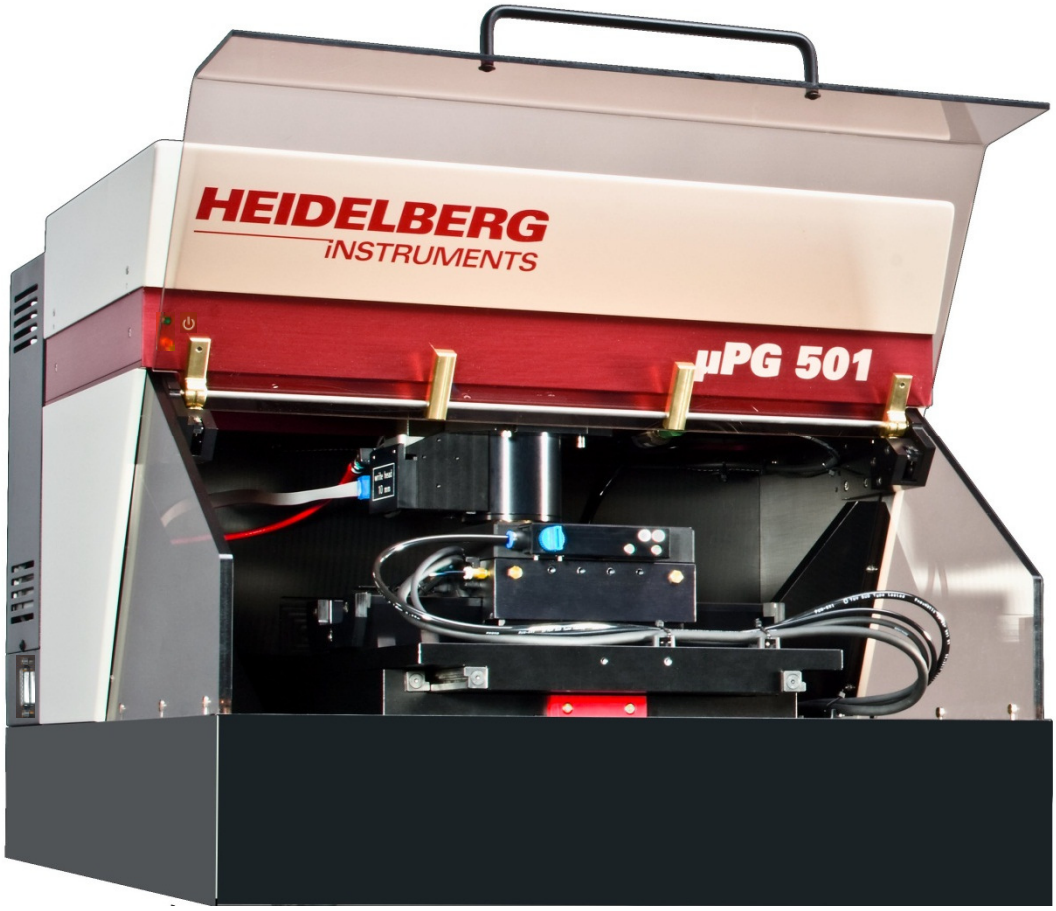
HEIDELBERG INSTRUMENTS

User Guide



µPG 501

Doc. No.: DWL-HI-049
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Preface

CONVENTIONS USED

Throughout this manual there are safety warnings. To classify the degree of danger in each of these situations, the following notation is used:

WARNING: Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION: Indicates a hazardous situation which, if not avoided, may result in minor or moderate injury.

NOTICE: Indicates a property damage risk.

In addition, notes give additional information or advice to get the best results.

SAFETY INFORMATION

The µPG 501 is fused for 10A. Electrical voltages of up to 230VAC and 120V DC are present within the system when it is connected and turned on.

WARNING: Removing any cover of the µPG 501 apart from those explicitly stated in this manual can make lethal voltages accessible. Only Heidelberg Instruments service engineers or trained personnel should perform any tasks that include the removal of such a cover while the system is energized.

CAUTION: The µPG 501 utilizes a high power LED as exposure light source. Opening of the optics cover gives access to a radiation level that is potentially harmful to the eye.
The optics cover may only be opened by Heidelberg Instruments service engineers, or trained personnel! Unauthorized opening of the optics cover leads to immediate loss of warranty.

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, Germany.

Pre-Installation Guide	System requirements, sizes and weights of components etc.
Quickstart Manual	A short introduction into the main steps of µPG501 operation
Conversion Software Manual	Manual for the HIMT conversion software used for data preparation and fractioning

CONTACT

Should you need assistance, please call Heidelberg Instruments during normal business hours (CET)

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You can also reach Heidelberg Instruments via e-mail: service@himt.de, or visit our site on the Internet: http://www.himt.de .

System Description

The µPG 501 lithography system consists of the lithography unit and a control PC.

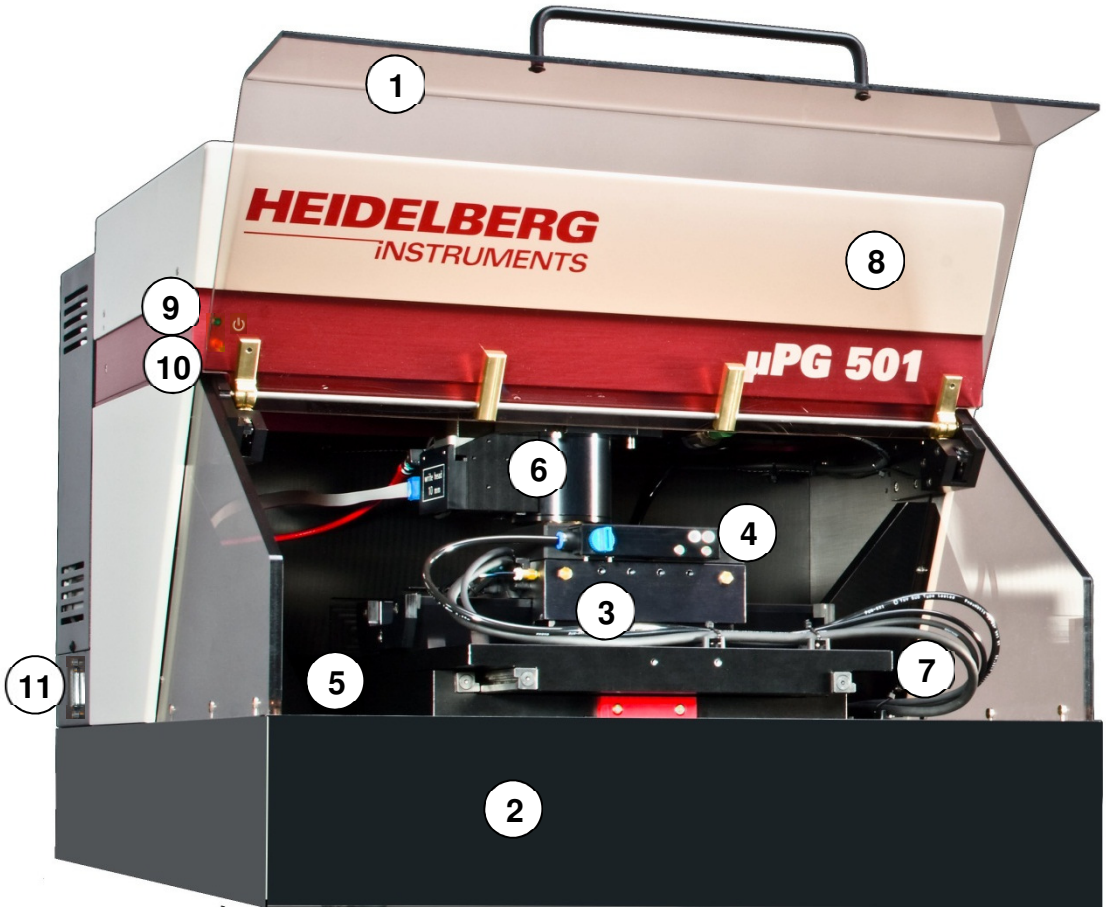


Figure 1: µPG501 lithography unit front side

1 - Cover lid with interlock circuit
2 - System base
3 - Stage
4 - Vacuum field adjustment screws
5 - Vacuum switch
6 - Write head
7 - Vacuum and compressed air supply lines
8 - Optics cover
9 - Power on/off indicator lamp
10 - Safety interlock lamp
11 - Service connector

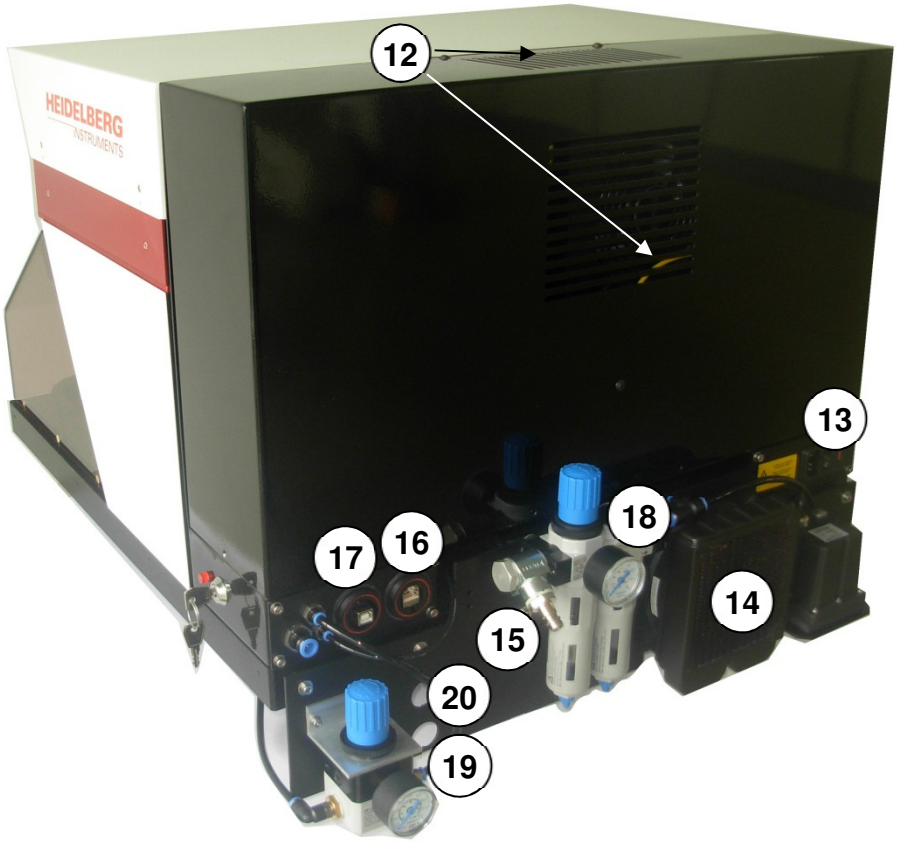


Figure 2: µPG501 lithography unit back side

12 - Ventilation slits (positions vary)
13 - Lithography unit power connector and On/Off switch
14 - Heat exchanger of LED water cooling circuit
15 - Compressed air connector (quick connector)
16 - USB connector for DMD data
17 - Network connector for LAN
18 - Compressed air regulation stage
19 - Compressed air regulation autofocus
20 - Ejector pressure regulator

System Startup and Shutdown

NOTICE: Updates of driver software can inhibit the µPG 501 from working properly.

- Whenever Windows offers updates, only select important updates
- Never change the settings for automatic updates to fully automatic.

STARTUP

1. At the Lithography Unit, switch on the µPG 501 with the On/Off switch (13). The Power On/Off Indicator Lamp (9) lights up.
2. Make sure that air pressure for the stage is applied and the lid is closed. The Safety Interlock Lamp (10) should be off.
3. Power up the Menu PC according to the manufacturer's instructions. Factory settings for login are user upg501, password upg501.
4. Start the Exposure Wizard. When starting the wizard after a shutdown, startup takes approximately a minute due to the necessary initialization processes.
5. With the wizard, the camera software HI Vision starts. **Do not close the camera window while the wizard is running**, otherwise the wizard may crash and has to be restarted.
6. Once the startup sequence of the wizard is finished, run a stage initialization (**Tools → Initialize Stage**)

SHUTDOWN

1. Close the wizard (**File → Exit**). It takes around 10 seconds for the software to finish all background processes before the wizard itself stops.
2. Switch off the µPG system with the On/Off switch (13). The Power On/Off Indicator Lamp (9) goes out.
3. Power down the Menu PC according to the manufacturer's instructions.

RESTART

1. Close the wizard (**File → Exit**).
2. Switch off the µPG system with the On/Off switch (13).
3. Wait ~20 seconds.
4. Switch on the µPG system.
5. If required (e.g., because of communication problems), reboot the User PC according to the manufacturer's instructions. Factory settings for login are user upg501, password upg501.
6. Start the Exposure Wizard.
7. With the wizard, the camera software HI Vision starts. **Do not close the camera window while the wizard is running**, otherwise the wizard may crash and has to be restarted.
8. Once the startup sequence of the wizard is finished, run a stage initialization (**Tools → Initialize Stage**)

Design Data

The µPG 501 can expose designs defined in several different formats. Each of these formats is implemented for different purposes:

- DXF, GDSII, Gerber: Standard formats for binary (2 dimensional) designs
- CIF: *Caltech Intermediate Form*, easy-to-use language for direct definition of binary (2D) structures in a text file. Good for fast definition of simple test structures without use of a special design program.
- BMP, STL, ASCII-XYZ: These formats are useable for grayscale exposures (3D resist structuring). Only elements can be processed.

To get correct exposure results, certain rules have to be followed when creating a design. Please refer to the ***Conversion Software Manual*** for more information.

Exposures

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 501.

Standard substrates:

- for mask making to use e.g., in a stepper:
  - soda-lime or quartz plates (depending on the requirements concerning temperature stability)
  - size between 2” and 5”
  - maximum thickness 6mm
  - flatness < ± 20µm
  - chromium coating with anti-reflection layer (e.g., chromium-oxide)
- for direct writing on wafers:
  - silicon wafers (for other wafer types, please contact the Heidelberg Instruments Customer Support on information if they are usable at all, and recommendations on exposure and processing)
  - size between 2” and 5”
  - maximum thickness 6mm
  - flatness < ± 20µm

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

Apart from SU-8, all resists listed are positive resists, i.e. exposed areas are developed during processing. Please refer to resist 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:

- Take care to protect the substrates from light (even safe light, as far as possible) and humidity 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.
- Never use out-of-date batches.
- Carefully clean the back side of the substrate before use to make sure it gets good vacuum suction on the µPG 501 stage chuck.
- Don't expose substrates to water, humidity, solvents, or solvent fumes.

EXPOSURE PROCEDURE

For easy use, the µPG 501 provides an ***Exposure Wizard*** that guides the operator through the steps of an exposure. There are three different types of exposure: the standard exposure, an exposure with alignment to existing structures, and the optional target mode exposure that allows to directly expose structures defined in the camera image.

STEPS OF A STANDARD EXPOSURE

A <u>Exposure Setup</u>

1. Prepare the design in the required format, as described in the Conversion Software Manual. Make sure the design complies with all design rules given there, the general as well as the specific.
2. If the design is not accessible via network from the Menu PC, transfer it to the µPG 501 PC e.g., using a memory stick or CD. Copy it to the directory `C:\HIMT\designs` or a sub-directory.

   Note: If any other directory is used, the design cannot be found.

   If the Exposure Wizard is already running, proceed with step 4.
3. Start the **µPG 501 Exposure Wizard** using the shortcut on the desktop.

   The **Welcome Screen** opens, showing the progress of the connection and initialization sequence. This includes a check of all hardware components. At the same time, the **HIVison** window opens.

   Note: Never close the **HIVision** window while the exposure wizard is running. Doing so will cause the wizard to crash.

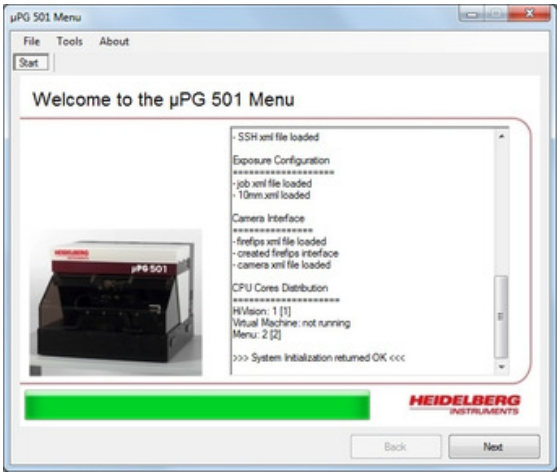


Figure 3: Startup panel

Once the startup sequence is finished and no error has occurred, the wizard automatically moves on to the next panel. If it is necessary to view the messages created during startup, the first screen can be reached anytime by clicking the **Back** button(s). If an error has occurred, the wizard does not switch to the next tab so the error message(s) can be viewed.

4. In the **Exposure Setup** panel, click on **Select Design** if a design has already been converted. Navigate to `C:\HIMT\LICSources`, open the subdirectory that contains the configuration files of the converted design, select any file and click **OK**.

   If the design to be exposed is new and has not yet been converted, or conversion options for a design should be changed, click on **Start Conversion Interface**. The Conversion Software GUI opens. Follow the instructions given in the ***Conversion Software Manual*** to prepare the design for exposure.

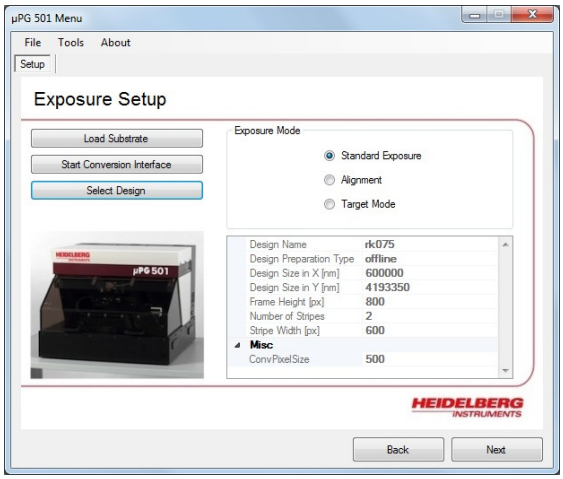


Figure 4: Exposure setup panel

   ***Note*:** Folders with converted designs must not be renamed.

   Check the design parameters listed in the window to make sure the design was converted with the correct parameters.

B <u>Substrate Loading</u>

1. Make sure the cover lid (1) is closed (interlock lamp (10) off) and the compressed air is present.
2. Click on the button **Load Substrate**. A message box opens that guides through the loading process. Click **OK**. The write head is raised and the stage moves to the loading position at the front of the machine.
3. Wait until all movement has finished. Open the cover lid. On the chuck, mount the alignment pins (masks: three, wafers: two) in the appropriate positions for the plate size to be used (see left part of Figure 5).
4. Switch off all light except safe light. Take a substrate out of its storage container. Check substrate quality.
   - Make sure the substrates comply with the specifications of the µPG 501 (Size between 2” and 5”, max. thickness 6mm, flatness tolerance < ± 20µm)
   - 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.

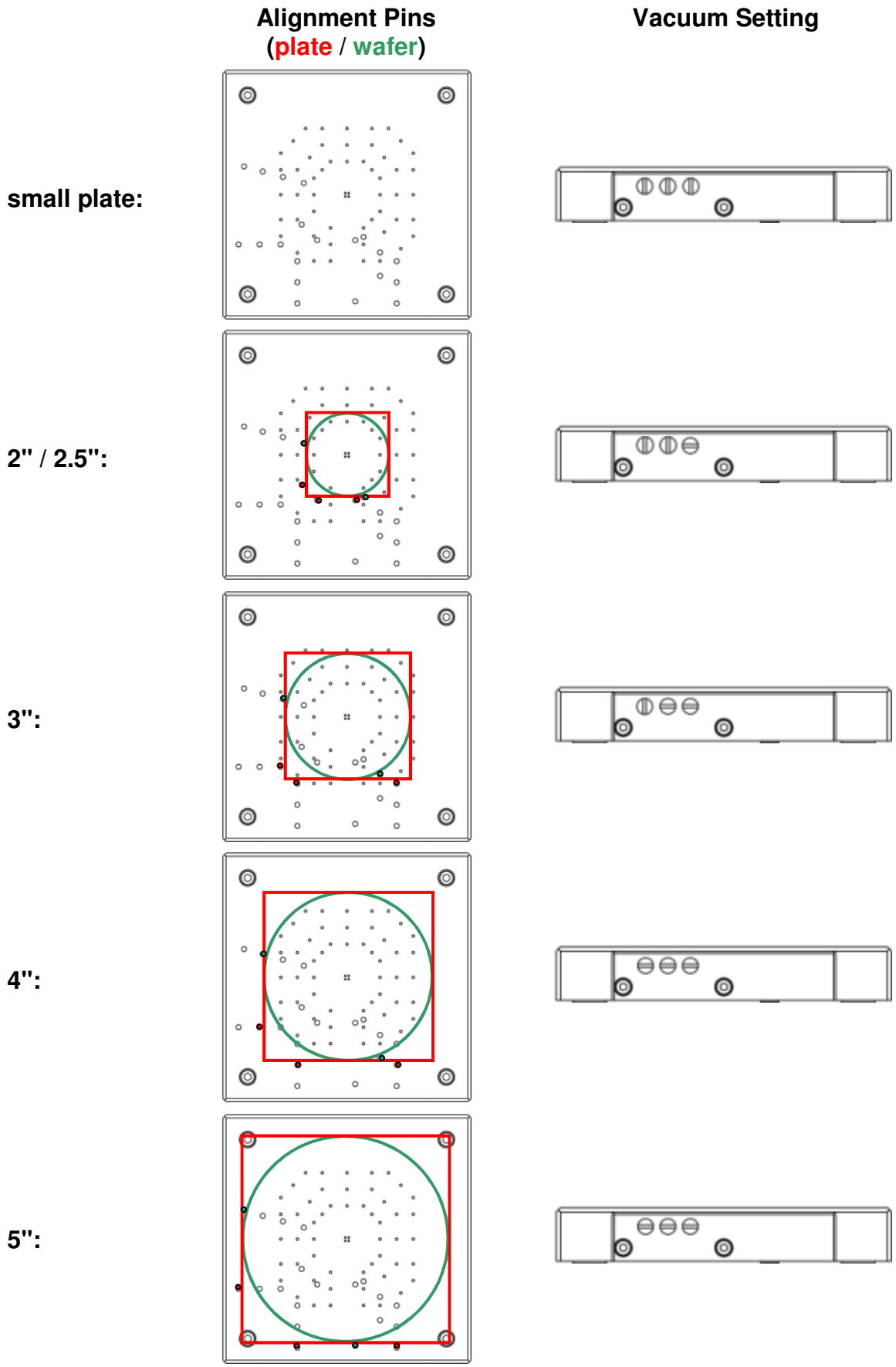


Figure 5: Alignment pins placement and vacuum region selection according to substrate size

5. Make sure the resist coated side of the substrate is turned up, and position it against the alignment pins. If the substrate bears alignment marks that should be used for exposure, **note that 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** (see Figure 6).

   The four center vacuum suction holes are always active when the vacuum is switched on, holding down small substrates. For substrate sizes of 2" or larger, additional vacuum region extensions can be added using the vacuum field selection screws (4) (see right part of Figure 5, and Figure 7). Switch on the vacuum with the vacuum switch (5). Check whether the plate is really held tight by trying to move it slightly sideways. If plate is not held, switch off the vacuum and clean plate backside and chuck before trying again. If problems persist, use a different substrate.

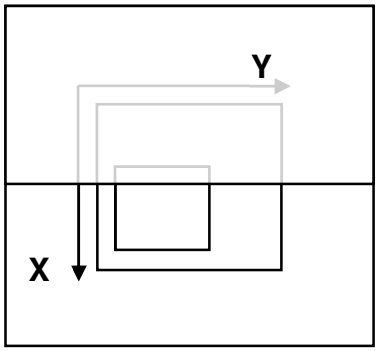


Figure 6: Stage coordinate system

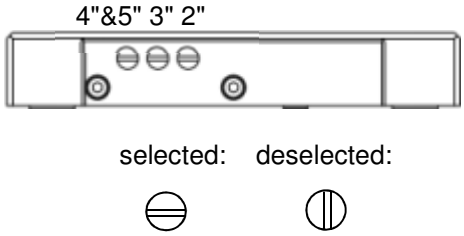


Figure 7: Vacuum region selection

6. Remove all alignment pins. Close the cover lid (1) and make sure the interlock lamp (10) is off.

   NOTICE: If the alignment pins are left on the stage during exposure of a thin substrate, the system can take **serious damage**!

7. Click **OK** in the message box. The stage moves to the center position, and the write head moves down until the focal point is on the substrate surface.
8. A message box opens, offering to start the Find Plate Center procedure. Click **OK** if the origin should be set in the center of the plate, or if it is for other reasons of interest to have the write head exactly above the substrate center (e.g., because it is a good starting point to find alignment sites).
9. The next message box offers to set the current position as coordinate origin. Click **OK**. For exposures without alignment, this is the only point where the coordinate system origin can be set.
10. In the *Exposure Mode* frame, select **Standard Exposure** for a simple exposure without alignment. For an exposure procedure with alignment, refer to the next section.
11. Click **Next** to proceed to the next panel.

C Exposing

1. In the **Expose** panel, parameters have to be set that depend on the substrate type that is used.

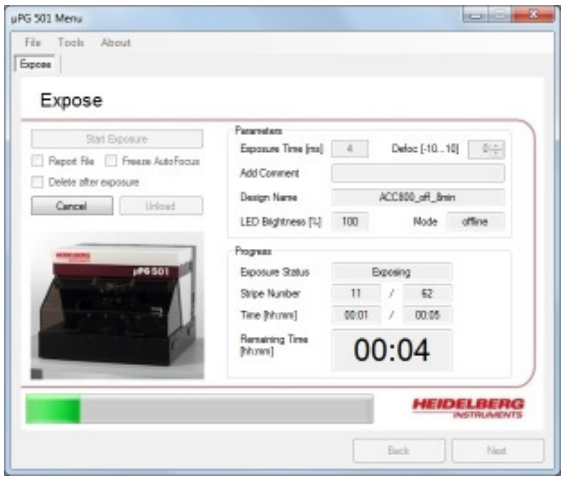


Figure 8: Expose panel

   - **Exposure Time**: There are two parameters that influence the amount of energy that is deposited in the resist. While the output power of the LED is usually fixed to 100% (can be adjusted during installation according to the requirements of the most common applications), the exposure time for each frame can be varied from 4 ms up to 90 s to adjust the energy deposited to the sensitivity of the resist.

     The energy needed for a certain exposure depends on the type and thickness of the photoresist used. For a resist with spectral sensitivity of 70 mJ/cm^2 and .5 µm thickness, an LED power of 100% in conjunction with an exposure time of 16 ms is needed to expose the resist.

   - **Defoc:** The best focus position for an exposure can depend on e.g., the resist thickness, or reflectivity. Therefore, it can be adjusted with the defocus parameter. The numbers used for defocus setting are arbitrary numbers and range from –10…10. The full range corresponds roughly to the focal depth of the exposure lens (~ 10 µm).

   For both exposure time and defoc(us), the Exposure Wizard contains a function to easily set up and run test exposure series. Please refer to the section on exposure optimization below for more information.

2. Enter a comment that helps to identify the exposure in the log files into the **Add Comment** text box. For each exposure, one line containing all relevant exposure data (design, exposure parameters, comments) is written into the continuous log file *C:\HIMT\LogFiles\ExposureLog.txt*. The header of the file contains the explanation of each entry.

3. Checkboxes offer some additional options for exposure:

   - For debugging in the case of problems, a checkbox offers the option **Report file**. Usually, this option should be left deactivated.

   - To save disk space, **Delete after exposure** can be selected. If this option is selected, the converted data is deleted after the exposure, only the source design is kept.

   - For small substrates that should be exposed up to the very edges, the option **Freeze AutoFocus** can be activated.

NOTICE: Manual focusing while this function is active can lead to irreversible damage to the system. Don't use any focusing functions before the freezing is deactivated.

4. Check again if air pressure is OK, the lid is closed, and no alignment pins have been left in the stage chuck.
5. Click **Start Exposure**.

   During an exposure, the exposure status is shown online in the window. Make sure that during the complete exposure time the cover lid stays closed, and no white light is switched on in the room. In addition, to get best results, avoid vibrations caused by people passing by or by heavy loads being moved on the floor close to the system.
6. To interrupt an exposure, click on **Cancel** and confirm.

D <u>Unloading</u>

1. After exposure is finished, if no further designs should be exposed on the same plate, click on **Unload**.
2. Wait until all movement has stopped.
3. Open the lid, switch off the vacuum with the vacuum switch (5) and carefully lift the substrate off the chuck. Store it in a light-proof transport box.
4. Process the substrate as soon as possible according to the substrate type and manufacturers recommendation.
5. For further exposures of the same design on the same substrate, adjust parameters if required and restart. For a different exposure on the same substrate, use the **Back** button to get back to the **Exposure Setup** panel.

STEPS OF AN EXPOSURE WITH ALIGNMENT

Alignment is done to expose a design in a defined position with respect to marks on the substrate. The coordinates of a clearly defined point within a mark (e.g., a corner) are used as anchor(s) for the coordinate system. Depending on the number of marks, different levels of accuracy can be reached:

- **one point alignment**: If only one mark is used for alignment, only the origin is shifted to match the origin of the existing pattern.
- **multiple point alignment**:

  Using 2 – 4 marks allow for a rotational adjustment of the design to the existing pattern. If this is used, the pattern is re-converted with the angle that has been found. A 3rd and 4th mark increase accuracy though more averaging.

Several different alignment methods are available in the wizard, a manual method and three automatic methods:

- **manual alignment**: The operator has to indicate the points that have the known coordinates
- **template matching**: An image template of the alignment mark is defined, and the design coordinates are assigned to the position where this template is found. This is useful if either a substrate has several identical marks, or the same marks are used on several substrates.
  A template does not have to contain a complete structure. Often, it is more useful to use e.g., one corner of a structure, as this gives a defined point for the template center position and the coordinates that are assigned to it. No similar feature may be close by, and the feature should be small enough that the template box is still within the image field even if the structure is displaced a bit.
- **cross alignment** This is the most precise method of alignment. One or more crosses are used for position and angle detection. The cross should have arms that are significantly longer than wide. For good results, the size should be at least so that it covers half the image field. Best results are obtained with sizes that are larger than the image field.
- **mask edge** Detects position and angle of the mask edges using the autofocus system, and calculates center position and rotation from that (rectangular samples only).

A Exposure Setup

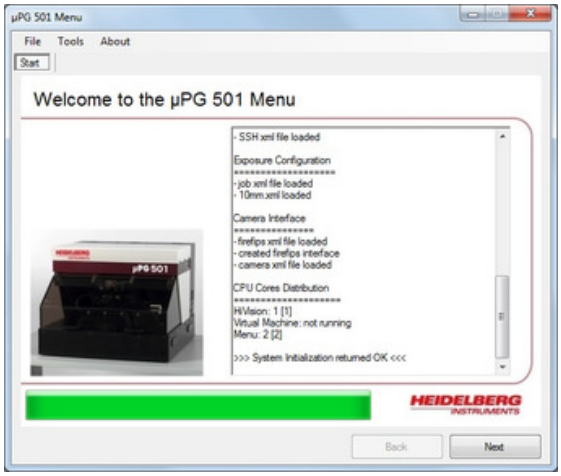
1. Prepare the design in the required format, as described in the Conversion Software Manual. Make sure the design complies with all design rules given there, the general as well as the specific.
2. If the design is not accessible via network from the Menu PC, transfer it to the µPG 501 PC e.g., using a memory stick or CD. Copy it to the directory `C:\HIMT\designs` or a sub-directory.

   Note: If any other directory is used, the design cannot be found.

   If the Exposure Wizard is already running, proceed with step 4.
3. Start the **µPG 501 Exposure Wizard** using the shortcut on the desktop.

   The **Welcome Screen** opens, showing the progress of the connection and initialization sequence. This includes a check of all hardware components. At the same time, the **HIVison** window opens.

   Note: Never close the HIVision window while the exposure wizard is running. Doing so will cause the wizard to crash.

   Once the startup sequence is finished and no error has occurred, the wizard automatically moves on to the next panel. If it is necessary to view the messages created during startup, the first screen can be reached anytime by clicking the **Back** button(s). If an error has occurred, the wizard does not switch to the next tab so the error message(s) can be viewed.
4. In the **Exposure Setup** panel, click on **Select Design** if a design has already been converted. Navigate to `C:\HIMT\LICSources`, open the subdirectory that contains the configuration files of the converted design, select any file and click **OK**.

   If the design to be exposed is new and has not yet been converted, or conversion options for a design should be changed, click on Start **Conversion Interface.** The Conversion Software GUI opens. Follow the instructions given in the Conversion ***Software Manual to*** prepare the design for exposure.

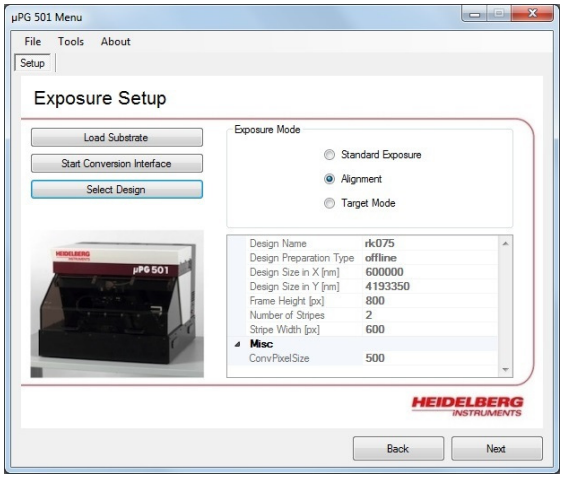
   

   Figure 10: Exposure setup panel

   Note: Folders with converted designs must not be renamed.

Check the design parameters listed in the window to make sure the design was converted with the correct parameters.

B Substrate Loading

1. Make sure the cover lid (1) is closed (interlock lamp (10) off) and the compressed air is present.
2. Click on the button **Load Substrate**. A message box opens that guides through the loading process. Click **OK**. The write head is raised and the stage moves to the loading position at the front of the machine.
3. Wait until all movement has finished. Open the cover lid. On the chuck, mount the alignment pins (masks: three, wafers: two) in the appropriate positions for the plate size to be used (see left part of Figure 5).
4. Switch off all light except safe light. Take a substrate out of its storage container. Check substrate quality.
   - Make sure the substrates comply with the specifications of the µPG 501 (Size between 2” and 5”, max. thickness 6mm, flatness tolerance < ± 20µm)
   - 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.
5. Make sure the resist coated side of the substrate is turned up, and position it against the alignment pins. If the substrate bears alignment marks that should be used for exposure, **note that 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** (see Figure 6).

   The four center vacuum suction holes are always active when the vacuum is switched on, holding down small substrates. For substrate sizes of 2" or larger, additional vacuum region extensions can be added using the vacuum field selection screws (4) (see right part of Figure 5, and Figure 7). Switch on the vacuum with the vacuum switch (5). Check whether the plate is really held tight by trying to move it slightly sideways. If plate is not held, switch off the vacuum and clean plate backside and chuck before trying again. If problems persist, use a different substrate.
6. Remove all alignment pins. Close the cover lid (1) and make sure the interlock lamp (10) is off.

   NOTICE: If the alignment pins are left on the stage during exposure of a thin substrate, the system can take **serious damage**!
7. Click **OK** in the message box. The stage moves to the center position, and the write head moves down until the focal point is on the substrate surface.
8. A message box opens, offering to start the Find Plate Center procedure. Click **OK** if the origin should be set in the center of the plate, or if it is for other reasons of interest to have the write head exactly above the substrate center (e.g., because it is a good starting point to find alignment sites).

9. The next message box offers to set the current position as coordinate origin. Click **OK**.
10. In the *Exposure Mode* frame, click on the checkbox for **Alignment**.
11. Click **Next** to proceed to the next panel.

C Alignment Procedure

In the **Alignment** panel, a text box on the right leads through all steps of alignment setup. The steps are nevertheless also described here.

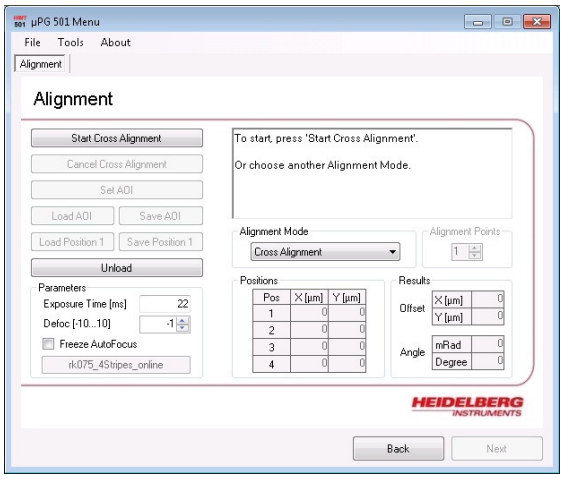


Figure 11: Alignment setup panel

1. In the *Alignment Mode* frame, select if **Manual** or one of the automatic modes (**Template, Cross, Mask Edge**) of alignment should be used by checking the related check button. If **Mask Edge** is selected, proceed directly to part D.
2. Click on **Start <alignment method>**.

   Note: Anytime during alignment, clicking **Cancel Alignment** resets the procedure.
3. Select the number of **Alignment Points** that should be used (1-4). Click **Continue**.
4. The **Control Panel** opens below the **Alignment** panel and shows the **XY Stage** register card.
5. Use the controls on the **XY Stage** register to move the (first) alignment mark into the field of view.

   Note: To interrupt a movement or procedure, click on the **Stop** button.

   - Choose between 'jog' mode (continuous movement at a certain speed) and 'step' mode (position change by defined increments)
   - Adjust the 'jog' speed with the slider, the 'step' increment in the text boxes
   - Move into a certain direction by clicking on the direction arrows arranged as a cross
   - If position (in the current coordinate system!) or distance are known exactly, use the absolute or relative movement. Enter position coordinates / distances into the fields and click on the arrow beside these to execute the movement.

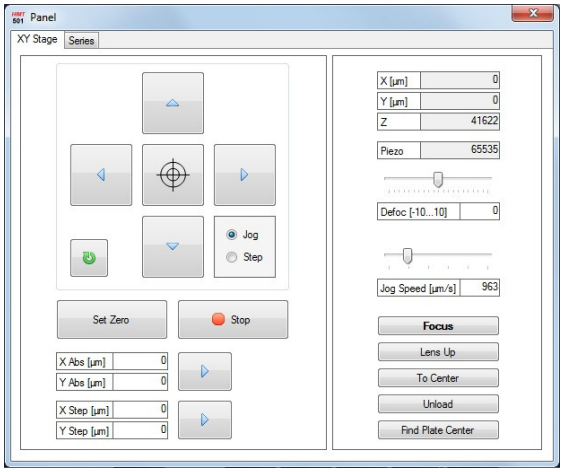


Figure 12: XY stage control panel

- If a certain feature in the camera field should be moved to the center, click on the cross hair button in the center of the button field, position the crosshair in the image and then click again on the button.
- Most of the time, coordinates are refreshed automatically after a movement. In cases where this did not happen, click on the **Refresh** button at the bottom left of the button cross to get the current position coordinates.

6. Once the (first) mark is visible in the **HIVision** window, click **Continue**.
7. A crosshair appears in the **HIVison** window. Drag the center of the crosshair onto the point with known coordinates / center of the template / center of the cross. Use the ***Alignment Fine-Tuning*** arrows for fine positioning of the crosshair.

   Template matching: The crosshair is accompanied by a box for definition of an area of interest (**AoI**). If a new template should be defined, adjust the size of the AoI box so that it contains the designated feature. Otherwise, use the function **Load Template/AOI 1** to load an existing template.

   Cross: If the cross is smaller than the image field, the size of the cross has to be marked. Click on **Set AOI** and resize the box so the cross fits into it.

   Click **Continue.**

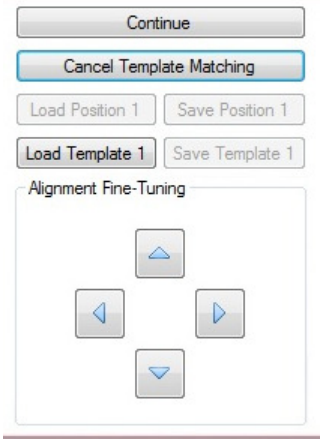


Figure 13: Cross-hair position fine tuning controls (Manual, Tempate)

8. *Template Matching only*: A check is done if the template can be detected. If not, the wizard gives a warning and does not go on to the next step. If yes, the button **Save Template** is activated, and the image can be saved. Click **Continue**.
9. The **XY Stage** panel closes, and the selected position is moved to the center of the image field.
10. The fields for entering the coordinates for **Position 1** change color to white and can be edited. Enter the coordinates of the (first) mark, or click **Load Position 1** to load a coordinate set from a file. After the coordinates have been entered, they can be saved into a file by clicking on the button **Save Position 1**. Click **Continue**.

    ***Note*:** If there is an error in an entry, the related text field turns red.
11. If more than one alignment point was selected, the entry fields for the next alignment points are activated one after the other. Enter or load the coordinates of the next mark and click **Continue**.
12. The stage executes a relative movement according to the coordinate difference of position 1 and the current position. If the current alignment mark is not positioned well in the field of view, use the re-opened **XY Stage** register card of the **Control Panel** to get it into good view. Click **Continue**.

13. If necessary, adjust the position of the crosshair / position and size of the area of interest box. *Template Matching*: If the previous template was saved, it is possible to simply **Re-Use** it by clicking the button. Otherwise, define and save a new template in the same way as before, or use the **Load Template** function to load a different template. Click **Continue**.
14. Repeat until all alignment points are defined.
    - If only one alignment point was selected, but the design was previously converted with a rotation, the wizard warns about the fact and offers to re-convert the design with rotation zero. Click **Yes** to re-convert, **No** to leave the converted design as it is. During re-conversion, a status window opens and shows the conversion progress.
    - If more than one alignment point was selected, the substrate rotation is calculated and shown. If **Confirm** is selected, the design is re-converted with that rotation angle. Some message windows appear during the process, and a status window opens and shows the conversion progress.

    ***Note*:** The total number of stripes shown during re-conversion is calculated for the complete design region. Due to optimization by omission of empty stripes, the real final number of stripes might differ from this number.
15. Click **Go To Exposure** to proceed to the next panel, or **Restart Alignment** to reset the measured values to zero.

    Note: The offset value is used until a new design is loaded or the current design is reloaded. The rotation is used for that design until it is re-converted with rotation zero.

D <u>Exposing</u>

1. In the *Exposure* frame of the **Alignment** panel, parameters have to be set that depend on the substrate type that is used.
    - **Exposure Time:** There are two parameters that influence the amount of energy that is deposited in the resist. While the output power of the LED is usually fixed to 100% (can be adjusted during installation according to the requirements of the most common applications), the exposure time for each frame can be varied from 4 ms up to 90 s to adjust the energy deposited to the sensitivity of the resist**.**

      The energy needed for a certain exposure depends on the type and thickness of the photoresist used. For a resist with spectral sensitivity of 70 mJ/cm2 and .5 µm thickness, an LED power of 100% in conjunction with an exposure time of 16 ms is needed to expose the resist.
    - **Defoc**: The best focus position for an exposure can depend on e.g., the resist thickness, or reflectivity. Therefore, it can be adjusted with the defocus parameter. The numbers used for defocus setting are arbitrary numbers and range from –10…10. The full range corresponds roughly to the focal depth of the exposure lens (~ 10 µm).

For both exposure time and defoc(us), the Exposure Wizard contains a function to easily set up and run test exposure series. Please refer to the section on exposure optimization below for more information.

2. For small substrates that should be exposed up to the very edges, the option **Freeze AutoFocus** can be activated.

   NOTICE: Manual focusing while this function is active can lead to irreversible damage to the system. Don't use any focusing functions before the freezing is deactivated.

3. Click **Start Exposure**.

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

4. To interrupt an exposure, click on **Cancel** and confirm.

E <u>Unloading</u>

1. After exposure is finished, if no further designs should be exposed on the same plate, click on **Unload**.
2. Wait until all movement has stopped.
3. Open the lid, switch off the vacuum with the vacuum switch (5) and carefully lift the substrate off the chuck. Store it in a light-proof transport box.
4. Process the substrate as soon as possible according to the substrate type and manufacturers recommendation.
5. For further exposures of the same design on the same substrate, adjust parameters if required and restart. For a different exposure on the same substrate, use the **Back** button to get back to the **Exposure Setup** panel.

STEPS OF A TARGET MODE EXPOSURE

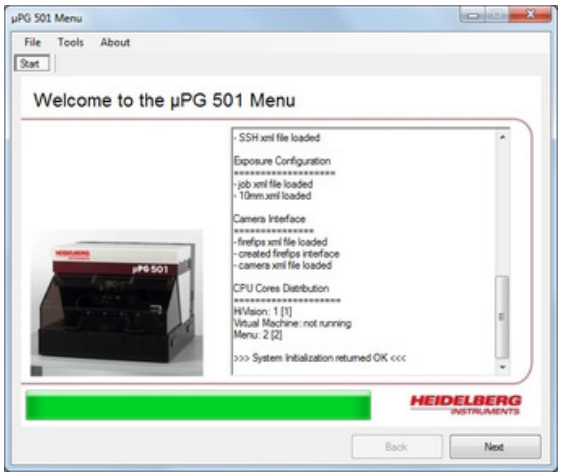
With target mode exposures, it is possible to expose boxes of arbitrary length and width limited only by the camera field size directly on a substrate, without need of a design and conversion. This can be used e.g., to create connections between structures, or to interrupt them.

A Exposure Setup

1. Start the **µPG 501 Exposure Wizard** using the shortcut on the desktop.

   The **Welcome Screen** opens, showing the progress of the connection and initialization sequence. This includes a check of all hardware components. At the same time, the **HIVison** window opens.

   Note: Never close the HIVision window while the exposure wizard is running. Doing so will cause the wizard to crash.



   Once the startup sequence is finished and no error has occurred, the wizard automatically moves on to the next panel. If it is necessary to view the messages created during startup, the first screen can be reached anytime by clicking the **Back** button(s). If an error has occurred, the wizard does not switch to the next tab so the error message(s) can be viewed.

2. The **Exposure Setup** panel opens.

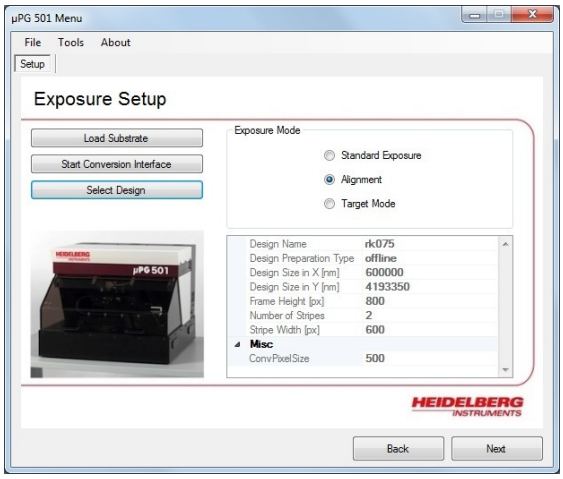


Figure 15: Exposure setup panel

B Substrate Loading

1. Make sure the cover lid (1) is closed (interlock lamp (10) off) and the compressed air is present.
2. Click on the button **Load Substrate**. A message box opens that guides through the loading process. Click **OK**. The write head is raised and the stage moves to the loading position at the front of the machine.
3. Wait until all movement has finished. Open the cover lid. On the chuck, mount the alignment pins (masks: three, wafers: two) in the appropriate positions for the plate size to be used (see left part of Figure 5).
4. Switch off all light except safe light. Take a substrate out of its storage container. Check substrate quality.

- Make sure the substrates comply with the specifications of the µPG 501 (Size between 2” and 5”, max. thickness 6mm, flatness tolerance < ± 20µm)
- 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.

5. Make sure the resist coated side of the substrate is turned up, and position it against the alignment pins. If the substrate bears alignment marks that should be used for exposure, **note that 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** (see Figure 6).

   The four center vacuum suction holes are always active when the vacuum is switched on, holding down small substrates. For substrate sizes of 2" or larger, additional vacuum region extensions can be added using the vacuum field selection screws (4) (see right part of Figure 5, and Figure 7). Switch on the vacuum with the vacuum switch (5). Check whether the plate is really held tight by trying to move it slightly sideways. If plate is not held, switch off the vacuum and clean plate backside and chuck before trying again. If problems persist, use a different substrate.

6. Remove all alignment pins. Close the cover lid (1) and make sure the interlock lamp (10) is off.

   NOTICE: If the alignment pins are left on the stage during exposure of a thin substrate, the system can take **serious damage**!

7. Click **OK** in the message box. The stage moves to the center position, and the write head moves down until the focal point is on the substrate surface.

8. A message box opens, offering to start the Find Plate Center procedure. Click **OK** if the origin should be set in the center of the plate, or if it is for other reasons of interest to have the write head exactly above the substrate center (e.g., because it is a good starting point to find alignment sites).

9. The next message box offers to set the current position as coordinate origin. Click **OK**.

10. In the *Exposure Mode* frame, click on the checkbox for **Target Mode**.

11. Click **Next** to proceed to the next panel.

C Target Mode Exposure Preparation

In the **Target Mode** panel, a text box on the right leads through all steps of alignment setup. The steps are nevertheless also described here.

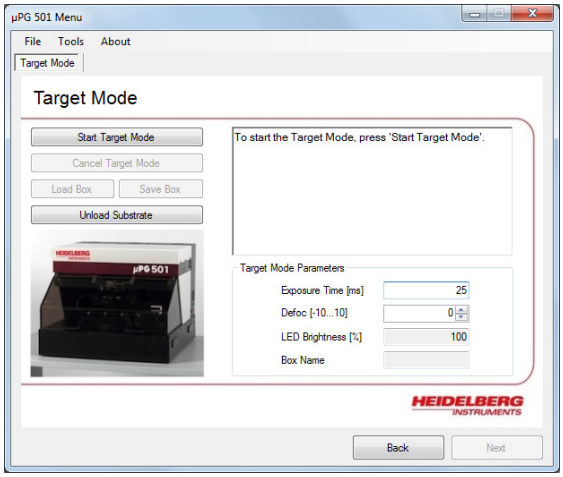


Figure 16: Target Mode panel

1. Click on **Start Target Mode**.

   ***Note*:** Anytime during alignment, clicking **Cancel Target Mode** resets the procedure.

2. The **Control Panel** opens below the **Target Mode** panel and shows the **XY Stage** register card.

3. Use the controls on the **XY Stage** register to move the position where a box should be exposed into the field of view.

   ***Note*:** To interrupt a movement or procedure, click on the **Stop** button.

   - Choose between 'jog' mode (continuous movement at a certain speed) and 'step' mode (position change by defined increments)
   - Adjust the 'jog' speed with the slider, the 'step' increment in the text boxes
   - Move into a certain direction by clicking on the direction arrows arranged as a cross
   - If position (in the current coordinate system!) or distance are known exactly, use the absolute or relative movement. Enter position coordinates / distances into the fields and click on the arrow beside these to execute the movement.
   - If a certain feature in the camera field should be moved to the center, click on the cross hair button in the center of the button field, position the crosshair in the image and then click again on the button.
   - Most of the time, coordinates are refreshed automatically after a movement. In cases where this did not happen, click on the **Refresh** button at the bottom left of the button cross to get the current position coordinates.

4. Once the position for exposure is in view, click on **Continue**.

5. A box for marking an area of interest appears in the camera image field. If a new exposure area should be defined, move and shape the box to mark the area that should be exposed. If a previously defined box should be loaded, press **Load Box**.

   For fine movement of the box, use the controls in the *Box Fine-Positioning* frame.

6. If the box should be re-used at a later time, press **Save Box**.

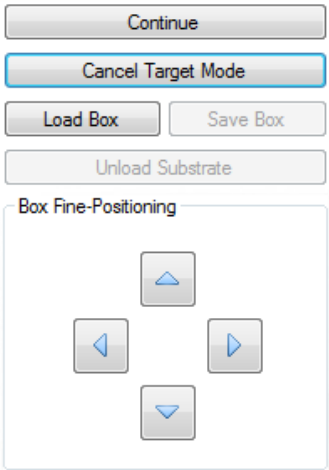


Figure 17: Box position fine tuning controls

D Exposing

7. In the *Parameters* frame of the **Target Mode** panel, parameters have to be set that depend on the substrate type that is used.

   - **Exposure Time**: There are two parameters that influence the amount of energy that is deposited in the resist. While the output power of the LED is usually fixed to 100% (can be adjusted during installation according to the requirements of the most common applications), the exposure time for each frame can be varied from 4 ms up to 90 s to adjust the energy deposited to the sensitivity of the resist.

     The energy needed for a certain exposure depends on the type and thickness of the photoresist used. For a resist with spectral sensitivity of 70 mJ/cm^2 and .5 µm thickness, an LED power of 100% in conjunction with an exposure time of 16 ms is needed to expose the resist.

   - **Defoc:** The best focus position for an exposure can depend on e.g., the resist thickness, or reflectivity. Therefore, it can be adjusted with the defocus parameter. The numbers used for defocus setting are arbitrary numbers and range from –10…10. The full range corresponds roughly to the focal depth of the exposure lens (~ 10 µm).

   For both exposure time and defoc(us), the Exposure Wizard contains a function to easily set up and run test exposure series. Please refer to the section on exposure optimization below for more information.

   LED brightness and the name of the box if it was saved/loaded are shown for information.

1. Click **Start Exposure**.

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

2. To interrupt an exposure, click on **Cancel** and confirm.

E Unloading

1. After exposure is finished, if no further designs should be exposed on the same plate, click on **Unload**.
2. Wait until all movement has stopped.
3. Open the lid, switch off the vacuum with the vacuum switch (5) and carefully lift the substrate off the chuck. Store it in a light-proof transport box.
4. Process the substrate as soon as possible according to the substrate type and manufacturers recommendation.
5. For further target mode exposures, click on **Expose another Box**. If no more target mode exposures should be done, click on **Finish Target Mode** and **Back** to return to exposure setup.

SUBSTRATE PROCESSING

The steps of processing of 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. 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 SU8, the developer removes the parts which were <u>not</u> exposed.

  Developing times depend on resist type, resist thickness, and developer type, as well as 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 linewidth 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 linewidth 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.

Material recommendations:

- **developer:** TMAH series (metal-ion free), or 351B.
- **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 plates can be cleaned using DI water and a mild detergent

Standard materials used with the resists explicitly mentioned above:

	binary (2D)	**gray value (3D)**
Resist	S1805 or AZ1550	*positive*: AZ4562 or AZ9260 *negative, UV option only*: SU-8
Developer	AZ351B / MF351B in 1:4 dilution (1 part developer, 4 parts DI water), alternatively MF319 undiluted	*AZ resists*: AZ400K in a 1:3.5 ... 1:5 dilution (depends on application) *SU-8*: SU-8 developer
Etcher	Shipley chrome etch 18	N/A

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. Alwayse 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.

Exposure Optimization

For optimum exposure results, the correct energy and defocus for a substrate type has to be determined. To avoid having to do many single exposures with manually changed values, the **Series** register card in the **Control Panel** offers fast setup of exposure series for one or both parameters. If both parameters should be tested, a matrix is exposed to find the best combination.
The required exposure energy and defocus depends 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 publications on photolithography.

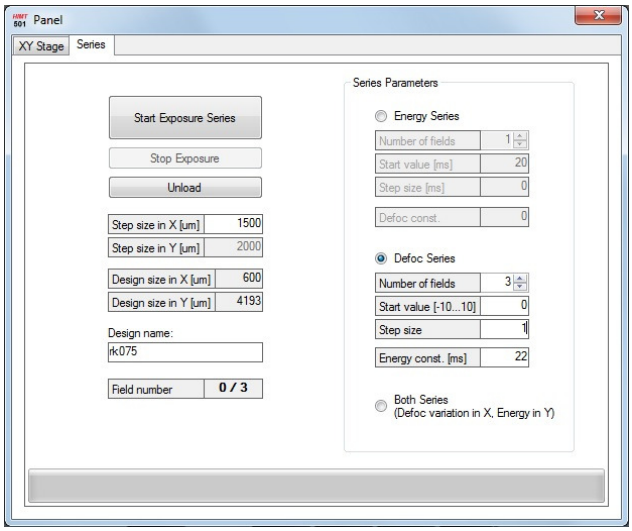


Figure 18: Calibration panel

The entries in the fields of the panel are checked. Entry field with wrong entries turn red and lead to an error. If an entry can lead to results that might or might not be desired, the related field turns orange, and a warning about the problem is issued (e.g., overlapping exposure fields, or an exposure area that is larger than the substrate size detected during loading).

1. In the **Exposure Setup** panel, select the design that should be used for the parameter test. If necessary, (re-)convert it according to the instructions given above and in the ***Conversion Software Manual***.
2. Open the **Control Panel** (**Tools → Control Panel**). It opens with the **XY Stage** register card in the foreground. Use the functions on this card to move that point of the substrate into view, around which the test series should be exposed. Set the coordinates of this position to zero.
   Refer to the section on the **Tools** menu for explanations of the **XY Stage** functions.
3. Click on the **Series** tab. A new register card comes to the foreground. Here, on the right side, the settings for the exposure series are selected. If only a series for either energy or defoc should be exposed, click on the checkbox for that parameter series (**Energy Series** / **Defoc Series**). If the option **Both Series** is selected, the design is exposed in a grid with defoc variation within the rows, and energy variation along the columns.
4. Set the number of fields, start value(s) and step size(s) for the exposure series. If only one of the parameters should be varied, enter a constant value for the other parameter in the corresponding field (*defoc const* / *energy const*).
   If invalid values are entered, an error message is issued, and the value is declined. A step size of 0 e.g., for testing of variation of other influences or of stability is possible.

5. On the left, select the distances between the fields. If only one series was selected, only a step size in x can be entered. If **Both Series** was selected, also a step size in y is required. The size of the design selected for exposure is shown below the text boxes for reference. If the entered step size values result in an overlap, a warning is issued, but exposure can nevertheless be started. The fields will be arranged symmetrically around the current position.
6. Click on **Start Exposure Series**. During exposure, the **Field Number** text box shows which field is being exposed, and the overall progress can be seen in the progress bar. The exposure can be interrupted at any time using the **Stop Exposure** button.
7. When the series is finished, click on **Unload** and follow the instructions. Process the substrate as usual and evaluate the structure quality to find the best (combination of) values.

Tools Menu

The **Tools** menu in the main menu bar of the Exposure Wizard gives access to some additional functions for troubleshooting and optimization of system performance.

INITIALIZE STAGE

The function **Tools → Initialize Stage** re-initializes the stage by moving it into the end switches, where the universal coordinate system is zeroed. It has to be used after each new start of the lithography machine. Also, it often helps in the case of problems with machine movement.

CONTROL PANEL

The **Control Panel** opens automatically during alignment, but it can also be opened from the wizard menu by selecting **Tools → Control Panel**. Besides the movement functions used during alignment, it contains some additional functions for the advanced user.

In the following, the contents of the **XY Stage** register card are explained more in-depth than in the step-by-step instructions. For information on the contents of the **Series** register card, see the section above on exposure optimization.

Note: Any stage movement can be interrupted at any time with the **Stop** button.

Free movement:

Movement according to sight is done via the arrow buttons arranged as a cross and the 'jog' mode. The speed of movement is decided either with the slider, or by typing a number into the **Jog Speed** text box. The unit is µm/s.

Incremental movement:

Incremental movement is helpful e.g., when inspecting the fields of a calibration exposure with the µPG camera system. Movement is triggered by clicking one of the arrow buttons arranged as a cross. For each click, the stage moves in the given direction by the increment given for the related axis in the **X Step** / **Y Step** text fields.

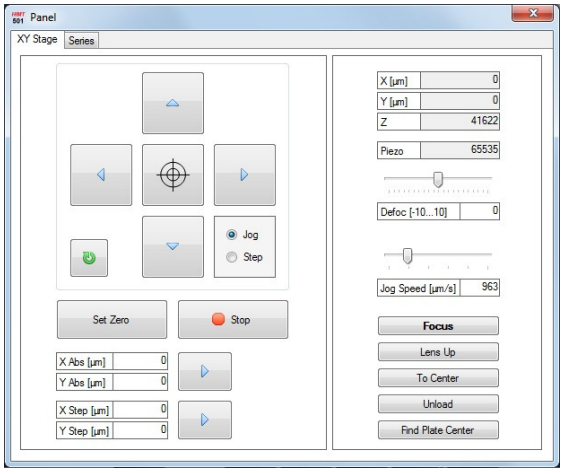


Figure 19: Control panel – XY Stage

Direct relative or absolute movement

If the stage should move to a point with known position either relative to the current position, or even in absolute coordinates, this does not have to be done one axis after the other, but can be done in one step. Enter the relative or absolute movement coordinates into the related fields (X / Y Step – relative movement / X / Y Abs –

absolute movement) and click on the arrow beside the fields. Keep in mind to use the correct signs. The stage moves directly to the distances / coordinates given.

Write head functions

The **XY Stage** register card also contains controls for write head movement. During standard operation, these functions are never required, as the write head is always moved automatically in conjunction with the process step that is being done.

NOTICE These controls have to be used with the utmost care. Crashing the write head nozzle against the stage or a substrate can damage the system severely.

With **Lens Up**, the write head can be moved away from the stage into the upper end switch. This should be done e.g., before unloading with the **Control Panel**, to make sure that the next substrate does not hit the write head nozzle.

With **Focus**, the write head moves into the position where the focus point of the objective is on the substrate surface.

- **Never focus on, or close to, the edge of a substrate**
- **Never focus beside a substrate**

Manual focusing could be helpful if focus values differ a lot across a plate, to make sure the focus values range around the center of the regulation range. It has to be done if a plate is loaded using the **Control Panel** rather than the automatic loading sequence from the Exposure Setup Panel.

If there is no explicit reason to use the **Control Panel** for unloading or loading, rather use the standard functions!

Another write head related function the **XY Stage** register card offers is a defoc slider. This only effects the focus of the camera image. During exposure, the defoc is automatically reset to the value given in the **Expose** panel.

Special movements

The stage **Center** position and the (**Un)load** position can be reached by a single click on the corresponding button. Make sure the write head is in the upper position before executing any of these movements.

Also, the **Control Panel** offers the possibility to manually start the **Find Plate Center** routine that detects the plate edges with the autofocus system and calculates the center position from that.

Troubleshooting and Maintenance

This section contains advice on some possible problems that might be encountered during operation of the **µPG 501**. If you encounter a problem that cannot be solved in this way, please contact your Heidelberg Instruments service office (see section *Contact* in the preface).

FUNCTIONAL PROBLEMS

Problem:
System does not start at all, power indication lamp off
Possible causes:
- facility power down
- main fuse blown (see section 'fuses')

Remedies:
- check facility power
- check fuse

Problem:
CAD design / LIC file folder cannot be found
Possible causes:
- stored in the wrong directory
- wrong name chosen

Remedies:
- make sure the design is stored in `C:\HIMT\designs` and the name of the LIC target directory complies with the file name rules of Linux and Windows (no distinguishing between capitals and normal letters)

Problem:
Exposure does not start
Possible causes:
- air pressure low
- lid not closed properly
- design data directory was renamed, or contents have been corrupted
- software hung up

Remedies:
- check air pressure (see system installation instructions on required values)
- check on interlock lamp
- reconvert design
- 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 (see system installation instructions on required values)
- check on interlock lamp before starting a new exposure
- reset stage (menu **Tools → Initialize Stage**)
- check and improve leveling as described in the system setup section

EXPOSURE RESULT PROBLEMS

Problem:

Plate is blank

Possible causes:

- structures too small
- energy too low
- developer too old /wrong type / wrong mixture
- LED off or damaged

Remedies:

- check design against design rules and lens resolution
- try higher energies
- use fresh developer
- check if light can be seen in the monitor during exposure

Problem:

Plate is completely exposed

Possible causes:

- stray light
- old materials

Remedies:

- check for possible stray light sources and eliminate them
- use fresh batch of plates and fresh chemicals

Problem:

Some structures are missing

Possible causes:

- structures do not comply with design rules or are too small
- developer or chrome etch old
- air bubbles in structures during etching

Remedies:

- check design against design rules and lens resolution
- use fresh chemicals
- 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
- wrong entry of coordinates during alignment

Remedies:
- check design
- check wizard entries

Problem:
Design looks completely mixed up
Possible causes:
- vacuum off
Remedies:
- check vacuum pump and vacuum on stage

Problem:
Design stretched or shrunk compared to previous layer
Possible causes:
- previous layer not exposed with µPG, coordinate system units do not match
Remedies:
- shrink or stretch design to compensate

ADVANCED TROUBLESHOOTING

When informing a service office about a problem with the µPG 501 to get further troubleshooting advice, please include the following:

- Information on settings of compressed air regulators
- Any error numbers and error descriptions provided by the wizard
- The wizard version that is shown when selecting **About** in the menu bar
- If available, screenshots / pictures of the problem, or descriptive sketches
- If the problems is connected to an exposure, create an extended report file by activating the option create detailed report file
- Send the folder `C:\HIMT` in archived form (.zip, .rar) to your service office. If the file gets too large or archiving takes too long, leave out the subfolder `LICSources`.

FUSES

Types and locations of fuses used in the **µPG 501**:

To the right of main power line: 6.3 A time delay

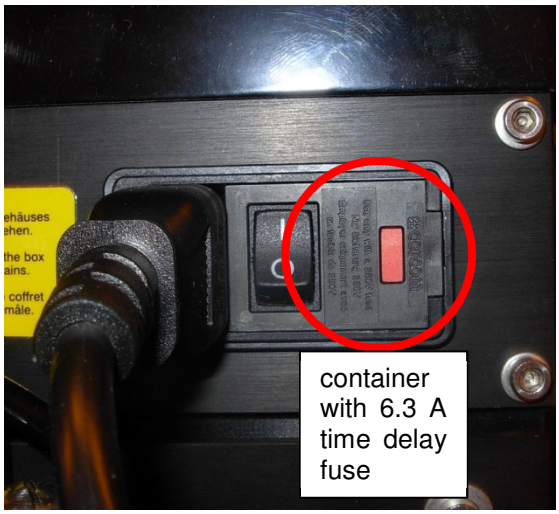


Figure 20: 6.3 A time delay fuse at Lithography Unit back side

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). Transfer the complete directory `C:\HIMT` to a backup device.

Notes

Notes

Notes