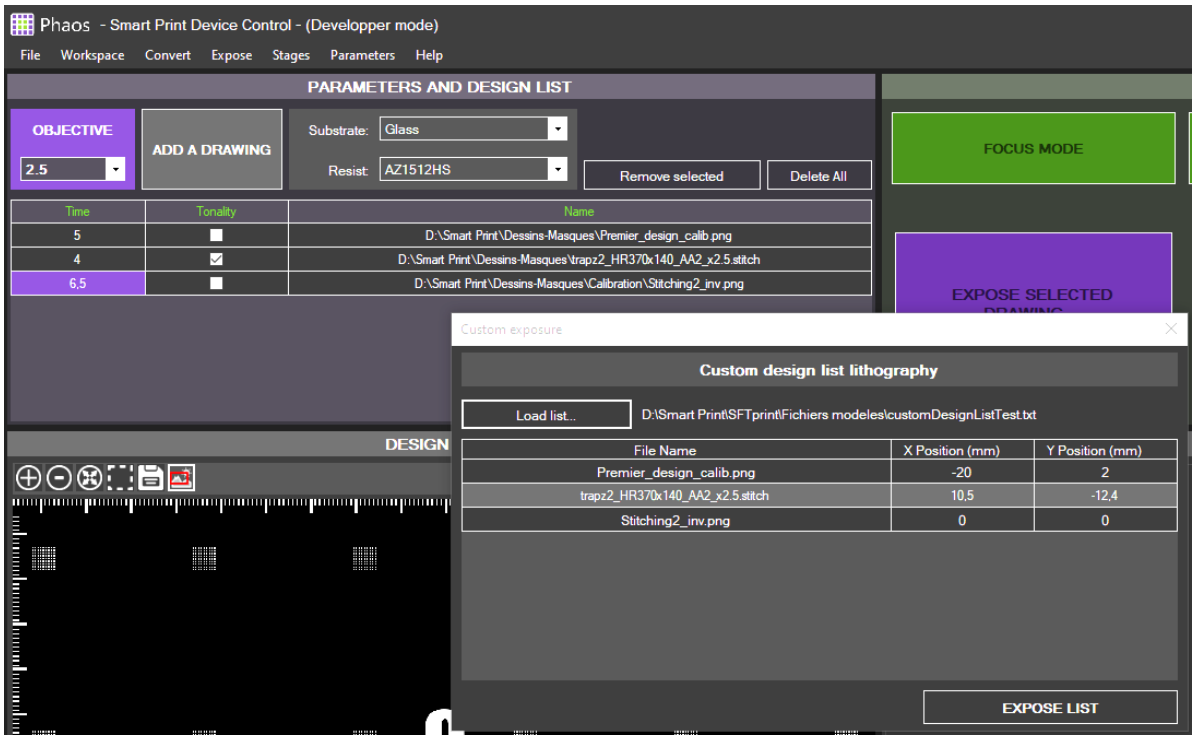


Figure 50 – Custom exposure: data loaded and ready for exposure

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 LIGHT ENGINE MONITORING AND ILLUMINATION ADJUSTMENT

4.2.1 MONITORING

The **SP-UV MONITORING** panel provides a series of information about the light engine of the equipment.
The **BASICS** sub-panel (Figure 51) contains the following data:

- Main power status: it must be ON to use the equipment. If status is OFF or ERROR refer to troubleshooting section.
- Optoelectronic head cooling status: it must be OK to use the equipment. If status is WARNING or ERROR refer to troubleshooting section.
- Protection lid status: The state can be either “Lid closed” or “Lid Opened”. The protection lid shall be kept closed as much as possible. It must be in closed state to perform a lithography.
- Light source status: it shows which kind of light source is currently used. It can be “Amber” (during focus, alignment and microscope modes), “UV” (during exposure) or “None”.

In addition to the above-mentioned data, the enclosure light system can be switched ON in the BASICS sub-panel. To do so, click on the **Switch ON room light** button. Click one more time on the button to switch it OFF. The purpose of the enclosure light system is to provide clear eye view of the inside of the enclosure by the user.

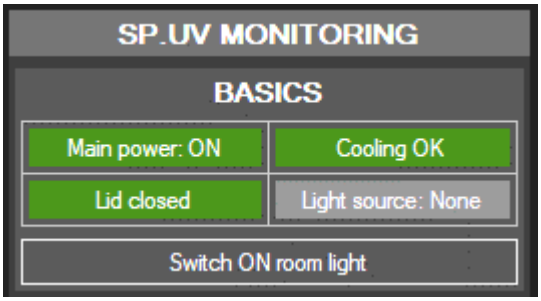


Figure 51 - SP-UV monitoring, sub-panel BASICS

The **ADVANCED** sub-panel (Figure 52) contains more detailed monitoring data and access to all illumination intensity values. The monitoring data available in this part are manually collected by clicking on the **Refresh (double arrow)** button and are described below:

- Fan in and fan out status: they show fan rotation frequency. Normal value are > 35 Hz.
- UV LED temperature: the UV LED temperature must be < 90°C. If the value is beyond it may permanently damage the LED. To avoid damage, immediately STOP exposure if running and contact the manufacturer.
- Stage power supply status: it must be OK to use the equipment. If status is WARNING or ERROR refer to troubleshooting section.

4.2.2 ILLUMINATION INTENSITY CHANGE

In the **ADVANCED** sub-panel of the **SP-UV MONITORING** panel, the illumination intensity of the 3 light sources available in the equipment can be modified by moving the cursor position of their respective range slider:

- UV LED: it is the illumination source used for lithography. The default value is 2.55 A (85% of its max intensity). Pushing the cursor above this value (red area) may decrease the lifetime of

the LED. The LED also has a minimum intensity value. If the cursor is put below (grey area), the LED will not emit light.

- Amber LED: it is the illumination source used in FOCUS, ALIGNMENT and MICROSCOPE modes and it preserves the properties of the photosensitive resist. The default value is 100%.
- Room LED: it is the illumination source used to illuminate the inside of the enclosure. The default value is 75%.

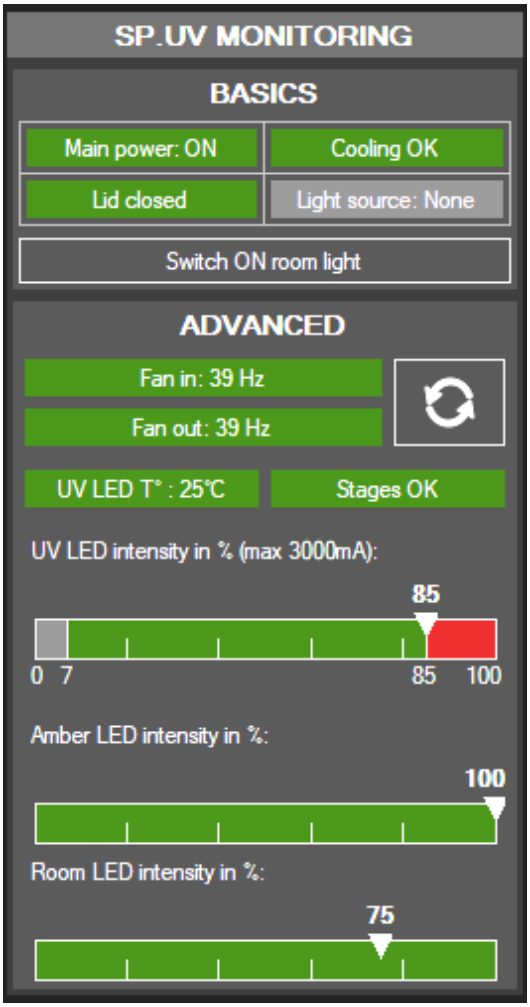


Figure 52 - SP-UV monitoring, all sub-panels

4.3 ADVANCED LITHOGRAPHY

4.3.1 MULTI-LITHOGRAPHY WITH ALIGNMENT MODE

Phaos can project a drawing under amber illumination (wavelength out of the light sensitivity range 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 53).
Two alignment modes, described later in the section, are accessible to the user: the **Free mode** and the **Semi-automatic mode**.

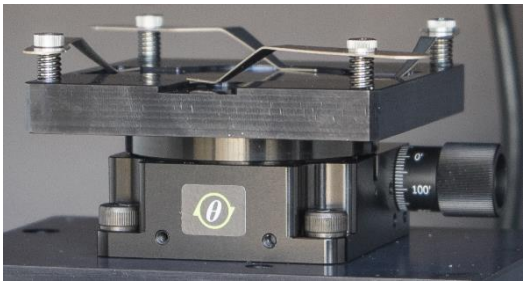


Figure 53 - Rotation stage module

DESIGN RULES

Details below are suggested design rules, known to work properly with Smart Print UV. 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 54 right). For each design, the crosses must be at the same relative position.
- Add a unique number to each cross (Figure 54 left) to avoid wrong substrate orientation.

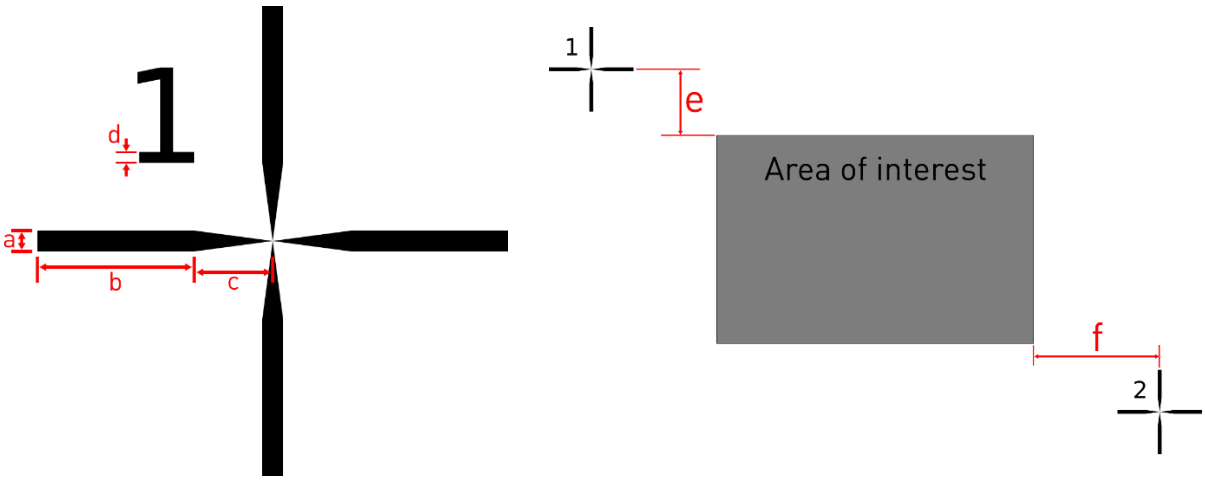


Figure 54 - Design rules. Left: focus on an alignment cross and its key dimensions. Right: cross positioning over the substrate

Table 1 - Suggested dimensions for the design in Figure 54

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 Table 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 Smart Print UV for a regular lithography (see section 3.3).
- 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 55). 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 3.4.3).
- Adjust the XY stage position and the rotation stage (Figure 53) 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 (see more details section 4.1.4).
- Quit the alignment mode by clicking on the **QUIT ALIGNMENT** button.
- Start the exposure by clicking on the **EXPOSE SELECTED DRAWING** button.

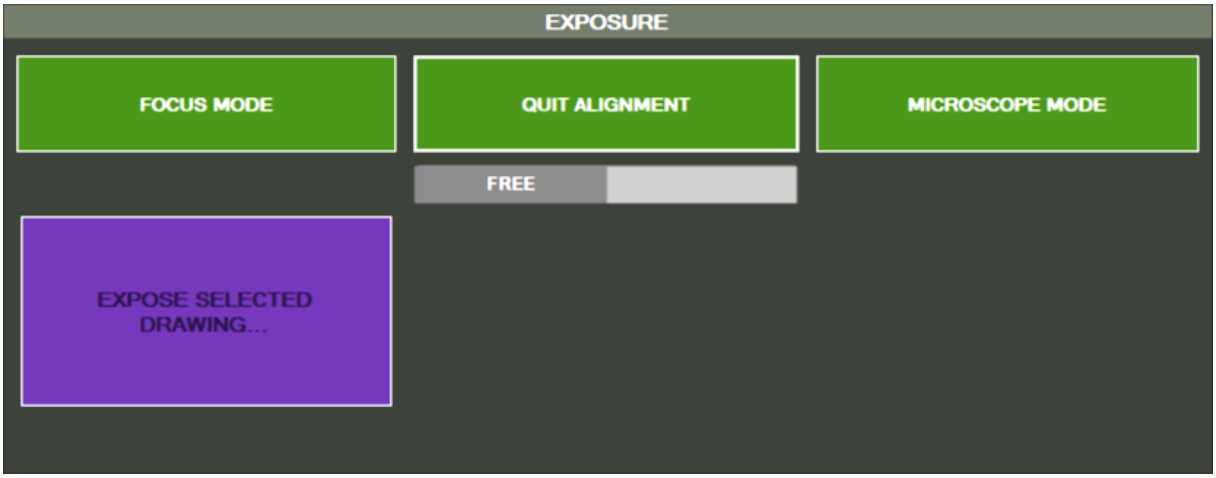
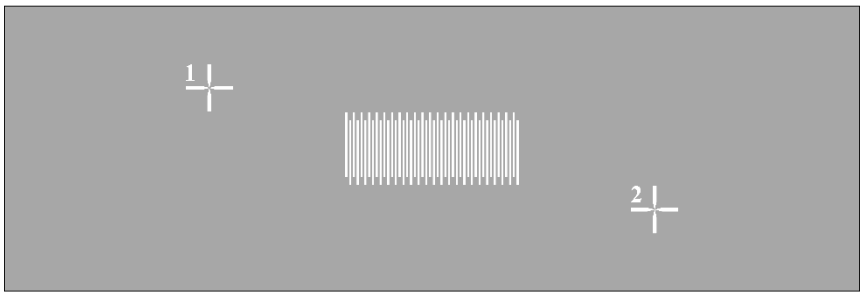


Figure 55 - Free alignment mode

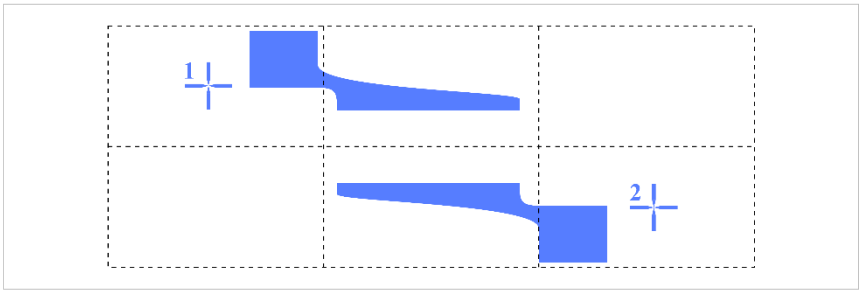
ALIGNMENT: SEMI-AUTOMATIC MODE

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 56a). Contact pads remains to be lithographed. Their drawing (Figure 56b) has been designed to fit with the patterned electrodes. In this example, the dashed rectangles in Figure 56b 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 56c.

a) Substrate with the 1st level of patterns



b) Drawing of the 2nd level to be lithographed



c) Final result on the substrate

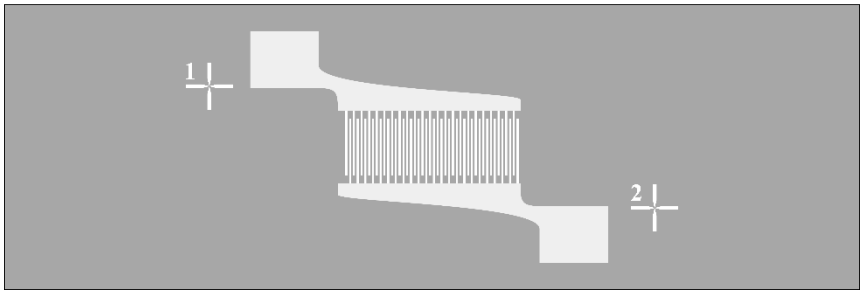


Figure 56 - Example of aligned lithography over already existing patterns

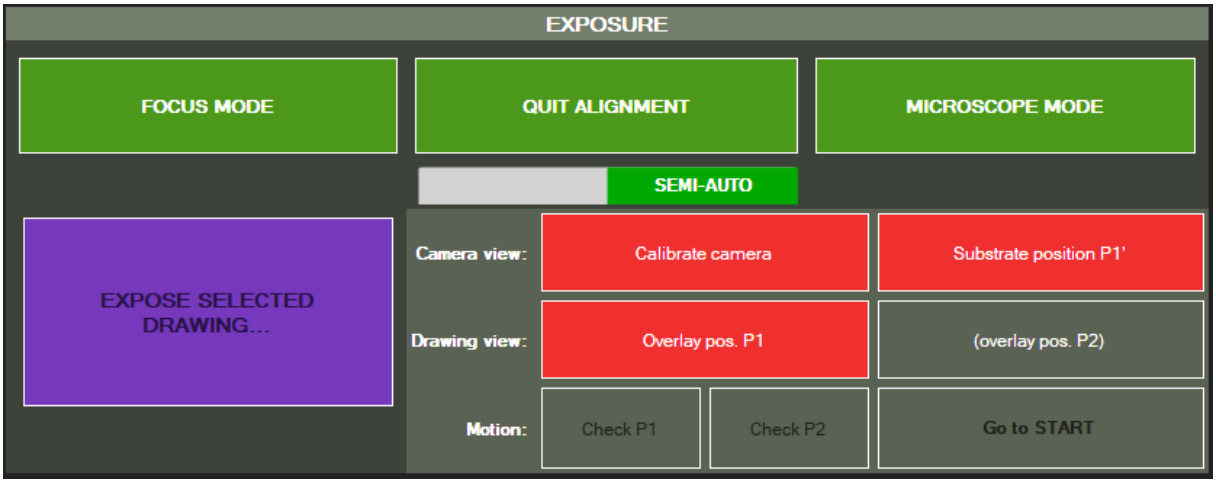


Figure 57 - Semi-automatic alignment mode

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

- Load your sample with the first layer already patterned and prepare Smart Print UV for a regular lithography (see section 3.3).
- 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 57).
- Camera calibration (Figure 58a): 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 59.

NOTE: 1) If the cross is not visible, adjust the camera settings (see section 3.4.4). 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 58b): 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 60.

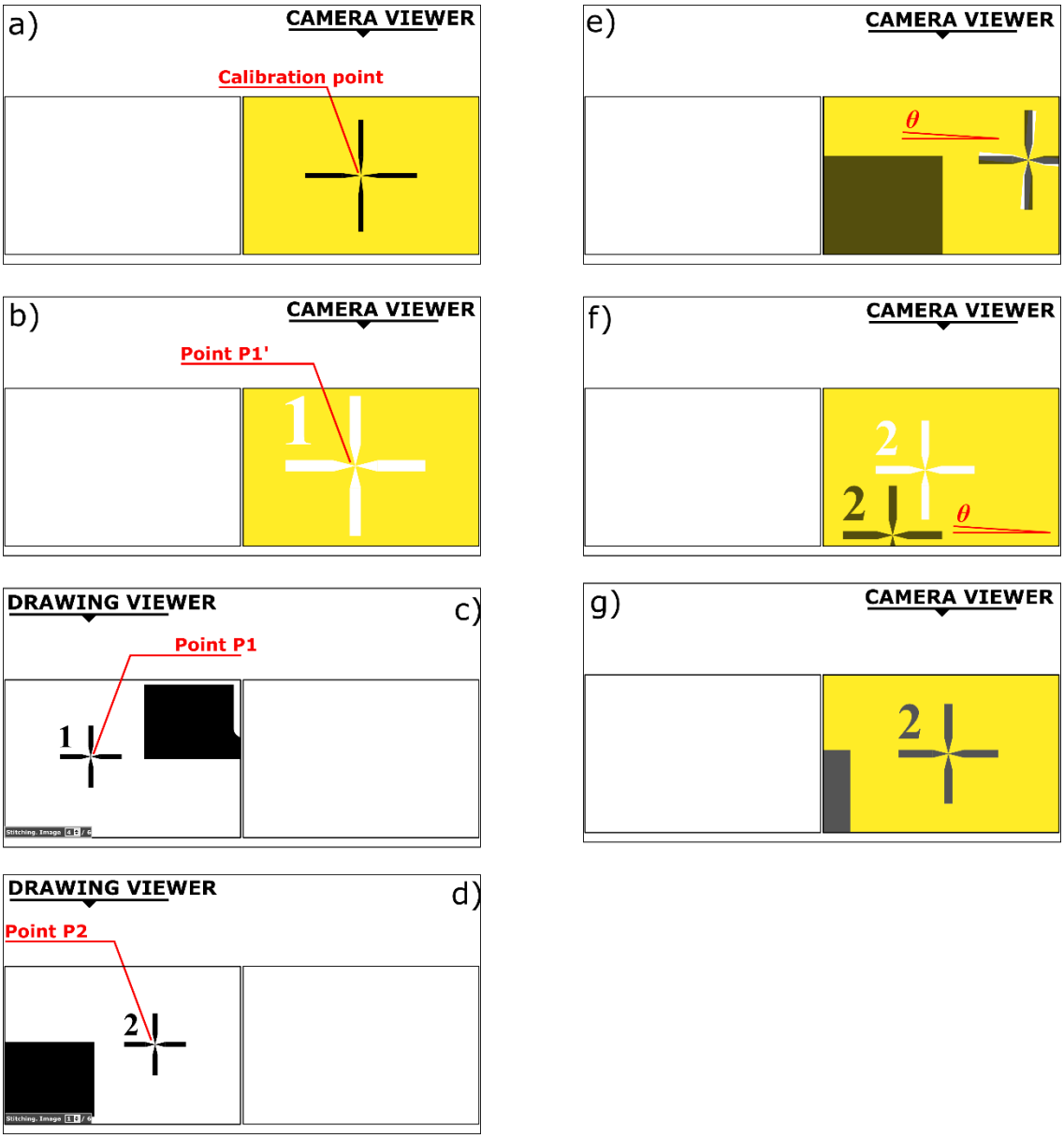


Figure 58 - Semi-automatic alignment main steps

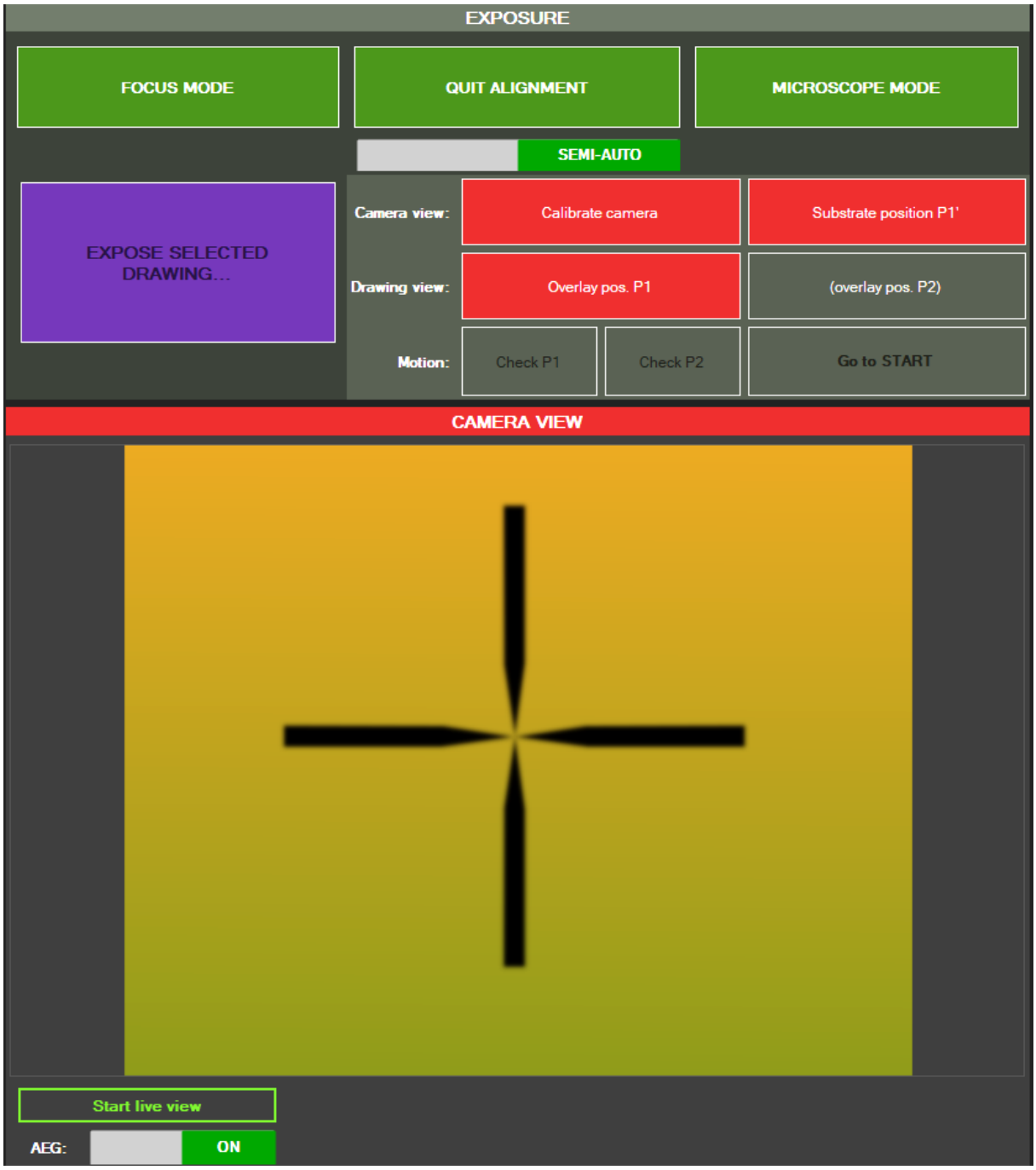


Figure 59 - Semi-auto alignment: camera calibration

- Selection of point P1 (Figure 58c): 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 61.
- Selection of point P2 (Figure 58d): 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 62.
- Alignment checking*:* in order to check the validity of the adjustment, click on the **Check P1** button (Figure 63). The stage will then move to align P1' (on the substrate) with P1 (on the drawing) as shown in Figure 58e. 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 58e), 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 58f, the rotation stage must be adjusted. To do so, move the wheel of the rotation stage (Figure 53) until *q* is suppressed. After every change of the rotation stage, P1' position selection must be redone.
- Redo the previously described steps from Figure 58b to Figure 58f until P2 is perfectly aligned as shwon in Figure 58g.

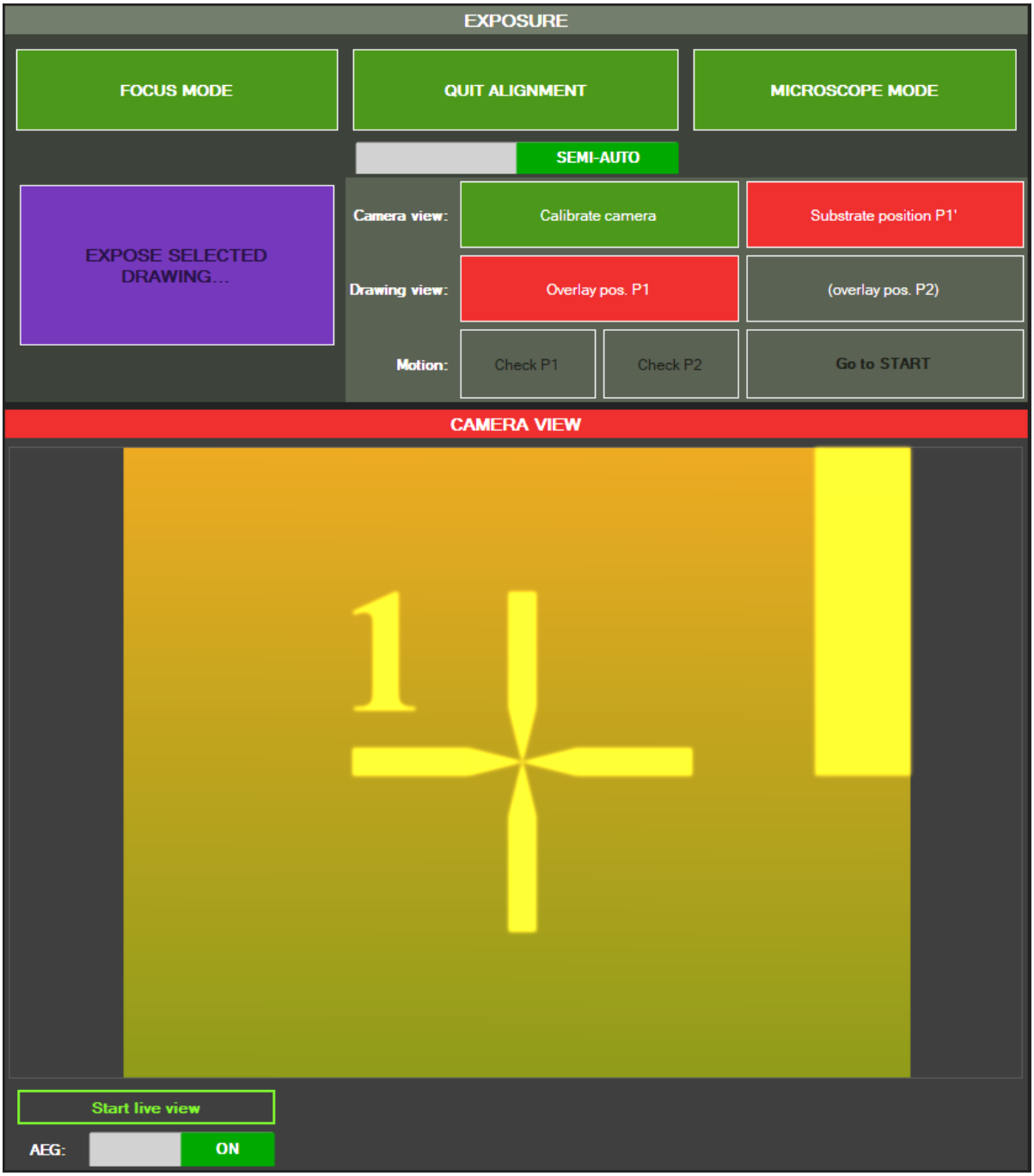


Figure 60 - Semi-auto alignment: defining point P1'

- Finishing the alignment setting: click on the **Go to START** button (Figure 63) and quit the alignment mode by clicking on the **QUIT ALIGNMENT** button.
- Start the exposure by clicking on the **EXPOSE SELECTED DRAWING** button.

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

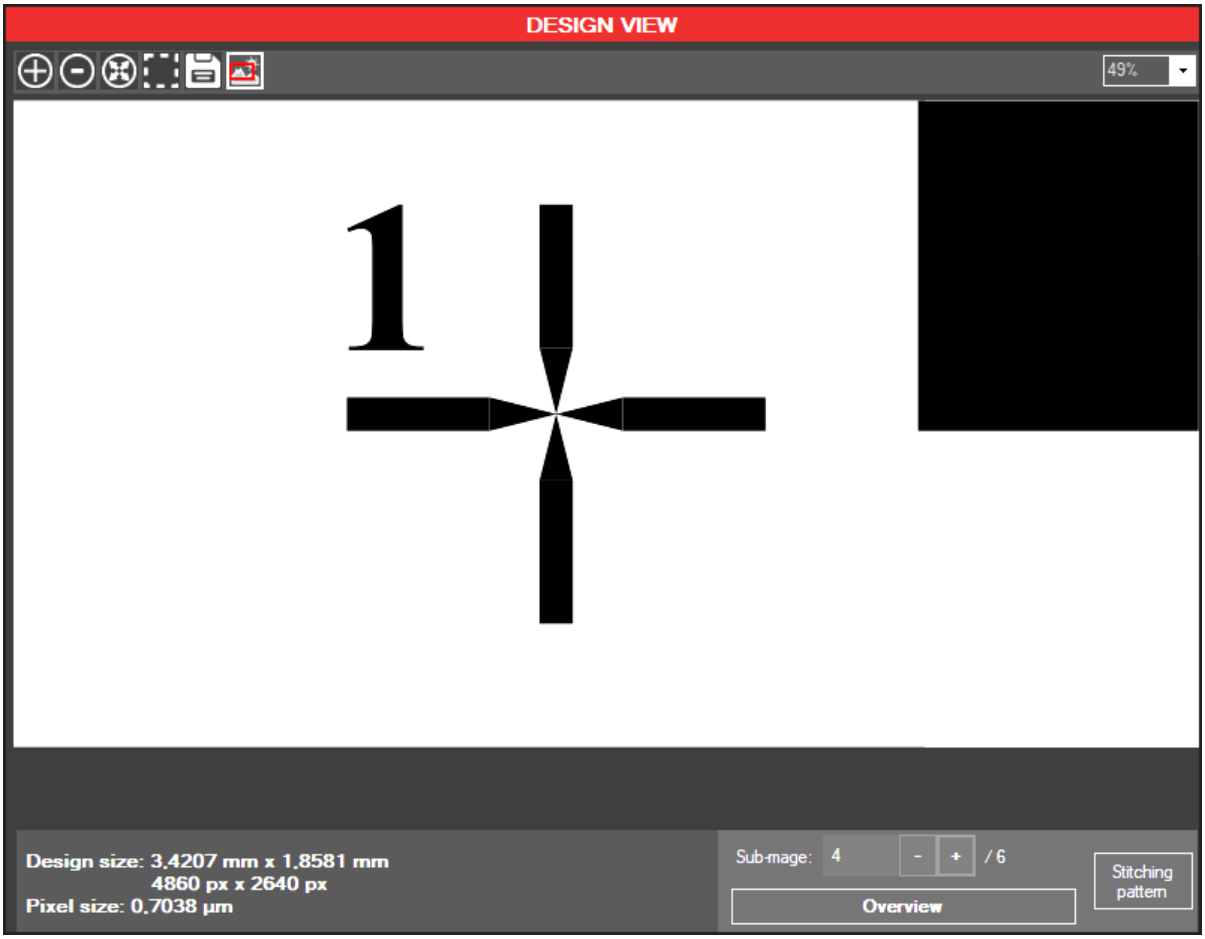


Figure 61 - Semi-auto alignment: defining point P1

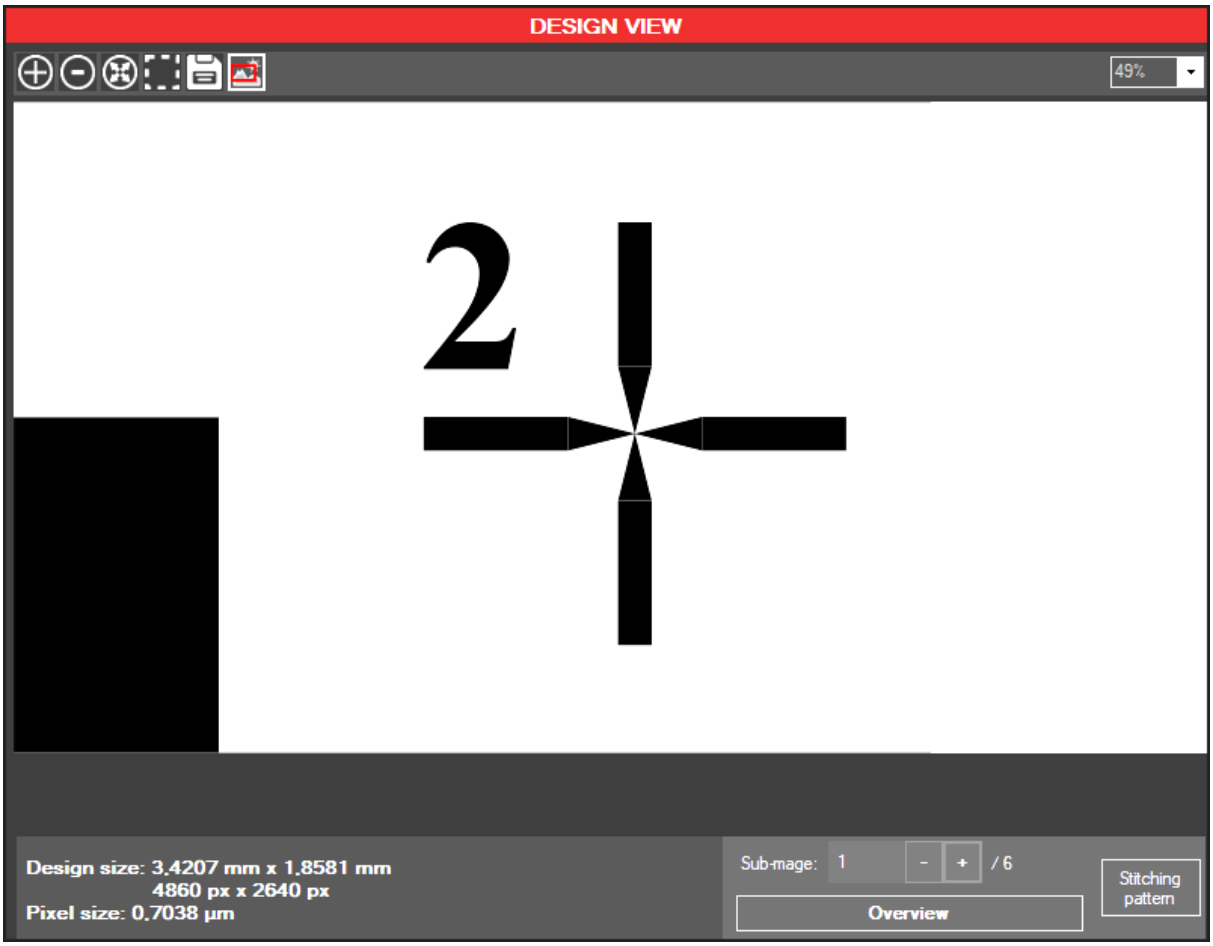


Figure 62 - Semi-auto alignment: defining optional point P2

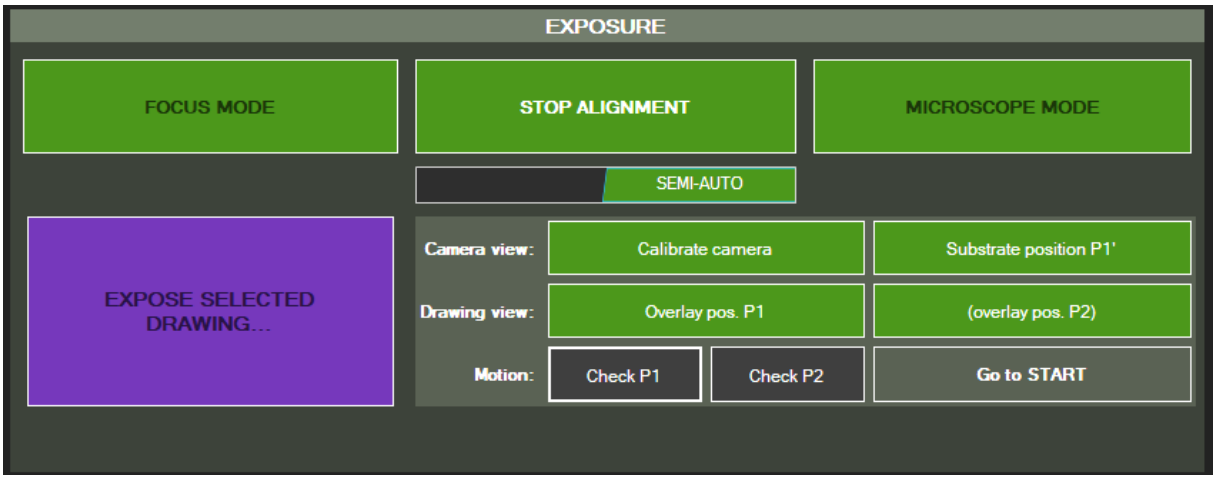


Figure 63 - Semi-auto alignment panel after defining P1', P1 and P2

4.3.2 GRAYSCALE LITHOGRAPHY

Smart Print UV can be used to pattern a photoresist in "2.5 dimensions". Indeed, the photoresist local height can be tuned by

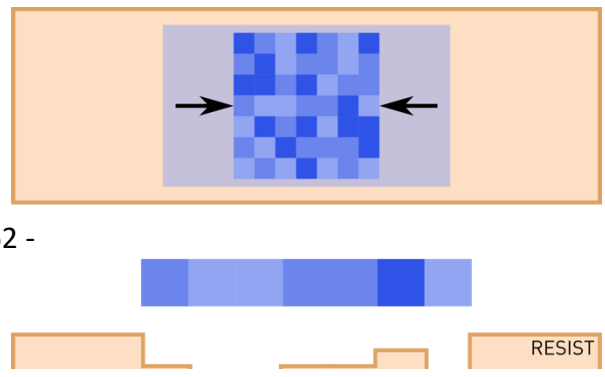
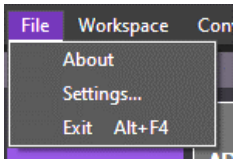


Figure 64 – Principle of grayscale lithography

adjusting the light intensity for each projected pixel (Figure 64).
With Smart Print UV, 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 dedicated photoresist for grayscale lithography. Other resists optimized for such lithography technique and with UV light sensitivity (385 nm) may also work.

4.4 GENERAL SOFTWARE APPLICATION SETTINGS

This section describes all settings available to configure Smart Print UV 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) is:

- All **Focus & Projection** settings (except Use green illumination for focus)
- **Auto exposure and gain** settings in **Camera** tab
- The **Importation** options

By default, when the application is run normally calibration data and basic settings are locked (Figure 65). 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, go to **File** → **Settings…** and click on the **Restart as administrator** button.

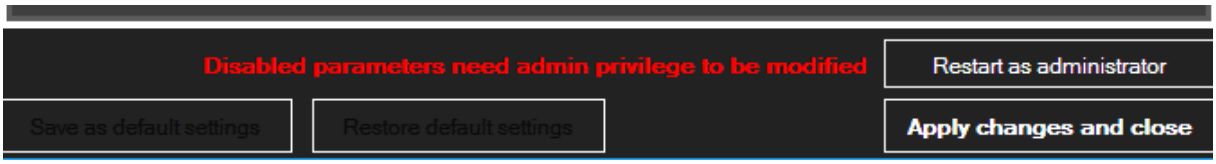
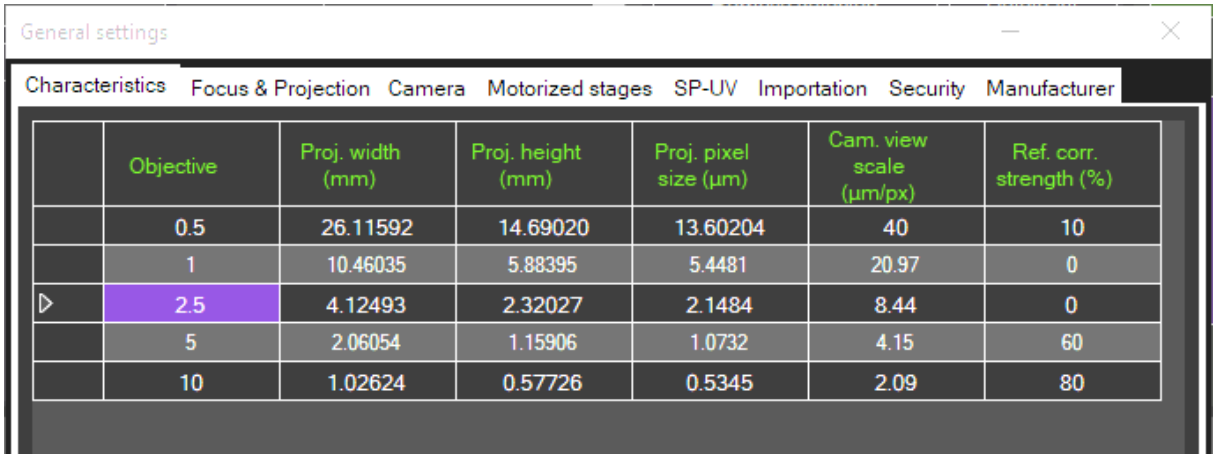


Figure 65 - Settings: admin access locked

OPTICAL CHARACTERISTICS



	Objective	Proj. width (mm)	Proj. height (mm)	Proj. pixel size (µm)	Cam. view scale (µm/px)	Ref. corr. strength (%)
	0.5	26.11592	14.69020	13.60204	40	10
	1	10.46035	5.88395	5.4481	20.97	0
▷	2.5	4.12493	2.32027	2.1484	8.44	0
	5	2.06054	1.15906	1.0732	4.15	60
	10	1.02624	0.57726	0.5345	2.09	80

Figure 66 – Settings: optical characteristics

The tab **Characteristics** contains a table with key optical characteristics according to the objective used during lithography (Figure 66):

- *Projected width*: projected image field-of-view width in mm (calculated from pixel size)
- *Projected height*: projected image field-of-view height in mm (calculated from pixel size)
- *Projected pixel size*: physical size of one pixel's drawing in µm
- *Camera view scale*: camera viewer scale in µm/px
- *Ref. corr strength*: dynamic image correction value (factory calibration)

Optical parameters for each objective can be modified by selecting the desired row and clicking on the **Edit row…** button (Figure 67). "Pixel size", "Camera scale" and "reference correction strength" can be adjusted. Click on the **OK** button to update the table. The projected width and height will be automatically adjusted from the new pixel size value. To save the change click on the **Apply changes and close** button.

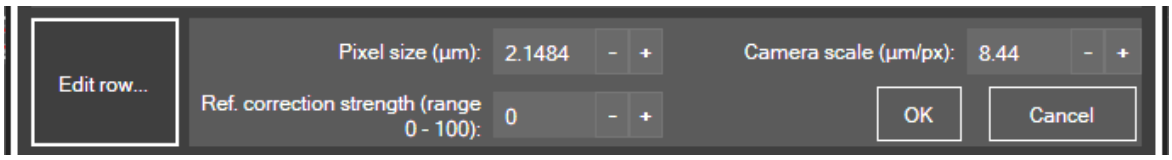


Figure 67 – Settings: optical characteristics edition panel

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 3.4.5 for more details)
- Display the camera live scale bar and save an image of your sample (section 3.4.3 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 66) 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. In the tab **Focus & Projection**, the drawing used during the focusing step can be set (Figure 68):

- *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

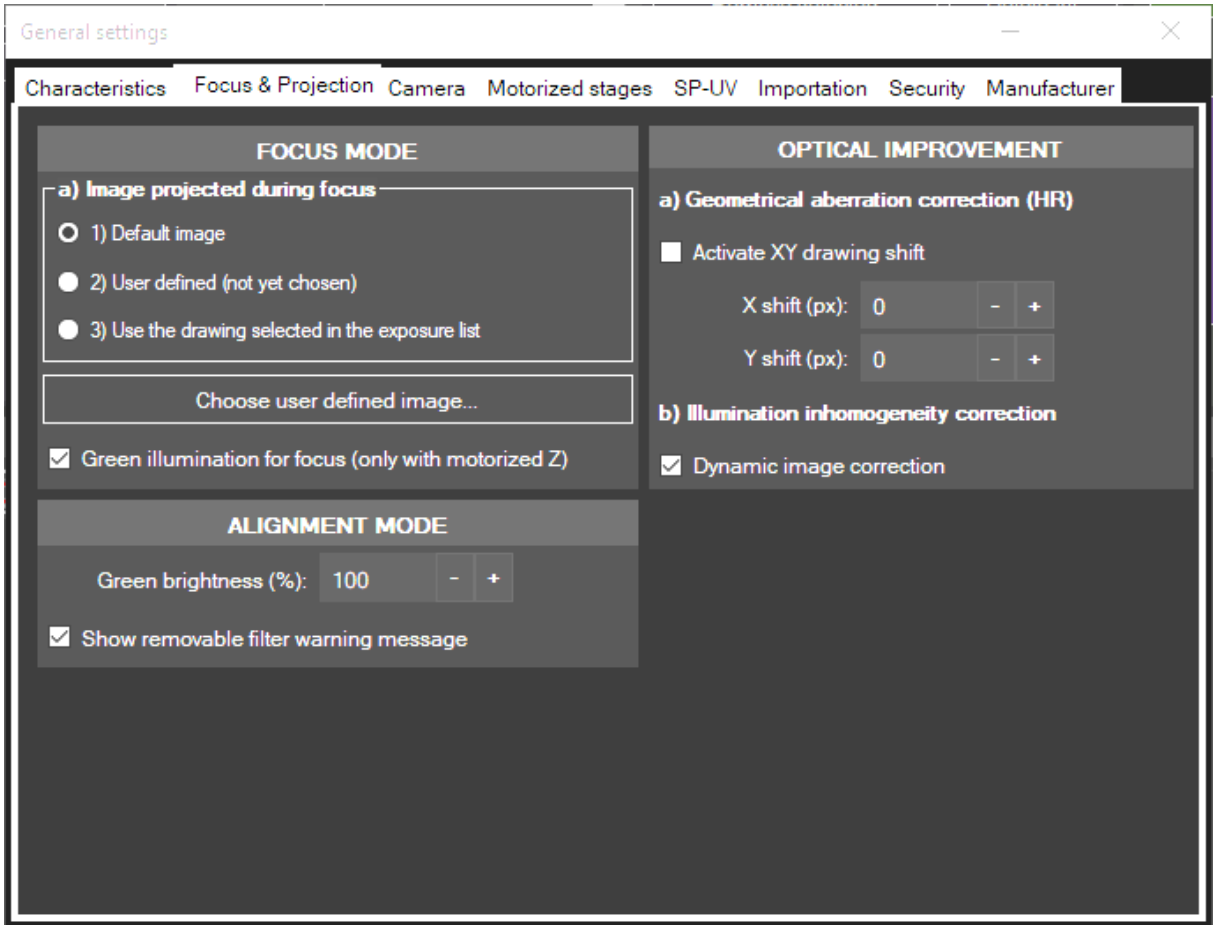


Figure 68 – Settings: focus and projection options

Green illumination for focus must always be checked when using a Smart Print UV. It is a feature specific to another Smart Print model (Smart Print 435 nm).

Alignment mode. The settings on this panel are not for Smart Print UV and must be kept untouched.

Optical improvements. Only for advanced optimization purpose with small images or sub-images from stitching with "HR" option.

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

CAMERA

Live image processing. Depending on user preferences the image displayed in the **Live view** panel can be mirrored horizontally and/or vertically with the options **Flip horizontally** and **Flip vertically**. By default, the horizontal flip is checked in order to display projected images as the corresponding drawing.
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**.

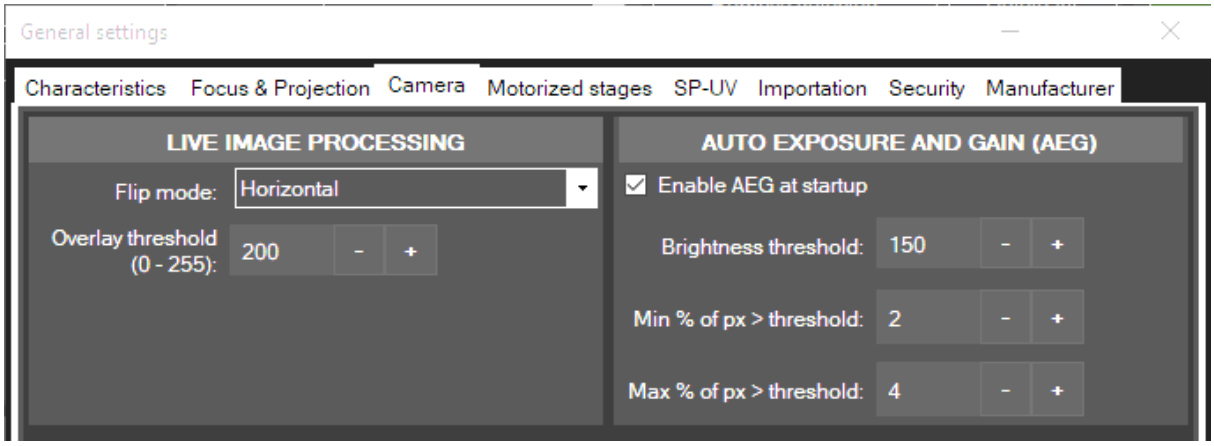


Figure 69 - Settings: camera

Auto Exposure and Gain (AEG). 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 > threshol**: min percentage of saturated pixels tolerated. Default = 2%
- **Max % of px > threshol**: max percentage of saturated pixels tolerated. Default = 4%

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

MOTORIZED STAGES SETTINGS

Axis communication. Each axis of the stage, has a distinct communication port with the computer displayed as "xi-com:\\.\COM1" with a unique COM number (Figure 70).

Depending on how the stage has been connected to its controller, the communication ports may be incorrectly assigned. If so, port assignation can be adjusted by choosing the relevant COM number from each list box.
Invert X direction and **Invert Y direction** options allow to change the stage motion direction of the manual controls in the **XY stage control** window (Figure 31). It is recommended to keep those parameters in their default configuration (Invert X checked, Invert Y and Z unchecked).

Mechanical play compensation (Only for Smart Print UV Standard with XY stepper motors). When the **Stage play compensation** option is checked in the **Automation** menu of the main window, the stage can make additional motions to correct the backlash mechanical play. The maximal motion allowed for that operation can be adjusted in the **X and Y antiplay (µm)** fields. Default values are 4500 µm.

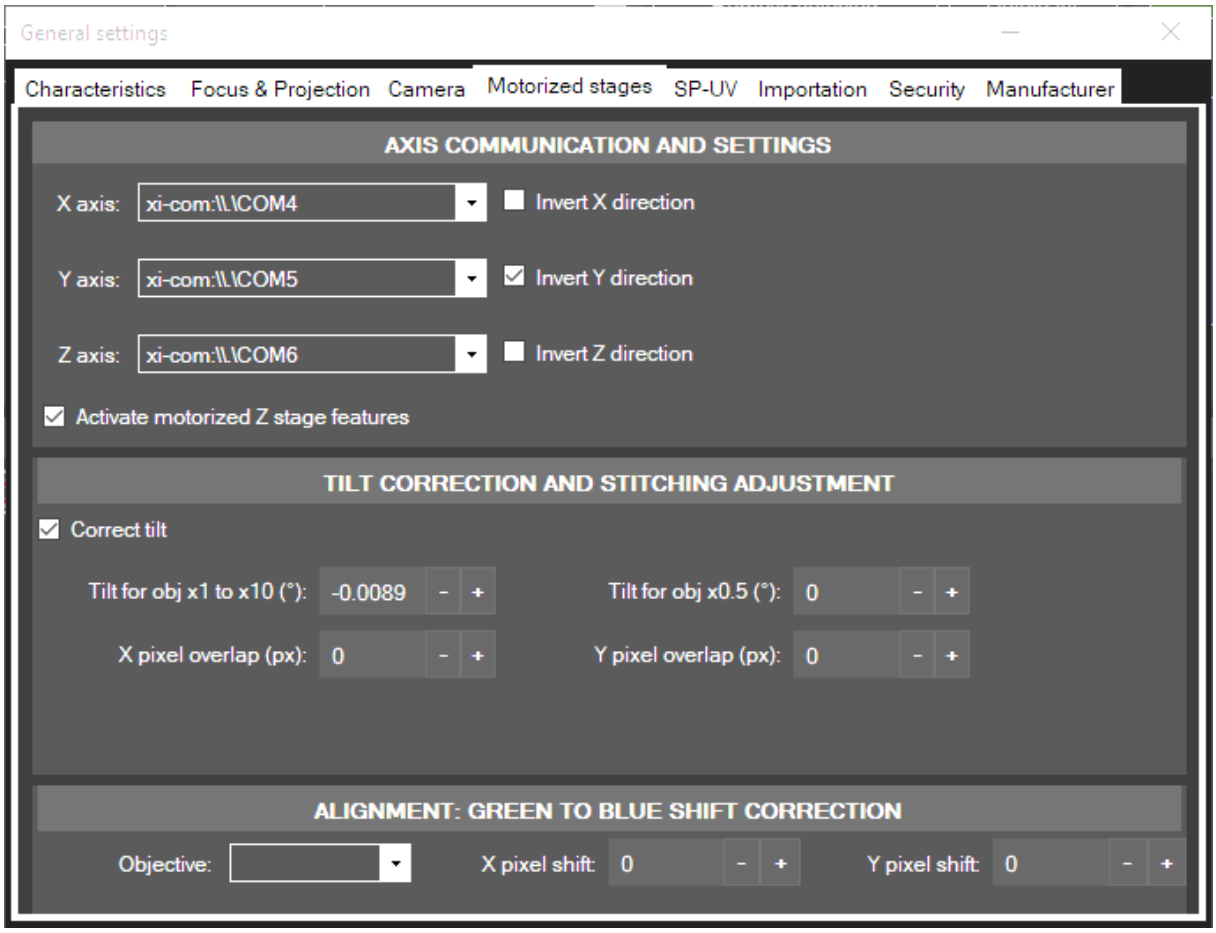


Figure 70 – Settings: motorized XY stage

Stage motion corrections. 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 checking **Correct tilt** option and adjusting the following parameters (Figure 70):

- *Tilt*: the measured angle between the X-edges of a projected image and the X-axis motion direction, expressed in degree (can be different for the x0.5 objective)
- *X pixel overlap and Y pixel overlap*: default field connection fine tuning values for stitching (section 3.4.2). Increase of each sub-image pixel size along X and Y axis, in order

to generate an inter-image overlap expressed in pixel (value can be positive or negative). If the value is negative each sub-image will be slightly cropped (gap) resulting in a small loss of information.

- *Green to Blue X and Y pixel shift*: Correction of the projection XY shift induced between blue (exposition) and green (alignment) images

To save changes, click on **Apply changes and close**.

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 5.2.4 for more details), *Phaos* will link automatically to KLayout. If not then click on **Define klayout_app.exe filepath** (Figure 71) and select the file *klayout_app.exe* in the main directory of KLayout.

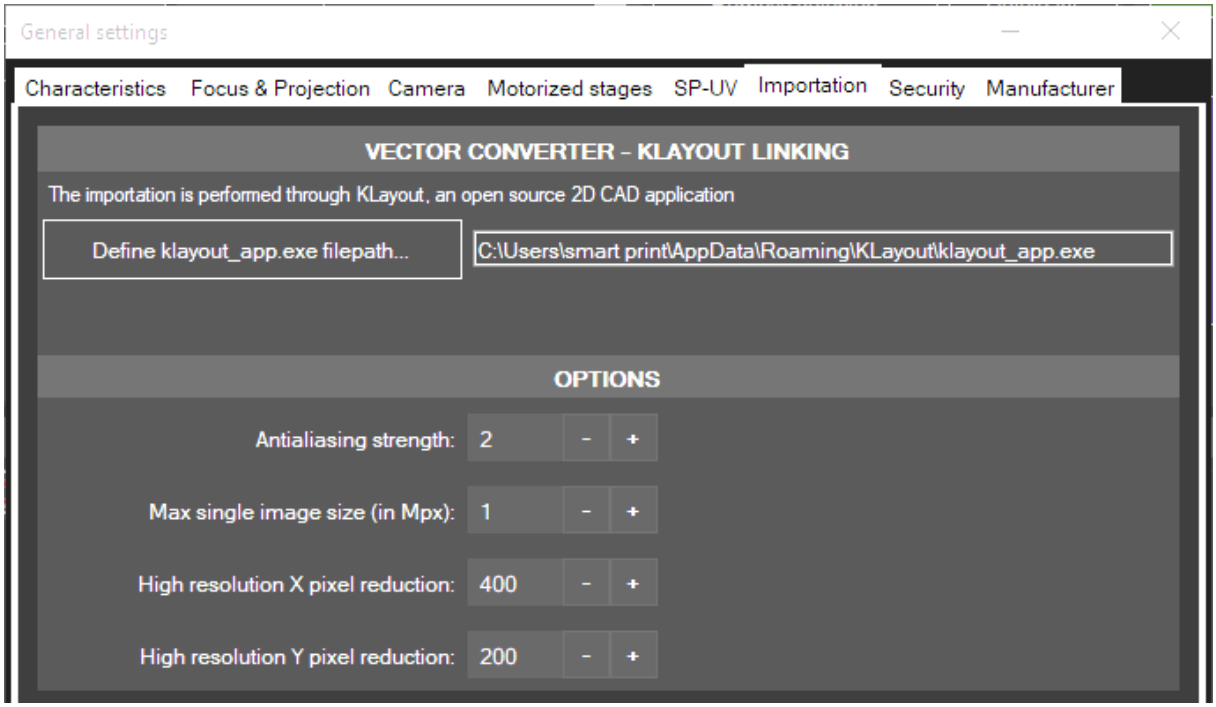


Figure 71 – Settings: vector drawing importation options

Other importation parameters:

- **Antialiasing strength**: 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
- **Max single image size**: when the conversion output image is very big, the conversion module uses a file specific format ".stitch" instead of rendering a standard png bitmap. The limit from ".png" to ".stitch" output is defined by this parameter (default value = 1 Mpx → Always ".stitch")
- **High resolution X/Y pixel reduction**: 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

SECURITY OPTIONS

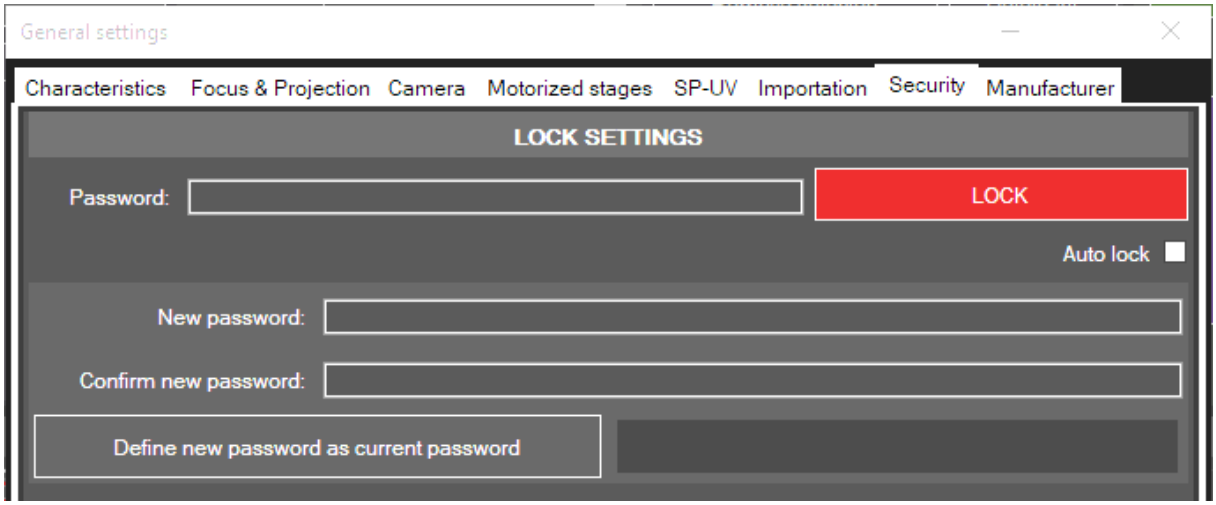


Figure 72 - Settings: security options

Although key settings can only be edited with administrator privilege, all settings can additionally be locked by a password on the **Security** tab (Figure 72). 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.

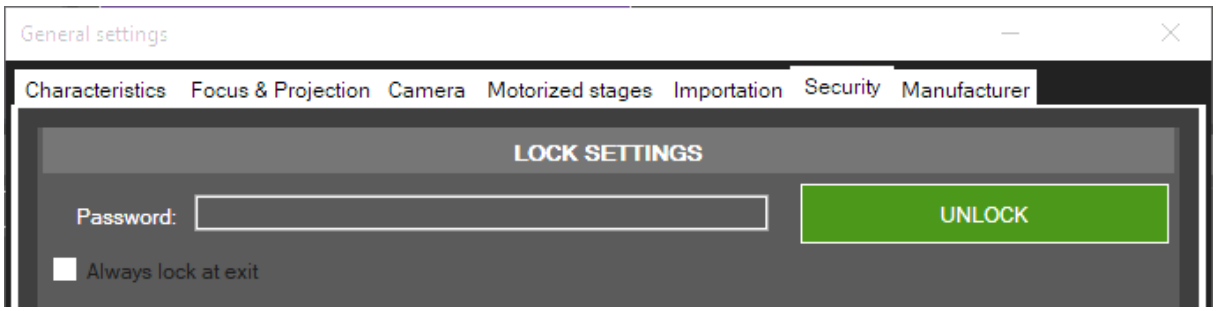


Figure 73 - Settings: unlock

To unlock the settings, enter the password on the field **Password** and click on **UNLOCK** (Figure 73).

ADVANCED MANUFACTURER OPTIONS

The **Manufacturer** tab contains a console-like interface (Figure 74). It is intended for diagnosis and repairing purposes only. DO NOT USE it by yourself.

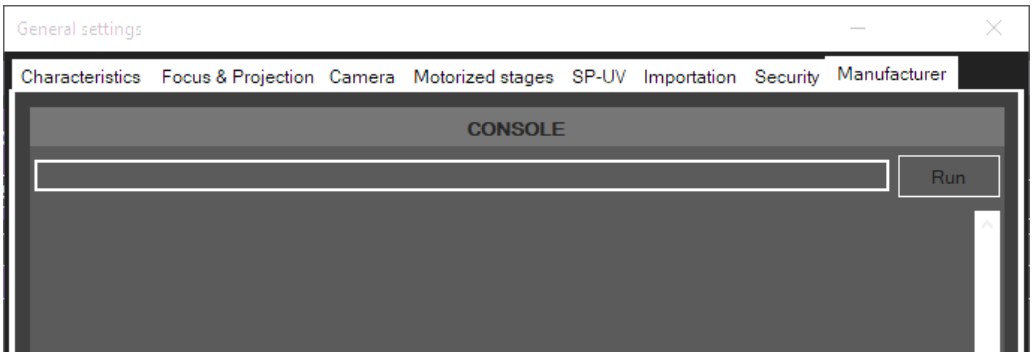
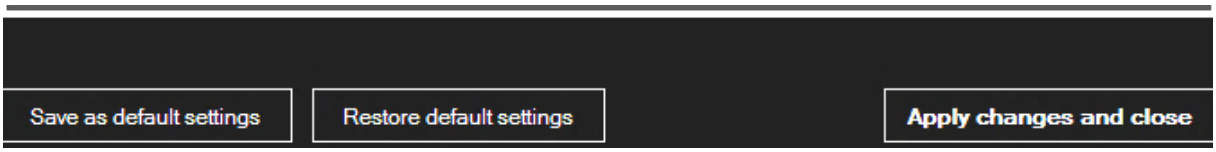


Figure 74 - Settings: Manufacturer

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 **Restore default settings** button. 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 MONTHLY MAINTENANCE: XY STAGE RE-CALIBRATION

(ONLY FOR SMART PRINT UV STANDARD – XY STEPPER MOTORS)

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 origin** (Figure 31).

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.

5.2 TROUBLESHOOTING

5.2.1 GENERAL ISSUES

Issue	Possible cause	Fixes
The equipment does not power on	• Power cord not plugged in • Power switch in OFF state • Safety fuse damaged	• Check the connection to the power outlet • Put the power switch to "I" • Replace the fuse as described below this table

The main power status in *Phaos* (Figure 51) is OFF or ERROR	• Communication error with the light engine • Light engine disconnected or damaged	• Exit *Phaos*, switch off the computer and then turn off the main power switch at the back off the machine • Restart the machine. If the problem persists, contact the manufacturer
Optoelectronic head cooling status in *Phaos* (Figure 51) is in WARNING mode	• Head cooling system does not work properly: fan speed is too low • UV LED is too hot	• Immediately STOP a lithography if running • Then, open the ADVANCED sub-panel (Figure 52) and click on the refresh button (double arrow) • If one of the fan frequencies is below 35 Hz, inspect the inlet and outlet grids in order to check if something can disturb their operation. If not contact the manufacturer • If UV LED temperature status background color is orange or red, the LED is too warm and must cool down before being reused

FUSE REPLACEMENT PROCEDURE

1. Put the power switch the OFF position “0”
2. Unplug the power cord from the wall outlet and then from the equipment outlet
3. Insert a flat screwdriver on top of the fuse compartment (purple arrow in Figure 75) and pull off the compartment from the outlet
4. Replace the current fuse by a new one with the same specifications (see section 6.1)
5. Push back the fuse compartment inside the outlet

Figure 75 - Back side of the optoelectronic head

5.2.2 CAMERA ISSUES

Issue	Possible cause	Fixes
In focus or alignment mode, the image is always black	Camera under-exposed or illumination lamp off	Adjust the camera exposure time as described in section 3.4.4
In focus or alignment mode, Pink spots appear on the image	Camera over-exposed	Adjust the camera exposure time as described in section 3.4.4

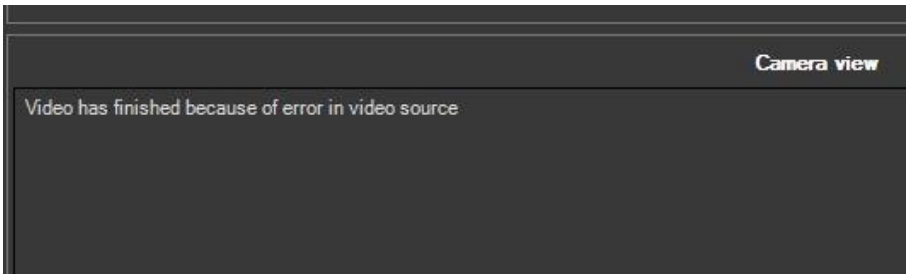


Figure 76 – Camera connection error 2

5.2.3 XY STAGE ISSUES

Issue	Possible cause	Fixes
No stage detected error message (Figure 77)	• Emergency button is pushed	• Follow procedure described in section 3.2.3, second warning note
XY stage menu disabled	Stage not connected to the computer	Same as above
XY stage buzzing – Alarm mode	• The stage moved at its limit range • The stage motion is blocked	• Immediately switch off the stage • Remove all external elements that may disturb the stage motion • If the problem persists, switch off the stage and contact us
Visible stage shift during manual control in the coordinates panel in the XY stage control window (Figure 31)	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 4.4) but will result in bad image stitching.

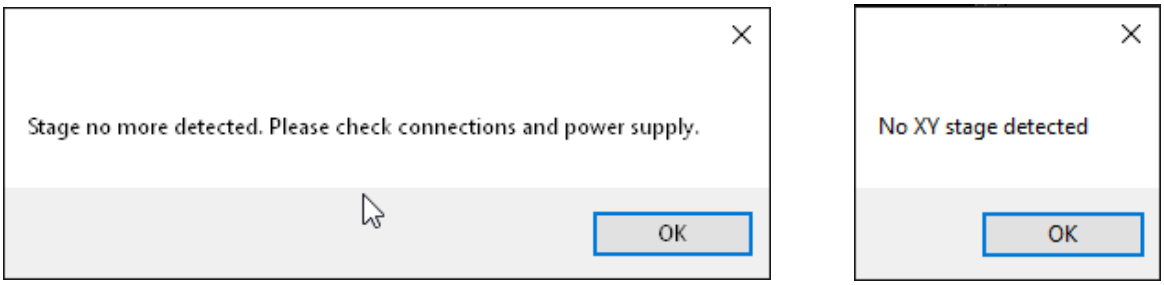


Figure 77 – XY stage connection errors

5.2.4 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	All layers (hidden or not) are converted	Open the vector file in KLayout, remove all undesired layers then save changes as a new file.

object		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 78). Klayout shortcut is installed in the Window menu or can be found by typing “KLayout” in the Windows search field.

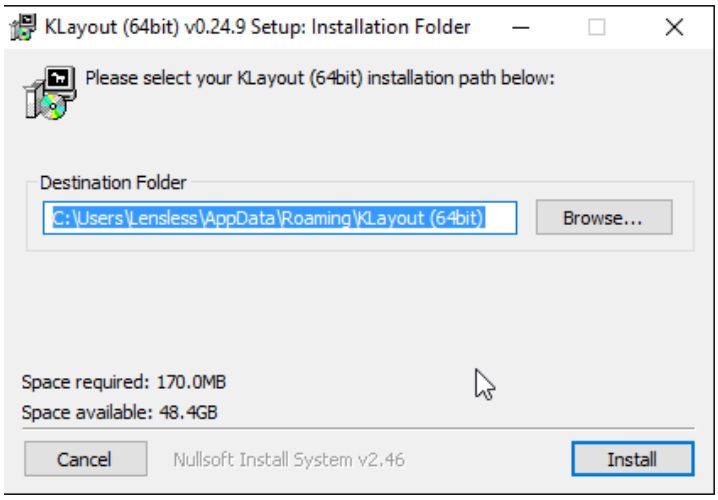


Figure 78 – KLayout installation window

Step 2: Configuration of KLayout

Run KLayout (first start may be longer because of the initialization index). Go to menu **File → Setup** (Figure 79, left). On the **Settings window**, go to **Display → Background** and uncheck **Show background decoration** (Figure 79, right). Click on **Apply** and then **OK**. Close KLayout.

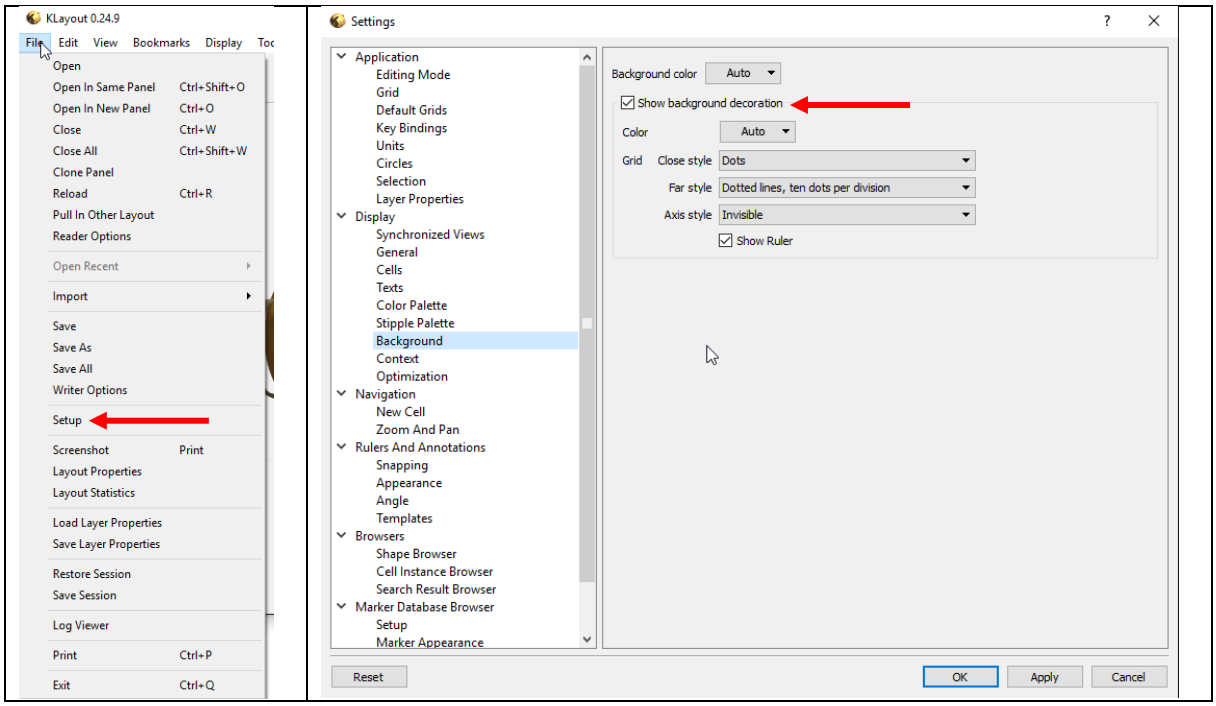


Figure 79 - Configuration of KLayout

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 **File → Settings**. In the **Importation** tab, click on **Define klayout_app.exe filepath…** (Figure 71). In the **Open** window, find and select the executable file *klayout_app.exe* (Figure 80).

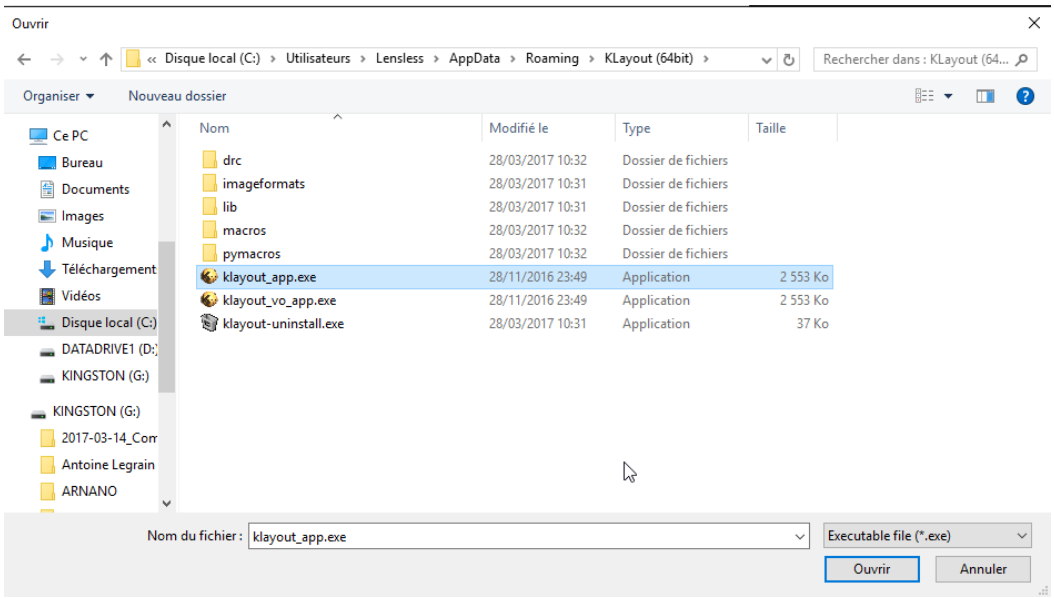


Figure 80 – Folder containing the KLayout executable

6 APPENDIX

6.1 SPECIFICATIONS

LITHOGRAPHY		
	Light illumination	UV LED at 385 nm Typical output power = 13 mW (UV LED @ 2.55 A) Max output power = 30 mW (UV LED @ 6 A)
	Resist compatibility	Broadband, h and i-line resists
Resists already known to work	AZ1500 Series *(MicroChemicals)*	Positive resist Thickness: 0,5 - 4 µm Typical exposure time (with obj. x2.5): 2 s
	S1800 Series *(Shipley)*	Positive resist Thickness: 0,5 - 4 µm Typical exposure time (with obj. x2.5): 2 s
	AZ4562 *(MicroChemicals)*	Positive resist Thickness: 5 - 40 µm Typical exposure time (with obj. x2.5): 5 s
	AZ 40XT *(MicroChemicals)*	Positive resist Thickness: 20 – 60 µm Typical exposure time (with obj. x2.5): 40 s
	AZ5214E *(MicroChemicals)*	Reversible resist (positive or negative) Thickness: 1 - 4 µm Typical exposure time (with obj. x2.5): 0.2 s (positive) + 100 s (negative)
	AZ125nXT *(MicroChemicals)*	Negative resist Thickness: 35 – 180 µm Typical exposure time (with obj. x2.5): 15 s
	SU8 GM7010 *(Gersteltec)*	Negative resist Thickness: 20 – 200 µm Typical exposure time (with obj. x2.5): 40 s
	Ormocomp *(MicroResist Technology)*	Negative resist Thickness: 20 - 60 µm Typical exposure time (with obj. x2.5): 0.2 s
Substrate compatibility	Dimensions	Up to 127 mm / 5'' wide flat substrates Thickness up to 20 mm
	Materials	All

Typical 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 1	10.6 x 5.9	5.4	< 17	20.7	945 ± 50
x 2.5	4.2 x 2.4	2.2	< 6.6	129.5	104 ± 5
x 5	2.1 x 1.2	1.1	< 3.3	518.1	36 ± 7
x 10	1.06 x 0.59	0.54	< 1.7	2072	10 ± 5

* Values may vary slightly for each equipment. Light power densities are given for UV LED set at 2.55 A

CAD AND COMPUTER		
Drawing	Native 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
Peripheral requirements	Monitor resolution	1920 x 1080
	Connections	1 USB-C 3.1 and 2 USB-A 2.0 or better
	Display size	At least 17''

MECHANICS		
	Dimensions	70 cm H x 52 cm W x 52 cm D
	Weight	100 kg (without accessories)
	Materials	Aluminum, steel and plastics

POWER REQUIREMENTS		
	Supply voltage	100 – 240 V AC ±10%, 50/60 Hz
	Supply current	3.6 – 1.5 A
	Input power	360 W
	Main input fuse	7.5 A (110 V) or 3.15 A (240 V)

ENVIRONMENTAL		
	Operating temperature	+5 to +35°C
	Operating humidity	5 to 95 RH, non-condensing
	Maximum altitude	2,000 m (at 25°C)
	Recommended conditions	20 °C +/- 2 °C at 50 RH