INDUSTRIAL IMAGE PROCESSING 2D &3D

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Productmanagement „Identification & Measuring“

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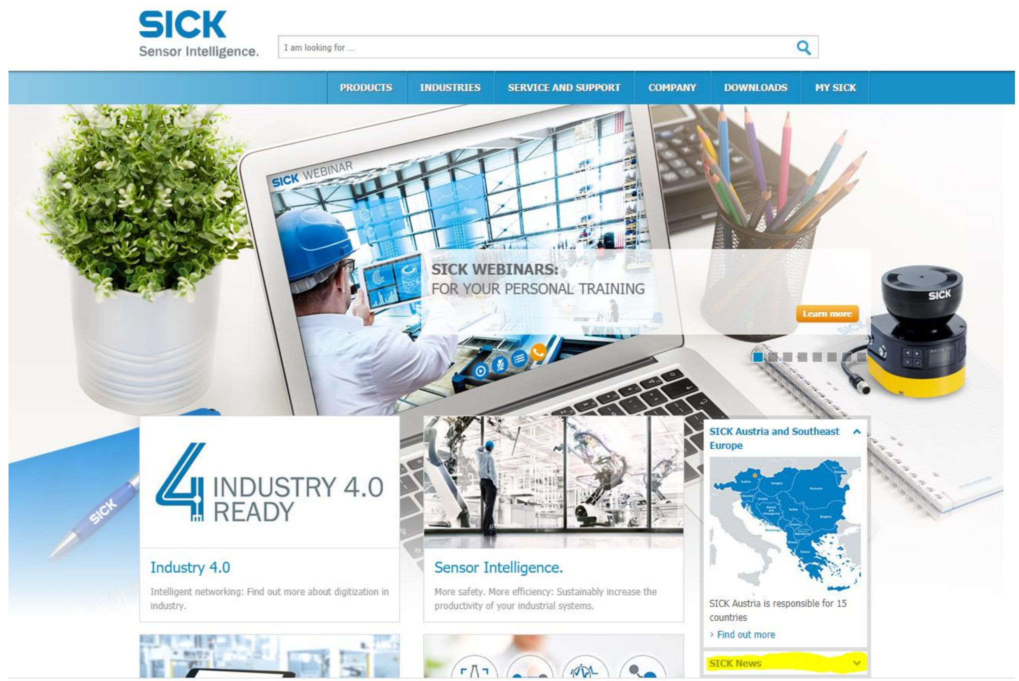
Sensor Intelligence.

NOTES ON THE WEBINAR

- The Webinar will be recorded!
- If you would like to receive the presentation and / or the recording afterwards you have to sign **GDPR**!

https://s.sick.com/newsletter_registration_at-de



INDUSTRIAL IMAGE PROCESSING 2D & 3D
CONTENT

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- **BASICS (2D – image processing)**
  - Working principle (explanations)
  - Focal length & Lens
  - Focus, aperture, depth of field
  - Image-, sensor and object resolution
  - Exposure, gain, blur, resolution, repeatability and accuracy

- **2. LIGHTING PRINCIPLES (2D – image processing)**
  - Basics (importance of light....)
  - Different kind of lightings (ring light, dark field illumination, backlight...)

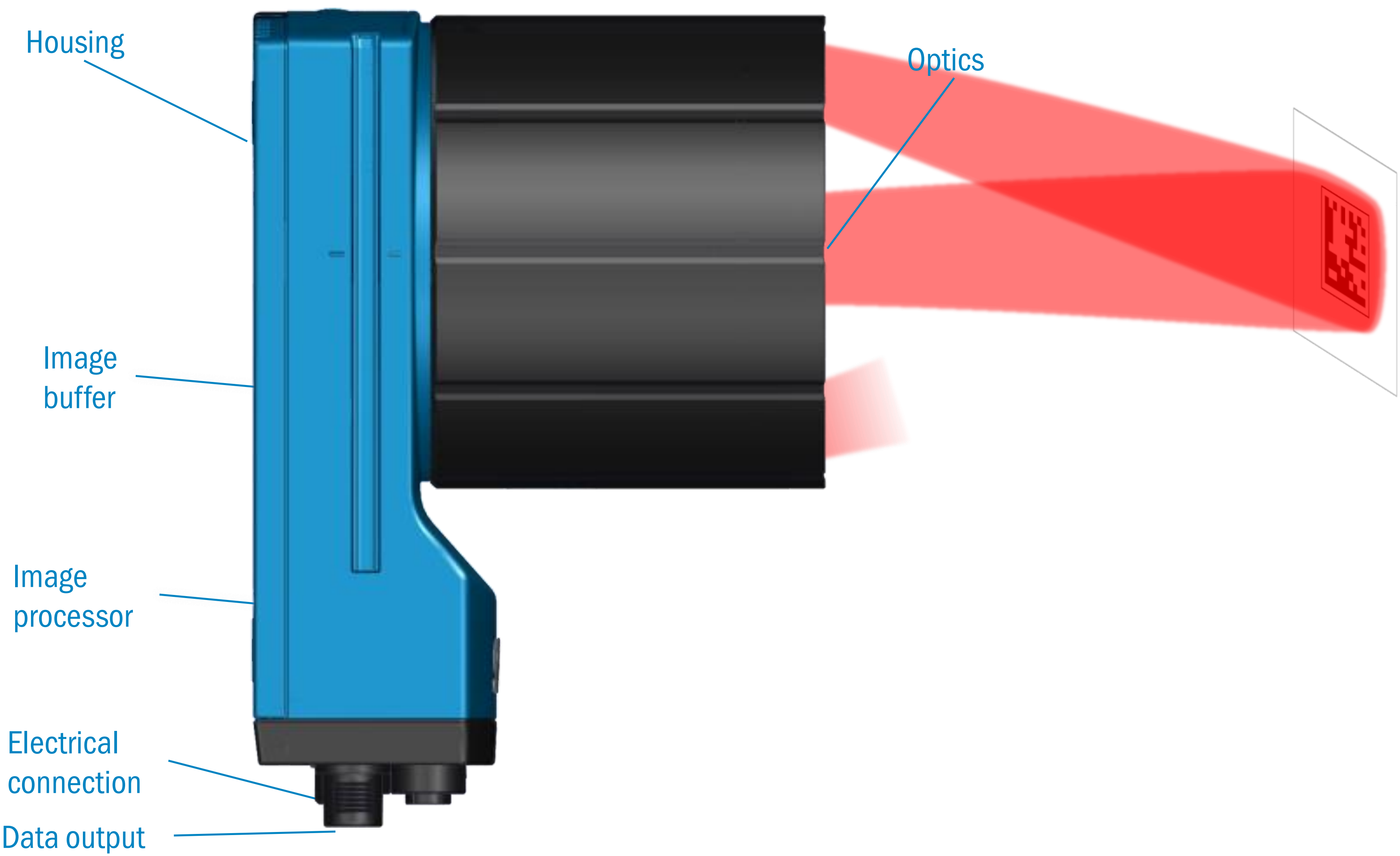
- **3. TARGET APPLICATION / PRODUCT PORTFOLIO (2D – image processing)**
  - 2D Vision

CONTENT

- **4. BASICS (3D – image processing)**
  - Working principle “Triangulation“
  - Working principle “Time of flight“
  - Working principle “Stereo“
  - When tu use 3D technology

- **5. TARGET APPLICATION / PRODUCT PORTFOLIO (3D – image processing)**
  - Configurabel cameras
  - Programmable cameras
  - Streaming cameras

INDUSTRIAL IMAGE PROCESSING 2D & 3D
1. WORKING PRINCIPLE



INDUSTRIAL IMAGE PROCESSING 2D & 3D
1. CAMERA TYPES BY DIMENSION

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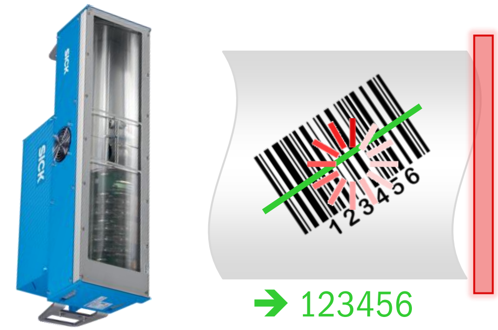
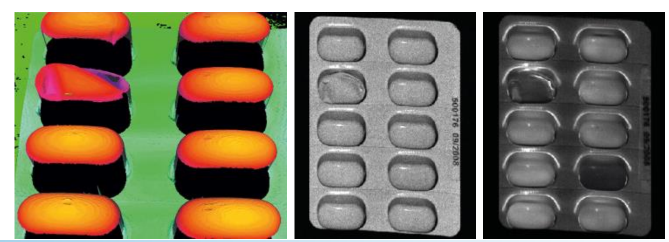
- **1D (line scan)**
  - Collects gray or color profiles
  - Profiles can be assembled into an image => 2D
  - Scanning requires object movement



- **2D**
  - Acquires an area image
  - Snapshot ”click”, no movement needed

- **3D**
  - Outputs a 3D image as a height map
    (seen from one direction) or a point cloud (360° imaging)
  - Can be snapshot (stereo) or scanning (laser triangulation)

- **MultiScan**
  - 1D, 2D, 3D and more with the same camera, at the same time



1. EXPLANATIONS (FOV, WD/RD, DOF)

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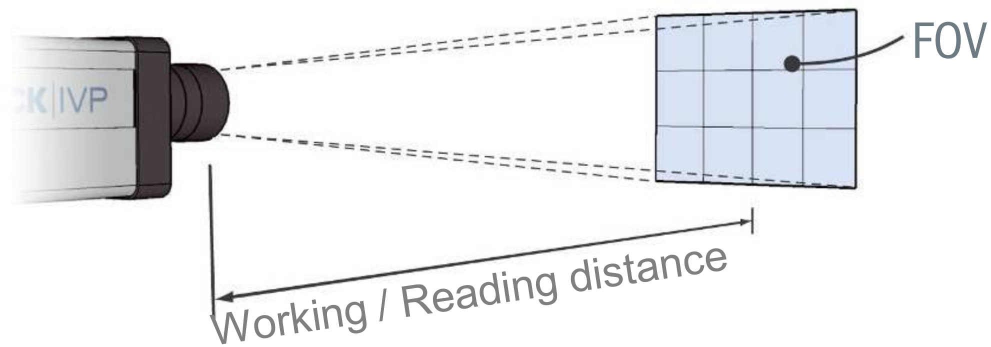
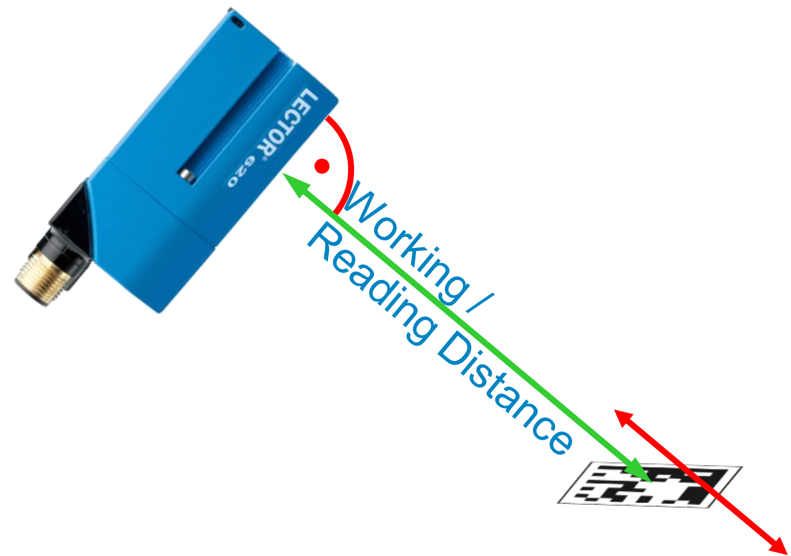
- **Field of view (FOV)**
  - Is what the camera sees (x & y)



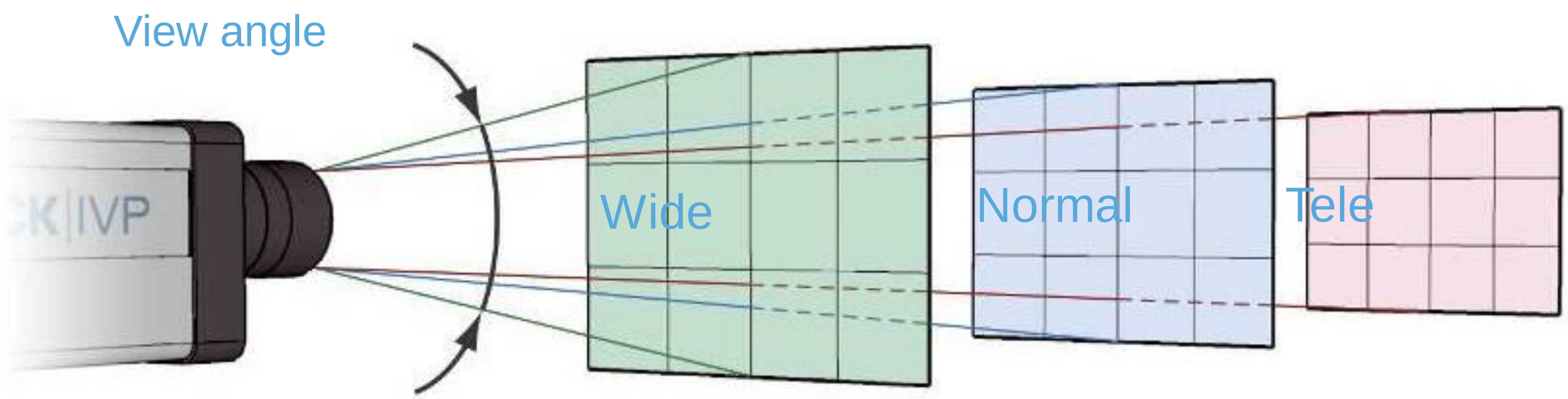
- **Working or Reading Distance (WD/RD)**
  - The Working Distance (WD) or Reading Distance (RD) is the lens-to-object distance



- **Depth of Field (DOF)**
  - Is the range in which a sensor can read a code, without changing focal position or lens.

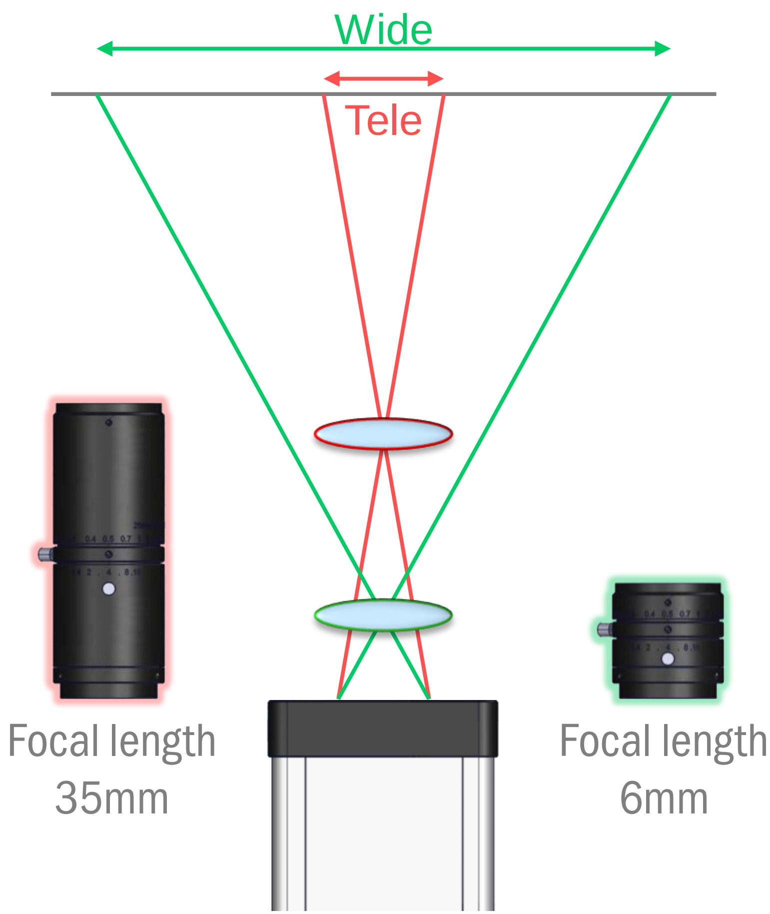
1. EXPLANATIONS (FOCAL LENGTH AND LENS)

- **The view angle of the lens determines how much of the visual scene the camera sees**
  - Wide angle (short focal length) captures a large scene
  - Normal
  - Narrow angle, or tele (long focal length), captures a small scene

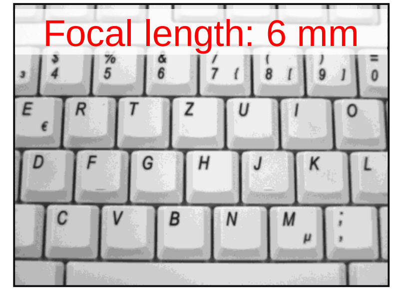


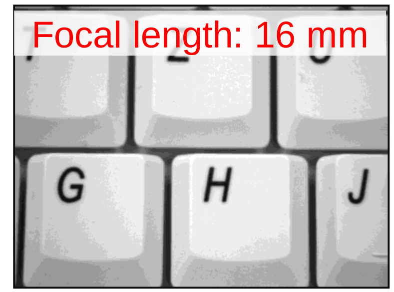
1. EXPLANATIONS (FOCAL LENGTH AND LENS)

- **Dependency**
  - Focal length ↔ Field of view



Looking at a computer keyboard with different lenses





- **A sharp image is well focused**

- The focus is used to sharpen the image. There are various types of focuses.
- Example:

1. EXPLANATIONS (TYPES OF FOCUSES)

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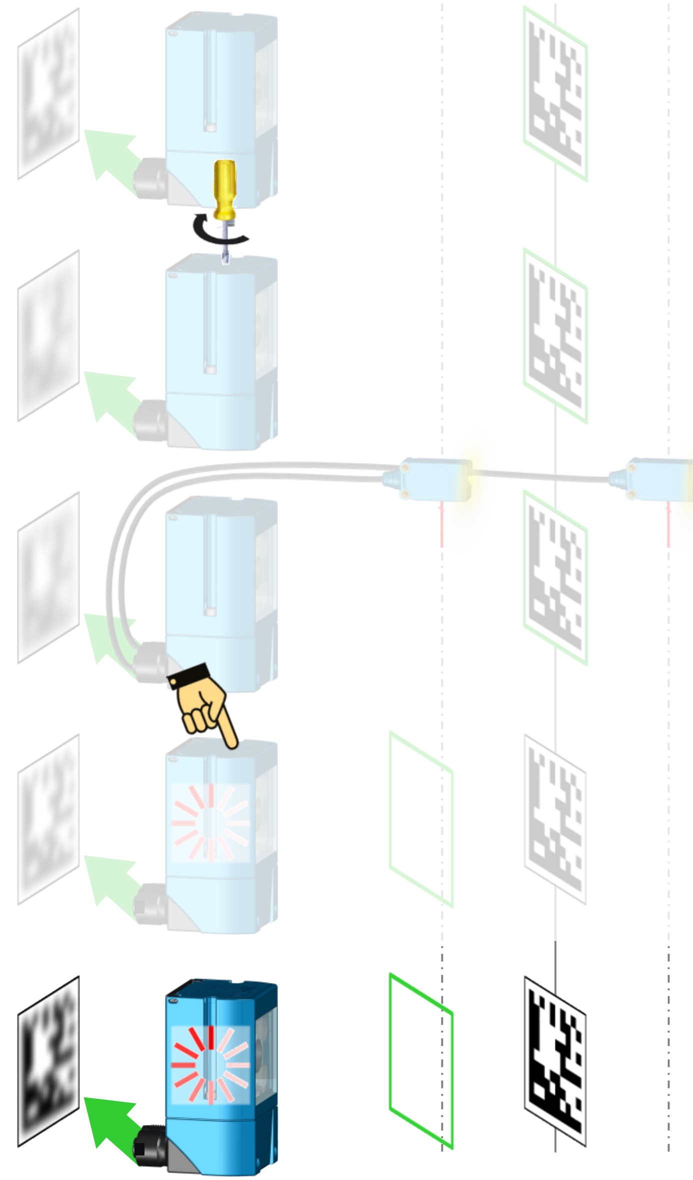
- **Fix Focus**
  - The focus is set to a certain reading distance and can not be changed.
- **Mechanical Focus**
  - The focus can be changed mechanically during commissioning.
- **Dynamic Focus**
  - The focus can be changed during the reading gate by command or incoming event such as hardware input.
- **Teach Auto Focus**
  - The focus can be set automatically by the device, but only when commissioning the device NOT during reading mode.
- **Auto Focus**
  - The focus is automatically done by the device even during reading gate / trigger



1. EXPLANATIONS (APERTURE)

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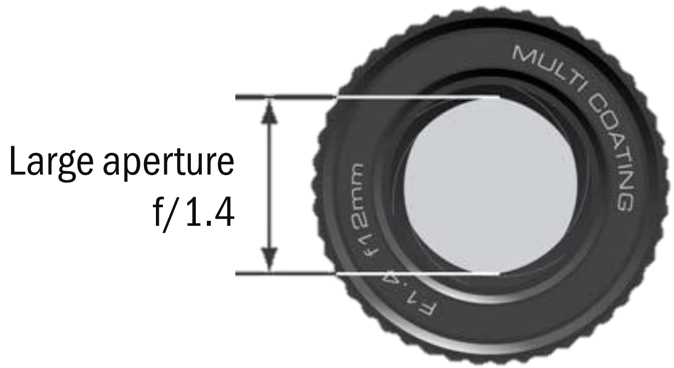
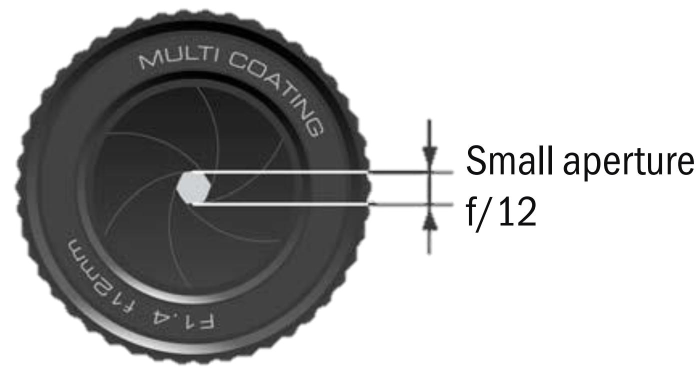
- **The aperture is the hole inside the optics through which the light enters the camera**
- **A small hole means a high aperture number (e.g. f/12)**





- Small hole → High aperture number → small amount of light → darker image
- Big hole → Small aperture number → big amount of light → brighter image

- **Example**

Aperture: f/4.5

Aperture: f/28

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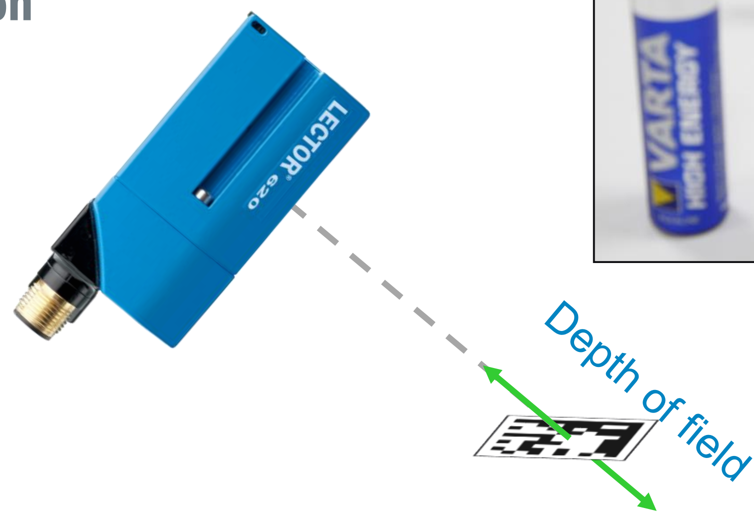
- **The "Depth of Field" (DOF) is the range in which a scene appears acceptably sharp.**
- **Within the DOF, a sensor can read a code or detect an object, without changing focal position or lens.**

- **The depth of field depends on**
  - Focal length / Focal position
  - Working / Reading distance
  - Lens
  - Aperture
  - Camera sensor resolution



- **Main effects**
  - Large aperture → small DOF / Small aperture → large DOF
  - Long focal length → small DOF / Short focal length → large DOF
  - Short working distance → small DOF / Long working distance → large DOF

1. PIXEL INFORMATION

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- **Black and white – binary values, 0 or 1**

0 1

1 bit/pixel

- **Gray scale – values from 0 to 255**

0 255

1 bit/pixel

- **Color – RGB (Red, Green, Blue), each channel has a value from 0 to 255**

0 255

0 255

0 255

1 bit/pixel

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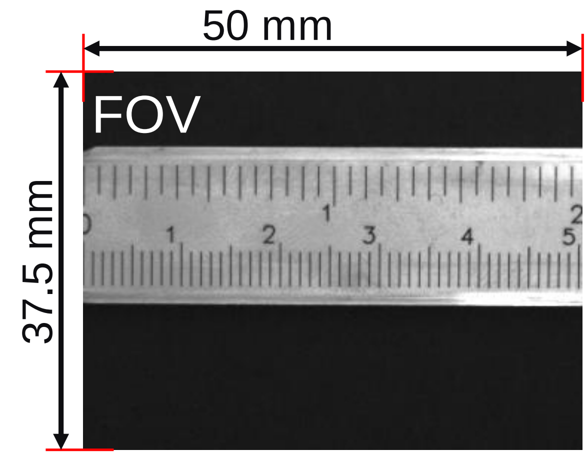
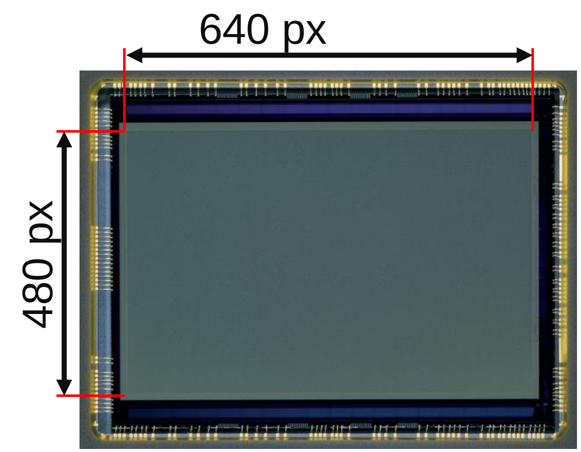
- **Object resolution**
  - Physical dimension on the object, that corresponds to one pixel on the sensor (mm/pixel)
  - → Which length (mm) is equal to one pixel



- **Example**
  - FOV size
    - Width (x): 50 mm
    - Height (y): 37.5 mm
  - **Sensor resolution**
    - Width (x): 640 px
    - Height (y): 480 px
  - **Object resolution (by width)**
    - 50 mm / 640 px = 0.08 mm/pixel

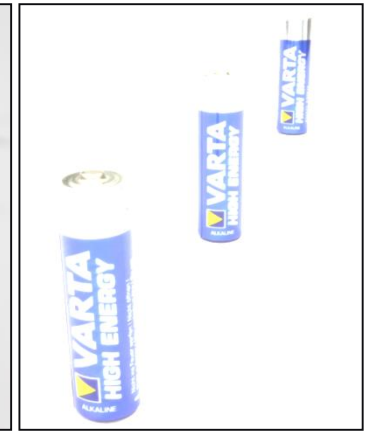


INDUSTRIAL IMAGE PROCESSING 2D & 3D
1. EXPOSURE / GAIN

- **Exposure is the amount of light that is recorded by the sensor**
- **Exposure depends on**
  - Exposure time
  - Aperture size
  - Object illumination
  - Sensor's light sensitivity

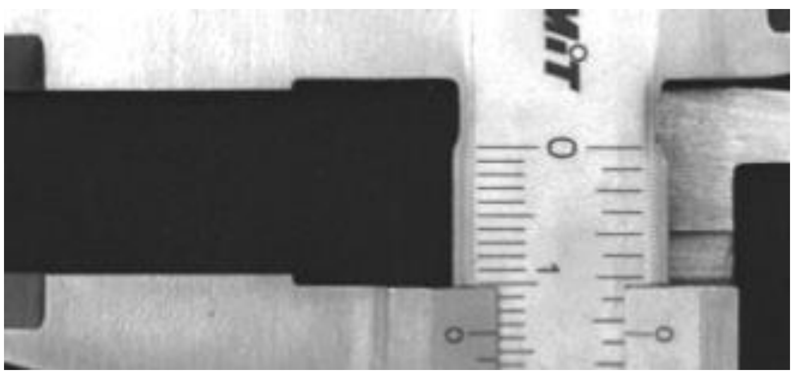
Underexposed

Normal

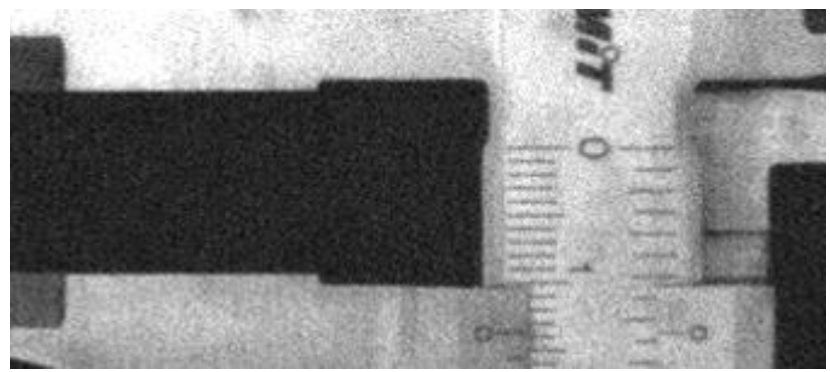


Overexposed

- **Electronic gain**
  - Increased gain allows shorter exposure time, but amplifies noise



Normal gain



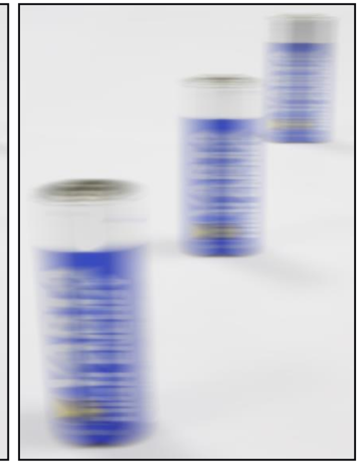
High gain

1. BLUR

- **Blur is caused by**
  - Lens is out of focus
  - Motion
  - Camera shake (e.g. vibrations)

Sharp

Out of focus



In motion

- **Blur is avoided by**
  - Focus adjustment
  - Short exposure time + intense light
  - Mount separately from vibrating machine

Reduce exposure time

Use stronger light

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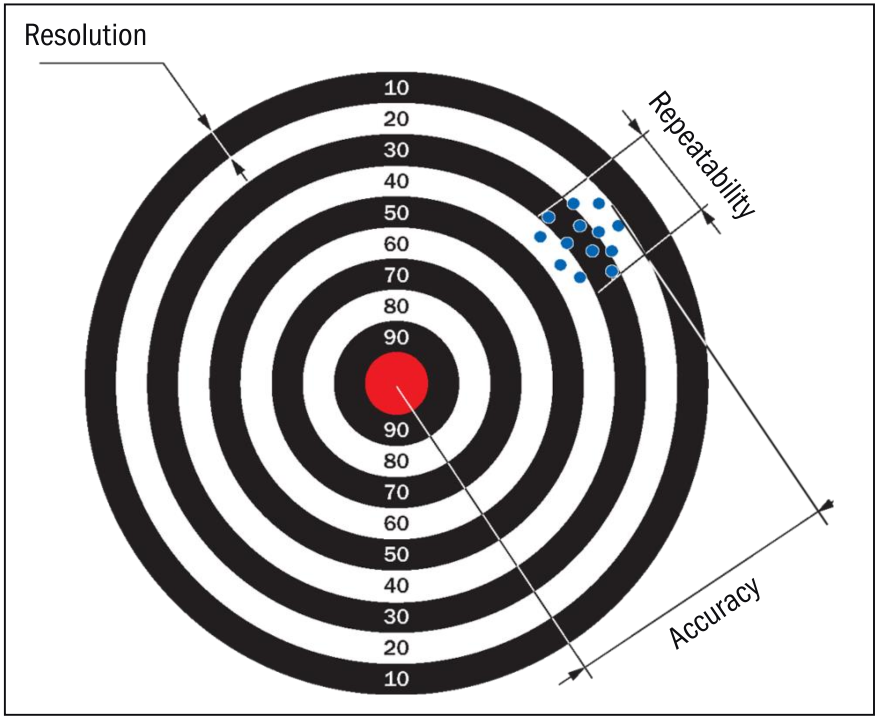
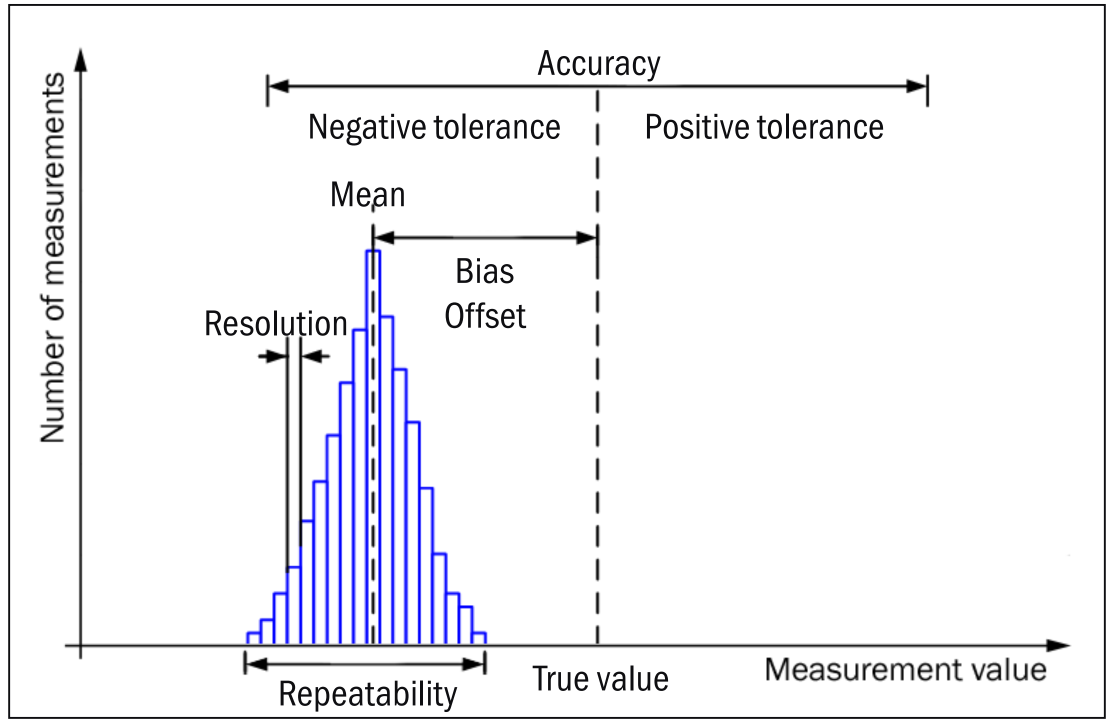
- **Resolution, repeatability and accuracy are connected, but not the same**

Intuitive definitions



Statistical definitions



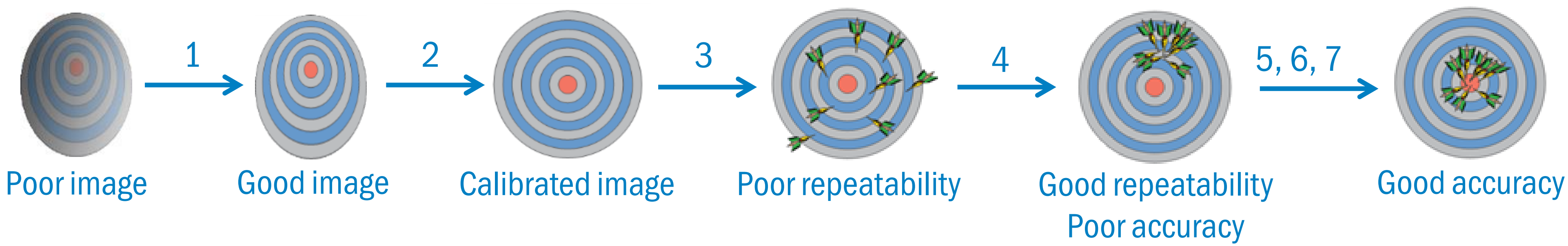
- **Off-set compensation makes accuracy = repeatability**
  - Requires that the true value (bull's eye) is known from a reference method

1. PROCEDURE TO ACHIEVE ABSOLUTE ACCURACY

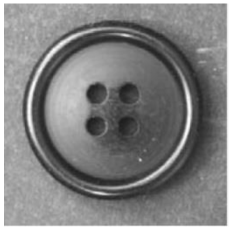
- **First get good repeatability**
  1. Ensure a good image quality
  2. Calibrate the setup with a checkerboard target

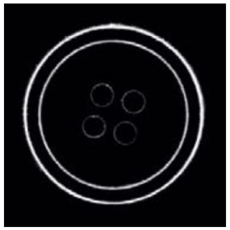
  3. Make >10 measurements on the same object to see the repeatability
  4. Improve the repeatability if needed

- **Then go from repeatability to accuracy**
  5. Measure the object(s) with a trusted reference method
  6. Calculate the average measurement error (off-set)
  7. Subtract the error by ”off-set compensation”



- **Just like the eye, machine vision depends on light and optics to work**
- **Different lighting methods can have very different visual effects**
- **The success of an application often depends on the image quality, which depends on a good lighting method**
- **Which method is ”right” depends on the surface characteristics, the feature type, and the object presentation**

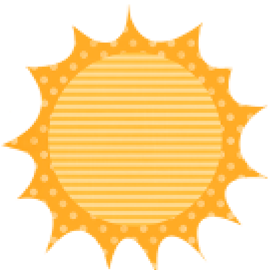




Button as seen in three different lighting situations

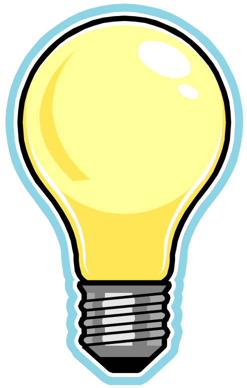
2. AMBIENT LIGHT

- **Ambient light is seldom used as light source for machine vision because of its variability**



Sunlight

\+



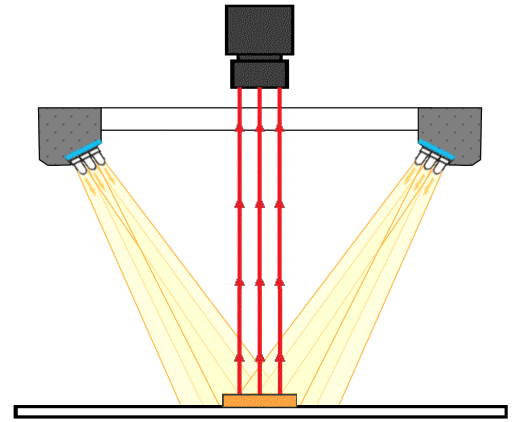
Indoor lighting

= Ambient light

- **Usually, the application is covered with a shroud to guarantee constant light**
  - Assume a shroud is needed until the opposite is proven
  - As an exception, controlled ambient light can be used as part of the vision application

INDUSTRIAL IMAGE PROCESSING 2D & 3D
2. RING LIGHT

- **The ring light principle**
  - Ring illumination on axis with camera
  - High intensity → short exposure times
  - Well-suited for easy and high speed applications



Ambient light

Ring illumination

A ring light
produces direkt illumination

2. DARKFIELD ILLUMINATION

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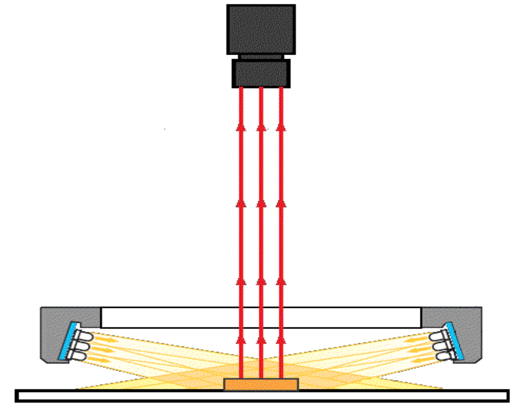
- **The darkfield principle**
  - Low-angle light
  - Enhances edges for pattern recognition and scratch detection
  - Well-suited for inspecting sharp edges and very small 3D features on flat surfaces

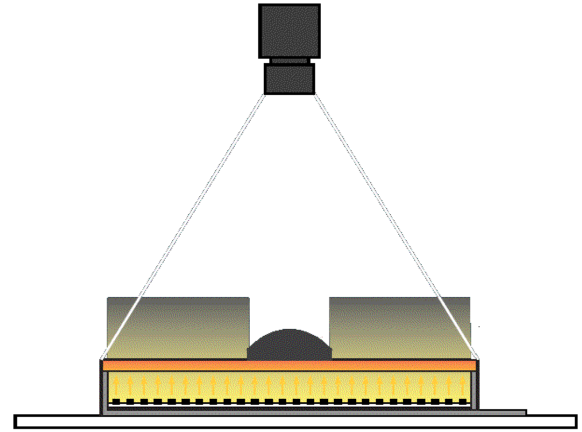


Ambient light

Darkfield illumination

A low angle ring light produces darkfield illumination

- **The backlight principle**
  - Light from behind the object
  - Enhances the object's silhouette
  - Well-suited for inspecting an object's contours, for example shape or dimensions



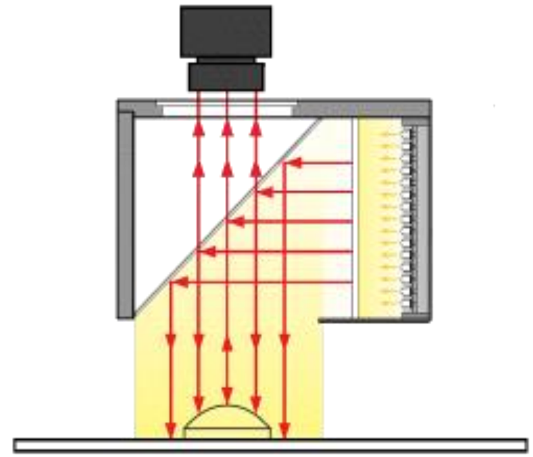
Ambient light

Backlight illumination

A backlight produces the silhouette

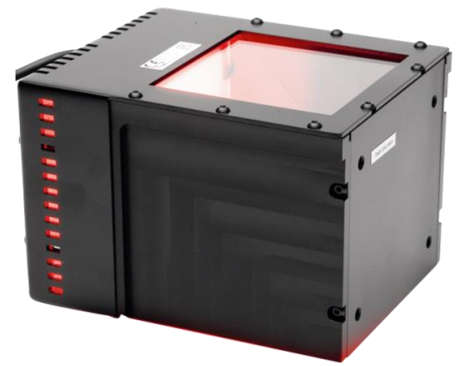
2. ON-AXIS-ILLUMINATION

- **The on-axis (co-axial) principle**
  - The light is parallel to the optical axis, thanks to a semi-transparent mirror
  - Enhances contrasts between flat and sloped areas
  - Well-suited for inspecting the inside of hollow objects and small 3D features on flat surfaces



Ambient light

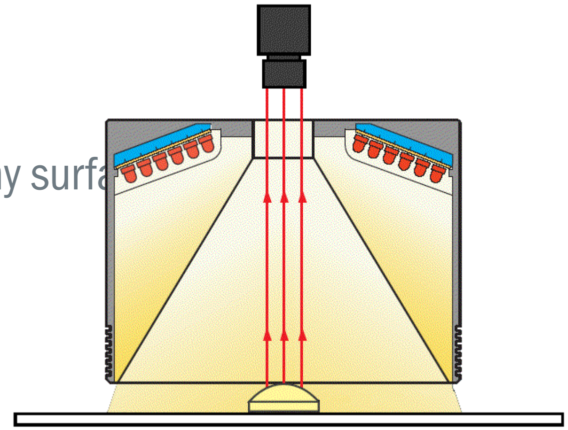
On-axis illumination

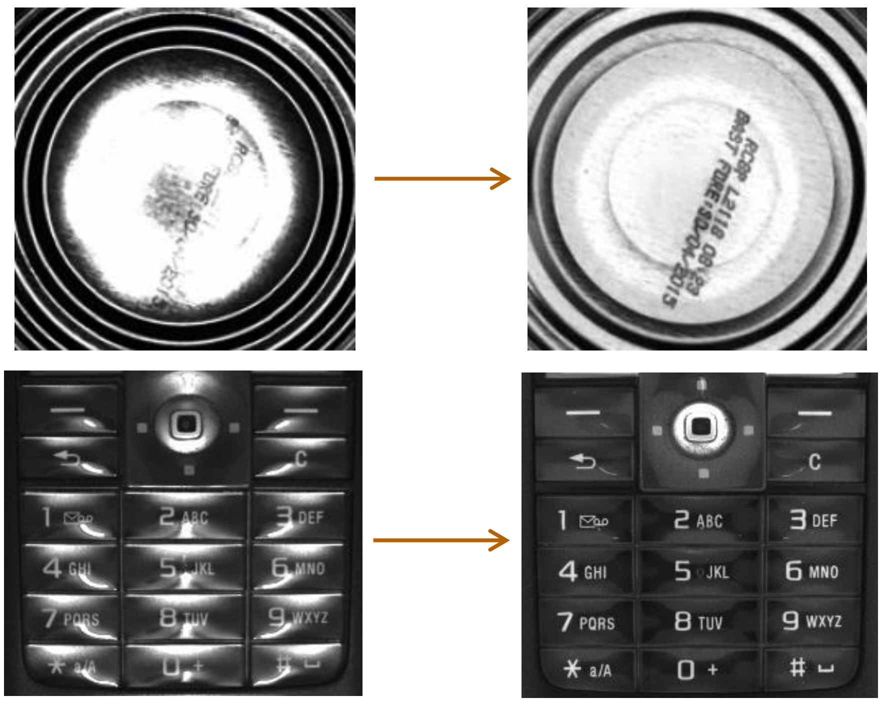


An on-axis light produces the silhouette

INDUSTRIAL IMAGE PROCESSING 2D & 3D
2. DOME ILLUMINATION

- **The dome principle**
  - The light is very diffuse thanks to an internal diffusor
  - Enhances true contrast and suppresses disturbing reflections in shiny surfa
  - Well-suited for inspecting shiny objects





Ambient light

Dome illumination

A dome light produces very diffuse light

2. SPOT AND BAR LIGHT ILLUMINATION

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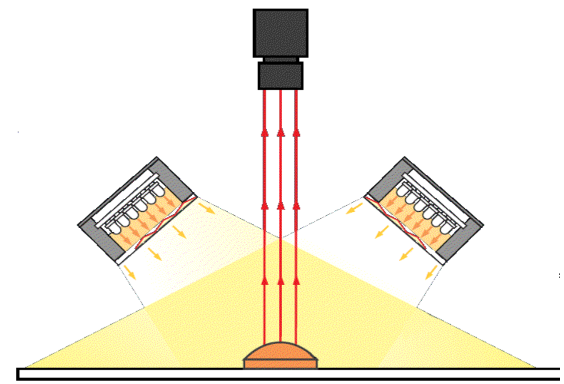
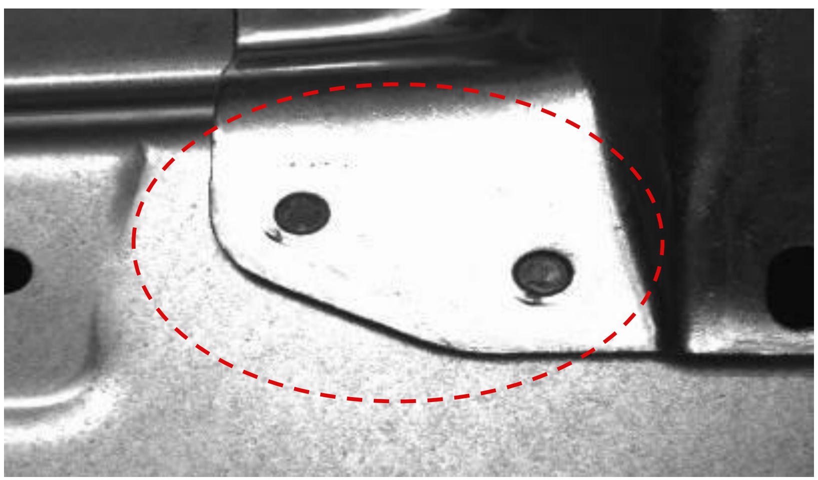
- **Spot and bar light principle**
  - Large freedom of geometry for targeted illumination
  - Which features are enhanced depends on the chosen geometry
  - Well-suited for low-cost (few LEDs), simple tasks





A spot light is enough to illuminate the critical features (weld spots, automotive)

A spot or bar light can illuminate in many ways thanks to its flexible mounting

INDUSTRIAL IMAGE PROCESSING 2D & 3D
2. AVOID HOT SPOTS > TILT THE CAMERA

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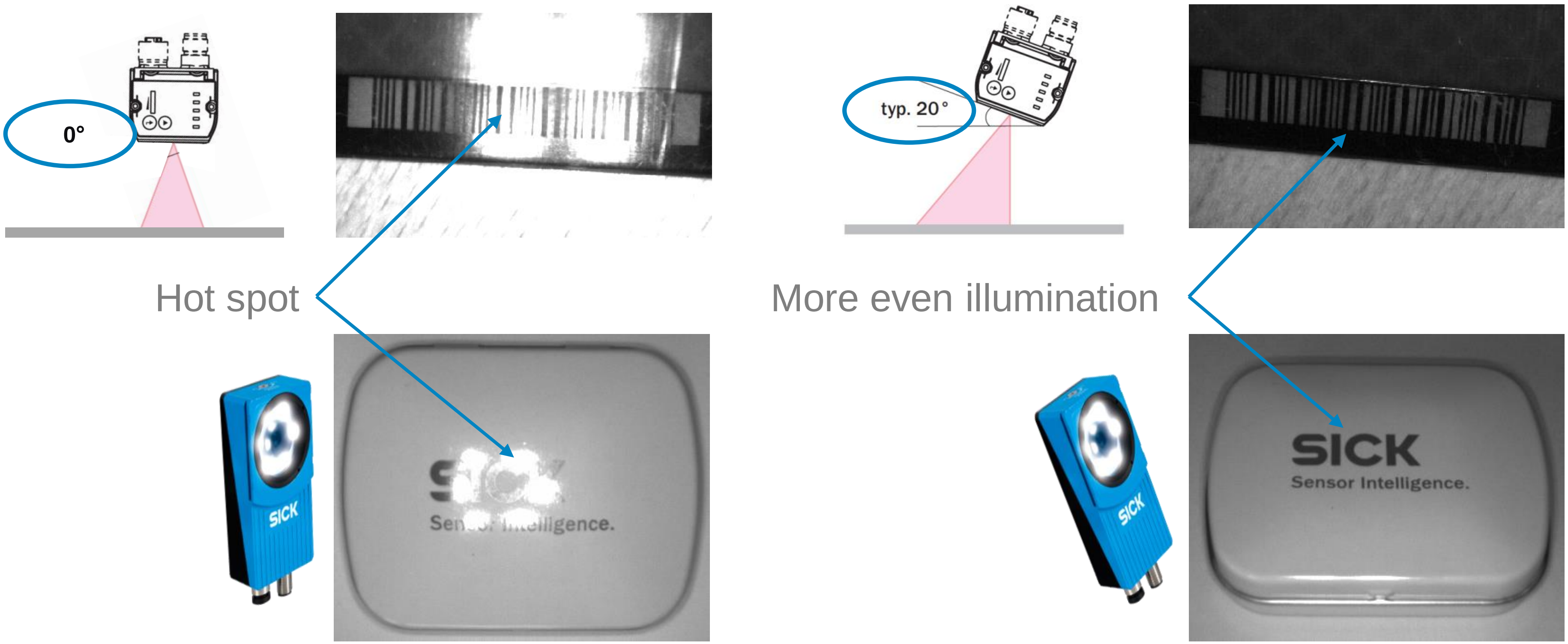
- **Glossy (shiny) materials reflect direct light sources → hot spots**
- **Tilt the camera to deflect the hot spots away from the lens**



- **Note: Tilting → perspective problems when**
  - High accuracy is needed
  - The object can rotated 360°

2. AVOID HOT SPOTS > DIFFUSE LIGHT

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- **If tilting the camera is no option**
  - Use diffuse light to avoid direct reflections

Ring light
gives direct light
and hot spots

Inspector with
built-in dome
gives diffuse light

Hot spot

Even
illumination

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2. OPTICAL FILTERS

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- **Use filters to enhance contrast and suppress ambient light**
  - Available in different colors
  - Depending on type, either mount on lens or between lens and camera
  - Filters reduce intensity → longer exposure time needed → increased motion blur
  -

Filters for Inspector

Filters for IVC-2D

Blue light + (optionally) blue filter maximizes contrast!

3. INSPECTION, POSITIONING, MEASUREMENT, READING

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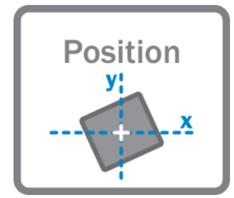
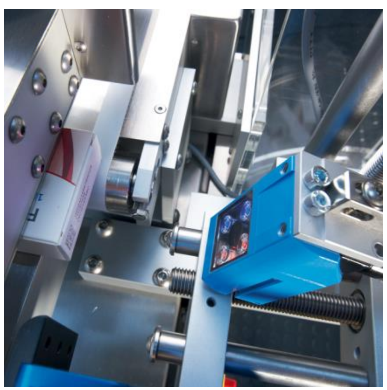
Precense detection of datcode

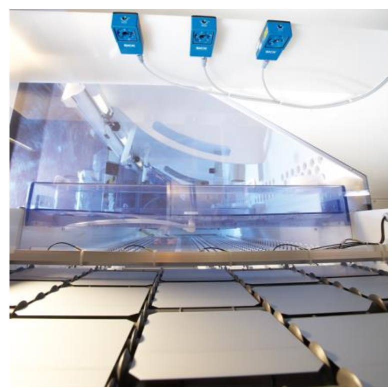
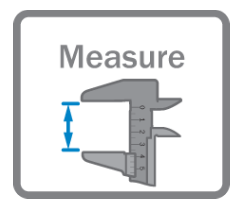

Roboter guidance

Barcode & OCR reading




Solar waver alignment

INDUSTRIAL IMAGE PROCESSING 2D & 3D
3. APPLICATION

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Nahrungsmittel


Getränke


Konsumgüter


Pharma


Elektronik


Solar


Druck


Verpackung


Holz


Autos & Fahrzeuge


Roboter


Reifen


INDUSTRIAL IMAGE PROCESSING 2D & 3D

3. DIFFERENT VARIANTS

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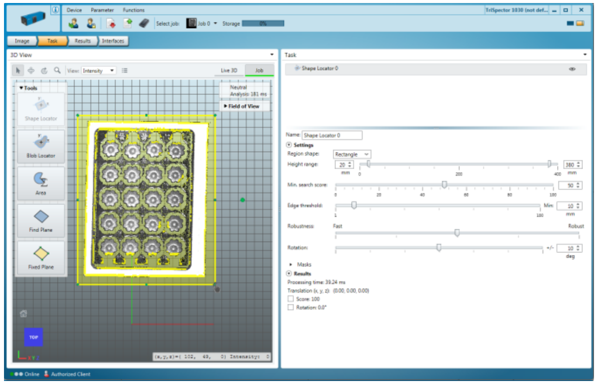
CONFIGURABLE SENSORS

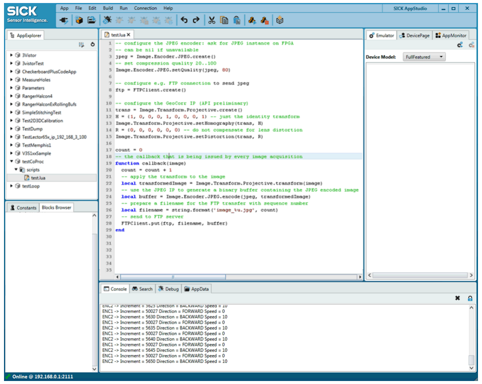
- **Configuration of parameters**
  - **Sliders**
  - Click
  - Drag'n'drop
  - Conditions



- Processing in the device
- Internally calculated results

PROGRAMMABLE CAMERAS

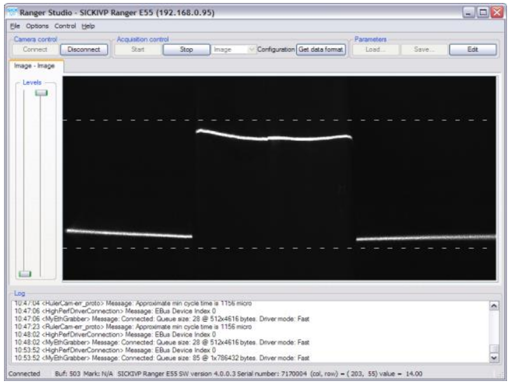
- **Device programing**
  - Block programs
  - Scripting
  - Low level programing (C, C++, Java)
  - Integration of external image libraries



- Processing in the device
- Internally calculated results

STREAMING CAMERAS

- **Raw data output to**
  - PLC
  - Computer
- Device configuration only to acquire images and to optimize the output of the raw data



- NO internally calculated results!

INDUSTRIAL IMAGE PROCESSING 2D & 3D

3. VISION PORTFOLIO - 2D

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CONFIGURABLE SENSOR

- **Lector62x/63x/64x/65x**
  (Barcodereading - Matrix)

- **ICR88x /89x**
  (Barcodereading - Line)

- **Inspector**
  (Vision - Matrix)

- **InspectorP (configurabel)**
  (Vision - Matrix)

PROGRAMMABEL CAMERA

- **InspectorP63x**
  (Vision -Matrix)

SICK APP SPACE
HALCON

- **InspectorP64x**
  (Vision - Matrix)

SICK APP SPACE
HALCON

- **InspectorP65x**
  (Vision - Matrix)

SICK APP SPACE
HALCON

STREAMING CAMERA

- **Midi-Cam**
  (Vision -Matrix)

- **PicoCam**
  (Vision - Matrix)

- **SIM4000**
  (Controler)

SICK APP SPACE
HALCON

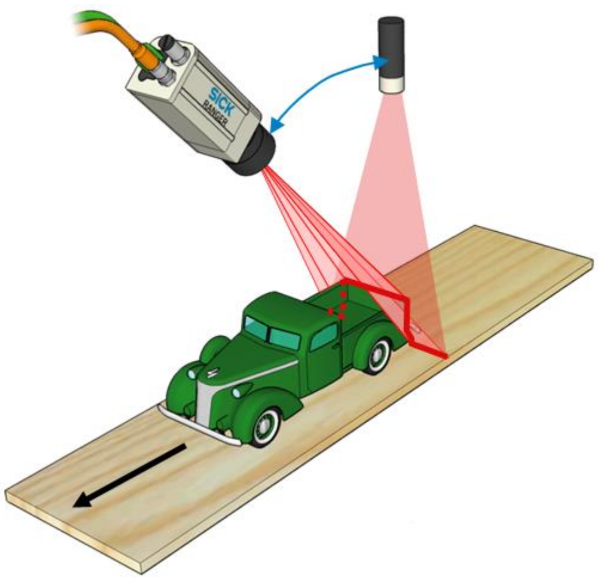
INDUSTRIAL IMAGE PROCESSING 2D & 3D

4. 3 DIFFERENT TECHNOLOGIES - TRIANGULATION

SICK
Sensor Intelligence.

TRIANGULATION

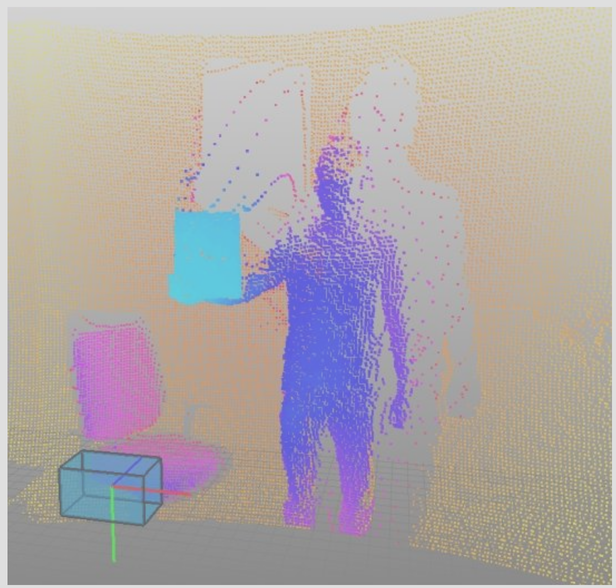
- **Triangulation ratio between**
  - laser line
  - camera
  - object height



- Range: ≤ 1,5 m
- Resolution: ≥ 0.05 mm

TIME OF FLIGHT

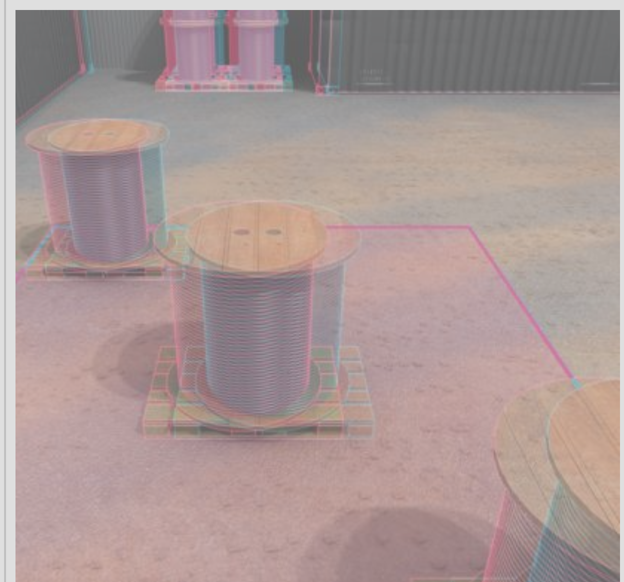
- Based on
  - time, the light needs to „fly“ from the sensor
  - speed of light
  - optical properties



- Range: ≤ 7.2 m
- Repeatability: ≤ 30 mm

STEREO

- Binocular principle
  - two cameras
  - passive system



- Range: ≤ 5m
- Repeatability : ≤ 1mm

4. TRIANGULATION - 2 DIMENSIONAL MEASUREMENT

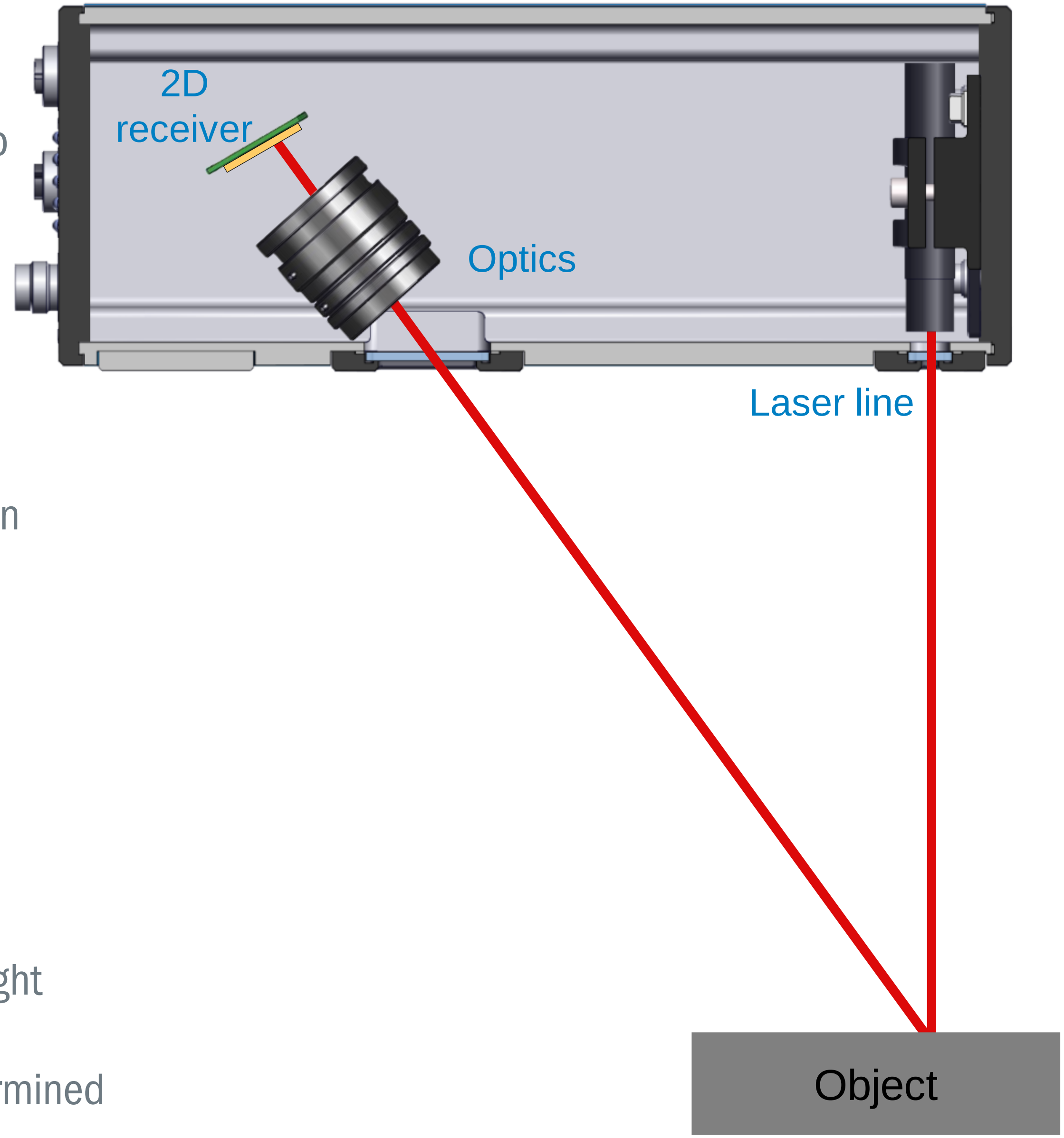
SICK Sensor Intelligence.

- **Triangulation**
  - Height information by triangulation ratio

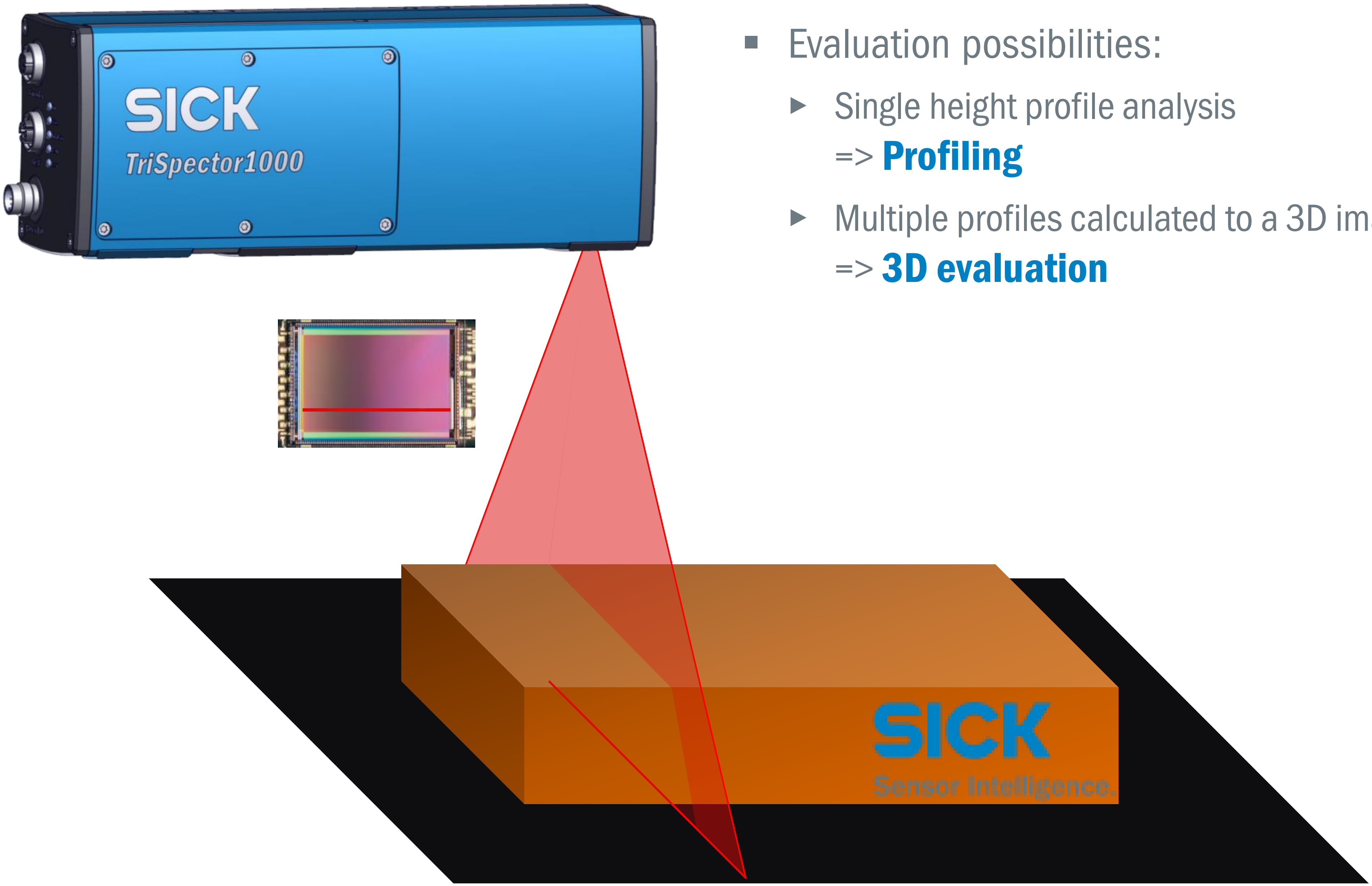
⇒ 3D information

- **Movement needed!**
- **Active system => light is sent out**
  - Special conditions for scene illumination

- **Functional principle**
  - A laser line is projected onto the object being measured
  - The reflection is mapped onto a light-sensitive element (2D camera imager)
  - Based on the position of the mapped light spots and the known geometry of the sensor optics, the height profile is determined



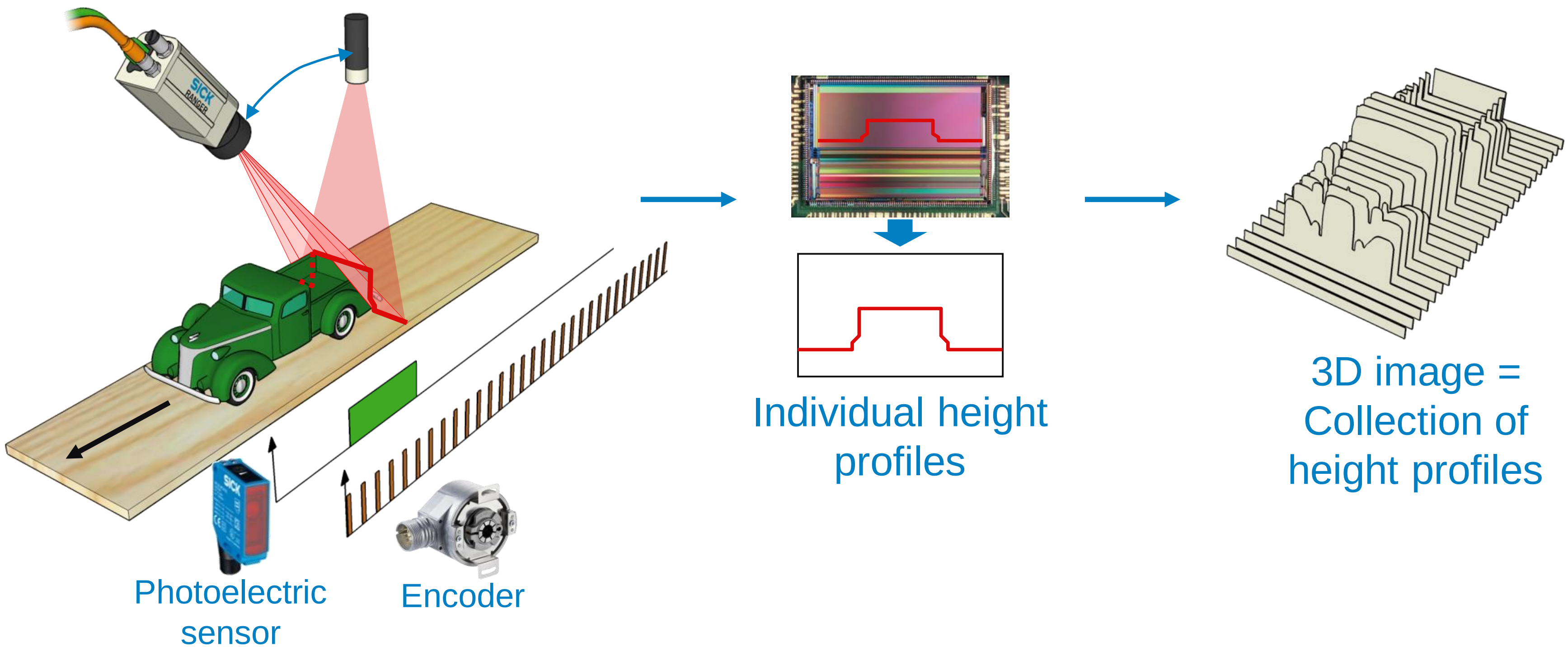
4. TRIANGULATION - 3 DIMENSIONAL MEASUREMENT



- Evaluation possibilities:
  - Single height profile analysis
    => **Profiling**
  - Multiple profiles calculated to a 3D image
    => **3D evaluation**

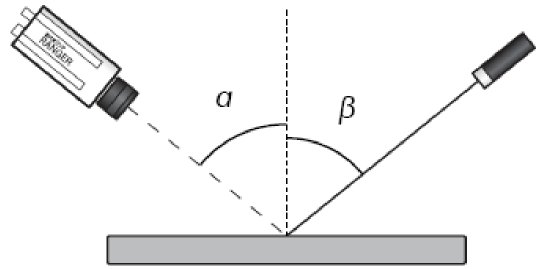
INDUSTRIAL IMAGE PROCESSING 2D & 3D
4. 3D EVALUATION

- Working principle
  - A laser line is projected on the object
  - Individual height profile (laser displacement) is recorded by the camera (angled view)
  - Movement → multiple contour profiles are collected → put together to a 3D image
  - Encoder pulses → control equal profile distances → no distortion
  - Photoelectric sensor → starts the image recording

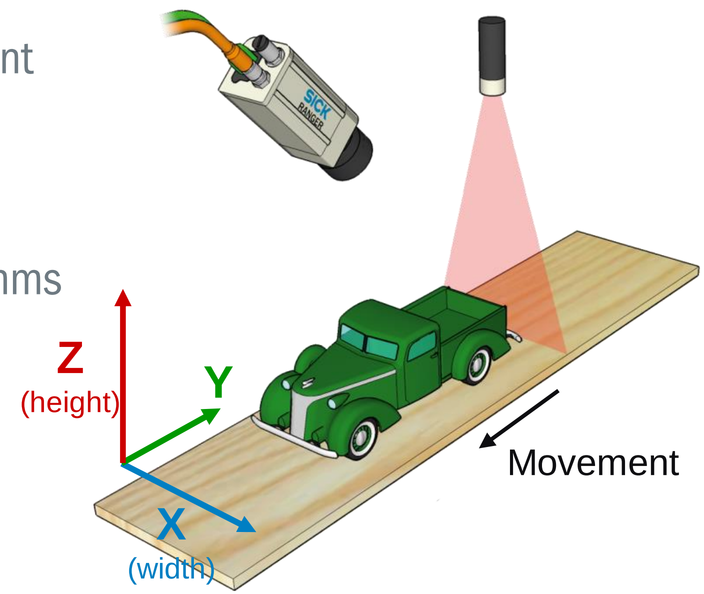


4. TRIANGULATION - RESOLUTION

- **Image resolution**
  - Image length (y) and width (x) in pixels
  - Height resolution in mm



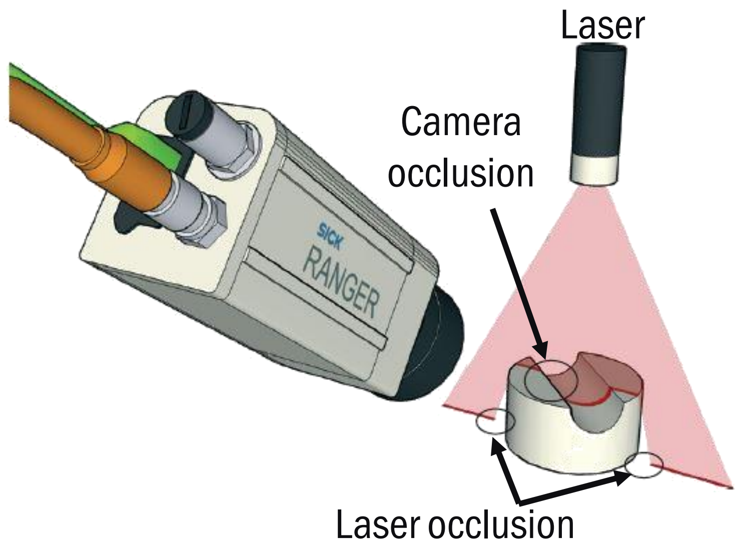
- **Object resolution**
  - Like a 2D setup with perspective, x and y resolution can be different
  - X resolution (mm/pix) determined by the pixel width and optics
  - Y resolution (mm/pix) determined by the scan rate
  - Z resolution (mm) determined by the geometry and sensor algorithms

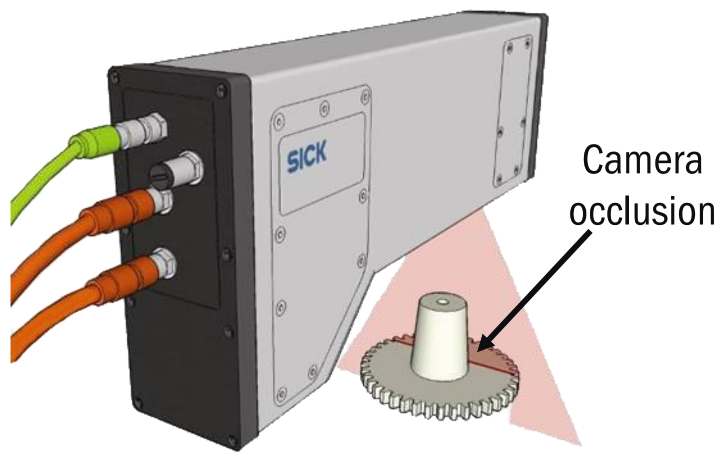


- **For systems with flexible lens and geometry (Ranger), 3D resolution is normally application specific → no common specification in data sheet possible**

4. TRIANGULATION - OCCLUSION AND MISSING DATA

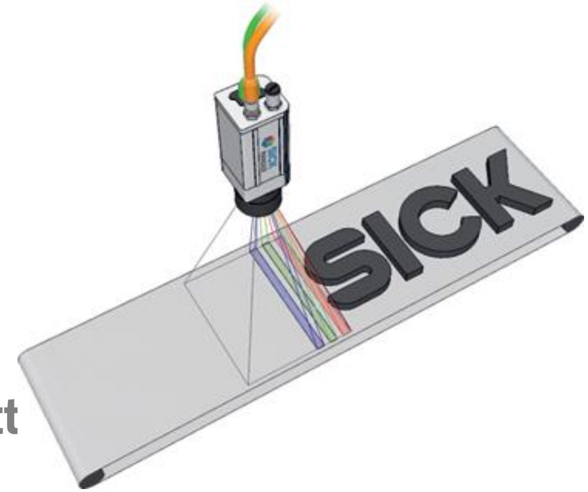
- **Camera occlusion / shadowing**
  - The laser line is hidden from the camera behind object features
- **Laser occlusion**
  - The laser cannot illuminate parts behind object features
- **Missing data**
  - Parts of the image contain no information because of occlusion or underexposure

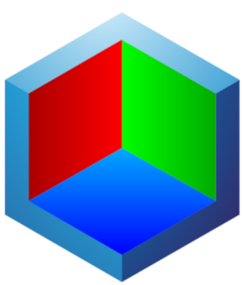




4. TRIANGULATION - 3D AND COLOR TECHNOLOGY

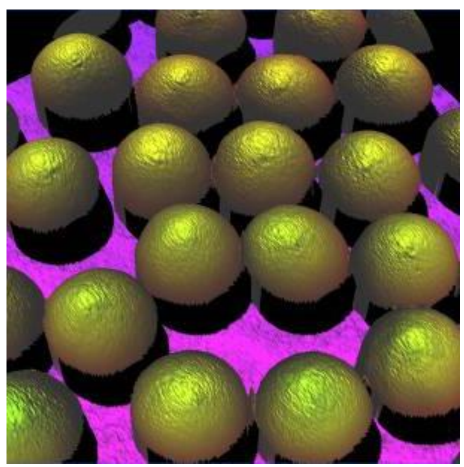
- **High-speed 3D and color in one camera**
- **Color = combination of three separate lines with red, green and blue filters on the sensor**
- **Color can be very useful in addition to 3D, grayscale and scatt**
- **Creation of a colored 3D image is possible**



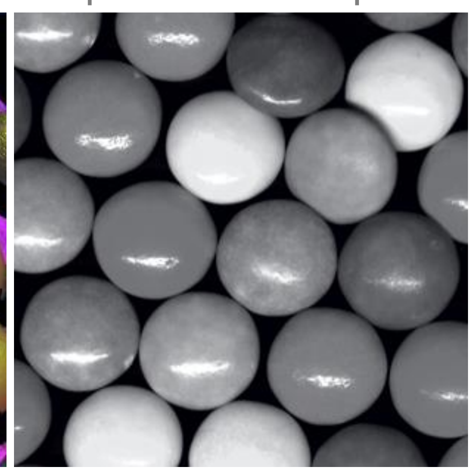


3D & COLOR

Example: M&M's separation



3D data



Gray scale

Color

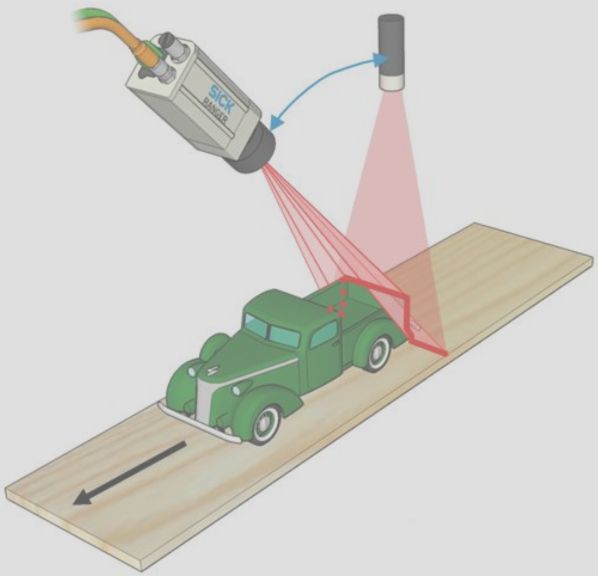
INDUSTRIAL IMAGE PROCESSING 2D & 3D

4. TIME OF FLIGHT

TRIANGULATION	TIME OF FLIGHT	STEREO

TRIANGULATION

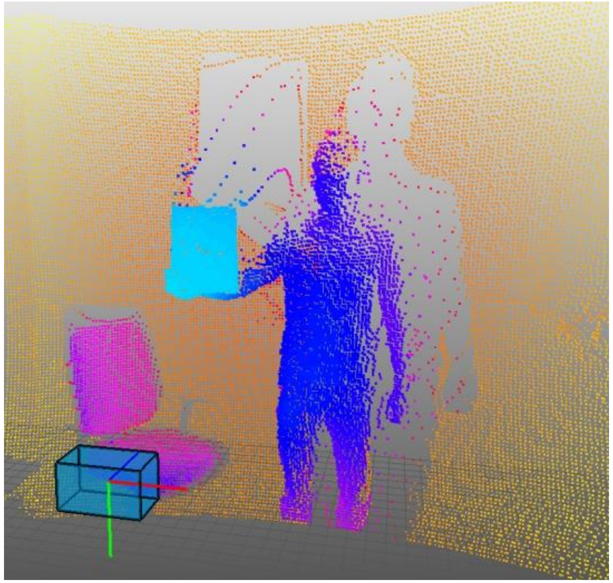
- Triangulation ratio between
  - laser line
  - camera
  - object height



- Range: ≤ 1,5 m
- Resolution: ≥ 0.05 mm

TIME OF FLIGHT

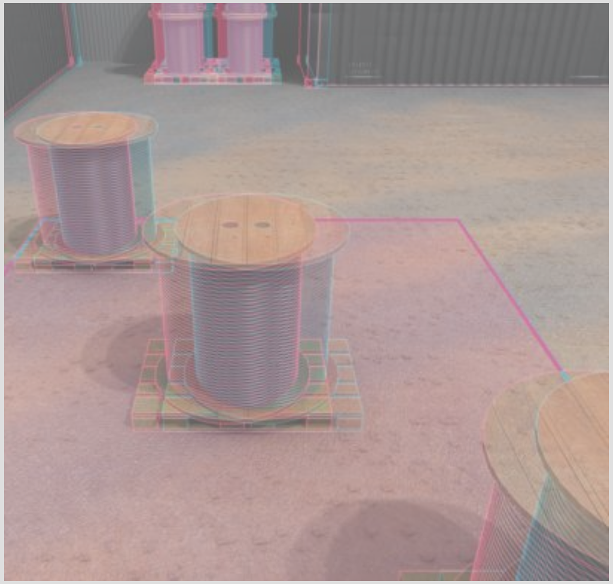
- **Based on**
  - time, the light needs to „fly“ from the sensor
  - speed of light
  - optical properties



- Range: ≤ 7.2 m
- Repeatability: ≤ 30 mm

STEREO

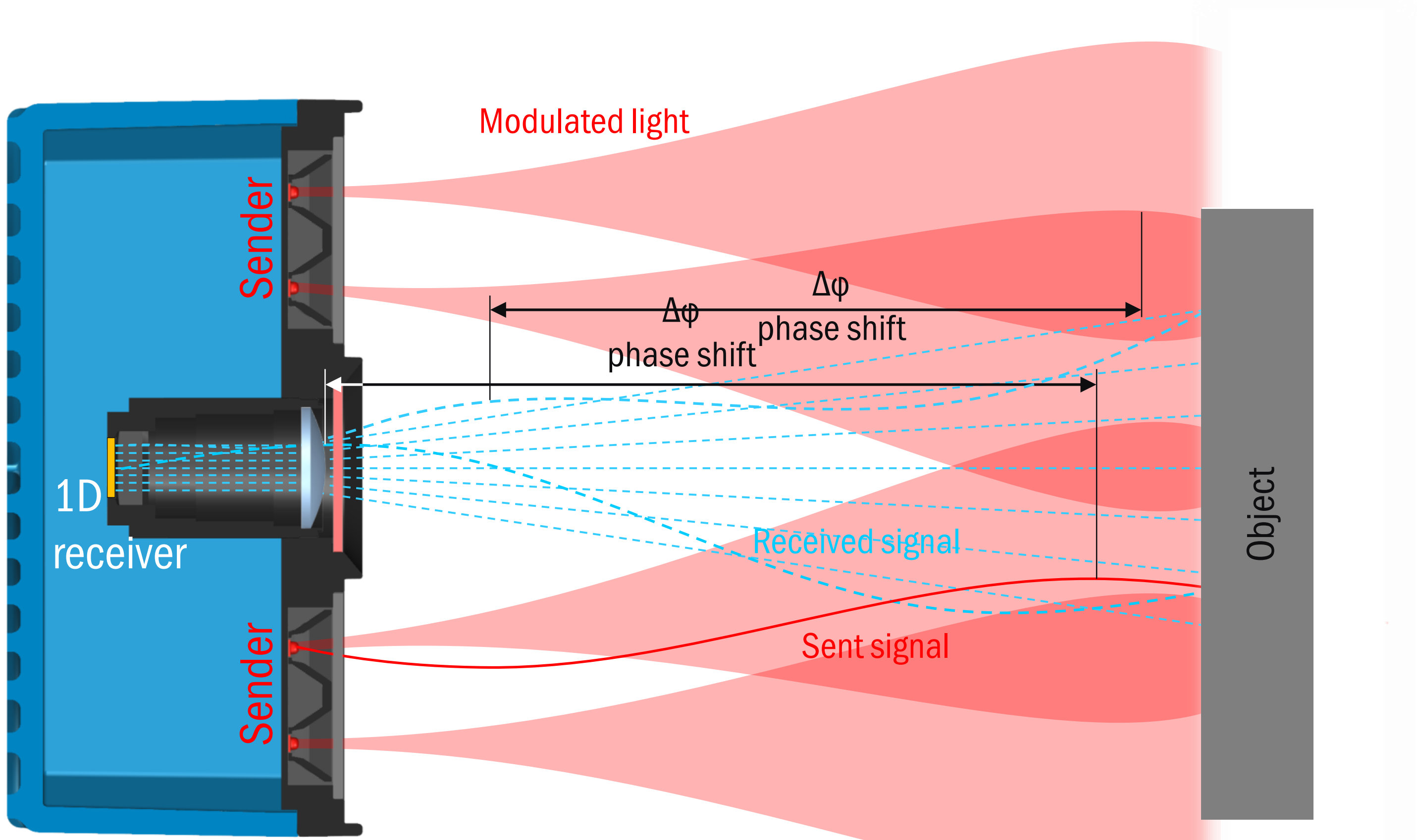
- Binocular principle
  - two cameras
  - passive system



- Range: ≤ 5m
- Repeatability: ≤ 1 mm

4. TIME OF FLIGHT – PHASE CORRELATION – 2 DIMENSIONAL

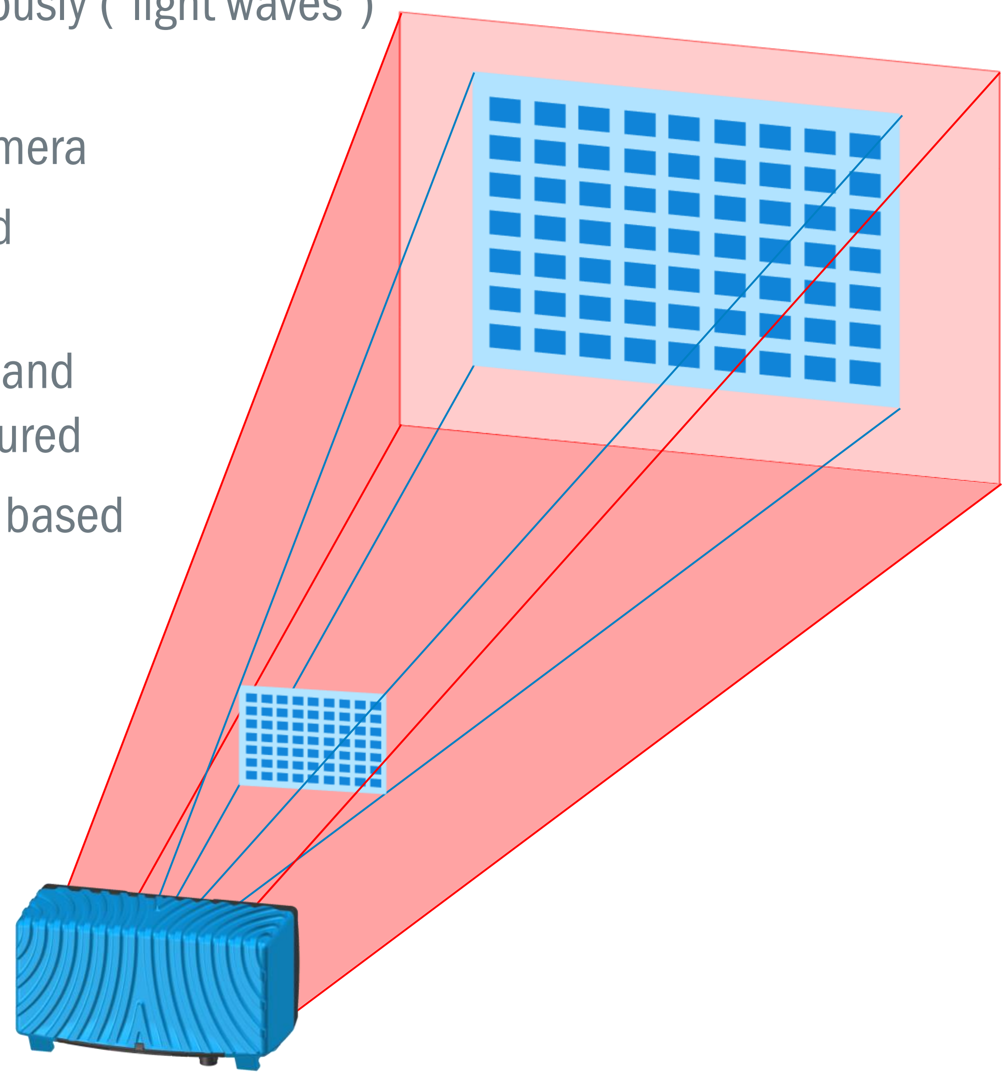
- Modulated light is sent out continuously ("light waves") – LEDs - no laser => illuminated area
- The reflected light wave is evaluated per pixel continuously
- The phase shift between sent wave and the received wave per pixel is measured
- The distance is calculated per pixel based on the phase shift



4. TIME OF FLIGHT – PHASE CORRELATION – 3 DIMENSIONAL

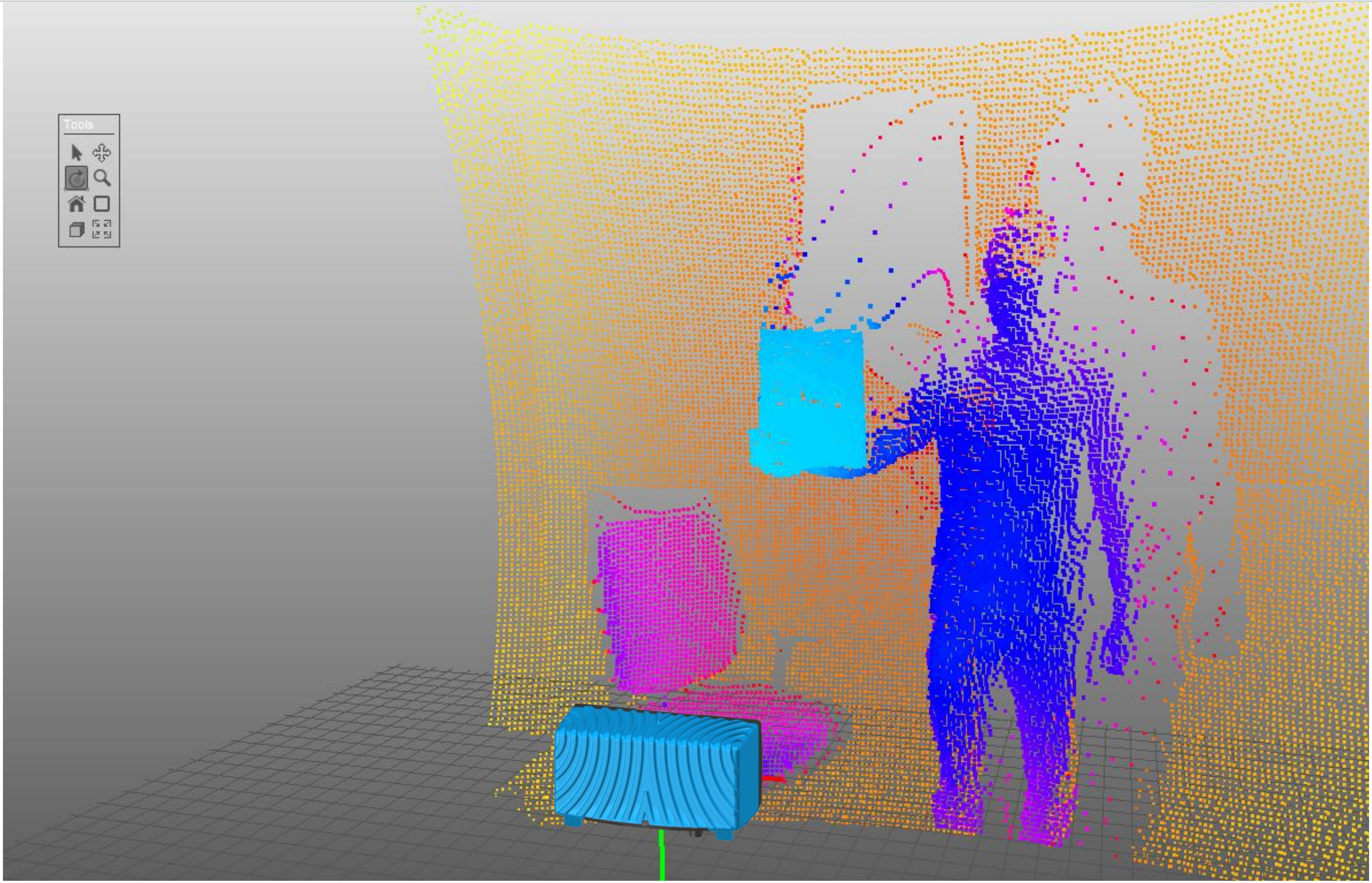
SICK Sensor Intelligence.

- Modulated light is sent out continuously (“light waves”) LED array => 3D illumination
- The light is reflected back to the camera
- The reflected light wave is evaluated per pixel at imager continuously
- The phase shift between sent wave and the received wave per pixel is measured
- The distance is calculated per pixel based on the phase shift



INDUSTRIAL IMAGE PROCESSING 2D & 3D

4. TIME OF FLIGHT – PHASE CORRELATION – 3 DIMENSIONAL



INDUSTRIAL IMAGE PROCESSING 2D & 3D

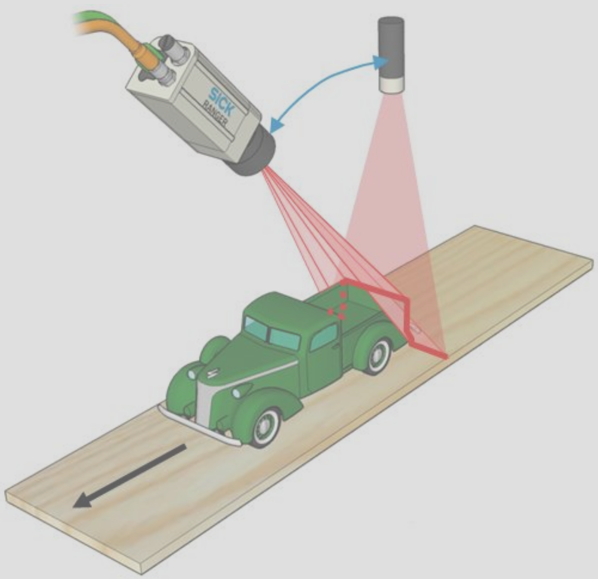
4. STEREO

SICK Sensor Intelligence.

TRIANGULATION	TIME OF FLIGHT	STEREO

TRIANGULATION

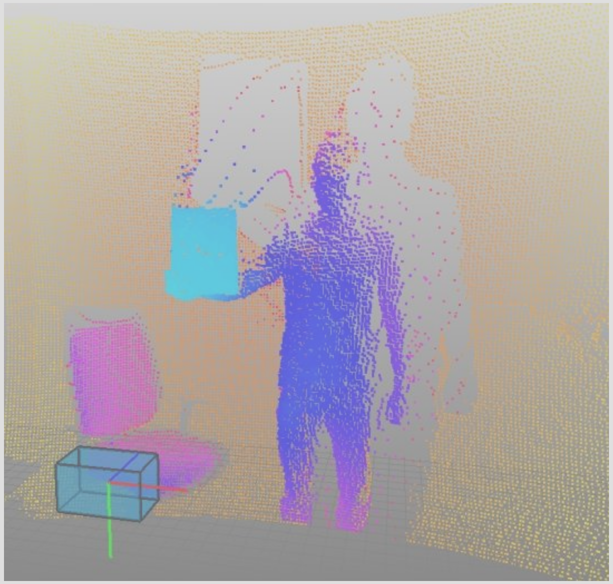
- Triangulation ratio between
  - laser line
  - camera
  - object height



- Range: ≤ 1,5 m
- Resolution: ≥ 0.05 mm

TIME OF FLIGHT

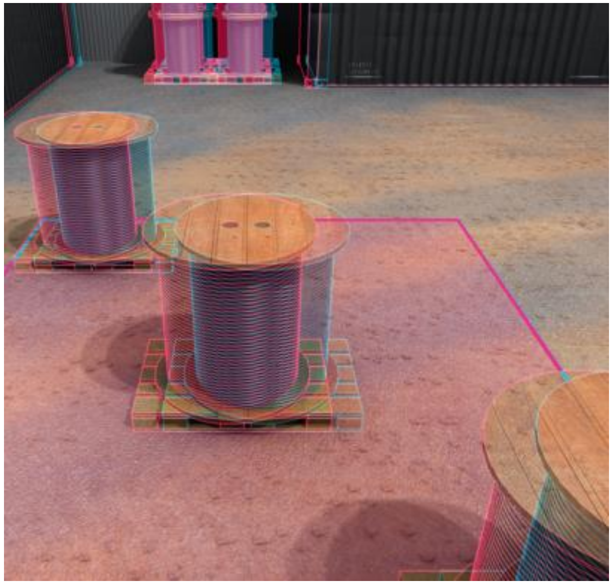
- Based on
  - time, the light needs to „fly" from the sensor
  - speed of light
  - optical properties



- Range: ≤ 7.2 m
- Repeatability: ≤ 30 mm

STEREO

- Binocular principle
  - two cameras
  - passive system



- Range: ≤ 5m
- Repeatability: ≤ 1 mm

- **Two 2D cameras with slightly different view angles**
  - Comparable to human binocular vision

$\Rightarrow$ 3D information

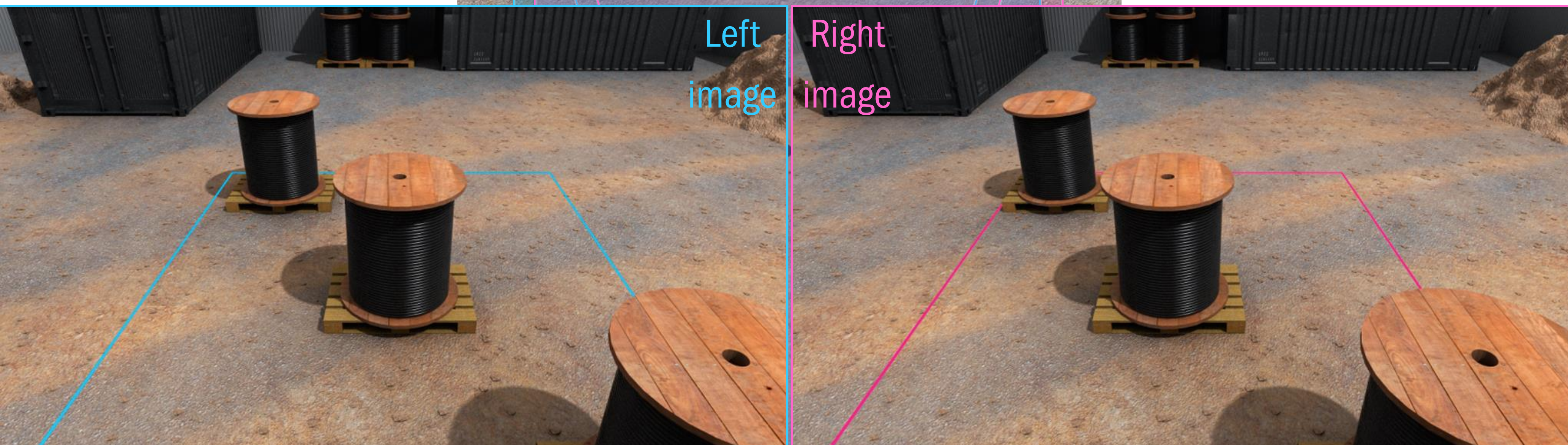
- **Snapshot camera – no movement needed !**

- **Passive system => no light is sent out**
  - No special conditions for scene illumination

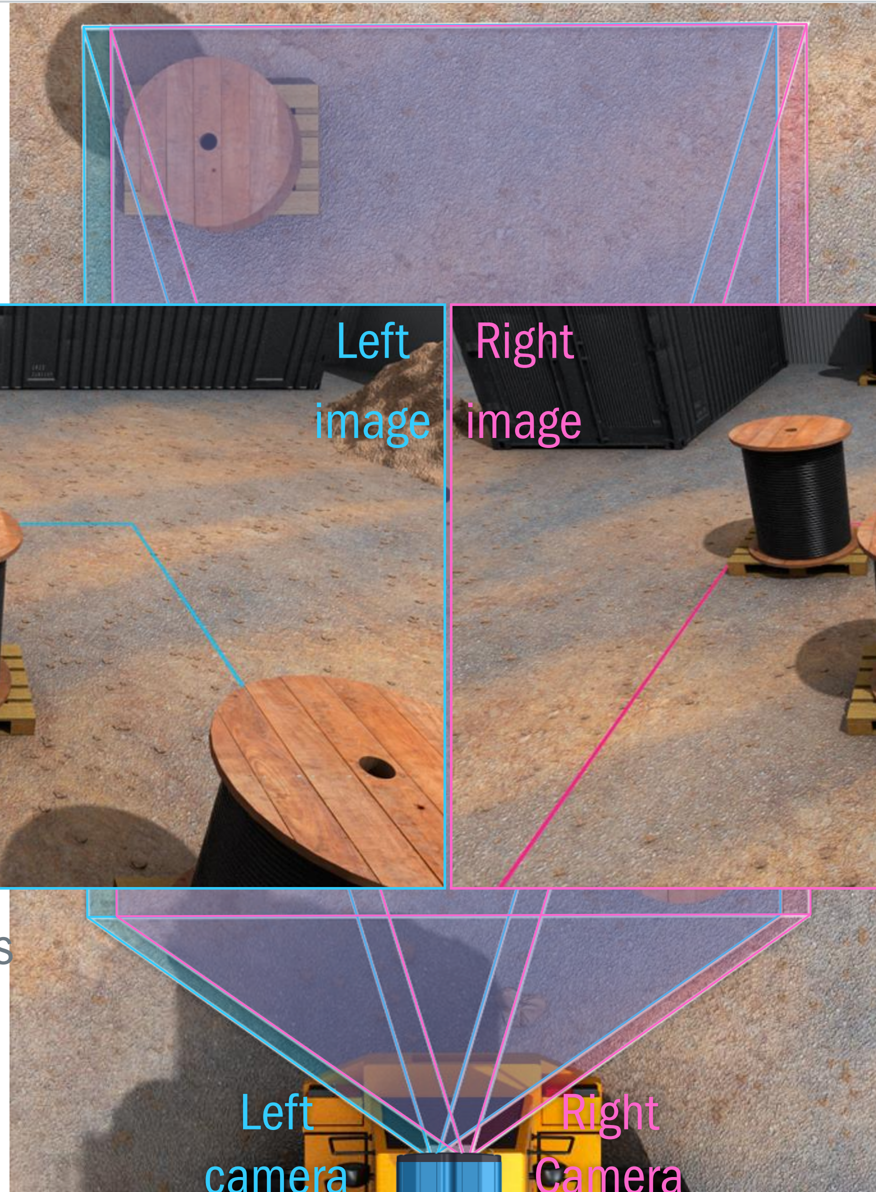
INDUSTRIAL IMAGE PROCESSING 2D & 3D

4. STEREO CAMERA

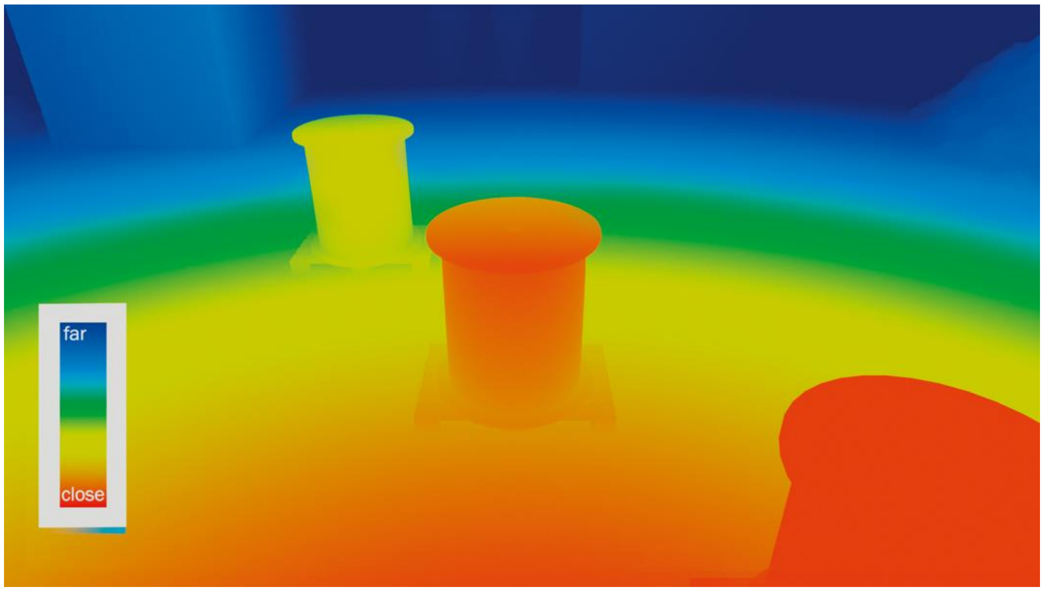
- Two 2D cameras with slightly different view angles



⇒ Overlay of both images



- **Two 2D cameras with slightly different view angles**



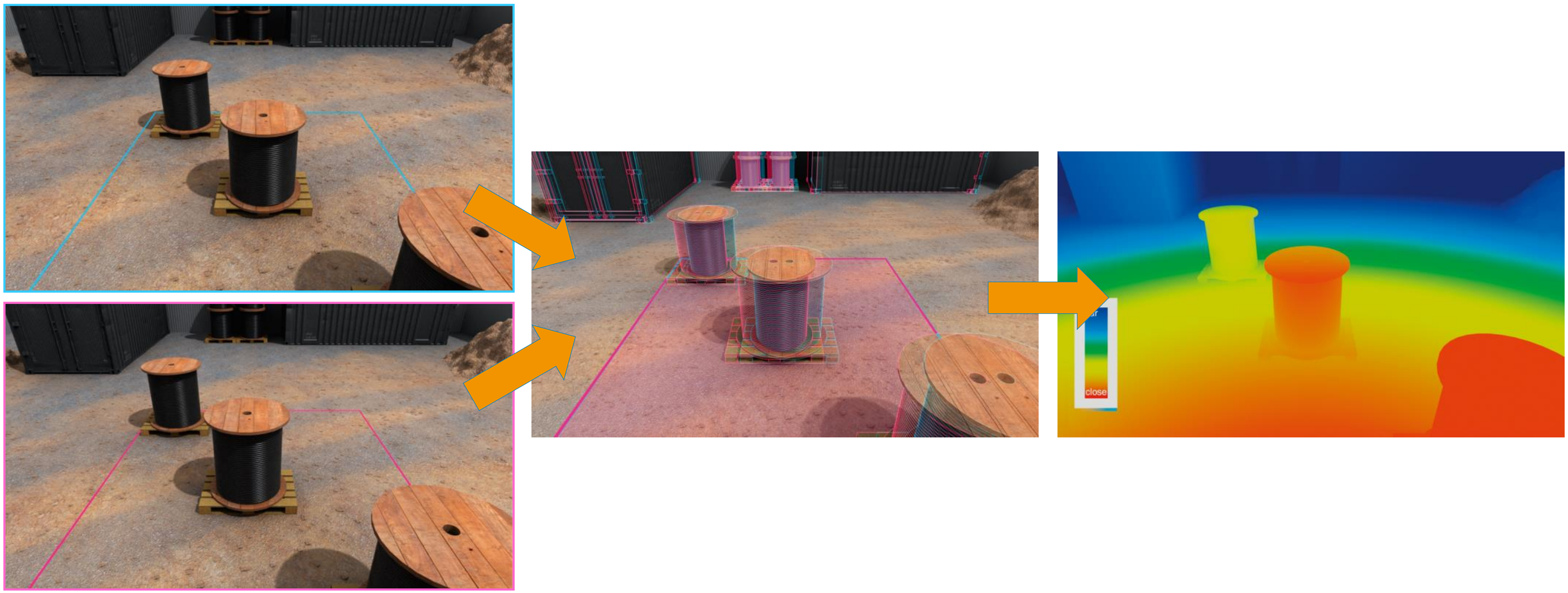
⇒ Overlay of both images

⇒ Depth calculation

INDUSTRIAL IMAGE PROCESSING 2D & 3D

4. STEREO CAMERA

TWO 2D IMAGES | OVERLAY | DEPTH CALCULATION

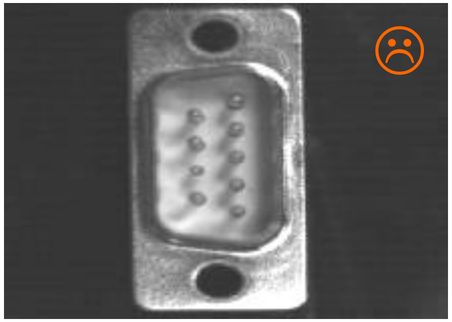


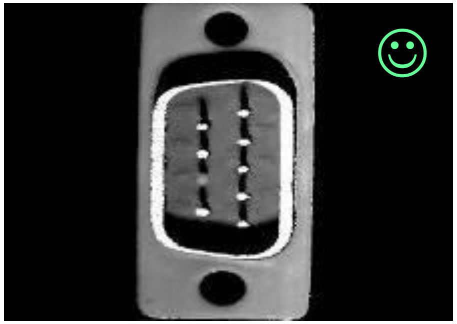
5. APPLICATION 2D OR 3D ?

- **When to use 2D?**
  - Information is in contrast difference
    - Printings
    - Surfaces
    - ...
- **When to use 3D?**
  - Information is in height difference
    - Sizes (Width, heights, volume, ...)
    - Shape
    - ...
- **Examples**
  - 1. Which pin is too low?
  - 2. Which steel part is on top?
  - 3. Which wrapper has misaligned text?

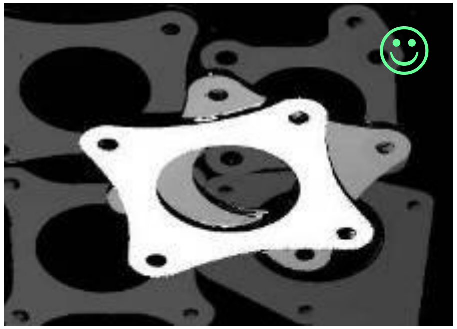
2D Image | 3D Image

1.





2.



3.

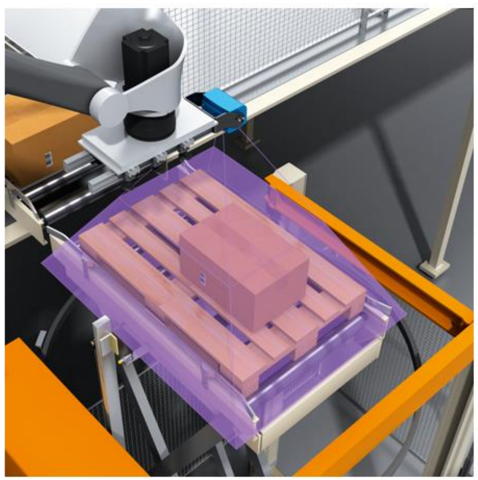
INDUSTRIAL IMAGE PROCESSING 2D & 3D
5. APPLICATION – 3D

SICK Sensor Intelligence.

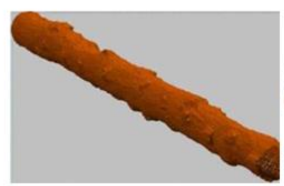
- **Application**
  - Inspect chocolate praline for completeness and correct orientation before final packaging
  - Color independent – just height based
  - Digital output for good / bad classification
- **Product**
  - TriSpector1000

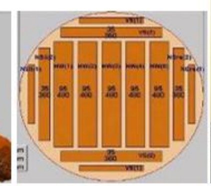
- **Application**
  - Checking brake pads using 3D vision
  - The sensor evaluates surfaces, heights, distances, angles, ...
- **Product**
  - IVC-3D

- Application
  - Measure the height and load of palettes in standstill applications
  - Used for automated loading and unloading
- Product
  - 3vistor-T



- **Application**
  - 360° measurement of logs
  - Automatic optimization of board cutting
- **Product**
  - Ruler





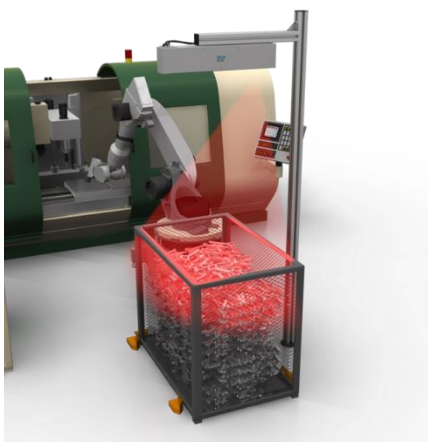
INDUSTRIAL IMAGE PROCESSING 2D & 3D

5. APPLICATION – 3D

PLB

Part **L**ocalization in **B**ins for Robotic part handling (Griff in die Kiste)

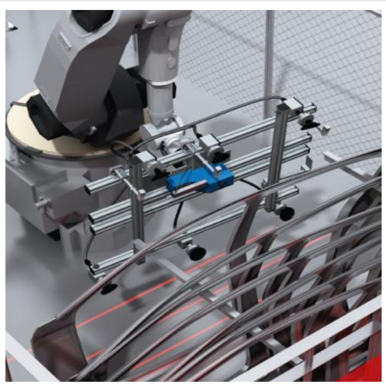
PLB



PLR

Part **L**ocalization in **R**acks (Teile Lokalisieren in Racks)

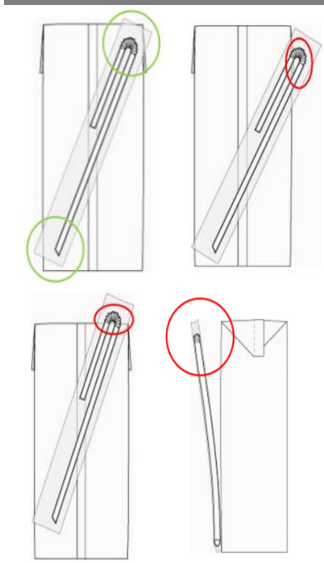
PLR



Straw

Straw & Cap Detector

Straw



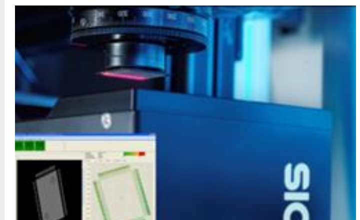
ConVer

Content **Ver**fification for flat Packs

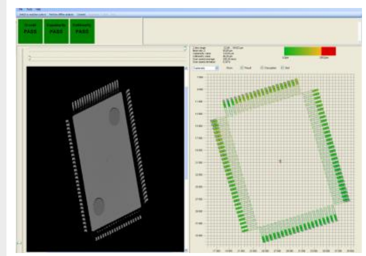
ConVer

CoPlan

Coplanarity Analyzer



CoPlan



5. PRODUCTS FOR 3D VISION APPLICATIONS

SICK
Sensor Intelligence.

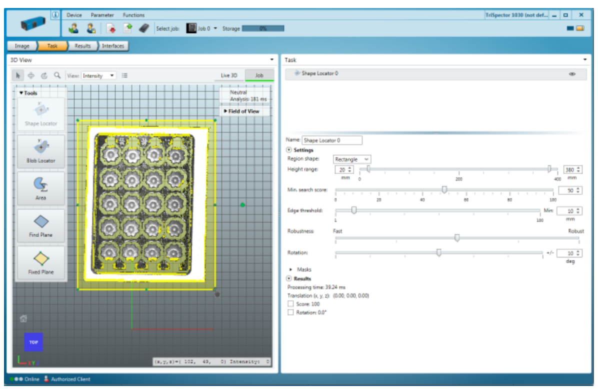
2D VISION	3D VISION

INDUSTRIAL IMAGE PROCESSING 2D & 3D
5. DIFFERENT VARIANTS

SICK
Sensor Intelligence.

CONFIGURABLE SENSORS

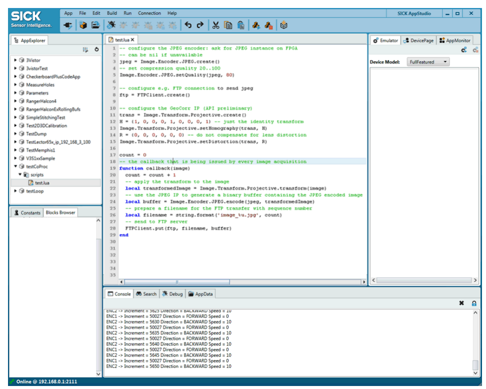
- **Configuration of parameters**
  - **Sliders**
  - Click
  - Drag'n'drop
  - Conditions



- Processing in the device
- Internally calculated results

PROGRAMMABLE CAMERAS

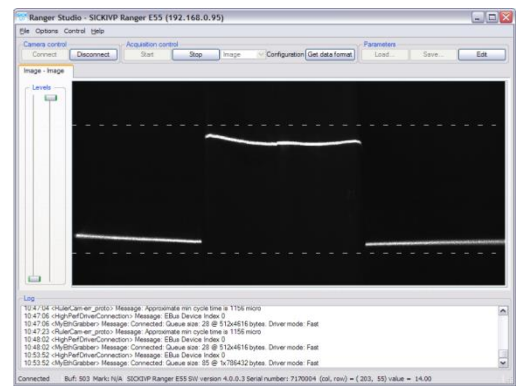
- **Device programing**
  - Block programs
  - Scripting
  - Low level programing (C, C++, Java)
  - Integration of external image libraries



- Processing in the device
- Internally calculated results

STREAMING CAMERAS

- **Raw data output to**
  - PLC
  - Computer
- Device configuration only to acquire images and to optimize the output of the raw data



- NO internally calculated results!

INDUSTRIAL IMAGE PROCESSING 2D & 3D

5. VISION PRODUCTS - 3D

Sensor Intelligence.

CONFIGURABEL SENSOR

- **TriSpector1000**
  (Vision - Triangulation)

- **Visonary**
  (Vision - TOF)

- **PLB520**
  (Vision - Stereo)

PROGRAMMABEL CAMERA

- **TriSpectorP1000**
  (Vision - Triangulation)
  SICK APP SPACE
  HALCON

- **IVC-3D**
  (Vision - Triangulation)

STREAMING-CAMERA

- **Ranger / Ranger3**
  (Vision - Triangulation)

- **Ruler / ScanningRuler**
  (Vision - Triangulation)

- **Visionary**
  (Vision - TOF)

- **SIM4000**
  (Controler)
  SICK APP SPACE
  HALCON

THANKS FOR YOUR ATTENTION!

Renè Klausrigler

Productmanagement „Identification & Measuring“

rene.klausrigler@sick.at

SICK
Sensor Intelligence.