HEIDELBERG
INSTRUMENTS

User Guide

µPG 101

Micro Pattern Generator

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Wizard version: 4.1.6

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Safety

This chapter gives information on the conventions used to signalize hazard potential.

Conventions

Throughout this user guide there are safety warnings. To classify the degree of danger, the following notation is used:

WARNING!	**Indicates a hazardous situation which, if not avoided, could result in death or serious injury.**
NOTICE	**Indicates a property damage risk.**
Note:	**Gives additional information or advice to get best results.**

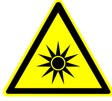
General safety warnings

WARNING!

Injury by electrical shock!
Electrical voltages of up to 230VAC and 120V DC are present within the system when it is connected and turned on. The μPG 101 is fused for 10A.

- Never use the equipment if cables or plugs have been damaged.
- Do not remove any cover of the μPG 101 apart from those explicitly stated in this manual. Open covers can make lethal voltages accessible.
- Only Heidelberg Instruments service engineers should perform any tasks that include the removal of such a cover while the system is energized.
- Only plug the μPG 101 and its components into approved outlets with correct ground. Power requirements are described in the ***Pre-Installation Guide***.

WARNING!



Eye injuries and/or skin burns by laser light!

Opening of the optics covers turns the µPG 101, as a **class 1** laser product, **into a class 3B** laser product. Severe damage to the eye and possibly to the skin can be caused by laser radiation of class 3B.

- Avoid possible direct or indirect exposure of eyes or skin to laser radiation at all times.
- Never operate the system with open optics cover, if not acting under explicit instruction of an HIMT service engineer.
- Never enter any area cordoned off by HIMT service engineers during adjustment work.
- Never put anything reflective or flammable into the beam path.

If the system has to be operated with open optics cover e.g., for trouble shooting:

- Cordon off the area and place warning signs.
- Wear appropriate safety goggles. Note that these cannot protect long against a direct beam, but are only meant as protection against stray light! Also keep in mind that you cannot see the laser beam with goggles on, so the risk of skin burns increases.
- Use the lowest possible laser power or reduce the power as far as possible with filters.
- Never leave the laser on when unattended. Make sure only qualified personnel may switch on the laser in such a machine state.
- Do not place reflective objects in, or near the laser beam path. Laser light scattered by reflective objects can be as damaging as the original beam. **Objects such as rings, watchbands, and metal pens or pencils can be hazardous.**

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Preface

Dear customer,

With this table top micro pattern generator for direct writing applications and low volume mask making you are equipped with a top-quality product that has given reliable service in many areas of professional use.

The µPG 101 system offers a small footprint of only 63 x 70 cm² and a compact design with all electronic components integrated into the system. A personal computer is used as system control. The GUI based control software makes it easy for you to convert the designs, to perform a manual or automatic alignment and to start the exposure.

With the **exchangeable write modes** you meet the resolution and write speed requirements of your specific application. The small address grid makes it easy to place structures with very high accuracy. During exposure, the **autofocus system** monitors and corrects focus position to guarantee high resolution and repeatability over the entire exposure area.

Depending on the type of diode laser you have chosen, the system is equipped with a diode laser at **405 nm or at 375 nm**. The 405 nm diode laser allows the exposure of standard photoresists. With a diode laser at 375 nm, your system is capable of exposing standard resists and UV resists such as SU-8. It also offers a r**aster-scan mode** and a **vector exposure mode** for high resolution 2D patterns. In addition, it is possible to create **complex 3D structures** in thick photoresists in a single pass.

The **camera** of the µPG 101 enables you to perform position measurements on the substrate as well as manual alignment. The **alignment system** provides tools for an advanced alignment to already existing structures on the substrate, making it possible to perform multi-layer overlay exposures with high accuracy.

In this preface you find a list of documents related to this user guide as well as a list of our offices and their contact data. Do not hesitate to contact us if any problems occur or if you should have any questions e.g., concerning the system itself or spare part orders.

Related Documentation

Heidelberg Instruments offers further manuals related to the machine and its operation. If you did not get one of these or need an update, please contact Heidelberg Instruments Mikrotechnik GmbH, Germany.

- ***Pre-Installation Guide*** — Environmental and electrical requirements, sizes and weights of components etc.
- ***Design Guide*** — Instructions on how to build up a design for the exposure

Contact

Should you need assistance, please contact your local service office:

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1 System Description

In this chapter you find illustrations of the main system (front side and backside) as well as of the supply unit. The operating elements of the system are marked with a number which leads you to the element's name in a list located below the illustration.

You also find a section about proper positioning of the system. The µPG 101 provides a wizard that guides the operator through the steps of an exposure. Information on the ***Exposure Wizard*** is given at the end of this chapter.

The µPG 101 lithography system consists of two units:

- Lithography unit
- Supply unit

The supply unit receives its power from the grid and provides the lithography unit with AC/DC power.

The lithography unit comprises the following elements (Figure 1):

- Optics
- Electronics
- Write head with write lens
- Stage

The system is controlled via wizard software installed on a standard PC, in this manual called User PC, which is part of the system package.

The optics consists of the exposure optics and the camera and illumination optics. The exposure optics is built together from a diode laser, mirrors, an acousto optics modulator (AOM) and telescope lenses. Its purpose is to deliver light into the write lens with intensity required at the position that is exposed.

The lithography unit is connected to a compressor (not part of system package) which provides compressed dry air (CDA) for the write head and for the air-bearing axis of the stage. The air bearing has the advantage that the air acts as vibration dampener and fast left-right movement is given without any interference. It is perfect for highest precision and highest smoothness of motion. The x-axis (forward-backward movement) of the stage travels on roller bearing.

The vacuum suction holes of the stage, which are used for fixation of the substrate, are supplied with a vacuum, which is produced from CDA by the ejector. The pneumatic autofocus of the write head is also supplied with CDA to measure the distance between the substrate and the write lens.

The electronics controls the optics, the write head and the stage (Figure 2). It contains a mainboard acting as a processor that provides embedded Linux as operating system. The data conversion software and all system control programs run here. Design data and other parameters are provided by the User PC and transferred to the electronics unit. The mainboard controls the electronic boards rack and the stage controller independently from each other. In the electronics boards rack the light modulation in the optics and the autofocus in the write head are regulated. The stage controller controls the movement of the stage and monitors its position.

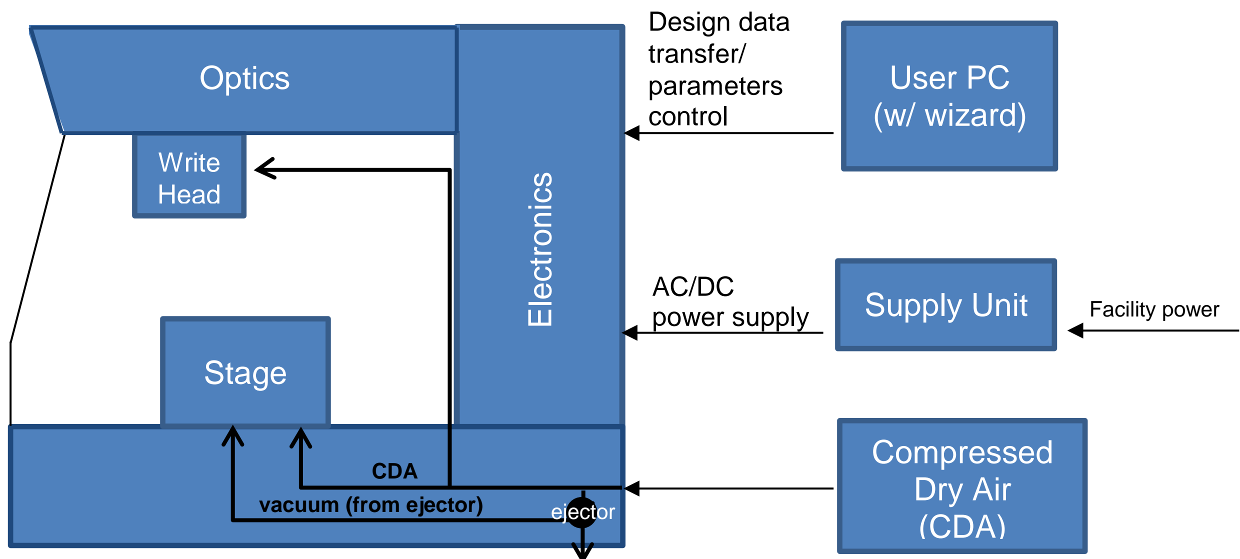


Figure 1: Lithography system setup (schematic illustration)

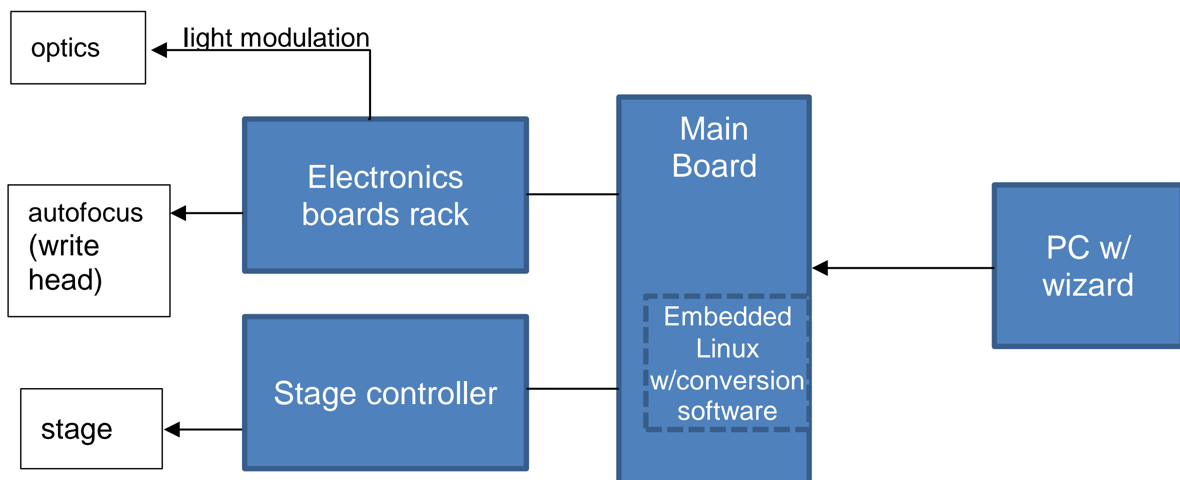


Figure 2: Description of the electronics components

1.1 Lithography Unit

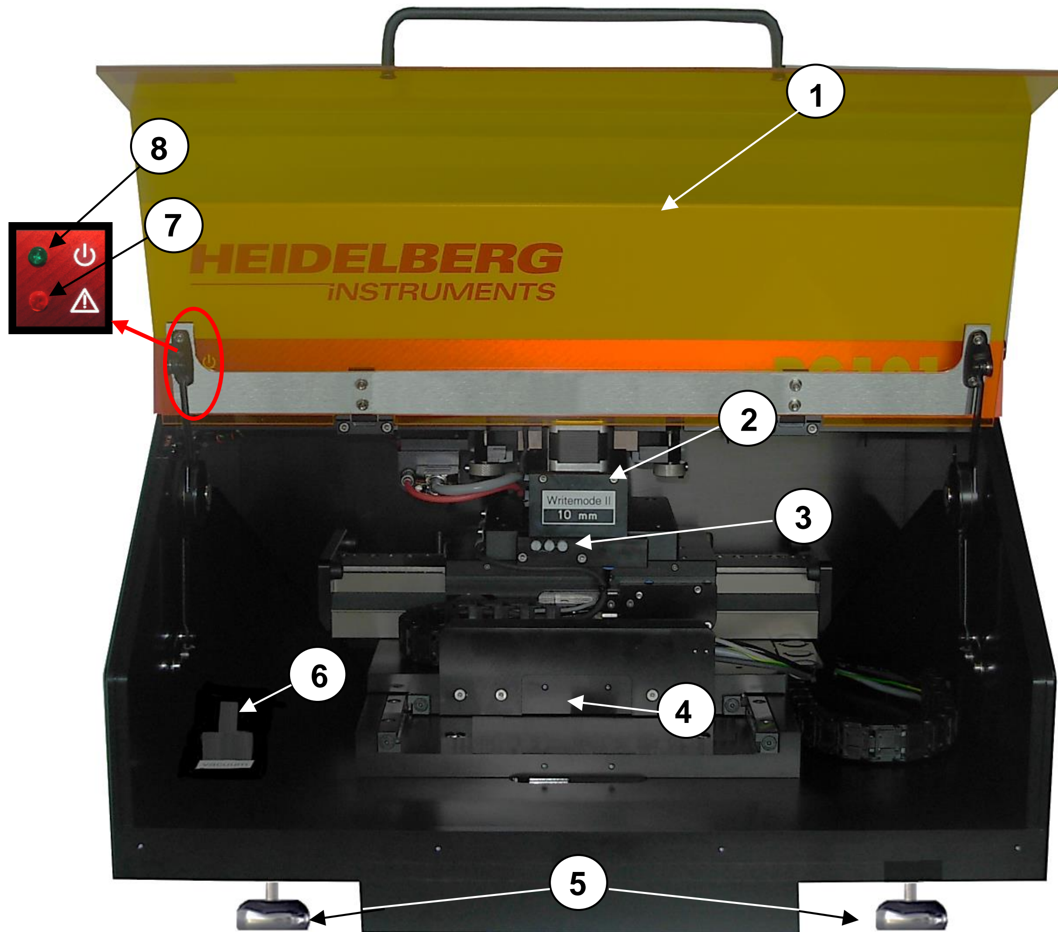


Figure 3: Lithography Unit front side

1	Cover lid with interlock circuit
2	Write head
3	Vacuum field adjustment screws
4	Stage
5	System base with four height-adjustable feet
6	Vacuum switch
7	Safety interlock lamp
8	Power On/Off indicator lamp

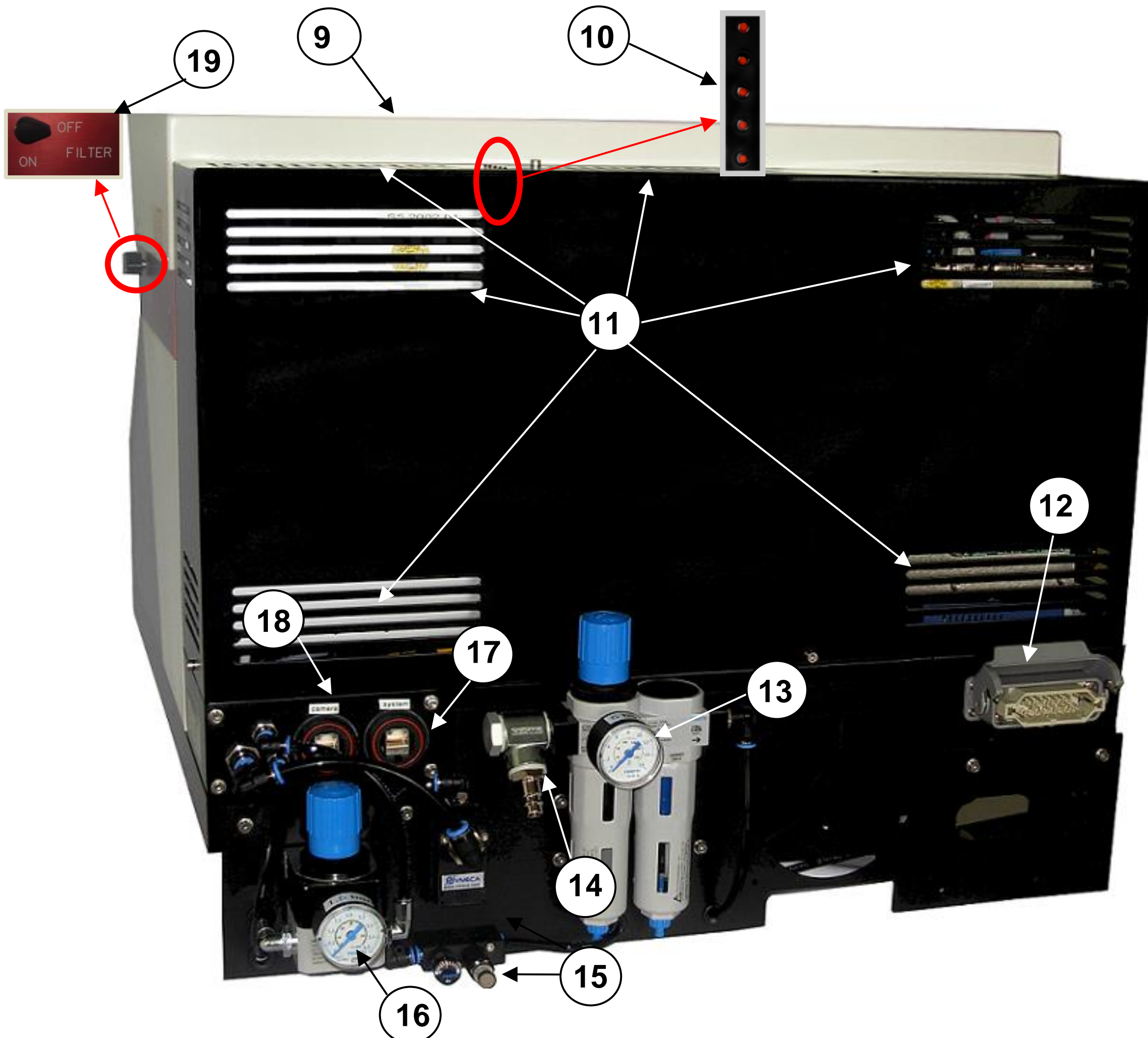


Figure 4: Lithography System back side

9	Optics cover
10	Backplane power LEDs
11	Ventilation slits (back, sides, top)
12	System power connector (from supply unit)
13	Main compressed air valve with particle filter and manometer
14	Compressed air inlet
15	Ejector pressure regulator for stage vacuum (vacuum strength adjustment)
16	Manometer for autofocus compressed air circuit
17	Network connector for LAN
18	Network connector for camera
19	Filter knob for energy adjustment

1.2 Supply Unit

Figure 5: Supply Unit

20	Power On/Off indicator lamp
21	Ventilation
22	Power connector to lithography system
23	Main power connector with main power switch and fuse

1.3 Positioning of the System

There has to be a clearance of at least 20 cm (~ 8 inches) for air ventilation between the sides and backside of the system and the wall. Never cover the ventilation slits (11, 21).

In order to provide coarse vibration isolation, the four height-adjustable feet of the µPG 101 system are coated with a rubber layer at their bottom acting as vibration dampener. For proper function of the system and for best exposure results it is very important to keep vibrations caused by environmental conditions as low as possible. We recommend you to install the system on a stable substructure. If you are not equipped with such a stable base plate e.g., a table with a heavy granite plate, you can order it from our company (see *Contact*). When implementing further damping measures, rigidness against additional forces caused by the stage movement of the system (up to 20N) is required (for further information see *Appendix, Environmental Requirements* .

As mentioned above, the four feet of the lithography unit are adjustable in height. We recommend you to check if the lithography unit stands firmly on all four feet. With a spirit level check if the unit is leveled. If the check reveals an inaccurate leveling of the unit, then follow the instructions given in 10.7 *Leveling*.

NOTICE

Never store the system in toxic, damp, humid or uncontrolled environment.

- Follow the information given on environmental requirements in the ***Pre-Installation Guide***.

1.4 Exposure Wizard

For easy use, the µPG 101 provides an ***Exposure Wizard*** that guides the operator through the steps of an exposure.

Note: At least **5 minutes** must have passed since power-up or reset of the main system **before starting the Exposure Wizard**. Otherwise, communication errors occur, that make a reboot of the User PC necessary.

To start the µPG 101 ***Exposure Wizard***, click on the link icon on the desktop:

The ***Exposure Wizard*** offers a window that stays open throughout the whole time that you work with the system (Figure 6). It contains a menu bar that offers various functions. Below the menu bar you find task panels containing frames and buttons. At the bottom below the task panel a navigation and status panel is located.

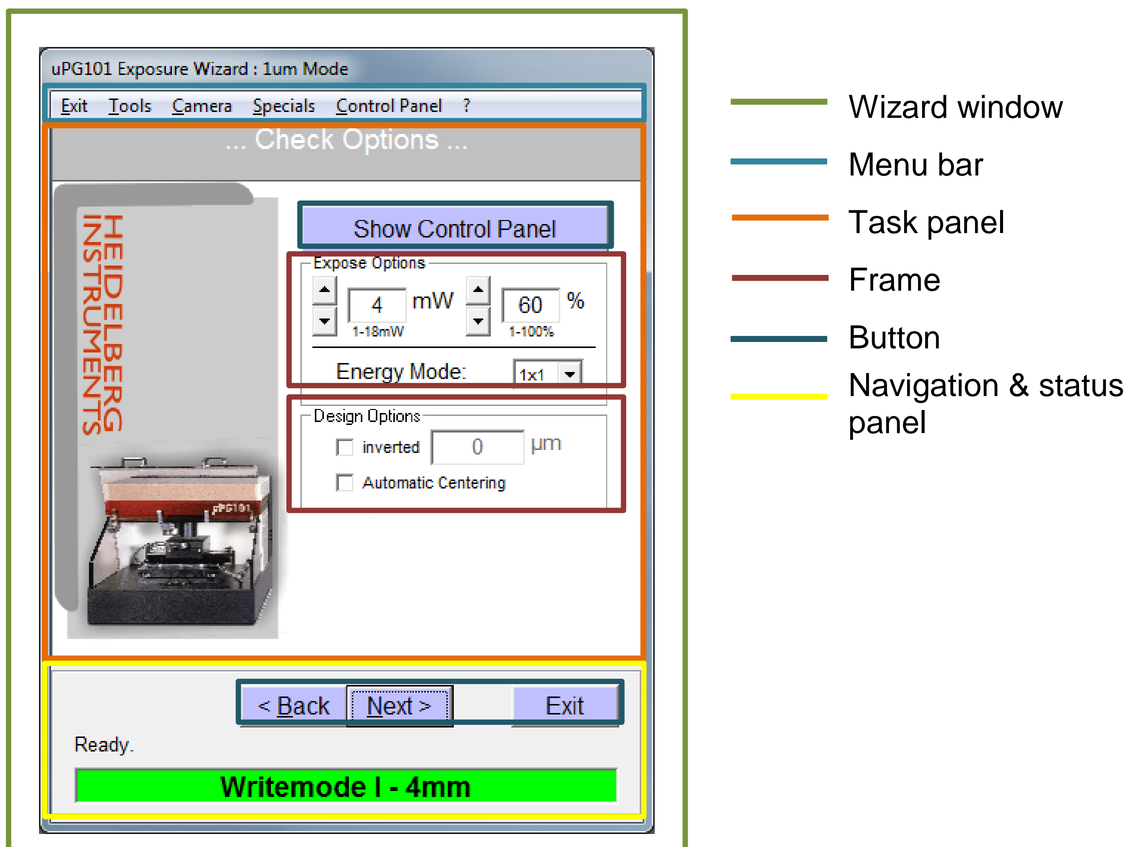


Figure 6: Parts of the Exposure Wizard window

The panels within the wizard window change according to the tasks that the system has to perform. In figure 6 the task panel's name is ***Check Options*** panel. A task panel can stay the same for a certain time until e.g., the task changes. In the task panel you find buttons that lead to the next task or to a different window. The task panel can also contain image boxes, or frames that group options. These frames can change within the panel. The frames you see in figure 6 are called ***Expose Options*** frame and ***Design Options*** frame. In these frames usually you select options or change settings.

There are also buttons within a frame. With a click on these buttons usually a window opens where you can change settings or set options. After having entered the kind of data that is required, you are lead back to the same panel with usually the same frames and buttons.

In the navigation and status panel, which is located at the bottom of the wizard window, you find navigation buttons (**Back**, **Next**, **Exit**). There is a bar, below the navigation buttons, that shows the write mode the system is currently working with. If a progress bar or a system status message shows up, it is located above the write mode bar.

2 General Procedures

This chapter gives information about general procedures concerning exposure preparation. Instructions on system start-up and shutdown, the available exposure modes and the design loading procedures are given. This chapter provides you with information on the types of substrate you need. You also get instructions on how to handle substrates.

2.1 System Start-up and Shutdown

Before putting the system into operation make sure that the transportation lock is removed. For instructions on how to remove the transportation lock, refer to *10.10 Transportation Lock*.

2.1.1 STARTUP

1. At the supply unit (Figure 5), switch on the μPG 101 with the power switch (23). The power indicator lamps at the supply unit (20) and at the lithography unit (8) light up.
2. At the lithography unit (Figure 3), close the cover lid (1) and make sure that air pressure for the stage is applied. The safety interlock lamp (7) should be off.
3. Power up the User PC according to the manufacturer’s instructions.
4. **Wait at least 5 minutes** before starting the Exposure Wizard (for information see *1.4 Exposure Wizard*). The internal controller of the system has to finish booting. Together with the wizard, the camera software HI Vision starts and creates a minimized window.

NOTICE **Wizard may crash and parameters get lost!**
Never close the camera window while the wizard is running.

Note: It is recommended to wait for at least 20 minutes for the system to warm up and stabilize before doing an exposure.

2.1.2 SHUTDOWN

NOTICE **Parameters get lost when system is switched off without having shutdown the wizard.**

- Shut down the Exposure Wizard prior to system shutdown.

1. In the **Exit** Menu, select **Shutdown μPG101** and confirm the operation. The wizard shuts down the operating system of the μPG system. This takes approx. 20 seconds.
2. When this is finished, a dialog window opens, click **OK**. The wizard closes.

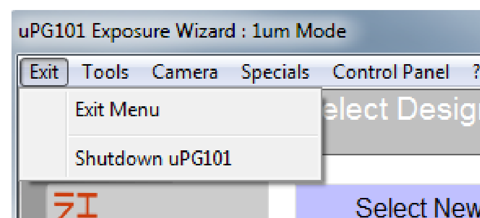


Figure 7: System Shutdown or Restart

3. Switch off the µPG system using the power switch (23) at the supply unit (Figure 5).
4. Power down the User PC according to the manufacturer's instructions.

2.1.3 RESTART

1. Choose **Exit →Shutdown** from the menu bar and confirm (Figure 7). The Wizard shuts down the operating system of the µPG system.
2. When this is finished, a dialog window opens, click **OK**. The wizard closes.
3. Switch off the µPG system using the power switch (23) at the supply unit.
4. Wait ~20 seconds.
5. Switch on the µPG system.
6. If required (e.g., because of communication problems), reboot the User PC according to the manufacturer's instructions.
7. **Wait for at least 5 minutes**. Then open the Exposure Wizard. Together with the wizard, the camera software HI Vision starts and creates a minimized window.

NOTICE **Wizard may crash and parameters get lost!**
Never close the camera window while the wizard is running.

Note: It is recommended to wait for at least 20 minutes for the system to warm up and stabilize before doing an exposure.

2.2 Exposure Mode Selection

The wizard offers two different paths, one for standard exposures and one for advanced exposures. The advanced exposure mode offers functions of the system like alignment, manual adjustment of the focus position and other modifications. If precise alignment of the exposed design on the substrate is an issue, an exposure with advanced options is required.

After you have started the Exposure Wizard (see *1.4 Exposure Wizard*), the ***Welcome Screen*** opens. It shows the progress of the connection and initialization sequence. This start-up sequence takes approximately two minutes.

During startup, the wizard identifies the available exposure mode options installed at the system. In the ***Options*** frame you find highlighted the options available at your system (Figure 8). You can also see which of the available write modes offers optical autofocus (if your system is equipped with optical autofocus).

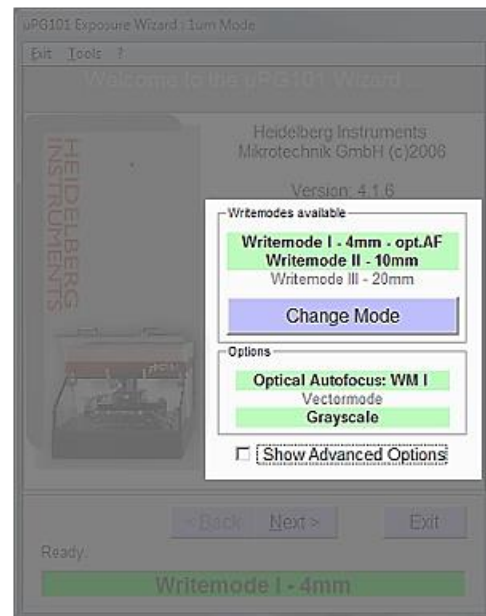
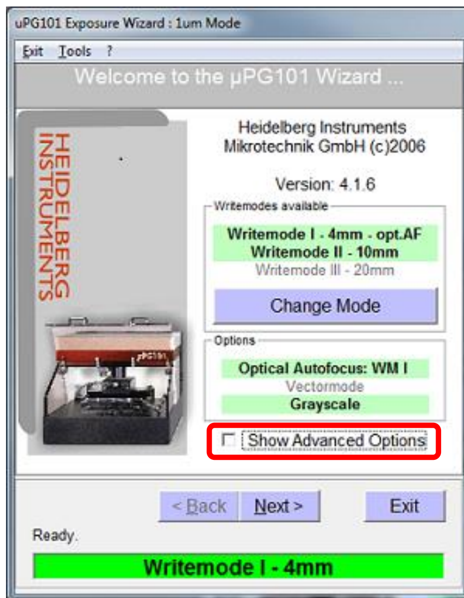


Figure 8: Welcome Screen with options

In addition, you can choose between the standard and the advanced exposure procedure by selecting or deselecting **Show Advanced Options**. It is also possible to change the mode later on by choosing **Tools→ Advanced Wizard** from the menu bar.

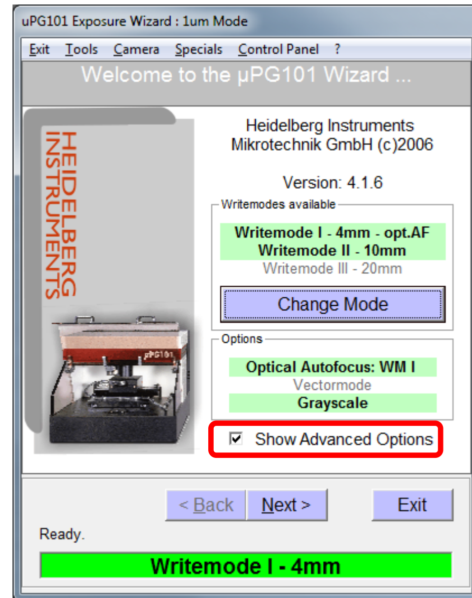
If multiple write modes are available they can be changed here. For further instructions see *2.3 Write Head Exchange for Write Mode Change*.

Standard Exposure Mode



1. Make sure that the checkbox **Show Advanced Options** is **deselected.**

Advanced Exposure Mode



1. Make sure that you selected the **Show Advanced Options** checkbox.

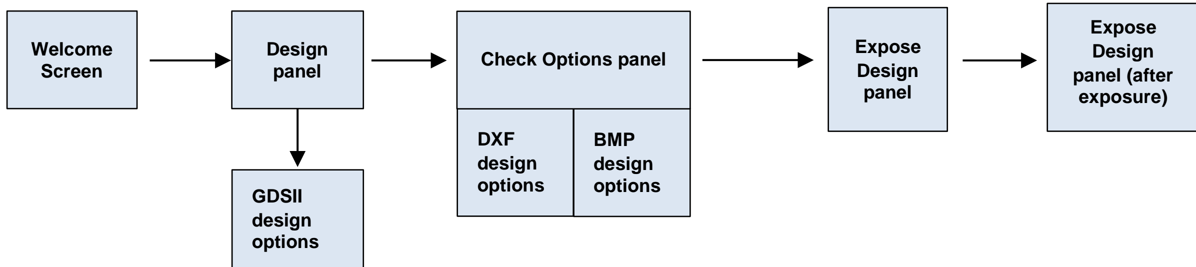
2. Click **Next**. The system moves on to the ***Design*** panel (see 2.6 *Design Loading Procedure*).

Note: As mentioned before, switching from one mode to the other is also possible with choosing **Tools → Advanced Wizard** from the menu bar.

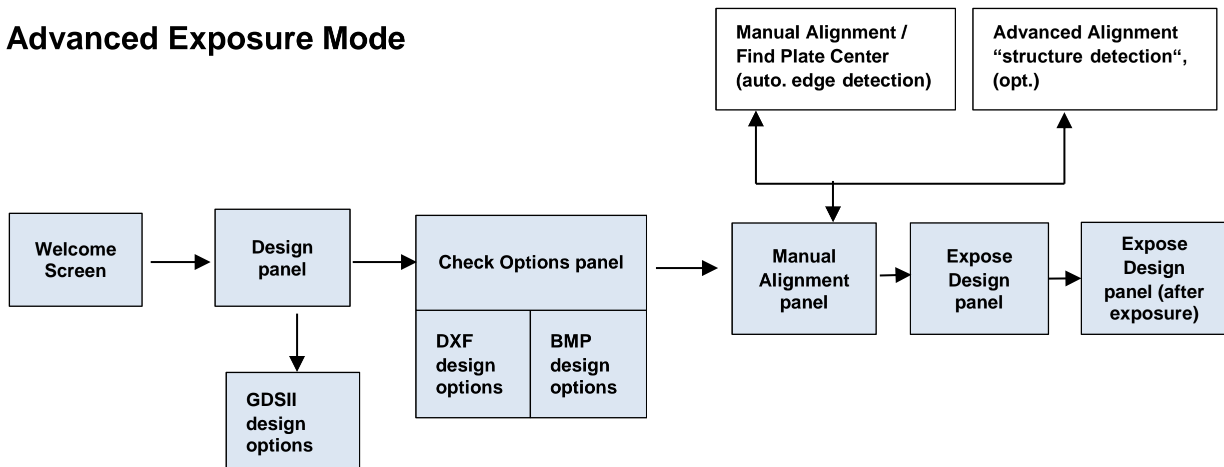
2.2.1 OVERVIEW: WIZARD PANELS

The following figures give an oveview of the panels that guide through one exposure. You can find one panel map for the standard exposure mode and one for the advanced exposure mode. The third map shows the two panel maps joint together as one. This is possible because some steps are completely or partly the same in both modes.

Standard Exposure Mode



Advanced Exposure Mode



Joint Panel Map

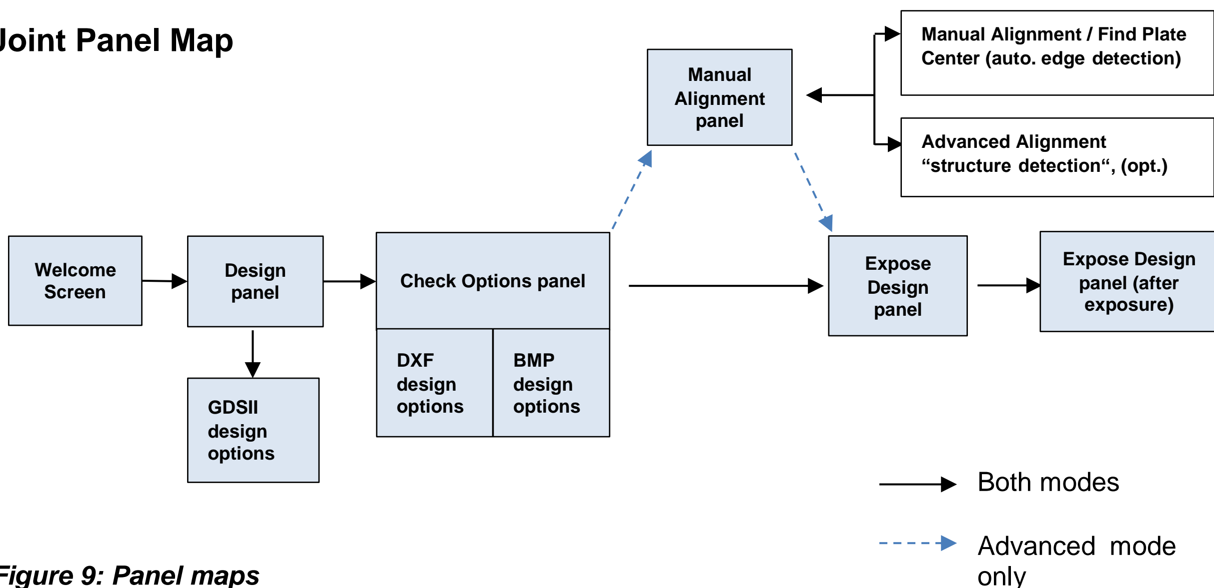
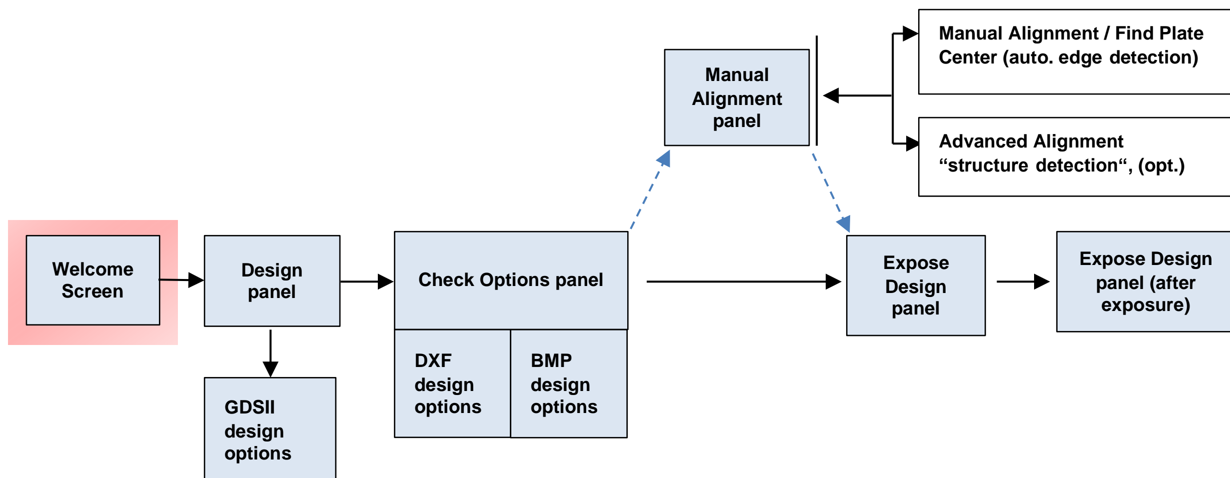


Figure 9: Panel maps

2.3 Write Head Exchange for Write Mode Change



It is possible to change the write mode (write lens + parameter settings) in order to achieve different resolutions matching the specific application. There are up to three write modes available depending on system specifications. Each of the write modes requires the installation of a write lens with a specific focal length:

WM	Focal length
I	4 mm
II	10 mm
III	20 mm

Table 1:Writes modes and their focal lengths

NOTICE

Recheck offset!
After the exchange of write heads, the offset has to rechecked and determined again. This is of importance, especially for overlay exposures. Refer to *8.2 Laser Offset Calibration*.

The ***Welcome Screen*** provides a ***Writemodes available*** frame where you can change the write mode (Figure 10).

During a change of the write mode, you have to manually exchange the write head.

To exchange the write head, follow the instructions given below:

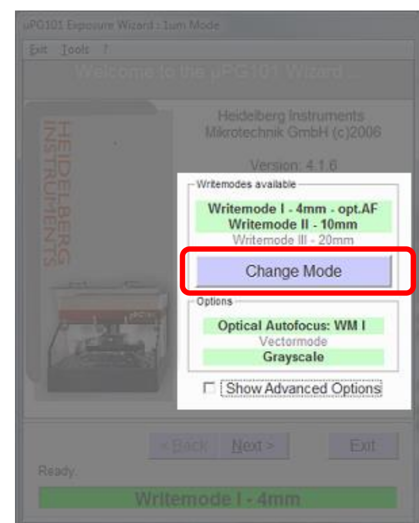


Figure 10: Write mode change

1. To change the write mode, click **Change Mode** and select the required mode. The stage moves into position for write head exchange.
2. At the connector board next to the write head, unplug the piezo cable (red) and the cable to the stepper motor (Figure 11).

NOTICE **Never let the write head drop onto the stage.**
Severe damage to the nozzle impairs focus stability or makes focusing impossible.

3. Hold the write head in position with one hand and unscrew the two screws with the other hand.
4. Now remove the write head.
5. Take the write head that you require, press it against the flange with one hand and fasten the screws with the other hand. For exposure stability it is very important that the write head snaps into the flange
6. Plug in the cables.
7. When finished, click **Done**. You are lead back to the ***Welcome Screen***.
8. After having exchanged the write heads, it is necessary to recheck the offset: Choose **Camera→Laser Offset Calibration** from the menu bar and follow the instructions given in *8.2 Laser Offset Calibration*.

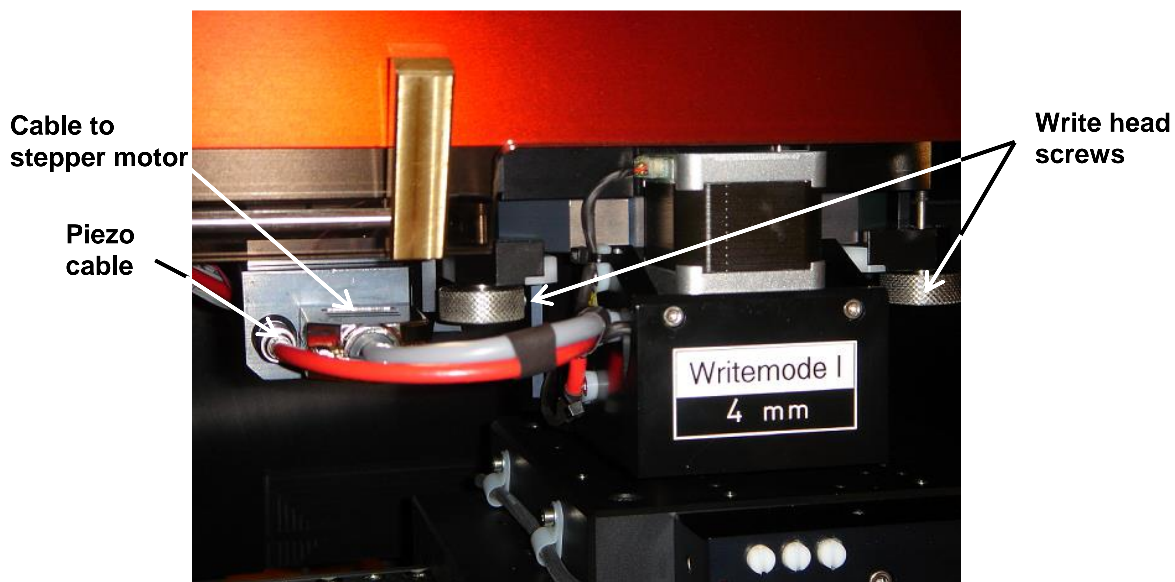


Figure 11: Write head exchange

Storage Information:

- Store the uninstalled write heads in a dry, dust-free environment.
- Always place down the write head with the nozzle faced up.

2.4 Coordinate System and Design Positioning

In standard mode alignment accuracy depends mainly on the repeatability of loading against the alignment pins. If precise alignment of the exposed design on the substrate is an issue, an exposure with advanced options is required.

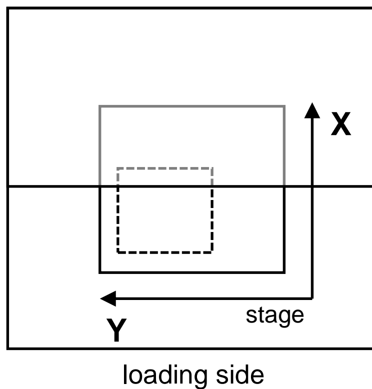


Figure 12: Stage coordinate system

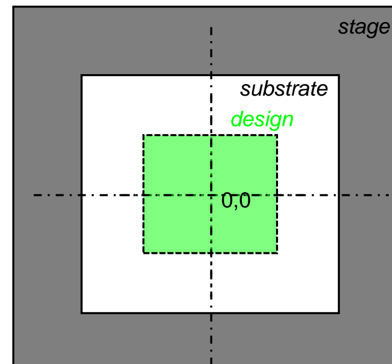


Figure 13: Standard design positioning

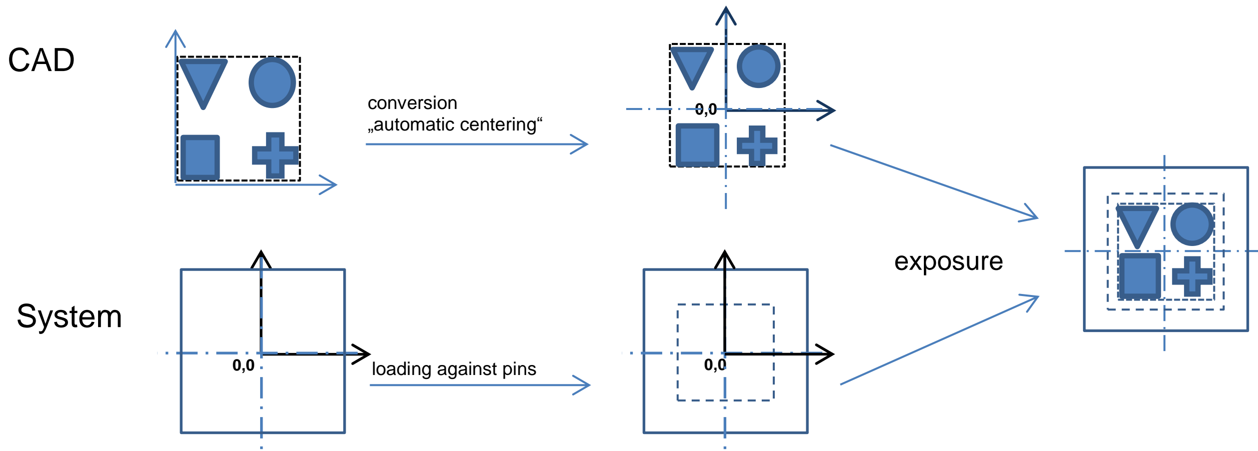
The coordinate system of the stage is oriented such that the x-axis corresponds to a backward-forward movement, while the y-axis corresponds to a left-right movement when standing in front of the machine (Figure 12). Keep this in mind if the substrate bears alignment marks that are to be used for exposure.

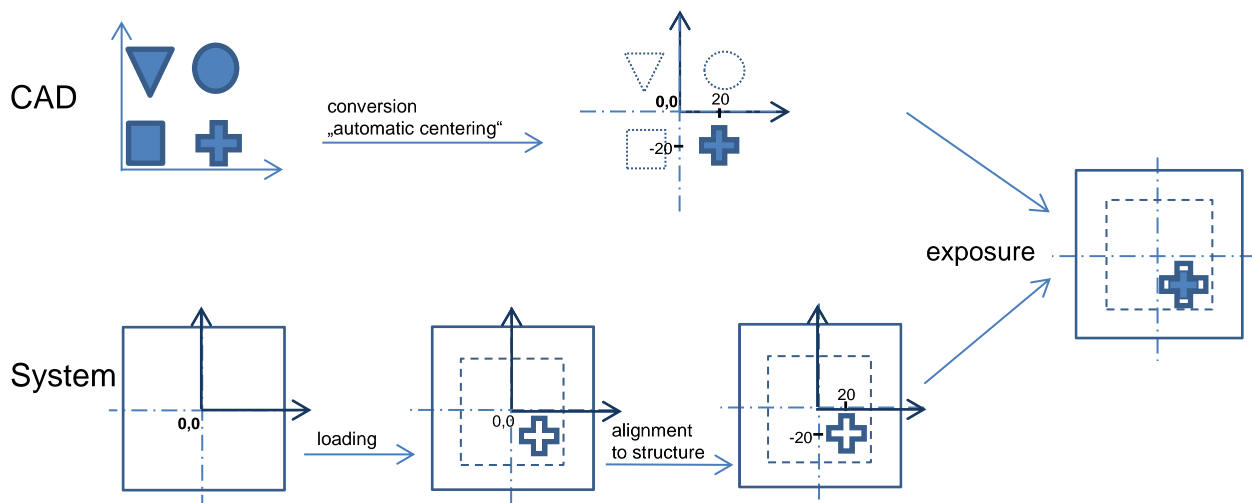
If the alignment pins have been properly placed on the stage, the center of the substrate matches the center of the stage (for instructions on substrate positioning see *2.8.1 Alignment Pins Placement*). In all further explanations, it is assumed that the substrate is positioned so that stage center corresponds to the substrate center.

For a successful outcome of the exposure, it is important to know the eventual position of the design on the substrate before starting the exposure procedure. Keep in mind that the accessible exposure area is 5” x 5” , also for substrates of 6” size.

The origin of the converted design matches the center of the stage (Figure 13). After design conversion, usually the origin of the converted design corresponds to the center of the design (Automatic Centering). Therefore the precision of design positioning is determined by the precision of substrate positioning on the stage. In standard exposure mode the option **Automatic Centering** cannot be deselected. In advanced mode, the option can be deselected which means that the origin determined in the design is kept and corresponds to the stage center.

Figure 14 (next page) shows the difference in design positioning of the two available exposure modes. The section designated *CAD* shows the position of the design given by the drawing software, before and after conversion. The section *System* displays the position of the origin in the machine’s coordinate system. In the end, the resulting design positioning during exposure is shown.





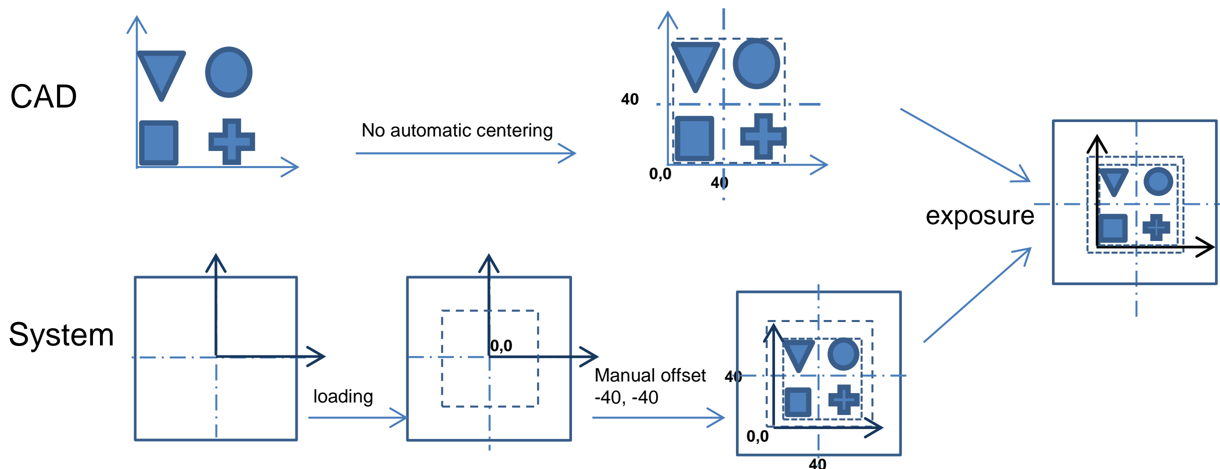


Figure 14: Design positioning in standard mode and advanced mode

2.5 Design Preparation

When you prepare the design in the required format, follow the instructions given in the ***Design Guide***. Make sure that the design complies with all rules given there, the general as well as the specific ones.

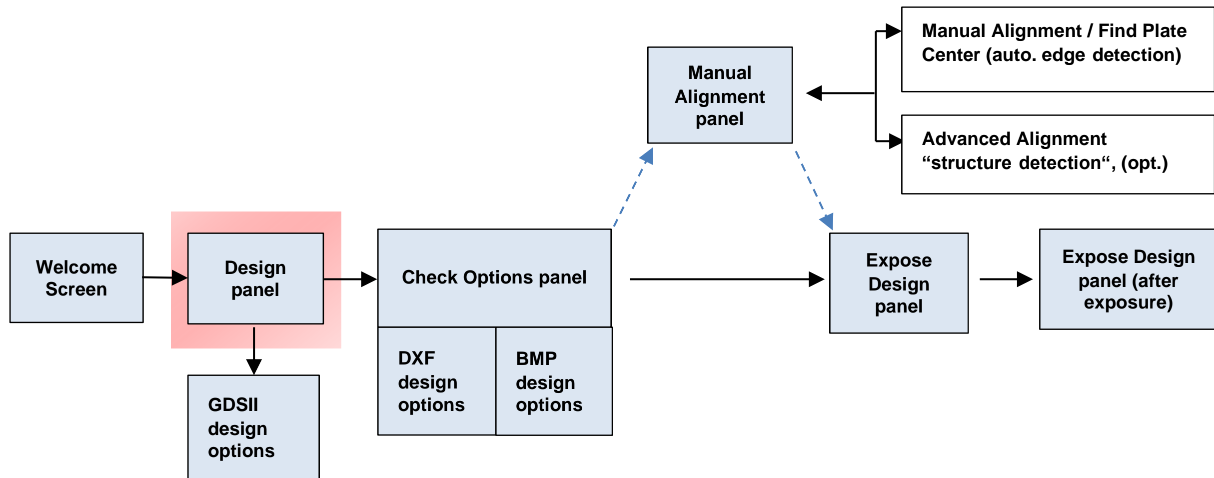
Keep in mind the maximum design sizes:

WM I	WM II and WM III
90 x 90 mm	125 x 125 mm

Table 2: Maximum design sizes

If the design is not accessible via network from the User PC, transfer it e.g., by using a memory stick or a CD. Any freely accessible directory can be used.

2.6 Design Loading Procedure



After you have started the ***Exposure Wizard*** (see *1.4 Exposure Wizard)* and selected one of the exposure modes (see *2.2 Exposure Mode Selection*), you load the design. During the design loading procedure the task panels differ from each other regarding their frames, depending on the design type you have chosen. Parameters and options have to be selected here. The instructions given in this section are valid for both exposure modes (standard/advanced).

1. In the ***Design*** panel, click **Load Design**.
2. Navigate to the directory on the PC or the network that contains the design file.
3. Select a design file and click **OK**.
4. If a dialog window requests now the size that was defined for one drawing unit during design creation, then enter the number and click **OK**.

   Note: Only integer values may be entered for DXF and BMP designs.

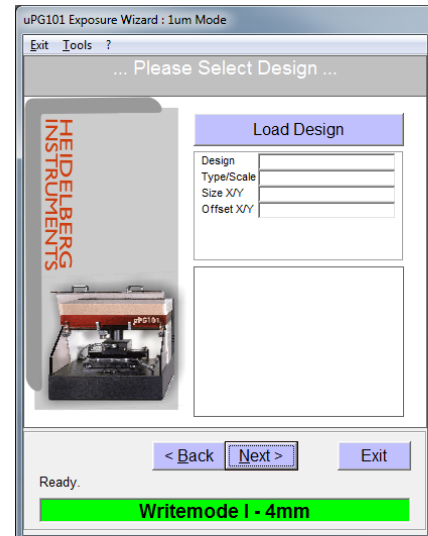


Figure 15: Design panel (standard)

   Now the design is transferred to the lithography unit. In order to provide you with a preview it is converted into an intermediate format.

   If you have selected a **GDSII Design**, a window opens where you enter parameters for the GDS II design (for instructions see *2.6.1 GDSII Designs*).

   In the ***Design*** panel some design parameters are listed. A preview of the design is given in the ***Preview*** frame. To get a larger image of the design, click on the preview window. The viewer application has restricted resolution abilities and might give a pixelated enlargement. Complex designs are shown only partly.

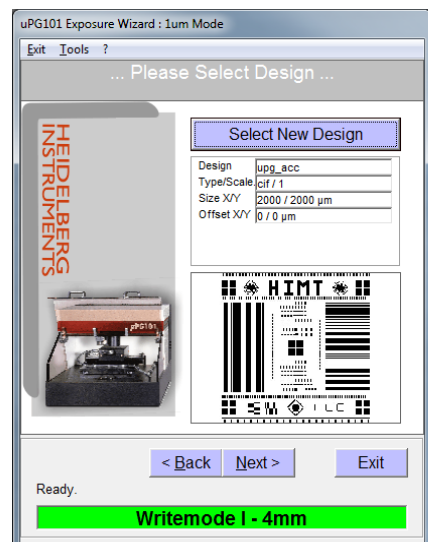


Figure 16: Parameters and design preview in Design panel

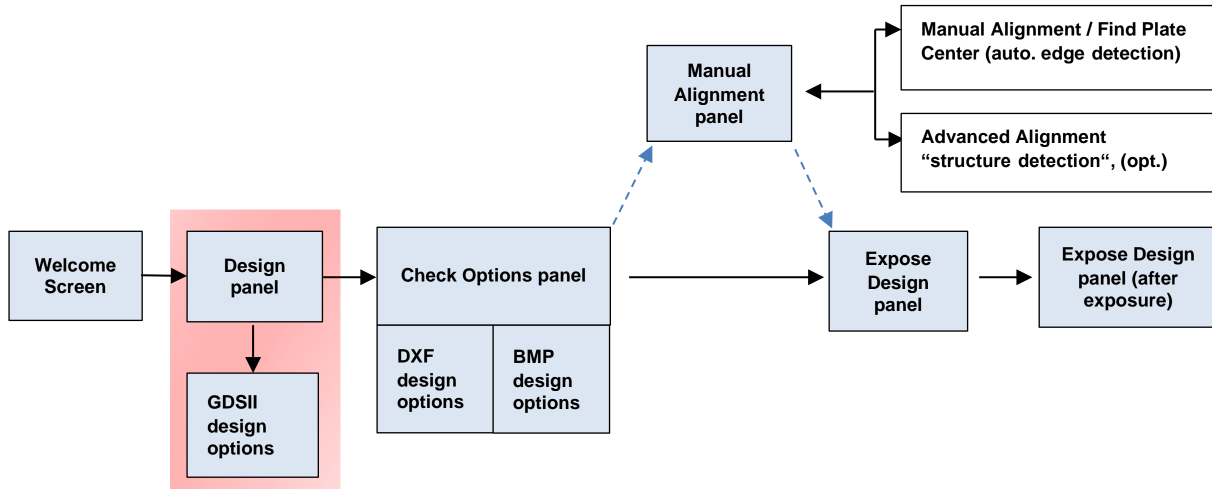
   No changes to the design itself or to its positioning on the substrate can be affected in the viewing application.

   To select a different design, click **Select New Design** and repeat the steps given above.

5. In advanced mode, you now can select further design options (see *3.1 Advanced Design Options*.)
6. Click **Next** to proceed to the ***Check Options*** panel.
7. If you have chosen a **DXF** or **BMP** design, the ***Check Options*** panel contains a frame where you set parameters for these designs. For instructions on DXF see 2.6.2 *DXF Designs*, for BMP see *6 Grayscale Exposures*.

When the design loading procedure is finished you continue with the substrate loading procedure (see *2.8 Substrate Loading*).

2.6.1 GDSII DESIGNS



If a GDSII Design was selected, a window opens (Figure 17).

1. From the dropdown list select a **GDSII Structure**
2. Choose the layers that should be exposed.
3. To confirm, click **Create** (To reset your selection, click **Reset.** To cancel, click **Cancel**).
4. You are lead back to the ***Design*** panel.

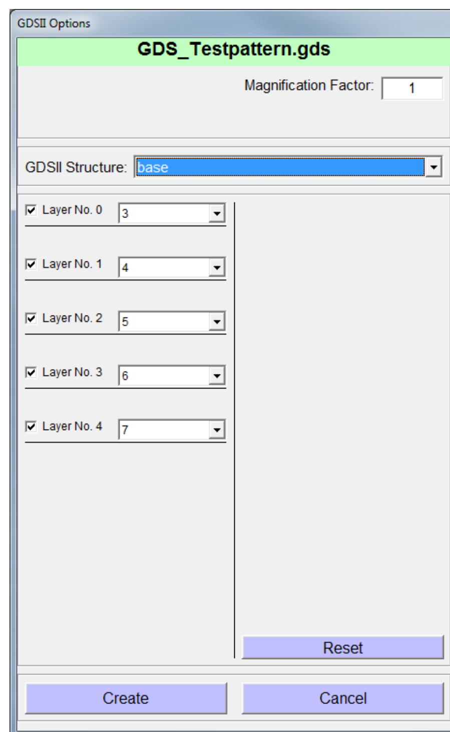
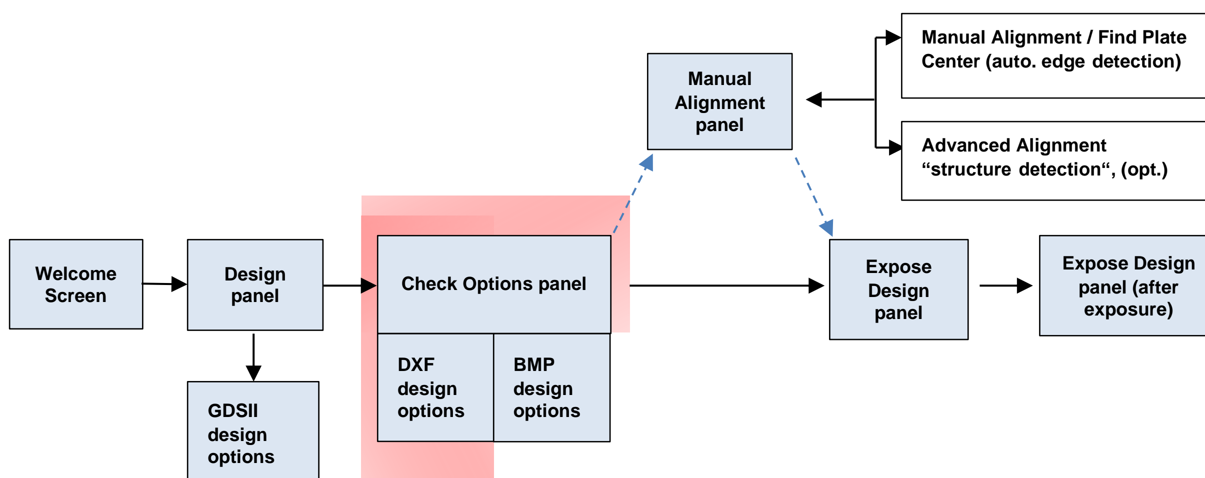


Figure 17: GDSII Options window

2.6.2 DXF DESIGNS



If a DXF design was selected, the option **XOR mode** is visible in the ***Check Options*** panel. By default, DXF design processing merges all available layers into one layer using the OR option. That means that every area defined in any layer is exposed. When activating **XOR mode** by selecting the checkbox, overlapping areas of different layers are omitted during exposure.

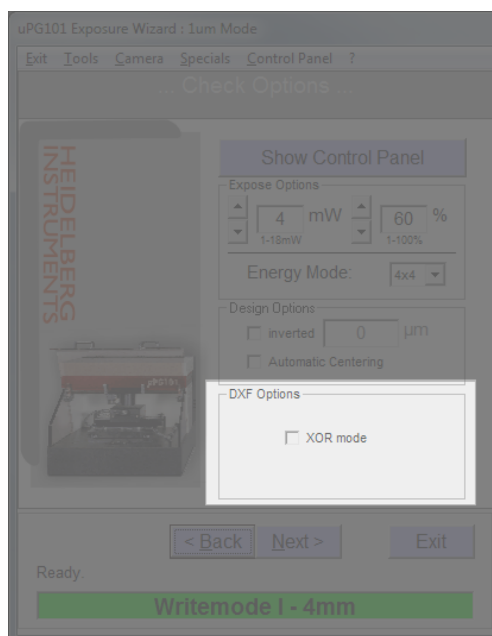


Figure 18: DXF design options

In the example below you see the difference between **OR** mode and **XOR** mode. Layer 1 and layer 2 build an overlay. In the OR mode the overlapping area is exposed, in the XOR mode this area is omitted (left blank in example). So **OR** mode results in a true merging of the structures, **XOR** leads to a cutting only in the overlap region (Figure 19).

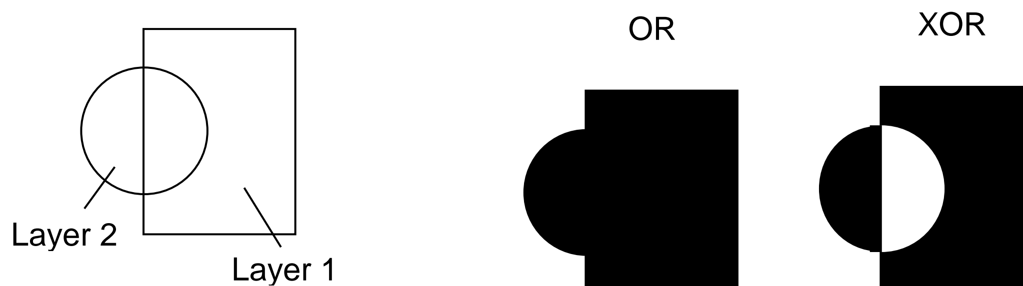


Figure 19: Difference between OR mode and XOR mode (2 layers)

If a design has more than two layers, the **XOR** operator is used successively. Each layer is cut from the design resulting from the cut of the previous layers (Figure 20).

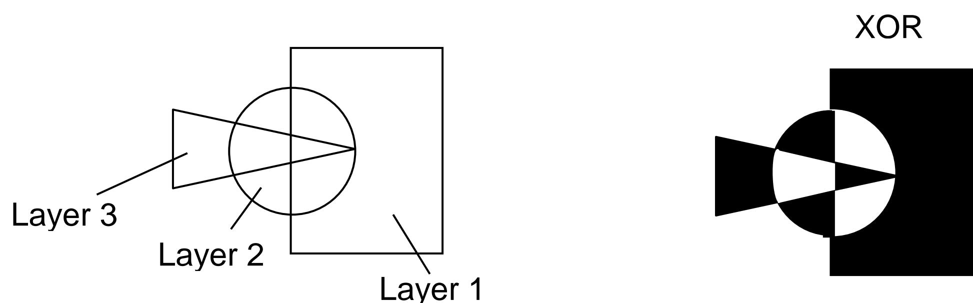


Figure 20: XOR operation with 3 layers

2.7 Choice of Substrate

To do lithographic exposures, substrates and especially the photosensitive coating of the substrates have to be chosen according to the intended application. In addition, the specifications have to fall into the specification range of the μPG 101.

Standard substrate types*:

- Soda-lime or quartz plates (depending on the requirements concerning temperature stability) with chromium coating with anti-reflection layer (e.g., chromium-oxide).
- Silicon wafers

*For other substrate types, please contact the Heidelberg Instruments Customer Support. We inform you if they are usable at all, and give you recommendations on exposure and processing.

General details for substrate choice

- Size*: 2" – 6"
- Maximum thickness: 6 mm
- Flatness/parallelism: < ± 20 μm

*At 5” and 6” there is no vacuum suction hole close to the edge.

Note: Alignment against pins is not possible for substrates of 6" x 6". The maximum exposure area is 5" x 5".

Recommended photoresist coatings:

For binary exposures (2D) on thin resists (~5000 Å):	
S18XX	A standard Shipley resist. S1805 is a resist of this family that is well tested on Heidelberg Instruments lithography systems. It can be spin-coated to 0.5 μm thickness.
AZ15XX	Clariant resists which are comparable to the S18XX Shipley family. Recommended type is AZ1505 for 0.5 μm resist thickness.

Table 3: Photoresist coatings for binary exposures

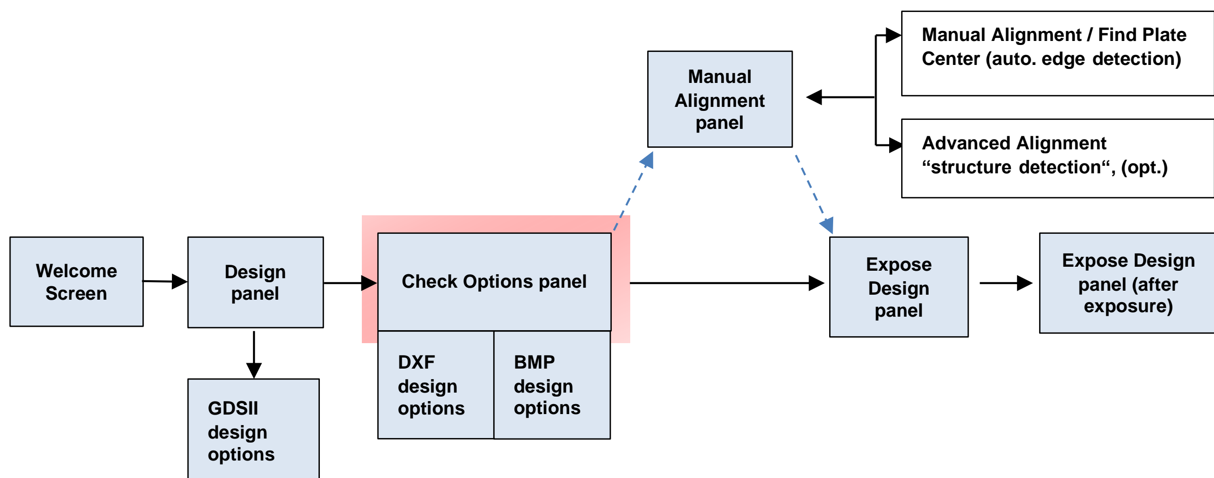
All resists listed are positive resists, i.e. exposed areas are removed during processing. Please refer to resist manufacturer's documentation or contact resist manufacturer for more detailed data and recommendations on applications as well as details on coating and processing procedures (e.g. spinning speed, pre-bake and post-bake parameters, recommended developer and developing time etc.).

General Advice for getting the best result:

- Never use out-of-date batches
- Take care to protect the substrates from light (even safelight, as far as possible) at all times until developing is finished.

- Always wear lint-free gloves (e.g. latex) when handling the substrates.
- Protect the substrate from scratches whenever transporting it. Use only designated transport boxes.
- Carefully clean the back side of the substrate before use to make sure it gets good vacuum suction on the µPG 101 stage chuck.
- Do not expose undeveloped substrates to water, humidity, solvents, or solvent fumes.
- Store the substrates in a temperature controlled environment. For temperature range information refer to the resist manufacturer's data

2.8 Substrate Loading

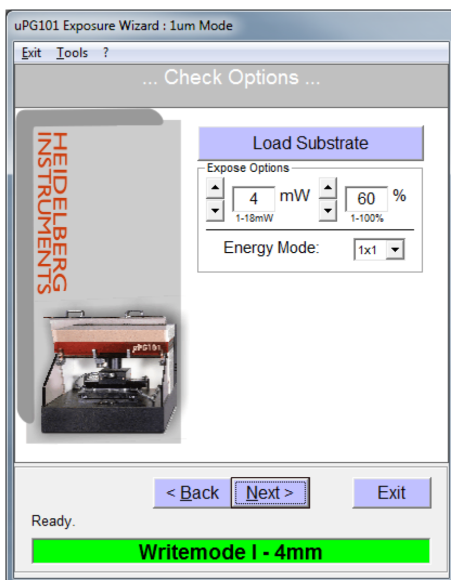


For loading the substrate you are in the ***Check Options*** panel. The available options in the panel in the standard mode differ slightly from those in the advanced mode.

Before starting the loading procedure, make sure that the cover lid (1) is closed, the safety interlock lamp (7) is off and the compressed air is present. Then follow the instructions subdivided according to the exposure mode given below:

Standard Mode

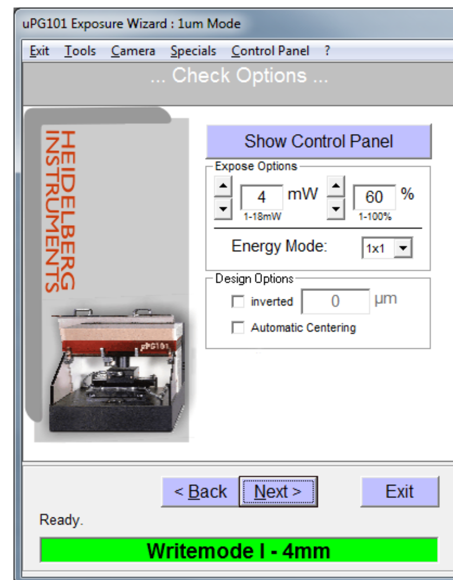
1. In the ***Check Options*** panel, click **Load Substrate**.



2. The stage moves to the loading position at the front of the machine. The ***Loading Status*** window opens on the User PC.

Advanced Mode

1. In the ***Check Options*** panel, click **Show Control Panel**. The ***Control Panel*** window opens offering a variety of direct controls (for instructions on the Control Panel window see *9.2 Control Panel).*



2. Click **To Un/Load**. The stage moves to the loading position at the front of the machine.

3. Wait until all movement has finished, then open the cover lid (1).
4. On the chuck, mount the alignment pins (masks: three, wafers: two) in the appropriate positions for the substrate size to be used (for instructions see *2.8.1 Alignment Pin Positioning*).
5. Switch off all light except safe light.
6. Take a substrate out of its storage container. Check substrate quality:
   - Make sure the substrates comply with the specifications of the µPG 101 (see *2.7 Choice* of Substrate).
   - Never use out-of-date substrates.
   - Do not use substrates with scratches on top or bottom, visible contaminations in the resist or non-uniform resist distribution in the area to be exposed.
7. Make sure that the resist coated side of the substrate is turned up.
8. Place the substrate on the chuck (regarding orientation see *2.4 Design Positioning and Coordinate System*). For substrates of 1” and 2.5” use the placement aid (*2.8.2 Placement Aid for Substrates*).

9. Remove all alignment pins with the pin removal tool (for instructions see *2.8.4 Alignment Pin Removal).*

NOTICE

Serious damage to the system by unremoved alignment pins.

- Never leave alignment pins on the stage.
- Never let the write head hit the pins.

10. Close the cover lid (1) and make sure the interlock lamp (7) is off.

Standard Mode

11. In the ***Loading Status*** window, click **OK**. The stage moves to the center position, and the write head (2) moves down until the focal point is on the substrate surface.

Advanced Mode

11. In the ***Control Panel*** window click **To Center**. The stage moves to the center position.
12. In the ***Writehead*** frame of the ***Control Panel*** window click **Focus**. The write head moves down until the focal point is on the substrate surface.
13. To close the ***Control Panel*** window, click **Close**.

When the substrate is loaded, proceed with setting options and parameters for the exposure procedure (see *2.9 Energy Settings for Exposure*).

2.8.1 ALIGNMENT PIN POSITIONING

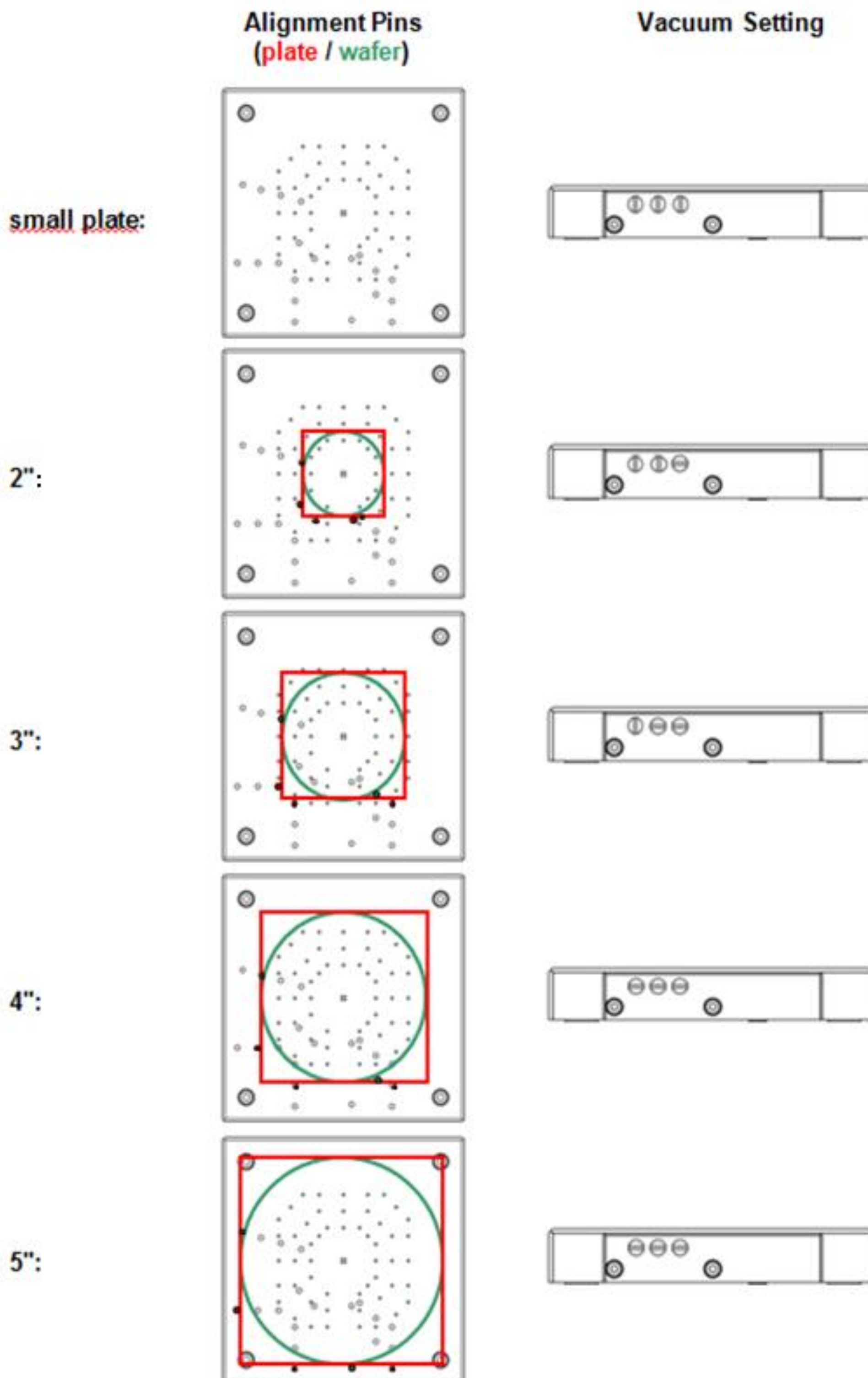


Figure 21: Alignment pins placement

2.8.2 PLACEMENT AID FOR SUBSTRATES

For substrates of 2.5” size we provide a try square making sure that the substrates are well positioned on the chuck. Follow the instructions below:

1. Mount the alignment pins in the position for 5” substrates.
2. Take the square and place it against the alignment pins on the chuck (Figure 22).
3. Place the substrate into the rectangular notch of the square.
4. Switch on the vacuum (see *2.8.3 Vacuum Region Selection*).
5. Remove the square.
6. Check if the substrate is held tight.
7. Remove the alignment pins before starting the exposure (see 2.8.4 *Alignment Pin Removal*).

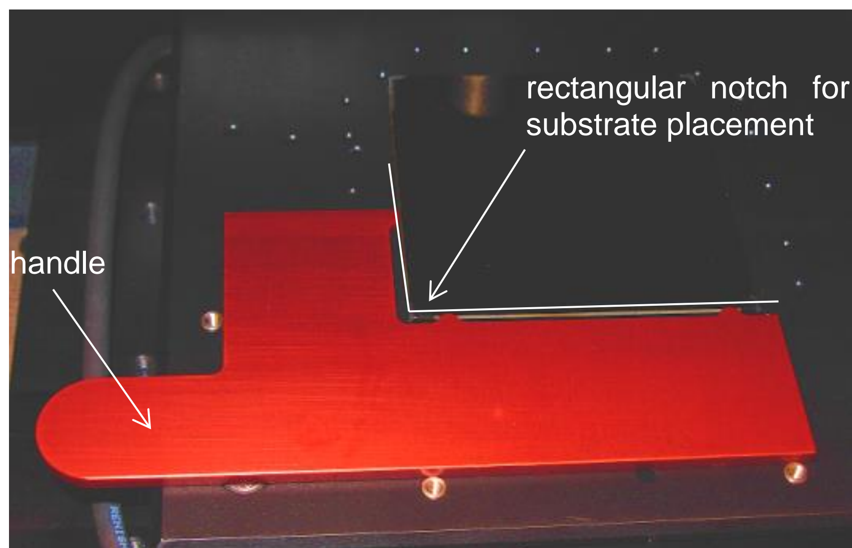


Figure 22: Placement aid for substrates of 1” and 2.5”

2.8.3 VACUUM REGION SELECTION

The four vacuum suction holes in the center of the chuck are always active when the vacuum is switched on. They hold down small substrates.

1. If the substrate has a size of 2” or larger, add vacuum region extensions by turning the vacuum field selection screws (3) (Figure 23, and right part of Figure 21 in *2.8.1 Alignment Pin Positioning*).
2. Switch on the vacuum with the vacuum switch (6).
3. Check if the substrate is held tight by moving it slightly sideways. If you can move the substrate, it is not held tight. In such cases, switch off the vacuum. Clean the chuck and the backside of the

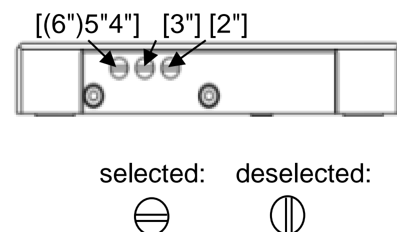


Figure 23: Vacuum region selection

substrate. Then try again. If problems persist, use a different substrate or a higher ejector pressure. For instructions on how to check and adjust the ejector pressure, refer to *10.9 Adjustment of Ejector Pressure*.

2.8.4 ALIGNMENT PIN REMOVAL

Remove all alignment pins before the exposure procedure starts. Due to the size of the alignment pins you are recommended to use the pin removal tool (Figure 24).

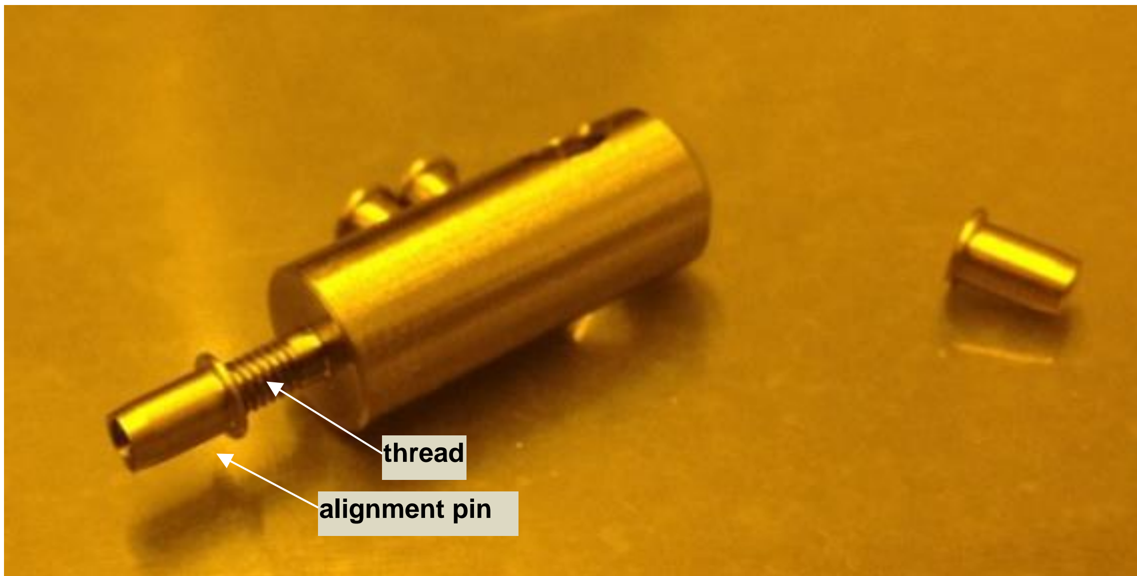


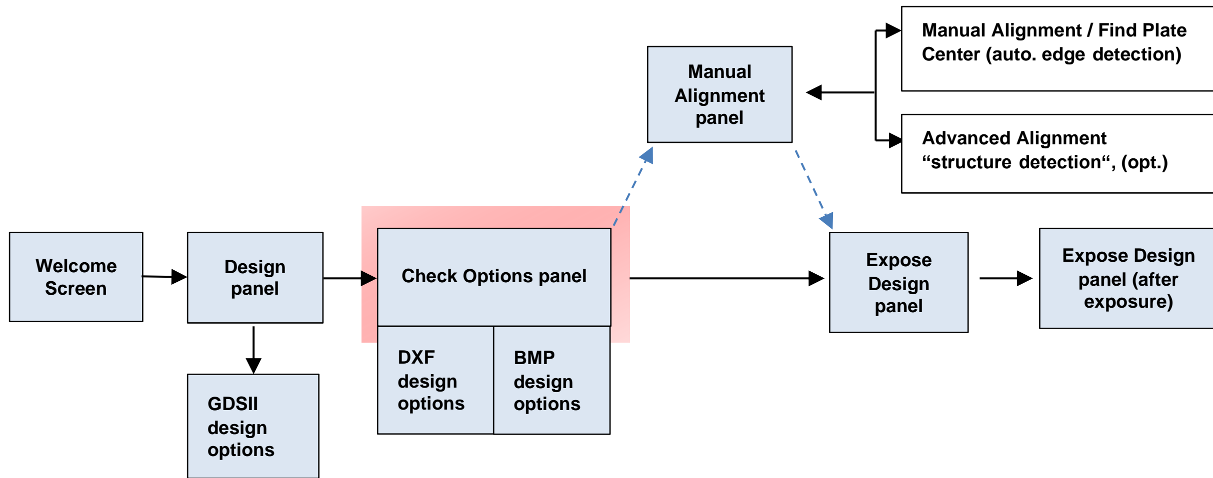
Figure 24: Pin removal tool

1. Take the pin removal tool.
2. Screw the threaded end of the tool into the alignment pin on the chuck. Now the tool is fixed inside the pin.
3. Pull out the tool together with the pin.
4. Now unscrew the pin from the tool.
5. Repeat step 1 to 4 with all alignment pins located on the chuck.
6. Make sure that no alignment pin is left on the chuck.

NOTICE **Serious damage to the system by unremoved alignment pins.**

- Never leave alignment pins on the stage.
- Never let the write head hit the pins.

2.9 Energy Settings for Exposure



After having loaded the substrate (see *2.8 Substrate Loading)* you select options and set parameters for the exposure procedure in the ***Check Options*** panel.

In the ***Expose Options*** frame you can influence the amount of energy that is deposited on the resist surface. In advanced mode, a few **Design Options** are offered in addition (Figure 27). For information refer to *3.1 Advanced Design Options.*

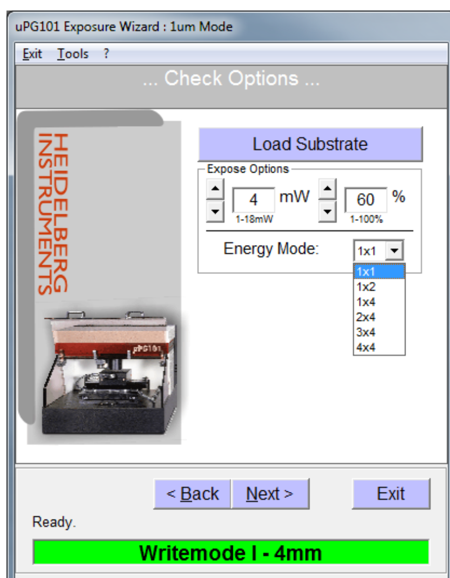


Figure 25: Check Options panel (standard)

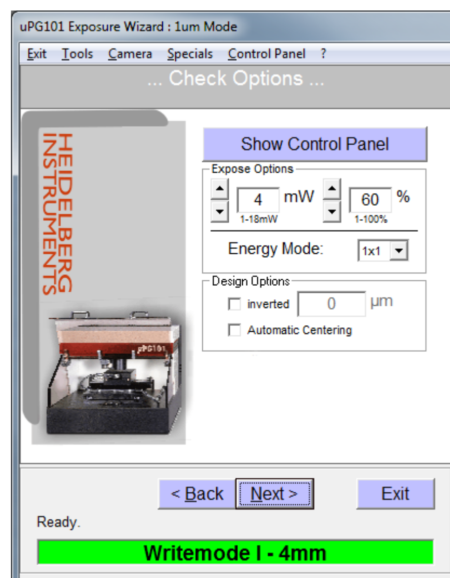


Figure 26: Check Options panel (advanced)

For a better understanding of the parameters involved in the expose options, see the following explanation.

The deposited energy per area (= dose) that is required to get a sufficient chemical reaction, depends on the type and the thickness of the photoresist. This dose is called dose to clear of the resist (in mJ/cm^2).

The amount of energy that is deposited in the area of the write spot, can be controlled by either adjusting the power or by determining the time span over which the laser light illuminates the resist. The following equations show the correlation of the values that can be adjusted in order to control the dose via the energy:

$$Dose = \frac{energy}{pixel\ area}$$

Energy = power on substrate x pixel exposure time
= ((laser power x efficiency) x filter transmission) x (relative pulse duration x stage speed factor x number of passes)

To find the right energy for a certain type of substrates, several exposures have to be done at different energy levels, until the energy is found that gives the best result in structure size and quality.

In the upper part of the ***Expose Options*** frame (Figure 25 or Figure 26) you find:

- The output power of the laser (left side).
- The pixel pulse duration in percent (right side).

Here, the exposure energy can be fine-adjusted according to the information given above. Usually no other adjustments are required.

Note: If good edge quality of the exposed structures is important, it is recommendable to decrease the design structure sizes by 1-2 µm and increase the laser power until the exposed structure sizes reach the required size.

Note: It is recommended to run the laser at highest laser output power when the pixel pulse duration is set to less than 50%, because the relative noise increases towards low output power levels.

For coarse adjustment, some more options are available:

Filter knob: If very low energy is needed, as can happen e.g., in vector mode exposures, the power can be further reduced by use of a filter with ~10% transmission to keep the laser power level in a reasonable region. The filter is located at one side of the system and can be added by turning the filter knob (19) to the **ON** position (Figure 27).

Figure 27: Filter knob for exposure power reduction

Energy Mode: For some applications, the energy of the installed laser might not be sufficient, or the energy should be deposited smoother e.g., to improve edge quality.

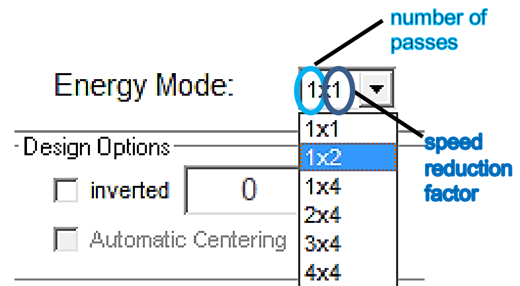


Figure 28: Energy Mode dropdown list

For these cases, doing multiple exposures or reducing the speed at which the system exposes is possible. In this way, the same area is exposed over a longer time, allowing to deposit more energy or to deposit the same amount of energy more slowly.

Up to 4 subsequent exposures and a speed reduction factor of 2 (x2) or 4 (x4) can be selected. Exposure time increases accordingly. Methods can be combined (Figure 28):

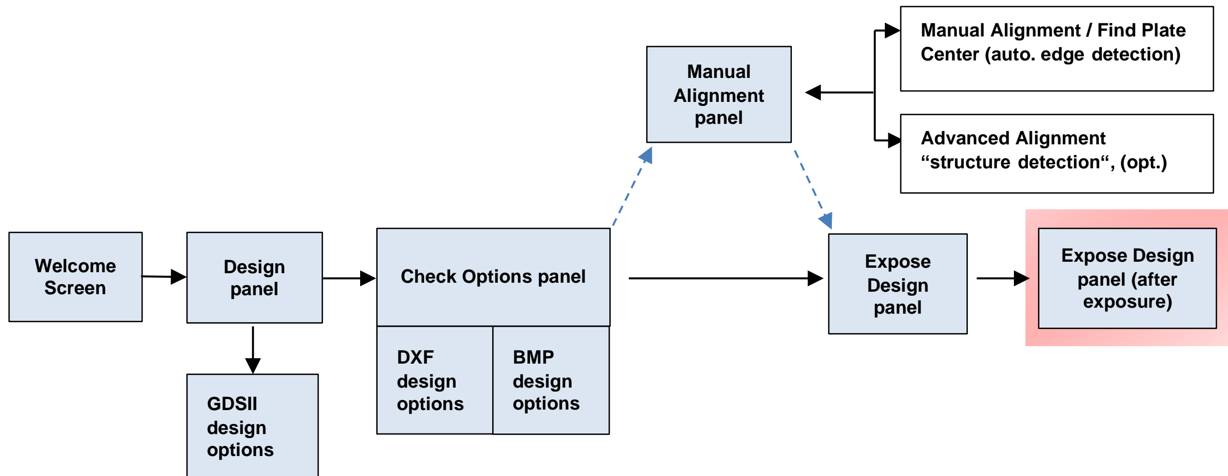
In the drop-down list, the first value of each entry indicates the number of exposures while the second one is the factor of energy added by speed reduction (see example).

Example:

- ***1x2*** will execute one exposure with double write energy. At this mode the stage speed is reduced by factor 2 ,leading to an increase of exposure time, and deposited energy per spot is doubled by factor 2.
- ***3x4*** mode will execute three exposures in a row, where stage speed is reduced by factor 4 and energy per spot and time is therefore increased by factor 4. The effective increase in energy is 3x4=12.

After you have set all parameters and options that you require, click **Next** to continue. In advanced mode the panel changes to the Manual Alignment panel (see *4 Alignment Methods and Batch Exposures).* In standard mode you can directly start the exposure procedure in the Expose Design panel (see *5 Exposures*).

2.10 Substrate Unloading



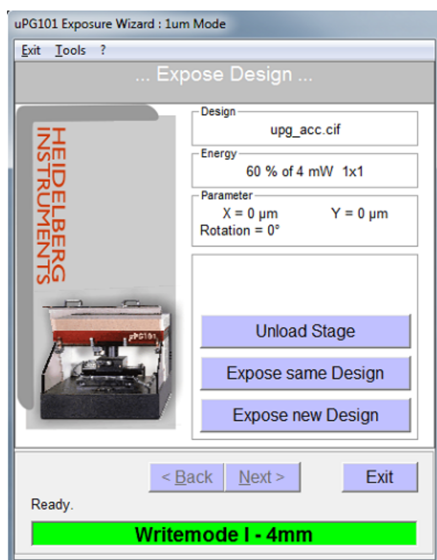
The exposure procedure is finished. The content of the ***Expose Design Panel*** has changed. To unload the substrate, follow the instructions given below according to the options (a or b) you have selected before:

a) If you have selected the option **Auto Unload after Exposure** (see *5.1 Exposure Procedure*), then the write lens is automatically set into its retracted position, which means that the write head is driven into its upper end position. The stage moves to the unloading position.

b) If you have not selected the **Auto Unload after Exposure** option**,** then:

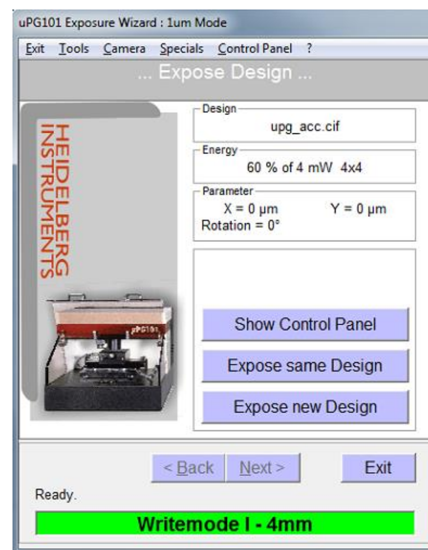
Standard Mode

1. Click **Unload Stage**



Advanced Mode

1. Click **Show Control Panel** and in the ***Control Panel*** window click **To Un/Load**.



2. Wait until all movement has stopped.
3. Open the cover lid (1) and switch off the vacuum with the vacuum switch (6).
4. Carefully lift the substrate off the chuck.
5. You can also choose one of the following options:
   - To expose the same design on a new substrate, click **Expose same Design**. Your design settings are kept and you are lead back to the ***Expose Design Panel*** in which you can change the energy settings.
   - To load a new design, click **Expose new Design.** You are lead back to the ***Design*** panel.

After you have unloaded the substrate, process it according to the substrate type (see *2.11 Substrate Processing*) and the manufacturer's recommendation.

2.11 Substrate Processing

The steps of processing a substrate are:

- **Post exposure bake:** Depending on application and resist type, a post exposure bake of the exposed substrate on a hot plate or in an oven may be required. Refer to the resist manufacturer's documentation for specific information on this.

  Note: The resists recommended here for standard purposes do not need a post exposure bake.

- **Developing:** The exposed parts of the resist have been chemically altered by the light and can now be washed out of the resist layer by use of specific developer chemicals. If the energy dose was sufficient to enable the reaction through the complete layer, after developing, the surface of the coated substrate is accessible wherever the resist was exposed with full intensity. In regions where the energy dose was below the limit, only a part of the layer is removed, thus allowing for three dimensional structuring of sufficiently thick resist layers.

  Note: In negative resist such as SU-8, the developer removes the parts which were not exposed.

  Developing times depend on resist type, resist thickness and developer type. It also depends on the energy dose used during exposure. Typical developing times are 1 –1.5 minutes for thin resists and around 0.5 minutes /µm for thick resists. The combination of energy and developing technique can influence the quality of an exposure result strongly. Using too high energy during exposure or using too strong developer makes the developing time very critical, leading to plate-to-plate structure size variations. On the other hand, too low energy or too diluted developer can lead to angled and irregular resist walls, causing bad line width stability and rough pattern edges. The best combination of exposure parameters and processing procedure for a specific application has to be found by series of test exposures.

- **Hardbake:** A hardbake can serve to better prepare the remaining resist layer for the next processing step by hardening it. On the down side, it can round sharp resist edges and lead to rifts in the resist layer. Again, it depends on application and resist if a hardbake is required and recommendable, and how it should be done. Please refer to the resist manufacturer's documentation concerning this.

- **Etching:** In 2D masks, the next step is to etch away the metal layer wherever it is accessible. This copies the design from the resist layer into the metal layer, creating a mask for further copies of the design onto other substrates with the help of e.g., flashes from a mercury vapor lamp. There are different methods of etching. The most common one is wet etching, where the developed substrate, after thorough rinsing, is put into a bath of etch. Etching time depends on the metal layer thickness and the etchant age (etch usually can be reused many times until it is saturated). If etching is done too short, small structures are not opened, or have irregular edges. If the substrate stays in the etcher too long, the so called 'under-etching' can happen, where the etch reaches under the resist, causing irregular edges and bad line width stability.

- **Stripping:** After etching and rinsing, the remaining resist is removed. This can be done by use of a solvent or stripper, or by exposing the resist with a UV lamp (for thin layers e.g., a facial tanner can be used for 10 minutes – ½ hour), and using the undiluted developer on it afterwards. To remove any residual resist, Isopropanol can be used for most resist types.

General material recommendations

Developer	TMAH series (metal-ion free), or 351B, for most resists*
rinsing	all rinsing during processing should be done with DI water
stripper	commercial stripper, or concentrated NaOH solution (e.g., undiluted developer) after exposure of the remaining resist with an UV lamp
cleaning	after the processing, chrome substrates can be cleaned using DI water and a mild detergent

*For other resists, refer to resist manufacturer's documentation.

Table 4: Recommended material for each processing step

Standard materials used with the substrates mentioned in *2.7 Choice of Substrate*

Developer	AZ351B / MF351B in 1:4 dilution (1 part developer, 4 parts DI water), alternatively MF319 undiluted
Chrome etcher	Shipley chrome etch 18

Table 5: Materials for standard substrates to meet the system specifications for binary exposures

General advice:

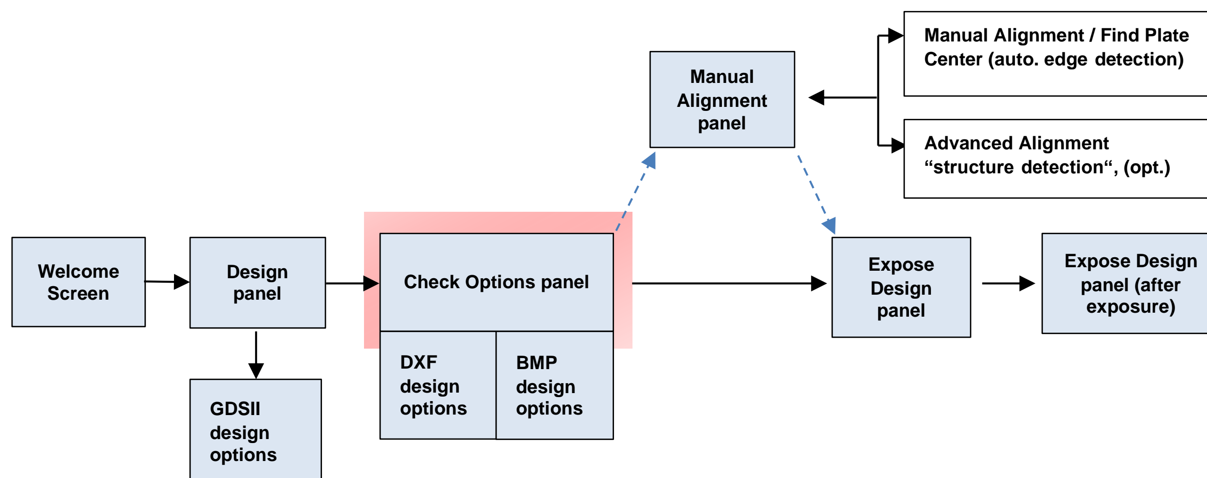
- Never use out-of-date chemicals.
- If a dilution is used as developer, always shake well before use so the heavier parts are well distributed.
- Take care that all materials and tools involved in processing – wipes, trays, sinks, taps, pincers etc. – are always clean.
- Take care that chemicals are not mixed. Always rinse well the substrate and any containers used before proceeding to the next step.
- For dilutions, only use DI water.
- Take care that no air bubbles stay on the substrate when submerging it into a chemical. This is especially critical during etching, where air might be caught in small structures or round holes in the resist, preventing them from being etched into the layer beneath.

3 Advanced Options

In this chapter information on advanced design options and focusing options is given. The previous chapter *2 General Procedures* informs about procedures that are performed for any exposure. In this chapter you find information on options that are only available in advanced exposure mode.

Advanced exposure procedures (alignment, batch) are described in *4 Alignment Methods and Batch Exposures.*

3.1 Advanced Design Options



If you have selected **Show Advanced Options** in the ***Welcome Screen***, a few ***Design Options*** are offered.

In the ***Check Options*** panel, where you adjust the exposure power (*2.9 Energy Settings for Exposure*), you can select **inverted** and deselect **Automatic Centering**. Automatic Centering is selected by default.

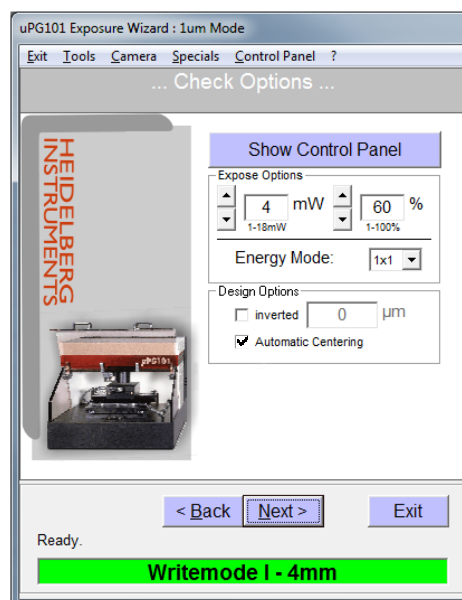


Figure 29: Design Options panel (advanced options)

Inverted

Per default, the structures that were defined in the design are exposed on the substrate. If **inverted** is selected, all areas with no structure defined are exposed instead. The limits of the exposure field are defined by the borders of the outmost structures. If a larger area should be exposed around the structures, a frame has to be defined by entering the required distance from the structures to the edge of the exposed area into the text box (Figure 29). This increases the size of the exposed design and thus also the exposure time. Maximum value for the frame is 10 000 µm (10 mm).

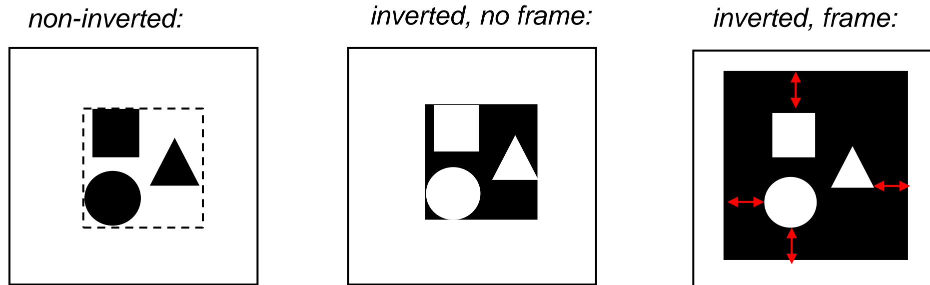


Figure 30: Inverted option

Automatic Centering

With **Automatic Centering** selected, the wizard automatically shifts any design so that the geometrical center is exposed in the center of the substrate, regardless of where the origin is located within the original design. If **Automatic Centering** is deselected, the design is positioned so that the design origin is exposed on the center of the substrate.

Note: Take care that no part of the design is shifted out of the write area.

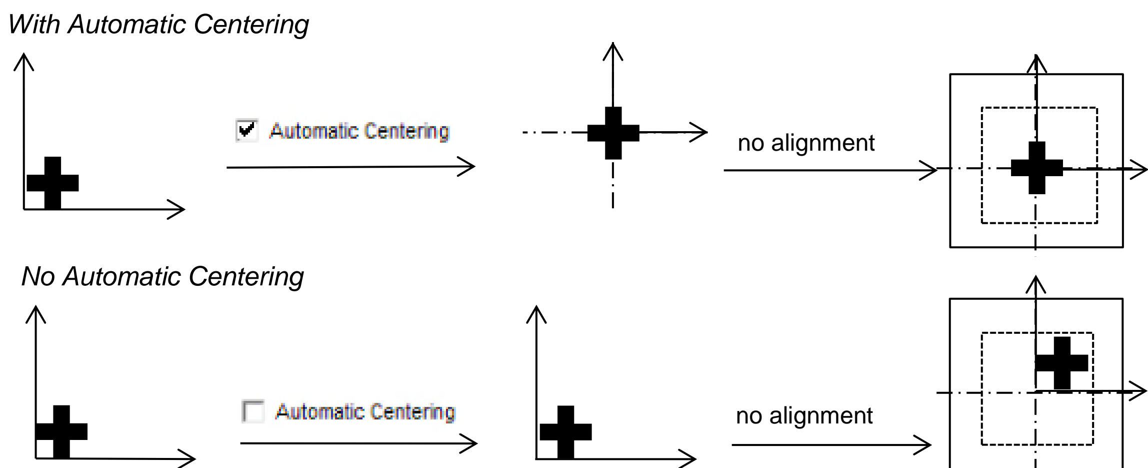


Figure 31: Design positioning with Automatic Centering selected and deselected

3.2 Focusing

The autofocus system makes sure that during focusing the same focus position (the distance between write lens and substrate surface) is reached regardless of substrate thickness. This distance is kept constant throughout the exposure. During focusing, the write head and the write lens are moved (for sketch of write head see Figure 32). The write head movement is provided by a stepper motor. It is moved by increments of 1.25 µm during focusing. The movement of the write lens is given by the piezo which takes over focus fine tuning during focusing and controls the write lens position at all times afterwards to keep the distance to the substrate surface constant.

3.2.1 FOCUSING OPTIONS

Focusing can happen regulated and unregulated. "Regulated" means that movement of the write head and of the write lens is monitored and controlled online and automatically by the autofocus system with respect to a distance measurement signal. When it is "unregulated" the operator controls the movement manually. In figures 33 and 34 you find schematically illustrated the difference between the function of the autofocus modes and the manual mode.

In the ***Control Panel*** window you select the focusing options. It is possible to choose between the pneumatic focusing mode, the optional optical mode and the manual mode. If the machine is not equipped with the optical autofocus, then only the pneumatic mode and the manual mode are available. However, the µPG 101 can be retrofitted with the optical mode (for further information contact Heidelberg Instruments).

Pneumatic (autofocus)
For probing the distance, compressed air passes through the write head and leaves it through a nozzle. Once the write head is close enough to the substrate, a pressure builds up between the nozzle and the substrate. This pressure build-up also increases the pressure within the write head with decreasing distance from the substrate. The pressure within the write head is monitored with a pressure sensor, and the sensor signal is used to regulate the voltage of the piezo that determines the write lens position. This function is only suitable for substrates larger than 1" and exposures performed not closer to the edge than 5mm.

Optical (autofocus)
For probing the focal distance, a laser beam gets reflected by the substrate. The shape of the reflection is measured and converted into a signal which controls and regulates the movement of the piezo.

Manual
In systems without optical autofocus option, the automatic focusing system does not work for substrates smaller than 1”. For exposures on such substrates automatic focusing can be replaced by manual focusing according to camera image. Now the operator controls the write head movement directly. Autofocus is

frozen, the piezo stays in center position plus any adjustments done via the piezo arrows (see *9.2 Control Panel* for details on the control elements).

NOTICE **System can be damaged severely. Manual Mode is only for advanced users.**

- Never let the write head touch the substrate.
- Use this option carefully.

Fixing the focus position: The piezo is the device that controls the write lens position at all times during exposure. It keeps the focal distance to the substrate surface constant, which means that the focal point position is also kept constant (autofocus). However, the distance measurement with pneumatic autofocus does not work close to regions with sudden changes in height e.g., close to the edge.

On the other hand, the optical autofocus can get problems with regions where surface reflectivity changes strongly. Therefore, in both cases results might be improved by freezing the objective position after initial focusing in an unaffected area. Freezing can then be achieved by selecting the **fix** checkbox in the ***Control Panel*** window (see *9.2 Control Panel*). If you choose **manual** (mode), this option is automatically selected and cannot be deselected.

Piezo setpoint adjustment leads to a change of focal point position. It can be necessary e.g., to compensate effects of resist thickness, back reflections or system focus drifts. The position of the write lens which the piezo regulates is changed. The focal point is put into a different position than the resist coating surface. By adjusting the position of the write lens the signal to the piezo is influenced. To find the best focus value for a substrate type, we recommend to run a Focus Series first (see *7 Exposure Optimization Utilities*).

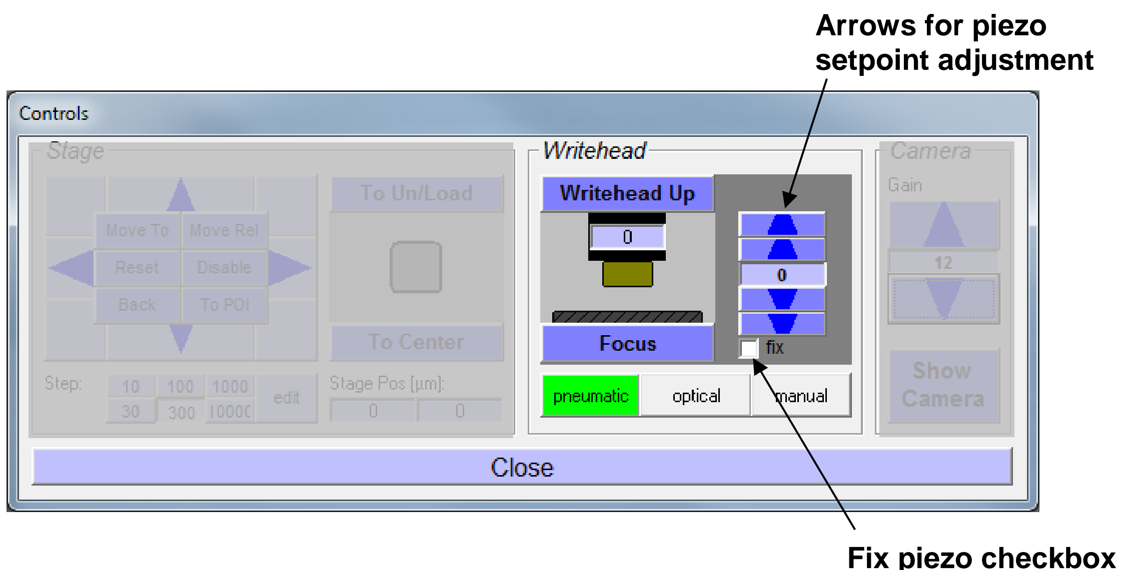
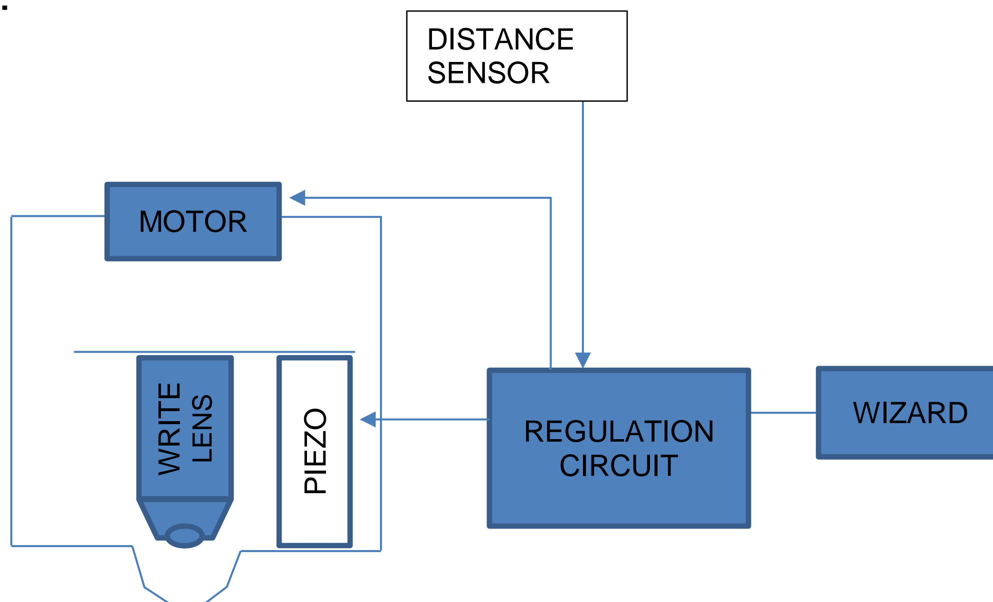


Figure 32: Writehead frame

AUTOFOCUS REGULATED (pneumatic/optical)

Focusing:



Exposure (online regulation):

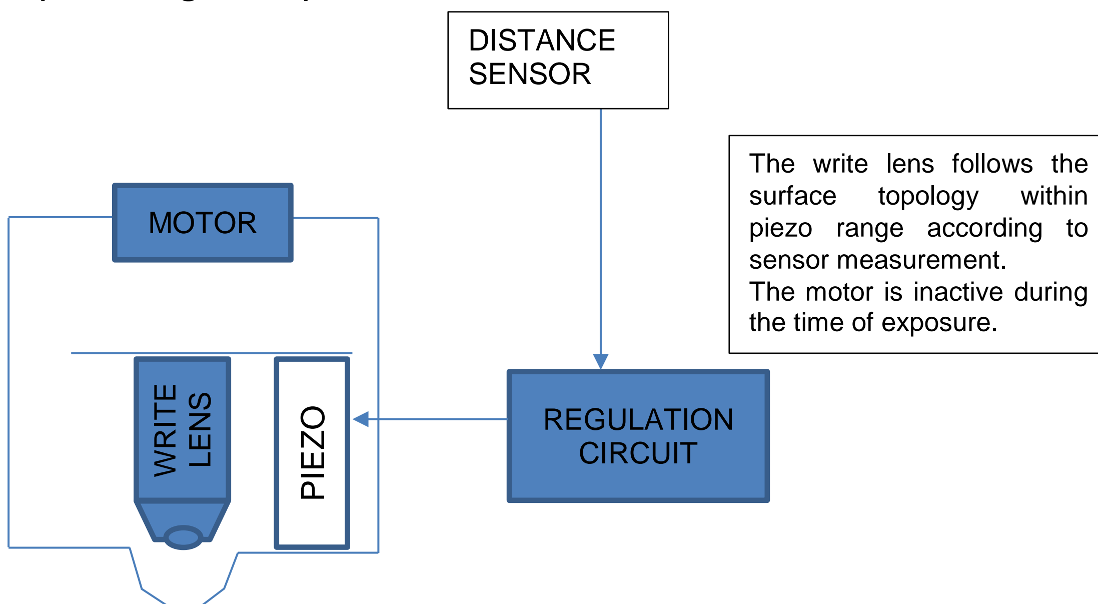
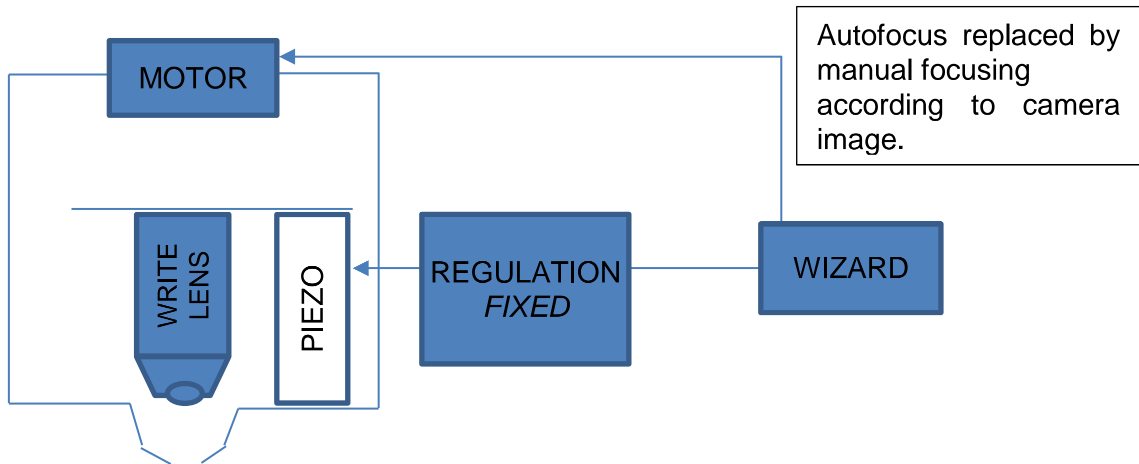


Figure 33: Autofocus function (schematic illustration)

MANUAL

Focusing:



Exposure (no regulation):

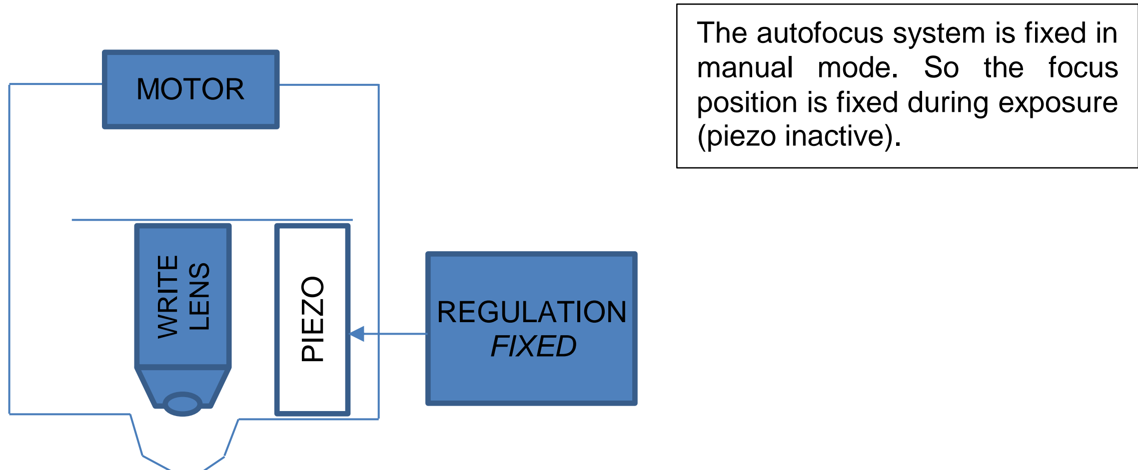
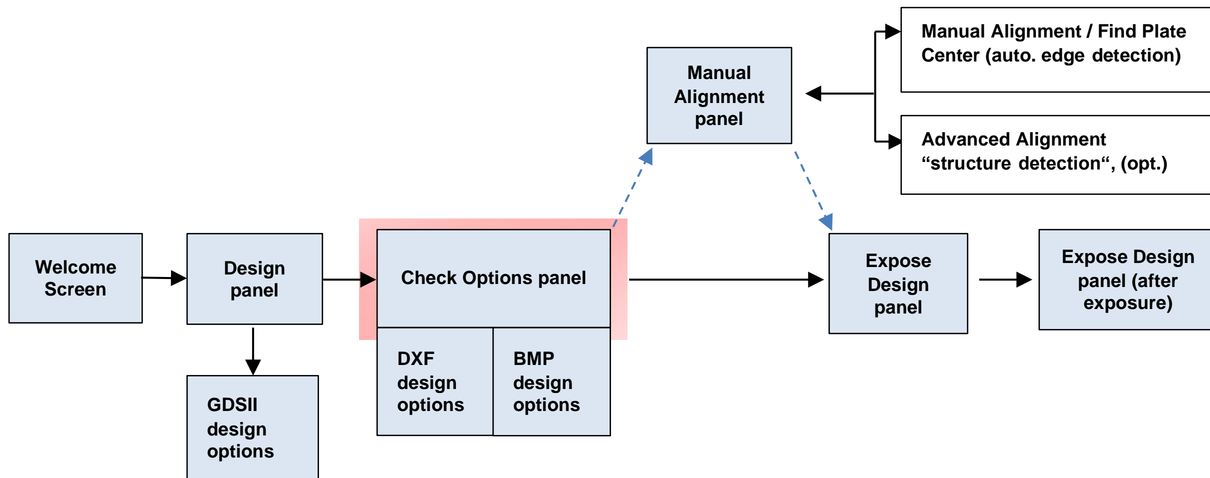
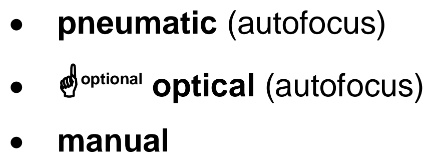


Figure 34: Manual focusing

3.2.2 FOCUSING MODE SELECTION AND SETTINGS



As mentioned before, the focusing mode can be selected in the ***Control Panel*** window. During an exposure job the ***Check Options*** panel features a **Show Control Panel** button that leads you directly to the ***Control Panel*** window. Alternatively the Control Panel window can be reached via **Control Panel** from the menu bar.
As mentioned before (3.2.1 Focusing Options) the available focusing modes are:



- **pneumatic** (autofocus)
- optional **optical** (autofocus)
- **manual**

Note: Switching between focusing modes is only possible while the write head is in retracted position. The focusing mode selection stays until another selection is made, or the wizard is closed. Default focusing mode at startup is pneumatic**.**

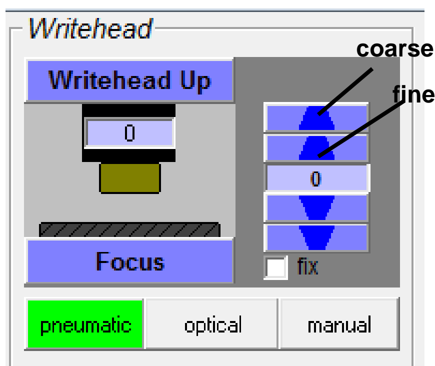
In the following you find instructions on how to use each mode. Manual mode is only for advanced users and should be used carefully. It is very important to attend every notice mentioned in this section.

Steps of Focus Mode Selection and Focusing Procedure

1. Before you select the focusing mode, click **Writehead Up** to bring the write head into its retracted position.
2. In the ***Writehead*** frame of the ***Control Panel*** window select the focusing mode that you require. If you select **manual**, the functions of the ***Writehead*** frame are replaced by arrows for manual control of the piezo and the stepper motor. The autofocus system is disabled.

Autofocus Mode (pneumatic/optical)

3. Click **Focus**. The write lens moves down and the system measures the distance between write lens and substrate. Focusing stops at a certain distance.
4. To adjust the position of the write lens, click on the arrows in the right part of the ***Writehead*** frame.

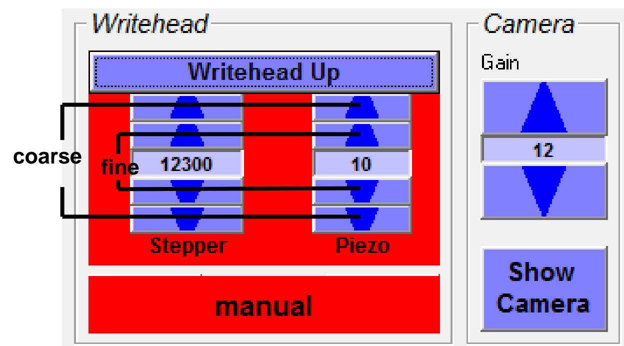


The number between the arrows shows the current position change in arbitrary numbers. The value range is -30 - +30. Coarse movement step is 5 with the outer arrows, fine movement steps with the inner arrows is 1.

This distance is kept constant during all stage movement until the edges of the substrate are reached.

Manual mode

3. If the camera window is not open, click **Show Camera** in the ***Camera*** frame, to open the camera window.



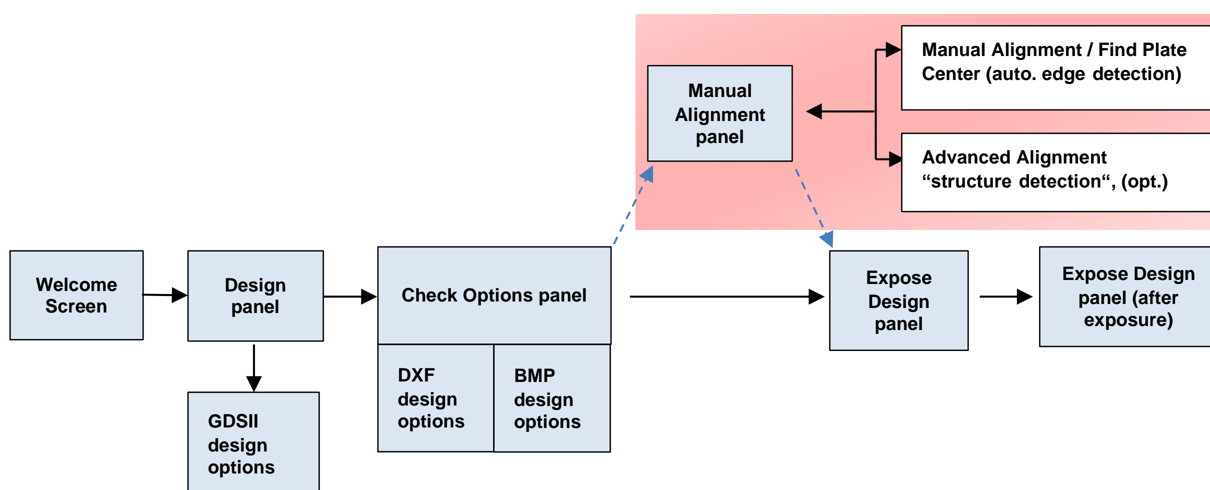
NOTICE

Severe damage to the equipment by improper handling.

- Never let the write head touch the substrate.
- Switch over to fine steps as soon as you see a change in the image (see step 5).
- Monitor the distance also directly on the machine not only via camera image.

4. Use the outer arrows to move down in coarse steps (300). Watch how the substrate comes into focus.
5. As soon as the image starts to change, use the inner arrows for moving down in fine steps (30).
6. When a position close to the focus is reached, use the **Piezo** arrows for fine tuning.

4 Alignment Methods and Batch Exposures



By default, the µPG 101 exposes designs such that the center of the design (usually coincident with the design origin, if recommendations are followed) is exposed to the position where the center of the plate should be, if loading was done properly with respect to the alignment pins.

If a different positioning of the design on the substrate is required, or the positioning against the pins is not precise enough for the application, the design can be shifted by adding or subtracting an offset in x and in y respectively, and/or a rotation angle, if required.

4.1 Alignment Procedure

In advanced mode, after selection of the design options, the wizard proceeds to the ***Manual Alignment*** panel where further alignment methods can be selected.

In the following, you find instructions on the general alignment procedure. You can also continue without selecting any of the methods. If you just need your design to be stepped several times on the substrate, you can set the parameters for a batch exposure here.

1. In the ***Manual Alignment*** panel, select the alignment method of your choice (Figure 35) or proceed to step 5 to set up a batch exposure. For information on the methods see the following sections in this chapter.
2. Now, content of the window changes and you can see the panel for the alignment method you selected in step 1. Follow the instructions given on-screen or in this chapter.
3. Confirm the alignment results. You are now lead back to the alignment method selection panel in the ***Manual Alignment*** window. After alignment has been executed, you can see the results in the ***Offsets and Rotation*** frame
4. If required, modify the alignment results.
5. If the same design should be stepped on the substrate several times, click **Create Batch** (see *4.3 Batch Exposures*).
6. Click **Next** to continue.

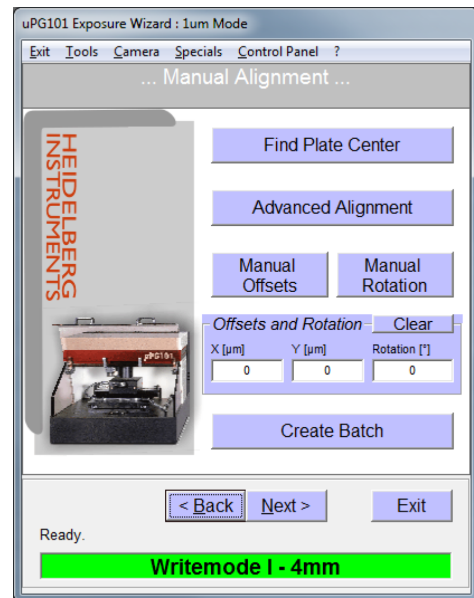


Figure 35: Manual Alignment window (advanced mode)

Note: If a new method is used, the previous result is dismissed automatically. To combine two methods of alignment (like, manually adding a manual offset after a **Find Plate Center** routine), it is therefore necessary to note down the previous result and add it to the next modification that is required.

4.2 Available Alignment Methods

The following diagram shows the available alignment methods:

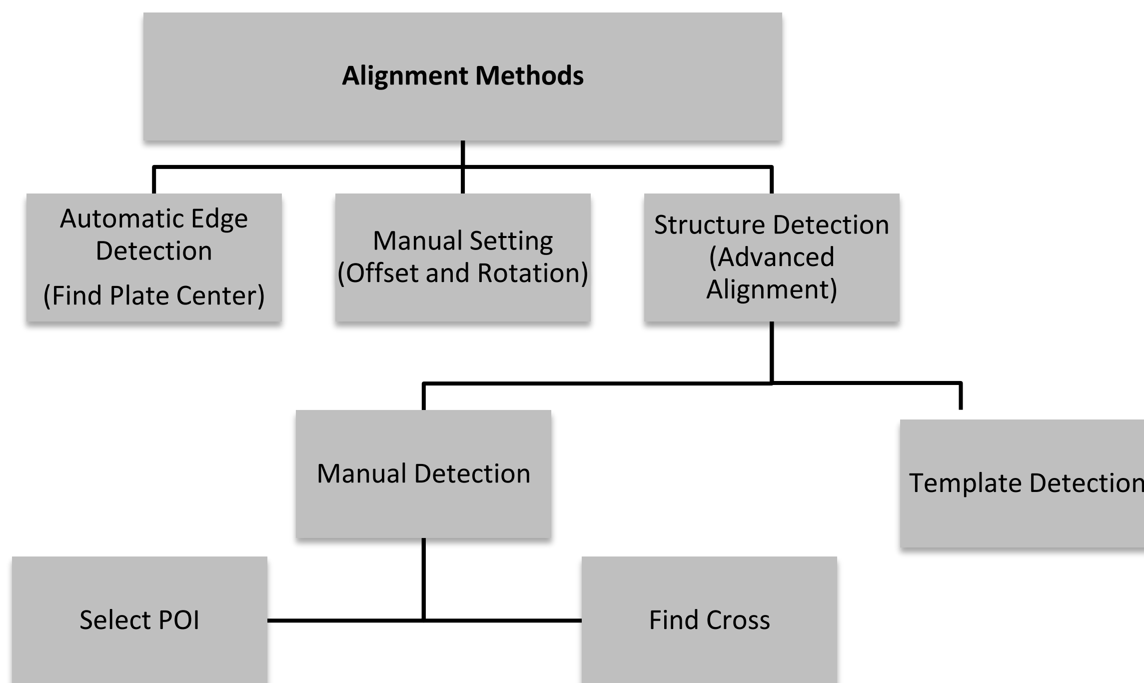


Figure 36: Overview of the available alignment methods

Note: Alignment methods cannot be combined. Whenever a new method is started, the previous result is discarded.

Note: For a precise positioning of a design with respect to existing structures (structure detection methods), it is important that the **Laser Offset Calibration** and the **Camera Calibration** are correct. If you encounter a systematic shift in exposures with alignment to existing structures, perform the calibrations as explained in *8 Calibration Procedures*.

In the ***Manual Alignment*** panel, several functions are offered to set shifts and rotation angles for the design. Shifts and rotations can be performed either manually or according to measurement (Figure 37). From this window you select the required alignment method.

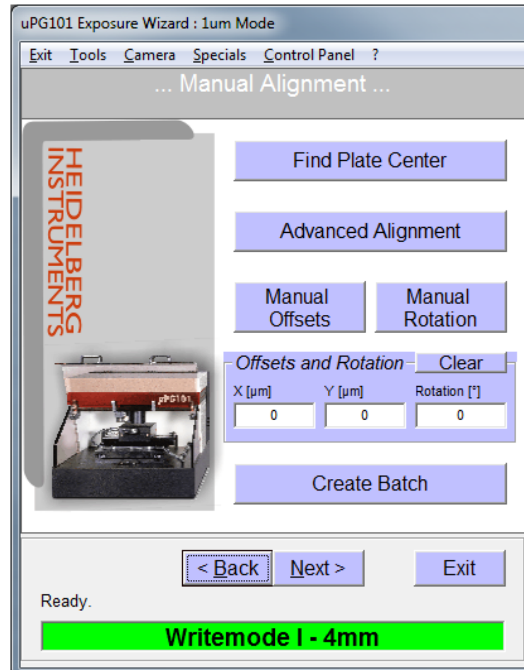


Figure 37: Manual Alignment window (advanced exposure mode)

4.2.1 AUTOMATIC EDGE DETECTION

If the design should be exposed at the center of an unstructured substrate, but with a higher precision than the mechanical alignment pins allow, the **Find Plate Center** function can be used. When it is started, the positions of all four edges are detected with the autofocus system. From these, the position of the center of the plate is calculated. All measurement results are shown. To accept them click **OK**. The substrate center coordinates are transferred as offset to the ***Offsets and Rotation*** frame. An additional design offset can be added by entering modified numbers via the **Manual Offsets** control before continuing to the exposure panel.

Note: The **Find Plate Center** function does only work for substrates up to 5" x 5". It does not work for wafers.

4.2.2 MANUAL SETTING

With the controls **Manual Offsets** and **Manual Rotation**, it is possible to directly enter values by which the design should be shifted and/or rotated during exposure preparation. A rotation angle of up to 360° is possible!

4.2.3 ALIGNMENT TO MEASURED STRUCTURE POSITIONS

The **Advanced Alignment** option gives access to tools that can be used to run an alignment sequence for manual or template detection of alignment structures on the substrate. ***Offsets*** as well as ***Rotation*** (if multipoint alignment is used) are calculated from the results of the alignment mark measurement and transferred to match the design to the real substrate position.

Note: For designs in bitmap (BMP) format, no rotational alignment is possible.

Manual measurement of alignment structure positions can be done either by semi-automatic detection of a cross (Find Cross), which gives the highest precision, or by pointing at the structure (POI). The structures have to comply with the following rules:

Find Cross:

- If you use a cross for alignment with the automatic cross detection method, it has to be bigger than the camera image field so the bars touch the borders even if it is not positioned in the very center. The bars should not be thicker than a quarter of the image field height.
- Make sure that there are no further lines located in the image field.

POI:

- Exact coordinates have to be known for a point of the structure that can be precisely marked with a crosshair (e.g., center of a cross with narrow lines, corner of an L-shape or square).

Template detection of alignment structures is done via comparison of the contents of the camera image field with a predefined sample image of the structure (alignment mark template). It gives a more precise and repeatable result than manual detection with POI method and does not require a cross. For template detection, each structure used as alignment mark has to fulfill certain properties:

- The structure should be simple (recommended: cross, L-shape, or square)
- The structure size has to be at least :

	WM I	**WM II**	**WM III**
Size	8 µm	20 µm	40 µm

Table 6: Minimum structure sizes for template alignment

- No similar structures may be within or close to the image field:

	WM I	**WM II**	**WM III**
Size	~180 x 115 µm	~450 x 285 µm	~900 x 570 µm

Table 7: Image field sizes per write mode

- If you use two structures, they should be as far apart from each other as possible to increase accuracy of the angular error detection. Different structures can be used for the two marks
- Exact coordinates have to be known for a point of the structure that can be precisely marked with a crosshair (e.g., center of a cross with narrow lines, corner of an L-shape or square).

In the following you find instructions on the set up of a new alignment sequence:

1. In the ***Manual Alignment*** panel, click **Advanced Alignment** (Figure 37). The ***Setup Automatic Alignment*** panel opens (Figure 38).
2. Select **Mark 1**. Click **Pos** to enter the design position of the (first) alignment mark with respect to the substrate center. *Do not enter the real position value, as otherwise the shift correction will not work.*

   If no template was created, the template image box shows only the word **manual**. In this state, the position of the alignment structure has to be marked manually once the alignment routine is run, or it can be detected with a cross detection routine if it is a cross.

Figure 38: Advanced alignment setup window

3. If manual or cross detection should be used, proceed to step 9.
4. If the position of the structure should be detected by template detection, click **Create** below the template image box. The stage moves to the theoretical mark position, the ***Camera Window (HIVision)*** opens.
5. If the alignment mark is not within the field of view, or the image in the camera does not have a good contrast, click **Show Control Panel** to move to the mark or to adjust camera settings (see *9.2 Control Panel).*

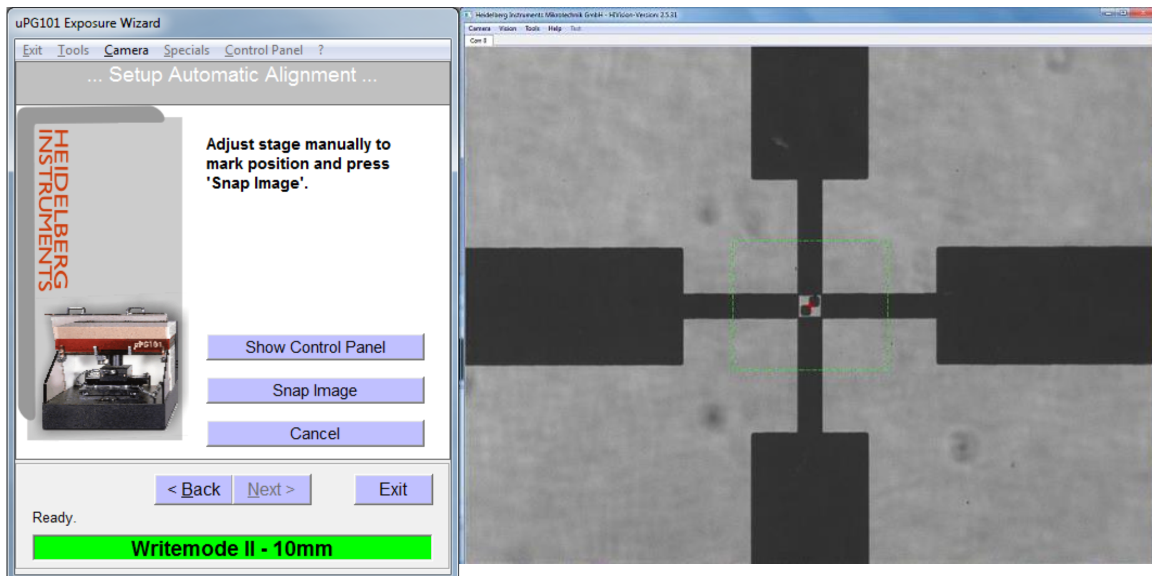


Figure 39: Camera image window (HIVision)

6. When the mark is in good view, click **Snap Image** (Figure 39). A box with a red cross in the center appears in the ***Camera*** window. Drag the red cross to the

location of the alignment structure. Resize the box by dragging the small blue squares so that the part of the structure that is inside is well recognizable.

Note: The box should be as small as possible. If the structure is bigger than 1/3 of the image field in any dimension, only a characteristic and singular part of it should be selected.

7. Now, drag the red center cross as precisely as possible to that point of the structure that corresponds to the previously entered coordinates. The position of this small cross defines the later alignment position. Therefore, accurate positioning of the cross on that point in the structure of which the coordinates are known is important:

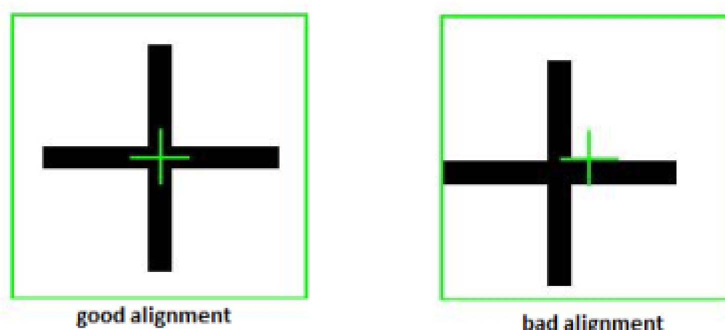


Figure 40: Examples for good and bad positioning of the template selection box

8. Confirm the position with a middle-click (= scroll wheel). The window content returns to the ***Setup Automatic Alignment*** panel and a thumbnail of the selected image is now visible in the template frame of Mark 1.

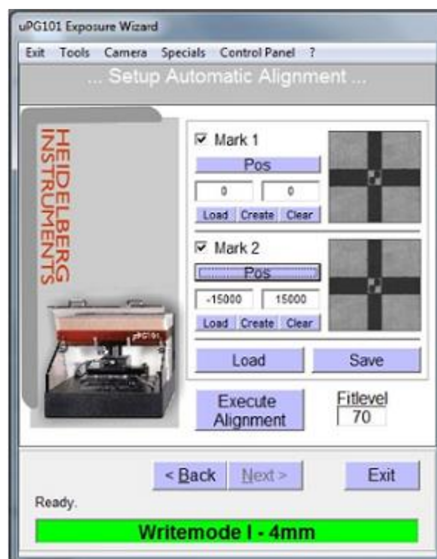


Figure 41: Advanced alignment setup example

9. If a second alignment mark should be defined, select the **Mark 2** checkbox. Click **Pos** to enter the design position of the second alignment mark with respect to the plate center.

10. If a template should be used for detection of this structure, follow the instructions given in steps 4 - 8 also for this mark.
11. You can save the alignment routine by clicking **Save**. To reload the alignment routine during another job run, click **Load**. However, especially if substrates have a thick resist coating, it is not sure that the routine will work as well on the next plate.
12. Click **Execute Alignment**.

    Now the alignment procedure runs in the predefined way (a or b):

    a. It prompts the operator to manually point to each mark/run the cross detection routine.

    b. It detects the marks automatically using the predefined templates.

a. **Manual Detection:** The panel changes to show the controls necessary for manual marking of the point of interest.

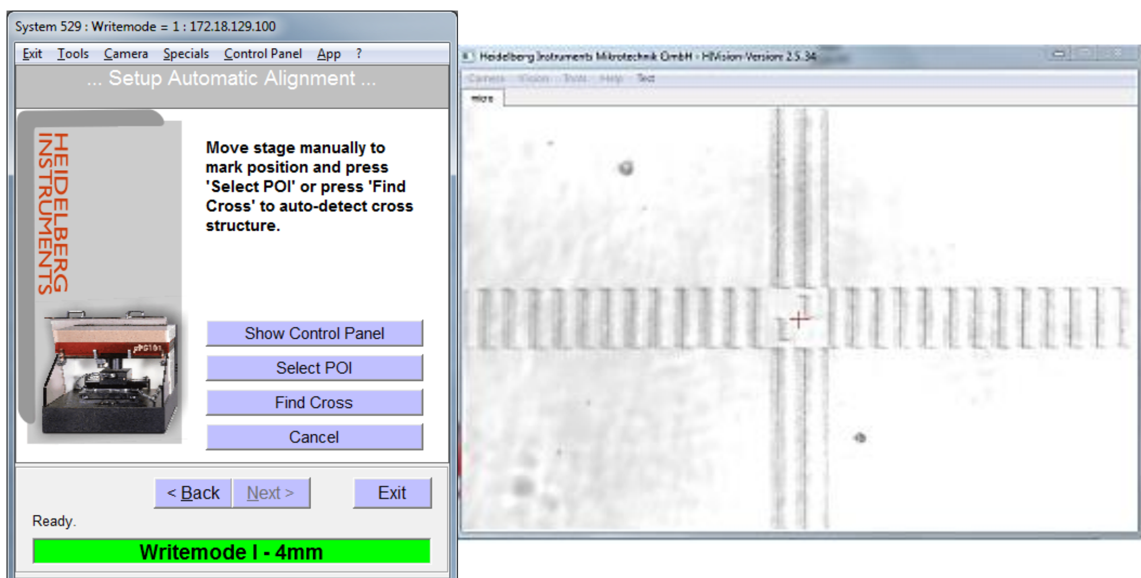


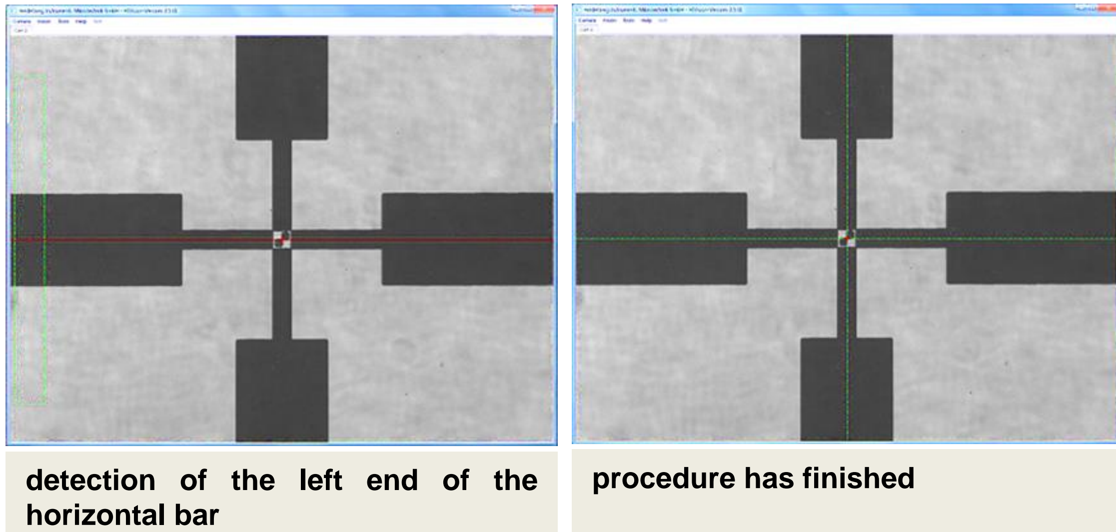
Figure 42: Setup panel of manual mode (advanced alignment sequence)

If the alignment mark is not within the field of view, or the image in the camera does not have a good contrast, use the **Show Control Panel** button to open the ***Control Panel*** window and move to the structure / adjust camera setting (detailed information on **Control Panel** window in *9.2 Control Panel).*

Select POI: For a purely manual detection, click **Select POI.** A cross-hair appears in the camera window. With the mouse, drag the crosshair center to the position in the camera image where the alignment mark coordinates should be set (e.g., on the structure center). Confirm by middle-clicking (= middle button or scroll wheel).

Find Cross: Alternatively, click **Find Cross**. The automatic cross detection routine runs and tries to find a cross structure in the image field.

In camera view, no further lines but only one horizontal and one vertical line should be visible for successful outcome of the Find Cross procedure. This procedure tries to detect four independent center positions of line fragments located at left, right, top and bottom of camera view.



detection of the left end of the horizontal bar	procedure has finished

Figure 43: Find Cross procedure

After correlating results, the stage moves the calculated center point of the cross into the center of the camera image. The procedure is repeated and will loop until the cross center position is confirmed by the next Find Cross run (without change of position). The procedure stops if no clear cross center position is identified after several runs. If the procedure is successful, a large cross-hair shows where the cross was detected and the system asks the operator to confirm the position with a middle-click on the mouse (= scroll wheel).

b. **Template detection:** During template detection, the ***Registration*** window shows the current status and results (Figure 44). In the camera window, a representation of the selection box pops up when the system has detected a matching structure. Watch these to be sure the correct structure was detected.

Failure: If automatic detection fails two times, the panel changes to alignment error handling state. This panel gives the option to open the ***Control Panel*** with **Show Control Panel**, move the structure into better view or improve camera settings and **Retry Search** afterwards (or directly, without modifications). Alternatively, the alignment sequence can be stopped by clicking **Cancel**.

Upon return to the initial state of the ***Setup Automatic Alignment*** panel, the fit level can be adjusted to a lower value for another try. However, the lower the fit level, the higher the probability that the structure is detected in a wrong position. If alignment still does not work properly, click **Cancel** and remove the templates from the routine by clicking **Clear** under each thumbnail and use manual detection, or click **Cancel** and **Back** and select an entirely different alignment method.

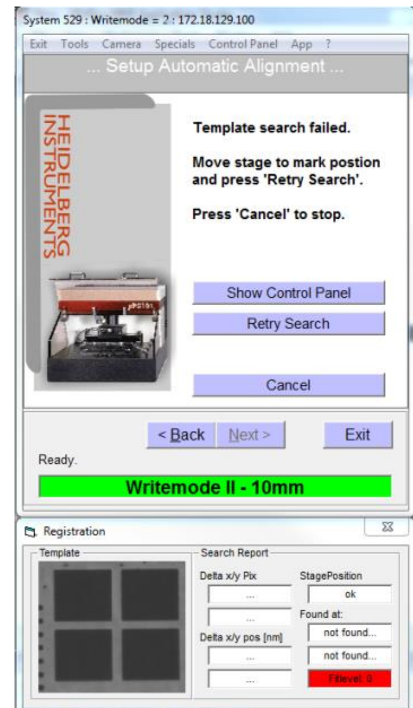


Figure 44: Template detection error handling

13. Once an alignment sequence has run successfully, the results for shift and rotation are shown in a dialog window. Click **OK** to confirm. The ***Setup Automatic Alignment*** panel closes and the wizard returns to the ***Manual Alignment*** window.

4.3 Batch Exposures

In advanced mode it is possible to step the same design on the substrate several times.

1. To open the editor, click ***Create Batch***. In the ***Expose Design*** panel the ***Step and Repeat*** frame appears. The **Step And Repeat** function allows the exposure of the same design several times in a X-Y-array.
2. Select the number of repeats in x and in y direction and the gap between the design borders.
3. Click **Create** and check the table.
4. To activate the exposure batch, confirm with **OK**. Now, the editor closes. If later on you click **Expose** in the ***Expose Design*** panel (see *5 Exposures*), the complete batch is executed

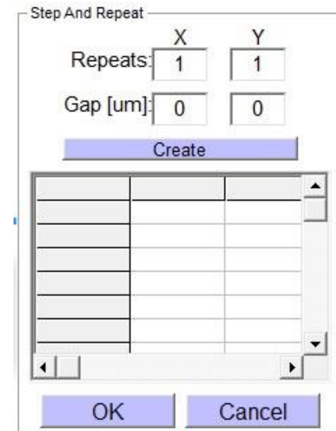


Figure 45: Step and Repeat frame

The batch function uses the positioning information from the ***Offsets & Rotation*** frame of the ***Manual Alignment*** panel, or X=0, Y=0 without alignment, for placing the designs on the substrate. The designs are arranged around this position (see examples).

Note: Be aware of the limits of the possible exposure area of 5" x 5".

Examples:

- You see a 3x3 array (Figure 46). In the centered field (field No. 5) of the array the design is exposed on the position that you have determined by manual alignment (0,0 without any alignment data given). The other fields with the design are arranged around the center field in a positive or negative XY- offset position relative to the center field.

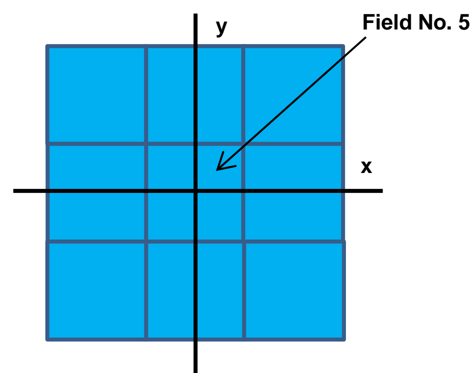


Figure 46: Position of 3x3 array

- You see a 2x2 array (Figure 47). The four designs with a supposed size of 2x2 mm (2000x2000µm) are arranged around the determined position (or 0,0 without alignment). Without leaving any gaps you get the following coordinate pairs
(X/Y): (1/1); (1/-1); (-1/1);(-1/-1) .

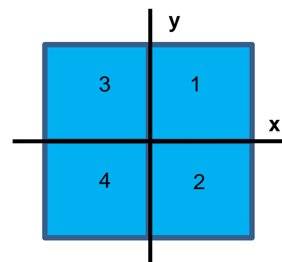
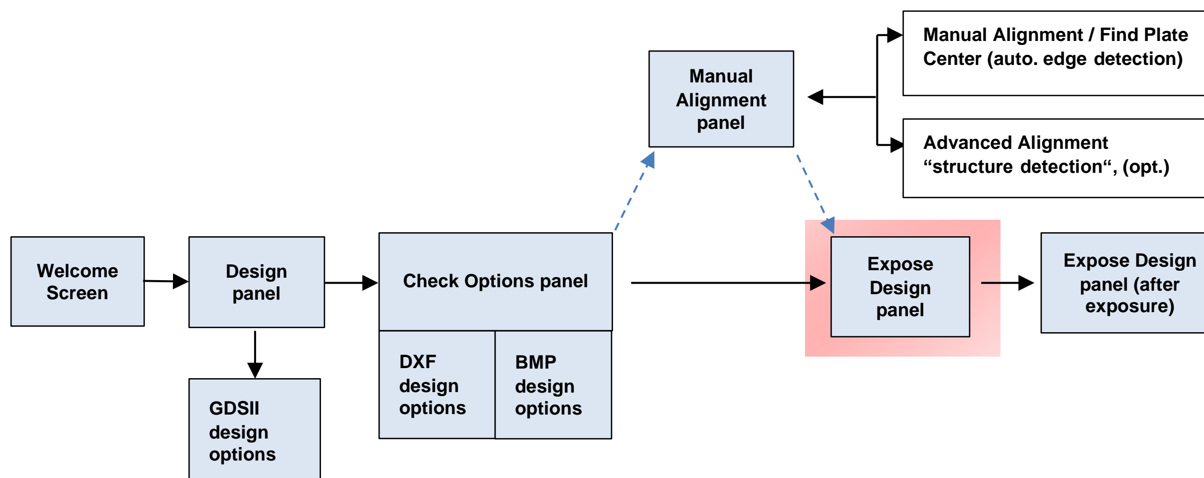


Figure 47: Position of 2x2 array

5 Exposures

In this chapter you find information and instructions on the exposure procedure.

5.1 Exposure Procedure



After you have set the exposure settings for standard or advanced mode (see *2.9 Energy Settings for Exposure)*, the exposure procedure begins. If you have not selected **Show Advanced Options** in the ***Welcome Screen,*** you are in the standard exposure mode. In this method, the accuracy of positioning is given by the repeatability of loading against the alignment pins.

To place the design more freely and with higher accuracy on the substrate, the advanced exposure mode (**Show Advanced Options** selected) offers further alignment methods (see *4 Alignment Methods and Batch Exposures*).

In standard mode, after the setting of the design options, the wizard proceeds directly to the ***Expose Design*** panel.

In advanced mode, alignment options can be selected first (see *4 Alignment Methods and Batch Exposures*). In the ***Expose Design*** panel all options and parameters are displayed for crosscheck (Figure 48).

In the following instructions on the exposure procedure are valid for both modes.

Steps of the Exposure Procedure

1. Check if exposure paramters are correct and select options:
   - **Auto Unload after Exposure**: Once the exposure has finished, the system automatically moves into the position for unloading.
   - **Uni-Directional Mode:** Generally, the µPG 101 exposes in bi-directional mode, which means that the stage travels back and forth, and data is written during each pass. In uni-directional mode, data is written only during forward movement. This leads to a better stability, which is especially interesting for critical structures close to the resolution limit, and 3D exposures. Uni-directional mode results in a longer exposure time (exact increase depends on design size and write mode).
2. After you have selected the required options, check if the cover lid (1) is closed and the interlock lamp (7) is off.
3. Make sure that no alignment pins are left on the stage chuck.
4. Check if the selected write mode corresponds to the write head that is mounted on the system.
5. To start the exposure, click **Expose** (Figure 48).
6. You can see the exposure status in the window (Figure 49). To interrupt an exposure, click **ABORT!**.

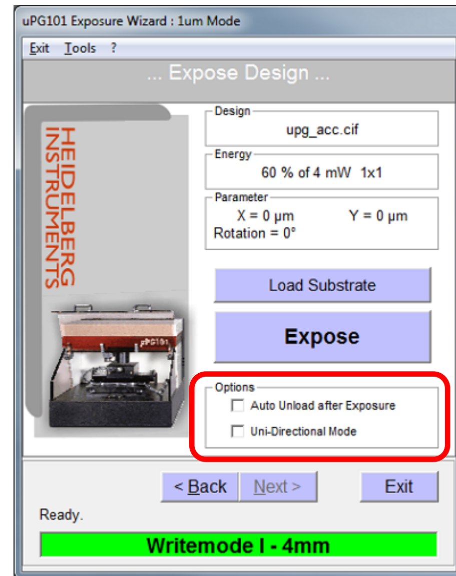


Figure 48: Expose Design panel

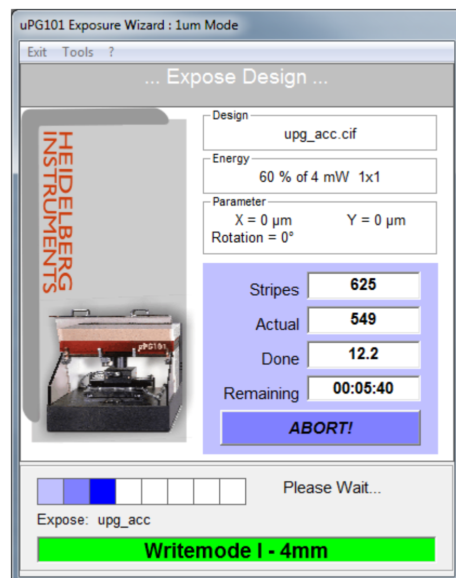
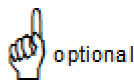


Figure 49: Expose Design panel with exposure status

Note: Make sure that during the complete exposure time the cover lid stays closed, and no white light is switched on. In addition, to get best results, avoid vibrations caused by people passing by or heavy loads being moved on the floor close to the system.

The content of the task panel changes again when the exposure is finished. You can continue with unloading the substrate. For instructions refer to *2.10 Substrate Unloading*.



6 Grayscale Exposures

Grayscale exposures can only be done with BMP format designs (for instructions on how to create a design refer to the related document ***Design Guide***). For 3D resist structuring, we recommend one of the following photoresist coatings:

Recommended photoresist coatings for 3D resist structuring:

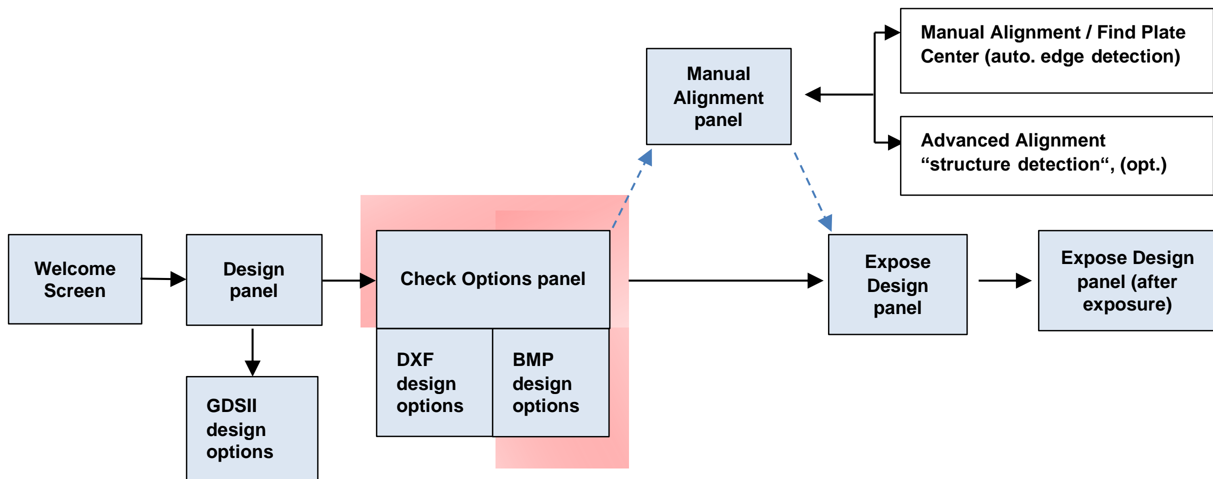
AZ45XX	A Clariant resist family for standard resolution quality. AZ4562 can be coated to thickness of ~6 µm (exact number depends on coating process), other resists of this family are available for other thickness.
AZ92XX	Another Clariant resist family with higher resolution quality, usable also with higher thickness (~10 µm). For high resolution 3D exposures in 6 µm thick resist, AZ9260 is recommended. For thicker resist layers, other members of this family may be used.
SU-8	A negative photoresist that requires **UV option**

Table 8: Photoresist coatings for 3D structuring

In standard lithography the exposed areas of the resist have to be completely cleared during developing. Remaining resist areas should have a rectangular cross-section with steep sidewalls.
In grayscale exposures gradients of the exposure dose are transferred into a certain resist topography during developing. The surface of the resist is in this way modelled by a lateral variation of the exposure dose.

In principle, gray scale exposures can be done in the same way as usual exposures. However, due to the limits in positioning accuracy especially stripe connections might exhibit increased surface roughness. Each design is written stripe wise, putting together stripes of 8 pixel width each. If position coordinates have drifted slightly between one stripe and the next this may already be visible in gray value exposures even if it does not show in 2D. To overcome this, an overlap mode is offered.

In overlap mode, multiple low power exposures of the design are added on top of each other with a different stripe connection position. In this way, the stripe connections get evened out by the subsequent exposures.



In the ***Design*** panel, if a BMP design was selected, a frame for selection of grayscale options is visible (Figure 50). In this ***Grayscale Options*** frame, the overlap function can be set and the modification of gray values can be done.

The **Overlap Factor** defines the number of stripes that overlap. Factor 1 means no overlap. By choosing factor 2 or 4, the surface roughness after exposure and development will be reduced, but also the time of exposure is extended by factor 2 or 4 (Figures 51 and 52).

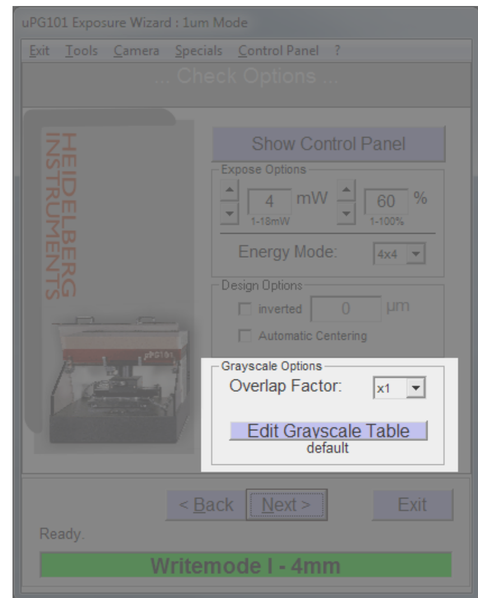


Figure 50: BMP grayscale options frame

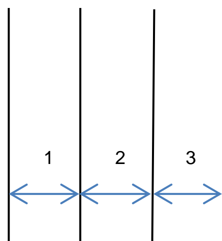


Figure 51: No overlap (x1)

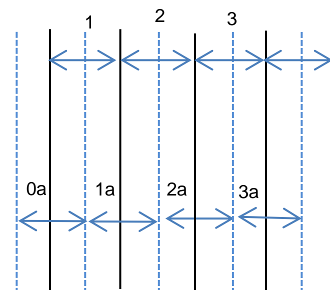


Figure 52: Overlap factor x2

Edit Grayscale Table: Here each single design grayscale level can be redirected to any other individual exposure gray level value provided by the system. In the example table (Figure 53), grayscale level 50 is redirected to exposure gray level 75. This can be used to compensate for thresholds and non-linearity in the resist, or to remove interpolation effects in a design.

The maximum pixel output level (= exposure gray level) is 100. All values higher than 100 are treated the same as 100.

Figure 54 shows an example of exposure results in a resist with non-linear response, without modification of the grayscale table. The intensity is the pixel output level. The depth of the exposure changes with modification of the intensity.

Figure 55 shows a corresponding example with a modified grayscale table. The non-linear response is compensated by the modification, leading to a linear correlation between design grayscale level and exposure depth.

After you have edited the value(s) in the grayscale table, click **Save** and then click **Continue**. The modified table is temporarily saved for the next grayscale exposure.

Note: The modified data in the grayscale table is saved but cannot be uploaded again for the next grayscale exposure. The values have to be entered again manually.

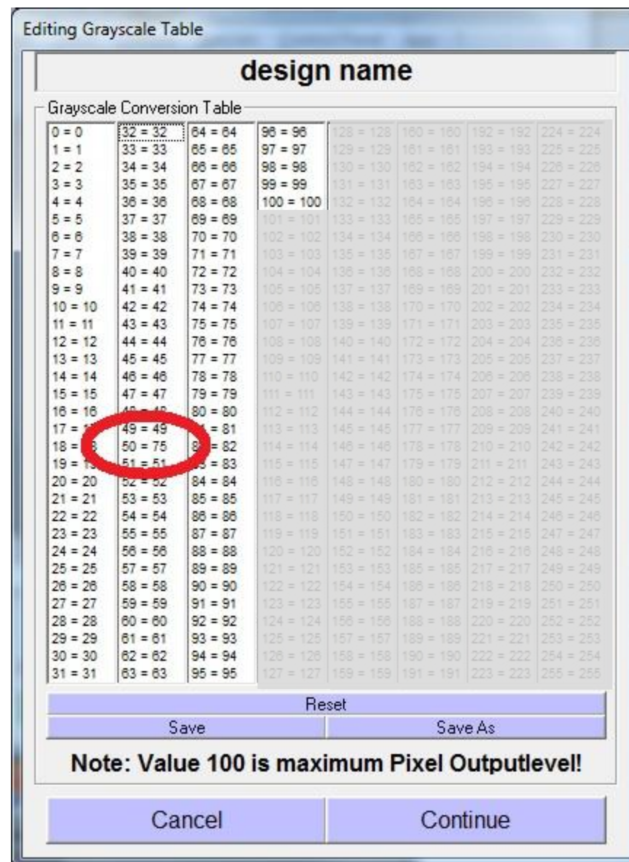


Figure 53: BMP grayscale table editing window

Examples of a standard grayscale table and a modified grayscale table:

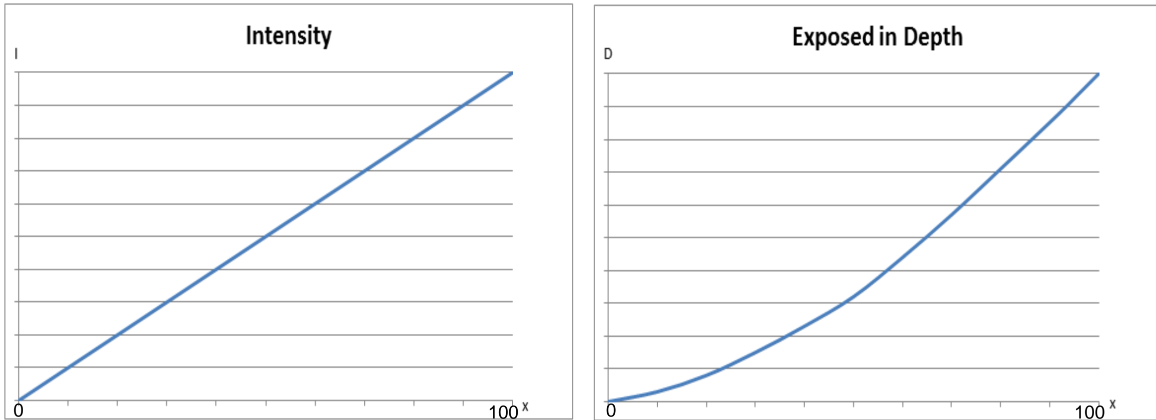


Figure 54: Standard table (intensity and exposed depth without compensation)*

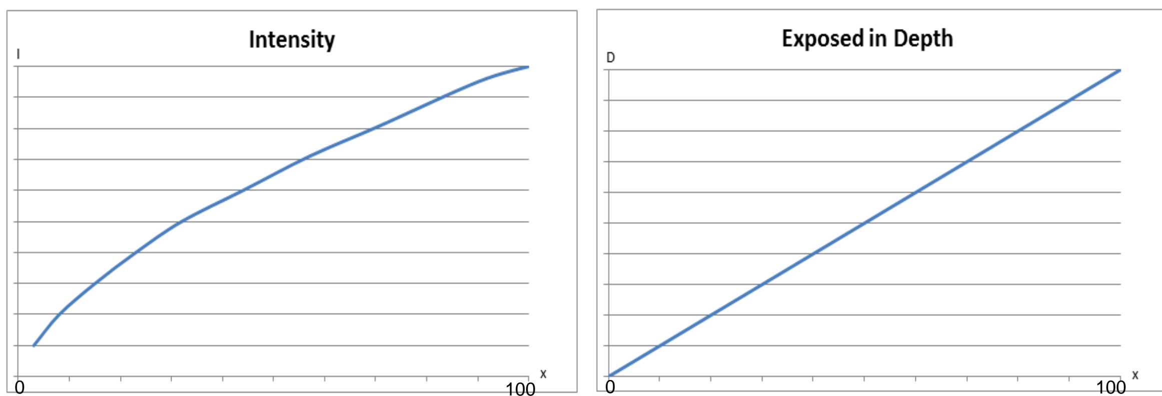


*Figure 55: Modified table (intensity and exposed depth with compensation *)*

*x = design grayscale level

After the exposure is done, process the substrate according to the instructions given in *2.11Substrate Processing.* For grayscale exposures the table below gives information about the required type of developer.

Resist Type	Developer
AZ92XX **AZ45XX**	AZ400K in a 1:3.5 ... 1:5 dilution (depends on application)
SU-8	SU-8 developer

Table 9: Standard materials for substrate processing

7 Exposure Optimization Utilities

This chapter introduces features for advanced users to help finding optimum exposure conditions. It assumes a good knowledge of the instructions given in the previous chapters.

7.1 Energy Series

For optimum exposure results, the correct energy for a substrate has to be determined. Necessary exposure energies depend on type and thickness of the photosensitive coating, reflectivity of the substrate, and the developing process. All these parameters have to be determined according to the intended application. For more information on choice of substrate types and processing, please refer to the corresponding sections in this manual (*2.7 Choice of Substrate, 2.11Substrate Processing*) and publications on photolithography.

To avoid having to do many single exposures with manually changed energies, use the Expose Energy Series procedure:

Steps of an Energy Series Procedure

1. Open the **Tools** menu and click **Expose Energy Series**. A window opens, where the series can be configured.
2. Select the basic energy settings. The laser power range is noted below the input field. In addition, the lowest pixel pulse duration used in a series can be selected. After having set the laser power it is fixed whereas the pixel pulse duration is varied throughout the series (see *2.9 Energy Settings for Exposure* for more information). In addition, with the **Energy Factor** dropdown list, there is the possibility of reducing the speed at which the system exposes. The exposure time for the area is increased and the energy per spot deposited on the substrate is higher.
3. Choose whether to expose a wide range energy series or a small one:
   - The ***coarse*** energy series exposes 10 fields from 10% until 100% pixel pulse duration, with steps of 10%. It is recommended to execute a coarse series first.

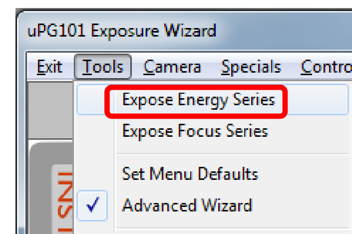


Figure 56: Menu item Energy Series

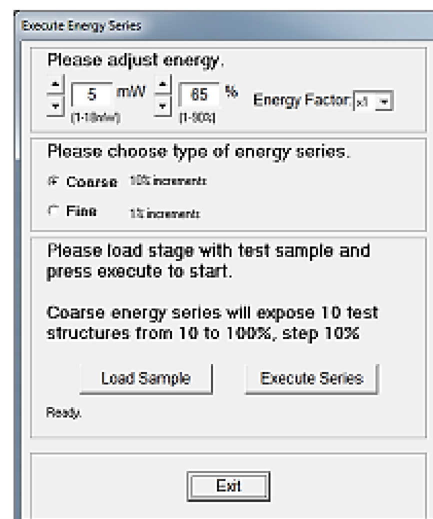


Figure 57: Energy Series window

- At the ***fine*** series, exposures start with the pixel pulse duration entered in step 2. With increments of +1%, 11 exposures will cover a smaller but finer area of exposure energy. It is recommended to use this option, if a coarse series was executed before and approximated energy was already determined.

4. Check the chosen settings displayed in the window.
5. Click **Load Sample** to load a substrate in the center position of the stage (follow the instructions given in *2.8 Substrate Loading* for standard mode). The size of the substrate should be at least 1x1 inch. The wizard guides you through the steps.
6. When the loading process has finished, click **Execute Series** to start the test exposure. Now, the standard µPG performance test pattern is exposed in a column of 10 fields (coarse series) or 11fields (fine series). Each of these fields is exposed with different pixel pulse duration, resulting in a different energy. The highest energy is at the top ('right' in stage coordinate system), the lowest at the bottom ('left' in stage coordinate system).
7. Once the series has been finished, unload the test sample and examine the exposures to determine the best energy.
8. To close the window, click **Exit**.

7.2 Focus Series

In a similar way as for the energy, the best position of the write spot focus can be determined by executing an exposure series (only useful in WM I and WM II).

To avoid having to do many single exposures with manual changes, a procedure for this is offered in the wizard:

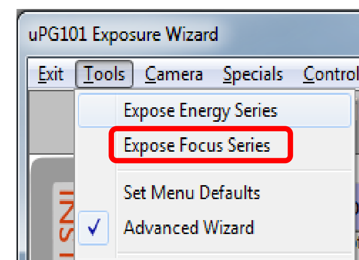


Figure 58: Menu item Focus Series

Steps of a Focus Series Procedure

1. Open the **Tools** menu and select **Expose Focus Series**. A window similar to the one for energy series opens.
2. Enter the usual exposure energy used for that kind of substrate into the top part of the window (see *7.1 Energy Series*, step 2 for explanation of the energy settings).
3. Choose which type of series should be run:
   - A ***coarse*** focus series will run an exposure series through the full value range of 0 – 40, with a change of focus value of 4 between the steps.

- If ***fine*** is selected, a starting value (lowest value) has to be entered into the input box, and 11 fields will be exposed with a change of focus value between the exposures of +1. This series should be run if a coarse test has already been done, and a rough value is known. It tests in a smaller range, but with more precision.

4. Check the chosen settings displayed in the window.
5. Click **Load Sample** to load a substrate on the stage (follow the instructions given in *2.8 Substrate Loading*). The wizard guides you through the steps.

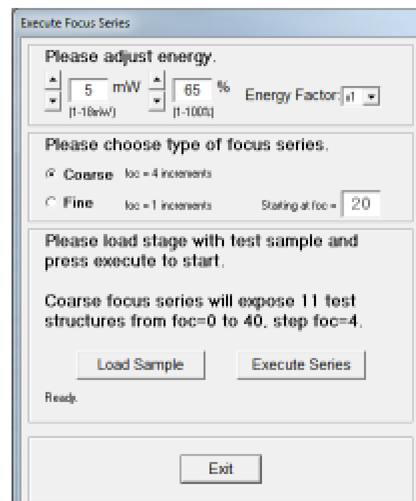


Figure 59: Focus Series window

6. When the loading process has finished, click **Execute Series** to start the exposure series. Now, the standard µPG performance test pattern is exposed in a column of 11 fields. Each of these fields is exposed with a different focus. The highest focus is at the top (‘right’ in stage coordinate system), the lowest one is at the bottom (‘left’ in stage coordinate system).
7. Once the series has been finished, unload the test sample and examine the exposures to determine the best focus value.
8. To close the window, click **Exit**.
9. If the results should replace the existing standard values, choose **Specials→ Edit System Parameters** from the menu bar (in advanced mode). Here, you can change the existing standard parameters by entering new values (see *9.1 Menu Utilities*).

7.3 Evaluation of Exposure Series

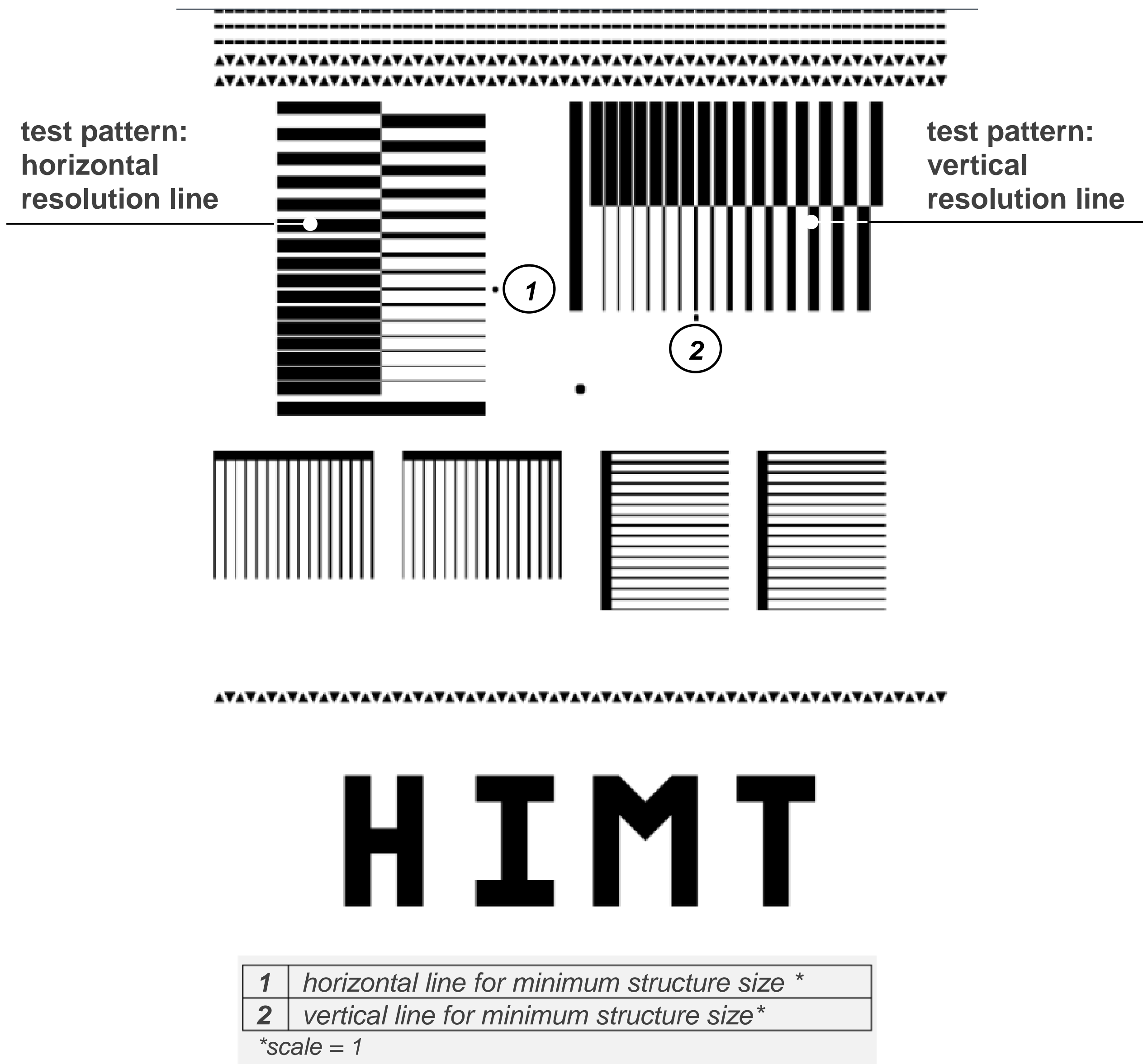
This chapter introduces features for the advanced user to help finding optimum exposure conditions. It assumes a good knowledge of the instructions given in the previous chapters.

In Figure 60 you find a magnification of the resolution pattern of the standard test design. The dots mark the lines down to which structure edges have to be well defined without any loss of edge quality. These minimum structure sizes are (see also *Appendix, Technical Data*):

	WM I	**WM II**	**WM III**
Size	1µm	2.5 µm	5µm

Table 10: Minimum structure sizes per write mode

The structure sizes for horizontal and for vertical lines are marked by numbers.



1	*horizontal line for minimum structure size **
2	*vertical line for minimum structure size**

**scale = 1*

Figure 60: Resolution test pattern

8 Calibration Procedures

For optimum exposure results, it is recommendable to repeat certain calibrations occasionally, especially before critical exposures. All instructions in this chapter assume that the operator is well acquainted with standard and advanced exposure procedures.

8.1 Camera Calibration

The camera calibration enables the system to accurately calculate the position on the stage of any structure found in the camera image. It measures the number of pixels in the camera image that correspond to a distance of 1 µm on the substrate. This is done by measuring the position of a specific structure in the camera image at different stage positions, and comparing both.

STEPS OF A CAMERA CALIBRATION PROCEDURE

1. Choose **Camera➔Camera Calibration** (menu bar). The camera window opens.
2. Click **Show Control Panel**. The ***Control Panel*** window opens. If no substrate is loaded yet, follow the instructions in *2.8 Substrate Loading)*.
3. Load a sample with an unambiguous and clearly distinguishable structure. Use alignment pins.
4. Adjust the structure to the camera center using one of the three options from the ***Stage*** frame in the ***Control Panel*** window:
   - If the coordinates relative to the stage center are known, use **Move To.** Use the arrow buttons for fine positioning.
   - If the position coordinates are not known use the arrow buttons to search for the structure.
   - If the structure is already in the camera image field, click **To POI** and move the cross to the point of interest (POI) in the image field. Then middle-click to confirm. The selected point is moved to the center of the image field.

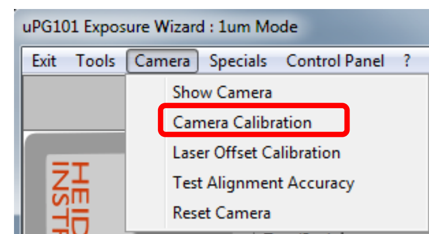


Figure 61: Menu item Camera ➔Camera Calibration

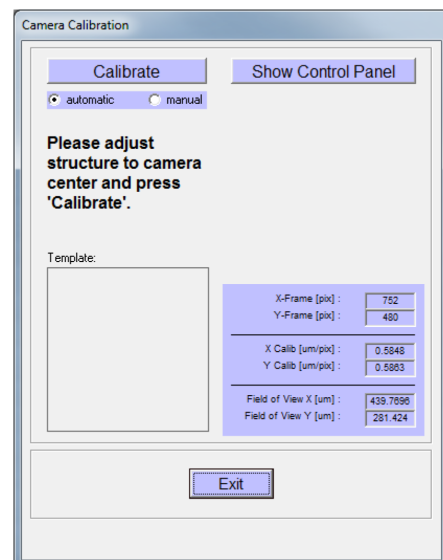


Figure 62: Camera Calibration window

5. To execute Camera Calibration, click **Calibrate**. Now a template is created automatically from the structure positioned at the center. The stage moves the center structure towards the corners of the camera image and tries to detect it with the help of the created template. For each stage position, the position in the camera field is noted where the template was found. Finally, camera calibration factors for x and y are calculated from this and displayed in a dialog box (Figure 62).
6. To accept the new calibration parameters, click **OK**. To quit the procedure without updating the parameters, click **Cancel**.
7. If calibration fails, it can be repeated. Follow the steps:
    - Select the checkbox **manual**. In each stage position, you are now requested to manually move the crosshair in the camera image to the position of the structure.
    - Confirm each point with a middle-click (middle mouse button or scroll wheel).
8. To accept the new values, click **OK**. To discard them, click **Cancel**.

Standard calibration values [µm per pixel]:

	WM I	WM II	WM III
X/ Y	~ 0.25	~0.6	~1.2

Table 11: Standard values for camera calibration

8.2 Laser Offset Calibration

On the µPG 101 system, special designs are offered to check the pattern overlay quality when using the automatic alignment procedure and to measure a systematical offset, if there is one.

If exposures should be done relative to existing structures, it is necessary to know the position of the laser beam relative to the center of the camera image, which is the reference point for the alignment measurements. If this calibration is not valid, it leads to a systematic shift in the overlay. After write head exchange, also recheck the offset.

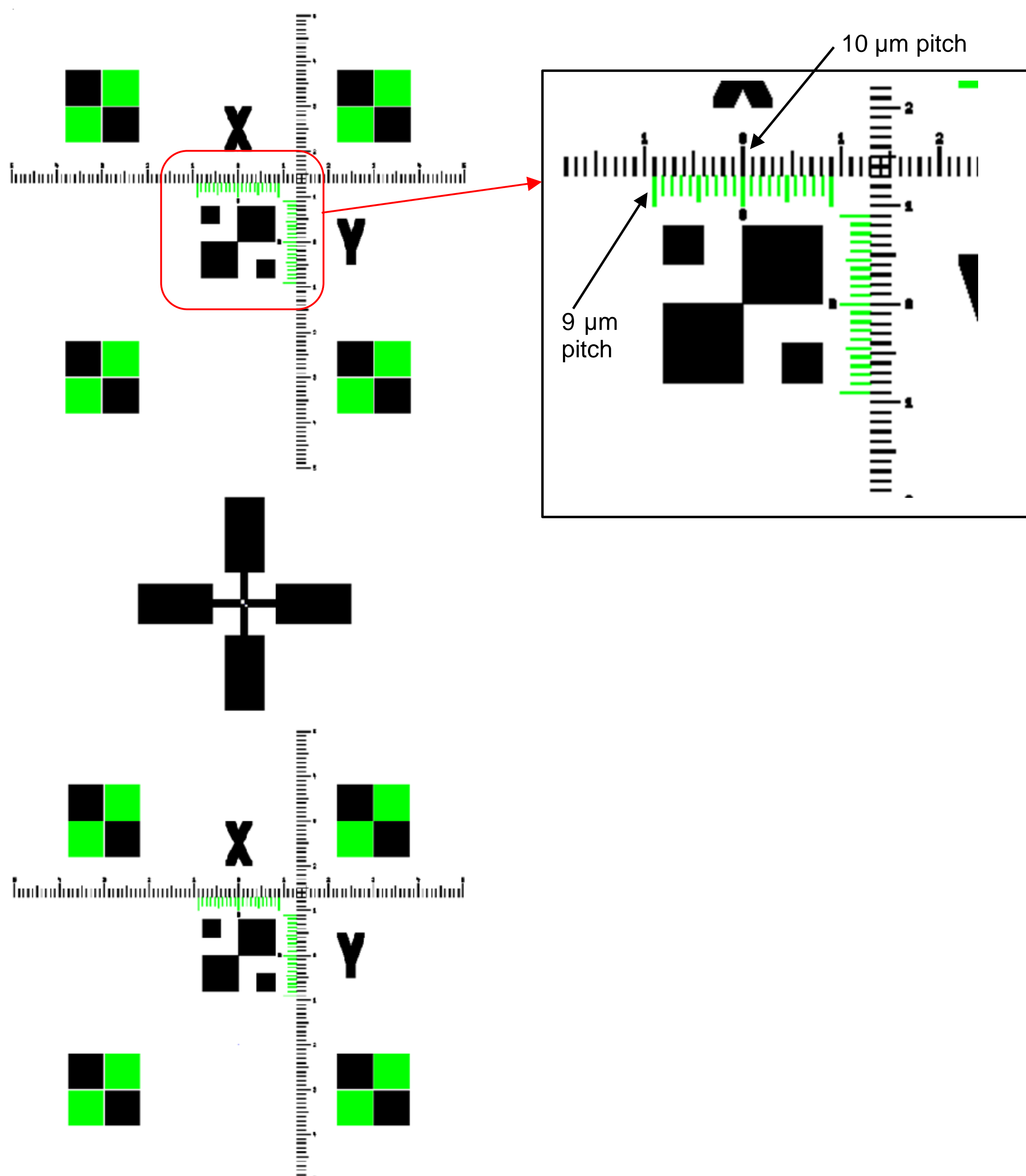


Figure 63: Laser Offset Calibration (design example, all layers)

For explanation of the calibration procedures, we refer to two designs which do not necessarily correspond in the other features to the test designs we offer you with the system (Figures 64, 65). The two designs represent two layers that contain the two parts of a vernier scale in each axis. One layer contains the (fixed) ruler with increments of 10µm and the other one contains the (sliding) secondary scale with increments of 9µm (Figures 63, 64, 65).

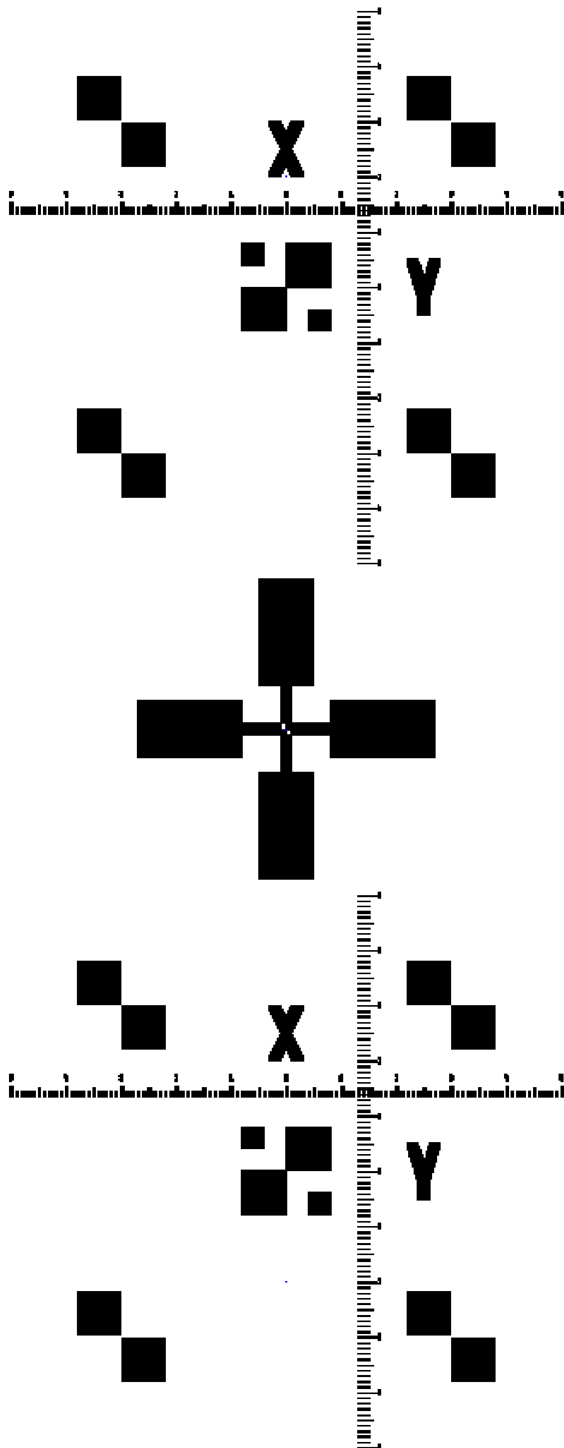


Figure 64: Design 1 (1st layer) with ruler

Figure 65: Design 2 (2nd layer) with secondary scale

STEPS OF A LASER OFFSET CALIBRATION PROCEDURE

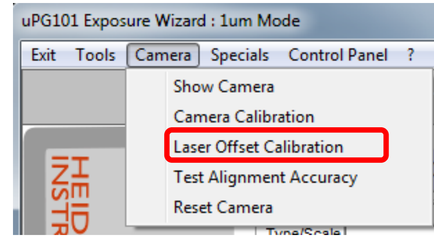


Figure 66: Menu item Camera→Laser Offset Calibration

1. Execute a Camera Calibration (see *8.1 Camera Calibration*).
2. Choose **Camera→Laser Offset Calibration.**
3. Enter "0 µm" for both laser offsets.
4. Expose the reference design (e.g., *CamOffset1.cif*, Figure 64) in standard mode with the following scaling:

	WM I	WM II	WM III
Scaling	0.5	1	2

5. Start an advanced exposure process and load the same substrate.
6. Select the second layer (e.g, *CamOffset2.cif*, Figure 65) and set scale to 1*.*
7. Execute an offset alignment (for instructions see *4 Alignment Methods*).
8. Expose the second layer.
9. After the exposure is finished, inspect the structures.
10. Determine the offset error:

    Example: Examine the offset at the vernier scales (close to the center alignment mark). The pitch difference between the two rulers of each vernier is 1µm, meaning that each division by which the match of lines is shifted from the origin means 1µm offset error. In the example shown below, the x-offset is approx. 4.5 divisions, y-offset is slighty above 2 divisions, but not yet 2.5. So, the Laser Offset Calibration parameters should be adjusted to X=4500nm and Y=2250nm.

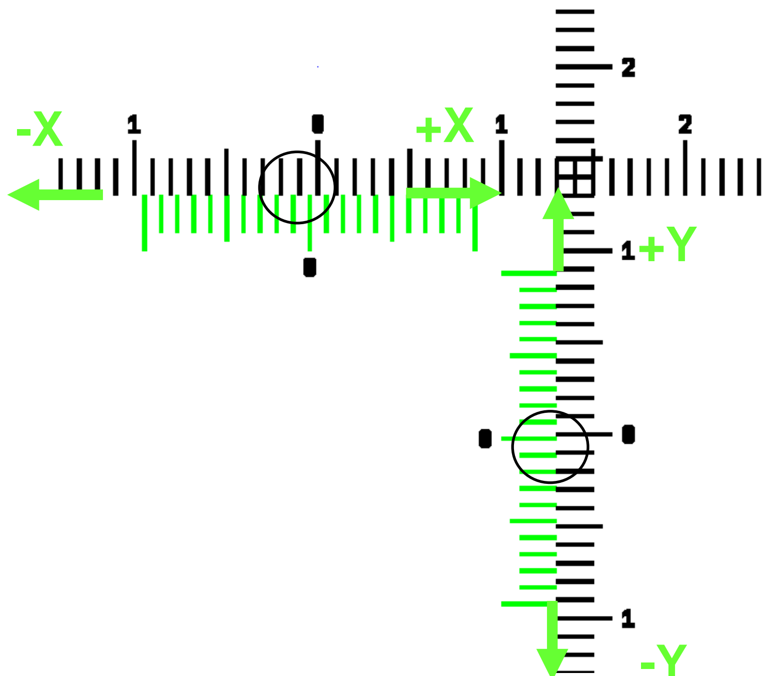


Figure 67: Bad alignment of 2nd layer

11. From the menu bar select **Camera→Laser Offset Calibration** and enter the new offset parameters in nm.
12. Repeat steps 4 to 9 with a different positioning or on a new substrate.
13. The offset error should be negligible now. Otherwise adjust the parameters for Laser Offset Calibration again and repeat exposure until the center lines in each vernier scale match (Figure68).

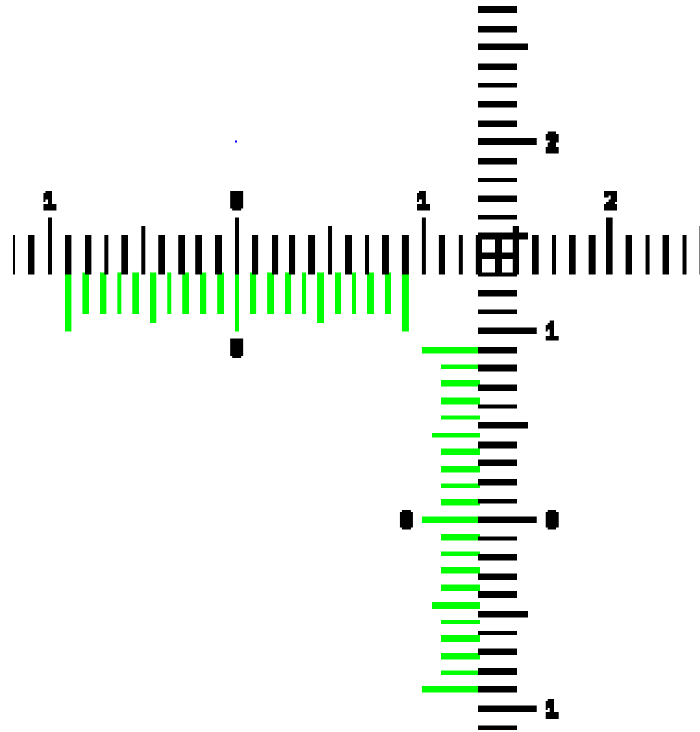


Figure 68: Good alignment of 2nd layer

9 System Utilities and Tools

Further elements of the main menu allow to run maintenance and troubleshooting tasks or to directly address certain system components e.g., to change the system state after an error has occurred.

9.1 Menu Utilities

General (both modes):

- **Save menu default values:**
  Tools → Set Menu defaults saves the current settings chosen in the wizard as default settings (checkboxes, energy values).
- **Shutdown µPG 101:**
  Exit → Shutdown µPG 101 completely shuts down the µPG 101 lithography unit, and the wizard.
- **Execute Exposure Series:**
  Tools→Expose Energy Series makes it possible to determine the correct energy for a substrate for optimum exposure result. **Tools→Focus Series** is for determining the best position of the write spot focus. For instructions see *7 Exposure Optimization Utilities*.

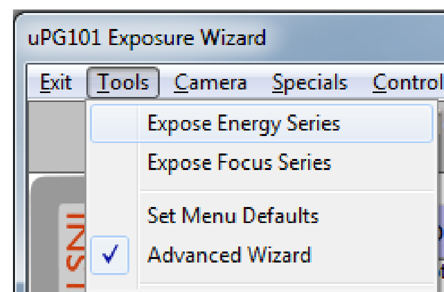


Figure 69: Menu item Tools advanced mode

Standard Mode:

- **Show camera window:**
  Tools → Show Camera opens the camera window (like **Show Camera** in the ***Control Panel*** window).

Advanced Mode:

- **Control Panel** (menu bar):
  Control Panel opens the Control Panel that gives access to numerous direct system controls regarding stage, write head and camera system (see *9.2 Control Panel* for description of the panel).

Figure 70: Menu item Control Panel

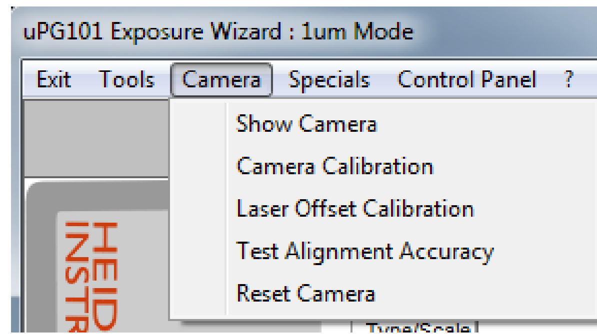


Figure 71: Menu item Camera

- **Show Camera:**
  Camera→Show Camera opens the camera window.
- **Camera Calibration:**
  Camera→Camera Calibration enables the system to accurately calculate the position of any structure found in the camera image. Usually, this function is necessary only during the installation of the system. For instructions see *8.1 Camera Calibration*.
- **Laser Offset Calibration:**
  Camera→Laser Offset Calibration for exposures that are done relative to existing structures. Gives the position of the laser beam relative to the center of the camera image, which is the reference point for the alignment measurements. For instructions see *8.2 Laser Offset Calibration.*
- **Test Alignment Accuracy:**
  Camera → Test Alignment Accuracy runs a test on positioning stability. The camera window opens. For instructions see *9.3 Alignment Accuracy Test.*
- **Reset Camera:**
  Camera→Reset Camera is done if any problems concerning the camera occur. The camera settings are reset.

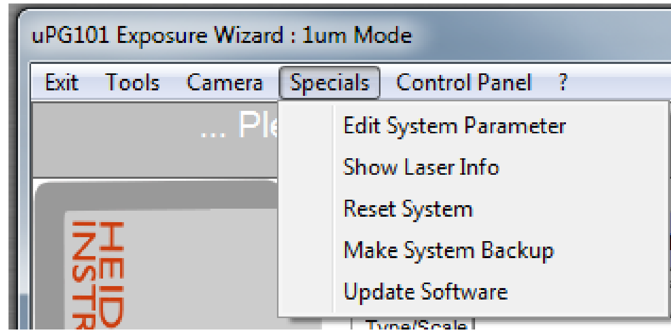


Figure 72: Menu item Specials

- **Edit System Parameters:**
  Specials → Edit System Parameter makes it possible to change basic exposure parameters:

  Focus: Fine focus parameter according to the result from the focus series test.

  Scan Width: Stripe width parameter

  Bi-Directional: Parameter that affects the longitudinal placement of adjacent stripes.

  Optical Focus: Only visible, when available. Fine focus parameter of oAF mode.

  Scaling X/Y: Parameter to adjust exposure dimensions e.g., to match exposures to a measurement tool or to layers exposed on a different lithography system.

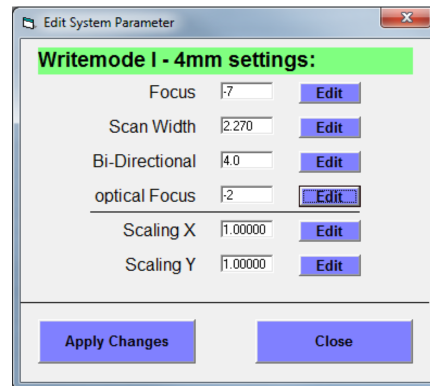


Figure 73: Edit System Parameters

- **Laser Information:**
  Specials→Show Laser Information informs about the laser type and the firmware installed. Power-up (energized) and power-on (lasing) times are displayed. If the system does not display the information at first click, click again.

- **Reset system:**
  Specials → Reset System allows reinitializing the wizard and the stage if for any reason the motors were disabled or the coordinate system is mixed up.

- **Create a backup of the system software :**
  Specials → Make System Backup creates a backup of the configuration installed on the lithography unit (not the User PC). The backup is stored on the User PC under `C:\\HIMT\Exposure Wizard\System`.

- **Install a software upgrade package:**

  Do not use this feature to copy back a backup!
  System settings can completely get lost.

  Specials → Update Software unpacks a software package that was copied to the User PC or is available via network. ***Use only with HIMT support and after explicit instruction!***

9.2 Control Panel

The ***Control Panel*** window is accessible several times when working with **Show Advanced Options** selected (in the ***Welcome Screen)***. **Show Control Panel** buttons appear in several panels and frames. In addition, the panel can be opened from the menu bar via **Control Panel**. To exit the ***Control Panel*** window, click **Close.**

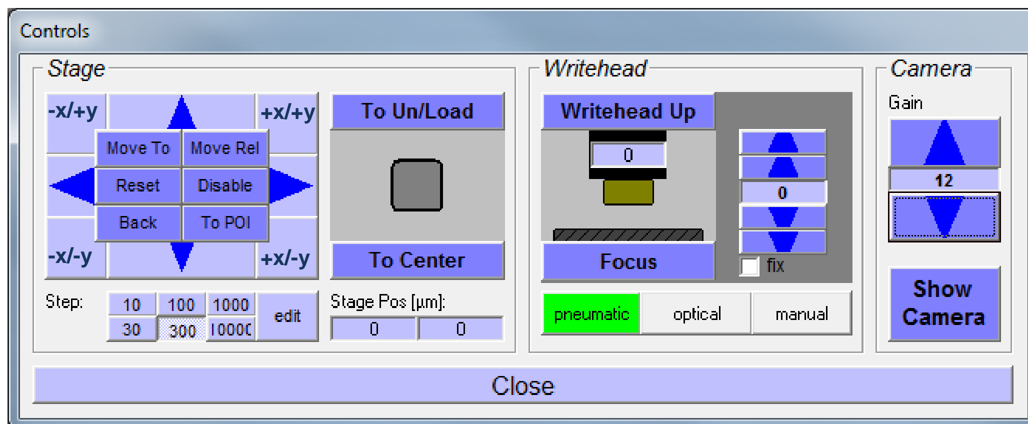


Figure 74: Control Panel window

The ***Control Panel*** window offers several possibilities for direct control of the stage movement, the write head movement and the camera:

9.2.1 STAGE

At the bottom of the ***Stage*** frame, the current position of the stage is shown at all times. The stage can be moved around freely using the arrow buttons, or directly towards specified positions with the other controls.

- **Arrow buttons and step size selector**
  The arrow buttons move the stage so the camera view moves towards the indicated direction. Stage movement happens stepwise, and the step size is selected in the button array below the array of arrow buttons. With **edit**, a custom step size can be selected for the active button. When moving the stage, keep in mind that the x-axis buttons move the stage from back to front, while the y-axis runs parallel to the loading edge (right to left). In the camera image on the other hand the x-axis is horizontal and the y-axis vertical
- **Move To**
  A dialog window opens. Enter a coordinate set to directly move to it.
- **Move Rel**
  Performs a relative movement from the current position by the distances in x and y that you determine.
- **Reset**
  Runs a stage reset and initialization routine

- **Disable**
  Switches off the stage motors and any stage movement is stopped. Now it is possible to move the stage by hand.
- **Back**
  The stage moves back to the previous position.
- **To POI**
  If not yet open, the ***Camera Window*** opens. The image is frozen and a green target cross appears. Drag the cross to the point of interest (POI) in the image field, then middle-click to confirm. The selected point is moved to the center of the image field.
- **To Un/Load**
  Moves the stage to the front, into loading position.
- **To Center**
  Moves the center of the stage below the write head.
- **StagePos**
  Shows the coordinates of the current stage position.

9.2.2 WRITEHEAD

- **Writehead up**
  Moves the write head into retracted position (upper end position).
- **Focus**
  Moves the write head down towards the substrate until the focal point is on the substrate surface and the piezo for autofocus adjustment is in center position.
- **Pneumatic**
  One of the autofocus modes. Click the button and the system switches to the pneumatic focusing mode. Distance between write lens and substrate is measured with compressed air. This function is only suitable for substrates larger than 1". For more information see *3.2.1 Focusing Options.*

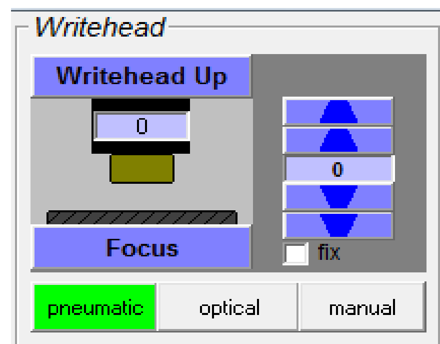


Figure 75: Writehead frame

- optional **Optical**
  One of the two autofocus modes. This mode is not offered with the basic equipment. It is only available when it was purchased as an extra option with the machine. For more information see *3.2.1 Focusing Options.*

- **Manual**
  The system switches to the manual focusing mode. Here, the operator controls the focusing movement manually. For more information see *3.2.1 Focusing Options.*

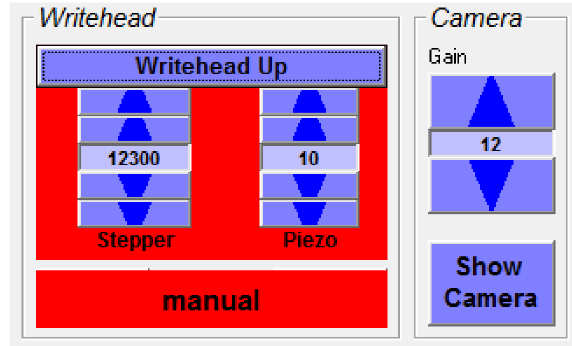


Figure 76: Writehead frame and Camera frame (manual mode)

- **Piezo setpoint adjustment arrows**
  Changes the position of the write lens to which the piezo regulates. Range of values is -30 - +30, coarse movement step with outer arrows is 5, fine movement with the inner arrows 1.
- **Fix** checkbox
  Activating the fix checkbox disables the autofocus. Then focusing is not possible. The piezo setpoint adjustment arrows still work. Disabling the autofocus is required for exposures close to the edges of a substrate or on small substrates. If **Manual Focus** is selected, this option is automatically selected and cannot be deselected.

  For more detailed information on the focusing modes see *3.2 Focusing*.

9.2.3 CAMERA

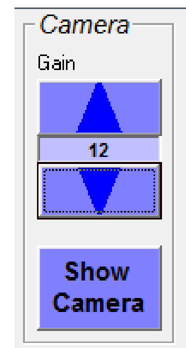


Figure 77: Camera frame

- **Gain adjustment arrows**
  The arrows regulate the sensitivity of the camera image by changing camera speed. If contrast is bad in the camera image, it may be improved by adjusting the gain.
- **Show Camera**
  Opens the ***Camera Window (HIVision)***.

9.3 Alignment Accuracy Test

To run a test on positioning stability, choose **Camera → Test Alignment Accuracy** from the menu bar. The camera window opens.

1. In the ***Test Alignment Accuracy*** window click **Show Control Panel**.
2. Load a substrate with a clear structure (see rules in *8.1 Camera Calibration.* For instructions on substrate loading refer to *2.8 Substrate Loading*).
3. Adjust the structure to the camera center using one of the three options from the ***Stage*** frame in the ***Control Panel*** window:
   - If the coordinates relative to the stage center are known, use **Move To.** Use the arrow buttons for fine positioning.
   - If the position coordinates are not known use the arrow buttons to search for the structure.
   - If the structure is already in camera image field, click **To POI** and move the cross to the point of interest (POI) in the image field. Then middle-click to confirm. The selected point is moved to the center of the image field
4. To start the test, click **Test Alignment Accuracy**.

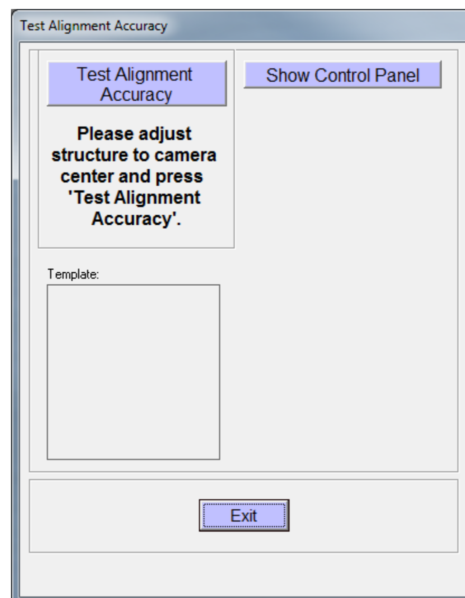


Figure 78: Test Alignment window

First, a template of the center structure is created. Next, the stage moves the structure back and forth into the camera field several times, and the system measures each time where the template can be found.

From the results, the accuracy is calculated with which the structure returns to the point where it was (standard deviation value). Typical values are (see also *Appendix, Technical Data*):

	WM I	WM II	WM III
Alignment Accuracy	>200 nm	>400 nm	>800 nm

Table 12: Alignment accuracy

9.4 HiVision Camera Window

It is possible to create and save a snapshot of the image that is visible in the camera window. Follow the instruction given below:

1. Choose **Camera→Snap** from the menu bar (see Figure 79). The section of the image that is currently displayed is snapped and can be saved.

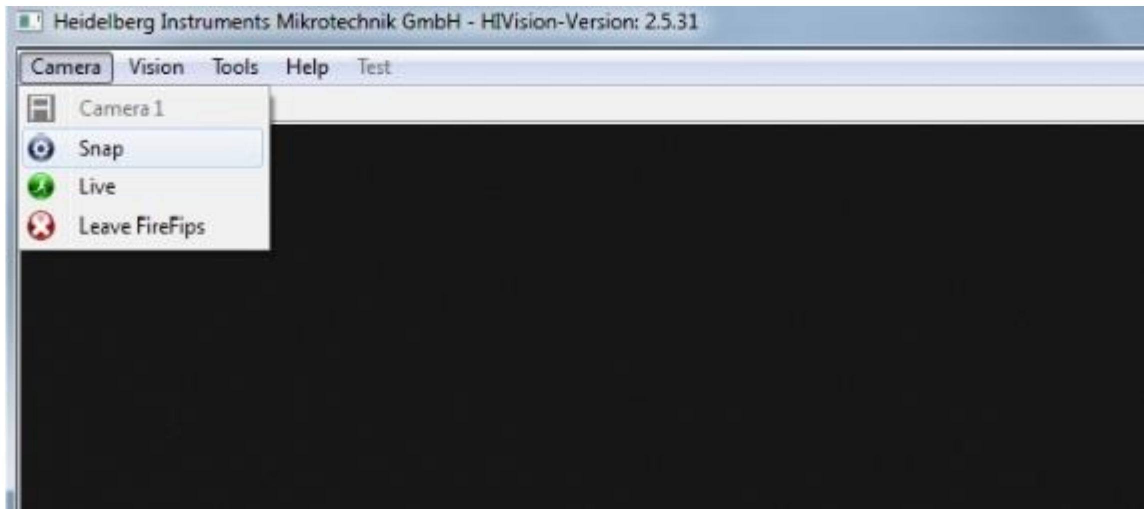


Figure 79: Snap camera image

2. Choose **Tools→Save Image** from the menu bar. A directory opens (see Figure 80). Select the storing location and give a name to the file. The image is now stored and can be used e.g., for troubleshooting purposes. It can be shown to our service assistant.

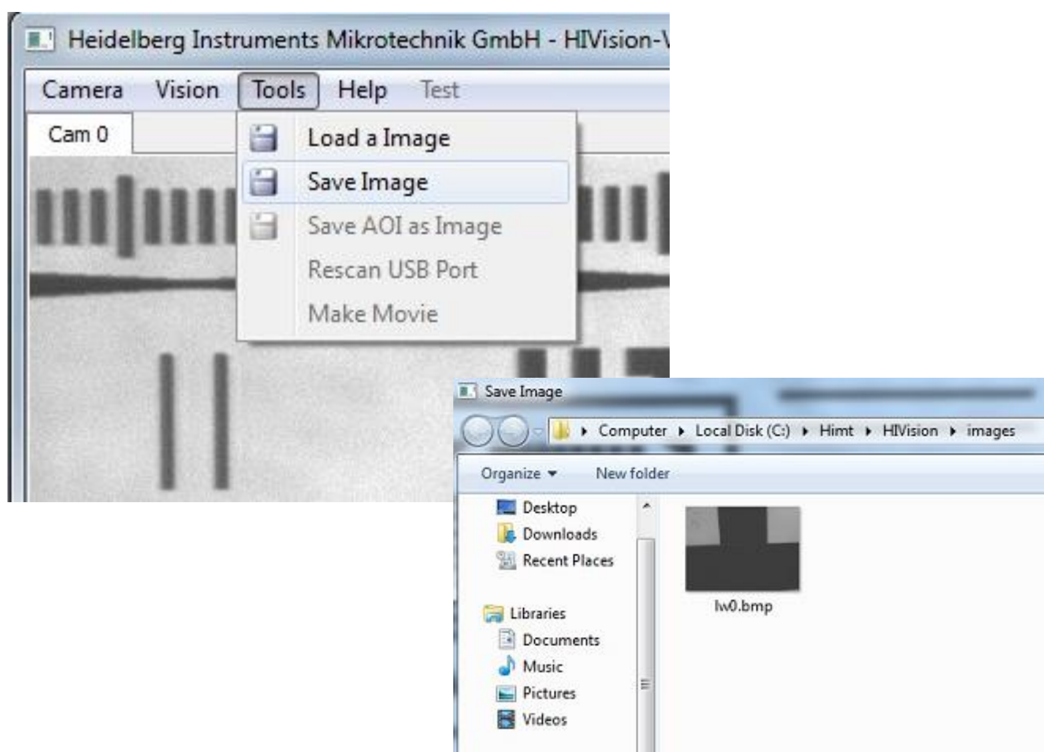


Figure 80: Save image

10 Troubleshooting and Maintenance

This chapter contains advice on some possible problems that might be encountered during operation of the µPG 101. When problems occur it is recommendable to reset the system or single elements of the system depending on where the problem is. If you encounter a problem that cannot be solved in this way, please contact your Heidelberg Instruments service office (see *Contact*).

10.1 Exposure Wizard Error Messages

Error messages of the exposure wizard contain information that leads you or the service staff to the root of the problem. If the problem cannot be solved directly, shut down the system, restart it, and try again. If the problem persists, contact your service office (for contact details see *Contact*).

10.2 Functional Problems

Problem	**System does not start at all, all LEDs off**
Possible causes	• facility power is down • fuse on supply unit is blown (see *10.5 Fuses*)
Remedies	• check facility power • check fuse

Problem	**Exposure does not start**
Possible causes	• air pressure low • cover lid not closed properly • software hang-up
Remedies	• check air pressure • check on interlock lamp before starting a new exposure • reboot system

Problem	**Exposure was interrupted, stage motors are disabled**
Possible causes	• air pressure low • lid was opened • motor capability to maintain stage speed against vibration / shock was exceeded • system is not well leveled
Remedies	• check air pressure • check on interlock lamp before starting a new exposure • reset stage (**Tools → Reset System**) • check and improve leveling (for instructions see *10.7 Leveling*).

10.3 Exposure Result Problems

Problem	Substrate is blank
Possible causes	• structures too small • energy too low / filter still active • developer too old /wrong type / wrong mixture • laser off or damaged • wrong write head or write mode • focusing failed
Remedies	• check design against design rules and lens resolution • try higher energies / switch off the filter • use fresh developer • check write head and write mode • check camera view after focusing

Problem	Substrate is completely exposed
Possible causes	• stray light • old materials
Remedies	• check for possible stray light sources and eliminate them • use fresh batch of substrates

Problem	Some structures are missing
Possible causes	• structures do not comply with design rules or are too small • chrome etch old • air bubbles in structures during etching
Remedies	• check design against design rules and lens resolution • use fresh chrome etch • avoid drying of the substrate between developing and etching, or water the plate thoroughly before etching

Problem	Design is shifted
Possible causes	• wrong selection of design origin • substrate not pushed properly against alignment pins • vacuum is not properly applied • wrong entry of design shift in manual alignment • wrong camera calibration (alignment to structure only) • wrong laser offset calibration alignment to structure only)
Remedies	• check design • check ejector pressure (vacuum), (for instructions see *10.9*) • check wizard entries • do camera calibration and laser offset calibration

Problem	Design looks completely mixed up
Possible causes	• vacuum off or not enough
Remedies	• check vacuum pump, ejector pressure and vacuum on stage.

Problem	Design stretched or shrunk (e.g., compared to previous layer)
Possible causes	• wrong write head or write mode • wrong units selected during design loading • wrong scaling set in **Specials→Edit System Parameters**
Remedies	• check write head and write mode • select correct units • set proper scaling

Problem	Structures or camera image are blurry
Possible causes	• nozzle not properly adjusted
Remedies	• check camera view • adjust the nozzle (*10.8 Adjusting the Write Head Nozzle*)

10.4 Advanced Troubleshooting

When informing a service office about a problem with the µPG 101, please include the following details:

- Serial number of the system
- Information on status of backplane power LEDs on top of system
- Information on settings of compressed air regulators
- Any error numbers and error descriptions provided by the wizard
- If available, screenshots / pictures of the problem, or descriptive sketches with coordinate arrows and scales.
- Choose **Advanced → Make System Backup** and send the folder C:\\HIMT (or at least the subfolder C:\\HIMT\Exposure Wizard\System) in archived form (.zip, .rar)

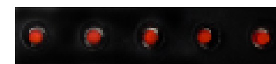


Figure 81: Backplane power LEDs on top

During consultation, the following procedure may be recommended by the service office for further troubleshooting:

NOTICE

Severe damage of the system!
Execute the following instructions only at EXPLICIT request from your service office!

Figure 82: Location of system main board

1. Power down the system.
2. Open the dark electronics cover at the back side.
3. Standing in front of the system, the system mainboard

is located at the left side.

4. Connect a monitor, a keyboard and a mouse to the designated connectors of the integrated mainboard.
5. Switch on the µPG 101 and follow the instructions of the service office.
6. Connect User PC to the internet and start the teamviewer software.

Figure 83: Main board connectors

10.5 Fuses

Types and locations of fuses used in the µPG 101:

Left of main power line: 10 A time delay fuse

Figure 84: 10 A time delay fuse at supply unit

10.6 Maintenance

Cleaning

The system covers and internal surfaces should be cleaned occasionally to avoid transfer of particles onto the substrate.

- Use clean, lint-free cloth.
- In case of stronger contamination, wet the cloth slightly with mild soap suds.

The base on which the stage air bearings are travelling is automatically cleaned from any dust particles due to the air pressure of the bearings. If the air bearing base was accidentally contaminated with oil or fat (e.g. due to touching with bare hands), it has to be cleaned to prevent damage to the air bearings due to stuck particles.

- Use clean, lint-free cloth and isopropanol

Data Backup

To make sure that the system can be rebuilt as fast as possible in a fairly recent state, the data should be saved occasionally to a backup data carrier (e.g. CD, floppy, other PC on the network).

- Use the Make Backup Utility (**Specials → Make System Backup**)
- Afterwards, transfer the complete directory `C:\\HIMT` to a backup device.

10.7 Leveling

In chapter *1 System Description* you learnt that the system base is mounted on four feet (5). These feet are adjustable in height in order to level the machine. Leveling the machine is important for proper function of the system and for good exposure results. Follow the instructions given below.

1. Check if the lithography unit stands firmly on all four feet. Check leveling with a spirit level.
2. If adjustment is necessary, take a #19 wrench to release the countering bolt of the system foot that has to be adjusted.
3. Then adjust the height of the foot according to the spirit level with a #10 wrench.
4. Repeat until system is leveled.

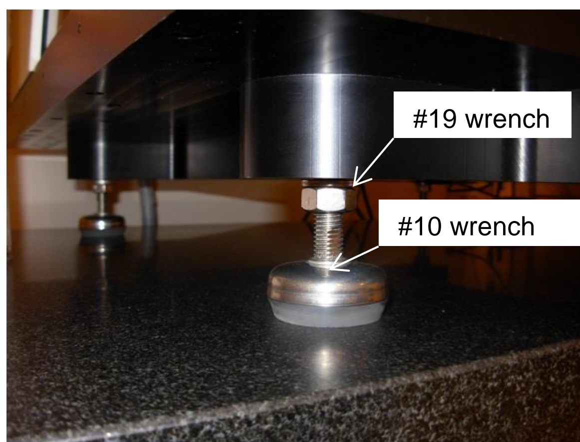
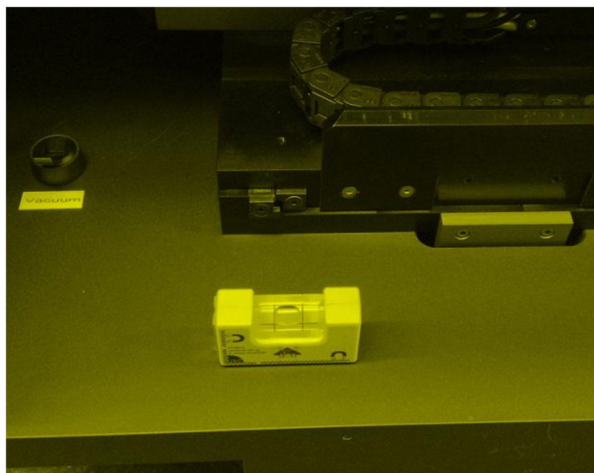


Figure 85: Lithography unit leveling



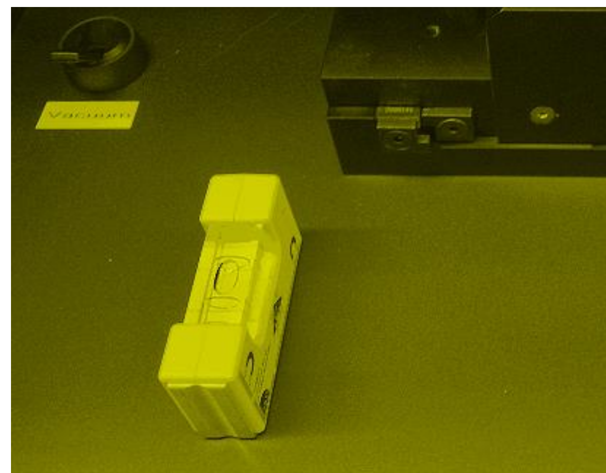


Figure 86: Check leveling with spirit level

10.8 Adjust the Write Head Nozzle

1. If the image is not sharp, screw in the nozzle a bit (5-10° for small focal length, up to 20° for larger focal length).
2. To move the nozzle, use either the hook wrench or a #2 Allen key to hold and turn the nozzle at one of the three holes at its side.
3. Focus again and check if the image is sharp now.
   - 3a. If it has improved but is not sharp, repeat step 2.
   - 3b. If it has gotten worse, move the nozzle back in a bit.
4. Repeat step 2 with decreasing changes in the nozzle position until the image is sharp at focus point.
5. Move up the write head completely and focus again using the menu.
6. Check if the image is still sharp at focus point.

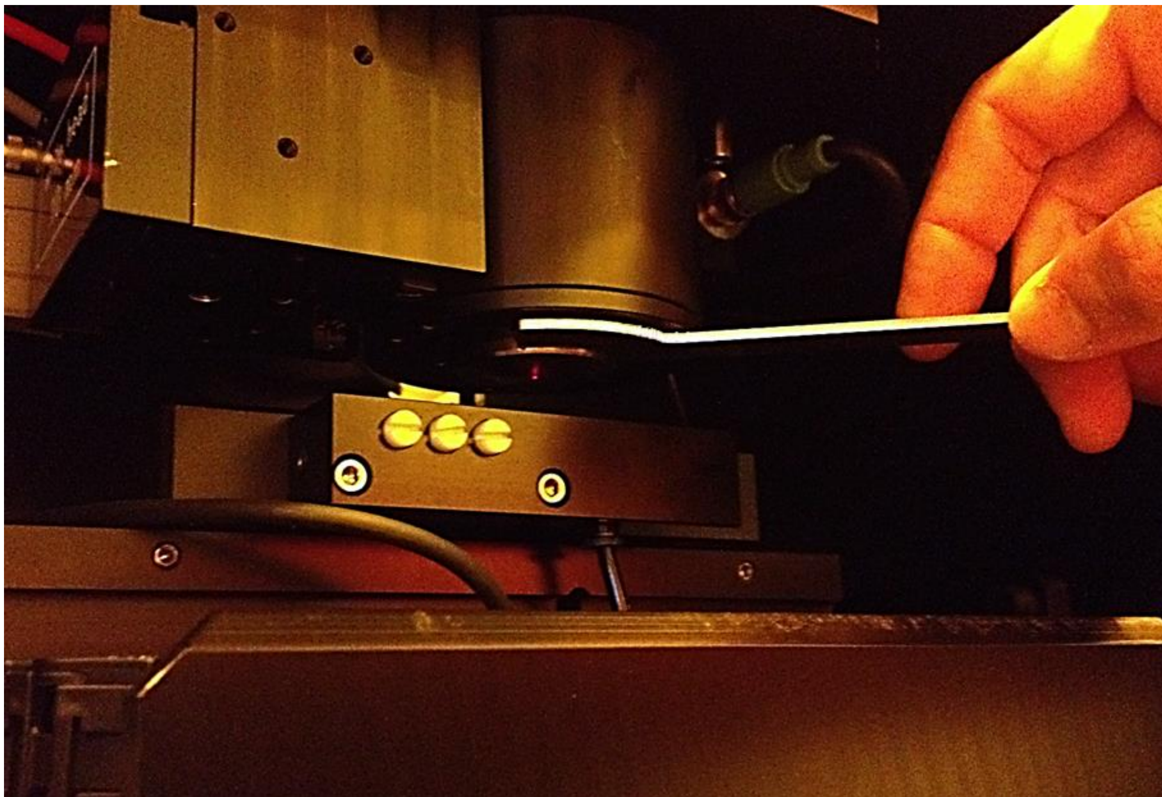


Figure 87: Adjustment of write head nozzle with hook wrench or Allen key

10.9 Adjustment of Ejector Pressure

If the substrate is not held tight by the vacuum, check the ejector pressure. At the backside of the lithography unit, you find an adjustment screw at the ejector. The pressure indicator next to the screw shows the pressure that is currently applied at the ejector. Turn the screw slightly to the right or to the left until the appropriate pressure is adjusted.

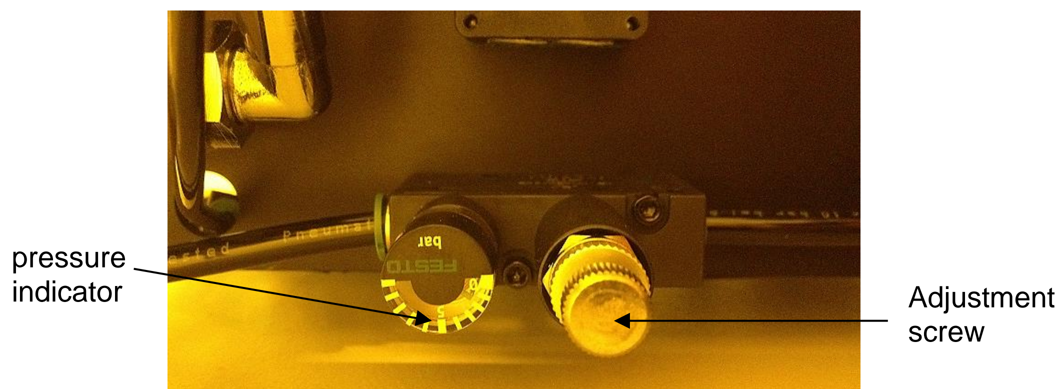


Figure 88: Adjustment of ejector pressure

10.10 Transportation Lock

Before installing the system and/or putting it into operation, it is necessary to remove the transportation lock.

Prior to transportation, make sure that the transportation lock is fixed in its designated place to avoid movement of the stage.

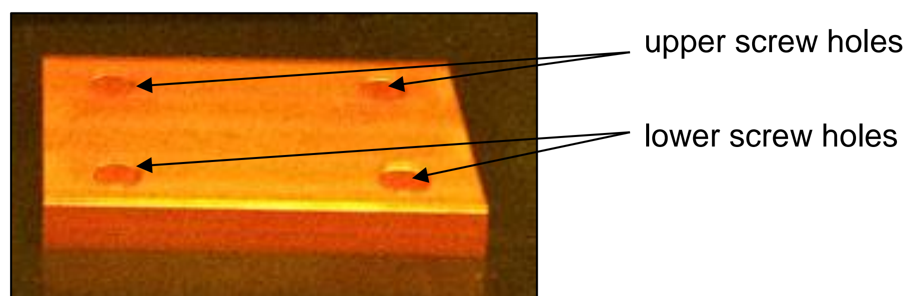


Figure 89: Locking plate

You are standing in front of the system. You have a locking plate with four screw holes (Figure 89). It might also be located in its storing position, which means that it is fixed to the base plate via screw connection. If so, loosen the screws with an #3 Allen key and remove them from the plate. You need four screws which are part of the equipment. Follow the instructions:

Locking the stage:

1. Take two screws and attach the two upper screw holes of the locking plate to the screw holes of the stage.
2. Drive two screws into the lower screw holes and attach the locking plate to the screw holes at the base plate. Now the locking plate is fixed to the stage and to the base plate, so movement of the stage during transportation is impossible (Figure 90).

Unlocking the stage:

1. To unlock the stage, loosen the screws and remove them from the screw hole.
2. Fix the upper part of the locking plate to the base plate by screwing in two screws into the designated screw holes.
3. The locking plate is now in its storing location (Figure 91).

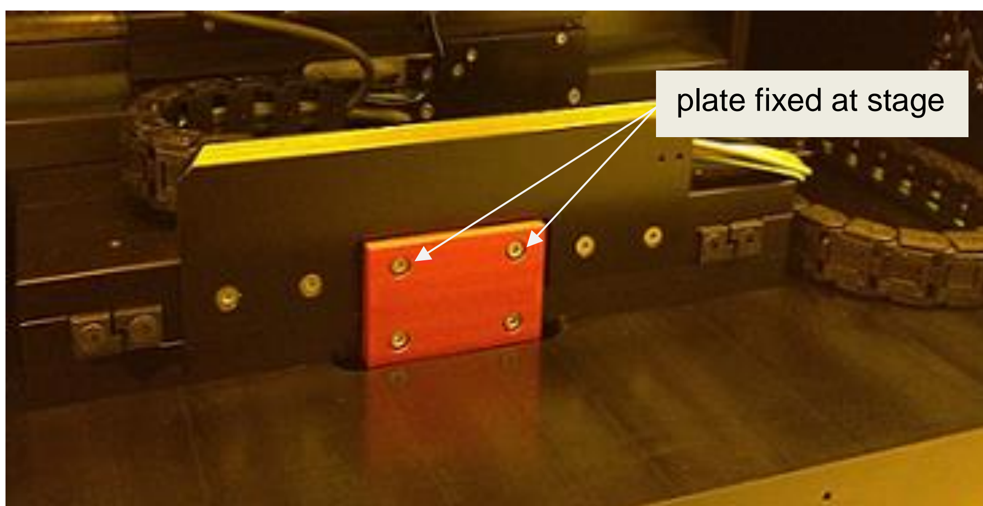


Figure 90: Stage locked

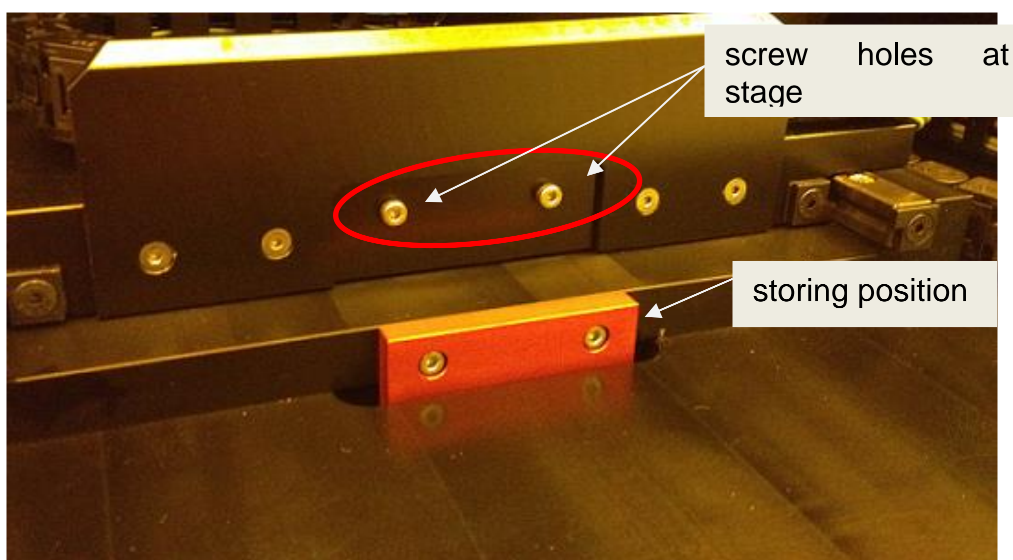


Figure 91: Stage unlocked

Appendix

In this appendix you find information on technical data, spare parts and a short glossary.

Technical Data

KEY FEATURES AND OPTIONS

- Substrates up to 6"x6"
- Substrates of 7 mm thickness
- Structures down to 0.9μ
- Address grid down to 40nm
- Basic grayscale exposure mode
- Real-time autofocus system (pneumatic, optional optical)
- Violet or UV diode laser source
- Vector and raster exposure mode
- Exchangeable write modes
- Camera system for alignment
- Multiple data input formats

SYSTEMS SPECIFICATIONS

	Write Mode		
	I	II	III
Address Grid	40	100	200
Minimum Structure size[μm]	0.9	2.5	5
Write Speed [mm²/minute]	5	35	90
Edge Roughness[3σ,nm]	120	200	400
CD Uniformity [3σ,nm]	200	400	800
Alignment Measurement Accuracy [3σ,nm]	200	400	800

Table 13: Specifications of the system

LASER TYPES

	Wavelength (nm)	Power (mW)	Laser Class
Diode, blue	405	120	3B
Diode, UV	375	70	3B

Table 14: List of laser types available with system

EQUIPMENT DIMENSIONS

	Width	Depth	Height	Weight
Lithography unit	630 mm 25 inch	700 mm 27.5 inch	500 mm 19.7 inch	120 kg 243 lbs
Supply unit	430 mm 17 inch	380 mm 15 inch	230 mm 9 inch	10 kg 22 lbs
optional **Anti-vibration table**	1095 mm 43 inch	700 mm 27.5 inch	750 mm 29.5 inch	385 kg 849 lbs
PC table	650 mm 25.5 inch	700 mm 27.5 inch	750 mm 29.5 inch	70 kg 154 lbs

Table 15: Equipment dimensions

ENVIRONMENTAL REQUIREMENTS

Temperature	within 18 - 25°C, stability ± 1°C
Humidity	50% ± 10%, non-condensing
Vibrations	as low as possible
Lighting	yellow light, or according to substrate manufacturers recommendation
Cleanliness	as few particles as possible in the air*
Heat production	Average heat generated by the µPG 101: ±500 W. (Important for calculating the required cooling capacity for temperature set point and stability of the room climate.)

*System specifications do not depend on the clean room quality. But the less particles are in the air, the less defects are expected.

Table 16: Environmental requirements

COMPRESSED AIR SUPPLY

Minimum Pressure	6 bar (88 psi)
Maximum Pressure	10 bar (140 psi)
Flow	7 sl*/min (0.2 scfm*/min) (17.5 l/min at standard pressure settings) ***Note**:* Do not use gas cylinders! With usual filling volume, gas cylinders can keep up this flow for only a few hours! Switching it off and on for exposures leads to unstable exposure conditions!
Conditions	The supply must be free of: • all contaminating fluids • oil • water, whether liquid or vapor.

Table 17: Compressed air supply

VACUUM SUPPLY

Minimum Pressure	0.5 bar (7 psi), negative
Capacity	Min. 5 sl*/min (0.2 scfm*/min)

Table 18: Vacuum supply

ELECTRICAL REQUIREMENTS

Power	230 VAC ±5% 50 Hz ±0.5% or 110 VAC ±5% 60 Hz ±0.5%
Service	230V: 6 Ampere, 110V: 12 Ampere dedicated, single phase (3-wire: phase, neutral, ground).
Peak power	< 350W
Average power consumption	75 W (idle) / 120 W (operating)

Table 19: Electrical requirements

List of Spare Parts

Consumables	HIMT Part-#
Exposure laser head (refurbishment)	none
Exposure laser head (spare) Diode laser 405nm (VIS) Diode laser 375nm (UV)	 15.0235.50 15.0237.50
Compressed air filter 5um (prefilter)	34.0605.50
Compressed air filter .01um (fine filter)	34.0606.50
Replacement parts	**HIMT Part-#**
Linear motor controller	S5.2021.01
System Mainboard	71.1061.50
Electronics board PTU	S5.2004.00
Electronics board PDU	S5.2013.00
Electronics board DMU	S5.2008.00
Electronics board Safety	S5.2007.00
Electronics board HF-AMP 2W	S5.0505.00
Electronics board AFP	S5.0327.00
Electronics board Autofocus	S5.0326.03
AF sensor	S5.0912.03
Write head piezo	37.0002.50
Write head nozzle WM I / 4mm WH WM II / 10mm WH WM III / 20mm WH	 35.0138.03 35.0138.06 35.0138.04
Placement aid (try square) for substrate loading	38.0339.00
User PC (PC only)	71.0300.63

Table 20: Spare parts

Glossary and Abbreviations

Alignment Accuracy
Accuracy of repeatability of positioning the stage to a point where it was without overlay alignment.

Alignment Measurement Accuracy / Overlay Accuracy
Positional accuracy with which a new pattern was printed on top of an existing pattern on the substrate , measured at any point on the substrate. Often refered to only as alignment.

AOM
The **A**cousto-**O**ptic **M**odulator uses the acousto-optic effect to diffract and shift the frequency of light using sound waves.

BMP
Abbreviation for Bitmap which is a raster graphics image file format. It is used to store bitmap digital images, independently of the display device.

CAD
Computer **A**ided **D**esign is a program that is used for design creation.

CD
Critical **D**imension is the smallest structure in a design, or respectively the smallest structure a system can write with acceptable stability.

Dose to clear
Dose to clear is the amount of exposure energy that is needed to clear the resist in the entire area to be exposed.

Ejector
A device that produces vacuum from compressed air. This vacuum is used to hold down the substrate through the vacuum holes.

Piezo
The piezo is the device that controls the write lens position at all times during exposure. It keeps the focal distance to the substrate surface constant.

POI
Point **o**f **I**nterest. The point, which has been selected before, is moved to the center of the image field

Retracted Position
Retracted position means the upper end position of the write head.

Safelight
Safelight is a light that has a colored filter so it can be used in a darkroom without affecting photosensitive film or paper.

WM
Abbreviation for **W**rite **M**ode

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