OPERATING INSTRUCTIONS

Stream Setup

3D machine vision

SICK

Sensor Intelligence.

Described product

Stream Setup

Manufacturer

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Legal information

Original document

This document is an original document of SICK AG.

Contents

1 About this document

1.1 Information on the operating instructions

These operating instructions provide important information on how to use devices from SICK AG.

Prerequisites for safe work are:

- Compliance with all safety notes and handling instructions supplied.
- Compliance with local work safety regulations and general safety regulations for device applications

The operating instructions are intended to be used by qualified personnel and electrical specialists.

NOTE
Read these operating instructions carefully to familiarize yourself with the device and its functions before commencing any work.

The operating instructions are an integral part of the product. Store the instructions in the immediate vicinity of the device so they remain accessible to staff at all times. Should the device be passed on to a third party, these operating instructions should be handed over with it.

These operating instructions do not provide information on the handling and safe operation of the machine or system in which the device is integrated. Information on this can be found in the operating instructions for the machine or system.

1.2 Explanation of symbols

Warnings and important information in this document are labeled with symbols. Signal words introduce the instructions and indicate the extent of the hazard. To avoid accidents, damage, and personal injury, always comply with the instructions and act carefully.

DANGER
... indicates a situation of imminent danger, which will lead to a fatality or serious injuries if not prevented.

WARNING
... indicates a potentially dangerous situation, which may lead to a fatality or serious injuries if not prevented.

CAUTION
... indicates a potentially dangerous situation, which may lead to minor/slight injuries if not prevented.

NOTICE
... indicates a potentially harmful situation, which may lead to material damage if not prevented.

NOTE
... highlights useful tips and recommendations as well as information for efficient and trouble-free operation.

1.3 Further information

More information can be found on the product page.

The page can be accessed via the **SICK Product ID**: **pid.sick.com/{P/N}/{S/N}**

{P/N} corresponds to the part number of the product, see type label.

{S/N} corresponds to the serial number of the product, see type label (if indicated).

The following information is available depending on the product:

- Data sheets
- This document in all available language versions
- CAD files and dimensional drawings
- Certificates (e.g., declaration of conformity)
- Other publications
- Software
- Accessories

Release notes:

- Included in Stream Setup.
- Available via SICK Support Portal: supportportal.sick.com

2 Safety information

2.1 Intended use

Stream Setup is a computer software application used to perform and evaluate calibration of the camera setup. Stream Setup can be used together with:

- Ruler3000
- Ranger3

SICK AG assumes no liability for losses or damage arising from the use of the product, either directly or indirectly. This applies in particular to use of the product that does not conform to its intended purpose and is not described in this documentation.

2.2 Limitation of liability

Relevant standards and regulations, the latest technological developments, and our many years of knowledge and experience have all been taken into account when compiling the data and information contained in these operating instructions. The manufacturer accepts no liability for damage caused by:

- Non-adherence to the product documentation (e.g., operating instructions)
- Incorrect use
- Use of untrained staff
- Unauthorized conversions or repair
- Technical modifications
- Use of unauthorized spare parts, consumables, and accessories

2.3 Modifications and conversions

NOTICE
Modifications and conversions to the device may result in unforeseeable dangers.

Interrupting or modifying the device or SICK software will invalidate any warranty claims against SICK AG. This applies in particular to opening the housing, even as part of mounting and electrical installation.

2.4 Cybersecurity

Overview

To protect against cybersecurity threats, it is necessary to continuously monitor and maintain a comprehensive cybersecurity concept. A suitable concept consists of organizational, technical, procedural, electronic, and physical levels of defense and considers suitable measures for different types of risks. The measures implemented in this product can only support protection against cybersecurity threats if the product is used as part of such a concept.

You will find further information at www.sick.com/psirt, e.g.:

- General information on cybersecurity
- Contact option for reporting vulnerabilities
- Information on known vulnerabilities (security advisories)

As the device complies with the GigE Vision®/GenICam™ standard, please note the following:

- The device does not support operating entity authentication. Anyone who can connect to the device over Ethernet can perform all operations (firmware update, reboot and configuration), without entering credentials such as passwords.
- All communication (images, configuration, logs) between the device and the computer is transmitted unencrypted using the UDP protocol.
- The device must be upgraded to the most recent firmware to get security updates.
- The GigE Vision® device discovery is done using UDP port 3956 and further communication is done using dynamic UDP ports.
- When connecting a device, it must be placed on a private network where access control is handled by, e.g., separate firewalls.

3 Getting started

The purpose of this chapter is to quickly and easily connect the camera and capture initial 2D and 3D images.

For mounting descriptions and electrical connection diagrams, see the Operating Instructions for the device.

NOTE
Before using the product in a production environment, the complete operating instructions must have been read and understood.

3.1 Connecting the camera

The last connected device is displayed at start-up together with a color bar indicating the device status:

Device is available, but not connected.

Device is available and already connected.

Device is available, but cannot be connected unless the IP settings on the device or the local NIC are modified.

Device is already in use.

1. If the suggested device is correct and available, click **Connect.**
2. If the suggested device is not correct or if the IP settings need to be modified,
   a) Click **Camera search** to see all devices that are available on the network.
   b) Select the correct device.
   c) If needed, click the three dots to the right and select **IP settings** to edit the IP settings of the device, see "Editing IP settings", page 69.
   d) Click **Connect.**

✓ When the device is connected, select **2D Image** to continue the workflow.

3. In the **2D Image** tab, click the play button to view the 2D image and the laser line.

4 Product description

4.1 Overview

Stream Setup is a computer software for 3D streaming cameras. The purpose of the software is to easily get started getting the first images from the camera. Use **Stream Setup** to configure camera parameters and evaluate the measurement results.

Stream Setup complies with the GenICam™ and the GigE Vision® standards. The **Stream Setup** GUI has, for simplicity, more descriptive names. For the same reason, there are only a few parameters available in the GUI.

5 Installation

5.1 Software installation

5.1.1 System recommendations

The computer requirements for the system will depend on your application, but as a general guideline the following is recommended for minimal operation:

- Windows 10, 64 bit.
- Gigabit Ethernet adapter that supports Jumbo Frames and is dedicated for camera communication, see "Recommended network card settings", page 92.

NOTE
Please read the release notes in the **3D Stream SDK** for detailed information.

5.1.2 Network preparations

Due to the amount of data that the camera delivers per second, it is required to connect it to the computer using a dedicated Gigabit Ethernet network, without other interfering traffic. If the computer must be connected to other equipment, for example network printers, the computer should be equipped with (at least) two network interface cards (NIC).

Multiple cameras can be connected using a NIC with multiple ports, or multiple NICs. To connect multiple cameras to a single NIC limits the maximum speed of the cameras. For best performance, connect each camera to a separate NIC.

For recommended network settings, see "Recommended network card settings", page 92.

5.1.3 Installing computer software

The latest version of the **Stream Setup** can be downloaded from the SICK Support Portal.

1. Log in to the SICK Support Portal.
2. Navigate to the **Stream Setup** page: supportportal.sick.com/downloads/stream-setup/.
3. Download the **Stream Setup Installer** and unzip the file.

The zip file contains the **Stream Setup** application, which is used for the configuration and operation procedures described in this manual. To start the installation, click the **StreamSetupInstaller.exe** file.

Follow the instructions in the setup wizard to install **Stream Setup**.

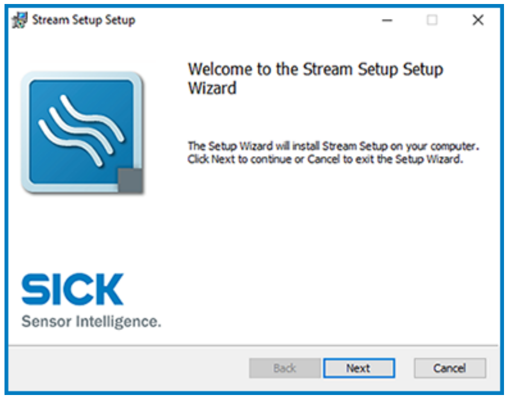


Figure 1: Setup wizard, Stream Setup

5.2 Capturing the first images

Before the device can be used in a machine vision system, it must be configured. This is done by adjusting parameters in the **Stream Setup** software until the image result is satisfactory.

For detailed information about how to edit the parameters in the user interface, see "Configuration", page 41. For a list of available parameters, see the Operating instructions for the device.

5.2.1 Finding and connecting the camera

In the **Cameras** tab, you see the last connected device and can reconnect to it. Use the **Camera search** button to search the network and see a list of all available devices.

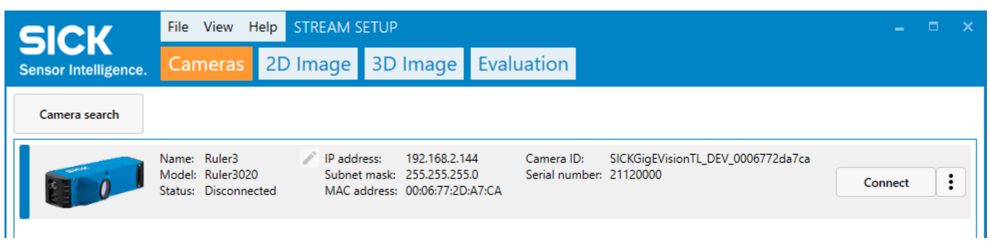


Figure 2: Connecting the camera

If the camera you want to connect to is not on the same subnet as the NIC you have to reconfigure the camera to the same subnet before you can connect to it. Configuring the subnet can be performed either on the camera or the computer. For information about editing the IP settings on the camera, see "Editing IP settings", page 69.

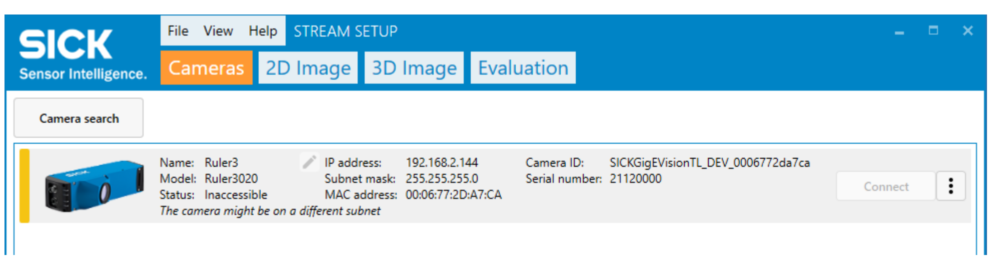
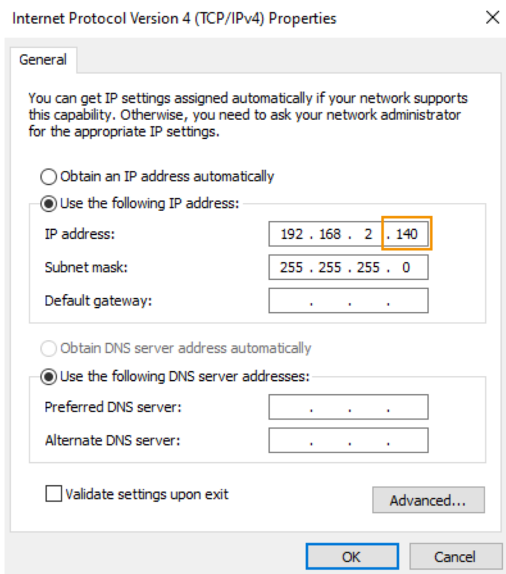


Figure 3: Camera on different subnet

Changing subnet on computer

1. Open the Network Connections on the computer.
2. Select the corresponding Ethernet link and open Properties.

3. Select Internet Protocol Version 4 and open Properties. The computer must be set up using a static IP Address.



4. Enter the same IP address as the camera for the first three sections. The last section in the IP address must be different.
5. Enter the same Subnet mask as the camera.
6. Select OK and return to **Stream Setup**.
7. Click **Camera search** to find the camera and **Connect**.

5.2.2 Getting a 2D image

Next, you capture and view the 2D image data in the **2D Image** tab. Click the play button to view the 2D image and the laser line. A 2D image is what the camera sees when it is used as an ordinary camera. You can edit parameter values related to the image acquisition and evaluate the result directly in the image viewer until the result is satisfactory.

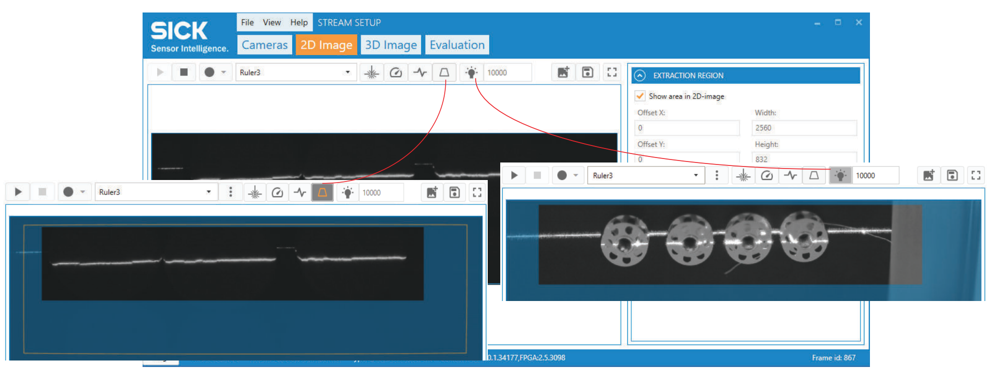


Figure 4: Getting the 2D image. The guaranteed FOV (left) and boost exposure (right) features are illustrated.

To see exactly where on the object the laser line goes, use the **Boost exposure** button to temporarily brighten the area. You also have the possibility to verify that the region you are viewing falls within the guaranteed field of view, by clicking **Guaranteed FOV**.

5.2.3 Getting a 3D image

In the **3D Image** tab, you view the 3D image that is the result of using laser triangulation. Click the play button to start acquiring profiles. A 3D image is generated from acquired profiles. You can edit parameter values and evaluate the result directly in the image viewer until the result is satisfactory.

You also have several options to visualize the 3D image, see "Image components and visualization", page 80.

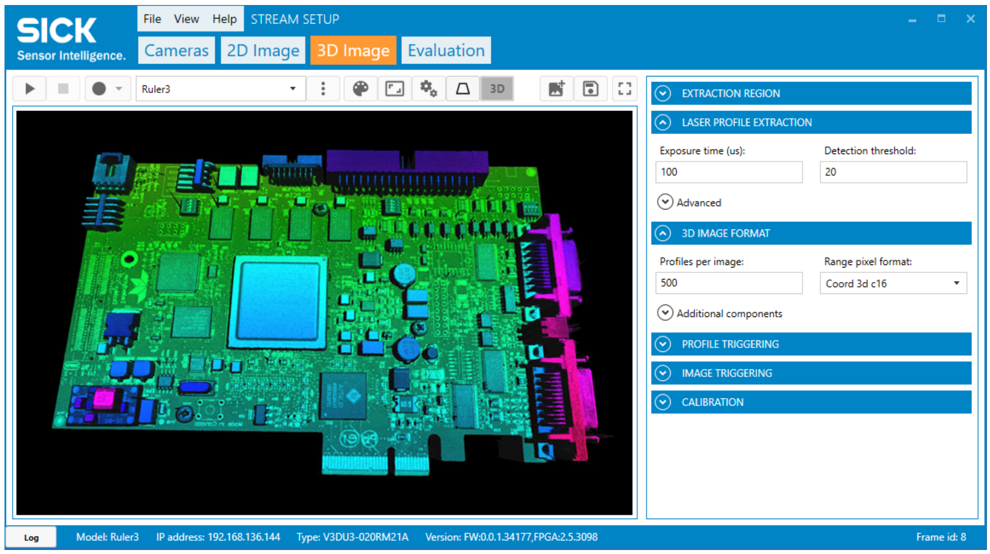


Figure 5: Getting the 3D image

6 Calibration

6.1 Calibration principles

In many applications, it is necessary to have the image in world coordinates (millimeters). Stand-alone triangulation cameras, such as Ranger3, generate measurement values expressed as positions in a sensor coordinate system (u,v).

A calibration procedure is required to find the relation between the sensor position and the real-world coordinates. To be able to convert the sensor coordinates to world coordinates, a calibration model needs to be estimated for the given camera setup. This estimation is done using a calibration target with known dimensions. The calibration target contains a number of distinct measurement points. By scanning the calibration target and detecting the target points, it is possible to estimate a calibration model.

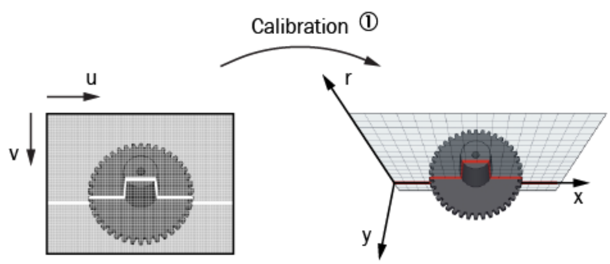


Figure 6: Calibrating sensor position to world coordinates

① Calibration

6.2 Calibration

Calibration of range data refers to the process of turning sensor coordinates (pixel positions) into real-world coordinates in mm. By using the calibration functions the sensor positions are translated into real-world coordinates. All calibration is done in the laser plane. The Ruler3000 delivers calibrated data per default.

Calibrated data is a set of points in real-world coordinates. During the configuration of the calibration when the device is produced, a direct relationship is established between each sensor position and the corresponding real-world coordinate. When applying the calibration to a range profile, each valid (u, v) point in the profile is translated into a calibrated (x, z) point in the real world. This representation is suitable if you need to find e.g. the distance between two points in the real world or measure the height of a certain object. The image below shows an example profile as seen by the sensor (on the left) and the corresponding calibrated points in the real-world coordinate system.

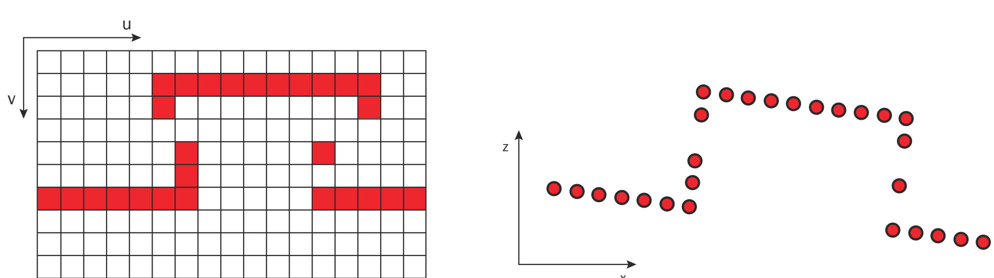


Figure 7: Sensor image and corresponding calibrated (x, z) points

The camera can operate both **Calibrated** and **Uncalibrated**. The default setting is **Calibrated (Camera)**.

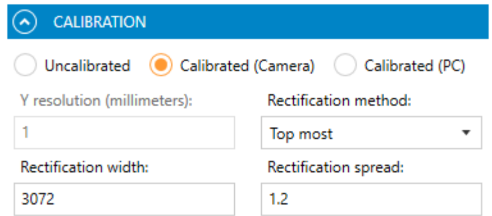


Figure 8: Calibration GUI reference.

6.2.1 Image rectification

Rectification of data means that a new profile is created by re-sampling the calibrated data onto a regular grid. The image rectification is performed along the X-axis only. The new profile is represented in a discrete coordinate system, which is directly related to the real-world coordinate system. This means that the distance in X between two adjacent values (pixels) in the profile is always the same regardless of where in the field of view they are positioned.

The following image shows how a set of calibrated data points translates into a rectified profile. The final z value is represented as a floating-point number to preserve the full resolution. Notice the green and yellow resulting values at the edges of the profile.

Select if the rectification should return the **Top most** (green) or **Bottom most** (yellow) pixel height within the discrete column. For more information, see table 1, page 17.

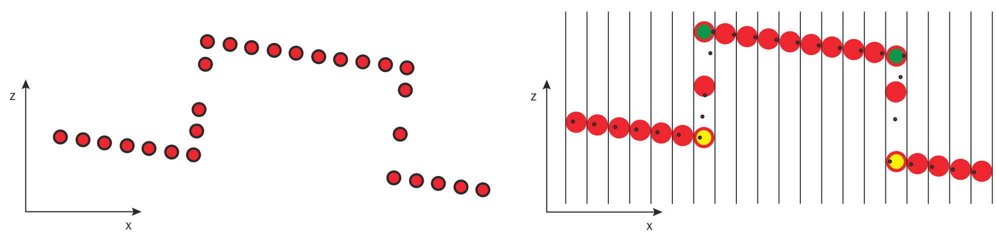


Figure 9: Calibrated points and corresponding rectified profile (to the right).

The image rectification is performed on the camera and is controlled via the setting for calibration. If **Calibrated** is selected, image rectification will also be performed.

Maximum **Rectification width** for in-device image rectification is 4096 and default is 3072. The image rectification is made to a higher resolution than the imager resolution to avoid losing X resolution close to the device. The **Rectification width** can be set to a lower value than the width of the **Extraction region**. The image will then be downsampled and data will be lost. The **Rectification width** determines the width of the 3D image.

Select which **Rectification method** to use.

Table 1: Image rectification methods

Method	Description
Bottom most	Always pick the lowest range value for each bin.
Top most	Always pick the highest range value for each bin.

The **Rectification spread** is used to distribute pixel values to neighboring pixels. If the **Rectification width** is larger than the width of the data, the image rectification can give holes in the data. The process of replacing those holes of missing data with neighboring pixel values is called spreading.

Due to the geometry between the laser plane and the camera, the number of holes in the image depends on the range value with typically no holes in the image at one end of the range scale and maximum number of holes at the other. Hence the spreading is adjusted to spread more at range values from the far end of the camera's field of view and less close to the camera where the resolution per mm is higher. It is important not to spread more than necessary since it potentially overwrites valid data with neighboring data.

Setting the **Rectification spread** to 0 disables spreading. Spreading 1.0 will fill all gaps in the output image in an ideal case, but default spreading is still set to 1.2 since in practice there might still be missing data at spreading 1.0 due to discontinuities in the image. The maximum value depends on other parameters and is typically 1.5 for in-device image rectification due to hardware limitations.

6.2.1.1 Setting image rectification method

Tabs: **2D Image**, **3D Image**

To enable image rectification, follow the steps below:

1. Open the **Calibration** section.
2. Select the **Calibrated** radio button.
3. Set the **Rectification width**, a value between 160 and 4096.
4. Select which **Rectification method** to use. For information about different methods, see see "Image rectification", page 17.
5. Set the **Rectification spread**, a value between 1 and 10.

6.3 Calibration methods

Stream Setup offers two different methods to estimate a calibration.

- Sawtooth calibration
- Dot wedge calibration

Which one to use depends on the camera and laser setup, the geometry, and the size of the field of view.

The first step before estimating a calibration is to decide which calibration method to use, and then order or manufacture a calibration target. Drawings and patterns are available via supportportal.sick.com.

6.3.1 Sawtooth calibration

The sawtooth calibration method is the simplest of the two calibration methods. SICK currently provides two versions of the calibration target[1], but it is also possible to manufacture a custom target suitable for a particular field of view.

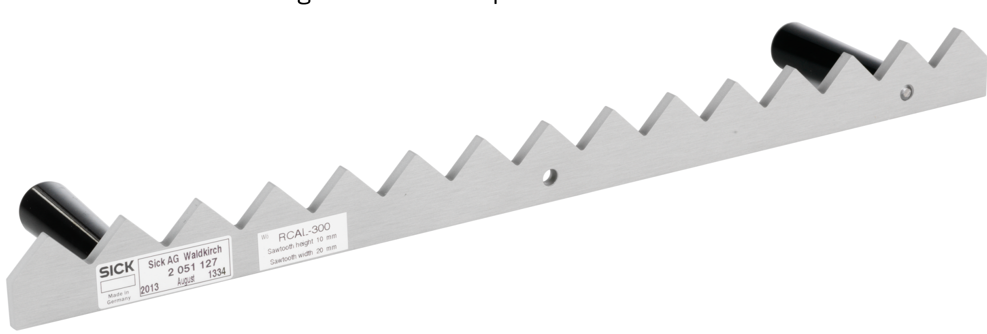


Figure 10: Example of a sawtooth calibration target

When estimating a calibration the first step is to detect feature points on the target. For the sawtooth method, the feature points are the teeth and valleys of the target.

1) RCAL-300 and RCAL-600

6.3.2 Dot wedge calibration

The Dot wedge calibration method is perfect for small field of views, where the saw-tooth target can be difficult to manufacture. The target consists of a white surface with black dots. The surface is tilted so that each dot row is at a different height in the laser plane.

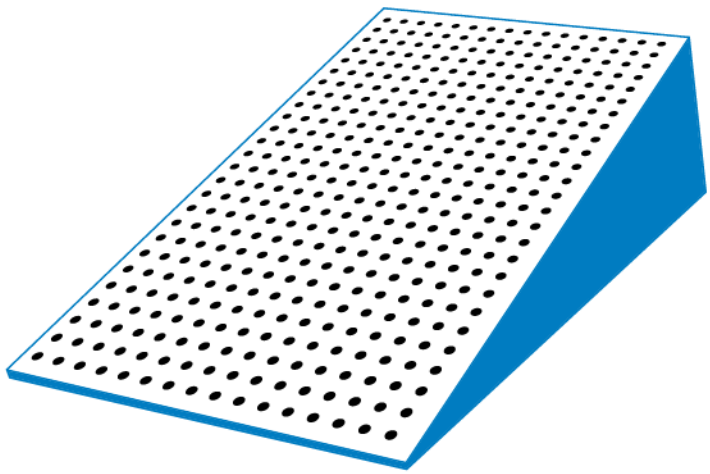


Figure 11: Example of dot wedge calibration target

For applications with low accuracy, it might be enough to print the dot pattern on a paper.

6.3.3 Geometry

The reverse ordinary geometry is the most common way to mount a streaming camera and laser. When describing the calibration methods, we assume this geometry is being used.

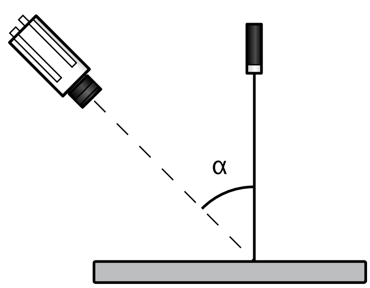


Figure 12: Reversed ordinary

For information about other mounting geometries, see the Operating Instructions for the device.

6.4 Using sawtooth calibration

When estimating a calibration the first step is to detect feature points on the target. For the sawtooth method, the feature points are the teeth and valleys of the target.

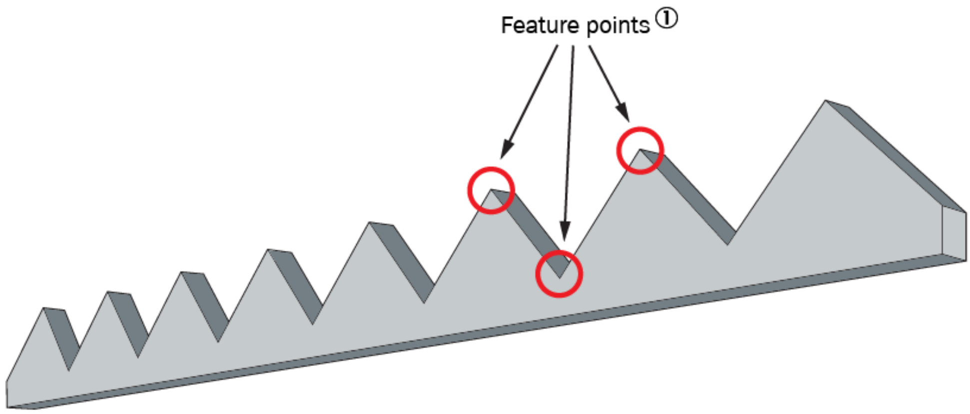


Figure 13: Detecting feature points

① Feature points

6.4.1 Collect sawtooth images

The sawtooth calibration images are acquired from the **2D Image** tab in **Stream Setup**. Place the sawtooth target under the laser line.

- The calibration target should cover at least 50% of the field of view width.
- The field of view must cover at least four feature points on the sawtooth target, and should include both teeth and valleys.

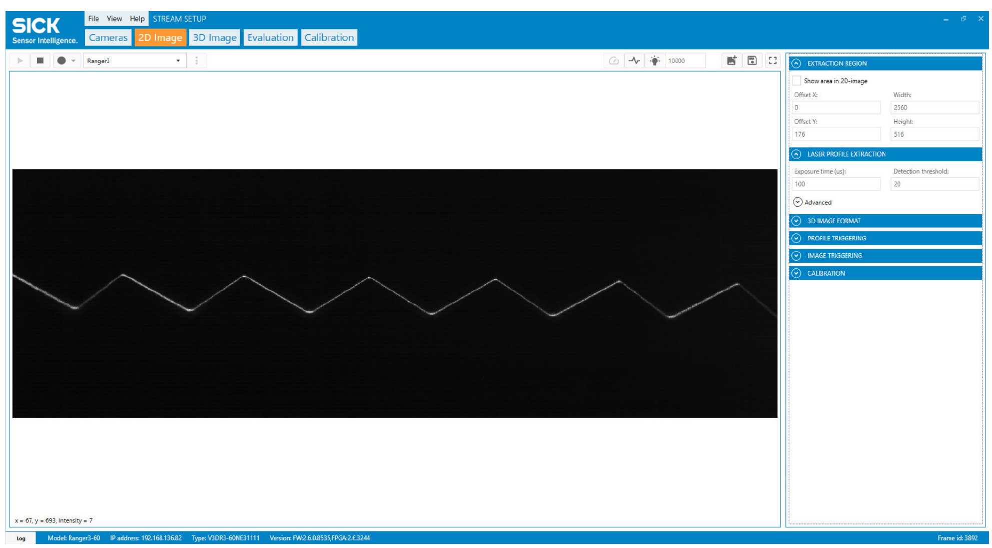


Figure 14: Sawtooth target image with teeth and valleys

Target placement

The sawtooth target should be placed in the laser plane. The target must not be tilted or rotated around its vertical axis. However, a small rotation around the horizontal axis is still valid. The figures show how the Sawtooth target can be placed in the laser plane.

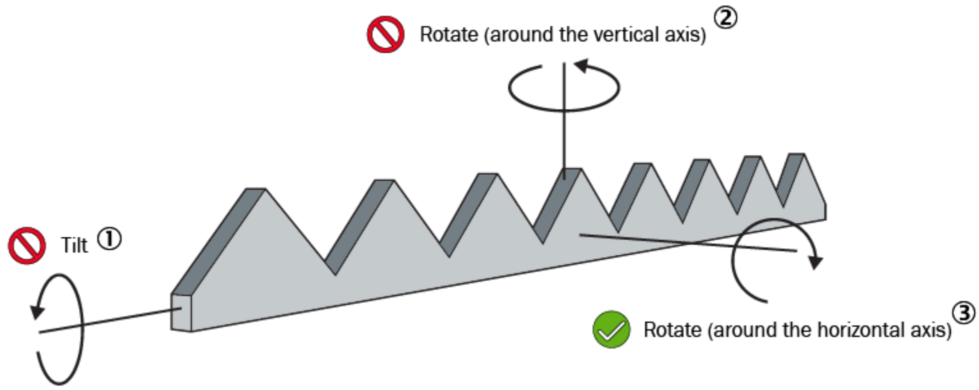


Figure 15: Valid and not valid positions of the Sawtooth target

① Tilt
② Rotate (around the vertical axis)
③ Rotate (around the horizontal axis)

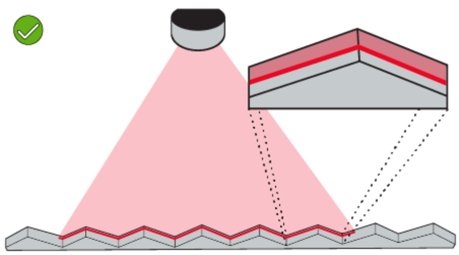


Figure 16: The laser line is parallel with the target when the calibration target is held straight in the laser plane.

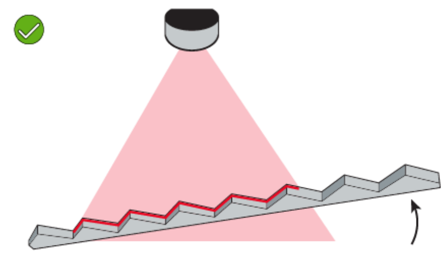


Figure 17: Rotating the calibration target around its horizontal axis improves the calibration results.

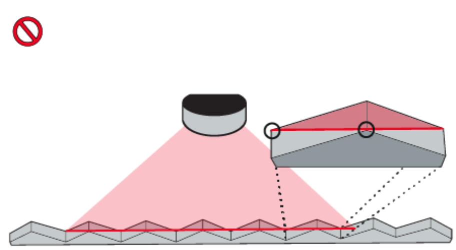


Figure 18: When the calibration target is tilted, the distance between the feature points appears too large and causes scaling errors.

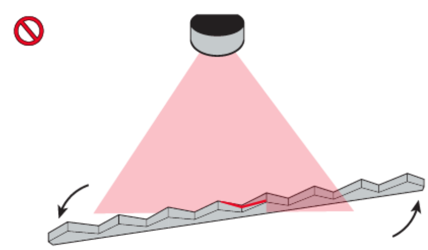


Figure 19: Rotating the calibration target around its vertical axis makes the laser line hit outside the target and coordinator cannot find enough feature points.

Image quality

Make sure that the lens and laser are in focus. Focus in the part of the field of view that is going to be used in the application. The focus cannot be changed after the calibration has been estimated. If the focus is changed, the setup needs to be recalibrated.

If the field of view covers a large part of the sensor, it can sometimes be difficult to get good focus everywhere. One way of handling this issue is to close the lens aperture as much as possible, and compensate by increasing the exposure time. There is also the possibility to use a scheimpflug adapter to ensure that you can get focus throughout the field of view.

Camera parameters can also be used in order to get good image quality. For the Sawtooth images, the relevant parameters are mainly the **Exposure time**, **Detection threshold**, and the **HDR mode**.

Save images

Click the **Save** button to save the images. Saving can also be done by using the recording functionally. Recording can be more practical if many images are needed. When using the recording functionality, make sure to select **Manual** recording. Put all collected sawtooth images in a folder that does not contain any other images.

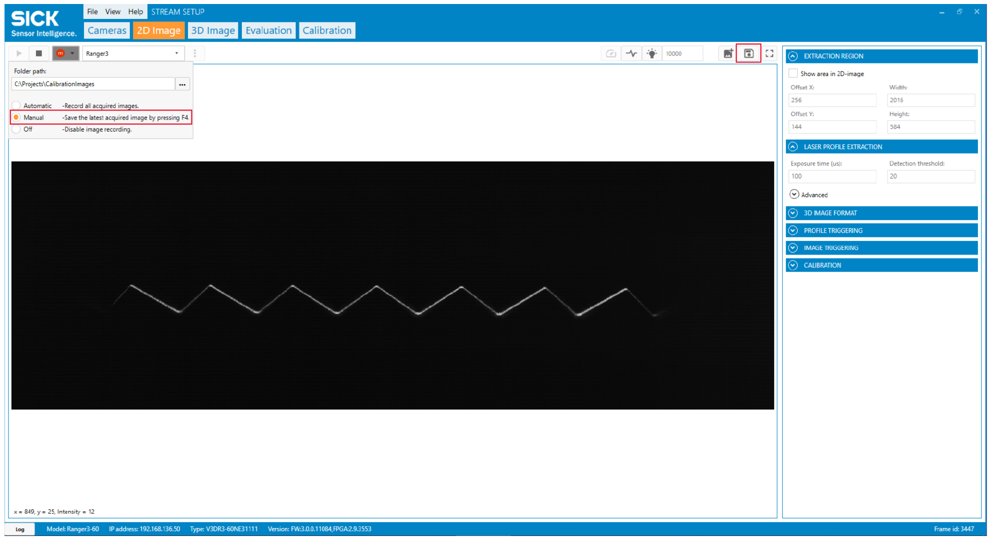


Figure 20: Save images using the Save button or recording functionality

When estimating a calibration with the sawtooth method, one or multiple calibration images can be used.

NOTE
Distribute the sawtooth images evenly over the part of the sensor that is used for measurements.

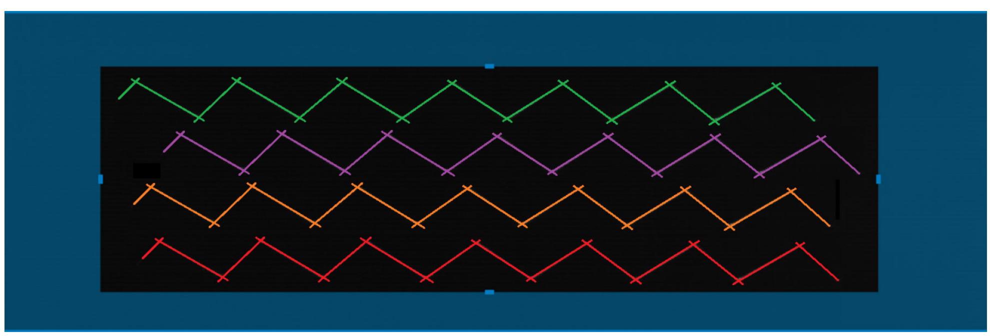


Figure 21: Evenly distributed sawtooth images

The required accuracy of the application, and the size of the extraction area determine how many images you need. At least 5-10 images are recommended for the extraction area in the figure, see figure 21, page 22. For an application which only use a few rows on the sensor, it might be enough with only one sawtooth image.

6.4.2 Sawtooth parameters

Use the buttons in the upper left corner to browse through all the images in the input folder. Select and deselect images in the drop-down menu. Only the images that are selected will be used when estimating the calibration.

Target dimensions

Specify the **Tooth width (mm)** and **Tooth height (mm)** parameters in the **Estimate calibration** section.

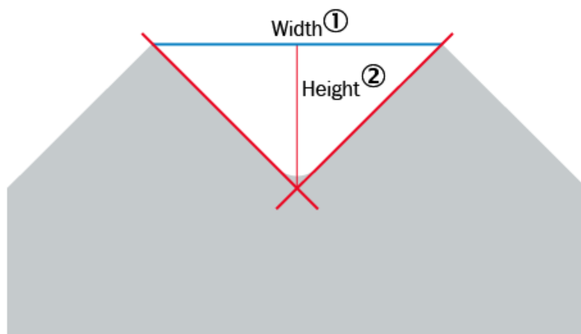


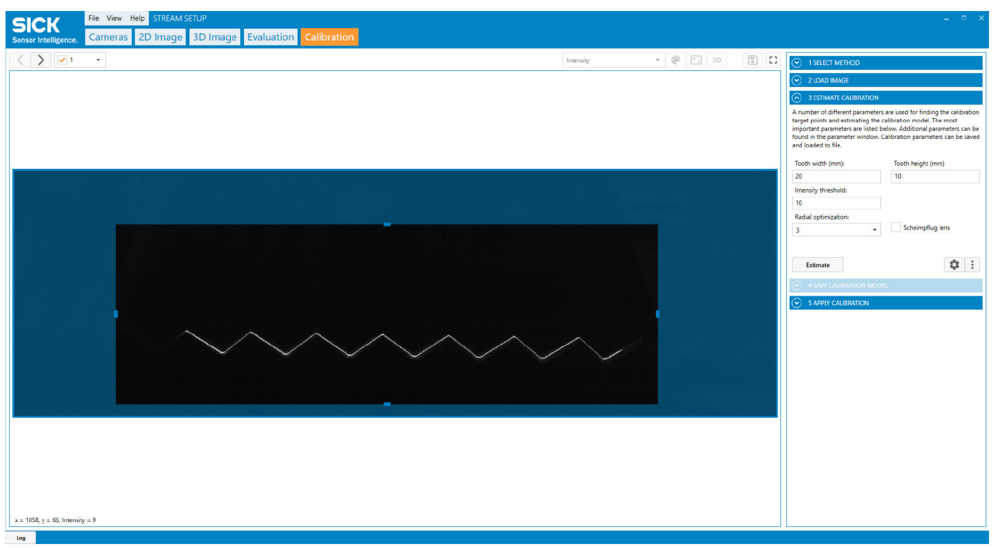
Figure 22: Measuring the tooth's height and width

① Width

② Height

Target detection

The **Intensity threshold** parameter is used when detecting the sawtooth target in the images.



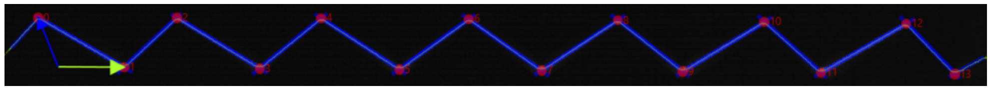
It is common to get noise and bright areas that are not part of the target along the edge of the image. Handle this issue by modifying the region of interest.

NOTE
The same region is used for all the sawtooth images in the folder.

Coordinate system

One of the calibration images in the folder is used to define the world coordinate system. Select which image to use from the image drop-down in the upper left corner. The x-axis will be aligned with the target points, and the z-axis is orthogonal with the target. The origin and coordinate axes are visualized in the feedback images.

It is also recommended that the origin image is aligned with the conveyor, which ensures that the x-axis is parallel to the conveyor surface and that the z-axis is pointing in the expected direction.



The reason the x-axis and z-axis are not orthogonal here, is because they are visualized in the camera sensor image, and not in the actual world coordinate system. It is possible to modify the coordinate system from the parameter window. You may e.g. wish to offset the coordinate system to let the origin be a point on the conveyor and slightly outside of the field of view rather than the point where the first tooth-base was found. This will avoid possibly confusing negative X and Z values in your data.

6.4.3 Sawtooth algorithm

How the sawtooth algorithm works

1. For each image in the folder:
   a) Find the brightest peak along each column. The peak position is found with subpixel precision.
   b) Detect line segments from the peak positions.
   c) Calculate the intersection points between the line segments. There is one point for each target tooth and one point for each target valley.
2. Use the target points from all the images to estimate the calibration model. The first image will be used as a reference to define the world coordinate system.

6.4.4 Sawtooth feedback images

When clicking on the **Estimate** button, a number of feedback images will appear on the left side. These images describe the different steps for finding the Sawtooth target. The images can be used to tune the parameters.

Calibration image

This feedback image shows the original calibration image with the region of interest.

Detected peaks

In this feedback image, you can clearly see if there are any incorrect detections in the peak detection step of the algorithm.

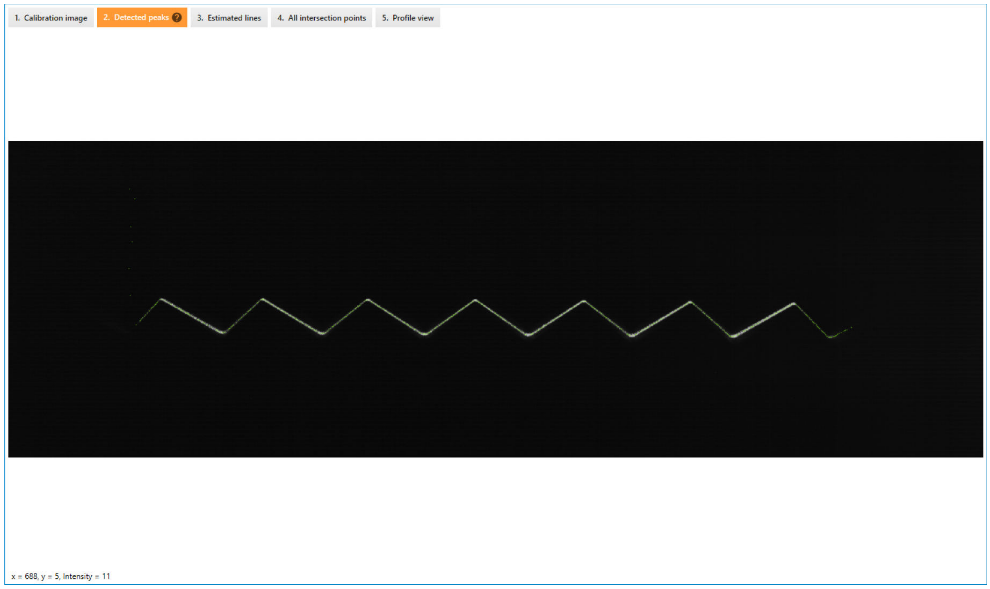


Figure 23: Detected peaks GUI reference

Estimated lines

This image shows the line segments and intersection points. The image also shows the origin and coordinate axes of the world coordinate system.

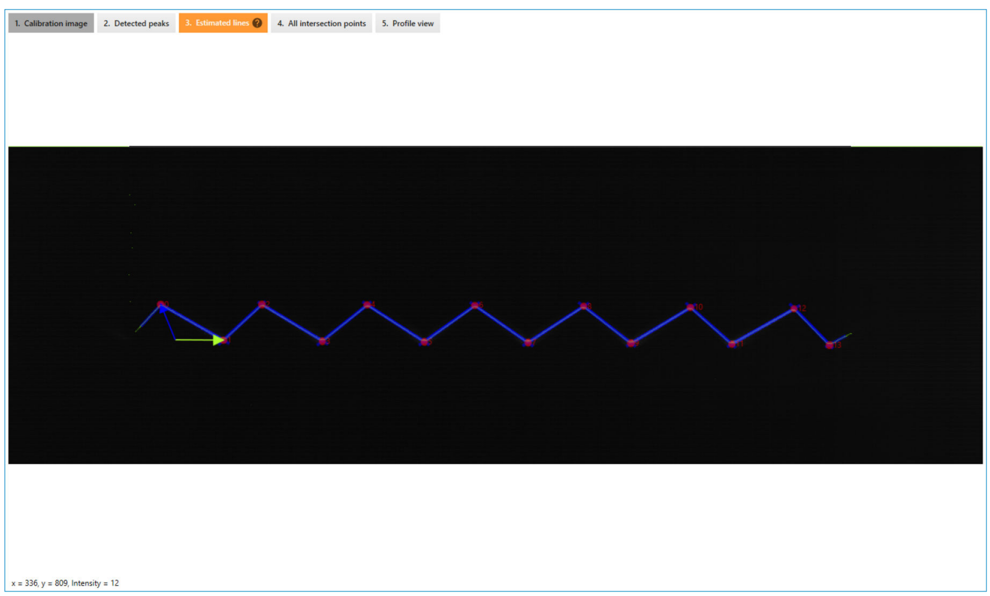


Figure 24: Estimated lines GUI reference

All intersection points

This image shows the detected target points from all calibration images that were included in the estimation. The green points are the target points from the currently selected image. This image clearly shows how well the points are distributed over the sensor. It is important that the points are distributed evenly over the part of the sensor that will be used in the application.

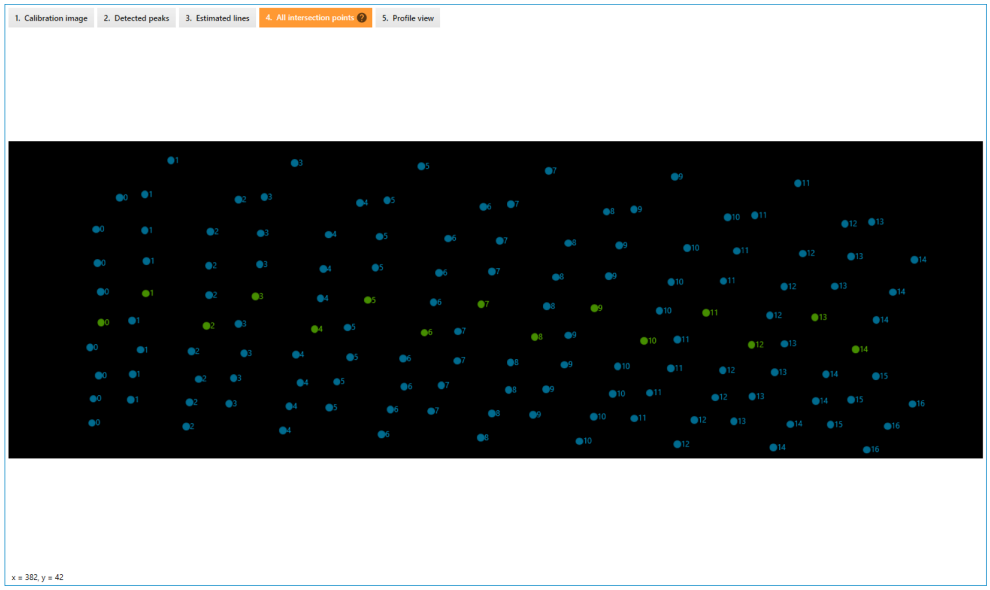


Figure 25: All intersection points GUI reference

Profile view

This image gives the same feedback as the **Estimated lines** image, but it is shown in the profile viewer. In the profile viewer it can sometimes be easier to see how well the lines (yellow) are estimated compared to the laser profile (green).

Figure 26: Profile view GUI reference

6.5 Using dot wedge calibration

6.5.1 Collect dot wedge images

The dot wedge method requires a scanned 3D image as input when estimating the calibration. The 3D image needs to contain a range component and a reflectance component. Only one calibration image is needed.

Target placement

Place the target according to the image, see figure 27, page 27. Make sure that the laser line is aligned with the dot rows.

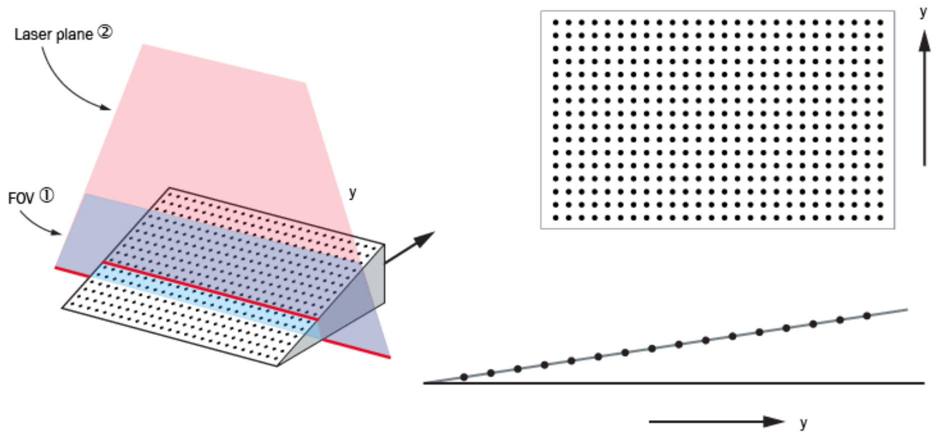


Figure 27: Dot wedge target placement

①	Field of view

②	Laser plane

Place the target angled towards the camera or angled away from the camera. The target can be scanned in two different directions, giving four different ways of scanning a dot wedge target. For information about how to set the parameter **Dot distance z (mm)** in the four situations, see table 2, page 27. For more information about the **Dot distance z (mm)** parameter, see "Dot wedge parameters", page 28.

Table 2: Scanning directions

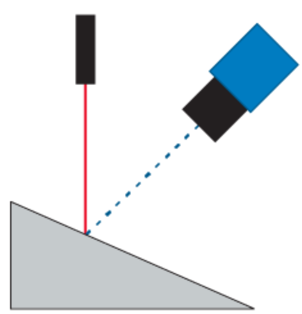


Figure 28: Dot wedge target angled towards the camera

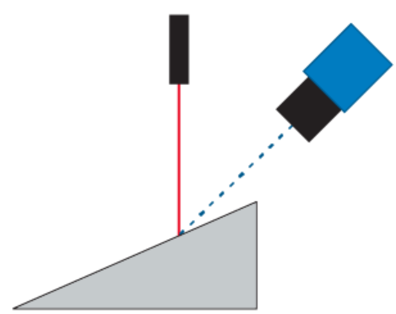


Figure 29: Dot wedge target angled away from the camera

Scanning direction	Dot distance z (mm)		Scanning direction	Dot distance z (mm)
→	+		→	+
←	-		←	-

Image quality

It is highly recommended to place the target so it is angled away from the camera. Using this position will reflect the laser line away from the sensor. Angling the target towards the camera, usually leads to reflections along the center columns of the image.

In the dot wedge algorithm, both the range component and reflectance component are used for detecting the dot positions. The calibration image should have a range component without too much noise, and a reflectance component with good contrast.

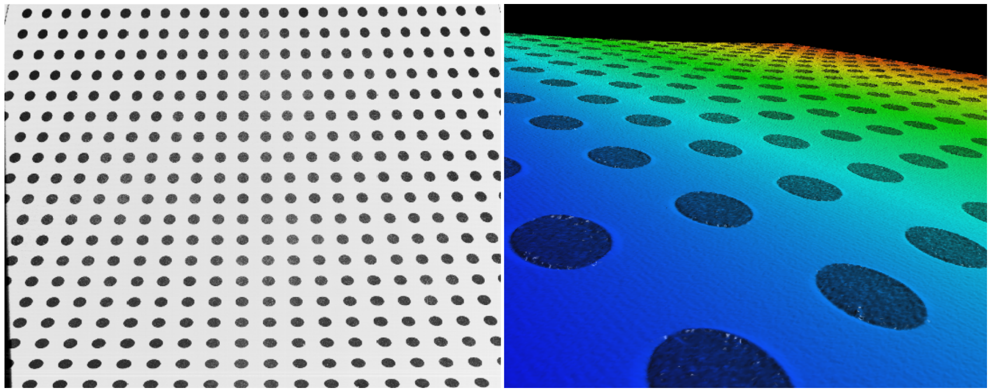


Figure 30: Getting a good calibration image

To achieve good image quality, it is important that the lens and laser have focus in the entire field of view. Both the upper and lower part of the target should be in focus.

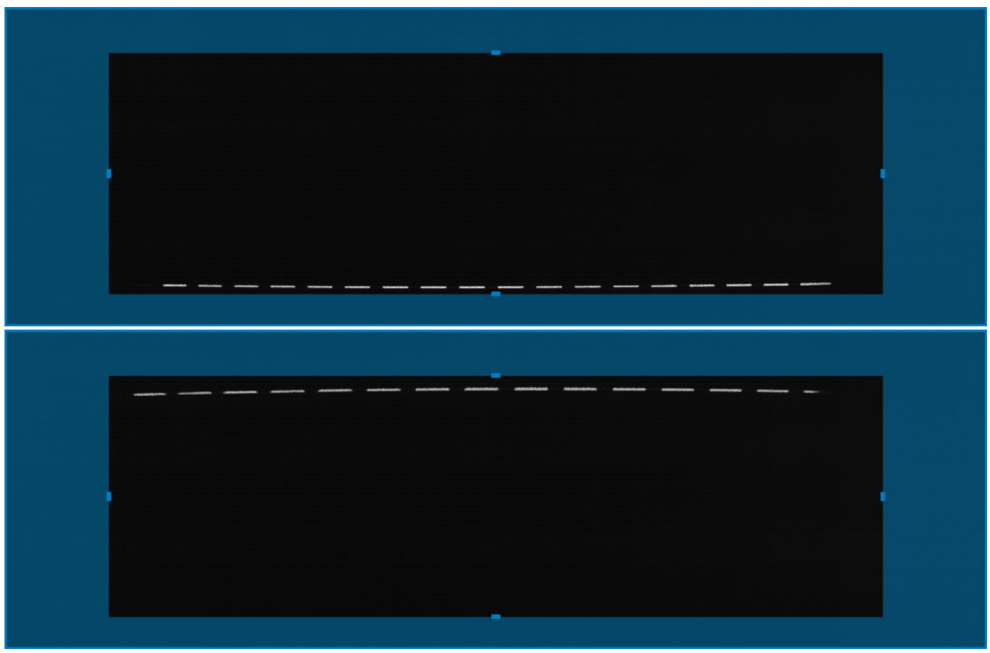


Figure 31: Setting focus

If the field of view covers a large part of the sensor, it can sometimes be difficult to get good focus everywhere. One way of handling this issue is to close the lens aperture as much as possible, and compensate by increasing the exposure time. Make sure to adjust the region of interest. Use only the part of the sensor that is needed for the application. It is easier to achieve a good calibration on a small part of the sensor. There is also the possibility to use a scheimpflug adapter to ensure that you can get focus throughout the field of view.

6.5.2 Dot wedge parameters

When using the dot wedge method, some parameters are important to consider.

Dot distance

Specify the distance between the dots to get a correct world coordinate system.

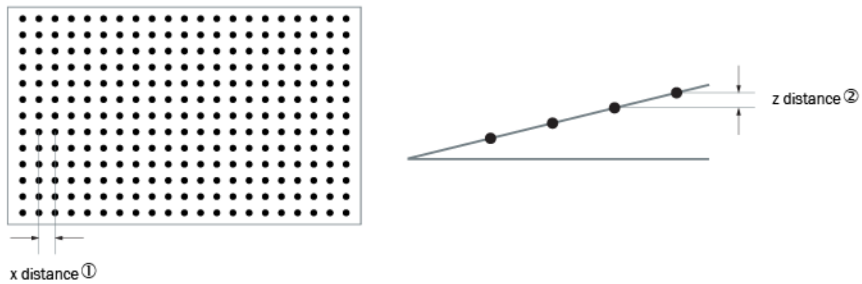


Figure 32: Measuring the distance between the dots

① x distance
② z distance

Dot distance x is the distance in millimeters, between two dot columns. This distance is usually well known.

Dot distance z is the height distance in millimeter between two dot rows. This parameter is either positive or negative depending on the scan direction and the orientation of the target, see figure 32, page 29.

It is always easy to measure the **Dot distance z.**

Calculating the z distance:

1. Set the **Dot distance z** parameter to 1.0 (even though it is not correct).
2. Estimate a calibration.
3. Use the estimated model to measure something with known height.
4. Use the known height and the measured height, to calculate the actual z distance.

For example:

Estimate a calibration where **Dot distance z** is 1.0 mm. Measure an object with a known height of 10.0 mm. The measuring returns a height of 7.8 mm. The actual z distance is 1.0 x (10.0 / 7.8) mm. Repeat the measuring, but with the new value for **Dot distance z** to verify the result.

Actual z distance = **Dot distance z** x Known height / Measured height

Target detection

When finding the 2D positions of the dots an adaptive thresholding algorithm is used for the segmentation of the reflectance image. The **Min area** and **Max area** parameters are used to detect the dots. The parameters are specified in pixels. Use the region of interest to omit part of the calibration image when performing the estimation.

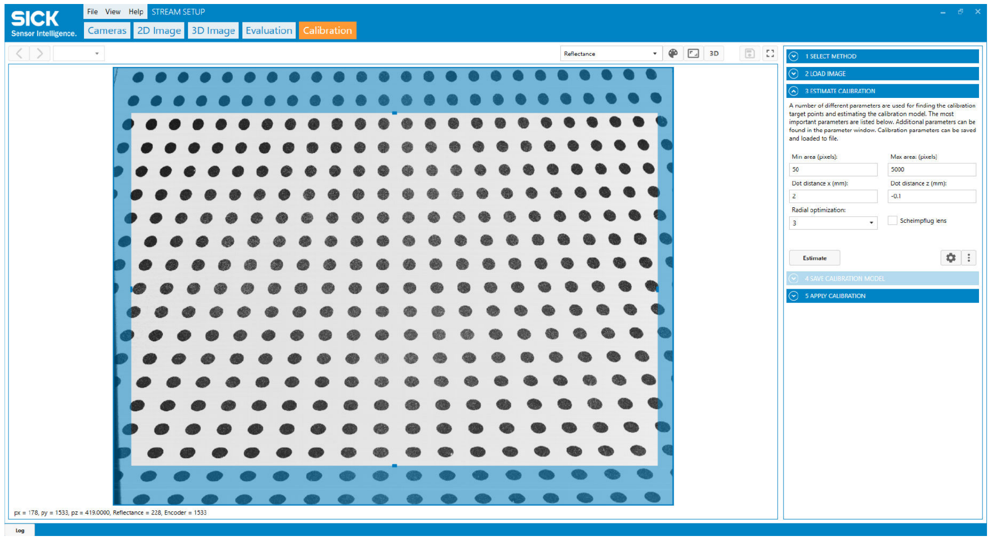


Figure 33: Target detection GUI reference

6.5.3 Dot wedge algorithm

How the dot wedge algorithm works

1. Find the 2D position for each dot by:
   a) Threshold the reflectance image.
   b) Extracting the dots.
   c) Calculating the center points of the dots.
2. Find the 3D position of the dots by:
   a) Fitting a small plane around each dot.
   b) Finding 3D positions by projecting 2D positions into its corresponding plane.
3. Calculate a grid from the dot positions.
4. From the grid, calculate the dots positions in millimeters.
5. Estimate a calibration model between the pixel positions and the millimeter positions.

6.5.4 Dot wedge feedback images

The feedback images show the different steps used in the dot wedge algorithm.

Calibration image

This feedback image shows the calibration image with the region of interest.

Detected dots

This feedback image shows the thresholded reflectance image in black and white. The areas that have been identified as dots are shown in red overlay. This image, and some of the other feedback images, also contains mouse over information about the detected dots. When hovering over a dot, you get information about its index, area, and calibration error.

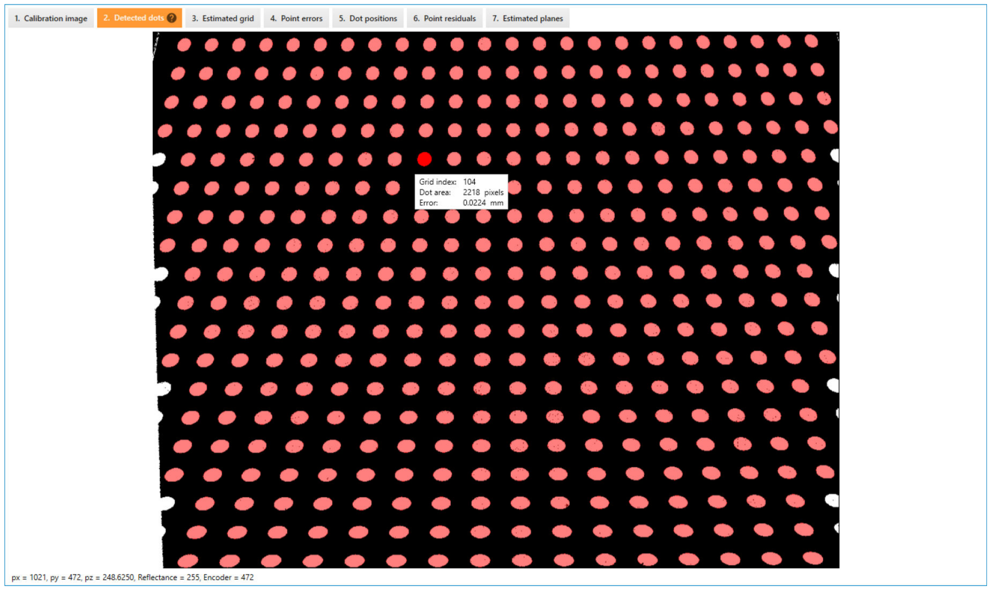


Figure 34: Estimated dots GUI reference

Estimated grid

This image shows the estimated grid that is calculated from the dot positions. If the grid has been calculated correctly, each dot should be connected to its neighbors orthogonally, but not diagonally. Holes in the grid however, can be acceptable. The image also shows the origin and the coordinate axes of the world coordinate system.

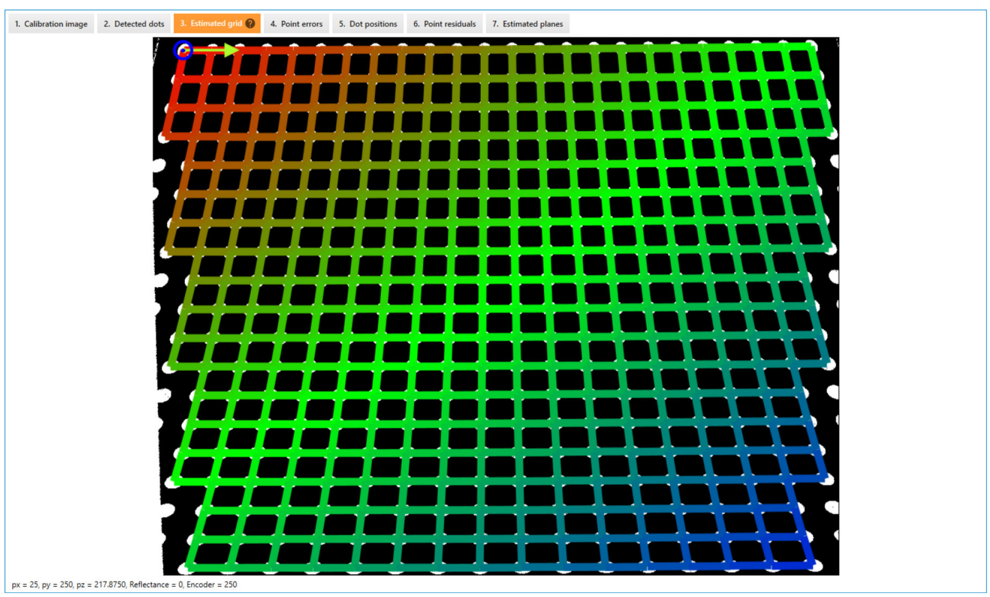


Figure 35: Estimate grid GUI reference

Point errors

This image shows the error for each detected target point. The colors are graded from red to green, where red symbolizes the maximum error.

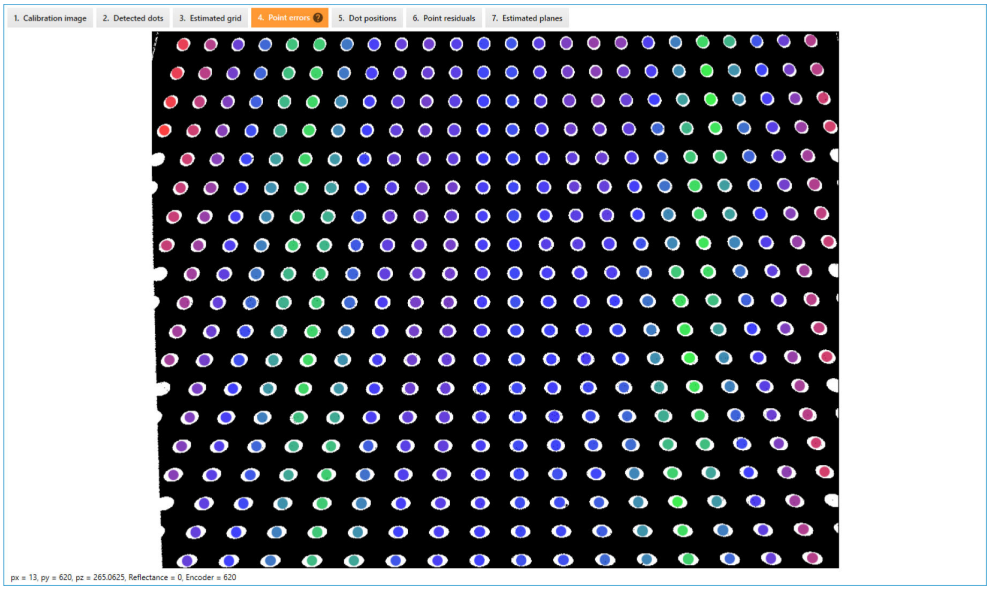


Figure 36: Point errors GUI reference

Dot positions

This image shows the dots' xz-positions on the sensor image. The dots should cover the part of the sensor that will be used for measurements. The image also shows the coordinate axes.

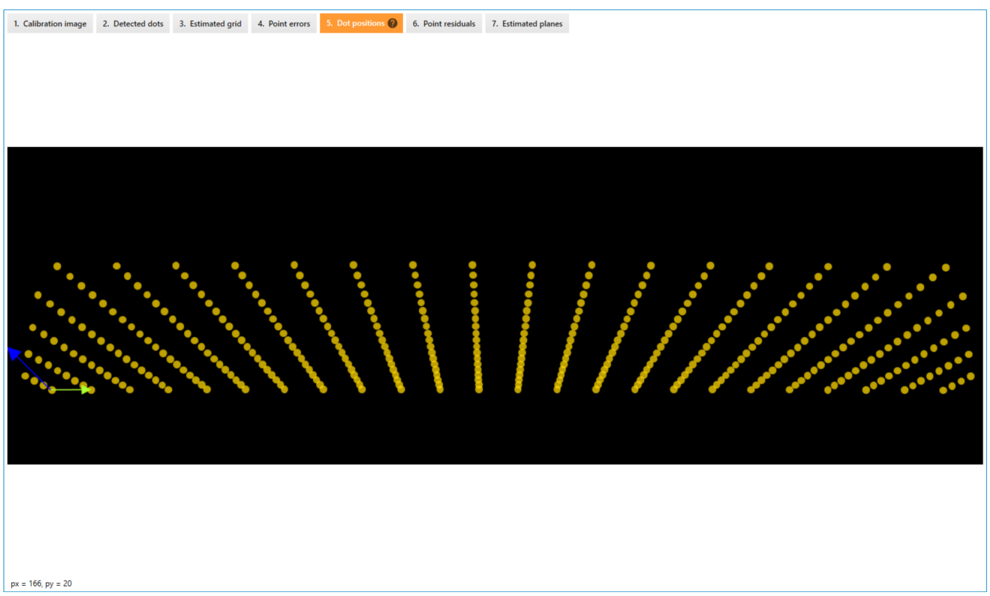


Figure 37: Dot positions GUI reference

Point residuals

This image shows the residuals in each detected target point. The colors are graded from red to green, where red symbolizes the maximum error. The arrows point in the direction where the target points should be located according to the estimated model.

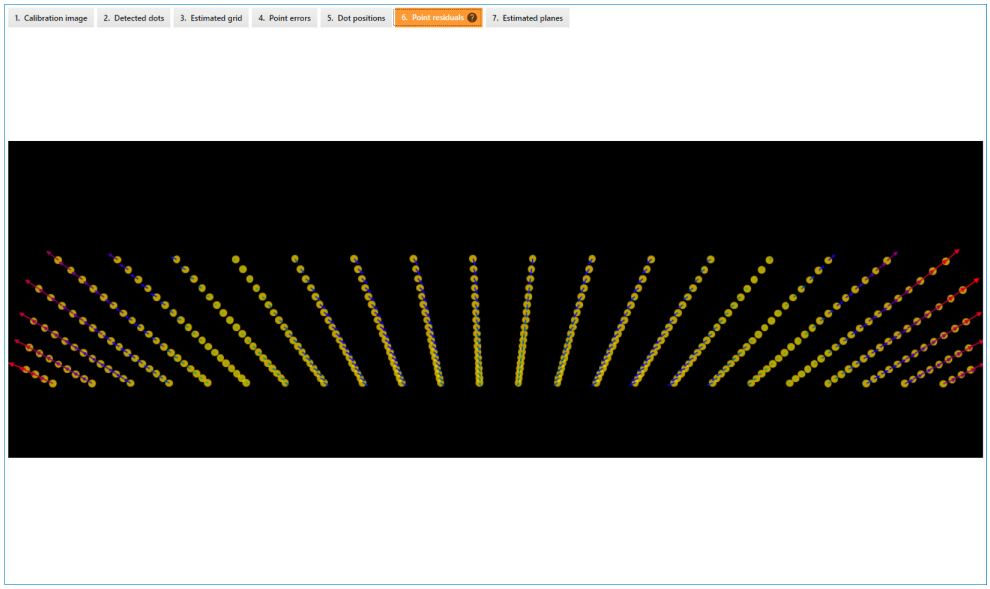


Figure 38: Point residuals GUI reference

Estimated planes

This feedback image is a 3D visualization of the calibration image, together with the estimated planes for each detected target point. The image also shows the calculated 3D positions.

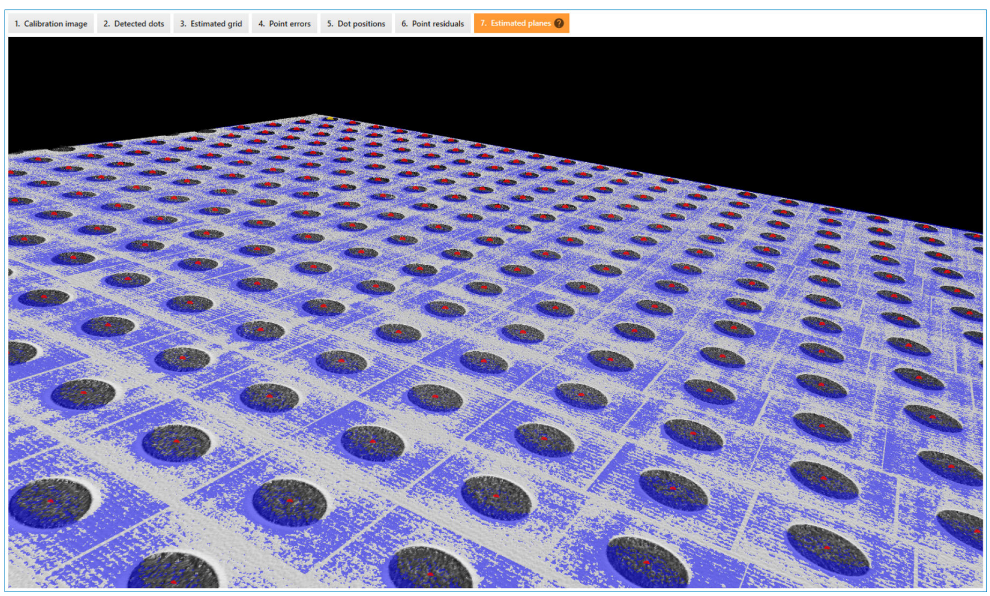


Figure 39: Estimated planes GUI reference

6.6 Calibration workflow

This workflow is independent of which calibration method that is used. Fo detailed information about the respective metod, see "Using sawtooth calibration", page 19 and "Using dot wedge calibration", page 26.

Select **View** and mark the **Calibration** checkbox to be able to use the calibration tools in **Stream Setup.** The **Calibration** tab will then be visible.

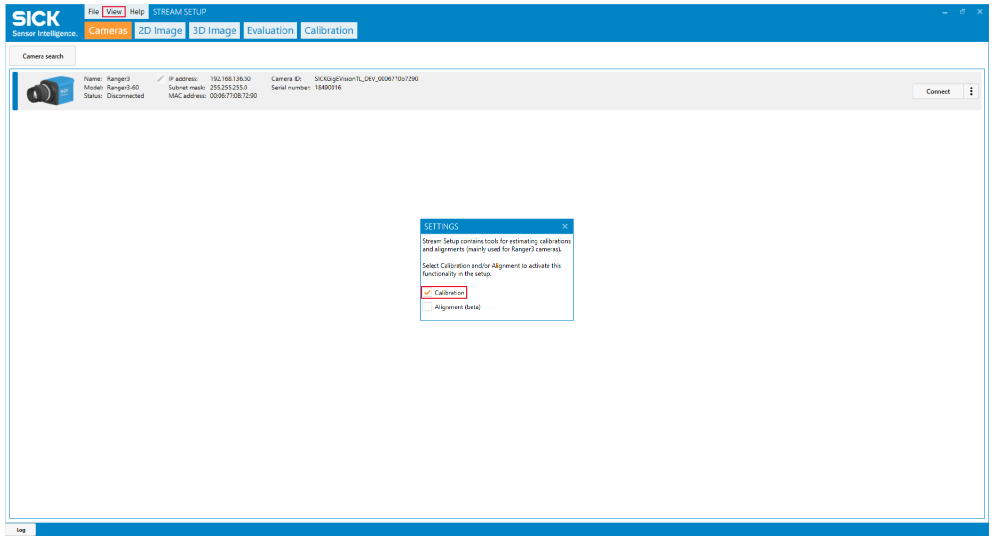


Figure 40: Showing the ***Calibration*** *tab*

6.6.1 Setting up the camera

When estimating a calibration, the estimated model will only be valid for the given geometry. Nothing in the camera and laser setup can change after the calibration has been done. This statement also includes laser and lens focus. For example, if the lens aperture is modified after the calibration is done, the setup needs to be recalibrated. Before estimating a calibration, make sure that the camera and laser setup is complete.

NOTE
The camera parameters do not affect the calibration model. You can, for example, use one exposure time when scanning the calibration target, and a different exposure time later on.

6.6.2 Acquiring calibration images

To estimate a calibration, you need to acquire one or multiple images of the calibration target. Acquiring images is performed in the tabs **2D Image** or **3D Image**, depending on the selected calibration method. The images need to be saved to disk.

6.6.3 Estimating the calibration

When the calibration images are acquired and saved, switch to the **Calibration** tab and follow the steps in the settings pane to the right.

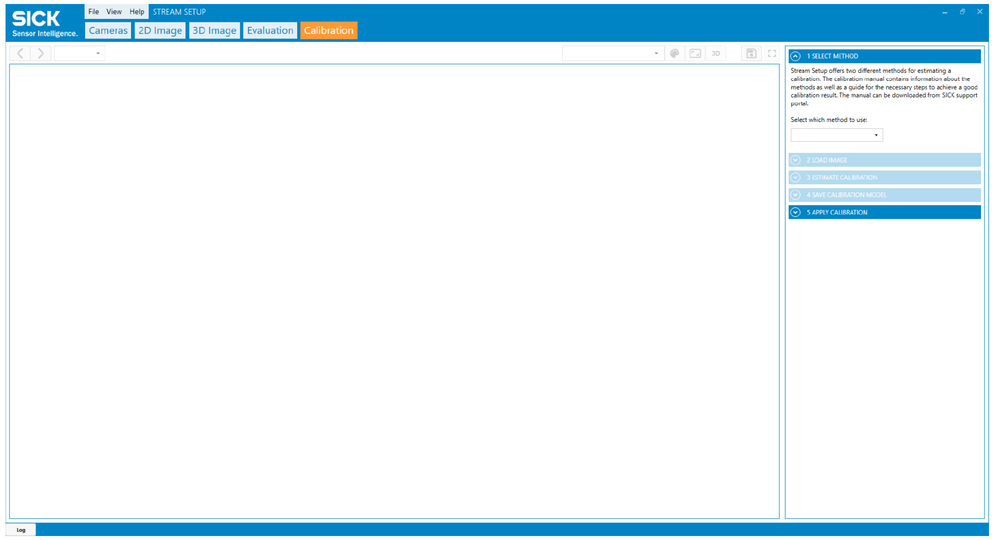


Figure 41: Selecting calibration method

Select the calibration method and load one or more calibration images. Select the **Estimate calibration** step.

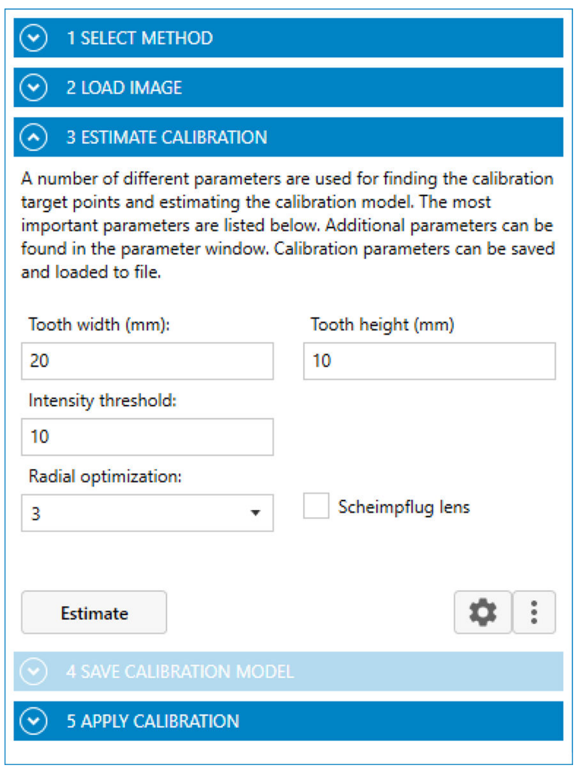


Figure 42: Estimate calibration where sawtooth method was selected in step 1

Two-step calibration algorithm

1. Detect the target points in the calibration images. This detection works different, for different calibration methods.
2. Estimate a calibration model from the detected points.

Parameters

The algorithm uses a number of different input parameters. The most important parameters are located directly in the **Estimate calibration** workflow panel. Additional parameters can be found in a separate parameter window. Use the cogwheel button to reach other parameters. The calibration parameters are different depending on the selected calibration method. The parameters generally cover the following areas:

- **Target dimensions**: Parameters defining the dimensions of the calibration target.
- **Target detection:** Parameters for finding the calibration target in the input image.
- **Coordinate system:** Parameters that define the origin and coordinate axes of the world coordinate system.
- **Estimation**: Parameters used when estimating the model from the detected target points.

Calibration result

Click on the **Estimate** button to start the estimation. The estimation will generate some feedback images that provide an indication about the accuracy of the estimation.

- **Feedback images**
  The estimation gives a number of feedback images that visualize different steps in the target detection algorithm. Each calibration method has different types of feedback images. The feedback images give a hint to the user how to tune the input parameters, in order to improve the result.
- **Calibration error**
  The estimation feedback includes a mean error and a maximum error, defined in millimeters. These errors are calculated by mapping the sensor points to the world points using the estimated calibration model. Please note that the calibration error cannot be directly used as a measurement of the accuracy of the estimation. The accuracy will depend on a lot of factors and needs to be validated on real objects.

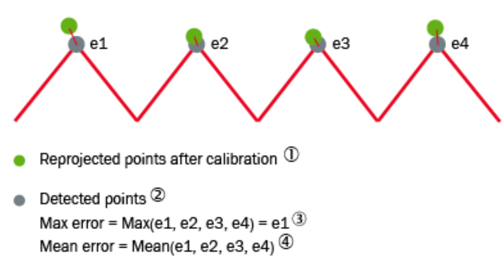


Figure 43: Calibration error feedback

① Reprojected points after calibration

② Detected points

③ Max error = Max(e1, e2, e3, e4) = e1

④ Mean error = Mean(e1, e2, e3, e4)

6.6.4 Saving the calibration

The calibration model can either be saved to disk or uploaded to the camera. For information about the different ways the calibration file can be used, see "Applying the calibration", page 37.

Save to disk

The calibration can be saved to disk on the computer. The file can be used to apply a calibration on uncalibrated images saved on disk. It can also be used when acquiring uncalibrated images from the camera, to calibrate the images on the computer.

Upload to camera

The calibration model can also be uploaded and stored on the camera. Having a calibration file stored on the camera, makes it possible to acquire images that are calibrated directly.

6.6.5 Evaluating the calibration

After the calibration has been estimated, some type of evaluation is needed. It is usually more practical to do the evaluation on the computer, before uploading the calibration file to the camera. For more information about the evaluation process, see "Evaluation", page 39.

6.7 Applying the calibration

There are different ways that the estimated calibration model can be applied after it is saved.

On-device calibration

When a calibration file is stored on the camera, the camera can be configured to acquire calibrated images. Upload and store the calibration model to the camera. Use the **Camera files** window to upload the file to the camera.

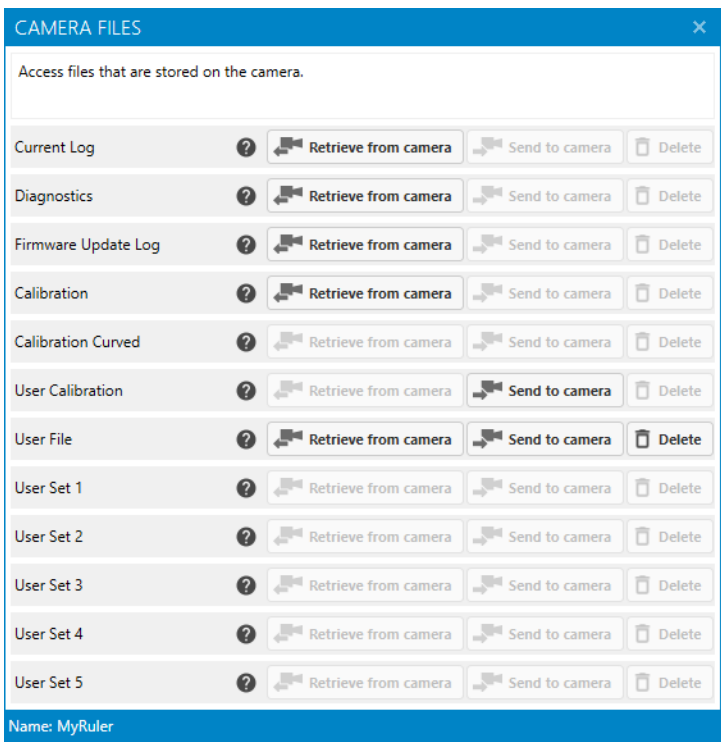


Figure 44: Camera files GUI reference

Select **Calibrated (camera)** in the **Calibration** parameter category. The camera uses the calibration file when acquiring 3D scans, and the image will be calibrated directly on the camera.

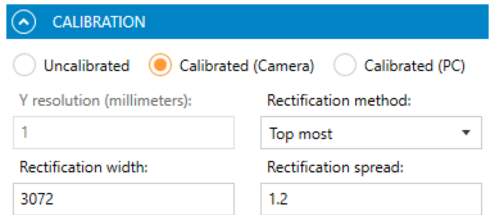


Figure 45: Calibration is performed on the camera

Calibration on computer

When acquiring uncalibrated images from the camera, the calibration is performed on the computer. Select **Calibration (PC)** and point out the path to the calibration file. Applying the calibration on the computer enables some additional options, which are not available for on-device calibration.

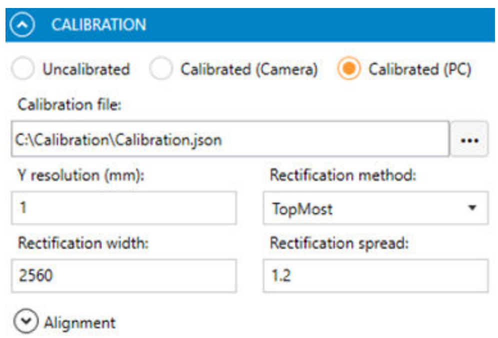


Figure 46: Calibration is performed on the computer

Offline calibration

The calibration file can also be used for calibrating saved, uncalibrated images. This calibration is performed in the **Calibration** tab. This mode is useful when evaluating the calibration model. The calibration can be applied to a single image, or to a folder with images. The resulting calibrated image can be saved to disk.

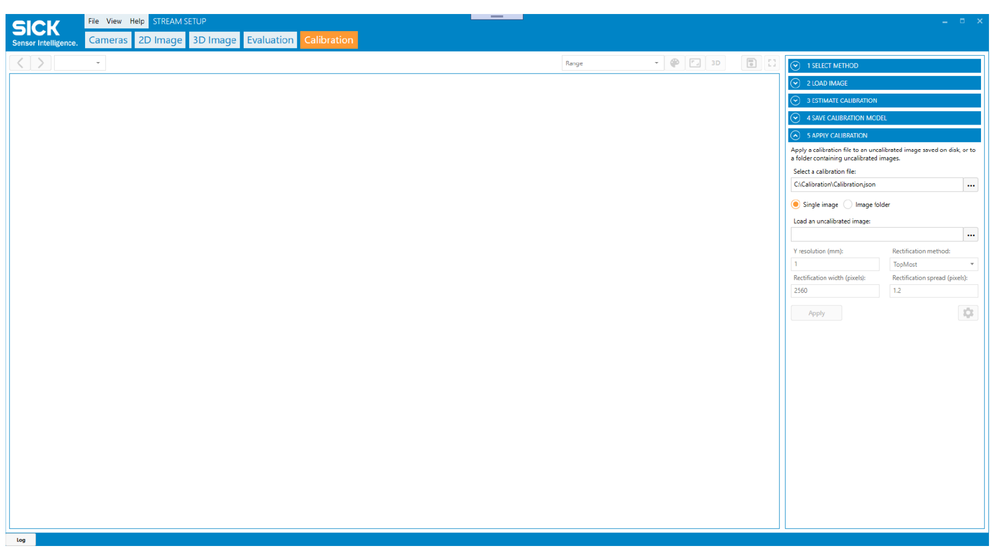


Figure 47: Calibration is performed offline

6.8 Evaluation

Before using an estimated calibration model in an application, it is a good idea to evaluate its accuracy. The evaluation is performed by scanning an object with known dimensions and measure it. There are some tools in the **Evaluation** tab for measuring objects in images.

Evaluation tools

With the tool **Surface distance**, it is possible to measure the distance between two flat surfaces. If the range accuracy is the most critical, this evaluation method is good to use.

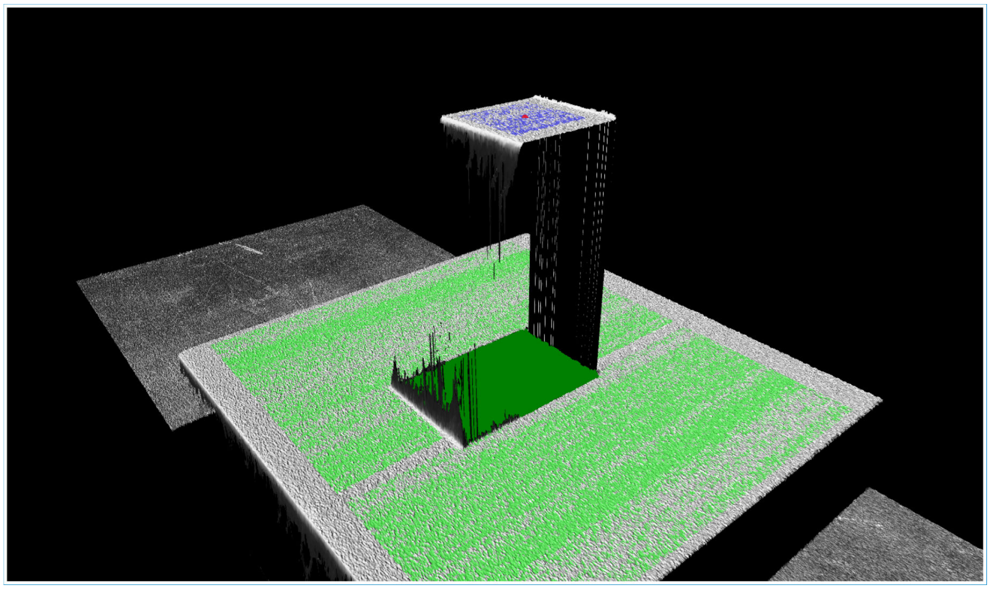


Figure 48: Measure distance using the tool Surface distance

The tool **Extract profile** is useful when analyzing image data. The tool extracts a profile along a row or a column in the image. The selected row is shown as a red line.

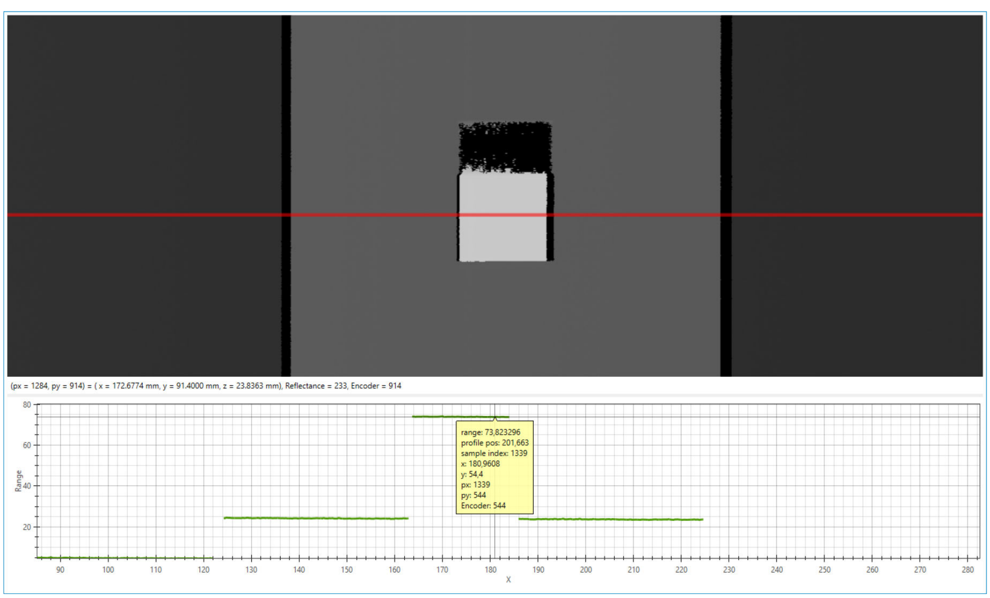


Figure 49: Extract profile GUI reference

Recommended procedure

The evaluation is usually more practical to do offline, on saved evaluation images.

1. Acquire the calibration and uncalibrated evaluation images.
2. Estimate a calibration.
3. Apply the calibration on the evaluation images.
4. Evaluate the accuracy of the calibrated evaluation images.
5. If the result is not good enough, tune the calibration parameters and return to step 2.

You can upload the estimated calibration model to the camera, and do the evaluation live instead of offline. The advantage of using saved uncalibrated evaluation images is that, if you need to re-do the estimation you can do the evaluation on the same evaluation images and compare the results.

In general it is easy to achieve a calibration which has good accuracy in just a part of the field of view. Sometimes the accuracy is good in the middle of the field of view but gets worse closer to the edges. For that reason it is important that the evaluation images are distributed in the entire field of view.

7 Configuration

7.1 Configuring Ruler3000

The Ruler3000 is designed to deliver good measurement data for both dark and bright objects by default.

Before the camera can be used in the system, it has to be configured. This is usually done by setting up the camera in a production-like environment and evaluate different parameter settings until the result is satisfactory. The Ruler3000 can be configured to fit many different applications.

The following sections describe what can be specified when configuring the Ruler3000 using **Stream Setup**.

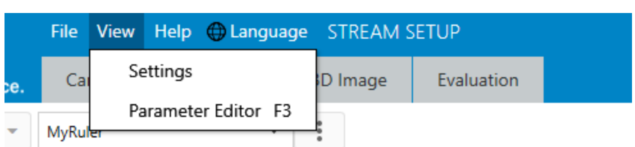
Extraction region	Where on the sensor to measure and dimensions of the 3D output image.
Laser profile extraction	For how long to expose the sensor, using HDR, etc.
3D image format	How many profiles to include for each 3D image. How to handle reflectance and scatter.
Triggering	When to make a measurement.
Calibration	If and how sensor data is converted to mm values.

7.1.1 Editing parameters

Tabs: **2D Image**, **3D Image**

When you adjust the parameters, you look at the 2D or 3D image to see the result. You can store the image to the image list in the **Evaluation** tab after each adjustment and compare the images to find the best configuration. You cannot edit the parameters while the camera is acquiring data.

The Ruler3000 also has a large number of parameters that are not exposed in Stream Setup but can be configured using GenICam™ or GenIStream, see "GenIStream API", page 93. It is also possible to access the parameters via the **Parameter editior**.



NOTE
All parameters in **Stream Setup** GUI are available in the **Parameter editor** but sometimes with a different name. In the **Parameter editor** all parameters have the GenICam name. In the **Stream Setup** GUI you can always see the GenICam name when hovering over a parameter, see figure 50, page 42.

1. Click the stop button to stop acquiring data.
2. In the Parameter settings section (see page 67, select the category the parameter belongs to).

✓ The parameters of the selected category are displayed in the right part of the window.

3. If the parameter you want to edit is not shown, select the down-arrow to make more parameters visible.

NOTICE
Always make sure that you have the right knowledge before you make any changes, otherwise the system can work incorrectly.

4. Select the parameter.
✓ A description of the parameter is shown as a tool tip.
5. Depending on the type of parameter, type or select the new value.
✓ The new value is saved automatically when you leave the input field or press Enter on your keyboard.

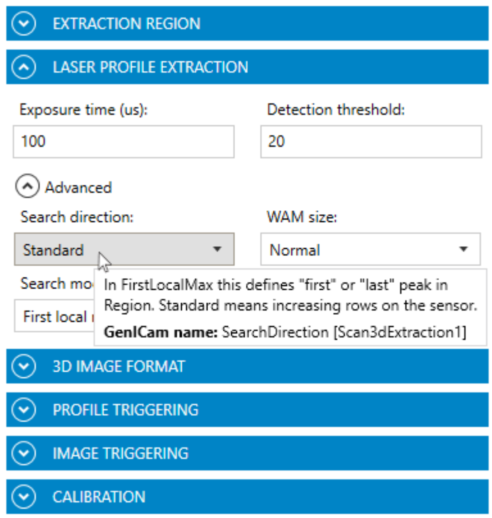


Figure 50: A selected parameter with help text and corresponding GenICam name

6. Click the play button to start the data collection.
7. To view the currently displayed image in the **Evaluation** tab, use the **Add image** button.

7.2 Extraction region

Data from the sensor is used to output either the raw data, i.e. a standard 2D image, or the 3D profile data.

The region of interest (ROI) is the area within the laser plane in which the device will look for a profile to capture. The parts of a profile that are outside the ROI are either ignored (if to the right or the left of the ROI) or treated as missing data (if above or below the ROI).

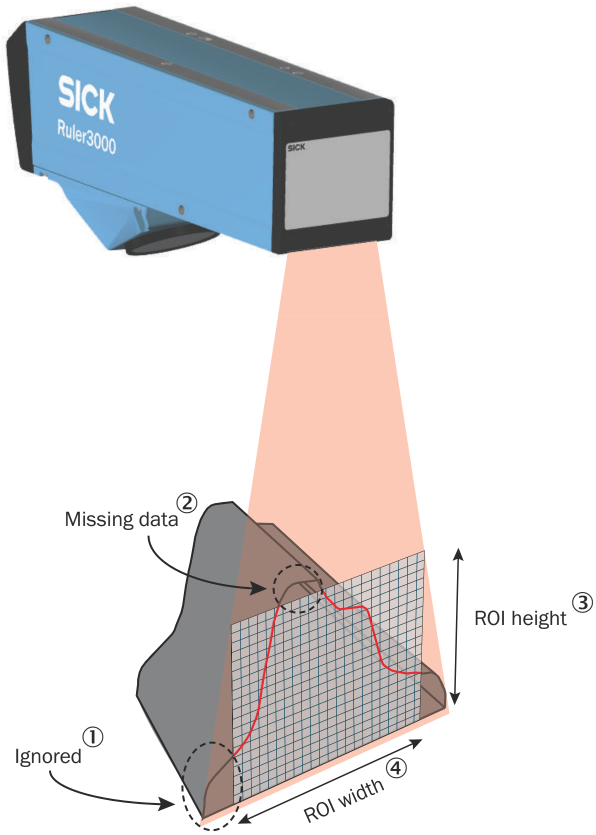


Figure 51: The region of interest and captured profile.

① Ignored
② Missing data
③ Region of interest height
④ Region of interest width

Using a smaller region on the sensor enables measurements at a higher rate. The region is specified by the parameters **Offset X**, **Offset Y**, **Width**, and **Height** as shown in the figure below.

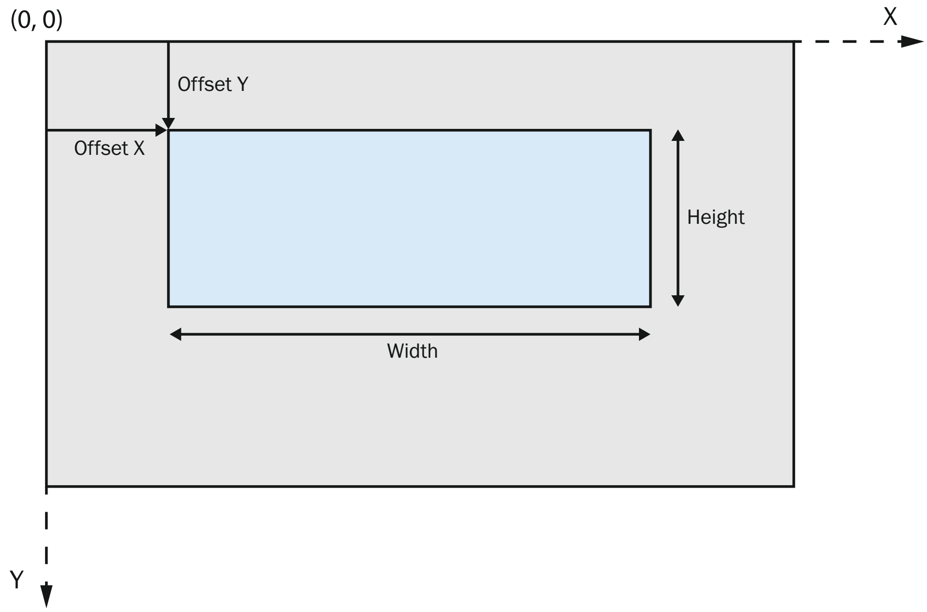


Figure 52: Image area and 2D region of interest.

The resulting image generated by the device will have **Width**[2] times **Profiles per image** pixels. **Offset X** and **Offset Y** are given with respect to the upper left corner of the image area. This corner has the coordinates (0,0) in the imager (x, y) coordinate system. All measures are given in sensor (pixel) or world (mm) coordinates.

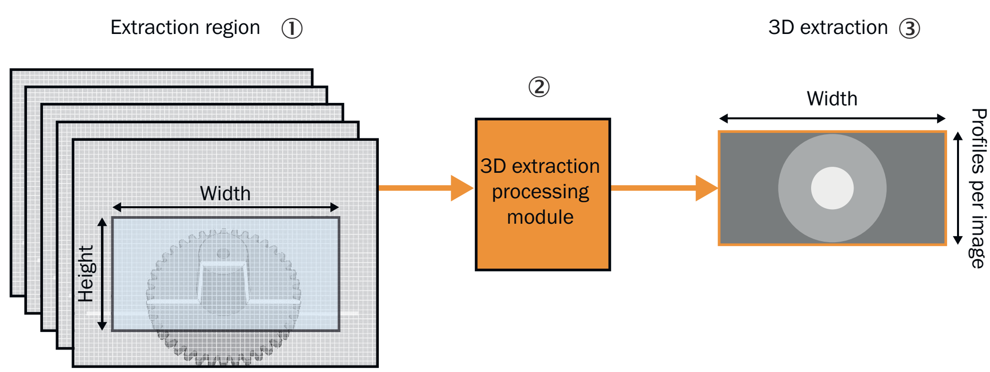


Figure 53: A 3D processing module defines the processing and formatting conditions of the generated 3D profile output data.

① Extraction region
② 3D extraction processing module
③ 3D extraction

2) For a rectified image the width is equal to **Rectification width**.

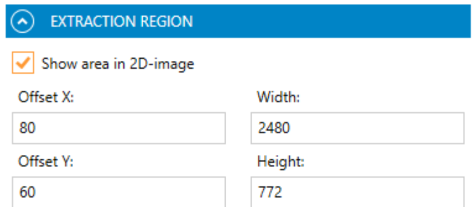


Figure 54: Extraction region GUI reference.

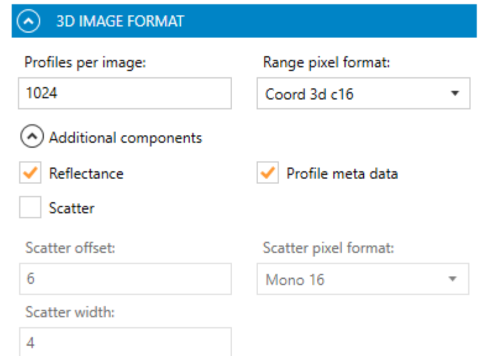


Figure 55: 3D Image format GUI reference.

The **Width** and **Height** parameters of the region define the dimensions of the 3D extraction output image. To visualize the region of interest, select the **Show area in 2D-image** checkbox.

To get a 3D image, several 2D images are required. Each 2D image corresponds to one profile. The 2D images are transformed into profiles in the 3D extraction output image. This means that the **Profiles per image** value tells how many 2D images are used to generate the resulting 3D image. The 3D image has **Width**[3)] times **Profiles per image** pixels.

7.2.1 Setting extraction region

Tab: **2D Image**

To adjust the height and position of the region that is used to generate the 3D image data follow the steps below.

NOTE
For best image quality, make sure that the whole width of the laser line is within the defined region. Use the **Guaranteed FOV** button to verify that the region is within the field of view guaranteed for the device, see "Visualizing 2D data", page 79.

1. Select the **Show area in 2D-image** checkbox.

✓ A blue overlay appears in the 2D image. The overlay represents the parts of the image to be excluded from the generation of 3D image data. The remaining dark area is the extraction region.

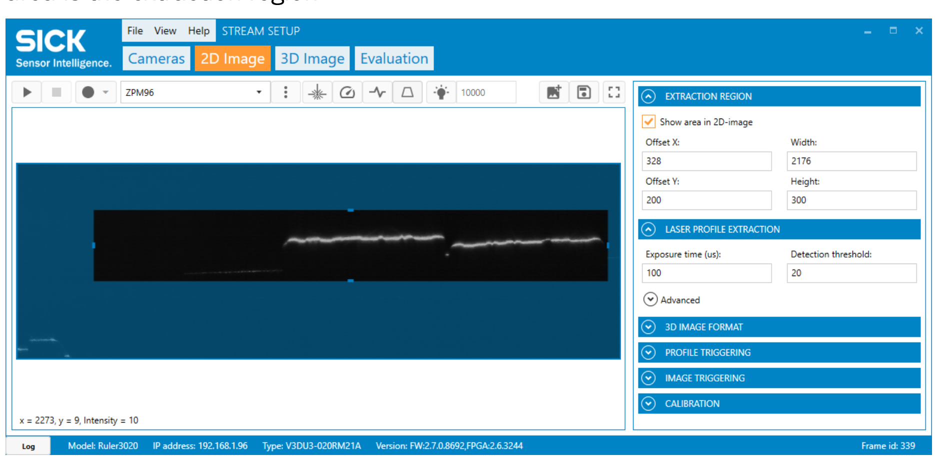


Figure 56: 2D image with blue overlay.

2. Hover over the edges of the extraction area to highlight its handles.

3) For a rectified image the width is equal to **Rectification width**.

3. Click and drag the handles to change the dimensions and offset:
    - Click and drag the top and bottom handles to adjust the **Offset Y** and **Height** parameters.
    - Click and drag the side handles to adjust the **Offset X** and **Width** parameters.
    - Click and drag the cross-shaped handle in the middle to change the position of the entire extraction region.

When a handle is moved, the corresponding parameter values are automatically updated. As an alternative to moving the handles, the parameter values can be updated manually.

NOTE
The **Width** parameter is fixed to factor 16 and **Height** to factor 4 and is automatically handled by **Stream Setup**.

7.2.2 Measurement mode

The camera can be configured to output either the raw data from the image sensor or the 3D profile data. In the user interface, you select **2D Image** to see the raw sensor data as a 2D image or **3D Image** to get the 3D profile data.

7.2.3 Maximum buffer size

The maximum size for an image buffer to be sent from Ruler3000 to the host computer is around 40 MB. The limit is due to the limited GigE Vision® retransmission buffer memory in the device.

The maximum buffer height, i.e **Profiles per image** depends on the data format, the region width or rectification width (if using image rectification), and the number of enabled components (e.g. reflectance, see "Reflectance", page 54). For example: With default settings, i.e. both rectified mode and reflectance enabled, the maximum buffer height is about 8700. When reflectance is disabled, the maximum buffer height increases to about 13000.

If the buffer size is maximized, the camera may block user actions that further increase the size. Examples of such actions are:

- Enabling another component, such as reflectance
- Increasing the region width or rectification width

The user must decrease the buffer size to make the blocked actions available again. This is done by decreasing the region or rectification width or decreasing the number of enabled components. You can also reduce the **Profiles per image** to allow more memory to be used by each profile.

7.3 Laser profile extraction

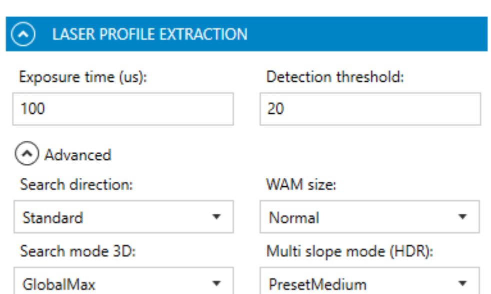


Figure 57: Laser profile extraction GUI reference

7.3.1 Exposure time

Once the height of the sensor region is set, there are two other settings that affect the profile rate of the camera:

Exposure time (µs)	The time (µs) during which the sensor region is exposed. This controls the duration where the photosensitive cells are exposed to light.
Timed profile rate (Hz)	The rate at which the profiles in an image are captured (Hz). Only applicable when the camera is in free-running mode. The **Timed profile rate (Hz)** is defined in the Profile triggering section.)

The exposure time and the profile rate are inter-dependent. The maximum exposure time cannot be longer than the time between two profiles, minus about three microseconds that are needed for readout and reset.

You can see the maximum profile rate possible for the current configuration by clicking on the **Timed profile rate** field. The maximum profile rate is shown in the information field at the bottom.

NOTE

The maximum exposure time and the maximum profile rate are stored as floating-point values and rounding-off effects may make it impossible to set the exact value returned by the GUI. The maximum deviation is 0.01 µs for the exposure time and 0.01 Hz for the line rate.

7.3.1.1 Setting exposure time

Tab: **2D Image**

1. Look at the 2D image and the laser line and adjust the **Exposure time** parameter until the laser line is imaged as a narrow bright stripe and the background is not visible, see the figure in the middle below. The laser line should be approximately 4 to 8 pixels wide.

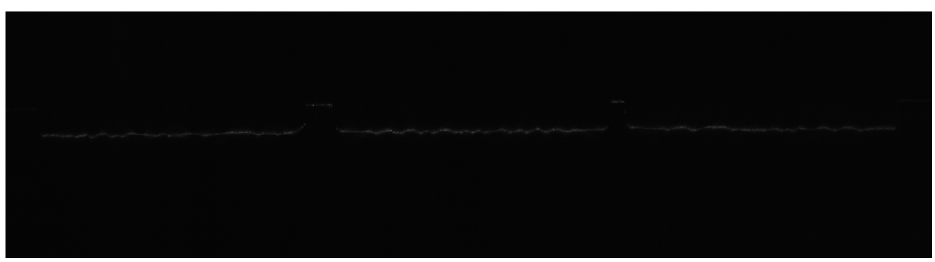


Figure 58: Too short exposure time: Laser line hardly visible.

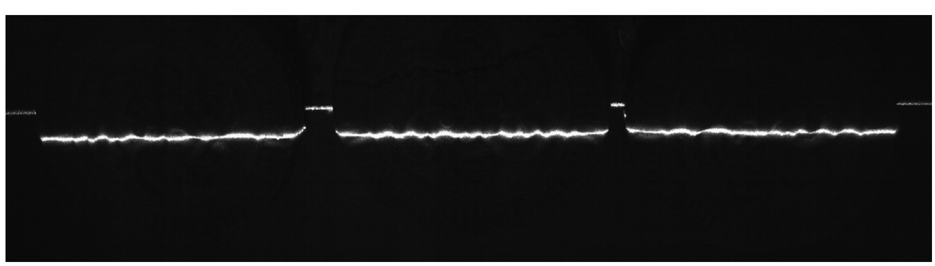


Figure 59: Normal exposure time: Laser line bright but not saturated. No background visible.

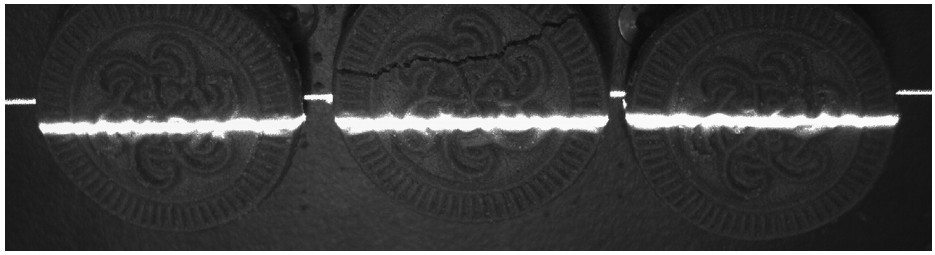


Figure 60: Too long exposure time: Laser line wide and saturated. The background is visible.

NOTE
If reflectance measurements are enabled, the exposure time can also be adjusted using a reflectance image as reference. For details, see "Setting exposure time using reflectance", page 54.

7.3.2 Detection threshold

The **Detection threshold** defines the minimum reflectance signal that can be detected as a peak position. Ideally, this parameter is set to a value that is higher than the amplitude of the noise, but still low enough to detect the laser signal, see the figure below. If **Detection threshold** is too low, noise will be registered as laser peaks. This will result in bad image quality. If **Detection threshold** is too high, not all laser peaks will be registered. This will result in an image where some parts are missing. Missing data will be registered with pixel value 0 if a laser peak cannot be found in that column.

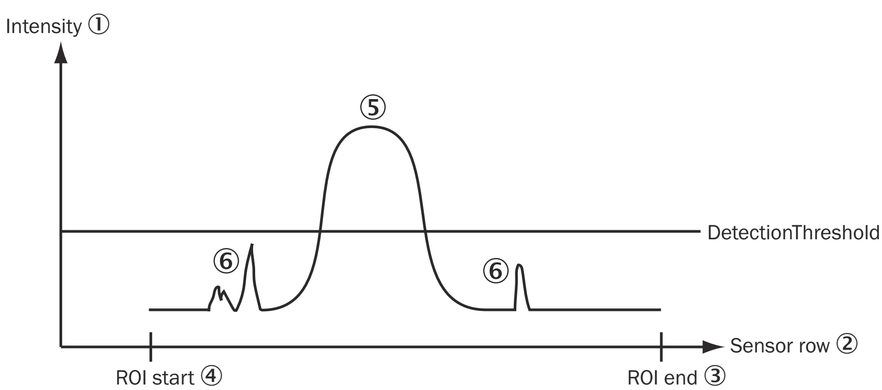


Figure 61: Analog signal with noise

① Intensity
② Sensor row
③ ROI end
④ ROI start
⑤ Detected peak
⑥ Not detected peaks

7.3.3 Advanced

7.3.3.1 Search direction

The search direction is used to define if the first or last peak should be used to represent the impact position of the laser line. The **Search direction** is only relevant when **FirstLocalMax** is used as **Search Mode 3D**.

Setting	Description
Standard	Finds the first peak in the region when searching from the top of the region of interest and down.
Reverse	Finds the last peak in the region when when searching from the bottom of the region of interest and up.

All relevant peaks must be above the given threshold value. The first peak is found when **Search direction** is **Standard** and **Search mode 3D** is set to **FirstLocalMax**. The maximum peak is found if **Search mode 3D** is set to **GlobalMax**. In this case the search direction is not relevant.[4] The last peak is found when **Search direction** is **Reverse** and **Search mode 3D** is set to **FirstLocalMax**.

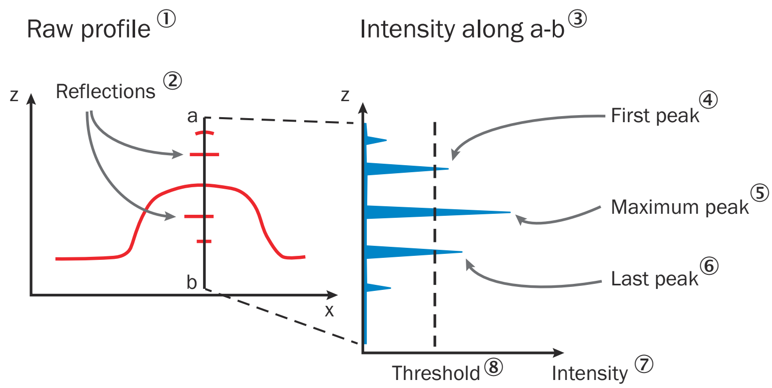


Figure 62: Search direction and possible peaks to find.

① Raw profile
② Reflections
③ Intensity along a-b
④ First peak
⑤ Maximum peak
⑥ Last peak
⑦ Intensity
⑧ Threshold

7.3.3.2 WAM size

The size of Window Around Maximum (WAM) is used for high-resolution peak fitting. The selected value should correspond to the laser peak width on the sensor.

If the laser peak is narrow, the selected **WAM size** should be small. If the laser peak is wide, the selected **WAM size** should be larger.

4) If the image is heavily saturated causing a very wide peak, the Search direction will have an impact also in GlobalMax mode, shifting the peak closer to the first peak depending on the Search mode 3D.

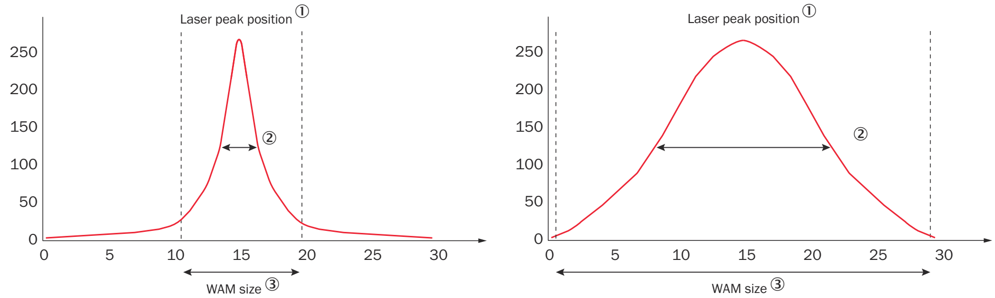


Figure 63: Laser peak width and corresponding WAM size.

① Laser peak position
② Laser peak width
③ WAM size

Setting	Description
Small	Size 7 pixels, peak width 2-4 pixels.
Normal	Size 15 pixels, peak width 3-8 pixels
Large	Size 31 pixels, peak width 7-15 pixels

7.3.3.3 Search mode 3D

The **Search mode 3D** defines the type of peaks to search for. There are two different modes available. For more information, see "Search direction", page 48.

Setting	Description
Global max	Searches for the maximum intensity peak in each column regardless of **Search direction**.
First local max	Searches for the first peak above the defined threshold in the **Search direction**.

7.3.3.4 High dynamic range (HDR) imaging

Ruler3000 supports high dynamic range (HDR) imaging, which increases the sensor's ability to adequately reproduce both bright and dark areas in a scene. HDR is suitable for improving the localization of the laser line when acquiring images containing both dark and bright materials, such as bright objects towards a dark background or dark objects with bright prints. The HDR function is on by default.

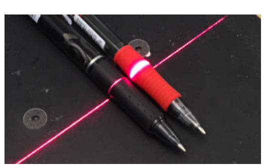


Figure 64: Acquisition of profiles

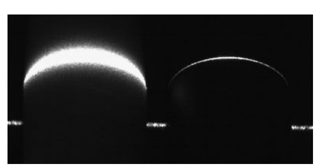


Figure 65: Resulting profile, linear (non-HDR) mode

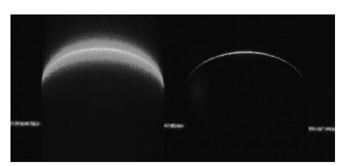


Figure 66: Resulting profile, HDR mode

Ruler3000 uses an HDR principle called multi-slope with one knee-point, which means that the normal linear relationship between the received light and the resulting pixel value (reflectance) is broken into two linear segments. The result is a compressed light-to-pixel value characteristic for high light intensities, according to figure 67.

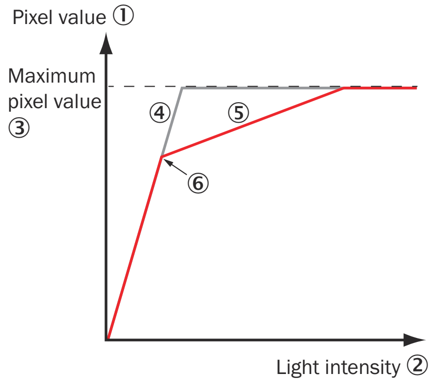


Figure 67: HDR multi-slope principle

①	Pixel value
②	Light intensity
③	Maximum pixel value
④	Linear (non-HDR) mode
⑤	HDR mode
⑥	Knee-point

The knee-point position and the slope after the knee-point are controllable by the **Multi slope mode (HDR)** setting. There are pre-defined parameter settings (**Off**, **PresetSoft**, **PresetMedium**, and **PresetAggressive**) that correspond to different amounts of compression. These settings result in a dynamic range increase of approximately 2, 6, and 15, respectively. See figure 68.

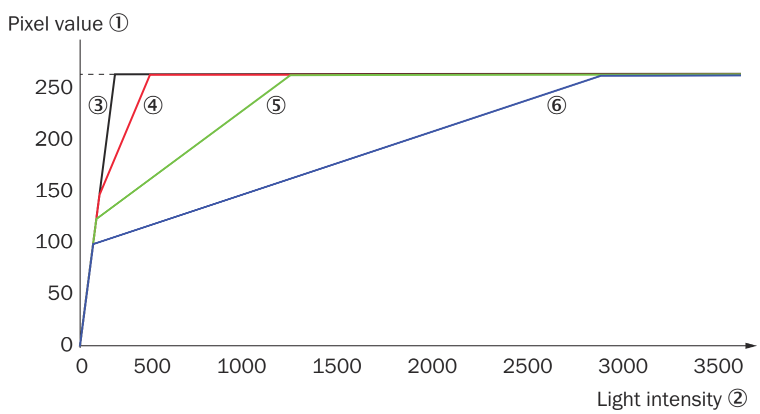


Figure 68: HDR settings for Ruler3000

①	Pixel value
②	Light intensity
③	Linear (non-HDR) mode
④	Soft pre-set
⑤	Medium pre-set
⑥	Aggressive pre-set

In HDR mode, the sensor readout must be finished before a new exposure can start. The sensor readout time is the time the sensor needs for the readout of the collected data. The minimum cycle time is the sum of the exposure time and the readout time. In linear mode, the sensor readout and a new exposure can be done in parallel.

For example: If the readout time is 33 µs and the exposure time is 30 µ, the total cycle time is 33 µs for linear mode and 63 µs for HDR, giving a maximum timed profile rate of 30 kHz and 16 kHz respectively.

7.3.3.4.1 Controlling HDR imaging

Tabs: **2D Image**, **3D Image**

To enable HDR imaging:

1. Open the **Laser profile extraction** parameter section.
2. Set **Multi slope mode (HDR)** to **Preset soft**, **Preset medium**, **Preset aggressive** or **Off**.
   - **Preset soft** increases the dynamic range by a factor ~2.
   - **Preset medium** increases the dynamic range by a factor ~6.
   - **Preset aggressive** increases the dynamic range by a factor ~15.

NOTE
Using HDR affects the maximum exposure time:

- In 2D mode, the maximum exposure time for **Preset soft**, **Preset medium** and **Preset aggressive** is about 16, 40 and 100 ms, respectively.
- In 3D mode, the maximum exposure time for **Preset soft**, **Preset medium** and **Preset aggressive** is about 4,10 and 26 ms, respectively.

7.4 3D image format

The **Range pixel format** setting defines the format of the pixels provided by the device. The data can be represented with 8, 10, 12, or 16 bits. A lower value allows a higher scan rate given the limitations of the Gigabit Ethernet link. The **Range pixel format** values derive from the GenICam™ standard, for example, **Coord 3d c16**. The last two digits represent the number of bits.

The Ruler3000 allows up to 16 subpixel levels on the 3D data. Ruler3000 can specify up to 1/16th, i.e. 0.0625, where on a column the laser line is centered. The 3D data is delivered with the optimal resolution of the pixel format. The range resolution is dependent on **Range pixel format** and the number of rows in **Height**, defined in **Extraction region**.

NOTE
It is not possible to obtain a resolution better than 16 subpixels. For information about maximum resolution, see the Operating instructions for the device.

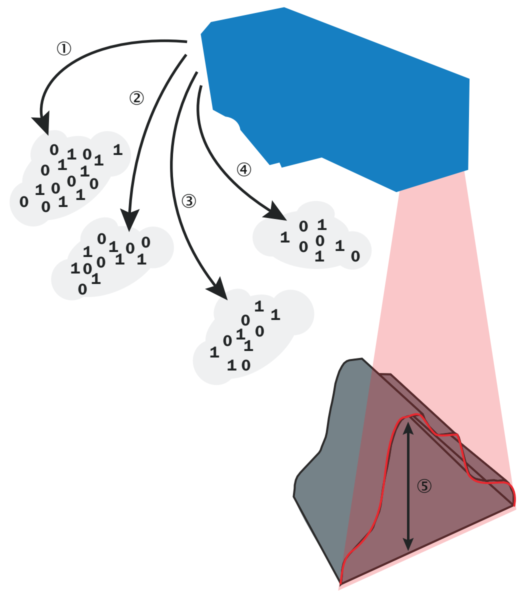


*Figure 69: Adapting the **Range pixel format** (calculation examples valid for Ruler3020)*

① **Range pixel format: Coord 3d c16**, i.e. 16-bit. 120 mm / 65536 = 0.0018 mm resolution. Since Ruler3000 is limited to 16 subpixels, the resolution will be 8 µm, which is the best possible resolution (Ruler3020).

② **Range pixel format: Coord 3d c12p**, i.e. 12-bit. 120 mm / 4096 = 0.03 mm resolution.

③ **Range pixel format: Coord 3d c10p**, i.e. 10-bit. 120 mm / 1024 = 0.12 mm resolution.

④ **Range pixel format: Coord 3d c8**, i.e. 8-bit. 120 mm / 256 = 0.46 mm resolution.

⑤ **Height** of the object, 120 mm.

If **Height** is 600 rows and **Range pixel format** is set to 12-bit data, i.e. **Coord 3d c12p**, the range resolution is 600 / 4096 = 0.15. 0.15 refers to where on a column that the laser line is found. This value corresponds to 1 / 0.15 = 6.66 subpixels. In this case, you will not get the best possible resolution, since the camera could use up to 16 subpixels, i.e. 1 /16 = 0.0625.

Since the Ruler3000 delivers calibrated data, it is more useful to calculate the resolution in mm. This calculation is performed using the same type of formula. Divide the **Height** in the region of interest with the number of output levels. **Height** is set to 600 rows, and let's say those rows span a height of 120 mm. **Range pixel format** is set to 12-bit data, i.e. **Coord 3d c12p**, the range resolution will be 120 / 4096 = 0.03 mm.

Also when calculating in mm you will realize that you loose som resolution. In this case, when running with 12-bits, since the best possible resolution of Ruler3020 is 8 µm. However, if 250 rows would be used instead, the resolution would still be the best possible when running with 12-bits.

Range pixel format	Number of output levels
Coord 3d c16	65 536 rows
Coord 3d c12p	4 096 rows
Coord 3d c10p	1 024 rows
Coord 3d c8	256 rows

Calculation formula:

Range resolution = Height[1)] / Number of output levels

1) Either in rows or mm

Adapting the **Range pixel format** can help with bandwidth issues. It allows a higher scan rate without sacrificing resolution when having few rows in **Height.** It also allows a higher scan rate when having a large number of rows in **Height**, but then resolution will be sacrificed.

The **Profiles per image** setting indicates how many profiles to include for each 3D image and is set in pixels. This value will be the height of the 3D image.

The pixel value 0 is dedicated to represent missing data, i.e. that no valid peak was found.

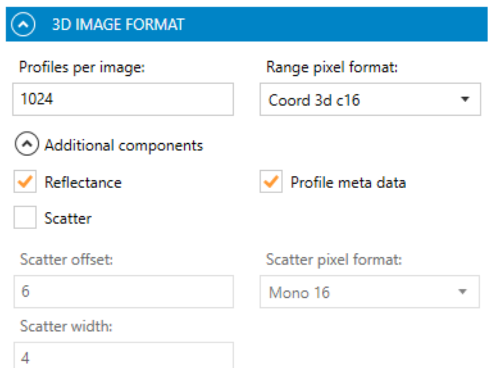


Figure 70: 3D Image format GUI reference

7.4.1 Additional components

7.4.1.1 Reflectance

The reflectance values along the laser line can be collected in parallel to the 3D data. The reflectance values are saved as an 8-bit grayscale image, with one value corresponding to each point in the range dataset.

The **Reflectance** checkbox enables collection of laser reflectance values in addition to the range data and is on per default.

To view the image with laser reflectance, select **Reflectance** from the drop-down list above the image viewer. see "Image components", page 80 for details.

Figure 71: 3D image with range information as brightness.

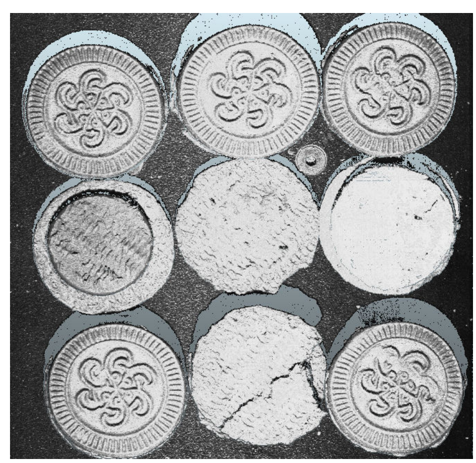


Figure 72: Reflectance image for a 3D image.

7.4.1.1.1 Setting exposure time using reflectance

Tabs: **2D Image, 3D Image**

Use the reflectance image as an indicator when adjusting the exposure time. Adjust the **Exposure time** in the **Laser profile extraction** parameter section.

- If the exposure time is too low, the objects in the reflectance image contain dark regions or regions with missing data. See figure 73.
- If the exposure time is too high, the objects contain bright saturated areas and artifacts. See figure 75.

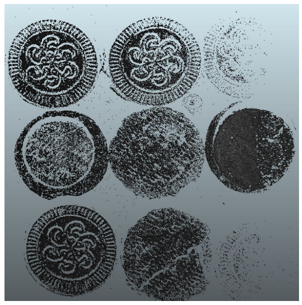


Figure 73: Low exposure time

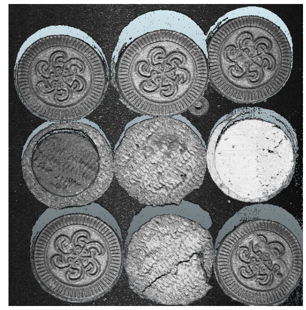


Figure 74: Normal exposure time

Figure 75: High exposure time

7.4.1.2 Scatter

The scatter component measures the intensity of the laser signal in defined parts of the Window Around Maximum (**WAM Size**), see "WAM size", page 49. The scatter signal can be explained as the amount of scattered light received in a sampling window at a distance from the peak laser position.

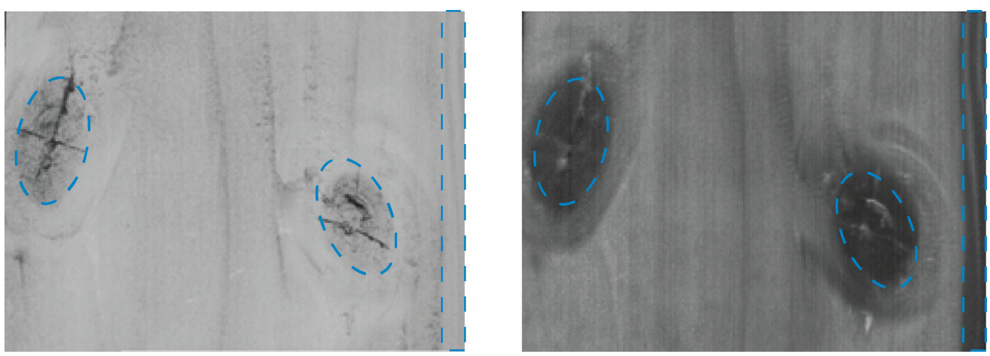


Figure 76: Wooden board displayed with reflectance (left) and scatter (right). The knots and the blue-stained right edge of the board (denoted in blue) appear dark in the scatter image.

Since the laser line spreads differently in different material, scatter measurements can distinguish material effects, which is useful for organic matters such as wood (wood fibers transmit light along their growth direction, and knots and rot affect this property) and meat (fat, bone, and meat have different scattering properties). In some cases, scattering can reveal sub-surface effects like delamination or the content of cavities beneath a surface.

The default pixel format for scatter is 16 bits. This is due to the large dynamic range of the scatter signal, which sums up to 29 individual 8-bit pixel values.

Basic scatter parameters

The scatter component measures the amount of light received in a defined sampling window, which is part of the extracted 31-row WAM window. The amount of light is added for all rows in the sampling window to get the total scattering value.

Select the **Scatter** checkbox to add scatter data to the image data. The sampling window is defined by the following parameters:

Setting	Description
Scatter offset	The distance (number of pixels) from the laser peak position to the row where the first scatter measurement is made. The offset can be set to 0, which means the center (reflectance) pixel is included and that an odd number of rows is used for summing the scatter data.
Scatter width	The number of rows to sum scatter data from.
Scatter pixel format	The number of bits in the scatter data.The default pixel format is 16 bits. Possible to select **Mono8** and **Mono16**.

figure 77 illustrates two cases of symmetric sampling, with low scatter to the left and high scatter to the right. The **Scatter offset** and **Scatter width** are denoted in the figure.

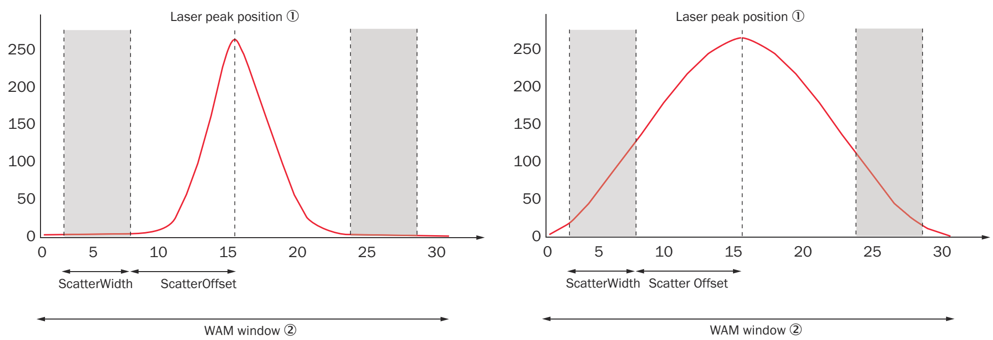


Figure 77: Examples of low scatter symmetric sampling (left) and high scatter symmetric sampling (right). The red line illustrates the laser signal in the extracted WAM window. The sampling window is shown in gray.

① Laser peak position

② WAM window

You can set additional scatter parameters. For more information about how to change parameter settings, see "Editing parameters", page 41.

7.4.1.3 Profile metadata

Profile metadata are tagged blocks of data, that are sent together with the image data. Profile metadata are used to add additional data to the image data. The profile metadata can only be added for 3D images. The following metadata is available for each buffer:

- The value of the encoder counter for each line in the buffer.
- The timestamp for each line in the buffer.
- The height of the buffer.
- The width of the buffer.
- The scaling information to transform the raw data into mm (calibrated and rectified data) or pixels (uncalibrated data).

To enable profile meta data, select the **Metadata** checkbox.

7.4.2 Range (3D) measurements

7.4.2.1 Laser impact position on the sensor

The basic function of the 3D measurements is to compute the impact position of the laser line for all columns of the selected region of interest (ROI). The light intensity distribution from the laser line along a sensor column across the laser line can be described as in the figure below.

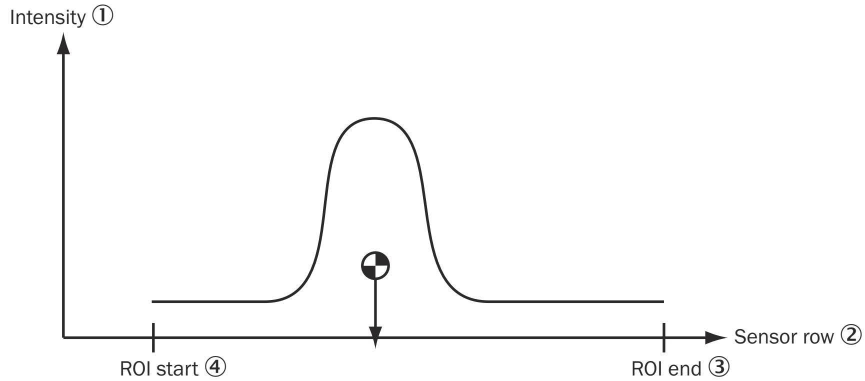


Figure 78: The impact position of the laser in one column

① Intensity
② Sensor row
③ ROI end
④ ROI start

The laser line will produce a distinct light peak distributed over a number of pixels along the sensor column. The center of this peak will be defined as the impact position of the laser line on that sensor column, which is the range value.

7.4.2.2 Measurement method

The default algorithm in is called **Hi3D**. It measures the impact position using a high-resolution peak fitting algorithm based on the pixels in a window around the extracted intensity peak position. The size of the window is defined by the **WAM size** setting.

This method measures range with a resolution of 1/16th pixel.

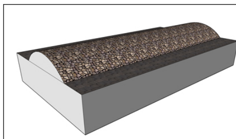
7.5 Triggering

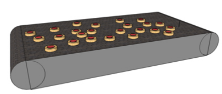
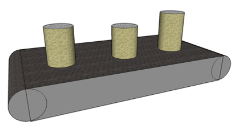
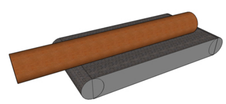
There are different ways to trigger the camera to acquire images and profiles. Triggering is used to control the initiation and rate of data acquisition. You can use an external signal to trigger each image or every single profile. The camera can also be configured to acquire images or profiles with regular time intervals, without an external trigger signal.

Note that when the camera acquires 3D images, each image is a set of profiles. This means that the acquisition of profiles in the Profile triggering concept is only applicable for 3D images, while the Image triggering concept is relevant for both 2D and 3D images.

7.5.1 3D triggering concepts

Different application types require different triggering concepts. Below is a table of the most common triggering situations.

	**Continuous flow**	No photoelectric sensor is used. Profiles are sent continuously to the computer, typically arranged in images of at least a few hundred profiles. Examples: Crushed stone, grain, sawdust.

	**Continuous flow of discrete objects**	No photoelectric sensor is used. Profiles are sent continuously to the computer, typically arranged in images of at least a few hundred profiles. The resulting image buffers on the computer can be analyzed in a rolling buffer fashion, ensuring that all objects are analyzed completely. Example: Cookies.
	**Shorter objects of equal length**	A photoelectric sensor is used. One image per object. Examples: Bottles, automotive parts, mobile phones.
	**Longer objects of variable size**	A photoelectric sensor is used. Acquire profiles as long as the object remains in front of the camera. Several sub-images can be stitched together on the computer. Examples: Logs, fish, postal packages.

7.5.2 Profile triggering

The camera will acquire each profile based on an external input signal. There are two possibilities:

- Connect an external input signal to the line trigger input of the device. (Activating this mode is only possible using GenICam or **GenIStream** parameters. For more information about how to change parameter settings, see "Editing parameters", page 41.)
- Use an encoder for profile triggering. In that case, pulses are received on the encoder inputs. The distance between the two profiles is determined by the number of pulses received.

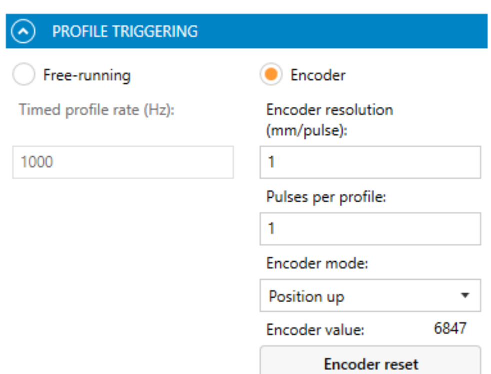


Figure 79: Profile triggering GUI reference.

Triggering each profile from an encoder will keep the object proportions if the object motion, tracked by the encoder, changes. Four-phase encoders also allow tracking different motion patterns, see "Encoder triggering", page 59. The motion pattern is defined by the **Encoder mode** parameter.

When triggering with an encoder the maximum line rate is still controlled by **Timed profile rate** used in **Free-running** mode. Thus you might need to change **Timed profile rate** when in **Encoder** mode to be able to set **Exposure time** to your wanted value.

Select **Free-running** or **Encoder** using the radio buttons.

7.5.2.1 Free-running triggering

When you use **Free-running** as triggering concept, the camera will acquire images or profiles with a regular time interval. The time interval is controlled by the **Timed profile rate (Hz)** parameter.

When the acquisition of profiles is free-running, the distance between two profiles varies if the speed of the object is not constant. This may distort the image. To avoid distortion, you can use an encoder and embed encoder data for each profile. This information makes it possible to calculate a correct image.

NOTE
The exposure time and the profile rate are inter-dependent. The maximum exposure time cannot be longer than the time between two profiles, minus about three microseconds that are needed for readout and reset.

When you use the **Free-running** mode input, profiles are acquired at fixed time intervals independent of the object motion. Note that the profile meta data contains valid encoder position information also in this mode if an encoder is connected and active. The **Encoder mode** parameter is not used.

7.5.2.1.1 Setting free-running triggering

Tabs: **2D Image**, **3D Image**

Open the **Profile triggering** category in the parameter settings section.

1. Select the **Free-running** radio button.
2. Set the rate at which the profiles in an image are captured in **Timed profile rate (Hz)** parameter.

For 2D image triggering, the encoder input is always used as trigger source.

7.5.2.2 Encoder triggering

When you use an encoder for triggering, the camera counts the number of pulses received on the encoder inputs using an internal counter. When the specified number of pulses has been received, a profile or a 2D image is triggered and the camera resets the triggering condition counter.

Four-phase (dual-channel) encoder

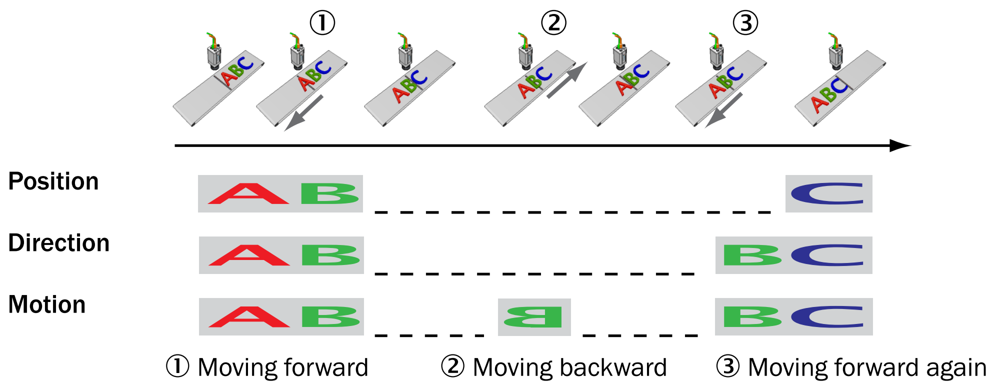
The default definition of a pulse is a full four-phase cycle on the encoder inputs. This gives a pulse counter that is robust to jitter and noise on the inputs. It is also possible to use a high-resolution encoder pulse counting mode, where each flank on an encoder input is counted. In this mode, a 4-times higher resolution is achieved, but in Direction and Motion modes (see below) jitter on the input may lead to unwanted triggering.

A four-phase encoder can handle movements in both directions (forward and backward). The camera can be configured to react to the pulses in different ways, resulting in different ways to trigger profiles. The different profile triggering modes are illustrated below.

Encoder mode	Description
Position up or **Position down**	The encoder triggers a profile for each object position. If the object has moved backward, no profiles are triggered until the object has moved (at least) an equal distance forward. **Position up:** "Forward" is defined as the positive direction. **Position down:** "Forward" is defined as the negative direction.

Encoder mode	Description
Direction up or **Direction down**	The encoder triggers profiles when the object is moving forward. If the object has moved backward, new profiles will be triggered as soon as the object moves forward again. **Direction up**: "Forward" is defined as the positive direction. **Direction down**: "Forward" is defined as the negative direction.
Motion	The encoder triggers profiles when the object is moving either backward or forward.

Table 3: Triggering modes



Single-channel encoder

A single-channel encoder uses only one encoder channel. The input from the encoder to the camera is a differential signal, and a profile is triggered each time the signal goes high.

When a single-channel encoder is used, the camera cannot differentiate between forward and backward movement. The single-channel encoder mode is therefore only visible and selectable when the **Encoder mode** (see table 3) is set to **Motion**.

State diagrams and trigger points

The encoder states and the possible transitions for a dual-channel encoder and a single-channel encoder are shown in figure 80. The trigger point depends on the type of encoder used:

- Dual-channel encoder, forward direction: The trigger point occurs when channel B goes from 1 to 0. See figure A.
- Dual-channel encoder, backward direction: The trigger point occurs when channel A goes from 1 to 0. See figure B.
- Single-channel encoder: The trigger point occurs when channel A goes from 0 to 1. See figure C.
- High-resolution encoder: The trigger point occurs for every single rising or falling edge on any channel.

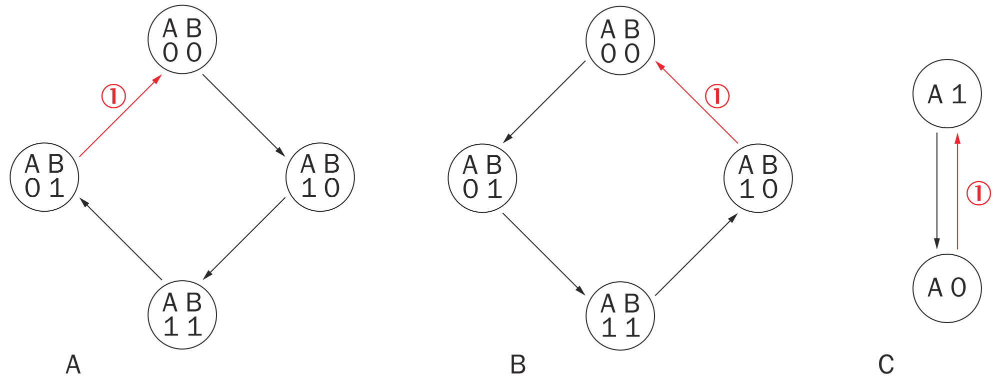


Figure 80: Encoder states and possible transitions

① Trigger point

7.5.2.2.1 Setting encoder triggering

Tabs: **2D Image**, **3D Image**

Follow the steps below to use encoder triggering. For more information about the encoder modes, see "Encoder triggering", page 59.

Open the **Profile triggering** category in the parameter settings section.

1. Select the **Encoder** radio button.
2. Set the **Encoder resolution (mm/pulse)** parameter. This value defines the resolution of one encoder step and can be a value between 0 and 10 000. The value defines how far in mm the encoder moves per pulse.
3. Set the **Pulses per profile** parameter. This value defines how many encoder increments/decrements are needed to generate a trigger.
4. Set the **Encoder Mode** to the desired mode.

The **Encoder value** is an informational field and can be reset to 0 by clicking the **Encoder reset** button.

7.5.3 Image triggering

The camera will acquire 3D images based on an external input signal, for example a photoelectric sensor. If the same photoelectric sensor is connected to several cameras then synchronization at the microsecond level can be achieved. The acquisition of profiles in the image can either be free-running or triggered by an input signal, as described in the sections Free-running triggering and Encoder triggering.

Figure 81: Image triggering GUI reference.

Select the **Image trigger** checkbox to enable image triggering. If **Image trigger** is not selected, the camera acquires images continuously.

When using **Image triggering**, the **Profiles per image** parameter specifies the number of profiles the camera acquires after the image trigger signal goes high. After the specified number of profiles, the camera will either idle or continue to acquire another series of profiles, depending on the state of the image trigger signal and the settings of the acquisition control parameters. See the table and the figure below.

Parameter setting	Description
Rising edge	The acquisition of a new series of profiles starts on a rising edge on the enable signal. Multiple enable trigs are ignored until all profiles (**Profiles per image** parameter) have been acquired. When all profiles have been acquired, the camera waits for a new rising edge.
Level high	The acquisition of a new series of profiles starts each time the image trigger input has a high level as input. For the very first profile, the camera requires not only a high level but also a rising edge

The system adapts the buffer height for the image grabber and the camera to the **Profiles per image** parameter to keep the image synchronized and receive a full image after the image capture is completed. To avoid unnecessary CPU load, set the **Profiles per image** parameter to no less than 100 pixels.

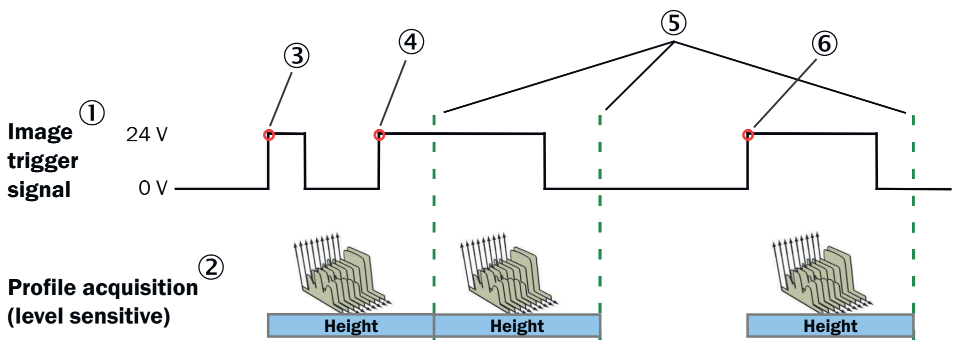


Figure 82: Timing diagram for Image trigger signal.

① Image trigger signal
② Profile acquisition (level sensitive)
③ Image trigger signal Rising edge and Level high. Acquisition of profiles starts.
④ Image trigger signal. Rising edge ignores, Level high acquires.
⑤ Acquisition complete. Interpretation of image trigger signal.
⑥ Image trigger signal. Both Rising edge and Level high acquire.

7.5.3.1 Setting image triggering

Tabs: **2D Image**, **3D Image**

Open the **Image triggering** category in the parameter settings section. For information about the triggering concepts, see "3D triggering concepts", page 57.

Enabling image triggering:

1. Select the **Image trigger** checkbox.
2. Set the triggering option to **RisingEdge** or **LevelHigh**.
3. Follow the steps in the Encoder section (see "Setting encoder triggering", page 61) to acquire profiles based on encoder input or profile trigger signal input, or in the Free-running (see "Setting free-running triggering", page 59) section to acquire profiles with a regular time interval.

7.5.3.2 Setting acquisition stop mode

The **Acquisition Stop Mode** controls how acquisition ends an ongoing image/frame. It is only possible to change the parameter using GenICam or GenIStream. For more information about how to change parameter settings, see "Editing parameters", page 41.

Option	Description
Complete	The acquisition stops at the end of the ongoing image/frame when the image/frame trigger signal goes low, but always captures the full image/frame buffer. This option is suitable for legacy receivers that expect full images/frames only.
Immediate	The acquisition stops immediately and only the profiles acquired at the time are captured. This option is useful when scanning objects of variable length, where the length is larger than the size of one image/frame.

In some cases, it is desired to verify that an image/frame is the last of an object. This verification is done in combination with the checkbox **Hold Frame Level One Line After Pulse End**. Enabling this checkbox there is always at least one scan line in the last image/frame marking the object has ended. If the image/frame trigger signal goes low at the end of an image/frame, an extra (empty) imge/frame is generated and transmitted.

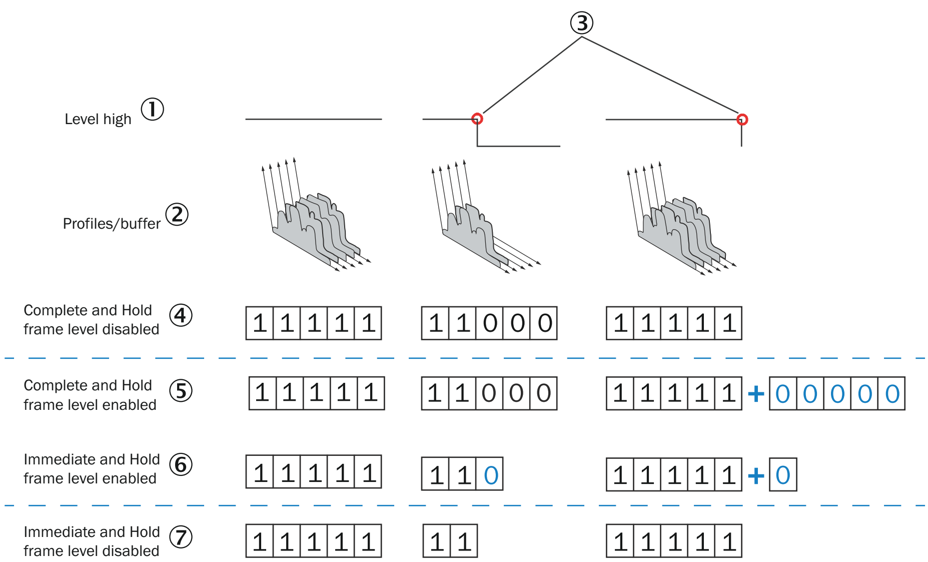


Figure 83: Complete vs immediate acquisition mode illustrating the image/frame trigger meta data for the captured profiles

① Image/frame trigger signal: Level high
② Profiles/buffer
③ Trigger end
④ Acquisition stop mode: Complete, Hold Frame Level One Line After Pulse End: disabled
⑤ Acquisition stop mode: Complete, Hold Frame Level One Line After Pulse Endend: enabled
⑥ Acquisition stop mode: Immediate, Hold Frame Level One Line After Pulse End: enabled
⑦ Acquisition stop mode: Immediate, Hold Frame Level One Line After Pulse End: disabled

Examples

The image/frame trigger signal is a part of the meta data for each profile, and can be either high (1) or low (0). In these examples this signal is used to indicate "profile high" or "profile low".

For all examples, the **Profiles/buffer** is 5.

④ Acquisition stop mode: Complete and Hold Frame Level One Line After Pulse End: Disabled

- A continuous flow of profiles: sends 5 profiles high.
- The trigger goes low after 2 profiles: sends 2 profiles high and 3 profiles low.
- The trigger goes low after 5 profiles: sends 5 profiles high.

⑤ **Acquisition stop mode: Complete and Hold Frame Level One Line After Pulse End: Enabled**

- A continuous flow of profiles: sends 5 profiles high.
- The trigger goes low after 2 profiles: sends 2 profiles high and 3 profiles low.
- The trigger goes low after 5 profiles: sends 5 profiles high and 5 profiles low.

⑥ **Acquisition stop mode: Immediate and Hold Frame Level One Line After Pulse End: Enabled**

- A continuous flow of profiles: sends 5 profiles high.
- The trigger goes low after 2 profiles: sends 2 profiles high and 1 profile low.
- The trigger goes low after 5 profiles: sends 5 profiles high and 1 profile low.

⑦ **Acquisition stop mode: Immediate and Hold Frame Level One Line After Pulse End: Disabled**

- A continuous flow of profiles: sends 5 profiles high.
- The trigger goes low after 2 profiles: sends 2 profiles high.
- The trigger goes low after 5 profiles: sends 5 profiles high.

Open the **Parameter editor** and go to the **Acquisition Control** category to adjust the settings.

The **Parameter editor** is hidden, but available in a Beta version. Use the short command `CTRL + SHIFT + I` to open the editor.

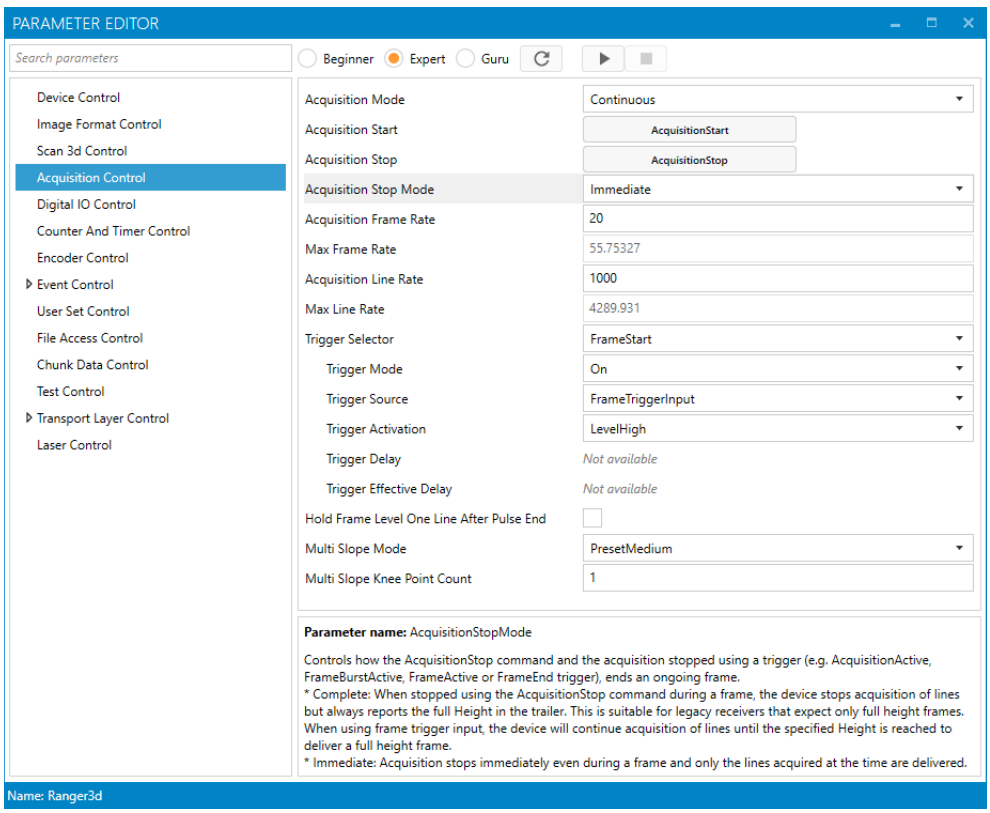


Figure 84: Parameter editor GUI reference

To set the acquisition stop mode:

1. Open the **Parameter editor**.
2. Click the **Acquisition Control** category.
3. Set the **Acquisition Stop Mode** parameter to **Complete** or **Immediate**.
4. Set the **Trigger Mode** parameter to **On**.
5. Set the **Trigger Activation** parameter to **LevelHigh**.
6. Enable or disable the **Hold Frame Level One Line After Pulse End** checkbox.

NOTE
The **Acquisition Stop Mode** parameter is only available in **Expert** and **Guru** mode.

7.6 Image rectification

Rectification of data means that a new profile is created by re-sampling the calibrated data onto a regular grid. The image rectification is performed along the X-axis only. The new profile is represented in a discrete coordinate system, which is directly related to the real-world coordinate system. This means that the distance in X between two adjacent values (pixels) in the profile is always the same regardless of where in the field of view they are positioned.

The following image shows how a set of calibrated data points translates into a rectified profile. The final z value is represented as a floating-point number to preserve the full resolution. Notice the green and yellow resulting values at the edges of the profile.

Select if the rectification should return the **Top most** (green) or **Bottom most** (yellow) pixel height within the discrete column. For more information, see table 1, page 17.

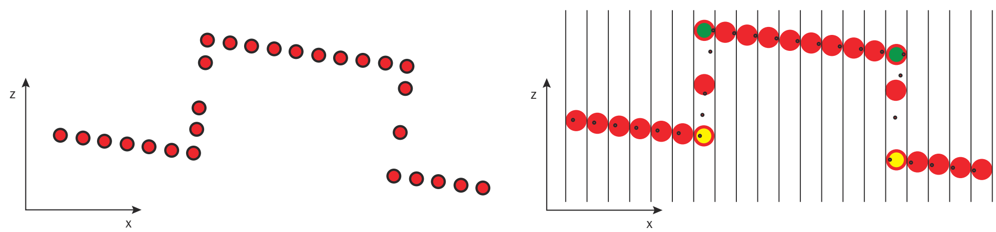


Figure 85: Calibrated points and corresponding rectified profile (to the right).

The image rectification is performed on the camera and is controlled via the setting for calibration. If **Calibrated** is selected, image rectification will also be performed.

Maximum **Rectification width** for in-device image rectification is 4096 and default is 3072. The image rectification is made to a higher resolution than the imager resolution to avoid losing X resolution close to the device. The **Rectification width** can be set to a lower value than the width of the **Extraction region**. The image will then be downsampled and data will be lost. The **Rectification width** determines the width of the 3D image.

Select which **Rectification method** to use.

Table 4: Image rectification methods

Method	Description
Bottom most	Always pick the lowest range value for each bin.
Top most	Always pick the highest range value for each bin.

The **Rectification spread** is used to distribute pixel values to neighboring pixels. If the **Rectification width** is larger than the width of the data, the image rectification can give holes in the data. The process of replacing those holes of missing data with neighboring pixel values is called spreading.

Due to the geometry between the laser plane and the camera, the number of holes in the image depends on the range value with typically no holes in the image at one end of the range scale and maximum number of holes at the other. Hence the spreading is adjusted to spread more at range values from the far end of the camera's field of view and less close to the camera where the resolution per mm is higher. It is important not to spread more than necessary since it potentially overwrites valid data with neighboring data.

Setting the **Rectification spread** to 0 disables spreading. Spreading 1.0 will fill all gaps in the output image in an ideal case, but default spreading is still set to 1.2 since in practice there might still be missing data at spreading 1.0 due to discontinuities in the image. The maximum value depends on other parameters and is typically 1.5 for in-device image rectification due to hardware limitations.

7.6.1 Setting image rectification method

Tabs: **2D Image**, **3D Image**

To enable image rectification, follow the steps below:

1. Open the **Calibration** section.
2. Select the **Calibrated** radio button.
3. Set the **Rectification width**, a value between 160 and 4096.
4. Select which **Rectification method** to use. For information about different methods, see see "Image rectification", page 17.
5. Set the **Rectification spread**, a value between 1 and 10.

8 Operation

8.1 Stream Setup graphical user interface

The **Stream Setup** application is downloaded from the SICK support portal, supportportal.sick.com. Select **Vision/3D vision** and **Ruler3000**. You use its graphical user interface (GUI) to configure camera parameters and evaluate the measurement results.

The GUI offers different ways to visualize the data. You can also store data to file for later use. You can change the settings of the camera and instantly see how the changes affect the measurement result. The GUI is therefore useful for finding the best parameter settings for a certain application.

NOTE
It is not possible to change the parameters while the image acquisition is running.

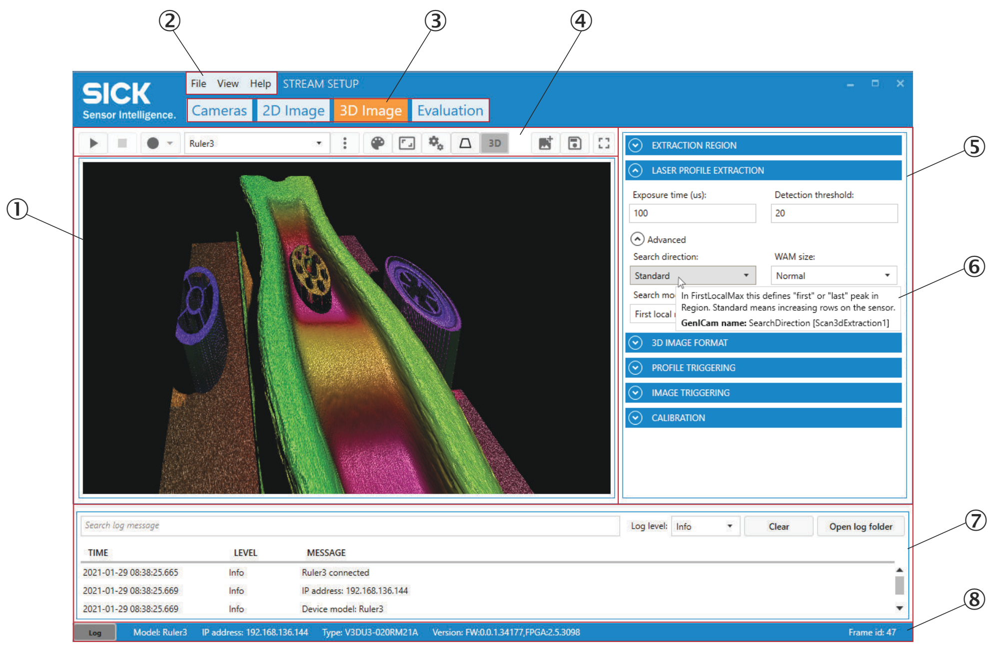


Figure 86: Graphical user interface

① Image viewer
② Menu bar
③ Tab section
④ Control bar
⑤ Parameter settings pane
⑥ Parameter description
⑦ Log section
⑧ Status bar

Once the camera has been configured, the settings can be saved in a parameter file on the computer or as camera configurations on the camera.

This chapter gives an introduction to **Stream Setup** with its different windows, functionalities, and also exemplifies how to use it to get a 3D image or adjust the data quality. The following different tabs are available: **Cameras**, **2D Image**, **3D Image** and **Evaluation**. In the following sections, each of these tabs is explained.

NOTE
It is possible to open **Calibration** and **Alignment** tabs from the **View** menu. These options are mainly used for Ranger3, hence not covered in this document.

8.1.1 Menu bar

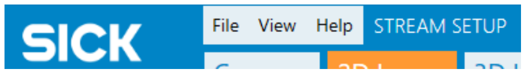


Figure 87: Menus

The **File** menu includes the possibility to save the currently shown image, load images, and exit the application.

The **View** menu includes options to hide or show the **Calibration** and **Alignment** tabs. These additional menus are mainly used for Ranger3, hence not covered in this document.

The **Calibration** menu includes options to handle parameters and images. It is also possible to select multiple calibrated images and use them for multishot saw tooth calibration.

The **Help** menu includes options to get further help with and knowledge about the application, for example, the application version and dll assembly version.

8.1.2 Tabs

8.1.2.1 General image handling

Use a mouse with a scroll wheel to manipulate regions and perspectives when viewing images.

2D Image and heightmap view handling controls

The actions for manipulating the view of an image are valid for images shown in the **2D Image** tab as well as the heightmap view in the **3D Image** tab and **Evaluation** tab.

Action	Description
Pan image	Right-click and drag to pan image.
Zoom	Rotate the mouse scroll wheel.

3D Image handling controls

The actions for manipulating the view of an image are valid for images shown in the **3D Image** tab and **Evaluation** tab.

Action	Description	Keyboard shortcut
Rotate around center point	Click and drag to rotate the image around the center point visualized by the crosshair.	Q / E
Rotate around camera center	**Shift** + Right-click to rotate the image around the camera center.	
Pan (x, y plane)	Right-click and drag to pan camera in x, y plane.	W / S / A / D
Pan (u,v plane)	**Shift** + click and drag to pan camera in u, v plane.	
Move crosshair	**Shift** + scroll the mouse wheel to change the position of the crosshair to allow rotation around different positions of the image.	Shift+M / Shift+N
Zoom	Rotate the mouse scroll wheel.	M / N

Action	Description	Keyboard shortcut
Reset view point	Reset the image and crosshair to their original positions. The **Reset** button is available in the additional settings section.	R
Toggle auto rotate	Turn the **Auto rotate** function on or off. The **Auto rotate** function can be controlled in the additional settings section.	T

8.1.2.1.1 Pointer information

If you move the mouse pointer over the image area, some information is shown. For a 2D image, the coordinates and the intensity value of each point are displayed. This information is useful, for example when you define the detection threshold, see "Detection threshold", page 48.

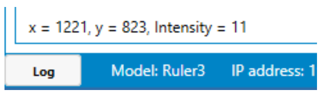


Figure 88: Pointer information (2D image)

For a rectified 3D image, the coordinates (pixel and mm value), the sensor row, and the encoder counter value of each point are displayed.

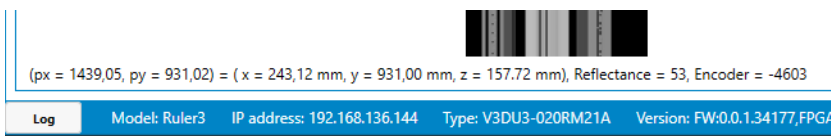


Figure 89: Pointer information (rectified 3D image)

8.1.2.2 Cameras

In this tab, you see the last connected device and can reconnect to it. You can also search the network and see a list of all available devices. You can select a device and connect or disconnect it.

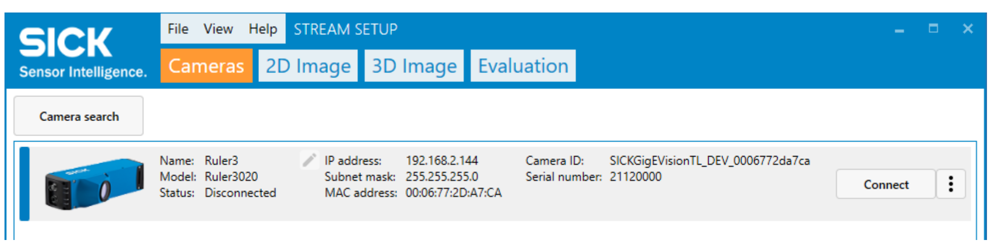


Figure 90: Tab ***Cameras***

It is also possible to reconfigure the camera IP settings. This is useful, for example when you want to connect to a camera that is not on the same subnet as the NIC, see "Recommended network card settings", page 92. Then you have to reconfigure the camera to the same subnet before you can connect to it.

8.1.2.2.1 Editing IP settings

Before you connect to the camera, you can set the IP address and subnet mask. Select the **Use persistent IP** checkbox, and the camera will keep the same IP address after a reboot.

Tab: **Cameras**

1. Select the correct camera and click on the three dots to the right.
2. Select **IP settings**.

✓ A new window opens.

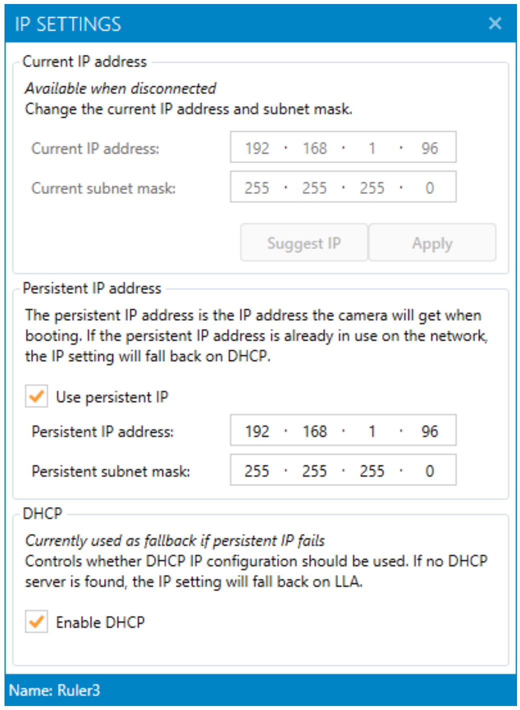


Figure 91: GUI reference IP settings.

3. Edit the IP settings. **Current IP address** is only available when the camera is disconnected. **Persistent IP address** is only available when the camera is connected.
4. Select the **Use persistent IP** checkbox to keep the same IP address after a reboot.
5. To use DHCP as fallback if the persistent IP fails, select the **Enable DHCP** checkbox.
6. Close the window.

8.1.2.3 2D Image

Here you view and acquire the 2D image data. A 2D image is what the camera sees when it is used as an ordinary camera. You can edit parameter values related to the image acquisition and evaluate the result directly in the image viewer. The list box above the image viewer contains all the cameras possible to select.

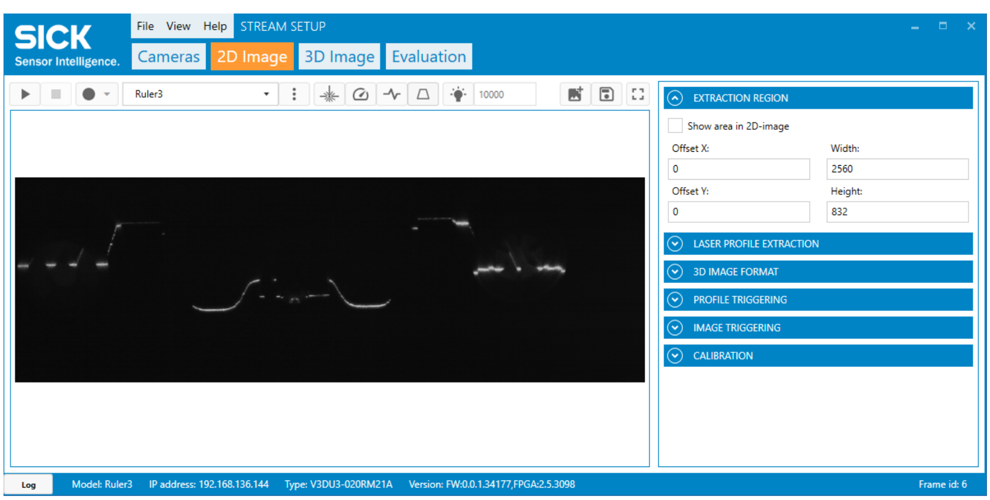


*Figure 92: Tab **2D Image***

This view shows a grayscale 2D image, which can be useful when adjusting the exposure time, or deciding the region of interest.

8.1.2.4 3D Image

Here you view the 3D image that is the result of using laser triangulation. The list box above the image viewer contains all the cameras possible to select. Click the play button to start acquiring profiles. A 3D image is generated of acquired profiles. You can edit parameter values and evaluate the result directly in the image viewer until the result is satisfactory. You also have several options to visualize the 3D image.

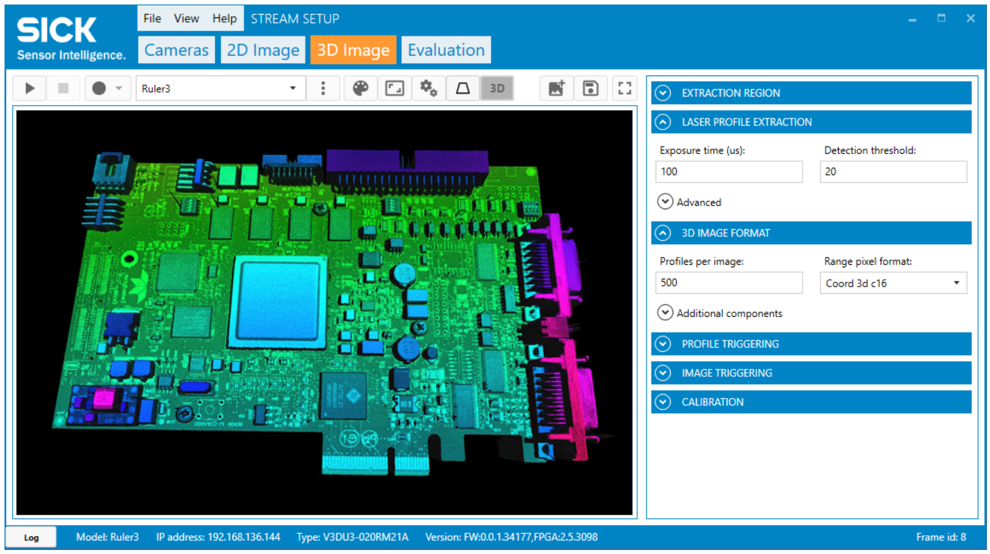


Figure 93: Tab ***3D Image***

8.1.2.5 Evaluation

In this tab, you can evaluate different images from the camera. You can study both the live image and images which have been saved previously. The list box above the image viewer contains all the cameras possible to select.

Select to study the live image or a previously saved image by selecting the corresponding radio button. The **Image info** section is updated with information about the selected image. The **Profile metadata** section shows information about the selected image row.

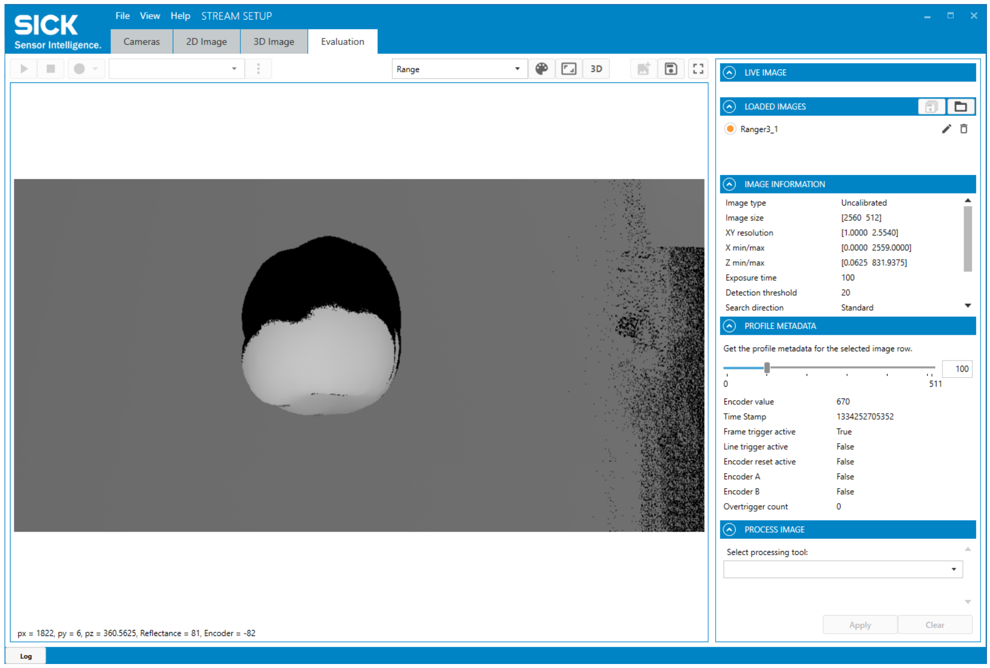


Figure 94: Evaluation GUI reference

8.1.2.5.1 Process image

The **Evaluation** tab contains a set of simple image-processing tools that can be applied to the currently selected image. In the **Select processing tool** list box, you can choose between three different evaluation methods.

Image filtering

Image filtering involves operations that perform useful functions, such as noise removal and image enhancement.

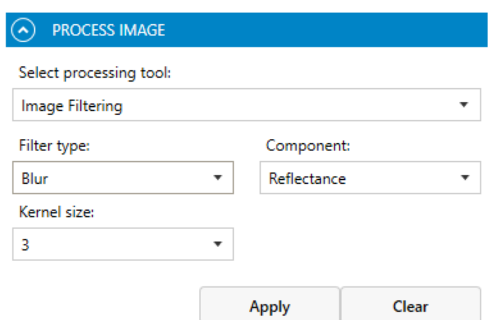


Figure 95: Image filtering GUI reference

Select the **Filter type** and set the **Kernel size** to either 3 or 5. You can set **Component** to either **Range** or **Reflectance.**

Filter type	Description
Blur	Replaces the value of each pixel with the average of neighboring entries, reducing noise and detail.
Median	Replaces the value of each pixel with the median of neighboring pixels.
Bilateral	Replaces the value of each pixel with a weighted average of nearby pixels.

Extract profile

The **Extract profile** tool shows the profile for each horizontal (X) or vertical (Y) line in the 3D image. Zoom in or out by rotating the mouse scroll wheel.

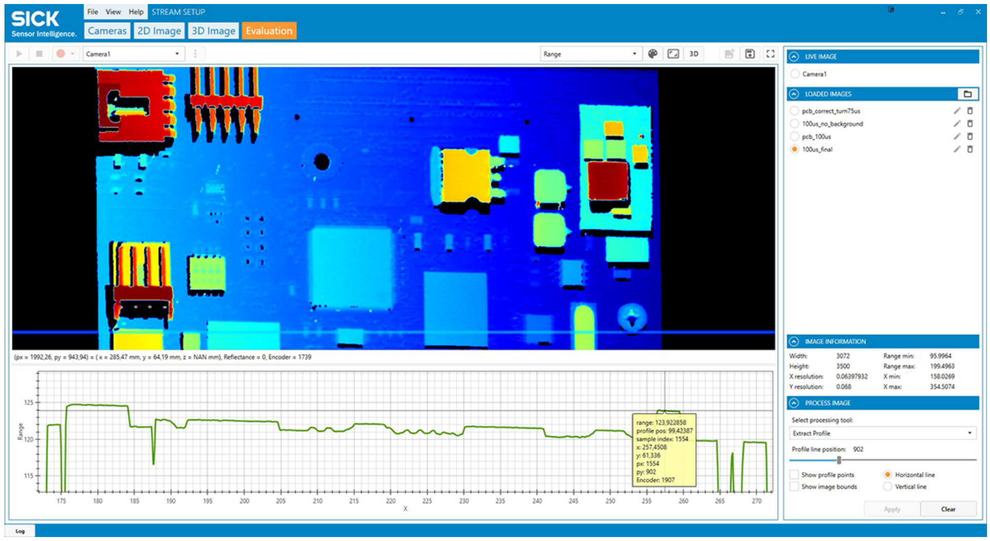


*Figure 96: Tab **Evaluation**, showing the extracted profile of the 3D image*

Surface distance

The **Surface distance** tool measures the shortest distance between one plane and the center point in another plane. You can define which pixels to include in the plane estimation for both planes.

Remove outliers

The **Remove outliers** tool removes noise and reflections from the image. By knowing the angle between the lens and the laser plane, it is possible to determine if the pixel values are noise or real data.

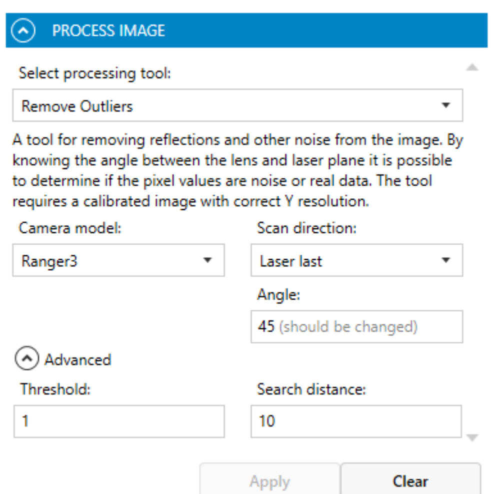


Figure 97: Remove outliers GUI reference

Select the **Camera model** and **Scan direction**. The **Angle** shows the angle between laser and camera.

NOTE
If using a Ranger3 camera, the angle should be changed to reflect the actual angle of the setup. If using a Ruler3000 device, the angle is already set and cannot be changed.

Set the **Threshold** to the level of uncertainty required for noise to be removed. The value 1 means that all conflicts are removed. Set the **Search distance** to reflect the distance in pixels of how far the algorithm should search for potential outliers.

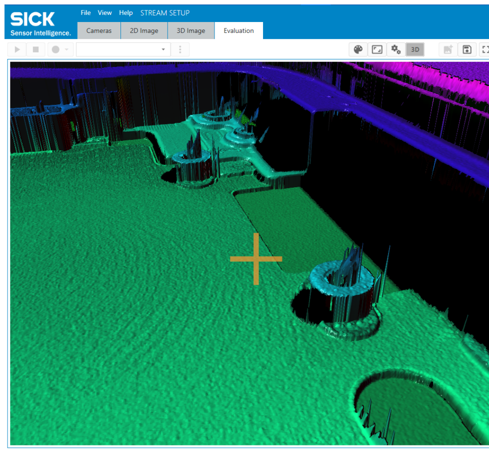


Figure 98: Before using the Remove outliers tool

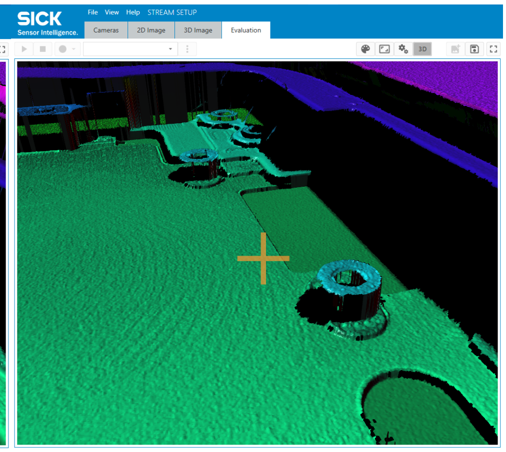


Figure 99: Noise and reflections removed with the Remove outliers tool

NOTE
The tool requires a calibrated image with correct Y resolution.

8.1.3 Control bar

Depending on the currently active tab, different options are available for the image. This is automatically updated when switching between the tabs.

Recording options

Button	Name	Description
▶	Start	Start image acquisition.
■	Stop	Stop image acquisition.
●	Record	Recording a set of images, the button turns red when recording is in progress.

Camera options

Button	Name	Description
⋮	Action menu	The camera action menu, which includes options for configuration handling and firmware updates. Firmware update is only available when the camera is disconnected. The button is located to the right in the **Cameras** tab, and to the left on the control bar when **2D Image** or **3D Image** tabs are open.

2D image view options

The list above the image viewer contains all the currently connected cameras.

Button	Name	Description
	Laser setting	Controls the laser mode. When activating this button, the laser is always active while the camera is started. This makes the laser line more visible and is useful when mounting the camera.
	Frame rate	Set the frame rate. The acquisition rate in Hz, at which frames are captured when streaming 2D images. This feature is useful for slower computers, such as laptops.
	Peak visualization	Shows the approximate result of the laser line extraction. The result is indicated with a red line.
	Guaranteed FOV	Shows the guaranteed field of view in the 2D viewer. This feature is only available for Ruler3000 cameras.
	Boost exposure	Brighten up the region of interest by temporarily increasing the exposure time for the 2D image. Specify a value in the adjacent field.

3D image view options

The left list above the image viewer contains all the currently connected cameras. The right list contains the view modes.

Button	Name	Description
	Palette	View image in color (various options) or grayscale.
	Aspect ratio	Options for image resolution and sampling of the 3D view.
	Settings	Additional settings for the 3D view.
	Guaranteed FOV	Shows the guaranteed field of view in the 3D viewer. This feature is only available for Ruler3000 cameras.
3D	3D options	Switch between heightmap view and 3D visualization.

Image options

Button	Name	Description
	Add image	Add the current image to loaded images in the **Evaluation** tab.
	Save image	Save the current image to disk.
	Fullscreen	Switch to fullscreen mode. This option will hide the parameter settings pane and the **Cameras**, **2D Image**, and **3D Image** tabs.

Button	Name	Description
	Load image	Opens a folder on the computer. This option is located in the **Evaluation** tab.

8.1.4 Parameter settings pane

The parameter settings pane retrieves the current parameters from the camera and allows you to modify them.

When you adjust the parameters, you look at the 2D or 3D image to see the result. You can load the image to the image list in the **Evaluation** tab after each adjustment and compare the images to find the best configuration.

NOTE
You cannot edit the parameters while the camera is acquiring data.

The parameter settings pane is located to the right of the image viewer, showing different parameter categories. It also shows a tooltip with a description when hovering over a parameter. The description gives a brief explanation of the parameter's purpose, any minimum and maximum limits, and the corresponding GenICam name.

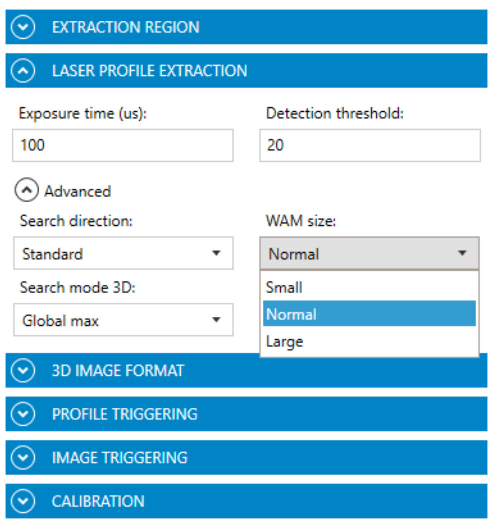


Figure 100: Parameter section GUI reference.

The Ruler3000 has a large number of parameters that are not exposed in **Stream Setup** but can be configured using GenICam, GenIStream, or the **Parameter Editor**. For more information about how to change parameter settings, see "Editing parameters", page 41.

8.1.5 Log section

At the bottom of the main window, there is a section where log messages are available. The messages can be hidden and shown by clicking the **Log** button.

The **Log** contains messages from the GUI and the device.

The system assigns each log message a level, either **Error**, **Warning**, or **Info**. You see log messages on the selected level and the levels above it. For example, selecting **Warning** shows log messages on level **Error** and **Warning**. Selecting **Info** in the list will show all log messages. With the **Search log message** function, it is possible to filter within the selected visible log messages.

The **Open log folder** button opens a file browser at the location of the log file, allowing easy access to the stored log.

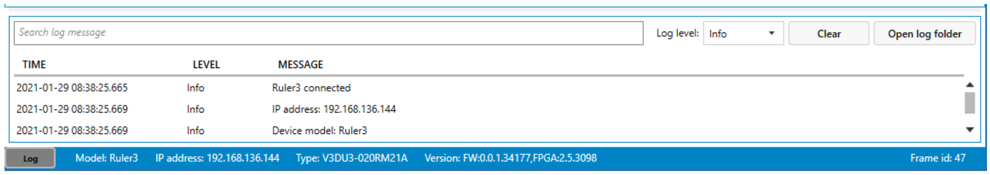


Figure 101: Log section

8.1.6 Status bar

At the bottom of the screen, the following information about the currently connected and selected device is shown:

- Model of the device
- IP address of the device
- Device type
- Software version
- Firmware version and FPGA
- Frame ID of the image that is currently displayed

NOTE
The frame ID is reset each time the camera is restarted.

8.2 Using the interface

The common way of working is to iterate until you are satisfied with the configuration and the quality of the received data.

It is assumed that the Ruler3000 and **Stream Setup** are installed and working properly. How to install the Ruler3000 and Stream Setup is briefly described in "Getting started", page 10. When capturing 3D images, it is beneficial if you also have movement and some kind of photoelectric sensor or similar device connected to the camera.

We also assume that you have placed some objects to measure in the laser plane. The object should fit into the field of view of the Ruler3000.

8.2.1 Importing and exporting configuration files

Tabs: **Cameras**, **2D Image**, **3D Image**

Configuration files (.csv format) can be saved and loaded to and from the device. The configuration files use a proprietary text-based format.

⋮ Click the camera action menu. The button is located to the right on the **Cameras** tab, and to the left on the control bar when **2D Image** or **3D Image** tabs are open.

Import configuration

To import a .csv file with pre-defined parameter settings, do as follows:

1. In the menu, select **Import configuration.**
2. Find and select the parameter file and click **Open.**

✓ The parameter settings are loaded.

Export configuration

To save the current parameter settings, do as follows:

1. In the menu, select **Export configuration**.
2. Find a place to store the file, name it, and click **Save**.

✓ The parameter settings are saved as a .csv file.

8.2.2 Booting the device using a camera configuration

A **Camera configuration** contains a full set of parameter values that can be used for booting and resetting the device to a known configuration state. Up to five camera configurations can be stored on the device.

The device can be programmed to boot from either one of the stored camera configurations, or from the built-in **Default** parameter values. If no camera configuration is selected, the **Default** configuration is used. The Default configuration is read-only and cannot be modified.

NOTE
A **Camera configuration** is only valid for the firmware version that was used when the configuration was saved.

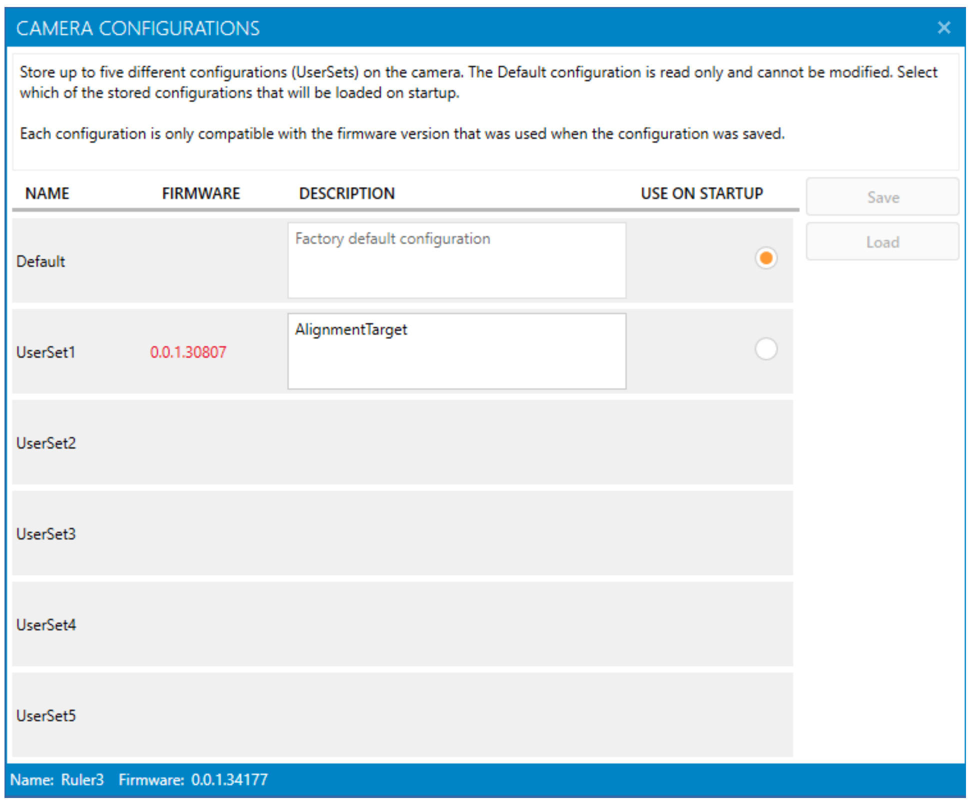


Figure 102: Camera configurations GUI reference

⋮ Click the camera action menu. The button is located to the right on the **Cameras** tab, and on the control bar when **2D Image** or **3D Image** tabs are open.

To save a camera configuration:

1. Make sure the parameter values are configured correctly.
2. Select **Camera configurations** from the menu.
3. Select a **UserSet** to use for storing the current parameter values.
4. Click **Save**. You also have the option to enter a description of the **Camera configuration** in the **Description** field.

To boot from a camera configuration:

1. Select **Camera configurations** from the menu.

2. In the **Use on startup** column, select the **Camera configuration** that you want the device to boot from.
✓ Next time the device boots, it will use the parameter values in the selected configuration.

To load a camera configuration to the camera:
1. Select **Camera configurations** from the menu.
2. Select a configuration.
3. Click **Load**.
✓ The configuration stored in the selected **Camera configuration** is now used on the device.

8.2.3 Visualizing 2D data

The control bar in the **2D Image** window contains visualization options for the acquired 2D image data. The control bar is located above the image viewer in the GUI, see figure 86, page 67.

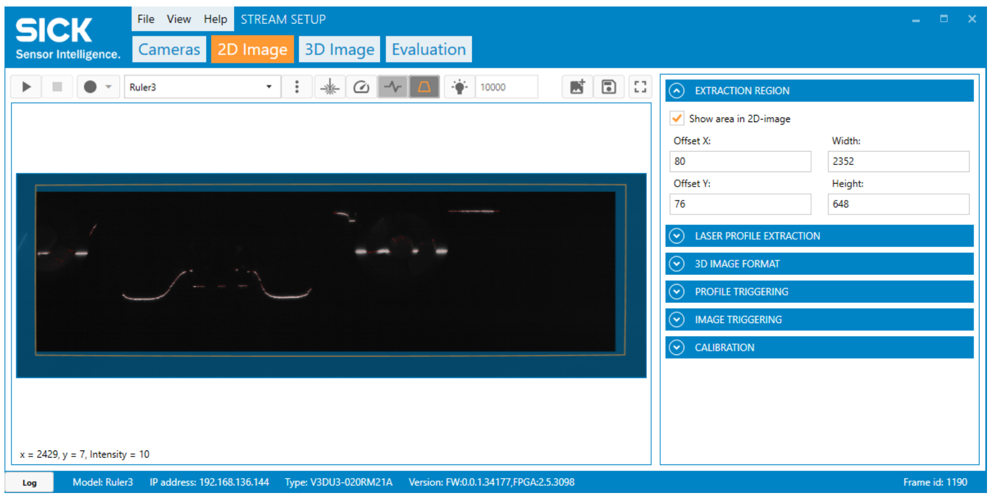


*Figure 103: Visualization options for the **2D Image** tab. The black region is the active extraction region. The red line represents the extracted laser line. The orange line represents the extension of the guaranteed field of view.*

Show extraction region

Select the **Show area in 2D-image** checkbox to visualize the selected extraction region. When the checkbox is selected, a blue overlay appears in the 2D image. The overlay represents the parts of the image to be excluded from the generation of 3D image data. The remaining dark area is the extraction area.

Simulate laser line extraction

Select the **Peak visualization** button to visualize an approximation of the extracted laser line. The visualization shows where the laser line is detected in the selected extraction region. This visualization aid is useful for tuning laser line extraction parameters such as the **Exposure time**, **Multi slope mode (HDR)**, **Detection threshold**, **Search direction** and **Search mode 3D**.

Simulate guaranteed field of view

Select the **Guaranteed FOV** button to visualize the guaranteed field of view for the device. The orange line shows the region guaranteed to be covered by the device.

8.2.4 Collecting 3D data

Tab: **3D Image**

New 3D profiles are being collected constantly, overwriting what is displayed in the visualization window. In order to get an entire 3D image of the object, an external enable signal can be used. A photoelectric sensor or similar device can be connected to the device. For information on electrical connections and pin configuration, see the Operating Instructions for the device.

1. Click the start button to start the collection of 3D image data.
2. To adjust the number of profiles in each grabbed 3D image, edit the **Profiles per image** parameter in the **3D image format** section.
3. To save the 3D image, there are several options:
   - Click the **Add image** button to save the image to the **Evaluation** window.
   - Click the **Save image** button, to save the image to disk.
   - Use the **Record** functionality to record all or selected images to disk.
4. Use the image handling controls to move, rotate, and zoom while you inspect the image, see "General image handling", page 68.
5. Use the **View** drop-down menu to select view mode, see "Image components", page 80.
6. To change the color range, click the Options button and select the **Aspect ratio** button, see "Aspect ratio", page 82.
7. To select data presentation, click the Additional settings button and select **Surface** or **Points**, see "Data rendering mode", page 83.
8. To adjust the scene lighting, use the menus and sliders in the GUI, see "Light settings", page 84.

8.2.5 Image components and visualization

8.2.5.1 Image components

A 3D Image can either be visualized as a heightmap, or rendered in the 3D view.

View as heightmap

The drop-down list contains all image components available in the current setup. It is possible to select between **Range** (3D data), **Reflectance** and **Scatter**, if the data is available. In **Reflectance** mode, color is proportional to the intensity values of the pixels. Select the **Palette** button for available color maps. The image can be viewed in both grayscale and color, with the option to adjust contrast. Data outside the contrast range is dark if too low and bright/red if too high.

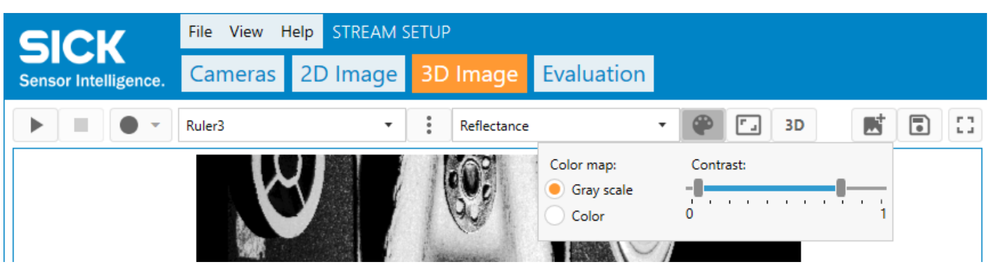


*Figure 104: 3D image **Reflectance** component.*

View as rendered 3D image

Click the **3D** button to switch to the rendered 3D image. When you view a rendered 3D image, you can select different ways to color it. Select the **Palette** button for available color maps, and the option to adjust contrast and light. Data outside the contrast range is visualized with a rotating color palette instead of a fixed color. The **Background color** can be set to a number of preset colors to make it easier to see dark objects. For more information about light adjustments, see "Light settings", page 84.

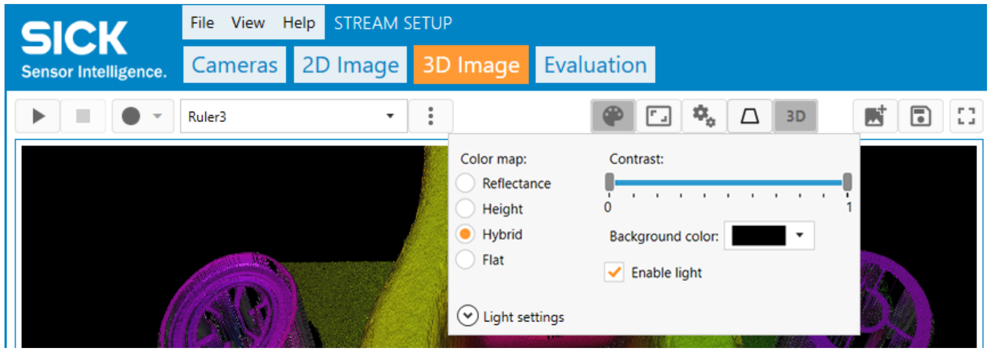
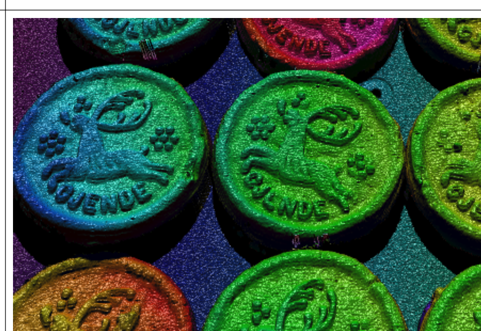
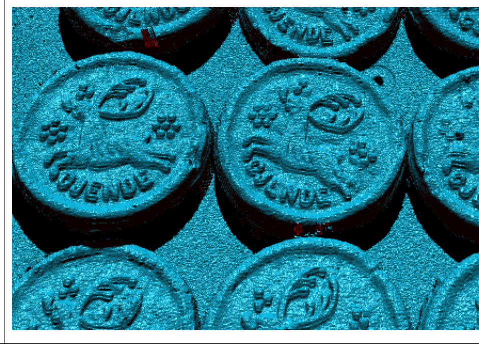


Figure 105: 3D image shown in ***Hybrid*** *color map.*

Color map	Description	Example
Reflectance	Grayscale intensity is proportional to the reflectance values of the pixels along the laser line. Suitable to show the surface details of an object, such as a print.	
Height	Color is proportional to depth (z-coordinate). Suitable to show large variations in depth.	
Hybrid	Color hue is proportional to depth (z-coordinate), color brightness is proportional to the laser reflectance. The **Hybrid** color map combines the **Reflectance** and **Height** color maps. Suitable to show large variations in depth together with surface details.	

Color map	Description	Example
Flat	Uses a solid color rendering.	

8.2.5.2 Aspect ratio

Using the **Aspect ratio** button, you can change the resolution and sampling of your data. Use the **Y resolution** (Profile distance) slider to set the distance between two rows in the image. For an uncalibrated image, the value is in pixel units, and for a calibrated image the value is in millimeters. If using encoder triggered mode the **Y resolution** defaults to the result given by the **Encoder resolution** multiplied by **Pulses per profile.**

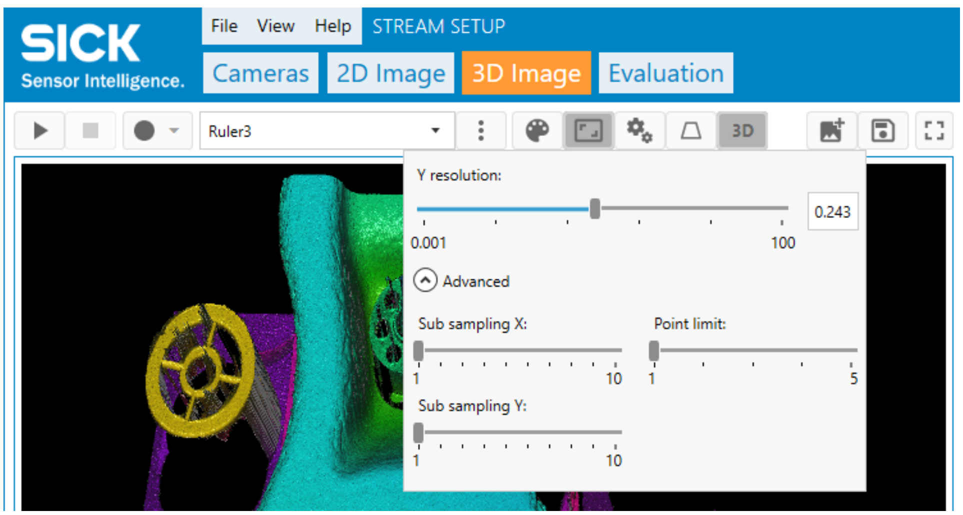


Figure 106: Aspect ratio GUI reference

Using the advanced options you can define if data should be skipped when showing the 3D image. Subsampling reduces the amount of data and gives a more responsive 3D display, especially for large data sets and a slow computer.

Parameter	Description
Sub sampling X	Defines how many samples in the direction across the sensor to skip. One means that all samples are displayed. This parameter could force the **Sub sampling Y** to be increased in case the data set is large.
Sub sampling Y	Defines how many samples in the transportation direction to skip. One means that all samples are displayed. This could be limited if the data size is large.
Point limit	Defines how much GPU memory is the maximum allowed to use. Can only be changed for computers with certain graphics board properties.

8.2.5.3 Data rendering mode

Using the **Settings** button, you can select different ways to render the image data, see table 5. The 3D visualization has a center point for object rotation and zoom. This is displayed as a crosshair which can be disabled. Use **Shift** and the mouse wheel to move the crosshair towards or from the viewer, allowing rotation around different positions of the data.

The **Viewer update frequency (Hz)** slider defines the number of images per second that can be visualized in 3D image mode.

The **Reset** button resets the rendered view to default.

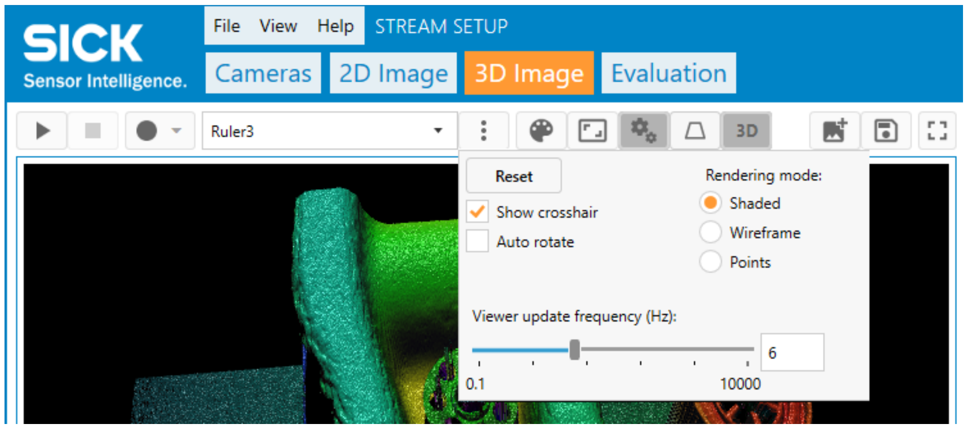
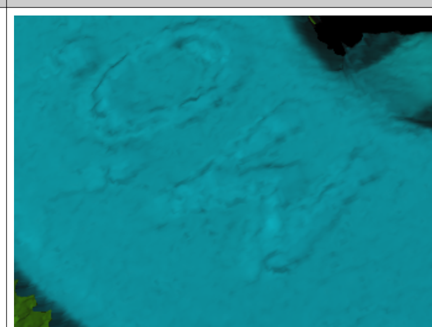
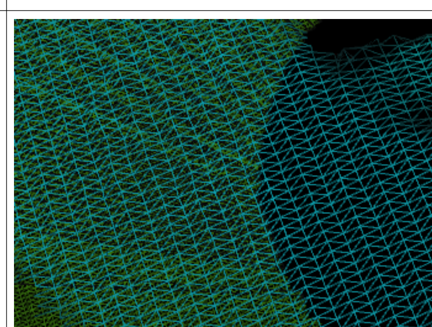
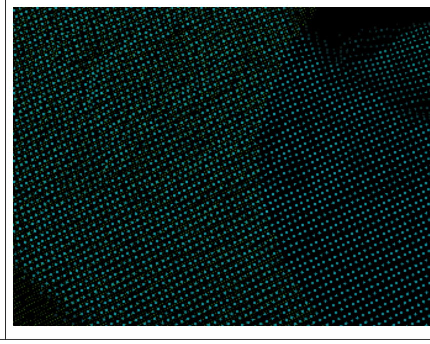


Figure 107: 3D image Settings options

Table 5: Rendering modes

Rendering mode	Description	Example
Shaded	Shows the data as a shaded mesh.	
Wireframe	Shows the data as a wireframe mesh.	

Rendering mode	Description	Example
Points	Shows the data as a point cloud. This visualization requires more processing and can be slower in response than the others.	

8.2.5.4 Light settings

In the **Light settings** section, you can select lighting effects for the dataset. Select the **Enable light** checkbox to adjust the settings.

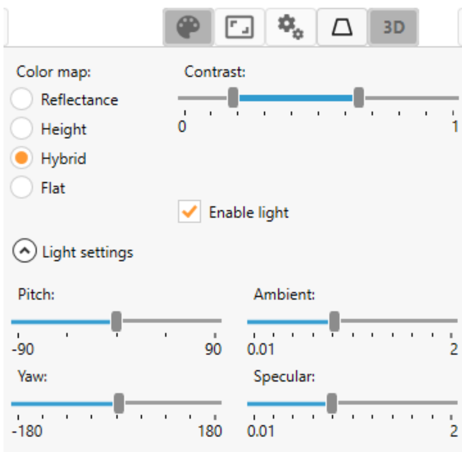


Figure 108: Light settings GUI reference

Parameter	Description
Pitch	Use the slider to control the vertical position of the light source.
Yaw	Use the slider to control the rotation of the light source around the vertical axis.
Ambient	Use the slider to adjust the ambient light level of the illumination model. The ambient light affects all objects equally.
Specular	Use the slider to adjust the specular light level of the illumination model. The specular light appears as a bright spot of light on shiny objects when illuminated.

8.2.6 Loading and saving image buffers

Tabs: **2D Image**, **3D Image**, **Evaluation**

When you save a 2D or 3D buffer, two separate files are created:

- A binary file that contains the image data (*.dat).
- An XML file that describes the binary file (*.xml).

In the **2D Image** tab, the currently displayed 2D image is saved. In the **3D Image** tab, the complete buffer of the currently displayed image is saved. This applies also if you have zoomed in so that only a part of the image is shown in the viewer.

Save image data

To save a single 2D image or 3D image, do as follows:

1. To save the currently displayed image, you have two options:
   - Click the **Add image** button, to load the image to the list in the **Evaluation** tab.
   - Click the **Save image** button, to save the image to disk.
2. Open the **Evaluation** tab to view the image.

Record buffers during the data collection

Use the record function in the user interface to record 2D or 3D buffers. When recording is active, i.e. the record button turns red, each acquired buffer is streamed to the connected computer and saved in a selected target folder.

NOTE
The record button is automatically released when the image acquisition stops.

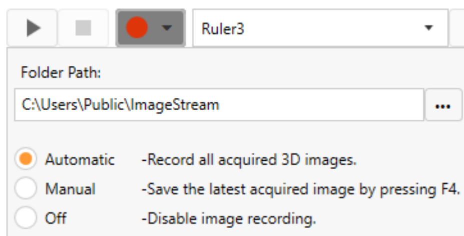


Figure 109: Recording images to file

1. Click the correct tab: **2D Image** for recording of 2D buffers, **3D Image** for recording of 3D buffers.
2. Click the record button and select a **Folder path**.
3. Enter a file name. The file name will be used as the folder name where all images (*.dat) will be saved.
4. Click **Save** to close the dialog box.
5. Click the record button to select **Automatic** or **Manual** image acquisition.
6. Click the start button to start the image acquisition.

✓ Each acquired buffer is saved in the selected target folder on the computer.

Load image data

You can load a 2D or 3D image that has been saved to disk, either by a recording or saved as a single image.

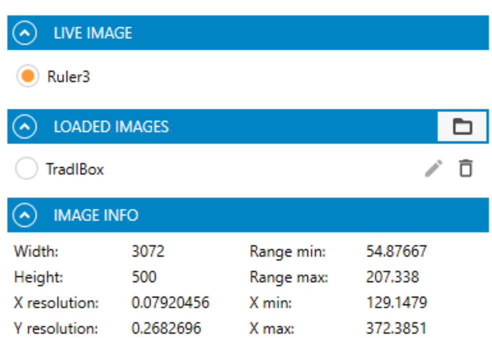


Figure 110: Loading and selecting an image GUI reference

To load a single 2D or 3D image, do as follows:

1. Open the **Evaluation** tab.

   - The **Live image** section, shows the current 3D image.
   - The **Loaded images** section, shows previously loaded images.
2. Click the **Folder** button to load a new image.
3. Find and select the image file (*.dat) and click **Open**.

✓ The image is added to the **Loaded images** section.

4. Select an image using the corresponding radio button.

8.2.7 Handling log messages

1. Search for log messages by typing in the **Search Log Message**. Possible matches will automatically appear.
2. In the **Log level** drop-down list, select which type of log messages you want to see and search for.
   You see log messages on the selected level and the levels above it. For example, if you select **Warning**, only log messages on level **Error** and **Warning** will be shown.
3. To delete all log messages, click **Clear**.

The log messages are always automatically saved as a log file. The saved log messages can be viewed when you use the **Open log folder** button. This will open the folder where the log file is stored and you can open the file in a text editor.

8.2.8 Camera files

Follow the steps below to access files that are stored on the camera:

1. In the **Cameras** tab, select **Camera files** by clicking the **Camera action menu** button, i.e the three dots to the right. You can also access the **Camera action menu** from the **2D Image** and **3D Image** tabs.

✓ The **Camera files** window opens and different files and actions are displayed in a list.

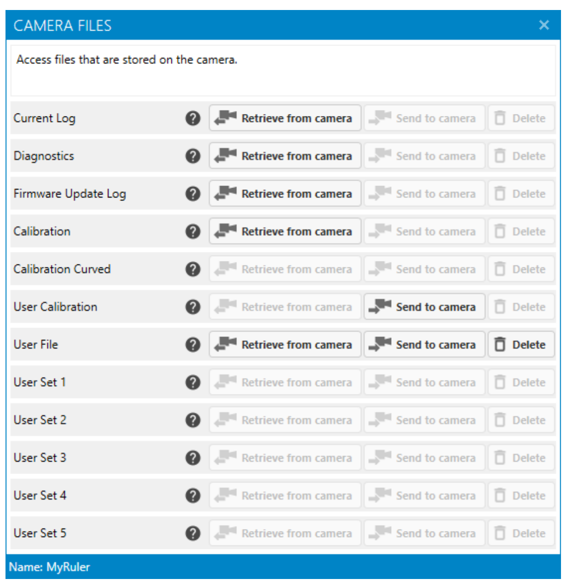


*Figure 111: **Camera files** GUI reference.*

2. Choose the file to process and click the button corresponding to the desired action.

8.2.9 Updating firmware

Follow the steps below to update the camera's firmware:

NOTE
The camera cannot be connected when updating the firmware.

1. In the step **Cameras**, select **Firmware update** by clicking the **Camera action menu** button, i.e the three dots to the right.
2. Find and select the firmware file (.aes) and click **Open**.

✓ The **Firmware update** window opens and the firmware update starts automatically.

Figure 112: ***Firmware update*** *GUI reference.*

✓ When the update is finished, the device restarts automatically.

3. Click **Close**.
4. Reconnect to the device, see "Connecting the camera", page 10.

9 Troubleshooting

9.1 Triggering the camera too fast

When you use Ruler3000 with an external line trigger source it is possible to trigger the camera too fast. This means that a new trigger arrives before the sensor can acquire new data. When configuring Ruler3000, the max value of the **Timed profile rate (Hz)** parameter indicates how fast the camera can be triggered. If the trigger rate exceeds this, triggers will be missed.

When a single trigger is missed, the triggering of the profile is delayed until the sensor is ready. If several triggers are missed before the sensor is ready, only one trigger will be used, and the others will be discarded. The camera will signal an error of class WARNING with information about the missed trigger event. This is also followed later by INFO messages giving details of the error. The details can be logged for further error analysis by technical support but contain no further user information.

If triggers are missed when it is not expected there might be noise on the trigger inputs.

9.2 Encoder line trigger setup tips

In the **Profile triggering** section the **Encoder value** parameter can be used to see how the encoder input signals are counted by the camera. The **Encoder reset** button will reset the counter to 0.

9.3 Network card settings

For problems related to the network card settings, see "Recommended network card settings", page 92.

9.4 Rescue mode

If the State LED on the device turns red, it means that the device has entered rescue mode and does not allow any data acquisition. There are two possible reasons:

- The device has discovered a problem with the installed application firmware.
- The device is overheated.

Open **Camera files** and select **Retrieve from camera** for **Diagnostics** to export log files with details about the error that put the device into rescue mode. For more information, see "Camera files", page 86.

To exit rescue mode, try one of the following options:

- Disconnect and then re-connect the power to the device.
- Upload new valid firmware, see "Updating firmware", page 86.

NOTICE
If the device enters rescue mode on multiple occasions and the reason is unknown, please contact SICK support.

10 Glossary

10.1 Terms and abbreviations

3D image	A point cloud where the object shape is represented by three coordinates or a rectified image where x and y coordinates are given by the image pixel locations and the image value gives the z coordinate.
block	In the GigE Vision transport protocol, a frame (image) is named block.
buffer	Each frame will be received in the PC as one buffer.
depth map	An image where the values represent height or depth and not intensity. Same thing as height map.
FPGA	Field Programmable Gate Array
frame	In Areascan mode: One 2D image. In Linescan3D mode: A set of 3D profiles and optionally additional data e.g. reflectance. Each line in the frame is created from one 2D image.
frame rate	The rate at which the frames are captured (Hz) in Areascan mode.
GUI	Graphical User Interface
height map	An image where the values represent height or depth and not intensity. Same thing as depth map.
intensity	The intensity value of the pixels in a 2D sensor image.
line	Contains one value for each measured point along a cross-section of the object of each aquired type. Same thing as profile.
line rate	The rate at which the profiles in an image are captured (Hz).
MTTF	Mean Time To Failure
NIC	Network Interface Card
PELV	Protective Extra Low Voltage
profile	Contains one value for each measured point along a cross-section of the objectof each acquired type. Same thing as line.
profile rate	The rate at which the profiles in an image are captured (Hz).
reflectance	The reflected peak intensity of the laser line when measuring 3D profiles.
ROI	Region Of Interest, the selected range, area or volume of meas-ured data.
scan (verb)	To collect measurements made by the 3D camera at one point in time. That is the same thing as capturing one single profile.
scatter	The intensity of the laser signal in defined parts of the WAM size.
SELV	Safety Extra Low Voltage
SoC	System on Chip
WAM	Window Around Maximum. A pixel region centered around a global or local peak used for high precision peak finding and laser scat-ter measurement.

11 Annex

11.1 Range (3D) measurement

The 3D camera measures range using triangulation. This means that the object is illuminated with a line light from one direction, and the camera is measuring the object from another direction.

The camera analyzes the sensor images to locate the laser line in them. The higher up the laser line is found for a point along the x-axis (the width of the object), the higher up is that point on the object.

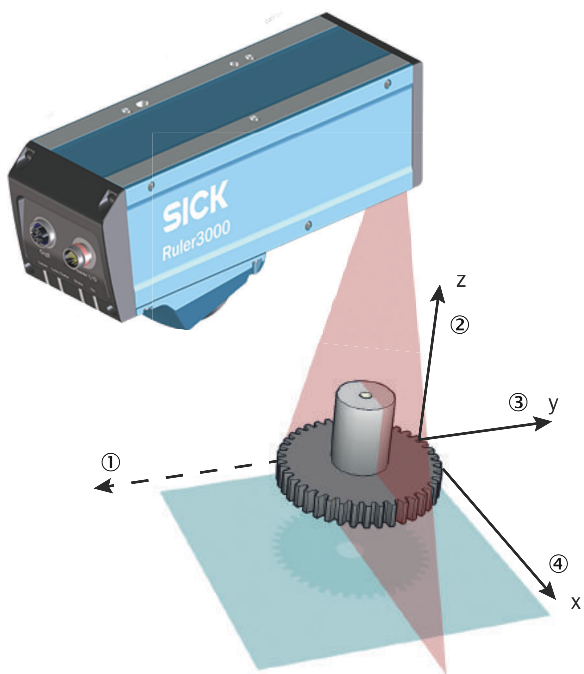


Figure 113: Coordinate system when measuring range

① Transport direction
② Range (Z)
③ Negative transport direction (Y)
④ Width (X)

The following is important to get correct measurement results:

- The laser line is orthogonal to the movement direction of the object.

11.1.1 Occlusion

Occlusion occurs when there is no laser line for the 3D camera to detect in the sensor image. Occlusion will result in missing data for the affected points in the measurement result.

There are two types of occlusion:

Camera occlusion When the laser line is hidden from the camera by the object.
Laser occlusion When the laser cannot properly illuminate parts of the object.

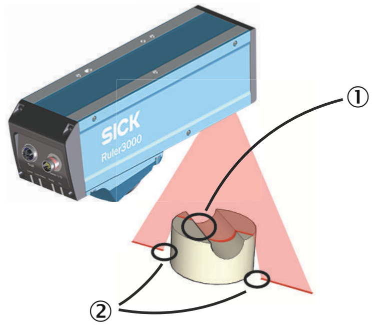


Figure 114: Different types of occlusion

① Camera occlusion

② Laser occlusion

11.1.2 Width resolution and resolution in the motion direction

In a laser triangulation system, the camera placement and optics determine the width of the field-of-view (FOV). The resolution across the object (ΔX) is the FOV width divided with the number of pixels.

The resolution along the motion direction (ΔY) is a direct function of the measurement frequency and the object speed.

11.1.3 Sensor coordinate system

This section is only relevant for 2D images and uncalibrated data. Normally a Ruler3000 uses the built-in calibration and receives 3D data as rectified Z data with Z pointing towards the device, i.e. inverse to the sensor v axis.

The camera views the object and the laser line from above, with a certain angle between the camera and the laser, as described in this document. The 2D image has its origo in the top left corner when you view the image on the screen, see the figure below. This means that the v-coordinate of a point that is close to the bottom of the screen (v_1) is greater than the v-coordinate of a point that is higher up on the screen (v_2).

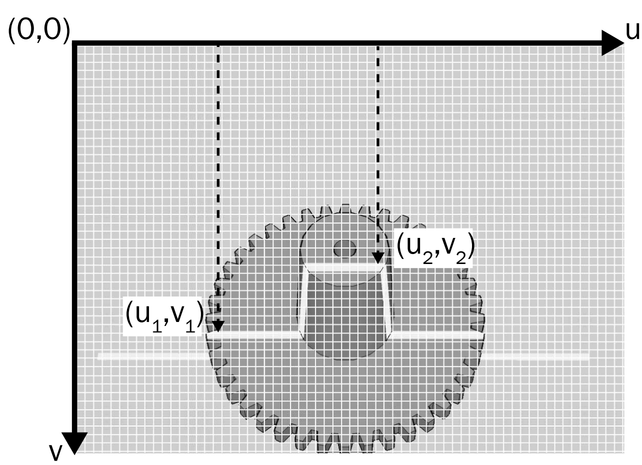


Figure 115: Sensor image and coordinate system

When the coordinates from the sensor image are used as 3D data, a high value of the v-coordinate will give a high range value.

In the coordinate system above, parts of the object that are far away from the camera will get a high range value, and parts that are close to the camera will get a low range value. That is, the range value represents distance from the camera. If you view the 3D image in a coordinate system that has its origo in the lower left corner, the 3D image will appear upside down.

11.2 Recommended network card settings

Due to the large amount of data that Ruler3000 delivers per second, it is required to connect the camera(s) to the computer using a separate Gigabit Ethernet network, without other interfering traffic.

The Network interface card (NIC) must support Gigabit Ethernet, and it is recommended that the NIC supports Ethernet Jumbo frames. Ethernet Jumbo frames are frames with more than 1500 bytes of Ethernet payload. Sending and receiving Ethernet Jumbo Frames can give a performance increase due to lower computer CPU usage.

The Ruler3000 camera has mainly been tested using network interface cards from Intel. See the tables below for recommended network settings. Note that the names of the settings may differ depending on NIC or driver version.

Receive buffers	
Recommended setting	512 or more
Default setting	256
Maximum setting	2048

Jumbo frames	
Recommended setting	>4200
Default setting	disabled
Maximum setting	16128

When using Jumbo frames the camera can support up to 4096 bytes of image data in each data package, which corresponds to 4200 bytes per Ethernet frame.

Camera IP settings

The GigE Vision® standard dictates that the factory default setting for devices is IP configuration using DHCP. If no DHCP server is found, the default for devices is to assign a Link-Local Address (LLA), also called a Zero Configuration IP, on the format 169.254.x.y.

It is recommended to define a persistent IP address which can be used when a device boots.

Ruler3000 also supports setting a static IP using the GigE Vision® forceIP method. This IP address is not persistent, which means it is lost at power-off, see "Editing IP settings", page 69.

Symptoms of possible problem

Receive buffers	Symptoms of too low setting: Multiple consecutive packets are lost, e.g. 31 consecutive packets are lost. Symptoms of too high setting: Use of memory increases.
Jumbo frames	Symptoms of too low setting: The camera will use a smaller frame size, which implies higher CPU load on the computer. Symptoms of too high setting: If you use a switch that is unable to support Jumbo Frames connected between the camera and the computer, it is impossible to receive streaming data from the camera.

IP settings	If the device and the NIC are not connected to the same DHCP server, or only one end is connected to a DHCP server, the device can not assign a correct IP.

11.2.1 Connecting multiple cameras

When you connect multiple cameras to the computer, you get the best performance if each camera is connected to a separate NIC. The camera and the NIC must be on the same subnet. You can also connect multiple cameras to the same NIC, using a switch. In that case, both the NIC and all the cameras that are connected to it must be on the same subnet.

If the computer has multiple NICs, all the NICs must be on different subnets. The subnet is indicated by the third section of the IP address, see an example in the figure below. This figure also shows that other equipment, such as network printers, should be connected to a separate NIC.

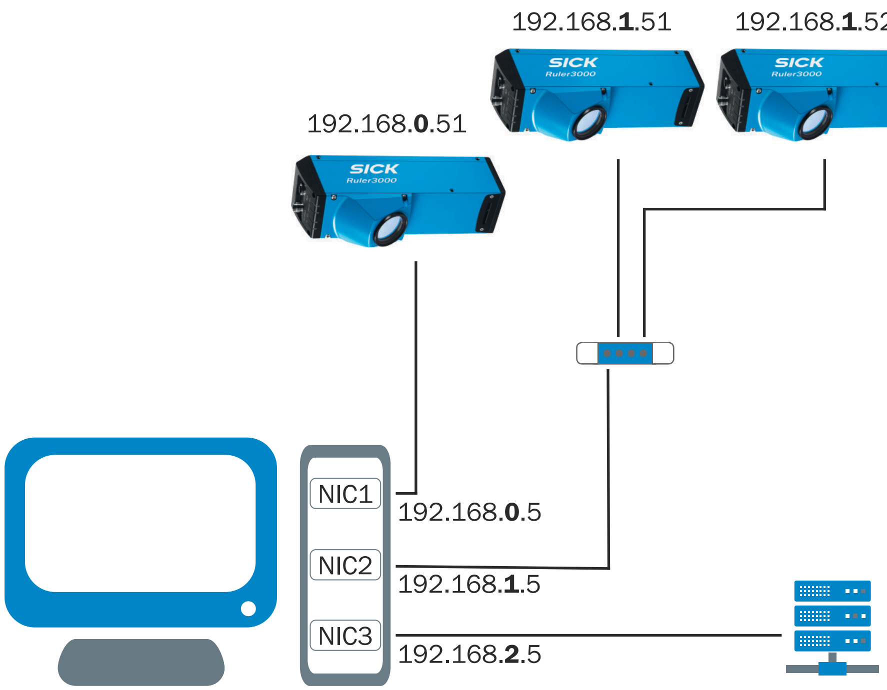


Figure 116: Computer conncted to three cameras and external network, using three separate NICs and one switch

11.3 GenIStream API

The **GenIStream API** is SICKs camera control and frame grabbing API. It is tailor-made for the Ranger3 and Ruler3000 camera families.

It includes functions for camera discovery and connection, parameter handling, grab-bing/loading/saving images, etc., and is provided for C++ and C#.

GenIStream is included in the **3D Stream SDK**, which also contains example programs written with **GenIStream**, documentation of **GenIStream**, parameter configuration files, and camera firmware. For information about installation, see "Software installation", page 12.

11.3.1 GenIStream API Examples

Grabbing an image

The most basic C++ code to grab an image:

```
std::shared_ptr<genistream::CameraDiscovery> discovery =
  genistream::CameraDiscovery::createFromProducerFile("SICKGigEVisionTL.cti");

std::shared_ptr<genistream::ICamera> camera =
  discovery->connectTo(genistream::Ip4Address("192.168.1.17"));

std::shared_ptr<genistream::FrameGrabber> grabber =
  camera->createFrameGrabber(1);

grabber->start();
genistream::GrabResult result = grabber->grabNext();
std::shared_ptr<genistream::frame::IFrame> frame = result.getOrThrow();
grabber->stop();

frame->save("my_image_file");
```

11.4 Declarations of conformity and certificates

You can download declarations of conformity and certificates via the product page.

The page can be accessed via the **SICK Product ID**: **pid.sick.com/{P/N}/{S/N}**

{P/N} corresponds to the part number of the product, see type label.

{S/N} corresponds to the serial number of the product, see type label (if indicated).

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