SMART PRINT

USER'S MANUAL FOR SMART PRINT MASKLESS LITHOGRAPHY EQUIPMENT

For SFTprint 1.6 or above

MICROLIGHT3D SAS
5, avenue du Grand Sablon – 38700 La Tronche – France
+33 (0)4 76 54 95 16

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1 GENERAL INFORMATION

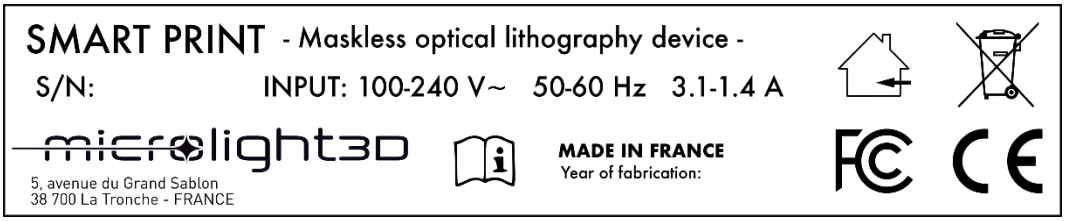
1.1 SAFETY INFORMATION

Smart Print 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:

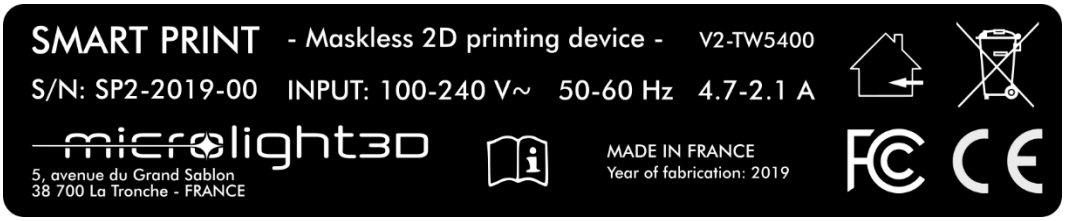
- Smart Print is an electrical instrument; to avoid electrical shock, please observe all standard precautions, such as not operating the device near water and operating the device at appropriate voltage and frequency.
- Do not remove panels or housing.
- If the equipment is used in a manner that is not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

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

1.2 IDENTIFICATION MARK



For Smart Print fabricated before 2019 August



For Smart Print fabricated after 2019 July

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

TECHNICAL SUPPORT

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

2 ABOUT SMART PRINT

2.1 GENERAL USE

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

PRINCIPLE OF OPERATION

- Smart Print 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’s objective used.
- The image is projected with blue light during a user defined time.
- With a time adapted exposure, the projected image can be replicated onto the resist.

2.2 EQUIPMENT DESCRIPTION

2.2.1 OVERVIEW

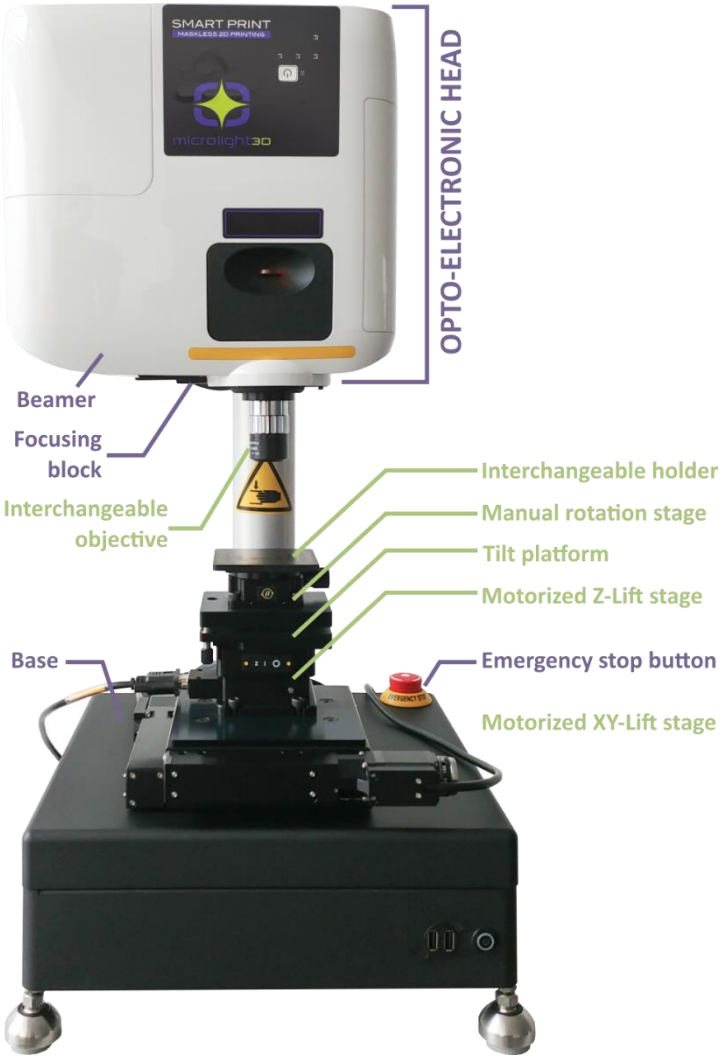


Figure 1 – Smart Print with its main accessories

2.2.2 OPTO-ELECTRONIC HEAD

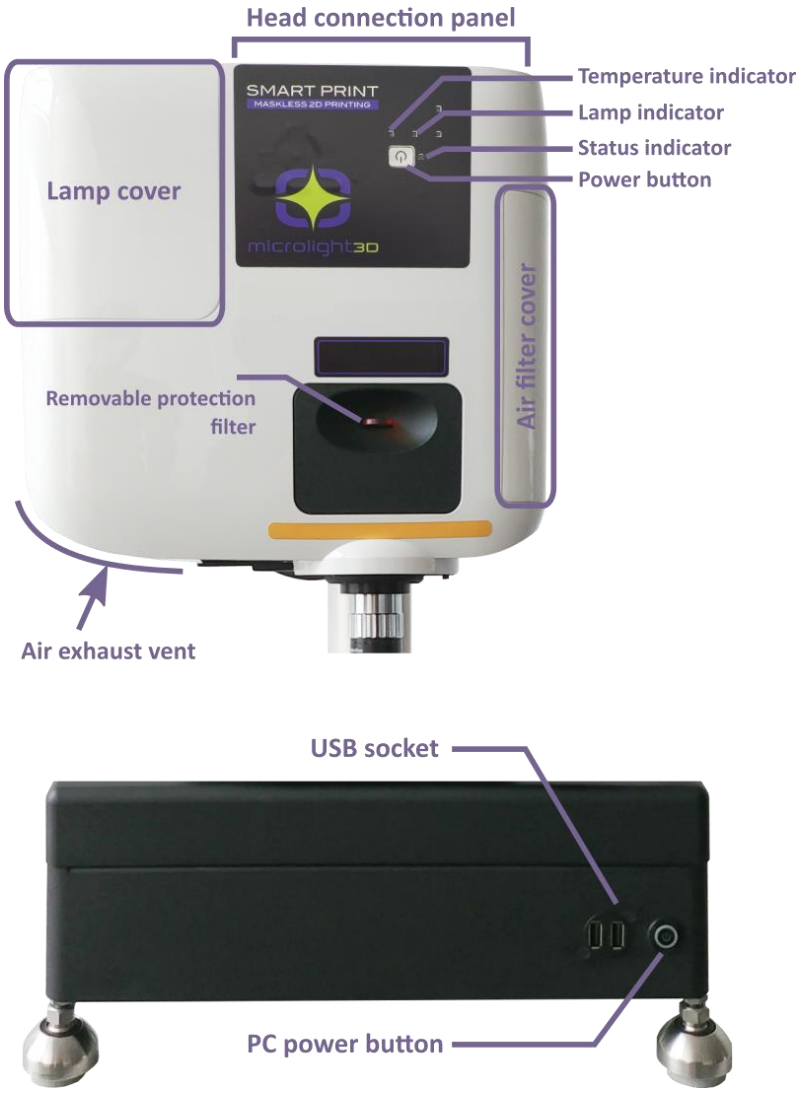


Figure 2 – Front view of the base and opto-electronic head

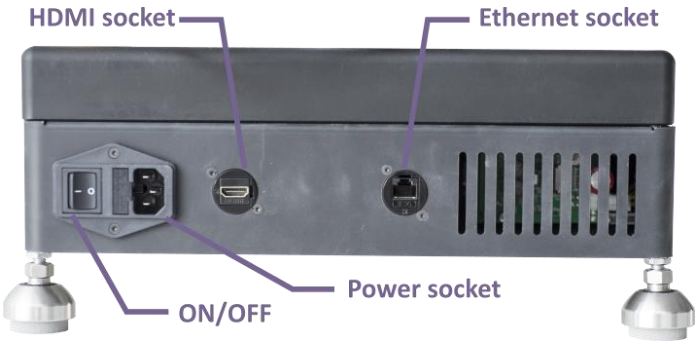


Figure 3 – Back side view of the base

Figure 4 – Connection panel

2.2.3 FOCUSING BLOCK & COLUMN

Figure 5 – Left and right side of Smart Print

2.2.4 OPTION 1: MANUAL Z-LIFT WITH TILT PLATFORM

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

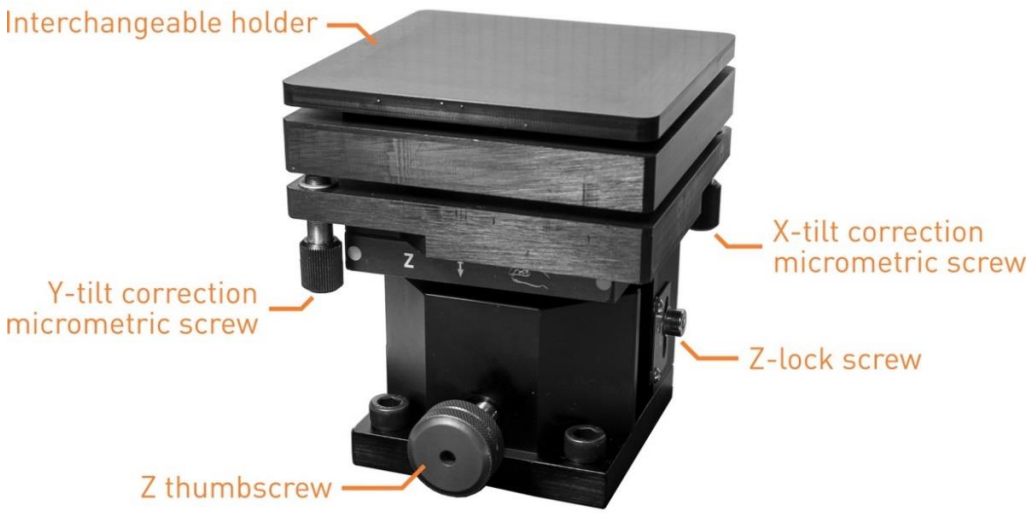


Figure 6 – Manual Z-lift

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

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

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

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

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

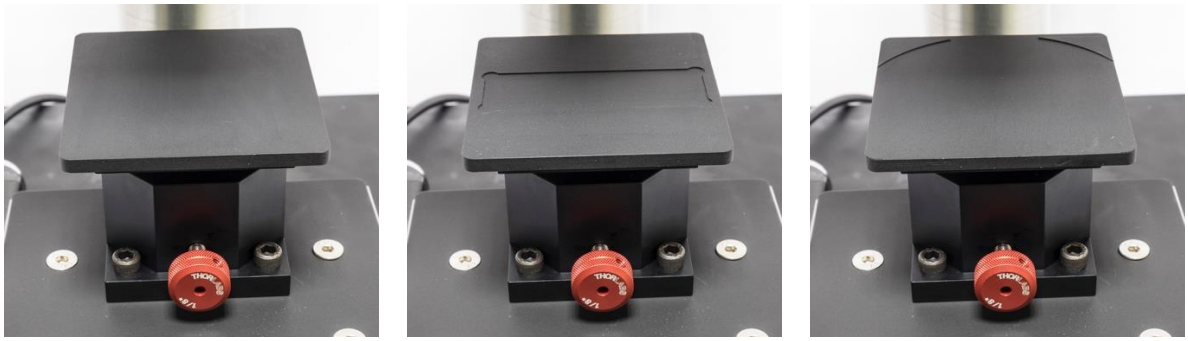


Figure 7 – From left to right: flat holder, microscope glass slide holder and 4'' wafer holder

2.2.5 OPTION 2: MOTORIZED XY STAGE

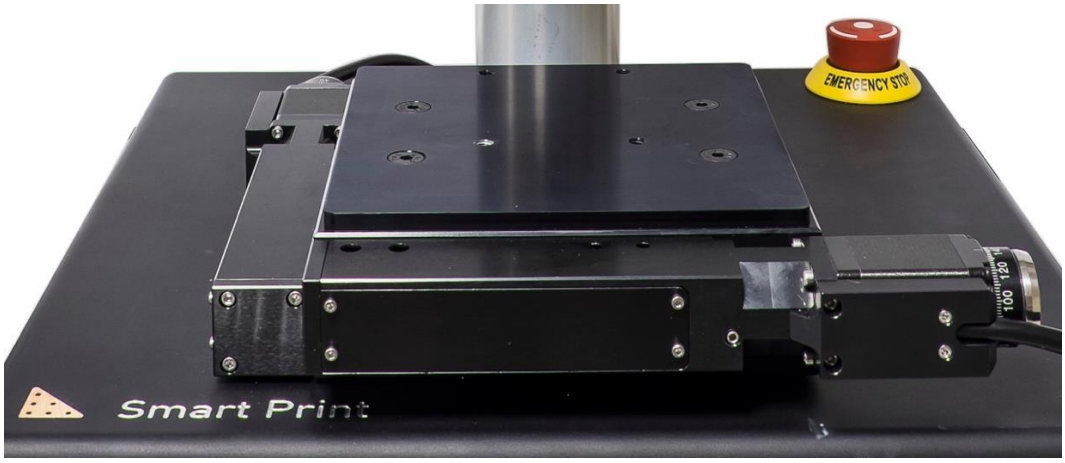


Figure 8 – Motorized XY stage

The motorized XY stage is configured with the following specifications:

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

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

2.2.6 OPTION 3: MOTORIZED Z LIFT WITH TILT PLATFORM

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

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

Figure 9 - Motorized Z-lift

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

2.3 SOFTWARE DESCRIPTION

The software main interface is composed of 4 panels:

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. **Stage Control Panel.** It contains the most common stage control options (visible only if Smart Print is equipped with XY(Z) motorized stage)

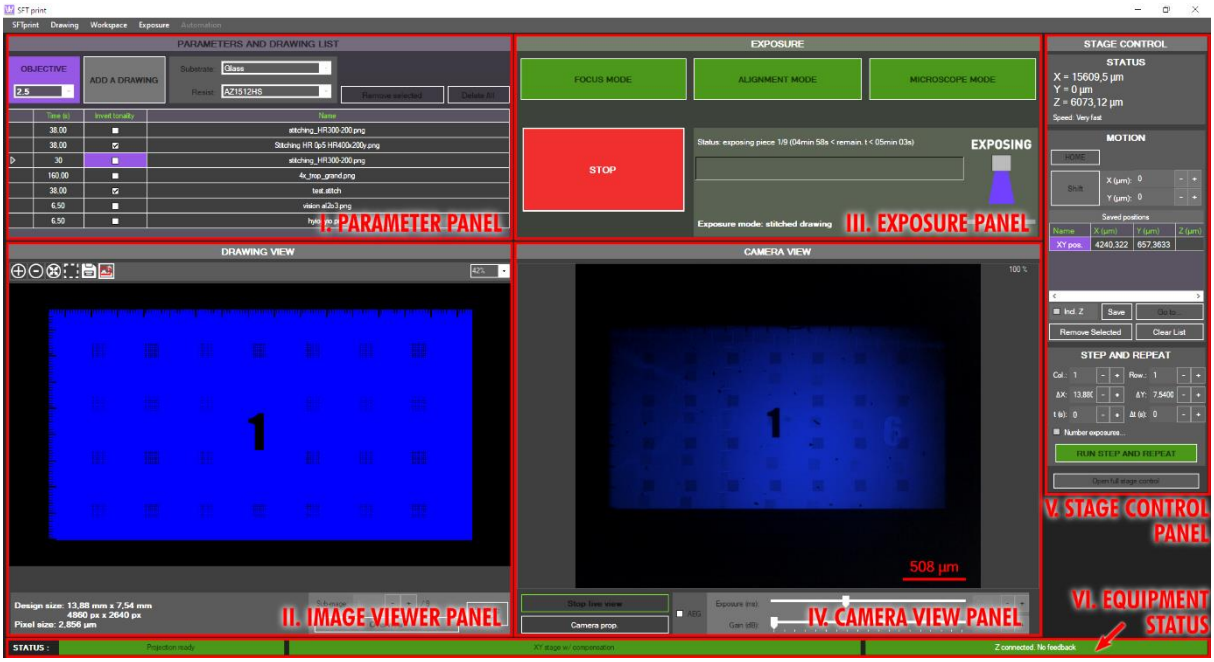


Figure 10 – SFTprint main window

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

3 PROCESSING WITH SMART PRINT

3.1 INSTALLATION AND HANDLING

The equipment must be installed in an appropriate operational environment:

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

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

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

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

3.2 ELECTRICAL CONNECTION

3.2.1 MAIN POWER SUPPLY

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

3.2.2 CONNECTIONS TO THE COMPUTER

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

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

3.3 QUICK USE WITHOUT MOTORIZED Z-STAGE

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

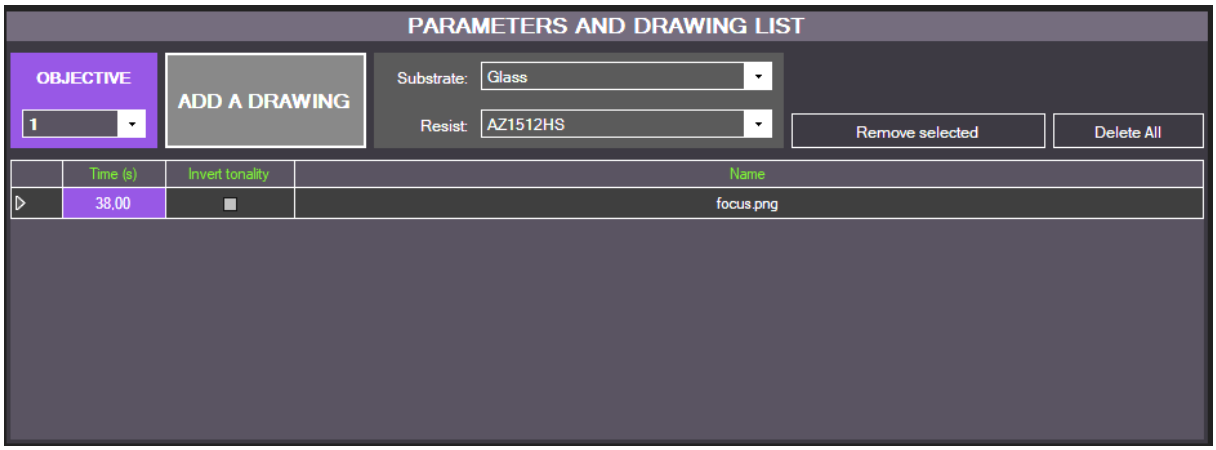


Figure 11 – « Parameters and drawing list » panel

- Make the focus on a blank substrate (more details in section 3.5.5):
  - Load a blank substrate

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

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

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

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

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

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

3.4 QUICK USE WITH MOTORIZED Z-STAGE

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

- Make the focus (more details in section 3.5.5):
  - Load the sample to be exposed
  - Click on **FOCUS MODE** in the **EXPOSURE** panel (Figure 10). Ensure that the protection filter is loaded (Figure 13)
  - Adjust the distance between Smart Print head and the sample by releasing the ***locking handle*** (Figure 5 left) and turning the ***adjustment wheel*** (Figure 5 right) until a sharp image is visible on the panel **camera view**

    NOTE: Use keyboard shortcut ctrl + numpad 9 and ctrl + numpad 3 for fine focus tuning (section 4.2.1).

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

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

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

3.5 BASIC OPERATIONS

3.5.1 LOADING/UNLOADING AN OBJECTIVE

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

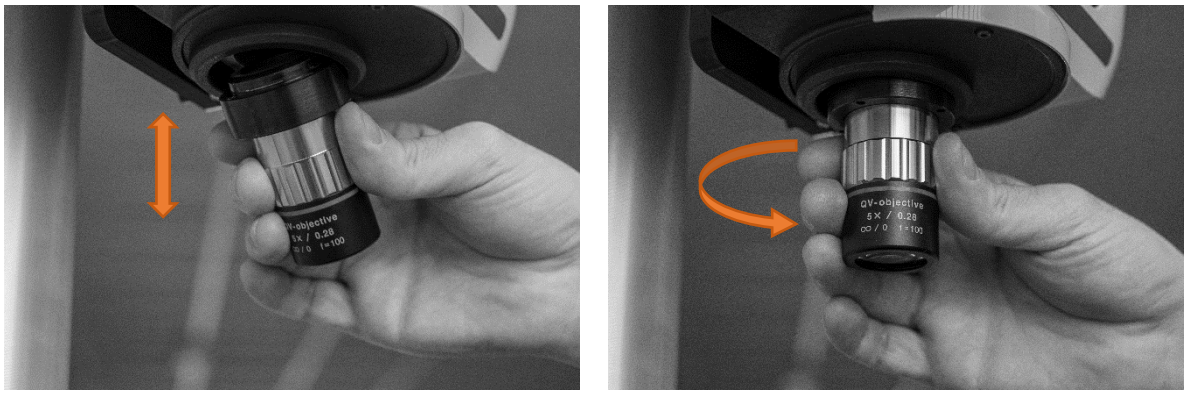


Figure 12 – Two-steps objective loading

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

3.5.2 LOADING/UNLOADING THE PROTECTION FILTER

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

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

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

3.5.3 EXPOSING A DRAWING WITHOUT STANDARD DIMENSIONS (1920x1080)

CASE OF ".STITCH" FILES

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

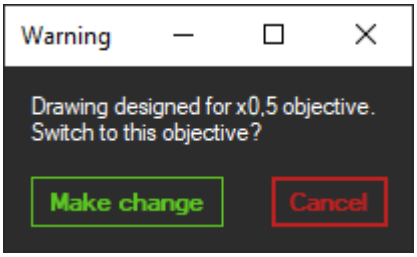


Figure 14 - Bad objective warning message

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

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

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

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

- **CROP:** only the central part of the drawing is kept
- **DOWNSIZE:** the drawing is resized through a bicubic interpolation to fit the standard dimensions (original aspect ratio is preserved). Depending on the original drawing dimensions, it may result in a significant image quality reduction
- **STITCH** (only available if a motorized XY stage is connected): 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's resolution (1920x1080), a **(Black)** or **(White)** frame will be added around the drawing

« STITCHING » MODE (XY STAGE REQUIRED)

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

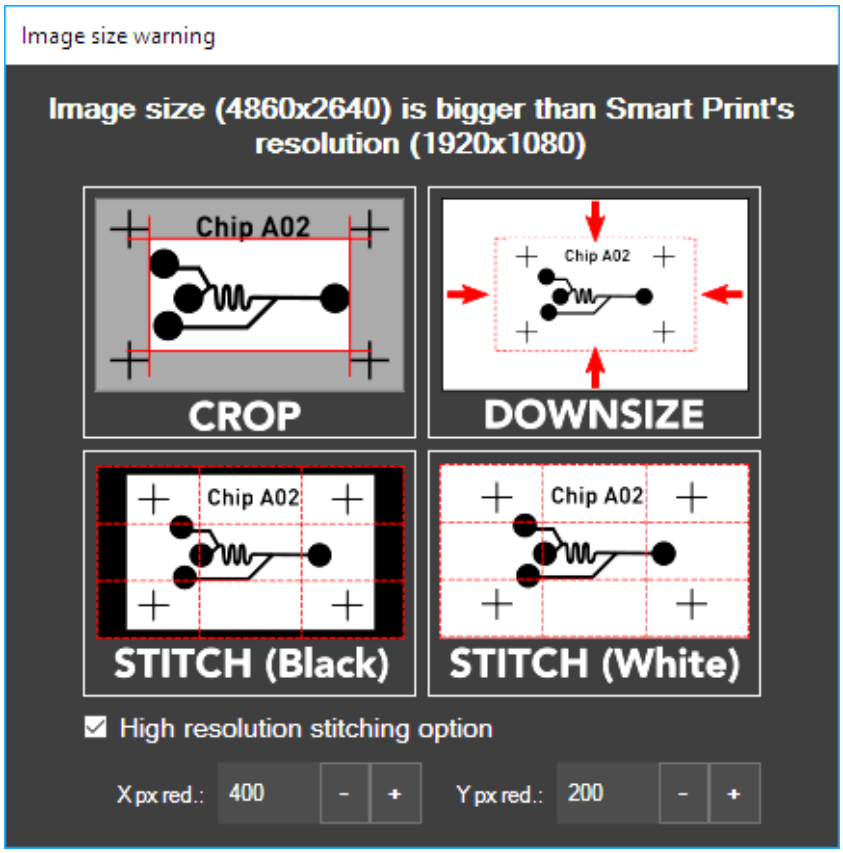


Figure 15 – « Big image » popup dialog

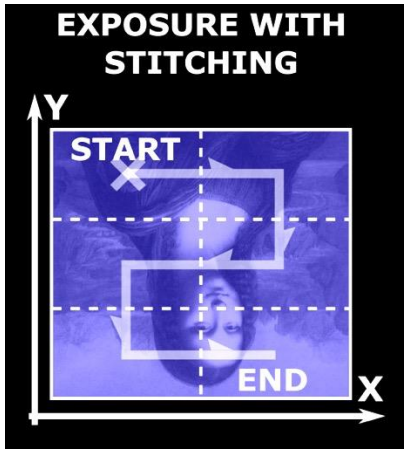
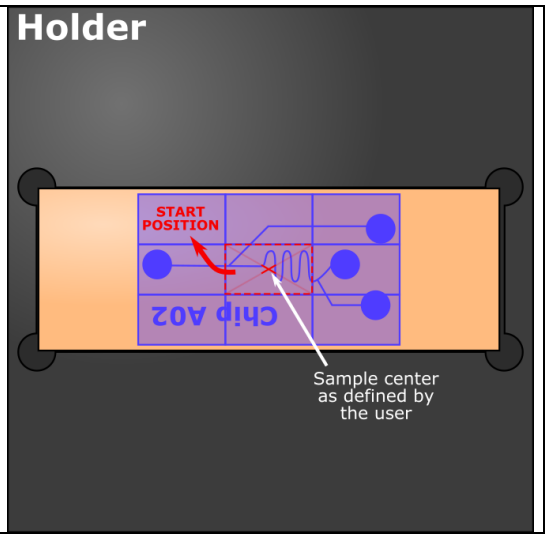


Figure 16 – Exposure principle of the "stitching mode"

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

- In the **PARAMETERS AND DRAWING LIST** panel (Figure 10), choose an objective, a resist and a substrate in the corresponding dropdown lists (Figure 11)
- Add a bitmap drawing on the drawing list by clicking on **add…** then select **STITCH (Black)** or **STITCH (White)** on the **Image size warning** popup dialog (Figure 15).
  → A ".stitch" file – preconfigured for exposure in stitching mode – can also be directly loaded (for more details, refer to section 3.5.9).
- Adjust the exposure time if necessary and make the focus (see section 3.5.5).
- Position the substrate, thanks to the XY stage, at the starting point for a stitched lithography (START position in Figure 16). If the stage status is XY out-of-range, the current start position cannot be used for stitching and must be changed

PRE-POSITIONING: if centering the drawing on the sample is required, you can move on the center of your sample and then go to **Automation** menu, select **Positioning** and click on **Move from current center position to start position**. The stage will then automatically go to the START position to get your design centered (see section 4.1.3).	

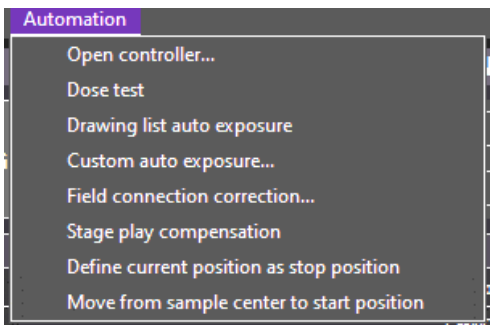
- Click on **EXPOSE SELECTED DRAWING**.

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

Figure 17 – Progression preview of a stitched lithography

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

IMPROVEMENT OF THE FIELD CONNECTION IN STITCHING MODE



SFTprint offers two complementary options to improve the field connection in stitching mode. The first one is the stage play (backlash) compensation option. To check/uncheck this option, go to **Automation** menu and click on **Stage play compensation**. If the XY stage status on the bottom left corner of the main window is XY stage not compensated, it means the compensation is disabled. If activated, the status becomes XY stage w/ compensation.
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).

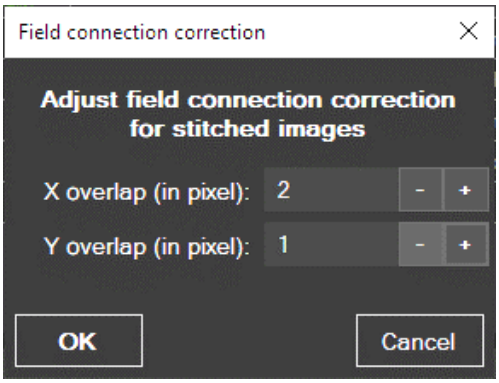
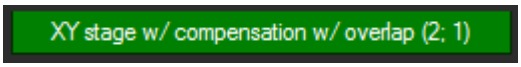


Figure 18 – Field connection adjustment window

The second option to improve lithography in stitching mode is called field connection correction and is only **available for High Resolution** (see the NOTE above) images. Smart Print 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 **Automation** menu and clicking on **Field connection correction…**. In the **Field connection correction** window (Figure 18), the desired additional overlap values along the X and Y axis can be selected. **Warning**: a negative value will add a gap between each sub-image leading to a small loss of information.
When an overlap is configurated and a compatible drawing selected the equipment status (Figure 10) is updated as shown below:



3.5.4 DRAWING OPTIONS AND PREVIEW

DRAWING SETTINGS

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

- **Time**: exposure time in seconds for the corresponding drawing. 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 drawing.

Figure 19 – Image viewer panel

DRAWING PREVIEW

Each selected drawing is directly displayed in the panel **Image Viewer** (Figure 19). The dimensions of projected image are visible on the top left corner of the viewer. Different actions are possible to navigate into the drawing:

- Zoom In: button
- Zoom Out: button

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

- Fit drawing size to window: button
- Zoom on a selected area: button, then select an area with the cursor
- Move into the image: button, then click and hold on the image and move the cursor in the desired direction
- Save current image: button, then give a name to the image to be saved. This option only saves the currently displayed sub-image in case of stitched drawing. It can then be used to extract a detail into a ".stitch" file
- Show/Hide a preview window: button

- Switch to full screen mode / normal mode: in the **Workspace** menu, select **Drawing only** or press the shortcut F2. To come back to normal mode, select **Standard** on the same menu or press F1

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

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

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

Finally, the **Stitching pattern** button displays the stitching reminder schematics in Figure 16.

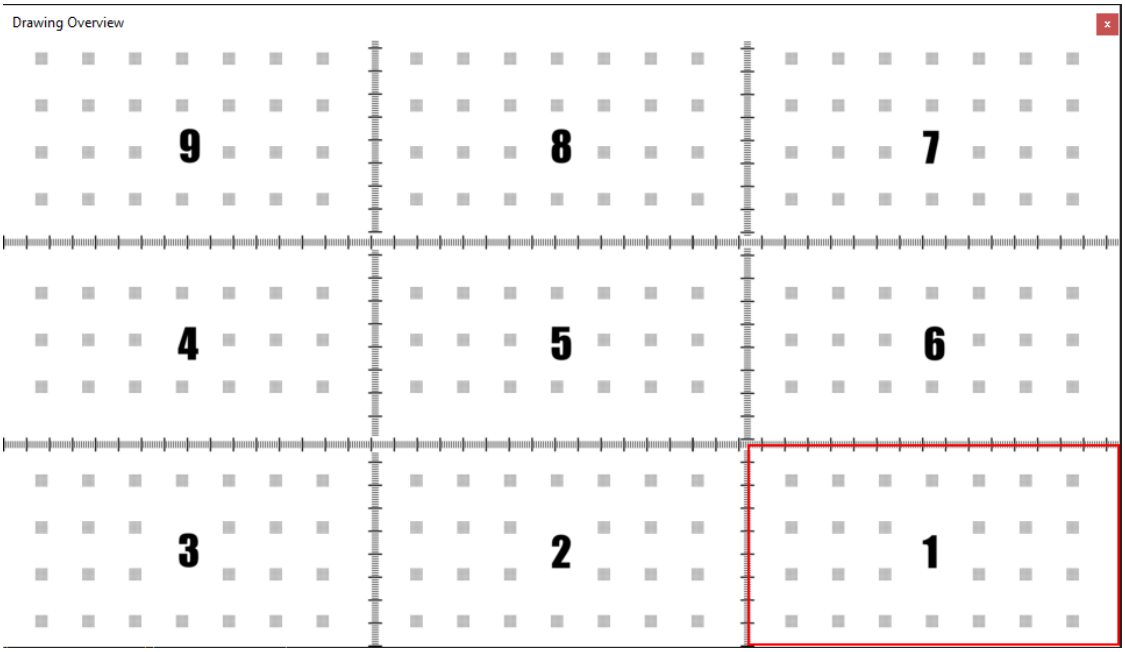


Figure 20 - Overview window corresponding to the stitched image selected in the previous figure

3.5.5 FOCUS ADJUSTMENT

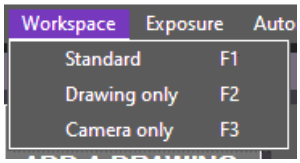
Smart Print is a projection-based photolithography equipment. Then it requires a precise adjustment of its focus on the photoresist plane.

WITHOUT MOTORIZED Z-STAGE

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

- Load a blank or reference substrate. That one must have the same thickness as the sample to be exposed.

- Click on the button **FOCUS MODE** in the **EXPOSURE** panel (Figure 10). The camera live view will start automatically in the **CAMERA VIEW** panel (Figure 21).
- Pull the protection filter to its unload position (Figure 13)
- If the image in camera view is to dark or to bright (area highlighted with pink color), adjust the camera exposure time by clicking on the button **Camera prop.** Then, tune the exposure slider or enter a new value on its right side in milliseconds. If the **Auto Exposure and Gain (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.



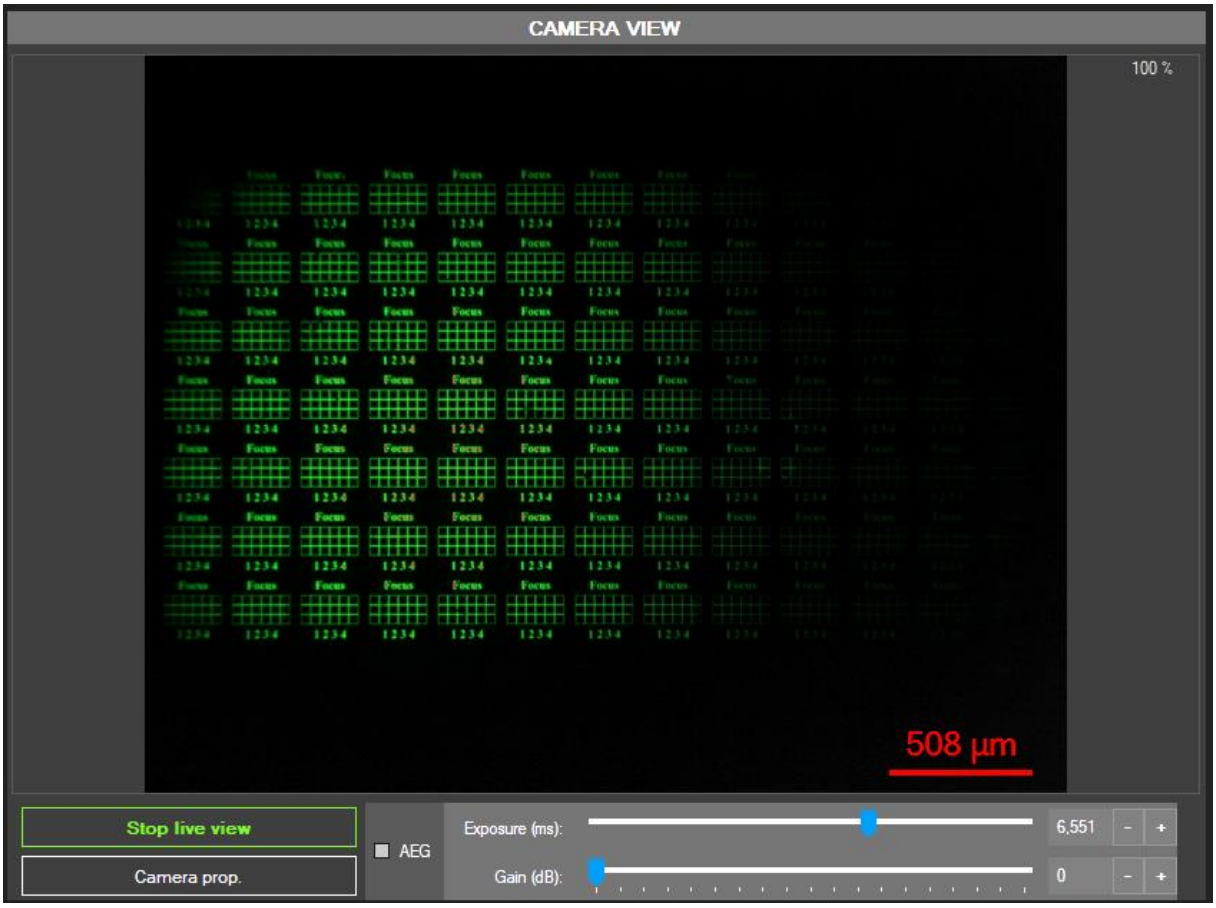


Figure 21 – Camera view panel during focus setting

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

- Adjust the distance between Smart Print head and the sample by releasing the ***locking handle*** (Figure 5 left) and turning the ***adjustment wheel*** (Figure 5 right) until a sharp image is visible on the **camera view** panel.

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

- Once adjusted, secure the ***locking handle*** and leave the focus mode by clicking on button **Stop Focus** in the **Exposure** panel.
- Remove the reference substrate

WITH MOTORIZED Z-STAGE

If configured in the application settings (4.4), this module allows making the focus under safe green illumination (no reference substrate needed). To set the focus, proceed to the steps as described below:

- Push the protection filter to its load position (Figure 13)
- Load the final substrate.
- On the panel **exposure list and parameters** (Figure 10), choose your objective
- Click on the button **FOCUS MODE** in the **Exposure** panel (Figure 10). The camera live view will start automatically in the **Camera View** panel (Figure 21).
- If the image in camera view is to dark or to bright (area highlighted with pink color), adjust the camera exposure time by clicking on the button **Camera prop.** Then, tune the exposure slider or enter a new value on its right side in milliseconds. If the **Auto Exposure and Gain** 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.

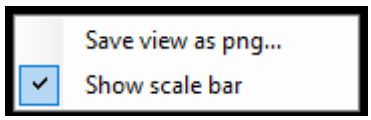
NOTE: If the image displayed in the camera view is too saturated (some area highlighted in pink), there is a risk of error in the focus adjustment.

- Coarse adjustment: Adjust the distance between Smart Print head and the sample by releasing the ***locking handle*** (Figure 5 left) and turning the ***adjustment wheel*** (Figure 5 right) until a sharp image is visible on the **camera view** panel. Once adjusted, secure the ***locking handle***.
- Fine adjustment: Adjust the height of the motorized Z-lift plate, using the software controls described in section 4.2.1, until a sharp image is visible on the **camera view** panel.
- Leave the focus mode by clicking on button **Stop Focus** in the **Exposure** panel.

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

EXTRA FEATURES ON CAMERA LIVE VIEW

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

3.5.6 MICROSCOPE MODE

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

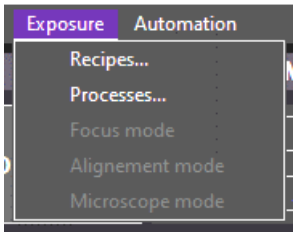
- Ensure that the protection filter is loaded
- Click on the button **MICROSCOPE MODE** in the **Exposure** panel (Figure 10). The camera live view will start automatically in the **Camera View** panel (Figure 21).
- If the image in camera view is to dark or to bright (area highlighted with pink color),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

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

3.5.7 EDIT OR ADD RECIPES

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

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



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

To add a new recipe, click on the button **Add**. An edition panel will appear as shown in Figure 23. Choose an objective magnification (0.5, 1, 2.5, 5 or 10) and fill the “Substrate”, “Resist” and “Exposure Time” fields. Click on the button **OK** to confirm the addition.
To edit an existing recipe, select it on the list and click on the button **Edit…**. Then follow the same instructions as described to add a new recipe.

To save changes, click on **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 button **Export…**. The factory recipe database can also be restored by clicking on the button **Restore factory recipes**. If the database is restored, all added or modified recipes will be deleted.

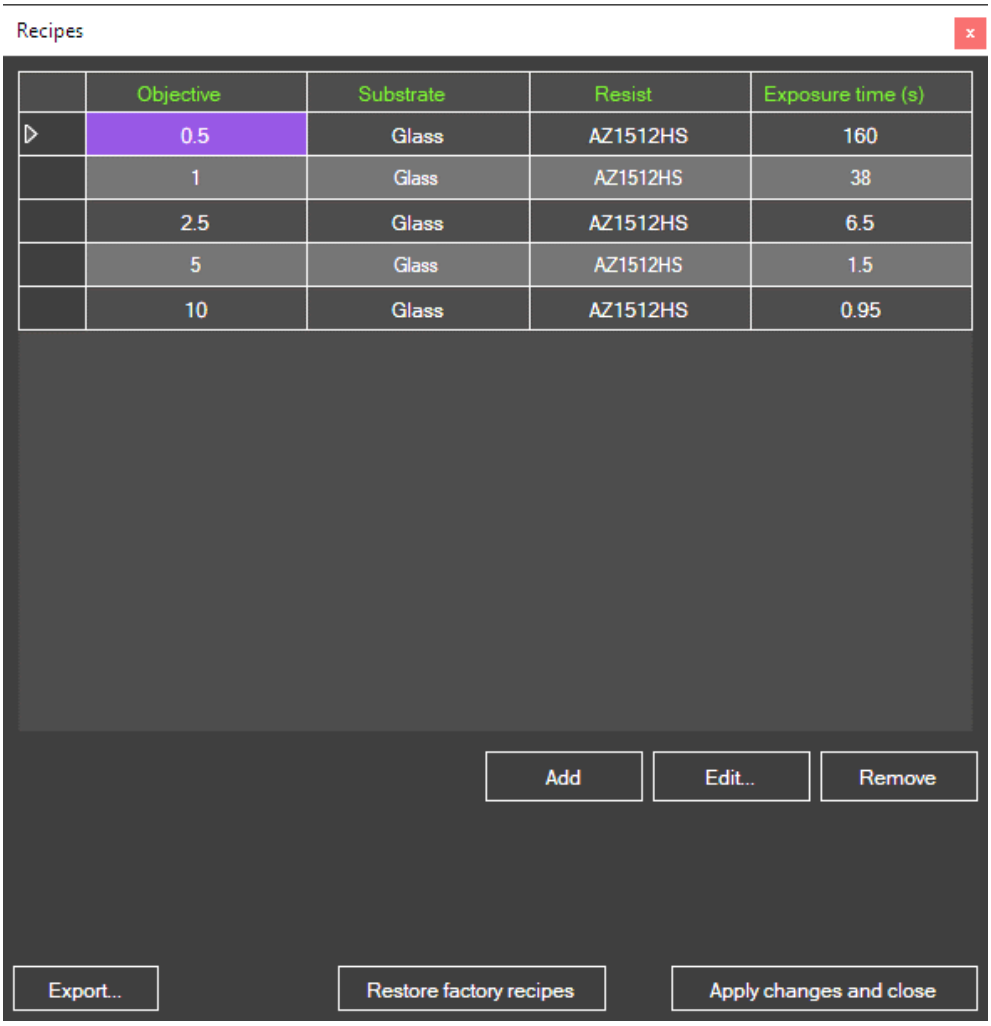


Figure 22 – Recipe database window

Figure 23 – Add/Edit a recipe panel

3.5.8 EDIT OR ADD LITHOGRAPHY PROCESSES

For users performing regularly the same lithography process, SFTprint 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
- Drawing tonality
- Inhomogeneity correction
- White background option

- Stage settings: antiplay compensation option, overlap settings and stop position if defined and enabled (section 4.1.7)
- (Optional) XY(Z) current position

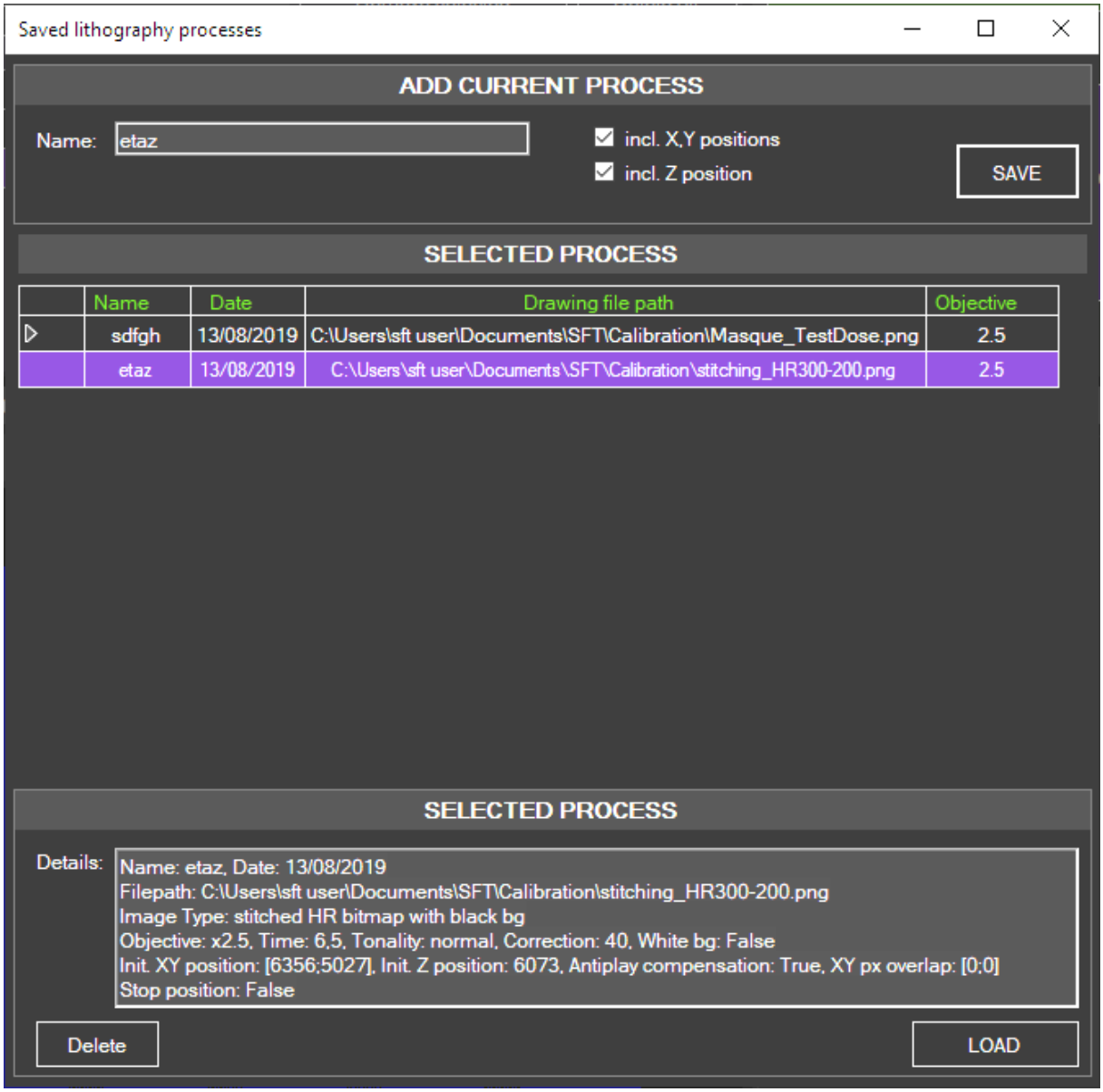


Figure 24 - Process database window

CREATE NEW ENTRY IN PROCESS DATABASE

To create a new process, first configure SFTprint for the lithography you wish to save. When all parameters are set, click on **Processes…** in the **Exposure** strip menu. On the **Saved lithography processes** window (Figure 24), 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.

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

WORKING PRINCIPLE

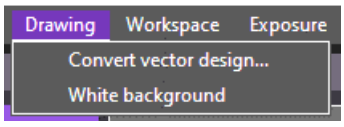
Smart Print is a lithography equipment based on light projection through a matrix of pixels. It then requires bitmap file type (png, tiff, etc.). Yet, SFTprint can convert a vector drawing (compatible format: gds, dxf, oas and cif) into a bitmap.

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

- Extract the total dimension of the vector drawing (**its base unit must be µm or mm**)
- According to the objective selected by the user, a bitmap file with a relevant dimension in pixels is created. Depending on the bitmap size output and the application settings, the result is an either a lossless .png or a .stitch file (Smart Print 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 SFTprint follow the instructions below:

- In the menu **Drawing**, select **Convert vector design…**
- In the vector Conversion Module window (Figure 25) click on **Load GDS, OAS, DXF or CIF…** 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 and the objective to be used for the lithography. A preview image of the conversion result is also dynamically generated and displayed (Figure 27). The red dashed grid on the preview image shows how the design will be sliced during conversion.
- In the layer panel (Figure 26), select the layer(s) to be converted (for multiple layer selection, hold Ctrl and click on the layer you want to add)

- Check the **High-resolution** option to improve the overall quality of the lithography. This option is especially recommended if the patterns are close to the critical dimension (refer to the NOTE about “high resolution” on section 3.5.3 for more information)
- Check the **Antialiasing** option if a smoothing of the edge is wanted (recommended, especially for complex geometries such as curved structures)
- Click on **CONVERT**. 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 **Load to drawing list and close**

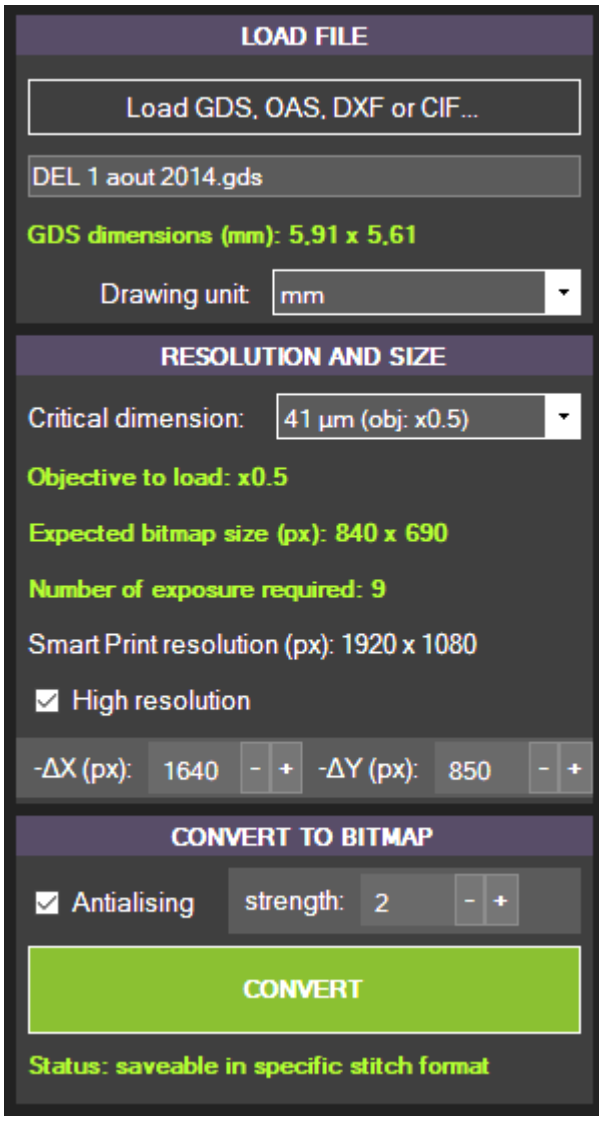


Figure 25 – Vector drawing conversion module – left panel

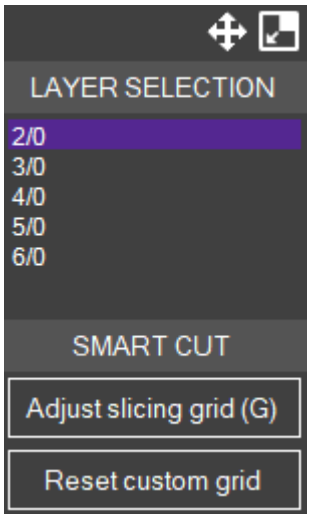


Figure 26 - Layer panel (moveable)

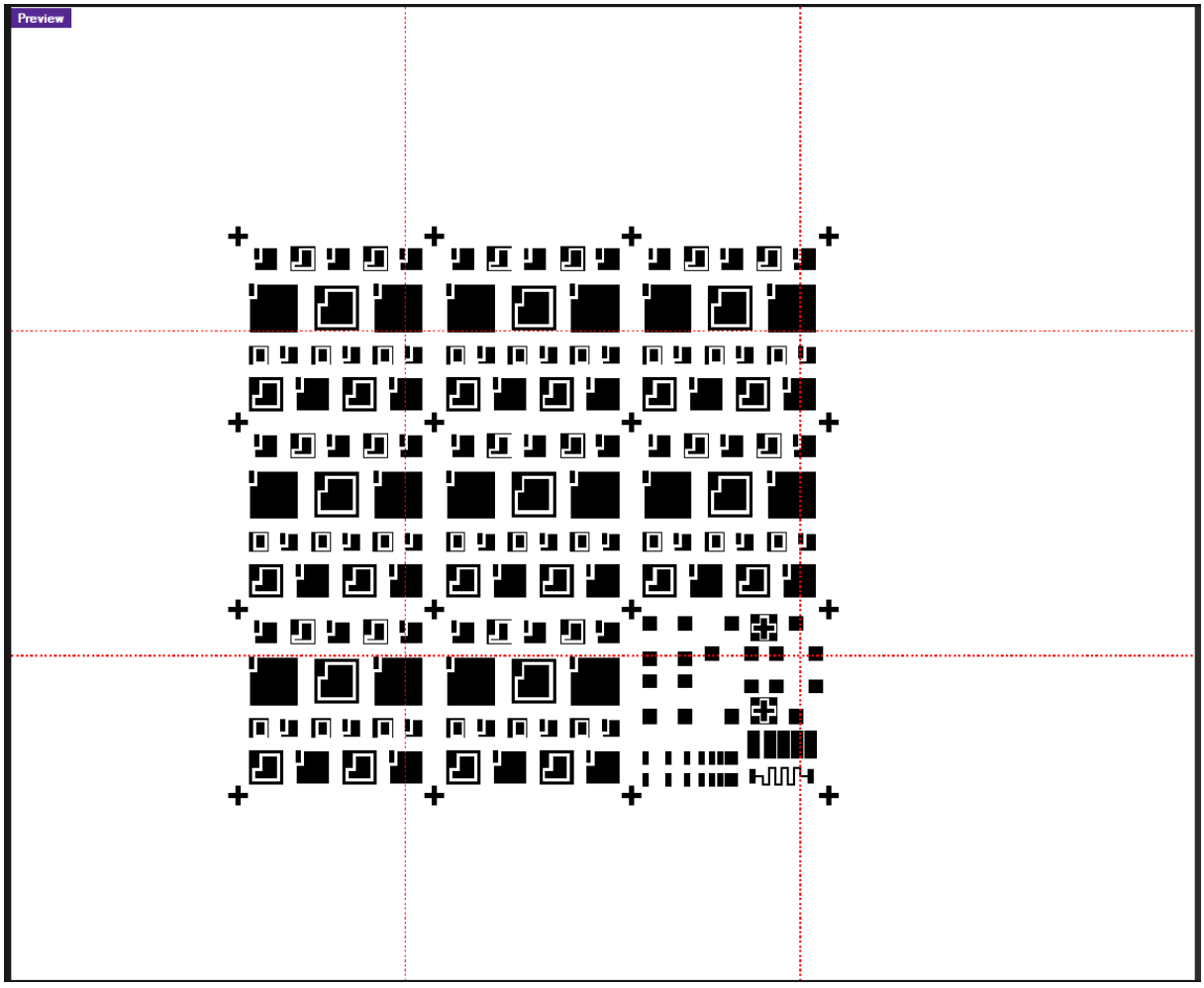


Figure 27 - Example of conversion preview with slicing grid

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 69 page - 62 -).
- Converting in « .stitch » is recommended, especially for big drawings as it records useful design information that will make the lithography simpler.
- If the state before conversion is *saveable as png*, the treatment takes only few tens of seconds. In the case of *saveable in specific stitch format*, the operation can take from few seconds to several minutes depending of the size of the output image.

CUSTOM SLICING OF THE DESIGN

Re-positioning. Sometimes, the slicing grid crosses key patterns on the design. In that case, it can be useful to manually re-position and/or resize the slicing grid. To do so, click on **Adjust slicing grid** in the layer panel (Figure 26) 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 28 :

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

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

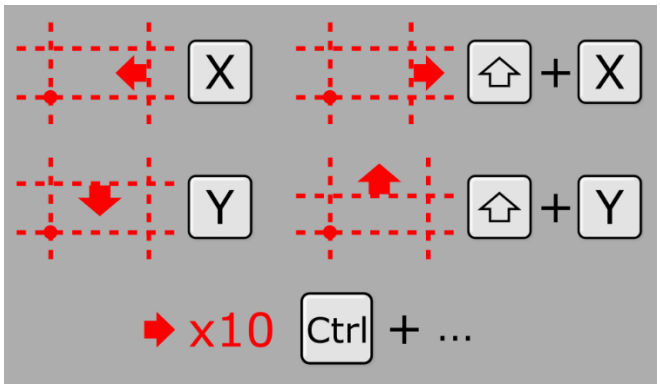
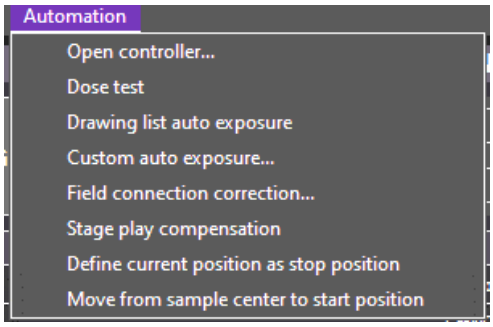


Figure 28 - Smart Cut re-scaling instructions

4 ADVANCED PROCESSING

4.1 AUTOMATED LITHOGRAPHY USING THE MOTORIZED XY STAGE

4.1.1 STAGE CONTROL



To open the XY stage control interface, go to the menu **XY stage** and click on **Open Controller…**. A new window will open as shown in (Figure 29). This interface can also be launched by clicking directly on XY stage status label 

at the bottom of the main window.

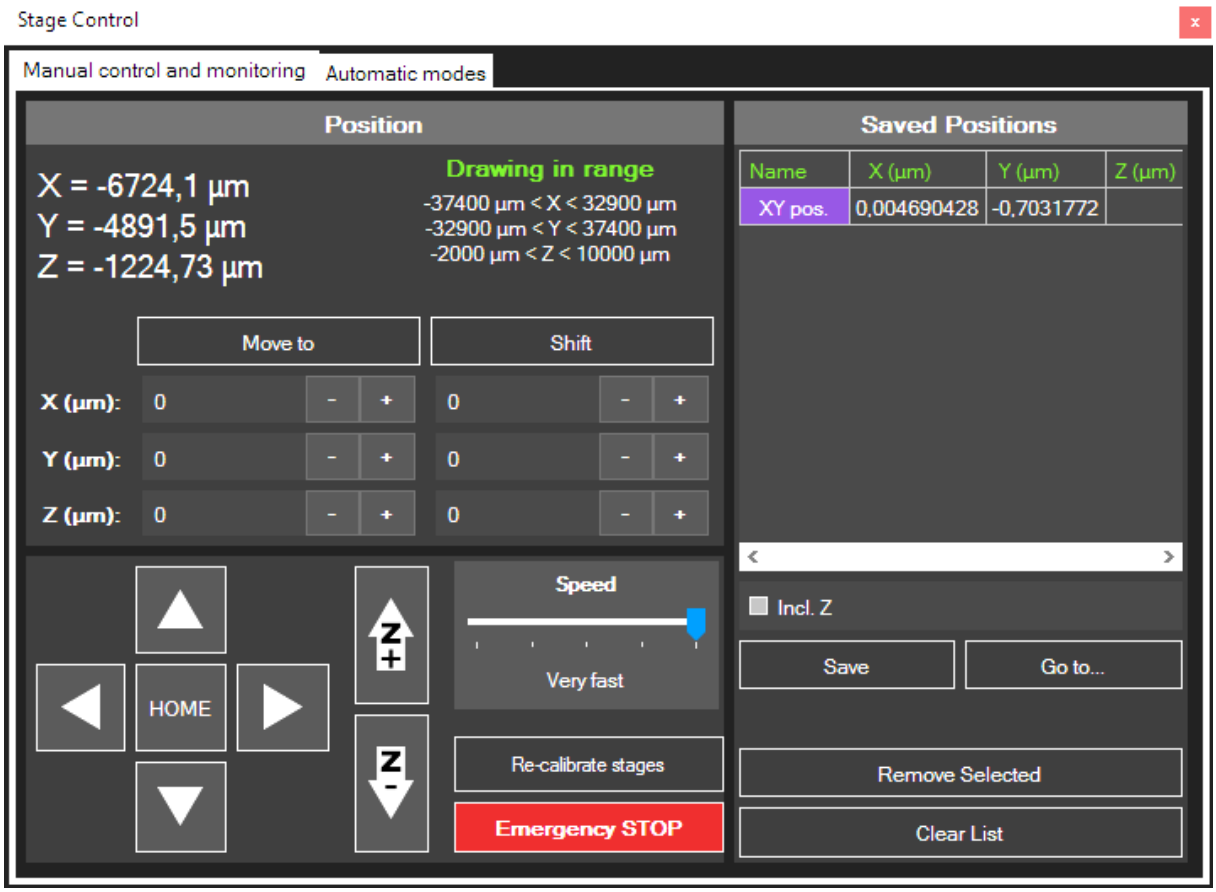


Figure 29 – XY stage control and monitoring interface

MONITORING

In the **Manual control and monitoring** tab, the panel **Position** 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 buttons **Up**, **Down**, **Left** and **Right Arrow** in the **Joystick** panel or thanks to the keyboard shortcuts Ctrl + numpad (8), (2), (4) and (6). Clicking on **HOME** 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 known position by entering coordinates in the corresponding X and Y fields and clicking on **Move to** (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 **Shift** (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 **Save** in the panel **Saved Positions**. 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 **Go to…**. 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 button **Remove Selected**. To erase all, click on the button **Clear list**.

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

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

4.1.2 SAMPLE TILT ADJUSTMENT

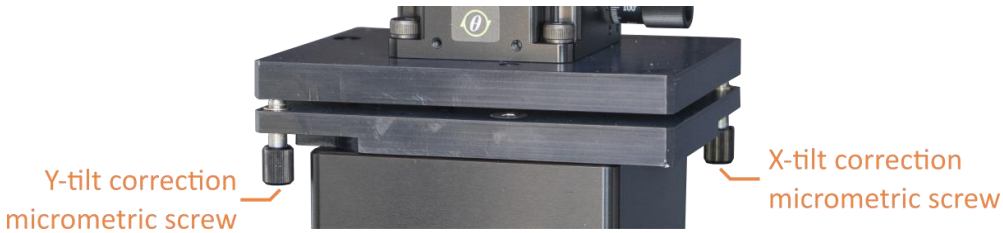


Figure 30 - Tilt correction platform

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 (see Figure 30) as follow:

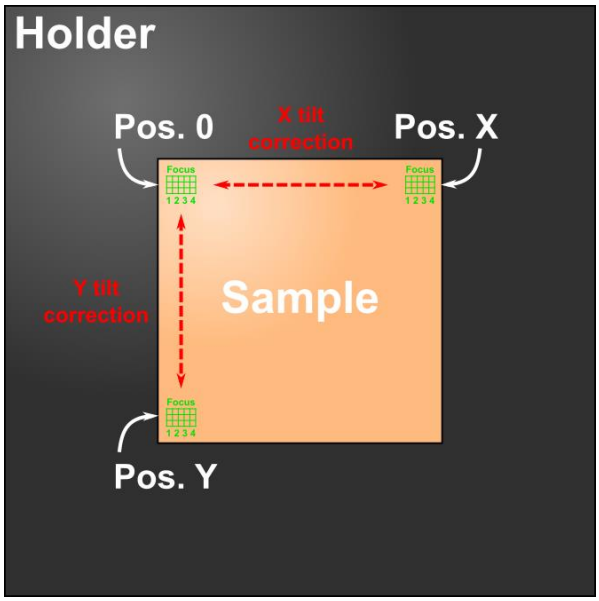


Figure 31 - Tilt correction principle

- Start the **FOCUS MODE** in the **EXPOSURE** panel (Figure 10).
- Position the top left corner of your sample under the projected light using the **XY stage control interface** (see 4.1.1). This position corresponds to the pivot point of the tilt platform (see Figure 31).
- Save the current position. Change the name of the position from XY pos. to Pos. 0 by clicking on the list in the **Saved Positions** panel.
- Adjust the focus using the Z motorized stage.
- Move along the Y axis to position the projected image on the bottom left corner of your sample (see Figure 31). Save the position and rename it by Pos. Y.
- Use the "**Y-tilt correction micrometric screw**" on the left side of the tilt correction platform (see Figure 30) to focus the image then select the saved position Pos. 0 and click on the **Go to…** button in the **Saved Positions** panel.
- Back at the pivot point (Pos. 0), focus the image using the Z motorized stage. Then go back to position Pos. Y using the **Go to…** button.
- Repeat the procedure until the projected image stays in focus when moving from Pos. 0 to Pos. Y.
- From position Pos. 0 move along the X axis to position the projected image on the top right corner of your sample (see Figure 31). Save the position as Pos. X.
- Repeat the previously described procedure to adjust the focus between Pos. 0 and 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.

4.1.3 POSITIONING OVERVIEW

The **Positioning Overview** button can be useful for fast positioning of the sample under the projected image bu also for alignment steps. I cas be accessed on the right side of the software (see Figure 32 surrounded in red). Once clicked it opens the **Position overview** window (see Figure 32 in the middle).

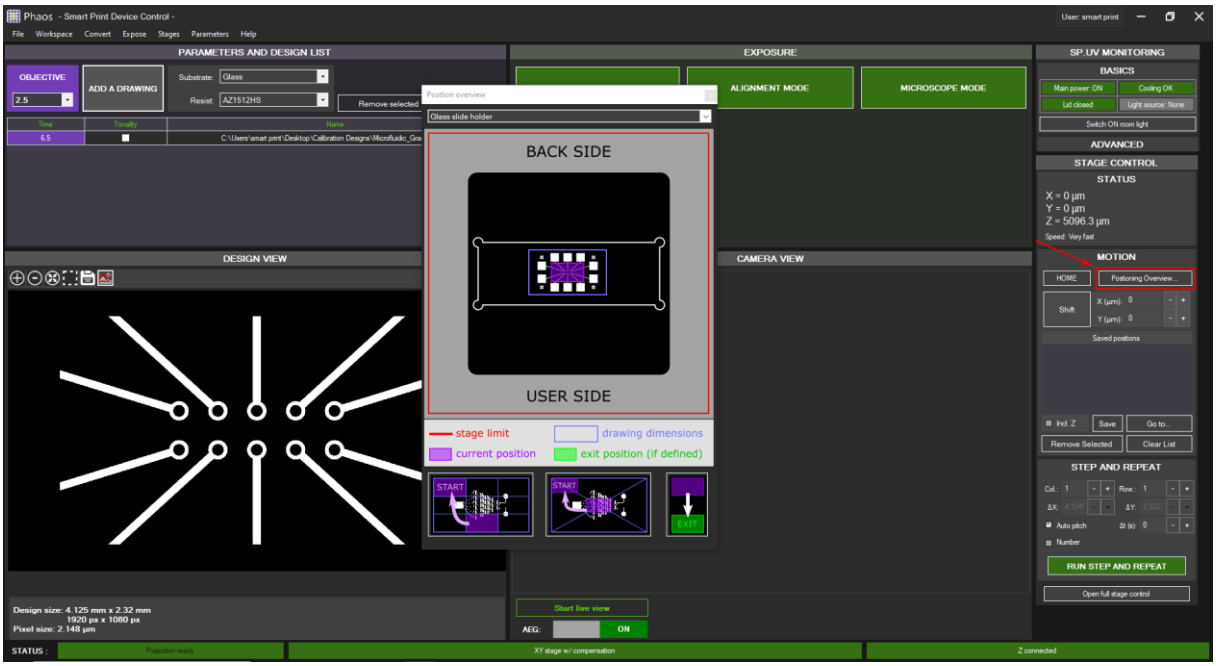


Figure 32 - Opening the positioning overview window

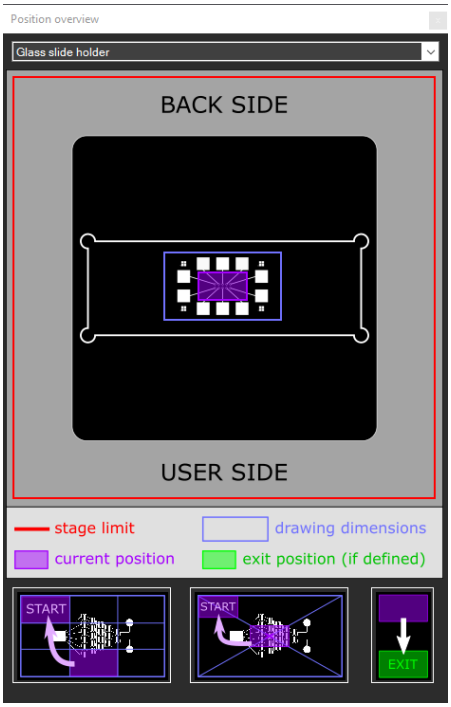


Figure 33 - Position overview window

The **Position overview** window 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.
- **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 33). *The red frame* is the stage motion limit. The blue frame is the full projected design to scale (dimensions depends on the selected objective).

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

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

(left) **Move from current sub-image to start position**. This button can be used when aligning with the Free alignment mode. 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 yellow light (with one of the 3 yellow 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.

4.1.4 STEP-AND-REPEAT & DOSE TEST

DRAWING AND OBJECTIVE SELECTION

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

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

NOTE: Using big drawing (stitching) is possible.

- Go to **Automation** menu and click on **Dose test**. A new window opens as shown in Figure 34. The “Step & Repeat / Dose Test” mode should be selected. “Selected drawing” and “Selected objective and Max FOV” fields respectively indicate which drawing will be exposing with which objective and the corresponding max projected field-of-view.

Figure 34 – Automatic mode tab in XY stage window

SETTING OF THE ARRAY

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

- **Nb of columns** and **Nb of rows**. They define how many times the drawing will be exposed.
- **X pitch** and **Y pitch** (in mm). They define the X and Y step sizes between each exposure. Their value must be higher than the field-of-view (FOV) to avoid exposure overlap.
- **Initial time** (in s). It corresponds to the exposure time of the first element of the array (Start position in the schematic Figure 34).
- **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.
- **"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 35) and their exposure time in s (Figure 36).

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).

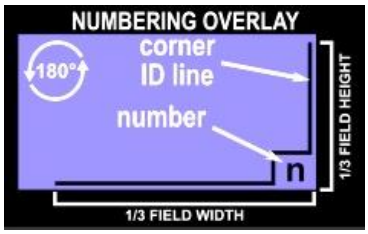


Figure 35 - Step & Repeat mode with "Number exposures" option

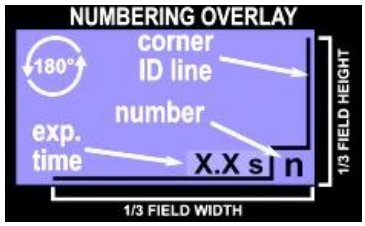


Figure 36 - "Add exposure time on overlay" option

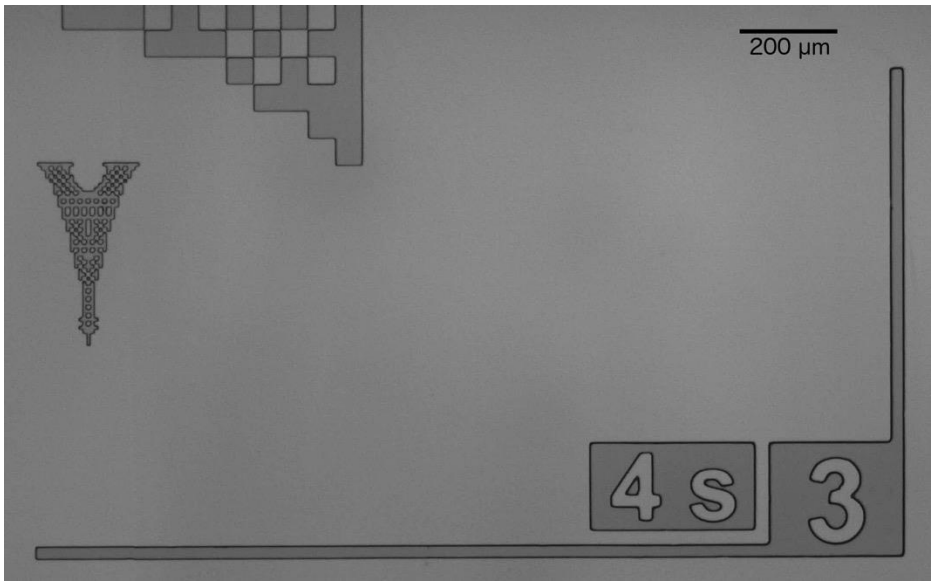


Figure 37 - Optical micrograph of the bottom right corner of the 3rd lithography of a drawing exposed in step-and-repeat mode with numbering and exposure time overlay options

COORDINATES ADJUSTMENT & START

Below the setting fields, on the left side of the button **Start**, the real-time stage status shows the top-left starting coordinates ("Start coor.") and the most bottom-right coordinates ("End coor."). If those coordinates are out of the stage range, the status will switch to red color and the Start button will be disabled (Figure 38). There are two possibilities to come back to in-range coordinates:

- The starting coordinates correspond to the stage current position. Thus, go to the tab **Manual control and monitoring** and move the stage using the available controls (Figure 29) 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 38 – Out of range stage status

Once the array is set correctly and the stage status is green, click on the button **Start**. The exposure in array will start immediately. For user information, the exposure status (current exposure time and element number) is displayed in the panel **Exposure** (Figure 39). The automatic exposure can be stopped at any time by clicking on the button **STOP** in the same panel.

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

Figure 39 – « Exposure » panel during auto mode

4.1.5 AUTOMATIC EXPOSURE OF A LIST OF DRAWING

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

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

- Choose the objective, resist and substrate on the corresponding dropdown lists
- Add one-by-one drawings by clicking on **Add…** in **Parameters and drawing list** panel

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

- Adjust exposure time and tonality of each drawing if needed and then adjust the focus (see section 3.5.5)
- Go to **Automation** menu and click on **Drawing list auto exposure**

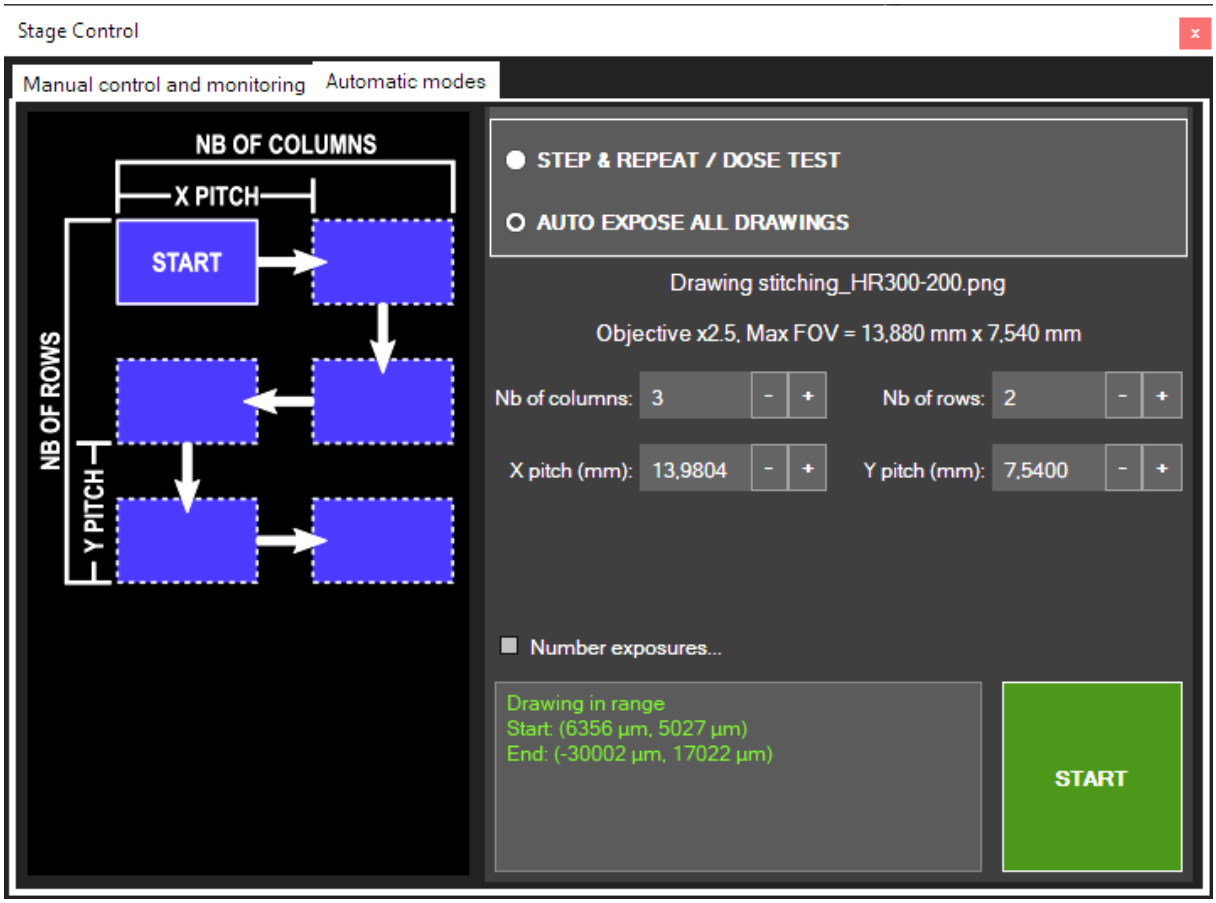


Figure 40 – « Auto Expose all drawings » mode in the stage control window

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

NOTE:

1) In the field « Selected objective and FOV », Max FOV indicate the width and height of the biggest drawing(s) of the list. In order to avoid lithography overlap, it is recommended to choose values for X pitch and Y pitch that are higher than the Max FOV

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

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

As for the step-and-repeat mode, the exposure status (current exposure time and element number) is displayed in the panel **Exposure** (Figure 39). The automatic exposure can be stopped at any time by clicking on the button **STOP** in the same panel.

4.1.6 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 41).

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

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

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

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

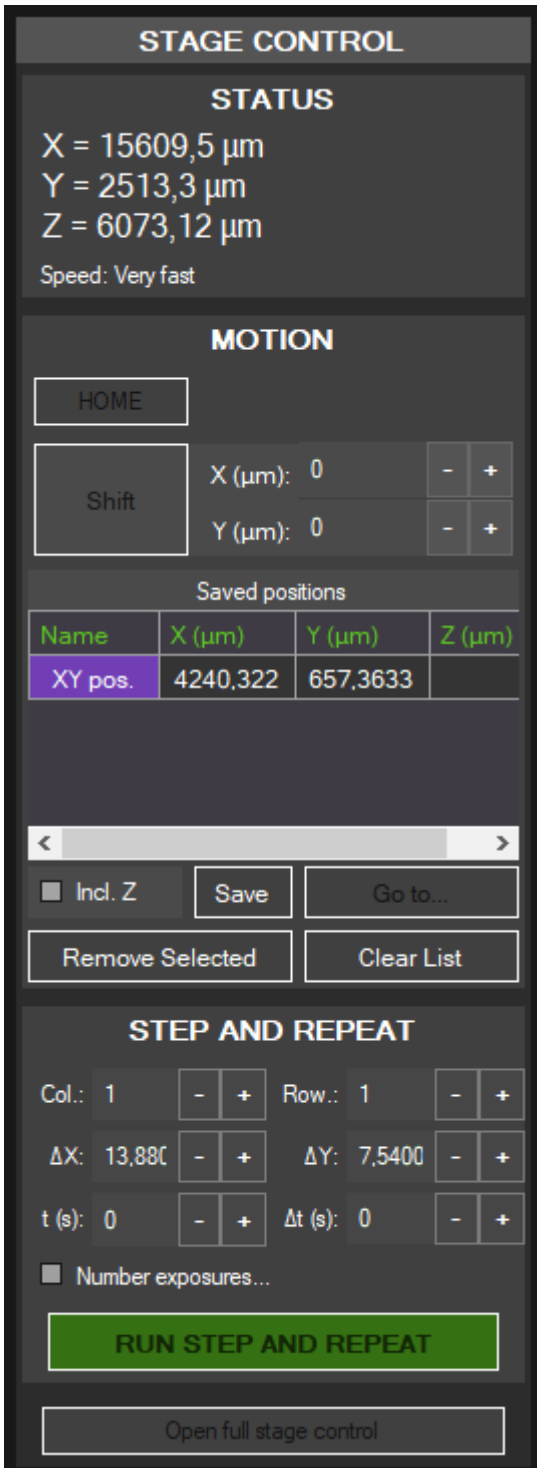


Figure 41 - Stage Control panel in the main window

4.1.7 LONG LASTING EXPOSURE FEATURES

STOP POSITION

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

unwanted sample exposure when the user is not in front of the equipment at the end of the lithography. Figure 42 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 **Define current position as stop position** in the **Automation** strip menu (Figure 43 Middle). Finally, check the **with stop position** box at the right of the **Expose Selected Drawing** button (Figure 43 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.

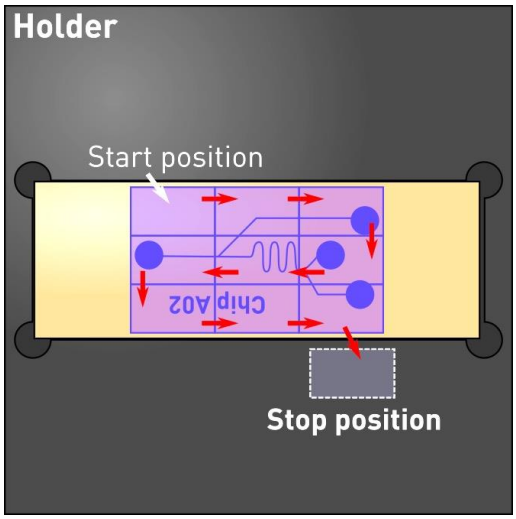


Figure 42 - "Stitched" lithography with used defined stop position

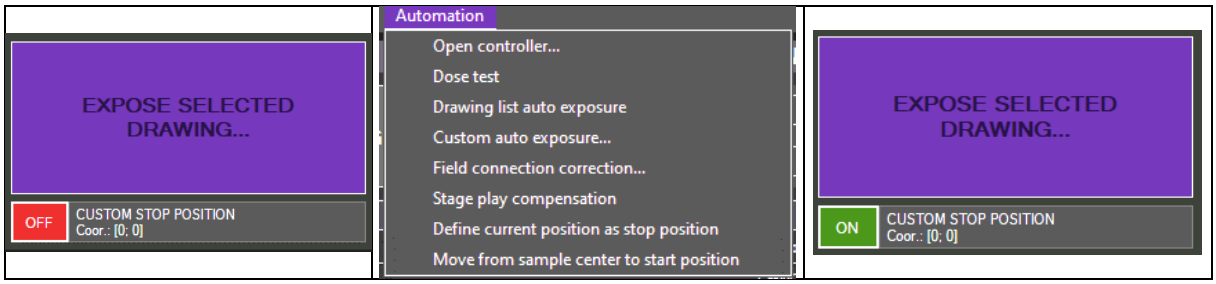


Figure 43 - Left: Stop position disabled, Middle: Automation strip menu, Right: stop position enabled

END OF LITHOGRAPHY NOTIFICATION (INTERNET CONNECTION REQUIRED)

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

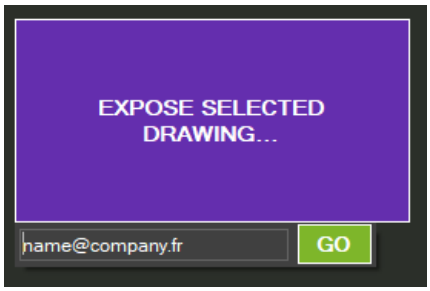


Figure 44 - End of lithography notification field

4.1.8 CUSTOM EXPOSURE (FOR ADVANCED USERS)

SFTprint 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 6 columns corresponding to the following information:

Exposure time in s	Drawing tonality (*Original* or *Inverted*)	Complete file path of the drawing (bitmap or .stitch format)	Field homogeneity correction (value between 0 and 100)	Stage absolute X coordinates (in mm)	Stage absolute Y coordinates (in mm)

Each column must be separated by a tab as shown in the example below (Figure 45).

testcustomlitho_pourmanuel.txt - Bloc-notes

Fichier Edition Format Affichage ?

```
5       Original        D:\Data\Olivier\electrode_array.png     100     0       0
8       Inverted        D:\Data\Olivier\electrode_array.png     0       5.5     0
7       Original        D:\Data\Olivier\widefovcheck.png        0       5.5     3,4
2       Original        C:\Users\Olivier\Desktop\makoto.stitch  0       18      23
```

Figure 45 – Typical parameter file for custom automated lithography

In order to start a custom series of lithography:

- Go to **Automation** menu and click on **Custom auto exposure…**
- In the **Custom exposure** window, select a compatible parameter file by clicking on **Select datafile** (Figure 46)

Figure 46 – 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 47)
- Choose how big drawings must be considered by selecting the appropriate option on the drop-down list **Big bitmap loading option** then click on **Load data**. The list of drawing will update on the main window in the **Parameters and drawing list** panel (Figure 48)
- At that stage, exposure time, tonality and image correction can be modified directly in the drawing list if needed
- Click on **EXPOSE** in the **Custom exposure** window (Figure 48)

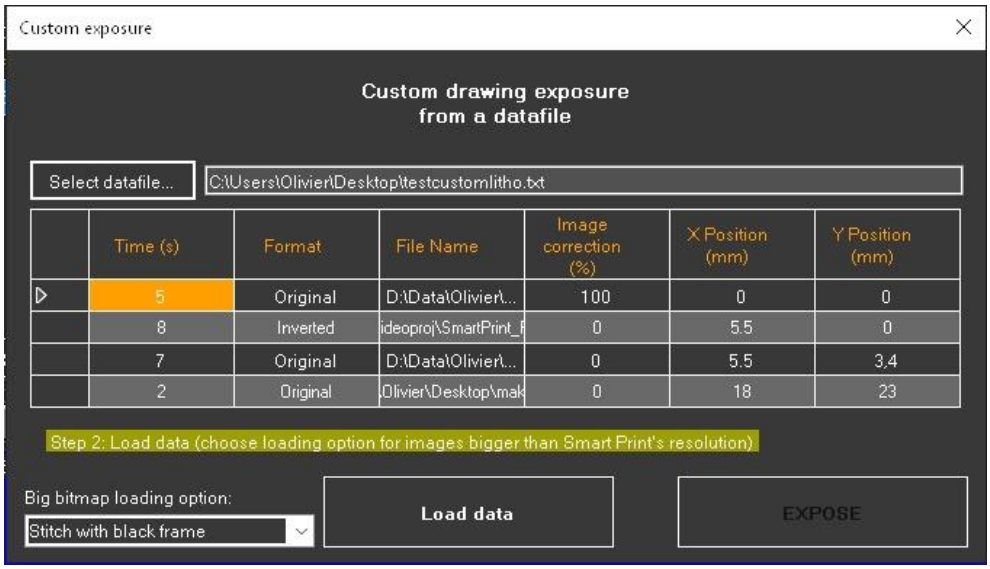


Figure 47 – Custom exposure: parameter file loaded

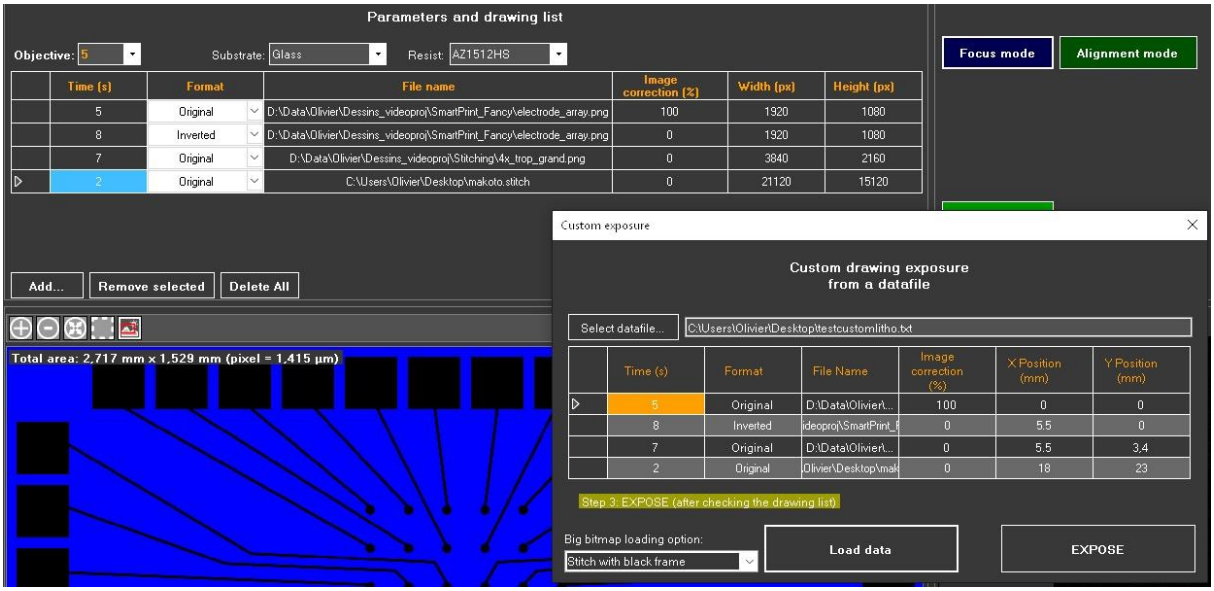


Figure 48 – Custom exposure: data loaded and ready for exposure

Once the automatic exposure is started, **Custom exposure** window close. The lithography progress is displayed in the **Exposure** panel (Figure 49). It can be cancelled at any time by clicking on **STOP**.

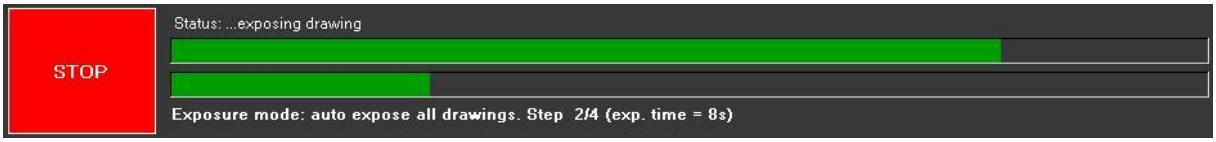


Figure 49 – Progress bar during a custom auto exposure

4.2 MOTORIZED Z-LIFT FEATURES

4.2.1 STAGE CONTROL

When the motorized Z stage is configured and detected, new features appear in the XY Stage Control window (Figure 50). 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 other axis, controlled motion can be performed with **Move To** (absolute coordinates) or **Shift** (relative coordinates) buttons.

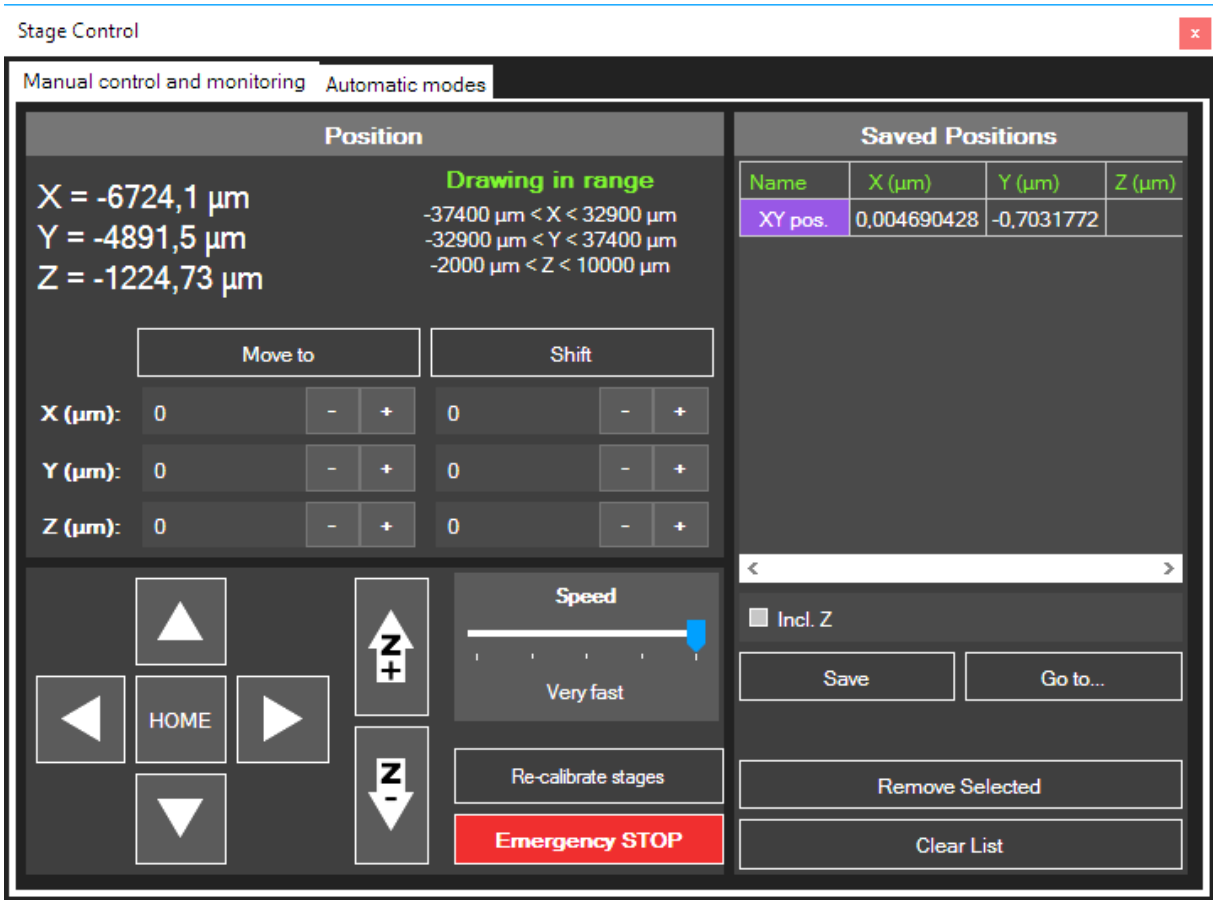


Figure 50 - XYZ stage control and monitoring interface

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

4.2.2 AUTOFOCUS ON CURVED SURFACES

Coming soon…

4.3 ADVANCED LITHOGRAPHY

4.3.1 MULTI-LITHOGRAPHY WITH ALIGNMENT MODE

SFTprint can project a drawing under green illumination (wavelength out of the light sensitivity area of the used photoresists) for alignment purposes. The mode is especially adapted if multiple lithography steps are required. It can be used with x1, x2.5, x5 et x10 only and requires the rotation stage module (Figure 51).
Two alignment modes, described later in the section, are accessible to the user: The Free mode and the Semi-automatic mode.

Figure 51 - Rotation stage module

DESIGN RULES

Details below are just suggested design rules, known to work properly with Smart Print. 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 (Figure 52 right). For each design, the crosses must be at the same relative position
- Add a unique number to each cross (Figure 52 left) to avoid bad substrate orientation

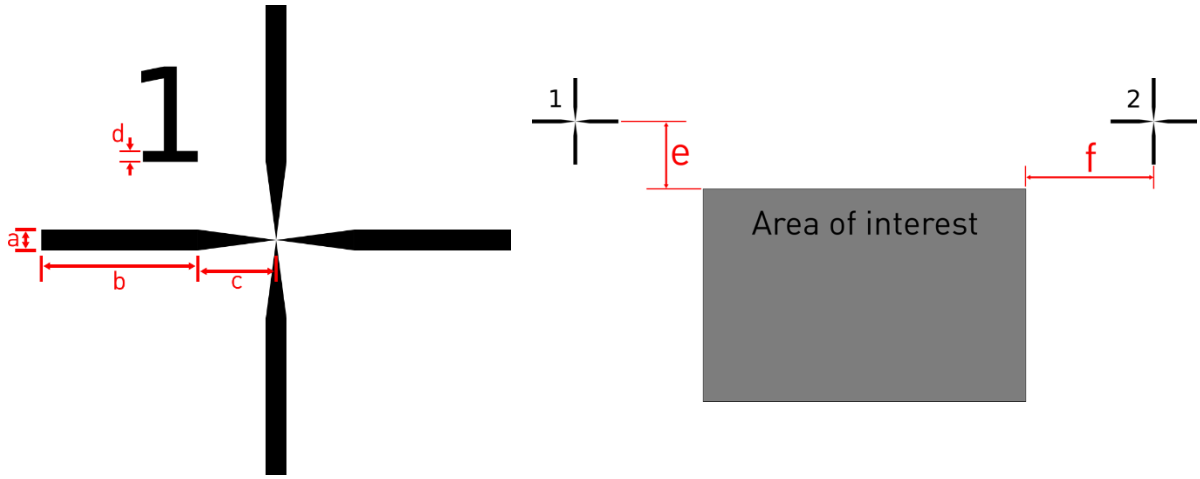


Figure 52 - Design rules. Left: focus on an alignment cross and its key dimensions. Right: cross positioning over the substrate

Tableau 1 - Suggested dimensions for the design in Figure 52

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

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

ALIGNMENT: FREE MODE

This fully manual mode is adapted for simple multiple lithography (no stitching required and low magnification objectives such as x1 or x2.5).

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

- Load your sample and set Smart Print for a regular lithography (see section 3.3 and 3.4)
- Load a drawing in SFTprint by clicking on **Add…** and choose a file
- Click on **ALIGNMENT MODE** and set the **toggle switch** below to **FREE** (Figure 53). Selected drawing will be projected on the sample under green illumination
- If not already running, start the camera by clicking on **Start live view**
- Adjust the XY stage position and the rotation stage (Figure 51) to fit the pattern on the substrate to the projected drawing
- Open the positioning overview and click on the **Move from current sub-image to start position** button as explained section 4.1.3.
- Quit the alignment mode by clicking on **STOP ALIGNMENT**
- Start exposure by clicking on **Expose selected drawing**

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

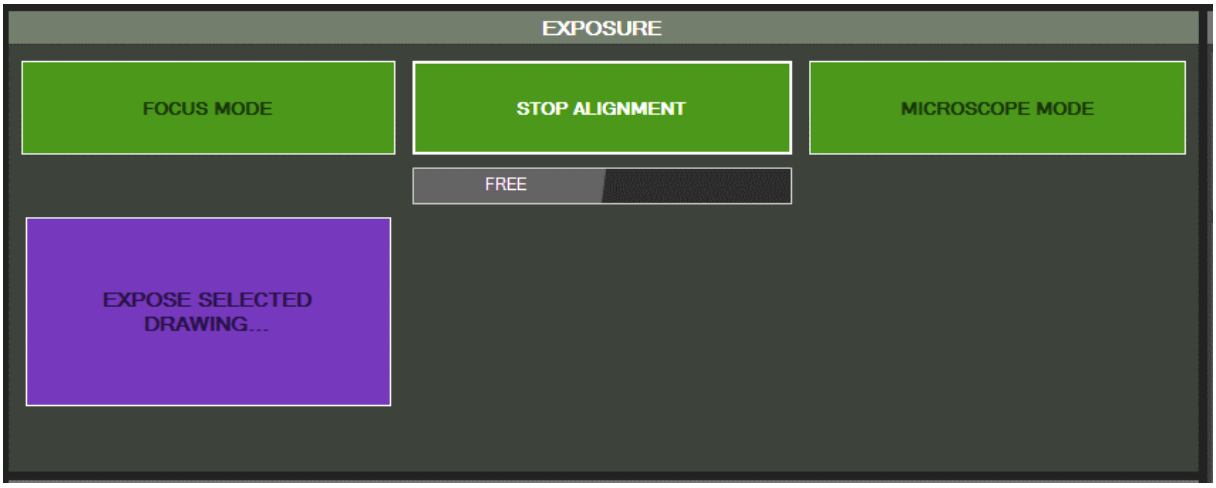


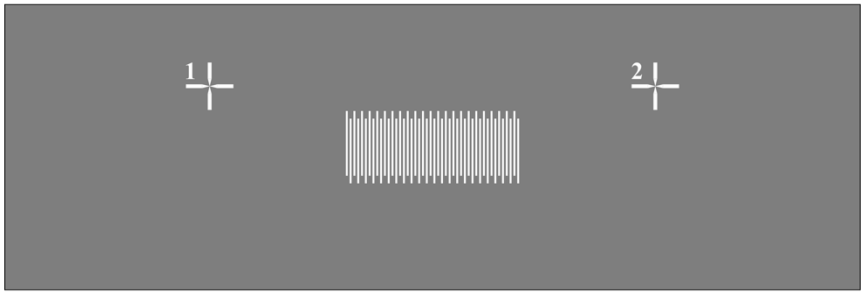
Figure 53 - Free alignment mode

ALIGNMENT: SEMI-AUTOMATIC MODE

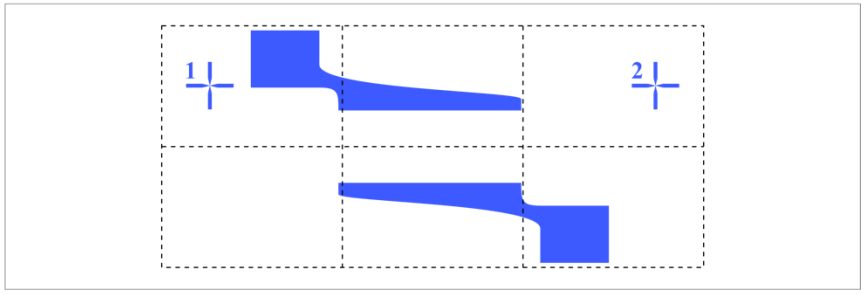
This mode is especially recommended when alignment with a stitched drawing is needed. To illustrate how this mode works, a design of interdigitated electrodes with contact pads will be used as example. In this example, the first layer, consisting in the interdigitated electrode alone, has already been processed on a substrate (Figure 54a). Contact pads remains to be lithographed. Their drawing (Figure 54b) has been designed to fit with the patterned electrodes. In this example, the dashed rectangles in Figure 54b show how the original design will be sliced and successively lithographed by SFTprint thanks

to its stitching capability. The expected result on the substrate after alignment and exposure of the contact pads is illustrated in Figure 54c.

a) Substrate with the 1st level of patterns



b) Drawing of the 2nd level to be lithographed



c) Final result on the substrate

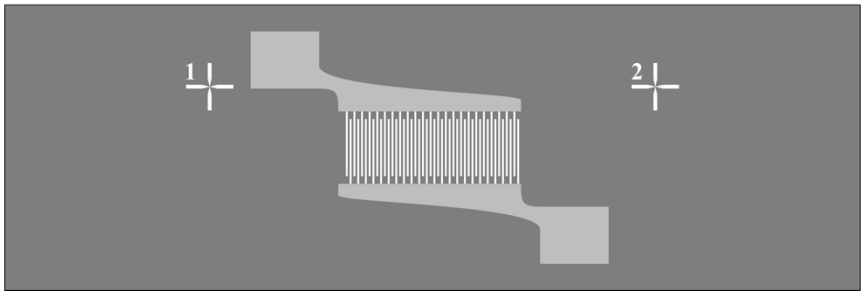


Figure 54 - Example of aligned lithography over already existing patterns

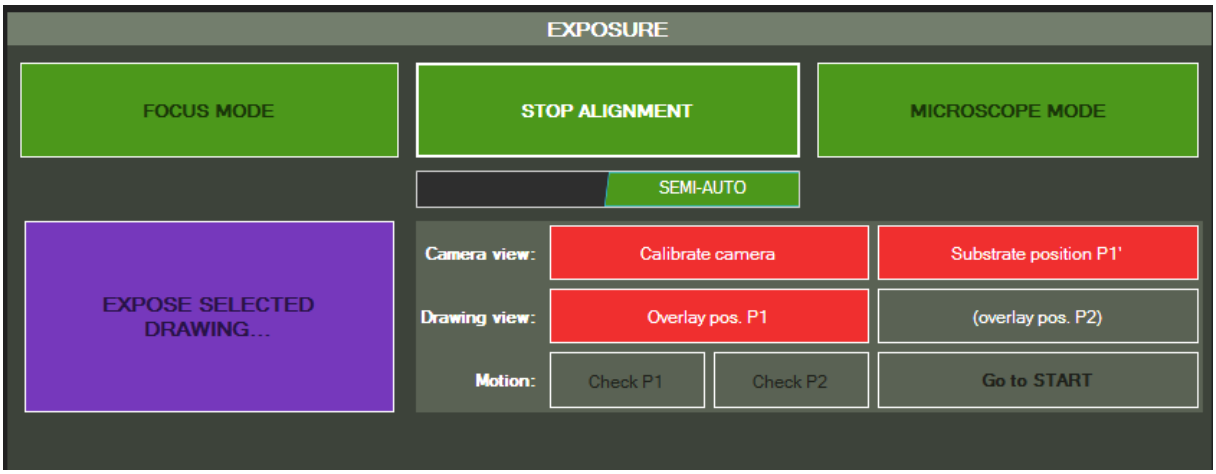


Figure 55 - Semi-automatic alignment mode

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

- Load your sample and set Smart Print for a regular lithography (see section 3.3 and 3.4). Ensure to select the correct objective in the **PARAMETERS AND DRAWING LIST PANEL**
- Load the drawing to be aligned in SFTprint by clicking on **Add…** and choosing your file
- Click on **Alignment mode** and set the **toggle switch** below to **SEMI-AUTO** (Figure 55).
- Camera calibration (Figure 56a): click on **Calibrate camera**. The camera live view may start and the mouse cursor shape may change. In the camera view, click on the central part of the displayed cross (Calibration point) as shown in Figure 57.

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

- Selection of point P1' (Figure 56b): click on **Substrate position P1'**. 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 58

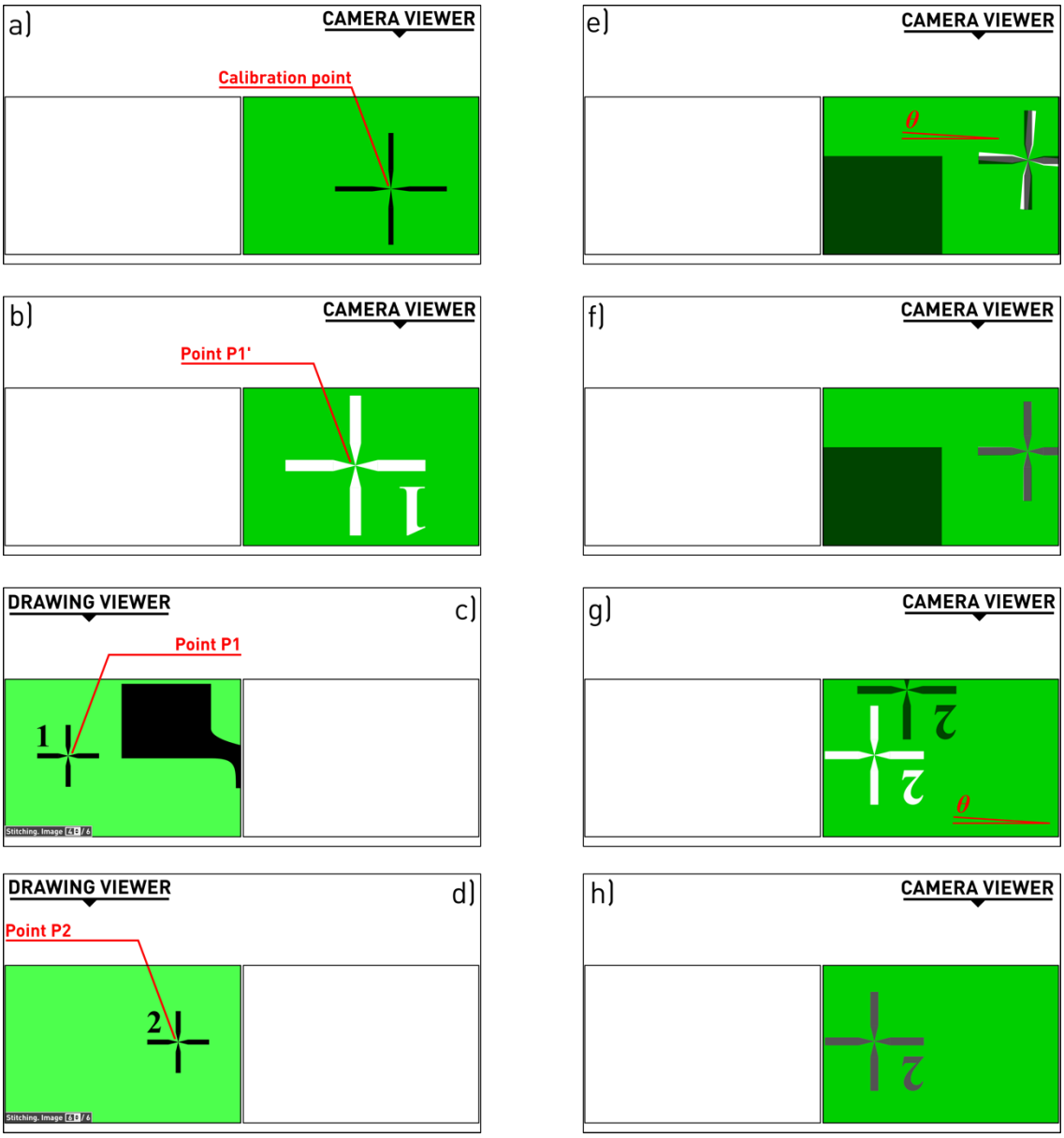


Figure 56 - Semi-automatic alignment main steps

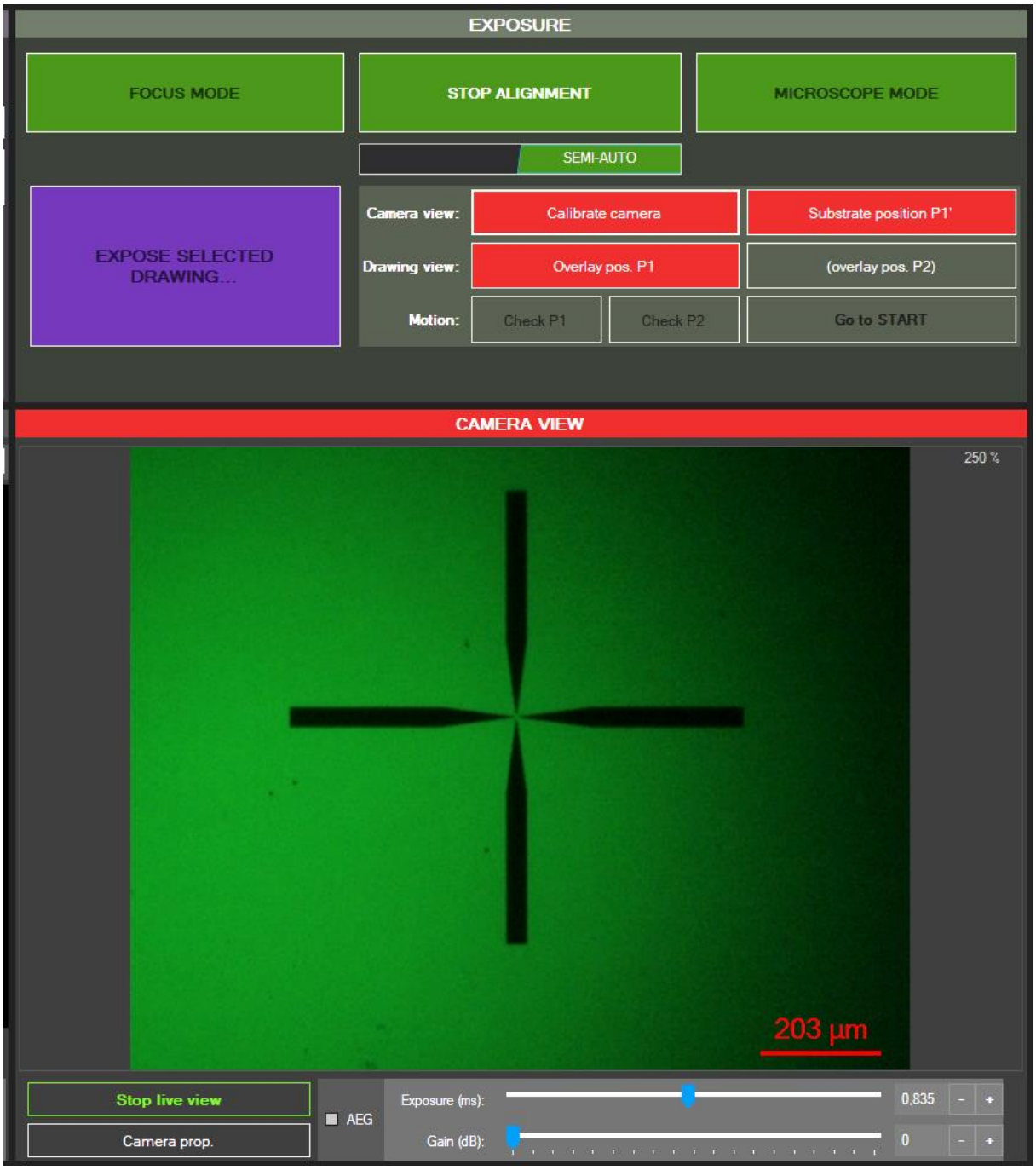


Figure 57 - Semi-auto alignment: camera calibration

- Selection of point P1 (Figure 56c): click on **Overlay pos. P1**. The mouse cursor will change to a cross. On the drawing viewer, select the point you want to align with P1' as shown in Figure 59
- [Optional step] Selection of point P2 (Figure 56d): selecting a second point of interest in stitched drawing is useful to improve the substrate rotation adjustment and then the overall quality of the alignment. To do so, click on **(Overlay pos. P2)**. Select a point in the drawing viewer on sub-image different from the one of point P1 as illustrated in Figure 60
- Alignment checking and adjustment of the substrate rotation angle *q:* in order to check the validity of the adjustment, click on **Check P1** (Figure 61). The stage will then move to align P1' (on the substrate) with P1 (on the drawing) as shown in Figure 56f. 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 56e), move the wheel of the rotation stage (Figure 51) until *q* is suppressed. After every change of the rotation stage, P1' position selection must be redone. When the checking is finishing click on End check. or press **esc** key.

- [Optional step] Fine alignment checking and angle adjustment: if a point P2 has previously been defined, click on **Check P2**. The stage will then move the expected position of P2. If a misalignment is visible as in Figure 56g, the rotation stage must be adjusted, as described in the previous step until a correct alignment is achieved as in Figure 56h.

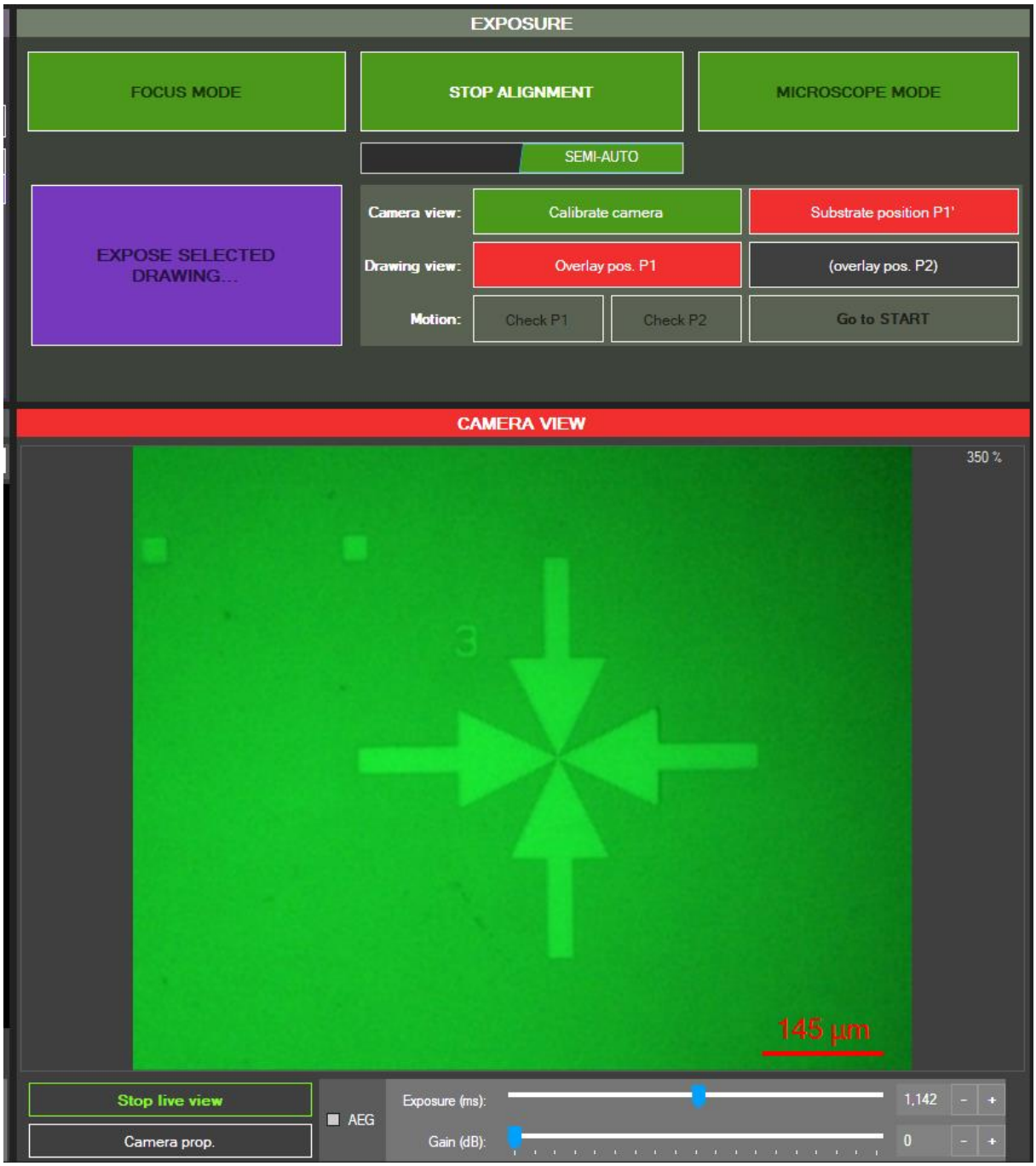


Figure 58 - Semi-auto alignment: defining point P1'

- Finishing the alignment setting: click on **Go to START** (Figure 61) and quit the alignment mode by clicking on **Stop alignment**
- Start exposure by clicking on **EXPOSE SELECTED DRAWING**

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

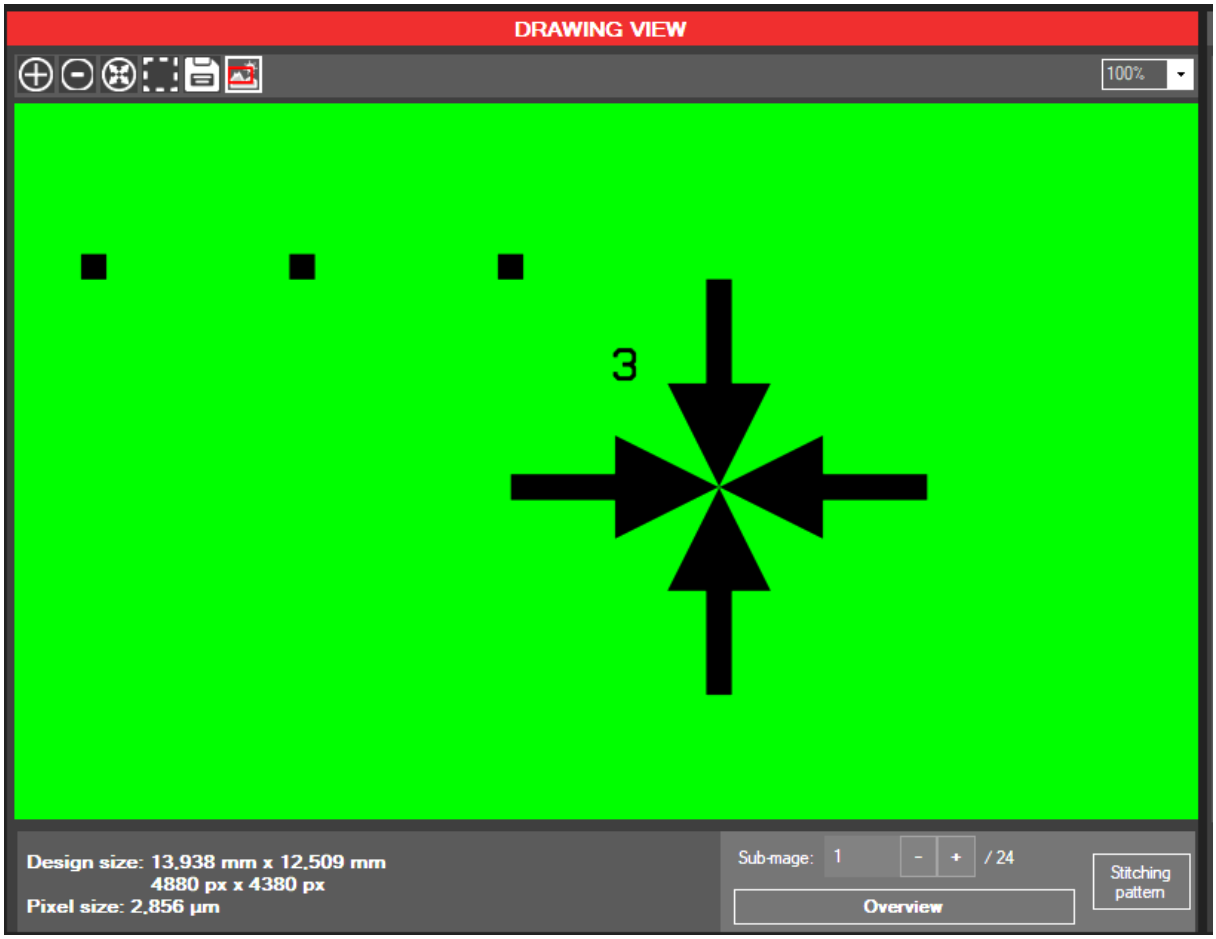


Figure 59 - Semi-auto alignment: defining point P1

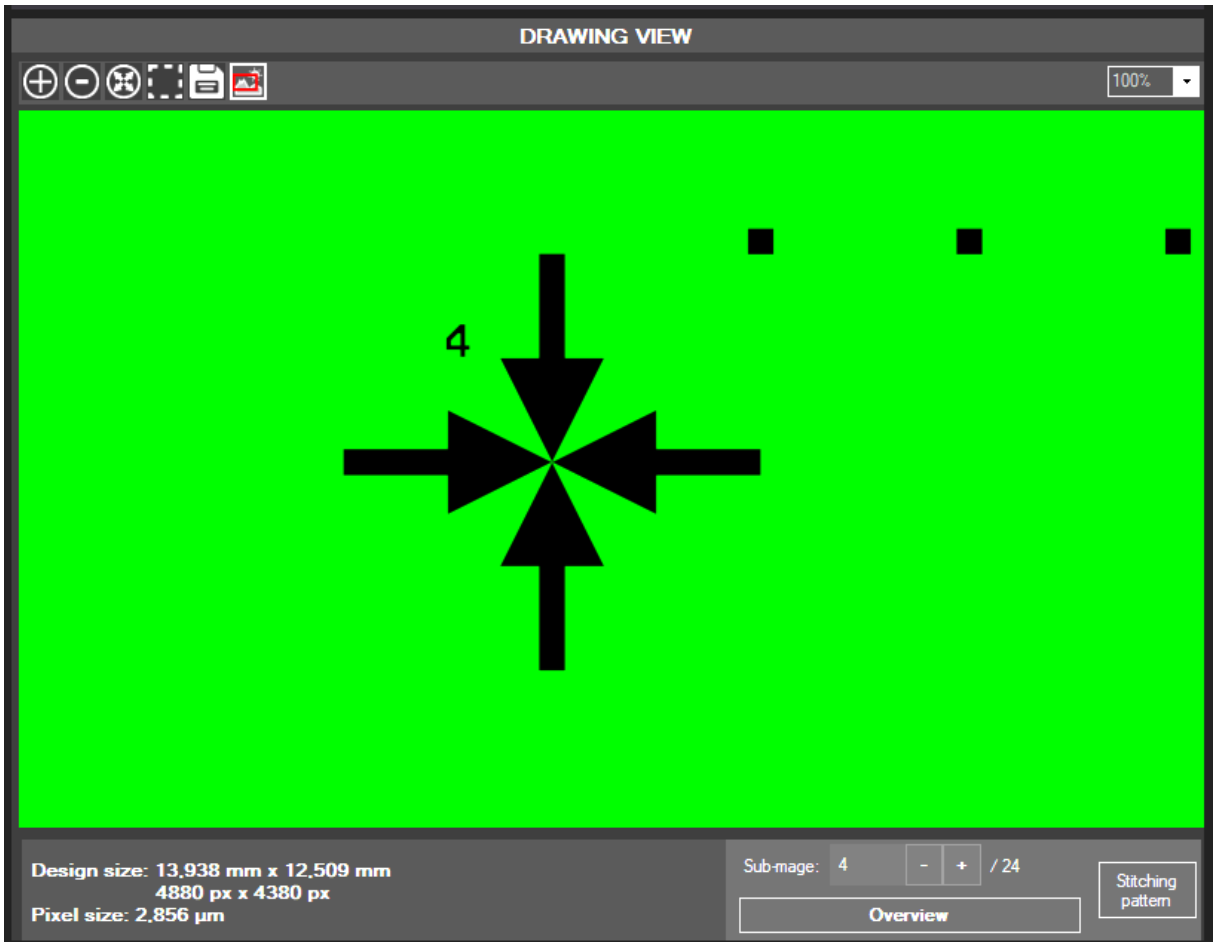


Figure 60 - Semi-auto alignment: defining optional point P2

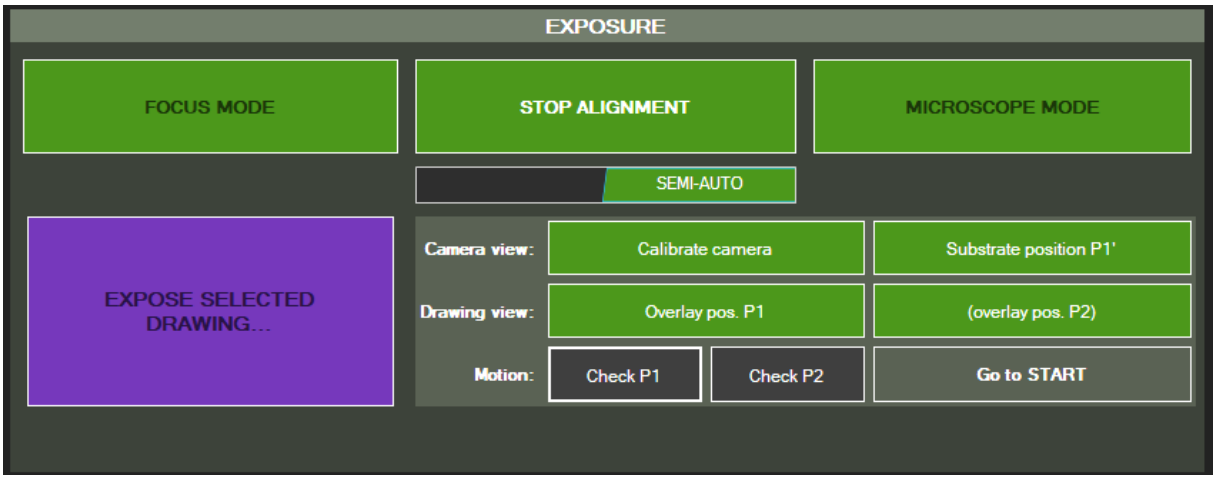


Figure 61 - Semi-auto alignment panel after defining P1', P1 and P2

4.3.2 GRAYSCALE LITHOGRAPHY

Smart Print can be used to shape a photoresist in "2.5 dimensions". Indeed, the photoresist local height can be tuned by adjusting the light intensity for each projected pixel (Figure 62).
With Smart Print, it consists in exposing an 8bit grayscale bitmap drawing with a relevant gray level range on a compatible photoresist.
AZ 4562 positive resist (*MicroChemicals GmbH*) or ma-P 1275G (*micro resist technology GmbH*) are known to work for grayscale lithography. Other resists optimized for such lithography technique and with g-line light sensitivity (wavelength between 430 and 470 nm) may also work.

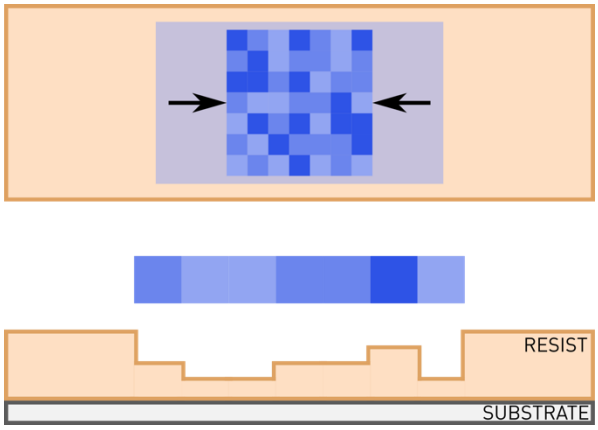
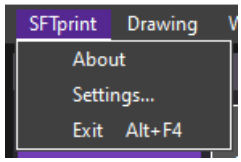


Figure 62 – Principle of grayscale lithography

4.4 GENERAL APPLICATION SETTINGS

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



PERMISSION ACCESS TO SETTINGS

From version 1.6, SFTprint 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 63). To edit those parameters, SFTprint 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 **SFTprint → Settings…** and click on **Restart as administrator** button.

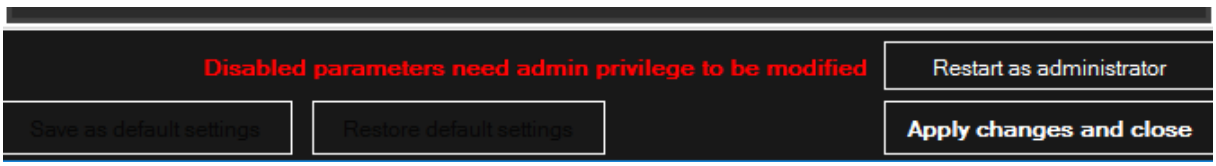
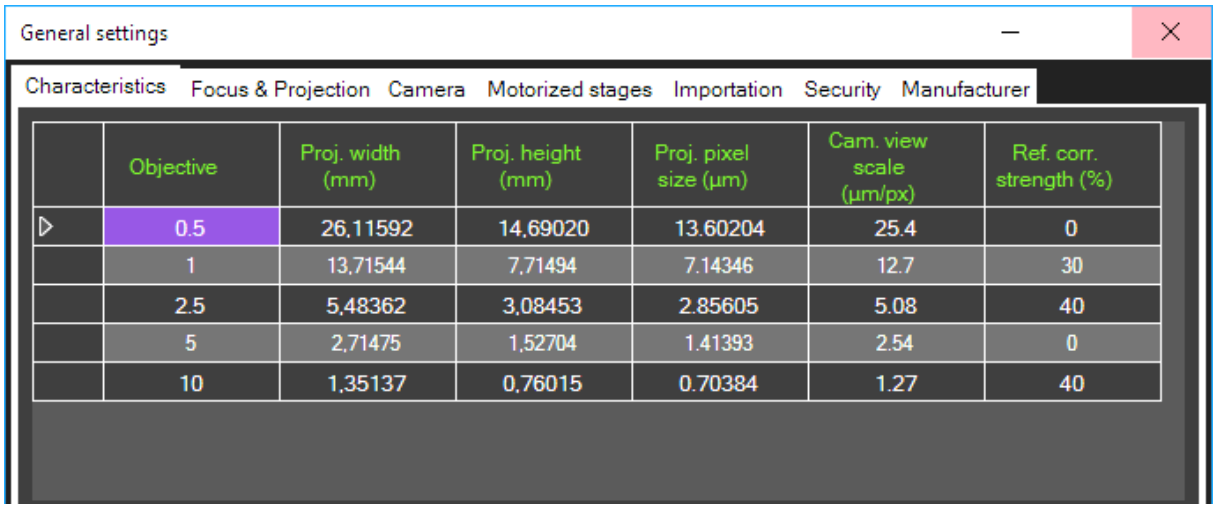


Figure 63 - Settings: admin access locked

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	25.4	0
	1	13,71544	7,71494	7.14346	12.7	30
	2.5	5,48362	3,08453	2.85605	5.08	40
	5	2,71475	1,52704	1.41393	2.54	0
	10	1,35137	0,76015	0.70384	1.27	40

Figure 64 – Settings: optical characteristics

The tab **Characteristics** contains a table with key optical characteristics according to the objective used during lithography (Figure 64):

- *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 button **Edit row…** (Figure 65). "Pixel size", "Camera scale" and "reference correction strength" can be adjusted. Click on the button **OK** 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 button **Apply changes and close**.

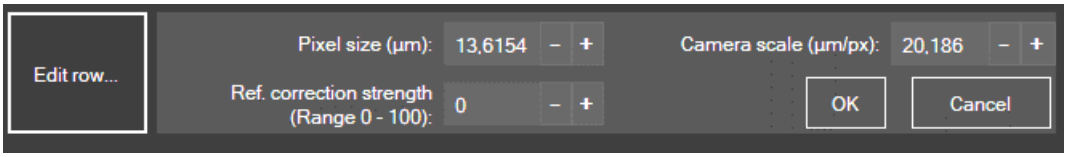


Figure 65 –Settings: optical characteristics edition panel

Calibration procedure of the camera scales:

- Load a sample containing patterns with known dimension, like microscope calibration glass slide
- On SFTprint main window check if the objective selected corresponds to the one loaded on the equipment
- Click on **MICROSCOPE MODE** (refer to section 3.5.6 for more details)
- Display the camera live scale bar and save an image of your sample (section 3.5.4 for more details)
- Measure the pixel to µm correspondence on the saved image with any image editor (like ImageJ) and adjust the **Cam. view scale** value (Figure 64) 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

Image projected during focus. In the tab **Focus & Projection**, the drawing used during the focusing step can be set (Figure 66):

- *Default image*: the default optimized design
- *User defined*: a custom 1920x1080 drawing chosen by clicking on the button **Choose user defined image…** 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

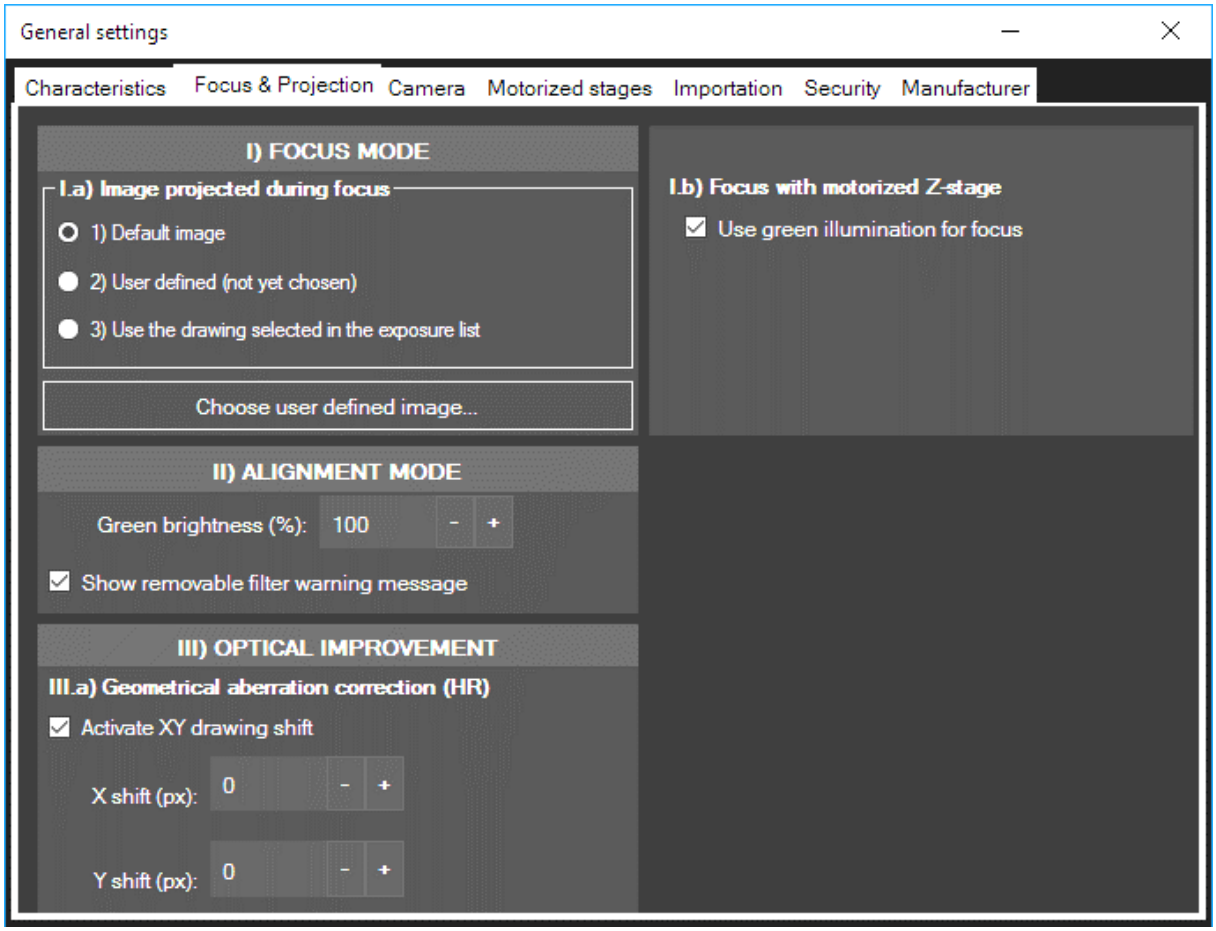


Figure 66 – Settings: focus and projection options

Focus with motorized Z-stage. If the motorized Z-lift stage is equipped, the focus step can be performed under green illumination to avoid exposing the substrate during that step. The green and blue focusing difference is automatically compensated by the Z stage. To activate this option, check **Use green illumination for focus**.

Alignment mode. The green illumination intensity in alignment mode can be reduced by choosing a **Brightness (%)** value. This option is useful if Smart Print is not equipped with the protection filter (section 3.5.2) for making alignment with high magnification objectives (x5 and higher) as the green light can still slowly expose some photoresists.
If a protection filter is equipped, put the brightness to 100% and check **Show removable filter warning message**.

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 button **Apply changes and close**.

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 red/pink overlay will highlight the pixels that are too bright. Those pixels are defined by an intensity above the **Overlay threshold**.

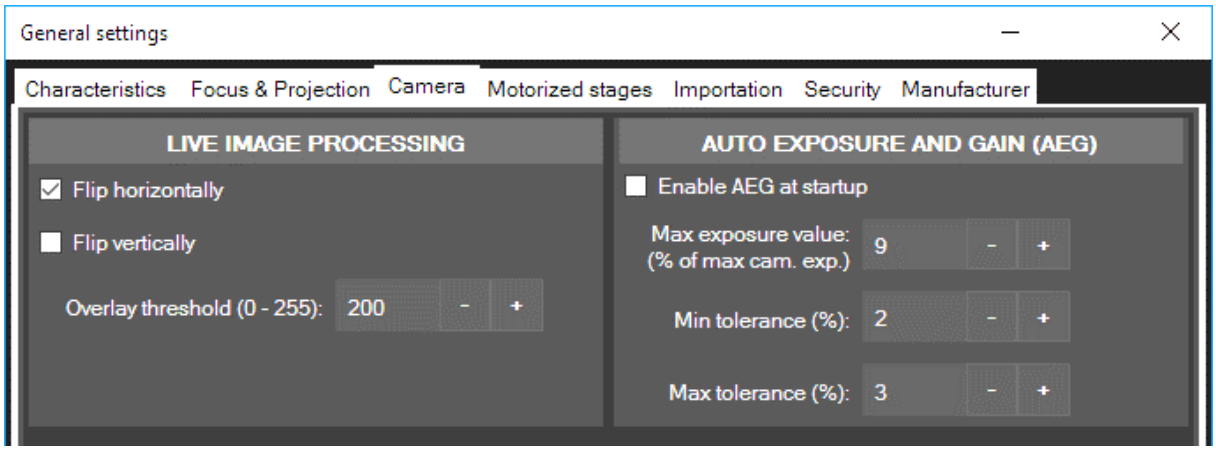


Figure 67 - Settings: camera

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:

- **Max exposure value**: define an upper camera exposure value as a percentage of the maximum exposure value of the camera (to reduce camera lag). Default = 10%
- Min tolerance: min percentage of saturated pixels tolerated. Default = 2%
- Max tolerance: max percentage of saturated pixels tolerated. Default = 3%

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

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 68).
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 29). It is recommended to keep those parameters in their default configuration (Invert X checked, Invert Y and Z unchecked).

Mechanical play compensation. 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.

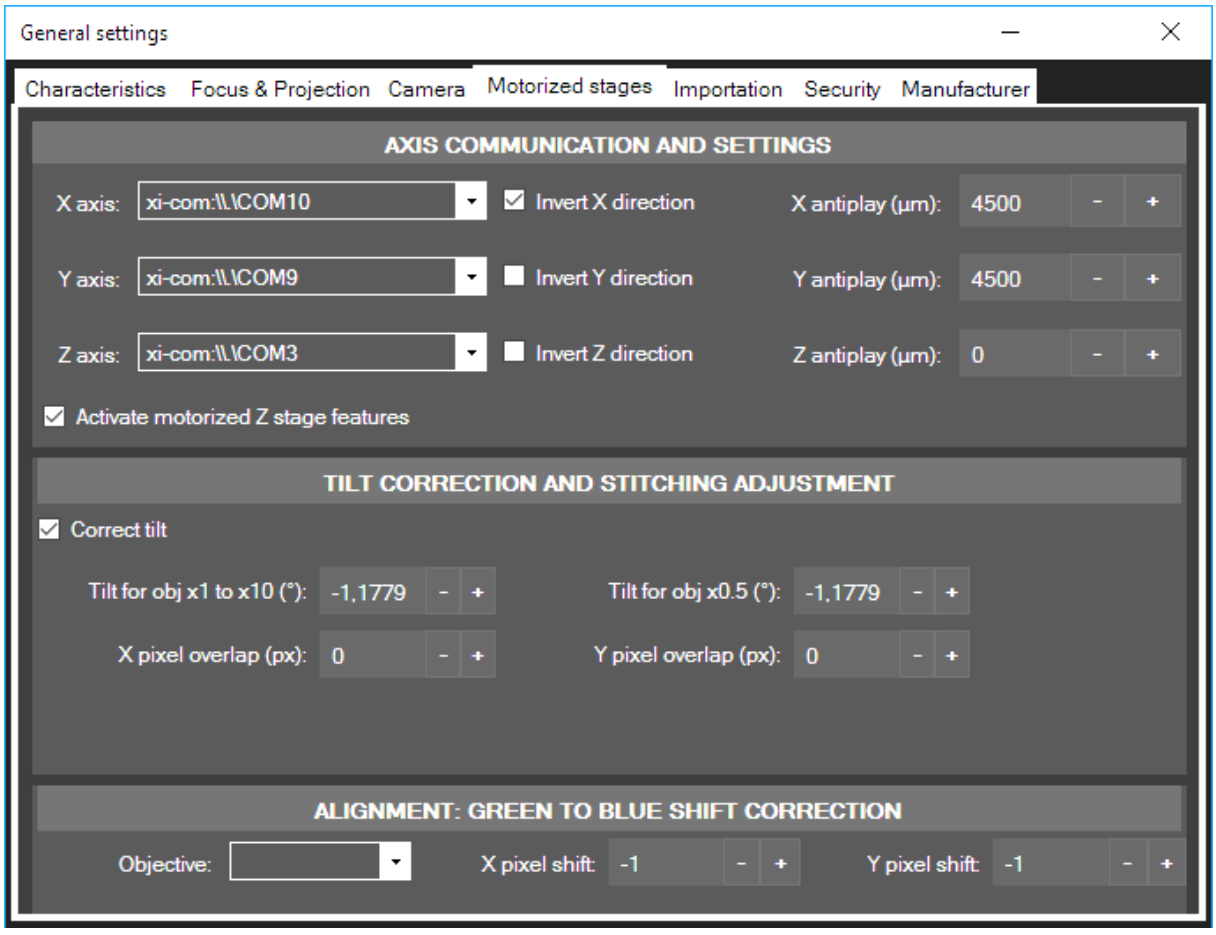


Figure 68 – Settings: motorized XY stage

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 68):

- *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 3.5.3). 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 5.3.3 for more details), SFTprint will link automatically to KLayout. If not then click on **Define klayout_app.exe filepath** (Figure 69) and select the file *klayout_app.exe* in the main directory of KLayout.

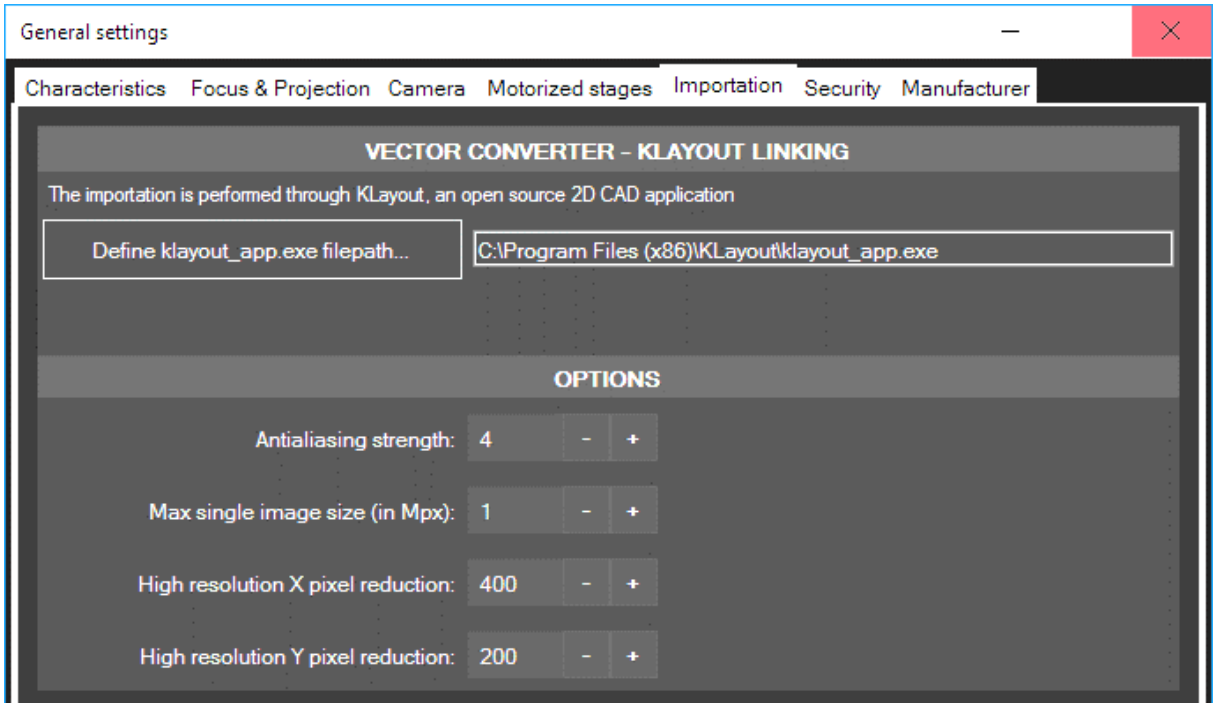


Figure 69 – Settings: vector drawing importation options

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 = 10 Mpx)

- **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

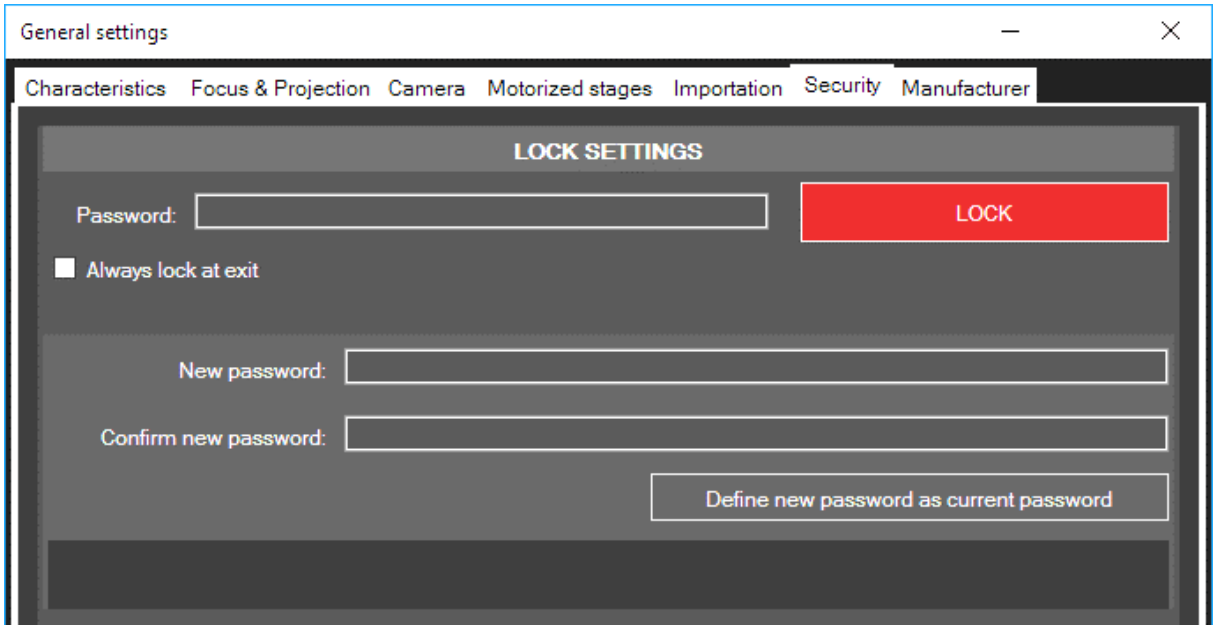


Figure 70 - Settings: security options

Although key settings can only be edited with administrator privilege, all settings can additionally be locked by a password on the **Security** tab (Figure 70). 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.

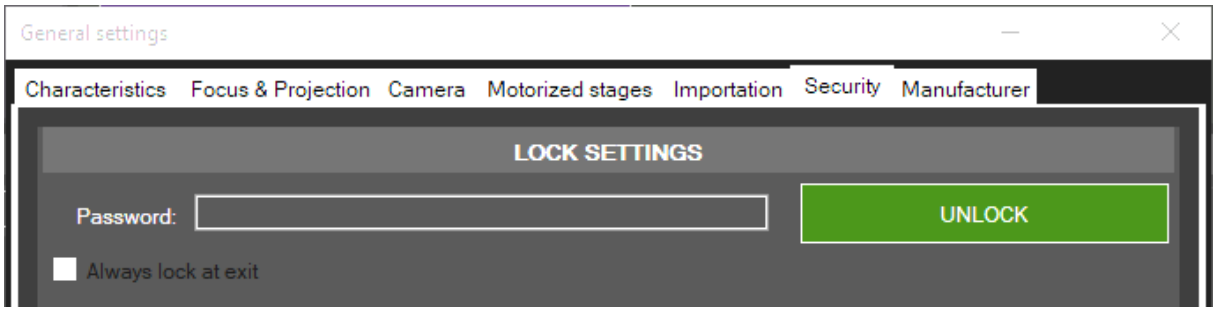


Figure 71 - Settings: unlock

To unlock the settings, enter the password on the field **Password** and click on **UNLOCK** (Figure 71).

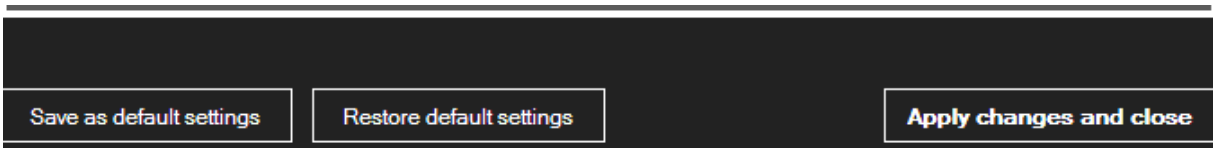
ADVANCED MANUFACTURER OPTIONS

The **Manufacturer** tab contains a console-like interface (Figure 72). It is intended for diagnosis and repairing purposes only. DO NOT USE it by yourself.

Figure 72 - Settings: Manufacturer

SAVE AND RESTORE DEFAULT SETTINGS (ADMINISTRATOR ONLY)

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



5 MAINTENANCE & TROUBLESHOOTING

5.1 LAMP REPLACEMENT

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

STEP A: LAMP CHANGE

a. Open the lamp cover (Figure 2) with a Phillips PH1 screwdriver (Figure 73 (1) and (2))
b. Unscrew the lamp block (Figure 73 (3) and (4))
c. Pull out the lamp block (Figure 73 (5) and (6))
d. Follow the previous instruction in the opposite order with the new lamp block (reference: ELPLP88 from *EPSON*)

STEP B: RESETTING LAMP LIFETIME COUNTER

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

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

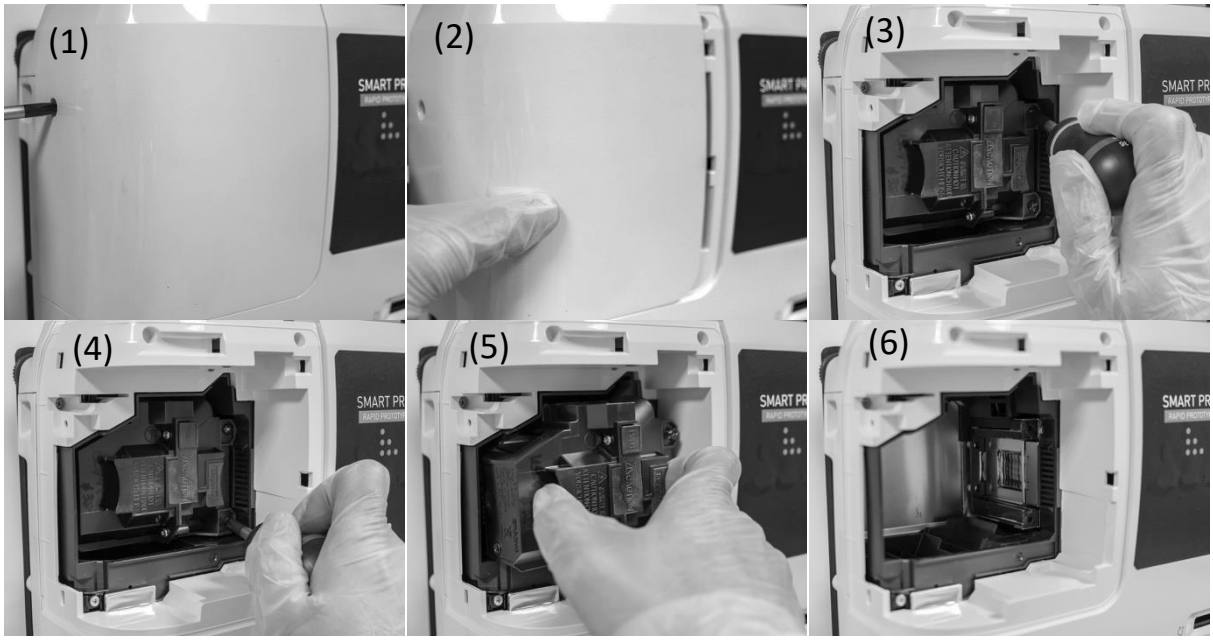


Figure 73 – main steps for lamp replacement

5.2 MONTHLY MAINTENANCE

STEP 1: AIR FILTER CLEANING

To avoid projector over-heating, the air filter (Figure 2) must be checked and cleaned regularly. Open the air filter cover, grip the filter cover tab and pull it straight up (Figure 74). Remove all dusts covering the filter using a vacuum cleaner and replace it in its place.

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

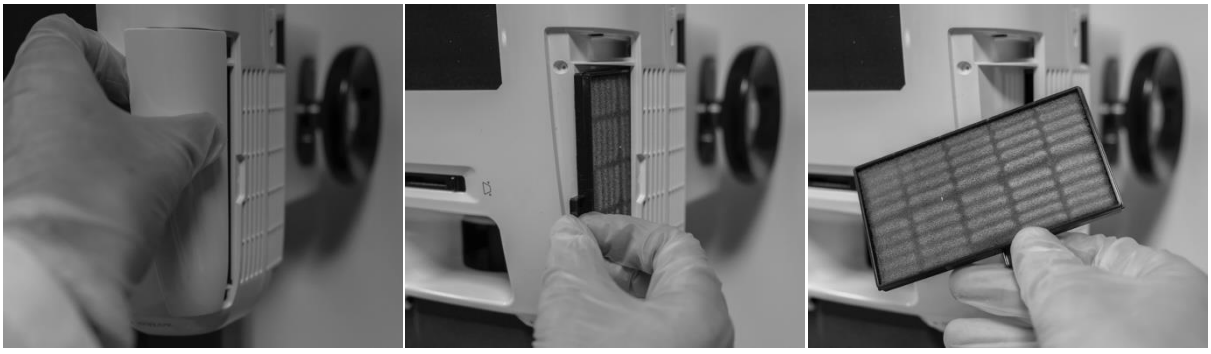


Figure 74 – Air filter cleaning

STEP 2: XY STAGE RE-CALIBRATION

Throughout its use, the XY stage origin may shift slightly. It is then recommended to re-calibrate it regularly. To do so, open the XY stage control window (refer to section 4.1.1) and click on **Re-calibrate origin** (Figure 29).

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

5.3 TROUBLESHOOTING

5.3.1 CAMERA ISSUES

Issue	Possible cause	Fixes
No camera detected error message (Figure 75)	Smart Print's USB cable not connected to the computer	Check and connect the USB cable to the computer
Interruption of the live view (Figure 76)	Smart Print's USB cable not properly connected to the computer	Check that the cable is well connected on an USB 3.0 port
In focus or alignment mode, the image is always black	Camera under-exposed or illumination lamp off	• Check if Smart Print is ON (continuous blue light on status indicator Figure 2) • If lamp or temperature indicator are illuminated refer to EH-TW5300 user guide • Adjust the camera exposure time as described in section 3.5.5
In focus or alignment mode, Pink spots appear on the image	Camera over-exposed	Adjust the camera exposure time as described in section 3.5.5

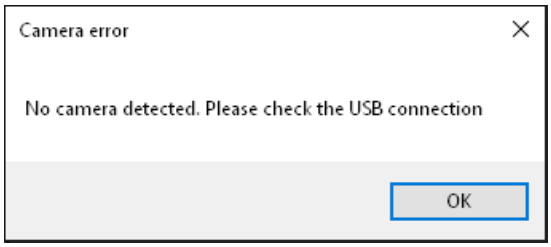


Figure 75 – Camera connection error 1

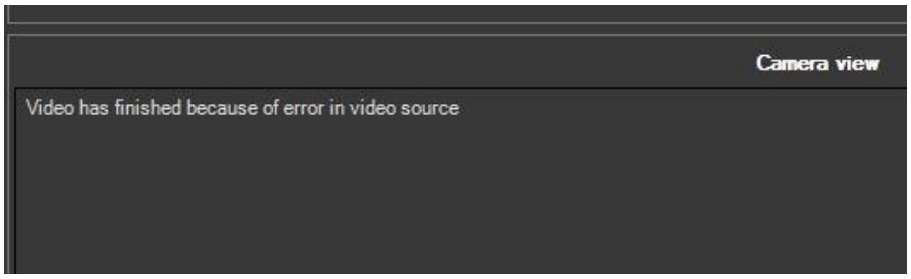


Figure 76 – Camera connection error 2

5.3.2 XY STAGE ISSUES

Issue	Possible cause	Fixes

No stage detected error message (Figure 77)	• Stage not properly connected to the computer • Controller powered off	• Check that the controller is powered on and properly connected to the computer • Check the connection between the stage and the controller
XY stage menu disabled	Stage not connected to the computer	Same as above
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 • Switch on the stage and move it toward its origin position using the manual B and F button located on the controller's front panel (**Erreur ! Source du renvoi introuvable.** left) • 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 29)	Software-corrected stage motion activated	SFTprint 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.

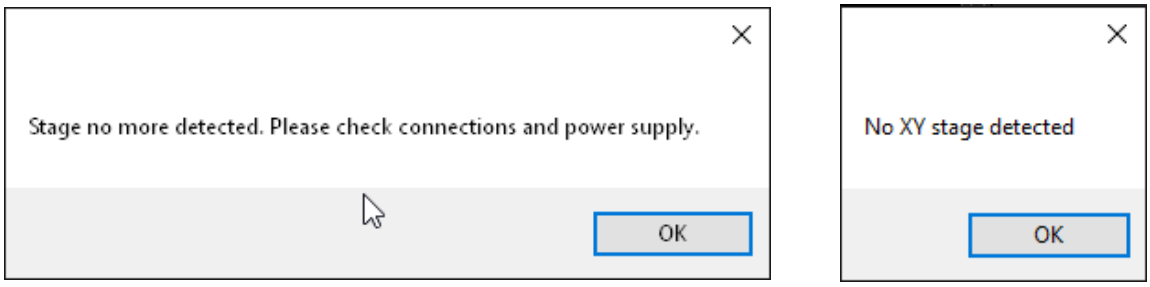


Figure 77 – XY stage connection errors

5.3.3 VECTOR DRAWING CONVERSION ISSUES

Issue	Possible cause	Fixes
The calculated dimensions of the vector drawing do not correspond to the real values	The dimensions calculated by KLayout had not be taken account by SFTprint (latency problems)	Reload the drawing in the conversion module (button **Load gds, dxf, oas, cif**)
The output image is blank	• Dimension error (refer to the problem above) • The vector file is corrupted or contains unknown elements to KLayout	Open the vector file in KLayout and check the drawing then save it in .gds from KLayout. If KLayout cannot displays some patterns it means the file is probably damaged. If so, try to save it again from the software used for its creation
The patterns of all layers overlap or are hidden by a big black object	All layers (hidden or not) are converted	Open the vector file in KLayout, remove all undesired layers then save changes as a new file. Try the conversion in SFTprint 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.

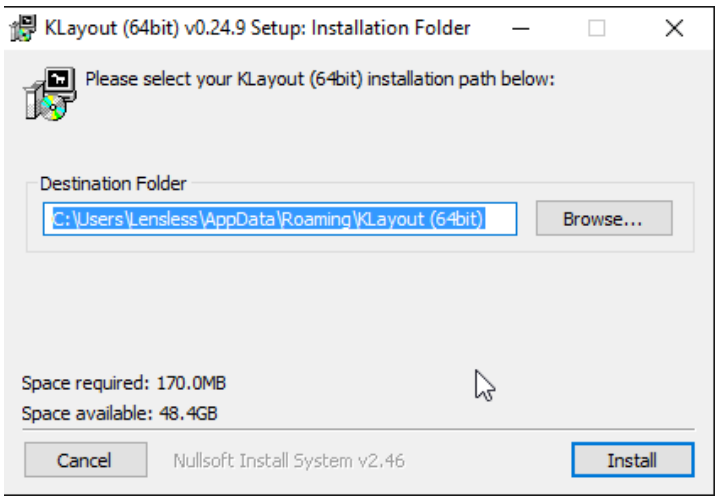


Figure 78 – KLayout installation window

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.

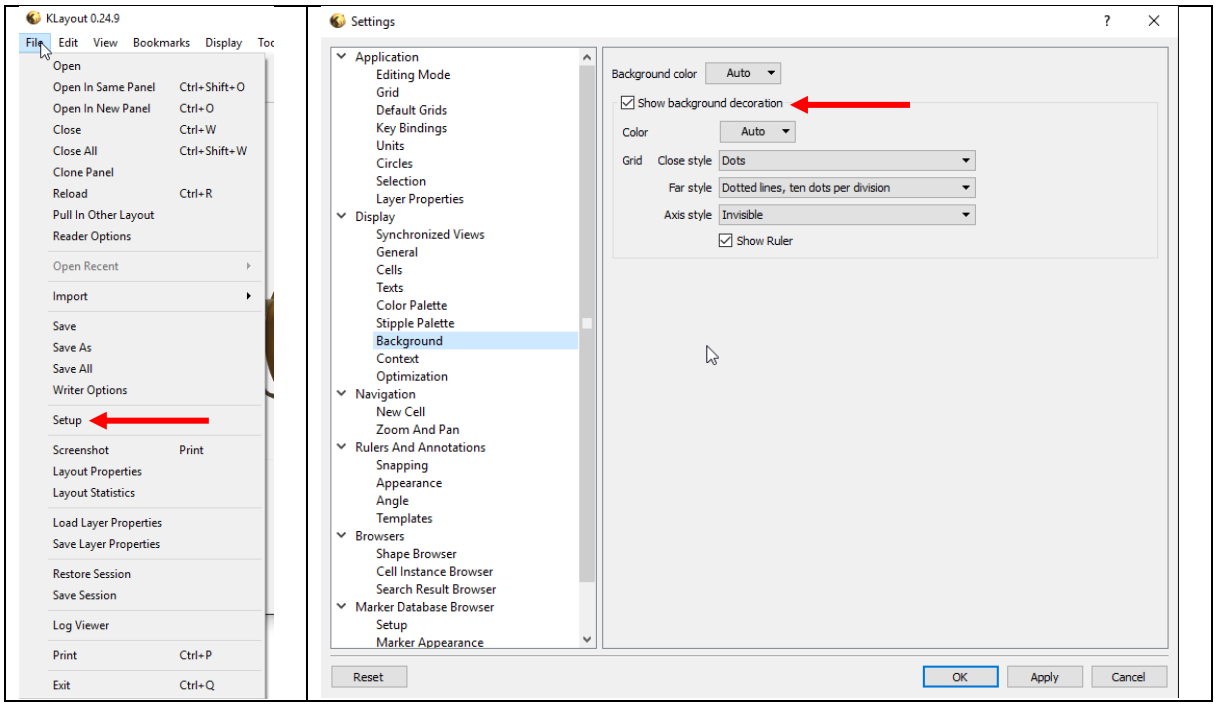


Figure 79 - Configuration of KLayout

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

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

If KLayout is not found by SFTprint (admin privilege required): Go to the menu **SFTprint → Settings**. In the **Importation** tab, click on **Define klayout_app.exe filepath…** (Figure 69). In the **Open** window, find and select the executable file *klayout_app.exe* (Figure 80).

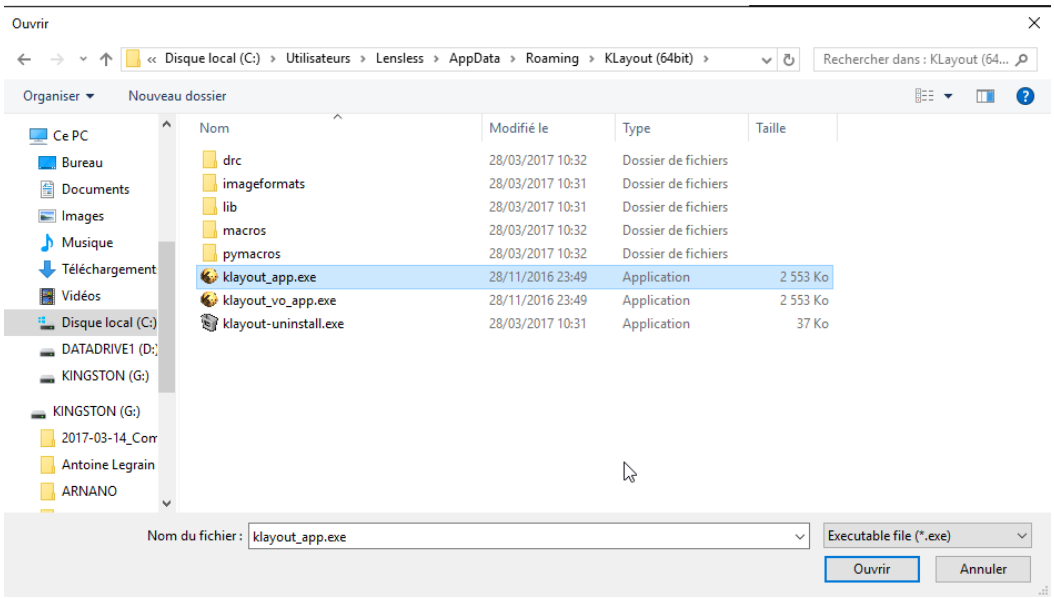


Figure 80 – Folder containing the KLayout executable

6 APPENDIX

6.1 SPECIFICATIONS

LITHOGRAPHY		
	Light illumination	Filtered blue light between 430 and 470 nm Power = 11 mW * or 17.7 mW **
	Lamp lifetime	3900 h
	Resist compatibility	g-line resists (with light sensitivity around 435 nm)
Resists already known to work	AZ1500 Series *(MicroChemicals)*	Positive resist Thickness: 0,5 - 4 µm Typical exposure time (with obj. x2.5): 6 s *
	AZ4562 *(MicroChemicals)*	Positive resist Thickness: 5 - 40 µm Typical exposure time (with obj. x2.5): 11 s *
	AZ5214E *(MicroChemicals)*	Reversible resist (positive or negative) Thickness: 1 - 4 µm Typical exposure time (with obj. x2.5): 10 s *
	AZ125nXT *(MicroChemicals)*	Negative resist Thickness: 35 – 180 µm Typical exposure time (with obj. x2.5): 100 s *
	S1800 Series *(Shipley)*	Positive resist Thickness: 0,5 - 4 µm Typical exposure time (with obj. x2.5): 6 s *
	ma-P 1275 G *(Micro Resist Technology)*	Positive resist optimized for grayscale lithography Thickness: 20 – 60 µm Typical exposure time (with obj. x2.5): 40 s *
	Laminar E9220 *(Eternal Mat.)*	Negative resist dry film Thickness: 6 – 100 µm Typical exposure time (with obj. x2.5): 30 s *
	Riston FX930 *(Dupont)*	Negative resist dry film Thickness: 30 µm Typical exposure time (with obj. x2.5): 40 s *
Substrate compatibility	Dimensions	Up to 100 mm wide flat substrates
	Materials	All

Performances

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

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

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

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

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

* for 2019/07 model or earlier

** *for 2019/08 model or later*