PICOMASTER 100

User Guide

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Disclaimer

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1 Safety and machine damage remarks

In this document, the following safety remarks will be used:

> Safety warning that indicates a hazardous situation, which, if the necessary safety precautions are not adhered to, could result in serious injury.

Note: Were applicable, signs that indicate the specific hazard are used.

The following machine damage notices will be used:

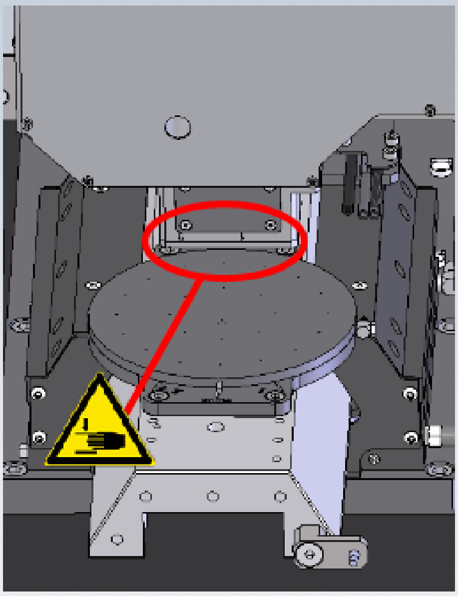
> Notice concerning possible machine damage and/or production loss.

Note: Safety remarks may include machine damage notices. In those cases, the warning sign is used and the safety warning is the first to mention.

1.1 Safety remarks

When giving low level movement commands

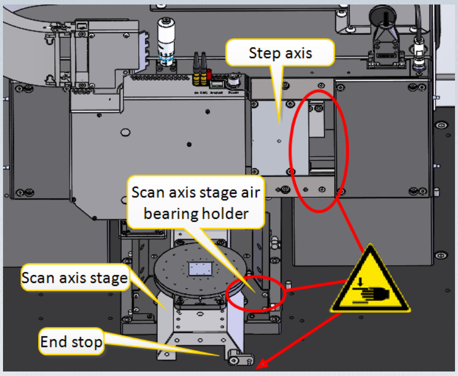
> Warning: Risk of entrapment. Do NOT put your hands in between the writing module and the vacuum chuck. Maintenance commands can move the writing module (in X, Y and Z) with reference to the vacuum chuck while the machine window is open.



Do not put a hand or fingers between the writing module and the vacuum chuck

When working close to the step axis

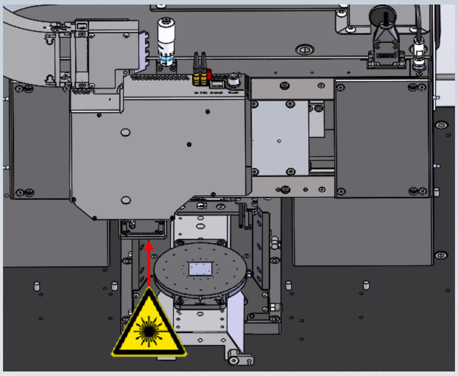
Warning: Risk of entrapment. Do NOT put a finger inside the gap between the step axis stage and the base plates. Do not put a finger in front of the air bearing holder or in front of the scan axis end stop. Maintenance commands can move the step axis while the machine window is open.



Do not put a finger in the gap

When giving low level laser commands

Warning: Class 3B laser, risk of eye injury. Maintenance commands can switch on the writing laser while the machine window is open. Avoid direct exposure to the laser beam at close distance.



Avoid direct eye exposure the writing laser beam at close distance

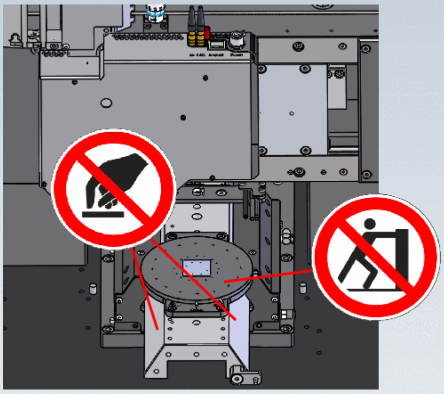
1.2 Machine damage remarks

General remark

Notice: Risk of machine damage and/or product loss. Do NOT change any setting of the windows computer (including network settings) without first consulting Raith Laser Systems.

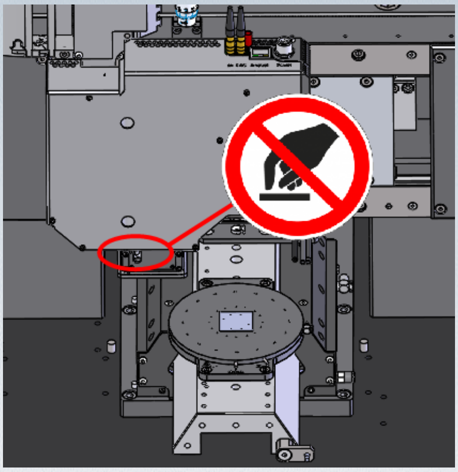
While working close to the step and scan axis

Notice: Risk of machine damage. Do NOT move the vacuum chuck without the correct air pressure applied to the system. Do NOT touch the surfaces of the air bearings .



Do not move the vacuum chuck without air pressure applied, do not touch the air bearings.

Notice: Risk of machine damage. Do NOT touch the optics at the bottom of the writing module or the (optional) alignment modules.



Do not touch the optics

While working with substrates and making substrate recipes

Notice: Risk of machine damage and/or product loss. If the substrate thickness has increased compared to the previous one, lift the writing module to avoid collision with the substrate.

While doing the motor driven writing module height adjustment

Notice: Risk of machine damage and/or product loss. Risk of production loss. Typing the incorrect writing module height can make the writing module touch the substrate.

Notice: Risk of machine damage and/or product loss. During writing module Z-adjustment, using the Jog buttons may lead to collisions.

While adjusting machine settings

Notice: Risk of production loss. Changing machine settings without proper understanding the impact could severely influence the output quality and/or the stability of the equipment.

2 PICOMASTER 100 description

The PICOMASTER can write an image in resist by moving a light spot over a substrate, see **Figure 2-1 below**.

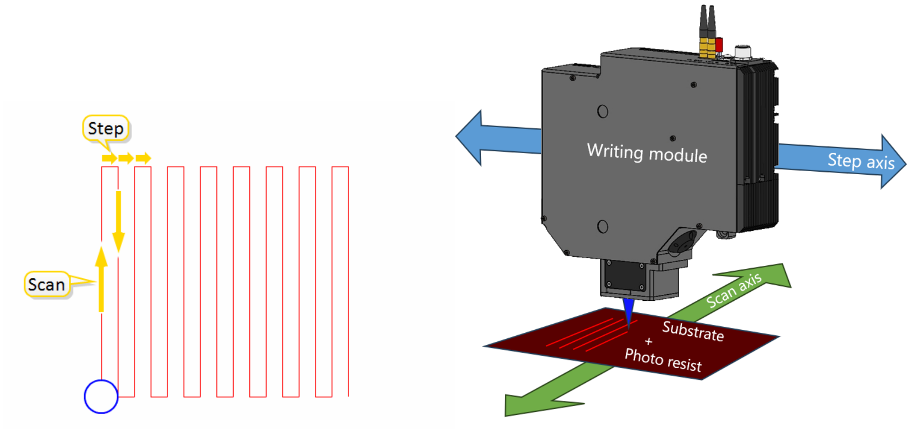


Figure 2-1 Writing an image

The system is able to expose a pattern on a substrate with high speed and high accuracy.

Writing system

The main components of the writing system are shown in **Figure 2-2 below**.

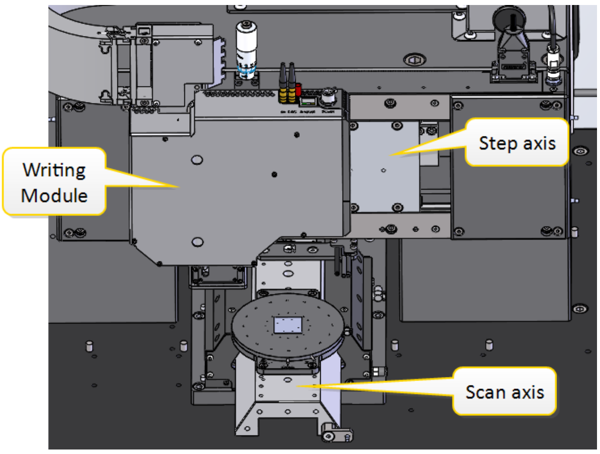


Figure 2-2 Machine main components

The writing module produces the writing laser beam, see **"Writing module" below**.

The step axis and scan axis position the writing laser beam with reference to the substrate on the vacuum chuck, see **"Scan axis and step axis" on page 8** .

Control system

The computer and the PLC control the PICOMASTER system, see **"Computer and PLC" on page 12** .

The software uses a Project file and Recipes to do an exposure, see **"Projects and recipes" on page 13**.

Important parameters that are used for exposures are described in **"Exposure parameters" on page 9**.

2.1 Writing module

The writing module has a writing laser, aperture switch, attenuator and an objective lens. It also has a vertical control system based on a red light beam. Further, it holds an alignment system with an alignment camera. It may also have the additional XL writing laser system as an option.

The writing module is shown in **Figure 2-3 on the next page**.

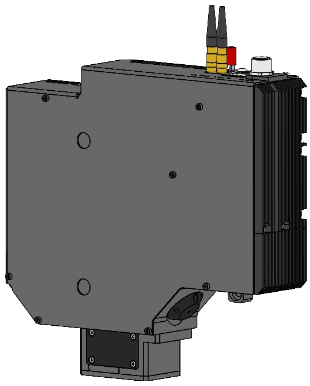


Figure 2-3 Writing module

Writing laser

Note: In some texts (SW interfaced, error codes, etc.), the writing laser is may also be called *blue laser*.

The writing laser produces a near UV beam that strongly diverges. It automatically switches off when the machine window is opened. However, when giving movement commands in the Maintenance tab, the writing laser can be switched on, even when the the machine window is opened. Therefore, a warning is given where applicable in this manual not to look at the beam at very close distance.

The laser has a lifetime of over 10 000 hours. It is available in 375nm and 405 nm wavelength versions. Laser intensity is adjustable over a wide range to allow for grayscale writing by selecting one out of 4095 different intensity levels.

The writing laser diode produces light when the current is above the threshold, see **Figure 2-4 below**.

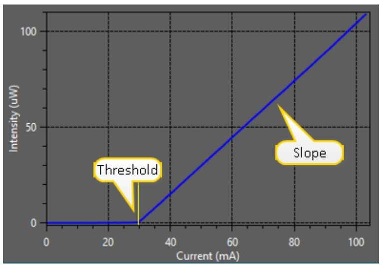


Figure 2-4 Laser intensity for different electrical currents

The threshold current and the current slope are used for laser control. They are checked before each exposure. If the threshold is too high, empty areas in the project will be exposed at a low dose. This may lead to image disturbances. The threshold current rises with temperature. This is compensated by the laser control system, see **"Compensating for temperature drift" on page 114**.

Aperture switch

An aperture can be put into the laser beam automatically. It has the following effects:

- Due to interference effects of the laser light rays, the aperture influences the laser spot size on substrate level and can make it as small as 300 nm.
- Because it blocks a part of the beam, the Aperture also reduces the maximum amount of laser power on substrate level.
- The Aperture also determines the depth of focus of the objective lens that ranges from 0.6 µm until 49 µm (depending on the machine configuration).

There are three aperture settings available:

- High NA (large opening): High resolution (smaller laser spot).
- Med NA (medium size opening): Medium resolution (medium laser spot size).
- Low NA (small opening): Low resolution (larger laser spot).

Attenuator

To produce a stable and reduced laser power on substrate level, several attenuation filters are available. They can be automatically be inserted into the beam. The available Attenuator filter are listed below:

- No Attenuation: No reduction of intensity.
- Low Attenuation: Low reduction of intensity.
- Medium Attenuation: Medium reduction of intensity.
- High Attenuation: High reduction of intensity.

Intensity sensor

The Intensity sensor measures the power of the laser beam on substrate level. It is used for the laser calibration before each project exposure.

2.1.1 Red Light system

The red light system is used to measure the Z-height of the Objective lens. A red LED sends light to the substrate. The substrate reflected beam is measured and feedback is send to the Z-control system system that accurately focuses the objective lens within ±300 µm in real time, see **"Focus Measurement System" on page 35**.

The red LED power can be adjusted in the substrate recipe (see **"Making a substrate recipe" on page 28**) or while adjusting the writing module height(see **"Writing module height adjustment" on page 22**).

Note: In some texts (SW interfaced, error codes, etc.), the red light LED may also be called Red laser.

2.1.2 Objective lens

The objective lens focuses the laser beam onto the substrate. At the same time, it also focuses the red light beam. The objective lens Z-height is under permanent control by a fast moving voice coil system. The actual Z-height is measured by the red light system as described above.

2.1.3 XL Laser system

As an option, the XL Laser can be present in the writing module. Is has its own optical system that does not interfere with the writing laser system as described above. It has more power than the normal writing laser, but has less control features. It does have an Intensity sensor.

2.1.4 Alignment camera

To write a new pattern on top of an existing pattern, the position and orientation of the substrate that holds the existing pattern has to be found. The writing module has an alignment camera module that can detect markers on the substrate. By measuring a number of these markers, the PICOMASTER software can reconstruct the position and orientation of the existing pattern on the substrate. The marker positions are retrieved from the camera image using an algorithm that can detect trained shapes in the image with an accuracy of 100 nm.

The optics of the alignment camera and the writing laser are aligned such that they have the same focus length with respect to your substrate. When the height of the writing module is controlled to match the substrate, the alignment camera will automatically be in focus as well.

The alignment camera optics position is shown in **Figure 2-5 below**. Two white arrows are present on the writing module, indicating the position of the writing laser and the Alignment optics.

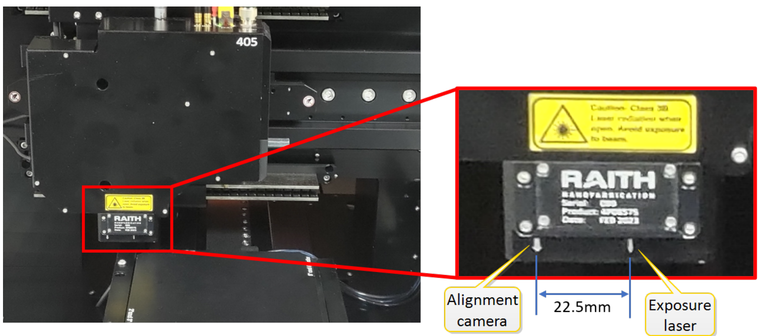


Figure 2-5 Alignment camera and writing laser relative distance

The distance between the writing laser and the Alignment camera is 22.5mm.

2.2 Scan axis and step axis

The PICOMASTER system has two axes that control the position of the writing module with reference to the substrate: the Step axis (left-right) and the Scan axis (front-back).

2.2.1 Step and scan axes

The scan axis uses high precision roller bearings and the step axis uses high precision air bearings. Both axes use linear motors and high resolution optical encoders for fast accelerations and stable speeds.

To ensure stable writing, the machine base frame is supported by isolation mounts that filter out ground frequencies to minimize vibrations in the system.

2.2.2 Machine coordinate system

The machine coordinates for the step and scan axes are given with reference to the home position of the writing module, see **Figure 2-6 below**.

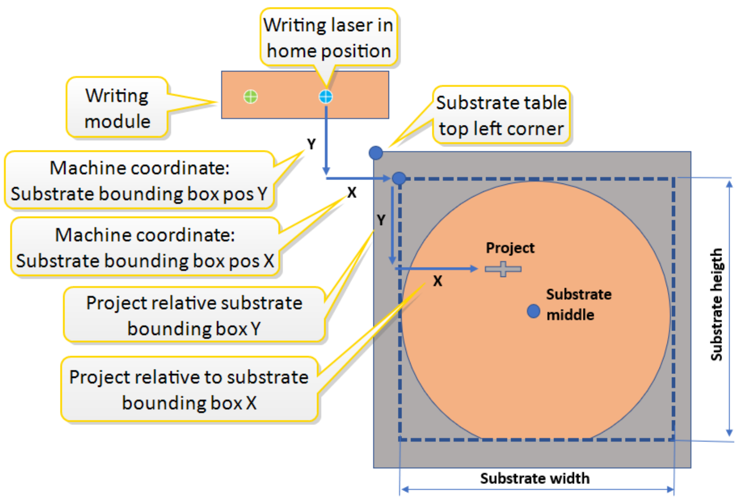


Figure 2-6 Coordinate system indicating the writing laser position with reference to the home position

Note: In **Figure 2-6 above**, the writing laser seems to move in X and Y direction. In the real situation, the writing module makes steps in X directions and the vacuum chuck scans in Y direction.

The writing module home (or origin) position is at the left machine side behind the vacuum chuck. These coordinates indicate the position of the writing laser. The writing module moves to the home position automatically on many occasions, and by using low level command, see **"Basic motion control" on page 117**.

Project coordinates in substrate recipes are relative to the top left corner of the substrate bounding box. The position of the substrate bounding box top left corner is given in machine coordinates.

2.2.3 Address grid and rasterizing mode

The positions that are visited (or addressed) by the exposure laser during an exposure are called the address grid. The address grid is built by scanning the slit up and down while making side steps in between as described above.

The address grid is shown in **Figure 2-7 on the facing page**.

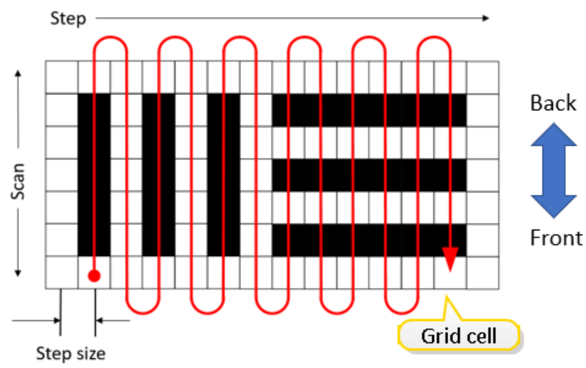


Figure 2-7 Address grid

The size of the laser beam is larger than the size of the steps in the address grid. This means that while writing, the scan lines made by the laser overlap. This gives a smooth light distribution.

The cell size of the grid can be calculated:

In stepping direction, the cell size is equal to the step size, which is recommended to be 50% of the spot size. In scanning direction, the cell size is determined by the scan speed and the frequency at which the exposure the laser can be switched on/off. This frequency is 10MHz. Using a spot size of 280 nm, and a scan speed of 200 mm/s, this would give a grid cell 140 nm x 20nm.

The usage of the address grid during exposures is called the rasterizing mode. While using the rasterizing mode, the PICOMASTER reads the project file and translates its information into scan lines with steps in between.

In the rasterizing mode, the PICOMASTER determines a rectangular bounding box around your project. This rect-angular area is completely scanned by the laser; even if a large part of this area is empty. The scan velocity is maximized to keep the exposure time as short as possible. This type of writing strategy is very efficient for projects in which a large percentage of the wafer needs to be exposed.

Apart from normal project files made in project manager, the PICOMASTER can also use GDS files,(optional) Gerber files, and raw data files, see **"Exposure file types" on page 37**.

2.2.4 Design and performance step and scan axes

In the table below, some data are given on design and performance of the PICOMASTER system.

	Scan Axis	Step Axis
Max speed	200 mm/s	Not applicable
Bearing type	Air bearing	Roller bearing
Encoder resolution	2 nm	1 nm
Exposable area	100 mm (4 inch)	100 mm (4 inch)
Max substrate size	125 mm (5 inch)	125 mm (5 inch)
Min substrate size	5 mm	5 mm

Table 2-1 Performance guidelines for step and scan axes

2.3 Exposure parameters

Project exposure results are controlled by the project design. At the same time, the project exposure output also depends on the Exposure Recipe values. These are important exposure parameters. They are described below.

2.3.1 Scan speed

The PICOMASTER can only write while the scan axis is moving at a constant speed. This constant writing speed is called the scan speed. The scan speed is the stable part of the velocity of the scan axis during a project, see **Figure 2-8 on the next page**.

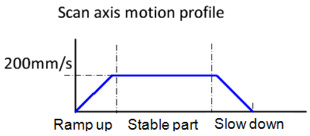


Figure 2-8 Example of scan speed versus time

The ramp up and slow down parts of the scan movement are not exposed, but they do add to the total exposure time of the project. They also influence how much of the substrate can be exposed.

Approximate values for scan speed and associated lengths are shown below.

Scan speed in stable area	Ramp up and slow down length	Total required length*
200 mm/s	5 mm	7 mm
100 mm/s	1.5 mm	2.5 mm
50 mm/s	0.5 mm	1.5 mm

Table 2-2 Approximate scan speed values

**Total required length includes stabilization length and safety margin*

2.3.2 Spot Size

The spot size is the diameter of the laser on substrate level. It is set by Aperture switch (see **"Aperture and attenuator control" on page 114**).

Note: The machine has one of the two optical configurations.

Approximate values are listed below.

	Aperture	Spot size [µm]	Depth of focus [µm]
Optical configuration 1	0.85*	0.3*	0.6*
	0.5	0.6	1.6
	0.295	0.9	4.6
Optical configuration 2	0.25*	0.8*	6*
	0.15	1.5	17
	0.1	2.5	49

*Values when only a fixed aperture is installed.

Table 2-3 Spot size and depth of focus for different apertures

2.3.3 Attenuation

The attenuator is used to produce a stable and reduced laser power on substrate level.

Very low laser light output can be made by reducing the laser current, but the laser light output will become less stable when the threshold current is approached. Then it is better to use the attenuator.

For example: The maximum output power of the 405 laser is typically 7000 µW. If a laser output of only 36 µW is required, the laser needs to operate at 0.5% of the maximum power. This means that the laser current will be just above the threshold current. The laser output will then be very sensitive to temperature changes and electrical noise. To prevent this, the attenuator is used to reduce the maximum output power The low laser power is now achieved while staying well above the threshold current.

2.3.4 Focus offset

The Focus system keeps the height of the writing module at the correct position, see **"Focus Measurement System" on page 35**. To fine tune the Focus height of the writing module, a Focus offset voltage can be typed into the exposure recipe. The offset is determined in the Focus Offset test, see **"Focus Test" on page 54**.

2.3.5 Step size

The step size determines how much the step axis moves between every scan line. In the example in **Figure 2-9 below**, the step size is given in percentage of the spot size.

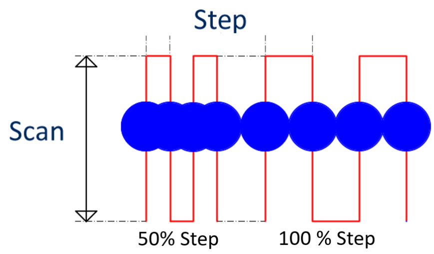


Figure 2-9 Step size 50% of the spot size (left side) and 100% of the spot size (right side)

The step size is adjustable per project in the exposure recipe. However, it is recommended to use a step size of 50% of the spot size.

2.3.6 Exposure dose

During an exposure, the exposure dose is delivered by the writing laser by making scan lines with steps in between. While following the address grid (see **"Address grid and rasterizing mode" on page 8**), the writing laser delivers a requested exposure dose to the substrate.

The exposure dose is the amount of energy on an area, like the example shown in **Figure 2-10 below**.

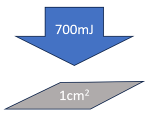


Figure 2-10 An exposure dose of 700 mJ/cm2

In general, an exposure dose is an amount of energy on a surface area in a specific time:

$$D = \frac{P*t}{A}$$

Where

D = exposure dose [J/m2]

P = light power [W]

t = exposure time on the area [s]

A=the exposed area = length* width = y*x [m2]

Note: This can best be compared with being in the sun light. The dose you get is the sun power times the exposure time.

To expose such a dose, the PICOMASTER writes scan lines with steps in between, see **Figure 2-11 on the next page**.

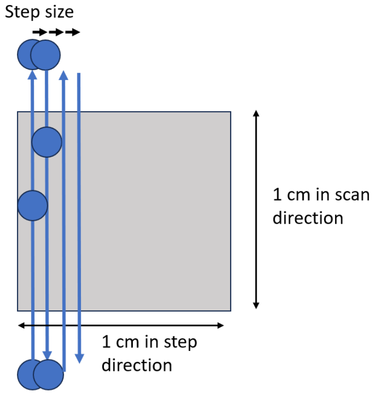


Figure 2-11 Building up a dose during an exposure

With this concept in mind, we can calculate how long the exposure time t on the area x*y is:

$t = t_{one\ scan\ line} * N$

Where:

$t_{one\ scan\ line}$ = duration of exposing one scanline [s]

$= \frac{y}{Scanspeed}$

N= *Number of scan lines* [-]

$= \frac{x}{Stepsize}$

With a little bit of mathematics, we get a simple formula:

$$D = P * \frac{1}{Scanspeed} * \frac{1}{Stepsize}$$

Note: The area size y*x is no longer present, as it can be crossed out as it was present on both sides of the equality sign.

The laser light power P in this formula is the required laser power P_{req} (which is the real power of the laser) divided by the attenuation factor Att. This attenuation can be set in the exposure recipe.

So we finally get:

$$D = \frac{Preq}{Att} * \frac{1}{scanspeed} * \frac{1}{stepsize} * 10^5$$

The number 10^5 is needed because the laser power P_{req} is in µW and the exposure dose D is in mJ/cm^2, while step size is in nm and scan speed is in mm/s.

The maximum step size is the laser spot size. A step size larger than the laser spot size would give unwanted stripes in the exposure with a lower intensity, because the laser would not cover the whole surface.

In **"Making an exposure recipe" on page 48**,you may check yourself that the formula is correct by typing in the values of the example recipe.

In the PICOMASTER software, the laser power is automatically calculated based on this formula after you type in the values for dose, step size and scan speed, see **"Making an exposure recipe" on page 48**. In the exposure recipe, the Dose, Scan speed and Attenuation factor are typed in, while the required Laser power P_{req} is automatically calculated.

2.4 Computer and PLC

2.4.1 Computer

The computer in the PICOMASTER runs Windows with a custom program specially designed for the system.

If the system is connected to the internet, it is possible for Raith Laser Systems BV to operate the PICOMASTER remotely. This may include troubleshooting to fix occurring issues.

Main pages on all machines are Projects, History, Maintenance, Alignment and Settings. An example is shown in **Figure 2-12 below**

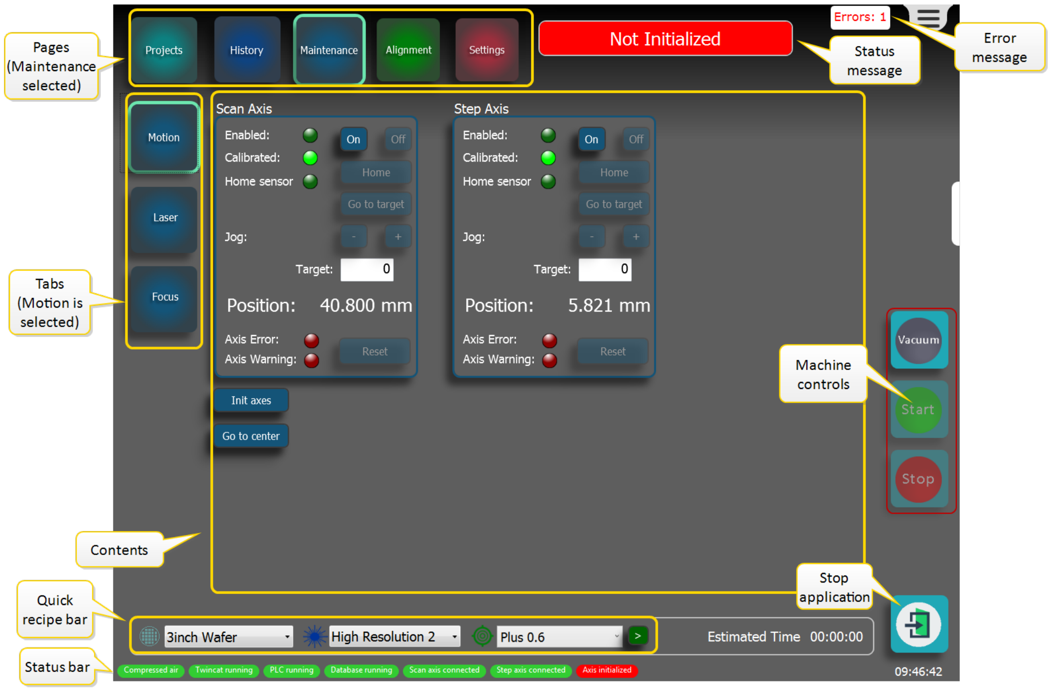


Figure 2-12 User interface overview

The detailed content of the pages that are available may vary slightly, depending on the options that are enabled on the machine.

2.4.2 PLC

The PLC (Programmable Logic Controller) is the part of the system that connects the computer to the machine. Through the PLC, the motors are controlled and the sensors are measured, allowing the system to operate correctly.

2.5 Projects and recipes

To start a project, the user needs to select several parameters before the project can be started.
The project processor in the PICOMASTER system combines these parameters internally to a job. This is shown in **Figure 2-13 below**.

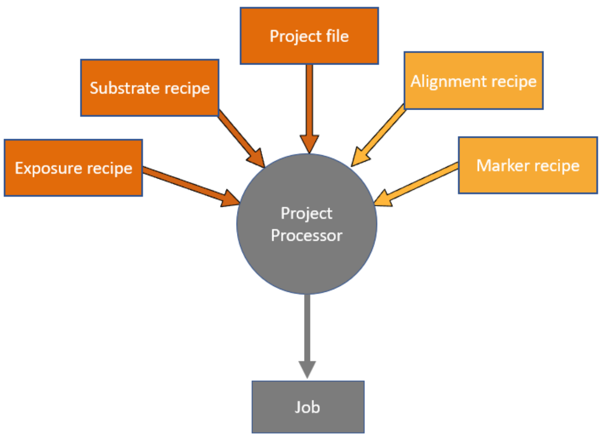


Figure 2-13 Project processor input and output

The project file can be generated with the Project Manager tool. This tool can be installed on a separate computer or it can run on the PICOMASTER system itself. The PICOMASTER system searches for project files in the assigned folders and project names, see **"Folder and project names" on page 129**.

The Project Processor combines the project file with the selected Substrate Recipes (see **"Preparing the substrate recipe" on page 22**), Exposure Recipes (see **"Preparing the exposure recipe" on page 47**), optional Alignment Recipes (see **"Preparing and doing alignment" on page 66**) and Marker Recipes (for example, see **"Training a frontside marker" on page 75**).

3 Making a product

The making of a product has the steps that are described below.

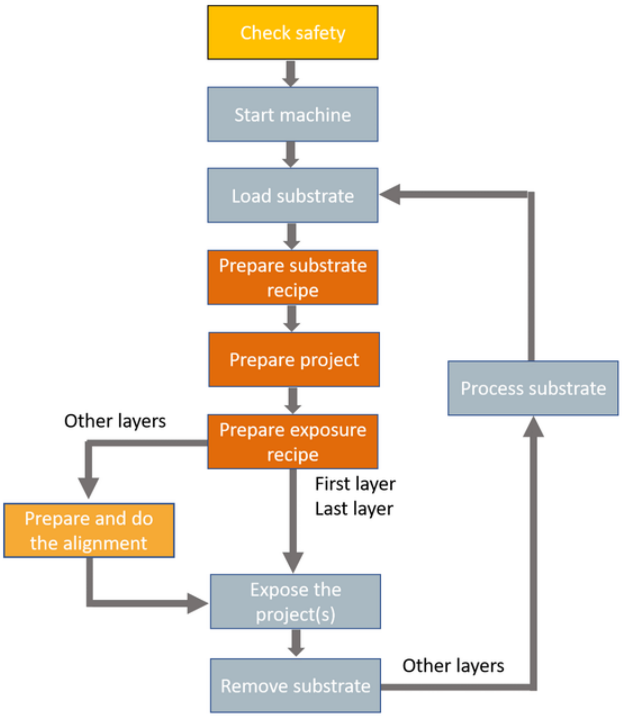


Figure 3-1 Product flow

Step	Content	Reference
Check safety	Carefully read the human and machine safety instructions,	**"Safety and machine damage remarks" on page 1**
Start machine	If required, start the PICOMASTER.	**"Starting the machine" below**
Load substrate	Safely load the substrate	**"Loading the substrate" on page 19**
Prepare substrate recipe	Select the substrate recipe or write a new one.	**"Preparing the substrate recipe" on page 22**
Prepare project	Select the project and position it on the substrate.	**"Selecting and positioning the project" on page 43**
Prepare exposure recipe	Select an existing exposure recipe or make a new one.	**"Preparing the exposure recipe" on page 47**
Prepare en do alignment	Select an existing alignment recipe or make a new one, do the alignment.	**"Preparing and doing alignment" on page 66**
Expose the project(s)	Exposure one project or exposure a project queue.	**"Exposing a project" on page 108**
Remove substrate	Safely remove the substrate.	**"Removing the substrate" on page 112**

3.1 Starting the machine

3.1.1 Switching on the PICOMASTER

1. Make sure all machine doors are closed.

2. Make sure all utilities are connected and in operating state.

3. Press the power switch on the back of the PICOMASTER, see **Figure 3-2 below**

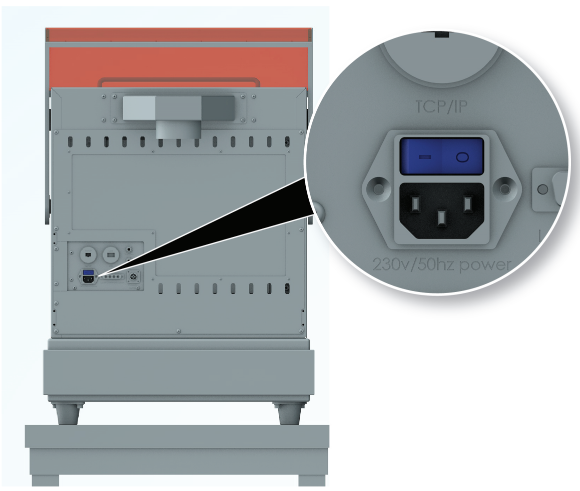


Figure 3-2 Turning on the PICOMASTER

4. Turn on the computer.

   4.1. Make sure the power switch on the computer back panel is ON.

   4.2. Open the front door and press the power switch on the computer front panel.

Note: The switch is located on the bottom right corner as seen from the front of the machine.

5. Wait 1 minute before launching the software.

3.1.2 Launching the PICOMASTER software

1. Press the yellow triangle on your system task bar to launch the PICOMASTER software, see **Figure 3-3 on the facing page**.

Figure 3-3 Starting the software

2. Wait for the loading pop-up to disappear and the application to start.

3. Wait approximately 10 to 15 minutes for the machine to heat up and reach thermal stability.

3.1.3 Initialize machine

1. Make sure the machine window is closed.

2. Press the Initialize button on the right side of the screen.

Note: When the control system is already in initialized state, the button is not visible.

3.1.4 Messages during startup

1. To interpret messages during machine startup, see **"Checking machine status" below**.

2. If errors occur, clear the error messages and solve the errors, see **"Clearing error messages" on the next page**.

3.1.5 Checking machine status

The machine status messages are visible at the right top of the screen, see **Figure 3-4 below**.

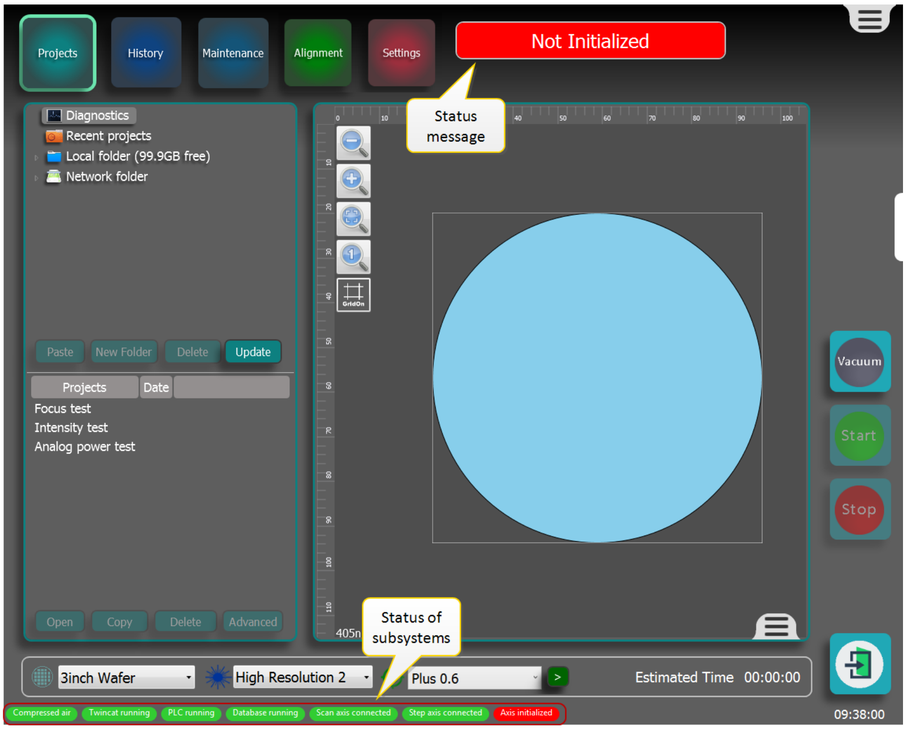


Figure 3-4 Checking the machine status

The status messages give information about the machine state. Possible states are:

- Not initialized: message tells if suspension/step axis/scan axis is not initialized.
- Not operational: see message for details.
- Waiting: awaiting substrate load and/or project load.
- Ready: ready to start exposure.
- Busy: busy doing a task (like exposure, automatic alignment, substrate scan, etc.).
- Paused: exposure is paused due to window unlock.
- Aborting: aborting exposure (the stop button was used).

- Aborted: after aborting until substrate unload and/or opening a new project.
- Done: project successfully exposed.

The status bar at the bottom of the PICOMASTER user interface (see **Figure 3-4 on the previous page**) allows you to quickly see if all the subsystems are operational. The bar is only visible if any of the states is red.

After start up, when all systems are up, the status bar disappears until a new machine status message of class red is displayed on the right top.

Note: On most screens that are shown in this documentation, the status bar is not shown.

Details on the status bar and how to act is listed below.

Reading the status bar

Item	Meaning of Green	Meaning of Red	If red, how to make green
Compressed air	Air pressure OK.	Main air pressure lower than 0.45 MPa **Note:** 1MPa=10 bar 0.45MPa=4.5bar	See **"Checking and adjusting the machine status" on page 135**.
Twincat running	PLC connection OK	PLC connection not detected.	
PLC running	PLC program in run mode.	PLC program not in run mode.	
Database running	Database running correctly.	MySQL database not connected or in error.	
Scan axis connected	Scan axis is detected correctly.	Scan axis controller not found in PLC.	
Step axis connected	Step axis is detected correctly.	Step axis controller not found in PLC.	
Axis initialized	Scan and step axis initialized	Red: Scan or step axis not initialized	

3.1.6 Clearing error messages

When an error situation in the machine occurs, the main machine status window turns red, see **Figure 3-5 below**.

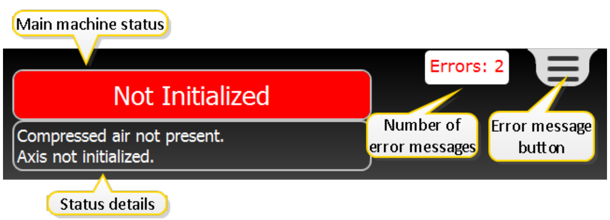


Figure 3-5 Error status and error details

By pressing the error message button (**Figure 3-5 above**), error messages (**Figure 3-6 below**) become visible.

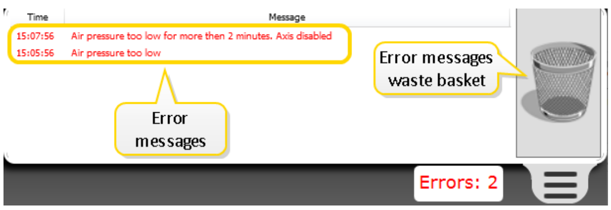


Figure 3-6 Error detail window

To delete all error messages, press the error messages waste basket.

Note: Error messages cannot be deleted individually.

Even after the deleting the error messages, the error remains in the machine status window and the machine cannot write projects.

To solve the errors, go to **"Troubleshooting" on page 134**.

After solving, the errors will disappear from the status window and the red error block will change colour.

3.2 Loading the substrate

3.2.1 Set the writing module to the correct height

1. Determine the height and size of the substrate, either by using supplier data or by measuring (for example with a ruler and a micrometer).
2. If not yet done so, press the Stop button to bring the axes in home position.

> Stop — Pressing Stop will cause all processes in the machine to stop. The scan and step axes will go to home position. This does not affect the vacuum.

3. Unlock the window of the PICOMASTER by pressing the Unlock button on the front panel. The button will light up green when the window is unlocked.

> Notice: Risk of machine damage and/or product loss. If the substrate thickness has increased compared to the previous one, lift the writing module to avoid collision with the substrate.

4. If the substrate thickness is larger then the thickness of the previously loaded substrate, then lift the writing module:
   4.1. If there is no motorized coarse Z-adjustment , then do step **5. below**.
   4.2. If a motorized coarse Z-adjustment system is installed, then do step **6. below**.
5. Lift the writing module (manual system):
   5.1. Turn the adjustment hand screw until the writing module is in the most upward position.

Figure 3-7 Turning the manual z-adjustment screw

   5.2. Continue at ***3.2.2 Load the substrate (frontside alignment)***.
6. Lift the writing module (motorized system):

> Warning: Risk of entrapment. Do NOT put your hands in between the writing module and the vacuum chuck. Maintenance commands can move the writing module (in X, Y and Z) with reference to the vacuum chuck while the machine window is open.

   6.1. Click Maintenance.
   6.2. Click Focus.
   6.3. Go to Motorized Z adjustment.
   6.4. Click On at Enabled to turn on the motor.
   6.5. Click Home to lift the writing module until the home position is detected.

3.2.2 Load the substrate (frontside alignment)

1. Make sure that the bottom side of the substrate and the topside of the vacuum chuck are clean.

Note: Particles or resist leftovers on the vacuum chuck or on the bottom of the substrate may block the build up of the vacuum.

2. Check if the text on the vacuum chuck front side corresponds to your substrate size, see **Figure 3-8 below**

Figure 3-8 Vacuum chuck front size

3. Take the placement tool set as shown in **Figure 3-9 below**.

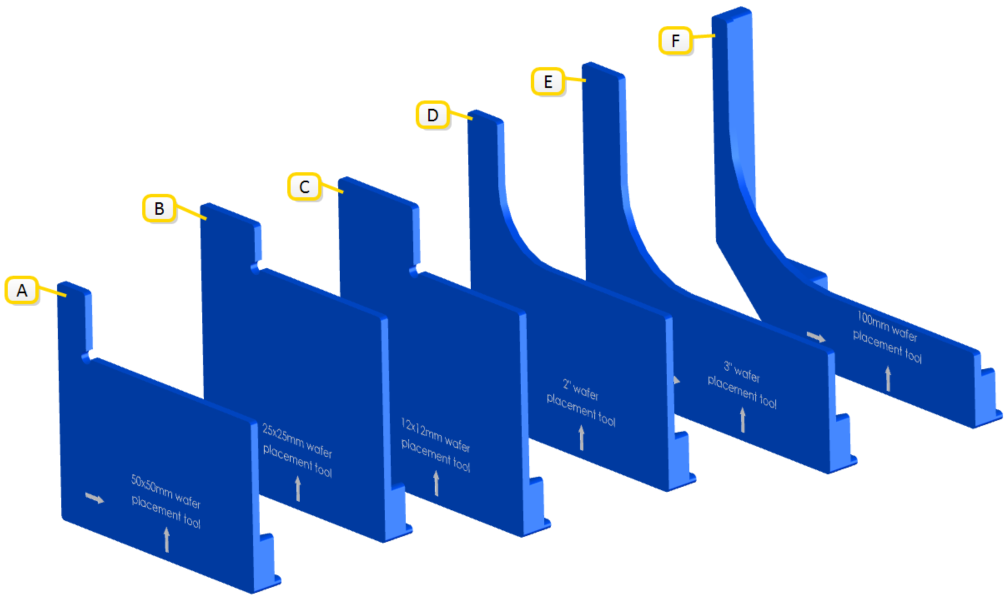


Figure 3-9 Substrate placement tools

Item	Code	Name
A	4P10272-B	PM100 50x50mm wafer placement tool
B	4P10432-B	PM100 25x25mm wafer placement tool
C	4P10269-B	PM100 12x12mm wafer placement tool
D	4P10268-B	PM100 2inch wafer placement tool
E	4P10270-B	PM100 3inch wafer placement tool
F	4P10271-B	PM100 100mm wafer placement tool

Table 3-1 Placement tool list

4. Install the placement tool that matches the size of your substrate on the right front corner of the vacuum chuck.

5. For very small substrates, for example a part of a wafer, choose 4P10269-B (PM100 12x12mm wafer placement tool).

6. Install the substrate against the placement tool.

   6.1. In case of a round substrate with a flat edge, make sure to place the flat edge on the front side of the machine against the placement tool.

7. Activate the vacuum by pressing the vacuum button on the screen or on the front panel.
8. Carefully remove the placement tool.
9. Close the machine window to complete the substrate loading.

3.2.3 Load the substrate (backside alignment)

1. Select the required backside alignment vacuum chuck and the placement tool needed for your substrate, see **Figure 3-9 on the previous page** and **Table 3-1 on the previous page**.

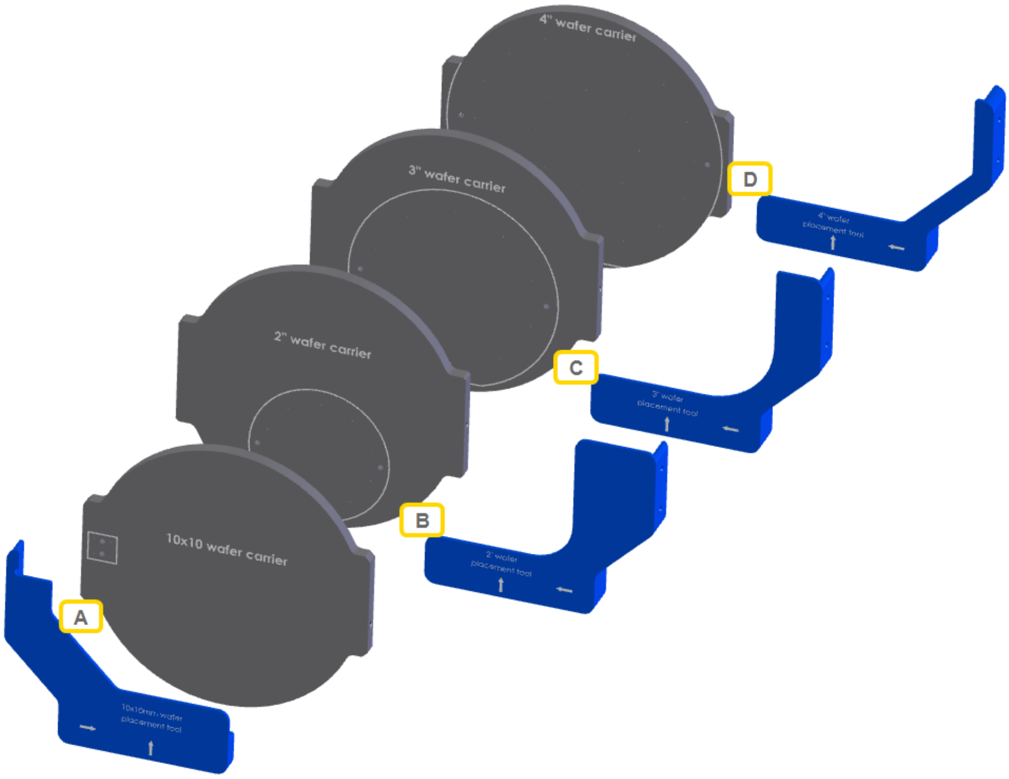


Figure 3-9 Substrate placement tools

Item set	Substrate carrier plate	Placement tool
A	10x10 wafer carrier	10x10 wafer placement tool
B	2' wafer carrier	2' wafer placement tool
C	3' wafer carrier	3' wafer placement tool
D	4' wafer carrier	4' wafer placement tool

Table 3-2 Placement tool list

2. If needed, change the substrate carrier plate:
   2.1. Manually lift the existing substrate carrier plate from the scan axis.
   2.2. Manually install the required substrate carrier plate on the scan axis.
3. Install the placement tool that matches the size of your substrate.
4. For very small substrates, for example a part of a wafer, choose the 10x10 wafer placement tool.
5. Install the substrate against the placement tool.

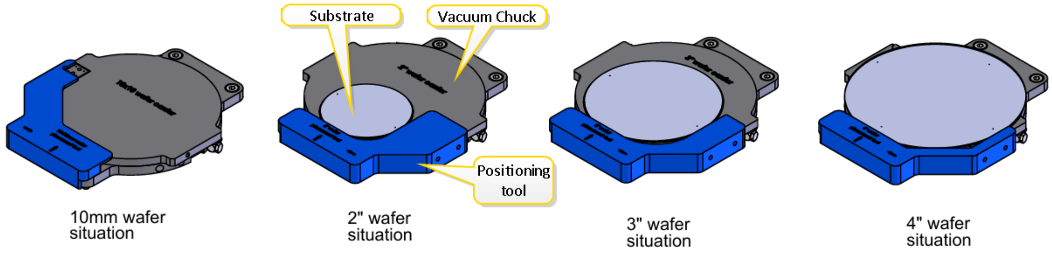


Figure 3-11 Substrate against placement tool

5.1. In case of a round substrate with a flat edge, make sure to place the flat edge on the front side of the machine against the placement tool.

3.3 Preparing the substrate recipe

The substrate recipe contains data used by the PICOMASTER concerning the size and the shape of the substrate.

There are two situations that may occur after loading a substrate:

1. If the substrate is completely equal to a previously used substrate AND the substrate positioning tools are used, then select the applicable substrate recipe and do not change it, see **"Select an existing substrate recipe" below**.
2. For other circumstances (substrate size, height or position changes were made), make a new recipe, see **"Making a substrate recipe" on page 28**.

3.3.1 Select an existing substrate recipe

Select the recipe in the quick recipe selection bar in the lower part of the user interface, see **Figure 3-12 below**

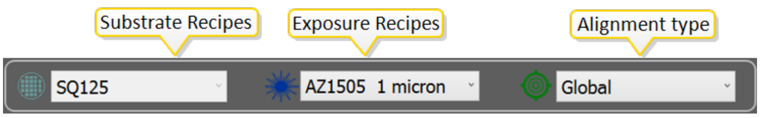


Figure 3-12 Quick selection bar

3.3.2 Writing module height adjustment

To be able to produce the correct writing laser beam size, the objective needs to have the correct distance with reference to the substrate. The distance is controlled during exposures. This is done by the **"Focus Measurement System" on page 35**.To bring the system in the correct control range, the writing module height needs to be adjusted.

1. Make sure to have height and size of the substrate available, either by using supplier data or by actual measurement.
2. Choose the Z-adjustment method:
   2.1. If the Z-axis can only be adjusted manually, use **"Manual writing module height adjustment" below**.
   2.2. If the Z-axis is motorized, use **"Motor driven writing module height adjustment" on page 26**.
3. During writing module height adjustment, make sure that the values given below are correctly noted:
   - Scan Axis Position and Step Axis Position. It is needed during the making of the substrate recipe.
   - Target Power of the Z-adjustment laser.
   - The micrometer value (manual Z-adjustment system) or the substrate thickness (automatic Z-adjustment system).

Manual writing module height adjustment

1. Make sure that the writing module is at the highest position, see **"Loading the substrate" on page 19**.
2. Select the Maintenance tab in the top bar.
3. For small substrates (< 1 Inch) only, do the substeps given below to switch on the red light, for larger substrates (> 1 Inch), continue at step **4. on the facing page**.
   3.1. select the Focus tab on the left side of the screen.
   3.2. Select the Red Laser check box.

3.3. At Target Power, type 500 and press *Enter* on your keyboard.

4. Select the Motion tab on the left side of the screen.

Warning: Risk of entrapment. Do NOT put your hands in between the writing module and the vacuum chuck. Maintenance commands can move the writing module (in X, Y and Z) with reference to the vacuum chuck while the machine window is open.

Warning: Class 3B laser, risk of eye injury. Maintenance commands can switch on the writing laser while the machine window is open. Avoid direct exposure to the laser beam at close distance.

5. While looking at the substrate, carefully move the writing module until it is visually in the middle of the substrate by using the Jogging buttons - and + .

6. Make a note of Scan Axis Position and Step Axis Position. It is needed during the making of the substrate recipe.

7. Select the Focus tab and go to the Focus section, see **Figure 3-13 below**

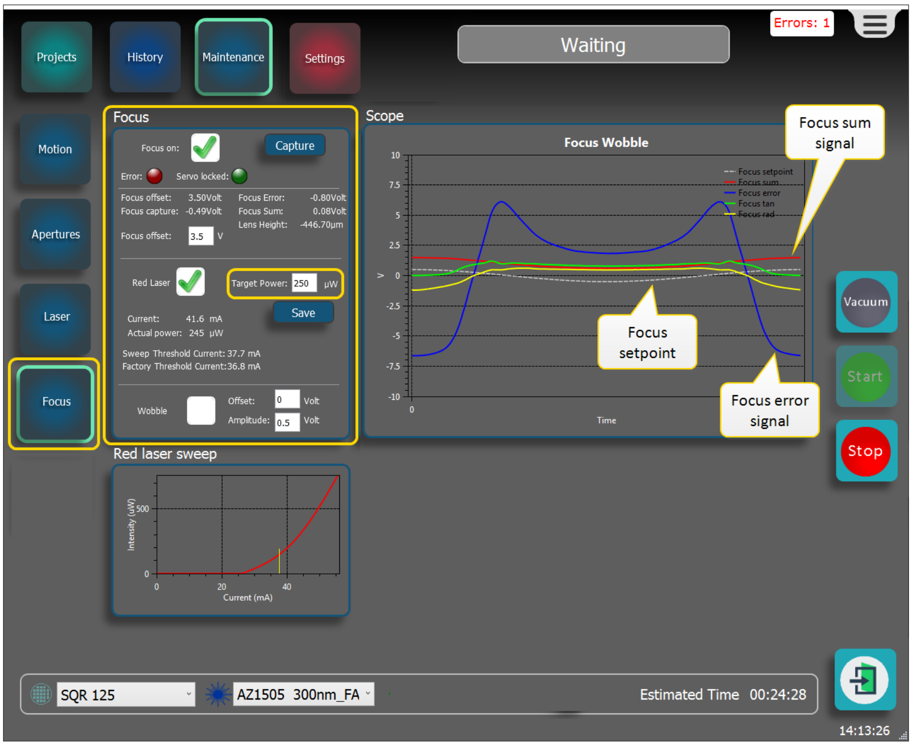


Figure 3-13 Preparing the z-adjustment

Note: The Focus On check box is automatically activated. The Capture button is not used.

8. If not yet done so, select the Red Laser check box.

9. At Target Power, type 150 and press *Enter* on your keyboard.

10. Select the Wobble check box to switch on the wobble.

Note: The wobble can only be switched on when the axes are not in home position, which is the case here.

Note: Do not change Offset and Amplitude. The Offset determines the middle position of the wobble, and the amplitude determines how much the objective moves up and down during the wobble, see also **"Focus Measurement System" on page 35** .

Figure 3-14 Turning the manual z-adjustment screw

Note: After starting the wobble, the Scope window shows noise signals.

11. Carefully turn the adjustment hand screw (see **Figure 3-14 above**) while checking the lines in the Scope window, see **Figure 3-13 on the previous page**.

12. Move the Optical Module until the noise signals in the Scope window disappear and turn into smooth lines. The writing module now approaches the substrate.

13. Carefully turn further until the Focus Sum signal starts to increase (the red line of the Focus Sum signal starts lifting). Light levels on the sensor are increasing now.

14. Check if the Focus Sum line maximum value as shown in **Figure 3-15 below** is between 2.5 and 7.5.

   14.1. If the Focus Sum Line maximum values is below 2.5, at Target Power, type a higher value and press the Enter key.

   14.2. If the Focus Sum Line maximum values is above 7.5, at Target Power, type a lower value and press the Enter key.

   Note: Correct levels for the Focus Sum line are required to bring the sensor system into the correct working range.

15. If needed, press Save to save the Target Power into current substrate recipe.

16. Make a note of the Target Power.

17. Turn the adjustment hand screw while watching the Scope window, see **Figure 3-15 below**.

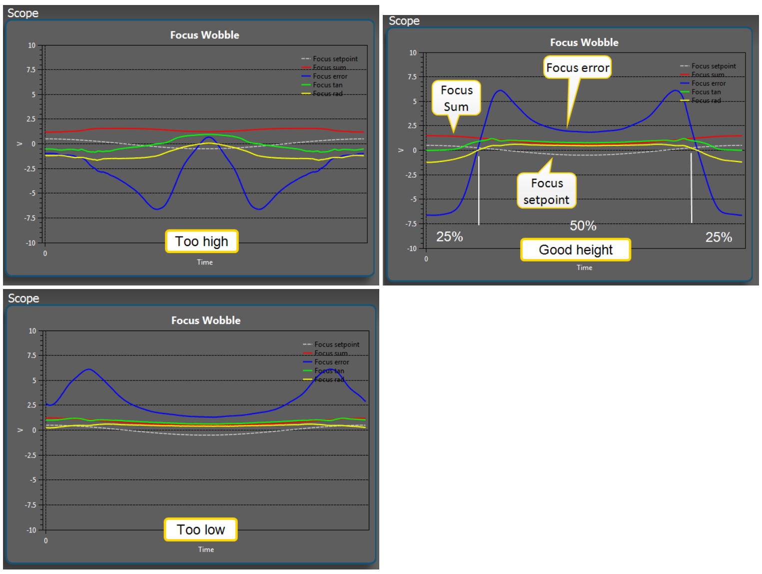


Figure 3-15 Scope window during writing module height adjustment: too high (l), good height (m), too low (r)

Note: Use the middle mouse wheel to zoom and double click the middle mouse wheel to go back to normal.

18. Turn the adjustment hand screw until both the gray dotted **and** the blue line cross the horizontal (0V) axis at the same point, see **Figure 3-16 below**.

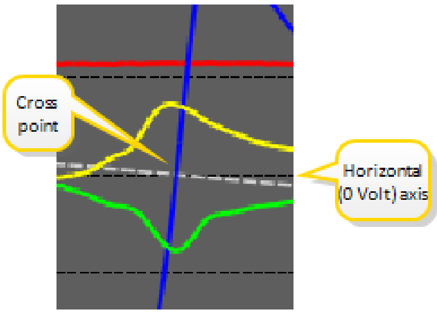


Figure 3-16 Dotted and blue line cross near horizontal axis

Note: If the gray dotted line and the blue line cross the horizontal axis at the same location, the correct writing module height is achieved

19. Make a note of the micrometer value.

Note: There is no locking as the system will stay stable itself.

Motor driven writing module height adjustment

1. Make sure that the writing module is at the highest position, see **"Loading the substrate" on page 19**.
2. Select the Maintenance tab in the top bar, see **Figure 3-17 below**.

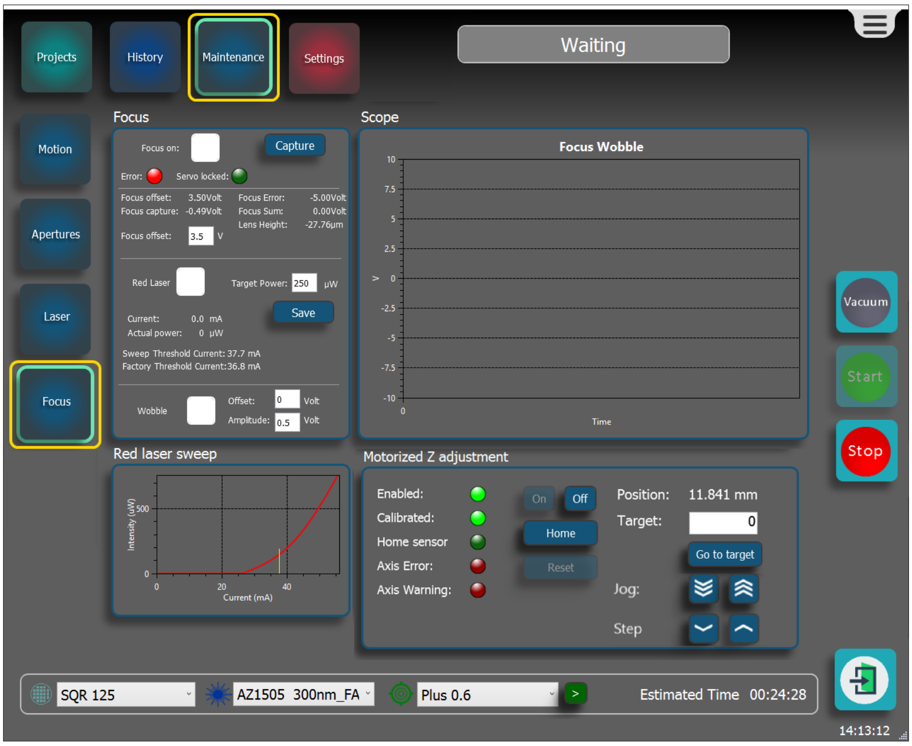


Figure 3-17 Starting semi-automatic height adjustment

3. Select Focus.
4. At Motorized Z-adjustment:
   4.1. Click On to turn on the motor.
   4.2. If the Calibrated light is OFF, then click Home to lift the writing module until the home position is detected.

Note: At Position, the actual distance between the writing module and the vacuum chuck is shown.

The Focus capture voltage indicates the height between the writing module and the substrate. After height adjustment, the capture voltage should be between -3.5V and +3.5V. Outside this range, the system will generate a warning. In the ideal situation the capture voltage should be 0 V, since this allows the auto focus to work in the nominal position. In addition, the capture voltage may have a slight influence on the focus offset. For this reason, we should fine tune the height of the writing module such that the capture voltage is as close as possible to 0 V

5. For small substrates (< 1 Inch) only, do the substeps given below to switch on the red light, for larger substrates (> 1 Inch), continue at step **6. below**.
   5.1. select the Focus tab.
   5.2. Select the Red Laser check box.
   5.3. At Target Power, type 500 and press *Enter* on your keyboard.
6. Select the Motion tab.

Warning: Risk of entrapment. Do NOT put your hands in between the writing module and the vacuum chuck. Maintenance commands can move the writing module (in X, Y and Z) with reference to the vacuum chuck while the machine window is open.

Warning: Class 3B laser, risk of eye injury. Maintenance commands can switch on the writing laser while the machine window is open. Avoid direct exposure to the laser beam at close distance.

7. While looking at the substrate, carefully move the writing module until it is visually the middle of the substrate by using the Jog buttons.

8. Make a note of Scan Axis Position and Step Axis Position. It is needed during the making of the substrate recipe.

9. Select Focus in the left bar to go back to the actual height adjustment.

Note: The Focus On check box is automatically activated. The Capture button is not used.

10. If not yet done so, select the Red Laser check box.

11. At Target Power, type 150 and press *Enter* on your keyboard.

12. Select the Wobble check box.

13. Carefully lower the writing module while watching the Scope window (**Figure 3-19 on the next page**).

14. At Position (**Figure 3-17 on the previous page**), check the actual distance between the writing module and the vacuum chuck and compare it to the known substrate height, see **Figure 3-18 below**.

Notice: Risk of machine damage and/or product loss. Risk of production loss. Typing the incorrect writing module height can make the writing module touch the substrate.

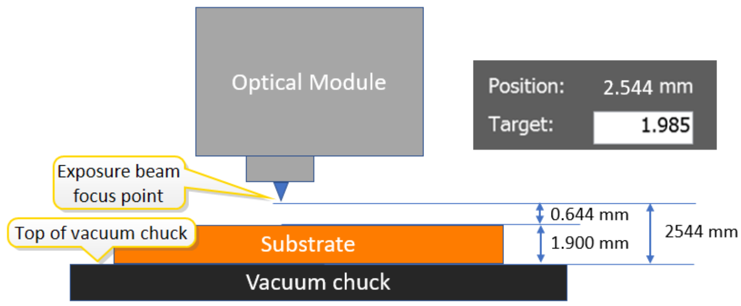


Figure 3-18 writing module motorized height adjustment

Note: The value at Position: is the distance between the top of the vacuum chuck and the exposure beam focus point.

15. Add 0.5 mm to the known substrate thickness and type in this value at Target .

16. Press Go to target to move the writing module towards this height.

17. Move the writing module further by using the below methods:

17.1. Click the Step buttons to make 0.025mm steps per click.

Notice: Risk of machine damage and/or product loss. During writing module Z-adjustment, using the Jog buttons may lead to collisions.

17.2. (Not recommended) Very rapidly touch the Jog buttons to lower the writing module with larger steps.

18. Move the writing module until the noise signals in the Scope window disappear and turn into smooth lines. The writing module now approaches the substrate.

19. Carefully move further until the Focus Sum signal starts to increase (the red line of the Focus Sum signal starts lifting). Light levels on the sensor are increasing now.

20. Check if the Focus Sum line maximum values is between 2.5 and 7.5.

20.1. If the Focus Sum Line maximum value is below 2.5, at Target Power, type a higher value and press *Enter* on your keyboard.

20.2. If the Focus Sum Line maximum value is above 7.5, at Target Power, type a lower value and press *Enter* on your keyboard.

Note: Correct levels for the Focus Sum line are required to bring the sensor system into the correct working range.

21. If needed, press Save to save the Target Power of the red light into the current substrate recipe.

22. Make a note of the Target Power.

23. Click the Step buttons to move the writing module further down while watching the gray dotted line (the focus mechanical set-point) and the blue line (the focus error) in the Scope window, see **Figure 3-19 on the next page**

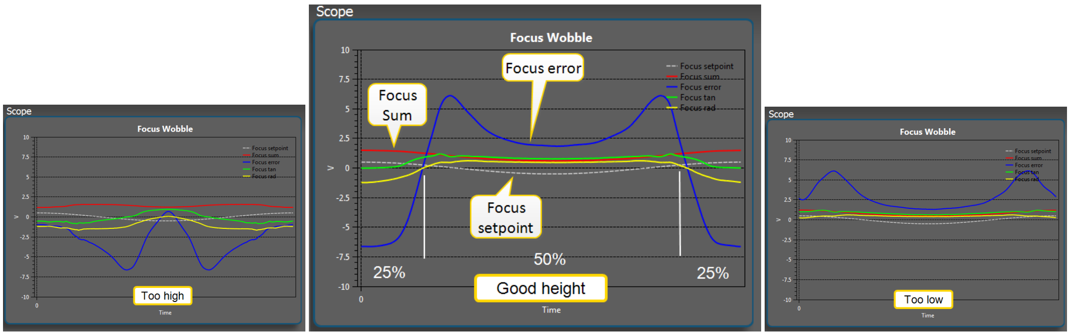


Figure 3-19 Test results: too high (l), good height (m), too low (r)

23.1. Use the middle mouse wheel to zoom and double click the middle mouse wheel to go back to normal.

24. Move the writing module until both the gray dotted **and** the blue line cross the horizontal (0 Volt) axis at the same point, see **Figure 3-20 below**.

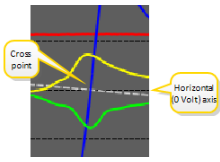


Figure 3-20 Dotted and blue line cross near horizontal axis

Note: If the gray dotted line and the blue line cross the horizontal axis at the same location, the correct writing module height is achieved.

25. Turn off the writing module height adjustment:

25.1. Press Off to turn off the Z-motor

25.2. Disable the Wobble and the Red Laser check boxes.

Note: There is no locking as the system will stay stable itself.

26. Make a note of the substrate thickness (also called the Z-height of the writing module) that you read out at Position.

3.3.3 Making a substrate recipe

Note: All recipe editors have similar buttons, see also **"Recipe editor generic information" on page 131**.

Note: If a project is part of a project queue, the recipe cannot be changed or deleted.

1. Make sure that the objective lens height is correct, do **"Writing module height adjustment" on page 22**.

2. Select Settings, see **Figure 3-21 on the facing page**.

Figure 3-21 Making a substrate recipe

Note: All sizes in this recipe setup are in mm

3. Select Substrates.

4. Start a new recipe by one of the two actions below:

 4.1. Select Add to make a new substrate recipe starting with default values.

 4.2. Select an existing recipe and select Copy to make a new recipe based on the original.

Type the recipe settings

1. Go to the Settings section.

2. At Substrate name, type a suitable substrate name.

 Note: It is recommended to use a name that tells what sort of substrate it is.

 Note: This name will also be used in the recipe quick selection list.

3. Select the Shape of the substrate:

 3.1. According to the shape of the substrate, select Round or Rectangle or Polygon.

4. At X pos and Y pos, fill in the values for the middle of the substrate as found in **"Writing module height adjustment" on page 22**.

5. At Width and Height, fill in 0.

6. Press Scan substrate for round and rectangular substrates and continue at **"Doing Round or Rectangle substrate scans" on the next page**.

7. Press Scan contour for polygon scans and continue at **"Doing Polygon substrate scans" on page 32**.

8. At Red laser power, type the power of the red laser:

 8.1. If the value was determined during the height adjustment of the optical module, make sure it is correctly filled in.

 8.2. If the value is well known for this substrate from previous recipes, you may use it, for example if you already know the reflection of the used resist.

9. Type the Edge clearance: this is the part of the substrate where no project is exposed.

Note: Below step is only applicable when a motorized Z-adjustment system is present.

10. If the substrate has large reflection variation, activate the Auto sum function:

 10.1. Click Enable auto sum.

 10.2. At Auto sum Voltage, type 4 (Volt).

When enabled, the Auto sum Voltage function adapts red the LED power of the focus measurement system to keep the output of the 4 quadrant sensor stable.

11. At Height map method, select the method for automatic height map determination (see also **"Automatic Focus control settings" on page 37** and the additional explanation block below):
    11.1. Select Focus from the drop down list to use the focus system only.
    11.2. Select Wobble from the drop down list to use the focus system with active wobble.

The height map that is used by the Focus control mode is automatically made during each start-up of an exposure. Two methods for making the height map can be chosen:

- Focus method: uses the focus system without active wobble. It is fast, but substrates/structures with large height variations or large reflection differences may lead to failing height map determination.
- Wobble method: uses the focus system with active wobble. It can cover large substrate/structure height variations or large reflection differences, but it is less fast than the focus method.

12. If needed, change the default values for the grid cell size of the height map:
    12.1. Press the Custom settings check box.
    12.2. At Measurement pitch X and Measurement pitch Y, set the new cell values in mm.
13. Type the Substrate thickness:
    13.1. If the value was determined during the height adjustment of the optical module, make sure it is correctly filled in.
    13.2. If needed, press Adjust WM height to do an automatic determination of the substrate thickness.
14. Press Save to save the recipe settings.

Note: The recipe is now available in the quick selection bar on the bottom of the screen.

15. To make the recipe active, go to Recipes and click the recipe check box, or select the recipe in the quick selection bar.

3.3.4 Scanning a substrate

The determine the shape and size of a substrate, the PICOMASTER uses two automated methods.

- The Focus capture method that uses the Focus system to find the edges of the substrate. The method determines substrate height, width and its position with reference to the machine home position.
- The Camera capture method that uses the alignment camera image to find the edges of the substrate. This method also determines substrate height, width and its position with reference to the machine home position. Additionally, in case the Polygon shape was selected, also the full shape of the substrate will be determined by a detailed contour scan.

Doing Round or Rectangle substrate scans

1. Make sure that the machine window is closed.
2. Press the Stop button to move the axes to home position.
3. Press Settings and Substrates to open the substrate recipe window.
4. At Shape, select Round or Rectangle.
5. Select Scan substrate.

The Scan Substrate starting window appears, see **Figure 3-22 below**.

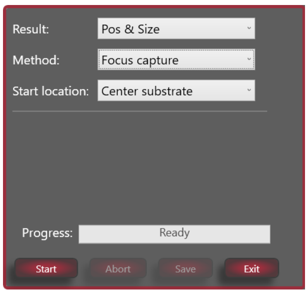


Figure 3-22 Scan Substrate starting window

6. At Start location, select where the edge scan must start:

6.1. Select Center substrate (preferred) to start at the substrate center.

6.2. Select Center machine to start at the center of the vacuum chuck.

7. At Method, select the edge scanning method:

7.1. Select Focus capture to use the Focus system, continue at step **8. below**.

7.2. Select Camera capture to use the alignment camera, continue at step **9. below**.

8. When the Focus system was selected:

8.1. Press Start.

8.2. Wait for the substrate scan to finish.

8.3. Press Save to save the scan results.

Note: Substrate width, height, and the Step and Scan positions of the top left corner of the substrate bounding box (see **"Machine coordinate system" on page 8**) are automatically filled in into the recipe after saving the scan results.

9. When the alignment camera was selected, the window enlarges, see **Figure 3-23 below**.

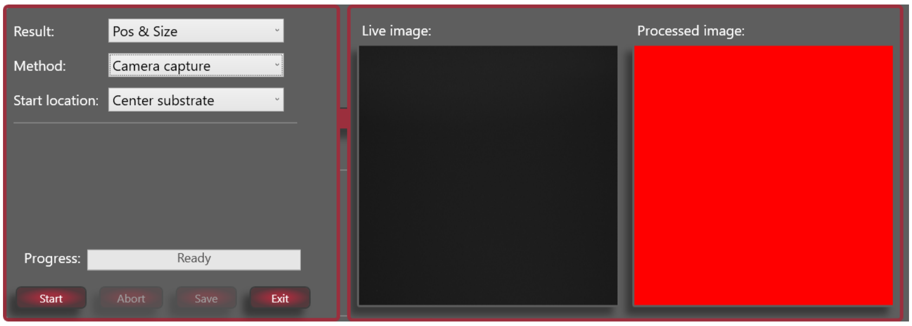


Figure 3-23 Scan substrate window after selecting the camera

9.1. Press Start.

9.2. When the first edge right of the starting position is found, check the Processed image window to see if this is a real edge, see **Figure 3-24 below**.

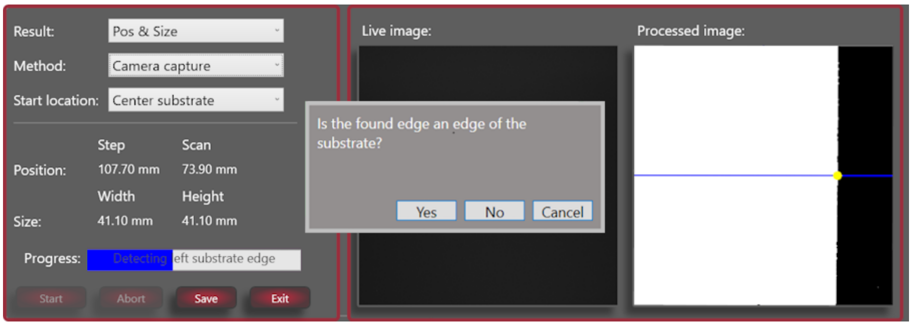


Figure 3-24 Detecting the first edge

9.3. Select Yes if the edge looks OK, the machine will now move into another substrate direction to find the next edge.

9.4. Select No if the edge looks NOK, the machine will now move on in the same direction to find the next edge.

9.5. Continue by selecting Yes or No at the all other edges until all edges are found by the camera.

9.6. Wait for the substrate scan to finish, see **Figure 3-25 on the next page**.

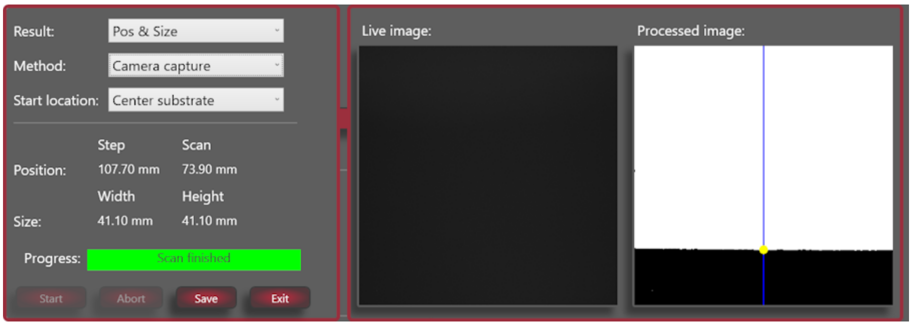


Figure 3-25 Scan finished while showing last edge

9.7. Press Save to save the scan results.

Note: Substrate width, height, and the Step and Scan positions of the top left corner of the substrate bounding box (see **"Machine coordinate system" on page 8**) are automatically filled in into the recipe after saving the scan results.

Doing Polygon substrate scans

1. Press Settings and Substrates to open the substrate recipe window.

2. At Shape, select Polygon.

3. Select Scan contour.The polygon scan selection window appears, see **Figure 3-26 below**.

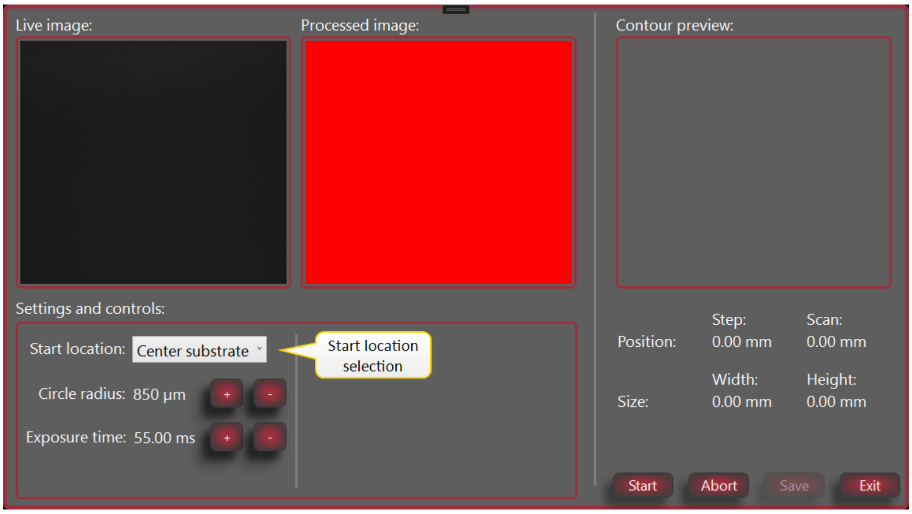


Figure 3-26 Polygon scan window

4. At Start location, select where the edge scan must start:

4.1. Select Center substrate (preferred) to start at the substrate center.

4.2. Select Center machine to start at the center of the vacuum chuck.

4.3. Select Custom location to start at selected position. Additional navigation buttons will pop up, see **Figure 3-27 on the facing page**.

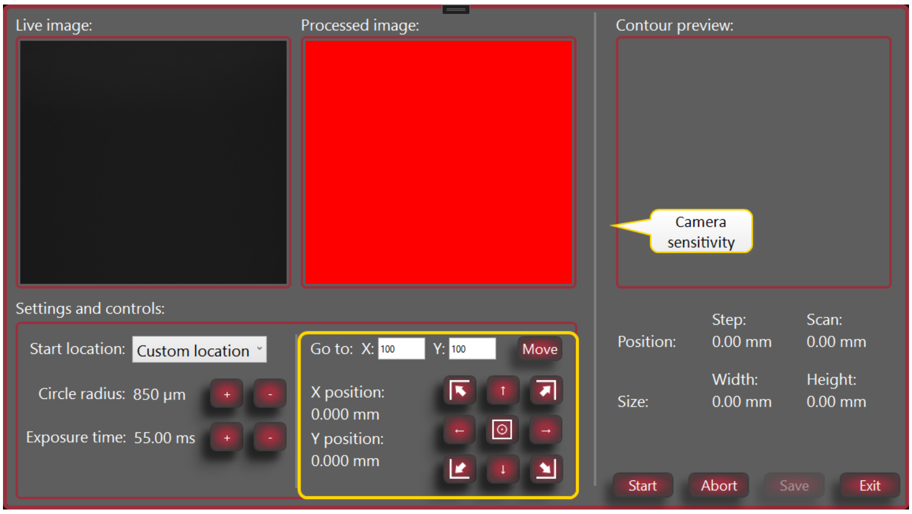


Figure 3-27 Polygon scan window with custom location selction part

5. If Custom start location was selected, position the camera using the methods below:
   - Use the navigation buttons to move the camera to the required position above the substrate.
   - Type the required position in machine coordinates, see **"Machine coordinate system" on page 8**.

   5.1. Press Set start location.
6. At Circle radius, set the radius of the circle used for the contour scan:

   6.1. Set to the maximum value (the full camera image size) to decrease the scanning duration at the cost of lower accuracy.

   6.2. Set to lower values to increase the scanning accuracy at the cost of a higher scanning duration.
7. Press Start to start the substrate scan.
8. Wait until the edge detection pop up becomes visible, see in **Figure 3-28 below**.

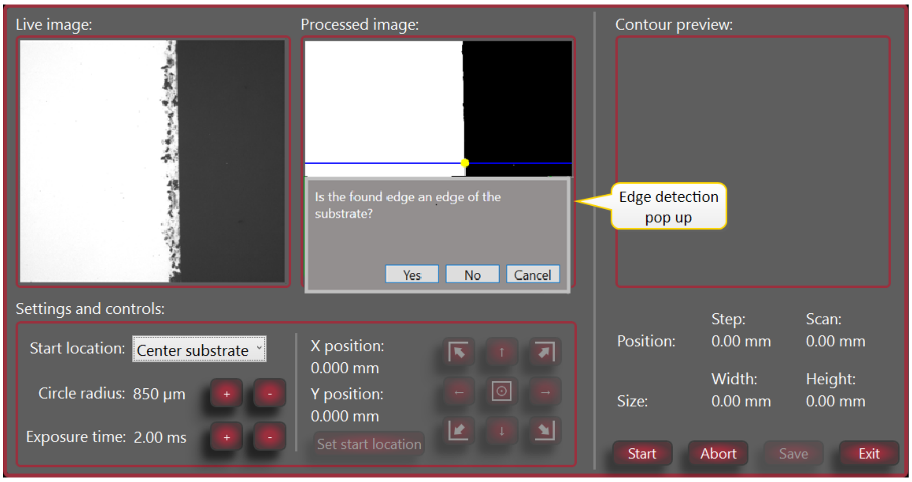


Figure 3-28 Polygon edge found

9. Inspect the Processed Image window and pres Yes to confirm or No to reject until all edges are found.
10. If the edge detection pop up does not show, or other messages appear, wait for the system to go back to home position (see **"Machine coordinate system" on page 8**).

    10.1. At Exposure time, adapt the exposure time until the intensity is correct.

    Note: Typical camera exposure times are 50-100 ms for glass substrates and 10 ms for wafers.

    10.2. Go back to step **7. above**.

The PICOMASTER automatically continues doing the contour scan, see **Figure 3-29 on the next page**.

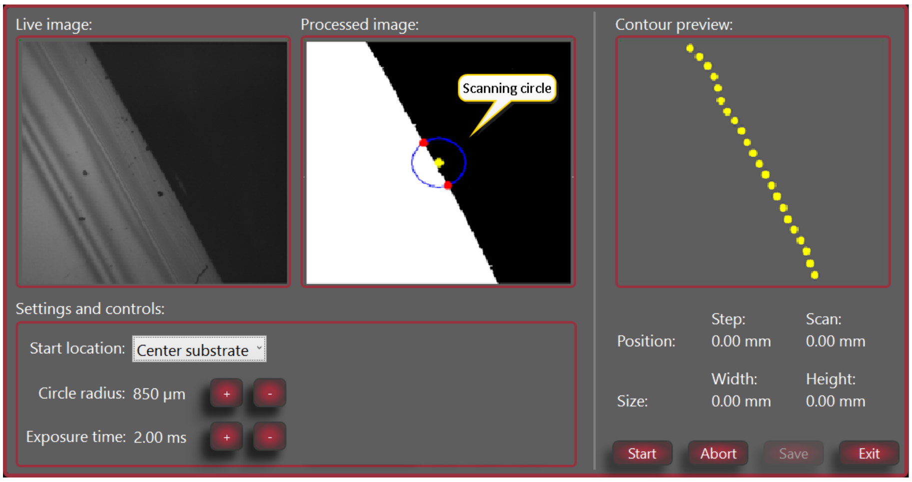


Figure 3-29 Contour scan ongoing

11. At Circle radius, if needed during the contour scan, change the radius of the scanning circle.

The scanning circle area is used to construct the full substrate shape. The automatic system moves the circle step by step while following the edge of the substrate, see **Figure 3-30 below**.

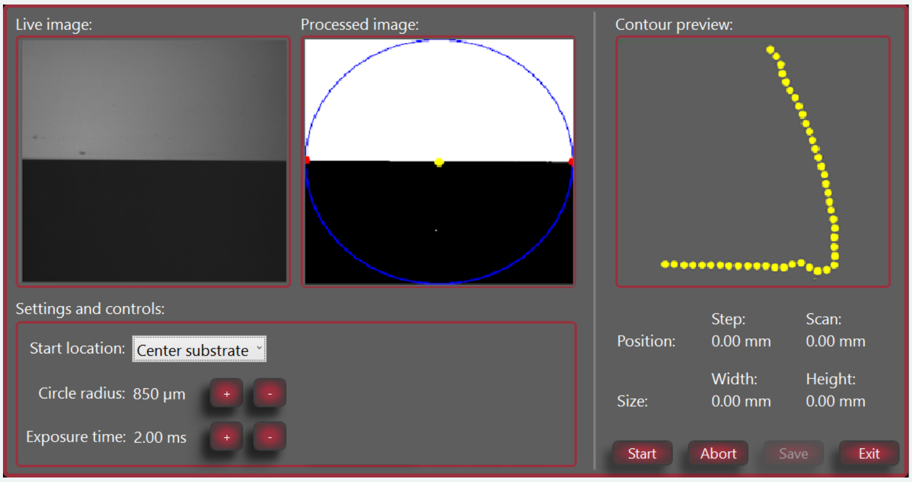


Figure 3-30 Building up the substrate contour

12. Wait for the contour scan to finish, see **Figure 3-31 on the facing page**.

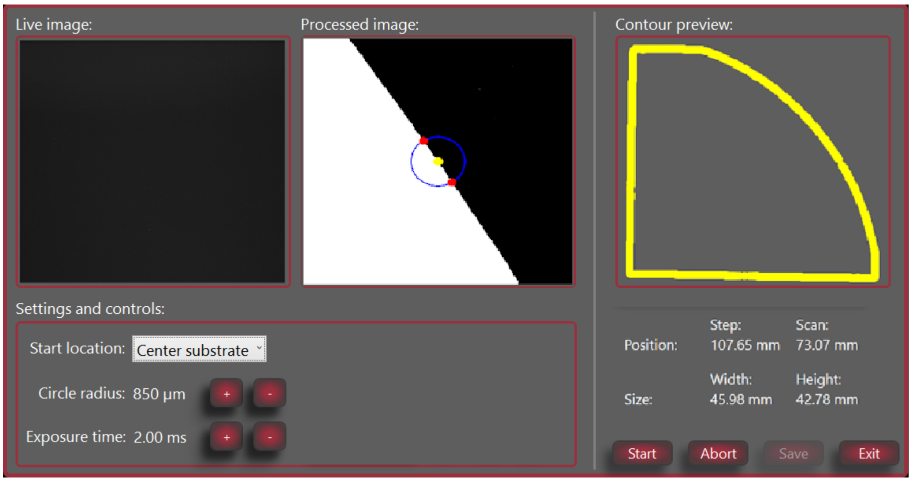


Figure 3-31 Substrate including contour scan ready

13. Press Save. to save the scan results.

Note: Substrate width, height, and the Step and Scan positions of the top left corner of the substrate bounding box (see **"Machine coordinate system" on page 8**) are automatically filled in into the recipe after saving the scan results.

14. To view the scanned substrate, select Projects in the top bar, see in **Figure 3-32 below**.

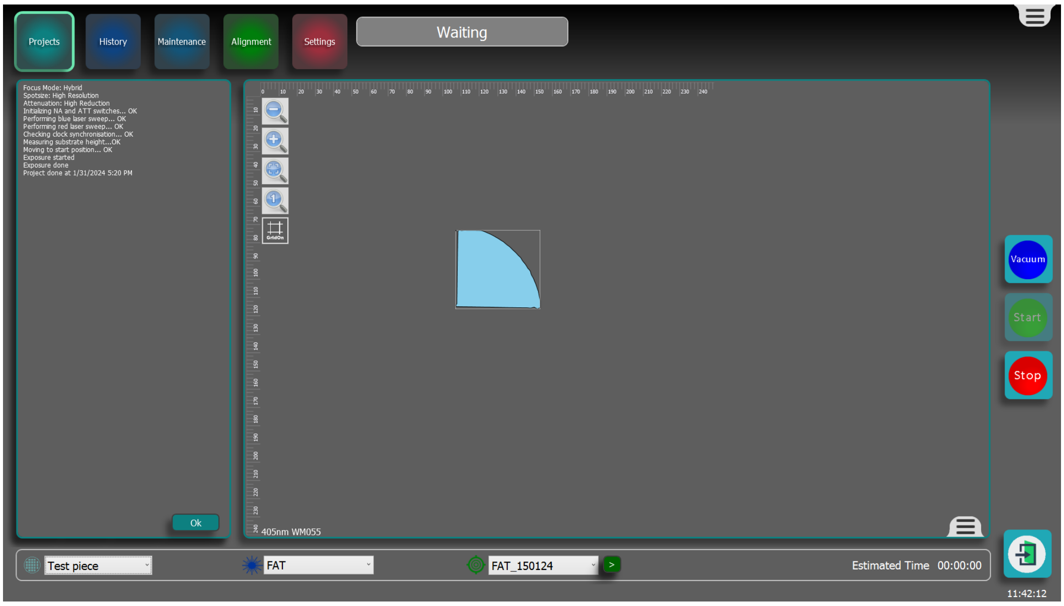


Figure 3-32 View the scanned polygon shape

3.3.5 Focus Measurement System

The Focus Measurement System uses a red LED, a sensor and additional optics.

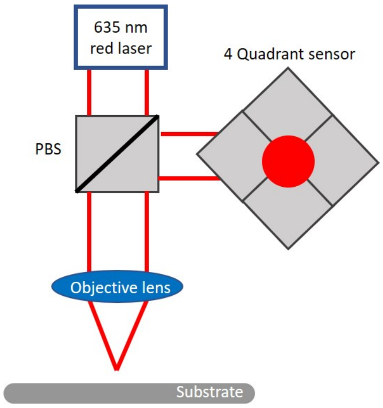


Figure 3-33 Red light system

The red LED sends the light to the objective lens that sends the light to the focus point. When the objective is close enough to the substrate, reflected light passes a Polarized Beam Splitter and is send towards a 4 quadrant sensor. The sensor data are used by the software to calculate the distance between the objective lens and the substrate. Based on this calculated distance, a voice coil actuator moves the optics. In this way, during exposures, the writing module always keeps the same distance with reference to the substrate.

Focus S-Curve

Each of the 4 quadrants of the sensor has a voltage. More light on a quadrant gives a higher voltage.

While moving the writing module towards the substrate, the 4 quadrants of the sensor get light as illustrated below, see the red spot on the sensor in **Figure 3-34 below**.

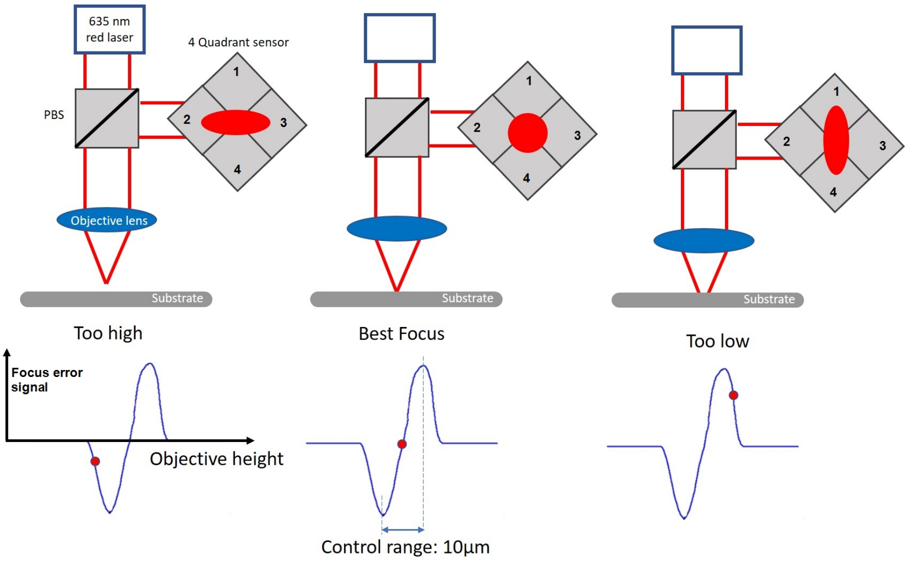


Figure 3-34 Sensor difference voltage versus writing module to substrate height

The Sum signal of all 4 quadrants indicates how much light is captured. If the value is at its maximum, the system is **close to best focus**.

The difference between quadrant 1+4 and 2+3 (also called the Focus Error Signal) indicates if the system is well focused on the substrate. If the difference is close to zero, the system is **in best focus**.

When a project is started, the Focus Measurement System first captures focus, and then continuous to follow the substrate surface.

Note: To be able to find and keep the correct focus, a reflective substrate surface is required.

Note: The Focus Measurement System cannot maintain focus when the substrate is not under the objective lens or when the distance between the lens and the substrate is too high.

Focus Wobble

The illustration below shows the movement of the objective lens in time versus the Focus Error Signal and Sum Signal. These signals can be visualized using the wobble function.

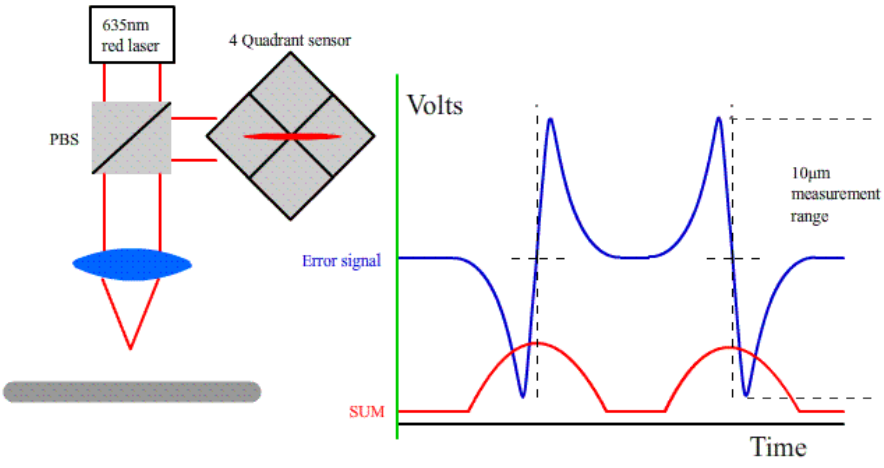


Figure 3-35 Sensor output during focus wobble

As a diagnostics tool, the PICOMASTER system has a built scope function which can visualize these signals while the wobble function is active.

Focus Offset

In theory, the optimum focus point is where the Focus Error Signal is 0 Volt. However, due to influences by electrical and/or optical offsets, type of substrate (reflection) and the used resist, the optimum focus might be slightly higher or lower. To correct for this, a Focus offset voltage can be typed into the exposure recipe. The offset is determined in the Focus Offset test, see **"Focus Test" on page 54**.

Automatic Focus control settings

There are three operation modes for focus control system. The operation mode can be selected in the exposure recipe under Focus mode.

1. Optical Mode: This is the S curve based control mode, see above. This setting has two disadvantages:
   1.1. Even one particle that is present on the substrate may already give a focus control error. This will be automatically corrected by exposing the remaining part of the stripe from the other scan direction. This gives time loss and possible line defects within the project.
   1.2. The objective lens needs to stay above the substrate, also during (de-)acceleration. This decreases the maximum exposable area of the substrate.
2. Fixed mode (also called Position Control mode): This is feed forward height control based on a height map of the project (automatically made during exposure start-up). It can be very useful under the following circumstances:
   2.1. There are particles in the resist.
   2.2. There is an unevenly coated substrate.

   Note: The accuracy of the Fixed setting is less good than the accuracy of the Optical setting.
3. Hybrid mode: this setting is preferred; it is a combination of Optical mode and Fixed mode. The Optical mode is used during the exposure until a disturbance is detected. Then, the height map is used.

Both Fixed mode and Hybrid mode have the advantage of a stable focus control and (de-)acceleration of the scan axis can be done outside the substrate. This will give a higher production.

3.4 Preparing the project

To prepare the project, exposure files have to be selected in the project browser.

There are four types of exposure files, see **"Exposure file types" below**.

To add exposure files to the project browser, see **"Adding exposure files to the computer" on page 39**.

To select projects that should be exposed on the substrate, see **"Selecting and positioning the project" on page 43**.

After selecting a project, additional features can be added, see **"Drawing additional project features" on page 44**.

3.4.1 Exposure file types

The PICOMASTER can expose different types of exposure files: project files made by Project Manager, GDS files, Gerber files and raw image files. These file types are described below.

Project files made by Project Manager

During exposures, project files are used to set exposure laser powers while writing the project, line by line, while following the address grid (see **"Address grid and rasterizing mode" on page 8**).

GDS files

A GDS (.GDS) file is a file that contains a project image that can be made using specific software (for example KLayout). During exposure of the GDS file, similar to the exposure of a project file made by Project Manager, the PICOMASTER writes the project line by line while following the address grid. The data will be rasterized on the fly during the writing process. Once the project is completed, all rasterized data will be erased.

GDS files can also be imported using Project Manager. Then, the GDS file is rasterized while making a bitmap. The rasterization may create very large files due to the high resolution that is required. During exposure, the PICOMASTER also exposes in an address grid, but now by using the bitmap data.

GDS files have specific settings that optimize the exposure results. These are described below.

Spot compensation

The rasterized data does not take the spot size of the laser into account. A point in the rasterized data is considered ON if the center of the laser spot falls within the designed structure. If these data are directly send to the laser, all structures will become larger by approximately the spot size. For this reason, a spot size compensation mode is available. In this mode, the laser is only enabled if the nearby data points also fall within the designed structure. In the advanced settings of the GDS project you can select how many data points are taken into account for this spot compensation. The compensation size can be selected on intervals that match the rasterization resolution. For this reason, the rasterization resolution can be selected independently from the step resolution of the PICOMASTER.

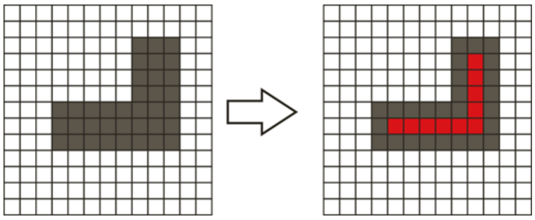


Figure 3-36 Left: No Spot Compensation; Right: Spot Compensation in use

Grayscale smoothening

Grayscale smoothening can be used to improve the result of diagonal and round features. Without grayscale smoothening, the laser can only be either fully on or off. This may result in visible steps in the diagonal and round structures in the design. When the grayscale smoothening mode is enabled, the laser power will be reduced if the laser spot falls partly outside the target structure. This has an effect that is very similar to anti-aliasing in bitmaps. The size of the grayscale compensation can be set in intervals of the rasterization resolution.

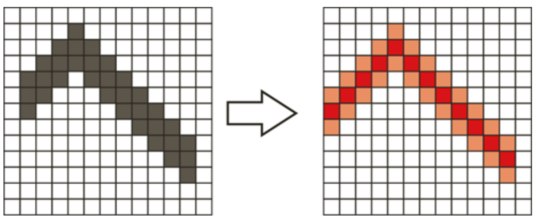


Figure 3-37 Left: No Grayscale smoothening; Right: Grayscale smoothening in use

Gerber files (option)

The rasterizing method used in project files made by Project Manager and in GDS files is not very time efficient. For projects with open spaces, during the exposure, a lot of time may be spend moving over areas that do not need to be exposed. To solve this problem, gerber files can be used.

A Gerber file (.gbr) describes the micro structures in a vector format that describes all lines to be written on the substrate. The Gerber file is made using software the can be ordered at . Raith Laser Systems BV

The original designs are typically made in Cad programs such as AutoCAD or Solid works. The software provided by Raith Laser Systems BV then converts the .DXF files that are used in these programs to Gerber files that can be used in the PICOMASTER.

During the exposure, the step and scan axis follow a path that is defined in the vector file, see in **Figure 3-38 on the facing page**.

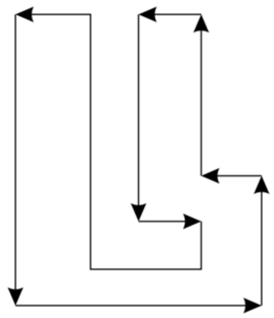


Figure 3-38 Vector Mode example of movements

The usage of a Gerber file can save time for projects in which only a small percentage of the surface area needs to be exposed.

Raw image files

Raw image files are .tif or .bmp files that contain an image that can be printed by the PICOMASTER by using the address grid.

3.4.2 Adding exposure files to the computer

There are two ways to add exposure files to the computer: using the Import function, or directly loading the files into the project folder.

Using the import function

1. Press Import, see **Figure 3-39 below**.

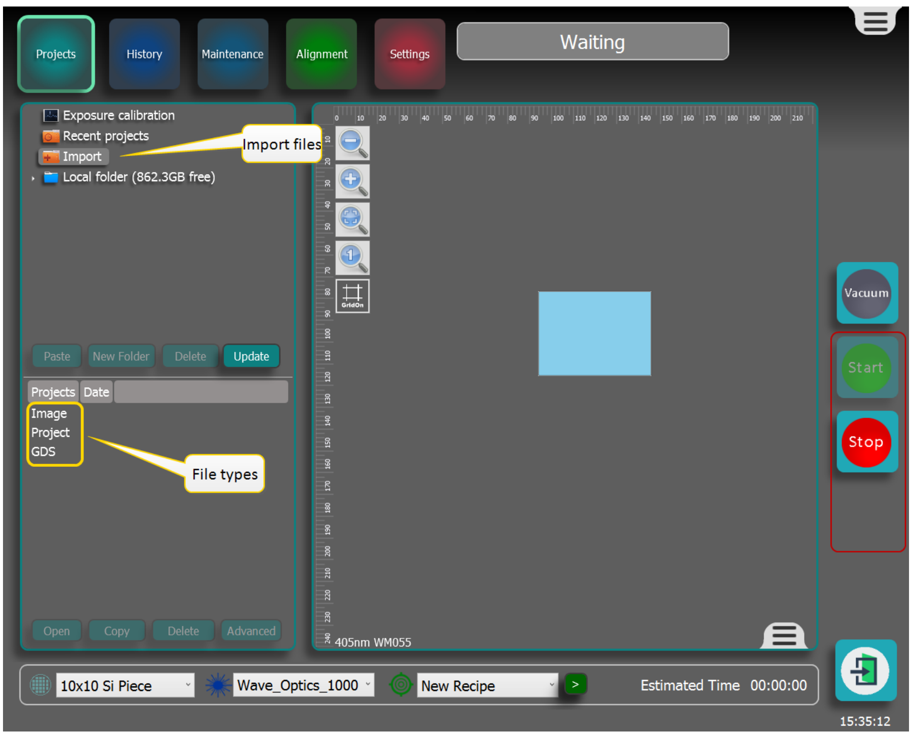


Figure 3-39 Importting a project file

2. Select the file type, see **Figure 3-39 above**.

   2.1. Select Project to import a project file made by Project Manager.

   2.2. Select GDS to import a GDS files.

   2.3. Select Image to import a raw image file (bmp or tif).

Note: Gerber files (option) cannot be imported but should be placed directly in the ProjectFolder.

3. In the file selection window, search and select the file.

Note: Under Local folder, an Import folder is automatically made that holds the imported files.

4. In the pop-up window, set the file parameters:

4.1. For Project files, see **"Set Project file parameters" below**.

4.2. For GDS files, see **"Set GDS file parameters" below**.

4.3. For Image files, see **"Set Raw Image file parameters" on page 42**.

Loading exposure files into the project folder

Save the files directly into the Project Folder.

Set Project file parameters

Note: These are files made by Project Manager.

When a Project file is imported or opened for the first time, or, after selecting it for a project, when you select Advanced, the Advanced Settings window pops up, see **Figure 3-40 below**.

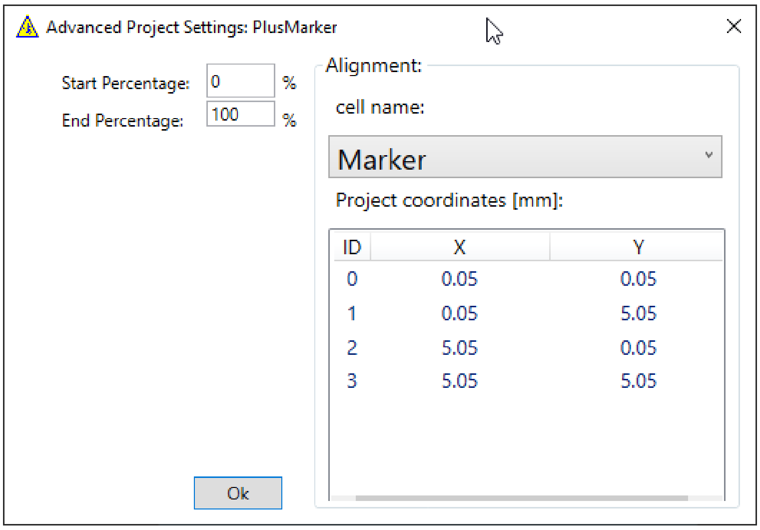


Figure 3-40 Project advanced window

1. Select the Start Percentage and End Percentage, see **Figure 3-40 above**. This determines the part of the project in x-direction that will be exposed. Normally, this is 0% and 100%.

2. Select Mirror X direction to mirror the direction of the X-steps for the project.

3. If local alignment is required (see **"Alignment introduction" on page 67**), select alignment markers:

3.1. Click to open the dropdown list that shows all available sets of exposure markers in the project file.

3.2. Select the alignment marker set.

Note: Alignment markers are defined in the project manager by adding multiple layers to the project with the same name. Only layer names for which there are at least three instances in the project can be selected.

4. Press Ok.

Set GDS file parameters

When a GDS file is imported or opened for the first time, or when you select Advanced, the Advanced Project Settings window pops up, see **Figure 3-41 on the facing page**.

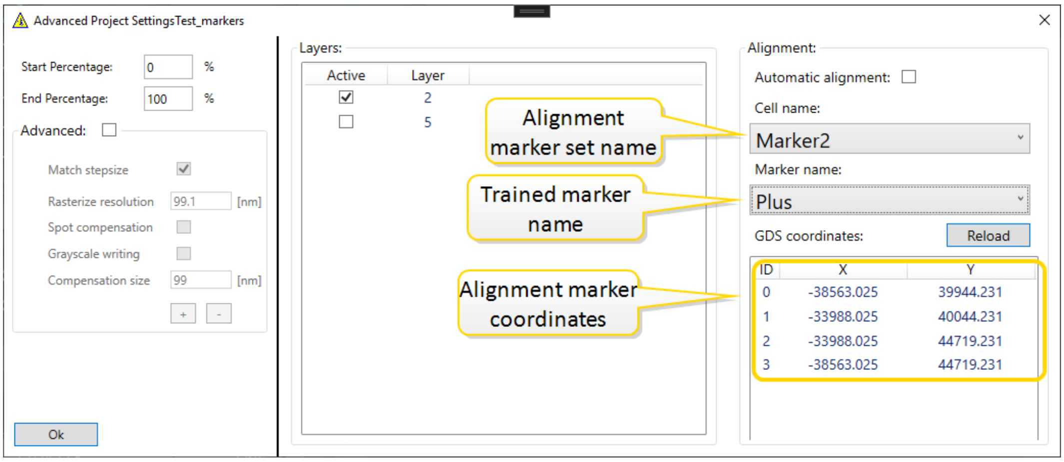


Figure 3-41 GDS Advanced Project Settings window

1. Start Percentage: Location in the project where the writing will begin.
2. End Percentage: Location in the project where the writing will finish.
3. Layers: Determines which layer in the GDS file is exposed.
4. Set the Advanced setting values:
   4.1. Activate the Advanced checkbox.
   4.2. Match stepsize: The rasterize resolution will be identical to the step resolution.
   4.3. Rasterize resolution: Resolution at which the GDS is converted into a .tif file. It is recommended that the rasterize resolution matches the step resolution. For example: for a step resolution of 160nm the rasterize resolution should either be 160, 80, 40, 20, or 10 nm.
   4.4. Spot compensation: Compensates for the Laser size to avoid overflowing the designed features, see **"Spot compensation" on page 38**.
   4.5. Grayscale smoothing: Improves diagonal and round features, see **"Grayscale smoothening" on page 38**.
   4.6. Compensation size: Selected on intervals that match the rasterization resolution. Use + and - buttons to adjust.
5. If local alignment is required (see **"Alignment introduction" on page 67**), select the alignment markers:
   5.1. Click to open the dropdown list that shows the names and coordinates of marker cell sets in the GDS file.

Note: By default, the cell sets with the name *AlignmentMarker* is shown (if in the GDS file). The GDS coordinates show the coordinates of the marker cells in the original GDS coordinate system.

   5.1. Select the marker cell set that needs to be detected during alignment.
   5.2. If the list of alignment marker coordinates is empty, press the Reload button.
   5.3. If, after pressing the Reload button, the list stays empty, check the design of the GDS file.
6. If needed, prepare for automatic alignment in a project queue:
   6.1. Select the Automatic alignment check box.
   6.2. At Marker name, select the trained marker to automatically align to.
7. Press Ok.

Set (optional) Gerber file parameters

When a Gerber file is imported or opened for the first time, or when you select Advanced, the Project Settings window pops up, see **Figure 3-42 on the next page**.

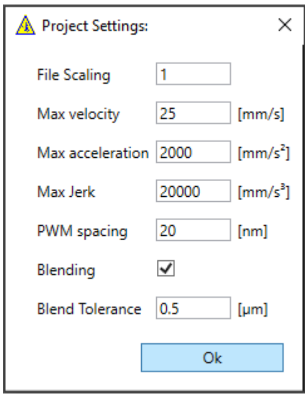


Figure 3-42 Gerber Project Settings window

Note: Leave empty to use recipe offset.

1. Set the Advanced setting values:
   1.1. File Scaling: Multiplies all coordinates with a fixed number.
   1.2. Max velocity: Maximum velocity of the combined axes.
   1.3. Max acceleration: Maximum acceleration of the combined axes.
   1.4. Max Jerk: Maximum jerk of the combined axes.
   1.5. PWM spacing: Distance between laser pulses
   1.6. Blending: Rounding corners between lines yes/no
   1.7. Blend Tolerance: Rounding radius, see **Figure 3-43 below**.

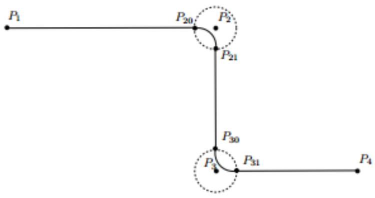


Figure 3-43 Blending tolerance

2. Press Ok.

Set Raw Image file parameters

When a Raw Image file is imported or opened for the first time, or when you select Advanced, the Advanced Project Settings window pops up, see **Figure 3-44 below**.

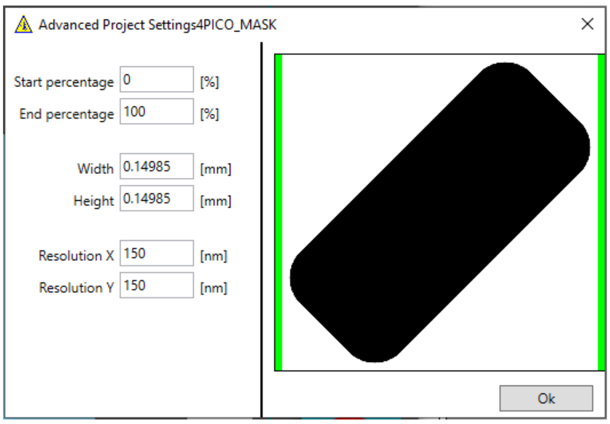


Figure 3-44 Image Advanced Project Settings window

1. Set the Advanced setting values:

1.1. Start Percentage: Location in the project where the writing will begin.

1.2. End Percentage: Location in the project where the writing will finish.

1.3. Width: Size of the image in stepping direction (x-direction) on substrate level.

1.4. Height: Size of the image in scanning direction (y-direction) on substrate level.

1.5. Resolution X: Selected width divided by image pixel size X.

1.6. Resolution Y: Selected width divided by image pixel size Y.

Note: If resolution is changed, image size will change automatically; if image size is changed, resolution will change automatically.

2. Press Ok.

3.4.3 Selecting and positioning the project

Note: Projects can be designed in the Project Manager application.

1. Select Projects, see **Figure 3-45 below**.

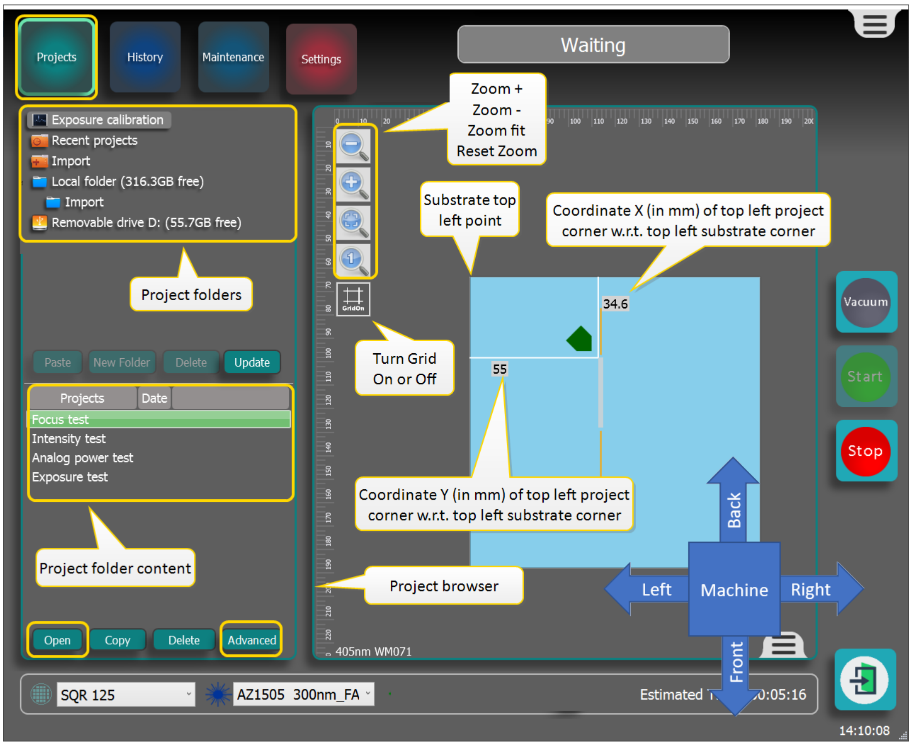


Figure 3-45 Selecting a project

2. Select the project folder:

2.1. Exposure calibration to select calibrations needed to make an exposure recipe, see **"Making an exposure recipe" on page 48** .

2.2. Recent projects to select recently used exposure files.

2.3. Local folder to select exposure files that are stored on the computer in the *ProjectFolder*.

2.4. Import to select exposure files that where imported, see **"Adding exposure files to the computer" on page 39**.

3. In the project folder content, select the project.

Note: Any selected project will be copied into the Recent projects folder.

4. If an exposure matrix of the project needs to be made, click the right mouse button and select Create exposure matrix, continue at **"Exposure Test" on page 60** .

5. To make the project active, double click it or press Open.

6. If the parameter window pops up, set parameters, see **"Adding exposure files to the computer" on page 39**.

7. Move the project to the desired location by applying the methods below:

Note: Check that the size of the project is not too large for the substrate.

7.1. Manually drag the green arrow to move the project the desired location.

7.2. Turn on the grid, drag the project over a circle and click on the red circle to center the project.

7.3. To adjust the X and Y coordinates (in mm) of the preview, click on the numbers to change them.

7.4. If the project needs to be aligned with a previously exposed project, make sure that the projects correctly overlap.

Example: if the first layer of the project was at position X=45mm and Y=65mm, the second layer of the project should also be at position X=45mm, Y=65mm. This position is used for the course positioning of the alignment cameras.

Exposure to alignment offset
The step axis has an end stop. The writing module cannot go further. Because the alignment camera is positioned 22.5mm **left** of the writing laser, for large substrates, not all positions on the substrate can be reached by the camera, see **Figure 3-46 below**.

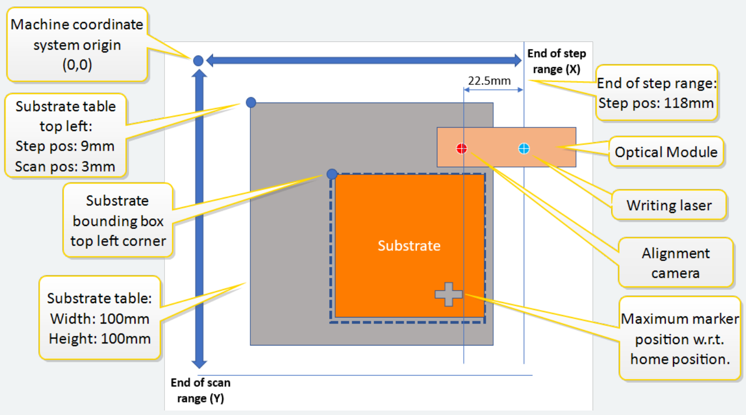


Figure 3-46 Alignment markers must be reachable by the alignment camera

8. If parameters need to be changed, select Advanced to fine tune exposure file settings:

8.1. For Project files, see **"Set Project file parameters" on page 40**.

8.2. For GDS files, see **"Set GDS file parameters" on page 40**.

8.3. For Gerber files (option), see **"Set (optional) Gerber file parameters" on page 41**.

8.4. For Raw Image files, see **"Set Raw Image file parameters" on page 42**.

Note: Any parameter update will be done in the files in the Local folder as well as in the files in the Recent projects folder.

Note: The first project that is selected for a substrate can be removed by starting another project. If more that one project is selected for the substrate, it can only be removed after adding it to a queue, see **"Queueing multiple projects" on page 111**.

3.4.4 Drawing additional project features

It is possible to manually design features on a specific location on the substrate and add them to the project.

Find the exact location for the additional features

To find a position on the substrate, the alignment positioning software is used.

1. Make sure you know the position on the substrate where you want to add features. The position values are with reference to the top left corner of the substrate bounding box, see in **Figure 3-47 below**.

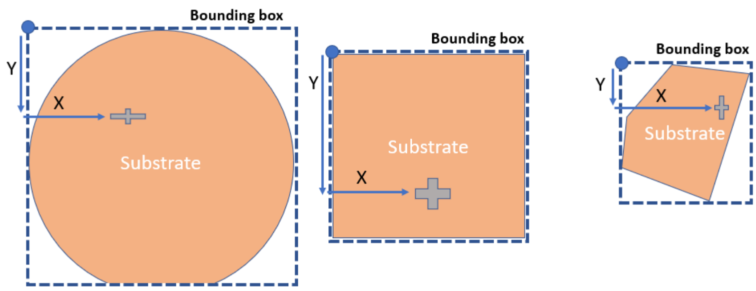


Figure 3-47 Position of an object on the substrate

Note: The position of the upper left corner of the substrate bounding box is already known by the system. It was determined during the making of the substrate recipe.

2. Select alignment type Global in the quick selection bar, see **Figure 3-48 below**.

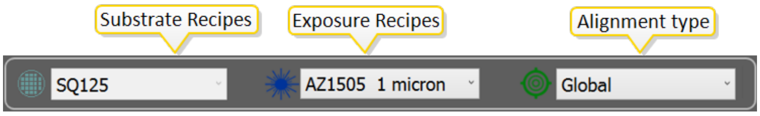


Figure 3-48 Quick selection bar

3. Press Alignment in the top bar to open the Alignment window.

4. Press Frontside AlignmentAlignment on the left side to open the alignment window.

5. Under Global Alignment Markers section, in top line, at PosX and PosY a, fill in the position with reference to the top left of the substrate bounding box that you found above.

6. At the right side of the top line, press GoTo, see **Figure 3-49 below**.

Figure 3-49 Going towards marker position

Note: The X and Y axes will now move until the writing module that holds the alignment camera is at the marker position.

7. Check if the alignment camera has the correct intensity (light gray).

7.1. If the camera intensity is not correct, go to Camera controls and adapt the exposure time until the intensity is correct.

Note: Typical camera exposure times are 50-100 ms for glass substrates and 10 ms for wafers.

8. Move the alignment camera by using one of the methods below:

8.1. Click in the Camera view window.

8.2. In the Positioning section, use the buttons with the small arrows, or fill in values at Step and Scan and press Move.

Open the draw tool

1. Make sure that the correct exposure recipe is selected, see **"Preparing the exposure recipe" on page 47**.

2. Press Draw mode to open the draw window, see **Figure 3-50 on the next page**.

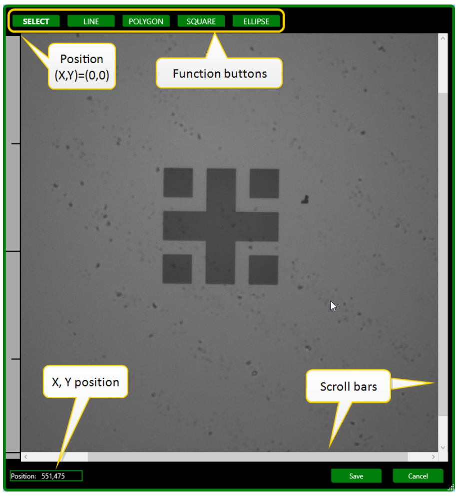


Figure 3-50 Draw window after opening

The top bar holds the function buttons. The active function has bold white text.
To Zoom, scroll the middle mouse wheel. After zoom, to move the image, use the scroll bars on the side.
The actual mouse position in micrometer is on the left bottom of the window.

Draw objects

1. Press LINE to draw a line, see **Figure 3-51 below**.

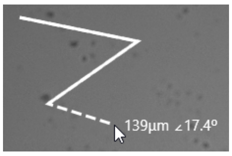


Figure 3-51 Drawing (l), clicking (m) and changing a line (r)

1.1. Hold the shift key to draw only rectangular lines.
1.2. Click the left mouse button for the starting point.
1.3. Click the left mouse button for each new corner point.
1.4. Click the right mouse button to finalize the line.
1.5. If needed, use the distance and angle information while drawing the line.

2. Press POLYGON to draw a polygon, see **Figure 3-52 below**.

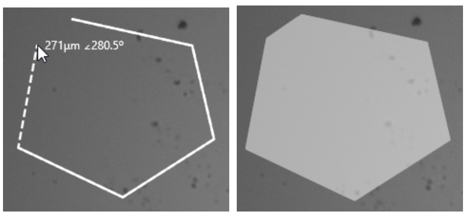


Figure 3-52 Drawing a polygon (l), polygon ready (r)

2.1. Hold the shift key to draw only rectangular polygon lines.
2.2. Click the left mouse button for the starting point.
2.3. Click the left mouse button for each new corner point.
2.4. Click the right mouse button to finalize the polygon. The polygon will be filled automatically.

3. Press SQUARE to draw a square, see **Figure 3-53 on the facing page**.

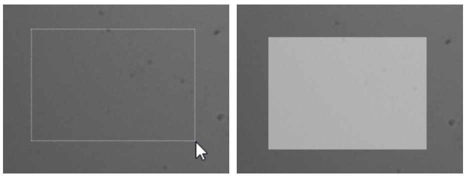


Figure 3-53 Drawing a square (l), square ready (r)

3.1. Click the left mouse button for the starting point.

3.2. Click the left mouse button to finalize the square. The square will be filled automatically.

4. Press ELLIPS to draw an ellipse, see **Figure 3-54 below**.

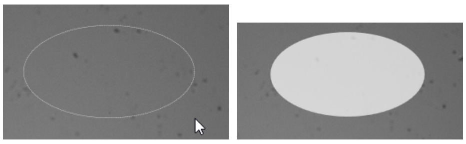


Figure 3-54 Drawing an ellips (l), ellips ready (r)

4.1. Click the left mouse button for the starting point.

4.2. Click the left mouse button to finalize the ellipse. The ellipse will be filled automatically.

5. Press SELECT to select and manipulate objects, see **Figure 3-55 below**.

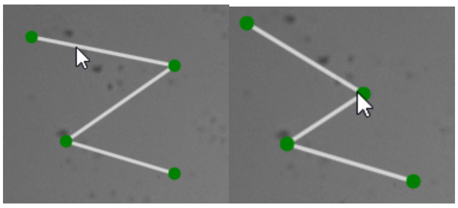


Figure 3-55 Selecting objects

5.1. After selecting, move the object by clicking and dragging.

5.2. Change object sizes by dragging the green handles.

5.3. Only squares and ellipses: rotate by dragging the outside part of the green handles.

5.4. All object changes can also be made by clicking the right mouse button and clicking on Object Properties, see **Figure 3-56 below**.

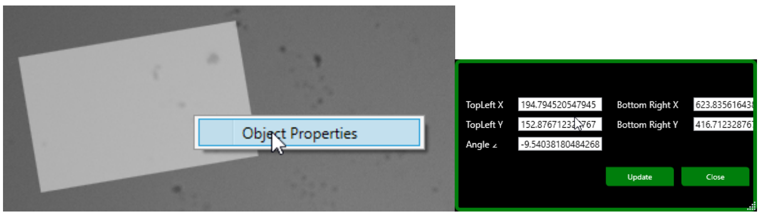


Figure 3-56 Object settings window

5.5. After selecting, objects can also be deleted.

6. Press Save to save the drawn object to the project queue.

7. Press Close to close the Draw tool.

Note: The drawn object will be exposed using the settings of the active recipe.

3.5 Preparing the exposure recipe

The exposure recipe contains exposure settings used by the PICOMASTER. It includes the exposure dose and the scan speed.

There are two situations that may occur after you loaded a substrate:

- If the process (resist type, thickness, etc.) is completely equal to previously used ones, then select the existing exposure recipe and do not change it, see **"Select an existing exposure recipe" below**.
- If the process (resist type, thickness, etc.) has changed, then make a completely new recipe, see **"Making an exposure recipe" below**.

3.5.1 Select an existing exposure recipe

If your exposure already has an existing exposure recipe , select that recipe in the recipe selection bar in the lower part of the user interface, see **Figure 3-57 below**.

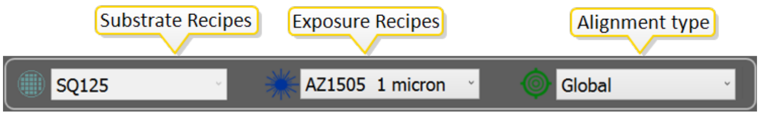


Figure 3-57 Quick selection bar

3.5.2 Making an exposure recipe

Note: All recipe editors have similar buttons, see also **"Recipe editor generic information" on page 131**.

1. Select Settings, see **Figure 3-58 below**.

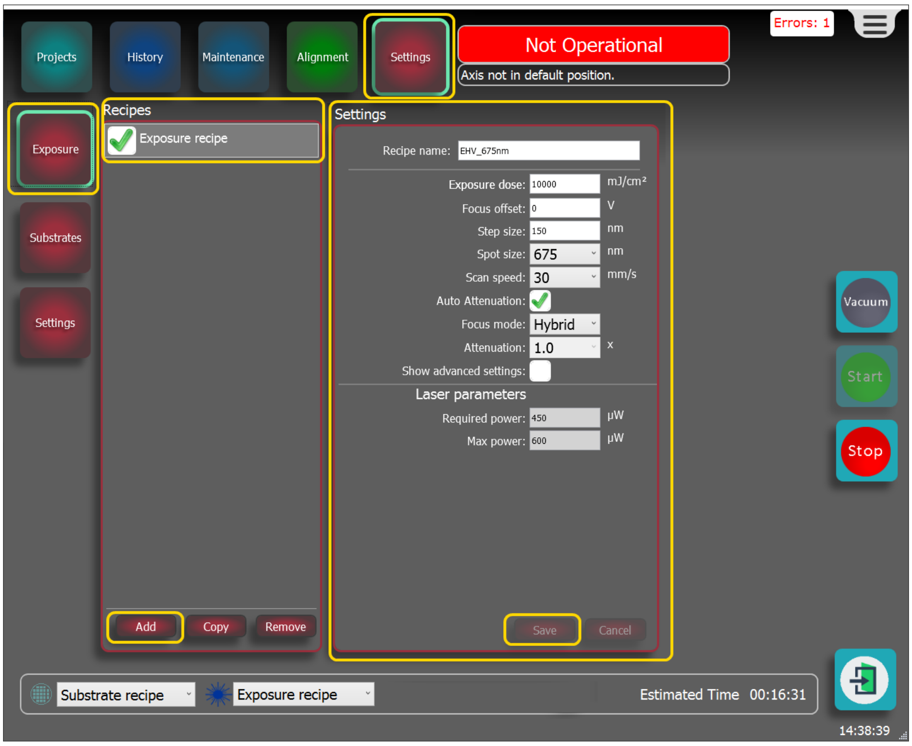


Figure 3-58 Making an exposure recipe

2. Select Exposure.

3. Start a new recipe by one of the two actions below:

   3.1. Select Add to make a new substrate recipe starting with default values.

   3.2. Select an existing recipe and select Copy to make a new recipe based on the original.

Type the recipe settings:

1. Go to the Settings part.

2. At Recipe name, type a name that represents the recipe features as good as possible.

Note: This name will also be used in the recipe quick selection list.

3. Type the Exposure dose: this is the energy dose used for the job in mJ/cm2.

Note: If no value is known, do the Intensity test to determine the exposure dose, see **"Intensity Test" on page 51**.

4. Type the Focus offset: this is the offset voltage that is applied to the Automatic Focus System, see **"Focus Measurement System" on page 35**.

Note: If no value is known, do the Focus test to determine the Focus offset, see **"Focus Test" on page 54**.

5. Type the Step size: see **"Step size" on page 11**.
6. Type the Spot size: see **"Spot Size" on page 10**.
7. Type the Scan speed : select the maximum value unless you need a higher resolution or if you need smaller acceleration length.
8. Auto Attenuation: automatically sets he attenuator such that the optimal maximum laser power is used.
9. Type the Focus mode: Hybrid (preferred), Optical or Fixed, see **"Focus Measurement System" on page 35**.
10. Attenuation: adjust until the maximum laser power (Max power) is just above the required laser power (Required power).
11. Show advanced settings: activate to fine tune the exposure results. Additional fill in fields become visible, see **Figure 3-59 below**.

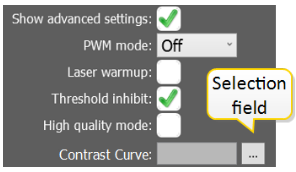


Figure 3-59 Exposure recipe advanced settings

11.1. PWM mode: Power Width Modulation: Laser on/off modulation, has a similar effect as attenuation. Disadvantage: loss of resolution in the scan direction. Advantage: for very low doses with maximum attenuation, the PWM mode can further reduce the dose.

11.2. Laser warmup: Activate to improve laser stability.

When activated, the laser threshold current is turned on as soon as the scan axis reaches 50% of it's max speed. Some resists are very sensitive, even for low doses. As the laser might show some minor intensity instability in the first hundreds of milliseconds after turning on due to heating up of the laser, the resulting structures might vary slightly from the beginning to the end of the scan stroke. Turning the threshold current on, before the actual image is started reduces this variation. However, when the threshold current is selected to high, there will be a visible exposed area outside the image area. The laser inhibit setting is only active where the actual image is written. Outside the image area, this setting has no influence. The Laser warmup setting determines the behavior of the laser outside the image area.

11.3. Threshold inhibit: normally activated, deactivate to turn on threshold current during the whole exposure.

When threshold inhibit is turned off, the laser threshold current is turned on during the exposure of the whole image. This might affect areas where no data is supposed to be written, as some photo resists are very sensitive, even for very low doses. Threshold inhibit on the other hand may lead to a less (thermally) stable laser control system (because of continuous switch off and on of the laser) which might effect the pattern edges of the project.

11.4. High quality mode: If activated, when Single Direction Writing is enabled, the PICOMASTER will only write while the step axis is moving in one direction.

Note: This setting will double the time it takes to write a project.

12. At Contrast Curve, if required, apply contrast corrections:

Exposure correction curve

During grayscale exposures, the Fast Dac setting (see **"Manual laser controls" on page 113**) is adjusted on the fly. By doing so, the system may use a contrast correction file. This file allows to correct for non-linear exposure/development effects. The contrast correction file defines a curve that maps the input (design value) to the output (laser power). It adds a correction factor to the requested writing laser intensities, as shown in the contrast curve examples of **Figure 3-60 below**.

Figure 3-60 Default uncorrected curve (l) and contrast curve with correction including csv file(r)

The default uncorrected linear contrast curve on the left side leaves the laser output values uncorrected. The contrast curve on the right side influences the output such that it fits better to the behaviour of the resist.

The corresponding file is a csv file (comma-separated values) which can easily be made in excel and saved in csv format. Different files can be used, like the step file shown in **Figure 3-61 below**.

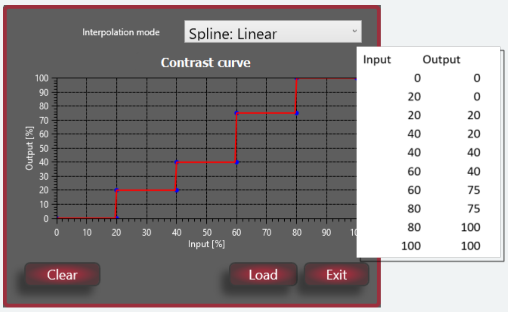


Figure 3-61 Correction curve with steps

12.1. If not available, make a new contrast correction file, for an example, see **"Making an exposure correction file - example" on page 63**.

12.2. At Contrast curve, press the selection field to open the contrast curve window that shows the current contrast correction file, see the example in **Figure 3-60 above**.

13. Press Load to select the contrast correction file, see **Figure 3-62 below**.

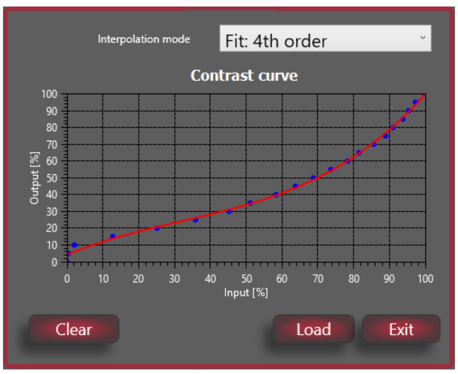


Figure 3-62 Contrast correction curve using 4th order interpolation

14. From the drop down list, select the fitting method:

- Spline: Linear: a straight line from point to point

- Spline: Cubic: an Akima spline is used to interpolate between data points. The Akima spline uses 5 consecutive data points to produce a moving value.
- Fit: 1st/2nd/3th/4th/5th order: a polynomial of 1st/2nd/3th/4th/5th order is used to fit all data points.

15. If the current contrast correction file needs to be deleted, then press Clear. The system will go back to default uncorrected linear contrast curve.
16. Press Exit.
17. Required power (read only): laser power, which is automatically set, needed to achieve the required dose given all other settings.
18. Max power (read only): Maximum reachable power for the selected attenuation.
19. Press Save to save the recipe settings.

Note: The recipe is now available in the quick selection bar on the bottom of the screen.

20. To make the recipe active, go to Recipes and click the recipe check box, or select the recipe in the quick selection bar.

3.5.3 Intensity Test

The Intensity Test determines the optimum exposure dose.

The intensity test allows you to quickly write a grating structure while varying the exposure dose. This allows you to quickly estimate a suitable exposure dose for the photo resist. The intensity test starts and ends with the dose that is set up in the currently active exposure recipe.

Expose en develop the substrate

1. If not yet done do, load a substrate, see **"Loading the substrate" on page 19**.
2. To start the Intensity Test, select Projects, see **Figure 3-63 below**.

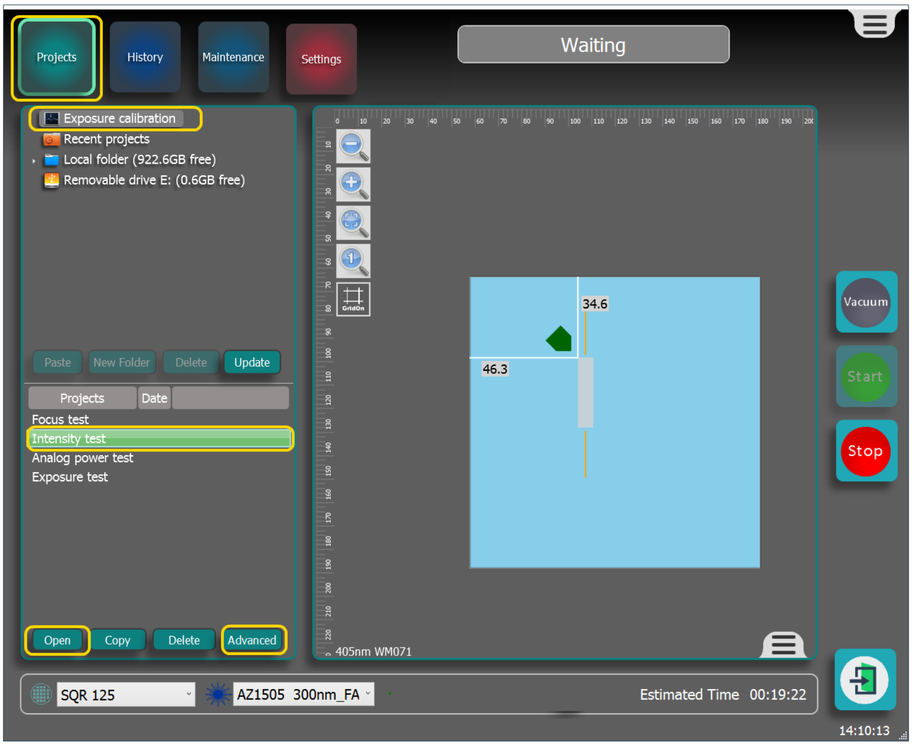


Figure 3-63 Starting the Intensity Test

3. Open the *Exposure calibration* folder from the Projects Browser
4. Select the *Intensity test* project by double clicking or by pressing Open.
5. If needed, drag the project to the desired position on the substrate.
6. Select Advanced to check and adjust the advanced settings, see **"Advanced Settings for Intensity Test" on the next page**.
7. Activate the vacuum by pressing the vacuum button on the screen or on the front panel.
8. Start the test by pressing the start button on the screen.

9. Wait for the test to finish.

10. Remove the substrate, see **"Removing the substrate" on page 112**.

11. Develop the resist.

1. Load the substrate.

2. Press Alignment in the top bar to open the Alignment window.

3. Press Frontside Alignment on the left side of the window.

4. In Global Alignment Markers section, in the top line, at PosX and PosY a, fill in the location of the exposure with reference to the top left of the substrate bounding box.

5. Press GoTo. see **Figure 3-64 below**.

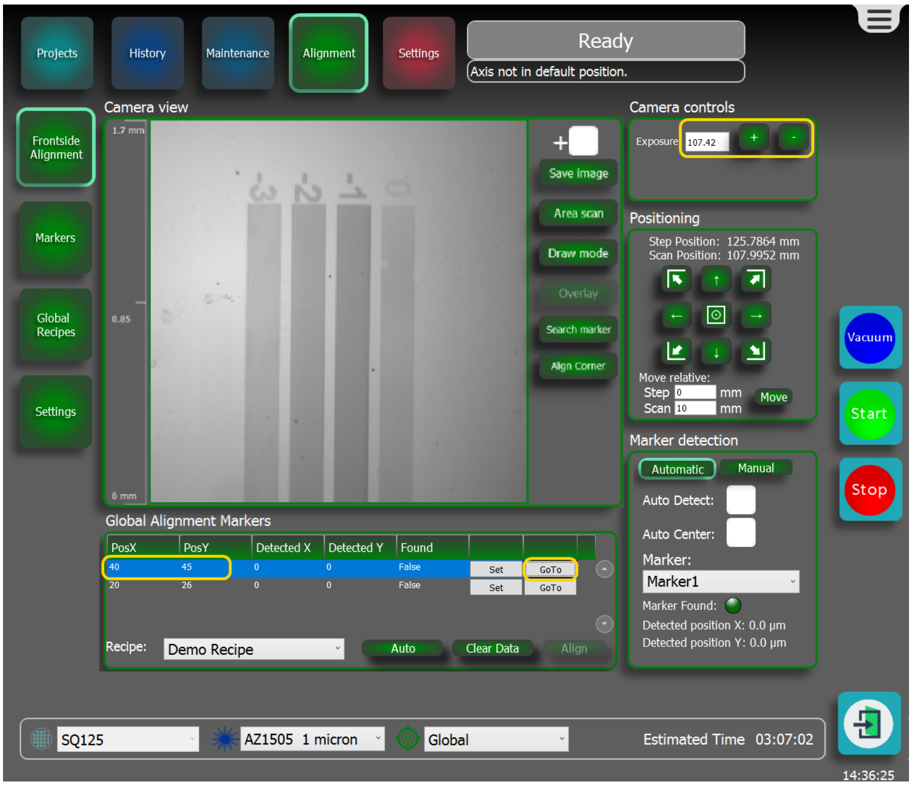


Figure 3-64 Going towards marker position

> **Note:** The X and Y axes will now move until the writing module that holds the alignment camera is at the marker position.

6. Determine the best dose, see **"Determining the best exposure dose" on the facing page**.

Advanced Settings for Intensity Test

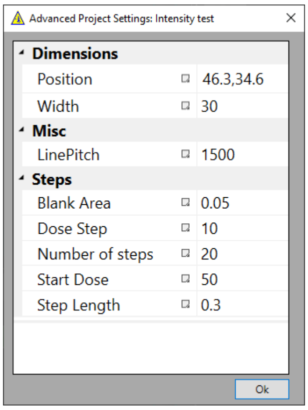


Figure 3-65 Intensity Test advanced settings

Dimensions

Position: exposure start position (X,Y, in mm and separated by a comma) relative to the left top of the substrate bounding box. (It is also possible to drag the image over the substrate surface or enter the coordinates in the project work area)

Width: Length of the lines in the test.

Misc

LinePitch: distance between the lines in nm.

Steps

Blank area: the amount of blank space (non-exposed area) between each block of lines in mm.

Dose Step [mJ/cm2]: dose increase per step.

Number of steps: number of dose steps to make.

Start Dose [mJ/cm2]: the value of the first dose.

Step length: Width of one set of lines.

Determining the best exposure dose

The Intensity Test exposes line sets. Each line set has a different dose.

An example of test results in resist is shown in **Figure 3-66 on the next page**.

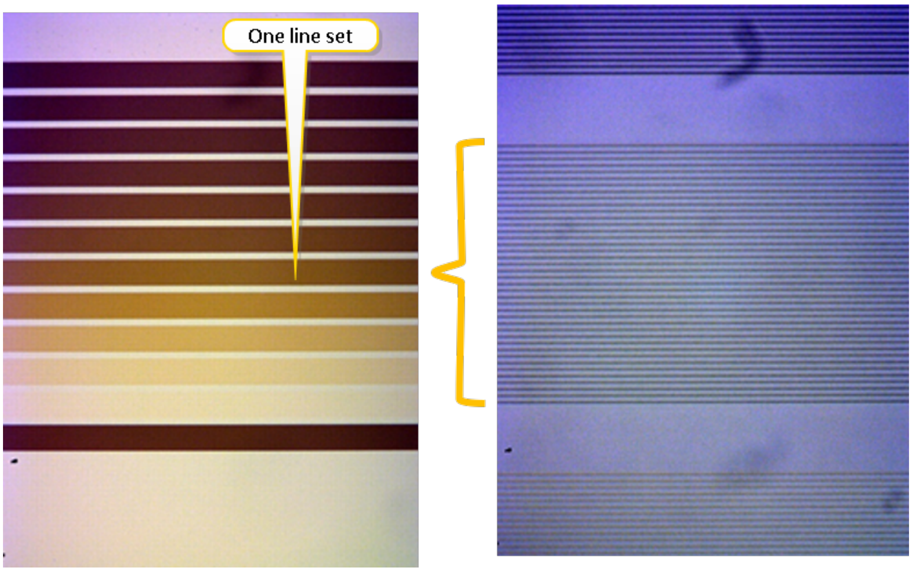


Figure 3-66 Intensity Test exposure results: sets of lines with different doses

By analyzing the contrast of each line set, it can be seen whether the grating is overexposed or underexposed.

In the underexposed blocks, the bottom of the photoresist is not reached. This is visible as shallow lines with a lack of contrast.

In the overexposed area, the width of the lines will start to increase.

There are numbers at the top of the lines that show the dose they were written with.

3.5.4 Focus Test

The Focus Test determines the optimum focus offset.

1. If not yet done do, load a substrate, see **"Loading the substrate" on page 19**.

2. To start the Focus offset test, select Projects, see **Figure 3-67 below**.

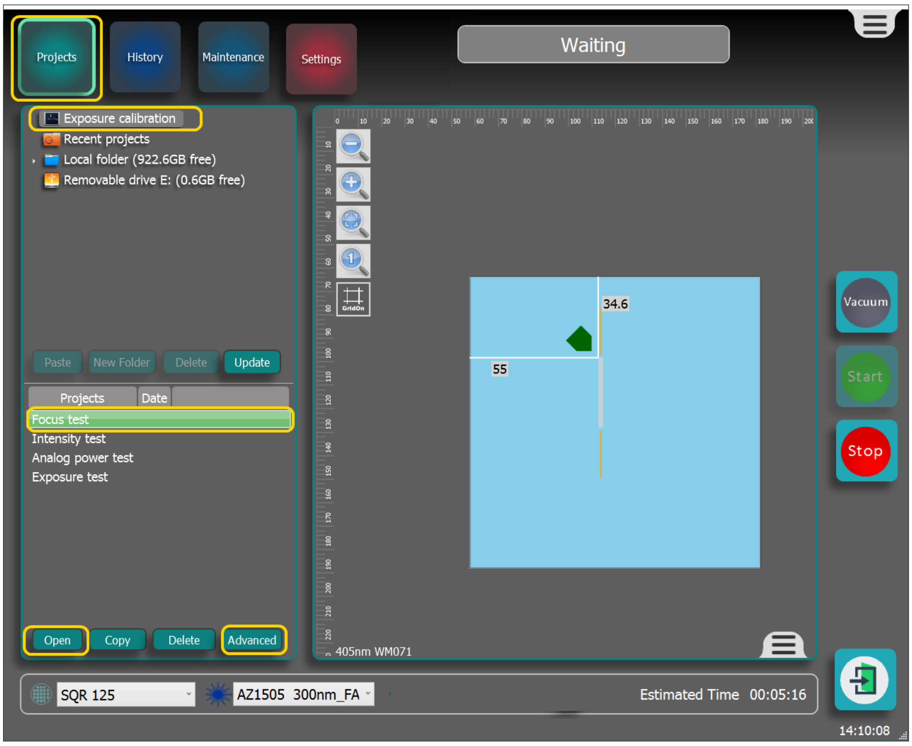


Figure 3-67 Preparing the Focus Test

3. Open the *Exposure calibration* folder from the Projects Browser.

4. Select the *Focus test* project by double clicking or by pressing Open.

5. If needed, drag the project to the desired position on the substrate.

6. Press Advanced to check and adjust the advanced settings, see **"Focus test parameters" on the next page**.

7. Activate the vacuum by pressing the vacuum button on the screen or on the front panel.

8. Start the test by pressing the start button on the screen.

Note: The focus test will expose a number of blocks consisting of lines in one direction. Each block will have a different focus offset. The focus offset used in each block is based on the current focus offset as set in the exposure recipe and the index of the block.

9. Wait for the test to finish.

10. Remove the substrate, see **"Removing the substrate" on page 112**.

11. Develop the resist.

1. Load the substrate.

2. Press Alignment in the top bar to open the Alignment window.

3. Press Frontside Alignment on the left side of the window.

4. In Global Alignment Markers section, in the top line, at PosX and PosY a, fill in the location of the exposure with reference to the top left of the substrate bounding box.

5. Press GoTo. see **Figure 3-68 below**.

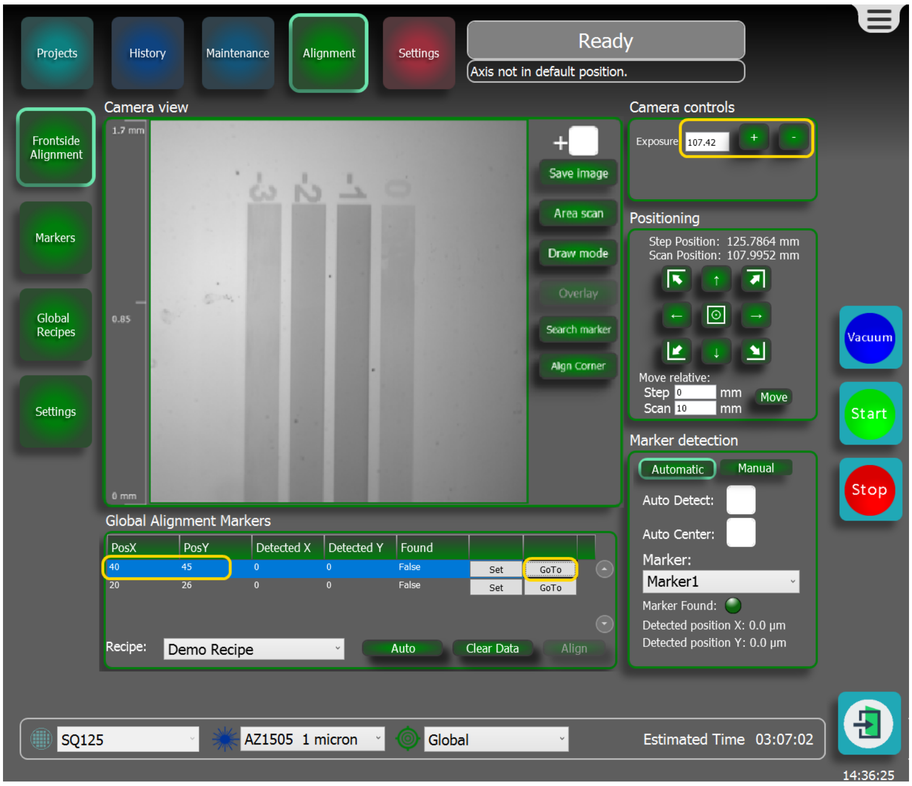


Figure 3-68 Going towards marker position

Note: The X and Y axes will now move until the writing module that holds the alignment camera is at the marker position.

6. Determine the focus offset, see **"How to determine the focus offset" on page 57**.

Focus test parameters

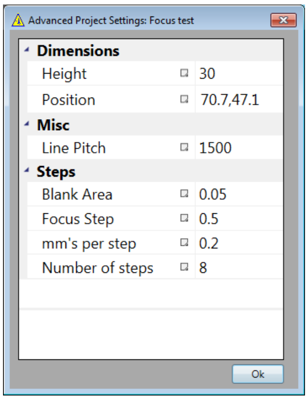


Figure 3-69 Focus test parameters

Dimensions

Height: (Default value: 30) The height of the image in mm.

Position:exposure start position (X,Y, in mm and separated by a comma) relative to the left top of the substrate bounding box. (It is also possible to drag the image over the substrate surface or enter the coordinates in the project work area)

Misc

Line Pitch: (Default value: 1000) The distance in nanometers between each line written.

Steps

Blank Area: (Default value: 0.1) The amount of blank space (non exposed area) between each block of lines in mm.
The 'mm's per step' parameter includes the blank area. Making the blank area larger then the 'mm's per step' parameter will result in an empty image.

Focus Step: (Default value: 0.5) The voltage the focus offset will increase between each step.

mm's per step: (Default value: 1) The width in mm of each step including the blank area.

Number of steps:(Default value: 5) The amount of focus steps positive and negative from the nominal focus offset as set in the currently selected exposure recipe. The total number of steps is 2* *n* + 3.
In the above image, n represents the *Number of steps*.

How to determine the focus offset

The focus test exposes 13 blocks. Each block is a grating that has lines in one direction.

In the figure below, you see the 13 focus block gratings.

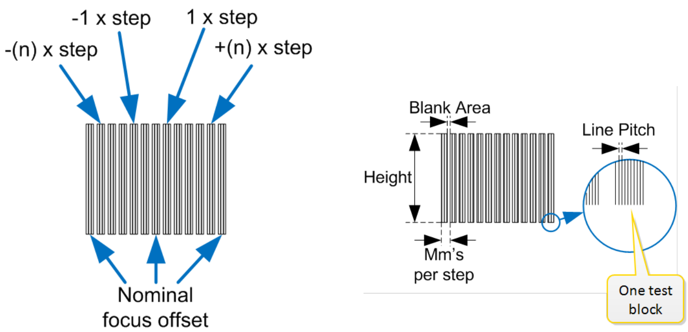


Figure 3-70 Focus test blocks after exposure

Each block was exposed at a different Focus height. In the middle and on the side, the focus is the set value in the exposure recipe. Going from the middle to the left, the focus gets lower in n steps. From the middle to the right, the focus get higher in n steps. The lines at the end help as a reference when you are inspecting the lines in all blocks under a microscope.

Using a microscope, inspect the contrast of the lines to determine the optimum focus offset. When the highest contrast line is found, it is possible to read the value at the top and bottom of each set of lines.

As an example, a focus test was run using 5 steps and a focus step of 0.5V.

Figure 3-71 Best focus determination by micriscope

In the used exposure recipe, the focus offset is set to +1V. This means, in this case, that the best contrast band is 3 steps left from the nominal band, This means that the optimal focus offset is +1 - 3*0.5 = -0.5V. Use this new value, -0.5V, as new focus offset for the current selected exposure recipe.

3.5.5 Analog Power Test

The test is used to determine the exposure dose for grayscale exposures.

The Analog Power Test is needed to find the exact dose at which we reach the bottom of the photoresist after developing.

1. If not yet done do, load a substrate, see **"Loading the substrate" on page 19**.

2. To start the Analog Power Test, select Projects, see **Figure 3-72 on the next page**.

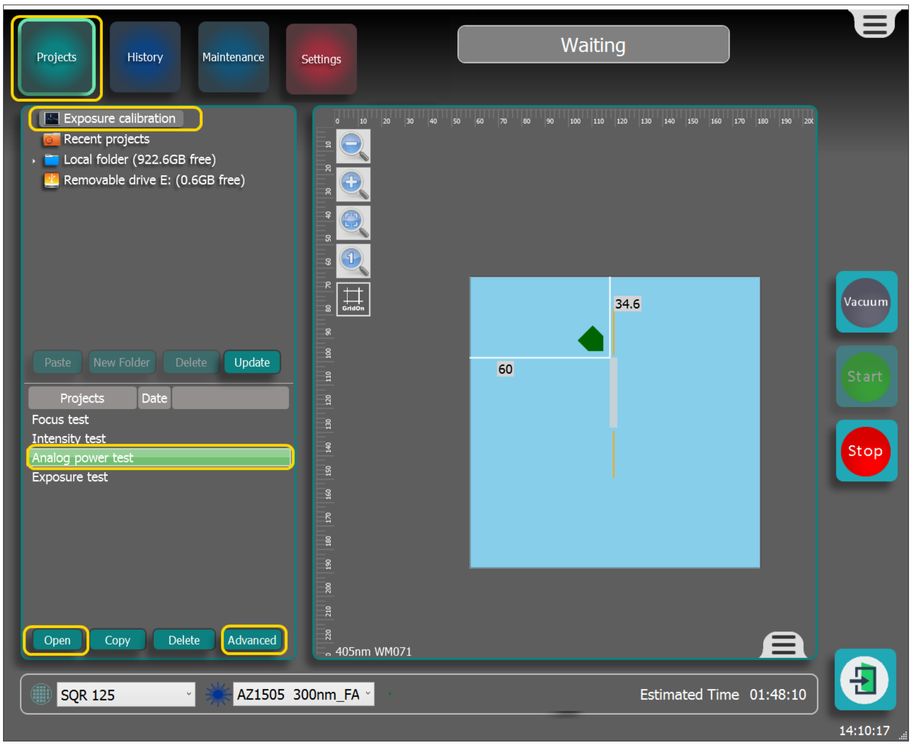


Figure 3-72 Starting the Analog Power Test

3. Open the *Exposure calibration* folder from the Projects Browser

4. Select the *Analog power test* project by double clicking or by pressing Open.

5. If needed, drag the project to the desired position on the substrate.

6. Press Advanced to check and adjust the advanced settings, see .**"Advanced Settings for Analog Power Test" on the facing page**

7. Activate the vacuum by pressing the vacuum button on the screen or on the front panel.

8. Start the test by pressing the start button on the screen.

9. Wait for the test to finish.

10. Remove the substrate, see **"Removing the substrate" on page 112**.

11. Develop the resist.

12. Place the product under a microscope.

13. Determine the best exposure energy, see **"How to determine the best exposure energy" on the facing page**.

Advanced Settings for Analog Power Test

The advanced settings window is shown in **Figure 3-73 below**.

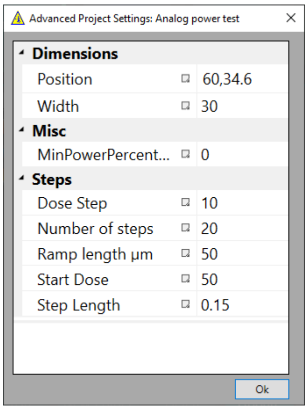


Figure 3-73 Analog Power Test advanced settings

Dimensions

Position: exposure start position (X,Y, in mm and separated by a comma) relative to the left top of the substrate bounding box. (It is also possible to drag the image over the substrate surface or enter the coordinates in the project work area)

Width: Length of the lines in the test.

Misc

MinPowerPertentage: Minimum power used during recording

Steps

Dose Step [mJ/cm2]: The amount of intensity increase in each step

Number of steps: The number of intensity steps to make

Ramp length[µm]: Length of the ramp in µm

Start Dose [mJ/cm2]: the intensity at which the first step will start

Step Length: Width of the saw tooth.

How to determine the best exposure energy

During the analog power test, the power to the laser is set in a sawtooth pattern, see **Figure 3-74 below**

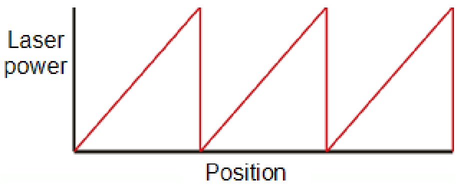


Figure 3-74 Laser power pattern during the Analog Power Test

If the exposure dose is too low, we do not recognize the saw tooth structure in the photoresist. If the power is too high, a flat area will be recognizable under the microscope. This flat area is caused by the fact that the exposure dose at the point of the sawtooth is higher than the required dose to reach the bottom of the photoresist.

We want to set the exposure dose such that we do not have this flat area.

When the best test results are identified, read the dose value (in mJ/cm^2) at the top of each column, see **Figure 3-75 on the next page**.

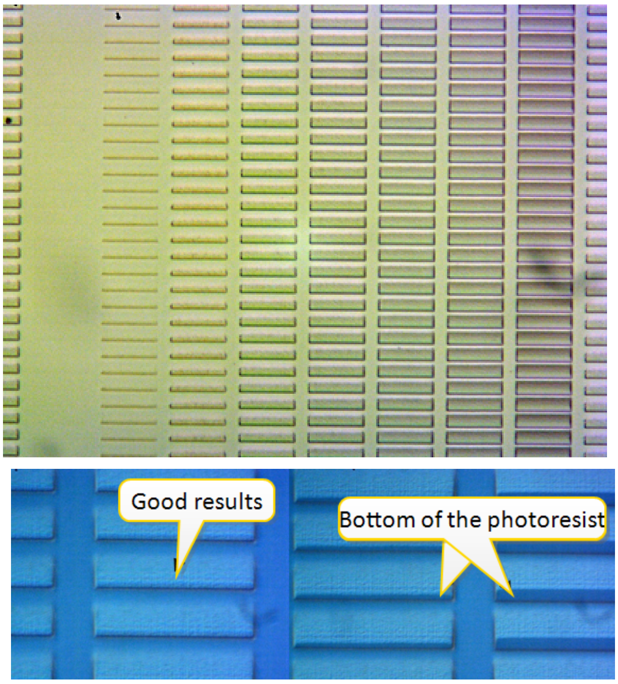


Figure 3-75 Analog Power Test exposure results: exposure block (l) and details (r)

3.5.6 Exposure Test

The Exposure Test is used to find the optimum combination of focus and dose.

The exposure test allows you to quickly write a block structure while varying the exposure dose and focus height. This allows you to quickly estimate the optimum combination of focus and dose for the photo resist.

The exposure test concept is shown in **Figure 3-76 below**.

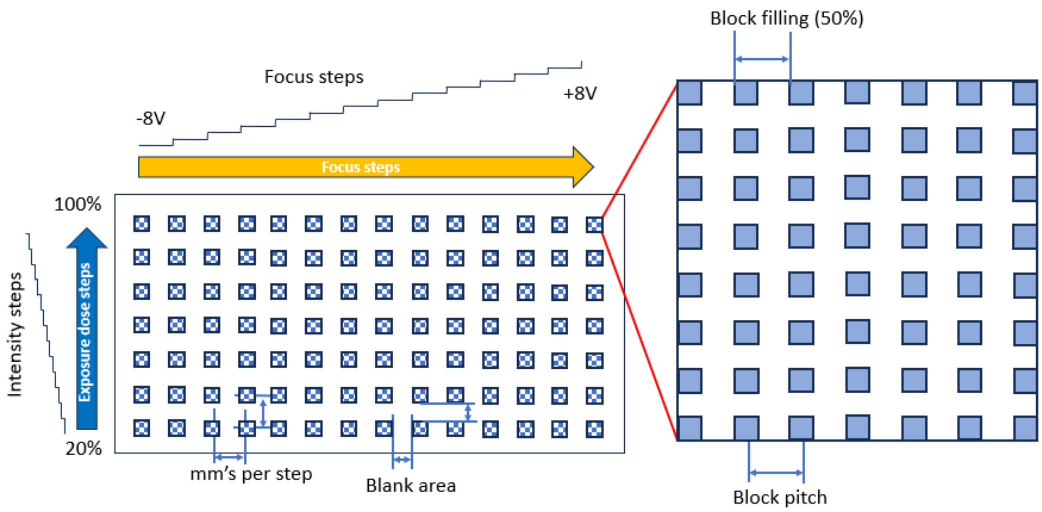


Figure 3-76 Exposure test concept

A grid of blocks is exposed at different laser powers (in scanning direction) and different focus heights (in stepping direction). Each block is filled with squares.

1. If not yet done do, load a substrate, see **"Loading the substrate" on page 19**.

2. To start the Exposure Test, select Projects, see **Figure 3-77 on the facing page**.

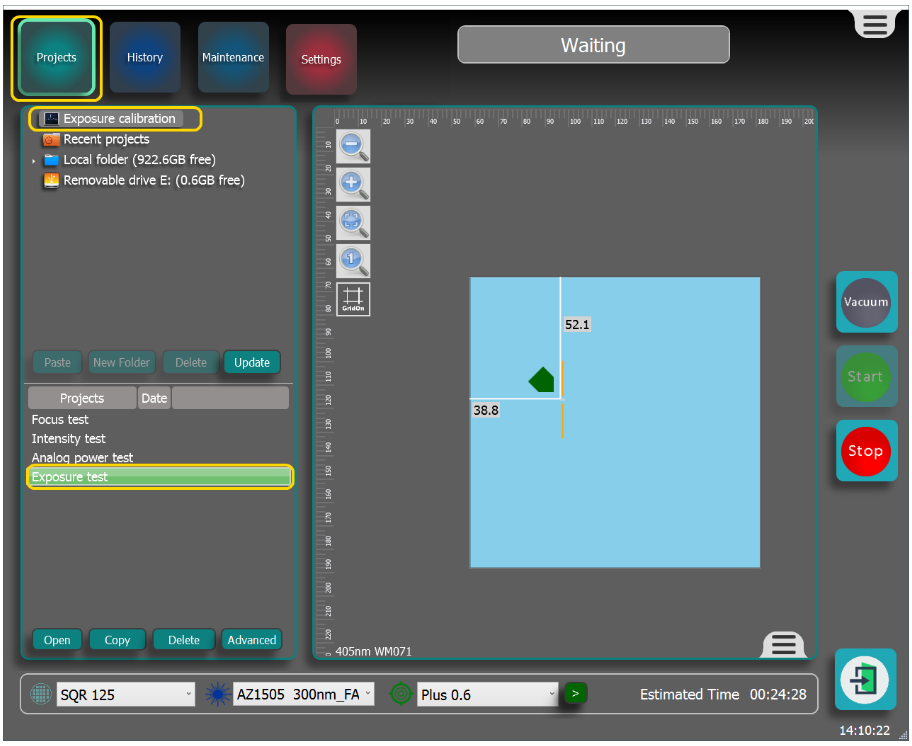


Figure 3-77 Starting the Exposure Test

3. Open the *Exposure calibration* folder from the Projects Browser

4. Select the *Exposure test* project by double clicking or by pressing Open.

5. If needed, drag the project to the desired position on the substrate.

6. Select Advanced to check and adjust the advanced settings, see **"Advanced Settings for Exposure Test" below**.

7. Activate the vacuum by pressing the vacuum button on the screen or on the front panel.

8. Start the test by pressing the start button on the screen.

9. Wait for the test to finish.

10. Remove the substrate, see **"Removing the substrate" on page 112**.

11. Develop the resist.

12. Place the product under a microscope.

13. Determine the best dose, see **"Determining the best exposure dose" on page 63**.

Advanced Settings for Exposure Test

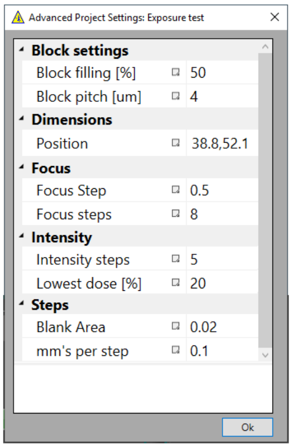


Figure 3-78 Exposure Test advanced settings

Block settings

Block filling [%]: Percentage with which an exposure block is filled with squares.

Block pitch[µm]: Distance between the squares, see **Figure 3-79 below**.

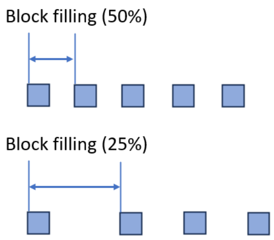


Figure 3-79 Block filling examples

Dimensions

Position: exposure start position (X,Y, in mm and separated by a comma) relative to the left top of the substrate bounding box. (It is also possible to drag the image over the substrate surface or enter the coordinates in the project work area)

Focus

Focus Step: Focus step size, given in Volt.

Focus steps: Number of focus steps in plus and minus direction around the central 0 value. For example, typing the number 3 gives the offsets: 0, -3, -2, -1, 0, +1, +2, +3, 0.

Intensity

Intensity steps: Number of dose steps from the lowest dose to the exposure dose in the current recipe.

Lowest dose: The lowest dose that is used in the test as a percentage of the exposure dose in the current recipe.

Steps

Blank Area: Size of the non exposed area between each focus step and each dose step in mm.

mm's per step: The length of each step (in scanning and in stepping direction) in mm.

Determining the best exposure dose

An example of test results in resist is shown in **Figure 3-80 below**.

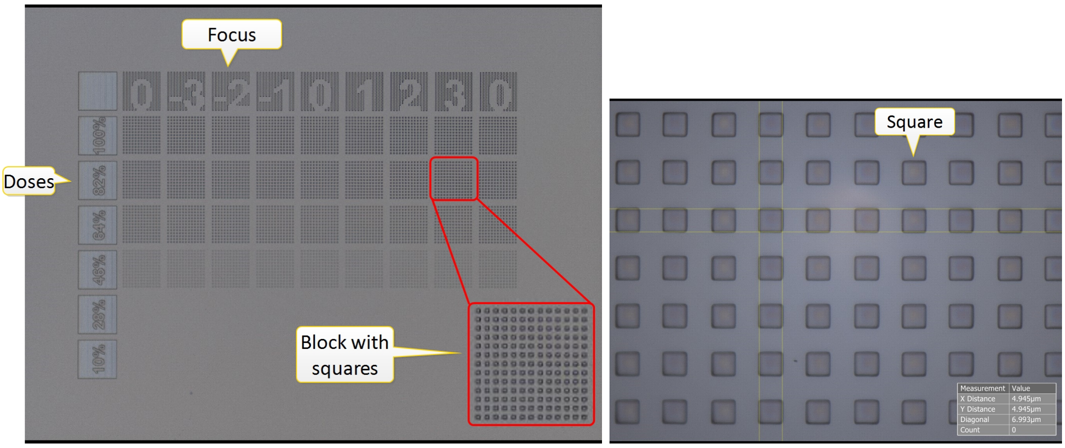


Figure 3-80 exposure Test results: Blocks at different Doses en Focus offsets that hold squares

There are numbers at the top of the block that show the focus steps, and percentages on the left side that show the dose.

By analyzing the shape of the squares for the different focus heights and different doses, the best combination of the two can be found.

Also, the shapes of the squares in a block are an indication of the shape of the writing laser spot.

3.5.7 Making an exposure correction file - example

The contrast correction file is used to account for the resist's grayscale response, see also **"Exposure correction curve" on page 50**.

1. Make sure a substrate is available with known resist thickness and known dose to clear the resist.
2. Make an exposure recipe using the required dose to clear, see **"Making an exposure recipe" on page 48**.
3. If not yet done so, load the substrate, see **"Loading the substrate" on page 19**.
4. Expose a project that has blocks that cover exposure doses from 0% up til 100% in steps of 5% (or lower), like the example in **Figure 3-81 below**.

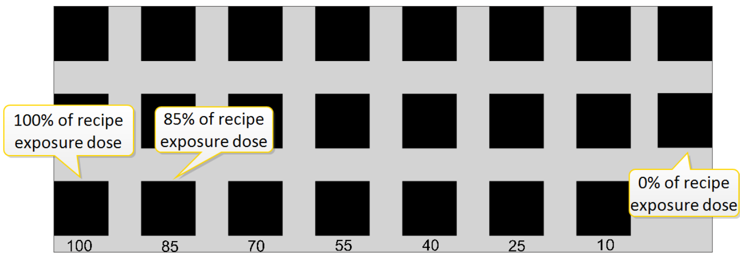


Figure 3-81 Project that holds exposures blocks for doses from 0% to 100% in steps of 5%

5. Remove the substrate, see **"Removing the substrate" on page 112**.
6. Develop the resist.
7. Place the product under a microscope that has the option to measure the resist thickness.
8. Measure the thickness of the remaining resist layer for all the exposed blocks.
9. Type the measured remaining resist thickness for the different doses between 0% and 100% into an excel sheet, see **Figure 3-82 on the next page**.

	A	B
1	% of recipe exposure dose	Resist thickness that is removed [µm]
2	0.00	0.00
3	5.00	4.96
4	10.00	7.64
5	15.00	9.77
6	20.00	11.48
7	25.00	13.07
8	30.00	14.28
9	35.00	15.5
10	40.00	16.51
11	45.00	17.39
12	50.00	18.1
13	55.00	18.81
14	60.00	19.16
15	65.00	19.55
16	70.00	19.68
17	75.00	19.85
18	80.00	20.01
19	85.00	20.18
20	90.00	20.56
21	95.00	21.74
22	100.00	23.06

Figure 3-82 Table showing dose percentage versus thickness of removed resist

10. Use excel features to set the removed resist thickness between 0% and 100% as shown in **Figure 3-83 below**.

C2 =B2/$B$22*100

	A	B	C
1	% of recipe exposure dose	Resist thickness that is removed [µm]	% of resist removed
2	0.00	0.00	0.00
3	5.00	4.96	
4	10.00	7.64	
5	15.00	9.77	
6	20.00	11.48	
7	25.00	13.07	
8	30.00	14.28	
9	35.00	15.5	
10	40.00	16.51	
11	45.00	17.39	
12	50.00	18.1	
13	55.00	18.81	
14	60.00	19.16	
15	65.00	19.55	
16	70.00	19.68	
17	75.00	19.85	
18	80.00	20.01	
19	85.00	20.18	
20	90.00	20.56	
21	95.00	21.74	
22	100.00	23.06	

C2 =B2/$B$22*100

	A	B	C
1	% of recipe exposure dose	Resist thickness that is removed [µm]	% of resist removed
2	0.00	0.00	0.00
3	5.00	4.96	21.51
4	10.00	7.64	33.13
5	15.00	9.77	42.37
6	20.00	11.48	49.78
7	25.00	13.07	56.68
8	30.00	14.28	61.93
9	35.00	15.5	67.22
10	40.00	16.51	71.60
11	45.00	17.39	75.41
12	50.00	18.1	78.49
13	55.00	18.81	81.57
14	60.00	19.16	83.09
15	65.00	19.55	84.78
16	70.00	19.68	85.34
17	75.00	19.85	86.08
18	80.00	20.01	86.77
19	85.00	20.18	87.51
20	90.00	20.56	89.16
21	95.00	21.74	94.28
22	100.00	23.06	100.00

Figure 3-83 Setting the removed resist thickness between 0% and 100%

10.1. Use the excel code '=B2/$B$22*100' in cell C2.

10.2. Pull down from cell C2.

11. Copy columns A and C as shown in **Figure 3-84 below**.

K27

Capital letter

	A	B	C	D	E	F
1	% of recipe exposure dose	Resist thickness that is removed [µm]	% of resist removed		Input	Output
2	0.00	0.00	0.00		0.00	0.00
3	5.00	4.96	21.51		21.51	5.00
4	10.00	7.64	33.13		33.13	10.00
5	15.00	9.77	42.37		42.37	15.00
6	20.00	11.48	49.78		49.78	20.00
7	25.00	13.07	56.68		56.68	25.00
8	30.00	14.28	61.93		61.93	30.00
9	35.00	15.5	67.22		67.22	35.00
10	40.00	16.51	71.60		71.60	40.00
11	45.00	17.39	75.41		75.41	45.00
12	50.00	18.1	78.49		78.49	50.00
13	55.00	18.81	81.57		81.57	55.00
14	60.00	19.16	83.09		83.09	60.00
15	65.00	19.55	84.78		84.78	65.00
16	70.00	19.68	85.34		85.34	70.00
17	75.00	19.85	86.08		86.08	75.00
18	80.00	20.01	86.77		86.77	80.00
19	85.00	20.18	87.51		87.51	85.00
20	90.00	20.56	89.16		89.16	90.00
21	95.00	21.74	94.28		94.28	95.00
22	100.00	23.06	100.00		100.00	100.00

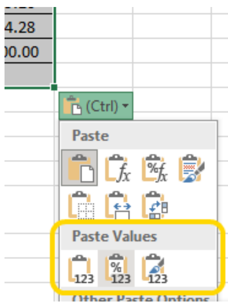


Figure 3-84 Creating the Input and Output columns

11.1. Use one of the *Paste Values* options to make sure that numbers are shown instead of formula's.

11.2. Column ***% of resist removed*** becomes column ***Input***

11.3. Column ***% of recipe exposure dose*** becomes column ***Output***.

11.4. Column ***Input*** is at the left side, column ***Output*** is at the right side.

11.5. Make sure that the words **Input** and **Output** column are spelled with a capital letter as shown in **Figure 3-84 on the previous page**.

12. Copy the **Input** and **Output** columns into a new worksheet, see **Figure 3-85 below**.

B28

	A	B
1	**Input**	**Output**
2	0.00	0.00
3	21.51	5.00
4	33.13	10.00
5	42.37	15.00
6	49.78	20.00
7	56.68	25.00
8	61.93	30.00
9	67.22	35.00
10	71.60	40.00
11	75.41	45.00
12	78.49	50.00
13	81.57	55.00
14	83.09	60.00
15	84.78	65.00
16	85.34	70.00
17	86.08	75.00
18	86.77	80.00
19	87.51	85.00
20	89.16	90.00
21	94.28	95.00
22	100.00	100.00
23		

Figure 3-85 Preparing the Input Output worksheet

13. Save the worksheet with an appropriate name as CSV UTF-8 (Comma delimited).

14. When an excel warning pops up, press *OK*, see **Figure 3-86 below**.

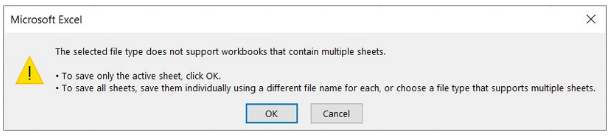


Figure 3-86 Saving the exposure curve file

14.1. At the next excel message, press *Yes*, see **Figure 3-87 below**.

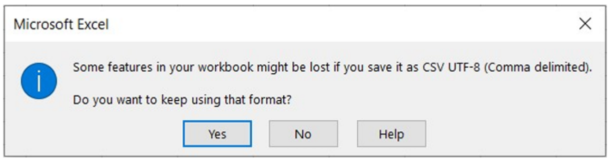
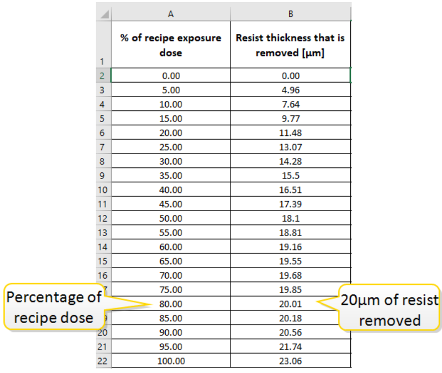


Figure 3-87 Saving the exposure curve file

> The contrast correction file described above can be used if, during grayscale writing, up till the **full** resist layer will be removed. In such a recipe, the exposure dose is the dose to clear **all** the resist.
> However, it may happen that only a part of the resist should be removed during grayscale writing. Then, a second test run is preferred to determine the contrast correction file. This is described in the step below.

15. If, during grayscale writing, only a part of the resist layer needs to be removed, then redo the exposure and the measurement:

15.1. Check which dose percentage is used to remove the required amount of resist, see **Figure 3-88 on the next page**



% of recipe exposure dose	Resist thickness that is removed [µm]
0.00	0.00
5.00	4.96
10.00	7.64
15.00	9.77
20.00	11.48
25.00	13.07
30.00	14.28
35.00	15.5
40.00	16.51
45.00	17.39
50.00	18.1
55.00	18.81
60.00	19.16
65.00	19.55
70.00	19.68
75.00	19.85
80.00	20.01
85.00	20.18
90.00	20.56
95.00	21.74
100.00	23.06

Figure 3-88 Checking the dose to remove 20µm of resist

Note: In Figure 1-3, the dose needed for removing 20µm of the resist is found to be 80% of the exposure dose of the recipe. This is the new dose to be filled into the recipe if you do the second run.

15.1. Go back to step 2 and redo all steps up till here, using the exposure dose you found above.

16. Go back to **"Making an exposure recipe" on page 48**, step **12.2. on page 50**.

3.6 Preparing and doing alignment

If a new layer needs to be exposed on top of a previously exposed layer (on the same machine, or on a different machine), alignment is needed in most cases.

3.6.1 Alignment flow

The steps to take when you do alignment are shown in **Figure 3-89 below**.

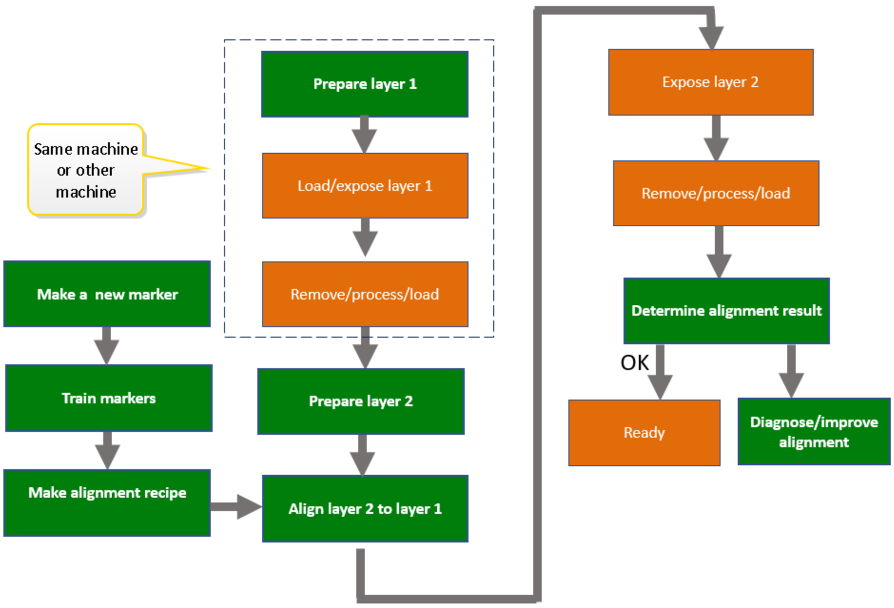


Figure 3-89 Alignment flow

Brown blocks indicate regular steps that are described in other parts of this user manual. Green blocks are alignment related.

Step	Content	Reference
Prepare layer 1	Embed markers in the project or GDS file layer	See Project Manager user guide
Prepare layer 2	Embed markers in the project or GDS file layer	See Project Manager user guide
Align layer 2 to layer 1	Align layer 2 on the alignment marks in layer 1	**"Performing global frontside alignment" on page 86** or **"Performing local (frontside) alignment " on page 90** or **"Performing backside alignment" on page 95**
Determine alignment result	Check that layer 2 is correctly positioned with reference to layer 1	**"Calibrate frontside alignment offsets" on page 96** or **"Calibrate backside alignment offsets" on page 101**
Make a new marker	Design marker and integrate into projects	**"Making a new marker" on page 72**
Train a marker	Train the software to be able to use a marker for automatic detection	**"Training a frontside marker" on page 75** or **"Training a backside alignment marker" on page 83**
Make an alignment recipe	Make a recipe to be able to do automatic global alignment	**"Making a global frontside alignment recipe" on page 69** or **"Making a backside alignment recipe" on page 71**

3.6.2 Alignment introduction

Alignment is needed if you expose two or more independently processed layers on a substrate.

An example of what could happen (strongly exaggerated for explanatory purposes) is illustrated in **Figure 3-90 below**.

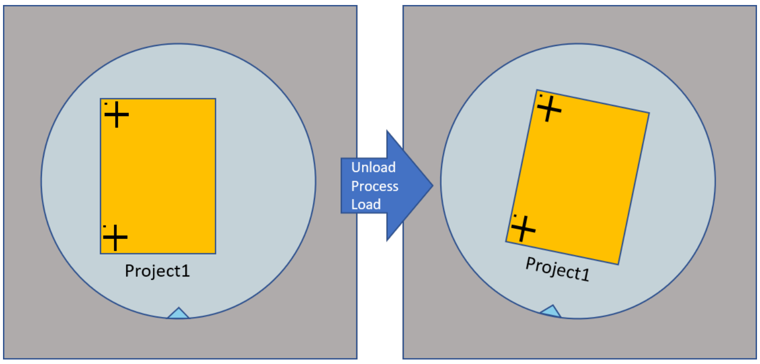


Figure 3-90 Substrate misplacement after reload substrate

Suppose you expose project1. You remove the substrate and process it. Now, you want to expose project2 on top of project one. After the substrate is loaded into the machine, before exposing project2, it is essential to know the exact location of project1.

To tell the machine exactly where project1 is located, the alignment system is used to find the locations of the markers that were exposed with project1. Then, the software adapts the step and scan movement to match project2 to the project1 image position. Alignment is also essential when project1 was exposed on a different machine.

The example above on two markers for exposing two layers on the same machine is shown in **Figure 3-91 below**.

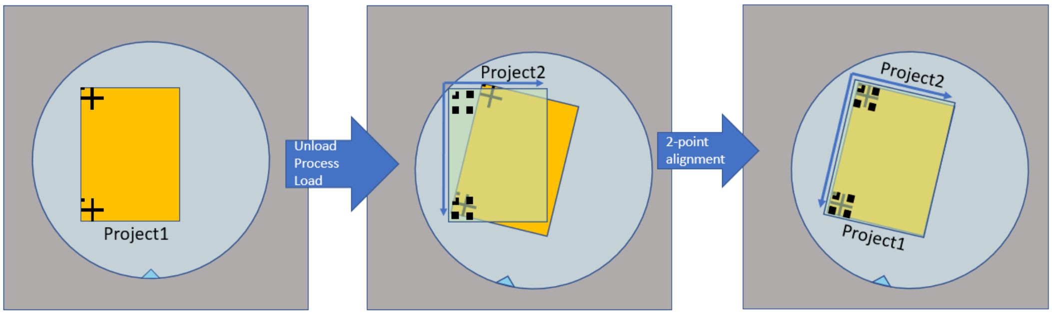


Figure 3-91 Matching images using alignment

The layer1 exposure (**Figure 3-91 above**, left) shows a project that has two markers. After unloading and processing, the substrate is reloaded (middle). During reloading, the substrate may be turned and shifted. Without alignment (middle), Project2 would be imaged at the original location of Project1, resulting in poor quality overlay. After alignment, the image of Project2 is well positioned on top of Project1, resulting in good overlay quality.

The PICOMASTER has the below listed alignment types:

- Global frontside alignment: **two** alignment markers are used. The marker positions are given with reference to the substrate. This alignment can be done manually, or automatically with the use of a global alignment recipe, see **"Performing global frontside alignment" on page 86**.
- Local frontside alignment: **three or more** alignment markers are used. The marker positions are given with reference to the project, see **"Performing local (frontside) alignment " on page 90**.
- Backside alignment: **two** alignment markers on the backside of the substrate are used. The marker positions are fixed with reference to the substrate, see **"Performing backside alignment" on page 95**.

In the example of **Figure 3-90 on the previous page**, the project is rotated and translated with respect to the origin. Apart from rotation and translation there may be tool specific distortions of the pattern, including scaling errors and skewed images. By using three or four markers, such distortions can also be accounted for and corrected, leading to a more precise alignment. These effects are summarized in **Figure 3-92 below**.

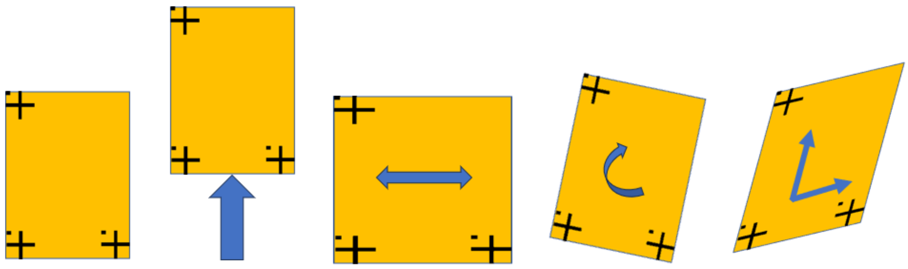


Figure 3-92 Image rotation, displacement, scaling and skew

Frontside alignment

The alignment markers are normally on the frontside (topside) of the substrate. This is called frontside alignment. The frontside alignment system uses a camera that is part of the writing module. Camera images are used by the software to automatically find trained markers during alignment. Marker positions can be choosen with reference to the substrate or to the project.

Backside alignment

The markers can also be on the backside (bottom side) of the substrate. This is called backside alignment. Backside alignment can be used, for example in case of double sided processing or if markers should not be influenced by processing.

Backside alignment uses two camera's, see **Figure 3-93 on the facing page**.

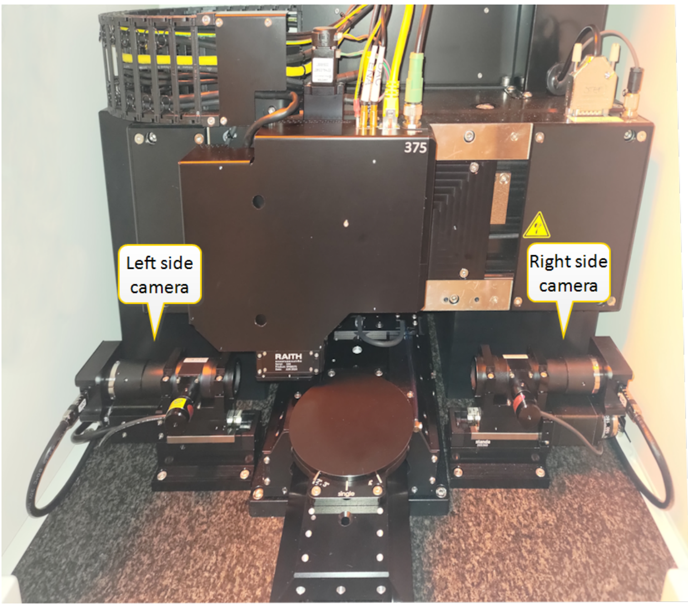


Figure 3-93 Backside alignment camera's

The vacuum chuck is specially designed for backside alignment, see **Figure 3-94 below**.

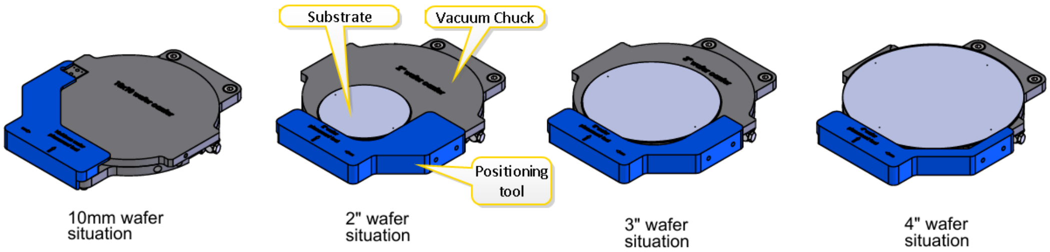


Figure 3-94 Backside alignment vacuum chuck with substrate positioning tools

Marker positions for different substrate sizes are shown in the table below.

Wafer	M1 X position	M1 Y Position	M2 X position	M2 Y Position
4” Wafer	5	50	95	50
3” Wafer	4.1	38.1	72.1	38.1
2” Wafer	2.9	25.4	47.9	25.4
10mm Wafer chip	5	2.5	5	7.5

To get an image of the backside markers, the vacuum chuck has channels to let the light pass and mirrors to reflect the light. Marker positions cannot be choosen but are fixed with reference to the substrate.

3.6.3 Making a global frontside alignment recipe

The global frontside alignment recipe is used by the automatic alignment (Alignment Wizard). In the recipe, the alignment details are stored, such as marker types and marker positions.

Open a new recipe

1. Make sure that the alignment markers on your substrate are in the area that can be reached by the alignment camera, see ***Exposure to alignment offset***.
2. Select Alignment in the top bar, see **Figure 3-95 on the next page**.

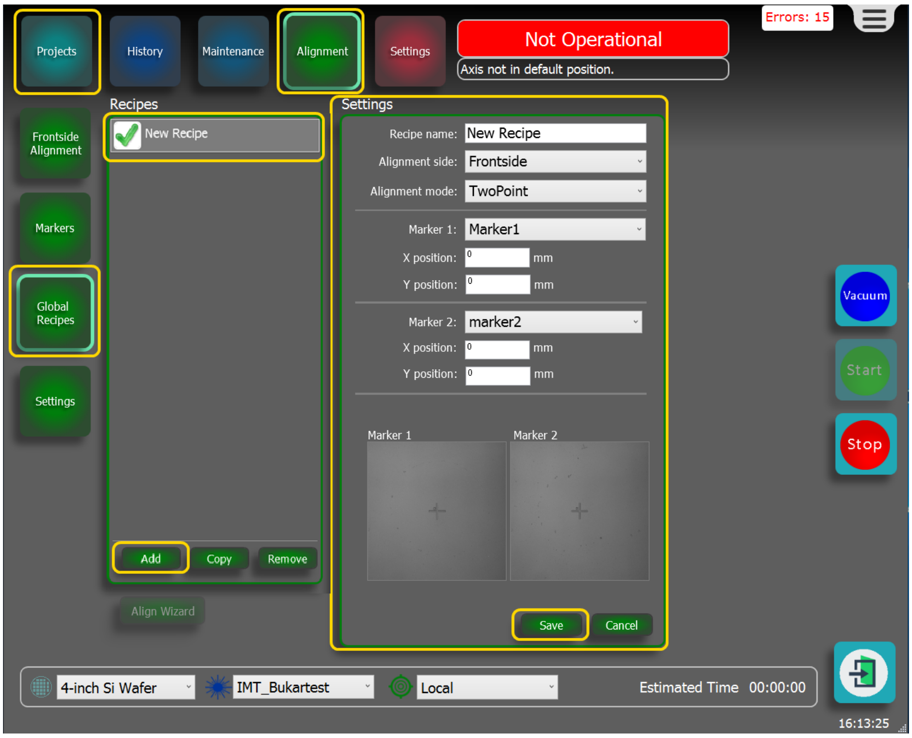


Figure 3-95 Making an alignment recipe

3. Select Global Recipes on the left side of the window.

4. Select Add.

Type the recipe settings

1. Under Settings , set the recipe values, see **Figure 3-95 above**.

2. At Recipe name, type a name that represents the recipe features as good as possible.

3. At Alignment side, select Front side.

Note: Alignment mode cannot be changed.

4. If you use new markers, do marker training, see **"Training a frontside marker" on page 75**.

5. At Marker 1 and Marker 2, select the markers from the drop down list.

Note: Marker previews are shown at the bottom of the Settings window.

6. Select Projects in the top bar.

7. Calculate the expected marker Step (X) and Scan (Y) positions with reference to the top left of the substrate bounding box, see **Figure 3-96 on the facing page**.

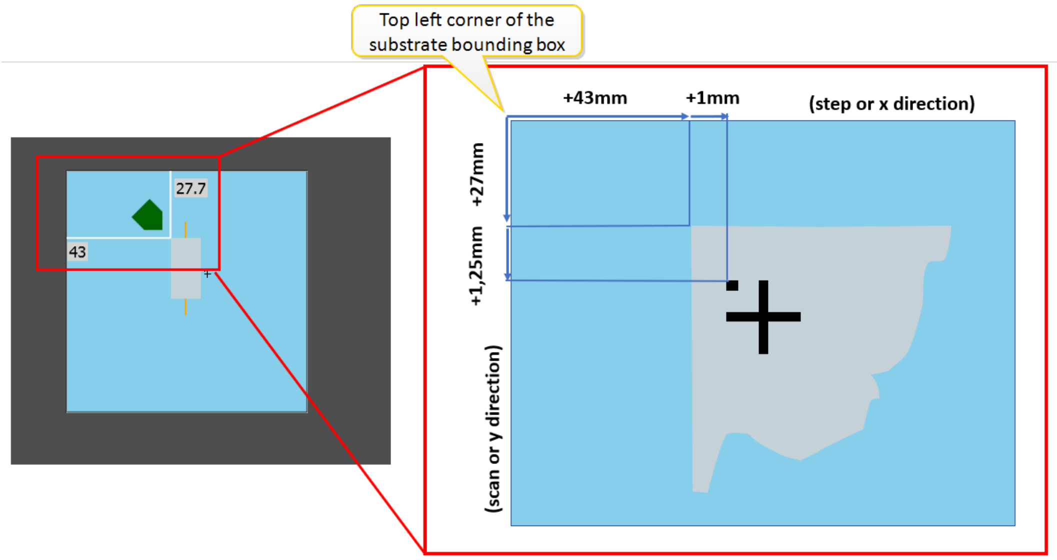


Figure 3-96 Project position (l) and marker position (r)

Note: In this case, with reference to top left of the substrate bounding box, the step (x) position of the marker is 43+1-1=44mm, the scan (y) position is 27+1.25=28.25mm

8. Select Alignment in the top bar to go back to the making of the recipe.

9. For each marker, type the step (x) position at X position and the scan (y) position at Y position.

10. Check the relative distance of the markers:

   10.1. Calculate the relative distances between marker 1 and 2 in step and scan direction by subtracting the position values.

   10.2. Check that the relative distances between marker 1 and 2 match the original specification, otherwise the automatic alignment (Alignment Wizard) will not work.

11. Press Save to save the recipe settings.

Note: To make the recipe active, go to Recipes and click the recipe check box.

3.6.4 Making a backside alignment recipe

The backside alignment recipe is used by the automatic alignment (Alignment Wizard). In the backside alignment recipe, the alignment details are stored, such as marker types.

Open a new recipe

1. Select Alignment, see **Figure 3-97 on the next page**.

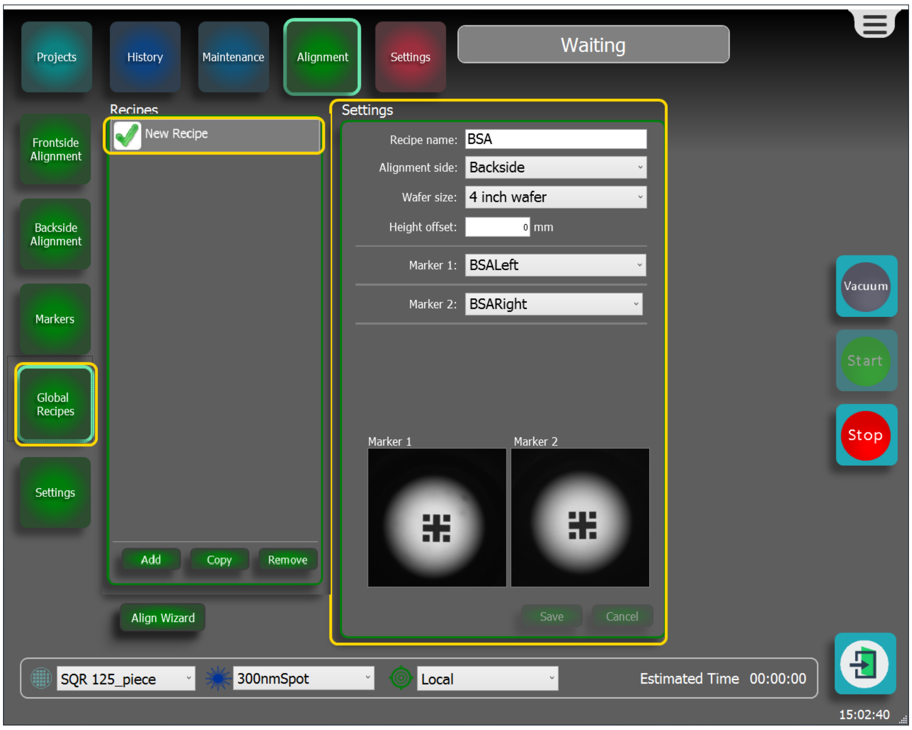


Figure 3-97 Making an alignment recipe

2. Select Global Recipes.

3. Select Add.

Type the recipe settings

1. Go to the Settings window to set the recipe values, see **Figure 3-97 above**.

2. Recipe name: type a name that represents the recipe features as good as possible.

3. Alignment side: select Backside.

4. Wafer size: select the substrate size.

5. Height offset: normally has value 0, however type a different value in the cases listed below:

- To focus on the top (frontside) of a transparent substrate.
- To improve Focus if the marker image is not sharp enough.

6. If you use new markers, do marker training, see **"Training a backside alignment marker" on page 83**.

7. At Marker 1 and Marker 2, select the markers from the drop down list.

Note: The X and Y positions of the markers are absent in the recipe because the marker positions are fixed for backside alignment.

Note: Marker previews are shown at the bottom of the Settings window.

8. Press Save to save the recipe settings.

Note: To make the recipe active, go to Recipes and click the recipe check box.

3.6.5 Making a new marker

This section gives guidelines on how to design and position markers and how to use them in projects.

Marker design guidelines

Design a marker using the guidelines below:

- The marker must have corners.
- The marker must have low rotational symmetry.
- Marker images used in subsequent layers should not overlap.

A marker set that was made according to the above listed guidelines is shown in **Figure 3-98 on the facing page**. .

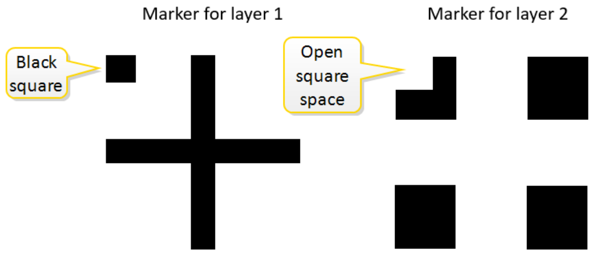


Figure 3-98 Marker set designed according to the guidelines

Without the black square, the marker would look the same when turned over 90 degrees. This could lead to a project turn over 90 degrees after alignment. Therefore, the black square is added.

To be able to check alignment results (in particular when using a microscope), markers of subsequent layers should be close, but not overlap. Therefore, the open square space in the layer 2 marker is made to be able to expose the black square of the layer 1 marker without touching the marker for layer 2.

Marker position guidelines

Position markers using the guidelines below:

- Do not place markers on top of project items. (In the example of **Figure 3-101 on the next page**, other project items are not present.)
- Not all markers should be placed in one line.

Using markers in a project file

1. Open a drawing program that can save bitmap (.bmp) formats.
2. Draw a marker according to the guidelines listed above.
3. Save the marker as a bitmap (.bmp)
4. Open the Project Manager application.
5. Select the Grayscale to Laser Power Renderer, see **Figure 3-99 below**.

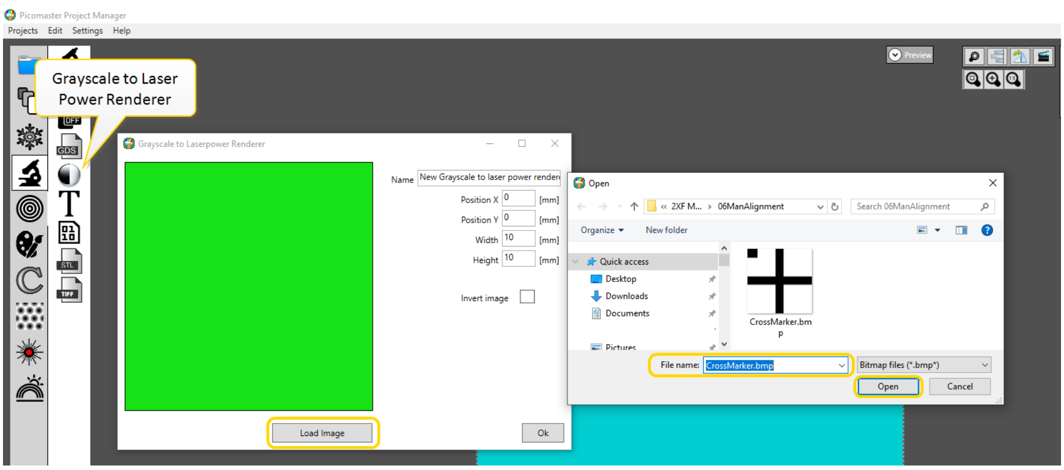


Figure 3-99 Selecting the marker

6. Press Load Image.
7. Select the marker file.
8. Press Open.
9. At Name, give the marker a suitable name.
10. At Width and Height, set the size of the marker within the project:
    10.1. It is advised to set marker sizes in between 100µmx100µm and 250µmx250µm.
11. Right click on the marker and copy it to create multiple marker images in the project, see in **Figure 3-100 on the next page**.

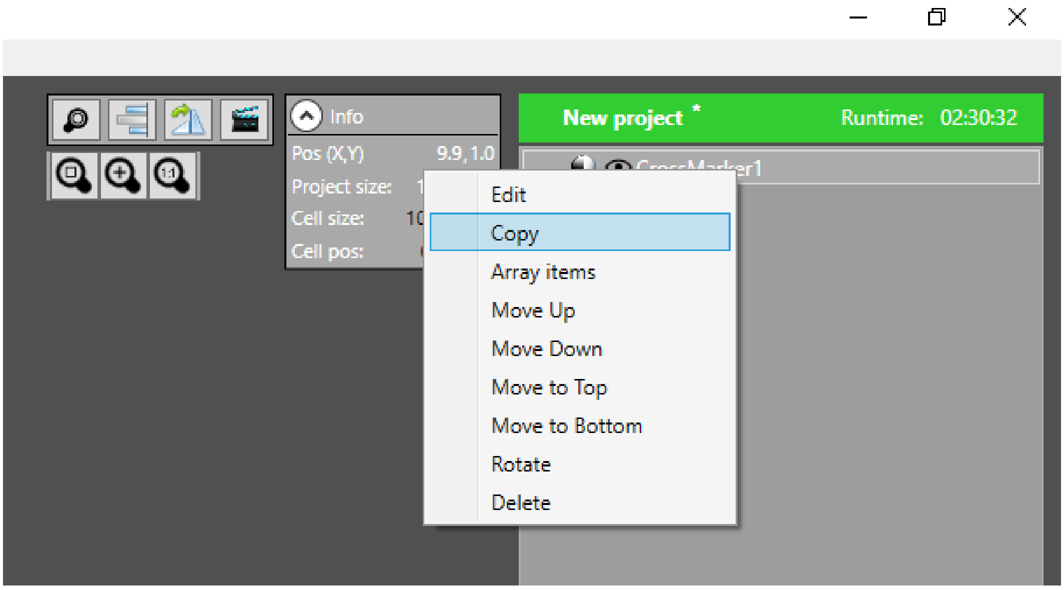


Figure 3-100 Making more markers with the same nam

11.1. For global alignment markers, create two markers.

11.2. For local alignment, create at least three markers. To be able to check alignment quality, it is strongly advised to use **four** markers,

12. Set the position of the markers, see **"Marker position guidelines" on the previous page** and see **Figure 3-101 below**.

12.1. Click on a marker in the main window and use your mouse to drag it to the required position.

12.2. Click on a marker in the list with project items and type in the marker positions for that marker in the Properties window.

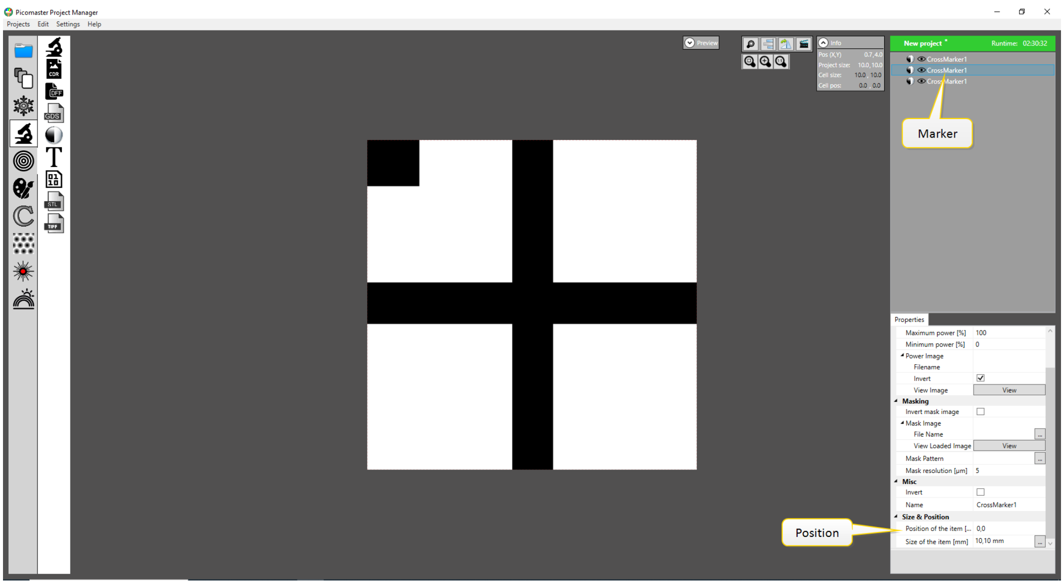


Figure 3-101 Set marker positions

Note: In **Figure 3-101 above**, at the start, three identical markers are mounted on top of each other. Also, other project items may be present.

13. Go to Projects in the top bar and press Save to save the project.

14. For loading the project before exposure, see **"Adding exposure files to the computer" on page 39**.

Using markers in a GDS file

1. Open a program used for making GDS files.

2. Create a cell with a suitable marker name.

3. Create a new layer used for the exposure of the marker.

4. Within the cell, draw a marker, see **"Marker design guidelines" on page 72**.

   4.1. It is advised to set marker sizes in between 100µmx100µm and 250µmx250µm.

5. Add enough instances of the marker cell, see **"Marker position guidelines" on page 73**.

   5.1. For global alignment markers, create two markers.

   5.2. For local alignment, create at least three markers. To be able to check alignment quality, it is strongly advised to use **four** markers,

6. Save the GDS file.

7. For loading the project before exposure, see **"Adding exposure files to the computer" on page 39**.

3.6.6 Training a frontside marker

To be able to use markers for alignment, the software needs to be trained to recognize the markers. This is done during marker training.

Note: Make sure that the objective lens height is correct, see **"Writing module height adjustment" on page 22**. Incorrect lens height may lead to failing marker training.

Note: Make sure that the new marker is exposed on a substrate.

Find the marker

1. Select Projects in the top bar.

2. Calculate the expected marker Step (X) and Scan (Y) positions with reference to the top left of the substrate bounding box, see **Figure 3-102 below**.

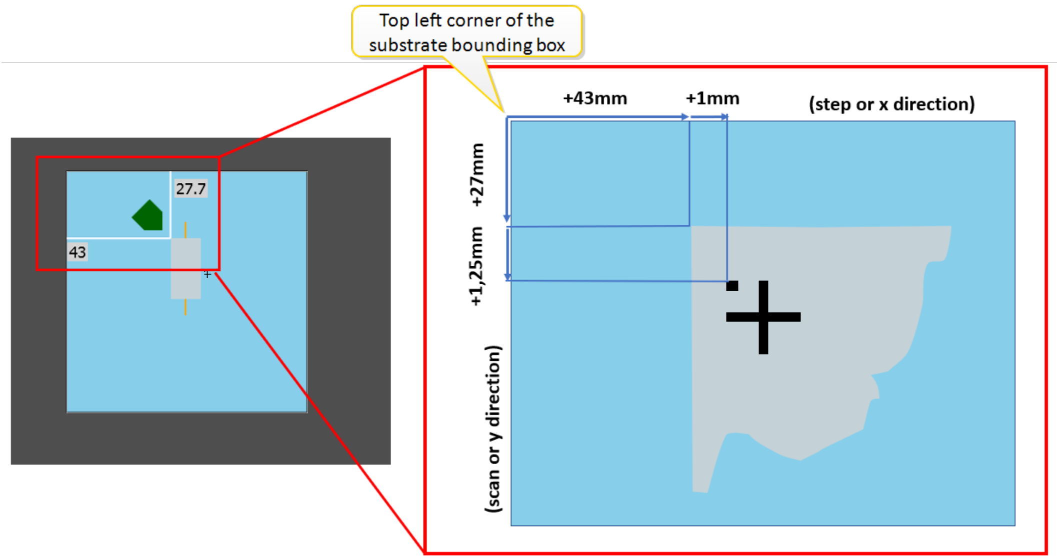


Figure 3-102 Project position (l) and marker position (r)

Note: In this case, with reference to top left of the substrate bounding box, the step (x) position of the marker is 43+1-1=44mm, the scan (y) position is 27+1.25=28.25mm

3. Select alignment type Global in the quick selection bar, see **Figure 3-103 below**.

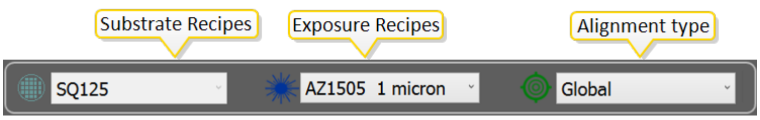


Figure 3-103 Quick selection bar

4. Press Alignment in the top bar to open the Alignment window.

5. Press Frontside Alignment on the left side of the window.

6. In Global Alignment Markers section, in the top line, at PosX and PosY a, fill in the location of the marker with reference to the top left of the substrate bounding box and press GoTo. see **Figure 3-104 below**.

Figure 3-104 Going towards marker position

Note: The X and Y axes will now move until the writing module that holds the alignment camera is at the marker position.

7. Check if the alignment camera has the correct intensity (light gray).

7.1. If the camera intensity is not correct, go to Camera controls and adapt the exposure time until the intensity is correct.

Note: Typical camera exposure times are 50-100 ms for glass substrates and 10 ms for wafers.

8. If the marker is not immediately visible, click on Area scan, see **Figure 3-105 on the facing page**.

Figure 3-105 Area scan

Note: Area scan shows a wider area around the position that the camera moved to. It does not do active detection. Every frame taken by the camera is approximately 1x1 mm, the maximum search range for Area scan can be adjusted in the machine settings for alignment, see maximum composite size in **"Adjust alignment settings " on page 123**.

8.1. During the Area scan, press 

if the marker is visible.

9. Click on the marker to put it in the center of the camera field (which is the center of the screen).

10. If needed, use the Positioning window buttons to move the camera towards the marker.

10.1. Press the horizontal or vertical arrow buttons to make small steps.

10.2. Hold the horizontal or vertical arrow buttons to do a continuous movement.

10.3. Type a step size and press Move.

Note: Arrows under 45 degrees go to the end of the substrate, the middle button goes to the substrate center.

11. If the marker is still not found:

11.1. Check if the substrate is placed correctly, see **"Loading the substrate" on page 19**.

11.2. Check if the marker position is filled in correctly.

Train the marker

1. To start the marker training, press Markers on the left side of the screen to open the marker window. The Train Image window of the activated marker pops up, see **Figure 3-106 on the next page**.

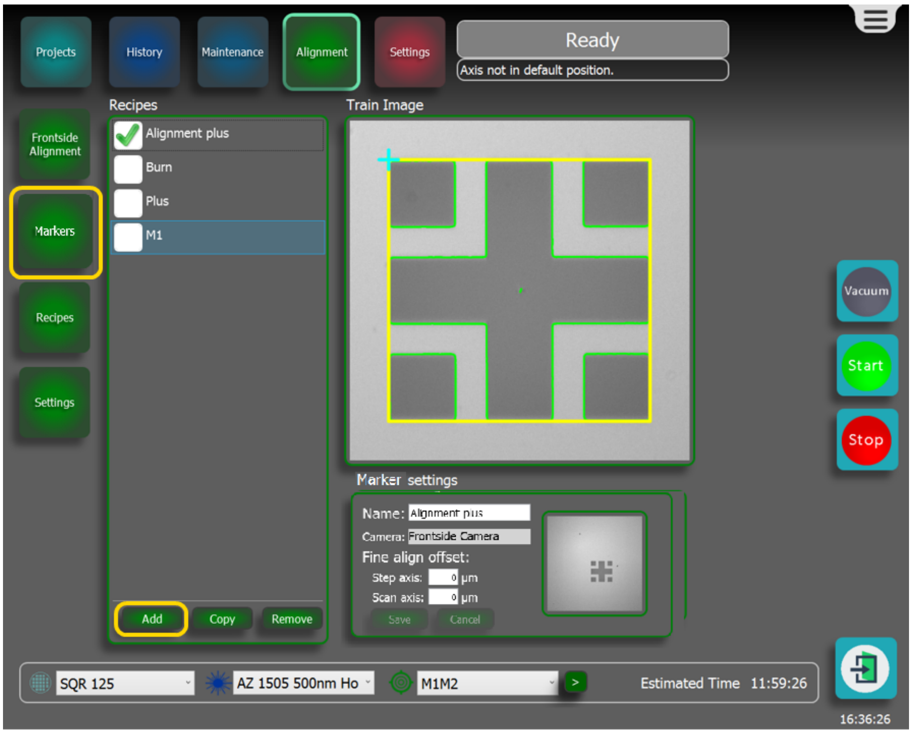


Figure 3-106 Train Image screen

2. Click Add to start a new marker training. The Live image window of the marker that you found in the steps above becomes visible, see **Figure 3-107 on the facing page**.

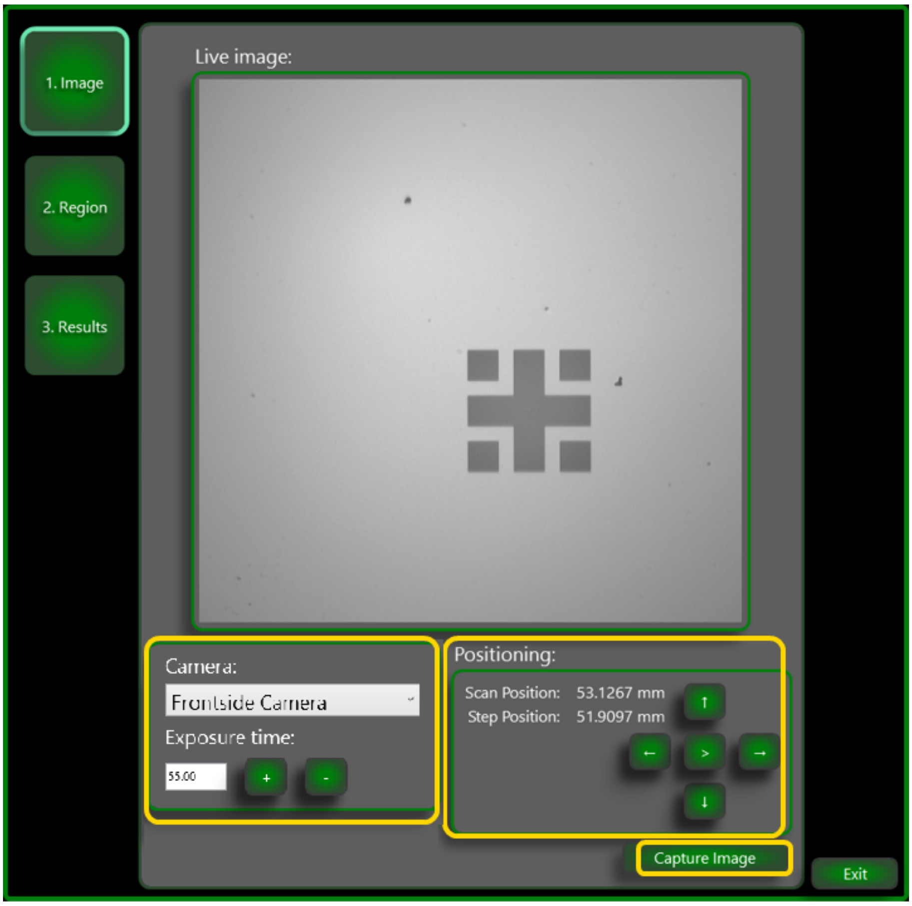


Figure 3-107 Live image window

3. Under Camera, select the frontside camera from the dropdown list.

4. If required, at Positioning, use the arrow buttons to move the marker image to the center of the camera image screen.

5. If needed, redo step **7. on page 76** to optimize the alignment camera intensity and return here.

6. Press Capture image.

The Region preview window becomes visible, see **Figure 3-108 on the next page**.

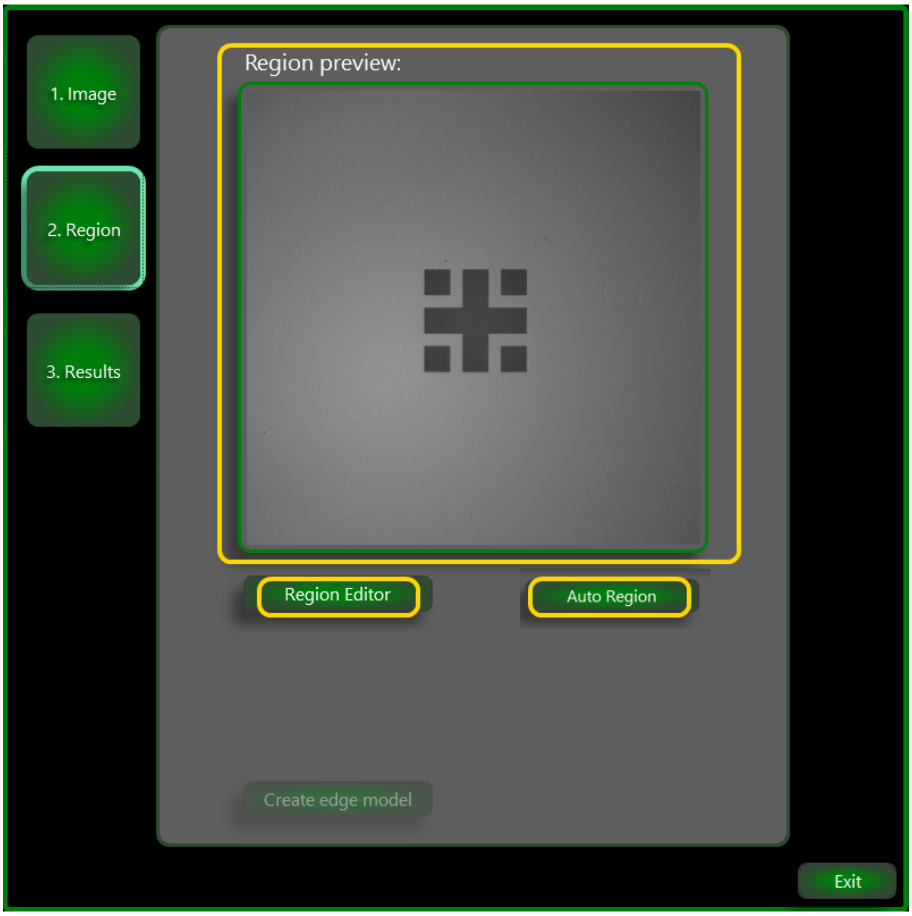


Figure 3-108 Region preview window

7. Continue the marker training automatically or manually:
   7.1. Press Auto Region for automatic training and continue at step **11. on page 82**.
   7.2. Press Region Editor for manual training and continue below.
8. Check the Region window that becomes visible, see **Figure 3-109 on the facing page**

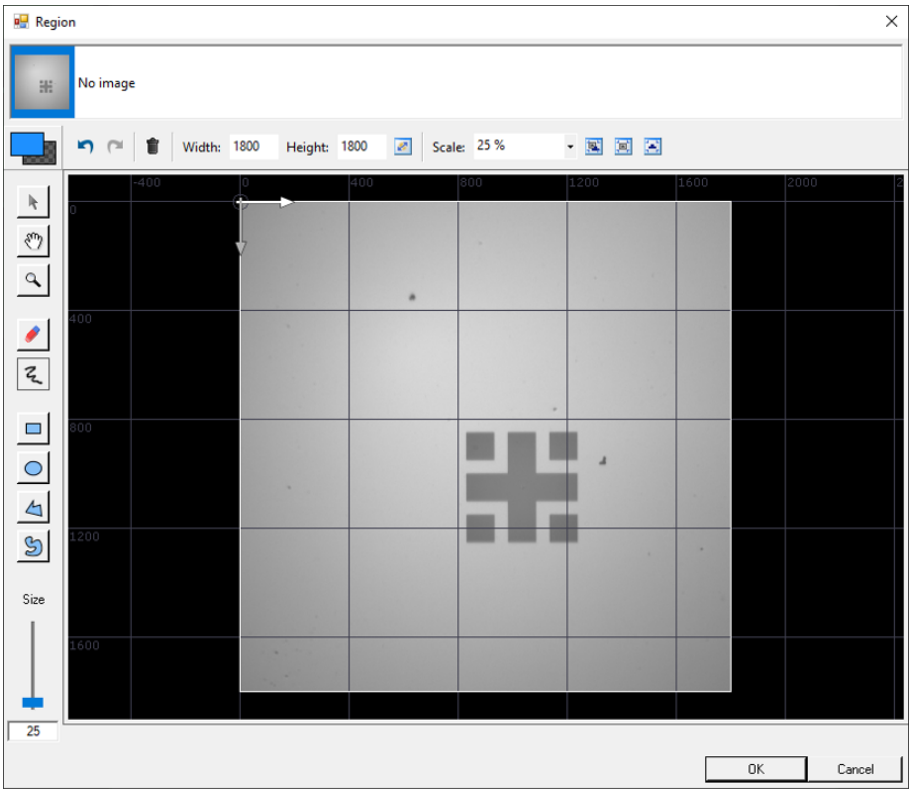
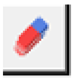
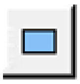


Figure 3-109 editing the marker image in the Region window

9. Draw the region of interest using the following tools:

9.1.  Free hand drawing: For drawing the region of interest directly with the mouse.

9.2.  Eraser: For erasing parts of the region of interest directly with the mouse. This is useful for removing unwanted features.

9.3.  Box region: For drawing rectangular regions.

10. Press OK

The Region preview window becomes visible, see **Figure 3-110 on the next page**.

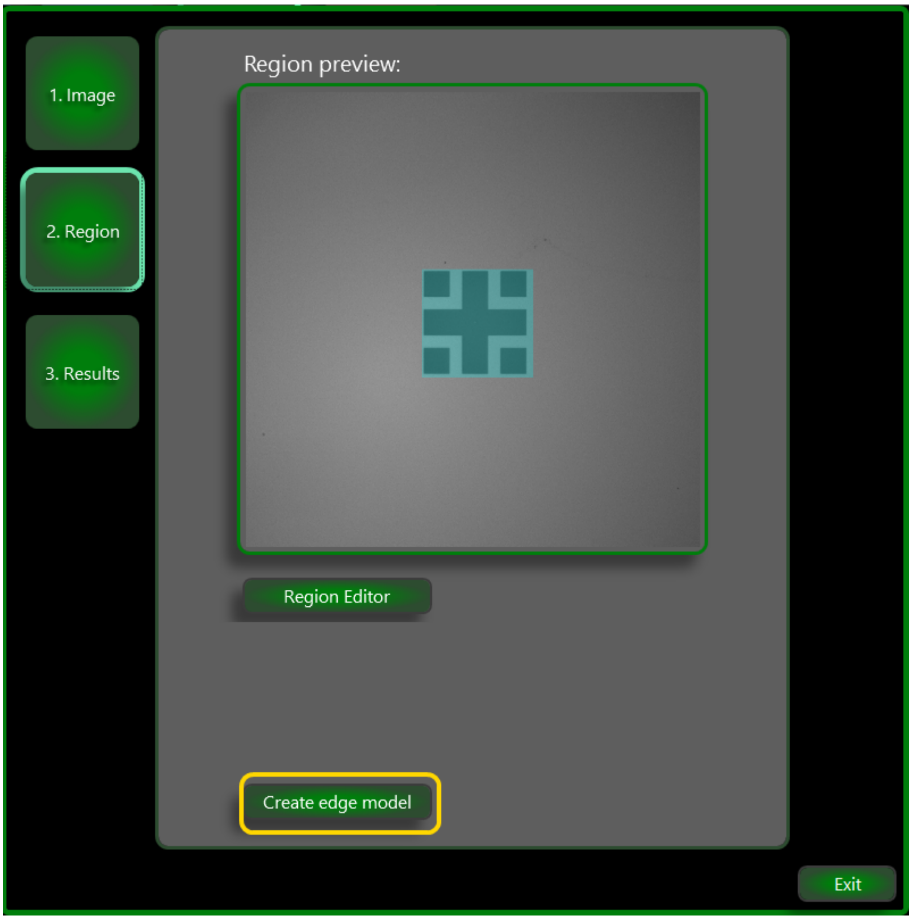


Figure 3-110 Region preview window after region selection

11. Click Create Edge Model. The Trained marker becomes visible, see **Figure 3-111 on the facing page**.

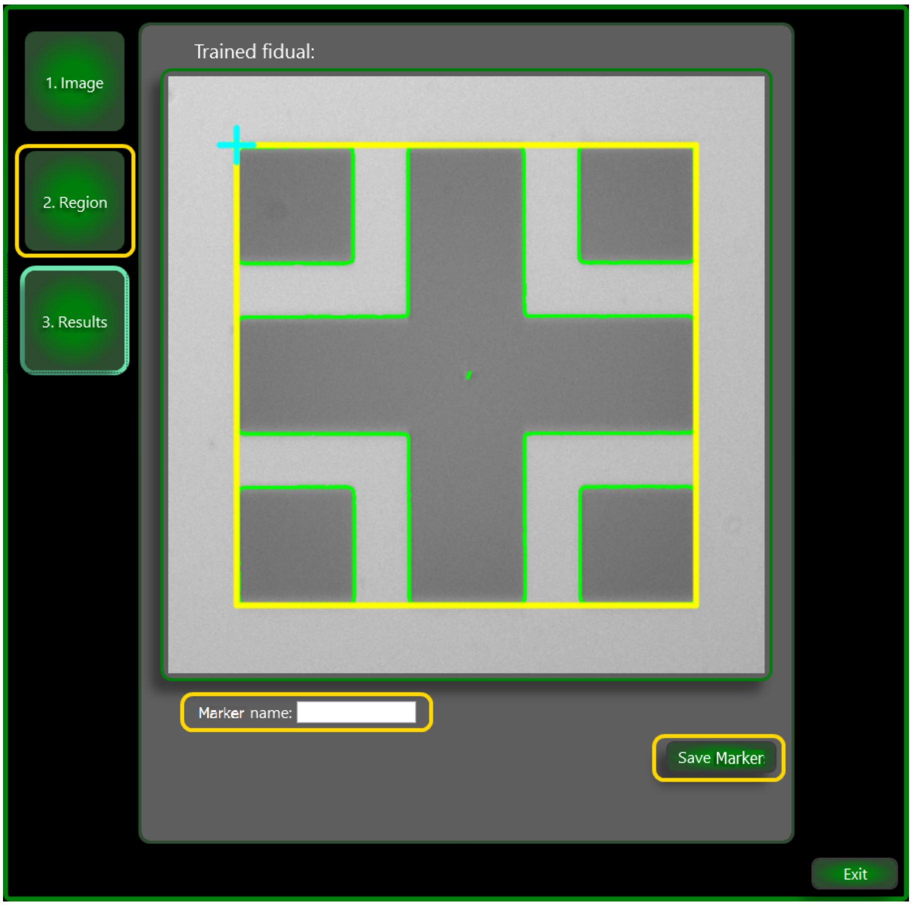


Figure 3-111 Results window

12. Check the marker:
    12.1. Check if the yellow box surrounds the marker.
    12.2. Check if unwanted features are NOT present.
13. If result of the check are OK, continue below; if results are NOK, press the Region tab and go back to step **7.2. on page 80**.
14. At Marker name, type a suitable name for the marker.
15. Press Save Marker.

3.6.7 Training a backside alignment marker

To be able to use markers for backside alignment, the software needs to be trained to recognize the markers. This is done during marker training.

Note: Make sure that the lens height is correct, see **"Writing module height adjustment" on page 22**. Incorrect lens height may lead to failing marker teaching.

Note: Make sure that the new marker is exposed on a substrate.

Move towards the marker

1. Press Alignment in the top bar to open the Alignment window.
2. Press Backside Alignment in the left bar to open the search window, see **Figure 3-112 on the next page**.

Figure 3-112 Searching the backside alignment markers

3. Under Camera positioning, select the applicable substrate size from the dropdown list.

4. Press Move to to move the vacuum chuck so that the channels are in front of the camera's. Both camera views should show markers now.

5. Check that the markers are fully visible in both camera views.

6. If the markers are not fully visible, adjust the substrate position:

   6.1. Pres the Stop button to home the axes.

   6.2. Press the Vacuum button to release the vacuum.

   6.3. Manually move the substrate until the both markers are in the camera fields.

   6.4. Press the Vacuum button to switch on the vacuum.

Train the marker

1. To start the marker training, press Markers on the left side of the screen to open the marker window, see **Figure 3-113 on the facing page**.

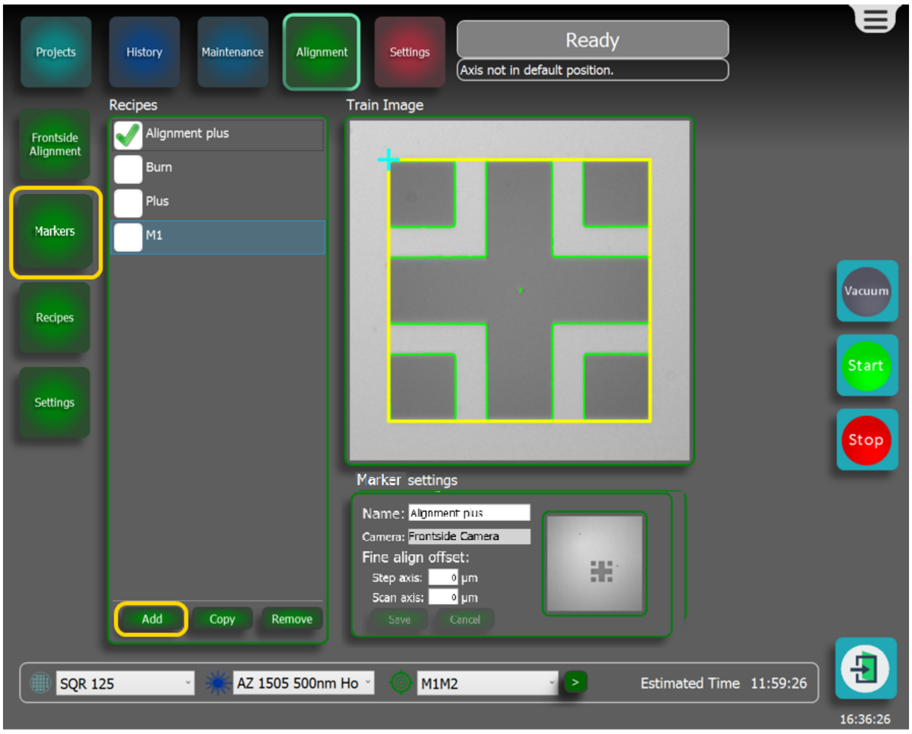


Figure 3-113 Marker window

2. Click Add to start a new marker training.

The Live image window of the marker that you found in the steps above becomes visible, see **Figure 3-114 below**.

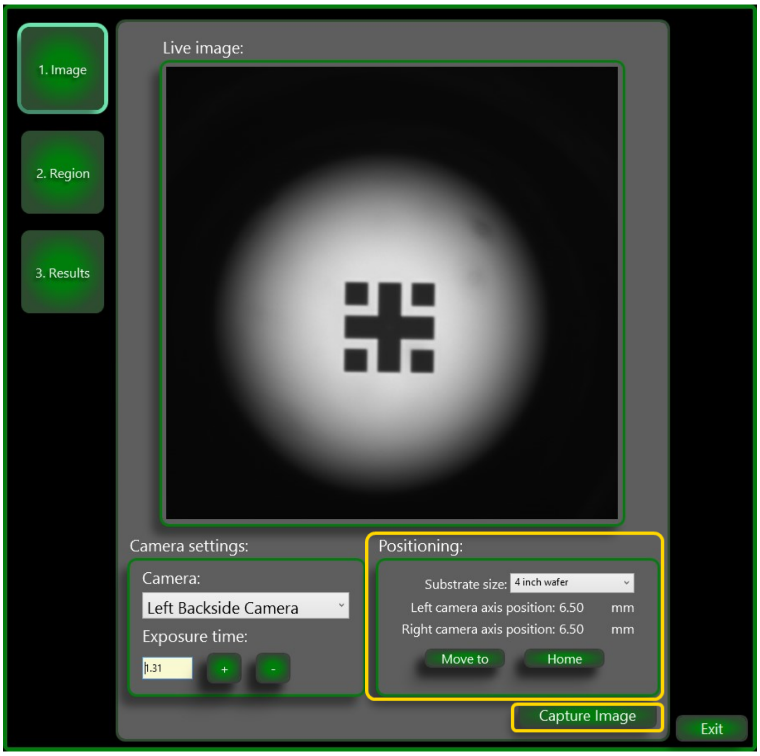


Figure 3-114 Live image window

3. Under Camera, select Left Backside Camera or Right Backside Camera from the dropdown list.

4. Under Positioning, select your substrate size from the dropdown list.

5. Press Move to, to move the vacuum chuck so that the camera's can see the markers on the bottom side of the substrate.
6. Check if the alignment camera has the correct intensity (light gray).
   6.1. If the camera intensity is not correct, go to Camera controls and adapt the exposure time until the intensity is correct.

   Note: Typical camera exposure times are 50-100 ms for glass substrates and 10 ms for wafers.
7. Press Capture image.
8. Continue at step **7. on page 80** untill step **15. on page 83** to finalize the marker training.

3.6.8 Performing global frontside alignment

1. Make sure that the objective lens height is correct, see **"Writing module height adjustment" on page 22**. Incorrect lens height may lead to failing alignment.

Searching the markers

1. Select alignment type Global in the quick selection bar, see **Figure 3-115 below**.

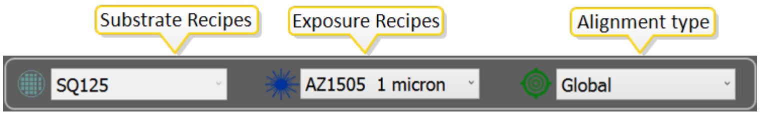


Figure 3-115 Quick selection bar

2. Press Alignment in the top bar to open the Alignment window.
3. Press Frontside Alignment on the left side of the screen to open the alignment window, see **Figure 3-116 below**.

Figure 3-116 Global alignment window

The Camera View shows a 1.7mm x 1.7mm image on substrate level.

On the right side of the camera image, the choices below can be made:

Save image: saves die camera image as a bmp file.

Area scan: makes a camera spiral search and stitches camera views into a larger area image.

Draw mode: can be used to create additional project features.

Overlay: used for marker free alignment.

Search marker: combines area search with marker automatic detection.

Align corner: after manual move of the camera to the top left substrate corner, this button saves the new corner position.

The check box beside the white cross activates a cross in the camera center.

In the Global Alignment Markers, section, all alignment markers that are present in the active global alignment recipe are listed.

PosX/PosY: [mm] Marker positions with reference to the top left corner of the substrate bounding box.

DetectedX/DetectedY: [mm] Marker detected positions in substrate coordinates.

4. Use the Global Alignment Markers section to move the Alignment camera to the marker:

   4.1. If you have a recipe, press GoTo for the marker which position you want to detect, see **Figure 3-117 below**.

   4.2. If you do not have a recipe, in the top line, at PosX and PosY a, fill in the location of the marker with reference to the top left of the substrate bounding box and press GoTo.

Figure 3-117 Going towards marker position

   Note: The X and Y axes will now move until the writing module that holds the alignment camera is at the marker position.

5. Check if the alignment camera has the correct intensity (light gray).

   5.1. If the camera intensity is not correct, go to Camera controls and adapt the exposure time until the intensity is correct.

   Note: Typical camera exposure times are 50-100 ms for glass substrates and 10 ms for wafers.

6. If the marker is not immediately visible, click on Area scan, see **Figure 3-118 on the next page**.

Figure 3-118 Area scan

Note: Area scan shows a wider area around the position that the camera moved to. It does not do active detection. Every frame taken by the camera is approximately 1x1 mm, the maximum search range for Area scan can be adjusted in the machine settings for alignment, see maximum composite size in **"Adjust alignment settings " on page 123**.

6.1. During the Area scan, press  if the marker is visible.

After searching the marker, the exact marker position needs to be detected. This can be done automatically or manually.

Automatic marker detection

1. At Marker detection, select Automatic.

   1.1. At Marker, select the marker that needs to be detected.

   1.2. Click the Auto Detect checkbox.

   1.3. Click the Auto Center checkbox.

Note: Auto Detect automatically finds the (trained) marker. Auto Center moves the anchor point of the marker to the middle of the camera field.

2. Wait for indicator light to turn green. This indicates that the automatic detection system has found the marker and has auto centered on it.

Note: Area scan and Marker Auto Detect/Auto Center can also be done automatically by selecting the marker and pressing the Search marker button.

Manual marker detection

1. At Marker detection, select Manual, see **Figure 3-119 on the facing page**.

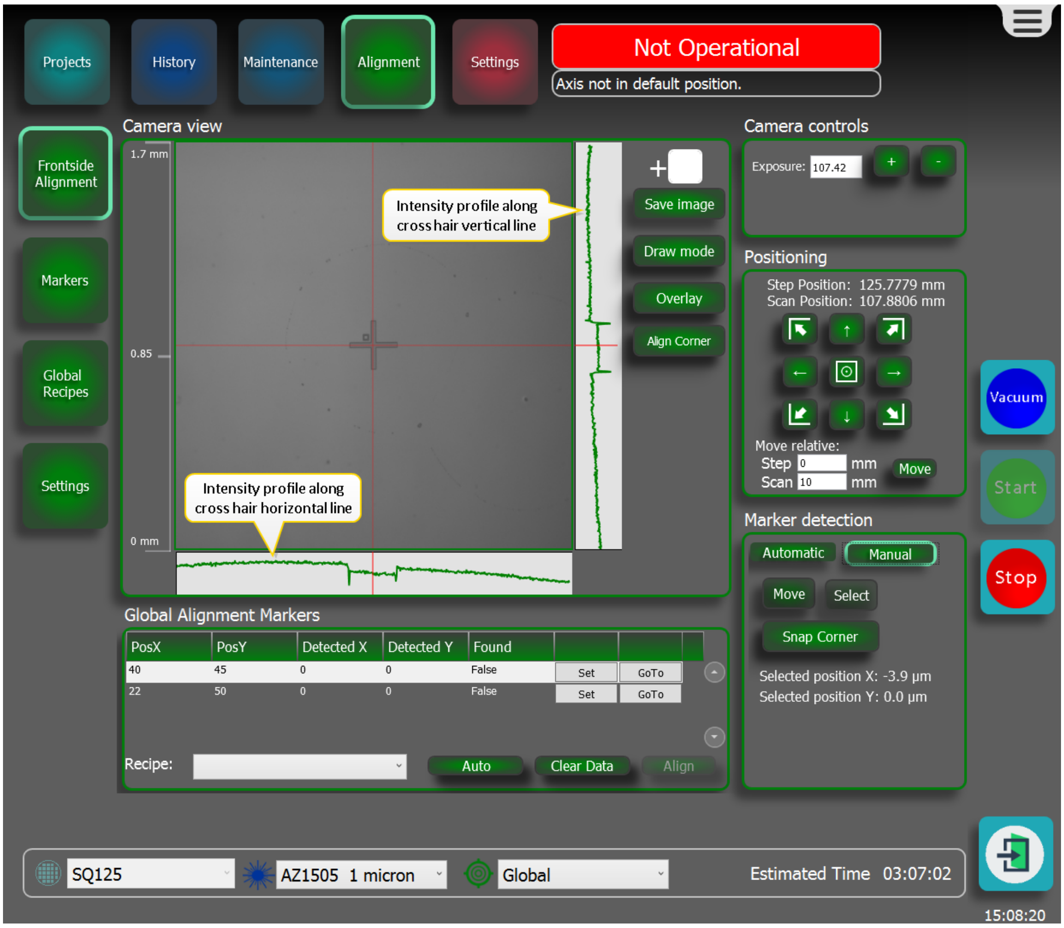


Figure 3-119 Doing manual marker detectionMarker

Under manual Marker detection, the buttons below can be selected:

Move: The camera center is **moved** to the spot that is clicked.

Select: The camera **stands still** and a cross hair center can be positioned by clicking on a spot. To help manual centering, intensity profiles of the horizontal and vertical cross hairs are shown on the sides of the camera image.

Snap corner: The software automatically sets the cross hair center to the nearest image corner.

Selected position X/Y: Position value of the cross hair center with reference to the center of the camera field.

2. Press Move.

3. In the Camera view section, click on a spot to move the camera center towards is.

4. Press Select. Cross hairs and intensity profiles will show.

5. Click in the camera window to position the cross hair center.

Note: The cross hair center is the alignment position that will be stored.

5.1. If needed, use the intensity profile of the cross hair to find the best position.

5.2. When visually close to a corner, press Snap Corner to automatically fine tune on the corner.

Store aligned positions and align the project

1. In the Global Alignment Markers section, press Set to store the alignment position. The detected position becomes visible at Detected X and Detected Y and the Found status changes to True.

2. To align the other alignment markers, go back to **"Searching the markers" on page 86**, step **4. on page 87**.

3. Press Align to align the substrate. The Alignment result window opens, see in **Figure 3-120 on the next page**

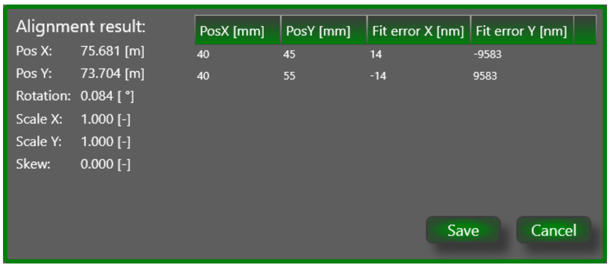


Figure 3-120 Alignment results

Alignment result meanings:

- Pos X/Y: Position in machine coordinates of the top left corner of the substrate bounding box .
- Rotation: Rotation of the substrate.
- Scale X/Y: Scaling factor needed to align the project: scaling is **not** included in global alignment and is set to zero.
- Skew: Skew (angle between axes) correction required to align the project: skew is **not** included in global alignment and is set to zero.

Fit error:

Due to the way the alignment software translates measured marker positions to corrections of the axis movements, an error is still present. The shown error is the remaining position error at marker positions. For project features within the marker area, errors are expected to be lower. For features outside the marker area, error are expected to be larger.

4. Press Save to save the alignment results.

Automatic global alignment

If a global alignment recipe is available for the substrate, alignment can be done fully automatically.

1. If the mark positions on the substrate as well as the mark types are completely equal to previously used ones, then select the existing frontside alignment recipe:

   1.1. Select Alignment in the top part of the screen.

   1.2. Select Global Recipes in the left bar.

   1.3. Under Recipes, select the required alignment recipe.

2. If mark positions and/or mark types have changed, then make a new recipe:

   2.1. Do **"Making a global frontside alignment recipe" on page 69**.

   2.2. Activate the required recipe.

3. Select Frontside Alignment in the left bar.

4. Under Substrate Alignment Markers, press Auto.

The automatic steps the alignment wizard takes are:

- The wizard will measure Marker 1
- The wizard will measure Marker 2
- The wizard will show the alignment result.

5. When the alignment wizard is ready, press Save to save the results.

3.6.9 Performing local (frontside) alignment

Note: Local alignment is only available for the frontside camera.

1. Make sure that the objective lens height is correct, see **"Writing module height adjustment" on page 22**. Incorrect lens height may lead to failing alignment.

2. Make sure the project layer that needs alignment is correctly positioned with reference to the substrate, see **"Selecting and positioning the project" on page 43**.

Searching the markers

1. Select alignment type Local in the quick selection bar, see **Figure 3-121 below**.

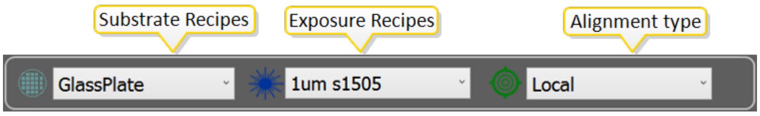


Figure 3-121 Quick selection bar

2. Press Alignment in the top bar to open the Alignment window.
3. Press Frontside AlignmentAlignment on the left side to open the alignment window.

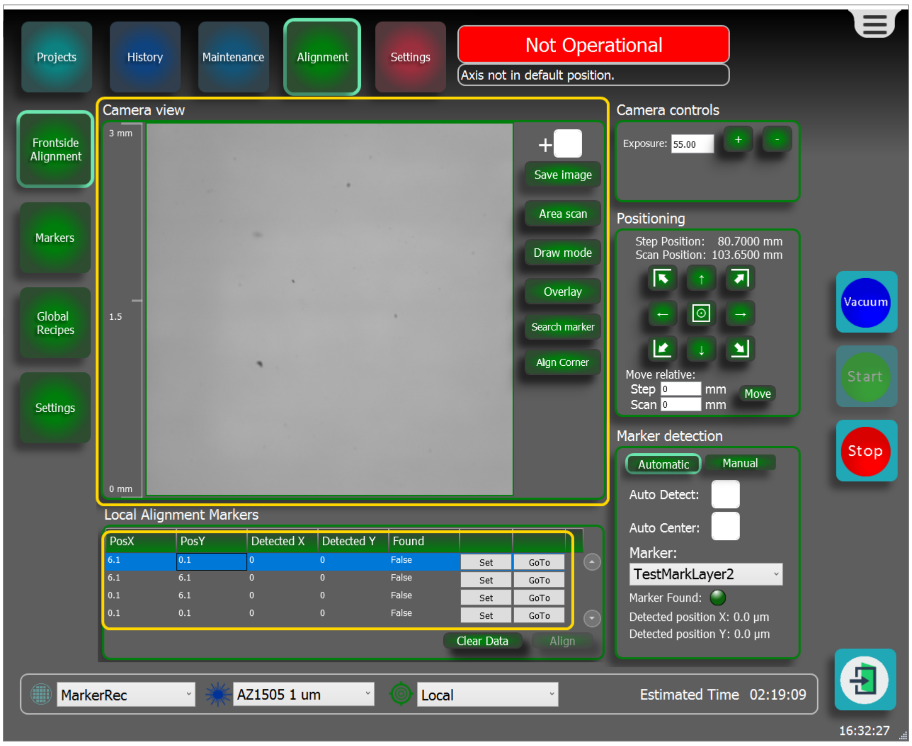


Figure 3-122 Going towards marker position

The Camera View shows a 1.7mm x 1.7mm image on substrate level.

On the right side of the camera image, the choices below can be made:

Save image: saves die camera image as a bmp file.

Area scan: makes a camera spiral search and stitches camera views into a larger area image.

Draw mode: can be used to create additional project features.

Overlay: used for marker free alignment.

Search marker: combines area search with marker automatic detection.

Align corner: after manual move of the camera to the top left substrate corner, this button saves the new corner position.

The check box beside the white cross activates a cross in the camera center.

In the Local Alignment Markers, section, all alignment markers within the project are listed.The Alignment Markers section is only visible if alignment markers are present in the currently opened project.

PosX/PosY: [mm] Marker positions with reference to project top left corner.

DetectedX/DetectedY: [mm] Marker detected positions in machine coordinates.

4. Under Local Alignment Markers, at the first marker, press GoTo .The alignment camera will now move towards the marker position.

   Note: The X and Y axes will now move until the writing module that holds the alignment camera is at the marker position.

5. Check if the alignment camera has the correct light intensity (light gray, see illustration above).

   5.1. If the screen intensity is not correct, go to Camera controls and adapt the exposure time until the intensity is correct.

6. If the marker is not immediately visible, click on Area scan, see **Figure 3-123 below**.

Figure 3-123 Area scan

Note: Area scan shows a wider area around the position that the camera moved to. It does not do active detection. Every frame taken by the camera is approximately 1x1 mm, the maximum search range for Area scan can be adjusted in the machine settings for alignment, see maximum composite size in **"Adjust alignment settings " on page 123**.

   6.1. During the Area scan, press 

if the marker is visible.

7. If needed, use the Positioning window buttons to move the camera towards the marker.

   7.1. Press the horizontal or vertical arrow buttons to make small steps.

   7.2. Hold the horizontal or vertical arrow buttons to do a continuous movement.

   7.3. Type a step size and press Move.

Note: Arrows under 45 degrees go to the end of the substrate, the middle button goes to the substrate center.

   Note: field, the automatic detect system can be used, see the steps below.

Detect the marker automatically

1. At Marker detection, select Automatic.

   1.1. At Marker, select the marker that needs to be detected.

   1.2. Click the Auto Detect checkbox.

   1.3. Click the Auto Center checkbox.

Note: Auto Detect automatically finds the (trained) marker. Auto Center moves the anchor point of the marker to the middle of the camera field.

2. Wait for indicator light to turn green. This indicates that the automatic detection system has found the marker and has auto centered on it.

Note: Area scan and Marker Auto Detect/Auto Center can also be done automatically by selecting the marker and pressing the Search marker button.

Detect the marker manually

1. At Marker detection, select Manual,see **Figure 3-124 below**.

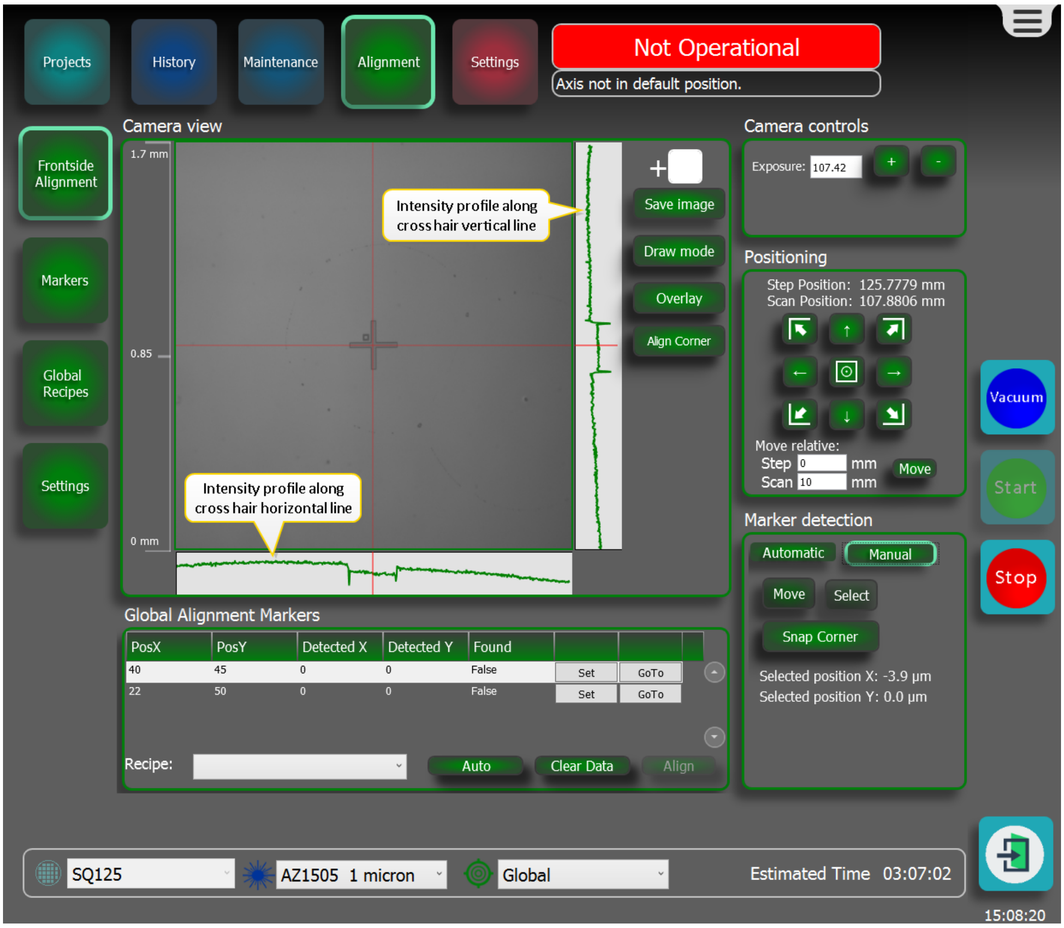


Figure 3-124 Doing manual marker detectionMarker

Under manual Marker detection, the buttons below can be selected:

Move: The camera center is **moved** to the spot that is clicked.

Select: The camera **stands still** and a cross hair center can be positioned by clicking on a spot. To help manual centering, intensity profiles of the horizontal and vertical cross hairs are shown on the sides of the camera image.

Snap corner: The software automatically sets the cross hair center to the nearest image corner.

Selected position X/Y: Position value of the cross hair center with reference to the center of the camera field.

2. Press Move.
3. In the Camera view section, click on a spot to move the camera center towards is.
4. Press Select. Cross hairs and intensity profiles will show.
5. Click in the camera window to position the cross hair center.

Note: The cross hair center is the alignment position that will be stored.

   5.1. If needed, use the intensity profile of the cross hair to find the best position.

   5.2. When visually close to a corner, press Snap Corner to automatically fine tune on the corner.

Store aligned positions and align the project

1. In the Alignment Markers section, select the alignment marker and press Set to store the marker location. The detected position becomes visible at Detected X and Detected Y and the Found status changes to True.
2. For the other alignment markers, go back to **"Searching the markers" on page 91**, step **4. on page 92**.

3. Make sure that at least three markers are found.

4. Press Align to align the project. The Alignment result window opens, see in **Figure 3-125 below**

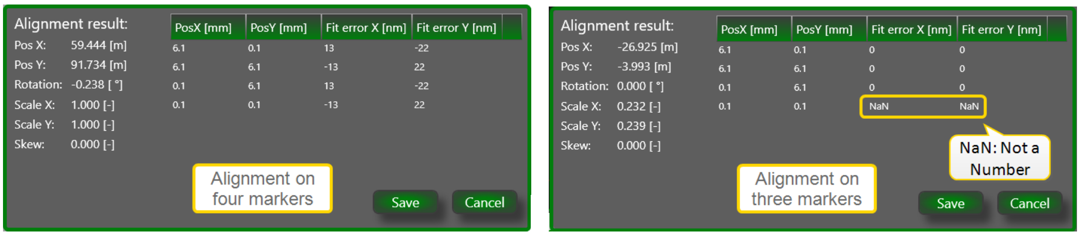


Figure 3-125 Alignment results window

Alignment result meanings:

- Pos X/Y: Aligned project position.
- Scale X/Y: Scale correction needed to align the project.
- Skew: Skew correction required to align the project.
- Rotation: Rotation correction value.

Fit error:

The fit error shows the least square fit error of the alignment.
In case of alignment on 3 markers, the fit error is always zero. The fourth line contains the positions of the fourth marker, but does not have fit errors (set to NaN: Not a Number).
In case of alignment on 4 or more markers, the fit error can be used as a measure for the alignment accuracy. The fit error should be small (below 150nm). A larger fit error indicates the alignment can not fit the measured marker.

5. If four or more markers are used (this is advised), check if the fit errors are smaller than 150 nm.

6. Verify that the Skew and Scale corrections are close to 0.000 and 1.000 respectively.

7. Press Save to save the alignment results.

Add alignment data to the queue

1. In the Alignment Markers window, the Add to queue button becomes visible, see in **Figure 3-126 on the facing page**.

Figure 3-126 Alignment marker values after alignment

2. Press Add to queue to add the project to the job queue.

Note: The project location is automatically calculated. After adding the project to the queue, the project location cannot be changed. Alignment data stay active until a new project has started. Stopping the PICOMASTER application will erase the alignment data.

3.6.10 Performing backside alignment

Note: If a backside alignment recipe is available for the substrate, alignment can be done fully automatically.

1. Make sure that the lens height is correct, see **"Writing module height adjustment" on page 22**. Incorrect lens height may lead to failing alignment.

2. Check in the top right side of the screen if the machine status is Waiting.

3. If the machine status is NOT Waiting, pres the Stop button to move all axes to the default position.

4. If the the substrate and marker types are completely equal to previously used ones, then select the existing backside alignment recipe:

   4.1. Select Alignment in the top part of the screen.

   4.2. Select Global Recipes in the left bar.

   4.3. Under Recipes, select the required backside alignment recipe.

   Note: The recipes list holds all frontside and backside recipes.

5. If marker positions and/or marker types have changed, then make a new recipe, do **"Making a backside alignment recipe" on page 71**.

6. Select Align Wizard to do the alignment.

The automatic steps the alignment wizard takes are:

- The wizard will measure Marker 1
- The wizard will measure Marker 2
- The wizard will show the alignment result.

7. When the alignment wizard is finished, the alignment results become visible, see **Figure 3-127 below**

Figure 3-127 Alignment results

Alignment result meanings:

- Pos X/Y: Position in machine coordinates of the top left corner of the substrate bounding box .
- Rotation: Rotation of the substrate.

8. Press Save to save the results.

3.6.11 Calibrate frontside alignment offsets

Marker offset concept explained

On an exposure layer, markers can be used as a position reference. The markers are found by the alignment wizard or manually. Because exposure positions are known with reference to the markers, the exposure positions can be found by the step and scan system. If two layers are exposed on top, in a perfect world, the second layer is exactly at the correct location. But in practice, there is a small deviation as shown in the example in **Figure 3-128 below**.

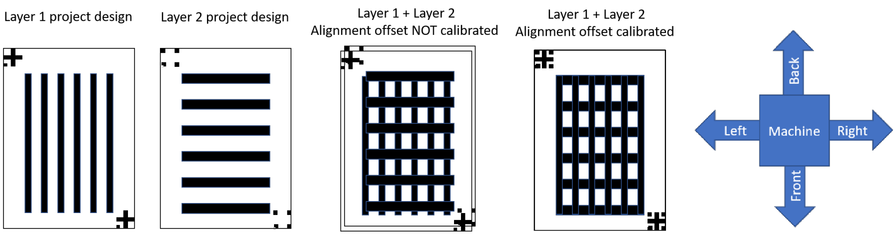


Figure 3-128 Two layers exposed with and without alignment offset calibration

In **Figure 3-128 above**, an alignment offset is present in positive X and positive Y direction. This alignment offset is removed applying fine align offsets in the marker recipe.

Measure marker fine align offsets (microscope)

Note: You have exposed a second layer that holds markers at well defined locations and you have developed the substrate.

1. In the project design data, check known size and the expected location of the markers that were exposed.
2. Put the substrate under a microscope.
3. Find the markers.

An example is shown in **Figure 3-129 below**.

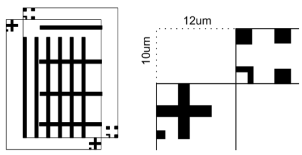


Figure 3-129 Correcting an alignment error of 10 and 12 micron

Note: In this example, the fine align offset should be changed to -10 µm for Y and -12 µm for X.

4. Using the microscope, determine the displacement in X and Y with reference to the expected location.
5. Determine the fine align offset in Y of the markers.
   5.1. If the displacement in Y with reference to the expected location is **towards the back** of the machine, then the marker offset is **negative**.
   5.2. If the displacement in Y with reference to the expected location is **towards the front** of the machine, then the marker offset is **positive**.
6. Determine the align offset in X of the markers.
   6.1. If the displacement in X with reference to the expected location is **towards the right** of the machine, then the marker offset is **negative**.
   6.2. If the displacement in Y with reference to the expected location is **towards the left** of the machine, then the marker offset is **positive**.

Note: If the fine align offsets measured by microscope are larger than 10µm, it is recommended to repeat the alignment offset calibration. It will typically take some iterations to get the best possible result.

Measure marker fine align offsets (alignment system)

Note: You have exposed a second layer that holds markers at well defined locations and you have developed the substrate.

1. Load the substrate after adding and processing the second layer.
2. Find and center on the markers in layer 1 for which offsets should be calibrated:

- For global alignment, do **"Searching the markers" on page 86** and **"Performing global frontside alignment" on page 86**.
- For local alignment, do **"Searching the markers" on page 91** and **"Detect the marker automatically" on page 92**.

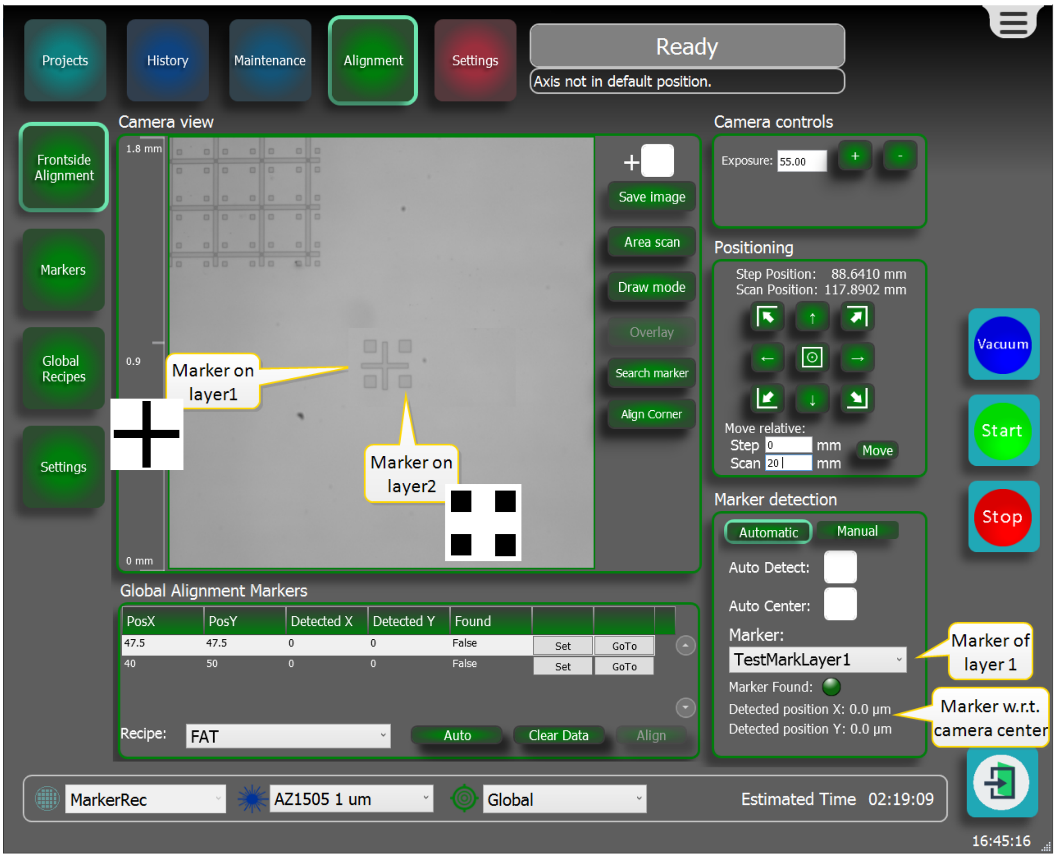


Figure 3-130 Calibrate marker offsets

3. Switch **off** Auto Detect and switch **off** Auto Center, see **Figure 3-130 above**.

4. At Marker detection, at the Marker drop down list, select the marker on layer 2, see the example in **Figure 3-131 on the facing page**.

Figure 3-131 Determining the alignment error

5. **Only** switch **on** Auto Detect and **leave off** Auto Center.

6. Check Detected position X and Detected position Y of the marker in layer 2. This a measurement of the alignment error.

> In the example, the marker of layer 1 was centered in the center of the camera image because Auto Center was **on**. The marker position of layer 2 is determined without moving to the camera because Auto Center is **off**. This gives the position offset between the two markers. This is the alignment error. In the example screenshot, there was a alignment error of X=7.57µm and Y=15.3µm.

Change alignment settings (marker specific)

If the offsets are expected to be applicable to one specific marker, the fine align offsets are applied to the alignment offsets of that marker:

1. Select Alignment.

2. Select Markers.

3. At Recipes, select the marker, see **Figure 3-132 on the next page**.

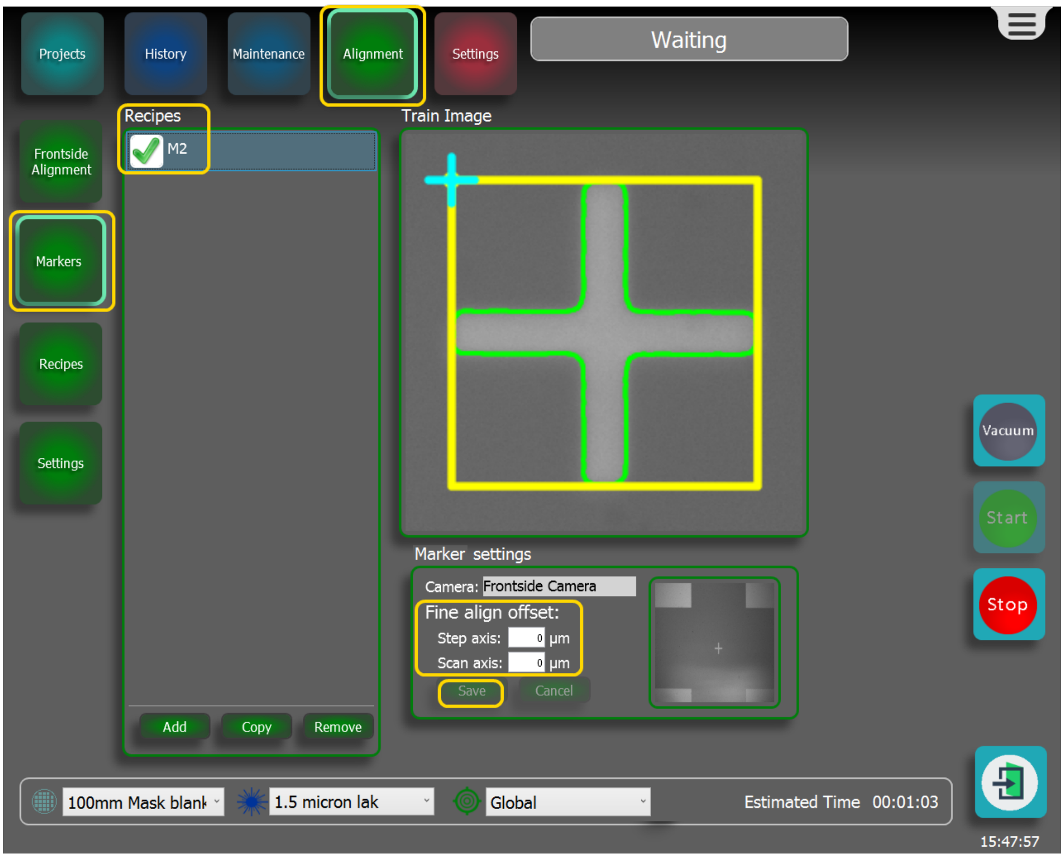


Figure 3-132 Changing marker fine align offsets

4. Under Fine align offset, find the existing Fine align offset values.

5. **Subtract** the measured alignment error from the Fine align offsets and type them in µm.

6. Press Save.

Change alignment settings (global)

If the offsets are expected to be applicable to every alignment action, the fine align offsets are applied to the alignment offsets in the alignment settings window:

Note: This will affect all alignment actions and should preferably be done by system owners.

1. Select Alignment in the top bar.

2. Select Settings in the left bar.

3. At **Misc**, find the Camera offset values, see **Figure 3-133 on the facing page**.

Figure 3-133 Global alignment offset values

4. Subtract the measured alignment error from the Camera ofsets and type in the results in mm.

Note: New value = Old value - Detected position/1000. The factor 1000 appears due to the fact that the calibration offset is defined in mm but the detected position is measured in µm.

3.6.12 Calibrate backside alignment offsets

To be able to use backside alignment in combination with frontside alignment, it is essential that the frontside and backside alignment systems find a marker at the same location.

Backside alignment offset calibration has the main steps listed below:

- Using the backside system, the markers are searched and found, and the position coordinates are written down.
- Using these coordinates, the front size alignment camera is moved to the marker.
- The deviation is the aligment offset that needs to be applied to the BSA substrate recipe.

Transparent and non-transparant substrates may be used, see **Figure 3-134 below**.

Figure 3-134 Transparent and non-transparent substrate with markers (cross section)

If a transparent substrate is used, the marker has to be present on top of the substrate. If a non transparent substrate is used, markers need to be present on both sides of the substrate on the same location.

Measure backside alignment offsets

1. Load the substrate.
2. Make sure that the lens height is correct, see **"Writing module height adjustment" on page 22**. Incorrect lens height may lead to failing alignment.

3. Make sure that you know which marker name belongs to which position on the substrate.

4. Press Alignment in the top bar to open the Alignment window.

5. Press Backside Alignment in the left bar to open the search window, see **Figure 3-135 below**.

Figure 3-135 Searching the backside alignment markers

6. Under Camera positioning, select the applicable substrate size from the dropdown list.

7. At Marker, select the marker that needs to be calibrated from the dropdown list.

8. Press Move to to move the vacuum chuck so that the channels are in front of the camera's. Both camera views should show markers now.

9. Check that the markers are fully visible in both camera views.

10. If the markers are not fully visible, adjust the substrate position:

11. Switch on Auto Detect.

Coordinate meanings:

- Camera pos X: the X location of the marker w.r.t. camera center
- Camera pos Y: the Y location of the marker w.r.t. camera center
- Substrate pos X: the X location of the marker w.r.t. top left of substrate bounding box
- Substrate pos Y: the Y location of the marker w.r.t. top left of substrate bounding box

12. Write down Substrate pos X and Substrate pos Y of the marker.

Note: This is the location of the marker with reference to the top left of the substrate bounding box

13. Select Frontside Alignment in the left bar.

14. Select alignment type Global in the quick selection bar, see **Figure 3-136 below**.

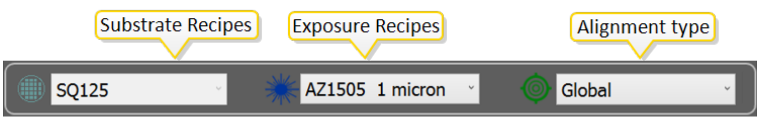


Figure 3-136 Quick selection bar

15. Use the Global Alignment Markers section to move the Alignment camera to the marker:

15.1. If you have a recipe, press GoTo for the marker which position you want to detect, see **Figure 3-137 below**.

15.2. If you do not have a recipe, in the top line, at PosX and PosY a, fill in the location of the marker with reference to the top left of the substrate bounding box and press GoTo.

Figure 3-137 Going towards marker position

Note: The X and Y axes will now move until the writing module that holds the alignment camera is at the marker position.

16. Check if the alignment camera has the correct intensity (light gray).

16.1. If the camera intensity is not correct, go to Camera controls and adapt the exposure time until the intensity is correct.

Note: Typical camera exposure times are 50-100 ms for glass substrates and 10 ms for wafers.

17. **Only** switch **on** Auto Detect and **leave off** Auto Center.

18. Write down the values at Detected position X and Detected position Y of the marker. This a measurement of the alignment error.

19. Go back to step **7. on the previous page** to repeat the measurement for the other markers.

Change backside alignment settings

If the offsets are expected to be applicable to every alignment action, the fine align offsets are applied to the alignment offsets in the alignment settings window:

Note: This will affect all alignment actions and should preferably be done by system owners.

1. Select Alignment in the top bar.

2. Select Settings in the left bar.

3. At Backside alignment settings, change the calibration offset values for both the markers, see **Figure 3-138 on the next page**.

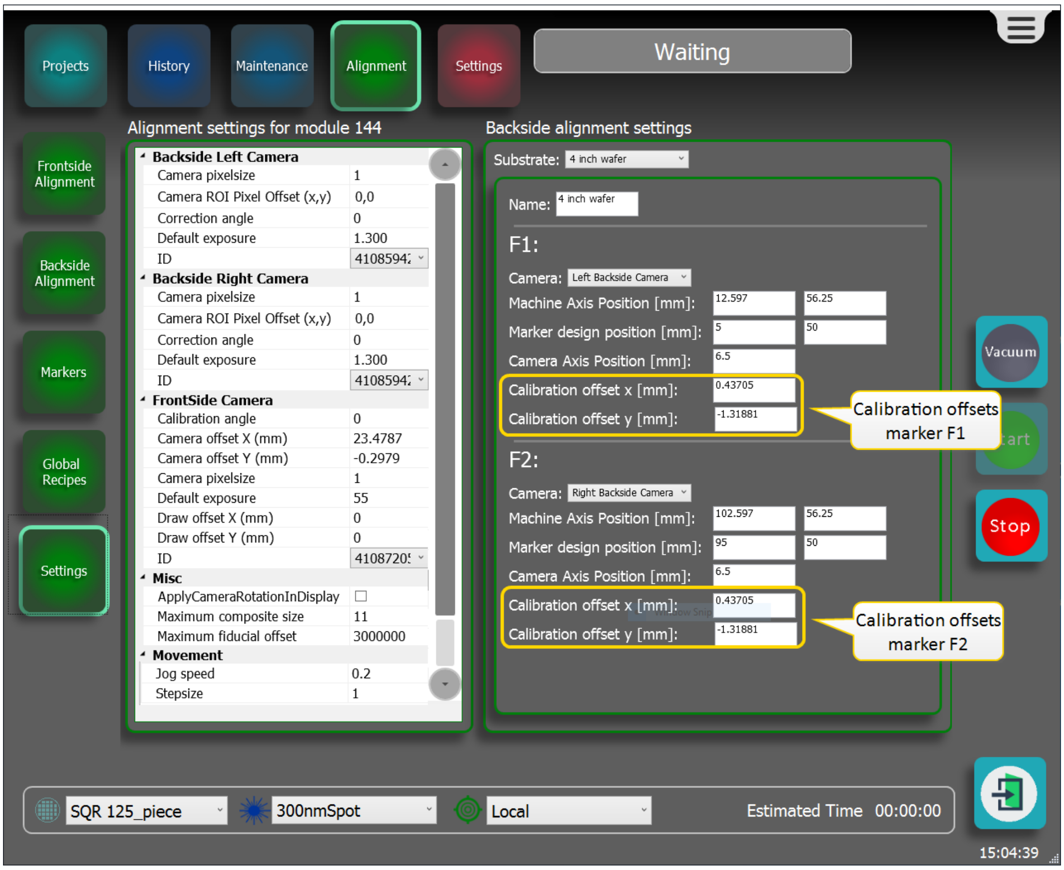


Figure 3-138 Changing the backside alignment offsets.

3.1. **Subtract** the measured alignment error you wrote down above from the Fine align offsets and type them **in mm**.

Note: New value = Old value - Detected position/1000. The factor 1000 appears due to the fact that the calibration offset is defined in mm but the detected position is measured in µm.

3.6.13 Marker free alignment using the Overlay tool

The Overlay tool is used to do a manual alignment of a position within a selected project to an existing project image on the substrate. The Overlay tool does not need trained markers.

1. Select Projects in the top bar, see **Figure 3-139 on the facing page**.

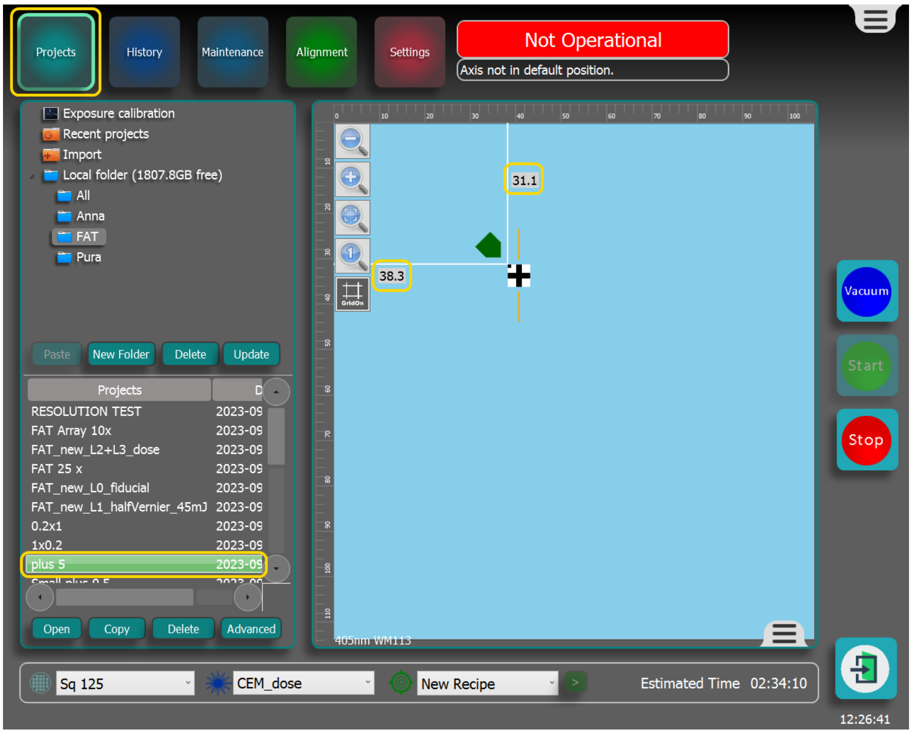


Figure 3-139 Project window

2. Select the project that you want to fine position and write.
3. Make a note of the project coordinates.
4. Select alignment type Global in the quick selection bar, see **Figure 3-140 below**.

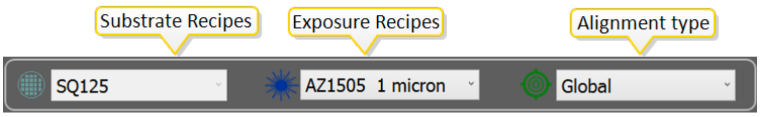


Figure 3-140 Quick selection bar

5. Press Alignment in the top bar to open the Alignment window.
6. Press Frontside Alignment on the left side of the window to open the alignment window.
7. Under Global Alignment Markers section, in top line, at PosX and PosY a, fill in the project coordinates that you found above.
8. At the right side of the top line, press GoTo, see **Figure 3-141 on the next page**.

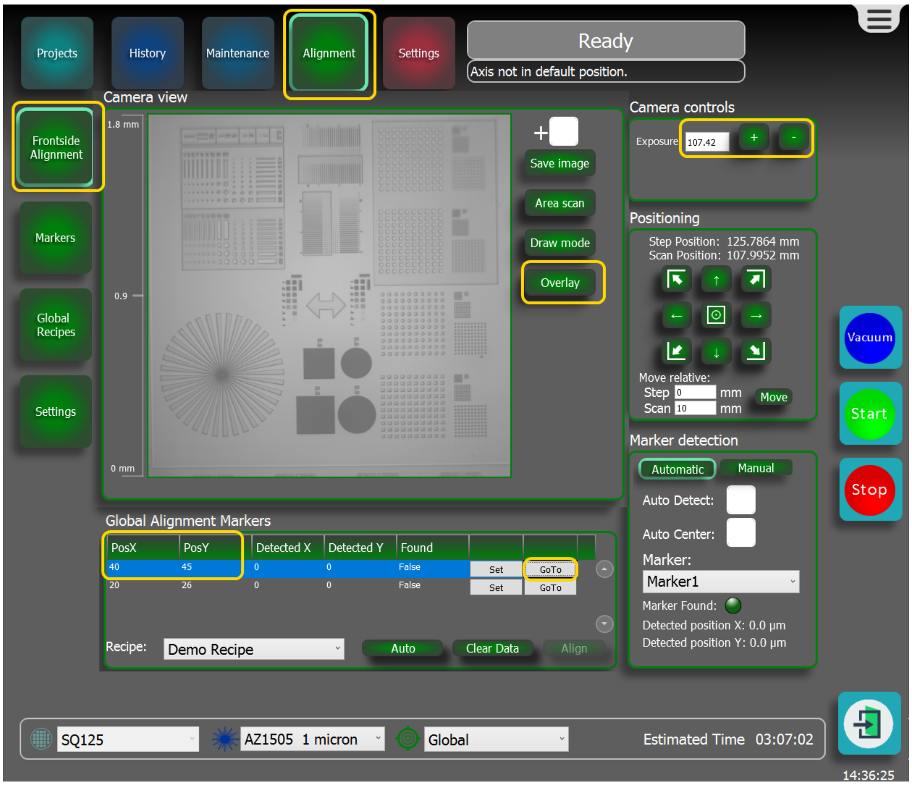


Figure 3-141 Going towards marker position

9. Check if the alignment camera has the correct intensity (light gray).

   9.1. If the camera intensity is not correct, go to Camera controls and adapt the exposure time until the intensity is correct.

   Note: Typical camera exposure times are 50-100 ms for glass substrates and 10 ms for wafers.

10. Move the alignment camera towards the position on the substrate where you want to align, use the methods below:

    10.1. Click in the Camera view window.

    10.2. In the Positioning section, use the buttons with the small arrows, or fill in values at Step and Scan and press Move.

11. Press Overlay. The Project preview window becomes visible, see **Figure 3-142 on the facing page**.

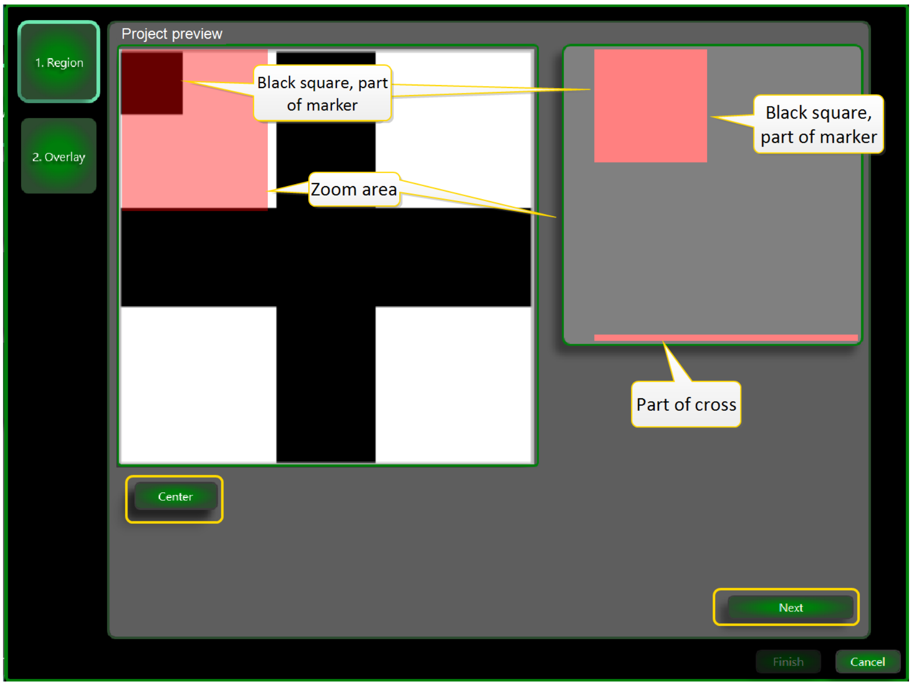


Figure 3-142 Project preview window

> The Project preview window shows the project image, NOT the alignment camera image. The Project preview window is used to select the part of the project that should be aligned to a part of the existing image on the substrate. The project shown in **Figure 3-142 above** is actually a marker.
>
> On the left side, the light red zoom area can be moved to select a part of the project. The selected area is zoomed in on the right side. The dark red square on the left top side is actually a square that belongs to the marker. The light red colour of the zoom area makes it become dark red. For larger projects, the zoom area has a size of 2mmx2mm. For projects smaller than 2mmx2mm, the zoom area is automatically made smaller.

12. Move the zoom area to select a project part, use the methods below:

    12.1. Press Center to move the zoom section to the center of the project.

    12.2. Click the left mouse button and drag the zoom section.

13. Press Next or press the Overlay button to go to the Live image window, see **Figure 3-143 on the next page**.

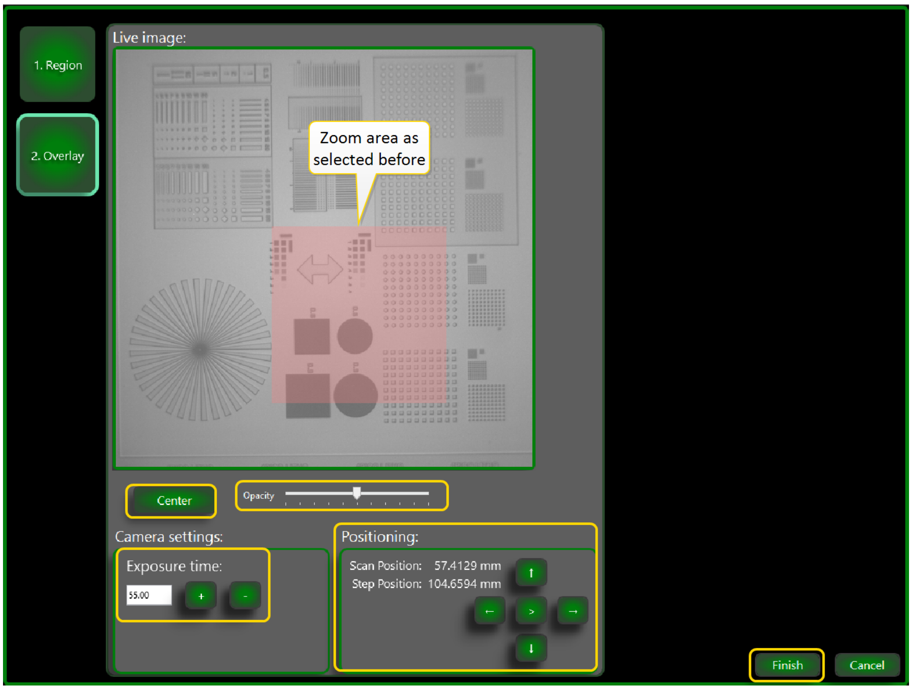


Figure 3-143 Project preview window

Note: **Figure 3-143 above** shows the zoom area that you selected in **Figure 3-142 on the previous page**.

14. Move the camera towards the required substrate position where you want to align to:

    14.1. Use the arrow buttons at Positioning.

    14.2. At Exposure time, adapt the camera light level.

15. Move the project towards the required position using actions listed below:

    15.1. Use Opacity to adapt the transparency of the light red block.

    15.2. Use your mouse Scoll button to zoom with reference to the middle of the camera image.

    15.3. Use the left mouse button and drag the project.

    15.4. Press Center to put the project in the middle of the camera image.

16. Press Finish to add the project with the newly found positions into the exposure queue.

Note: The general project settings are not changed, only the setting in the active queue.

3.7 Exposing a project

Note: If needed, make a project queue, see **"Queueing multiple projects" on page 111**.

1. Make sure all projects are at the desired position on the substrate, see **Figure 3-144 on the facing page**.

2. If a project queue is used with GDS files and automatic alignment is activated (see **"Set GDS file parameters" on page 40**), **it is recommended** to first perform a global alignment (see **"Searching the markers" on page 86**)

> With automatic alignment activated, you can manually add a few projects to the queue that should be aligned right before their exposure. To ensure that the alignment is performed successfully, you should use a global alignment such that the initial search location for the automatic alignment is close to the real marker location.

3. Activate the vacuum by pressing the vacuum button on the screen or on the front panel.

Note: The button on the machine will blink blue while the vacuum is building up. When the light is constant, the vacuum seal is activated correctly.

4. To start the project or, if present, the project queue, press the Start button, see **Figure 3-144 on the facing page**

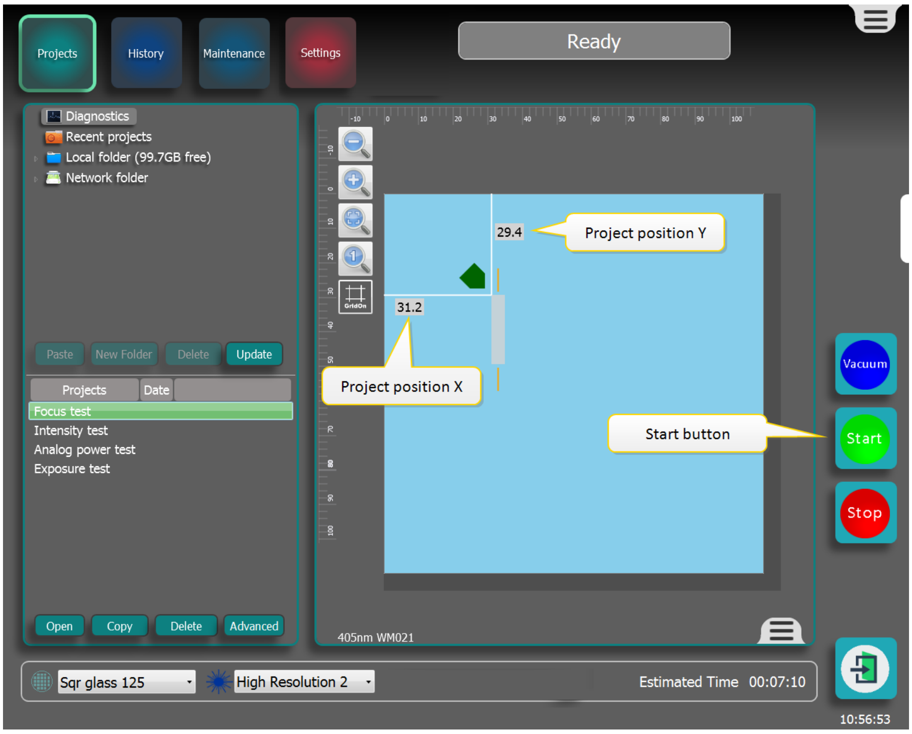


Figure 3-144 Starting a project queue

The project will load and do a pre-writing check. When this check is passed the project will load into the buffer and start writing.

The status of the exposure can be viewed while the exposure is progressing, see **Figure 3-145 below**.

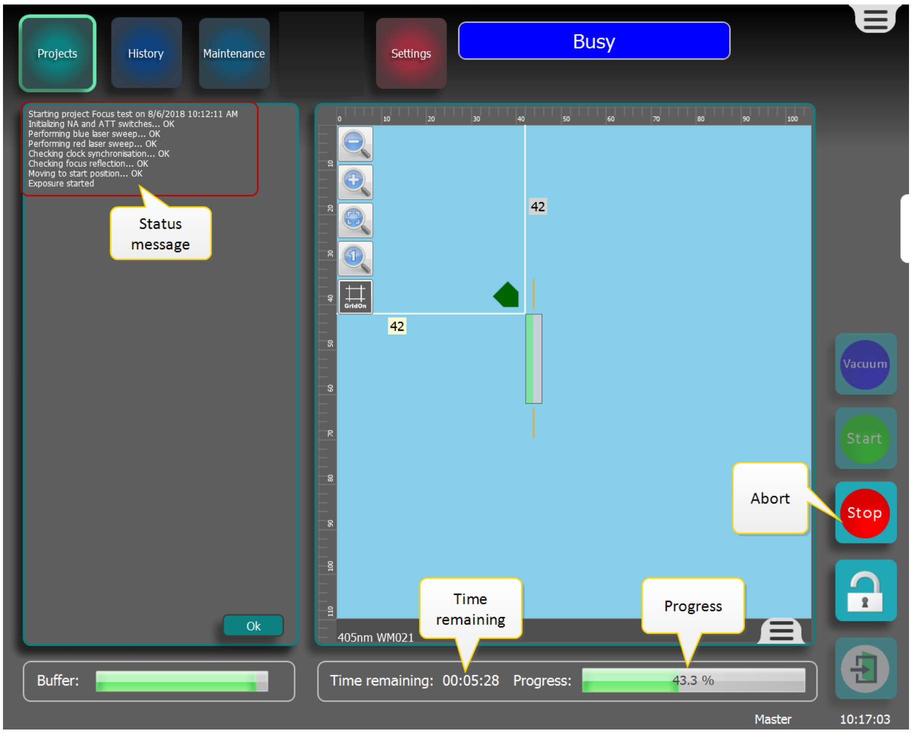


Figure 3-145 Project in progress

If a queue is running, queue status information can be viewed, see **Figure 3-146 on the next page**.

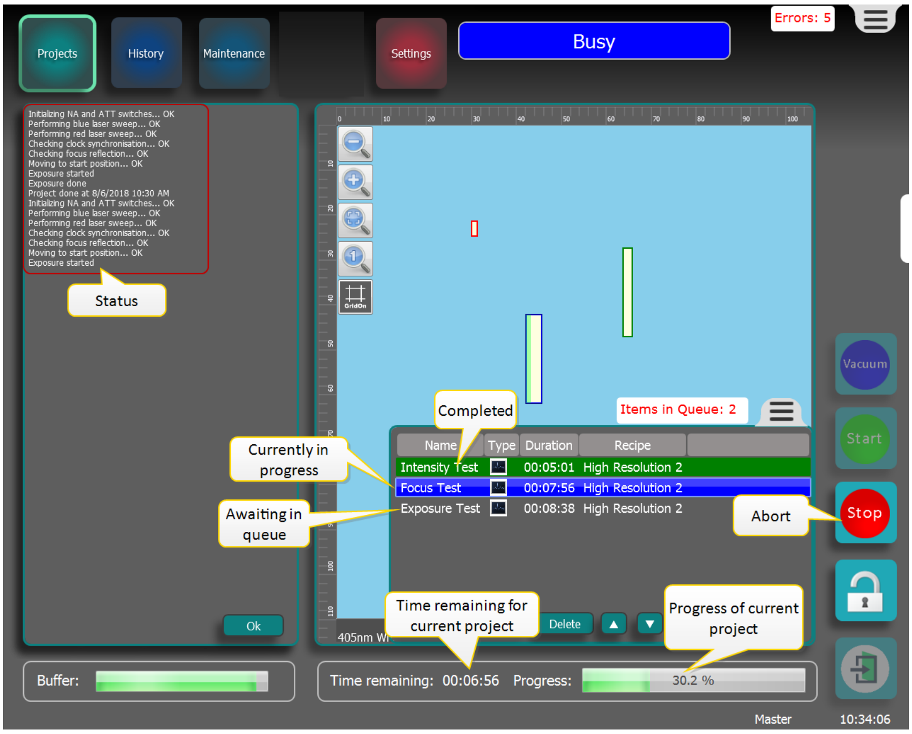


Figure 3-146 Queue in progress

Note: In case you have to do an intermediate stop, see **"Intermediate stopping of a project" on page 112**.

5. Check that the project is done, see **Figure 3-147 below**.

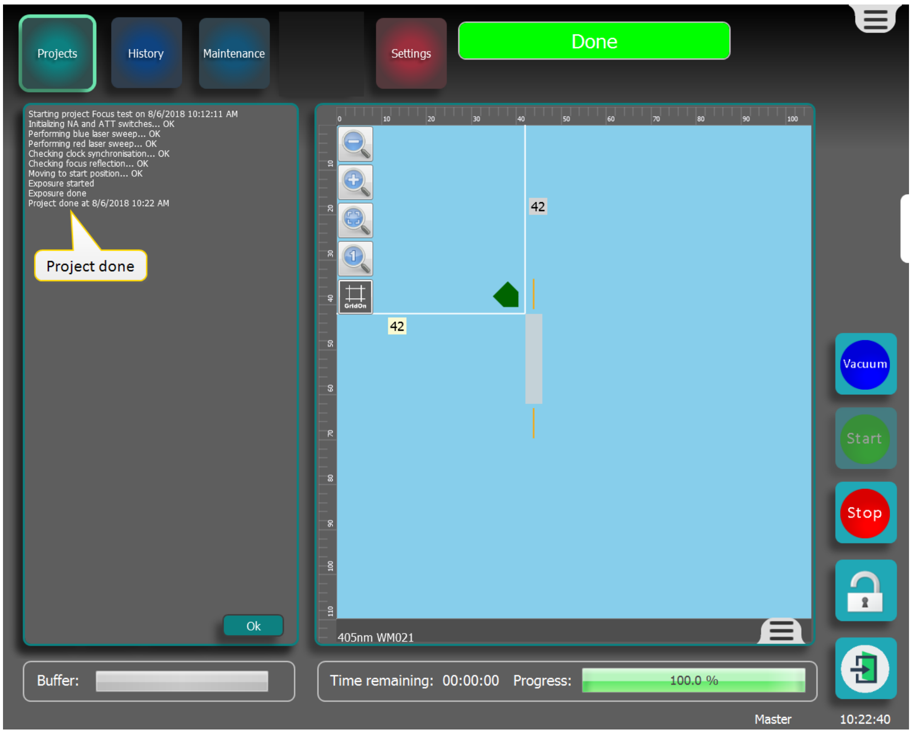


Figure 3-147 Project done

6. Press Stop to move the axes to the home position.

7. Either start a new project on the same substrate, or remove the substrate, see **"Removing the substrate" on page 112**.

8. After a project (queue) has finished, the Recent projects folder is cleaned using 'first in, first out', with only a number of files remaining as defined in the machine settings.

3.7.1 Queueing multiple projects

Adding projects to a queue allows the user to expose many projects without having to manually start the next project. When a project in the queue is completed, the PICOMASTER will automatically start the next one until the whole queue is completed.

An example of a project queue is shown in **Figure 3-148 below**.

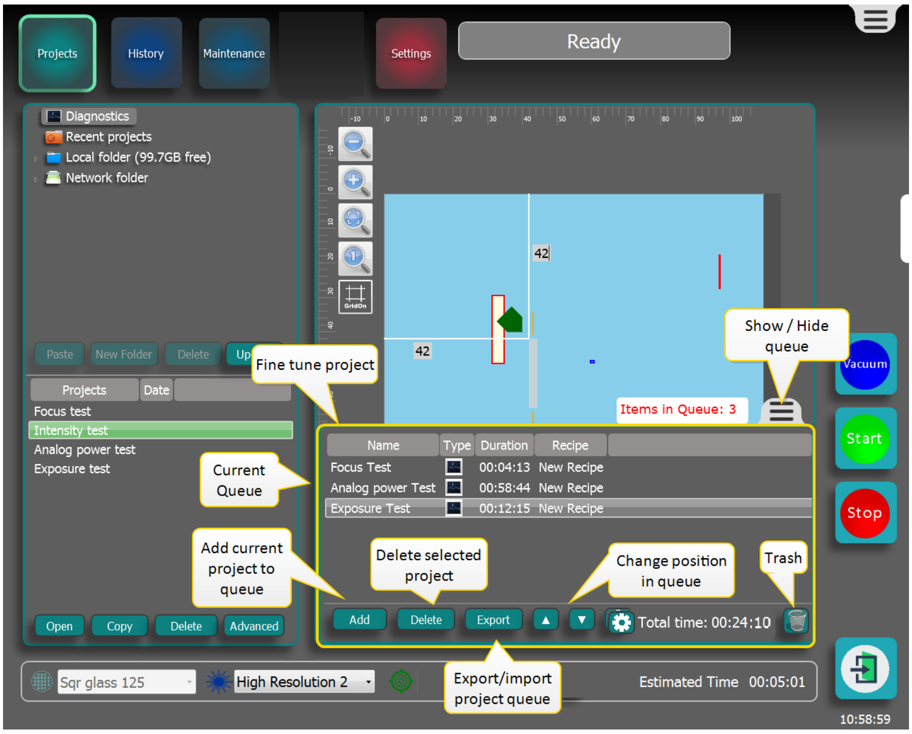


Figure 3-148 Project queue example

Making a new queue

1. Open the queue tab by pressing the show/hide queue button.
2. Add project queue from an external location directly to the queue:
   2.1. Press Import.
   2.2. Select the existing project queue from any file location.

Note: The Import button changes to Export when the queue contains one or more projects. As the queue in **Figure 3-148 above** contains projects, the Export button is shown.

3. Add a new project to the queue
   3.1. Select and position the project you wish to add, see **"Selecting and positioning the project" on page 43**.
   3.1. Press Add to insert the project into the queue.

   Note: When a project has been added to the queue, it is no longer possible to displace it on the substrate.

4. Repeat these steps for as many projects as required.

Note: Projects added in the queue receive an outline in the preview window. The currently selected project (in the queue) has a blue outline, the others have a red outline.

5. Press the show/hide queue button to hide the project queue.

Note: The queue is automatically saved when closing the window.

Changing the queue

1. To delete an item from the queue, select it in the list and press Delete.
2. To delete the whole queue, click the trash can icon at the bottom right of the queue tab.
3. To change the order of the queue, select a project and use the and buttons to move the item up or down.

Project fine tuning

For a project in the queue, exposure values can be fine tuned.

Note: Fine tuning is only applicable for the project that is open

1. Press the  button to open the project fine tuning window, see **Figure 3-149 below**.

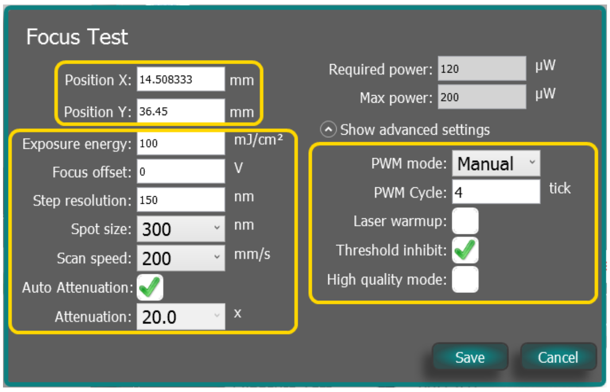


Figure 3-149 Project fine tuning window

Note: No project data will be saved in any recipe.

2. If required, at Position X and Position Y, adjust the project position on the substrate.
3. If required, adjust the settings, see **"Making an exposure recipe" on page 48**.
4. If required, press Show advanced settings and adjust the advanced settings, see **"Making an exposure recipe" on page 48**.
5. Press Save to save the adjusted values.

3.7.2 Intermediate stopping of a project

Note: Stopping a project does NOT deactivate the vacuum. This has to be done separately.

Press the Stop button.

Pressing Stop will cause all processes in the machine to stop. The scan and step axes will go to home position. This does not affect the vacuum.

Note: After Stop is pressed a Restart button appears.

Pressing Restart continues the current project from the point where it was when it was stopped. Moving or adding a project removes the restart button.

3.7.3 Removing the substrate

Note: Removing the substrate from the PICOMASTER is the reverse of installing the substrate.

1. Unlock the window of the PICOMASTER by pressing the Unlock button on the front panel.

Note: The button will light up green when the window is unlocked.

2. Release the vacuum by pressing the vacuum button on the front panel.

Note: The blue light around the button will turn off once the vacuum is no longer active.

3. Carefully lift the substrate from the vacuum chuck.

4 Additional Service Information

This chapter gives information on the subjects listed below:

For basic machine control, see **"Low level control" below**.

Setting machine constants can be found in **"Adjust machine settings " on page 118** and in **"Adjust alignment settings " on page 123**.

Loggings can be viewed in **"Checking project and event history" on page 125**.

Information on the file systems is available in **"Folder and project names" on page 129**.

Generic information on the buttons in the recipe editors is available in **"Recipe editor generic information" on page 131**.

Obtaining and using a software key can be found in **"Using a software key" on page 132**.

Periodic maintenance for the PICOMASTER is described in **"Periodic Maintenance" on page 132**.

4.1 Low level control

Low level control can be done for:

- Laser: see **"Writing Laser manual control" below**.
- Apertures: see **"Aperture and attenuator control" on the next page**.
- Motion: see **"Basic motion control" on page 117**.

4.1.1 Writing Laser manual control

The writing laser can be accessed by pressing Maintenance and then Laser.

The writing laser settings can be divided into three sections, see **Figure 4-1 below**.

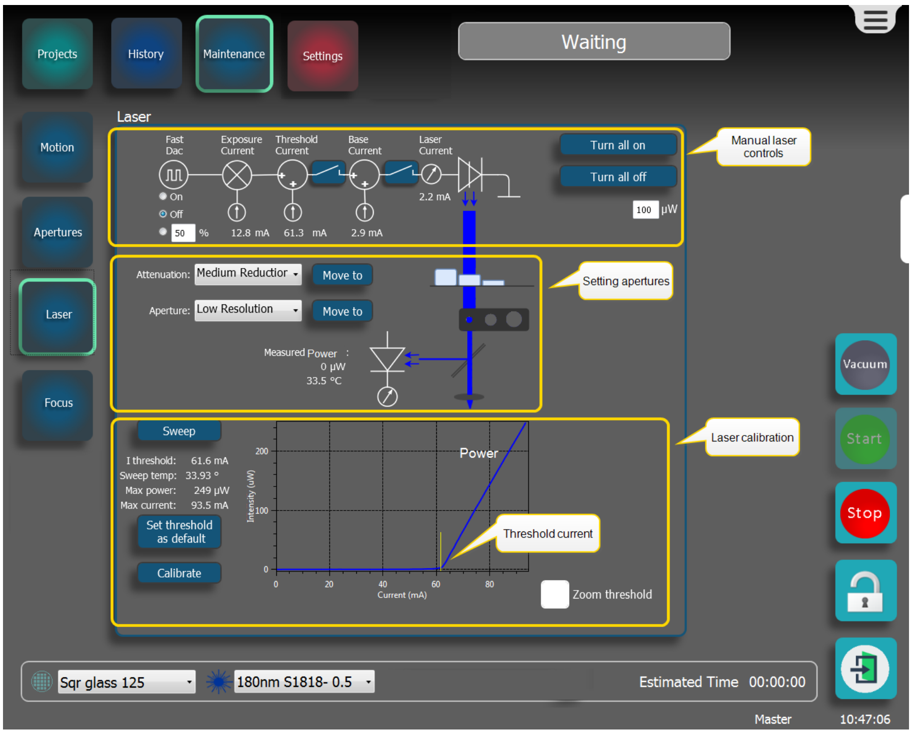


Figure 4-1 Laser manual control screen

Manual laser controls

When giving laser commands under the maintenance tab while doing any manual actions within the vicinity of the writing module, mind the below safety remark:

Warning: Class 3B laser, risk of eye injury. Maintenance commands can switch on the writing laser while the machine window is open. Avoid direct exposure to the laser beam at close distance.

The buttons Turn all on and Turn all off activate and deactivate the laser.

The Fast Dac setting decides how much of the exposure current is active. On is 100%, Off is 0% or any specific value between 0 and 100%.

Setting Apertures

1. At Attenuator and Aperture, select the required aperture from the drop down list.

2. Press Move to.

Detect and set threshold current

The threshold is the current above which the laser is active. The steps below perform a sweep of the writing laser power and set the threshold current.

1. Press Sweep to start a writing laser power sweep.

2. Wait for the values to update.

3. Press Set threshold as default.

4. Activate Zoom threshold to inspect the threshold area in the graph in detail.

4.1. If required, manually type the threshold current into the advanced machine settings, see **"Adjust machine settings " on page 118**.

Compensating for temperature drift

Note: For the best results, run this test after turning on the machine and half an hour of stabilizing.

To compensate for the temperature the calibration takes two measurements and checks for the difference in current while measuring the actual temperature of the writing module.

1. Press Calibrate to start the test.

The test window is shown in **Figure 4-2 below**.

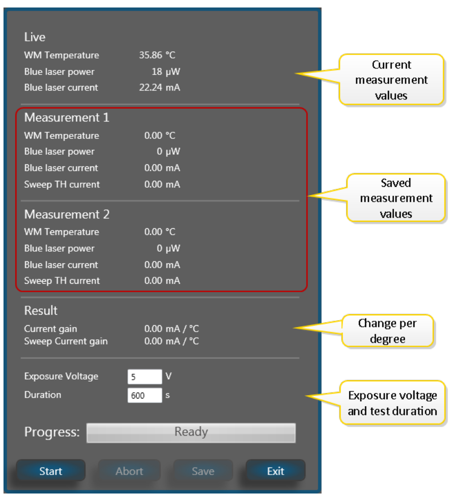


Figure 4-2 Threshold calibration settings

2. Type the test values:

2.1. Exposure Voltage: between 1 and 10 V

2.2. Duration: 10 - 20 minutes (600 - 1200 seconds)

3. Press Start to initiate the calibration.

4. Wait for the calibration to finish.

5. Press Save.

4.1.2 Aperture and attenuator control

For aperture and the attenuator explanations, see **"Writing module" on page 5**.

Open apertures control window

1. Select Maintenance in the top bar.
2. Select Apertures in the side bar.

The window is shown in **Figure 4-3 below**.

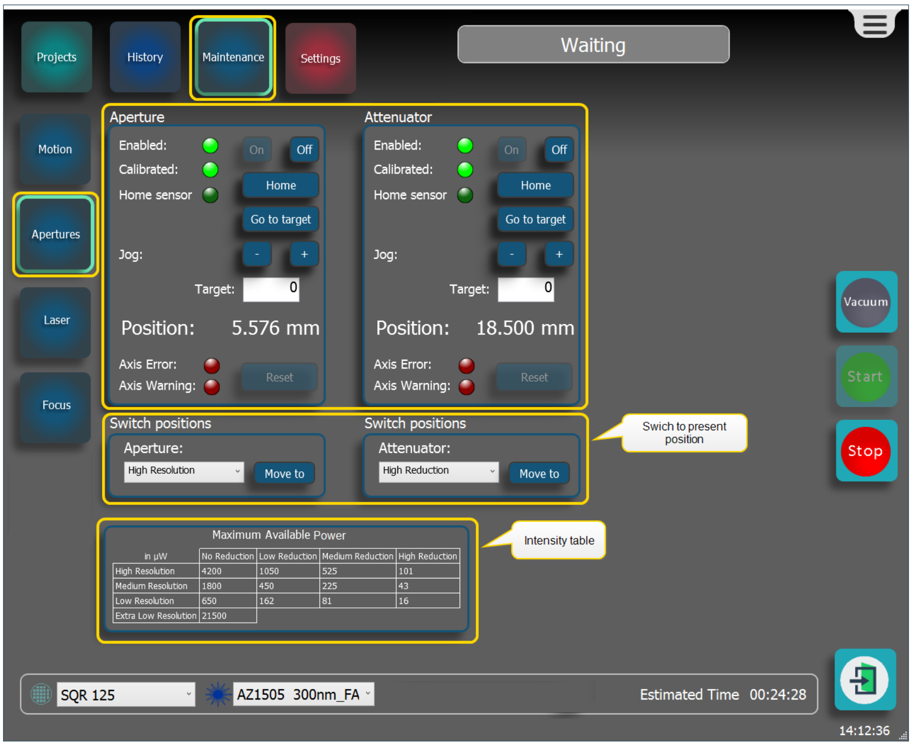


Figure 4-3 Aperture and attenuator control window

Aperture or attenuator low level control

1. Enable a motor by clicking On
2. Home the motor by clicking Home
3. Apply the required changes to the aperture or the attenuator using one of the techniques below:
   3.1. Type the value at Target and click Go to target.
   3.2. Use the Jogging buttons.
4. After moving to a desired settings, click Off to disable the motors.

Reset error state

Press Reset.

Switch the aperture and attenuator to a preset position

1. At Switch positions, select the required aperture from the drop down list.
2. Press Move to.

Intensity table

The intensity reduction for different combinations of aperture and attenuator settings is shown in the intensity table.

4.1.3 Basic motion control

> Warning: Risk of entrapment. Do NOT put your hands in between the writing module and the vacuum chuck. Maintenance commands can move the writing module (in X, Y and Z) with reference to the vacuum chuck while the machine window is open.

1. Select Maintenance in the top bar.

2. Select Motion in the side bar The Motion screen becomes visible, see **Figure 4-4 below**.

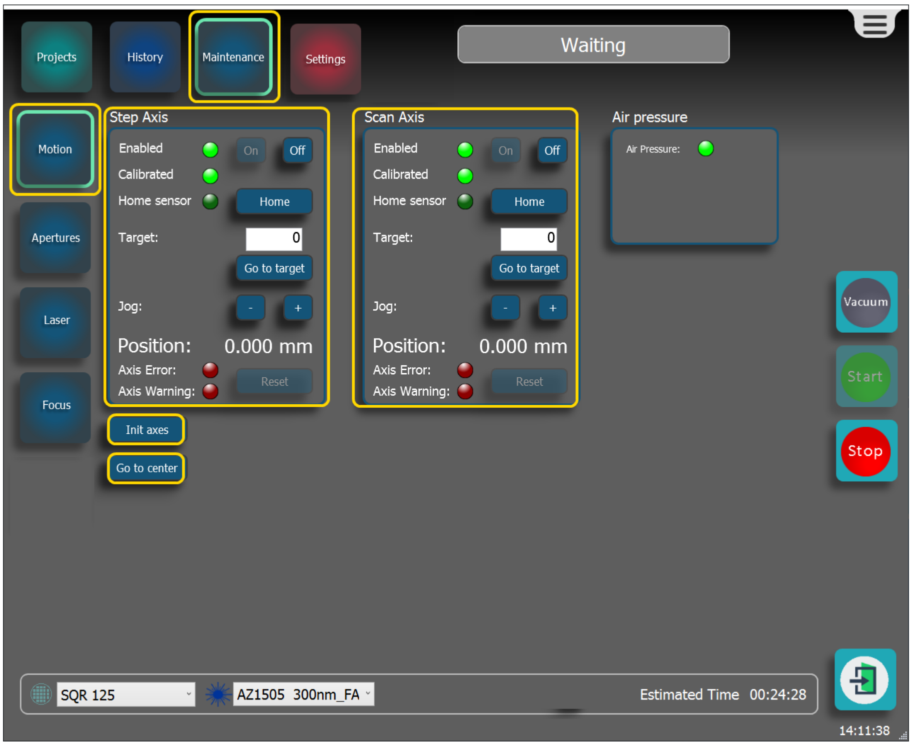


Figure 4-4 Basic motion control window

Step and scan axis motion control commands

Go to the Scan Axis and Step Axis part.

3. To go to center of the substrate, press Go to center .

Note: The center is defined in the substrate recipe.

4. Enable, initialize and disable the axis:

4.1. Enable a motor by clicking On.

4.2. Initialize the motor by clicking Home. The motor will move the axis to the home sensor.

Home sensor positions are:

- At the back side of the machine axis for the scan axis.
- At the left or right side (machine type dependent) of the machine for the step axis.

4.3. To disable the motor control system of the axis, press Off .

5. Moving the step and scan axis motors to a preset position

5.1. Enter Target position in mm. Up to three decimal places are supported [0.000].

5.2. Click Go to target.

6. Moving the step and scan axis motors by jogging.

6.1. Click + to increase the position.

6.2. Click - to decrease the position.

7. Press Init Axes to automatically find the step and scan axis home positions and move the writing module to the origin of the machine coordinate system, see **"Machine coordinate system" on page 8**..

8. To reset an error state, press Reset .

4.1.4 Basic motion control

> Warning: Risk of entrapment. Do NOT put your hands in between the writing module and the vacuum chuck. Maintenance commands can move the writing module (in X, Y and Z) with reference to the vacuum chuck while the machine window is open.

1. Select Maintenance in the top bar.
2. Select Motion in the side bar The Motion screen becomes visible, see **Figure 4-5 below**.

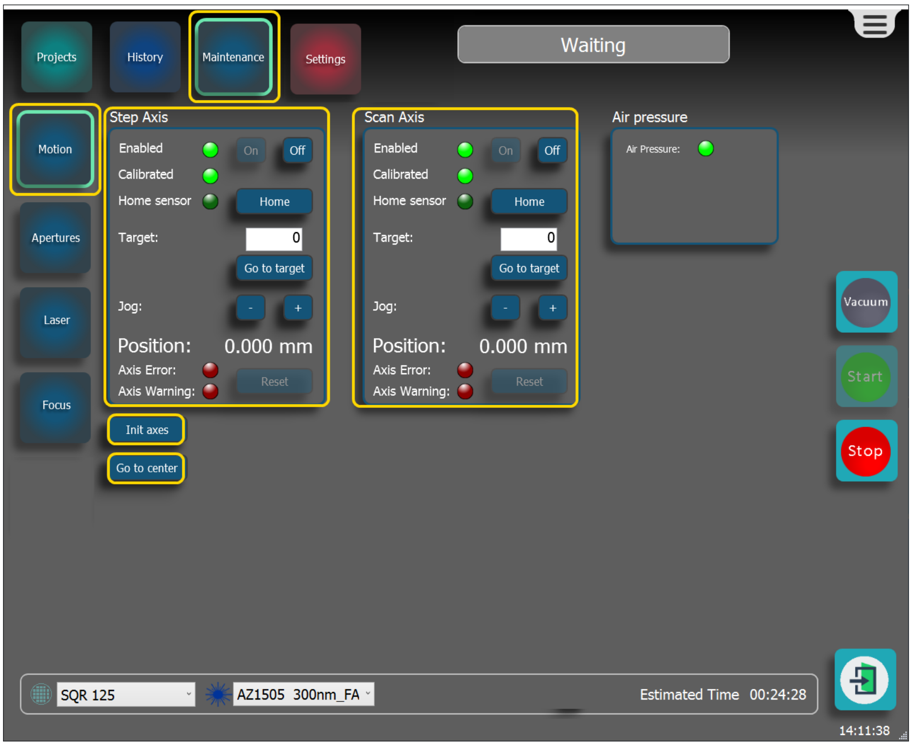


Figure 4-5 Basic motion control window

Step and scan axis motion control commands

Go to the Scan Axis and Step Axis part.

3. To go to center of the substrate, press Go to center.

Note: The center is defined in the substrate recipe.

4. Enable, initialize and disable the axis:
   4.1. Enable a motor by clicking On.
   4.2. Initialize the motor by clicking Home. The motor will move the axis to the home sensor.

> Home sensor positions are:
> - At the back side of the machine axis for the scan axis.
> - At the left or right side (machine type dependent) of the machine for the step axis.

   4.3. To disable the motor control system of the axis, press Off.

5. Moving the step and scan axis motors to a preset position
   5.1. Enter Target position in mm. Up to three decimal places are supported [0.000].
   5.2. Click Go to target.
6. Moving the step and scan axis motors by jogging.
   6.1. Click + to increase the position.
   6.2. Click - to decrease the position.

7. Press Init Axes to automatically find the step and scan axis home positions and move the writing module to the origin of the machine coordinate system, see **"Machine coordinate system" on page 8**..
8. To reset an error state, press Reset .

4.2 Adjust machine settings

> Notice: Risk of production loss. Changing machine settings without proper understanding the impact could severely influence the output quality and/or the stability of the equipment.

The machine setting window are shown in **Figure 4-6 on the facing page**.

1. Press Settings in the top bar.
2. Press Settings left bar.
3. If needed, activate Show advanced settings, see **Figure 4-7 on page 122**.
4. If required, adjust settings, see setting details below.
5. Press Save.

Machine settings

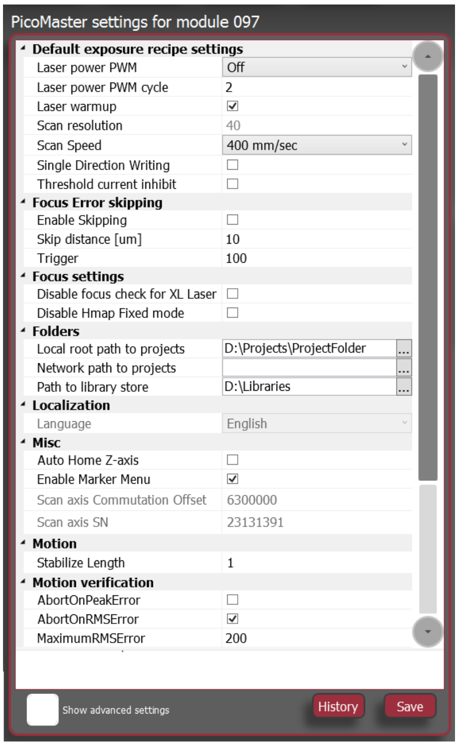


Figure 4-6 Machine settings

Default exposure recipe settings

laser power PWM: Power Width Modulation: Laser on/off modulation, has a similar effect as attenuation. Disadvantage: loss of resolution in the scan direction. Advantage: for very low doses with maximum attenuation, the PWM mode can further reduce the dose.

Laser power PWM cycle: Ratio between PWM laser off and on. Example: factor 3 means: each 3 time intervals, the laser is on for during 1 interval and off during 2 intervals.

Laser warmup: When activated, the laser threshold current is turned on as soon as the scan axis reaches 50% of it's max speed.

Some resists are very sensitive, even for low doses. As the laser might show some minor intensity instability in the first hundreds of milliseconds after turning on due to heating up of the laser, the resulting structures might vary slightly from the beginning to the end of the scan stroke. Turning the threshold current on, before the actual image is started reduces this variation. However, when the threshold current is selected too high, there will be a visible exposed area outside the image area. The laser inhibit setting is only active where the actual image is written. Outside the image area, this setting has no influence. The Laser warmup setting determines the behavior of the laser outside the image area.

Scan resolution: (read only) the distance the scan axis travels during 1 laser period.

Note: The scan resolution is reversely proportional to the PWM cycle.

Scan Speed: The speed at which the Scan axis moves during a project.

Single Direction Writing: If Single Direction Writing is enabled, the PICOMASTER will only write with the step axis moving in one direction.

Note: This setting will double the time it takes to write a project.

Threshold current inhibit: When turned off, the laser threshold current is turned on during the exposure of the whole image.

This might affect areas where no data is supposed to be written, as some photo resists are very sensitive, even for very low doses.
The laser inhibit setting is only active where the actual image is written. Outside the image area, this setting has no influence. The Laser warmup setting determines the behavior of the laser outside the image area.

Focus Error skipping

Enable Skipping: Switch on the feature to skip focus errors. This means that after a specific consecutive amount of focus detection errors, the step axis gets a specified skipping distance.
Note: Note that a small part of the project is lost.

Skip distance [µm]: Distance in step direction during skipping action.

Trigger: Number of consecutive focus errors that trigger a skipping action.

Focus settings

Disable focus check for XL Laser: disable the height check for the XL laser if the substrate surface is too rough for measurement by the automatic focus correction system. Use the manual (motorized) height adjustment to set the laser height.

Disable Hmap Fixed mode: when selected, at the start of a project, instead of measuring a height map, it only measures the height at the center of the substrate. This setting should only use used in special cases. For example when writing extremely close to the edge of a 8x8mm wafer chip.

Folders

Changes made to these settings require a restart of the PICOMASTER application.

Local root path to projects: (Default: C:\) Sets the path to the local folder (folder on a local hard drive) where the project browser will scan for project folders.

Network root path to projects: Default: Sets the path to the network folder where the project browser will scan for project folders. The network folder needs to be shared with the proper credentials set within windows.

Path to library store: Sets the path to the Project Manager libraries.

Localization

Language: the language of the user interface.

Machine settings

Auto Init Motion: When turned on, all axis will be initialized when the machine is turned on.
Note: This will cause all axes to move by itself when the machine is powered on.

Misc

Auto Home Z-axis: enable the automatic movement of the Z-axis to the home position after exposing a project.

Enable Marker Menu: enable the additional projects marker option in the software.

Motion

Stabilize Length: The length in mm between the acceleration part and the constant velocity part. This part of the axis needs to stabilize before starting to write data.

Motion verification

AbortOnPeakError: activate to stop exposure when peak outside range is detected.

Abort OnRMSError: activate to stop exposure when position error RMS value exceeds maximum RMS error, see below.
MaximumRMSError: maximum allowed RMS error during axes motion.

Advanced machine settings

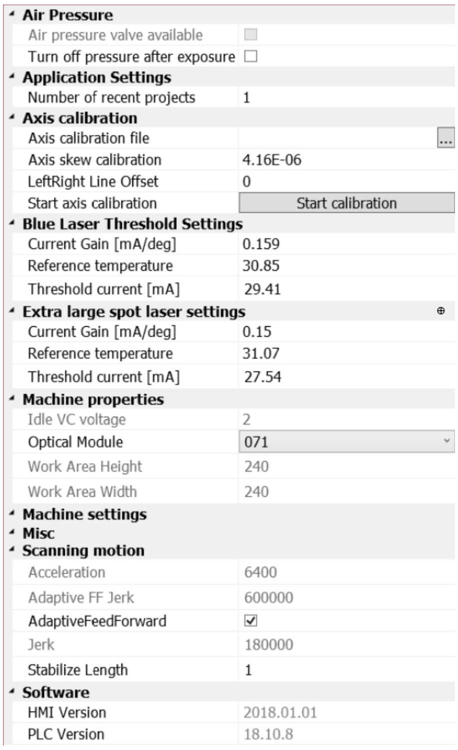


Figure 4-7 Advanced machine settings

Air Pressure

Air pressure valve available: (read only) message that (optional) servo valve for air pressure is present.

Turn off pressure after exposure: if above servo valve (option) is present, automatically turns off the air pressure after each exposure.

Application settings

Number of recent projects: Sets the number of projects stored in the recent projects folder.

Note: A copy of the last started project is made and placed in the recent projects folder. Large projects and a high number of recent projects may use a large amount of hard disk space.

Axis calibration

Axis calibration file: file that contains axis calibration data (file made by Raith Laser Systems BV).

Axis skew calibration: Skew angle in radians.

LeftRight Line Offset: Shifts the Left to Right line to correct for offset between both motions. Offset in nanometer [nm].

Start axis calibration: button that starts the axis calibration procedure (uses special calibration tools to be put on the chuck).

Blue Laser Threshold Settings

Current gain [mA/deg]: Change in threshold current per degree temperature difference.

Reference temperature: Reference temperature at which the threshold current was determined.

Threshold current: The current in mA to use as laser threshold.

Extra large spot laser settings

Current gain [mA/deg]: similar as above, but for the XL laser if installed.

Reference temperature: similar as above, but for the XL laser if installed.

Threshold current: similar as above, but for the XL laser if installed.

Machine properties

Idle VC voltage:

writing module: The serial number of the currently installed writing module

Work Area Height: maximum Y (scan) axis range.

Work Area Width: maximum Y (scan) axis range.

Machine settings

Misc

Motion

Stabilize Length: The length in mm, between the acceleration part and the constant velocity part. This part the axis needs to stabilize before starting to write data.

Scanning motion

Acceleration: Acceleration for scan movement [mm/s^2].

Adaptive FF Jerk: enables the adaptive feed forward jerk. Adaptive feed forward jerk is used to decrease the tracking error. This allows a higher jerk to be set for the machine.

AdaptiveFeedForward: Enables the adaptive FF Jerk and the get to speed action of the machine.

Jerk: Jerk for scan movement [mm/s^3].

Stabilize Length: The length in mm between the acceleration part and the constant velocity part. This part of the axis needs to stabilize before starting to write data.

Software

HMI Version: installed software version.

PLC Version: installed machine code version.

4.3 Adjust alignment settings

Notice: Risk of production loss. Changing machine settings without proper understanding the impact could severely influence the output quality and/or the stability of the equipment.

1. Press Alignment in the top bar.
2. Press Settings left bar.
3. If required, adjust settings as explained below.

Note: Changed values are automatically saved.

The window is shown in **Figure 4-8 on the next page**.

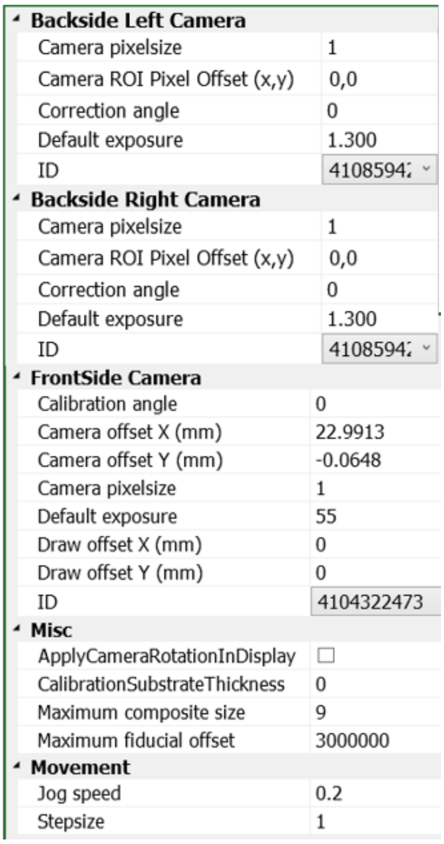


Figure 4-8 Alignment settings

Backside Left Camera (optional)

Camera pixelsize: the size on the substrate that corresponds to a camera pixel.

Camera ROI Pixel Offset (x,y): offset of the region of the camera CCD that is used for the image. Center = (0,0)

Correction angle: rotation of camera image to bring in line with machine coordinate system.

Default exposure: default exposure time that determines the image brightness.

ID: unique backside camera identifier.

Backside Right Camera (optional), see above

FrontSide Camera

Camera offset X (mm): Offset in stepping direction between camera center and writing position.

Camera offset Y (mm): Offset in scanning direction between camera center and writing position.

Camera pixelsize: the size on the substrate that corresponds to a camera pixel.

Default exposure: exposure time in ms.

Draw offset X (mm): additional alignment offset in X that is applied when using the drawing mode or overlay project mode.

Draw offset Y (mm): additional alignment offset in X that is applied when using the drawing mode or overlay project mode.

ID: unique identifier for the camera.

Misc

ApplyCameraRotationInDisplay: when selected, the alignment camera rotation angle is already applied in the camera image (before the marker detection) When deselected, the camera angle is only corrected when using the drawing mode.

Maximum composite size: length and width of the image used in the area scan, for example 3 corresponds to a 3x3 camera images in the area scan.

Maximum fiducial offset: maximum distance that a marker is allowed to be from the expected position alignment.

Movement

Jog speed: [mm/s] speed the stage moves at in the jogging mode during manual alignment.

Step size: [mm] the size of each step in the step mode.

4.4 Checking project and event history

The window is shown in **Figure 4-9 below**.

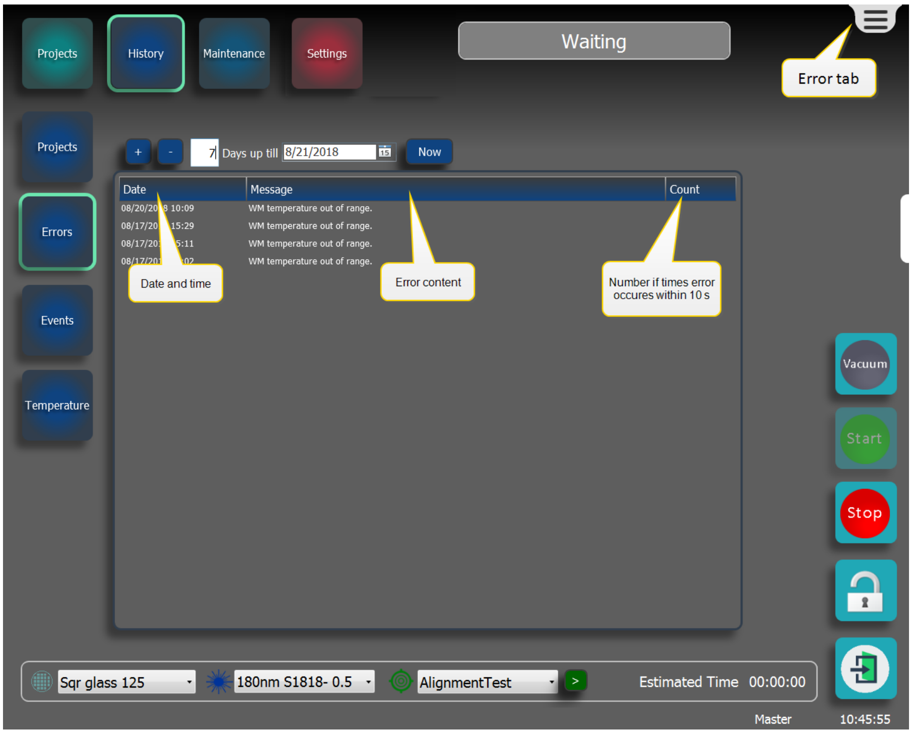


Figure 4-9 Project and event history

The history pages provide information on the PICOMASTER system for a selected time frame. The data stored will be available to the users for the lifetime of the machine.

1. To open the history selection window, select History in the top bar.

2. In the history windows for projects, errors and events, you can set the time frame by number of days, date, or select the current day, see **Figure 4-10 below**.

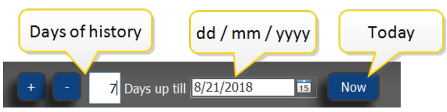


Figure 4-10 History time frame selection

4.4.1 Check project history

1. If the projects history is not yet open, select Projects.

The projects history is shown in **Figure 4-11 below**.

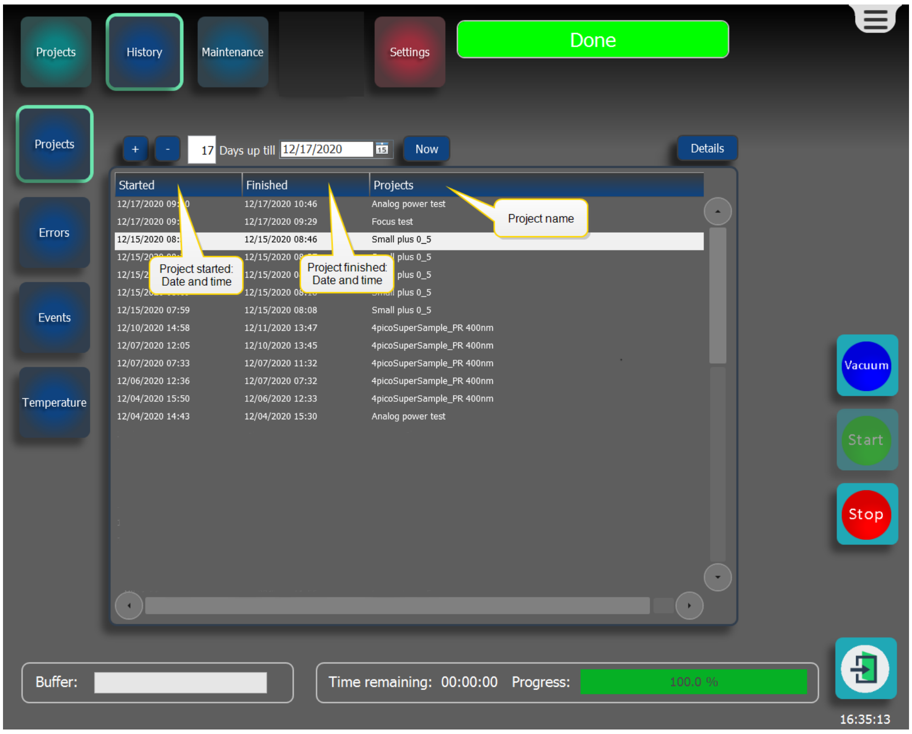


Figure 4-11 Project history

2. Double click a project to show the project details, see **Figure 4-12 below**.

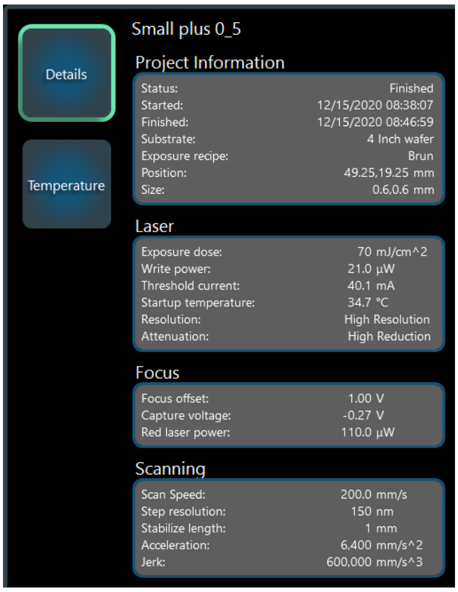


Figure 4-12 Project details window

2.1. In the Details window, click Details to see all the key data of the project.

2.2. Click Temperature to see the temperature data for the project, see **Figure 4-13 on the facing page**. Data are given for the writing module and the machine air intake.

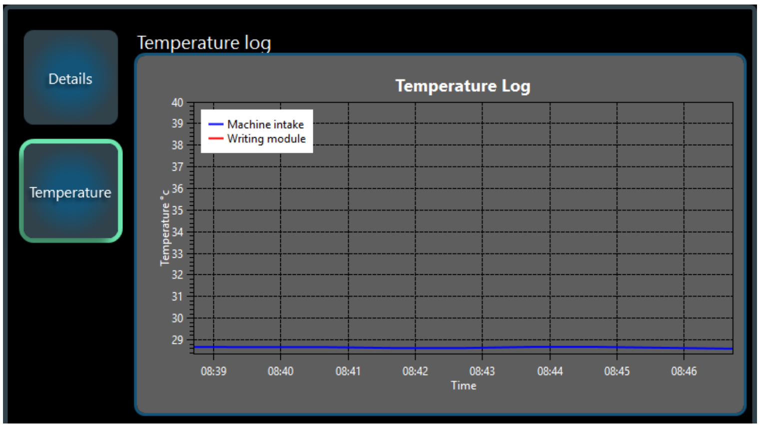


Figure 4-13 Temperature data

2.3. If Hybrid or Fixed focus control mode is used (see **"Automatic Focus control settings" on page 37**), click Substrate to see a height map of the substrate, see **Figure 4-14 below**.

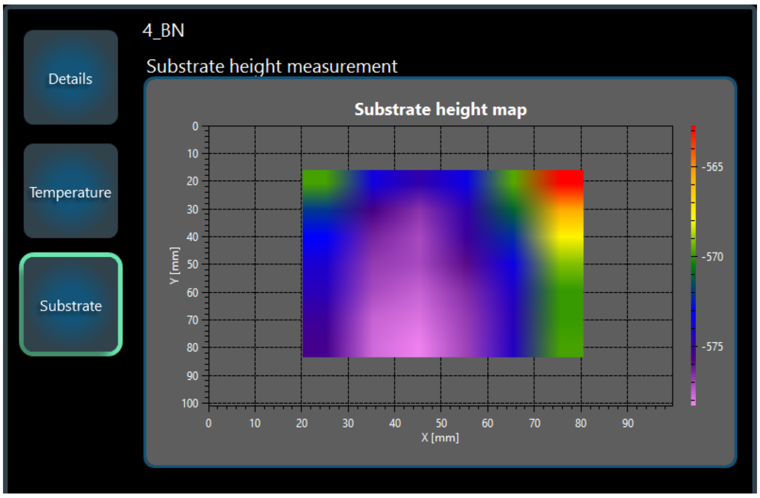


Figure 4-14 Substrate height map

4.4.2 Error log

When an error occurs it is shown in the Error tab on the top right of the page. These errors are stored and are available in the Error page.

If the same error occurs within 10 seconds it will increase the count instead of registering a new error.

1. If the error window is not yet open, select Errors.

The error window is shown in **Figure 4-15 on the next page**.

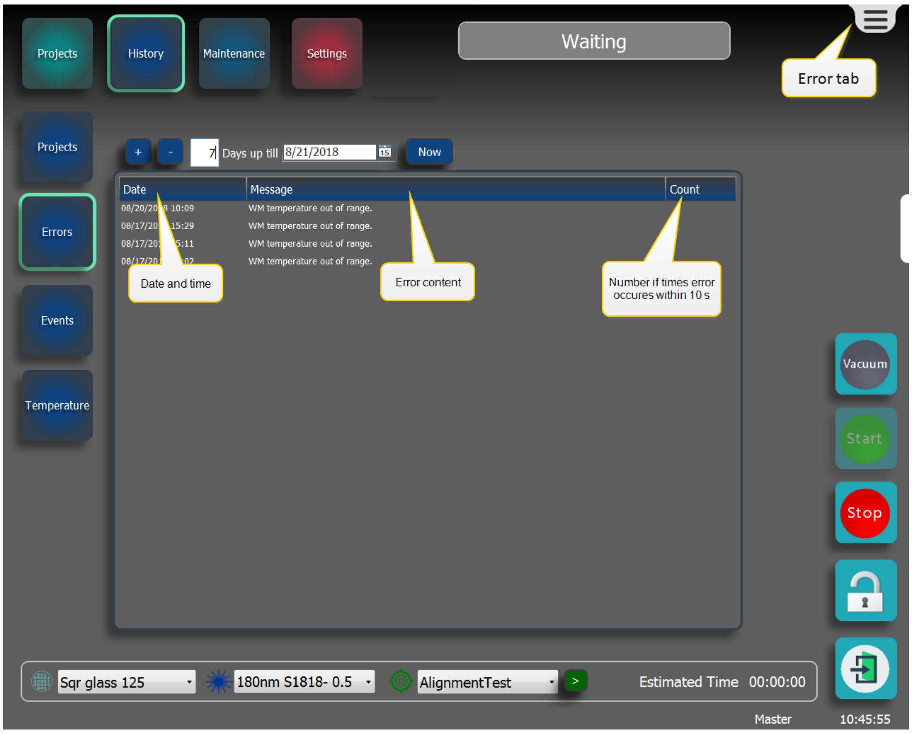


Figure 4-15 Error log

4.4.3 Event log

Any changes made to a project or settings inside a project or the PICOMASTER will appear in the Event log.

1. If the event window is not yet open, select Events.

The Event log shows what properties were changed along with the previous and current values, see **Figure 4-16 below**

Figure 4-16 Event history

4.4.4 Temperature log

There are two temperature probes inside the machine, one at the writing laser and one at the air intake. The temperature page plots these two values in a graph.

1. If the temperature window is not yet open, select Environment.

The temperature log is shown in **Figure 4-17 below**.

Figure 4-17 Environment log

2. Use the scroll wheel to zoom in and out.

Note: The values only update when the PICOMASTER software is running.

4.5 Folder and project names

4.5.1 Project Browser

The Project Browser is a tool within the PICOMASTER operating software where the operator can find, manage and start projects. The overview will show all available folders. These folders may include network locations as well as removable devices.

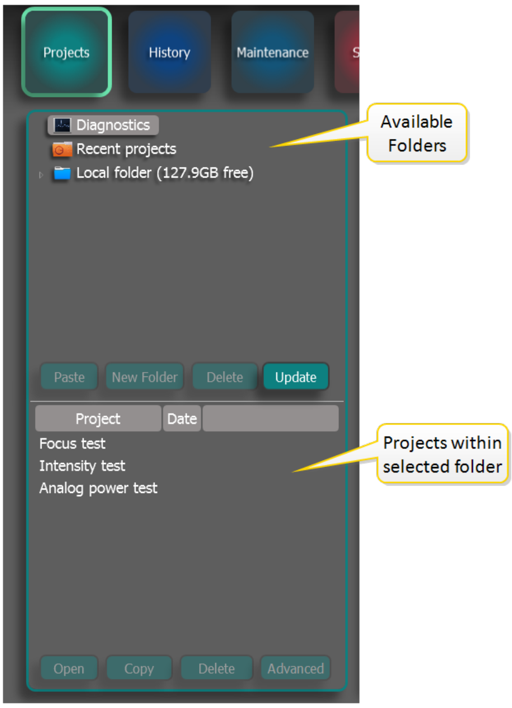


Figure 4-18 Project Browser

Removable devices

Removable devices are automatically shown in the list of Folders.

Note: Some USB drives are not recognized as a removable drive and will therefore not show up in the folder list.

Network folder

Within the advanced machine settings (see **"Adjust machine settings " on page 118**), you can configure a path to a network folder (shared folder) on a server or remote PC. The PICOMASTER will scan this folder for projects. This allow designers to create projects remotely and let operators pull projects from the remote server.

4.5.2 Projects

The PICOMASTER organizes projects in folder structures. Each project is stored in it's own folder. The project folder name always starts with 'PROJECT_', followed by the name of the project.
Within the project folder all source files are stored. These include the original bitmaps, GDSII or other files.

The folder will also contain a file named 'project.4pp'. This file stores all settings made by the designer with the Project Manager.

Note: When manually moving a project, make sure you copy or move the entire folder.

4.5.3 Folders

All projects must be stored in folders.with names that start with 'FOLDER_'.

Note: The PICOMASTER and Project Manager will only look for proects and subfolders within folders with names that start with 'FOLDER_'.

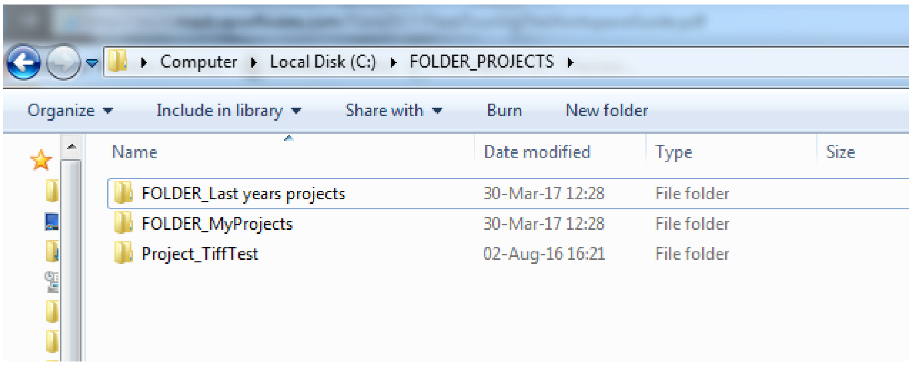


Figure 4-19 Folders with the correct names

4.5.4 Special Folders

There are two special folders. The Diagnostics folder and the recent projects folder.

- Diagnostics folder: This folder contains special projects which can help the operator to determine optimum process parameters. The folder is simulated by the software and does not actually exists. Projects cannot be added to or removed from this folder.
- Recent Projects folder: The recent projects folder stores a copy of the last started projects. The number of projects stored can be set in the machine settings, see **"Adjust machine settings " on page 118**.

4.6 Recipe editor generic information

All Recipe Editors have the following functions in common:

- Add: Adds a new recipe. A valid name has to be assigned to the recipe.
- Copy: Copy the selected recipe.
- Remove: Remove recipe.

All Recipe Editor Settings windows have the following functions in common:

- Save: Save the changes to the recipe parameters. For existing recipes, this button is only active if one or more recipe settings have been changed.
- Cancel: Cancel any changes made to the recipe parameters.

The active recipe is marked by a green check mark, see **Figure 4-20 below**. Changing the selected recipe will immediately affect the next job. The current running job will not be affected.

Figure 4-20 Active recipe

For Substrate and Exposure recipes, you can select the active recipe within the recipe editor boxes, or on the quick selection bar in the bottom of the main screen, see **Figure 4-21 below**.

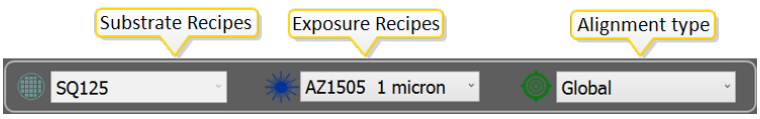


Figure 4-21 Quick selection bar

4.7 Using a software key

Every PICOMASTER system is equipped with a software key which the PICOMASTER system uses to determine the installed options and time limitations on certain features.

Key data can only be obtained from Raith Laser Systems BV.

4.7.1 How to apply for a new key

1. Press Settings in the top bar.
2. Press Settings left bar.
3. Insert a USB drive into the PICOMASTER system.
4. Pres the Export key button under Key Data in the right top part of the window.
5. The current key file will be copied to the USB drive.
6. Locate the key file on your USB drive. The file name has the following convention: *PMxxxx.key*, where xxx is replaced with date and time info.
7. Send this file to Raith Laser Systems BV.

4.7.2 Set a new key

1. Press Settings in the top bar.
2. Press Settings left bar.
3. Insert a USB drive into the PICOMASTER system.
4. When you have received a key file from your supplier, you can copy it to a USB drive and insert the drive into the PICOMASTER system.
5. Press the Load key file button under Key Data in the right top part of the window, see **Figure 4-22 below**

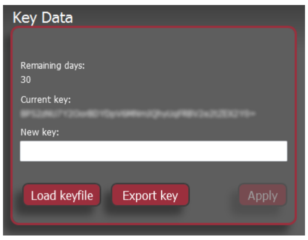


Figure 4-22 Key fill-in window part

6. The PICOMASTER system will search for the most recent key file on the USB drive and load the key file automatically.
7. When the new key is valid, the apply button will be enabled.
8. Press the Apply button to activate the new key.

Note: Changes made to this setting require a restart of the PICOMASTER application.

4.8 Periodic Maintenance

Periodic maintenance for the PICOMASTER concerns HEPA filter replacements and pressurized air filter checks.

4.8.1 Replace HEPA filters

Interval: depending on air input cleanliness and on air input flow, guideline: 2 years.

Note: Work clean while replacing the filters. Preferably use gloves.

1. Find the filter housing, see **Figure 4-23 on the facing page**.

Figure 4-23 HEPA filter location

2. If present, remove the air input hose.

3. Open the machine cover.

4. Remove the four filter housing fixation screws while holding the air filter housing by hand.

5. Carefully remove the filter housing including the filter from the machine.

6. Remove the old filter and dispose of it according to local regulations.

7. Install the new filter into the filter housing.

8. Carefully install the filter housing including the new filter into the machine.

9. Install the filter housing fixation screws.

10. Install the air input hose.

4.8.2 Check the pneumatic air filters

Interval: 2 months

Needed: a clean cloth to catch drops of oil or water.

1. Find the pneumatic air filters, see **Figure 4-24 below**.

Figure 4-24 Pressurized air filter location

Note: The air filters are normally located under the machine table or under the monitor table.

2. Check if the filter housing contains droplets of air or oil, see in **Figure 4-25 on the next page**.

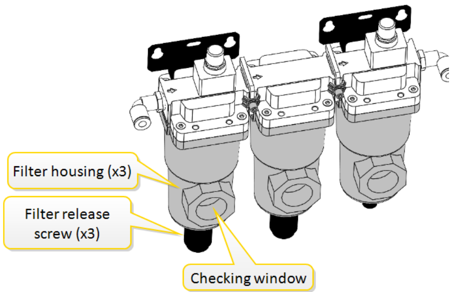


Figure 4-25 Checking the pneumatic filter for water or oil

3. If any droplets are found, empty the filter:
   3.1. Close the pneumatic air flow to the machine .
   3.2. Hold a clean cloth that can easily absorb water and oil under the filter housing.
   3.3. Manually turn the filter release screw counter clockwise to let out the water or the oil.
   3.4. Turn the filter release screw clockwise to close the filter housing.
   3.5. Turn the closing valve to open the air flow to the machine.

4.9 Troubleshooting

In the event that an error message appears, it can be found in the list of errors with a short explanation of the possible cause.

If the bottom status bar shows red icons, go to **"Checking and adjusting the machine status" on the facing page**.

For a list of common errors and solutions, see **"Common errors and fixes" on the facing page**.

For the error message list, go to **"Error message list" on page 137**

To power cycle the machine, go to **"Power cycle the machine" on page 140**.

4.9.1 Checking and adjusting the machine status

Details on the status bar and how to act is listed below.

Reading the status bar

Item	Meaning of Green	Meaning of Red	If Red, how to make Green
Compressed air	Air pressure OK.	Main air pressure lower than 0.45 MPa **Note:** 1MPa=10 bar 0.45MPa-a=4.5bar	Verify air pressure connection to machine.
Twincat running	PLC connection OK	PLC connection not detected.	Check machine power breakers in electronics cabinet. If all breakers are in up position, power cycle the main machine power, see **"Power cycle the machine" on page 140**. If still not working, contact Raith Laser Systems BV for support.
PLC running	PLC program in run mode.	PLC program not in run mode.	Power cycle the PICOMASTER, see **"Power cycle the machine" on page 140**.
Database running	Database running correctly.	MySQL database not connected or in error.	Contact Raith Laser Systems BV for support.
Scan axis connected	Scan axis is detected correctly.	Scan axis controller not found in PLC.	Contact Raith Laser Systems BV for support.
Step axis connected	Step axis is detected correctly.	Step axis controller not found in PLC.	Contact Raith Laser Systems BV for support.
Axis initialized	Green: Scan and step axis initialized	Red: Scan or step axis not initialized	Initialize the axes, see **"Basic motion control" on page 117**.

4.9.2 Common errors and fixes

Start-up

PLC not found

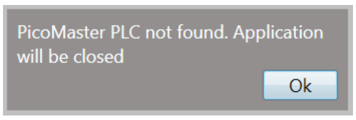


Figure 4-26 PLC not found pop up

Possible causes:

- PLC not ready
- Cable not connected properly

Solution:

- Wait 1 minute and try again
- Check cable and try again after 2 minutes
- If it still does not work, restart the computer and try again

Initializing axes

Possible causes:

- Timeout
- Something blocking the axes

Solution:

- Check if anything is blocking the axes
- Reset axes if button is available
- Wait 30 seconds and try again
- If it still does not work, contact Raith Laser Systems BV

Window not opening

Possible causes:

- Unlock button not pressed

Solution:

- Press Unlock and open

No Vacuum Seal

Possible causes:

- Vacuum button not pressed
- Particles on vacuum chuck
- Substrate not even
- Vacuum chuck size setting wrong

Solution:

- Clean vacuum chuck and bottom of substrate
- Push down on the substrate when the light is blinking
- Make sure the size setting is correct
- Press vacuum button

Homing not possible

Possible causes:

- Axes not initialized
- Cables not connected

Solution:

- Initialize axis and try again
- Check cable

Laser power not reached (Project start)

Possible causes:

- Wrong substrate recipe selected
- Laser power set too low
- Attenuator or Aperture settings incorrect

Solution:

- Check substrate recipe
- Select Laser Power
- Select Attenuator or Aperture

Unable to capture focus (Project start)

Possible causes:

- Dust or particle on wafer
- Uneven photoresist
- Focus offset wrong
- Not enough Red laser power
- writing module height wrong

Solution:

- Check / clean wafer
- Focus wobble in the middle of the substrate
- Adjust the writing module height

Loss of focus during project

Possible causes:

- Dust or particle on wafer
- Uneven photoresist
- Wrong substrate recipe selected

Solution:

- Check / clean wafer
- Check substrate recipe

4.9.3 Error message list

Error number	PICOMASTER Error Message	Cause
Start-up errors		
0701	System temperature out of range.	No temperature measurement in machine
0702	WM temperature out of range.	No temperature measurement in writing module
0101	Local project folder not found.	The project folder selected in settings cannot be found
0102	Network project folder not found.	The network folder selected in settings cannot be found
Registration Key Errors		
0201	Key expired	Key expired, load a new key from the settings page
0202	Key not valid	The key entered is not valid
0203	Key does not exist	
0204	Key write error	
0205	Key read error	
0206	Can not execute. Key expired.	No project can be started without a valid key
Focus Errors		
0301	Focus Error: Red laser power low.	Not enough red light during capture process
0302	Focus Error: Focus lost after closing loop.	Focus error within 100 ms of entering closed loop
0303	Focus Error: Focus lost after setting offset.	Focus error occurred after giving an offset

Error number	PICOMASTER Error Message	Cause
0304	Focus Error: No sum signal detected (no substrate).	No sum signal during focus capture. Possible causes: 1) No substrate, 2) Not enough red laser power, 3) Defect or particle on the substrate
0305	Focus Error: No S-curve detected.	Minimum s-curve signal not reached (-2.5 V not reached)
0306	Focus Error: S-curve did not return to zero.	Signal did not return to 0 volt during focus capture
0307	Too much sum signal while capturing focus: Reduce red laser power	Too much sum signal during capture (>7 V). Reduce red laser power
0308	Could not capture focus, safety capture voltage reached	During a project a safety voltage is set to stop the objective lens touching he substrate.
0309	Focus lost while writing at position: *.** mm	Focus error during a project. The position is relative from the start of the project
0310	Focus lost while writing at percentage: **%	Focus error during a vector project
0311	Maximum focus offset exceeded. Can not set focus offset: ***	The focus offset cannot be higher than 7V
0312	Minimum focus offset exceeded. Can not set focus offset: ***	The focus offset cannot be lower than -7V
	Laser Errors	
0401	Red laser error: No current increase while sweeping	No current increase detected while sweeping red laser
0402	Red laser error: No intensity increase while sweeping	No intensity increase detected while sweeping red laser
0403	Blue laser error: No current increase while sweeping	No current increase detected while sweeping blue laser. Possibly caused by lose cables to the writing module or computer
0404	Blue laser error: No intensity increase while sweeping	No intensity increase detected while sweeping blue laser. Possibly caused by lose cables to the writing module or computer
0405	Target blue laser power exceeds maximum power	The set laser power cannot be reached. Possible solutions: ■ Set a lower exposure dose ■ Choose a different attenuator ■ Use a lower velocity
0406	Detected threshold current does not match threshold current settings.	Detected threshold current is more than 1mA away from the set threshold
	Air supply and UPS Errors	
0501	Air pressure too low	After 2 minutes the scan en step axes are disabled.
0502	Air pressure too low for more then 2 minutes. process aborted	The project is automatically stopped after 2 minutes.
0503	Air pressure too low for more then 2 minutes. Axis disabled	After 2 minutes the scan en step axes are disabled.
1001	UPS warning for more then 12 seconds. All processes aborted.	Project is stopped because of UPS warning
1002	UPS warning for more then 12 seconds. Axis disabled	Axes are disabled because of UPS warning
	Project File Errors	

Error number	PICOMASTER Error Message	Cause
0103	Project folder could not be opened	Project folder could not be located when starting the project
0104	Project files could not be opened	Project file could not be located when starting the project
0105	Unable to remove the recent folder.	Error while deleting projects from the recent folder
0106	Project files not copied to local folder	Error while moving projects to the recent folder
0107	Error in Execute thread	Error while running a project. The project is stopped due to project file error
0602	NI DAQ in Error	Problems while controlling the National Instruments DAQ card.
Alignment Camera Errors		
0801	Camera Disconnected	The alignment camera is disconnected while the system is operational
0802	Failed to acquire alignment image	The alignment camera does not receive images

4.9.4 Power cycle the machine

1. Wait until any running project is finished.
2. Stop the PICOMASTER software by pressing the stop application button in the bottom right part of the screen.
3. Shutdown the computer using normal windows shutdown sequence.
4. Turn off the power switch on the back of the PICOMASTER, see **Figure 4-27 below**

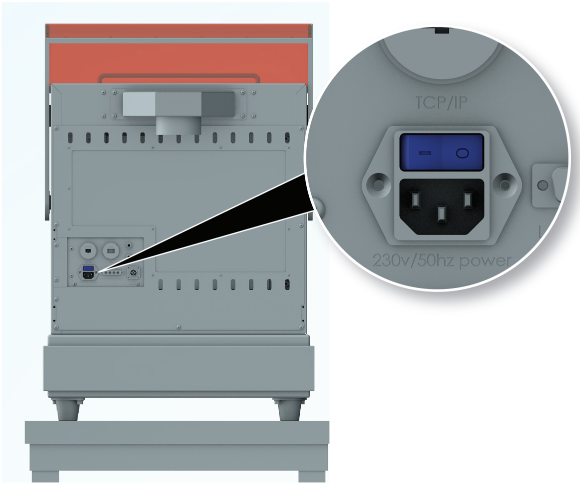


Figure 4-27 Turning on the PICOMASTER

5. Wait 1 minute.
6. Start the machine, see **"Starting the machine" on page 16**.

Contact information

For help or other questions, please contact your local vendor or contact:

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