RAYGUIDE VISION SOLUTIONS

RAYGUIDE CLICK & TEACH | RAYGUIDE MATCH

RAYGUIDE VISION SOLUTIONS

RAYGUIDE CLICK & TEACH
RAYGUIDE MATCH

USER MANUAL

Document: MN_RAYGUIDE VISION SOLUTIONS

Status of the information: V1.0 [2025-04-01]

TABLE OF CONTENTS

1 INTRODUCTION

1.1 About CLICK & TEACH

RAYGUIDE Click & Teach, in the following often abbreviated as C&T, is an extension of the RAYGUIDE laser software. C&T uses cameras mounted on the optical axis of deflection units to display an image of the actual workspace in the viewport of RAYGUIDE.

NOTE: The RAYGUIDE Click & Teach additional option can be used independently of RAYGUIDE MATCH.

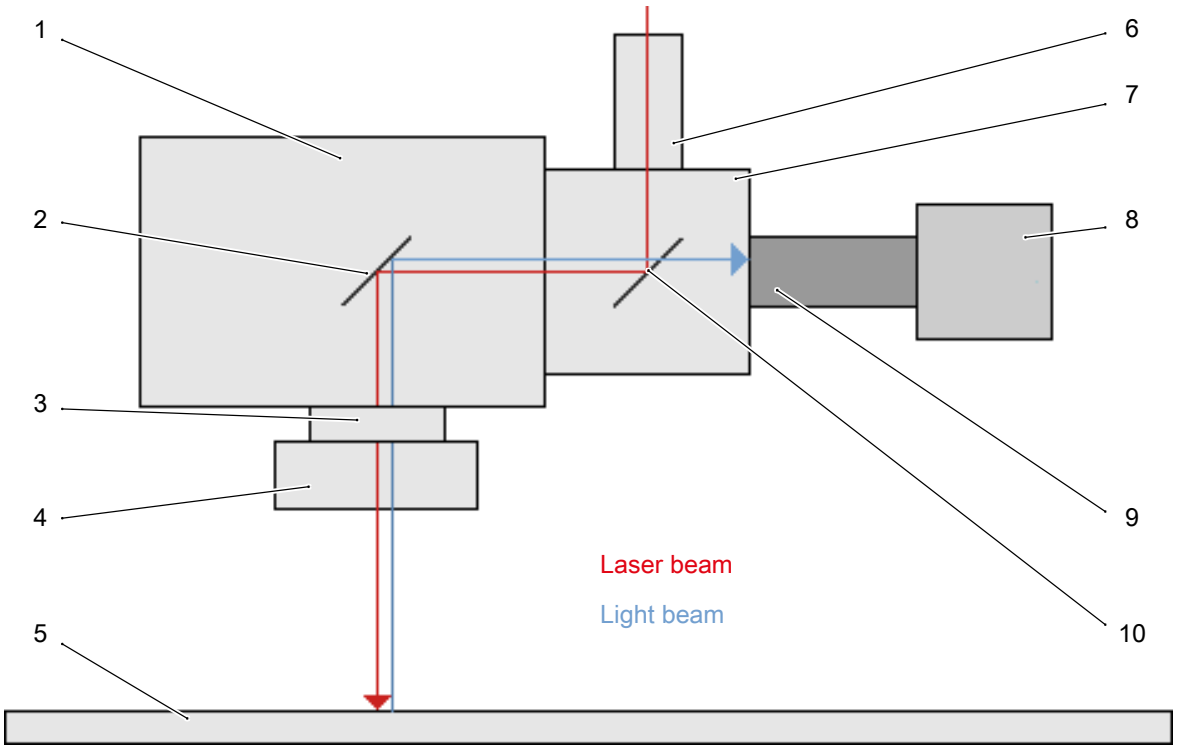


Fig. 1.1: CT-AAA

1	Deflection unit	6	Collimator
2	Deflection mirror	7	Camera adapter
3	Spacer ring	8	Camera
4	F-Theta-lens	9	Camera lens
5	Working area	10	Dichroic element

In this way it is possible to trace the contours of real objects with the graphic features of the RAYGUIDE software and to easily generate laser jobs. Existing objects in a job can be easily superimposed with the positions of real objects.

The camera image generally shows only a small section of the workspace. The overall image is created from individual tiles.

1.2 About RAYGUIDE MATCH

RAYGUIDE MATCH, also referred to as MATCH in the following, like the RAYGUIDE Click & Teach is an extension of the RAYGUIDE laser software.

MATCH operates on the basis of the RAYGUIDE Click & Teach and is therefore always used in connection with CLICK & TEACH. That means the functions for setting up and calibrating the coaxial camera and the illumination controller are therefore part of the description of RAYGUIDE Click & Teach.

The additional RAYGUIDE MATCH option is used to

- Determine workpiece positions based on detection of workpiece features and
- Correct the deviation from a taught-in workpiece position by setting the so-called process transformation.

The images of the workpiece features captured by the coaxially coupled camera can then be post-processed using digital image filters before being evaluated using image processing algorithms.

1.3 About this manual

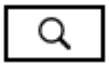
The RAYGUIDE VISION Solutions manual describes the functionality, installation and operation of the additional C&T and MATCH application of the RAYGUIDE software when used with the graphical user interface (GUI).

The manual section is contained in the PDF edition of the RAYGUIDE manual by default. It is not issued as a separate document.

NOTE: Consequently, the same rights apply as for the main manual of the RAYGUIDE application and the same rules also apply to the warranty and support.

Conventions

- Emphasized phrases are printed in **bold**.
- Important notes and remarks are introduced with **NOTE:, RULE:,** etc.
- Folder and file names are printed in *italics*.
- The names of windows, dialogs and tabs are given as normal text: On the Settings tab.
- Menu options to be selected are marked in bold and italics: Select ***File > Save as...***
- The names of dialog options (function buttons, checkboxes) are specified in italics: Select the *Manual* calibration mode.
- Buttons are bold and in italics and shown in brackets: Click on ***[Start calibration]***.
- Buttons labeled with graphic icons are described by words.

  Example:  is the ***[Search]*** button.
- References to other pages in the manual are indicated by italics: See *page 22, Setup*.
- Links to web addresses are underlined: Visit RAYLASE.

1.4 Compatibility

The additional CLICK & TEACH and MATCH applications are compatible with the RAYGUIDE laser software.

Please note that currently only the cameras of the GO-PGE series from JAI and the cameras of the Genie Nano GigE series from Teledyne DALSA are supported. The software has been successfully tested with the GO-5100M-PGE, GO-2400M-PGE (JAI) and Genie Nano 5G M2450 Mono (Teledyne DALSA) modules.

The illumination controllers from GARDASOFT are compatible for activation of the illumination elements from the RAYGUIDE software. For more details, see *page 71, Illumination*.

NOTE: We recommend primarily operating the camera via a peer-to-peer network connection and advise against using an internal company network in light of the data volume.

1.5 PC requirements

To operate the RAYGUIDE software with the supplementary RAYGUIDE VISION SOLUTIONS feature, the PC must meet the following requirements:

- A Windows 10 / Windows 11 operating system with a 64-bit platform
- A working memory of at least 16 GB
- It is highly recommended that the network card for the connection have an INTEL chip as this type of network card was demonstrated to enable trouble-free connection to the camera. Support is not guaranteed if other network cards are used.

NOTE: We recommend using two monitors in order to transfer overlapping dialogs to a second monitor, thus making full use of the viewport.

1.6 Scope of delivery

The scope of delivery of the RAYGUIDE VISION Solutions installation includes

- The camera plug-ins for general communication for the respective camera type.
- The panel for the RAYGUIDE Click & Teach application and
- The automation object for generating image processing jobs including the associated libraries.

The required and tested hardware drivers for the supported camera models and illumination controller are also provided.

2 INSTALLATION

2.1 Hardware

In addition to the components necessary for operation of RAYGUIDE (deflection unit, laser, control card, etc.), the following components are also required for C&T:

- For 2-axis deflection units: suitable camera adapter plus camera lens
- For pre-focused deflection units: RAYLASE monitoring module RAYSPECTOR with associated correction file for controlling the optical axis in RAYSPECTOR
- Camera (see Compatibility)
- Illumination equipment for illuminating the processing field

  NOTE: The illumination equipment (consisting of illumination controller and lamps) can be purchased from RAYLASE on request.

  When using the additional RAYGUIDE MATCH application, use of the illumination integrated by RAYLASE is generally advisable since the ability to set the illumination intensity from RAYGUIDE is fundamental for image processing.

NOTE: Agree on the optomechanical coupling of the camera and the components required for this with your RAYLASE sales employee to ensure compatibility with the laser and camera.

NOTE: In principle, it is possible to retrofit existing laser systems for camera integration. Depending on the situation, manufacturer service for the deflection unit may be required. Contact your RAYLASE sales employee if needed.

NOTE (ADJUSTMENT): The dichroic element of the RAYLASE camera adapter must be adjusted after mounting and fastening the fiber collimator of the laser to couple the beam precisely with the deflection unit. Observe the RAYLASE *Standard Camera Adapter* and *High Power Camera Adapter* manuals. When using preadjusted High Power welding modules with a collimator, it is not necessary to adjust the *High Power camera adapter*.

2.2 Software

2.2.1 Install RAYGUIDE CLICK & TEACH and RAYGUIDE MATCH

For installation of all RAYLASE software products, RAYLASE provides the so-called RAYBOARD PRODUCT INSTALLER (RBPI) free of charge as a central tool on its website.

Since the two additional *CLICK & TEACH* and *MATCH* options both use the same hardware, and MATCH is built onCLICK & TEACH, they are installed together through separate installation of *RAYGUIDE VISION Solutions*.

Using the “Select the targeted software configuration” menu item, select the right version of *RAYGUIDE VISION Solutions*.

IMPORTANT: The version of *RAYGUIDE VISION Solutions* must correspond to the *RAYGUIDE* version.

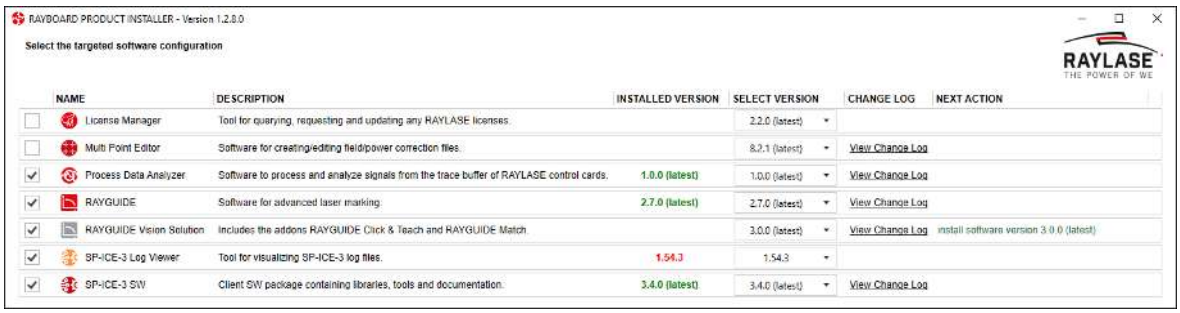


Fig. 2.1: RG_V-AAA

IMPORTANT: The additional *CLICK & TEACH* and *MATCH* options can only work together with the actual *RAYGUIDE* application. For this reason, it is essential to also select installation of the *RAYGUIDE* application, or else it must already be installed.

You can use the direct link to the change log to get an overview of the latest changes to the previous version. There is a separate change log for all changes regarding the additional *RAYGUIDE VISION Solutions* applications. The RBPI then downloads the *RAYGUIDE VISION Solutions* installation file and displays the installation options:

The following installation options are available for *RAYGUIDE VISION Solutions*:

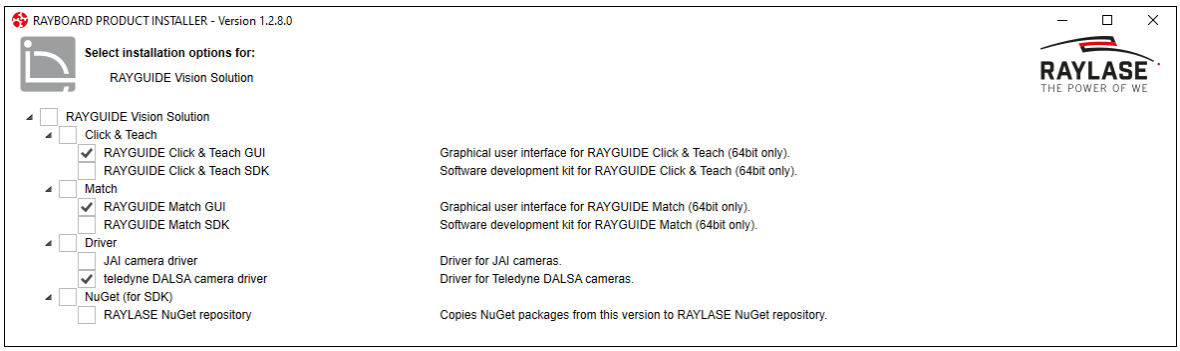


Fig. 2.2: RG_V-AAC

1. Select whether you would like to install the *GUI* and / or the *SDK components of RAYGUIDE Click & Teach* or *RAYGUIDE MATCH*.
2. Select the camera variant in order to install the appropriate camera driver.

NOTE: When installing or upgrading the camera drivers with other setup files, RAYLASE will not be able to provide support in case of faults.

After selecting the installation options, you need to consent to the license agreement; then the additional *CLICK & TEACH* and *MATCH* options will be installed.

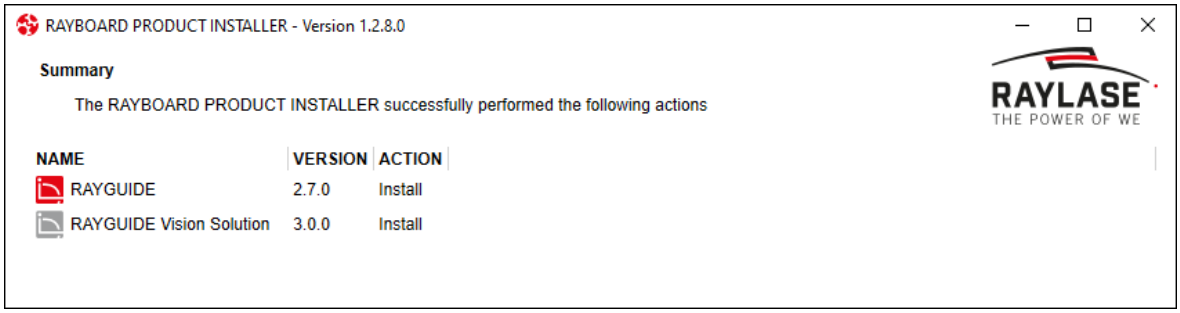


Fig. 2.3: RG_V-AAB

2.2.2 Licenses

In order to be able to use the additional CLICK & TEACH application, your RAYGUIDE licenses requires an additional “license product.”

In order to be able to use the additional MATCH option, your RAYGUIDE license also requires an additional license product.

These license products can be ordered during the initial order of the RAYGUIDE or can be purchased later.

For this purpose, your existing RAYGUIDE license is extended with a file upload.

NOTE: Only the serial number of the existing RAYGUIDE license is needed.

Viewing license products

Select ***Help > About RAYGUIDE*** to view the existing license products.

If the RAYGUIDE Click & Teach entry is listed as a license product, the CLICK & TEACH supplementary application is activated.

Example:

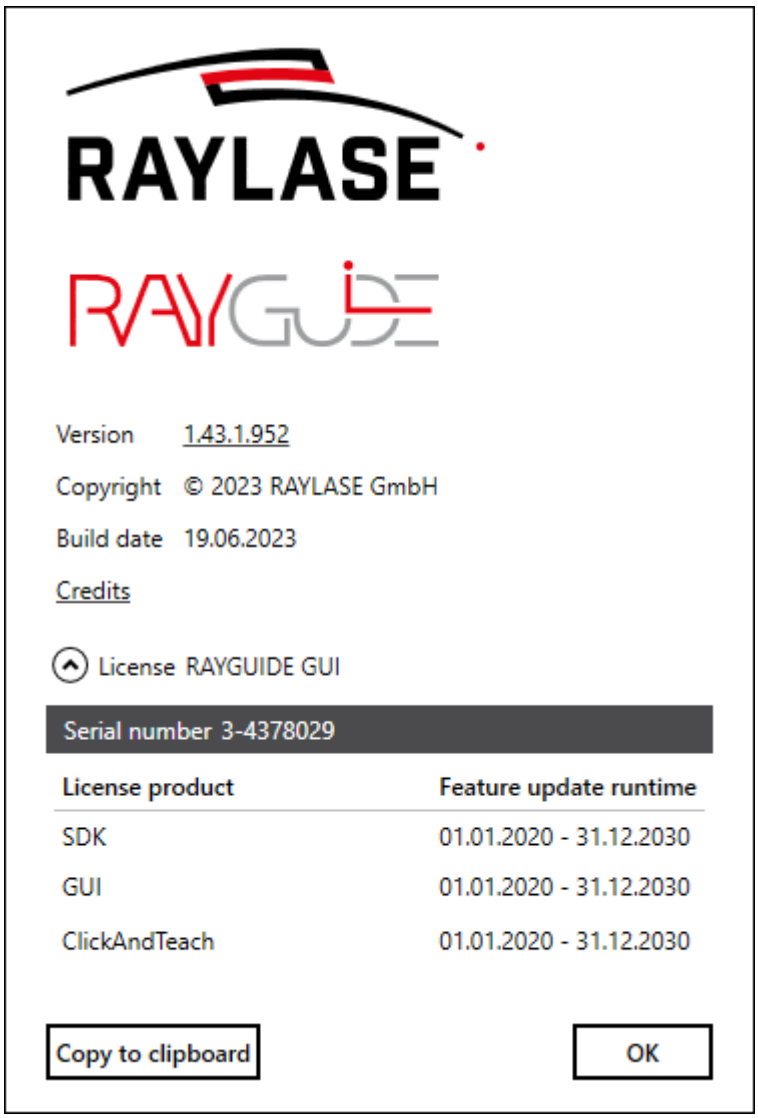


Fig. 2.4: CT-AAE

2.2.3 Software updates

If you update your RAYGUIDE application by loading new versions, ***RAYGUIDE VISION Solutions*** installation must also be performed as well. This is necessary to ensure compatibility between the main application and the additional applications.

The camera drivers can be selected during an update but do not have to be. This is the case unless it is noted explicitly that the drivers are updated with the new version.

2.3 IMPORTANT: System preparation

Before the application using CLICK & TEACH or MATCH, it must be ensured that the deflection unit and laser of your system have already been configured and the scan field has been calibrated.

The way the scan field is calibrated relative to the laser is decided by your accuracy requirements.

You can find the options RAYGUIDE offers in the

- RAYGUIDE GUI manual, chapter 5.3.2 or
- in the MULTI POINT EDITOR manual.

Entries for the process transformation are also taken into account:

- The background image is automatically displayed with corresponding transformation and
- A congruently traced or positioned contour is displayed undistorted again when marked

It is advisable to already have a pen in the library pen set available marked as "default" that you can use later to mark your material for camera calibration with good contrast and sharp results.

3 RAYGUIDE CLICK & TEACH

3.1 CLICK & TEACH components

From the user's point of view, C&T essentially consists of two components that are completely integrated in the RAYGUIDE software:

- Camera (as a device) with associated device dialog for configuration and calibration.

  See *page 23, Setting up the camera as a device in RAYGUIDEpage 17, Setting up the camera*.

- CLICK & TEACH panel for using the camera.

  See *page 55, CLICK & TEACH panel*.

Optional illumination control can also be purchased from RAYLASE and then used. The following components are available in the software for this purpose:

- The illumination controller (device) with corresponding device dialog for configuration.

  See *page 71, Illumination controller*.

- The *Illumination* panel to set the illumination intensity directly from the user GUI.

  See *page 76, Illumination panel*.

To add the required panels to the RAYGUIDE GUI, select these under the ***View > Panels > Plugins > Click & Teach*** menu item and, if applicable, ***Illumination***:

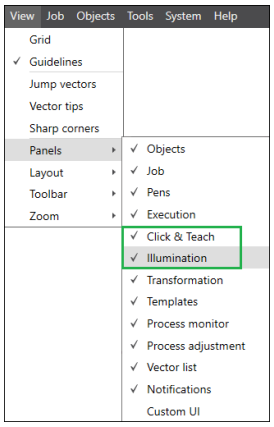


Fig. 3.1: CT-AAF

3.2 Setting up the camera

Before beginning to set up the camera, ensure that all mechanical components are correctly aligned and that the camera is mounted on the deflection unit using the adapter and is connected to the network card with the Ethernet cable.

The matching correction file must be loaded for the deflection unit and the F-Theta lens used (see Click&Teach software installation). When using a pre-focused deflection unit plus RAYSPECTOR, a correction file must be loaded which supports the so-called sensor axis.

Focus the camera objective in such a way that a sharp image is displayed.

3.2.1 Configuration of the network connection with the camera

Use the configuration tools of the camera manufacturer to perform the basic setup of the camera. Set the necessary network parameters for your network card and supply the camera with a valid IP address.

3.2.1.1 JAI cameras

JAI makes the *eBUS Player or JAI* program available for configuring their cameras. The *eBUS Player* enables more extensive settings than the Settings dialog (see *page 16, CLICK & TEACH components*), which can only be used to adjust the most important parameters.

The steps necessary for configuring the IP address are described below:

1. Start the *eBUS Player* and click on the ***[Select / Connect]*** button. You will find the executable file in a standard driver installation under

   C:\Program Files\JAI\eBUS SDK\Binaries\eBUSPlayerJAI64.exe.

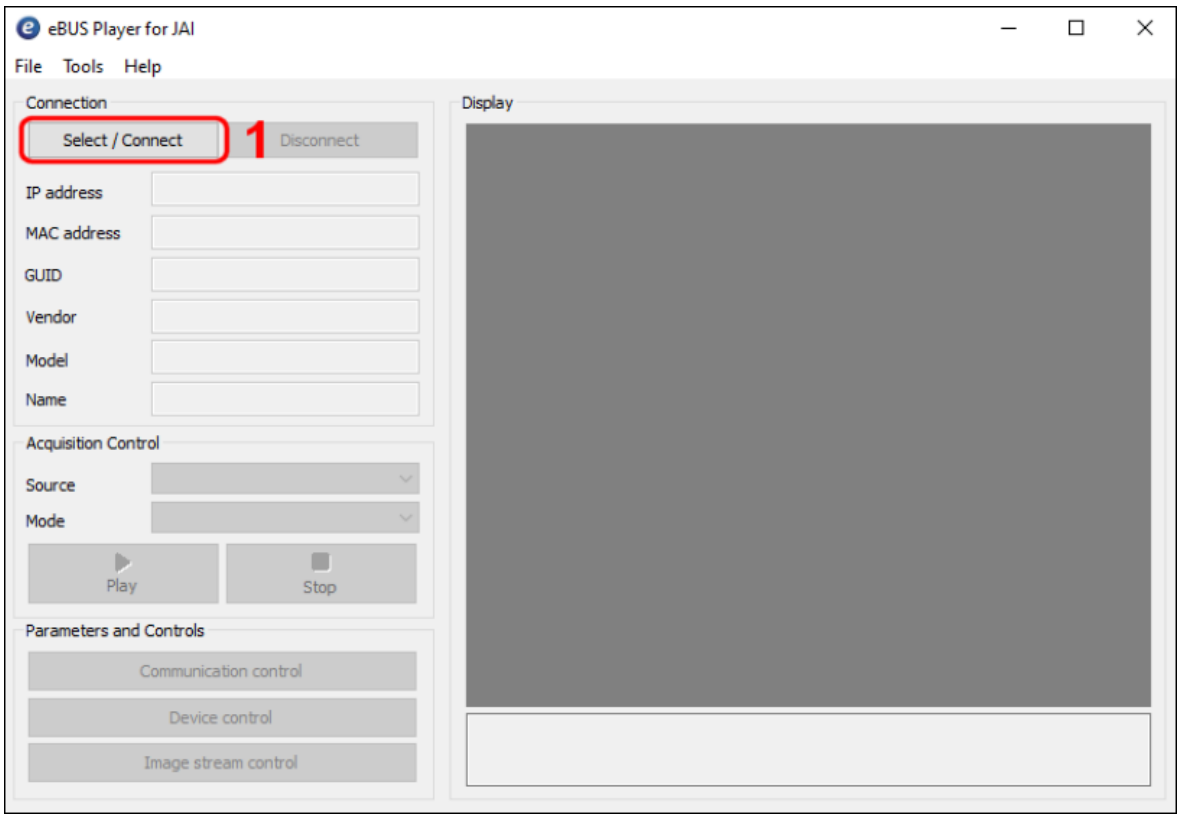


Fig. 3.2: CT-AAG

2. In the Device Selection dialog, all network adapters that are known to your PC are listed on the left side. Since your camera does not yet have an IP address, it cannot be reached at this time. Activate *Show unreachable Network Devices*:

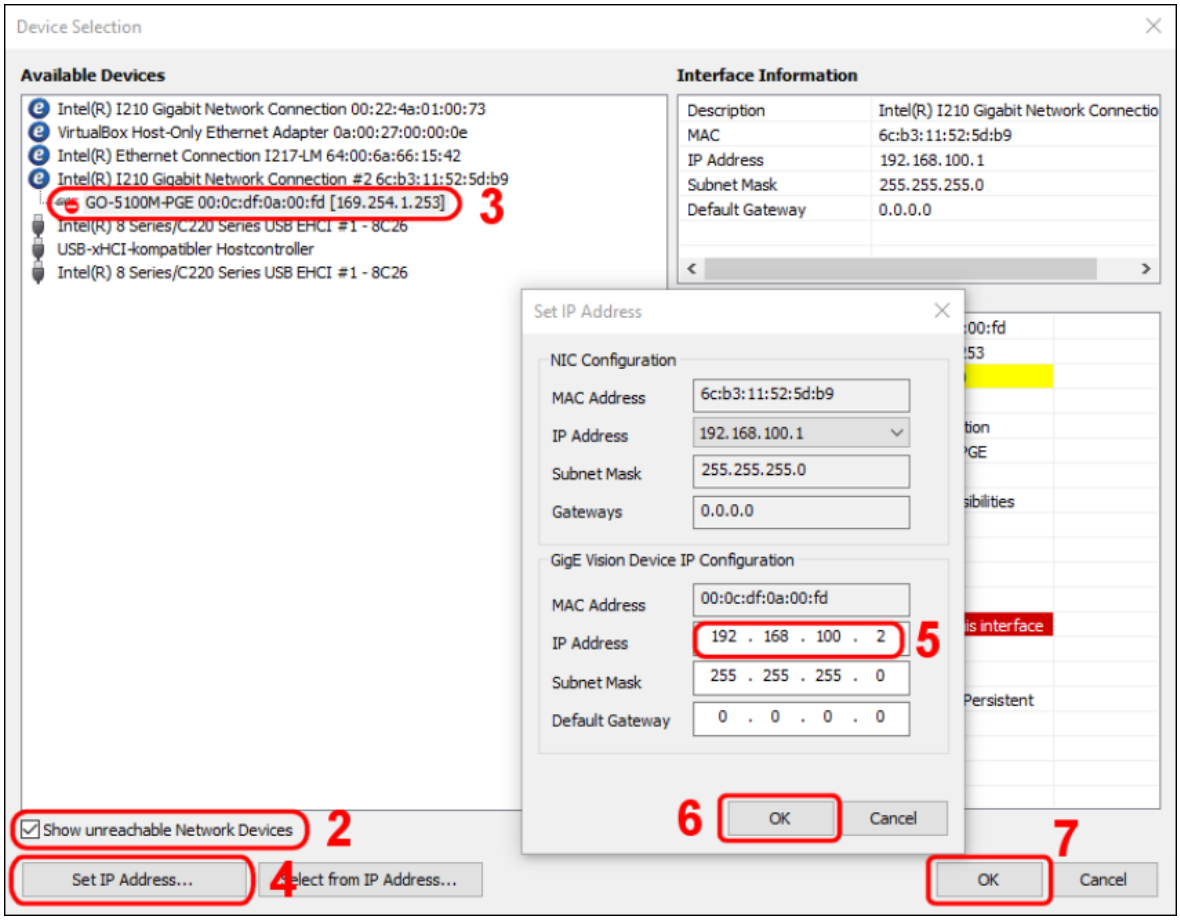


Fig. 3.3: CT-AAH

3. The camera (in the example: GO-5100M-PGE) appears below the network adapter it is connected to. Click on the entry to display the Interface Information and Device Information.
4. Click on ***[Set IP Address...]*** to open the dialog for configuring the IP address.
5. Enter an IP address that is still free in your network.
6. The red warning symbol in the device list disappears when you close the Device Selection dialog.
7. Close the Device Selection dialog by clicking on ***[OK]***.
8. Click on ***[Play]*** to display a live image. First, however, the IP configuration is completed. Click on ***[Device control]***:

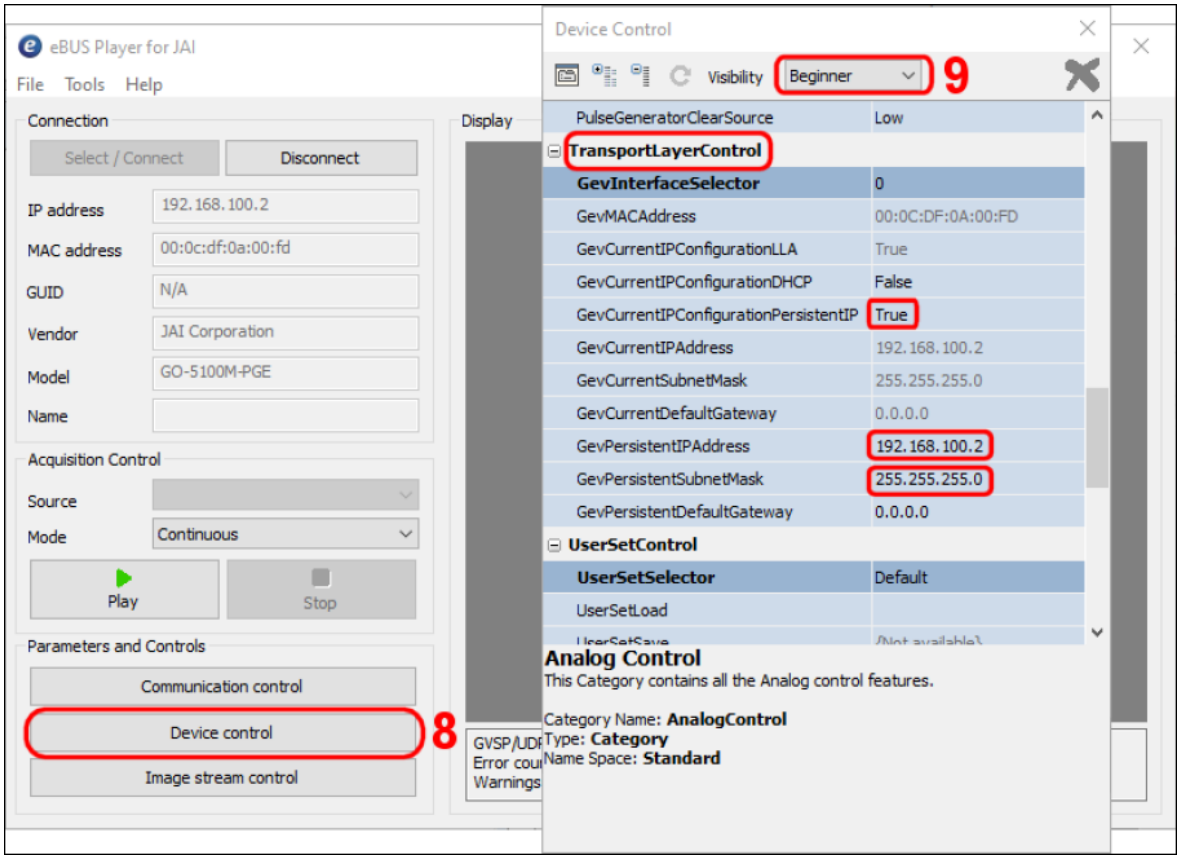


Fig. 3.4: CT-AAI

9. In the Device Control dialog, select the *Beginner* visibility level to reduce the parameter list.
10. In the TransportLayerControl area, you can set how the camera should be supplied with an IP address in the future. If there is a DHCP server in your network, the camera can obtain the address from there. For this purpose, set the *GetCurrentIPConfigurationDHCP* element to *True*.

    In the case described above, the camera is connected directly to a network card installed in the computer so that the IP address is typically specified. To do so, set the *GetCurrentIPConfigurationPersistentIP* element to *True* and enter the fixed IP address and subnet mask into the respective fields.

3.2.1.2 TeledyneDALSA cameras

Teledyne DALSA makes several programs available for configuring its cameras.

3.2.1.2.1 Sapera Network Configuration Tool

Use the Sapera Network Configuration Tool to set the IP address.

You will find the executable file in a standard driver installation under:

C:\Program Files\Teledyne DALSA\Network Interface\Bin\CorNetConfigApp.exe

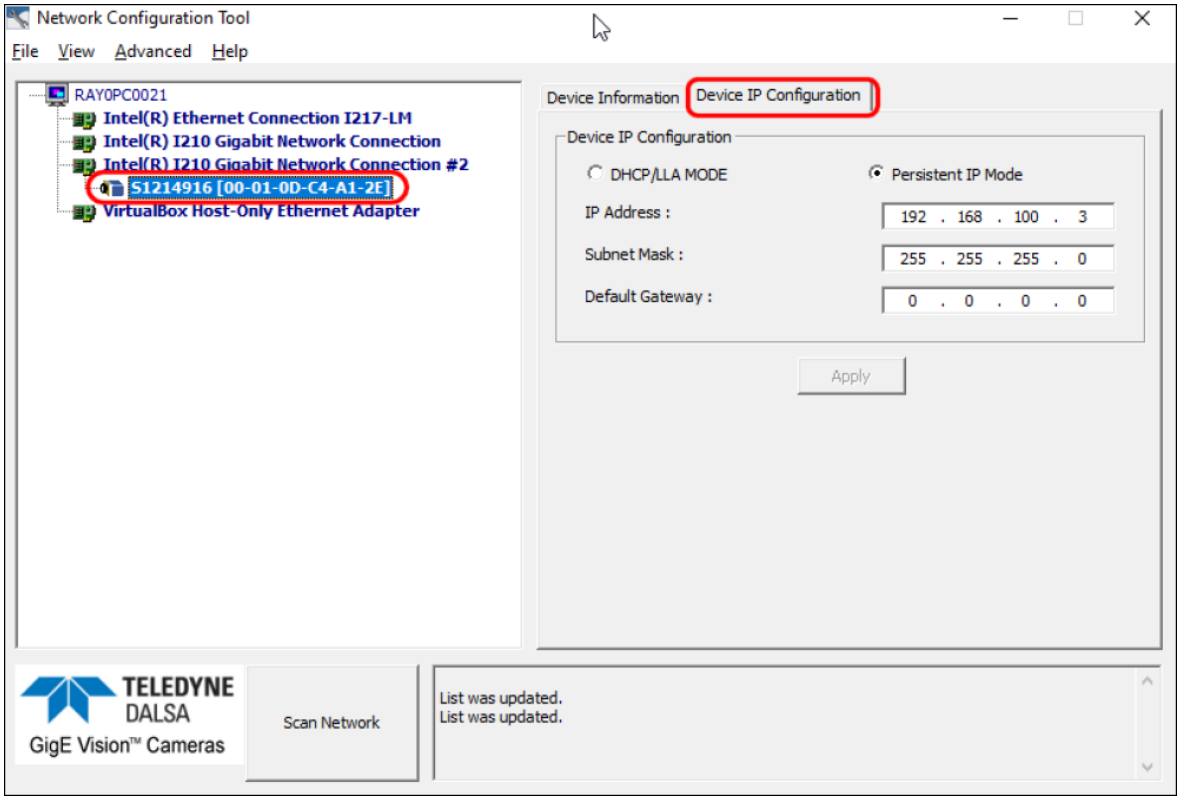


Fig. 3.5: CT-AAJ

1. Select the camera in the list of network adapters.
2. Change to the Device IP Configuration tab and enter the desired IP configuration.

3.2.1.2.2 Sapera CamExpert

Use the Sapera CamExpert to set camera parameters such as exposure time, to test the basic camera function (image recording should be possible) or to change camera parameters that are not offered in the Configuration dialog.

You will find the executable file in a standard driver installation under:

C:\Program Files\Teledyne DALSA\Sapera\CamExpert\camexpert.exe.

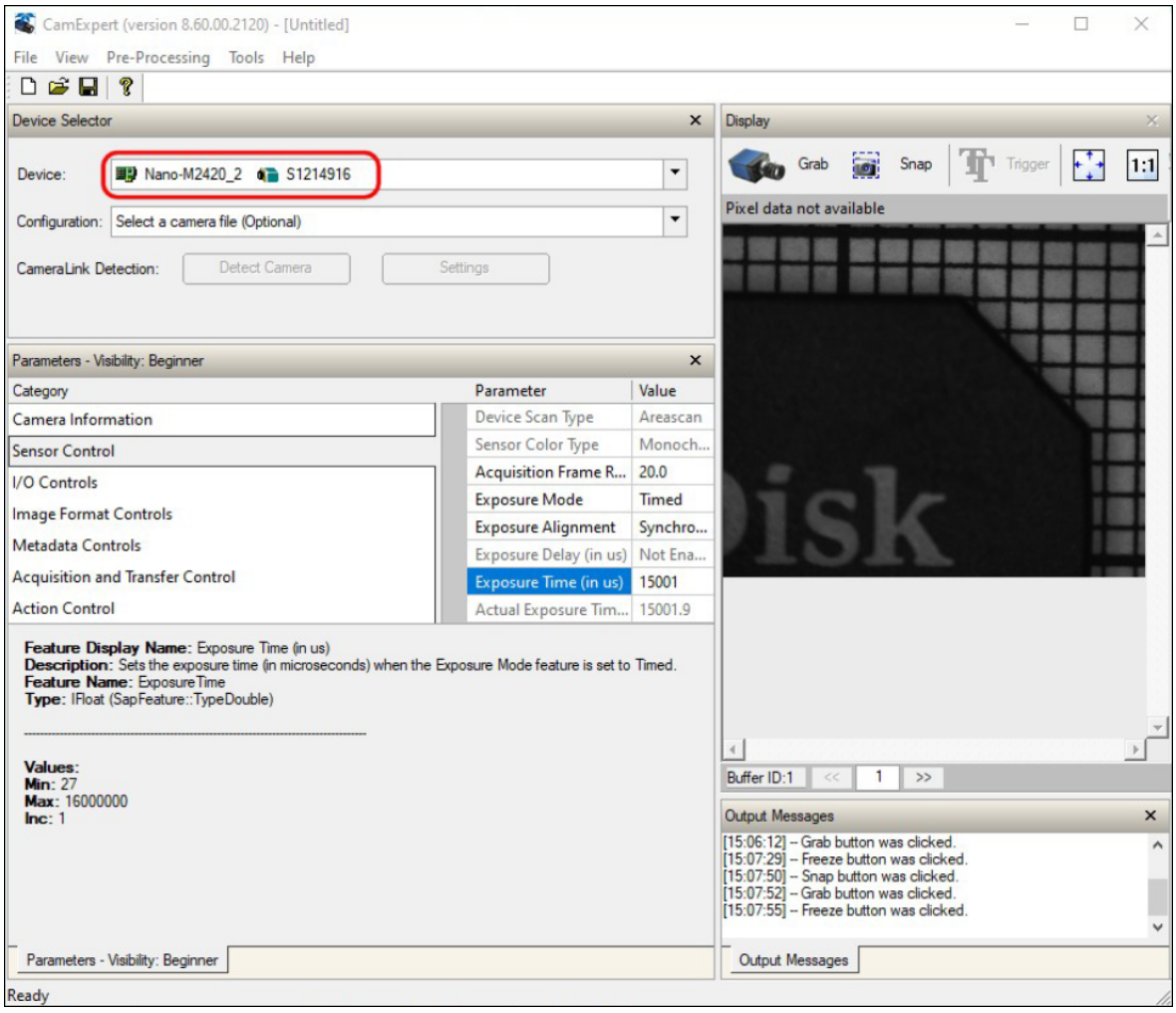


Fig. 3.6: CT-AAK

1. Select your camera in the *Device* drop-down list in the Device Selector area.
2. Enter the desired camera parameters.

3.2.2 Setting up the camera as a device in RAYGUIDE

3.2.2.1 Setting up the camera as a device

The camera is added to RAYGUIDE via the Device Configuration dialog. In the menu, select ***System > Devices > Configure...***.

Configuration window with sample content:

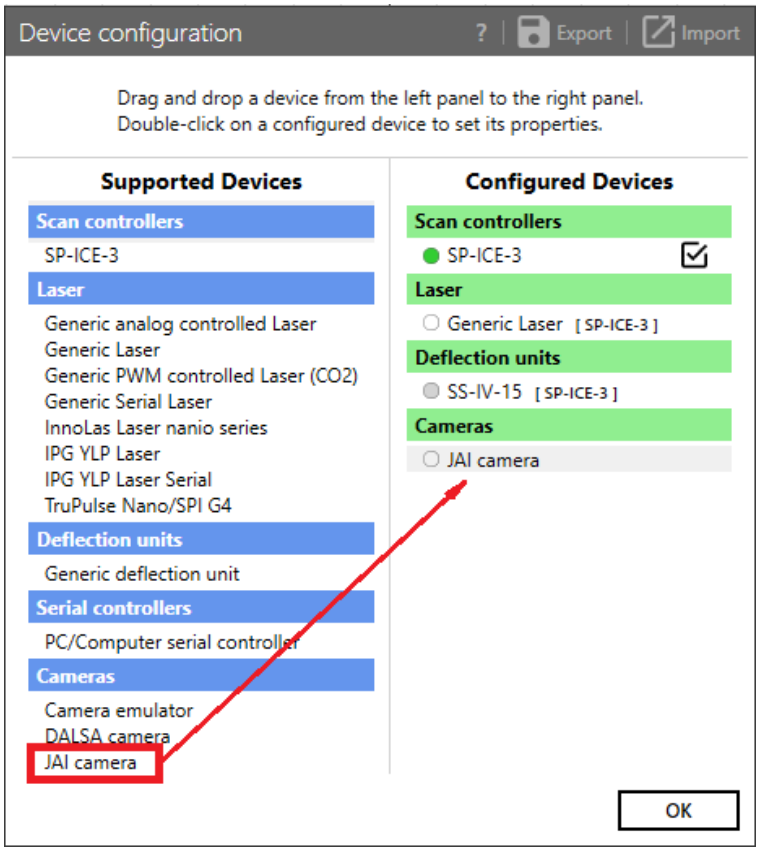


Fig. 3.7: CT-AAL

If the C&T extension is installed and a valid license is available, the existing camera plug-ins appear in the **Supported Devices** window area on the left side.

Use the mouse to drag the desired camera from the **Supported Devices** window area to the **Configured Devices** area.

3.2.2.2 Camera dialog

For each connected camera there is a Settings dialog that is executed as a RAYGUIDE device plug-in.

NOTE: The camera dialog is the same for the available camera models.

Open the camera dialog e.g. by double-clicking on the corresponding entry in the device configuration, or use the context menu of the camera and select ***Properties***.

Alternative navigation: ***System > Devices > Cameras > (Device name)***

Setup tab

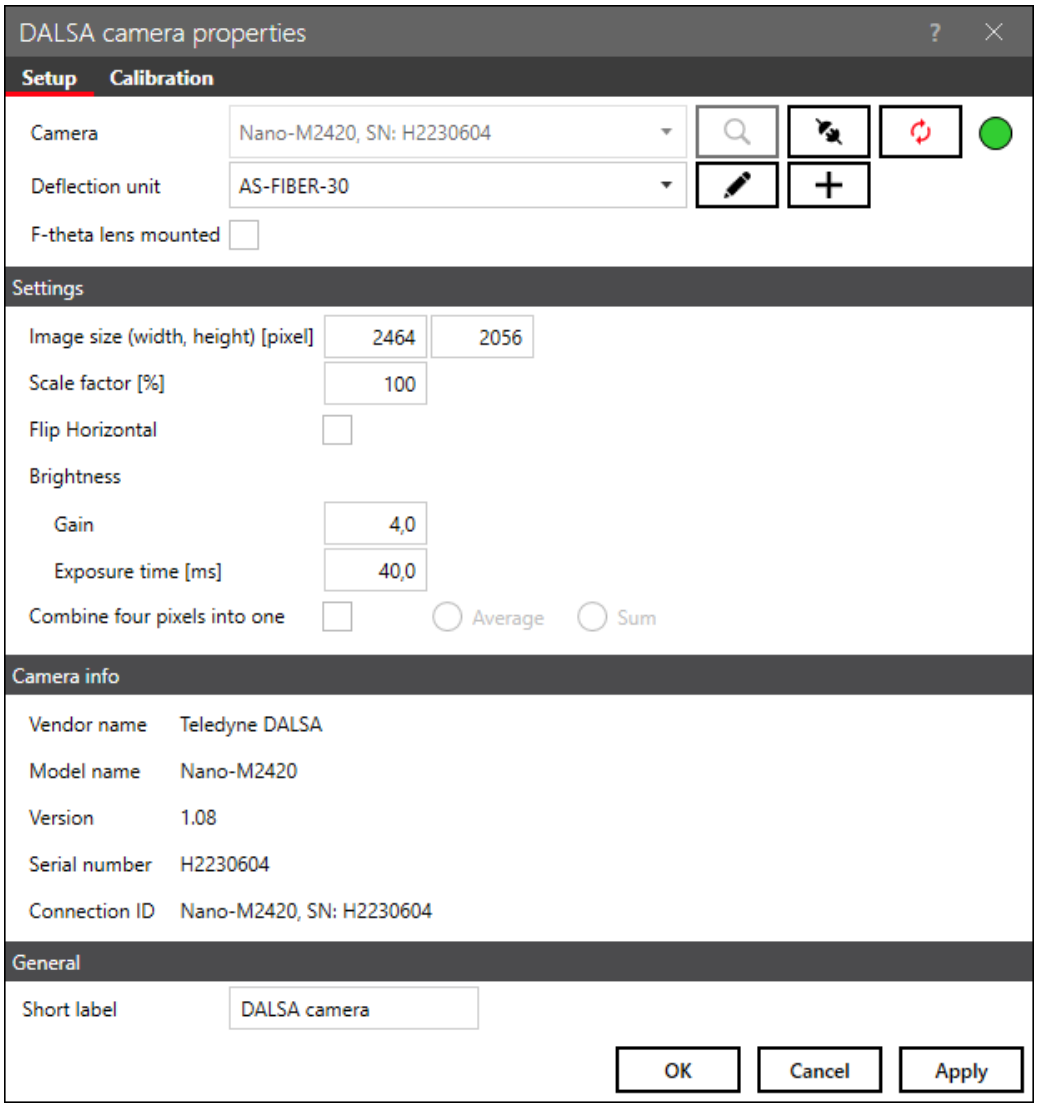
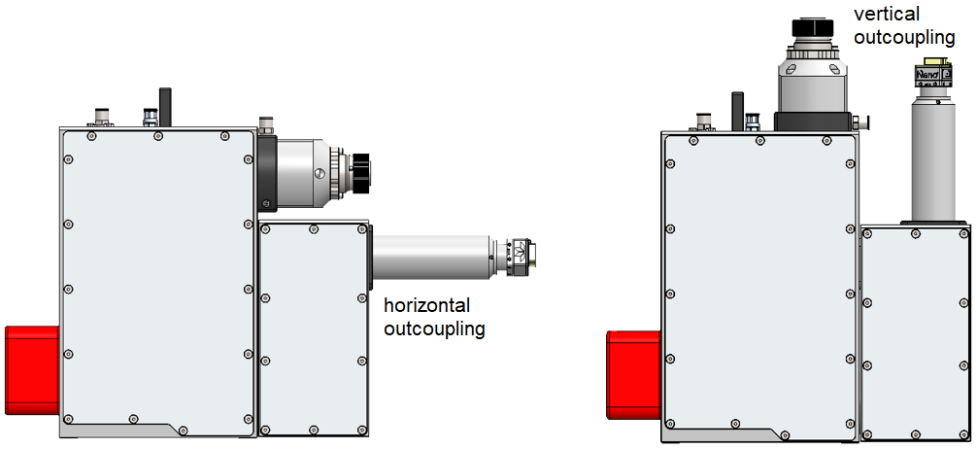


Fig. 3.8: CT-AAM

Setting	Explanation
Setup	

Setting	Explanation
For defining several camera parameters, such as the exposure time.	
Camera	Selection of the desired camera if multiple cameras are found on the system.
Deflection unit	Selection of the deflection unit at which the corresponding camera has an optomechanic docking point.
F-Theta-lens mounted	Specify whether your deflection unit has an F-Theta lens or not. **NOTE:** This information is important for calculation of the equalization (see *page 49, Equalization calibration*).
Settings	
Field of view (width, height) [pixels]	The size of the produced tiles can be reduced here. **NOTE:** This is not recommended for classical CLICK & TEACH applications, especially if equalization calibration is used.
Downscale factor [%]	The resolution of a tile or the overall image after it is taken is reduced by this factor to save memory and increase performance.
Horizontal flipping	When a camera is attached to a RAYSPECTOR module in combination with an AS FIBER, the light for the camera can be decoupled vertically or horizontally:  In the event of vertical decoupling, the camera image must be mirrored, as well as in the event of vertical decoupling with the FOCUSSHIFTER RD-14.

Setting	Explanation
Brightness	The brightness of the camera images is influenced by the following settings: ■ Gain: The cameras permit the electrical amplification of the detected incident light to lighten the camera image. **NOTE:** Increasing the amplification may result in more noise in the image. ■ Exposure time [ms] The cameras permit the setting of the exposure time to be set for an individual image. A longer exposure time makes the camera image lighter. **NOTE:** Increasing the exposure time makes the recordings and therefore the tiling slower. A good compromise between amplification and exposure time is therefore crucial.
Combining four pixels into one	The cameras permit so-called "pixel binning". In this process, pixels are combined. This reduces image noise at the expense of the resolution. Optionally, the gray values of the pixels can be summed or their average calculated to calculate the result image point. **NOTE:** Pixel binning occurs at the hardware level of the camera. This significantly reduces the amount of data transferred, which in turn significantly increases the speed of image capture.
Camera info Information on the manufacturer, model, version, serial number and connection ID	
General	
Short label	Enter the name under which the camera is to be listed in the device list.

Table. 3.1: CT-001

Calibration tab

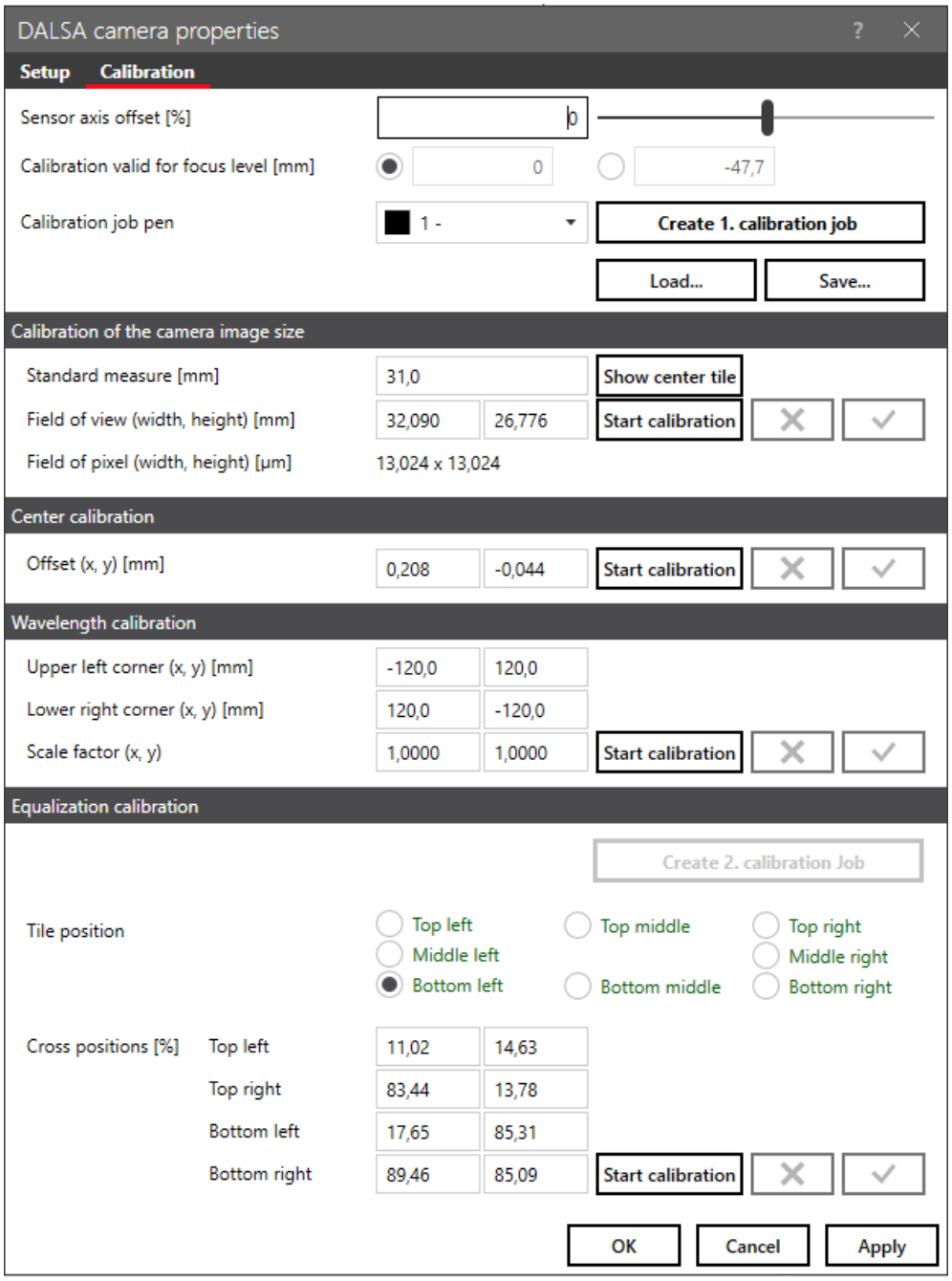


Fig. 3.9: CT-AAN

Setting	Explanation
Calibration For setting and / or determining the calibration parameters.	
Sensor axis offset [%]	The slider can be used to adjust the focus of the camera for the reference position (at the working distance). **CAUTION:** A positive value will shift the focus “downwards“. **NOTE:** The input field and slider are grayed out if the correction file has no z-range.
Calibration for focal plane [mm]	For systems that work with a correction file including the z-range, the camera must be calibrated in different focal planes to be able to record images in different focal planes. The data between the two calibrated planes is interpolated. For this reason, it is advisable to calibrate the uppermost and lowermost planes. **NOTE:** If no z-range is defined in the correction file, these fields are grayed out.
Calibration job pen	Selection of the pen for marking the calibration job. **NOTE:** The pen number refers to the library pen set defined as the “default". After the job is created, this pen can still be edited if necessary.
Calibration of the camera image size	
Standard measure [mm]	The distance between the two scale markings used for the calibration of the camera image size in the real world.
Field of view (width, height) [pixels]	The image size is the result of the image size calibration and indicates how large the area recorded by the camera is in reality.
Field of pixel (width, height) [µm]	Indicates how large the area is in reality that is recorded by a single pixel.
Center calibration	
Offset (x,y) [mm]	For design reasons, there is a deviation between the point to which the laser points and the center point of the camera image. This offset relative to the coordinate axis is determined by means of center point calibration and is then compensated for accordingly during tiling.

Setting	Explanation
Wavelength calibration	
Upper left corner (x,y) [mm]	At this position, a cross is generated in the calibration job that, on account of the different wavelengths of visible and laser light, appears in a slightly different position in the camera image. This difference is used to calculate the scale factors for the wavelength correction.
Lower right corner (x,y) [mm]	The second cross position is located at the diagonally opposite side only for the purpose of better accuracy of calculation.
Scale factor (x,y)	The result of the wavelength correction indicates a factor that must be applied to the mirror positions to compensate for the different angles of refraction of visible and laser light.
Equalization calibration	
Tile position	Selection of the eight tile positions to be processed, in each of which four cross positions must be taught. The color of the labeling changes during the calibration process when the respective tile position has been taught.
Cross positions	Display of the X/Y-coordinates as a percentage of the camera image width and height for each of the four cross positions. Valid for the currently selected tile position.

Table. 3.2: CT-002

3.2.2.3 Connecting / assigning the camera

Select ***System*** > ***Devices*** > ***Cameras*** > ***(Device name)*** from the menu to open the Settings dialog. Select the ***Setup*** tab to set up the camera connection.

1. Click on ***[Search]*** to search for existing cameras.
2. Select the desired camera in the drop-down list and click on ***[Connect]*** / ***[Disconnect]*** to establish a connection or interrupt a connection. An active connection is indicated by a green traffic light.

   As soon as a connection is established, several parameters, such as the image size or the current exposure time, are read out of the camera.
3. Assign the associated deflection unit to the camera.

4. Specify whether your system is equipped with F-Theta lens. This specification is relevant for the equalization of the camera images.

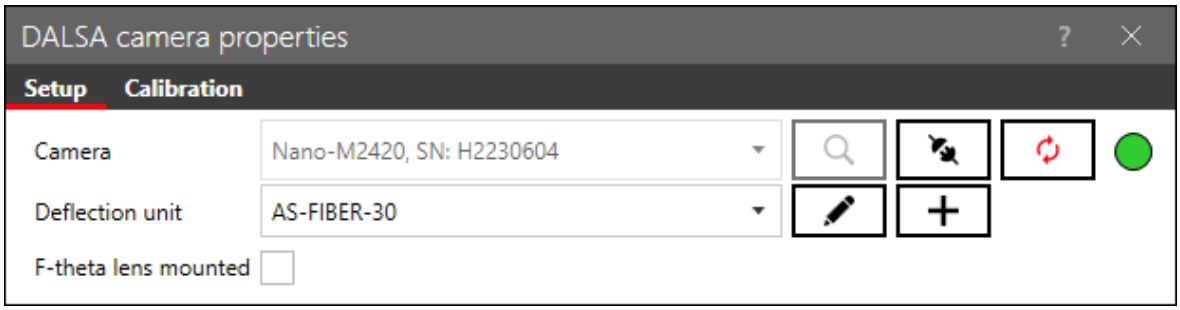


Fig. 3.10: CT-AAO

5. Edit the parameters in the Settings area.

   NOTE: To adapt additional camera parameters, use the configuration program from the camera manufacturer.

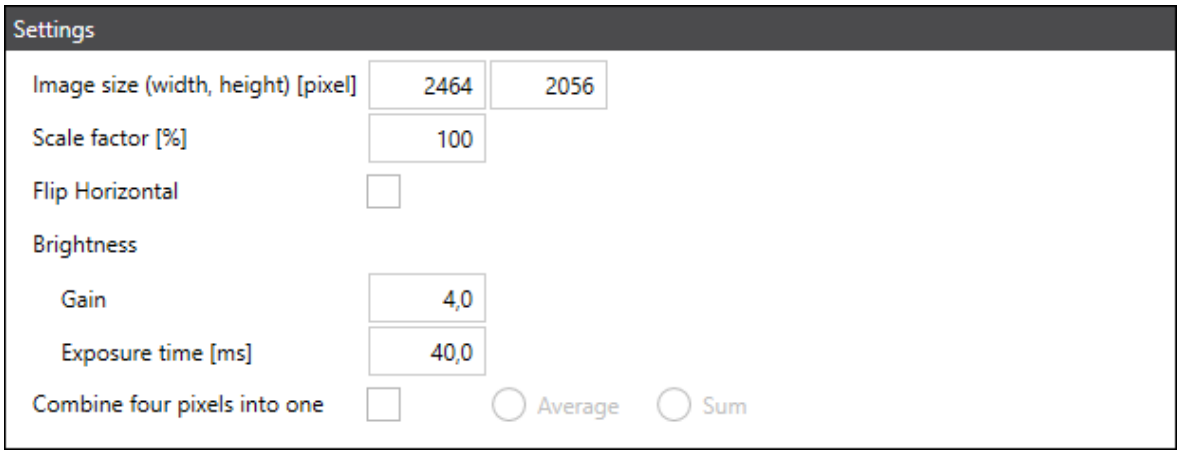


Fig. 3.11: CT-AAP

The *scale factor* has special significance. A complete image of the workspace consists of many (e.g. ten by ten) image tiles. If, for example, a camera generates images with 2000 pixels along the width, the overall image has a width of 20,000 pixels. This can in turn affect the performance in terms of time and is also not always necessary. That means you should select the scale factor so that the images have enough resolution for your needs, but no higher than necessary so as not to make handling too difficult.

NOTE: Calibration requires a high accuracy, which is why the images are always shown with the full resolution in this case.

6. Close the dialog with ***[OK]*** to apply the changes. Click ***View > Panels > Click & Teach,*** from the menu to open the C&T panel.

3.2.3 Aligning camera and adjusting focus

This step ensures that the camera images are focused or “clear” and displayed orthogonally aligned to the workspace.

NOTE: Changing the field alignment does not require a new alignment of the camera, but the live image rotation should be adjusted.

In preparation, we recommend marking the calibration job with a suitable pen on suitable material. The parallel lines contained in the calibration job then serve as a reference for the alignment of the camera.

To do this, select the Calibration tab in the Camera dialog, select the pen and then click on ***[Create 1. calibration job]***.

NOTE on the calibration job and field transformation: If an angle for the rotation is specified in the field transformation (see RAYGUIDE manual, chapter 5.3.2), each rotation is counterbalanced by CLICK & TEACH. The calibration job is then displayed rotated inversely in the viewport.

NOTE on calibration jobs and RAYGUIDE workspace: The workspace can be one composed of several scan fields in the RAYGUIDE software. It can be smaller or larger than the scan field and may have an offset relative to the scan field.

CLICK & TEACH always automatically positions the calibration job centered to the scan field and not centered to the workspace, because each coaxial working camera always acts per scan field.

If the geometries are within an area of the scan field that cannot or should not be targeted by the laser, the job will have to be adjusted manually (scaling would not be permissible since this would destroy the dimensions of the scale).

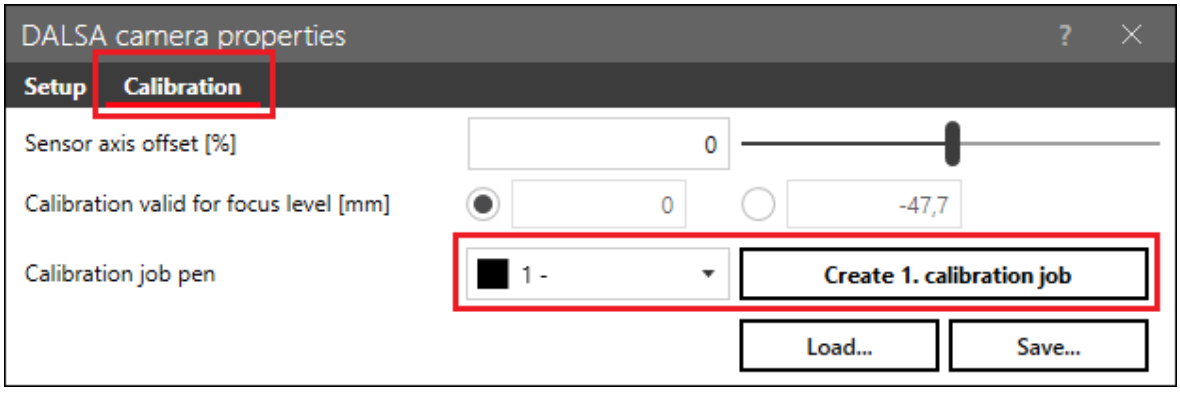


Fig. 3.12: CT-ACH

Only the center part is of interest here, which contains two texts and horizontal lines. The cross positions are described in the actual camera calibration routine.

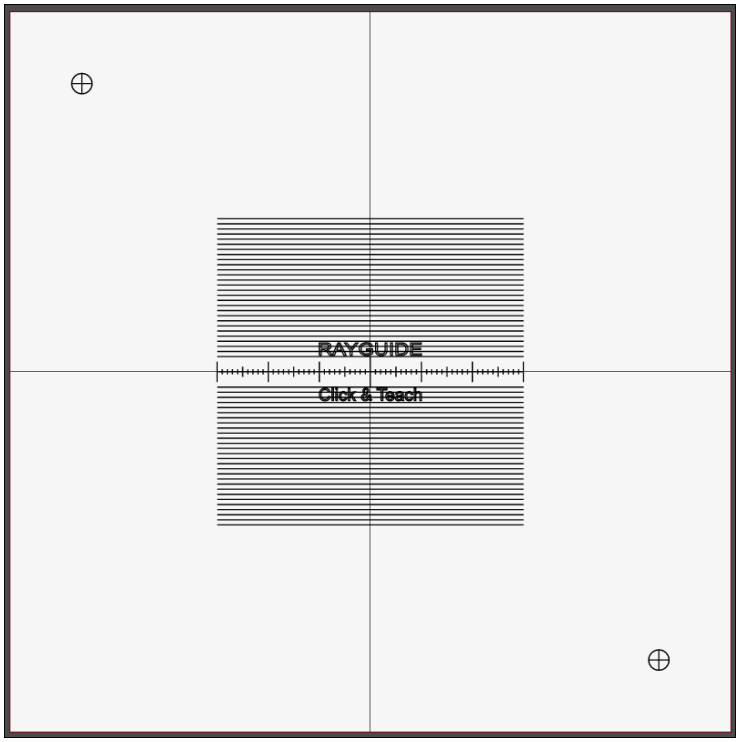


Fig. 3.13: CT-ACI

Execute the calibration job like a normal RAYGUIDE job and activate the live image of the camera by clicking on the camera icon in the C&T panel:

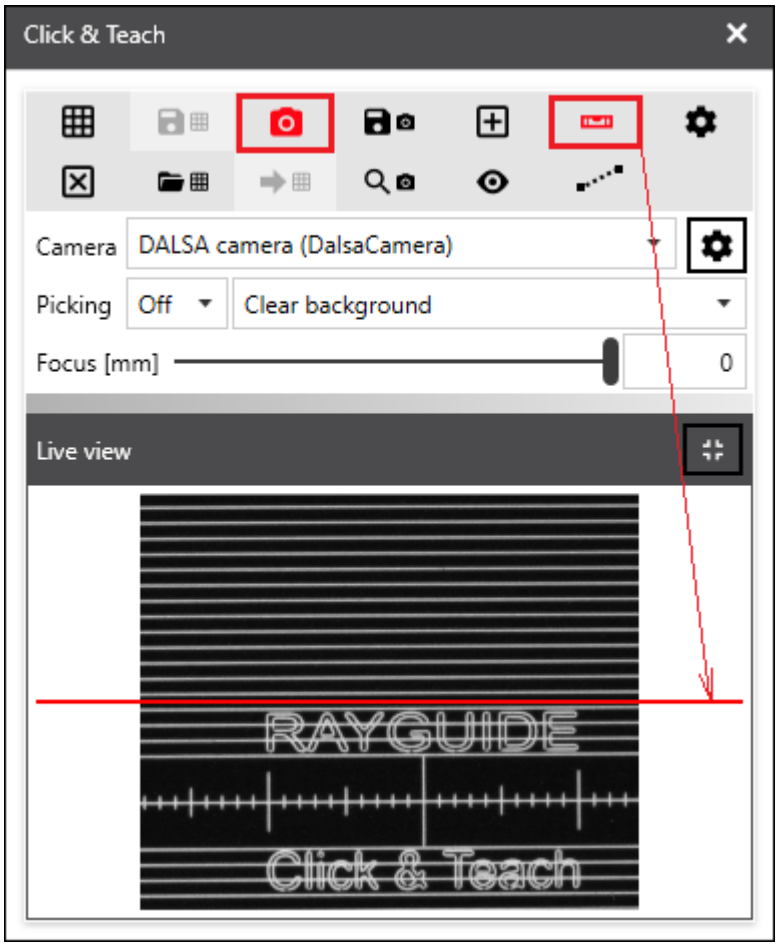


Fig. 3.14: CT-ACJ

In addition, activate the display of the adjustment line in the live image (see *page 57, Buttons*). Using the mouse wheel, you can move the line up or down to be positioned where the horizontal lines of the marking are visible.

The live image can also be enlarged if required, for details see *page 65, Live image*.

NOTE: To navigate the camera position to the center of the scan field, simply click on the ***[Stop]*** button in the Execution panel.

Now turn the camera lens or camera mount in such a manner that the texts are not upside down and not sideways, and the horizontal lines are parallel to the displayed horizontal adjustment lines. For details, see the next chapter.

3.2.3.1 Procedure for deflection units with camera adapter

This procedure applies, for example, to 2-axis deflection units or the FOCUSSHIFTER 14 MVC with corresponding camera lens:

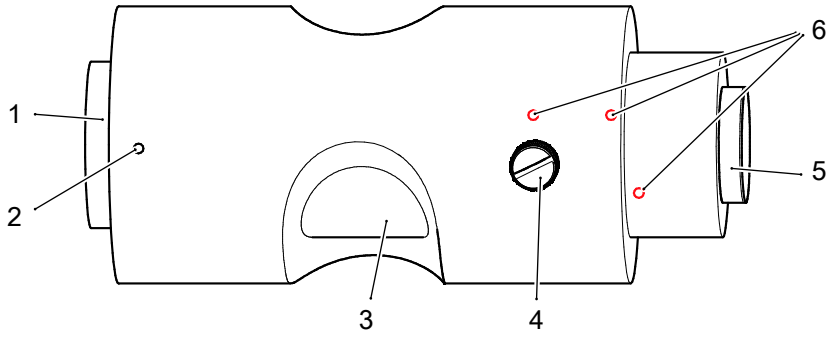


Fig. 3.15: CT-AAQ

1	Connection thread for camera lens	4	Knurled screw (for focus adjustment)
2	Grub screws (for rotation)	5	Connection thread for camera (C-mount)
3	Inner cylinder	6	Locking screws (thread-locked, do not open)

1. Screw the connection thread of the camera lens (1) into the camera adapter all the way to the stop. Tighten the camera lens only lightly at the stop.
2. Screw the camera all the way onto the connection thread (5). Tighten the camera only very lightly at the stop. Tightening the camera too tightly will damage the thread and will lead to destruction of the camera or the camera lens.
3. Open the knurled screw (4), adjust the [1] focus roughly and tighten the knurled screw again.
4. Slightly loosen the three grub screws (2) and rotate the entire camera lens until the marked lines appear horizontally in the live image. While the grub screws are open, the focus must not be changed, or else there will be a risk of mechanical damage.
5. Lightly tighten one of the grub screws (2) again to prevent accidental turning.
6. Adjust the [1] focus exactly and secure this setting by lightly tightening the knurled screw (4).

[1] **NOTE:** With the RAYLASE FOCUSSHIFTER, there is the option to set the focus position as desired in the focus area (defined by the correction file). However, since the FOCUSSHIFTER does not have dynamic focus tracking, only a single focus position can be adjusted. Subsequent calibration of the camera image must then take place in this focus position.

3.2.3.2 Procedure for AS FIBER with RAYSPECTOR

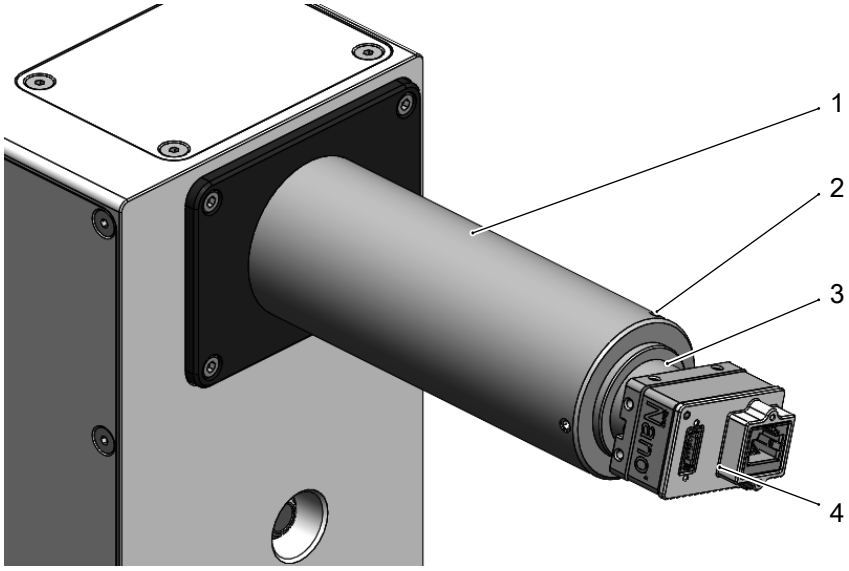


Fig. 3.16: CT-AAR

1	Spacer tube	3	Mounting option for camera (C-Mount)
2	Screws on spacer tube	4	Camera

1. Screw the camera with the connection thread into the camera mount (C-mount) up to the stop. Tighten the camera only lightly at the stop.
2. Slightly open the three screws on the spacer tube so that you can rotate the camera mount.
3. Turn the camera into position until the marked lines visible in the live image appear horizontally.
4. Fix this position by carefully tightening the three screws again. **NOTE:** Make sure that there is no tension in the cables to the camera.

3.2.4 Calibrating the camera image

For an optimal result when assembling the image tiles, it must be known how large the area of the processing field is that is shown in a single image tile. Also, the center point of the camera image before calibration is not identical with the point onto which the mirrors would direct the laser beam. This deviation must be compensated for. The laser generally has a different wavelength than the visible light that generates the camera image and is therefore deflected differently by the optics. This chromatic aberration is taken into account with a calibration step.

Furthermore, the F-theta lens installed in the beam path as well as the pure deflection via the deflection mirrors cause distortion of the camera images. The distortion is greater the more the mirrors are deflected. These distortions can also be largely compensated for by a calibration step.

Starting calibration

1. In the menu, select ***System > Devices > Camera > (Device name)*** to open the laser diagnostic file.
2. Select the ***Calibration*** tab.

3.2.4.1 Focus calibration

When using the camera with a RAYSPECTOR module that is coupled to an AS-FIBER deflection unit, the sensor Z-axis in RAYSPECTOR, in combination with the fitting correction file, is set at the factory such that the camera is in focus at the working distance. It can still be necessary to adjust the focal plane slightly.

CAUTION: This step must be performed once prior to calibration.

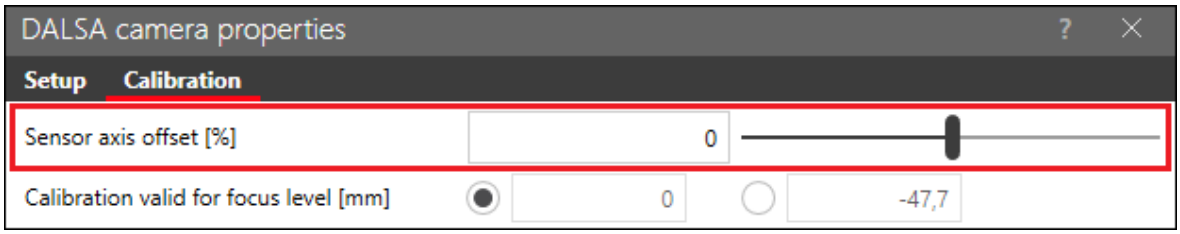


Fig. 3.17: CT-AAS

In this case, use the slider.

Note that a positive sensor axis offset corrects the focus "downward", while a negative sensor axis offset corrects the focus "upward".

NOTES:

- If another focal plane is used for the camera calibration below, the focus calibration only needs to be performed for one focal plane.
- The sensor axis offset is also displayed on the Calibration tab in the dialog of the corresponding deflection unit.
- If the camera is used in a 2-axis unit with an F-Theta lens and the corresponding correction file, this point is not applicable.

CAUTION: If the focus is calibrated, the image ratio of the camera changes. That means that all other calibration steps that may have already been carried out must be repeated.

3.2.4.2 Manual calibration of the (actual) camera

The calibration is performed in five simple steps using two marked calibration jobs.

NOTE: The marking must always take place in the focal plane of the system.

- With 2-axis deflection units, the marking must always be made at the working distance = focal plane.
- For the AS FIBER and when using a 3D correction file, it is intended to mark and calibrate in two focal planes (top edge and bottom edge) of the focus range (3D volume).
- With a FOCUSSHIFTER MVC (with camera observation), a single but freely selectable focus position can be defined.

A total of two different calibration jobs are needed for the different calibration steps

NOTES:

- Not marking the two jobs together on the same material is recommended.
- To generate the second calibration job, values are also required that were first determined in the first calibration steps (i.e. in the first calibration job).

Primary calibration job

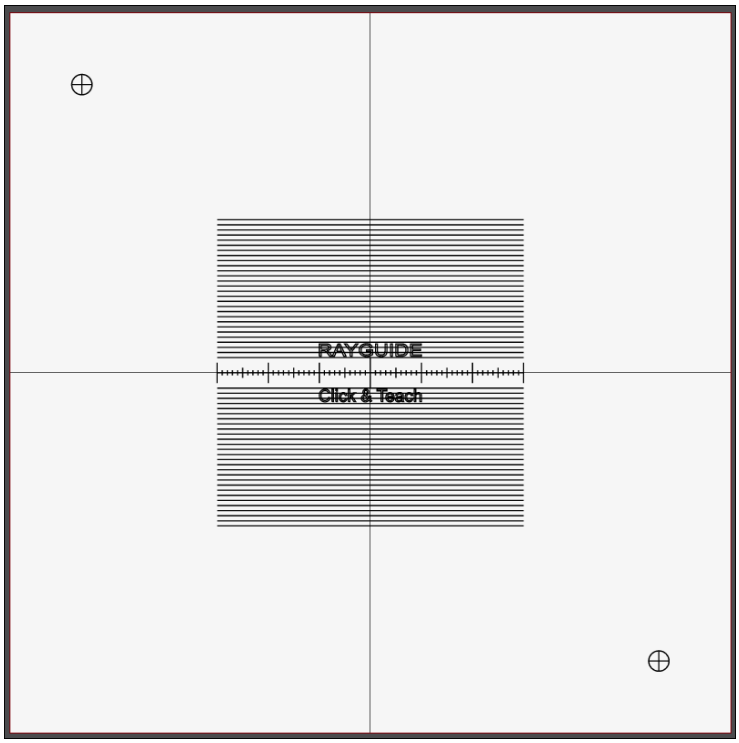


Fig. 3.18: CT-AAT

Calibration job for distortion calibration

With patterns for eight image tiles

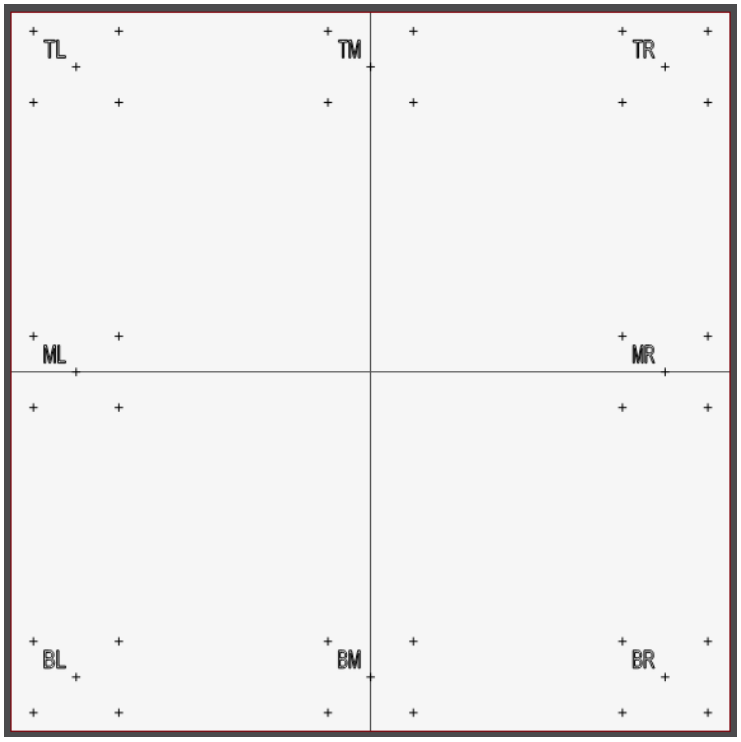


Fig. 3.19: CT-ACK

With patterns for 16 image tiles

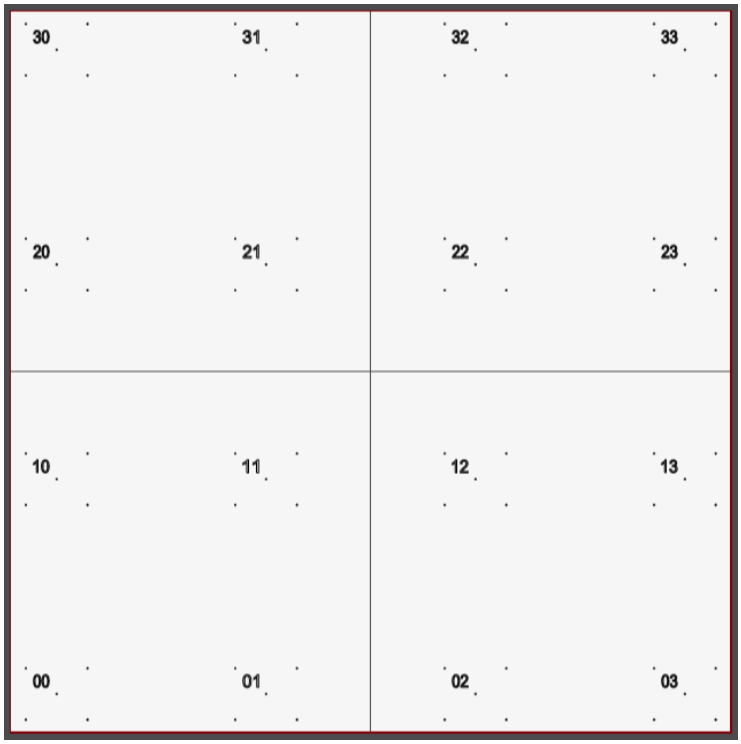


Fig. 3.20: CT-ACL

3.2.4.2.1 Semi-automatic support of calibration steps

Each of the following calibration steps can be automated using feature recognition. Cross positions in particular are searched for and found using the template search function. This generally eliminates the need to manually position the auxiliary lines or crosses.

The guidelines can still be corrected manually at any time.

IMPORTANT: Automatic position detection of the positions to be taught in is generally very reliable. However, checking the position before transfer or teach-in is strongly recommended, as this position determines the calibration data.

NOTE: When using automatic position detection, the two calibration jobs must not be marked on the same material. Otherwise, the crosses of the wavelength calibration may mix with those of the distortion calibration and the image processing may detect incorrect cross positions.

3.2.4.2.2 Generating calibration reference

Usually, a laser processing job of the two calibration jobs on a paper or foil suitable for the laser wavelength serves as a reference.

NOTE: Make sure that the material to be marked does not shift or curl during calibration.

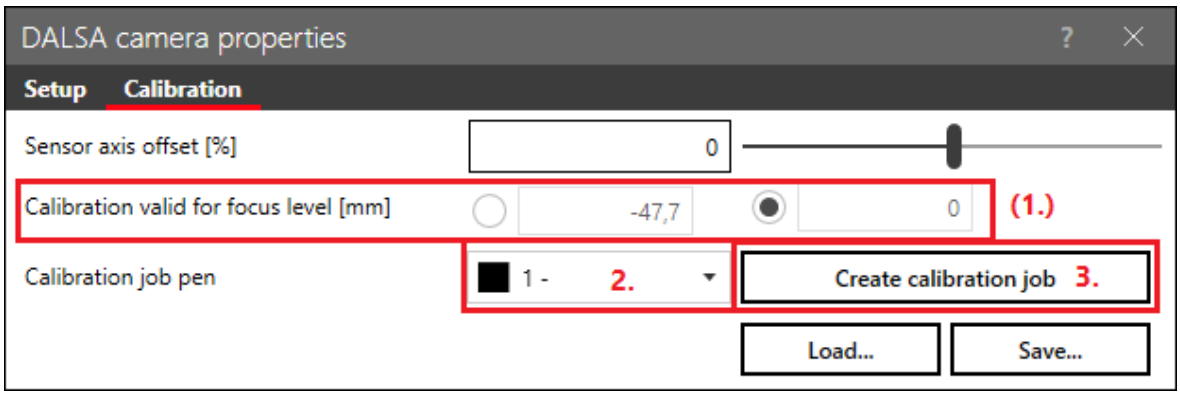


Fig. 3.21: CT-AAU

1. **Optional**: Defining focal plane for camera calibration

- *AS FIBER with RAYSPECTOR*

  If the workspace used should have an extension in the Z direction, the calibration steps described below must always be carried out on two different planes:

  – At the highest point (z-position = 0 mm)
  – And again, if possible, at the lowest point (depends on the values in the correction file).

  The obtained calibration data is then automatically interpolated (linearly) for the intermediate z-positions.

  NOTE: The value for the lower focal plane is always specified as per the correction file. If a marking is not possible in this focal plane because of the system design, an alternative value can be entered.

- *FOCUSSHIFTER MVC*

  Enter the position of the camera focus that you have adjusted so calibration and generation of the calibration job takes place in this focus position.

  NOTE on the calibration job and field transformation:

  If an angle for the rotation is specified in the field transformation (see RAYGUIDE manual, chapter 5.3.2), each rotation is counterbalanced by CLICK & TEACH. The calibration job is then displayed rotated inversely in the viewport.

2. Select a pen (process parameter) that is suitable for marking on your material. The pens listed here come from the standard pen set of the pen library.

3. Click on the ***[Create 1. calibration job]*** button to create the job. This is then executed like a regular laser processing job in RAYGUIDE.

   NOTE: The crosses with circle for wavelength correction are automatically positioned at 80% of the field size in two corners. If necessary, the position can be changed manually before creating the job.

NOTES on calibration jobs and RAYGUIDE workspace:

– The workspace can be one composed of several scan fields in the RAYGUIDE software. It can be smaller or larger than the scan field and may have an offset relative to the scan field.

  If the workspace is smaller than the scan field and remains centered, the first of the two calibration jobs automatically fits into the workspace. The second optional calibration job always covers the entire scan field.

– Reference is always made to the workspace that is defined by default in the Job presets.

– CLICK & TEACH always automatically positions the calibration job centered to the scan field and not centered to the workspace, because each coaxial working camera always acts per scan field.

– If the graphic elements of a job fall into an area of the scan field that cannot/should not be hit by the laser, the job must be adjusted manually. Scaling is not permitted as this would destroy the scale.

NOTE on the calibration job and field alignment:

Before the calibration job is generated, the field alignment must be defined, as its alignment is determined in the RAYGUIDE viewport.

4. Perform the job with the RAYGUIDE software.

3.2.4.2.3 Calibration of the camera image size

In this step, the area of the processing field that a single tile displays is determined. For this purpose, the system is informed about how large a known comparative measure appears to be in the camera image.

The camera image size can be calibrated automatically or manually.

... process

Click on the ***[Start calibration]*** button in the calibration area of the camera image size.

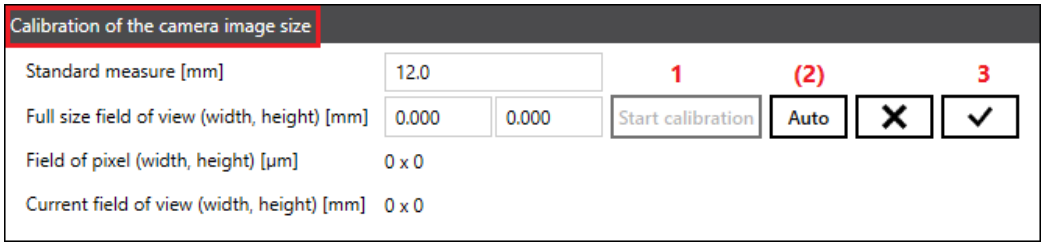


Fig. 3.22: CT-AAV

This step positions the mirrors of the deflection unit to the zero point and the associated camera image of an image tile is displayed in the workspace of RAYGUIDE in its full format.

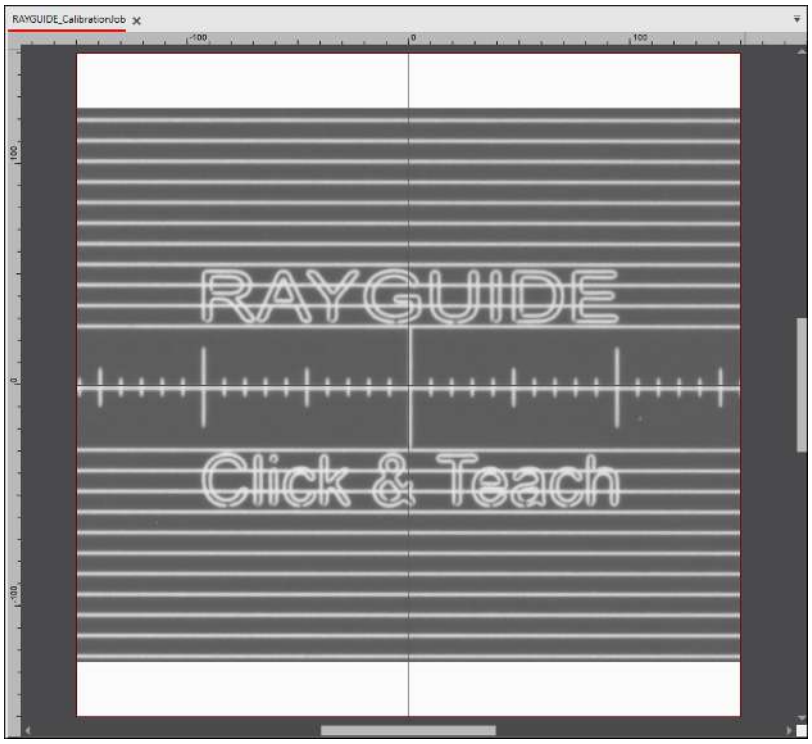


Fig. 3.23: *CT-AAW*

You can see the scale of the marked job. Each scale line is 1 mm from its neighbor in the real world.

Automatic calibration of the camera image size

Click on the ***[Auto]*** button to automatically determine the value for the standard measure and automatically position the guidelines on the two outermost scale lines.

Check the position of the guidelines; adjust them manually if necessary.

Accept the values and teach in the position by clicking on the ***[✓]*** button.

Alternative: Manual calibration of the camera image size

Select two scale lines that are as far out on the edges as possible but still fully visible, and count the distance between these two elements.

In the example below, the two outermost scale lines that are just barely visible are 31 mm apart.

NOTE: The measurement becomes more accurate as the distance between the two selected scale line increases.

Enter the distance between the two selected markings in the *Standard measure* field.

Then move the two guidelines to a position directly over the two selected scale lines. To increase the accuracy, you can zoom into the workspace.

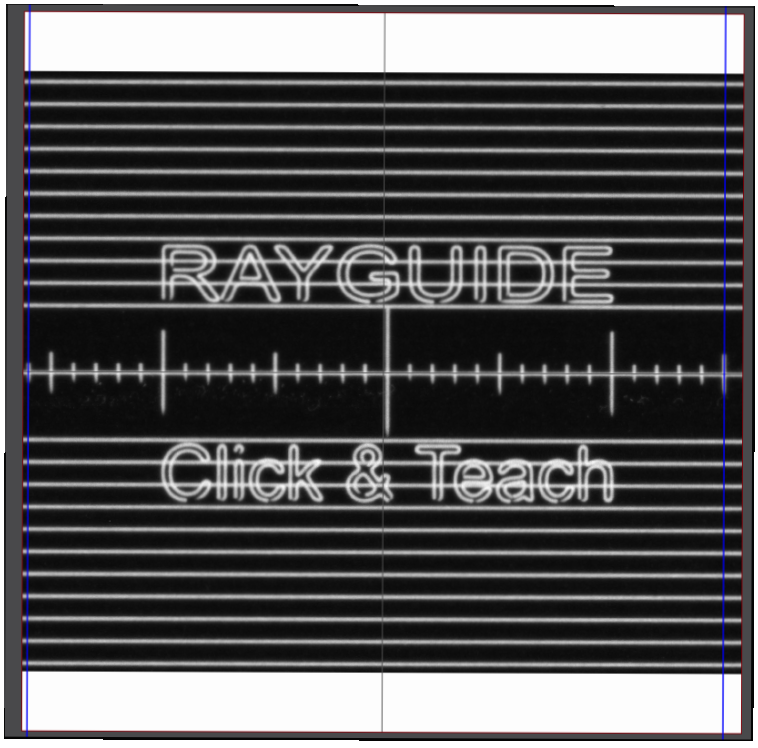


Fig. 3.24: CT-AAY

When the two guidelines are precisely positioned, click on the ***[✓]*** button to complete this calibration step.

The result is displayed in the *Current field of view [width, height) [mm]* and *Field of pixel (width, height) [µm]* fields.

3.2.4.2.4 Calibration of the center point

For design reasons, there is a deviation between the point to which the laser points and the center point of the camera image. This offset is determined by center point calibration and can be compensated for during tiling.

... process

In the ***Center calibration*** area, click on the ***[Start calibration]*** button:

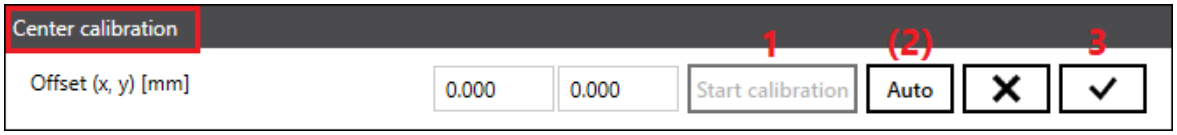


Fig. 3.25: CT-AAZ

In the same manner as for calibration of the camera resolution, the camera image is displayed in the workspace of the RAYGUIDE as a background image, but this time with a vertical and a horizontal guideline.

Automatic calibration of the center point

The ***[Auto]*** button can be used to automatically align the intersection of the two guidelines with the center point of the marked calibration reference. Check the result anyway!

Manual adjustment

If necessary, make the adjustment manually.

Move the blue lines in such a way that their intersection is directly over the center point of the marked calibration reference.

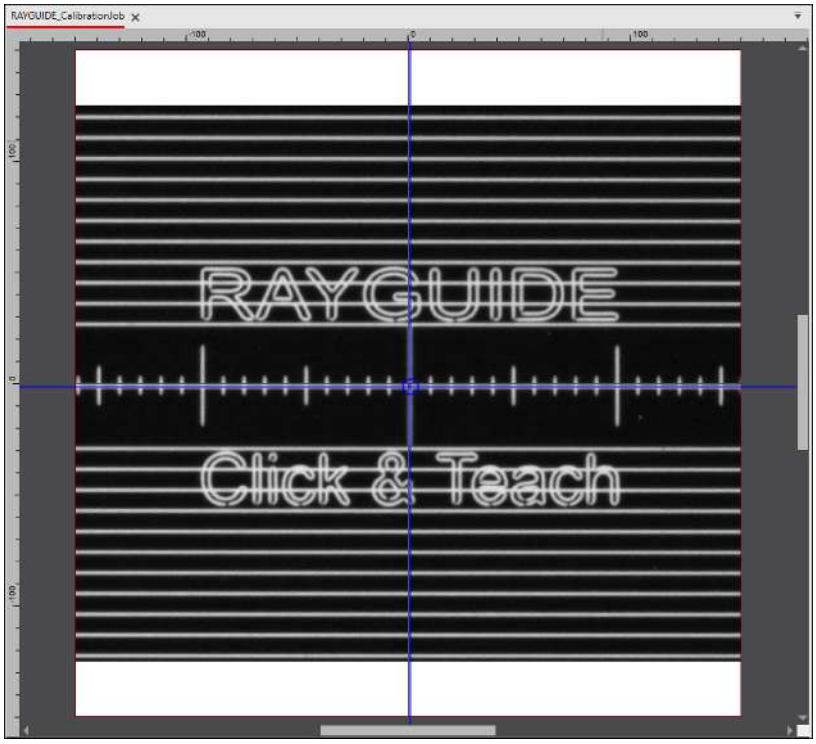


Fig. 3.26: CT-ABA

Click on the *[✓]* button to complete this calibration step.

3.2.4.2.5 Wavelength calibration

Next comes a calibration step to compensate for chromatic aberration due to different wavelengths from laser to the camera observation wavelength.

... process

In the ***Wavelength calibration*** area, click on the ***[Start calibration]*** button.

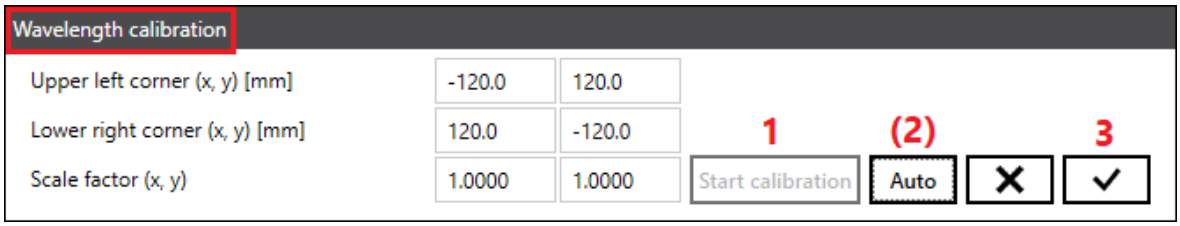


Fig. 3.27: CT-ABB

The camera is first aligned with the top left corner and the image is shown in the workspace. The circled cross that the calibration job marked there should be visible.

Automatic wavelength calibration

The ***[Auto]*** button can be used to automatically align the intersection of the two guidelines with the center point of the marked calibration reference. Check the result anyway!

Repeat the steps for the second cross of the wavelength calibration (bottom right corner).

Manual adjustment

If necessary make the adjustment manually:

Move the two blue guidelines in such a way that their intersection is directly over the center point of the marked cross. Click on the ***[✓]*** button to apply the first of the two positions.

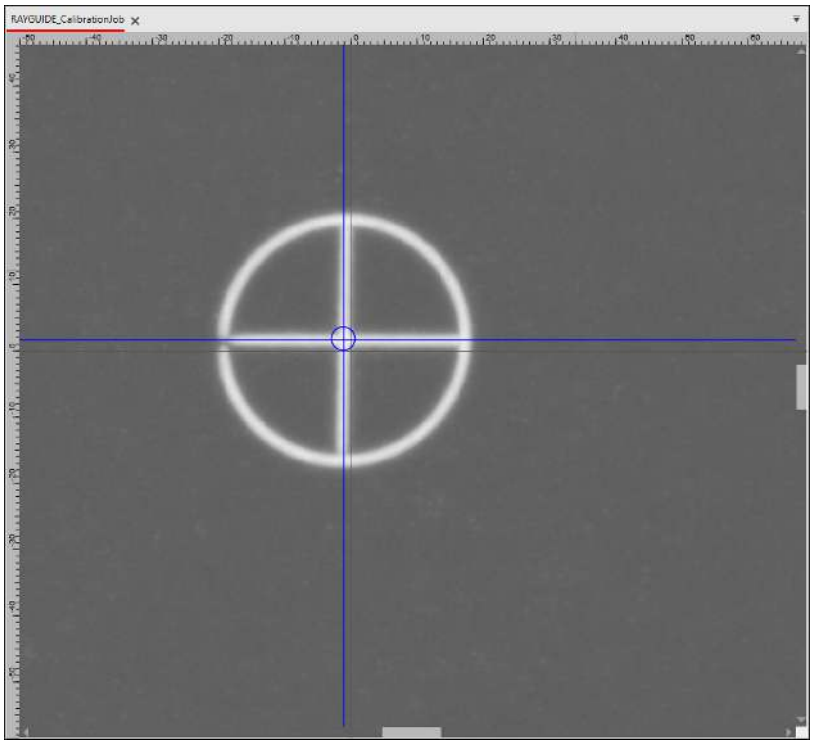


Fig. 3.28: CT-ABC

The camera jumps to the position of the lower right corner, where the second circled cross was marked.

You can also adjust this cross position manually as needed.

The result is two scale factors that compensate for the wavelength difference during tiling.

3.2.4.2.6 Equalization calibration

The images recorded by the camera naturally show distortions in the beam path via the deflection mirrors and, if applicable, the F-Theta lens, which are strongest if there are image tiles at the field border. If the center point of an image tile does not match the point to be “taught,” this leads to position deviations.

The aim of distortion calibration is to correct this effect.

Depending on your accuracy requirements, in particular the transitions between the image tiles, you can choose if you would like to use

- “Only” 8 image tiles or
- 16 image tiles

for data generation.

NOTE:

For 8 image tiles, the distortion is calculated using quadratic interpolation, while a cubic interpolation method is used for 16 image tiles. Also see *page 68, Example of tiling*.

Variant with 8 image tiles

Here the calibration job contains a 5 cross pattern in all four corners as well as in all coordinate directions.

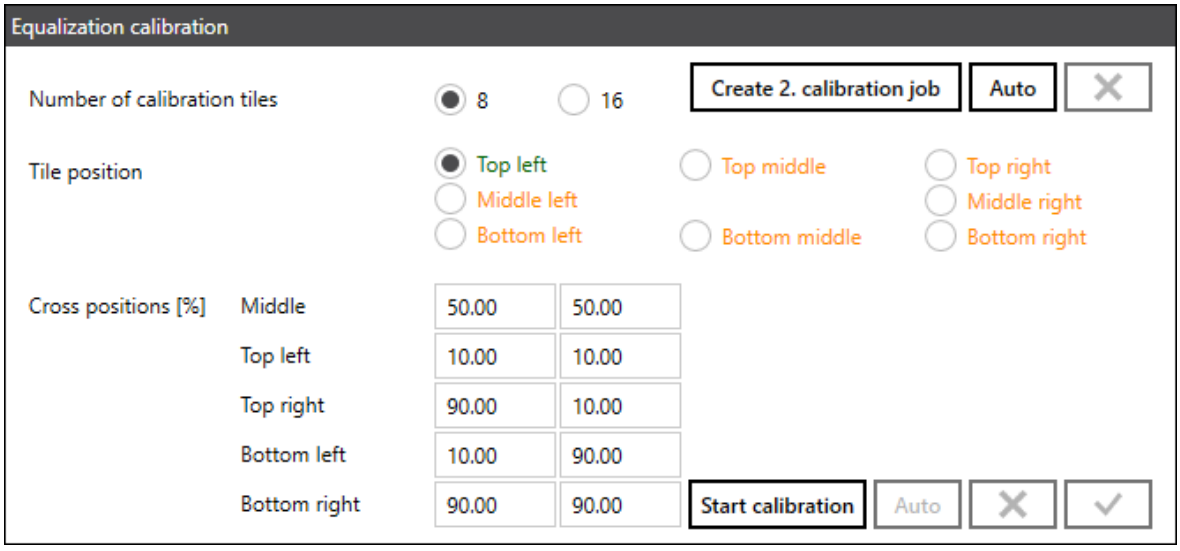


Fig. 3.29: CT-ABD

Variant with 16 image tiles

In this case, the calibration job contains 4 rows and 4 columns evenly distributed over the working area with a 5 cross pattern. The naming of the tiles follows the “row index column index” scheme.

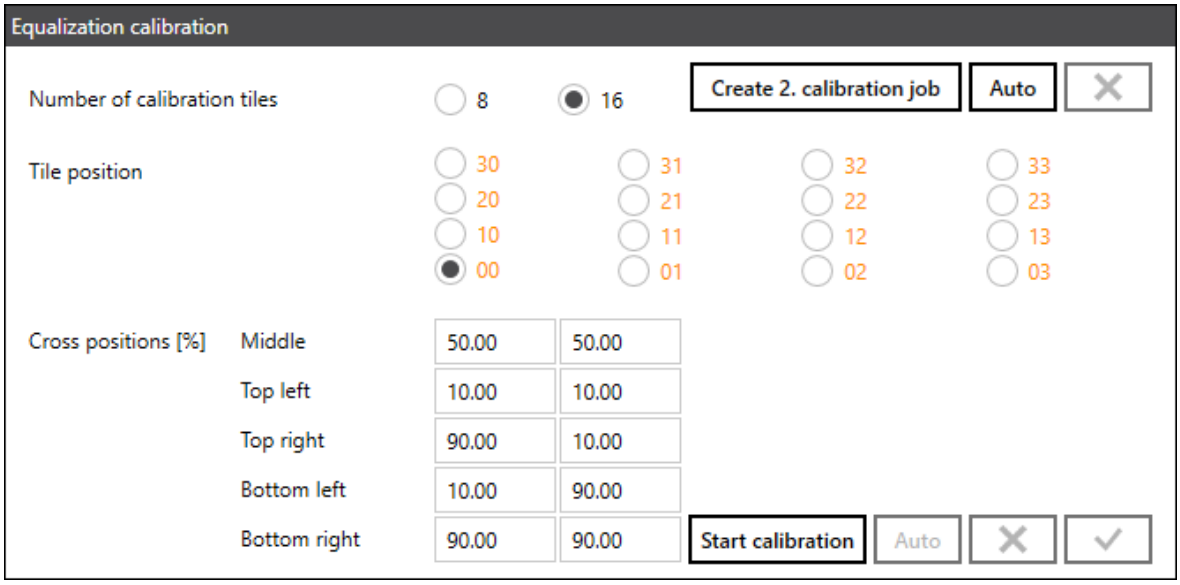


Fig. 3.30: CT-ACM

The value table shows the X/Y-coordinates as a percentage of the camera image width and height of the five cross positions for the selected tile position.

… process

Before you can start with this calibration step, click on the ***[Create 2. calibration job]*** button to generate the required pattern as an additionalRAYGUIDE job. Also mark this pattern type on your calibration material.

Example job with 8 image tiles

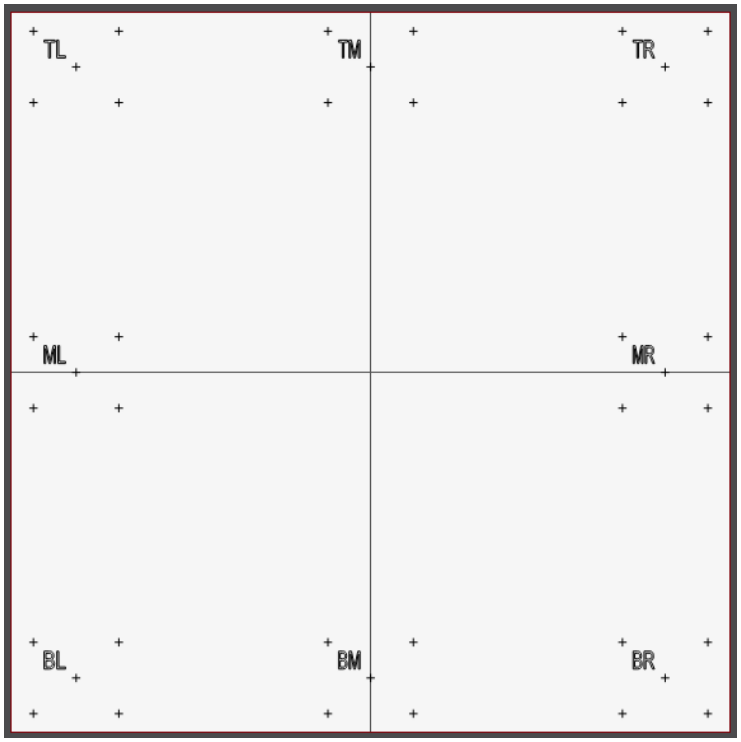


Fig. 3.31: CT-ABE

You can choose between three procedures.

Fully automatic distortion calibration of the image tiles

Here, all tile positions are recorded in a fixed sequence, the five cross positions are automatically taught in and the system jumps to the next tile position until all cross positions have been taught in for all tile positions.

If not all five cross positions are found in an image tile, or they are found in “implausible” positions, you will be informed of this at the end of the routine and you should reprocess the corresponding image tiles manually.

Semi-automatic distortion calibration of the image tiles

To do this, select each image tile in any order and then click on the ***[Start calibration]*** button.

You will then see the corresponding image tile with the five crosses of the marked calibration job in the viewport. If you now click on the ***[Auto]*** button, the five cross positions are found automatically and the blue guidelines are positioned accordingly.

Check the found positions again. If necessary, you can readjust each cross position manually. If all five cross positions match, you can teach them in for the corresponding image tile by clicking on the ***[✓]*** button.

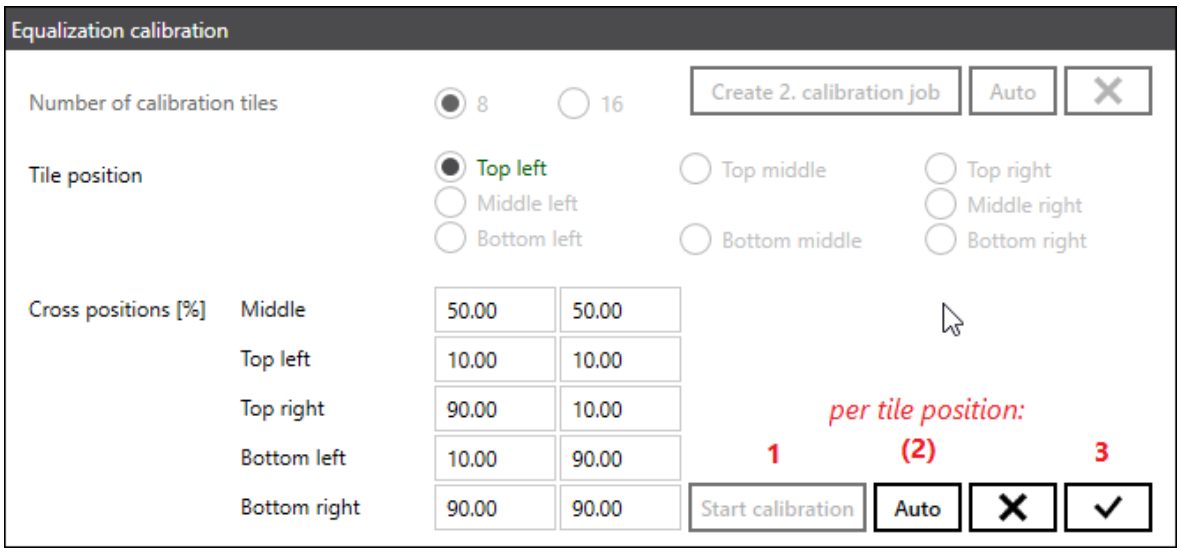


Fig. 3.32: CT-ACN

Manual distortion calibration of the image tiles

As with the semi-automatic process, you select the individual image tiles yourself in any order and then click on the ***[Start calibration]*** button.

Each tile position has five cross positions (one cross in the center and one cross in each of the four corners). These must then be aligned with the blue auxiliary lines (“crosshairs”).

NOTE: It is advisable to zoom into the respective cross position with as high a resolution as possible in order to match the positions as accurately as possible.

At the beginning, the crosshairs are not congruent with the reference cross. You can see all the lines of all five crosshairs.

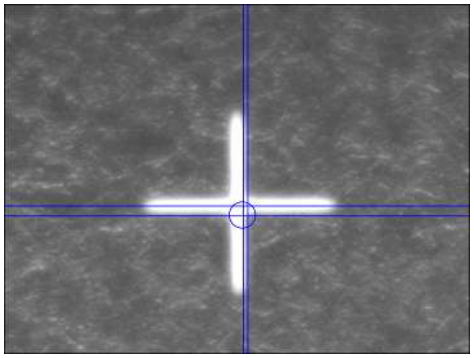


Fig. 3.33: CT-ABF

As soon as you start moving the crosshairs, you only see the relevant crosshairs.

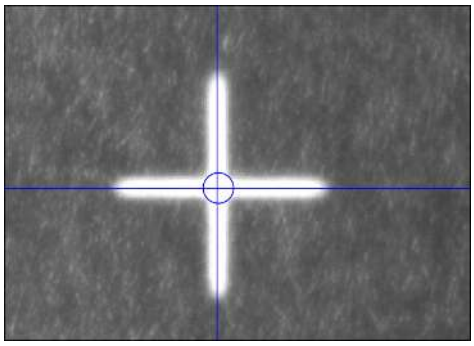


Fig. 3.34: CT-ABG

Once you have positioned the crosshairs so they are congruent and “let then go”, you can see all the crosshair lines again.

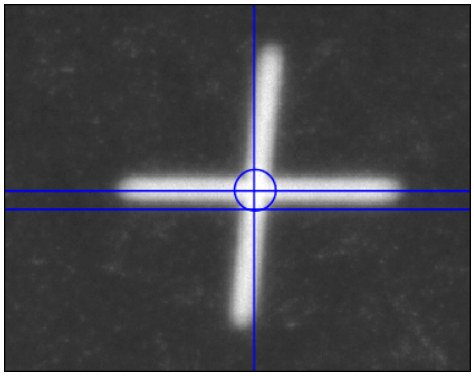


Fig. 3.35: CT-ABH

Finally, all five crosshairs are adjusted. This tile position can be taught in with a click on the ***[✓]*** button so that the position values of the crosshairs are included in the calibration calculation.

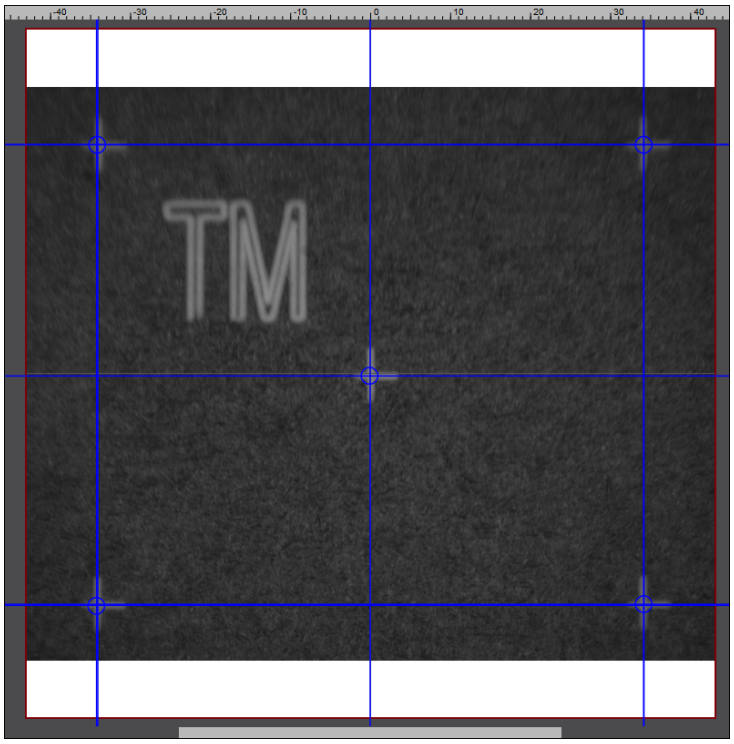


Fig. 3.36: CT-ABI

NOTES:

At the beginning, all unprocessed calibration positions are colored orange in the dialog. As soon as a calibration position has taught in all five cross positions, the color coding changes to dark green.

If you leave out a calibration position, no equalization correction will be able to take place in this area of the scan field.

3.3 CLICK & TEACH panel

In the RAYGUIDE menu, select ***View > Panels > Click & Teach*** to display the C&T panel. It can be shown or hidden, as desired, and is located in the same area as the panels for transformation and process adjustment (the standard position is on the right side of the screen). The panel can also be detached from this anchoring position. For example, it can be slid onto a second monitor and enlarged there to display the live image in full format.

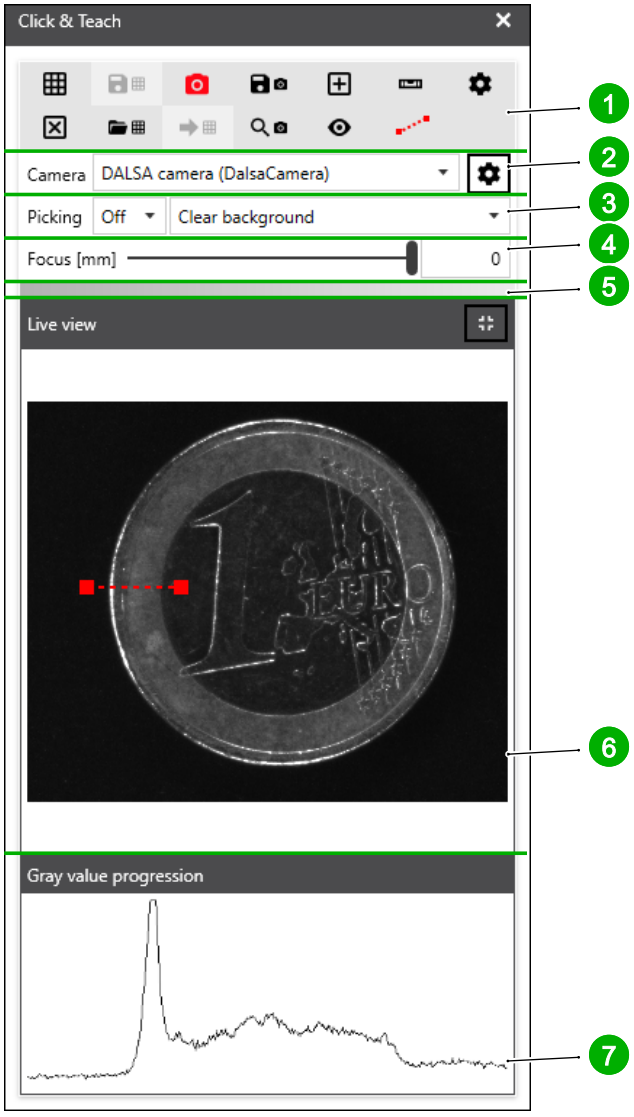


Fig. 3.37: CT-ABJ

1 Buttons
2 Camera selection
3 Picking
4 Focal plane of slider (optional)
5 Progress bar
6 Live image
7 Grey value gradient display

NOTE: If the correction file used for the deflection unit provides a 3D working volume, this focal plane slider can be used to adjust the camera focus within the available working volume. The displayed z-value pertains to the coordinate axis in the field domain.

The C&T panel is subdivided into several areas, which are described below in detail.

See also

- *page 56, Camera selection*
- *page 57, Buttons*
- *page 60, Picking*
- *page 62, CLICK & TEACH settings*
- *page 65, Live image*

3.3.1 Camera selection

Multiple deflection units can be equipped with cameras. Select the camera to be controlled in the *Camera* drop-down list.

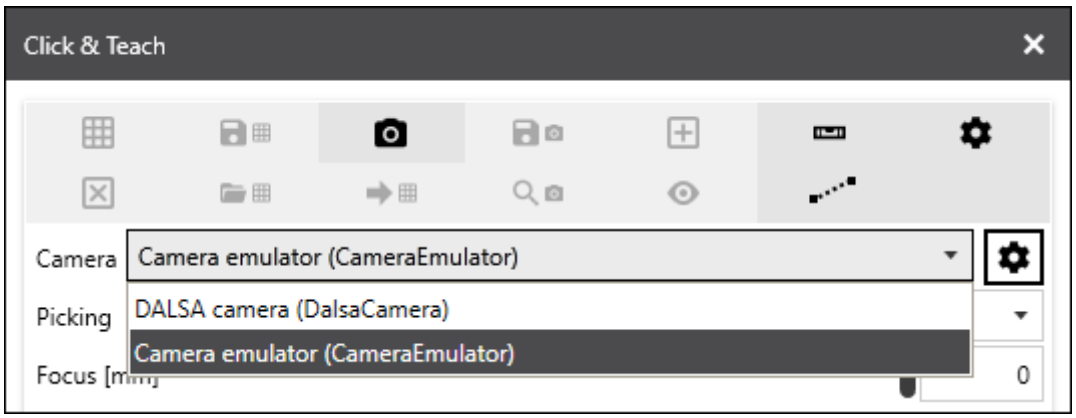


Fig. 3.38: CT-ABK

The name of the camera consists of the short designation of the camera and the camera type. With the button next to the camera selection, you can open the associated camera device dialog directly.

Communication is only possible with the camera selected here. This refers not only to picking and tiling, but also to calibration: if the camera is not selected in the panel, all buttons for calibration are grayed out in the ***Calibration*** tab of the camera dialog.

3.3.2 Buttons

Icon buttons

The following icon buttons are offered in the C&T panel and explained in the following table:

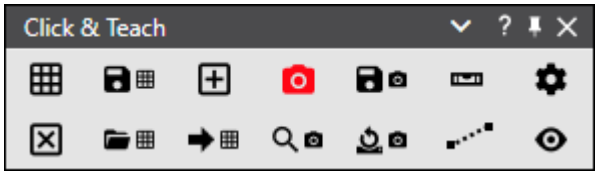


Fig. 3.39: CT-ABL

Button / buttons	Referenced as	Function
	***[Tile workspace]***	Toggle button for tiling the entire workspace. The button appears red when the tiling process is running. Clicking the button again cancels the tiling process. **NOTE:** If ***[Tile workspace]*** is clicked while the left shift key on the keyboard is pressed, all tiles are stored as PNG files in the *ClickAndTeach* subdirectory of the *Temp* directory. **NOTE:** If the workspace is smaller than the scan field, only this area is tiled. If the workspace extends beyond the scan field, tiling only takes place up to the border of the scan field.
	***[Save current background]***	Saves the current tiled scan field background to a file. Two variants are always saved: ■ A *Without field rotation* variant (for reloading via CLICK & TEACH) and ■ An *Including field variation* variant if this image is to be used as the background image for RAYGUIDE jobs. These variants can be identified by the supplement to the file name.
	***[Show / hide live image]***	Switches the live image on and off. The frame rate is 10 images per second.

Button / buttons	Referenced as	Function
	***[Save live image]***	Saves the current live image in a file.
	[Adjustment line]	Shows or hides the adjustment line in the live image. The adjustment line is used to support camera alignment, see *page 31, Aligning camera and adjusting focus*. **NOTE:** The position of the adjustment line can be moved up and down with the mouse wheel.
	***[Settings]***	Opens the dialog with the C&T settings, see *page 62, CLICK & TEACH settings*.
	***[Crosshairs on / off]***	Switches the crosshairs on and off. The crosshairs mark the location at which the laser is positioned. **NOTE:** The size; thickness and color of the crosshairs can be changed in the settings.
	***[Clear background]***	Deletes the background of the workspace.
	***[Load background]***	Loads the background of the workspace from a file.
	***[Load background loaded last]***	Reloads the background loaded last without opening a file selection dialog.
	***[Zoom into live image]***	Zooms the viewport to the position of the live image. The selected option in the *Pick* drop-down list is taken into account: Example: If the *3 x 3 tiles option* is selected, then this area is zoomed to this size.
	***[Reset camera image size]***	Resets the image size of the camera to the default values of 2464 x 2056 pixels.
	***[Display gray value gradient]***	Displays a dotted line with two “thumb points” in the live image. The position of the line in the live image can be freely selected via the position of the thumb points. ■ Blue thumb point = Start ■ Red thumb point = End For this purpose, an area appears below the live image in which the gray value gradient is displayed along this line.

Button / buttons	Referenced as	Function
	***[Preview]***	Starts a special marking preview. The live image is switched on and crosshairs are displayed in it, which represent the position of the laser point. The current job geometry is then traced so that the crosshairs in the live image move along the geometry. This makes it possible to verify that the job geometry exactly matches the desired part contour. **NOTES:** ■ Whether all or only selected geometry elements are run in the job can be defined in the ***Execution*** panel in the Preview area. ■ The scanning speed used here can be defined in the CLICK & TEACH settings. ■ By default, the selected geometry is approached once completely. ■ A running preview can always be stopped via the ***[Abort]*** button in the ***Execution*** panel. If you want the preview to repeat automatically, this can also be set in the CLICK & TEACH settings. ■ When running the preview, the wave length calibration must be taken into account. This is done by automatically applying the factors for the wavelength correction that were determined during camera calibration to the scaling of the current process transformation. After the preview is closed, the old scaling is restored.

Table. 3.3: CT-003

NOTE: The opacity of the background images recorded via the camera can be adjusted with a slider. For details, see RAYGUIDE manual, chapter 4.3.

3.3.3 Picking

Apart from tiling the overall scan field, it is also possible to separately tile selected areas of the scan field by clicking on the desired position with the mouse pointer.

The picking tool is defined via two presets, which can be selected via two drop-down lists:

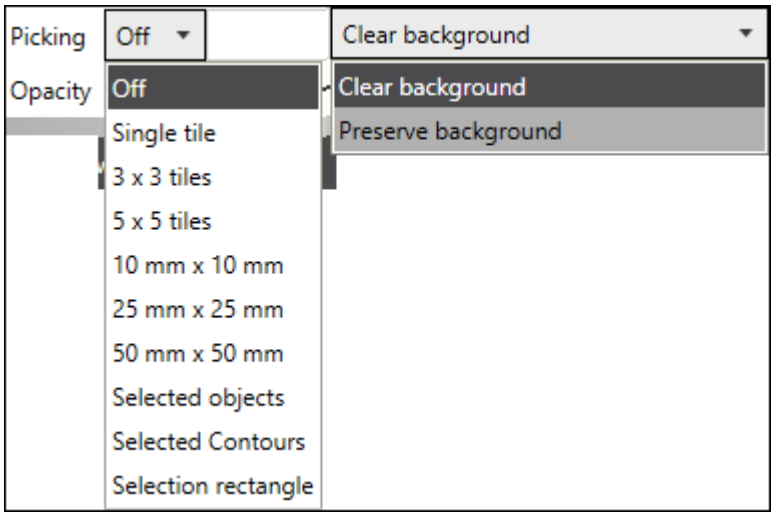


Fig. 3.40: CT-ABM

Setting	Explanation
Left drop-down list Select the size of the area to be tiled or switch off picking.	
Individual tile	A single camera image is recorded in which the mouse pointer indicates the mirror positions. **NOTE:** If you hold down the ***[Alt]*** key during picking, a dialog appears to save the single image including metadata.
Tile area	An area consisting of multiple camera images is recorded, where the mouse pointer indicates the mirror positions of the middle tile. The following combinations are available for the number of tiles in the tiling area: ■ 3x3 ■ 5x5 ■ 10x10 ■ 25x25 or ■ 50x50
Size in millimeters	Assign a minimum size to the tiled surface. Protruding areas that result from the tile size (field of view) are not cut off.

Setting	Explanation
Selected objects	Selected objects are completely tiled (rectangular). The location where picking occurs in the workspace is unimportant.
Selected contours	Tiles are generated along the selected contour. The selection of the contour can be a whole object, a layer, or a path. The location where picking occurs in the workspace is unimportant.
Selection rectangle	Use the cursor to drag open a rectangle on the workspace. The opened rectangle is tiled when the mouse is released. **NOTE:** Protruding areas that result from the tile size are not cut off. **NOTE:** If you hold down the ***[Alt]*** key during tiling, a dialog appears with the option of saving an overall image of the selected area including metadata as an image file.
Right drop-down list Two setting options for the background of the workspace.	
Clear background	Existing C&T background images are deleted before new C&T image tiles are displayed.
Preserve background	Existing C&T background images are retained and new C&T image tiles are added or laid over the existing image tiles.

Table. 3.4: CT-004

As is the case when tiling the entire scan field, all image tiles are also stored as PNG files during picking in the *ClickAndTeach* subdirectory of the *Temp* directory of the user if the left shift key on the keyboard is pressed while the mouse is clicked.

NOTES on multi-field workspaces:

- If you pick at a position that can only be reached by one of the available cameras / deflection units, this camera is selected automatically.

  The desired camera must be selected manually at positions that lie in a field overlap area.
- When picking along a contour, only the part of the contour that lies in the scan field of the actively selected camera is tracked.
- Press the ***right [Shift]*** key to, for example:
  - Automatically tile all workspaces (one after the other) and
  - Delete the background images from all cameras all at once

3.3.4 CLICK & TEACH settings

Under ***Settings***, various configuration parameters can be set for different C&T functions:

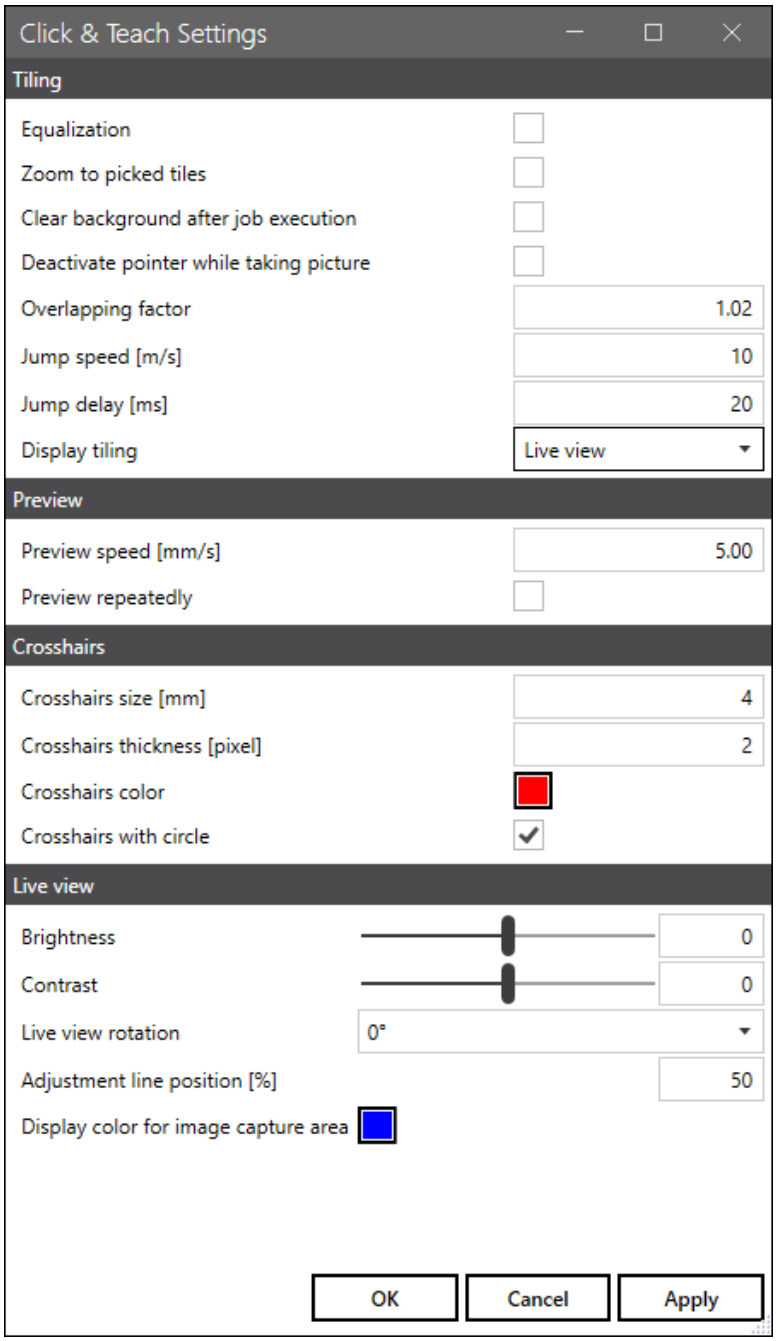


Fig. 3.41: CT-ABN

Setting	Explanation
Tiling	
Equalization	Activates / deactivates the equalization, which can be achieved in the last calibration step of the camera. **NOTE:** The integration of the equalization takes some additional computing time and is not always mandatory, therefore it can be used as an option.
Zoom to the picked tiles	If activated, the workspace is automatically zoomed so that the picked tile(s) is / are displayed in full format. This can also be achieved by clicking on the ***[Zoom into live image]*** button.
Clear background after job execution	If enabled: After the job has been executed, background images generated by CLICK & TEACH are automatically deleted.
Deactivate pointer while taking picture	If enabled: To avoid interference in the image due to reflections of the pointer beam on the material, the pointer is switched off as soon as the camera records an image. The pointer can be switched on again after the image has been recorded.
Overlapping factor	Due to unavoidable rounding errors, a one-pixel gap may arise between two individual image tiles. To avoid this, the tiles may overlap slightly. Example: A value of 2 means that twice as many tiles will be generated, which will then overlap by 50% each. Default value: 1.02.
Jump speed [m/s]	Speed with which the mirrors jump from one tile position to the next. Default value: 10 m/s.
Jump delay [ms]	The time the system waits after the mirrors have reached the desired positions before the image is taken. This can be useful if the camera can determine the exposure time and / or gain automatically and requires some time for this. Default value: 0 ms.
Tile display	Select where you want to see the progress when tiling sections: ■ In live image window ■ Directly in the workspace (viewport) You can also deselect this display completely if you want.

Setting	Explanation
Preview	
Preview speed [mm/s]	Defines the value for the C&T preview speed.
Preview repeatedly	Switches the special C&T preview into an automatic repeat loop. The repeat loop can be canceled by clicking the ***[Preview]***toggle button again or the general RAYGUIDE ***[Stop]*** button.
Crosshairs	
Crosshairs size [%]	The length of the crosshair bars is indicated as a percentage of the tile size.
Crosshairs thickness [pixels]	The thickness of the crosshair bars is indicated in pixels.
Crosshairs color	Selection of the color used to display the crosshairs.
Crosshairs with circle	Selection of whether the crosshairs are surrounded by a circle.
Live image	
Brightness	Slider to increase or decrease the brightness of the live image and all future image tiles. This does not influence image tiles that have already been recorded. **NOTE:** This setting does not change the camera settings, but is digital post-processing of the images.
Contrast	Slider to increase or decrease the contrast of the live image and all future image tiles. This does not influence image tiles that have already been recorded. **NOTE:** This setting does not change the camera settings, but is digital post-processing of the images.
Live view rotation	The life image can be rotated in 90° steps.
Adjustment line position [%]	Specification of the position of the adjustment lines in the live image in [%] of the live image height. The position can be moved directly using the [+] / [-] buttons or the mouse wheel.
Display color for the image recording section	Selection of the color used to display the areas in the viewport where the camera records background images. These camera recordings are controlled by the *Acquire and save image* automation object (see *page 79, Acquire and save image*) **NOTE:** To display the areas, select the automation object in the job tree.

Table. 3.5: CT-005

3.3.5 Live image

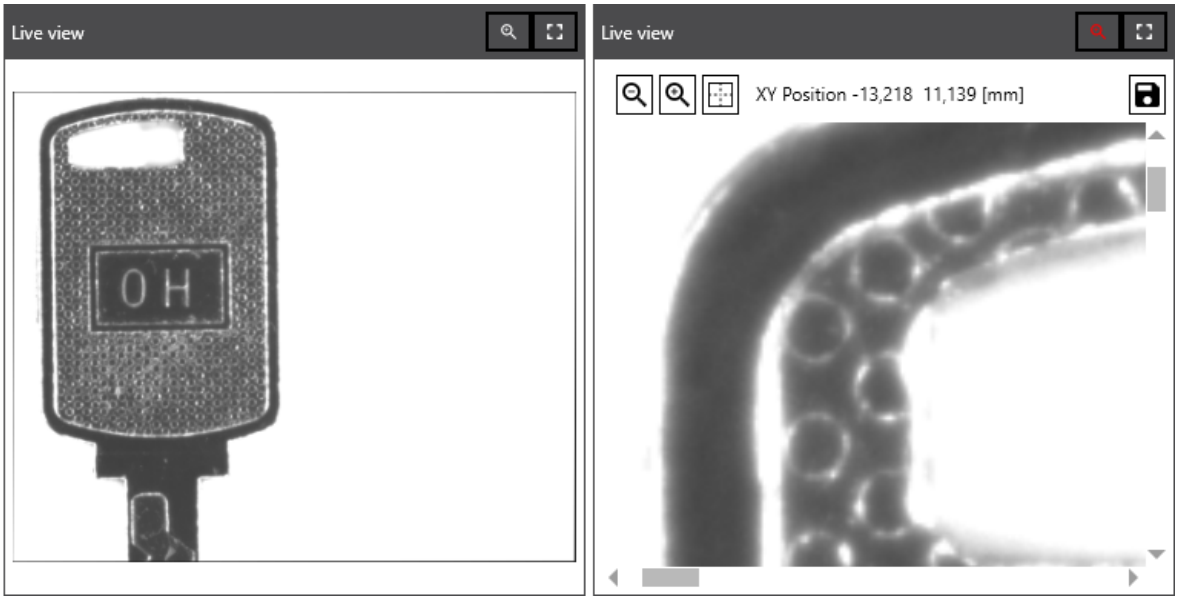


Fig. 3.42: CT-ABO

The live image is shown and hidden using the ***[Show / hide live image]*** button and can be stored using the ***[Save live image]*** button.

In addition, a gray value gradient can be displayed in the live image, for instance to optimize the illumination for possible image processing tasks. To do so, use the ***[Display gray value gradient]*** button and position the line accordingly in the live image:

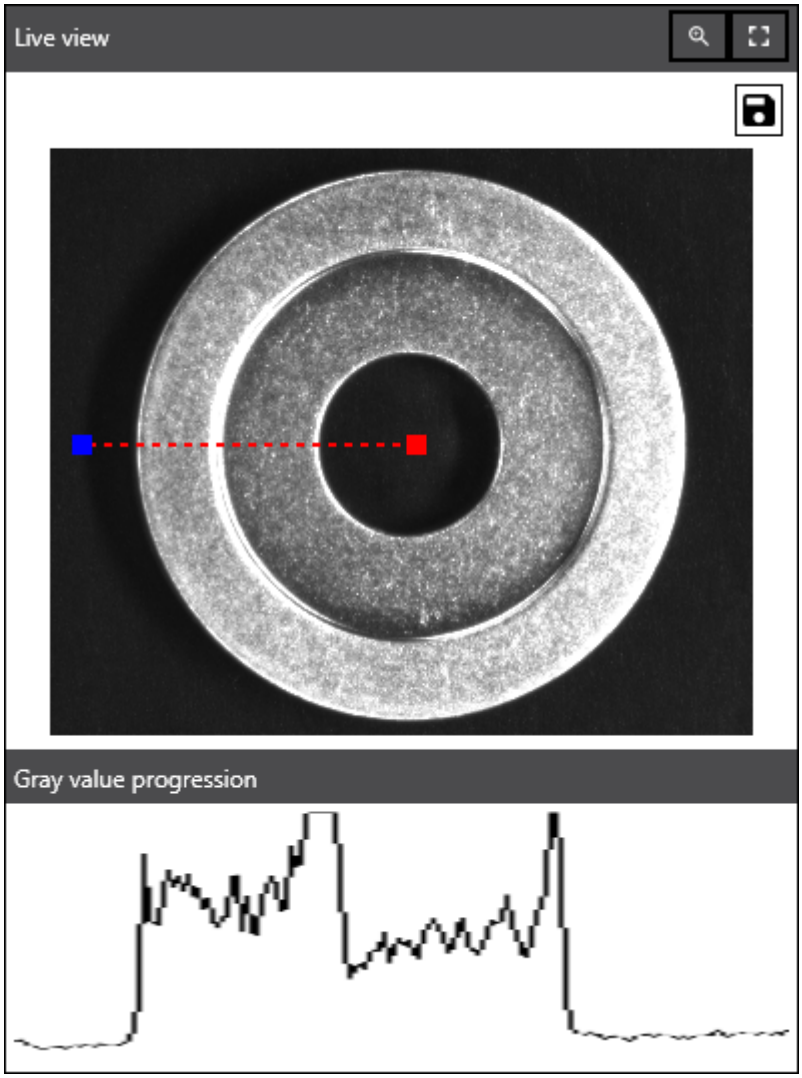


Fig. 3.43: CT_ACF

Other options for the live image are:

Setting	Explanation
	Enlarges the live image so that it takes up the entire area of the C&T panel and switches to so-called “full screen mode”. **NOTE:** Any displayed adjustment lines or position lines of the gray value gradient are switched off.
	Adjusts the live image to the normal size in the C&T panel.
	Toggle button for activating / deactivating the zoom function even when the live image has the normal size.
	The three buttons serve to zoom into or out of the live image or to fit it back in. In addition, the absolute cursor position in the workspace is displayed with X/Y-coordinates. **NOTE:** The zoom functions are only available in full screen mode of the live image.
	Saves the current view of the live image.

Table. 3.6: CT-006

The life image can be rotated in 90° steps. This allows it to be adjusted to a possible field alignment other than 0°.

NOTE: Note that the live image is not shown in the full camera resolution but is scaled down to the value set in the Scale factor field in the camera settings (see *page 29, Connecting / assigning the camera*).

3.3.6 Example of tiling

Example:

The following figure shows tiling of a quadrant of a scan field with a marked line grid pattern and with the full image size of the camera model used of 2464 x 2058 pixels:

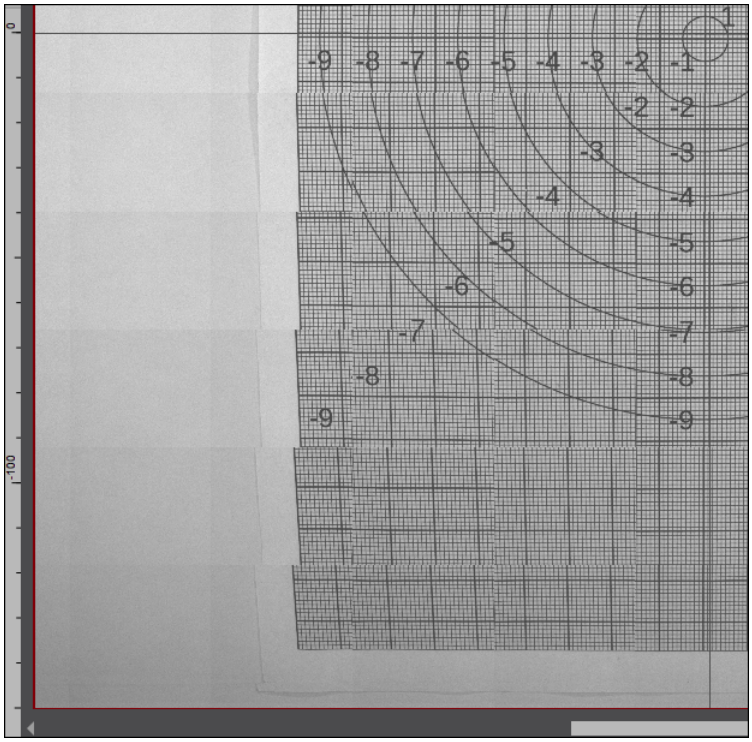


Fig. 3.44: CT-ABP

The distortions and the offset at the tile transitions can be caused by the F-theta lens in 2-axis deflection units. For pre-focused deflection units such as. AS FIBER, this is due to the so-called geometric distortion (see example image).

However, if you pick individual contour points directly, this distortion effect is not so relevant. However, it can cause inaccuracies, especially when teaching positions in the area of the field border.

It is therefore advisable to carry out the equalization calibration and to activate equalization when tiling (see*page 62, CLICK & TEACH settings*).

Example:

Example of a quadrant with activated equalization based on *Equalization calibration* with eight image tiles and quadratic interpolation:

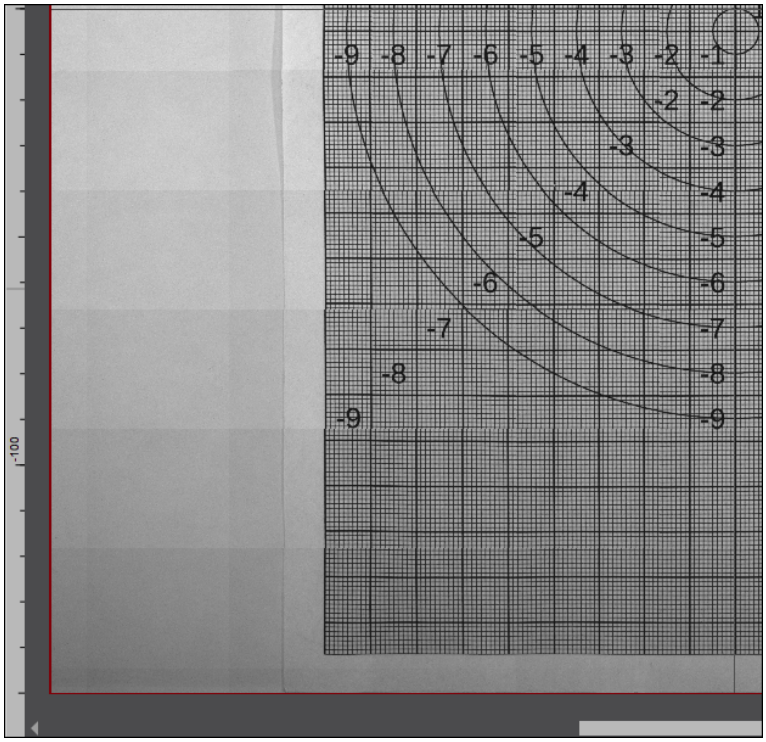


Fig. 3.45: CT-ABQ

Example:

Example of a quadrant with activated equalization based on *Equalization calibration* with 16 image tiles and cubic interpolation:

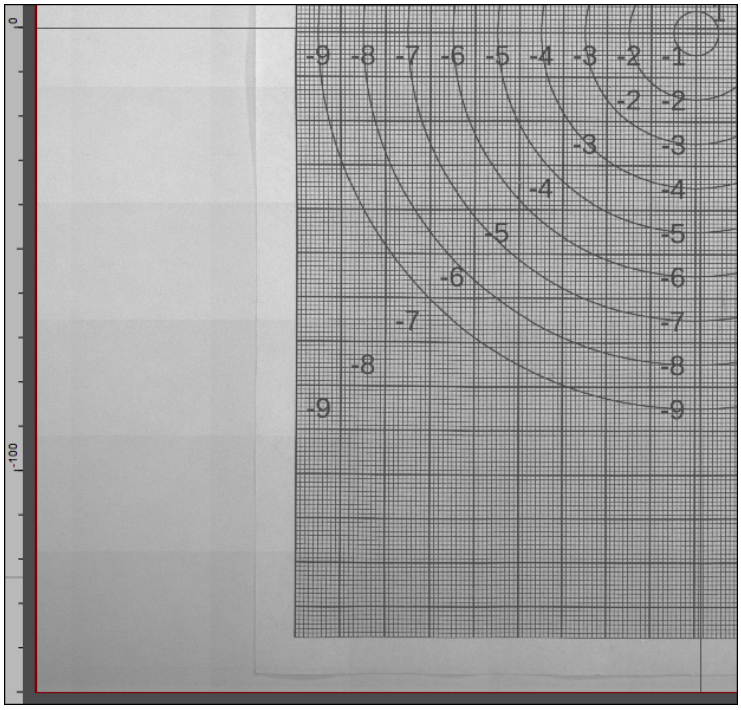


Fig. 3.46: CT-ACO

3.4 Illumination

3.4.1 Illumination controller

RAYLASE offers you the option of using a 1-, 4- or 8-channel illumination controller from Gardasoft Vision Ltd. to light up your scan field. The illumination controller communicates with your computer or the RAYGUIDE application via Ethernet.

Fig. 3.47: CT-ABR (source: http://www.gardasoft.com)

NOTE: The illumination controller from GARDASOFT can also be addressed directly via a web interface if required. We recommend that you obtain the necessary documentation and software tools directly via the official website of GARDASOFT: www.gardasoft.com.

First add the illumination controller as a device to the RAYGUIDE device configuration:

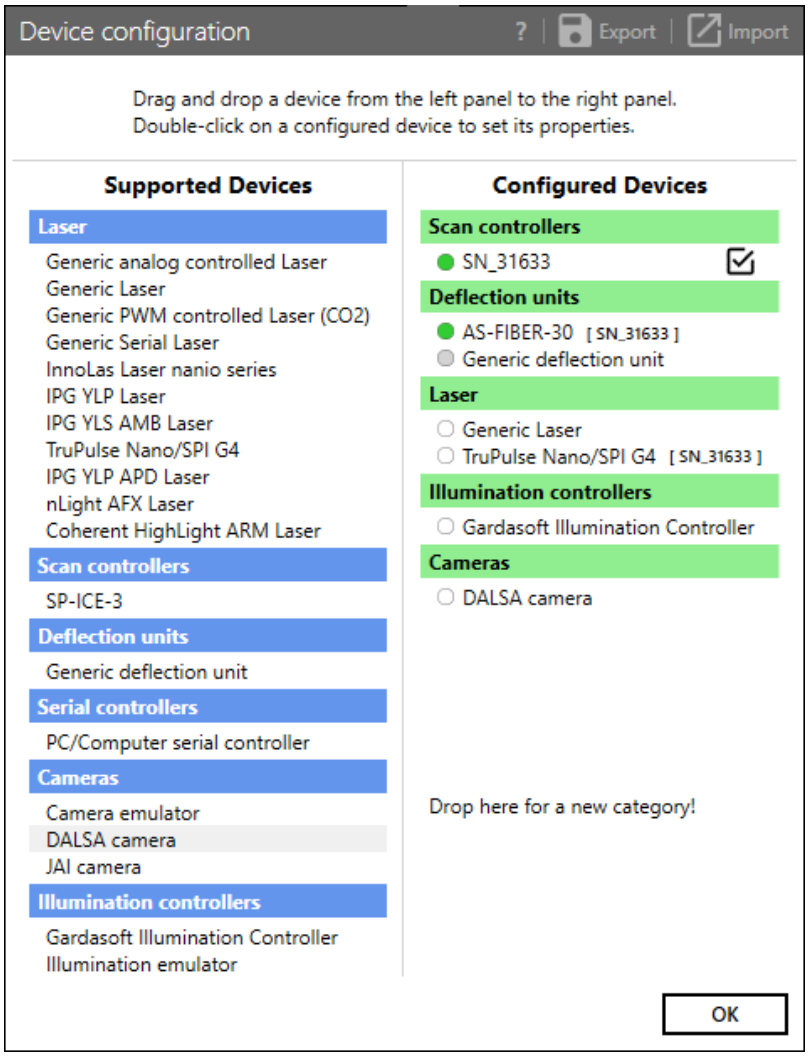


Fig. 3.48: CT-ABS

Open the Properties dialog by double-clicking on the new device entry (alternatively right-click and then select Properties):

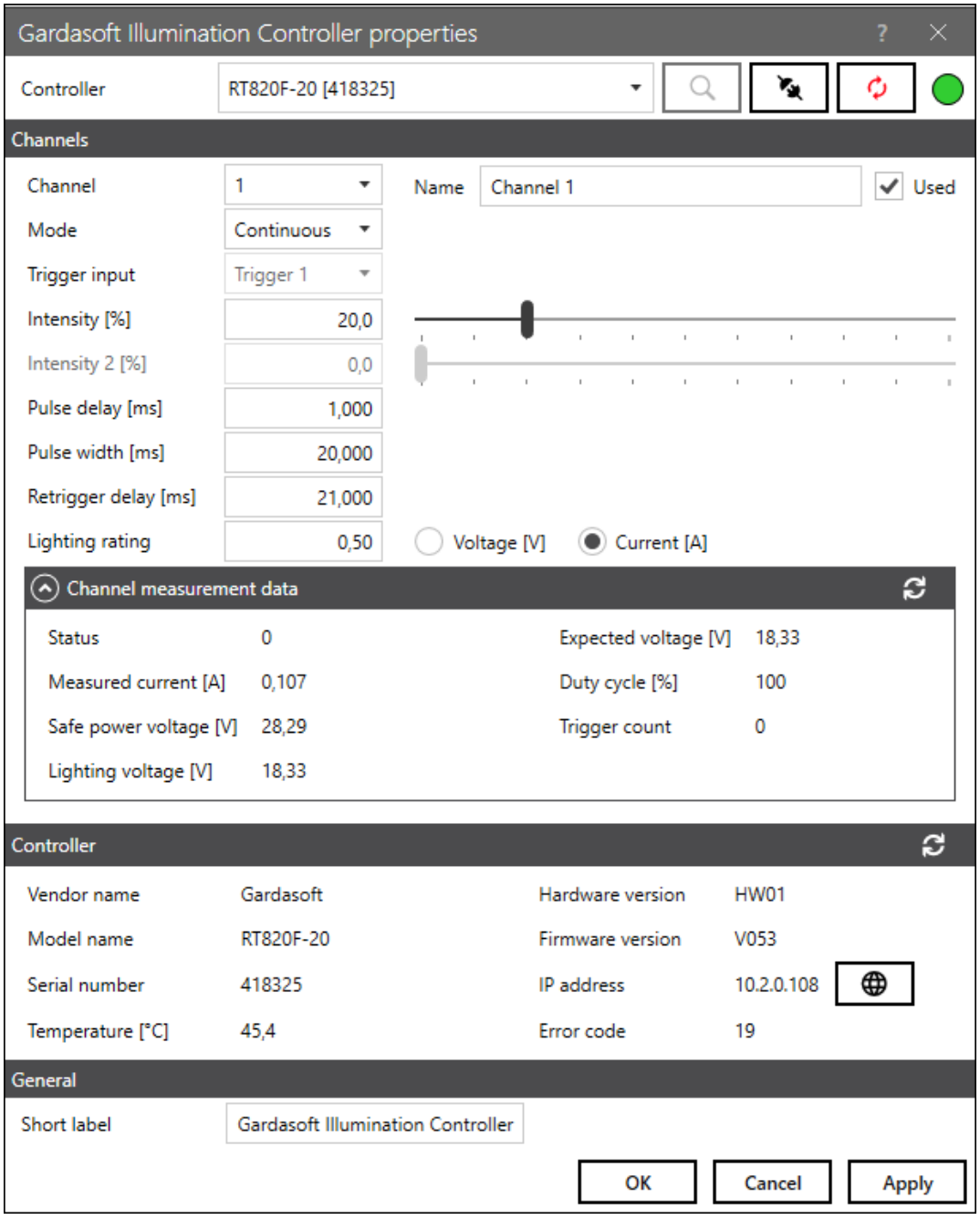


Fig. 3.49: CT-ABT

Setting	Explanation
Controller	Name and [serial number] of the illumination controller Click on the ***[Search]*** button to search for illumination controllers available in the network. The illumination controllers available in the network are listed with their model name and serial number. Identify the illumination controller by its serial number and select it. Then click on ***[Connect]*** / ***[Disconnect]*** to establish / disconnect the connection to the illumination controller. An active controller connection is indicated by a green traffic light. Use the ***[Auto connect at startup]*** toggle button to define whether the illumination controller should be connected when starting RAYGUIDE. The button is activated by default. If you disconnect from the controller and do not want it to reconnect automatically the next time you start the program, you must disable this button. **NOTE:** Even with auto connect active, it can take a few seconds until the connection to the illumination controller is established after the RAYGUIDE program starts.
Kanäle	
Channel	Select the channel number you want to edit. Depending on the model of the GARDASOFT illumination controller, you have 1, 4 or 8 channels at your disposal. All the following setting options apply per channel.
Mode	There are three modes to choose from: ■ ***Continuous:*** The current for the illumination elements is constant and continuous (mode to be used by default). ■ ***Pulse:*** A single pulse is emitted as specified in the settings when a trigger signal is received at the controller. ■ ***Switch:*** This mode uses a trigger signal on the controller to switch the current on and off. ■ ***Selected:*** This mode uses a trigger signal to switch between intensity value 1 and intensity value 2. The following applies: Intensity value 1 > intensity value 2.
Trigger input	Define which trigger input on the illumination controller is used for this channel.
Intensity [%]	Define the default value for the illumination intensity of the illumination element connected to the respective channel.
Intensity 2 [%]	Define a second intensity value to be switched to in *Selected* mode.

Setting	Explanation
Pulse delay [ms]	Amount of time waited in *Pulse* mode after the trigger signal until the current for the pulse is switched on.
Pulse width [ms]	Amount of time until the current in *Pulse* mode is switched on.
Retrigger delay [ms]	Defines the minimum time allowed between two consecutive trigger signals. If a following trigger signal comes earlier, it is ignored.
Lighting rating	Defines the voltage or current value that causes 100% intensity for the connected illumination elements. **NOTE:** This value, as well as the information on whether the illumination elements are voltage or current controlled, must be taken from their technical data.
Voltage / current	Select whether the light intensity is controlled by current or voltage at the controller.
Measurement data channel Use the expander to view available measurement data from the illumination controller.	
Controller	
NOTE: Use the ***[Refresh]*** button to update the displayed information	
Illumination controller information	Display of the most important information about the connected illumination controller such as ■ Model name ■ Serial number ■ Hardware or software version ■ Temperature ■ Error code
General	
Short label	Enter the name under which the illumination controller is to be listed in the device list.

Table. 3.7: CT-007

NOTE: The illumination elements connected to the illumination controller light up as soon as the illumination controller receives its supply voltage. With which intensity depends on whether default values have already been set up in RAYGUIDE for this controller or if it still has the factory settings.

The illumination elements go out as soon as either the connection to the illumination controller is disconnected (which can also be done by exiting the RAYGUIDE application) of when the power supply is shut off. As soon as the RAYGUIDE application starts and the connection with the illumination controller is established, the values stored in the unit configuration are set.

3.4.2 Illumination panel

NOTE: The default values of the illumination intensity of the illumination elements are set in the device configuration of the illumination controller (see chapter *page 71, Illumination controller*).

If the default values for the illumination intensity of the illumination elements have to be adjusted often, doing this using the ***Illumination*** panel is recommended. In this panel, the intensity of the connected illumination elements can be set directly.

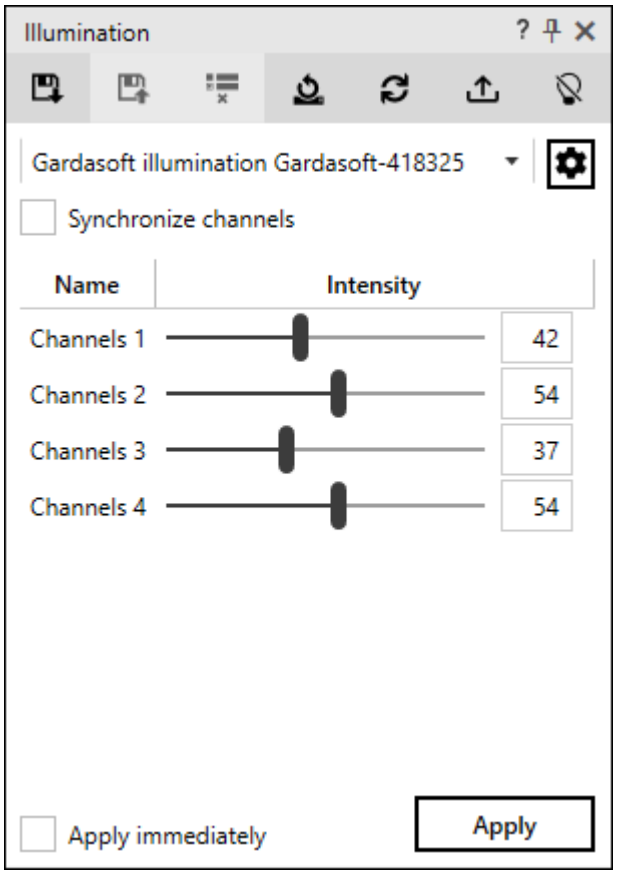


Fig. 3.50: CT-ABU

Setting	Explanation
	The buttons allow you to save the settings defined in the dialog, load already saved settings or delete a saved setting.
	Button to reset the settings to the basic setting as defined in the device configuration.

Setting	Explanation
	Button to read back the last values commanded to the illumination controller from the illumination controller and to set the sliders to the corresponding position. **NOTE:** This option is useful if another instance has written the illumination intensities to the controller.
	Button for transferring the intensity values set in the panel to the device configuration.
	Toggle button to switch off all lighting elements ■ directly (intensity = zero) or ■ switch them on again (intensity = last set value).
Selection of illumination controller The ***[Device dialog]*** button enables direct opening of the device configuration of the selected illumination controller.	
Synchronize channels	Select this option if you want to set all channels to the same intensity.
Intensity slide regulator per channel with value field for setting the desired intensity The ***Name*** column shows the names – which can be freely defined in the device dialog of the illumination controller – per channel. **NOTE:** Only the channels that have been marked as "used" in the device configuration are displayed.	
Apply immediately	Automatically writes the intensity values to the illumination controller as soon as the values have been changed.
[Apply]	Button to send the set intensity values directly to the illumination controller.

Table. 3.8: CT-008

3.5 Webcam

This plug-in allows the integration of live images from a webcam into the RAYGUIDE GUI.

Images from the laser chamber interior are often not visible to the user. With the help of the webcam, you can get a direct view of the laser process in the laser chamber.

Fig. 3.51: CT-ABV

Setting	Explanation
	Click on the ***[Search]*** button to search for available webcams. When the search is complete, select one of the available webcams.
	Click on the ***[Camera]*** button to start / stop streaming from the live image.

Table. 3.9: CT-009

3.6 Automations

The two automation objects of the CLICK & TEACH extension are integrated in the Objects panel in the Automation objects category.

3.6.1 Acquire and save image

Button

This automation object is used to automatically record and save images of the workpiece in a job sequence with or without the contour superimposed in the GUI. One can use the images this way to check whether the laser contour still superimposes with the part contour as desired.

This automation object can be inserted at any point in the job sequence.

It acts like all other automation objects in RAYGUIDE (see RAYGUIDE manual, chapter 7.2.7.

NOTE: As this automation object uses the camera function, it cannot be used with the *"On card"* job execution variants or *stand-along control card operation*.

NOTE on the automation object in a RAYGUIDE duplication container

In principle, this automation object can be placed in a duplication container. This means that the recording area can be copied to various positions across the workspace according to the rules of the container.

The following rules must be observed:

- In addition to this automation object, there must always be at least one marking object in the container.
- As this automation object uses a camera that is assigned to a deflection unit, the section that the container creates with its copies must *only be in one scan field*.

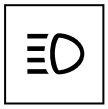
  This rule must be observed when setting up *multi-scan field workspaces*!

Setting	Explanation
Camera	Select the camera device that will be used to make recordings from the list of available cameras.
Region of interest	
	Use the ***[Pick]*** button to drag the mouse cursor to the desired image area in the viewport. The center and size are then entered automatically.
Center (x, y, z) [mm]	Display of the position of the area to be recorded by the camera. If the image is to be recorded in a focus position other than z = 0, enter the corresponding Z-coordinate.

Setting	Explanation
Size (width, height) [mm] 	Display of the dimensions of the area to be recorded by the camera. The selected area is visualized with a blue rectangle in the view window. Use the ***[Reset]*** symbol to reset the area to the size of a single image tile.
Reduce camera field of view to ...x...pixels	Set this option if only the selected recording section is to be retrieved by the camera to save data transfer time. The values show how many pixels the selected section requires.
Location	
File name 	Enter any file name you want for the recordings. The ***[Enter variable]*** button opens a list with variables (e.g. date/time stamp, increment or job variable). Select a variable from the list to add it to the file name of the image file.
Edition	Display of the resulting file name. This consists of the name and ■ The default date/time stamp ***or*** ■ The variable(s) selected from the list The file format is *.png by default.
Settings	
Overlay workspace	Select: ■ Whether the contours located in the recording area of the workspace are to be saved in the image. ■ Or if only the background images recorded with the camera should be saved.
Stroke thickness	Specification of the line width for the contour lines in the result image.
Line color	Select a color for all contour lines or whether the contour lines are displayed with your respective pen color.
Preview	
	Use the ***[Refresh]*** button to display the preview again.
General	
NOTE: The generally valid properties of automation objects can be found in the RAYGUIDE manual, chapter 7.2.7.	

Table. 3.10: CT-010

3.6.2 Set illumination



Button

With the help of this automation object, the illumination elements connected to the illumination controller can be automatically set to a certain intensity in a job sequence.

This automation object can be inserted at any point in the job sequence.

It acts like all other automation objects in RAYGUIDE (see RAYGUIDE manual, chapter 7.2.7.

The following properties of the automation object can be set:

Setting	**Explanation**
Controller	Selection of an illumination controller
Synchronize channels	Select this option if you want to set all channels to the same intensity.
Channel	
Use the **tab** to determine whether this channel or its intensity value should be set or whether it remains unchanged when the automation object is executed. Intensity slide regulator per channel with value field for setting the desired intensity. The ***Name*** column shows the names – which can be freely defined in the device dialog of the illumination controller – per channel. **NOTE:** Only the channels that have been marked as "used" in the device configuration are displayed.	
Delay [ms]	The time to wait after setting the intensity values since the illumination elements need some time to adjust.
General	
NOTE: The generally valid properties of automation objects can be found in the RAYGUIDE manual, chapter 7.2.7.	

Table. 3.11: CT-011

4 RAYGUIDE MATCH

4.1 Basic information

4.1.1 Process guide

Note: In general, we only recommend the use of RAYGUIDE MATCH after sufficient training and application consultation by our Technical Expertise Center.

1. First, put the camera into operation, including adjustment and calibration. For details, see *page 17, Setting up the camera*.
2. Define which workpiece features are suitable for detection. The following aspects must be considered:
   - Do these features have a fixed reference to the desired laser processing contour?
   - Can these features be well lit and pictured by the camera?
   - Are the features large enough, but not so large so that not too many image tiles are required?
3. Work out the detection task using as many corresponding workpieces as possible so that it is reliable.

   This contains parameterization of the image processing job elements up to **Result processing,** definition of possible parameter loops and behavior in the event of an error.
4. Teach in the reference position of the “Golden Master”, which then serves as a reference for the following detection processes. For details, see *page 173, Testing and teaching in*.
5. Check that the workpieces are processed correctly with the corresponding position correction function before switching to automated operation.

4.2 MATCH as an integrated part of a RAYGUIDE laser processing job

4.2.1 Image processing element (image processing job)

Icon

RAYGUIDE MATCH works within RAYGUIDE like an automation object and can be inserted at any point in the job process.

NOTE: Placing the so-called image processing element (also referred to as image processing job in the following) in front of those marking objects that will then be executed in a position matching the workpiece position is generally recommended.

Example: Job tree with image processing element in front of welding geometry

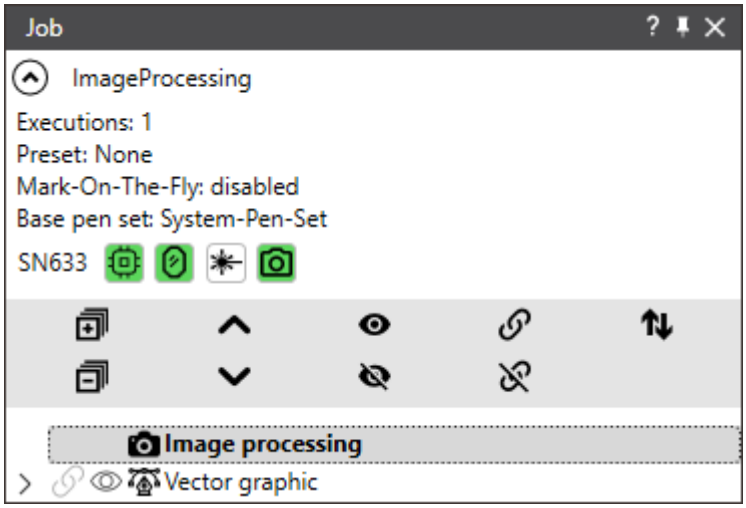


Fig. 4.1: RG_M-AAA

4.2.2 Interactions between image processing job and RAYGUIDE functions

4.2.2.1 Process transformation

The basic task of the image processing job is to determine and set the process transformation at the end in order to position the following laser processing to match the workpiece position.

The image processing job also resets the process transformation if various events occur. This is done to prevent the position for the following image capture from being influenced by a remaining process transformation. These events are:

- As soon as the image processing job dialog is opened. [2]
- When the ***[Run]*** button is pushed in the image processing job dialog. [2]
- If a RAYGUIDE job is executed with an image processing job, the transformation is then reset in the job sequence before the image processing job is executed as the next step. [2]
- In the *Result processing* image processing job element when the ***[Reset process transformation]*** button is pressed.

For more information, see also RAYGUIDE manual, chap. 7.8.6.

[2] When this event occurs, the process transformation is automatically reset.

4.2.2.2 Permissions

In the permission manager of RAYGUIDE, there is an option of allowing or preventing user roles from editing image processing jobs.

For more information, see also RAYGUIDE manual, chap. 6.1.5.

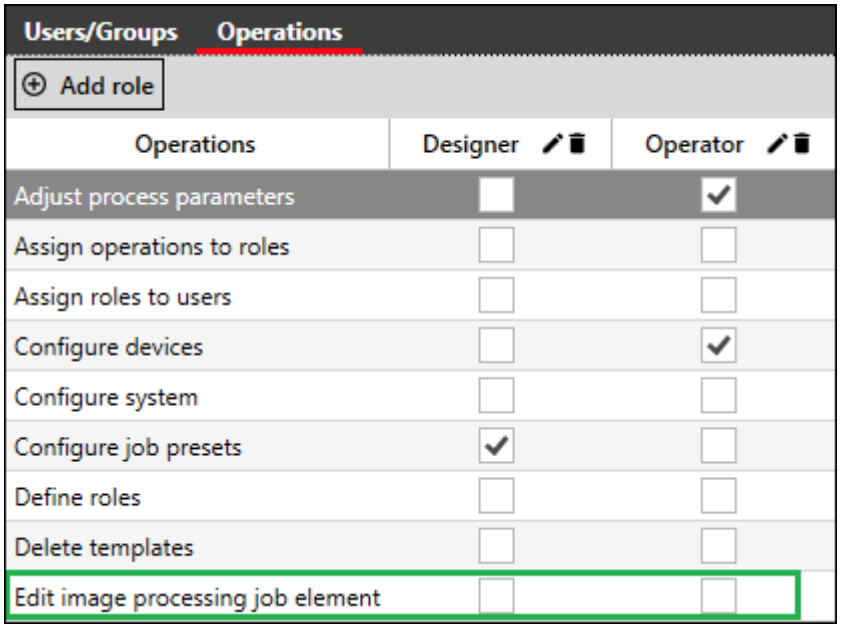


Fig. 4.2: RG_M-ABP

4.2.2.3 Automatic error handling

There are two error events on the part of the image processing jobs that can be communicated with this option:

- The search was not successful.
- The search was successful, but output validation of the result processing fails because the calculated transformation values exceed the expected limits of the transformation.

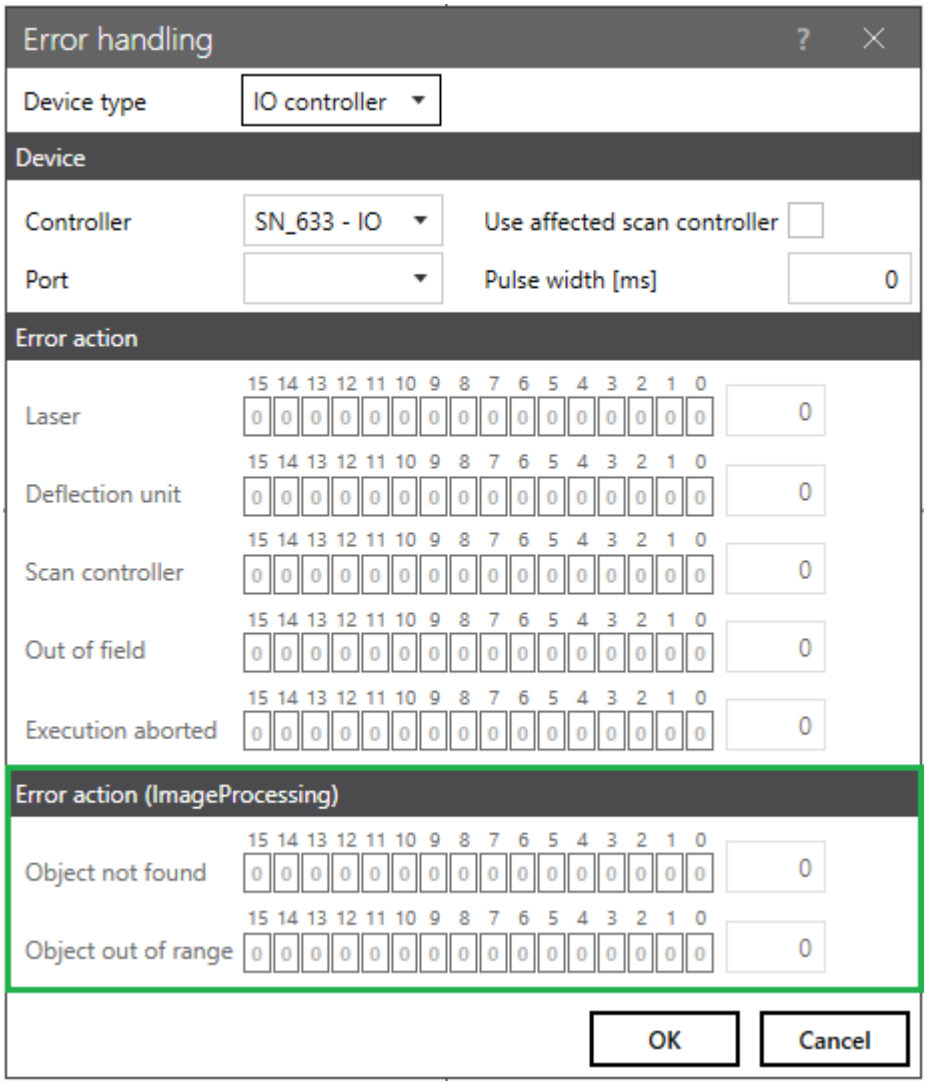


Fig. 4.3: RG_M-ABQ

For more information, see also RAYGUIDE manual, chap. 7.8.4.

4.2.2.4 Remote interface

Information can be returned when using the remote interface:

- Detection was successful: Here you get back both: the time for detection including process transformation setting and the set transformation values.
- Detection was not successful: Here you can see which of the searches has failed or whether, for example, the tolerance values from the output validation have been exceeded that were defined in the *Result processing* image processing job element.
- To do this, subscribe to the “MessageEvent” with the “ImageProcessing” attribute. For details, see the RAYGUIDE manual, chapter 8.4.3, List of available commands.

Examples of possible responses:

1. Detection was successful:

   The message contains the calculated process transformation and the consumed process time.

```
> enableevent,messageevent,PlugIn-ImageProcessing
Waiting for response to command 'enableevent,messageevent,PlugIn-ImageProcessing,eol' ...
received
content-length: 3
timing        : 101 ms
response      : ACK
> run
Waiting for response to command 'run,eol' ...
received
content-length: 3
timing        : 23 ms
response      : ACK
> EVT,MessageEvent,Plugin-ImageProcessing,IMAGE_PROCESSING: Process transformation: Offset. (-0.003; 0), scale: (1; 1),
rotation: 0. 'Image processing' ended successfully. Total time: 148 ms.
>
```

Fig. 4.4: RG_M-ABX

2. Detection failed.

```
> run
Waiting for response to command 'run,eol' ...
received
content-length: 3
timing        : 12 ms
response      : ACK
> EVT,MessageEvent,Plugin-ImageProcessing,IMAGE_PROCESSING_ERROR: Expected number of objects: 1
Found objects: 0 No found objects in search(es): 1
```

Fig. 4.5: RG_M-ABY

3. Detection itself was successful, but the determined position was outside the tolerance range.

```
> run
Waiting for response to command 'run,eol' ...
> received
content-length: 3
timing        : 106 ms
response      : ACK
EVT,MessageEvent,Plugin-ImageProcessing,IMAGE_PROCESSING_ERROR: Offset x: 2.541 mm.
Max. allowed offset x: ±0.3 mm.
```

Fig. 4.6: RG_M-ABZ

4.2.3 Limitations

- RAYGUIDE jobs that contain a MATCH automation object (or image processing job) can only be executed in the “On PC” execution mode.

  Execution from the control card (“on card” or also “stand-alone control card mode” execution type) is not possible, as the camera images are processed by libraries on the PC to determine the position.
- Use of RAYGUIDE MATCH in a system with multiple control cards/deflection units is currently limited by detecting the workpiece features in the scan field of a single deflection unit.
- It is basically not possible to detect the position of workpieces moving through the scan field (MOTF processes).

4.3 The RAYGUIDE image processing job

Each RAYGUIDE image processing jobs can be set up in modules depending on the detection task, but usually consist of at least the following three image processing job elements:

- Image capture
- Search
- Result processing

Optional additions: One or more image filters.

NOTE: Before you start creating the image processing job, you should use the CLICK & TEACH functions to “tile” (to picture) the relevant area of the workspace over which the workpiece extends so that background images of the workpiece are already present in the viewport.

In most applications, not only one workpiece feature is evaluated, but at least a second one is as well. This can be done in an image processing job sequence.

Example:

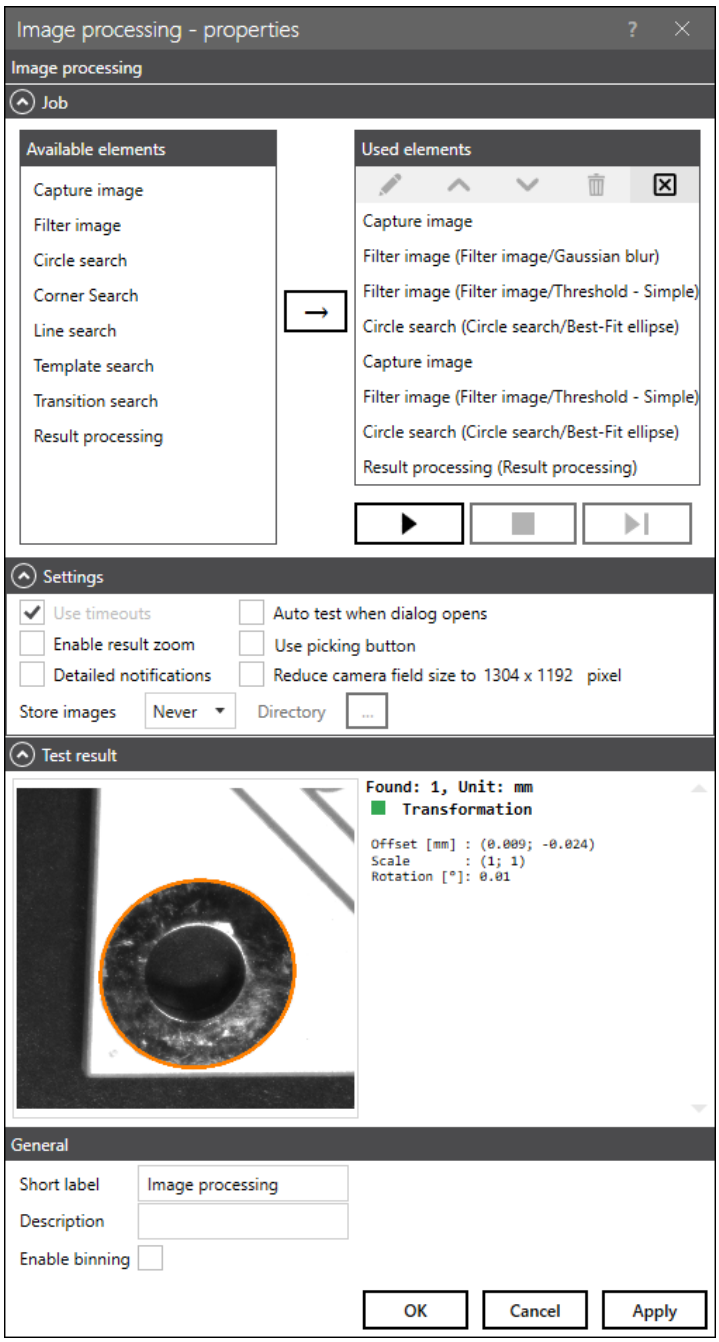


Fig. 4.7: RG_M-ABZ

4.3.1 Creating and executing an image processing job

The image processing job dialog and its functions:

Element	Explanation
Jobs	
Available Elements	List of image processing job elements available for setting up the image processing job. To use an element in the image processing job, either drag and drop it into the "Used elements" list, using the mouse or use the ***[Arrow]*** button. New elements are added at the end of the list by default. The following are available: ■ Capture image ■ Filter image ■ Circle search ■ Corner search ■ Line search ■ Template search ■ Transition search ■ Result processing For a detailed description of the individual elements, see *page 95, Capture image* to *page 172, Result processing*.
Used elements	List of the image processing job elements that are actually used for the detection task(s).
	Opens the dialog for editing the respective job element
	Moves an element forward or backward in the sequence by one position per click
	Deletes the selected image processing job element from the list
	Removes all image processing job elements from the list

Element	Explanation
Under the *Used elements* list you will find buttons that enable **test runs** while the image processing job is being worked out:	
 ***[Run test]***	The image processing job elements used are run through completely in the test. **NOTE:** This is primarily used for testing when setting up the detection task. It does not set a process transformation.
 ***[Abort test]***	Cancels the current test execution of the image processing job.
 ***[Run stepwise]***	Executes the test of the image processing job elements step by step with buttonstrokes, starting with the selected job element.
Settings **NOTE**: The display of the setting options can be shown or hidden by the expander.	
Use timeouts	Activate this option if you want to use the timeout (5000 ms by default) for all image processing job elements in order to cancel any excessively long calculation times. May lead to a timeout error message.
Auto test when dialog opens	Activate this option if you want to initiate a test run for this element as soon as you open the individual job elements.
Enable result zoom	Activate this option if you want to be able to zoom directly into the result image.
Use picking button	■ If activated, the ***[Pick]*** button appears in the *Capture image* job element. It is then only possible to drag a search area with the mouse cursor after clicking on this button. ■ If not activated, the search area in the *Capture image* job element will redrawn immediately with each mouse click in the processing field.
Detailed notifications	■ If activated, the notifications are displayed for each individual image processing job element in the RAYGUIDE *Notifications* panel. ■ If not activated, only the essential notifications such as total processing time and determined process transformation are listed.

Element	Explanation
Reduce camera field size to ... pixels	Use this option to set the camera image size to the minimum required size. This can save a certain amount of time when transferring image data from the camera to the RAYGUIDE application. Minimum required size: ■ Covers all defined search regions ■ But is smaller than the standard camera image size
Store images	Make a selection here, for which events you would like to save the (final) result images. Choose between: ■ *Never* ■ *Always* ■ *On error* Here you can also define the file path under which the images will be saved. The file format is PNG by default. **NOTES:** The image files are saved with the following logic: ■ One subfolder per day with the date as the folder name. ■ The syntax for the file name is: *hh.mm.ss.ms_label.png* ■ Creating the images takes time. That is why you should consider whether you always want to invest this time (especially in the automatic sequence) or only in the event of an error.

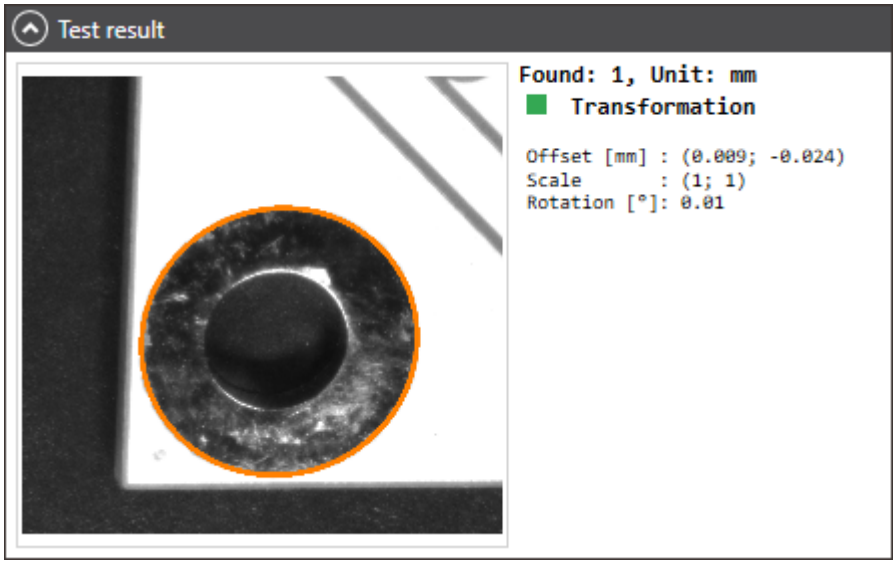
Element	Explanation
Test result	
Result image	If the result image shows ■ The intermediate result before the current image processing job element either after the last search including the search result/results or ■ In a stepwise run The data for the search result or results is displayed depending on the current image processing job element. Example: 
General	
Short label	Enter a label that will help you identify this image processing job within the RAYGUIDE job.
Description	If necessary, provide a more detailed description of this image processing job.
Enable binning	Activate *Enable binning* if you want this image processing job to be executed depending on a digital signal pattern or not. For more details, see RAYGUIDE manual, chapter 7.2.4.

Table. 4.1: RG_M-001

4.4 Image processing job elements

NOTE: Several image processing job elements offer the option of expanding the available parameters (so-called *Advanced parameters*). These parameters require a good understanding of the image processing algorithms. Advanced parameters do not absolutely have to be edited to achieve the desired result.

4.4.1 Capture image

The *Capture image* job element is used to make all the settings relevant for image capture. This includes:

- Selection of the hardware to be used (camera and usually the illumination controller)
- Optional: Setting the illumination intensities
- Optional: Setting the camera parameters
- Definition of search area (“region of interest”, RoI)

The dialog is divided into several areas. Each dialog area can be expanded and collapsed.

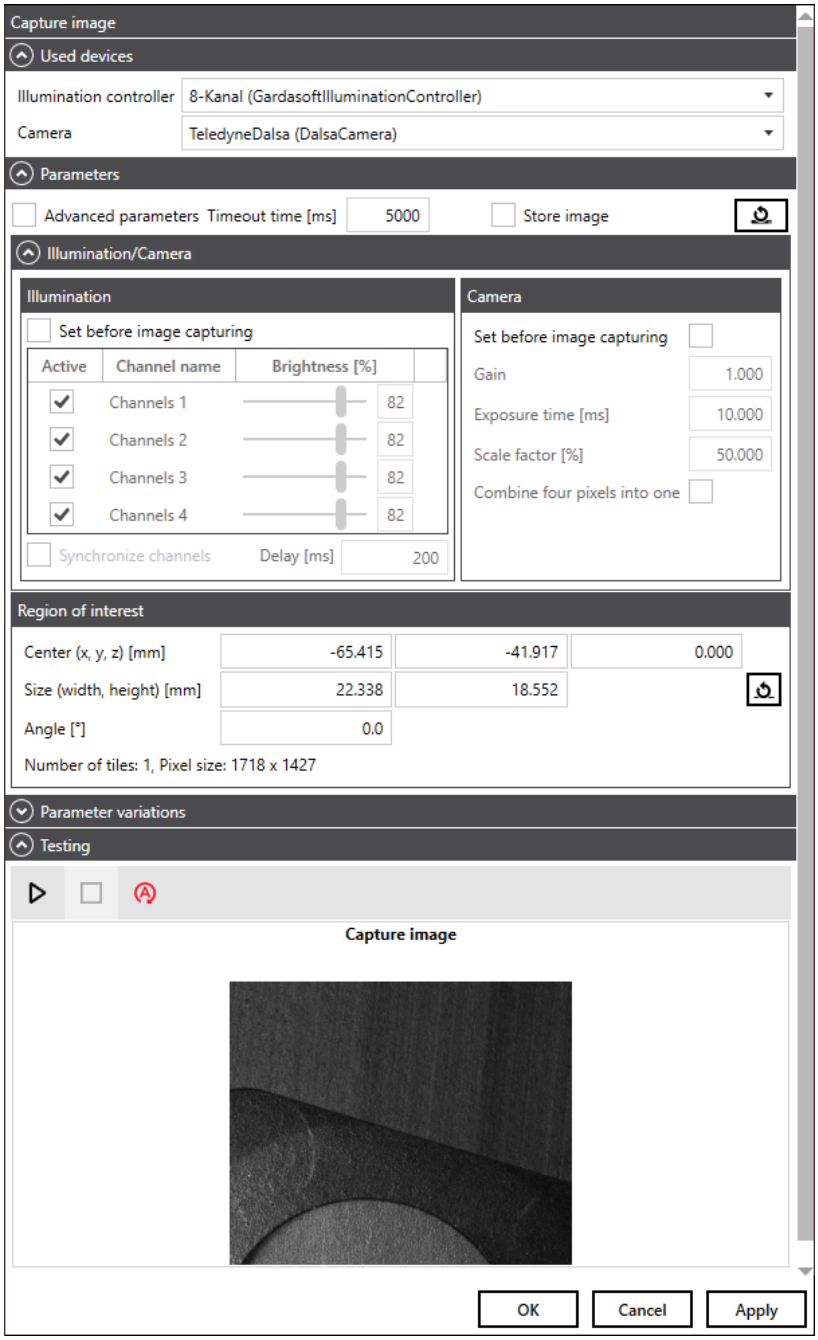


Fig. 4.8: RG_M-AAB

4.4.1.1 “Used devices” dialog area

Element	Explanation
Illumination controller	Specification of the illumination controller that controls the lighting for this image capture. **NOTE:** If only one illumination controller has been configured under device configuration, it is selected automatically.
Camera	Specification of the camera for this image recording. **NOTE:** If only one camera has been configured under device configuration, it is selected automatically. It should be the same camera, that is selected in the CLICK & TEACH panel.

Table. 4.2: RG_M-002

4.4.1.2 “Parameter” dialog area

At the top you will find general settings such as timeout time, a checkbox for image storage and a reset button.

When resetting, the illumination intensities for all channels are set to 50% and the camera settings are set to their default values.

4.4.1.2.1 Group field: Illumination/Camera

The following settings for illumination and camera are optional. As a rule, the globally set values should be used for both the illumination and the camera.

Only change parameters here if, for example, the contrast between two features is so different that the image quality for processing each feature needs to be adjusted.

Element	Explanation
Illumination	
Set before image capturing	■ If activated, the illumination is set as parameterized below before the image is captured. ■ If not activated, the illumination intensities are used, that were set in the CLICK & TEACH *Illumination* panel.
Synchronized channels	If activated, all channels are set to the same intensity using a single slider.
Active	Select which of the channels should be assigned with a new intensity by the Capture image job element or which channels can remain unchanged.

Element	Explanation
Channel name	Display of the channel names as they were assigned in the configuration of the illumination controller.
Brightness	Use the slider for each channel to define the desired brightness. You can enter the value directly as an alternative.
Delay [ms]	Specify a waiting time to ensure that the illumination elements have adjusted to the new intensity values before the actual image capture takes place. A good starting value is approx. 200 ms
Camera	
Set before image capturing	■ If activated, the camera settings are set as parameterized below before image capture. ■ If not activated, the camera settings of the camera device dialog are used for image capture.
Gain	Specification of the electrical gain of the pixel intensity. **NOTE:** A higher gain factor makes the images brighter, but at the same time the image is noisier.
Exposure time [ms]	Specification of the exposure time in [ms] Shorter exposure times automatically mean less brightness. On the other hand, the longer the exposure time, the longer the processing time for the image processing job.
Scale factor [%]	After image capture, the resolution of a tile or the overall image is reduced by this factor. **NOTE:** The search is faster with a lower image resolution because fewer pixels are aligned. For example, the full image resolution is not always necessary when searching for templates.
Combine four pixels into one	In this case, four pixels are combined to form one pixel. This reduces image noise at the expense of the resolution. To calculate the result image point, you can either add up the gray values of the pixels or calculate their average. **NOTE:** The pixels are merged directly on the camera. This reduces the amount of data for image capture, which results in faster image capture.

Table. 4.3: RG_M-003

NOTES:

- Changing the illumination intensity takes a relatively long time (possibly several seconds). That means this should only be used if there is not enough light/contrast at the search regions with a single, global intensity setting for all following detection tasks.
- Please note that the values for the camera that are set using the image capture job element are also transferred to the camera device dialog. This means that these values are then globally valid until further notice.
- Use the CLICK & TEACH live image and the gray value gradient display available in it, to optimize alignment of the lighting elements so that the gray value transitions on the selected features are as sharp as possible. See *page 55, CLICK & TEACH panel*.

4.4.1.2.2 Group field: Search area (region of interest, "RoI")

This is where the area of the workspace is defined from which a picture(s) is / are taken for the following image processing. The workpiece feature to be detected must be located in this area.

USER INSTRUCTIONS:

- The search area should be as small as possible, but as large as necessary.

  Make sure that you leave enough space around the actual workpiece feature so that the workpiece feature is still completely within the search area despite the expected position deviations.
- If possible, the search area should not be larger than one image tile.

  Transitions between image tiles could have a negative effect on image detection and the image capture time also increases.
- Drag the desired search area in the workspace with the left mouse button pressed.

  Depending on the general settings, the ***[Pick]*** button must be used to activate so-called picking (see *page 60, Picking*). This prevents an already defined search area from being discarded due to accidental clicking again in the workspace.

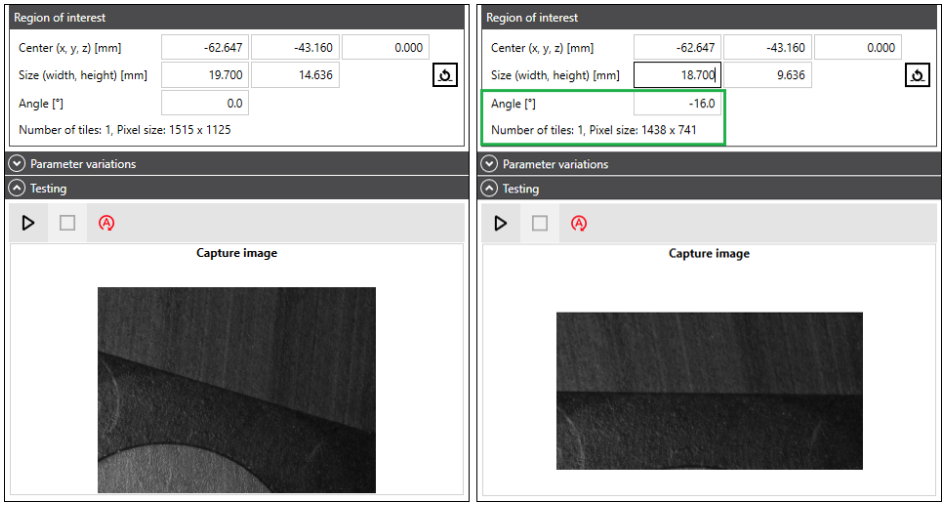
Element	Explanation
 ***[Pick]***	This optional button activates picking of the search area with the mouse cursor.
Center (x, y, z) [mm]	Specification of the center coordinates of the search area for the X and Y coordinates derived from the dragged search area. The Z coordinate is zero by default. **NOTE:** If the workpiece feature is in a focus position other than Z = 0, the Z position can also be defined below the zero plane with a suitable hardware setup (pre-focusing deflection unit with 3D correction file).
Size (width, height) [mm]	Dimensions of the search area in the X and Y directions. The values are calculated automatically after dragging the search area. They can be edited directly to enlarge or reduce the search area. Clicking on the ***[Reset]*** button resets the size of the search area to the dimensions of an image tile.
Angle [°]	Specification of the angle of the search area relative to the X-axis of the workspace. You can use this option, for example, if you search for an edge and align the search area with the edge - the search area then becomes smaller. Example: 
AdvPNumber of tiles	This expert parameter can be used to take not just one, but possibly several images of a feature, which are then combined by the software to built an averaged image. Depending on the number, this leads to longer processing times, but can significantly reduce image noise.

Table. 4.4: RG_M-004

The search areas are also highlighted graphically in the RAYGUIDE viewport with selection of the image processing job in the tree (usually in blue). This provides an immediate overview of where the features for the image processing are located.

Example:

The following example shows the search areas of two circle searches.

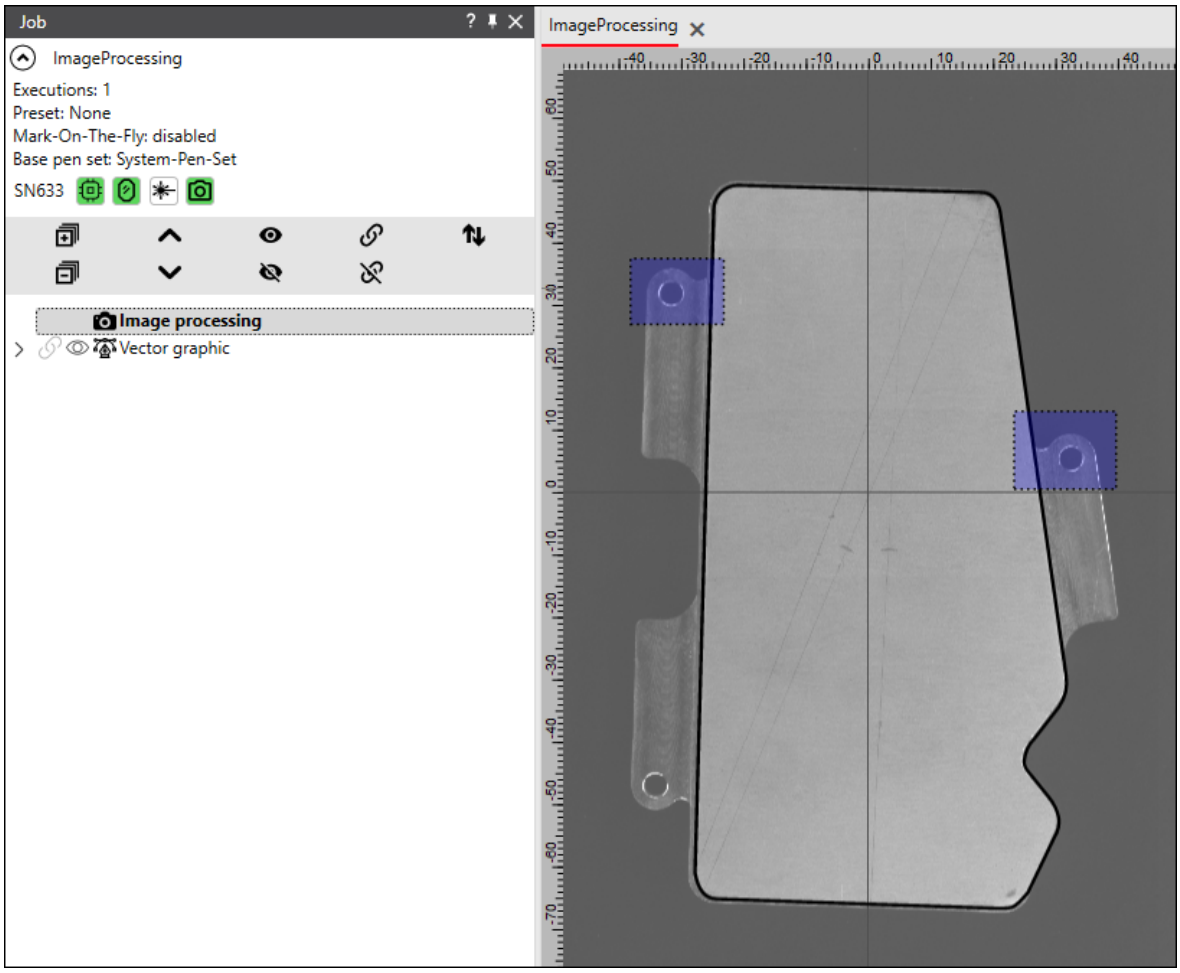


Fig. 4.9: RG_M-AAC

4.4.1.3 "Parameter variations" dialog area

The *Parameter variations* dialog area is common to all image processing job elements. See also *page 185, Dialog area: Parameter variations*.

4.4.1.4 "Testing" dialog area

The *Testing* dialog area is common to all image processing job elements.

See also *page 179, Dialog area: Testing* .

4.4.2 Image filter

RAYGUIDE MATCH offers a wide selection of image filters.

This makes it possible to digitally post-process images taken by the camera. This can make detection of the search features more reliable or simpler.

The dialog provides several algorithms to change each pixel of an image. In principle, there are two types of pixel manipulation:

- A pixel can be changed by an operation that only takes this one pixel into account.

  For example, a value can be added. Or the value of the pixel is set to zero if its original value is below a threshold, as is the case with binarization.
- A pixel can be changed by an operation that also takes the adjacent pixels into account.

  In this case, the adjacent pixels are weighted with values that are stored in a so-called kernel.

A **kernel** is a matrix that contains the weightings. You can imagine the kernel as a small window that is moved over the image, stops at each pixel and calculates a new value for this pixel. All adjacent pixel values are weighted according to the elements of the matrix and added up.

Formula:

$$g'(x,y) = \sum k_{i,j} \cdot g(x+i, y+j)$$

Fig. 4.10: RG_M-ACA

g(x,y):	Gray value of the pixel with the x and y coordinates
g'(x, y):	Modified gray value of the pixel
i:	Line
j:	Column
k:	Kernel

Example:

For example, the Sobel filter calculates the derivatives of an image in the X direction, thereby detecting horizontal edges:

-1	0	1
-2	0	2
-1	0	1

Available filters:

- Invert,
- Brightness / Contrast,
- Blur filter,
- Median blur fitler,
- Gaussian blur filter,
- Bilateral blur filter,
- Threshold - simple
- Threshold - adaptive
- Histogram equalization filter,
- Add noise filter,
- Remove noise filter,
- User-defined (kernel) filter,
- Dilatation,
- Erosion,
- Mask filter.

NOTES:

- Note that not all kernel-based filters can be expressed in a formula as above.

  For example, the morphological transformations (dilation, erosion) or median blur are not linear. They use a maximum value of the pixels over which the kernel is located.
- For all filters that use a kernel that covers a pixel area, the total size of the image in pixels and the size of the pixel disturbances must be taken into account when selecting the size of the pixel area.
- In principle, several filters can also be applied in series before the actual feature search. Whether and which filters are suitable depends entirely on the original image, its illumination and the following feature search.

4.4.2.1 Invert

Inversion inverts the gray values of the individual pixels. There are no additional settings here.

4.4.2.2 Brightness / Contrast

You can use this image filter to change both, the brightness and the contrast of the images.

- Brightness:

  When adjusting the brightness, the gray value gradient line is shifted in parallel, so to speak.

- Contrast:

  When adjusting the contrast, the slope of the gray value gradient line is changed (made steeper/flatter).

The value range for brightness/contrast ranges from -100 to +100.

NOTE: Please note that pixels fall into the saturation range of the gray value gradient, both when changing the brightness and the contrast. That means the image loses gray value information.

4.4.2.3 Smoothing filters

Image noise is caused by thermal fluctuations in the image sensor and is magnified by image gain. By using smoothing filters, the image noise and any small-scale surface structures of objects can be reduced within certain limits so that the features to be detected stand out more clearly.

It is assumed here that local disturbances of the surrounding gray values can be reduced by a suitable averaging process.

4.4.2.3.1 Blur filter

The blur filter calculates the average value of the gray values of all pixels in a neighborhood of the pixel as the new gray value of the pixel.

This filter operation is based on a “kernel”: This is a matrix of weighting factors that are used when a pixel value is changed taking into account the adjacent pixels.

All elements of the kernel have the value 1, and the result after adding them up is divided by the number of elements in the kernel.

The following parameters must be defined:

Parameter	Explanation
Kernel size X/Y	Definition of kernel size (window size) The maximum window size is limited to 200 x 200 pixels. **NOTE:** Please note that the larger you make the window, the more computing time is required for this filter.
AdvP Anchor point X/Y	(Advanced parameter) The anchor point of the pixel to be changed is in the center of the kernel by default. This anchor point can be moved here. ■ Value (-1, -1): The anchor point is in the center of the kernel. ■ Value (0, 0): The anchor point is the upper left corner of the kernel.

Table. 4.5: RG_M-005

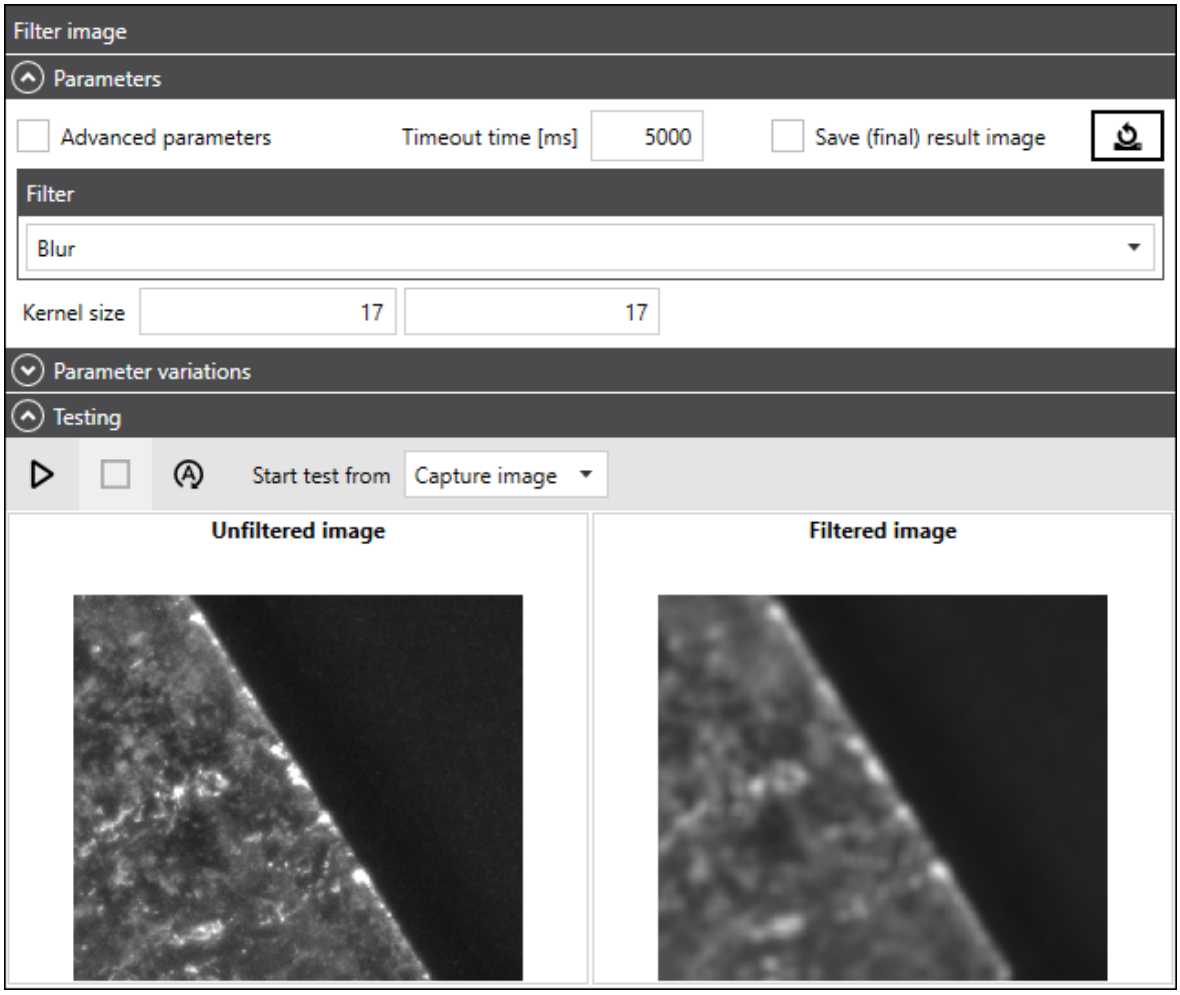


Fig. 4.11: RG_M-AAE

4.4.2.3.2 Median blur fitler

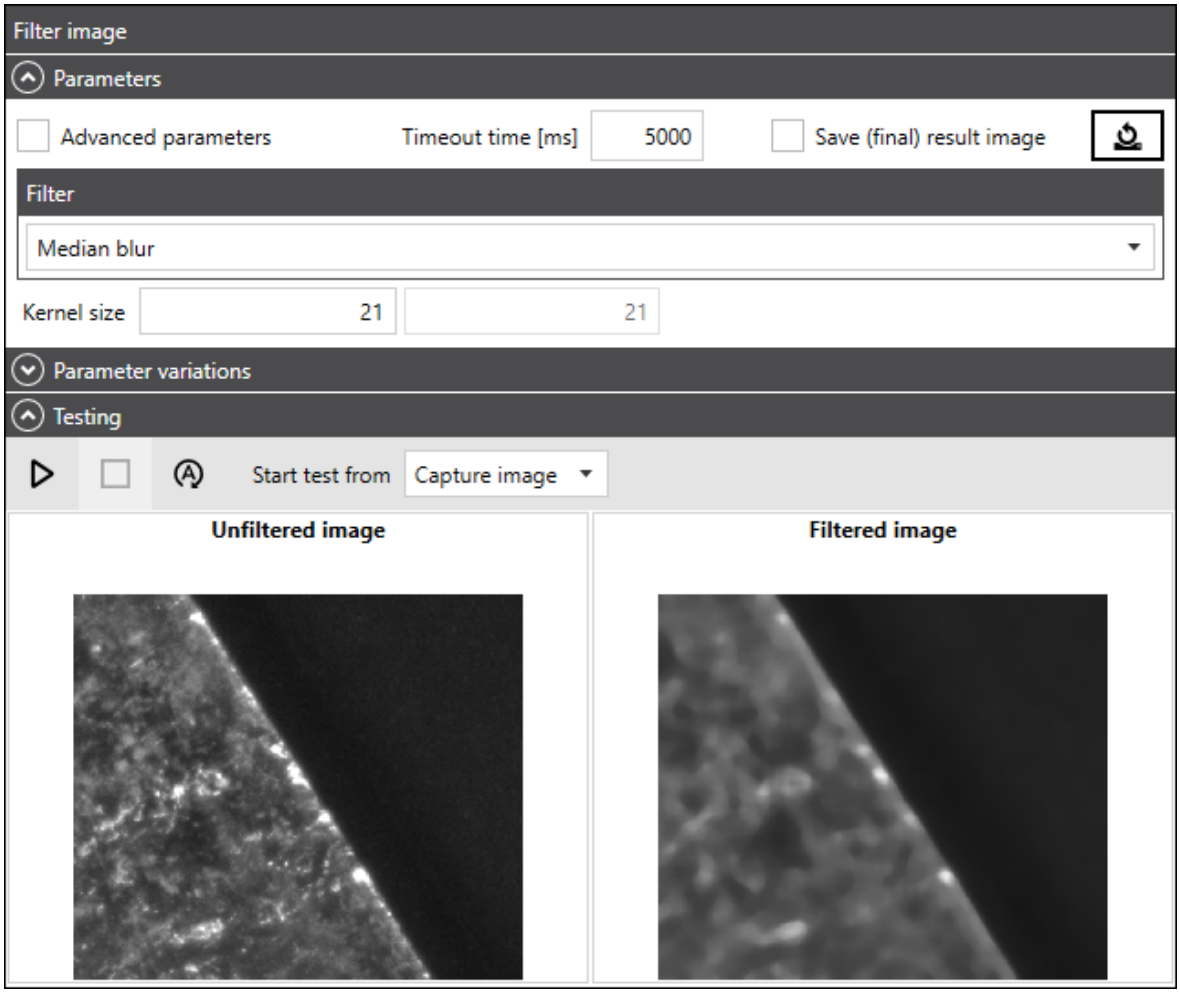
The median filter replaces the gray value of each pixel in a rectangular region around the pixel with the median gray value. That means it reacts less sensitively to outliers (“noise”).

This filter operation is based on a “kernel”: This is a matrix of weighting factors that are used when a pixel value is changed taking into account the adjacent pixels.

The following parameters must be defined:

Parameter	Explanation
Kernel size X/Y	Definition of kernel size (window size) The maximum window size is limited to 200 x 200 pixels. **NOTE:** Please note that the larger you make the window, the more computing time is required for this filter.

Table. 4.6: RG_M-005



4.4.2.3.3 Gaussian blur filter

This filter operation is based on a “kernel”: This is a matrix of weighting factors that are used when a pixel value is changed taking into account the adjacent pixels.

The Gaussian blur filter uses a kernel with a Gaussian distribution.

The result gray value of a pixel results from a weighted average of a pixel with its surroundings. Each kernel element is multiplied by the reciprocal of the sum of the kernel elements (normalization factor).

Example: Kernel with a size of 5 x 3 elements and sigmaX = 1 and sigmaY = 0.5:

1	4	7	4	1
7	26	41	26	7
1	4	7	4	1

- Sum of elements = 141
- Standardization factor = 1/141.

The following parameters must be defined:

Parameter	Explanation
Kernel size X/Y	Definition of kernel size (window size) The maximum window size is limited to 200 x 200 pixels. **NOTE:** Please note that the larger you make the window, the more computing time is required for this filter.
Sigma	Half the width of half the maximum of the Gaussian bell curve. Sigma determines the width of the Gaussian bell curve that defines the kernel. This value has no unit.

Table. 4.7: RG_M-005

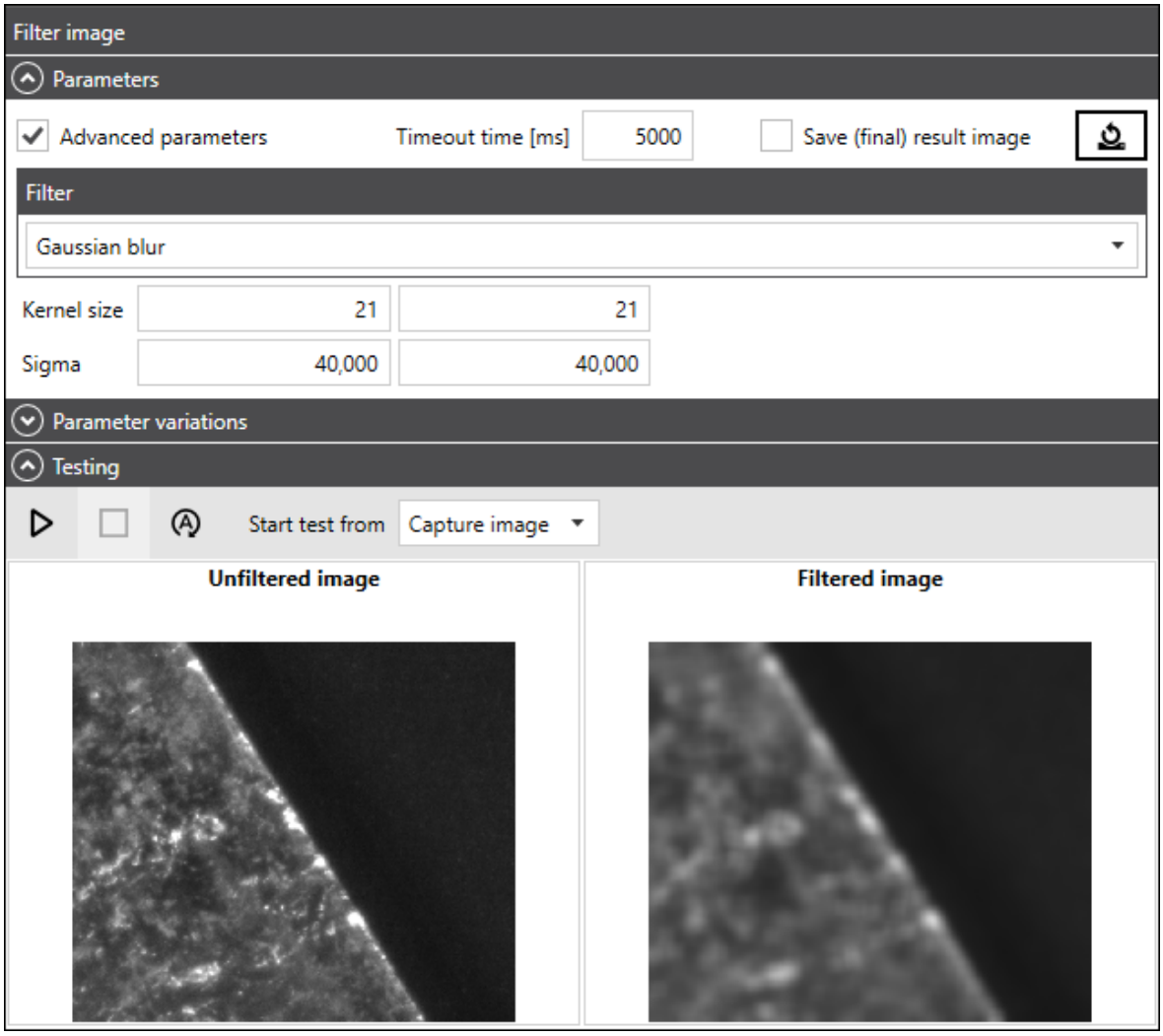


Fig. 4.12: RG_M-AAG

4.4.2.3.4 Bilateral blur filter

In contrast to the other smoothing filters, the bilateral blur filter contains the edges.

Similar to the Gaussian blur filter, the resulting gray value of a pixel results from a weighted average with its surroundings.

It consists of two components:

- A Gaussian weighting and
- A weighting based on the gray value difference to the middle pixel.

NOTE: The bilateral blur filter requires more computing time than the other blur filters.

The following parameters must be defined:

Parameter	Explanation
Diameter pixel neighborhood [pixels]	The diameter of the pixel neighborhood that is taken into account. ■ Value = -1: Automatic calculation depending on “Sigma (location)”
Sigma color	Half the width of half the maximum of the Gaussian bell curve in the *gray value space*.
Sigma space	Half the width of half the maximum of the Gaussian bell curve in the *gray value locations*.

Table. 4.8: RG_M-006

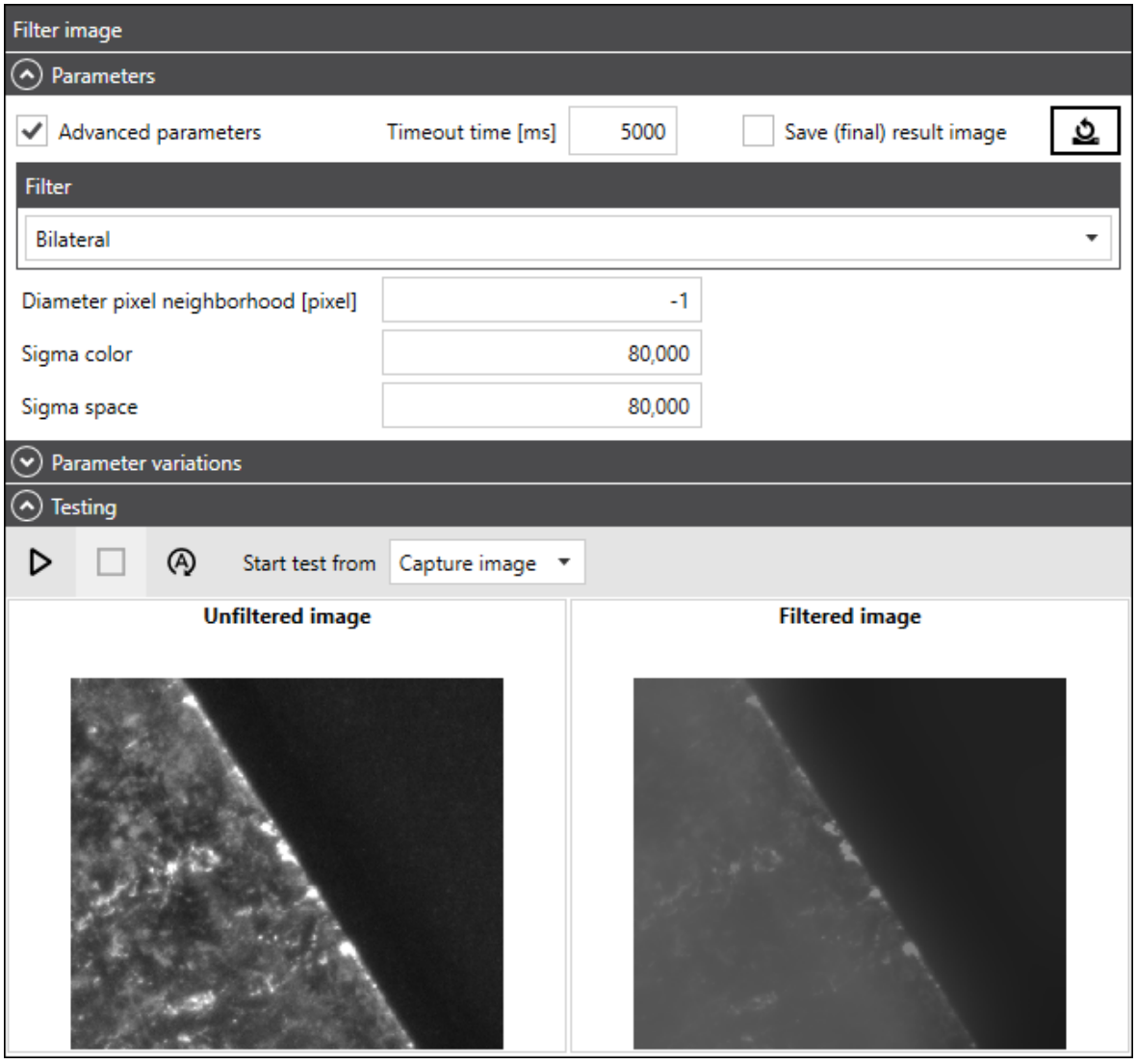


Fig. 4.13: RG_M-AAH

4.4.2.4 Threshold filters

In a threshold value filter, all pixels below and above the threshold are set to a uniform gray value.

4.4.2.4.1 Threshold – simple

The simple threshold filter changes a pixel depending on its gray value and the threshold value. The gray value is changed in different ways depending on whether it is above or below the threshold value.

How the gray value is changed depends on other parameters.

Example: Classic binarization, for example, sets all lighter pixels with a gray value < 128 to gray value = 255 and all darker pixels (> 128) to gray value = 0.

The following parameters must be defined:

Parameter	Explanation
Threshold [0...255]	Gray value limit Pixels above this value are treated in a certain way. Pixels with gray values below this value are treated in a different way. How the pixels are treated depends on the **threshold value type**.
Max. value [0...255]	The maximum value limits the end value for upward threshold operations.
AdvPThreshold type	(Advanced parameter) The threshold value type determines how gray value **g'** of a pixel is calculated from original gray value **g**. ■ *Binary*: g' = If *g* > Threshold, then *maximum value*; otherwise *0.* ■ *Binary and inverted* : g' = If *g* > Threshold, the *0*; otherwise *maximum value.* ■ *Cut*: g' = If *g* > Threshold, then *Threshold*. ■ *To zero*: g' = If *g* > Threshold, then *Threshold*; otherwise *0.* ■ *To zero and inverted* : g' = If *g* > Threshold, then *0*; otherwise *Threshold.* The selection is set to *Binary* by default.
Otsu´s auto threshold	Typically, the threshold value is given as a fixed number. The Otsu algorithm attempts to automatically calculate an optimal threshold value for the image.

Table. 4.9: RG_M-007

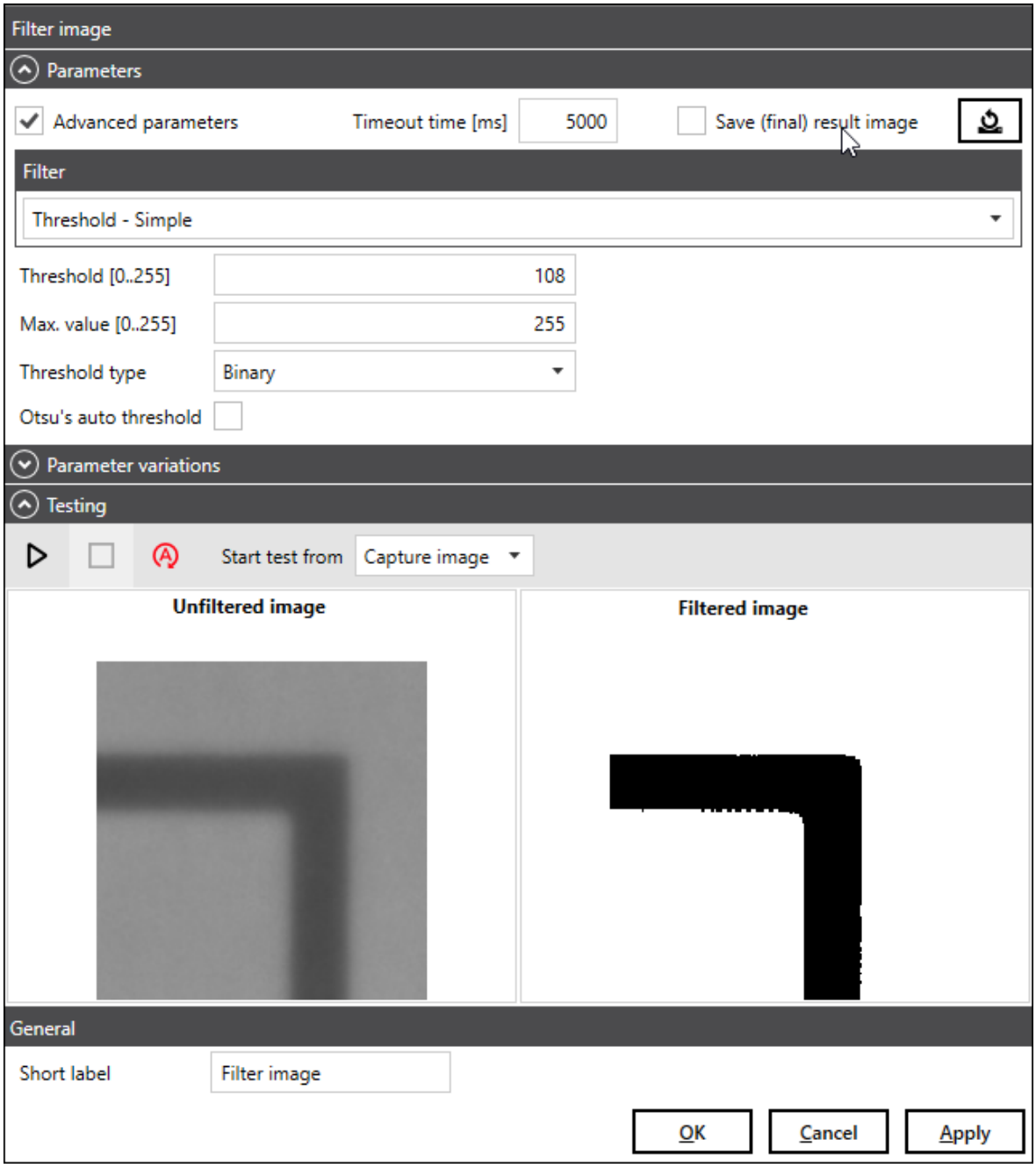


Fig. 4.14: RG_M-AAI

4.4.2.4.2 Threshold – adaptive

The adaptive threshold filter does not use a constant threshold value for the entire image, but modifies it automatically depending on the local contrast in the neighborhood of each pixel. If the illumination in the search area is not uniform, this can be compensated for.

There are two adaptive threshold value types. An individual threshold value is calculated for each pixel, which depends on the neighboring pixels in a quadratic area.

After the threshold value of a pixel has been calculated and the neighboring pixels have been weighted, a constant gray value is subtracted in the last step.

The following parameters must be defined:

Parameter	Explanation
Max. value [0...255]	The maximum value limits the end value for upward threshold operations.
AdvP Adaptive threshold type	(Advanced parameter) The threshold value is based on the calculation of a weighted average of the gray values in a quadratic region around the pixel minus a constant. ■ *MeanC:* All pixels in the surrounding area are weighted equally. ■ *GaussianC*: All pixels in the surrounding area are weighted using a Gaussian function and based on the distance from the center. The selection is set to *MeanC* by default.
AdvP Threshold type	(Advanced parameter) The threshold value type determines how gray value **g'** of a pixel is calculated from original gray value **g**. ■ *Binary*: g' = If *g* > Threshold, then *maximum value*, otherwise *0* ■ *Binary and inverted*: g' = If *g* > Threshold, then *0*; otherwise *maximum value* The selection is set to *Binary* by default.
AdvP Size of neighbourhood [pixels]	(Advanced parameter) The size of the quadratic area around the pixel. The default value for the neighborhood size is 3 pixels.
AdvP Offset	(Advanced parameter) Constant gray value that is subtracted in the last step. The default value for the offset is zero.

Table. 4.10: RG_M-008

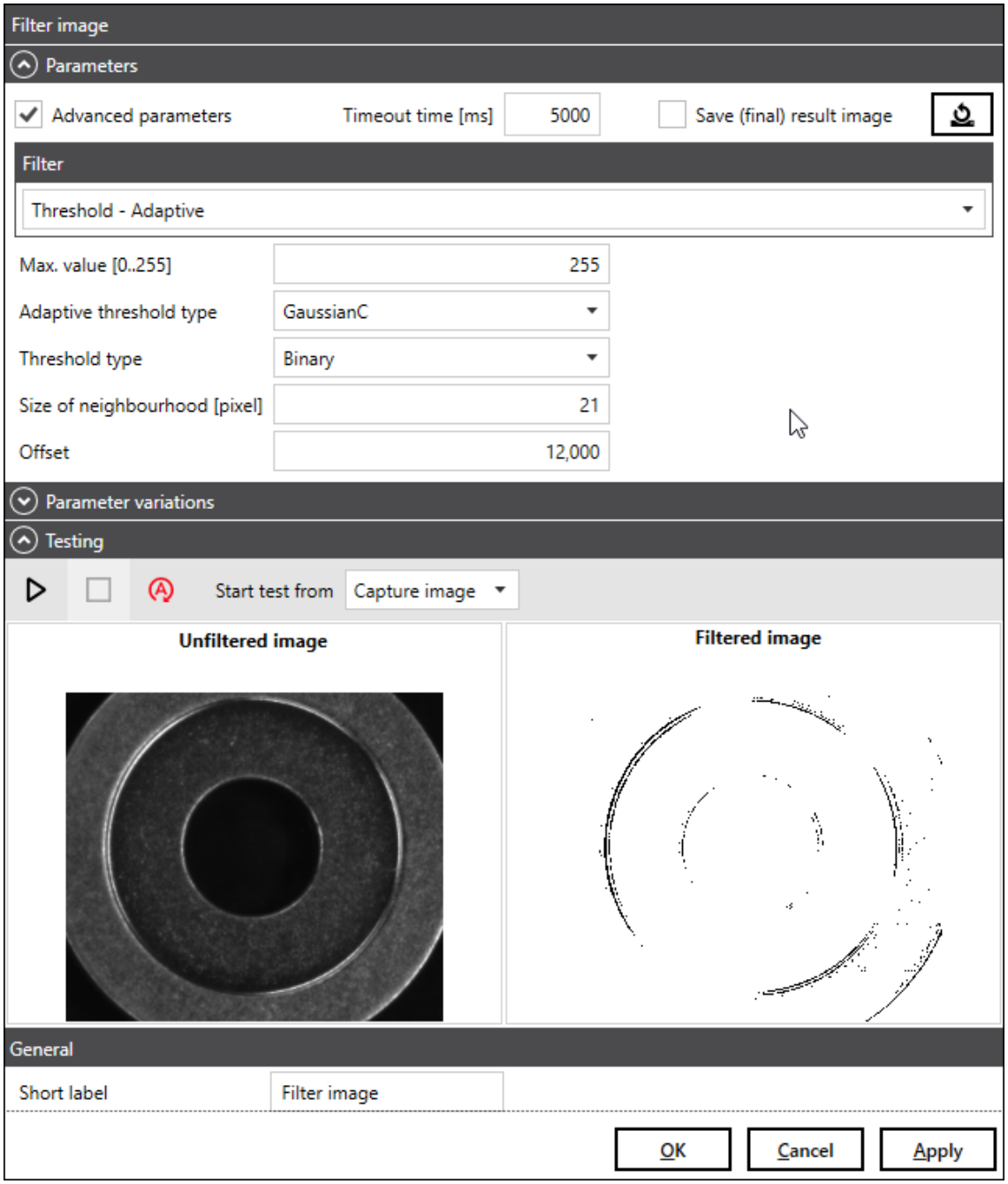


Fig. 4.15: RG_M-AAJ

4.4.2.5 Histogram equalization filter

Histogram equalization is based on the histogram spread method. If there are only relatively few dark or bright pixels in the gray value image, histogram compensation leads to a significant increase in contrast.

This filter does not require parameterization.

Example:

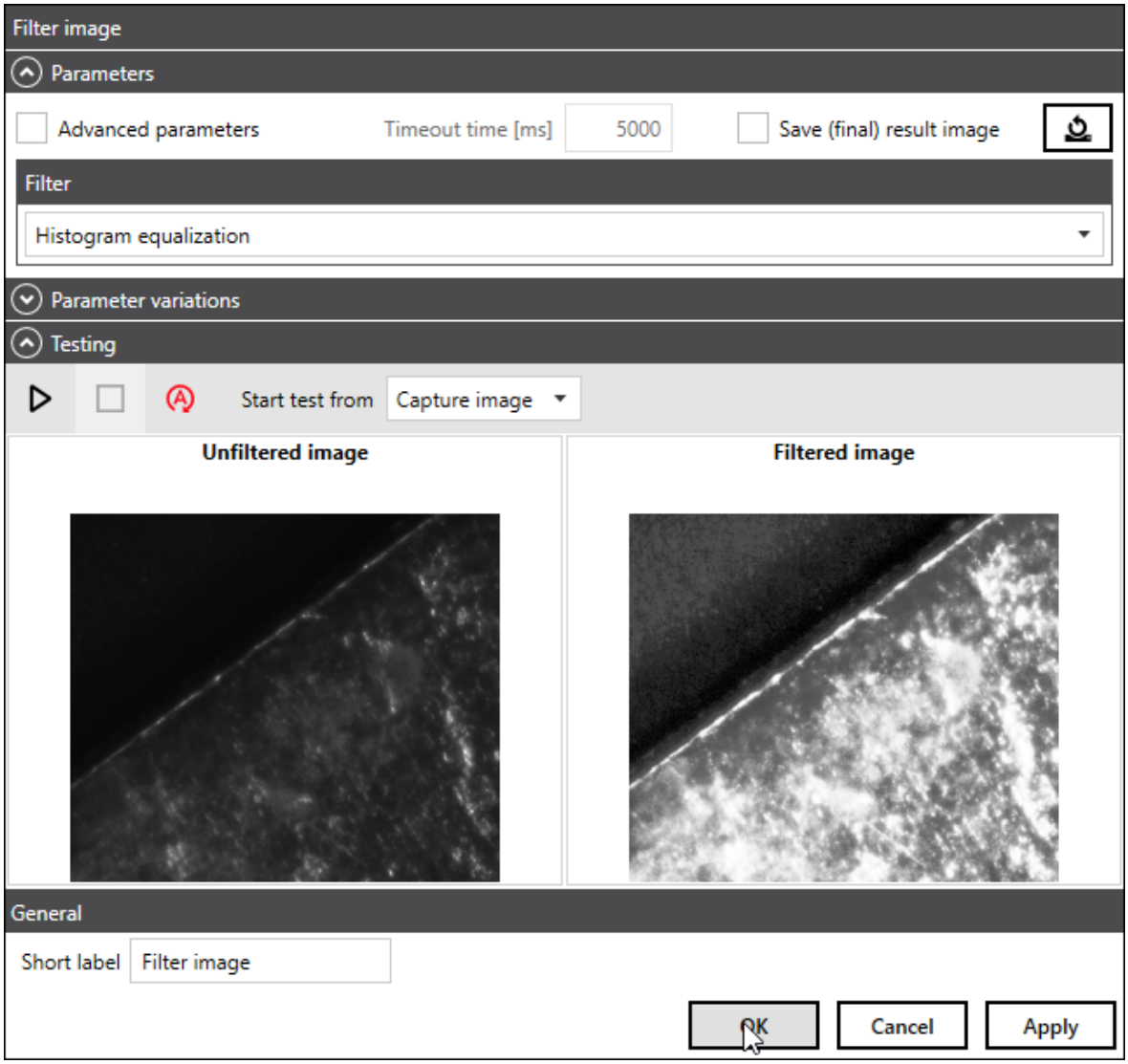


Fig. 4.16: RG_M-AAD

Corresponding histogram curves:

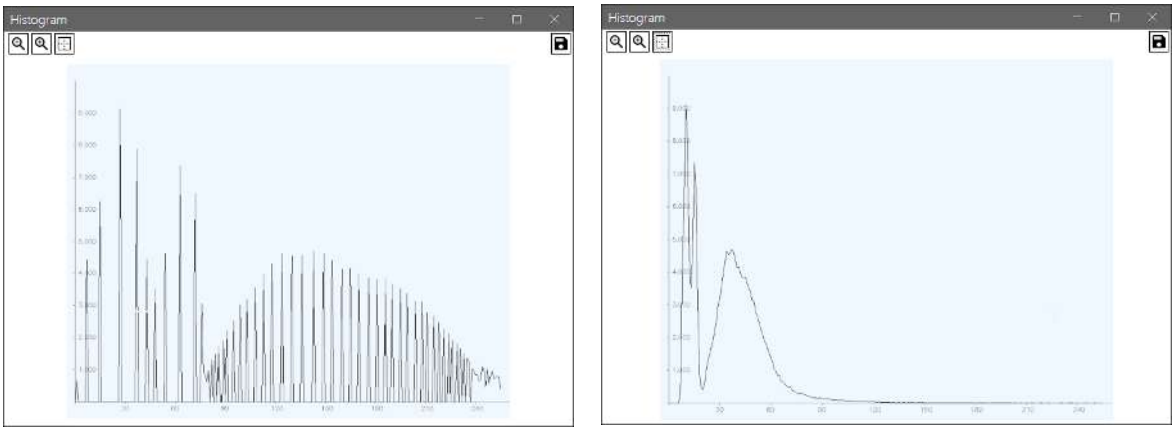


Fig. 4.17: RG_M_AAE

4.4.2.6 Add noise filter

This filter adds various types of image noise to the original image.

Unlike most other filters, this type of filter is used to deliberately change the original image in order to test image detection for reliability.

Alternatively, you can deliberately set offset and rotation values in order to obtain these as a process transformation, testing image detection.

The following parameters must be defined:

Element	Explanation
Type: **Salt and Pepper** This type adds salt and pepper noise to the image. Black pixels are added first. That means white pixels can overwrite black pixels.	
Threshold [0...1000]	A random number between 0 and 1000 is generated for each pixel in the image. Only if this number is greater than or equal to the threshold value will the pixel be changed.
AdvPRandom seed	(Advanced parameter) If this value is not 0, it is used as the base value (“seed”) for the random number generator. This means that the generator then always generates the same sequence of numbers.
Salt	If activated, white pixels are added to the image at random positions.
Pepper	If activated, black pixels are added to the image at random positions.

Element	Explanation
Type: **Offset variation** This type moves the image randomly or by a fixed value.	
Offset [mm] X/Y	The image of the search area is shifted by these values. If the “random values” are activated, random values within the specified plus/minus limits are generated; in this case, the sign is irrelevant.
Random values	If activated, random values are generated in the specified plus/minus range. Otherwise the specified values are used.
Type: **Rotation variation** This type rotates the image randomly or by a fixed value.	
Rotation [°]	The image of the search area is shifted by this value. If “random values” is activated, angle values are randomly generated in the specified plus/minus range; the sign is not important in this case.
Random values	If activated, random values are generated in the specified plus/minus range. Otherwise the specified values are used.

Table. 4.11: RG_M-009

4.4.2.7 Remove noise filter

This filter removes noise from an image using the so-called “Fast Non-Local Means Denoising” algorithm (FNLMD).

In contrast to local noise removal, which is done with the median filter, for example, not only the local surroundings of a pixel are taken into account, but also similar pixels and their surroundings in a larger area.

If an image contains repeating structures, good results are achieved with this method.

On the one hand, a “template” window is used, which is moved over the image and may contain a noisy pixel in the middle. There is also a larger “search field” window that is searched for a similar pixel arrangement.

The noisy pixel can be repaired if a similar pixel arrangement is found.

When comparing the template with the search window, the “Weighting” parameter is used to control how quickly a pixel becomes irrelevant as the distance increases.

The following parameters must be defined:

Parameter	Explanation
Template window size [pixels]	A window of this size is moved over the image to check whether the center pixel is noisy. The field only allows odd numerical values for this reason.
Search window size [pixels]	In the surrounding area of this size around each pixel, the algorithm searches for a region similar to that in the template window. **NOTE:** The search field should be larger than the template window.
Weighting	This parameter controls how relevant a region is with increasing distance from the template window.

Table. 4.12: RG_M-010

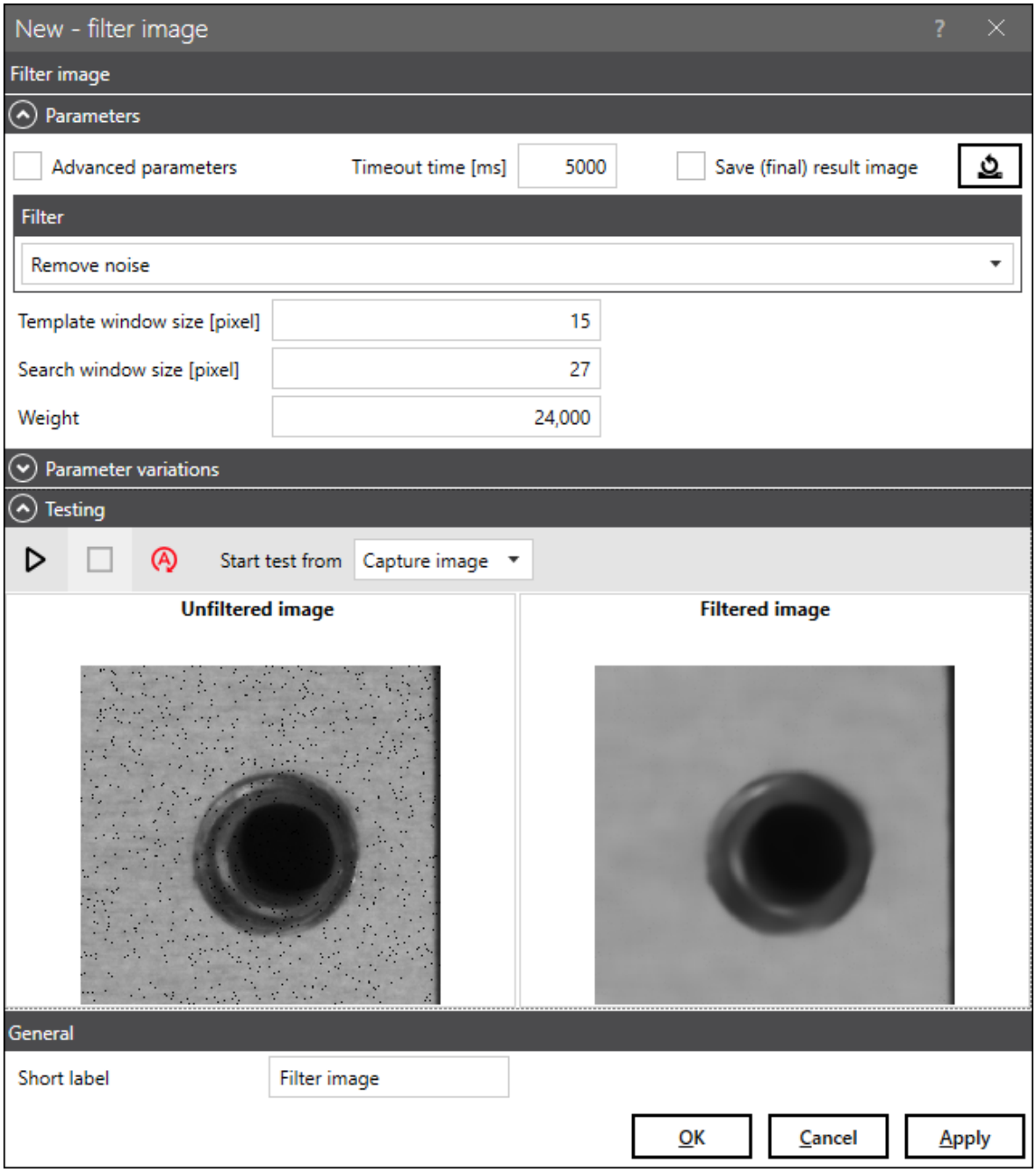


Fig. 4.18: RG_M-AAK

4.4.2.8 User-defined (kernel) filter

This filter operation is based on a “kernel”: This is a matrix of weighting factors that are used when a pixel value is changed taking into account the adjacent pixels.

In contrast to other kernel-based filters, the kernel structure can be freely defined here.

With this filter, structures can be emphasized if the kernel is defined appropriately.

The following parameters must be defined:

Parameter	Explanation
Kernel size X/Y	Definition of kernel size (window size) The maximum window size is limited to 21 x 21 pixels. **NOTE:** Please note that the larger you make the window, the more computing time is required for this filter.
AdvP Anchor point X/Y	(Advanced parameter) The anchor point of the pixel to be changed is in the center of the kernel by default. This anchor point can be moved here. ■ Value (-1, -1): The anchor point is in the center of the kernel. ■ Value (0, 0): The anchor point is the upper left corner of the kernel.
Delta	The delta value is added to the result after the convolution has been calculated, making the image lighter or darker.
[Set all]	Click on this button to fill the entire matrix with ones values.
[Reset all]	Click on this button to reset the entire matrix with zero values.

Table. 4.13: RG_M-032

4.4.2.9 Structure-based filters

These filters can be used to generate kernels with certain structures (e.g. ellipses, crosses), which then either add or remove pixel areas with the same structure.

4.4.2.9.1 Dilatation (extension)

This filter performs a so-called morphological transformation.

Dilation is a convolution process that returns the maximum gray value in the kernel area for a pixel. This means that dilation thickens light regions. Individual dark pixels are eliminated as a result.

The following parameters must be defined:

Parameter	Explanation
Kernel size X/Y	Definition of kernel size (window size) The maximum window size is limited to 21 x 21 pixels. **NOTE:** Please note that the larger you make the window, the more computing time is required for this filter.
AdvPAnchor point X/Y	(Advanced parameter) The anchor point of the pixel to be changed is in the center of the kernel by default. This anchor point can be moved here. ■ Value (-1, -1): The anchor point is in the center of the kernel. ■ Value (0, 0): The anchor point is the upper left corner of the kernel.
AdvPIterations	(Advanced parameter) The same dilation or erosion can be applied multiple times according to this parameter.
Kernel shape	This list simplifies the entry of zeros and ones in the kernel in specific forms. For example, a cross can remove grid lines in the image.
Kernel matrix	A matrix of input fields corresponding to the previously defined window size. In principle, only a distinction is made between zero and non-zero (e.g. 1) for these values.
[Set all]	Click on this button to fill the entire matrix with ones values.
[Reset all]	Click on this button to reset the entire matrix with zero values.

Table. 4.14: RG_M-032

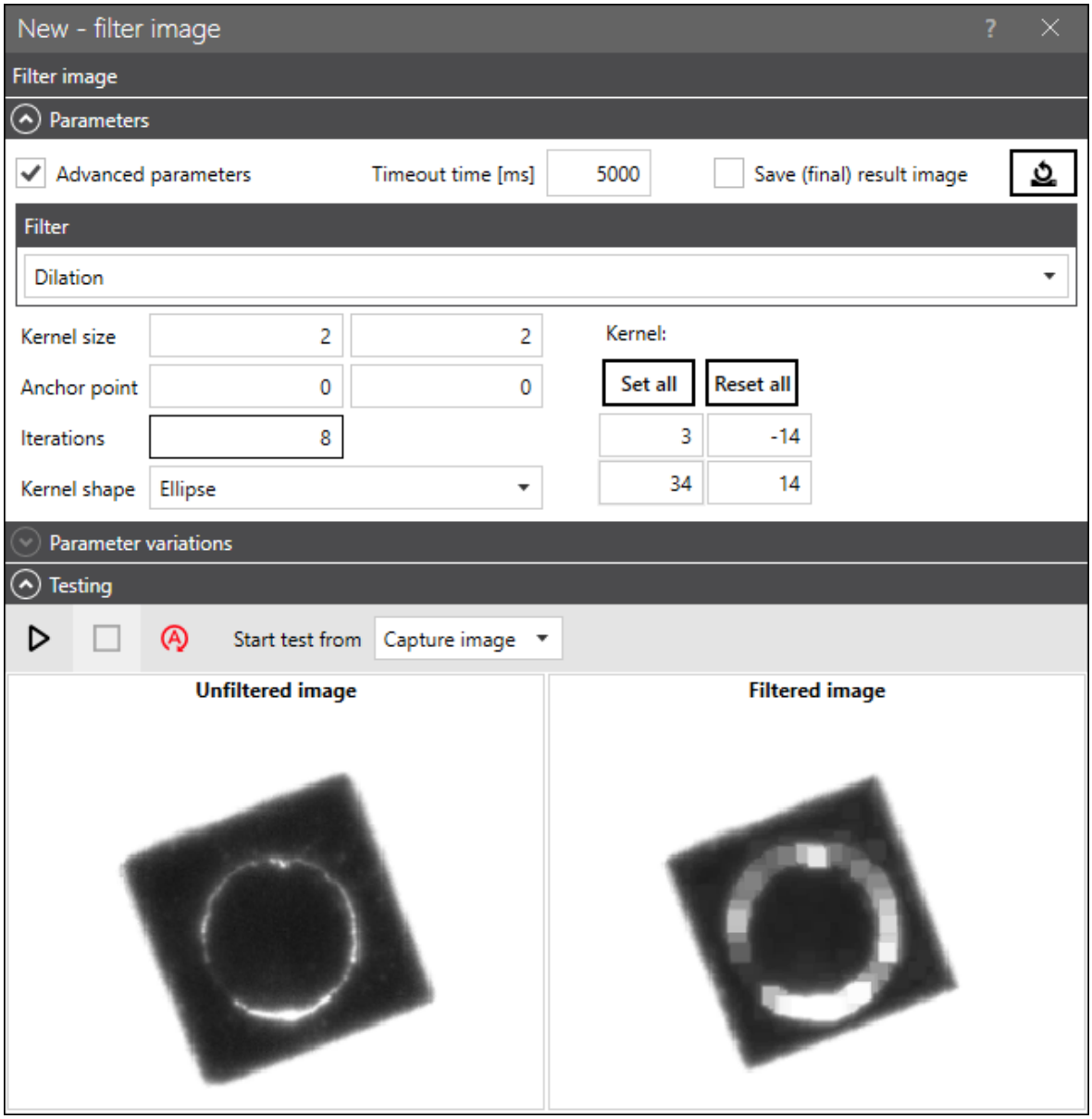


Fig. 4.19: RG_M-AAL

4.4.2.9.2 Erosion (ablation)

This filter performs a so-called morphological transformation.

Dilation is a convolution process that returns the minimum gray value in the kernel area for a pixel. This means that erosion thins out light regions.

Individual light pixels are eliminated as a result.

The following parameters must be defined:

Parameter	Explanation
Kernel size X/Y	Definition of kernel size (window size) The maximum window size is limited to 21 x 21 pixels. **NOTE:** Please note that the larger you make the window, the more computing time is required for this filter.
AdvP Anchor point X/Y	(Advanced parameter) The anchor point of the pixel to be changed is in the center of the kernel by default. This anchor point can be moved here. ■ Value (-1, -1): The anchor point is in the center of the kernel. ■ Value (0, 0): The anchor point is the upper left corner of the kernel.
AdvP Iterations	(Advanced parameter) The same dilation or erosion can be applied multiple times according to this parameter.
Kernel shape	This list simplifies the entry of zeros and ones in the kernel in specific forms. For example, a cross can remove grid lines in the image.
Kernel matrix	A matrix of input fields corresponding to the previously defined window size. In principle, only a distinction is made between zero and non-zero (e.g. 1) for these values.
[Set all]	Click on this button to fill the entire matrix with ones values.
[Reset all]	Click on this button to reset the entire matrix with zero values.

Table. 4.15: RG_M-032

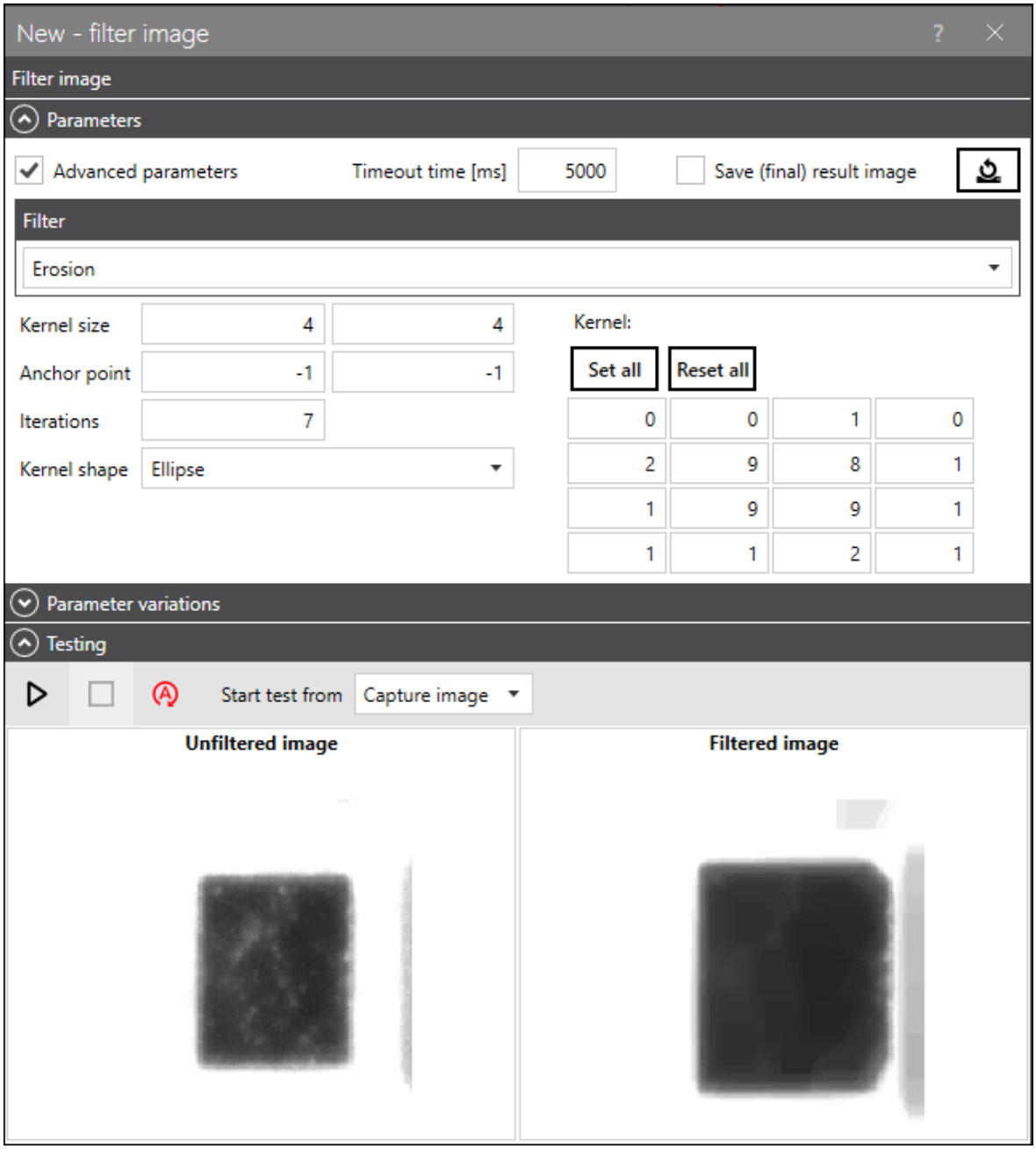


Fig. 4.20: RG_M-AAN

4.4.2.10 Mask filter

This filter overlays the image with a user-defined image as a mask.

All pixels in the image at whose position the mask has black pixels are retained, all other pixels are set to a uniform, predefined gray value.

Recommended procedure:

1. Double-click on the “Before” image and save it as a template for the mask.
2. Open the saved image in a graphics program (for pixel graphics).
3. Cover all pixels in black that you want to keep later.
4. Save this modified image as a mask.
5. Enter the path and file name in the *Mask file* field.
6. Set the gray value to a suitable value.

The following parameters must be defined:

Parameter	Explanation
Mask file	Select the image file that has been “masked”.
Gray value	Enter the gray value to be assigned to all pixels within the mask.

Table. 4.16: RG_M-012

Example: Original image with various structures, whereby only the circle should be detected.

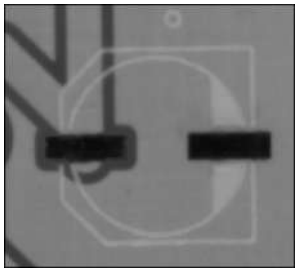


Fig. 4.21: RG_M-AAO

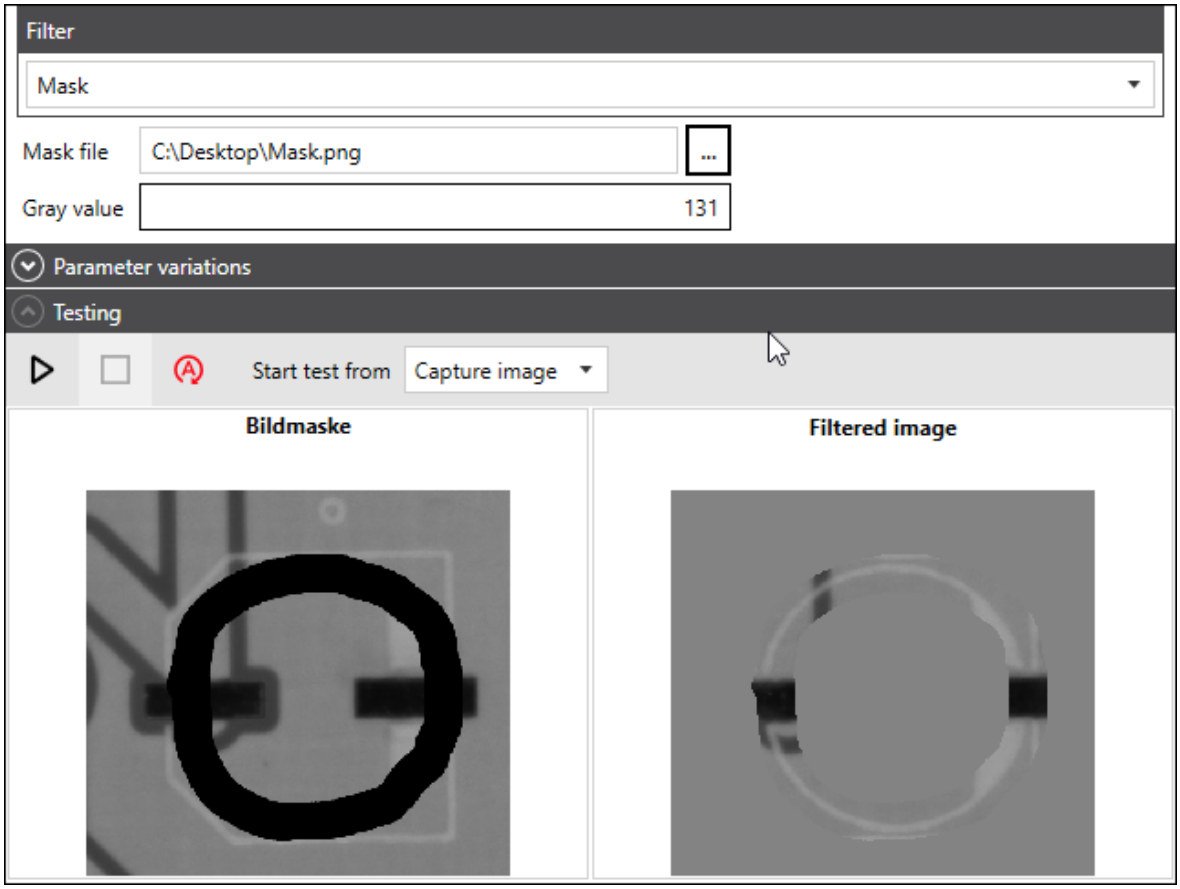


Fig. 4.22: RG_M-AAP

4.4.3 Search for features

RAYGUIDE MATCH offers a defined range of searches for workpiece features.

As a rule, these algorithms search for defined geometries on the workpiece, such as straight edges, circles and corners.

Which search is suitable depends primarily on the shapes of the workpiece to be detected.

NOTES:

- The feature to be detected must have a fixed reference to the geometry to be processed.

  If, for instance, two corners of a rectangle are searched for, in order to weld a contour inside the rectangle, the position of the welding contour in relation to the outer contour must remain unchanged.
- The position of the features in the scan field should be such, that they are easy to illuminate and are not shadowed by other attachments.
- The surface quality should be as uniform and clean as possible. This applies in particular to the features.
- You can also use markings on the workpiece. In this case, however, observe in particular note 1. This also applies if the workpiece to be marked consists of several components.
- Each search may return exactly one result. Searches that return no results or more than one result are considered as errors in the automatic process.

The number and type of searches that are suitable for correctly defining the position of the workpieces depends on whether you expect only an offset, only a rotation or a combination of offset and rotation per workpiece.

Which misalignment is expected per workpiece?	Which search or searches are suitable for this?
Misplacement due to XY offset only	A circle search
	A corner search
	A template search
	Two gray value transition searches (right angles if possible)
Misplacement due to rotation only	A line search
	Two corner searches
	Two circle searches
Misplacement due to offset and rotation	Two corner searches
	Two circle searches
	Two template searches
	Corner, circle and template searches in a mixed two-feature combination
	Two line searches, where the intersection of the lines should be near the two search areas.

Table. 4.17: RG_M-031

USER NOTE:

For most searches, you can choose the search parameters so that you get several search results, which you can then reduce to one search result using suitable selection criteria.

Exception: Searches based on gray value transitions.

4.4.3.1 Searching for geometric features

4.4.3.1.1 Line search

When searching for a line, the feature to be detected is a straight edge.

The components that can be used to describe a straight line are listed in the drawing below:

- Two points, for example, start and end points P1 and P2.
- Center C of the straight line, i.e. the midpoint between P1 and P2.
- The distance of center C from the origin.
- The plumb point at which the vertical to the straight line passing through the origin intersects the straight line.
- Distance r of the straight line from the origin, i.e. the distance between the origin and the plumb point.
- Angle *phi* between the x-axis and the perpendicular through the plumb point.
- The *angle* between the straight line and the x-axis.

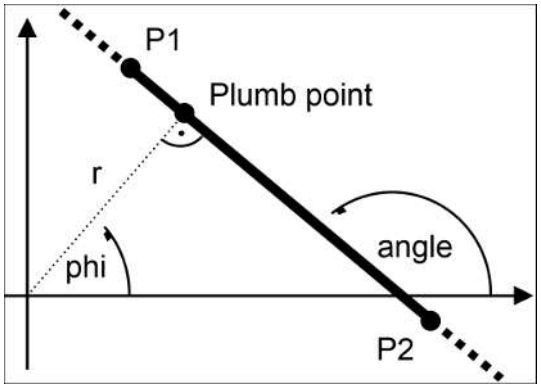


Fig. 4.23: RG_M-AAQ

Result:

The line search essentially only provides a 1-dimensional offset perpendicular to the line and the angle of the line. That means it is not as effective as searches that deliver a full coordinate.

There are three detection methods to choose from, which are described in more detail below:

- Best-fit line
- „Fast Line“ and
- Gray value transition line

4.4.3.1.1.1 Line search with “best-fit line” detection method

The following algorithm, which runs in three steps, describes the characteristic part of this search:

1. The found edges are converted into contours.

   Contours are lists of connected points.

2. Each found contour is split into several contours by approximating it with a polygon (green lines in the drawing).

   The contour points from which a polygon leg emerges form the sub-points of the split contour.

3. The points in each sub-contour are used to calculate a best-fit line (blue line in the drawing).

Adjustment is done by minimizing a cost function (sum of the distances between the points and the line searched for):

$$\sum \rho(r)$$

Fig. 4.24: RG_M-ACB

Various ρ(r) distance functions are available. They differ, for example, in how they influence outlier points. One of the distance functions is the frequently used least-squares adjustment.

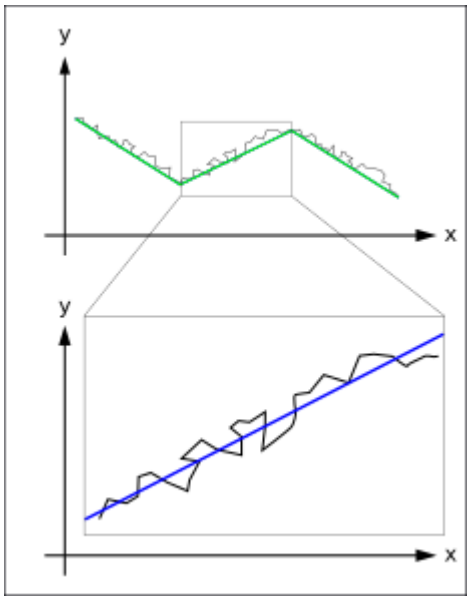
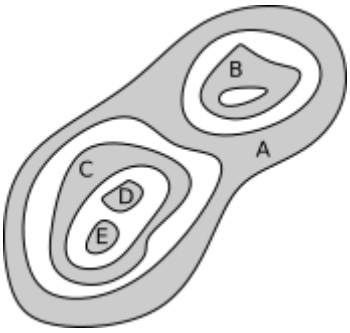


Fig. 4.25: RG_M_ABB

The following parameters must be defined:

Parameter	Explanation
Edge detection (Canny) Edge detection is often the first step in finding objects. The Canny edge detector is an improvement on the simple Laplacian filter. The Laplacian filter calculates gray value gradients in only two directions. The Canny edge detector uses those two gray value gradients to calculate gradients in four directions. There is also a second threshold value that allows for a kind of contour detection.	
Skip	The Canny edge detector can detect unwanted edges if filters with binary threshold values were used beforehand. That means feature detection works better in this case without the Canny edge detector.
Canny threshold 1 / ExpPCanny threshold 2	There are two threshold values: ■ Canny threshold 1 and ■ Canny threshold 2 (Advanced parameter). One is the upper threshold value, the other the lower threshold value. It does not matter which threshold value is the upper or the lower – they are swapped if necessary. The following threshold value rules apply: ■ *Gradient of a pixel > upper threshold value*: The pixel is accepted as an edge pixel. ■ *Gradient of a pixel < lower threshold value*: The pixel is rejected. ■ *upper threshold value > Gradient of a pixel > lower threshold value:* The pixel is only accepted as part of the edge if it is connected to a pixel whose gradient is above the upper threshold value. The default values are 120 and 180.
Window size	The first phase of Canny Edge Detection is filtering with the Sobel operator. The Window size is the size of the matrix used. The value 5, for example, means that the matrix has a size of 5 x 5 pixels. The standard value here is 3 pixels.

Parameter	Explanation
[AdvP]L2 gradient	(Advanced parameter) When calculating the directional gradient, the correct L2 norm can be used or the less accurate but faster L1 norm. This option is not active by default.
Fit line	
Contours detection Multiple pixels of an edge form a contour. A contour is a list of points that represent a curve in an image. Contours can be nested inside each other; they separate dark from light regions in the image. Depending on the application, displays as a contour tree, as a list of all contours, or even just as the outermost contour, may be of interest. Example: In the drawing, there are five dark regions (A to E) that have nine contours. Due to the nesting, a contour tree can be constructed that shows which contour is contained in which other contour.  	
[ExpP]Retrieve type	(Advanced parameter) There are different ways in which contours are determined: ■ *External*: Only the outermost contour of a contour hierarchy is returned. ■ *List*: All contours of a contour hierarchy are returned. The selection is set to *External* by default.

Parameter	Explanation
ExpPApproximation method	(Advanced parameter) There are different ways to represent a contour: ■ *ChainCode*: Contours are output in the Freeman chain code. All other methods return polygons (point lists). ■ *ChainApproxNone:* Translates all points of the contour code into points. Each point is one of the eight neighbors of a point. No reduction of the contour size is performed by approximation. ■ *ChainApproxSimple*: Compresses horizontal, vertical and diagonal segments by storing only the end points. In the case of a horizontal rectangle, for example, only the corner points remain. ■ *ChainApproxTc89L1:* The Teh-Chin chain approximation algorithm is used. It is more elaborate than *ChainApproxSimple*. ■ *ChainApproxTc89Kcos:* Also a Teh-Chin chain approximation, but with minor differences. The selection is set to *ChainApproxSimple* by default.

Parameter	Explanation
Line approximation A rough polygon approximation is used to split a contour into several contours. Each part of the contour can then be processed separately.	
AdvPEpsilon [mm]]	(Advanced parameter) This parameter controls the accuracy of the approximation. It indicates the maximum permissible deviation between the contour and the result lines. The default value is set to 0.1 mm.
AdvPAuto	(Advanced parameter) If activated, the Epsilon parameter is automatically determined based on the contour length. This option is active by default.
AdvPMinimum length [mm]	(Advanced parameter) This is the minimum length that a polygon leg must have in order to be accepted. This is equal to 0 [mm] by default

Parameter	Explanation
Compensation parameters These parameters are used when points of a contour are approximated to a line.	
[AdvP]Distance calculation	(Advanced parameter) This parameter determines how the distance ρ(r) between a pixel and the line is calculated. x1, y1 and x2, y2 are the coordinates of two pixels:
	L1: $\lvert x_1 - x_2\rvert + \lvert y_1 - y_2\rvert$
	L2: $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ (smallest squares)
	C: $\max(\lvert x_1 - x_2\rvert, \lvert y_1 - y_2\rvert)$ (currently not implemented)
	L12: $2\left(\sqrt{1 + \frac{x^2}{2}} - 1\right)$
	Fair: $c^2\left(\frac{\lvert x\rvert}{c} - log\left(1 + \frac{\lvert x\rvert}{c}\right)\right),\ c = 1.3998$
	Welch: $\frac{c^2}{2}\left(1 - e^{-\left(\frac{x}{c}\right)^2}\right),\ c = 2.9846$
	Huber: $\lvert x\rvert < c:\ \frac{x^2}{2}$ $\lvert x\rvert \geq c:\ c\left(\lvert x\rvert - \frac{c}{2}\right),\ c = 1.345$
	User: User-defined distance (currently not implemented)
	The selection is set to *L1* by default.
Distance accuracy [mm]	Required accuracy for calculated distance r between the line and the origin.
Angle accuracy [°]	Required accuracy for calculated angle *phi* between the perpendicular of the line and the x-axis.

Table. 4.18: RG_M-013

Example: In this example, a search is done for the edge or edge profile of a linear guide.

Original image of the search area:

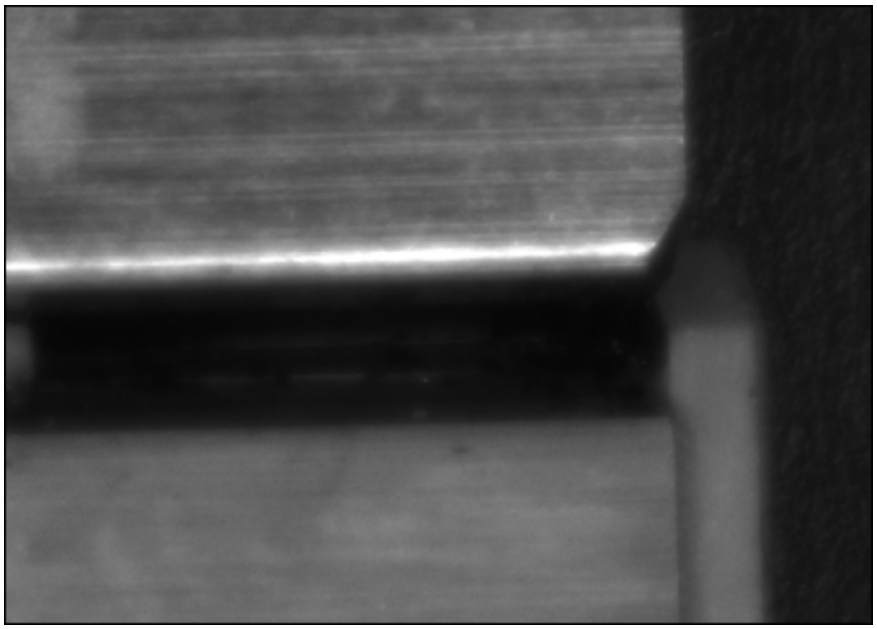


Fig. 4.26: RG_M-AAZ

Test result of the search using a best-fit line:

Fig. 4.27: RG_M-ABA

4.4.3.1.1.2 Line search with “Fast Line” detection method

This method uses the “Fast Line Detector” (FDL) algorithm as proposed by Lee Jin Han, Lee Sehyung, Zhang Guoxuan, Lim Jongwoo and Suh Il Hong.

The first step here is also a Canny edge detection, this time integrated directly into the algorithm.

The following parameters must be defined:

Parameter	Explanation
Fast line detection.	
Min. length threshold [mm]	Only lines of this length or longer are accepted.
ExpPDistance threshold [mm]	(Advanced parameter) A point further away from the hypothetical line segment is considered an outlier and ignored. The standard value is 1 µm.
ExpPCanny threshold 1 / ExpPCanny threshold 2	(Advanced parameter) There are two threshold values: ■ Canny threshold 1 and ■ Canny threshold 2. One is the upper threshold value, the other the lower threshold value. It does not matter which threshold value is the upper or the lower – they are swapped if necessary. The following threshold value rules apply: ■ *Gradient of a pixel > upper threshold value*: The pixel is accepted as an edge pixel. ■ *Gradient of a pixel < lower threshold value*: The pixel is rejected. ■ *upper threshold value > Gradient of a pixel > lower threshold value:* The pixel is only accepted as part of the edge if it is connected to a pixel whose gradient is above the upper threshold value. The default values are 120 and 180.

Parameter	Explanation
ExpPWindow size	(Advanced parameter) The first phase of Canny Edge Detection is filtering with the Sobel operator. The window size is the size of the matrix used. The value 5, for example, means that the matrix has a size of 5 x 5 pixels. The standard value here is 3 pixels.
ExpPMerge	(Advanced parameter) If activated, line segments are combined. This option is active by default. **NOTE:** This process may take some time. The time increases exponentially with the number of lines, which in turn increases with the size of the window.

Table. 4.19: RG_M-018

Example: In this example, a search is done for the edge or edge profile of a linear guide.

Original image of the search area:

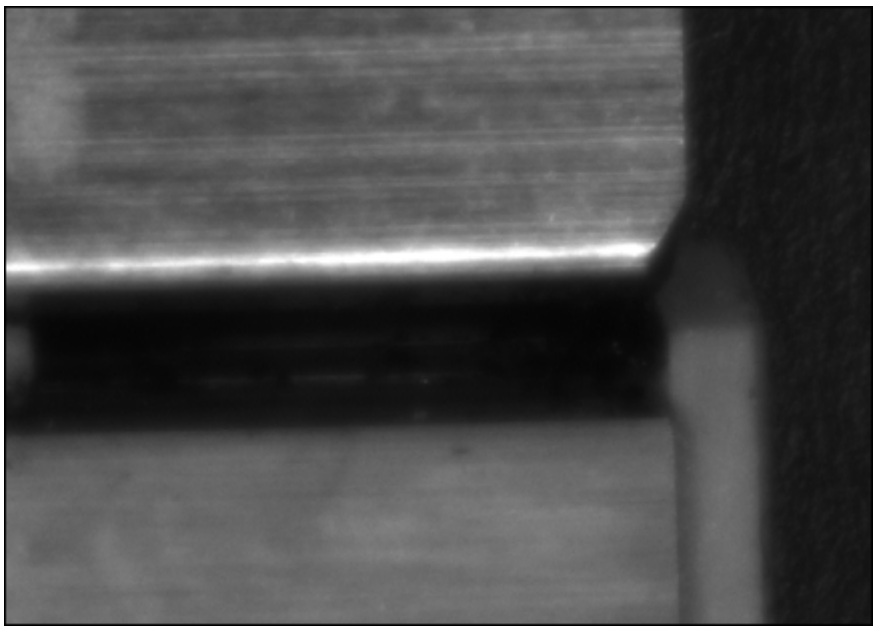


Fig. 4.28: RG_M-AAZ

Test result of the search using the Fast Line method:

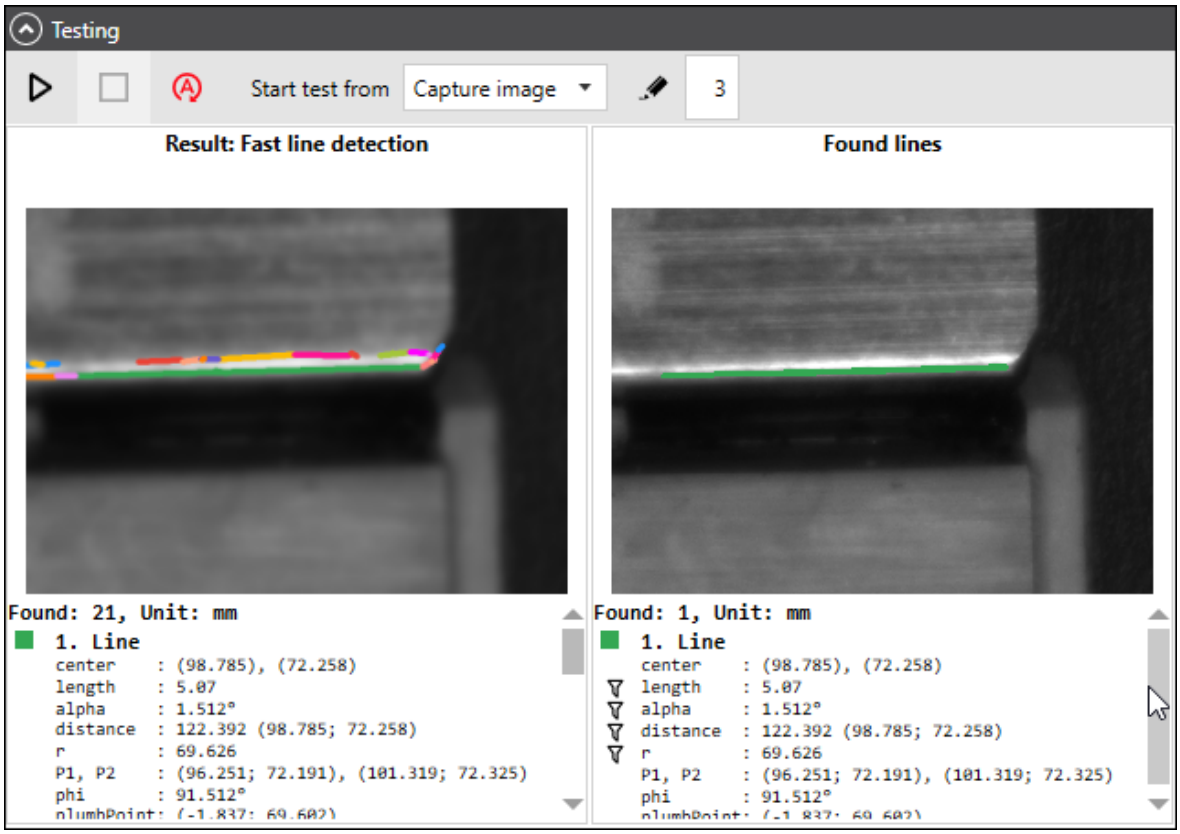


Fig. 4.29: RG_M-ABC

4.4.3.1.1.3 Line search with two gray value transitions

In this method, gray value transitions are searched for at two positions on the line. For details on the gray value transition search, see *page 156, Gray-value-transition search*.

Both transition searches can be configured separately and each returns a point with a defined gray value on a scanning line (in blue). These two points then define the searched transition line (in green).

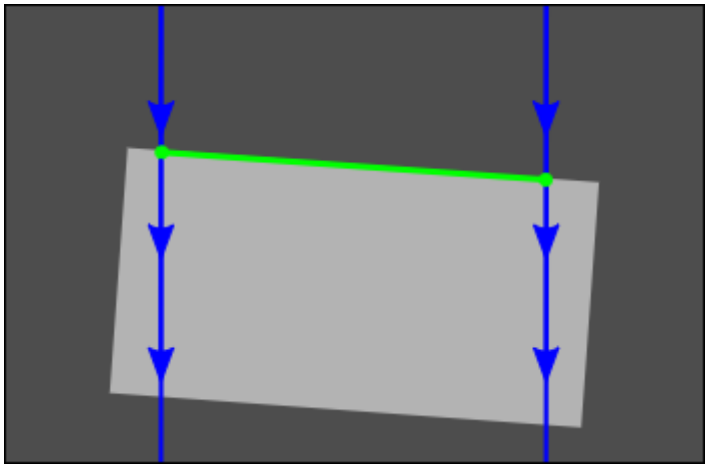


Fig. 4.30: RG_M-ABD

The following parameters must be defined:

Parameter	Explanation
Transition lines	
Transition no.	Select for which of the two searched gray-value-transitions transitions the following parameters apply. ■ *Blue line*: The active scanning line is shown in blue in the “Scanning lines” image. ■ *Green line*: The found transition point is shown in the “Scanning lines” image as a small green circle. You can also select the scanning line directly in the test image by clicking one of the end points with the mouse.
Search direction	Select whether you want to search more for ■ The maximum at the transition from *light to dark* or ■ The minimum of the gray value gradient at the transition from *dark to light*.

Parameter	Explanation
Peak	**Option 1**: The transition point is determined by the maximum or minimum gray value.
Absolute gray value [1...255]	**Option 2**: The transition point is determined by a predefined gray value and the scanning direction. It lies at the point where the predefined value is reached for the first time.
Difference gray value [1…255] / Pixel area [pixels]	**Option 3**: If activated, the transition point is determined by a definable gray value difference: Each pixel along the scanning direction is considered a start pixel. The following number of pixels within the *pixel area* are examined. That means the gray value difference between a pixel and the start pixel is calculated. If the difference is equal to or greater than the *gray value difference*, the position of that pixel is returned as the result. If no sufficient gray value difference is found within the *pixel area*, the procedure is repeated with the next start pixel.
AdvPRelative to gray value range [%]	**Suboption for option 2 of 3**: (Advanced parameter) When activated, the search for an absolute or relative threshold value is modified. The threshold value is given as a percentage of the difference between the lightest and darkest gray value found on the scanning line. **NOTE:** This makes the search independent of the absolute brightness and allows the brightness of the image to be changed without affecting the result.
AdvPScan line start point [%] X / Y	(Advanced parameter) The start point of the scanning line in [%] of the height and width of the search area. As a rule, the point in the “Scanning lines” test image is defined using the mouse.
AdvPScan line end point [%] X / Y	(Advanced parameter) The end point of the scanning line in [%] of the height and width of the search area. As a rule, the point in the “Scanning lines” test image is defined using the mouse.

Parameter	Explanation
[Flip scan line]	Use the button to invert the scanning direction along the line.
AdvPScan line lenth [mm]	(Advanced parameter) Shows you the resulting length of the scanning line in [mm].

Table. 4.20: RG_M-019

Example:

In this example, an edge or the straight edge profile is determined using two gray value transitions. This requires a very strong contrast transition and one that is as sharp as possible at the edge.

Original image of the search area:

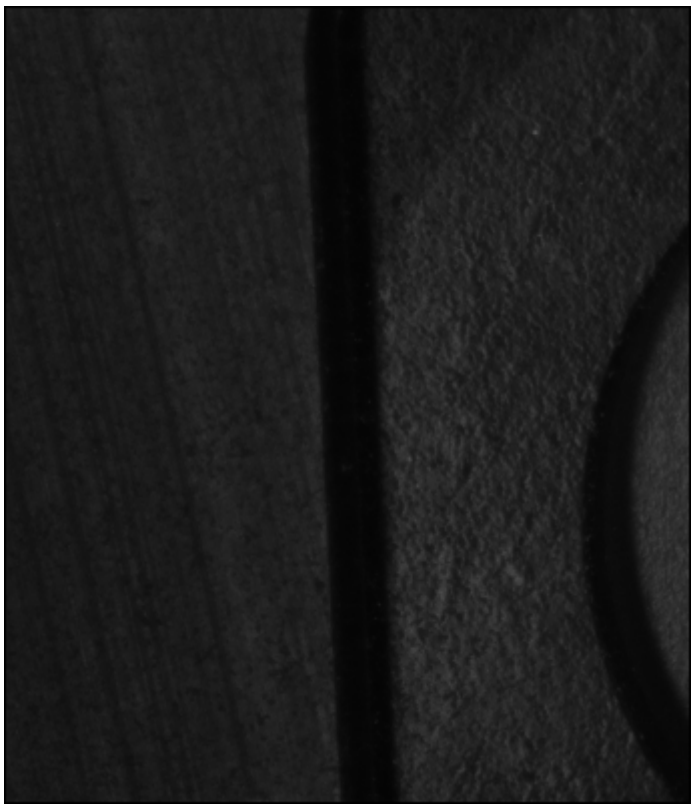


Fig. 4.31: RG_M-ABE

Test result of the search with two gray value transitions:
(**NOTE:** Only the gray-value-gradient along the active blue line is displayed.)

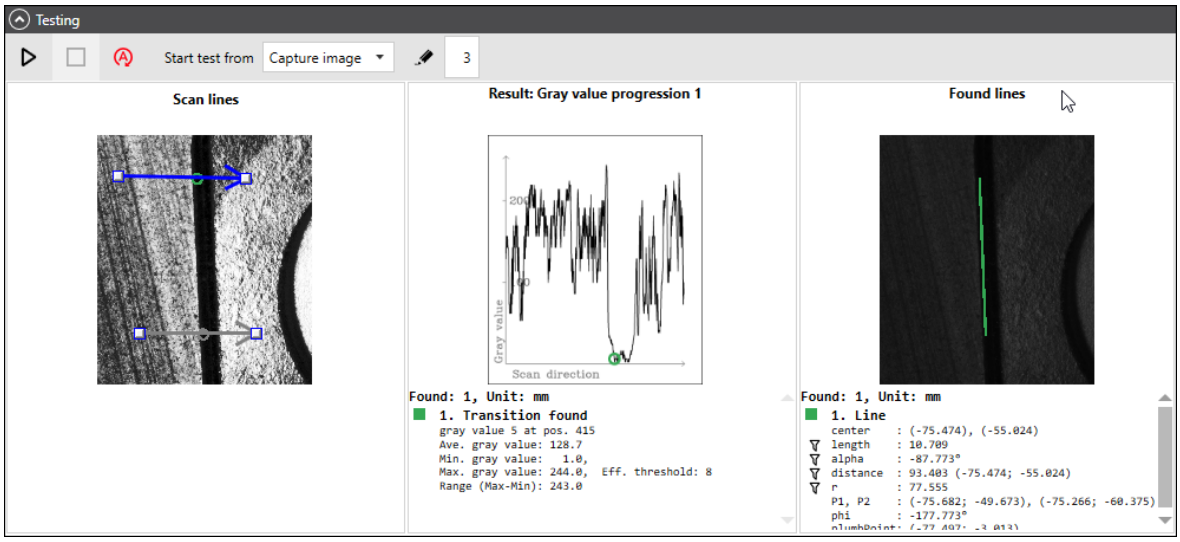


Fig. 4.32: RG_M-ABF

4.4.3.1.1.4 Selection parameters for the line search

The selection parameters can be used to filter the result of the line search by selecting suitable geometric parameters so that exactly one line remains at the end. This line should then correspond with the searched feature.

Parameter	Explanation
Selection	
Length [mm] Min. / Max.	Only lines with a length in this range are accepted.
Center distance [mm] Min. / Max.	Plumb from the center point of the line to the center of the search area. Only lines with a distance to the origin in this range are accepted.
Angle [°] Min. / Max.	Only lines with an *alpha* angle between the x-axis and the line in this range are accepted.
Dominant line	Usually, several lines are found, but only one is of interest. This line can be selected here: ■ *Least central* : The line with the longest plumb to the center of the search area. ■ *Most central* : The line with the shortest plumb to the center of the search area. ■ *Average:* All found lines are averaged into one. ■ *Longest:* The longest line, meaning the one with the greatest distance between start and end point. ■ *Shortest*: The shortest line, meaning the one with the shortest distance between start and end point. ■ *Keep all:* All lines remain in the result list. **NOTE:** This only applies to testing; result processing only accepts one line.

Table. 4.21: RG_M-020

4.4.3.1.2 Circle search

In a circle search, the feature to be detected is circular.

Depending on the variant of the circle search, the complete circle does not necessarily have to be visible in the search-image. However, if only a piece of an arc is visible in the search image, the circle search may not be able to calculate the circle center with sufficient accuracy.

Another aspect of the circle search is the ellipticity. Except for the method of the *best-fit ellipse*, a perfect circle and no ellipse is assumed.

Result: As a result, a circle search with the circle center returns a full-fledged coordinate.

In addition, the radius (or, if it is an ellipse, the axis lengths) is also provided in the result and can be used for a scaling calculation.

There are two detection methods to choose from, which are described in more detail below:

- Best-fit ellipse and
- Three gray-value-transitions.

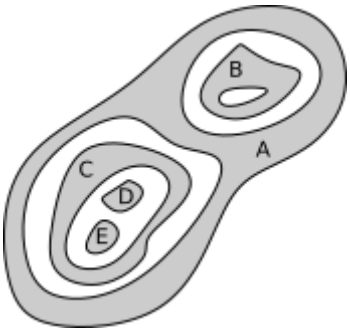
4.4.3.1.2.1 Circle search with “best-fit ellipse” detection method

This method collects all contours using a Canny edge detector and collects the points that make up each contour.

For each of these point sets, the least-squares method is then used to determine an ellipse that best approximates the points.

The following parameters must be defined:

Parameter	Explanation
Edge detection (Canny) Edge detection is often the first step in finding objects. The Canny edge detector is an improvement on the simple Laplacian filter. The Laplacian filter calculates gray value gradients in only two directions. The Canny edge detector uses those two gray value gradients to calculate gradients in four directions. There is also a second threshold value that allows for a kind of contour detection.	
Skip	The Canny edge detector can detect unwanted edges if filters with binary threshold values were used beforehand. That means feature detection works better in this case without the Canny edge detector.
Canny threshold 1 / ExpPCanny threshold 2	There are two threshold values: ■ Canny threshold 1 and ■ Canny threshold 2 (Advanced parameter). One is the upper threshold value, the other the lower threshold value. It does not matter which threshold value is the upper or the lower – they are swapped if necessary. The following threshold value rules apply: ■ *Gradient of a pixel > upper threshold value*: The pixel is accepted as an edge pixel. ■ *Gradient of a pixel < lower threshold value*: The pixel is rejected. ■ *upper threshold value > Gradient of a pixel > lower threshold value:* The pixel is only accepted as part of the edge if it is connected to a pixel whose gradient is above the upper threshold value. The default values are 120 and 180.
Window size	The first phase of Canny Edge Detection is filtering with the Sobel operator. The Window size is the size of the matrix used. The value 5, for example, means that the matrix has a size of 5 x 5 pixels. The standard value here is 3 pixels.

Parameter	Explanation
AdvPL2 gradient	(Advanced parameter) When calculating the directional gradient, the correct L2 norm can be used or the less accurate but faster L1 norm. This option is not active by default.
Contours detection Multiple pixels of an edge form a contour. A contour is a list of points that represent a curve in an image. Contours can be nested inside each other; they separate dark from light regions in the image. Depending on the application, displays as a contour tree, as a list of all contours, or even just as the outermost contour, may be of interest. Example: In the drawing, there are five dark regions (A to E) that have nine contours. Due to the nesting, a contour tree can be constructed that shows which contour is contained in which other contour.  	
ExpPRetrieve type	(Advanced parameter) There are different ways in which contours are determined: ■ *External*: Only the outermost contour of a contour hierarchy is returned. ■ *List*: All contours of a contour hierarchy are returned. The selection is set to *External* by default.

Parameter	Explanation
ExpPApproximation method	(Advanced parameter) There are different ways to represent a contour: ■ *ChainCode*: Contours are output in the Freeman chain code. All other methods return polygons (point lists). ■ *ChainApproxNone:* Translates all points of the contour code into points. Each point is one of the eight neighbors of a point. No reduction of the contour size is performed by approximation. ■ *ChainApproxSimple*: Compresses horizontal, vertical and diagonal segments by storing only the end points. In the case of a horizontal rectangle, for example, only the corner points remain. ■ *ChainApproxTc89L1:* The Teh-Chin chain approximation algorithm is used. It is more elaborate than *ChainApproxSimple*. ■ *ChainApproxTc89Kcos:* Also a Teh-Chin chain approximation, but with minor differences. The selection is set to *ChainApproxSimple* by default.

Table. 4.22: RG_M-013

Example:

In the following example, a solder joint is being searched for. Since the spot is in the corner of the scan field, the circular solder joint is displayed as slightly elliptical

Original image of the search area:

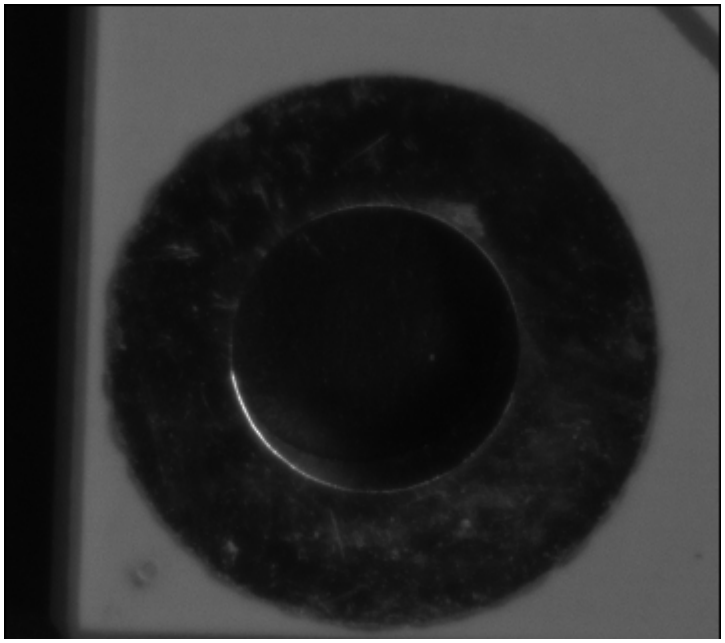


Fig. 4.33: RG_M-AAR

The test result of the search with the “best-fit ellipse” method:

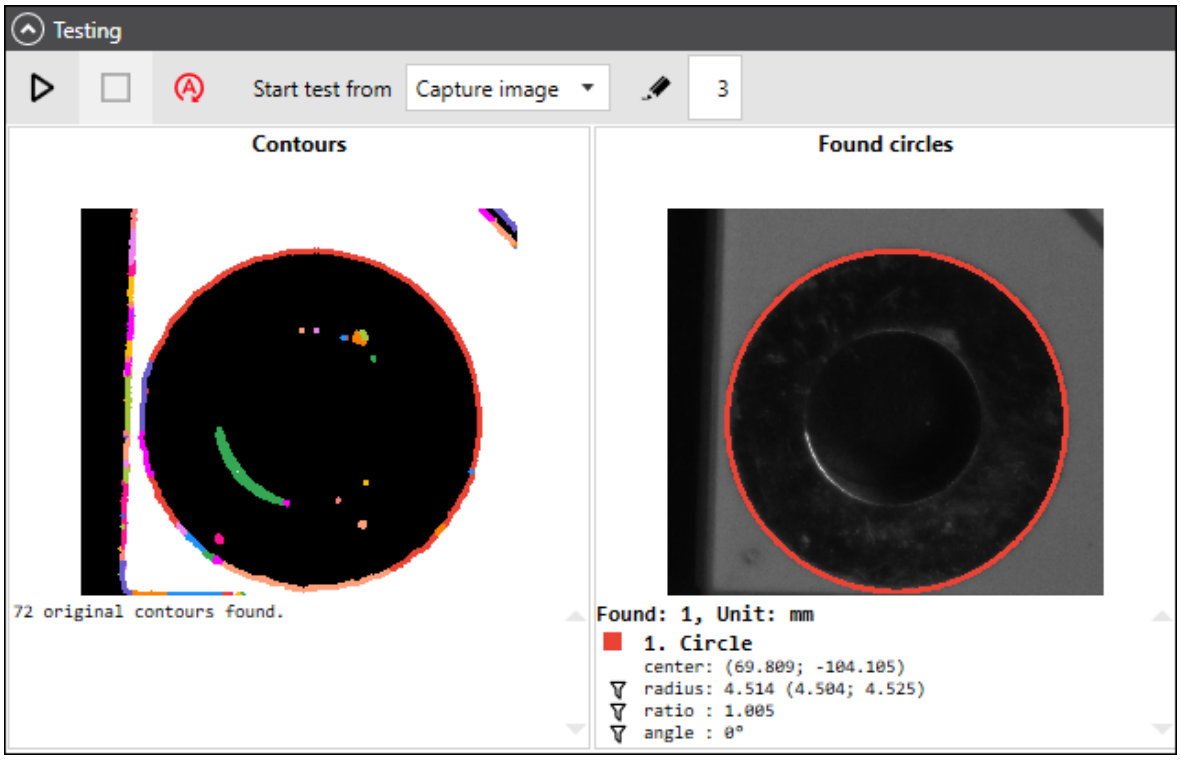


Fig. 4.34: RG_M-AAS

4.4.3.1.2.2 Circle search with “three gray-value-transitions” detection method

For this method, three scanning lines must be defined that intersect the circle being searched for at suitable points. A gray value transition is searched for along each line, which is indicated by a threshold value.

If the threshold values are selected carefully enough, three points of intersection are found, from which the circle center and the radius are then calculated.

The following parameters must be defined:

Parameter	Explanation
Transition lines	
Transition no.	Select for which of the two searched gray-value-transitions transitions the following parameters apply. ■ *Blue line*: The active scanning line is shown in blue in the “Scanning lines” image. ■ *Green line*: The found transition point is shown in the “Scanning lines” image as a small green circle. You can also select the scanning line directly in the test image by clicking one of the end points with the mouse.
Search direction	Select whether you want to search more for ■ The maximum at the transition from *light to dark* or ■ The minimum of the gray value gradient at the transition from *dark to light*.
Peak	**Option 1**: The transition point is determined by the maximum or minimum gray value.
Absolute gray value [1...255]	**Option 2**: The transition point is determined by a predefined gray value and the scanning direction. It lies at the point where the predefined value is reached for the first time.

Parameter	Explanation
Difference gray value [1…255] / Pixel area [pixels]	**Option 3**: If activated, the transition point is determined by a definable gray value difference: Each pixel along the scanning direction is considered a start pixel. The following number of pixels within the *pixel area* are examined. That means the gray value difference between a pixel and the start pixel is calculated. If the difference is equal to or greater than the *gray value difference*, the position of that pixel is returned as the result. If no sufficient gray value difference is found within the *pixel area*, the procedure is repeated with the next start pixel.
AdvPRelative to gray value range [%]	**Suboption for option 2 of 3**: (Advanced parameter) When activated, the search for an absolute or relative threshold value is modified. The threshold value is given as a percentage of the difference between the lightest and darkest gray value found on the scanning line. **NOTE:** This makes the search independent of the absolute brightness and allows the brightness of the image to be changed without affecting the result.
AdvPScan line start point [%] X / Y	(Advanced parameter) The start point of the scanning line in [%] of the height and width of the search area. As a rule, the point in the “Scanning lines” test image is defined using the mouse.
AdvPScan line end point [%] X / Y	(Advanced parameter) The end point of the scanning line in [%] of the height and width of the search area. As a rule, the point in the “Scanning lines” test image is defined using the mouse.
[Flip scan line]	Use the button to invert the scanning direction along the line.
AdvPScan line lenth [mm]	(Advanced parameter) Shows you the resulting length of the scanning line in [mm].

Table. 4.23: RG_M-019

Example:

In this example, the center of a washer must be determined. For the three transitions, distributing them evenly over the available circumference/arc is recommended.

Original image of the search area:

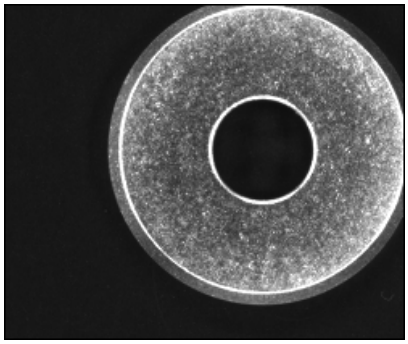


Fig. 4.35: RG_M-ABG

Test result of the search with three gray value transitions:

(**NOTE:** Only the gray-value-gradient along the active blue line is displayed.)

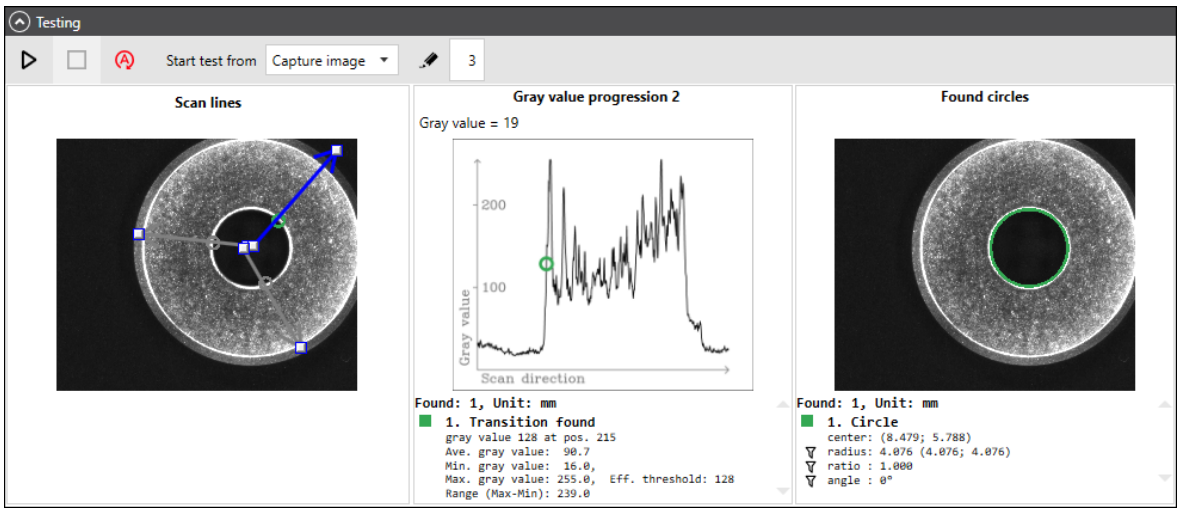


Fig. 4.36: RG_ABH

4.4.3.1.2.3 Selection parameters for the circle/ellipse search

The selection parameters can be used to filter the result of the circle search by selecting suitable geometric parameters so that exactly one circle remains at the end. This circle should then correspond with the searched feature.

Parameter	Explanation
Selection	
Radius [mm] Min. / Max.	Only circles whose radius lies within this value range are accepted. For ellipses, the average of the two half-axes is considered.
Axes ratio Min. / Max.	Only ellipses whose axis ratio lies within this range of values are accepted. The closer the limit values are to 1, the more circular the ellipse must be.
Angle [°]	Only ellipses with an angle that lies within this range of values are accepted. However, the angle here is defined very specifically according to the image processing library and cannot be described unequivocally. That is why using the filter symbol in the search results to specify an appropriate value range is recommended.
Dominant circle	The search results can be additionally limited to a circle or an ellipse by the following selection: ■ *Most central :* The circle with the smallest distance between the center of the circle and the center of the search area ■ *Largest:* Circle with the largest area ■ *Smallest:* Circle with the smallest area ■ *Most circular:* Select the ellipse whose axis ratio is closest to 1. ■ *Keep all*: All found circles remain in the result list. **NOTE:** Only for testing, because the result processing only accepts one corner.

Table. 4.24: RG_M-022

4.4.3.2 Gray-value-transition search

This search finds gray-value-transitions along a scanning line from dark to light pixels (or vice versa) using a threshold value.

The result is the pixel position of the found gray-value-transitions, transformed into the world coordinates of the workspace.

In general, the search is used to calculate the offset of an edge in relation to another image (the one from the teaching process).

The offset is determined perpendicular to the edge. That means this search is primarily recommended only if you are calculating with an offset in one direction only.

The following parameters must be defined:

Parameter	Explanations
Search direction	Select whether you want to search more for ■ The maximum at the transition from *light to dark* or ■ The minimum of the gray value gradient at the transition from *dark to light*.
Peak	**Option 1**: The transition point is determined by the maximum or minimum gray value.
Absolute gray value [1...255]	**Option 2**: The transition point is determined by a predefined gray value and the scanning direction. It lies at the point where the predefined value is reached for the first time.
Difference gray value [1…255] / Pixel area [pixels]	**Option 3**: If activated, the transition point is determined by a definable gray value difference: Each pixel along the scanning direction is considered a start pixel. The following number of pixels within the *pixel area* are examined. That means the gray value difference between a pixel and the start pixel is calculated. If the difference is equal to or greater than the *gray value difference*, the position of that pixel is returned as the result. If no sufficient gray value difference is found within the *pixel area*, the procedure is repeated with the next start pixel.

Parameter	Explanations
AdvPRelative to gray value range [%]	**Suboption for option 2 of 3**: (Advanced parameter) When activated, the search for an absolute or relative threshold value is modified. The threshold value is given as a percentage of the difference between the lightest and darkest gray value found on the scanning line. **NOTE:** This makes the search independent of the absolute brightness and allows the brightness of the image to be changed without affecting the result.
AdvPScan line start point [%] X / Y	(Advanced parameter) The start point of the scanning line in [%] of the height and width of the search area. As a rule, the point in the “Scanning lines” test image is defined using the mouse.
AdvPScan line end point [%] X / Y	(Advanced parameter) The end point of the scanning line in [%] of the height and width of the search area. As a rule, the point in the “Scanning lines” test image is defined using the mouse.
[Flip scan line]	Use the button to invert the scanning direction along the line.
AdvPScan line lenth [mm]	(Advanced parameter) Shows you the resulting length of the scanning line in [mm].

Table. 4.25: RG_M-015

NOTE: This search does not offer any other selection parameters to narrow down the search results.

Example:

In the following example, the gray value transition is searched for at a point in a workpiece geometry.

Original image of the search area:

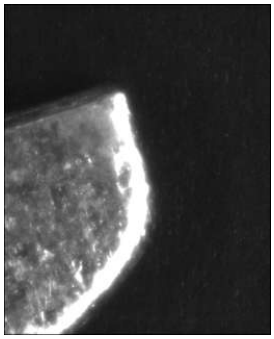


Fig. 4.37: RG_M-AAV

Test result of simple gray value transition search:

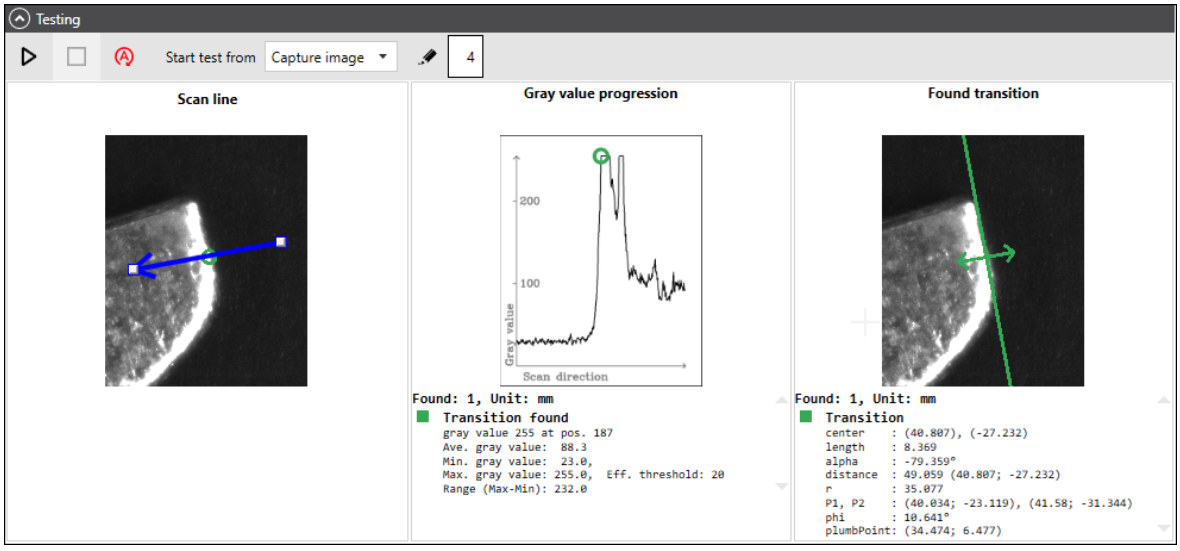


Fig. 4.38: RG_M-AAW

4.4.3.3 Corner search

There are two classes of algorithms:

- The first searches for corners directly and can, for example, detect the corners of a rectangle.

  This is done by moving a window pixel by pixel across the image. The gray values found in the window are weighted and the differences are calculated.

  Large differences indicate corners, whereby a threshold value is taken into account.

  Rounded corners cannot be found this way (these are lines with gradients in only one direction).
- The second class first performs a line search and calculates all intersection points of all found lines.

  This can lead to many unwanted corner points, but allows for the detection of “corners” of rounded objects.

  As with the normal line search, the first step is Canny edge detection.

The following detection methods are available:

- “Shi/Tomasi” method
- Line intersection point (line search with fit-line-method)
- Line intersection (line search with fast-line method)

4.4.3.3.1 Corner search with “Shi and Tomasi” detection method

This search works in much the same way as the Harris algorithm, but with improvements from J. Shi and C. Tomasi. These improvements lead to fewer but more relevant points.

However, this method is somewhat more sensitive to noise and can only detect sharp corners.

The following parameters must be defined:

Parameter	Explanations
“Shi and Tomasi” parameters The corner search with the Shi and Tomasi method works similarly to the Harris search. A convolution window is moved over the image and differences are calculated. However, the parameters are different; for example, there is a quality parameter instead of a threshold value.	
AdvPMax. number of corners	(Advanced parameter) Maximum number of corners found. The search is stopped after this number of corners has been found. 100 corners are defined by default.
Quality level	Instead of a threshold value, a quality level is used for the calculation. The quality level is defined as a fraction of the largest intrinsic value. The value of the quality level should be between 0.1 and 0.001. A value of 0.1 corresponds to higher quality. This results in fewer corners being found.
Min. corner distance [mm]	(Advanced parameter) If corners of lower quality are found in the vicinity of a corner of higher quality, they are ignored within a radius of this value.
AdvPBlock size [pixels]	(Advanced parameter) This is the size of the window used for the convolution calculation. That means the value controls how many neighboring pixels are considered in the convolution. The default value is set to 3.
AdvPHarris metric	(Advanced parameters) If activated, the normal Harris algorithm is used, without the improvement of the Shi and Tomasi method. This option is not active by default.
AdvPHarris metric value	(Advanced parameter) A constant to control the Harris metric used.

Parameter	Explanations
Subpixel calculation The following settings control the Subpixel calculation. This is an iterative process that is controlled by ■ The specification of an accuracy at which the iteration stops as soon as it is achieved ■ Or the maximum number of iterations The process ends as soon as one of the two criteria is met.	
Activate	Activates the Subpixel calculation
AdvPWindow size [pixels]	(Advanced parameter) This value controls how many neighboring pixels of a pixel are taken into account in the subpixel calculation.
AdvPZero zone size [pixels]	(Advanced parameter) During subpixel calculation, the neighboring pixels taken into account are defined by the *Window size [pixels]* parameter. However, the algorithm used can become unstable due to the pixels in the center of the window. These pixels can be excluded by defining an exclusion area. Default setting: No exclusion area, values: (-1, -1).
AdvPAccuracy	(Advanced parameters) If activated, the iteration ends as soon as this accuracy has been achieved. Default setting: 0.1.
AdvPMax. iterations	(Advanced parameters) If activated, the iteration ends as soon as this number of iterations has been achieved. Default setting: 5.

Table. 4.26: RG_M-016

Example:

In the following example, a sharp corner of a contact tab must be found. The corner search for “Shi and Tomasi” is suitable here because the corner is relatively sharp.

Original image of the search area:

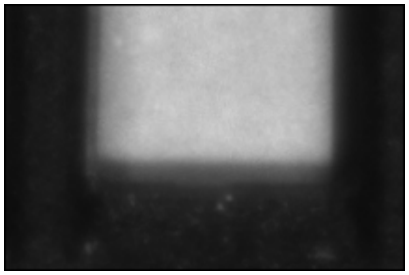


Fig. 4.39: RG_M-AAX

Test result of the corner search using the Shi and Tomasi method:

Fig. 4.40: RG_M-AAY

4.4.3.3.2 Corner search with the “line intersection” detection method

This search is based on an algorithm that searches for two lines. The point where the lines intersect is evaluated as a corner, which also allows searching for rounded or beveled corners.

The following line searches are available:

- Fit-line method:

  For parameter *page 131, Line search with “best-fit line” detection method*.
- Fast-line method:

  For parameter *page 138, Line search with “Fast Line” detection method*.

4.4.3.3.3 Selection parameters of the corner search

The selection parameters can be used to filter the result of the corner search by selecting suitable geometric parameters so that exactly one corner remains at the end. This corner should then correspond with the searched feature.

Parameter	Explanation
Selection	
Distance [mm] Min. / Max.	Only corners with a distance to the center of the search area within this value range are accepted.
Length [mm] Min. / Max.	**Only for line intersection points:** Only intersections with lines whose length lies within the value range defined here are accepted as corners.
Cutting angle [°] Min. / Max.	**Only for line intersection points:** The intersection of two lines is only accepted as a corner if the intersection angle lies within this value range.

Parameter	Explanation
Dominant corner	Usually, several corners are found, but only one is of interest. This corner can be selected here: ■ *Most central:* The corner with the smallest distance between the corner point and the center of the search area. ■ *Least central*: The corner with the largest distance between the corner point and the center of the search area. ■ *Intersection point fo two longest lines*: The corner that results from the intersection of the two longest lines is selected **NOTE:** Can only be selected if a corner search with line intersection is used. ■ *Average*: All found corners are averaged into one. ■ *Keep all*: All found corners remain in the result list. **NOTE:** Only for testing, because the result processing only accepts one corner.

Table. 4.27: RG_M-023

Example: In the example, a search is done for a rounded corner of a housing.
Original image of the search area:

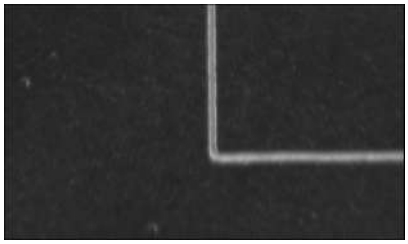


Fig. 4.41: RG_M-ABI

Fast-line method

Lines are determined whose intersection point then yields the corner point.

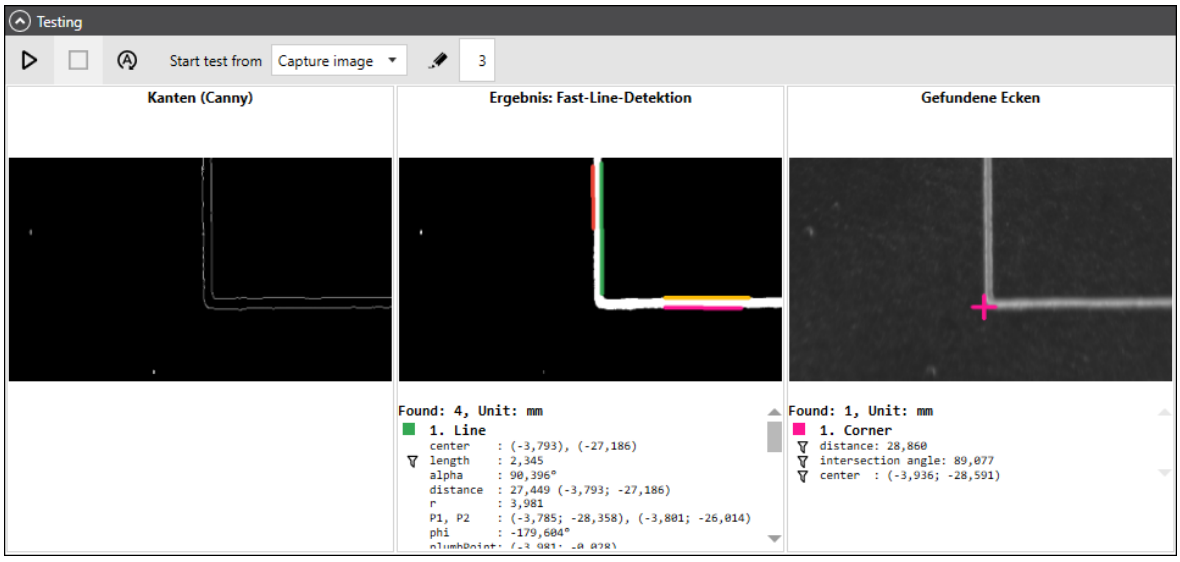


Fig. 4.42: RG_M-ABJ

Method of the best-fit line (alternative)

Lines whose intersection point then yields the corner are searched for:

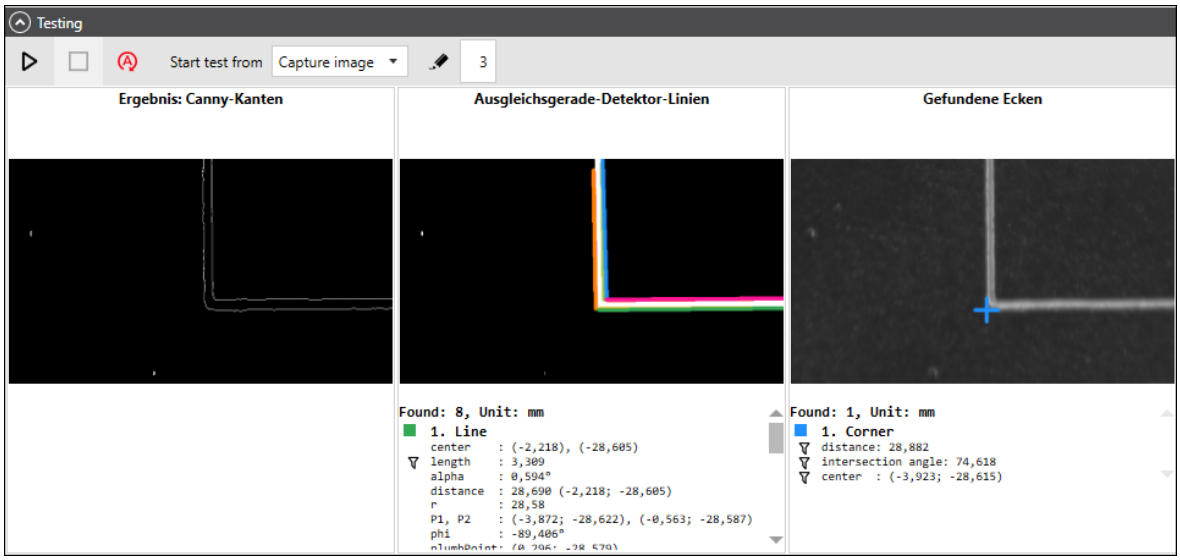


Fig. 4.43: RG_M-ABK

4.4.3.4 Searching for feature using template

4.4.3.4.1 Template search

When searching with templates, the algorithm searches a feature in the large search area, which equals the feature in the small template-image.

NOTE: The template must be smaller than the search area.

The main advantage of this search is that the feature can be of any shape. The template search is particularly well suited when the workpieces do not have any clear geometric features.

However, this search can be relatively time-consuming because the search area is scanned with the template image.

NOTE: When using this search, the use of filters should be avoided. These lead to more differences between the image of the search area and the template. That means that a pixel-perfect match is less likely.

The following parameters must be defined:

Parameter	Explanation
Template file name	Select the image file that will serve as a template. **CAUTION:** The camera resolution of the template image must match that of the search area image.
Quality threshold [0...1]	Indicates how similar the location of the template is. A point that is found again in the search area has a quality value between 0 and 1.

Parameter	Explanation
AdvPComparison procedure	(Advanced parameter) Two different metrics are available here for comparing the template with a location in the search area. ■ **CCorrNormed**: (Standard) $$Q(x,y) = \frac{\sum_{x',y'} T(x',y') \cdot I(x+x',y+y')}{\sqrt{\sum_{x',y'} T(x',y')^2 + \sum_{x',y'} I(x+x',y+y')^2}}$$ ■ **CCoeffNormed**: The same formula as above is used, but T and I are replaced by T' and I', which are defined as follows: $$T' = T(x',y') - \frac{\sum_{x'',y''} T(x'',y'')}{w \cdot h}$$ $$I'(x+x',y+y') = I(x+x',y+y') - \frac{\sum_{x'',y''} I(x'',y'')}{w \cdot h}$$ Formula characters: Q = Quality value T = Template image I = Search region (image) w = Width of a template h = Height of a template
AdvPAngle [°] (of the template)	(Advanced parameter) This angle can be entered here if the expected angle of the feature in relation to the template has changed. This saves having to record a new template image. If the rotation angle is not known, you can define an angle search range in the following input fields and have them searched automatically. That means you can specify the angle or have it determined. However, determining the angle will take time.
AdvPMin. search angle	(Advanced parameter) Enter the smaller of the two angles at which the template is expected to rotate relative to the search area.
AdvPMax. search angle	(Advanced parameter) Enter the larger of the two angles at which the template is expected to rotate relative to the search area.

Parameter	Explanation
AdvPIncrement	(Advanced parameter) If the smallest and largest search angles differ, the system automatically searches for rotated occurrences of the template in the search area. In this field, you can specify the step size used to repeat the template search in the angle area. **NOTE:** The larger the range for the angle and the smaller the step size, the more search iterations are performed, which makes the search more time-consuming. On the other hand, an exact angle match of the template increases the quality score of the search.
AdvPOptimize angle	(Advanced parameter) If activated, the angular accuracy of a found template is optimized in an additional iterative process. This process searches for a better result around the found angle in a range ± *Increment*. This optimization is only applied if the value for the step size is ≠0

Table. 4.28: RG_M-024

Example:

The following example shows a search for an irregular hole in a key.
Original image of the search area:

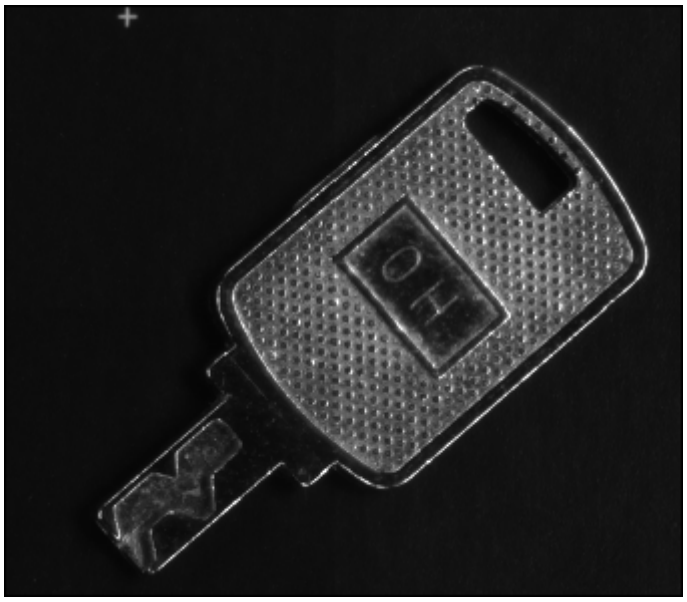


Fig. 4.44: RG_M-ABL

Test result of the template search:

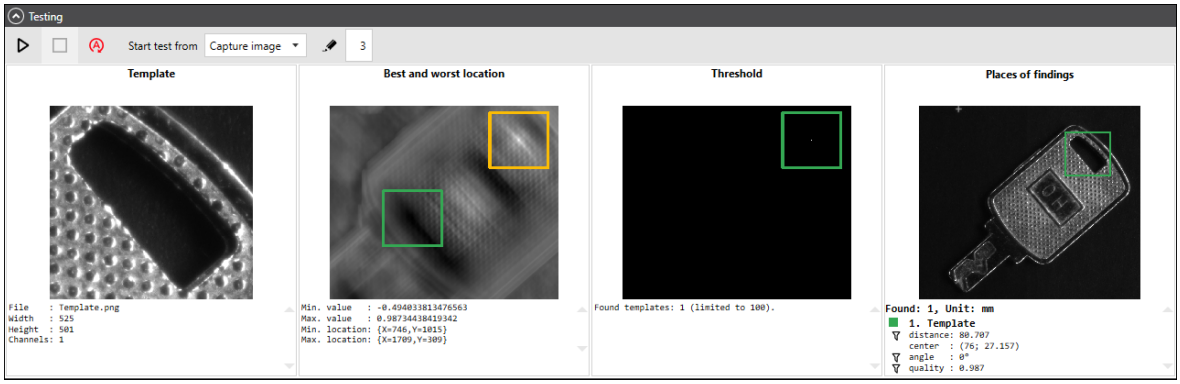


Fig. 4.45: RG_M-ABM

4.4.3.4.2 Selection parameters for the template search

The selection parameters can be used to filter the result of the template search by selecting suitable geometric parameters so that exactly one template position remains at the end. This template position should then correspond to the searched feature.

Parameter	Explanations
Selection	
Center distance [mm] Min. / Max.	Matching templates are only accepted as results if their distances lie within this value range (measured from the center of the the template-bounding-box to the center of the search area).
Angle [°] (of the template) Min. / Max.	Matching results are only accepted as a result if their rotation angles lie within this value range.
Allowed object distance [mm]	If the distance between two matching results is smaller than this value, they are considered to be the same result. The result with the lower quality level is removed from the list.
Dominant place of finding	The search results can be limited to one result using the following selection: ■ *Best quality:* Only the reference point with the best quality is selected. ■ *Least central:* The result with the largest distance between the center of the result and the center of the search area. ■ *Most central:* The result with the smallest distance between the center of the result and the center of the search area. ■ *Keep all*: All results remain in the result list.

Table. 4.29: RG_M-025

4.4.4 Result processing

At the end of a processing job, the image processing job element of the **Result processing** is needed to process the results of the individual **searches** and determine the necessary process transformation.

Element	Explanation
Input	
Detect objects automatically	When this option is set, both the number and the type of objects are automatically determined from the image processing job sequence through to processing of the results. **NOTES:** The integrated logic also informs you if too many searches have been added to the job sequence in advance. This causes over-determination. Depending on the search and its information content, it may not be possible to determine all values of the process transformation (e.g. scaling). If this is the case, the value cannot be selected.
Number of objects to find	This field is set automatically if *Detect objects automatically* is used. If you do not use this option, enter the number of features to be searched for respectively the number of searches to be analyzed. The object list below contains more or fewer entries depending on the number entered here.
n-th object	This field is automatically set with the search entry in the order defined in the job sequence if *Detect objects automatically* is used. If you do not use this option, specify here which search returns a search result first, second, etc. in the job sequence.
Expected coordinate / Expected bounding box angle / Expected start point / Expected end point	Depending on the search, the expected coordinates, angles and line-points of the search are displayed here for the taught-in position. As long as no teach-in has taken place, these values are zero by default.

Table. 4.30: RG_M-030

4.4.4.1 Testing and teaching in

At the beginning, image processing has no reference. This means that all values (“expected coordinate”, etc.) have the value zero. If additional test runs are carried out, the process transformation determined for offset and angle should be approximately zero.

Deviations that can still be seen can primarily be explained by image noise. However, larger deviations indicate that detection is not yet reliable.

Once you have optimized the detection task to such an extent, that the features to be detected are detected reliably, you can position a reference-workpiece. In the result-processing, you can determine the location of this workpiece and then teach it in using the ***[Set reference data]*** button.

Teaching is the step in which a position of a workpiece to be detected is defined as a reference for all subsequent workpieces.

Before teaching, the contour is usually adjusted with CLICK & TEACH and positioned appropriately in relation to the reference workpiece.

CAUTION: Do not change any relevant settings of the job-elements used for detection after teach-in. This would affect the detection result and the previous reference would become invalid.

Parameter	Explanations
Output validation The transformation determined from the searches can still be validated to be meaningful. Define here the tolerance range within which the values of the process transformation are valid. An error message is displayed if this range is exceeded. Transformation values that exceed the expected position tolerances indicate that incorrect features may have been detected or that the workpiece is in an unexpected position.	
Max. allowed offset [± mm] X / Y	Enter the values for the maximum expected offset in [mm] here.
Max. allowed scale [1± mm] X / Y	Enter the values here as a summand by which the expected scaling may deviate from the factor 1.
Max. allowed rotation [± °]	Enter the value for the maximum expected rotation in [degrees] here.
Output The core task of position detection is to determine and set the process transformation to be used by the control card.	
AdvPWrite port	(Advanced parameter) If desired, information can be output via the I/O port or serial interface if the detection task has been successfully completed.

Parameter	Explanations
Process transformation	Select here which parts of the process transformation must be set in order to adapt the following laser processing to the appropriate workpiece position after position detection. **Selection**: ■ Offset , ■ Rotation, ■ Scale. **NOTES:** ■ The process transformation is only set automatically if the image processing job is started as part of a RAYGUIDE job using the regular execution panel with the *Execution* panel. ■ If the image processing job is executed in its main dialog using the ***[Run]*** button, the process transformation is not set. ■ To set the process transformation when the results processing dialog is open, this must be done directly using the ***[Set process transformation]*** button.
Testing It is also possible to carry out test runs to test the foregoing detections and the resulting process transformation. In particular, this can be used to test the repeatability: With a number of test runs ≠ 1 and the same conditions (illumination, workpiece), the same transformation can always be expected for n runs.	
[Start test-run] 	Click the button to start the test run(s).
[Abort test-run] 	Button for canceling the current test run(s).
Test runs	Number of test runs to be performed.
Start test from	Specify here from which image processing job element the test run should start. The selection list is automatically filled with the image processing job elements used. The first image processing job element is always selected by default.
Line width 	Define the thickness of the lines in pixels that mark the search results in the result images.

Parameter	Explanations
[Set reference data] 	If the searches reliably detect the features and a workpiece is present in the so-called reference position, this position (or the information obtained from the searches) is **taught in** to the workpiece by clicking on the ***[Set reference data]*** button. This sets the values for the expected coordinates in the **input** area. A process transformation with an offset of approximately 0, rotation = 0 and scaling = 1 is to be expected in a test run done right after. Any otherwise varying and detected workpiece position results in a process transformation. **NOTE:** If several test runs have been carried out (by entering a value > 1 in the *Test runs* field), the average values of the found data are used as reference data.
[Set process transformation] 	You can use this button to transfer a determined process transformation to the control card and apply it.
[Reset process transformation] 	Use this button to reset a currently active process transformation. When the process transformation is otherwise usually automatically reset, see *page 84, Process transformation*.

Table. 4.31: RG_M-026

4.4.4.2 Evaluation of test runs

If you run the search multiple times to check the repeatability and reliability of the search

- For one and the same feature
- In one and the same workpiece (without changing its position)

the following scenarios or results may occur when the program is run in automatic sequence:

All test runs were successful

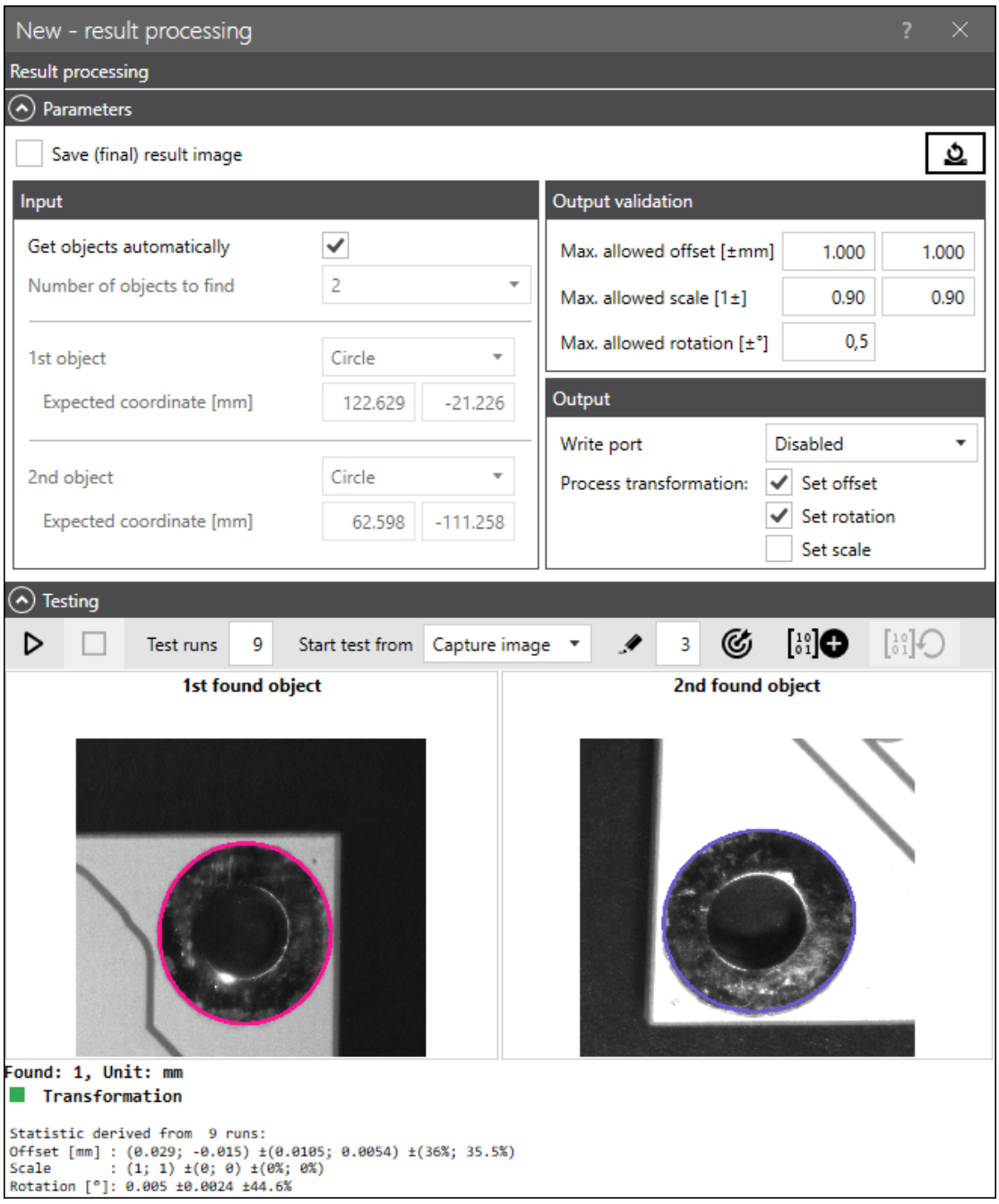


Fig. 4.46: RG_M-ABN

The average value and the standard deviation from the taught-in position are displayed in the statistics. This provides an indication of how precise the detection is despite image noise.

One or more test runs have failed

A list of all test runs is displayed, showing which run failed for which search. The corresponding searches should then be optimized for reliability before switching to automatic mode.

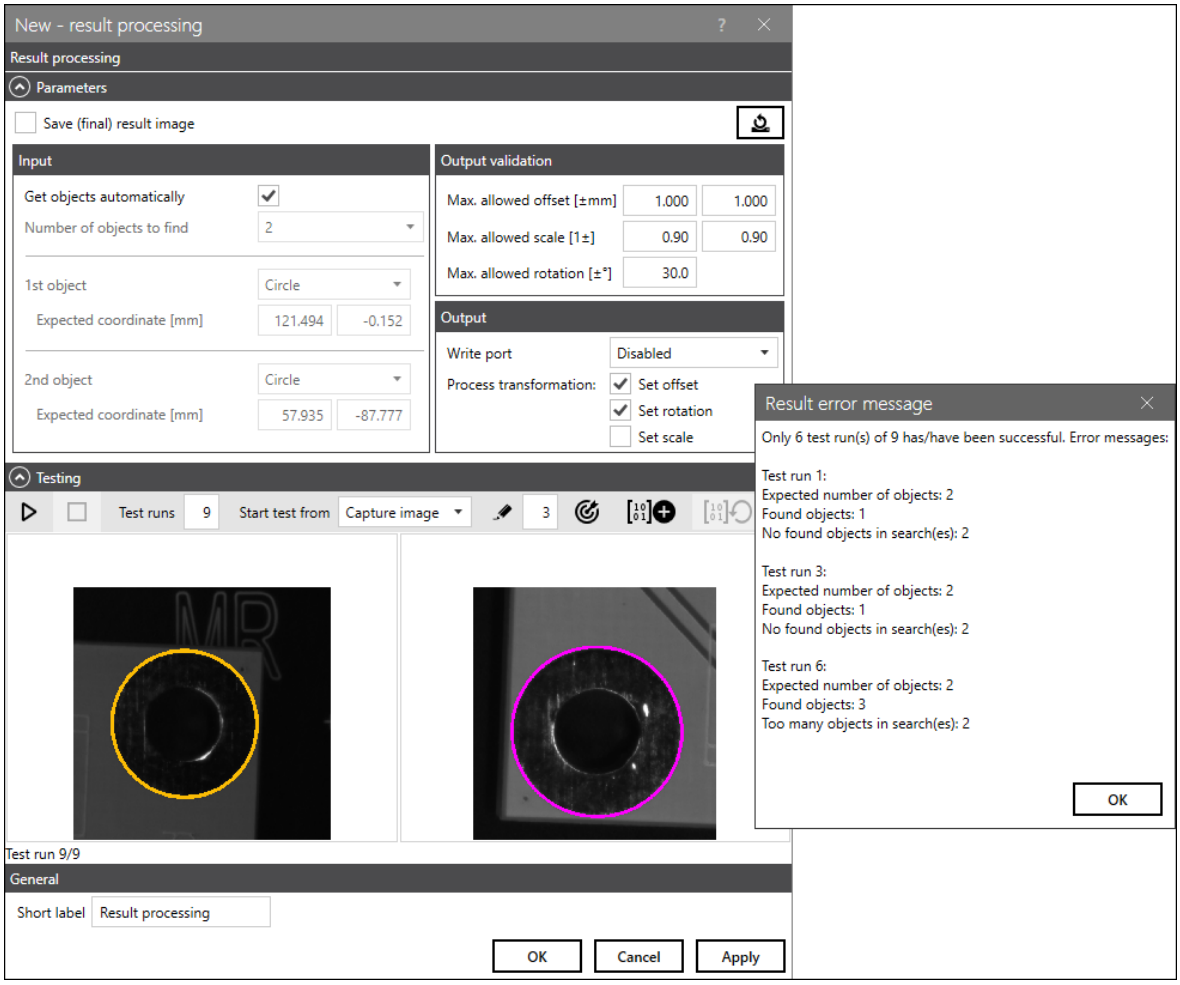


Fig. 4.47: RG_M-ABO

In the example, you can see that...

- In one search run, one of the two circle searches (in this case the second) returns too many circles as a result.
- In another search run, one of the two circle searches (in this case the second) does not find any circles at all and returns no result.

4.5 General settings and functions of the image processing job elements

4.5.1 Settings per Image processing job element

All image processing job elements, namely *Capture image*, *Filter image*, *Search* and *Result processing*, offer the following settings by default at the top of the dialog:

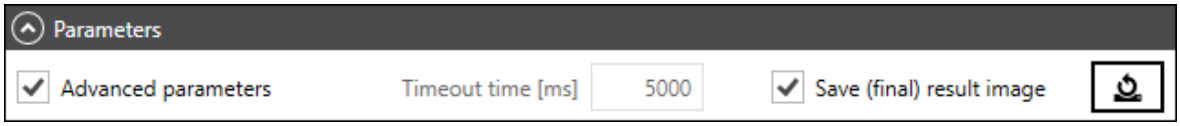


Fig. 4.48: RG_M-AAT

Parameter	Explanations
Advanced parameters	Activates the view of the so-called Advanced parameters. It requires in-depth expertise to adjust these parameters favorably. These Advanced parameters are preset according to experience so that adjustment is rarely necessary. **NOTES:** ■ The mere visibility of the parameters does not determine whether these parameters are used or not. ■ Activation of the Advanced parameters automatically starts a new test run, provided that the ***[Automatic testing]*** is activated.
Timeout time [ms]	Define the time from which a timeout will result in cancellation. This cancellation is treated the same as a failed search during error handling.
Save (final) result image	Activates saving of the final result image including the marked search results. Whether and when the image is saved can be defined in the settings options of the image processing job, see *page 91, Creating and executing an image processing job*.
[Reset] 	Resets all values to default values (including currently invisible Advanced parameters). This also includes the selection parameters.

Table. 4.32: RG_M-014

4.5.2 Dialog area: Testing

4.5.2.1 Performing test runs

All image processing job elements (*Capture image*, *Filter image*, *Search*, *Result processing*) have the option of performing a test run to understand and evaluate the effect of the currently set parameters.

To test the ***Result processing*** image processing job element, see *page 173, Testing and teaching in*.

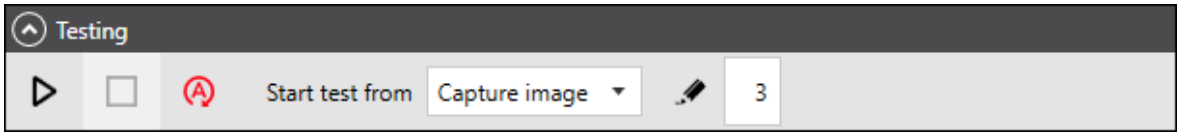


Fig. 4.49: RG_M-AAU

Element	Explanation
[Start test-run] 	Button for starting the test run.
[Abort test-run] 	Button for canceling the current test run.
[Automatic testing] 	Toggle button When activated, it ensures that a new test run starts immediately after each parameter change.
Start test from	Specify here from which image processing job element the test run should start. The selection list is automatically filled with the image processing job elements used and the first image processing job element is selected by default.
Line width 	Define the thickness of the lines in pixels that mark the search results in the result-images.

Table. 4.33: RG_M-027

4.5.2.2 Result images of the test runs

4.5.2.2.1 Capture image

The result displayed here is the so-called raw image for the following search.

This makes it possible to check whether the feature to be searched for was captured with enough leeway for position tolerances.

4.5.2.2.2 Filter image

There are usually always two images presented here: The raw image and the filtered image.

This makes the effect of the filter immediately visible.

4.5.2.2.3 Search

The number of result images displayed can vary depending on the search. Selecting or deselecting expert mode also usually has an influence on which intermediate steps of a search are displayed using a result image.

The results are marked in the images using colored lines. The line width is adjustable.

In most cases, the first image shows the results of the edge search. The other images show the results of the contour search or the active gray value transition. The last image (far right) shows the actual search result.

Information on the number of objects searched for can be found below the images.

Depending on the feature searched for, the results are also displayed for all images (intermediate steps, final result image).

If there are multiple results, the following option is available to reduce the result to one:

1. Identify the desired search result from the set of results.
2. Use the ***[Set filter]*** button to transfer the values of the desired result for a selection parameter including tolerance.

Example:

In this example, instead of just one circle or ellipse, two circles or ellipses were found with the used search parameters. The aim now would be to use the selection filters to reduce the results to just the desired circle.

The selection parameters can be defined most effectively by transfer using the filter-buttons.

The corresponding selection criterion is sized with a range around the corresponding value of the desired result.

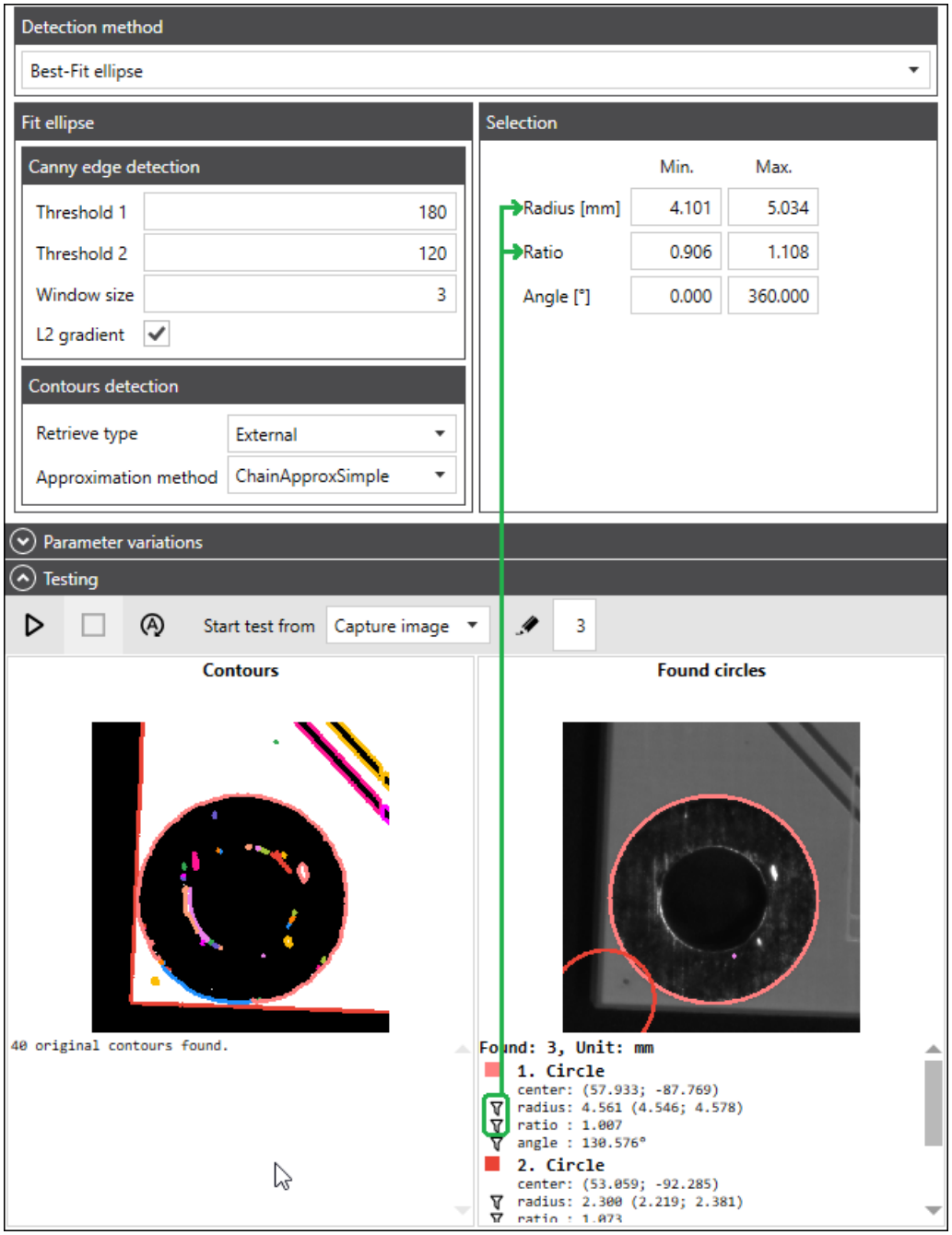


Fig. 4.50: RG_M-ABS

4.5.2.2.4 Result processing

When processing the results, the final result image is displayed for each search involved. The search result is marked in color.

The result values are displayed under the result images. The process transformation derived from the search results for offset, rotation and scaling relative to the taught-in reference is also displayed.

NOTE: If one of the searches returns no results, no result image for that search will be displayed. That means that, for example, it may happen that only one result image is available for two searches.

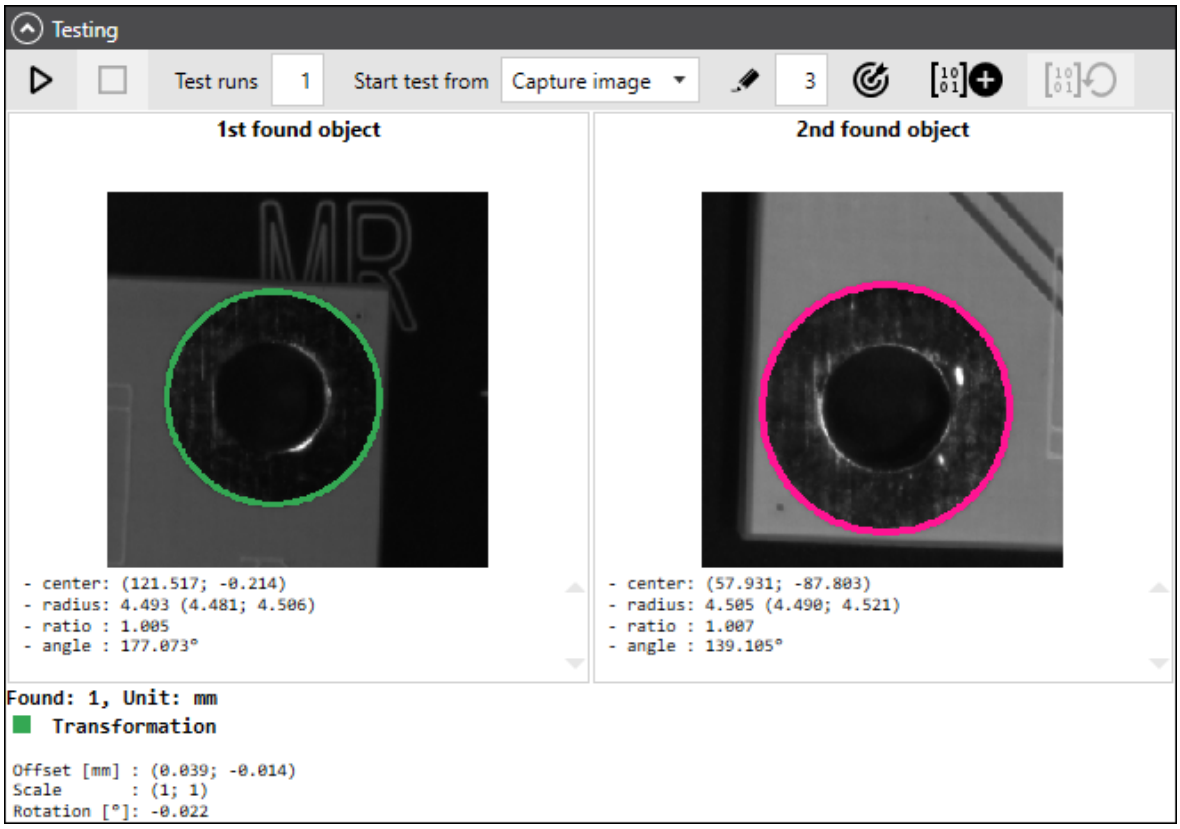


Fig. 4.51: RG_M-ABR

4.5.2.3 General options for result images

The following options are available via the context menu (right-click) independently of the image processing job element:

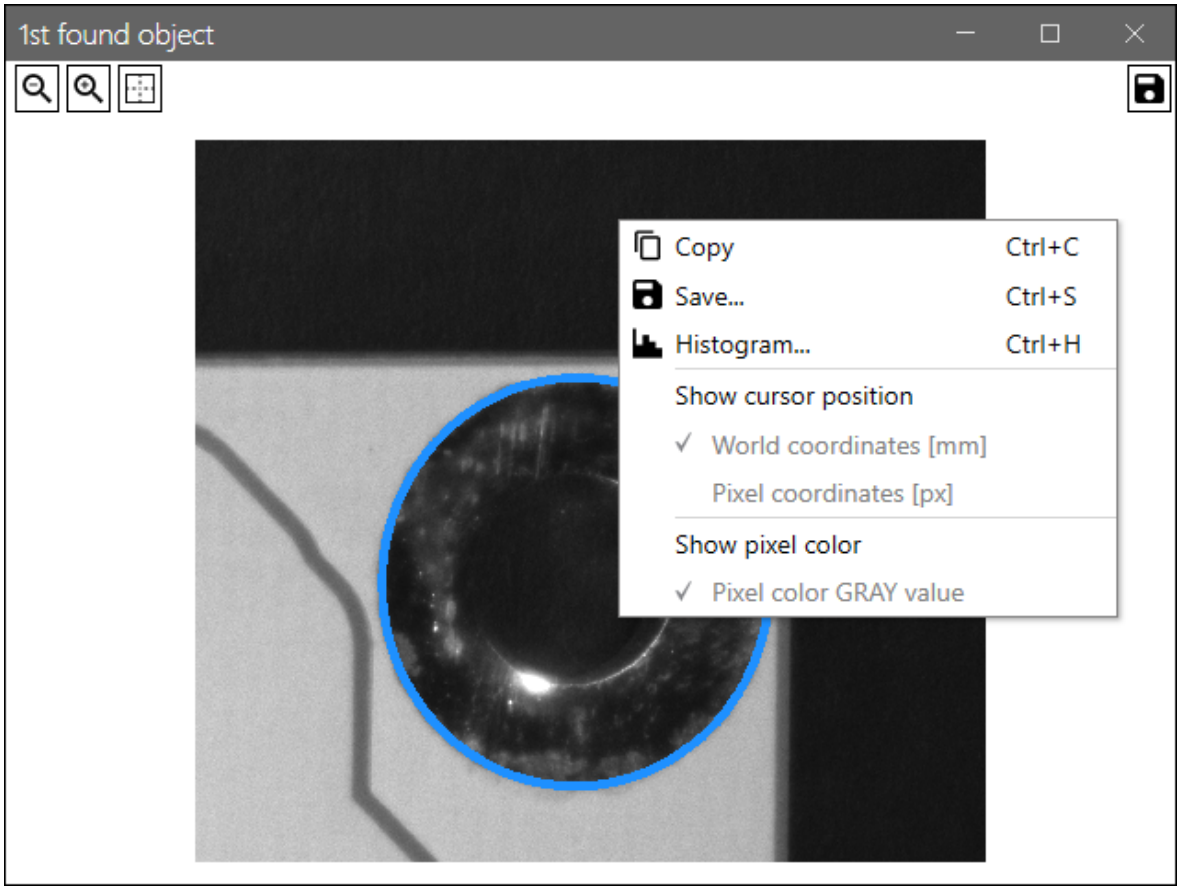


Fig. 4.52: RG_M-ABT

Element	Explanation
Copy	Copy image to clipboard
Save...	Opens the standard dialog for saving files. The default format for result images is PNG.
Histogram	Opens a window to display the statistical distribution of the gray values
Show cursor position	The cursor position is displayed above the image either in *world coordinates* with the unit [mm] (relative to the origin of the RAYGUIDE workspace) or in *pixels* with the unit [px] (relative to the respective image).
Show pixel color	Select this option if you want to see the gray value at the cursor position in addition to the coordinates

Table. 4.34: RG_M-028

Detail zoom

Double-click on the images to open them in a separate window. This also gives you the option to zoom into the details of the image. You can also save images from this window.

Automatic saving of result images

There is an option to save the result images. To do so, see the settings in *page 91, Creating and executing an image processing job* and *page 178, Settings per Image processing job element*.

4.5.3 Dialog area: Parameter variations

The *Parameter variations* option can be found both in the *Capture image*, *Filter image* job elements and in all *searches*.

You can use this option to repeat a search with different settings that influence the result, thus preventing a failed search.

Of course, every parameter variation takes time. However, it may be worth investing the time if it increases the probability of a successful search result.

Not only the parameters of the actual *search*, but also parameters of the upstream objects such as the *Capture image* or *Filter image* can be used for parameter variation.

In order to be able to use parameters of a filter in the subsequent search and its parameter variation, for example, these must be selected and set in the *Filter image* job element.

Whether the parameters are used or not is then set via the *Use when varying* checkbox.

Element	Explanation
Select parameter	Select the parameter to be varied. **NOTE:** Only parameters that are defined by a numerical value are available for selection.
[Add]	Click on the ***[Add]*** button to create a new table row with the selected parameter.
Use when varying	**Only for job elements of the Capture image, Filter image** type: Only when active, the parameters selected here for these image processing job elements are also taken into account for the parameter variation of the following job elements of the *Search* type.
Vary	**Only for job elements of the Search** type: The parameters are only varied if this option is active.
Permutate	If you select this option, all possible combinations of all selected parameters are tried out. Sequence using the example of two parameters: ■ Parameter 1 (all variations); Parameter 2 at Base value ■ Parameter 1 (all variations), Parameter 2 at Base value + 1. Delta ■ Parameter 1 (all variations), Parameter 2 at Base value + 2. Delta ■ Parameter 1 (all variations), Parameter 2 at Base value + 3. Delta etc.

Element	Explanation
Parameters to vary **NOTE:** Parameters that are set by a previous job element are grayed out and cannot be edited directly.	
Parameter	Display of the previously selected parameter
Base value	Defines the starting value from which the value is varied. This value corresponds to the set value by default.
Delta	Defines how much the value is varied per attempt.
Trials	Defines the number of attempts.
Alternate delta	If activated, the value used is increased by the delta, then decreased, then increased again, and then decreased again, etc., starting from the starting value. Example: Initial value = 100, delta = 10 1. Value = 110 2. Value = 90 3. Value = 120 4. Value = 80, etc.
Current value	Displays the currently set value. **NOTE**: Some parameters have a limited value range. If a value outside of the valid range is obtained through the variation, only the permissible values are used.
Counter	The counter shows the current number of attempts made.

Table. 4.35: RG_M-029

NOTE: The parameter variations are ended as soon as the search is successful. Successful means that the search returns exactly one result (not several or no results), but this does not necessarily mean that the feature being searched for has been optimally detected.

Example: Example of parameter variation, composed of two image processing job elements

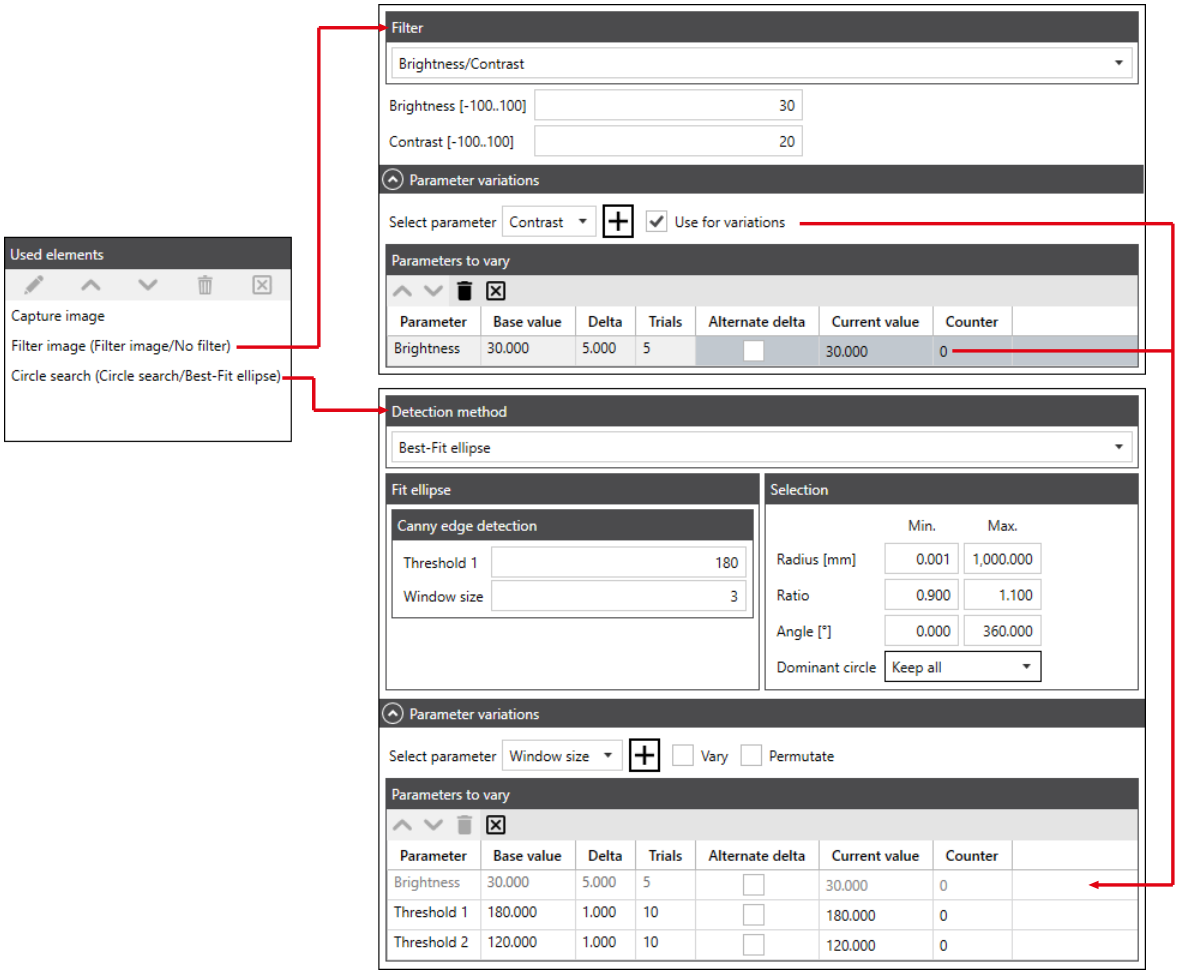


Fig. 4.53: RG_M-ABU

5 CAMERA EMULATOR

The camera emulator is available for testing, presentation and training purposes. It can be used to simulate the operation of most C&T functions, such as calibration and picking / tiling, without having to connect an actual camera.
If a deflection unit with a pilot laser is available, the functionality of C&T can be demonstrated clearly even without a real laser.

Instead of having to record images, the emulator already contains a large image from which, depending on the mirror position, sections can be shown as "live" images or image tiles. As with real cameras, the emulator is designed as a RAYGUIDE plug-in. To work with an emulated camera, first add it as a device:

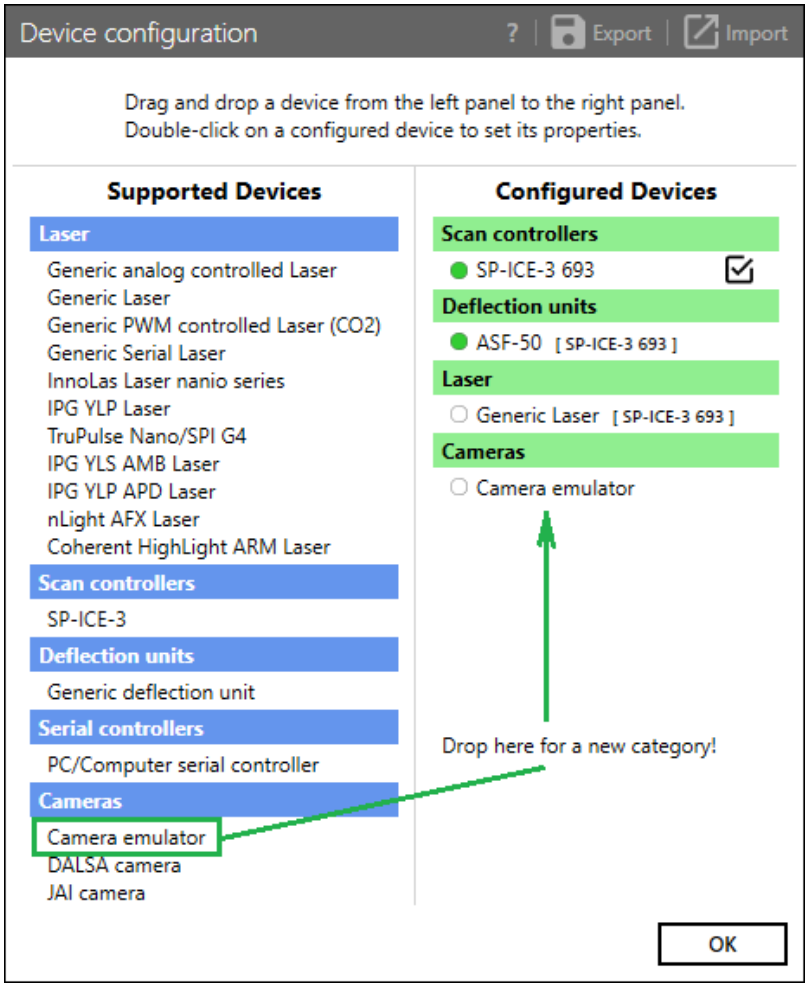


Fig. 5.1: CT-ABW

In the next step, select one of the four available emulated cameras and activate the connection.

Just as with a real camera, a deflection unit must be assigned to the emulated camera.

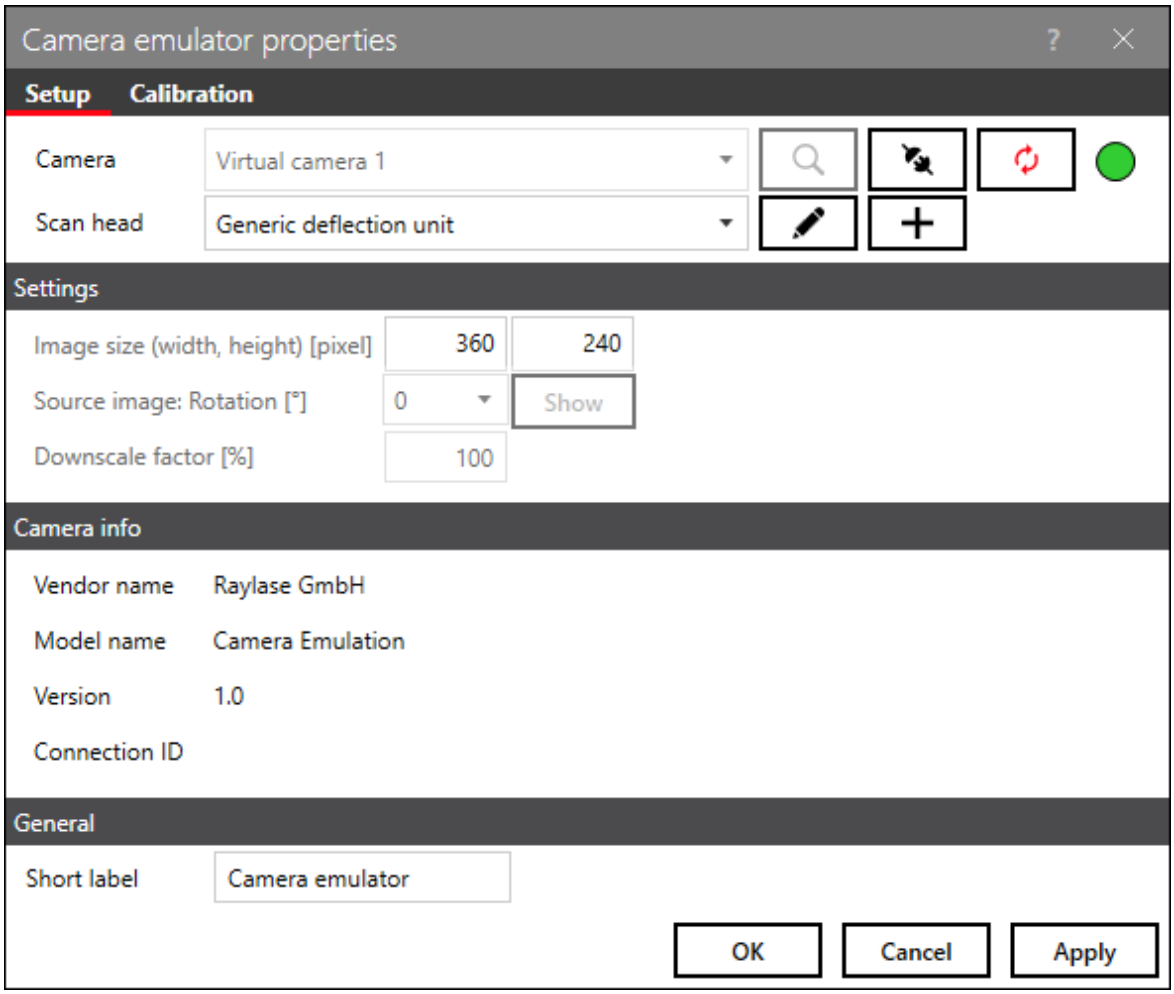


Fig. 5.2: CT-ABX

Setting	Explanation
Setting	
Field of view (width, height) [pixels]	Setting of the image size. The maximum size of the camera image is limited to 360 x 240 pixels. With real cameras, it may make sense to reduce the size; however, this is rarely the case with the emulator (except for demonstration purposes).
Source image rotation [°]	If a rotation is set in the deflection unit, it can be compensated here to achieve a vertically oriented image.
[Show]	Clicking on ***[Show]*** shows the background image in the workspace. This can be useful for the calibration of the emulator; see *page 193, Manual calibration*.
Downscale factor [%]	Adjustment of the downscale factor. The source image of 3000 x 3000 pixels is small enough so that the scale factor can be set to 100% without reductions in performance.

Table. 5.1: CT-012

Afterwards, the emulated camera is ready for simulation within the scope of its possible options.

5.1 Calibration

5.1.1 Automatic calibration

The automatic calibration simplifies the calibration process through the use of image processing algorithms.

NOTE: This option is only available for the emulated camera.

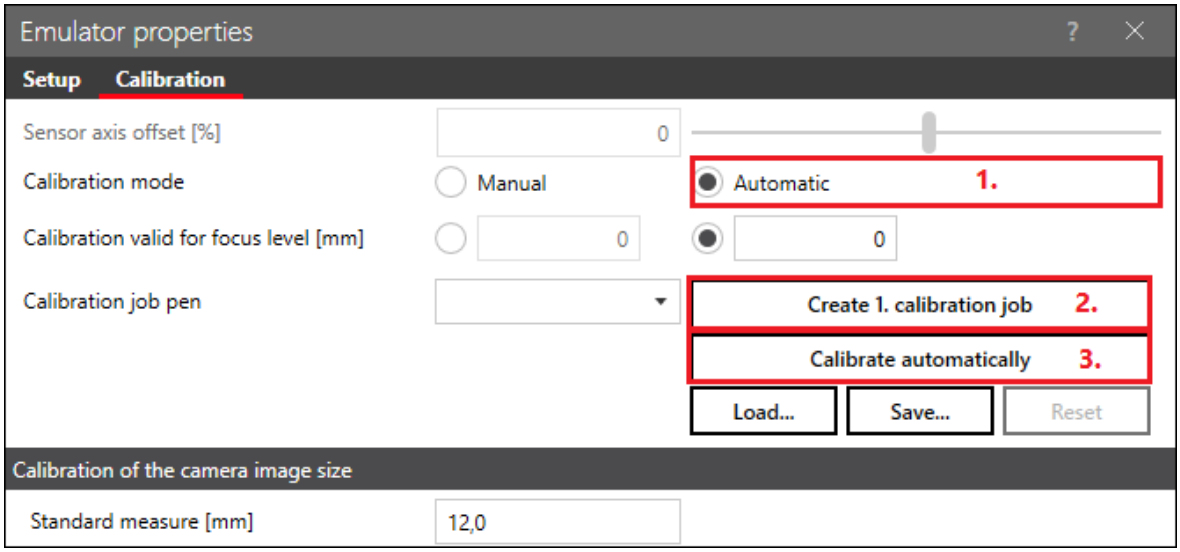


Fig. 5.3: CT-ABY

1. Set the calibration model to *automatic*.
2. Optional**:** Defining focal plane for camera calibration

   If the workspace used should have an extension in the Z direction, the calibration described below must always be carried out at least twice:

   – At the highest point (z- position = 0 mm) and
   – Again, if possible, at the lowest point (depends on the values in the correction file)

   The obtained calibration data is then automatically interpolated (linearly) for the intermediate z- positions.

   NOTE: The value for the lower focal plane is always specified as per the correction file. If a marking is not possible in this focal plane because of the system design, an alternative value can be entered.

3. Select a pen that achieves good results on the surface to be marked.

   ATTENTION: A good marking result is required for pattern recognition to be successful. The laser parameters must have been determined in advance on the basis of simple marking tests. Image recognition requires good illumination with sufficient contrast.

4. In the *Standard measure* field, enter the approximate width of the area in the workspace that is displayed by the camera. This value determines the size of the checkerboard pattern that the calibration job will contain and that will later need to be recognized during image processing.

5. Generate the calibration job and carry it out. It consists of several sensibly arranged squares that are to be detected by the image detection feature.

6. Perform the automatic calibration. While it is running, the calibration step that was just executed is logged in the status bar of the RAYGUIDE software at the bottom right.

Then a dialog appears that displays either the success of or the failure of image recognition. If calibration was successful, the determined values are automatically entered in the corresponding fields of the Settings dialog. The dialog is closed by clicking on ***[OK]***.

If calibration fails, try to improve the illumination or to adjust the laser parameters. You can also see the results of image processing directly as images by pressing the left shift key and clicking on ***[Calibrate automatically]***. In this case, RAYGUIDE places five PNG files into the *temp* directory of the user (enter *%temp%* into the address line of Windows Explorer to open it). These files all begin with *ClickAndTeach* and mark identified checkerboard patterns with a gray border.

Because the size of the source image from which the sections are displayed and the dimensions of the processing field are known, automatic calibration always works perfectly because the calibration parameters can simply be calculated. It is not necessary to create a calibration job.

Switch to automatic calibration mode and click on ***[Calibrate automatically]***.

NOTE: Automatic center point calibration only works with the integrated source image since the center point shift is known (12 pixels in the x direction and 24 pixels in the negative y direction at 3000 x 3000 pixels overall size). When using a separate source image, you need to perform the center point calibration manually.

5.1.2 Manual calibration

For demonstration purposes or when using your own source image, the calibration can be performed manually. The procedure is slightly different than for a real camera because the creation of the calibration job is replaced by the manual measurement of suitable distance markers in the source image.

Problem: The integrated source image has a size of 3000 x 3000 pixels and contains scales on the x- and y-axes, where the individual “millimeter" markings are spaced 10 pixels.

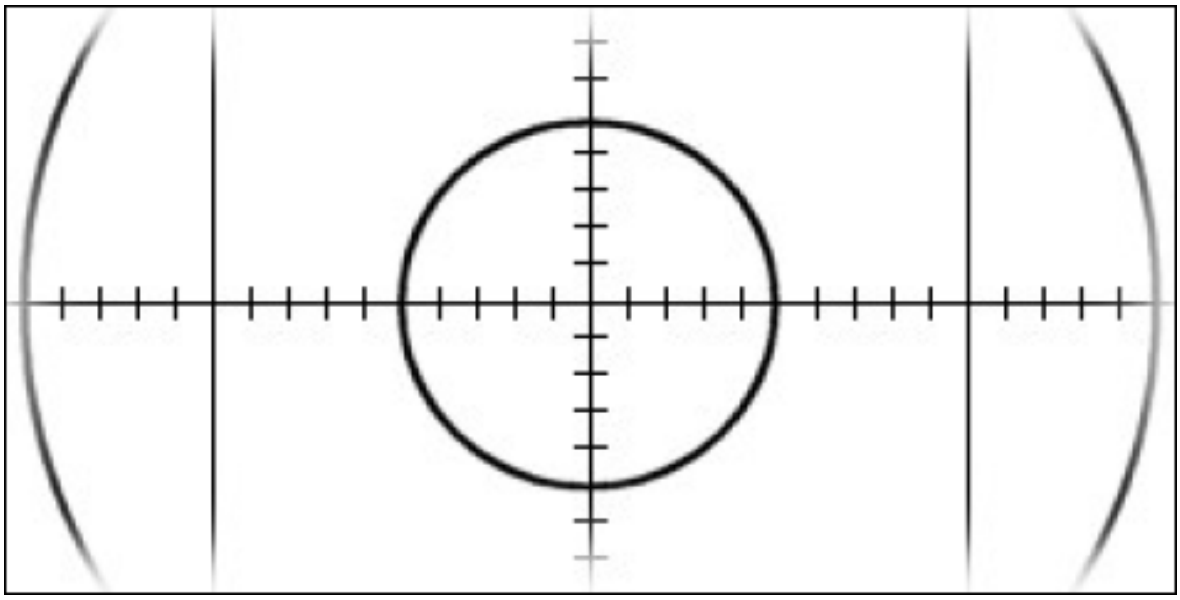


Fig. 5.4: CT-ABZ

The source image is now always shown in the background of the processing field with its full width and height.

- The width of the processing field is always 3000 pixels.
- In a processing field of 300 mm x 300 mm, 10 pixels are equivalent to exactly one millimeter.

However, this is not the case for processing fields of different sizes, meaning that a suitable reference value must be determined before the actual calibration.

The necessary steps for manual calibration are described below:

1. Click on the ***[Start calibration]*** button in the Calibration area of the camera image size. The center of the imaging field is enlarged in the workspace:

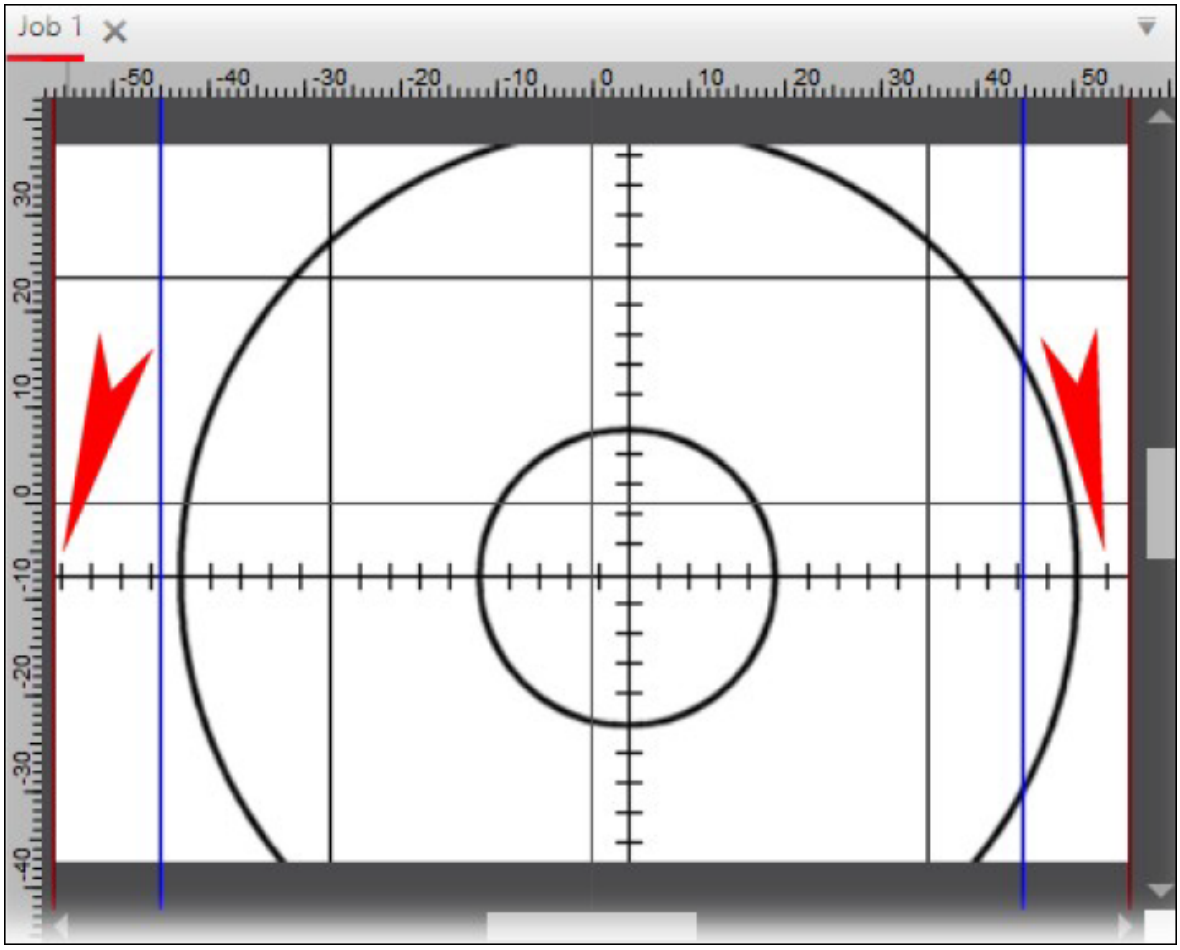


Fig. 5.5: CT-ACA

2. Find two points in the image that are as far apart as possible and that can be easily found again.

   In the example, the “millimeter" markings identified with red arrows at -19 and +16 are convenient points. The question now is how far apart these points are in the real world. With a 300 mm field, it would be exactly 35 mm. In this example, however, we use a field of 112 mm x 112 mm. With a pixel distance of 35 * 10 pixels, one could now convert the true distance according to the formula 112 mm / 3000 pixels * 350 pixels = 13.067 mm. This distance can also be measured. To do so, terminate the calibration procedure by clicking on ***[Cancel calibration]***. Display the overall image in the background by clicking on ***[Show]*** under Settings:

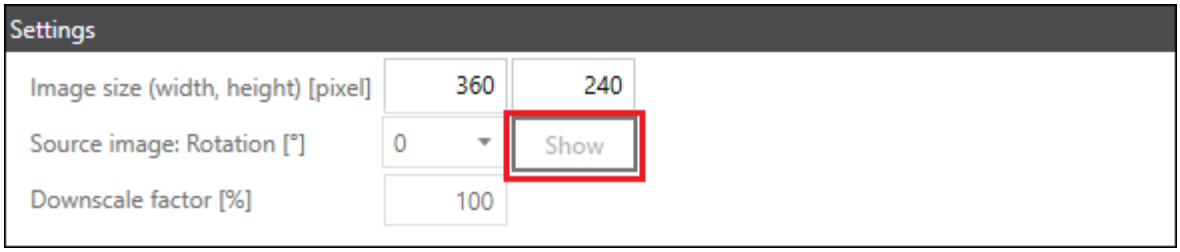


Fig. 5.6: CT-ACB

3. Zoom into the image until both markings are easy to see. Measure the distance using the *Measure distance* tool of RAYGUIDE:

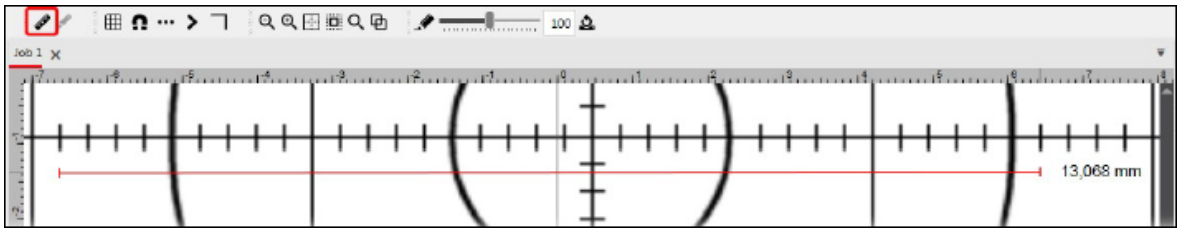


Fig. 5.7: CT-ACC

4. Enter the value (recommendation: calculated value) into the *Standard measure* field:

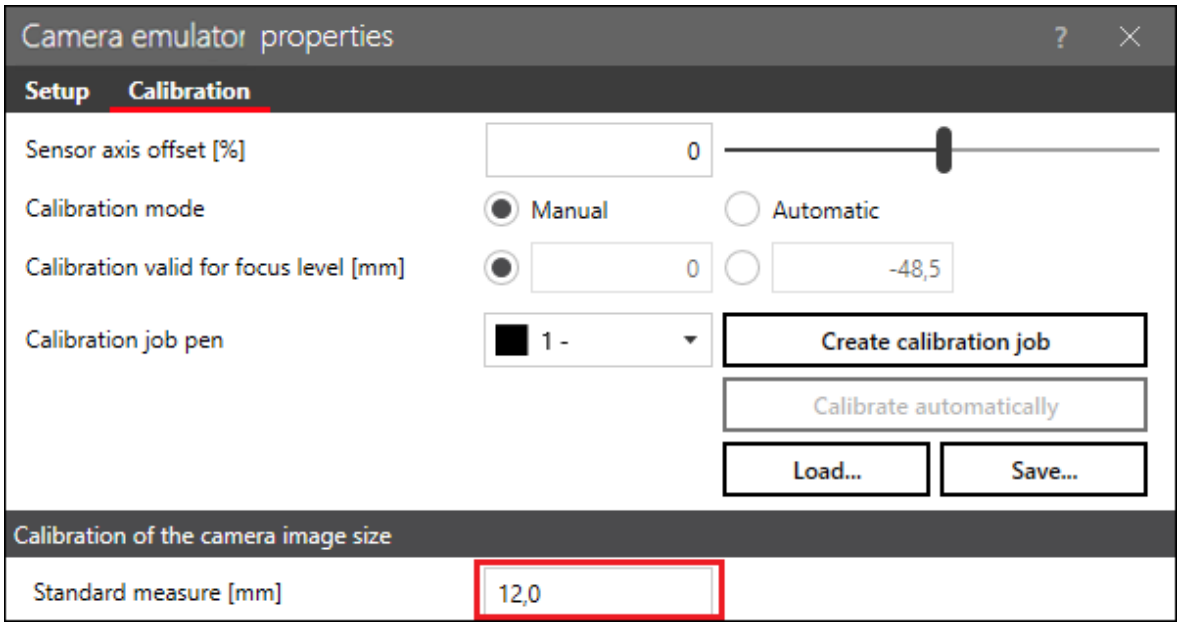


Fig. 5.8: CT-ACD

5. Proceed with the calibration as described in *page 43, Calibration of the camera image size*. The integrated background image intentionally has an offset of 6 pixels in the x direction and 12 pixels in the negative y direction in order to be able to demonstrate the center calibration.

5.2 Changing the background image

The integrated background image, which is used by the emulator as a template, can be replaced by another image if desired. To do this, simply copy your PNG image to the folder *C:\ProgramData\RAYLASE \RAYGUIDE\Configurations*.

The file name must have the exact same name as the connected virtual camera, i.e. *Virtual Camera 1.png, Virtual Camera 2.png, Virtual Camera 3.png* or *Virtual Camera 4.png*.

The fastest way to open the directory is by simply entering *%programdata%* in the address line of Windows Explorer.

CAUTION: The center autocalibration only works with the integrated background image since the deviation from the actual center point is only known for this image.

6 TROUBLESHOOTING

6.1 RAYGUIDE Click & Teach

6.1.1 General

C&T panel is not visible.

Activate the C&T panel via the ***View > Panels > Click & Teach*** menu item.

The C&T panel cannot be activated.

Check whether the RAYGUIDE license has the necessary product code.

Desired camera does not appear in the drop-down list of the C&T panel.

- Check whether the camera was added to the Device Configuration dialog.
- Check whether the camera is connected in the Settings dialog.

The illumination controller is not found for the device configuration.

If the illumination controller is not integrated via the network, but connected directly to the PC network card by a network cable in a peer-to-peer connection, please note the following:

- The “Network profile type” of the network card must be set to “Private network” in the Windows network settings
- The firewall must permit communication between the network card and RAYGUIDE.

Otherwise, RAYGUIDE cannot find the illumination controller, the “Controller” selection list in the properties dialog remains empty and a connection to the device is not possible.

If in doubt, please contact your IT specialist.

The camera does not output a live image

1. Check that the camera provides a live image in the camera manufacturer's software application.

   A. JAI camera

   – Start the eBUS Player application (see also *page 18, JAI cameras*).
   – Connect to the camera.
   – Start the live image with the ***[Play]*** button.

   B. Teledyne DALSA camera

   – Start the CamExpert application (see also *page 22, Sapera CamExpert*)
   – Connect to the camera.
   – Start the live image with the ***[Grab]*** button.

2. If the camera does not output a live image in the respective software tool of the camera manufacturer, it may be because a camera parameter has been adjusted.

   To restore the camera to an operational state, proceed as follows:

   A. JAI camera

   – Start the eBUS Player application.
   – Connect to the camera.
   – Load the appropriate recovery file via the ***File > Open*** menu item from the folder:
   C:\ProgramData\RAYLASE\RAYGUIDE\Resources\Camera

B. Teledyne DALSA camera

– Start the CamExpert application.
– Connect to the camera.
– In the *Camera Information* category, press the ***[Press...]*** button under the *Device Reset* parameter:

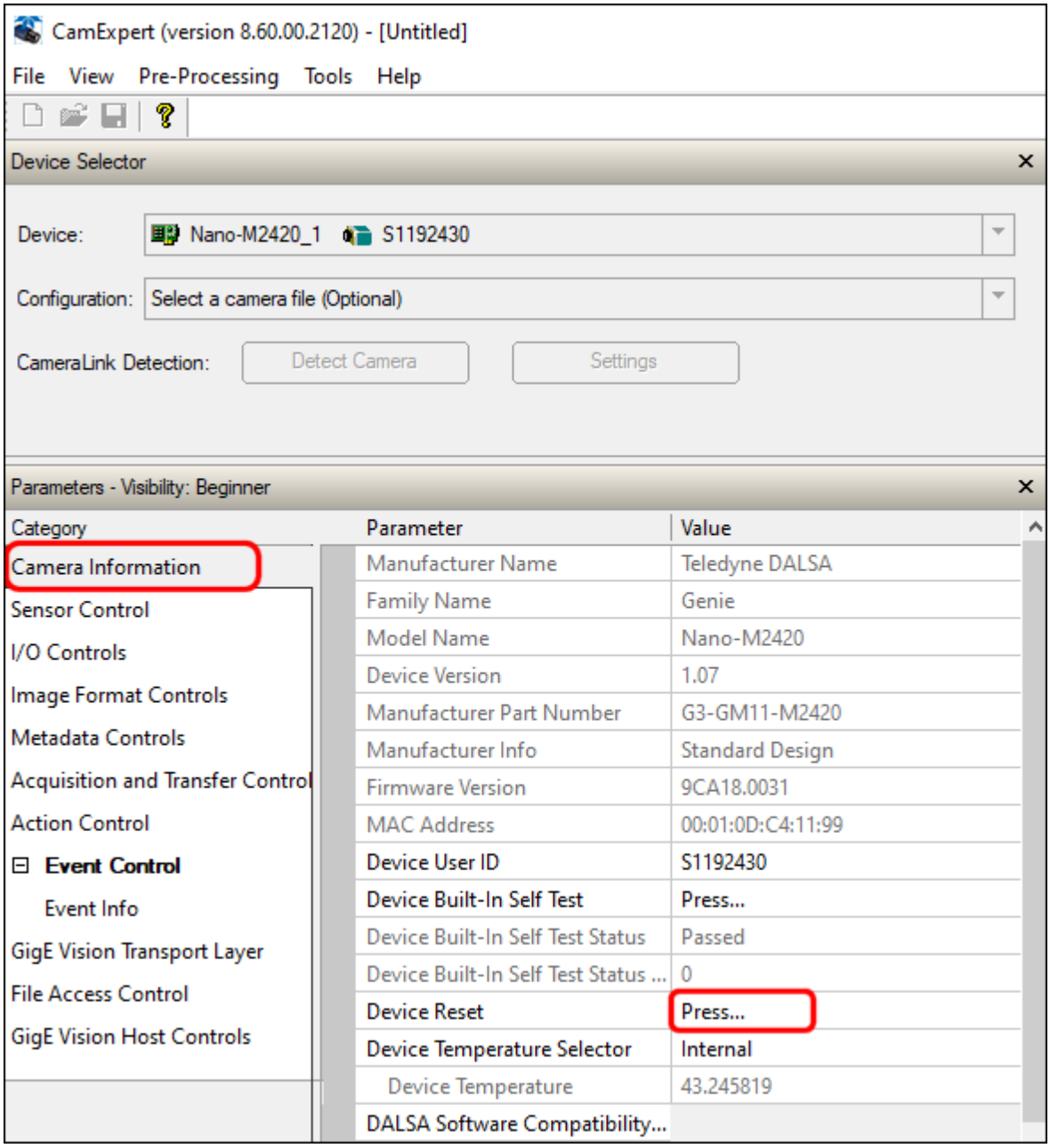


Fig. 6.1: CT-ACE

The buttons for calibration are grayed out in the Settings dialog.

- If necessary, repeat the camera calibration or load a saved calibration.
- Check whether a deflection unit is assigned to the camera in the camera configuration dialog > Setup tab.

Tiling button is grayed out in the C&T panel.

- Calibrate the camera.
- In the configuration dialog of the camera, check whether the desired camera is connected to a deflection unit.

6.1.2 Tiling

The tiles do not join up properly in the center of the image (the outer areas are normal because there is no distortion).

Calibrate the camera image size.

The middle of the processing field is not displayed in the center of the RAYGUIDE window.

Calibrate the center point.

Marked objects in the tiled image are displayed with increasing deviations toward the edges of the workspace.

Perform a wavelength correction.

Images that are recorded in a focal position other than the zero position exhibit "gaps" between the tiles.

The camera was only calibrated in one focal plane. A corresponding second camera calibration must be made in another focal position. (See *page 38, Manual calibration of the (actual) camera*

- If necessary, briefly disconnect the network connection to the corresponding camera in the device configuration and reconnect.
- In the eBUS Player application, check whether a live image is available there and check the network settings.

6.2 RAYGUIDE MATCH

6.2.1 General

The icon for the image processing job is not displayed.

- Check if MATCH is installed.

  The following file must be present:

  C:\Programme\RAYLASE\bin\Plugins\Vision\RAYLASE.Marker.ImageProcessingPlugin.dll.
- Check the display options to see if the icon is always present. If so, display it
- Check whether the RAYGUIDE license has the necessary product code.

Detection fails even though it worked during teaching.

- Check whether the shape of the workpiece has changed.
- Check whether the surface finish of the workpiece has changed or whether it is dirty.
- Check whether the feature to be found is covered.
- Check whether the illumination is still set up as desired and the illumination intensities are appropriate.
- You can request the assistance of the RAYLASE support team for this purpose: If a detection task fails, please save the images of the search area and send them together with the RAYGUIDE job to support@raylase.de.

Output validation reports an exceedance.

This means that detection has found the feature outside of the expected tolerance range.

- Check whether the workpiece position has changed significantly.

Detection repeatedly returns a timeout error.

- Adjust the parameters so that the algorithms are processed more quickly, e.g.:
  - Reduce window sizes
  - Reduce camera resolution
  - Reduce kernel sizes for filters, etc.
- Switch off the timeout message.

6.2.2 Image capture

Image is very noisy, therefore there are fluctuating results.

- Reduce the camera gain, and in turn increase the exposure time and/or increase the illumination intensity.
- Increase the number of images. The images are averaged.

The feature to be detected does not fit well into the image section in terms of orientation.

- Rotate the search area. This may make it smaller and reduce the processing time.

6.2.3 Image filter

Various filters have little effect or require large windows or kernels.

- Reduce the camera resolution.

Various filters require long execution times:

- Reduce the camera resolution.

The results vary when adding offset and rotation noise.

- The values are varied by a randomization generator. If necessary, switch off this randomization.

Dilatation and erosion have no effect.

- The kernel must also have values outside the center position.

6.2.4 Gray value transition search

The point in question is not found on a scanning line.

- Depending on the image situation, you have to set the "Search direction" expert parameter to “From dark to light” or “From light to dark”.

6.2.5 Circle search

6.2.5.1 Circle search with “best-fit ellipse”

An excessive number of structures are found during edge detection.

- Reduce the Kernel size.
- Reduce the camera resolution.

The ellipse is not found.

- The “axis ratio” is set to circular ellipses by default. Adjust this filter if necessary.

Several almost identical ellipses are found when combined with a threshold filter.

- Deactivate the Canny filter.

6.2.5.2 Circular search with “gray value transitions”

See *page 203, Gray value transition search*.

6.2.6 Line search

6.2.6.1 Line search with “best-fit line”

An excessive number of structures are found during edge detection.

- Reduce the Kernel size.
- Reduce the camera resolution.

Inner edges of a structure are not found.

- Switch the “Detection Type” expert parameter from “External” to “List”.

6.2.6.2 Line search with “gray value transition line”

See *page 203, Gray value transition search*.

6.2.6.3 Line search with “fast line”

Many short lines are found.

- Increase Advanced parameters "Min. length threshold [mm]”.
- Activate Advanced parameters "Merge”.

6.2.7 Corner search

Rounded corners are not found.

- Use a line search-based detection method.

6.2.7.1 Corner search with “Shi and Thomasi” method

Too many or too few corners are found.

- Adjust the "Quality level”.

6.2.7.2 Corner search with “fast line”

See *page 204, Line search with “fast line”*.

6.2.7.3 Corner search with “best-fit line”

See *page 204, Line search with “best-fit line”*.

6.2.8 Template search

Template search returns a ”The template must be smaller than the search area” error message.

- Check that the template image is smaller than the search area.

The template search returns no results, although the feature is clearly in the template and search area.

- Check that the search area and template have the same camera resolution.

The template is not found or is only found with a very low quality threshold value.

- Check whether the template image was recorded with the same camera resolution as the current camera image.

The template is not found in any or in very many places.

- Adjust "Quality threshold [0...1]”.

The object to be detected has turned and can no longer be found.

- In the expert parameters, enter the expected angle or search in an angle range.

6.2.9 Result processing

Result fluctuation is relatively high.

- See *page 203, Image capture*, image noise topic.
- The results can be stabilized by reducing the camera resolution.
  The final accuracy often does not suffer as a result.

The results fluctuate: Which one should be used as a reference?

- You can have several "Test runs" performed.
  When setting as a reference, the mean value of these Test runs is used.

Camera

The cameras used here have a monochromatic CMOS image sensor. The image sensor converts the light intensity of the illumination wavelength into electrical voltage and then translates it into gray values. The camera is coaxially coupled into the deflection unit, which means the light for the image sensor is guided via the deflection mirrors.

Dilatation

Dilation thickens bright image areas by adding border pixels. It is used primarily on binary images.

Erosion

Erosion thins out light image areas by removing border pixels of a structure. It is used primarily on binary images.

Features

A feature of a workpiece has a fixed relationship to the workpiece position. These can be, for example, edges, corners or radii of the actual workpiece shape, but also recesses (holes). Other features can also be used, such as markings, screws or the like applied at a later time, provided they have a fixed relationship to the workpiece position.

Gray value

Each pixel (image point) of the camera image is characterized by its gray value. The gray value has no unit and is between 0 (black) and 255 (white) with a standard resolution of 8 bits per pixel. The gray value corresponds to the light intensity of the camera sensor pixels at the illumination wavelength.

Gray value transition

Significant change in the gray value along a scanning line.

Histogram

Graphical representation that illustrates the frequency distribution of gray values in an image. The possible gray values (from 0 to 255) are plotted on the abscissa and the number of pixels with the corresponding gray value on the ordinate.

Image acquisition time

The time that elapses between the request for image capture and the time at which the image is available for additional processing. It is made up of the time for sending the command to the camera, the exposure time and the time for transporting the image data from the camera to a memory buffer in the software (via Ethernet).

Image filter

An image filter is a process based on mathematical operations to change images in a targeted manner. In most cases, kernels (matrices) are used to offset the original gray value of a pixel with the gray values of its surrounding pixels. The matrix elements serve as weighting factors.

Image noise

Image noise refers to random, unwanted disturbances in the image, which are mainly caused by thermal fluctuations in the sensor. The electrical gain also amplifies image noise. Pixel noise can be effectively reduced by pixel binning or by averaging several images.

Image processing job

Automatic sequence from setting the camera and lighting, image capture, image post-processing, image analysis through to calculating and setting a process transformation. The image processing job is in turn an automation object in the RAYGUIDE laser process job sequence.

Image processing job elements

This is the name given to the components that make up an image processing job. These are the capture image, filter, various feature searches and result processing elements.

Kernel

A kernel is a matrix that contains the weightings. You can imagine the kernel as a small window that is moved over the image, stops at each pixel and calculates a new value for this pixel. All adjacent pixel values are weighted according to the elements of the matrix and added up.

Parameter variation

If a search returns no results, MATCH can repeat the search using one or more varied image processing parameters. This also allows the parameters of upstream job elements, such as filters or search ranges, to be modified. A parameter variation will inevitably take more time, but can make the search more reliable.

Picking

Picking refers to the process of determining the area for image capture by positioning the mouse cursor and requesting image capture with the left mouse button.

Pixel binning

In pixel binning, four pixels are already combined in the camera electronics. This reduces image noise at the expense of resolution, for example, because the average gray value is usually used. The data volume of the image is also reduced, which results in faster image capture.

RAYGUIDE CLICK & TEACH

Product name for a RAYGUIDE software extension. Coaxial images of workpieces are captured and displayed in the software interface. These images can be used to teach in or position contours at the actual workpiece position.

RAYGUIDE MATCH

Product name for a RAYGUIDE software extension for position detection of workpieces by image processing of coaxially recorded images.

Scanning line

A scanning line is a line along which (in the image) the gray values of the individual pixels are analyzed. In most cases, a scanning line is used to search for a steep increase or decrease in the gray value.

Search area (region of interest, "RoI")

The area in which workpiece features are located. The area must be visible to the camera and easy to illuminate. The rule is that the search area should be as large as necessary (to cover expected deviations) and as small as possible (preferably never larger than one image tile).

Threshold value

Usually a gray value (0...255) that provides for collective treatment of those pixels that have a gray value greater or less than the threshold value.

Tile size (field of view)

The tile size defines the area that the coaxial camera can photograph using its optical image path over the deflection mirrors. The tile size depends on the size of the scan field (or the working distance of the deflection unit) and on the aperture of the deflection mirrors.

Tiling

Process in which several image tiles are recorded in a defined sequence and then combined to form an image (often a background image).

Head office:
RAYLASE GmbH
Wessling, Germany
+49 8153 9999 699
info@raylase.de

Subsidiary China:
RAYLASE Laser Technology (Shenzen), Ltd.
Shenzhen, China
+86 199 25 48 3946
info@raylase.cn

Subsidiary USA:
RAYLASE Laser Technology Inc.
Newburyport, MA, USA
+1 (313) 552-7122
info@raylase.com