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SMART PRINT

USER'S MANUAL FOR SMART PRINT MASKLESS LITHOGRAPHY EQUIPMENT

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TABLE OF CONTENTS

1 GENERAL INFORMATION

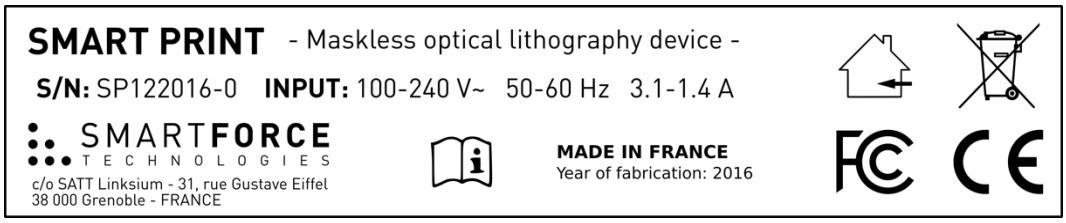
1.1 SAFETY INFORMATION

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 or EH-TW5350 from Epson. All precautions and safety instructions described in the EH-TW5300 or EH-TW5350 user guide must be applied.

1.2 IDENTIFICATION MARK



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)4-38-78-95-08
+33-(0)4-38-78-96-91
or e-mail your questions to: contact@smartforcetechnologies.com

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

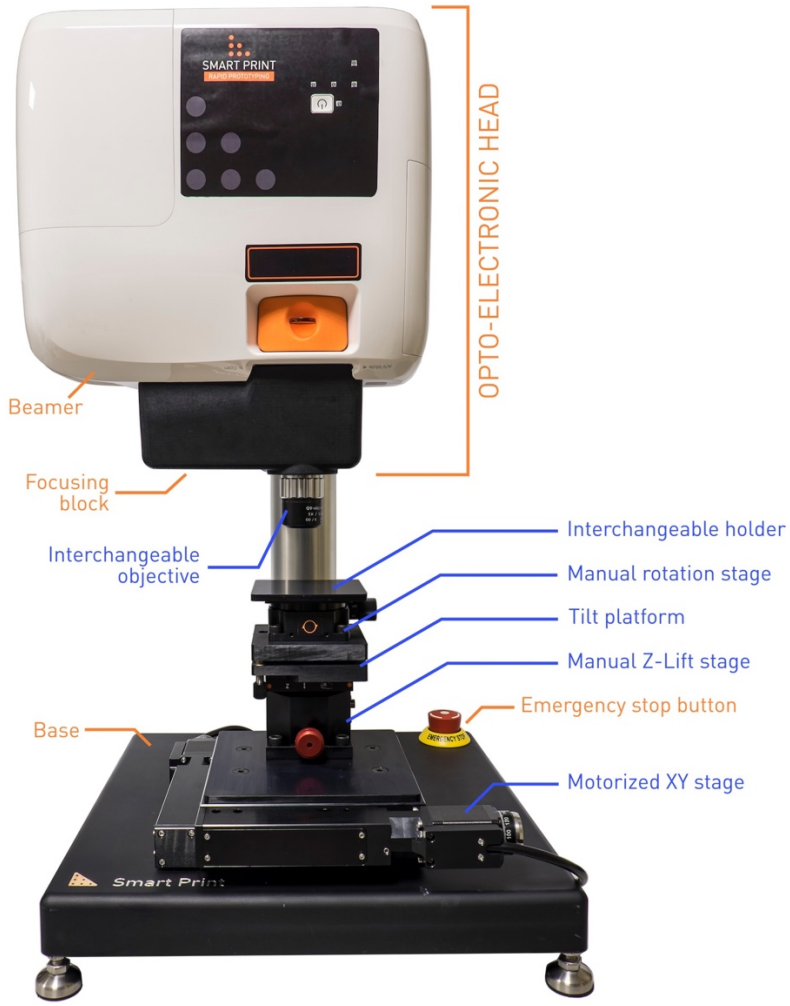


Figure 1 – Left: Smart Print basic configuration. Right: Smart Print with its main accessories

2.2.2 OPTO-ELECTRONIC HEAD

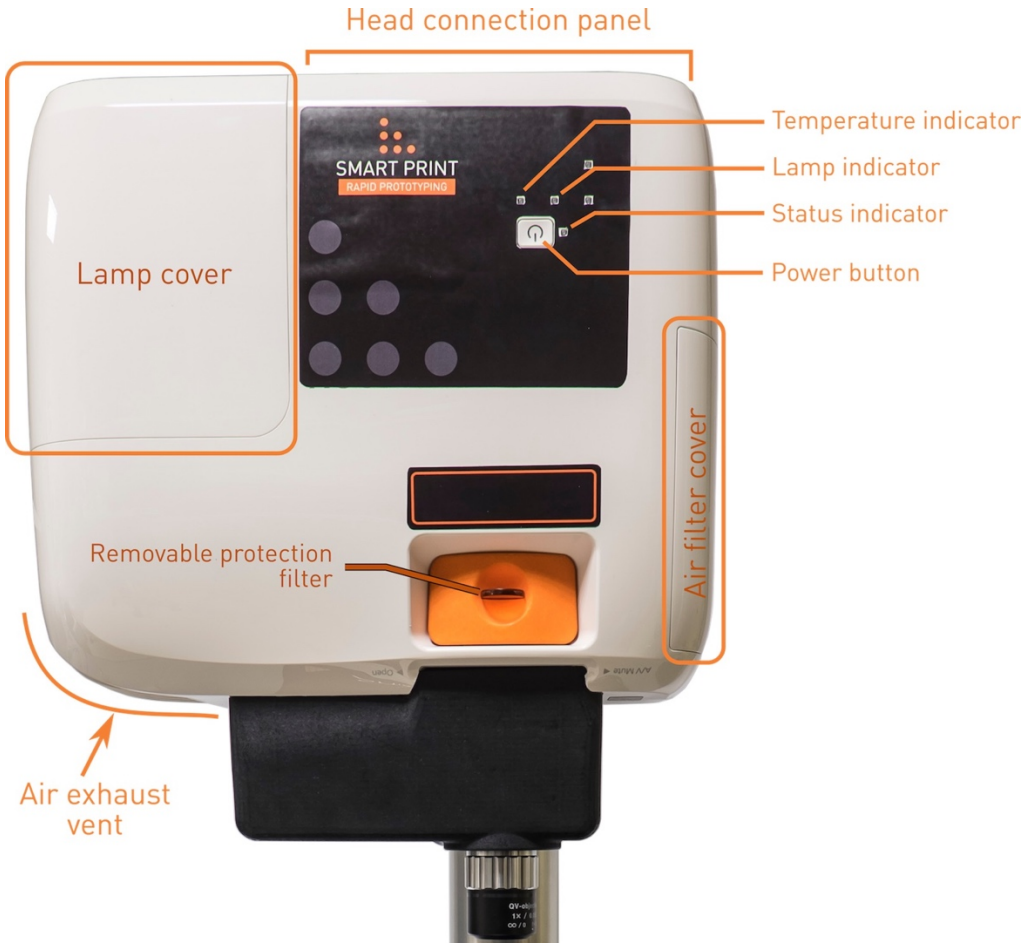


Figure 2 – Front view of the opto-electronic head

Figure 3 – Connection panel

2.2.3 FOCUSING BLOCK & COLUMN

Figure 4 – 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 5) made of: a Z-lift (bottom), a tilt platform (middle) and an interchangeable holder (top).

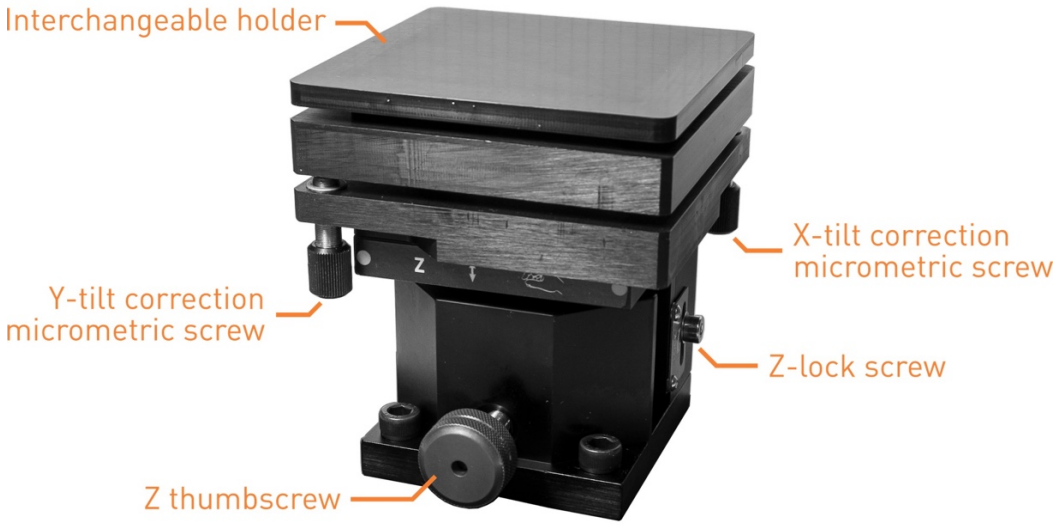


Figure 5 – Manual Z-lift

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 6 left). Two other substrate specific holders can be alternatively used (separate order):

- For standard microscope glass slides (25 mm x 75 mm) > Figure 6 middle
- For 4 inches (100 mm) circular wafers with notch or slab > Figure 6 right

CAUTION:
The wafer holder must always be placed as shown in Figure 6 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.

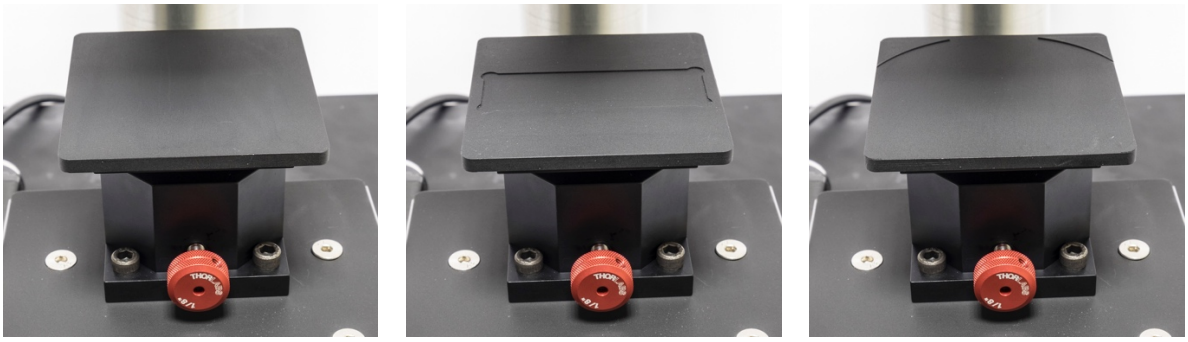


Figure 6 – From left to right: flat holder, microscope glass slide holder and 4'' wafer holder

2.2.5 OPTION 2: MOTORIZED XY STAGE

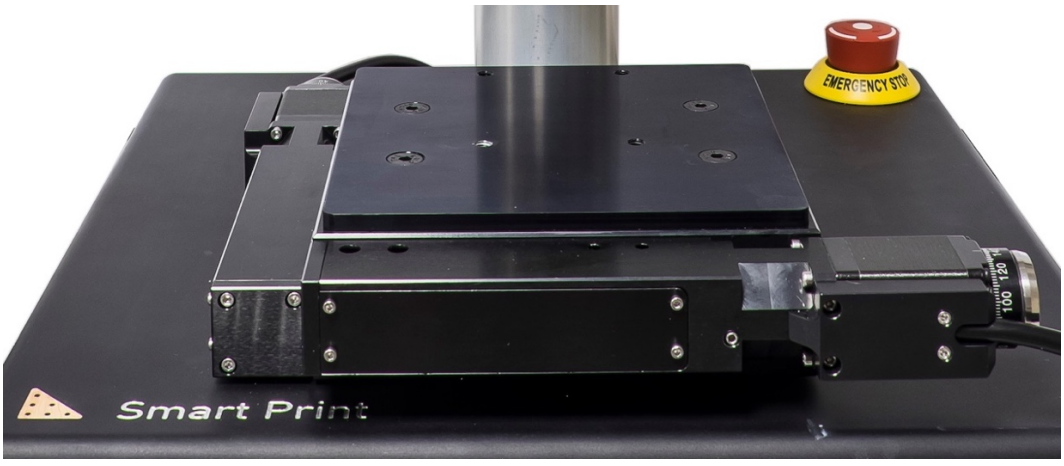


Figure 7 – Motorized XY stage equipped with Z-lift and flat holder

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 exposing 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

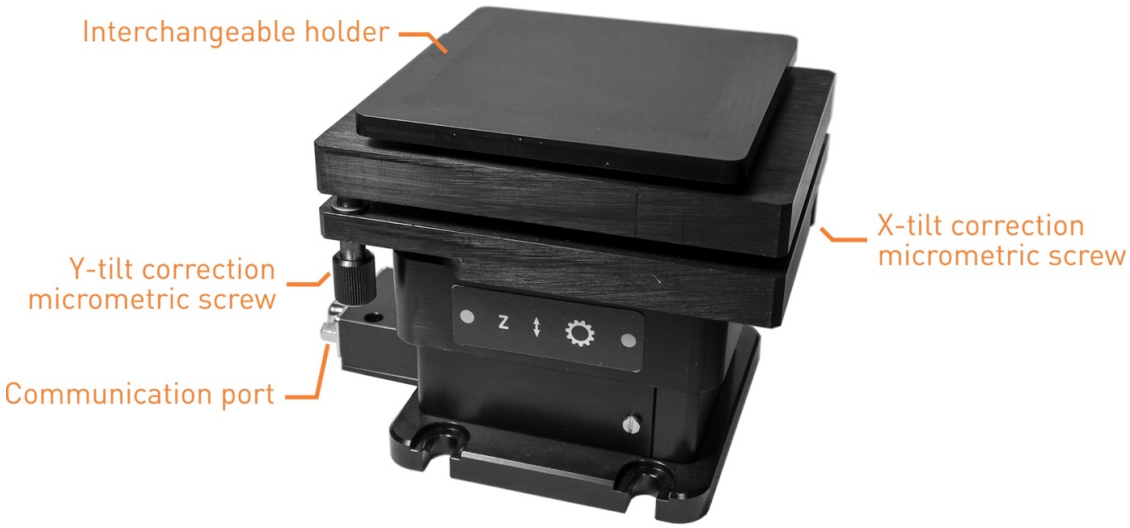


Figure 8 - Motorized Z-lift

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.

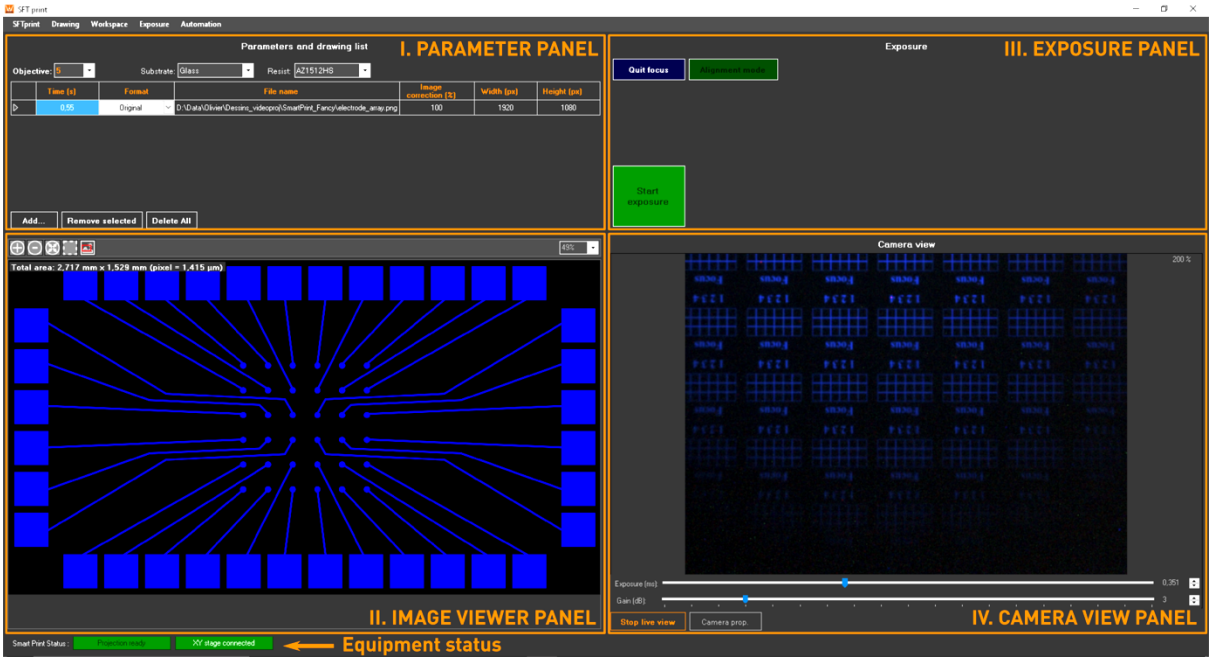


Figure 9 – SFTprint main window

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 head connection panel (Figure 3) via the appropriate cable.

3.2.2 CONNECTIONS TO THE COMPUTER

- The focusing block must be connected to a computer (refer to the NOTE below) via its USB cable to a USB 3.0 port.
- The opto-electronic head must be connected with the appropriate HDMI cable from the head connection panel HDMI port n°2 (Figure 3) to the computer.

NOTE: The USB connector of the focusing block must be connected only to a computer in compliance with the ENC60950-1 standard.

3.2.3 CONNECTIONS WITH THE MOTORIZED XY STAGE (OPTIONAL)

- The stage must be connected to the controller back panel (Figure 10 right) on the axis 1 and axis 2 ports via cables axis 1 and axis 2.
- The controller must be connected to a computer with the appropriate USB cable via its front panel (Figure 10 left).
- The controller must be connected from the power inlet on the front panel (Figure 10 left) to the power supply via its main adapter.

NOTE:
The controller must be connected only with the power supply provided with the equipment. Power supply can be a PUP120-17 from *Protek Power*.

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.

Figure 10 – Front (left) and back (right) panel of the XY stage's controller

3.3 QUICK USE

- Switch on Smart Print by pressing the power button (Figure 2) until the status indicator LED becomes blue
- On the computer, start *SFTprint* software
- On the panel **exposure list and parameters** (Figure 9), 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 3.4.3) by clicking on **Add...**
- 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

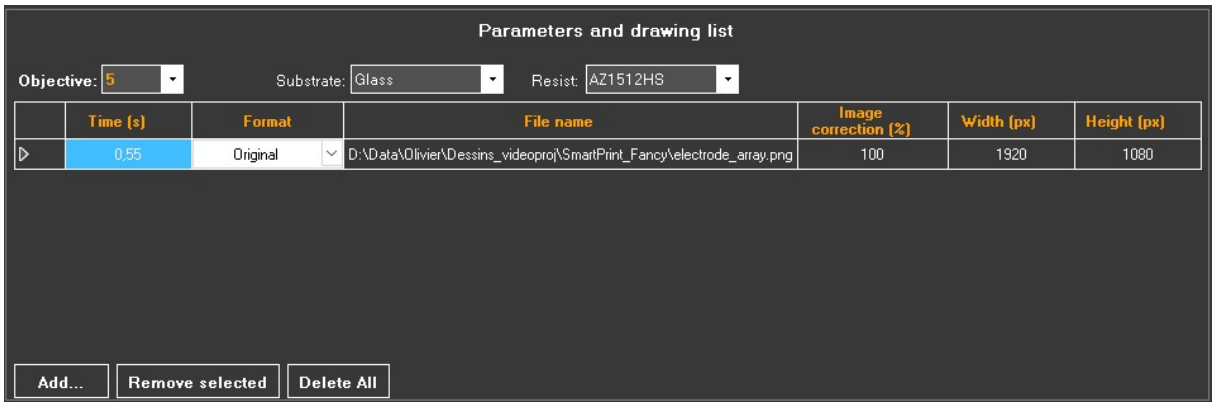


Figure 11 – « Parameters and drawing list » panel

- Make the focus on a blank substrate (more details in section 3.4.5):
  - 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 9). 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 4 left) and turning the ***adjustment wheel*** (Figure 4 right) until a sharp image is visible on the panel **camera view**

    NOTE: if the Manual Z-Lift is installed, fine focus tuning can be done by turning the thumbscrew (Figure 5 left). If the Motorized Z-lift is installed, 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**
  - Remove the blank substrate
- Load the sample to be exposed, click on **EXPOSE SELECTED DRAWING** (Figure 9) 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 BASIC OPERATIONS

3.4.1 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.

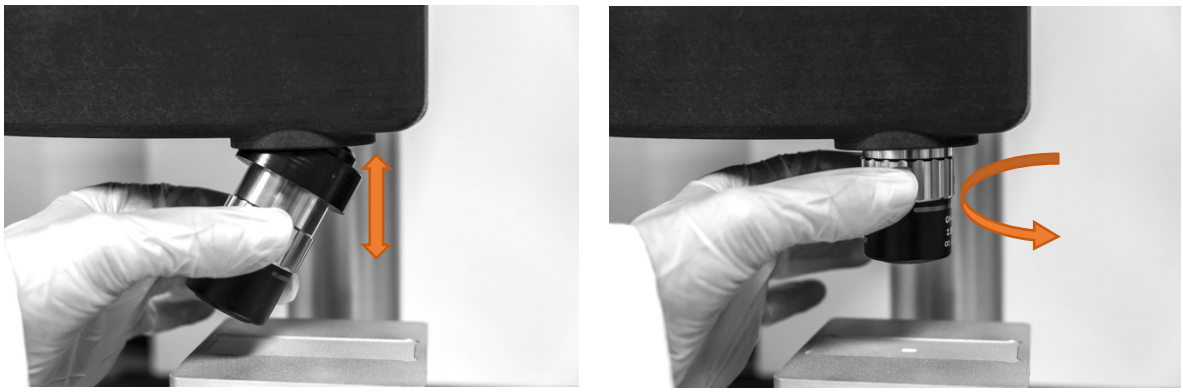


Figure 12 – Two-steps objective loading

3.4.2 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.

3.4.3 EXPOSING A DRAWING WITHOUT STANDARD DIMENSIONS (1920x1080)

CASE OF SMALL DRAWINGS – Dimension < 1920x1080

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

CASE OF BIG 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 14). 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

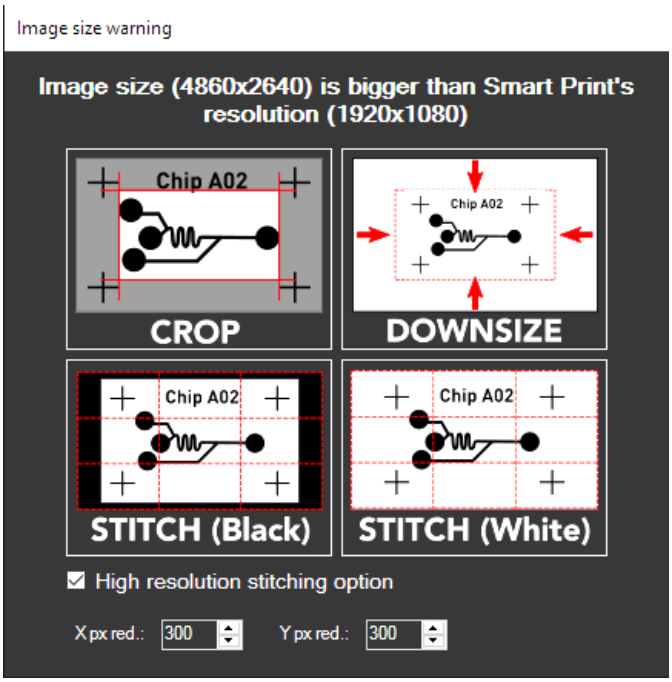


Figure 14 – « Big image » popup dialog

« 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 15. 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.

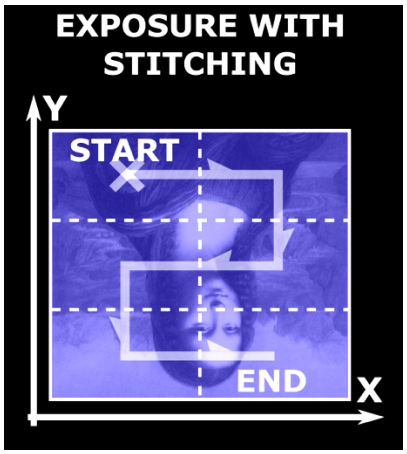


Figure 15 – Exposure principle of the "stitching mode"

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

- In the **Parameters and drawing list** panel (Figure 9), 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 14).
  → A ".stitch" file – preconfigured for exposure in stitching mode – can also be directly loaded (for more details, refer to section 3.4.8).
- Adjust the exposure time if necessary and make the focus (see section 3.4.5).
- Position the substrate, thanks to the XY stage, at the starting point for a stitched lithography (START position in Figure 15). If the stage status is XY out-of-range, the current start position cannot be used for stitching and must be changed
- Click on **EXPOSE SELECTED DRAWING**.

Once the exposure is started, a progress bar displays the remaining time (estimated) in the **Exposure** panel (Figure 16).

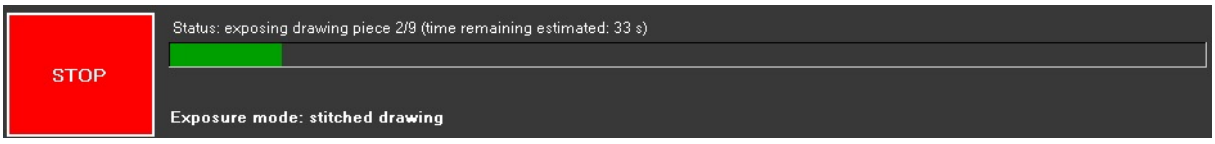
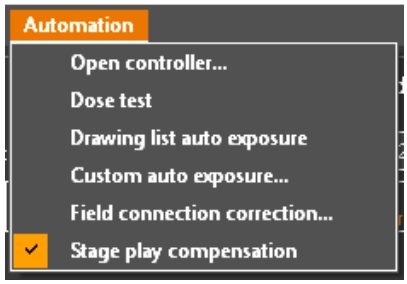


Figure 16 – Progression preview of a stitched lithography

NOTE ON "**HIGH RESOLUTION**" STITCHING: If the high-resolution option is checked on the popup dialog Figure 14, 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 

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

.

That option allows to correct the mechanical stage play "backlash" and then *significantly improves the quality and reproducibility* of the field connections in stitching mode. However, it requires to allocate a part of the stage range to that operation and then *reduce the total stage range.* The default stage range loss in compensation mode is 4.5 mm but it can be adjusted in the general settings (section 4.4).

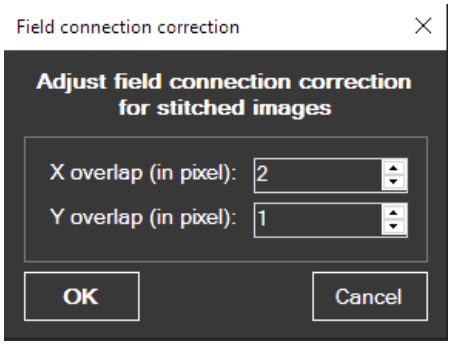
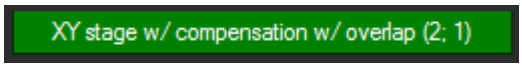


Figure 17 – Field connection adjustment window

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 17), 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 9) is updated as shown below:



3.4.4 DRAWING OPTIONS AND PREVIEW

DRAWING SETTINGS

For each design added in the drawing list (panel I, Figure 11), four parameters can be modified:

- **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.

- **Format**: drawing tonality. On the corresponding dropdown list, select "Original" to keep the drawing unchanged or "Inverted" to reverse the tonality (black becomes white and vice versa).
- **File name**: name and file path of the loaded drawing. Double-click on the cell to edit.

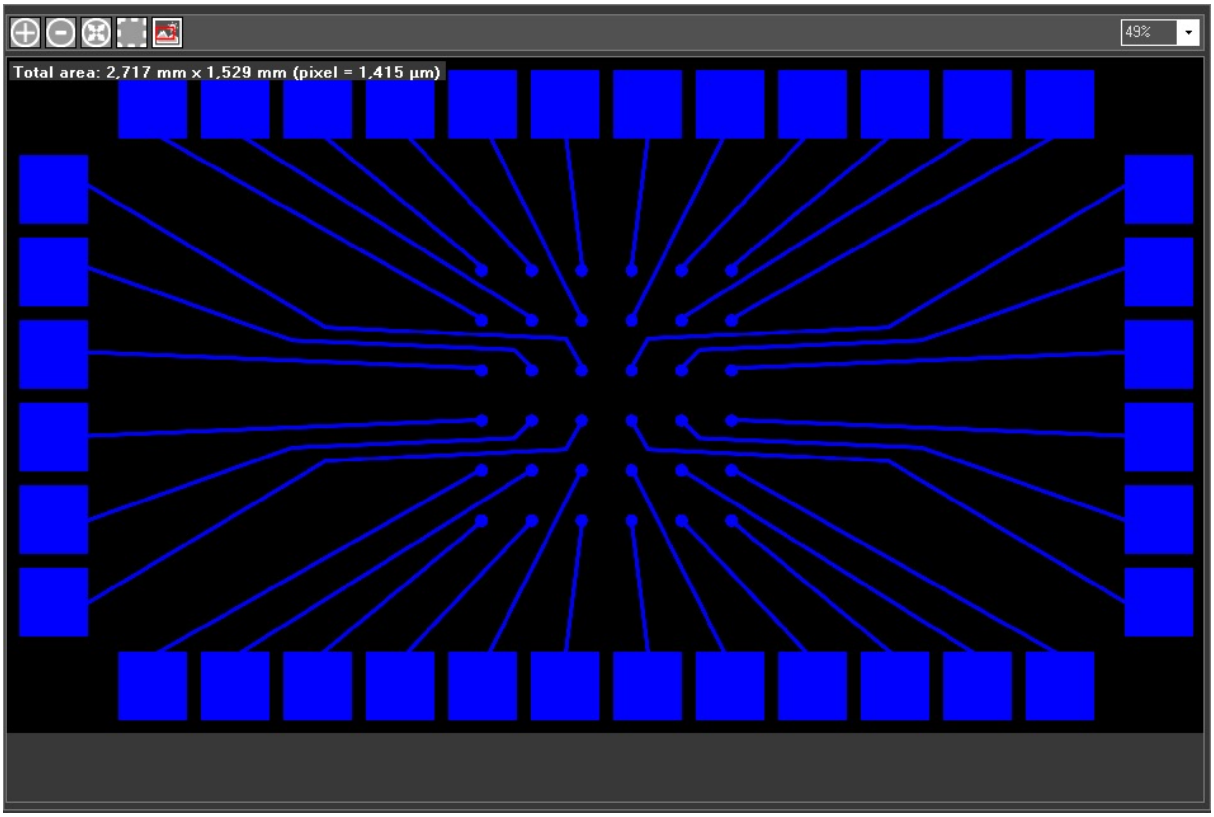


Figure 18 – Image viewer panel

- **Image correction**: each drawing will be corrected during exposure to counter-balance vignetting effects (lower light intensity at the corners of the projected image). A reference value is automatically entered when a drawing is added. Reference value depends on the selected objective. To edit the value, just click on the field and enter a new value on the keyboard. The effects of the image correction values are described in the table below:

Image correction	0 %	Reference value	100 %
Effects	• Corners of the drawing under-exposed • Short exposure time	• Homogeneous exposure all over the drawing • Medium exposure time	• Some area may be over-exposed • Long exposure time

Columns **width** and **height** are the total dimension of each drawing in pixels. If the width is higher than 1920 px or the height higher than 1080 px, the exposure will require the motorized XY stage (« stitching » mode → see section 3.4.3).

DRAWING PREVIEW

Each selected drawing is directly displayed in the panel **Image Viewer** (Figure 18). 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
- 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

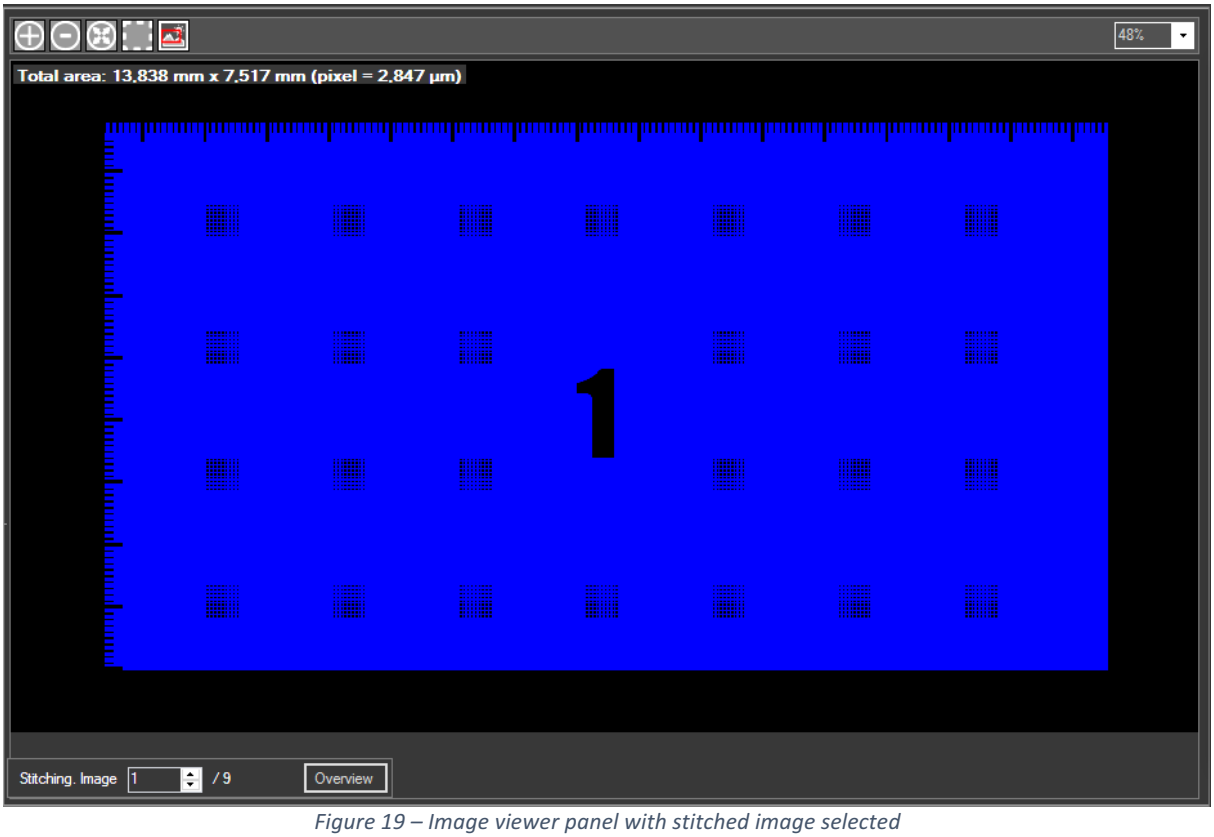


Figure 19 – Image viewer panel with stitched image selected

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 upper/lower arrows on the Stitching sub-panel located on the lower left 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 currenctly 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.

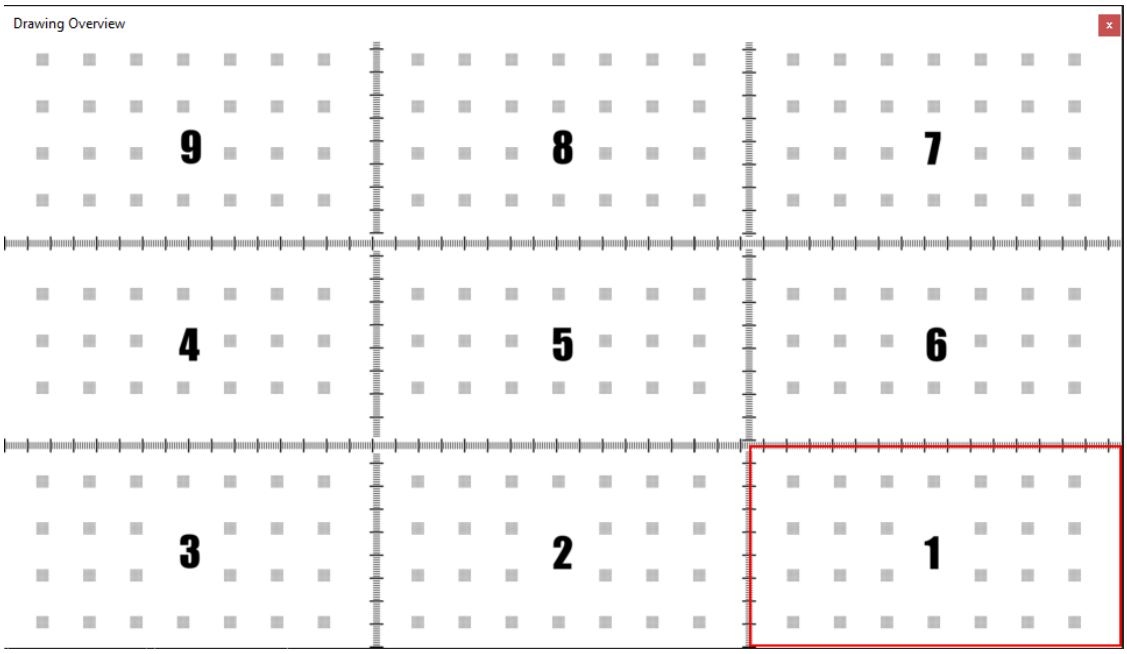


Figure 20 - Overview window corresponding to the stitched image selected in the previous figure

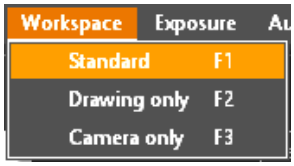
3.4.5 FOCUS ADJUSTMENT

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 9). 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** 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.



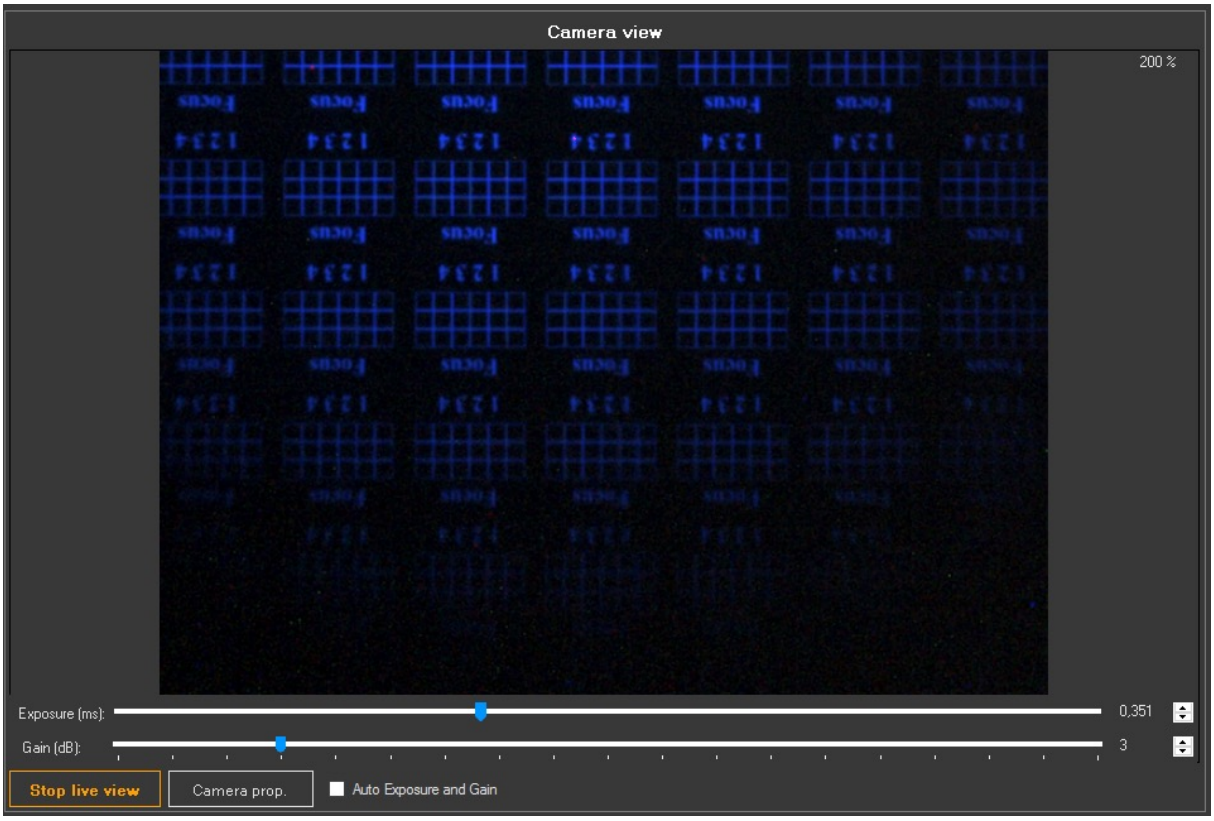


Figure 21 – Camera view panel during focus setting

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 4 left) and turning the ***adjustment wheel*** (Figure 4 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 5 left).

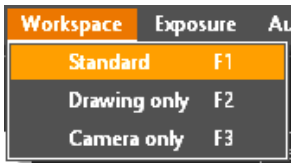
- Once adjusted, secure the ***locking handle*** and leave the focus mode by clicking on button **Stop Focus** in the **Exposure** panel.
- Remove the reference substrate

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 9), choose your objective
- Click on the button **Focus Mode** in the **Exposure** panel (Figure 9). 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 4 left) and turning the ***adjustment wheel*** (Figure 4 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.

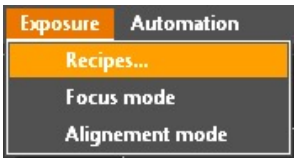
NOTE: Do not forget to unload the protection filter before an exposure.

3.4.6 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.

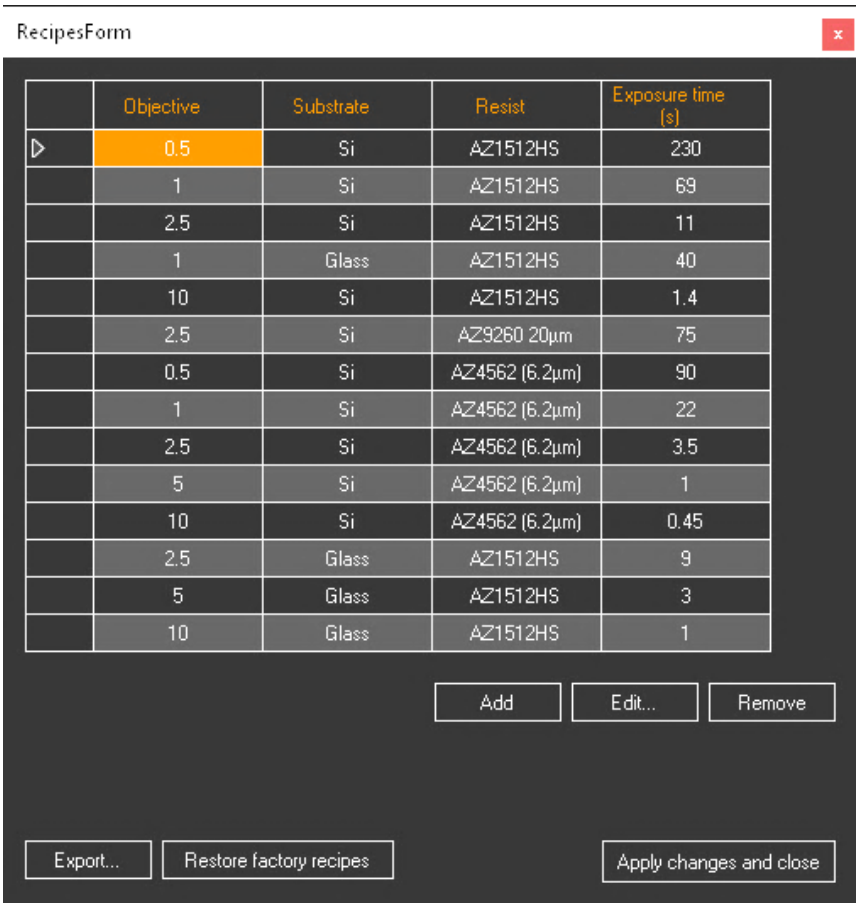


Figure 22 – Recipe database window

Figure 23 – Add/Edit a recipe panel

3.4.7 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 filepath
- 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 4.1.4)
- (Optional) XY(Z) current position

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.

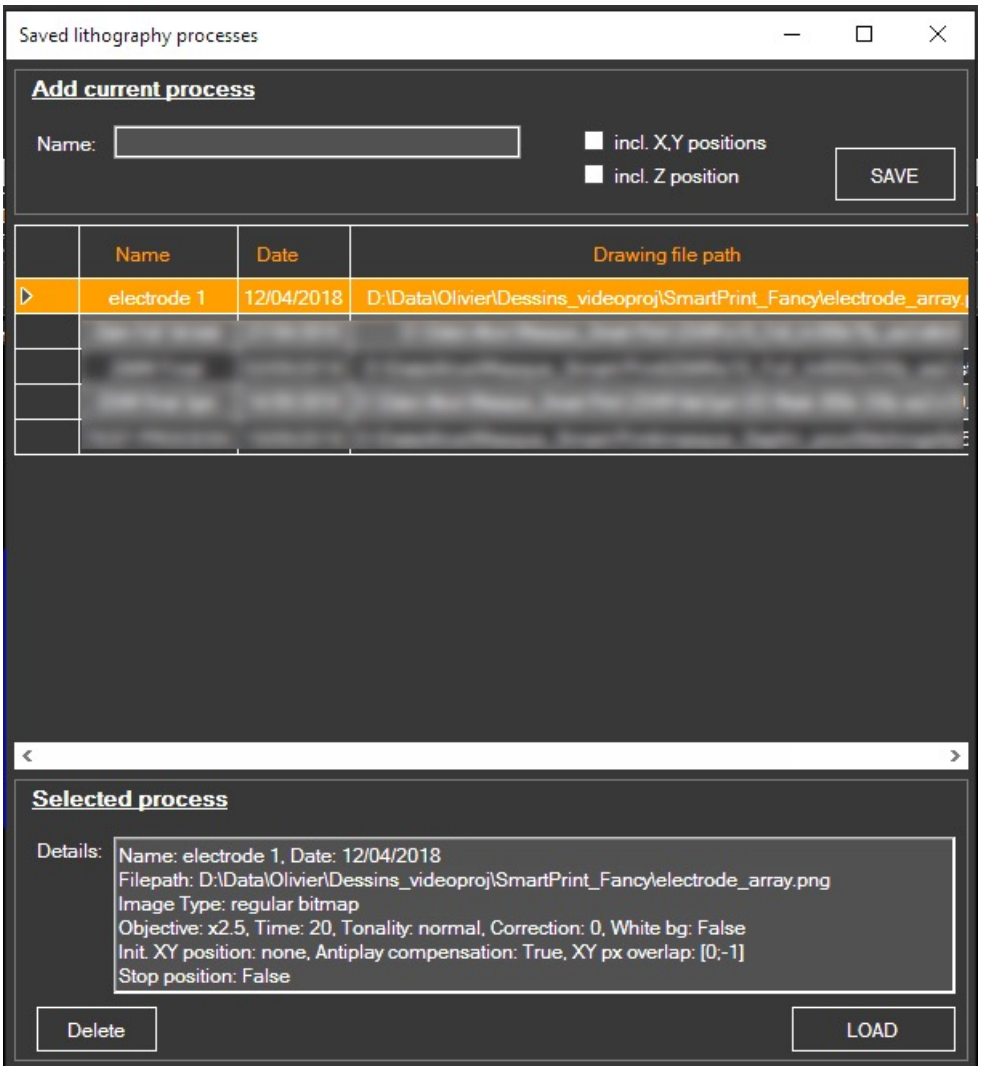


Figure 24 - Process database window

CHECK PROCESS DATABASE

To check a process from the database, just select it in the datatable. 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 datatable and click on the **Load** button.

3.4.8 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.

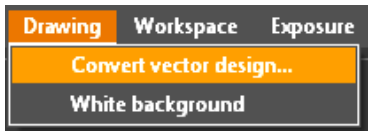
For that purpose, a conversion module is included in SFTprint. The conversion is performed in synergy with the open-source application KLayout (installation and configuration detailed in section 5.3.3). The conversion is based on a two-step operation:

- 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 **all patterns of the TOP CELL (for all 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 extract the drawing size (operation may take a few seconds). Extracted dimensions are displayed in the **1) Load file** panel.
- Choose the appropriate base unit: "mm" or "µm"
- Select the desired objective for the exposure in the **2) Choose objective** panel. The module calculates on-the-fly the dimension in pixels of the output image and the number of exposure required to make the lithography of the whole drawing at the selected objective(stitching)
- Check the high-resolution option 

to improve the overall quality of the lithography. This option is especially recommended if the patterns are small compared to the pixel size (refer to the NOTE about "high resolution" on section 3.4.3 for more information)
- Check the **Antialiasing** option if a smoothing of the edge is wanted (recommended for complex geometries such as curved structures)
- Click on **CONVERT**. A "save file" dialog box opens. Enter an output 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**

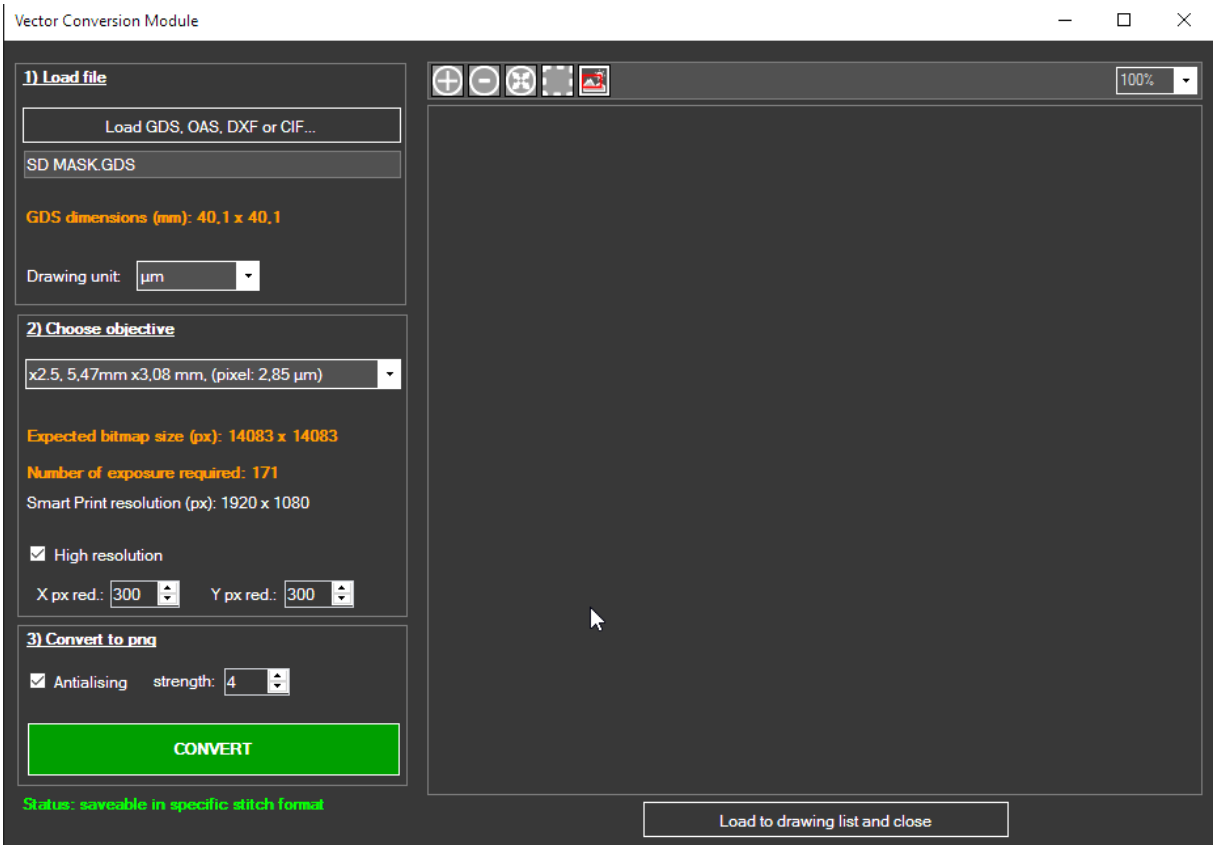


Figure 25 – Vector drawing conversion module

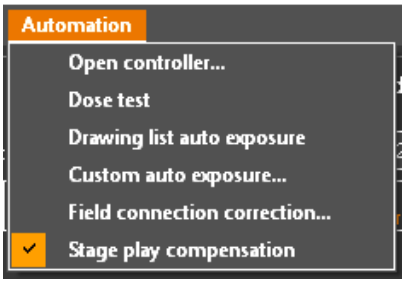
NOTE about the output format « .png » and « .stitch »:

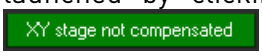
- If the size of the output image is big (default values: > 100 Mpx or > 25 Mpx with antialiasing), « .stitch » will be the output format instead of « .png ». Those limit values can be set in **settings**, **importation** tab (Figure 60 page -48 -).
- Converting in « .stitch » is especially recommended for big drawings with complex shapes as the antialiasing option is more efficient in this format.
- 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.

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 26). This interface can also be launched by clicking directly on XY stage status label 

at the bottom of the main window.

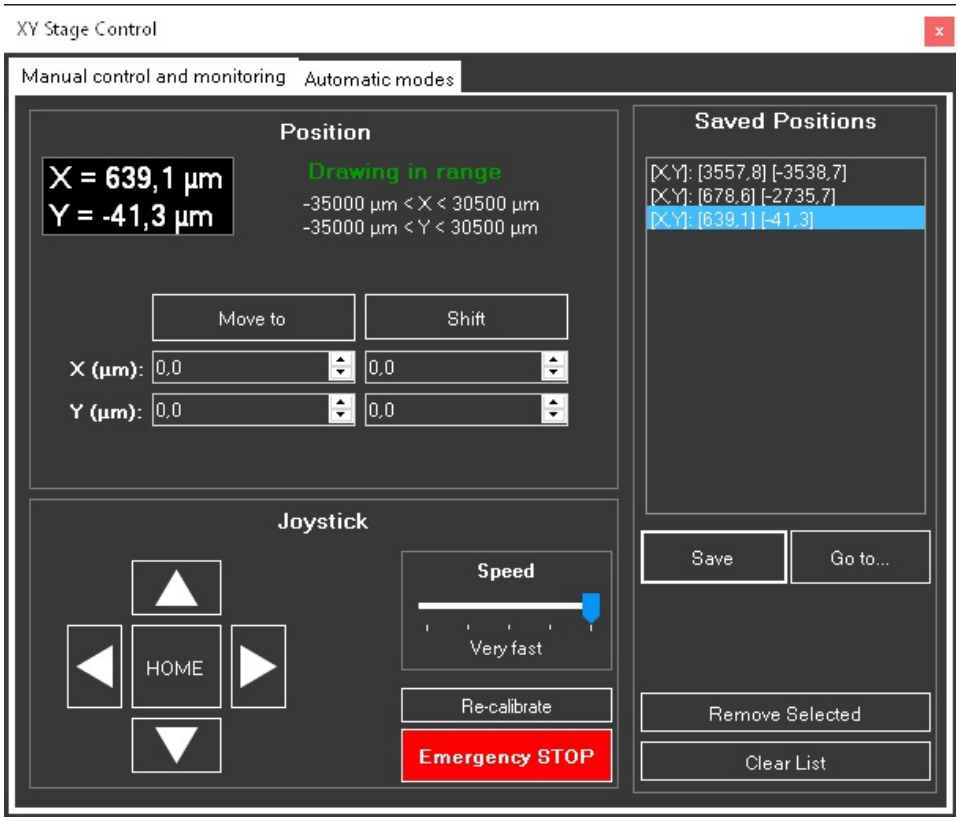


Figure 26 – XY stage control and monitoring interface

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).

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+plus and ctrl+minus (on the numpad).

Registered motion. Current position can be saved by clicking on **Save** in the panel **Saved Positions**. 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**.

Figure 27 - Right-click option relative to registered positions

Export/Import coordinates. A copy of the position list can be saved by right-clicking on the list box and choosing **Export list...** (Figure 22). 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...** (Figure 22). 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 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 28. 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.

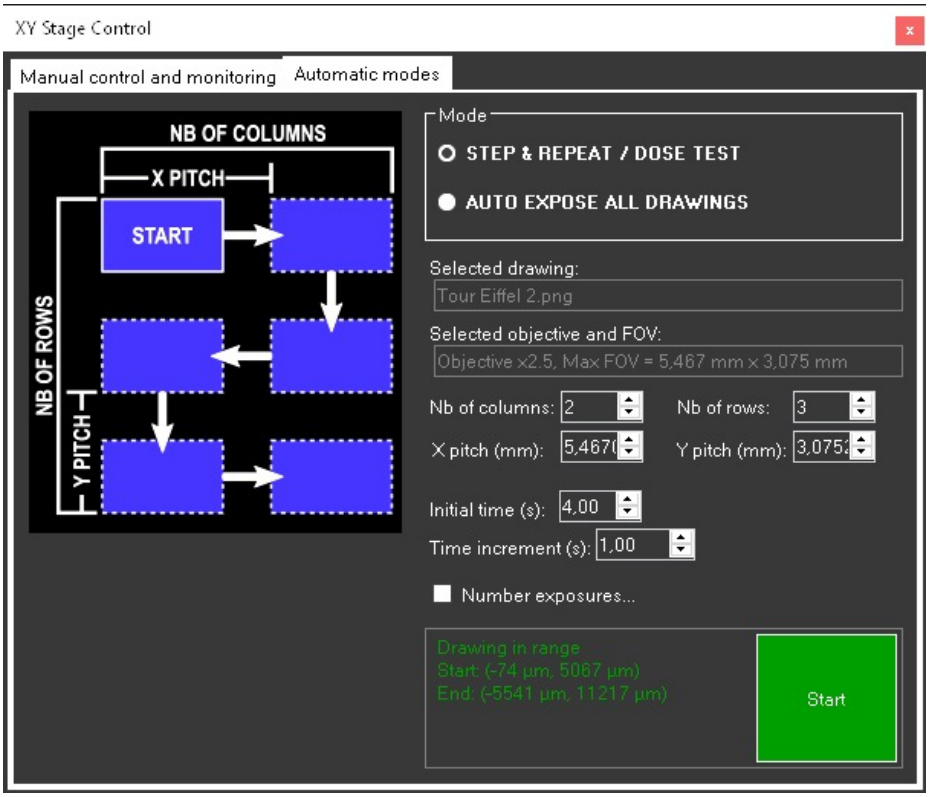


Figure 28 – Automatic mode tab in XY stage window

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 time 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 28).
- **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 29) and their exposure time in s (Figure 30).

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).

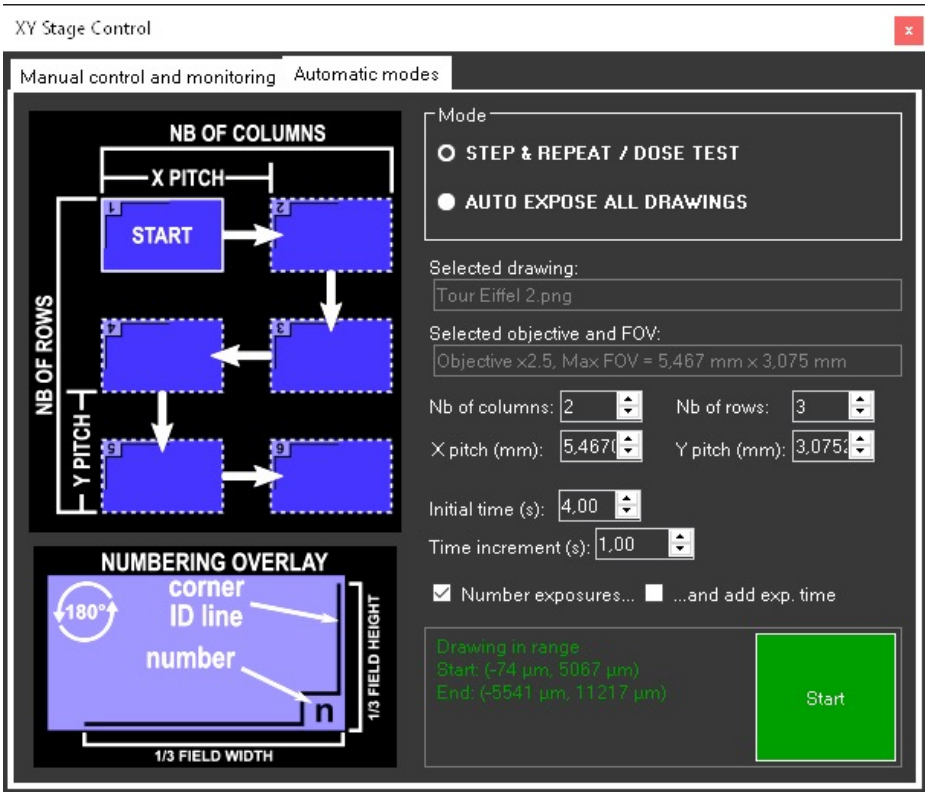


Figure 29 - Step & Repeat mode with "Number exposures" option

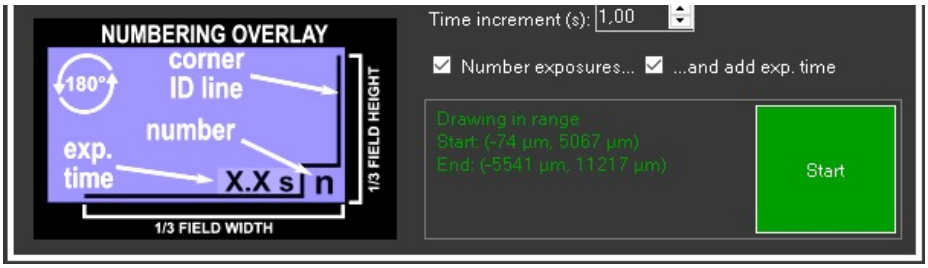


Figure 30 - "Add exposure time on overlay" option

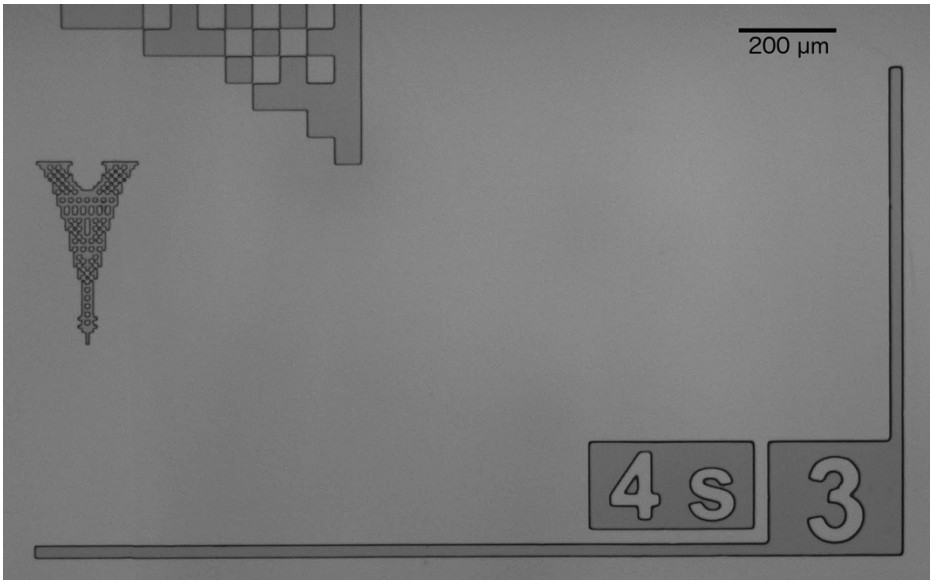


Figure 31 - Optical micrograph of the bottom right corner of the 3rd lithography of a drawing exposed in step-and-repeat mode with numbering and exposure time overlay options

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 32). 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 26) 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 32 – 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 33). 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.

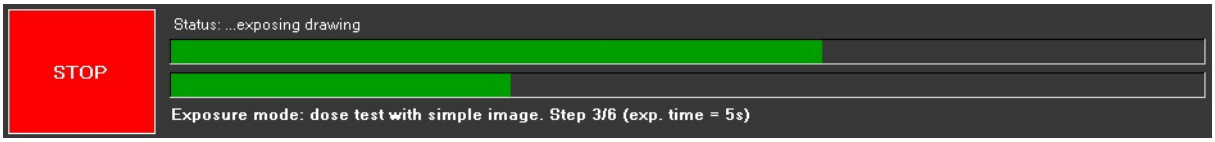


Figure 33 – « Exposure » panel during auto mode

4.1.3 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 3.4.5)
- Go to **Automation** menu and click on **Drawing list auto exposure**

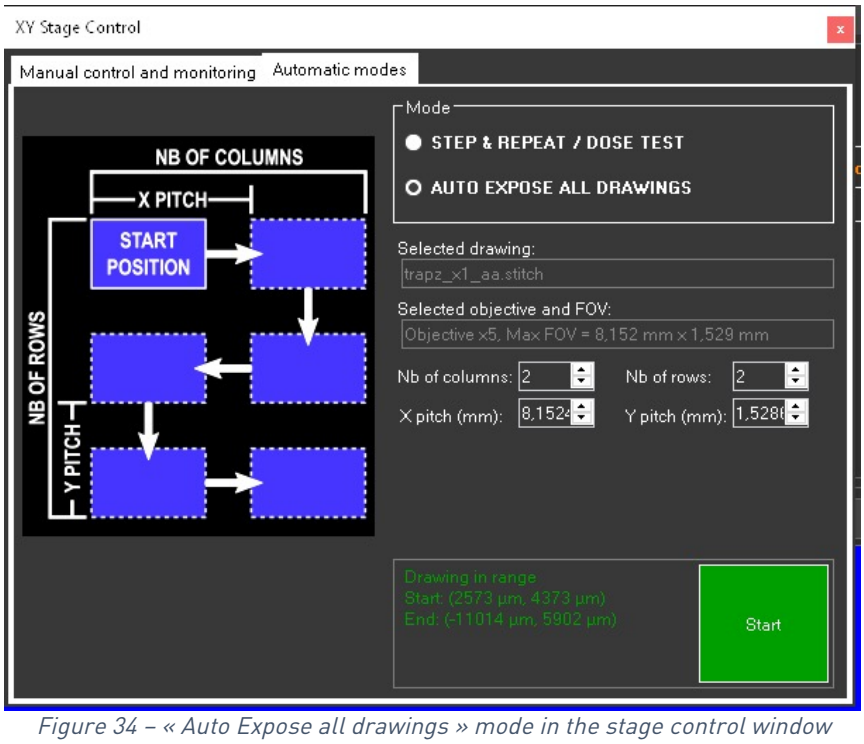


Figure 34 – « Auto Expose all drawings » mode in the stage control window

- 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 4.1.2 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 4.1.2, 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 33). The automatic exposure can be stopped at any time by clicking on the button **STOP** in the same panel.

4.1.4 LONG LASTING EXPOSURE FEATURES

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. FIG 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 36 Middle). Finally, check the **with stop position** box at the right of the **Expose Selected Drawing** button (Figure 36 Right).

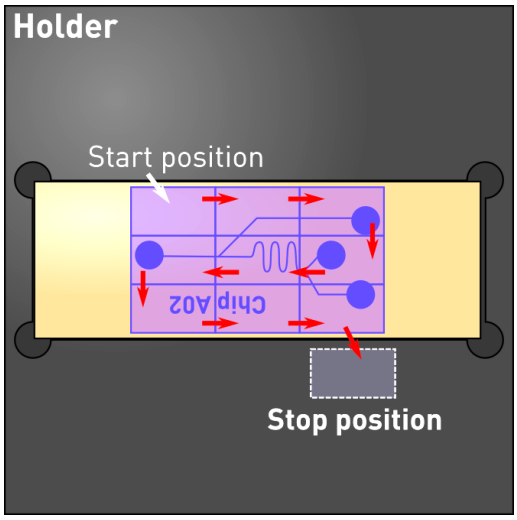


Figure 35 - "Stitched" lithogrpahy with used defined stop position

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.

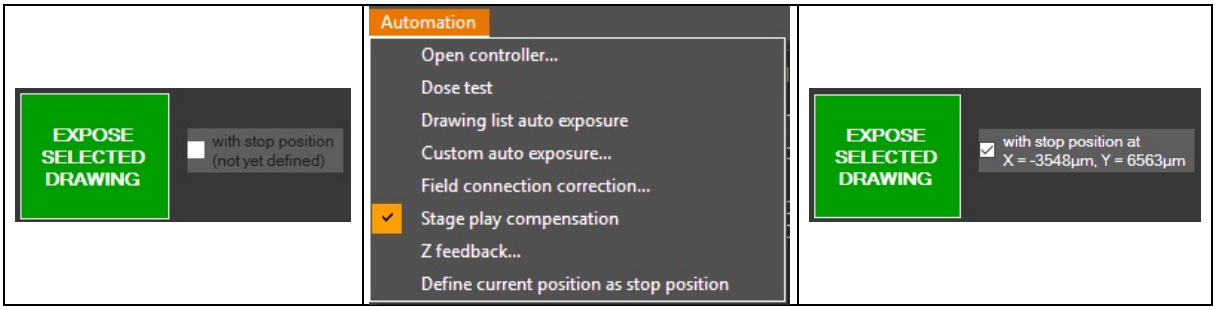


Figure 36 - Left: Stop position disabled, Middle: Automation strip menu, Right: stop position enabled

4.1.5 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 37).

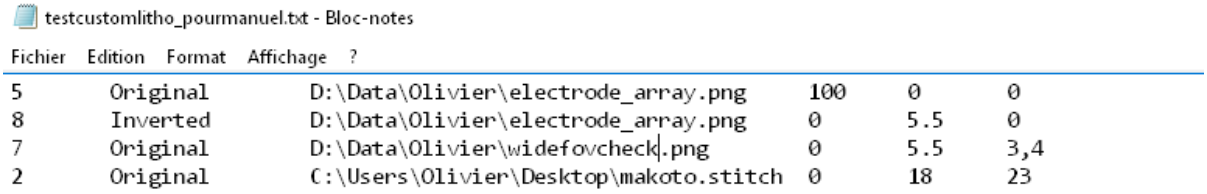


Figure 37 – Typical parameter file for custom automated lithography

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 38)

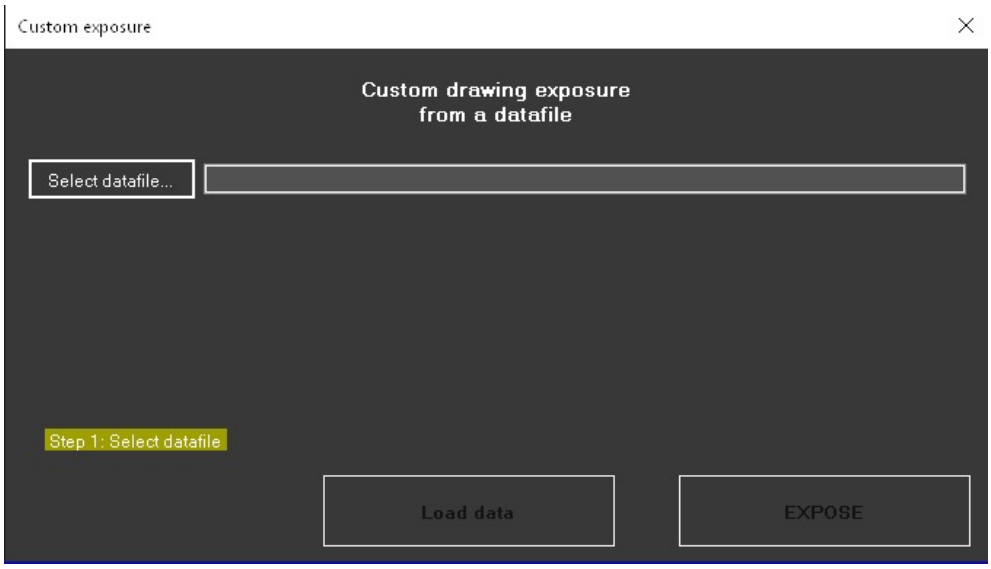


Figure 38 – Custom exposure window at startup

- If the parameter file contains no mistakes (drawing not found, unknown characters, etc.), the file will load on the window (Figure 39)
- 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 40)
- 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 40)

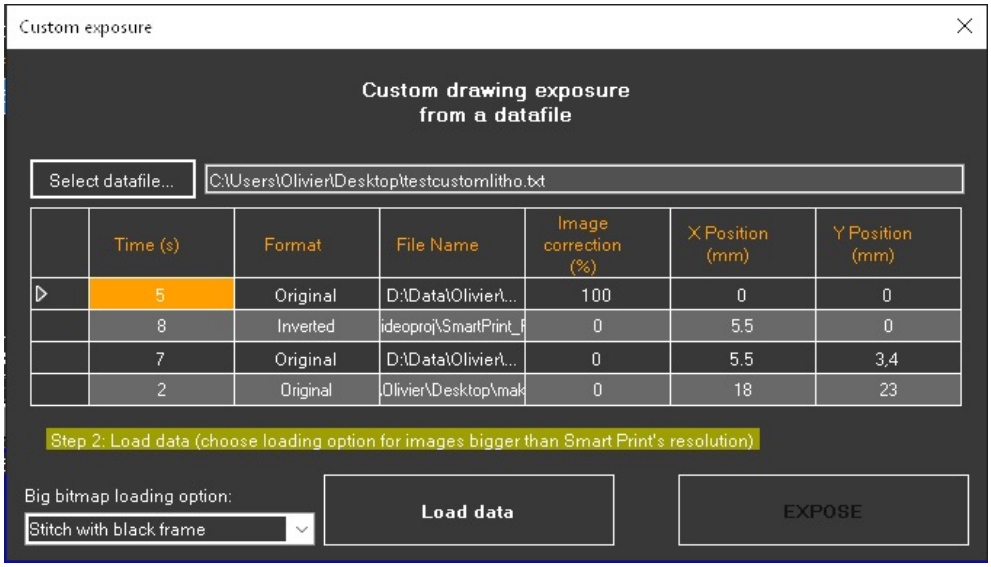


Figure 39 – Custom exposure: parameter file loaded

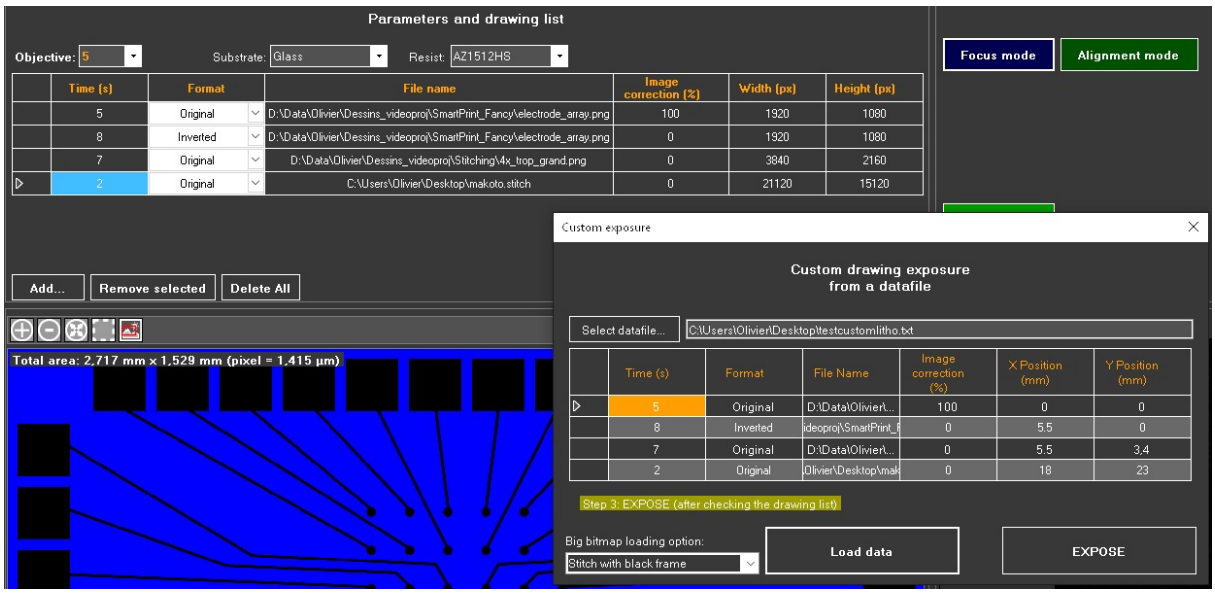


Figure 40 – Custom exposure: data loaded and ready for exposure

Once the automatic exposure is started, **Custom exposure** window close. The lithography progress is displayed in the **Exposure** panel (Figure 41). It can be cancelled at any time by clicking on **STOP**.

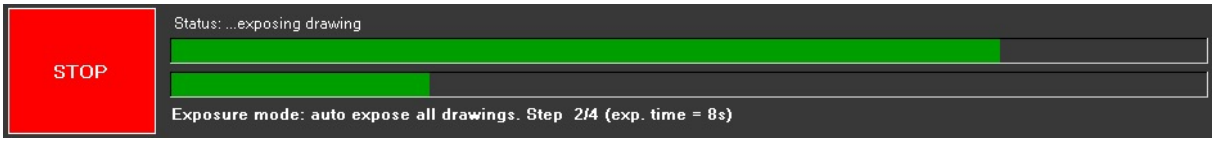


Figure 41 – Progress bar during a custom auto exposure

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 42). 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.

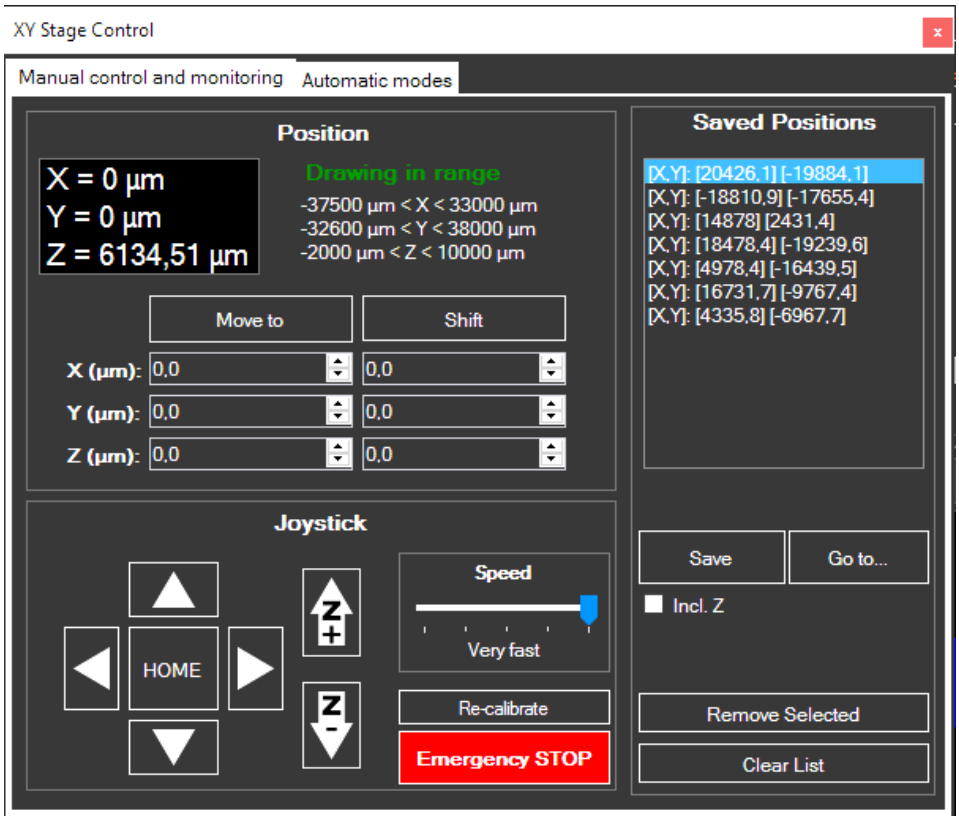


Figure 42 - XYZ stage control and monitoring interface

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 31).
Two alignment modes, described later in the section, are accessible to the user: the Free mode and the Semi-automatic mode.

Figure 43 - 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 θ 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 44 right). For each design, the crosses must be at the same relative position
- Add a unique number to each cross (Figure 44 left) to avoid bad substrate orientation

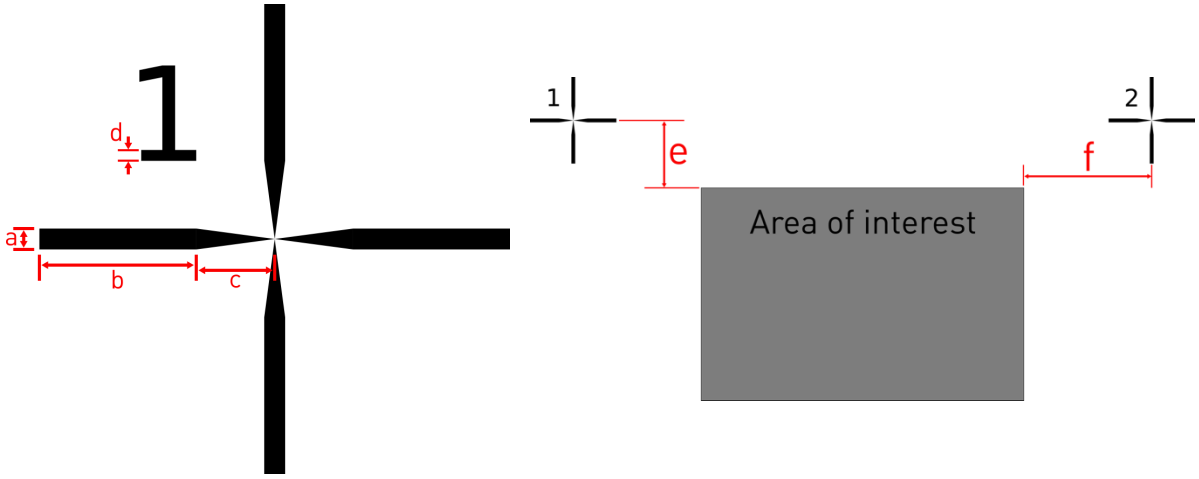


Figure 44 - Design rules. Left: focus on an alignment cross and its key dimensions. Right: cross positionning over the substrate

Tableau 1 - Suggested dimensions for the design in Figure 44

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 perfom 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 45). 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 31) to fit the pattern on the susbtrate to the projected drawing
- Quit the alignment mode by clicking on **Stop Alignment**
- Start exposure by clicking on **Expose selected drawing**

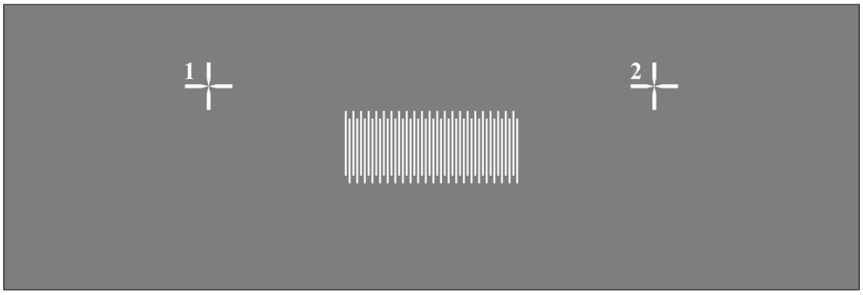
NOTE: The focus setting is different between blue and green light projection. If possible, proceed to the alignment step without changing the focus setting when alignment mode is ON. Else, a focus adjustment under blue light projection will have to be made after the alignment step.

Figure 45 - Free alignment mode

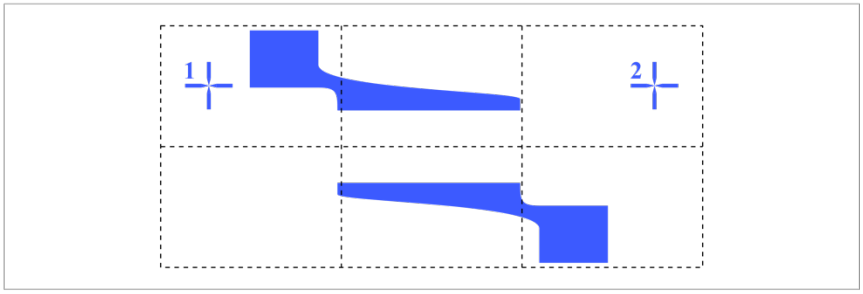
ALIGNMENT: SEMI-AUTOMATIC MODE

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 46a). Contact pads remains to be lithographed. Their drawing (Figure 46b) has been designed to fit with the patterned electrodes. In this example, the dashed rectangles in Figure 46b 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 46c.

a) Substrate with the 1st level of patterns



b) Drawing of the 2nd level to be lithographed



c) Final result on the substrate

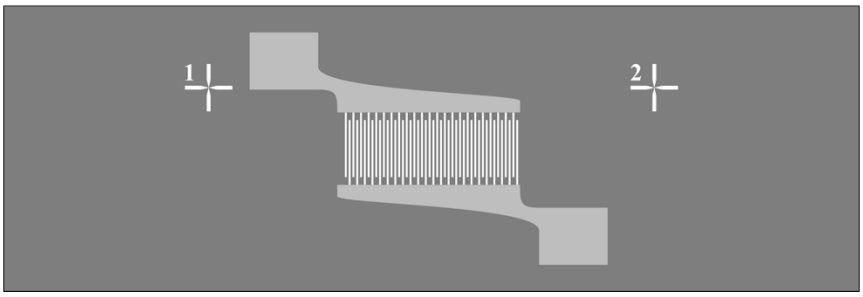


Figure 46 - Example of aligned lithography over already existing patterns

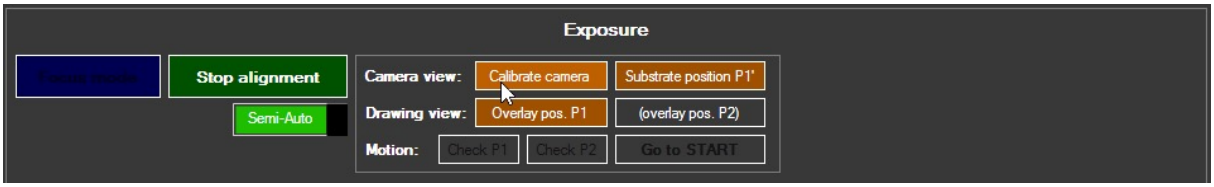


Figure 47 - Semi-automatic alignment mode

To perfom 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 47).
- Camera calibration (Figure 48a): 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 49.

NOTE: 1) If the cross is not visible, adjust the camera settings (see section 3.4.5). 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 48b): 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 50

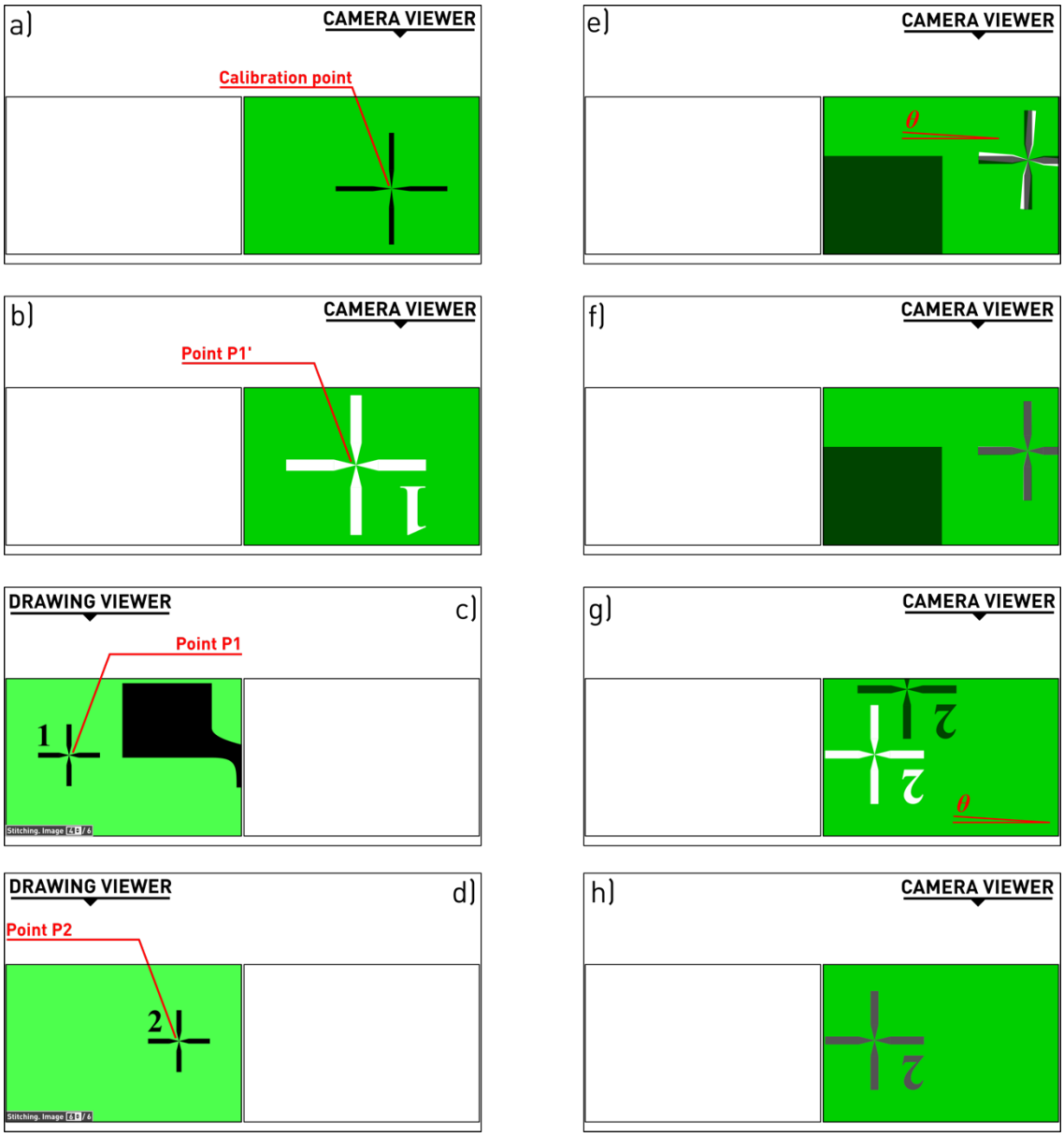


Figure 48 - Semi-automatic alignment main steps

- Selection of point P1 (Figure 48c): 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 51
- [Optional step] Selection of point P2 (Figure 48d): 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 52
- Alignement checking and adjustment of the substrate rotation angle θ : in order to check the validity of the adjustment, click on **Check P1** (Figure 53). The stage will then move to align P1' (on the susbtrate) with P1 (on the drawing) as shown in Figure 48f. 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 48e), move the wheel of the rotation stage (Figure 31) until θ 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 the expected position of P2. If a misalignment is visible as in Figure 48g, the rotation stage must be adjusted, as described in the previous step until a correct alignment is achieved as in Figure 48h.
- Finishing the alignment setting: click on **Go to START** (Figure 53) and quit the alignment mode by clicking on **Stop alignment**
- Start exposure by clicking on **Expose selected drawing**

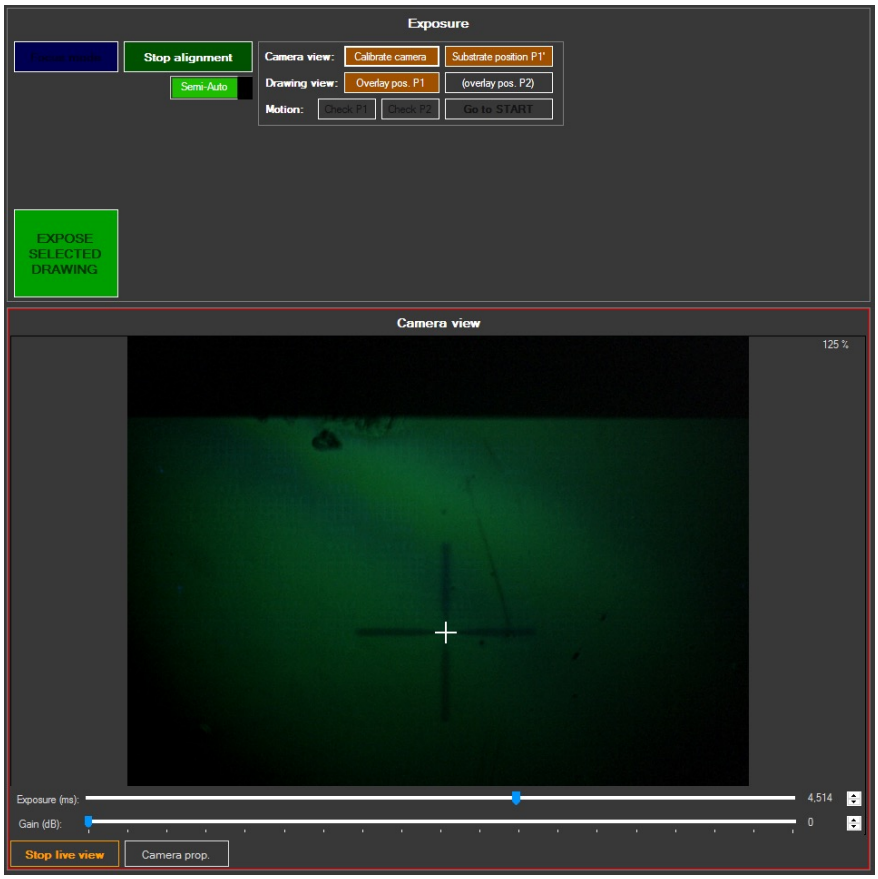


Figure 49 - Semi-auto alignment: camera calibration

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.

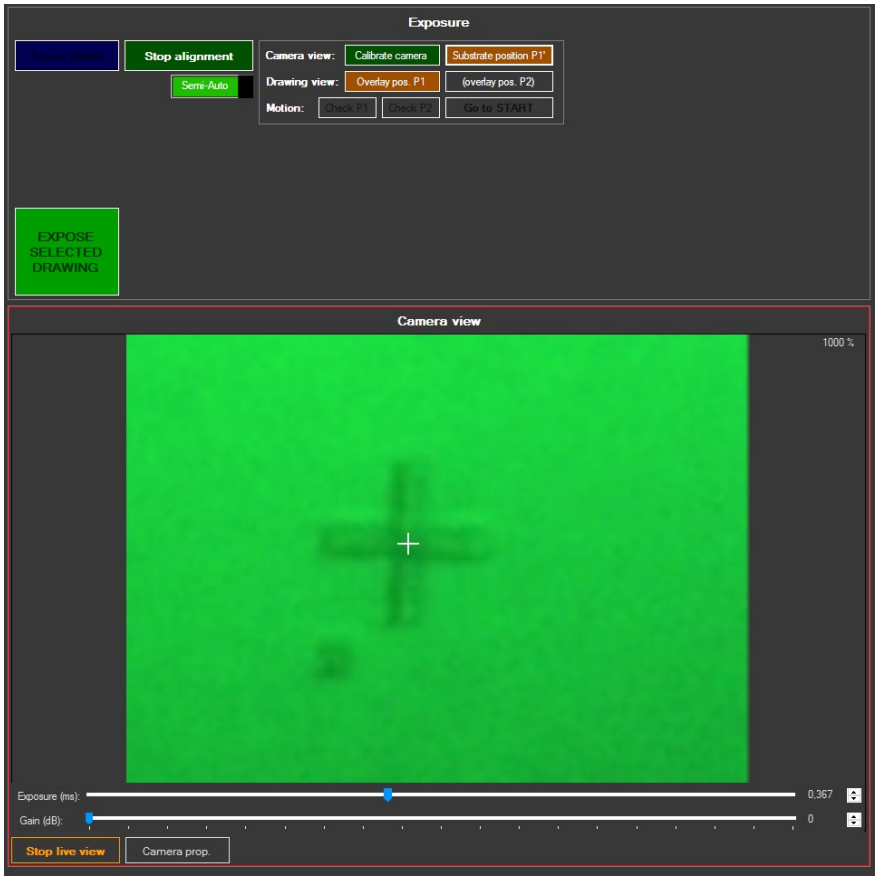


Figure 50 - Semi-auto alignment: defining point P1'

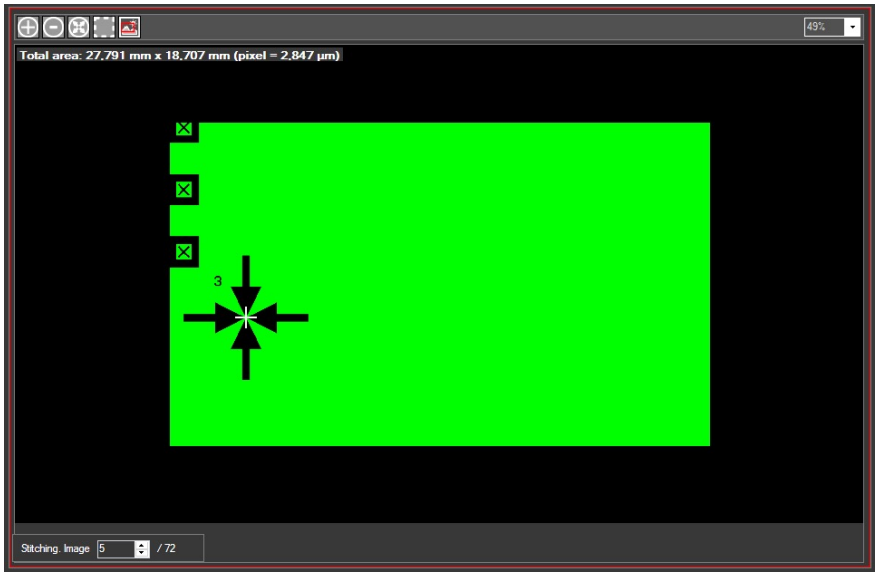


Figure 51 - Semi-auto alignment: defining point P1

Figure 52 - Semi-auto alignment: defining optional point P2

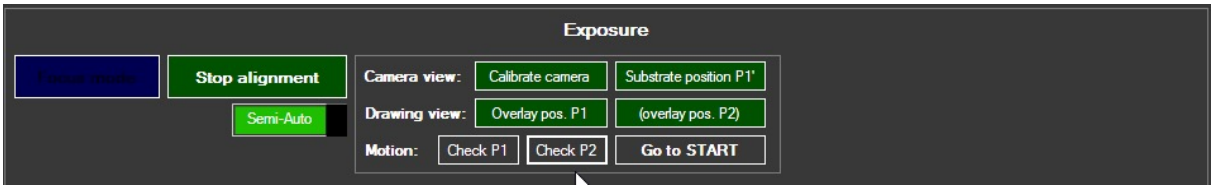


Figure 53 - Semi-auto alignment panel after defining P1', P1 and P2

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 42).
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.

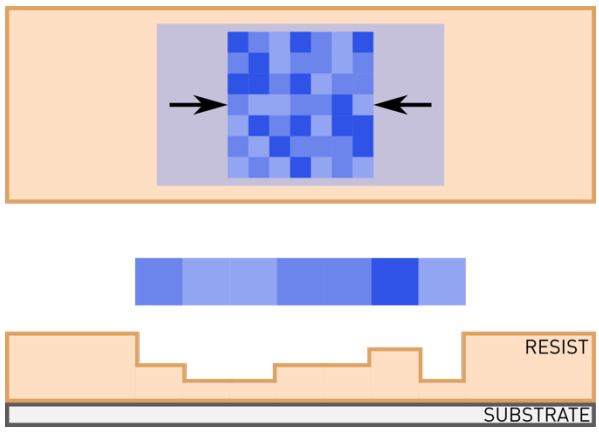


Figure 54 – Principle of grayscale lithography

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...**.

OPTICAL CHARACTERISTICS

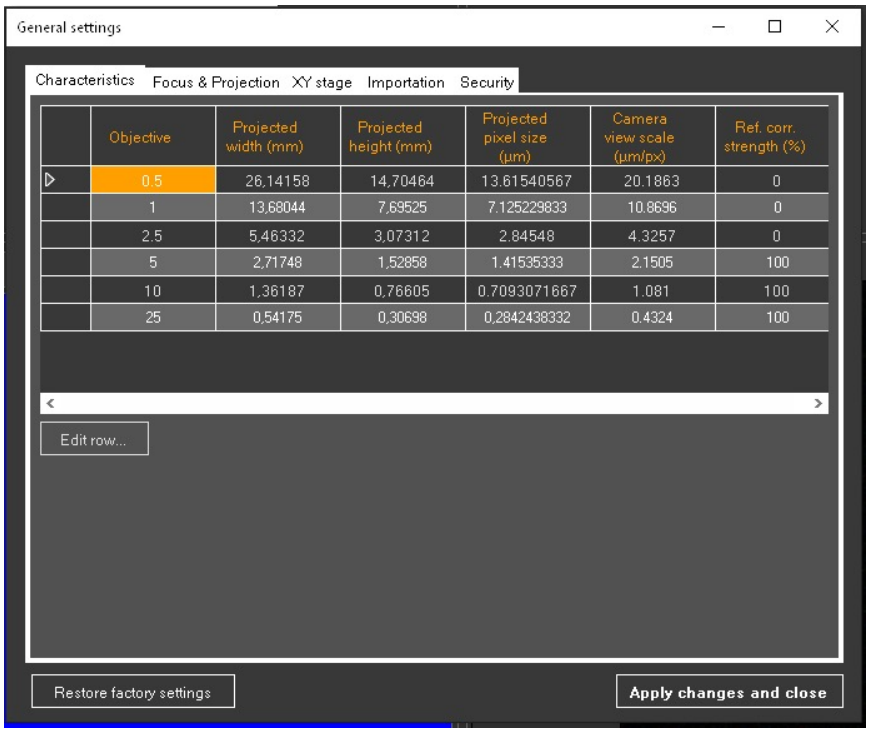


Figure 55 – Settings: optical characteristics

The tab **Characteristics** contains a table with key optical characteristics according to the objective used during lithography (Figure 55):

- *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 (parameter not used yet)
- *Ref. corr strength*: dynamic image correction default value (for more information about image correction, refer to section 3.4.4)

Optical parameters for each objective can be modified by selecting the desired row and clicking on the button **Edit row...** (Figure 56). "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**.

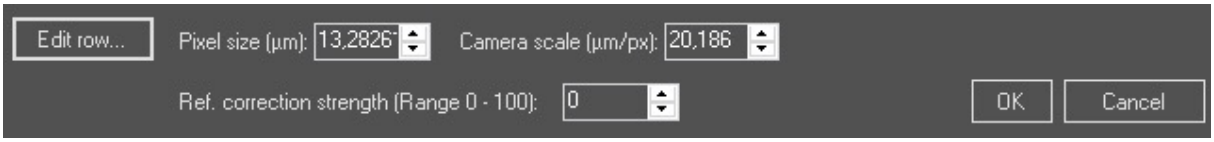


Figure 56 – Settings: optical characteristics edition panel

FOCUS AND PROJECTION OPTIONS

Image projected during focus. In the tab **Focus & Projection**, the drawing used during the focusing step can be set (Figure 57):

- *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

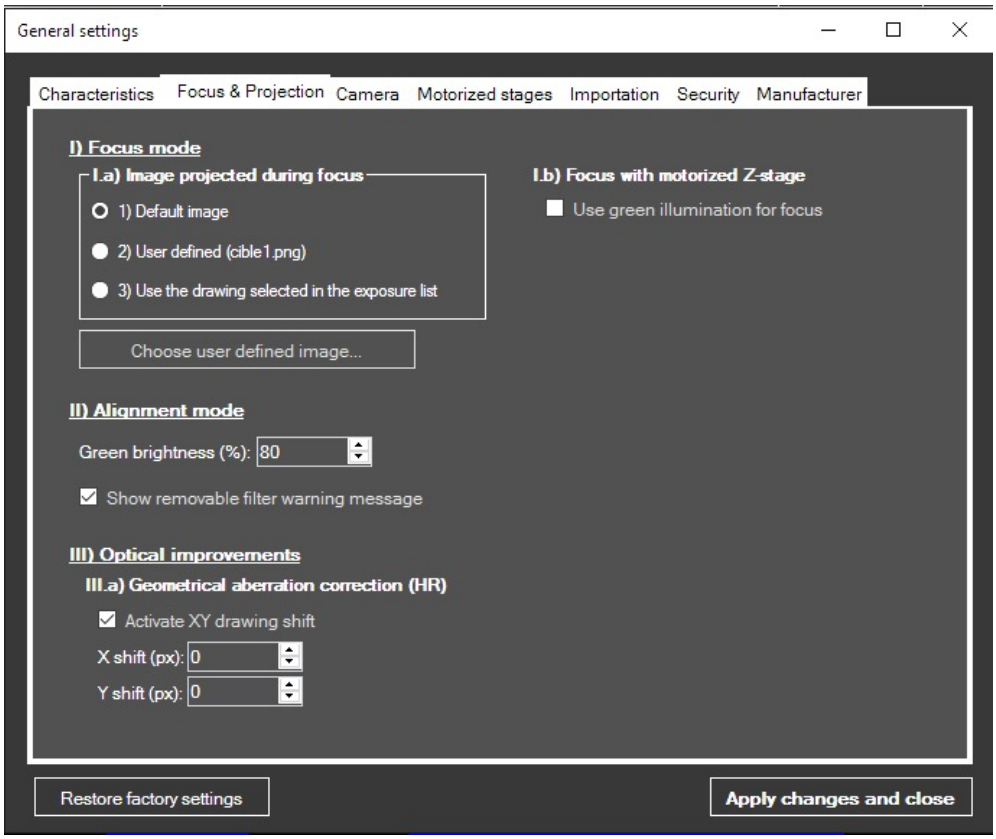


Figure 57 – Settings: focus and projection options

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 3.4.2) 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 brights. Those pixels are defined by an intensity above the **Overlay threshold**.

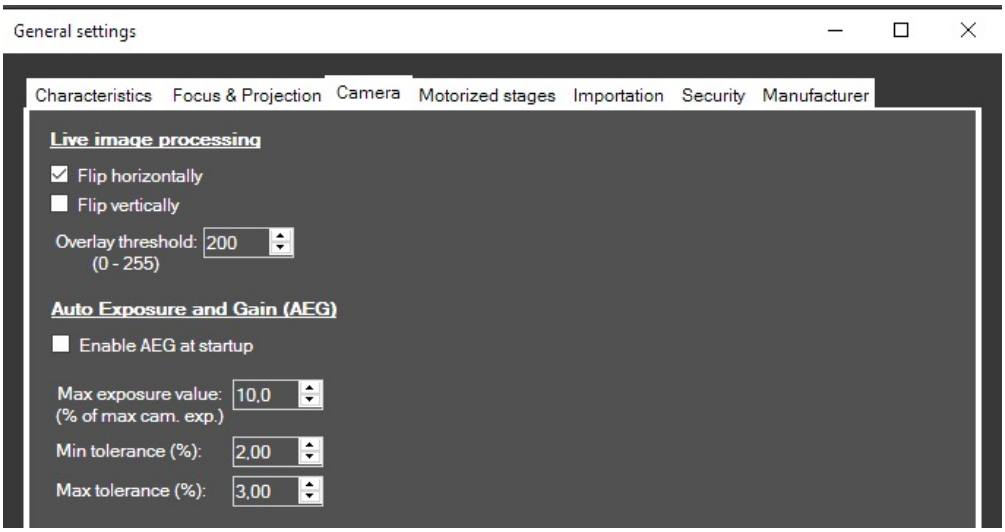


Figure 58 - Settings: camera

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**.

XY STAGE SETTINGS

Communication with the stage. Each axis of the stage, has a distinct communication port with the computer displayed as "xi-com:\\.\COM1" with a unique COM number (Figure 59).
Depending on how the stage has been connected to its controller, the communication ports may be incorrectly assigned. If so, port assignation can be reversed by clicking on the button **Reverse X and Y axis**.
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 26).

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 59):

- *Tilt*: the measured angle between the X-edges of a projected image and the X-axis motion direction, expressed in degree (can be different for the x0.5 objective)
- *X pixel overlap and Y pixel overlap*: default field connection fine tuning values for stitching (section 3.4.3). 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

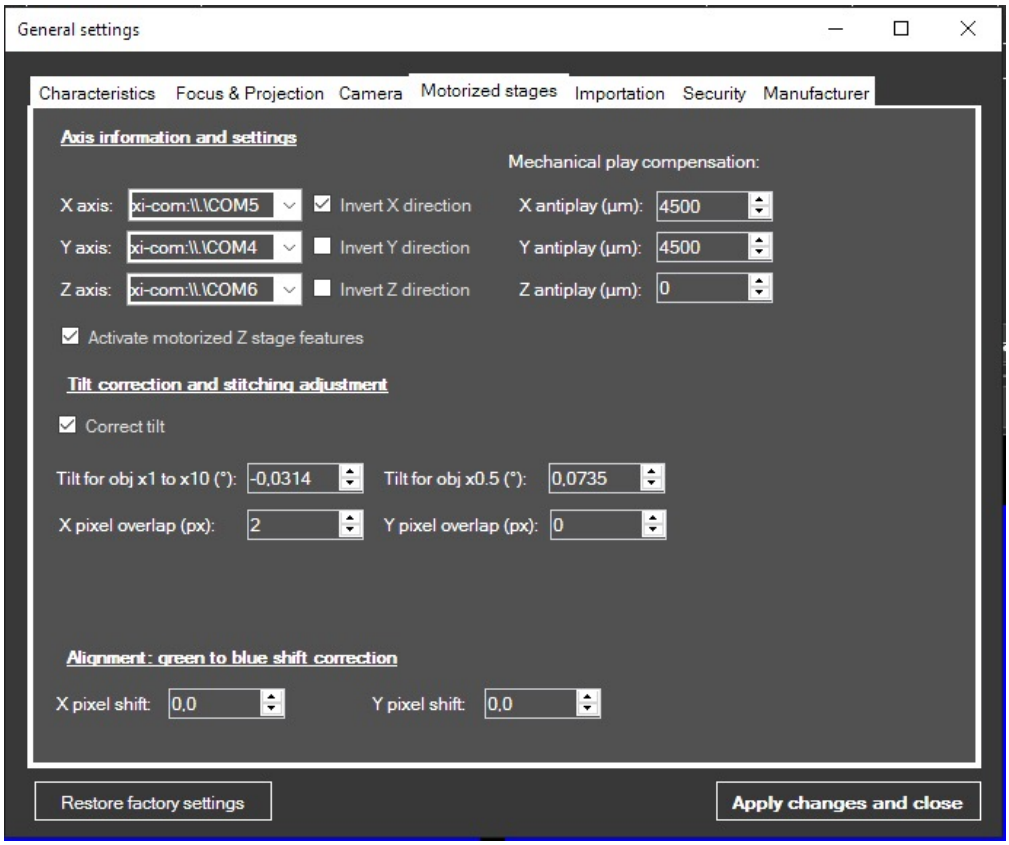


Figure 59 – Settings: motorized XY stage

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.

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

IMPORTATION OPTIONS

The vector drawing importation module use a third-party open source software (KLayout). To link SFTprint and KLayout, click on **Define klayout_app.exe filepath** (Figure 60) and select the file *klayout_app.exe* in the main directory of KLayout. The conversion requires an additional

property file *layerProp.lyp* in the directory of the SFTprint application. It can be defined by clicking on **Define layer properties filepath**.

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 is 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 use 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 to optical geometrical aberration effects. Those parameters allow to adjust the sub-image size reduction

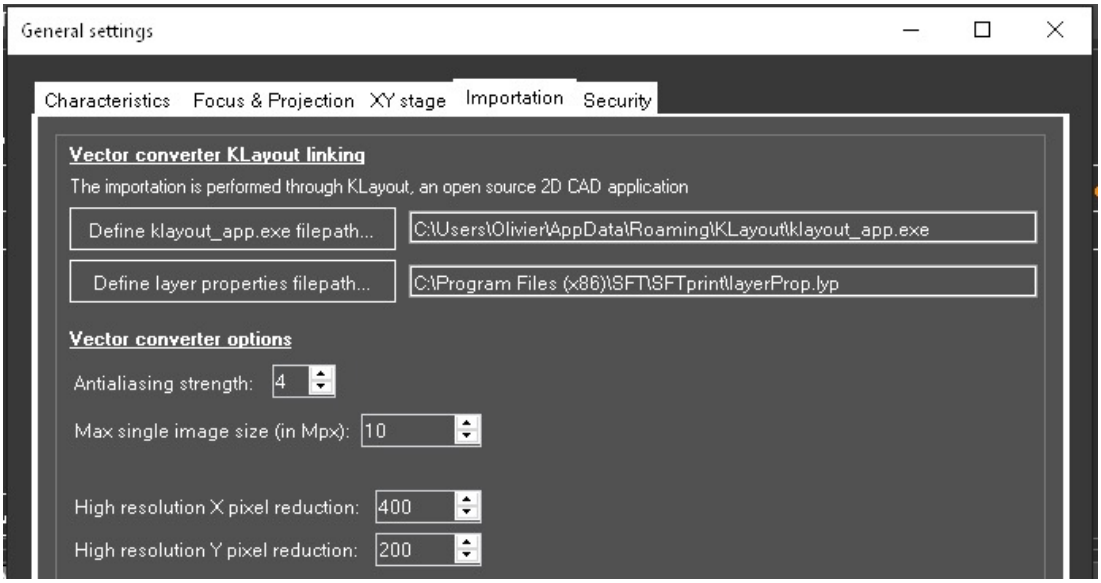


Figure 60 – Settings: vector drawing importation options

SECURITY OPTIONS

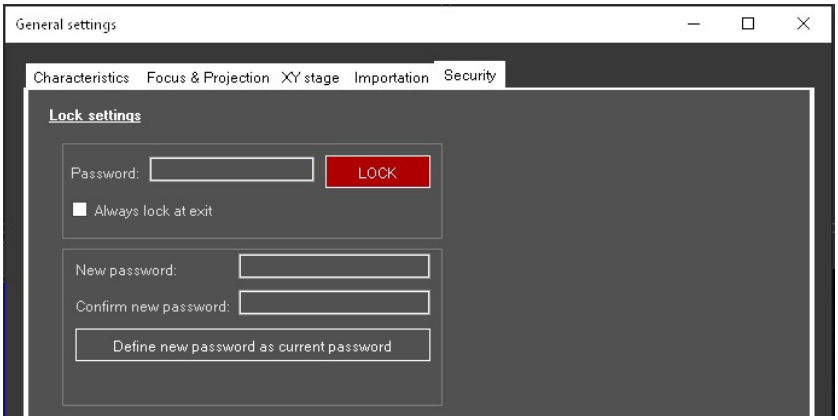


Figure 61 - Settings: security options

All general settings can be locked by a password on the **Security** tab (Figure 61). 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 62 - Settings: unlock

To unlock the settings, enter the password on the field **Password** and click on **UNLOCK** (Figure 62).

ADVANCED MANUFACTURER OPTIONS

The **Manufacturer** tab contains a console-like interface (Figure 63). It is intended for diagnosis and repairing purposes only. DO NOT USE it by yourself.

Figure 63 - Settings: Manufacturer

RESTORE FACTORY SETTINGS

Defaults values can be reinitialized to factory settings by clicking on the button **Restore factory settings**. All general settings from all tabs will be restored to generic factory 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 64 (1) and (2))
b. Unscrew the lamp block (Figure 64 (3) and (4))
c. Pull out the lamp block (Figure 64 (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.

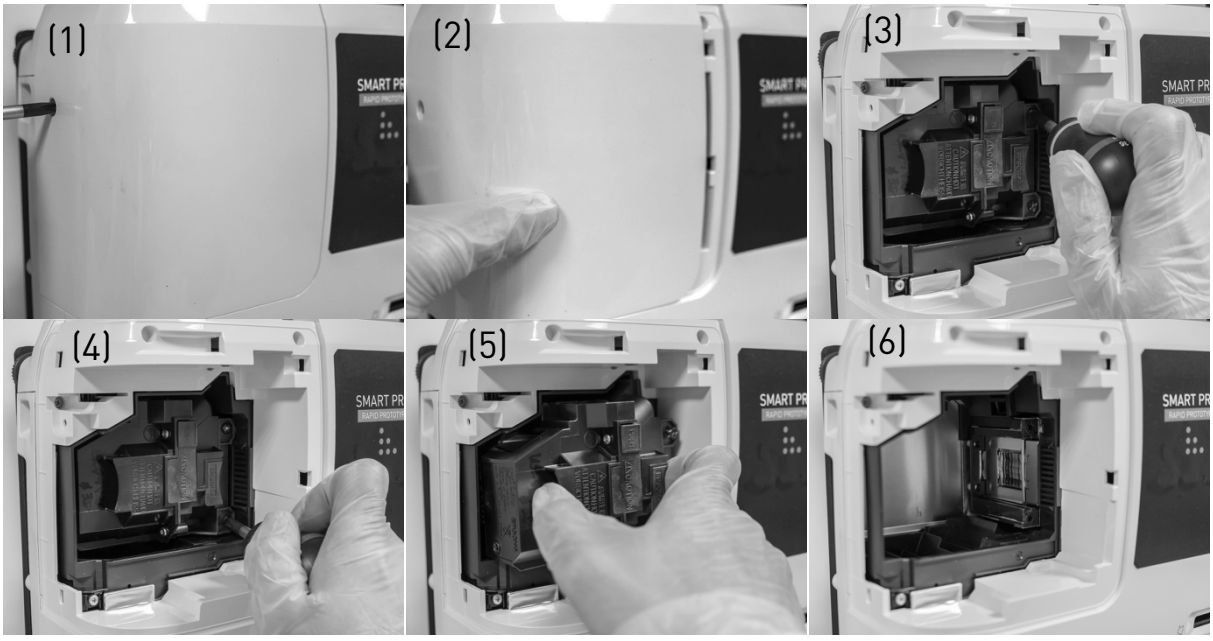


Figure 64 – main steps for lamp replacement

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 65). 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.

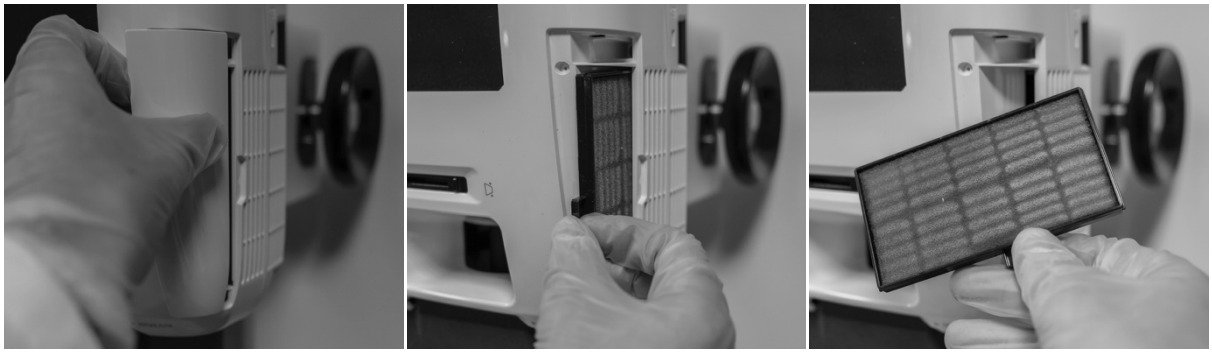


Figure 65 – Air filter cleaning

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 26).

> 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 66)	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 67)	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 3.4.5
In focus or alignment mode, Pink spots appear on the image	Camera over-exposed	Adjust the camera exposure time as described in section 3.4.5

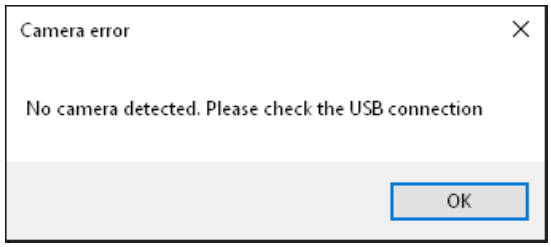


Figure 66 – Camera connection error 1

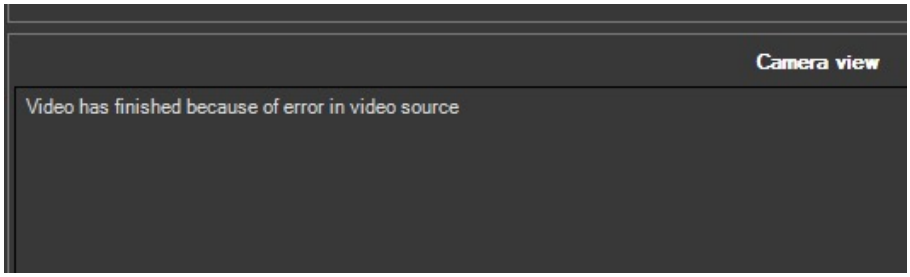


Figure 67 – Camera connection error 2

5.3.2 XY STAGE ISSUES

Issue	Possible cause	Fixes
No stage detected error message (Figure 68)	• 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 (Figure 10 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 26)	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.

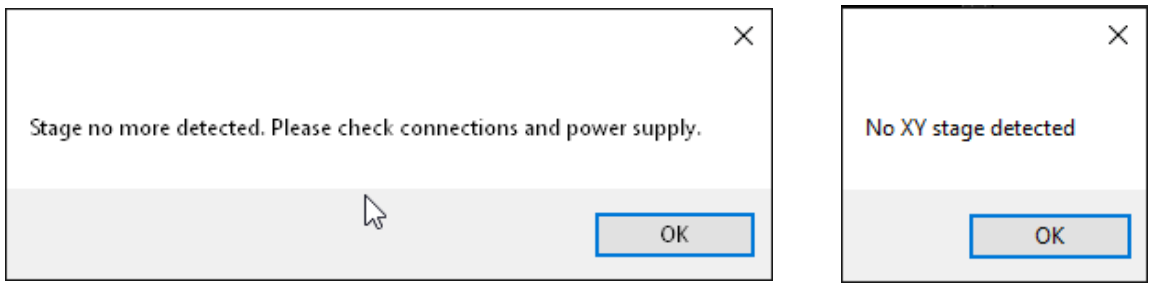


Figure 68 – XY stage connection errors

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)	Open the vector file in KLayout and check the drawing then save it in .gds from KLayout. If

	• The vector file is corrupted or contains unknown elements to KLayout	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. When the installation window is opened click on **Install** (Figure 69). Klayout shortcut is installed in the Window menu or can be found by typing "KLayout" in the Windows search field.

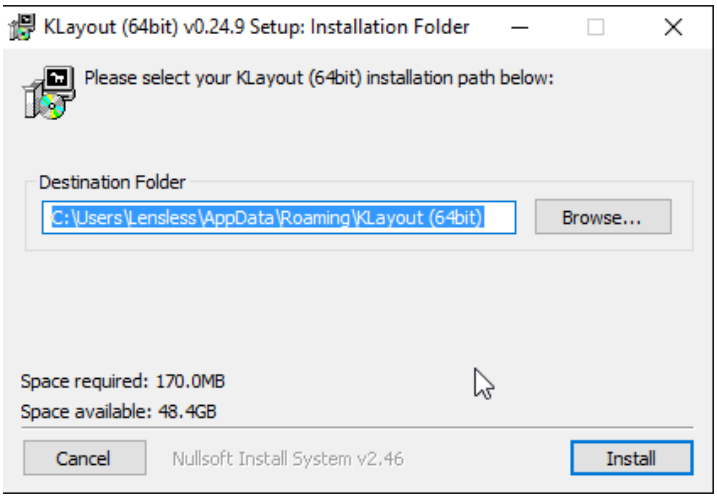


Figure 69 – KLayout installation window

Step 2: Configuration of KLayout

Run KLayout (first start may be longer because of the initialization index). Go to menu **File → Setup** (Figure 70, left). On the **Settings window**, go to **Display → Background** and uncheck **Show background decoration** (Figure 70, right). Click on **Apply** and then **OK**. Close KLayout.

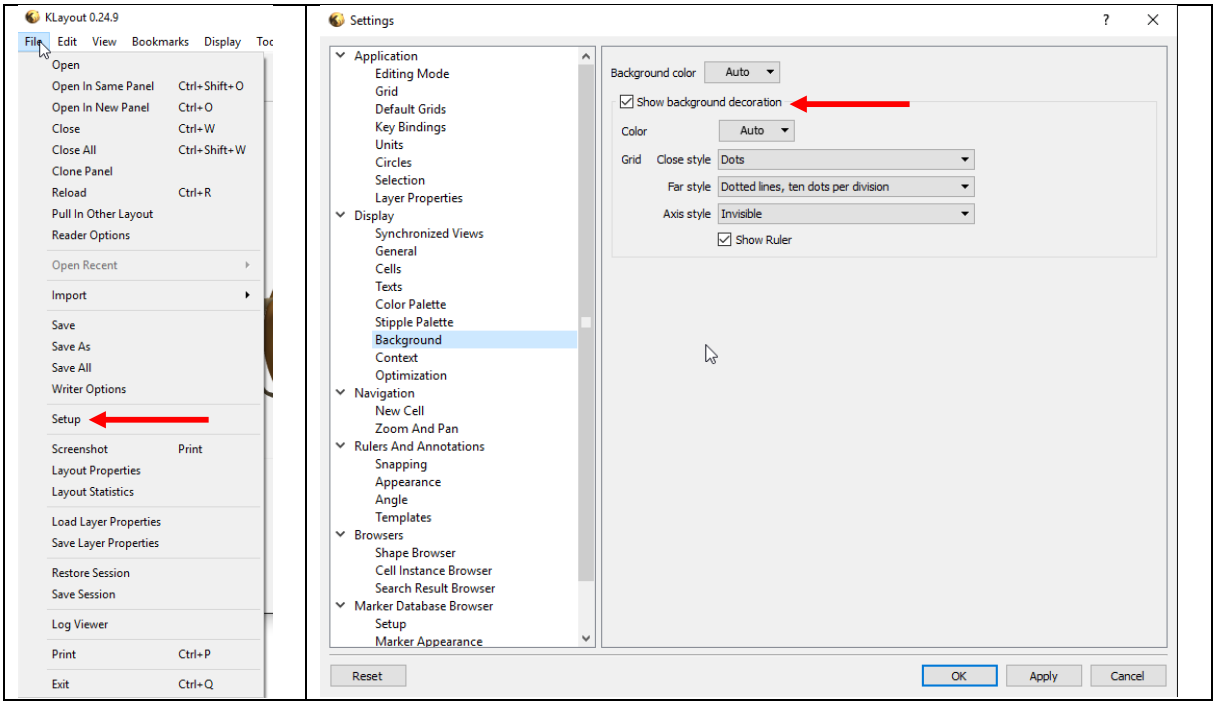


Figure 70 - Configuration of KLayout

Step 3: Configuration of SFTprint

Run SFTprint. Go to the menu **SFTprint → Settings**. In the **Importation** tab, click on **Define klayout_app.exe filepath...** (Figure 60). In the **Open** window, find and select the executable file *klayout_app.exe* (Figure 71). In similar way, Define the **layer properties filepath** by clicking on the corresponding button and then selecting the file **layerProp.lyp** (usually located in *Program Files (x86)\SFT\SFTprint* directory) in the **Open** window.

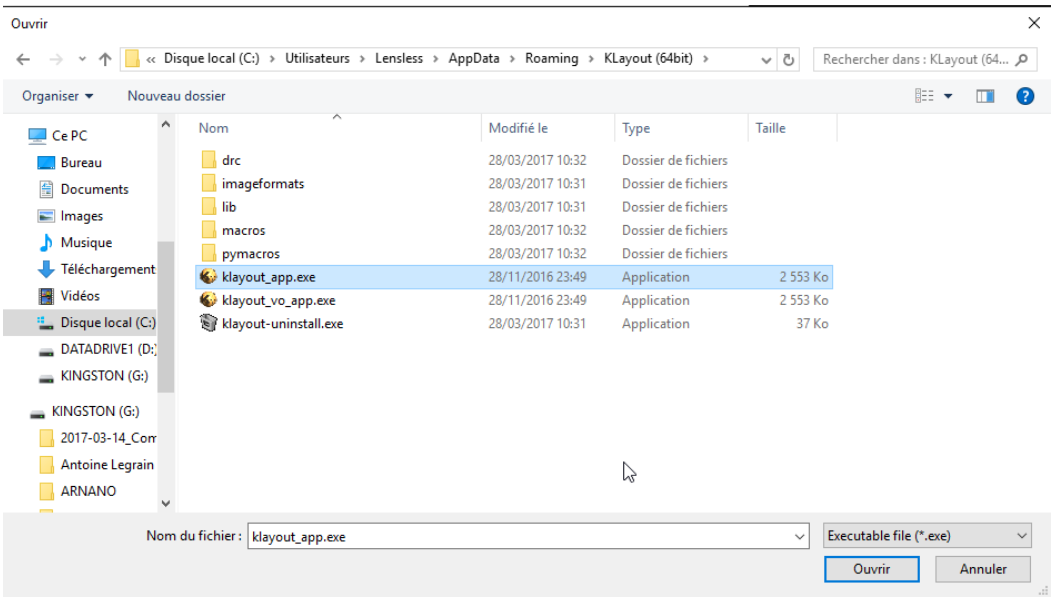


Figure 71 – Folder containing the KLayout executable

Method to find KLayout executable file on Windows 10:

- In the Windows menu or search window, right-click on the icon of **KLayout (default)** and select **Open the file's location** (Figure 72(1)). It will open a window containing all KLayout shortcut
- Right-click on the **Klayout (Default) shortcut → Open the file's location** (Figure 72(2))**.** The window containing the executable will open
- Copy the file path located in the address bar (Ctrl-C) (Figure 73(3))
- Paste (Ctrl-V) the file path into the address bar of the window opened by clicking on **SFTprint → Settings → Importation → Define klayout_app.exe filepath…** (Figure 74(4)) and press enter. Finally select klayout_app.exe and click on **Open**

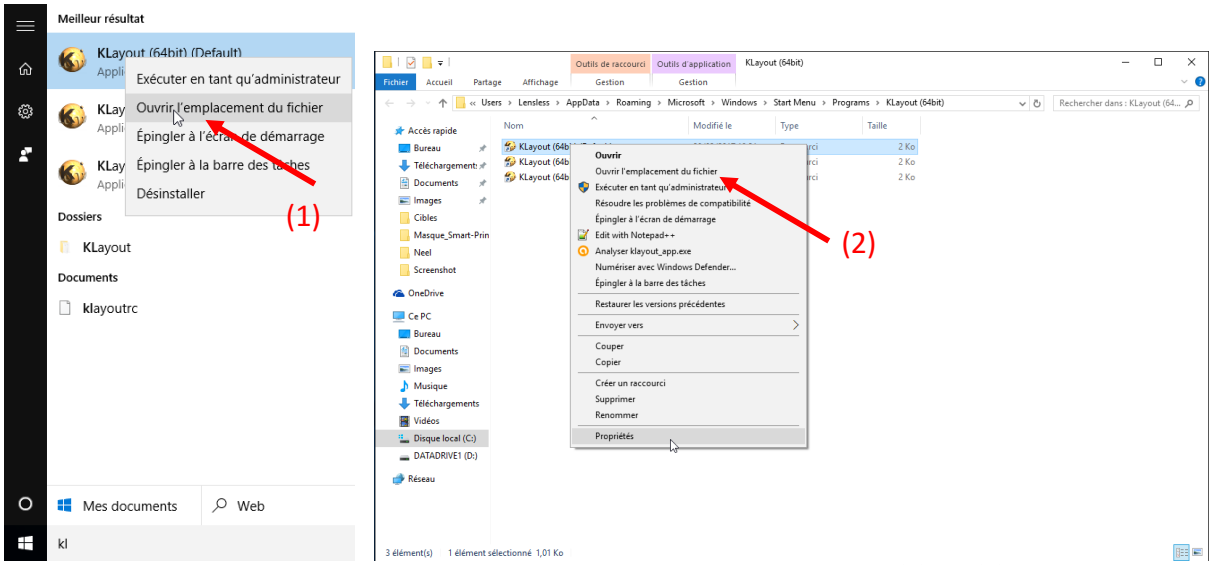


Figure 72 – Finding the file path of KLayout executable file, step (1) and (2)

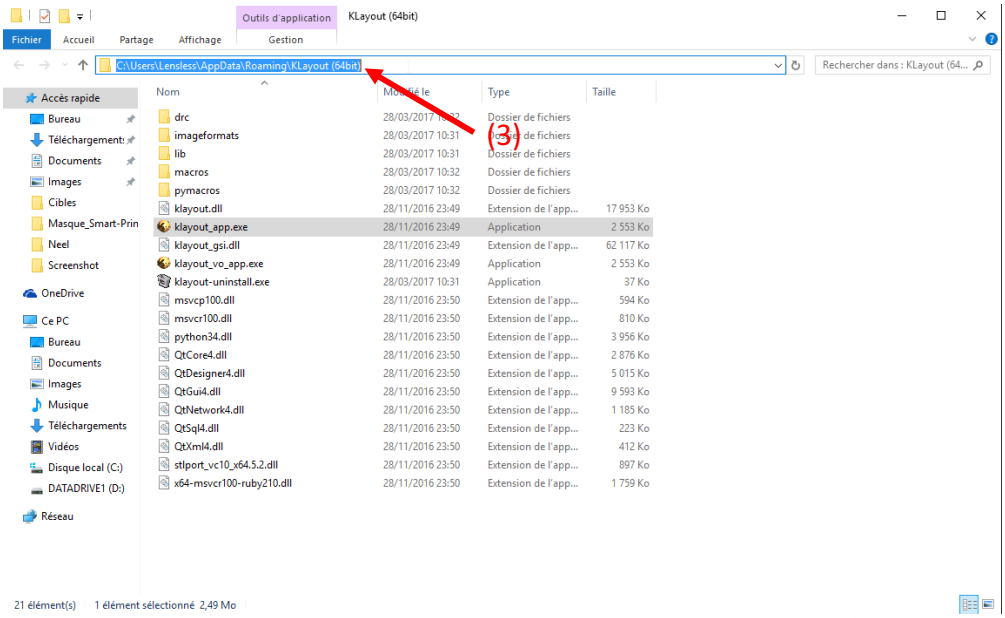


Figure 73 - Finding the file path of KLayout executable file, step (3)

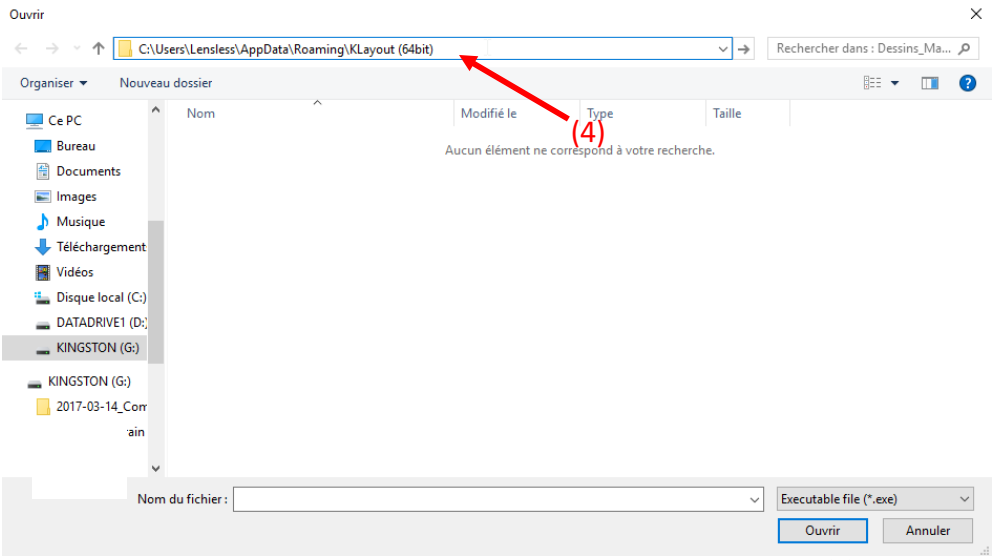


Figure 74 - Finding the file path of KLayout executable file, step (4)

6 APPENDIX

6.1 SPECIFICATIONS

LITHOGRAPHY		
	Light illumination	Filtered blue light between 430 and 470 nm (Power = 11 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	2080 ± 220
x 1	13.6 x 7.7	7.12	< 23	10.2	1850 ± 50
x 2.5	5.4 x 3	2.82	< 8	63.7	155 ± 5
x 5	2.7 x 1.5	1.41	< 4	254.8	51 ± 7
x 10	1.35 x 0.75	0.705	< 2	1019	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	60 cm H x 36 cm W x 36 cm D
	Weight	20 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
	Input power	307 – 291 W

ENVIRONMENTAL		
	Operating temperature	+5 to +35°C

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