

HEIDELBERG
INSTRUMENTS

User Guide Part I
System Operation



DWL 66⁺

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Preface

This manual is meant to help the user to start working with the main applications of the DWL 66⁺ laser lithography system. It contains brief system descriptions and step-by-step instructions for the standard tasks of the system operator.

This preface lists general safety advices and some general information.

In the first chapter, a brief overview of the system components and their interaction is given.

The second chapter contains simple step-by-step instructions for exposure jobs. They guide the operator through preparation and completion of exposure jobs using the **Lithography Menu**, the graphical user interface designed to give the operator an easy-to-use control over the system functions.

Chapter three explains the set up and use of alignment recipes for precise alignment to already exposed structures.

Chapter four deals with the measurement features of the DWL 66⁺. This set of functions is dedicated to measurements of position and linewidth for system calibration or quality checks.

Chapter five gives general information on maintenance procedures as well as some simple troubleshooting procedures.

In the Appendices, information on the handling of optional components can be found.

Precautions and Safety

The DWL 66⁺ protects operators from exposure to laser radiation, dangerous voltages or moving parts while operating the equipment. All moving parts, lasers and their associated optics are enclosed within a flow box. During operation, opening the flow box window will immediately stop any exposure or measurement process.

LIMITATIONS

No untrained person, or person not familiar with the contents of this guide may be allowed to operate the system. If instructions are not followed carefully, danger to personal health and damaging the equipment is at risk.





No covers or panels may be removed that require the use of tools!

At all times, follow all warnings and instructions given in this manual, the system software, safety labels on the system, or by our engineers.

The system may only be used for the lithographic exposures or measurement processes it was manufactured for, as stated in the descriptions of this manual and all related documentation (including purchase documents and acceptance report).

CONVENTIONS USED

Throughout this manual there are safety warnings. To classify the degree of danger in each of these situations, this guide uses the conventions defined in ANSI Z535.6-2011:

	Fatal or severe injuries can occur if instructions are not followed.
	(Severe) injuries can occur if instructions are not followed.
	Mild injuries are possible if instructions are not followed.
	Denotes warnings against possible misuse that can lead to machine damage, as well as hints for a more effective use of the machine.

LASER SAFETY

The DWL 66⁺ employs two types of continuous wave lasers, one for position measurement of the stage (interferometer laser), one for design exposure (exposure laser). When the window is closed, all laser light is blocked or absorbed, and the system has effectively laser class 1.

When the window is opened for loading or unloading, the interferometer laser beam is accessible. Under this condition, the system has the same laser class as the interferometer laser in use, which is laser class 2.

Laser Type	Wavelength (nm)	Power (mW)	Laser Class
HeNe	632	<.6	2

The exposure laser beam is a powerful beam that is usually covered completely by optics covers. Power and wavelength of the exposure laser depend on the specific configuration, but the exposure laser beam is always dangerous for the eye, sometimes also for the skin. Even reflected light may be dangerous.

If the optics covers are opened, the accessible energy is of the class 3B or 4 category (DIN EN-60825-1), depending on the laser type.

Laser Type	Wavelength (nm)	Power (mW)	Laser Class
DPSS	355	250	4
Diode, blue	405 - 410	120 / 300	3B
Diode, UV	375	18	3B

If conditions require the opening of the optics covers, such as for servicing or troubleshooting by trained service personnel, then personnel must observe all precautions required for a laser of above mentioned class in the whole area surrounding the DWL 66⁺.

⚠ WARNING!**Eye injuries and/or skin burns!**

Severe damage to the eye and possibly to the skin can be caused by laser radiation of class 3B or 4.

- Avoid possible direct or indirect exposure of eyes or skin to laser radiation at all times.
- Do not operate the system with open optics cover if not acting under explicit instruction of an HIMT service engineer.
- Do not enter any area cordoned off by HIMT service engineers during adjustment work.
- Do not 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.***

ELECTRICAL SAFETY

A CEE type 220-240 V, 16 A single-phase cable connector supplies operating power in the DWL 66⁺. It is also possible to attach a local-type cable to a local-type wall connector. Please refer to the ***Pre-Installation Guide*** for details.

⚠ DANGER!**Electrical shock!**

Fatal electrical shock and/or severe burns can be caused by the supply voltage of up to 240VAC 16A for the system, and up to 420VAC 32A for certain laser types.

- Never use the equipment if cables or plugs have been damaged.
- Only plug the DWL 66⁺ and its components into approved outlets with correct ground. Power requirements are described in the ***Pre-Installation Guide***.

- Ensure that both the voltage and frequency of a power source match the voltage and frequency stated on the equipment's electrical label.
- Not all power cords have the same current ratings. Household extension cords do not have overload protection and are not meant for use with sensitive electronic equipment. Never use household extension cords for any component of the DWL 66⁺.
- Always follow the five safety steps if equipment containing electrical circuits with voltages >50VAC has to be opened: disconnect, apply restart lockout, check if equipment is de-energized, ground / short circuit equipment, cover neighbouring elements that are still energized
- If access to the interior of any electronics component is necessary while system is in operation, exercise extreme caution. *Only qualified service personnel may have access to the interior.*

OTHER SAFETY RISKS DURING OPERATION

⚠ WARNING!



Injuries by moving parts or heat!

If covers are removed, the operator may be exposed to dangerous collisions with moving parts, or heated components.

- Do not remove any covers that are fixed with screws
- Heed the warnings if removing any other covers

⚠ CAUTION!



Pinch risk by closing window!

Mild pinch injuries are possible if fingers are brought between the upper window frame and the window while the window closes. The loading window is driven pneumatically with low pressure. It does not have enough force to injure a body or limb, but skin may be pinched.

- Don't close the window while resting a hand at the upper frame or upper window edge.
- Don't grab through the window while it is already closing.

⚠ WARNING!



Injuries / dangers (poisoning, flammability) by coolant additives! (Systems with Genesis laser option only)

Depending on the cooling fluid selected by the customer for the heat exchanger of the cooling plate, additional safety risks may apply.

- Before deciding on a coolant or doing any refilling, refer to the manufacturer manuals and the coolant / additives safety data sheets for further information.

INTERLOCK

To protect the operator from hazards by laser light or moving stage, interlock circuits prevent stage movement and access to laserlight as soon as the window opens. A safety switch stops the stage, holding it in position, and closes the laser shutter. If an exposure has been running at that moment, the result is irreversably lost.

The stage interlock can be overridden by service engineers by a key switch for servicing, together with a confirmation from the menu. While this service mode is activated, the **Lithography Menu** main bar and background turns red.

WARNING!

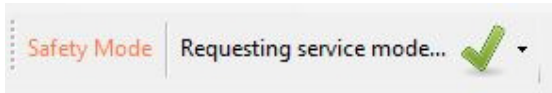


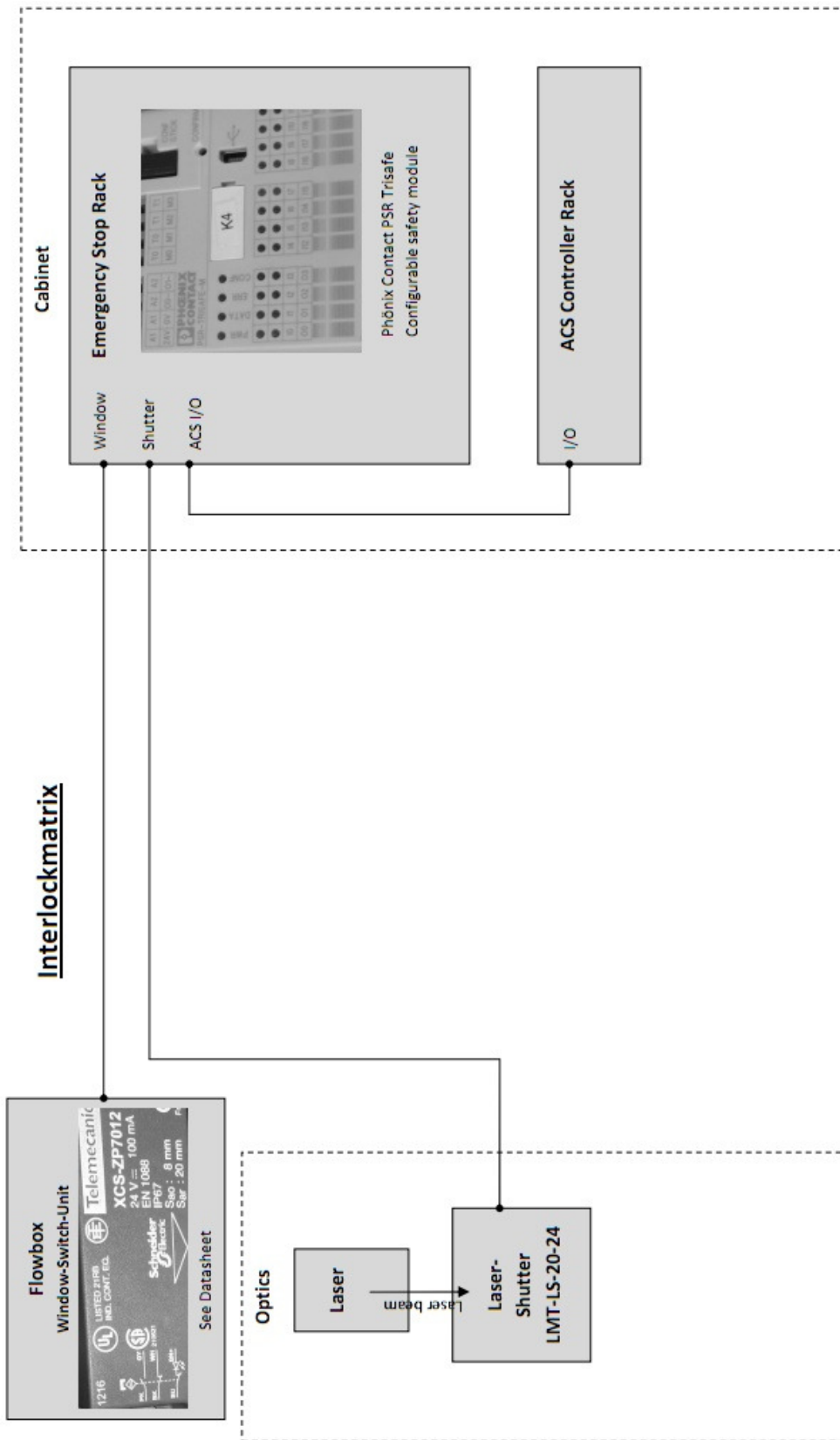
Injuries by moving parts or laser light!

While the system is in service mode, dangerous levels of laser light are accessible, and the stage can move with window open. Only HIMT service engineers are allowed to put the machine into service mode.

- During servicing or maintenance by service engineers, heed the warnings given in the **Safety Guide** and the **User Guide Part III** for this situation.
- If service mode was left active accidentally, switch back to safe mode and remove the key. Return it to the local service office.

To return from service mode into safe mode, open the drop down list in the **Safety Mode** toolbar located in the main menu bar, and select **Safe Mode**.





EMERGENCY OFF

An 'Emergency Off' button is located at the flow box front, close to the window switch. It is marked with a large label to increase visibility.

When this button is hit, all power supplies of more than 24V are interrupted immediately. This means that the stage is released, the air conditioning stops, and power supply to all racks the laser and all peripheral units is interrupted. The light in the flow box can still be used, and the electronics cooling fan keeps running.



NOTICE:

Repeated use of the 'Emergency Off' button may cause damage to some electrical circuits.

- Only use the 'Emergency Off' button in potentially dangerous situations!
- In any other situation, use the normal 'Off' button provided above it. This switches off only the racks including the motor controller and the laser. Follow the instructions on powering down the system given in the next chapter.

The 'Emergency Off' button is self-securing to prevent accidental powering up of the machine while the dangerous situation has not yet been resolved. After an Emergency Off, the machine can only be switched on again after the switch has been released by turning it in the direction indicated on the switch.

WARNING!

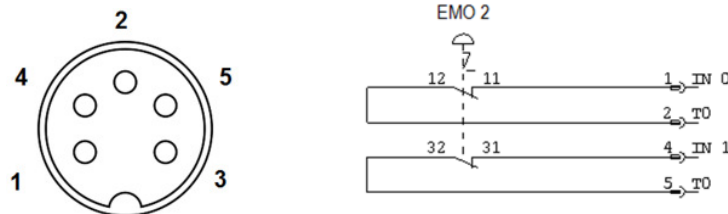


Increased risk by delayed emergency stop!

DWL 66⁺ systems are delivered with only one Emergency Off switch at the flow box front.

- Set up the work station for the operator at not more than three meter distance from the system.
- If the work station for the operator is more than three meters away from this point, additional switches have to be installed.

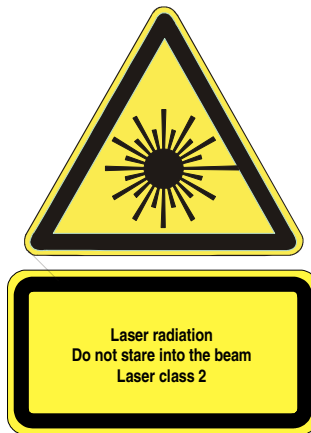
Additional switches may be ordered as option and added to the circuit by connecting them to the female 240° 5-pole diode connector provided at the power distribution rack in the electronics cabinet.



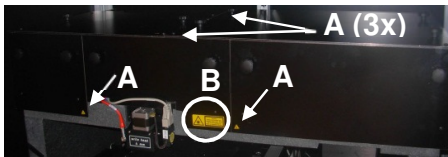
If other units than the ones provided by HIMT should be included into the Emergency Off circuitry, please contact Heidelberg Instruments to discuss feasibility and specifications of the required units.

LABELS

DWL window:



DWL Optics Cover:



DWL electronics rack:



Exposure laser(s) / interferometer laser / heat exchangers:

Please refer to manufacturers manual(s).

Related Documentation

Heidelberg Instruments offers several 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, Germany.

<i>Safety Guide</i>	Describes necessary safety measures during move-in, installation as well as servicing and maintenance times.
<i>Pre-Installation Guide</i>	System requirements, sizes and weights of components etc.
<i>Conversion Software Manual</i>	Manual for the HIMT conversion software used for data preparation and fractioning
<i>User Guide, Part II</i>	Reference Manual for functions of the Lithography Menu GUI
<i>User Guide, Part III</i>	Guide for Maintenance and Troubleshooting, as well as an overview of typical service tasks

Contact

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

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Chapter 1: General

INTRODUCTION

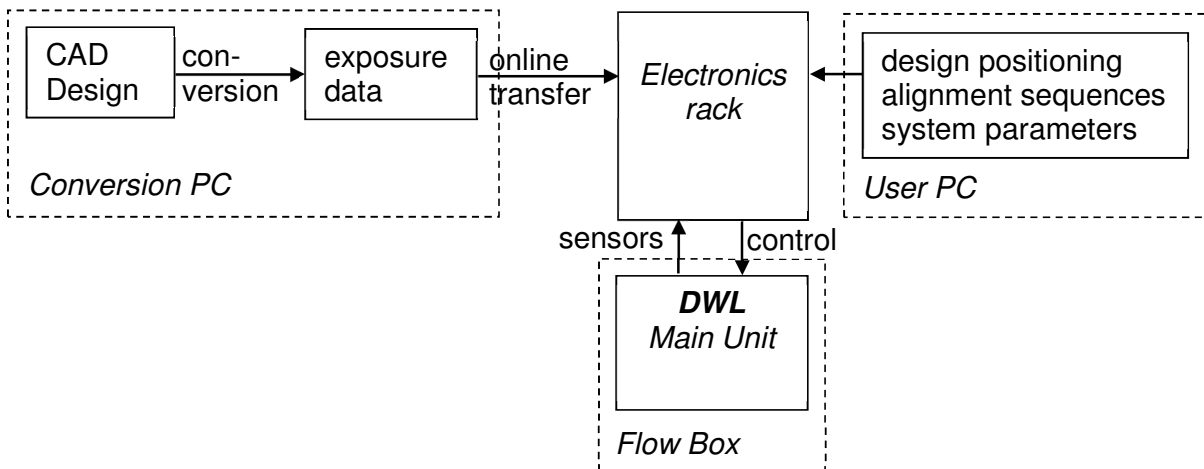
The DWL 66⁺ is a high-resolution imaging system developed to expose on metalized plates or silicone wafers with a photoresist coating. Achieving a resolution of up to half a million dpi using a 50-nanometer writeable address grid, the DWL 66⁺ accommodates media up to 8" x 8".

Design data can be created by any program using DXF, Gerber, GDSII, or CIF format, and is converted into a machine specific so called 'LIC' format that can be processed by the DWL 66⁺ system. Conversion is done on a conversion PC working under Linux. For systems with gray values option, designs can be created in DXF grayscale format (gray value definition via layers), or in the form of 3D elements that are stepped over the substrate. These can be set up in STL, BMP or an ASCII-xyz format.

System Components

A DWL 66⁺ system consists of the following main sub units:

- Granite System (Main Unit)
- Optics System (Main Unit)
- Laminar Flow Box
- Electronics Control Rack
- User PC
- Conversion PC



GRANITE SYSTEM

The main system design utilizes a heavy granite base. Granite has been selected for its weight and stability. These properties ensure effective vibration isolation in connection with the air buffer system, and a low thermal expansion coefficient.

In order to maintain an even expansion coefficient, many other system parts are constructed from granite as well. Although this material has certain advantages, granite is not completely insensitive to external influences. Temperature and humidity play an important role in the stability of the machine, therefore its external environment must be kept extremely stable. The large mass of the system results in an adaptation period before the machine may be utilized to produce consistent results. Therefore, final calibration can only be started after the complete system has stayed in its final environment for at least 1-2 days. This condition is usually automatically fulfilled in the normal course of system setup, where the first few days are taken up by assembly and function tests. However, after any period where the environment was out of control, this adaption period is required again.

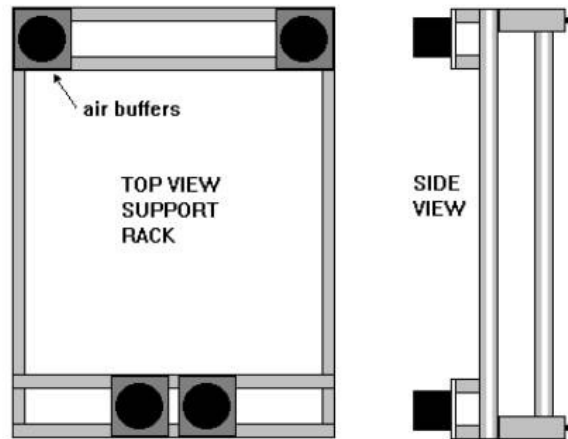
Elements of the Granite Construction

- **System Support:**

The granite base is supported by a heavy-duty aluminum construction and four air filled buffers for vibration isolation. These buffers are arranged in a quasi-three point system as to avoid any unnecessary bending forces in the granite.

- **Main Block:**

The main granite block is cut so that the blocks' center of gravity lies below the attachment points of the air buffers. This increases the stability of a system during writing. The block also contains screw holes as to accept other components of the granite system.

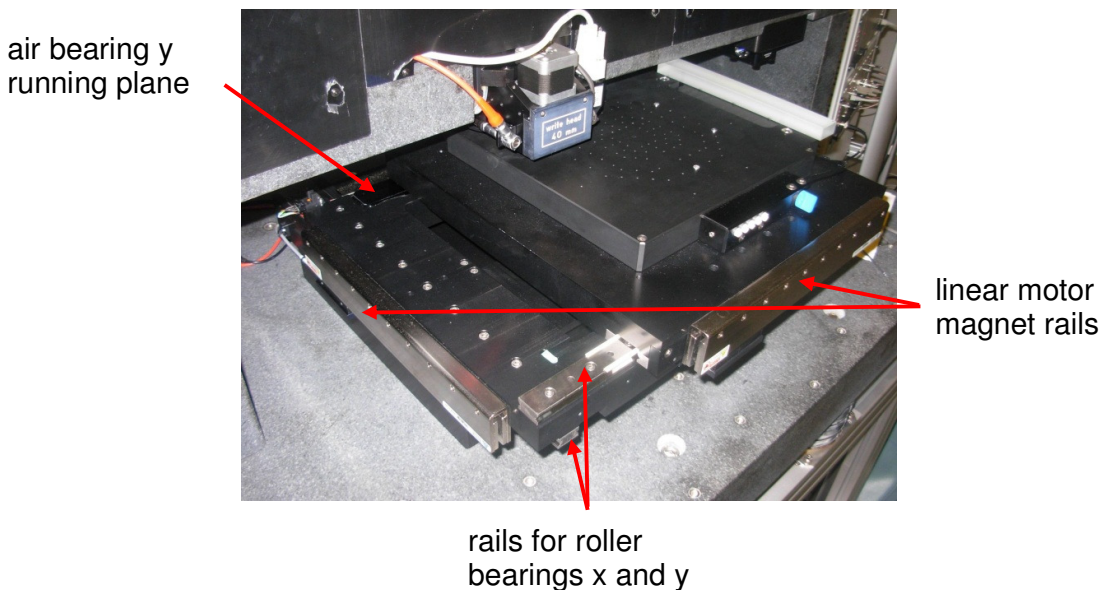


- **Stage System:**

The DWL 66⁺ is equipped with a linear motor X/Y-stage with sideways roller bearings, supported in the y axis by an air bearing for smooth movement. Linear motors are used in both axes, ensuring a swift and constant movement with low positioning errors.

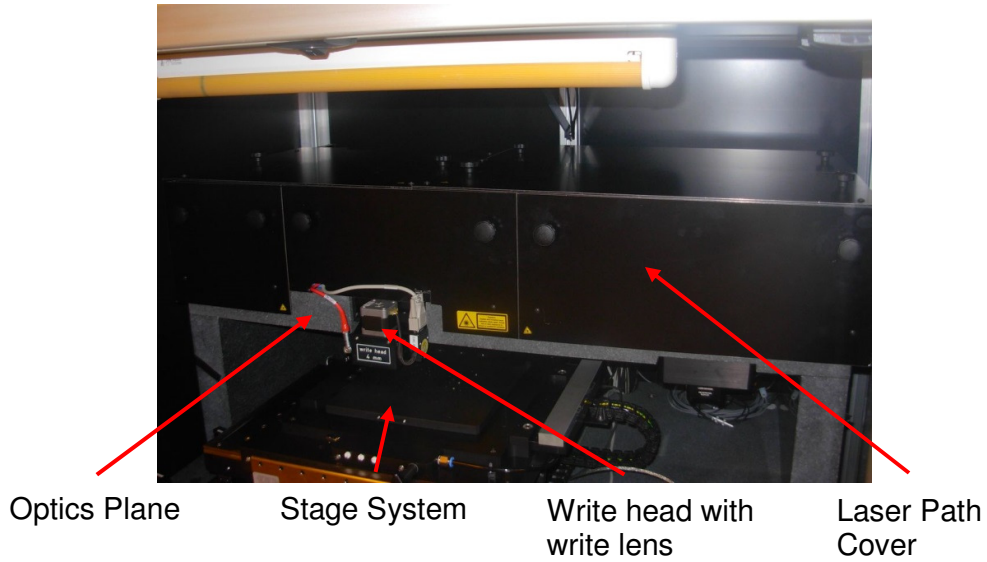
The stage surface is equipped with vacuum holes to hold the substrate in place during exposure. In systems with the back side alignment option, the stage top is equipped with an open frame that can accept various open or closed tiles.

The system is designed for optimum performance and minimum heat generation. Any possible mechanical position errors are cancelled by a writing beam positioning system coupled in real time with the stage position measurements.



- **Optics Plane:**

The optics plane contains all beam scan elements and all camera components. The write lens is also mounted on the optics plane and is directed downwards onto the substrate. Again, to minimize heat generation in this area, medium- and high-power lasers are mounted above the optics plane.



OPTICS SYSTEMS

The DWL 66⁺ comprises several optics systems. One is the exposure optics, the second one is the camera system, and a third one the interferometer system for on-line position control. An additional optional optical component is the optical autofocus.

NOTICE:

All systems are factory adjusted and can only be worked on in the field by experienced Service Engineers.

Elements of the Optics Systems

- **Laser Unit:**

The laser light emitting head of the laser unit is mounted directly on or above the granite base, while the power supply as main source of heat is usually set up outside the flow box. Only lasers with high reliability, long lifetime and low noise level (< 0.5%) are used, which is necessary when exposing high end photo masks or using the system for direct writing on the substrate. Field replacement of the lasers is simple and can be accomplished by our local service engineer.

- **Intensity Modulator:**

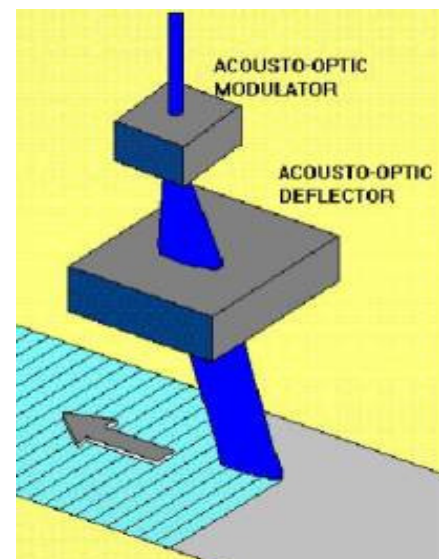
An intensity modulator is a relatively low frequency acousto-optic modulator, which is used in combination with gray filters to adjust the energy dose of an exposure in system configurations where the laser power cannot be controlled directly.

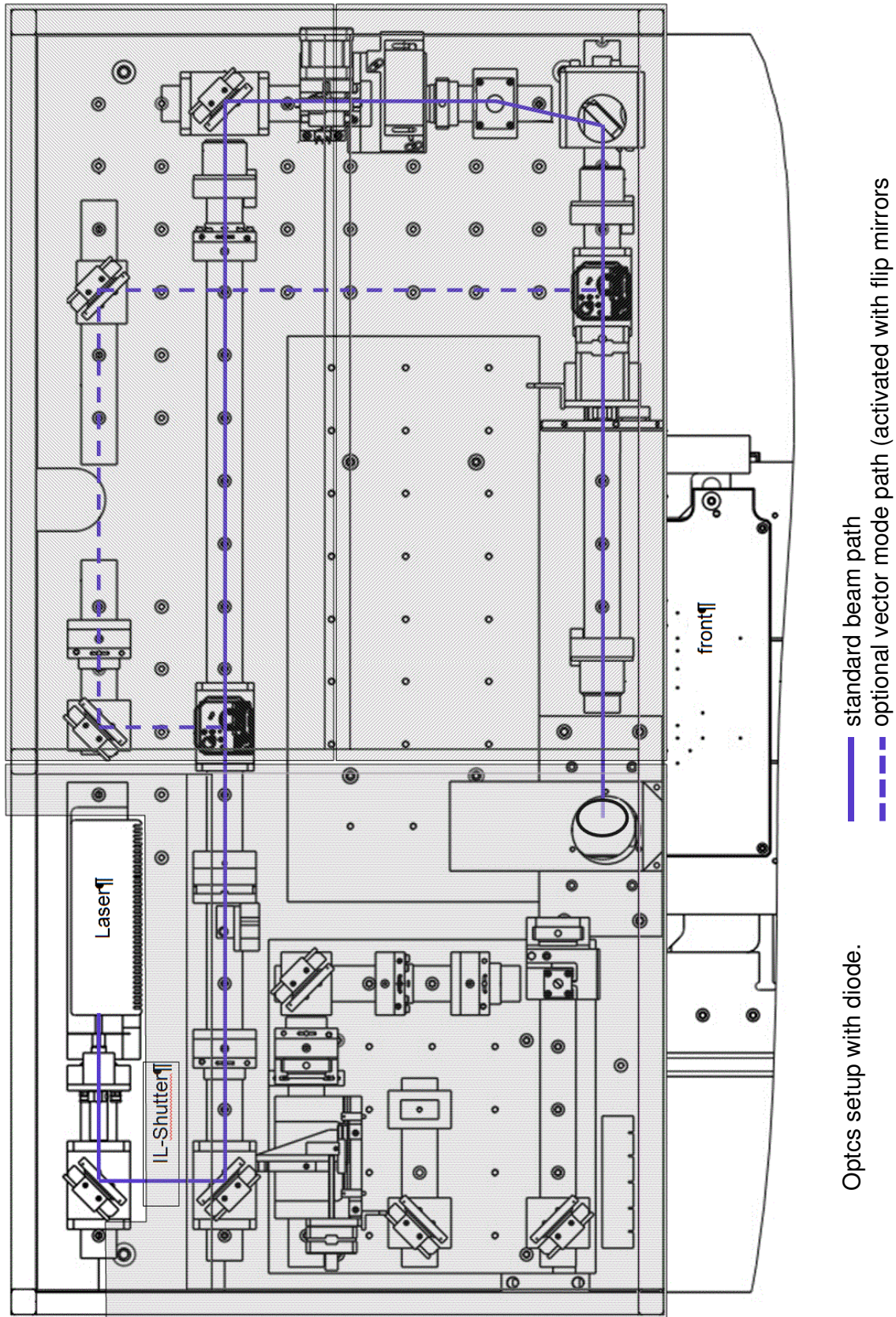
- **Data Modulator:**

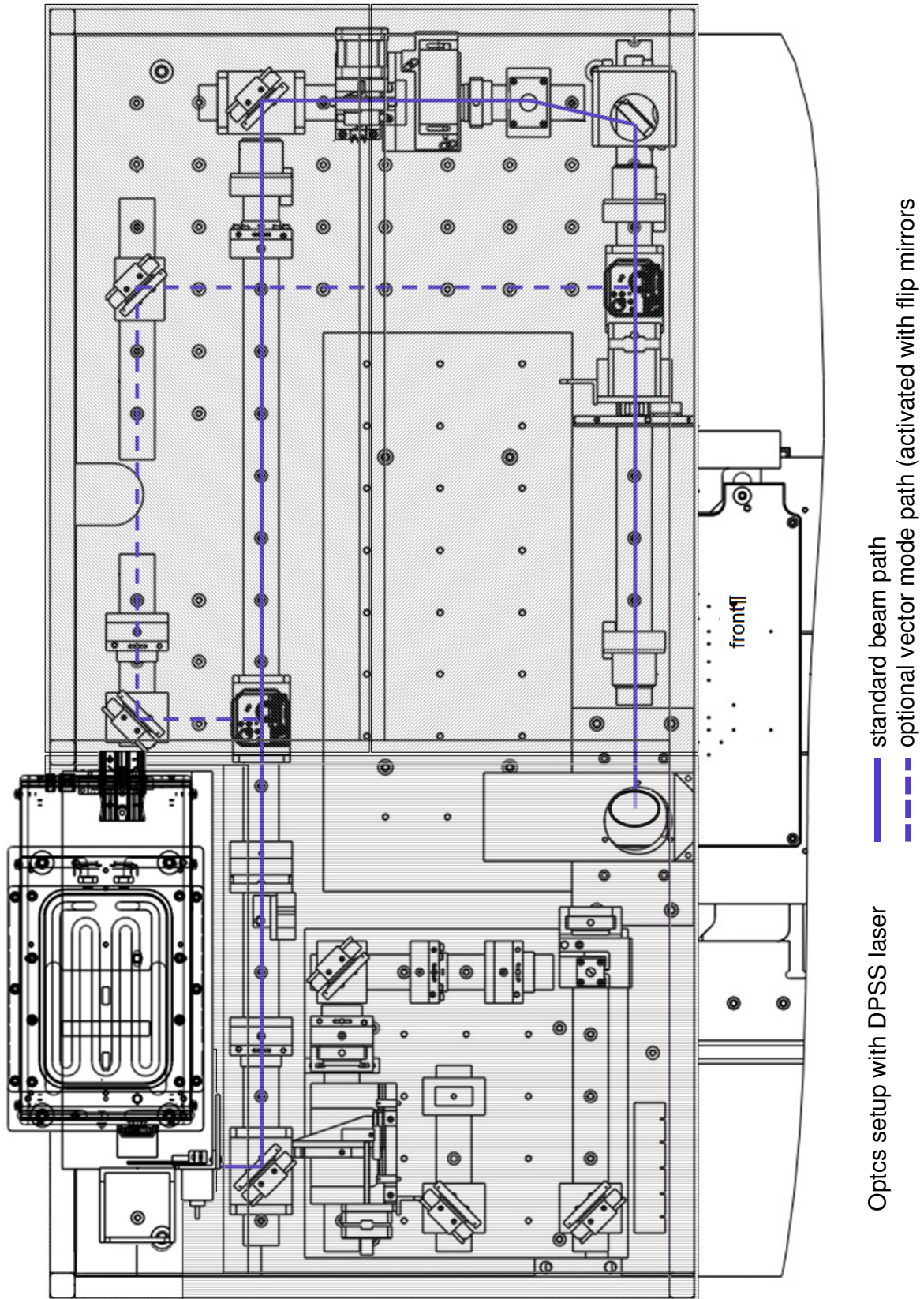
The data modulator, controlled by digital electronics for stability and reliability, swiftly regulates the laser light, generating up to 255 different gray values according to the design data.

- **Fast Scan Deflector:**

The acousto-optic deflector device generates a swift laser scan with a resulting sweep rate of more than 30 kHz. The scan angle is imaged into the back focal plane of the write lens resulting in a telecentric scan arrangement, so that the laser beam is always perpendicular to the substrate.







- **Write Lens System and Write Mode:**

The focal length of the write lens used determines the resolution of the system (write mode). Several write modes can be ordered with the system, and the lenses can be installed according to application requirements. The available write modes are:

Write Mode	focal length of write lens
I	2mm
II	4mm
III	10mm
IV	20mm
V	40mm

For details on specifications of each write mode please refer to the system data sheet.

When adapting the system to a specific application, the customer can exchange the lens easily. The write heads are connected to an air gauge auto-focus system to correct variations in substrate thickness by fine positioning the lens with a piezo element, keeping the distance constant. The piezo element features a fine Z range of ~100 µm.

- **Camera Unit:**

The camera unit is comprised of a micro camera, a macro camera, and an LED light source. Such a unit can be used to inspect and measure the exposed substrates. In addition, the cameras can be employed for precise alignment of an exposure to an existing structure. The cameras are connected to a video image processing system offering a vast number of metrology functions.

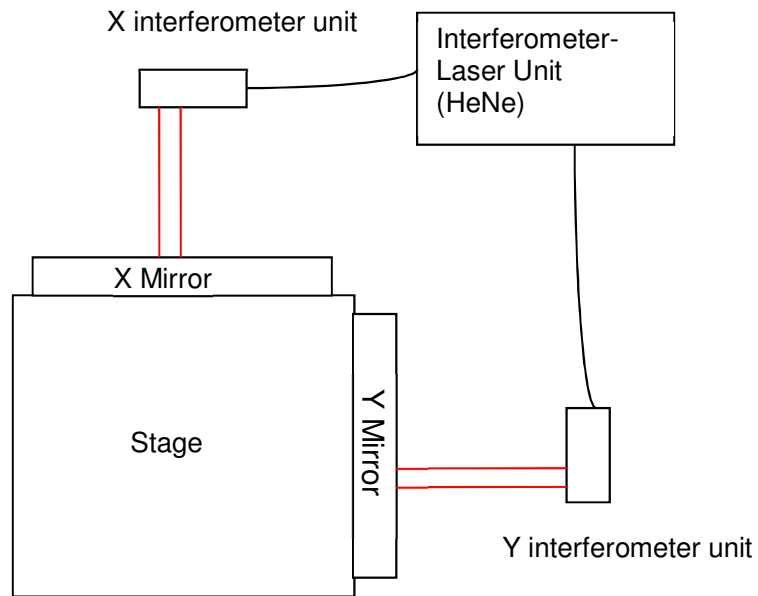
Systems with back side alignment option have a complete second camera unit for back side viewing. These record the image created by an objective mounted inside the stage and looking up.

- **Optical Autofocus (optional)**

The optical autofocus is an alternative system to the pneumatic autofocus to keep the focal point of the write beam stable on the surface of the substrate. It avoids the problems the pneumatic autofocus experiences when exposing close to an edge. The optical autofocus uses a low-power red laser beam that is reflected from the surface and then detected by a four quadrant diode.

- **Interferometer:**

An interferometric stage position measurement device provides the necessary information for the machine's position error compensation system. A machine can achieve its required level of positioning precision only through this function. Industry standard interferometer systems with proven qualifications are utilized.



LAMINAR FLOW BOX

The flow box provides a stable environment for the DWL 66⁺ in terms of temperature, laminar airflow and clean air, guaranteeing constant exposure conditions and thus minimal variation of exposure parameters.

The front of the flow box features buttons for powering up or down the system, an emergency STOP button, and a switch for opening and closing the window. The covers of the flow box can be removed for service.

⚠ WARNING!

Injuries by moving parts or laser light!

Flow box covers may be opened only by, or under direct instruction from, experienced service personnel!



Elements of the Flow box

- **Window:**

Used for loading and unloading. Must not be opened during operation (opening window will stop any movement and close laser shutter).

The toggle switch on the front of the flow box controls the compressed air system that moves the window.

- **Temperature Control:**

Temperature control is maintained by means of regulated heating of the incoming air. The heating system is situated within the top compartment of the flow box, and is regulated automatically by a temperature control unit.

The temperature stability, assuming $\pm 1\text{ }^{\circ}\text{C}$ / $\pm 1.8\text{ }^{\circ}\text{F}$ outside the unit, is $\pm 0.1\text{ }^{\circ}\text{C}$ / $\pm 0.2\text{ }^{\circ}\text{F}$ on the inside.

⚠ WARNING!

Fire hazard by overtemperature!

A change of the safety temperature at the temperature controller can lead to overheating of the filters, which may result in fire!

Do not make any changes in the settings of the temperature controller!

NOTICE:

A change of the temperature control's set temperature can lead to changes in the optical alignment and therefore a potentially massive decrease in exposure quality. For this reason, only factory service engineers should do such a change. If you need a change of the set temperature, contact your local HIMT service office.

- **Light:**

Depending on the application, yellow or red light is provided within the flow box.

ELECTRONICS CONTROL RACK

The electronics rack consists of several units. The precise contents depend on system configuration.

A. User PC

B. System Control Rack:

The system control rack contains all control units for data processing and positioning. Central units are:

MAIN PROCESSOR – A state-of-the-art CPU running under a multitasking OS9 operating system controls all processes handled by the sub units. An integrated PMC board is programmed to process the exposure data according to internal timing signals.

VCI CAMSYNC – CAN bus interface board and image synchronization for measurements

DETC INTERFACE – A multi-channel ADC, DAC, and digital I/O board, used for control of sensors and actuators.

SLAVE PROCESSOR – real-time processing of the stage position. Includes a PMCVME adapter board

PCC7 – creates timing signals for data processing and error compensation.

OSC – Central clock board for process synchronization.

C. AOM Rack:

This rack contains the electronics for control of the data modulator.

D. Stepper Motor Control and AF Rack:

This rack contains the stepper motor drivers and the autofocus electronics.

E. DAOD rack

The electronics in this rack controls the beam scanning.

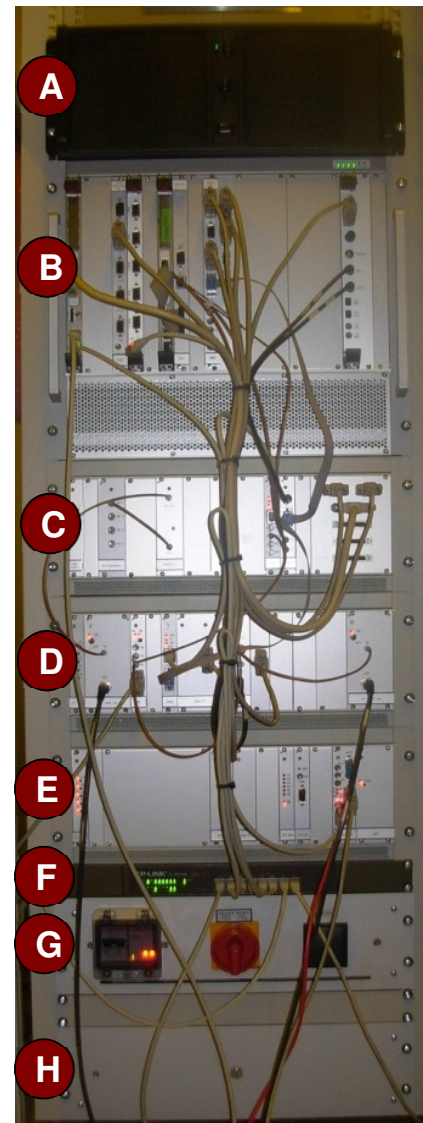
F. Integrated Network Hub

G. Power Supply / Emergency Stop Module:

This rack houses the system power distribution.

H. Linear Motor Controller (hidden behind panel):

The linear motor controller drives the linear motors of the stage.



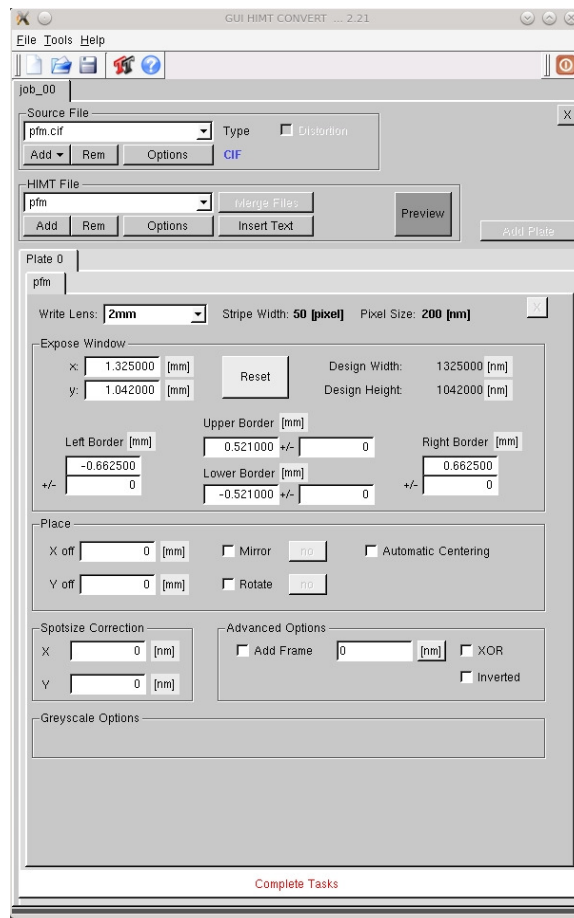
CONVERSION WORKSTATION

Design files in gerber, dxf, cif or gdsii format have to be converted into a group of internal machine files in LIC format (Laser Internal Code) in order to be read by the DWL 66⁺. A Linux PC dedicated to this task is part of the system network.

The conversion software running on this PC offers many options such as positive / negative exposure, rotation, or scaling to customize the design data before it is translated to the LIC format. In addition to changing the data format, the conversion software also splits up the original file into a set of lic files, which are smaller and thus easier to handle than one single file. Once the data is in the lic format it can be converted real-time into the final pixel data set. In theory, a source file may also be converted directly into the final pixel data set, yet this data file would be much larger than the lic files, increasing demands on the hardware.

Systems with the gray value option accept additional input formats for 3D modeling.

For more information on conversion, see the **Conversion Software Manual**.



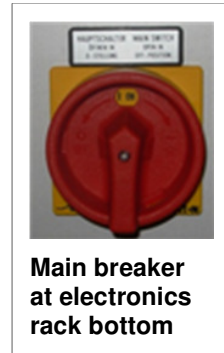
Powering Up / Powering Down

STEP-BY-STEP: APPLYING POWER

1. **Switch on laser:** If the system is equipped with a laser option that includes a key switch, turn the key switch to 'On' position.
2. **Switch on system power:** Press the **green "I"** power button on the flow box twice.

In case the system was switched off by using the EMERGENCY OFF button, this has to be released first by turning it in the direction indicated on the button before the system power can be switched on. Press the **green "I"** power button **twice** (first switches on the climatic control and other external units, second activates all electronics rack components).

If power is not coming up, check whether the main breaker on the bottom of the electronics rack is turned off.



3. **Switch on User PC**
4. **If system was powered down completely** (emergency stop, blackout):
Start Julabo control software and switch on flow box temperature controller. The software can be started using the desktop link. Make sure the system is stable at the original temperature before starting an exposure.

5. **If the interferometer laser was switched off:**
Warm up phase of 30 minutes.

6. **Start the Lithography Menu**

Start the **Lithography Menu** by clicking on the desktop link. Login with your user name and password.

Note: During system setup, default users with differing access levels are created and stored in the file passwords.txt on the desktop.

- Take care that each user of the machine knows only his own login details or that of the group he belongs to.
- Make sure the login details are stored safely. Only HIMT can make a full reset if login data is lost.

At each startup, the menu checks for necessary component initializations. A window shows the status of hardware initialization.



STEP-BY-STEP: POWERING DOWN

In case of an emergency, press the red **EMERGENCY OFF** button on the front of the flow box.

1. Close Lithography Menu and shut down PC

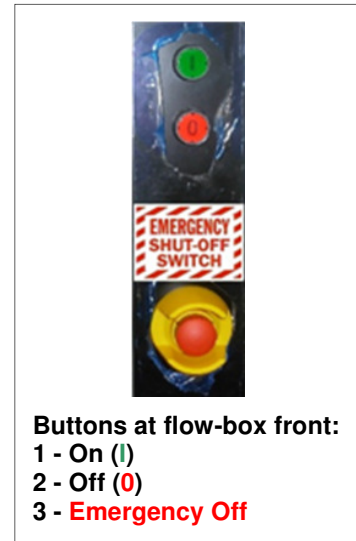
2. Switch off laser

For standard laser types, lasing is automatically stopped when the **Lithography Menu** is closed. For longer shutdown times, it is recommendable if the laser has a key switch to use it to shut down the laser completely before cutting the power.

3. Press the red “O” button on the front of the flow box.

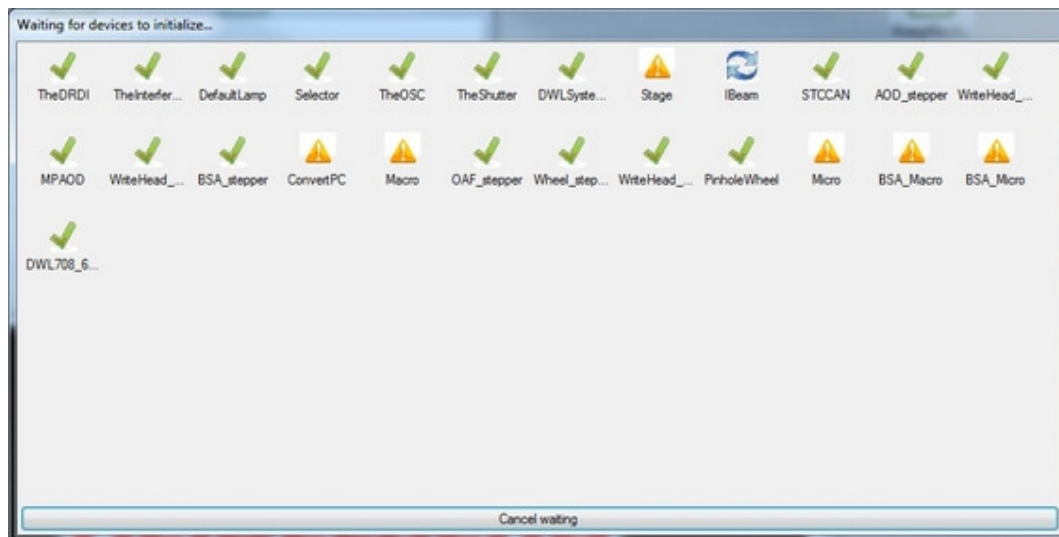
4. For a **complete shutdown**, turn off main breaker located on the front of the power distribution rack at the bottom of the electronics rack.

Note: In general, the system should be powered down completely **only if absolutely necessary**. If the exposure laser is off, idle power consumption of the system is low, and keeping it in standby enhances stability.



POWERING DOWN FOR MAINTENANCE

The main circuit breaker in the bottom compartment of the electronics cabinet is equipped with holes for a padlock. If the system is powered down for maintenance or servicing, after above steps, secure the main circuit breaker in the **Off** position with such a padlock.



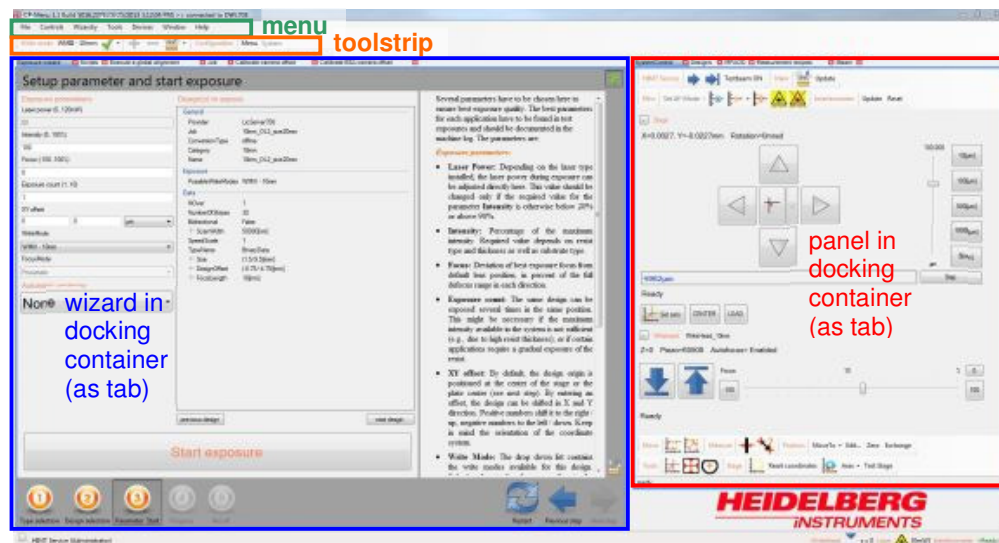
General menu handling

The **Lithography Menu** is a highly flexible tool that can be adjusted to the daily needs of the operator. The settings of each operator are saved during the session, so at the next login, the setup is the same as when the menu was last used by this user.

The **Lithography Menu** consists of the following components:

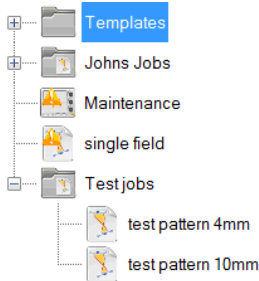
- docking containers** – in these containers, all components necessary for everyday use should be docked in.
- wizards** – wizards lead through certain common operations in a sequential way, requesting any necessary parameters when they are needed.
- panels** – panels group together all the functions related to a certain task. Both wizards and panels can be opened from the main menu. Panels may contain menus and toolstrips.
- menus** – the **Main Menu** is the fixed starting point of the **Lithography Menu**. Menus also exist in most panels, offering tools necessary or helpful for the tasks that panel is designed for. Menus cannot be modified by the operator. Their availability and contents depend on user permissions.
- toolstrips** – toolstrips contain assortments of icon buttons that start functions or offer additional options. They can be adjusted to the needs of the operator via the **Options** settings of each panel. If toolstrips are too long for the panel size, the last icons are hidden and can be called by opening a drop down list at the end of the visible toolstrip (small arrow). Availability of functions may depend on user permissions.

For more detailed information on how to customize the menu, refer to **User Guide II: Reference Guide**.



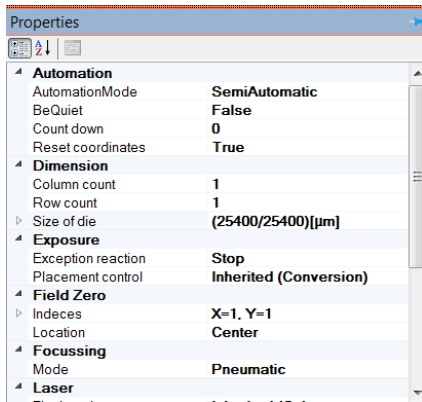
Among other items, panels may contain folder lists or grids with parameters. To help to get a quick overview, not all contents are always visible at once.

- Opening / closing folders:



Folders can only be opened or closed by clicking on the plus (+) or minus (-) signs attached to them. Double-clicks on folders open properties windows.

- Extending / collapsing parameter lists:



Main groups are usually extended by default. Subgroups that can also be displayed as one parameter are collapsed. Control over extended or collapsed view is given by the small triangles:

▲ filled triangle: parameters below up to the next heading belong to a group that may be collapsed to have a better overview.

▶ empty triangle: a sub-group of parameters exists and may be accessed by clicking on the triangle.

- Changing parameters in parameter lists:

Generally, all parameter lists are tables with the parameter or parameter group names in the left column and an editable field in the right column at each parameter. Some fields can be edited directly (text fields), for some, only certain options are available that are offered in a drop down list, or a separate window is required to make a selection.

For **direct editing**, just click into the field. A cursor appears, and the content can be edited.

If a **drop down list** exists, the click makes an arrow appear. Click on the arrow to open the list. Click on a list item to select it. It is transferred to the text field, and the list closes.

If a **separate window** is required for the selection (e.g., for location and selection of a file), the click makes a button with three points appear at the right side of the text field. This button opens the required window. As soon as that window is closed again, the result of the operation(s) done there is transferred to the text field.

Preparing System Settings

For correct exposure and measurement results, the system configuration has to be adjusted to the application demands.

In exposures, software parameters are loaded automatically according to the configuration a design was prepared for. However, a change in resolution requires a manual change of the write head hardware. The operator is prompted to do this exchange whenever it is needed for exposure (semi-automatic mode).

For measurements, a resolution change has to be done fully manually.

A #3 metric Allen wrench is required.

STEP-BY-STEP: CHANGING THE SYSTEM RESOLUTION

1. Measurements only: Select new write mode

In the **Write Mode** toolstrip below the main menu, open the drop-down list of write modes by clicking on the small arrow at the right end. Select the write mode that should be used.

- If there is no **Write Mode** toolstrip, you do not have the necessary permission for write mode change. Please contact your administrator.

2. Move stage to Exchange position

Open the **System Control** panel (**Controls** → **SystemControl**). In the **Positions** toolstrip, click on **Exchange**.

- If the **Exchange** button is not visible in the toolstrip and the toolstrip has a small arrow at the end, click on the arrow to open the selection list of tools that did not fit into the bar. Click on **Exchange** here.
- If the **Exchange** button is neither in the toolstrip nor in a drop down list, it has been removed from the bar. Refer to the section on system control panel toolstrip customization in the **User Guide II: Reference Manual** for instructions on how to add it.
- When the stage is in the exchange position, its lower right corner is under the write head.

3. Unmount current write head

NOTICE:

Do not touch the plane interferometer mirrors at any time! Touching the mirrors with bare hands will damage them beyond repair.

NOTICE:

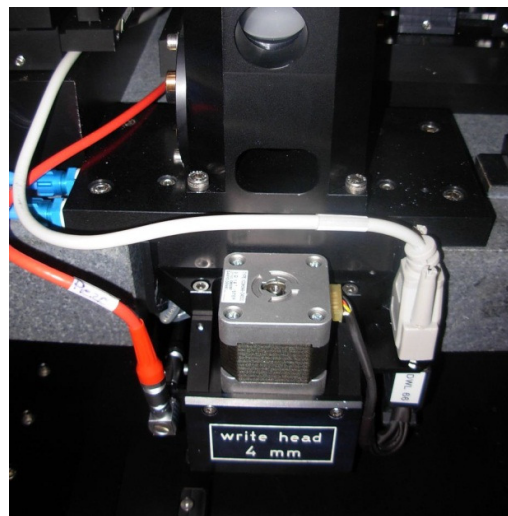
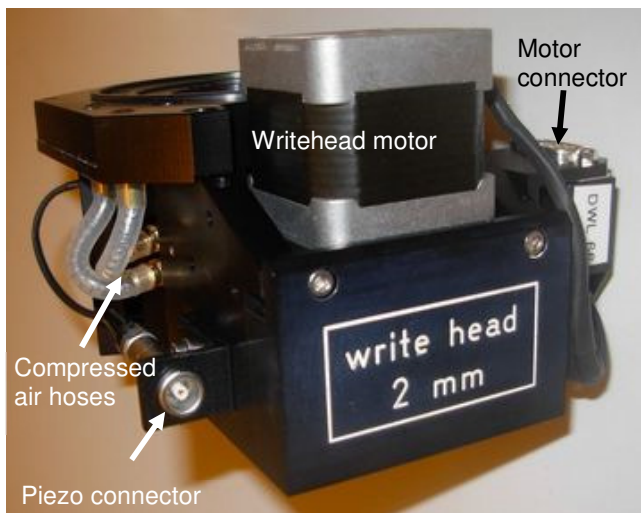
Take care not to let the write head drop onto the stage, as this might damage the nozzle. A damaged nozzle deteriorates focus stability, or focusing might even become completely impossible.

Open the center front optics cover. Unplug the cables on the write head, then use the #3 metric Allen wrench to loosen the four screws located on the top of the write head. Hold the write head up while loosening the screws. Once all four screws are loose, move the write head down until it rests safely on the designated rails, and pull it out carefully.

4. Mount required write head

Place new write head onto the rails, then push it in as far as it will go. Hold it up against the mounting plate and tighten all four screws X wise in the order noted in the sketch below. Finally, connect motor and piezo cable.

Click OK to confirm that the write head matching the configuration has been mounted. After configuration change has finished, the current configuration name in the **Write mode** toolstrip is updated.



Loading / Unloading Substrates

Every operation with the DWL 66⁺ begins with the loading of a substrate, and ends with its unloading. The instructions for these general procedures are therefore given here at the beginning and not further mentioned in detail in the following procedure descriptions. Depending on the settings in a job, the loading can be run as a semi-automatic procedure, or fully manual. Please refer to the section on exposure job options for more information. Instructions for both options are given here.

STEP-BY-STEP: LOADING

1. Semi-Automatic:

The loading process is initialized automatically in the course of the exposure or measurement execution (see corresponding instructions later in this manual). The stage moves toward the front and a window opens prompting the operator to load the substrate on which exposure should be done.

Manual / AutoUnload:

Open the **System Control** panel (**Controls** → **SystemControl**). Click on the **Load** button.

- The write head moves up, the stage moves to the substrate accept position.
 - No reset of coordinate system or alignment angles occurs.
2. Open flow box window.
 3. To avoid exposing a substrate, switch off the white light and switch on the safelight.
 - Leave any non-safe light switched off until the substrate is developed
 4. Before loading the DWL 66⁺ (i.e., putting a substrate onto the chuck), plug the stopper pins into the required chuckholes for easy substrate alignment.

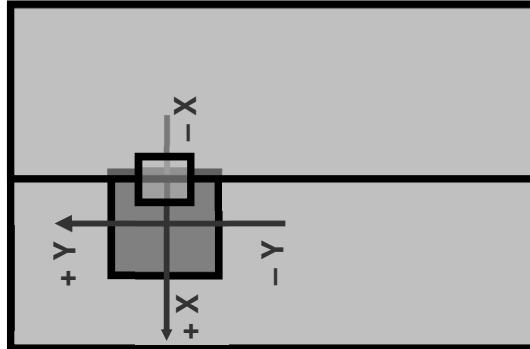
NOTICE:

Do not touch the emulsion or resist on areas to be exposed!

5. Take the substrate out of the container.
6. Make sure substrate and chuck are clean and smooth.
7. Make sure coated side of substrate is facing up.
 - *Emulsion:* The best way to determine which side is coated on emulsion plates is to breathe onto one side. If the surface is coated with emulsion, there won't be any condensate. When breathing onto uncoated glass, condensate will appear.

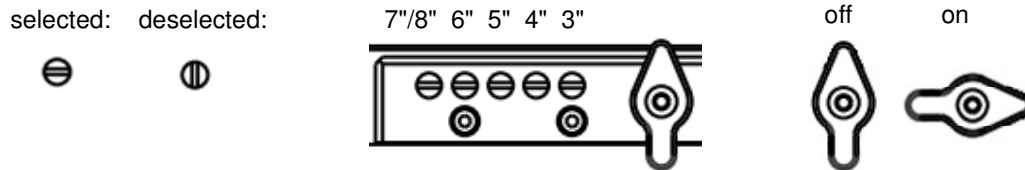
8. Put substrate onto chuck.

- The substrate should be roughly centered on the chuck. Orientation has to match the machine coordinate system:



- If a substrate is smaller than the vacuum field, cover open vacuum holes (e.g., with thick foil), to improve suction.

9. Once substrate is in place, switch on the vacuum. Activate all vacuum fields covered by the substrate:



Note: The sketch shows the standard vacuum switches. For systems with BSA option, refer to the BSA option section in the appendix.

Make sure vacuum holds down properly by gently pushing the substrate sideways. If everything is OK, remove the stopper pins and cover the pin vacuum holes.

- If substrate can be moved, there is an air leak. Pressing the substrate down carefully onto the chuck or covering any remaining open chuckholes should improve suction.
- If, after pressing down the substrate, it is still not held down tightly, check the surfaces again for dirt or scratches
- If necessary, try a new substrate

10. Close the window.

Semi-automatic:

Click **OK** in the menu. The stage moves to the center position, and the write head focuses on the substrate.

Manual / AutoUnload:

In the **System Control** panel, click on the **Center** button. The stage moves to the center position. In the **Writehead** control section, click on the Focus button. The write head focuses on the substrate.

STEP-BY-STEP: UNLOADING

This instruction differs depending on the **AutomationMode** setting of a job. Please refer to the section on exposure job options for more information.

1. Semi-Automatic / AutoUnload:

After exposure / measurement execution, the write head retracts automatically and the stage moves to the front. The operator is prompted to unload the exposed substrate.

- Depending on the settings defined in the current job (Reset = False / True), an unload sequence might reset the coordinate system, including angular alignment, to the initialization coordinate system (origin in center, zero rotation). Please refer to the section on exposure job options for more information.

Manual:

Open the **System Control** panel (**Controls** → **SystemControl**). In the **Stage** control section, click on the **Load** button.

The write head moves up, the stage moves to the substrate accept position

2. Switch off vacuum.
3. Take substrate off the stage and stow it in an opaque box impermeable to light. Only now may non-safe light be switched on again.
4. Close window. If required, click **OK** in the menu to close the unloading dialog.

Note: Stage coordinates are not automatically reset during unloading. Reset can be done either manually from the **System Control** panel, or automatically if the related option is selected in a job (**Properties** → **Automation** → **Reset coordinates** = true).

Using the camera panel

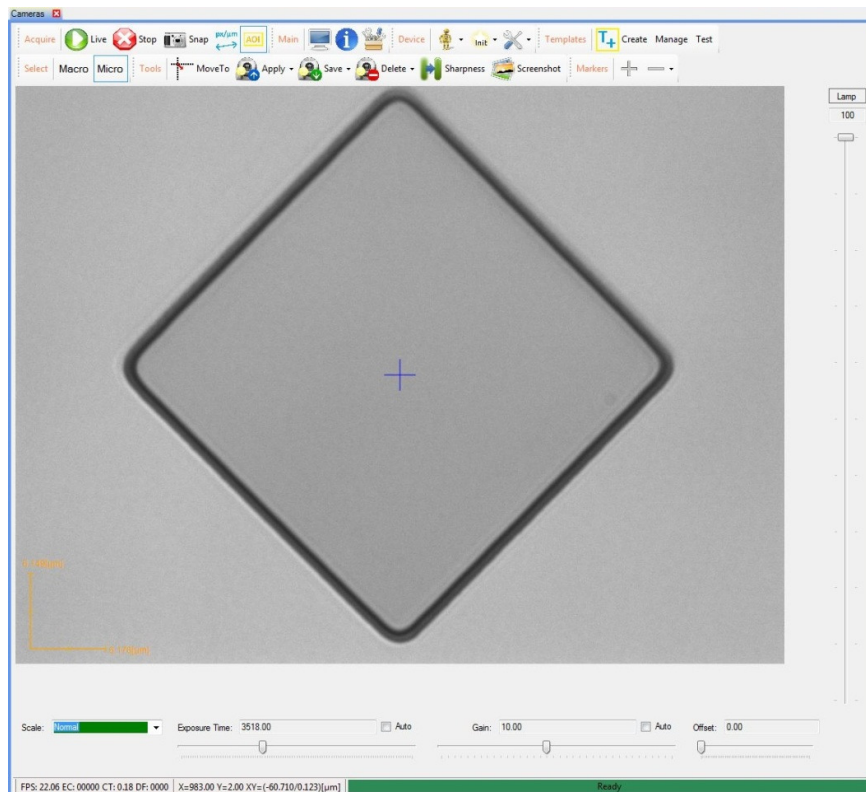
From the main menu bar, select **Devices** → **Camera selector** → **Cameras**. The **Cameras** control panel opens.

In general, the **Cameras** window shows the field of view of the currently selected camera. During any setup operations related to the camera image (template definition, setup of calibrations or measurements), the following operations are offered depending on the type of selection that is intended:

Area of Interest – if an area of interest should be defined e.g., to define a template, a box appears in the camera image. The box size can be changed by grabbing and pulling the sides and corners with the mouse (move cursor onto frame, click and move the cursor while holding the button down; release when the box size is correct). The box position can be changed by drag-and-dropping the inner area of the box (click anywhere within the frame). Where required, confirm box by middle mouse click (mouse wheel click).

Point of Interest – if a point of interest should be defined e.g., a line edge or structure center for distance measurements, a target cross appears at the cursor position. Click on the desired position in the image.

Both operations can be aborted any time with the red cross in the upper right corner of the camera image.



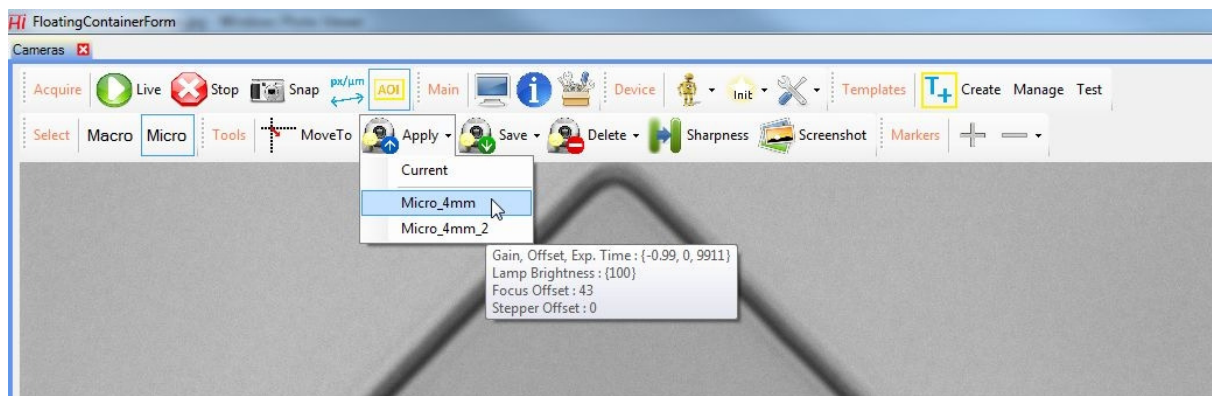
Defining imaging parameter sets

In both optical alignment to reference marks and measurements, it is important to achieve a good contrast in imaging to get stable and reliable results.

Adjustment of settings for illumination and contrast are done in the **Cameras** control panel. Sliders are available for adjustment of lamp brightness (side) as well as the camera parameters signal gain, background offset subtraction and camera exposure time (bottom). Adjust for maximum contrast without saturation of the camera pixels.

Imaging parameter sets can also be saved in so-called Camera Setup Keys. These keys can then be loaded to avoid having to set all the parameters again each time. Camera setup keys are managed in the **Tools** toolstrip:

- Save -** To save the current camera setup, open the drop down list and select **As new setup**. To replace an existing key, choose one from the list.
- Apply -** Reload a saved Camera Setup Key. Choose one from the drop down list. The properties of each key can be reviewed in the tooltip in the list.
- Delete-** Delete a saved Camera Setup Key. Choose one from the list.



Chapter 2: Exposures

The **Lithography Menu** offers control over all steps and many parameters of an exposure. Depending on the complexity of the job, different tools are offered to help in the preparation and execution of such tasks.

In this chapter, first the execution of jobs that have already been prepared is explained. Afterwards, a section on job preparation and information on job templates follows. Instructions on preparation and use of alignment scripts, e.g. for overlay exposures, are given in the following chapter. Some advanced exposure tasks are described in the Appendix (advanced parameter optimization, overlay exposures, back side alignment exposures). For more detailed information on all features of the **Lithography Menu**, refer to **User Guide II: Reference Guide**.

Note: Availability of the functions described here depends on the user right settings. If any functions are not available, contact the administrator responsible for user permissions management.

Running Exposures

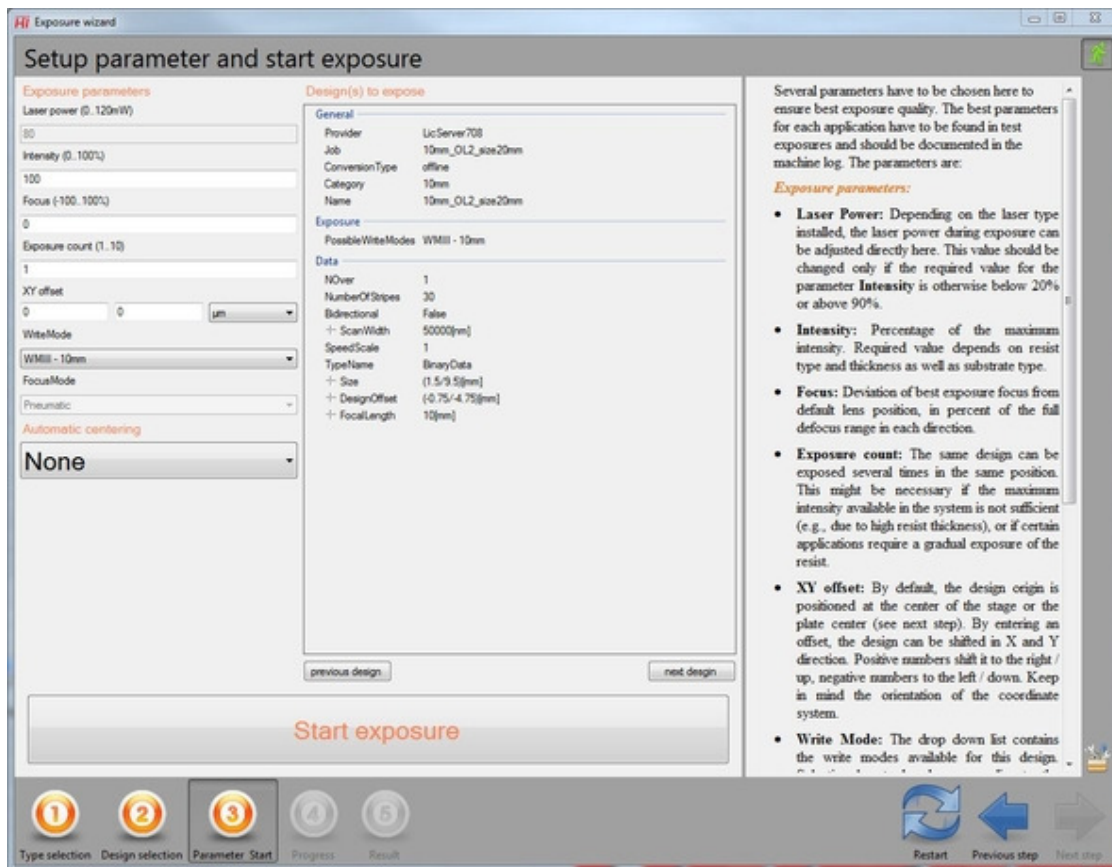
Exposures can be run in two ways:

- using the **Exposure wizard**, or
- executing an exposure job from the **Job control** panel.

The **Exposure wizard** leads through the steps of creating and executing a single field exposure, meaning the exposure of just one design. Positioning is done either relative to the stage center, or relative to the substrate center, if the related option is selected. The wizard creates and executes a temporary job, which is deleted after execution.

If multiple designs are to be exposed on the same substrate, or if exposures need a different alignment than the ones provided by the wizard, or the same job should be repeated several times and should therefore not be created only temporarily, an exposure job has to be prepared in the **Job control** panel.

This section describes first how to use the wizard, and afterwards, how to expose a more complex job. For details on job preparation see the next section.



STEP-BY-STEP: EXPOSING WITH THE EXPOSURE WIZARD

0. Start the job wizard

Open the **Wizardry** menu and select **Exposure wizard**. The **Exposure wizard** opens.

- Numbers at the bottom show the current step.
- Arrows at the bottom of the wizard panel allow free navigation between the current step and all previous steps. The double arrow resets the wizard.
- With a click on the green manikin at the top right of the panel, the **QuickMode** can be deactivated or activated. Per default, it is activated at the start of the wizard. **QuickMode** means that the wizard automatically jumps to the next step whenever possible.

1. Type selection

Only one option is offered here at the moment. Click on the **ExposureJob** control.

2. Design selection

This panel shows all available designs and their folders. Open the directory that contains the design that should be exposed, and select it.

- In **QuickMode**, the wizard proceeds immediately.
- If quick mode is deactivated, or after navigating back with the arrow button, arrow buttons offer the possibility to scroll through the designs of a folder. Also, the design properties shown in the next panel can also be viewed here.

3. Parameter setup

Several parameters have to be chosen here to ensure best exposure quality. The best parameters for each application have to be found in test exposures and should be documented in the machine log. The parameters are:

Exposure parameters:

- **Laser Power:** For certain types of laser sources, the laser power during exposure can be adjusted directly here. This value should be changed only if the required value for the parameter **Intensity** is otherwise below 20% or above 90%.
 - **Intensity:** Percentage of the maximum intensity. Required value depends on resist type and thickness as well as substrate type.
 - **Focus:** Deviation of best exposure focus from default lens position, in percent of the full defocus range in each direction.
 - **Exposure count:** The same design can be exposed several times in the same position. This might be necessary if the maximum intensity available in the system is not sufficient (e.g., due to high resist thickness), or if certain applications require a gradual exposure of the resist.
 - **XY offset:** By default, the design origin is positioned at the center of the stage or the substrate center (see next step). By entering an offset, the design can be shifted in X and Y direction. Positive numbers shift it to the right / up, negative numbers to the left / down. Keep in mind the orientation of the coordinate system.
-

- **Write Mode:** The drop down list contains the write modes available for this design. Selection has to be done according to the requirement of the application.
- **Focus Mode:** The drop down list contains the focus modes available for this design. Selection has to be done according to the requirement of the application.

Automatic centering:

Selection from the drop down list decides what mode of centering is executed before the exposure starts.

- **None:** The origin of the machine coordinate system stays in the current position, usually the stage center.
- **PlateCenter / WaferCenter:** The autofocus is used to detect the edges of a substrate. The position of the center of the substrate is calculated and used as origin. Select **WaferCenter** for wafers or **PlateCenter** for rectangular mask blanks.

On the right, some properties of the selected design can be viewed. Some points offer + signs that expand the information given into even more detail. With the controls **previous design** and **next design**, the selected design can still be changed to a different design within the same folder.

Once all parameters are selected, click on **Start Exposure**.

4. Progress

The stage moves to the front, and the operator is prompted to load the substrate that should be exposed. Follow the instructions given in the section on loading (option semi-automatic) in **Chapter 1: General**.

After loading is finished, **PlateCenter / WaferCenter** is executed if selected.

Exposure starts. Progress of the exposure is shown in the wizard

The exposure can be stopped any time by clicking on **Stop exposure**.

5. Result

After the exposure is finished, the stage moves to the load position. Follow the instructions given in the section on unloading (option semi-automatic) in **Chapter 1: General**.

If any errors occurred during exposure, the tree on the left opens to the related exposure log, and the messages are shown.

STEP-BY-STEP: EXPOSING FROM THE JOB CONTROL PANEL

1. Open the job control panel

From the main menu bar, select **Controls** → **Job**. The **Job** control panel opens.

2. Select job

On the left, all jobs that can be executed are listed. Some may be sorted into folders. If necessary, open the exposure job folder with the exposure job to be executed. Double-click on the exposure job to select it.

Note: Folders with multiple exposures may also be exposed. Make sure if folder or job is highlighted before starting the job.

3. Start exposure sequence

Click on the **Execute** button (green star) to execute the exposure job.

Note: The **Stop** button (red minus) next to this button can be clicked any time to interrupt the exposure job execution.

The **Executing**: register card of the **Job** control panel goes to the foreground if it still was behind the map window, the job name appears in the header and the map is displayed.

- Fields in dark blue are activated for exposure
- Fields in light blue will not be exposed

The menu checks the settings of the job and issues messages if there are problems. If optional map parameters have been set (parameters other than design name, intensity and power), a window opens that requires the activation of a checkbox to confirm that these settings should be used.

4. Load substrate

The stage moves to the front, and the operator is prompted to load the item that should be exposed. Follow the instructions given in the section on loading (option semi-automatic) in **Chapter 1: General**.

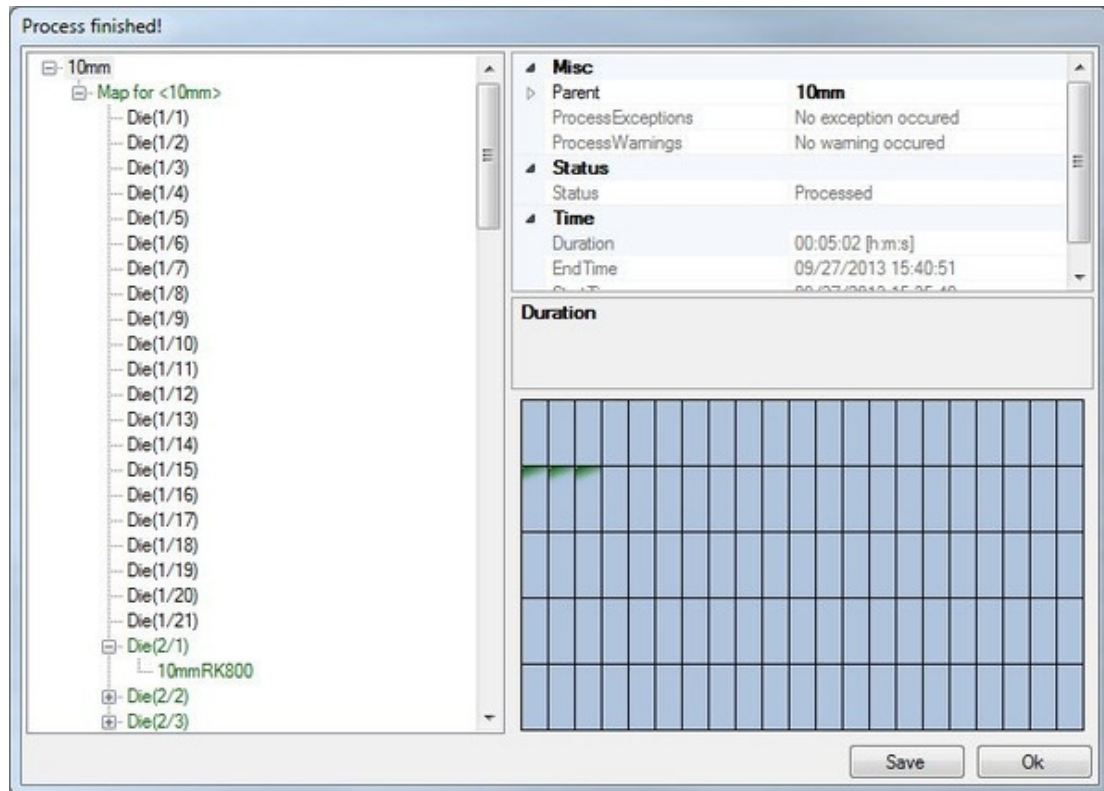
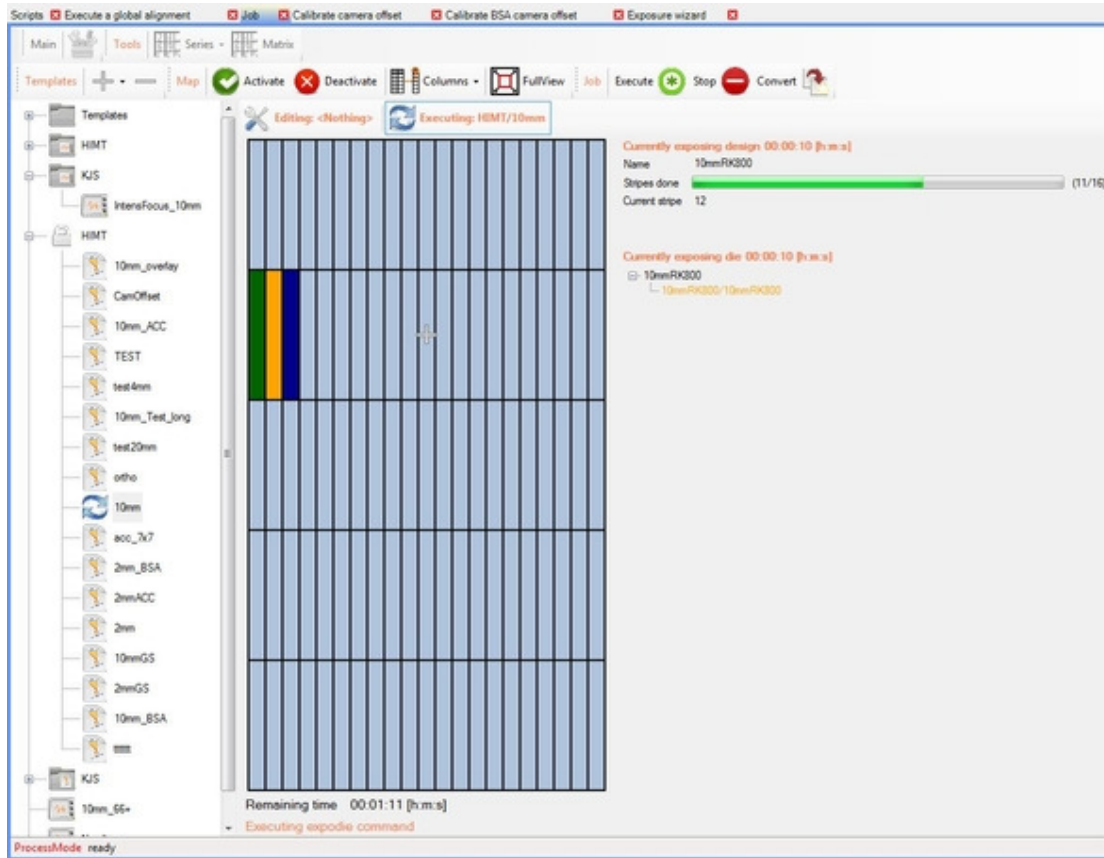
5. Alignment and Origin Position

Per default, the origin is set in the stage center. If a preceding alignment sequence has been defined to change the origin position and possibly also the angle of the coordinate system, dialog windows may open according to the functions that were included in the sequence. In such cases, follow the instructions given in the dialog windows.

6. Exposure

Once all preceding sequences have finished, the exposure starts.

- If a countdown was defined to allow the substrate to reach equilibrium temperature on the stage, the system waits for the specified time before exposure starts



- In standard color setting, the **Executing** register card of the **Job control** panel, the field being currently exposed turns orange, and successfully exposed fields turn green afterwards. If an error occurred during exposure of a field, it turns red (failed) or orange (stopped).
- A progress bar and a stripe counter to the right of the map show the progress of the current design exposure.
- Below the map, an estimated remaining duration of the exposure is shown.
- A log file is written to: C:\HIMT\LOG\

During exposure, user-defined scripts might run before and after each field, as well as at the end of the job. If dialog windows show up, follow the instructions given.

After the job is finished, a dialog window opens asking if the write head should be moved to standby position, and depending on the settings in the job, the laser might be automatically switched off.

7. Unload substrate

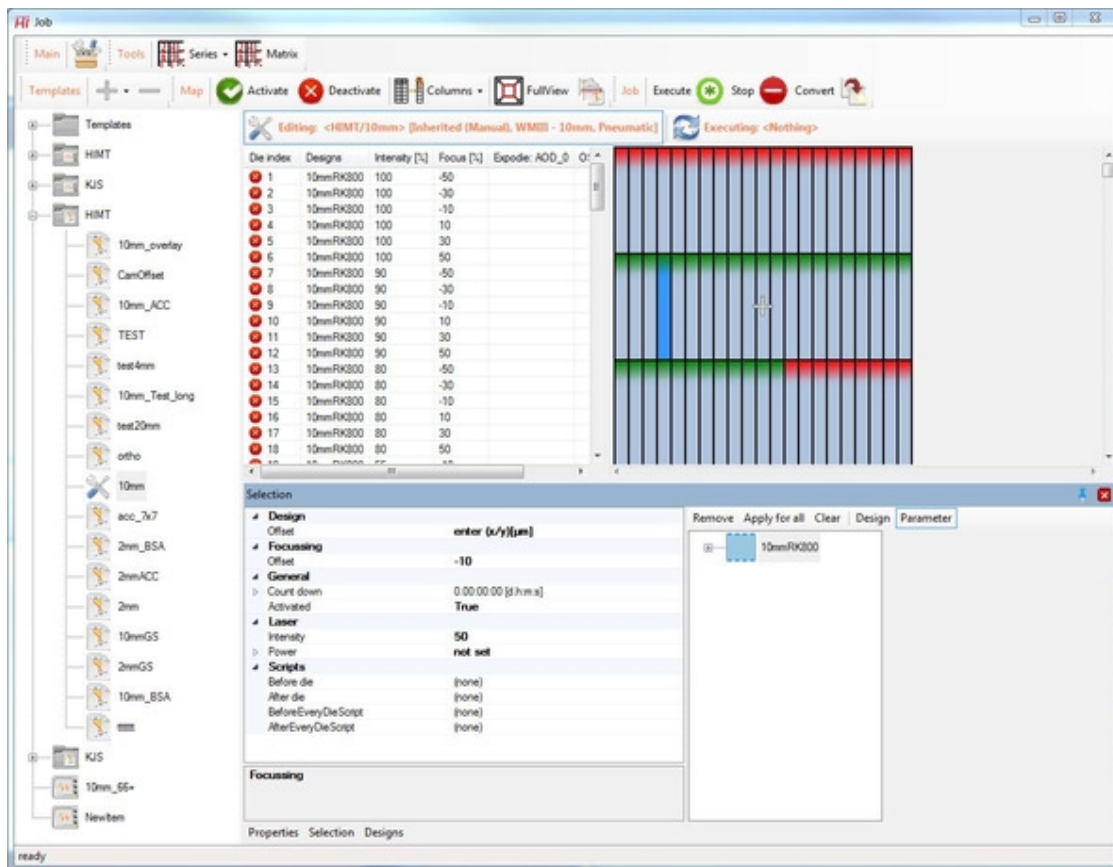
Depending on the settings in the job, the stage either moves out automatically after the job is finished (AutomationMode = AutoUnload or SemiAutomatic), or this has to be done manually. Follow the respective instructions given in the section on loading in **Chapter 1: General**.

8. View Report

After the end of the exposure, a process report window opens. A graphical representation of the map shows successfully exposed fields with green upper-left corner. Where errors have occurred, the corner is red or orange.

In the list to the left, the job can be expanded by clicking on the plus (+) sign to make the reports for each field accessible, and in the same way, each field can be expanded to show the list of designs and check the results for each. Clicking on the item of interest loads the report parameters into the box on the top left where they can be browsed. If parameters for a die or a design are requested, the map closes.

The report is automatically saved for later reference if **Autosave** was selected in the job. If this option was disabled, the reports can be saved manually from the process report window by clicking on the **Save** button. Select a folder and name for the saved report file. All details available in the window are stored in the file.



Setting up an Exposure Job

The **Editing** part of the **Job control** panel gives the operator control over a variety of exposure parameters, like focus and intensity, or stitching parameters (AOD values, ramp length).

Note: Certain advanced user permissions are required to be able to see and use the functions described in this section. If you cannot access some of these functions, contact your administrator.

The **Job control** panel can be opened via the menu **Control** → **Job**. The panel consists of two parts: The **Job list** on the left, and the register cards for **Editing** and **Execution** on the right. How the register card **Execution** is used was described in the previous section. This section describes how to create or modify an exposure job using the functions of the **Editing** register card.

Jobs created with the Job control panel have several additional features:

- a grid (the so-called **Map**) can be defined that divides the substrate into fields, (**Dies**), sorted in columns and rows, of which each may contain one or several different designs and different exposure parameters
- more than just the basic parameters are accessible,
- scripts can be included in the exposure process to adapt it to the requirements of the application (alignment, re-focusing on each field ...)

The **Editing** register card is brought to the front by clicking on the **Editing** tab. It consists again of several parts: A spreadsheet on the left where all parameters for the exposure are listed, and a graphical representation of the current map on the right.

An additional window appears at the bottom when the mouse hovers over one of the controls at the bottom bar. It closes when the mouse leaves the region of the window. Contents of the window change depending on which control the mouse hovers over. It gives access to the available **Designs** as well as the map **Properties**, or the properties of the current **Selection** within the map. By a click on one of the controls, the window is made to stay open until a click outside occurs or the red x is used to close it. If the window is pinned down, it will stay open even if outside clicks occur (refer to **User Manual II: Reference Manual** for more information on general menu controls).

To view the properties and parameters defined in a certain job, double-click on it in the list on the left. If the job is stored in a folder, the folder has to be opened first by clicking on the plus (+) sign in front of it. A double-click on a folder shows the properties of the folder, which might be inherited by the jobs stored inside, depending on the job settings.

In the following, the setup of exposure jobs is explained on the basis of three examples. The first is an exposure with just one field, similar to what can be done with the **Exposure wizard**. However, the wizard does not give the possibility of re-use of the setup, while the preparation as a job in the **Job control** panel does.

Next follows a setup of a job that combines several designs, and afterwards the preparation of a job containing several test series. The sum of all three instructions gives the operator understanding of all the necessary tools for all common as well as many advanced applications.

For more complete explanations of the features introduced in these step-by-step instructions, refer to the chapter on the **Job control** panel in *User Guide II: Reference Guide*.

STEP-BY-STEP: SETTING UP A ONE-FIELD EXPOSURE

1. Create Exposure Job

In the **Job list** on the left, open the folder **Templates/ExposureJob** by clicking on the plus (+) sign. Select any job template and drag-and-drop it to the region below the **Templates** folder. Give it a characteristic name, like 'single field'.

- Usually, an orange warning triangle lies on top of the job icon, and the tooltip shows that the map is invalid. This tooltip helps to not forget necessary settings and shows what is missing
- Creation of templates works in the same way as creation of jobs, but a different user permissions group is required to do it. For more explanations on Job templates, refer to the next section

2. Prepare Map

Double-click on the new job. All information already stored in the template appears.

Click on **Properties**. Scroll down to the section **Dimension**. If the arrow beside the title is empty and pointing to the left, click on it to make the contents of the section visible. At **Column Count** and **Row Count**, click into the text fields at the right and enter '1'. Now only one field is represented in the **Map Diagram**. Correspondingly, only the first row in the spread sheet shows an index number in the **Die index** column.

The other parameter in this section, **Size of die**, is usually not important in exposures with just one field, as it decides the distance between fields.

Look further down at the section **Field Zero**. With the reduction of the map to just one field, the entry in the **Indices** field has automatically changed to 'X=1 Y=1'. In the same section, the parameter **Location** is set to **Center**. This means the die is centered on the coordinate origin set during loading (usually substrate center or stage center).

3. Choose Exposure Execution Mode

In the section **Automation** of the **Properties** list, locate **AutomationMode**. Click on the currently selected mode to get an arrow that allows to open a drop-down list of available options.

- **Semi-Automatic**. The menu automatically moves to load and unload position when required
- **AutoUnload**: Loading has to be controlled manually, only the movement to the unload positions happens automatically
- **Manual**, both loading and unloading have to be done manually.

Select **SemiAutomatic**.

4. Select Design

Click on the button **Designs** at the bottom of the **Edit** partition. If required, open the design directory. Click on the design to highlight it. Click on **Properties**. Some design

information is shown. Check if everything is correct. Now, drag-and-drop the design either into the first field in the spreadsheet, or onto the **Map**. The path to the design shows up in the **Design** column of the field, and an icon appears in the map showing that the die contains a design.

5. Choose Exposure Parameters

Beside **Die index** and **Designs**, the spreadsheet shows by default two more columns. These columns stand for the main exposure parameters which always have to be actively chosen:

- **Intensity:** Percentage of the maximum intensity. Depends on resist type and thickness as well as substrate type.
- **Focus:** Deviation of best exposure focus from default lens position, in percent of the full range.

More parameters that influence the quality of an exposure follow further down.

There are two ways these parameters can be edited:

- a. Double-click on the **Intensity** field of the first spreadsheet line. A cursor appears showing that the field is ready for editing. Enter the intensity value. Repeat for the **Focus** field.
- b. Highlight the first spreadsheet line, or click on the die in the map, and click on **Selection**. A list of parameters connected to this die appears. Locate the parameters **Laser → Intensity** and **Focusing → Offset**. Enter the numbers that work best for the required application into the text fields to the right of these parameters.

6. Activate Die for Exposure

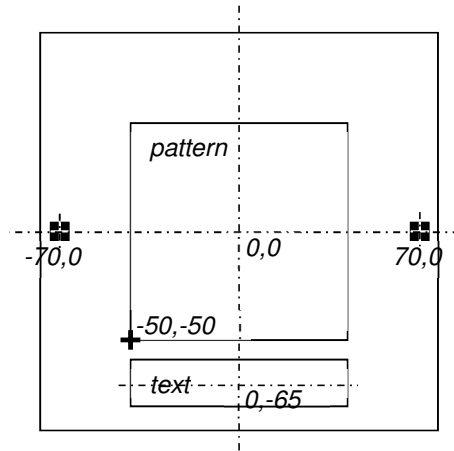
While the first line in the spread sheet is highlighted, click on the green **Activate** button to activate it for exposure. In the spreadsheet, a smaller representation of the button icon appears in front of the index number in the **Die index** column. At the same time, the upper left corner of the activated die turns green in the **Map**, and the same icon appears there, if the field is large enough.

Now, the job is ready for exposure and can be executed in the way described above.

STEP-BY-STEP: SETTING UP A JOB WITH SEVERAL DESIGNS

Example: Three separate designs should be exposed on a 6" plate:

- Main pattern: 100mm x 100mm, design origin is in the lower left corner, to be exposed in the center of a 6" plate
- Text line: 100mm x 10mm, design origin is in the center, to be exposed beneath main pattern (left flush) and close to the plate edge (center at x =center of main pattern, y =65mm below center of main pattern)
- Alignment mark: 500 μ m x 500 μ m, origin in the center, to be exposed on both sides of the pattern close to the edge (center at x = ± 70 mm from main pattern center, y =main pattern center)



This requires three dies in a row (the main pattern and the alignment marks), and another die beneath the main pattern.

1. Create Exposure Job

In the **Job list** on the left, open the folder **Templates/ExposureJob** by clicking on the plus (+) sign. Select any job template and drag-and-drop it to the region below the **Templates** folder. Give it a characteristic name e.g., 'combi-job'.

2. Prepare Map

Double-click on the new job. Click on **Properties**. Scroll down to the section **Dimension**. If the arrow beside the title is empty and pointing to the left, click on it to make the contents of the section visible.

At **Column Count**, click into the text field at the right and enter '3'. At **Row Count**, enter '2'.

The **Map Diagram** shows a grid of 3x2 dies, and the spread sheet shows index numbers in the first 3x2=6 rows.

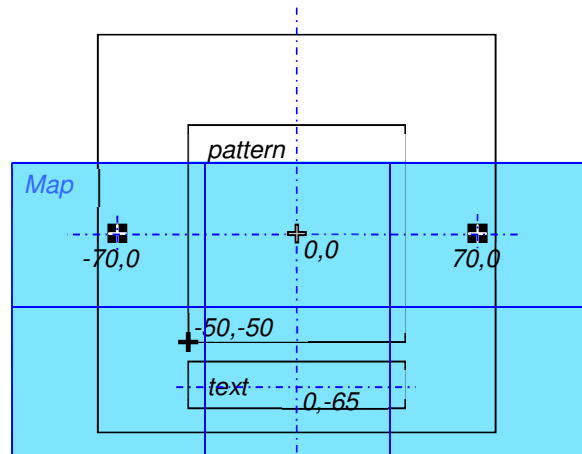
Now, the parameter **Size of die** has to be set so that the dies have the correct distances. Extend the parameter into the separate coordinates and the unit by clicking on the empty arrow to the left of it. At **Unit**, click into the text field to get a drop-down list, and select mm from it. At **X**, enter 70. This is the distance the center of the die for the main pattern should have to the two dies for the alignment marks. At **Y**, enter 65, the distance towards the text field below the pattern.

Note: It does not matter that in this way the grid extends beyond the plate. The **Size of die** parameter mainly determines the distances of the designs exposed in them.

Go to the section **Field Zero** and expand it. Also expand the **Indices** parameter. We want the center of the die containing the main pattern to be exposed at the center of

the plate. For **X**, enter '2', for **Y**, enter '1'. The parameter **Location** has to be set to **Center**.

The small grey cross in the **Map** moves to the center of the second die in the first row, indicating that this is where the origin (usually the substrate center or the stage center) will be.



3. Choose Exposure Execution Mode

In the **Properties** list, set the **AutomationMode** to **SemiAutomatic**.

4. Select Designs

Click on the button **Designs** at the bottom of the **Edit** partition. If required, open the directory or directories where the designs are stored. Now, drag-and-drop each design to the die it should be exposed in (alignment mark → dies 1 and 3, main pattern → die 2, text → die 5), either in the spreadsheet, or on the **Map**.

5. Choose Exposure Parameters

Mark all dies, by either marking the complete map (click in the upper left corner and hold down the mouse button, moving towards the lower right corner, until all dies have turned color), or all spreadsheet rows (click on first row and hold down the mouse button while moving the pointer down to the last row). Click on **Selection**.

Change the entries in **Laser** → **Intensity** and **Focusing** → **Offset** to the values for best exposure results.

Click on die 2. Here, we want to expose the main pattern with the center of the pattern in the center of the die. Unfortunately, the design was created with the origin in the lower left corner of the pattern, and no automatic centering was used during conversion. Therefore, an offset has to be added.

Click on **Selection**. In the parameter list on the left, look for **Design** → **Offset**. Expand the details. Again, there is a field for the **Unit**, and two fields for the shift in **X** and **Y** to be applied to the design. Change the unit to mm, and enter -50 for both x and y. Now, the design origin is exposed at -50mm/-50mm relative to the die origin, putting the design center into the die center.

To make the offset also visible in the spreadsheet, click on the **Columns** button in the **Map** toolbar at the top of the **Job control** panel and select **Common** → **XY Offset**.

An additional column in the spreadsheet is filled with design offset data for all dies. It might be necessary to shift the border line between spreadsheet and map to see it.

6. Activate Dies for Exposure

Highlight all dies and click on the green **Activate** button to activate them for exposure. However, there are two dies with no design in them (dies 4 and 6 flanking the text field). This immediately makes the job invalid. A warning triangle shows up on the job icon in the job list.

Click on die 4. Hold down the `Ctrl` key and click on die 6. Now only these two empty dies are marked. Click on the red **Deactivate** button to deactivate them.

Now, the job is complete and valid and can be executed.

STEP-BY-STEP: SETTING UP A TEST EXPOSURE JOB

When testing for optimum exposure parameters, exposures have to be done with varying parameter values, and these have to be compared with each other. In the case of focus and intensity, simple rows cannot show the optimum, as both parameters affect structure quality in a similar way. Therefore, a matrix should be exposed. In this example, we use 11x5 dies.

Below this matrix, we put an additional row for test exposures for stitching and registration, extending the required map to 11x6 dies. Please refer to the appendix on exposure optimization for more information about stitching and other exposure characteristics.

The same design is used for all test exposures. The design has the origin in the center. It consists of two layers, CM and CU. The first is used for all tests, the second only for the registration test.

As a test like this should be prepared for each available write mode, we also use this opportunity to use the possibility of sorting jobs into folders.

1. Create Exposure Job

In the **Job list** on the left, open the folder **Templates/ExposureJobContainer** by clicking on the plus (+) sign. Select any template and drag-and-drop it to the region below the **Templates** folder. Give it a characteristic name e.g., 'Test jobs'.

Open the folder **Templates/ExposureJob** and drag a template into the new container. Give it a characteristic name e.g., 'test_series_<write mode>'.

2. Prepare Map

Double-click on the new job. Click on **Properties**. Scroll down to the section **Dimension**. If the arrow beside the title is empty and pointing to the left, click on it to make the contents of the section visible.

At **Column Count**, click into the text field at the right and enter '11'. At **Row Count**, enter '6'.

The **Map Diagram** shows a grid of 11x6 dies, and the spread sheet shows index numbers in the first 11x6=66 rows.

Set the parameter **Size of die** to a slightly larger size than the design size, so the designs can be separated from each other.

Go to the section **Field Zero** and expand it. Also expand the **Indices** parameter. The map should be exposed around the origin. However, as we have 6 rows, the origin cannot be positioned in one die, but has to be on the border between rows 3 and 4. Therefore, we have to make use of the **Location** parameter this time.

For **X**, enter '6', for **Y**, enter '3'. Set the parameter **Location** to **BottomCenter**.

The small grey cross in the **Map** moves to the center of the bottom borderline of die 6/3. This is the center of the complete map.

3. Choose Exposure Execution Mode

In the **Properties** list, set the **AutomationMode** to **SemiAutomatic**.

4. Select Designs

Mark all dies, either in the map or the spreadsheet. Click on the button **Designs**. If required, open the directory or directories where the designs are stored. Drag-and-drop layer 1 to the map. The design is entered into the **Designs** column of all fields.

Select the last 5 fields in the last row (dies 62-66). This is where we want to check registration quality and stability. Drag-and-drop the second layer to the highlighted fields. The second layer is added in the **Designs** column of these fields. In the map, the icon for one design changes to an icon showing a stack of designs.

Note: Icons only show up in map fields if they are large enough. While this is usually the case in single field exposures, it might not in exposures with several fields.

In the spreadsheet, three points appear after the first design. To view which designs are loaded into a multiple-design die, either double-click on the **Designs** field of a die to open a small window showing all the designs, or open the **Selection** window.

During exposure, the two layers are exposed directly after each other. This shows the quality of short-term positioning stability.

5. Choose Exposure Parameters

Mark the dies of the first row. Here, we will start the energy/focus matrix by creating the basic focus series first. In the **Tools** toolbar, click on the **Series** control button. A drop-down list opens offering several parameters. Select **Focus**. In the dialog window, select -100 as starting point, and 20 as step. As we have 11 dies in the row, this means variation will be done over the complete range of -100% to 100% in steps of 20%. Click on **Selection** and set **Laser → Intensity** for this row to 100%.

With the row still marked, copy it into the clipboard: Either right-click into the marked region of the spreadsheet and select **Copy**, or type `Ctrl-C`. Highlight the dies of the next row and paste the contents: Either right-click and select **Paste**, or type `Ctrl-V`. Click on **Selection** and change **Laser → Intensity** to 90%.

Repeat for the next three rows, reducing the Intensity to 80%, 70% and 60%. With that, the energy/focus matrix is complete.

Note: A faster way to create a parameter matrix is to use the **Matrix** function in the **Tools** toolbar. For more information, refer to *User Guide II*.

Mark the first field of the last row. In the fields **Focus** and **Intensity**, enter the values that were so far the best by double-clicking and editing them. Now, mark all fields of the last row. Right-click on the selection in the spreadsheet and select **FillDown →**

Intensity. Repeat with **FillDown → Focus**. This is an alternative to the use of the **Selection** window when changing parameters in whole regions.

Select the first 5 fields of the row (dies 56-60). From the **Series** drop-down list, select **Expodie → Expodie: AOD_0**. In the spreadsheet, a new column is automatically defined for this parameter. Enter a starting value 20 counts below the current optimum value, and a step size of 10.

6. Activate Dies for Exposure

Highlight all dies and click on the green **Activate** button to activate them for exposure. However, to be able to quickly find the border between the AOD series and the registration series, the center die in the last row was not used for either. Click on this die (die 61), then click on the red **Deactivate** button to deactivate it.

Note: Icons only show up in map fields if they are large enough. While this is usually the case in single field exposures, it might not in exposures with several fields.

Now, this job is also complete and can be executed.

Exposures with Optional Write Modes

The DWL 66⁺ can be configured with two additional write mode types: Gray Scale Exposure Mode and Vector Exposure Mode. These exposures are started in the same way as exposures in standard mode. The correct write mode type is selected automatically.

GRAY SCALE MODE

The intensity setting determines the overall depth of the structure in the resist. In very thick resist, depending on the resist reaction to exposure, it might be required to use several repeated exposures of the same design to reach the required depth.

VECTOR MODE

For vector mode, in addition to the standard selections, a pen has to be chosen. This can be done either in the **Job spreadsheet**, or in the **Selection** panel.

Job spreadsheet:

1. From the **Columns** list, select **Common → Pen**. The currently selected pen is shown
2. Double-click on the cell to activate a drop down list of the available pens
3. Open the list and select the pen to be used for exposure

Selection panel:

1. Select a die with a vector mode design
2. Open the **Selection** panel
3. In the design section, activate the **Parameter** view and click on the design
4. Select the Pen entry to activate a drop down list of the available pens
5. Open the list and select the pen to be used for exposure

Job Templates and Job Batches

Templates can be very helpful tools to save time. They can contain all the features that keep reappearing in many applications e.g., alignment mark designs, certain map geometries, standard exposure parameters, alignment scripts ... anything that can be part of a job.

Job templates – exposure job templates as well as measurement job templates – are prepared in the same way as the related jobs. However, a different user access level is required to create or edit them. This is to prevent accidental altering of job templates, which would make them less usable for other projects.

A user with the required user permissions group assigned has an additional toolbar **Templates** available in the **Job control** panel. This toolbar contains the controls to create new templates, and to delete a highlighted template. If a new template is created, it appears in the related subfolder of the **Templates** folder (**MeasurementJob / ExposureJob**). It can be edited in the same way as jobs, adding all the standard features that are often required. The background color of the **Job control** panel turns to orange to warn about the fact that a template is being changed.

As a template hardly ever is a complete job in itself, it usually will retain the 'Invalid' warning sign. However, this is not significant. Only the jobs created from the templates need to be valid so they can be exposed.

Another way to create templates is to move an existing job into the template section via drag-and-drop. A copy of that job is then stored in the related section (**MeasurementJob / ExposureJob**) and can be modified to serve as template for future jobs.

In addition to job templates, the Templates section also contains job containers (**MeasurementJobContainer / ExposureJobContainer**). These can be used like folders to sort and group jobs. Jobs grouped into a container can be executed as a batch by selecting **Execute** while the container is highlighted.

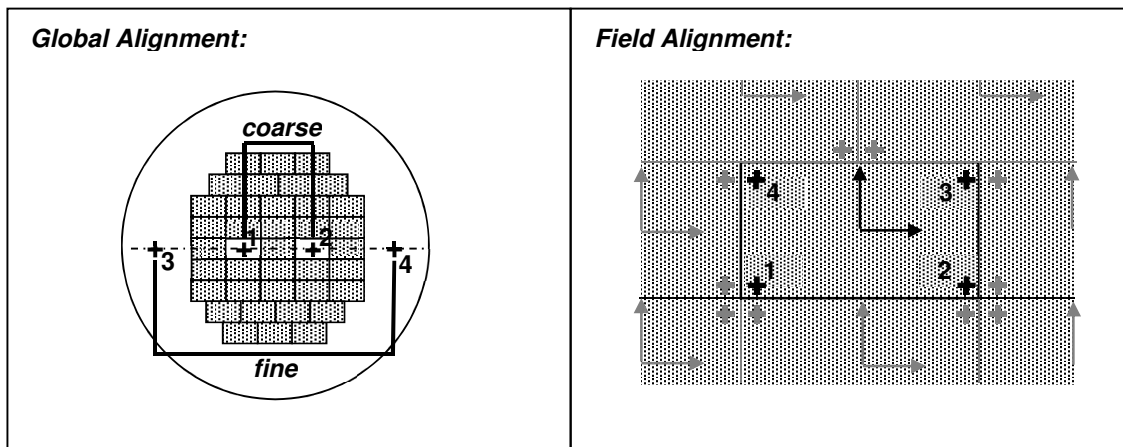
Chapter 3: Alignment Procedures

Alignment might be done for different purposes: In exposures, it ensures a defined alignment of the design with respect to the substrate geometry or a previously exposed design (overlay). For measurements, it is a prerequisite for any precise measurement to know the angle between system axes and substrate axes to get correct results. In addition, alignment procedures allow the operator to set up fully automatic measurement procedures. If pre-exposed structures are to be used for alignment, these have to be clearly identifiable and separable from the surrounding structures in the camera image.

The DWL 66⁺ system offers two different principal alignment functions:

- **Global Alignment** – The global alignment is an angular alignment of the system coordinate axes to the substrate as whole. Depending on the hardware configuration, this might even include a physical rotation of the substrate. Global alignment can be done according to substrate geometry or pre-exposed reference marks. It is executed in batch jobs after automatic substrate loading and may include the setting of an origin. Global alignment can include mechanical measurement of the substrate position and rotation as well as optical detection of alignment marks on the substrate.
- **Field Alignment** – The field alignment is a method of setting a local origin for each field, according to the fields of a pre-exposed layer. It requires alignment marks with good contrast. For overlay exposures covering several fields with alignment structures, field alignment allows for a more accurate field-by-field coordinate alignment. Field alignment is purely optical and requires separate field alignment marks for each field.

An **Execute a global alignment** wizard is available in the menu that leads through the steps of a pre-defined standard global alignment procedure. In addition, the menu offers an **Create an alignment script** wizard that guides through the steps of preparing user-defined alignment routines. These can then be coupled to exposure jobs prepared in the **Job control** panel.



Global Alignment Wizard

The **Execute a global alignment** wizard leads through a routine where two alignment marks on a virtual horizontal or vertical line are used as reference points. The line connecting the two marks is used as reference for the X (horizontal) or Y (vertical) axis. After calculation of the measured angle, the machine coordinate system is rotated accordingly.

Note: No origin is set in the course of this routine. It is a purely angular alignment, with the current origin as center of rotation.

STEP-BY-STEP: GLOBAL ALIGNMENT WITH THE WIZARD

0. Load the substrate and start the global alignment wizard

Follow the instructions given in the section on loading (option Manual) in **Chapter 1: General**.

Open the **Wizardry** menu and select **Execute a global alignment**. The **Execute a global alignment** wizard opens.

- Numbers at the bottom show the current step.
- Arrows at the bottom of the wizard panel allow free navigation between the current step and all previous steps. The double arrow resets the wizard.
- With a click on the green manikin at the top right of the panel, the **QuickMode** can be deactivated or activated. Per default, it is activated at the start of the wizard. **QuickMode** means that the wizard automatically jumps to the next step whenever possible.

In the **Cameras** control panel (**Devices → Camera selector → Cameras**), select the camera that should be used for alignment. Use **Exposure time**, **Gain** and **Offset** sliders to optimize the visibility and contrast of the image. If the defocus setting is not optimal, use the **Focus** slider in the **System Control** panel to adjust it. The camera may be switched any time during the process.

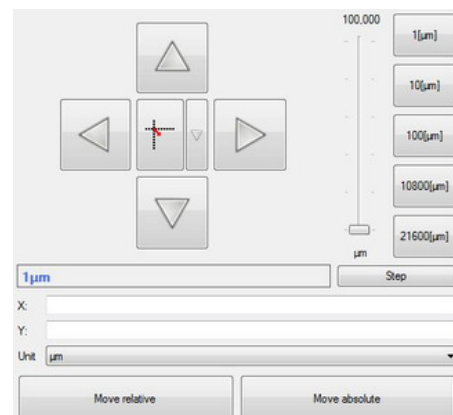
1. Axis selection

Select if the alignment should be done along the X or Y axis.

2. Move to point 1

Using the controls in the panel, move the stage so that the first alignment mark is visible in the camera window.

- If the coordinate of the mark is known, enter it into the text fields, adjust the unit and click on **Move absolute**. This starts an absolute movement to the given coordinates.
- To move the stage a certain distance, enter the distances for X and Y into the text fields, adjust the unit, and click on **Move relative**. This starts a relative movement by the given distances.



- To move around freely, use the arrow buttons. Each click moves the stage a step in the direction indicated by the arrow. Keep in mind the orientation of the coordinate system: The up/down arrows move the stage in y, i.e. parallel to the loading window, while the right/left buttons move it in x, i.e. back and forth. The size of the step is determined by the number in the text field below the arrows. Coarse adjustment of that number can be done with the control buttons, fine adjustment with the slider or the mouse wheel.
- To move a certain spot that is visible in the camera to the image center, click on the **MoveTo** button in the camera panel. The cursor turns into a crosshair. Click on the point of interest to select it.

Once the structure is well visible, continue.

3. Acquire point 1

Follow the instruction in the wizard panel to point to the position of point 1: Move the cursor to the point in the camera image and click to confirm.

Note: For a manual detection as this one, it is recommendable to use the edges of structures as reference points, not the centers, as edges can be targeted more precisely with the crosshair. The corners of crosses, boxes or L-shapes give best results (be careful to use always the same corner). Also, for alignment to x, only the vertical position is important, and for y, only the horizontal.

4. Move to point 2

In the same way used before to move to point 1, move to point 2 now. If necessary, the camera can be changed e.g., to a lower resolution with larger image field during movement, and back again to higher resolution before proceeding to the position acquisition.

5. Acquire point 2

In the same way used before with point 1, point to point 2 now.

6. Submit angle

The angle between a virtual connecting line between the two points and the selected axis is calculated and displayed, together with the measured positions of the points. Two options are given:

a) Save and go to x=0 y=0

The angle is used for all further movements and measurements. The stage moves to the new origin calculated with this angle.

b) Save and start next iteration

The angle is used for all further movements and measurements. The wizard loops back to step 2 for a next iteration to refine the measurement e.g., by using the micro camera.

During the new iteration, the positions of the previous reference points may be reached directly using the now activated control buttons **P#1** and **P#2** in the navigation panel. However, it is also possible to use new points e.g., to get a longer baseline for the measurement, adding reliability to the result.

Iterations should be repeated until no significant position change is required after movement to the second point. The required precision depends on if field alignment methods can be used in the exposure / measurement locations, making less global precision acceptable, and in case of exposures, the required overlay precision.

Alignment script wizard

The alignment script wizard leads through the steps of alignment setup, offering all possible options at the points where they are required. Here, only two examples for the two different kinds of alignment are shown. For a more in-depth explanation of the options, refer to ***User Manual II: Reference Manual***.

STEP-BY-STEP: GLOBAL ALIGNMENT SCRIPT SETUP

0. Start the alignment script wizard

Open the **Wizardry** menu. From **Alignment**, select **Create an alignment script**. The **Create alignment script** wizard opens.

- Numbers at the bottom show the current step.
- Arrows at the bottom of the wizard panel allow free navigation between the current step and all previous steps. The double arrow resets the wizard.
- With a click on the green manikin at the top right of the panel, the **QuickMode** can be deactivated or activated. Per default, it is activated at the start of the wizard. **QuickMode** means that the wizard automatically jumps to the next step whenever possible.

1. Select write mode

Available write modes are shown as control fields. Click on the write mode the script should be created for.

2. Select focus mode

Available focus modes are shown as control fields. Click on the focus mode the script should be created for.

3. Alignment type selection

Select **Global alignment**.

4. Find center setup

Decide if the alignment should start by detecting the center of the substrate, or not. All available methods of substrate center detection are offered. Starting with substrate center detection usually makes it easier to locate alignment marks.

5. Aligned parameters

In contrast to the process of the **Execute a global alignment** wizard, a global alignment script can also be set up to shift the coordinate system origin, not only rotate it to match the substrate rotation. Any one of these alignments is possible separately, or both alignments can be done. Select what the script should serve for:

- **OffsetCoordinateAlignment:** only alignment of the origin to the substrate position, or a certain mark on the substrate,
- **OffsetRotationCoordinateAlignment:** alignment of both origin and angle of the coordinate system to the substrate position and rotation, or
- **RotationCoordinateAlignment:** angular alignment only.

6. Define positions

The contents of this step depend slightly on the choice of parameters to be aligned.

OffsetCoordinateAlignment: Offset alignment needs only one reference position. However, more reference positions can be defined by clicking on the **+** button of the position after which another one should be defined. Results are averaged. To remove a position, click on its **-** button.

Enter the default position(s) of the reference mark(s) (first field X, second field Y). If required, adjust the unit by clicking on the unit button and selecting a different unit.

If the substrate was loaded before script setup start, click on the **Move absolute** button(s) to check if the entered coordinates are correct.

Check how many seconds it takes after a movement until the image is completely stable. Enter this time into the **StageDelay** textfield at the top. A typical time is 5 seconds.

7. Select measurement

In the drop-down list at the top, the wizard offers three possibilities to identify the position of a reference structure:

- **Manual** – the operator manually marks the structure in the camera window as point of interest (PoI) when prompted.
- **Template detection** – the current camera image is compared to an image of the reference structure that has been stored as a template. Requires that the template was created with the same write mode and camera as will be used during the measurement, and that template image and camera image have a comparable contrast.
- **Cross detection** – for cross structures, a pre-defined detection mechanism exists that detects the arms of a cross and calculates the center of the cross from the results

As soon as a measurement method has been selected, the required parameters are displayed and can be adjusted.

In **Devices** → **Camera selector** → **Camera**, select a camera for the measurement. If distinct settings for camera, illumination and focus should be connected to the script, select a **Camera Setup Key** with the related parameters.

Template detection:

At **Image processing** → **Template**, click on the button with the three points to open the template selection window. Select a template from the list. If no template of the structure has yet been created under the required conditions, a new template can be created from here. Click on the **+** (= create template) button and select a name for the

template. Mark the reference structure with a frame as an area of interest (AoI) in the camera window. The following rules apply:

- the frame should not be larger in extent than half the image size in each axis
- the structure within the frame has to be characteristic so it can be recognized even if other close by structures appear in the image field
- the structure has to be visible with a good contrast against the surrounding area

Select the template for the script using the button with the green tag. Close the window.

Note: Templates may also be defined in the function **Controls → Metrology → Templates** of the main menu

Cross detection:

Extend the parameter list **Image processing → Area of Interest**. The numbers are coordinates and sizes for a frame in the camera window. Click on the button in the main text field to create a new frame. Adjust if required. The frame serves to mark the size of the cross if it is smaller than the image field. If it is bigger, the frame should be extended to maximum.

Once all parameters for the reference mark detection have been set, the detection can be tested by clicking on **Test Measurement**. Detection may be interrupted with the button **Stop Measurement**.

Note: For more information on the camera functions and Camera Setup Keys, refer to the related sections of **Chapter 1: General**.

8. Accept script

Enter a characteristic name for the script in the top text field. Click on **Create script** to save the defined procedure as a script under this name and make it available for jobs.

If not yet done, load a substrate with the defined structures. Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**. Click on **Test script** to find out if the script works correctly. If errors occur, refine the procedure until it works reliably.

STEP-BY-STEP: FIELD ALIGNMENT SCRIPT SETUP

0. Start the alignment script wizard

Open the **Wizardry** menu. From **Alignment**, select **Create an alignment script**. The **Create an alignment script** wizard opens.

- Numbers at the bottom show the current step.
- Arrows at the bottom of the wizard panel allow free navigation between the current step and all previous steps. The double arrow resets the wizard.
- With a click on the green manikin at the top right of the panel, the **QuickMode** can be deactivated or activated. Per default, it is activated at the start of the wizard. **QuickMode** means that the wizard automatically jumps to the next step whenever possible.

1. Select write mode

Available write modes are shown as control fields. Click on the write mode the script should be created for.

2. Select focus mode

Available focus modes are shown as control fields. Click on the focus mode the script should be created for.

3. Alignment type selection

Select **Field alignment**.

4. –

Step 4 is skipped during a field alignment setup.

5. Aligned parameters

Field alignment can only be used for offset correction, so it is the only option offered in this case.

6. Define positions

Offset alignment needs only one reference position. However, more reference positions can be defined by clicking on the + button of the position after which another one should be defined. Results are averaged. To remove a position, click on its – button.

Enter the default position(s) of the reference mark(s) (first field X, second field Y). If required, adjust the unit by clicking on the unit button and selecting a different unit.

If the substrate was loaded before script setup start, click on the **Move absolute** button(s) to check if the entered coordinates are correct.

Check how many seconds it takes after a movement until the image is completely stable. Enter this time into the **StageDelay** textfield at the top. A typical time is 5 seconds.

7. Select measurement

In the drop-down list at the top, the wizard offers three possibilities to identify the position of a reference structure:

- **Manual** – the operator manually marks the structure in the camera window as point of interest (PoI) when prompted.
- **Template detection** – the current camera image is compared to an image of the reference structure that has been stored as a template. Requires that the template was created with the same write mode and camera as will be used during the measurement, and that template image and camera image have a comparable contrast.
- **Cross detection** – for cross structures, a pre-defined detection mechanism exists that detects the arms of a cross and calculates the center of the cross from the results

As soon as a measurement method has been selected, the required parameters are displayed and can be adjusted.

In **Devices** → **Camera selector** → **Camera**, select a camera for the measurement. If distinct settings for camera, illumination and focus should be connected to the script, select a **Camera Setup Key** with the related parameters.

Template detection:

At **Image processing** → **Template**, click on the button with the three points to open the template selection window. Select a template from the list. If no template of the structure has yet been created under the required conditions, a new template can be created from here. Click on the + (= create template) button and select a name for the template. Mark the reference structure with a frame as an area of interest (AoI) in the camera window. The following rules apply:

- the frame should not be larger in extent than half the image size in each axis
- the structure within the frame has to be characteristic so it can be recognized even if other close by structures appear in the image field
- the structure has to be visible with a good contrast against the surrounding area

Select the template for the script using the button with the green tag. Close the window.

Note: Templates may also be defined in the function **Controls** → **Metrology** → **Templates** of the main menu

Cross detection:

Extend the parameter list **Image processing** → **Area of Interest**. The numbers are coordinates and sizes for a frame in the camera window. Click on the button in the main text field to create a new frame. Adjust if required. The frame serves to mark the size of the cross if it is smaller than the image field. If it is bigger, the frame should be extended to maximum.

Once all parameters for the reference mark detection have been set, the detection can be tested by clicking on **Test Measurement**. Detection may be interrupted with the button **Stop Measurement**.

Note: For more information on the camera functions and Camera Setup Keys, refer to the related sections of **Chapter 1: General**.

8. Accept script

Enter a characteristic name for the script in the top text field. Click on **Create script** to save the defined procedure as a script under this name and make it available for jobs.

If not yet done, load a substrate with the defined structures. Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**. Click on **Test script** to find out if the script works correctly. If errors occur, refine the procedure until it works reliably.

Adding alignment scripts to jobs

There are several points during a job execution at which scripts may be executed:

- before or after the complete job,
- before or after each die.

Preceding scripts are usually alignment scripts (global alignment: before job, field alignment: before die). Scripts can be added at two lists in the Job control:

- **Properties → Scripts**
 - **Before / After item:** Before / after the complete job
 - **Before / After every die:** A general setting for all dies
- **Selection → Scripts**
 - **Before / After Die:** Setting just for the selected die(s). If scripts were defined for all dies in the map properties, both scripts the scripts defined there and the ones defined here are executed.

Chapter 4: Measurements

With its high precision positioning system and the camera system, the DWL 66⁺ can also be used as a measurement tool. Limitations are given by the fact that the illumination is top-illumination only. For measurements of absolute values, dedicated measurement machines are required.

The **Lithography Menu** offers a number of basic measurement methods that can be combined to quantify exposures. Some have also already been combined to measurement recipes for evaluation of the final acceptance measurements during system setup. However, for the advanced user with the necessary user permissions, the **Lithography Menu** offers the possibility to freely combine the basic methods according to the requirements of the individual measurement task.

Measurements can be done directly, or included in measurement jobs.

STEP-BY-STEP: PREPARING FOR MEASUREMENTS

There are certain preparatory steps that are needed for measurements that are not started from a job.

1. Choose write mode

To get good measurement results, the write mode used for a measurement should always be chosen such that the structures to be measured are clearly distinguishable from surrounding structures in the video image. Follow the related instruction given in **Chapter 1: General** if the write mode has to be adjusted.

2. Load Substrate

Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**.

3. Global Alignment

Depending on the available structures on the substrate, either run the **Execute a global alignment** wizard, or use the **Create alignment script** wizard and its **Test** function to run a global alignment.

4. Camera Calibration / Camera offset calibration (optional)

Usually, both camera calibration and camera offset calibration have to be done only once during installation. However, if write heads are changed on a regular basis and critical measurements are to be done, it is recommended to refresh the calibrations. Please refer to the subchapters on **Camera Calibration** and **Camera Offset Calibration** for more information.

Preparing Measurement Recipes

For setup of measurements, the following principle measurement methods are available:

- **SingleEdgeDetection:** A method that detects the first vertical (X) or horizontal (Y) edge within an area of interest (AOI)
- **CenterDetection:** Returns the center coordinate between the first two vertical (X) or horizontal (Y) edges within an area of interest
- **TemplatePosition:** Compares the current camera image with a template to detect the location of a similar structure within the image, and returns the first Match detected
- **ManualPosition:** Calculates the coordinates of a position of interest marked in the camera image
- **LineWidth:** Returns the width of a line detected in an area of interest

In addition, some more complex methods that are combinations of the basic methods are available:

- **LineEdgeDetection:** An extension of the SingleEdgeDetection method that returns the positions of both edges of a line
- **Stitching:** Using the CenterDetection method, this method detects the centers of two lines within an area of interest and compares the positions in the selected axis
- **CrossPosition:** This method combines the result of four CenterDetection measurements along the borders of an area of interest to calculate the positions of the arms of a cross and from these, the cross center position
- **EdgeRoughness:** The roughness of an edge is calculated by measuring the edge position by SingleEdgeDetection at several positions within the area of interest and calculating the standard deviation from the average

These methods can be used directly on one structure, or they can be combined with a position grid into a recipe where the same kind of structure is measured in multiple positions.

Measurement recipes can be loaded into measurement jobs. Several of them may be added to the same die of the job map. In this way, different measurement methods can be combined to be executed on the same substrate in just one go.

In this chapter, first the setup of measurement recipes is explained using examples of increasing complexity. Finally, the setup of a measurement job for these recipes is described. For more in-depth explanation of all features and parameters refer to ***User Guide II: Reference Guide***.

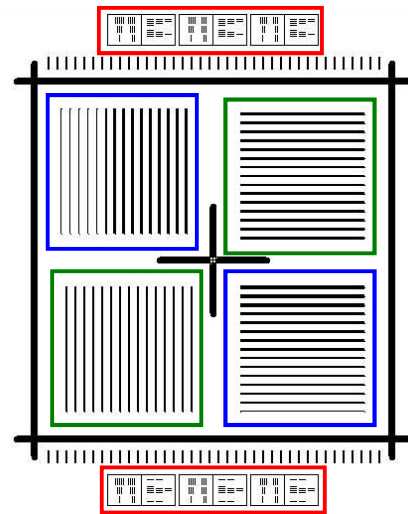
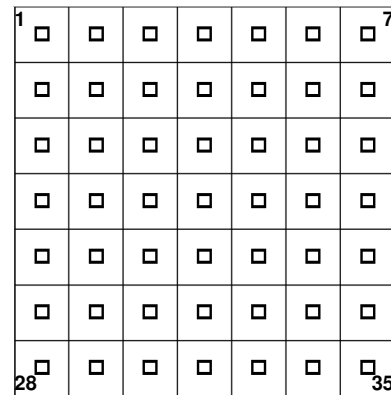
All following examples are based on the standard exposure for measurements on system performance, as used during system acceptance. The values are valid for an exposure with write mode III. The exposure uses a standard pattern that is exposed repeatedly in a grid on the substrate.

Pattern distribution:

- 7 rows
- 7 columns
- equidistant pitch 10mm

Each pattern contains features that help to quantify system performance. The relevant contents are:

- for **alignment** and **position measurements**: cross-in-cross at 0,0 (large cross for coarse orientation, small inlay cross at center for fine alignment)
- to determine the **resolution limit linewidth**: several boxes containing arrays of lines with linewidth around the resolution limit at $y=\pm 1290\mu\text{m}$, distributed over the width of the pattern
- for **linewidth linearity** measurements:
 - array of vertical lines with increasing line width around $x=-500\mu\text{m}$, $y=+500\mu\text{m}$
 - array of horizontal lines with increasing line width around $x=+500\mu\text{m}$, $y=-500\mu\text{m}$
- for **linewidth stability** (CD uniformity) measurements:
 - array of vertical lines with constant line width and pitch around $x=-500\mu\text{m}$, $y=-500\mu\text{m}$
 - array of horizontal lines with constant line width and pitch around $x=+500\mu\text{m}$, $y=+500\mu\text{m}$



In the following examples, the structures for resolution measurement and position measurement are used.

The examples are based on each other. Preparatory steps are only described in the first example.

STEP-BY-STEP: PART I – SINGLE LINEWIDTH MEASUREMENT

Measurement purpose: Find out the linewidth of the optically determined smallest stable line

Target structure: In one of the resolution boxes, the resolution test line that is optically determined to have the required stability

1. Prepare for measurement

Follow the instructions at the beginning of this chapter. At the end, the center cross of the center pattern should be in the camera view.

2. Open measurement recipes panel

From the main menu bar, select **Controls → Metrology → Measurement recipes**. The **Measurement recipes** setup panel opens. The left side shows a tree view for folders and files, while the right side is currently blank.

3. Create measurement recipe

In the toolbar, click on the plus (+) symbol. A drop-down list opens. Select **GridMeasurementRecipe**. In the dialog window, enter a descriptive name, like `Resolution_X`.

An icon for the new recipe appears in the file tree. An orange warning triangle informs that so far, the recipe is invalid, as parameters are missing.

On the right, a set of parameter lists opens. These are the parameter lists connected to the recipe.

4. Define grid

The **Grid** parameter list is displayed. A measurement grid is defined by

- the position of its origin relative to the die center (**Starting point → Offset**),
- the number of measurement points in each axis (**X/Y-Step → Count**), and
- the distance between the measurement points (**X/Y-Step → Step**).

Also, via the parameter **General → Order** it is possible to select if measurements in the grid should be done row-by-row (XY) or column-by-column (YX).

For the moment, we only want to do one single measurement. Therefore, we only have to define the position of the origin. There are two ways to do this:

- direct entry of the coordinates in the list, or
- show the coordinate in the camera view.

As we do not know yet which line is our target, we use the latter possibility.

To get a correct value for the coordinates in the end, first the current location of the die center has to be determined. Below the display of the **Die center coordinates**, click on **from camera**. In the camera window, mark the center of the cross. Now all measurements will be done relative to this point.

Use the functions of the **System Control** panel (**Controls → SystemControl**) to move down to the boxes with the resolution limit lines. In the leftmost of the boxes with vertical lines, determine which is the smallest line that shows a stable linewidth. Move the line into the center of the view.

Note: If the rough coordinates of the target are known, they can be entered in the parameter list under **starting point → Offset**. Now, a click on the **To** button right of the **Set starting point** button moves this point into view.

Click on **Set starting point** in the camera window, mark the center of the line that should be measured.

5. Define measurement

Click on **Measurement**.

In the drop-down list at the top of this control set, the type of measurement is selected. Depending on the choice, different parameters are displayed in the parameter list below.

Select **LineWidth**.

As long as **Show only required parameters** is activated at the bottom of the panel, only two parameter groups are visible.

In **Devices** → **Camera**, the camera that should be used for the measurement is determined. In **Devices** → **Camera setup key**, *Current* means that the settings active at the moment of measurement should be used. To make sure that the measurement is made with the same contrast as used during setup, it is recommendable to define a separate Camera setup key with the functions of the **Cameras** control panel (**Devices** → **Camera selector** → **Cameras**) and select it here.

In **Image processing**, the parameter **AreaOfInterest** defines the location and size of the box that contains the target feature – in our case, the line. Select it and click on the three-points-button. Now, the area can be marked in the camera. The frame shown when the button is pressed corresponds to the current parameters.

Adjust the height so it encompasses as much as possible of the line, but without the top and bottom ends, and the width to half the distance to the next lines. Confirm with middle mouse button (mouse wheel) click. The parameters are transferred into the list.

Note: Alternatively, parameters can be entered directly into the parameter list and checked by clicking on the button.

The parameter **Direction** determines the axis of measurement. Select **X_Axis** for the measurement of the vertical lines (detection of first and second edge within the Aoi along the x axis).

6. Test method

As there is no difference in evaluation methods for a single measurement, we can directly proceed to **Test**. Here, a click on the **Execute** button starts a test of the defined measurement. The test can be stopped any time by clicking on the **Stop** button.

When the recipe has finished, the process report opens in a separate window, and the measurement result is displayed in the standard editor selected in the lithography system configuration. If an error has occurred, open the layers of the process report until the point of the exception has been reached, and check on the reason given. Improve the method until it finishes successfully.

STEP-BY-STEP: PART II – EXTENSION TO AN ARRAY, DUPLICATION FOR 2ND AXIS

Measurement purpose: Find out for both vertical and horizontal lines if the lines of the determined linewidth are stable enough to qualify as resolution limit

Target structure: In all resolution boxes, the resolution test line that is optically determined to have the required stability

7. Add grid

Now that we have a measurement recipe for the line, it is easy to extend it to measure it in every of the boxes so the stability of the linewidth can be determined.

Click on **Grid**.

To find out the distance between the boxes, use the **System Control** panel to move to the top right box. Move the same line into view. Now, click on **Set x-step**. In the camera window, mark the line. Enter 3 at **Index of position** and 3 at **Total number of positions**. Repeat the same for **Set y-step** and enter 2 and 2. By using the most distant point, the precision of step size calculation is better than it is when using the directly neighboring points.

Both step sizes and numbers of steps have automatically been transferred to the parameter list (**X/Y-Step** → **Shift**, **X/Y-Step** → **Step**) and can be adjusted there if necessary.

8. Select evaluation method

As eventually we want to use this recipe also in other locations to determine an overall stability, now is the moment where we should determine what happens if the recipe is used several times in a measurement job.

The first question is if there should be any global **Averaging** at all. If the results make sense only locally and not in a global context, it can be disabled. The results of each execution are then only added separately into the job report. If **Averaging** is enabled, an overall evaluation of the results is added at the end of a measurement job. If **Summary** is enabled, the numbers used as basis for the averaging are also repeated in a table at the end of the report.

Which results are reported depends on the type of measurement. For example, in the case of a linewidth measurement, it is the average linewidth as well as a standard deviation of the results. Especially regarding the latter, it is important to decide which **Averaging mode** should be used. The two possibilities are:

- **Values** – a new standard deviation is calculated from all measurement values
- **Mean Values** – the global standard deviation is calculated as the mean value of all local standard deviations

Enable **Averaging** and **Summary** and select the **Values**.

9. Test method

Proceed to the **Test** control set and **Execute** a test run. The test can be stopped any time by clicking on the **Stop** button.

10. Create horizontal linewidth measurement

For measurements of the y axis, the same sizes apply, and the same grid can be used, only shifted towards the other boxes. Therefore, instead of setting up a completely new recipe, it is more convenient to create it from a duplicate of the X linewidth measurement.

In the file list, highlight the *Resolution_X* recipe. Click on the **Duplicate recipe** button in the toolbar. Rename the duplicate to *Resolution_Y*.

In the **Grid**, use **Set starting point** to move the origin of the grid to a fitting line in the lower left box with horizontal lines.

In **Measurement**, swap the **X** and **Y** size of the **AreaOfInterest**. Extend the parameter to find out which number is which. Change **Direction** from X to Y.

Test the method.

Note: Both recipes can also be duplicated and adjusted to different lines of the same arrays by just changing the **Offset** parameter (**Set starting point**) so that the recipe can be used on different lines until the first that is stable enough is found.

11. Group resolution measurements in a folder

Measurement recipes may be stored directly in the General folder. However, if measurements should be executed together, it is recommendable to store them in a common folder. In this way, the whole folder can be imported into a job at once.

In the top toolbar, click on the button showing a folder and a plus (+). Select a characteristic name for the folder e.g., 'ResolutionMeasurements', and confirm. The new folder appears in the file tree.

- Folder names can be edited any time by double-click on the name
- To delete a folder, select it and click on the button showing a folder and a minus (-) sign

Drag-and-drop all resolution measurements into the folder.

STEP-BY-STEP: PART III – POSITION MEASUREMENT MATRIX

At the center of each pattern is a large cross with a smaller cross formed by four blank squares inside. The large cross serves mainly for coarse orientation, the small one for measurements. The data for the small cross is:

- overall size: 25µm x 25µm
- linewidth of arms: 5µm

A measurement of the cross positions in the patterns at the four corners of the substrate (dies 1, 7, 28, 35) can be used to check if there is an orthogonality error.

1. Create measurement recipe

Create a new **GridMeasurementRecipe** and give it a descriptive name, like *PositionCross4*.

2. Define grid

As this time we know exactly where our measurement crosses are, we can enter the numbers directly.

First, move back to the center cross of the center pattern. Make sure it still is the defined die center.

At **starting point** → **Offset**, enter the coordinates of the cross in the the lower left corner: **Unit** = mm, **X** = **Y** = -30. Click on the **To** button right of the **Set starting point** button to move this point into view and make sure the numbers are correct.

For both **X-Step** → **Count** and **Y-Step** → **Count** enter 2. For **X/Y-Step** → **Shift** enter 60mm.

3. Define measurement

Click on **Measurement**. From the drop-down list, select **Position[Cross]**.

As long as **Show only required parameters** is activated at the bottom of the panel, only the same two parameter groups are visible that were also visible for *LineWidthMeasurement*. However, they contain fewer parameters.

In **Devices** → **Camera**, select the camera that should be used for the measurement. Use the same setting here for all sample measurements. The same **CameraSetupKey** as used for the previous measurement should also yield the best result here, so enter it again (or leave it on *Current*).

In **Image processing**, activate the parameter **AreaOfInterest**. Adjust the height of the frame so it contains the complete cross, but no outside area. Confirm with middle mouse button (mouse wheel) click. The parameters are transferred into the list.

Note: Alternatively, the frame size can be calculated from the known cross size and the camera calibration result, and entered directly into the parameter list. Check by clicking on the three-point-button afterwards.

4. Select evaluation method

In this measurement, global evaluation does not make sense. It can be deactivated.

5. Test method

Proceed to the **Test** control set and **Execute** a test run. The test can be stopped any time by clicking on the **Stop** button.

Preparing and Running Measurement Jobs

Any measurement recipe can be run automatically from a measurement job. This means also that instead of extending a recipe to cover the whole substrate, a map can be created with the number of fields and field distances corresponding to the points on the substrates where measurements should be done, and a single measurement can be repeated in any of these field positions. If just the global result is of interest, it is preferable to define all measurement positions in the recipe. But if separate evaluations for the dies are required, the measurement recipe should only cover the measurement points of one die, and the extension to the whole substrate should be done in a job.

Note: Similar to exposure job templates, measurement job templates can be created for measurement tasks that are repeated regularly. Refer to the section on job templates in **Chapter 2: Exposures** for more information.

Measurement jobs require at least a global alignment with offset adjustment included. For high precision results, field alignment in each die is also recommendable. The field alignment recipe has to put the die origin on same point that was used as die origin during setup of the measurement recipe(s). Refer to the previous chapter for information on the setup of alignment recipes.

STEP-BY-STEP: PREPARING MEASUREMENT JOBS

1. Create Measurement Job

Open the **Job control** panel (**Controls** → **Job**). In the **Job list** on the left, open the folder **Templates/MeasurementJobContainer** by clicking on the plus (+) sign. Select any template and drag-and-drop it to the region below the **Templates** folder. Give it a characteristic name e.g., 'Test jobs'.

Open the folder **Templates/ExposureJob** and drag a template into the new container. Give it a characteristic name e.g., 'test_measurements_<write mode>'.

2. Prepare Map

Double-click on the new job. Click on **Properties**. Scroll down to the section **Dimension**. If the arrow beside the title is empty and pointing to the left, click on it to make the contents of the section visible.

Set both **Column Count** and **Row Count** to '7'.

The **Map Diagram** shows a grid of 7x7 dies, and the spread sheet shows index numbers in the first 7x7=49 rows.

Set the parameter **Size of die** to 10mm.

At **Field Zero**, enter '4' for both **X** and **Y**. Set the parameter **Location** to **Center**. The center of the substrate is now also the center of the grid.

At **Scripts** → **Before item**, open the list and select the global alignment script to be used.

Set **AutomationMode** to **Manual**.

3. Choose Report Settings

In **Properties**, look for the section **Report**. Select a **ReportFolder** where the measurement report with the results should be stored. By default, the **ReportName** comprises of the job name plus date and time of execution (<Name>, <Date> and <Time> are fields that are filled automatically). If **ViewReport** is set to *True*, the measurement report opens in an editor after the job has finished.

1	□	□	□	□	□	□	7
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	□	□	□	□	□	□	□
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28	□	□	□	□	□	□	35

■ orthogonality measurement dies
■ stability measurements dies

4. Select Measurement Recipes

a) Orthogonality measurement

Mark the center die (X=4, Y=4), either in the map or the spreadsheet. Click on the button **Measurements**. Drag-and-drop *PositionCross4* (recipe from Step 3 of the recipe setup example) to the selected field. The measurement is entered into the **Measurement** column of the field, and an icon appears in the map field.

Note: As this measurement recipe already contains the locations of the four crosses in the corner dies, it can be started from the center die. An alternative would have been to prepare just a single position measurement and add it to the four corner dies.

b) Resolution measurements

Select the center field and 4 fields in the direction of the corners (dies 9, 13, 25, 37, 41). This is where we want to check resolution and stability. Drag-and-drop the complete folder *ResolutionMeasurements* onto the selection. In the center die of the map, the icon for one measurement changes to an icon showing a stack of measurements. The same icon appears in each of the selected fields. In the spreadsheet, three points appear after the first measurement recipe. To view which designs are loaded into a multiple-design die, either double-click on the **Measurement** field of a die to open a small window showing all the designs, or open the **Selection** window.

5. Select field alignment

While the five dies are still selected, click on **Selection**. In **Scripts** → **Before die**, open the list and select the field alignment recipe to be used.

6. Activate dies for measurement

With the five dies still selected, click on the green button with the tag mark to activate them for exposure.

STEP-BY-STEP: RUNNING MEASUREMENT JOBS

1. Prepare for measurement

Follow the instructions given at the beginning of this chapter.

2. Open the job control panel

From the main menu bar, select **Controls** → **Job**. The **Job control** panel opens.

3. Select job

On the left, all jobs that can be executed are listed. Some may be sorted into folders. If necessary, open the folder with the measurement job. Double-click on the measurement job to select it.

4. Start measurement sequence

Click on the button with the green star to execute the measurement job.

Note: The red minus button next to this button is now activated and can be clicked any time to interrupt the job execution.

In the **Executing**: register card of the **Job control** panel, the job name appears in the header. It goes to the foreground if hidden behind another window, and the map is displayed.

- Fields in dark blue are activated for exposure
- Fields in light blue will not be exposed

The menu checks the settings of the job and issues messages if there are problems.

5. Load substrate

Confirm that the substrate has been loaded.

6. Alignment and Origin Position

Depending on the global alignment sequence defined, dialog windows may open according to the functions that were included. In such cases, follow the instructions given in the dialog windows.

7. Measurement

Once all preceding sequences have finished, the measurement starts. Field alignment is repeated at the start of each die, setting the local origin for recipe execution according to the result.

- In the **Executing** register card of the **Job control** panel, the field being currently executed turns orange, and fields where all measurements finished successfully turn green afterwards. If an error occurred during exposure of a field, it turns red.

- A progress bar to the right of the map shows the progress of the current measurement.
- Below the map, an estimated remaining duration of the job execution is shown.

During measurement, whenever dialog windows show up, follow the instructions given. Whenever a structure is measured, the area of interest is visible in the camera window.

8. View Report

After the end of the measurement, a process report window opens. A graphical representation of the map shows successfully executed fields with green upper-left corner. Where errors have occurred, the corner is red or orange. This report is similar to the process report created after exposures and only contains information on the success or failure of the process itself, not the measurement results. These are stored in a separate report, the measurement results report.

For later reference, the process reports can be saved by clicking on the **Save** button. Select a folder and name for the saved report file. All details available in the window are stored in the file.

If the settings of the measurement job include that the measurement results report should also be shown at the end (View report = true), an editor window with the measurement results opens at the same time.

9. Unload substrate

If all measurements were executed successfully, the substrate can be unloaded. Follow the instructions given for manual unloading in the section on loading in **Chapter 1: General**.

Otherwise, edit the measurement job to deactivate the dies with successful measurements, and run the measurement again.

Camera Calibration

All measurements done with the DWL 66⁺ are a combination of information about the current stage position and positions in the camera field. However, in the first step, any detection in the camera field yields only pixel values. From these values, positions or distances within the camera field have to be calculated.

To find out the correlation between pixels and distances, a **Camera Calibration** has to be done. During this calibration, a structure is moved stepwise through the image field, and the position is measured in pixels. Afterwards, these values are compared to the distances measured by the interferometer for each step, and a calibration value in nanometer per pixel is returned.

This calibration should be repeated occasionally if write head changes occur on a regular basis, to avoid measurement errors.

Note: The camera calibration uses the template detection measurement routine for automatic calibration

STEP-BY-STEP: CAMERA CALIBRATION

0. Prepare calibration

Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**.

Using the functions of the **System Control** panel (**Controls** → **SystemControl**), move a clearly defined structure on the substrate (e.g., a cross) to the approximate center of the monitor image.

Note: The **MoveTo** button on the **Cameras** control panel allows moving a structure to the center of the image by simple mouse-click on the structure.

In the **Cameras** control panel (**MetrologyDevices** → **Camera selector** → **Cameras**), select the camera for which calibration should be done. Use **Exposure time**, **Gain** and **Offset** sliders to optimize the visibility and contrast of the image. If the defocus setting is not optimal, use the **Focus** slider in the **System Control** panel to adjust it.

Open the **Wizardry** menu. From **Camera**, select **Calibrate Camera**. The **Calibrate camera** wizard opens.

- Numbers at the bottom show the current step.
- Arrows at the bottom of the wizard panel allow free navigation between the current step and all previous steps. The double arrow resets the wizard.
- With a click on the green manikin at the top right of the panel, the **QuickMode** can be deactivated or activated. Per default, it is activated at the start of the wizard. **QuickMode** means that the wizard automatically jumps to the next step whenever possible.

1. Select camera

Select the camera for which the calibration should be done by clicking on the respective control.

2. Select template

If no template of the structure that should be used as a mark for the calibration has been prepared, a temporary template can be created. Click on **create temporary template**. Define an area of interest (AOI) in the camera window that contains a characteristic part of the structure, but is still small enough to allow significant movement without moving the area outside the camera field. After confirmation, the selected image part is copied into the right frame.

If a template for the structure has already been created and saved in a file (see instruction below) e.g., for use as alignment mark, it can be loaded from here. The template appears in the left frame. Click on the arrow button to select it for use during calibration. The image is transferred to the right frame.

3. Algorithm setup

The **Parameters** control set is active when this step is reached. The sequence for calibration has to be set up here.

From the drop-down list at the top, select the algorithm that should be used:

- **Manual:** At each position, a crosshair has to be moved onto the structure manually. This is the least precise method, but can be used under any lighting and contrast conditions.
- **NxN:** A routine based on template detection where the number of measurement points per axis can be chosen freely

The important parameters are:

- **Motion → Border:** Minimum distance from the image border for the measurement fields (point plus template size). Depends on the homogeneity of illumination. Recommended values are 50-100
- **Motion → TestVector:** Defines the small movement that is executed first to get a rough estimation of the calibration. Has to contain values for both axes that should be around 10% of the image field size. Required for optimum placement of calibration measurement positions
- **Motion → UseStartPosition:** Set to False to use the current position as the start position. Otherwise, the coordinates given in **Motion → StartPosition** are used.
- **Points → XCount/:** Number of positions that should be used for calibration. Should be at least 3 and not higher than 9. Not available if **Standard** was selected. Both numbers together define the measurement grid.
- **Devices → CameraSetupKey:** If a template is used for calibration and a CameraSetupKey was defined together with the template, this key should be used. Refer to the chapter on template definition below for more information.

All other parameters usually don't have to be touched.

4. Execute calibration

Click on the **Execute measurement** button to start execution of the routine.

- The stage first makes the test vector movement for a rough calibration, then moves stepwise through the measurement grid, covering in each axis the movement range

defined by the border setting. In each position, the position of the structure in the camera window is measured.

- If manual mode was chosen, the operator must manually point to the same characteristic point of the structure (e.g., a corner) at each measurement position.

After all measurements have been finished successfully, the **Results** control set comes to the front. In it, the resulting **Scaling** values in nm/pixel for X and Y are displayed, plus the calculated **AngleOfRotation** between the camera axes and the stage movement. Click on **Accept & Close** to transfer them into the configuration for future use. Click on **Accept & Restart** if calibration should be refined, or calibration for another camera should be done next. If the result should be discarded, simply close the wizard.

Camera Offset Calibration

The system has two cameras for top side structure detection, a macro camera for coarse view, and a micro camera for high resolution measurements. If the system has been equipped with the back side alignment option, a second pair of cameras views a loaded substrate from the stage bottom.

All cameras are adjusted to look at the same point on the stage. However, this adjustment can never be perfect. To make sure the cameras still yield the same position results, the distance between the view field center points has to be measured and saved as offset values. The micro camera is used as reference camera for these calibrations.

This instruction concentrates on determining the offset of the macro camera. However, it can be used as well for the coarse calibration of the back side alignment cameras' offsets, if a thin, transparent substrate is available with a feature that can be viewed from both sides. While this calibration is precise enough for the top macro camera, for precise back side alignment, another fine calibration has to be done afterwards. This is described in the related section of **Appendix B: Align**.

STEP-BY-STEP: CAMERA OFFSET CALIBRATION

0. Prepare calibration

Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**.

Open the **Wizardry** menu. From **Camera**, select **Calibrate camera offset**. The **Calibrate camera offset** wizard opens.

- Numbers at the bottom show the current step.
- Arrows at the bottom of the wizard panel allow free navigation between the current step and all previous steps. The double arrow resets the wizard.
- With a click on the green manikin at the top right of the panel, the QuickMode can be deactivated or activated. Per default, it is activated at the start of the wizard. **QuickMode** means that the wizard automatically jumps to the next step whenever possible.

1. Select camera

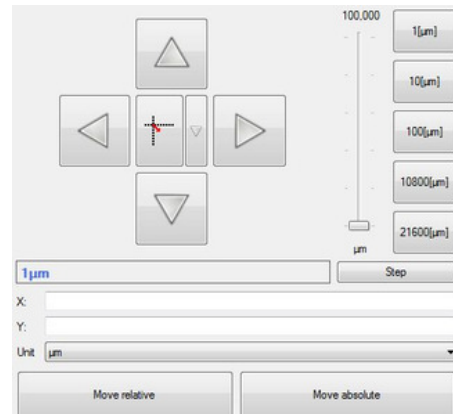
In this first step, the camera for which the offset should be measured has to be selected. For top side offset measurement, only **MacroCamera** is available, as the micro camera is the reference camera.

2. Search marker

The selected camera is activated.

Using the controls in the panel, move the stage so that the marker is visible in the camera window.

- If the coordinate of the mark is known, enter it into the text fields, adjust the unit and click on **Move absolute**. This starts an absolute movement to the given coordinates.
- To move the stage a certain distance, enter the distances for X and Y into the text fields, adjust the unit, and click on **Move relative**. This starts a relative movement by the given distances.
- To move around freely, use the arrow buttons. Each click moves the stage a step in the direction indicated by the arrow. Keep in mind the orientation of the coordinate system: The up/down arrows move the stage in y, i.e. parallel to the loading window, while the right/left buttons move it in x, i.e. back and forth. The size of the step is determined by the number in the text field below the arrows. Coarse adjustment of that number can be done with the control buttons, fine adjustment with the slider or the mouse wheel.
- To move a certain spot that is visible in the camera to the image center, click on the **MoveTo** button in the camera panel. The cursor turns into a crosshair. Click on the point of interest to select it.



Once the structure is well visible, continue.

3. Measure marker

In the drop-down list at the top, the wizard offers three possibilities to identify the position of a reference structure:

- **Manual** – the operator manually marks the structure in the camera window as point of interest (PoI) when prompted.
- **Template detection** – the current camera image is compared to an image of the reference structure that has been stored as a template. Requires that the template was created with the same write mode and camera as will be used during the measurement, and that template image and camera image have a comparable contrast.
- **Cross detection** – for cross structures, a pre-defined detection mechanism exists that detects the arms of a cross and calculates the center of the cross from the results

As soon as a measurement method has been selected, the required parameters are displayed and can be adjusted.

In **Devices** → **Camera selector** → **Camera**, select a camera for the measurement. If distinct settings for camera, illumination and focus should be connected to the script, select a **Camera Setup Key** with the related parameters.

Template detection:

At **Image processing** → **Template**, click on the button with the three points to open the template selection window. Select a template from the list. If no template of the structure has yet been created under the required conditions, a new template can be created from here. Click on the + (= create template) button and select a name for the template. Mark the reference structure with a frame as an area of interest (AoI) in the camera window. The following rules apply:

- the frame should not be larger in extent than half the image size in each axis
- the structure within the frame has to be characteristic so it can be recognized even if other close by structures appear in the image field
- the structure has to be visible with a good contrast against the surrounding area

Select the template for the script using the button with the green tag. Close the window.

Note: Templates may also be defined in the function **Controls** → **Metrology** → **Templates** of the main menu

Cross detection:

Extend the parameter list **Image processing** → **Area of Interest**. The numbers are coordinates and sizes for a frame in the camera window. Click on the button in the main text field to create a new frame. Adjust if required. The frame serves to mark the size of the cross if it is smaller than the image field. If it is bigger, the frame should be extended to maximum.

When all preparations are done, click on the **Execute measurement** button. The measurement can be stopped any time by clicking the **Stop measurement** button.

Once the measurement is finished, the result is shown (only visible if not in **QuickMode**, or after scrolling back with the navigation arrows).

4. Search marker

The system switches to the reference camera. Again, move the structure that should be used as marker to the center of the camera field of view.

Once the structure is well visible, continue.

5. Measure marker

Measure the position of the marker in the camera that should be calibrated.

6. Save offset

The results of all measurements are shown, together with the resulting offset values for x and y. To confirm and save them as offset parameters, click on **Save offset**.

Template Setup

Camera templates can be used for calibration and alignment whenever no cross is available. They are sample images that the system tries to find in the current image field whenever template recognition is activated by some function.

For alignment, a template can be defined and stored in a file during sequence setup in the wizard. For camera calibration, a temporary template can be defined directly in the wizard.

Independent from these wizards, templates can also be created and managed in the **Cameras** control panel.

STEP-BY-STEP: TEMPLATE SETUP

1. Prepare setup

Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**.

Using the functions of the **System Control** panel (**Controls** → **SystemControl**), move a clearly defined structure on the substrate (e.g., a cross) to the approximate center of the monitor image.

Note: The **MoveTo** button on the **Cameras** control panel allows moving a structure to the center of the image by simple mouse-click on the structure.

In the **Cameras** control panel (**Devices** → **Camera selector** → **Cameras**), select the camera the template should be captured from. Use **Exposure time**, **Gain** and **Offset** sliders to optimize the visibility and contrast of the image. If the defocus setting is not optimal, use the **Focus** slider in the **System Control** panel to adjust it.

Use the **Save** button to save the settings as a Camera setup key. Choose a name that later clearly connects the key to the template.

2. Define Area of Interest

In the **Cameras** control panel, activate the button **AOI**. Now, use the mouse cursor to define the area in the camera window that contains the structure to be used as template.

- the frame should not be larger in extent than half the image size in each axis (for camera calibration, it has to be even smaller)
- the structure within the frame has to be characteristic so it can be recognized even if other closeby structures appear in the image field
- the structure has to be visible with a good contrast against the surrounding area

3. Acquire template

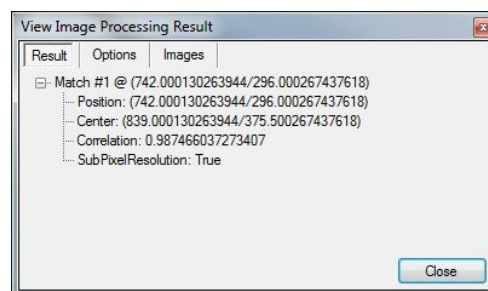
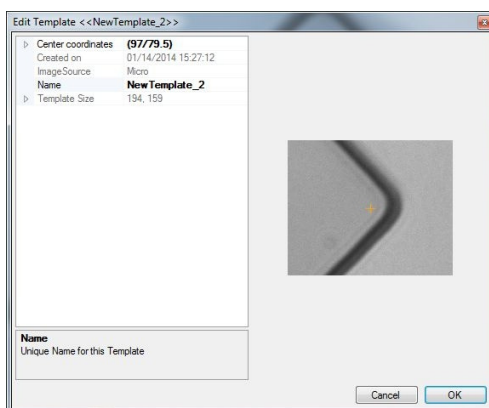
In the **Templates** toolbar, click on the **Create** button. Select a name for the new template. By default, the template center is the reference point. To select a different reference point, click on the desired position on the template image. The little orange cross is now re-positioned.

4. Test template

To test the quality of template detection, click on the **Test** button in the **Templates** toolbar. A result window opens. The coordinates of the center point of the template are returned, together with a correlation result on a scale of 0-1. The images used for the detection can be reviewed in the **Images** tab of the results window.

Move the structure and repeat the test.

Note: For review and modification of existing templates, use the **Manage** button on the **Templates** toolbar.



Chapter 5: Operator Maintenance and Troubleshooting

This chapter contains some notes on the daily system maintenance by the operator as well as some troubleshooting for the most common problems. For more in-depth maintenance and trouble-shooting information, refer to the *User Service Guide*.

Operator Maintenance

DWL 66⁺ systems require some minimal operator maintenance that does not involve opening any covers or protective panels and can be done by any trained operator. These tasks are described below.

SYSTEM CHECKS

Before operation the following routine maintenance should be performed:

1. Clean the chuck surface with a dry clean wipe. *Never use Acetone!* If more thorough cleaning is required, use industry-grade ethanol or isopropanol.
2. Verify that the clean room conditions are within the following limits:
 - TEMPERATURE:** 65° - 75°F (18° - 24°C), stability +/- 1°C
 - RELATIVE HUMIDITY:** 40% to 60% (non-condensing)
 - CLEAN ROOM:** Class 100
3. Make sure nothing was placed inside the system that obstructs stage movement

ENVIRONMENTAL ADJUSTMENT

1. Allow room humidity to come within the specified range before using the DWL 66⁺.
2. If temperature is out of range, determine how long this condition has prevailed.
3. Adjust room temperature to within the specified temperature range and allow the DWL 66⁺ to stabilize.
4. For stabilization of the system, allow an amount of time at least equal to the time the temperature was out of range.

NOTICE:

- During exposure, the most accurate results are obtained when the environment remains at a constant temperature and humidity.
- To achieve the optimum accuracy, place substrate on chuck 2-3 hours before exposure and close the window.

Troubleshooting

This section suggests corrective action for common difficulties.

THE DWL 66⁺ DOES NOT EXPOSE

- Verify that the AC power cord is plugged into the wall outlet and that the outlet is receiving power.
- Check whether the laser is switched on and running.
- Verify that the loading window is completely closed.
- Try rebooting the OS9-system.

LINES NOT TO SIZE

Line thickness problems may have the following causes:

- Poor developing chemicals
- Wrong developing speed
- Wrong resist type or thickness
- Focus or energy setting incorrect
- Out of date resist

THE DWL 66⁺ STOPS ANYTIME DURING THE EXPOSURE

- The DWL 66+ reached an end switch, because the imaging area was set incorrectly
- The interferometer head is broken

PLATES COME OUT COMPLETELY CLEAR

- Wrong filter
- Amplifiers switched off

ONLY PART OF THE SCAN IS EXPOSED

- Write mode does not match write head

SUBSTRATE-TO-SUBSTRATE REGISTRATION IS BAD

- Check stability of flow box temperature
- Check vacuum quality, make sure no vibrations are transferred via vacuum
- Check stage vibrations
- Check for drift in position measurement with stage standing still in home position to find if interferometer laser has to be replaced

Appendix A: Optimizing Stitching Parameters

Over a longer time, or if for some reason temperature control within the system failed, exposure parameters might drift. An instruction on how to find the new best values for energy and focus has already been given in **Chapter 2: Exposures**. here, instructions are given on how to check and adjust stitching parameters.

The term *Stitching* refers to the connection between the stripes into which a design is split up during design conversion. If the parameters for writing of each stripe are not optimized, these connections might get visible, either because a gap or an overlapping occurs between the stripes (x-stitching), or because the stripes are not written perfectly orthogonally, causing what looks like a vertical shift between the stripes, visible as steps in structure borders (y-stitching).

STEP-BY-STEP: SETTING UP A STITCHING PARAMETER TEST

In the chapter on exposure, a test was described to find out the best energy and focus settings. In addition, a first more advanced parameter was already introduced: the **AOD_0** value. This is related to y-stitching. In this section, both x- and y-stitching are explained more in-depth, including a sample setup of a test job for both.

1. Create Job

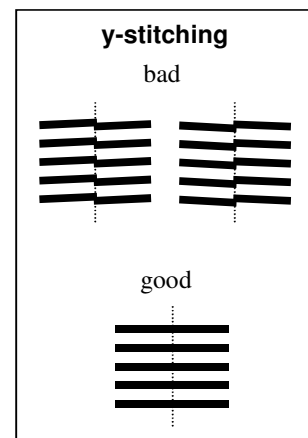
As described in **Chapter 2: Exposures**, create a job. Configure the map to 7x2 dies with a distance that is slightly bigger than the test pattern size. Load the test design into all dies. In the columns for **Energy** and **Focus**, enter the optimum values that were determined with the test_series_<write mode> job.

2. Y-stitching test

This test is best done with horizontal lines that reach across several stripe connections. In the standard test pattern e.g., the horizontal lines of the CD linearity test block qualify for this.

In the **Columns** drop down list of the **Job control** panel, choose **Expodie** → **AOD_0**. Either in the map or in the spreadsheet, mark the first row of dies. Open the **Series** drop-down list, select **Expodie** → **Expodie: AOD_0**.

Enter a starting value 30 counts below the current value, and a step size of 10. If the values are out of range or invalid for other reasons, a warning appears and the related value has to be corrected before the dialog window can be closed. Step sizes may be negative as well as zero. Once the values have been accepted, values appear in the **AOD_0** column fields of all selected dies, starting with the start value and changing from die to die by the step size given.



3. X-stitching test

If structures do not connect properly across stripe borders, forming gaps or thickened overlap regions, the stripe size does not match the stripe distance. The stripe size is determined by the slope of the HF signal ramp that steers the writing beam during a scan. If the slope is too steep, the stripe is too wide, leading to overlap. A slope that is too gradual creates gaps.



To measure and optimize the x-stitching, a design should be used that has a set of vertical lines with a defined pitch in the horizontal direction (“ruler”) that extends across at least one stripe connection. In the standard test pattern, such a ruler is included above and below the center square with test lines.

In the **Columns** drop down list of the **Job control** panel, choose **MPAOD → Linear coefficient (dfT)**. Either in the map or in the spreadsheet, mark the second row of dies. Open the **Series** drop-down list, select **MPAOD → Linear coefficient (dfT)** as well.

As starting value, enter a slope value below the current value. For a significant difference in exposure, change the value by 0.015. Choose 0.005 as step size.

4. Activate fields and Expose

Mark all dies and activate them by clicking on the button with the green tag mark. Run exposure as described in **Chapter 2: Exposures**.

5. Process and Evaluate Exposure

After processing, the exposed structures can be viewed under a microscope, measured in a measurement machine, or measured on the DWL 66⁺. Refer to **Chapter 4: Measurements** for more information on the measurement capabilities of the system.

In the first row, identify the die where both sides of a stripe are at the same height. Find out which AOD_0 this corresponds to. In the second row, identify the die where the distance of the lines across a stripe border is the same as inside a stripe. Find out which dfT value this corresponds to.

If unsure which values were used during a certain exposure, refer to the exposure log:

```
C:\HIMT\LOG\Processing\<Job name>_<date>_<time>.log
```

STEP-BY-STEP: USING OPTIMIZED STITCHING PARAMETERS

If better values have been found for parameters, these have to be entered into job and template files so they are used for all future exposures.

Note: A log should be kept about any parameter changes, and each log entry should include which configuration the change was made for, and what the original value was.

- **AOD_0:**

1. In the **Columns** drop down list of the **Job control** panel, choose **Expose** → **AOD_0**.
2. Double-click into the first field of this column and enter the optimum value.
3. Mark all fields. Right-click on the selection. In the context menu, select **Fill down** → **Expose: AOD_0**.

- **dfT**

For the dfT value, an operator with the necessary user permissions can change the default value:

1. In the **Write mode** toolbar of the main menu, open the **Edit write mode** drop down list and select the write mode which was used during the test. The **Edit write mode** panel opens.
2. In the parameter list, look for **Ramps** → **AODRampData**. Click into the text box beside it to make it editable, then click on the button to open the setup panel for ramp data.
3. Edit the entry after **Base Ramp** → **F1: Frequency slope [MHz/μs] (dfT)** and enter the new optimum value.

Operators without these permissions have to enter the parameter into jobs and templates as usual:

1. In the **Columns** drop down list of the **Job control** panel, choose **MPAOD** → **linear coefficient (dfT)**.
2. Double-click into the first field of this column and enter the optimum value.
3. Mark all fields. Right-click on the selection. In the context menu, select **Fill down** → **linear coefficient (dfT)**.

Appendix B: Aligned Exposures

In aligned exposures, usually called overlay exposures, the first exposed layer contains alignment marks that are used as reference for the positioning of the following layers. The positions of the marks are measured before each exposure, and the machine coordinate system is shifted (and, if global alignment is used, can also be rotated) so that it matches the position and orientation of the previously exposed layer.

Alignment mark measurements can be done from the top side or, if the system is equipped with back side alignment option (BSA), from the bottom, measuring structures on the substrate back side. This method has the advantage that the contrast of the alignment marks is not decreased by resist layers. Each measurement system offers a large image field from a macro camera and a high resolution micro camera image.

For proper alignment, two offsets have to be known so they can be accounted for in the calculation of the coordinate shift from measurement results. These are:

- The position of the laser beam with respect to the image field center of the reference camera (usually the top side micro camera), and
- The image field shifts of all other cameras (top macro camera, BSA cameras) relative to the reference camera.

Usually, these offsets change only by small amounts, if at all, but if high precision is required, they have to be checked after each write head exchange. The menu provides wizards for measurement of these offsets:

- The **Calibrate beam offset** wizard serves to determine from a two layer exposure aligned with the reference camera the distance between the writing beam on the substrate and the center of the reference camera's image field. This offset is then added to the result of any future alignment measurement with any camera, together with the respective camera offset.
- The **Calibrate camera offset** wizard is required for calibration of the distance between the image fields of the various cameras, via direct position measurement of a calibration structure. It can only be used for coarse alignment. For back side camera offset measurements, a thin substrate with a feature visible from both sides is required, and it has to be made sure that the same part of this structure is used as reference point in both measurements. Fine alignment of back side camera offset has to be done according to position error measurements on back side aligned exposures.

As this calibration is also important for measurements, it was already described in the related section of **Chapter 4: Measurements**.

- In systems equipped with BSA option, the **Calibrate BSA camera** wizard supports the measurement of a two layer exposure done with back side alignment for fine tuning of the overlay calibration.

This chapter provides first a description of the **Calibrate beam offset** wizard. Descriptions of the calibration procedures for overlay and back side alignment follow in the related sections, including the description of the **Calibrate BSA camera** wizard in the section on back side alignment.

Beam Offset Calibration

STEP-BY-STEP: USE OF THE CALIBRATE BEAM OFFSET WIZARD

0. Prepare offset measurement

Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**.

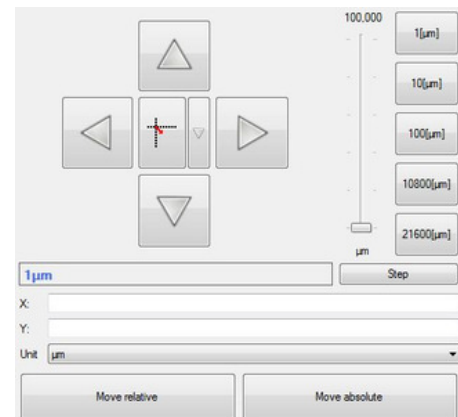
Open the **Wizardry** menu. From **Writehead**, select **Calibrate beam offset**. The **Calibrate beam offset** wizard opens.

- Numbers at the bottom show the current step.
- Arrows at the bottom of the wizard panel allow free navigation between the current step and all previous steps. The double arrow resets the wizard.
- With a click on the green manikin at the top right of the panel, the QuickMode can be deactivated or activated. Per default, it is activated at the start of the wizard. **QuickMode** means that the wizard automatically jumps to the next step whenever possible.

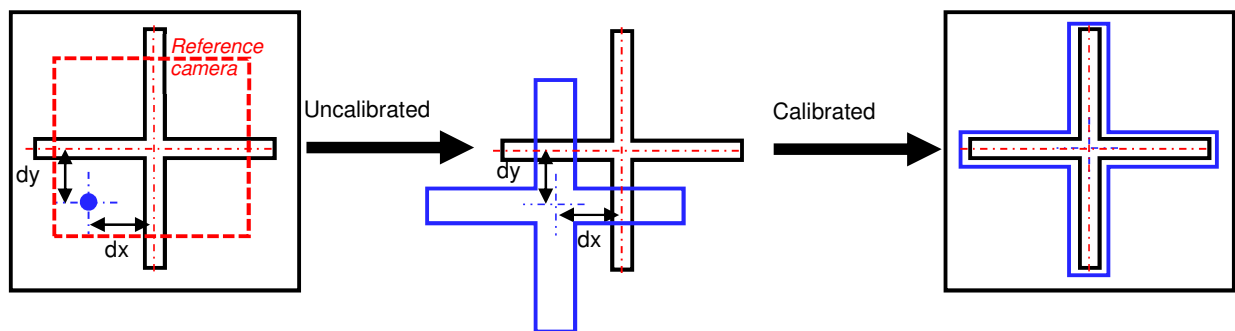
1. Move to position

Using the controls in the panel, move the stage so that the mark exposed with the **first** layer is visible in the camera window.

- If the coordinate of the mark is known, enter it into the text fields, adjust the unit and click on **Move absolute**. This starts an absolute movement to the given coordinates.
- To move the stage a certain distance, enter the distances for X and Y into the text fields, adjust the unit, and click on **Move relative**. This starts a relative movement by the given distances.
- To move around freely, use the arrow buttons. Each click moves the stage a step in the direction indicated by the arrow. Keep in mind the orientation of the coordinate system: The up/down arrows move the stage in y, i.e. parallel to the loading window, while the right/left



Beam offset calibration:



buttons move it in x, i.e. back and forth. The size of the step is determined by the number in the text field below the arrows. Coarse adjustment of that number can be done with the control buttons, fine adjustment with the slider or the mouse wheel.

- To move a certain spot that is visible in the camera to the image center, click on the **MoveTo** button in the camera panel. The cursor turns into a crosshair. Click on the point of interest to select it.

Once the structure is well visible, continue.

2. Measure position

Measure the position of the mark in the first layer. From the first drop-down list at the top, select the camera that should be used for the measurement.

In the drop-down list at the top, the wizard offers three possibilities to identify the position of a reference structure:

- Manual – the operator manually marks the structure in the camera window as point of interest (PoI) when prompted.
- Template detection – the current camera image is compared to an image of the reference structure that has been stored as a template. Requires that the template was created with the same write mode and camera as will be used during the measurement, and that template image and camera image have a comparable contrast.
- Cross detection – for cross structures, a pre-defined detection mechanism exists that detects the arms of a cross and calculates the center of the cross from the results
- As soon as a measurement method has been selected, the required parameters are displayed and can be adjusted.

In **Devices** → **Camera** selector → Camera, select a camera for the measurement. If distinct settings for camera, illumination and focus should be connected to the **script**, select a Camera Setup Key with the related parameters.

Template detection:

At Image processing → **Template**, click on the **button** with the three points to open the template selection window. Select a template from the list. If no template of the structure has yet been created under the required conditions, a new template can be created from here. Click on the + (= create template) **button** and select a name for the template. Mark the reference structure with a frame as an area of interest (AoI) in the camera window. The following rules apply:

the frame should not be larger in extent than half the image size in each axis

the **structure within the frame** has to be characteristic so it can be recognized even if other close by structures appear in the image field

the structure has to be visible with a good contrast against the surrounding area

Select the template for the script using the button with the green tag. Close the window.

Note: Templates may also be defined in the function Controls → **Metrology** → Templates of the main menu

Cross detection:

Extend the parameter list Image processing → Area of Interest. The numbers are coordinates and sizes for a frame in the camera window. Click on the button in the main text field to create a new frame. Adjust if required. The frame serves to mark the size of the cross if it is smaller than the image field. If it is bigger, the frame should be extended to maximum.

Note: For more information on the camera functions and Camera Setup Keys, refer to the related sections of **Chapter 1: General**.

Make sure to select a method that detects only the first layer mark, and cannot accidentally detect the second layer mark instead.

Once all parameters for the mark detection have been set, execute it to measure the position of the first layer mark by clicking **Execute measurement**. The measurement can be interrupted any time by clicking **Stop measurement**.

3. Move to position

Using the controls in the panel, move the stage so that the mark exposed on the **second** layer (the one exposed after alignment with the reference camera) is visible in the camera window.

As soon as the second layer mark is in position, click on **Next step** to proceed.

4. Measure position

Measure the position of the mark in the aligned layer. Make sure to select a method that detects only the second layer mark, and cannot accidentally detect the first layer mark instead.

Once all parameters for the mark detection have been set, execute it to measure the position of the second layer mark by clicking **Execute measurement**. The measurement can be interrupted any time by clicking **Stop measurement**.

5. Submit beam offset

The results of the measurements are shown. The **Save axis** checkboxes allow to use it for just one axis e.g., if the type of mark allows only relative measurement in one axis at a time. For the axis with unselected checkbox, the previous value will be kept.

If values should be entered manually instead of using the measured values, click on **Overwrite offset**. A dialog window opens where values can be entered for one or both axes.

To save the result as new calibration value, click on **Save and close**. If another measurement should be done e.g., with a different measurement method for refinement, or with another substrate, click on **Save and restart**. To close the wizard without changing the current offset calibration, click **Close without saving**.

Top Side Overlay Exposures

In this manual, the term “Overlay Exposures” is used for multi-layer exposures where the second, third etc. layer are exposed after an optical alignment of the coordinate system to an already exposed layer. As alignment is done on the base of the camera image, it is important to compensate for the distance between the position of the exposure laser beam and the center of the camera image. **This position changes and has to be recalibrated whenever the write head was dismantled.**

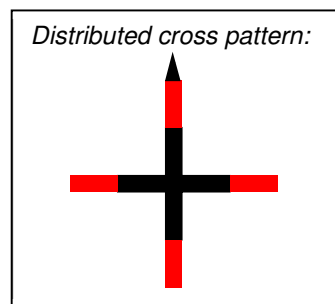
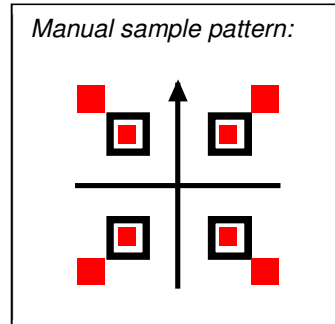
The reference laser beam position is the position at exposure start. The parameters denoting the distances in X and Y between this position and the camera image center of the reference camera (usually the micro camera) can be checked via the **Edit lithography system** panel (**Tools → Configuration → Lithography system**), by opening the **Write head pool → Setup** editor. Here, the last calibration values for each write head are shown. Approximate values for each write head are half the stripe width in X, and 0 (zero) in Y.

For overlay exposures using the reference camera for alignment, the calibration is done with the **Calibrate beam offset** wizard. Overlay calibration for any other camera can only be done after the beam offset calibration has been done, and requires the use of the **Calibrate camera offset** wizard.

STEP-BY-STEP: PREPARATIONS

1. Select or prepare a design for the overlay test. The design needs two layers.

- For a coarse manual overlay measurement, the layers should contain structures that just touch each other at a corner, if correctly aligned. As gaps are better to measure than overlaps, it is important that this pattern combination exists in all four possible combinations, so that always in one of the occurrences, the second layer pattern is shifted away from the first layer pattern.
- For a precise calibration using the cross measurement method offered in the wizard, a cross with arms extending over two layers is recommended (see sketch 'Distributed cross pattern'). The method can be used with first a small area of interest (AoI) containing only the first layer cross in the center, and next a large AoI containing the full cross, so that the ends of the arms are measured, which have been exposed on the second layer.
- In addition, the first layer needs an alignment mark e.g., a cross, in the origin position, and a structure that clearly identifies the direction of exposure, to avoid accidental turning of the substrate between exposures (e.g., an arrow).



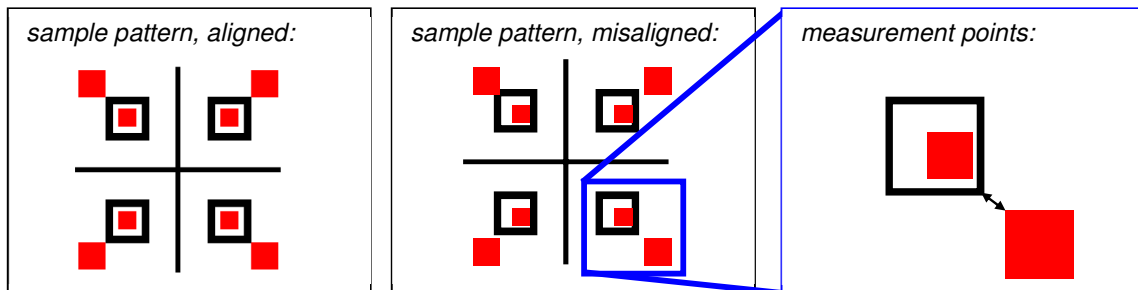
In this instruction, all further steps are described based on the sample patterns for shown here.

2. Convert the two layers of the design into separate exposure data sets, using the same magnification and the same origin (do NOT use automatic centering if not both layers are symmetrical around the origin!).
3. Choose a substrate that will provide a high contrast for later alignment. Load the substrate as explained in the loading/unloading section of **Chapter 1: General** (option manual). Using the controls of the **System Control** panel (**Controls** → **SystemControl**), move the stage to center and focus.
4. Create a new job as described in **Chapter 2: Exposures**. Set the exposure map to 3x3 dies. Choose the die sizes such that the centers of the corner fields are close to the edges of the substrate to be used, but still well away from any coating irregularities. Set **Field Zero** to X=2 Y=2, center. Choose the converted first layer as design and enter standard exposure parameters. Activate all four corners and the center of the exposure map (dies 1, 3, 5, 7, 9) for exposure.
5. Expose the job as described in **Chapter 2: Exposures**. Develop, etch, strip and recoat the substrate.
6. Load the substrate in the same orientation as before. Using the **Global alignment** wizard, align the coordinate system along x with respect to the two designs exposed at the top (fields 1 and 3).
7. Using the **System Control** panel (**Controls** → **SystemControl**), move to center. Use the **Move point to camera center** function to move the alignment cross of field 5 close to the center of the camera window. Set zero.
8. Using the **Create alignment script wizard**, set up a field alignment script that aligns to this cross, using the micro camera. For instructions on how to set up a field alignment, refer to **Chapter 3: Alignment Procedures**. It is important that the reference point is really the center of the cross, as otherwise an offset is caused. Therefore, no template should be used. Also, it is mandatory to use the micro camera, as this is the reference camera for all other offset calibrations, and beam offset has to be measured relative to it.
Enter the script into the job (**Properties** → **Scripts** → **Before every die**).
9. In the **Job control**, exchange the layer 1 design data for the one from layer 2.

Now, everything is prepared to continue with second layer exposure combined e.g., first with a manual measurement, and then in another iteration for fine tuning with a measurement using the cross method. Instructions for both sequences follow below and are based on above preparations.

STEP-BY-STEP OPTION 1: MANUAL BEAM OFFSET CALIBRATION

1. Deactivate the corner dies, leaving only die 5 activated for exposure.
2. Expose.
3. Develop the second layer. No etching, no stripping!
4. Load and align the substrate in the same way as before. Using the **System Control** panel (**Controls** → **SystemControl**), move to center.
5. Start the **Calibrate beam offset wizard** (**Wizardry** → **Writehead** → **Calibrate beam offset**). For a general description of this wizard, see previous section.



6. Move the manual sample pattern into view. Look for the quadrant in which the pattern shift creates a gap in both directions between the frame and the square that are supposed to connect. Move it into the field of view. Proceed.
7. Select manual measurement. Mark that corner of the first layer frame that is supposed to connect to the corner of the second layer square. Proceed.
Note: It is important to first mark the first layer structure, then the second layer structure. If measurement is done in the wrong order, the signs of the result are wrong, and the overlay error is doubled.
8. If required, move the stage to get the second layer square corner that is supposed to connect to the first layer frame into the camera view. Proceed.
9. Mark the second layer square corner. Proceed.
10. The measurement result is shown in the upper part of the panel. Select **Submit and close**.

**STEP-BY-STEP OPTION 2:
BEAM OFFSET CALIBRATION WITH CROSS MEASUREMENT**

1. Deactivate the corner dies, leaving only die 5 activated for exposure.
2. Expose the (re-)coated substrate prepared in the way described at the beginning of the chapter.
3. Develop the second layer. No etching, no stripping!
4. Load and align the substrate in the same way as before. Using the **System Control** panel (**Controls** → **SystemControl**), move to center.
5. Start the **Calibrate beam offset wizard** (**Wizardry** → **Writehead** → **Calibrate beam offset**). For a general description of this wizard, see previous section.
6. Look for the distributed cross pattern. Move it into the field of view. Proceed.
7. Select cross measurement. Define the area of interest around the inner part of the cross, which was exposed with the first exposure. Proceed up to the next measurement.

Note: It is important to first measure the first layer structure, then the second layer structure. If measurements are done in the wrong order, the signs of the result are wrong, and the overlay error is doubled.

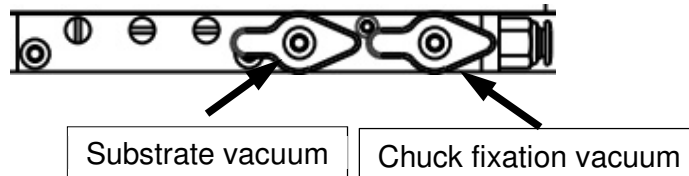
8. Define the area of interest around the complete cross, so that the measurement boxes capture the outer parts of the arms, which were exposed with the second layer. Proceed.
9. The measurement result is shown in the upper part of the panel. Select **Submit and close**.

Back Side Alignment

Back Side Alignment (BSA) is used in the same way as the normal top side alignment. The main difference is that back side alignment has a fixed precision depending on the lens installed (usually a 10mm lens), while in top side alignment, precision increases with write lens resolution.

LOADING / UNLOADING IN SYSTEMS EQUIPPED WITH BSA

A stage equipped for back side alignment has removable stage chucks. An objective for measurement of structures on the substrate backside is installed below the center of the stage area, looking up towards the center of the frame holding the removable chucks. Closed chucks can be installed for exposures without BSA. Several additional open frame chucks are usually available for exposures with BSA, one chuck for each substrate size that should be exposed with this option. To keep these removable chucks fixed to the stage frame, an additional vacuum channel is used that has a separate switch:



In closed chucks, vacuum fields can be selected as usual, with vacuum field size increasing from right to left. Each closed chuck offers a maximum of three vacuum fields. Therefore, usually more than one closed chuck is delivered with the system to cover all required substrate sizes.

ALIGNING WITH BSA

When setting up a field alignment with back side alignment, the back side camera system has to be selected in the same way as top side cameras are. Using the functions of the **Cameras** control panel, settings can be adjusted and saved as **CameraSetupKey** just as for the top side cameras. Refer to **User Guide II: Reference Guide** for a more detailed description of the **Cameras** control panel.

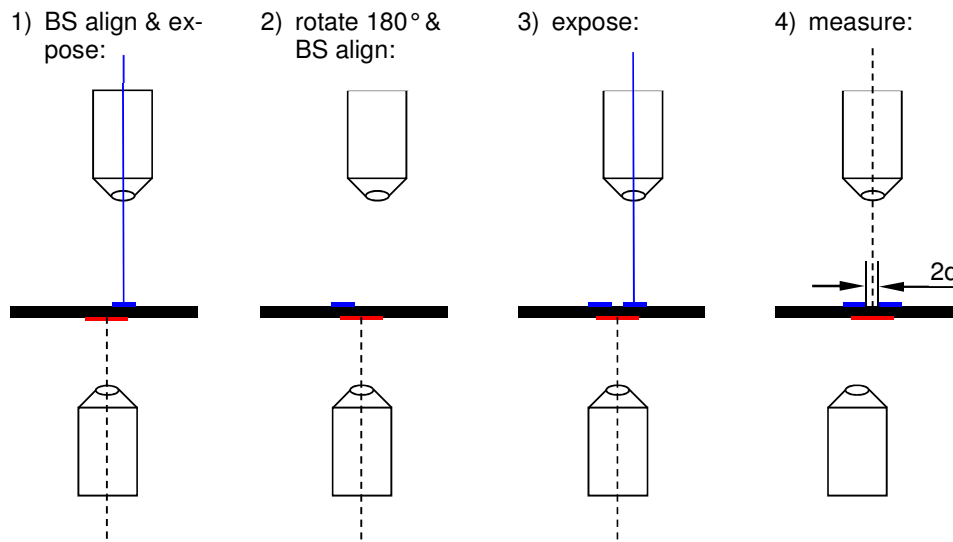
A pre-requisite of correct back side position measurements is a correct calibration of the offset between the centers of view of the back side cameras, and the reference camera (usually top side micro camera). As the beam offset is also calibrated with respect to the reference camera, the calibration of these offsets is mandatory for correct exposures with back side alignment. **This calibration has to be repeated whenever the write head has been removed for any reason.**

There are two ways of calibration. If a transparent substrate is available, the **Calibrate camera offset** wizard can be used to directly compare the measurement results for a certain marker between the reference camera and the BSA cameras and calculate offsets from it. This method however is limited in precision due to refraction. The description of this wizard can be found in the related section of **Chapter 4: Measurements**.

A more complicated, but also more precise way is to use two back side aligned exposures with the substrate turned by 180° in between, and the **BSA camera offset calibration** wizard to measure these and calculate the offset from the result.

**STEP-BY-STEP:
EXPOSURES FOR FINE BSA CAMERA OFFSET CALIBRATION**

A substrate with alignment marks on the back side is required. These marks can be created lithographically in a first step. Using these marks, two exposures have to be done where the substrate is rotated by 180 degrees in between. Each exposure is shifted by the camera offset, once in one direction, the second time, due to the substrate rotation, in the other direction. Measuring the distance between same points yields twice the error:



Note: For this method, it is important that the beam offset calibration is correct. Otherwise, it will add to the shift and distort the result.

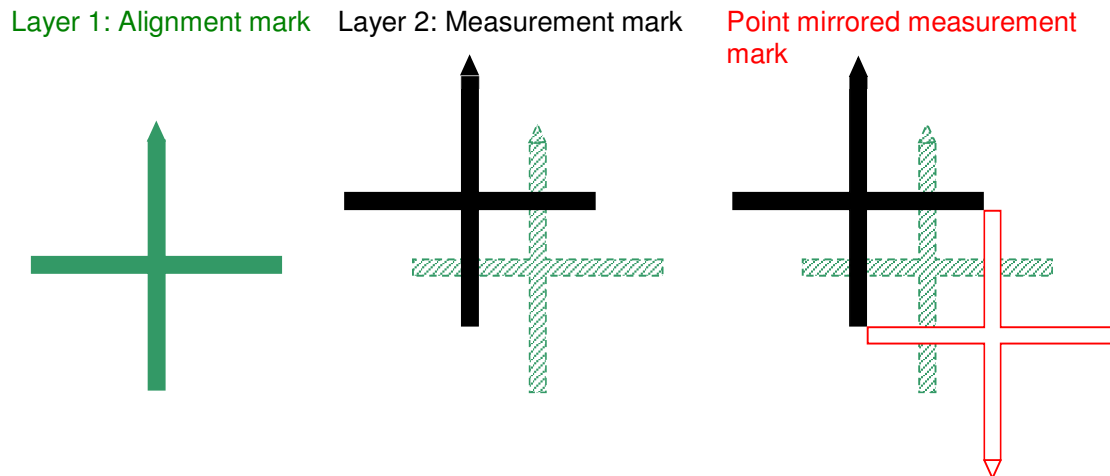
1. Prepare design

Prepare a two layer design.

Layer 1 should contain an uneven number of well separated alignment marks, distributed along y. Add a mark that defines a direction. It is helpful if each mark also goes with a number.

The second layer should contain a mark in the vicinity of the center alignment mark that can be measured well (e.g., a cross). Size and position have to be chosen so that it is far enough away from the center alignment mark that no overlap occurs if a point reflection at the center of that alignment mark structure is done, but close enough that it is still closer to the center mark than to the neighbouring one. This mark also needs a structure that defines a direction.

A possible choice would be a cross with one arrow point for both layers, where the measurement mark on Layer 2 is positioned such that the arms just touch if a point reflection is done relative to the center of the alignment mark in Layer 1:



Convert the design layers with automatic centering enabled.

2. Expose alignment marks

Load a substrate with the future back side up. Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**.

Expose Layer 1 with the repeating alignment structures using e.g., the **Execute an exposure** wizard. Develop, etch and strip it.

Coat the top side.

3. Make 1st calibration exposure

Load the substrate so that the arrows point in *positive* y direction. Using the **Execute a global alignment** wizard, align along the set of alignment marks using the backside cameras. Set zero at the first (in later runs: the second, third ...) alignment cross from the top.

With the **Create alignment script** wizard, set up a field alignment for the first alignment mark, using the back side camera that should be calibrated. Save it for later use in further runs of the calibration procedure.

Expose Layer 2 using e.g., the **Execute an exposure** wizard.

4. Make 2nd calibration exposure

Move the stage to the unload position. Rotate the substrate so that the arrows point in *negative* y direction. Repeat the loading sequence.

Using the the **Execute a global alignment** wizard, align along the set of alignment marks using the backside cameras. Set zero at the same alignment mark as before.

Expose Layer 2, using the previously defined alignment sequence on the same mark again.

Develop exposure. If contrast is too bad with resist still on the substrate, etch and strip. Otherwise, further test exposures might be done on the same resist as long as the result after developing doesn't deteriorate significantly.

STEP-BY-STEP: FINE BSA CAMERA OFFSET CALIBRATION MEASUREMENT

0. Prepare calibration

Load a substrate exposed in the way described above with the alignment mark arrows pointing in positive y direction. Follow the instructions given in the section on loading (option manual) in **Chapter 1: General**.

In the main menu, select **Wizardry** → **Camera** → **Calibrate BSA camera offset** to open the **BSA camera offset calibration** wizard.

1. Select camera

Select the camera that was used for back side alignment during the exposure.

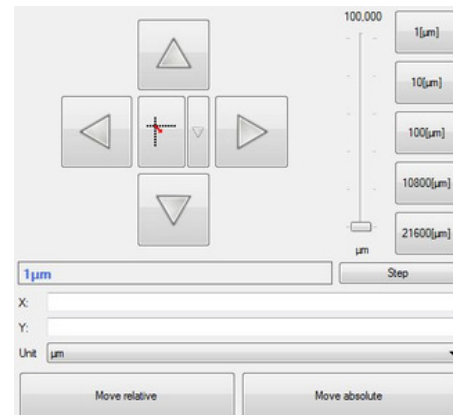
2. Select measurement camera

Select the camera that should be used to measure the structure positions in the two exposures. Usually, this should be the top side micro camera.

3. Search marker #1

Using the controls in the panel, move the stage so that the marker that was exposed during the first exposure is visible in the camera window. In the sample design described above, the arrow of this marker points in the same direction as that of the back side alignment mark.

- If the coordinate of the mark is known, enter it into the text fields, adjust the unit and click on **Move absolute**. This starts an absolute movement to the given coordinates.
- To move the stage a certain distance, enter the distances for X and Y into the text fields, adjust the unit, and click on **Move relative**. This starts a relative movement by the given distances.
- To move around freely, use the arrow buttons. Each click moves the stage a step in the direction indicated by the arrow. Keep in mind the orientation of the coordinate system: The up/down arrows move the stage in y, i.e. parallel to the loading window, while the right/left buttons move it in x, i.e. back and forth. The size of the step is determined by the number in the text field below the arrows. Coarse adjustment of that number can be done with the control buttons, fine adjustment with the slider or the mouse wheel.
- To move a certain spot that is visible in the camera to the image center, click on the **MoveTo** button in the camera panel. The curser turns into a crosshair. Click on the point of interest to select it.



Once the structure is well visible, continue.

4. Measure marker #1

This panel offers all necessary functions to measure the position of the first marker.

In the drop-down list at the top, the wizard offers three possibilities to identify the position of a reference structure:

- **Manual** – the operator manually marks the structure in the camera window as point of interest (PoI) when prompted.
- **Template detection** – the current camera image is compared to an image of the reference structure that has been stored as a template. Requires that the template was created with the same write mode and camera as will be used during the measurement, and that template image and camera image have a comparable contrast.
- **Cross detection** – for cross structures, a pre-defined detection mechanism exists that detects the arms of a cross and calculates the center of the cross from the results

As soon as a measurement method has been selected, the required parameters are displayed and can be adjusted.

In **Devices** → **Camera selector** → **Camera**, select a camera for the measurement. If distinct settings for camera, illumination and focus should be connected to the script, select a **Camera Setup Key** with the related parameters.

Template detection:

At **Image processing** → **Template**, click on the button with the three points to open the template selection window. Select a template from the list. If no template of the structure has yet been created under the required conditions, a new template can be created from here. Click on the + (= create template) button and select a name for the template. Mark the reference structure with a frame as an area of interest (AoI) in the camera window. The following rules apply:

- the frame should not be larger in extent than half the image size in each axis
- the structure within the frame has to be characteristic so it can be recognized even if other close by structures appear in the image field
- the structure has to be visible with a good contrast against the surrounding area

Select the template for the script using the button with the green tag. Close the window.

Note: Templates may also be defined in the function **Controls** → **Metrology** → **Templates** of the main menu

Cross detection:

Extend the parameter list **Image processing** → **Area of Interest**. The numbers are coordinates and sizes for a frame in the camera window. Click on the button in the main text field to create a new frame. Adjust if required. The frame serves to mark the size of the cross if it is smaller than the image field. If it is bigger, the frame should be extended to maximum.

Note: For more information on the camera functions and Camera Setup Keys, refer to the related sections of **Chapter 1: General**.

When all preparations are done, click on **Execute measurement**. The measurement can be interrupted any time by clicking on **Stop measurement**.

5. Search marker #2

Move the marker that was exposed during the second exposure, after the rotation by 180°, into view. In the sample design, the arrow shows in the opposite direction as that of the backside alignment mark.

Once the structure is well visible, continue.

6. Measure marker #2

Measure the position of the marker.

7. Transfer Offset

The measurement results are displayed. Click **Save offset** to confirm the calculated result and save it as calibration parameter.

Appendix C: Glossary

Job coordinate system

(also: **user** coordinate system)

This term denotes a temporary coordinate system that can be adjusted to the requirements of each job. After stage initialization, the origin of the job coordinate system is located in the center of the stage, and rotation with respect to the interferometer coordinate system (see below) is zero. Via manual choices or alignment sequences, the job coordinate system can be e.g., adjusted to the center of the substrate, or optical alignment marks.

Interferometer coordinate system

(also: **raw** or **absolute** coordinate system)

This is the basic coordinate system based on the optical setup of the interferometer system that measures the stage position. The origin for each axis is located at the related interferometer receiver beam in/output window.

Die

(also: **field**)

Originally, the term **die** or **dice** comes from the cutting of a wafer (**dicing**) into small units, each of which is the basis of a chip. In the present documentation, the term is used synonymously for the area on a substrate that is covered by just one design. This corresponds to one field of the map grid defined to divide up the available area into sections that contain one design.

Overlay

In the present documentation, the term **Overlay** denotes the exposure of several design layers on top of each other with an optical measurement in between to determine the current position of the previous layer(s). The precision of a second exposure that is done directly after the first one without such a measurement is referred to by the term **Registration**.

Gray scale exposure

The gray scale exposure mode is an option that allows 3D structuring of resists to form e.g., molds for micro-optical components, in a single exposure. In this mode, 100% corresponds to an energy that exposes the resist just down to the required depth. 126 equidistant energy values are defined in between 100% and 0, each of which reaches less deep into the resist.

The resulting depth of each step within the resist depends on the resist response. Therefore, for 3D structuring, resists with linear response are most useful. No undercuts are possible with this method.

Gray scale exposure settings are determined during design conversion. Refer to the **Conversion Software Manual** for more information. Only designs defined in DXF, STL, BMP or X,Y,Z-ASCII format can be converted. For exposure of designs converted for gray scale mode, the correct write mode is selected automatically.

Machine coordinate system

(also: **user** coordinate system)

This is the temporary coordinate system that is used for exposures or measurements. Its origin and rotation with respect to the interferometer coordinate system is determined by alignment procedures (plate / wafer center detection, alignment mark detection), or manual setting of the origin position.

Vector mode

With vector write mode, designs that consist only of a few narrow lines but cover a large area (like e.g., waveguides or micro-fluidic channels) can be exposed in a more effective way. In standard write mode, the whole area within which structures exist is scanned, and the laser beam is turned off and on with the required energy wherever there is a design part. In this way, lines are created by many exposure flashes.

In vector mode, a line is written in one stroke, where the laser beam is switched on at the beginning, and off at the end of the line, and the stage moves in between according to the line direction(s). This improves line quality a bit, but mainly, it can save time if in the usual way a lot of empty areas would have to be scanned. Vector mode can only be used for designs created in Gerber format.

Notes

Notes